FACTSHEET

EUROPEAN DIISOCYANATE & POLYOL PRODUCERS ASSOCIATION

Risk Assessment of Smoke in Buildings:
Fire safety Engineering & PU Insulation Products

Summary

Safety in the case of fire and the exposure of occupants to smoke are of general concern [1]. Combustible products can ignite and burn when exposed to a fire source of sufficient energy. Buildings today contain many combustible products, either built into the fabric (walls, roofs, etc.) or as contents. This fact sheet provides information about smoke development and explains which tools can be used to assess the risk from smoke in a building and the significance of the smoke potential from building products based on, for example, rigid polyurethane foam (PUR). The smoke classification of building products alone, does not characterise the smoke hazard in a building. PUR-based building products have been assessed according to the principles of Fire Safety Engineering (FSE) and examples of safe solutions are shown.

Polyurethane Insulation as Product of Choice

Building elements based on PUR insulating foam are often the products of choice as they offer significant benefits in terms of insulation value, versatility, light weight etc. Better thermal insulation of buildings leads to significant energy savings and as a consequence results in reduced CO_2 emission from heating or cooling, in lower energy bills and less usage of energy resources [2,3,4]. Better insulation is a strong factor for more sustainable buildings and can contribute most to meet energy efficiency requirements.

Figure 1: The external cladding of this public building is made from steel faced PUR sandwich panels and glass
Figure 2: PUR insulation boards on corrugated steel deck roof of an industrial building

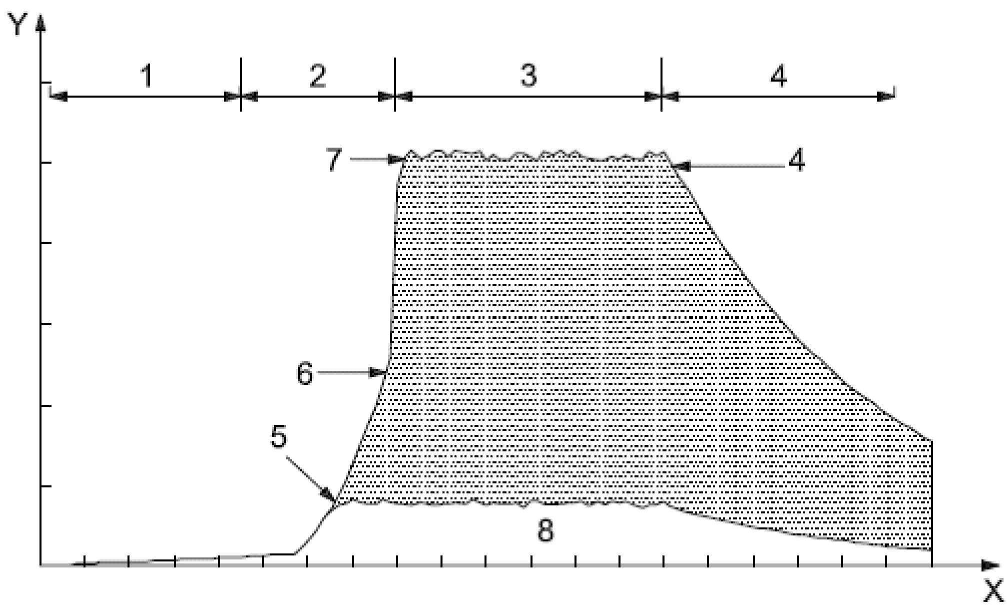
The fire properties of a PUR-based product can be modified to suite a wide variety of building applications, by optimising the foam itself, but also by the choice of the facings material over the core. The way the polyurethane product is incorporated in the construction is also important for the performance in a fire. Based on these parameters, PUR –based building products are fulfilling the fire requirements for buildings existing today.

The Importance of Smoke in Fires

Statistics have shown that the most common cause of death in a fire is to be overcome by smoke and gases. This is confirmed by UK and US statistical data [5,6,7,8].

