EXECUTIVE SUMMARY

E.1 INTRODUCTION - STYRENE

E.1.1 Styrene, $C_6H_5CH = CH_2$, is an unsaturated aromatic monomer, which polymerizes to give polystyrene. Though, it was discovered way back in 1786, its commercial production and applications were developed in the nineteen thirties. Post world war period witnessed a boom in styrene demand due to its application in the manufacture of synthetic rubber. This led to a dramatic increase in styrene capacity. Since then demand and capacity have grown continuously.

E.1.2 Applications

Styrene finds wide application in the plastics and synthetic rubber industry. It is used in the manufacture of polystyrene; styrene-butadiene rubber (SBR); acrylonitrile-butadiene-styrene (ABS) resin; styrene acrylonitrile (SAN) resin; protective coatings (styrene-butadiene latex; alkyds); expandable polystyrene; block copolymers like styrene-butadiene-styrene (SBS), styrene-isoprene-styrene (SIS), styrene-ethylene- butadiene-styrene (SEBS) and miscellaneous uses like textile auxiliaries, pigment binders polyester resin, aromatics and intermediate industries. In India, applications of styrene are well-developed.

E.2 MANUFACTURING PROCESS - STYRENE

E.2.1 Worldwide, Styrene is predominantly manufactured from Ethyl Benzene (EB). This consists of two steps:

— Alkylation of benzene with ethylene/ethanol (ethyl alcohol) to produce EB.

— EB conversion to styrene by either dehydrogenation or indirect oxidation with propylene.

E.2.2 Ethylene and benzene are alkylated in presence of a catalyst to produce EB. Instead of ethylene, ethanol can also be used. Under such circumstances, ethanol is either dehydrated to produce intermediate ethylene and then alkylated with benzene, or reacted directly with benzene to produce EB.

Alkylation of benzene with ethylene is carried out either in liquid phase or vapour phase. Liquid phase alkylation uses aluminium chloride catalyst, which is corrosive and produces a polluting liquid effluent.

A more recent development is vapour phase alkylation at higher temperature, using synthetic zeolite catalyst. The vapour phase process is more energy efficient and produces medium and low pressure steam, which is used in the process. Liquid phase alkylation using zeolite catalyst has also been commercialised. These processes eliminate usage of corrosive catalyst and produce non-toxic effluents.

E.2.3 Albene technology, jointly developed by Hindustan Polymers and NCL, Pune, is the first in the world to produce EB directly from ethanol and benzene, without the intermediate production of ethylene. NCL has also developed zeolite (Encilite-2) catalyst to effect direct conversion. This technology is currently used commercially by HPL's 13,000 TPA capacity EB plant.

E.2.4 Worldwide, more than 90% of the styrene is manufactured by adiabatic dehydrogenation of EB using iron based catalyst. (EB can also be isothermally dehydrogenated, though this process is not much in use). The remaining is manufactured by indirect oxidation with propylene to produce propylene oxide and styrene as co-products.

E.2.5 Worldwide, almost all the styrene manufacturers have backward integration (i.e., manufacture of ethyl benzene) or forward integration (i.e., manufacture of polystyrene, ABS, SAN, etc.) or both. In India, styrene is available in two grades viz. polymer and rubber grades.

E.3 INDIAN INDUSTRY STATUS - STYRENE

E.3.1 In India, styrene manufacture started in 1963, simultaneously by M/s. Polychem Limited and M/s. Synthetics and Chemicals Limited (SACL). Plants were set up in collaboration with Dow Chemicals of U.S.A. and Huls of Germany, respectively. In 1973, one more unit, M/s. Hindustan Polymers (HP), commenced production in collaboration with M/s.

Universal Oil Products of U.S.A. All the three units use molasses based distilled alcohol to manufacture EB. EB is manufactured by liquid phase alkylation process using promoted aluminium chloride catalyst complex. Styrene is manufactured by catalytic dehydrogenation of EB.

E.3.2 HPL has planned expansion of its 15,500 tpa styrene capacity to 80,000 tpa employing UOP's Smart SM technology. Implementation has presently been suspended due to the high cost of benzene and increased project cost.

