

EXECUTIVE SUMMARY

1. HDPE

Is a polymer of ethylene having density in the range of 0.94 gm/cc to 0.97 gm/cc. Important parameters affecting its properties are:

- Density,
- Long chain branching,
- Melt Flow Index, and
- Molecular weight distribution.

Use : Grades and End Products:

- Blow Moulding grade resin : Barrels, bottles, cans, drums (for chemicals, cosmetics, detergents, dairy products, etc.).
- Extrusion grade resin : Bags, Film, Liner, Pipes, Sheet, wire and cable sheathing, woven sacks.
- Injection grade resin : Buckets, crates, housewares and luggage.
- Rotomoulding grade resin : Storage tanks.

2. CURRENT PRODUCTION AND CONSUMPTION IN INDIA

- Installed Capacity : 50,000 TPA
- No. of Plants : One
- Production : 40,566 tonnes (1989)
- Imports : 1,35,000 tons (1989-90)
- Consumption : 1,68,000 tones (1989-90)
- New Capacities :
- HPL : 1,00,000 TPA (Completion expected by 1992)

MGCC : 80,000 TPA (Completion expected by 1991-92)

RPL : 1,00,000 TPA (Completion expected by 1991)

3. DEMAND PROJECTIONS

(Perspective Committee Level II Projections)

Plan/Year	Demand (Tons per annum)	New Plants Needed	Investment Needed
7th Plan - 1989-90	190,000	3x60,000 TPA	3XRs.100 crores
8th Plan - 1994-95	378,000	4x60,000 TPA	4xRs.100 crores
9th Plan - 1999-2000	555,000	4x60,000 TPA	4XRs.100 crores

Expected Demand/Supply Gap (based on existing plant and sanctioned capacity).

1989-90 : 40,000 Tons

1994-95 : 33,000 Tons

1999-2000 : 2,10,000 Tons

Major Constraints : Feedstock availability.

4. CONTEMPORARY TECHNOLOGIES

(a) Gas Phase, Fluidised bed : Streamlined-Union Carbide
Conventional-BP-MGCC

(b) Solution, Medium Pressure : Du Pont-Reliance
Light diluent-Phillips-
Haldia

(c) Slurry : Stirred tank, heavy diluent-
Hoechst-PIL-Solvay

5. COMPARISON OF TECHNOLOGIES

- BP Chemicals - Dual process, lower technology fees, higher investment, can produce only injection and rotomoulding grades.
- DuPont - Very good high flow injection moulding grades, can produce LLDPE, high technology cost, difficult to produce HMW grades.
- Hoechst - Good for HMW grades, uneconomical compared to gas phase.
- Phillips - Can produce all grades, uneconomical compared to gas phase.
- Union Carbide - Most economical, lowest investment, dual process, high grade change penalties, difficult to master.

6. INDIGENOUS TECHNOLOGY STATUS

Hoechst Process

Slurry Process

Very low scale of operation, small sized reactors, first/second generation catalyst with low activity. Virtually obsolete process.

7. ABSORPTION AND DEVELOPMENT EFFORTS

Part indigenisation and modification in catalyst system.

Indigenisation of additives.

Production of butene-1.

Production of HMW grades - and higher ESCR grades.

8. SUGGESTIONS FOR TECHNOLOGY ACQUISITION

There is no absolute answer that one technology is better than the other. A situation will develop in India, as it is in developed

countries, whereby individual plants will specialise in certain specific product grades. For each such plant, a different process is most appropriate.

As such, Union Carbide Process is considered most economical, but it has heavy grade change penalties.

Other suitable technologies are DuPont, BP, Phillips and Hoechst.

Dual or Swing process for producing LLDPE and HDPE will continue to be most popular.

Future development is towards a single catalyst system for producing all densities of polyethylenes.

Hence, there may be large operating scales:

- Any of the contemporary 5 technologies may be selected, depending on product range desired.
- Dual process is recommended - Union Carbide is probably the best.

