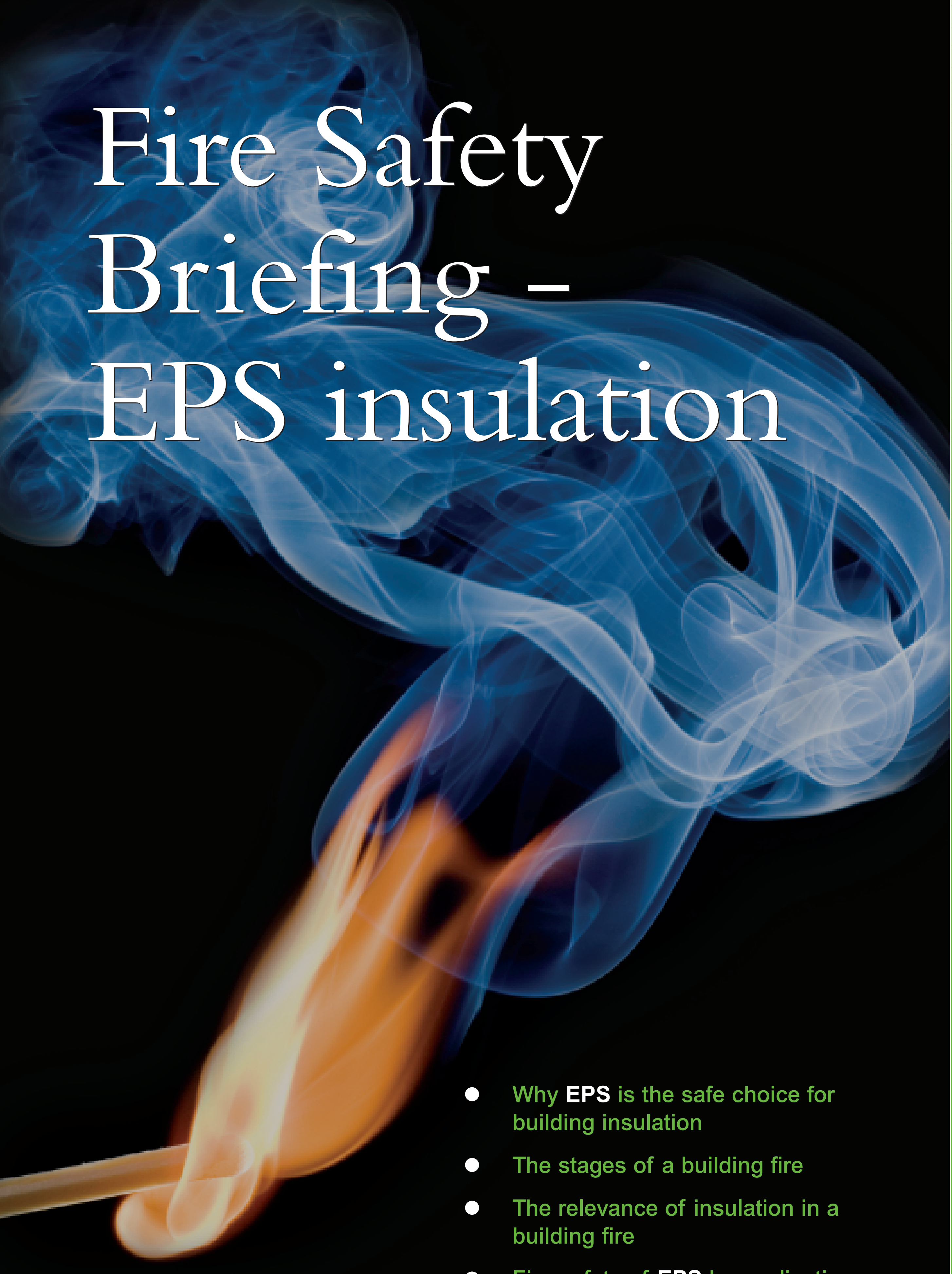
Fire Safety Briefing – EPS insulation



- Why **EPS** is the safe choice for building insulation
- The stages of a building fire
- The relevance of insulation in a building fire
- Fire safety of **EPS** by application

