Standard Category 1

S1085 A5 Fire Safety Performance of Materials - Stations and Tunnel Infrastructure

Contents

1 Purpose

The purpose of this standard is to define the requirements for the fire safety performance of materials, installed on the London Underground (LU) Stations and Tunnel Infrastructure.

The business objective of this standard is to ensure that the risk to which the public and employees are exposed is controlled to a level that is as low as reasonably practicable.

2 Scope

This standard specifies the requirements for materials within all locations as listed in LU standard S1086 'Fire safety classification of stations and shafts' with regard to:

a) Combustibility

b) Smoke emission

c) Toxic fume emission.

This standard applies to LU and Suppliers working on Building and Station Structure assets owned and/or operated by LU.

Rolling stock shall comply with S1180 'Standard for Rolling Stock'.

Note:	This standard does not cover the wider aspects of fire engineering. It may be necessary to invoke other London Underground, National or European Standards to cover fully all aspects of fire safety for a particular application. Guidance is available in G085.

2.1 Installations

This standard shall apply to installations:

a) In stations covered by The Fire Precautions (Sub-surface Railway Stations) England Regulations 2009 (FPSSR) and LU standard S1086

b) In running tunnels

c) In other locations that are not effectively separated from locations covered by a) or b) above

d) In all other locations where risks from combustibility, smoke or toxic fumes are not controlled to a level as low as reasonably practicable by other means.

2.2 Separation

Locations will be considered to be 'effectively separated' if they are either:

a) completely divided from the relevant stations and/or running tunnels by construction complying with Table 9, and there is no personnel access via that construction or

b) configured such that it can be demonstrated that the stations/tunnels are adequately protected by means of fire and smoke control, in accordance with

the relevant British Standards. This will require the support of a Fire Strategy, prepared, assured and accepted to be in accordance with LU standard S1080.

3 Requirements

3.1 General Requirements

Material and equipment for premises and locations to which this standard applies shall be selected on the basis of providing the best possible compliance to the fire safety performance described below with due consideration of the suitability and whole life cost of that material or equipment. Where alternatives in construction of equipment are or can be selected to improve performance or to mitigate risk these shall be considered to minimise the fire load, toxic fume and smoke emissions to as low as reasonably possible.

Where compliance to this standard cannot be fully achieved concession applications shall be submitted for approval, justifying the selection of such equipment and material for the application proposed, describing how the most suitable material and equipment has been selected and how its residual risk has been mitigated.

All tests for combustibility, smoke emission and toxic fume should be undertaken by test houses accredited by the National Accreditation bodies, preferably, within the UK or relevant European Union country. A copy of any test reports shall be made available to LU on request.

All materials shall be tested to replicate their intended application, i.e. a panel or surface to be used free-standing, with no backing or substrate, shall be tested in that manner. Similarly, where a panel or coating is to be used on a particular substrate, that substrate shall be used as backing for the sample to be fire tested. If there are direct application rules available, testing of one substrate can be applicable to other substrates (i.e. BS EN 13238).

Note:	Where it is intended to use the material on a number of substrates or in different applications, it may be prudent to consult the testing body so that the desired range of applications can be covered by the minimum amount of physical testing. It is usually appropriate (for assurance purposes) for the relevant test laboratory to issue a report containing a 'Field of application' that defines the allowed use of the material, substance or treatment, in the context of this standard.

3.2 Toxic Fume emission – All products

Toxic fume emissions shall be tested according to the following process:

a) Evidence shall be provided to confirm that all combustible materials do not contain the following elements, which are known to potentially give rise to toxic fume emission: Halogens, Nitrogen, Sulphur. This evidence shall be in the form of qualitative analysis using x ray fluorescence spectroscopy, and the instrument used shall be able to detect elements with atomic numbers down to Nitrogen. All layers of composite materials shall be tested. This test may however be omitted if the tests described in (b) or (c) below are undertaken.

b) If any of the proscribed elements are detected, the potential for toxic fumes to be produced during combustion shall be quantified using either the area based

test detailed in Attachment A.2 for surfaces or the mass based test detailed in Attachment A.1. The requirement shall be that the calculated Immediately Dangerous to Life or Health Concentrations (IDLH) level of the gases detected, as detailed in the The National Institute for Occupational Safety and Health (NIOSH) Guide to Chemical Hazards, shall not impair escape, for the intended location or environment.

Note:	The toxic fume test methodology is described in Attachment A of this standard.

c) Paint materials can be tested in accordance with BS EN 45545-2:2013+A1:2015, Method 1. The requirement shall be a maximum Conventional Index of Toxicity (CIT) value of 0.75. Additionally, the parts per million (PPM) values of the detected gases shall be recorded.

d) In cables, only the outer sheathing materials shall be tested for toxic fume emissions when separated by a non-combustible layer (i.e. continuous layers of metal, steel wire armour, steel tape armour, concentric conductors which offer mechanical protection or fire resistant tapes).

3.3 Vertical and ceiling surfaces

3.3.1 Combustibility - walls and ceiling

All public facing vertical wall and ceiling surfaces shall meet the requirements of class B-s1, d0, when tested in accordance with BS EN 13501-1. Alternatively, products shall comply with the requirements of an index of performance (I) not exceeding 12 and sub-index (i_1) not exceeding 6 when tested to BS 476: Part 6 and class 1 to BS 476: Part 7.

