

Guide to fire characteristics and fire performance of expanded polystyrene materials (EPS and XPS) used in building applications

ICS 13.220.50

Confirmed October 2008

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to PRI/26, Burning behaviour of plastics and rubbers, upon which the following bodies were represented:

- Association of Building Component Manufacturers
- British Cables Association
- British Electrical Systems Association
- British Plastics Federation
- British Railways Board
- Building Research Establishment
- Electrical & Electronic Insulation Association
- Electrical and Electronic Insulation Association (BEAMA Ltd.)
- Electrical Insulation Association
- Electricity Association
- ERA Technology Ltd.
- GAMBICA
- Home Office
- Lighting Industry Federation Ltd
- MoD — UK Defence Standardization
- National Supervising Inspectorate
- RAPRA Technology Ltd
- University of Ulster
- Warrington Fire Research Centre

This British Standard was published under the authority of the Standards Policy and Strategy Committee and comes into effect on 23 April 2003

© BSI 23 April 2003

First published February 1991

The following BSI references relate to the work on this British Standard:
Committee reference PRI/26
Draft for comment 00/124251 DC

ISBN 0 580 41516 3

Amendments issued since publication

Amd. No.	Date.	Comments

Contents

	Page
Committees responsible	Inside front cover
Foreword	ii
1 Scope	1
2 Normative references	1
3 Terms, definitions and abbreviations	2
4 Relevant legislation and insurance requirements	3
5 Grades and types of expanded polystyrene boards	6
6 Fire characteristics	7
7 Fire test methods	12
8 Handling and storage recommendations	17
9 Procedure in the event of fire	18
Annex A (informative) Examples of locations of expanded polystyrene materials in buildings — Guidance for installation, fire hazards and protection	19
Annex B (normative) Unprotected expanded polystyrene ceiling tiles, up to 12 mm thick, fixed to a substrate	39
Annex C (informative) Contribution to fire spread by expanded polystyrene tiles up to 12 mm thick and veneers up to 5 mm thick	40
Bibliography	41
Table 1 — Euroclassification of fire growth of some typical expanded polystyrene products	5
Table 2 — Additional Euroclassification of smoke production and flaming droplets of some typical expanded polystyrene products	6
Table 3 — Cut board stripe colours and moulded board codes	7
Table 4 — Additional identification for all grades of type A boards	7
Table 5 — Comparison of polystyrene and cellulosic materials	8
Table 6 — Rate of heat release measured by BS 476-15:1993 for standard and FR grades of EPS	9
Table 7 — Comparison of smoke test results	10
Table 8 — Fire tests for materials	13
Table 9 — Fire tests for structures	15
Table A.1 — Examples of locations of expanded polystyrene materials in buildings	20

Foreword

This British Standard has been prepared by Technical Committee PRI/26, Burning behaviour of plastics and rubbers, with the active cooperation of Technical Committee PRI/72, Cellular plastics. This standard provides information on the fire characteristics and fire performance of expanded polystyrene materials used in building applications and supersedes BS 6203:1991, which is withdrawn.

The information given in this guide is in accordance with the principles recommended in BS 6336 which was established to develop a general policy and philosophy for the development and use of fire tests.

Examples of methods of installation in building construction representative of good practice in respect of fire performance are given in annex A. Annex B gives fire information on unprotected expanded polystyrene ceiling tiles fixed to a substrate, while annex C gives information on the contribution to fire spread by tiles and veneers.

The numbers in square brackets in the text refer to reference documents in the Bibliography. Comments on the Bibliography are welcomed as it is hoped that more up-to-date references can be inserted and any errors corrected.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii pages 1 to 42, an inside back cover and a back cover.

The BSI copyright notice displayed in this document indicates when the document was last issued.

1 Scope

This British Standard provides information on the fire characteristics and performance in fire tests of expanded polystyrene materials for use in building applications. This standard illustrates a number of suitable constructions incorporating expanded polystyrene materials, including moulded and extruded products conforming to BS EN 13164 and BS EN 13165. This guide does not apply to expanded polystyrene materials with densities greater than 100 kg/m³.

This guide draws attention to the unsuitability of some standard fire test methods for certain applications of expanded polystyrene materials in buildings.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the reference cited applies. For undated references, the latest edition of the referenced document (including any amendments).