9. SUGGESTIONS FOR TECHNOLOGY DEVELOPMENT

- Catalyst Development : Efforts by NCL, RRL-H, IIP or SIIR in collaboration with catalyst manufacturers
- Process Development : Efforts by IPCL/EIL
- Product Development : Efforts by each manufacturer of HDPE

10. INTRODUCTION ABOUT THE PRODUCT

The polyethylenes are classified into three categories according to density and molecular structure:

- (a) Conventional low density (LDPE) with a density less than 0.94gm/cm^3 and a highly branched molecular structure;

- (b) Linear low density (LLDPE) with a density below 0.94 gm/cm³ and a basically linear structure and short chain branches, and
- (c) High density (HDPE) with a density between 0.94 and 0.97 gm/cm³ and basically linear molecular structure having little or no side chain branching.

The success of a particular HDPE resin for a given end-use depends on the producer's ability to control certain resin characteristics very closely and, as nearly as possible, independently of one another.

The primary characteristics are the melt index (a function of molecular weight), the density, the molecular weight distribution and the presence or absence of long chain branching.

The important physical properties of HDPE are high stiffness modulus, toughness, relatively high softening point, electrical resistance and impermeability to water and air. The copolymers have, in addition, stress, crack and creep resistance. The melt properties may vary from low to high shear sensitivity and elasticity by adjusting the molecular weight and the molecular weight distribution. The properties of the melt are thus adjustable to fit the particular requirements to produce a desired moulded item, film, fibre or coating.

The major applications of HDPE are in the manufacture of containers, pipes, housewares, toys, filament, woven sacks, film, wire and cable insulation.

There are many processes for the manufacture of HDPE. The operations that are common to most of the processes are:

- Catalyst formation and activation
- Monomer purification (drying)
- Polymerisation reaction and addition of co-monomers
- Flashing and separation of unreacted monomer and co-monomers for recycle via a compressor

- Drying or purging of monomer (and solvents, if used) and catalyst deactivation
- Monomer and solvent recovery and purification by distillation
- Addition and blending of additives with the polymer powder or granules
- Melting, mixing, devolatilizing, melt filtering and pelletizing in an extrusion line
- Bulk storage, blending, bulk loading and packaging.

The major raw materials required for the manufacture of HDPE are Ethylene (99.99% pure), alpha-olefins as co-monomers (C_3-C_6), catalysts and additives (antioxidants, heat stabilizers, UV-absorbers, colouring agents and processing aids).

The major capital equipments used are main reactors, compressors, heat exchangers, tanks, vessels, columns, pumps, finishing equipment like extruders, dryers, etc.

11. HISTORICAL DEVELOPMENT OF TECHNOLOGY

Polyethylene has been known for almost 90 years. However, the commercial production began in late 1930s, when researchers at the ICI were able to develop a process for the conversion of ethylene into low density polymer by subjecting it to high pressure and temperature.

The catalytic polymerisation of ethylene at low pressure to high density polymer was discovered in the early 1950s in three separate laboratories, independently pursuing the problem.

12. STRUCTURE OF INDIAN INDUSTRY

At the moment Polyolefins Industries Ltd. (PIL) is the only unit manufacturing HDPE in India. It was started in 1968 with an installed capacity of 50,000 TPA, its production was 40,566 MT in 1989. Major constraint to higher production has been inadequate availability of ethylene. Once Maharashtra Gas Cracker Complex is commissioned, more ethylene may be available.

The import of HDPE in India started in early 1960s. The quantum of imports has grown from 75 MT in 1971-72 to 135,000 MT in 1989-90. There is negligible export of HDPE from India. The net domestic availability has grown from 20,500 MT in 1971-72 to 1,68,000 MT in 1989-90. This represents an average annual compounded growth rate of 12.0% during the last 19 years.

