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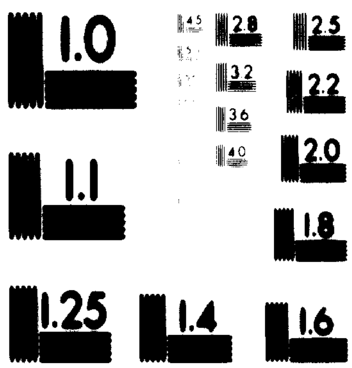

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HUMPHREYS & GLASGOW LIMITED

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

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANISATION

VOLUME II

The Further Development of the Petrochemical Complexes Planned for East and West Pakistan

22 Carlisle Place London S.W.1 England

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

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for

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VOLUME II

THE FURTHER DEVELOPMENT OF THE PETROCHEMICALS COMPLEXES PLANNED FOR EAST AND WEST PAKISTAN

July 1970

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VOLUME II

THE FURTHER DEVELOPMENT OF THE PETROCHEMICALS COMPLEXES PLANNED FOR EAST AND WEST PAKISTAN

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VOLUME II

THE FURTHER DEVELOPMENT OF THE PETROCHEMICALS COMPLEXES PLANNED FOR EAST AND WEST PAKISTAN

Summary of Report

The Report studies the possible new products that could be manufactured at Ashuganj, East Pakistan and Korangi, West Pakistan. It establishes the market requirements additional to production from existing and sanctioned plants, including the Phase I developments at both of these sites.

In the preparation of plans for the second stage in the development of the two projects, the current production schemes envisaged by E.P.I.D.C. and Fauji for Phase I of their projects were used as the basis. The products and capacities recommended are also related to the future market requirements, suitability of the sites for manufacture of the products concerned and the scale of production needed for economic viability. The specific developments recommended are:-

East Pakistan; Ashuganj (E.P.I.D.C.)

Increase acetylene production from 36,000 MTPA to 55,000 MTPA
Produce:- 16,000 MTPA dioctyl phthalate
8,420 MTPA vinyl acetate
1,650 MTPA acetic acid

West Pakistan; Korangi (Fauji Foundation)

Increase ethylene production from 30,000 MTPA to 60,000 MTPA (already planned)
Produce:- 23,600 MTPA polyethylene, low density
10,000 MTPA dodecyl benzene
5,300 MTPA ethylene for sale to Valika

After establishing the capital and operating costs of the individual plants and recommended developments as a whole, the Rupee cost of saving foreign exchange and the Cash Flow (including the D.C.F. rate of return on the Rupee investment) were studied. These were found to be:

East Pakistan, Ashuganj

Cost of Saving Foreign Exchange	Rs. 5.8 U.S. $
D.C.F. Rate of Return on Rupee Investment	16.4%

West Pakistan, Korangi

Cost of Saving Foreign Exchange	Rs. 4.38/U.S.$
D.C.F. Rate of Return on Rupee Investment	43.8%

It was concluded that the cost of saving foreign exchange was favourable for both East and West Pakistan. In East Pakistan, the D.C.F. rate of return was considered acceptable, but its improvement by delaying start-up after 1976 was suggested. In West Pakistan, the economic aspects of the project are so favourable that an earlier start-up date than 1976 could well be considered by Fauji Foundation.

The Report also provides process descriptions, flow charts, and operating data for the individual processes.

VOLUME II

THE FURTHER DEVELOPMENT OF THE PETROCHEMICALS COMPLEXES CURRENTLY PLANNED FOR EAST AND WEST PAKISTAN

SECTION I

INTRODUCTION AND ACKNOWLEDGEMENTS

At present there are two major petrochemicals complexes projected for Pakistan.

The Fauji Foundation are in the final stages of contract negotiations for their naphtha-based, PVC/Polyethylene complex at Korangi, near Karachi. EPIDC is in the stage of detailed planning for a project at Ashuganj based on natural gas and acetylene.

In each case the projects are being planned in two phases. While the production units envisaged for phase I of each project are now well defined, the phase II plant units have yet to be specified. This report is concerned with the specification of the phase II projects. The market data upto 1985, so far as they exist, have been analysed and products for phase II manufacture have been selected. These have been incorporated in an overall production pattern. The benefits of the scheme have been analysed.

The production schedules for phase I of the two projects are as follows:

(a) Fauji Foundation, Korangi

	MTPA
Ethylene(to Valika)	5,800
P.V.C.	15,000
Polyethylene	15,000
Polypropylene	10,000

Estimated capital cost Rs 344 million (Chemcon)

(b) EPIDC, Ashuganj

	MTPA
Acetylene	3,600
P.V.C.	50,000
Acrylic Fibres	16,000
Methyl Methacrylate	2,600
Polymethyl Methacrylate	4,000
Caustic Soda	42,000
Ammonium Sulphate	28,000
Bleaching Powder	1,000
Methanol	37,000
Urea	320,000

Estimated capital cost Rs 957 million (EPIDC Jan. 1970)

In the Interim Report prepared by H & G in November 1969 and now summarised as Volume I of this report, two products additional to those above were recommended for production in Pakistan. These are dodecyl benzene, required as a detergent precursor, and dioctyl phthalate, a plasticiser used with PVC. These have, therefore, been included in our recommendations for phase II of the Fauji and EPIDC projects.

No allowance has been made for possible exports of those products considered for the extensions to the two petrochemical complexes. The reasons for excluding exports are a) the basis of H & G's study is primarily the Pakistan market, and b) the particular products considered could probably not be produced at a cost which would justify extra investment based on sales over a long period in the world market. Exports should, however, be attempted during the years (up to about 1980) when domestic requirements are lagging behind production capacity. It should be possible to achieve a certain amount of such sales at prices above total variable cost, which would improve the economics and profitability of the proposed extensions beyond the figures quoted in this report. It is recommended that a survey of export possibilities be undertaken.

The basis for assessment of additional production has been the total Pakistan market, the initial part of our study, culminating in the Interim Report, having shown that it is generally more attractive to make products required on such a scale in a single plant serving both Wings. We have also taken into account any potential requirements for use in the aromatics based industries proposed in Volume III.

In this Volume, cost analysis of the projects is made in two distinct ways. In the analysis of foreign exchange savings, 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 exports. To present this information in the most useful form, we have kept foreign exchange and local currency costs separate, looking at the petrochemical industry as a whole. The ratio of rupees expended to foreign currency (expressed in dollars) is then calculated.

Commercial profitability is analysed separately on a cash flow basis. In calculating the cash flows, foreign exchange is converted to rupees at the official rate, and duty and bonus payments are included. Foreign exchange loan repayments and interest, and interest on working capital, are treated as cash outflows from the project. The DCF rate of return is calculated from the resulting cashflows, which is equivalent to treating all rupee finance (other than for working capital) as equity.

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

The Government Project Representative in Rawalpindi, the U.N.I.D.O. Project Manager, and Co-Project Manager, and U.N.I.D.O. Experts.

SECTION 2

MARKET ESTIMATES

2.1 Planned Production and Net Market Requirements for 1980 and 1985

Table 11.2.1 (p.2-2) summarises the production of petrochemicals planned for Phase I of the Petrochemicals Complexes in both Wings. This, together with other sanctioned or existing production and the market demand quantities for 1980 and 1985, gives, by difference, the net additional market requirements for these two years, which are then considered in later sections of the report.

The product list is, as described in Section 1, extended beyond that applicable to Phase I production.

Market demand data for 1980 is, with a few exceptions discussed later in this section, taken from our Interim Report. Market demand data for 1985 is taken very largely from the Battelle Institute Report. Battelle's information has been analysed and correlated with data provided by UNIDO documents and by Chemical Consultants Ltd.

2.2 Fauji Foundation Phase I Production Quantities

The quantities listed in column 1 of Table 11.2.1 for Phase I of the Fauji Project are based on an initial Phase I cracker capacity of 30,000 MTPA, and a material balance on this basis establishes that there will be, approximately, surpluses of propylene and ethylene to the following extent:

Propylene	1900 MTPA
Ethylene for sale to Valika	5500 MTPA

Surplus propylene, which is not for the present purposes defined as an end product. may either be burnt as fuel or at least partially utilised if the capacity of the polypropylene plant exceeds its nominal design rate.

In the previous work for the Interim Report, a sale of 10,500 MTPA of ethylene to Valika and a sale of 5,500 MTPA of vinyl chloride to Arokey were envisaged. The sale of ethylene to Valika is still probable, whereas we are advised that the sale of vinyl chloride to Arokey now seems unlikely. Accordingly, it is assumed that there will be no sales of vinyl chloride monomer, and that a total of 10,500 MTPA of ethylene will be sold to Valika when Phase II is in full production. This implies that Valika will continue to operate their ethylene plant to make up the balance of their requirements, amounting to about 5,000 MTPA of ethylene from molasses, at their full sanctioned capacity of 15,000 MTPA of polyethylene.

TABLE II.2.1

PETROCHEMICALS - MARKET REQUIREMENTS AND PRODUCTION PLANNING

(All quantities are expressed in M.T.P.A.)

Product	Fauji Foundation Phase 1 Production	EPIDC Ashuganj Phase 1 Production	Other Existing/ Sanctioned Capacity		1980 Market Demand		1985 Market Demand		1980 Net Requirements Additional to Fauji EPIDC and other Existing/ Sanctioned Capacity		1985 Net Requirements Additional to Fauji EPIDC and other Existing/ Sanctioned Capacity	
			West	East	West	East	West	East	West	East	West	East
Polyethylene	15000		15000		40000	22000	109000	60000	10000	22000	79000	60000
H.D. Polyethylene					4200	-	10500	-	4200	-	10500	-
Polyvinyl Chloride	15000	50000	5000		28000	32000	56000	64000	8000	-18000	36000	14000
Polypropylene	10000				9700	5200	30000	16000	-300	5200	20000	16000
Dioctyl Phthalate					7000	9000	14000	18000	7000	9000	14000	18000
Dodecyl Benzene					8200	5500	16400	11000	8200	5500	16400	11000
Polyvinyl Acetate			1300	250	6500	1500	13000	3000	5200	1250	11700	2750
Vinyl Acetate					6840	1580	13680	3160	6840	1580	13680	3160
Acetic Acid					850	800	1130	1070	850	800	1130	1070
Urea/Formaldehyde Resins			3920	1680	6100	6700	14000	15400	2180	[illegible]	10080	13720

Footnote: EPIDC Ashuganj phase 1 production plans also include 3600 M.T.P.A. acetylene, 2600 methylmethacrylate monomer, 4000 M.T.P.A. polymethylmethacrylate and 16000 M.T.P.A. acrylic fibre. These quantities are sufficient to satisfy the Pakistan market beyond 1985.

2.3 Ashuganj Phase I Production Quantities

The quantities stated in column 2 of Table II.2.1 were based on E.P.I.D.C.'s proposal for a petrochemical complex in East Pakistan, dated January 1970 which in turn was based very largely on the Austrian Petrochemical Consultants Ltd. investment study of an East Pakistan petrochemical complex, prepared for the E.P.I.D.C. The quantities were taken from diagram 2 (Simplified Flow Chart) of the E.P.I.D.C. proposal. It is clear that dioctyl phthalate is not now envisaged for Phase I at Ashuganj, and we have accordingly used the E.P.I.D.C. data as the most complete, up-to-date, and reliable representation of E.P.I.D.C.'s plans.

A simple material balance of the E.P.I.D.C. scheme confirmed the basic acetylene capacity of 36,000 MTPA (the only discrepancy being 400 MTPA more acetylene for direct sales). The only other discordant fact was that, when producing 42,000 MTPA caustic soda - as stated by E.P.I.D.C., there was a surplus of approximately 5,000 MTPA chlorine in addition to its utilisation for the manufacture of bleaching powder.

The products covered by Table II.2.1 do not include some of the products, such as urea, bleaching powder, and ammonium sulphate, planned for Phase I production at Ashuganj, as they arise as by-products in the E.P.I.D.C. petrochemicals plant. It now seems likely that the urea plant at Ashuganj will proceed independently of the petrochemicals project as recommended by H. & G. in the Interim Report.

2.4 Other Existing or Sanctioned Capacity

The quantities stated in columns 3 and 4 of Table II.2.1 are taken from our Interim Report. The Battelle Institute Report discusses many of these in detail.

Further discussion of the existing or sanctioned capacity is included in the subsequent sections for the individual petrochemical end products.

2.5 Polyethylene

The existing production of polyethylene at Valika is 5,000 MTPA and a further 10,000 MTPA is sanctioned, making a total of 15,000 MTPA in all.

The 1980 market demand is based on the figures in our Interim Report. The 1985 market demand is taken from the Battelle Institute Report, with the same distribution of demand between the two Wings as for 1980.

The net additional requirements are obtained by difference.

2.6 High Density Polyethylene

There is no existing or sanctioned production capacity at present in Pakistan. The 1980 and 1985 market demands have been taken from the Battelle Institute Report.

2.7 Polyvinyl Chloride

The present production of polyvinyl chloride at Arokey is 5,000 MTPA and future extensions to their existing capacity are uncertain. The existing/sanctioned capacity has only, therefore, been stated at 5,000 MTPA, for West Pakistan. At present no polyvinyl chloride is produced in East Pakistan.

The 1980 market demand is based on the figures in our Interim Report. Those for 1985 are taken from Battelle Institute with the same distribution of demand between the two Wings as for 1980. Although the demand in East Pakistan is expected to increase at a greater rate than in West Pakistan over the period 1968 to 1975, as the Battelle Report points out, this picture may well change if PVC pipes are used in the public sector of West Pakistan to the same extent as in East Pakistan. In addition 1985 is so far ahead that even the total demand figures must be viewed as being relatively less reliable than those for earlier years.

The net additional requirements for the two years are obtained by difference and it should be noted that, according to this reckoning, polyvinyl chloride will be overproduced in East Pakistan even in 1980 as far as the home market is concerned. Even allowing for the requirement of 8,000 MTPA in 1980 in West Pakistan, and the necessary interwing transfer, there will still be a surplus of 10,000 MTPA for which an export market should be found. The surplus in earlier years will be greater assuming that the plant is to be utilised to the maximum extent.

2.8 Polypropylene

There is no existing or other sanctioned production in Pakistan, and the 1980 market demands are taken from our Interim Report. The 1985 market demands are taken from the Battelle Institute Report, and, as with polyethylene and PVC, the distribution of demand between the two Wings has been taken as for 1980.

2.9 Dioctyl Phthalate

Dioctyl phthalate is not at present produced in Pakistan, and there is no production for Pakistan sanctioned.

At Ashuganj, the production of dioctyl phthalate for Phase I has been considered, but according to the latest information available to H. & G. it will be excluded. The production of this petrochemical end product was recommended in our Interim Report, and further consideration still shows it to be economically profitable both from the national and commercial points of view.

The 1980 market demands are taken from our Interim Report. The 1985 market demands are based on the increased demands for PVC shown in Table II.2.1 maintaining the same proportion of plasticiser to polymer. It must be noted, however, that these figures may well be high, as a result of the increasing use of the more rigid form, such as PVC pipes. The distribution of demand between the two Wings has been taken as for 1980.

2.10 Dodecyl Benzene

There is no existing production of dodecyl benzene in Pakistan, and, apart from Phase I of the Fauji complex to be erected at Korangi, no other sanctioned production either.

At Korangi, the production of 5,000 MTPA of dodecyl benzene has been considered for Phase I, with an extension to 10,000 MTPA for Phase II. According to the latest information available to H. & G., Fauji now intend to delay the installation of the dodecyl benzene plant until Phase II, and instal a plant with a capacity of 10,000 MTPA.

The production of dodecyl benzene was recommended in our Interim Report and further consideration has not altered this recommendation.

The 1980 market demands are taken from our Interim Report. The Battelle Institute Report gives market demands for dodecyl benzene sulphonate, and for 1980 these are equivalent to our estimate. This report has been used as the basis for the 1985 market demands, with the same split between the two Wings as in 1980.

2.11 Polyvinyl Acetate

The Interim Report gave the estimated market demands for polyvinyl acetate in 1980 as 3,400 MTPA and the existing plus sanctioned capacity as 3,100 MTPA. Both quantities refer to emulsion, containing between 40% and 60% of polymer. This was based mainly on the Battelle Institute Report. The very small incremental requirement was not considered to be economically viable, and production was not recommended.

Two of the U.N.I.D.O. references, viz:-

Reference 1 "General Survey of the Existing Situation in the Petrochemical and Fertiliser Industries (C. Jenic)."

Reference 44 "Proposal of Feasibility Pattern of Petrochemical Complex Industry in Pakistan. Volume III (T. Janakievski)."

both indicated that the 1980 market demands were approximately 8,000 MTPA, but gave no evidence in support of this conclusion.

The Battelle Institute Report indicates that the main uses of polyvinyl acetate will be for the manufacture of paints, textile finishing, and adhesives. For 1975 these uses were expected to account for 76%, 22% and 2% of the total usage respectively.

An independant survey by Chemical Consultants Ltd. ("The Manufacture of Petrochemicals in East Pakistan" Volume II, July 1969.) indicates that the requirements for 1975 are 960 MTPA of polymer and for 1980 are 3,000 MTPA of polymer. Briefly, these figures are based on 20% and 30% respectively of the total paints production being of the emulsion type.

The use for textile sizes, in the form of polyvinyl alcohol produced from polyvinyl acetate, is dependant on the growth of the textile industry, and specifically of synthetic fibres and fine cottons. The requirement for textile sizes in both Wings for 1980 is conservatively estimated to be about 30,000 MTPA, expressed as starch. Of this quantity, a conservative 7% is estimated to be required for synthetics and fine cottons, viz. 2100 MTPA, expressed as polyvinyl alcohol. The equivalent quantities of vinyl acetate required would be 4,000 MTPA.

A further use not mentioned in the Battelle Institute Report is for the manufacture of polyvinyl chloride/polyvinyl acetate co-polymer floor tiles. This is expected to give rise to a demand for about 300 MTPA of vinyl acetate in 1980.

The results of our further investigations are summarised below in Table II.2.2

TABLE II.2.2

Expected 1980 Market Demand for Polyvinyl Acetate

End Use	MTPA
Paints	3000
Textile Finishes	4700
PVC/PV Acetate Floor Tiles	300
TOTAL	8000

This revised 1980 market demand is in agreement with the two U.N.I.D.O. references mentioned earlier in this section, and is now considered to be more realistic than that given in our Interim Report. The split between the two Wings given in Table II.2.1 is based mainly on the Battelle Institute Report. Market demands for 1985 have not been investigated in the same detail, although an average growth rate of 15% per annum as used by Battelle, gives an approximate guide.

The existing and sanctioned capacity for the production of polyvinyl acetate emulsions is taken from the Battelle Institute Report. The existing capacity is 600 MTPA at Karachi (Futehally Chemicals Ltd.). Sanctions have been granted for 1,000 MTPA capacity at Karachi (Hoechst Chemicals) and for 500 MTPA capacity at Dacca (Pakbay Co.). In addition, Shuja Industries are reported to be planning a capacity of 1,000 MTPA at Karachi. It is assumed that the polymer content of the emulsion is 50% in all cases.

2.12 Vinyl Acetate

The small quantities of vinyl acetate polymerised at present in Karachi (15 tons in 1967, and an estimated 35 tons in 1968) are imported.

The vinyl acetate requirement corresponding to the total market demands of polyvinyl acetate (see Section 2.11) are given in Table II.2.1 and split between the two Wings in the same ratio as the demand for polyvinyl acetate.

Vinyl acetate is included in Table II.2.1 because the manufacture of this product is recommended whereas the polymerisation to polyvinyl acetate is not recommended at Ashuganj. It is considered that the additional polymerisation facilities will be provided by extension of the existing facilities at the "point of usage", where the individual plant capacities will still be relatively small.

2.13 Polyvinyl Alcohol

The requirements for this end product are included in requirements for polyvinyl acetate (see Section 2.11) and are not listed separately in Table II.2.1.

The conversion of polyvinyl acetate to polyvinyl alcohol (approximately 1800 MTPA of the alcohol) is on a very modest scale and should be closely integrated with the polymerisation of vinyl acetate.

2.14 Acetic Acid

In addition to the requirements of vinyl acetate production for acetic acid, there is an additional demand for acetic acid itself. The 1980 market demand has been taken from our Interim Report and is exclusive of any acid produced by the fermentation route.

The relative demand for the two Wings is assumed to be equal. The 1985 market demand is based on an average growth rate of 6% in line with that used by the Battelle Institute for ethanol.

2.15 Urea-Formaldehyde Resins

Existing and sanctioned capacity for the production of urea-formaldehyde resins is taken from our Interim Report. The figures are in terms of dry resin, and existing production is centred in Karachi and Chittagong. The urea and formaldehyde are purchased from internal sources of supply. The sanctioned capacity at Jhelum in West Pakistan is included.

The 1980 market demands are also taken from our Interim Report, and the split between the two Wings is based on information contained in the Battelle Institute Report. The 1985 market demands are taken from this report also.

2.16 Demand for Intermediates linked with Aromatics Products

These include:-

(a) **Butadiene** required for synthetic rubbers. Butadiene may be extracted from the Fauji ethylene plant C_4 stream, which contains 39% $^{W}/w$ for Phase I operation and 55% $^{W}/w$ for Phase II operation. The manufacture of synthetic rubbers, and the extraction of butadiene is considered in Volume III of this Report.

(b) **Ethylene Glycol** required for polyester fibres. This intermediate is not required in quantities sufficient to justify its manufacture in Phase II of the Fauji project, and its supply is discussed in further detail in Volume III of this Report.

(c) **Styrene** required for S.B.R. rubbers and polystyrene. The manufacture of these two end products is considered in Volume III of this Report. The quantity of styrene required is inadequate to justify manufacture in Pakistan within the timescale under consideration.

2.17 Demand for End-Products or Intermediates Planned for Ashuganj Phase I

These consist essentially of:-

Methyl methacrylate
Polymethyl methacrylate

In the case of polymethyl methacrylate, our estimate of the market demand for 1980 is based on the finding of the Battelle Institute Report, viz. 1800 MTPA. This scale of production would not have led us to recommend its manufacture for Phase I of petrochemical development in Pakistan and the planned E.P.I.D.C. capacity of 4,000 MTPA for Phase I is considered quite adequate to meet the demands up to and beyond 1980.

The same remarks apply to the production of the monomer, where it is noted that some of the Phase I production at Ashuganj is to be used in the finishing of the planned acrylic fibres production.

The demand for intermediates (acetone, acetone cyanhydrin, and acrylonitrile) required for these two products, and also acrylic fibres, has not, therefore, been considered any further than in our Interim Report.

The planned production rates for methyl methacrylate and polymethyl methacrylate, have been noted in Table II.2.1. In the case of acetylene, some is to be sold in pressurised bottles on the market. Other non-petrochemical products have been excluded from Table II.2.1

SECTION 3

FAUJI FOUNDATION, WEST PAKISTAN, PETROCHEMICALS COMPLEX

3.1 Analysis of Development Schemes for Fauji Foundation, West Pakistan

3.1.1. Development Schemes related to Fauji Foundation's Future Plans

The further development of Phase I of the Fauji Foundation petrochemical complex has been considered in the light of Fauji's tentative plans for Phase II. Details of these tentative plans were obtained from Chemical Consultants Ltd., who were authorised by Fauji to disclose the information for the purposes of this study.