BS 476-3:1975, *Fire tests on building materials and structures — Part 3: External fire exposure roof test.*

BS 476-4:1970, *Fire tests on building materials and structures — Part 4: Non-combustibility test for materials.*

BS 476-6:1989, *Fire tests on building materials and structures — Part 6: Method of test for fire propagation for products.*

BS 476-7:1997, *Fire tests on building materials and structures — Part 7: Method of test to determine the classification of the surface spread of flame of products.*

BS 476-11:1982, *Fire tests on building materials and structures — Part 11: Method for assessing the heat emission from building materials.*

BS 476-12:1991, *Fire tests on building materials and structures — Part 12: Method of test for ignitability of products by direct flame impingement.*

BS 476-13:1987, *Fire tests on building materials and structures — Part 13: Method of measuring the ignitability of products subjected to thermal irradiance.*

BS 476-15:1993, *Fire tests on building materials and structures — Part 15: Method for measuring the rate of heat release of products.* (ISO 5660-1:1993)

BS 476-20:1987, *Fire tests on building materials and structures — Part 20: Method for determination of the fire resistance of elements of construction (general principles).*

BS 476-21:1987, *Fire tests on building materials and structures — Part 21: Methods for determination of the fire resistance of loadbearing elements of construction.*

BS 476-22:1987, *Fire tests on building materials and structures — Part 22: Methods for determination of the fire resistance of non-loadbearing elements of construction.*

BS 476-23:1987, *Fire tests on building materials and structures — Part 23: Methods for determination of the contribution of components to the fire resistance of a structure.*

BS 476-33:1993, *Fire tests on building materials and structures — Part 33: Full-scale room test for surface products.* (ISO 9705:1993)

BS 4735, *Laboratory method of test for assessment of the horizontal burning characteristics of specimens no larger than 150 mm × 50 mm × 13 mm (nominal) of cellular plastics and cellular rubber materials when subjected to a small flame.*

BS 5306-2:1990, *Fire extinguishing installations and equipment on premises — Part 2: Specification for sprinkler systems.*

BS 6336, *Guide to the development of fire tests, the presentation of test data and the role of tests in hazard assessment.*

BS 7899-1:1997, *Code of practice for the assessment of hazard to life and health from fire — Part 1: General guidance.*

BS EN 13164, *Thermal insulation products for buildings — Factory made products of extruded polystyrene foam (XPS) — Specification.*

BS EN 13165, *Thermal insulation products for buildings — Factory made rigid polyurethane foam (PUR) products — Specification.*

BS EN 13823, *Reaction to fire tests for building products. Building products excluding floorings exposed to the thermal attack by a single burning item.*

BS ISO TR 9122-5, *Toxicity testing of fire effluents — Part 5: Prediction of toxic effects of fire effluents.*

BS ISO 11925-2, *Reaction to fire tests — Ignitability of building products subjected to direct impingement of flame — Part 2: Single flame source test.*

BS EN ISO 5659-2, *Plastics. Smoke generation — Part 2: Determination of optical density by a single chamber test.*

BS EN ISO 1182, *Reaction to fire tests for building products — Non-combustibility test.*

BS EN ISO 1716, *Reaction to fire tests for building products — Determination of the heat of combustion.*

BS EN ISO 13943, *Fire safety — Vocabulary.*

3 Terms, definitions and abbreviations

For the purposes of this British Standard, the terms and definitions of BS EN ISO 13943 and the following terms, definitions and abbreviations apply.

3.1

expanded polystyrene materials

polystyrene cellular materials with densities not exceeding 100 kg/m^3 which are produced from expanded polystyrene beads or by an extrusion process

NOTE Examples of expanded polystyrene materials are expanded polystyrene boards conforming to BS EN 13164 and BS EN 13165.

3.2

EPS

expanded polystyrene in the form of cut or moulded boards as specified in BS EN 13164

3.3

XPS

extruded polystyrene foam in the form of integral skinned or planed boards as specified in BS EN 13165

3.4

loadbearing capacity

R

ability of an element to withstand fire exposure on one or more faces for a period of time without loss of structural stability

3.5

integrity

E

ability of an element with a separating function to withstand fire exposure on one side only, without the transmission of fire to the non-fire side as a result of the passage of significant quantities of flames or hot gases from the fire to the non-fire side, thereby causing ignition either of the non-exposed surface or of any material adjacent to that surface

3.6

insulation

I

ability of an element to withstand fire exposure on one side only, without significant transfer of heat from the exposed to the unexposed side

NOTE In BS 476-6, *I* is used to denote a performance rating index.

