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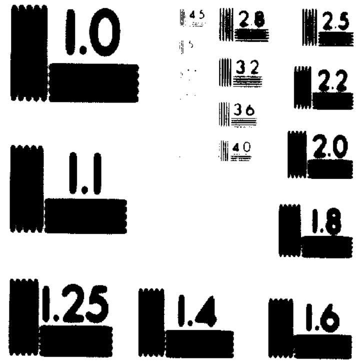

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VOLUME III

PROPOSALS FOR THE DEVELOPMENT OF THE AROMATICS, FIBRES AND SYNTHETIC RUBBER INDUSTRIES IN PAKISTAN IN ASSOCIATION WITH REFINERY AND PETROCHEMICAL OPERATIONS

SUMMARY OF REPORT

The report is concerned with planning the development of the synthetic fibres, aromatic petrochemicals and synthetic rubber industries in Pakistan.

The first step is the analysis of end-product requirements for the period upto 1985.

End-products and intermediates required, and processes for their manufacture, are reviewed.

Nylon and polyester fibres, the most important end-products, should be produced in plants of at least 5,000 MTPA ultimate capacity, in order that they can be supplied at competitive cost to the textile industry. It is shown that manufacture of caprolactam and terephthalic acid feedstocks becomes an attractive proposition at a minimum capacity equivalent to about 15,000 MTPA of each fibre.

Two further products which are attractive are phthalic anhydride and SBR synthetic rubber. The phthalic anhydride is feedstock for a 16,000 MTPA di-octyl phthalate plant in East Pakistan (see Volume II). Butadiene for the SBR unit would be extracted from the C_4 by-product stream of the ethylene cracker in Fauji Foundations West Pakistan Petrochemical Complex.

The production of BTX aromatics for these end-products is analysed in detail and schemes in East and West Pakistan are analysed. A site at Karachi in West Pakistan would have two advantages which have a decisive effect on costs of BTX production. These are:

(a) The presence of 12,000 MTPA of benzene in high concentration in the pyrolysis gasoline from the Fauji cracker.

(b) The larger market in West Pakistan for high octane gasoline; this is an attractive use for the raffinate stream from the aromatics extraction unit, and for aromatics surplus to chemical feedstock requirements.

Based on the detailed analysis, a development strategy for the industry is proposed. As well as the products, process units and capacities, the locations, timing and capital costs for these are stated. This strategy is summarised in the table on page 6-2.

SECTION 1

INTRODUCTION AND ACKNOWLEDGEMENTS

In this Volume, the development of the synthetic fibres, aromatic petrochemicals, and synthetic rubber, industries is analysed.

The development of a sound synthetic fibres industry should bring great economic benefit to Pakistan. The most important synthetic fibres, generally in the world and also in Pakistan, are nylon and polyester. They are derived from aromatic hydrocarbons, and a major proportion of the aromatics petrochemicals industry, generally and potentially also in Pakistan, is concerned with supplying the monomers for these fibres.

Study of the synthetic rubber industry is included in this Volume since styrene, which is used in the manufacture of SBR synthetic rubber, is in part an aromatic petrochemical.

In the Interim Report it was stated that at present an economic source of aromatics was lacking, but we recommended that nylon 6 and polyester fibre production should be developed on the basis of imported monomers.

After the Interim Report had been presented, H. & G. examined the availability of feedstocks for an aromatics units of around 50,000 MTPA capacity, to start up in the 1975-1980 period.

Suitable feedstocks can be made available in the form of naphtha whose alternative uses would be mainly as industrial fuel or export, with comparatively little competition from automotive fuel use. This is an advantage which Pakistan enjoys in aromatics production compared with the developed countries, where automotive fuel provides increasingly strong competition for aromatics feedstocks.

Throughout this Volume, costs and benefits are expressed in terms of estimated effects on the economy of Pakistan as a whole. For this reason, duty payments and cost of bonus vouchers are excluded from the cost of imported items, and bonus value from the credit value of any exports. To present the cost information in the most useful form, we have kept foreign exchange and local currency costs separate, looking at each industry as a whole. That is to say, the C & F value of materials and services which the industry imports into Pakistan are regarded as foreign exchange costs, while F.O.B. value of exports and C & F value of imports replaced by the industry, are regarded as savings.

The economic basis of the study and the costing techniques adopted are discussed in more detail in Section 5.

Note: Reference should be made to Section 5 for information on the basis for cost tables and data presented in Sections 3 and 4.

Acknowledgements

Humphreys & Glasgow Ltd. wish to express their appreciation of the help and information given to them by:

The Pakistan Government Representative, the U.N.I.D.O. Project Manager, the Government co-Project Manager and the U.N.I.D.O. experts resident in Rawalpindi.

The Directors, Managers, and staff members of the Eastern Refinery Ltd. Chittagong, Pakistan Refinery Ltd., and National Refinery Ltd., Karachi.

SECTION 2

MARKET ESTIMATES

2.1 Synthetic Fibres

The synthetic fibres are potentially the most important end-products of aromatics, although their consumption in Pakistan is still very small compared with cotton. In the developed countries, synthetic fibre consumption is still growing rapidly and is now comparable with the consumptions of the natural and cellulosic man-made fibres group, both of which are relatively static.

Currently, total world production of synthetic textile fibres is about 4.5 million tons/year; it is growing at about 20% p.a. and showing only slight signs of slackening its rate of growth. The estimated market share and rate of growth of each of the main categories is:-

	% of total	% p.a. growth
Nylon fibres	42	15
Polyester fibres	30	20 - 25
Acrylic fibres	20	20 - 25
Other synthetic fibres	8	25 - 30
	100	

The high strength (both wet and dry) of nylon and polyester yarns makes them extremely valuable in a wide range of industrial uses. However, non-industrial uses of the synthetic fibres account for a large proportion of world consumption, and in such uses their advantages are not easy to quantify. The hard wearing property of synthetics does in many cases confer a longer life on articles made from them, but there is little evidence that the availability of synthetic fibres has lessened total consumption of fibres of all types. Possibly, people obtain benefits from the higher performance of synthetic fibres in easier cleaning, few repairs, etc. rather than in longer use. Mainly, however, it is a matter of consumer preference and here the versatility of synthetic fibres is a major factor; new varieties of textiles made from them are still being developed.

When synthetic fibres become more freely available in Pakistan, rapid increase in consumption can be expected, at least by the upper income groups. Cotton will be released and become available for the export market, in amount at least equal to the synthetic fibre consumption. It will be shown in this Volume that the foreign exchange so earned can pay for most of the foreign exchange element of the cost of production of the synthetic fibres, at first from imported intermediates, and later from oil. It should thus be possible to obtain the benefits of improved industrial and consumer products made from these fibres, at small cost to the external balance of payments.

In this Study we have not taken into account the possibility of stepping up exports of textiles and textile goods with a synthetic fibres content. The manufacture of synthetic fibres in Pakistan will become even more attractive if export markets for such products can be found.

Thus, the development of a sound synthetic fibre industry should bring great economic benefit to Pakistan. Nylon and polyester, which are the two most important types of synthetic fibre generally in the world, and also in Pakistan, are both derived from aromatic petrochemicals. Indeed, a major proportion of the aromatics petrochemical industry generally, and potentially also in Pakistan, is concerned with supplying the monomers for these fibres.

2.1.1 Domestic Consumption Estimates

T.V. Janakievski (UN Expert) has analysed the market for synthetic fibres in Ref. 2. The Battelle Institute has also discussed the demand for these fibres in Ref. 11.

Estimates of consumption of nylon and polyester fibres, from both these sources, are quoted again by T.V. Janakievski in Ref. 14, and the figures for 1975 and 1980 are repeated below:-

		1975 MTPA	1980 MTPA
Battelle (Ref.11)	(Nylon fibre	11,000	22,000
	(Polyester fibre	5,000	12,000
T.V. Janakievski (Ref. 2)	(Nylon fibre	13,500	23,000
	(Polyester fibre	15,000	27,000

It can be seen that these authors took a broadly similar view of the market for nylon, but that Janakievski was more optimistic than Battelle about the prospects for polyester fibre.

In Ref. 2, Janakievski pointed out the great potential importance of polyester fibre to Pakistan, because of its resistance to wear and the effects of sunlight, and especially the favourable durability to cost ratio of textiles made from cotton/polyester blends.

H. & G. entirely accepts this view, as applied to the relative merits of polyester and nylon in Pakistan in the longer term. However, a swing to synthetic fibres as rapid as that proposed in Ref. 2, although in many ways desirable, may be difficult to accomplish. In the meantime, nylon has a lead because of its lower price and its ready acceptance for certain applications.

Janakievski has recently reviewed the prospects for the textile industry in Pakistan, in a report which was complete in draft form in August 1970. From this draft report his revised estimates are:-

		1975 MTPA	1980 MTPA
1.V. Janakievski (To be published)	(Nylon fibre	8,000	17,000
	(Polyester fibre	10,600	20,500

It should be noted that Battelle's predictions were based mainly on extrapolation of historical consumption data, while Janakievski's are based mainly on consideration of the demand for particular end uses. In the case of nylon fibre, the growth rate of consumption has slackened somewhat since Battelle made their prediction. Extrapolation would now be in fair agreement with Janakievski's revised estimate, which is therefore used by H. & G. in this Study.

In the case of polyester fibre, prediction of demand is particularly difficult because, in contrast to nylon, there is no domestic production at present yet polyester is potentially the more important fibre for cotton replacement, particularly in a hot climate. Battelle's estimate does not, in H. & G.'s opinion, take enough account of the effect of availability of polyester fibres at relatively low prices from domestic manufacture, and therefore tends to be pessimistic.

The following independent analysis and estimate of polyester fibre demand has been made in collaboration with Chemical Consultants Ltd. The internal consumption of cotton in Pakistan is estimated at 250,000 MT in 1975, thereafter growing at about 4% p.a. to 304,000 MT in 1980. An initial rapid penetration by polyester is expected, following the availability of the fibre at 'normal' prices from domestic production, to the extent of 2.5% of the internal cotton consumption by 1975, say, 6,500 MT. In countries where synthetic fibres and cotton are both readily available, the tendency has been for cotton consumption to remain static, while the growth of synthetic fibres is such as to maintain the growth of synthetics plus cotton combined at about the same rate as would have been expected in the absence of the synthetics. In Pakistan, however, on the basis of Chemcon's consumer demand studies, the situation would apply only to the 15% of the textiles market at the upper end of the quality scale, and the increase would be nearly all polyester. Increase in annual consumption, for this sector of the market, from 1975 to 1980 is therefore estimated at:

15% x (304,000 - 250,000) = 8,100 MTPA

In addition, a certain amount of increased penetration of the remaining 85% of the market, to the extent of 0.5% is anticipated,

i.e. 0.85 x 0.5% x 304,000 = 1,300 MTPA,

plus an equal further quantity for wool-type uses. Summing these contributions to increasing consumption during the period 1975 - 1980 gives a total increase of about 11,000 MTPA, and estimated 1980 consumption is 17,500 MTPA. This figure is some 15% lower than Janakievski's most recent estimate as given above. These figures may be accepted as a slightly conservative estimate. Thus the figures used in this Study are as follows:

		1975 MTPA	1980 MTPA
H. & G. projections of Pakistan fibre consumption	Nylon fibre	8,000	17,000
	Polyester fibre	6,500	17,500

A recent study by Chemcon confirms that polyester/cotton blends can be spun with existing cotton spinning equipment, with only minor modifications to the fibre blending stage, and that cotton displaced by the use of synthetic fibres will be exported.

The availability of synthetic fibre at 'normal' prices in Pakistan should make possible increased exports of textiles containing them; such exports, however, have not been taken into account in the above estimate so that in this respect also the figures tend to be conservative. As far as H. & G. are aware, there has been no study of the potential export market for blended cotton/polyester fibre textiles made in Pakistan.

It should be kept in mind that the strategy which is proposed in this Volume of the report is flexible, and therefore the above figures do not crucially affect its validity. If the markets for these fibres are found to be developing somewhat differently from the 'planning' estimates, it will be sufficient to advance or retard the development programme to suit the updated market estimates.

The estimated split of the above consumption figures between East and West Pakistan is (H. & G. 'planning' figures):-

		East MTPA	West MTPA	Total MTPA
Nylon fibre	1975	2,000	6,000	8,000
" "	1980	5,000	12,000	17,000
Polyester fibre	1975	2,000	4,500	6,500
" "	1980	5,500	12,000	17,500

2.1.2 Possible Exports to RCD Countries

There is a proposal for a joint venture between the RCD countries in the production of polyester fibres (Ref. 11). It is envisaged that Pakistan would supply Iran and Turkey with fibre and polymer chip respectively at the annual rates shown below, for an unspecified period. We therefore include these quantities in our estimates for 1975, but not 1980:-

	1975 MTPA	1980 MTPA
Polyester fibre to Iran	3,000	-
Polyester chip (mainly filament grade) to Turkey	2,000	-

2.2 Phthalic Anhydride

2.2.1 For Dioctyl Phthalate (DOP)

According to the estimates in our Interim Report (summarised in Volume I), and our recommendation that 16,000 MTPA of DOP capacity should be included in the EPIDC Petrochemical Complex, we estimate the following potential demand and consumption of phthalic anhydride, all in East Pakistan.

	1975 MTPA potential demand	1980 MTPA consumption
DOP	8,000	16,000
Phthalic Anhydride (x.385)	3,080	6,160

However, we consider that the DOP plant should be planned to come on stream in 1977.

2.2.2 For Alkyd Resins

As in our Interim Report, we follow the consumption estimates of Battelle (Ref. 11). We now further assume (a) 60% of the consumption will be met from domestic production, and (b) on average, 0.33 tons of phthalic anhydride will be required per ton of alkyd resin produced, and hence obtain:-

	1975 MTPA	1980 MTPA
Alkyd resin consumption	5,800	8,500
Alkyd resin production	3,500	5,100
Phthalic anhydride consumption for Alkyd resins	1,150	1,700

At present, existing and sanctioned capacity for alkyd resins production is entirely in the West, however, we assume, for the purpose of this Study, that some 30% of alkyd production will be developed in the East.

2.2.3 Total Phthalic Anhydride Demand/Consumption

Hence, our estimates for phthalic anhydride demand/consumption:-

	East MTPA	West MTPA	Total MTPA
1975 potential demand:	3,430	800	4,230
1980 consumption:	6,670	1,190	7,860

2.3 Styrene Based Plastics and Synthetic Rubbers

The demand for styrene-containing materials in Pakistan is made up from polystyrene (PS) and related thermoplastics, styrene butadiene rubber (SBR) and glass fibre reinforced plastics (GRP).

For the purpose of assessing whether domestic production of PS, SBR and styrene itself is viable in the period up to 1980, we have estimated potential demand for these products if they could be made available at, say, 20% lower than the present prices of the imported materials.

The estimates for PS and SBR are based on those given by Battelle (Ref. 11), extrapolated from 1975 to 1980, and increased somewhat to allow for the effect of a hypothetical price reduction, as explained above. The SBR figures assume that the majority of car and truck tyres will be made locally, and that there will be substitution of some of the existing natural rubber applications. We have no reliable estimate for GRP demand, but in view of the growing importance of

GRP construction generally in the world, its suitability for Pakistan conditions, and the inclusion of styrene in some of the liquid resin formulations, an arbitrary quantity of styrene for GRP has been included in the 1980 ertimate.

Estimated potential demands for products:-

	1975 MTPA	1980 MTPA
Polystyrene	6,000	10,000
SBR	5,000	10,000

Estimated potential demand for styrene:-

	1975 MTPA	1980 MTPA
For polystyrene	6,000	10,000
For SBR	930	1,850
For GRP	-	1,000
Total Styrene	6,930	12,850

2.4 Benzene

2.4.1 For Nylon 6

The use of benzene for Nylon 6 production is discussed in Section 3 of this Volume.

2.4.2 For Insecticides

Reference 14 gives estimated consumption of benzene for this purpose, based in turn on Ref. 11. The figures in our estimate below are slightly lower in view of the increasing tendency to use, wherever possible, insecticides of lower long-term toxicity than the chlorinated aromatic hydrocarbons, in particular those based on benzene (BHC and DDT).

Estimated consumption of benzene for insecticides:-

	1975 MTPA	1980 MTPA
Benzene	1,300	2,000

divided as 25% East, 75% West Pakistan.

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for

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

VOLUME III

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2.4.3 For Dodecyl Benzene (DDB)

Following Ref. 11 and our Interim Report, we state below the estimated consumption of DDB in Pakistan. We assume domestic production capacity of 10,000 MTPA will be set up in West Pakistan, as recommended in Volume II of this report.

	1975 MTPA	1980 MTPA
DDB consumption	6,850	13,700
DDB domestic production	6,850	10,000
Hence Benzene (x 0.47)	3,220	4,700

2.4.4 Miscellaneous Uses of Benzene

According to Ref. 11, current imports of benzene into Pakistan are almost entirely accounted for by the known production of DDT and BHC.

2.5 Toluene

2.5.1 For Nylon and Polyester

The potential use of toluene for Nylon 6 and polyester production is discussed in Section 3 of this Volume, but benzene and p-xylene are, respectively, the more likely starting chemicals for the conditions of Pakistan.

2.5.2 For Solvent and Miscellaneous Chemical Uses

Toluene is a useful solvent and also finds chemical uses. For the purpose of this study, we include the following estimated consumptions of toluene for such uses:-

	1975 MTPA	1980 MTPA
Toluene	4,000	5,000

equally divided between East and West Pakistan.

2.6 p-Xylene

Polyester fibre production is the only potential outlet for p-xylene. Consumption of the fibre is discussed above, and p-xylene production in Section 3 of this Volume.

2.7 o-Xylene

Phthalic anhydride, the sole potential outlet for o-xylene, is discussed above.