TABLE II.3.1

FAUJI FOUNDATION'S TENTATIVE PHASE II PLANS

	MTPA (PHASE I & II)	Remarks
Total Ethylene	60,000	Twice Phase I
Polyvinyl Chloride	15,000	No change
Polyethylene	30,000	Twice Phase I
Polypropylene	10,000	No change
Dodecyl Benzene	10,000	New product

The developments considered have, therefore, been restricted to a total ethylene capacity of 60,000 MTPA. No further expansion of the PVC production capacity has been considered as the Pakistan Government has given sanction to the production of PVC via the acetylene based route in East Pakistan using indigenous supplies of natural gas. This is reflected in Fauji's tentative plans above. Further, as stated in Section 2.7, according to our market demand estimates, PVC will be overproduced for Pakistan as a whole until beyond 1980.

The possible developments have therefore resolved themselves into the alternative ways of utilising the surplus ethylene and propylene produced from a 60,000 MTPA ethylene cracker, excluding any expansion of PVC.

High severity cracking conditions, which maximise the ethylene yield and minimise the propylene yield, are necessary for 60,000 MTPA of ethylene and this provides sufficient surplus ethylene to increase the production of polyethylene from 15,000 MTPA to 38,600 MTPA, after providing for the transfer of 10,500 MTPA of ethylene to Valika. The increase in polyethylene production is 23,600 MTPA and is still less than the 1980 net additional requirement of 32,000 MT for both wings shown in Table II.2.1 (which takes into account the total output from Valika as well as that from Fauji Phase I). Only 10,000 MTPA of this increase in polyethylene production will be required for the West Pakistan market in 1980.

Including inter-wing transport of the remainder to East Pakistan, however, the Interim Report indicated that the foreign exchange savings resulting from the manufacture of polyethylene were much greater than from the manufacture of polypropylene or dodecyl benzene, and the choice of cracking conditions which maximises ethylene production is therefore justified on this score alone.

Excluding the manufacture of dioctyl phthalate via Oxo Synthesis, the surplus propylene may be used either to manufacture additional polypropylene or start the manufacture of dodecyl benzene. In view of the greater uncertainty in the estimated market demands for polypropylene, and the higher foreign exchange savings indicated in our Interim Report for dodecyl benzene (over twice as much per M.T. of product), it was considered that the surplus propylene should be utilised entirely for the manufacture of dodecyl benzene.

The Fauji Foundation are understood to have fairly firm plans for the production of 10,000 M T P A of dodecyl benzene and the final recommended scheme has, in this case, been adjusted to coincide with their plans. This does, however, leave a surplus of 1,300 MTPA of propylene. Slight increases in the severity of cracking may be possible in practice to reduce this surplus, which will otherwise be used as fuel. Alternatively, Fauji may make the necessary 10% increase in the capacity of the DDB unit.

The Block Diagram II.3.1 summarises these conclusions and depicts our recommended development for this site. In addition to the main petrochemical end products, by-products have also been shown at the foot of the diagram. These have been grouped into categories which are useful for assessing the production of aromatics and butadiene, as well as the obvious identification of caustic soda and hydrogen. "Other By-products" are used as fuel.

3.1.2 The Production of Dioctyl Phthalate from Propylene in West Pakistan

The alternative use of propylene to produce dioctyl phthalate was examined in the Interim Report, where it was concluded that, once a reasonable capacity for acetylene production is established in East Pakistan, there is a considerable saving to be gained in foreign exchange by producing dioctyl phthalate via the acetylene route in that wing. This conclusion was based on the comparison of schemes producing 16,000 MTPA of dioctyl phthalate completely from naphtha or completely from natural gas.

The total production costs showed a very slight advantage to the propylene route. This difference, however, was within the limits of accuracy of the underlying estimates and assumptions.

Furthermore, it should be noted that in these comparative schemes the scale of naphtha cracking was very much larger than that for Phase II of the Fauji project, and thus yielded cheaper ethylene and propylene, whereas the scale of acetylene production was of the same magnitude envisaged for Phase II of the Ashuganj project.

Further consideration has been given to the conditions now applicable at the Fauji site. In view of the restricted ethylene capacity up to 1980, and the economic preference for maximising ethylene production for the manufacture of polyethylene, the manufacture of dioctyl phthalate from propylene would inevitably mean splitting the total Pakistan production between the two wings. The reduced scale of production would result in higher production costs at each petrochemical complex. Even if it were acceptable that no dodecyl benzene at all was produced, the total quantity of propylene available, including the surplus indicated in the Block Diagram II.3.1, would only be sufficient to produce 15,000 MTPA of dioctyl phthalate. Since the surplus of 1,300 MTPA of propylene mentioned above is too small to justify the production of dioctyl phthalate, some reduction in the 10,000 MTPA of dodecyl benzene would be necessary. The DDB production rate is already well below the estimated market demands for 1980, and not only would foreign exchange expenditure increase because of the production of dioctyl phthalate from propylene as indicated earlier, but it would also increase because of the import of dodecyl benzene, or a substitute detergent. These undesirable results can be avoided by the manufacture of the total Pakistan requirements for DOP from acetylene in East Pakistan, where such manufacture would contribute appreciably to the development of the petrochemicals industry in that wing.

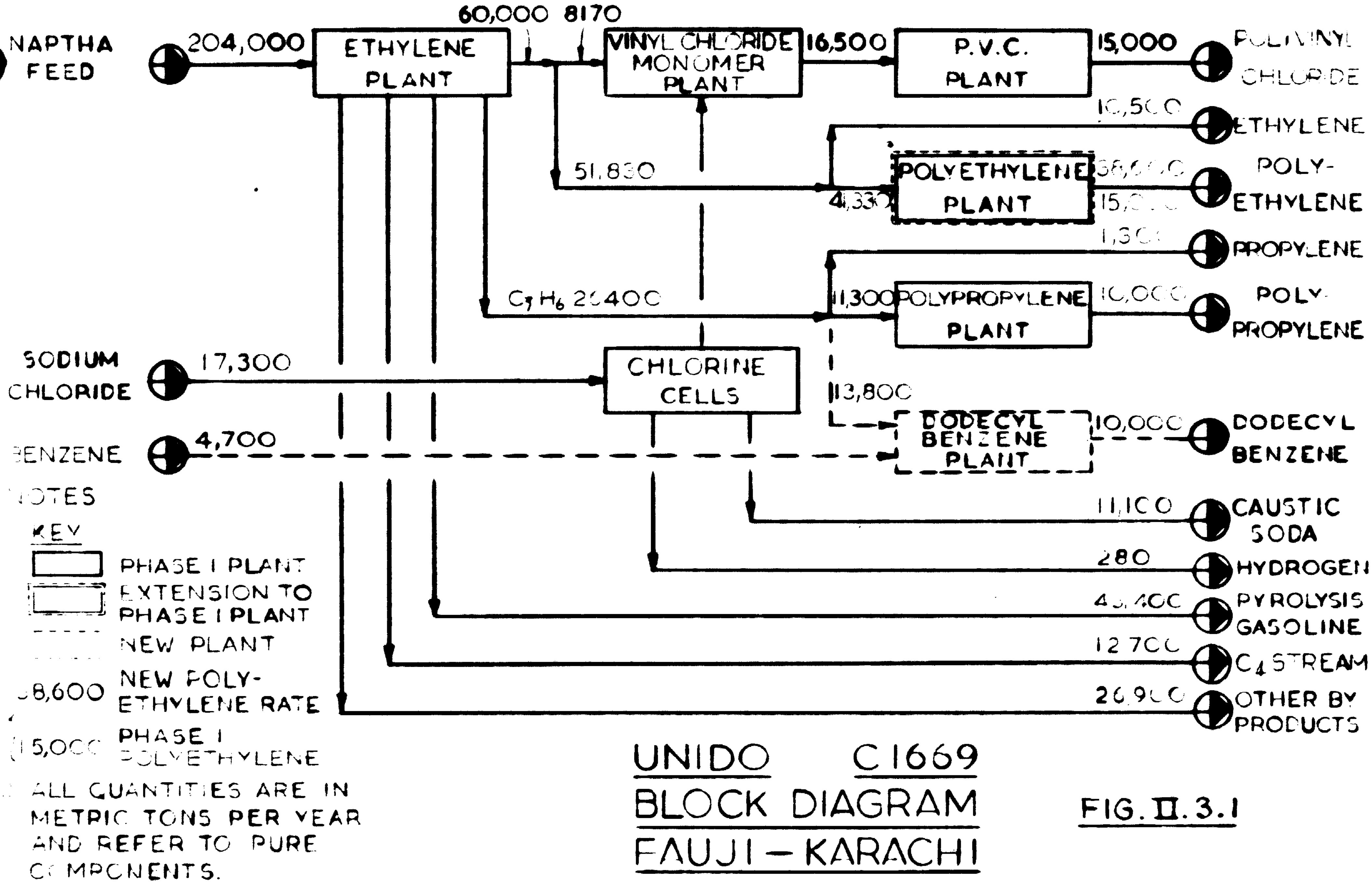
A final aspect for consideration arises from the development of aromatics production in West Pakistan. The production of phthalic anhydride in this wing would offer some savings in transport costs if the manufacture of dioctyl phthalate were at Korangi. The foreign exchange savings resulting from production of DOP in Pakistan will not, however, be affected by the selection of East or West Pakistan as the plant location. The transport of phthalic anhydride from West to East Pakistan, and the transport of dioctyl phthalate back to West Pakistan would result in slightly increased cost to the consumer in West Pakistan.

3.1.3 Consideration of Other End-Products

Apart from the end-products discussed above, the other end-products listed in Table II.2.1 were considered.

Some of these, e.g. Urea-Formaldehyde resins, would obviously be produced at the Ashuganj site in East Pakistan because of the availability of urea and of formaldehyde from methanol. High density polyethylene is considered to be uneconomic at the scale indicated by the 1980 market demands.

The acetylene route is recommended for production of vinyl acetate and acetic acid. Therefore, these products are not recommended as outlets for ethylene in Phase II of the Fauji project. These products and polyvinylacetate are discussed further in Section 4.1.



UNIDO C1669
BLOCK DIAGRAM
FAUJI-KARACHI
WEST PAKISTAN-PHASE 2

FIG. II.3.1

3.2 Recommended Development and Financial Evaluation for Fauji Foundation, West Pakistan

3.2.1 Introduction

The recommended development for Phase II of the Fauji Project is shown in the Block Diagram II.3.1 and its evolution has been discussed in Section 3.1

Before considering the development scheme as a whole, the individual process units are described below; capital and operating costs, and the foreign exchange analysis are dealt with in a subsequent section. This part of Volume II concludes with the financial analysis of the scheme as a whole including the year-by-year cash flows and the D.C.F. rate of return on the investment.

3.2.2 Individual Process Units

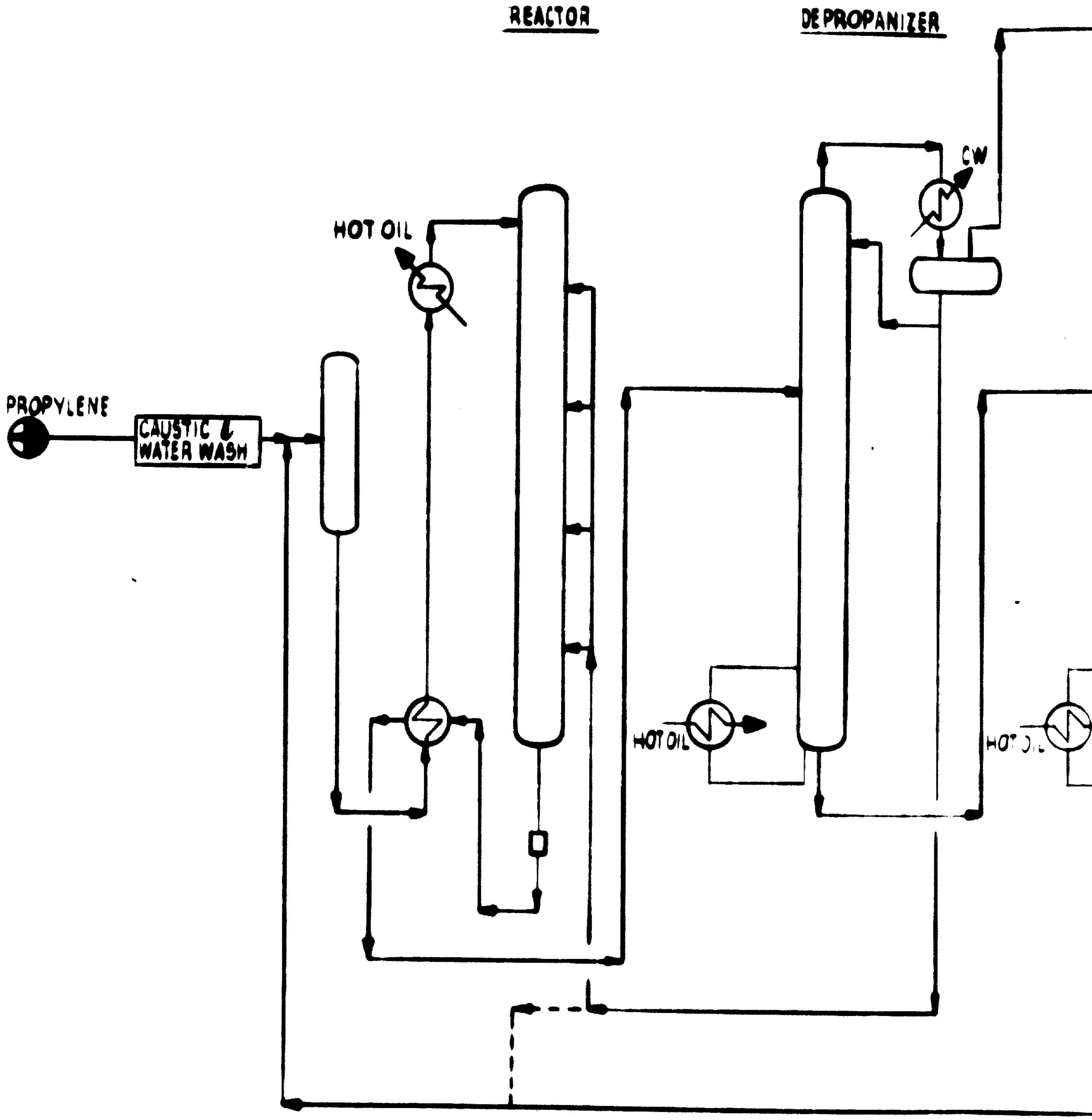
3.2.2.1 Dodecyl Benzene Plant

Process Description and Flow Chart

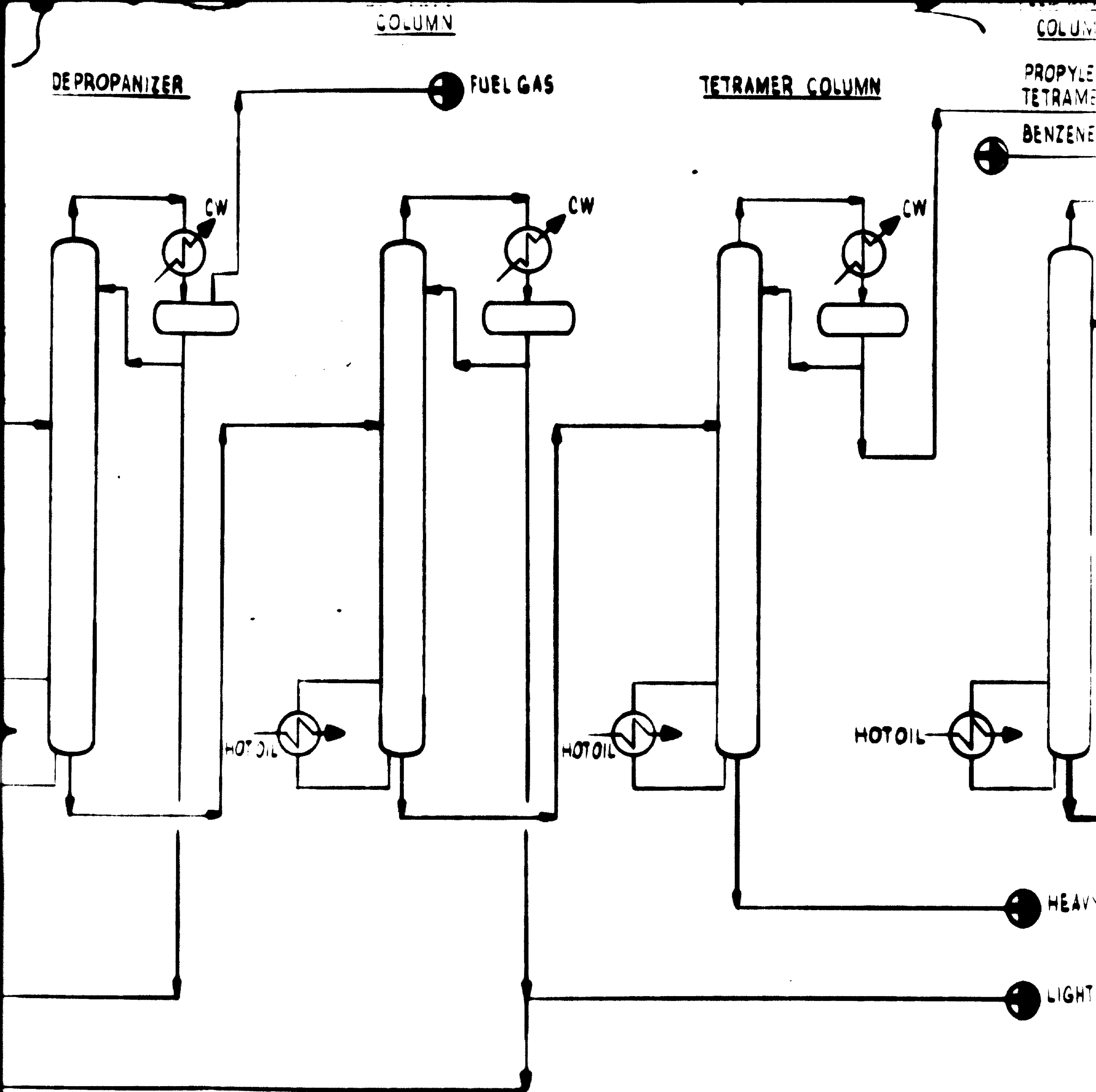
A simplified flow chart for the production of dodecyl benzene is presented in Table II.3.2. The simplified flow charts omit such items as pumps, blowers and auxiliary systems (e.g. hot oil system).

The first part of the process may be considered as the preparation of propylene tetramer. Propylene from the ethylene plant is washed, vapourised, and polymerised over solid, phosphoric acid-based catalyst maintained in separate beds in the reactor, suitable propane quench points being provided between the beds for temperature control. The reactor effluent is depropanised, the liquid overheads being recycled (because of the unreacted propylene content) or used for quench. The gaseous overheads is withdrawn as fuel gas. The depropaniser bottoms pass to a recycle column, from which light polymer is withdrawn overhead; some of this is recycled to achieve further polymerisation to the tetramer. The bottoms from this column are purified in the tetramer column, from which heavy polymer is also withdrawn.

In the second part of the process, propylene tetramer is dried. and then reacted with benzene in the presence of hydrofluoric acid catalyst. The use of aluminium chloride gives lower yields, higher corrosion rates, and handling difficulties; it is not recommended. Sulphuric acid catalyst has been proved acceptable commercially, but gives relatively high utility and catalyst consumptions, and somewhat lower yields. More commercial experience has been gained with the hydrofluoric acid process.