3.7

product

materials, components, structures, elements, composites, systems, etc.

3.8

cavity barrier

construction, other than a smoke curtain, provided to close a concealed space against penetration of smoke or flame, or provided to restrict the movement of smoke or flame within such a space

4 Relevant legislation and insurance requirements

4.1 General

Early reference at the design stage should be made to all appropriate enactments and codes relating to the construction and operation of new buildings and to the fire precautions to be provided in existing buildings. The designer should consult the building and fire authorities at an early stage to make certain the building as planned will meet the requirements those authorities may make, particularly if a fire certificate or licence is likely to be necessary.

4.2 Building regulations

The design and construction of new buildings, and of alternations of existing buildings, are controlled by the following statutory provisions which are collectively referred to as Building Regulations in this guide.

England and Wales

The Building Regulations 1991 [1].

Scotland

The Building Standards (Scotland) Regulations 1990 [2].

Northern Ireland

The Building Regulations (Northern Ireland) 1994 (as amended 1995) [3].

These Building Regulations do not specify technical requirements but merely state functional requirements. Guidance on means by which the regulations with regard to fire may be met is given in the following supporting guidance documents [4] to [7].

England and Wales

The Building Regulations Approved Document B 2000 — Fire Safety [4].

Scotland

The Building Standards (Scotland) Regulations Technical Standard D Structural Fire Performance [5] and Technical Standard E, *Means of escape from fire, facilities for fire-fighting and means of warning of fire in dwellings* [6]

Northern Ireland

The Building Regulations (Northern Ireland) Technical Booklet E Fire Safety [7]

4.3 Legislation and other regulations for fire safety in existing buildings

NOTE 1 Some regulations and Approved Documents contain direct references to British Standard specifications and codes of practice.

NOTE 2 Under the Fire Precautions Act 1971 [8], fire authorities in England and Wales cannot, as a condition of the issue of a fire certificate, require structural or other alterations relating to escape from the premises if the plans of the building conform to building regulations, unless the fire authority is satisfied that the means of escape in case of fire are inadequate by reason of matters or circumstances of which particulars were not required to be supplied to the local authority in connection with the deposit of plans for building regulation purposes.

NOTE 3 For premises subject to the Fire Certificates (Special Premises) Regulations 1976 [9], the regulations apply to all buildings within the premises.

In addition to the controls mentioned in 4.2, fire safety and means of escape for a wide variety of buildings are dealt with under the following legislation.

England and Wales

The Fire Precautions Act 1971 [10], as amended by the Health and Safety at Work etc. Act 1974 [11], the Fire Safety and Safety of Places of Sports Act 1987 [12] and the Fire Precautions (Work Place) Regulations 1997 [13].

The Building Act 1984 [14] (except in Inner London where the fire provisions of the London Building Acts 1939-1982 [15], as amended by the Local Government Act 1985 [16], apply).

Scotland

The Fire Precautions Act 1971 [17], as amended by the Health and Safety at Work etc. Act 1974 [11], and the Fire Safety and Safety of Places of Sports Act 1987 [12].

NOTE 4 Attention is also drawn to local acts, as well as entertainment and other licensing legislation which deal with fire safety and means of escape.

The Building (Scotland) Act 1959 (as amended) [18].

Northern Ireland

The Fire Services (Northern Ireland) Order 1984 [19]

The Health and Safety at Work (Northern Ireland) Order 1978 [20].

The Building Regulations (Northern Ireland) Order 1979 [21].

4.4 Insurance requirements

Insurance requirements relevant to this guide include the following Loss Prevention Council publications:

- *Rules for the construction of buildings – grades 1 and 2*; [22];
- *Rules for Automatic Sprinkler Installations* [23].

4.5 Euroclassification of reaction-to-fire performance of building products

4.5.1 The future objectives for establishing a single European Market for Construction Products and the requirements regarded as essential in relation to the fire of safety of construction products are defined in the EC Construction Products Directive [24] and in the Interpretative Document No. 2, Safety in Case of Fire [25]. Subsequent to the publication of these documents and after receiving proposals from a representative committee of National Regulators, the Commission of the European Communities published a Commission Decision [26], which detailed how a harmonized solution to reaction-to-fire performance would be developed based on a system of Euroclasses. This approach was designed to enable national regulations to relate their own required fire safety performance to harmonized European Standards and Euroclasses; it is not intended to herald new European Regulations for Fire Safety since each country will want to retain their independent policy towards national fire regulations.

