

PU Europe FIRE SAFETY HANDBOOK

FIRE SAFETY IN BUILDINGS

► FIRE SAFETY OBJECTIVES

When considering the fire safety of buildings, there are a number of key objectives to be achieved. The primary objective is clearly to prevent loss of life of occupants and fire fighters. A secondary objective is the limitation of damage of property and the protection of the environment.

HOW TO ASSESS FIRE SAFETY?

A fire safety assessment identifies the conditions needed to meet these objectives and looks at the balance of risk. However, in order to do that it is necessary to understand the different factors that will influence the outcome in case of fire. On this basis it can be decided, whether the assessment should focus on the products themselves or the system including the product or a combination of products.

Country	Population [million]	Fatalities per capita per year [approx.]	% fatal fires [related to all residential fires]
Belgium (2014-2015)	11.4	0.6 per 100 000	0.5%
Denmark (2011-2012)	5.8	1.1 per 100 000	1.2%
Estonia (2013-2017)	1.3	3.7 per 100 000	4.6%
Finland (2011-2012)	5.5	1.4 per 100 000	
Netherlands (2011-2014)	17	0.2 per 100 000	0.6%
Norway (2016-2017)	5.3	0.5 per 100 000	1.3%
Poland (2011-2012)	38	1.3 per 100 000	
Sweden (2011-2013)	10	1.1 per 100 000	1.2%
UK (2014)	66	0.6 per 100 000	
Total	160.3		
Total Europe	742.9		

Table 1: Population, fatalities per capita and percentage of fatal fires in selected European countries [1]

RISK ASSESSMENT

- Is the product likely to be the source of ignition?
- Is the product likely to be the secondary ignited item?
- Is the product a potential significant fuel source even if it is not the first or secondary ignited item?
- What is the potential route to contribution to the risk (and hazard)?
- How close are occupants and/or critical equipment to the origin of a fire?

Whether the assessment focuses on a material, product or system is determined by an investigation of the risk.

¹ <https://www.europeanfiresafetyalliance.org/wp-content/uploads/2018/11/20181120-Fatal-residential-fires-in-Europe.pdf>, p. 66, Table 10

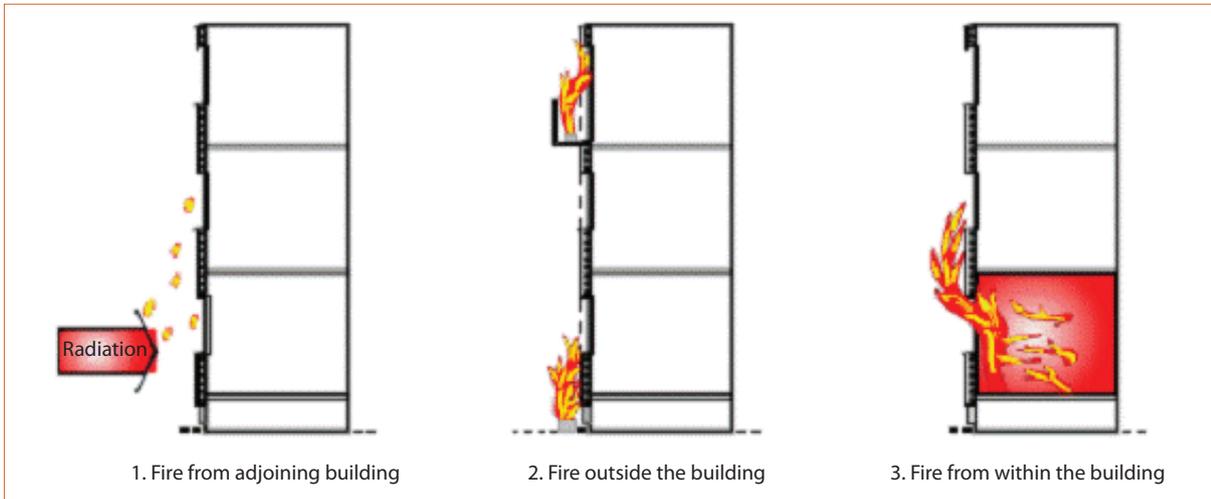


Figure 1: External fire spread mechanisms for façades (Kothoff, 2004)

Test methods can help to determine product behaviour in the case of a fire. For the assessment to be valid, it is necessary that the outcome of the fire test gives a valid estimate with regards to the specified fire scenario(s).

