THE FEASIBILITY STUDY REPORT ON THE LUBRICATING OIL REFINERY PROJECT IN THE KINGDOM OF THAILAND

DECEMBER, 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

THE FEASIBILITY STUDY REPORT ON THE LUBRICATING OIL REFINERY PROJECT IN THE KINGDOM OF THAILAND

DECEMBER, 1984

JAPAN INTERNATIONAL COOPERATION AGENCY

PREFACE

In response to the request of the Government of the Kingdom of Thailand, the Government of Japan decided to conduct a feasibility study on the Lubricating Oil Refining Project and entrusted the study to the Japan International Cooperation Agency (JICA). The JICA sent to Thailand a survey team headed by Mr. Yoshiyasu MIKAMI from February 19 to March 17, 1984.

The team exchanged views with the officials concerned of the Government of the Kingdom of Thailand and conducted a field survey in the Project-related areas, including Bangkok, Bangchak and Sri Racha. After the team returned to Japan, further studies were made and the present report has been prepared.

I hope that this report will serve for the development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the team.

Tokyo, December 1984

Keisuke Arita

Keisuke ARITA

President

Japan International Cooperation Agency

GLOSSARY

Base oil	means "lube base oil" in this document which is a raw material and major component of lubricating oil.
Base oil plant	this term is used interchangeably with "lube base oil paint" or "lubricating oil refinery" which produces base oil.
Consultant, the	Ad hoc team formed to undertake the feasibility study on the Project under the name of JICA, or parent organizations of such team's members.
Lube oil	a final product of base oil blended with various kinds of additives for different purposes. Short form of "lubricating oil".
Plant, the	the base oil plant specifically planned by NEA and for which the Consultant is studying from technical, financial and other aspects.
Project, the	Overall project including planning, design, construction, operation, etc. related to the plant.
S/W	"Scope of Work" which is a written scope of feasibility study on the lubricating oil refining project contained in the agreement between NEA and JICA.

ABBREVIATIONS AND SYMBOLS

Unit and Conversion

mm	Millimeter
cm	Centimeter
m	Meter
km	Kilometer
in	Inch (1 in = 2.54cm)
ft	Foot (pl. feet)(1 ft = 0.305m)
cm^2	Square centimeter
m^2	Square meter
ha	Hectare (1 ha = 10,000m^2 = 2.471acres)
ft^2	Square foot (1 ft^2 = 0.0929m^2)
Rai	(1 Rai = 1,600m^2)

m^3	Cubic meter
Nm^3	Normal cubic meter
MMm^3	Million cubic meters
ft^3, cu ft, cft	Cubic foot (1 ft^3 = 0.0283m^3)
SCF	Standard cubic foot
MMSCF	Million standard cubic feet
l	Liter
kl	Kiloliter
gal	Gallon (1 British gallon = 4.546litters, 1 U.S. gallon = 3.785litters)
bbl	Barrel (1 barrel = 42 U.S. gallons)
g	Gram
kg	Kilogram
t, T, ton, Ton	Metric ton
lb(s)	Pound (1 lb = 0.454kg)
LMT	Liquid metric ton (50% aques solution of caustic soda)
sec	Second
min	Minute
h, hr, Hr	Hour
d, D	Day
m, M	Month
y, Y	Year
°C	Degree centigrade
°F	Degree fahrenheit
cal	Calorie
Kcal, K cal	Kilo calorie
BTU, Btu	British thermal unit (1 BTU = 0.252 K cal)
MMBTU, MMBtu	Million British thermal units
LHV	Low heating value
HHV	High heating value
A	Ampere
V	Volt
W	Watt
kW	Kilowatt
mW	Megawatt

kVA	Kilo-volt ampere
mVA	Mega-volt ampere
kWH, kWh	Kilowatt-hour
mWG, mWh	Megawatt-hour
HP	Horsepower
%	Percent
ppm	Parts per million
g/Nm^3	Gram per normal cubic meter
pH, PH	Hydrogen ion concentration
kg/cm^2	Kilogram per square centimeter
lb/in^2	pounds per square inch
mmAq	mm aqua (= water)
t/d, ton/day, T/D	Tons per day
t/y, ton/year, MTA, MT/Y, T/Y	Tons per year
MMSCFD, MMscfd	Million standard cubic feet per day
BPCD	Barrels per calendar day
BPSD	Barrels per stream day
TPCD	Tons per calendar day
TPSD	Tons per stream day
MD	Man days
F/Ton, F/T	Freight tons
SCF/Bbl	Standard cubic feet per barrel

Technical Terms

HDPE	High density polyethylene
LDPE	Low density polyethylene
PP	Polypropylene
PVC	Polyvinyl chloride
VCM	Vinyl chloride monomer
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
NG	Natural gas
BFW	Boiler Feed Water
BS	Bright Stock
CTW	Cooling Tower Water

DAO	Deasphalted Oil
EFO	Equivalent of Fuel Oil
E.P.C.	Engineering, Procurement and Construction
Flash Point (COC)	Flash Point (Cleveland Open Cup)
H/C	Hydrocracking
H/F	Hydrofinishing
LVGO	Light Vacuum Gas Oil
MEK	Methyl-Ethyl-Ketone
MM	Millions or Man-Months
NMP	N-Methyl-2-Pyrrolidone
PDA	Propane Deasphalting
S. Wax	Slack Wax
T/C	Thermalcracking
V/B	Visbreaking
VGO	Vacuum Gas Oil
VI	Viscosity Index
VR	Vacuum Residue
WWT	Waste Water Treating
60 N	60 Neutral Base Oil
150 N	150 Neutral Base Oil
300 N	300 Neutral Base Oil
500 N	500 Neutral Base Oil
150 BS	150 Bright Stock Base Oil
140 P	140 Paraffin
150 P	150 Paraffin

Financial and Economic Terms

DCF	Discounted cash flow
IRR, IRROI	Internal rate of return on investment
EIRR, EIRROI	Economic internal rate of return on investment
FIRR, FIRROI	Financial internal rate of return on investment
IRROE	Internal rate of return on equity
GDP	Gross domestic product
GDPR	Real gross domestic product
GNP	Gross national product
C&F	Cost and freight
CIF	Cost, insurance and freight

FOB	Free on board
EMP	Energy Master Plan

Exchange Rate

Baht	Thailand Baht (1 U.S. dollar = 23 Baht)
$, U.S.$,	U.S. dollar
yen	Japanese yen (1 U.S. dollar = 230 yen)

Organization and Company

NEA	National Energy Administration
GOT	The Government of Thailand
PTT	Petroleum Authority of Thailand
BOI	Office of the Board of Investment
NESDB	Office of the National Economic and Social Development Board
DTEC	Department of Technical and Economic Cooperation
MOI	Ministry of Industry
EGAT	Electricity Generating Authority of Thailand
PEA	Provincial Electricity Authority
NEB	National Environmental Board of Thailand
PAT	Port Authority of Thailand
MOR	Military Oil Refinery in Bangchak (= Bangchak Refinery)
TORC	Thai Oil Refinery
ESSO	Esso Refinery
JICA	Japan International Cooperation Agency
JETRO	Japan External Trade Organization
FDA	The U.S. Food and Drug Administration
OPEC	Organization of Petroleum Exporting Countries

THE FEASIBILITY STUDY REPORT
ON
THE LUBRICATING OIL
REFINERY PROJECT
IN
THE KINGDOM OF THAILAND

TABLE OF CONTENTS

Page

LIST OF TABLES

LIST OF FIGURES

Part I

INTRODUCTION

(OUTLINE OF THE PROJECT)

Part I INTRODUCTION (OUTLINE OF THE PROJECT)

Chapter 1 Background of the Project

Although 170,000 kl of lube oil had been consumed in 1981, no lube base oil plant to produce raw material for lube oil blending is established in Thailand. Meanwhile, demand for fuel oil including feedstock for base oil production, is expected to decline, and fuel oil will become even oversupplied due to production and utilization of natural gas from Gulf of Siam.