The main issues with smoke are that it can cause loss of visibility during escape and that the inhalation of smoke is toxic. Reduction or loss of visibility leads to delays in escape, disorientation and longer exposure times. Inhalation of smoke can lead to impairment and irritation and can even result in incapacitation or death. The control of smoke is therefore an important element in buildings.

Smoke is the consequence of a fire and its generation is therefore always dependent on the fire scenario. A fire scenario describes the course of a fire, including the various stages of its development, the ventilation conditions, the physical environment, etc.



Key

X: time
Y: heat output

1. incipient
2. growth
3. fully developed
4. decay
5. sprinkler activation
6. flashover
7. ventilation-controlled
8. sprinkler-controlled

Figure 3: Example of fire scenarios and stages (design fire) [16]

The following stages 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

Each of the fire stages can be associated with a specific smoke hazard of which a detailed description can be found in the literature [9]. Figure 4 gives an example of a product in which higher smoke production is observed during the non-flaming combustion stage compared to the developing flaming combustion stage. Post-flashover fires represent the highest smoke hazard in the majority of fires, because of the high amounts of dense smoke that quickly fills the room and then may spread through the whole building. The amount of smoke produced is directly related to the extent of the fire. Keeping the fire confined and preventing its spread is an important factor in controlling the consequences of fire.

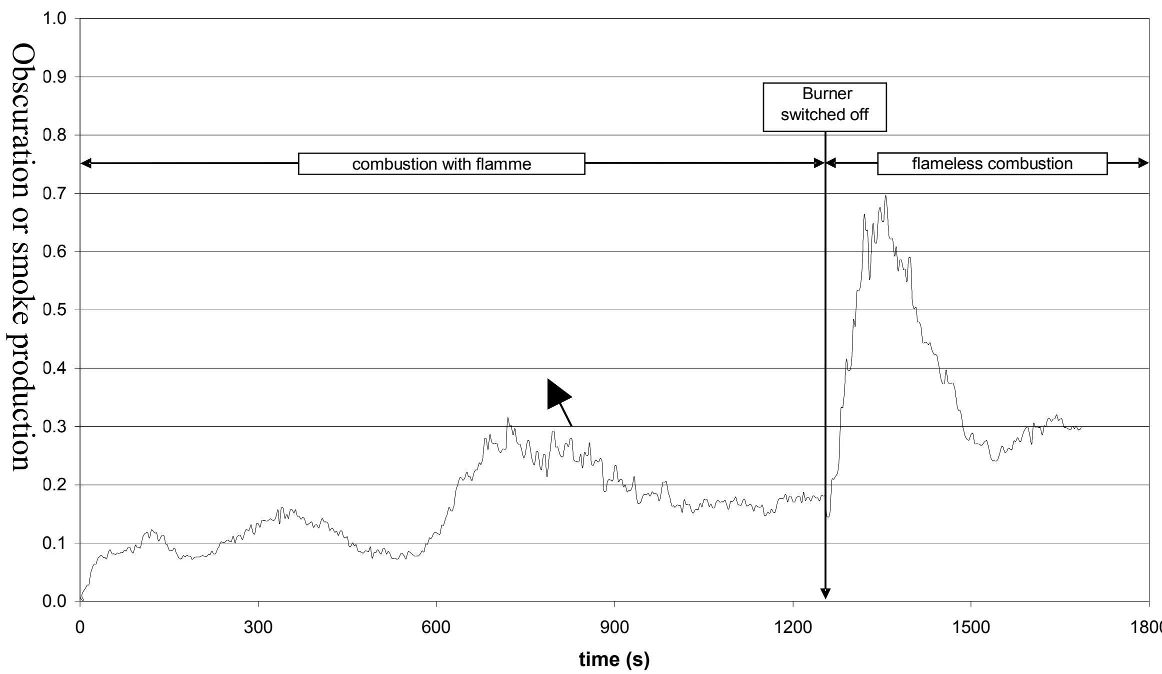


Figure 4: Smoke production of a cellulosic product (plywood) during flaming and non-flaming fire condition. Smoke production is highest after the ignition source has been switched off, during non-flaming or smouldering condition [10].

