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3 Properties

Fire characteristics of Styropor foams

The raw materials used to produce Styropor foams consist chemically of polystyrene or styrene-acrylonitrile copolymer containing a mixture of low-boiling hydrocarbons as blowing agent. Both the polymer components and the blowing agent are flammable substances.

In the production of foams from Styropor approximately 50% of the blowing agent in the raw material is given off. After final expansion the blowing agent content of the foams falls relatively quickly to a residue of 10–15% which is then given off only very slowly. In order for most of this residue to escape also the expanded material must be stored for a time.

Particular attention is drawn to the fact that Styropor foam blockware which has not been stored for long enough may still contain residual amounts of the flammable blowing agent. As a result when it is stored, transported or used in enclosed spaces explosive atmospheres can form. When handling such blocks special fire safety precautions have to be taken. If the blowing agent is present in dangerous concentrations, a fact which can be established with the aid of gas detectors, the room in question has to be ventilated thoroughly. In doing so it should be noted that the blowing agent vapor is heavier than air. In tasks involving naked flames the usual fire safety precautions also apply.

Accordingly, adequately aged foams made from Styropor consist in the main only of polystyrene (Styropor P and F grades) or styrene-acrylonitrile copolymer (Styropor FH). Styropor F and FH grades additionally contain a flame-retardant additive. Insulating materials for the construction industry in the Federal Republic of Germany, Austria and Switzerland generally have to be made from Styropor F grades.

Flammability and flame spread

Styropor foams slowly begin to soften at temperatures above 100 °C and in doing so shrink. When heated further they melt. On prolonged exposure to the action of heat the melt gives off gaseous, flammable decomposition products. The point at which the concentration of these products suffices for ignition by flames, sparks, etc. depends substantially on the temperature, the duration of exposure to heat and any movement of the air. Tests based on DIN 54 836 yield an ignition point (EMF-A) for Styropor P foams of 362 °C and for Styropor F foams of 374 °C. In practice, therefore, it may be assumed that ignitable gases are first given off by the foam melt at temperatures above 350 °C.

If no source of ignition is present the thermal decomposition products ignite only at temperatures between 450 and 500 °C on hot surfaces or in the gas phase. Combustion may then continue independently.

According to studies by the Federal Institute for Materials Research and Testing (Bundesanstalt für Materialforschung und -prüfung), Berlin, Styropor P and F foams do not ignite spontaneously at temperatures below 450 °C.

Apart from the intensity and prolonged action of heat, key factors determining the course and extent of a fire include the special properties of the types of raw material used to produce the foam.

Foam made from Styropor P can be ignited relatively quickly after a brief sintering phase both on contact with glowing welding parts and by flash ignition and the flame rapidly spreads over the surface. The foam finally burns completely as long as excessive thermal energy is not removed by conduction, there is an adequate supply of oxygen and the fumes can escape.

Foam made from Styropor F on brief exposure to a flame, e.g. a lighted match, shrinks away from the source of ignition without igniting. Only on relatively long exposure

to the flame can it burst into flame but the speed of spread is very low and the flames spread only to a limited extent over the surface of the foam. As soon as contact with the extraneous flame is lost no further burning or secondary combustion, not even an afterglow, is observed. Only under the direct action of other flammable materials having poorer fire safety properties, such as fine wood shavings, loose paper, etc., does foam made from Styropor F burn to completion.

When foams made from Styropor F grades have been aged for long enough flammability and flame spread are reduced to such an extent that sheeting and panels made from them usually achieve the best possible classification for flammable building materials. These different properties give rise in German-speaking countries to the classifications of foams made from Styropor P and F compiled in Table 1.

Table 1

Field of application	Rating specification	Classification term	Classification of foam made from	
			Styropor P	Styropor F
Germany	DIN 4102, Part 1 – Fire characteristics of building materials and building parts: terms, requirements and tests	Building materials class	B3 highly flammable and dripping on burning; does not comply with DIN 18164 Foams for the construction industry 6.1979	B1 – flame-retardant; not rated as dripping on burning
Austria	Austrian standard B 3800, Part 1 – Fire characteristics of building materials and building parts; Building materials: requirements and tests – Provisional standard 12.1988	Flammability class	B3 – highly flammable	B1 – low flammability
		Smoke emission class	Q3 – very smoky	Q3 – very smoky
Switzerland	Precursor for fire inspection regulations; Building materials and building parts, plasterwork (flammability and smoke emission) 1997 issue	Drop formation class	Tr3 – drips on ignition; does not comply with Austrian standard B 6050 Insulants for thermal and/or sound insulation in over-ground construction; expanded polystyrene particulate foam PS-M; 12.1988	Tr1 – nondripping
		Flammability level	3 – highly flammable ($\rho < 15 \text{ kg/m}^3$) 2 – readily ignited	5 – low flammability
International	ISO 3582 – Cellular plastics and rubber materials – Laboratory assessment of horizontal burning characteristics of small specimens subjected to a small flame 12.2000	Smoke emission level	1 – high	1 – high ($\rho < 20 \text{ kg/m}^3$)
		Burning rate	2–3 mm/s	
		Mean extinction time		4–10 s
		Mean extent of burning		30–40 mm