2.8 Mixed Xylenes

Mixed xylenes are useful as a solvent or diluent in surface coatings, insecticide formulations, and miscellaneous industrial uses. Although Battelle (Ref. 11) could only positively identify as xylene less than 600 MTPA of the imports of solvents to Pakistan in the period 1963 to 1967, the actual consumption may have been greater than this figure.

When available at the lower price which should be possible from domestic production, use of solvent xylene is likely to expand greatly.

We, therefore, include in our estimate of consumptions:-

	1975 MTPA	1980 MTPA
Solvent xylene	2,500	5,000

equally divided between East and West Pakistan.

2.9 Ethylene Glycol

Polyester fibre is the main potential outlet for ethylene glycol in Pakistan. Other minor markets for ethylene glycol, and possible outlets for ethylene oxide which could be co-produced, have not been allowed for in the figures below:-

	1975 MTPA	1980 MTPA
Ethylene glycol equivalent to polyester fibre consumption	3,200	7,000

SECTION 3

PRODUCTS AND INTERMEDIATES

3.1. Nylon 6 fibre

3.1.1. Fibre Types

The market demand for nylon 6 yarn in Pakistan appears to be almost entirely for continuous filament yarn for the production of fabrics and fishing net twine. There are indications that tyre and industrial yarns may be required later, but that market has not yet emerged. At present, there is no demand for nylon staple fibre and nylon carpet yarn. The plant and production costs in the economic assessments which follow are based on 60 denier c.f. yarn production on draw twist kops. This denier has been taken as the standard; the costs for the production of yarns with a denier higher than 60 will generally be lower because of higher throughput per machine, and vice versa. The production cost for nylon staple fibre is very much lower than for c.f. yarn because of large processing differences, higher throughput and quality requirements. Because of these factors a careful assessment of present and future end-use is essential before plant construction.

3.1.2. Economic Assessment

3.1.2.1. Plant Cost and Yarn Production

The existing nylon 6 spinning units in both East and West Pakistan are by Western standards too small to be economic. The projected market demand for 1980 for the whole of Pakistan i.e. 17,000 MTPA would be most adequately met by the production from one large fibre plant. The geography of Pakistan, however, is such that the shipping costs of the fibre end-products to that part of the country remote from the plant would not be justifiable, also there are manufacturing units at present existing in both the East and the West. Thus, from an economic point of view, two spinning plants, one in each side of Pakistan, would be the best arrangement. Whilst this can be achieved in East Pakistan where there is only one plant at present, it may not be possible in the West where there are already three plants in production. If, however, the aim of future planning in Pakistan is the production of nylon 6 yarn at a cost competitive with those in Europe, U.S.A. and Japan, then a reduction in the number of plants should be seriously considered and the production capacity increased in the one(s) remaining.

An alternative would be the erection of a fourth plant with a production capacity in 1980 of say 10,000 M.T.P.A.

In considering the minimum economic size of a nylon polymerisation and spinning plant for Pakistan, it is necessary to compare costs of local production from caprolactam imported at World market prices with cost of imported nylon fibre. The analysis is much the same for Pakistan as for any other location. The current situation in the U.K., for example, is that it is possible to import caprolactam and produce fibre in a 6,000 M.T.P.A. unit such that the product is competitive with imported fibre. At any time this capacity level is sensitive to the changing, relative World market prices of caprolactam and nylon fibre. It is concluded, plants for ultimate capacity of at least 6,000 M.T.P.A. should be developed.

3.1.2.2 Technical Factors

Apart from careful quality control and good housekeeping, one of the major technical factors which affects yarn production costs is the recovery of caprolactam from chip wash liquor and from waste nylon 6 arising in the polymer, spinning and drawing areas. In countries where caprolactam production facilities already exist the recovery is usually done in plants constructed adjacent to the caprolactam production plants and the recovered purified caprolactam is diluted with the new caprolactam stream.

In other countries, such as Pakistan, where a caprolactam plant does not exist or is remote from the nylon 6 plants, it is the practice to recover caprolactam from the wash liquors and wastes in evaporation and depolymerisation plants constructed adjacent to the fibre production plant.

The cost of a recovery plant along with its operating costs is generally not justified in the case of small nylon 6 production plants.

It is because of this factor that in some small plants the chip wash liquor is discarded to drain, and the nylon waste is burnt.

This again is a factor which raises the costs of production in small units.

3.1.3. Plant Sites

3.1.3.1. West Pakistan

The port of Karachi, equipped with good facilities for sea and land transport and situated in the centre of the West Pakistan textile processing industry, is an obvious site for nylon 6 production. A further point is that two nylon 6 plants already exist in the area and consideration should be given to expanding one of the existing plants.

If it is decided to produce nylon 6 at more than one plant, consideration should be given to the expansion of the existing plant at Lyallpur, which would then serve the Northern portion of the country.

3.1.3.2. East Pakistan

Two alternative sites should be considered; the port of Chittagong, which is equipped with facilities for sea and land transport and which already has a nylon 6 plant, and the town of Dacca, which is situated nearer the majority of the textile processing units.

As in the case of West Pakistan, consideration should be given to the expansion of the existing nylon 6 plant (at Chittagong).

3.1.4. Nylon 6 Process

The process description which follows, refers to production of continuous filament yarns.

3.1.4.1. Polymer Production

Caprolactam is continuously polymerised in the presence of catalysts and other additives, usually by passage through a vertical tubular reactor. The final polymer is extruded into water where it is cooled and the resulting strands cut into chips. Due to chemical reaction equilibria about 10% caprolactam monomer remains in the polymer, and this is removed from the polymer chip by washing with water. The extracted chip is dried and conveyed to the spinning area. The aqueous extract is sent to the lactam recovery plant.

3.1.4.2. Spinning

The dry polymer chip is converted to filaments possessing a low degree of molecular orientation. The filaments are formed by extruding molten polymer through fine capillaries and the molecular orientation is introduced by collecting the solidified filaments at a velocity considerably greater than that at extrusion. A dilute solution of spin finish and antistatic lubricant is applied to the spun yarn and it is then collected as a spun package.

3.1.4.3. Draw-twisting or Draw-winding

Spun yarn possesses only a small degree of molecular orientation and to make it useful for textile applications it is necessary to increase its crystallinity and molecular orientation. This is done by applying a cold drawing process known as draw-twisting. The spun yarn packages are mounted on a creel on top of the machine. Yarn is unwound from the package and fed to the drawtwist machine. The amount of stretch applied depends on the speed ratio between the feed rolls and draw rolls and is carefully controlled. The amount of twist in the yarn is dependent on the relative draw roll and drawtwister spindle speeds.

A variation of this machine is a draw winder which produces large drawn yarn packages with no twist.

After drawing, the yarn is then ready for textile processing in customers' plants.

A machine called a spin-drawer is now being developed which combines the operations of spinning and drawing, but its economics have not yet been proven.

3.1.4.4. Recovery Unit

The aqueous extract from the polymer area is concentrated and recycled to the beginning of the polymer process. The waste polymer and yarn arising in the polymer spinning and drawtwisting areas is depolymerised and the caprolactam produced is distilled and then recycled to the polymer unit.

3.1.4.5 Miscellaneous Process Areas

1. Spin Finish - spin finish preparation.
2. Pump & Pack Maintenance - servicing of pump packs and spinnerets.
3. Chemical & Physical Testing Laboratories
4. Inspection and Packing - of yarn packages for sale or processing
5. Recovery - stripping and cleaning for re-use.

3.1.5 Raw Materials Consumption

The raw material consumption is 1.00 MT of caprolactam per MT of Nylon 6 fibre, for a plant incorporating a lactam recovery unit.

In addition to caprolactam, small quantities of titanium dioxide (delustrant) and catalyst chemicals are required in the process.

3.1.6 Typical Utility Consumptions

Utility	Unit	Quantity per MT product
Electricity	kWh	2960
Steam	M.T.	1.7
Cooling Water (25°C)	m^3	90
Compressed Air including instrum.	Nm^3	700
Nitrogen	Nm^3	25

The above utilities are those required for process only, they do not include air conditioning or general services.

3.1.7 Capital Costs

For the production of 60 denier nylon yarn from caprolactam, including full monomer recovery facilities from washwater and polymer wastes, estimated plant costs are (in Rs.million):

	Total Production Capacity	
	6,000 MTPA	12,000 MTPA
Foreign exchange element	53.0	81.9
Local currency, excluding duty	15.9	24.6
Duty	15.9	24.6
Total 'battery limits' cost	84.8	131.1

It should be noted that the above costs do not include:

utilities plants and offsites land and site development, owner's start-up expenses, consultancy fees, training, interest on loan during construction.

3.1.8 Production Cost

Production cost has been estimated for a plant of capacity 6,000 MTPA of 60 denier nylon textile fibre. Fixed costs have been calculated on the basis of the capital cost estimate given above, and the cost structure described in Section 5, with the following exceptions:-

(a) maintenance was assumed to be 6% p.a. of total 'battery limits' cost, exclusive of duty, rather than the 4% p.a. figure assumed for petrochemical plants.

(b) labour for process operation and quality control, also supervision, administration, sales, technical service, and management were estimated separately. It was estimated that the aggregate of these costs for such production would amount to 38^d/Kg in the U.K.; under Pakistan conditions these costs are estimated at Rs. 2.9/Kg, together with a continuing foreign exchange cost of 1.5^d/Kg. to cover the costs of obtaining up-to-date production and applications technology from overseas sources.

Variable costs were calculated on the basis of the consumption data given above, and the unit costs stated in Section 5. It was estimated that packaging would cost Rs. 100/MT.

TABLE III.3.1

Production Cost of Nylon 6 Fibre from Caprolactam

Basis : 6,000 MTPA of 60 denier nylon textile fibre.

Foreign exchange element of 'battery limits' capital :
11.13×10^6 (equivalent to $1.855/MTPA fibre capacity)

Per MT fibre	$ Foreign Exchange	Rs. Local Currency
Financial cost (including interest on working capital)	312	1043
Maintenance	76	423
Management) Labour) Supervision) Labour) Administration) Technical Service)	15	2900
Total fixed cost	403	4366
Caprolactam 1.0 MT	420	-
Catalysts and Chemicals	20	-
Utilities	18	188
Packages	-	100
Total variable cost	458	288
Production cost	861	4654
Price of equivalent imports	1703	
Saving in foreign exchange	842	

Ratio Rs. 4654 / $842 = 5.5 Rs./$

It should be noted that duty and bonus are excluded from the cost of plant and materials in the above costs.

The price of equivalent imports was estimated on the basis of 50% each of Grade 1 and Grade 2 60 denier yarns, both at present day C & F prices, which are $2020/MT and $1386/MT respectively. In spite of possible future improvements to spinning machinery, textile yarns will remain labour-intensive, and future prices are expected to be, on average, about the same as now or slightly higher.

On the basis of the above analysis, it is more attractive to produce nylon fibre in a 6,000 MTPA plant based on imported caprolactam, than to import the equivalent quantities of fibre.

On the conservative assumption that only 1 MT of cotton/1 MT of nylon is freed for export, earning $ 500 - 600 /MT, as much as 58-70% of the foreign exchange element of the cost of nylon fibre produced is offset by cotton export.

PRE-INVESTMENT STUDIES FOR THE PROMOTION OF THE FERTILIZER AND PETROCHEMICAL INDUSTRIES IN PAKISTAN

for

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

VOLUME III

PROPOSALS FOR THE DEVELOPMENT OF THE AROMATICS, FIBRES AND SYNTHETIC RUBBER INDUSTRIES IN PAKISTAN IN ASSOCIATION WITH REFINERY AND PETROCHEMICAL OPERATIONS

July 1970

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3.1.9. Summary of Recommended Production Planning

3.1.9.1. Alternative 'A'

East Pakistan

Year of start-up	No. Plant Units	Production Capacity MTPA	Site	Feedstock
1975	1	3000	Chittagong	Caprolactam
1980	1	6000	Chittagong	Caprolactam

West Pakistan

Year of start up	No. Plant Units	Production Capacity MTPA	Site	Feedstock
1975	1	6000	Karachi	Caprolactam
1980	1	12,000	Karachi	Caprolactam

3.1.9.2. Alternative 'B'

In East Pakistan the planning remains unchanged.

West Pakistan

Year of start up	No. Plant Units	Production Capacity MTPA	Site	Feedstock
1975	1	3000	Karachi	Caprolactam
1975	1	3000	Lyallpur	Caprolactam
1980	1	6000	Karachi	Caprolactam
1980	1	6000	Lyallpur	Caprolactam

In both alternatives the aim should be to install initial polymer plants based on units of 3000 MTPA. The reason for this choice is that modern continuous polymer reactors are generally designed to produce 1500 or 3000 MTPA per year of nylon chip.

It is realised that the market figure for East Pakistan for 1975 is only 2000 MTPA but a 3000 MTPA plant operated on a turned down basis is recommended.

The spinning and drawing units can be tailored to meet market demand.

3.1.10. Recommendations

a) The number of nylon 6 plants should be planned on the basis that each has a final production capacity not less than 6000 MTPA of nylon 6 fibre.

b) Each nylon 6 plant should be equipped with a recovery unit for the recovery of caprolactam from chip wash liquor and nylon 6 waste.

c) If nylon 6 plants with production capacities less than 6000 MTPA are built in West Pakistan, consideration should be given to the erection of one evaporation and depolymerisation unit capable of processing the waste liquor and waste from more than one nylon 6 product plant. In this event the chip wash liquor should be concentrated to say a 50/50 caprolactam/water mixture at each plant to save shipping costs.

3.2 Polyester Fibre

3.2.1. Fibre Types

The end-use pattern in Western Europe is such that its requirements are met by 45% filament yarn and 55% staple fibre. In Eastern Europe and America the breakdown is 30% filament and 70% staple. The higher figure for filament in Western Europe is principally due to the high demand for bulked, crimp set yarns similar to "Crimplene" which are used by the knitting trade.

Our view is that in Pakistan, where there is no current polyester production, but where there is a substantial cotton production, the demand for staple fibre will be a higher percentage of the total requirement than in E. Europe. We have therefore assumed an end-use pattern of 80% staple fibre, 20% continuous filament as the basis for plant costs and material balance. We regard the present reported use of 10% staple fibre to 90% continuous filament yarn as artificial, and caused by high excise duty on staple and staple/cotton blends.

3.2.2 Economic Size of Plant Units

As described above in the case of nylon, the economic size of unit for the production of polyester fibre in Pakistan is sensitive to the relative World market prices of product fibre and fibre precursor - DMT, TA or polymer. The prices in turn fluctuate under the influences of supply and demand. The current situation in the U.K. is that, while there are reasonable profit margins on continuous filament yarn, staple fibre margins are very low. In deciding the scale of production in Pakistan, therefore, the key factors to take into account are:

(i) that it is economically attractive overall to establish polyester fibre production to supply the textile industry.

(ii) that it is most economic to build up the polymerisation and spinning sections initially on a single plant site - ultimately achieving a scale of production comparable with those in developed countries.

Thus, assuming that the demand figures quoted for 1975 (i.e. 10,500 MTPA for West Pakistan, including 5,000 MTPA for Iran and Turkey, and 2,500 MTPA for East Pakistan are correct), the best plan for 1975 would be the erection of a single polymer production and spinning plant in West Pakistan. Since demand in 1980 in West Pakistan (12,000 MTPA) is close to this 1975 total of 12,500 MTPA, the simplest and most effective plan for West Pakistan would be the erection of a single plant capable of producing 12,000 MTPA of polymer chip, and equipped with a spinning and drawing capacity for 7,500 MTPA of fibre in 1975. This assumes that the joint venture scheme with Iran and Turkey goes ahead. The excess polymer from West Pakistan would be shipped to East Pakistan where it would be spun into fibre in a 2,500 MTPA (spinning only) plant to be started up in 1975.

To achieve the 1980 market figures, additional spinning capacity would be installed in West Pakistan and polymerisation plus additional spinning capacity installed in East Pakistan.

3.2.3. Choice of Process Route

A major problem for the development of a polyester fibre unit in Pakistan is the choice between the DMT and TA routes.

Processes for production of terephthalic acid from paraxylene and direct polymerisation of TA have been developed by a number of companies.

In spite of the fact that the weight of terephthalic acid required per MT of polyethylene terephthalate is some 15% less than the corresponding DMT requirement, the established fibre producers have been slow, however, to change their processes to accept the new feedstock. The factors involved were

a) There was considerable doubt about the quality and properties of the fibre produced from TA, i.e. end-user trials were necessary.

b) There was a marked shortage of fibre grade TA, and the price per MT, was higher than that of DMT.

c) Fibre prices were such that the producers were making a comfortable profit using DMT.

d) Capital was needed to equip existing polymer plants with mechanical equipment to handle TA, which is a powder insoluble in glycol and with no melting point. (DMT flake is melted and fed into a molten state to the ester interchange vessel).

The swing towards TA, commenced in Japan where firms were experimenting with sizeable quantities of fibre grade terephthalic acid via the Henkel route as long ago as 1964. Toyo Rayon and Mitsubushi then commenced the production of fibre grade terephthalic acid in commercial quantities on a joint venture, with Toyo providing a captive end use for the product. Teijin of Japan also started a production line based on TA, about the same time. Between 1966 and 1969 this lead was followed by Fiber Industries Inc. (American Celanese and I.C.I. Ltd), Du Pont, and later by Monsanto, all in the U.S.A. I.C.I. also began commercial production in the U.K. around 1967.

The position now is that I.C.I. both in the U.S.A. and the U.K., Monsanto, Goodyear, Allied Chemicals, Du Pont, all in the U.S.A. and Toyo Rayon, Teijin in Japan, are all very heavily committed to polyester production from TA, monomer.

The main reason for the change to TA, is to maintain economic fibre production costs to meet the highly competitive world prices.

The first TA processes were coupled with the direct spinning, i.e. without intervening chip production, of large quantities of standard fibre (3 and 4 denier per filament) in the form of staple, but processes for continuous filament yarns have since been developed.

The advantages claimed are:-

(i) Elimination of methanol recovery facilities.