Under such circumstances, the Government of Thailand asked the Government of Japan to conduct the feasibility study of constructing a base oil plant solving the fuel oil surplus problem as well as saving foreign exchange outflow incurred in importation of lube oil and base oil. In response to the above request, the Japanese Government has agreed to conduct a feasibility study on lube base oil refining project and JICA (Japan International Cooperation Agency) has taken up the study.

Chapter 2 Objective and Scope of the Survey

The purpose of the survey is to study the base oil project in Thailand from the technical, financial and economic points of view and to prepare the report on the feasibility of the project. Scope of the study is as follows:

(1) Review on the background and relevant conditions of the Project.

1) General economic situation of Thailand
2) Present situation of and policies on industrial development
3) Present situation of and policies on petroleum industry
4) Relevant laws and regulations

(2) Study on the market of lubricating oil

1) Market study of lubricating oil in the world
2) Trend of the consumption in the Kingdom of Thailand
3) Present situation of import and its price
4) Present demand by sectors such as industry, automobile and others
5) Marketing and distribution system of base oil and their finished products
6) Estimation of future demand

(3) Study on the crude oil and fuel oil

1) Types of crude oil to be fed to the refineries in future
2) Past and present supply of fuel oil
   - Production
   - Properties
   - Price
3) Estimation of future supply of fuel oil

(4) Study on the plant location and site

1) Natural conditions of the site and its surrounding area such as meteorology, geology and topography.

2) Utilities and infrastructure such as electricity, water, transportation and communication.

3) Regional development policy and/or plan.

4) Comparative study on the candidate sites.

5) Selection of the plant site and recommendation whether the plant should be annexed to or separated from any of existing refineries.

Note: Candidate sites will be shown by NEA.

(5) Study on the basic plan and the conceptual design of the Project.

1) Selection of optimum feedstocks
2) Selection of optimum products blend and their production scale
3) Determination of the most suitable process
4) Alternative of refining process
5) Design standard of the plant
6) Process flow sheet
7) Plan layout of main plant and auxiliary facilities
8) Transport plan of equipment and materials for plant construction
9) Construction cost
10) Implementing program of plant construction
11) Organization and manpower plan for plant construction and operation

(6) Study on environmental protection.

(7) Financial analysis

1) Capital requirement
   - Fixed capital (land cost, construction cost of plant and other facilities and pre-operation cost, etc.)
   - Working capital
   - Investiment schedule

2) Production cost

3) Projected income statement

4) Projected balance sheet

5) Projected flow statement

6) Financial internal rate of return

7) Sensitivity analysis based on possible variations in:
   - Investment cost
   - Price of fuel oil
   - Interest rate
   - Sales price

(8) Economic and social evaluation

(9) Conclusion and recommendations

Chapter 3 Steps and Schedule of the Study

The survey was carried out in accordance with the following schedule to meet the purpose and scope of the survey stated above. The survey in Thailand was executed with a full support of NEA of Thailand.

1. Prior to the field survey, a questionnaire was distributed through NEA to lube oil blenders, who import base oils to blend them into lube oil for marketing, as well as lube oil consumers, representing different industrial fields. The answers were collected while the survey team was in Thailand.

2. An advance party of the survey team arrived in Thailand on February 19, 1984 to explain the method of study and to prepare the survey schedule with the representatives of NEA.

3. The rest of the survey team arrived in Thailand on February 26, 1984 to join the advance party, and stayed there until March 17, 1984 conducting the following surveys:

   (a) Answers to the questionnaire, which had been distributed earlier, were collected through NEA. (The greater results than had been expected were obtained through cooperation of NEA. In some instance, the additional answers were obtained by cooperation of NEA.)

   (b) The survey team discussed with NEA and decided the future economic growth of Thailand and petroleum product demand forecast as the base of study.

   (c) From NEA-owned reference materials, information was obtained on the present, future plan and job site of the three refineries. Also, visit was paid to Bangchak Refinery and TORC Refinery as well as PTT Office to get the information concerning the refining.

   (d) Import statistics and answers to blenders' questionnaire, which provide a base for macro-economic market forecast, were analyzed. Also, an equation for estimating the number of vehicles (which was obtained

from sub-system to Energy Master Plan (EMP)), present condition and future growth of each industrial field, and lube oil demand per unit, which provide a base for micro-economic forecast, were obtained through NEA and by visiting various companies.

(e) Data necessary for financial and economic analysis were collected, and discussion was made on the economic analysis method.

4. The results of the above survey were summarized in a progress report to explain to NEA, and some discussions on the progress report were made, for example, on effects of crude oil types as the base oil feedstocks. When NEA official visited Japan later, we could obtain some comments on the progress report.

5. After the survey team returned to Japan, the team conducted macro and micro lube oil demand forecasts, based on materials collected in Thailand. The team also analyzed and forecasted the price of lube oil, base oil and petroleum products which are produced from the base oil plant during the process as by products, as well as that of long residue as feedstocks.

Meanwhile, several plans of the base oil plant were studied, and process and equipment for the plan were decided, material balance was calculated, and construction cost was worked out. On a basis of what was obtained, economic analysis and evaluation were made.

6. During the July 5 - August 15 period, we accepted trainees of NEA to explain the project, and gave them on-the-job training, including the inspection of the base oil plant.

At the same time, senior staff of NEA was accepted, and discussions were made on the contents of the report.

7. As a result of the above works, the Draft Report was completed.

How the survey was conducted on each item is explained in the order listed in Chapter 2, that is, Scope of the Survey. Results of the survey are given in the chapter indicated at the end of each item.

(1) Background Survey of the Project

1) Thai Economy

As shown in Fig. 1-1, the forecast for Thai economy and its industrial development policy are necessary for (1) energy demand forecast, (2) justification of expansion program of each refinery, (3) demand/supply balance of each energy source (particularly the availability of long residue which is feedstocks of the base oil plant), and (4) lube oil demand forecast. The NESDB forecast was adopted as the present and future forecast for Thai economy. It is because NESDB forecast is most reliable, and Energy Master Plan (EMP) based on it. The adoption of NESDB forecast is also aimed to keep consistency with energy forecast calculated by running of EMP. (For details, see Chapter 4 of Part I.)

When the survey team was still in Thailand, NESDB adopted the GDPR growth rate of 6.6% in its 5th 5-year plan while 6% was adopted for EMP. After the team returned to Japan, NESDB revised its future economic growth rate from 6.6% to 5.5%. In this respect, it was decided to study the effects the revision has on the lube oil demand.

