BRITISH STANDARD

BS 6853:1999

Incorporating Amendment No. 1

Code of practice for fire precautions in the design and construction of passenger carrying trains

ICS 45.060.20

British Standards

Committees responsible for this British Standard

The preparation of this British Standard was entrusted to Technical Committee FSH/19, Fire precautions in transport, upon which the following bodies were represented:

BEAMA Electrical Cable and Conductor Accessory Manufacturers' Association

British Cable Makers Confederation

British Railways Board

British Resilient Flooring Manufacturers Association

Building Research Establishment

Chief and Assistant Chief Fire Officers Association

Faverdale Technology Centre

Health and Safety Executive

Institution of Fire Engineers

London Underground Ltd.

Nationwide Fire Services

Queen Mary and Westfield College

RAPRA Technology Ltd.

Railway Industry Association

Warrington Fire Research Centre

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Contents

Foreword

This British Standard was prepared by Technical Committee FSH/19.
It supersedes BS 6853:1987 which is withdrawn.

The standard has been extensively revised to assist railway vehicle builders in interpreting guidance from the Safety Regulatory Authority on fire performance. It is envisaged therefore that this standard will have a wider use than the previous edition and reflects the concern of the Fire Standards Committee by upgrading the responsibilities of railway vehicle designers, builders and manufacturers, encouraging them to produce safer materials which release less toxic effluent in a fire, for future safety.

The start and finish of text introduced or altered by Amendment No. 1 is indicated by tags [A1⟩ ⟨A1].

It has been assumed in the drafting of this standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people.

As a Code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

It is recognized that some of the fire safety performance recommendations given in this British Standard may be difficult to achieve in practice. The standard lays down, through its numerical and design guidance, criteria which are considered to represent an optimum level of fire safety and which should be the objective of all train design activity within the scope of this standard. Thus adherence to the code should be considered to have provided an environment for which it has been demonstrated that:

— acceptable control of the risk of ignition has been achieved;

— acceptable control of the rate of and total emission of heat, smoke and toxic fume has been achieved for all major usage materials and surfaces when exposed to a source of ignition;

— acceptable resistance to fire has been achieved for all materials and items required to perform as a barrier to fire or which are required to perform some function when exposed to fire.

Failure to achieve compliance with the numerical or design guidance does not predetermine that an unacceptable situation exists but does determine that additional evidence needs to be supplied to the Safety Regulatory Authority to demonstrate that an acceptable level of fire safety has been achieved. This evidence may include results of additional testing, alternative testing, theoretical studies or expert assessments.

Annex D is normative, Annex A, Annex B, Annex C and Annex E are informative.

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 in itself confer immunity from legal obligations.

Summary of pages

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Introduction

The aim of this standard is to ensure the safety of passengers in the event of fire on or around a vehicle or vehicles comprising a passenger carrying train. Fire safety in this environment depends upon a range of interdependent measures which may include: detection and alarm/warning systems, manual or automatic fire suppression systems, emergency lighting and way-guidance systems, means of escape and egress provisions, escape route or exit door widths, places of safety, occupancy levels, normal supervision, staff management of an incident (which includes staff training), control of materials and contents, ventilation, compartmentation and fire resistance.

This standard necessarily concentrates upon the properties and fire performance of the construction and materials that form the train, with some advice provided on a number of other aspects. The engineer does, however, need to be aware that the fire safety design of the train may need to include all the above range of measures.

In the event of a fire on board a moving train, immediate evacuation to a place of ultimate safety is not possible and, even once the train is stationary such evacuation may be delayed or prevented for reasons of location, e.g. tunnel or viaduct, or for operational reasons, e.g. trains moving on adjacent tracks and/or live rails.

For this reason evacuation may only be possible along the train. Such evacuation may be considered as travel to a place of relative safety.

As, by definition, a place of relative safety cannot be guaranteed to be maintained in a safe condition indefinitely should a fire develop, it is essential that the materials used in the construction and furnishing of vehicles are such that they are not easily ignited and have low total emission of heat, smoke and toxic fume when exposed to an ignition source. These properties are collectively defined as reaction to fire.

For trains which run underground, the tunnel itself is commonly the escape route but may not be a place of relative safety if a fire develops which generates smoke and toxic fumes within the tunnel. This will commonly be the case for an underbody fire, where fire barriers may only inhibit breakthrough of the fire into the vehicle.

Moreover, in case of fire within the vehicle, fire barriers will generally be less effective on trains, especially in tunnels, than when used in buildings. While they may play a valuable role in delaying the spread of fire products so as to provide a place of relative safety, there is a greater tendency in the confined space of a tunnel for any leakage to be channelled to other occupied areas and in case of a well developed fire, combustion products are likely to bypass the barrier and affect other vehicles and the tunnel beyond.

This limitation of the benefit of fire barriers is recognized by recommendation of materials with enhanced reaction to fire performance for this category of vehicles.

Other vehicles for which special recommendations need to be considered are sleeper vehicles where there may be delays in the occupants becoming aware of a fire.

There are some operating environments where it may not be reasonable to assume that there is any effective place of relative safety, and it would be necessary, by particular attention to control of possible ignition sources and selection of materials with exceptional fire performance, to reduce further the risk of a fire starting and/or developing. Examples of such conditions are where:

— escape times are particularly protracted (relative to likely times for which the escape route could be maintained as a place of relative safety);

— the integrity of barriers cannot be relied on because, for example, they are penetrated by significant ventilation openings under passenger control;

— for operational or other reasons a train takes the form of a single extended compartment.

Such conditions are beyond the scope of this standard and would need to be the subject of specific hazard analysis.

It is also necessary to consider ignition sources, in particular:

— electrical equipment, particularly high power equipment;

— power derived from the combustion of fuel;

— cooking and catering facilities;

— arson attacks.

The objectives of this British Standard are thus:

— to control the power and duration of ignition sources and the frequency of their occurrence;

— to control the reaction of materials to ignition sources of a variety of sizes;

— for smaller ignition sources, of the order of 1 kW, to ensure that conditions within the affected vehicle remain tenable almost indefinitely;

— for larger ignition sources, of the order of 10 kW, to ensure that the period during which conditions remain tenable is consistent with the time required for people to move from or through the affected vehicle;

— for largest ignition sources, of the order of 100 kW, to ensure that the probability of a transition to flash-over within the vehicle is minimized;

— to limit the rate of heat release from the vehicle on flash-over;

— to limit the impact of the products of fire on areas remote from the seat of the fire.

1 Scope

This British Standard makes recommendations in respect of fire safety for the design and construction of railway vehicles comprising or forming part of passenger carrying trains. The recommendations are applicable to new vehicles and also to substantial changes to existing vehicles.

NOTE In respect of existing vehicles, the recommendations in this standard are applicable to any item or material which is being substantially replaced or renewed.

[A1⟩ Where a vehicle is subject to an engineering change involving the replacement/substitution of materials, or the introduction of new or revised systems/components the fire performance of the vehicle should not be degraded and the relevant sections of this standard should be used to assess the required fire performance. ⟨A1]

The recommendations in this British Standard cover:

a) the reaction to fire of materials;

b) the use of fire resisting barriers;

c) general aspects of design for fire safety.

Recommendations on measurement of smoke and toxic fume emission are given in Annex A and Annex B.

[A1⟩ Systems and materials that comprise the fire safety component of a passenger carrying train need to remain effective for the whole working life of the item. Such systems and materials should be compatible with the expected levels of wear and tear, including ageing, weathering, cleaning and passenger abuse for that duration. Where materials need to be replaced during the working life of the vehicle then the replacement materials should meet this standard. Operators of the vehicle should take this into account to ensure a suitable level of fire safety is maintained throughout the life of the vehicle in so far as it is reasonably practicable to do so. ⟨A1]

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this British Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. For undated references, the latest edition of the publication referred to applies.

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

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

BS 476-7, *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 476-15, *Fire tests on building materials and structures — Part 15: Method for measuring the rate of heat release of products.*

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

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

BS 4066-3, *Tests on electric cables under fire conditions — Part 3: Tests on bunched wires or cables.*

BS 5438:1989, *Methods of test for flammability of textile fabrics when subjected to a small igniting flame applied to the face or bottom edge of vertically oriented specimens.*

BS 6387, *Specification for performance requirements for cables required to maintain circuit integrity under fire conditions.*

BS EN 3 (all parts), *Portable fire extinguishers.*

[A1) BS EN 50200, *Methods of test for resistance to five of unprotected small cables for use in emergency circuits.* (A1]

BS ISO 4589-2, *Plastics — Determination of burning behaviour by oxygen index — Part 2: Ambient-temperature test.*

BS EN ISO 4589-3:1996, *Plastics — Determination of burning behaviour by oxygen index — Part 3: Elevated temperature test.*

BS ISO 5659-2, *Plastics — Smoke generation — Part 2: Determination of specific optical density.*

BS ISO 9239-1, *Reaction to fire tests — Horizontal surface spread of flame on floor-covering systems — Part 1: Flame spread using a radiant heat ignition source.*

prEN 2824[1)2)], *Aerospace series — Burning behaviour, determination of smoke density and gas components in the smoke of materials under the influence of radiating heat and flames — Test equipment, apparatus and media.*

prEN 2825[1)2)], *Aerospace series — Burning behaviour, determination of smoke density and gas components in the smoke of materials under the influence of radiating heat and flames — Determination of smoke density.*

prEN 2826[1)2)], *Aerospace series — Burning behaviour, determination of smoke density and gas components in the smoke of materials under the influence of radiating heat and flames — Determination of gas components in the smoke.*

NF X 70-100[2)], *Fire tests — Analysis of pyrolysis and combustion gases — Tube furnace method.*

3 Terms and definitions, and symbols

3.1 Terms and definitions

For the purposes of this British Standard the following terms and definitions apply.

3.1.1
emergency system
train system that maintains the passenger and operator environment at a safe level, and facilitates escape to a place of relative or ultimate safety

NOTE This includes:

— emergency lighting and way-guidance systems (where fitted);
— emergency egress;
— ventilation and emergency ventilation (where fitted);
— fire detection (where required);
— fire extinguishment;
— passenger emergency communications.

1) Published by AECMA (the European Association of Aerospace Industries).
2) Available through BSI Foreign Documents, 389 Chiswick High Road, London W4 4AL.

3.1.2
essential system
train system that allows the train to be driven

NOTE This includes:

— control of traction;
— control of service brakes;
— control of emergency brakes;
— associated auxiliary distribution for the above.

3.1.3
fire detection system
system which responds to one or more of the products of fire by triggering an audible and/or visual alarm

3.1.4
fire resistance
ability of an item to fulfil for a stated period of time the required stability and/or integrity and/or thermal insulation and/or other expected duty specified in a standard fire resistance test

3.1.5
fixed fire suppression system
system fixed within a particular area which, when it is activated, either manually or automatically, delivers a fire extinguishing medium

3.1.6
flash-over
transition to a state of total surface involvement in a fire of combustible materials within a compartment (in a railway vehicle)

3.1.7
place of relative safety
area that is both separated from a fire, commonly by fire resisting construction, and provided with a safe means of egress

3.1.8
place of ultimate safety
area that has no physical boundaries and in which people are no longer at risk from the fire or its effluent

3.1.9
power arc
fault condition electrical discharge through air where the nominal power dissipated exceeds 10 kW

3.1.10
reaction to fire
response of a material under specified test conditions in contributing, by its own decomposition, to a fire to which it is exposed

3.1.11
safety regulatory authority
body or bodies with statutory responsibility for setting or agreeing the safety requirements for a railway and ensuring that the railway conforms to the requirements

3.1.12
surfaces

3.1.12.1
horizontal prone surface (HP surface)
"ceiling like" downward facing surface within 45° of the horizontal

3.1.12.2
horizontal supine surface (HS surface)
"floor like" upward facing surface within 45° of the horizontal

3.1.12.3
vertical surface (V surface)
"wall like" surface within 45° of the vertical

3.1.12.4
limited extent surface (L surface)
an HP surface (see **3.1.12.1**) the maximum horizontal extent of which is less than 1 m and which has no point on its surface which is closer to any other limited extent surface than a distance, measured in any direction, equal to its maximum horizontal extent; or a V surface (see **3.1.12.3**) the maximum vertical extent of which is less than 1 m and which has no point on its surface which is closer to any other limited extent surface than a distance measured vertically upwards equal to its maximum vertical extent

NOTE These are designated "HPL" surfaces and "VL" surfaces respectively.