EPS
ECONOMY PERFORMANCE SUSTAINABILITY

FIRE SAFETY BRIEFING

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EXECUTIVE SUMMARY

A serious building fire is a disaster for those involved. Not only is the potential for loss of life and catastrophic effect on business a major concern, so too are the increasing insurance premiums. In this document we address the role of insulating material in the fire safety of buildings, with a special focus on EPS. We will show that, in a properly designed and constructed building, insulation material plays an insignificant role in fire safety. Conversely, insulating material contributes enormously to energy savings for the heating and cooling of buildings. This is not only a financial saving but also a contribution to CO_2 reduction and the prevention of global warming. The unique properties of EPS make it the ideal, sustainable insulating material for many applications.

The purpose of this document is to clarify the performance of expanded polystyrene foam (EPS) when used as insulation material. It provides an overview of the facts on fire safe constructions using EPS building products. All interested parties such as building owners, architects, builders, the fire service, insurers, risk managers and risk engineers should use it as an authoritative reference.

Why is EPS the preferred insulation material?

Technical advantages

- Low weight, high compression strength, excellent "walkability"
- High insulation value, constant over time (without ageing effects, for example from decreasing content of blowing agents and/or increasing moisture content)
- Easy, clean and safe to work with
- Freedom to design practically any shape by moulding or cutting
- Closed cell foam, inert, biologically neutral
- Available in fire safe FR quality

Health and safety aspects

- No irritation to skin, eyes or lungs from released fibres or dust
- No personal protective equipment or clothing needed

Environmentally friendly

- Durable, because it does not degenerate through moisture, rotting, mould, UV exposure or compaction by vibration
- Low environmental impact during production
- Easily and completely recyclable
- Free from formaldehyde, (H) CFC's and other ozone depleting blowing agents