► FIRE SCENARIOS

Fires can be initiated and can develop in numerous ways, dependent on a number of factors, including:

- Type, intensity and location of the ignition source (see example in [Figure 1](#))
- Primary and secondary ignited items
- Location of the fire
- Fire load density
- Building/room type and size
- Ventilation conditions
- Availability of passive (compartmentation, fire walls/doors, and natural ventings) and active (smoke extraction devices, sprinkler systems, intervening of the fire brigade) protection measures
- Degree of enclosure

Having an understanding of how a particular construction is likely





Figure 2: Steel deck flat roof test according to DIN 18234-1:2003-09 in Germany

to behave in a fire scenario is an important aspect of fire safety assessment. Eight different fire scenarios have been identified in an EU pre-normative research programme which was finalised in 1995 [2]: a small and large room, a vertical and horizontal cavity, a façade, a corridor, a staircase and a roof. All these scenarios presume a larger secondary ignited item.

The Room Corner Test ISO 9705 was chosen as the fire test scenario to simulate a fire in a small room. This test was used to help in the development of the ‘Euroclassification’ system in order to standardise the classification and testing of construction products, especially in relation to flashover. However, the Room Corner Test (later published as EN 14390) was developed for internal lining products, which are directly exposed to the fire. This has led to some inconsistency when it comes to insulation, as the latter is rarely used as an internal lining product, but is almost always installed in a building element behind a thermal barrier lining (see section: **European fire standards and national legislation**). This aspect is taken into account in the mounting and fixing standard for reaction to fire testing of thermal insulation products (EN 15715), which allows for reaction to fire testing in simulated end-use applications.

The concept of fire scenarios is used extensively in fire safety engineering. The choice of the appropriate fire scenario is vital for the correct assessment of the fire risks and the fire hazards. Scenario testing is application-related testing and follows the development of the fire until a late stage, possibly until an uncontrollable stage of fire spread. The use of specific application-related tests is increasing in European countries in order to confirm that the product performance determined is in accordance with the level of fire safety applicable in specific countries (including in end-use applications). An example is façade testing where large-scale system testing is the preferred option. System testing should be conducted replicating the intended system for installation (Figure 1). Another example is testing of large industrial light weight flat roofs according to DIN 18234 in Germany (Figure 2).

² A. Pinney: *Update on the European Construction Harmonisation Programme*, Conference “Flame Retardants 96” (1996), p. 23-33



➤ INTERNAL FIRE DEVELOPMENT

There are four key stages of fire development within a building:

- Ignition
- Growth
- Fully developed fire
- Decay

Initially, a source of heat, fuel and oxygen is needed for ignition to take place. As flames spread and hot gases develop the temperature of the room or compartment increases. Provided there is sufficient oxygen the fire starts to grow, and other sources of fuel become involved. With additional fuel, the level of heat released increases, and a layer of hot gas will form from the ceiling down. Towards the floor a cooler layer of gas will be found, and unless the compartment is sealed, the lower pressure of this cooler layer allows an exchange of air from outside, providing the oxygen required for the fire to continue to grow. It is at the growth stage that the **reaction to fire** of exposed materials is crucial in determining whether or not they will contribute to the fire development, with factors such as ignitability, heat release and flame spread coming into play.

The transition from a growing to a fully developed fire can be extremely rapid depending on the fire load and the size of the compartment. The International Fire Training Centre gives the following definition of this mechanism: *“In a compartment fire, there can come a stage where the total thermal radiation from the fire plume, hot gases and hot compartment boundaries causes the generation of flammable products of pyrolysis from all exposed combustible surfaces within the compartment. Given a source of ignition, this will result in the sudden and sustained transition of a growing fire to a fully developed fire. This is called a Flashover.”*^[3]

It is generally recognised that if a fire reaches flashover, the chance of escape for occupants in the vicinity becomes considerably less, since heat and smoke is released in significantly greater quantities after flashover. Once a fire is fully developed, the ability to **resist fire**

³ International Fire Training Centre: *Firefighter Initial, Working in Smoke*, Issue 1 (January 2003)



Figure 3: Development of fires in enclosures [4]