4.5.2 The EC Decision implementing Article 20 of the Construction Products Directive concerning establishment of Euroclasses [26] includes two classification systems for reaction-to-fire performance, one for floor-coverings and the other for building products excluding floorings. The EC Decision clearly states that products should be considered for evaluation of reaction-to-fire performance in their end-use conditions. This reference document also defines the fields of application for Euroclassification; the product areas detailed are as follows:

- a) products for walls and ceilings including their surface coverings;
- b) building elements;
- c) products incorporated within building elements;
- d) pipes and duct components (including externally applied insulation);
- e) products for façades/external walls (including insulation layers, etc.);
- f) floorings (including surface coverings).

NOTE 1 Roof-coverings are excluded from the reference document.

Reference scenarios constitute the basis for Euroclassification. In the case of wall and ceiling linings, the reference scenario is a fire initiating in a small room and growing to flashover and beyond. Hence, this reference scenario may be envisaged to involve three main fire stages, which are used for assessing the contribution of these building products at any particular stage.

- 1) Initiation of the fire by ignition of a building product with a small flame (e.g. a simulated match).
- 2) Fire growth to eventually reach flashover; this stage is considered to be realistic if the fire is initiated by a single burning item (e.g. a wastepaper basket) in a corner of the room. This position is chosen to ensure a worst case situation such that a heat flux of the order of 40 kW/m^2 would impinge on the adjacent walls and ceiling.
- 3) During the post-flashover stage, all combustible products in the room would contribute their calorific contents to the fire load. This is the fully developed stage of the room fire.

NOTE 2 The validation of the Euroclassification of wall and ceiling linings is based on this single small room reference scenario, as given in BS 476-33 (ISO 9705:1993). Whilst it is a simplification, it is also assumed that this classification (with the exception of floor-coverings), can be applied for all other scenarios. Indeed, a similar simplifying assumption is considered to be relevant so that the same classification will apply to different orientations, geometries and to product types other than the surface products of rooms. Even allowing for this broad assumption, it is still necessary for the end-use concept to be adhered to as closely as possible; this means that substrates, joints, facings, adhesives, air-gaps, etc., should be as realistic as possible. This can be difficult to achieve for more complex building systems that incorporate expanded polystyrene.

4.5.3 In order to reach a Euroclassification decision on the reaction-to-fire performance of a building product (except for floorings), all of the following parameters should be considered:

- a) ignitability;
- b) spread of flame;
- c) heat release;
- d) smoke opacity;
- e) burning debris or droplets.

The main test method which will be used to classify these parameters (except for floorings) is the Single Burning Item (SBI) test.

It is assumed that products which qualify to be Euroclass A1 make no contribution to fire growth nor to the fully developed fire. Euroclass A1 is determined using a bomb calorimeter (BS EN ISO 1716) and the BS EN ISO 1182 furnace test. See Table 1 and Table 2 [40].

Table 1 — Euroclassification of fire growth of some typical expanded polystyrene products

Product description	Thickness mm	Foam density kg/m ³	BS EN ISO 11925-2 small flame test		BS EN 13823 SBI test		Class
			Time (s) to 150 mm	Flaming droplets/ particles	FIGRA W/s	THR _{600s} MJ	
XPS	50	29	Not reached	None	386	9.77	D
FR-EPS (Type A)	50	15	Not reached	None	625	9.57	D
NFR-EPS (Type N)	50	15	10	Flaming	3 021	23.47	F
9 mm Plasterboard faced XPS	32	32	Not reached	None	29	0.89	B

Table 2 — Additional Euroclassification of smoke production and flaming droplets of some typical expanded polystyrene products

Product description	Thickness mm	Foam density kg/m ³	BS EN 13823 SBI test				Class
			SMOGRA m ² /s ²	TSP _{600s} m ²	Flaming droplets/ particles	Droplet/ particle flames ≥ 10s	
XPS	50	29	123	276	Yes	None	s3,d1
FR-EPS (Type A)	50	15	129	220	None	None	s3,d0
NFR-EPS (Type N)	50	15	324	312	Yes	Yes	s3,d2
9 mm Plasterboard faced XPS	32	32	6	41	None	None	s1,d0

5 Grades and types of expanded polystyrene boards

5.1 Two methods are used to manufacture expanded polystyrene boards. The products from the two processes used in building applications should be characterized by the test methods specified in BS EN 13164 (EPS) and BS EN 13165 (XPS).