Polychem has taken steps for modernisation and improving process efficiency. Its approved R&D Department has been active and has been able to develop styrene based speciality polymer powder, styrene acrylic copolymer, and 20% aluminium chloride solution. Also non sulphur inhibitors for styrene distillation were introduced in the existing production process, which resulted in reduction of air pollution.

SACL has also planned to expand its existing 9,000 tpa styrene capacity.

E.3.3 Besides expansion of the existing producers, new entrepreneurs are also planning to enter this field. Supreme Petrochemicals Limited (a new company formed by Supreme Industries Limited), Reliance Industries Limited and Haldia Petrochemicals Limited have plans to manufacture styrene and polystyrene. Haldia Petrochemicals Limited also has an approved foreign collaboration with Lummus Crest. All the three projects are ethylene based. Supreme Petrochemicals is reported to have tied up with MGCC (Maharashtra Gas Cracker Complex) for supply of ethylene. Reliance and Haldia Petrochemical will have ethylene available from their own cracker complexes.

E.3.4 Against the current total installed capacity of 43,500 tpa, the demand for styrene in India is estimated at about 62,000 T in 1991- 92. The gap between supply and demand, which is increasing, is bridged by imports. The demand is estimated to be about 1,44,000 T in 1994-95 which would further increase to about 2,31,000 T by the end of the decade.

E.4 INTERNATIONAL INDUSTRY STATUS

E.4.1 The current global capacity is distributed among more than 75 units. Total capacity, considering both, those existing and those under construction, is estimated at around 17 million tpa; with U.S.A. having about 4.5 - 5 million tpa capacity. U.S.A. represents about 30% of the total global capacity, followed by West Europe, Japan and Korea. Average global capacity utilization is in the range of 70 - 75%. A representative list of styrene manufacturers is given in *Annexure-1.*

Highlights of the licensors of both EB and Styrene technology are shown in the following tables :

PROCESS LICENSORS FOR EB TECHNOLOGY (ALKYLATION)

Sr. No.	Licensor	Type of License	Approved Contractors	Feedstocks	Characteristics
1.	Mobil/Badger	Non-exclusive	Badger	Ethylene, benzene	Vapour phase catalytic alkylation (Uses Mobil Zeolite catalyst)
2.	CD Tech	Non-exclusive	ABB Lummus Crest	Ethylene, benzene	Superior catalyst life
3.	Eurotecnica	Non-exclusive, world wide	Eurotecnica	Mixture of C_8	Extraction and purifi-cation
4.	Industrial export import (Romania)			Ethylene, benzene	Benzene alkylation, Ethylbenzene purity min. 99.6%
5.	Monsanto/ABB Lummus Crest/	Non-exclusive	ABB Lummus Crest	Ethylene, benzene	Freidel - Craft Process using $AlCl_3$
6.	Petroflex	Know-how and basic engg.	Dyna	Ethylene, benzene	Freidel-Crafts Catalyisis in heterogeneous liquid phase
7.	UOP	-	Generally available through any contractor	C_8 aromatics	Recovery of ethylbenzene from C_8 aromatic by liquid phase adsorptive separation Ebex process
8.	UOP	-	Generally available through any contractor	Benzene ethylene containing stream	Alkylation of benzene with ethylene. Alkar process. Can use very low concentration ethy-lene streams as well as high purity ethylene feedstock
9.	Hindustan Polymers and NCL, Pune	Non-exclusive	-	Ethanol, Benzene	Direct conversion to EB using synthetic Zeolite catalyst.

