5–2 CAUSTIC SODA DEMAND PROJECTION

5–2–1 Demand projection

As noted in the preceding section, if casutic soda is supplied at a low price and in a stable manner, markets beyond the existing ones, shown in Table II-70 – particularly the inorganic and organic chemical industries – can be expected to provide new demand.

Table II-72 shows the expected growth of existing market and that of markets to appear in the future, projected by means of aggregating individual areas of demand. It is expected that from 1980 on total caustic soda demand will grow at the annual average of about 10%.

5–2–2 Supply projection

In aggregate, the Thai caustic soda industry producers consume 45% of their own output, and market the rest. But because the situation is close to being one of monopoly, supply projection using macroeconomic methods are not possible. Moreover, because any expansion plans which these producers have are treated as company secrets, it is difficult to obtain accurate information.

Therefore, the following assumptions are made in order to project supply.

(a) Caustic soda makers which consume output will expand capacity in keeping with expansion of their own requirements.

(b) The plants owned by these makers are operated at full capacity.

(c) The electrolysis plant which is to be constructed in accordance with the chlorine requirement of the VCM plant[1] producting byproduct caustic soda (see Table II-73).

The quantity of caustic soda supply projected on the basis of the above is as shown in Table II-74.

1) It is assumed that operation is begun in mid-1985.

Table II–72 DEMAND FORECAST FOR CAUSTIC SODA IN THAILAND

(Unit: 1,000 LMT/y)

	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Textile	29.4	30.6	31.8	33.1	34.4	35.8	37.2	38.7	40.2	41.8	43.5	45.3	47.1
Mono-sodium Glutamate	28.8	30.0	33.6	36.3	39.2	42.3	45.7	48.4	51.3	54.4	57.7	61.2	64.8
Soap and Detergent	16.8	17.6	18.5	19.4	20.4	21.4	22.5	23.6	24.8	26.1	27.4	28.7	30.2
Pulp and Paper	6.0	6.3	6.6	6.9	7.3	7.7	8.0	8.6	9.2	9.8	10.5	11.2	12.0
Food Industry	4.8	5.5	6.3	7.3	8.4	9.7	11.1	12.8	14.7	16.9	19.4	22.3	25.7
Petroleum	3.6	3.8	4.0	4.3	4.5	4.8	5.1	5.4	5.7	6.1	6.4	6.8	7.2
Aluminum	3.0	3.2	3.4	3.6	3.8	4.0	4.3	4.5	4.8	5.1	5.4	5.7	6.0
Chemical Industry	–	–	–	4.1	7.5	11.7	21.5	38.0	40.3	42.7	45.3	48.0	41.7
Other Usage	13.6	13.0	14.8	17.0	19.6	19.6	19.6	46.0	54.0	61.4	72.4	81.8	98.1
Total	106	110	119	132	148	157	175	226	245	266	288	311	342

Source: Estimated by the study team.

Table II–73 PRODUCTION OF CAUSTIC SODA AND CHLORINE BY NEW ELECTROLYSIS PLANT

(Unit: 1,000 t/y)

	Production of Chlorine Consuming Product		Production by Electrolysis Plant	
	PVC	VCM	Chlorine	Caustic Soda[1)]
1985	56.1	29.0	17.5	37.3
1986	61.0	63.1	37.9	81.1
1987	66.4	68.7	41.2	88.2
1988	72.2	74.5	44.8	95.9
1989	75.6	80.0	48.0	103.2
1990	77.7	80.0	48.0	103.2

Note: 1) As 50% aqueous solution.
Source: THASCO.

Table II–74 PRODUCTION FORECAST FOR CAUSTIC SODA IN THAILAND

(Unit: LMT/t)

	Production by		Total
	Existing Plants[1)]	New Electrolysis Plant	
1979	70	–	70
1980	72	–	72
1981	80	–	80
1982	109	–	109
1983	116	–	116
1984	122	–	122
1985	143	37	180
1986	153	81	234
1987	165	88	254
1988	177	96	273
1989	186	103	289
1990	(186)	(103)	(289)
1991	(186)	(103)	(289)

Note: 1) Including expansion.

5–2–3 Projection of the supply-and-demand balance

As is demonstrated by the comparison in Table II-75 of projected demand and supply given in preceding sections of this chapter, prior to the start of operation of the electrolysis plant (in 1985) there will be shortfalls of supply of 30,000 to 40,000 LMT/y, signifying need for imports, but after 1985 production will exceed demand.

However, because the surplus caustic soda will be at maximum about 9,000 LMT/y, it is thought that the possible effects of this surplus can be averted by slight reduction of output (including that of new plants) and by adjustment among the producers as a group.

Table II–75 SUPPLY/DEMAND BALANCE FOR CAUSTIC SODA IN THAILAND

(Unit: LMT/y)

	Demand	Production	Balance
1979	106	70	–36
1980	110	72	–38
1981	119	80	–39
1982	132	109	–23
1983	148	116	–32
1984	157	122	–35
1985	175	181	6
1986	226	234	8
1987	245	245	9
1988	266	273	9
1989	288	289	1
1990	311	(289)	(–22)
1991	342	(289)	(–53)

ATTACHMENT

ATTACHMENT

METHOD FOR DEMAND FORECAST AND ELASTICITY ANALYSIS ON PLASTICS MATERIALS

SUMMARY

1. Demand for plastics has been projected by use of time series analysis and by analysis using the relation of demand to gross national product, but subsequent to the 1974 oil shock and recent decline in the growth of demand in Asean countries, due to the increases in prices, it has become possible to provide a better explanation of what to expect regarding demand by including the element of prices in an econometric model.

2. At the present time it is absolutely necessary for there to be a review of market conditions for petrochemical planning in developing countries and it has become vital to develop methods to accomplish that.

3. In order to make reliable projections it is necessary to begin with accurate analysis of the present conditions.

4. As one such method, elasticity analysis has been carried out by employing a logarithmic linear regression equation in which price and GNP (GDP) are used as independent variables.

5. The plastics which are the object of study are the general-purpose resins PE, PP, PS and PVC, and analysis is done for three countries, namely Japan, Korea and the Philippines.

6. Elasticity will vary according to such matters as the structure of plastics demand and in Japan we can recognize considerable differences between three periods, the first half of the 1960s, the second half of the 1960s, and the first half of the 1970s.

7. Projections of a market in accordance with structural change requires the making of projections by aggregation and other methods, concurrent with use of a macromodel.

1. INTRODUCTION OF THE PRICE FACTOR

It has been since the occasion of implementing a study of the Thai plastics market in the summer of 1974 that the auther has used the concept of elasticity analysis and particularly price elasticity analysis, which be previously had not given much attention, for projecting plastics demand.

The auther suspected that demand for plastics in Thailand at that time had dropped relative to less than half of the level of 1973, the preceding year. The most important question which that study was concerned with was whether the drop in demand was temporary or long-term in nature.

The major causes of the decline in plastic products demand in Thailand at that time were:

(1) Decline in desire to consume, due to the pressure of inflation on household finances, and

(2) Switch to other materials or products as a consequence of increase in plastic products prices,

while the reasons for the decline in plastics materials demand is attributed to:[1]

(1) Decline in demand for raw materials, reflecting decline in demand for plastic products,

(2) Too-high inventory levels, caused by speculative purchases,

(3) Reduced purchases by processing companies, and

(4) Decline in importers' desire to import because imported products were higher in price than the market price.

1) This also is applicable to 1980, year of the "second oil crisis".

Examination of the 1974 Thai economy indicates, from the increase in prices of primary products for export markets, the steady increase in production of those goods, and the low dependence of the economy on petroleum compared to industrially advanced nations, that the balance of trade was being improved. It was forecast that therefore if economic activities in the rural sector recovered, demand for plastic products would increase. From the above, the four causes of a decline in demand were judged to be of short-term nature.

Although the data are somewhat old, for the sake of the present inquiry the trend of Thiland's import quantities of plastics materials, by year, is shown in Fig. AII-1, and the trend of import prices is shown in Fig. AII-2. The supply/demand balance as derived from the information Figs. AII-1 and AII-2 is depicted in Fig. AII-3. That is,

(1) 1972 and early 1973 is a period when demand grew,

(2) In mid-1973 a supply shortfall resulted in liquidation of inventory, and imports from the West were used to compensate for a shortage of supply from Japan which previously had provided 90% of total imports.

(3) Even though demand declined during the second half of 1973, speculative buying continued, and inventories were built up.

(4) Imports began to decline in about February, 1974, but prices remained firm, at peak levels and if consideration is given to inflation it may be thought that in real terms prices fell. Demand increased gradually after that, and imports continued to fall until inventories reached normal levels. It is therefore thought that it was early 1975 when the quantity of imports again began to increase.

What, then, would be the cause of the decline in actual demand as shown in Fig. AII-3? According to the methods usually used to project demand, the demand for plastics, or the quantity of demand per capita, is related to the GNP or per capita GNP, and therefore if the GNP increases, the quantity of plastics demand should also increase. But in 1974 the Thai GNP certainly did not decrease relative to the 1973 level.

If Figs. AII-1 and AII-2 are compared, the outstanding phenomenon which can be observed is the increase in prices in 1973, and, in contrast to that, a decline in demand. This is an indication that the fundamental factor influencing the decline in plastics demand in Thailand is the increase in price, and that at the same time that it can be a cause of a long-term situation of weak demand.

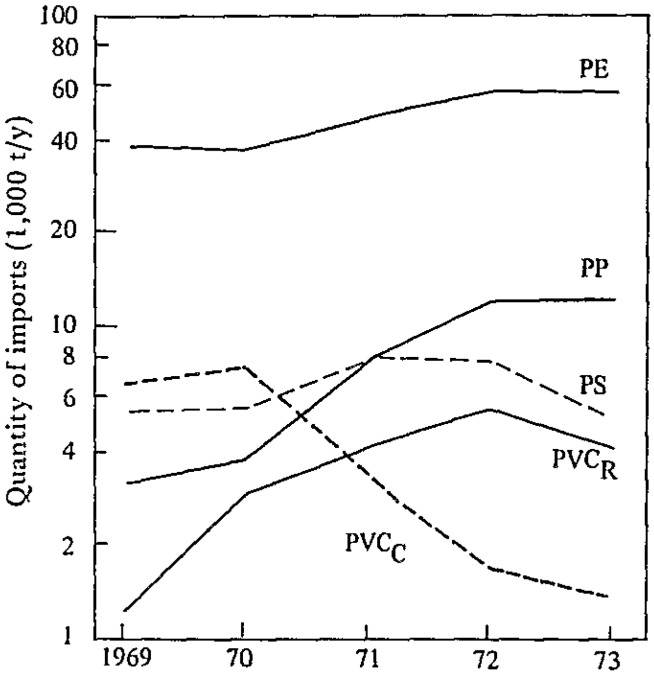


Fig. AII-1 QUANTITY OF THAILAND'S PLASTICS IMPORTS, 1969—1973

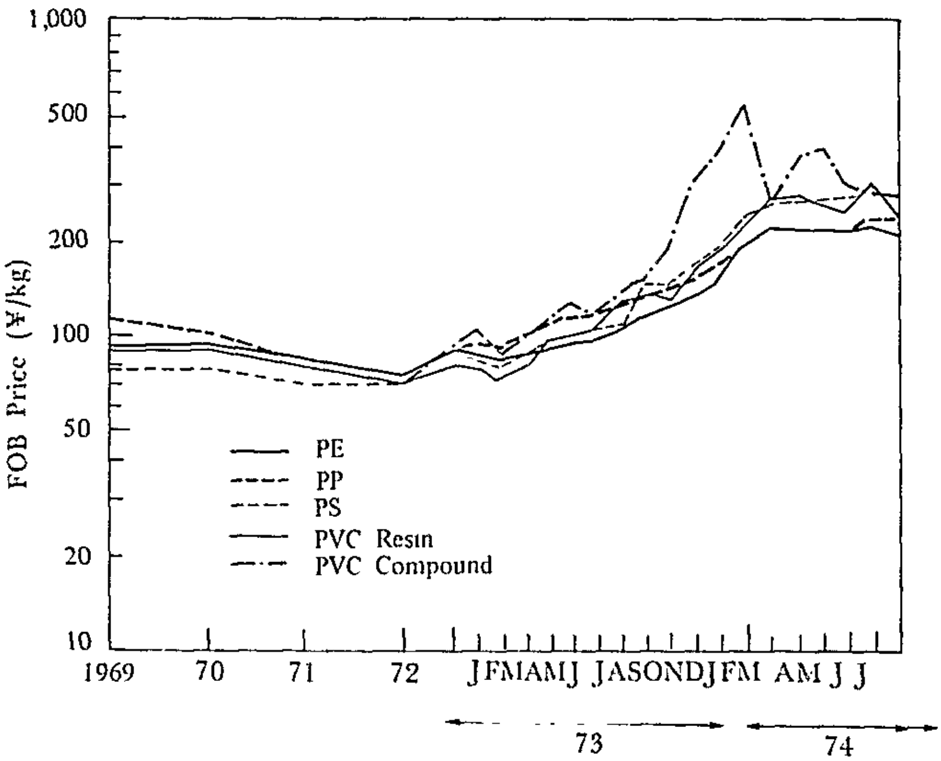


Fig. AII-2 THAILAND'S PLASTICS IMPORT PRICE (FOB JAPAN), 1969 – 1974

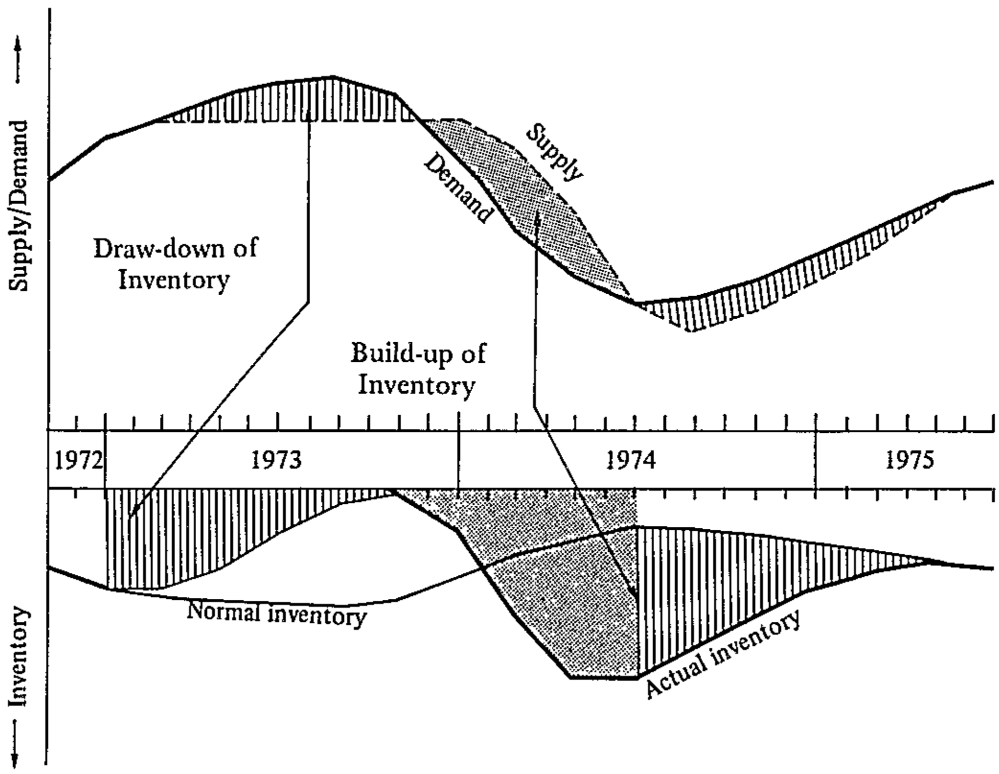


Fig. AII-3 SCHEMATIC ILLUSTRATION OF SUPPLY AND DEMAND BALANCE

2. NEED FOR DEMAND PROJECTIONS, AND METHOD OF PROJECTING DEMAND

In the past few years there have been a number of instances of planning of the development of petrochemical industries by developing countries, but it is necessary first of all necessary to determine the scale of those industries by projecting future demand, in order to establish the feasibility of such an effort, whether it is intended to satisfy domestic demand through substituting for imports, or is to be export-oriented.

Nevertheless there is tendency to forego making such projections, because they are difficult to make. Further, there are a number of schools of thought regarding demand projections and the ways they are made, and results differ depending on what method is used. It is by no means a simple task to decide which is (or are) suitable methods.

Demand projections, in the experience of the auther, do not present a question of whether they will be correct or incorrect, but rather are one form of simulation. Therefore it is not only the results of demand projection which are to be assigned importance but, also, the process whereby those results are obtained are of importance. That is, it is the method and the assumption which are important, and results will differ according to changes in assumed conditions, and conversely can indicate problems in the market.

2–1 Classification of Methods of Projecting Demand

"Demand projections" differ according to the technique used, the data used, and the objective for which they are made. Methods which have been in use to date are classifiable as follows, and are described below.

- Continuation of time series trends
- Econometric model analysis (correlation analysis)
- Analogous reasoning
- Direct survey, by ascertaining intentions to purchase
- Logical estimation

(1) Continuation of time series trends

This is a method of forecasting the future on the basis of past chronological data. This method is used when factors influencing demand are not fully known. Although a variety of causes are likely to give rise to a variety of results, when in the case of one factor or more there is a regularity of change over time it is to be expected that it will be reflected in a similar regularity of change in the results. In such a case, continuation of past trends into the future can be employed.

(2) Econometric model analysis

This method forecasts future demand by use of the quantitative relationship which is found to exist between causes and their effects on past volume of demand.

(3) Analogous reasoning

When past data are not available (or not available to a satisfactory extent), and quantitative relationships can not be determined between factors influencing the level of demand and the effects of those factors, future demand can be projected by analogous comparison with past demand of related products on the basis of the assumption that the demand for the product in question will be similar to that of the product(s) used for comparison.

(4) Ascertaining intention to purchase

For projecting demand of industrial goods, this method, namely determining the extent that users expect to purchase the subject product when it is made available to them, is the most direct of the five methods taken up here, but it involves the problem of the extent that respondents will really act as they say they will.

(5) Logical estimation

Logical estimation of demand may be performed by, for example, when demand of an intermediate product is to be determined, by combining a demand projection for the end product(s) and technical data giving unit requirements of the intermediate which are needed to produce the end product(s).

Ordinarily, more than one of the above methods are used when a demand projection is to be made.

There are both distant and close causes of demand. For exaple, plystyrene is used in ordinary articles for houshold use, toys, automobile parts, electrical parts and other goods. When polystyrene demand for use in making automobile parts is determined by taking the level of production of those parts and the unit requirement of polystyrene for them, this is projection by use of a close factor.

But demand of these parts may also be projected by use of national economic indicators, such as personal consumption expenditures and manufacturing production indices. This is projection by use of a distant factor. It is also projection by use of a macro model. This method is useful for obtaining a general idea of demand for a product, but has a defect in that the results are made unusable by change in the structure of demand. Conversely, because there is no provision for interplay among demand causes when close factors are used, in general there is some probability that results will be on the high side.

A method which resembles the former use of a close factor is that which is called aggregated projection. There are various methods of aggregation, and they are classifiable as follows.

- Aggregation by product item
- Aggregation by type of use
- Aggregation by geographic region

Although it is possible to use aggregation of distant factors, this method is generally used with close factors. Futhrer projections at this stage are facilitated by use of industrial input/output tables.

There are two types of factors which determine the level of demand, namely external factors which are beyond control and internal factors which are subject to change by implementation of policy or by the actions of businesses. Change of both types of factors may be quantitative, continuous change, or qualitative, discontinuous change.

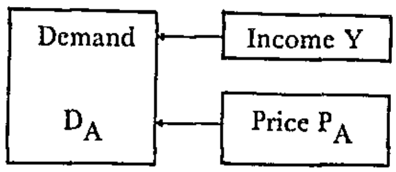
The method of projecting demand solely by continuous change of external factors is called a projective projection.

In contrast to this, when an estimate of future demand is made by means of market research, forecasting of future consumer behavior patterns or of change in the structure of consumption, or in the case of industrial goods when demand quantity is estimated on the basis of a change in technology, it is called volitional projection. While there will inevitably be differences from company to company, it is necessary to possess the elements needed for volitional projection, and to devise marketing strategy on the basis of that.

2–2 Analysis of Determinants of Demand

The procedure for projecting demand is as shown in Fig. AII-4.

First of all, the factors influencing demand are thoroughly reviewed, after which the most important factors are identified and a logical model is constructed. After this, parameters are selected from the past data, and if the values calculated thereby closely match actual results, it can be said that the model is a good predictor of performance, and if they do not closely match, it is necessary to return to the step of selection of demand determinants and repeat the procedure thereafter. If a model is accepted for use, proejcted values are calculated by use of it, and at that time the projected values obtained by simply extending past trends of exogenous variables are called simple projection values. For example, in determining demand projection values, if attention is to be given to marketing strategy, it is possible to perform simulation analysis in relation to change in policy. For that, it is desirable to include strategy factors in addition to exogenous variables, and it analysis and selection of demand determinants is extremely important for demand projection.



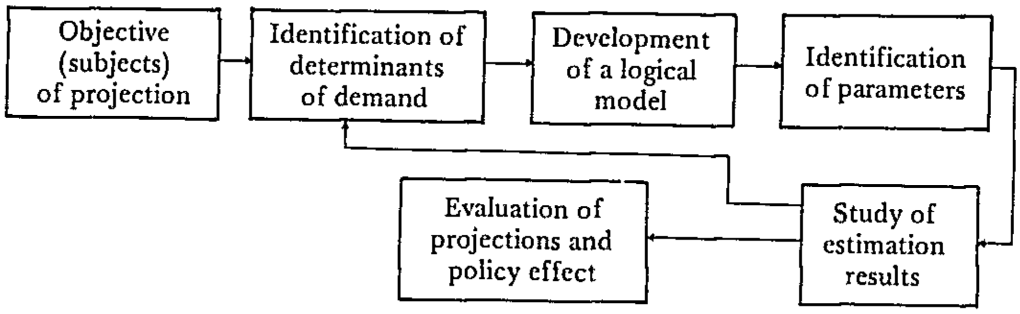


Fig. AII-4 PROCEDURE FOR PORJECTION DEMAND

Here, "income" is the income of the person having demand for the good, and in the case of the locus of demand for plastics materials, because this is expressed by economic indices such as manufacturing production indices and the gross national product, GNP or GDP is used as a variable.

It is essentail to use real prices, not current prices. The real price is the result of dividing the current price by the comprehensive price index or GNP(GDP) deflator. By use of real prices, it is possible to nullify to an extent changes of other goods' prices. That is, even if the price of plastics materials increases, if the prices of all other goods, taken together, increases even more, it means that there has been a relative decrease in the price of plastics.

A demand equation for plastics can have various forms but it is convenient to adopt the following logarithmic linear regression equation, and moreover is deemed apporopriate to do so.

$$\log Q = \beta - e_p \log P + e_\theta \log \Theta$$

where,

Q = quantity of demand
p = real price
Θ = real GNP or real GDP and
β, e_p and e_θ = coefficients.

Not only are, e_p and e_θ coefficients in this equation but they are also coefficients of price elasticity as well as GDP or GNP elasticity.

3. CHARACTERISTICS OF ELASTICITY ANALYSIS

Taking GDP elasticity for example, the original definition is, when there is a change in the GDP, there is a corresponding change in the quantity demanded, both changes taken as percentages, with the coefficient of elasticity obtained by the formula.

$$e_\theta = \frac{\Delta Q}{Q} \cdot \frac{\Delta \Theta}{\Theta}$$

When this coefficient of elasticity, strictly stated, is as follows as the change becomes infinitely small:

$$e_\theta = \lim_{\Delta\Theta \to 0} \frac{\Delta Q}{Q} \cdot \frac{\Delta \Theta}{\Theta} = \lim_{\Delta\Theta \to 0} \frac{\Delta Q}{\Delta \Theta} \cdot \frac{\Theta}{Q} = \frac{dQ}{d\Theta} \cdot \frac{\Theta}{Q}$$

If this is integrated,

$$\log Q = a + e_\theta \log \Theta$$

or

$$Q = A\,\Theta^{e_\theta}$$

which is the same as the above equation for demand, and the coefficient of $\log\Theta$ is the same as the GDP elasticity.

However, for some products, such as when a plastic is newly introduced to a market, even if $Q = 0$, Θ does not equal zero. Therefore, in the early stage of marketing, this equation does not hold. It would be necessary to express the demand equation as

$$Q = A(\Theta - \Theta_0)^{\bar{e}_\theta}$$

In this equation, $\bar{e}_\theta$, compared to the e_θ of the previous equation, shows the following relationship

$$e_\theta = \left(\frac{\Theta}{\Theta - \Theta_0} \right) \bar{e}_\theta$$

and according to this equation at the phase of market entry, that is, when the value of $\Theta - \Theta_0$ is low, e_θ is very high, and when a product is in a mature stage, or when $\Theta - \Theta_0$ is very high, the value of e_θ is low. This relationship is depicted in Fig. AII-5.

The same may be shown with regard to price elasticity. The equation for price elasticity is properly, as follows

$$Q = B(p_o + p - p_{min})^{\bar{e}_p}$$

Price p comes to be between price p_o in the market entry phase and p_{min}, the minimum price and no matter how low the price may fall it will not become zero.

The $\bar{e}_p$ of the above equation in this instance becomes the positive value.

In general, however, the following logarithmic equation is used,

$$\log Q = b + e_p \log p$$

whereby price elasticity e_p is obtained by

$$e_p = - \left(\frac{p}{p_o + p_{min} - p} \right) \bar{e}_p$$

and since in the early phase $P \approx Po$,

$$e_p \to - \left(\frac{p_o}{p_{min}} \right) \bar{e}_p$$

while in the mature phase

$$e_p \to - \left(\frac{p_{min}}{p_o} \right) \bar{e}_p$$

and as there is an advance from the initial phase to the phase of maturity in the market, elasticity gradually declines. This substantiates the generally held idea that during the development phase of a product's life cycle price elasticity is high and when the decline begins during the phase of maturity price elasticity falls. Conversely, to apply this rule, it is first necessary to correct the apparent value of elasticity.

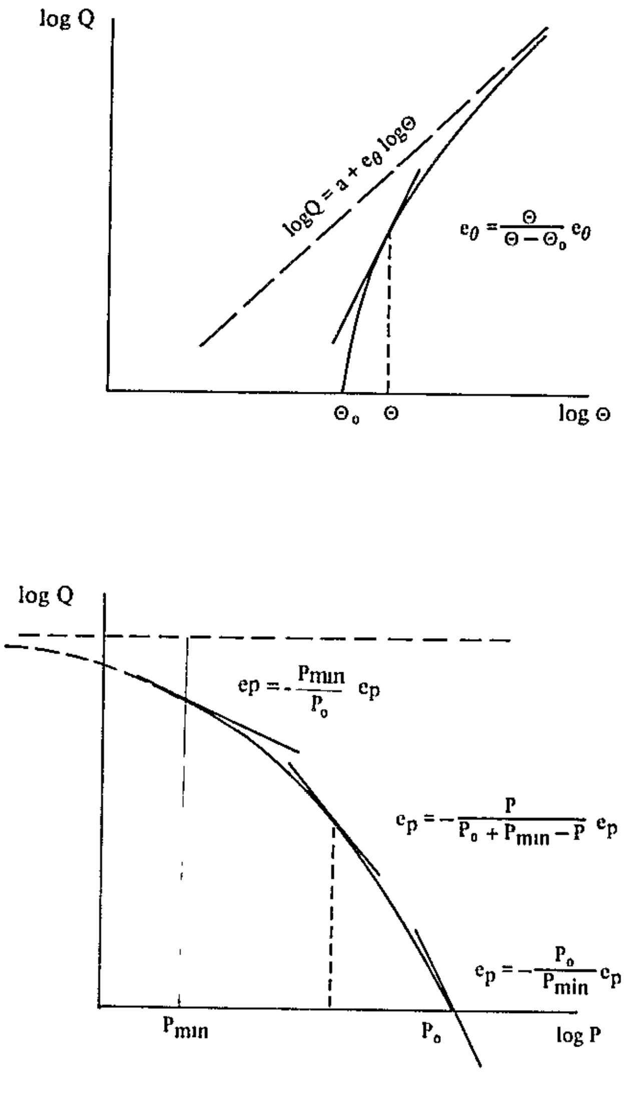


Figure AII—5 APPARENT ELASTICITY AND ABSOLUTE ELASTICITY

Accordingly, the above-noted e_θ and e_p and called apparent elasticities and the $\bar{e}_\theta$ and $\bar{e}_p$ are called absolute elasticities.

It is believed that absolute elasticities tend to be constant for any given product, and are determined by factors including the structure of demand. This value, however, does not necessarily remain the same after entry of the product to market. It is suitable to expect the value to change when the structure of the market changes.

On the other hand, according to elasticity theory, when discussing the percentage change of the demand corresponding to a certain percentage change of the GDP, it is necessary to use apparent elasticity, and it is calculated from absolute elasticity, as required and accordingly will vary accoridng to the year or period of the projection.

4. RESULTS OF ANALYSIS OF ELASTICITIES OF PLASTICS DEMAND

Domestic demand of general-purpose plastics PE, PP, PS and PVC in Japan, South Korea and the Philippines was calculated by use of the econometric model

$$\log Q = \beta - e_p \log p + e_\theta \log \Theta$$

to obtain elasticity coefficients e_p and e_θ. Here, Q represents quantity of domestic demand; p, real price; Θ real GNP in the case of Japan and real GDP in the case of the other two countries. For all, calendar year totals or averages were used.

4–1 Japan

Domestic demand in Japan during the period 1960 – 1974 was divided into three periods of demand, 1960 – 1964, 1965 – 1969 and 1970 – 1974[1]. The results of elasticity analysis as described above, for these plastics, are shown in Table AII-1 and Fig. AII-6. The figure shows real price and real GNP. In the figure, the solid line represents actual demand and the broken line represents calculated demand. Values of apparent elasticity are shown in Table AII-1.

The quantity of domestic demand is sought by using the quantities of shipments given in the annual statistical report on the chemical industry, and import and export quantities from customs data. Price is obtained from the average shipment prices and FOB prices, and divided by the GNP deflator to obtain real prices.

1) PP was studied for periods 1962 – 1965, 1966 – 1969 and 1970 – 1974.

