0. EXECUTIVE SUMMARY

0.1 PRODUCT INTRODUCTION :

0.1.1 Polyester filament yarn (PFY) is a long chain of synthetic polymer composed of an ester of a substituted aromatic carboxylic acid such as terephthalic acid. Polyester filament yarns are manufactured in a wide range of deniers and properties to suit virtually all textile requirements.

0.1.2 Polyester filament yarns are manufactured either from molten polymer or polyethylene terephthalic acid (PET) chips by melt spinning process. In this process molten polymer from a manifold is metered through various spinnerettes, having number of holes, to form filaments. These filaments are then solidified by air-quenching and wound on take-up winders after application of spin-finish. The yarns manufactured could be UDY (un-drawn yarn), POY (partially oriented yarn) or FDY (fully drawn yarn) depending upon the winder speed and heatsetting methods.

0.1.3 PET is made by condensation of pure terephthalic acid (PTA) or a derivative such as di-methyl terephthalate (DMT), with Ethylene Glycol (EG). The reaction involved is direct esterification in case of PTA and trans-esterification in case of DMT, followed by polycondensation. The reaction is carried out in one or more reactors above atmospheric pressure and at elevated temperature. Excess glycol is used for carrying out the reaction, which is recovered during polycondensation and recycled. Proper control of temperature, pressure, time of reaction and vacuum is necessary for better quality of polymer and for this, different designs of reactors and new and better additives and catalysts are used.

0.1.4 Out of the two alternative raw materials i.e. DMT and PTA, it is advantageous to use PTA as it gives 15% higher production and requires less investment in capital equipments; as well as requirement of glycol is lower. In case of DMT, methanol is generated as a by-product, which is hazardous in nature and requires special plant and equipments. During recent years, almost all new plants all over the world are being put-up with PTA as feedstock but due to availability, the use of DMT is still continuing though its percentage share as a feedstock for polyester is enormously declining.

0.1.5 PET was earlier manufactured by batch process having a small capacity of 1 to 2 TPD and without close control of process parameters. The spinning process used was based on grid-star melting, with poor control on performance, followed by winding of yarn at low speeds, yielding small packages. Over a period of time, developments have resulted into large size of batches and continuous polymerisation process giving mass production. Sophisticated instruments and computer controls are used for monitoring

the process. Single polymerisation plant having size of 200 TPD is now possible. Grid-star spinning is replaced by extruder melt-spinning in case of PET chips. Spinning processes directly coupled with polymerisation, having compact high speed spinning plants are preferred now for cost economy. Spinning plant output has increased as number of spinning positions and number of ends per position has increased in a spinning line.

0.1.6 Along with the process developments, product developments have resulted into manufacture of partially oriented yarns and fully drawn yarns. Moreover, POY and PFY do not require some of the subsequent processes like drawing. New and better products such as finer denier per filament, trilobal and multilobal yarns, high tenacity industrial yarns, different lustre yarns, cationically dyeable yarns, mass-coloured yarns etc., are now produced having better product properties for different end uses.

0.2 STATE OF ART (INDIAN) :

0.2.1 Total licenced and installed annual capacity as on 31.3.86 was 74281 and 66142 M.T. respectively. The Government has recently liberalised its licensing policy and licenced capacity is likely to increase to 4 lacs M.T. per year. Thus a phenomenal growth is expected in near future. The capacity could even be higher, if manufacturing capacity for other synthetic yarns such as NFY is diverted to PFY as allowed under broad-banding policy.

0.2.2 Major manufacturers of PFY in India are Baroda Rayon, Century Enka, Garware Nylons, J.K. Synthetics, Modipon, Nirlon, Orkay, Reliance and Shree Synthetics. The production of PFY has increased from 199 tonnes in 1969 to 99,917 tonnes in 1987. The production was just 9250 tonnes in 1980 and thus major growth has been only during the last seven years. The demand projections by market analysis shows that demand of PFY will be 1,65,000 M.T. by 1990 and 2,67,000 M.T. by 1995. The import of PFY is declining. Export is quite negligible even in form of fabrics. Performance of Indian industry is quite impressive both in physical and financial terms and they have been virtually enjoying a seller's market position.

