SELECTION GUIDE

INTRODUCING
EXPANDED POLYSTYRENE
(EPS)

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EPSASA

EXPANDED POLYSTYRENE ASSOCIATION OF SOUTH AFRICA

Introduction:

The Expanded Polystyrene Association of Southern Africa (EPSASA) under the aegis of AAAMSA promotes that part of the building industry which specializes in home and cold room insulation.

Membership consists of raw material suppliers and converters of expanded polystyrene as well as machinery suppliers.

We are grateful for the information provided by:

- EUMEPS – European Manufacturers of EPS (Construction) and
- STYBENEX - Vereniging van Fabrikanten van EPS bouwproducten.
- EPS International Task Force c/o The British Plastics Federation

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1. INTRODUCTION

Expanded Polystyrene, or EPS for short, is a lightweight, rigid, plastic foam insulation material produced from solid beads of polystyrene. Expansion is achieved by virtue of small amounts of pentane gas dissolved into the polystyrene base material during production. The gas expands under the action of heat, applied as steam, to form perfectly closed cells of EPS. These cells occupy approximately 40 times the volume of the original polystyrene bead. The EPS beads are then moulded into approximate forms suited to their application.

In addition to many significant user benefits, EPS offers substantial environmental advantages. Use of EPS actively contributes to a better environment. Some of the ways in which it does so are outlined below. Moreover, EPS makes this positive contribution at all stages of its life cycle, from manufacture, to application, to recycling or disposal.

Anyone who needs to thermally and acoustically insulate walls, roofs or floors will find EPS the ideal, cost effective and easy-to-use material in all types of buildings, from houses and offices to factories and schools. EPS is used by civil engineers as a lightweight fill or void-forming material. It is also used as a floatation material.

Today, people in all walks of life are concerned about the environment, and measures are being taken in all industries to reduce the impact that activities have on our surroundings.

For today's building and construction industry, concerns are being addressed by the careful choice of building materials, and in particular, the selection of insulation. One product which can contribute towards a better environment in this field is EPS.

1.1 USER BENEFITS

- **Excellent thermal insulant** - EPS is 98 percent air, and is therefore an excellent thermal insulant.
- **Proven acoustic insulant** – EPS absorbs sound, both impact sound in floating floors and airborne sounds for walls.
- **Moisture resistant** – EPS resists degradation by water.
- **Lifetime durability** – EPS does not decompose. It therefore provides lifetime durability.
- **Flexible mechanical properties** – With its flexible production process, the mechanical properties of EPS can be adjusted to suit every specified application.
- **Versatile** – EPS can be manufactured in almost any shape or size and is compatible with a wide variety of materials.
- **Cost-effective** – EPS offers the best price/performance ratio compared to any other insulation material.
- **Easy to transport** – EPS is almost as light as air, so it saves fuel in transport.
- **Easy to install** – EPS is light, practical, safe and easy to handle and install.
- **Fire retardant** – In addition to standard "EPS" there is also a "self extinguishing" version that includes a fire retardant.

1.2 ENVIRONMENTAL BENEFITS

- **Extremely safe** – EPS is non-toxic and totally inert. Unlike gas extruded polystyrene (XPS) it contains no Chlorofluorocarbons (CFCs) or Hydrofluorocarbons ($HCFC_s$), and never has at any time during its life cycle. It is also totally absent of any nutritional value, so no fungi or microorganism can grow within EPS.

- **Recycable** – EPS can be recycled in many ways once it comes to the end of its life. These include recycling directly into new building products and incineration to recover its inherent energy content. The choice of a recycling method is based on technical, environmental and economic considerations.

- **Health aspects** – EPS presents no dangers to health in insulation and use.

1.3 MANUFACTURE

THERE ARE FIVE MANUFACTURING STAGES:

1.3.1 PRE-EXPANSION

Polystyrene granules are expanded by free exposure to steam to form larger beads, each consisting of a series of non-interconnecting cells.

1.3.2 CONDITIONING

After expansion, the beads still contain small quantities of both condensed steam and pentane gas. As they cool, air gradually diffuses into the pores, replacing, in part, the other components.

1.3.3 MOULDING

The beads are moulded to form boards, blocks or customized products. The mould serves to shape and retain the pre-foam, and steam is again used to promote expansion. During moulding, the steam causes fusion of each bead to its neighbours, thus forming a homogeneous product.

1.3.4 SHAPING

Following a short cooling period, the moulded block is removed from the machine, and after further conditioning, may be cut or shaped as required using hot-wire elements or other appropriate techniques.

1.3.5 POST-PRODUCTION PROCESSING

The finished product can be laminated with foils, plastics, roofing felt, fibreboard and other facings such as roof or wall cladding material.

1.4 APPLICATION

1.4.1 USE OF EPS PRODUCTS MAKES A POSITIVE CONTRIBUTION TO HEALTH AND SAFETY

It remains effective for the entire life of the construction in which they are used. The energy used in the EPS production process is recovered many times over by the energy saved in the buildings in which it is installed. EPS construction product complies with all building, fire and safety regulations for the application in which they are used.

Some insulation materials are not usually associated with "good health". EPS, however, is universally recognized as a non-harmful, pleasant material to work with. It is non-toxic, does not sting hands, irritate skin or nostrils, and has no known adverse effective on health. In its end-use condition, EPS presents no health risk whatsoever.

1.4.2 PERFORMANCE

In use, EPS is resistant to moisture and maintains a consistent level of thermal and acoustic performance.

1.4.3 REDUCED FIRE RISK

EPSASA EPS grades are fire retardant. These are more difficult to ignite than standard grades, offering further protection during installation.

The gases and vapours given off by EPS in a fire are less dangerous than those from many natural materials, such as timber or cork.

In almost all applications, EPS is covered by other building materials, such as concrete, brickwork or plasterboard, therefore minimizing the fire risk to EPS.

1.5 RECYCLING / RECOVERY

EPS can be treated in the most environmentally appropriate manner via a range of waste management options.

1.5.1 REDUCTION

It is a common misconception that many of our waste problems are caused by plastics. In fact, the total amount of plastics in our municipal solid waste is only seven percent by weight. Of this, EPS accounts for only a very small fraction – just 0.1 percent. EPS products used in the construction industry have a very long effective lifetime because of their durability, so disposal of the product is minimized.