Table AII–1 PRICE AND GNP ELASTICITIES OF MAJOR PLASTICS IN JAPAN BY MULTIPLE CORRELATION METHOD

		1960s		1970s
		First	Last	First
PE	Price	0.76	1.42	0.50
	GNP	2.08	1.11	0.54
PP	Price	2.10	1.65	0.35
	GNP	4.55	1.75	0.50
PS	Price	1.86	1.48	1.20
	GNP	1.74	1.40	0.52
PVC	Price	0.74	1.65	0.76
	GNP	0.74	1.08	0.54

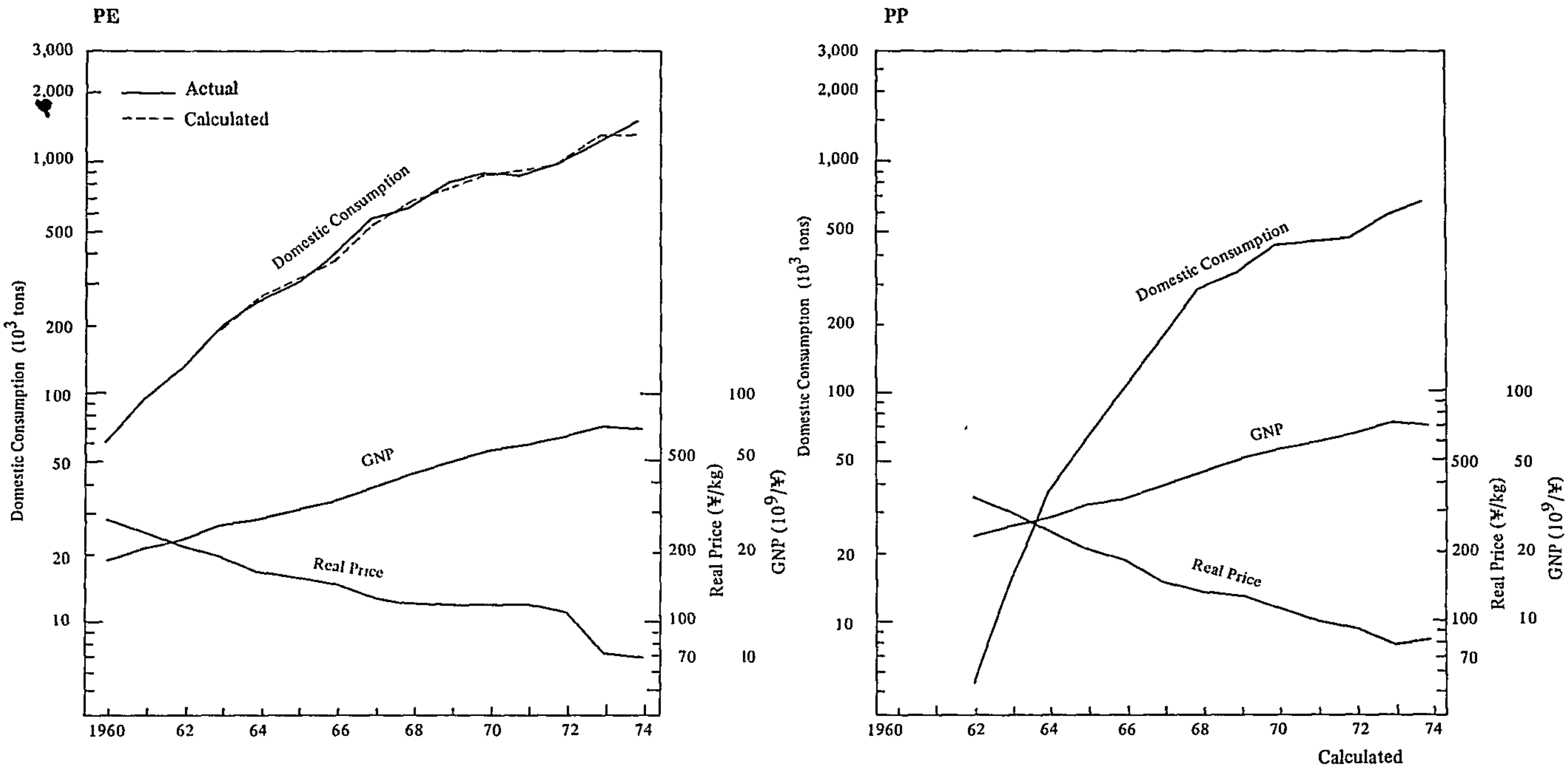
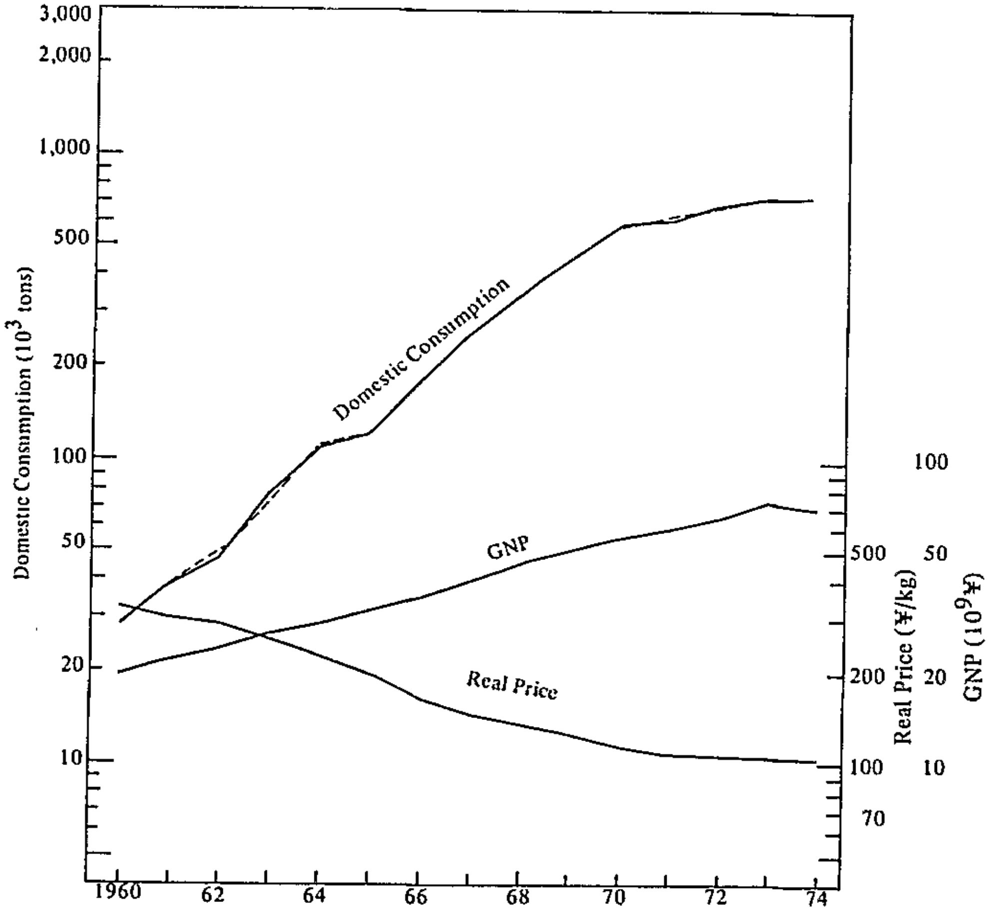


Fig. AII–6 RELATIONSHIP BETWEEN LEVEL OF DOMESTIC DEMAND AND REAL PRICE, AND BETWEEN REAL PRICE AND REAL GNP, FOR GENERAL–PURPOSE PLASTICS IN JAPAN

PS



PVC

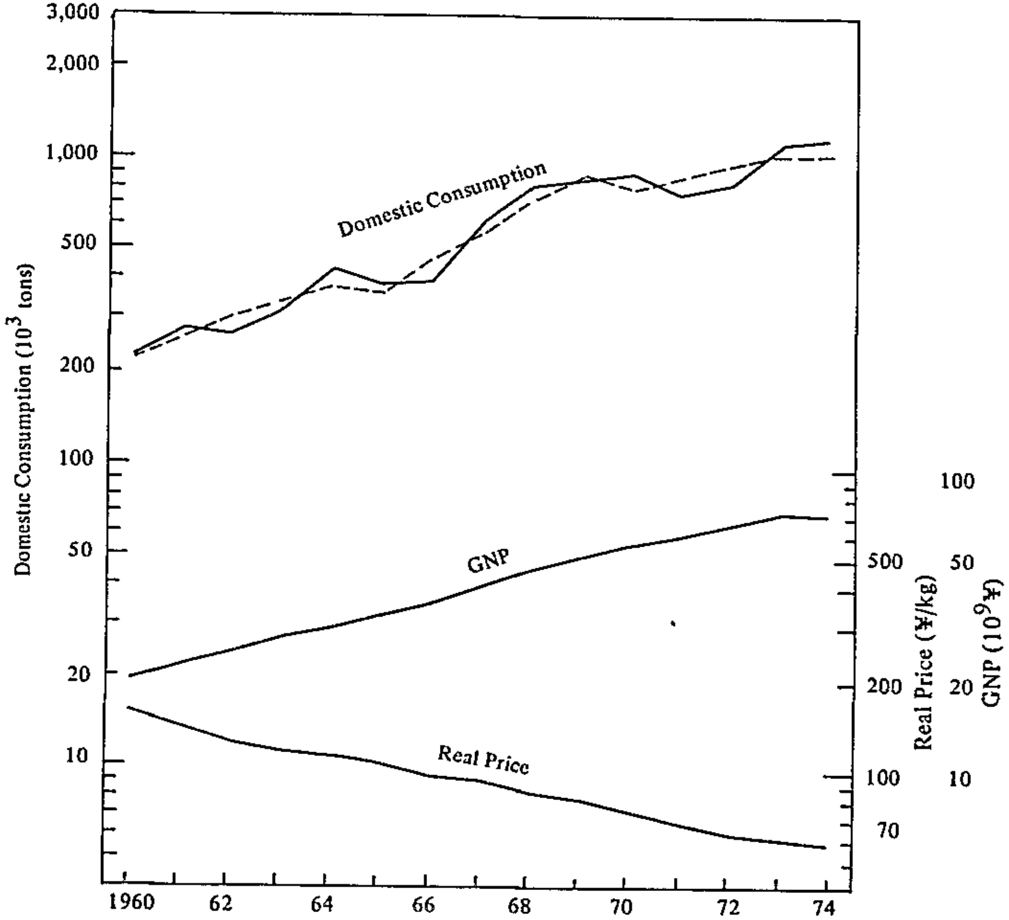


Fig. AII—6 (Cont'd)

Because all of the above elasticities are apparent elasticities, it is not possible to compare GNP elasticities for different years. As an example of the convension from apparent to absolute elasticity, for PE and PP the results are as follows.

	Absolute GNP Elasticity	
	PE	PP
First half of 1960s	0.54	1.01
Second half of 1960s	0.62	0.85
First half of 1970s	0.39	0.33
Average	0.52	0.73

Even after this correction is made, it is evident that there was a marked decline of GNP elasticity of general-purpose plastics during the 1970s. The reason elasticity of PP was high during the first half of the decade is thought to be that this was a time when there was a vigorous substitution for other products in keeping with the new introduction of PP, and it is thought that the reason the elasticities of PE and PP declined during the first half of the 1970s is that the structure of demand for both resins underwent a change relative to what it was in the 1960s. As one manifestation of this, mention may be made of the emergence of a problem regarding pollution relating to discarding and disposal of plastic wastes, the supply shortage and the price hike since 1973.

It is not possible to go beyond this in elasticity analysis which is merely use of a macro model, and therefore it is necessary to make use of multiple correlation on the basis of a study of the structure of the market, in order to anticipate what the demand of plastics will be in Japan.

Price elasticity, similar to GNP elasticity, requires time series data for absolute elasticity values, but because this involves a problem regarding determining the price during the entry phase, and the minimum price, it is not taken up in this study report.

4–2 South Korea and the Philippines

As mentioned above, with regard to the examples of South Korea and the Philippines, elasticity analysis has been performed, and the values obtained by use of the econometric model thereby obtained are compared with actual or observed values in Figs. AII-7 and AII-8.

A significant spread is evident in the Philippines for PE and PP (see Fig. AII-8) between the calculated quantity of demand and the observed demand, in 1973; this is thought to reflect surplus stock not included in the model.

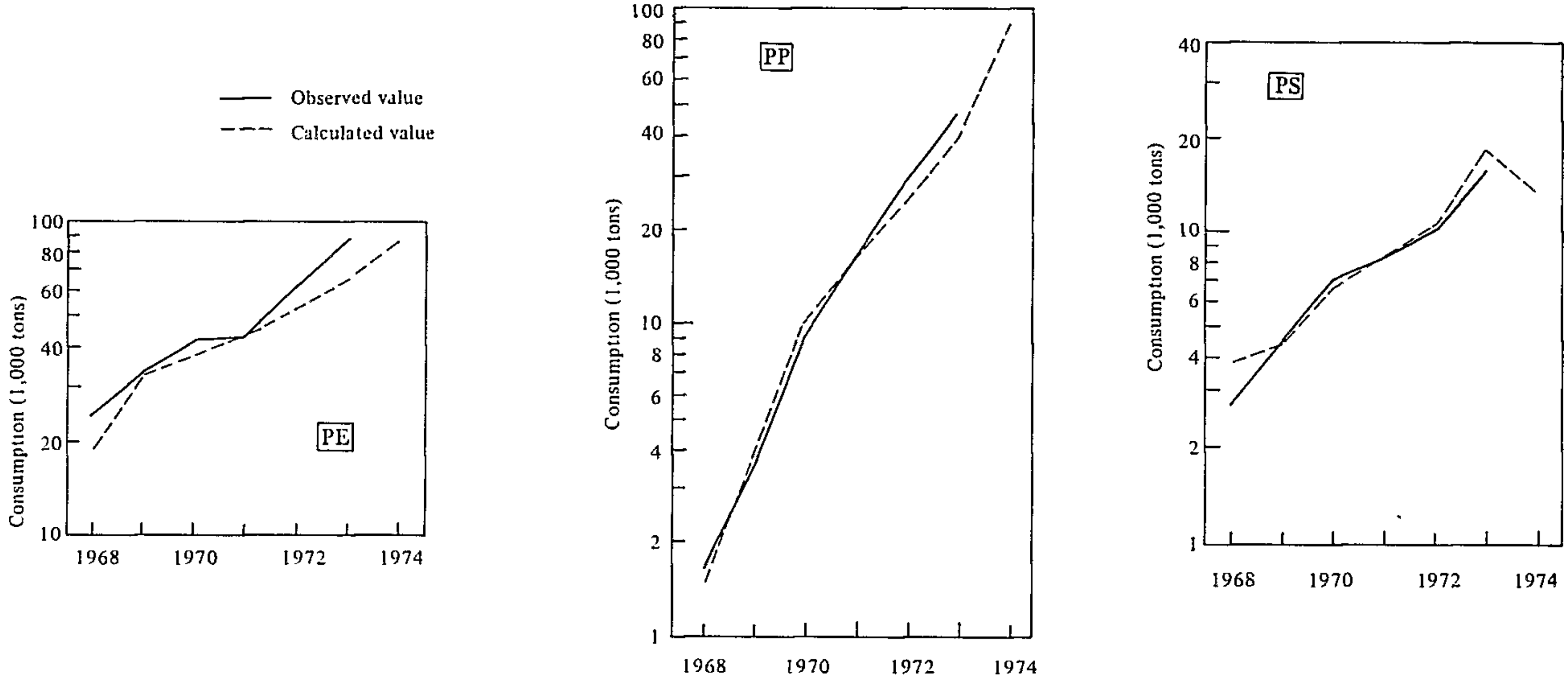
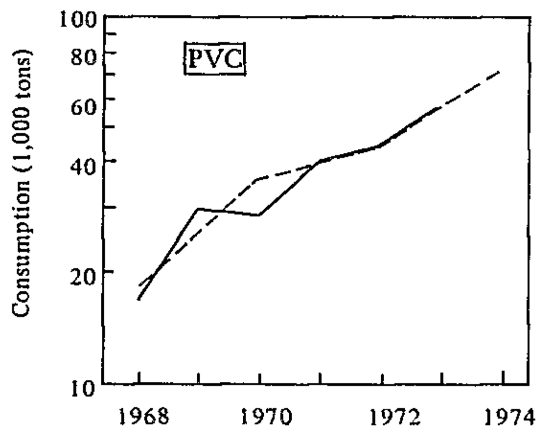


Fig. AII—7 COMPARISON OF OBSERVED VALUE AND CALCULATED VALUE OF PLASTIC CONSUMPTION IN KOREA



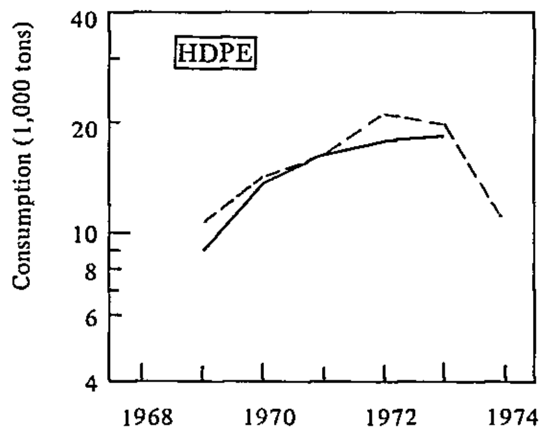


Fig. AII—7 (Cont'd)

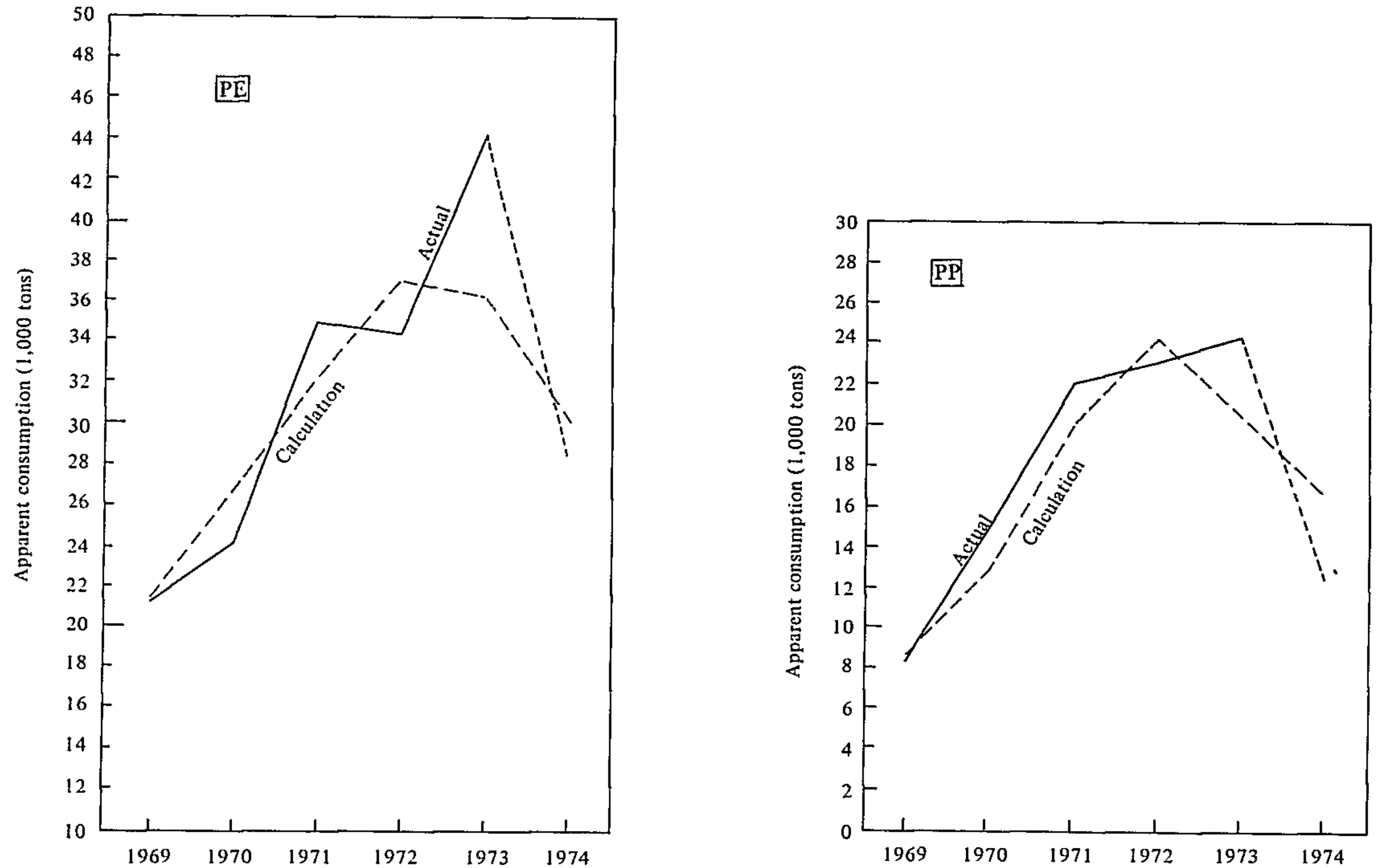
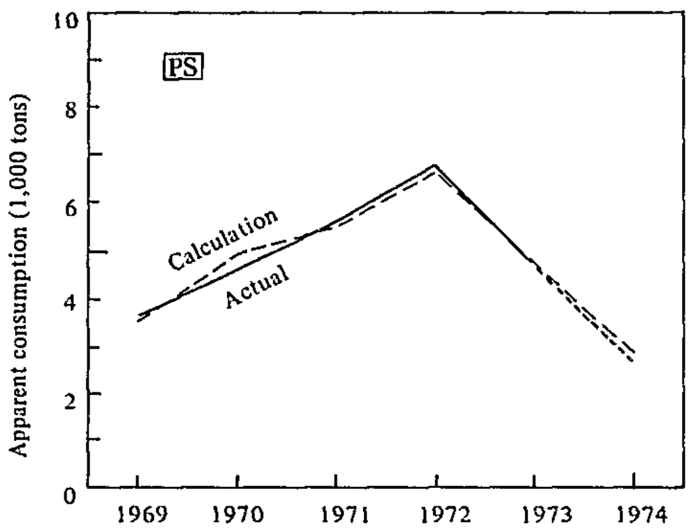


Fig. AII–8 TREND OF DEMAND QUANTITY OF GENERAL-PURPOSE RESINS IN THE PHILIPPINES



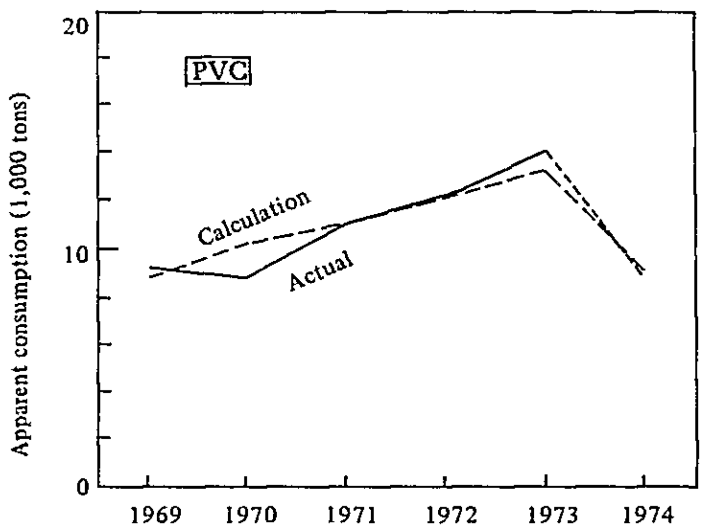


Fig. AII–8 (Cont'd)

A comparison of apparent elasticities in these countries for general-purpose resins and those in Japan is provided in Table AII-2. In this table, the values for Japan are averaged for 1960 – 1972.

In general, for each resin, the GDP elasticity is higher in South Korea and the Philippines than it is in Japan, and the price elasticity is lower than in Japan. This can be taken to represent an apparent difference due to the different time when each plastic, such as PE, was introduced to each country's market. For instance, absolute GDP ealasticities are calculated to be as follows in the Philippines.

	Absolute GDP Elasticities
PE	0.62
PP	0.97
PVC	0.90

These values resemble absolute elasticities from the former half of the 1960s to the latter half of the 1960s in Japan. That is, it is suggested that overall demand for plastics in the Philippines has almost the same structure as existed in Japan during the period of sustained expansion.

Table AII–2 THREE-NATION COMPARISON OF ELASTICITIES OF PLASTICS

	Elasticity	PE	PP	PS	PVC
Japan	Price	1.32	1.55	1.24	0.90
	GNP	1.02	1.74	1.48	0.64
Korea	Price	1.01	2.48	0.93	0.63
	GNP	1.32	3.44	2.05	1.34
Philippines	Price	0.68	1.16	1.15	0.60
	GNP	1.89	3.15	1.50	1.74

In this way, for understanding the present macro structure of demand, elasticity analysis is extremely useful, and can also indicate some of the problems which may be expected in regard to demand in the future. But in order for it to be useful for projecting demand for the medium term – patting the question of short-term projection aside – it is necessary for projections to be made of the coefficient of elasticity itself. This resembles the way that change in industrial structure and in input coefficients must be taken into consideration when using an industrial input/output model to forecast future conditions.

In the foregoing, differentiating between apparent and absolute elasticities is advocated but there are no guaranties that absolute elasticity coefficients will not change in the future, so it is necessary to estimate the future coefficient by use of other projection methods, including therein international cross-section analysis. In particular, in the case of plastics, it is necessary not only to take into account factors such as inflation but also the effects of external factors such as increases in crude oil prices, or the influence of policy on price increases.

PART III RAW MATERIALS STUDY

PART III RAW MATERIALS STUDY

CHAPTER 1 ETHANE AS ETHYLENE PLANT FEEDSTOCK

1–1 OUTLINE OF GAS PROCESSING PLANT

PTT is promoting a project for transporting natural gas from wells in the Bay of Siam to Rayong through a submarine pipeline, and constructing a plant for natural gas processing in this district. The natural gas is obtained from two gas fields which are 425 km (Union Field) and 595 km (Texas Pacific Field) off the coast of Rayong respectively; the natural gas supply schedule is as shown in Table III-1.

While various projects for effective use of the natural gas are under study and review, at the present time the projects which are to be realized first are one for utilizing the gas as fuel for power generation, and another project for separating LPG and natural gasoline from the gas, to be used as fuel for domestic sale and for blending of gasoline.

Installation of an offshore and onshore pipeline for natural gas has been started and is smoothly progressing. Further, a dew point control unit intended to separate heavy fraction from natural gas is now under construction at Rayong. Both are to be completed by the end of July, 1981.

Basic design of a gas processing plant for LPG separation, to be mechanically completed by the end of 1983, is now being prepared. In addition to this, work is proceeding on the basic design for recovering ethane simultaneously with separation of LPG and natural gasoline in the gas processing plant; the recovered ethane is to be used as ethylene plant feedstock. Table III-2 shows the natural gas composition. The block flow diagram of the gas processing plant is illustrated in Fig. III-1.

(1) Dew point control unit

Natural gas, transported through the submarine pipeline, is considered to be almost equal in temperature to the sea water; morever, it is considered that the heavy hydrocarbon fractions[1)] are in a state of saturation at this temperature. When the gas is further cooled due to change in atmospheric temperature, there is a risk that a part of the heavy hydrocarbon fractions will condense, resulting in a liquid-vapor mixed flow. To prevent this from occurring in the onshore portion of the pipeline, the natural gas must be cooled to an adequate temperature until the heavy hydrocarbon fractions are condensed and separated. The dew point control unit is a plant installed for this purpose and is a facility necessary for onshore

1) This refers to C_5 heavier (hydrocarbon) in this case.

Table III–1 NATURAL GAS SUPPLY SCHEDULE

(Unit: MMSCFD)

Fiscal Year (Oct–Sept)	UNION "A" 12	UNION "K" 10	UNION "B" 13	TEXAS "B" 15	Total — MMSCFD	Caloric Value BTU/SCF
1982	200				200	1,060
1983	250	75			325	1,067
1984	250	125	75	150	600	1,005
1985	250	125	125	200	700	998
1986	250	125	125	250	750	983
1987	250	125	125	250	750	983
1988	250	125	125	250	750	983
1989	250	125	125	250	750	983
1990	250	125	125	250	750	983
1991	250	125	125	250	750	983

Note: Natural Gas Production of UNION "K" 10 may be at the level of 250 MMSCFD from 1986.

Table III–2 NATURAL GAS COMPOSITION

	UNION "A"		UNION "K"		UNION "B"	TEXAS PACIFIC "B"	
Component	Mole %	Wt %	Mole %	Wt %	Mole %	Mole %	Wt %
Nitrogen	0.90	1.00	1.55	1.77	0.907	0.78	0.82
Methane	63.34	40.17	68.46	44.96	66.648	61.00	36.52
Carbon dioxide	17.20	29.92	13.67	26.63	12.380	31.97	52.51
Ethane	10.61	12.61	6.98	8.60	9.928	3.71	4.16
Propane	5.17	9.01	5.47	9.86	5.693	1.15	1.89
Isobutane	1.07	2.46	1.39	3.31	1.410	0.32	0.69
n-Butane	0.89	2.04	1.36	3.23	1.339	0.27	0.59
Isopentane	0.28	0.80	0.44	1.29	0.432	0.14	0.38
n-Pentane	0.14	0.40	0.33	0.98	0.339	0.08	0.22
Hexane	0.12	0.41	0.18	0.63	0.265	0.14	0.45
Heptane	0.12	0.48	0.07	0.29	0.264	0.19	0.71
Octane	0.12	0.54	0.07	0.34	0.264	0.19	0.81
Nonane	0.03	0.15	0.02	0.10	0.066	0.05	0.24
Water	0.01	0.01	0.01	0.01	0.015	0.01	0.01
Total	100.00		100.00		100.00	100.00	
Gross Heating Value	1,060 BTU/SCF		1,091 BTU/SCF		1,145 BTU/SCF		771 BTU/SCF
Specific Gravity	0.876		0.848			0.886	

Note: Texas Pacific Composition for Heptane, Octane and Nonane has been assumed based on a given Heptane plus fraction of 0.43 mole percent.

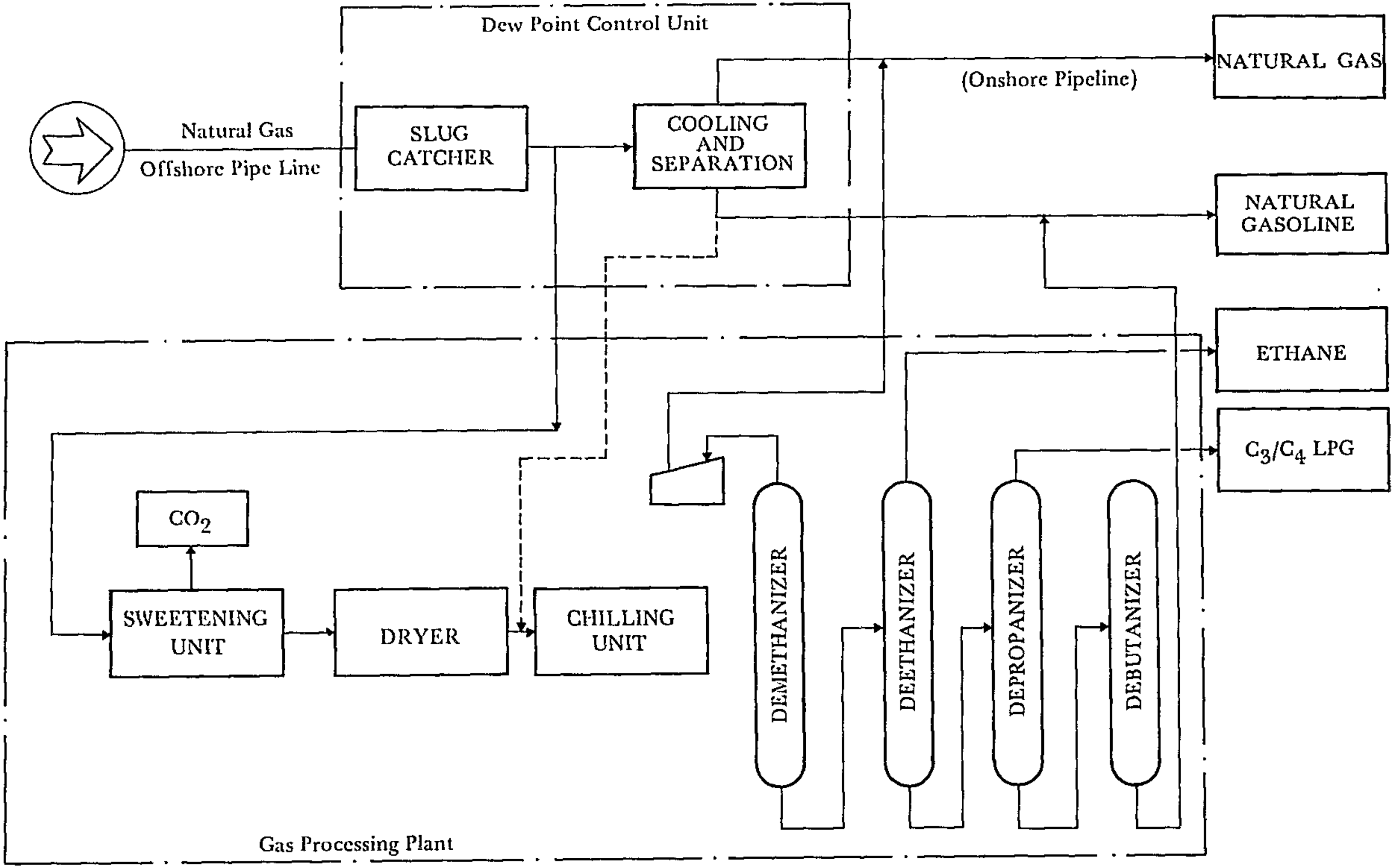


Fig. III–1 BLOCK FLOW DIAGRAM FOR GAS PROCESSING PLANT

transportation of natural gas through a pipeline. However, according to the natural gas composition (Table III-2) the heavy hydrocarbon content in this natural gas is low. Thus, the heavy fractions to be separated in this dew point control unit is estimated to be only about 0.5%.

(2) Gas processing plant

In the dew point control unit, only a part of the heavy fractions in the gas is separated while hydrocarbon fractions of high utility including propane and butane remain unrecovered, and as a result are all consumed as fuel gas. Therefore, the gas processing plant is planned with the objective of more effectively utilizing hydrocarbon fractions in the natural gas by recovering such fractions as ethane, propane, butane, and natural gasoline which constitute approximately 15% of the gas. Fractions heavier than C_3, such as propane, butane, and natural gasoline, can be comparatively easily separated from natural gas as liquid for transportation or storage, thus providing more ease of handling as compared to gas, which is a decided advantage in regard to marketing the products.

To separate ethane from material gas, the gas must be cooled to a temperature lower than that for LPG separation. This can be achieved by adding a demethanizer and its related equipment. Since ethane is the optimum material for ethylene production, several plants have been constructed in various parts of the world for separation of ethane from natural gas and use as ethylene feedstock.

PTT's basic design of the gas processing plant is now being prepared with the intention as mentioned above. Given below is an outline description of the process, by referring to the block flow diagram shown in Fig. III-1.

Since a large quantity of carbon dioxide is contained in gas supplied to the gas processing plant, there is a possibility of freezing and solidification troubles caused by moisture and carbon dioxide. This makes it necessary to decarbonate and dehydrate the gas in a preprocessing section.

Upon completion of decarbonation and dehydration, the gas is delivered to the chilling-separation section to be cooled to a temperature low enough to separate ethane. This low temperature level necessary for ethane separation may be attained by means of propane refrigerant for self-cooling generated through a turbo-expander utilizing the pressure of supply gas. The cooled gas (which is in a vapor-liquid mixed flow) is fed to a demethanizer, in which methane fractions are separated as overhead gas while ethane and fractions heavier than this are separated as bottoms. The bottoms in this demethanizer are delivered to a deethanizer, a depropanizer, and a debutanizer, in which ethane, propane, and butane fractions, are separated, leaving the natural-gasoline fraction. The methane at the top of the demethanizer is compressed to a pressure high enough to permit the compressed gas to be mixed with the gas at the outlet of the dew point control unit. This methane, which has been decarbonated, is best suited for use as material for ammonia and methanol production.

Shown below are the gas processing plant design criteria set forth by the PTT as assumptions for this feasibility study.

(a) Plant capacity

1st stage: 350MMSCFD

2nd stage: 350MMSCFD

While the second stage is scheduled to start in 1989, it may be started earlier depending on the demand for LPG.

(b) Design operation time

350 days/year

(c) Average composition of raw gas

Component	mol %
Nitrogen	0.87
Carbon dioxide	20.00
Methane	64.10
Ethane	8.00
Propane	4.50
Isobutane	0.97
n-Butane	0.83
Isopentane	0.26
n-Pentane	0.14
n-Hexane	0.12
Heptane heavier	0.20
Moisture	0.01
Total	100.00

(d) Ethane recovery factor

84.24% (2593.26 lb-mols/hr)

(e) Products

Methane rich gas

Ethane

LPG (propane and butane)

Natural gasoline

Fig. III-2 shows the result of overall balance estimated on the basis of the above criteria.

Since there is no use of ethane before an ethylene plant starts operation, ethane may be delivered together with methane as fuel gas without being separated until that time.

When another train of the gas processing plant is installed, there is a possibility that the dew point control unit can be used as a spare plant.

1–2 ETHANE AVAILABILITY FROM THE GAS PROCESSING PLANT AND SUPPLY CONDITIONS

1–2–1 Ethane Supply Conditions

Ethane as ethylene plant feedstock is to be supplied from the deethanizer of the gas processing plant as described in 1–1. No special technology is required to separate ethane. As long as the gas processing plant is in operation, ethane is "automatically" obtained as ethylene plant feedstock. In such plants the ethane is usually delivered in the state of gas directly to an ethylene plant. When ethane has to be stored in tanks in an ethylene plant, it will be supplied at a required rate as liquid ethane. The ethane storage tank must be installed so that if the gas processing plant suddenly stops due to some reason on another, or if its rate of production temporarily drops, there will not be adverse effects on the ethylene plant operation. It may be sufficient for this purpose to insure that enough ethane – as liquid ethane – required for 4 day's operation of the ethylene plant is on hand.

