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## Properties

### Fire behaviour of foam Styropor

The raw materials from which Styropor foam is derived are styrene polymers (also styrene/acrylonitrile/copolymers) and a blowing agent, which is a mixture of low-boiling hydrocarbons. Both the polymer and the blowing agent are combustible.

About 50 % of the blowing agent is used up in expanding the Styropor. Afterwards, the remainder escapes rapidly until only 10–15 % is left behind. Thereupon, this residual amount is released very slowly. It must be given the opportunity to escape by allowing the Styropor foam to stand for a sufficiently long period before it is taken into use.

Consequently, it must be noted that inadequately aged Styropor blocks may still contain residues of the inflammable blowing agent. Thus the atmosphere may become ignitable during storage, transportation, or use in enclosed spaces. Special fire precautions must be taken in handling these blocks. If the blowing agent is present in dangerous concentrations – a situation that can be revealed by a gas detector – the room concerned must be thoroughly ventilated. Attention is drawn to the fact that the blowing agent vapour is heavier than air. The usual safety precautions must be observed during firefighting.

Thus Styropor foam that has been stored for sufficiently long periods consists essentially only of polystyrene (Styropor P and F) or a styrene copolymer (Styropor FH). The Styropor F grades also contain a flame-retardant, and are thus specified for the building trade in Germany, Austria and Switzerland.

#### Flammability rating, spread of flame

On exposure to temperatures above 100 °C, Styropor foam starts to soften and shrink until it eventually melts. On further exposure to heat, gaseous combustible products are

formed by decomposition of the melt. Whether or not these products can be ignited by a flame or spark depends largely on the temperature, the duration of exposure to heat, and the presence of air currents. The ignition temperature EMF-A, as determined by the DIN 54836 method, for Styropor P foam is 362 °C; and for Styropor F foam 374 °C. Consequently, it can be safely assumed that ignitable gases are not formed from melted Styropor foam until the temperature rises above 350 °C.

If there is no source of ignition, the products of thermal decomposition will not ignite unless they are in contact with surfaces or spaces at temperatures between 450–500 °C. Under these circumstances, they can continue to burn.

According to the BAM, Federal Institute for Materials Research and Testing\*, Styropor P or F foams do not ignite spontaneously at temperatures below 450 °C.

The factors that govern how and to what extent Styropor foam burns are the intensity and duration of exposure to heat or flame and the particular properties of the grades used.

After a brief period during which it sinters, **Styropor P foam** exposed to glowing sparks or an external flame may take fire fairly quickly. The flame then propagates rapidly over the surface. Subsequently, if heat is not removed by conduction from the melt, sufficient oxygen is present, and the fumes are expelled, the plastics will be burnt completely.

If **Styropor F foam** is briefly exposed to a flame, from a burning match, it shrinks from the source of ignition without igniting. Although it may ignite on longer exposure to a flame, the rate and propagation of the fire over its surface is very slight. As