0.2.3 Source of technology for PFY manufacturing is either from PFY manufacturing companies like Du-Pont, Toray, Teijin or from engineering companies like Zimmer, Lurgi, Didier, Inventa, Chemtex etc. Technology from manufacturing companies is comparatively better as they have vast production experience. They have a research and development base and have developed new products and established production parameters for process optimisation. Technology from engineering companies is comparatively cheaper and due to experience of engineering companies in plant erection and basic engineering, it offers better plant design and equipment selection. Due to small size of plants and quantum of technical know-how

fees, Indian industries have preferred to use technical know-how from engineering companies till 1980. Frontline manufacturers were reluctant to offer technology due to the small size of plants. During 80's M/s. Reliance have obtained latest technical know-how from Du-Pont. M/s. Indian Rayon have proposed to obtain Toray's technology. Plant sizes in India, have remained below economical level though number of plants have increased. Technology in most of the plants is based on old batch process having small sizes of batches and number of small polymerisation and spinning lines.

0.2.4 Due to phenomenal growth of PFY industry, ancillary industries such as twisting, texturising, etc., have grown to a considerable extent. There are about 300 texturisers and 2000 twisters in the country operating at small scale and medium scale level.

0.3 STATE OF ART SCENE (INTERNATIONAL) :

0.3.1 Global Scenario :

World production of polyester filament yarn has increased from 3600 tonnes in 1960 to 27,94,000 tonnes in 1985. Major producers are Du-Pont, Celanese (USA), Hoechst (W.Germany), Chung Shing, Far Eastern, Hualon Teijin, Nan Ya Plastics, Oriented Chemical (Taiwan), Kolon, Sung Yong, Tong Yang (Korea), Toyobo, Toray, Teijin, Kanebo (Japan). Production of PFY is showing a shifting trend from western countries to newly developed industrial countries like Korea and Taiwan. Percentage share of Western Europe and U.S.A., in the total world production has reduced from 68% in 1970 to 38% in 1985. Polyester is becoming more popular amongst all the synthetic fibres. Its share, in total synthetic fibre produced in the world, has increased from 34% in 1970 to 49% in 1985.

0.4. CONTEMPORARY TECHNOLOGIES :

0.4.1 Supplies of PFY technology are Zimmer, Inventa, Lurgi, Didier, Toray, Du-Pont, Teijin, Enka, Snia and Samsung. All these suppliers now offer both batch and continuous polymerisation process with PTA as feedstock, and POY and FDY high speed spinning systems. Salient features of contemporary technologies have been depicted in Annexure 8. Basic process of polycondensation and spinning remains the same in all the technologies. Difference lies only in the hardware design and product development know-how.

0.4.2 Zimmer has supplied polyester plants all over the world. It has developed a disc type polycondensation reactor which ensures acceleration of reaction by faster evaporation of glycol and uniform quality of polymers. Process uses microprocessor controls. Process ensures low energy consumption. It has supplied a polycondensation plant having a capacity of 200 TPD.

0.4.3 Inventa has supplied 10 continuous and 50 batch process plants all over the world. It uses a special reactor having rotating cage without centre shaft. Reactor agitators are having bottom mounting providing for a vibration-free agitator shaft. Due to this design, shaft remains free from oligomer deposits. Vacuum and vapour system ensures a reliable operation to eliminate deposits of sublimates causing blockage of pipes.

0.4.4 Lurgi is supplying technology for manufacturing synthetic yarns since 1964. It has supplied 40 plants for polyester polymer, fibres and yarns all over the world. Polycondensation takes place in 3 series connected autoclaves. The third autoclave is designed as a disc reactor. The product passes consecutively through all rotating discs which guarantee a defined product residence time.

0.4.5 Didier has developed their own spinning technology. For batch polymerisation process, it has a tie-up with M/s. Agfa Gavert and for continuous process with M/s. Sam-Yung of Korea. Didier has supplied 20 plants for polyester polymer, fibre and yarn all over the world. Didier offers a special cage type reactor for final polycondensation. In this design, inside the reactor there is a cage. In the middle of cage a shaft having wire mesh attached to it, is rotating. On side walls, baffles are provided for cleaning of walls. Didier has developed compact spinning plants. Spinning plants are duly assembled on a steel structure and occupies 3 to 7.5 metre height of a building in place of conventional 15 metre height.

0.4.6 Toray is a leading manufacturer of PFY in Japan. It has developed speciality yarns suitable to Asean markets such as Trilobal, thick and thin, hi-count, bi-shrinkage, cationically dyeable, fine denier per filament, co-polymer filaments, etc. Toray offers its own-spinning equipments and high speed winders. Toray's continuous process has 2 esterification reactors and 3 polycondensation reactors. Its polycondensation reactor is having screw vanes mounted on rotating shaft.