3.2
Symbols
For the purposes of this British Standard the following symbols apply.

A_0	Optical density generated across the faces of a 1 m cube when one "unit" of material is tested under specified conditions, in $m^2 \cdot$"unit"$^{-1}$ (the "unit" varies with the method).
A_m	Optical density measured in the 3 m cube test chamber during the test, (dimensionless).
k	Number of units of material used in the test piece.
N	Number of bundles of cable used in the cable test.
n	Number of strands in each bundle of cable used in the cable test.
t	Time, in seconds.
R	Weighted summation of toxic fume, (dimensionless).
I_0/I_t	Ratio of the initial luminous intensity to the transmitted luminous intensity at time t, (dimensionless).
V	Volume of the 3 m cube, in cubic metres.
l	Optical path length in the 3 m cube, in metres.
d	Cable diameter, in millimetres.
a	Integer part of $(9 + d)/2d$, (dimensionless)
w	Nominal width of an array of bundles of cable, in millimetres.

4 Classification of vehicle categories

There are two main classes of operating environment which are designated as follows:

— Category I: underground;

— Category II: surface.

Category I is subdivided as follows (see note):

— Category Ia;

— Category Ib.

The three categories are served by different tiers of performance which represent differences in the perceived likelihood and scale of ignition and the hazard which may result when it occurs.

NOTE The precise categorization of the operating service of trains is dealt with on a case by case basis through the safety regulatory authority but the following guidance should be taken into account.

— Category Ia: Substantial operating periods in a single track tunnel with no side exits to a walkway and escape shafts, or sleeper vehicles which operate underground for significant periods, or trains that operate without staff.

— Category Ib: Substantial operating periods in a multi-track tunnel, or a tunnel with side exits to a walkway and escape shafts, or sleeper vehicles which do not operate underground for significant periods.

— Category II: Surface stock with no substantial operating periods in tunnels.

5 Design considerations

5.1 Avoidance of hiding places for fire sources

Open recesses and gutter shaped open elements (e.g. for indirect lighting) should not be used in passenger compartments. Overhead luggage racks should be designed such that objects placed there are visible from below. Designated staff-only areas should be capable of being securely locked.

5.2 Minimizing combustible material, and provision for cleaning

The inside and outside of the vehicle should be designed to minimize the accumulation of combustible products. Heater enclosures should be designed and positioned to inhibit ingress or retention of combustible material. Ventilation systems should be capable of being easily cleaned. Filling points for combustible liquids should be designed such that spillages of liquid can be readily seen and cleaned up.

5.3 Litter bins

Litter bins should have a solid construction and should be fitted with a self-closing device, in order to prevent spillage of litter and enable the bin to contain a fire. Their material of construction should be fire resistant in accordance with **7.7**.

5.4 Provision for smoking

Where smoking is permitted, an adequate number of ashtrays should be provided. The ashtrays should have a solid construction and should be fitted with a self-closing device, in order to prevent spillage of ash or litter and enable the ashtray to contain a fire. Their material of construction should be fire resistant in accordance with **7.7**.

5.5 Protection of combustible materials from heaters

The design of heaters (excluding cooking equipment) should be such that the temperature of the surface casing of the heaters does not exceed 60 °C in normal operation. Inlet and outlet grilles should be so designed that they cannot be easily blocked.

5.6 Designated luggage areas

Designated luggage areas, where luggage is not within the view of passengers or staff, should be contained in a manner that ensures that combustion of the luggage cannot readily breach the containment, and also that an external fire cannot involve the luggage by readily breaching the containment.

5.7 Catering and cooking areas

Cooking equipment which utilizes oils or fats for frying or similar processes should be designed so that vehicle movements cannot cause a fire hazard from the mobile flammable liquid. Provision should be made for the storage of any such oils and fats such that they are protected from sources of ignition. Cooking equipment which utilizes liquefied petroleum gases (LPG) should not be used.

5.8 Electrical protection

Creepage and clearance distances should be set with due regard for the propensity of the materials to track and with due regard for the voltage used and whether it is a.c. or d.c., so as to minimize the occurrence of electrical faults. Suitable electrical protection should be provided to ensure that the energy release rate on occurrence of a fault and the duration of the fault is minimized. This guidance applies to electrical power both as an ignition source and as a power output hazard when in the form of a power arc.

5.9 Protection against power arcs

Suitable arc resisting barriers should be used to protect the passenger compartments with particular consideration being given to areas where faults are electrically unprotected other than by substation circuit breakers.

5.10 Protection against high current circuit breaker output

Suitable shields should be provided to prevent any effluent from the train-borne circuit breaker acting as an ignition source for materials or debris and also to prevent the degradation of other systems such as cables which would increase the risk of ignition should they fail.

5.11 Protection against sparks from current collectors

Suitable shields should be provided to prevent incandescent particles from current collectors from acting as an ignition source for underbody materials and debris.

5.12 Cables and wiring

The design and installation of electrical cables and wiring should be such as to ensure minimization of the risk of fire due to internal heating of the cables or wiring or due to external exposure to sources of heat. When determining the size of cables, the following should be taken into account:

a) the grouping of wires, whether in conduits, trunking or free air;

b) ambient temperature, with particular reference to elevated local temperature during vehicle operation;

c) the normal and peak temperature rating of the cable;

d) the normal and peak power carried by the cable;

e) the magnitude and duration of the power which might be carried by the cable under fault conditions;

f) the proximity of other combustible materials.

5.13 Internal combustion engines: diesel

A valve should be fitted in the supply line such that when the valve is operated the engine shuts down and the supply of fuel ceases. The fuel reservoir should be contained within a suitably fire resisting envelope including all pipework at least up to and including the valve. It should be possible to operate the shut down procedure and valve from within the driver's cab and also from a point external to the vehicle. The means by which the valve is operated remotely should have adequate resistance to fire so that it is not disabled by fire before it can be utilized.

5.14 Internal combustion engines: petrol

Where petrol engines are carried on railway vehicles during passenger service a risk assessment should be carried out.

6 Materials

6.1 General

Materials are classified into one of a limited number of types determined by their position on the vehicle and the type assigned determines the test regime that is applied (see Table 1 to Table 14). There is a distinction made in the tables between interior and exterior performance.

Surfaces are subdivided according to their orientation on the vehicle. The orientation of a surface is critical in determining the risk of flame spread and fire development as it determines the efficiency with which heat can be inputted into the surface. Surfaces are therefore classified, in decreasing order of fire risk, as follows:

a) "ceiling-like" (horizontal prone, HP, see **3.1.12.1**);

b) "wall-like" (vertical, V, see **3.1.12.3**);

c) "floor-like" (horizontal supine, HS, see **3.1.12.2**).

HP surfaces and V surfaces can be further classified as limited extent (L) surfaces if they fulfil certain criteria (see **3.1.12.4**).

In classifying surfaces in this manner it is possible to bring a variety of miscellaneous surfaces into the general scheme without the need for specific guidance values being identified for the particular item. For example, seat shells may be classified in this manner and it is possible and logical to classify seat trim in this manner.

It should be noted that the values applied to the true ceiling of some vehicles (see Table 3) recognizes the importance of controlling flame spread on an extended horizontal prone surface. For areas where an extended horizontal prone surface does not exist, e.g. the underside of a seat shell or a small area within a larger area that is fully in accordance with the appropriate values, the recommended values may be relaxed to those applicable to V surfaces.

Further types of material which cannot readily be incorporated into the surfaces classification scheme may be classified as follows:

1) cable;

2) textiles (free standing, [A1⟩ if less than 0.2m^2 ⟨A1] and lying, [A1⟩ any area ⟨A1]);

3) minor usage materials.

An item or material, unless specifically classified otherwise in the above classification scheme, should be considered as a surface if its exposed surface area exceeds 0.2 m^2 [A1⟩ when measured over a maximum linear distance of 1 m (unless it is an unclassified material when the full extent of the material should be considered) ⟨A1] or if its mass exceeds 500 g (interior use) or 2 kg (exterior use). If the item or material has a mass or surface area lower than this, it may be classified as a minor usage material. If the mass of an item is greater than the relevant minimum given above and its geometry does not allow a ready identification of which of the surface criteria to apply, those given for a V surface should be applied. [A1⟩ For free standing texiles which qualify as a surface, (such as curtains or drapes), testing should be carried out with test pieces which have an air-spaced arrangement. ⟨A1]

Minor usage material of mass less than 100 g (interior), or less than 400 g (exterior) is unclassified in respect of fire performance.

Grouping considerations should be applied to unclassified minor usage materials to ascertain whether they need to be classified, as well as to minor usage materials in general, to ascertain whether they should be treated as a surface.[A1⟩ For vehicles other than Category 1a, when considering a minor usage material for the purposes of classification and grouping, its mass should be calculated over its full extent unless it has compliant flame retardancy, in which case a maximum extent of 1 m should be used. The same conditions on the extent of the material considered should be applied when determining whether it should be treated as a surface. ⟨A1]

In considering groupings of minor usage materials, if there is a separation of 0.5 m for an HP or V surface and a separation of 0.2 m for an HS surface between any two minor usage materials, they may be considered on an individual basis. If such a separation is not achieved, their masses and areas should be added and they should be considered as a single material for the purposes of further classification and grouping.

6.2 Control of reaction to fire

NOTE A discussion of the principles underlying the provisions of this clause is given in Annex C.

Only materials which have the relevant reaction to fire performance properties as given in Table 1 to Table 14 should be used.

Materials which achieve the appropriate class rating but which are given a “Y” designation when tested in accordance with BS 476-7 should not be considered to be in accordance with the recommendations for use as HP or V surfaces but should be considered to be in accordance with the recommendations for the related L designated surfaces, (HPL or VL), provided that they are also in accordance with Table 7 or Table 8 as appropriate. [A1⟩ Materials which are rated “Invalid” when tested to BS 476-7 should neither be considered to have failed nor passed the recommended performance level. They should be subjected to additional testing in accordance with Table 7, Table 8 and Table 11 or other table as appropriate. Additional options are indicated in **C.2**. ⟨A1]

Table 1 — Interior horizontal supine surfaces

Test method	Parameter	Vehicle category		
		Ia	Ib	II
BS 476-7	Surface spread of flame (worst permissible class)	Class 2	Class 2	Class 2
or				
BS ISO 9239-1	Critical radiant flux at extinguishment [A1⟩ (min.) ⟨A1]	$7.5\ \text{kW}\cdot\text{m}^{-2}$	$7.5\ \text{kW}\cdot\text{m}^{-2}$	$7.5\ \text{kW}\cdot\text{m}^{-2}$
Annex D Flooring test	A_0 (max.)	220	350	nc[a]
See Annex B	R (max.)	5.0	8.0	18.0

nc: no criterion.

[a] The permissible level is outside of the measuring range of the method. The value is so high that it has been decided not to offer a numerical criterion.

Table 2 — Interior vertical surfaces

Test method	Parameter	Vehicle category		
		Ia	Ib	II
BS 476-6	i_1 (max.)	6 (VL surfaces: nc)	6 (VL surfaces: nc)	nc
	I (max.)	12 (VL surfaces: nc)	12 (VL surfaces: nc)	nc
BS 476-7	Surface spread of flame (worst permissible class)	Class 1 (VL surfaces: Class 2)	Class 1 (VL surfaces: Class 2)	Class 1 (VL surfaces: Class 2)
Annex D	A_0 (ON)	2.6	4.2	9.4
Panel test	A_0 (OFF)	3.9	6.3	14.0
See Annex B	R (max.)	1.0	1.6	3.6

nc: no criterion.

NOTE Values of A_0 are maxima.

Table 3 — Interior horizontal prone surfaces

Test method	Parameter	Vehicle category		
		Ia	Ib	II
BS 476-6	i_1 (max.)	6 (HPL surfaces: nc)	6 (HPL surfaces: nc)	nc
	I (max.)	12 (HPL surfaces: nc)	12 (HPL surfaces: nc)	nc
BS 476-7	Surface spread of flame (worst permissible class)	Class 1 0 mm[a] (HPL surfaces: Class 1)	Class 1	Class 1
Annex D	A_0 (ON)	2.6	4.2	9.4
Panel test	A_0 (OFF)	3.9	6.3	14.0
See Annex B	R (max.)	1.0	1.6	3.6

nc: no criterion.

NOTE Values of A_0 are maxima.

[a] No spread of flame.

Table 4 — Exterior horizontal supine surfaces

Test method	Parameter	Vehicle category		
		Ia	Ib	II
BS 476-7 or BS ISO 9239-1	Surface spread of flame (worst permissible class) Critical radiant flux at extinguishment (max.)	Class 2 $7.5\ kW \cdot m^{-2}$	Class 2 $7.5\ kW \cdot m^{-2}$	Class 2 $7.5\ kW \cdot m^{-2}$
Annex D Flooring test	A_0 (max.)	370	590	nc
See Annex B	R (max.)	8.5	13.5	nc
nc: no criterion.				