Evolution of heat

Apart from flammability and flame spread, fire safety engineering criteria also include the evolution of heat. The relatively high calorific value of polystyrene ($H_u = 40 \text{ MJ/kg}$) does not, however, allow the conclusion that there is a high contribution to the evolution of heat. On the contrary, this depends substantially on the burning rate.

On account of their low weight Styropor F foams installed as insulants and packaging units made from Styropor P or F can usually make only a small contribution to the evolution of heat.

The situation is different for the storage of large quantities of foam in production and processing areas.

Assessment of fire characteristics in applications

The fire characteristics of products made from flammable solid materials including Styropor foam are largely determined not just by the nature of the material but also by their shape, their surface texture, their arrangement in space and relative to the source of ignition, the composites they form with other materials and also by the nature, energy and duration of action of the source of ignition and by their thermal pretreatment and the level of ventilation. These effects arising from the nature of the material, its shape and its environment must be carefully taken into account when assessing the fire safety properties of products made from Styropor with respect to the differing hazard situations which may occur in use.

Fire safety properties can be altered substantially, especially by paints and coatings and by the formation of composites with other materials. Insofar as fire safety requirements have to be fulfilled in the use of the foam the necessary confirmatory tests have to be carried out on finished products.

DIN 4102, Part 16, contains appropriate details for applications of Styropor F which is classed as flame-resistant. A special confirmatory test is not needed when the foam is used adjacent to massive mineral building materials or in association with these if the composite is produced using an adhesive whose suitability is certified by a PA III test symbol. Horizontal applications are only covered by the test certificate or the general building inspection test certificate when the foam is employed under screed or as visible ceiling cladding having a thickness $\leq 80 \text{ mm}$.

Appropriate information for applications of foam which is rated as normally flammable can be found in the test certificates drawn up in accordance with DIN 4102, Austrian standard B 3800 or other national specifications.

Emissions from foam made from Styropor involved in fires

The risks to health from thermal decomposition products given off by foam made from Styropor in the event of a fire were studied as early as 1967 in a joint project by the Laboratory for Plastics Technology at the Technologisches Gewerbemuseum (Industrial Technology Museum) in Vienna and the toxicology laboratory of BASF Aktiengesellschaft. The results were published in the Styropor Handbook, Chapter 1 "Fire safety", by Professor E. Neufert.

Specifically, in the studies conducted in accordance with DIN 53 436 in which, in addition to foam made from Styropor, cellulose building materials were included for comparison, the concentrations of individual components in the thermal decomposition products given in Table 2 were determined.

As is generally known, the toxicity of fumes from combustion and smoldering cannot be evaluated solely on the basis of the individual constituents they are composed of. Studies on biological models are necessary for this purpose.

Biological studies of acute inhalation toxicity yielded the result that the smoldering and combustion gases given off by foam made from Styropor can have a toxic effect, as is the case in the decomposition of all organic substances. In these

investigations the toxicity was attributable solely to the carbon monoxide in the fumes. It was additionally demonstrated that the relative risk of poisoning by fumes from a fire or smoldering material which can form when foam made from Styropor is involved in a fire is low by comparison with the thermal decomposition products from those cellulose building materials which were studied for comparison and have long been in use, e.g. wood fiber panels and cork.

As far as the constituents of the fumes itemized in Table 2 are concerned the following conclusions about their toxicity as a function of concentration may be drawn.

Carbon monoxide and styrene monomer were measured in significant quantities. The acute toxicity of harmful gases is quantified by the lethal concentration (LC 50), e.g. when inhaled for half an hour. For carbon monoxide it is 0.55 % and for styrene monomer it is more than 1.0 % (by volume). Accordingly, the concentration of styrene monomer would have to be twice as high as that of carbon monoxide to have the same acute toxic effect. Since, as Table 2 shows, its concentration in the decomposition products of foam made from Styropor from 300 °C upwards was substantially lower than that of carbon monoxide it may be assumed that in the event of an acute fire any hazard to health will be determined solely by carbon monoxide. The quantities of aromatics in the fumes from Styropor foam are comparatively low and do not pose any particular threat to health.