Table Contd... next page

Sr. No.	Licensor	Type of License	Approved Contractors	Feedstocks	Characteristics
10.	UNOCAL	Non-exclusive	Lummus Crest	Ethylene, Benzene	Liquid phase Zeolite based alkylation.
11.	Norsolor (CDF Chimie)	-	Technip	Ethylene, Benzene	Freidel Craft using $AlCl_3$

PROCESS LICENSORS FOR STYRENE TECHNOLOGY (DEHYDROGENATION)

Sr. No.	Licensor	Type of License	Approved Contractors	Feedstocks	Characteristics
1.	FINA/Badger	Non-exclusive	Badger	Ethylbenzene	Vapour-phase catalytic alkylation, dehydrogenation
2.	Monsanto/ABB Lummus Crest/ UOP	Non-exclusive	ABB Lummus Crest	Ethylbenzene	1) Catalytic dehydro genation 2) Oxidative dehydrogenation
3.	Petroflex	Know-how and basic engg.	-	Ethylbenzene	Catalytic dehydrogenation
4.	Stone and Webster	Direct	-	Ethylbenzene	QC (quick contact) reactor system - a fluidised dehydrogenation process
5.	UOP	-	Generally available through any contractor	Ethylbenzene	Catalytic dehydrogenation using high-conversion, high selectively process. UOP Smart SM process
6.	Norsolor	-	Technip	Ethylbenzene	Based on UOP Smart SM Reactor
7.	Hindustan Polymers, India	-	-	Ethylbenzene	Catalytic Dehydrogenation using NCL's catalyst

E.5 INTRODUCTION - POLYSTYRENE

E.5.1 Polystyrene is a versatile thermoplastic available in a wide range of formulations, from crystal and impact grades to highly specialized resins for foam moulding and extrusion, and resins that offer ignition - retardant properties. The wide range in physical properties and relative ease of processing, makes polystyrene an extremely attractive material, capable of competing favourably with more expensive resins in a number of demanding applications.

E.5.2 Polystyrene is generally classified as

– Crystal polystyrene (general purpose)

– Impact polystyrene (HIPS)

Crystal Polystyrene

Crystal polystyrene, usually referred to as general purpose polystyrene (GPPS) is a high molecular weight (Mw = 2-3 x 10^5) crystal-clear thermoplastic that is hard, rigid, and free from odour and taste. Its ease of heat fabrication, thermal stability, low specific gravity, and low costs results in moldings, extrusions, and films of very low unit cost. In addition, PS materials have excellent thermal and electrical properties which make them useful as low cost insulating materials.

Crystal PS is commercially processed and fabricated by an array of techniques. Applications of crystal PS are shown below:

CRYSTAL PS (GENERAL PURPOSE)

Injection Moulding

- Packaging
- Cosmetic containers
- Toys and novelties
- Imitation jewellary
- Louvres/Lamp shades
- Crystalwares
- Stationery items
- Audio Cassettes
- Office fixtures
- Computer disk reels
- Medical applications
  - Petri dishes
  - Pill bottles
  - Pipettes
- Ball Pens
- Beads

Extrusion

- Packaging
- Egg cartons
- Meat & poultry trays
- Packages for fast food takeouts
- Oriented PS
- Blister packs
- Food packaging

New Applications

- Clear or embossed panels
- Glazing
- Lighting
- Home decoration

Impact Polystyrene

Elastomers are incorporated into PS, primarily to impart toughness. The resulting material is commonly called High Impact Polystyrene (HIPS) and is available in many different varieties. Stereoregular polybutadiene elastomers are used for impact modification. The rigidity, impact - resistance, clarity, and processability vary according to the rubber morphology and distribution in the polymer matrix.

Impact polystyrene can be processed easily by all conventional thermoplastic fabricating techniques which include film, sheet and profile extrusion, thermoforming, injection moulding, injection blow moulding, and structural blow moulding.

Different applications for HIPS are listed below:

Thermoformed packaging

- Fast food containers
- Cups and Lids
- Containers for Fruit Juices & dairy products

Houseware/officeware

- Toilet seats and bath room fittings
- Mirror casings
- Trays and hangars
- Shaving accessories
- Kitchenware
- Hair brush handles and other toiletries
- Disposable thin wall containers
- Video parts
- Camera parts

Industrial applications

- Liners for refrigerators
- Air conditioner components
- Transistor/TV/Tape recorder cabinets
- Wall clocks
- Electrical Fittings
- Video and Audio cassettes
- Consumer electronics products
- Automobile tail lightings and reflectors
- Novelties, toys, shoe heels, furniture

E.5.3 Polystyrene - Special Grades

Recently introduced improvements include impact modified grades, with improved resistance to environmental stress - cracking for use in refrigerator liners. Ignition-resistant grades have also been introduced for housing business machines, electrical appliances and components. Speciality grades like grades with improved contact clarity, super high impact grades, antistatic grades and flame retardant grades have also been developed, but they have yet to find a significant market.