0.4.7 Du-Pont is pioneer in synthetic fibres and supplies a technology of continuous polymerisation directly coupled with spinning. Spinning lines are having 32 positions and 16 ends per position. Du-Pont has developed speciality yarns such as non-circular cross-section, fine denier per filaments and high tenacity yarns. Du-Pont offers both. process and product know-how.

0.4.8 Teijin is a world reputed manufacturer of synthetic yarns. It has developed speciality yarns such as bi-component and multi-component filament yarns, ultrafine filaments, new silky yarns having fine touch, cationically dyeable yarns etc. The process employs an esterification reactor of horizontal type, the inside of which is divided into plural chambers with

partitions. In every chamber agitation is performed with the stirrer blade attached to one common reaction shaft. Polycondensation takes place in two prepolymerisers and a finisher. The finisher has a rotating shaft having radial vanes which are adapted to impart a forward movement to the molten reactant in the reaction compartments through overflow openings.

0.4.9 Enka is a division of Akzo group and offers technology to its group companies only. It has a large research centre. Enka has developed a special design polymer finisher having a pair of horizontally supported parallel drive shaft adopted to be driven in opposite directions and positioned throughout the length and just above the bottom of the housing. Thus there is a two zone tubular heated housing. There is a screw conveyor for conveying the resultant molten polymer. By use of this reactor a highly viscous PET having high degree of polymerisation and low percentage of free carboxyl groups is obtained.

0.4.10 Snia offers spin-draw and spun-dyeing technology and POY technology with batch process of polymerisation.

0.5 CRITICAL EVALUATION OF CONTEMPORARY TECHNOLOGIES :

0.5.1 While evaluating a technology following aspects are looked into :

(a) Manufacturing process and process know-how

(b) Product-mix

(c) Plant design and cost of capital goods

(d) Plant capacity

(e) Know-how and basic engineering

(f) Know-how fees.

Contemporary technologies are divided into two broad categories. Category I is technology supplied by frontline manufacturers and Category II is technology supplied by engineering companies. Technology supplied by Category I companies is more expensive. It is best suited for a new company having large size of plant and varied product mix. Technology supplied by Category II companies is less expensive and is suitable for plants with standard products and moderate size. Wide range of plant and equipments having different designs are available worldwide and a proper evaluation of capital equipment should be carried out before selecting a technology supplier.

0.6. LATEST DEVELOPMENTS AT INTERNATIONAL LEVEL :

0.6.1 Major change in technology at international level is change in feedstock from DMT to PTA for cost economy. The plant sizes have increased from 2 to 10 t.p.d. to more than 50 t.p.d. for achieving economy of scale. Latest development is in construction of large size plants having continuous process coupled with the flexibility of production of speciality yarns for a small percentage of the total plant capacity.

0.6.2 Spinning plant efficiency is being raised from 95-97% to 99% by better quality of polymers having less deviation in melt viscosity, melt temperature and melt pressure. Yarn breakage and rejections are reduced by efficient quenching process and vibration-free take-up machines. With the increase in number of spinning positions, emphasis is being put on design of compact spinning plants. For better control and online monitoring, microprocessor is installed which diagnoses and rectifies the fault before breakage. For control of yarn properties, better spin finishes are used. For more uniform output and large package size, automatic doffing system is used in place of manual doffing.

0.6.3 Very high speed winding in the range of 6,000-10,000 r.p.m. for manufacturing FOY is in trial stage. This one step process eliminates integral drawing operations and yarns with better dye affinity can be manufactured. This process is more useful for speciality yarns. This process for manufacturing FOY is not yet commercialised even at international levels. After having commercialised, it will require substantial modernisation of weaving and yarn preparatory processes to make use of FOY.

0.6.4 Spin-draw process with high speed and compact machine is another area of development for making Fully Drawn Yarn. For obtaining coloured yarn spun-dyeing and mass colouration technology is developed. Mole ratio is PTA to EG has been reduced to 1:1.08 from 1:1.7 and mole ratio of DMT to EG has been reduced to 1:1.56 from 1:2.0. The ratio indicates the requirement of EG in moles against one mole of PTA or DMT.

0.6.5 Technology for manufacture of PFY has reached at almost maturity stage. Research and development efforts are towards product development for new uses and also better quality of polyester filament yarns. Products having antistatic characteristics, better dyeing affinity, silky and fine touch etc., are being developed.

0.7 STATUS OF INDIAN INDUSTRY

0.7.1 Nirlon started manufacturing PFY for the first time in India in 1967. Its present licensed capacity is 3500 M.T. and installed capacity is 5,000 M.T. It is operating on conventional batch process with small sizes of batches.