1.5.2 RECYCLING / DISPOSAL SCHEMES

There are several options to treat EPS building and demolition waste, each with environmental, technical and economic implications to consider when choosing the best option to implement in any one place.

Generally the most beneficial is direct re-use by grinding clean EPS waste and adding it to virgin material during production. This waste can also be used to improve soil condition.

Alternatively, EPS can be melted and extruded to make compact polystyrene, for items such as plant pots, coat hangers and a wood substitute. Medium toughened polystyrene from which sheets for thermoformed articles, such as trays, can also be made. As part of mixed plastic waste, EPS can be recycled to make, for example, park benches, fence posts and road signs, ensuring the plastic material has a long and useful second life.

1.5.3 ENERGY RECOVERY

This involves the recovery of energy, usually in the form of heat from incineration. This gives EPS-waste a genuine post-consumer use. The calorific value of EPS available for heat recovery is slightly more than that of coal by weight.

In a modern incinerator, EPS releases most of its energy as heat, aiding in the burning of municipal solid waste and emitting only carbon dioxide, water vapour and a trace of non-toxic ash. The fumes are non-toxic and are not harmful to the environment as no dioxins or furans are emitted. The energy gained can be used for local heating and generation of electricity.

1.5.4 LIGHTWEIGHT CONCRETE

EPS is used successfully as an aggregate for lightweight concrete for both structural and thermal insulation applications. Optimum physical and thermal properties are achieved with low density spherical EPS aggregate due to it's effective "arching properties within the cement matrix, low moisture absorption to minimize water/cement ratios and maximum strength/weight ratios and a permanent uniform resistance to the flow of heat. Consequently, lightweight concrete containing EPS aggregate has captured a growing market throughout the world for such structural and thermal insulation applications including sandwich panels, precast concrete building systems, insulation roof fill and decorative architectural and landscaping products.

1.5.5 LANDFILL

Although currently a large proportion of EPS waste is disposed of in landfill, it is EPSASA's least preferred option since it does not create a "second life" and is therefore not an optimal use of natural resources.

However, landfill-using EPS does bring advantages. EPS waste is inert and non-toxic, so the landfill site becomes more stable. EPS aerates the soil, encouraging plant growth or reclaimed sites. EPS does not degrade and will not leach any substances into ground water, nor will it form explosive methane gas.

2. BEHAVIOUR OF EPS IN CASE OF FIRE

The purpose of this chapter is to clearly quantify the fire performance of expanded polystyrene (EPS) when used as an insulation material in buildings. This chapter will consider all aspects of the fire performance of EPS in terms of heat release, flame spread, smoke production and toxicity and its contribution to the propagation of fire. Detailed information is provided on the characteristics of EPS foam as a basis for evaluating its behaviour when subjected to ignition sources. The performance of fire retardant additives is also evaluated. This information can be used for hazard assessment taking into account the complexity of a real fire and the difficulty of modeling real fire situations from scaled tests.

Expanded polystyrene is derived mainly from styrene monomer and expanded to form a cellular structure substantially of closed cells. When considering the fire behaviour of any building material it is important to realize that the assessment thereof is based on its performance in end-use conditions. This performance will depend on not only the chemical nature of the material but to a greater extent on its physical state.

Thus the important factors which must be considered in determining the potential fire hazard of EPS are:

- The foam density and shape of the products.
- Its configuration relative to an ignition source.
- The use of any bonding to a substrate of facing.
- The location of the product (which will influence the heat transport)
- The availability of oxygen (ventilation).

2.1 STAGES OF A BUILDING FIRE

(How a building fire develops)
When a building is in everyday use at normal temperature conditions, there is a natural balance between flammable materials and oxygen in the environment. However at the initial stage of a fire, ignition energy comes into contact with the flammable material. Above a temperature of approximately 200°C, the material will give off flammable gases, which will combust either due to the original ignition energy or spontaneously. In the case of gases, combustion can lead directly to flames whereas with solid materials, such as furniture, they first become glowing ignition sources. In the first stage of a fire, there is a gradual building up of heat energy in the form of combustible gases. Up to this point the temperature is still relatively low and the fire is still localized within the building. Then all of a sudden a development takes place, called "flash-over", in which the temperature increases significantly and the fire suddenly spreads all over the compartment. After this flashover the chances of rescuing people and equipment are greatly reduced. The fire then spreads throughout the whole of the building and will finally go out without human intervention due to the lack of flammable materials.

2.2 THE BEHAVIOUR OF EPS IN A FIRE

Like practically all-organic building materials polystyrene foam is combustible. However in practice its burning behaviour depends on the conditions under which it is used, as well as the inherent properties of the material. These inherent properties differ depending on whether the cellular material is made from EPS with or without a fire retardant additive. The bonding of other materials to cellular polystyrene also considerably affects its burning behaviour. For example, foil-faced products have an improved surface spread of flame performance. When installed correctly, expanded polystyrene products do not present an undue fire hazard. It is strongly recommended that expanded polystyrene should always be protected by a facing material, or by complete encapsulation.

When burning, expanded polystyrene behaves like other hydrocarbons such as wood, paper etc. The products of combustion are basically carbon monoxide and styrene: during a fire, the styrene may be further decomposed, giving off oxides of carbon, water and a certain amount of soot (smoke).

EPS is produced in two types: the standard quality and the flame-retardant modified quality, designated by the code "FR". Flame retarded FR grades as specified by EPSASA, which make the expanded material much more difficult to ignite, considerably reduce rates of spread of flame.

In South Africa EPSASA recommends that FR grade be used. However, in many countries, both grades are used.