NOTE Expanded polystyrene is also available as a loose fill material for cavity wall insulation in the form of expanded beads.

5.2 The following two types of EPS products are specified in BS EN 13164.

- Type N material which consists of polystyrene expanded to form a cellular structure consisting substantially of closed cells.
- Type A material which is similar to type N but additionally, when tested in accordance with BS 4735, specimens of 150 mm × 50 mm × 13 mm subjected to a small flame show an “extent burnt” of less than 125 mm. This requirement is met by incorporation of a flame retardant additive or by another appropriate modification (see Annex B).

NOTE 1 The term FRA is commonly used to indicate type A materials.

NOTE 2 All products conforming to BS EN 13165 contain flame retardant additives and have a type A fire performance.

5.3 Products conforming to BS EN 13164 are identified in the following ways.

- Cut boards are identified by a coloured stripe of minimum width 10 mm, across the edge of each board on at least one side and located near the centre of the board. The colours for each grade are as given in Table 3.
- Moulded boards are identified by a code added by moulded impression to each board, as given in column 3 of Table 3.
- Type N boards are identified only as detailed in Table 3, whilst type A boards are additionally identified as in Table 4.

Products conforming to BS EN 13165 are marked, preferably on the boards (or failing this on the packaging label), with at least the following information:

- 1) the number and date of the British Standard, i.e. BS EN 13165;¹⁾
- 2) the grade, i.e. E1, E2, E3, E4, E5, E6 or E7;
- 3) the manufacturer’s name or trade mark.

¹⁾ Marking BS EN 13165 on or in relation to a product represents a manufacturer’s declaration of conformity, i.e. a claim by or on behalf of the manufacturer that the product meets the requirements of the standard. The accuracy of the claim is solely the claimant’s responsibility. Such a declaration is not to be confused with third-party certification of conformity.

Table 3 — Cut board stripe colours and moulded board codes

Grade	Cut board stripe colours	Moulded board codes
SD	Yellow	SD:BS EN 13164
HD	Black	HD:BS EN 13164
EHD	Green	EHD:BS EN 13164
UHD	Orange	UHD:BS EN 13164
ISD (compressed)	Yellow and violet	ISD:BS EN 13164

Table 4 — Additional identification for all grades of type A boards

Board structure	Identification
Cut board	Appropriate grade identification with the addition of a red stripe of minimum width 10 mm across the edge of each board on at least one side, located near the centre of the board and adjacent to any stripe indicating the grade
Moulded board	Appropriate grade identification, followed by the letter “A” impressed on each board

6 Fire characteristics

6.1 Reaction to fire

6.1.1 Combustibility

All grades, types and densities of expanded polystyrene materials are combustible as defined by BS 476-4:1970 and Euroclass A.

6.1.2 Ignitability

Under certain circumstances, expanded polystyrene materials can be ignited by a naked flame. Care should be taken to avoid contact with such sources when handling and storing the material before and during installation.

It is recommended that installed expanded polystyrene boards should always be covered by a protective facing, suitably fixed to prevent collapse in the event of fire.

NOTE Recommendations on the use of unprotected expanded polystyrene ceiling tiles fixed to a substrate are given in Annex B and Annex C.

Protection of the surface of expanded polystyrene materials by 9 mm thick plasterboard or plaster of minimum thickness of 10 mm has been shown to provide resistance to ignition, if the protective facing is mechanically supported [27, 28]. An unsupported coating, applied directly on the expanded polystyrene materials, with adequate insulation to maintain the interface temperature below 100 °C for a specified time provides protection, as long as the integrity of the facing is preserved.

Thin finishes, such as plaster skim coats, aluminium foil, flame retardant paints or intumescent coatings applied directly on the expanded polystyrene materials, can delay ignition to a limited extent, but once the underlying material softens under the effect of heat, penetration and progressive failure of the coating can occur [29, 30]. Such thin finishes are not recommended without specific practical demonstration of their ability to inhibit or delay ignition.

If the protective coating fails in a fire, the polystyrene melts onto either the substrate or the coating. The thermal properties of these surfaces largely determine the rate of evolution of flammable decomposition products from the polystyrene and the possibility of ignition of the molten polystyrene. Sustained flaming of the polystyrene can be initiated by a spark or flame (pilot ignition), provided that there is adequate ventilation and the surface temperature is maintained above about 350 °C. Spontaneous ignition can occur in the gaseous layer above the surface at temperatures above about 490 °C, provided that the gas/air mixture is within flammability limits [27].