(ii) TA yields about 15% more polymer per kg of feedstock

(iii) Some TA processes require less ethylene glycol in the reaction mixture than their DMT based counterparts; more production is thus achieved per unit volume of reactor.

(iv) For chip producing processes the cost saving on staple is of the order of 10% and appears to be decisive.

Finally, it should be noted that major producers have now developed equipment for converting their existing DMT-based plant to TA at low cost.

We therefore conclude that Pakistan should adopt the TA route for manufacture of Polyester fibres. The only possible proviso to this recommendation, would be if a long term contract could be negotiated for supply of cheap DMT.

3.2.4. Polyester Process Information (Polymerisation and Spinning)

The polymerisation process is different for the two monomers - DMT and TA. The spinning process is the same.

3.2.4.1. Polymerisation

Two distinct stages, each requiring a separate reaction vessel and different processing conditions, are required in the main polymer process. Some TA based processes involve a third, prepolymer, stage but the overall chemical reactions which take place are similar. In the first vessel DMT or TA is reacted with excess ethylene glycol to give bis-(β hydroxyethyl) terephthalate "monomer" which is then polymerised (polycondensation) in the second vessel to give poly ethylene terephthalate . Methanol in the case of DMT, or water in the case of TA feedstock, is given off from the first stage of the process, and glycol from the second. The polymer is usually produced in the form of chip, which is dried, blended and pneumatically transported to the spinning area.

3.2.4.2. Spinning

The dry blended polymer chip is converted into filaments by a melt process where the chip is changed into a molten state using electrical heating, followed by extrusion where the molten polymer is pumped through a filter and spinneret. The filaments are cooled by air, than a dilute solution of spin finish is applied to the spun yarn, which is finally collected on a package.

In the case of staple fibre, several spun yarns from adjacent spinning positions are brought together to give a tow of denier convenient for subsequent processing, and collected in a large can.

In both cases, a low degree of molecular orientation is given to the spun yarn by arranging a take-up speed considerably higher than the filament extrusion velocity.

3.2.4.3. Drawing - Continuous Filament Yarn (uncrimped)

To make the spun yarn useful, it is necessary to increase its crystallinity and molecular orientation. This is done by a hot drawing process where the yarn is stretched by several hundred per cent. The drawn yarn properties depend on the degree of stretch applied at drawing and different degrees of stretch are used for medium and high tenacity yarns.

3.2.4.4. Processing - Staple Fibre and Crimped Yarn

The processing of spun tow to crimped fibre involves several stages carried out in sequence. The first stage is drawing, where the spun material from several cans of tow is combined together via a creel and the combined tow is hot stretched between a set of feed rolls and draw-rolls.

The tow is then crimped so that the material can be processed on conventional textile machinery, dried, and heat stabilised to maintain the mechanical properties of the fibre.

For products required as continuous tow, the heat stabilised material is carefully packed in boxes. In those cases where the product is required in staple form, the heat stabilised tow is cut and then compressed into a bale.

3.2.4.5. Recovery Facilities

a) Methanolysis

Waste polymer, waste yarn and waste staple fibre is reacted with excess methanol to produce DMT and glycol. The DMT is isolated, re-distilled, and re-crystallised to produce polymer grade material which is then returned as feed material to the polymerisation reaction.

The liquor containing methanol and glycol is sent to the methanol recovery section where the methanol is separated and purified and the glycol fraction is sent to the glycol recovery section.

In the case where terephthathic acid is used as the feed material a process of hydrolysis is used for its recovery from waste polymer.

b) Glycol Recovery

Impure glycol from the polymerisation section is refined by distillation. Crude glycol from the methanolysis or hydrolysis plant is first distilled to remove impurities such as spin finish oil. This product is then bulked with impure glycol from the polymerisation section and refined by distillation. The refined glycol is finally mixed with new glycol and used as a portion of the feed material to the polymerisation section.

The methanol/water fraction is sent to the methanol recovery section.

c) Methanol Recovery

Impure methanol from methanolysis, glycol recovery and polymerisation sections, is distilled to produce a refined methanol containing around 1% impurities (mostly water). Part of the methanol is available for the manufacture of DMT, the remainder is sent to the methanolysis plant.

In the case where TA is used a methanol recovery plant is not required.

3.2.4.6. Miscellaneous Process Areas

Areas similar to those mentioned under the section on Nylon 6 are required.

3.2.5 Raw Material & Utility Consumption

The figures below are for the Polymerisation and Spinning processes in the TA route to Polyester Fibre. They include allowance for the recovery of TA and glycol from 0.16 MT of waste polymer per MT of saleable fibre, arising from the polymerisation and spinning operations.

Raw Materials	Consumption per MT of Polyester Fibre
Terephthalic Acid	0.90 MT
Ethylene Glycol	0.40 MT

Utilities	Consumption per MT of Polyester Fibre
Steam	10 MT
Power	2000 Kwh
Cooling water	300 m^3
Clarified water	30 m^3
Potable water	4 m^3
Compressed air	500 m^3
Natural gas	20 m^3
Nitrogen	200 m^3

(these figures are for process plant and do not include air conditioning, etc.)

3.2.6 Capital Costs

The capital costs of polyester fibre plants based on DMT, or alternatively TA, would be very similar. For the production of 80% staple, 20% continuous filament yarn, including facilities for the recovery of monomers from polymer and fibre wastes, estimated capital costs (for either feedstock) are, in Rs.million:

	Total Polyester Fibre Production Capacity 6,000 MTPA	12,000 MTPA
Foreign exchange element	54.5	83.4
Local currency, excluding duty	16.3	25.0
Duty	16.3	25.0
Total 'battery limits' cost	87.1	133.4

It should be noted that the above costs do not include:

utilities plants and offsites,
land and site development,
owner's start-up expenses,
consultancy fees,
training,
interest on loans during construction

3.2.7 Production Cost

Production cost has been estimated, for a plant of capacity 6,000 MTPA of polyester fibre (80% staple, 20% continuous filament yarn). Fixed costs have been calculated on the basis of the capital cost estimate given above, and the cost structure described in Section 5, with the following exceptions:-

(a) maintenance was assumed to be 6% p.a. of total 'battery limits' cost exclusive of duty, rather than the 4% p.a. figure assumed for petrochemical plants.

(b) labour for process operation and quality control, also supervision, administration, were estimated separately.

It was estimated that the aggregate of these costs, for such production, would amount to 27^d/Kg in the U.K.; under Pakistan conditions it was estimated that these costs would amount to Rs. 2.13/Kg, together with a foreign exchange cost of 1.1^d/Kg, to cover the costs of obtaining up-to-date production and applications technology from overseas sources.

Variable costs were calculated on the basis of the consumption data given above, and the unit costs stated in Section 5. It was estimated that packaging would cost Rs. 50/MT.

TABLE III.3.2

Polyester Fibre Production Cost

Basis : 6,000 MTPA capacity, 80% staple, 20% continuous filament yarn.

Foreign exchange element of 'battery limits' capital : $11.75 x 10^6, equivalent to $1,960/MTPA of fibre capacity.

Per MT Polyester Fibre	$ Foreign Exchange	Rs. Local Currency
Financial cost (including interest on working capital)	329	1100
Maintenance	80	447
Management, process labour, supervision, administration, and technical service	11	2130
Total fixed cost	420	3677
Terephthalic acid 0.9 MT	342	-
Ethylene glycol 0.4 MT	88	-
Catalysts and chemicals	23	-
Utilities	16	231
Packages	-	50
	469	281
Production cost	889	3958
Price of equivalent import	1452	
Saving in Foreign Exchange	563	

Ratio Rs.3958/$563 = Rs. 7.0/$

It should be noted that duties and bonus are excluded from the cost of plant and materials in the above costs.

The price of equivalent imports was estimated as below, on the basis of 50% Grade 1 and 50% Grade 2 quality in each category, and current prices. Current prices, particularly of staple fibre, have reached remarkably low levels, and future prices are expected to be on average, about the same as now or slightly higher.

Polyester fibre price $ per MT	Grade 1	Grade 2	Grades 1/2 50/50
Staple	1320	1060	1190
75 denier continuous filament yarn	2750	2250	2500
80 staple/20 continuous filament yarn	-	-	1452

On the basis of the above analysis, it is more attractive to produce polyester fibre in a 6000 MTPA plant based on imported monomer, than to import the equivalent quantities of fibre.

On the conservative assumption that only 1MT of cotton/1MT of polyester is freed for export, earning $500 - 600/MT, as much as 57-68% of the foreign exchange element of the cost of the polyester fibre produced is offset by cotton export.

3.2.8 Plant Sites

3.2.8.1 West Pakistan

The same site as the nylon 6 facility envisaged in Karachi should be considered, so that the same off-site plants such as nitrogen and demineralised water facilities can be used forboth types of fibre production.

There would also be a common trained labour pool in the area for both types of production, which have many similarities.

3.2.8.2 East Pakistan

Again, the same site as that envisaged for the nylon 6 facility in Chittagong or Dacca should be considered for reasons mentioned in 3.1.3.1

3.2.9 Summary of Recommendations for Production Planning

3.2.9.1 West Pakistan

It is recommended that a site at Karachi be selected and that production is developed there according to the schedule below.

Start-Up Year	Spinning Units		Polymerisation		Source & Type of Feedstock
	Total Units	Total Capacity MTPA	Units	Capacity MTPA	
1972/ 1973	2	3000	-	-	Imported Polymer Chip
1975	3	5500	1	12000	Imported TA
1976/ 1977	4	8000	1	12000	Home Produced TA
1980	6	12000	1	12000	Home Produced TA

3.2.9.2 East Pakistan

It is recommended that a site at Chittagong is selected and that production is developed as follows.

Start-Up Year	Spinning Units		Polymerisation		Source & Type of Feedstock
	Total Units	Total Capacity MTPA	Units	Capacity MTPA	
1975	2	2500	-	-	Polymer Chip from West Pakistan
1980	3	5500	1	5500	TA produced in Pakistan

Note:- Until the polymerisation plant is set up at Chittagong, spinning waste should be returned to Karachi.

3.2.10 Recommendations

1. Pakistan should develop polyester fibre manufacture on the basis of terephthalic acid.

2. The polyester plant should be based on polymer chip-making rather than direct spinning. Direct spinning requires

considerable technical expertise, and some flexibility is lost; it is cheaper than chip-making only where there is a market established for a large volume of a standard fibre.

3. There should be a maximum of two plants, one in West Pakistan, the other in East Pakistan.

4. The plant in East Pakistan should be spinning only, until combined production of continuous filament and staple fibre of at least 6000 MTPA is required.

3.3 Styrene and Polystyrene

3.3.1 Styrene

We have assessed the viability of a styrene plant of capacity equal to the total potential 1980 demand, as stated in Section 2.3 above, i.e. 12,850 MTPA. The plant would come on stream in 1977. Benzene is taken to be available at the production cost estimated in Section 4 below. Ethylene is assumed to be available from the Fauji 60,000 MTPA ethylene complex, at the production cost which we have estimated in the table below. Unit costs of materials and utilities are assumed to be as stated in Section 5, where costing techniques and scope of capital costs are described. Throughout the rest of this Section foreign exchange element of battery limits erected capital cost is used as the basis for developing "Fixed Costs".

TABLE III.3.3

Production Cost of Ethylene

Plant Capacity, ethylene	60,000 MTPA	
Plant Capacity, propylene	26,400 MTPA	
Capital Cost (foreign exchange element of 'battery limits' erected) :	$\$11.6 \times 10^6$	(equivalent to $193.5 per MTPA ethylene capacity)

Per MT Ethylene	Quantity	Foreign Exchange $		Internal Currency Rs
Gaseous by-products MT (net)	0.51	NIL		45.9
Fuel, Oil MT	0.15	1.7		3.2
Gasoline (Table III 4.2)	0.70	14.4		16.3
Total Credit for by-products	3.4	16.1		65.4
Naphtha feedstock MT	3.3	48.5		47.5
Net cost of feedstock and by-products		32.4	credit	17.9
Steam MT	0.23	0.05		1.8
Power Kwh	300	1.5		15.0
Cooling Water M^3	417	1.65		20.8
Chemicals		0.1		0.5
Cost of utilities and chemicals		3.3		38.1
Variable cost		35.7		20.2
Fixed costs		37.5		195.4
Production cost of (1MT ethylene plus 0.44 MT propylene)		73.2		215.6

Taking the value of ethylene to be twice that of propylene, then the production costs are as follows:

	Foreign Exchange $	Internal Currency Rs.
Ethylene production cost per MT	60.0	176.7
Propylene production cost per MT	30.0	88.4

TABLE III.3.4

Production cost of Styrene

Plant capacity : 12,850 MTPA
Capital cost (Foreign Exchange element of 'battery limits erected'): $ 3.61 x 10^6 (equivalent to $ 281.0 per MTPA capacity)

Per MT Styrene	Quantity	Foreign Exchange $	Internal Currency Rs
Benzene MT	0.865	36.2	132.0
Ethylene MT	0.32	19.2	41.8
Utilities 44 $/MT 15% foreign exchange		6.6	178.0
Variable cost		62.0	351.8
Fixed costs		54.5	283.8
Production cost		116.5	635.6
Cost of alternative import		176.0	-
Saving in Foreign Exchange		59.5	-
Ratio 635.5/56.5 = Rs.10.7/$			

Thus, we estimate that the production of styrene would save 59.5$/MT, but that Rs. 10.7 would be expended to save each $. On this basis, we consider styrene production would not be attractive.

3.3.2 Polystyrene

We have examined the viability of a polystyrene plant of 10,000 MTPA capacity, equal to the estimated 1980 demand, to start-up in 1977. Our costing is on the basis of uncoloured crystal chip, although in practice a range of products, including rubber - modified high impact grades, would be produced, and colourants would be incorporated.

Styrene is assumed to be available at the production cost estimated above; alternatively imported at $ 176/MT.

The cost estimate is an approximate one, and we have used 'optimistic' figures so as to examine whether production could be viable.

TABLE III.3.5

Production Cost of Polystyrene

(bulk process, to make crystal chip)

Plant capacity : 10,000 MTPA

Capital cost (foreign exchange element of 'battery limits erected'):
\$ 2.0 x 10^6 (equivalent to \$ 200 per MTPA capacity)

Per MT Polystyrene	Quantity	Foreign Exchange \$	Internal Currency Rs.
Styrene MT	1.04	121.2	676.3
Steam MT	0.5	0.1	4.0
Power kWh	300	1.5	15.0
Cooling water m^3	20	0.1	1.0
Variable cost		122.9	696.3
Fixed cost		38.8	202.0
Production cost		161.7	898.3
Cost of alternative import		240	-
Saving		78.3	-
Ratio 898.3/78.3 = Rs. 11.4/\$			
Alternatively,			
Production cost from imported styrene at \$ 176/MT		223.8	222
Cost of alternative import \$/MT		240	
Saving in Foreign Exchange		16.2	
Ratio 222/16.2 = Rs. 13.7/\$			

On the basis of the above figures, we consider that the production of polystyrene is un-attractive, whether from imported or indigenous styrene.

We have therefore omitted styrene and polystyrene production from further consideration in this report.

3.4 Synthetic Rubber

The greater part of the market for synthetic rubber in Pakistan could be satisfied by styrene butadiene rubber (SBR). This market would include considerable replacement of natural rubber by SBR if the prices were about equal, which is the case at present in the world market.

The next most generally useful rubber is butadiene rubber (BR), but it has a narrower range of applications, andhigher cost of production than SBR. In Pakistan, it is estimated that the potential market for BR is at most half of that estimated for SBR i.e., 5000 MTPA. Since BR is being produced generally on a 40,000 MTPA scale or greater, production from such a small plant would certainly be uneconomic compared with imports.

We therefore consider that BR is not an attractive product for manufacture in Pakistan, at least up to 1980, and that SBR is potentially a more economical end product for the limited quantity of butadiene which could be extracted locally.

Styrene is assumed to be imported at $176/MT.

Butadiene cost has been estimated at its cost of production from the C4 hydrocarbon by-product of the Fauji complex, to which we have given fuel value only. The quantity of butadiene potentially available from Fauji at full output will be 6,750 MTPA, equivalent to about 11,500 MTPA of SBR.

Extender oil is assumed to be available from local production at Rs. 800/MT.

TABLE III.3.6

Cost of Production of Butadiene

Plant capacity : 5,800 MTPA of SBR quality butadiene
Capital cost (foreign exchange element of 'battery limits erected'):
$ 1.38×10^6 (equivalent to $ 238/MTPA capacity).

Per MT Butadiene	Quantity	Foreign Exchange $	Internal Currency Rs.
Feedstock (net) MT	1.06	-	95.5
Steam MT	2.5	0.5	2.5
Power kWh	400	2.0	20.0
Demineralised water m^3	0.2	0.04	0.2
Cooling water m^3	180	0.72	9.0
Catalysts and chemicals		1.2	-
Variable cost		4.5	127.2
Fixed cost		46.7	240.4
Production cost		51.2	367.6

TABLE III.3.7

Cost of Production of SBR Rubber

(30% 1500 types/70% 1700 types, i.e. oil extended)

Plant Capacity: 10,000 MTPA

Capital Cost (foreign exchange element of 'battery limits erected'):

$ 3.46 x 10^6 (equivalent to $ 346/MTPA capacity)

Per MT of SBR Rubber	Quantity	Foreign Exchange $	Internal Currency Rs
Butadiene kg	580	29.7	213.0
Styrene kg	185	32.6	-
Extender Oil kg	200 at say Rs 0.8	-	160
Emulsifier, Initiator, Defoamer, Modifier, Short-stop, Coagulant, Stabiliser (kg)	250 approximately	52.0	-
Steam MT	4.0	0.8	32.0
Power kWh	700	3.5	35.0
Process Water m^3	10	0.7	5.4
Cooling Water m^3	200	0.8	10.0
Packages			8.0
Variable Cost		120.1	463.4
Fixed Cost		67.0	349.5
Production		187.1	812.9
Cost of alternative import		300	-
Saving		112.9	

Ratio 812.9/112.9 = Rs. 7.2/$

Future C & F price of imported SBR is assumed to be $ 300/MT, for the above product mix. This figure is about the lowest price being quoted currently in Europe (for small lots) and about 10% lower than the present day price of SBR, C & F., Pakistan, both for 1712 grade, i.e. general purpose oil extended.