Table 5 — Exterior vertical surfaces

Test method	Parameter	Vehicle category		
		Ia	Ib	II
BS 476-7	Surface spread of flame (worst permissible class)	Class 1 (VL surfaces: Class 2)	Class 1 (VL surfaces: Class 2)	Class 2
Annex D	A_0 (ON)	4.4	7.0	nc
Panel test	A_0 (OFF)	6.6	10.5	nc
See Annex B	R (max.)	1.7	2.7	nc
nc: no criterion. NOTE Values of A_0 are maxima.				

Table 6 — Exterior horizontal prone surfaces

Test method	Parameter	Vehicle category		
		Ia	Ib	II
BS 476-7	Surface spread of flame (worst permissible class)	Class 1 0 mm[a] (HPL surfaces: Class 1)	Class 1 (HPL surfaces: Class 2)	Class 1 (HPL surfaces: Class 2)
Annex D	A_0 (ON)	4.4	7.0	nc
Panel test	A_0 (OFF)	6.6	10.5	nc
See Annex B	R (max.)	1.7	2.7	nc
nc: no criterion.				
[a] No spread of flame.				

Table 7 — Interior minor use materials of mass 100 g to 500 g

Test method	Parameter	Vehicle category		
		Ia	Ib	II
BS EN ISO 4589-3:1996,Annex A or BS ISO 4589-2 (see note)	Flammability temperature (FT) (min.) Oxygen index (OI) (min.)	300 °C 34 % (*V*/*V*)	300 °C 34 % (*V*/*V*)	250 °C 28 % (*V*/*V*)
Annex D Small-scale test	A_0 (max.)	0.017	0.027	0.061
See Annex B	R (max.)	1.0	1.6	3.6
NOTE The preferred method is determination of the flammability temperature (FT) but the oxygen index (OI) should be used where the behaviour of the material at temperature makes it unsuitable for FT testing.				

Table 8 — Exterior minor use materials of mass 400 g to 2 000 g

Test method	Parameter	Vehicle category		
		Ia	Ib	II
BS EN ISO 4589-3:1996,Annex A	Flammability temperature (FT) (min.)	300 °C	300 °C	250 °C
or				
BS ISO 4589-2 (see note)	Oxygen index (OI) (min.)	34 % (*V*/*V*)	34 % (*V*/*V*)	28 % (*V*/*V*)
Annex D Small-scale test	A_0 (max.)	0.029	0.046	nc
See Annex B	*R* (max.)	1.7	2.7	nc
nc: no criterion.				
NOTE The preferred method is determination of the flammability temperature (FT) but the oxygen index (OI) should be used where the behaviour of the material at temperature makes it unsuitable for FT testing.				

Table 9 — Seat trim

Test method	Parameter	Vehicle category		
		Ia	Ib	II
Back				
BS 476-6	i_1 (max.)	6 (VL and HPL surfaces: nc)	6 (VL and HPL surfaces: nc)	nc
	I (max.)	12 (VL and HPL surfaces: nc)	12 (VL and HPL surfaces: nc)	nc
BS 476-7	Surface spread of flame (worst permissible class)	Class 1 (VL and HPL surfaces: Class 2)	Class 1 (VL and HPL surfaces: Class 2)	Class 1 (VL and HPL surfaces: Class 2)
See Annex B	*R* (max.)	2.0	3.2	7.2
Base				
BS 476-7	Surface spread of flame (worst permissible class)	Class 2	Class 2	Class 2
See Annex B	*R* (max.)	3.5	5.6	13.0
Assembly				
Annex D Seating test	A_0 (max.)	8.7	14.0	nc
nc: no criterion.				

Table 10 — Seat shell (back and base)

Test method	Parameter	Vehicle category		
		Ia	Ib	II
BS 476-6	i_1 (max.)	6 (VL and HPL surfaces: nc)	6 (VL and HPL surfaces: nc)	nc
	I (max.)	12 (VL and HPL surfaces: nc)	12 (VL and HPL surfaces: nc)	nc
BS 476-7	Surface spread of flame (worst permissible class)	Class 1 (VL and HPL surfaces: Class 2)	Class 1 (VL and HPL surfaces: Class 2)	Class 1 (VL and HPL surfaces: Class 2)
Annex D	A_0 (ON)	2.6	4.2	9.4
Panel test	A_0 (OFF)	3.9	6.3	14.0
See Annex B	R (max.)	1.0	1.6	3.6

nc: no criterion.

NOTE Values of A_0 are maxima.

Table 11 — Textiles (free standing and lying) (HS, HP and V surfaces)

Test method	Parameter	Vehicle category		
		Ia	Ib	II
BS 5438:1989, Test 2A (15 s flame application time)	Burn length	<100 mm	<100 mm	<100 mm
	Time to extinguish[a]	<8 s	<8 s	<8 s
Annex D Small-scale test	A_0 (max.)	0.017	0.027	0.061
See Annex B	R (max.)	1.0	1.6	3.6

[A1] NOTE For HP and V free standing textiles of area >0.2 m^2 the appropriate "surfaces" recommendations should be applied (see **6.1**) prior to any use of the recommendations of Table 11. [/A1]

[a] Duration of flaming plus duration of afterglow.

Table 12 — Mattresses

Test method	Parameter	Vehicle category		
		Ia	Ib	II
BS 476-7	Surface spread of flame (worst permissible class)	Class 2	Class 2	Class 2
Annex D Flooring test	A_0 (max.)	220	350	350
See Annex B	R (max.)	5.0	8.0	8.0

Table 13 — Interior cables

Test method	Parameter	Vehicle category		
		Ia	Ib	II
BS 4066-3 (see notes 2 and 3)	Burn length (max.)[a]	2.5 m	2.5 m	2.5 m
Annex D Cable test (see note 3)	A_0 (ON)	see note 1	Ia × 1.6	Ia × 3.6
	A_0 (OFF)	see note 1	Ia × 1.6	Ia × 3.6
See Annex B	R (max.)	1.0	1.6	3.6

NOTE 1 The maximum permissible values of A_0 (ON) and A_0 (OFF) for any particular cable are calculated from the following expressions by inserting the value for the nominal cable diameter, d, measured in millimetres:

$$A_0(\text{ON}) = \frac{\tan^{-1}(d/45)}{45} - \frac{\tan^{-1}d}{2\,025}$$

$$A_0(\text{OFF}) = 1.5A_0(\text{ON})$$

The angle generated by the above expressions is calculated and quoted in degrees.

The formulae are a numerical convenience only and nothing more fundamental should be inferred from their form.

NOTE 2 [A1) The individual bundles forming the array should be prepared as described in **D.8.7** except that the length of cable bundle should be 3.5 m for the BS 4066-3 test. The array of bundles subjected to the BS 4066-3 test should comprise a spaced arrangement in which the centre to centre spacing of the bundles is twice the nominal bundle diameter. The number of bundles used should be the maximum number such that the width of the test piece array is less than 300 mm. The flame application time is 20 min. (A1]

NOTE 3 Within a range of cables of the same type, if a cable of diameter d meets the performance criteria, then it may be assumed that cables having a diameter in the range d/1.5 to 1.5d will also meet the performance criteria.

NOTE 4 The R value applies to all components of the cable on an individual basis.

[a] Measured from the bottom edge of the burner.

Table 14 — Exterior cables

Test method	Parameter	Vehicle category		
		Ia	Ib	II
BS 4066-3 (see notes 2 and 3)	Burn length (max.)[a]	2.5 m	2.5 m	2.5 m
Annex D Cable test	A_0 (ON)	see note 1	Ia × 1.6	nc
	A_0 (OFF)	see note 1	Ia × 1.6	nc
See Annex B	R	1.7	2.7	nc

nc: no criterion.

NOTE 1 The maximum permissible values of A_0 (ON) and A_0 (OFF) for any particular cable are calculated from the following expressions by inserting the value for the nominal cable diameter, d, measured in millimetres:

$$A_0(\text{ON}) = 1.7\left(\frac{\tan^{-1}(d/45)}{45} - \frac{\tan^{-1}d}{2\,025}\right)$$

$$A_0(\text{OFF}) = 1.5A_0(\text{ON})$$

The angle generated by the above expressions is calculated and quoted in degrees.

The formulae are a numerical convenience only and nothing more fundamental should be inferred from their form.

NOTE 2 [A1) The individual bundles forming the array should be prepared as described in **D.8.7** except that the length of cable bundle should be 3.5 m for the BS 4066-3 test. The array of bundles subjected to the BS 4066-3 test should comprise a spaced arrangement in which the centre to centre spacing of the bundles is twice the nominal bundle diameter. The number of bundles used should be the maximum number such that the width of the test piece array is less than 300 mm. The flame application time is 20 min. (A1]

NOTE 3 Within a range of cables of the same type, if a cable of diameter d meets the performance criteria, then it may be assumed that cables having a diameter in the range d/1.5 to 1.5d will also meet the performance criteria.

NOTE 4 The R value applies to all components of the cable on an individual basis.

[a] Measured from the bottom edge of the burner.

7 Control of spread of fire and its products

NOTE A discussion of the principles on which the provisions in the clause are based is given in Annex C.

7.1 Floors

7.1.1 For all categories of vehicle, when tested in accordance with BS 476-20 and -22, using test samples and test conditions in accordance with **7.1.2**, the total floor construction should achieve 20 min integrity and insulation.

The average temperature of the surface, as recorded by fixed internal thermocouples, should not exceed 250 °C. The temperature recorded by any single fixed thermocouple on the surface should not exceed 300 °C.

[A1⟩ The insulation criteria should be met, travelling from the underbody into the passenger compartment at the first surface of the first material that is combustible in accordance with BS EN 476-4:1970 and which has the potential to vent significant smoke and fume from the cold face. The relevant surface or surfaces which should be monitored should be agreed prior to the test. ⟨A1]

NOTE Localized insulation failures at penetrations and fixings are permitted provided that they do not lead to integrity failures.

7.1.2 The test should be performed horizontally on an indicative scale, nominally 1 m^2, without additional loading. In view of the open nature of the underside of the vehicle the test should be performed at a low furnace pressure which should be in the range 0 Pa to 2 Pa. The test piece should be of a sufficient size to include representative examples of any floor penetrations used on the vehicle. These should also achieve the fire resistance recommended in **7.1.1**. The test piece should include all floor coatings and coverings.

7.2 Vehicle body ends and the partition between the passenger compartment and the driver's cab

7.2.1 For all categories of vehicle, when tested in accordance with BS 476-20 and -22, using test pieces and test conditions in accordance with **7.2.2**, a pair of vehicle body ends including doors should demonstrate, in total, 30 min fire resistance, in respect of integrity only, except where there is a driver's cab in which case the insulation criteria given in **7.1.1** should also be met.

The fire barrier surfaces should be near the physical body end of the vehicle but need not be at the physical body end. In particular, where the body end has a driver's cab, the fire barrier surface should be at the partition between the passenger compartment and the driver's cab and not at the physical body end, thus affording enhanced protection to a driver if present.

The 30 minute criterion for two barriers should be considered to have been met if, in such tests, one entire end barrier including doors, fitted within an adequate depth of wall and floor, achieves 20 min integrity (and insulation where appropriate).

NOTE For partitions where no insulation criteria are given it should be demonstrated that the absence of insulation does not give rise to excessive radiated heat emission from the cold face such that integrity failure can occur of materials not included in the test or such that persons remote from the structure would be placed at risk. Particular attention should be given to large glazed elements in this respect.

7.2.2 The test should be performed vertically at full scale. The test piece should include representative examples of all materials and items fixed to both the hot and cold faces and also fixed within it, as well as representative examples of any penetrations. The penetrations should also achieve the recommended fire resistance.

In performing the test, measures should be taken to avoid spurious effects caused as a result of the metallic circumference of the wall/floor of the train expanding within the fixed ceramic structure used in testing, an eventuality that would not occur in practice.

7.3 Sleeping berth to sleeping berth and sleeping berth to corridor partitions in sleeper vehicles

7.3.1 For all categories of vehicle, when tested in accordance with BS 476-20 and -22, using test pieces and test conditions in accordance with **7.3.2**, the sleeping berth to corridor and the sleeping berth to sleeping berth partition, (where this latter partition is designated as a fire separating element), should achieve 20 min integrity.

In addition, the sleeping berth to corridor partition should meet the insulation criteria given in **7.1.1**.

NOTE 1 Localized insulation failures at penetrations and fixings are permitted provided that they do not lead to integrity failures.

NOTE 2 The berths along the length of the sleeper car should be separated in respect of fire resistance into not less than three blocks.

7.3.2 The test should be performed vertically at full scale. The test piece should include representative examples of all materials and items fixed to both the hot and cold faces and also fixed within it, as well as representative examples of any penetrations. The penetrations should also achieve the recommended fire resistance.

7.4 Cavity barriers

NOTE 1 The function of the cavity barrier is to prevent ready movement of air through the void producing conditions of high heat transfer efficiency, which, in the event of a fire, would promote rapid spread of flame over extended distances within the vehicle.

