TECHNICAL REPORT

ISO/TR 11696-2

First edition
1999-12-15

Uses of reaction to fire test results —

Part 2: **Fire hazard assessment of construction products**

Utilisation des résultats des essais de réaction au feu —

Partie 2: Évaluation du risque-feu des produits de construction

Reference number
ISO/TR 11696-2:1999(E)

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In exceptional circumstances, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example), it may decide by a simple majority vote of its participating members to publish a Technical Report. A Technical Report is entirely informative in nature and does not have to be reviewed until the data it provides are considered to be no longer valid or useful.

Attention is drawn to the possibility that some of the elements of this part of ISO/TR 11696 may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TR 11696-2 was prepared by Technical Committee ISO/TC 92, *Fire safety*, Subcommittee SC 1, *Fire initiation and growth*.

ISO/TR 11696 consists of the following parts, under the general title *Uses of reaction to fire test results*:

— *Part 1: Application of test results to predict fire performance of internal linings and other building products*

— *Part 2: Fire hazard assessment of construction products*

Introduction

This part of ISO/TR 11696 provides guidance on how to assess reaction to fire test results for construction products from tests developed in ISO/TC92/SC1. It provides a basis for reaching an informed judgement when balancing out any conflicting elements which may arise in a risk assessment exercise, where, of necessity, account must always be taken of many practical considerations.

The document has been designed to provide guidelines to be followed when assessing reaction-to-fire test results within the context of the overall hazard presented by a defined fire scenario. When using this guide, account should be taken of any statutory or control requirements (for example building regulations), information obtained from fire tests such as those developed by other organizations, published literature on non-standard tests and analytical and biological studies of fire atmospheres.

By establishing a toolkit of new fire tests, ISO/TC92/SC1 has provided a greatly improved facility for measuring the fire behaviour of materials and products more meaningfully than hitherto. The new test methods also provide data which can also be used in extended calculations and computer models to provide predictions of fire performance in a wide range of environments. The use of the test results in extended calculations and models has been explained in detail in ISO/TR 11696-1. At present, only a relatively small number of people and organizations are able to make use of the fire test data in this way, although a much larger number of organizations are able to conduct the tests and obtain the measurements. ISO/TR 11696-2 is intended to provide advice and guidance on the use of ISO toolkit test data by people and organizations who do not have facilities for extended calculations or computer models. Large numbers of test systems have been constructed and installed in many commercial fire test laboratories, the laboratories of materials manufacturers, universities and research institutions. A large number of users of the test apparatus currently require guidance in the use and interpretation of the results obtained.

Assessment of test results needs guidance, which provides a simplified method. With such guidance, results from the tests can be used by those who may not have knowledge of the mathematical modelling and the more complex fire science calculations. ISO/TR 11696-2 has been designed to encourage widespread acceptance of the tests by providing simplified guidance on the use of the results.

This guide enables assessment to be made of the likely fire hazards to occupants of existing buildings and transport as well as the effect that alterations to these structures may have on possible hazards. Experience with the specific procedure of this guide is limited to a few applications at present and more validation of the decision tree method is required. The concept of controlling the fire performance of construction products by assessing the contribution of products in reaction to fire tests is used widely by regulators.

It is recognized that the limitation and control of fire hazards will enable people to be confident in the safety of buildings and transport since fires would then be unlikely to occur and if one did, people would be able to escape. Fire testing is, however, only one of the techniques by which fire hazards and risks are limited and controlled. Other techniques include the application of codes of practice, laws controlling flammable materials and their misuse, inspection and education services provided by fire brigades, as well as fire detectors, sprinklers and other firefighting equipment.

Uses of reaction to fire test results —

Part 2: Fire hazard assessment of construction products

1 Scope

This part of ISO/TR 11696 provides guidance on the principles and use of fire test data and other relevant information concerning construction products and their end-use environment, so that potential fire hazards and/or risks may be assessed. It suggests procedures for expressing results and how to interpret the data to aid the fire hazard assessment process. The guidance given is aimed at materials manufacturers and convertors, designers, wholesalers and retailers, specifiers and regulating bodies, and consumer representatives.

2 References

ISO/IEC *Guide 52*, *Glossary of fire terms and definitions*.

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

ISO 1210, *Plastics — Determination of the burning behaviour of horizontal and vertical specimens in contact with a small-flame ignition source.*

ISO 1716, *Reaction to fire tests for building products — Determination of the gross calorific value.*

ISO 5657, *Reaction to fire tests — Ignitability of building products using a radiant heat source.*

ISO/TR 5658-1, *Reaction to fire tests — Spread of flame — Part 1: Guidance on flame spread.*

ISO 5658-2, *Reaction to fire tests — Spread of flame — Part 2: Lateral spread on building products in vertical configuration*.

ISO 5658-4, *Reaction to fire tests — Spread of flame — Part 4: Intermediate-scale test of vertical spread of flame with vertically oriented specimen*.

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

ISO 5660-1, *Reaction to fire tests — Heat release, smoke production and mass loss rate — Part 1: Heat release rate (Cone calorimeter method)*.

ISO 5660-2, *Reaction to fire tests — Heat release, smoke production and mass loss rate from building products — Part 2: Smoke production rate (dynamic measurement)*.

ISO 6925, *Textile floor coverings — Burning behaviour — Tablet test at ambient temperature.*

ISO 6941, *Textile fabrics — Burning behaviour — Measurement of flame spread properties of vertically oriented specimens.*

ISO/TR 9122-6, *Toxicity testing of fire effluents — Part 6: Guidance for regulators and specifiers on the assessment of toxic hazards in fires in buildings and transport.*

ISO 9239-1, *Reaction to fire tests for floor coverings — Part 1: Determination of the burning behaviour using a radiant heat source.*

ISO 9239-2, *Reaction to fire tests — Horizontal surface spread of flame on floor coverings — Part 2: Flame spread at higher heat flux levels.*

ISO 9705, *Fire tests — Full-scale room test for surface products*.

ISO 10093, *Plastics — Fire tests — Standard ignition sources.*

ISO 10351, *Plastics — Determination of the combustibility of specimens using a 125 mm flame source.*

ISO/TR 11696-1, *Uses of reaction to fire test results — Part 1: Application of results to predict fire performance of internal linings and other building products.*

ISO/TR 11925-1, *Reaction to fire tests — Ignitability of building products subjected to direct impingement of flame — Part 1: Guidance on ignitability.*

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

ISO 11925-3, *Reaction to fire tests — Ignitability of building products subjected to direct impingement of flame — Part 3: Multi-source test.*

ISO 12992, *Plastics — Vertical flame spread determination for film and sheet*.

ISO/TR 13387 (all parts), *Fire safety engineering.*

ISO 13784-1, *Reaction to fire tests — Scale tests for industrial sandwich panels — Part 1: Intermediate scale test.*

ISO 13784-2, *Reaction to fire tests — Scale tests for industrial sandwich panels — Part 2: Large-scale test.*

ISO 13785-1, *Reaction to fire tests on façades — Part 1: Intermediate scale test.*

ISO 13785-2, *Reaction to fire tests on façades — Part 2: Large scale tests.*

ISO/TR 14696, *Reaction to fire tests — Determination of fire parameters of materials, products and assemblies using an intermediate-scale heat release calorimeter (ICAL).*

IEC 61034-1, *Measurement of smoke density of cables burning under defined conditions — Part 1: Test apparatus.*

IEC 61034-2, *Measurement of smoke density of cables burning under defined conditions — Part 2: Test procedure and requirements.*

ASTM E1321, *Standard Test Method for Determining Material Ignition and Flame Spread Properties*.

3 Terms and definitions

For the purposes of this part of ISO/TR 11696, the terms and definitions given in ISO/IEC Guide 52 and the following apply.

3.1
fire hazard
the potential degree of personal injury or damage to property by a fire

3.2
fire risk
the expected loss from a fire is defined in terms of probability as the product of:

— frequency of occurrence of an undesired event to be expected in a given technical operation or state; and,

— consequence or extent of damage to be expected on the occurrence of the event

3.3
smoke
visible part of fire effluent

3.4
thermal inertia
a parameter usually represented as kDc where:

k is thermal conductivity (W/mK);

D is density (kg/m^3);

c is specific heat (J/g·°C).

NOTE This is an important parameter which governs the rate of surface temperature rise of a product when it is exposed to a heat flux.