3.3.2 Combustibility - other than walls and ceiling (e.g. small panels)

All vertical and horizontal prone surfaces other than walls and ceilings are considered compliant with combustibility requirements if they meet the criteria given above in clause 3.3.1. Alternately, the following tests can also be carried out to demonstrate compliance:

Test Method	Requirement
ISO 5658-2	*CFE* ≥ 20 kWm^{-2} with no flaming droplets/particles
ISO 5660-1: 50 kWm^{-2}	*MARHE* ≤ 60 kWm^{-2}

Table 1 – Combustibility requirements for surfaces other than walls and ceiling

3.3.3 Smoke Emission

Location	Test method	Requirement
Option 1		
Vertical and ceiling surfaces in tunnels	S1085, Attachment B.6	Ao(ON) < 2.4sq.m/burn area Ao(OFF) < 3.6 m^2/burn area
Vertical and ceiling surfaces in stations	S1085, Attachment B.6	Ao(ON) < 3.6 m^2/burn area Ao(OFF) < 5.4 m^2/burn area
Option 2		
Vertical and ceiling surfaces in stations	EN ISO 5659-2: 50 kWm^{-2}, without pilot flame	*a)* *D*s maximum, dimensionless, ≤150 b) *VOF*4 minutes ≤ 300

Table 2 – Smoke emission requirements for all vertical and ceiling surfaces

3.4 Flooring surfaces

3.4.1 Combustibility

All flooring surfaces shall comply with the requirements of class B_{fl} outlined in BS EN13501-1 or, alternatively, BS476: Part 7, class 2.

3.4.2 Smoke Emission

Location	Test method	Requirement
Option 1		
Flooring surfaces in tunnels	S1085, Attachment B.7	Ao < 250 m^2/m^2
Flooring surfaces in stations	S1085, Attachment B.7	Ao < 350 m^2/m^2
Option 2		
Flooring surfaces	EN ISO 5659-2: 25 kWm^{-2}, with pilot flame	*D*s maximum, dimensionless, ≤ 150

Table 3 – Smoke emission requirements for floor composites

3.5 Seats

The backs of seats on station platforms shall be considered as vertical surfaces and the bases of seats on station platforms shall be considered as supine surface, i.e. flooring mode. If a seat is formed from a single fabrication, the material shall meet the requirement for vertical surfaces.

3.6 Cables

Cables can be considered compliant for combustibility and smoke emission by meeting the requirements listed in one of the following options.

3.6.1 Option 1

3.6.1.1 Combustibility & smoke emission

Cables that are subject to the Construction Products Regulation (CPR) in Great Britain shall meet the test requirements of class C_{ca}-s1a,d0,a3 as defined in BS EN 13501-6 or the equivalent classification required for UKCA marking.

3.6.2 Option 2

3.6.2.1 Combustibility

The burn height results obtained from tests described in the following standards, shall comply with the values given below in Table 4.

Cable overall diameter	Test method	Requirement
greater than 12mm	BS EN 60332-3-24	< 2.5 m
equal to or less than 12mm	BS EN 60332-3-25	< 2.5 m

Table 4 – Flame spread requirements for cables

There shall not be any flaming droplets and/or particles during the first 10 minutes of the test. Flaming droplets and/or particles are defined in BS EN 13501-6.

Note:	If a cable is fully encased in a non-combustible enclosure (i.e. steel conduit), there is no need to comply with the requirements of flaming droplets and/or particles.

Alternatively, for cables which have an overall diameter of < 3.5 mm, the vertical ladder tests described above may be substituted for a temperature index test, according to the criteria given below in Table 5.

Standard	Radial Thickness of Sheath	Requirement
BS EN ISO 4589-3	>0.4mm <0.4mm	280 ^{o}C 350 ^{o}C

Table 5 – Combustibility requirements for small diameter cables

3.6.2.2 Smoke Emission

The maximum permitted smoke emission which is related to overall cable diameter as tested in accordance with BS EN 61034-2 shall be:

a) $Ao(ON) < 0.7[\tan^{-1}(d/45)/45 - \tan^{-1}(d)/2025]$

b) $Ao(OFF) < 1.8Ao(ON)$

Where d = cable diameter in mm. A minimum of two tests shall be undertaken. If one result represents a failure, a third test shall be required to confirm the result.

3.7 Non-listed items

3.7.1 Public locations

Small electro-technical components and all other miscellaneous items and materials not included in 3.2, 3.3, 3.4 and 3.5 shall be tested on the basis that the results

obtained will relate to the composite construction of the particular item unless otherwise stated.

The results of tests, described in the following standards for extensive and grouped usage, shall comply with the values given below in Table 6:

Test Method	Requirement
Combustibility Test Options	
BS EN ISO 4589-2: Limiting Oxygen Index	LOI > 40% or
BS EN ISO 4589-3: Temperature Index	TI > 350 ^{o}C
Smoke Emission Test Options	
S1085, Annex B.5	A0 < 0.005 m^2/g or
EN ISO 5659-2: 25 kWm^{-2}, with pilot flame	*D*s maximum, dimensionless, ≤ 150

Table 6 – Flammability and smoke emission requirements for non-listed items (extensive and grouped usage)

The results of tests described in the following standards for limited and dispersed usage shall comply with the values given below in Table 7:

Test Method	Requirement
Combustibility Test Options	
BS EN ISO 4589-2: Limiting Oxygen Index	LOI > 30% or
BS EN ISO 4589-3: Temperature Index	TI > 300 ^{o}C
Smoke Emission Test Options	
S1085, Annex B.5	A0 < 0.02 m^2/g or
EN ISO 5659-2: 25 kWm^{-2}, with pilot flame	*D*s maximum, dimensionless, ≤ 300

Table 7 – Flammability and smoke emission requirements for non-listed items (limited and dispersed usage - public)

3.7.2 Non-public locations

Items within within a non-public compartment,where a fire detection and alarm system compliant with LU standards is installed to cover that room, can meet the test requirements listed in Table 8. The requirements for a fire resistant structure are given Table 9. Alternatively materials will also be accepted when meeting the requirements of Clause 3.6.1

Electrotechnical and other non-listed items	
Combustibility	BS EN ISO 4589-2: LOI > 28% (UL94 V0 is also acceptable for the respective thickness of the material)
Smoke Emission	EN ISO 5659-2: 25 kWm^{-2}, Ds(max) <600
Light diffuser and any transparent/translucent items of surface area < 0.2 m^2	
Combustibility	BS ISO 5658-2, CFE > 13 EN 11925-2, Flame spread < 150 mm within 60 s with no flaming droplets.