The consumption of 1,68,000 tonnes in India (1989-90) is distributed in following sectors:

Blow moulding	30,000 MT
HMW HDPE	18,000 MT
Injection moulding	30,000 MT
Pipes	9,000 MT
Woven sacks	65,000 MT
Other misc.	16,000 MT
Total	1,68,000 MT

Two different committees appointed by Govt. of India have projected following demand estimates:

Year	Demand (MT)	
	RWG on petrochemicals	Committee for perspective planning of petrochemicals
1989-90	146,000	205,000
1994-95	235,000	378,000
1999-2000	346,000	555,000

The Govt. of India has issued letter of intent to Reliance Petrochemicals Ltd. (100,000 TPA), IPCL (55,000 TPA) and Haldia Petrochemicals Ltd. (100,000 TPA) for the manufacture of HDPE. It is anticipated that all the three units are expected to be commissioned by 1990-1992. Table-2.5 in the report gives the demand/supply scenario till year 2000, from which it is evident that further additional capacity will be required to meet the demand during the 8th and 9th Plan period.

13. STRUCTURE OF INDUSTRY (INTERNATIONAL)

Since its discovery in the 1930s, polyethylene has grown to be the world's largest consumed thermoplastic material. The overall capacity of HDPE production, worldwide, in 1989 was some 10 MMT/year, with a regionwise break-up as given below:

Region	Capacity ('000 TPA)
Eastern Europe	1,000
Japan	1,013
North America	3,692
Western Europe	2,649
Rest of the world	1,800
Total:	10,154

Consumption of HDPE, in 1986, was 7,94,000 tons in Japan, 3,185,000 tons in U.S.A. and 19,46,000 tons in Western Europe.*

It has been estimated that during the decade (1981-1991) consumption of HDPE will rise at an average annual rate of 3.9% in Japan, 5.5% in North America and 3.1% in Western Europe. There will be a general trend in all regions towards increased use of HMW grades.

Closures of existing outdated HDPE capacity is expected, hence new HDPE production capacity will be required in all the three regions in the second half of the decade to meet the increasing demand. Any new investment at this time is expected to be for the production of both HDPE/LLDPE.

Consumption in other regions of the world (excepting the above three) is projected to grow at about 6-8% per annum.

Mexico and Latin America are expected to become more dependent on imports, despite capacity increase.

Countries, other than Asia and Africa are expected to become less dependent on imports. Significant increase in capacity and production are expected for Canada and Middle East.

* Please refer to Tables 3.6, 3.7 and 3.8 for details.

14. **STATE-OF-THE-ART AND COMPARATIVE EVALUATION OF CONTEMPORARY TECHNOLOGIES**

At least 30 companies have developed processes for manufacture of polyethylene. In addition, many other companies manufacture polyolefins under licence. Since licensing activity for this technology has been high, many processes have benefited from cross licensing. Notable for its popularity in the last five years is the Union Carbide vapour phase process for HDPE/LLDPE. Other recently active licensors include: BASF, British Petroleum, Du Pont, Hoechst, Mitsubishi, Montedison, Phillips and Sumitomo.

All the processes currently in use for the polymerisation of HDPE fall into one of the three categories:

- (a) Solution Polymerization,
- (b) Polymerization in suspension (slurry) or
- (c) Gas Phase Polymerization.

These processes, the economics of which are well established, use second and third generation catalysts, are capable of continuous or discontinuous operation, and are run as nearly closed loops, causing a minimum of pollution.

For the most efficient HDPE production technology, low investment costs, consistency of product, low operating costs and the yield of polymer per gram of catalyst are important considerations. Each of these polymerisation processes have their pros and cons with regard to these factors.

15. **SOLUTION PROCESSES**

In solution processes, ethylene monomer and co-monomers are dissolved in hot cyclohexane or other solvent suitable for polyethylene. Catalyst is introduced into the reactor and the temperature maintained above 140°-150°C - the polyethylene melting point - at reactor pressure. Polymerisation ensues giving out large heat energy. Some processes use water jacketting to remove reaction heat, while in others cooling is done by monomer refrigeration.