If EPS is exposed to temperatures above 100°C, it begins to soften, to contract and finally to melt. At higher temperatures, gaseous combustible products are formed by decomposition of the melt. Whether or not these can be ignited by a flame or spark depends largely on the temperature, duration of exposure to heat and air flow around the material (the oxygen availability). Molten EPS will normally not be ignited by welding sparks or glowing cigarettes; however, small flames will ignite EPS readily unless it contains flame retardant additives (FR Grade). The transfer ignition temperature is 360°C. In the case of EPS- FR, this is 370°C. These values indicate that if melted EPS disintegrates then combustible gases are only formed above 350°C. In the absence of an energy source (pilot flame) the self-ignition temperature of melted EPS in its standard grade is 450°C. After ignition of standard grade EPS, burning will readily spread over the exposed surface of the EPS, and it will continue to burn until all EPS is consumed. While the low density of the foam contributes to the easy of burning through a higher ratio of air (98%) to polystyrene (2%), the mass of the material present is low and hence the amount of heat released is also low.

2.3 FIRE-RETARDANTS

The presence of fire retardant additives in EPSASA FR grades leads to significant improvements in the fire behaviour of EPS. While the complexity of a real fire situation makes it very difficult to predict overall fire performance from laboratory tests, there are several, small-scale tests which clearly show that it is much more difficult to ignite EPS made from grades with a fire retardant additive than standard grades.

In the presence of large ignition sources or significant heat fluxes, e.g. greater then 50 kW/m^2, from fires involving other material, EPSASA FR grades will eventually burn, reflecting the organic nature of polystyrene. In such instances the building is usually beyond the point of rescue.

EPS-FR grade contains a small quantity of fire-retardant agent (max. 0.5%). This is normally the fire retardant hexabromocyclododecan (HBCD). This has a beneficial effect when EPS is exposed to a fire source. The foam shrinks rapidly away from the heat source, thus reducing the likelihood of ignition. The decomposition products of the additive(s) cause flame quenching, so that when the ignition source is removed, the EPS will not continue to burn.

HBCD is a so-called cyclo-aliphatic organobromine compound and is not comparable with the aromatic fire retardants (PBBs and PBBOs), the use of which has been banned for some time. Indeed, HBCD does not form any toxic dioxins and furans during combustion. This was concluded by the German Ministry for the Environment in 1990, for the combustion of polystyrene with an HBCD content that was at least five times greater than normal (3 percent by weight). They found that HBCD is not a source for the build-up of polybromodibenzofurances and –dioxins when using different types of combustions oven over a temperature range of 400 to 800°C. The same result had previously been concluded by the Dutch Ministry for the Environment in 1989 for pyrolysis of polystyrene with an HBCD content of 10 percent (in fire retardant modified EPS there is only 0.5%). A study in 1992 by the well-known German Fresenius Institute itself showed that in the HBCD itself there were no brominated dioxins or furanes to be demonstrated. Recent research at the Karlrusher test incinerator "Tamara" has demonstrated that the combustion of polystyrenes in a modern combustion oven is an environmentally friendly method of recycling in terms of emissions.

Also as HBCD is insoluble in water there is therefore no risk due to migration to water.

2.4 HEAT RELEASE

The rate of heat release has lately been considered an important parameter for assessing the fire behaviour of materials. The test method developed as ISO 5660 uses a range of impressed heat fluxes. Tests in an industry-laboratory showed that EPS board shrank rapidly away from the heat source and collapsed into a film of molten polystyrene.

RESULT FROM HEAT RELEASE TEST FOR EPS FOAM (ISO) 5660; cone calorimeter)

Fire parameter	Flux (kW/m²)	EPS Regular	EPS FR
Time to ignition (s)	20	Nl[1]	N1
	30	73	77
	40	28	40
	50	18	24
Mean peak rate of heat release (kW/m²)	20	Nl	N1
	30	299	238
	40	394	321
	50	407	379
Mean effective heat of combustion (MJ/kg)	20	N1	N1
	30	27	27
	40	28	26
	50	28	27
Mean rate of heat release from ignition time to 60 s (kW/m²)	20	N1	N1
	30	146	168
	40	173	153
	50	158	173
Mean rate of heat release overall (kW/m²)	20	N1	N1
	30	214	93
	40	228	110
	50	209	119
Mean specific extinction area [2] (m²/kg)	20	N1	N1
	30	1317	1461
	40	1200	1334
	50	1346	1297

1) N1 = no ignition under stated flux conditions
2) Smoke density expressed as mean specific extinction area SEA

No flaming ignition was observed at a heat flux of up to 20kW/m². For higher heat fluxes, the overall rate of heat release (RHR) and peak RHR were lower for FR grades than for standard grades.

The calorific value of expanded polystyrene materials (40 MJ/kg) is about twice that of timber (18.6 MJ/kg) but taking into account the comparative densities of the two products, the calorific volume by volume of expanded polystyrene materials is 540 MJ/m³ to 1250 MJ/m³ compared with 7150 MJ/m³ to 10 400 MJ/m³ for cellulosic products, such as fibre, insulating board, or timber.

The overall heat content of materials influences fire severity in terms of fire growth and the rate of release of heat content is of major importance. This is very dependent on combustion conditions. Heat release from expanded polystyrene materials is about three times as rapid as from softwood timber, but is of much shorter duration.

The extent and rate of heat release is limited primarily by ventilation. For example a foam density 16 kg/m³ requires over 150 times the volume of air to achieve complete combustion. This is unlikely to occur, so its full potential heat is rarely released.

A 200mm-thick layer of EPS with a density of 20kg/m³ represents the same amount of energy as a 17mm-thick layer of pine wood. But who hesitates to use 17mm-thick pine as unprotected surface on a ceiling or wall?

2.5 SMOKE

Smoke is an important factor in fire. A high density of smoke will inhibit the search for an emergency exit thereby increasing the risks to occupants. Smoke fumes can also be toxic or have a low oxygen content, while (hot) soot particles are able to block and adversely affect the breathing organs.

When assessing potential smoke emission from expanded polystyrene materials in a building under fire conditions, essential factors to be considered include the possible extent of flame spread over any surface designed to protect expanded polystyrene materials, the ventilation conditions and the rate of decomposition of the polystyrene. Effective surface protection will restrict flaming to areas where the coating has failed and where molten polystyrene or gaseous decomposition products have escaped through joints and small fissures.

Prediction of the precise smoke-producing potential of polystyrene is difficult because of the wide range of combustion conditions likely to be met within the actual fire. Generalised conclusions from small-scale tests have been substantiated by evidence from fire incidents. In a flaming fire expanded polystyrene materials produce more smoke from a given mass of material than most other materials. It should however be noted that expanded polystyrene materials contain only 2% by vol. of solids.