On the above basis, we consider that SBR production is attractive.

3.5 Phthalic Anhydride

We have examined the viability of a phthalic anhydride plant, of capacity 7,860 MTPA, i.e., equal to the estimated 1980 demand. Cost Data which are typical for the Krebskomo process were used.

The cost of o - xylene feedstock was assumed to be as estimated in Section 4., below.

Transport costs have been included because production would be at Karachi, but the main user would be the proposed DOP plant in East Pakistan.

TABLE III.3.8

Production Cost of Phthalic Anhydride

Plant capacity : 7,860 MTPA
Capital cost (foreign exchange element of ' battery limits erected'):
$ 2.39 x 10^6 (equivalent to $ 304/MTPA capacity)

Per MT of Phthalic Anhydride		Quantity	Foreign Exchange $	Internal Currency Rs
o - xylene (95% pure)	MT	1.11	51.5	199.0
Power	kWh	1100	5.5	55.0
Cooling Water	m^3	60	0.2	3.0
Fuel	10^6 kcal	1.0	-	7.5
Catalysts and Chemicals			2.0	-
Packages			-	8.0
Variable Cost			59.2	272.5
Fixed Cost			59.0	307.0
Production			118.2	579.5
Cost of shipping 80% of production to East			-	45
Production and transport			118.2	624.5
Cost of alternative import			200	
Saving in Foreign Exchange			81.8	
Ratio 624.5/81.8 = Rs. 7.6/$				

On the above basis, we consider phthalic anhydride production to be attractive although only marginally so. We have therefore included this product in our recommended schemes.

3.6 Caprolactam

3.6.1 Caprolactam Plant Capacity Selected for Study

We have examined the economics of a plant of 15,000 MTPA capacity, equivalent to approximately 15,000 MTPA of nylon 6 fibre (including about 4.5% content of water, spin finish etc., in the fibre). This capacity is close to our estimate of the 1979 demand (See Section 2.1 above). 15,000 MTPA capacity was chosen for study because (a) it is a standad size for which there may be some economy in engineering cost, and (b) a preliminary analysis showed it to be about the minimum economic size. Production would be planned to start in 1976.

3.6.2 Production Costs and Choice of Process Route to Caprolactam

Three alternative process routes were considered:-

(a) Cyclohexane Route i.e.,

Cyclohexane oxidation to cyclohexanone, reaction with hydroxylamine to the oxime, which is re-arranged to caprolactam. Nitric oxide is used in place of sulphur dioxide in the preparation of hydroxylamine, in the latest version of the process, for which DSM supplied the basic assessment data. Ammonium sulphate by-product is thereby reduced to 1.77 MT/MT caprolactam. Closely similar technology is available also from Inventa.

(b) Photonitrosation of cyclohexane to the oxime, then re-arrangement as (a) above (Toyo Rayon Process). Ammonium sulphate by-product is 2.5 MT/MT caprolactam.

(c) Toluene oxidation to benzoic acid, then hydrogenation to hexahydrobenzoic acid, which is reacted with nitrosylsulphuric acid to give caprolactam (Snia Viscosa Process). Ammonium sulphate by-product is 4.25 MT/MT caprolactam. So far, only Snia Visosa themselves operate the process.

In our opinion, out of the currently available caprolactam technology selection of a caprolactam process must be made from among the above three routes. They are the only routes for which the processes are at the same time well proven, competitive and suited to Pakistan.

In particular, we could not recommend for Pakistan any process which avoids the production of ammonium sulphate altogether.

Although such processes are known, including one operated commercially (by Union Carbide), they all have drawbacks which outweigh the advantage of avoiding ammonium sulphate by-product.

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VOLUME III

PROPOSALS FOR THE DEVELOPMENT OF THE AROMATICS FIBRES AND SYNTHETIC RUBBER INDUSTRIES IN PAKISTAN IN ASSOCIATION WITH REFINERY AND PETROCHEMICAL OPERATIONS

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However, any decision on choice of caprolactam process is probably at least three years in the future, and new or improved processes may reach commercial production in the interval.

In calculating the costs of caprolactam production below, we have used raw material costs as follows:-

(i) For benzene, or alternatively toluene - the calculated cost of their production in an aromatics extraction unit in Pakistan (Section 4.0).

(ii) For cyclohexane - calculated cost of production in the IFP process. This process has costs comparable with other routes.

(iii) For ammonia - cost at site is estimated at Rs 320/MT. None of the sites considered has a modern ammonia plant nearby and their cost includes transport to the selected site. By-product ammonium sulphate has been credited at Rs 200/MT.

(iv) For Sulphuric Acid and Oleum. Production costs have been estimated on the basis of imported sulphur available at $40/MT (C and F Pakistan).

TABLE III.3.9

Production Cost of Cyclohexane (IFP Process)

Plant Capacity: 14,400 MTPA of cyclohexane

Capital Cost (foreign exchange element of 'battery limits erected'):
$ 490,000 (equivalent to $ 34.0/MTPA capacity)

Per MT Cyclohexane	Quantity	Exchange $	Currency Rs
Benzene MT	0.94	39.4	143.5
Hydrogen as 100% kg	80	0.8	40.0
Power kWh	30	0.15	1.5
Demineralised Water m^3	0.16	0.03	0.2
Cooling Water m^3	2.5	0.10	1.3
Catalyst		1.0	-
		41.5	186.5
Steam (Credit) MT	0.685	(-0.1)	(-5.5)
Variable Cost		41.4	181.0
Fixed Cost		6.6	34.3
Production Cost		48.0	215.3

TABLE III.3.10

Production Cost of Oleum

Plant Capacity: 20,200 MTPA

Capital Cost (foreign exchange element of 'battery limits erected'):
$ 1.21 x 10^6 (equivalent to $ 59.9/MTPA capacity)

Per MT Oleum as H_2SO_4	Quantity	Exchange $	Currency Rs
Sulphur, MT	0.34	13.6	-
Power kWh	8	0.04	0.4
Cooling Water m^3	25	0.1	1.3
Process water m^3	1	0.07	0.5
		13.8	2.2
Steam (credit) MT	0.5	(- 0.1)	(-4.0)
Variable Cost		13.7	(-1.8)
Fixed Cost		11.6	60.5
Production Cost		25.3	58.7

TABLE III.3.11

Production Cost of Caprolactam (DSM Process)

Plant Capacity: 15,000 MTPA

Capital Cost (foreign exchange element of 'battery limits erected'):
$ 12.3 x 10^6 (equivalent to $ 820/MTPA capacity)

Per MT Caprolactam	Quantity	Foreign Exchange $	Internal Currency Rs
Cyclohexane MT	0.96	46.1	217
Caustic Soda MT	0.051	-	34
Oleum (as H_2SO_4) MT	1.35	34.2	79
Ammonia MT	0.71	-	227
Hydrogen MT	0.08	0.8	40
Boric Acid MT	0.01	2.0	-
Ammonium Sulphate MT	1.77 (Credit)	-	(-354)
Total for materials		83.1	243
Power kWh	600	3.0	30
Steam MT	14.3	2.9	115
Process Water m^3	6.5	0.5	4
Cooling Water m^3	1150	4.6	58
Catalysts and Chemicals		12.0	-
Total of utilities and chemicals		23.0	207
Packages			8
Variable Cost		106.1	458
Fixed Cost		159.0	828
Production Cost		265.1	1286
Cost of alternative import		420	-
Saving in Foreign Exchange		154.9	

Ratio 1286/154.9 = Rs8.3/$

TABLE III.3.12

Production Cost of Caprolactam (Toyo Rayon Process)

Plant Capacity 15,000 MTPA

Capital Cost (foreign exchange element of 'battery limits erected'):
\$ 12.3 x 10^6 (equivalent to \$ 820/MTPA capacity)

Per MT caprolactam	Quantity	Foreign Exchange \$	Internal Currency Rs
Cyclohexane MT	0.93	43	190
Oleum / Sulphuric Acid (as H_2SO_4 MT)	1.72	42	114
Ammonia MT	0.82	-	263
Ammonium Sulphate (Credit) MT	2.29	-	(-459)
Combined utilities (\$80, 30% foreign)		24	267
Chemicals		15	-
Variable Cost		124	375
Fixed Cost		159	828
Production Cost		283	1203

TABLE III.3.13

Production Cost of Caprolactam (Snia Viscosa Process)

Plant Capacity: 15,000 MTPA of caprolactam

Capital cost (foreign exchange element of 'battery limits erected'):
$ 11.5 x 10^6 (equivalent to $770/MTPA capacity)

Per MT caprolactam	Quantity	Foreign Exchange $	Internal Currency Rs
Toluene MT	1.135	39.6	144
Ammonia MT	1.312	-	418
Oleum (as H_2SO4) MT	3.18	77	213
Hydrogen MT	0.075	0.8	38
Caustic Soda MT	0.177	-	118
Chlorine MT	0.018	-	14
Ammonium Sulphate MT	4.25 (Credit)	-	(-850)
Total for materials		117.4	95
Steam MT	11.0	2.2	50
Power kWh	1,000	5.0	50
Cooling Water m^3	1,400	5.6	70
Catalysts and Chemicals	-	18	
Packages		-	8
Variable Cost		148	273
Fixed Cost		149	778
Production Cost		297	1051

On the basis of the above cost estimates the production cost of caprolactam is affected very little by the choice of process route. However, cyclohexane processes are offered by DSM and Inventa among others, and both of these processes have a good record of successful operation. We would also expect these processes to be rather more simple to operate than those employing the other two routes (Toyo Rayon and Snia Viscosa). We have therefore based our full economic assessment in section 6., on the cyclohexane route, using data for the DSM process.

We estimate the foreign exchange saving resulting from the manufacture of caprolactam on the 15,000 MTPA scale would be $155/MT and that Rs 8.2 would be spent to save each $1.0. On this basis, we consider that such an operation would bring a marginal overall benefit to the Pakistan economy.

3.6.3 Choice of Site for a Caprolactam Plant

The production cost estimate above is applicable to an integrated petrochemical complex near Karachi. The Multan fertiliser complex is another possible site, offering comparable opportunity for rationalisation of utilities plants. However, additional equipment for hydrogen supply and additional inland freight will increase the plant cost. Fibre production would most economically be concentrated at Karachi, so transport cost difference is estimated below on the basis that caprolactam would have to return to Karachi.

Caprolactam Plant at Multan instead of Karachi; Additional Transport Costs per MT Caprolactam

	Quantity MT	Rs/MT	Rs
Sulphur	0.5	33	16.5
Cyclohexane	1.0	44	44
Ammonia	0.7	120 (saving)	(-85)
Ammonium Sulphate	1.8	No difference	
Caprolactam	1.0	44	44
Net Difference			19.5

Thus location of the caprolactam plant at Multan would result in increased costs of transport with no other compensating benefits.

Also Karachi as a site for a caprolactam plant offers better opportunity of rationalisation of caprolactam recovery from the fibre plant i.e. final purification of both new and recovered caprolactam could be combined within the caprolactam plant. Overall, Karachi is the most suitable site in West Pakistan for caprolactam manufacture.

In the East, a parallel situation exists in the choice between Chittagong and Ashuganj as sites for a caprolactam plant. On similar grounds to those above, Chittagong is the more suitable site, in East Pakistan.

Another possible site in East Pakistan is at Fenchuganj. There are two main factors against using Fenchuganj. Firstly, the ammonium sulphate plant would be reaching the end of its normal life by the time the caprolactam unit is established. Secondly the ammonium sulphate plant capacity is less than the rate at which ammonium sulphate is produced as a by-product in a 15,000 MTPA caprolactam unit. The position of Fenchuganj in relation to the main nylon consumption areas is also unattractive. Chittagong is therefore the most suitable location in East Pakistan.

3.7 Dimethyl Terephalate or Terephalic Acid

In this section, an analysis is made for alternative plants of capacity

16,200 MTPA of DMT,

or 13,500 MTPA of TA: either unit will provide sufficient monomer precursor for 15,000 MTPA of polyester fibre. This capacity is close to the estimated 1979 demand (See section 2.1 above). Capacity equivalent to 15,000 MTPA of fibre was chosen for study because

a) the timing of its installation ensures that the nylon and polyester fibre schemes can jointly utilise the aromatic feedstocks available from the proposed BTX production scheme, which supplies mainly the raw materials for these fibres.

b) a preliminary analysis indicated that 15,000 MTPA was the lowest capacity likely to be economically attractive.

For DMT, combined esterification and oxidation of p-xylene by the well-proven Witten process was selected as the basis of cost estimation. This route is slightly cheaper than those via esterification of crude terephalic acid, where only DMT is required as product.

For TA, direct oxidation of p-xylene was chosen and our cost estimate is for the Mobil process. A somewhat similar process is available from Amoco. The Henkel I and II processes, based on orthoxylene or toluene feedstock, are no longer competitive and licences for such processes are not available. In making this statement we are quoting a recent letter from Lurgi, who have had a lot of experience with the Henkel processes. We also learned from Mitsubishi, who operate such a process in Japan, that they are not interested in licensing it in Pakistan.

Cost of p-xylene feedstock is taken as the production cost calculated for the appropriate BTX scheme in Section 4. In the case of TA, the unit cost of p-xylene was increased by an appropriate amount to allow for the smaller scale of production.

TABLE III.3.14

Production and Transport Cost (to Karachi) of Methanol

Plant Capacity: 40,000 MTPA

Capital Cost: (foreign exchange, element of 'battery limits erected'): $\$3.37 \times 10^6$ (equivalent to \$84.3/MTPA capacity)

Site: Ashuganj, East Pakistan.

Per MT methanol	Quantity	Foreign exchange \$	Internal currency Rs
Natural Gas/10^6kcal	8.5	-	18.0
Elec. energy kWh	180	0.9	5.4
Cooling water m^3	250	1.0	12.5
Demin. water m^3	2.3	0.5	2.0
Catalyst & Chemicals		2.5	-
Variable		4.9	37.9
Fixed		16.2	85.1
		21.1	123
Drums			60
Transport			111
Production and transport cost		21.1	194

TABLE III.3.15

Production Cost of Dimethyl Terephthalate (Witten Process)

Plant Capacity : 16,200 MTPA

Capital Cost (foreign exchange element of 'battery limits erected'):
$ 11.8 x 10^6 (equivalent to $ 729/MTPA capacity)

Per MT of DMT	Quantity	Foreign Exchange $	Internal Currency Rs.
p-xylene MT	0.716	62.6	288.3
Methanol MT	0.561	11.8	108.8
Steam MT	10.0	2.0	80.0
Elec. energy kWh	2,030	10.2	101.5
Cooling water m^3	285	3.3	41.2
Catalyst & Chemicals		1.5	-
Variable		91.4	619.8
Fixed		141.2	736.3
Production		232.6	1356.1
Cost of alternative import		380	-
Saving in Foreign Exchange		147.4	-

Ratio 1356.1/147.4 = Rs. 9.2/$

TABLE III.3.16

Production Cost of Terephthalic Acid (direct oxidation process)

Plant Capacity: 13,500 MTPA of fibre grade TA.

Capital Cost (foreign exchange, element of battery limits erected):

$ 10.6 x 10^6 (equivalent to $787/MTPA capacity)

per MT of fibre grade TA	Quantity	Foreign exchange $	Internal currency Rs
(note: fixed cost element of production of p-xylene from mixed xylenes has been increased by 10% to allow for the 20% lower requirement than by the DMT route, for the same quantity of polyester fibre end-product)			
p-xylene, MT	0.69	62.2	298.0
Hydrogen, kg	6.4	0.1	3.4
Fuel 10^6 kcal	3	-	22.5
Steam MT	8	1.6	64.0
Elec. energy kWh	700	3.5	35.0
Cooling water m^3	140	0.5	7.0
Demin. water m^3	7.5	1.5	7.5
Catalyst & Chemicals & other services		27	-
Variable		96.4	437.4
Fixed		152.8	795.3
Production		249.2	1232.7
Cost of alternative imports		380.0	
Saving in Foreign Exchange		130.8	

Ratio 1232.7/130.8 = Rs.9.4/$

On the basis of the above estimates, the cost of production of one MT of either DMT or TA is about the same. In our opinion, the relationship will also apply elsewhere in the world. In the next few years, we expect that DMT and TA will be available at about the same price per MT, with TA becoming the cheaper in the long term.

Prices of DMT and TA are not generally published, but in our opinion either material will be available on contract, C & F Pakistan, at about $380 /MT, or possibly less. On this basis, we consider that the production of either intermediate, to supply polyester fibre production of 15,000 MTPA capacity is marginally attractive.

3.8 Ethylene Glycol

We have examined the viability of ethylene glycol production, to supply the needs of 15,000 MTPA of polyester fibre production i.e. the estimated 1979 demand. 4,450 MTPA of ethylene would be required, from the Fauji ethylene complex, to make the requisite 6,000 MTPA of ethylene glycol.

A direct oxidation process would be employed; the older chlorohydrin process is no longer competitive. It may not be possible to get a licence for a plant as small as 6,000 MTPA capacity. Our cost estimate which follows is an approximate one, based on data supplied by Snam-Progetti.

Although the present day price of ethylene glycol, C & F Pakistan, has been quoted to us as $312 /MT, the published prices in Europe (for small quantities) are as low as $220 /MT. We consider that the contract price, C & F Pakistan, will also be about $220 /MT, or even lower.