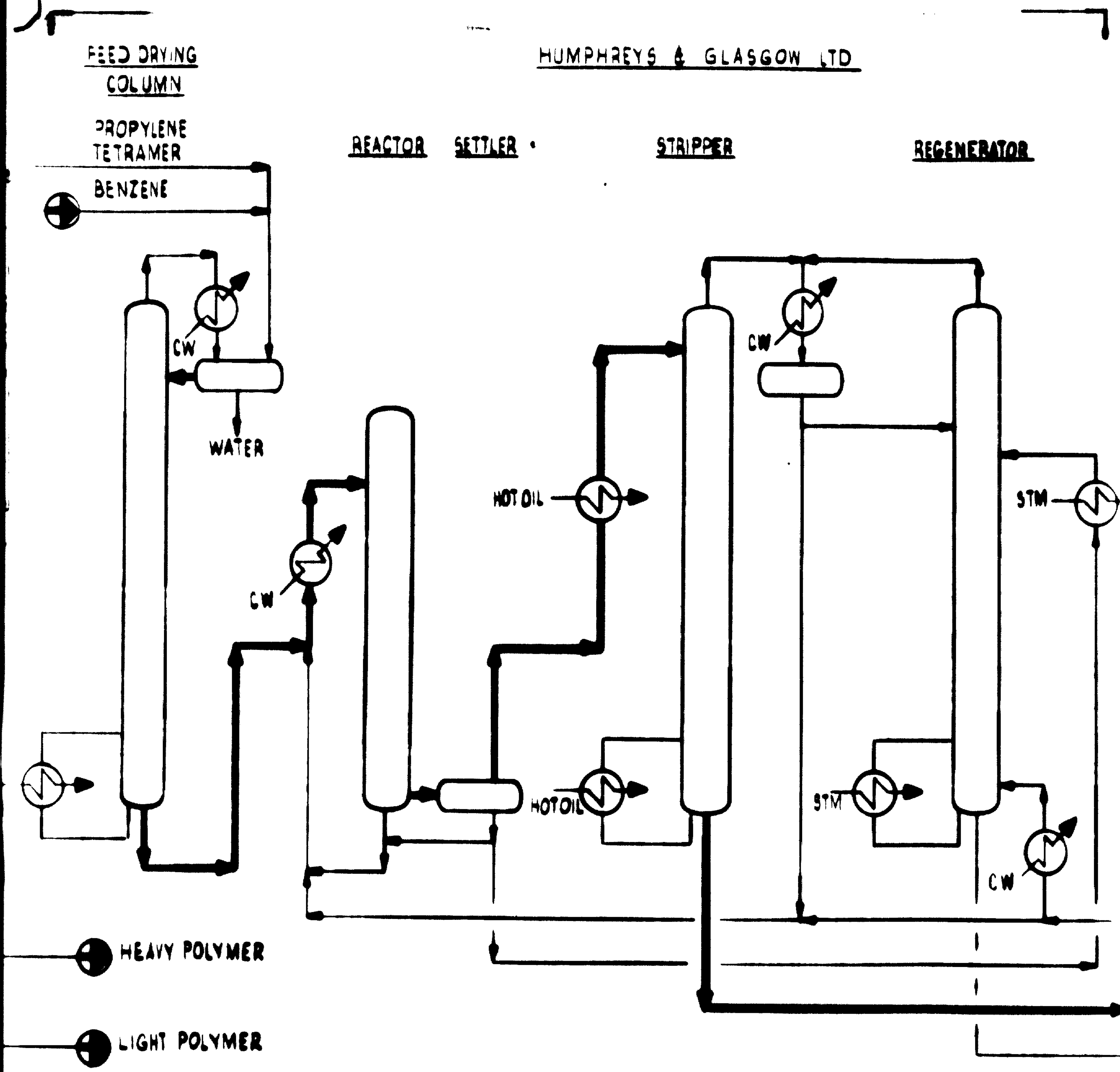

REACTOR
DEPROPANIZER
CW
HOT OIL
PROPYLENE
CAUSTIC & WATER WASH
HOT OIL
HOT OIL

SECTION 1



SECTION 2

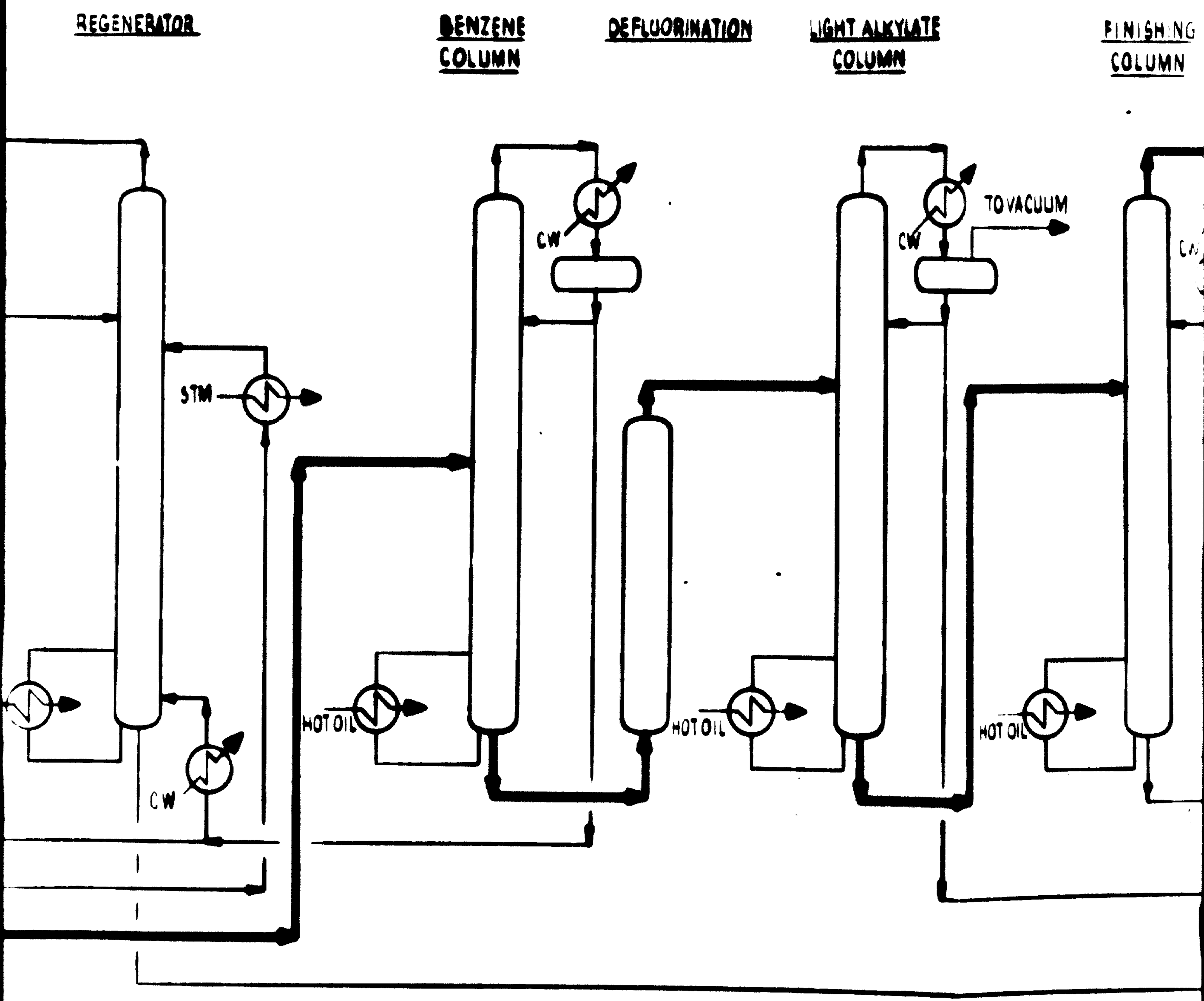
FIG II.3-2



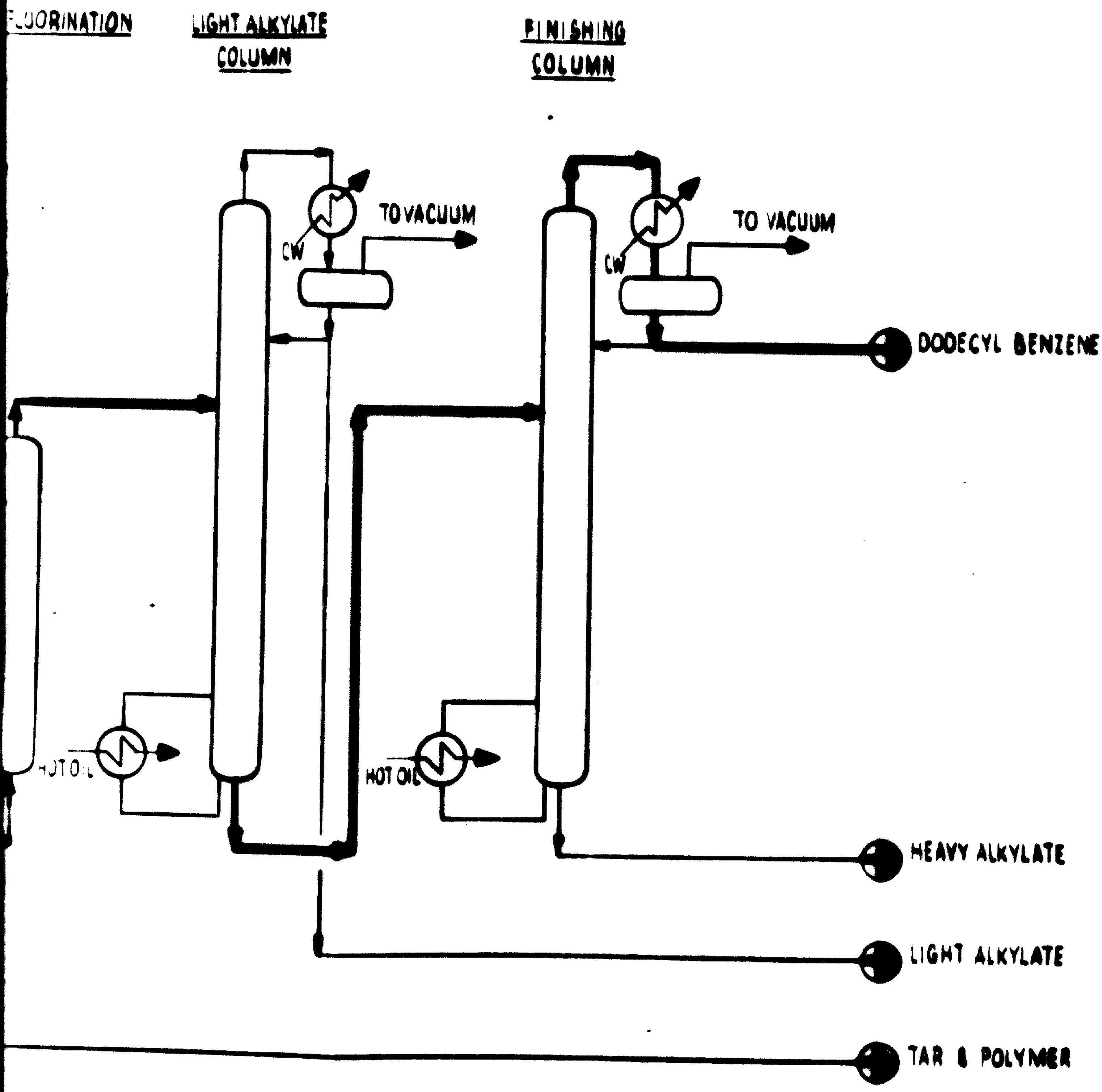
SECTION 3

U.N.I.D.O - C-1669
FLOW CHART DODECYL BENZENE
FAUJI - KARACHI - WEST PAKISTAN PHASE 2

5 II. 3.2


REGENERATOR
BENZENE COLUMN
DEFLUORINATION
LIGHT ALKYLATE COLUMN
FINISHING COLUMN
CW
TO VACUUM
STM
HOT OIL
HOT OIL
HOT OIL
CW
CW
HOT OIL

SECTION 4


FLUORINATION
LIGHT ALKYLATE COLUMN
FINISHING COLUMN
TO VACUUM
CW
TO VACUUM
CW
DODECYL BENZENE
HOT OIL
HOT OIL
HEAVY ALKYLATE
LIGHT ALKYLATE
TAR & POLYMER

SECTION 5

A recirculating reactor system is employed. Acid is removed from the net reactor effluent in a settler. Most of this is returned to the reactor, while a small proportion passes through the hydrofluoric acid regenerator. The hydrocarbon layer from the settler passes to a stripper, the overheads from which combine with the regenerator overheads, and after condensation are recycled to the reactor and used as regenerator reflux. The regenerator bottoms, tar and polymer, pass to a neutralisation pit. The stripper bottoms pass to the benzene column. Benzene is taken overhead and recycled to the reactor. Only a very small portion of this recycle would require neutralisation (to prevent the build up of impurities) if high quality benzene feed is used; this is not shown on the flow chart. The bottoms from the benzene column are passed through a bauxite tower to remove combined fluorides, and light and heavy alkylates are separated in the Light Alkylate and Finishing Columns respectively.

The dodecylbenzene is a water-white liquid having a boiling range of 280°C. to 320°C.

Source of Know-How and Licence

The process scheme and operating data given subsequently have been based on the Universal Oil Products' process. An alternative licensor is Chevron.

Operating Data

Table 11.3.2 below lists the major consumptions of raw materials, catalysts/chemicals and utilities, and direct labour requirements.

TABLE II.3.2

Operating Data - Dodecyl Benzene (Basis 1 MT DDB)

Propylene (as 100%) MT	1.380
Benzene (nitration grade) MT	0.472
Net Byproducts, MT	0.850
Catalyst/Chemicals, $	4
Power, kwh	232
Steam (medium pressure) MT	7.4
Cooling Water, M^3	31
Labour Requirement	18

Area of Battery Limits

The approximate area within the plant battery limits is 13,000 M^2.

3.2.2.2 Polyethylene Plant

Process Description, Source of Know-How and Licence

The extension of the polyethylene plant from 15,000 MTPA to 38,600 MTPA (in 300 operating days per year) will require the addition of a second stream. It is highly probable that, in the interest of economy of spares, integration of the two streams, and utilisation of operating know-how gained on the first stream, the second stream will also utilise the I.C.I. process.

Operating Data

Table II.3.3 below lists the major consumptions of raw materials, catalysts/chemicals, utilities, and direct labour requirements.

TABLE II.3.3

Operating Data - Polyethylene (Basis 1 MT)

Ethylene (as 100%) MT	1.070
Catalysts/Chemicals, $	15
Power, kwh	2000
Steam (300 psig, saturated) MT	1.5
Steam (100 psig, saturated) MT	0.6
Cooling Water, (30°C), M^3	200
Condensate, M^3	0.2
Nitrogen, Nm^3	7
Labour Requirements	50

Area of Battery Limits

The approximate area within the plant battery limits is 13,000 M^2. This is based on the overall plot plant for Phase I of the Fauji complex obtained from Simon Carves Ltd., showing the plot area for the 15,000 MTPA plant.

3.2.2.3 Ethylene Plant

The operating data for ethylene production is required for evaluating the variable cost of production in Section 3.2.6 (Foreign Exchange Analysis) and the average cost of production in Section 3.2.7 (Cash Flow). The major consumptions of raw materials, catalysts and chemicals, utilities, and incremental labour requirements for expansion to 60,000 MTPA capacity are given below.

TABLE II.3.4

Operating Data - Ethylene (Basis 1 MT)

Naphtha, MT	3.40
Catalyst/Chemicals, $	0.4
By-Products	
Pyrolysis gasoline (hydro-treated), MT	0.70
Fuel Oil, MT	0.15
Light Gases, MT	0.51
Propylene, MT	0.45
Power, kwh	300
Steam (high pressure), MT	0.23
Cooling Water, M^3	417
Increase in Labour Requirements (30,000 to 60,000 MTPA)	5

It should be noted that the ethylene plant cracked gas and propylene compressors are driven by steam turbines. Electric motor drives are retained for the ethylene compressors.

3.2.3 Complete Development Scheme

3.2.3.1 Utilities and Offsites Installations

The utilities plants and any new off-site facilities needed for Phase II at the site must be an extension to those already provided by Fauji for Phase I of their project. The detailed provisions being made in Phase I are not available. We have therefore provided a summary of the utility consumptions demanded by the Phase II project outlined above. In carrying out subsequent cost estimating, unit costs for utilities have been used. These data were supplied by Fauji Foundation (via Chemical Consultants Ltd.)

With the exception of tank storage for raw materials and end-products, the same arguments apply to offsite installations. Facilities such as administrative office blocks, canteen and medical services, and workshop facilities, etc. are expected to be adequate for Phase II.

3.2.3.2 Utilities Consumption

Table II.3.5 below summarises the major utilities consumption resulting from the recommended development for Phase II of the Fauji project.

TABLE II.3.5

Summary of Total Utility Requirements for Phase II

Power, kw	8960
Steam, MT/Hr	20.0
Cooling Water, M^3/Hr	2700
Condensate/Demin Water (for process) M^3/Hr	0.75

3.2.3.3 Management, Personnel and Labour

The direct process labour requirements for the polyethylene plant extension and the dodecyl benzene plant are estimated as 68 men. This covers the requirements for a 4-shift system of operation and the requirements for day men. It does not include:

(a) Maintenance personnel

(b) Plant Manager, or partial supervision at higher levels

(c) Administrative and "overhead" staff associated with the activities of these plants.

As far as assessing the costs of labour, personnel and management are concerned, categories (a) and (c) are covered by maintenance charges and overheads, category (b) is allowed for in the rate of 9000 Rs/year used for each member of direct operating staff. This figure is a weighted cost of labour which allows for management and supervision and assumes that, in a single organisation the supervisor : subordinate ratio is constant.

The polyethylene plant extension, although larger than the Phase I installation, may fall under the control of the one plant manager. The dodecyl benzene plant will require a plant manager, however.

3.2.3.4 Plot Plan of the Recommended Development

Drawing No. C.1669-L51-4 gives the plot plan showing the Phase II expansion. This is based on the most recent plot plan for the site. The expansion thus forms a logically integrated part of the whole complex.

The disposal of effluents has been viewed in a similar way to the provision of utilities installations, and it is expected that the Phase I Effluent Disposal System will be capable of handling the additional load.

3.2.4 Capital Costs

3.2.4.1 Dodecyl Benzene Plant

TABLE II.3.6

Capital Cost of Dodecyl Benzene Plant

		Rupees x 10^6 Foreign Exchange	Rupees x 10^6 Local Currency
1.	Equipment, spares, procurement, freight and insurance, tools and plant, insurance	14.55	-
2.	Engineering, expenses and overheads, licence, site supervision and commissioning.	4.72	-
3.	Construction labour, civil work, local tools and plant, local insurance, inland freight and dock clearance, local spares, local expenses	-	5.48
4.	Duty on equipment and spares	-	6.10
TOTALS		19.27	11.58
Start-up Charges and Training		1.54	1.54
Interest on Foreign Exchange during Construction		2.12	-
		22.93	13.12
TOTAL COST		36.05	
ESTIMATED WORKING CAPITAL (Max.)		4.00	

The above capital cost estimate covers all fixtures which are normally within the plant battery limit, and all expenses required to bring the plant into operation.

Included:- Raw materials and product storage and handling sufficient for normal operation. Civil work, control rooms, minor office buildings and workshops, fire equipment, telephones etc. within the plant boundary, as necessary.

Excluded:- Major offsite storage facilities, civil work, piping, and services distribution outside plant boundary site development, and land.

Interest during construction on the rupee element is omitted because details of the method of finance are not known.

3.2.4.2 Polyethylene Plant

TABLE II.3.7

Capital Cost of Polyethylene Plant

		Rupees x 10^6	
		Foreign Exchange	Local Currency
1.	Equipment, spares, procurement, freight and insurance, tools and plant, insurance	25.40	-
2.	Engineering, expenses and overheads, licence, site supervision and commissioning	19.47	-
3.	Construction labour, civil work, local tools and plant, local insurance, inland freight and dock clearance, local spares, local expenses	-	9.39
4.	Duty on equipment and spares	-	10.55
TOTALS		44.87	19.94
Start-up Charges and Training		3.24	3.24
Interest on Foreign Exchange during Construction		4.94	-
		53.05	23.18
TOTAL COST		76.23	
ESTIMATED WORKING CAPITAL (MAX)		11.64	

For definition of scope of the above capital cost estimated, see footnote to Table II.3.6.

3.2.4.3 Expansion to Phase II Ethylene Plant

Chemical Consultants Ltd. have provided the foreign exchange cost which Fauji Foundation will incur in expanding the capacity of the ethylene plant from 30,000 to 60,000 MTPA. The foreign exchange cost of expanding the utilities installation for this increased ethylene capacity has also been provided. These costs have been used in the Foreign Exchange Analysis in Section 3.2.6, and are tabulated below.

TABLE II.3.8
Capital Cost of Ethylene Expansion

Rupees x 10^6

	Foreign Exchange	Local Currency Including duty
Ethylene Plant Expansion	7.14	
Utilities Installation Expansion	11.90	
	19.04	
Allowance for Erection, and Commissioning	2.62	
TOTAL	21.66	13.12
Interest on Foreign Exchange during Construction	2.38	-
TOTAL	24.04	13.12
TOTAL COST	37.16	

The local currency capital cost given in the above Table is based on the cost analysis of typical petrochemical plants.

3.2.4.4 Summary of Capital Costs

TABLE II 3.9

Summary of Capital Costs of Fauji Expansion

Rs x 10^6

	Foreign Exchange		Local Currency (including duty)	
Estimated cost of Fauji Phase I including pre-investment for expansion, bags and pipe plants, utilities, start-up costs, and interest on foreign exchange (but not local currency):	216.33		128.25	
TOTAL COST:		344.58		
ESTIMATED WORKING CAPITAL:		18.00		
Dodecyl Benzene Plant	19.27		11.58	
Second Polyethylene Plant	44.87		19.94	
TOTALS FOR NEW PLANTS	64.14		31.52	
Start-up charges and training	4.78		4.78	(b)
Interest during construction	6.64		-	(4.00)
	75.56(a)		36.30	(40.30)(a)
TOTAL COST OF NEW PLANTS:		111.86		
Ethylene Plant Extension	21.66		13.12	
Interest during construction	2.24		-	
	23.90		13.12	
TOTAL COST OF ETHYLENE EXTENSION		37.02		
New Plants plus ethylene extension	99.46		49.42	
TOTAL COST OF EXPANSION:		148.88		
ESTIMATED WORKING CAPITAL:		15.64		

The costs given above for Phase I are those estimated by Fauji, and were provided through Chemcon.

The capital costs for the new plants(a) are used for the cash flow calculation, in Section 3.2.7.6, in which the average costs of ethylene include an element to cover the capital costs of the complete ethylene plant and offsites. 'Interest' amounting to 11%(b) is added to the local currency capital cost to allow for the time value of money paid out before start-up.

3.2.5 Unit Costs and Prices

Table II.3.10 below lists the unit costs of the various raw materials and utilities used in the subsequent financial analyses. It also gives the credit values for the various byproducts and the expected selling price of the end-products (including ethylene sold to Valika). The costs, values, and prices are subdivided as shown, for the purpose of specific financial analyses.

In the table, the "total" prices for polyethylene and dodecylbenzene are those proposed by Fauji (before sales tax), as quoted to us by Chemcon. The foreign exchange prices for these end-products are the expected C & F prices of the replaced imports, as in our Interim Report, and are based on current C & F prices. The foreign exchange prices shown in brackets are an estimate of the C & F price which would be competitive, under cash cum bonus, with the proposed total price.

The "total" price of ethylene sold is H & G's own estimate, based on approximately 50% mark-up of our estimate of the production cost of ethylene as stated in 3.2.7.2 below, to cover liquefaction, transport, and profit.

TABLE II.3.10

Unit Costs and Prices

	($)	$ Foreign Exchange	Rs Local Currency (excluding duty)	Rs Total
End Products				
Polyethylene, MT	(248)	270	-	2960
Dodecyl Benzene MT	(202)	300	-	2400
Ethylene MT		-	-	1000
By Products				
Pyrolysis Gasoline (Hydro-treated) MT		14.2	52	-
Fuel Oil (C_4 product ex Ethylene Plant) MT		11.5	21	-
Byproduct ex DDB plant MT		-	70	86
Raw Materials				
Light Naphtha MT		14.3	14	-
Benzene (local manufacture) MT		-	700	700
Utilities				
Electricity (local purchase) kwh		-	0.085	0.085
Steam, MT		-	5.7	15.0
Cooling Water, M^3		-	0.06	0.06
Raw Water M^3		-	0.44	0.44
Demineralised Water M^3		0.05	0.61	2.0
Packages				
Sacks (per MT Polyethylene)		-	8.0	8.0
Steel Drums (per MT DDB)		-	60.0	60.0

3.2.6 Foreign Exchange Analysis

3.2.6.1 General

The incremental production of end-products beyond that of Phase I of Fauji is shown in the Block Diagram II.3.1. It is assumed that in Phase I, 5,300 MTPA of ethylene are produced for Valika. It should also be noted that for both Phase I and Phase II, operating at maximum severity cracking with the production of 0.45 MT of propylene per MT of ethylene, the surplus propylene (burnt as fuel) is 1700 MTPA and 1300 MTPA respectively. It is, therefore, assumed that propylene remains sufficiently in balance for the purposes of this analysis.

The incremental production of ethylene, polyethylene and dodecyl benzene is summarised below:

TABLE II.3.11

Incremental Production Rates

	MTPA
Ethylene	30,400
Polyethylene	23,600
Dodecyl Benzene	10,000

The basis of the foreign exchange analysis is the evaluation of the foreign exchange saving and the local currency cost (excluding duty) for this incremental production, and hence the statement of the cost in local currency of saving foreign exchange. It is applied specifically to the quantities in the above Table, i.e. to full rate production.