In actual fires where much smoke is produced, it is often anticipated that this originates from burning EPS roof insulation. In extreme cases this claim is made even for fires in buildings without any EPS insulation. In fact, most of the smoke originates from materials such as burning wood, asphalt felt and furniture, especially after the first short phase of fire.

The smoke particles produces in a flaming fire are large, black and irregular in shape. The density of the smoke produced increases with increasing temperature and with the intensity of the heat flux onto the material. In a smouldering fire e.g. where the expanded polystyrene materials remain effectively protected and decomposition occurs in oxygen deficient conditions. Small spherical grey particles predominate and the specific optimal density values are lower than for flaming conditions.

When exposed EPS burns, it generates a considerable amount of heavy, dense, black smoke, which is usually proportional to the mass consumed by the fire. It is sometimes argued that the toxicity of the smoke fumes will be in proportion to the density of the smoke but this appears not to be the case.

For applications where EPS is used without a protective facing, the amount of smoke is limited by the favourable mass to surface area ratio of the low-density foam. Although, exposed burning EPS in its standard design produces a lot of smoke, the total quantity of smoke is small due to the low density of EPS. But given that EPS in virtually all cases is not used in an exposed form or in rooms without any risk of fire and is sandwiched between other materials, it is more realistic to assess smoke production in these practical situations.

Normally, EPS is protected from the fire by the surrounding materials and it will only catch fire, when the whole of the building is ablaze. In these cases, the EPS will contract due to the heat, but does not ignite and does not contribute to the propagation of the fire and the amount of smoke may be limited. The production of smoke is also therefore accordingly small. Consequently it can be concluded that EPS, when used correctly in recommended applications, does not lead to an increased risk of smoke density.

2.6 FLAME SPREAD

Flame spread is a process of progressive ignition along a continuous surface. The extent and rate of flame spread depend largely on the ignitability of, and rate of heat release from, a combustible material. In linings where expanded polystyrene material is attached to a rigid substrate and is provided with a protective exterior facing, the risk of flame spread is also affected by the physical/thermal properties of the surface on to which the expanded polystyrene material may have melted.

The proximity of the substrate and the degree of integrity of the protective facing (where it still remains) as well as the design of fixings and joints govern the distribution of any molten polystyrene and the supply of air and heat to the combustion zone.

If adhesive has been used overall to attach expanded polystyrene material to a surface facing, melting will result in attachment to this surface but where thick sheets have been installed, particularly horizontally, failure of the surface facing can result in the formation and falling of molten drops, often flaming.

Where localized failure of a protective facing has occurred, air supply to, and the orientation of, the surface of the exposed expanded polystyrene material are important in determining the subsequent risk of flame spread, (e.g. in a cavity wall insulated with expanded polystyrene material), extensive spread is unlikely because of lack of circulation of combustion air.

From recent research it is possible to quantify the contribution made, separately by the insulant, to fire growth in free ventilated enclosures where expanded polystyrene material insulant is used in wall panels or wall and/or ceiling linings. The extent of involvement of the insulant, amongst other factors, is dependent on the failure pattern of the protective facings. With good design and careful selection of protective facings, the rate at which the insulant subsequently contributes heat, smoke etc. to fire development inside an enclosure can be effectively reduced; the time to involvement can also be substantially delayed.

A large scale experimental research programme conducted by the Building Research Establishment (BRE) in England simulating the effects of a fully developed room fire over a large area of externally insulated masonary assemblies, has identified the design features affecting their fire performance. Where expanded polystyrene sheeting is used, by careful selection of the protective weathering finish, with suitable design and insulation of its support and correct installation around reveals, together with appropriate fire barriers, it is possible to reduce effectively the contribution made by an insulant to progressive vertical fire spread over the external finish or through the insulant/cavity; the extent of fire damage can also be limited. The fire performance of homogeneous lightweight renders containing expanded polystyrene beads as aggregates applied externally to solid masonry walls has been shown to be satisfactory.

2.7 TOXICITY

As discussed earlier it is difficult to predict the behaviour in fires from small-scale tests. The same considerations apply to assessing the hazards of gaseous emissions from burning materials. In practice, two approaches are follows; firstly the determination of thermal decomposition products and, secondly studies of their biological effects. It is necessary to combine the two approaches to obtain a realistic overall estimate of the hazards.

Although burning EPS gives off black smoke, the toxicity of the released smoke fumes is considerably less than those of other commonly used materials. This was already concluded in 1980 by the TNO Centre for Fire Safety for EPS in both standard FR grades.

Extensive research into the toxicity of smoke fumes from burning EPS has also been conducted in accordance with the DIN 53436 method which is a small scale combustion toxicity test, which gives results of relevance to full scale fires.

In this test samples are heated respectively to 300, 400, 500 and 600°C. As well as various types of EPS, individual natural products such as pine wood, chipboard, expanded cork and triplex, rubber, felt and leather were also studied. The results are summarized in the table below. The smoke fumes from EPS appeared at most to be equally toxic as, or less toxic than those from the natural products throughout the whole of the range. EPS itself scored very well based on equal volumes of the test samples, due to the extremely low density and lightweight of EPS (98% air). In addition, no negative effect on smoke development from the fire retardant was found in FR grades of EPS.

The table shows that insignificant amounts of carbon monoxide and styrene monomer are given off when EPS is burnt. Their relative toxicity can be estimated from the figures for their acute inhalation-toxicity value (L/C_{50} inhalation period 30 min) of 0.55% v/v for carbon monoxide and 1.0% v/v for styrene. Thus, the acute inhalation toxicity of styrene is less than that of carbon monoxide, and its concentration in the EPS composition products is also less at elevated temperatures found in a fire. Carbon monoxide can be fatal if inhaled for 1 minute to 3 minutes at concentration of 10 000 p.p.m. to 15 000 p.p.m. Styrene has an odour which can be detected at 25 p.p.m and which becomes intolerable between 200 p.p.m and 400 p.p.m. This warns of the necessity of immediate evacuation of an area. Eye irritation and nausea may occur at 600 p.p.m and some neurological impairment may occur at 900 p.p.m. In a fire the styrene is likely to be further decomposed to form carbon monoxide, carbon dioxide and water.