Solution processes are generally run at moderately high pressures and temperatures and require heavier wall reactors than other processes. However, because of the beneficial effect of increased temperature on reaction rates, catalyst efficiencies are usually higher with short residence times. This allows a higher production rate for a given size reactor.

Processes can be highly automated. For example, product molecular weight can be controlled by monitoring reaction parameters, and reactor conditions can be changed via feedback loops.

This type of process is inherently limited in the amount of polymer which can be kept in solution: 35-40% is the absolute maximum. Also, making high molecular weight polymer gives difficulties by putting high torque on the stirrer, dropping out of the solution as gel, and fouling the reactor. Thus, it is more difficult to make extrusion blow moulding grades of HDPE with solution processes, particularly those requiring a very high molecular weight component for high melt strength and die swell. On the other hand, solution processes generally excel in producing injection moulding grades, where narrow MWDs and lower MWs are required.

16. SLURRY PROCESSES

In this type of process, polymerisation of ethylene in suspension in a hydrocarbon diluent is carried out. Diluent is a poorer solvent of polyethylene. Hence the polymer or copolymer separates out from the diluent as fine particles. Hence, the viscosity of the diluent does not increase as rapidly as in the solution process. As a result, a higher concentration of polymer can be maintained in the reactors.

Some of the advantages of slurry-type processes include a higher volume yield of product for a given size reactor, as well as the greater ease of diluent removal. On the other hand, residence times are usually longer than in most solution processes. Still another advantage is the potential for making powders, suitable for rotomoulding, directly in the reactor, thus cutting out the expensive grinding step.

Reactors used for slurry processes may take any of several forms, from kettles to loop-type designs. The latter have high surface-to-volume ratios, which are advantageous for controlling reactor temperature, so necessary in maintaining molecular weight and molecular weight distribution as desired.

A disadvantage of the slurry type process is the greater difficulty of automation, since there are fewer ways to immediately sense any changes in the product itself. Also, slurry processes tend to make more 'twilight' material in switching from one grade to another. Also, many processes are susceptible to fouling.

In practice, most slurry processes, unless modified, tend to yield very high molecular weight materials which are not commercially useful. Thus, a "chain stopper" or chain transfer agent is often required. For Ziegler-type catalysts, hydrogen is generally used; it tends to give a "clean" product and is not extensively expensive.

Because of their tendency to make higher molecular weights, most slurry processes perform well in making blow moulding grades; in some instances, however, tandem reactors may be required for broad MWDs. Injection moulding grades are harder to make.

Suspension polymerisation, like the Hoechst-Ziegler technology, is still one of the most mature, flexible, versatile and widely used processes. It is the only technology capable of producing the wider range of HDPE polymers - and polymerisation of ultra-high molecular weight HDPE as well.

17. GAS PHASE PROCESSES

During the last one decade, vapour phase processes have become a commercial reality. Initially there were many problems, such as preparation of a suitable catalyst, excessive catalyst particle size and finding catalyst of sufficiently high activities along with the desired MW and MWD. Still another problem was in heat removal and in maintaining constant temperatures. Several companies have been very active in research, one being Union Carbide, which solved most of the technical problems listed above about five years back. Since then it has been the most widely used HDPE process. Reportedly, the process may require two, or

perhaps more, different supported catalysts to make a complete grade slate.

The process operates on a fluidized bed principle. At start up, a bed of catalyst-rich polymer is fluidized by an upward stream of ethylene, hydrogen, and possibly a carrier gas. As the particles begin to grow due to build up of polymer, larger particles tend to fall to the bottom of the reactor, where they are drawn off through a special valve system.