With the growth of the company, it has added more polymerisation lines of small capacity but technology has remained obsolete and progress in updating technology is far below a contemporary level. Due to this, it now finds difficulties in facing the competitive market.

0.7.2 Modipon started manufacturing PFY in 1973. Its present licensed and installed capacity is 3500 M.T. It is having conventional batch process with small batch sizes. It has recently gone for modernisation of its plant with collaboration from M/s. Snia whereby spin-draw and spun-dye technology will be adopted. Modipon has developed certain speciality yarns. Due to this they have been able to survive in the competitive market though their plant capacity is much below the level of economy of scale.

0.7.3 Petrofils started manufacturing PFY in 1977, with the conventional spinning plant and technical know-how from M/s. J.K.Synthetics. Subsequently they set up a polymerisation plant with technical know-how from Inventa and POY spinning plant with technical know-how from Lurgi. Company's performance is impressive. It has a batch process of considerably large batch size. Its present capacity is 7000 tonnes. It is going for substantial expansion with modern technology in near future.

0.7.4 Orkay started manufacturing PFY in 1982 in technical collaboration with M/s. Didier. Its licensed and installed capacity is 6000 M.T. It has a conventional batch process with comparatively large batch size and modern plant design. The spinning plant is compact and modern. Its performance is quite impressive.

0.7.5 Reliance has the largest plant for manufacture of PFY in the country having started production in 1982. Its capacity is 25000 M.T. per annum. It has the latest technology of continuous polymerisation directly coupled with spinning, from Du-Pont. Due to large and economical size of plant and better technology, its product enjoys a good reputation in the market and its financial performance is very much encouraging. It uses PTA as feedstock which results into economy in cost of production. It has its own facilities of texturising and weaving and is now going in for backward integration, by entering into the manufacture of PTA and EG.

0.7.6 Baroda Rayon started manufacturing PFY in 1978 by conversion of existing nylon filament yarn line into manufacture of PFY. Its capacity is 1777 M.T., which is far below the minimum economic scale and it is operating with a conventional technology of batch process and POY spinning. Its product doesn't enjoy good reputation in the market. It has developed polyester viscose blended yarns. BRCL is going for substantial expansion with Korean technology.

0.7.7 Shree Synthetics started manufacturing PFY in 1972 in technical collabo-

ration with Chemtex. Its present licensed and installed capacity is 3500 M.T. It has conventional batch process with small batch sizes. Its plant size is below the level of minimum economic scale and hence company's performance is adversely affected in last year.

0.7.8 Century Enka is having collaboration with Enka International. It started manufacturing PFY in 1978. Its present capacity is 6600 M.T. It has a conventional batch process. It is going for substantial expansion in its capacity with modern continuous process.

0.7.9 Garware started production of PFY in 1975-76 with a small capacity of 360 M.T. Its present capacity is 3500 M.T. It has a conventional batch process technology with high speed spinning plant.

0.7.10 New units such as DCL Polyester, Indian Rayon, Bharat Synthetics, Raasi Synthetics, Khoday Distilleries, are coming up with continuous process technology. DCL has Inventa technology of continuous and batch process. 85% of total capacity is continuous process and 15% is batch process for speciality yarns. M/s. Indian Rayon has proposed the same type of combination but having additional facilities for U.D.Y. It has proposed to have Toray technology. Raasi Synthetics has proposed Chemtex collaboration. Bharat Synthetics has proposed Didier technology. All these plants will have an installed capacity of 15000 TPA each.

0.8 TECHNOLOGY ABSORPTION AND GAPS :

0.8.1 Technology Absorption :

(a) National level research institutions like SASMIRA and National Chemical Laboratory are actively engaged in technology absorption efforts for PFY manufacturing. They undertake certain research projects for study and optimisation of production parameters. These studies are on conventional batch process of polymerisation and POY spinning process. Studies are conducted on pilot plants and sometimes results are utilised at scale up level in industry.

(b) Research institutions do not have scale-up test facilities. Due to lack of co-operation from industry, results of studies, sometimes remains on paper only. Industry is operating in watertight compartment. Research institutions are not engaged in developing latest technology which will have more commercial value. For this purpose an organised effort is required.

(c) Private research institutions, like Sir Padampat Research Centre (SPRC) of M/s. J.K. Synthetics, is carrying out many research projects in the field of synthetic fibre and has fully absorbed and

developed know-how for conventional technology. For latest technology however, SPRC also has to depend on foreign know-how.