4 Fire characteristics

By its nature, fire is a complex phenomenon, with its growth and ultimate severity depending upon a number of interrelated factors. For the purpose of this part of ISO/TR 11696, uncontrolled development of most fires can be divided into the following stages.

a) **Initiation:** The process of heating a material to ignition and thereby establishing a fire, during which the continued release of flammable vapours leads to sustained combustion;

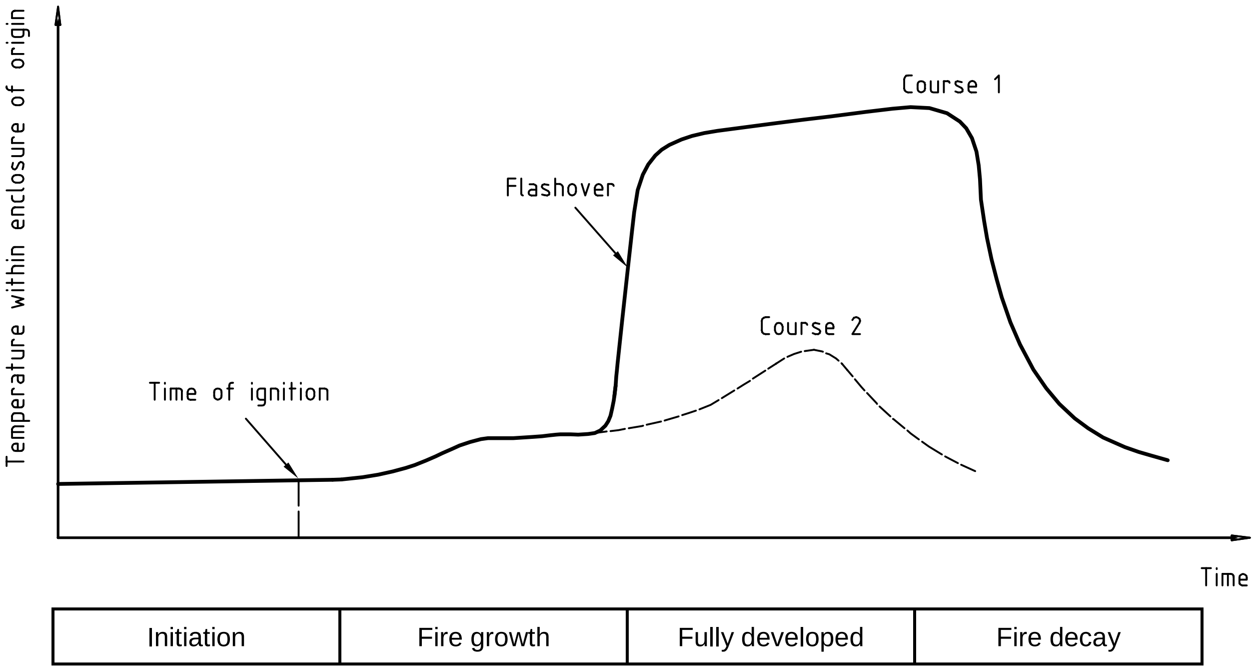
b) **Growth:** The spread or propagation of the fire which continues until there are no further supplies of immediately accessible fuel (combustibles) or air to become involved. This stage may involve the ignition of adjacent combustible materials;

c) **Flashover:** The sudden transition from a localized fire to combustion of all exposed fuel surfaces within an enclosure;

d) **Fully developed fire:** The stage at which the fire may be said to be "fully developed" and all combustible materials are burning at a rate controlled by the supply of air to burning surfaces;

e) **Decay:** The final stage during which the fire is burning itself out.

Heat produced by a typical uncontrolled fire in an enclosure changes with time (see Figure 1) and is affected by the design of the compartment and the ventilation conditions. Figure 1 also shows the four stages of development of the fire and the flashover point. The duration and severity of the fire at each stage varies markedly with the rate of air supply to the combustion zone. The degree of risk to life and property is, in turn, largely controlled by the stage to which the fire has progressed. The contribution of different products, components and elements of construction to those risks may also change considerably from one stage to another.



NOTE Not all fires go to flashover.

Figure 1 — Diagram showing the different phases in the development of a fire within an enclosed space

5 Fire hazard assessment

Realistic assessment of the fire performance of a product can only be obtained by considering a representative sample in the form and orientation in which it is actually used; an isolated assessment of this kind can only indicate the response of the product to the combustion environment selected. It must be emphasized, however, that no fire test can in normal circumstances measure fire hazard, nor can it be assumed that satisfactory results on a single standard fire test will guarantee a certain level of safety. Results from a variety of fire tests will provide information to assist in the determination and subsequent control of fire hazard assessment. A schematic representation of hazard assessment is given in Figure 2.

If a fire chain as depicted in Figures 1 and 2 can develop, a detailed appraisal of the proposed use of the product should be carried out. This process is necessary so that decisions may be taken about the type of action which will eliminate or reduce the severity of any potential fire hazards. It is recommended that this appraisal process is performed in a standardized procedure so that all relevant factors are considered.

The standardized procedure recommended is to consider the input data from the ISO toolkit tests as providing the bottom layer of a decision tree triangle (that is, the database is the roots of the tree) (see Figure 3). Where no evidence exists from modelling studies for the scenario under consideration, there will be a need to conduct additional testing (probably on a large scale, and possibly of an ad hoc nature). The middle layer of the decision tree triangle is therefore a correlation table between the test results and the full-scale behaviour. There will be gaps in this table initially and so it is recognized that additional validation information (often of an ad hoc nature) will need to be provided at the revision stages of this part of ISO/TR 11696.