3.2.6.2 Variable Costs of Production

From the operating data given in Section 3.2.2 and the unit operating costs given in Section 3.2.5, the variable costs of production for ethylene, polyethylene, and dodecyl benzene is calculated. In order to make the figures independent of any judgement on the relative unit values of ethylene and propylene, the variable cost of ethylene plus the co-produced propylene is calculated, and the cost of these intermediates is excluded from the variable costs of the products. These costs are stated in Table II 3.12.

TABLE II.3.12

Variable Production Costs

Basis	Foreign Exchange ($)	Local Cost Excluding Duty (Rs.)
Ethylene 1 MT + Propylene 0.45 MT	38.9	14.3
Polyethylene 1 MT (excl. ethylene cost)	15.0	204
Dodecyl Benzene 1 MT (excl. propylene cost)	4.0	394

Notes on Table II.3.12

1. The local costs in the above Table include the cost of packages.

2. Summation of the variable costs listed enables the total variable costs of the complex extension to be calculated.

3.2.6.3 Fixed Costs of Production

Maintenance

The basis for calculating the maintenance charges as a percentage of the total fixed capital (excluding interest during construction, site development, etc.) is:

Foreign Exchange	1.8%
Local Cost	1.57%

This basis makes due allowance for materials and labour and is applicable to Pakistan conditions.

For the purpose of this calculation, however, it was more convenient to base the maintenance on the foreign exchange investment and the percentages used were

Foreign Exchange element of maintenance costs	- 2.9% of foreign exchange capital cost
Local Cost element of maintenance costs	- 2.5% of foreign exchange capital cost

From the total foreign exchange investment of $ 18.0 x 10^6 (see Section 3.2.4), the maintenance charge per annum is:

Foreign Exchange	$ 522,000
Local Cost (excluding duty)	Rs. 2,147,000

Labour and Supervision

The direct labour requirements of the ethylene plant expansion, the additional polyethylene plant, and the dodecyl benzene plant are 73 men (see Section 3.2.2). At an average cost of 9,000 Rs. per man per year, which allows for supervision, the labour charges are:

Local Cost	Rs. 657,000

Overheads

These, which include selling and marketing expenses, are estimated at 3% of the total sales revenue. This is calculated using the data from Table II.3.10, thus:

Sales	23,600 MTPA Polyethylene	70.0 Rs. x 10^6
	10,000 MTPA DDB	24.0 Rs. x 10^6
	5,200 MTPA Ethylene	5.2 Rs. x 10^6
		99.2 Rs. x 10^6

The overheads are thus Rs. 2,976,000 (local cost only)

Interest on Working Capital

Working capital was assumed to be equivalent to the value of 2 months' finished product. As output rises during initial years, so also does working capital. Interest on working capital is equivalent to 1.5% of the year's sales revenue.

The interest on working capital is thus Rs. 1,488,000 for 100% production capacity.

The fixed costs of production are summarised below.

TABLE II.3.13

Fixed Production Costs

	Foreign Exchange $ x 10^3/yr	Local Cost Excluding Duty Rs. x 10^3/yr
Maintenance	522	2147
Labour and Supervision	Nil	657
Overheads and Selling Expenses	Nil	2976
Interest on Working Capital	Nil	1488
TOTAL	522	7268

3.2.6.4. Foreign Exchange Saving and Rupee Cost Comparison

The following Table gives the comparison and is compiled using the data given in the previous sections. The Rupee element of the investment excludes duty on equipment, but includes start-up expenses. The use of the average interest rate ensures that the early years are not penalised, nor the results for the later years over optimistic.

TABLE II.3.14

Foreign Exchange Analysis (Fauji - Phase II)

	Foreign Exchange $ x 10^3/yr		Local Cost Excluding Duty Rs. x 10^3/yr
Variable Production Costs			
P.E. 23,600 MTPA	354		4810
DDB 10,000 MTPA	40		3940
Ethylene 30,400 MTPA	1182		435
Fixed Production Costs	522		7268
TOTAL PRODUCTION COSTS	2098		16453
Foreign Exchange Value of Products			
P.E. 23,600 MTPA @ 270 $/MT	6370		
DDB 10,000 MTPA @ 300 $/MT	3000		
Ethylene 5,200 MTPA	Nil		
TOTAL F.E. VALUE OF PRODUCTS	9370		
Average Interest Over First 10 Years at 8% p.a. ($ 4% on Total Foreign Exchange Loan of $ 20.92 x 10^6)	837		
Annual Repayments	2092		
TOTAL INTEREST AND REPAYMENTS	2929		
Foreign Exchange Savings	4343		
COST OF F.E. SAVING Rs/$ EXCLUDING DEPRECIATION ON RUPEE ELEMENT		3.79	
Depreciation @ 10% on Rupee Element			2584
Rupee Cost Including Depreciation			19037
COST OF F.E. SAVING Rs/$ INCLUDING DEPRECIATION		4.38	

3.2.6.5 Foreign Exchange Analysis for Each Product

The variable and fixed production costs of ethylene, propylene, polyethylene, and dodecylbenzene, have been calculated, on exactly, the same basis as in the preceding sections. The cost of 1 MT of propylene has been taken to be 50% of the cost of 1 MT of ethylene, and the fixed costs (both operating and financial) have been suitably distributed between the ethylene expansion and the process units. As before, the duty and bonus elements have been omitted from the costs of plant, materials and utility services. Financial costs, as before, cover repayments and average interest on the foreign exchange element of fixed capital, depreciation only on the local currency element of fixed capital, and interest on working capital.

The production costs and foreign exchange savings figures so calculated are:-

	$ Foreign Exchange	Rs Local Currency
per (1 MT ethylene + 0.45 MT propylene):		
Variable	38.9	14.3
Fixed	28.7	96.7
Production cost	67.6	111.0
ethylene, per MT:		
Variable	31.8	11.7
Fixed	23.4	78.9
Production cost	55.2	90.6
propylene, per MT:		
Variable	15.9	5.8
Fixed	11.7	34.5
Production cost	27.6	45.3
polyethylene, per MT:		
Ethylene 1.07 MT	59.0	96.7
Other variable	15.0	204
Fixed	76.5	257
Production cost	150.5	557.7
Cost of import (C&F)	270	
Foreign exchange saving	119.5	
Ratio Rs 557.7/$119.5 = Rs 4.7/$		
Dodecylbenzene, per MT:		
Propylene 1.38 MT	38.0	62.5
Other variable	4.0	394
Fixed	77.4	260
Production cost	119.4	716.5
Cost of import (C&F)	300	—
Foreign exchange saving	180.6	
Ratio Rs 716.5/$ 180.6 = Rs 4.0/$		

3.2.7 Cash Flow and D.C.F. Rate of Return

3.2.7.1 General

The sales revenue is based on the pattern of market build-up stated in the Interim Report. Production by the individual plants is only limited to 30% and 90% in the first two years of operation as existing plants and utilities will be well established. The lower figure of the two (market requirement or production capacity) establishes the output (and sales rate) for any particular year up to 1980, after which the full production rate can be maintained and sold. For the purposes of this analysis it was decided to use the average, and not the marginal, cost of ethylene and propylene production in establishing the production costs of the polyethylene and dodecyl benzene (see Section 3.2.7.2 below). Total costs of the manufacturer are used through this analysis so that the D.C.F. rate of return can be determined from the viewpoint of the Pakistan investor.

3.2.7.2 Ethylene and Propylene Costs

In Phase II, the Fauji plant is planned to produce 60,000 MTPA ethylene with a propylene to ethylene ratio of 0.45 under severe cracking conditions. For the purposes of analysing Phase II of the project, ethylene and propylene are taken as feeds to the new plants proposed. Propylene is regarded as a less valuable product than ethylene and, even after Phase II, there will be surplus production from the Fauji cracker. The cost of propylene per MT has been taken as half that of ethylene. Both ethylene and propylene costs have been averaged over total production; the Phase II plants do not therefore benefit from ethylene and propylene at marginal costs of production.

The estimated total costs of ethylene and propylene as feeds to the Phase II units are:

Ethylene	Rs. 635 /MT
Propylene	Rs. 317 /MT

3.2.7.3 Variable Cost of Polyethylene and Dodecyl Benzene Production

Using the average production costs of ethylene and propylene from the previous section, the operating data given in Section 3.2.2, and the total unit cost of raw materials and utilities from Section 3.2.5, the variable costs of polyethylene and dodecyl benzene were calculated. These are summarised below:

Polyethylene	Rs. 1080 /MT
Dodecyl Benzene	Rs. 932 /MT

These costs include the cost of packages.

3.2.7.4 Fixed Costs of Production

The fixed costs are estimated for the extension project as a whole and are not subdivided between end-products. In the cash flow table and D.C.F. calculation, the presence of the full capacity ethylene plant on the site is assumed.

Maintenance

The basis for the maintenance charge is 4.27% of the total fixed capital (excluding the duty paid on equipment). This is consistent with the rates given in Section 3.2.6.3. On this basis the figure of 4.27% includes allowance for the duty element on the materials used in maintenance.

Labour and Supervision

The direct labour requirements for the two plants are 68 men, charged at 9,000 Rs. per man per year.

Overheads and Selling Expenses

These are estimated to be 3% of the total sales revenue, as in the Foreign Exchange analysis. They are based on the "full-up" year as by definition they are considered to be fixed.

Foreign Exchange Repayments

The repayments are made in equal sums over the first ten years of operation. The total foreign exchange loan for the polyethylene and dodecyl benzene plant is:

Rs. 75.56×10^6

It includes interest on the loan during the construction period and the foreign exchange capital covering start-up expenses (See Section 3.2.4).

3.2.7.5 Other Fixed Costs

Interest on Foreign Exchange Loan

This is based on 8% of the outstanding loan. It includes interest on the foreign exchange capital borrowed to cover start-up expenses.

Interest on Working Capital

As in the Foreign Exchange Analysis, this is based on 1.5% of the total sales revenue. The total sales revenue applicable to the particular year is used. Ethylene is excluded.

3.2.7.6 Cash Flows and D.C.F. Rate of Return

The cash inflows, cash outflows and the net cash flows are set out in Table II.3.2.15 below. The net cash flow is before tax and depreciation.

A total span of 15 years is covered; year 0 is the reference year in which it is assumed that all the capital is invested. In practice this is not the case, but the allowance mentioned above for the interest during construction permits this simplification. 1976 is taken as the year in which the recommended development commences production and sales. It is justified by the D.C.F. rate of return obtained.

The costs in this table are based on 1970 costs of equipment, materials and labour. This is in accordance with accepted practice where price trends are not available. Labour is the only element of costs for which a reasonably reliable trend prediction is available. However, labour cost is a very small element in this table, and in practice reductions of the work force might be made over the life of the plant by improved methods, to counteract rising wages and salaries. Therefore, allowance for rising labour cost was not considered to be useful in the present case.

The proposed selling prices are those estimated by Fauji Foundation, as quoted to us by Chemical Consultants. They are well below the current import prices on cash-cum-bonus; the C & F prices which would be competitive with the proposed selling prices have been estimated and are shown in Table II 3.10. For explanation of capital costs used, see Section 3.2.4.4.

The D.C.F. rate of return based on the Rupee investment in the fixed assets is calculated at

TABLE II 3.15

CASH FLOW AND D.C.F. RATE OF RETURN
([illegible])

CALENDAR YEAR Reference Year	1975 0	1976 1	1977 2	1978 3	1979 4	1980 5	1981 6	1982 7	1983 8	1984 9	1985 10	1986 11	1987 12	1988 13	1989 14	1990 15
PRODUCTION AND SALES, M.T.P.A.																
Ethylene (to [illegible])		NIL	NIL	NIL	3,400	5,380	5,380	5,380	5,380	5,380	5,380	5,380	5,380	5,380	5,380	5,380
Polyethylene		5,600	12,000	18,300	25,600	25,600	25,600	25,600	25,600	25,600	25,600	25,600	25,600	25,600	25,600	25,600
Dodecyl Benzene		3,000	7,000	9,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
CASH INFLOW																
Ethylene @[illegible] Rs/MT		NIL	NIL	NIL	3,400	5,380	5,380	5,380	5,380	5,380	5,380	5,380	5,380	5,380	5,380	5,380
Polyethylene @[illegible] Rs/MT		16,576	35,520	54,760	69,856	69,856	69,856	69,856	69,856	69,856	69,856	69,856	69,856	69,856	69,856	69,856
Dodecyl Benzene @[illegible] Rs/MT		7,200	16,800	21,600	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
TOTAL CASH INFLOW		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CASH OUTFLOW																
1. Variable Costs of Production																
Ethylene		NIL	NIL	NIL	2,286	3,386	3,386	3,386	3,386	3,386	3,386	3,386	3,386	3,386	3,386	3,386
Polyethylene		[illegible]	[illegible]	[illegible]	25,380	25,380	25,380	25,380	25,380	25,380	25,380	25,380	25,380	25,380	25,380	25,380
Dodecyl Benzene		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Total Variable Production costs		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2. Fixed Costs																
Interest on Foreign Exchange Loan		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NIL	NIL	NIL	NIL	NIL
Interest on Working Capital		[illegible]	[illegible]	[illegible]	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400
Foreign Exchange Repayments		7,386	7,386	7,386	7,386	7,386	7,386	7,386	7,386	7,386	7,386	NIL	NIL	NIL	NIL	NIL
Overheads & Selling Expenses		2,486	2,486	2,486	2,486	2,486	2,486	2,486	2,486	2,486	2,486	2,486	2,486	2,486	2,486	2,486
Maintenance		3,374	3,374	3,374	3,374	3,374	3,374	3,374	3,374	3,374	3,374	3,374	3,374	3,374	3,374	3,374
Labour and Supervision		697	697	697	697	697	697	697	697	697	697	697	697	697	697	697
Total Fixed Costs		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	16,415	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL CASH OUTFLOW		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
NET CASH FLOW		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
RUPEE EXPENDITURE ON FIXED ASSETS	40,305															
D.C.F. RATE OF RETURN	43.8%															

3.3 Conclusions

1. The extension of the ethylene plant capacity to 60,000 MTPA for Phase II of the Fauji Foundation complex makes an additional 30,400 MTPA of ethylene available. It is recommended that this is used to produce:

23,600 MTPA polyethylene

10,000 MTPA dodecyl benzene

5,300 MTPA ethylene (to Valika)

These products are the most beneficial from the national and commercial points of view. A scheme including these products has been developed and a start-up date of 1976 is proposed.

2. The Rupee cost of saving foreign exchange is estimated at Rs. 4.38/ U.S. $, and is very favourable.

Ethylene sold to Valika is eventually transformed to polyethylene which saves further foreign exchange and improves this figure.

3. Taking ethylene as a feedstock from the extended cracker, the D.C.F. rate of return on new Rupee capital invested in the polyethylene and DDB plants has been calculated at 43.8% (before tax). This is a high rate of return on the Rupee capital; the figure would be much smaller if calculated on the total project cost because of the high proportion of foreign exchange cost in the units.

4. The substantial savings in foreign exchange and attractive D.C.F. rate of return indicate that a scheme of this type would still be viable at lower capacity. Alternatively the scheme could be brought into operation earlier than the assumed date of 1976. An earlier date may, however, be difficult to achieve for the second phase of this project. Fauji Foundation should attemtpt to bring their Phase II into effect as early as possible.

SECTION 4

E.P.I.D.C., EAST PAKISTAN PETROCHEMICAL COMPLEX

4.1 Analysis of Development Schemes for E.P.I.D.C., East Pakistan

No information was available to H & G regarding the further development of Phase I of the E.P.I.D.C. scheme at Ashuganj. Accordingly, the developments for Phase II were logically derived from the planned production for Phase I, taking into account the recommendations made in Section 3 for Fauji Foundation.

From these recommendations, and the list of petrochemical products given in Table II.2.1, it can be seen that the following products can be considered for natural gas based manufacture at Ashuganj:-

Dioctyl phthalate
Polyvinyl acetate
Vinyl acetate
Acetic acid
Urea/formaldehyde resins

As mentioned in Section 2.9, the production of dioctyl phthalate was recommended in our Interim Report as being economically profitable from both the national and commercial points of view. Section 3.2 discusses in detail the reason for excluding dioctyl phthalate from the production scheme for the Fauji Foundation in West Pakistan; since the 1980 market demand for this product is considerable (16,000 MTPA for Pakistan as a whole), it is the major product for consideration in East Pakistan. Further consideration shows that the foreign exchange element of the total production cost of dioctyl phthalate is considerably less than the current C & F price in Pakistan. This product is therefore included in the recommended development scheme.

Section 2.11 discussed the requirements for polyvinyl acetate in detail and Section 2.12 explained that it is generally accepted that the additional polymerisation facilities would be provided by extensions to existing plants, situated at the point of usage. There are four existing and sanctioned plants in Pakistan (three in Karachi and one in Dacca) and the individual plant capacities would still be relatively small even after extension. The manufacture of polyvinyl acetate in one polymerisation plant at Ashuganj is not, therefore, recommended for Phase II.

The manufacture of vinyl acetate, on the other hand, is recommended for Phase II. The total market demand for 1980 is shown in Table II.2.1 to be estimated at 8,420 MTPA for the whole of Pakistan and includes the supply of vinyl acetate to existing and sanctioned polymerisation units. The market demand is next to dioctyl phthalate in the list of products given earlier. Investigation showed that the foreign exchange element of the production cost, including both variable and fixed components, was less than the cheapest F.O.B. European source of supply (based on Dutch supply, early 1970 rates).

When freight and insurance to Pakistan, and landing costs are added, the comparison is more favourable. This product is, therefore, included in our recommended development scheme.

The concomitant production of acetic acid, the precursor for vinyl acetate, makes it possible to satisfy the relatively small market demand for acetic acid, as a product in its own right. This demand is estimated to be 1,650 MTPA for 1980 for the whole of Pakistan. The total consumption of acetic acid for all purposes is 8,180 MTPA in 1980, and the foreign exchange element of the total production cost for this scale of production was calculated. This was found to be lower than the cheapest F.O.B. European source of supply (based on Belgian supply, early 1970), excluding freight, insurance and landing costs for Pakistan. In addition, the containers for this chemical are expensive and its internal manufacture, rather than importation, is justified.

The Block Diagram Figure II.4.1 summarises these conclusions and depicts our recommended development for this site. Table II.4.1 summarises the end products additional to Phase I.

TABLE II.4.1

END-PRODUCTS ADDITIONAL TO PHASE I

	MTPA
Dioctyl Phthalate	16,000
Vinyl Acetate	8,420
Acetic Acid	1,650

The manufacture of the remaining products in the list given above viz urea/formaldehyde resins, is not recommended. Although the raw materials for these resins are manufactured at Ashuganj (methanol being the source of formaldehyde), existing plants already take these materials from relatively larg internal producers. This situation is considered to be analogous to that for the production of polyvinyl acetate, and it is considered that the additional market requirements will be provided by extensions to the existing and santioned plants, situated near the point of usage.

These resins vary considerably in their formulation, according to their end use, and many of them have a relatively short shelf-life. The additional 1980 market requirement of 7,200 MTPA for the whole of Pakistan is not very great, and it is our opinion that the present mode of manufacture by a number of small producers will continue.

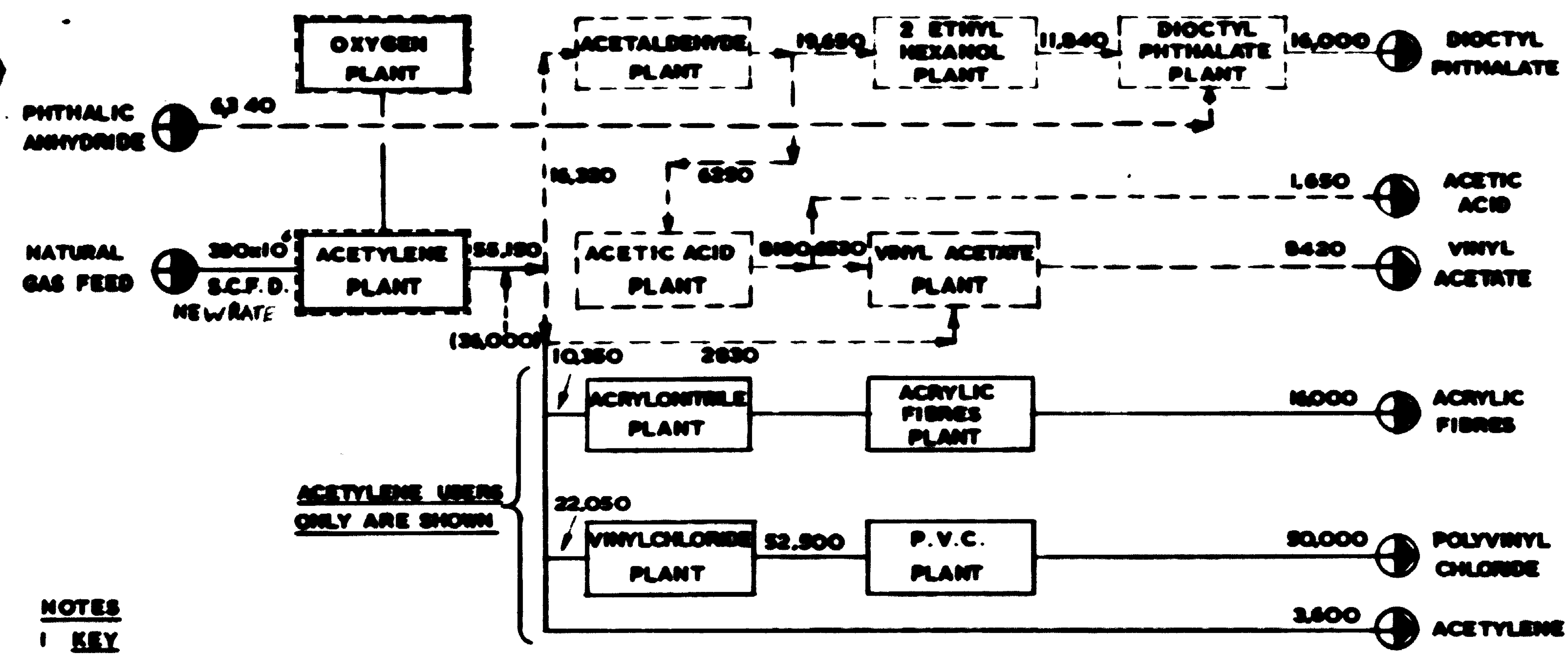
It seems appropriate at this point to amplify the reasons for H & G's recommendation of acetylene routes for the manufacture of dioctylphthalate, acetic acid and vinylacetate, contrary to the present world trend which is towards the use of ethylene for these chemicals.

The sanctioned Phase I of the EPIDC petrochemical complex, including 50,000 MTPA of PVC, is a starting point for this part (Volume II) of H & G's Study. However, H & G also recommended this route to PVC in our Interim Report, after examining a number of possible schemes. In effect, we found that the cost of such PVC production would be about the same <u>either</u> via acetylene <u>or</u> via ethylene supplied by a cracker of some 80,000 MTPA capacity, but the acetylene route (based on indigenous natural gas) would have a lower foreign exchange element of cost.