Competitive price

- The most cost-effective insulation

1 EFFECTS AND PREVENTION OF BUILDING FIRES

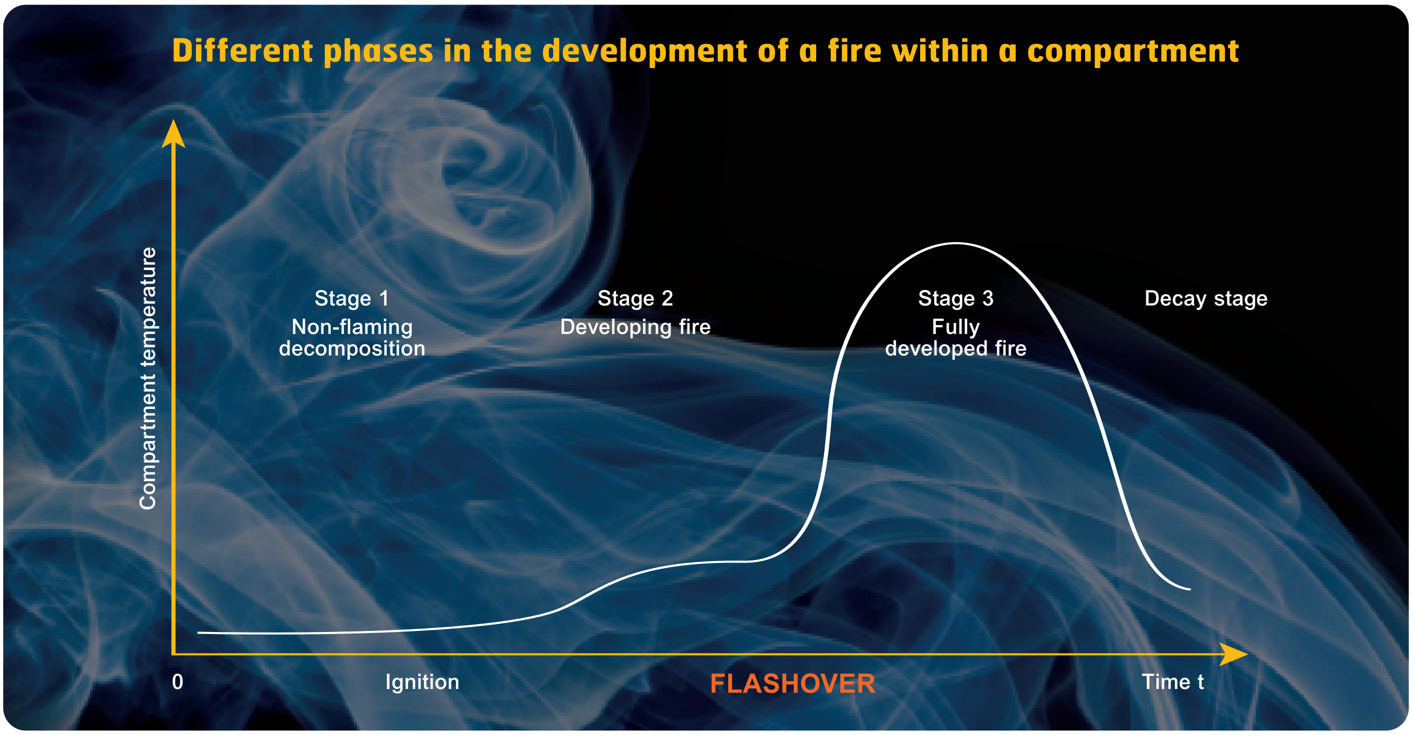
A fire can only start and continue to burn if three essential factors are present - the availability of combustible material, oxygen and a source of ignition. Normally, combustible material and oxygen are always available. The third factor, a source of ignition, can be provided intentionally or unintentionally, e.g. by a flame, a spark, a cigarette or by an electrical short circuit.

1.1 Stages of a building fire

A fire passes through a number of phases: ignition, growth/development, fully developed and decay. Solid materials do not burn directly but give off combustible gases when heated. It is the gases that burn. In the first phase of a fire, combustible gases develop and build up while the temperature is still relatively low. After some time there can be a rapid development of the fire: the flash over. An increasing number of elements reach their ignition temperature; the temperature then rises quickly from about 100°C to 750°C. The accumulated gases ignite and the fire spreads through the whole room. For humans, temperatures above 45°C are uncomfortable; a prolonged stay in a temperature above 65°C can cause damage to the lungs and people cannot survive for long if temperatures are higher. After the occurrence of a flash over, the fire reaches its full scale and further development is limited by the availability of oxygen through ventilation.

After flash over the chances of saving people or the contents of a room are minimal because of the temperature, lack of oxygen and damage to materials by heat and soot. Left to burn, a fire will eventually decay due to the lack of flammable material.

EPS starts to soften at a temperature of about 100°C, a temperature at which people already have minimal chance of survival. At this phase of a fire there is hardly any oxygen left and the air is toxic because of high levels of carbon dioxide and carbon monoxide. During the phase of rapid fire development, the flash over, wood will self-ignite at a temperature of about 340°C and EPS at a temperature of about 450°C. So the time for saving people and material is limited to the first stage of a fire and this is independent of the insulation material. EPS has a limited role in the design of fire resistant constructions used to compartmentalise buildings. EPS should only be applied in such constructions in combination with other fire resistant materials which perform the fire resistant role.



ISO TR 9122-1 [ref 1]

1.2 Fire prevention measures related to insulation

Although normally not the first material affected by fire, guidelines for the use of insulation material should be applied.

Always use a covering material

The covering material protects the insulation material not only from fire but also from mechanical damage, moisture and mould problems. It is important for all insulating materials to be durable to effectively perform their insulating role.