Reaction temperature is controlled by introducing chilled monomer through the bottom porous plate. For satisfactory conversions, a number of passes are required. The product from the reactors is low in ash and can be pelletized without further purification.

By its very nature, a fluidized process is expected to yield broad MWD products. In general this comparatively new technology has some limitations with respect to flexibility and consistency.

18. SALIENT FEATURES OF CONTEMPORARY TECHNOLOGIES

The salient features of contemporary technologies are given in Table 1. The economic evaluation attempted in Chapter four indicates that Union Carbide streamlined gas phase process appears to be the most economical of all the processes in terms of capital investment as well as production costs. In addition to having very direct process with a simple flow-sheet, Carbide process, with its fluidized bed reactor, achieves a high space time yield.

The evaluation further indicates that the Du Pont process is economically closest to the Union Carbide process. This is followed by processes of Dow and Phillips which are nearly equivalent to each other. The Solvay process is more expensive than Phillips process, but its advantage is that it is capable of producing HDPE in all MFI ranges, while Phillips process is limited to low MFI range. The processes of Hoechst and Stamicarbon are nearly equivalent but more expensive than the above processes.

TABLE - 1 : SALIENT FEATURES OF CONTEMPORARY TECHNOLOGIES

Process Licensor	Dupont	Hoechst	Mitsubishi Chemical Industries	Montedison	Phillips	Solvay	Stam-carbon	Union Carbide
Process type	Liquid phase solution process	Liquid phase slurry process	Liquid phase slurry process	Liquid phase slurry process	Particle from slurry process using loop reactor	Liquid phase slurry process using loop reactor	Liquid phase cow-foresure solution process	Fuidized bed gas phase
Temp. °C	180-270	70-90	90	85	85-100	80	>130	85-100
Pressure kg/cm ²	50-200	7-10	35	12	7-30	30	30	20
Residence time	2 min.	2 hr.	2 hr.	2 hr.	1.5 hr.	2.5 hr.	5 min.	5 hr.
Conversion per pass	95%	97%	N.A.	N.A.	90%	N.A.	N.A.	2%
Solvent or diluent	Cyclo-hexane	n-hexene or isobutane	n-hexene	n-heptane	Isobutane	n-hexane	n-hexane	-
Co-monomer	Butene-1 Octene-1	Propylene Butene-1	Butene-1 Propylene	Propylene Butene-1	Butene-1 Hexene-1	Propylene Butene-1	Butene-1 Octene-1	Propylene Butene-1 4 MP-1 Hexene-1

Process Licensor	Dupont	Hoechst	Mitsubishi Chemical Industries	Montedison	Phillips	Solvay	Stam-carbon	Union Carbide
Catalyst	Ziegler Natta	Ti compound supported on Mg compounds reduced with aluminium alkyls	Ti/V compounds reduced with Al alkyls	Ti Compounds supported on MgCl ₂ with Al alkyls in catalyst particle	1-3% chromic oxide on silica	Ti/V compounds supported on Mg compounds reduced with Al alkyls	Solution from catalyst of Ti, Mg and Al compound	Bis-tri-phenyl silyl chromate on silica alumina + dialkyl aluminium alkoxide
Heat removal	Adiabatic reactor	Jacket cooling	Jacket cooling	Jacket cooling	Jacket cooling	Jacket cooling	Adiabatic reactor	Cooling of feed ethylene adiabatic reactor
Polymer recovery method	Solvent stripping of molten polymer followed by pelletization	Centrifuging, then stripping with steam	Partial flash and centrifuging, then stripping nitrogen	Stream stripping of reactor slurry	Flash with heat added via super heated solvent vapour	Steam stripping of reactor slurry	Flash vaporisation, polymer in liquid form to finishing	Intermittent discharge through purge tanks
Yield	4.4 kg/gm catalyst	10 kg/gm catalyst	150 kg/gm catalyst	400 kg/gm of Ti	5-50 kg/gm catalyst	11 kg/gm catalyst	0.5 kg/gm catalyst	40 kg/gm catalyst

(Source: SRI report HDPE (No.PEP 19C) and Report of Technology Development, Advisory Committee for Polymers, appointed by Government of India.)

