

General Introduction to Expandable Polystyrene

I. EXPANDABLE POLYSTYRENE MANUFACTURING

Expandable polystyrene is the raw material or resin used for the molding of expanded polystyrene products. It is manufactured in the form of very small polystyrene beads with a weight-average molecular weight between 160,000 and 260,000 and contains blowing agent, usually pentanes or butane. The bead diameter can vary between 0.007-inches (0.2 mm) to 0.12-inches (3.0 mm).

A. Polymerization and Impregnation

The first methods developed for the manufacture of EPS involved a two step process of polymerization of styrene monomer followed by impregnation of the polymerized polystyrene bead with a blowing agent. Today, almost all processes carry out polymerization and impregnation in a one-step process. The reactions occur in a single reactor designed to control the temperature and pressure of the reaction. A typical production process is shown in Figure 1.

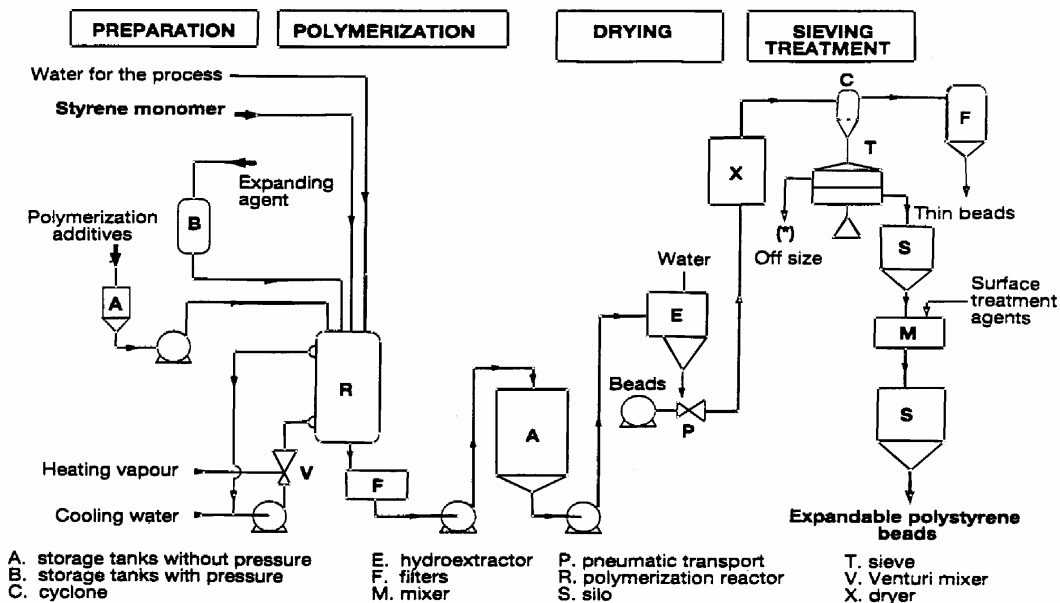


Figure 1 - Manufacturing unit of expandable polystyrene

Styrene monomer and water are charged to the reaction kettle equipped with an agitator. Various chemicals are added to affect suspension of the monomer in water and to control the polymerized bead growth, molecular weight and other parameters necessary to produce the desired product. The polymerization is an exothermal reaction and is controlled by reactor temperatures and pressures, as well as various catalysts.

In the second phase of the process, the blowing agent is added under pressure and impregnates the soft polystyrene beads. When completed, the entire batch consisting of water and the impregnated polystyrene beads are dumped to de-watering systems.

B. Finishing Operations

Following the de-watering process, the beads are transferred to dryers for drying. The expandable polystyrene beads are, at this point, characterized with a bead size distribution which can be described by a standard "bell-shape" curve. The conditions used to polymerize the beads play a controlling part in determining the exact shape and or skewness of the particle size distribution. The dried beads are then screened through a separation system to provide the desired size cuts. Various surface lubrication materials are added at this point to aid in screening and to eliminate potential lumping during pre-expansion. The resulting bead size(s) are typically defined as:

Large	"A"
Medium	"B"
Small	"C"
Cup Grade	"T"

Various intermediate cuts may be made to meet specific processes and applications. Thus there may be an "AA", "AB", "BC", etc., made available by the manufacturer.

C. Packaging and Storage

The screened beads are then packaged in specially designed low hydrocarbon permeability liners within 2205-lb. flexible bulk packages. The United States Department of Transportation (DOT) has classified expandable polystyrene as a Class 9 miscellaneous hazard material and, consequently, the containers used must meet specific construction requirements.