E.5.4 Expandable PS Beads

Expandable polystyrene is a generic term for polystyrene and styrene copolymers, supplied as a compound with blowing agents and other additives, which can be processed into low density foamed articles. EPS type materials can yield products as diverse as a coffee cup, an energy absorbing bumper for an automobile or a 300 cu.ft. foam block. Major end-uses for EPS are disposable drinking cups, cushioned packaging, and thermal insulation.

E.6 MANUFACTURING PROCESS

E.6.1 Polystyrene is produced by suspension, bulk/mass, or solution polymerisation. Over half of the resin was being manufactured using suspension polymerisation, as was the majority of the expandable bead polystyrene (EPS) since the polymer was produced in a readily usable form. Suspension polymerisation has excellent versatility for the production of numerous grades of PS. However, high purity products are more difficult to obtain, since water, suspension stabilizers, and unreacted initiators tend to be contaminants. The operating cost of the plant increases due to added cost for the water, stabilizers, and waste water treatment, thus making mass polymerisation a more favourable process. Due to narrowing price differential between styrene monomer and polymer, mass polymerisation has now become the major process used for polystyrene production.

Crystal PS : Mass or Bulk Polymerisation

Mass polymerisation, consists of four basic steps :

1. Prepolymerisation
2. Polymerisation
3. Devolatization
4. Extrusion

The equipment used in the pre-polymerisation step usually consists of a stirred reactor with a reflux condenser. When peroxidic initiators are used, the reaction is carried out at a lower temperature (80°C) than that used for thermal initiation (130°C). The polymer content of the resulting mixture varies from 25 to 35 percent.

From the prepolymerisation section, the monomer-polymer mixture is fed into a series of stirred reflux reaction kettles or reaction towers. The temperature is progressively raised through the reaction zone to prevent fall off in polymerisation rate and to reduce the viscosity of the polymerising mass. Typical final temperatures in the polymerisation section range from 150 to 200°C. Solvents may be incorporated in the feed to the polymerization reactor so as to improve process temperature control, heat transfer and flow properties.

In order to remove unreacted monomer, solvent, if used, and low molecular weight polymers, the reaction mixture is fed to a static devolatizer where the volatiles are flashed off and distilled. The styrene monomer, solvents and oligomers are recycled while the low molecular weight polymers are sent to a landfill. The purified polymer is then extruded through a vented extruder and pelletized. Construction materials for the reactors are aluminium, stainless steel, glass lined or stainless steel clad materials. Copper is not used because it causes discolouration of the polymer.

E.6.2 Impact, or rubber modified polystyrene (HIPS) is a translucent to opaque white polymer, produced by the addition of either polybutadiene or styrene-butadiene rubber to the styrene monomer. The rubber remains as discrete particles dispersed in the polymer after polymerisation. HIPS is usually classified according to rubber content as : medium impact, with 3 to 10 percent rubber; high impact, with upto 25 percent rubber.

The rubber can be added by : blending the rubber latex with the polystyrene latex followed by coagulation and drying; mechanical milling of the dry rubber with dry polystyrene; and grafting of preformed unsaturated rubber with styrene in mass, suspension or solution polymerisation processes. The copolymerisation process is often referred to as graft polymerisation and is the most widely used since it produces superior products with less rubber.

E.6.3 Polystyrene : Process Comparison

The table in the next page gives a comparison of operating parameters in different processes used to manufacture polystyrene, both general purpose and HIPS.