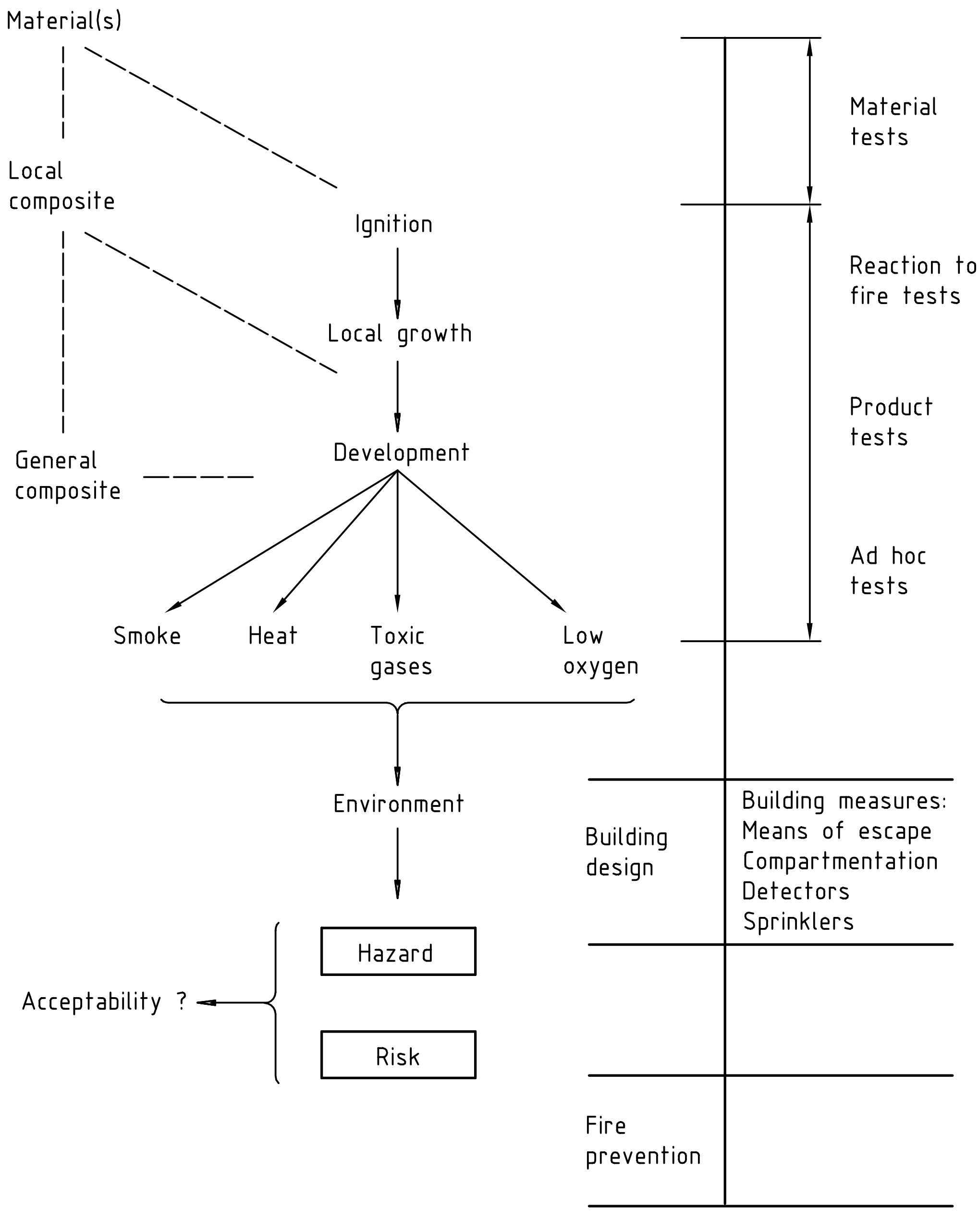


Figure 2 — Hazard/risk assessment

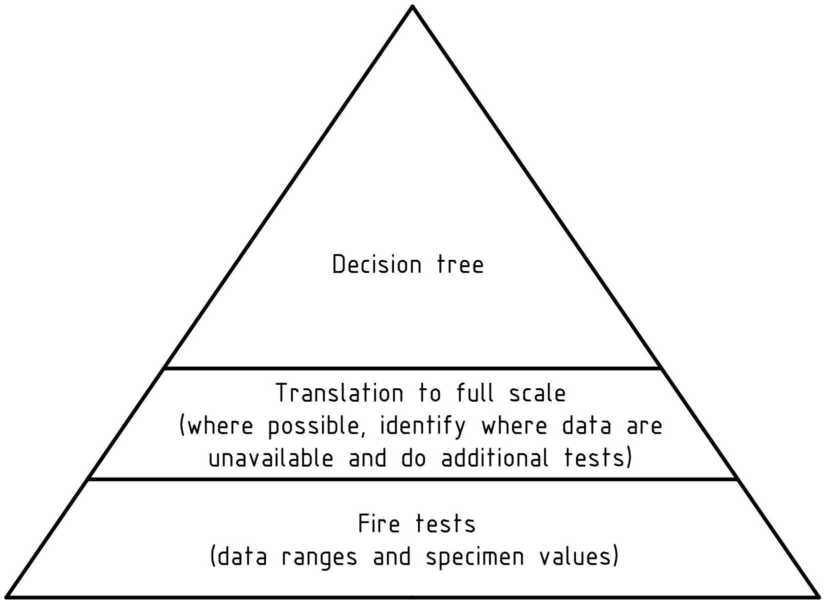


Figure 3 — The decision tree triangle showing input of test data

This part of ISO/TR 11696 suggests a 5-step approach to fire hazard assessment based upon a decision tree; the decisions about the acceptability of the fire safety questions may be made using classification techniques or mathematical modelling (or combinations of both). The decision process used and the level of acceptable results is the responsibility of individual regulators, users, etc.

The procedure for fire hazard assessment assumes that fires develop in the manner indicated in clause 4. It is then possible to consider the stages of a potential fire in different steps. It is particularly important to note that at each step data from fire tests are considered together with information on the product design and anticipated conditions of the fire scenario.

6 The decision tree

NOTE The complete 5-step process is illustrated in Figure 4.

6.1 Step 1 — Definition of fire scenario (probabilistic)

Consideration should be given to both the immediate fire site and to the surrounding areas which may subsequently become involved. Once the scenario has been defined, the probability of its occurrence should be assessed. It is important to include a diagram of the scenario and the anticipated smoke movement at this step.

6.2 Step 2 — Ignition hazard (deterministic)

Fire statistics are available on ignition sources and the causes of fire in different environments (for example, domestic and industrial buildings) and they should be consulted. These statistics can be used to assess the relative probability of specific ignition incidents.

Ignition sources selected for tests should be relevant to those considered to be realistically capable of existing in the defined scenario.

Factors influencing the decision about whether there is an ignition risk are shown in Figure 5. A reliable decision can only be made if each factor is carefully considered in terms of potential influences on the ignition hazard (see clause 7).

6.3 Step 3 — Fire growth hazard (deterministic)

After ignition, the surroundings affect fire growth to an increasing extent. Factors influencing the decision about whether the rate of fire growth presents an acceptable hazard or not are shown in Figure 6 (see clause 7).

6.4 Step 4 — Smoke (deterministic)

The rate of smoke development is important in determining the effective obscuration of vision which determines when escape becomes impossible. It is therefore a contributor to the overall life hazard.

It is widely recognized that the actual smoke evolution at any point in time is dependent not only on the inherent smoke generating properties of the materials involved, but also on the total amount burning and on decomposition conditions. Indeed, in many circumstances the latter may be more important. Similarly, the rate of fire spread determines how much new material becomes involved in a fire and hence has a relationship to the smoke and toxic gas development.

Data from as many relevant smoke tests as possible should be considered at step 4. These tests may include material as well as product tests. They should cover smoke opacity and smoke toxicity and rate of generation of smoke. It is important also to collect data on rate of mass loss for consideration at step 4 (see Figure 7 and clause 7).

6.5 Step 5 — Rate of hazard development (probabilistic)

Fire generates a hazardous environment when it is developing. It is vital to be able to assess the point at which the hazard becomes unacceptable. Factors influencing this decision are shown in Figure 8 (see clause 7). When the available data indicate that the supplier or user should "redesign", alternative approaches should be taken to improve the fire performance of the product, for example use improved formulation or incorporate protective layers to inhibit fire growth.