Shown below are the composition and condition of ethane to be supplied to the ethylene plant.[1]

Ethane feedstock			
Methane		2.0 mol% max.	
CO_2		0.1 mol% max.	
Propane		3.0 mol% max.	
Ethane		Balance	
		Normal	Alternative
Pressure	:	10 kg/cm^2G	20 kg/cm^2G
Temperature	:	Ambient	–7°C
Phase	:	Vapor	Liquid

1) According to PTT.

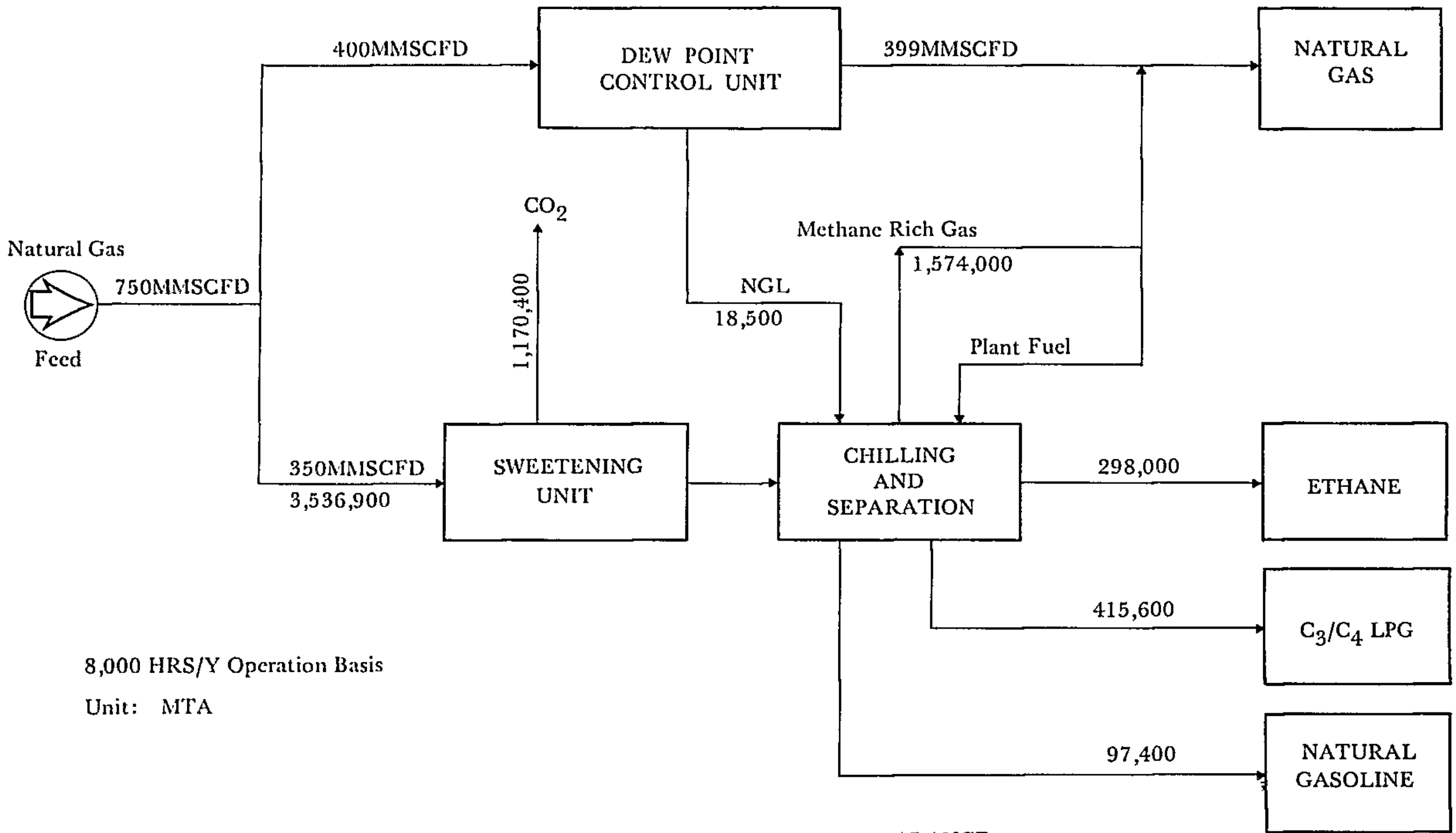


Fig. III–2 ESTIMATED OVERALL BALANCE

Since a gas processing plant and an ethylene plant are planned to be constructed side by side, both plants will be connected through rack-mounted piping for supply of ethane.

1–2–2 Availability of Ethane

From the above-mentioned ethane supply conditions and the design criteria for the gas processing plant given in 1–1, the ethane production in the gas processing plant is estimated at 298,000 t/y (8,000 hours of operation[1]). The design figure of 84.24% for the ethane recovery factor is considered to be the maximum for an ordinary gas processing plant. Thus, this figure of ethane may be regarded as the maximum quantity of ethane which can be delivered from the gas processing plant, during the first stage, to the ethylene plant.

Assuming that an ethylene plant having the capacity of 230,000 t/y is constructed, 277,500 t/y of pure ethane (converted to purity 100%) is required as feedstock. This is converted to 287,000 t/y of the ethane having the above composition. This figure indicates that there is 10,000 tons excess of the quantity of ethane recoverable from the gas processing plant. Hence, this feasibility study proceeds on the assumption that feedstock ethane necessary for producing a minimum of 230,000 t/y of ethylene; that is, 287,000 t/y of specification ethane, can be supplied from the gas processing plant.

1–2–3 Supply Cost

At present, the supply price of ethane feedstock remains to be determined. According to PTT, the guideline for setting the cost is as follows. The minimum opportunity cost of ethane feedstock should be equal to heavy oil on the basis of heating value, while the maximum cost may be equal to that of LPG. The supply price of ethane feedstock, which should have originally been established as a given condition, must be determined conversely by considering the result of this feasibility study. Thus, this will be discussed in the following Parts IV, VII, VIII, and IX.

1) While the gas processing plant is capable of operation of 8,400 hr/y, the ethane availability has been calculated based on 8,000 hr/y of operation.

CHAPTER 2 AVAILABILITY OF SALT

2–1 SOURCE OF SALT

The following two sources of salt supply are conceivable for the electrolysis plant.

(1) Marine salt

Most marine salt is obtained from salt fields located along the seashore from south of the mouth of the Menam Chao Phraya River to the mouth of the Menam Mekong River. Since salt is manufactured by small-scale producers, the quality is poor – the purity is as low as 84 – 85% and there is great dispersion of quality.

(2) Rock salt

There are vast rock-salt deposite in the north-eastern region of Thailand. At present, however, no salt is produced from these deposits for marketing. In the ASEAN Rock Salt – Soda Ash Project, rock salt produced from Bammet Narong district is to be used as crude salt. Because of high purity, the deposits in this district are regarded as a promising source of raw material for this project.

2–2 TRANSPORTATION

(1) Marine salt

Salt fields are located along the national road, and water channels run through salt fields. Thus, salt is transported by truck or small barge. If trucking is used, the cost of transport becomes higher than the salt price FOB at the site of production, depending on the site. It is possible to reduce the cost by using barges for transport lot sizes greater than that carried by trucks for transport to a relay base and by using trucks for transport from there to the plant site.

(2) Rock salt

For the proposed soda ash plant, it is planned to transport rock salt by rail to the plant site in Laem Chabang. It is expected that lowering of the transport cost will be possible by transporting salt by truck from Laem Chabang to the electrolysis plant site.

2-3 TENTATIVE PROCUREMENT OF SALT

Although no problem will occur if this project agrees in timing with the ASEAN Rock Salt – Soda Ash Project, the process has not been made clear yet. In this project, therefore, plans are based on use of sea salt which we consider can be procured without fail.

Regarding the quality of the salt, if the salt makers take measures for improvement, under the guidance of the Government of Thailand, it may not only benefit this project but also make possible to export salt. We consider that rock salt, which is to be used for the soda ash project by the Government of Thailand and is expected to be inexpensive, should also be used for this project in future. The supply price of salt[1)] is estimated at 450 Baht/t (at constant 1980 prices).

1) Delivered price at the industrial salt electrolysis plant, assuming it is constructed at Rayong.

RART Ⅳ COMPARISON OF ALTERNATIVES, AND DETERMINAION OF BASIC CONDITIONS OF THE PROJECT

PART IV COMPARISON OF ALTERNATIVES, AND DETERMINATION OF BASIC CONDITIONS OF THE PROJECT

CHAPTER 1 INTRODUCTION

The objective of this chapter is to determine the optimum conditions from among several alternatives, as the basic conditions of the project, on the basis of the findings and results gained from the study reported in Part II, "Market Study" and Part III, "Raw Materials Study". The most important judgment to be reached herein is the determination of the production scale of the ethylene plant. These basic conditions, comprising those which had previously been identified as conditions for this feasibility study, and those identified during the course of the study, are as follows.

1–1 ETHYLENE PLANT

Production scale: With consideration given to the outlook for ethylene demand in Thailand, and conditions related to raw materials, the most economically rational scale of production is determined.

Location: The location of the ethylene plant has been decided to be Rayong, and the present study is based on this earlier decision.

Raw materials: Ethane fraction, recovered at the PTT gas processing plant[1] (350 MMSCFD)

Project owner: PTT

1–2 VCM PLANT

Production scale: With consideration given to the outlook for PVC demand in Thailand, the most rational scale of production is determined.

Location: The advantages and disadvantages of alternative sites are considered, in view of the supply system for chlorine and ethylene which are needed as raw materials for VCM production; shipment and transport of products; and the economies of integration of production plants, and on the basis thereof the location is decided.

1) Also referred to as the LPG plant.

Raw materials: The most suitable method of supplying chlorine is determined, in view of the outlook for caustic soda demand in Thailand.

Project owner: Not determined.

On the basis of the foregoing matters related to this project, in the following chapters of this part, the basic scheme of the project is determined, by

(1) studying alternatives related to different production scales of the ethylene plant and determining the optimum production scale, and

(2) study of basic conditions related to scale of production, raw materials, location, etc. of the plant for production of VCM.

The parts following this one, which are concerned with technical, financial and economic studies, are in accordance with the basic scheme determined as reported below.

CHAPTER 2 COMPARISON OF ALTERNATIVES WITH REGARD TO THE SCALE OF PRODUCTION OF THE ETHYLENE PLANT, AND DETERMINATION OF THE OPTIMUM PRODUCTION SCALE

2–1 PRELIMINARY DETERMINATION OF ALTERNATIVES REGARDING ETHYLENE PLANT PRODUCTION SCALE AND THE BASIS FOR THAT DETERMINATION

On the basis of the results of the market study and the study of conditions related to raw materials, the following three alternatives were selected for consideration in order to determine the optimum production scale.

Base Case-1:	170,000 t/y ethylene plant
Base Case-2:	200,000 t/y ethylene plant
Base Case-3:	230,000 t/y ethylene plant

Base Case-1 has been defined primarily by market constraints. That is, consideration was given to the ethylene demand of downstream projects presently being constructed or projects now being planned, such as the LDPE plant (73,000 t/y; ethylene equivalent 80,000 t/y[1]), the HDPE plant (50,000 t/y; ethylene equivalent 52,000 t/y) and the VCM plant (80,000 t/y[2]; ethylene equipvalent 38,000 t/y) and the production scale was determined accordingly. This scale is in approximate conformity to the levels of demand of LDPE, HDPE and PVC in Thailand at the end of the Eighties. Base Case-3 is defined primarily by maximum availability of raw material ethane, as an approach to an alternative ethylene scale. As is explained in the consideration of conditions related to raw materials, in Part III, the maximum quantity of ethane which can be recovered from a 350 MMSCFD gas processing plant is 298,000 t/y and if all of this is used as raw material for ethylene production, it is possible to make about 238,000 t/y of ethylene. In this case, no consideration is made of market constraints, and particularly to constraints based on the scale of various downstream project plants which are now under construction or being planned. In other words, in order to absorb 230,000 t/y of ethylene, the need is emphasized[3] for there to either be future expansion of the scale of plants in downstream projects, or new commercialization of ethylene derivatives. Base Case-2 has been additionally provided so that there could be evaluation of an alternative intermediate between Case-1 and -2.

1) According to Thai Petrochemical Industry Co. This is somewhat high in comparison to ordinary levels of ethylene requirements, but this is thought to be because the plant is to be constructed at the distance of 20 km from the ethylene plant, and therefore there is no outlook for recovery and refining of recycled ethylene.

2) See Chapter 3 of this part The scale of the VCM plant is determined to be 80,000 t/y, on the basis of the PVC demand forecasts given in Part II.

3) That is, even if all of the plants in downstream projects now being constructed or planned, such as the LDPE (73,000 t/y), HDPE (50,000 t/y! and VCM (80,000 t/y) plants are constructed and operated at the stipulated capacities, there will still be a surplus of 60,000 t/y of ethylene.

2–2 METHODOLOGY FOR COMPARISON OF ECONOMIC SUPERIORITY

Determination of the suitable production scale of the plant, on the basis of size of the market, availability of raw materials, and other factors, is one of the most vital aspects of the feasibility study.

The petrochemical industry and within that ethylene plant in particular is a typical example of "capital intensive industry" which requires a high level of investment cost. Further, with an increase in plant scale, because the increase in investment cost is moderate in comparison to the increase in scale of production [1], the larger the scale of production (within the limits of the range of commercially proven scales) the lower the cost of production of per unit ethylene production. This is what is generally referred to as "economy of scale." Therefore, with no restrictions such as might arise from conditions related to raw materials, as long as a suitable level of demand exists it is proper to plan construction of, and make corresponding appropriate investment decisions for, a large scale plant where effects of economies of scale may be obtained. However, in actuality there are very few instances when decisions are made solely on the basis of the effects of economies of scale, and it is suitable to consider such inquiries to be hypothetical cases.

At such times as when the scale of the market is limited,[2] and a rapid increase in demand is not expected in the near future, if an ethylene plant is constructed with an initial production capacity which is much larger than current demand, the plant must be operated at a low rate of utilization of capacity for a period of years after the start of commercial operation. In such a case, the diseconomy resulting from low efficiency of the use of invested capital and plant facilities tends to drive the cost of ethylene up through the higher burden of fixed costs.[3] Because of that a tendency arises for it to be unavoidable to produce ethylene at a cost higher than that of a smaller scale plant (with capacity more closely matching demand).

Therefore, it is important to be fully aware that in such circumstances not only is there likely to be a complete absence of the economies of scale which are inherent in capital-intensive industry but instead for the opposite to occur; diseconomies of scale.[4] It is obviously not sufficient to determine production scale only on the basis of the concept of the

1) It is common for the following relationship to exist, with construction cost for production scale C_1 as I_1, and that for production scale C_2 as I_2:

$$I_2 = I_1 (C_2 / C_1)^n$$

Here, n is called the scale factor. Although the value of n varies according to plant type and range, it is often 0.6 to 0.8.

2) Of course in actuality this is a general situation.

3) Referring to depreciation and interest. The problem is particularly serious in cases when borrowings account for a large share of capital invested in plant and equipment.

4) Scale merit turns to scale demerit. Examples may be found in Japan where management of petrochemical projects suffered because of a decision such as this.

economy of scale of the ethylene plant [1] and this is a grave danger for those who must bear responsibility for actual investment decisions.

It would be irrational and facilitate wrong decisions if the economic superiority or inferiority of several alternative ethylene plant scales were to be compared in terms of differences in production cost of ethylene in a base year [2] following the start of plant operation. Further, even if an effort is made to compare ethylene production cost year by year of the 15 years' economic life span of a project, it would not alter the fact that the method was wrong. [3] In other words, it is not possible to determine the suitable production scale from the viewpoint of production cost.

Ultimately it is necessary, to choose from among several alternatives, to compare differences in terms of the opportunity cost of the investment, and to study that case in which the highest opportunity cost of capital is offered. The most rational way to do this is to introduce market conditions as a factor for consideration and in addition to determining the profit-and-loss situation and cash flow balance over the project life span for several alternatives, to make a comparison of the internal rate of return for each alternative.

In accordance with the above line of thought and method, the alternate production scales of the ethylene plant are studied as described below.

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1) Particularly in recent times the rapid increase in the price of hydrocarbons such as petroleum and natural gas has served to increase the ratio of main raw material cost, and to decrease the fixed cost ratio. Therefore it is no longer as effective as in the past to increase ethylene plant scale with the intention of lowering the fixed costs. There is a tendency for a slight change in the cost of raw materials to nullify cost reduction attained by increasing the size of an ethylene plant. This should be readily apparent from the results of study given in this Part.

2) For example, at the time that the plant operation attained full capacity, or when depreciation or repayment of borrowings had passed the 50% mark.

3) For example, see Fig. IV-2.

2–3 BASIS FOR COMPARATIVE STUDY OF ECONOMIC ADVANTAGE

Comparative study was undertaken for the alternative ethylene plant scales through use of data and acceptance of assumptions as given below.

2–3–1 Sales Quantity of Ethylene

This section is based on the results of the market study, given in Part II.

The quantity of ethylene sold will be determined by the situation regarding rates of capacity utilization at the downstream projects, namely the LDPE, HDPE, VCM and other plants. These rates will be determined, in turn, by the domestic Thai demand for LDPE, HDPE and PVC. Therefore to the extent that demand for these plastics does not exceed the limit represented by the production capacity of these downstream plants, domestic demand for LDPE, HDPE, and PVC may be converted to ethylene equivalent which may be considered the ethylene sales quantity for that time period. Moreover, at such a time as when domestic demand has increased to the extent that it exceeds the capacity of downstream plants now being constructed or planned, as is explained in Part II in connection with market aspects, it is expected that at a suitable time the existing facilities' capacity will be expanded. In accordance with this line of thinking, three alternatives were calculated for ethylene plant capacity with the outlook for sale of ethylene taken as according to section 2-1. The results are as follows.

Sales Forecast of Ethylene from Three Alternative Production Capacities of Ethylene Plant in Thailand

	Sales Volume of Ethylene (t/y)		
	Base Case-1 Ethylene Capacity 170,000 t/y	Base Case-2 Ethylene Capacity 200,000 t/y	Base Case-3 Ethylene Capacity 230,000 t/y
1985 (7/12)	67,000	67,000	67,000
1986	142,700	142,600	142,000
1987	149,700	149,700	149,700
1988	170,000	170,600	170,600
1989	170,000	182,600	182,600
1990	170,000	189,400	189,400
1991	170,000	199,300	199,300
1992	170,000	200,000	206,600
1993	170,000	200,000	214,300
1994	170,000	200,000	230,000
1995	170,000	200,000	230,000
1996	170,000	200,000	230,000
1997	170,000	200,000	230,000
1998	170,000	200,000	230,000
1999	170,000	200,000	230,000

2–3–2 Estimation of Investment Amount

For each of the three alternative scales of ethylene plant capacity, the plant cost and amount of investment were calculated, as given below. That it is assumed that the location of the ethylene plant will be within the PTT gas processing plant in Rayong has already been noted. For a more detailed breakdown, see Part VI.

Investment Cost Estimates for Three Alternative Production Capacities of Ethylene Plant in Thailand

(US$ Thousand in constant 1980 prices)

	Base Case-1	Base Case-2	Base Case-3
	Ethylene Capacity 170,000 t/y	Ethylene Capacity 200,000 t/y	Ethylene Capacity 230,000 t/y
Land Aquisition 1)	373	373	373
Plant Cost 2) (as erected)	173,000	180,442	186,605
Pre-operation & Start-up Expenses 3)	7,566	8,104	8,641
Interest During Construction 4)	16,920	17,666	18,292
Total Fixed Capital	197,859	206,585	213,911
Initial Working Capital 5)	5,845	5,875	5,900
Total Capital Investment	203,704	212,460	219,881

Notes:
1) Requirement calculated as 160,000 m^2 for the ethylene plant, and 146,000 m^2 for housing, for a total of 306,000 m^2, acquired at 40,000 Baht/1,600 m^2.
2) Including all of the ethylene plant, tank yard, utilities center and off-site facilities. For details see the capital cost estimate in Part VI.
3) Including the costs of labor before the start of operation and during test operation, training fee, initial cost of business, cost of raw materials and fuel consumed during test operation. For details, see Part VI.
4) Fixed capital; 75% to be obtained as long-term loans and at an interest rate assummed to be 8%. See Part VI.
5) Ethane stock, 3,500 t; ethylene stock, 3,500 t. Sight for accounts payable and accounts receivable, 45 days, assuming that prices of ethylene and ethane are $800/t and $350/t respectively.

2–3–3 Required Raw Materials, Utilities and Staff Quantities and Levels

The requirements of ethane, fuel gas and industrial water (other utilities are to be supplied from the utilities center constructed adjacent to the ethylene plant), as well as of personnel for plant operation are as shown below. For details regarding the utilities balance and composition of the workforce, see Part V.

	Alternative		
	Base Case-1	Base Case-2	Base Case-3
	Ethylene Capacity 170,000 t/y	Ethylene Capacity 200,000 t/y	Ethylene Capacity 230,000 t/y
Ethane (t/y)	212,100	249,530	286,960
Fuel gas[1] (MMBtu/y)	1,494,463	1,758,191	2,021,920
Industrial water[1] (t/y)	2,802,780	3,297,390	3,792,000
Personnel[2]	344	344	344

Notes: 1) For convenience of calculation, requirements for both the ethylene plant and the utilities center are combined. Therefore, it must be noted that this includes some fuel gas and water which will be supplied to outside (e.g., to the VCM plant). For details, see Part V, Table VII-1.

2) Including all of the ethylene plant, tank yard, utilities center and off-site facilities. For details see Part V, Fig. V-25.

2–3–4 Other Assumptions

The internal rate of return (IRR) for each case has been calculated based on the above data, and the relative superiority of the alternatives for ethylene plant production scale were compared. Other assumptions necessary for calculation of the IRR are noted in detail in Part VII which is concerned with financial evaluation; although reference should be made to that part for details, major assumptions are as given below.

(a) Plant construction period: From July, 1982 (award of contract) to March, 1985 (mechanical completion)

(b) Test operation period: April to June, 1985

(c) Start of commercial operation: July, 1985

(d) Economic life span: From July, 1985 to December, 1999

(e) Sources of capital, and financial terms and conditions:

Owner's equity: Assumed as 25% of fixed capital.

Long-term loans: Long-term loans for 75% of fixed capital, and initial working capital, at 8%; grace period, 3 years; repayment period, 10 years (semiannual installments)

Short-term loan: In the event of a capital shortage, short-term loan (one-year) is to be utilized; interest assumed to be 13%.

(f) Depreciation: Straight-line, over the period of 10 years starting from the commencement of commercial operation and not including land acquisition cost.

(g) Products, raw materials, utilities and personnel costs:

Ethylene (product): In view of the trend of ethylene prices in transactions between petrochemical complexes in industrialized countries, and trends of LDPE, HDPE, PVC and other product market prices, sensitivity analysis is to be performed for within the range of US$600 ~ 800/t.

Ethane (feedstock): Same as above. In consideration of the trend of ethylene price, and of the price of fuels, sensitivity analysis is to be performed for within the range of US$200 ~ 400/t.

2–4 COMPARISON OF THE ECONOMIC SUPERIORITY OF THE ALTERNATIVES

On the basis of the methods, assumptions and data as noted in the preceding section, the internal rate of return (IRR) has been calculated for each of the alternatives. The results[1] of calculation are given in Table IV-1. A graphic representation of the results is provided as Fig. IV-1. The results enable the following conclusions to be made.

(1) A large difference in the IRR, or a large difference in economic superiority, can not be recognized among the three alternatives for ethylene production scale (namely, 170,000 t/y, 200,000 t/y and 230,000 t/y). The 170,000 t/y plant has an IRR only about 1% lower than that of the 230,000 t/y plant (there is a slight difference depending on the combination of ethane price and ethylene sales price).

(2) It is evident, from Fig. IV-1, that a differential of this extent [2] can be offset by about US$10/t difference in the ethane price. From this finding it is seen that a difference in the price of ethane feedstock has greater influence than the scale of ethylene production.

(3) Firmly stated, the 200,000 t/y alternative, and the 230,000 t/y alternative, show higher values for the IRR than the 170,000 t/y alternative at all combinations of ethane and ethylene prices, and are the economically superior of the three.

(4) Both the 230,000 t/y plant with an IRR ranging less than about 20%, and the 200,000 t/y plant with an IRR ranging more than about 20%, have relatively high IRR values, but the extent of the difference cannot be said to be significant. Therefore, there is no economic superiority of one over the other. In other words, even if the scale of the ethylene plant is increased from 200,000 t/y to 230,000 t/y, no economic improvement results.

(5) A comparison of the trend of the ethylene production cost [3], year by year from the start of commercial operation in 1985 to 1999 and for each of the three alternatives, is given as Table IV-2. Part of this table is graphically presented as Fig. IV-2. From what

1) It must, however, be noted that the internal rates of return calculated here are principally for comparative purpose. More detailed calculation will be shown in Parts VII and IX

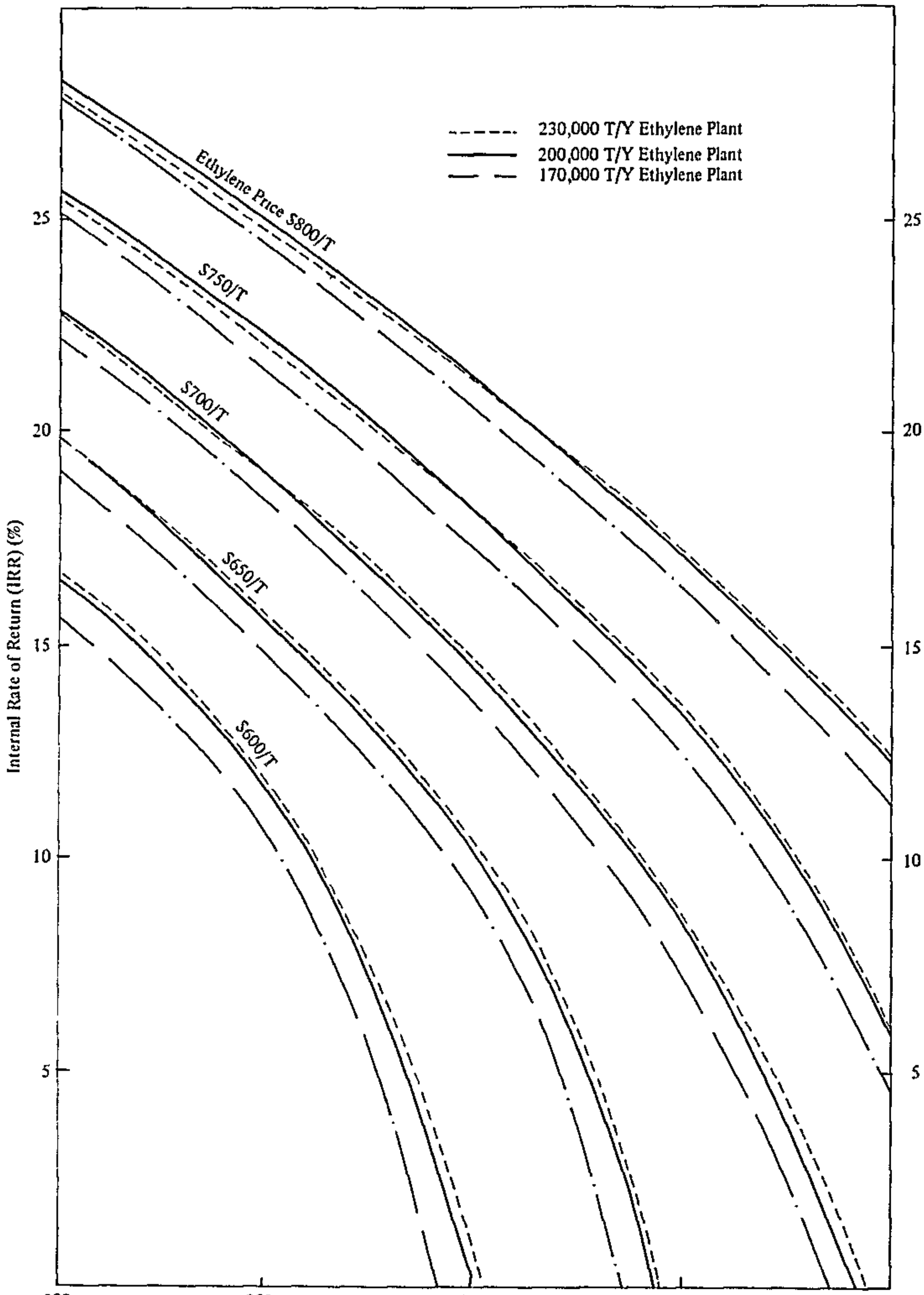
2) If the price at which ethane is supplied is assumed to be US$350/t, it would be only 2.8% of that.

3) Total cost including interest and general administrative costs at the head office.

Table IV–1 COMPARATIVE PRODUCTION ECONOMY (IN TERMS OF IRR) FOR DIFFERENT PRODUCTION CAPACITY OF ETHYLENE PLANT BASED ON DOMESTIC DEMAND IN THAILAND

Selling Price of Ethylene (US$/t) 1)	Price of Feedstock Ethane (US$/t) 1)	IRR (%) Internal Rate of Return (IRR) for Different Production Capacity of Ethylene Plant		
		Ethylene Capacity		
		Base Case – 1 170,000 t/y	Base Case – 2 200,000 t/y	Base Case – 3 230,000 t/y
600	200	15.63	16.51	16.60
	250	10.63	11.62	11.80
	300	0	0.34	0.98
	350	0	0	0
	400	0	0	0
650	200	19.04	19.82	19.80
	250	14.62	15.53	15.65
	300	9.23	10.23	10.40
	350	0	0	0
	400	0	0	0
700	200	22.15	22.83	22.71
	250	18.13	18.93	18.94
	300	13.58	14.52	14.68
	350	7.29	8.51	8.64
	400	0	0	0
750	200	25.03	25.61	25.41
	250	21.31	22.01	21.92
	300	17.19	18.02	18.06
	350	12.49	13.46	13.63
	400	4.25	6.09	6.28
800	200	27.73	28.22	27.93
	250	24.25	24.85	24.67
	300	20.45	21.18	21.12
	350	16.23	17.09	17.11
	400	11.32	12.29	12.46

Notes: 1) In constant 1980 prices.
2) Comparison purpose only.



Note: Comparison purpose only

Fig. IV–1 COMPARATIVE PRODUCTION ECONOMY FOR THREE PRE-SELECTED PRODUCTION CAPACITIES OF ETHYLENE PLANT AT DIFFERENT PRICES OF ETHANE AND ETHYLENE

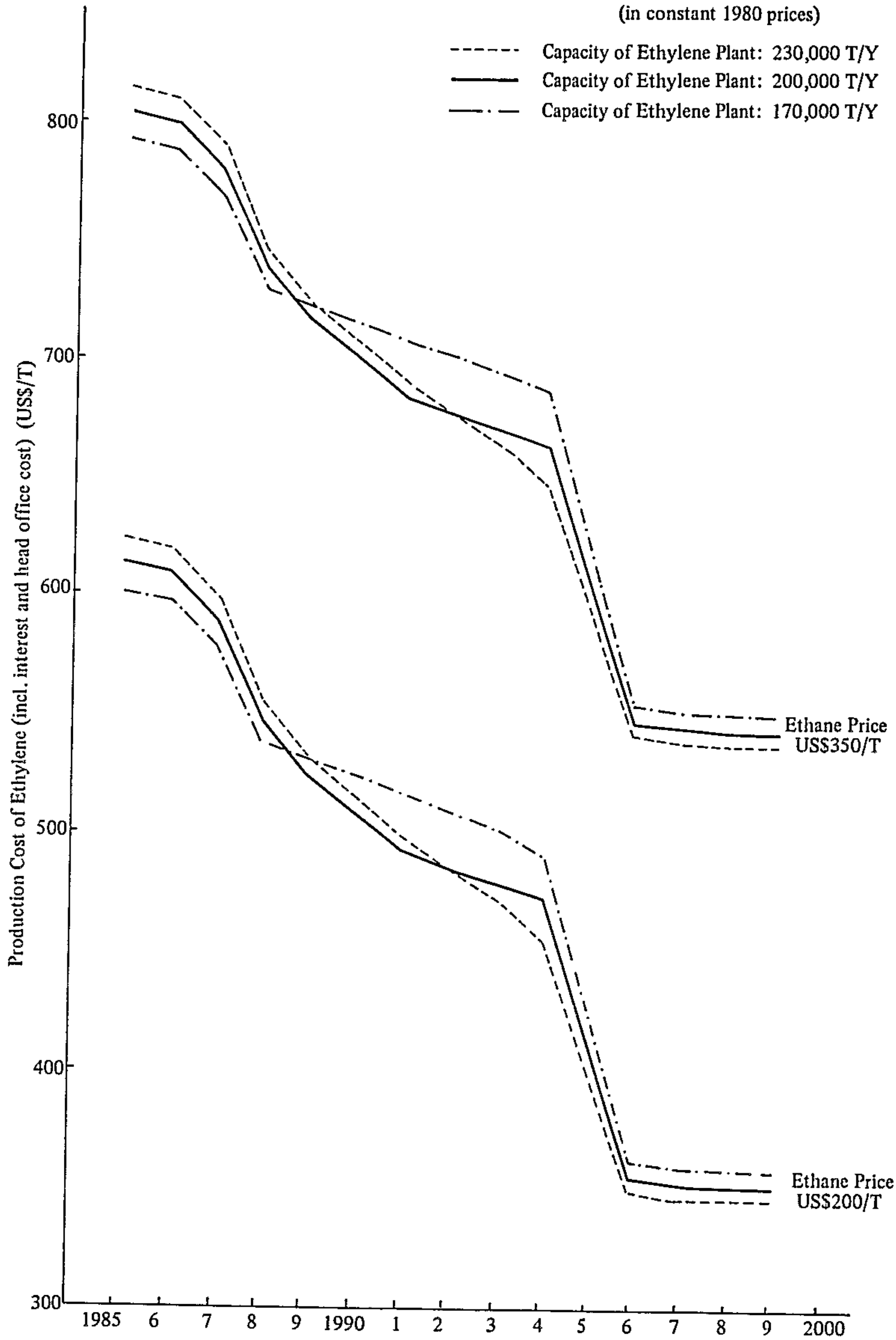
Table IV–2 COMPARATIVE PRODUCTION COSTS OF ETHYLENE FOR PRE-SELECTED PRODUCTION CAPACITIES OF ETHYLENE PLANT AT DIFFERENT PRICES OF FEEDSTOCK ETHANE

(Unit: US$/t of Ethylene in constant 1980 prices)

		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
	170,000	601.1	595.9	577.4	538.2	530.9	523.6	516.3	509.0	501.7	494.4	427.8	362.7	359.5	358.5	358.5
200	200,000	613.6	608.1	588.9	547.1	523.9	509.0	492.2	485.1	478.6	472.2	413.1	355.3	352.5	351.6	351.6
	230,000	624.0	618.4	598.5	555.3	531.3	516.0	498.6	485.1	472.3	454.8	401.6	349.6	347.0	346.2	346.2
	170,000	664.6	659.4	640.9	601.7	594.4	587.1	579.8	572.5	565.3	558.0	491.4	426.3	423.1	422.1	422.1
250	200,000	677.1	671.6	652.4	610.6	587.4	572.6	555.8	548.7	542.2	535.8	476.7	418.9	416.1	415.2	415.2
	230,000	687.5	681.9	662.0	618.8	594.8	579.5	562.1	548.7	535.9	518.4	465.2	413.2	410.7	409.9	409.9
	170,000	728.1	722.9	704.4	665.2	657.9	650.6	643.4	636.1	628.8	621.6	555.0	489.9	486.8	485.8	485.8
300	200,000	740.6	735.1	715.9	674.1	650.9	636.1	619.3	612.2	605.8	599.3	540.3	482.5	479.7	478.8	478.8
	230,000	751.0	545.4	725.5	682.3	658.3	643.0	625.7	612.3	599.4	582.0	528.8	476.8	474.3	473.5	473.5
	170,000	791.6	786.3	767.9	728.7	721.4	714.2	706.9	699.7	692.4	685.2	618.6	553.5	550.4	549.4	549.4
350	200,000	804.0	798.6	779.4	737.7	714.5	699.7	682.9	675.8	669.4	662.9	603.9	546.1	543.4	542.5	542.5
	230,000	814.5	808.8	789.0	745.9	721.9	706.6	689.3	675.8	663.0	645.6	592.4	540.4	537.9	537.1	537.1
	170,000	855.1	850.3	835.2	794.8	785.4	777.7	770.5	763.2	756.0	748.7	682.2	617.1	614.0	613.0	613.0
400	200,000	867.5	862.9	848.2	806.3	782.1	763.2	746.5	739.3	733.0	726.5	667.5	609.8	607.0	606.1	606.1
	230,000	878.0	873.5	859.0	816.6	792.6	773.9	752.8	739.4	726.6	709.2	656.0	604.0	601.5	600.7	600.7

Notes: 1) Production cost including head office cost and interest charges.