Further, comparison of the appropriate schemes in the Interim Report showed that, having decided to use the acetylene route to PVC it then becomes slightly cheaper to use the acetylene route also for dioctylphthalate, rather than either of the routes via ethylene or via propylene (see also Section 3.2 of this Volume).

Acetaldehyde is an intermediate for 2-ethylhexanol and hence dioctylphthalate, from acetylene. Having decided to use this route, the cheapest way to meet the requirement for acetic acid is via acetaldehyde.

Acetic acid makes up the greater part of the raw material cost of vinyl acetate, whether ethylene or acetylene is used as the source of the vinyl group. Although there is a world trend towards the use of ethylene for new vinyl acetate production, this route is only attractive for fairly large scale production of vinyl acetate, based on cheap ethylene from a really large cracker. In Pakistan the estimate requirement is for only 8,420 MTPA of vinyl acetate and the choice lies between acetylene from the EPIDC natural gas, based plant, or, the use of some of the ethylene from Fauji's naphtha cracker. In this situation, the acetylene route to vinyl acetate is clearly the cheaper.



NOTES

1 KEY

PHASE I PLANT

EXTENSION TO PHASE I PLANT

NEW PLANT

55,150 NEW ACETYLENE RATE

(36,000) PHASE I ACETYLENE RATE

2 ALL QUANTITIES ARE IN METRIC TONS PER YEAR UNLESS SPECIFIED OTHERWISE, AND REFER TO PURE COMPONENTS.

3 S.C.F.D. (STANDARD CUBIC FEET PER DAY) MEASURED AT 60°F, 30 IN. Hg, SAT.

FIG. II.4.1

UNIDO C1669

BLOCK DIAGRAM

ASHUGANJ

EAST PAKISTAN—PHASE 2

4.2 RECOMMENDED DEVELOPMENT AND FINANCIAL EVALUATION FOR ASHUGANJ SITE, EAST PAKISTAN

4.2.1 Introduction

The recommended development for Phase II of the Ashuganj project is shown in the Block Diagram II 4.1. Section 4.1 discusses the reasons underlying its composition.

The layout of this section follows that of Section 3.2, dealing first with the individual process units, then the development scheme as a whole. Subsequent sections deal with capital and operating costs. Finally, the section concludes with the Foreign Exchange Analysis and the year-by-year Cash Flows, including the D.C.F. rate of return on the investment.

4.2.2 Individual Process Units

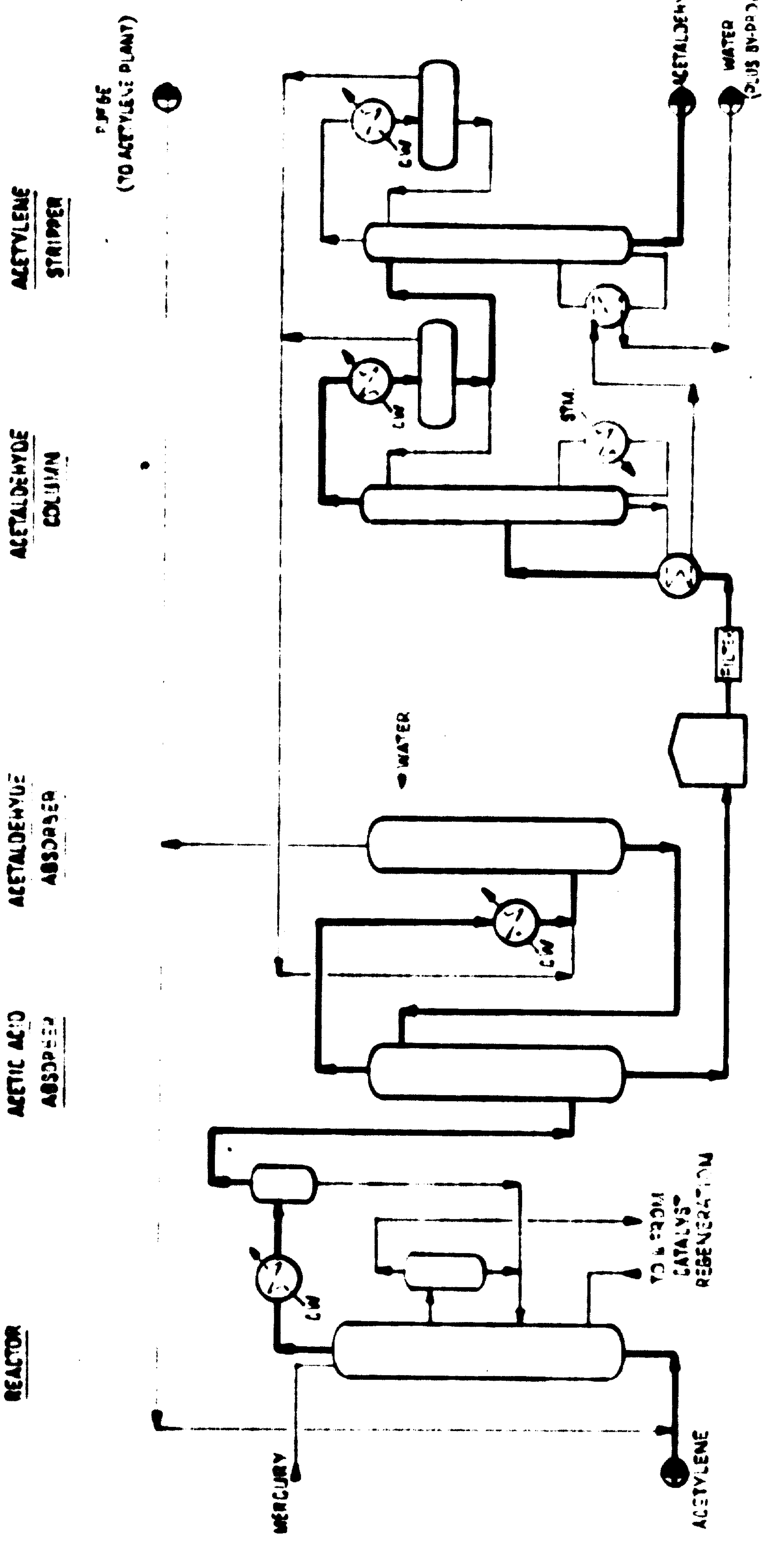
4.2.2.1 Acetaldehyde

Process Description and Flow Chart

A simplified flow chart for the production of Acetaldehyde is shown in Figure II 4.2.

Acetaldehyde is produced by direct hydration of acetylene, catalysed by mercuric ions. Acetylene is injected into mercuric sulphate solution, acidified by sulphuric acid, contained in the reactor. Acetaldehyde vapours mixed with steam, acetic acid and unreacted acetylene from the reactor are cooled and passed to an absorber where the acetic acid is absorbed by the aqueous acetaldehyde solution from the bottom of the next absorber. The gas from the acetic acid absorber is further cooled before passing to the acetaldehyde absorber mentioned above, and the unreacted acetylene, together with some inerts, is recycled back to the reactor, while a small portion is continuously purged to maintain the inerts level. This purge, still containing some acetylene, is returned to acetylene plant for acetylene recovery.

The aqueous acetaldehyde solution from the absorption system flows through a mercury settling tank, and after filtration is preheated before entering the first distillation tower from which water and byproducts are removed as a bottom stream. This stream, after heat recovery, is sent to drain. The distilled acetaldehyde is finally purified in the acetylene stripper, leaving as a bottom stream of 99.8% purity. The uncondensed overhead gases from both towers contain acetaldehyde and are recycled to the bottom of the acetaldehyde absorber.



UNIDO C-1669
FLOW CHART-ACETALDEHYDE PLANT
EPIDC-ASHUGANJ-EAST PAKISTAN-PHASE 2

FIG II.4.2

The mercuric sulphate catalyst solution is continuously regenerated by hot treatment with nitric acid in the presence of an air stream blown into the solution. Mercury-containing muds from this catalyst regeneration plant are sent to mercury retorts for the recovery of metallic mercury. This part of the process is not included in the flow chart.

Source of Know-how and Licence

The process as described above is available from Montecatini Edison Spa. A similar process is available from Lonza Ltd.

Operating Data

Table II 4.2 below lists the major consumptions of raw materials, catalysts/chemicals, utilities and direct labour requirements.

TABLE II 4.2
OPERATING DATA - ACETALDEHYDE (BASIS 1 MT ACETALDEHYDE)

Acetylene (as 100%) MT	0.63
Catalyst/Chemicals $	4.8
Power, KWH	300
Steam (low pressure) MT	2.2
Cooling Water M^3	90
Labour Requirements	18

Area of Battery Limits

The approximate area of the battery limits plant is 1250 m^2. This is based on a layout of the plant items, including those omitted from the flow chart.

4.2.2.2 2-Ethyl Hexanol

Process Description and Flow Chart

A simplified flow chart for the production of 2-ethyl hexanol is shown in figure II 4.3.

The first part of the process may be considered as the preparation of crotonaldehyde. Acetaldehyde from the acetaldehyde plant, together with recycle from the process, is mixed with dilute caustic soda catalyst in the reactor mixer. The condensation reaction is arrested by the introduction of acetic acid near the base of the column as the reaction mixture flows downwards and thence to the reactor

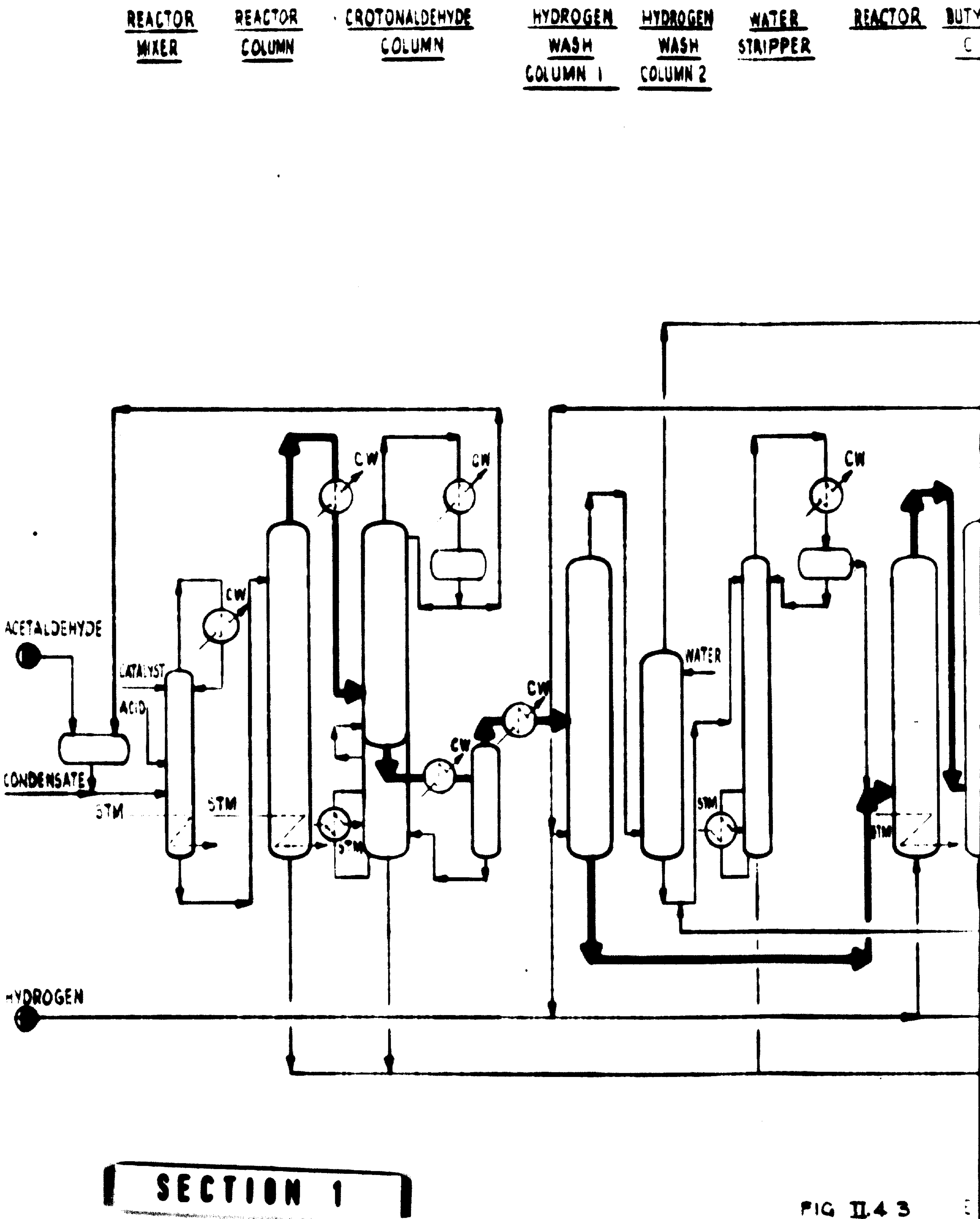
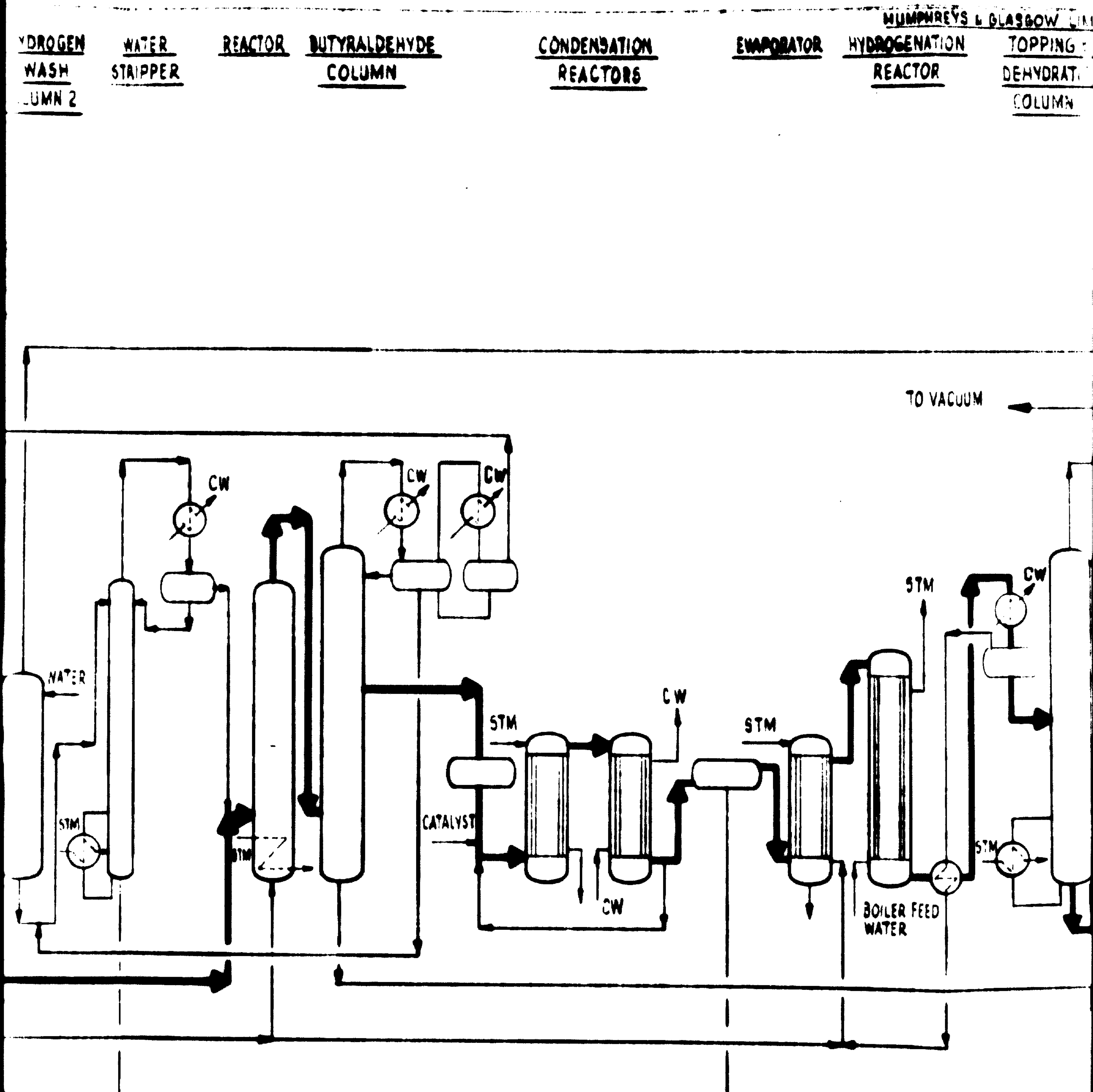
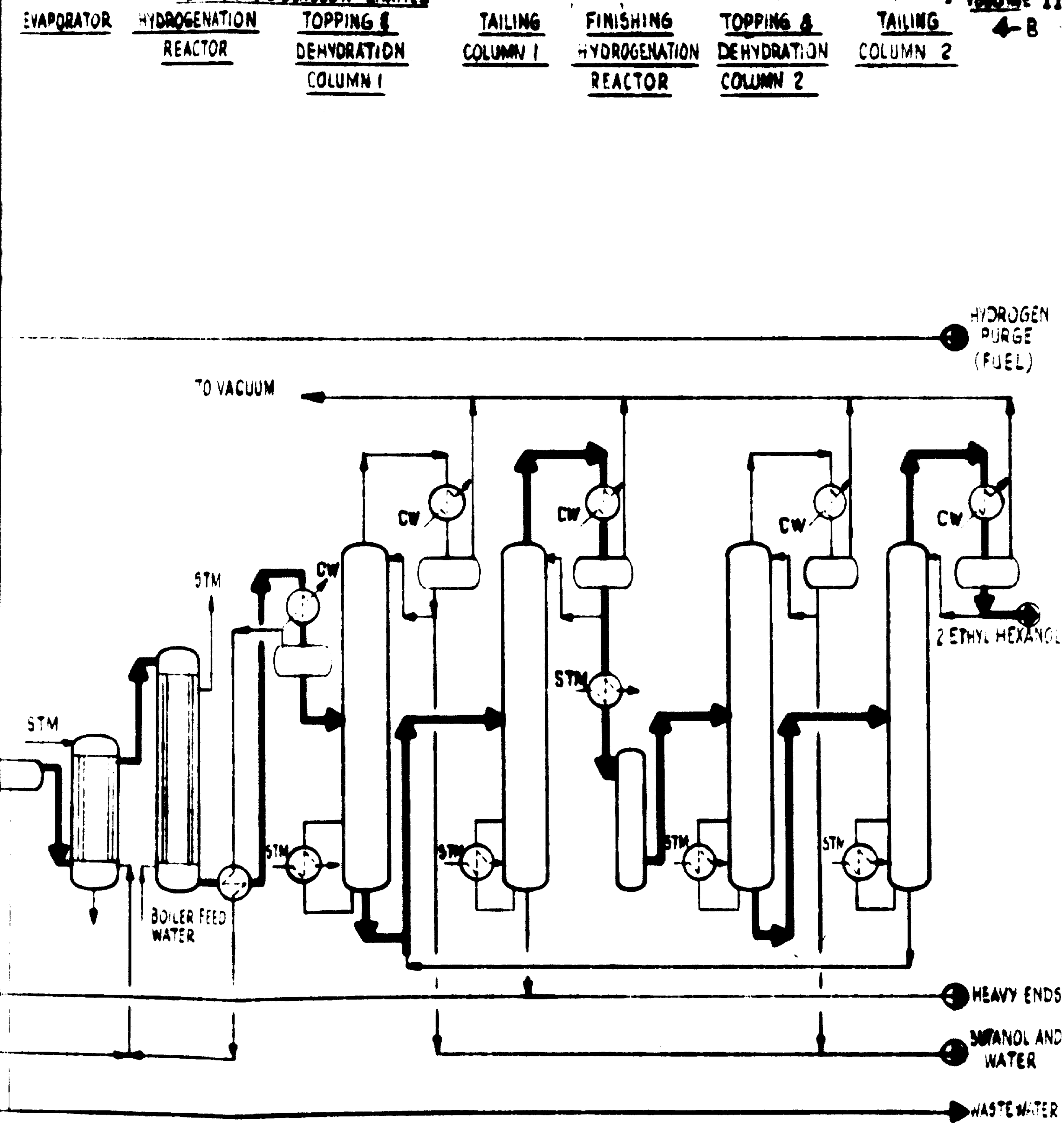

REACTOR MIXER
REACTOR COLUMN
CROTONALDEHYDE COLUMN
HYDROGEN WASH COLUMN 1
HYDROGEN WASH COLUMN 2
WATER STRIPPER
REACTOR
ACETALDEHYDE
CATALYST
ACID
CONDENSATE
STM
CW
WATER
HYDROGEN
SECTION 1

FIG II.4 3



SECTION 2

U.N.I.D.O. C-1669
FLOW CHART - 2 ETHYL HEXANOL
FIG II.4.3 E.P.I.D.C. - ASHUGANJ - EAST PAKISTAN - PHASE 2


EVAPORATOR
HYDROGENATION REACTOR
TOPPING & DEHYDRATION COLUMN 1
TAILING COLUMN 1
FINISHING HYDROGENATION REACTOR
TOPPING & DEHYDRATION COLUMN 2
TAILING COLUMN 2
HYDROGEN PURGE (FUEL)
TO VACUUM
CW
STM
BOILER FEED WATER
2 ETHYL HEXANOL
HEAVY ENDS
BUTANOL AND WATER
WASTE WATER

SECTION 3

column. Here the aldol is converted into crotonaldehyde under the influence of pressure and temperature. The overhead vapours from this column are cooled and pass to a distillation column. Here acetaldehyde is recovered overhead and recycled, while from the base a mixture of water and crotonaldehyde is withdrawn and separated by cooling and decantation. Crotonaldehyde is recovered from the water rich phase in a small stripping column at the base of the crotonaldehyde column.

The second part of the process involves the preparation of butyraldehyde. Crotonaldehyde from the previous part of the process is first used to wash the hydrogen purge stream. It then passes to the reactor into which is blown a large excess of hydrogen and which is heated by steam coils in the base. Overhead reaction products pass to the butyraldehyde column (which has no reboiler). Butyraldehyde is withdrawn from this column as a side stream, while heavy ends are withdrawn from the base. The overhead condensate is separated into two phases, the aqueous phase being next to a water stripper. The overhead hydrogen is recycled after further cooling. The hydrogen purge, required to maintain the inerts level, is washed with the feed crotonaldehyde and then with water which is stripped of organics in the water stripper. The recovered organics pass to the reactor.