There need be no additional compartmentation for any cavity in the floor, wall or ceiling which meets one or more of the following criteria.

a) The cavity is filled to both faces with a material which is non-combustible when tested in accordance with BS 476-4.

b) [A1) The cavity is formed entirely from a material which is in accordance with the interior HP surface flame retardancy guidance values given in Table 3, and contains only materials in accordance with the Clause **6** flame retardancy guidance.

c) The cavity is lined with a material which is in accordance with the interior HP surface flame retardancy guidance values given in Table 3 and which, when tested in accordance with BS 476-20 and -22, has 20 min integrity, and contains only materials in accordance with the Clause **6** flame retardancy guidance. (A1]

If the cavity does not meet one or more of these criteria, it should be compartmented across its width at distances not exceeding 7 m or 1/3 of the vehicle body length, whichever is the greater, by the inclusion of a cavity barrier. The barrier should be made from a material that, when tested in accordance with BS 476-20 and -22 is capable of achieving 20 min integrity at an indicative scale in the appropriate orientation.

NOTE 2 A fire resistance test of the full structure is not needed.

Any cavity of one type, (i.e. floor, wall or ceiling) should be prevented from communicating with a cavity of another type, preferably by the inclusion of a cavity barrier at the interface.

The interface between a cavity barrier and the interior faces of the cavity should be protected or bonded in such a way that ready movement of air between the barrier and either of the faces is prevented.

7.5 Seat shell back and base

The material or combination of materials used to form the seat shell (back and base) should protect the seat trim from the effects of fire occurring under or behind the seat.

Protection to the trim from the rear/under-side should be deemed to have been supplied if the material or collection of materials forming the shell, when tested in accordance with BS 476-20 and -22, achieves 10 min integrity at an indicative scale in the appropriate orientation.

If such protection is absent, the rear of the seat back and the under-side of the seat base, including the soft trim, should be subjected to testing as for a surface.

7.6 Cables

Those cables that need to exhibit circuit integrity under fire conditions should have AX performance as specified in BS 6387. [A1) Alternatively BS EN 50200 may be used. The minimum integrity time under BS EN 50200 should be 90 min. (A1]

7.7 Litter bins

Litter bins should be capable of containing a fire within the bin.

Litter bins should be made of material which, when tested in accordance with BS 476-20 and -22, has 10 min integrity at an indicative scale in the appropriate orientation. Fabrications used to make litter bins should achieve the same level of performance.

7.8 Materials within equipment cases

Materials within an equipment case need not be in accordance with the recommendations of this British Standard provided that the case has fire resistance commensurate with the potential fire risk within the case, and that it is adequate to resist external fires likely to occur local to it.

8 Fire detection and suppression systems and passenger communication devices

8.1 General

Fire detection systems should be reliable and should activate consistently in all modes of operation and under all operating conditions. They should not initiate a significant number of false alarms.

NOTE Fire suppression systems may be either fixed or portable. A fixed system may be manual or automatic discharge; a portable system is, by definition, manual discharge only. The medium used in a fire suppression system should not present a hazard to train crew, passengers or staff.

8.2 Location

A minimum of two passenger communication devices should be fitted to every passenger carrying vehicle. These devices should allow a spoken two-way exchange of information with staff and should be clearly marked and readily identifiable.

Wherever a fixed fire suppression system is required then an associated automatic fire detection and audible alarm system should also be fitted. The system should be capable of informing crew and/or staff remotely, as to which vehicle has been affected, and, where relevant, which zone within the vehicle.

A suitable portable fire suppression system should be present in all vehicles that may contain people under normal or engineering operation. A minimum of one fire extinguisher of an appropriate size and type, conforming to BS EN 3, should be provided for each passenger compartment. Two extinguishers should be provided in sleeping cars.

Portable fire suppression or a fixed fire protection system should be available for any area of the vehicle that contains equipment which uses combustion of a fuel as a source of power.

Fire detection and suppression systems should be fitted to any area or vehicle which has the potential to present an increased risk. This should incorporate, as a minimum, automatic detection and audible warning, and portable extinguishing agents. Trains that may operate uncrewed/unstaffed, particularly those that may carry passengers, should be given particular consideration.

Examples of vehicles or areas at increased risk are as follows:

— any area which contains combustion of fuel as a source of power for train systems e.g. diesel engines;
— sleeping cars;
— locomotives;
— vehicles that are to operate without staff trained in emergency procedures.

8.3 Sleeper vehicles

Fire detectors should be provided in each sleeping compartment, in each general area which forms a separate fire compartment and within the air conditioning or ventilation ducting.

The fire detection system should be such that, on detection of a fire, an audible alarm sounds in all areas of the affected vehicle and a signal is sent to warn the responsible crew or staff member. The system should also activate the mechanisms which inhibit or control the movement of smoke within the vehicle and through the ventilation or air conditioning ducting.

8.4 Locomotives

Audible or visual alarms should be used inside and outside the body of the locomotive to indicate that the detection system has triggered. Where reliance is placed on audible alarms only, these should be audible when the engine is idling and other equipment is operating normally.

Locomotives should have a fixed fire suppression system which should be capable of automatic activation if the vehicle is unmanned except where a locomotive is operating close coupled in multiple with, and controlled from, an adjacent locomotive.

Automatic activation protocols should also take into account the possibility that it may be necessary, if the suppression is to be effective or for other reasons, for there to be a delay between detection and discharge to avoid ineffective dissipation of the extinguishing medium.

NOTE This delay may be automatic or may be under manual control.

For manual activation there should be an activation device within each driver's cab which should be protected from inadvertent use but which should be operable without the use of special tools or keys. There should also be suitably sited devices external to and on either side of the vehicle, either of which should be capable of activating the suppression system.

8.5 Diesel multiple units

Where the vehicle concerned is a diesel multiple unit, each driver's cab and guard's compartment should be fitted with an alarm which should be audible within the cab/compartment under all operating conditions. The alarm should also be audible in the immediate vicinity external to the vehicle. Any activation should trigger all alarms on the train.

Any fixed fire suppression system which has automatic activation should be designed so that, if necessary, a suitable delay occurs between detection and discharge to avoid ineffective dissipation of the extinguishing medium whilst the vehicle is in motion.

NOTE This delay may be automatic or may be under manual control.

8.6 Status

Means should be provided to isolate any fixed fire suppression system to prevent accidental discharge during general maintenance.

When the system is isolated, there should be a visual indication of a fault condition status. A fault condition status should also be indicated following discharge of the system. All system indicators situated in the driver's cab should be visible from the normal seated driving position under all operating conditions.

9 Control and function of essential and emergency systems

9.1 General

During a fire on a vehicle, safety critical systems such as braking and signalling should only fail in a manner that minimizes total risk. Thus, when exposed to fire all such systems should fail such that the train can continue in a controlled manner or come to a standstill in a controlled manner.

NOTE 1 It is desirable during a fire incident that certain essential and emergency systems should continue to function, as they perform, or may perform, a useful function in mitigating the primary fire risk or in the execution of some emergency procedure.

The function of these systems should be protected as far as is practicable from the effects of fire. In assessing whether the necessary degree of protection has been achieved the consequences of the incident being considered should be compared for the cases where the system does and does not fail.

NOTE 2 Means by which systems can be protected against fire include but are not limited to the following:

a) redundancy and segregation of system circuits and equipment;

b) use of cabling with fire resisting performance (see **7.6**);

c) use of air lines and hydraulic lines with fire resisting performance;

d) use of equipment cases with fire resisting performance (see **7.8**);

e) circuit design ensuring electrical isolation of failed equipment to maintain function of other equipment;

f) use of thermal fuses and remotely activated switches to physically isolate failed or failing systems.

9.2 Essential systems

Essential systems should be designed to protect persons from potential fire risks within the system as well as exhibiting adequate resistance to likely external local fires.

NOTE As an illustrative example, should a small fire occur within a piece of equipment, failure of which would stop the train, it should not be considered essential to cater for this provided that it could be shown that the fire could not develop, and hence would present no risk. Should a fire occur external to the piece of equipment and have the potential to develop and present a risk to persons, and should this fire also have the potential, prior to it becoming a significant risk to persons, to cause a failure of the piece of equipment, then further consideration should be given to the protection of the equipment.

9.3 Emergency systems

Emergency systems should be designed so that they continue to function when exposed to fire until emergency evacuation has been completed or until the system is no longer required.

Within the vehicle directly affected by fire, the failure of any part of an emergency system should not cause failure of any emergency system in any vehicle not directly affected by fire.

Thus, where an emergency system may be required to operate across the fire affected vehicle (e.g. passenger communications), protection of several systems against failure may be necessary by one or more of the techniques given for essential systems.

NOTE As an illustrative example, should a fire occur and directly impact a microphone of the passenger emergency communications equipment, it would not be considered practicable to require the specifically affected item to continue to function. As the presence of such a fire would preclude its use; it is no longer required to perform a function. A failure of the microphone should, however, not have any adverse consequences for the communications system as a whole. If this was the case and if the fire had the potential to become a significant risk to persons, then further consideration should be given to the protection and design of the equipment.

10 Aiding passenger and crew escape

10.1 Provision of emergency exit doors

All trains should have doors which can be used for emergency exit. In the case of trains designed for running on routes where emergency side exit is not possible, the emergency doors should be at the ends of the train, and it should be possible to gain access to both of these doors from any part of the train.

No passenger seat should be more than 15 m from an emergency exit door on the train, and no more than 6 m in the case of dead ends without an emergency exit at the end. Where these distances are not achievable, window exits should be adopted to achieve these limits.

Sleeping berths should have at least two means of escape.

10.2 Properties of emergency exit doors

Emergency doors which are normally, or which may be, locked should be capable of being opened in an emergency by passengers without the use of keys or tools. This facility should be available on both sides of intermediate doors, on the inside of end doors and on doors leading into driver's cabs, where these doors form part of the designated escape route.

NOTE The provision for emergency opening may, for example, be a handle, secured to the door locking mechanism, under a frangible cover.

Where accommodation is provided for disabled people provision should be made for their safe egress in an emergency.

10.3 Powered external doors

Power operated external doors should be capable of being opened in an emergency by passengers, without the use of keys or tools, from inside the vehicle even if the power or powered operating mechanism has failed. An emergency access device should be provided to allow staff, or the emergency services, to open external side passenger doors at diagonally opposite locations on every vehicle from outside the vehicle.

10.4 Powered internal doors

Power operated internal doors should be capable of being opened from either side in an emergency by passengers, without the use of keys or tools, even if the power or powered operating mechanism has failed. The manner in which a door opens, i.e. by pushing or sliding, should be indicated on the door. When considering the automatic means by which such doors are operated, consideration should be given to ensuring that the doors, particularly if part of a fire barrier, do not open or remain open due to any effect caused by the products of the fire. Specific attention should be given to photo-electric devices and their sensitivity to operation as a result of the presence of particulate smoke.

10.5 Passenger compartment doors and swing doors

Swing doors in corridors should generally open in both directions but where only a single direction is used this should be towards the nearest external door. Passenger compartment doors should generally be sliding doors. Where passenger compartment doors are swing doors the door should open into the compartment and not into the corridor to avoid causing obstruction to the means of escape. Where these doors can be locked from the inside, the locks should be designed such that train staff can open them in the event of an emergency.

10.6 Emergency lighting

All passenger and crew areas should have emergency lighting available for 1.5 h after the main power is removed. The level of illumination should be not less than 20 lx (measured at floor level) in the vicinity of emergency exit doors, and not less than 5 lx (measured at floor level) along exit routes. The level of illumination on emergency equipment provided to assist egress from the train should be not less than 20 lx.

10.7 Escape route facilities and avoidance of obstructions

The design of the vehicle should avoid including fixed elements which restrict or obstruct exit routes. Doors should not open outwards onto exit routes (see also **10.5**). Adequate provision should be made for the stowage of passenger luggage clear of the main vestibules, exits and passages.

Whenever the height between the top of the rail and the lowest point readily accessible to passengers from inside the vehicle exceeds 0.9 m, a means should be provided in the vicinity of the emergency egress doors for passengers and staff to alight to ground level. This equipment should be simple and safe to operate, e.g. portable ladders, fixed swing ladders, moveable steps or ramps. Where powered steps for descent to either rail or platform are installed, provision should be made for them to be operated manually in the event of a power failure.

10.8 Provision of emergency instructions

Passengers should be made aware of the proper action to take in the case of fire. The location of the emergency alarms and of fire extinguishers should be clearly indicated by notices. Where certain doors and windows are to be used as emergency exits, these should be clearly indicated as such.

Provision should be made for instructions to be given to passengers by the train crew or by pre-recorded announcements, preferably using a public address (PA) system.