2) Comparison purpose only



Note: Comparison purpose only

Fig. IV–2 COMPARATIVE PRODUCTION COST OF ETHYLENE FOR THREE DIFFERENT PRODUCTION CAPACITIES OF ETHYLENE PLANT is shown here, during the first four years of commercial production the plant with the smallest capacity, 170,000 t/y, has the lowest ethylene production cost. During this period the 230,000 t/y plant would have a low rate of utilization, and that would increase the burden of fixed cost in ethylene production cost so that this plant scale would have the highest production cost of the three.

(6) Thereafter scale effects would gradually be attained in accompaniment with expansion of demand, and from the fifth through the eight year the 200,000 t/y plant would have the lowest ethylene production cost. Even though the 170,000 t/y plant would be operating at full capacity at this stage, it would have the highest production cost of the three, and would be higher than that of the 230,000 t/y plant operating at 75 ~ 80% of its capacity. From the ninth year onward, the lowest production cost would be that of the 230,000 t/y plant, and it is at this time that there would be realization of the effects of scale.

Because the IRR discussed above incorporates all of the influences of the economic effects of ethylene plant scale, and the economics of the rate of utilization of plant capacity, it is believed that the IRR is a rational index for comparative evaluation of alternatives for decision-making and selection of the best alternative.

From consideration of the study findings given above, it should be evident that even if it can be assumed that an ethane supply adequate to enable operation of a plant whose capacity is larger than 230,000 t/y is possible, and a plant of that large scale is constructed, that economic effects commensurate with the increment in investment would not be obtained. Therefore, in this situation mentioned above, when LPG fractions including propane and butane are used as ethane supplements[1)] in order to increase the ethylene plant capacity, not only does increasing plant scale fail to improve the return on investment but it also does not help to attain the objectives of effective use of the natural gas resources in Thailand.

For reference, statements giving (a) the IRR calculated on the basis of an anticipated product sales price of US$800/t for the ethylene, and an ethane supply price of US$350/t and (b) calculation of the ethylene production cost are provided as an Attachment to this part.[2)]

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1) In the case of ethane, when there is no opportunity to use it as ethylene feedstock, unlike other LPG fractions, it is mainly used as fuel for power generation, the same as methane, and has the opportunity cost in terms of the calorific value equal to that of fuel oil.

2) Attachment V-1, Base Case – 1 (170,000 t/y ethylene)
Attachment V-2, Base Case – 2 (200,000 t/y ethylene)
Attachment V-3, Base Case – 3 (230,000 t/y ethylene)

2–5 DETERMINATION OF THE OPTIMUM PRODUCTION SCALE OF THE ETHYLENE PLANT

According to the results of the study of market aspects of this project, the ethylene sales price is expected to be about US$800/t.[1] In order to attain an IRR of 15%[2] the supply price of feedstock ethane, from Fig. IV-1, must be as follows.

Base Case-1 (170,000 t/y ethylene): US$364/t
Base Case-2 (200,000 t/y ethylene): US$373/t
Base Case-3 (230,000 t/y ethylene): US$374/t

Even if the ethane supply price is lowered somewhat out of consideration of the risk premium of the project, to US$350/t the project would be feasible for each of these cases. Further, even though there is a degree of difference in the results between the 170,000 t/y plant and the 200,000 t/y plant, or the 230,000 t/y plant, it would be difficult to say that selection of any of the three was irrational.

On the basis of the figures, there is only a slight superiority of the 200,000 t/y plant, or the 230,000 t/y plant, over the 170,000 t/y plant, as noted above.

However, it is not possible to judge the relative superiority of ethylene plant with a scale of 200,000 t/y or 230,000 t/y solely on the basis of the study presented thus far. However, according to PTT the ehtane recovery conditions[3] in the gas processing plant have already been determined, and it is said that the plant should be built in accordance with that. According to PTT, it will be possible to recover about 290,000 t/y of ethane. Therefore, from the viewpoint of the gas processing plant, a question arises as to the scale of income which can be obtained from sale of 290,000 t/y of ethane.[4] Ethane which is not used to produce ethylene, different from LPG and natural gasoline, as fuel for power generation or other industrial uses, is valued no higher than methane. Therefore even if conditions are such that this ethane which is not used as ethylene feedstock can be recovered as pure ethane in the gas processing plant, it only has the same opportunity cost as fuel oil in terms of heat value, namely US$4.218/MMBtu.[5]

1) It is necessary to set the ethylene price at about US$800/t (at constant 1980 prices) in order to enable Thailand to produce LDPE and HDPE at costs competitive with importaing LDPE and HDPE from sources in the international market.

2) It is not possible to simply argue that an IRR above a certain percentage was "feasible" and one blow a certain percentage was "unfeasible". While it depends on the accuracy of the basic data, precision of the demand projection, nature of the project, etc., in this case, if the IRR is above 15%, the project can be judged to be feasible.

3) The recovery rate of ethane in gas entering the gas processing plant is to be 84%, and from the quantity of gas of 350 MMSCFD, it is possible to recover 298,000 t/y of ethane.

4) If there is not such a high demand for ethane for the ethylene plant, even though it is physically possible for the gas processing plant to recover 280,000 t/y of ethane, because there would be no need to use the energy needed to separate any more ethane than is needed by the ethylene plant itself, it is thought that the gas processing plant would be operated so as to meet the ethane requirement of the ethylene plant.

5) According to PTT, equivalent to $25.5/bbl (at constant 1980 prices).

In this case the opportunity cost of ethane can be considered to be US$190/t.[1] The net income which can be expected over a project life of 15 years from the gas processing plant's recovery of 290,000 t/y of ethane, for both a 200,000 t/y ethylene plant and a 230,000 t/y ethylene plant and in accordance with the thinking given above, is shown in Table IV-3. Naturally, for the sales of the same 290,000 t/y of ethane, the income is higher in the case of the 230,000 t/y ethylene plant.[2] The difference is US$40,000,000.

Further, when feedstock ethane (at US$350/t) and fuel ethane (at US$190/t) are pooled the average sales price when a 200,000 t/y ethylene plant is constructed is US$318/t, and when a 230,000 t/y ethylene plant is constructed it is US$328/t, and the latter instance results in the higher price. Consequently even though no significant economic difference can be discerned within the scope of the ethylene project, if the evaluation[3] of the gas processing plant which is external to the ethylene project is incorporated in study of the alternatives, it can be stated that in overall terms construction of the 230,000 t/y ethylene plant is the desirable choice. Therefore in this feasibility study, from the viewpoint of endowing the ethane fraction of the natural gas with the highest value added possible, Base Case-3 (230,000 t/y) is selected. The technical, financial and economic study which follows assumes this scale of ethylene production.

1) The low heat value (LHV) of ethane being 11,349.6 Kcal/kg, US$4,218/MMBtu ethane is equivalent to
$(\$4,218/MMBtu)(11,349.6\ Kcal/kg)(10^{-3})/(0.252) = US\$190/t$

2) To simplify the comparison, the difference in energy cost at the gas processing plant when ethane is recovered, between the two cases, namely production of 230,000 t/y and 200,000 t/y of ethylene, is ignored.

3) Because it too is under the jurisdiction of the PTT

Table IV—3 COMPARISON OF VALUE ADDED TO ETHANE RECOVERED FROM GAS PROCESSING PLANT

(in constant 1980 prices)

				1985 7/12	86	87	88	89	90	91	92	93	94	95	96	97	98	99	Total	
Base Case–2 Ethylene 200,000 T/Y	Utilization of Ethane	As Feedstock to Ethylene Plant @$350/T	Quantity (T/Y)	88,000	178,000	186,800	212,900	227,800	236,300	248,700	249,500	249,500	249,500	249,500	249,500	249,500	249,500	249,500	3,374,500	
			Sales Amount (US$'000/Y)	30,787	62,317	65,374	74,501	79,741	82,711	87,034	87,340	87,340	87,340	87,340	87,340	87,340	87,340	37,340	1,181,185	
		As Fuel @$190/T	Quantity (T/Y)	57,000	112,000	103,200	77,100	62,200	53,700	41,300	40,500	40,500	40,500	40,500	40,500	40,500	40,500	40,500	830,500	
			Sales Amount (US$'000/Y)	10,830	21,280	19,608	14,649	11,818	10,203	7,847	7,695	7,695	7,695	7,695	7,695	7,695	7,695	7,695	157,795	
		Total	Quantity (T/Y)	145,000	290,000	290,000	290,000	290,000	290,000	290,000	290,000	290,000	290,000	290,000	290,000	290,000	290,000	290,000	4,205,000	av. selling price of ethane
			Sales Amount (US$'000/Y)	41,617	83,597	84,982	89,150	91,559	92,914	94,881	95,035	95,035	95,035	95,035	95,035	95,035	95,035	95,035	1,338,950	$318.4/T
Base Case–3 Ethylene 230,000 T/Y	Utilization of Ethane	As Feedstock to Ethylene Plant @$350/T	Quantity (T/Y)	88,000	178,000	186,800	212,900	227,800	236,300	248,700	257,800	267,400	287,000	287,000	287,000	287,000	287,000	287,000	3,625,700	
			Sales Amount (US$'000/Y)	30,787	62,317	65,374	74,501	79,741	82,711	87,034	90,222	93,585	100,441	100,441	100,441	100,441	100,441	100,441	1,268,918	
		As Fuel @$190/T	Quantity (T/Y)	57,000	112,000	103,200	77,100	62,200	53,700	41,300	32,200	22,600	3,000	3,000	3,000	3,000	3,000	3,000	579,300	
			Sales Amount (US$'000/Y)	10,830	21,280	19,608	14,649	11,818	10,203	7,847	6,118	4,294	570	570	570	570	570	570	110,067	
		Total	Quantity (T/Y)	145,000	290,000	290,000	290,000	290,000	290,000	290,000	290,000	290,000	290,000	290,000	290,000	290,000	290,000	290,000	4,205,000	av. selling price of ethane
			Sales Amount (US$'000/Y)	41,617	83,597	84,982	89,150	91,559	92,914	94,881	96,340	97,879	101,011	101,011	101,011	101,011	101,011	101,011	1,378,985	$327.9/T

CHAPTER 3 STUDY OF BASIC CONDITIONS RELATED TO VCM PRODUCTION

3–1 PRODUCTION CAPACITY OF THE VCM PLANT

According to the results of the market study presented in Part II, the outlook for demand of PVC in Thailand is as follows.

	PVC demand (t/y)	VCM equivalent (t/y)
1985	56,100	57,780
1986	61,000	62,830
1987	66,400	68,390
1988	72,200	74,370
1989	78,600	80,960
1990	85,600	88,160

Frequently the production capacity of a plant which is to be newly constructed, as long as there are no special circumstances requiring otherwise, is set at the level equal to demand five years after the start of commercial operation. Not only is this a simple means to determine production scale, it is known from experience that this results in a scale which is close to the most economic scale. This may be understood from comparison of economic superiority of the three alternatives for ethylene plant production scale, discussed in the preceding chapter.

From the usual viewpoint of a private concern, when investment in plant is to be made using borrowed capital, usually allowance can not be made for constructing a large-scale plant to meet the level of demand in the distant future, because of the burden of fixed costs during the intervening period until the plant can be operated at full capacity. Therefore the scale of the VCM plant has been set to match the level of Thai demand five years from the start of commercial operation – that is, 80,000 t/y.

To produce 80,000 t/y of VCM, 48,000 t/y of chlorine are required. If a source of that much chlorine does not exist in such manner and location as can be used for the VCM plant, it is necessary to construct an electrolysis plant having that much capacity for chlorine production. From an industrial salt electrolysis plant of this scale, 51,600 t/y[1] of caustic soda are produced simultaneously with the chlorine.

It therefore becomes important to determine whether the domestic Thai market can absorb that caustic soda, in order to decide on the method of supplying chlorine to the VCM plant.

1) In terms of 50% NaOH solution, 103,200 t/y.

3–2 CHLORINE SOURCES FOR VCM PRODUCTION, AND ACCOMPANYING PROBLEMS

The following methods of supplying chlorine to the VCM plant are conceivable.

(1) Construct a new electrolysis plant (adjacent to the Rayong ethylene plant).

(2) Use surplus chlorine from existing electrolysis plants in Thailand (including that available after expansion of those plants).

(3) Instead of importing VCM, which is now being done, to import EDC, crack it to obtain VCM, use the byproduct hydrogen chlorine to produce EDC through oxychlorination reaction with ethylene produced by this project, and crack that EDC to obtain VCM.

As is noted in the market study, because industries which use large quantities of chlorine, such as petrochemical and pulp industries, are not highly developed in Thailand, demand for chlorine is low in comparison to that for caustic soda and consequently the pattern has emerged of operating electrolysis plants to match the demand for chlorine, and relying on imports to compensate for shortfalls in caustic soda supply. Therefore if there is new demand for chlorine, there is a tendency for it to be necessary to improve utilization of capacity of existing electrolysis plants so as to satisfy demand for caustic soda, and to plan construction of a new plant or plants. But there is virtually no possibility of succeeding in use of the second method, in view of the location of electrolysis plants and their capacity,[1] and the technical- and economic-related problems which would be encountered in long-distance conveyance of chlorine, in comparison to the conveyance of VCM, caustic soda or industrial salt.

Below is provided a study on newly constructing an electrolysis plant. If the scale of such a plant, (producing 48,000 t/y of chlorine and 51,600 t/y of caustic soda) is constructed in order to supply chlorine to an 80,000 t/y VCM plant which is to be expected to start commercial operation in July, 1985, and operated to meet the VCM plant requirements in 1985 onwards, in this case the supply-and-demand balance for caustic soda[2] is projected to be as follows.

1) There is absolutely no possibility that a new supply of 48,000 t/y of chlorine could be provided from existing electrolysis plants in Thailand, even including expanded capacity planned thus far.

2) See the market study, Part II.

Supply-and-demand outlook for caustic soda in Thailand

(Unit: 1,000 t as 50% NaOH solution)

		1984	1985	1986	1987	1988	1989	1990	1991
Supply	From existing electrolysis plants	122	143.2	152.9	165.3	177.3	185.9	(185.9)	(185.9)
	From new electrolysis plant	–	37.3	81.1	88.2	95.9	103.2	(103.2)	(103.2)
	Total	122	180.5	234	253.5	273.2	289.1	(289.1)	(289.1)
Demand		157	175	226	245	266	288	311	342
Balance		–35	+5.5	+8.0	+8.5	+7.2	+1.1	–21.9	–52.9

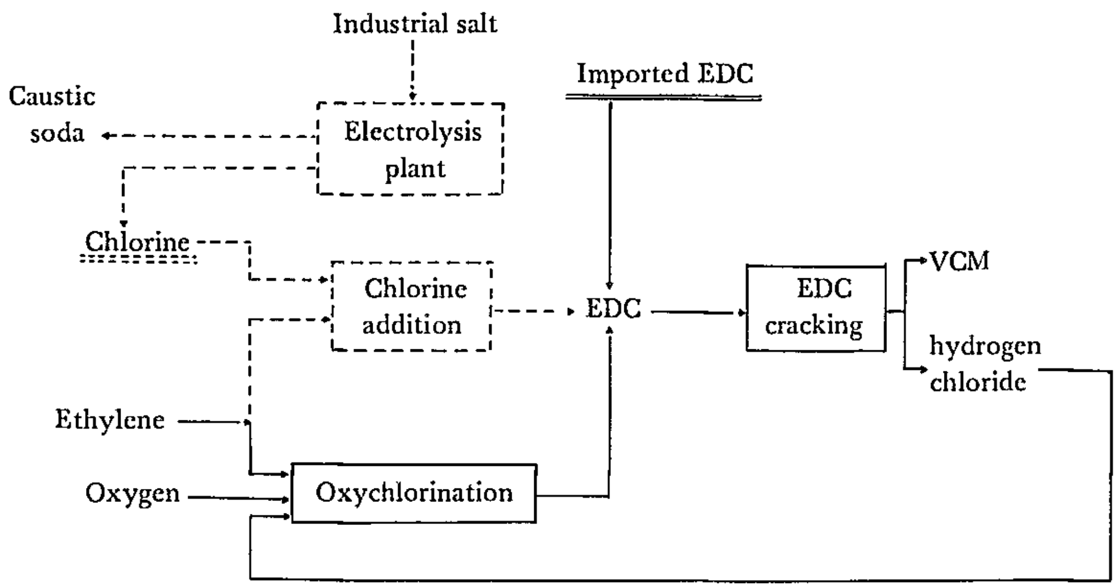
Note: Expansion of plant capacity from 1990 onwards is not taken into account.

If the situation is one of an extreme unbalance of caustic soda supply-and-demand (a large surplus of supply) and if there are no concrete means to rectify this situation, there will be no simple way to justify production of VCM using chlorine supply from a new plant for electrolysis of industrial salt. But the balance is such that the surplus, while substantial, is not enormous and to the extent shown by these results, the supply-and-demand balance for caustic soda in Thailand, will not show a great surplus.

There is cause to welcome a plan to construct a new electrolysis plant, which by supplying caustic soda to the domestic market would substitute for imports which are now necessary because of a shortfall of domestic supply, and would tend to lower the price of caustic soda, so that construction of an electrolysis plant to supply chlorine to the VCM plant is to be welcomed by the Thailand's industrial users of caustic soda. Therefore, the study of the VCM plant in this feasibility study adopts the assumption that the plant will be supplied chlorine from an electrolysis plant constructed for that purpose.

The possibility of importing EDC also exists as an alternative source of chlorine, EDC is a chemically stable intermediate obtained when VCM is produced from ethylene and chlorine; it boils at 83.4°C and is liquid at normal temperatures. In contrast to these properties, VCM boils at –13.9°C, and is gaseous at normal temperatures. Therefore the conveyance of VCM must be done in pressure vessels or by special tankers, as is true for LPG, while in the case of EDC it is easily shipped by an ordinary tanker, it is easy to handle and therefore it is inexpensive to transport. Due to these points, the trend is for world trade in EDC to increase.

The process of producing VCM from ethylene and chlorine normally consists of three major sections namely chlorine addition, EDC cracking, and oxychlorination. As shown in the diagram below, this method involves reacting hydrogen chloride, a byproduct of EDC cracking, with ethylene under the presence of oxygen.



When imported EDC is used as the chlorine source, only the part shown by real lines is enough for VCM production. There is no need for chlorine in this case or, because construction of an electrolysis plant is not required, no attention need be paid to the outlook for the caustic soda market trend in Thailand. Therefore use of imported EDC enables a VCM plant to be planned with no need to take this problem into account. Besides there being no need to construct an electrolysis plant, the chlorine addition section is not required in the VCM plant, and all that is needed is the EDC cracking and the oxychlorination sections.

As a consequence of the large reduction in required investment in plant and facility which this makes possible, in such cases as when there are constraints on acquisition of funds, or when it is desired to avoid investing a large sum at one time, the production of VCM from imported EDC is highly attractive.

However, adoption of this process presents a problem in that in comparision to producing VCM from ethylene and chlorine, because this method requires about half of the quantity of ethylene, it makes little contribution to increasing domestic demand for ethylene, or to constructing the ethylene plant so as to be larger in scale, or to facilitating attaining higher rates of utilization of capacity. Further, even though EDC is less expensive than VCM, given the situation wherein VCM can be produced entirely from domestically-available materials, there would be a great reduction in the contribution to the Thai economy made over the long run by this project through the outflow of foreign currency accompanying the importation of EDC. Therefore, the use of imported EDC can be thought of as a satisfactory and realistic method for helping the Thai petrochemical industry grow during an early transition period. By adopting this method, when studying the construction of an electrolysis plant, it is possible to have adequate time to investigate the matter of the caustic soda market and the trend of the chlorine and caustic soda balance, both of which are important. Further, once a system for the supply of chlorine is established through construction of an electrolysis plant, it becomes possible to cease importing EDC at any time as all that is necessary is to expand the VCM plant by equipment so that chlorine addition can be carried out, and in such a case there is no duplication of capital investment. In such a case the EDC cracking and oxychlorination sections are continued just as before.

As noted above, even if an electrolysis plant is newly constructed, because no serious problem is anticipated in regard to the balance of caustic soda supply-and-demand, this feasibility study has been carried out on the assumption that such a plant is to be built, but VCM production based on imported EDC may have to be studied in detail at the implementation stage.

3–3 LOCATION OF THE VCM PLANT

Three alternatives are conceivable as the location of the VCM plant. In each case, an electrolysis plant must be constructed on the same site as the VCM plant. These alternatives are:

Case-1 : Adjacent to the ethylene plant, in Rayong.

Case-2: Adjacent to the LDPE plant under construction by the Thai Petrochemical Industry Co., east of Rayong City.

Case-3: Bangkok[1)]

The characteristics[2)] of the three alternatives are shown in the table on the next page .

In the final analysis, from technical and economical problems related to the transport of ethylene and chlorine, as well as the possible effects of an unforeseeable accident, it is clearly a common-sense, natural decision to locate the VCM production plant together with the electrolysis plant, on a site adjacent to the ethylene plant. The majority of existing VCM plants in the world have been constructed close by both the ethylene and chlorine source, and there are very few instances when a VCM plant has been constructed at independent locations from one of them. [3)]

In this feasibility study, in accordance with this worldwide pattern, and because it has already been decided to locate the ethylene plant in Rayong, as well as in view of the economies possible by centralization of utilities facilities, off-site facilities and infrastructure-related facilities, i.e., to assign high importance to the advantages of an integrated petrochemical complex[4)] and with a long-term vision for development of Thailand's petrochemical industry in mind, it has been assumed, in proceeding with this feasibility study, that the VCM plant and electrolysis plant are to be constructed adjacent to the ethylene plant.

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1) At present, the precise location of a possible Bangkok site has not been determined. Location within the TAPLACO or THASCO sites would be suitable, but neither has enough available space for ethylene receiving facilities, an ethylene storage tank, the VCM plant, the electrolysis plant, and all related utilities and offsite facilities.

2) For general criteria to be used in selecting a site, refer to Chapter 2, Part V

3) Except VCM plants using ethylene and EDC as feedstock, or plants using acetylene as feedstock.

4) In the future as well there will be no reason why PVC production must be done in Bangkok. To an extent matters depend on the level of importance assigned to an existing fact but in principle it is desirable to produce PVC at the site of the VCM plant.

COMPARISON OF ALTERNATE VCM PLANT LOCATIONS

	Case – 1	Case – 2	Case – 3
Receiving feedstock ethylene	Easily done: No problems.	27 km pipe needed. Supply from pipe to the LDPE plant possible.	The most critical criteria. Problems would be presented in the form of facilities for tanker transport of ethylene or for a pipeline, as well as technical and economic problems
Proximity to VCM users and the caustic soda market	Tank lorry transport of caustic soda to users in the Bangkok area. VCM transport by tanker using the jetty built for the LDPE palnt or tank lorry transport to the TAPLACO plant in Bangkok.	Same as left.	If location adjacent to TAPLACO is possible, only caustic soda would require tank lorry transport to users in Bangkok. When that location is not available it will be necessary to transport VCM to TAPLACO.
Construction cost	Integration of utilities facilities waste processing facilities etc with the ethylene plant is possible and reduction of construction cost can be expected.	Relatively high, because construction of a small utilities facility for exclusive use of the plant will be necessary.	Same as left.
Environment and safety	No problem	Same as left	Environmental protection and safely measures stricter than in Case 1 would be needed.
Availability of utilities and their supply prices	Easy availability. Low fuel price	Fuel gas pipe, parallel to the ethylene pipe, would be needed.	It is not desirable to use fuel oil as fuel for EDC cracking, and fuel price would more than in Case 1.
Thai industrial location strategy	No special problem. Concentration of natural gas based industry in the Rayong area is in accord with Thai industrial policy.	Almost same as left.	Not known.
Effects of complex integration	Effects of an integrated complex would be expected.	None	None
Infrastructure conditions	Sattahip port. LDPE plant jetty at Rayong; direct access to Bangkok by highway. Telecommunications and other facilities not well developed.	Same as left	Ocean transport in Menam River basin; in general good compared to Case 1.
Other aspects (land, housing, availability of salt, etc.)	Easy to acquire land at low cost. Need to construct employee housing. Salt transport increased but future improvement possible when salt can be supplied from a stockpile to be installed in Laem Chabang.	Same as left.	More difficult and expensive to acquire land than in Case 1 or 2. Reduced need to construct worker housing. Less transport cost for salt.

CHAPTER 4 BASIC CONDITIONS OF THE PROJECT

On the basis of the findings resulting from the study through the preceding chapter, the basic conditions which are to be used for the feasibility study for this project are as enumerated below.

(1) Plant scale

Ethylene plant	:	230,000 t/y
VCM plant	:	80,000 t/y
Electrolysis plant	:	48,000 t/y (as chlorine)
		51,600 t/y (as 100% caustic soda)

(2) Location : Rayong

(3) Raw materials

Ethylene plant	:	Ethane
VCM plant	:	Ethylene and chlorine
Electrolysis plant	:	Industrial salt

(4) Project Owner

PTT	:	Ethylene plant
Not determined[1]	:	VCM and electrolysis plant

1) The outlook in Thailand is for production of downstream petrochemical products other than ethylene to be done by the private sector.

ATTACHMENT IV–1

ATTACHMENT IV–2

ATTACHMENT IV–3

ATTACHMENT IV–1

– COMPARATIVE PRODUCTION ECONOMY FOR PTT ETHYLENE PROJECT –
PRODUCTION COST STATEMENTS
(CASE–1 ETHYLENE 170000 T/Y)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
PRODUCTION	70500.	142700.	149700.	170000.	170000.	170000.	170000.	170000.	170000.	170000.	170000.	170000.	170000.	170000.	170000.
ETHANE	30787.	62317.	65574.	74239.	74239.	74239.	74239.	74239.	74239.	74239.	74239.	74239.	74239.	74239.	74239.
CATALYSTS & CHEMICALS	494.	999.	1048.	1190.	1190.	1190.	1190.	1190.	1190.	1190.	1190.	1190.	1190.	1190.	1190.
RAW MATERIAL COST	31281.	63316.	66622.	75429.	75429.	75429.	75429.	75429.	75429.	75429.	75429.	75429.	75429.	75429.	75429.
FUEL GAS(NG)	2608.	5280.	5539.	6290.	6290.	6290.	6290.	6290.	6290.	6290.	6290.	6290.	6290.	6290.	6290.
RAW WATER	113.	228.	240.	272.	272.	272.	272.	272.	272.	272.	272.	272.	272.	272.	272.
UTILITIES COST	2721.	5508.	5778.	6562.	6562.	6562.	6562.	6562.	6562.	6562.	6562.	6562.	6562.	6562.	6562.
VARIABLE COST	34002.	68824.	72200.	81991.	81991.	81991.	81991.	81991.	81991.	81991.	81991.	81991.	81991.	81991.	81991.
DEPRECIATION (PROCESS PLANT)	8650.	17300.	17300.	17300.	17300.	17300.	17300.	17300.	17300.	17300.	8650.	0.	0.	0.	0.
DEPRECIATION (PRE-INVEST)	378.	757.	757.	757.	757.	757.	757.	757.	757.	757.	378.	0.	0.	0.	0.
DEPRECIATION (INTEREST DUR.)	846.	1692.	1692.	1692.	1692.	1692.	1692.	1692.	1692.	1692.	846.	0.	0.	0.	0.
DEPRECIATION	9874.	19749.	19749.	19749.	19749.	19749.	19749.	19749.	19749.	19749.	9874.	0.	0.	0.	0.
AMORTIZATION	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DEPRECIATION & AMORTIZATION	9874.	19749.	19749.	19749.	19749.	19749.	19749.	19749.	19749.	19749.	9874.	0.	0.	0.	0.
LABOR COST	465.	929.	929.	929.	929.	929.	929.	929.	929.	929.	929.	929.	929.	929.	929.
OVERHEAD	465.	929.	929.	929.	929.	929.	929.	929.	929.	929.	929.	929.	929.	929.	929.
EMPLOYMENT COST	929.	1858.	1858.	1858.	1858.	1858.	1858.	1858.	1858.	1858.	1858.	1858.	1858.	1858.	1858.
MAINTENANCE COST	2595.	5190.	5190.	5190.	5190.	5190.	5190.	5190.	5190.	5190.	5190.	5190.	5190.	5190.	5190.
TAX & INSURANCE	1298.	2595.	2595.	2595.	2595.	2595.	2595.	2595.	2595.	2595.	2595.	2595.	2595.	2595.	2595.
OTHER FIXED COST	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DIRECT FIXED COST	4821.	9643.	9643.	9643.	9643.	9643.	9643.	9643.	9643.	9643.	9643.	9643.	9643.	9643.	9643.
EX-FACTORY PRODUCTION COST	48696.	98216.	101592.	111383.	111383.	111383.	111383.	111383.	111383.	111383.	101508.	91634.	91634.	91634.	91634.
UNIT DIRECT OPERATING COST	0.6908	0.6883	0.6786	0.6552	0.6552	0.6552	0.6552	0.6552	0.6552	0.6552	0.5971	0.5390	0.5390	0.5390	0.5390
HEAD OFFICE EXP.	974.	1964.	2032.	2228.	2228.	2228.	2228.	2228.	2228.	2228.	2030.	1833.	1833.	1833.	1833.
INTEREST ON LOAN NO.1	890.	1647.	1469.	1291.	1113.	935.	757.	579.	401.	223.	45.	0.	0.	0.	0.
INTEREST ON LOAN NO.2	2078.	4051.	3636.	3220.	2805.	2389.	1974.	1558.	1143.	727.	312.	0.	0.	0.	0.
INTEREST ON LOAN NO.3	2078.	4155.	4051.	3636.	3220.	2805.	2389.	1974.	1558.	1143.	727.	312.	0.	0.	0.
INTEREST ON LOAN NO.4	890.	1781.	1781.	1736.	1558.	1380.	1202.	1024.	846.	668.	490.	312.	134.	0.	0.
INTEREST ON LOAN NO.5	234.	468.	468.	456.	409.	363.	316.	269.	222.	175.	129.	82.	35.	0.	0.
INTEREST ON LONG-TERM DEBT	6170.	12102.	11404.	10339.	9105.	7871.	6637.	5403.	4169.	2936.	1702.	705.	169.	0.	0.
INTEREST ON SHORT-TERM DEBT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL PRODUCTION COST	55842.	112282.	115028.	123949.	122715.	121482.	120248.	119014.	117780.	116546.	105240.	94172.	93635.	93467.	93467.
UNIT PRODUCTION COST	0.7921	0.7868	0.7684	0.7291	0.7219	0.7146	0.7073	0.7001	0.6928	0.6856	0.6191	0.5540	0.5508	0.5498	0.5498

ATTACHMENT IV–1 (cont'd)

- COMPARATIVE PRODUCTION ECONOMY FOR PTT ETHYLENE PROJECT -
IRR CALCULATION ON TOTAL INVESTMENT
(CASE-1 ETHYLENE 170000 T/Y)

YEAR	TOTAL INVESTMENT	PROFIT BEFORE TAX	DEPRECIATN	INTEREST ON L-T DEBT	RETURN BEFORE TAX	DISCOUNT FACTOR	(BEFORE TAX) PRESENT VALUE INVEST.	(BEFORE TAX) PRESENT VALUE RETURN	(LESS) INCOME TAX	RETURN AFTER TAX	DISCOUNT FACTOR	(AFTER TAX) PRESENT VALUE INVEST.	(AFTER TAX) PRESENT VALUE RETURN
1982	27080.	0.	0.	0.	0.	1.0000	27080.	0.	0.	0.	1.0000	27080.	0.
1983	61307.	0.	0.	0.	0.	0.8607	52764.	0.	0.	0.	0.8607	52764.	0.
1984	62820.	0.	0.	0.	0.	0.7407	46532.	0.	0.	0.	0.7407	46532.	0.
1985	35580.	176.	9874.	6170.	16220.	0.6375	22682.	10340.	0.	16220.	0.6375	22682.	10340.
1986	0.	1877.	19749.	12102.	33728.	0.5487	0.	18506.	0.	33728.	0.5487	0.	18506.
1987	0.	4732.	19749.	11404.	35885.	0.4722	0.	16945.	0.	35885.	0.4722	0.	16945.
1988	0.	12051.	19749.	10339.	42138.	0.4064	0.	17125.	0.	42138.	0.4064	0.	17125.
1989	0.	13285.	19749.	9105.	42138.	0.3498	0.	14739.	0.	42138.	0.3498	0.	14739.
1990	0.	14518.	19749.	7871.	42138.	0.3010	0.	12685.	0.	42138.	0.3010	0.	12685.
1991	0.	15752.	19749.	6637.	42138.	0.2591	0.	10917.	0.	42138.	0.2591	0.	10917.
1992	0.	16986.	19749.	5403.	42138.	0.2230	0.	9396.	0.	42138.	0.2230	0.	9396.
1993	0.	18220.	19749.	4169.	42138.	0.1919	0.	8087.	0.	42138.	0.1919	0.	8087.
1994	0.	19454.	19749.	2936.	42138.	0.1652	0.	6960.	0.	42138.	0.1652	0.	6960.
1995	0.	30760.	9874.	1702.	42336.	0.1422	0.	6018.	0.	42336.	0.1422	0.	6018.
1996	0.	41828.	0.	705.	42533.	0.1223	0.	5204.	0.	42533.	0.1223	0.	5204.
1997	0.	42365.	0.	169.	42533.	0.1053	0.	4478.	0.	42533.	0.1053	0.	4478.
1998	0.	42533.	0.	0.	42533.	0.0906	0.	3854.	0.	42533.	0.0906	0.	3854.
1999	-6220.	42533.	0.	0.	42533.	0.0780	-485.	3317.	0.	42533.	0.0780	-485.	3317.
TOTAL	180566.				593271.		148572.	148572.		593271.		148572.	148572.