Although, licensors generally claim a wide range product capability, particular processes make certain ranges of products more easily than other processes do, because of specific polymerisation conditions and catalysts. As a result, there is not a single process which is most economical from point of view of all grades. A dedicated single product plant is always better for achieving better control and quality, than a multiple product plant or a swing process plant. The trend all over the world is to adopt a process dependent on the grades required to be produced. Thus, large plants having different operating processes, are making different grades and catering to distinct markets. Sooner or later, this will be a situation in India also, and we may find plants specialising in certain specific product grades. In view of this, there can not be an absolute answer that one technology is better than the other.

Product range capability is a less tangible factor in process selection than economics but is probably a major determinant in any final licensing decision.

Latest technical developments focus on greater sophistication in HDPE tailoring, better understanding of the complex relationships between fundamental properties and their effects on resin performance, effect of catalyst on MWD, *in situ* branching catalyst, post reactor modification of HDPE, search for better and less expensive additives and development of new resin grades.

19. TECHNOLOGICAL STATUS OF INDIAN INDUSTRY

Polyolefins Industries Ltd.

This company was promoted by NOCIL in collaboration with Hoechst AG, West Germany. The plant in India was constructed during 1966-68. The basic engineering was by Hoechst-Uhde and detailed engineering by Uhde. Around 60% of the capital equipment had to be imported and it largely consisted of proprietary equipment.

The manufacturing activities commenced in January 1968 with an installed capacity of 20,000 MT of HDPE per annum. The initial process technology was based on a comparatively low-activity catalyst. During the initial years catalyst as well as

comonomer i.e. n-butene-1 were imported. In 1977, the company switched over to a new highly active catalyst. As a result, polymerisation capacity of the plant increased to 30,000 TPA. In 1978, the company also started manufacture of Ziegler catalysts, partly for captive use and partly for market sale. This unit also manufactures pipes and other processed polyethylene products. In 1982, the company submitted an application to the Government to endorse the installed capacity as 46,970 tonnes per annum. The present licensed and installed capacity of the HDPE plant is 50,000 tonnes per annum. In 1985 the company introduced an ultra high molecular (UHMW) grade as well as low molecular grade of HDPE developed by its R & D centre.

The original technical collaboration agreement with Hoechst AG has been renewed twice, in 1978 and 1983, mainly for obtaining technical assistance to streamline the new process adopted in 1977 and also for the new product/application development.

During early 1960s, when the technology was acquired by PIL, it was appropriate and as efficient as any other technology at that time. However, this technology is now rather obsolete and rates poorly in comparison with current technologies in the world. For example, the current available technologies are operating with 80m³ size reactor, while PIL is still operating with 8 nos. 20 m³ size reactors, hence they are unable to install computerised process, control systems on such reactors, which affects their product quality. The current technologies are more energy efficient, use third generation highly active Zeigler catalyst and better dispersing medium.

Since PIL has a constraint on ethylene availability, due to which their HDPE output cannot cross 35-38 thousand tonnes a year, they have not opted for the new technological developments in their existing Hoechst process.

In comparison with other processes, Hoechst process is not the most economic one. However, this may not hold true for some specific grades of HDPE required by the market, e.g. the slurry process of Hoechst is better for producing high molecular and ultra high molecular grades. These grades are becoming more and more popular in India - HMHDPE film for packaging, and UHMHDPE grades for blow moulding of large size containers, such as 200 litre ring type of HDPE barrel.

In the slurry process, work on catalyst development is continuing. Many leading multinational companies are progressing in their R & D to develop a catalyst which can give polymer of lower densities, i.e. it can produce LLDPE as well as HDPE. When this is achieved, the slurry process will also have the same advantage as other swing processes, i.e. flexibility.