Table 8 – Flammability and smoke emission requirements for non-listed items (limited and dispersed usage – non-public)

Profile	**Test Standard**	**Classification (BS EN 13501-2)**
Walls and glazing	BS EN 1364-1	EI 60
Ceilings / Soffits	BS EN 1364-2	EI 60 (a↔b)
Floors	BS EN 1365-2	REI 60
Doors	BS EN 1634-1	EI_2 60
Fire doors with a minimum classification of E 60 are also acceptable, provided they satisfy the requirements of BS 9999 and the Approved Document B and are suitable for the proposed use.The door openings must not exceed maximum of 25% of the length of a compartment wall.		
Cable Penetrations	BS EN 1366-3	EI 60
Linear gap seals	BS EN 1366-4	EI 60
Profile	**Test Standard**	**Classification (BS EN 13501-3)**
Ducts	BS EN 1366-1	EI 60 (i↔o) ve,ho S
Dampers	BS EN 1366-2	EI 60 (i↔o) ve,ho S

Table 9 – Requirements for fire-resistant structures

3.8 Surface Locations

The following are applicable to public areas of surface stations, in addition to any relevant regulatory requirements (i.e. Building Regulations 2010 for England.- Approved Document B) :

a) All materials used in the construction of internal walls and ceilings should be classified as A2-s3, d2 or better in accordance with EN 13501-1;

b) Surface finishes applied to all walls and ceiling should be classified as B-s3, d2 or better in accordance with EN 13501-1;

c) Items within public and non-public areas of sub-surface locations where those areas are fitted with fire detection and suppression systems compliant with LU standards shall be treated as a surface location. Escalator Machine Chambers (EMCs) are not part of this exemption. Requirements for a smoke management system shall be determined from the Fire Strategy for the specified location in accordance with LU standard S1080.

Note: All public facing walls and ceiling of a sub-surface station, including retail areas, must comply with the requirements of FPSSR

3.9 Enclosed Locations

Enclosed locations that are not classified as sub-surface should meet the Clause 3.7 with the addition of achieving Classification B_{fl} to EN 13501-1

3.10 Commentary on smoke emission tests

The smoke emission test methodology for items detailed in clauses 3.2, 3.3, 3.4 and 3.6 is described in Attachment B of this standard.

If a risk assessment is required for non-compliance with smoke emission, it can only be conducted using data from the test methodology described in Annex B. This risk assessment must form part of a concession application that details other mitigations.

The smoke emission results when tested to EN ISO 5659-2 will only be valid for the specified thickness in the test report.

3.11 Non-applicable and excepted materials and locations

The requirements in this standard shall not apply to:

a) Items which are temporarily used and then removed from public areas (including tunnels) prior to start of traffic hours

b) Consumables, portable electrical equipment, portable furniture and personal effects where these items are contained within staff accommodation, ticket offices and administration areas and where those areas are covered by fire detection and alarm systems compliant with LU Standards

c) Items within public areas, such as retail units, where those areas are fitted with fire detection and suppression systems compliant with LU standards. Requirements for a smoke management system shall be determined from the Fire Strategy for the specified location in accordance with LU standard S1080

d) Minor use materials – single, or joined items, providing they have:

   i) A total mass not more than 100 g or

   ii) An area (in the case of surface coatings) of not greater than 0.2 m^2.

e) Material samples which differ only in colour from those already tested, providing the colourant does not exceed 5% (w/w)

f) Material of class A2-s1, d0 or better as defined in EN 13501-1

g) Materials and enclosures within a fire-resistant structure listed in Table 10. The requirements of a fire-resistant structure are given in Table 9.

Excepted Materials	Conditions
1) All materials	When located within a fire-resistant, non-public room where the volume of the room is <120m^3; and where a fire detection and alarm system compliant with LU standards is installed to cover that room.
2) All materials	When located within a fire-rated, non-public room where the volume of the room is <240m^3; where the room has multiple means of escape, of which two will be opposite to each other; and where a fire detection and alarm system compliant with LU standards is installed to cover that room.

3) Materials within minimum IP5X non-combustible enclosures	When located within a fire-resistant, non-public room; and where a fire detection and alarm system compliant with LU standards is installed to cover that room. Multiple enclosures are permitted.
4) Materials within non-combustible enclosures (non IP-rated)	When located within a single non-combustible enclosure in a fire-resistant, non-public room; and where a fire detection and alarm system compliant with LU standards is installed to cover that room. Multiple enclosures are permitted when separated by a minimum distance of 0.7 m.

Table 10 – Excepted materials in fire-resistant structures

3.12 Evidence of compliance

Compliance with the requirements of this standard shall be demonstrated to LU by each party contracted to LU. Additionally, LU may audit compliance as part of its surveillance regime.

4. Responsibilities

Principal Engineering Leader (Fire) or his representative, London Underground is responsible for:

a) the custodianship and quality of this standard, and for its programmed review

b) ensuring that the content is appropriate and correct for the purposes of the standard

c) operation of the concession process.

The LU Procurement agent shall be responsible for incorporating the requirements of this engineering standard into any contract to which it is relevant and shall stipulate that a programme of audits are implemented by the contractor which ensures that these requirements are met.

5 Supporting information

5.1 Background

The requirements of this standard are separate and independent from the fire resistance, fire protection and fire prevention requirements of FPSSR, excepting paragraphs 8(1) and 8(2). In particular, a material's installation that complies with those Regulations may not necessarily comply with this standard. This is, in part, because the Regulations do not address the smoke and toxic fume emission requirements, which are covered in this standard.