Even with the special care taken in packaging expandable polystyrene, the blowing agent, being a volatile hydrocarbon, will disperse over time. The rate of emissions is primarily dependent upon storage temperature. A general rule of thumb advises that the higher the storage temperature the shorter the shelf life.

II. EXPANDED POLYSTYRENE

Expanded polystyrene is a closed-cell, lightweight, rigid plastic foam. It is manufactured by one of two basic processes, extrusion or steam molding. The extrusion process was introduced into the United States in 1944 and is currently used to produce either rigid boards (referred to as XEPS or XPS) for building insulation, flotation, or as thin sheets of foam which are subsequently thermoformed into desired shapes such as meat trays and disposable food containers.

The steam molding process was introduced into the United States in 1954 by the Koppers Corporation and is referred to as EPS. EPS is primarily used for building insulation, insulating concrete forms (ICF), Geofoam, flotation, and, because of its unequalled versatility, packaging of virtually anything requiring cushioning or insulation properties.

Molded expanded polystyrene (EPS) is manufactured by the expansion and subsequent steam molding of expandable polystyrene. There are two basic types of expandable polystyrene, regular and modified.

The regular grades are designed primarily for packaging and related uses. Usually these grades comply with FDA requirements for use in direct food contact use. The modified grades contain a flame retardant to decrease the potential of fire spread from a small flame source. These grades are specifically tailored to meet the requirements of the various building codes in the United States and Canada.

III. EXPANDED POLYSTYRENE PROCESSING

A. Principle

The processing of expandable polystyrene (including R-MER®II) into a molded part has three stages. In the first stage, the beads are fed to a vertical tank containing an agitator and a controlled steam input. This is referred to as pre-expansion. It is at this stage that the final material density is determined. The expanded beads, whose volume can be up to 40 times the volume of the raw beads prior to expansion, are then stored for several hours in the open air; in this stage, the vacuum developed in the cell structure of the prepuff is allowed to come to equilibrium with the ambient atmosphere. After pressure stabilization, the prepuff is fed to a closed mold and again subjected to steam heat. The prepuff at this point has no room for further expansion and consequently fuses solid, producing a part defined by the mold. The production process is depicted in Figure 2.

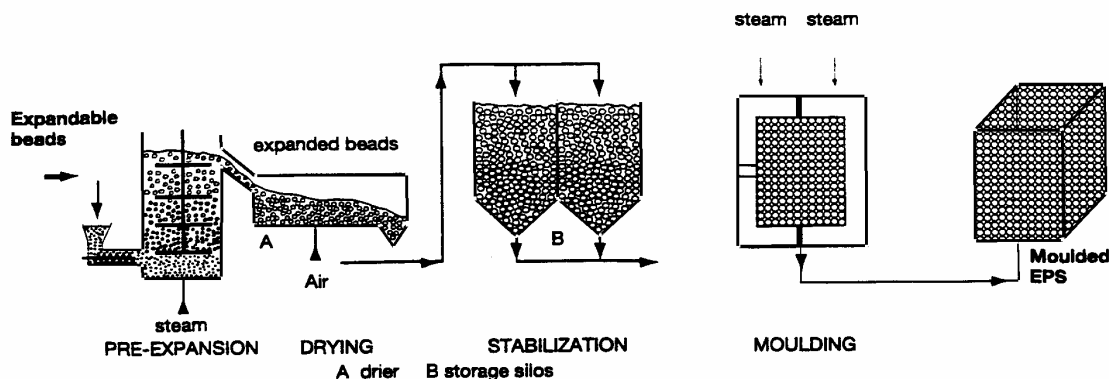


Figure 2 - Manufacturing unit of moulded expanded polystyrene

B. Pre-expansion

In order to mold the desired part at the required density, it is necessary to first generate a prepuff particle the size of the required density. Expandable polystyrene, as received, has a density of about 40-lbs./cu.ft. The pre-expansion of this raw material is carried out in vessels (pre-expanders) equipped with a controlled steam inlet, an air inlet, agitation and an automatic system for feeding the raw bead into the vessel.

By controlling the bead feed rate, the steam and air flow, and the agitator rpm, the bead will soften at around 90°C (194°F), which is above the normal boiling temperature of the blowing agent, in this case pentane, at around 35°C° (95°F). The internal vapor pressure will increase and these two simultaneous phenomena cause the bead to expand to the required density.

