POLYSTYRENE TECHNOLOGY & PRODUCTION OF POLYSTYRENE IN EGYPT

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Abstract

WHAT IS POLYSTYRENE?

Polystyrene is one of the fourth big demand polymers in the thermoplastic family in addition to polyethylene, polyvinyl chloride, polypropylene and polyester, as the consumption and demand for the polystyrene products are increasing rapidly in Egypt and world wide

The major products of polystyrene products used in Egypt and worldwide are as follows:-

General purpose polystyrene (GPPS) with its grads.

High Impact Polystyrene (HIPS) with its grads.

GENERAL PROCESS CHEMISTRY

Polystyrene is produced by polymerization of styrene monomer. When polymerized in the presence of rubber it is called High Impact Polystyrene (HIPS). When no rubber is present, it is called General Purpose or Crystal Polystyrene (GPPS). Styrene monomer (vinylbenzene) (C8H8) is a clear liquid with a distinct odor. Styrene monomer is also a flammable liquid whose vapor is heavier than air and, therefore, must be handled properly.

Polymerization consists of three steps: (1) initiation, (2) propagation and (3) termination. The polymerization reactions are as follows:

(1) **M-- >M·**
(2) M· + M-- > MM· + M -- > MMM· + M -- > [MMMM·]
(3) -- [MMMM·] + [·MMM] -- -- > [MMMMMMM] ---

Step (1) - Initiation

In step (1) the double bond on the carbon atom is broken to form a free radical. This is accomplished by the application of heat or by a catalyst.

Step (2) - Propagation

The free radical, which is highly unstable, combines with another styrene molecule thus forming a new free radical. This process continues and the polymer chain continues to grow.

Step (3) - Termination

In the termination reaction, two free radicals can combine to terminate a chain or other chemicals can be used to terminate a chain.

The above is an oversimplification but illustrates the steps involved in the polymerization process. It is the control of these steps, that is, the amount of free radicals formed, the length of the polymerization chain, etc. which governs the physical properties of the polymer produced.

PROCESS OVERVIEW

The HIPS process consists of semi-continuous (rubber dissolving) and continuous (polymerization, styrene recycle recovery and pelletization) operations. The rubber dissolving operation is common for both the HIPS and Swing lines.

The GPPS process consists of a continuous operation, as rubber is not required. However the styrene inhibitor, TBC, must be removed as it causes a yellow color in the final product.

The following describes the functional areas of the plants:

Rubber Dissolving: Polybutadiene rubber, in bale form, is dissolved in Styrene monomer in preparation of producing High Impact PS.

Polymerization: Polymerization consists of a series of reactors. The first two reactors, for pre-polymerization, are CSTR-type with proprietary agitator designs. The last reactor, for polymerization, is a plug-flow type, again of proprietary design.

Devolatilization: Devolatilization is a two-step operation, under vacuum, which is enhanced with the addition of water in the 2nd stage. The stripping effect with water reduces the residual monomer content to typically 200 ppmw.

Recycle Styrene Recovery: Unreacted Styrene and diluents from the devolatilization operation are distilled, under vacuum, and recycled to the front end of the process. Two purges are provided: a lights purge consisting of styrene and ethylbenzene and a heavy purge consisting of oligomers and other heavy organics. These purges are used as fuel for the Hot Oil Heater.

Pelletization: Pelletization consists of taking the polymer melt from devolatilization and forming strands and cutting these strands to a prescribed length to produce pellets.

PLANT OVERVIEW

The plant is designed using INEOS / CBI Lummus technology and implemented with a Consortium Enppi / Petrojet to produce 200,000 MTA Polystyrene products within the premises of El Dekhella, Alexandria, Egypt.

The plant consists of two polymerization lines; High Impact Polystyrene (HIPS) line with capacity of 100,000 MTA and Swing line capable to produce both High Impact Polystyrene (HIPS) and General Purpose Polystyrene (GPPS) products with capacity of 100,000 MTA.