Table 2

Type of sample	Constituents of fumes	Composition of combustion fumes in ppm ¹⁾ at a test temperature of			
		300 °C	400 °C	>500 °C	600 °C
Foam made from 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
Foam made from 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
Whitewood	Carbon monoxide	400*	6000**	12000**	15000**
	Aromatics	—	—	—	300
Wood fiber insulating panels	Carbon monoxide	14000**	24000**	59000**	69000**
	Aromatics	traces	300	300	1000
Expanded cork	Carbon monoxide	1000*	3000**	15000**	29000**
	Aromatics	traces	200	1000	1000

Note:

Test conditions as in DIN 53 436, air supply 100 l/h, sample size in mm: 300 x 15 x 10

¹⁾ ppm = parts by volume per 1 million parts (parts per million)

* smoldering fire
** tongues of flame
— not measured

The flameproofing agent present in Styropor F is hexabromocyclododecane (HBCD, concentration < 1 percent by weight), a brominated cycloaliphatic hydrocarbon. The production of hydrogen bromide, the formation of toxic dioxins and furans and the contamination of firefighting water were investigated in fire safety studies.

Only traces of hydrogen bromide were found (see Table 2). Its acute lethal concentration is of the same order of magnitude as carbon monoxide. Due to its low concentration it cannot be of much importance for any acute threat to health from burning fumes from foam made from Styropor. The low levels of hydrogen halide do not present an unusual risk of corrosion either, since the fumes from burning most organic substances contain acid constituents. For example, the decomposition products from wood contain acetic acid.

In tests with Styropor F carried out in accordance with DIN 53 436 brominated dioxins were not found either in the gas phase or in the fire residues. Negligible amounts of multiply brominated furans (mainly monobromofuran) were formed which were predominantly bound to the fire ashes and none of them fall under the new banned chemicals ordinance published in July 1994 which defines threshold values for toxicologically relevant dioxins and furans.

During the cutting of polystyrene foam by hot wire the Office of Industrial Affairs in Münster found in 1990 that air at the workplace contained only brominated furans whose concentration was less than 1 % of the daily tolerable intake

Two research reports from the German Federal Ministry for the Environment support these findings. They conclude that halogenated dioxins and furans are bound almost totally to soot particles (Report No. 10409222, 1991) and that the tendency of HBCD to form such compounds in the event of a fire is negligible (Report No. 10403363, measured on polystyrene granules containing 3 % of HBCD, 1990).

Fire residues and firefighting water

a) Solid fire residues

Fire residues from Styropor and foam made from Styropor contain no appreciable amounts of toxic substances capable of being eluted by water.

Measures for the removal of fire residues were published by the Federal Ministry of Health (Bundesgesundheitsblatt 1/1990). According to these recommendations scorched and charred plastic products should be incinerated provided analysis of the residues does not permit any other possible use.

b) Firefighting water

In general, firefighting water must not be passed into natural watercourses.

In fire tests on blocks of foam made from Styropor P and F the firefighting water was collected in each case and analyzed. In tests on water fleas and fish this firefighting water yielded no negative findings for the ecosphere. The test results support the conclusion that even in the worst case unwanted contamination of watercourses should pose no threat.

The substances present in the firefighting water do not interfere with the operation of biomechanical water treatment plants and the dissolved organic carbon is eliminated adequately.

A firefighting water retention system is not necessary in production units where Styropor foam is produced or stored.

If for extinguishing purposes the fire service should add a foaming agent to the water, the firefighting water may only be discharged into the sewage system after discussions with the staff of the treatment plant.

Conclusions

In summary it may be concluded that when fires occur in plants producing foam from Styropor the emission of fire and smoldering products may be expected. The acute inhalation toxicity of these is under no circumstances to be rated higher than those emanating from plants processing wood materials.

The products given off by foams made from Styropor during a fire pose no special threats to the environment.

Further information

Further information concerning regulations in other countries may be obtained from the following sources.

Great Britain

BS 6203, 1991: British Standard Guide to Fire characteristics and fire performance of expanded polystyrene (EPS) used in building applications.

Spain

Información Técnica 0/1-130 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.

BASF Aktiengesellschaft
67056 Ludwigshafen, Germany

BASF