OPERATING PARAMETERS : POLYSTYRENE PRODUCTION PROCESS

Sr. No.	Process	Temperature	Pressure	Batch/ Continuous
1.	Mass Polymerisation Process	80-200°C	Slightly reduced to 10-20 mm Hg	(Continuous)
2.	Suspension Polymerisation Process	110-170°C	Reduced	5-9 hours (Batch)
3.	Solution Polymerisation process	90-130°C to 10-20 mm	Atmospheric*	6-8 hours (Continuous) Hg

* *Including devolatisation step.*

E.6.4 Reactor Process Elements

A characteristic of styrene polymerisation processes is that different reactor types are frequently used in varying series combinations. The table below gives an overview of general reactor designs used with PS and HIPS processes on the basis of reactor function. Currently, bulk polymerisation is generally carried out as a continuous process.

STYRENE POLYMER REACTORS : CLASSIFICATION

Reactor Function	PROCESS TYPE			
	Batch	Continuous		
BULK POLYMERISATION	**CONVENTIONAL KETTLE WITH:**	**CSTR* WITH:**		
Polymer < 20% concentration	Turbine agitator	a) Turbine Agitator	b) Turbine Agitator	c) Agitated Tower
Polymer < 20-50% concentration	Large turbine, anchor or helical agitator	a) Turbine, anchor or helical agitator	b) Tubular Reactor	c) Agitated Tower
Polymer < 30-80% concentration	Anchor/helical agitators proprietory and patented stirred reactors	a) Anchor, helical agitators or special designs	b) Tubular Reactor	c) Agitated Tower
Polymer < 80% concentration	Press type; unagitated batch tower	-	Tubular reactor	Unagitated Towers
SUSPENSION	Conventional kettle with turbine agitator	No commercial application		

* *Continuous Stirred Tank Reactor.*

E.6.5 POLYSTYRENE MANUFACTURE - RAW MATERIALS

Different input materials used in the manufacture of polystyrene, in addition to styrene monomer and rubber (in case of HIPS) are :

1. Free Radical Initiators
2. Chain Transfer Agents
3. Retardants and Inhibitors
4. Solvents
5. Suspension Stabilisers (protective colloids)
6. Flame retardants
7. Lubricants
8. Antioxidants

E.6.6 ENVIRONMENTAL CONSIDERATIONS AND HEALTH HAZARDS

None of the chemicals which have been identified as inputs to polystyrene processing are known human carcinogens. However, there is some evidence from tests conducted and reported, of styrene causing tumors in test animals. Although these results are not conclusive, standards have been set for styrene and polystyrene exposure. Three other input materials are suspected human or known animal carcinogens : carbon tetrachloride, a chain transfer agent; polyvinyl alcohol, a suspension stabiliser; and antimony oxide, a flame retardant. Here, better alternatives are also available and are being used by the Indian industry. Other highly toxic inputs include tertbutyl hydroperoxide, a free radical initiator, and benzoquinone, a retardant.

One environmentally significant portion of polystyrene processing is the devolatisation step. Residual styrene monomer in the polymer is reduced, thereby reducing the exposure risk and rendering the polymer usable for food applications such as meat trays, egg cartons, and wrap for non-fatty foods.

Also, independent studies at various universities have demonstrated that styrene monomer is one of the safest of industrial chemicals and poses no risk to workers or to the general public. It is not classified as a carcinogen by the U.S. FDA.

E.7 POLYSTYRENE : INDIAN INDUSTRY SCENARIO

E.7.1 Polystyrene is a first generation plastic; its major advantages of cost, low density and easy mouldability over the conventional materials have made it quite a success. Consumption increased from 19,700 MT in 1984-85 to about 42,600 MT in 1990-91 registering a Cumulative Average Rate of Growth (CARG) of about 19% in the Seventh Plan. (Consumption was in the range of 48,000 tons in 1989-90).

E.7.2 There are only two manufacturers of polystyrene in India. They are :

1. Polychem Ltd, Bombay
2. Hindustan Polymers, Vizag
   (A unit of McDowell & Co. Ltd)

These two companies together, have catered to approximately 60% of the country's needs of polystyrene in the Seventh Plan. Imports of PS have increased over six fold in the Seventh Plan, from a mere 3700 T in 1984-85 to about 23,000 T in 1989-90 and 19,000 in 1990-91. (1990-91 registered low consumption because of the Gulf War)

E.7.3 Consumption figures for the last five years are shown in the table below.

