EXECUTIVE SUMMARY

LLDPE is the youngest member of the polyolefin family. Although LLDPE was produced by DuPont, Canada sometime in sixties, it is only during the last decade its importance and potential was recognised by converters and end users.

i) **Structures and Properties of LLDE**

LLDPE is a copolymer of ethylene with one or more alpha-olefins (C4-C8). It is a linear polymer having short side chain branches of uniform size and regularity. Density of LLDPE ranges from 0.900 to 0.940 gm/cm^3. This low density in the linear polymer is caused by the presence of short side branches.

Mechanical properties like tensile strength, stiffness, heat resistance hardness and others increase as density increases, whereas permeability, ESCR, impact strength and tear strength decrease. Density is a measure of crystallinity.

Melt flow index is a measure of melt viscosity or the molecular weight of polymer. LLDPE is available in the MFI range of 0.1-100. Molecular weight distribution gives an idea of the range of molecular sizes in a polymer and its processability. LLDPE has a narrow MWD and exhibits higher impact strength and better low temperature toughness. LLDPE resins are stiff in shear and soft in extension.

ii) **LLDPE Market Structure**

In 1988 world LLDPE production was 4.2 million tonne which was about twice the production in 1985. The projected value of world production in 1993 is 7.5 million tonne. Rapid expansion of LLDPE capacity coupled with successful capture of many existing conventional LDPE markets was the main reason for LLDPE growth in the last five years. The U.S. LLDPE market currently accounts for almost two-thirds of world demand. The Western Europe LLDPE market has now reached 1 million tonne. Japanese consumption of LLDPE in 1988 was about 300,000 MT. Canada is the second largest world

LLDPE producer and in 1988 its production was about 775,000 MT.

LLDPE penetration into the low density market in the developed regions has been quite steady. By 1995 LLDPE's share in the low density market of USA is expected to reach more than 50% and that in the world about 35%.

LLDPE has been very successful in the U.S. Market of trash bag film, injection moulding, communication wire jacketing, and rotomoulidng. Pallet stretch wrap film is a new application area. In Western Europe, pallet stretch wrap is nearly as large a market for LLDPE film resin as trash bags. Pipes and conduits have a much larger proportion of the non-film LLDPE market. In both USA and Western Europe, film grades have a share of 75% of LLDPE market, whereas in Japan film grades occupy 50% of the LLDPE market. In Japan little less than 20% of LLDPE is used in paper treating.

In India, the first LLDPE plant of 80,000 TPA capacity is likely to be commissioned soon. Through IPCL's market seeding programmes which started in 1985, about 65,000 MT of LLDPE, mostly film grades, has been introduced in the Indian market. LLDPE consumption in India is likely to grow to about 145,000 MT in 1994-85. Price of LLDPE has been less than that of LDPE over last five years.

iii) Review of LLDPE Technology

There are three broad types of polymerization processes based on the phase of reactants and products. They are gas-phase process, solution phase process and slurry phase process.

Gas phase fluidized bed process was originally developed by Union Carbide. Subsequently BP Chemicals commercialised a similar process. Today, more than 70% of the world LLDPE capacity is based on gas phase process. In this process purified ethylene and comonomer are fed to a large, vertical reactor. These reacting gases along with an inert gas fluidize the growing polymer particles. The hot reaction gases at the top of the reactor, carrying the heat of reaction are cooled in a Shell and Tube heat extinguisher using cooling water. The cooled gases are compressed and fed back to the bottom of the reactor. Catalyst is injected into the fluidised bed in the particle form. Polymer product is withdrawn into a product discharge vessel, from where it is degassed, passed through an additivation stage, extruded and stored. This process is characterised by its simplicity and stable reactor operations.

Solution processes for LLDPE have been commercialised by DuPont, Dow, and Stamicarbon. In these processes polymerization takes place in an inert hydrocarbon solvent, at a temperature above the melting point of the polymer. Dow process is not available for licensing. DuPont process has been widely licensed whereas Stamicarbon is relatively new in the area of licensing. Both have their reactors operating under adiabatic condition. These processes differ in their use of catalyst, reactor conditions and their down-stream recycling steps. Residence time is very short and this makes the processes very flexible in terms of grade change. Solution processes do not have any limitations in the use of higher alpha -olefin comonomers but it is very difficult to make low MFI grades.

Slurry process for LLDPE is not very common. However, Phillips who have widely licensed HDPE process, have started producing certain LLDPE grades.

CdF Chimie, known for their high pressure LDPE process, have a retrofit high pressure process, using Ziegler catalyst to produce linear PE with wide density range, 0.910—0.965 g/cm^3. This technology does not compete with other linear PE processes. This has been developed to enable existing high pressure LDPE producers to retrofit their plants to produce LLDPE grades.

iv) Application Performance of LLDPE

LLDPE has wide ranging applications like film, injection moulding, rotational moulding and blow moulding. About 75% of LLDPE is used in film, world over. This is because of its excellent mechanical properties and high draw-down ratio. Very thin LLDPE films have high puncture resistance, good ESCR and low temperature resistance. In India, LLDPE is mostly being used in blends with LDPE. At present there is a strong market for stretch film where 100% LLDPE can be used. In injection moulding LLDPE grades which are stiffer and more resistant to impact and distortion at elevated temperatures, are replacing many of the LDPE and HDPE grades. Low temperature impact properties are superior to those of polypropylene. Rotational moulding takes advantage of the higher impact strength and very high ESCR of LLDPE compared to LDPE and HDPE.