THE TOXICITY OF SMOKE FUMES FROM EPS IN VARIOUS "NATURAL" MATERIALS

Sample		Emitted fractions (v/v) in ppm at different temperatures			
	Smoke gases in a fire	300 °C	400 °C	500 °	600 °C
EPS (standard grade)	Carbon monoxide Monostyrene Other aromatic compounds Hydrogen bromide	50* 200 fractions 0	200* 300 10 0	400* 500 30 0	1,000** 50 10 0
EPS- FR (fire-retardant grade)	Carbon monoxide Monostyrene Other aromatic compounds Hydrogen bromide	10* 50 fractions 10	50* 100 20 15	500* 500 20 13	1,000* 50 10 11
Deal	Carbon monoxide Aromatic compounds	400* --	6,000** --	12,000** --	15,000** 300
Chip board	Carbon monoxide Aromatic compounds	14,000 ** fractions	24,000** 300	59,000** 300	69,000** 1,000
Expanded cork	Carbon monoxide Aromatic compounds	1,000* factions	3,000** 200	15,000** 1,0000	29,000** 1,000

* smouldering/glowing
** as a flame
-- not detected
Remarks: Test conditions specified in DIN 53436; air flow rate 100 1/h;
300mm x 15mm 20mm test specimens compared at normal end-use conditions

For FR grades, traces (10 – 15 p.p.m) of hydrogen bromide were detected by the DIN 53436 method. The LC_{50} value of HBr is similar to that of carbon monoxide. Since its concentration is so low, relative to carbon monoxide, its presence in the fumes given off from burning FR grade EPS does not add significantly to the health hazard. Owing to the small amounts of HBr generated, no significant corrosive effects are expected.

Combustion of FR grade EPS under the conditions prescribed in DIN 53436 yields no traces of brominated dibenzodioxins, either in the gaseous phase or in the solid residue, only negligible proportions of brominated dibenzofurans, none of which are a toxic substance as defined in of the (German) Prohibited Chemicals Order 1994.

2.8 PROTECTIVE COVERINGS

As previously discussed, EPS, like most plastics, is flammable. As a standard rule EPS should never be installed "unprotected", if a room has any risk of fire. When EPS insulation has been professionally installed it will only catch fire, in the case of a building fire, if the materials surrounding it are already burnt or collapsed. This means that the building and its contents were already ablaze before the fire reached the EPS. It is only as a result of indifference, ignorance or carelessness that EPS should catch fire at the start of a fire. One area of application that, for example, is often "under fire", is the flat, insulated roof. Yet it has been shown, that with good design, incorporating compartmentalization, detailed planning, and a careful implementation to ensure that preventative measures are taken, a fire-safety roof using EPS insulation can be made without difficulty.

It is therefore recommended that installed expanded polystyrene boards should always be covered by a protective facing, suitably fixed to prevent collapse in the event of fire. Protection of the surface of expanded polystyrene with 9mm thick plasterboard or plaster of minimum 10mm has been shown to provide resistance to ignition, if the protective facing is mechanically supported. An unsupported coating, applied directly on the expanded polystyrene materials, with adequate insulation to maintain the interface temperature below 100°C for a specified time will provide protection, as long as the integrity of the facing is preserved. Thin finishes, such as plaster skim coat, aluminium film, flame retardant paints or intumescent coatings applied directly on to the expanded polystyrene materials can delay ignition to a limited extent, but once the underlying material softens under the effect of heat, penetration and progressive failure of the coating may occur.

2.9 FIRE RESIDUES OF EPS AND DISPOSAL

CLEANING AND BUILDING AFTER A FIRE

The emissions given off and the residues remaining when EPS (with and without flame retardant) is burnt do not present any particular danger to the environment. Extinguishing water resulting from EPS fires and fire residues can be disposed of without any special treatment in municipal installations for sewage and solid waste, respectively.

In most fires, a large number of materials are involved. After a fire with EPS, the building should be cleaned as follows:

1. Remove dust and soot by means of dry vacuum cleaners, assisted by mechanical brushing.
2. Grit-blast porous surface such as concrete.
3. When procedures according to 1 and 2 are insufficient, then alkaline detergent solutions can be used. Residues from the cleaning operations should be collected and disposed of by incineration; the recommended minimum temperature to operate the incinerator is 850 °C. This work should preferably be done by companies specialized in this field.

2.10 GENERAL PRECAUTIONS FOR STORAGE OF EPS ON SITE

As discussed earlier under certain circumstances, expanded polystyrene materials can be ignited readily by exposure to a naked flame. Care should be taken to avoid contact with such sources of ignition when handling and storing the material before and after installation. Fire-retardant grades are available for use where appropriate, and particularly to take account of spread of flame requirements. In regard to the generation of dust during the production and processing of EPS, e.g. by mechanical treatment of the foam, the same safety procedures must be observed as generally for dust of other organic materials.

3. HEALTHY BUILDING WITH EPS

EPS does not present a risk to health during production, handling, or during demolition and renovation.

Expanded Polystyrene (EPS), is a material which is used extensively in the building industry as an insulator, as well as being a natural choice for packaging purposes. EPS has many positive attributes, not the least of which is its proven safety record during all stages of its life cycle – from production, during use, through to re-use or recycling.

Health and safety are of paramount importance in everyday life. It is therefore not surprising that health and safety take top priority in the building industry. However, the evaluation of building materials is not only concerned with technical specifications, but with factors such as total environmental impact. The increasing demand for sustainable buildings means that the building industry has had to take a fresh look at the materials it uses, and the way it uses them.

Insulation is of course a necessity in any building. But most materials used for insulation are not readily associated with safety and good health. This is due in part to the fibres associated with mineral wool, and the perceived problems with radon and quartz. There is one insulation material however, which performs particularly well when it comes to health and safety: EPS, whose physical properties make it an ideal insulation material.

3.1 HEALTH DURING PRODUCTION

During the manufacturing of EPS, emission levels are negligible, due in part to the fact that its volume constitutes 98% air.