The minimum density obtainable varies according to the product. It depends on factors such as the initial size of the beads, the blowing agent content, and/or the presence of certain additives. An extended period in the expander (or a vapor temperature which is too high) may lead to increased density and subsequent collapsing of the beads. The collapsing is due to a pressure drop within the bead as the blowing agent dissipates (Figure 3).

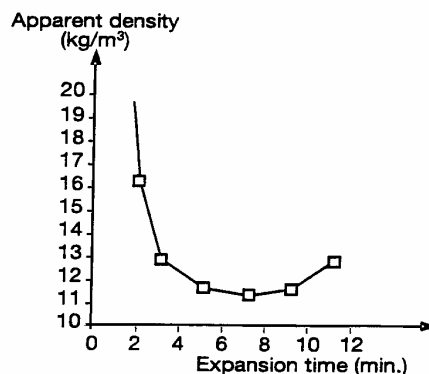


Figure 3 - Expansion curve for the EPS beads

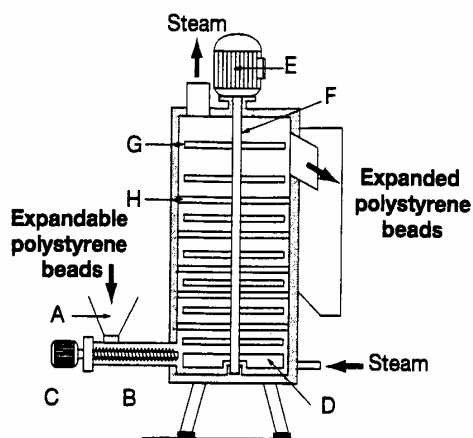
This initial pre-expansion process can be carried out in either a continuous or batch (discontinuous) operation. In the continuous pre-expander, expandable polystyrene beads are introduced continuously by way of an endless screw at the bottom of the pre-expander and the expanded beads (prepuff) come out the top (similar to a popcorn popper) (Figure 4). In the batch process, the beads are loaded from the top and emptied after the operation at the bottom of the apparatus.

Density adjustment of the product is carried out by controlling the length of time the beads remain in the expander and/or the pressure in the pre-expander. With batch pre-expanders, a very low density can be obtained as a result of being able to operate under pressure and higher temperatures.

The prepuff exiting the pre-expander is usually fed to a fluid bed drier where it is gently dried. The prepuff is very sensitive exiting the pre-expander due to the development of vacuum in the newly created cellular structure of the foam, which is still warm and soft.

C. Stabilization of the Prepuff

The prepuff leaving the pre-expander and the fluid bed drier is transferred to plastic mesh holding bins and allowed to reach ambient temperature. This process can take as long as three days or as little as four hours, depending upon density, upon air flow, temperature and other variables. This stabilization process is required to allow for air diffusion inside the beads in order to reach a pressure balance with the outside. The stabilization, or maturing stage, also allows for the elimination of excess water contained in and on the surface of the prepuff that is harmful to the molding process. For high density applications, the maturing stage also allows for the excess blowing agent to dissipate preventing most heat sensitivity in the mold.



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|----------------------|-------------------|
| A. feed hopper | E. motor agitator |
| B. feed screw | F. agitator axis |
| C. screw drive motor | G. agitator arm |
| D. spreading device | H. fixed bars |

Figure 4 - Continuous pre-expander

D. Block Molding

Block molds (Figure 5) are generally of the following dimensions: 3 to 4 feet (1.0 to 1.25m) high, 2 to 3 feet (0.5 to 1m) wide, and 16 to 26 feet (6 to 8m) long. They are built in stainless metal (steel or an aluminum alloy). The six walls in contact with the expanded beads to be molded are usually Teflon™ -coated or stainless steel and have many openings (small holes, nozzles or slits less than 1mm wide) that allow steam to enter, air to escape, and the vapor to penetrate inside the mold.

Behind each wall, there is a chamber called the vapor chamber which has a vapor inlet and a condensation water outlet (the lower part). Most block molds are equipped with a vacuum installation (tank or pump). The vacuum is employed to assist with the steam penetration and evacuation during molding.