Details

The quality of a construction is highly influenced by the quality of the details as designed by the architect. The solutions for the details, the places where different building elements meet, are essential for the quality of the construction, not only in respect of fire properties but for many other essential construction properties as well.

Fire retarded EPS

Most of the EPS insulation products being sold in Europe are made of a fire retarded quality. The main purpose of this is to fulfil the regulatory and market requirements. Fire retarded EPS shrinks away from the heat when exposed to ignition energy. When ignited by the heat source, it self-extinguishes when the heat source is taken away.

1.3 CE-marking

Since May 2003 CE-marking of insulation products is mandatory under the Construction Products Directive (CPD). CE-marking can be seen as the 'passport' for the free trade of building products within the European Union. Part of the CE-mark is the declaration of the reaction to fire classification of the product. This classification applies to the naked product as placed on the market. For naked EPS this classification is Euroclass D or E in case of fire retarded material and Euroclass F in case of non fire retarded material (which is often used for packaging). In fact, this classification says little about the fire performance of the building element in which the insulation product is used.

Regulatory demands vary from country to country but in many cases the reaction to fire performance of the naked product is just a formal mandatory criterion.

Reasons for extensive damage

- Insufficient fire prevention measures
- Increased business continuity damage caused by a concentration of production facilities and supplies
- More expensive, yet vulnerable, production facilities
- Lighter but at the same time bigger and more complex buildings
- Larger fire compartments
- Failing fire compartmentalisation measures and fire doors
- High fire load
- Insurance and claim behaviour: lower own risk and wider coverage
- Non-compliance with regulations in force

Where regulation is dominantly performance-based, as intended by the CPD, requirements are based on building or construction elements. Recent European developments address this point of view and make it possible to show reaction to fire tests on standardised build-ups, simulating end use applications. Producers can then declare the classification on the reaction to fire, simulating end use applications, on the product labels just outside the formal CE-box. Research by EUMEPS points out that the classification for reaction to fire for EPS in the standardised build-up behind gypsum is Euroclass B-s_1d_0. The same classification applies for EPS behind profiled steel, which uses a standardised build-up simulating the end use of EPS in a flat roof construction with profiled steel. In both cases, this results in the same classification as the identical construction with mineral wool or PIR insulation.

	Prevention costs (% GNP)	Damage (in % GNP)	Casualties (per million inhabitants)
Netherlands	0,30	0,20	6,4
New Zealand	0,18	0,11	9,6
Western-Europe	n.a.	0,27	13,3
USA	0,39	0,35	25,0
Denmark	0,49	0,39	14,6

Overview of casualties and damage per region. [ref 2, 3]

2 FIRE BEHAVIOUR OF EPS INSULATION PRODUCTS

The fire behaviour of naked EPS insulation material is not relevant in construction specifications. The material is generally covered by other material which determines the fire behaviour. The insulation material is only affected by fire after the covering material fails and by this time the building or the compartment cannot be saved from total loss.

2.1 Fire behaviour of fire retarded EPS insulation products

Like most organic materials, polystyrene foam is combustible. However, in practice, its fire behaviour depends upon the conditions under which it is used, as well as the inherent properties of the material. The inherent properties depend on whether or not the foam is made of fire retarded material. Most EPS insulation products have been made of fire retarded quality for decades. This is achieved by adding a very small quantity (<1%) of a fire retardant agent to the material. The fire retardant is polymerised into the molecular structure and is insoluble in water, which ensures no fire retardant leaches from the material into the environment. Research shows that the fire retardancy remains effective for decades **[ref 10]**.
Exposed to heat, fire retarded EPS shrinks away from the heat source. The probability of ignition of the material is significantly reduced and welding sparks or cigarettes will not normally ignite it. Another effect of the fire retardant is that its decomposition products cause flame quenching: when the heat source is taken away the flame extinguishes. The effect is clearly illustrated by a demonstration in which a hole is burned into a large block of EPS using a torch. When the torch is taken away the fire dies and extinguishes.