Polystyrene can be produced by polymerization of styrene using:-

1. Free radical polymerization (using initiators).
2. Thermal polymerization

- Polystyrene will be distributed in the local market by trucks and exported by road truck, to the port.
- Truck loading and weighting facilities are provided onsite.
- E-Styrenics will share the existing loading facilities at the port for Styrene importing

PRODUCTION OF HIGH IMPACT POLYSTYRENE (HIPS)

High impact polystyrene produced by using free radical polymerization (using initiators)

Feed Preparation

The production of high impact polystyrene begins with the dissolving of rubber in styrene. Styrene is stored and maintained at 10°C by circulating through the external Styrene Tank Chiller.

Rubber used for high impact polystyrene is a high-cis polybutadiene packaged in bale form, weighing approximately 34 kg each.

The ground rubber and antioxidant (chemical additive) are mixed with preheated fresh styrene @ 50°C.

The rubber slurry is transferred batch wise to the Pre-poly Feed Drum.

The rubber feed solution along with recycle styrene, fresh styrene, blue dye and PIB (poly-isobutene), if required, are mixed in the Feed In-Line Pre-mixer No.1 and preheated in the Pre-polymerization Feed Heater. PIB is used as an environmental stress cracking resistance (ESCR) agent. The preheated mixed rubber solution is then combined with initiator solution in the Feed In-line Pre-mixer No. 2 prior into entry to the 1st Pre-poly Reactor.

Pre-polymerization

Pre-polymerization is chemically initiated for HIPS products. Pre-polymerization requires two reactors in producing impact polystyrene. This is a critical phase of the process since the rubber morphology and physical properties of the product are controlled during pre-polymerization.
In the 1st Pre-poly Reactor approximately 7-8% conversion takes place in this reactor. As the polymerization is exothermic, heat must be removed to maintain the desired temperature.

In the 2nd Pre-poly approximately 28% more conversion takes place in this reactor. Thus the pre-polymer leaving this reactor is approximately 35% converted.

The pre-polymer is then pumped to the Polymerization Reactor via the Reactor Feed In-Line Mixer. In this mixer, mineral oil from the Mineral Oil Drum is added, if required. The function of mineral oil, when required, is to lower the Vicat Softening Temperature of the polystyrene product.

Polymerization

The Polymerization Reactor is a plug flow reactor consisting of two towers, in series. These towers consist of heat transfer bundles of proprietary design. Five separate heat transfer loops are used to control the temperature profile in the reactor. Heat is removed by the use of heat transfer oil. There are three cooling zones in the first tower and two zones in the second tower. Precise reactor temperature control is important as it determines the conversion and molecular weight distribution of the final product. Heat transfer oil functions as a utility and is used for cooling in the Polymerization Reactor zones as well as heating purposes throughout the plant. The hot oil used is Therminol 66.

The polymer exiting the Polymerization Reactor is at a minimum of 87% (HIPS 641) conversion.
For all practical purposes, the polymerization is complete. To remove the unreacted styrene and impurities, the polymer is then devolatilized in the Devolatilization Section.

Devolatilizer Preheater

Prior to devolatilization the polymer is preheated to about 240°C in Devolatilizer Preheater, which is mounted on top of the 1st Stage Devolatilizer.

The Devolatilizer Preheater contains static elements in the tubes, in which the polymer flows, to enhance the heat transfer. Hot oil is used as heat transfer medium on the shell of the preheater.

Devolatilization

Devolatilization is a process in which the polymer is subjected to a high vacuum at elevated temperature. To obtain a very low residual styrene monomer in the final product, a two-stage devolatilization process is required.
The residual styrene monomer and impurities are flashed off in the Devolatilizer and enter the Recycle Styrene Column. The polymer is then pumped by the parallel 1^{st} Stage Devolatilizer Discharge Pumps to the 2^{nd} Stage Devolatilizer via the Devo Water Injector and the Devo Distributor.
Demineralized water is used as a stripping agent to obtain the very low residual styrene monomer levels in the final product having residual volatile concentration of about 200 ppmw.

The polymer melt is then pumped to the Pelletization Section, via the parallel 2^{nd} Stage Devolatilizer Product Pumps. Internal Lubricant is added to the polymer melt just prior to entering the Pelletization Section.