The prime objective of fire related regulations is life safety. In the building sector limitation of smoke generation and exposure to occupants is achieved by preventing ignition and limiting growth of fire and by ensuring adequate means of escape for occupants with appropriate building design (e.g. exit routes). For some building applications there is an additional requirement for the visible smoke performance of construction products. However in general, smoke classification of products is not a good way to characterise the smoke hazard in a building. For an adequate assessment FSE is needed.

Nevertheless, test methods to measure smoke obscuration are mostly applicable to products. Smoke properties can be measured via static or dynamic methods [11]. In static methods, the combustion is taking place in a closed volume with the smoke accumulating and the oxygen being depleted (vitiated conditions). Amongst the static methods are the NBS smoke test (ASTM E 662 or ISO 5659-2), which is used in some countries for building products, or the XP2 chamber (ASTM D 2843), which was historically used in the Netherlands. The cone calorimeter (ISO 5660) is a dynamic test method, which is characterised by a free-ventilated combustion. For construction products in Europe, the smoke class of construction products is now determined by the SBI test [12] and the classification standard EN 13501-1 [13]. The SBI test is also a dynamic test method. Both ways, either testing in static (vitiated) or well ventilated conditions only one fire scenario is addressed.

In recent years, large scale tests that have been designed for determining heat release have been used for dynamic smoke measurement. One example is the room corner test, according to ISO 9705, where construction products are tested as wall and ceiling linings within a room. A hood is used to collect the smoke gases. The exhaust system has a defined volume flow and can be used for measuring smoke obscuration. These tests show that the amount of smoke is strongly correlated with the extend of the fire. However such test results can only be correlated to smoke hazard in the building if the large scale test and the mounting of the specimens is representative of the real application.

Fire Safety Engineering Tools and Application to PUR Building Products

In many applications authorities worldwide recognize the benefits of performance and objective-based codes, taking into account features of the scenario in question. This has also been brought about by the need for increased flexibility in methods of designing cost-effective buildings and transportation vehicles, which use innovative construction materials and still maintain fire safety. This has provided the impetus behind design approaches founded on fire safety engineering principles. Instrumental to such approaches are either "design fires" or experimentally determined reaction to fire characteristics.

An example in which an authority takes into account scenarios is the new UK Reform Fire Safety Order 2005, effective since October 2006, which places a greater emphasis on fire prevention in non-domestic premises. A result is that the responsible person must carry out a risk assessment. EPIC, the UK association of producers of factory-engineered steel faced composite panels has produced a brochure, which is a guidance for carrying out a risk assessment for its products [14].

Figure 5: Use of PUR steel faced sandwich panels in the external wall and roof cladding of a retail building [14].

The evaluation of the smoke performance and determination of hazard in a building should take into account the number of relevant fire scenarios. This collection together with the associated fire characteristics is called the "design fire". Design fires have been utilised for many years in the design of smoke management systems. The evaluation is the risk assessment. Smoke is part of the fire risk assessment. Such assessment looks at the complete building and not just at the smoke performance of a building product in a smoke test. There are now concerted international efforts, co-ordinated by the International Organization for Standardization (ISO), for the development of technical guidelines for the specification of design fires and fire safety engineering methods in general [15,16].

Fire risk is defined as a combination of the probability of a fire event or scenario and the magnitude of its consequence. Fire hazard is the potential for injury and/or damage from fire. Smoke hazard is the potential for injury and/or damage from smoke [17].

A design fire is essentially a quantitative description of assumed fire characteristics, such as heat release rate, fire size, yield of products of combustion and temperatures, based on appropriate design fire scenarios. A design fire scenario is a description of the course of a particular fire, which may also include the impact on the fire of boundary features, occupants, fire safety systems, the ignition source and process, the growth and spread of fire from the first item ignited, and the decay and extinction of the fire [11].