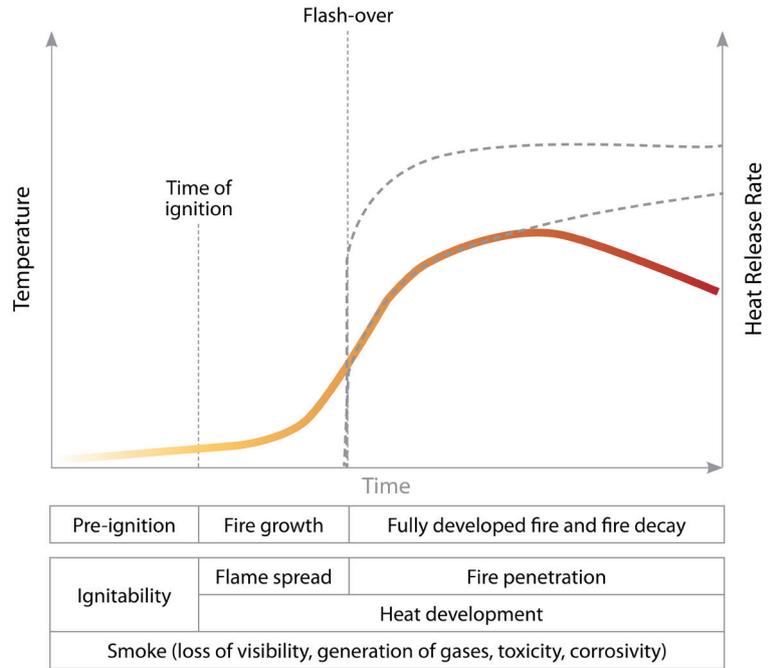


Figure 4: Fire façade test set up according to NFPA 285

⁴ ISO/TS 3814:2014, Standard tests for measuring reaction to fire of products and materials – Their development and application

becomes of the utmost importance by having the load-bearing, insulation and integrity capacity upon which the stability of the building and prevention of further fire spread may depend.

A fully developed fire releases the maximum amount of energy, but is generally limited by the amount of oxygen left available to it, and if oxygen remains in short supply and/or the available fuel is consumed the fire will fall into decay.

➤ EXTERNAL FIRE DEVELOPMENT

Fires develop differently on external horizontal or external vertical surfaces of buildings. The four key stages of the fire apply but the development is different as various factors influence the fire, for example wind effects, surroundings such as proximity of other buildings, design of the walls or roof including type and design of the external cladding. Regulations take into account external fire scenarios and specific test standards exist, for example for façades



and for roofs. Vertical and horizontal flame spread and break through into the building or to other levels is also considered important. Flashover is not relevant where there cannot be formation of a hot layer of fire effluents under the ceiling or roof, and the decay phase will not be triggered by lack of oxygen.

➤ SMOKE AND SMOKE TOXICITY

THE RELEVANCE OF SMOKE

Smoke is a significant hazard. UK and USA statistics have shown that the most common cause of death in a fire is to be overcome by smoke and gases. Smoke can originate from any burning object, and usually initially results from building contents (rather than building structure) combustion, which may or may not be visibly flaming. [5, 6]

There are two key hazard aspects about smoke, namely loss of visibility during escape and intoxication after inhalation of a certain dose of asphyxiant gases (concentration of effluents multiplied by the exposure time) and/or exposure to a certain concentration of irritant gases. Reduction or loss of visibility leads to delays in escape, disorientation and longer exposure times. Inhalation of smoke can lead to narcotic effects and irritation and can even result in incapacitation or death. The control of smoke is therefore considered an important element in buildings.

Correctly installed insulation products will not contribute to fire and smoke development in the early phase of a room fire, as there will always be a barrier (e.g. gypsum plasterboard) between the room and the insulation product installed at or in the wall. Tests performed at Exova Gent [5] demonstrated clearly that in a fire in a furnished room untenable conditions in the room are reached long before the insulation products installed behind a layer of gypsum plasterboard start to contribute to fire and smoke development. Therefore it would not improve the safety level of occupants, if the insulation products were tested and classified for the toxicity of their combustion gases.

⁵ Weghorst et al., *An investigation into the relevance of the contribution to toxicity of different construction products in a furnished room fire*

⁶ PU Europe factsheet n° 24D: *Fire performance of thermal insulation products in end-use conditions - Building envelope vs building content*, (2019)



HOW TO CONTROL SMOKE HAZARD [7]

Smoke is always toxic, irrespective of the material that is burning, and impedes escape by reducing visibility. The main steps to control smoke hazard are:

- to make sure fires remain small, by avoiding propagation and ensuring early detection and extinction;
- to limit development and spread of visible smoke to allow safe evacuation of occupants;
- to avoid exposure and inhalation of smoke to allow safe evacuation and avoid injury.