(d) Technology absorption efforts have resulted in indigenisation of certain equipments like reactors, condensers, fractionating columns, ejectors, dryers, storage tanks etc. Many spares and sub-assemblies are now developed in the country. But due to lack of consistent demand, equipments like extruders, spinning beams, take-up winders, polymer metering pumps, etc., are still imported.

(e) Tendency of industry to have package import for the sake of performance guarantee, hampers the growth of indigenous machinery manufacturers and to that extent technology absorption efforts get retarded.

(f) Technology absorption efforts have resulted into self-sufficiency in manufacture of raw materials for PFY industry such as DMT but there has been a considerable time lag in indigenous manufacture of PTA.

(g) Due to prevalence of seller's market, industry has refrained from know-why exercises and opted for package import of available technology and commercialising the same in shortest possible time. This has resulted into quicker returns for Indian industry in the past. The scenario is changing now due to liberalised licensing policy.

(h) The industry has only made efforts in increasing its production capacity, in small steps, but there has not been any substantive effort for change in the level of technology.

(i) Technology absorption efforts were retarded due to constraints like non-availability of PTA indigenously and lack of innovative management of Indian companies.

0.8.2 **Comparison between Studied Units :**

(a) Majority of units manufacture POY for resultant 76-80 and 150 deniers yarn. Quality of PFY/POY of Reliance is considered quite good. Quality of yarn of Orkay, Petrofils and J.K. Synthetics is also considered satisfactory.

(b) Reliance can be said to have one of the latest manufacturing technology. Petrofils, Orkay and Padam Polyester have comparatively good level of technology. While others can be classified as having conventional technology.

(c) Plant and equipments vary from unit to unit. Reliance has large size reactors with automatic controls and spinning lines with maximum end positions. Orkay, Petrofils, etc. have comparatively large batch reactors, chip formation plants and spinning lines having moderate end positions and compactness. Other units are having small batch reactors and conventional spinning lines.

(d) Trend in respect of obsolete plants in western countries is to shut it down. Indian industry is reluctant to do so and keeps on operating the plants with outdated technology. Some of our existing old batch process plants should be modernised for the production of speciality yarns keeping in view the market demand and cost-benefit analysis. Suitable incentives and liberal financing schemes should be announced for modernisation.

0.8.3 **Technology Gap :**

(a) The technology has undergone lot of changes at international level and technological gaps exist between India and developed countries.

(b) Use of PTA in place of DMT for cost economy, large size of plants with continuous polymerisation process directly coupled with spinning, high speed spin-draw and spun dyeing techniques, sophisticated controls and new product developments are the areas where technology gaps exist.

(c) There has been a controversy regarding use of PTA and in the process, Indian plants are not using and developing technology to use PTA as feedstock. DMT is continued to be in use and due to this, cost of production is higher.

(d) Due to inexplicable reasons, plant capacity in India has remained very low for years. Only recently, licensing policy is liberalised for approving comparatively large size of plants. Due to small capacity, a technological gap is generated which has kept Indian industry, at least 10 years behind the world, in PFY manufacturing. As the size of plants were small, continuous process could not be used.

(e) Due to lack of R&D efforts at industry level, development of new products have not taken place substantially and a technological gap is generated in use of better additives, catalyst and control of process parameters for development of new products.

0.9 THRUST AREAS OF INDIGENOUS TECHNOLOGY, TARGETS, METHODOLOGY AND RESOURCES :

0.9.1 Thrust Areas :

(a) Thrust area of indigenous technology should be for technological upgradation rather than technological self-reliance. Immediate target should be to import latest technology and modernise existing plants.

(b) A central level organisation having engineering expertise in plant erection, equipments procurement and inspection, and basic engineering should be created. This organisation should have close association with national level research institutions and industry. Latest technology should be imported by this organisation and consistent efforts should be made to absorb, and upgrade the technology and for horizontal transfer of latest technology.

(c) Another thrust area should be in the direction of reduction of unit cost of production by making use of better and cheaper raw materials, reducing the cost of conversion and reduction in excise duty to make the product available at reasonable price in indigenous market as well as to compete in export market.

0.9.2 Methodology and Resources :

(a) Import policy should be restructured for import of latest know-how and modern capital goods.

(b) Policy regarding R&D incentives and back-up should be restructured so that industry spends more amount on fruitful R&D projects. Close watch on industry is required for proper utilisation of R&D plant and equipments and funds. Separate funds should be created by industry for R&D activities.

(c) Technological status of industry should be updated from time to time with the help of central level engineering organisation and research institutions.

(d) Development of indigenous plant and machinery, sub-assemblies, spares etc. should be undertaken with the help of central level engineering organisation like EIL.