20. OTHER COLLABORATIONS

As stated earlier, Government of India has given licence to following three parties for the production of HDPE.

- (a) Indian Petrochemicals Corporation Ltd.(IPCL),
- (b) Haldia Petrochemicals Ltd. (HPL) and
- (c) Reliance Petrochemicals Ltd. (RPL)

These companies have obtained approval of foreign collaboration.

IPCL-BP Chemicals Ltd., UK - Gas phase process

BP Chemicals was the first company to combine the performance of superactive Ziegler catalysts with the advantages of fluidized bed polymerisation. The BP catalyst can produce full range of LLDPE and injection and rotational moulding grades of HDPE. They are working on development of extrusion and blow moulding grades of HDPE.

Under this collaboration, equipment worth Rs.24 crores (46% of total equipment cost) will have to be imported.

HPL-Phillips Petroleum Company, USA - slurry process (loop reactor technology)

Phillips process can produce product in different density and melt index range covering various categories, such as blow moulding, injection moulding, extrusion, rotomoulding etc.

Under this collaboration, equipment worth Rs.20 crores (43% of total equipment cost) will have to be imported.

RPL-Du Pont, Canada - solution process

Du Pont solution process is well known for high-flow and super high-flow linear polyethylene grades. The imported equipment cost is estimated at Rs.30 crores (cif) and know-how fees at Rs.40 crores.

21. GRADES OF HDPE

PIL manufactures and markets about one dozen HDPE grades for different uses (five for injection moulding, four for blow moulding and three for extrusion).

IPCL, which is going to adopt technology developed by BP Chemicals, is going to produce seven grades for injection moulding and two grades for rotational moulding. The development of extrusion and blow moulding grades is still under development in the BP group technical department.

Haldia Petrochemicals Ltd. is expected to produce four injection moulding grades, two blow moulding grades, two extrusion blow moulding grades and one film extrusion grade. In addition they will sell polymer in fluff form.

Reliance Petrochemicals Ltd. proposes to produce all the standard grades now used in India and certain speciality grades.

It is seen that Indian processors will have about 30 grades to choose from, as against their counterparts in USA, who have the choice of about 330 grades.

22. TECHNOLOGY ABSORPTION AND DEVELOPMENT EFFORTS

Absorption Efforts at PIL

PIL's current investment in R & D is approximately Rs.4.5 crores, and annual recurring cost is around Rs.75 lakhs to Rs.1 crore. They have most of the facilities for characterisation of polymers and also for pilot processing by different techniques such as injection moulding, blow moulding, extrusion etc. They also have a separate building (area 3,000 m²) for research centre at their factory premises in Thane. Their R & D manpower consists of about 30 persons.

The following R & D projects are in progress at their research centre:

- (a) Development of superactive catalyst for polymerisation and co-polymerisation of lower olefins.
- (b) To dimerise and oligomerise ethylene, propylene, and butene for manufacture of alpha-olefins.
- (c) To generate industrial know-how for co-polymerisation of ethylene with propylene for the production of wax or low molecular weight polyethylene.
- (d) Modification of polyolefin polymers such as polyethylene, polyethylene through incorporation of fillers, elastomers, and other additives to obtain special grades with reduction of material cost and/or improvement in physical properties.
- (e) Improvement in properties of present grades and development of new grades of HDPE.
- (f) Improvements in existing production process.

The company has been able to indigenise part of the catalyst system, improve the efficiency of the process and reduce energy consumption. In addition, it has developed new grades of product like paper coating, UHMWHDPE, fire retardant grade and products with high Environmental Stress Crack Resistance.

PIL has made following specific efforts in the absorption, adaptation and upgradation of HDPE technology.

- (i) **Catalyst System:** Modification in the catalyst system in order to produce the appropriate grades of product required by the market in India e.g. product with improved Environmental Stress Crack Resistance (ESCR).