\* *Bundesanstalt für Materialforschung und -prüfung, Berlin*

**Table 1**

| Validity   | Specification  | Category                | Classification of cellular Styropor  |   |
|--|--|-------------------------|--|---|
|  |  |                         | P  | F   |
| Federal Republic of Germany                              | DIN 4102 Teil 1 – Fire behaviour of building materials and building components, building materials, concepts requirements and tests<br>May 1981                            | Building material class | B 3 – leichtentflammbar und brennbar abtropfend (readily ignitable, forms falling burning particles [droplets]); does not conform to DIN 18164 on cellular plastics for the building trade (June 1979)                                     | B 1 – schwerentflammbar (non-readily ignitable [low flame spread]; does not form falling burning particles [droplets]); proofmark PA-III 2.1001 |
| Austria  | ÖNORM B 3800 Teil 1 – Behaviour of building materials and components in fire; building materials: requirements and tests<br>December 1988                                  | Combustibility          | B 3 – leichtbrennbar (readily combustible)<br>Q 3 – starkqualmend (dense smoke)  | B 1 – schwerbrennbar (difficultly combustible)<br>Q 3 – starkqualmend (dense smoke)<br>Tr 1 – nichttropfend (does not form drops)               |
|  |  | Drops formation         | Tr 3 – zündend tropfend (forms igniting drops) does not conform to ÖNORM B 6050 Materials for thermal and/or acoustic insulation in building construction; expanded polystyrene particle foam PS-M; marking of conformity<br>December 1988 |   |
| Switzerland  | Guidelines to fire regulations; Building materials and building components, load-bearing structures<br>Part A: Classification and specifications<br>Edition 1988           | Combustibility          | 3 – leichtbrennbar (readily combustible) ( $\rho < 15 \text{ kg/m}^3$ )<br>2 – leichtentzündbar (readily ignitable)  | 5 – schwerbrennbar (difficultly combustible)  |
|  |  | Smoke emission          | 1 – stark (dense)  | 1 – stark (dense)   |
| International  | ISO 3582 – Cellular plastics and rubber materials – Laboratory assessment of horizontal burning characteristics of small specimens subjected to a flame<br>November 1978   | burning rate            | 2–3 mm/s   |   |
|  |  | mean extinction time    |  | 4–10 s  |
|  |  | mean extent burnt       |  | 30–40 mm  |
| Federal Republic of Germany Fire insurance for packaging | Guidelines on premiums issued by the <i>Verband der Sachversicherer</i> (Property Assurance Association) April 1989<br>Guidelines for sprinkler installations<br>June 1987 | Type of packaging       | VP 5 – Lager ohne Sprinklerschutz (warehouses without sprinklers)<br>V 4 – Lager mit Sprinklerschutz (warehouses with sprinklers)  | VP 4 – Lager ohne Sprinklerschutz (warehouses without sprinklers)<br>V 2 – Lager mit Sprinklerschutz (warehouses with sprinklers)               |

soon as the external flame is removed, the Styropor F foam does not continue to burn, nor is any afterglow observed. Styropor F foam does not burn completely unless under the direct influence of other, more combustible substances, eg wood-wool, loose paper, etc.

If Styropor F foam has been stored for a sufficiently long period, the ignitability and flame spread are reduced to such an extent that board produced from it can usually be awarded the best possible fire behaviour rating for combustible building materials. The classifications for Styropor P and F foams in various countries are listed in table 1.

### Evolution of heat

Another factor that has to be taken into consideration in fire prevention is the evolution of heat. The fact that polystyrene has a high calorific value, ie 40 MJ/kg, does not necessarily mean that Styropor foam gives off much heat when it burns. The factor that actually counts most in this case is the rate of burning.

Owing to their low mass, Styropor F insulation and Styropor P or F packaging usually do not contribute very much to the evolution of heat in the event of a fire.

The situation is quite different if large volumes of foam are stored near production and processing plants.

### Assessment of fire characteristics in practice

The fire behaviour of solids, including Styropor foam, depends on a number of factors besides the properties of the material itself. These factors include the nature of the articles, ie their geometry, surface, proximity to other articles and the source of ignition, and composite structure; the nature and energy of the source of ignition and the duration of exposure to this source; and heat treatment and ventilation.

All these factors must be taken into careful consideration in assessing the fire hazards involved in the use of Styropor foam.

The fire behaviour may be substantially altered by surface coatings, lamination, and the formation of composites with other materials. If the foam has to satisfy specifications on fire resistance, evidence to this effect must be given.

Test certificates issued by the *Institut für Bautechnik* define applications in which Styropor F foam conforms to fire resistance specifications. According to Certificate PA-III 2.1001, no special evidence is required for applications in which Styropor F foam borders on massive mineral building materials or forms composites with these materials, providing that the adhesive forming the bond has been awarded a PA-III proofmark.