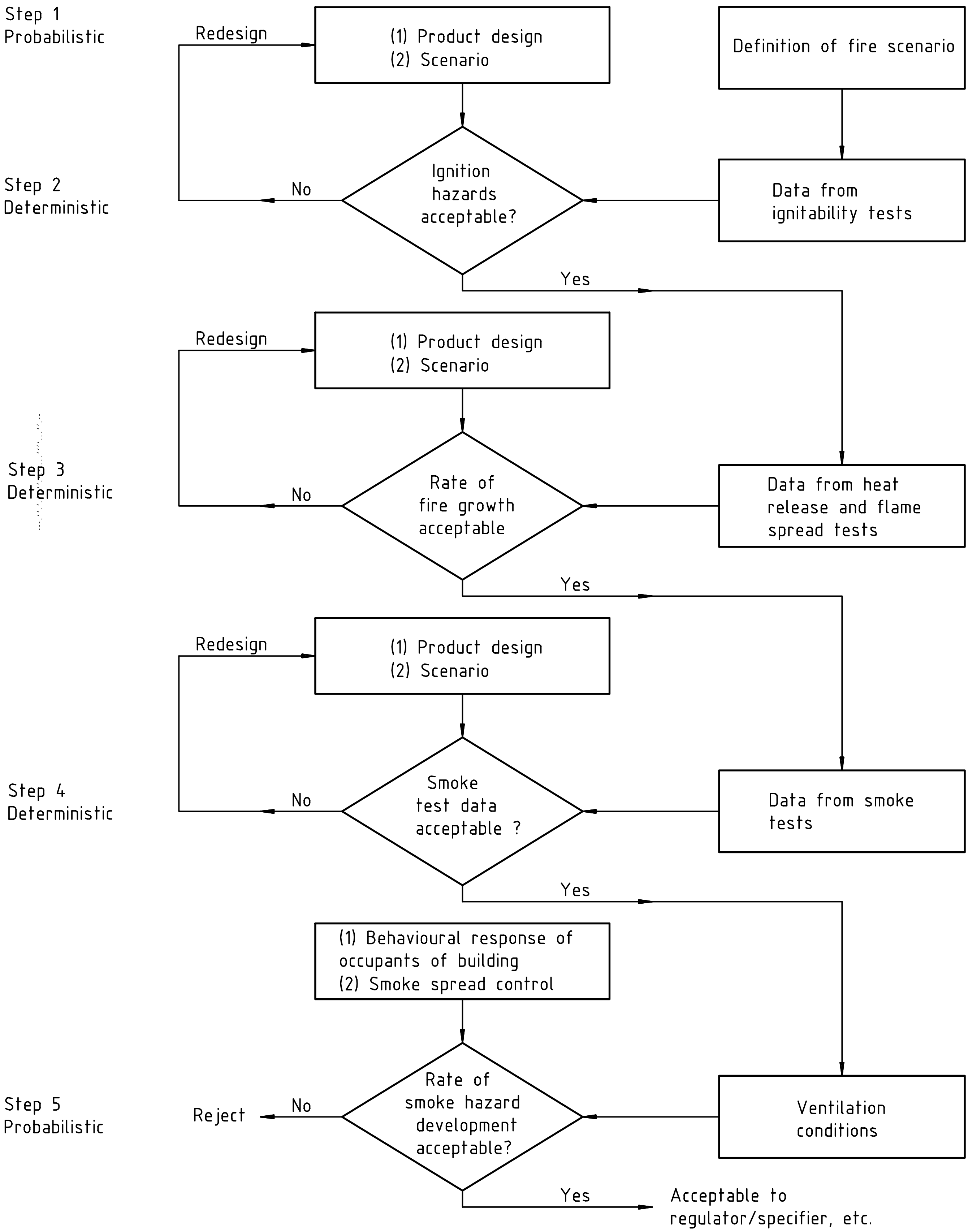


Figure 4 — Decision tree for fire hazard assessment

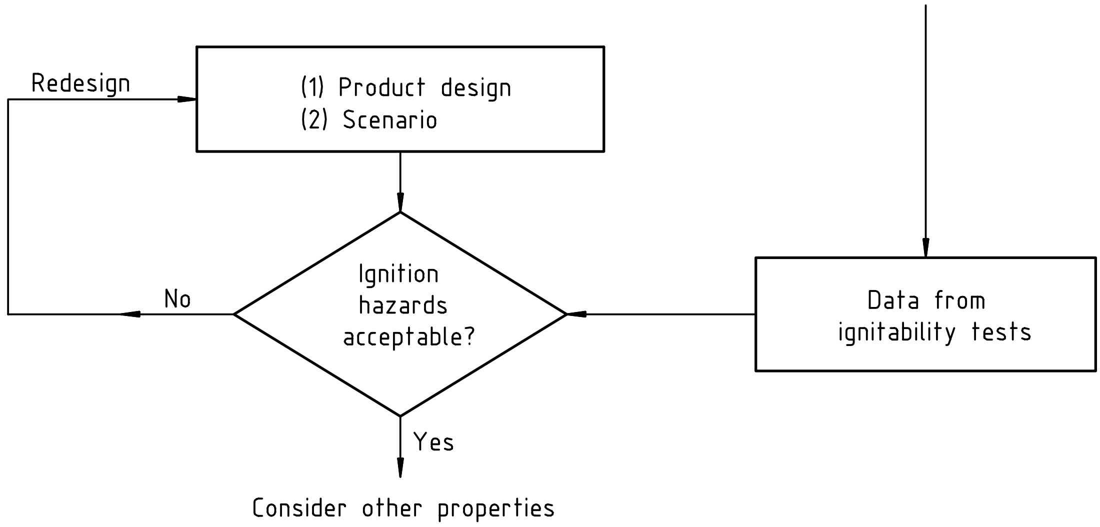


Figure 5 — Fire hazard assessment: Step 2

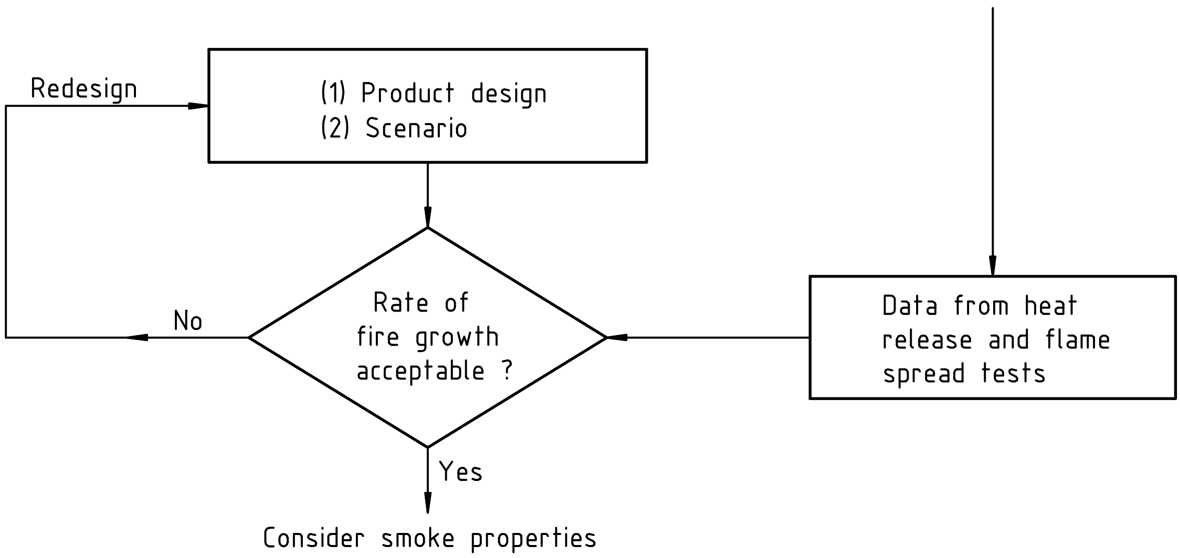


Figure 6 — Fire hazard assessment: Step 3

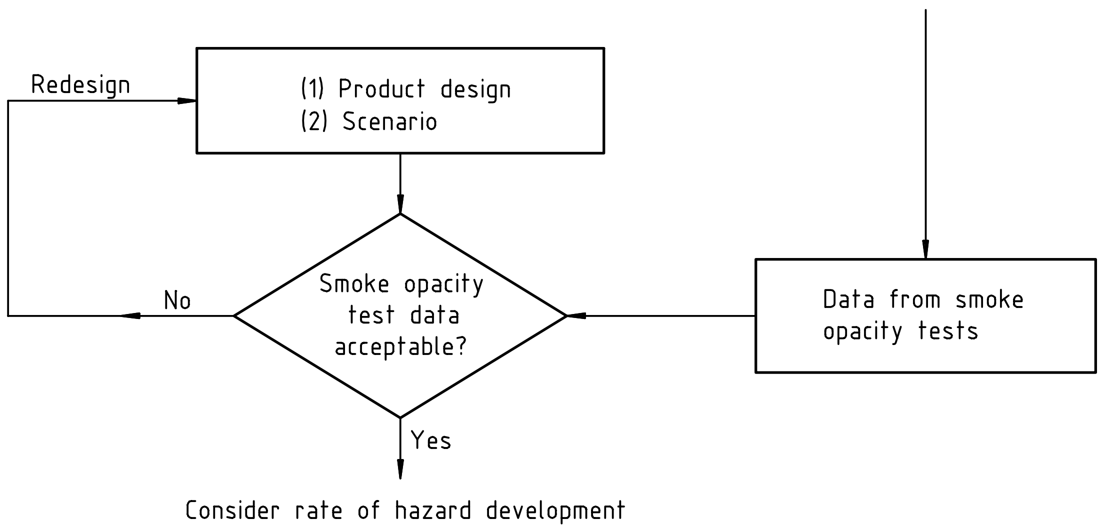


Figure 7 — Fire hazard assessment: Step 4

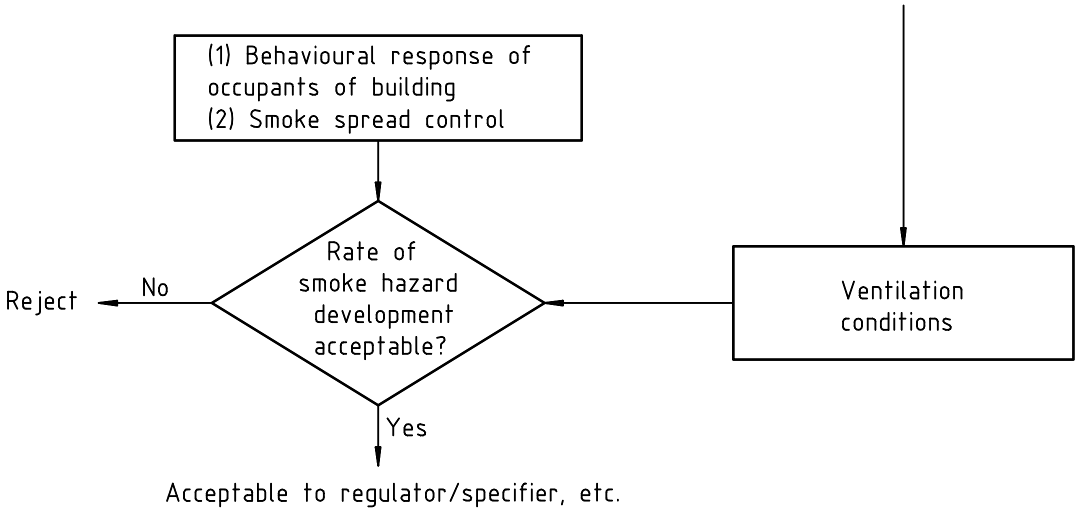


Figure 8 — Fire hazard assessment: Step 5

7 Factors affecting fire growth and the extent of their importance

7.1 Step 1 — Definition of fire scenario

7.1.1 Product description

The product for which hazard assessment is required should be described as fully as possible. This description should include details about its composition and assembly (such as type of substrate, orientation, fixing and presence of air gaps). Particular consideration should be given to description of end-use fixing in the fire scenario to be assessed.

7.1.2 Geometry

The geometry of the fire scenario should be described as closely as possible. This description, which should be supported by drawings, should include the dimensions of the fire enclosure and any relevant features which may affect air and smoke flow. The possible sites of ignition sources should in particular be identified.

7.1.3 Ventilation

The ventilation conditions in the fire scenario should be detailed. This description should include positions of the doors and windows as well as ducts or other air-conditioning systems.

7.1.4 Active fire protection systems

The presence of smoke detectors and sprinklers should be described. For specific guidance on active fire protection other documents should be consulted (see ISO/TR 13387).

7.2 Step 2 — Ignition

7.2.1 Product design

7.2.1.1 Area exposed

A reduction in the area exposed reduces the probability of contact with the ignition source.

The size of the exposed area will increase or decrease the ease of ignition depending on the thermal inertia of the surface.