Where expanded polystyrene materials are completely encapsulated with the consequent exclusion of air, e.g. in voids within certain masonry elements, it has been found that, under fire test conditions, there is extensive thermal decomposition but no evidence of active flaming or of serious pressure build-up [32 to 40]. Incorporation of expanded polystyrene materials in structural elements has not been found to reduce the overall fire resistance of those elements.

6.1.3 Rate of heat release

The gross calorific value of polystyrene materials is about twice that of timber but, taking into account the comparative densities of the two products, the gross calorific value by volume of expanded polystyrene materials is significantly lower than for cellulosic products such as fibre insulating board or timber (see Table 5).

Table 5 — Comparison of polystyrene and cellulosic materials

Material	Approximate gross calorific value	
	By mass MJ/kg	By volume MJ/m ³
Polystyrene materials	40	400 to 2 000
Timber and fibre insulating board	20	7 100 to 10 500

The gross calorific value of materials influences fire severity in terms of fire duration while the rate of heat release is of major importance for fire growth and is very dependent on combustion conditions.

The rate of heat release directly influences many of the other reactions to fire, such as smoke and toxic gas production. The ability to accurately measure the heat released from items such as wall linings is viewed as essential to fire protection engineering [33].

The rate of heat release from expanded polystyrene materials is about three times as rapid as from softwood timber, but is of much shorter duration. The extent and rate of heat release is limited primarily by ventilation. A foam of density 16 kg/m³, for example, requires over 150 times its volume of air to achieve complete combustion. Complete combustion of expanded polystyrene material is unlikely to occur, so its gross calorific value is rarely released.

Until relatively recently it was not easy to determine the rate of heat release from fires and calculations were made from heats of combustion. Measurement of oxygen consumption in fires now makes it possible to determine the rate of heat release more directly.

The cone calorimeter (see BS 476-15) is an instrument designed to measure heat released from burning materials by measurement of oxygen consumption, regardless of how complete the degree of combustion is. Specimens tested on the cone calorimeter can be subject to various levels of incident heat flux thus modelling different stages of a developing fire. This model has been shown to correlate well with results from some large scale flammability tests such as BS ISO TR 9705-2.

When expanded polystyrene is tested on the cone calorimeter, it proves difficult to ignite at low heat fluxes. At higher heat fluxes ignition takes place but the combustion process finishes relatively quickly because of the low amount of available fuel. As the incident heat flux arriving at the specimen surface is increased, the value for the peak heat release rate (HRR) from the material also increases. Use of flame retardants in the material causes a decrease in the value of the peak HRR ([34] and Table 6).

Whilst an increase in the incident heat flux on the specimen causes an increase in the value for peak HRR, it also accelerates the rate of pre-ignition shrink-back thus removing the potential fuel from the source of ignition. This shrink-back phenomenon is much less pronounced at low levels of incident heat flux and thus low heat flux ignition sources such as match flames (20 kW/m² to 25 kW/m²) represent as great, if not greater, potential danger than other larger, hotter ignition sources.

In all cases, the facing and substrate materials are critical to the burning behaviour of the material.

Table 6 — Rate of heat release measured by BS 476-15:1993 for standard and FR grades of EPS

Parameter	Time to ignition s	Mean peak rate of heat release kW/m ²	Mean effective heat of combustion MJ/kg
Heat flux(kW/m ²)	20 30 50	20 30 50	20 30 50
EPS FR grade	NI ^a 77 24	NI 321 379	NI 27 27
EPS standard	NI 73 18	NI 394 407	NI 27 28

^a NI = no ignition

6.1.4 Flame spread

The extent and rate of flame spread depend largely on the ignitability of, and rate of heat release from, a combustible material. In linings where expanded polystyrene material is attached to a rigid substrate and is provided with a protective exterior facing, the risk of flame spread is also affected by the physical/thermal properties of the surface onto which the expanded polystyrene material might have melted.

The proximity of the substrate and the degree of integrity of the protective facing (where it still remains) as well as the design of fixings and joints govern the distribution of any molten polystyrene and the supply of air and heat to the combustion zone. If adhesive has been used overall to attach expanded polystyrene material to a surface facing, melting will result in attachment to this surface. Where thick sheets have been installed, particularly horizontally, failure of a surface facing can result in the formation and falling of molten drops, often flaming. Such flaming drops can pose a serious fire hazard if they come into contact with combustible materials.