NOTE If pre-recorded messages are to be used, examples of what should be communicated include the following:

— instructions to disembark from one or other end of the train, or on one or other side of the train away from adjacent lines;

— information on the availability of fire extinguishers and their location;

— instructions regarding the location and use of devices to be used to break or otherwise open windows for emergency evacuation of a train in which the doors are obstructed.

Annex A (informative) Discussion of smoke and toxic fume emission measurement

A.1 General

There are two aspects of toxic fume that lead to hazards in fires. Lethality from toxic fume emission is of primary importance but of almost equal importance is non-lethal escape impairment due to the narcotic or irritant effects of the gas present at sub-lethal levels. Such effects may be the reason a person does not escape, even if they are not the ultimate cause of death. This can be equated to the escape impairment resulting from the reduction of visibility caused by the opacity of smoke particles in fires.

In the case of both toxic gas emissions and optical impairment by smoke, this annex is concerned with the escape impairment hazard rather than lethality, on the basis that if escape is seriously impaired and the fire continues to develop, the consequences are overwhelmingly likely to be fatal.

A.2 Assessment protocols

Toxic gases can be assessed either by exposing animals to combustion products generated by tested materials, by analysing the gases emitted and summing the toxic contributions of each, or by assuming all gases have the similar toxic potency and using mass loss as an indicator of the quantity of toxic species generated in a fire. Animal studies are costly, difficult to regulate and ethically questionable. The correlation of human response with results from commonly used test rodents is unproven, and the non-availability of animal tests adequately to assess incapacitation or, more generally, escape impairment, rule out this type of test for railway applications. Monitoring mass loss is insufficiently sensitive, and for many products commonly used in the railway industry, which contain high levels of water releasing fillers, may actually be misleading. The chemical analysis of combustion gases is therefore the preferred assessment technique.

Ideally, if a concentration versus time plot for all toxic gases generated in fires can be formed, the dose of each product received by a person exposed to this fire effluent can be calculated. These can be summed and the time to reach incapacitation and/or death calculated. Fire gases contain scores of different products which make comprehensive routine analysis impossible. Detailed analysis is too costly for routine product selection uses and many common analytical techniques do not yield concentration versus time data. Techniques which analyse the major toxic gases found in fires are the preferred route for toxic potency assessment. Several of the gases measured (e.g. hydrogen cyanide) also reflect the potential presence of higher molecular weight toxic substances (e.g. organic nitriles) which are not assessed directly, and there is an expectation that, for example, control of HCN emission will reflect a control of organic nitriles, although this latter species may not form part of the analysis protocol. Similar inferences may be drawn in respect of other species.

A.3 Test methods

For the purposes of a code of practice it is unrealistic to expect a time based summation to be carried out on a routine basis, (although it may be carried out on a case by case basis in support of a material), as the test methodologies to achieve this are still being developed. It is necessary, therefore, to provide a simplified scheme which uses standardized "single point, cumulative" methods as a means of generating a value for the weighted summation of toxic fume, R. The test methods which should be used are given in Annex B.

Annex B (informative) Determination of weighted summation of toxic fume, *R*

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

This method should be applied to minor use materials (see Table 7 and Table 8), textiles (see Table 11) and cables (see Table 13 and Table 14).

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.

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

B.2 Area based test method (prEN 2824, prEN 2825 and prEN 2826)

An area based test method should be used for surfaces (see Table 1, Table 2, Table 3, Table 4, Table 5 and Table 6), seat trim and seat shells (see Table 9 and Table 10) and mattresses (see Table 12). Alternatively, a mass based test method in accordance with **B.1** may be used and the data applied to an area by taking account of the depth of burn.

The area based test method should be in accordance with prEN 2824, prEN 2825 and prEN 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 **B.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 m^2. [A1⟩ The grams of material should be calculated as follows:

$$\frac{(\text{Measured Concentration ppm}) \times 0.51 \times (\text{Molecular Weight})}{1\,000 \times 24.5}$$ ⟨A1]

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

B.3 Gases to be analysed

The eight gases listed in Table B.1 with their common limiting values (IDLH values, see **B.4.1**) should be the minimum set for which analysis is performed.

Table B.1 — IDLH values

Gases	IDLH values	
	p.p.m.	$mg\cdot m^{-3}$
Carbon dioxide	40 000	73 000
Carbon monoxide	1 200	1 400
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.		

B.4 Calculation of *R*

B.4.1 *General*

The quantities listed in columns 2 and 3 of Table B.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 B.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 NIOSH Guide [1].

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 B.1 have been converted into reference values and these are given in Table B.2. The values in Table B.2 have units of milligrams per gram if used with NF X 70-100 data or grams per square metre if used with prEN 2824, prEN 2825 and prEN 2826 data. This coincidence of numerical values arises because of the selection of 0.5 m^2, (0.5 m width, 1.0 m height) and 500 g as the general design levels for surfaces (HP and V) and materials respectively. The values in Table B.2 are given to two significant figures which is sufficient for, and consistent with, the general nature of the analysis and guidance.

Table B.2 — Reference values for gases

Gas	Reference value, *f* $mg \cdot g^{-1}$ or $g \cdot m^{-2}$
Carbon dioxide	14 000
Carbon monoxide	280
Hydrogen fluoride	4.9
Hydrogen chloride	15
Hydrogen bromide	20
Hydrogen cyanide	11
Nitrogen dioxide	7.6
Sulfur dioxide	53

B.4.2 *Calculation*

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

Divide the value for each species by its reference value 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:

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

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 B.2;

r_x is the individual index for the x^{th} species.

Should it be found, for a material or composite that the "single point, cumulative" methods given in this standard, give an *R* value that does not meet the recommended criteria, it is possible that recourse to a time based analysis may also allow a technically sound hazard assessment. Several methodologies are available at a development level whereby toxic fume, (and other), emissions can be measured in real time in either a dynamic flow or cumulative situation.

Annex C (informative) General commentary on methodology

NOTE When testing materials for either HS or HP applications in the vertically oriented BS 476-7 test, note should be taken of any aspects of the behaviour of the material in a fire which may influence the result in either an adverse or a beneficial manner. Consideration should be given to these behavioural aspects and their influence when assessing the suitability of the material in the end application.

C.1 Reaction to fire

Annex B gives information in respect of smoke and toxic fume in which specific levels of emission are listed as being appropriate for the various gases considered. This annex considers why the various categories of vehicle are allowed to have varying levels of emission.

The absolute levels quoted in clause **6** do not represent the levels expected to be tolerated by the occupants when these levels are reached.

In the absence of widely used time based testing for reaction to fire properties, it has been necessary to make a notional linkage between the final value which a material may develop for some property, such as smoke emission, and the rate at which this level will be approached under the design fire conditions chosen.

At some point in the progression towards the stated smoke [A1⟩ and/or toxic fume ⟨A1] emission value, the true limiting threshold within the vehicle will be reached. The minimum acceptable length of time before this limiting threshold is reached varies and reflects differences in the times considered necessary to move occupants to a place of relative safety and in some cases, a place of ultimate safety.

Thus, there is one design level of emission but it is acceptable for this level to be reached in different times. The minimum necessary length of time before this design level is reached is determined by the respective times needed to move occupants to a place of relative or ultimate safety for different vehicles. Using this, the rate of emission is projected to give an estimated final value which is used for "single point" recommendation purposes.

In effect, the selection of any single point value is equivalent to selecting the fire against which the vehicle is being designed. This "design fire" is considered to involve a certain amount of material and the [A1⟩ rate of ⟨A1] reaction of this material to the fire determines the consequences.

The A_0 values recommended in Table 1 to Table 14 are based on the need to maintain a nominal 10 m visibility [2] within a vehicle of volume of 100 m^3 bearing in mind allowances for the time taken to reach this condition [A1⟩ and then to reach the actual A_0 value. These times vary significantly between the various fire models (i.e. they are dependent on the typical nature of the test piece and the test conditions) and hence there is not a 1:1 correspondence between the recommended values of A_0 and the design amounts across different models. ⟨A1] In the estimation of the recommended values of A_0, the amounts of material given in Table C.1 are considered to be involved on an individual basis, (not concurrently). In each case the combustion conditions are as given in Annex D, with the appropriate scaling factor, listed in Table C.1, used to determine the relationship between the nominal unit amount exposed in the test (and also the unit amount relative to which A_0 is expressed) and the design amount exposed within the vehicle.

Table C.1 — Amounts of material for measurement of A_0

[A1⟩ Item	Units in which A_0 is stated	Nominal unit amount exposed in the test	Design amount
Seat trim	m^2 "Burn area"$^{-1}$,	0.12 m^2	0.15 m^2
Surface (HS)	m^2, m^{-2}	0.04 m^2	0.05 m^2
Cable	m^2 "Burn length"$^{-1}$,	0.2 m	Variable (Dependent on cable diameter)
Surface (V or HP)	m^2 "Burn length"$^{-1}$,	0.1 m^2	0.4 m^2
Minor usage material	m^2, g^{-1}	Variable, g	500 g ⟨A1]

The same approach has been applied in the selection of the *R* values except that the concept of a limiting level of toxicity has been used instead of visibility distance. Ideally, all the *R* values should be unity and there should be a separate table giving weightings for each case. However, it is more convenient and concise, and is mathematically equivalent, to fix the reference weightings and to allow *R* to vary. This is the approach which has been adopted. [A1⟩ As for smoke emission there is an absence of 1:1 correspondence for *R* values as the fire model, (in this case only the nature of the test piece), varies and there is similarly no 1:1 correspondence between A_0 and *R*. ⟨A1]

C.2 Heat release

The objectives of minimizing the risk of flash-over and of limiting the heat release from any such flash-over are generally served by the control of flammability exerted by the limits given in clause **6**. However, it is important to quantify rates of heat output for two reasons. Firstly, it is necessary for cross-checking of the performance achieved in the “pass/fail” tests, but secondly and crucially, it provides the potential for obtaining realistic time-based data to assist in specifying the handling capacity of tunnel ventilation systems as well as offering general support to the case for fire safety.

Such data should be obtained from testing in accordance with BS 476-15 where rates of heat release and their variation with time can be determined for a variety of heat fluxes.

The following values should be used: 50 $kW·m^{-2}$ for HP surfaces, 35 $kW·m^{-2}$ for V surfaces and 25 k $W·m^{-2}$ for HS surfaces (see DD 246).

[A1⟩ This methodology may also be useful in supplying information for materials or composites which are not amenable to testing by the standard techniques. For examble, a thin film applied to a surface may be considered to give “Invalid” performance under BS 476-7 testing. In this circumstance the film may be tested to BS 476-15 and the Average Rate of Heat Emission (ARHE) determined. ARHE (T) is defined as the average rate of heat emission over the period t = 0 to t = T. The Maximum Average Rate of Heat Emmission (MARHE) is defined as the maximum value of ARHE found over all values of t; i.e. it is the peak value of the ARHE vs time curve. When testing thin films the sampling intervals should not exceed 2 s.

For use as a surface (unlimited) it is suggested that the value of MARHE should be less that the value of the flux used in the test. For use as a limited extent surface it is suggested that the value of MARHE should be less than 2 times the flux used in the test. This methodology should not be used as a substitute for standard testing, it should be used to supplement standard testing when such testing is not supplying useful data. Generally, values of MARHE which are low compared to the applied flux are indicative of materials which will exhibit good control of fire development at the prescribed flux level. ⟨A1]

C.3 Fire resistance

It is necessary to recognize that fire resisting separation as it is widely understood and practised for buildings cannot be fully applied to railway vehicles, particularly underground vehicles, as the separating planes can never be taken to the structure.

The most obvious example of this would be the floor of the train. Whilst it may be possible to demonstrate a floor’s formal resistance to penetration, it will not act as a barrier to fire products flowing along its surface and around the side of the train. A similar effect may be seen in buildings where the impact of a fire may travel from floor to floor via an external path. This is a rare event for buildings as compared to railway vehicles, where it would occur in every case. It would be particularly crucial in underground environments where the fire products cannot vent directly to atmosphere.

Whilst the testing and terminology applied to railway vehicles are therefore similar to those applied in buildings it needs to be recognized that the aims and expectations with regard to fire resistance are different.

The first fundamental property of fire resistance for a separating element is integrity. The second fundamental property of fire resistance is insulation.

Considering firstly the floor of a vehicle, the function of integrity is to ensure that the products of an underbody fire do not have easy access to the passenger compartment directly through the floor. Thus there is an expectation that persons will be able to move from or through the passenger compartment for a period during an underbody fire.

Considering secondly aspects of insulation, it should be noted that the function of insulation is to ensure that any combustible materials forming the floor of the passenger compartment do not produce significant amounts of smoke or toxic fume directly within the compartment by being heated to temperatures at which they could be expected to decompose rapidly.