The third part of the process is the preparation of 2-Ethyl Hexanol. Butyraldehyde from the previous stage is introduced into a circulating reaction system with an alkaline catalyst. The conversion to the hexanal is complete, and after decantation from the water formed, it is vapourised, mixed with hydrogen and passes through catalyst packed tubes of the hydrogenation reactor. The heat of reaction is used to generate steam in the shell side of the reactor. The reaction mixture is cooled, and the separated hydrogen reheated and recycled to the hydrogenation stage. The crude Ethyl Hexanol passes to two distillation columns, which remove the secondary products, and then to a finishing hydrogenation reactor. The stream passes through two further distillation columns which remove the last traces of secondary products. The Ethyl Hexanol is suitable for the production of plasticisers. The concurrent production of butanol cannot be avoided and is at least 70 Kg per ton of Ethyl Hexanol.

Source of Know-how and Licence

The process as described above is available from Melle-Bezons S.A.

Operating Data

This is given below in Table II 4.3.

TABLE II 4.3
OPERATING DATA - 2 ETHYL HEXANOL (BASIS 1MT 2 ETHYL HEXANOL)

Acetaldehyde (100%) MT	1.66
Hydrogen (100%) NM^3/Kg	830/74.5
Catalysts/Chemicals $	16.8
Power, KWH	406
Steam (high pressure) MT	0.14
Steam (medium pressure) MT	11.15
Steam (low pressure) MT	2.96 (CREDIT)
Cooling Water M^3	300
Labour Requirements	30

Area of Battery Limits

The approximate area of the battery limits plant is 1450 m^2. This is based on a layout based on the flow chart, but including for those plant items not included in the chart.

4.2.2.3 Dioctyl Phthalate

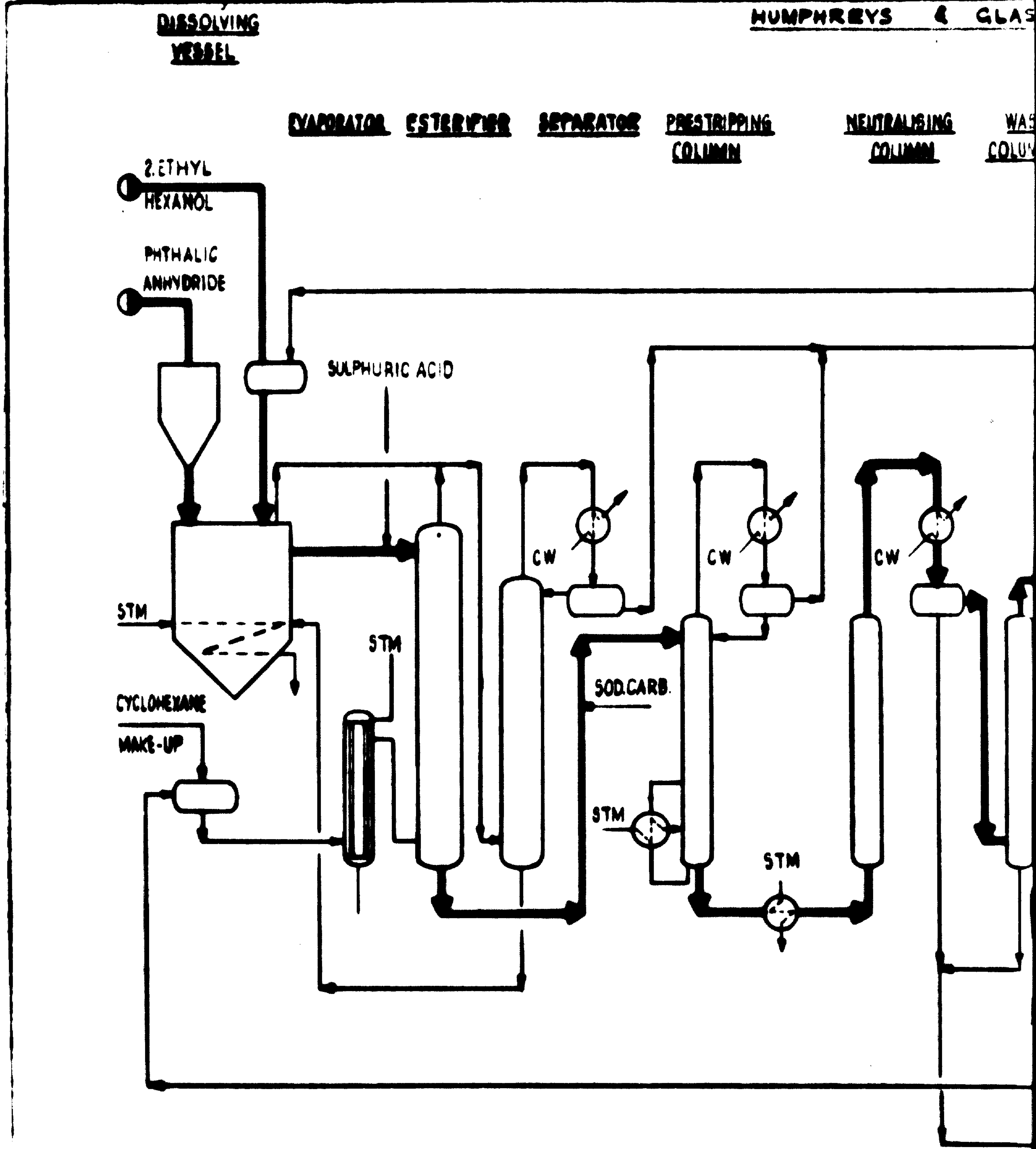
Process Description and Flow Chart

A simplified flow chart for the production of Dioctyl Phthalate is shown in figure II 4.4.

Phthalic anhydride is dissolved in 2 ethyl hexanol from the ethyl hexanol plant and flows, together with sulphuric acid catalyst, to the top of the esterifier. Cyclohexane is used as a water entrainer and is vapourised and introduced into the bottom of the esterifier.

The vapour from the top of the esterifier, together with that from the dissolving vessel, pass to a separator. The overheads from this separator are condensed and separated into two phases. The alcohol rich phase is returned as reflux to the separator, and after contacting the upflowing vapours is recycled to the dissolving tank. The cyclohexane and water phase still containing some alcohol, pass to the alcohol and cyclohexane recovery columns.

The crude ester leaves the bottom of the esterifier and enters a steam heated prestripping column, from the top of which the bulk of the cyclohexane is removed. The cyclohexane



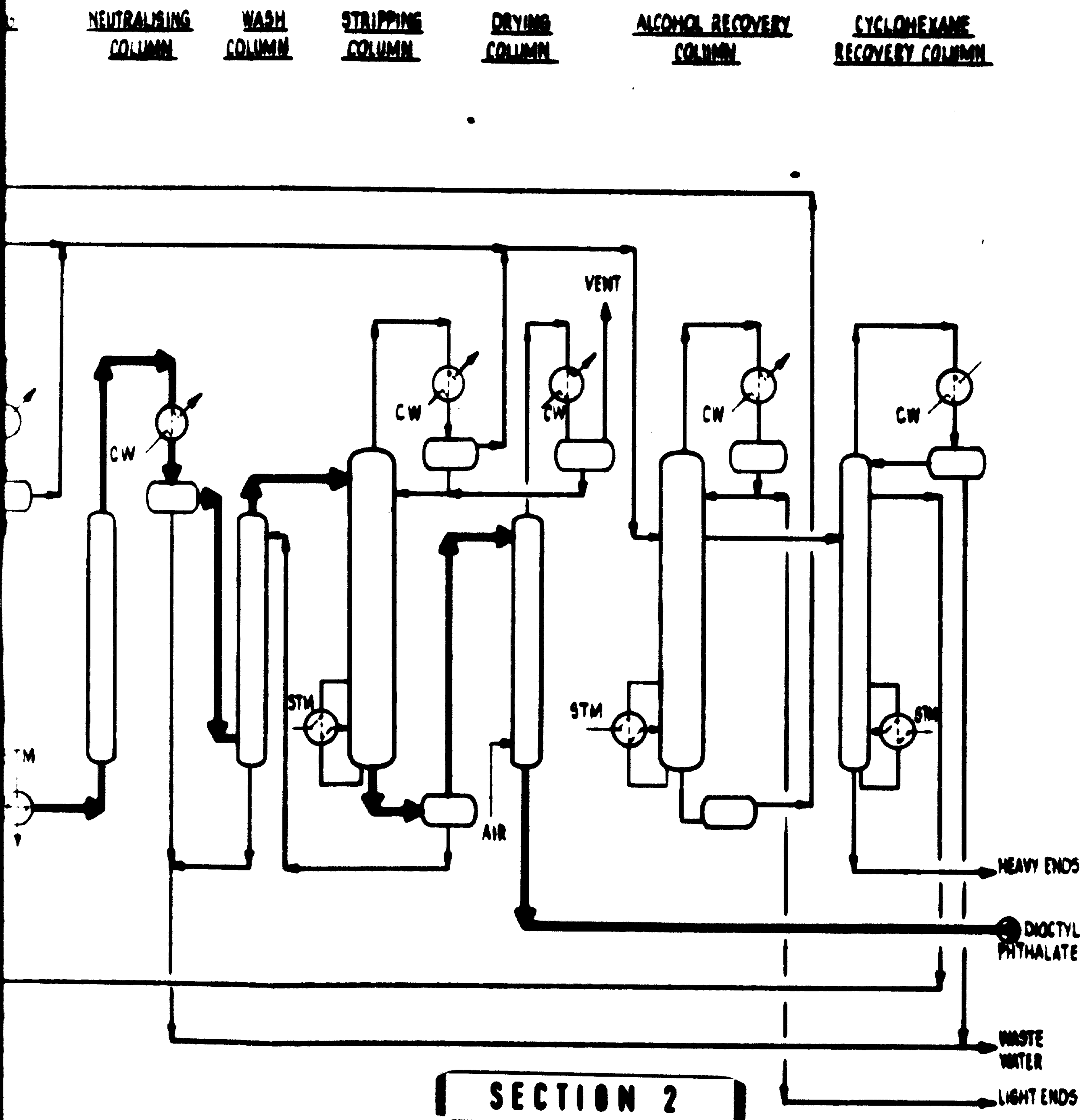
SECTION 1

U.N.I.D.O. - C - 1669

FLOW CHART - DIOCTYL PHTHALAT

FIG. II.4.4

E.P.I.D.C. - ASHUGANJ - EAST PAKISTAN -



SECTION 2

U.N.I.D.O. - C-1669
CHART - DIOCTYL PHTHALATE
SHUGANJ - EAST PAKISTAN - PHASE 2

phase which separates after condensation is passed to the alcohol/cyclohexane recovery system. The ester, after further heating, next passes to a neutralising column where the added sodium carbonate completely neutralises the acid catalyst and ensures the thermal stability of the dioctyl phthalate. The stream is then cooled, and the water which separates flows to drain. The ester stream next passes to column in which water, separated in a downstream column, washes out the neutralising sodium carbonate and then also flows to drain. The alcohol is then steam stripped from the ester, and is concentrated in the alcohol rich phase obtained after condensation of the overheads and decantation. This also passes to the alcohol/cyclohexane recovery system. The ester and water, leaving the bottom of the stripper are separated into two phases, the water rich phase being used to wash the crude ester in the preceding wash column, and the ester being passed to a column where it is finally dried with air before passing to storage. The air from the top of this column is cooled before venting to recover the ester.

The alcohol recovery column recycles ethyl alcohol from the bottom while light secondary products are taken overhead. A sidestream from this column takes the cyclohexane to the cyclohexane column: heavy ends are taken from the bottom while water is separated overhead. Cyclohexane is removed as a sidestream and recycled to the start of the process. The feature of sidestream removal arises because of the presence of azeotropes and the fact that the maximum cyclohexane concentration occurs in the liquid phase from the upper trays.

Source of Know-how and Licence

As for 2-ethyl hexanol, the process technology is available from Melle-Bezons S.A. Comparable technology is available from B.P. Chemicals Ltd.

Operating Data

The essential data is given below.

TABLE II 4.4
OPERATING DATA - DIOCTYL PHTHALATE (BASIS 1MT DIOCTYL PHTHALATE)

2 Ethyl Hexanol (as 100%) MT	0.73
Phthalic Anhydride (as 100%) MT	0.385
Catalysts/Chemicals $	2.4
Power, KWH	25
Steam (medium pressure) MT	1.9
Cooling Water, M^3	66
Process Water, M^3	0.4
Labour Requirements	18

Area of Battery Limits

The approximate area of the battery limits plant is 760 m^3. This was obtained by a layout based on the flow chart, but including those items omitted from the chart.

4.2.2.4 Acetic Acid

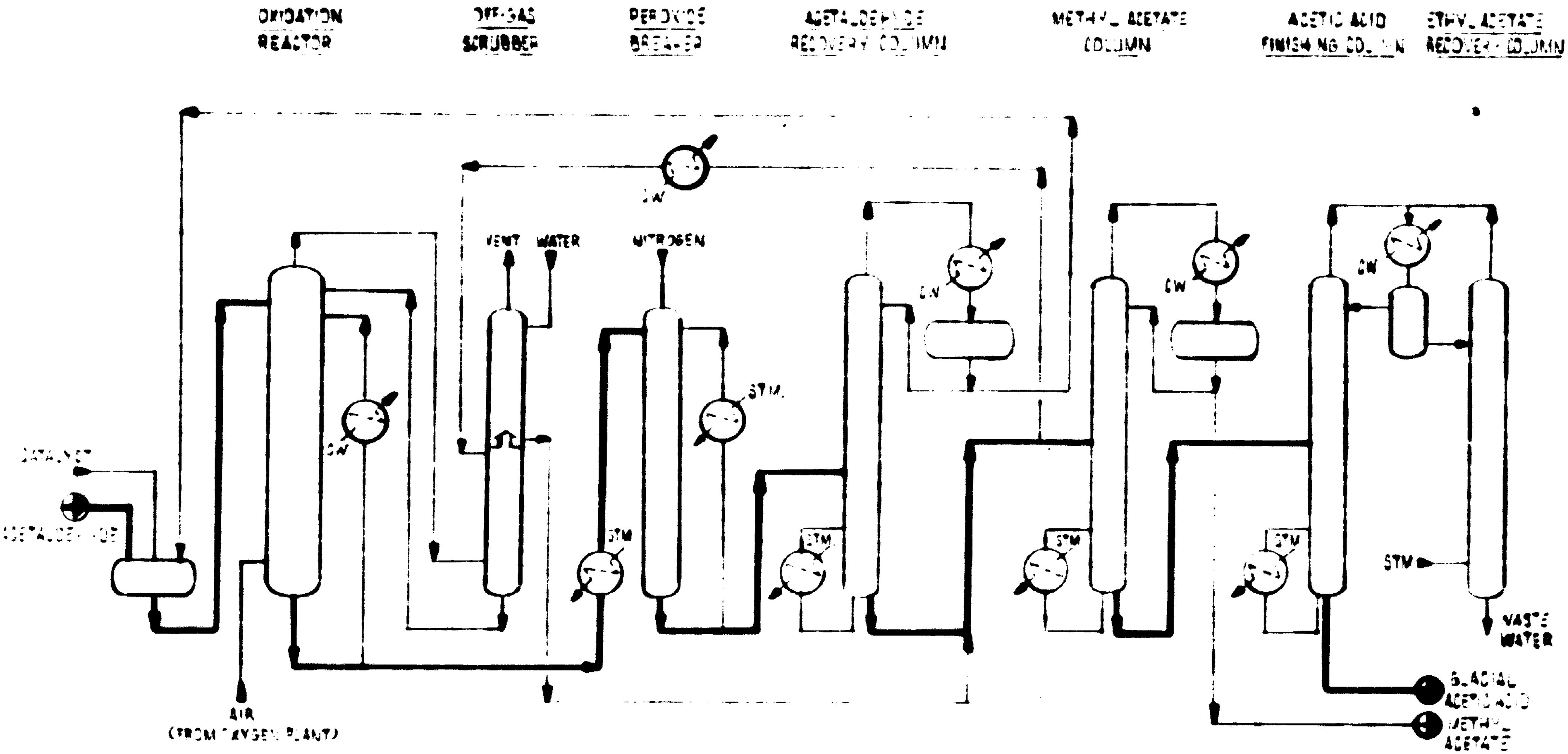
Process Description and Flow Chart

A simplified flow chart for the production of the Acetic Acid is shown in figure II 4.5.

Acetic acid is produced by air oxidation of acetaldehyde, in the presence of manganese acetate catalyst. Acetaldehyde from the acetaldehyde plant, and recycled acetaldehyde, is charged to the oxidation reactor into which passes air from the Air Separation Plant after water washing in the direct contact coolers. The reaction temperature is maintained by circulating the mixture through an external cooler.

The crude acetic acid from bottom of the reactor passes to the peroxide breaker, where the explosive peracetic acid concentration is reduced by long residence at high temperatures. The reactor off-gas is scrubbed first with crude acetic acid to recover acetaldehyde and then with water to recover acetic acid. The crude acetic acid wash stream is returned to the reactor, and the water wash stream passes to the methyl acetate column.

From the peroxide breaker, crude acetic acid is fed to the acetaldehyde column. Unreacted acetaldehyde is recovered overhead and recycled to the acetaldehyde surge drum. The bottom stream from this column is cooled, part being used to wash the off-gas as described above, and the remainder is charged to the methyl acetate column, from which a net



FLOW CHART - ACETIC ACID

FIG. II.4.5

methyl acetate stream is taken overhead. The bottom stream from the column is charged to the acetic acid finishing column, from the bottom of which glacial acetic acid of 99.8% purity is withdrawn (actually withdrawn from above bottom plate as a vapour and the bottom liquid stream, containing manganese acetate catalyst is recycled to the reactor. This has not been shown in the flow chart).

The overheads from the finishing column is an azeatropic mixture of ethyl acetate and water. Condensation and decantation separate two layers: the ethylacetate rich phase is used as reflux, while the aqueous phase is fed to the ethyl acetate column. The overhead azeotrope from this column is returned to the condensation/decantation stage described above, while the bottom stream from this tower is waste water, and is sent to drain.

Source of Know-how and Licence

This process is a well known chemical process which has been operated by many major companies. Melle-Bezons S.A., British Petroleum and Hoescht are suggested as potential licensors.

Operating Data

The essential data is given below.

TABLE II 4.5
OPERATING DATA - ACETIC ACID (BASIS 1MT ACETIC ACID)

Acetaldehyde (as 100%) MT	0.77
Power, KWH	260
Steam (low pressure) MT	3.58
Cooling Water M^3	300
Process Water M^3	13
Nitrogen NM^3	15
Labour Requirements	18

(Note: Catalysts and chemicals used in the process are about equal in valve to the methyl acetate by-product.)

Area of Battery Limits

The approximate area of the battery limits plant is 480 m^2. This was obtained by a layout based on the flow chart, including those items omitted from the chart.

4.2.2.5 Vinyl Acetate

Process Description and Flow Chart

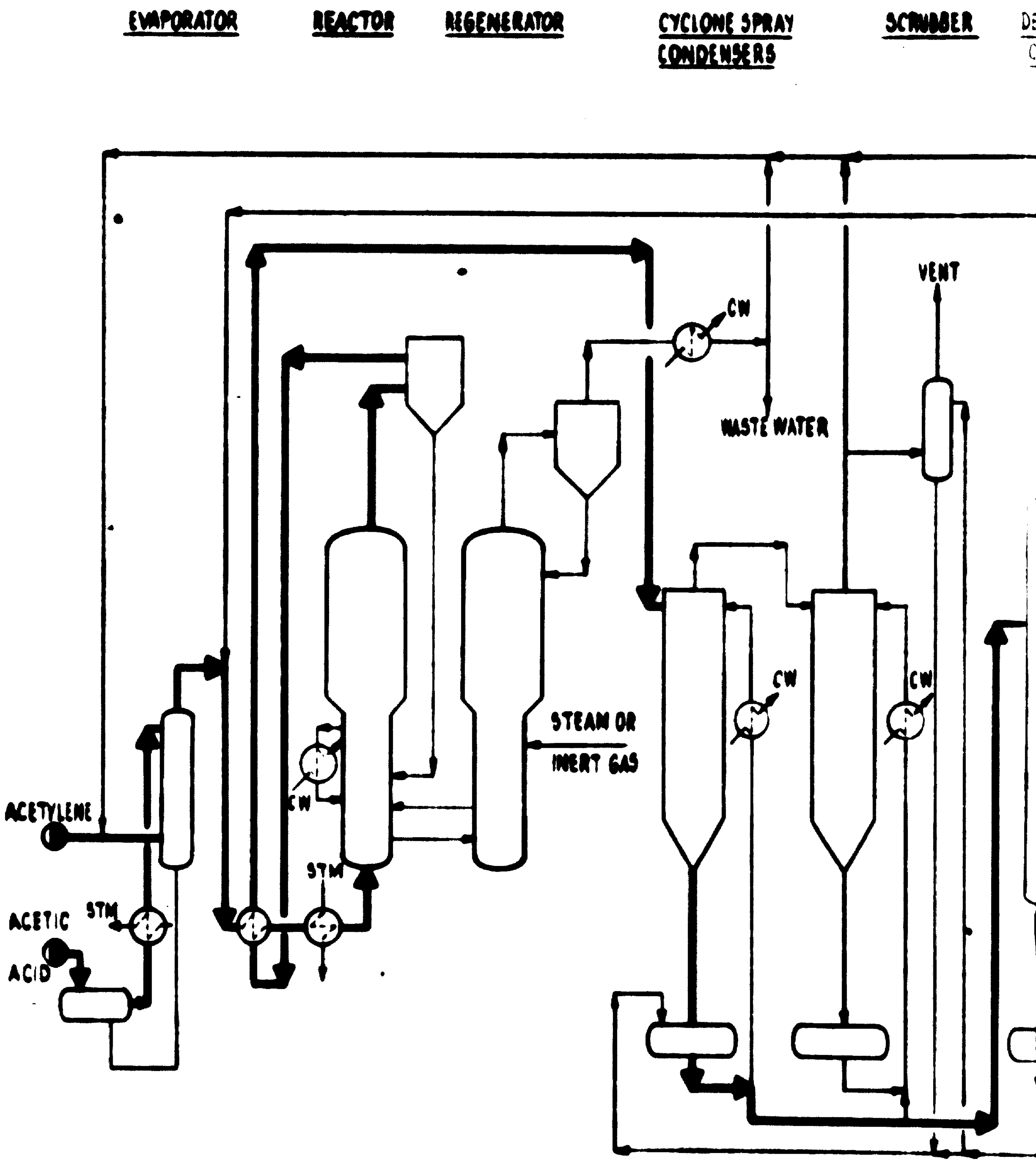
A simplified flow chart is given in figure II 4.6.

Acetic acid from the acetic acid plant is vapourised and mixed with acetylene, some of which is recycled from the process. Acetic acid vapour recycled from the process joins the feed stream after the evaporator. After preheating the acetic acid and acetylene vapours pass to a fluidised-bed type reactor, which is cooled both internally and externally by (for example) Mobiltherm Light. A portion of catalyst is taken continuously from the bottom of the reactor to a regenerator (via a storage vessel which is not shown). Here it is subjected to blowing with superheated steam, hot inert gas and zinc acetate and active carbon are replenished. The regenerated catalyst is returned continuously to the reactor via another storage vessel (not shown in flow chart). Vent gas from the regenerator is cooled before joining the recycle acetylene stream. The reaction products pass through a bag filter to remove catalyst dust, are cooled and then contacted with cold crude vinyl acetate in two cyclonic spray towers in series. In these vinyl acetate and acetic acid are condensed to form crude vinyl acetate. Non-condensible gases,(mainly acetylene) are recycled, with a small portion being vented after scrubbing with crude acetic acid to control the level of inert gases. The scrubbing stream passes to the condensing system.