2) Present Condition and Policy of Industrial Development in Thailand

This was prepared based on data presented by Thai NESDB and BOI. At present, tenders are being invited for the construction of fertilizer, selecting of consultant for petrochemical is also in progress and construction of soda ash project was approved by ASEAN nations.

Although some problems are left unsolved, making the project delayed, however the construction of these projects is expected to be materialized by the time the base oil plant is assumed to be built and begin operations at begining of 1991. (For details, see Chapter 1 of Part IV.)

3) Present Condition and Policy for the Oil Refining Industry

The oil refining industry is closely related to the materialization of the base oil plant. It is affected by (1) supply of long residue, as feedstocks for the base oil plant, (2) utilization of by-products obtained in the base oil production, (3) operation of the base oil plant, and (4) marketing of base oil.

From the above points of view, the survey was conducted on the refinery as follows.

(1) In forecasting the future petroleum product demand in Thailand, NEA's EMP estimation was used, (2) the modernization and expansion programs of the refineries at present and in the future was checked by the petroleum product demand forecast, and (3) for the configuration of the existing refineries, usable land and utilities, the survey was conducted through the refinery visit to Bangchak and TORC and through interview with PTT representatives (however, visit to Esso was not made). (For details, see Chapter 5 of Part II.) In EMP's energy and petroleum product forecast, GNPR growth rate of 6.0% for the 5th 5-year program was adopted.

With regard to Bangchak refinery, the corporate fund position was made partly available and we have decided to make effort to prepare financial statements in case the base oil plant is operated as part of the existing refinery. Nevertheless, due to lack of information on basic data used for future plan of the refinery, it was identified that there is no way to project consolidated financial paper of renovated refinery and lube base oil plant with consistency. Thus, it was caused to despair to prepare consolidated financial papers.

4) Related Laws, Regulations and Rules

The survey of codes and regulations, covering the plant construction as well as the environmental pollution control, was conducted. Also, the survey was made on investment conditions, including taxes and fund arrangement, for making financial and economic analysis. (The former is given in Chapter 5 of Part III and the latter in Chapter 1 of Part IV.)

(2) Lube Oil Market Survey

1) World-wide Demand and Supply

The survey of the world-wide demand/supply trend of lube oil, at present and in the future was made, and an emphasis was placed on the Asian region. (For details, see Chapter 8 of Part II.)

2) Consumption Trend In Thailand

The following three methods were used to obtain the consumption trend in Thailand of lube oil and base oil. Based on the results, the estimation for 1983 was made.

a) Import statistics of base oil and lube oil in Thailand were analyzed.

b) Blenders' imports of base oil and lube oil together with the actual production of lube oil based on imported base oil have been obtained.

c) The lube oil demand was estimated by accumulation method with the data of questionnaire distributed among the auto and vehicle industry, agriculture and fisheries and other consumers and obtained through the visit to lube oil marketing firms, service stations and other lube oil consumers. (For details, see Chapter 1 of Part II.)

3) Import and Price of Base Oil

Imports of base oil and lube oil into Thailand was obtained from import statistics and the questionnaire of the blenders.

The base oil price by types was estimated by comparing and studying import statistics in Thailand, export price of Singapore (Platt's Oilgram Price Report) and answers from blenders. The price of petroleum products which are obtained as by-products from the base oil plant, and are not found on the market, was estimated by using viscosity, specific gravity and octane value in comparison with other petroleum products found on the market.

The future prices of base oil, long residue and other petroleum by-products were estimated based on the relative price with crude oil. The estimated future crude oil price was obtained from NEA's price forecast used in EMP. (For details, see Chapter 3 of Part II.)

4) Lube Oil Demand for Each Uses

From the quantities of lube oil sold to each consumer (vehicles, industry, and others) by blenders, which they imported or produced from imported base oil, and from the lube oil demand forecast for each consumer (prepared by the survey made in site and in Japan), demand forecast was made for each uses. (For details, see Chapter 1 and Chapter 2 of Part II.)

5) Distribution Channels of Base Oil and Petroleum Products

Prior to the departure from Thailand, the survey team had a good knowledge of distribution channels of the base oil and petroleum products. But the team confirmed the knowledge by the survey of blenders (answers to questionnaire as well as hearings) and personal visit to service stations and retailers during its stay in Thailand. At the same time, the team inspected blender firms to know the receiving facility. (For details, see Chapter 7 of Part II.)

6) Forecast for Demand and Supply of Lube Oil in Thailand

From the present condition of the lube oil demand in Thailand stated in (2)-2), lube oil demand forecast was made through macro- and micro- methods. In the macro-lube oil demand forecast, the lube oil demand for vehicles was obtained from the growth rate of consumption in gasoline, diesel oil, and LPG for transportation. The lube oil demand forecast for industrial fields was obtained from the increase rate of value added which were calculated by NESDB in the economic growth forecast. In the micro-lube oil demand forecast, the lube oil demand for each consumers was forecasted, considering the future growth rate of each consumer. Although the unit lube oil consumption for vehicles in Thailand is greater than in Japan per distance covered due to the longer use of vehicles, the forecast was made assuming that the unit lube oil consumption in Thailand per distance covered will be much improved in the future. Since the economic forecast for Thailand was revised by NESDB after the survey team returned to Japan, we have decided to watch the effects of the lowered economic growth rate by uning elasticity value of lube oil demand on GDP. (For details, see Chapter 3 of Part II.)

(3) Crude Oil Survey

1) Types of Crude Oil Used (Including Future Supply Forecast in (1)-3)

Considering the types of crude oil imported by Thai refineries now, future availability of crude oil, demand structure of petroleum products in Thailand, price difference among various types of crude oil, analysis was made to find crude oil type which Thailand will use in the future.

It is desirable for saving equipment cost, operating cost and minimizing by-products to use crude oil containing as much desired ingredients for producing lube oil as possible. (For details, see Chapter 5 of Part II.)

2) Trend of Crude Oil Price

As the OPEC becomes less powerful, the crude oil price has come to be determined by demand/supply relations. Considering that forecast by various research institutions are close to that of NEA, and that NEA used its forecast in EMP, we have decided to adopt the NEA forecast. (For details, see Chapter 4 of Part II.)

(4) Site Survey

1) Natural conditions of the site and its surrounding

Natural conditions of the site and its surrounding area such as meteorogy, geology and topography were investigated and was collected relevant information for the site of Bangchak and Siracha as a candidate site. (Described in Chapter 5 of Part III)

2) Utility and Infrastructure

Possibility of utilities supply such as electricity, water and provision of infrastructure such as transportation and communication for the plant construction and operation were investigated. (Described in Chapter 5 of Part III)

3) Regional development plan or policy

Taking into account of planned regional development plans and special conditions of the region, the basic plan for the lube base oil facilities was prepared. (Described in Chapter 5 of Part III)

4) Site comparison

Based upon the above-mentioned investigations of 1)-3), two site candidates were compared and evaluated as for following factors;

a) Feed oil supply
b) Delivery and transportation of product base oils (distance from

lube blenders)

c) Utilities condition

d) Availability of required area for the plant

e) Environmental control

f) Availability of labor and infrastructure

g) Possibility and availability of investment by existing refineries

h) Regional development plan and industrial development policy

(Described in Chapter 5 of Part III)

5) Site selection

Based upon the site comparison described in 4) and economics, recommendation of the site selection was made. (Described in Chapter 1 of Part III.)