5.2 Regulations

Users of this standard should note that compliance with the requirements in this standard would not necessarily achieve compliance with the legal requirements of FPSSR. The technical criteria outlined in this legislation and the associated

governmental guidance reproduced are therefore to be considered as applying to all materials used in the construction of an internal wall or ceiling in any public area of all railway stations within the scope of this standard.

Note: FPSSR has two prescriptive requirements in relation to this standard

"*Materials used in internal construction of premises*

8. (1) Any material which is used in the construction of an internal wall or ceiling in any public area must be of limited combustibility (class A2 or better as defined in EN 13501-1).

(2) To inhibit the spread of fire within the premises, any material which is applied to the surface of an internal wall or ceiling in any public area must—

(a) adequately resist the spread of flame over the surface; and

(b) have, if ignited, either a rate of heat release or a rate of fire growth, which is reasonable in the circumstances"

5.3 Safety considerations

Failure to meet the test criteria or the requirements set out in this document may mean that an installation does not meet the requirements of the Fire Precautions (Sub-Surface Railway Stations) Regulations 2009, paragraphs 8(1) and 8(2) or other safety-related legislation.

6 Person accountable for the document

Name	Job title
Tom Kardos	Principal Engineering Leader (Fire)

7 Definitions

Term	Definition	Source
Smoke	visible part of fire effluent	Jargon Buster
Limited / dispersed materials	Where the mass is greater than 100g and less than 500g, and where there is a separation of not less than 0.5m between materials.	Jargon Buster
Extensive / grouped materials	Where the mass and separation exceed the definition of limited/dispersed materials.	Jargon Buster
Minor use materials	Where total mass and surface area do not exceed 100g or 0.2sqm respectively, regardless of separation between materials.	Jargon Buster
Enclosed location	Station where at least one platform accessible to the public and any part of its associated permanent way is covered by a roof, building, bridge or tunnel continuously for over 50 m.	Jargon Buster

8 Abbreviations

Abbreviation	Definition
IDLH	Immediately Dangerous to Life or Health
LOI	Limiting Oxygen Index
TI	Flammability Temperature Index
CPR	Construction Products Regulation
FPSSR	The Fire Precautions (Sub-surface Railway Stations) England Regulations 2009

9 References

Document no.	Title or URL
SI 2009/782	The Fire Precautions (Sub-surface Railway Stations) (England) Regulations 2009
BS 4422: 2005	Fire - Vocabulary
BS 6853: 1999 Incorporating Amendment No. 1	Code of practice for fire precautions in the design and construction of passenger carrying trains
BS EN 13238:2010	Reaction to fire tests for building product — Conditioning procedures and general rules for selection of substrates
BS EN 45545-2:2020	Railway applications. Fire protection on railway vehicles. Requirements for fire behaviour of materials and components
BS EN ISO 4589-2:2017	Plastics. Determination of burning behaviour by oxygen index. Ambient-temperature test
BS EN ISO 4589-3:2017	Plastics. Determination of burning behaviour by oxygen index. Elevated temperature test
BS EN IEC 60332-3-24:2018	Tests on electric and optical fibre cables under fire conditions. Test for vertical flame spread of vertically-mounted bunched wires or cables. Category C
BS EN IEC 60332-3-25:2018	Tests on electric and optical fibre cables under fire conditions. Test for vertical flame spread of vertically-mounted bunched wires or cables. Category D
BS EN 13501-6:2018	Fire classification of construction products and building elements. Classification using data from reaction to fire tests on electric cables
BS EN 13501-1:2018	Fire classification of construction products and building elements. Classification using test data from reaction to fire tests
BS 476-6:1989+A1:2009	Fire tests on building materials and structures. Method of test for fire propagation for products
BS 476-7:1997	Fire tests on building materials and structures. Method of test to determine the classification of the surface spread of flame of products

BS ISO 5658-2:2006+A1:2011	Reaction to fire tests. Spread of flame. Lateral spread on building and transport products in vertical configuration
BS ISO 5660-1:2015+A1:2019	Reaction-to-fire tests. Heat release, smoke production and mass loss rate. Heat release rate (cone calorimeter method) and smoke production rate (dynamic measurement)
BS EN 61034-1:2005+A2:2020	Measurement of smoke density of cables burning under defined conditions. Test apparatus
BS EN 61034-2:2005+A2:2020	Measurement of smoke density of cables burning under defined conditions. Test procedure and requirements
BS EN 1364-1:2015	Fire resistance tests for non-loadbearing elements. Walls
BS EN 1364-2:2018	Fire resistance tests for non-loadbearing elements. Ceilings
BS EN 1365-2:2014	Fire resistance tests for loadbearing elements. Floors and roofs
BS EN 1634-1:2014	Fire resistance and smoke control tests for door and shutter assemblies, openable windows and elements of building hardware. Fire resistance test for door and shutter assemblies and openable windows
BS EN 1366-1:2014+A1:2020	Fire resistance tests for service installations. Ventilation ducts
BS EN 1366-2:2015	Fire resistance tests for service installations. Fire dampers
BS EN 1366-3:2009	Fire resistance tests for service installations. Penetration seals
BS EN 1366-4:2006+A1:2010	Fire resistance tests for service installations. Linear joint seals
BS EN 13501-2:2016	Fire classification of construction products and building elements. Classification using data from fire resistance tests, excluding ventilation services
BS EN 13501-3:2005+A1:2009	Fire classification of construction products and building elements. Classification using data from fire resistance tests on products and elements used in building service installations: fire resisting ducts and fire dampers
BS 7671:2018+A1:2020	Requirements for Electrical Installations. IET Wiring Regulations
BS 9992: 2020	Fire safety in the design, management and use of rail infrastructure — Code of practice
G085	Code Of Practice - Fire Safety Of Materials And Fire Safety Of Specific Items And Materials Used In The Underground
S1080	Standard for Rolling Stock