Characteristics of	EPS-FR Temperature	EPS non-FR Temperature
Softening, shrinking, melting	from 100°C	from 100°C
Ignition temperature with pilot flame	370°C	350°C
Self ignition temperature	500°C	450°C

The reaction to fire behaviour should be evaluated not on the material or product, but on the building element or construction element level (also called works). A basic design rule with EPS and other insulating materials is never to use the material uncovered. The layer which actually determines the reaction to fire behaviour is the surface layer of the construction, which faces the fire and effectively covers the EPS insulation material. Using a combination of EPS insulation and specific cover layers, it is always possible to design a construction which fulfils the fire requirements. **Correctly applied and installed, EPS does not influence the occurrence or the development of fire in a building.**

The excellent behaviour of EPS in constructions has been confirmed by recent studies by EUMEPS. Testing according to EN 13501-1 for the standardised build-ups of EPS covered with gypsum and steel resulted in a B-s_1d_0 classification. The smoke part of this classification, the s_1, is the best possible classification for a construction, which means there is little or no contribution to the production of smoke.

2.2 Heat of combustion

The heat produced by burning material is one of the factors determining how a fire develops. That is why the fire load is often one of the criteria in regulations and must be calculated at the design stage. The calorific value of EPS per kilogram is 40 MJ/kg, e.g. double that of timber products with about 20 MJ/kg. However, 98% of the volume of EPS consists of air, giving a typical product density of 15-20 kg/m^3, which results in a low contribution to the overall fire load. EPS is also favourable compared to other insulating materials [ref 4]. The contribution of EPS to the fire load of the most common flat roof construction with a bituminous roof felt is about 10% [ref 4]. A case study showed that in a warehouse for a grocery store chain, the contribution of EPS flat roof insulation to the overall fire load was 3% [ref 6 and ref 12]. **Exchanging EPS with other insulating materials makes no difference at all to the fire load.**

In the table below Prager [ref 8] shows that there is little difference in the contribution to the fire load from the various insulation materials if compared at an equal insulation value.

	Material		
	EPS	XPS	MW
Thermal conductivity λ (W/mK)	0,035	0,040	0,045
Density ρ (kg/m^3)	20	32	170
Heat of combustion H (MJ/kg)	39,6	39,6	4,2
Fire load/m^3 Q_V (MJ/m^3)	792	1.267	714
Fire load/m^2 Identical R-value Q (MJ/m^2)	92	169	107

In [ref 8] Prager shows the contribution to the fire load for a number of common

The toxicity of smoke fumes from EPS and various 'natural' materials

Sample		Emitted fractions (v/v) in ppm at different temperatures			
EPS (standard grade)	Smoke gases in a Fire	300ºC	400ºC	500ºC	600ºC
	Carbon monoxide	50*	200*	400*	1,000*
	Monostyrene	200	300	500	50
	Other aromatic compounds	fractions	10	30	10
	Hydrogen bromide	0	0	0	0
EPS-SE (fire retardant grade)	Carbon monoxide	10*	50*	500*	1,000*
	Monostyrene	50	100	500	50
	Other aromatic compounds	fractions	20	20	10
	Hydrogen bromide	10	15	13	11
Deal	Carbon monoxide	400*	6,000*	12,000*	15,000*
	Aromatic compounds	-	-	-	300
Chip board	Carbon monoxide	14,000**	24,000**	59,000**	69,000**
	Aromatic compounds	fractions	300	300	1,000
Expanded cork	Carbon monoxide	1,000*	3,000*	15,000*	29,000*
	Aromatic compounds	fractions	200	1,000	1,000

Remarks: Test conditions specified in DIN 53 436; air flow rate 100 1/h; 300mm x 15mm 20mm test specimens compared at normal end-use conditions. * smouldering/glowing ** as a flame - not detected

APME research according to DIN-53436.