(5) Basic plan and conceptual design

Basic plan and conceptual design were prepared from the following reasons;

- Cost estimation of base oil plant
- Estimation of operation cost
- Clarifying of technical problems regarding the project execution
- Solution of above problems

1) Selection of optimum crude oil

The suitability of crude oil were examined from the viewpoint of;

a) potential crude oil production capability

b) supply stability

c) Suitability of feed oil in terms of products pattern met with Thai demands and production of high VI lubricants.

2) Selection of base oil grade and production rate

a) Base oil grade

From the analysis of import statistics of lube oil, the production of five base oil grades were selected i.e. 60N, 150N, 300N, 500N and 150BS were defined in the plant.

b) Production capacity

The production capacity of the base oil plant is defined on the basis of forecasted base oil demand in 1993 taking into account the construction period thereof.

3) Process selection

Lube oil process scheme is basically divided into conventional type and hydrocracking type, and thorough study were made on such types of processes.

4) Process alternatives

Since how to treat by-products affects generally the economics of base oil plant, are examined by-products treating processes to be attached to base oil processes.

5) Basic plan of the facilities/Codes and Standards

Planning and conceptual design of the base oil plant were conducted for the six cases defined as follows:

Case	Note
a. BANGCHAK-A	New Company
b. BANGCHAK-B	Expansion
c. SRI RACHA-A	New Company
d. SRI RACHA-B	Expansion
e. BANGCHAK-AX	New Company, Wax Production
f. BANGCHAK-AY	New Company, No Asphalt Production

(Described in Chapter 5 of Part III)

The plant facilities were planned based on the internationally acceptable codes and standards.

Reliable and stable supply of utilities is generally requested for the successful operation of the base oil plant. Better utilities supply system for the base oil plant was planned for the above six cases considering the present status and problems on the existing refineries' system.

Necessary factors for planning of feed supply and product loading facilities are to confirm the present status of the facilities, the location of base oil blending companies, operation of the base oil plant, and so on. Tankage for feedstock, intermediate products, and products was planned considering the adequate inventory which was defined in view of stable operation and the minimum plant cost based on the assumption that the existing blending companies in Thailand have tanks capable of more than 60 days' consumption. Furthermore necessary offsite facilities were planned.
(Described in Chapter 5 of Part III)

6) Process flow sheet

Process flow sheet was prepared for each process unit selected for this project taking account of energy conservation and environmental control standards as well as specified production rate and product qualities.
(Described in ANNEX III-1)

7) Plan layout of main plant and auxiliary facilities

For the purpose of estimating the required area for the base oil plan, planned facilities were laid out taking account of the following factors:

- Safety, maintenance, operation
- Construction, plant cost
- Expansion
- Environmental control

(Described in Chapter 5 of Part III)

8) Transport plan of equipments and materials for plant construction

Equipments and materials for the base oil plant construction are to be purchased in Thailand as much as possible and others are to be purchased from Japan, Europe or U.S.A. In order to develop a transport plan, monthly shipping schedule for foreign equipments and materials were prepared. Furthermore transportation plan for each site was investigated taking account of site survey results on status of infrastructure such as ports, roads, rail ways, bridges and so on.

(Described in Chapter 5 of Part III)

9) Construction cost

The plant cost was estimated based on the consultant's experience in construction of base oil plants executed in Japan and overseas. For estimates, wages and quality of construction labors, availability of indigenous construction contractors, purchasable goods in Thailand and so on were investigated.

(Described in Chapter 1 of Part IV)

10) Implementing program of plant construction

Implementing program of plant construction was prepared based on the consultant's experience in construction of similar type of plants executed in Japan and overseas. It was assumed that basic design was finished by bidding stage. (Described in Chapter 5 of Part III)

11) Organization and manpower plan for plant construction and operation

According to the implementing program of plant construction, organization was developed and manpower was estimated. Maximum employment of Thai people for construction was considered.
(Described in Chapter 3 of Part IV)

Furthermore, organization was developed and manpower required was estimated for plant operation taking account of the consultant's experience in base oil plants in Japan and overseas, and of the current status of world refinery operation.

(6) Study on environmental protection

Environmental control standards in Thailand were investigated. Sources of wastes were clarified and control measures were prepared for each source.

As a result of the above investigation, environmental protection facilities were planned.
(Described in Chapter 5 of Part III)

(7) Financial and Economic Analysis

1) Total Project Investment

Total project investment required for the project is estimated on each of the following item:

a. Land acquisition and site preparation costs
b. Plant construction cost
c. Pre-operational expenses
d. Initial working capital
e. Interest during construction

2) Financing Plan

The total project cost is assumed to be financed with debt-equity ratio of 60:40 of which loans portion is assumed to be financed by long term commercial credit.

3) Preparation of Financial Papers

In addition to the above assumptions, other detailed conditions including project schedule, operating plan, etc. are assumed (refer Part IV), then major financial papers were prepared in current term basis.

4) Financial Analysis

Based on the financial papers as above, various ratio analysis (financial indicators), calculation of financial internal rate of return (in current terms and in real term) and sensitivity analysis on major parameters were made.

5) Economic Analysis

Based on the economic direct costs and benefits for the project, economic internal rate of return and economic net present value were calculated, and further, major indirect items were evaluated.

Details of the above are to be referred to Part IV and V and its annexes hereto.

Chapter 4 Economic Environment of Thailand

4-1 Thai Economy

High official of National Economic and Social Development Board, cited the "Euromoney" magazine (Thailand ranks among the world's 85 best economic performance nations) and the Asian Wall Street Journal (Thailand enjoys the benefit of getting loan at 0.37 of a percentage point over the London Interbank offered rates) to explain the sound economic operation of Thailand. He listed the following reasons contributing to sound economy during the past 20 years:

(1) Thailand has an abundant food crop, and ranks among the top 5 food exporting countries.

(2) So far, the Thai Government has taken a sound fiscal and monetary policy.

(3) Economy has been operated chiefly by civilian enterprises that were almost free from the government intervention.

(4) The economic operation policy has been worked out and executed by an elite corps of technocrats.

Further, he situated the following five years as a transformation stage from traditional agriculture-rural-resource based to more modern and complex forms of urban modern industry. He pointed out that the discovery and tapping of natural gas in Gulf of Siam and crude oil in Lan Krabue have drastically changed Thailand's map of natural resources, and laid his hopes on the development program of Eastern Seaboard. Of course he cited the trends of world economy,crude oil price, and production of natural gas and crude oil in Thailand as unknown factors. He also said that he had estimated the growth rate of the medium-range development program lasting until 1987 at 6.5% (as of February 7, 1984), which is undertaken jointly by NESDB and the World Bank.

In June this year, NESDB revised its economic growth rate to 5.5% from the original 6.5%.