Styrene Recovery System

This system will recover the residual styrene monomer and ethyl benzene (EB) from the Devolatilization Section. Ethyl benzene is used for filling during start-up and as a diluent during potential upset scenarios. The recovered styrene monomer and EB are recycled back to the Pre-polymerization Section. The two packed-column systems have also been designed to control the concentration of impurities in the recovered styrene and the purge. Oligomers and any heavies are not recycled, but sent as fuel to the Hot Oil Heater via the Oligomers Drum.

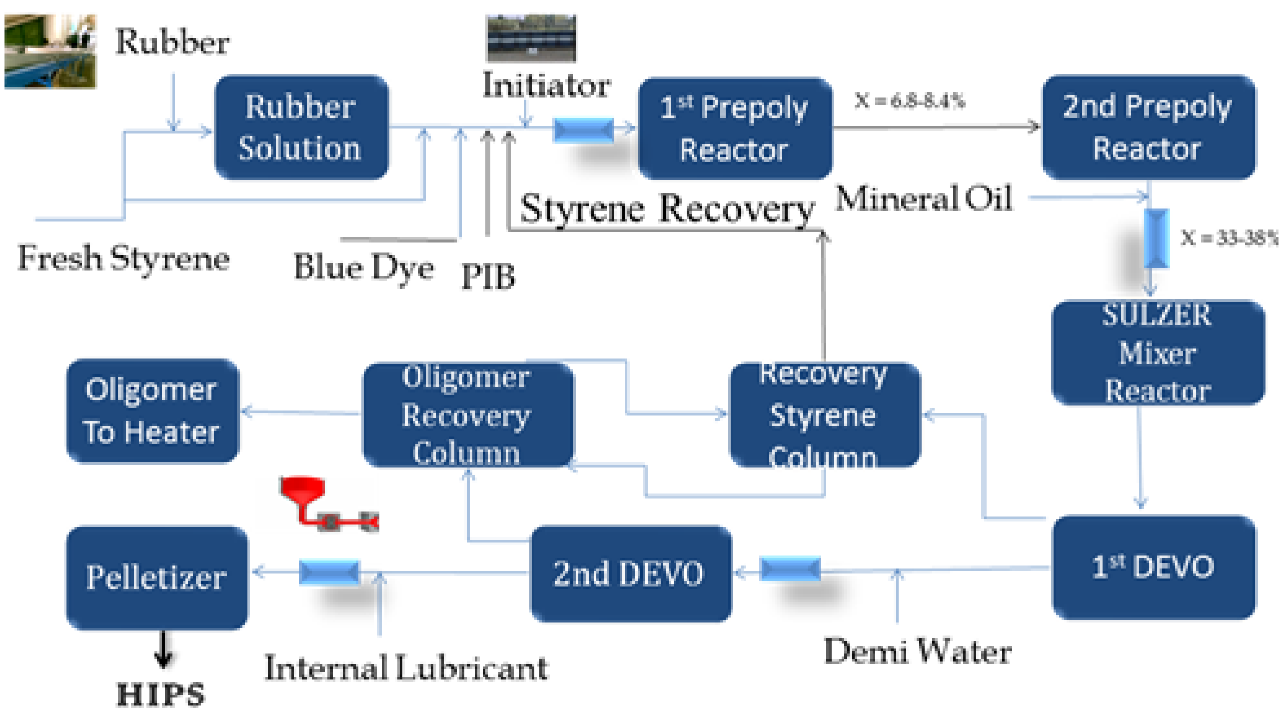
Pelletization and Storage

Two identical pelletizer lines are used to produce pellets. The polymer from the 2^{nd} Stage Devolatilizer is pumped to the Pelletizing Section via the Pelletizer Feed Mixer. Here, an internal lubricant is introduced to the melt, between the transfer pump and the Pelletizer Feed Mixer. Following the mixer, the polymer enters the Underwater Pelletizer Package. The polymer first enters the continuous Screen

Changer which removes particulate contamination from the polymer. The molten polymer then enters a Die Head Plate where the polymer is formed into strands. The strands fall onto a grooved chute where water sprays on it to cool the strands. By gravity, the strands of molten plastic are fed to the draw-in section of the cutter where pellets are formed. The surface of the strands is cooled by water flowing to the cutter. The draw-in section of each pelletizer catches the strands and feeds them to the cutting point. The strands are cut underwater between a bed knife and a Pelletizer rotary cutter head. The pellets are then conveyed with the water to the Pellet Dryers and are dewatered and dried.
The pellets then pass over the parallel-operating Product Classifiers which are a series of vibrating screens that removes "overs" and "fines".