THE COMPONENT PARTS OF EPS ARE AS FOLLOWS:

STYRENE
Extensive research has shown that Styrene monomer, the raw material for the production of expandable polystyrene, is perfectly safe in use. Polystyrene has a maximum styrene content of only 0.1% by weight, and since EPS contains only 2% polystyrene by volume, this minute trace of styrene monomer poses no threat to health whatsoever.

PENTANE
About 6% of pentane is incorporated into the expandable polystyrene granules as a blowing agent. It is a saturated hydrocarbon, not to be confused with (H)CFCs. Pentane is non-toxic and constitutes no threat to the ozone layer.

FIRE RETARDANT
EPS is available either with or without the fire retardant hexabromocyclododecane (HBCD), which constitutes a weight of maximum 0.5% of the final product. It is a cycloaliphatic fire retardant and not comparable with the aromatic fire retardants (PBBs and PBBOs). HBCD is present in EPS in such a minute quantity that it poses no risks to health whatsoever. Moreover, it remains within the closed cells of EPS and does not dissolve in water.

3.1.1 FIBRES AND DUST

The insulation manufacturing industry continuously evaluates its products. Research into fibres and dust in production premises is mainly concentrated in mineral wool plants, where it may be assumed sufficient protective measures are taken.

However, the situation is less satisfactory in the handling of insulating materials on the building site, or in demolition and renovation work. Perhaps the practical inconvenience of wearing protective equipment during work does some way to explain this. Workers do not always follow safety regulations which can cause health problems, and will make the work slower, and therefore less profitable. The structure of organic plastics such as EPS is very different from the inorganic fibre structure of mineral wool, so no fibres whatsoever are released. This explains why no protective equipment is necessary when working with EPS.

There are virtually no physiological or toxic effects of EPS and EPS dust will therefore have no adverse effects on health, beyond the minor nuisance associated with any dust – such as sneezing.

3.1.2 RADIATION AND RADIOACTIVITY

Misunderstandings about radiation in plant manufacturing insulation materials have arisen, possibly as a result of recent discussions on radon and mineral building products.

Natural geological processes can cause higher than average concentrations of radioactive isotopes to be present in certain minerals. This means that in many mineral building materials, radioactivity can be detected. Extensive scientific research has shown however, that no radioactivity is emitted by EPS, nor does it contain radon or cause radon emission.

3.2 HEALTH DURING HANDLING ON THE BUILDING SITE

Close supervision on the building site is often difficult. As a result health and safety regulations are not always fully complied with. Moreover, it is here at the handling stage, when personnel are in direct contact with building materials that they can suffer most from the effects of harmful products and substances.

FIBRES AND DUST
Sawing, cutting and just touching certain building products can lead to irritation of the skin, eyes and respiratory tract. The degree of irritation depends on how the products are handled and the level of ventilation in the area. Although this is not life threatening, it is of course essential to minimize any risk to workers in the building industry. EPS is universally recognized as a pleasant material to work with. It does not sting hands, skin, or mucous membranes. EPS does not have any of the adverse effects on health often associated with some other building products.

EXCEPTIONALLY LIGHT WEIGHT
Another benefit of EPS in respect of safety, health and well being is its exceptional light weight. Even assembled EPS building products do not normally causes heavy work for construction personnel.

3.2.1 THE EFFECTS OF BINDERS

Binders are used to stabilize and strengthen many of the building materials used today. These binders may be given off during handling of materials on the building site, which can lead to health problems, EPS does not contain binders of any kind. This is because the loose EPS beads are bonded together with only the help of steam to produce the familiar EPS building products, so nothing more than pure water is used.

3.2.2 PROTECTIVE EQUIPMENT

Building workers generally find protective equipment unpleasant and inconvenient to wear. So in practice protective equipment is frequently not used. From a health point of view, this is quite difficult to understand. However if you consider having to wear gloves, a dust mask, overalls, safety goggles, a P2 mask, a P3 mask, and cream during the working day it is understandable that some personnel will take risks. Because none of these precautions are needed with EPS, it therefore scores highly in terms of safety, health and well-being.

3.3 HEALTH IN USE-INDOOR ENVIRONMENT

Indoor climate quality is of prime importance when a building is in use, both for the health of the occupants and for the continued stability of the building itself. Good thermal insulation is known to contribute to a comfortable interior, and it is recognized that insulation and ventilation should go hand in hand.

When the right materials are used, the lifespan of a building increases considerably.

IN CONSIDERING CLIMATE QUALITY THE FOLLOWING PARAMETERS COME INTO PLAY:

3.3.1 MOISTURE

Moisture in buildings is one of the greatest problems faced by builders. It can lead to fungal growth, undermining the integrity of the structure, and creating a poor, unhealthy indoor environment. Remarkably, EPS is virtually insensitive to moisture and will absorb almost no water even when immersed for long periods. This means that moisture has virtually no effect on EPS insulating products after installation, and the original insulation value of EPS is therefore guaranteed for a long time.

3.3.2 EMISSION IN USE

German research in 1987 showed that styrene emissions from EPS are very low, even less than 1% of the Maximum Admissible Concentration (MAC) value in Germany at the time (100 mg/m^3). Even when the detection limit of 0.05 mg styrene m^3 was lowered to 0.01 mg/m^3, no styrene was measurable. The fire retardant which may be present in EPS is insoluble in water, and does not leach out of the product. There is widespread use of EPS as packaging in the food industry, an industry which must adhere to the most stringent hygiene and safety standards. Even accidental ingestion of EPS has no effect on humans or animals, since it will pass straight through the digestive tract and remain unchanged.

3.4 HEALTH DURING DEMOLITION AND RENOVATION

Insulating material has been used to an increasing extent in Europe since the 1960s. Slowly but surely some of the building stock from that period is now reaching the demolition stage. In the future, selective demolition should ensure that insulating materials are carefully removed and recycled for appropriate re-use, which will mean some changes for workers involved in demolition or renovation. An example of this change came with the comprehensive regulations on removal of asbestos, which by now is very familiar. But it is absolutely clear from what we have seen that there need be no fears on health grounds about the removal of EPS after a building has reached the end of its useful life.