Shown in Table 1-1 is the target and achievement of growth rate for each five-year program, which are broken down into industrial sectors. The annual GDP growth rate of each five-year program were satisfactory, and in the fourth five-year program (1976-1981), including the 2nd oil crisis period, the growth rate showed a rise of 7.3%.

Shown in Table 1-2 is the GDPR value estimated by NESDB and used for NEA's Energy Master Plan (EMP) for obtaining the energy demand forecast. In EMP case, the annual growth rate was estimated at 6.0% until 1986 and 6.5% after 1986. The economic forecast varies according to the trends of world economy, crude oil price, and production of natural gas and crude oil in Thailand. It is also affected by economic operation of the Thai Government. From the past economic growth of Thailand, it is considered proper to expect a growth rate of around 6%. The World Bank Development Report in 1984 revealed that the real GDP growth rate in developing nations during 1985-1995 period is estimated at 4.7-5.5%. The NESDB forecast is based on macro-economic model. If Thailand achieves a smooth "takeoff" during the period, it can be expected that the growth rate will become as high as around 10%, as shown in the Japanese, Korean and Taiwan examples. An important is that "takeoff" is not achieved too early, crashing the whole economy. But there are many problems lying ahead such as economic feasibility of a large projects, natural gas cost of Thailand is higher than other nations, requirement of huge fund, and the necessity of organizing ability for construction and operation of plant, and recruiting large numbers of experienced men for running the corporation. For Thailand that operated its economy on private initiative, a strong Government support will be necessary to tide over the transformation stage, because future project is especially large. This is illustrated by examples in Korea and Taiwan.

4-2 Present Condition and Future Forecast of Industrial Development of Thailand

Since around 30 years ago, Thailand has been carrying out the investment policy of private initiative, providing a base for its economic development, as stated in the previous section. This economic policy, aimed at minimizing inefficiency of state-run corporation, is correct in itself. But as stated in the preceding section, this policy will pose many problems in fund requirement and operation when going ahead with a large project. In Thailand, the Joint Public-Private Consultative Committee was established under the chairmanship of the Prime Minister to promote the partnership between the Government and private sectors. High official of Board of Investment, said that he would do the following things to promote the industrial investment by private sectors.

(1) Reducing an investment risk
(2) Reducing an initial investment
(3) Improvement of profit ratio with investment

In order to reduce an investment risk, Thailand considers to give a guarantee against nationalization and competition from public sectors. Thailand also concluded the investment protection agreement with many countries. To reduce the initial investment amount or improve the profit ratio against investment, special privilege, including taxation and tax exemption measures, are being contemplated. If an investment program is in line with national policy, the following incentive package is under contemplation.

1) Corporate income and dividend tax holidays for between 3 and 8 years. This allows good returns on investment in the early years and a quicker reduction in loan costs.

2) Special deductions from taxable income are available for;

- A proportion of incremental export earnings;
- Doubled-up expenditures on transport and utilities by companies located in our designated Investment Promotion Zones;
- Carried forward losses, and
- Fees relating to goodwill, copyright and other such fees.

3) Exemption of import duties and business taxes on;

- Approved machinery imports, which lower overall investment costs and depreciation charges, and
- Imported and local raw materials, especially for export-oriented projects, in order to lower the direct costs of production.

4) Exemption of duties and business taxes on export sales and reduced business taxes on sales of goods produced in the Investment Promotion Zones designed to increase your competitiveness by world standards.

5) Temporary tariff surcharges/to prevent unfair competition from imports, especially dumping.

6) Permission for;

- foreign ownership of land;
- the entry and employment of foreign experts, skilled workers and their families; and
- The free repatriation of capital and remittance of profits.

The following industries are listed as qualified for the incentive package:

1) Industry whose employment sharply rises.

2) industry that is located in other area than Bangkok

3) Energy-saving industry or industry that substitutes for imported crude oil.

4) Industry contributing to the acquisition of foreign exchange reserves, or to the reduction of its spending.

5) Industry contributing to the progress of the key industry.

With regard to the investment ratio between domestic and foreign, the investment in the domestic market must have a majority of Thai capital, but for the investment in the exportoriented industry, a majority of foreign capital, or even 100% is allowed.

NESDB made progress forecast for each industry, such as cement, sugar and textile, and that forecast is used in this study for forecasting lube oil demand.

What is expected to bring prosperity to the Thai industry, in addition to expansion of the existing industry, is the industrialization program of Eastern Seaboard. The project, based on natural gas, includes fertilizer, petrochemical and soda ash. In future, a steel plant may also be contained. The production and utilization program of natural gas currently under planning is as follows:

(Unit: million cft/day)

	1983	1985	1990
For electric power generation	147	340	480
For industrial fuel	-	40	40
For LPG	-	70	70
For industrial feedstock	-	-	110
Total	147	450	700

Natural gas deposit in Thailand is not confirmed yet. However, according to the Petroleum Authority of Thailand, the deposit is enough to cover the project under planning. As shown in the above table, natural gas production in 1983 was used almost for generating electric power (Bangkok and Bangpakong).

But it will be also used as fuel at Siam Cement Company's two cement plants. At present, a gas separation plant is under construction and is

expected to come into operation next year, where 460,000 tons of LPG, 320,000 tons of ethane (for petrochemical use), 66,000 tons of natural gasoline can be produced. Using ethane and propane thus produced, 300,000 tons of ethylene and 73,000 tons of propylene are expected to be manufactured. For this project, a new company has been already established, and the selection of consultant, including re-study of a feasibility study and construction, is in progress. It is also expected that 100,000 tons of LDPE, 110,000 tons of HDPE, 80,000 tons of VCM, and 70,000 tons of PP plant will be constructed, using ethylene and proplylene. Along with the petrochemical project, a new company has been inaugurated to produce fertilizer. At present, tender is being invited. The fertilizer plant's daily capacity is 900 tons of ammonia, 1,000 tons of urea, 2,110 tons of sulfuric acid, 720 tons of phosphoric acid, and 2,800 tons of MPA, DAP and NPK. Also, a soda ash plant is under contemplation as ASEAN project with its location eyed along the Eastern Seaboard.

It is reported that discussion has begun about the delay of some projects, because all those projects require enormous fund. Since feedstock is available and the markets are accessible, the project will be sooner or later materialized, though it will undergo the partial revision and the delay in materialization. Therefore, we counted those industries as consumers of lube oil.