This latter criterion is crucial and it implies that the standard insulation criterion is not fully relevant to railway vehicles. It would, for example, be entirely possible (and is actually common) for a structure to meet the normal Building Regulations criteria for insulation but to generate large quantities of smoke and toxic fume from the cold face, (which remains in conformity with the criteria in respect of its temperature rise).

To avoid this occurrence it is necessary to give insulation criteria for combustible materials within the floor, rather than at the upper surface, but with an absolute value of insulation appropriate to controlling the rate of production of smoke and toxic fume from this material. Similar principles are applicable to some other barriers.

Annex D (normative) Methods for measuring smoke density

D.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.

D.2 Apparatus

D.2.1 *Cubic enclosure*, comprising a chamber of interior side 3 000 mm ± 30 mm constructed from sheets of steel of 2 mm nominal thickness fixed to a steel framework. There should be a door and at least one window enabling observation of the tests, with hermetic sealing of all joints. The walls of the cube should have holes evenly distributed around the base, close to floor level, with a nominal total area of 5 000 mm^2, for atmospheric pressure equalization. The upper part of the cube should have a port connected to a fume extraction system which can be used to purge the cube between tests. There should be a means of sealing this port during a test.

D.2.2 *Optical system windows*, comprising two sealed glass windows having nominal dimensions 100 mm × 100 mm, in laterally opposed faces of the cube (**D.2.1**), for the transmission of light through the horizontal photometric system from source to receiver.

The centres of the windows should be at a height of 2 150 mm ± 100 mm from the floor.

D.2.3 *Fan*, table type, to ensure uniform distribution of the smoke. The fan should be placed on the floor of the cube (**D.2.1**), as shown in Figure D.1, the fan axis being horizontal at a height between 200 mm and 300 mm from the floor, and the distance from the wall being 500 mm ± 50 mm. The fan should have a blade diameter of 300 mm ± 60 mm and a flow rate of 0.12 $m^3 \cdot s^{-1}$ to 0.25 $m^3 \cdot s^{-1}$. Air should be blown horizontally by the fan during the tests but the ignition source should be protected by a draught screen **D.2.4**).

D.2.4 *Draught screen*, made of sheet steel and having dimensions of 1 500 mm × 1 000 mm, curved along its length to produce a chord of 1 400 mm. It should be placed as shown in Figure D.1, nominally 75 mm from the back wall, but may be adjusted between 0 mm and 150 mm to ensure a stable flame in the fire model.

D.2.5 *Photometric system*, consisting of a light source, (**D.2.6**) and a receptor (**D.2.7**) placed horizontally in the mid-vertical plane of the cube at a height of 2 150 mm ± 100 mm.

The light beam should traverse the cube through the glass windows in the side walls. The optical path length between windows should be 3 000 mm ± 30 mm. The system is illustrated in Figure D.2. The light source and the receptor should be disposed externally on the line of two observation windows and without physical contact with the walls of the chamber.

D.2.6 *Light source*, comprising a halogen lamp (type M28) with a tungsten filament and a clear quartz bulb, having the following characteristics:

— power: 100 W;

— voltage: 12 V.

Neither flux nor temperature are critical, as long as they remain constant throughout the test.

The bulb should be supplied with a voltage of 12.0 V ± 0.1 V (mean value). During the test the voltage should be stabilized to a range of ±0.01 V. The lamp should be mounted in a housing and the beam adjusted by a lens system to give an evenly illuminated circular area of 1 500 mm ± 100 mm diameter on the interior of the opposite wall.

D.2.7 *Receptor*, comprising a photocell of a filtered selenium type giving a spectral response similar to a CIE standard photopic observer (human eye). The photocell should be mounted at one end of a 150 mm ± 10 mm tube with a dust protection window at the other end. The inside of the tube should be matt black to prevent reflections. The cell should be linked to a potentiometric recorder by the electrical circuit shown in Figure D.3.

The signal from the photocell, which is proportional to the transmission of light, should be recorded during the test, either continuously or at intervals not exceeding 5 s, or 2 s for small-scale tests as in **D.8.3**.

D.3 Environment

The cube should be located away from direct sunlight, in still air, at a temperature of 23 °C ± 5 °C, and not subject to climatic variations.

NOTE Satisfactory calibration will be more easily achieved, and testing proceed more quickly, if the ambient temperature is not less than 20 °C. It will be easier to achieve consistent results if the cube is contained within a building so as to maintain a stable environment.

D.4 Fire sources

D.4.1 *General*

Depending on the test being performed, one of the fire sources described in **D.4.2** and **D.4.3** should be used.

D.4.2 *Fire source 1*

The fire source should consist of 1 000 cm^3 ± 5 cm^3 of alcohol having the following composition by volume:

— ethanol:	90 % ± 1 %;
— methanol:	4 % ± 1 %;
— water:	6 % ± 1 %.

The fire source should be contained in a tray made of sheet steel having a pyramidal trunk of rectangular section and so fabricated as to contain the alcohol without leakage. The interior dimensions should be as follows:

— base:	210 mm × 110 mm;
— top:	240 mm × 140 mm;
— height:	80 mm.

The tolerance on all dimensions should be ±2 mm. The thickness of the metal used should be 1 mm ± 0.1 mm.

The tray should be situated close to floor level and supported so that excessive heat loss through the base is prevented (e.g. it should not be stood directly on a metal floor).

D.4.3 *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 °C ± 5 °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:

— four wire corner posts 50 mm high;

— 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.

D.5 Blank test

Using fire source 1, a blank test should be performed, without a test specimen, to ensure that the cube is at a temperature of not less than 20 °C.

After the burn, the inside of the cube should be purged of all combustion products by operating the extraction system.

The temperature inside the cube should then be measured adjacent to the internal door, at a height of 1 500 mm to 2 000 mm and a minimum of 200 mm from the walls.

D.6 Verification

D.6.1 The test described in **D.6.2** should be performed as a check that the combination of the test cube and the optical system will produce results consistent with those from other test cubes when identical materials are burned under the same conditions. It should be performed prior to the commencement of a series of tests, or at intervals of not longer than 60 days. The values of A_0 calculated in accordance with **D.6.3** should fall between the following limits:

4 % toluene mixture: 0.18 $m^2 \cdot \%^{-1}$ to 0.26 $m^2 \cdot \%^{-1}$;

10 % toluene mixture: 0.80 $m^2 \cdot \%^{-1}$ to 1.20 $m^2 \cdot \%^{-1}$.

D.6.2 Clean the windows of the photometric system to ensure 100 % light transmission. Prepare two different calibration fire sources using toluene/alcohol mixtures. The concentration of toluene should be 4 % toluene and 10 % toluene by volume, respectively, the balance being alcohol. The alcohol used to make up to 100 % volume should be to the same specification as that of the standard fire source 1, detailed in **D.4.2**. Use pipettes and volumetric flasks for accuracy of measurement.

Perform two blank tests using 1 000 cm^3 ± 5 cm^3 of the calibration fire source mixtures; one test for each mixture. In both cases, record the minimum transmittance.

D.6.3 Calculate the measured optical density in the cube, A_m, (in accordance with the Beer-Lambert law) 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.

Calculate the A_0 value, according to the following equation:

$$A_0 = \frac{A_m \times V}{T \times l}$$

where

A_m is the optical density measured in the cube;

V is the volume of the cube, in cubic metres;

l is the length of the optical path between the windows, in metres;

T is the quantity of toluene in the fire source mixture, as a percentage by volume.

D.7 Conditioning of test specimens

All test specimens should be conditioned before testing by maintaining them for a minimum of 72 h in indoor ambient conditions and then for a minimum of 16 h at 23 °C ± 2 °C and at 50 % ± 5 % relative humidity.

D.8 Test procedures

D.8.1 *General*

A blank test to preheat the cube should be performed prior to commencement of testing (see **D.5**), when necessary to achieve the minimum temperature of 20 °C.

The duration of each test should be 40 min.

The blank test should be repeated if the temperature in the cube falls below 20 °C prior to commencement of a test.

The cube should be purged after each test, blank or otherwise.

The windows of the photometric system should be cleaned prior to each test to ensure 100 % light transmission.

NOTE Examples of A_m curves are shown in Figure D.4, Figure D.5, Figure D.6, Figure D.7 and Figure D.8. Schematic arrangements of the tests are illustrated in Figure D.9, Figure D.10, Figure D.11, Figure D.12 and Figure D.13.

D.8.2 *Numbers of specimens to be tested*

[A1) 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. (A1]

D.8.3 *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 × 60 mm × 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 in Figure D.9. 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.

Ignite the fire source and record the optical density in the cube. Calculate A_0 in accordance with **D.8.8**.

The curve shape is typically as shown in Figure D.8, but for exceptionally thick samples may be as shown in Figure D.4, Figure D.5 or Figure D.6.

D.8.4 *Panel test*

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

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.

Use fire source 1 for this test.

The test specimen size should be 1 000 mm × 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 60° to the horizontal with the short side of the specimen horizontal [A1⟩ and with the unexposed surface facing the back wall (see **D.2.4**). ⟨A1] The general arrangement is shown schematically in Figure D.10. 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. [A1⟩ 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. ⟨A1] 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 **D.8.8**.

The curve shape is typically as shown in Figure D.4, Figure D.5 or Figure D.6.

D.8.5 ***Seating test***

Tests should be performed on actual specimen seats.

NOTE For development purposes, specimens of the materials and approximate construction may be used, and it is recommended that two simulated squab units of a minimum size 400 mm × 400 mm and of 2 mm thickness of the core and cover composite be used, suitably fitted together in an approximate seat configuration. Results from such tests cannot be regarded as more than indicative of probable performance of an actual seat.

Use fire source 2 for this test.

Position the fire source on the centre of the seat base squab, up against the seat back squab [A1⟩ and with the unexposed surface of the seat back squab facing the back wall (see **D.2.4**). ⟨A1] Figure D.11 shows a schematic arrangement for the test.

Ignite the fire source and record the optical density in the cube. Record the depth of burn. Calculate A_0.

The curve shape is typically as shown in Figure D.7.

D.8.6 ***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 × 300 mm and a maximum of 600 mm × 600 mm. For a mattress, a whole mattress should be tested. The fire source should be positioned centrally on the specimen. Figure D.12 shows a schematic arrangement for the test.

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

The curve shape is typically as shown in Figure D.7.

D.8.7 ***Cable test***

The sole parameter to be used in determining the nature of the test array is the minimum cable diameter, d, measured in millimetres.

The lengths comprising the test array should be 1 m long. The number of strands in each bundle should be derived from parameter a, where:

$$a = \mathrm{int}\left(\frac{9 + d}{2d}\right)$$

NOTE 1 The expression "int" stands for the integer part of a number.

The number of strands in the bundle, n, should be derived from a by use of the standard formula for generating close packed hexagonal structures as follows:

$$n = 3a^2 + 3a + 1$$

The number of bundles in the array, N, should be determined by the minimum number of bundles required to give an array of nominal width greater than or equal to 45 mm. The nominal width, w, should be given by:

$$w = Nd(2a + 1)$$

All multi-strand bundles should be laid up so that the lay length is 15 ± 3 times the nominal bundle diameter $d(2a + 1)$.

NOTE 2 For up to 19 strands, care should be taken to ensure that the bundles are correctly close packed. From 37 strands upwards perfect close packing is not essential provided that the bundles are tightly packed and reasonably circular in section.

Each multi-strand bundle should be bound together with two turns of approximately 0.5 mm diameter wire in the centre, and at every 100 mm each side of the centre.

The cables or bundles of cables should be laid touching and should be bound together at the ends. They should also be bound together at 300 mm from each end, and clasped at this point to the support by means of wire binders. The test array should be supported horizontally over the fire source tray with its length parallel to the long side of the tray, at a height of 175 mm ± 5 mm above the surface of the alcohol [A1] and with the cables parallel to the back wall (see **D.2.4**). [A1]

Use fire source 1 for this test.

Ignite the fire source and record any observed dripping of liquid from the cables and/or flaming involvement of the cables during the test.

NOTE 3 Flaming involvement means any observed flaming which can be visually distinguished from the flames produced by the alcohol fire source. In particular, if flames are observed on parts of the cable not directly affected by the fire source this fact should be recorded.

Record the transmittance within the cube and calculate A_0 (ON) and A_0 (OFF) in accordance with **D.8.8**.

The curve shape for A_m is typically as shown in Figure D.4, Figure D.5 or Figure D.6.

D.8.8 *Calculation and expression of results*

The measured optical density (A_m) 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 in Figure D.4, Figure D.5 or Figure D.6.

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 burned 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 (m^3);

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

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

[A1⟩ The value of k is 1 for the panel and seat tests, 0.04 m^2 for the floor test, the mass of the test piece (g) for the small scale test and the number of lengths of cable for the cable test. ⟨A1]

One unit of material is one panel or one seat for the panel and seating test, 0.04 m^2 of floor for the flooring test, 1 g of material for the small scale test, and one length of cable for the cable test.