4. LIFE CYCLE ASSESSMENT (LCA)

Recent years have shown growing concern for the environment, and in particular an increased demand for sustainable building and development. For the construction industry this means a need for accurate information about the environmental impact of the building materials and products that they use. The most reliable way to present this information has proved to be the Life Cycle Assessment (LCA) approach.

This approach investigates the processing involved in the manufacture, use and disposal of a product or system – from cradle to grave.

4.1 ABOUT LCA – FREQUENTLY ASKED QUESTIONS

What are the steps in the Life Cycle Assessment?	Goal Definition and Scoping, Inventory, Impact Assessment, Evaluation, and Improvement Analysis.
What does Goal Definition and Scoping imply?	The unit (in this case 1kg of EPS material) is defined, data gathering and validation procedures are determined, and the required level of data quality is established.
What does inventory mean?	First, an inventory of relevant inputs and outputs to and from the environment are compiled. From this information, know as the Life Cycle Inventory (LCI), any potential environmental impacts are evaluated and interpreted.
What’s Impact Assessment?	In this stage all the environmental impacts and effects are calculated from the data gathered at the Inventory stage, such as global warming, smog etc.
What’s involved in the Evaluation process?	In this final stage of the study all the information gathered throughout the study is analyzed. There are several considerations: sensitivity analysis, reliability analysis, qualitative and quantitative analysis, and finally, appraisal.
What about the data gathered?	All data has been gathered Europe wide and is based on 1998 research. However, LCA studies are dynamic and will be updated, should new information relevant to EPS become available.

4.2 LIFE CYCLE ASSESSMENT OF EPS

Expanded polystyrene (EPS) is a material widely used in the building sector, mostly for insulation purposes, and also in the packaging industry. A cost-effective, easy-to-use material, it performs as an acoustic and thermal insulator, is moisture resistant, recyclable and environmentally sound.

It is produced when pentane is dissolved in a polystyrene base material, which is then steam-heated to form EPS beads. The beads can then be moulded to exact specifications, to form insulation boards, blocks or customized shapes for the building and packaging industry.

ENVIROMENTAL EFFECT/ASPECT	ABB.	CHARACTERISATION SCORES	UNIT	NORMALISATION SCORES	UNIT
ENVIRONMENTAL EFFECT					
Abiotic depletion	APD	0,83	-	1,04E-11	yr
Global warming	GWP	5,98	kg	1,42E-12	yr
Ozone depletion	ODP	2,11E-06	kg	3,75E-14	yr
Human toxicity	HCT	0,0357	kg	9,06E-13	yr
Aquatic ecotoxicity	ECA	101	m^3	2,29E-13	yr
Smog	POCP	0,0207	kg	3,28E-12	yr
Addidification	AP	0,0278	kg	8,19E-13	yr
Nutrification	NP	0,00241	kg	2,81E-13	yr
Land use	LU*t	0,00274	m^2		yr
ENVIRONMENTAL ASPECTS					
Cumulative energy demand (excl. feedstock energy)	CED-	48,9	MJ (lhv)*	8,45E-13	yr
Cumulative energy demand (incl. feedstock energy)	CED+	93,1	MJ (lhv)*	1,61E-12	yr
Not toxic final waste	W-NT	0,0453	kg	8,43E-14	yr
Toxic final waste	W-T	0,0124	kg	3,09E-13	yr

* lhv = lower heating value

The figures above show the weighted averages of the characterization and normalization scores for the life cycle of 1kg of EPS material. These are European averages for densities varying from 15-20 kg/m^3. Proper comparison with other insulating materials is only possible when the same "functional unit" is used in calculations, e.g. one square meter of insulated area with the same thermal properties.

With this LCA we now have a complete picture of EPS, and it can support its inherent benefits with detailed, accurate information. The following environmental impacts and indicators were disregarded in the study: biological depletion potential, terristic exotoxity, noise, casualties, radiation and heat to water.

The study was carried out in 1998 by PRC-Bouwcentrum in the Netherlands, fulfilling the requirements of the SETAC – approach and the international ISO 14040 standard [1)].

INTRON B.V., the Quality Assessment Institute for the Building Industry carried out the external critical expert review [2)] according to ISO 14040 and concluded "that the EUMEPS LCA was carried out in a very scrutinized way, which was transparent and very well documented. It reflects the best available LCA data on EPS that can be made available in 1999."

1) European LCA-data for EPS building products, Seijdel R.R., Bouwcentrum report 886.001, August 1998.
2) Critical review on LCA-data for EPS, Schuurmans A., Intron report M715490, 13 October 1998.

5. PHYSICAL PROPERTIES*

MATERIAL PROPERTIES	UNIT	TYPE		
		EPS 15	**EPS20**	**EPS 30**
Density	kg/m^3	15	20	30
K value Thermal conductivity	W/m.K	0,040	0,038	0,036
Water-Vapour Diffusion Resistance Value	-	20	30	60
Compression strength at 10% deformation	KPa	60	100	165
Short term compression strength	KPa	80	120	210
Long term compression strength	KPa	20	30	50
Shear strength	KPa	190	270	460
Tensile strength	KPa	200	280	440
Water absorption fully submerged after 7 days	% volume	1,7	0,6	0,5
Water absorption fully submerged after 1 year	% volume	5,0	4,0	3,0
Linear expansion co-efficient	M/m	7.10^{-5}	7.10^{-5}	7.10^{-5}
Co-efficient of friction		0,5	0,5	0,5
Heat capacity	J/kg K	1500	1500	1500
Temperature range		-110/+70	-110/+70	-110/+70
Limited exposure maximum temperature		+110	+110	+110
Youngs modulus	kPa	4000	6000	10000

* The above figures are for design purposes only. Actual values for comparative property calculation purposes must be obtained from EPS Converters.

6. EPS IN PACKAGING

Any product of any shape or size may be packed with expanded polystyrene. The following range of applications might not be comprehensive.

In packaging there are two main applications:

6.1 PACKAGING OF INDUSTRIAL PRODUCTS

Imagine any industrial product and the best packaging will certainly be EPS. Completely protected and safe from risk in transport and handling, EPS provides industrial products with the ideal material for their total protection.