7.2.1.2 Orientation

A vertical orientation allows hot volatiles to diffuse upwards, diluting with air to form a range of concentrations.

A horizontal (facing up) orientation ensures that volatiles will mix with air but at low concentrations.

A horizontal (facing down) orientation will restrict volatiles mixing with air but will increase their concentration.

7.2.1.3 Interaction of angled surfaces

Angled surfaces conserve heat, re-radiate and exaggerate the effect of physical properties such as thermal inertia.

7.2.1.4 Form of surface

A rough surface increases the area exposed to the source and thus increases the effect of thermal inertia.

7.2.1.5 Thickness of product

Thin products increase the rate of temperature rise of a surface and speed of ignition. The nature of the substrate can have a significant influence on the thermal behaviour.

7.2.1.6 Composition of material

The chemical properties of a material will determine the rate of emission of volatiles and the ignition temperature of volatiles.

The nature of a plastic material (whether thermoplastic or thermoset) will determine whether melting or slumping behaviour may be expected.

Some materials (for example plastics) may contain fire retardants, fillers or reinforcing fibres; if possible their chemical composition and concentrations should be recorded.

7.2.1.7 Physical nature of material

The thermal inertia of the surface and of the substrate should be considered together with the effectiveness of the adhesion to the substrate.

It is important to note that a material with a low thermal inertia value will retain heat in the surface layers and the temperature will more rapidly reach that at which decomposition begins.

7.2.2 Scenario

7.2.2.1 Enclosures

The size of the enclosure is not an important consideration at the ignition stage.

7.2.2.2 Ignition source

The ignition source is of fundamental importance when defining the scenario and the following characteristics of ignition sources should be considered:

a) intensity of the ignition source. The thermal transfer to the product may be by radiation, conduction and convection;

b) area of contact of the ignition source, or the distance between ignition source and exposed surfaces;

c) orientation of the product relative to the ignition source;

d) ventilation conditions around the ignition source.

Details of ignition sources such as typical heat outputs and duration of exposure are given in ISO 10093 and ISO 11925-1. For fire hazard assessment, it is useful to categorize heat sources to place their role in a chain of events characterizing a fire scenario. For example, primary ignition sources are those which may cause the initial fire. Primary sources include the following types:

1) open flame (match, candle);

2) spontaneous heating/self-heating (rubbish);

3) smouldering (cigarette);

4) overheating due to prolonged exposure to conducted, convected or radiated heat (space heaters, other electrical appliances);

5) electrical discharge (lighting circuits).

Secondary sources include those fires which develop from a primary ignition source within a discrete burning product; for example, a waste bin ignited by a cigarette or an electrical component ignited by a power fault. These sources have been described conveniently as single burning items; their characteristics may be simulated in a test laboratory. Flaming drips from a burning plastic product may also be defined as a secondary ignition source.

7.2.2.3 Proximity of ignition source to product ignited

The probable distance of an ignition source from the potentially ignitable product should be estimated.

7.2.2.4 Airflow round product ignited

An airflow introduces a cooling effect and causes dispersal of volatiles.

7.2.2.5 Composition of atmosphere

An atmosphere with 21 % oxygen is normal at the ignition stage but under some unusual circumstances there may be atmospheres which are wet and/or have high or low oxygen concentration.

7.2.2.6 Extraneous effects

Fire detectors may be activated by emission of heat, radiation or smoke.

7.2.3 Data from ignitability tests

Data may be necessary from a range of sources and tests, for example

a) data from flame ignition tests — ISO 11925-2, ISO 11925-3;

b) data from ignition by radiation tests — pilot ignition ISO 5657, ISO 5660-1;

c) data on non-piloted ignition — ad hoc tests and ISO 5657 without pilot flame;

d) data from electrical ignition sources.

Possible effects of air movement, initial oxygen concentration and humidity should also be considered.

7.3 Step 3 — Fire development

7.3.1 Product design

7.3.1.1 Area exposed

The area exposed to direct flame spread should be considered. Flame spread is a process of continued ignition. Vertical height is more important than lateral width.

7.3.1.2 Orientation

The orientation is important when the vertical height is extensive. Flame spread over horizontal surfaces is small unless tall flames radiate onto adjacent surface or flames are deflected by wind or any obstruction.

Expansion of hot gases under a horizontal surface preheats an area in advance of the flame front and causes accelerated flame spread. With ceilings, this can result in significantly extended flames.

Where there is a emission of volatiles, a layer of gases may be formed under any extended horizontal surface. This layer may become overly rich and can lead to "flashover" if mixing with air below the layer occurs. Otherwise a flaming layer forms at the interface which generates high irradiance on any surface below.

The physical process of fire growth leading to flashover is illustrated in Figures 9 and 10.

7.3.1.3 Shape of the product

The height of exposed vertical face of a product is of primary importance.

Channelling of flame into vertical folds or corners accelerates flame spread by confining hot buoyant gases and by reflecting radiation.

Thin products, which may have been exposed on one face only, will give an acceleration of flame spread or rate of burning when the combustion zone approaches or penetrates to the unexposed face.

Freely-supported products with maximum surface area exposed to fire are most vulnerable.

7.3.2 Scenario

7.3.2.1 Proximity of walls/ceilings

Where the product comprises or lies adjacent to extensive areas of walls or ceilings this provides a risk of rapid spread.

Where the vertical surfaces are combustible the risk of flame spread is increased because of interaction between these and the product.

Where the product is isolated but near ceiling level, the risk of generation of an over-rich layer of decomposition gases is highest.

For involvement of ceilings see 7.3.1.2.

7.3.2.2 Proximity of other combustibles

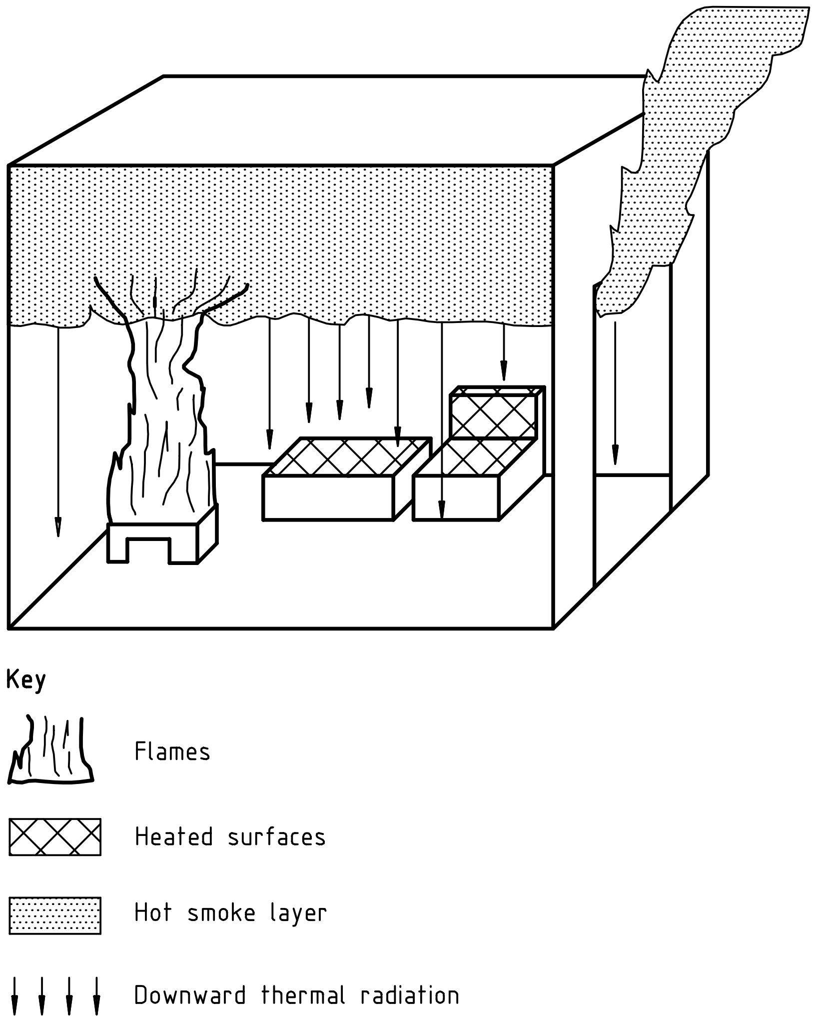
Irradiance from flames from a burning product will increase with their proximity to other potentially ignitable products but the rapidity of ignition of these will depend on their physical/chemical properties and their form/structure (see 7.1.1).

Interactions in terms of loss or conservation of heat (depending on thermal inertia) will increase with proximity.

The aerodynamics of the fire now largely govern flame spread, i.e. cooling effects of air drawn over/through adjacent products due to buoyancy of gases above the burning zone.

