Properties, Performance and Design Fundamentals of Expanded Polystyrene Packaging

Expanded Polystyrene

Expanded polystyrene (EPS) is a generic term for polystyrene and styrene copolymers that are expanded into a variety of useful products. EPS is supplied to molders in the form of a polystyrene bead; EPS beads are loaded with a blowing agent, usually pentane, and other chemical agents and additives that give the beads expansion vibrancy and allow them to be processed and molded into low-density foam articles; EPS is comprised of 90 percent air. The shock absorbing properties and other qualities of EPS foam, combined with its low-cost, high insulating properties, custom moldability and ease of processing make it a popular packaging material.

According to San Jose State University, temperature variations in the distribution environment have virtually no affect on the cushioning performance of EPS foam.

End-Use Applications

For more than 50 years, the effectiveness of EPS has been proven in numerous packaging applications used by a wide variety of industries, consumer product manufacturers and catalogue and shipping companies. Lightweight EPS is ideal for these packaging applications due to its physical properties, in particular its cushioning characteristics, dimensional stability and its thermal and moisture resistance.

Custom-molded EPS interior packaging has been highly effective in protecting sensitive electronic components, consumer goods and office equipment; its moldability allows interior packaging components to hold products snugly in place. High insulating properties and moisture resistance have made EPS a popular choice in the food packaging, medical and pharmaceutical industries. EPS is also used to protect a myriad of other products used for component assembly, during internal distribution and storage and delivery to the end user.

Because EPS can be molded into vir-

Table 1. ***Typical Properties of EPS Molded Packaging (70F Test Temperature)***

Density (pcf)	Stress @ 10% Compression (psi)	Flexural Strength (psi)	Tensile Strength (psi)	Shear Strength (psi)
1.0	13	29	31	31
1.5	24	43	51	53
2.0	30	58	62	70
2.5	42	75	74	92
3.0	64	88	88	118
3.3	67	105	98	140
4.0	80	125	108	175

Note: *Values based on ASTM short-term, laboratory-load conditions. Both temperature and time period of loading may affect end-point values.*

Table 2. ***Typical Thermal Conductivity (k factor)***

Density (pcf)	*Mean Test Temperature (F)*	*K factor (BTU-In./Ft.2Hr F)*
1.0	0	0.22
	40	0.24
	75	0.26
	100	0.28
2.0	0	0.20
	40	0.21
	75	0.23
	100	0.25

tually any shape or size, it is well suited to automated production lines. End caps, rails and other interior EPS packaging pieces can be customized to accommodate the needs of automated integrated production systems; EPS interior packaging pieces can be quickly and efficiently put into place via automated procedures during the packaging assembly process.

Expanded polystyrene manufacturers use pentane as its primary blowing agent. EPS transport packaging has never been made with CFCs (chlorofluorocarbons) or HCFCs.

A key benefit of EPS is that it is recyclable. EPS materials can be reprocessed and molded into new packaging products or durable goods; Formal EPS recycling programs have been established in several countries throughout the world.

Engineered for Optimal Performance

Regional EPS molders utilize a multi-stage production process to expand and mold the beads into EPS products. They use one of two different processes to expand EPS beads: continuous pre-expansion and batch pre-expansion.

Physical Properties

Mechanical Properties

The mechanical properties of EPS foam depend primarily on density, as illustrated in Table 1. Generally, strength characteristics increase with density, however the cushioning characteristics of EPS foam packaging are affected by the geometry of the molded part and, to a lesser extent, by bead size and processing conditions, as well as density. This unique characteristic allows a packaging engineer to fine-tune cushioning performance by simple processing changes, without the need to redesign or retool.

For shock cushioning, the EPS packaging industry has developed typical cushioning curves for use by designers of EPS transport packaging. Shock cushioning properties of EPS are not significantly affected by change in temperature. Recent studies conducted at San Jose

Table 3. ***Water Absorption and Vapor Transmission***

Mean temperature (F)	**Type I 0.90 pcf**	**Type VIII 1.15 pcf**	**Type II 1.35 pcf**	**Type I 1.80 pcf**
Maximum water vapor transmission (WVT)[g]	2.0–5.0 perms	1.5–3.5 perms	1.0–3.5 perms	0.6–2.0 perms
Maximum absorption % by volume[h]	<4.0%	<3.0%	<3.0%	<2.0%
Capillary action	None	None	None	None

University, Packaging Program, have shown that the optimum performance characteristics of EPS are not affected by changes between –17 C and 43 C. Packaging engineers should regard the following data as an accurate representation of the performance of EPS foam.