S1086	Fire safety classification of stations and shafts
G0137	Guidance - Walls, partitions and ceilings in Sub-Surface Stations

10 Document history

Issue no.	Date	Changes	Author
2-01001-002 A1	December 2003	Standard E1042 A6, re-formatted and re-numbered to 2-01001-002,	Mr Martin Weller
1-085 A1	March 2008	Re-written by LU in consultation with Infracos between July 2004 and July 2007	Mr Martin Weller
1-085 A2	December 2008	Clause 3.2.4.2 amended in line with outcome from the October 2007 Concessions Forum	Mr Martin Weller
1-085 A3	March 2011	Update as per DRACCT 00274 – Correction of references to British and European Standards	Mr Martin Weller
S1085 A4	December 2015	Renumbered and re-written to reflect the changes to the national and European standards, regulations and the industry best practice as per DRACCT No.04304.	Dr Sam Sambasivan
S1085 A5	January 2023	Renumbered and re-written to reflect the changes to the national and European standards, regulations and the industry best practice as per change request No. CR-17100.	Dr Sam Sambasivan

11 Attachments

11.1 Attachment A - Determination of toxic fume

A.1 Mass based test method (NF X 70-100)

The test method given in NF X 70-100 should be used with the following modifications. Qualitative screening should not be used. All species should be quantified in all cases. Test should be carried out at 600°C.

Note:	There is a requirement to determine nitrogen dioxide and nitric oxide and to express the results as nitrogen dioxide.

A.2 Area based test method (BS EN 2826)

The area based test method should be in accordance with BS EN 2826, with the following modifications.

The test fire model should be replaced by the heating arrangement specified in BS ISO 5659-2; i.e. a conical heating element with a horizontal test piece.

The flux used should be 25 $kW \cdot m^{-2}$, in the flaming mode only.

A single smoke emission only test should be carried out and the time at which 85 % of the peak smoke emission is reached, (or the value at 20 min if no maximum is reached), should be determined.

Toxic fume emission testing should then be carried out in triplicate and the average of these used to calculate the R value in accordance with clause A.4.

The collection/measurement of toxic fume should commence at the previously determined time to reach 85 % of the peak smoke emission.

The toxic fume emission should be expressed in grams per square metre of material, assuming that the area of the test piece is 0.005 8 m2. This is calculated as follows:

$$TFE = (VF \times V_{chamber} \times M) / (V_m \times A)$$

where:

VF = the measured volume fraction of the toxic species under consideration, usually measured in parts per million (ppm);

$V_{chamber}$ = the volume of the test chamber = 0.51 m^3;

M = the molar mass of the toxic species under consideration;

V_m = the molar volume at 25 °C and 1 atm (assuming ideal gas behaviour)

= 0.024 5 $m^3 \cdot mol^{-1}$;

A = the area of the test specimen = 0.005 8 m^2.

Example

Given that the measured volume fraction of carbon monoxide is 200 ppm, (200×10^{-6}), then:

$$TFE = (200 \times 10^{-6} \times 0.51\ m^3 \times 28\ g \cdot mol^{-1}) / (0.0245\ m^3 \cdot mol^{-1} \times 0.0058\ m^2)$$

$$= 20.1\ g \cdot m^{-2}$$

There is a requirement to determine nitrogen dioxide and nitric oxide and to express the results as nitrogen dioxide.

A.3 Gases to be analysed

The eight gases listed in Table A.1 with their common limiting values (IDLH values, see A.4) should be the minimum set for which analysis is performed.

Gases	IDLH value	
	ppm	mg/m^3
Carbon dioxide	40000	73000
Carbon monoxide	1200	1400
Hydrogen fluoride	30	25
Hydrogen chloride	50	76
Hydrogen bromide	30	101
Hydrogen cyanide	50	56
Nitrogen dioxide	20	38
Sulfur dioxide	100	270
Note: Nitrogen dioxide includes nitric oxide expressed as nitrogen dioxide.		

Table A.1 - IDLH Values

A.4 Calculation of Toxicity Index (R)

A.4.1 General

The quantities listed in columns 2 and 3 of Table A.1 are the parts per million and milligrams per cubic metre levels used as the basis for generating the reference values which convert the analytical results for the combustion products generated in the test into an overall toxicity rating. The values in Table A.1 are the IDLH values of the listed gases (the concentration of the gas in the atmosphere which for an exposure time of 30 min is Immediately Dangerous to Life or Health) given in The National Institute for Occupational Safety and Health (NIOSH) Guide.

These values have been chosen because it is anticipated that much of the hazard analysis will be carried out using data generated in cumulative tests which generate single point potency values for each gas or where time based data is used to generate a single point value.

The values in Table A.1 have been converted into reference values and these are given in Table A.2. The values in Table A.2 have units of milligrams per gram if used with NF X 70-100 data or grams per square meter if used with BS EN 2826. This coincidence of numerical values arises because of the selection of 0.5 m, (0.5 m

width, 1.0 m height) and 500 g as the general design levels for surfaces and materials respectively. The values in Table A.2 are given to two significant figures which is sufficient for, and consistent with, the general nature of the analysis and guidance.

Gases	**Reference value** Mg g^{-1} or g m^{-2}
Carbon dioxide	14000
Carbon monoxide	280
Hydrogen fluoride	4.9
Hydrogen chloride	15
Hydrogen bromide	20
Hydrogen cyanide	11
Nitrogen dioxide	7.6
Sulfur dioxide	53

Table A.2 - Reference values for gases

A.4.2 Calculation

Calculate the weighted summation index, R, from the data obtained in accordance with A.1 or A.2 as follows.

Divide the value for each species by its reference value given in Table A.2 to obtain its individual index, r, and then sum the individual indices to give the weighted summation index, R, in accordance with the following equations:

$$r_x = c_x / f_x$$
$$R = \sum r$$

where:

c_x is the emission of the x^{th} species, in the appropriate units;
f_x is the reference value for the x^{th} species, as given in Table A.2;
r_x is the individual index for the x^{th} species.