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

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

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:

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

NOTE The values quoted in Table 1 to Table 14 are as follows:

— $A_0\ (\mathrm{ON})_{\mathrm{max}}$, which for the purposes of reporting is designated A_0 (ON); and

— $A_0\ (\mathrm{OFF})_{\mathrm{corr}}$, which for the purposes of reporting is designated A_0 (OFF).

D.8.9 ***Test report***

The test report should include the following information:

— the name of the testing establishment;

— the date of the test;

— a reference to this British Standard;

— identification of the material tested;

— the test specimen form and any variation from the recommended dimensions;

— the bundling arrangements (for cable tests);

— the A_0 value recommended for the material;

— the A_0 value obtained in each test;

— mean and standard deviation of the A_0 values;

— the number of specimens tested;

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

— observations about timings for the ignition and extinction of the specimen;

— the depth of burn (where appropriate);

— 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 **D.8.4**). Any numerical results to which such observations apply should have the letter X appended to them. Thus, A_0 3.9(X).

All dimensions are in millimetres

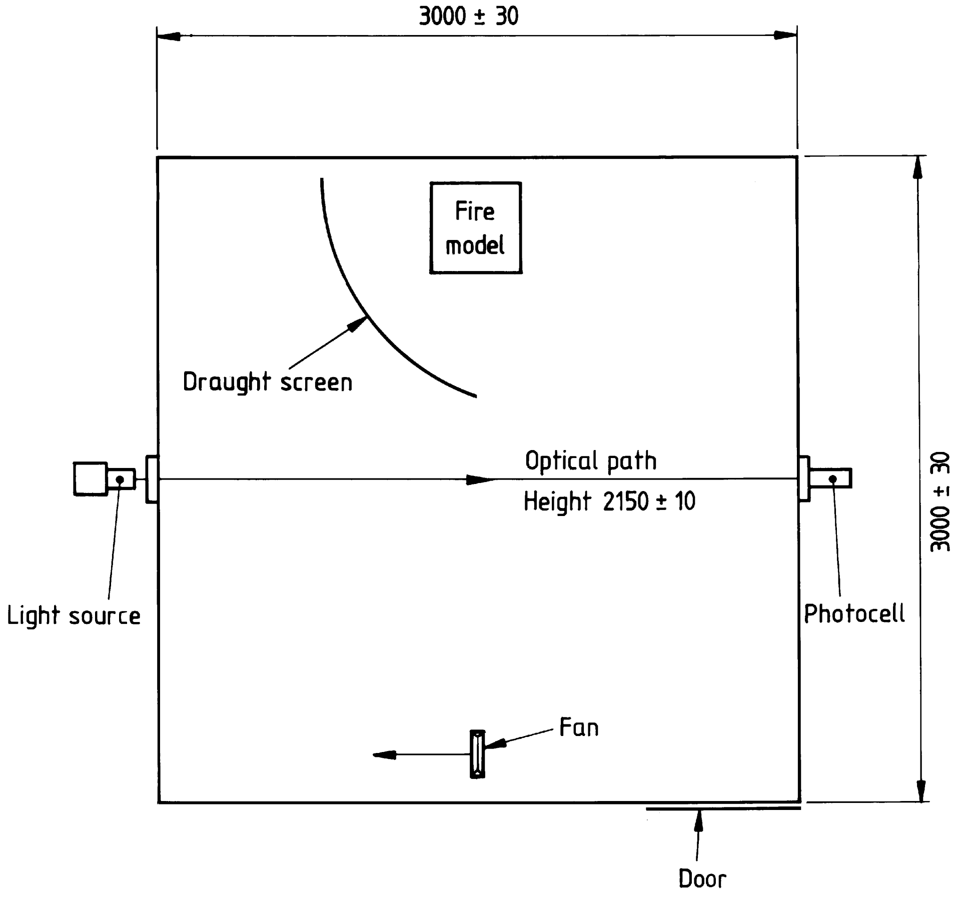

Figure D.1 — Plan view of test chamber

All dimensions are in millimetres

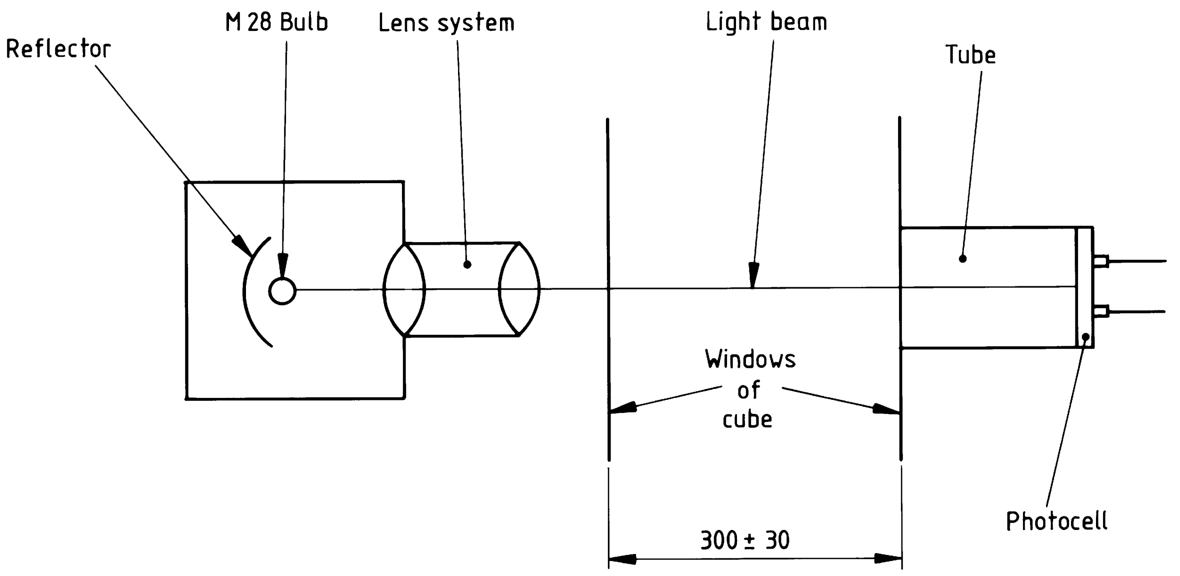

Figure D.2 — Photometric system

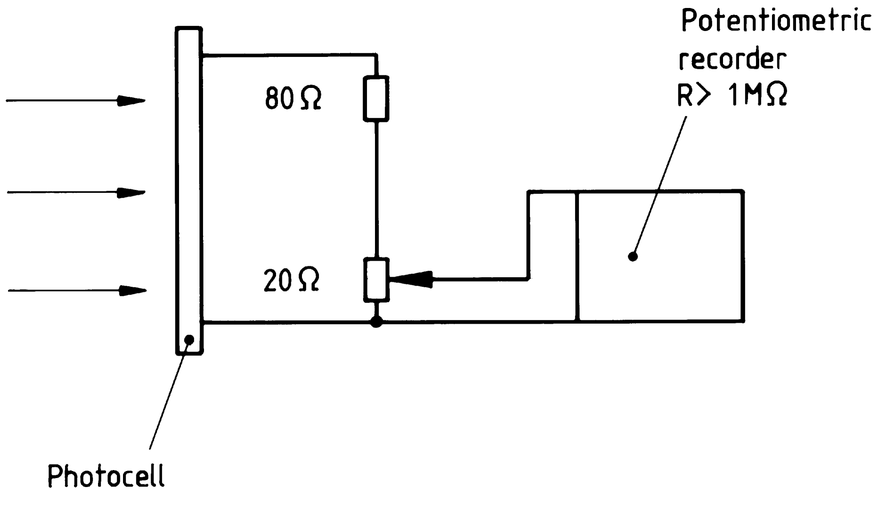

Figure D.3 — Electrical circuit for photocell

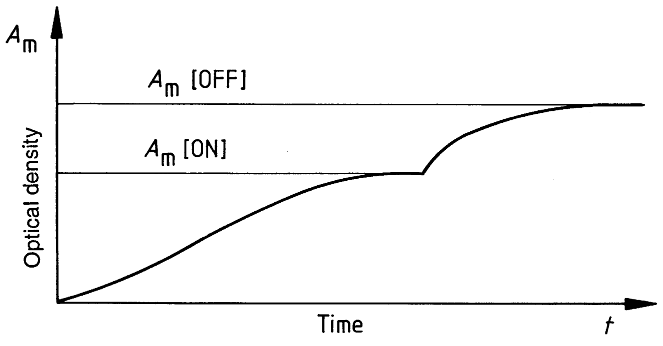

Figure D.4 — Ideal curve

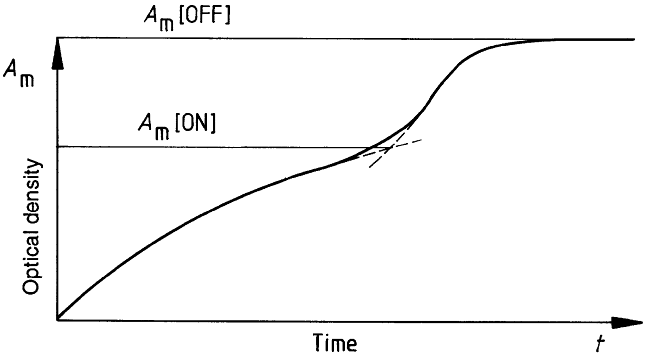

Figure D.5 — Extrapolation of "knee" point

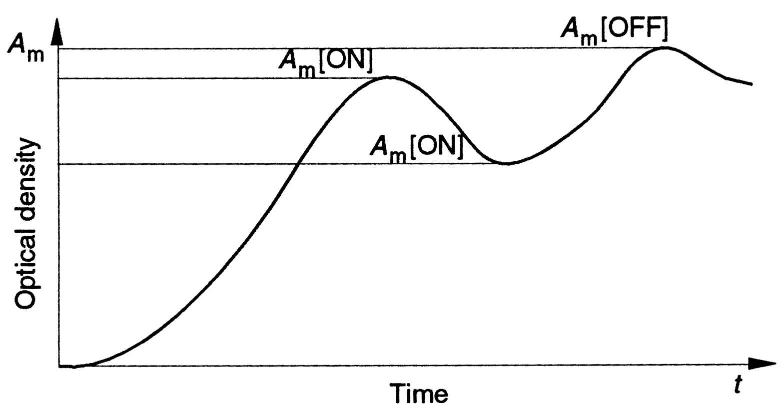

Figure D.6 — Variation in A_m(ON) due to various loss mechanisms

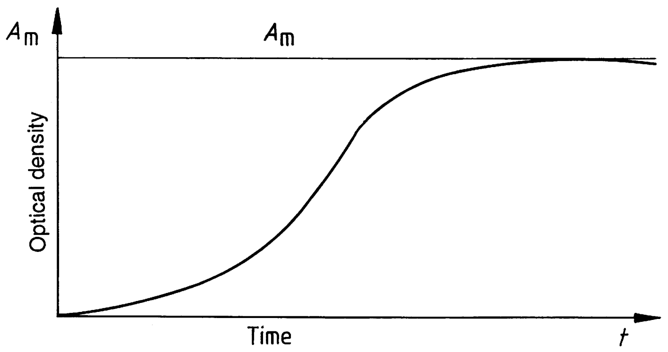

Figure D.7 — Single phase (flooring) test

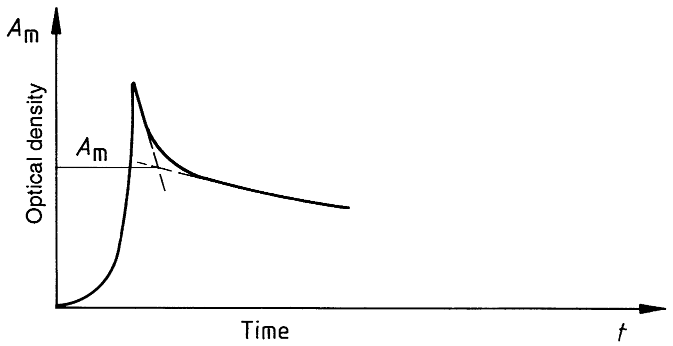

Figure D.8 — Single phase (small-scale) test

All dimensions are in millimetres

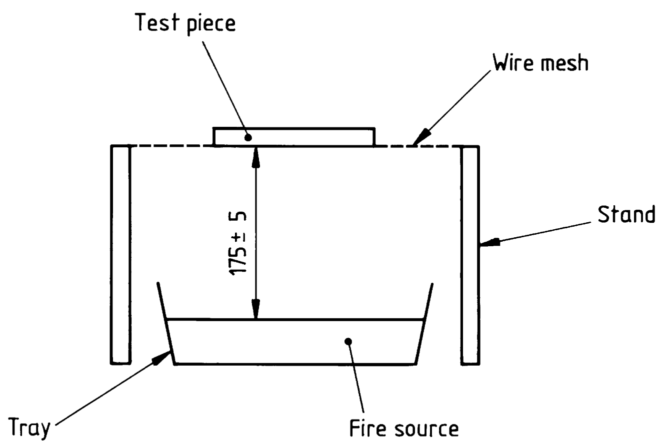

Figure D.9 — Schematic arrangement of small-scale test

All dimensions are in millimetres

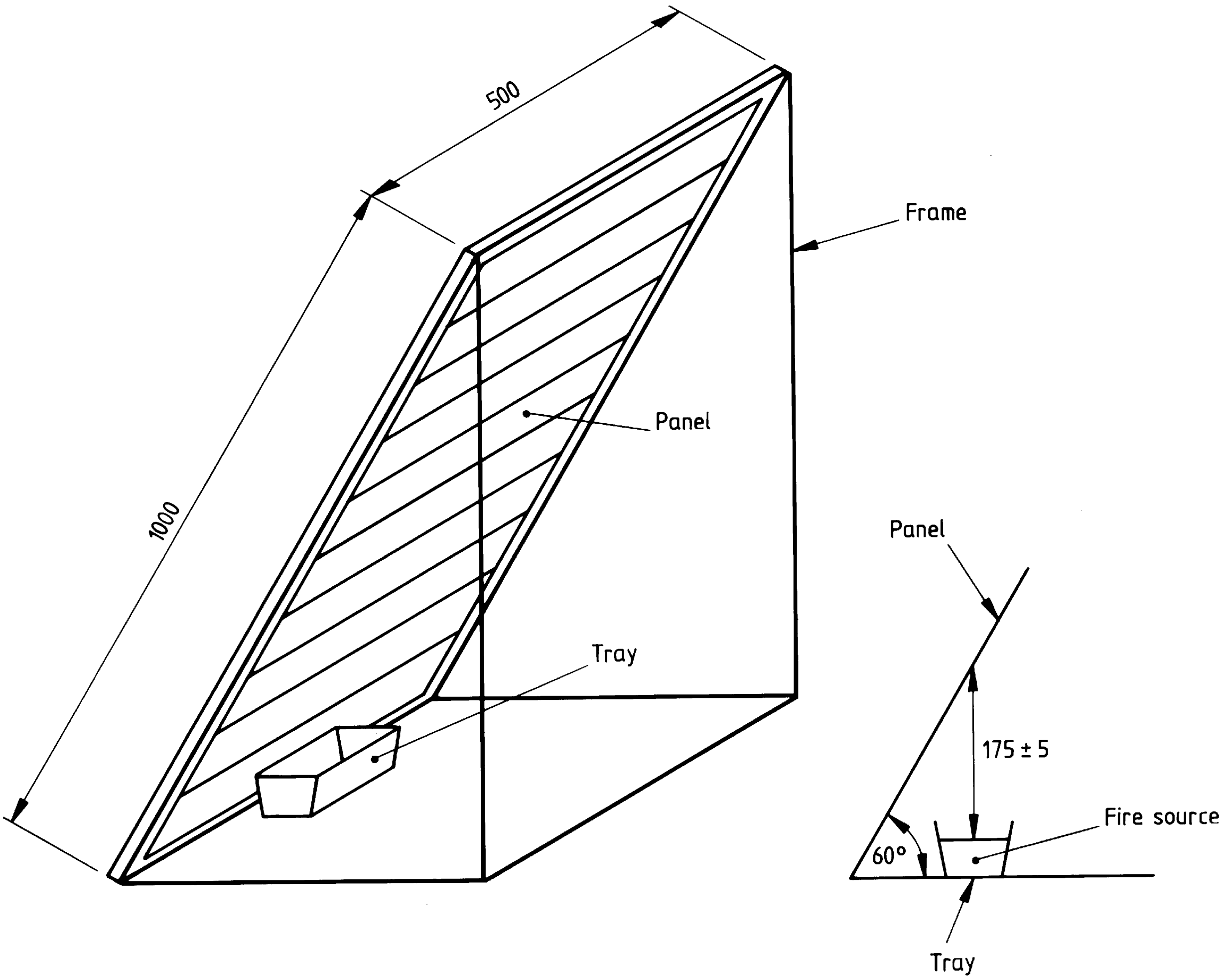

Figure D.10 — Schematic arrangement of panel test

