TechnipFMC

Polystyrene Technologies

General Purpose Polystyrene (GPPS)
High Impact Polystyrene (HIPS)

TechnipFMC is the exclusive worldwide licensor of Total's state-of-the-art polystyrene technologies

With 45 years of manufacturing, licensing and research and development experience, Total Refining & Chemicals is the second largest producer of polystyrene in the world. Total has seven operating plant sites with a combined capacity of nearly 1.5 million MTA,[1] including the largest single polystyrene production unit in the world. The polymers produced serve a wide range of applications from packaging, food service and electronics to housewares and insulation.

Through an exclusive alliance, TechnipFMC Process Technology licenses Total's general purpose polystyrene (GPPS) and high impact polystyrene (HIPS) technology on a worldwide basis. In addition to licensing to third parties, we prepare technical offerings and Process Design Packages and support clients during project execution and plant operation.

[1]metric tons per annum

Total's technology at a glance:

- Installed in 50 units in 20 countries
- Capacities range from 10,000 to 250,000 MTA
- Combined capacity of 3.4 million MTA

At 250,000 MTA, the largest single polystyrene production unit in the world is located in Carville, Louisiana (USA).

Combining the best of both companies

The alliance between TechnipFMC and Total assists clients with developing new polystyrene manufacturing facilities and modernizing existing facilities to increase capacity, expand the product portfolio and improve competitive position.

TOTAL

- Technology owner with broad patent coverage
- Understands regional polystyrene markets
- R&D centers in U.S., Belgium and Spain
- Training centers in U.S.A., Asia and Europe
- Continuous product development
- Expansion/modernization experience
- Proven safety record (ISRS Level 8)
- Environmentally sound process (ISO 14001 Certification)

TechnipFMC

- World-class downstream technology licensor
- Engineering, procurement and construction services
- Project management leader in the petrochemical industry
- Plant modernization experience
- Advanced design tools
- Leader in upstream styrene monomer technology
- Training support and field services
- Worldwide footprint

TechnipFMC Project Services

- Feasibility studies
- Conceptual design
- Licensing
- Basic design package
- Cost estimating
- Detailed engineering of equipment, piping, civil and instrumentation
- Project planning and estimating
- Procurement including purchasing, expediting and inspection
- Construction
- Plant operation supporting services

Polystyrene technology highlights

Continuous mass polymerization process

- Multiple reactor configurations supported by advanced simulation tools
- Proven, reliable distributive control systems for:
  - Short, smooth grade transitions
  - Reliable, efficient operation
  - Consistent, predictable quality
- Wide range of capacities and reactor volumes
- Extensive experience in debottlenecking existing lines
- Continuous process development supported by licensing team

Low capital investment

- Know-how for building facilities at minimum capital cost
- Major equipment is carbon steel: efficient removal of air/water
- Optimized plot and building requirements

Superior product performance

- Wide range of competitive GPPS and HIPS products
- High-quality products, with solid reputation
- Versatile product line, easily customized
- Low polymer volatile content exceeds food packaging requirements
- Continuous product development supported by global R&D efforts

Low operating and maintenance costs

- Industry leading on-stream performance
- High-efficiency heat transfer system
- No process steam required
- High polymer yields (typically 99 percent or greater)
- Simple process control scheme
- Low raw materials and utility requirements

Polystyrene plant efficiency

Typical raw material and utility consumptions per ton of HIPS

Raw materials	1006 kg
Electric power	120 kwh
Fuel, 80% efficiency	140,000 kCal
Cooling water circulation	100 m^3
Nitrogen	7 Nm^3
Instrument air	25 m^3

Typical polystyrene plant layout

Questions for Clients to consider

- What are the targeted markets for the products?
- What are our client's requirements?
- What initial capacity is required?
- Can my plant be easily debottlenecked?
- Will my plant meet today's stringent environmental standards?
- What is the safety record of the technology?
- Are products available for specialty applications?

A continuous mass polymerization process

A polystyrene plant includes sections for feed preparation, polymerization, devolatilization and pelletization. Typically, a unit designed for HIPS can produce GPPS with a few procedural changes. For HIPS production, polymerization of styrene grafted to polybutadiene rubber produces high impact polystyrene. Variation of the feed composition and process conditions allows a variety of grades to be manufactured. For the dedicated production of consistent high quality GPPS, a specific low capital cost reactor configuration is available.

Feed preparation

For the production of general purpose grades, specific ratios of styrene monomer and mineral oil are prepared upstream of polymerization. High impact grades require the preparation of a polybutadiene rubber solution dissolved in the styrene monomer feed. The ratio of the feed components and selected additives is dependent on the desired grade properties.

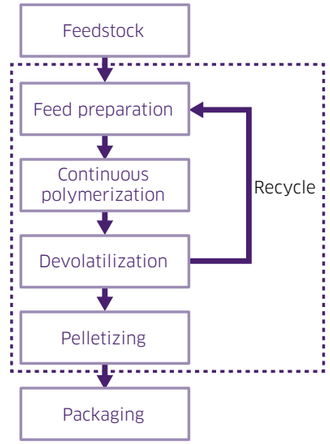
Polymerization

The technology is based on a proprietary polymerization process that employs specialized reactor designs. The technology that produces both GPPS and HIPS includes continuous stirred tank reactors (CSTR), plug flow reactors (PFR) and/or a combination. Reactions can be either thermally or chemically initiated. Single line capacities ranging from 10,000 to 250,000 MTA are available for license.