Using these design fires, the risk assessment and the resulting design of a compartment with regard to escape routes, venting, detection and suppression systems is mainly done by advanced computational procedures. These tools have been developed over decades and are still being improved. Some recently developed computer codes even can predict the fire dynamics themselves and hence visibility, provided fundamental smoke characteristics, especially the soot yield, is available as a necessary input parameter. Unfortunately the soot yield is not a value provided by a standardized smoke test and costly extra tests are necessary if data can not be taken from, for example, published literature. Data expressed via a smoke classification alone can not be used for a suitable risk assessment.

ISOPA, BING and EPPF have studied the influence of ventilation conditions and specimen orientation representing end-use condition on smoke potential [10]. Several PUR insulation boards and PUR-cored sandwich panels were investigated in different intermediate scale tests and a comparison was made with results from the SBI test. The smoke values were used as input parameters for CFD (Computational Fluid Dynamics) fire simulation calculation. The conclusion was that a realistic risk assessment of smoke development in a building in a case of fire has to consider FSE tools for the building itself. Smoke classification of the building products will not provide the complete information.

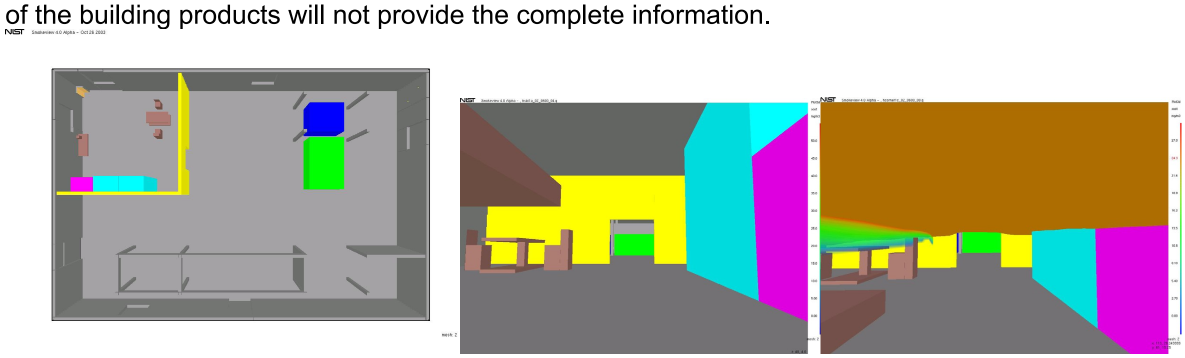


Figure 6: a. ground plan of industrial building with office, fire sources indicated, b. situation before ignition, view from the office facing the doorway, c. smoke layer after 600 s, boundary layer with soot mass concentration of 24 mg/m^3, extinction-coefficient: 0.27 m^{-1}, visibility: 30 m [10]

SNPPA, the French Sandwich Panels and Profiles Producers Association, has studied the fire test data of constructions using PUR and PIR[1]- cored steel faced sandwich panels. According to the French regulation for public buildings, thermal insulation needs to be either Euro-class A2-s2,d0 or should be protected to the internal side by a thermal barrier. PUR or PIR-cored steel faced sandwich panels do not fulfill this requirement. With the FSE study it was proven that the fire risk of the PUR/PIR cored steel faced sandwich panels was acceptable and the results of the study have been accepted by the French authorities [18]. Smoke based on SBI TSP_{600}[2] was part of the FSE assessment.

Conclusions

1. Smoke is a consequence of the fire and is therefore dependend on the fire scenario.

2. The amount of smoke depends on the fire intensity but also on the ventilation and building design and properties. The smoke classification of products does not characterise the smoke hazard in a building.

3. With engineering methods a fire safe compartment can by designed while at the same time it is possible to introduce innovative and cost effective constructions.

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[1] PIR is poly isocyanurate modified polyurethane foam and such foams have been developed to meet specific fire performance requirements.

[2] SBI TSP_{600} is one of the criteria for smoke classification of construction products in the EU. The other smoke criterium is SMOGRA, or smoke growth rate, but this is not considered in FSE assessments.

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