If the requirement of R < 1 is achieved, the material can be considered compliant with this standard. For materials that do not meet this requirement, additional calculations can also be carried out to determine the risk in accordance with LU Code of practice G085.

11.2 Attachment B: Methods for measuring smoke density

B.1 General

This annex gives the test apparatus and verification procedure to be used for the measurement of smoke density of the products of combustion of materials. It includes details of the 3 m cube test apparatus, the photometric system for light measurement, the qualification procedure, the fire sources appropriate to the different materials to be tested, and the smoke mixing method.

B.2 Apparatus

The details of the test apparatus for measuring smoke emission and the verifications procedures shall be as defined in the BS EN 61034-1.

B.3 Fire Sources

B.3.1 Fire source 1

The fire source shall be as defined in BS EN 61034-1.

B.3.2 Fire source 2

The fire source should consist of 0.5 kg of softwood charcoal, cut and sieved so that the particles pass through a 37 mm sieve but are retained by a 25 mm sieve; any bark or uncharred wood should be discarded. The charcoal should be conditioned immediately before the test by maintaining it for 16 h at 20 ^{o}C ± 5 ^{o}C and at 50 % ± 20 % relative humidity.

A wire frame should be constructed from metal wire of nominal diameter 2 mm, arranged into a square construction as follows:

a) four wire corner posts 50 mm high;

b) connecting wires 200 mm long connecting the posts at the top and a second row of connecting wires connecting the posts at their mid-points.

Prior to performing a test, the measured amount of charcoal should be immersed in alcohol, as used in fire source 1, for a minimum of 20 min before being placed on a wire mesh over a tray and allowed to drain for a period of 5 min ± 1 min. The fire source should then be positioned evenly within the wire frame and ignited within 5 min of being drained.

B.4 Numbers of specimens to be tested

Initially two specimens should be tested for each sample of material. Where there is greater than 20 % variation in the results, a third test should be performed. The mean value of all tests should be used to establish the category of performance.

B.5 Small-scale test

Note:	Where small specimens, such as will be consumed within 5 min, are to be tested, fire source 1 would continue to burn long after smoke levels have stabilized. In such cases, testing time may be reduced by using half the quantity of alcohol given for fire source 1, but in the same container. Care needs to be taken to ensure that the specimen is mounted at the correct height above the alcohol surface.

The nature of any irregularly shaped article should be stated in the test report. Comparisons between specimens are only valid if testing is carried out in the same manner, using the same support.

Fire source 1 should be used for this test.

The test specimen size should be 140 mm x 60 mm x 3 mm and the specimen should be supported horizontally over the tray, with the long side of the specimen

parallel to the long side of the tray, at a height of 175 mm ± 5 mm above the surface of the alcohol. A schematic arrangement is shown below in Figure B.1.

All dimensions are in millimetres

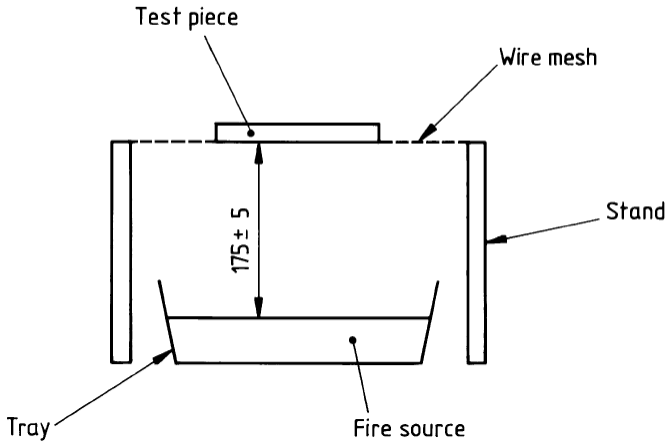


Figure B.1: Schematic arrangement of small-scale test

A wire mat of nominal 25 mm mesh should be used for samples which are self-supporting throughout the test; a wire mat of nominal 12 mm mesh should be used for samples which show some thermoplasticity and are inclined to sag, and a copper foil tray (having a thickness of copper of 0.1 mm) should be used for samples which form a mobile phase. The mat should be at least 10 mm wider and longer than the sample, with turned up edges of nominally 5 mm.

Test pieces which do not conform to the defined size and thickness can be used provided this is noted in the test report. Where the material is either significantly thinner than 3 mm or is of low density and where this results in levels of smoke emission which are so low as to compromise accuracy, the material can be piled to increase the mass combusted. The number of layers used should be noted in the test report.

Ignite the fire source and record the optical density in the cube. Calculate A_0 in accordance with B.8.

B.6 Panel Test

Note:	This test gives reliable information about the smoke emission from surfaces and relatively thin panels. It is not suitable for testing thermoplastic materials. Where multi-layer constructions are used, great care should be taken in the interpretation of the results because of the modest rate of heat input of the test. For example, an organic material faced with a thin (e.g. 0.7 mm) aluminium sheet may perform extremely well, whereas under larger or real fire conditions, penetration may occur giving much higher levels of smoke.

CAUTION: If a specimen collapses this test method may result in the burning alcohol becoming spread over the floor of the cube.

Use fire source 1 for this test.

The test specimen size should be 1 000 mm x 500 mm and of thickness appropriate to the intended end use. The sample should be supported continuously along all edges on an angle frame of 25 mm maximum width and inclined at 60º to the horizontal with the short side of the specimen horizontal and with the unexposed surface facing the back wall.

The general arrangement is shown schematically in Figure B.2.