All dimensions are in millimetres

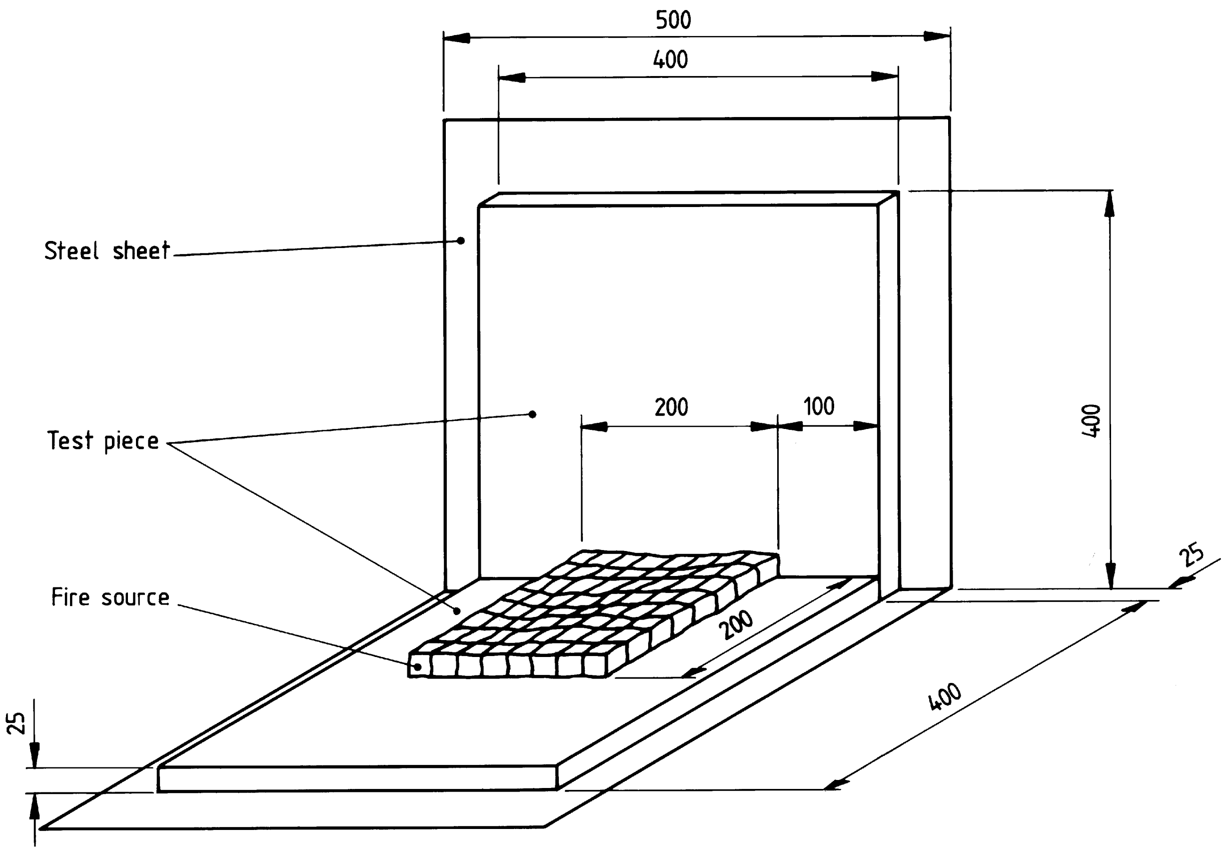

Figure D.11 — Schematic arrangement of seating test

All dimensions are in millimetres

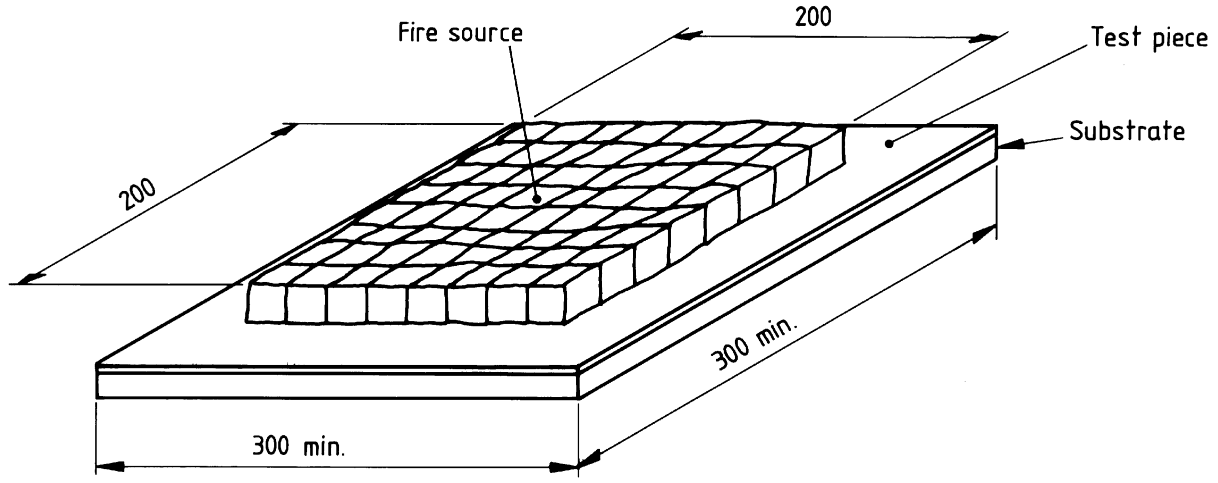

Figure D.12 — Schematic arrangement of flooring test

All dimensions are in millimetres

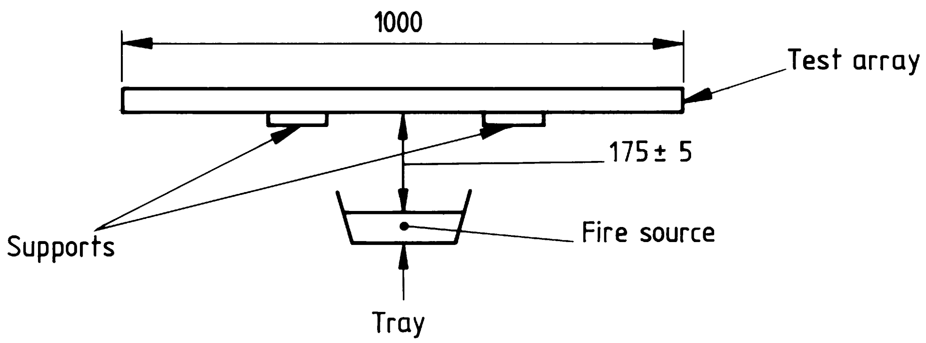

Figure D.13 — Schematic arrangement of cable test

Annex E (informative) Interpretation of test data

Observations of optical density within a test cube (see **D.2**) are made by plotting smoke emission against time. Generally, five types of curve are observed (see Figure D.4, Figure D.5 or Figure D.6, Figure D.7 and Figure D.8). The cable test (**D.8.7**) and the panel test (**D.8.4**) normally give curves as shown in Figure D.4, Figure D.5 or Figure D.6, whereas the curves for the flooring test (**D.8.6**) and the seating test (**D.8.5**) are typically as given in Figure D.7, and the small-scale test (**D.8.3**) gives a curve of the type shown in Figure D.8.

The curve given in Figure D.4 is an idealized representation of a typical two-phase test involving fire source 1. The first phase (ON) applies during the time that the alcohol source is burning. The second phase (OFF) applies after the source has been extinguished and the material is smouldering or, in some cases, burning.

The curves given in Figure D.5 and Figure D.6 are more typical of curves obtained in practice [see **D.8.8** for details of the convention which has been adopted when quoting results for tests in which a maximum is produced in either or both of the (ON) and (OFF) phases].

The curve given in Figure D.7 is typically produced in tests on flooring using fire source 2 and shows only a single phase. This is a function of the source behaviour, i.e. an initial flaming of the alcohol followed by a (mainly) smouldering combustion of the charcoal.

The curve given in Figure D.8 is a typical single-phase type commonly found in tests using fire source 1 in the small-scale test. In such a test, the test piece normally, at some stage, ignites, which leads to smoke production at a rate which is too fast for the fan (and up draught from the source) to mix. This leads to a "spike" in the curve which is ignored in the assessment. The extrapolation shown in Figure D.8 is used as the measure of smoke emission.

blank

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