SMOKE AND REGULATIONS

The prime objective of fire related regulations is to prevent loss of life. In the building sector limitation of smoke generation and exposure of occupants is achieved by preventing ignition and limiting growth of fire and by ensuring early alerting of occupants and adequate means of escape through appropriate building design (e.g. provision of exit routes).

One of the most important measures which is used increasingly in many countries is the mandatory installation of smoke detectors in dwellings and in some cases of sprinklers alongside provisions for smoke evacuation especially in escape ways. In addition, compartmentation is one of the key measures for limiting spread of fire and smoke in a building.

Depending on the country, for certain building applications, there may be a requirement for the visible smoke performance of construction products, applying mainly for internal fire situations. For external fire situations, smoke is not considered a life hazard and in general there are no or low requirements. Smoke obscuration classification is part of the European reaction to fire standards.

To date, there are no relevant smoke toxicity standards for

⁷ S Levchik, M Hirschler, E Weil: *Practical guide to smoke and combustion products from burning polymers – Generation, assessment and control*, Smithers Rapra (2011)

construction products in the EU member states. Prevention of exposure is mostly achieved nationally via the above measures and, in some cases, via fire safety engineering (FSE) . Nevertheless, some national regulations may include certain rules, e.g. France for combustible insulation that is applied to the internal side of a publicly accessible building without a thermal barrier lining and some rules for appliances and furniture.

LATEST EUROPEAN UNION WORK ON SMOKE TOXICITY OF CONSTRUCTION PRODUCTS

In 2018, a study was published on behalf of the European Commission [8], with the goal to evaluate the need to regulate within the Framework of the CPR on the toxicity of smoke produced by construction products in fires . The results of this study are based on contributions from European regulators, scientists and industry stakeholders.

The study confirmed that only seven EU Member States referenced regulations on the toxicity of smoke from construction products, but in each case their application is defined and limited in scope. A general conclusion of the study is that most of the interviewees did not agree that regulation of toxicity of smoke from construction products is required.

There were many comments questioning the usefulness of singling out construction products and emphasising that if legislation related to the toxicity of smoke from construction products were considered to be appropriate, it would need to be part of an holistic approach to fire and effectiveness of measures and would need to address the issues associated with the toxicity of smoke produced by building contents.

In addition, recent publications have shown, that currently no laboratory scale test method is available, which can be used for measuring and classifying the toxicity of smoke from all types of construction products taking into account different fire scenarios [9].

Based on the results of this study the European Commission did not

⁸ *Study to evaluate the need to regulate within the Framework of Regulation (EU) 305/2011 on the toxicity of smoke produced by construction products in fires*, 15/10/2017, published 18/01/2018

⁹ FSE covers the use of fire safety engineering principles in the assessment of constructions related to their fire performance and for their 'safe use' in building construction. This is a move away from the traditionally accepted way of testing a product to an appropriate fire test to see if it meets the relevant fire requirements. It is also used when a particular structure cannot be tested



plan to introduce requirements to test, classify or regulate smoke toxicity of construction products.

SMOKE AND FSE (FIRE SAFETY ENGINEERING)

Smoke is the consequence of a fire and its generation is therefore always dependent on the fire scenario. Smoke can come from a number of ignited sources, and the building contents are likely to be important contributors to smoke emissions. The involvement of the building envelope, including insulation, in smoke production will vary hugely depending on the construction and the conditions under which the fire develops. Each of the distinct stages of a developing and developed fire carries a specific smoke hazard, which may be at its greatest during a non-flaming combustion stage. The stages and scenarios described below are important and are distinctly different in terms of smoke generation:

- smouldering fires or non-flaming fires
- well ventilated fires or developing flaming fires
- poorly ventilated fires
- post flashover fires

The evaluation of the smoke performance and determination of hazard in a building should take into account the relevant fire scenarios (= risk assessment) [10]. Smoke is part of the fire risk assessment. Such an assessment looks at the complete building design and not just at the smoke performance of a building product in a smoke test. FSE is deemed to be the best route to identify and manage potential risk from smoke, regardless of the type of insulation being used [11].