POLYSTYRENE : PRODUCTION, IMPORTS AND CONSUMPTION

(Tonne)

Year	Polychem's Production	McDowell's Production	Total Indigenous Production	Imports	Total
1985-86	7977	8641	16618	8400	25018
1986-87	8369	11108	19477	9000	28477
1987-88	9155	12404	21559	12000	33559
1988-89	11450	13383	24833	15000	39833
1989-90	10850	14113	24963	23000	47963
1990-91	8756	14550	23306	19000	42306

E.7.4 The major sectors in India which consume general purpose PS & HIPS are the refrigerator sector, consumer electronic goods (including audio and video cassettes), packaging, the automotive sector and household articles and miscellaneous uses which includes : novelties, stationery items, toys, ballpens, beads, toothbrushes, building materials and sanitarywares, structural foam, crystalware, wall clocks and the defence sector.

E.7.5 Expandable Polystyrene

EPS production in the country in 1990-91 was close to 3500 T with Hindustan Polymers producing 1300 T and the balance being produced by BASF Ltd. The demand for EPS in 1990-91 was estimated to be about 7000 T and is expected to grow at 15% p.a. during the Eighth and Ninth Plans. The demand is expected to go upto 12000 tpa and 22000 tpa by 1994-95 and 1999-2000 respectively. A number of LOIs has been issued for large capacities (20,000 tons each) and if 2 or 3 such projects gets implemented, then complete import substitution can be achieved by 9th plan period.

E.7.6 DEMAND PROJECTIONS

The table below summarises the demand projections for PS in the various sectors upto the year 2000 A.D.

PROJECTED DEMAND FOR POLYSTYRENE UPTO 1999-2000

(Tonne)

Sector ------ Year	Refrigerators	Consumer Electronic	Cassettes	Packaging	Others	Total
1990-91	6000	9600	14100	4600	8000	42300
1994-95	9500	15100	29200	9500	16600	79900
1999-2000	14000	22200	47100	19200	33400	135900

Source : Consultants' Estimate based on field survey.
* Total is rounded of to nearest hundred

E.7.7 Polystyrene Supply Scenario

The table below gives the expected indigenous supply of PS upto 2000 A.D.

POLYSTYRENE : EXPECTED INDIGENOUS SUPPLY SCENARIO

(Tonne)

Year	Polychem	McDowell	Supreme	Reliance	Total
1994-95	14,400	19,800	24,000	-	58,200
1995-96	24,000	24,000	30,000	-	78,000
1996-97	30,000	30,000	36,000	24,000	120,000
1997-98	36,000	36,000	36,000	30,000	138,000
1998-99	36,000	36,000	36,000	36,000	144,000
1999-2000	36,000	36,000	36,000	36,000	144,000

E.7.8 DEMAND SUPPLY GAP

The demand supply gap upto the year 2000 A.D. has been worked out as follows :

POLYSTYRENE : ESTIMATED DEMAND - SUPPLY GAP

(Tonne)

Year	Demand	Indigenous Supply	Demand-Supply Gap/Excess(-)
1991-92	42,300	34,200	8,100
1994-95	79,900	58,200	21,700
1999-2000	135,900	144,000	- 8,100

E.7.9 Technology Selection By Indian Companies

The table below summarises the technology selection by the Indian manufacturers.

TECHNOLOGY SELECTION BY INDIAN COMPANIES

Sr. No.	Company's Name	Collaborator	Type	Remarks
1.	Polychem Ltd	DOW Chemical, USA	Technical & Financial	Collaboration expired
	Polychem Ltd	Huntsman Chemical Corpn. USA		Collaboration for their new PS capacity of 40000 TPA
2.	Hindustan Polymers	BX-Plastic, UK	Technical	Collaboration was for the existing plant
	Hindustan Polymers	Atochem, France	Technical	Expansion of PS capacity to 40000 TPA
3.	Reliance Industries	Hunstan Chemical Corpn. USA	Technical	New capacity of 40,000 TPA
4.	Supreme Petrochemicals	Hunstan Chemical Corpn. USA	Technical	New capacity of 40,000 TPA