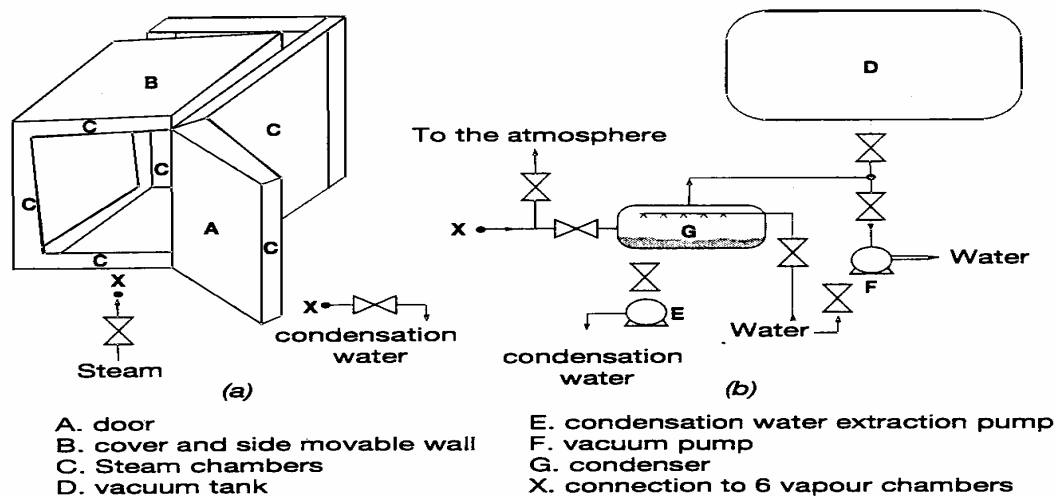


Figure 5 - EPS block mould and vacuum installation

E. Molding Cycle

The molding cycle is described and charted below (Figure 6).

*Fill Cycle - Filling the mold involves the closing of the mold and the air transport of the aged prepuff into the cavity.

*Vacuum Cycle - A quick drop in pressure is accomplished by opening up the vacuum tank connection (Period 1); the vacuum pump then allows the vacuum level to drop again (Period 2). This prior vacuum stage allows the air and water present in the mold to be eliminated, facilitating subsequent pre-fusion.

*Steaming Cycle - With the condensation outlets closed, the mold is subjected to steam until atmospheric pressure is reached (Period 3). When atmospheric pressure is reached, the outlet valves for releasing the condensate are opened (Period 4). Steam pressure is then increased by sending the steam into the two side steam chambers while the outlet condensation valves on the other four chambers are left open (Period 5). The steam, supplying heat to the inside of the mold, causes the prepuff to soften and attempt to expand. With no place for expansion to occur, fusion ensues.

*Autoclave Cycle - In this stabilization period (Period 6), all the outlet valves for condensation are closed and the vapor pressure is maintained with the chambers for a short moment (3 to 10 seconds). This results in final fusion of the product.

*Cooling Cycle - In this cycle, the condensation outlet valves are opened, decreasing the pressure inside the mold (Period 7). The valves are then closed again and the vacuum is then applied (Period 8 and 9). Any residual condensate remaining in the mold is then evacuated. During this cycle, the block cools. When the vacuum in the mold reaches a value which is close to 0.1 bar, the vacuum is stopped (Period 10). When the mold pressure reaches atmospheric conditions, the mold is opened. Normally, the door is opened, then a side wall and the top of the mold swivel together, (see Figure 5a) and the block of expanded polystyrene is ejected with the help of an ejector.

* This entire molding cycle generally lasts from 3 to 15 minutes (depending on the type of block mold, the density of the pre-expanded beads and the type of raw material used). The temperature of the block, when ejected from the mold, is about 194-203°F (90-95°C) and the cells still contain a partial vacuum. For this reason, care must be exercised to insure that a temperature "shock" does not occur which could result in block shrinkage. Fresh molded blocks are usually allowed to stabilize for at least 24 hours in a non-shocking atmosphere (free of cold drafts and temperatures less than 70°F).