The pellets are then air conveyed to a QC Holding Silos via the Line Conveyor Package. The pellets are accumulated and held in one silo for quality control checks, while batch transferring acceptable product out of the other silo. From the QC Holding Silo, the pellets are subsequently air conveyed to the Product Silos, via the Recycle/Product Conveyor Package.

Polystyrene Main Process Facilities (HIPS PLANT)

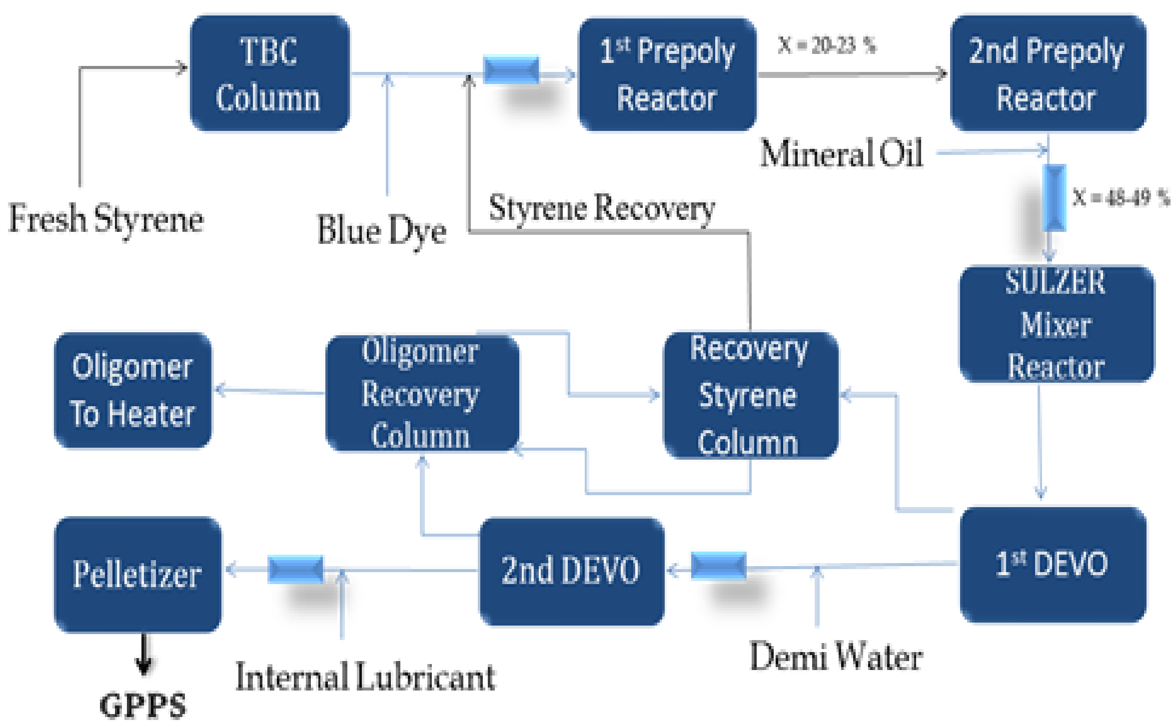


PRODUCTION OF GENERAL PURPOSE POLYSTYRENE (GPPS)

General purpose polystyrene produced by using thermal polymerization; in this method requires heat.
If styrene monomer is heated sufficiently, it will polymerize.

The production steps of the General purpose polystyrene (GPPS) is same as the production steps of High Impact Polystyrene (HIPS) except addition of rubber and initiator

Polystyrene Main Process Facilities (GPPS PLANT)



USES OF POLYSTYRENE