Extrusion of pipes or use in wire and cable insulation has been difficult with 100% LLDPE. But today licensors are capable of producing broad MWD LLDPE which perform very well in such applications.

v) **Indian Industry Status**

First LLDPE plant is likely to be commissioned by the end of 1991, at MGCC, Nagothane. This plant of IPCL has a swing capacity of 135,000 TPA. The second plant of 100,000 TPA swing capacity will be commissioned by 1992 at Hazira by RPL. IPCL will be using BP Chemical's gas-phase-fluid-bed process, whereas the Hazira plant of RPL is licensed by DuPont Canada. At MGCC raw material will be supplied by the gas-cracker plant inside the complex whereas the Reliance plant is based on imported ethylene at present.

IPCL started their market seeding activity in 1985 with an import of about 2000 MT of LLDPE, mostly film grades. Analysing the reaction of the processors and the impact on the market, they formulated their strategy for the subsequent years. Mostly this was used in blends with LDPE as processing of 100% LLDPE in LDPE machines was difficult in film production lines. Since then lot of trials and evaluations have gone in trying to retrofit the conventional LDPE extruders and other machines for processing 100% LLDPE. IPCL is now in a position to guide the industry on processing of 100% LLDPE with or without modification of the conventional extruders.

In polymer recycling industry in India, volume of recycle material is very large but technology employed is poor. It is reported that during 1987-88, the total production of recycled material was over 3 lakh MT. Scientific methods used by the developed countries, are not being followed by the Indian processors. General procedure followed for reprocessing is extrusion, followed by granulation. Recycling procedure for LLDPE is similar to that of LDPE.

vi) **International Industry Status**

Gas-phase-fluid-bed process accounts for about 70% of the world LLDPE capacity. All LLDPE plants have the potential to produce HDPE. Growth of LLDPE capacity in USA has been quite phenomenal and by 1997 LLDPE is likely to have more than 50% share in the total low density PE Production. In 1993, U.S.A., Western Europe and Japan will be net import rs. Primary exporting regions will be Canada, the Middle-East and China.

vii) **Latest Development & Future Scenario**

In LLDPE market there is a trend towards very low melt index grades for production of very tough film for heavy duty sacks etc. Higher alpha olefin grades of LLDPE can also replace LDPE in this nonspeciality market, if premium on these copolymers is limited to 10 to 15% over classical LDPE. Generally LLDPE grades have narrow MWD providing good toughness. In future better processability could be achieved by broadening MWDs; the lower mechanical properties of such grades could be partly compensated by using higher alpha-olefin comonomers. There is a demand for very low density PE grades which have the flexibility of EVA. One major trend for polyolefins in general, is towards more reactive and functionalized material system.

viii) **Technology Absorption & Gaps**

In India expertise is available in the fields of process engineering, detailed engineering, procurement, construction, plant operation, management and product applications technology development. Technology is said to be absorbed totally when capabilities are also developed in the areas of catalysis, process chemistry, reaction engineering, process design, and product grade development.

Research and development have been going on in the country and individual organisation have achieved high level of excellence. To achieve self-sufficiency in polyolefin technology, an orchestrated approach involving industry, research organisations and the academic institutions, has to be evolved. The lead should come from the operating companies. In this regard necessary process design package for a pilot plant has already been acquired by IPCL from M/s BP Chemicals. This unit will be similar to the commercial unit being set up at Nagothane. A scheme has been drafted by IPCL involving engineering consultants and R&D organisations.

ix) **Recommendation**

(a) In the polyolefin technology development, technology gaps mainly remain in the areas of catalyst and process development. It has been widely accepted that the low and medium pressure Ziegler processes are the most economical and Versatile processes. Intensive development activities should be centered around such a process.

(b) Experience on a plant operating on Ziegler process has been acquired by an Indian company. This fact alongwith the experience that has been gained in the allied areas of equipment, maintenance, corrosion and safety can be put together when a total package is prepared.

(c) The technology development effort may be directed to be carried out in the following broad manner :

- Study of catalyst recipes and yield data.
- Experimental runs on pilot plant for varying process conditions.
- Product grades characteristics, features and additivation recipes that are required to achieve these.
- Plant/unit operational features and facilities, systems for safe and reliable normal run, start-up and shutdown operations.
- Property Data generation for thermophysical and hydrodynamic application for all process streams.
- Study of reaction mechanism and modelling based on experimental data generated.
- Reactor parameter optimisation and fixing of reaction conditions.
- Process design of all equipments and associated systems like piping and instrumentation.
- Developing appropriate control schemes for optimal, safe and reliable operation of the plant.

(d) To absorb a technology, a combined approach involving industry, research organisations and academic institutions, need to be evolved.

Indeed, to mount such an effort with a reasonable assurance of success in a defined time period, it is very necessary to organizationally integrate an interdisciplinary group of personnel with specializations in chemistry, polymer science, catalysis , chemical reaction engineering and process engineering under the leadership of an operating company.