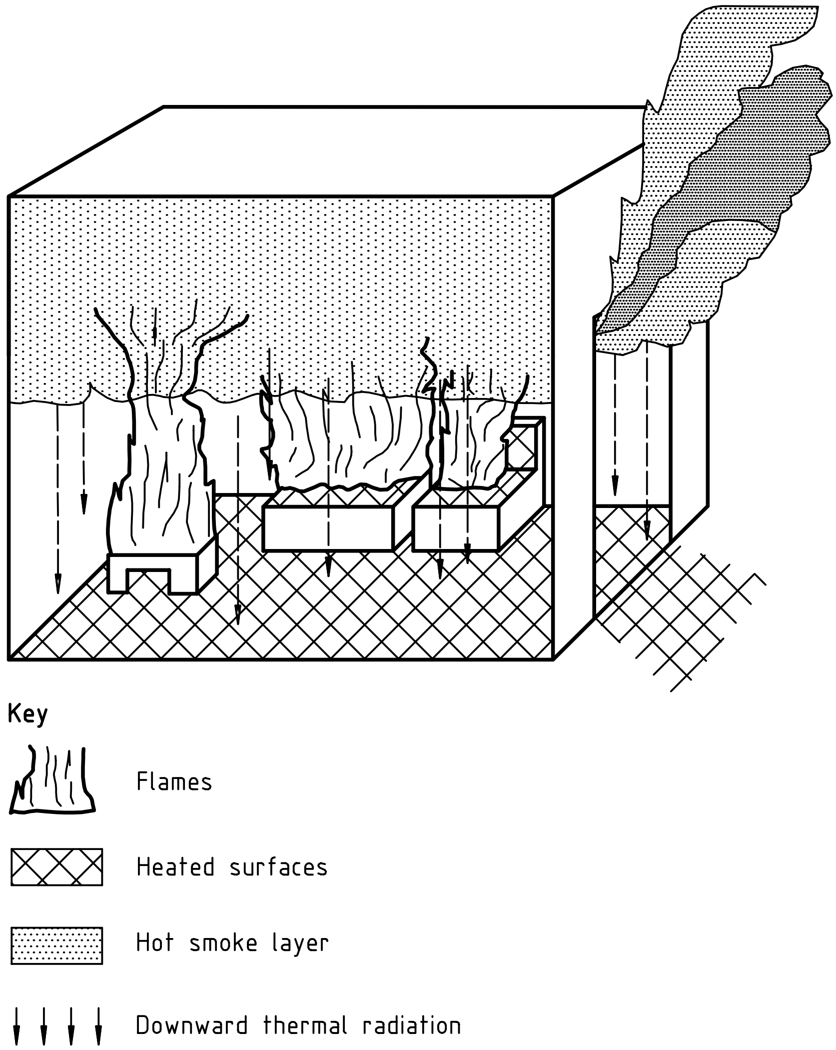
Initially, at lower levels, cool but oxygenated air will flow over irradiated products and this may disperse volatiles which will be drawn into the existing fire area. At higher levels, products are likely to become heated by fire gases; these, becoming progressively vitiated, will delay ignition. Such conditions favour the formation of smoke and carbon monoxide.

Exposure of horizontal surfaces of combustible products to the hot gas layer under the ceiling (whilst still themselves surrounded by oxygenated air) will constitute the most hazardous situation, i.e. that which initiates flashover. Under these conditions, the rapidity of ignition and rate of burning will be at their maximum.



NOTE Immediately prior to flashover, a layer of hot smoke is formed under the ceiling of the compartment.

Figure 9 — Fire growth: developing stage



NOTE At the point of "flashover", the intense thermal radiation from the hot smoke layer causes the upper surfaces of all the flammable products in the room to ignite spontaneously.

Figure 10 — Fire growth: developed stage

7.3.2.3 Ventilation of compartment

The surrounding enclosure becomes more important as the fire develops, particularly in small rooms where the area of openings in the walls controls the ventilation. This becomes of overriding importance as the fire becomes fuel rich, when the area, shape and distribution of the openings governs the rate of burning.

The presence of open doors/windows can determine whether a fire will develop or not, so probability again must be considered.

An increase of temperature may cause failure of the structure, for example windows. Additionally, the resistance to collapse of load-bearing elements becomes important, particularly if the fire has caused structural failure of contents which can penetrate a dividing element.

7.3.2.4 Active intervention

Fire detection equipment will be activated soon after ignition and intervention may be expected during the early stages of spread.

Fire fighting (manual and sprinkler application) will significantly affect fire growth by cooling, preventing ignition and reducing radiation.

In large buildings, smoke extract systems will operate causing removal of decomposition products and inflow of cooling air from lower vents, affecting the pattern of fire growth aerodynamically.

Interaction of smoke extracts and sprinkler systems will affect aerodynamics.

7.3.3 Data from tests

7.3.3.1 Ignitability tests

Data relevant to secondary ignition are needed for the product itself and also for adjacent products and structure. Tests applied are those listed in 7.2.3 (as appropriate).

7.3.3.2 Flame spread tests

Data are more limited in their application, the tests representing the performance of specimens of materials or composites only under a prescribed heating regime.

b) ISO 5658-2, lateral surface spread of flame over vertical surface, from 50 kW/m^2 down to 5 kW/m^2;

c) ISO 5658-4, vertical spread of flame with specimen irradiated to 40 kW/m^2 in the presence of a pilot flame;

d) ISO 9239-1, horizontal flame spread over floor specimens irradiated up to 11 kW/m^2, with pilot flame. This test provides a measure of rate of flame spread and critical radiant flux at flame-out;

e) Textile and thin film flammability, ISO 6941 and ISO 12992, provide data on vertical spread using a microburner;

f) Small-scale tests on plastics materials such as ISO 1210 and ISO 10351.

7.3.3.3 Heat release tests

Data are required for the product itself and also for adjacent products and structures. Appropriate small and intermediate-scale tests include:

a) ISO 5660-1, cone calorimeter at heat flux levels from 10 kW/m^2 to 100 kW/m^2;

b) ISO 1716, bomb calorimeter is used to determine the calorific value, which may be required to calculate heat potential of a product or material to assess possible duration of fire and to estimate the fire load within an enclosure;

c) ISO 1182, non-combustibility test;

d) Furniture calorimeter (or similar) using oxygen consumption method of calculation and ad hoc source;

e) ISO 9705, room/corner test for surface linings;

f) Ad hoc tests may be necessary for a more realistic simulation where no relevant standard tests are available. These may be based on a furniture calorimeter but simulating the products and environments, especially for thermoplastics which may not easily be assessable by standard test methods. Laboratory data on performance in specialized atmospheres (oxygen deficient, high moisture content, etc,) can be obtained using a modification of the cone calorimeter.

7.3.4 Fire safety engineering

Based on assessment of real fires, four categories of fire growth rate curves have been defined for design used in fire safety engineering. Test-data from the cone calorimeter (ISO 5660), room/corner test (ISO 9705) and realistic full-scale tests may be used to assist the fire engineer in allocating the performance of a building product to one of these design fire growth curves. The decision about this categorization would be taken at Step 3 of this part of ISO/TR 11696; this decision would be made in a pragmatic way depending on the availability of suitable test-data and the use of heat release rate data in this way is not intended to be the sole way in which fire hazards can be quantified within the enclosure of origin. Hazards may also be identified from the statistics of real fires, personal knowledge and experience (probabilistic methods) and from reports of standard fire tests (deterministic methods).

7.4 Step 4 — Smoke

7.4.1 Smoke opacity

The visibility within a fire enclosure is a function of the opacity of smoke within the enclosure and the volume of the enclosure. In real fires, hot smoke is buoyant and usually descends as a layer from the upper surfaces of the enclosure.

Smoke opacity tests are of two types; a *static method* providing information on the density of smoke emitted from a specimen of material under specified test conditions; the products are accumulated within a closed container and opacity is measured by an optical method. The *dynamic method* measures continuously the emission of smoke from a product under specified test conditions, applying an optical or gravimetric measuring system to the flowing gases to record optical density together with volume flow rate.

Within the fire enclosure some recirculation and secondary combustion of smoke particles may occur. In the static tests, these processes are simulated.

In a fire the smoke particles generated may be dispersed in the flowing effluent. This situation is represented by the dynamic type of test. In practice, decay of the smoke involves coagulation of particles and/or their deposition on cooling.

a) ISO 5659-2 is a single chamber, static smoke test, which exposes the specimen to intensities of 25 kW/m^2 and 50 kW/m^2 in the horizontal mode as well as recording mass loss to give a mass optical density. The test is usually run with a pilot flame when tests are done at 25 kW/m^5 irradiance;

b) ISO 5660-2 cone calorimeter. Dynamic data are obtained under a range of free-ventilated heating conditions from 10 kW/m^2 to 100 kW/m^2;

c) Room tests (for example ISO 9705) with hood and duct systems can be used to assess continuously the rate of smoke emission from lining products under standardized thermal and ventilation conditions in terms of m^3/min of smoke of optical density per metre equal to one;

d) IEC 61034 (parts 1 and 2) is a 3 m cube chamber, static smoke test, which uses an alcohol tray as ignition source;

e) Ad hoc smoke test data. Where a specific fire risk is anticipated in a known environment, this may be simulated by test and the resulting effect of failure of the structure on fire growth and smoke spread can be established. Where the exposure risk is uncertain, a "worst case" approach to the severity of the test conditions should be adopted.