2.3 Toxicity of smoke from combustion of EPS

The contribution of EPS to the production of smoke and toxic gases depends upon the amount of available insulation material and the density of the material. The relative importance of this contribution is determined by the share of EPS in the total fire load. As mentioned previously, the share of EPS and other insulation materials in the total fire load is generally very low, e.g. about 3% in a case study for a warehouse [ref 6].

Furthermore, EPS insulation is normally covered by surface materials like gypsum, stone, wood or steel which protect the EPS during the first phase of a fire. Initially, the surface of the construction heats up after a fire starts. Subsequently, the heat flows through the construction. If the heat penetrates to the EPS within this construction, the material is not ignited but shrinks away from the heat and eventually melts. Only if the surface material is fully burnt through and the molten EPS is directly exposed to the flames will EPS contribute to the fire and produce smoke and combustion gases. Normally the fire consumes only part of the molten EPS material, leaving the rest as a solidified resin after the fire.

The toxicity of the smoke of combustion of EPS was investigated by TNO in 1980. The results proved EPS to produce considerably less toxic fumes than natural materials like wood, wool or cork [ref 13]. EPS is a pure hydrocarbon (C_8H_8)n which decomposes ultimately into CO, CO_2 and H_2O.

The influence of the fire retardant used in EPS is very small since the desired effect is achieved at a load content of only 0.5% to 1.0%, whereas for some other materials a content up to 30% fire retardant is needed. The influence of the fire retardant on toxicity is therefore minimal for EPS.

Extensive research by APME (Association of Plastics Manufacturers in Europe - now Plastics Europe), performed according to DIN-53436, at temperatures from 330°C to 600°C also proved that fire retarded EPS produces less toxic fumes than natural materials, producing no gases such as chlorine or cyanide [ref 11]. EPS combustion is relatively clean.

2.4 Obscuration by smoke

Smoke production is of particular importance for building materials used in escape routes. In its normal end use, EPS is covered by surface materials like gypsum, stone, wood or steel. These materials protect the EPS during this phase of a fire. Tested according to EN 13501-1, many applications will achieve a B-s_1d_0 classification. The S_1 classification for smoke production is the best possible classification. Without such protection, EPS would produce a considerable amount of heavy, black smoke, which is proportional to the consumed mass.

When used correctly in recommended applications, EPS does not contribute to the spread of fire and produces little smoke and toxic gases. The choice of the insulation material has little influence on the amount of toxic gases and smoke produced during a fire.

FIRE SAFETY OF EPS INSULATION PRODUCTS AND INSURANCE

Some insurance companies vary the insurance premium on a building depending upon the insulation materials used. There is no statistical foundation for this practice. We should expect insurance companies to base their judgement on facts and solid evidence. The facts speak for themselves.

3.1 Analysis of large fires (greater than 1 million Euro damage)

Dutch scientific research into the causes of large fires led to the following conclusions:

Type of building

Most fires occurred in schools, industrial and public meeting buildings. Modern buildings built under recent regulations tend to be marginally less vulnerable to fire than old buildings. More than half of the buildings had not been inspected by the fire service during the past three years, although advice for improvement was given in 87% of the cases where buildings were inspected.

Compartments

All buildings contained some kind of fire compartments but only in 62% of the cases was this known to the fire fighters, who could then adapt their fire-fighting tactics accordingly. In 30% of the cases the compartmentalisation failed, of which half was due to failure of the self-closing fire doors.

Time of the start of the fire

Most fires started outside the normal opening hours of the building: between 18.00 hours and 09.00 hours.

Extinguishing the fire

Analysing shows that fire fighters arrive at the fire within the acceptable time span after the fire was reported. In about 5% of the cases there was a problem in reaching the fire and in 5% of the cases there was a problem with the availability of water to extinguish the fire. In 13% of the cases the fire fighters were not able to prevent the spread of fire to neighbouring buildings. The fire fighters initially tried to fight the fire from the inside of the building in two-thirds of the cases.

Cause of fire

Many fires were caused by malfunctioning or mis-used equipment (26%) or arson (23%). In reality, both these percentages are probably much higher since the cause of 40% of the fires remains unknown.