Secondly, today only the active component of catalyst is imported, quantity of which is too small.

- (ii) **Import Substitution for Polymer Additives:** Initially all additives were imported; today only one particular type of antioxidant is imported.
- (iii) **Modification in Dispersing Media:** PIL is at present using an indigenous product from Hindustan Petroleum Corporation Ltd after suitable pretreatment.
- (iv) **Production of Butene-1:** When PIL started its production, neither butene-1 nor the appropriate raw materials, from which it is derived, were available. As a result, PIL started producing butene-1 by dehydration of butanol which was freely available.
- (v) **Reduction in Raw Materials and Energy Consumption:** A saving of around 1% and 15% in the consumption of ethylene and utilities respectively has been achieved, compared to the levels at beginning of production.
- (vi) **Product Development:** PIL has developed and marketed UHMHDPE, blow moulding grades with high ESCR, low molecular weight PE waxes, fire retardant grades etc.

They have now fully absorbed the technology. In fact, if a similar plant were to be erected today, there would be a great reduction in the foreign exchange quantum of capital goods. Compared to their own import of around 60% of capital goods by value in 1966-68, they now expect the import level for capital goods to come down drastically for an HDPE project.

They are in a position to transfer technology to a third party or for their own expansion project, without the need for further collaboration, if such a hypothetical situation would arise. However, such a situation will not arise because their operating technology is not contemporary, and hence no one will need it. If they are allowed to expand their capacity substantially, they may like to go in for improved contemporary technology relating to the slurry process, and then the technology tie-up will have to be entered into.

23. DEVELOPMENT EFFORTS IN INSTITUTIONS

At the moment there is no research and developmental programme in any of the national laboratories concerning the catalyst synthesis or process development for polyolefins manufacture. About two decades back, in the National Chemical Laboratory some basic work was done, but there was no tie-up of industry with these research projects.

The Indian Petrochemicals Corporation Ltd., have the biggest stake in the polyolefins technology, hence they have started research programme on the synthesis of catalyst as well as process development. They claim to have developed, on laboratory scale, processes for the synthesis of HDPE by solution and slurry process. In order to scale-up these processes, IPCL has planned to set up a pilot plant for polyolefins at a cost of Rs.3.5 crores. In addition, they plan to install a pilot plant for the gas phase process at the cost of Rs.7.0 crores in near future.

24. PRODUCT DEVELOPMENT

The direct customers of PIL are mostly in small scale sector who buy the HDPE granules and process them into various end-products by different processes.

PIL is very close to its customers and gives them all the help by way of proper selection of grades, machinery, design of moulds, trouble shooting in processing and development of various end-products.

PIL has also done a considerable amount of product application development work not only in order to help the processors, but also to expand the HDPE market in India.

In some cases, PIL not only has developed the suitable HDPE grades, but also the end-products and supplied them to consumers for quite sometime. Later on, they have passed on this activity to other processors in small sector, e.g. containers for vanaspati and lube oils.

PIL was also the pioneer in introducing HDPE pipes for natural gas, water supply and sewerage systems, and similarly also the grades for detergent and pesticide bottles.

PIL has recently developed UHMHDPE and is offering all the help for product/application development to its processors.

25. TECHNOLOGY GAPS

Technology gaps in Indian HDPE industry are mainly in the following three areas:

- (a) Catalyst research and development
- (b) Process development and research
- (c) Product development.

26. FUTURE COURSE OF ACTION

A strategy for indigenous technology development has been suggested under which catalyst development should be undertaken at national laboratories, with which catalyst manufacturers should be associated. The process development should be undertaken at IPCL, with which EIL should be associated in order to generate basic design data. Later on IPCL/EIL can transfer this technology to third party. The product development should be done by the manufacturers of HDPE themselves. The expenses of technology development should be shared by all the polyolefin manufacturers.