TABLE III.3.17

Production Cost of Ethylene Glycol

Plant Capacity: 6,000 MTPA

Capital Cost (foreign exchange, element of 'battery limits erected'):
$ 3.44 x 10^6 (equivalent to $ 573/MTPA capacity)

Per MT of Ethylene Glycol	Quantity	Foreign exchange $	Local currency Rs
Ethylene, MT (Table III 3.3)	0.74	44.4	131
Fuel 10^6 kcal	2	-	15
Elec. energy kWh	600	3.0	30
Cooling water m^3	750	3.0	38
Demin. water m^3	8	1.6	8
Higher glycols MT	0.1 (Credit)	-	(-50)
Variable		52	172
Fixed		111	579
Production		163	751
Cost of alternative imports		220	-
Saving in Foreign Exchange		57	

Ratio 751/57 = Rs. 13.1/$

On the basis of the above estimates, we consider that the production of ethylene glycol in Pakistan is not attractive.

SECTION 4

BENZENE, TOLUENE, AND XYLENES

Consumption estimates for B, T, and X in Pakistan were listed in Section 2 and these form the basis of a number of alternative plans for BTX processing schemes which will be developed in this section. Essentially, aromatics extraction plants can be based on the refineries at either Chittagong or Karachi or both; these locations are the sites for the schemes which are described in Section 4.2, costed in Section 4.3 and analysed in Section 4.4.

4.1 Production Capacities Selected for Study

Production capacities for the schemes in this section of the report were based on the market estimates for 1980, as stated in Section 2, and the capacities chosen for the petrochemicals products in Section 3.

There are three alternative processing schemes (A, B, C, below):

Scheme A

In this scheme, the major BTX production would be in the East at Chittagong, along with the three main user plants for caprolactam, DMT or TA, and phthalic anhydride and planned to start up in 1976. A separate small BTX production unit would start up in the West in 1974, to take advantage of the pyrolysis naphtha and to supply the West BTX needs up to 1980; no BTX would have to be transported between wings in 1980.

Scheme B

In scheme B all BTX production would be in the West, at Karachi, together with plants for the synthetic fibre monomers and phthalic anhydride. BTX production would be planned to start in 1974 or 1975, except that production of pure xylene isomers would be delayed until 1976, to suit the user plants.

Scheme C

Here, all BTX production would be at Karachi, starting in 1974, but no synthetic fibre monomers are provided for; phthalic anhydride production would be included. (Inclusion of this scheme allows the viability of phthalic anhydride production, without fibre monomers, to be assessed).

So that basically the same schemes could be used for costing either DMT or TA, the higher consumption of p-Xylene was used in the first place, i.e. based on DMT. The consumption of p-Xylene per MT of fibre is 20% less by the TA route, and an appropriate adjustment was made to the production cost of p-Xylene for estimating the production cost of TA.

The production capacity, locations of the units and dates of plant start-up are listed below:

Scheme A Project in E. Pakistan

BTX Products		Capacity, MTPA
Benzene	for 15,000 MTPA Caprolactam:	13,580
	for Insecticides:	500
	Total:	14,080
Toluene	Miscellaneous:	2,500
Solvent xylene		2,500
p-Xylene	for 15,000 MTPA polyester fibre (via DMT):	11,600
o-Xylene	for 7,800 MTPA of phthalic anhydride:	8,720
	Total BTX:	39,340

Location: Chittagong

Start-up Date: 1976 (Full capacity reached in 1980)

Scheme A Project in W. Pakistan

BTX Products		Capacity, MTPA
Benzene	for 10,000 MTPA DDB:	4,700
	for insecticides:	1,500
		6,200
Toluene	Miscellaneous:	2,500
Solvent xylene		2,500
	Total BTX:	11,200

Location: Karachi

Start-up Date: 1974

Scheme B Project in W. Pakistan

BTX Products	Capacity, MTPA
Benzene	20,220
Toluene	5,000
Solvent xylene	5,000
p-Xylene	11,600
o-Xylene	8,720
Total BTX:	50,540

Location: Karachi

Start-up Date: 1974/5 (xylene separation in 1976)

Scheme C Project in W. Pakistan

BTX Products	Capacity, MTPA
Benzene	6,700
Toluene	5,000
Solvent xylene	5,000
o-Xylene	8,720
Total BTX:	25,420

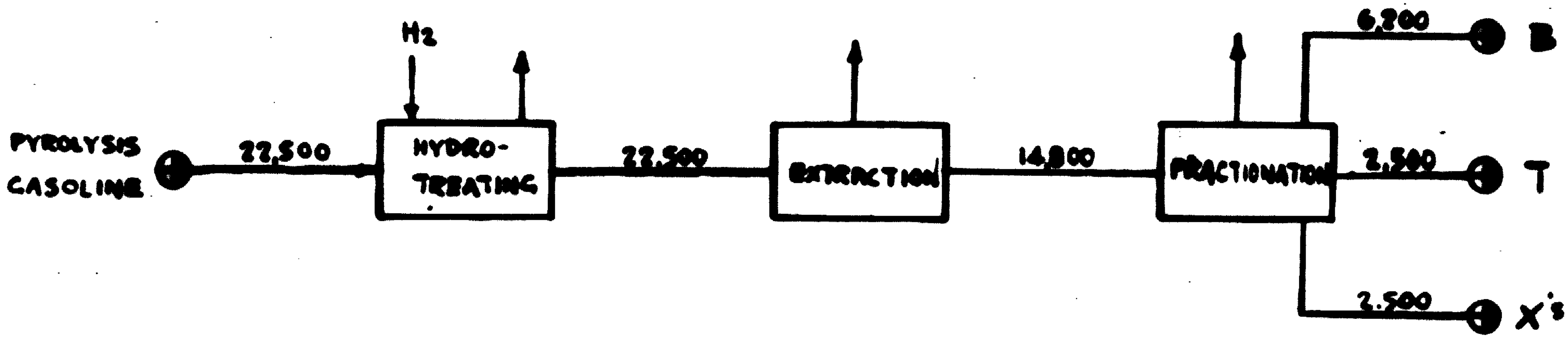
Location: Karachi

Start-up Date: 1974

4.2 Description of Schemes

In this section the aromatics processing plants for the three schemes A, B, and C are discussed.

For East Pakistan, there are four possible processing plants which could be erected to meet the requirements of scheme A (schemes B and C do not include BTX extraction in the East wing). These four are numbered Scheme A East (i) to Scheme A East (iv).



NOTE. ALL QUANTITIES ARE IN METRIC TONS PER YEAR.

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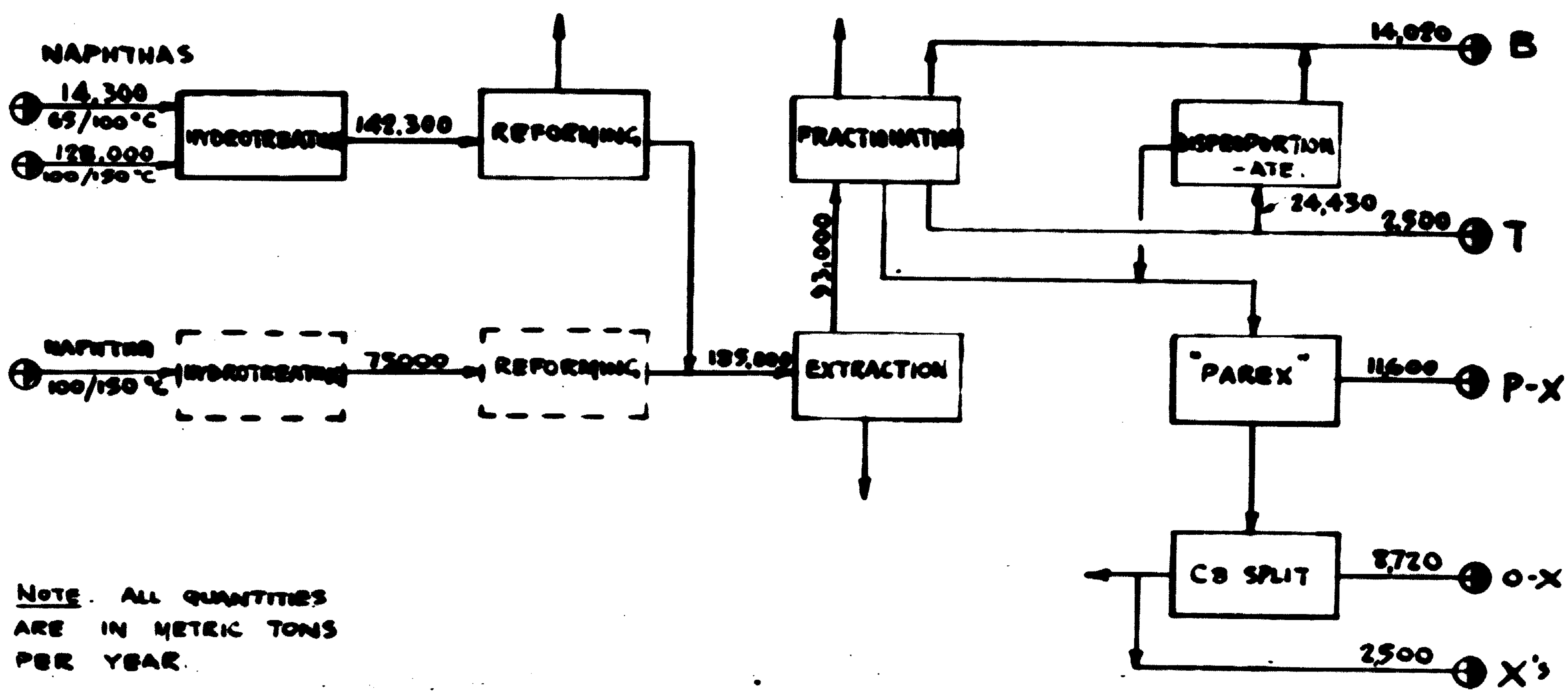
FIG. III.4.1 BLOCK DIAGRAM - SCHEME 'A' - WEST



NOTE. ALL QUANTITIES ARE IN METRIC TONS PER YEAR.

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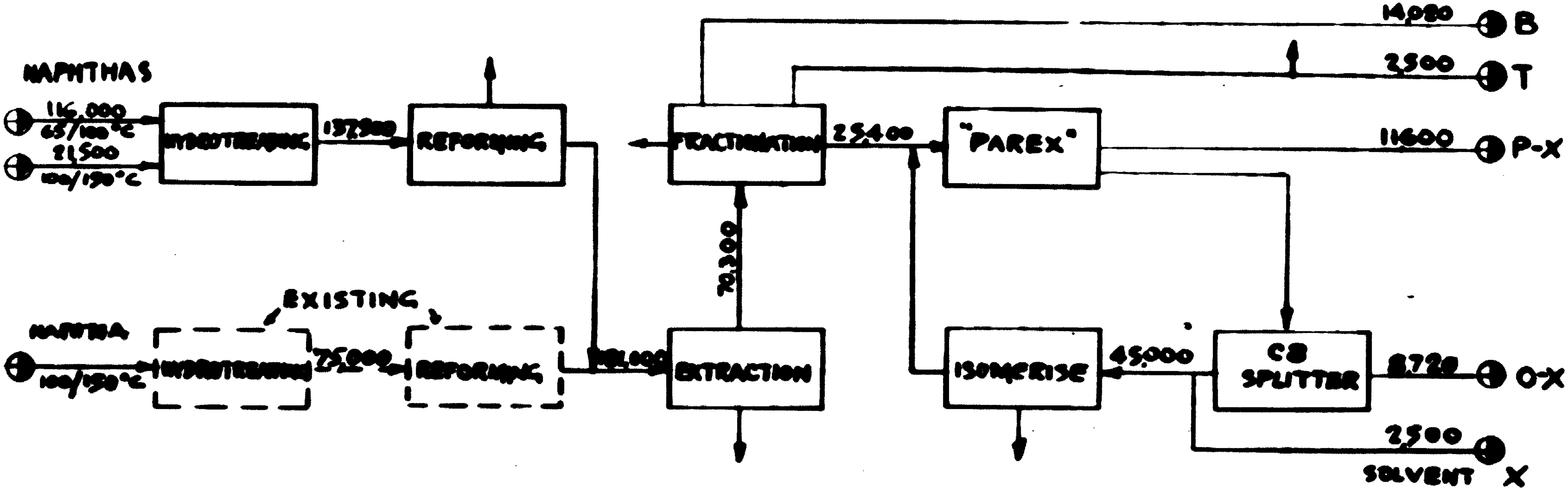
FIG. III.4.2 - BLOCK DIAGRAM - SCHEME 'A' - EAST (i)



NOTE. ALL QUANTITIES ARE IN METRIC TONS PER YEAR.

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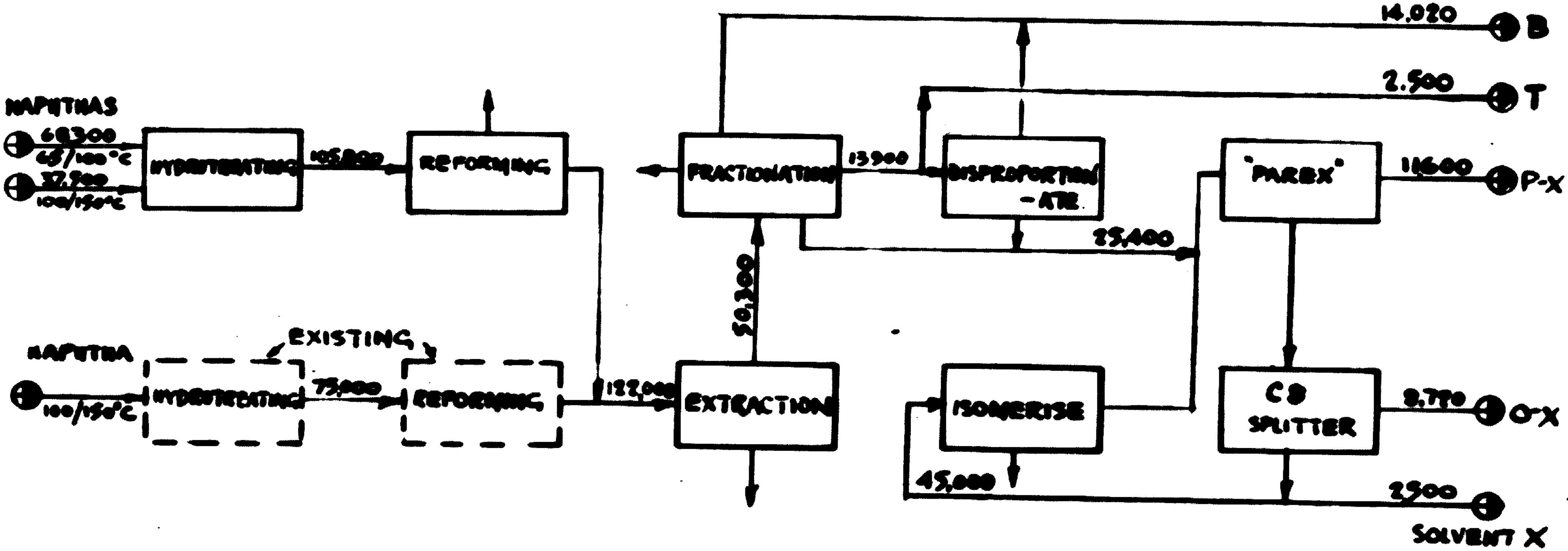
FIG. III 4.3. BLOCK DIAGRAM - SCHEME 'A'-EAST (ii)



NOTE. ALL QUANTITIES ARE IN METRIC TONS PER YEAR.

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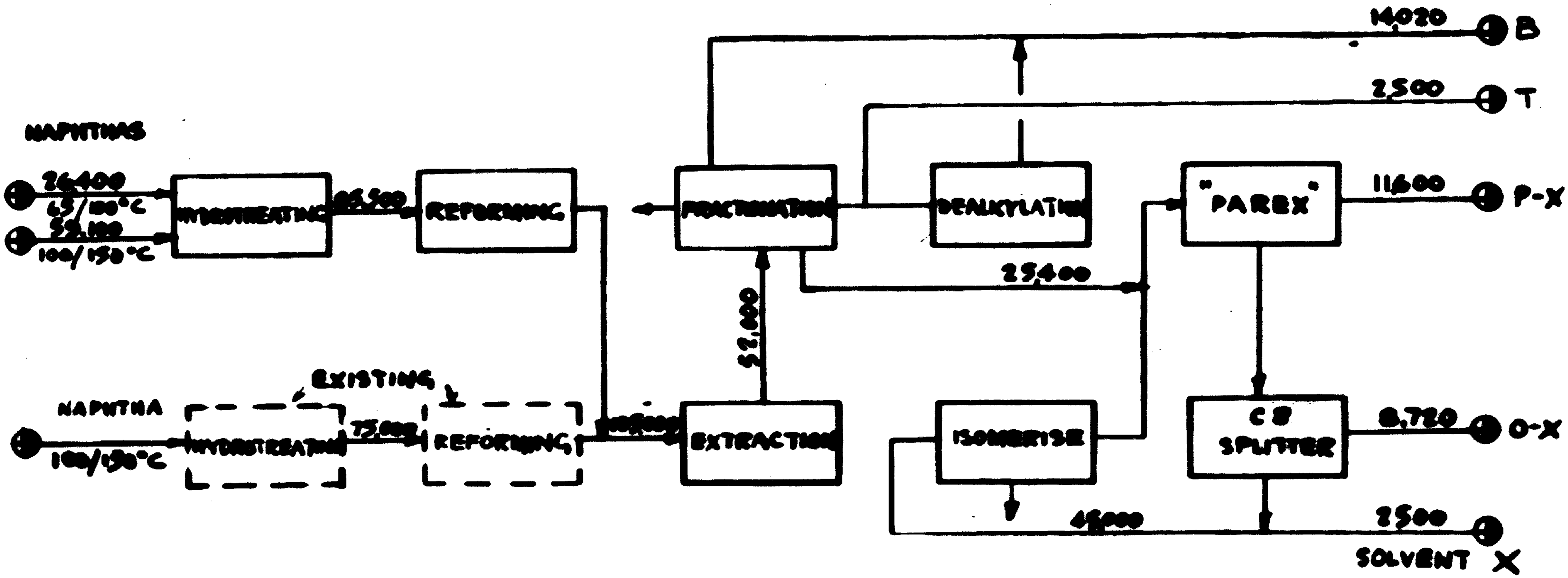
FIG. III.4.4. BLOCK DIAGRAM - SCHEME 'A' - EAST (iii)



NOTE. ALL QUANTITIES
ARE IN METRIC TONS
PER YEAR.