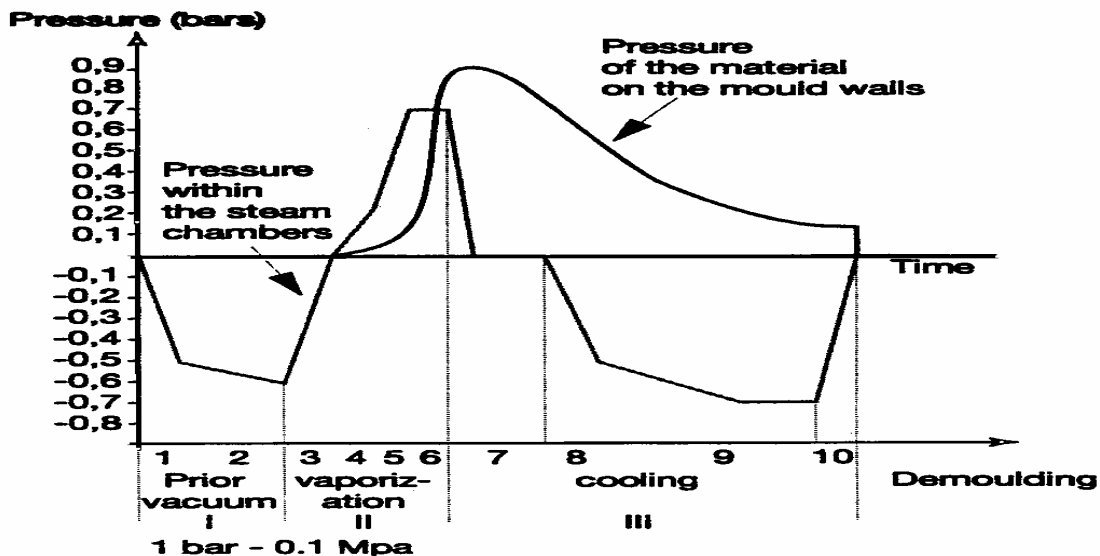


Figure 6 - Moulding cycle of a block of expanded polystyrene

F. Shape Molding

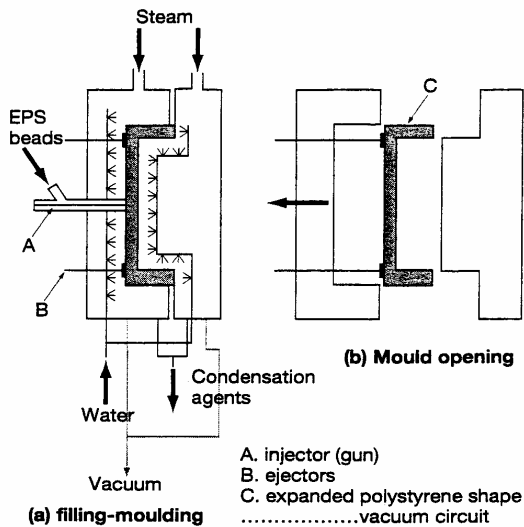


Figure 7 - Expanded polystyrene shape moulding

Automatic fill, mold, and ejection machines for shape molding are designed to allow for the manufacturing of expanded polystyrene shapes of nearly unlimited size and design. They operate on the same principle as block molds. The molds (or tools) (Figure 7) are in two parts; one which moves — the movement controlled by a cylinder system — and one which is stationary. There are three basic types of shape molds: vacuum, transfer, and complex.

G. Vacuum Molding

Expanded polystyrene (pre-puff) is fed into the closed mold by way of one or several fill guns.

The steaming cycle operates in accordance with similar stages to that of the block mold (pre-heating the steam chamber, transversal steaming, increasing pressure, maintaining pressure). Cooling of the molded piece is first carried out by water projected onto the back walls of the molds, then by creating a vacuum in the steam chamber. The mold can then be opened and the part is removed from the mold by ejectors or by compressed air pressure.

H. Transfer Molding

In transfer molding, two molds are incorporated in the process. The pre-expanded bead is first molded in the HOT mold and then transferred, while still hot, to a COLD mold. The part is then stabilized in the COLD mold prior to ejection. This type of molding consumes less energy than vacuum molding. However, significant initial investment is required.

I. Complex Molding

The molding machines designed for complex molding allow expandable polystyrene to be molded simultaneously with another plastic film. There are two types of these processes: by molding the expanded polystyrene part first, then laminating a plastic film to the part, or by thermoforming a plastic film on a heated form and then molding the object in expanded polystyrene on the inside of the film.

The film is generally polystyrene to make recycling more convenient. These processes generally create an expandable polystyrene part with improved mechanical behavior and allows for excellent quality in printing.

IV. PROPERTIES OF EXPANDED POLYSTYRENE (EPS)

Recommended safety practices and mechanical/chemical properties of expanded polystyrene are found in the appropriate EPS Technical Bulletins. Expanded polystyrene exhibits a number of outstanding properties meeting the needs of a number of general applications including but not necessarily limited to building insulation, packaging, flotation, geotechnology, product displays, stage settings, etc. Among the outstanding properties, most noted are:

- * low density
- * thermal insulation capacity
- * excellent mechanical properties (resistance in compression, capacity for dampening shocks)
- * insensitivity to water
- * ability to be molded or cut into nearly unlimited shapes
- * ability to be recycled

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