Crude vinyl acetate is degassed, and the acetaldeyde condensed from the overheads. This contains some vinyl acetate which is separated in the vinyl acetate column and recycled to the degasser column. Acetaldehyde is returned to the acetaldehyde plant. Non-condensibles from the two columns, consisting mainly of acetylene, are recycled.

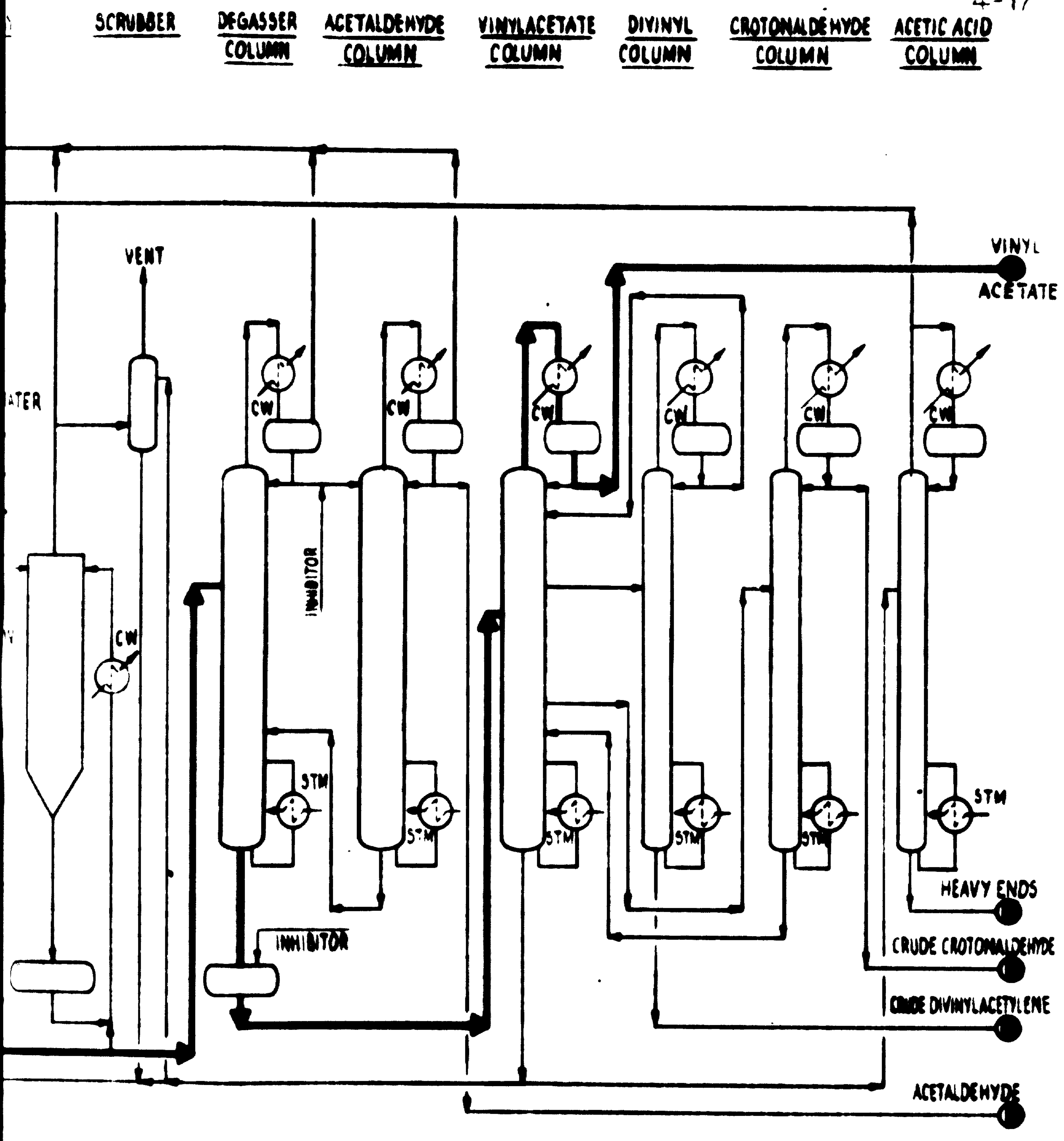
The vinyl acetate stream from the bottom of the degasser passes to a column from pure vinyl acetate is taken overhead, and acetic acid from the bottom. Two side-streams are drawn from this tower. The one from the top section contains mainly divinylacetylene, and the one from the bottom section contains crotonaldehyde. These are distilled separately in two smaller columns. They may be treated separately in a batch still to further recover vinyl acetate and acetic acid.

Crude acetic acid from the vinyl acetate column contains appreciable amounts of heavy impurities. These are removed by passing part of the crude acetic acid to the acetic acid column. The pure acetic acid is recycled to the beginning of the process. Polymerisation inhibitor is added to the



SECTION 1

UNIDO C-1669
FLOW CHART - VINYL ACETA
FIG. II. 4 6 - E.P.I.D.C. - ASHUGANJ - EAST PAKIST



UNIDO C-1669
FLOW CHART - VINYL ACETATE
ASHUGANJ - EAST PAKISTAN - PHASE 2

SECTION 2

degassing and vinyl acetate columns

Source of Know-how and Licence

This process is well established technology and is expected to be readily available. British Petroleum, I.C.I. and Hoechst are proposed as possible licensors.

Operating Data

The essential data is given below:-

TABLE II 4.6

OPERATING DATA-VINYL ACETATE (BASIS 1 MT VINYL ACETATE)

Acetylene (as 100%) MT	0.32
Acetic Acid (as 100%) MT	0.72
Catalyst/Chemicals $	1.8
Power kWh	110
Steam (medium pressure) MT	2.28
Cooling Water M^3	120
Inert Gas NM^3	150
Labour Requirements	18

Area of Battery Limits

The approximate area of the battery limits plant is 640 M^2. This was obtained by a layout of the plant items.

4.2.2.6 Acetylene

The extension of the acetylene plant from 36,000 MTPA to 55,150 MTPA (in 300 days per year), is analagous to the extens on of the ethylene plant at Fauji. It is extremely likely that the make-gas treatment section of the plant will be designed for the larger capacity required by Phase II, and that add tional burner units will be added to the existing plant at the appropriate time.

In view of this fact, the process description, flow chart, licensor information and consideration of the battery limits area, have been omitted. Operating data is required, however, for evaluating the variable and average costs of production for use in later sections. This data is given below :-

TABLE II 4.7

OPERATING DATA-ACETYLENE (BASIS 1 MT ACETYLENE)

Natural Gas, scf.	214,000
Catalysts/Chemicals $	1.0
Byproduct Off-gas (credit) K cal x 10^6	27.8
Power kWh	3290
Steam (net) MT	3.9
Cooling Water M^3	870
Process Water (net) M^3	1.3
Increase in labour requirements (36,000 to 55,000 MTPA)	5

4 2.3 Complete Development Scheme

4.2.3.1 Utilities and Offsites Installation

With regard to these installations for the E.P.I.D.C. scheme at Ashuganj, the same arguments already discussed in Section 3.2.3.1 of this report apply.

It was therefore considered that the most realistic costs of the various utilities required for Phase II would be those based on a utilities installation of a similar size to that required for the complex after the addition of Phase II. Based on previous work for the Interim Report, such utilities costs have been evaluated for the Ashuganj site; these are derived from unit capital costs and operating data in a similar way to the derivation of petrochemica' production costs. They are based on a fully integrated utilities scheme, and are given in Section 4.2.5

4.2.3.2 Utilities Consumption

The following table summarises the main utilities consumption required by the recommended development for Phase II :-

TABLE II 4.8

SUMMARY OF TOTAL UTILITIES CONSUMPTION FOR PHASE II

Power kw	12,000
Steam MT/hr	47.2
Cooling Water M^3/hr	4,140
Condensate/Demin. Water (for process) M^3/hr	21.1
Inert Gas (Nitrogen from A.S.U.) NM^3/hr	212

4.2.3.3 Management, Personnel and Labour

The direct process labour requirements for Acetaldehyde, Ethyl Hexanol, Dioctyl Phthalate, Acetic Acid and Vinyl Acetate Plants are 107 men. A further 5 men are allowed for the expansion of the Acetylene Plant, and this number is considered adequate to cover any additional requirements of a possible extension to the Utilities Installation.

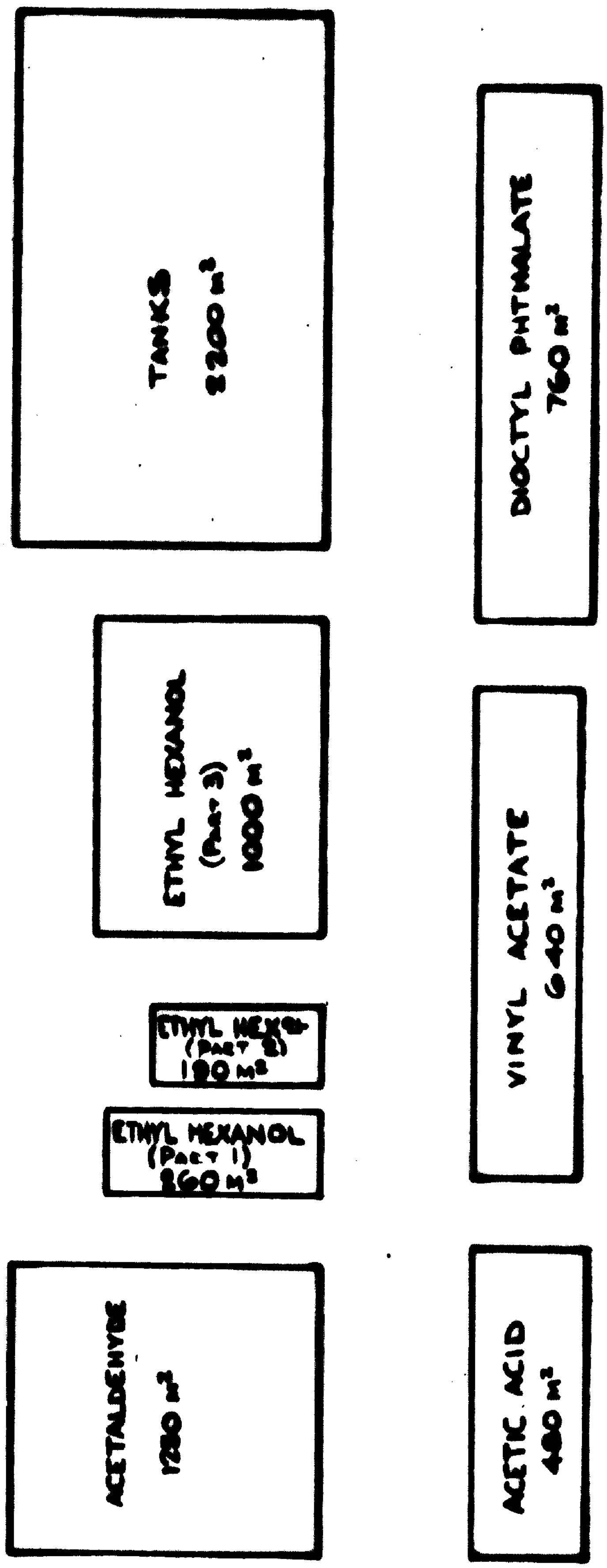
Plant Managers and partial supervision at higher levels are not included. Their cost is covered by the use of a weighted rate of 9,000 Rs/year for each man, as explained in Section 3.2.3.3 of this report for the Fauji Foundation. Each of new plants above would require a Plant Manager, i.e., 5 in all.

4.2.3.4 Plot Plan of the Recommended Development

Figure II 4.7 gives the plot areas of the process plants a possible arrangement. A tank farm of approximately 2,200 M^2 area for the storage of liquid products is included in the plan.

The disposal of effluents has been viewed in a similar way to the Fauji Foundation scheme (see Section 3.2.3.4) and it is assumed that either the Phase I Effluent Disposal System will be capable of handling the additional load, or will be extended as necessary.

U.N.I.D.O - CK660
E.P.I.D.C - ASHUGANJ - EAST PAKISTAN
FIG. II 4.7



PLOT AREAS OF PROCESS PLANTS
FOR PETROCHEMICAL COMPLEX
PHASE 2 EXPANSION

4.2.3.5 Use of Acetylene Off-gas

It is possible to make use of all the off-gas from the acetylene plant as fuel within the EPIDC petrochemical complex. This is confirmed by the following estimates, based on the complex being self-supporting in steam and electrical power generation in normal operation.

It can be assumed for Phase I that steam and electricity consumption in normal operation will be about 85% of the design capacities specified in the APC Study document (reference 45A), hence:-

Phase I	HP Steam	51 MT/hr
	LP Steam	161 MT/hr
	Electricity	51,000 kw

By adding to these figures the Phase II consumption rates as already stated in Table II 4.2 above, we obtain, the following consumption figures for the completed complex:-

Phase I & Phase II	HP Steam	51 MT/hr
	LP Steam	208 MT/hr
	Electricity	63,000 kw

The total process steam requirement of 259 MT/hr, all raised initially at high pressure, will require approximately 200×10^6 kcal/hr of fuel energy, while approximately 27,000 kw would be obtained by passing-out the LP Steam requirement of 208 MT/hr from turbo-alternator sets. A further quantity of steam would be raised, and eventually condensed at subatmospheric pressure, to generate the balance of electrical power required, i.e. 36,000 kw. The additional steam would require about 100×10^6 kcal/hr of fuel energy. Hence, the total fuel required for steam and electricity generation is equivalent to about 300×10^6 kcal/hr. Additional fuel will be required to fire the steam reforming furnaces making synthesis gases for the ammonia and methanol plants, only a small part of which is satisfied by purge gases from the synthesis plants.

The off-gas rate (based on 55,000 MTPA of acetylene in 300 days/year operation and the operating data of Table II 4.7 above) is equivalent to 217×10^6 kcal/hr. Hence all the off-gas can be used as fuel.

APC proposed that the off-gas be used as feedstock for the ammonia/urea and methanol process plants. We estimate that there would be sufficient off-gas available to satisfy the process feedstock requirement of the methanol plant, and a large part of the feedstock requirement for the ammonia/urea plant as well.

The advantage gained by such use of the off-gas is the partial or complete elimination of the natural gas reforming step in the ammonia and methanol synthesis processes. There are a number of possible ways in which the normal synthesis processes could be modified and integrated with the acetylene/oxygen plants so that such a utilisation of the off-gas is achieved. There are,however, two major - and in our view over-riding - disadvantages in such an integration. The first is the fact that, while natural gas is available at a pressure in excess of 1200 psi the acetylene plant off-gas is only marginally above atmospheric pressure. Thus the cost of gas compression in capital and operating costs is higher if acetylene off-gas is used for the synthesis processes. Secondly, it seems very unwise to link such large complexes in this way. The ammonia and methanol plants would both suffer the downtime of the acetylene complex as well as downtime resulting from their own internal failures. This could easily mean 10% additional downtime equivalent to the design requirement of 10% higher daily capacity for the complete urea and methanol sections of the plant. Similarly off-gas from the acetylene plant would be wasted when the ammonia or methanol plants were out of operation. We consider, however, that it would be possible to design the two synthesis plants to use the acetylene off-gas as fuel if this is shown to be attractive.

4.2.4 Capital Costs

4.2.4.1 Acetaldehyde Plant

TABLE II 4.9

CAPITAL COST OF ACETALDEHYDE PLANT

	Rupees x 10^6 Foreign Exchange	Local Currency
1. Equipment, Spares, Procurement, Freight and Insurance, Tools and Plant, Insurance.	12.94	-
2. Engineering, Expenses and Overheads, Licence, Site Supervision and Commissioning.	6.20	-
3. Construction Labour, Civil work, Local tools and plant, Local insurance, Inland Freight and Dock clearance, Local Spares, Local Expenses.	-	4.98
4. Duty on Equipment and Spares	-	3.13
TOTALS:	19.14	8.11
Start-up charges	1.36	1.36
Interest on Foreign Exchange during construction	2.11	-
	22.61	9.47
TOTAL COST	32.08	

The above capital cost estimate covers all fixtures which are normally within the plant battery limit, and all expenses required to bring the plant into operation.

Included:- Raw materials and products storage and handling sufficienct for normal operation. Civil work, control rooms, minor office buildings and workshops, fire equipment, telephones etc. within the plant boundary, as necessary.

Excluded:- Major offsite storage facilities, Civil work, piping, and services distribution up to the plant boundary, site development, and land.

Interest during construction on the local currency element is omitted from this estimate because details of the method of finance are not known.

4.2.4.2 2-Ethyl Hexanol Plant

TABLE II 4.10

CAPITAL COST OF 2-ETHYL HEXANOL PLANT

Rupees x 10^6

	Foreign Exchange	Local Currency
1. Equipment, Spares, Procurement, Freight and Insurance, Tools and Plant, Insurance.	6.51	-
2. Engineering, Expenses and Overheads, Licence, Site Supervision and Commissioning.	4.64	-
3. Construction Labour, Civil work, Local tools and plant, Local Insurance, Inland Frieght and Dock clearance, Local Spares, Local Expenses.	-	2.33
4. Duty on Equipment and Spares	-	1.54
TOTALS :	11.15	3.87
Start-up charges	0.75	0.75
Interest on Foreign Exchange during construction	1.23	-
	13.13	4.62

For definition of the scope of the above capital cost, see footnote to Table II 4.9.

4.2.4.3 Dioctyl Phthalate Plant

TABLE II 4.11

CAPITAL COST OF DIOCTYL PHTHALATE PLANT

		Rupees x 10^6	
		Foreign Exchange	Local Currency
1.	Equipment, Spares, Procurement, Frieght and Insurance, Tools and Plant, Insurance.	6.08	-
2.	Engineering, Expenses and Overheads, Licence, Site Supervision and Commissioning.	2.50	-
3.	Construction Labour, Civil work, Local Tools and Plant, Local insurance, Inland Freight and Dock Clearance, Local Spares, Local Expenses.	-	2.31
4.	Duty on Equipment and Spares	-	1.47
	TOTALS :	8.58	3.78
	Start-up charges	0.62	0.62
	Interest on Foreign Exchange during construction	0.94	-
		10.14	4.40
	TOTAL COST	14.54	
	ESTIMATED WORKING CAPITAL (max.)	7.47	

For definition of the scope of the above capital cost, see footnote to Table II 4.9.

4.2.4.4 Acetic Acid Plant

TABLE II 4.12

CAPITAL COST OF ACETIC ACID PLANT

		Rupees x 10^6 Foreign Exchange	Local Currency
1.	Equipment, Spares, Procurement, Freight and Insurance, Tools and Plant, Insurance.	5.51	-
2.	Engineering, Expenses and Overheads, Licence, Site Supervision and Commissioning.	1.53	-
3.	Construction Labour, Civil wrok, Local Tools and Plant, Local insurance, Inland Freight and Dock Clearance, Local Spares, Local Expenses.	-	2.08
4.	Duty on Equipment and Spares	-	1.33
	TOTALS :	7.04	3.41
	Start-up charges	0.52	0.52
	Interest on Foreign Exchange during construction	0.77	-
		8.33	3.93
	TOTAL COST	12.26	
	ESTIMATED WORKING CAPITAL (max.)	0.35	

For definition of the scope of the above capital cost, see footnote to Table II 4.9

4.2.4.5 Vinyl Acetate Plant

TABLE II 4.13

CAPITAL COST OF VINYL ACETATE PLANT

	Rupees x 10^6 Foreign Exchange	Rupees x 10^6 Local Currency
1. Equipment, Spares, Procurement, Freight and Insurance, Tools and Plant, Insurance.	6.18	-
2. Engineering, Expenses and Overheads, Licence, Site Supervision and Commissioning.	1.83	-
3. Construction Labour, Civil work, Local Tools and Plant, Local insurance, Inland Freight and Dock Clearance, Local Spares Local Expenses.	-	2.35
4. Duty on Equipment and Spares	-	1.50
TOTALS :	8.01	3.85
Start-up charges	0.59	0.59
Interest on Foreign Exchange during construction	0.88	-
	9.48	4.44

TOTAL COST	13.92
ESTIMATED WORKING CAPITAL	2.49

For definition of the scope of the above capital cost, see footnote to Table II 4.9

4.2.4.6 Expansion to Acetylene and Oxygen Plants, Utilities and Offsites

The cost of expanding the production capacity of the Acetylene and Oxygen plant from 36,000 MTPA to 55,150 MTPA has been estimated, and is given, in Table II 4.14 below. Allowances for expansion of Utilities and Offsites are also given.

TABLE II 4.14

CAPITAL COSTS OF ACETYLENE, UTILITIES AND OFFSITES EXPANSIONS

	Rupees x 10^6	
	Foreign Exchange	Local Currency (Inc. Duty)
Acetylene and Oxygen Plants Expansion	14.39	8.71
Utilities Plants Expansion	.75	.46
Offsites Expansion	3.45	6.91
Interest on Foreign Exchange During Construction	1.98	-
TOTALS :	20.57	16.08
TOTAL COST	36.65	

4.2.4.7 Capital Costs Summary for Expansion

TABLE II.4.15

Capital Costs Summary for Expansion of Acetylene Complex

	Capacity MTPA	Rupees x 10^6 Foreign Exchange	Local Currency (Inc.Duty)
Acetaldehyde Plant	25,900	19.14	8.11
2-Ethyl Hexanol Plant	11,840	11.15	3.87
Dioctyl Phthalate Plant	16,000	8.58	3.78
Acetic Acid Plant	8,180	7.04	3.41
Vinyl Acetate Plant	8,420	8.01	3.85
T O T A L S:		53.92	23.02
Start-up, training and consultancy costs		3.84	3.84
Interest during construction		6.22	- (2.53)
TOTALS FOR NEW PLANTS:		63.98	26.86(29.39)
TOTALS FOR ACETYLENE, UTILITIES AND OFFSITES EXPANSIONS		20.57	16.08
TOTALS FOR EXPANSION OF COMPLEX		84.55	42.94
TOTAL COST		127.49	
ESTIMATED WORKING CAPITAL		10.31	

The 'totals for new plants' are needed for the cash flow calculation in Section 4.2.7.6 in which the average unit cost of acetylene includes an element to cover the capital costs of expansion of the acetylene and oxygen plants, utilities and offsites.

For the cash flow calculation, the figures used for local currency costs are shown in brackets. 'Interest' amounting to 11% of the local currency element of plant cost is included, to allow for the time value of money during the construction period.

4.2.4.8 Pre-Investment for Phase II

It will be necessary to lay out a significant proportion of the capital cost of the expansion in the initial construction stage, so as to achieve the most economical result overall.