Test certificates drawn up along the lines indicated in DIN 4102, ÖNORM B 3800, and other national or international standards describe applica-

tions in which Styropor foam has to meet the requirements imposed on a normal-burning material.

### Substances emitted when Styropor foam is burnt

As far back as 1967, a joint study was made by the Plastics Technology Laboratories in the Viennese *Technologisches Gewerbemuseum* and the BASF Toxicological Laboratories with the aim of investigating the health hazard caused by the thermal degradation products of burning Styropor foam. The results were published in chapter 1 "Brand-schutz" in Professor E. Neufert's *Styropor Handbuch*.

Concentrations of the individual products of thermal decomposition given off by various cellulosic building materials and Styropor foam are listed in table 2. They were determined along the lines given in DIN 53436.

It is generally realized that the toxicity of gases given off during burning and smouldering cannot be assessed solely from their composition. Studies on biological models are also required to obtain the necessary information.

Biological studies on the acute inhalation toxicity have revealed that the gases given off during smouldering or burning of Styropor foam may have the same toxic effect as those emanating from any other burning organic substance. It was thus demonstrated that the toxicity could be ascribed solely to the carbon monoxide in the fumes. The study

**Table 2**

| Specimen                  | Gases given off in a fire | Volume fractions (ppm) of the gases given off at a temperature of |         |         |         |
|---------------------------|---------------------------|---|---------|---------|---------|
|                           |                           | 300 °C  | 400 °C  | 500 °C  | 600 °C  |
| Expanded Styropor P       | Carbon monoxide           | 50*   | 200*    | 400*    | 1000**  |
|                           | Styrene monomer           | 200   | 300     | 500     | 50      |
|                           | Other aromatics           | traces  | 10      | 30      | 10      |
|                           | Hydrogen bromide          | 0   | 0       | 0       | 0       |
| Expanded Styropor F       | Carbon monoxide           | 10*   | 50*     | 500*    | 1000**  |
|                           | Styrene monomer           | 50  | 100     | 500     | 50      |
|                           | Other aromatics           | traces  | 20      | 20      | 10      |
|                           | Hydrogen bromide          | 10  | 15      | 13      | 11      |
| Pine                      | Carbon monoxide           | 400*  | 6000**  | 12000** | 15000** |
|                           | Aromatics                 | —   | —       | —       | 300     |
| Insulating wood fireboard | Carbon monoxide           | 14000**   | 24000** | 59000** | 69000** |
|                           | Aromatics                 | traces  | 300     | 300     | 1000    |
| Expanded cork             | Carbon monoxide           | 1000*   | 3000**  | 15000** | 29000** |
|                           | Aromatics                 | traces  | 200     | 1000    | 1000    |

**Remarks:** Test conditions as laid down in DIN 53436; air admission rate 100 l/h; 300 x 15 x 10 mm specimen

\* smouldering/glowing

\*\* flame

— not measured

also proved that the gases given off by smouldering or burning Styropor are less injurious to health than the thermal decomposition products emitted by conventional building material, eg fibreboard and cork.

It is evident from table 2 that significant amounts of carbon monoxide and styrene monomer are given off when Styropor foam is burnt. Their relative toxicity can be assessed from the figures for their lethal concentrations ( $LC_{50}$ ), ie 0.55 % vol. for carbon monoxide and 1.0 % vol. for styrene over an inhalation period of a half-hour. In other words, the acute toxicity of styrene is decidedly less than that of carbon monoxide. In addition, its concentration in the Styropor degradation products was significantly less than that of carbon monoxide in the tests mentioned. Hence it can be concluded that, in the event of a serious fire, carbon monoxide would present the greatest toxic hazard. The proportions of aromatics in the gases given off by burning Styropor foam are very much less and do not constitute a health hazard.

Styropor F contains a minor proportion (less than 1 % by weight) of a brominated cycloalkane, hexabromocyclododecane (HBCD), which acts as a flame retardant. The formation of hydrogen bromide and toxic dibenzol[1,4]dioxin or dibenzofuran derivatives by burning polystyrene containing HBCD has been investigated specially. Water used to extinguish the burning material has also been examined for contamination.