From delicate pharmaceutical products through electronic components, electrical consumer goods and toys to horticultural or garden products, all of these products are able to arrive at their destination in perfect condition protected with EPS packaging.

Moreover, it is important to highlight the fact that EPS packaging fits perfectly into automated production lines, where products come out ready packed. EPS packing adapts superbly to integrated production systems, and it embodies the best alternative in terms of cost, versatility and efficiency with ease of use for the workers or to the sophisticated machinery which handles the products until they come off the production line.

6.2 PACKAGING OF FOODSTUFFS

Fish and shellfish, meat, fruit, ice-cream… EPS packaging is the best way of keeping foodstuffs fresh. In much the same way as in the case of industrial products where we mentioned perfect protection which avoids hazards, breakages and wastage in the different stages of production and transport, EPS packaging ensures that different foodstuffs reach the retailer or the final consumer in perfect conditions.

We are dealing here with foodstuffs that cannot be subject to risk, since a badly protected or poorly insulated product could arrive in substandard conditions and the subsequent risk of consuming sullied foodstuffs is truly serious. For this reason we could broaden the ecological benefit of EPS packing/packaging to its capacity for conserving food since it enables animal and vegetable products to be preserved and optimizes product life-cycles by avoiding their loss or spoiling before consumption.

Here we will make a slight aside to recall the difference already mentioned “What is EPS”: We are talking about EPS packaging which has nothing to do with the small XPS trays which are sometimes compared or confused with our material.

For these packaging applications that we have seen, it is worth underlining the following properties of EPS:

SHOCK ABSORPTION: the material has a high-energy absorption index should it fall or be knocked and this makes it the ideal material for protecting sensitive products during transport and storage.

THERMAL INSULATION: protecting products, especially foodstuffs, from sudden changes in temperature.

LOW WEIGHT: its low density reduces the packaging weight and consequently provides savings in transport.

RETENTION OF VITAMIN C: recently studies have shown that fruit and vegetables when packed on EPS keep their content of Vitamin C for a longer period.

RESISTANCE TO HUMIDITY: EPS maintains its excellent mechanical and thermal properties are maintained by the fact that it does not absorb water. This is significant because moisture can affect other packaging materials.

COMPRESSIVE RESISTANCE: allows stacking of merchandise-filled packages and packs without any difficulties in storage, transport or at point of sale.

CHEMICAL RESISTANCE: EPS allows many products to be packed without the goods being affected.

DISPLAY EFFECT (Promoting sales): given its appealing appearance and the ease with which it can be coloured, printed on, stacked and subjected to other product dressing techniques to attract customers.

HYGIENIC NATURE: since the material is inert, inalterable and innocuous it can come into direct contact with foodstuffs whilst complying with the laid down health and safety standards.

ADAPTABILITY: it is easy to adapt to any product or any design.

6.3 ECOBALANCES OR LIFE-CYCLE ANALYSES

Life-cycle analyses have shown that Expanded Polystyrene packaging clearly has much less effect on the environment than other competitive materials for the same use.

Expanded Polystyrene packaging has a significantly lower impact on the environment during production than cardboard products. This is especially so in terms of atmospheric pollution, energy consumption, water pollution and global warming potential.

The table shows a comparison of EPS with other materials and provides data which is interesting from an ecological point of view.

PACKAGING STUDIES	**ENVIROMENTAL-LOAD INDEX**	
VENDING MACHINES CUPS (1)	**EPS CUPS**	**PAPER CUPS**
Chemicals	1	15
Electricity	1	13
Cooling water	1	1,3
Process water	1	170
Steam	1	6
Crude Petroleum	1	0,6
SHAPED/MOULDED PACKAGING (2)	**EPS**	**PULP AND FIBREBOARD**
Energy Consumption	1	2,3 – 3,8
Air pollution	1	3,1 – 4,1
Water pollution	1	2,3 – 2,8
Global warming potential	1	4,0 – 4,4
Volume of solid waste	1	0,69 – 0,79
PACKAGING MATERIALS (3)	**EPS**	**WOOD, PAPER, ETC**
Cost	1	1,3
Weight	1	6,4
Energy consumption	1	2,0
Volume of solid waste	1	1,2

SOURCES:

(1) University of Victoria, British Columbia, “Polyfoam versus paper cups..”
(2) Info Kunstsoff, Berlin, “EPS and corrugated cardboard – a life cycle study”
(3) Study of GVM, Wiesbaden

7. CONCLUSIONS

Now that the whole environmental aspect of EPS have been examined in detail. The conclusions that can be drawn are:

7.1 EPS is a good example of an efficient use of natural resources.

7.2 The manufacture and use of EPS do not generate any risk to health or to the environment.

7.3 EPS does not damage the ozone layer since it does not and never has used CFCs of HCFCs in the manufacturing process.

7.4 The transformation process consumes little energy and does not generate waste.

7.5 The use of EPS for thermal insulation in the construction industry means significant energy savings on heating and cooling buildings and a drastic reduction in the emission of polluting gasses (CO_2 and SO_2). It therefore contributes to alleviating the greenhouse effect and acid rain.

7.6 EPS packaging, given its characteristics, in addition to providing full protection to packed products also saves transport fuel. This is because it is a very light material and means it does not raise the product's cost because of the weight of its packing i.e. in transporting products packaged with EPS, the product and not the packaging is what is paid for.

7.7 EPS packaging can come into direct contact with foodstuffs as it meets all the prevailing international health regulations.

7.8 Fungi and bacteria cannot grow on EPS.

7.9 EPS makes up only a tiny part of the average Municipal Solid Waste (0.1%). In addition, the incidence of EPS is a minimal portion of the overall waste generated by our society.

7.10 EPS products hold a high calorific value (1kg of EPS is the equivalent of 1.3 litres of liquid fuel), something which turns them into ideal materials for energy recovery.

7.11 Since it is insoluble in water, EPS does not emit hydrosoluble substances that could contaminate subterranean water supplies.

7.12 EPS is 100% recyclable.

FINAL CONCLUSION

Life-cycle analyses have shown that Expanded Polystyrene has far less of an impact on the environment than other competitive materials for the same use!!

8. EPSASA MEMBERS

8.1 RAW MATERIAL SUPPLIERS

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