3.2 Role of insulation in fire

Objective analysis shows that the influence of insulating material on the occurrence and development of fire is marginal, or non-existent. Independent work, validated by KPMG, has been carried out by the well known Dutch institutes TNO and BDA on the role of the insulation material into the cause and development of more than 40 large industrial fires in the Netherlands [ref 15, 16, 17, 18]. This was initiated in 2002 and continues to the present day. **The conclusion is that EPS does not contribute to the start or the development of these fires. It has been demonstrated that there is no proven relationship between the type of insulation material used and the fire damage.** Contributory factors have been identified, amongst which are: careless use of high temperature equipment and processes, absence of extinguishing equipment and the fire properties of the building contents.

FIRE SAFETY OF EPS PER APPLICATION

If applied correctly, EPS has no influence on the start or development of fire in a building. If covered by a surface material, EPS is never fire-facing or impacting on the fire behaviour of the construction. It is normally possible to design a construction with EPS meeting all criteria, including fire requirements.

4.1 Fire safe floors and foundations using EPS

EPS is frequently used as insulation beneath concrete ground floors or as a lost mould for foundations. EPS insulation under higher floors, e.g. when the ground floor is used as parking area, is not recommended if the EPS is uncovered. Uncovered use is acceptable for a crawl space.

4.2 Fire safe walls using EPS

Wall constructions are the perfect example of why specifications should be performance-based for a building and not for a product or material alone. EPS is excellent for insulation to the inner side of a wall, for cavity insulation boards, for loose fill insulation, for external thermal insulation systems (ETICS) or for pre-fabricated composite panels, such as structural insulating panels (SIPS) or steel sandwich panels.

In all of these examples the EPS insulation is covered by an inorganic or metal surface layer. These layers make it possible to fulfil all requirements for reaction and resistance to fire, dependent on the surface material applied. Tests commissioned by EUMEPS illustrate that a wall construction with only 9mm gypsum has a classification of B-s1d0 [ref 21]. Normally, no tests are required for a cavity wall construction with an inner wall made out of stone [ref 20].

Tests performed by Austrian testing institutes as well as the fire police and the Austrian fire fighters of Graz proved that EPS for ETICS also performs excellently. ETICS can achieve a reaction to fire classification of B-s1d0 and a full scale test confirms these results [ref 25]. Extensive statistical research on 175 fires by the Polish fire fighters' organisation pointed out that the occurrence of fires with ETICS using EPS was proportional to the market share of EPS and similarly for mineral wool [ref 26].

4.3 Fire safe EPS steel sandwich panels

Extensive research has been carried out on the reaction to fire classification for steel sandwich panels [ref 9 and ref 20]. This clarifies that it is not the core materials which determine the classification but the coating that is applied on the outside of the steel. This coating protects the steel from corrosion and gives colour to the building. If, for example, this coating is a thin 50 micron polyester coating (giving little protection to the metal sheet) the classification will probably be Euroclass B. If a thicker and better protecting 200 micron plastisol coating is used, the classification will probably be a Euroclass C.

The results are confirmed by "Free standing room corner tests" (analog to ISO 13784). The tests showed that no flash over occurs for EPS cored steel sandwich panels with a well-designed joint detail [ref 23].

A report by the Association of British Insurers (ABI) acknowledges that in the case of buildings for the food industry or coldstores, foam plastic cores are to be preferred to other solutions for hygienic reasons. They also comment that "sandwich panels do not start a fire on their own" and, with appropriate fire safety management, risks associated with the food industry can be controlled acceptably. Around hot work areas (frying pans, etc) special measures are needed and EPS is not recommended.