Density

Packaging density must be considered when choosing the correct level of cushioning needed for the job. In the preliminary design stages, cushion curves developed from dynamic drop testing are used to determine the correct package configuration—foam thickness and density—to adequately protect the product. By varying the density, thickness and shape of the EPS foam, the designer can meet the protection requirements of a wide range of delicate products.

Dimensional Stability

Dimensional stability is another important characteristic of EPS foam. It represents the ability of a material to retain its original shape or size in varying environmental conditions. Different plastic polymers vary in their reaction to the conditions of use and exposure to changes in temperature and/or relative humidity. Some shrink, some expand and some are unaffected. EPS offers exceptional dimensional stability, remaining virtually unaffected within a wide range of ambient factors. The maximum dimensional change of EPS foam can be expected to be less than 2%, which puts EPS in accordance with ASTM Test Method D2126.

Thermal Insulation

For construction insulation applications the polystyrene foam industry has developed test data as reported in ASTM C 578 Standard Specification for Rigid Cellular Polystyrene Thermal Insulation. This standard addresses the physical properties and performance characteristics of EPS foam as it relates to thermal insulation in construction applications. There has been no need to develop such a formal document for the packaging industry. EPS is an effective, economical packaging material for produce, pharmaceuticals and other perishables, when these items must be shipped and stored in temperature-controlled environments. The uniform, closed cellular structure of EPS is highly resistant to heat flow. The thermal conductivity (k factor) of EPS packaging varies with density and exposure temperature, as shown in Table 2.

Fruits and vegetables stored in EPS boxes retain a greater level of Vitamin C than other packaging materials, as reported by the Korea Food Research Institute.

Water Absorption and Vapor Transmission

Moisture resistance is the ability of a packaging material to prevent water from entering its structure and eroding its mechanical properties. The cellular structure of EPS is essentially water resistant and provides zero capillarity. However, EPS may absorb moisture when it is completely immersed, due to the fine interstitial channels between the molded beads. While molded EPS is nearly impervious to liquid water, it is moderately permeable to water vapor under pressure differentials. Vapor permeability is determined by both density and thickness. Generally, neither water nor water vapors affect the mechanical properties of EPS.

Chemical Resistance

Water and aqueous solutions of salts

In a recent opinion survey conducted by AFPR, eighty-four percent of OEM respondents that currently use EPS indicated that their EPS usage would increase or remain stable in the future.

and alkalis do not affect expanded polystyrene. Most organic solvents are not compatible with EPS. This should be taken into consideration when selecting adhesives, labels and coatings for direct application to the product. All substances of unknown composition should be tested for compatibility. Accelerated testing may be carried out by exposing molded polystyrene to the substance at 120 – 140 F. UV radiation has a slight effect on molded polystyrene. It causes superficial yellowing and friability, but does not otherwise effect its physical properties.

Electrical Properties

The volume resistively of molded polystyrene within the 1.25 – 2.5 pcf density range, conditioned at 73 F and 50% r.h. is 4 x 10^{13} ohm-cm. The dielectric strength is approximately 2KV/mm. At frequencies up to 400 MHz, the permittivity is 1.02 – 1.04 with a loss factor less than 5 x 10^{-4} and less than 3 x 10^{-5} at 400 MHz. Molded EPS can be treated with anti-static agents to comply with electronic industry and military packaging specifications.

When Properly Engineered, There is No Substitute for EPS

The fundamental objectives of transport packaging materials are to preserve and protect a product from damage, through the manufacturing process all the way to delivery to the consumer. Choosing the right packaging material requires a balance of many factors, including ease of handing and storage, weight, cushioning characteristics, manufacturing efficiency, ease of identification, customer requirements, cost and more.

EPS protective packaging offers a broad range of physical properties to allow packaging designers to meet the many challenges of protection and distribution. These properties, in combination with appropriate engineering design considerations, provide the design flexibility required to create truly cost effective protective packaging.

Sources

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