An example of a way in which smoke opacity data may be used to calculate visibility within an enclosure is given in annex C.

7.4.2 Smoke toxicity

The toxic hazard of a material can be gauged from the combination of the toxic potency of its fire effluents and its rate of burning, or in simple terms its rate of mass loss. For hazard assessment taking into account a variety of products, an averaged toxic potency value may lead to appropriate simplified results. This guide does not extend to cover toxic potency, which is described in ISO/TR 9122. If required, an optional input can be introduced into the Step 4 decision to consider relevant toxicity test data.

7.5 Step 5 — Rate of hazard development

7.5.1 Product design

7.5.1.1 Quantity of combustibles

The total quantity of each combustible component of a given product determines the potential for generation of heat and decomposition products. The rate of their generation is usually of greater importance to life threat and quantity and composition of the resultant decomposition products will vary according to the combustion atmosphere and the exposure conditions within the enclosure.

7.5.1.2 Protection of combustibles

The provision of a non-combustible facing material over a combustible product can delay the contribution of that component to the overall hazard. Care in the selection of a protective facing and its fixings is necessary to ensure that there is no additional risk.

7.5.1.3 Calorific potential

To estimate roughly the potential energy of a fire, the individual values of mass $\times$ calorific value for each combustible should be combined. No indication of fire severity can be obtained from this value.

7.5.2 Scenario

7.5.2.1 Ventilation

Following fire growth and its development to flashover, the rate of burning within an enclosure will be determined by the ventilation conditions unless active extinguishing action is being undertaken. The rate of burning, roughly estimated, may be assumed to be related to the ventilation opening of the enclosure. The rate of burning, R, expressed in kilograms of wood per minute, may be defined by the following expression:

$$R = A\sqrt{H} \times 5,5$$

where

A is the area of opening;

H is the height of opening.

The point at which ventilation is free enough to allow the fire to be fuel-controlled, rather than ventilation-controlled, may be assumed to occur once the air supply is increased well above 0,1 m^3/s per 1 m^2 of burning surface of wood.

7.5.2.2 Integrity of enclosure

Large scale structural failure of the enclosing walls will allow free burning of the contents and massive emission of combustion products. Subsequent flow and dilution of these products is dependent on pressure conditions outside the enclosure.

Fire resistance test data should be considered. Although giving only a rough guide to the probable performance of a given structural element in an actual fire, the rating in ISO 834 indicates performance in terms of stability, integrity and insulation of a product under simulated fully-developed fire conditions. The failure of the dividing element will alter the ventilation conditions of a growing fire. Failure of stability is usually followed by breakdown of the enclosure.

7.5.2.3 Fire effluent

Movement of the effluent may be predicted using computer modelling once the output of the initiating fire has been calculated.

7.5.2.4 Effect of fire-fighting or extinguishing systems

The application to the fire of water as extinguishing agent has the following effects:

a) cooling of compartment;

b) delay in ignition of other surfaces when wet;

c) formation of steam which blankets off incident combustion air from solid fuel;

d) inhibiting action of steam on gaseous mixtures, reducing flammability limits.

Other extinguishing systems may either:

1) inhibit by reducing flammability limits, for example halogenated hydrocarbons, or

2) smother by excluding air from burning surface, for example foam, dry powder.

7.5.2.5 Effect of extinguishing agents on the composition of the fire gases

Extinguishing agents may cause:

a) reduction in visibility by formation of steam.

b) alteration of combustion processes which may increase the smoke density and/or toxicity.

c) significant reduction in rate of emission of all decomposition products because of reduced rate of burning.

7.5.2.6 Escape

The time available to ensure escape of occupants varies with their mobility, the design of the premises, the obscuration of the visibility and the toxic or irritant effects of the decomposition gases. A suitably designed building will have adequate provision of escape routes to ensure safe evacuation.

Annex A

An example of a quantitative assessment of fire test data

A.1 General

This informative annex is provided to illustrate one way in which data generated by the ISO test methods may be used in fire hazard assessment. It is an example based on the ISO reaction to fire tests currently available [3] and it suggests the use of a methodology based on zones of performance. The approximate limits of these zones reflect current technical knowledge in respect of materials presently available and in common usage. The concept of classification zones is different from rank ordering of products. As in national classification systems, no products should be regarded as being at the top of a class whilst other products are at the bottom of a class.

At present, the variety and complexity of construction products limits the application of mathematical modelling techniques to simple products in clearly defined fire scenarios (see ISO/TR 11696-1). This part of ISO/TR 11696 suggests a calculation technique for quantifying the reaction to fire hazard parameters described in clause 7 for any construction product in any fire scenario.

In any calculation of hazard factors for ignitability, fire growth and smoke, decisions have to be taken about what levels of contribution to fire behaviour are indicated by test results on the construction product under consideration. Test data suitable for classification are given in annex B and that information needs to be used in the calculation procedures outlined in this annex.

A.2 Step 2 — Classification of ignitability hazard

Materials and products may be evaluated with a variety of relevant primary and secondary ignition sources as well as different test conditions (see ISO/TR 11925-1 and ISO 10093). The classification zone of performance can be recorded for each ignitability test and the test data may be assessed according to the following suggested classification system:

Performance zone	Class
Non-ignitable	I
Difficult to ignite	II
Easy to ignite	III

The criteria for selection of the limits of performance in each zone can then be determined by the assessor. Further guidance in this is given in clause 7 and annex B.

For a reliable assessment of ignitability performance, it is recommended that the product is tested to a range of both flame and radiant heat ignition sources. The range should include sources of both low and high intensity. It cannot be assumed that a product will automatically show a good ignition performance to a low intensity source because good performance has already been obtained with a high intensity source.

The decision about classes resulting from performance zones and acceptability for the scenario under consideration will be taken by the regulator.

A.3 Step 3 — Classification of fire growth hazard

Materials and products should be evaluated using a combination of relevant flame spread and heat release tests. Classification of performance can then be determined using the following classification system:

Performance Zone	Class
Zero (or very limited) contribution	I
Limited contribution	II
Moderate contribution	III
Large fire growth potential	IV

The criteria for selection of the limits of performance in each zone may then be determined by the user based upon the further guidance given in clause 7 and the information provided in annex B.

The decision about classes resulting from performance zones and acceptability for the scenario under consideration will be taken by the regulator.

It is recommended that a lower performance classification be allocated if fire growth is fast. It is also recommended that preference be given to rate of flame spread and rate of heat release data over total flame spread or total heat release data obtained on individual tests.

Simple fire models may be used to assist in the estimation of specific criteria considered to be valuable in determining fire growth potential; for example, in calculating time to flashover in ISO 9705 small room tests. Data from small-scale tests such as ISO 5660 and ASTM E1321 (LIFT) may be used to predict time to flashover for wall-linings by using formulae detailed in ISO/TR 11696-1. In addition, the design curves of heat release versus time used by fire safety engineers should be considered when deciding upon relevant performance zones.

A.4 Step 4 — Classification of smoke hazard

It is important to note that smoke hazards are scenario-dependant.

Materials and products may be evaluated using a variety of relevant smoke opacity tests. Wherever possible, data should be included from both static and/or dynamic smoke tests under relevant decomposition conditions; ref. annex C. Classification of performance can be determined using the following classification system for each smoke test.

Performance Zone	Class
Low opacity	I
Medium opacity	II
High opacity	III

The criteria for selection of the limits of performance in each zone can be determined by the user based upon the guidance given in clause 7 and the information provided in annex B.

The decision about classes resulting from performance zones and acceptability for the scenario under consideration will be taken by the regulator. It is possible that some regulators may prefer to reduce the smoke classes to two.

This determination of the smoke classification factor will help in the decision of step 4 but if a total hazard assessment is required, it may be necessary to proceed to the probabilistic step 5 so that additional occupancy and environmental aspects of a potential fire scenario can be assessed.

A.5 Relationship of quantitative assessment of fire test data to the decision tree

Performance determined in A.2, A.3 and A.4 will be related to the decision tree described in clause 6 so that a user may determine the fire safety of a construction in its end-use application. The results of these investigations and the decisions taken at each step can lead to a classification recorded typically as shown in Table A.1.