E.8 POLYSTYRENE : INTERNATIONAL SCENARIO

E.8.1 Global consumption of PS has been increasing at a steady rate of approximately 5% p.a. Consumption, which stood at 6.6 million tons in 1985 has increased to about 8.5 million tons in 1990. However, there was only a marginal rise in consumption between 1990 and 1991, with the developed countries showing a slight decrease. Both General Purpose Polystyrene and High Impact Polystyrene have had an equal share in the total consumption of PS. Manufacturing capacity has increased by 2 million tons from 8.5 million in 1985 to about 10.5 million in 1990. The table below shows global consumption figures of PS during the last six years.

POLYSTYRENE : GLOBAL CONSUMPTION

('000 Tonne)

Region	1985	1986	1987	1988	1989	1990	1991
U.S.A.	1838	1987	2187	2224	2292	2260	2216
Western Europe	1735	1806	1892	2160	2185	2321	2294
Japan	728	746	748	913	995	1055	1028
Canada	144	147	161	171	166	163	164
Rest of the World	2190	2237	2400	2500	2700	2800	2900*
TOTAL	6635	6923	7388	7968	8338	8599	8602

* Estimated

E.8.2 LEADING TECHNOLOGY LICENSORS

Today, majority of the commercial processes, world wide are based on the continuous bulk/mass polymerisation process. This process is popular for the manufacture of both general purpose polystyrene (GPPS) and high impact polystyrene (HIPS). The batch suspension polymerisation process is being used extensively for the manufacture of expandable polystyrene (EPS). Some leading technology suppliers in the world are :

1. Atochem, France
2. Badger Company, USA
3. Fina Technology, USA (Formerly Cosden Technology, Inc.)
4. Chevron Chemical Company, USA
5. Dow Chemical Company, USA

6. Huntsman Chemical Corporation, USA

7. Toyo Engineering Company, Japan
   (TEC - Mitsui Toatsu Chemicals PS Technology)

8. Montedipe, Italy

9. Sulzer-Dai Nippon Ink and Chemicals

10. BASF, USA

BASF, Arco, Shell, Huntsman of USA, INA-OKI of Yugoslavia, and Shin-a of Korea are leaders in technology for expandable PS. Generally Dow and BASF are not known to license their technologies.

The table below gives a comparison of the different technology licensors.

PS CONTINUOUS BULK PROCESS : LICENSORS COMPARISON

Sr. No.		Material	Fina	ATO Chem	Badger	TEC	Chevron
1.	Investment (Million $)	N.A.	10.5/ 30000 TPA	10.5/ 20000 TPA	6.5/ 15000 TPA	N.A.	N.A
2.	Material usage (T/T PS) *	HIPS/GPPS	1.01	1.025	1.015	1.01	1.02
3.	Electric Power (KWH/Tonne)	HIPS GPPS	120 140	140 165	135 150	100 120	135 150
4.	Fuel (Kcal/T of PS)	HIPS GPPS	140000 200000	120000 215000	100000 250000	140000 360000	110000 260000 (refrigeration)
5.	Cooling water per T of PS (Ton)	HIPS GPPS	40 80	N.A. -	30 60	33 53	25 50
6.	Type and No. of reactors	N.A.	Horizontal 3	Horizontal or vertical 2	Vertical 2	Vertical 2-3	Vertical 3
7.	Diluent	HIPS/GPPS	N.A.	Ethyl benzene	N.A.	Toluene	Toluene

* Material used includes monomers, rubber and others.

Source : Licensors' Catalogues. (1989-90 Figures)

E.9 R &D EFFORTS, TECHNOLOGY ABSORPTION AND GAPS

E.9.1 R &D Efforts - Styrene

R & D efforts have always been directed towards maximising operating flexibility, improving process efficiency for achieving better raw material and energy utilisation, minimising process waste and pollution, development of more efficient catalysts, and improving process vessel designs and economics.

A major break through achieved in India is the development of Albene technology, jointly by Hindustan Polymers and NCL, Pune. In this technology, ethyl benzene (a major raw material for styrene producton) is produced directly from benzene and ethanol derived from molasses, while abroad, EB is manufactured from benzene and ethylene. India being a cane rich country, agro-waste molasses from sugar mills is economically utilised for the manufacture of ethanol.