Mere traces were detected of hydrogen bromide, the lethal concentration of which is of the same order of magnitude as that of carbon monoxide. In view of its very low concentration in the fumes given off from Styropor foam, it does not constitute an acute health hazard. Such low concentrations of hydrogen bromide are also relatively harmless from the corrosion aspect in view of the fact that fumes from most organic substances are acidic. For instance, the decomposition products of wood contain acetic acid.

In tests on Styropor F in accordance with DIN 53436, no brominated dibenzodioxins were found in either the gaseous phase or the solid residues. There were however traces of several brominated dibenzofurans (mainly monobromo-derivatives), especially in the solid residues, but the quantities involved were negligible. The limits for these toxic compounds are given in the German Prohibited Substances Order published in July 1994.

Brominated dibenzofurans can occur in air where expanded polystyrene is cut with hot wires. However, the Münster office for commercial and industrial supervision found in 1990 that the concentration of these compounds did not exceed 1 % of the recommended limit; there were no dibenzodioxin halo-derivatives.

Two research reports published by the German Ministry of the Environment support these conclusions. The first (No. 10403363, 1990) establishes that any tendency of polystyrene bead containing 3 % HBCD to yield halogenated dibenzodioxins or dibenzofurans when it burns is negligible. The second (10409222, 1991) states that when these compounds are formed, they are almost entirely adsorbed on soot particles.

### **Fire residue and extinguishing water**

#### **a) Solid fires residues**

The residue left behind by a Styropor fire contains insignificant amounts of water-elutable substances.

In January 1990 the German Health Office published measures on how to deal with fire residue. It recommended that burnt and charred plastic should be disposed of in a suitable incinerator, provided that an analysis of the residue shows that no better alternative exists.

#### **b) Extinguishing water**

It is generally unacceptable – and in many countries, forbidden – to put water that has been used to fight a fire directly into natural water courses.

Samples of water used to extinguish burning Styropor F and Styropor P have been analysed. In neither case was there evidence of ecologically harmful contamination, and the samples had no effect on either Daphnia or fish. It may be concluded that accidental contamination of open waters through firefighting measures is not a serious hazard.

Matter contained in the firefighting water has no deleterious effects on either mechanical or biological sewage treatment, and dissolved organic matter is eliminated adequately.

The concentration of substances in water used on Styropor fires is not so high as to make purification in a community water-treatment plant doubtful.

Styropor processing plants do not require a pond in which to store spent extinguishing water. However, "drop-over" covers for sealing rain-water run-off drains should always be on hand as a precaution.

Permission must be obtained from the operators of the treatment plant before allowing extinguishing water to which a fire-fighting foaming agent has been added into the drainage system.

### **Conclusions**

It can be concluded that the acute inhalation toxicity of the fumes given off when Styropor foam burns or smoulders is no greater than that of the fumes given off by wood-based materials. It is even less in relative terms because of Styropor's low density compared with that of other materials.

The substances given off when Styropor foam is burnt do not present any particular danger to the environment.

### **National Specifications**

Great Britain  
BS 6203: 1989; British Standard Guide to fire characteristics and fire performance of expanded polystyrene (EPS) used in building applications.

Spain  
Información Técnica 130 s:  
Comportamiento ignífugo de los materiales expandidos de Styropor.

USA  
E-8: Building Code and Specification Compliance (Styropor BF).

### **Note**

The information submitted in this publication is based on our current knowledge and experience. In view of the many factors that may affect processing and application, these data do not relieve processors of the responsibility of carrying out their own tests and experiments; neither do they imply any legally binding assurance of certain properties or of suitability for a specific purpose. It is the responsibility of those to whom we supply our products to ensure that any proprietary rights and existing laws and legislation are observed.

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