Table A.1 — Summary of fire hazard assessment for the deterministic steps

Assessment step	Test data reference	Considered conditions	Performance zone	Fire hazard classification
2 Ignitability				
2.1 Primary ignition source	ISO 11925-2	Small flame 20 s	Non-ignitable	I
	ISO 11925-3 C	Small flame 180 s	Difficult to ignite	II
2.2 Secondary ignition source	ISO 11925-3 D	Flame 180 s	Difficult to ignite	II
	ISO 5657			
3 Fire growth	ISO 5660-1	25 kW/m^2	Limited contribution	II
	ISO 5660-1	50 kW/m^2	Moderate contribution	III
	ISO 5658-2	50 kW/m^2	Moderate contribution	III
	ISO 9705	100 kW/10 min 300 kW/10 min	Flashover in 13 min	III
4 Smoke opacity	ISO 5660-2	25 kW/m^2 and 50 kW/m^2	Low opacity	I
	ISO 5659-2	25 kW/m^2 and 50 kW/m^2	Low opacity	I
	ISO 9705	Small room	Medium opacity	II

NOTE The decision about suitability of the above test data and fire hazard classifications will depend on the product end-use scenario.

Annex B

Guidelines to classification data from ISO fire tests

The classification of test-data from tests developed in ISO/TC 92/SC 1 requires expert knowledge of the specific test conditions and their relevance to the fire hazards and risk which may occur in a defined fire scenario. Tables B.1, B.2 and B.3 have been compiled to provide guidance on the range of possible test methods from which data may be generated to allow a fire hazard and risk assessment to be conducted according to this part of ISO/TR 11696.

The test methods given in Tables B.1, B.2 and B.3 are only examples; other methods may also be deemed to be relevant for the defined scenario. The lists of tests may be expanded as ISO/TC 92/SC 1 develops new test methods.

Many tests only provide information about how a product reacts to a primary fire source. Classification information should also be provided about how the product behaves when exposed to secondary fire sources (for example, a single burning item or flaming drips).

Clauses A.2, A.3 and A.4 of annex A have indicated the possibility of classifying products to three or four performance zones. It should be noted that some tests will only differentiate products into two zones based on a pass/fail decision, for example, ISO 1182. For a range of different tests evaluating a particular hazard parameter, the levels of performance for Classes I, II and III are not intended to be exactly equivalent; some broad equivalency may be possible according to the classification to be established.

Table B.1 — Tests which provide data for the determination of the ignitability performance of construction products

Reference	Test conditions	Comments
ISO 11925-2	Small flame applied for 20 s	Primary source
ISO 11925-3		
Source A	Needle-flame	Primary source (small flames simulating fault conditions in electrical equipment).
Source B	Kleinbrenner (as ISO 11925-2)	Primary source
Source C	Small diffusion flame	Primary source (simulating burning match)
Source D	Diffusion flame	Primary source (simulating cigarette lighter)
Source E	3 kW gas burner	Secondary source (simulating burning crumpled newspaper)
Source F	17 kW gas burner	Secondary source (simulating an SBI such as flaming chip pan)
Source G	Premixed flame: 100 kW/m^2	Primary source (plumbers blow torch)
Source H	Premixed flame: 140 kW/m^2	Primary source (13 kW roofers torch)
ISO 5657	Radiant heat source in presence of pilot flame. Range: (10 to 50) kW/m^2	Secondary source
ISO 5660-1	Radiant heat source in presence of spark lighter. Range: (10 to 100) kW/m^2	Secondary source
ISO 6925	Methenamine tablet for floorcoverings	Primary source (simulating flaming drips)

NOTE When selecting ignitability test-data for any hazard or risk assessment, it is essential to include data produced using a primary source *and* a secondary source.

Table B.2 — Tests which provide data for the determination of the fire growth performance of construction products

Reference	Test conditions	Comments
ISO 5658-2	Piloted ignition with radiant heat source on vertically-orientated specimen; Measures lateral flame spread	Developing fire stage
ASTM E1321	Piloted ignition with radiant heat source (as ISO 5658-2)	Developing fire stage. Material properties measured as input for models
ISO 5658-4	Piloted ignition with radiant heat source on intermediate-scale vertical specimen.	Developing fire stage with radiant heat source.
ISO 9705	Room-corner test for lining products	Variety of ignition sources possible. Full-scale small room test. Fixed ventilation.
ISO 9239-1	Radiant panel test for floor-coverings. Max flux to specimen is 11 kW/m^2	Developing fire stage.
ISO 9239-2	Radiant panel test for floor-coverings. Max flux to specimen is 25 kW/m^2.	Developed fire stage (flashover) in room adjacent to corridor.
ISO 13784 (all parts)	Large room test for industrial sandwich panels	Developing fire stage.
ISO 13785-1	Intermediate-scale test for façades	Post-flashover fire exposure onto façade above window of fire room.
ISO 13785-2	Full-scale test for façades	3-storey building test. Developed fire (flashover) in room on ground floor.
ISO/TR 14696	Intermediate-scale calorimeter. Vertical specimen. Flux range (0 to 50) kW/m^2	
ISO 5660-1	Radiant heat source in presence of spark igniter. Range: (10 to 100) kW/m^2	Provides range of material properties as input for models. Fixed ventilation.
ISO 1182	Furnace test	Developed fire stage. Mainly restricted to homogeneous products. Fixed ventilation.
ISO 1716	Bomb calorimeter	Developed fire stage
ISO 1210	Small-scale flammability test for plastics (vertical and horizontal specimens)	Determines flaming drips. Small burner test.
ISO 10351	Flammability test for plastics (vertical and horizontal specimens)	Can be applied to non-plastics materials also.

Table B.3 — Tests which provide data for the determination of the smoke opacity performance of construction products

Reference	Test conditions	Comments
ISO 5660-2	Dynamic test. Radiant heat source in presence of spark igniter. Range (10 to 100) kW/m^2	Developing and developed fire stages; well-ventilated fire model
ISO 5659-2	Cumulative single-chamber test. Exposes specimen to 25 kW/m^2 and 50 kW/m^2 without and with pilot flame.	Developing fire stage. Standardized by ISO/TC61/SC4 for plastics but may also be used with other materials. Adopted by IMO for shipping applications.
ISO 9705	Dynamic test. Small room scenario for lining products.	Generally simulates well-ventilated fire conditions.
IEC 61034 (parts 1 and 2)	Cumulative test (3 m cube). Flaming ignition source.	Used mainly for classifying low-smoke products (for example some cables and railway components).
ISO 9239-1	Dynamic test. Radiant panel exposure of floor-coverings.	Optional smoke measurements added by CEN/TC 127 for use within European Union.

Annex C

An example of a calculation of visibility within a building on fire

C.1 Task

To carry out a simple prediction of the quantity of combustible material which may generate enough smoke to reduce the visibility to 10 m if the smoke flows into a typical 30 m long hotel corridor.

NOTE The distance of 10 m has been chosen arbitrarily based on human measurements [8] and should not be taken as an acceptable criterion.

C.2 Assumptions

Corridor dimensions:

Length	=	30,0 m
Width	=	2,0 m
Height	=	2,4 m

Corridor volume = 144 m^3

C.3 Equations

$$D_m = \frac{DV_c}{\Delta M} \quad (C.1)$$

where

D_m is the mass optical density;

ΔM is the burnt mass of the specimen in the test;

V_c is the dispersal volume;

D is the optical density per metre.

NOTE The mass optical density may be selected from a static test or a dynamic test, but the values may be different. Small-scale, intermediate-scale or large-scale test-data may be used; in this exercise, ISO 5660-2 data has been selected at 35 kW/m^2 flux level.

$$K \times s = 8 \quad (C.2)$$

where

K is the extinction coefficient;

s is the visibility distance in metres.

This is an empirical equation that relates to the visibility of a light-emitting sign. A factor of three can be used for a light reflecting sign.

$$K = 2{,}303\ D \qquad \text{(C.3)}$$

where

D is the optical density per metre;

K is the extinction coefficient.

This expression is applicable to light extinction methods that use monochromatic light.

Combining equations C.1, C.2 and C.3 gives:

$$\Delta M = \frac{8\ V_c}{2{,}303\ s\ D_m}$$

For a given scenario and for well ventilated conditions, the visibility is inversely proportional to the mass loss of fuel.

For the task defined at the start,

V_c = 144 m^3,

D_m = 100 m^2/kg for flaming combustion of a material burning at the end of the corridor,

s = 10 m,

and therefore

ΔM = 0,5 kg.

Limitations of this approach:

1) It has been assumed that the smoke produced will homogeneously mix throughout the entire space and therefore occupy the entire corridor volume. This calculation procedure does not take into account the geometry of the space, only the volume.

2) The empirical data used in this calculation are for fully ventilated tests and so the calculation should not extend to cases where this will not be true.

3) This calculation is not time-based. The empirical data used are time-averaged and therefore the rate of smoke production is neglected.

4) The calculation is clearly dependent upon the relationship that defines visibility and the value of mass optical density for a particular material which is test method dependent i.e. open versus closed methods. It is important to remember that the equation applies to the mass of material burnt, not the initial mass of the material.

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