Where localized failure of a protective facing has occurred, air supply to and orientation of the surface of the exposed expanded polystyrene material are important in determining the subsequent risk of flame spread. For example, in a cavity wall insulated with expanded polystyrene material, extensive spread is unlikely because there is a lack of circulation of combustion air [32, 33].

It is possible to quantify the contribution made by the insulant to fire growth in freely ventilated enclosures where expanded polystyrene material insulant is used in wall panels or wall and/or ceiling linings. The extent of involvement of the insulant, amongst other factors, is dependent on the failure pattern of the protective facings and joints. With good design and careful selection of protective facings, the rate at which the insulant subsequently contributes heat, smoke, etc. to fire development inside an enclosure can be effectively reduced and the time to involvement substantially delayed [34, 35].

A large scale experimental research programme conducted by the Building Research Establishment (BRE) [31], simulating the effects of a fully developed room fire over large area of externally insulated masonry wall assemblies, has identified the design features affecting their fire performance.

Where expanded polystyrene sheeting is used, it is possible to reduce effectively the contribution made by the insulant to progressive vertical fire spread over the external finish or through the insulant/cavity provided:

- the protective weathering finish is carefully selected;
- the support for the expanded polystyrene sheeting is suitably designed and installed;
- there is correct installation around reveals;
- appropriate fire barriers are used.

The extent of fire damage can also be limited by taking these measures.

The fire performance of homogeneous lightweight renders containing expanded polystyrene beads as aggregates applied externally to solid masonry walls has been shown to be satisfactory [36].

Where expanded polystyrene materials are used as insulation above a metal deck, localized distortion of the joints can occur if a fire in the space below impinges on the soffit. Molten polystyrene or flammable decomposition products, formed under the influence of heat transferred through the deck, can be emitted through the resultant gaps formed in joints/junctions and their ignition contributes to the risk of fire spread below the roof [35]. Thick vertical sections of expanded polystyrene materials, e.g. in a cold store, can, in a fire, sometimes give rise to molten polystyrene flowing out onto the floor thus spreading the fire.

Large roof spans (e.g. five metres) containing ceiling sandwich panels of EPS can become unstable in a fire due to softening and melting and delamination of the core from the facings. Roof spans should not be used to support equipment or installations since loading data become inapplicable at elevated temperatures.

Standard small scale test methods are not always suitable for materials that are dimensionally unstable under the test conditions. 7.3 considers the suitability of the currently available test methods for EPS. Furthermore, since the fire performance of products including flame spread is to a great extent dependent on the composition of the product including any fixings, standard small scale tests are not always appropriate. Large scale test methods that more appropriately reflect end-use conditions are discussed in 7.3 and 7.4.

6.1.5 Smoke

Burning exposed expanded polystyrene materials are usually characterized by the emission of heavy, dense, black smoke. When assessing potential smoke emission from expanded polystyrene materials in a building under fire conditions, essential factors that should be considered include the possible extent of flame spread over any surface designed to protect expanded polystyrene materials, the ventilation conditions and the rate of decomposition of the polystyrene. Effective surface protection restricts flaming to areas where the coatings have failed and where molten polystyrene or gaseous decomposition products have escaped through joints and small fissures [34 and 48 to 50].

Prediction of the precise smoke-producing potential of polystyrene is difficult because of the wide range of combustion conditions likely to be met within an actual fire. Generalized conclusions from small scale tests have been substantiated by evidence from fire incidents. In a flaming fire, expanded polystyrene materials produce more smoke from a given mass of material than most other materials but it should be noted that expanded polystyrene materials contain typically only 2 % by volume of solid. The smoke particles produced in a flaming fire are large, black and irregular in shape. The density of the smoke produced increases with increasing temperature and with the intensity of the heat flux onto the material. In a smouldering fire, e.g. where the expanded polystyrene materials remain effectively protected and decomposition occurs in oxygen deficient conditions, small spherical grey particles predominate and the specific optical density values are lower than for flaming conditions.

Table 7 shows results obtained during comparative tests during interlaboratory trials with BS EN ISO 5659-2.

Table 7 — Comparison of smoke test results

Material	Thickness mm	Irradiance kW/m ²	Mean $D_{s,10}$
Expanded polystyrene (non-flame retardant; 14 kg/m ²)	25	25	112
		25 + pilot flame	102
		50	270
Plywood	25	25	251
		25 + pilot flame	33
		50	113
Medium-density fibreboard	25	25	420
		25 + pilot flame	68
		50	688

6.1.6 Toxicity

When organic materials such as wood, paper or plastics are burned, hot gases and smoke are evolved. All combustion gases produced can prove fatal in a short time if inhaled in sufficient concentration.