In India, NCL has also been able to develop a promoted iron oxide based catalyst for the dehydrogenation of EB to styrene and a Zeolite catalyst for the manufacture of EB from ethanol and benzene on their own.

Another significant break through in India is the development of process technology for the production of Styrene from Ethylbenzene by Hindustan Polymers, using the dehydrogenation catalyst developed by the National Chemical Laboratory. Hindustan Polymers has offered this technology for commercial exploitation at world scale levels of 96,000 TPA.

E.9.2 Research Highlights - Polystyrene

Internationally, research efforts have been directed towards improving reactor designs, better operating parameters, lowering monomer content in the final product, and reduced energy consumption.

In India, technology for manufacture of HIPS was developed on a laboratory scale at Shri Ram Institute for Industrial Research, under the sponsorship of Gujarat Industrial and Investment Corporation Limited.

Attempts to scale up this technology to a commercial level have yet to be made.

E.9.3 Technology Absorption and Gaps - Styrene

Hindustan Polymers has successfully absorbed Albene Technology for their 13,000 tpa styrene plant. Besides this, the iron based catalyst for dehydrogenation of EB to styrene has also been tried out at Polychem Styrene Plant.

Worldwide plants of 50,000 to 100,000 tpa are common, but in India, there is no plant of comparable size. Though majority of the capital equipments required for the project are indigenously fabricated, some critical equipments have to be imported due to non-availability of special materials of construction.

E.9.4 Technology Absorption and Gaps - Polystyrene

Although technology for manufacture of PS was imported as early as 1957, no significant technology absorption efforts have been put in. Consequently, in future too, tendency to rely upon imports of technology would continue.

Comparison of PS grades manufactured in India vis-a-vis abroad, reveals that grade availability is limited to 4 general purpose and 5 to 6 HIPS grades. Abroad certain manufacturers produce as many as 10 GPPS grades and 25 to 30 HIPS grades. Besides several speciality grades are being tailor made to meet special end-use applications. PS grades commonly available abroad are between MFI range of 1 to 25, while in India PS is available only upto 15 MFI.

Indian processing sector is far behind in terms of applications of PS. This includes areas such as fast food packaging, containers, foamed articles, consumer electronics etc. These gaps are attributed to overall high cost of production, poor processing technology and lack of general market awareness. Special grades like glass reinforced and flame retardant grades have just been developed in India.

Plant And Machinery

A high level of indigenisation has been achieved in the case of plant and machinery. Fabricators in India have today attained a high level of modernisation and sophistication. In terms of delivery schedules too, there has been a considerable improvement. Constraints faced by the industry include poor availability of raw materials, equipment, tools, tackles, specialised technical manpower, training facilities; import policies, and guarantee conditions imposed by the suppliers.

The capital goods requirement of the Styrene and Polystyrene industry, which requires a foreign tie-up for technology, is usually governed by the conditions laid down by the technology suppliers. However, the capabilities and constraints of the fabrication industry in India, as highlighted above, also apply to styrene and PS which forms a part of the petrochemical industry.

E.10 RECOMMENDATIONS

1. Planned expansions of existing capacities as well as implementation of 2 to 3 new capacities already in the pipeline for Styrene and Polystyrene should be speeded up to prevent outgo of foreign exchange by imports. The high cost of benzene is a deterrent to the implementation of new projects. Hence, steps need to be taken to reduce the price of benzene.

2. Export possibilities should be explored in both cases as there is a likelihood of a surplus in the Ninth plan.

3. A Centralised Research Institute should be set up for the development of commercially viable polymer technologies.

4. Steps should be taken to continuously absorb and upgrade imported technology so that the products are always competitive/compatible in the international market.

5. Proper attention to consistency in quality and process control should be paid by the polymer manufacturers in India.

6. Attempts should be made to maximise indigenisation of plant and machinery and to remove the constraints faced by the fabrication industry.

7. Manufacturers and Research Institutions should work towards new applications development, besides new product developments.