***** INTERNAL RATE OF RETURN ***** 16.19 PER CENT (BEFORE TAX) 16.19 PER CENT (AFTER TAX)

***** PAY-OUT PERIOD ***** 5.80 YEAR (BEFORE TAX) 5.80 YEAR (AFTER TAX)
(THE YEAR WHEN THE TOTAL CAPITAL COST WILL BE PAID OUT BY ACCUMULATED TOTAL RETURN, FROM THE BEG. OF OPERATION)

CAPITAL REQUIREMENTS		SOURCE OF FUNDS	
LAND COST	373.	OWN CAPITAL	49465.
PLANT COST	173000.	LONG TERM DEBT	154241.
PRE-OPE.	7566.	SHORT TERM DEBT	0.
INTEREST	16920.	FINANCIAL RESOURCES	203706.
TOTAL FIXED CAPITAL	197859.		
INITIAL WORKING CAPITAL	5847.		
TOTAL CAPITAL COST	203706.		

ATTACHMENT IV–2

– COMPARATIVE PRODUCTION ECONOMY FOR PTT ETHYLENE PROJECT –
PRODUCTION COST STATEMENTS
(CASE-2 ETHYLENE 200000 T/Y)

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
PRODUCTION	70500.	142700.	149700.	170600.	182600.	189400.	199300.	200000.	200000.	200000.	200000.	200000.	200000.	200000.	200000.
NAPHTHA	33787.	62317.	65374.	74501.	79741.	62711.	87034.	87340.	87340.	87340.	87340.	87340.	87340.	87340.	87340.
CATALYSTS & CHEMICALS	494.	999.	1048.	1194.	1278.	1326.	1395.	1400.	1400.	1400.	1400.	1400.	1400.	1400.	1400.
RAW MATERIAL COST	34281.	63316.	66422.	75695.	81020.	84037.	88429.	88740.	88740.	88740.	88740.	88740.	88740.	88740.	88740.
FUEL GAS(NG)	2606.	5280.	5539.	6312.	6756.	7008.	7374.	7400.	7400.	7400.	7400.	7400.	7400.	7400.	7400.
RAW WATER	111.	228.	240.	273.	292.	303.	319.	320.	320.	320.	320.	320.	320.	320.	320.
UTILITIES COST	2721.	5508.	5778.	6585.	7048.	7311.	7693.	7720.	7720.	7720.	7720.	7720.	7720.	7720.	7720.
VARIABLE COST	37002.	68824.	72200.	82280.	88068.	91348.	96122.	96460.	96460.	96460.	96460.	96460.	96460.	96460.	96460.
DEPRECIATION (PROCESS PLANT)	9022.	18044.	18044.	18044.	18044.	18044.	18044.	18044.	18044.	18044.	9022.	0.	0.	0.	0.
DEPRECIATION (PRE-INVEST)	405.	810.	810.	810.	810.	810.	810.	810.	810.	810.	405.	0.	0.	0.	0.
DEPRECIATION (INTEREST DUR.)	883.	1767.	1767.	1767.	1767.	1767.	1767.	1767.	1767.	1767.	883.	0.	0.	0.	0.
DEPRECIATION	10311.	20621.	20621.	20621.	20621.	20621.	20621.	20621.	20621.	20621.	10311.	0.	0.	0.	0.
AMORTIZATION	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DEPRECIATION & AMORTIZATION	10311.	20621.	20621.	20621.	20621.	20621.	20621.	20621.	20621.	20621.	10311.	0.	0.	0.	0.
LABOR COST	465.	929.	929.	929.	929.	929.	929.	929.	929.	929.	929.	929.	929.	929.	929.
OVERHEAD	465.	929.	929.	929.	929.	929.	929.	929.	929.	929.	929.	929.	929.	929.	929.
EMPLOYMENT COST	929.	1858.	1858.	1858.	1858.	1858.	1858.	1858.	1858.	1858.	1858.	1858.	1858.	1858.	1858.
MAINTENANCE COST	2707.	5413.	5413.	5413.	5413.	5413.	5413.	5413.	5413.	5413.	5413.	5413.	5413.	5413.	5413.
TAX & INSURANCE	1353.	2707.	2707.	2707.	2707.	2707.	2707.	2707.	2707.	2707.	2707.	2707.	2707.	2707.	2707.
OTHER FIXED COST	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
FIXED COST	4989.	9978.	9978.	9978.	9978.	9978.	9978.	9978.	9978.	9978.	9978.	9978.	9978.	9978.	9978.
FACTORY PRODUCTION COST	49302.	99423.	102799.	112875.	118667.	121947.	126721.	127059.	127059.	127059.	116748.	106438.	106438.	106438.	106438.
UNIT DIRECT OPERATING COST	0.6993	0.6967	0.6867	0.6617	0.6499	0.6439	0.6358	0.6353	0.6353	0.6353	0.5837	0.5322	0.5322	0.5322	0.5322
NET FINANCE EXP.	966.	1988.	2056.	2258.	2373.	2439.	2534.	2541.	2541.	2541.	2335.	2129.	2129.	2129.	2129.
INTEREST ON LOAN NO.1	930.	1720.	1534.	1348.	1162.	976.	790.	604.	418.	232.	46.	0.	0.	0.	0.
INTEREST ON LOAN NO.2	2169.	4230.	3796.	3362.	2928.	2495.	2061.	1627.	1193.	759.	325.	0.	0.	0.	0.
INTEREST ON LOAN NO.3	2165.	4338.	4230.	3796.	3362.	2928.	2495.	2061.	1627.	1193.	759.	325.	0.	0.	0.
INTEREST ON LOAN NO.4	930.	1859.	1859.	1813.	1627.	1441.	1255.	1069.	883.	697.	511.	325.	139.	0.	0.
INTEREST ON LOAN NO.5	235.	470.	470.	458.	411.	364.	317.	270.	223.	176.	129.	82.	35.	0.	0.
INTEREST ON LONG-TERM DEBT	6433.	12617.	11889.	10777.	9491.	8204.	6918.	5631.	4345.	3058.	1772.	732.	175.	0.	0.
INTEREST ON SHORT-TERM DEBT	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL PRODUCTION COST	56720.	114029.	116745.	125914.	130531.	132590.	136174.	135231.	133945.	132658.	120855.	109300.	108741.	108567.	108567.
UNIT PRODUCTION COST	0.8045	0.7991	0.7799	0.7381	0.7148	0.7001	0.6833	0.6762	0.6697	0.6633	0.6043	0.5465	0.5437	0.5428	0.5428

ATTACHMENT IV–2 (cont'd)

- COMPARATIVE PRODUCTION ECONOMY FOR PTT ETHYLENE PROJECT -
IRR CALCULATION ON TOTAL INVESTMENT
(CASE-2 ETHYLENE 200000 T/Y)

YEAR	TOTAL INVESTMENT	PROFIT BEFORE TAX	DEPRECIATN	INTEREST ON L-T DEBT	RETURN BEFORE TAX	DISCOUNT FACTOR	(BEFORE TAX) PRESENT VALUE INVEST.	(BEFORE TAX) PRESENT VALUE RETURN	(LESS) INCOME TAX	RETURN AFTER TAX	DISCOUNT FACTOR	(AFTER TAX) PRESENT VALUE INVEST.	(AFTER TAX) PRESENT VALUE RETURN
1982	28250.	0.	0.	0.	0.	1.0000	28250.	0.	0.	0.	1.0000	28250.	0.
1983	63965.	0.	0.	0.	0.	0.8543	54645.	0.	0.	0.	0.8543	54645.	0.
1984	65585.	0.	0.	0.	0.	0.7298	47865.	0.	0.	0.	0.7298	47865.	0.
1985	36995.	-673.	10311.	2433.	16070.	0.6235	23065.	10019.	0.	16070.	0.6235	23065.	10019.
1986	0.	131.	20621.	12617.	33369.	0.5326	0.	17773.	0.	33369.	0.5326	0.	17773.
1987	0.	3015.	20621.	11889.	35526.	0.4550	0.	16165.	0.	35526.	0.4550	0.	16165.
1988	0.	10566.	20621.	10777.	41964.	0.3887	0.	16312.	0.	41964.	0.3887	0.	16312.
1989	0.	15549.	20621.	9491.	45661.	0.3321	0.	15163.	0.	45661.	0.3321	0.	15163.
1990	0.	18930.	20621.	8204.	47756.	0.2837	0.	13548.	0.	47756.	0.2837	0.	13548.
1991	0.	23266.	20621.	6918.	50805.	0.2424	0.	12313.	0.	50805.	0.2424	0.	12313.
1992	0.	24769.	20621.	5631.	51021.	0.2070	0.	10563.	0.	51021.	0.2070	0.	10563.
1993	0.	26055.	20621.	4345.	51021.	0.1769	0.	9024.	0.	51021.	0.1769	0.	9024.
1994	0.	27342.	20621.	3058.	51021.	0.1511	0.	7709.	0.	51021.	0.1511	0.	7709.
1995	0.	39145.	10311.	1772.	51227.	0.1291	0.	6613.	0.	51227.	0.1291	0.	6613.
1996	0.	50700.	0.	733.	51433.	0.1103	0.	5672.	0.	51433.	0.1103	0.	5672.
1997	0.	51259.	0.	175.	51433.	0.0942	0.	4845.	0.	51433.	0.0942	0.	4845.
1998	0.	51433.	0.	0.	51433.	0.0805	0.	4139.	0.	51433.	0.0805	0.	4139.
1999	-6250.	51433.	0.	0.	51433.	0.0688	-430.	3536.	0.	51433.	0.0688	-430.	3536.
TOTAL	188546.				681175.		153396.	153395.		681175.		153395.	153395.

***** INTERNAL RATE OF RETURN ***** 17.06 PER CENT (BEFORE TAX) 17.06 PER CENT (AFTER TAX)

***** PAY-OUT PERIOD ***** 5.83 YEAR (BEFORE TAX) 5.83 YEAR (AFTER TAX)
(THE YEAR WHEN THE TOTAL CAPITAL COST WILL BE PAID OUT BY ACCUMULATED TOTAL RETURN, FROM THE BEG. OF OPERATION)

CAPITAL REQUIREMENTS		SOURCE OF FUNDS	
LAND COST	373.	OWN CAPITAL	51646.
PLANT COST	160442.	LONG TERM DEBT	160816.
PRE-OPERATION AND START-UP	8104.	SHORT TERM DEBT	0.
INTEREST DURING CONSTRUCTION	17666.	FINANCIAL RESOURCES	212462.
TOTAL FIXED CAPITAL	206585.		
INITIAL WORKING CAPITAL	5877.		
TOTAL CAPITAL COST	212462.		

ATTACHMENT IV–3

– COMPARATIVE PRODUCTION ECONOMY FOR PTT ETHYLENE PROJECT –
PRODUCTION COST STATEMENTS
(CASE-3 ETHYLENE 230000 T/Y)

	1985	1986	1987	1988	1989	1990	1991	1992
PRODUCTION	70500.	142700.	149700.	170600.	182600.	189400.	199300.	206600.
ETHANE	30787.	62317.	65374.	74501.	79741.	82711.	87034.	90222.
CATALYSTS & CHEMICALS	494.	999.	1048.	1194.	1278.	1326.	1395.	1446.
RAW MATERIAL COST	31281.	63316.	66422.	75695.	81020.	84037.	88429.	91668.
FUEL GAS(NG)	2608.	5280.	5539.	6312.	6756.	7008.	7374.	7644.
RAW WATER	113.	228.	240.	273.	292.	303.	319.	331.
UTILITIES COST	2721.	5508.	5776.	6585.	7048.	7311.	7693.	7975.
VARIABLE COST	34002.	68824.	72200.	82280.	88068.	91348.	96122.	99643.
DEPRECIATION (PROCESS PLANT)	9330.	18660.	18660.	18660.	18660.	18660.	18660.	18660.
DEPRECIATION (PRE-INVEST)	432.	864.	864.	864.	864.	864.	864.	864.
DEPRECIATION (INTEREST DUR.)	915.	1829.	1829.	1829.	1829.	1829.	1829.	1829.
DEPRECIATION	10677.	21354.	21354.	21354.	21354.	21354.	21354.	21354.
AMORTIZATION	0.	0.	0.	0.	0.	0.	0.	0.
DEPRECIATION & AMORTIZATION	10677.	21354.	21354.	21354.	21354.	21354.	21354.	21354.
LABOR COST	465.	929.	929.	929.	929.	929.	929.	929.
OVERHEAD	465.	929.	929.	929.	929.	929.	929.	929.
EMPLOYMENT COST	929.	1858.	1858.	1858.	1858.	1858.	1858.	1858.
MAINTENANCE COST	2795.	5598.	5598.	5598.	5598.	5598.	5598.	5598.
TAX & INSURANCE	1400.	2799.	2799.	2799.	2799.	2799.	2799.	2799.
OTHER FIXED COST	0.	0.	0.	0.	0.	0.	0.	0.
DIRECT FIXED COST	5126.	10255.	10255.	10255.	10255.	10255.	10255.	10255.
EX-FACTORY PRODUCTION COST	49807.	100433.	103809.	113889.	119677.	122957.	127731.	131252.
UNIT DIRECT OPERATING COST	0.7065	0.7038	0.6934	0.6676	0.6554	0.6492	0.6409	0.6353
HEAD OFFICE EXP.	996.	2009.	2076.	2278.	2394.	2459.	2555.	2625.
INTEREST ON LOAN NO.1	963.	1781.	1586.	1396.	1203.	1011.	818.	626.
INTEREST ON LOAN NO.2	2246.	4360.	3931.	3481.	3032.	2583.	2134.	1685.
INTEREST ON LOAN NO.3	2246.	4492.	4380.	3931.	3481.	3032.	2583.	2134.
INTEREST ON LOAN NO.4	963.	1925.	1925.	1877.	1685.	1492.	1300.	1107.
INTEREST ON LOAN NO.5	236.	472.	472.	460.	413.	366.	319.	271.
INTEREST ON LONG-TERM DEBT	6653.	13050.	12296.	11145.	9815.	8484.	7153.	5822.
INTEREST ON SHORT-TERM DEBT	0.	0.	0.	0.	0.	0.	0.	0.
TOTAL PRODUCTION COST	57456.	115492.	118182.	127312.	131885.	133900.	137439.	139700.
UNIT PRODUCTION COST	0.8150	0.8093	0.7895	0.7463	0.7223	0.7070	0.6896	0.6762

	1993	1994	1995	1996	1997	1998	1999
PRODUCTION	214300.	230000.	230000.	230000.	230000.	230000.	230000.
ETHANE	93585.	100441.	100441.	100441.	100441.	100441.	100441.
CATALYSTS & CHEMICALS	1500.	1610.	1610.	1610.	1610.	1610.	1610.
RAW MATERIAL COST	95085.	102051.	102051.	102051.	102051.	102051.	102051.
FUEL GAS(NG)	7929.	8510.	8510.	8510.	8510.	8510.	8510.
RAW WATER	343.	368.	368.	368.	368.	368.	368.
UTILITIES COST	8272.	8878.	8878.	8878.	8878.	8878.	8878.
VARIABLE COST	103357.	110929.	110929.	110929.	110929.	110929.	110929.
DEPRECIATION (PROCESS PLANT)	18660.	18660.	9330.	0.	0.	0.	0.
DEPRECIATION (PRE-INVEST)	864.	864.	432.	0.	0.	0.	0.
DEPRECIATION (INTEREST DUR.)	1829.	1829.	915.	0.	0.	0.	0.
DEPRECIATION	21354.	21354.	10677.	0.	0.	0.	0.
AMORTIZATION	0.	0.	0.	0.	0.	0.	0.
DEPRECIATION & AMORTIZATION	21354.	21354.	10677.	0.	0.	0.	0.
LABOR COST	929.	929.	929.	929.	929.	929.	929.
OVERHEAD	929.	929.	929.	929.	929.	929.	929.
EMPLOYMENT COST	1858.	1858.	1858.	1858.	1858.	1858.	1858.
MAINTENANCE COST	5598.	5598.	5598.	5598.	5598.	5598.	5598.
TAX & INSURANCE	2799.	2799.	2799.	2799.	2799.	2799.	2799.
OTHER FIXED COST	0.	0.	0.	0.	0.	0.	0.
DIRECT FIXED COST	10255.	10255.	10255.	10255.	10255.	10255.	10255.
EX-FACTORY PRODUCTION COST	134966.	142538.	131861.	121184.	121184.	121184.	121184.
UNIT DIRECT OPERATING COST	0.6298	0.6197	0.5733	0.5269	0.5269	0.5269	0.5269
HEAD OFFICE EXP.	2699.	2851.	2637.	2424.	2424.	2424.	2424.
INTEREST ON LOAN NO.1	433.	241.	48.	0.	0.	0.	0.
INTEREST ON LOAN NO.2	1235.	786.	337.	0.	0.	0.	0.
INTEREST ON LOAN NO.3	1685.	1235.	786.	337.	0.	0.	0.
INTEREST ON LOAN NO.4	914.	722.	529.	337.	144.	0.	0.
INTEREST ON LOAN NO.5	224.	177.	130.	83.	35.	0.	0.
INTEREST ON LONG-TERM DEBT	4492.	3161.	1830.	756.	180.	0.	0.
INTEREST ON SHORT-TERM DEBT	0.	0.	0.	0.	0.	0.	0.
TOTAL PRODUCTION COST	142157.	148550.	136329.	124364.	123788.	123608.	123608.
UNIT PRODUCTION COST	0.6634	0.6459	0.5927	0.5407	0.5382	0.5374	0.5374

ATTACHMENT IV–3 (cont'd)

– COMPARATIVE PRODUCTION ECONOMY FOR PTT ETHYLENE PROJECT –
IRR CALCULATION ON TOTAL INVESTMENT
(CASE-5 ETHYLENE 230000 T/Y)

YEAR	TOTAL INVESTMENT	PROFIT BEFORE TAX	DEPRECIATN	INTEREST ON L-T DEBT	RETURN BEFORE TAX	DISCOUNT FACTOR	(BEFORE TAX) PRESENT VALUE INVEST.	(BEFORE TAX) PRESENT VALUE RETURN	(LESS) INCOME TAX	RETURN AFTER TAX	DISCOUNT FACTOR	(AFTER TAX) PRESENT VALUE INVEST.	(AFTER TAX) PRESENT VALUE RETURN
1982	29228.	0.	0.	0.	0.	1.0000	29228.	0.	0.	0.	1.0000	29228.	0.
1983	60176.	0.	0.	0.	0.	0.8538	56498.	0.	0.	0.	0.8538	56498.	0.
1984	67904.	0.	0.	0.	0.	0.7289	49496.	0.	0.	0.	0.7289	49496.	0.
1985	36213.	-1384.	10677.	6653.	15947.	0.6223	23780.	9924.	0.	15947.	0.6223	23780.	9924.
1986	0.	-1332.	21354.	13050.	33072.	0.5313	0.	17571.	0.	33072.	0.5313	0.	17571.
1987	0.	1578.	21354.	12296.	35228.	0.4536	0.	15980.	0.	35228.	0.4536	0.	15980.
1988	0.	5168.	21354.	11145.	41667.	0.3873	0.	16136.	0.	41667.	0.3873	0.	16136.
1989	0.	14195.	21354.	9815.	45363.	0.3306	0.	14999.	0.	45363.	0.3306	0.	14999.
1990	0.	17620.	21354.	8484.	47458.	0.2823	0.	13396.	0.	47458.	0.2823	0.	13396.
1991	0.	22001.	21354.	7153.	50508.	0.2410	0.	12172.	0.	50508.	0.2410	0.	12172.
1992	0.	25500.	21354.	5822.	52757.	0.2058	0.	10855.	0.	52757.	0.2058	0.	10855.
1993	0.	25283.	21354.	4492.	55129.	0.1757	0.	9684.	0.	55129.	0.1757	0.	9684.
1994	0.	35450.	21354.	3161.	59965.	0.1500	0.	8993.	0.	59965.	0.1500	0.	8993.
1995	0.	47671.	10677.	1830.	60179.	0.1280	0.	7705.	0.	60179.	0.1280	0.	7705.
1996	0.	59636.	0.	756.	60392.	0.1093	0.	6602.	0.	60392.	0.1093	0.	6602.
1997	0.	60212.	0.	130.	60392.	0.0933	0.	5636.	0.	60392.	0.0933	0.	5636.
1998	0.	60392.	0.	0.	60392.	0.0797	0.	4812.	0.	60392.	0.0797	0.	4812.
1999	-6275.	60392.	0.	0.	60392.	0.0680	-427.	4108.	0.	60392.	0.0680	-427.	4108.
TOTAL	195246.				738840.		158575.	158575.		738840.		158575.	158575.

***** INTERNAL RATE OF RETURN ***** 17.13 PER CENT (BEFORE TAX) 17.13 PER CENT (AFTER TAX)

***** PAY-OUT PERIOD ***** 6.02 YEAR (BEFORE TAX) 6.02 YEAR (AFTER TAX)
(THE YEAR WHEN THE TOTAL CAPITAL COST WILL BE PAID OUT BY ACCUMULATED TOTAL RETURN, FROM THE BEG. OF OPERATION)

CAPITAL REQUIREMENTS		SOURCE OF FUNDS	
LAND COST	373.	OWN CAPITAL	53478.
PLANT COST	186605.	LONG TERM DEBT	166335.
PRE-INVEST AND START-UP EXP.	8641.	SHORT TERM DEBT	0.
INTEREST DURING CONSTRUCTION	18292.	FINANCIAL RESOURCES	219813.
TOTAL FIXED CAPITAL	213911.		
INITIAL WORKING CAPITAL	5902.		
TOTAL CAPITAL COST	219813.		

PART V TECHNICAL ASPECTS

PART V TECHNICAL ASPECTS

CHAPTER 1 PROJECT SCHEME

This part of the study report presents the project scheme of the petrochemical complex, in accordance with the examination of alternatives as reported in Part IV and with results of decisions on basic conditions of the project. This project shceme will form the basis for conceptual design of the project which is given in Chapter 4.

1–1 ETHYLENE PLANT

An ethylene plant is to be constructed; it is to use as feedstock ethane to be recovered at the gas processing plant for which PTT is now proceeding with the basic design. On the basis of study of the results in Part IV, it is to have the capacity of 230,000 t/y. This capacity exceeds the 134,000 t/y estimated demand of ethylene at the time of the start of production in 1985 and because this implies operational and economic problems, it is desirable that the following countermeasures be adopted.

(a) Although six cracking furnaces are needed for operation at full capacity, construction of two of them may be postponed to a later time, and at the initial stage four are to be operated.[1)]

(b) Each of the three compressors (for charge gas, propane and ethylene refrigerant) which will consume the greater part of power required by the ethylene plant is to be equipped with a 75% capacity initial rotors, in order to prevent low efficiency during low-load operation times. After the operating load passes the 75% level, they are to be replaced with 100% rotors.

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1) Until the quantity of ethylene production reaches 170,000 t/y.

1–2 DESTINATION OF PRODUCT ETHYLENE

Product ethylene from the ethylene plant is to be supplied to the following downstream projects.

(a) LDPE plant

Supply is to be provided to an LDPE plant being constructed by the Thai Petrochemical Industry Co. at the east of Rayong City. For the planned production volume of 73,000 t/y of LDPE, 80,000 t/y of ethylene are to be supplied. Supply is to be by pipeline from the ethylene plant, and as gas phase ethylene under normal temperature and high pressure conditions.

(b) HDPE plant

Supply is to be provided to an HDPE plant which the Thai United Polymers Co. plans to construct. It is assumed that this plant is to be constructed adjacent to the ethylene plant.[1] Plant capacity is to be 50,000 t/y, for which it will be necessary to supply 52,000 t/y of ethylene.

(c) VCM plant

A VCM plant is to be constructed as part of this project. Plant capacity, as a result of the study reported in Part IV, is to be 80,000 t/y. The quantity of ethylene to be supplied in order to produce this is 38,000 t/y. In accordance with the results and discussion of Part IV, the VCM plant is to be adjacent to the ethylene plant.

(d) Future plants

The quantity of ethylene which the above three plants can consume is 170,000 t/y. From the results of study of market aspects (in Part II) and alternatives (Part IV) it is expected that this level will be attained in 1988. For ethylene production of up to 170,000 t/y, four cracking furnaces and an initial rotor will be enough. Therefore mechanical completion of the other cracking furnaces and installation of an ultimate rotor is to be done in 1988 or thereafter. Because the ultimate production scale of ethylene is 230,000 t/y, there will be a surplus of 60,000 t/y of ethylene. This surplus ethylene is to be supplied to LDPE, HDPE, VCM or other plants to be expanded at or after that time, or consumed as feedstock for new ethylene derivative plants such as EO/EG plants.

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1) According to Thai United Polymers Co.

1–3 ELECTROLYSIS PLANT

On the basis of the results of the study presented in Part IV, it is decided that the source of chlorine for the VCM plant is to be an electrolysis plant to be constructed and operated adjacent to the VCM plant. Chlorine produced there will be supplied to the plant by a pipe. The supply quantity of chlorine needed for an ultimate production level of 80,000 t/y of VCM in 48,000 t/y. This is taken to be the capacity of the electrolysis plant.[1] In this case, the quantity of byproduct caustic soda will be 51,600 t/y.[2] Both the crude salt and caustic soda are to be transported to and from the plant by truck/trailer.

The basic scheme for the above project is shown in Fig. V-1.

1–4 UTILITY CENTER

Stable, uninterrupted operation of the ethylene plant is an indispensable condition for insuring feasibility of this project. On the basis of this, in order to attain high reliability in plant operation, an utility center is to be provided as an adjunct to the ethylene plant. Moreover, in order to improve the economics of the petrochemical complex as a whole, this utility center is to supply utilities also to the downstream VCM, electrolysis and HDPE plants. Electricity will be supplied to the downstream projects by EGAT/PEA.[3]

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1) It is noted in Part IV that even if an electrolysis plant is newly constructed, it will not result in such a great surplus of caustic soda as to represent a problem.

2) As 50% caustic soda aqueous solution, 103,200 t/y.

3) This has been suggested by PTT. In the case of the electrolysis plant in particular, power consumption is high, to the extent that acquiring that much power from the utility center would conflict with policy and laws related to power generation and supply as a public utility.

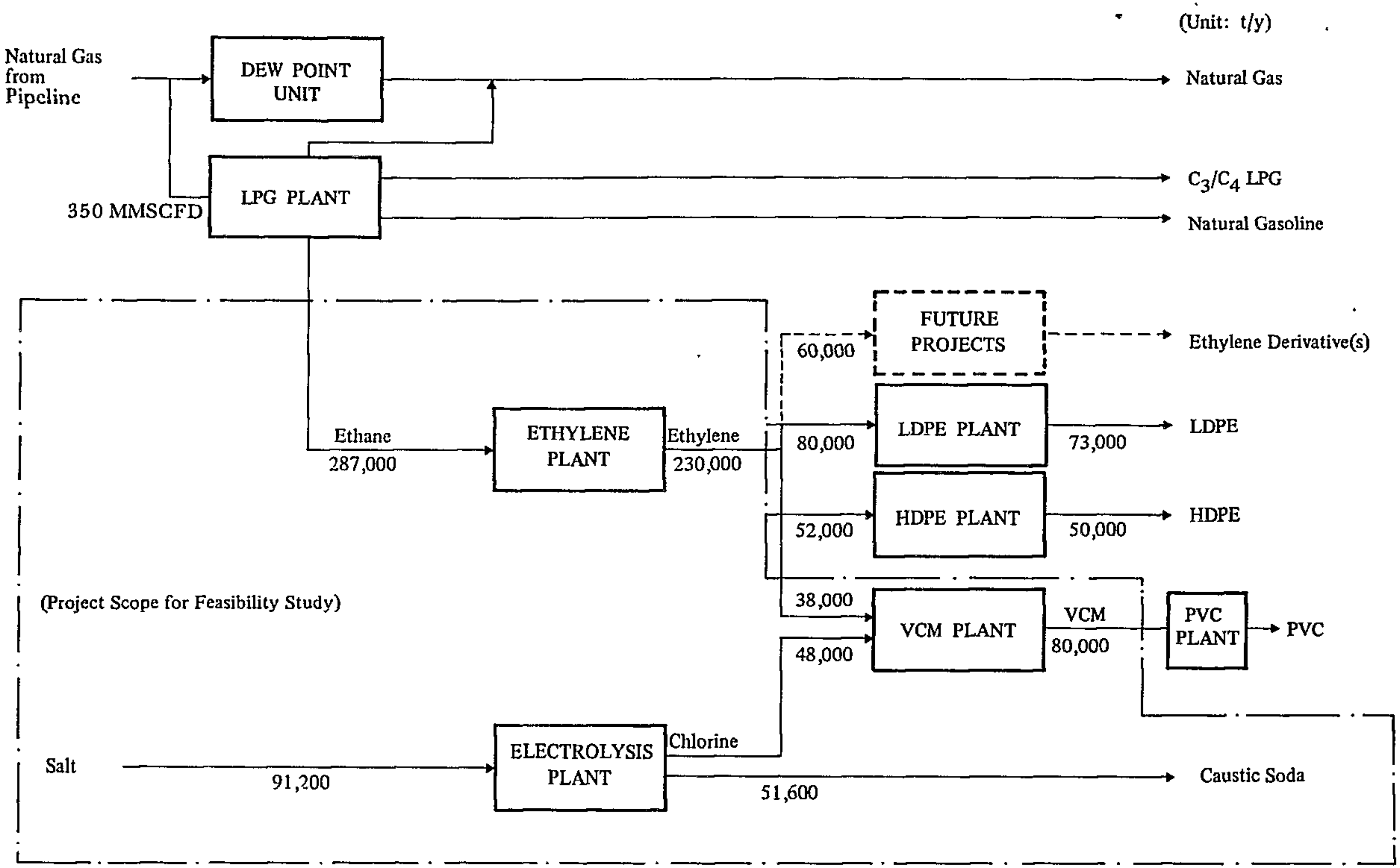


Fig. V–1 BLOCK FLOW DIAGRAM FOR PETROCHEMICAL COMPLEX IN THAILAND

CHAPTER 2 SITE LOCATION AND CONDITIONS

2–1 CRITERIA FOR SITE SELECTION

With the location of the ethylene plant in Rayong being a given condition, as discussed in Part IV, it is desirable for both the VCM plant and the industrial salt electrolysis plant to be located adjacent to the ethylene plant. In this chapter, considerations are given to general features which the site location must satisfy, as enumerated below.

(1) The location must be such that raw materials can be supplied at low cost.

In order to obtain ethane feedstock easily, it is most desirable to locate the ethylene plant adjacent to the gas processing plant. As two sources of industrial salt for the electrolysis plant, marine salt and rock salt are conceivable; both can be supplied from domestic sources. Because a plan for development of rock salt resources has not been adopted as of this time, the study has assumed that marine salt will be used. In this case, supply would be from the Bangkok area, and by truck.[1)]

(2) The location must be such that the product can be transported to points of consumption at low cost.

Product ethylene can be supplied to the downstream VCM and HDPE plants by means of a piping connection. Because the LDPE plant is at a distance of about 27 km, an underground pipeline to that plant would be installed. Product VCM must be supplied to the PVC plant in Bangkok. It is more desirable to transport VCM by tanker than by tank lorry. For this project it has been assumed that use would be made of the shipping jetty constructed at the LDPE plant for receipt of shipments of imported ethylene, for shipment of VCM to Bangkok by means of coastal tanker. The VCM is to be moved from the VCM plant to the jetty area by means of an underground VCM pipeline laid together with the ethylene supply pipeline, to a VCM shipping terminal near the jetty.