However the toxic hazard in fire arises through many factors including the rate of fire growth and the ambient ventilation conditions, as well as the inherent toxicity of the combustion products. This philosophy is embodied in BS 7899-1:1997 which details guidelines to be followed in the assessment of likely toxic hazard of a defined scenario. In this code of practice, a stepwise approach is used to include such factors as risk of ignition, rate of fire growth, flame spread, smoke producing potential, location and mobility of occupants and fire protection measures. An estimation of the risk (the likelihood of that hazard occurring) is also made.

The products of the thermal decomposition of polystyrene and their toxicity have been investigated in a study performed at the USA National Bureau of Standards (now NIST) [36]. According to this study, the most significant toxic products from burning polystyrene are carbon monoxide and styrene. Carbon monoxide can be fatal if inhaled for 5 min at a concentration of 15 000 ppm (see BS ISO TR 9122-5). Styrene has an odour which can be detected at 25 ppm to 50 ppm and which becomes intolerable at between 200 ppm and 400 ppm [37]. Eye irritation and nausea can occur at 600 ppm and some neurological impairment can occur at 800 ppm. In a fire, the styrene can be further decomposed to form carbon monoxide, carbon dioxide and water and other degradation products.

6.2 Structural fire performance

6.2.1 General

An essential regulatory requirements in buildings is the need to ensure that fires are wherever possible confined to the compartment of fire origin. The required structural fire performance is usually assessed by fire resistance tests on elements of the building structure. Various levels of thermal action may be used to simulate different fire scenarios. Probably the most widely used is the standard temperature/time curve, which serves as a simulation for a fully developed fire (see ISO 834-1). Other test fires used in certain situations include the smouldering fire, the semi-natural fire, the hydrocarbon fire and the external fire (such as exposure to fire emerging from a window of a building or from a free-burning external fire).

Resistance to fire performance characteristics which are assessed include load-bearing capacity, *R*, integrity, *E*, and insulation, *I* (see 3.4, 3.5 and 3.6). Other characteristics which may be specified under certain conditions for some elements include radiation, mechanical aspects, self-closing ability and smoke leakage.

Expanded polystyrene alone provides no fire resistance. When faced, expanded polystyrene assemblies will give different levels of fire resistance depending on the thermal inertia of the facing, the design and efficiency of the assembly and its installation; the key issue is the performance of the joint.

6.2.2 Walls

The fire resistance of masonry structures containing expanded polystyrene as partial or full fill cavity insulation is unaffected by the presence of the expanded polystyrene. Solid masonry walls lined internally or externally with expanded polystyrene, will retain their uninsulated fire resistance for *R* and *E*.

I performance will depend on which side of the wall is subjected to the fire. Other aspects of reaction to fire of internal and external insulation will depend largely on the facing materials and fixing systems. Where the expanded polystyrene is suitably protected, the onset of foam softening can be considerably delayed depending on the thermal efficiency of the protection and its ability to remain in position.

The fire resistance of expanded polystyrene light weight wall assemblies is governed by the ease with which the low density foams shrink away from the heat source. Hence, a large area heat source as applied in the tests given in parts 20 to 24 of BS 476 will result in the formation of air-gaps through which heat can be transferred more quickly than if the insulating foam had retained its position. The shrink-back time will depend on the thermal conductivity, density and specific heat of the facing; for example steel sheet will conduct heat quickly into the foam (usually within 5 min) whereas plasterboard will afford significantly longer protection (up to 20 min). Other coatings can offer significant protection to steel and the resultant effect is to increase shrink-back time.

6.2.3 Floors

Expanded polystyrene is primarily used in ground floor construction, for example as a floor finish, protected by structural concrete or cement screed/chipboard wearing surface. There is no fire resistance requirement for this element of structure in Building Regulations.

In floors, other than the lowest floor of a building, fire resistance is determined by the construction of the structural floor.

6.2.4 Ceilings and roofs

Where expanded polystyrene is used as an infill i.e. non-structurally, the fire resistance is determined by the design and materials of the structure. Reaction to fire aspects will depend largely on the facing materials and fixing system. Where the expanded polystyrene is suitably protected, the onset of foam softening can be considerably delayed depending on the thermal efficiency and its ability to remain in position.