Table I-1 GDP GROWTH RATE - TARGET AND ACHIEVEMENT
(First - 4th Plan)

(Unit: %)

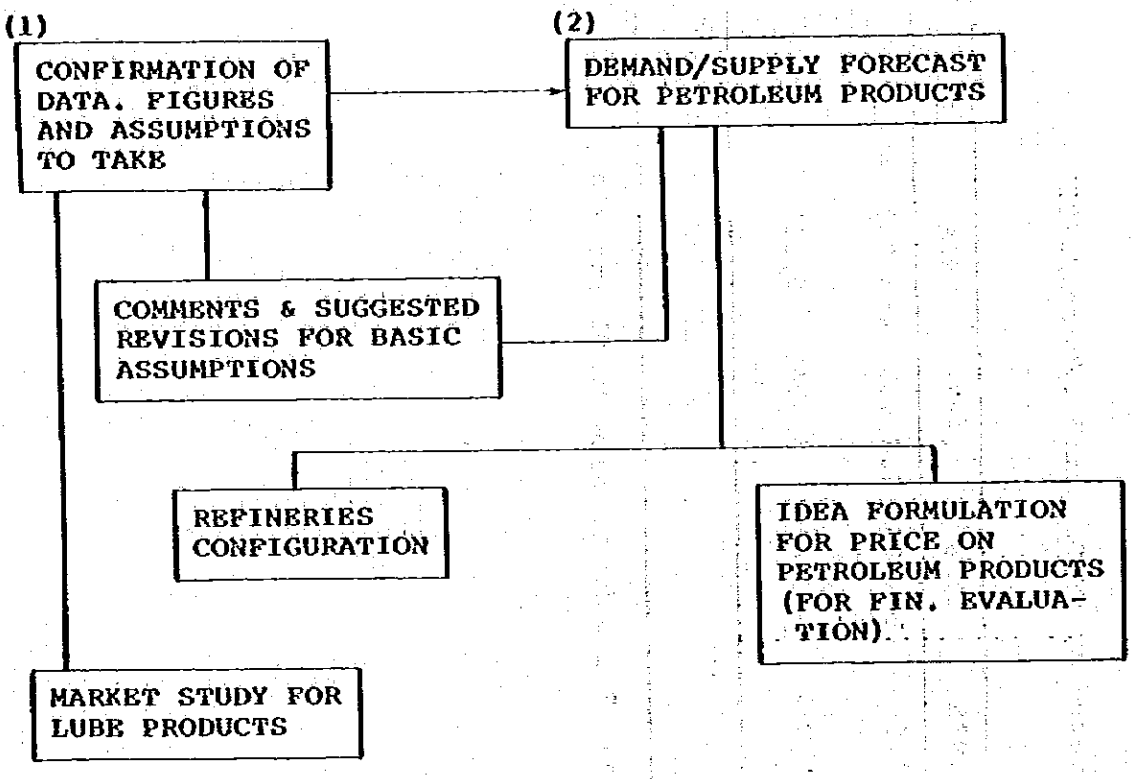
	1st Plan '61,1-'66,9	2nd Plan '66,10-'71,9		3rd Plan '71,10-'76,9		4th Plan '76,10-'81,9	
	Achievement	Target	Achievement	Target	Achievement	Target	Achievement
Agriculture	4.6	4.3	4.1	5.1	3.9	5.0	3.0
Mining & Quarrying	10.9	6.6	8.1	6.0	-0.5	3.2	11.2
Industry	10.2	10.9	9.2	8.0	8.6	9.6	9.0
Construction	12.3	11.4	8.4	6.5	4.0	3.0	11.7
Electricity & Water Supply	18.2	18.0	20.7	15.0	14.4	11.3	10.9
Transport & Communication	9.0	11.0	7.5	6.0	8.1	7.4	8.7
Wholesale & Retail Trade	8.0	8.4	7.7	7.0	4.8	6.3	6.2
Banking Insurance & Real Estate	16.6	17.0	14.4	15.0	5.1	8.1	14.4
Ownership of Dwellings	3.7	5.0	4.1	2.5	3.6	4.4	5.0
Public Administration & Defence	7.2	12.0	10.0	6.0	6.0	6.5	9.0
Services	6.0	9.5	8.8	7.0	8.2	7.8	9.7
GDP	7.3	8.5	7.2	7.0	6.2	7.0	7.3

Table I-2 GDPR (Estimated by NESDB dated 2/March/1982)

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
GDP (10 Bahts)	324,290	343,512	363,584	385,698	410,386	436,489	463,998	484,103	526,700	561,647
Growth Rate (%)	4,183	5,928	5,843	6,082	6,401	6,356	6,307	6,488	6,597	6,635
Each 5 Years Average— (by NEA)		6.0%						6.5%		

NEA extended 6.5% growth rate between 87 and 91 to between 91 and 2001.

Figure I-1 MARKETING SCHEME OF LUBE OIL AND BASE OIL



Part II

MARKET STUDY OF THE LUBRICATING OIL AND BASE OIL

IN THE KINGDOM OF THAILAND

Part II MARKET STUDY OF THE LUBRICATING OIL AND BASE OIL IN THE KINGDOM OF THAILAND

Chapter 1 Present Condition of Supply and Demand of the Lubricating Oil in the Kingdom of Thailand

Base oil used for production of lube oils is not manufactured in today's Thailand, and lube oils for domestic consumption are supplied through the following three channels:

(1) Lube blenders import base oil and blend them and mix some additives with them to produce lube oils, and then they place the new products on the domestic market.

(2) Importers, mostly lube blenders, import lube oil itself for domestic distribution.

(3) To collect used lube oils and recycle them for domestic sales.

Figure II-1 shows main exporting countries of base oil and lube oils to Thailand as well as the distribution and sales channels of lube oils, together with lube blenders and importers in Thailand.

Lube oils produced, imported, and recycled are marketed through service stations, vehicle repairing shops and other lube oil sales firms. State-run corporations receive lube oils from PTT that, in turn, procure it by means of public tender. Vehicle assembling factories purchase lube oils for their new vehicles.

Recycled lube oils are estimated at several percentage points of the total lube oil sales. But recycled lube oils are excluded from the current base oil production study, because the recycling practice is here to stay and nobody can do anything about it.

The market study of lube oils in Thailand has been conducted on a basis of the following three method --import statistics, surveys by lube blenders and surveys of lube oil consumers.

1-1 Survey of Lube Oils on a Basis of Import Statistics

Shown in Table II-1 is the past record of base oil and lube oil imports. The same quantities are also given after conversion in terms of base oil in Table II-2. The following table shows the example of conversion from product to base oil as of 1983.

		In base oil equipment (Unit: kl)
Lubricating oil	70,514kl x 0.92*	64,873
Other non-lubricants	33,228kl x 0.5	16,614
Lubricating grease	1,610ton x 0.7 / 0.884	1,275
Lube oil mixture	962ton x 0.7 / 0.884	762
Imported base oil	90,996kl	90,996
Total		174,520

Note: * Dosage of additives in Thailand was estimated as 8 percent, as per following estimation. Additives dosage in Japan is estimated at 9% or more on an average, and required amount of additives in Thailand is estimated based on consultants experiences as shown below;

Estimated of additive requirement

Kind	Base Oil Q'ty (Kl/Y) in 1983		Additive Vol %		(Vol %)
Automobil Use	121,367	High Grade 94,899 (High VI Base Oil)	57.6		9 - 11
		Low Grade 26,468 (Low VI Base Oil)	16.1		3 - 4
Industrial Use	25,475	Auto Use 14,622 (High VI Base Oil)	8.9	15.5	4 - 5 / 3 - 4
		Ind. Use 10,853 (High VI Base Oil) (Except Grease)	6.6		1 - 2
Other	17,884	(High VI Base Oil)			9 - 11
Total	164,726		Weighted Average		7.1 - 8.8%

According to Table II-2, Thailand began importing base oil in 1977, and reversely, lube oil imports began decreasing. Lube oil imports, as

calculated in terms of base oil, showed a considerable fluctuations on an annual basis. The fluctuations stemmed from inventories (imports rose to take chance of the price hike of crude oil) as well as from statistical discrepancy. There was a case where base oil imported by a lube blender was classified as lube oil imports in statistics. According to the import statistics, imports of lube oil products amounted to 143,843kl in 1982 which is less than the previous year. This is because imports in the previous year was probably a bit larger than usual. From the import statistics in the past, 174,500kl in 1983 (in base oil equivalent) is considered most adequate as an annual import volume of lube oil products.