The acetylene purfication equipment would be designed and erected as a single stream for the final (55,150 MTPA) capacity. Six burner units would be required for this capacity and of these, two would be omitted from their allotted places until the second stage of construction, together with the associated gas scrubbing and cooling equipment.

The oxygen plant and the main utilities plants would be installed in their final form in the first stage of construction, apart from a few items, such as a cooling water cell, which could be delayed.

The 'offsites' (utilities distribution etc.), attributable to the expansion, would also nearly all be installed during the first construction phase.

4.2.4.9 Capital Cost Summary for Project

In the following table, the estimate of the capital cost for Phase I, as sanctioned, is taken from EPIDC's proposal document dated January 1970. The additional capital cost for the recommended expansion has been calculated by adding together the estimates already given for the process plants and for the expansion of the acetylene and oxygen plants, utilities and offsites. Of this additional capital, the pre-investment as described above has been estimated, and is given below under the heading Phase II A. The remainder of the capital cost, necessary to complete the recommended expansion, is given under the heading Phase II B.

TABLE II.4.16

Capital Cost Summary for EPIDC Petrochemical Project

	Rs. x 10^6		
	Foreign Exchange		Local Currency (Inc.Duty)
Phase I as sanctioned (including land, site development and housing colony):	562		395
TOTAL COST:		957	
ESTIMATED WORKING CAPITAL:		31	
Phase IIA as defined above:	18.51		15.81
TOTAL COST:		34.32	
Hence, Stage 1 of construction:	580.51		410.81
TOTAL COST:		991.32	
ESTIMATED WORKING CAPITAL:		31	
Phase IIA (Stage 2 of construction):	66.04		27.13
TOTAL COST:		93.17	
ESTIMATED WORKING CAPITAL		10.31	
Complete Project:	646.55		437.94
TOTAL COST:		1,084.49	
ESTIMATED WORKING CAPITAL		41.31	

4.2.5 Unit Costs and Prices

TABLE II 4.16 lists the unit costs of the various raw materials, utilities and packages used in the subsequent financial analysis. It also gives the credit values assigned to the various by-products, and the proposed selling price of the end-products. These costs, credit values and prices are sub-divided for the purpose of specific financial analyses.

TABLE II 4.17

UNIT COSTS AND PRICES

	($)	$ Foreign Exchange	Rs. Local Currency Excl. Duty	Rs. Total
End Products				
Dioctyl Phthalate, MT	(235)	384	-	2,800
Acetic Acid, MT	(107)	161	-	1,280
Vinyl Acetate, MT	(149)	222	-	1,775
By-products				
Off-gas, 10^6 K.Cal.		-	2.34	3.89
Raw Materials				
Natural Gas, 10^3 s.c.f.		-	0.6	1.0
Phthalic Anhydride, MT 1. indigenous		-	1510	1510
" " " 2. imported		276		
Hydrogen, MT		-	320	320
Utilities				
Electricity, kWh		0.005	0.035	0.063
Steam, MT		0.176	2.23	4.90
Cooling Water, m^3		0.004	0.048	0.075
Process Water, m^3		0.071	0.43	1.00
Demin. Water, m^3		0.22	0.85	2.68
Packages				
Steel Drums (per MT of D.O.P. or V.A.)		-	60	60
Polythene Containers (per MT of Acetic Acid)		-	30	30

Note on Prices

The "total" prices for the end products are the proposed selling prices before tax estimated by H & G on the basis that they would give a reasonable return on the capital employed, suitably distributed over these end products. The cash flow calculation provides an overall check on these estimates. The foreign exchange prices of these end products are the expected C & F prices of the substituted imports, and they are based upon current C & F prices. The foreign exchange prices shown in brackets are an estimate of the C & F price which would be competitive, under cash cum bonus, with the proposed selling price.

Phthalic anhydride (i) estimated total cost at Ashuganj, including transport from plant at Karachi, using data from Volume III (ii) C & F price of imported material.

4.2.6 Foreign Exchange Analysis

4.2.6.1 General

The incremental production beyond that of Phase I of the E.P.I.D.C. scheme is shown in the Block Diagram FIG. II 4.1. This is summarised below :-

TABLE II 4.18

INCREMENTAL PRODUCTION FOR PHASE II

	MTPA
Acetylene	19,150
Dioctyl Phthalate	10,000
Acetic Acid	1,650
Vinyl Acetate	8,420

The basis for the Foreign Exchange Analysis is the comparison of the foreign exchange saving and the local currency cost (excluding duty) for this incremental production, and hence a statement of the cost in local currency of saving foreign exchange. It is applied to the increment in production at the full (design) rate.

4.2.6.2 Variable Costs of Production

From the operating data given in Section 4.2.2 and the unit operating costs given in Section 4.2.5, the variable costs of production for acetylene, acetaldehyde, 2-ethyl hexanol, dioctyl phthalate, acetic acid and vinyl acetate may be calculated.
Phthalic anhydride from indigenous manufacture is assumed.
These variable costs are summarised below :-

TABLE II 4.19

VARIABLE PRODUCTION COSTS
(Basis 1 MT of Product)

	Foreign Exchange $	Local Cost Excluding Duty Rs
Acetylene	22.0	229.9
Acetaldehyde	7.1	19.7
2-Ethyl Hexanol	21.5	71.2
Dioctyl Phthalate	3.2	650.0
Acetic Acid	4.1	67.1
Vinyl Acetate	3.3	74.8

Notes on Table II 4.19

1. The local costs in the above table include the cost of packages where necessary.
2. Summation of the variable costs listed enables the total variable costs of the complex extension to be calculated. Thus, the variable cost of any precursor which also appears in the list is excluded.

4.2.6.3 Fixed Costs of Production

Maintenance

For the purposes of this calculation, maintenance was based on the foreign exchange investment in a similar way to that for the Fauji development (see Section 3.2.6.3). The following basis was used -

Foreign Exchange Element of Maintenance costs	2.9%	of foreign exchange capital cost
Local Cost Element of Maintenance costs	2.5%	of foreign exchange capital cost

For the total foreign exchange investment of 14.47×10^6 $, (see Section 4.2.4), the maintenance charge per year is:-

Foreign Exchange	$	420,000
Local Cost (excluding duty)	Rs	1,726,000

Labour and Supervision

The direct labour requirements of the acetylene plant expansion and the other plants corresponding to the petrochemicals lists in Table II 4.17, are estimated to be 107 men (see Section 4.2.2). At an average cost of 9,000 Rs per man per year, which allows for supervision, the costs are :-

Local Cost	Rs	963,000

Overheads

These are estimated at 3% of the total sales revenue. This is calculated using the data from Table II 4.16, thus :-

		Rs x 10^6
Sales	16,000 MTPA Dioctyl Phthalate	44.8
	1,650 MTPA Acetic Acid	2.1
	8,420 MTPA Vinyl Acetate	15.0
		61.9

The overheads are thus Rs 1,856,000 (local cost only).

Interest on Working Capital

Working capital was assumed to be equivalent to the value of 2 months of finished product. As output rises during the initial years, so also does working capital. The interest on this working capital is equivalent to 1.5% of the years sales revenue. It is thus Rs 928,000 for full production capacity.

The fixed costs of production are summarised below:-

TABLE II 4.20

FIXED PRODUCTION COSTS

	Foreign Exchange ($ x 10^3/yr)	Local Cost Excluding Duty (Rs x 10^3/yr)
Maintenance	420	1,726
Labour and Supervision	Nil	963
Overheads and Selling Expenses	Nil	1,856
Interest on Working Capital	Nil	928
TOTAL :	420	5,473

4.2.6.4 Foreign Exchange Saving and Rupee Cost Comparison

The following table compares the foreign exchange saving and the Rupee costs of production, and is compiled using the data given in the previous sections.

The Rupee element of the investment excludes duty on equipment, but includes start-up expenses. The use of the average interest rate ensures that the early years are not penalised nor the results for the later years over-optimistic.

4.2.6.4 Foreign Exchange Saving and Rupee Cost Comparison (cont'd.)

TABLE II.4.21

FOREIGN EXCHANGE ANALYSIS

		Foreign Exchange	Local Cost Excl. Duty
		$ x 10^3/yr.	Rs x 10^3/yr.
Variable Production Costs			
Acetylene, 19,150 MTPA		421	4,400
Acetaldehyde, 25,900 MTPA		184	510
2-Ethyl Hexanol, 11,840 MTPA		255	843
Dioctyl Phthalate, 16,000 MTPA		51	10,400
Acetic Acid, 1,650 MTPA) 6,530 MTPA)		34	549
Vinyl Acetate, 8,420 MTPA		28	630
Fixed Production Costs		420	5,473
TOTAL PRODUCTION COSTS		1,393	22,805
Foreign Exchange Value of Products			
Dioctyl Phthalate, 16,000 MTPA @ $384		6,140	
Acetic Acid, 1,650 MTPA @ $161		266	
Vinyl Acetate, 8,420 MTPA @ $222		1,870	
TOTAL F.E. VALUE OF PRODUCTS		8,276	
Average Interest over First 10 years @ 8% (= 4% on total F.E. Loan of $17.72 x 10^6)		709	
Annual Repayments		1,772	
TOTAL INTEREST + REPAYMENTS		2,481	
Foreign Exchange Savings		4,402	
Cost of F.E. saving Rs/$ excluding depreciation on Rupee element	5.2		
Depreciation @ 10% on Rupee element Rs.42.94 x 10^6 minus duty Rs.14.54 x 10^6 = Rs.28.40 x 10^6			2,840
			25,645
Rupee cost, including depreciation cost of F.E. saving Rs/$ including depreciation	5.8		

4.2.6.5 Foreign Exchange Analysis for Each Product

The variable and fixed production costs of each intermediate and product have been calculated, on exactly the same basis as in the preceding sections. The fixed costs (both operating and financial) have been suitably distributed between the acetylene expansion and the process units. As before, the duty and bonus elements have been omitted from the costs of plants, materials and utility services. Financial costs include depreciation on the local element of fixed capital.

The production costs and foreign exchange savings fibures so calculated are:-

	$ Foreign Exchange	Rs Local currency
Acetylene, per MT		
Variable	22.0	229.9
Fixed	38.9	111.3
Production Cost	60.9	341.2
Acetaldehyde, per MT		
Acetylene, 0.63 MT	38.4	215.0
Other variable	7.1	19.7
Fixed	29.5	84.7
Production Cost	75.0	319.4
2-Ethyl hexanol, per MT		
Acetaldehyde 1.66 MT	124.5	530.2
Other variable	21.5	71.2
Fixed	37.6	107.9
Production Cost	183.6	709.3
Dioctyl phthalate, per MT		
2-ethyl hexanol, 0.73 MT	134.0	517.8
Other variable	3.2	650.0
Fixed	21.4	61.5
Production Cost c/f	158.6	1229.3

Production cost b/f	158.6	1229.3
Cost of alternative import (C & F)	384	
Foreign exchange saving	225.4	

Ratio Rs 1229.3/$225.4 = **Rs 5.4/$**

Acetic acid, per MT

Acetaldehyde, 0.77 MT	57.8	245.9
Other variable	4.1	67.1
Fixed	34.5	98.7
Production cost	96.4	411.7
Cost of alternative import (C & F)	161	
Foreign exchange saving	64.6	

Ratio Rs 411.7/$64.6 = **Rs 6.4/$**

Vinyl acetate, per MT

Acetylene, 0.32 MT	19.5	109.2
Acetic acid 0.72 MT	69.4	296.4
Other variable	3.3	74.8
Fixed	38.0	109.0
Production cost	130.2	589.4
Cost of alternative import (C & F)	222	
Foreign exchange saving	91.8	

Ratio Rs 589.4/$91.8 = **Rs 6.4/$**

4.2.7 Cash Flow and D.C.F. Rate of Return

4.2.7.1 General

The sales revenue is based on the pattern of market build-up stated in the Interim Report. Production by the individual plants is only limited to 30% and 90% in the first and second years of operation in view of the fact that existing plants and utilities will be well established. The lower figure of the two (market requirement or production capacity), establishes the output, and thus the sales rate, for a particular year. After 1980, the full production rate can be maintained and sold.

In this analysis, it was decided to use the average and not the marginal cost of acetylene production in establishing the production costs of the products (see Section 4.2.7.2 below). Total costs of the manufacturer are used throughout this analysis so that the D.C.F. rate of return can be determined from the viewpoint of the Pakistan investor.

4.2.7.2 Average Cost of Acetylene

Phase I of the E.P.I.D.C. project at Ashuganj is planned to produce 36,000 MTPA acetylene. Our recommended development would require this capacity to be increased to 55,150 MTPA. For the purposes of analysing Phase II of the project, acetylene is taken as a feed to the new plants proposed, and the average cost of acetylene production is based on the capacity of 55,150 MTPA.

The estimated total cost of acetylene as a feed to the Phase II units is Rs 1,037/MT.

4.2.7.3 Variable Cost of Dioctyl Phthalate, Acetic Acid and Vinyl Acetate Production

Using the average cost of acetylene production from the previous section, the operating data in Section 4.2.2 and the total unit costs of raw materials and utilities from Section 4.2.5, the variable costs of the three sales products were calculated. The variable costs include the cost of all raw materials used, and also the cost of packages. They are summarised below :-

Dioctyl Phthalate	Rs	1712.4/MT
Acetic Acid	Rs	696.0/MT
Vinyl Acetate	Rs	915.6/MT

4.2.7.4 Fixed Costs of Production

The fixed costs are estimated for the extension project as a whole and are not subdivided between end-products. In the cash flow table and D.C F. calculation, the presence of the full capacity acetylene unit on the site is assumed.

Maintenance

The total annual maintenance charge for the extension project is estimated as a proportion of the fixed capital for the whole extension project. The basis adopted (consistent with Section 4.2.6.3) is 4% of total fixed capital (duties excluded). On this basis, the figure of 4.0% includes allowance for the duty element of materials used in maintenance.

Labour and Supervision

The direct labour requirements for all five plants is estimated to be 102 men, charged at 9,000 Rs per man per year.

Overheads and Selling Expenses

These are estimated to be 3% of the total sales revenue, as in the Foreign Exchange Analysis. They are based on full production rates.

Foreign Exchange Repayments

The repayments are made in equal sums over the first ten years of operation. The total foreign exchange loan for the plants producing the intermediates and sales products (i.e., excluding the Acetylene Plant Extension) is :-

$$\text{Rs } 63.98 \times 10^6$$

It includes interest on the loan during the construction period and the foreign exchange capital covering start-up expenses (see Section 4.2.4).

4.2.7.5 Other Fixed Costs

Interest on Foreign Exchange Loan

This is taken as 8% of the outstanding loan.

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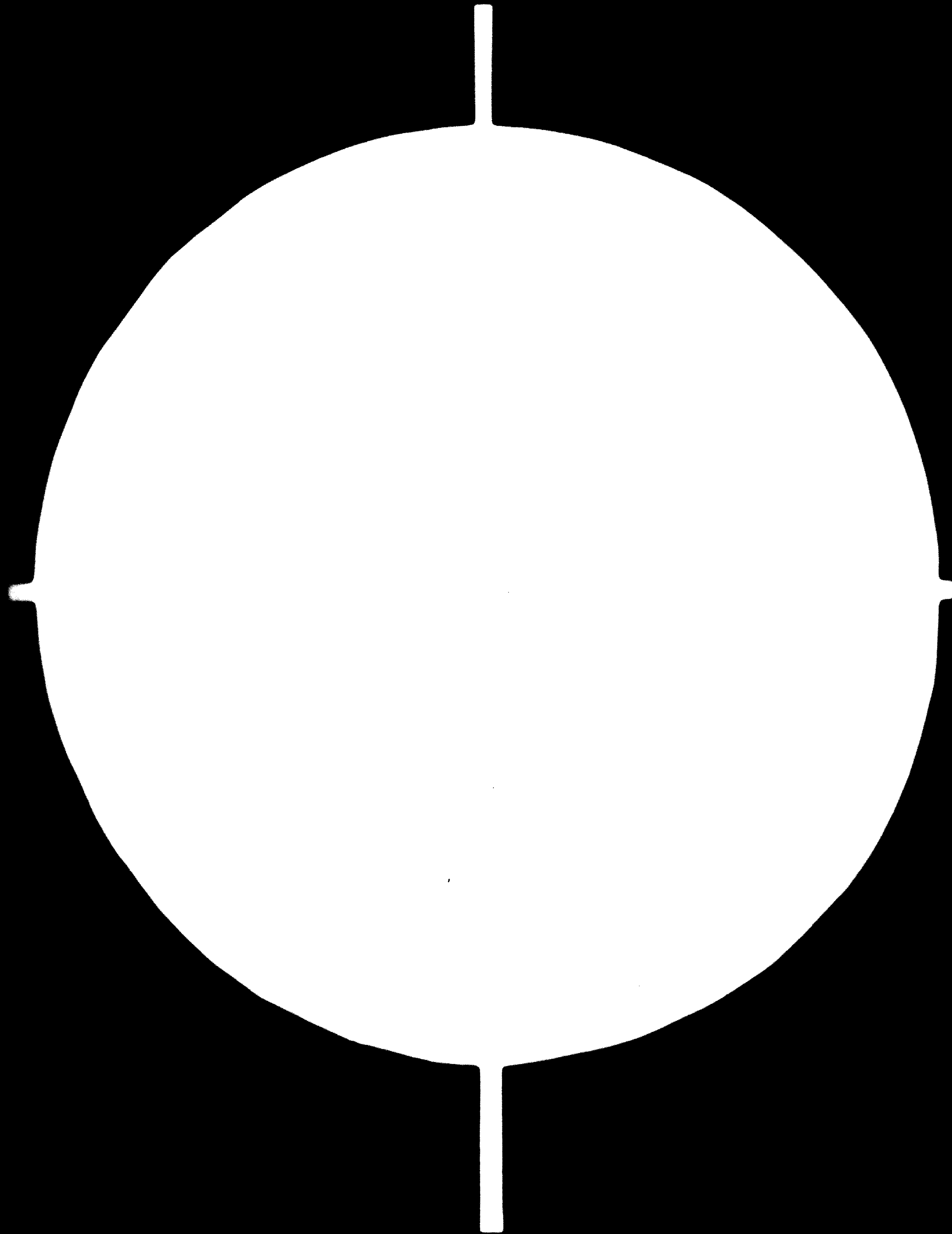

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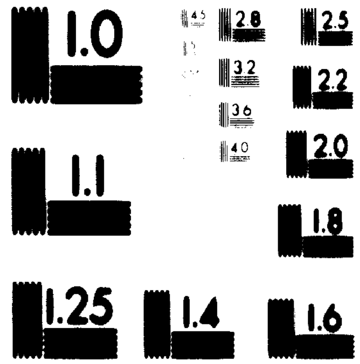

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Interest on Working Capital

As in the Foreign Exchange Analysis, this is based on 1.5% of the total sales revenue. The total sales revenue applicable to the particular year is used.

4.2.7.6 Cash Flows and D.C.F. Rate of Return

The cash inflows, cash outflows and the net cash flows are set out in Table II 4.21. The net cash flow is before tax and depreciation.

A total span of 15 years is covered; year 0 is the reference year in which it is assumed that all capital expenditure is incurred. (The allowance mentioned above for the interest during construction permits this simplification.)

The costs in this table are based on 1970's costs of equipment materials, and labour. (see 3.2.7.6 for detailed comment). The proposed selling prices of the products are on the same basis and were arrived at by making a preliminary calculation (not shown) of the price which would give a reasonable return on the total capital employed, suitably allocated between the products. They are well below the current import prices on a cash-cum-bonus; the C & F prices which would be competitive with the proposed selling prices are shown in Table II 4.17.

The D.C.F. rate of return based on the Rupee investment in the fixed assets is calculated at 16.4%. This D.C.F. level indicates the viability of starting-up the extension in 1976 at the capacities proposed.

For explanation of the capital costs used, see Section 4.2.4.7.

[illegible]

CALENDAR YEAR / Reference Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
PRODUCTION AND SALES, M.T.P.A.																
Dioctyl Phthalate		[illegible]	[illegible]	12,100	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Acetic Acid		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Vinyl Acetate		[illegible]	[illegible]	6,730	7,570	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CASH INFLOW																
Dioctyl Phthalate @ [illegible] Rs/MT		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Acetic Acid @ [illegible] Rs/MT		[illegible]	[illegible]	[illegible]	[illegible]	2,112	2,112	2,112	2,112	2,112	2,112	2,112	2,112	2,112	2,112	2,112
Vinyl Acetate @ 1775 Rs/MT		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL CASH INFLOW		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
CASH OUTFLOW																
1. Variable Costs of Production																
Dioctyl Phthalate		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Acetic Acid		[illegible]	700	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Vinyl Acetate		[illegible]	[illegible]	[illegible]	[illegible]	7,700	7,700	7,700	7,700	7,700	7,700	7,700	7,700	7,700	7,700	7,700
TOTAL VARIABLE PRODUCTION COST		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2. Fixed Costs																
Interest on Foreign Exchange Loan		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Interest on Working Capital		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Foreign Exchange Repayments		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Overheads and Selling Expenses		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Maintenance		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Labour and Supervision		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL FIXED COSTS		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
TOTAL CASH OUTFLOW		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	42,722	42,722	42,722	42,722	42,722
NET CASH FLOW		[illegible]	-32	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	29,390 16.4%															

4.3 Conclusions

1. Consideration of the Phase I plans for production at Ashuganj and our recommendation for Phase II in West Pakistan, indicates that the new products for Phase II at Ashuganj should be:

16,000 MTPA Dioctyl Phthalate

8,420 MTPA Vinyl Acetate

1,650 MTPA Acetic Acid

Each of the above products shows a saving on foreign exchange. A scheme including these products, and requiring an expansion of acetylene capacity from 36,000 MTPA to 55,000 MTPA, has been developed and a start-up date of 1976 is proposed.

2. The Rupee cost of saving foreign exchange for the scheme as a whole is estimated at Rs. 4.78/U.S. $, and is very favourable.

3. Considering acetylene from the expanded acetylene plant as a feedstock, the D.C.F. rate of return on new Rupee capital invested in the plants for the above products has been calculated at 16.4% (before tax).

It may well be thought adequate for a publicly-owned development corporation such as EPIDC and will allow EPIDC to pay the interest rate on the ivestment which will be required by the central authorities.

4. If the D.C.F. rate of return is considered too low by EPIDC the proposed start-up date for the scheme could be delayed. This would increase the rate of return as the utilisation of plant capacity in the first 4 years would be improved. (Under the scheme proposed at present, start-up is in 1976 but capacity is designed to meet the estimated consumption for the products in 1980). Any delay, however, postpones the date when the foreign exchange starts to accrue.

5. If the Phase II scheme proposed here is accepted by EPIDC, then the acetylene plant and associated facilities should be designed at the outset for the full required capacity of 55,000 MTPA acetylene.

6. An export survey should be undertaken of the products proposed for Phase I and Phase II of the EPIDC Petrochemicals Project.

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SOME FIGURES
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