The electrolysis plant is to be located adjacent to the VCM plant, and chlorine is to be supplied by means of a piping connection, which will avoid the greater danger inherent in transporting this toxic gas by other means. Byproduct caustic soda is to be shipped directly to users, who are mostly in the Bangkok area, by trailer lorry.

---

1) It has been reported that plans exist for stockpiling of rock salt in Laem Chabang; in such a case, acquisition of industrial salt would be facilitated.

(3) It is desirable for a shipping jetty to be built near to the plant.

Use of railway freight and ocean-going tankers are commonly preferable over use of trucks and trailers for transporting the large quantities of raw materials and products needed or produced by a petrochemical complex. The plant site which is planned to be used, in Rayong, is 5 km from the shore, and the coastal water is shallow, so that for a coastal tanker to be used, a jetty of at least 2 km length would be required. The cost of constructing such a jetty would be a high percentage of total plant construction cost and would impart adverse influence on the economics of the project.

In the course of the field survey, it was ascertained that a jetty is to be constructed for the LDPE plant, now being constructed at a point 20 km east of the location of the PTT ethylene plant.[1] This jetty is being constructed in order to receive shipments of ethylene from abroad, and is being constructed at the point in the region where coastal water is deepest and where a jetty length of one kilometer provides access to a point where water depth is 6 ~ 8 m and where, accordingly, an ocean tanker of several thousand tons can moor.

It is assumed that use may be made of this jetty for the present project, and that shipments of VCM are to be made from it.

(4) The subsurface soil conditions must be such as to be suitable for construction of a large industrial plant.

The proposed site in Rayong is gently sloping and the surface elevation is from 30 m to 40 m; with the exception of one portion of it, the site has suitable bearing strength for a large plant to be constructed.

(5) The location should be separated from densely-populated areas, resort areas, and military installations.

Although technological advances have made it possible to construct petrochemical plants which are non-polluting, when they are to be located in densely-populated areas, measures are needed regarding noise and landscaping. Also, it is desirable for the site to be such that in the event of a fire or explosion at the plant, the neighboring areas would not be subject to the direct effects of such an accident. In this connection, because the Rayong district is sparsely populated, no problem will be encountered in providing a suitable distance around the plant for purposes of safety.

1) Information received at a later time indicates that the construction of the jetty has been begun.

(6) It must be possible to supply the plant with electric power, water, and other utilities which may be required.

It will be possible to obtain electric power from a large-capacity transformer station which EGAT will construct at a site 3 km from the plant site. Water is to be supplied from the Dok Krai reservoir, 20 km inland.

(7) There must be adequate infrastructure, in the form of roads, railroads, harbor facilities, telecommunications, and the like.

With regard to roads, the situation is excellent and Bangkok is 210 km (only 3 hours) away by means of a highway. Railroads are not well developed in the area of the site, and although it is planned that track will be laid to Sattahip (about 37 km west of the site) in 1983, no plans now exist for providing rail service to Rayong. There is a deep sea port at Sattahip, and it is desirable for the equipment and materials for the plant to be landed there. Although the location is well suited for the shipping facilities of products, Sattahip being a military port, it is not expected to be easy to obtain authorization for permanent use of the port for shipping products. It is therefore judged that the use of the LDPE plant jetty, as noted above, is more realistic. Telephone service is the major form of telecommunications which would be required, but transmission lines servicing the Rayong district are not adequate in view of the demand, and there are often difficulties in placing calls to Bangkok. It will be suitable to make use of radio equipment which is provided at the gas processsing plant.

2–2 CONDITIONS AT THE PROPOSED SITE

2–2–1 General Conditions

The industrial estate in which the gas processing plant and ethylene plant are to be situated, is located in the central part of Thailand, and are to be supplied with natural gas by means of a pipeline from wells in the Bay of Siam. This industrial estate is about 37 km east of Sattahip harbor, on the south side (ocean side) or Route 3, about 20 km west of Rayong City, Rayong Province. The site, which is about 5 km from the shore, is now primarily fields and woods. Rayong is the city nearest to the estate site, and is the seat of government for the province. Agriculture and fisheries are flourishing, and in some places there are shrimp farms.

2–2–2 Location and Area

The designation of the location is Amphoe Muang, Changwat Rayong. The area of land which PTT has acquired for the industrial estate is 800 rai (1,280,000 m^2).

2–2–3 General Description of Rayong City

Agriculture and fisheries are the major industries of Rayong City. At present there is no manufacturing industry there. This is one of the two locations in Thailand where shrimp farming is being undertaken. The population of the city is 330,000. There are banking, hotel, hospital and other facilities of various kinds.

2–2–4 Geological Conditions at the Site

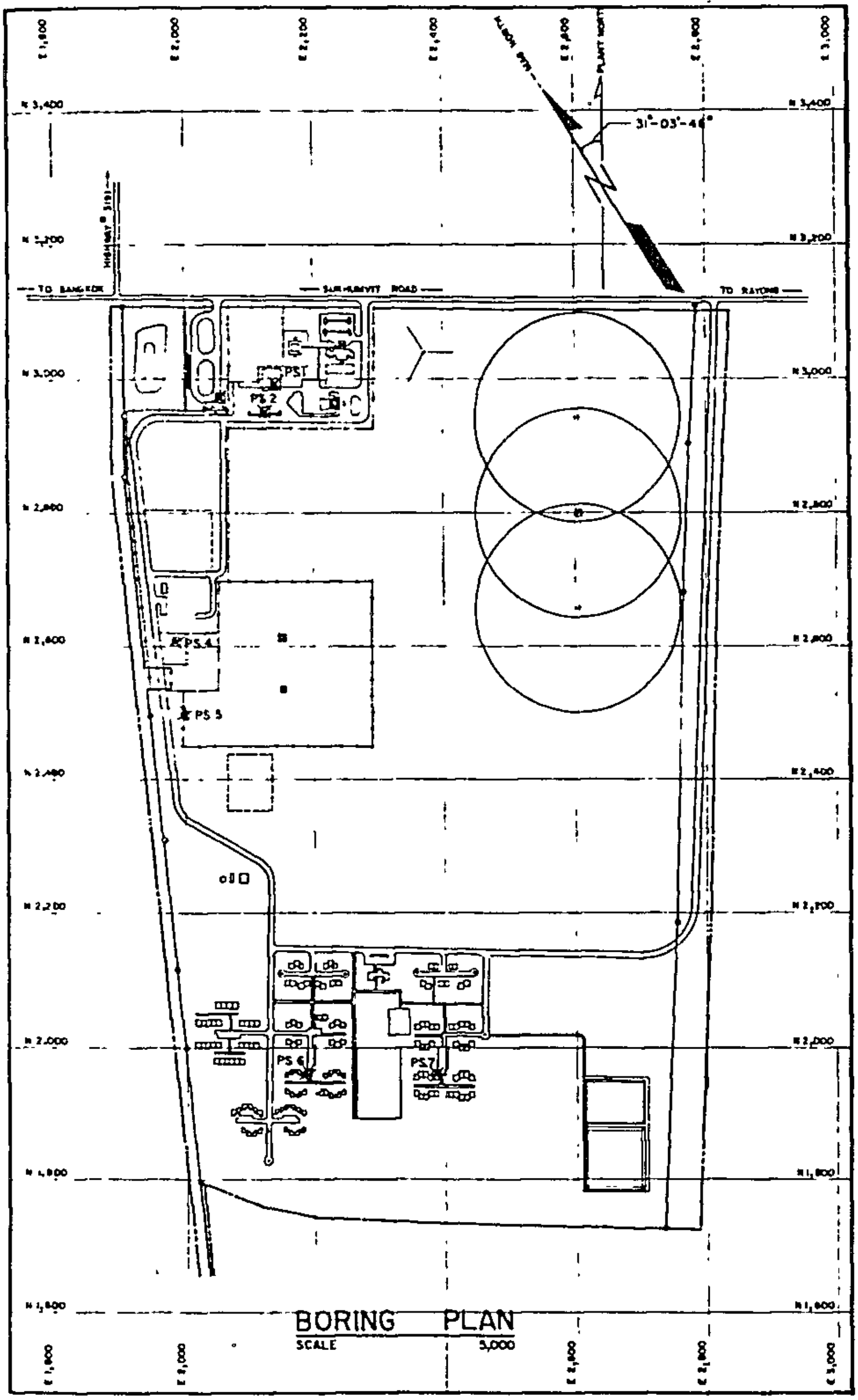
Reference should also be made to Fig. V-2 (A, B, C and D). At present, construction of off-site facilities including housing is proceeding. The site is characterized by a gentle grade. The higher elevations are MSL+39m and lower elevations are about MSL+25m. According to PTT boring data obtained in connection with construction of the off-site facilities including housing, the higher elevations have good soil conditions. At Borings No. PS 1 and No. PS 2 the soil is quite loose down 3 to 4 m from the surface. At these points, the soil cannot be expected to have high bearing strength. At No. PS 3, the soil is loose to 2 m below the surface, and bearing strength of 2 to 3 t/m^2 can be expected. Soil at Nos. PS 4, 5, 6 and 7 is hard and bearing strength at these points can be expected to be higher than 15 t/m^2. In view of these data, piling will be necessary to the area around Nos. PS 1, 2 and 3.

In any case, a more detailed geological survey should be made, because those data mentioned above are not sufficient for the plant construction.

2–2–5 Meteorological Conditions

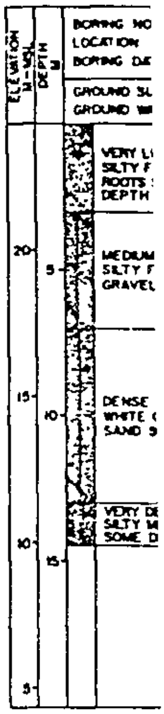
(1) Rainfall

Table V-1 gives rainfall records at Sattahip. The rainy season in Thailand is from May to October and the other months comprise the dry season. During the rainy season there are squalls lasting one to two hours and accompanied by lightning. Annual rainfall is 1,300 mm, and instantaneous maximum rainfall is 50 mm/min.



BORING PLAN

SCALE 5,000



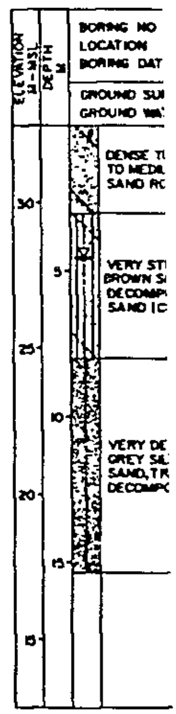
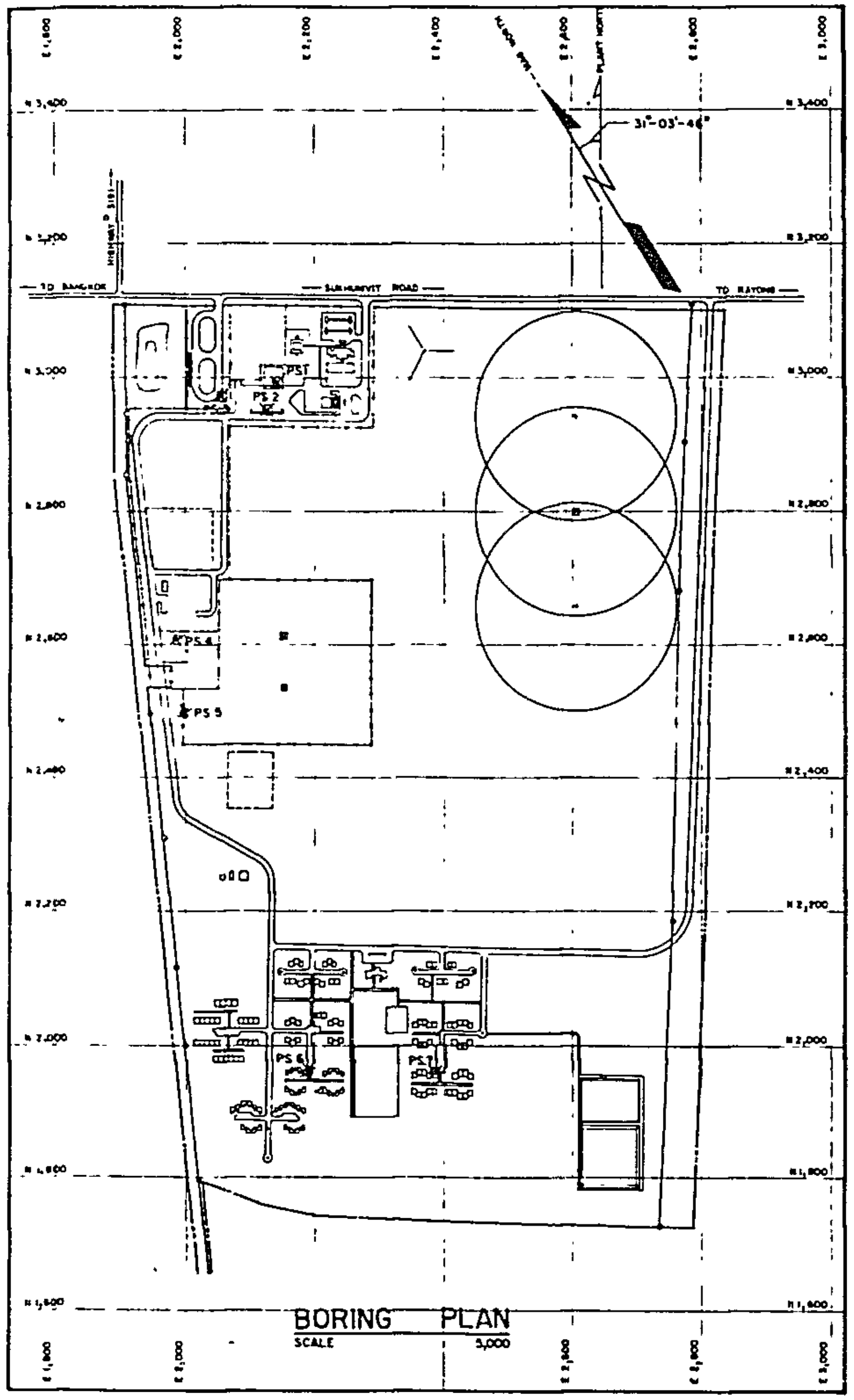
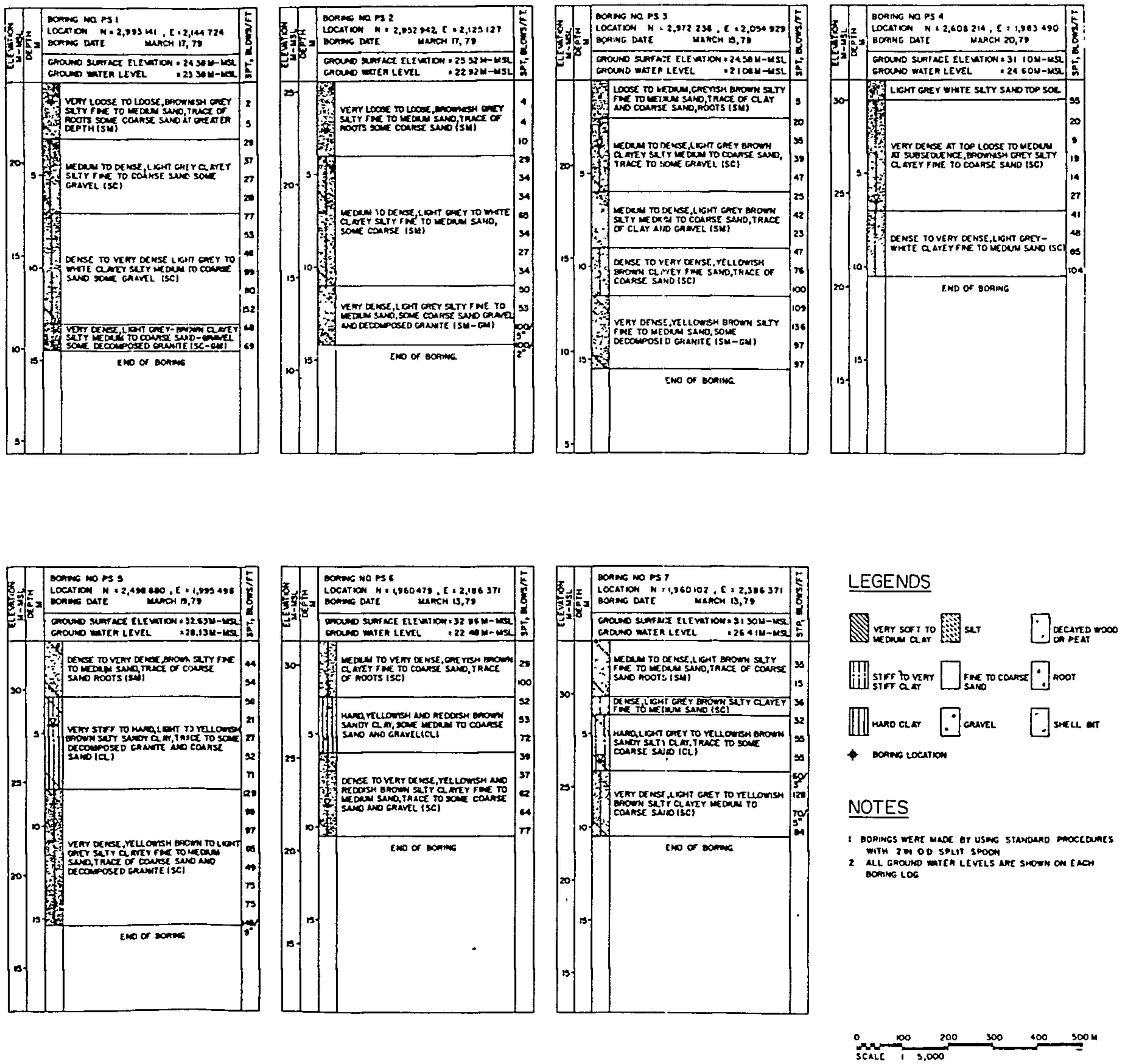
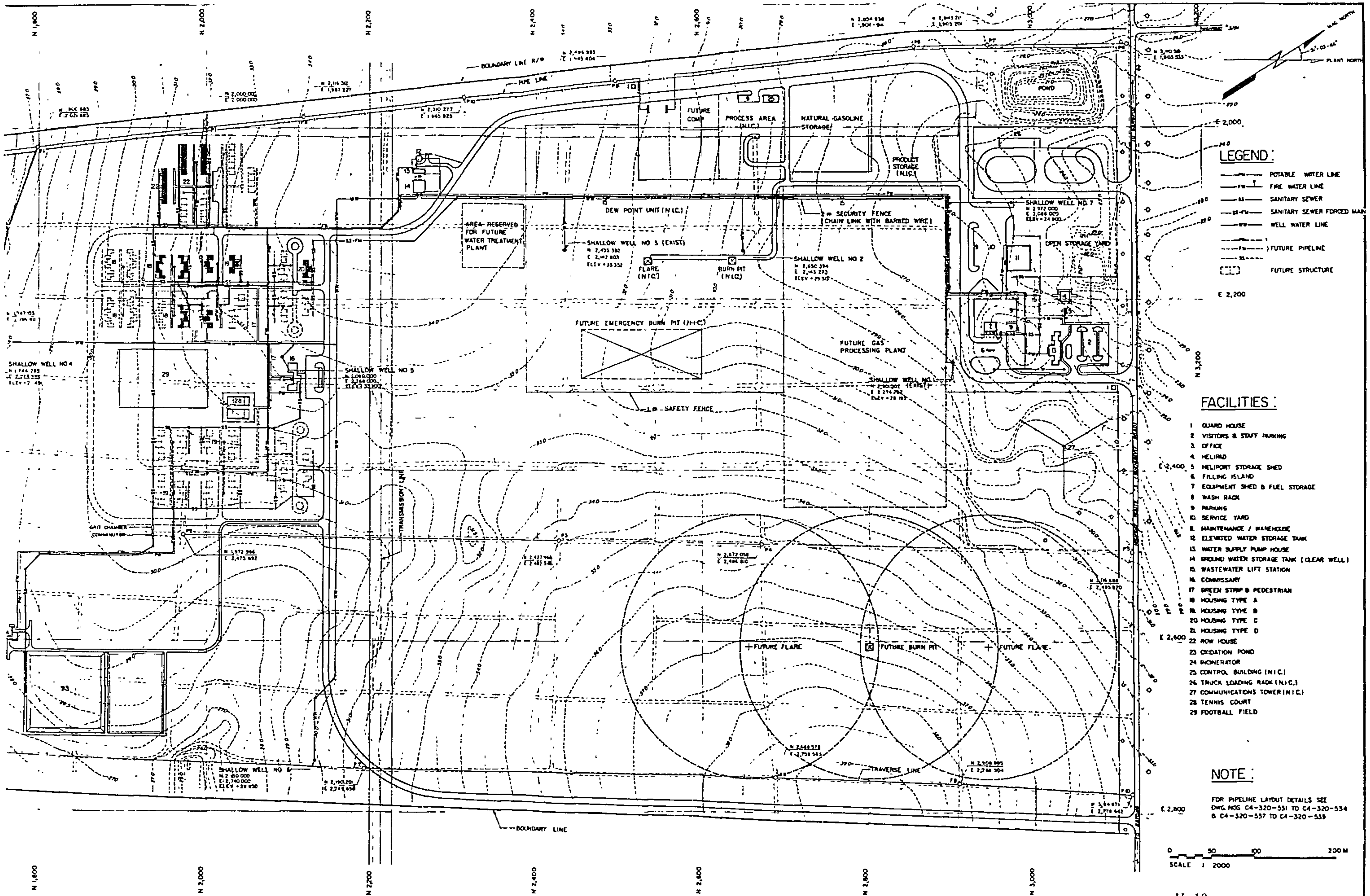
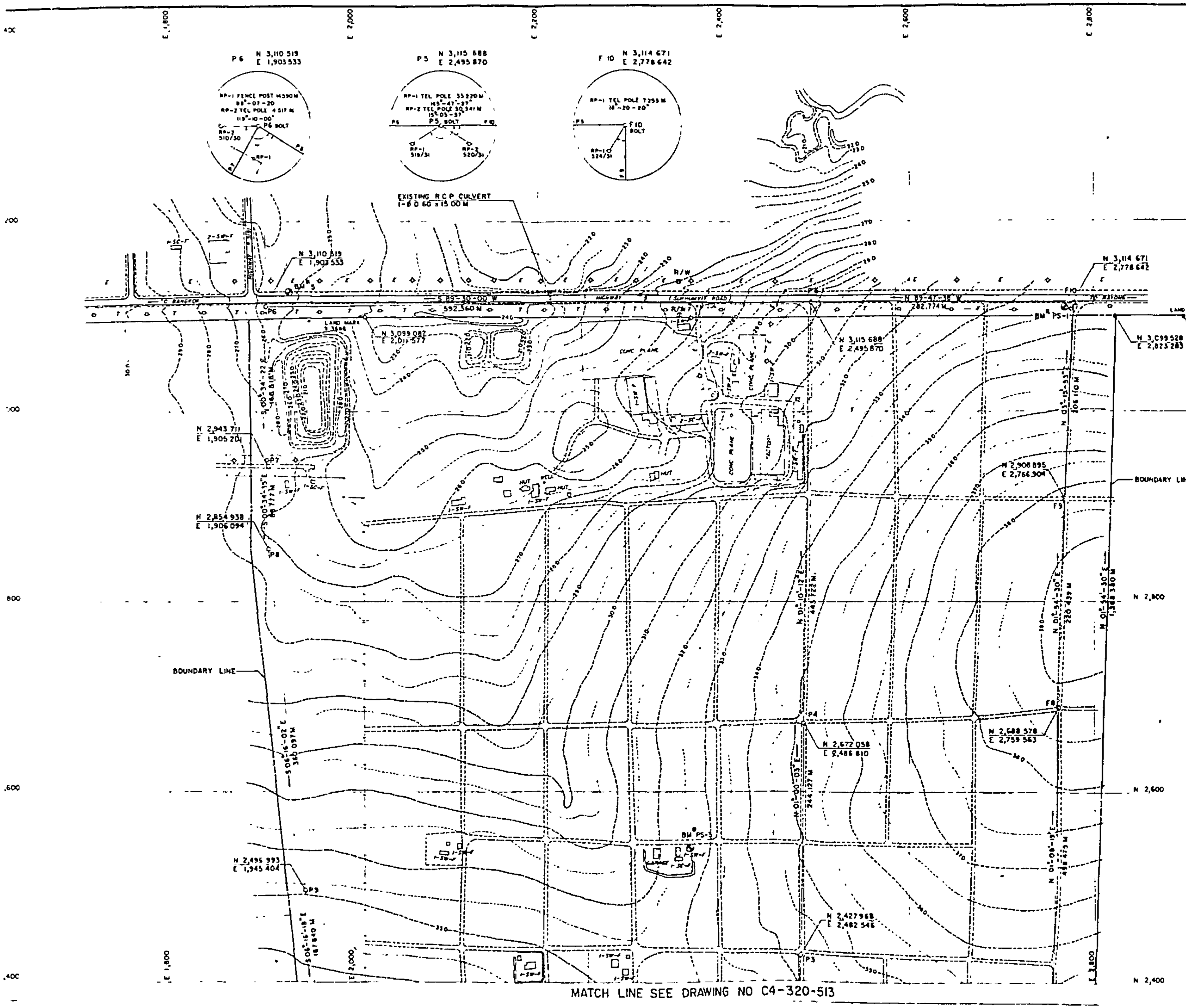


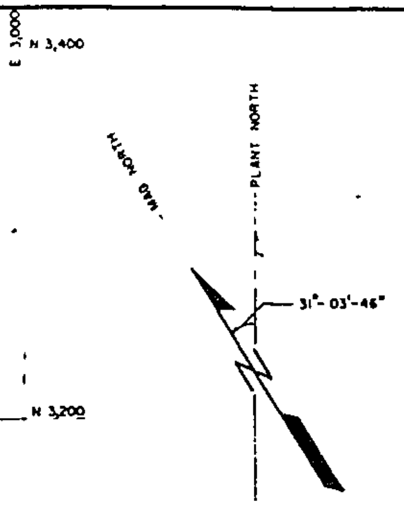
Fig. V–2(A) SUBSOIL PROFILE AT TERMINAL SITE






LEGEND :
POTABLE WATER LINE
FIRE WATER LINE
SANITARY SEWER
SANITARY SEWER FORCED MAIN
WELL WATER LINE
FUTURE PIPELINE
FUTURE STRUCTURE
FACILITIES :
1 GUARD HOUSE
2 VISITORS & STAFF PARKING
3 OFFICE
4 HELIPAD
5 HELIPORT STORAGE SHED
6 FILLING ISLAND
7 EQUIPMENT SHED & FUEL STORAGE
8 WASH RACK
9 PARKING
10 SERVICE YARD
11 MAINTENANCE / WAREHOUSE
12 ELEVATED WATER STORAGE TANK
13 WATER SUPPLY PUMP HOUSE
14 GROUND WATER STORAGE TANK (CLEAR WELL)
15 WASTEWATER LIFT STATION
16 COMMISSARY
17 GREEN STRIP & PEDESTRIAN
18 HOUSING TYPE A
19 HOUSING TYPE B
20 HOUSING TYPE C
21 HOUSING TYPE D
22 ROW HOUSE
23 OXIDATION POND
24 INCINERATOR
25 CONTROL BUILDING (N.I.C.)
26 TRUCK LOADING RACK (N.I.C.)
27 COMMUNICATIONS TOWER (N.I.C.)
28 TENNIS COURT
29 FOOTBALL FIELD
NOTE :
FOR PIPELINE LAYOUT DETAILS SEE DWG. NOS C4-320-531 TO C4-320-534 & C4-320-537 TO C4-320-539
0 50 100 200 M
SCALE 1 2000
BOUNDARY LINE R/W
PIPE LINE
BOUNDARY LINE
TRANSMISSION LINE
TRAVERSE LINE
FUTURE COMP
PROCESS AREA (N.I.C.)
NATURAL GASOLINE STORAGE
PRODUCT STORAGE (N.I.C.)
POND
DEW POINT UNIT (N.I.C.)
2 m SECURITY FENCE (CHAIN LINK WITH BARBED WIRE)
AREA RESERVED FOR FUTURE WATER TREATMENT PLANT
SHALLOW WELL NO 3 (EXIST)
SHALLOW WELL NO 2
SHALLOW WELL NO 7
OPEN STORAGE YARD
FLARE (N.I.C.)
BURN PIT (N.I.C.)
FUTURE EMERGENCY BURN PIT (N.I.C.)
FUTURE GAS PROCESSING PLANT
SHALLOW WELL NO 5
SHALLOW WELL NO 4
SHALLOW WELL NO 1 (EXIST)
1 m SAFETY FENCE
SHALLOW WELL NO 6
FUTURE FLARE
FUTURE BURN PIT
FUTURE FLARE
N 1,800
N 2,000
N 2,200
N 2,400
N 2,600
N 2,800
N 3,000
N 3,200
E 2,000
E 2,200
E 2,400
E 2,600
E 2,800





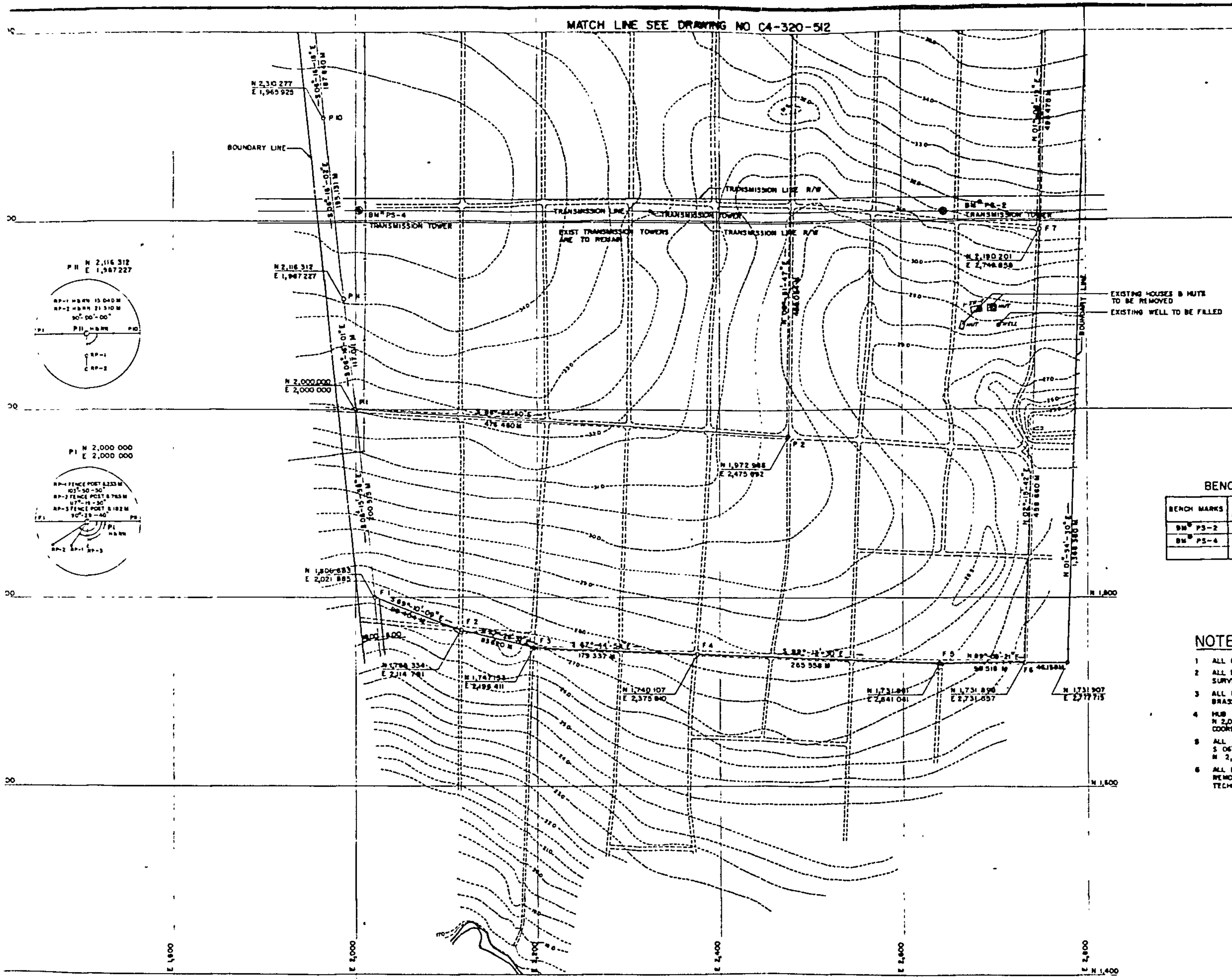
BENCH MARKS ELEVATION AND COORDINATION

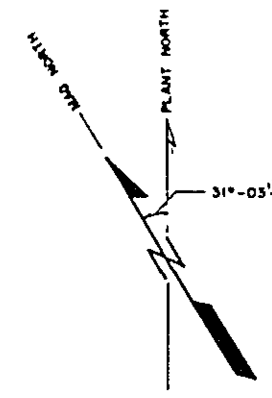
BENCH MARKS	ELEVATION (ABOVE M.S.L.)	COORDINATION N	COORDINATION E	REMARK
BM 5	25.153	3,127.231	1,929.106	–
BM PS-1	33.217	3,109.866	2,768.415	–
BM PS-3	32.636	2,541.857	2,361.639	–

NOTES:

1. ALL COORDINATES, ELEVATIONS AND DISTANCES ARE IN METERS
2. ALL ELEVATIONS ARE BASED ON M.S.L. DATUM AT SATTAHIP
3. ALL BENCH MARKS ARE INDICATED BY A BOLT HEAD ON BRASS PLATE EMBEDDED IN CONCRETE MONUMENT
4. HUB AND RED NAIL AT POINT OF INTERSECTION WITH COORDINATES N 2,000.000, E 2,000.000 SHALL BE THE ORIGIN OF NORTH AND EAST COORDINATES FOR SITE DEVELOPMENT
5. ALL BEARINGS SHOWN ARE BASED ON THE ASSUMED BEARING OF S 06°-16'-01" E ESTABLISHED BETWEEN TWO COORDINATES N 2,000.000, E 2,000.000 AND N 2,116.312, E 1,987.227
6. ALL EXISTING STRUCTURES WITHIN THE SITE BOUNDARY SHALL BE REMOVED FROM THE SITE BOUNDARY IN ACCORDANCE WITH THE TECHNICAL SPECIFICATION