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FIG III.4.5 BLOCK DIAGRAM - SCHEME 'A' EAST (iv)

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For West Pakistan, a plant unit is described for scheme A, two alternative units for scheme B (Scheme B West (i) and Scheme B West (ii)) and one for Scheme C.

4.2.1 East Pakistan Production Units

In East Pakistan, the only practical source of BTX is naphtha from the refinery at Chittagong. Taking the refinery capacity to be 2.9×10^6 MTPA of Aga Jhari crude, if all the naphtha were catalytically reformed, it would be possible, using commercial physical separation methods only, to separate the quantities of BTX required. Large new reforming, extraction, and fractionation capacity would be required, however, and the surplus aromatics and raffinate together would considerably exceed the requirements of the market for high octane motor gasoline. Such a scheme would be uneconomical, therefore, for East Pakistan, we preferred schemes which included at least one chemical reaction stage following catalytic reforming, in order to improve the yield of benzene and/or p-Xylene from naphtha.

Scheme A (East) - Alternative (i)

In this scheme, the whole output of the existing catalytic reforming unit, plus a substantial quantity of reformate from a new reformer, go to a solvent extraction unit which separates the aromatics. The raffinate, consisting mainly of paraffins, is a major by-product. The aromatics are separated in the fractionation unit into benzene, toluene, C_8 aromatics and a by-product C_9 + aromatic stream.

Some toluene is removed as product, and the remainder is disproportionated, i.e., by chemical reaction, two molecules of toluene are converted to (ideally) one molecule each of benzene and xylene. Several such processes are either commercial or in an advanced stage of development; they will certainly be used increasingly in future aromatic plants. For this scheme, we have used data provided by UOP for their "Tatoray" toluene disproportionation process. "Tatoray" is in full scale operation in Japan; yields are good, and operation is straight forward.

C_8 aromatics from the fractionation unit are combined with those from the disproportionation unit and fed to the "Parex" unit.

"Parex" is a newly developed process, but several commercial units are currently being designed. It operates in a manner which provides, in effect, counter-current contact of the solid adsorbent first with the feed stream, then with a high boiling solvent. Instead of actually moving the solids, however, a similar effect is obtained by switching the fluid streams, progressively on a time cycle, to multiple zones of a stationary bed of the solids. The engineering features of the process are well proved, being taken directly from a UOP process for the separation of n-paraffins; a large number of these n-paraffin units are in operation.

"Parex" has comparable capital and operating costs to modern cystallisation processes, when separating a given quantity and purity of p-xylene product. It has the important advantage of recovering about 95% of the p-xylene in the feed stream, compared with 60 - 65% for crystallisation.

The remaining C_8 aromatics are distilled to produce o-xylene and solvent xylene; surplus C_8 aromatics are available for gasoline.

In costing this scheme, and the others for East Pakistan, we have taken no extra credit for any surplus of octane potential which will be available over that of the replaced reformate and naphtha.

It is assumed that by-products surplus to motor gasoline requirements would be bulked with, and be sold at the same price as, surplus naphtha. The net cost of feedstock for the production of aromatics for chemical use is equal, on this basis, to the same weight of naphtha plus the loss in value of the naphtha converted to fuel gas and light hydrocarbons by chemical reaction.

Scheme A (East) - Alternative (ii)

This scheme employs isomerisation of xylenes, so that a much smaller quantity of C_8 aromatics is required from the upstream unit, to produce the desired xylene products. The data used for the isomerisation units are typical for the Engelhard "Octafining" process. In this scheme, toluene is in surplus.

Scheme A (East) - Alternative (iii)

This scheme employs both disproportionation and isomerisation and therefore requires less reforming, extraction and fractionation capacity than either i) or ii). Since the main by-products available for gasoline blending would be raffinate and C_9 + aromatics, this scheme would in practice be adjusted by providing marginal additional reforming capacity to produce a satisfactory motor gasoline. This could have been taken into account, however, the scheme was found to be unattractive even on the present, slightly optimistic basis.

Scheme A (East) - Alternative (iv)

This scheme employs hydrodealkylation of toluene to benzene, and isomerisation of xylenes. As for scheme A(East) iii), the scheme as it stands is slightly optimistic, in that some additional reforming capacity should be added, to meet the needs of the motor gasoline market.

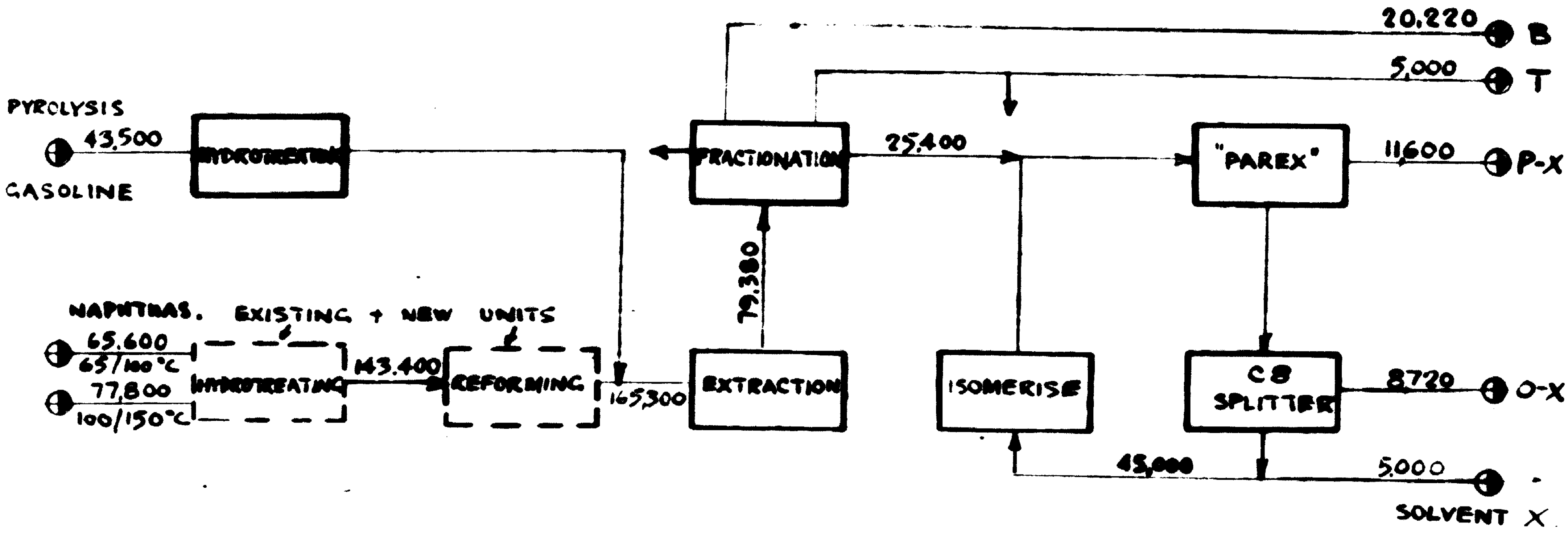

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FIG III 4.6. BLOCK DIAGRAM SCHEME 'B' (i)

NOTE. ALL QUANTITIES ARE IN METRIC TONS PER YEAR

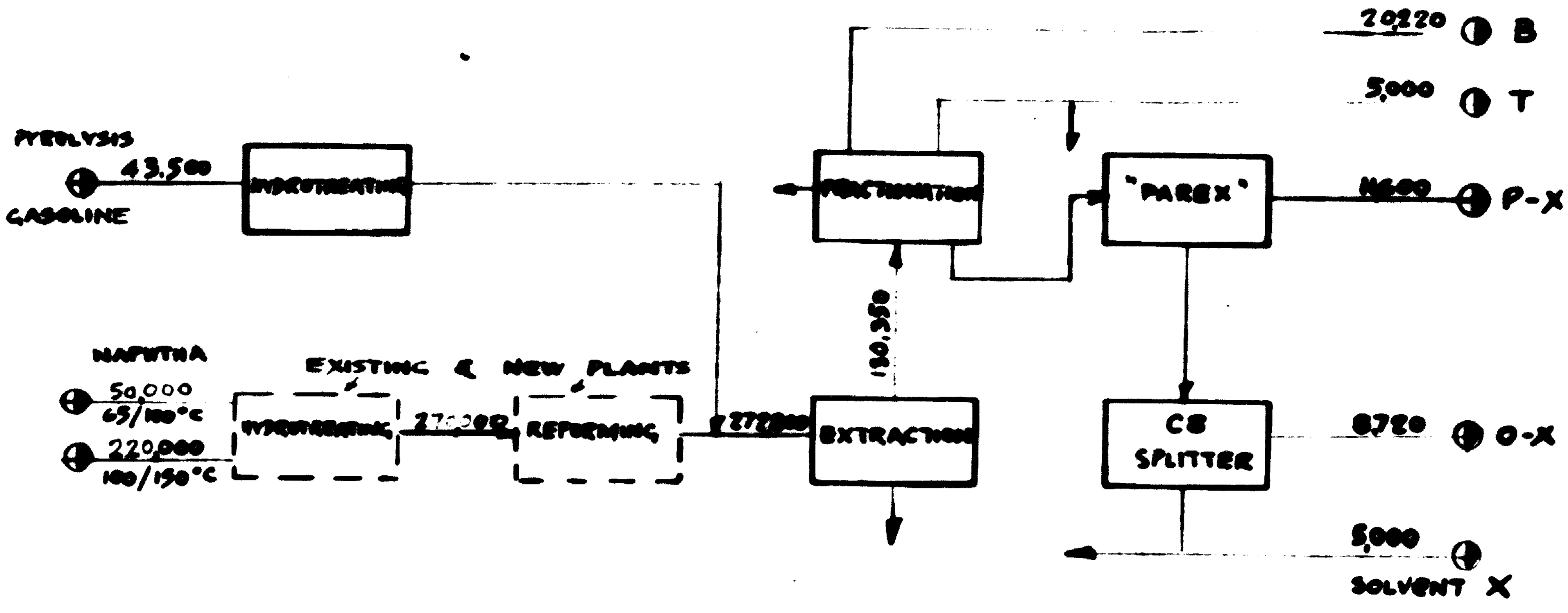

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FIG III.4.7 - BLOCK DIAGRAM SCHEME 'B' (ii)

NOTE. ALL QUANTITIES ARE IN METRIC TONS PER YEAR.

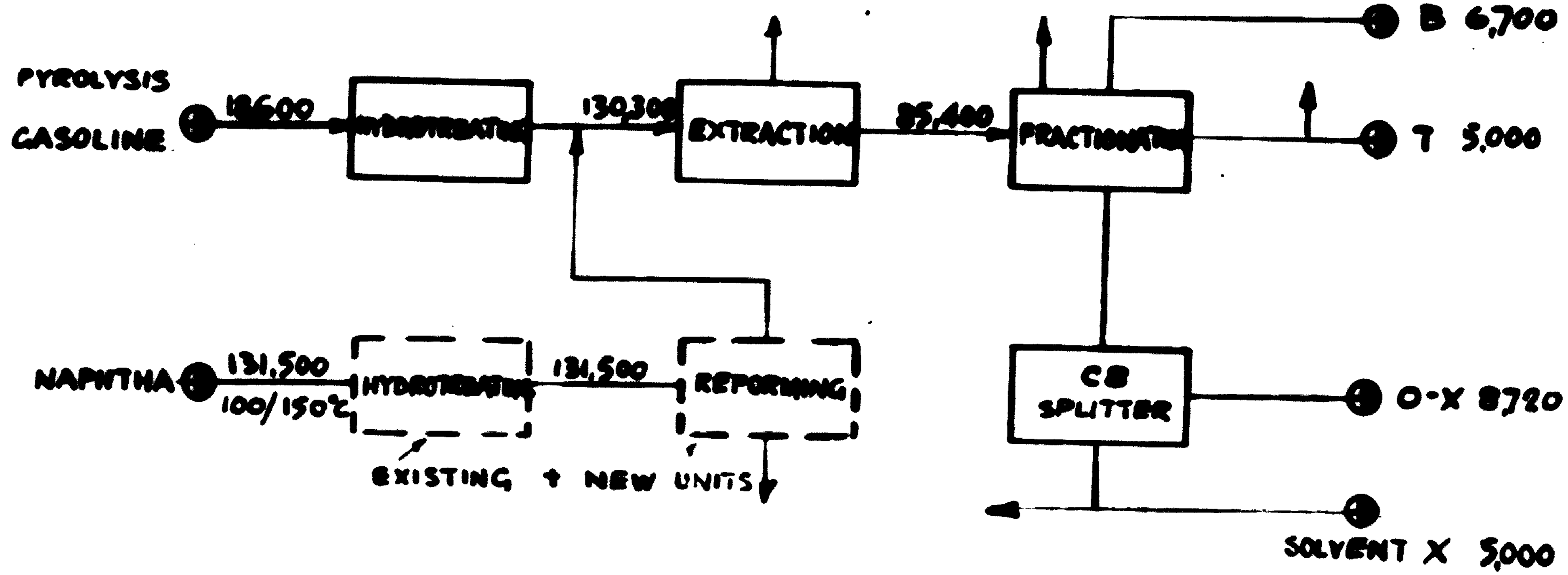

FIG. III.4.8. U.N.I.D.O. - C 1669
BLOCK DIAGRAM.
SCHEME 'C' - (WEST, WITHOUT FIBRE MONOMER PRODUCTION)

NOTE. ALL QUANTITIES ARE IN METRIC TONS PER YEAR.

4.2.2 West Pakistan Production Units

Scheme A (West)

This unit could be combined with any of the East schemes to meet the requirements for BTX in the West, if the main aromatics petrochemicals complex were to be sited in the East Wing.

Pyrolysis gasoline, an ideal feedstock for the purpose, will be available at Karachi from the planned olefins plant. Only a part of the available pyrolysis gasoline would be required for this scheme. The usual process units, i.e. hydrodesulphurisation, followed by extraction and fractionation, are employed.

Scheme B (West) - Alternative (i)

In this scheme, total Pakistan requirements for BTX are produced in the West. The whole of the available pyrolysis naphtha is used, together with substantial quantities of reformate from one of the refineries at Karachi.

The reformate would not all have to come from new equipment, however. Since the liquid by-products from the BTX plant have similar properties, overall, to reformate, the amount of additional reformate production capacity required will be equal to the BTX products, plus any gaseous by-products.

This scheme includes isomerisation of xylenes. Toluene is produced surplus to forecast consumption.

Scheme B (West) - Alternative (ii)

In this scheme, xylenes are not isomerised. As a result, a considerably greater quantity of reformate feed, and correspondingly greater throughput in extraction and fractionation, is required. Both toluene and mixed xylenes are produced surplus to forecast requirements.

Scheme C (West)

As mentioned earlier, scheme C provides for no production of polyester fibre or nylon precursors. Para-xylene production is therefore eliminated and benzene capacity is reduced. The remaining required quantities of benzene, toluene, o-xylene, and solvent xylene are produced from a mixed feed of hydrotreated pyrolysis gasoline and catalytic reformate, by extraction and fractionation.

4.3 Production Cost Basis

This section lists the yields, capital cost data, and consumption of raw materials, utilities etc. used as a basis for calculation of production costs in Section 4.4.

4.3.1 Yields and Separation Efficiencies

The following yields were assumed on the basis of 100% use of Aga Jhari crude (wt.% on crude):-

Naphtha cut	65 - 100°C	100 - 150°C
Naphtha yield	5.1	8.29
Aromatics in reformate:-		
Benzene	0.6	0.1
Toluene	0.5	1.1
o-Xylene	-	0.53
p-Xylene	-	0.42
C_8 aromatics	-	2.3
$C_{9}+$ aromatics	-	0.7

95% extraction efficiency of aromatics was assumed.

95% extraction of p-xylene from the stream fed to the "Parex" process was assumed.

Dealkylation was assumed to yield 0.82 MT benzene per MT toluene.

Disproportionation of 1 MT toluene was assumed to yield:

Benzene MT	0.414
C_8 aromatics	0.418
C_9 aromatics	nil (total recycle)
$C_{10}+$ aromatics	0.005

Proportion of p-xylene in C_8 aromatics from disproportionation, isomerisation or pyrolysis gasoline assumed to be 18%.

4.3.2 Capital Costs

Capital cost estimates were made for the BTX plants in each of the schemes, and are summarised in the table below. These costs are on the basis of battery limits erected cost for the BTX plant i.e. excluding only the following:-

(i) Utilities plants, main storage tanks, and other offsites
(ii) Owners' start-up expenses, consultancy and training
(iii) Interest on loans during construction.

The cost of facilities, such as control room, which are shared by the process units of the BTX plant, has been appropriately distributed between the units, to arrive at the breakdown shown in the table.

The approximate capital cost figures listed in the table are the Foreign Exchange element only. For all of these units, the Rupee cost element (excluding duties) would amount to about 30% of the F.E. element quoted. Thus total capital costs (excluding duty) will be approximately 1.3 times the figure quoted. See Table III 4.1.