1-2 Survey by Lube Blenders Firms

More detailed answers than had been expected were obtained from all lube blenders, whereby we could seize the imports and prices of base oil for each kind, lube oil quantities produced from base oil, and imports of lube oil.

According to the survey, six lube blenders (Shell, Caltex, Esso, Mobil, Thai Oil and Asia Oil) showed the following combined figures in 1983.

(Unit: kl)

			In base oil equipment
Base oil Imports	132,338		132,338
Lube Products Manufactured	Lube Oil	Rate of Conversion	
For vehicles	110,952	0.92[1)]	102,076
For industry	13,413	0.92[1)]	12,340
Others	50,376	0.92[1)]	46,346
Lube Oil Imported			
For vehicles	1,600	0.92[1)]	1,472
For industry	2,637	0.92[1)]	2,426
Grease	387	0.7[2)]/0.884[3)]	304
Total			164,964

Notes: 1) Additives in lubricating oil is assumed 8%.
2) Base oil contents in lube oil mixture and in grease is assumed 70%.
3) Specific gravity of lube oil and lubricating grease is assumed 0.884.

The above figures are summerized as follows according to uses:

	In base oil equivalent of base oil (kl)	Adjusted figures[1)] (kl)
For vehicles	103,548	135,765
For industry	15,070	18,311
Others	46,346	10,888
Total	164,964	164,964

Note: 1) The survey of a certain lube blender revealed that lube oil classified in the "others" column reached 65%. The site investigation further disclosed that the lube blender classified its lube oil sold to other firms into the "others" column. Shown in the extreme right are the figures adjusted the amount of others to the use.

1-3 The Survey of a Lube Oil Consumers

The largest consumers of lube oils are road transportation sector consisting of vehicles, motorcycles, and tricycles. Other industrial segments that use lube oils include means of transportation (railroad diesel cars, river boats and ocean-going vessels), agriculture, forestry and fishery, construction and electric power generation manufacturing industry and others.

Lube oils used by vehicles, motorcycles and tricycles in 1983 are shown in Table II-3 (upper part) and Table II-4 (upper part). The lube oil quantity per vehicle needed to be changed has been obtained from annual distance covered, interval of oil change, and the capacity of oil pan. Also, the quantity needed to be replenished has been obtained from interval and volume of replenishment. By multiplying the needed lube oil qunatity for each vehicle thus obtained by the registered number of vehicles, the total quantity necessary for the entire vehicles has been obtained. It was disclosed in the survey that interval of oil change was shorter than in Japan, and probably this represents the result of how long the vehicle has been in use.

Other demands than road transportation sector use of lube oil have been carefully studied based on the results of the questionnaire. (When no questionnaire is available, the actual data in Japan has been used.) For factories now under planning, a forecast has been attempted, using the projected production capacity of factories and the lube oil consumption performance in Japan.

The detailed information is given in ANNEX II-1, and herewith Table II-5 has been summarized.

The consumer demand for lube oil in 1983, including lube oil for vehicles and others, is as follows (in base oil equivalent):

	Lube oil	In base oil equivalent (Unit: kl)
Lube oil for vehicles	128,286	
Gear oil for vehicles	3,635	
Sub-total	131,921	121,367
Industry	27,991	25,713
Total	159,912	147,080

1-4 Summary of Market Study for Lube Oils in the Kingdom of Thailand in 1983

The annual demand for lube oil (in base oil equivalent) in 1983, as obtained using the above three methods, is forecasted as follows:

(Unit: kl)

Method of survey	In base oil equivalent
Import statistics	174,520
Lube blenders	164,964
Consumers	147,080

Since import statistics involve problems of inventories and statistical errors, and the survey of consumers is hard to seize the consumption for others than vehicle and industry entire picture, we have decided to adopt the figures provided by lube blenders as the total demand for base oil in 1983.

However, the answers provided by lube blenders have also another problems for distribute the consumption to the each use, and therefore we have decided to replace their figures for vehicles and industry with those obtained in the consumer survey.

	In base oil equivalent (1983 kl/y)
Vehicles	121,367
Industry	25,713
Others	17,884*
Total	164,964

* Including Military use

Chapter 2 Demand for Lubricating Oil by Types

Shown on the left side of Table II-6 is the base oil imported by lube blenders as classified by types. Since it will be highly uneconomical to work out the production plan according to what was reported, it has been decided to make 600N, 650N and 700N by mixing 500N and 150BS at the blender and or base oil plant in the following ratios:

(Volume %)

	500N	150BS
600N	86.5	13.5
650N	80.0	20.0
700N	76.0	24.0

As a result, the production quantity and ratio for each type have been calculated as shown in the left side of Table II-6 and obtained the following figures.

	60N	150N	300N	500N	150BS	Total
Quantity (kl)	12,637	6,980	7,960	73,324	31,437	132,338
Volume %	9.6	5.3	6.0	55.4	23.7	100

Chapter 3 Future Demand Forecast of Lubricating Oil in Thailand

The future demand forecast has been attempted with the lube oil demand in 1983 as a base. Considering the construction period of the base oil plant and its operating conditions (refer to Part IV Chapter 1), we have forecasted the demand quantity in 1993.

In forecasting the future demand, we conducted the macro forecast method based on the survey of consumption by uses in 1983 as well as the micro forecast method based on the consumer research.

3-1 Macro Forecast

With regard to vehicles, the increase in gasoline, diesel oil and LPG for transportation uses (Table II-7) calculated for EMP model run has been used as a base for obtaining lube oil for vehicles in 1993. With regard to industry, the increase in value added of industrial sector (Table II-8) calculated by NESDB has been used. Also with regard to other demands, an estimated GDP growth rate (Table II-9) calculated by NESDB has been used as a base.

(Unit: kl)

	1983	Multiplier	1993
Vehicles	121,367	1.855	225,136
Industry	25,713	2.0284	52,156
Others	17,884	1.851	33,103
Total	164,964		310,395

3-2 Micro Forecast

The micro forecast has been obtained by gaining quantities in each sector in 1993 through each figures or each growth rate, and by myltiplying them in principle by lube oil consumption unit in 1983.

The quantity of lube oil for vehicles is shown in the lower part of Table II-3. The interval of oil change in Thailand estimated is longer than normal, because as the new models are introduced year after year, we believe lube oil consumption and other conditions will become more similar to Japan. The oil replenishment period has been also assumed closer to Japanese figures. The increase in the registered vehicles by types has been obtained using an equation employed by NEA EPM model. (See ANNEX II-1.)

For the existing industry, the micro forecast has been conducted based on the production forecast of each industry. For the under planning industries using natural gas (fertilizer, petrochemical and soda ash), the micro forecast has been conducted by multiplying the expected capacity by unit figures in Japan. The results are summed up in Table II-5, and detailed information are given in ANNEX II-1.