Upstream of the reactors, feed and recycle are combined and preheated. Typically, polymerization occurs stepwise in multiple (CSTR or PFR) reactors arranged in series. Residence time, initiator and reactor temperature profile are controlled to achieve the target conversion rate and finished product properties.

Devolatilization

Polymer melt from the reactors is directed to the devolatilization system, which consists of preheating and devolatilizing steps. To facilitate separation of polymer and unreacted monomer, the temperature of the polymer melt is increased. To avoid product degradation caused by high temperature, residence time is minimized. Devolatilization operates under vacuum conditions resulting in low residual styrene monomer levels.



Polystyrene block flow diagram

Pelletization

The selection of the technology for pelletizing is based on local market and customer preference. Pelletization technologies including dry cut, wet cut and underwater cut are available. The finished polystyrene pellets are pneumatically conveyed to storage and packaging.

Broad product range with the highest quality

The alliance between TechnipFMC and Total offers a broad product range suitable for all segments of major applications, including GPPS, HIPS and specialty grades. Product properties and applications are detailed below.

Typical GPPS Product Properties and Applications

Description	Total Product Name	Melt Index g/10'	Flexural Modulus MPa	Vicat Temp °C	Extrusion	Injection	Applications/Markets
High heat resistance, high molecular weight	1160	2.4	2900	101	x	x	Food packaging, foamed trays, disposables, industrial sheets, films
High molecular weight	1240	2.5	2900	92	x	x	Cups, foamed trays, shower screens
High molecular weight	1340	4	2900	93	x	x	HIPS dilution for packaging and disposables, CD boxes, toys, office equipment
Easy flow	1540	12	2900	86	x	x	HIPS dilution for packaging and disposables, dairy sheets, CD boxes, toys, office equipment
Very easy flow	1810	20	2900	85	x	x	Thin wall containers: Transparent boxes and cups, masterbatches

Typical HIPS Product Properties and Applications

Description	Total Product Name	Melt Index g/10'	Flexural Modulus MPa	Notched Izod Impact Strength kJ/m²	Vicat Temp °C	Extrusion	Injection	Applications/Markets
High heat resistance	3450	7	2250	8	95	x	x	Food packaging, office equipment, disposables, profiles, electrical and electronics
Easy flow	3630	15	2400	6	82	x	x	Office equipment, disposables, bathroom accessories, toys
High heat, easy flow	4440	10	2000	10	88		x	Television front and back covers, office equipment
Easy flow	6540	11.5	2100	9.5	83	x	x	Toys, television sets, food packaging, office equipment, household items
Improved dilution capability	7240	4.5	1850	11	87	x	x	Dairy sheet, cups, food trays, disposables, bottles
Improved Environmental Stress Cracking Resistance (ESCR)	8350	4.5	1600	13	84	x	x	Cabinet and door liners for refrigerators, fat and low temperature packaging

Optional Specialty Grades

Description	Product Name	Melt Index g/10'	Flexural Modulus MPa	Notched Izod Impact strength kJ/m²	Vicat Temp °C	Extrusion	Injection	Applications / Markets
Very high molecular weight	1070	1.5	2900	-	101	x		Clamshells for fast food, meat trays, insulation boards, shower screens
High heat, easy flow	1450N	6.5	2900	-	101	x		Insulation boards (XPS)
Very easy flow	1960N	30	2900	-	101	x		Insulation boards (XPS), masterbatches
High gloss, high heat	6351	3.5	2000	10.5	100		x	Air conditioning, office automation, electrical and electronics, toys
Improved Environmental Stress Cracking Resistance (ESCR)	8260	2.8	1600	11	90	x	x	Refrigerator parts: door liners, injected parts, fat and low temperature packaging

Polystyrene Reference Plants

Location	Date	Capacity (MTA)
Asia	2008	95,000
	1995	100,000
	1990	30,000
	1990	12,000
	1989	45,000
	1989	40,000
	1987	60,000
	1987	60,000
	1987	40,000
Central America	1987	10,000
China	**2017**	**200,000**
	2014	**200,000**
	2011	**100,000**
	2010	**100,000**
	1997	40,000
	1997	40,000
	1993	50,000
	1993	30,000
	1989	50,000
	1986	10,000
Eastern Europe	2008	40,000
	2005	40,000
	2000	40,000
	1997	50,000
	1982	40,000
Middle East	1997	10,000
	1986	50,000
	1986	30,000
South America	1999	80,000
Turkey	1997	40,000
USA	2001	250,000
	1996	150,000
	1989	190,000
	1985	80,000
	1983	80,000
	1976	20,000

(**Bold** signifies most recent)

USA
Dana Johnson
+1 617 748 7220
dana.johnson@technipfmc.com

Peter Vallieres
+1 617 748 7284
peter.vallieres@technipfmc.com

TechnipFMC.com

PT00X