TABLE III 4.1

Capital Costs of [illegible] Plants

(foreign exchange element of 'battery limits' cost)

Unit	Basis	Scheme A: Plant Part(i)	Part(ii)	Part(iii)	Part(iv)	Scheme B Plant only (i)	(ii)	Scheme C Plant only
		Capacities of units, M.T.P.A.						
Hydrotreater	Feed	22,500	142,000	137,500	165,000	65,500	48,500	48,500	11,000
Reformer	Feed	None	142,000	137,500	165,000	65,500	None	None	None
Aromatics Extraction	Feed	22,500	165,500	[illegible]	[illegible]	[illegible]	165,300	272,000	130,300
Aromatics Fractionation	Feed	14,000	55,000	70,300	50,300	32,000	73,400	130,400	65,400
Dealkylation	Feed	None	None	None	None	12,200	None	None	None
Disproportionation	Feed	None	24,400	None	13,500	None	None	None	None
Isomerisation	Feed	None	None	46,000	46,000	46,000	46,000	None	None
"Parex"	product	None	11,000	11,000	11,000	11,000	11,000	11,000	None
C_8 Splitter	product	None	8,500	8,500	8,500	8,500	8,500	8,500	8,500
		Foreign exchange element of 'battery limits' cost, in $ x 10^3						
Hydrotreater		510	1,500	1,600	1,600	[illegible]	800	800	[illegible]
Reformer		-	1,700	1,600	1,400	1,300	-	-	-
Aromatics Extraction		470	1,200	1,170	[illegible]	[illegible]	1,160	1,600	1,000
Aromatics Fractionation		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	770
Dealkylation		-	-	-	-	[illegible]	-	-	-
Disproportionation		-	1,600	-	1,300	-	-	-	-
Isomerisation		-	-	1,500	1,500	1,500	1,500	-	-
"Parex"		-	2,500	2,500	2,500	2,500	2,500	2,500	-
C_8 Splitter		-	250	250	[illegible]	250	250	250	[illegible]
Total for Plant		1,300	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2,500
Total for Scheme		-	10,700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2,500

4.3.3 Consumption and Cost of Utilities and Chemicals

Consumptions of utilities and chemicals by the BTX plants were estimated on the basis of typical consumption figures for each unit, as stated in the table below. Costs of utilities were then estimated using the unit costs listed in Section 5.

Consumption of Utilities and Chemicals per MT feed or product

Unit	Basis	Fuel 10^6 Kcal	Steam MT	Elec. Energy KWh	Cooling Water M^3	Catalyst + Chemicals $
Hydrotreater	Feed	.19	-	10	8	0.05
Reformer	"	.045	-	46	21	0.23
Aromatics Extraction	"	-	0.4	4	11	0.53
Aromatics Fractionation	"	.053	0.2	2	19	-
Dealkylation	"	.40	0.1	3	34	0.27
Disproportionation	"	.91	1.7	85	4	1.7
Isomerisation	"	.58	credit 0.3	44	0.6	2.24
"Parex"	Product p-xylene	5.25	-	172	208	8.9
C_8 splitter	Product o-xylene	-	1.2	20	115	-

4.3.4 Net Consumption of Feedstock

Net consumption of feedstock (i.e. feedstocks minus liquid by-products) was estimated as (BTX products plus gaseous by-products), gaseous by-products were estimated as the following percentages of the feed to particular units.

Unit	Gaseous by-products (wt % of feed to unit)
Catalytic Reformer	15
Dealkylation	18
Disproportionation	3.6
Isomerisation	1.5

The assumed unit cost of naphtha, and average unit value (as fuel) of the gaseous by-products, were as stated in Section 5.

4.3.5 Treatment of Production Costs

In the analysis which follows in Section 4.4, we are concerned with assessing the projects from the viewpoint of the Pakistan economy. For this reason duties payable in Rupees are excluded from both fixed and variable elements of production costs.

4.4 Production Cost Analysis

4.4.1 Comparison of Alternative Scheme A plants in East Pakistan

The plants are fairly close to each other in capital cost. Plant East (ii) has slightly higher capital cost than East (iv) which is the cheapest. East (ii), however, has a better balance of by-products for the motor gasoline market and has the advantage of simplicity. Both East (ii) and East (iv) have similar running costs. The alternative (ii) was selected for comparison with the Scheme B in which all BTX production is situated in the West Wing.

4.4.2 Comparison of West Pakistan Schemes B (i) and B (ii)

The two schemes are compared in the table below:

	Unit	B(i)	B(ii)	Differences B(i)	Differences B(ii)
Foreign Exchange Element of Capital Cost	10^3 $	4,380	3,600	+780	0
Gaseous by-products	MTPA	685	0	+685	0
Fuel	10^9 kcalPA	38.5	15.1	+23.4	0
Steam	10^3 MTPA	78.5	145	0	+66.5
Electrical power	10^3 kWhPA	3,500	2,050	+1,450	0
Cooling Water	10^3 m^3 PA	4,700	4,200	+500	0
Catalysts and Chemicals	10^3 $ PA	192	65	+127	0

The above comparative estimates do not include the "Parex" unit, which costs the same in either scheme. They show that Scheme B(ii) has significantly the lower capital and running costs. It is also the simpler scheme. It requires a large quantity of reformate as feed, but this is not considered a problem, provided that the operation of the plant is closely integrated with the operation of the refineries at Karachi.

4.4.3 Production Cost of Reformate

The production cost of reformate, as feed to a BTX plant at Karachi, is estimated on the basis of a catalytic reforming unit of 75,000 MTPA feed capacity. This is needed for costing in Section 4.4.4.

We consider that pyrolysis gasoline, and also the total liquid by-products from BTX production at Karachi, can satisfactorily replace an equal quantity of reformate in the production of motor fuels. We

therefore assumed in our estimates of BTX production cost that these liquids had the same value as the estimated cost of production of reformate.

TABLE III.4.2

Production Cost of Catalytic Reformate at Karachi

Capacity: 63,750 MTPA of reformate

Capital : $1.0 x 10^6, (F.E. element, B.L. Pakistan)
i.e. $15.7 per MTPA of output capacity.

Costs per MT of reformate:-

per MT reformate	Quantity	Foreign exchange $		Internal (excluding duties) Rs
Naphtha, MT	1.18	16.9		16.5
Fuel gases, Mt	credit 0.18	Nil	credit	16.2
Fuel 10^6 kcal	0.276	Nil		2.1
Electrical Energy kWh	66	0.3		3.3
Cooling Water m^3	34	0.1		1.7
Catalysts		0.3		Nil
Direct variable cost		17.6		7.4
Fixed costs (see Section 5)		3.0		15.8
Total production cost		20.6		23.2

4.4.4 General Comparison between Scheme A and Scheme B

Scheme A consists of the combination of a plant to make 11,200 MTPA of BTX from pyrolysis gasoline at Karachi, and a larger plant to make the balance of BTX requirements, i.e. 39,340 MTPA, from naphtha at Chittagong. As explained in 4.4.1 above, the most attractive of the various schemes considered for the Chittagong plant was found to be alternative Scheme A East (ii) which includes a xylenes isomerisation step to improve the yield of p-xylene, but no dealkylation or disproportionation of toluene. This combination of East and West plants, which we will refer to as Scheme A (ii), is therefore compared in the table below with Scheme B.

Scheme B consists of a single BTX plant at Karachi. The more attractive alternative was found in 4.4.2 above to be Scheme B West (ii) which separates the BTX products by purely physical processes from mixed reformate plus pyrolysis gasoline feed. This scheme is compared in the table below with Scheme A (ii).

The existing catalytic reformer at Chittagong (75,000 MTPA feed capacity) will be adequate to meet the automotive fuel requirements of East Pakistan until 1980 at least. Therefore, the BTX plant at Chittagong included in Scheme A (ii) is made to bear the whole of the capital and running costs of the additional new catalytic reforming unit, in the table below.

In the West, however, it is considered that additional reforming capacity will be required only equivalent to the difference between feed (including pyrolysis gasoline) and liquid by-products. Capital and consumption figures for this additional reformate production have been included in the comparison table, in proportion to the figures given above for a unit of 75,000 MTPA feed capacity. Pyrolysis gasoline quantities have been replaced in the table by the equivalent quantity of naphtha and gaseous by-products which would have been fed and derived respectively, in the production of an equal quantity of reformate.

Schemes A (ii) and B West (ii) are compared in Table III.4.3.

TABLE III.4.3

Basis: 50,540 MTPA of BTX products

	Scheme A(ii)	Scheme B West (ii)
Net consumption of naphtha, MTPA	73,940	59,640
Capital cost, foreign exchange element of battery limits cost, $10^3$$	7,810	4,600
Gaseous by-products MTPA	23,400	9,100
Fuel 10^9 kcal PA	67.4	16.5
Steam 10^3 MTPA	95	145
Electrical power 10^3 kWh PA	11,800	5,400
Cooling Water $10^3 m^3$ PA	6,700	5,900
Catalysts + chemicals 10^3 $PA	253	80
Interwing transport costs in 10^3 RsPA:-		
BTX 6,600 MTPA @ 102 Rs	0	607
Phthalic Anhydride 6,160 MTPA @ 56 Rs	0	345
Caprolactam 7,000 MTPA (diff.) @ 56 Rs	392	0
DMT 6,500 MTPA (diff.) @ 56 Rs	364	0
	756	952
Total of production + transport costs: For. exch. element 10^6 $PA	2.211	1.182
Total of production + transport costs: internal currency 10^6 RsPA	9.068	6.761

Capital cost is substantially lower for Scheme B West (ii), as also is the combined production plus transport cost.

Capital cost and consumption figures for reformate production, in proportion to the quantity of BTX products made, has been included in the case of the BTX plants in the West, to bring the figures to a comparable basis to those for the East plant.

Capital cost and consumptions of utilities for the "Parex" unit, which would be the same for either scheme, have been excluded from the comparison.

We conclude that BTX production will be markedly cheaper in West Pakistan than in the East. Therefore, we prefer Karachi as the site for an aromatics petrochemicals complex, and have based our detailed cost analysis of these petrochemicals on this site.

4.4.5 **Production Costs of Benzene, Toluene, and Xylenes for Scheme B - West Alternative (ii)** (i.e. including synthetic fibre monomer production)
These costs are used for the calculation of production costs of aromatics petrochemicals in Section 5.

Capacities in MTPA:-

Benzene		20,220
Toluene		5,000
p-Xylene	11,600	
o-Xylene	8,720	
solvent 'xylene'	5,000	
C_8 aromatics products		20,320
Total products		50,540

Capital costs (foreign exchange element, battery limits):-

	Cost 10^3 $	Capacity MTPA	Cost/Capacity $/MTPA
BTX	3,450	50,540	68.2
C_8 splitter	250	8,720	28.7
"Parex"	2,500	11,600	215.0

As indicated earlier, Rupee costs (excluding duty) will be equivalent to 30% of the foreign exchange element figures quoted above.

TABLE III.4.4
Average production cost of BTX (Scheme B West (ii))

Production cost BTX per MT		Consumption	Foreign exch. $	Internal currency Rs
Feedstock (cost as reformate)	MT	1.0	20.6	23.2
Utilities:-				
Fuel	10^6 kcal	.30	-	2.2
Steam	MT	2.7	.5	21.6
Electrical Energy	kWh	37	1.9	18.5
Cooling Water	m^3	63.5	.3	3.2
Cats. + Chems.	-		1.3	-
Variable			24.6	68.7
Fixed (F.E. as 19.4% of F.E. element $68.2) (Internal as 21.2% of F.E. element)			13.2	68.9
Total			37.8	137.6

We consider that benzene should be valued 20% higher than toluene and mixed 'xylenes', which is approximately the price relationship in Europe at the present time.

benzene production cost, per MT	41.9	152.7
toluene or mixed 'xylenes', per MT	34.9	127.1

TABLE III.4.5

o-Xylene Production Cost (Scheme B West (ii))

o-Xylene production cost per MT	Consumption	Foreign exch. $	Internal currency Rs
Feedstock MT	1.0	34.9	127.1
Steam MT	1.2	0.2	9.6
Electrical Energy kWh	20	0.1	1.0
Cooling Water m^3	115	0.5	0.6
Variable		35.7	138.3
Fixed	($/MTPA 28.7)	5.6	29.0
Production cost		41.3	167.3

TABLE III.4.6 p-Xylene Production Cost (Scheme B West (ii))

p-Xylene Production Cost per MT			
Feedstock MT	1.0	34.9	127.1
Fuel 10^6 kcal	5.25	-	39.4
Electrical Energy kWh	172	0.9	8.6
Cooling Water m^3	208	0.8	10.4
Cats. + Chems -		8.9	-
Variable		45.5	185.5
Fixed	($/MTPA 215.0)	41.7	217.2
Production cost		87.2	402.7

4.4.6 Production Costs of Benzene, Toluene, and Xylenes for Scheme C

(i.e. omitting production of synthetic fibre monomers)

These costs can be used to see how the costs of other aromatics end-products would be affected by omitting production of these monomers.

Capacities in MTPA:-

Benzene		6,700
Toluene		5,000
o-Xylene	8,720	
solvent 'xylene'	5,000	
C_8 aromatic products		13,720
Total products		25,420

Capital costs (foreign exchange, battery limits):-

	Cost 10^3 $	Capacity MTPA	Cost/Capacity $/MTPA
BTX	2,290	25,420	90.0
C_8 splitter	270	8,720	31.0

TABLE III.4.7 Production costs BTX (Scheme C)

Production cost of BTX per MT		Consumption	Foreign Exch. $	Internal Currency Rs
Fuel	10^6 kcal	.315	-	2.4
Steam	MT	2.76	0.6	22.0
Electrical Energy	kWh	35	0.2	1.8
Colling Water	m^3	127	0.5	6.3
Cats. + Chems.			2.8	-
Feedstock	MT	1.0	20.6	23.2
Variable			24.7	55.7
Fixed	($/MTPA)	(90.0)	17.5	90.9
Production (average, for BTX)			42.2	146.6
benzene production cost, per MT			48.1	162.0
toluene and mixed xylenes, per MT			40.0	139.0
o-Xylene production cost, per MT:-				
Feedstock, MT		1.0	40.0	139.0
Utilities, (as 4.4.4 above)			0.8	11.2
Variable			40.8	150.2
Fixed (as 4.4.4 above)			5.6	29.0
Production cost			46.4	179.2

4.5 Viability of BTX Production in Pakistan

Published European prices for benzene (in small lots) are in the range 70-80 $/MT, and for toluene and mixed xylenes 60-70 $/MT. The costs we have estimated, in this section of the report, for production of BTX in West Pakistan, are of the same order. We conclude that costs of local production of BTX are competitive with Europe, or only slightly more expensive. Certainly, local production will be cheaper than imports, because transport costs of these materials would be heavy, even in the most favourable circumstances i.e. regular shipment in a compartment tanker.

We have used the production costs of BTX estimated in this section, in deriving production costs for petrochemicals in Section 3.

4.6 Conclusions

4.6.1 The most attractive of the schemes listed in Sections 4.1 and 4.2 for BTX production including requirements for the synthetic monomers is Scheme B (ii). This scheme produces the BTX products by purely physical processes from mixed feed of catalytic reformate plus pyrolysis gasoline at Karachi. Costs of production by this shheme will be less than cost of the equivalent imports.

4.6.2 If the synthetic fibre monomer plants are not set up, Scheme C is recommended. By Scheme C, the (reduced) requirements for BTX would be separated from catalytic reformate plus pyrolysis gasoline at Karachi. Costs of production will again be lower than the cost of the equivalent imports.

SECTION 5

BASIS OF ECONOMIC ANALYSIS

The purpose of this volume of the report is not to produce detailed pre-investment studies, but to analyse a large number of possible products, process routes and production capacities. In order to do this it is necessary to have a simplified costing method for comparing the various possibilities.

Basically, the requirement is a simplified production cost per MT of product which is split between foreign exchange and Rupee elements. The foreign exchange element can be compared with the C & F value of equivalent imported material and Rupee costs and foreign exchange savings can then be used as a basis for determining whether or not local production is attractive.

This section of the report describes the build up of such a "simplified production cost". The normal costing is adopted for such "variable costs" as raw materials, utilities, etc. Fixed costs, (including depreciation, loan repayments, interest, maintenance, labour, administrative costs) have all been related to the capital cost of the plant; they are in fact expressed as percentages of the foreign exchange element of capital cost on the 'battery limits erected' basis defined in the table below.

Since the cost figures are to be used to analyse the relationship between foreign exchange saved and Rupees expended from the viewpoint of the Pakistan economy, Rupee costs used here do not include duties.

In Section 5.1 the capital cost structure and means of finance are discussed, and Section 5.2 demonstrates the build up of the fixed costs element of production costs.

5.1 Capital Cost Structure and Finance

The capital cost structure of a group of petrochemical units was estimated for Pakistan conditions, and a typical relationship was found to be:-

		Foreign Exchange		Internal Rupee Costs excluding duties
'Battery limits erected' cost (i.e. excluding only items below)		100		30
Owner's start-up expenses, consultancy fees and training.		5		5
Interest during construction at 11% of above		11.6		7.2
		116.6		42.2
Allowance for offsites at	(5%)	5.8	(10%)	4.2
Total fixed capital at start-up (excluding utilities plants, land and housing schemes)		121.4		46.4

The capital cost of utilities plants was allowed for separately, by including a capital cost element in the unit costs of utility services.

Land cost was excluded from consideration because it is usually a small proportion, and there is no depreciation on it.

Housing schemes would probably not be required at Chittagong or Karachi, and have not been regarded as part of the capital costs of the projects.

Peak capital requirement of the "typical project" was estimated as:

Foreign exchange capital cost	121.4
Internal before duty	46.4
Duty	30
	197.8
Allowance for working capital plus initial operating losses, 10% of above	19.8
Peak capital requirement	207.6
Hence, equity requirement at 30% of peak capital was estimated:	62

We considered that the cost of the equity should be distributed between the duty and local costs exclusive of duty. Hence, the portion attributable to the before-duty fixed capital cost of the project =

$$\frac{46.4}{76.4} \times 62 = 37.6$$

By difference, Rupee loan required	= 8.8
Total local currency fixed capital	46.4

5.2 Fixed Costs

The financial element of the fixed costs was first converted to the equivalent constant annual cost (depreciation plus interest or return), over the whole of the operating life of the plant, which we have taken to be 15 years.