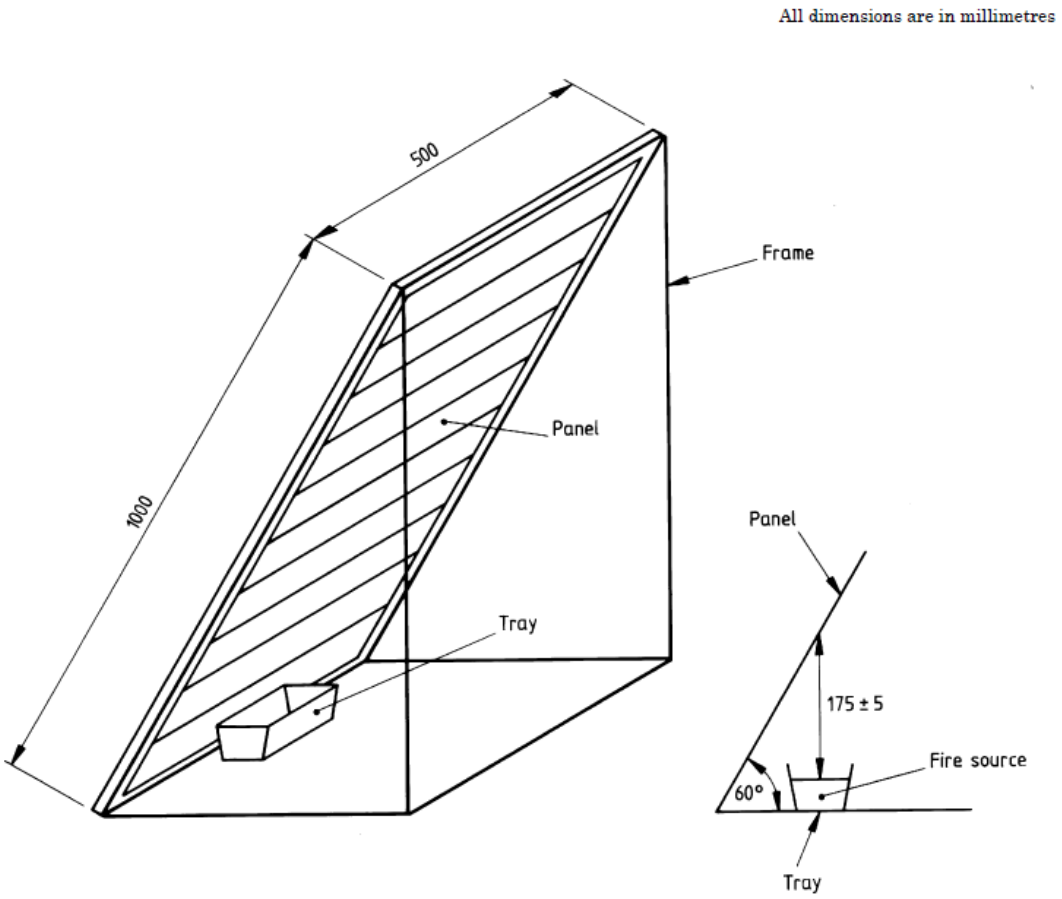


Figure B.2: Schematic arrangement of panel test

The fire source should be placed so that the centre of the surface of the alcohol is 175 mm ± 5 mm from the surface of the specimen when measured normal to the alcohol surface, with the long side of the tray parallel to the short side of the specimen. With this arrangement there is an approximate 10 mm gap between the long side of the tray (nearest to the test piece) and the test piece. With some specimens it may be necessary for restraining clips or bolts to be used to prevent excessive movement in the test.

Ignite the fire source and record the optical density in the cube. Record the depth of burn. Calculate A_0 in accordance with clause B.8.

B.7 Flooring test

The specimen tested should be of the total proposed flooring system including, for example, the fixing technique (e.g. adhesive).

Note:	Individual flooring materials may be tested for development or comparison purposes, but the results cannot be taken as necessarily representing the performance of the material as it will be used.

Use fire source 2 for this test.

The test specimen size should be a minimum of 300 mm x 300 mm and a maximum of 600 mm x 600 mm.

For a mattress, a whole mattress should be tested. The fire source should be positioned centrally on the specimen. Figure B.3 shows a schematic arrangement for the test.

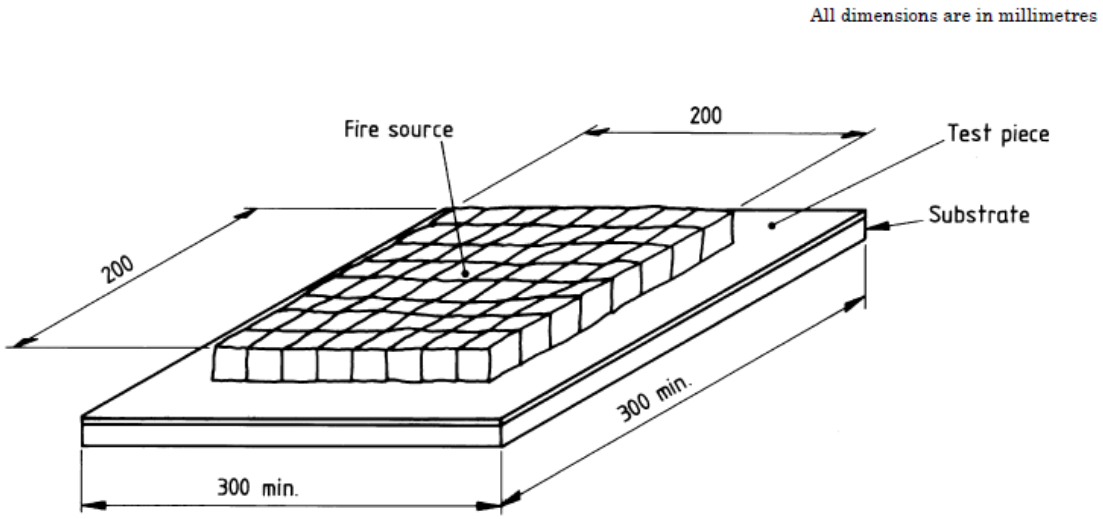


Figure B.3: Schematic arrangement of flooring test

Ignite the fire source and record the optical density in the cube. Calculate A_0. The depth of burn shall be recorded.