¹⁰ Fire risk is defined as a combination of the probability of a fire and a quantified measure or its consequence. Fire hazard is the physical object or condition with a potential for an undesirable consequence from fire (ref: ISO 13943:2018 Fire Safety – Vocabulary)

¹¹ ISOPA Factsheet: *Risk assessment of smoke in buildings: Fire Safety Engineering and PU insulation products* (January 2008)



EXAMPLES OF SMOKE HAZARDS

- A smouldering fire in the room of origin may be a hazard to a sleeping person who does not wake up in time.
- A ventilated, developing fire is not a great hazard for vigilant occupants who are in the room of origin of the fire or in the vicinity of it as they can escape before the fire grows to a threatening size. However, it could be problematic in spaces from which no escape is possible, e.g. prisons or in occupancies with disabled people who need assistance with the evacuation.
- Poorly ventilated fires are characterised by a low oxygen content and higher toxicity of the smoke. Often the size of the fire remains small, however it can grow large instantaneously when oxygen becomes available and then surprise remote occupants or rescue teams.
- One of the greatest smoke hazards is to occupants who are remote from the fire source and who are overcome by smoke from an unnoticed fire that has grown large or that is in post flashover stage.

SMOKE HAZARD POSED BY MATERIALS AND PRODUCTS

All organic materials produce smoke (visible and toxic) when burning. Smoke toxicity, to a certain degree, is not a material property. Depending on the environment, availability of oxygen, thermal attack, flow conditions and surface areas available for combustion, the chemistry of the combustion of a given material can proceed along various routes and produce species in very different quantities [12].

Smoke from fire is always highly toxic, irrespective of the materials that are burning. Combustion products of all materials include carbon monoxide (CO), carbon dioxide (CO₂) and water. Nitrogen containing materials, such as wool, silk, nylon and PU can also produce hydrogen cyanide (HCN) or nitrogen oxides. Halogen containing materials such as PVC and some flame retarded materials can produce hydrogen

¹² ISO/TR 13571-2:2016
*Life-threatening components of fire -
 Part 2: Methodology and examples of
 tenability assessment*

chloride (HCl) or hydrogen bromide (HBr). Wood and cellulosic materials produce acrolein, which is one of the most toxic components in smoke.

Asphyxiants such as CO and HCN can cause narcotic effects or can even lead to incapacitation or death. A reduced level or lack of oxygen also causes asphyxiant effects. Irritants, such as halogen chlorides and acrolein can cause irritation or pain during breathing, in the eyes, or on the skin and can hamper escape or can also add to the overall intoxication.

The dominant toxicant in fires is carbon monoxide (CO), which is produced from any burning organic material. Organic materials give off about 10 to 20 % of their weight in the form of CO when they are involved in a flashover fire. [13]

Therefore, the chemical composition of the fire load is not the decisive factor regarding tenability conditions (visibility, heat, toxic hazard) in the fire compartment.

➤ FIRE SAFETY ASPECTS TO CONSIDER

The below list needs to be considered by anyone involved in the construction sector (please also look at the [EU Fire safety guide](#) from the www.modernbuildingalliance.eu):

- Fire safety assessments need to take into account a wide range of factors, including occupancy and use, not just building construction;
- Compartmentalisation can greatly increase the chances of controlling the spread and magnitude of a fire, but it is also quite possible to have a number of compartments involved, each at different stages of fire development;
- Smoke detectors greatly increase the likelihood of the fire being discovered early, allowing a safe evacuation and also the chances of the fire remaining smaller and being contained;

¹³ *Fire safety, smoke toxicity and acidity*, MM Hirschler, Proceedings of the Flame Retardants 2006 Conference, p. 47-58, organised by British Plastics Federation, Interscience Communications Ltd. In collaboration with Plastics Europe and European Flame Retardants Association

- Sprinkler systems ensure an early suppression in the developing stage of a fire;
- The time required to evacuate depends on the size and design of the building, and the purpose to which it is put. For example, a nursing home would need to allow for a longer period of evacuation than an office building, and a multi-storey building would need longer than a single storey one;
- The European classification of insulation materials is based on tests developed for internal lining products. A broader perspective is needed on insulation fire performance taking account the context in which it is being used. This is gradually being developed, e.g. for façades.

Based on all the above, PU insulation can meet the required fire safety provisions for many applications.