The key conclusions for the fire behaviour of EPS steel sandwich panels are:

- Independent of the core materials, all steel sandwich panels with a plastisol coating will have the same Euroclass: B

- Comparative research shows the results of the SBI tests are fully in-line with the larger and therefore more expensive room corner test, ISO 9705 [ref 19]

- The differences in the test results of steel sandwich panels with an EPS core are minimal when compared to other core materials

- The joint detail and the mounting and fixing details of the sandwich panel are very important to the result of the fire test. IACSC, the International Association for Cold Store Construction, strongly advocates that structures are designed to be 'fire stable' to ensure life safety during fire fighting and that fire compartmentation is built to a high standard [ref 28].

4.4 Fire safe steel decks insulated with EPS

Hot works on roofs are responsible for a considerable number of roof fires. Analysis of these roof fires leads to the conclusion that they mainly occur when open fire torches are used around details. At the connection between the flat roof and the vertical wall the roofing contractor often has no clear knowledge of the materials used in the wall. During renovation the collected dirt can ignite easily. Details around water drains or ventilation channels are also notorious for causing fires. Further development work is ongoing with a view to reducing the number of fires. Insurers increasingly require hot work permits and strict procedures connected to this kind of work. Recommendations are also being developed relating to the use of self-adhesive membranes instead of torch-applied membranes where there is a considerable risk of fire [ref 27]. Hence, it is not the insulation material that is the main concern but the hot work combined with the risk of details. Both issues can, and will, be solved by the industry to make the flat roof a safer place.

Many modern industrial buildings are made of a lightweight steel construction. If a fire starts in a compartment of such a building and is able to grow into a developed fire, then this part of the building is a total loss. Within 10 to 20 minutes the steel construction can collapse and fire fighters will not be able to enter the building. What is the role of the insulation material in this scenario? The true answer is that it has an insignificant overall role.

Research has been commissioned by the EPS industry to determine the behaviour of different insulating materials in such a lightweight steel construction [ref 12]. The conclusion of this research is that for EPS the time taken for a fire to spread from within the building to the surface of the roof is about 20 minutes. Practical experience shows that fire will not spread to the roof through the construction but by details such as a roof light, a water drain, a ventilation pipe, a window in the wall, etc. Once the fire is on the roof, fire incident reports show that the fire can spread with a speed of up to 4m/min depending on the weather conditions.

EPS shrinks away from heat, returning to its original solid granular form and by doing so it loses its insulating properties. Therefore, part of the heat produced by the fire escapes through the roof. Because of this, the time to flash over is longer and the time before the steel structure collapses is extended. Hence, fire fighters have more time to protect neighbouring compartments [ref 12].

In conclusion, the insulating material does not play a decisive role in the development of a fire in a lightweight building with a steel deck. If a fire starts within a compartment of such a building, this compartment is generally a total loss, if not because of fire damage then because of smoke and the lingering acrid smell.

Building design is important in order to find the right balance between the advantages and disadvantages of big compartments. On the one hand, bigger compartments are cheaper to build with logistics advantages, but they have higher risks and higher insurance premiums. On the other hand, smaller compartments are more inconvenient and the costs of prevention higher. Compartmentalisation is key to management of the fire risk. Proven constructions and details need to be used to maximise fire and smoke resistance. Design is important but attention must also be given to the construction and maintenance phases.

Recent research commissioned by EUMEPS, carried out by TNO/EFECTIS and by Warrington Fire Gent, concerned the reaction to fire of EPS on a steel deck according to EN 13501-1. This d_0 classification is the best possible classification with regard to the forming of burning droplets. If fire retarded EPS is exposed to fire it will shrink away. If further heated, it will melt and droplets can fall. However, these droplets extinguish as soon as they touch the ground and cool down. Tests prove that even tissue paper is not ignited by these droplets, therefore the chance of personal injury from EPS droplets is minimal.

CONCLUSION

Fire safety is one of the essential requirements when designing a building. It cannot be compromised. The role of insulation in respect to fire safety is often over-rated. This document shows that it is perfectly possible and, indeed, desirable to design a building using EPS as insulation material and fulfil all insulation requirements, including fire safety.

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FIRE SAFETY BRIEFING

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PRP09/0151/5m/02.09