B.8 Calculation and expression of results

The measured optical density (Am) is calculated as follows:

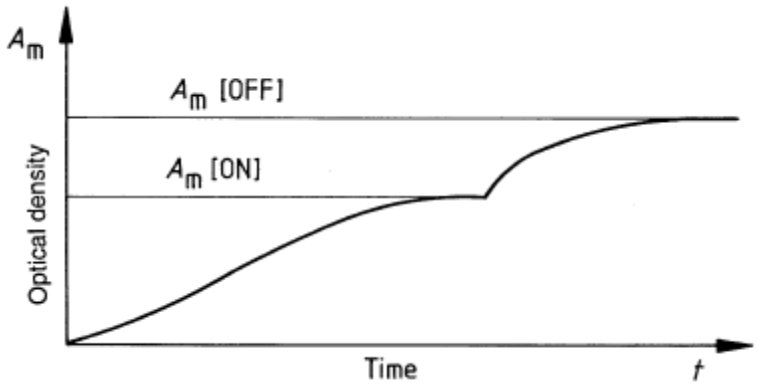
$A_m = \log_{10} (I_0/I_t)$

where

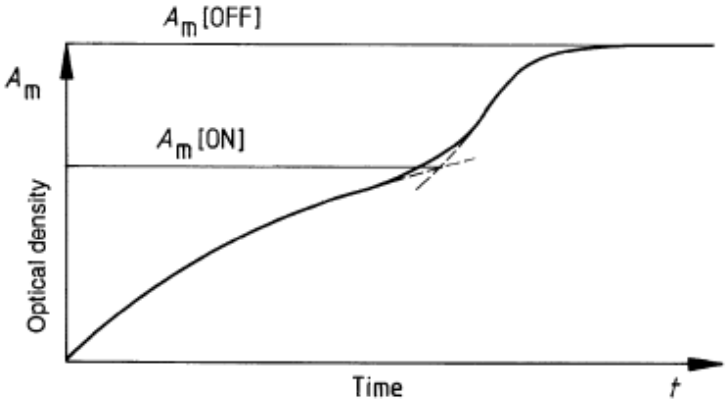
I_0 is the initial luminous intensity;

I_t is the transmitted luminous intensity.

In two-phase tests, i.e. where a smouldering phase occurs, the value of A_m is calculated for the two points shown below in Figure B.4.

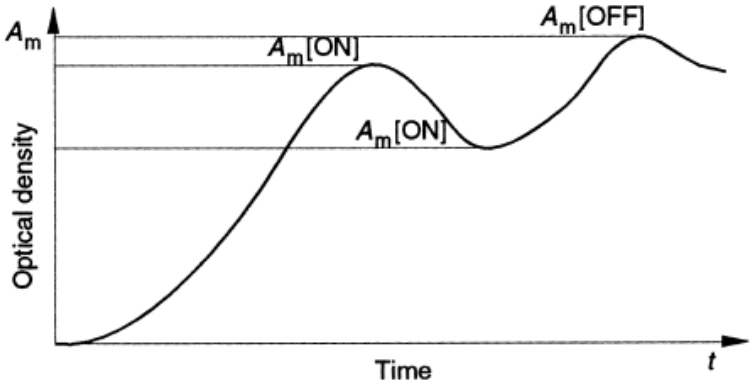


a) Ideal curve



b)

b) Extrapolation of “knee” point



b) Variation in A_m(ON) due to various loss mechanisms

Figure B.4: Smoke emission curves

The A_0 value is the optical density produced across the opposite faces of a cube of side 1 m when one unit of material is burnt under the specified conditions, and is calculated to three significant figures using the following equation:

$A_0 = A_m \times V/(k \times l)$

Where

A_m is the optical density measured in the cube;

V is the volume of the cube (m3);

l is the length of the optical path between windows (m);

k is the number of units of material constituting the test specimen.

The value of *k* is 1 for the panel and seat tests, 0.04 m^2 for the floor test and the mass of the test piece (g) for the small scale test.

Where a maximum is reached in the (OFF) phase this is defined as the end point of the test. Thus:

A_0 (OFF)$_{end}$ = A_0 (OFF)$_{max}$

Where a maximum occurs during the (ON) phase of a two-phase test, the A_0 (OFF) value is corrected for the reduction in optical density between the maximum value and the end of the ON phase in accordance with the following equation:

A_0 (OFF)$_{corr}$ = A_0 (OFF)$_{end}$ + A_0 (ON)$_{max}$ - A_0 (ON)$_{end}$

Note: The values quoted shall be as follows:

- A_0 (ON)max, which for the purposes of reporting is designated A_0 (ON); and

- A_0 (OFF)corr, which for the purposes of reporting is designated A_0 (OFF).

B.9 Test report

The test report should include the following information:

a) the name of the testing establishment;

b) the date of the test;

c) a reference to this Standard;

d) identification of the material tested;

e) the test specimen form and any variation from the recommended dimensions;

f) the bundling arrangements (for cable tests);

g) the A_0 value recommended for the material;

h) the A_0 value obtained in each test;

i) mean and standard deviation of the A_0 values;

j) the number of specimens tested;

k) the % transmittance/time (and preferably A_0/time) graphs. These data should be made available electronically, for example in ASCII format on a disc;

l) observations about timings for the ignition and extinction of the specimen;

m) the depth of burn (where appropriate);

n) observations and any unusual or unsatisfactory phenomenon observed, such as migration (by collapsing or otherwise) of the test material from the source (e.g. see **B.6**). Any numerical results to which such observations apply should have the letter X appended to them. Thus, A_0 3.9(X).