We assumed rates of interest of 8% p.a. on the foreign loan, and 9% p.a. on the local loan. The constant annual sums to repay these loans, with interest, over 15 years, were found to be 11.7% p.a. and 12.4%, respectively, of the initial loans. 16% p.a. rate of return on the equity was assumed.

To calculate the annual sum equivalent to 16% p.a. return on the equity, we assumed that the rate of interest on short term borrowing, and the earning rate on surplus funds during the life of the project, were both equal to 9% p.a.

i.e. the same as the rate of interest on the internal currency loan. We found the annual sum which, invested over 15 years at 9% compound, would yield the same figure as the single equity subscription at 16% p.a. compound, to be 21.5% of the equity subscription.

To these financial costs we added estimated constant annual expenditures on maintenance, labour, supervision, sales and overheads, over the same period. The total of these constant annual costs were multiplied by a factor, to convert them to an average charge on the annual capacity of the plant, i.e. to allow for initial below-capacity operation of the plant. On the assumptions that the plant operates at 30%, 50%. 90%, thereafter 100% of capacity, in successive years following the start-up date, and that the marginal costs of capital are 8% for foreign exchange and 9% for local currency, these factors were calculated as 1.13 and 1.14 respectively. Estimated interest on working capital was not adjusted for below-capacity operation, because interest on working capital would vary directly with production rate.

The total charges for fixed costs, on the annual capacity of the plant, were built up as shown in the table III.5.1.

TABLE III.5.1

Fixed Costs (% p.a. on the foreign exchange element of "battery limits" capital cost)

Item and Basis	% p.a. of total B.L. exclusive of duty	Ratio of Foreign to Internal Costs	Foreign Exchange Cost	Internal Currency Cost
Repayment + 8% interest on foreign loan				
$\frac{121.4}{100}$ x 11.7			14.2	-
Repayment + 9% interest on Rupee loan				
$\frac{8.8}{100}$ x 12.4			-	1.1
Repayment + 16% return on equity				
$\frac{37.6}{100}$ x 21.5			-	8.1
Total annual financial costs			14.2	9.2
Maintenance	4.0	46 · 54	2.4	2.8
Process Labour) Supervision) Sales + Overheads)	5.0	Nil foreign	-	6.4
Total fixed annual operating			2.4	9.2
Total fixed annual operating + financial			16.6	17.5
Factor for below-capacity operation in start-up years			x1.13	x1.14
			18.75	19.9
Interest on Working Capital	1.5	1 : 2	0.65	1.3
Total Fixed Charge on Plant Output			19.4	21.2

Simpler methods of estimating fixed costs are more commonly used. Typically, straight line depreciation of the plant over 10 years would be charged, plus arithmetic average of interest payments over the same period. No adjustment would be made for below capacity operation. We show in the following table how fixed costs would be built up by this method.

TABLE III.5.2.

Fixed Costs by Simplified Method
(% p.a. on foreign exchange "battery limits" capital)

		Foreign Exchange Cost	Internal Currency Cost
Depreciation 10.0) Interest ½ x 8.0)	14.0 x (foreign exchange capital, 121.4)	17.0	-
Depreciation 10.0) Interest ½ x 9.0)	14.5 x (internal currency capital, 46.4)	-	6.7
Fixed operating costs, as before		2.4	9.2
Interest on working capital, as before		1.5	1.2
Total		20.9	17.1

Estimates of foreign exchange costs are in fair agreement by the two methods, but the simplified method gives a 20% lower figure for internal currency costs.

Overall, the figures we have used are slightly the more conservative. We have preferred them for this reason, and also because we consider that a reasonable return to the equity, and under-capacity operation of the plant, are both important factors for which allowance must be made. Our more elaborate treatment allows for these factors directly, rather than by the use of a depreciation period less than the expected life of the plant.

5.3 Costs of Materials and Services

In this section are listed the unit costs of materials, services, packages and transport, which we have used for the production cost estimates of petrochemicals in Section 3 and Section 4.

Costs of import duties, bonus vouchers and sales tax have been excluded from the internal, Rupee, element of costs, also the excise duty on natural gas.

Costs of utilities have been built up from estimates of the capital and operating costs of utilities plants typical for the type of petrochemical complex being considered.

5.3.1 Unit Costs of Utilities at Karachi or Chittagong

	Unit	Foreign Exch. $	Local Currency Rs.
Natural Gas	10^6 kcal	Nil	7.50
Steam	MT	0.2	8.0
Electrical Energy	kwh	0.005	0.05
Cooling Water	m^3	0.004	0.05
Raw Water	m^3	Nil	0.44
Process Water	m^3	0.07	0.54
Demineralised Water	m^3	0.2	1.0

5.3.2 Unit Costs of Utilities at Ashuganj

	Unit	Foreign Exch. $	Local Currency Rs.
Natural Gas	10^6 kcal	Nil	2.12
Steam	MT	0.2	3.0
Electrical Energy	kwh	0.005	0.03
Cooling Water	m^3	0.004	0.05
Raw Water	m^3	Nil	0.33
Process Water	m^3	0.07	0.43
Demineralised Water	m^3	0.2	0.85

5.3.3 Unit Costs of Raw Materials and By-products

Cost per MT:-

Material	Location	Foreign Exch. $	Internal Currency Rs.
Naphtha	Karachi or Chittagong	14.3	14
Fuel Oil	" " "	11.5	21
C_1 to C_5 Hydrocarbons as fuel (average)	" " "	Nil	90
Hydrogen	" " "	10	500
Caustic Soda	" " "	Nil	670
Sulphur	" " "	40	Nil
Boric Acid	" " "	200	Nil
Ammonia	Multan	Nil	200
Ammonia	Karachi	Nil	320
Extender Oil for SBR	Karachi	Nil	200

5.3.4 Cost of Packages

(i) Reusable steel drums — 60 Rs/MT of product

(ii) Paper sacks — 8 Rs/MT of product

5.3.5 Cost of Transport between Wings

Inclusive of loading and unloading -

(i) Liquids in drums, non-hazardous — 56 Rs/MT of 40 cu.ft.

(ii) Liquids in drums, hazardous, including BTX — 102 Rs/MT of 40 cu.ft.

(iii) Bagged or bulk solids — 56 Rs/MT.

5.3.6 C & F Prices of Petrochemicals

	1970 Rs/MT	Future (predicted) Rs/MT
Styrene	-	176
Polystyrene (crystal chip)	240	240
SBR rubber (general grade)	331	300
Caprolactam	460	420
Dimethylterephalate	-	380
Terephthalic Acid	-	380
Ethylene Glycol	312	220
Phthalic Anhydride	204	200

SECTION 6

DEVELOPMENT PLAN FOR THE INDUSTRY

6.1 Development Programme

In this Section, we present our recommended plan for the overall development of the synthetic fibres, aromatics petrochemicals, and synthetic rubber industries.

The plan is based on the analysis of markets, production capacities, and processing schemes in the preceding sections 2, 3 and 4 of this Volume.

According to the plan, production of monomers for 15,000 MTPA each of Nylon 6 and polyester fibres would start in 1976. The plan also includes production of o-xylene, and from it, phthalic anhydride, mainly to supply a plant to make 16,000 MTPA of dioctylphthalate, which we propose (in Volume II of this Report) should be included in the second phase of the EPIDC petrochemical complex at Ashuganj.

A butadiene extraction unit would start up also in 1976, fed with the mixed C_4 hydrocarbon stream which will be available from the Fauji ethylene complex at Karachi. The extracted butadiene, plus imported styrene, would be used to make SBR rubber in a plant of 10,000 MTPA capacity.

The viability of domestic production of the fibre monomers on the proposed scale is marginal. A further economic assessment on the basis of competitive quotations both for the plants and the alternative supply of the monomers on contract, is desirable. It may then be found that it would be better to postpone the production of the monomers for a few years, until the market demand would support larger monomer capacities - equivalent to 25 to 30,000 MTPA of each fibre. In that case, the fibres would continue to be made from imported monomers until about 1980. Meanwhile, BTX production would be set up to meet the remaining requirements of Pakistan along the lines proposed in Scheme C in Section 4 of this Volume.

The future development of the nylon and polyester fibres market is difficult to forecast with precision. The timing of the large part of the programme which is linked to these fibres, including the terephthalic acid, caprolactam, and BTX plants, may need to be adjusted as the developing pattern of market requirements becomes clear.

In Table III 6.1, the construction programme for the plan is set out together with an estimate of the capital investment for each phase.

The investment figures include allowance for all expenses needed to set up production except working capital, housing estates, and land. To the foreign exchange element of 'battery limits' cost of the individual plants, as given in Sections 3 and 4, were added the estimated cost of:

- local currency element of 'battery limits' cost
- offsites and utility plants
- site development
- start-up expenses, consultancy, and training
- duty
- interest on loans during construction period.

TABLE III.6.1

CONSTRUCTION PROGRAMME

Product	Capacity MTPA	Feedstock	Investment in 10^6 Rs. Total	Investment in 10^6 Rs. Foreign Exchange
West Pakistan, Karachi				
Start-up in 1972/73:-				
Polyester fibre	3,000	Polymer chip	40	24
Start-up in 1974/75:-				
(Benzene	20,000	(Reformate +		
(Other aromatics	110,000	(Pyrolysis	39	24
		(Gasoline		
(Polyester fibre expand to	5,000	(Terephthalic		
(Polyester chip		(Acid + Ethylene	100	56
		(Glycol		
Nylon 6 fibre	6,000	Caprolactam	110	63
Start-up in 1976:-				
p-Xylene	9,300	Aromatics	25	15
o-Xylene	8,720	Aromatics	3	2
Terepthalic Acid	13,500	p-Xylene	120	74
Oleum	20,200	Sulphur	14	8
Caprolactam	15,000	(Benzene, Oleum,	144	88
		(NH_3		
Start-up in 1980:-				
Polyester fibre expand to	12,000	(Terephthalic	40	24
		(Acid		
Nylon 6 fibre expand to	12,000	Caprolactam	70	41
East Pakistan, Chittagong				
Start-up in 1975:-				
Nylon 6 fibre	3,000	Caprolactam	66	38
Polyester fibre	2,000	Polymer chip	40	22
Start-up in 1980:-				
Nylon 6 fibre expand to	6,000	Caprolactam	47	29
Polyester fibre expand to	5,500	Terephthalic Acid	79	49

6.2 Future Technological Developments

Nylon and polyester are expected to dominate the world market for synthetic fibres for many years to come. Other polymers, including some new to the market, will no doubt take a larger share than at present, but the physical properties and versatility of nylon and polyester are good enough to meet most forseeable needs. Their leading position, therefore, seems reasonably secure. As noted in the introduction to this volume, polyester seems set to overtake nylon within a few years. However, antistatic properties and increased moisture absorption will be sought increasingly for some applications, and such properties are likely to be provided most easily by modified nylon polymers.

It is in the series of operations by which the polymers are made into textiles that the greatest changes will be seen. Already in Eurôpe, various types of texturised yarns and high speed knitting have replaced spun yarns and weaving operations in some parts of the textiles market.

In the technology of BTX production processes, useful developments will be seen which will provide a more versatile range of chemical and physical operations, and slightly improved economics. Only moderate cost reduction is expected in terephthalic acid production. There is greater scope for cost reduction in caprolactam production, and some improved process might well become commercial within the next 5 to 10 years featuring lower quantities of ancillary raw materials and by-product than the current commercial processes.

The above considerations tend to confirm the choice of nylon and polyester as synthetic fibres to be produced in Pakistan. The rapid changes taking place in synthetic fibre textile technology point to the need for careful analysis of end-product markets when deciding what types of spinning and textile machinery to buy.

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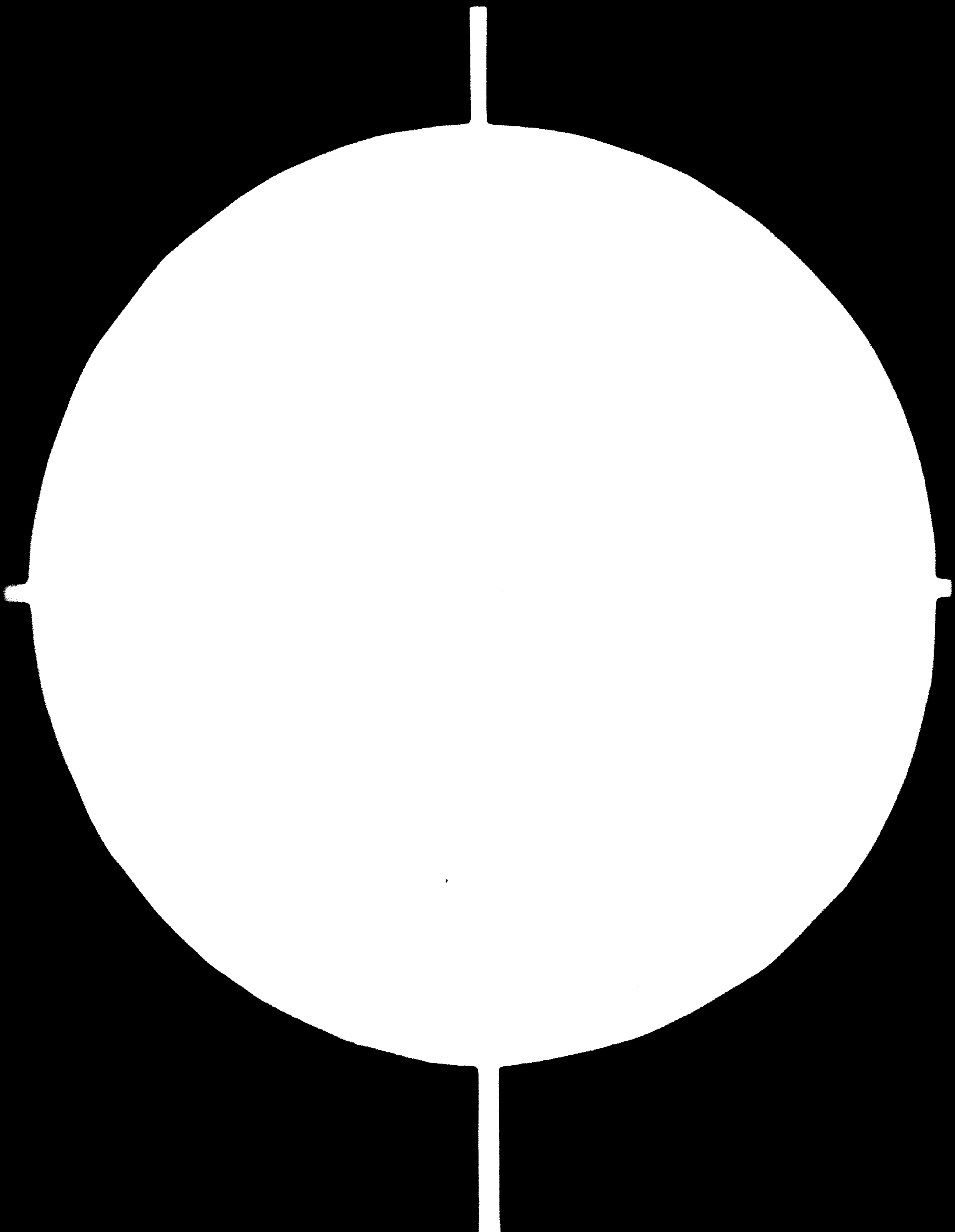

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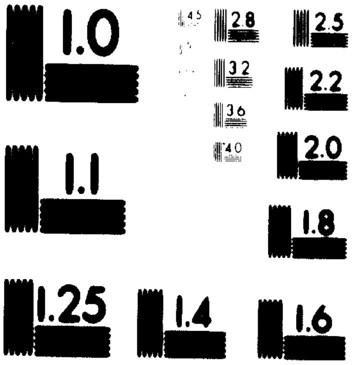

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SECTION 7

CONCLUSIONS

1. The production of nylon and polyester fibres in Pakistan at low costs would be an important contribution to the development of export business in textile goods. A study of export markets for such goods should be undertaken.

2. Nylon 6 fibre should be produced from caprolactam feedstock, in plants of at least 3,000 MTPA capacity, with provision for increase of capacity to at least 6,000 MTPA. There should be one such plant in East Pakistan and not more than two in West Pakistan.

3. Polyester fibre should be produced in plants of at least 2,500 MTPA capacity, with provision for increase of capacity in steps of at least 2,500 MTPA. One such plant is proposed for each wing. It will be beneficial to concentrate polymerisation capacity initially at the fibre plant in the West: this first unit would also produce polymer chip for the spinning plant in the East, and for export of polymer chip to Iran and Turkey. Polymerisation capacity of 5,500 MTPA would be installed later at the fibre plant in East Pakistan, as the market demand approached this capacity.

4. It is recommended that polyester fibre production be based on terephthalic acid feedstock.

5. The most attractive form of longer term development of the industry would be the construction of a major complex for the extraction of aromatics and production of fibre monomers. The minimum economic capacity is equivalent to 15,000 MTPA of each fibre.

6. Caprolactam and terephthalic acid must be imported up to about 1976. They should then be manufactured in plants of capacity equivalent to 15,000 MTPA of each fibre, located adjacent to a BTX plant which would supply them with benzene and p-xylene respectively.

7. The Pakistan requirements for aromatics hydrocarbons, including the benzene and p-xylene feedstocks for caprolactam and terephthalic acid can be produced most economically by physical separation processes from a mixed feed of pyrolysis gasoline plus catalytic reformate, and in close association with refinery operations. In principle, such production could be undertaken in association with the refinery at Chittagong or with the two refineries at Karachi, but there are cost advantages favouring the Karachi location.

8. A phthalic anhydride plant should also be included in the aromatics complex. The feedstock would be o-xylene and the product would be for shipment to East Pakistan where a dioctylphthalate plant of 16,000 MTPA capacity is proposed.

9. It is also proposed that an SBR synthetic rubber plant of 10,000 MTPA capacity be set up at Karachi to start up in 1976, fed with butadiene extracted from the Fauji cracker C_4 hydrocarbon by-product.

APPENDIX I

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