0 50 100 200 M
SCALE 1 : 2,000





BENCH MARKS ELEVATION AND COORDINATION

BENCH MARKS	ELEVATION (ABOVE M S L)	COORDINATION N	COORDINATION E	REMARK
BM PS-2	31 681	2,209 114	2,848 440	UNDER TOWER OF TRANSMISSION LINE
BM PS-4	35 027	2,210 781	2,002 085	

NOTES:

1 ALL COORDINATES, ELEVATIONS AND DISTANCES ARE IN METERS
2 ALL ELEVATIONS ARE BASE ON ROYAL THAI SURVEY DEPARTMENT BMS 2885 AT RAYONG
3 ALL BENCH MARKS ARE INDICATED BY A BOLT HEAD ON BRASS PLATE EMBEDDED IN CONCRETE MONUMENT
4 HUB AND RED NAIL AT POINT OF INTERSECTION WITH COORDINATES N 2,000,000, E 2,000,000 SHALL BE THE ORIGIN OF NORTH AND EAST COORDINATES FOR SITE DEVELOPMENT
5 ALL BEARINGS SHOWN ARE BASED ON THE ASSUMED BEARING OF S 06°-16'-01" E ESTABLISHED BETWEEN TWO COORDINATES N 2,000,000, E 2,000,000 AND N 2,116 312, E 1,987 227
6 ALL EXISTING STRUCTURES WITHIN THE SITE BOUNDARY SHALL BE REMOVED FROM THE SITE BOUNDARY IN ACCORDANCE WITH THE TECHNICAL SPECIFICATION

0 50 100 200 M
SCALE 1 : 2,000

Table V–1 CLIMATOLOGICAL DATA FOR THE PERIOD 1951 – 1975

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Pressure (+1,000 or 900 mhs.)													
Mean	12.81	11.76	10.98	09.59	07.99	07.66	07.74	07.80	08.48	10.20	11.56	12.59	09.93
Ext. Max.	21.37	20.27	18.04	17.97	14.62	13.84	13.64	13.77	14.63	16.84	18.62	20.27	21.37
Ext. Min.	06.17	05.47	04.68	02.02	01.54	00.27	00.93	00.76	00.67	99.64	96.52	05.66	96.52
Mean daily range	3.74	3.83	3.93	3.95	3.66	3.08	2.99	3.22	3.84	3.90	3.74	3.71	3.63
Temperature (°C)													
Mean	26.7	27.9	28.9	29.7	29.2	28.9	28.4	28.4	27.9	27.1	26.5	26.1	27.9
Mean Max.	33.2	33.6	34.1	34.6	33.3	32.7	32.4	32.5	32.2	31.9	32.2	32.4	32.9
Mean Min.	22.1	24.2	25.6	26.5	26.2	26.4	25.7	25.6	25.0	24.0	22.6	21.6	24.6
Ext. Max.	39.0	39.4	39.5	40.5	40.5	37.2	37.8	37.2	37.4	36.2	37.4	38.3	40.5
Ext. Min.	12.3	16.8	18.7	21.0	21.5	20.9	19.0	21.5	19.0	19.5	15.0	12.8	12.3
Relative Humidity (%)													
Mean	70.0	75.0	76.0	77.0	79.0	76.0	77.0	77.0	81.0	83.0	76.0	70.0	76.0
Mean Max.	84.2	88.2	87.6	87.3	88.8	86.0	87.4	87.6	90.7	93.3	89.0	84.7	87.9
Mean Min.	51.2	57.0	59.9	61.1	66.6	65.5	64.2	65.9	68.3	69.1	60.7	53.0	61.9
Ext. Min.	25.0	17.0	29.0	33.0	43.0	43.0	47.0	48.0	45.0	38.0	28.0	21.0	17.0
Dew Point (°C)													
Mean	20.2	22.7	24.0	24.9	24.9	24.3	24.0	23.9	24.2	23.8	21.9	20.0	23.2
Evaporation (mm.)													
Mean – Piche	98.0	75.9	84.2	83.6	73.1	79.4	77.7	76.6	59.9	47.2	73.9	97.1	926.6
– Pan						No Observation							
Cloudiness (0 – 8)													
Mean	3.9	4.1	4.3	4.9	6.4	6.5	6.8	6.9	6.9	6.0	4.8	3.7	5.4
Visibility (Km.)													
0700 L.S.T.	7.8	7.8	8.1	9.6	10.6	11.2	10.9	10.8	10.6	9.8	9.8	9.3	9.7
Mean	8.6	8.3	8.6	10.0	11.0	11.4	11.1	11.3	11.0	10.4	10.4	9.9	10.2
Wind (Knots)													
Prevailing Wind	N	S	S	S	S, SW	SW	SW	WSW	WSW	N	N	N	–
Mean Wind Speed	6.0	6.8	7.4	7.2	7.2	9.8	9.4	9.1	7.4	5.8	6.8	7.1	–
Max. Wind Speed	35N	36NE	48SE	46E,SE	57NW	58WSW	52W	52W	49WNW	59W	73NNW	40N	–
Rainfall (mm.)													
Mean	28.4	56.8	66.2	90.9	205.5	76.4	95.8	99.7	226.1	288.4	99.7	17.1	1,351.0
Mean rainy days	2.7	4.7	5.0	7.8	13.8	10.9	13.8	13.5	16.6	17.5	8.8	2.0	117.1
Greatest in 24 hr.	53.2	117.6	116.1	108.7	170.0	62.8	155.0	89.7	107.7	302.7	319.6	87.0	319.6
Day/Year	26/73	27/68	22/70	28/71	4/71	17/72	22/51	25/65	23/63	22/52	30/70	1/70	30/70
Number of days with													
Haze	20.6	15.6	16.1	8.6	0.9	1.0	1.8	2.2	1.1	4.3	8.8	16.1	97.1
Fog	5.8	4.9	3.4	2.0	0.5	0.8	0.7	0.6	0.7	1.3	1.9	3.4	26.0
Hail	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1
Thunderstorm	0.7	1.4	3.5	7.7	10.3	3.8	3.9	3.7	8.3	10.2	4.8	1.0	59.3
Squall	0.0	0.1	0.2	0.4	0.2	0.4	0.4	0.2	0.2	0.1	0.1	0.0	2.3

Remark: Station Sattahip
Index Station 48 477
Latitude 12°41'N.
Longitude 100°59'E.

Elevation of station above MSL. 16.00 meters
Height of barometer above MSL. 18.00 meters
Height of thermometer above ground 1.35 meters
Height of wind vane above ground 12.00 meters
Height of raingauge 0.73 meters

(2) Temperature and humidity

The mean annual temperature is 28°C. The mean annual relative humidity is 76%. Records do not indicate a great difference in temperature between the rainy and dry seasons.

(3) Wind

The wind is generally mild, at 5 m/sec, but during typhoons the wind has reached 38 m/sec instantaneous maximum speed. Wind direction is southerly during the rainy season and northerly during the dry season.

(4) Earthquakes

There are no records of earthquakes in Thailand, which does not lie in a zone of seismic activity.

CHAPTER 3 UTILITIES AND INFRASTRUCTURE FOR THE PROJECT

3–1 WATER SUPPLY

On the basis of the basic scheme to be adopted for this project, defined in Chapter 1, the water supply requirement for each process plant, the common utilities center, and the off-site facilities has been calculated, and the water balance has been determined. The results are shown in Fig. V-3.

The volume of water required is about 500 m^3/hr. This water is to be supplied by means of a pipeline from the Dok Krai Reservoir, about 20 km north of the plant site. This reservoir, formed by damming the Dok Krai River, impounds 50 million tons of water and it is estimated that the annual catchment volume averages 119×10^6 t. At present, it is used for supply of irrigation water.

Another reservoir, the 100-million-ton Nong Pla-lai Reservoir, is planned to be made near the dam (see Fig. V-4). Completion of this reservoir would mean that it will be possible to supply 35×10^6 to 45×10^6 tons of industrial water a year.

Judging from the scale of this project's water requirements, the pipeline size of 16" should be adequate, but a 20" pipe is recommended in anticipation of future expansion. Because piping for this water is included in the project scope[1)] of the gas processing plant which is now being designed (according to PTT), in the present feasibility study the pump station, pipeline etc. is excluded from consideration and the cost of water at the project fence is taken as 2 Baht/m^3.

1) According to PTT, it is now implementing a water pipeline from the reservoir to the proposed site of the gas processing plant, and is going to oversize the water pipeline taking into account the requirements of ethylene, VCM, electrolysis, HDPE and off-site facilities concerned. Therefore, it is the basic understanding that the raw water should be supplied to the plant site at the cost of 2 Baht/m^3, and there is no need to consider the installation of water pipeline in this feasibility study.

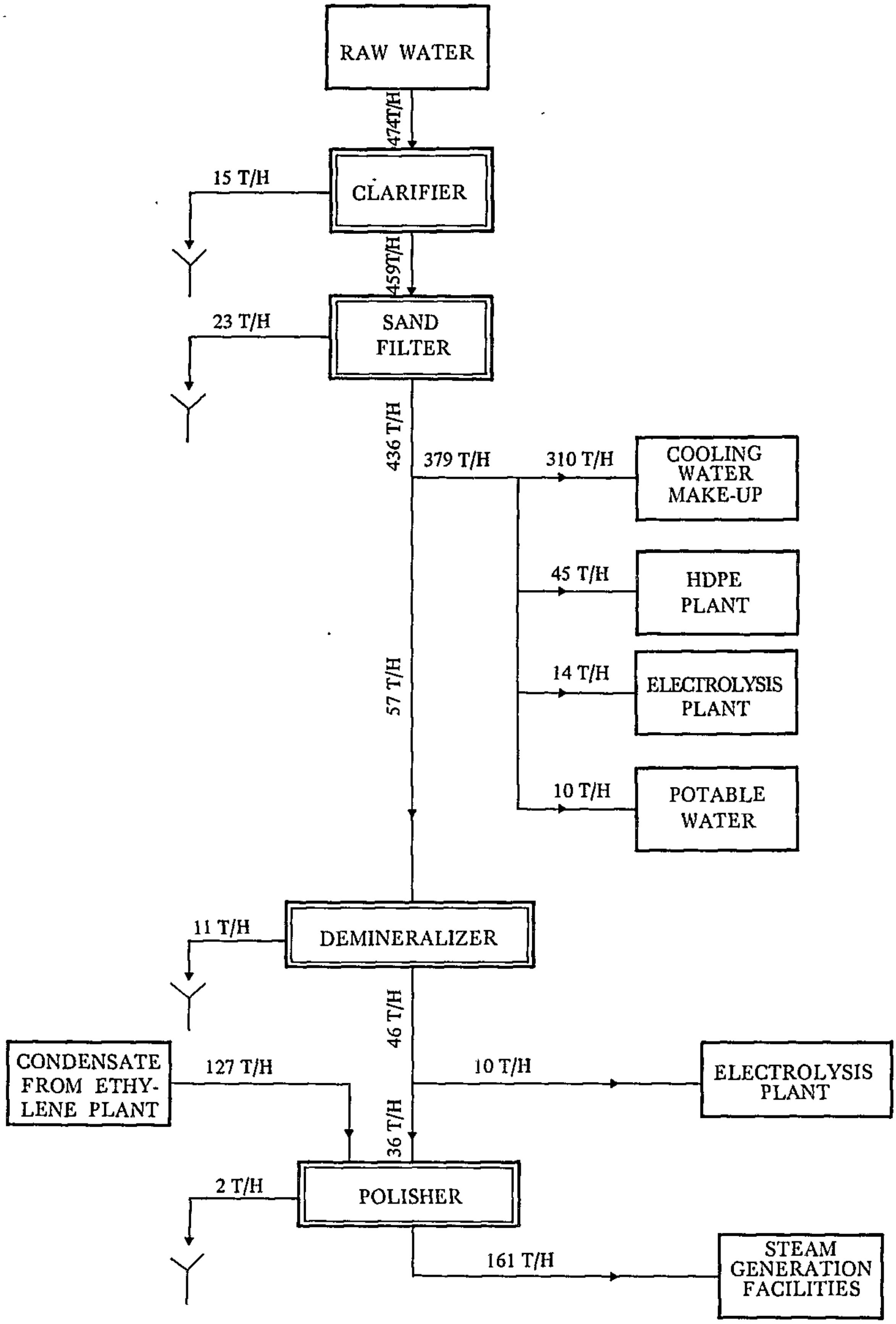
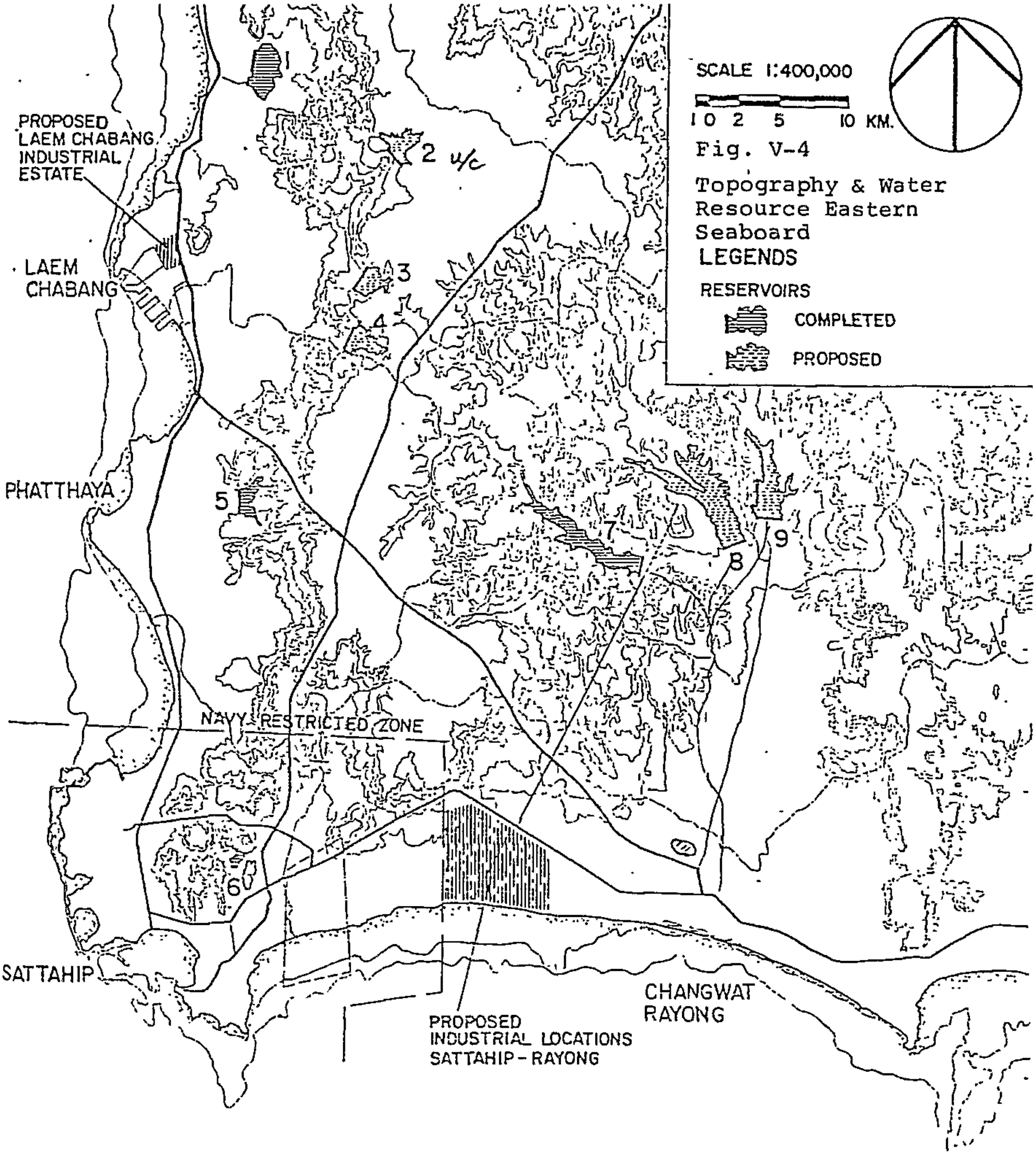


Fig. V–3 WATER BALANCE



LISTS OF RESERVOIRS

No.	Name	Quantity M.m^3	No.	Name	Quantity M.m^3
1	BANG PHRA	100	6	PHLU TA LUANG	2.8
2	NONG KHO	20	7	DOK KRAI	50
3	HUAI BUNG	26	8	NONG PLA-LAI	100
4	TAKHIAN TIA	13.6	9	KHLONG YAI	45
5	MAP PRACHAN	15	10	THAP MAI	30

3–2 ELECTRIC POWER SUPPLY

The power balance for this project, according to the basic scheme, is as shown in Fig. V-5. The total electricity requirement is about 30,000 kw. Of this requirement, 3,200 kw for the ethylene and utilities center are to be provided by a gas turbine generator installed within the utilities center, and 25,000 kw for the electrolysis, VCM and HDPE plants are to be purchased from EGAT/PEA.

An unscheduled shut-down of the ethylene plant would result in a great loss. Therefore, use is to be made of on-site power generation, for maximum reliability. It is desirable that the generator is installed parallel to the EGAT/PEA line, so that in the event that the gas turbine is tripped, back-up power supply would be available and a shut-down would be prevented. Further, overall thermal efficiency is improved by installing a waste heat boiler at the gas turbine exit.

At present a 115 kV EGAT transmission line from the Ao-Phai Substation to the local substations at Rayong, Bang La Mung, Sattahip 1 and Sattahip 2 (see Fig. V-6) crosses the site which is to be used for this project. It does not have sufficient capacity in view of this area's future growth of power demand, and EGAT is now constructing a new substation (called the Rayong-2 Substation) 3 km north of the project site, and will provide power to it by a 230 kV transmission line from the Ao-Phai Substation. It is also planned to connect the existing 115 kV line to this substation. When these efforts are completed, and the Bang Pakong thermal power plant, now under construction, is completed, there will be a suitable system for stable supply of electricity for the project.

It is assumed that power for the ethylene plant and common utilities center is to be supplied from Rayong-2 Substation by a 22 kV line, and that a 115 kV line will supply power to the electrolysis, VCM and HDPE plants.

3–3 FUEL SUPPLY

The fuel balance, based on the basic scheme of the project, is as shown in Fig. V-7. The total fuel requirement is 277 MMBtu/hr. The entire fuel requirement is to be met by supply from the adjacent gas processing plant, at the price of US$4.218/MMBtu. Hydrogen, a byproduct of the electrolysis plant, is to be used as fuel for the VCM plant.

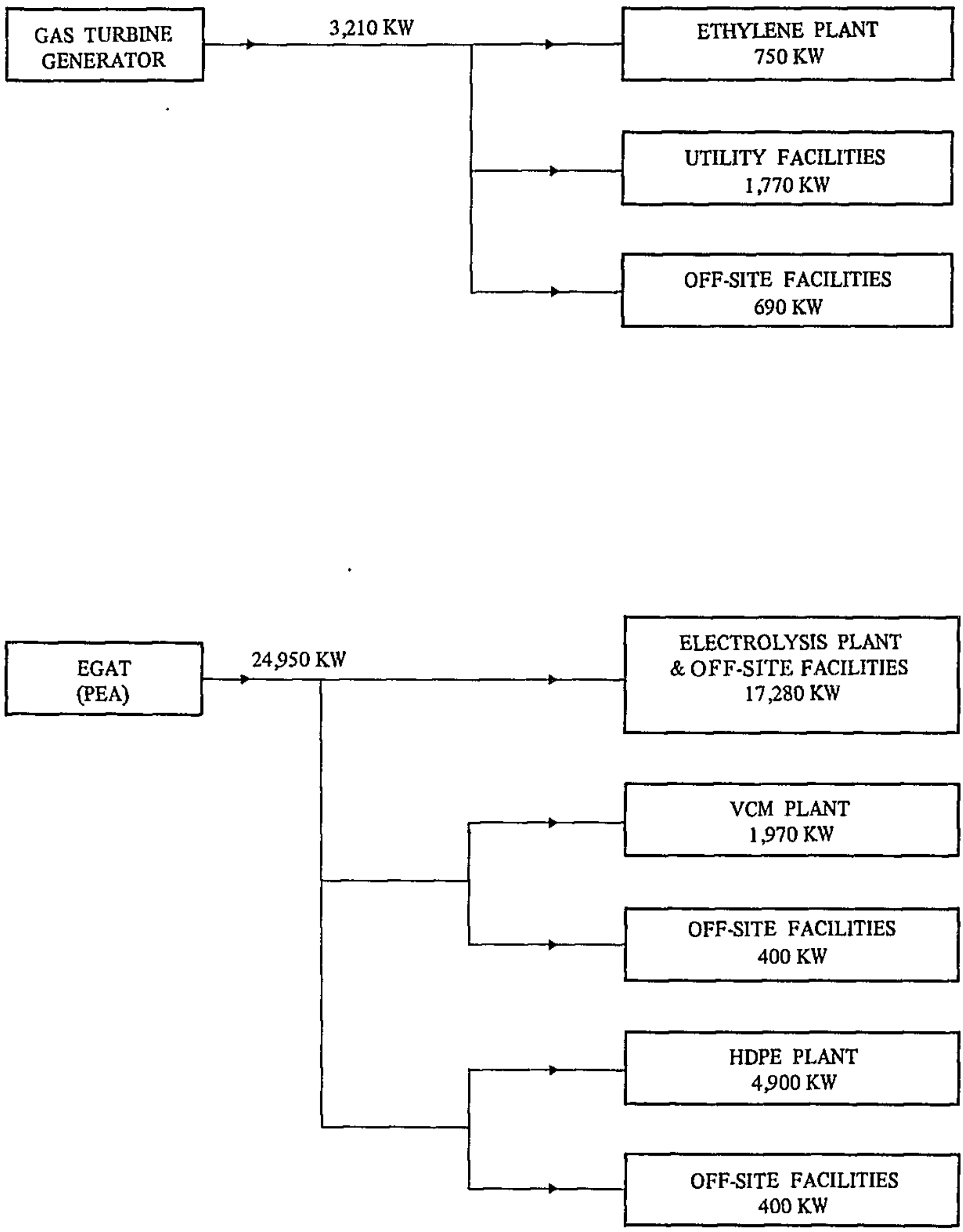


Fig. V–5 ELECTRIC POWER BALANCE

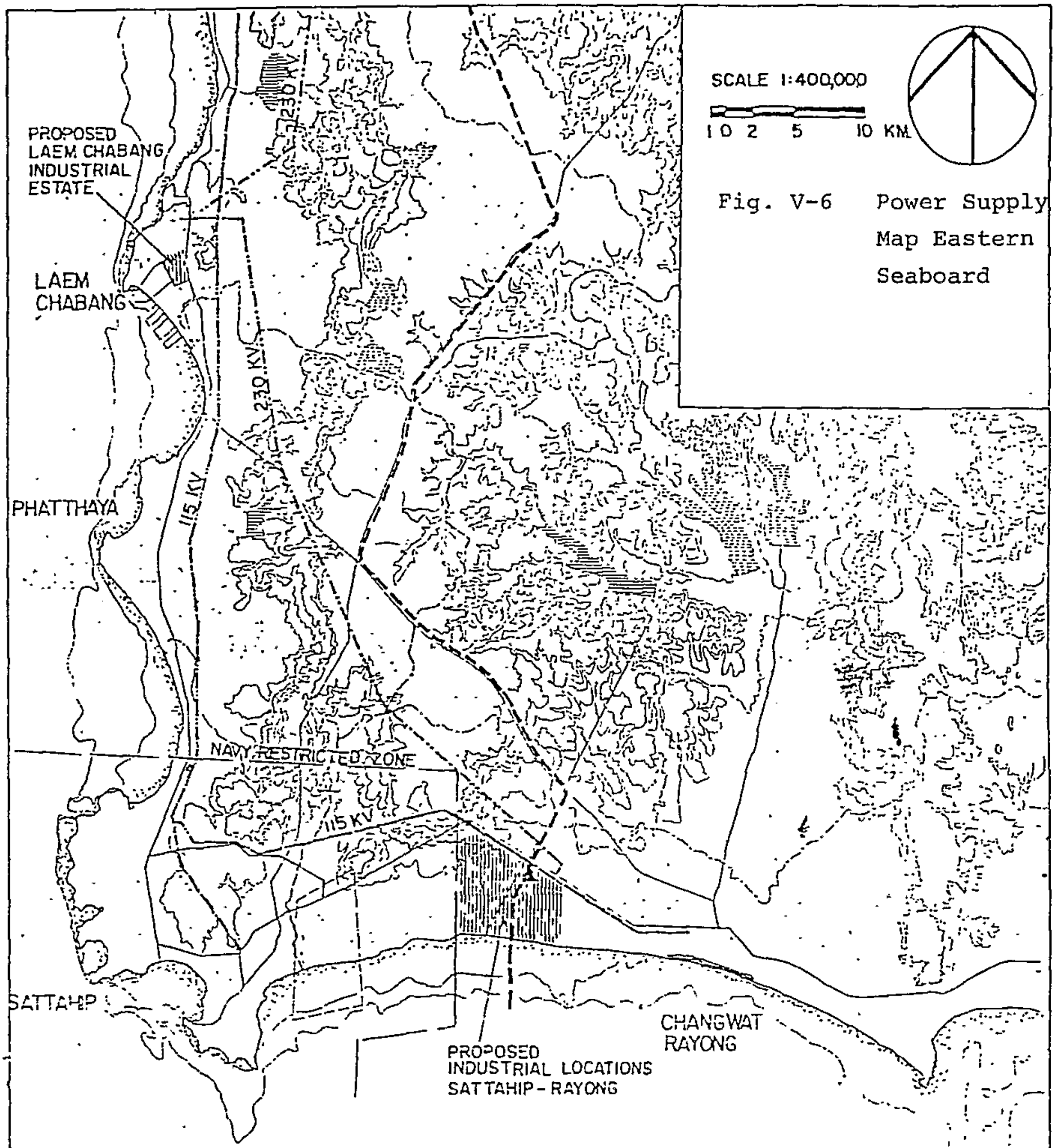


Fig. V-6 Power Supply Map Eastern Seaboard

LEGENDS

- ---- NATURAL GAS PIPE LINE
- —·— TRANSMISSION LINE
- ▲ GAS PLANT
- ----- CHANGWAT BOUNDARY
- —-— AMPHOE BOUNDARY

WORK SCHEDULE FOR TRANSMISSION SYSTEM EXPANSION & REINFORCEMENT

ACTIVITIES	1980	1981	1982
A CONSTRUCTION OF TRANSMISSION LINES: 230 KV FROM AO PHAI TO RAYONG			
B CONSTRUCTION OF SUB-STATION AO PHAI - RAYONG 2			

▨ BIDDING
▬ CONSTRUCTION PERIOD

SOURCE: System Planning Div. EGAT.

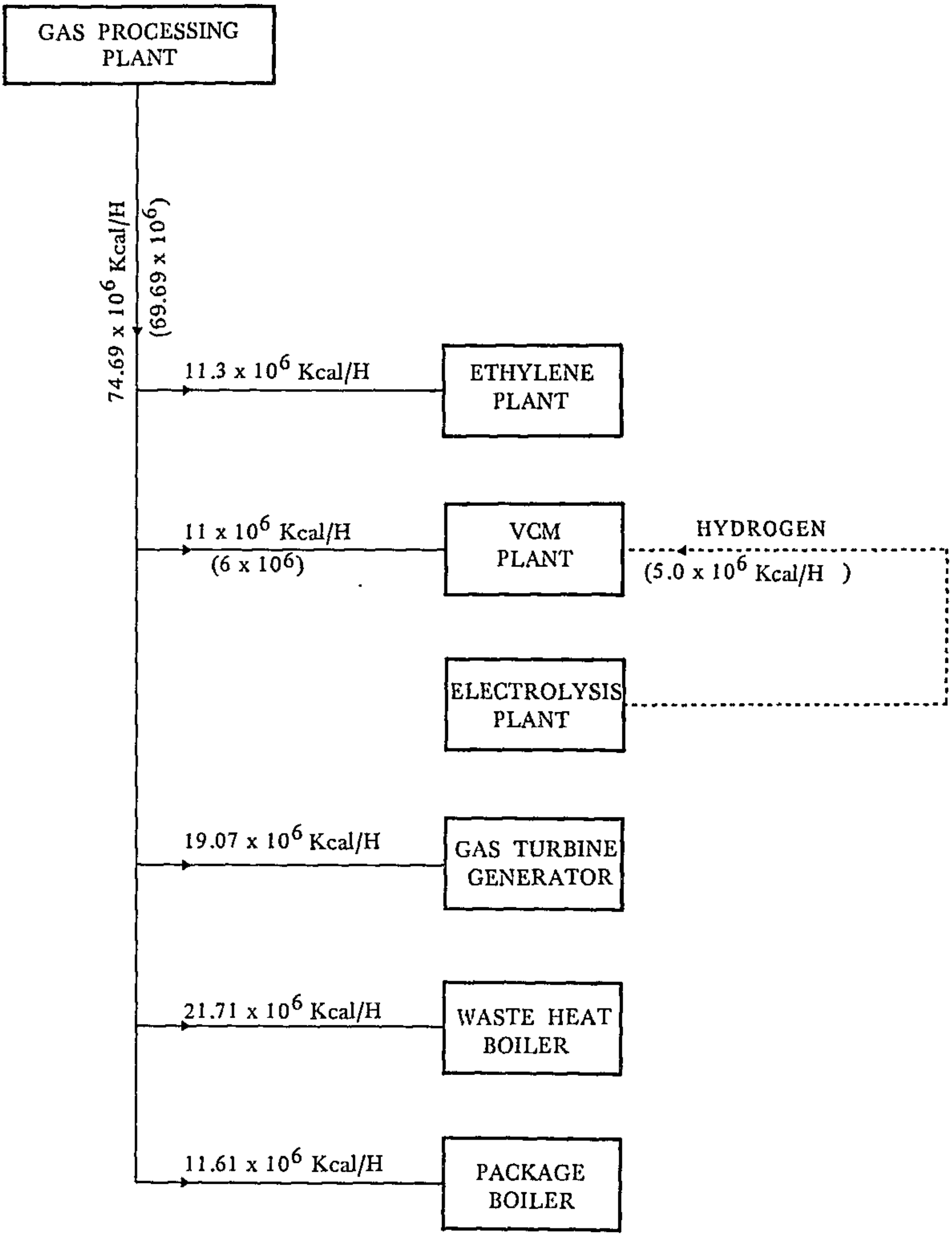


Fig. V–7 FUEL BALANCE

3–4 ROADS

The major roads in Thailand are Primary Highways and Secondary Highways, which are national roads. Road standards, conforming to the AASHO, are 7 m paved width, two-lane, or four-lane roads. Roads between Bangkok and Rayong are either two-lanes or four-lanes wide, and Route 3 between Sattahip and Rayong is two-lanes wide. Road bridges also conform to AASHO. Road shoulders are 2.5 m wide and widths including shoulders are 12 m for two-lane roads and 19 m or more for four-lane roads. Road width is thought to be 60 ~ 80 m in the case of Primary Highways and 40 ~ 60 m in the case of Secondary Highways (see Fig. V-8). Roads are normally well maintained. The road conditon on Route 36 between Bangkok and Rayong is excellent. Although there are some places where paving repair is needed on Route 3 between Sattahip and Rayong, they do not impede the flow of traffic. There are sharp curves on Route 3 coming from Sattahip harbor.

It is thought that the longest equipment which can be transported overland to the site would be about 35 m. For overland transport of heavy equipment from Sattahip to the plant site, bypassing the two reinforced-concrete bridges, which can accommodate lights loads, will be necessary. The bypass road can be expected to take 7 t/m^2.

3–5 RAILROADS

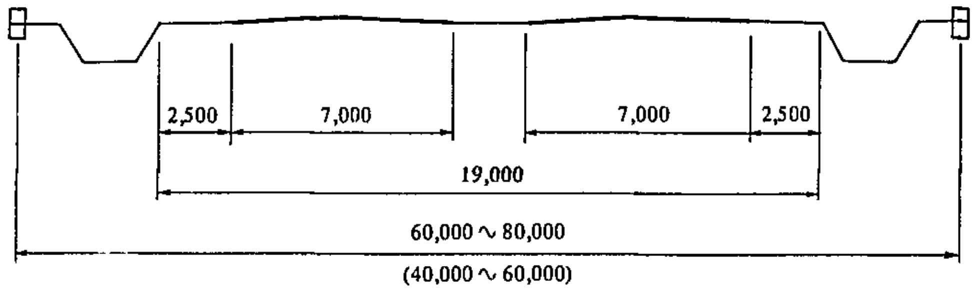
At present the railroad terminates at Chachoengsao Station. The Royal State Railway (RSR) plans to extend the railroad from Chachoengsao to Sattahip Port and this extension is expected to be completed by the end of 1983. There is now no plan for a railroad between Sattahip and Rayong. It will be desirable to consider the value of providing rail service to Rayong in view of the industrial development of the area. It may be expected that in this case a branch would be laid from the junction station between Ban Thung Lahan Station and Sttahip Port. (see Fig. V-9).

At the present time it is not realistic to anticipate use of the railroads by this project.

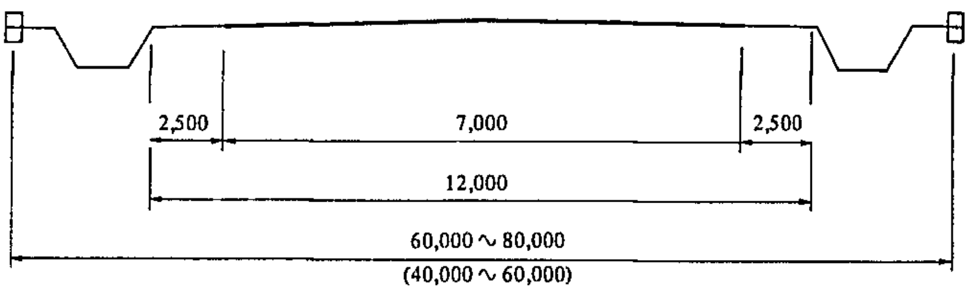
3–6 PORTS

The only port equipped with facilities which is in the area and can be used for the project is the one in Sattahip. Sattahip Port (seeFig. V-10) is provided with the following capability and facilities. In view of the military nature of the port, it is expected that it will be available for use only in connection with construction of this project's plants and facilities.

FOUR-LANE ROAD PRIMARY HIGHWAY



TWO-LANE ROAD PRIMARY HIGHWAY



Note : ( ) indicates dimensions of secondary highway.

Fig. V–8 SKETCH OF PRIMARY HIGHWAYS IN THAILAND

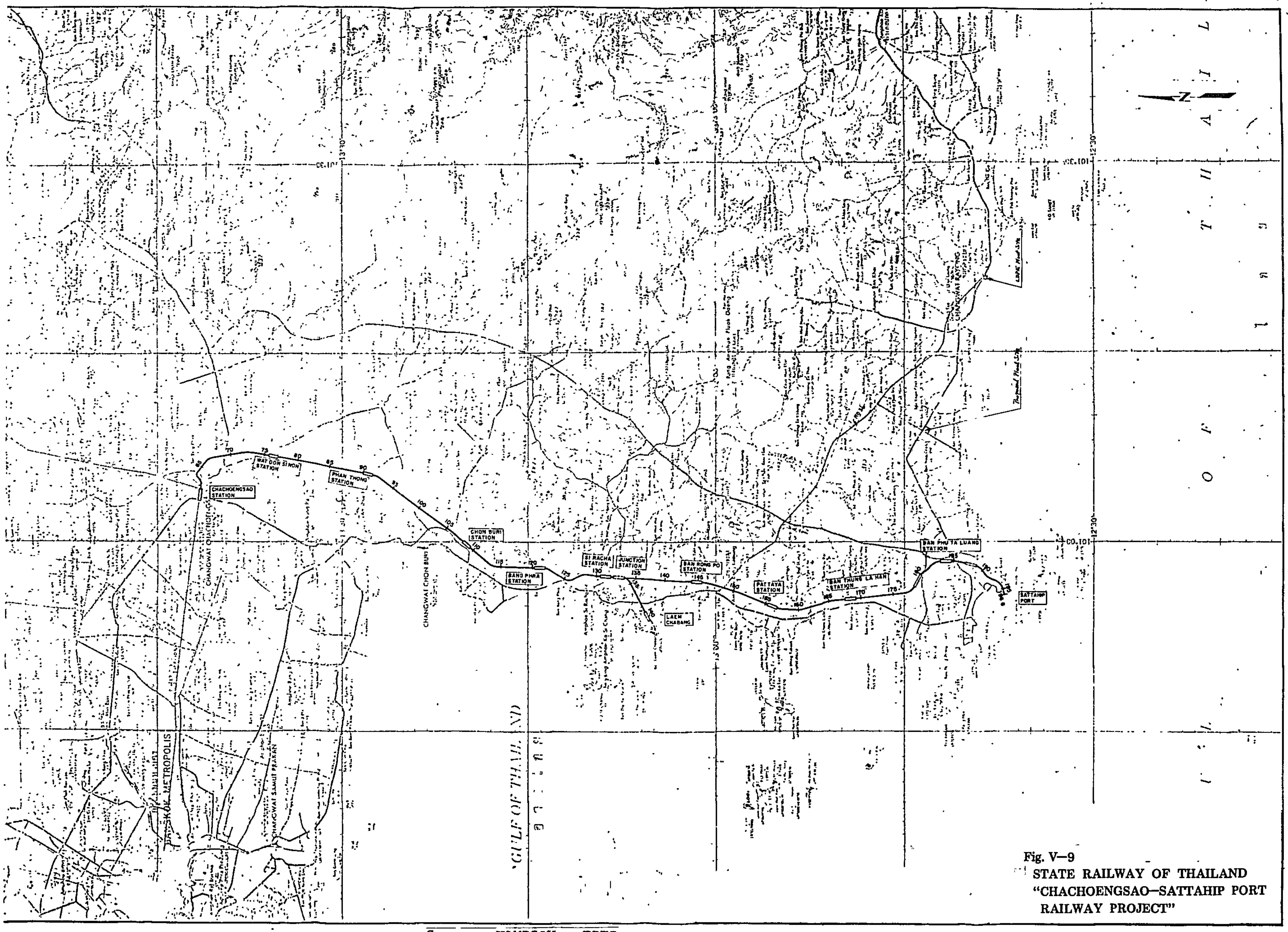


Fig. V–9
STATE RAILWAY OF THAILAND
"CHACHOENGSAO–SATTAHIP PORT
RAILWAY PROJECT"

Source: KAMPSAX - TPEC

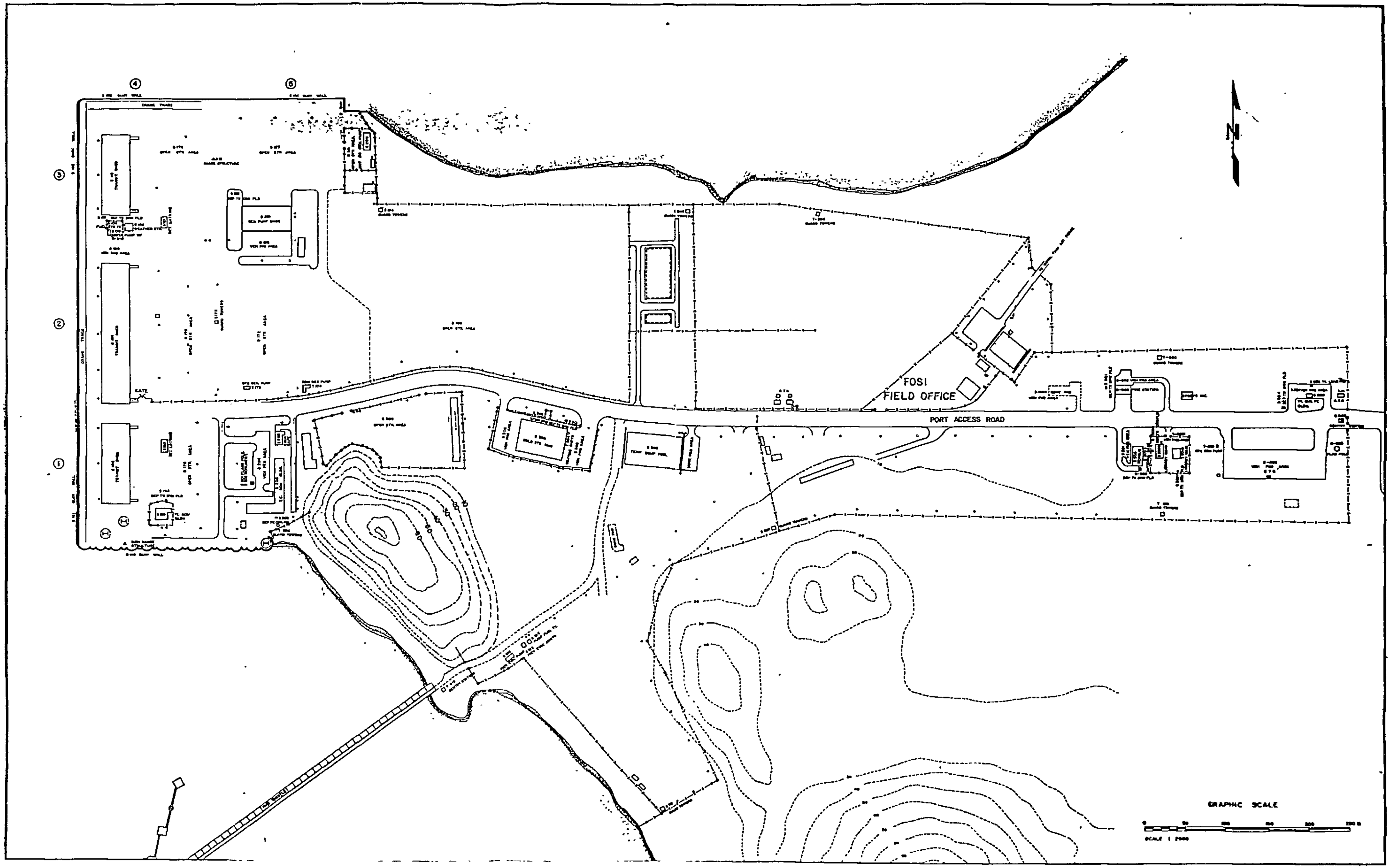


Fig. V—10 CHUK SAMET PORT, SATTAHIP

Source : Natural Gas Organization of Thailand

West Pier:

Usable by 20,000 DWT class ships
Draught, 9.6 m
Pier length, 550 m
Three berths; mooring possible
Crane capacity, 45 t; 2 cranes, movable over 550 m

North Pier:

Usable by 10,000 DWT class ships
Draught, 8.5 m
Pier length, 330 m
Two berths; mooring possible
Crane capacity, 25 t; one crane, movable over 190 m

Storage yard:

18,000 m^2

Warehouses:

10,000 m^2 (three buildings)

Tugboats:

Four tugs each 1,200 HP

Other facilities:

Night lights installed
Customs office present
1,000 m breakwater for smooth cargo handling

3–7 COMMUNICATIONS

At present, a radio system is adopted for the communication between the site and Bangkok for the reason that the communication is also needed between the gas processing plant and the offshore platform. In the future the installation of new telephone lines will be an absolute necessity. At present there are only two lines between Rayong and Bangkok, but it is necessary to increase that to at least 10.

CHAPTER 4 CONCEPTUAL DESIGN

4–1 INTRODUCTION

4–1–1 Philosophy of Conceptual Design

In this chapter, the conceptual design of each plant is made based on the project scheme described in Chapter 1. Care is used to make the conceptual design sufficiently detailed and concrete to be used as the basis for implementation of the project.

As previously mentioned, the greatest economy can be achieved by establishing the petrochemical complex in such manner that petrochemical plants are constructed adjacent to one another, to enable the transfer of raw materials, products, and utilities in shortest possible ways. Thus, design is set forth hereafter on the basic assumption that an ethylene plant and a common utility center are constructed in the PTT industrial estate in Rayong and a VCM and an electrolysis plant are constructed in an area adjacent to the estate.

In developing the conceptual design of this petrochemical complex, conditions are set and studied with priority given to reliability of the plants, assurance of safety, harmony with the environment, conservation of resources, and pursuit of economy.

(1) Reliability of the plants

Petrochemical plants, typical of large-scale production facilities in capital-intensive industry, suffer serious loss of economy if it is necessary to stop their operation due to accidents or other unforeseen troubles.

If an ethylene plant stops operation, it will take plant about one week to again obtain on-specification products even if operation is resumed immediately, resulting in huge loss due to consumtpion of raw materials and utilities during that period. Thus, the highest priority must be given to reliability of the plant. In this feasibility study, the conceptual design is developed on the assumption that the ethylene plant is based on CE Lummus Process, the VCM plant uses the Mitsui Toatsu Oxychlorination Process; and the electrolysis plant uses the Asahi Glass Process. Each of these processes are recognized internationally as being among the best in the world, and for each there are abundant satisfactory references whereby their reliability has been commercially verified. It is confirmed that each plant is comprised of equipment and materials which are proven in the actual instllations.

Adequate consideration to be made so that, unless an externally-caused disturbance occurs, each plant is capable of 8,000 hours of continuous operation, fully achieving the level of annual production required. To protect the ethylene plant against emergency shut-down such as may be caused by fluctuation or failure of purchased electric power supply, a backup system is adopted in which the utility center is to include a power plant which shall be used as the source of power for the ethylene plant, and purchased power is to be used as backup.

(2) Safety

While each facility is designed for high reliability as mentioned above, it is highly important in terms of design to protect the plants against disasters due to fire, storm and flood, lightning, and man-made destruction. Each facility is to be designed based on the latest related laws and regulations of Japan. The control system of each plant is provided with an emergency shut-down mechanism and fail-safe mechanism. Safety valves, vent stacks, and flare stacks are properly installed. Further, adequate consideration is given to gas detectors, fire alarms, fire hydrants, and sprinklers to cope with an emergency. A fire-fighting team equipped with chemical fire trucks is to be organized.

(3) Harmony with the environment

The beautiful nature of Thailand is a great asset of mankind. It is intolerable that this greatest asset be damaged by industrialization. This makes it incumbent on project planners to adopt the latest non-polluting process when designing the plants. Waste from the plants is to be processed by facilities of the latest design, so as to completely meet the standards of Japan which as a whole are the most strict regulations in the world. In this report, one chapter is devoted specifically to environmental aspects.

(4) Conservation of resources

In each plant, improved processes are to be adopted in view of energy conservation goals. Further, in the utility center, high thermal efficiency is to be obtained through a combination of a gas turbine generator with a waste heat boiler.

In the ethylene plant, reduced capacity rotors are to be used for compressors to prevent the efficiency of energy consumption from decreasing during light-load operation.

(5) Economy

In developing this conceptual design, efforts are exerted to minimize fixed costs and variable costs by reducing the cost of equipment and the personnel, etc. while satisfying the above requirements.

4–1–2 Assumptions

In developing the conceptual design presented in this chapter, the assumptions thereof are enumerated as follows.

(1) This project is located in Rayong.

(2) The following facilities are constructed within the grounds of PTT property and are to be operated by PTT:

(a) Ethylene plant : 230,000 t/y

(b) Utility center : Supplies service water, air, steam, oxygen, and nitrogen to respective companies of the complex. This utility center is also equipped with an independent power plant, receiving substation, and common waste-water treatment facility.

(c) Tankyard : Tankage for feedstock ethane and product ethylene.

(d) All required buildings, structures, facilities and equipment for operation and maintenance of the plant which include administration facility, maintenance shop, laboratory, and fire fighting equipment, and so on.

(e) It is assumed that the flare stack and the raw water pond are to be in common with the adjacent gas processing plant.

(f) A pipeline is to be used to supply ethylene to the LDPE plant 20 km from the site.

(3) The following facilities are constructed adjacent to the PTT site and are to be operated by an enterprise separate from that of PTT (tentatively referred to as the Thai-VCM Co.)

(a) VCM plant : 80,000 t/y

(b) Salt electrolysis plant :
Chlorine ; 48,000 t/y
Caustic soda ; 51,600 t/y[1)]

(c) Utility facilities
Include facility for electric power receiving from EGAT and cooling water[2)] which are not supplied from the utilities center.

(d) All required buildings, structures, facilities and equipment for operation and maintenance of the above-mentioned plant which include administration facility, maintenance shop, laboratory, and fire fighting equipment, etc.

(e) Pipeline and shipping terminal for shipping of VCM. It is assumed that the jetty is not included in this project since the one under construction by another company[3)] is to be utilized.

(4) Raw water is to be supplied to the site through a pipeline from the Dok Krai reservoir. In this plan, raw water is to be delivered to the fence of the site at 2 Baht/m^3.

(5) A plan is made to have a large capacity substation constructed 3 km north of the site by EGAT (Rayong-2). Electric power is to be supplied from the substation to the ethylene plant at 22 kV and to the Thai VCM plant 115 kV. Installation of power cables from this substation is to be included in this project.

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1) 103,200 t/y for 50% NaOH.

2) Assuming that make-up cooling water is to be supplied from the utility center.

3) Thai Petrochemical Industry Co. is constructing the jetty at the site of the LDPE plant.

(6) For fuel, only natural gas is to be used; it is to be supplied from the gas processing plant.

(7) All housing necessary for construction and operation of facilities of the PTT and Thai VCM is included in this project.

4–1–3 Applicable Laws and Regulations

This project is to be designed in accordance with the laws and regulations of Thailand applicable to the petrochemical complex. However, since the related laws and regulations covering some aspects of this project have not yet been established in Thailand, it has been agreed that this conceptual design be made in accordance with the related laws and regulations and standards applied in Japan.

As to preservation of the environment, the design conforms to the standards of Thailand. For details, refer to Chapter 6.

4–2 ETHYLENE PLANT

4–2–1 Introduction

In the most ethylene plants in the world, thermal cracking based on the vertical-coil type cracking furnace is currently in use.

Recently, especially since the energy crisis, with regard to operation of large-scale plants such as ethylene plants, diversification of feedstocks has become necessary, and several types of ethylene production process have been improved and new techniques (including ethane cracking and vacuum gas-oil cracking) have been put to practical use together with energy-conserving, high-efficiency process improvements.

In this study, the conceptual design is developed by adopting the ethylene process based on the CE Lummus technology which meets the above mentioned requirements and is used to produce a large share of ethylene output in the world.

4–2–2 Plant Elements

(1) What constitutes the plant

(a) Plant definition

The plant shall consist of an ethylene unit and supporting facilities. The ethylene unit shall be designed to produce 230,000 metric tons per year of high-purity ethylene by thermal cracking of ethane feedstock and ethane recycle.

(b) Plant sections

The ethylene unit may be subdivided into the following sections:

Cracking and Quench
Charge Gas Compression and Acid Gas Removal
Drying and Feed Chilling
Dementhanization and Deethanization
Acetylene Hydrogenation and Ethylene Fractionation
Propane Refrigeration
Ethylene Refrigeration
Ethane and Ethylene Storage

(c) Supporting Facilities

The supporting facilities shall consist of the following:

Cooling Water Distribution System
Steam and Condensate Distribution System
Fuel Gas Distribution System
Plant and Instrument Air Distribution System
Electrical Distribution System
Nitrogen Distribution System
Safety System
Flare System
Spent Caustic Soda Neutralization System
Tankage and Storage – Caustic Soda, Compressor Wash Oil, Methanol Storage and Distribution System.

The supporting facilites include all inside-battery-limits distribution plus fuel gas drums and flare drums, but exclude the flare stack which is outside-battery-limits.

(2) Process description

The following is a brief description of the processing sequence as shown on process flow diagram attached Fig. V-11.

(a) Cracking and quench

Ethane feedstock plus ethane recycle are cracked in tubular heaters in the presence of dilution steam. The heater effluents are cooled to 315°C in transfer line exchangers which generate high pressure steam.

The effluents from the transfer line exchangers are combined and directed to the quench tower. By direct contact water cooling, the greater part of the dilution steam and some heavier hydrocarbons are condensed. Net overhead vapor flows to the compressor system. Quench water plus condensed steam are separated from the condensed hydrocarbons in a quench water surge drum. The circulating hot water is used for low level heat in several process services and further cooled against cooling water. Condensed dilution steam is sent to process water treatment unit, where hydrocarbons are removed, and then revaporized against medium pressure steam for reuse as heater dilution steam.

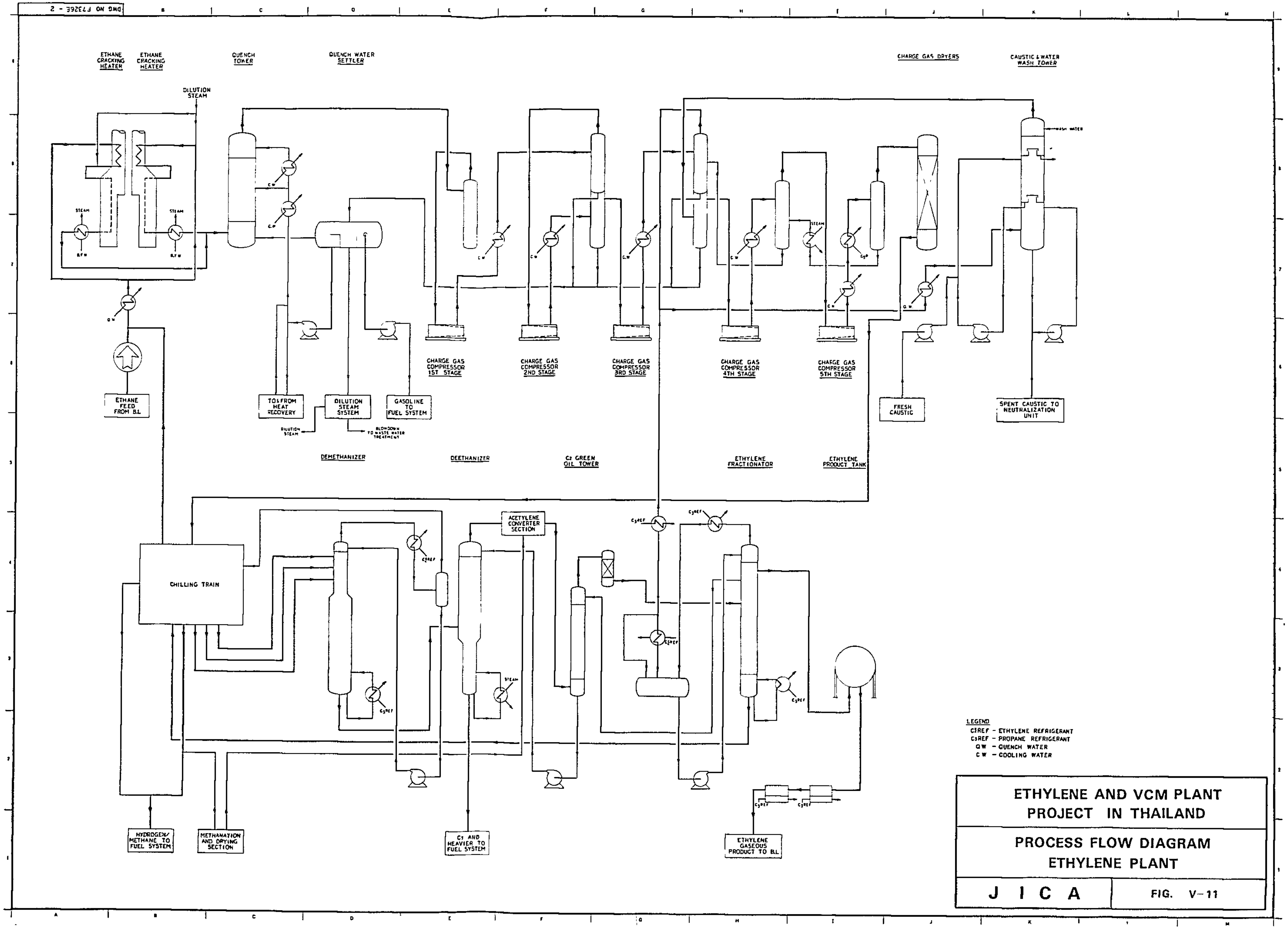
(b) Charge gas compression and acid gas removal

The quench tower overhead vapors are compressed in five centrifugal compressor stage with interstage cooling. Between the third and fourth stages, the gas is treated for acid gas removal in the caustic and water wash tower. The fifth stage discharge is cooled with water and with propane refrigerant to 15°C.

Liquid condensate is separated and the vapor is sent to the desiccant dryers. Interstage hydrocarbon and water condensates from the first three stages are sent back to the quench water surge drum. Fourth stage discharge condensate is recycled to the third stage discharge drum; fifth stage discharge condensate, after heating, is recycled to the fourth stage discharge drum.

(c) Drying and feed chilling

The final compressor discharge gas is dried in a packed bed dryer before passing to the low temperature recovery section. Two dryers are provided. One is on stream, while the second is regenerated. The dried gas is progressively chilled and partially condensed with condensate removal. The remaining vapor is the hydrogen-rich off-gas. The condensates are fed to the demethanizer. The chilling is achieved with propane



ETHYLENE AND VCM PLANT PROJECT IN THAILAND

PROCESS FLOW DIAGRAM ETHYLENE PLANT

J I C A FIG. V-11

and ethylene refrigeration, vaporizing recycle ethane, and reheating hydrogen and methane off-gas streams. The hydrogen rich off-gas and the methane rich off-gas are used as fuel after reheating in the chilling train.

(d) Demethanization and deethanization

The demethanizer is reboiled with propane refrigerant and reflux is condensed with ethylene refrigerant. The demethanizer overhead is the methane off-gas, which is used as fuel after reheating in the chilling train. The demethanizer bottoms flow to the deethanizer.

The deethanizer is reboiled with low pressure steam and reflux is condensed with propane refrigerant. The overhead is sent to acetylene converter.

The bottoms product is flushed, heated and mixed with the hydrogen/methane fuel gas and sent to fuel gas system.

(e) Acetylene hydrogenation and ethylene fractionation

The deethanizer overhead vapor, after preheating, is sent to the acetylene converter. Acetylene is hydrogenated over a palladium catalyst in a packed-bed reactor. Hydrogen off-gas, after methanation and drying, is injected into the converter feed to provide the hydrogen requirements. Two vessels are provided, one is on-stream, while the other is on stand-by. The converter effluent is used to preheat the feed and flows to an absorber where green oil formed during the hydrogenation is removed.

The green oil absorber overhead flows to a guard dryer and is sent to the ethylene fractionator. The feed contains ethylene, ethane, propylene, unreacted hydrogen, and a little methane that was contained in the hydrogen gas. Condensing and reboiling of the tower are done by propane refrigerant. The ethylene product is withdrawn as a side-stream liquid from the tower. Hydrogen and methane after passing through a vent condenser are recycled to the charge gas compressor. The ethylene product is sent directly to the storage tank. From this tank a low pressure product and a high pressure product will be withdrawn. A pump is provided for the high pressure product. Both liquid ethylene product are delivered to battery limits as a vapor, after vaporizing and superheating.

The ethane recycle is withdrawn from the bottom of the ethylene fractionator, vaporized, superheated, and sent to the cracking heaters.

(f) Propane refrigeration

The propane refrigeration system is a closed, multi-stage system using a centrifugal compressor. The compressor effluent is cooled and condensed against cooling water and partly subcooled against process streams.

(g) Ethylene refrigeration

The ethylene refrigeration system is a closed, multi-stage system using a centrifugal compressor. The compressor effluent is desuperheated against propane refrigerant and then condensed against lower level propane refrigerant.

(h) Ethane and ethylene storage

High pressure ethane storage tank, four spheres with storage capacity of 4 days consumption, is provided to secure stable feedstock to the plant when the gas processing plant is shut down. Ethane feed to the storage shall be supplied as liquid phase from the gas processing plânt.

The liquid ethylene product is sent to the high pressure storage tanks, four spheres with storage capacity of 5 days production, which are provided to prevent upsets in one unit from causing shutdowns in another.

From this tank a low pressure and a high pressure product are withdrawn. The high pressure product for the LDPE plant is pumped, vaporized and superheated against propane refrigerant before being delivered to the LDPE plant through pipeline as vapor product. The low pressure product is delivered to other plant as vapor product after being vaporized and superheated.

(i) Low-load operation measures

The ethylene plant will have to operate at a low operation rate for several years after the start of commercial operation due to the large extent of the expected difference between the plant capacity and ethylene demand. In connection with this, the following consideration is made.

Cracking furnace :

This design is made on the assumption of cracking furnaces each having ethylene production capacity of 46,000 t/y with 5 furnaces used for ordinary operation and 1 furnace for standby.

According to the result of market study given in Part II, the ethylene production will reach 170,000 t/y in 1988. Since this production can be attained by that time with a total of four cracking furnaces, the construction of the other furnaces may be delayed. When considering the operation cycle of the cracking furnace, namely 45-day operation and 3-day shut down for decoking, the total production capacity of four cracking furnaces in operation is,

46,000 t/y × 4 × 45/48 = 172,500 t/y.

This production capacity is large enough to fully meet the ethylene demand of up to 170,000 t/y. This consideration makes it possible to delay the investment necessary for 2 cracking furnaces for several years[1].

Cmpressor :

Most of the power requirement for the ethylene plant will be consumed by the charge-gas compressor, propane refrigerating compressor, and ethylene refrigerating compressor. The total power amounts to 30,000 HP or above at regular operation. plant

In low-load operation, recycling of a part of gas is required to maintain operation of these compressors. This decreases efficiency resulting in a large amount of wasted power. To prevent this decrease of efficiency, it is desirable that the compressors are equipped with a rotor of 75% capacity to cope with the problem presented by low-load operation until the ethylene production amounts to 170,000 t/y. This measure will prevent loss of power at low-load operation of 130,000 ~ 140,000 MTA.

When the operation rate of the ethylene plant has increased in accordance with increased demand for ethylene, the initial rotors above will be replaced with full-capacity ones and be used as spare rotors thereafter.

1) In financial analysis in Part VII, construction of six furnaces is assumed.

4–2–3 Process Specifications

(1) Basis for design

(a) Function

The function of the plant shall be the production of polymer grade ethylene by pyrolysis of ethane feedstock supplied from the gas processing plant and ethane recycle.

The plant shall also be designed to produce hydrogen/methane gas and the C_3 and heavier product which is used as plant fuel gas after mixing.

(b) Capacity

The plant shall be designed for the production of 230,000 t/y of polymer grade ethylene in 8,000 operating hours per calendar year.

(c) Feedstock specification

The plant shall be designed to process ethane feedstock with the composition given below:

Components	Estimated Composition
Methane	2.0 mol% max.
CO_2	0.1 mol% max.
Propane	3.0 mol% max.
Ethane	Balance

(d) Products and their specifications

The plant shall be designed to produce simultaneously the products specified below when processing the design feedstock.

(i) Polymer Grade Ethylene

Components	Estimated Composition
Ethylene	99.9 mol% min.
Methane & saturates	0.1 mol% max.
Acetylene	5 mol ppm max.
Hydrogen	5 mol ppm max.

C_3 & heavier	10 mol ppm max.
CO	5 wt. ppm max.
CO_2	5 wt. ppm max.
Sulfur as H_2S	1 wt. ppm max.

(ii) Hydrogen plus methane off-gas

Components	Estimated Composition
Hydrogen	84.9 mol%
Methane	14.8 mol%
C_2's	0.3 mol%

(iii) C_3 and heavier product

Components	Estimated Composition
C_3's	36 wt%
C_4's	42 wt%
C_5's and heavier	22 wt%

(e) Yield of product

The plant shall be designed to deliver the following estimated yield of products with specifications as per indicated in (d) when supplied with design feedstock as specified in (c) above.

Products	Kg/Hr
Hydrogen plus methane gas	4,942
Polymer-grade ethylene product	28,750
(High pressure product)	(10,000)
(Low pressure product)	(18,750)
C_3 and heavier product	2,178
	35,870

Feedstock	Kg/Hr
Ethane rich gas (95 mol%)	35,870

(f) Battery limit conditions

The plant shall be designed to receive feedstocks and deliver products to the battery limits at the conditions specified below:

Stream	State	Pressure ($kg/cm^2 g$)	Temperature (°C)
Ethane feedstock			
Normal	Vapor	10	Amb.
(Alternative to the storage)	Liquid	20	-7
Polymer grade ethylene product			
Low pressure product	Vapor	16	30
High pressure product	Vapor	20	30
Fuel gas*	Vapor	4	40

Note: * Hydrogen plus methane gas and the C_3 and heavier product are normally mixed and sent as fuel gas to cracking furnace. There is normally no export.

(g) Utility conditions and characteristics

The battery limits conditions and characteristics of the utilities which will be used in the plant and are to be supplied to or exported from the plant shall be as follows:

(i) Steam

	Pressure ($kg/cm^2 g$)	Temperature (°C)
High pressure	42	440
Medium pressure	15	280
Low pressure	3	Sat.

(ii) Boiler feed water

Pressure ($kg/cm^2 g$)	55
Temperature (°C)	135
Type	Deaerated water
Dissolved oxygen (mg/l)	0.03 max.
Silica content (ppm)	0.02 max.

(iii) Steam condensate

The plant shall be designed to export steam condensate to the battery limits (to the utilities center).

	No. 1 Condensate	No. 2 Condensate
Pressure ($kg/cm^2 g$)	3.5	2.0
Temperature (°C)	138	60
Electric conductivity (M℧/cm at 25°C)	10 max.	10 max.

(iv) Cooling water

Cooling water shall be supplied at and returned to battery limits at the following conditions:

	Pressure ($kg/cm^2 g$)	Temperature (°C)
Cooling water supply	5 min.	32 max.
Cooling water return	2 min.	45 max.

(v) Fuel gas

The plant shall be designed to burn the mixed fuel gas produced by the plant. Make up and start-up fuel gas is an external natural gas supplied from the gas processing plant at battery limits.

Pressure ($kg/cm^2 g$)	4
Temperature (°C)	10 ~ 40

	Plant Gas	Natural Gas
Low heat value ($kcal/Nm^3$)	3,830	9,400

Composition (Estimated)		
Hydrogen	82.2 mol%	
Methane	14.2 mol%	Methane
C_2's and heavier	3.6 mol%	rich gas

(vi) Electricity

The following nominal voltage shall be used for operation of electrical equipment:

	Voltage	Type	Frequency
High voltage line	6,000V	3 phase	50 Hz
Low voltage line	400V	3 phase	50 Hz
Lighting	250V	Single phase	50 Hz

(vii) Plant air

Pressure ($kg/cm^2 g$)	7.0
Temperature (°C)	Ambient

(viii) Instrument air

Dew point (°C) (at 7 $kg/cm^2 g$)	-40
Pressure ($kg/cm^2 g$)	7.0
Temperature (°C)	Ambient

(ix) Nitrogen

Purity (mol%)	99.5 min.
Pressure ($kg/cm^2 g$)	7.0
Temperature (°C)	Ambient

(x) Potable water

Pressure ($kg/cm^2 g$)	2 max.
Temperature (°C)	Ambient

(xi) Fire fighting water

Pressure ($kg/cm^2 g$)	9
Temperature	Ambient

(h) Estimated utility consumption

(i) Steam

Import (42 kg/cm^2g steam)	13.9 t/hr

(ii) Cooling water

Circulation	6,900 m^3/hr
Temperature rise	13°C Max.

(iii) Fuel gas

Import	44.84 MMBtu/hr

(iv) Electric power	750 kWH/h

(i) Catalysts and Chemicals

The design of the plant shall be based upon the catalysts and chemicals shown below:

Acetylene hydrogentation catalyst
Methanation catalyst
Desiccant
Caustic soda solution
Methanol
Injection sulfur
Charge gas compressor wash oil
Corrosion inhibitor