The micro forecast for vehicles and industry (transportation other than vehicles, agriculture, fishery, forest, construction, and manufacturing industry) is as follows:

(Unit: kl)

	In base oil equivalent
Vehicles	168,618
Industry	44,219
Others	33,103
Total	245,940

3-3 Lube Oil Demand Forecast in 1993 (in Base Oil Equivalent)

The result of macro and micro forecast is as follows.

	Marco-economic Forecast	After Adjustment[1)]	Micro Forecast
Vehicles	225,136	160,811	168,618
Industry	52,156	52,156	44,219
Others	33,103	33,103	33,103
Total	310,395	246,070	245,940

Note: 1) In the macro forecast, the lube oil consumption in 1993 is estimated at 310,395kl. However, this forecast does not pay attention to the lengthened oil change period for vehicles and the reduction of oil to be replenished. Therefore, the lube oil demand will be reduced as the improvement measures are taken. After adjusting such discrepancies, the lube oil consumption forecast will be 246,070kl.

Such being the case, the base oil demand for 1993 is estimated at 250,000kl, as the base and the effect on the feasibility of difference of demand forecasted is checked by the sensitivity of the operational rate.

The forecast of base oil demand in 1993 for the case of lower economic growth is under-mentioned in consideration of recent revise of forecast of GDP growth rate by NESDB.

Case 1 corresponds to the aforementioned estimation, and Case 2 and Case 3 correspond to the lower GDP growth rate by 0.5% and 1% from the Case 1. Estimation of demand for Case 2 and Case 3 has been obtained by using GDP growth rates by elasticity obtained from Case 1.

	1983	1993 Case 1	1993 Case 2	1993 Case 3
GDP as of 1972 (million Bahts)	343,512			
Ratio (1993/1983)		1.8508[1)]	1.7657[2)]	1.6841[3)]
Annual Average Growth Rate of GDPR (1993/1983) (% p.a.)		6.35 [4)]	5.85 [4)]	5.35 [6)]
Lube Base Oil Demand 1993 (kl)	164,964	250,000	242,822	235,128
Ratio (1993/1983)		1.51548	1.47197	1.42533
Annual Average Growth Rate of Lube Demand (1993/1983) (% p.a.)		4.244958[8)]	3.9417[9)]	3.6076[10)]

GDP as of 1972 Growth Rate (% p.a.)

	1982-1986	1986-1992	1992-2001	Ratio 1993/1983	Annual Average Growth Rate (% p.a.) 1993/1983
Case 1	6.0	6.5	6.5	1.8508[1)]	6.35[4)]
Case 2	5.5	6.0	6.0	1.7657[2)]	5.85[5)]
Case 3	5.0	5.5	5.5	1.6841[3)]	5.35[6)]

The base oil production pattern for 1993 is assumed the same as in 1983 shown below.

(Unit: %)

60N	150N	300N	500N	150BS
9.6	5.3	6.0	55.4	23.7

At present, lube oil for vehicles are changing to the lighter one, and lube oil for industry is usually lighter than the one for vehicles. But for

the production of base oil, it is easier to produce the lighter one, and we believe it safe to adopt the actual figures in 1983.

From the data of blenders, it can be realized that the ratio of high and low grade base oils which are being imported is estimated at 80% to 20%.

At the same time, from the result of market survey, it is supposed that 20% of low grade base oil is used as the materials of the products for taxi (old type) and tricycle, however, with the changing of old type cars into new type ones, such lubricants being used for old type cars seems to be changed into high grade lubricants, and it is supposed that requirements for low grade lubricants would become very small within ten years after.

In Japan, statistics show the production of about 24% of low grade lubricants, however, of the amount of low grade lubricants, 40% is so-called naphthenic base oil and used for specific use of such as transformer oil, refrigerating oil etc. and other 60% of paraffinic base oil is also used for specific use of such as cutting oil, process oil, etc. which have negligible amount of requirement in Thailand.

From the above viewpoint, it is considered that lube oil complex in Thailand shall be designed for the production of high grade base oil.

As for the standard of Ministry of Commerce, the standard shows only commercial grade of SAE number and it seems undesirable to make reference this standard for the definition of qualitative specification.

Chapter 4 Petroleum Product Prices, Including Lubricating Oil and Base Oil

Petroleum product prices, including base oil, have varied in the past according to the changing price of crude oil as raw material. The petroleum product relative price ratio with the crude oil price has also changed.

In assessing economical viability of the base oil plant, it is important to forecast the price of raw materials, that is, residual oil obtained from the crude distillation unit as well as the prices of base oil and other petroleum by-products (including intermediary products) produced in the base oil plant. Stated below is the price forecast for crude oil, petroleum products and base oil.

4-1 Forecast for the Crude Oil Price

The price variations in the past are shown in Figure II-2. Although it is extremely hard to forecast the future price course of crude oil with certainty, predictions made by a few institutions are given in Figure II-3.

Those predictions show that the crude oil price will continue to decline in real terms until around 1985, and thereafter turn upward due to improvement of the supply and demand balance. Taking those predictions into accout, it is assumed that the increase in the crude oil price in and after 1986 at 2 to 3% annually in real terms.

NEA also applied in its EMP that the current crude oil price will remain unchanged until 1986 (the current price will be pushed down as deep as inflation rates.), and that in and after 1987 the real price will rise 2.5% a year in and after 1987.

In this study, we have decided to adopt NEA assumption. International market price inflation in and after 1986 has been assumed to grow at an annual rate of 6%.

4-2 Forecast for Petroleum Product Price

The comparative study of the following three price trends has been made as a base for forecasting the future petroleum product price --The petroleum product price on FOB terms Singapore, one of main exporting countries to Thailand and which is accepted as an international price trend, Thai import price on CIF terms, and Thai ex-refinery prices. Each price trend showed a strong relation to the crude oil price. Thai import price on CIF terms in 1979 and 1981 was lower than the price on FOB terms Singapore, and in 1980, 1981 and 1982, Thai ex-refinery price was lower than Thai import price on CIF terms Thailand and FOB price Singapore. No one can explain these phenomena convincingly enough. However, Consultant has decided to adopt the Thai ex-refinery price, because (1) it is determined reflecting the Thai market condition, (2) five different prices are available for fuel oil; the diesel oil price is available in high speed and low speed; and the gasoline price is available in regular and premium, and (3) it is hard to identify the difference price in quality from CIF Thailand and FOB Singapore because they obtained from statistics, and therefore it is difficult to seize its effects. (See ANNEX II-2.)

Shown in Table II-10 are the Arabian Light prices (FOB Ras Tanura) along with Thai petroleum product ex-refinery price from 1975 through 1983. Coefficient of correlation in the equation of the two showed high percentage points of over 0.994, excepting bitumen which stood at 0.984. Using the equation, petroleum product prices up to 2010 are forecasted as shown in Table II-11. For reference, the price ratio with crude oil is provided in Table II-12.

Shown in Figures II-4 and II-5 (refer Part III, Chapter 4) are raw materials and petroleum products manufactured when a base oil plant is built in the Bangchak and TORC refineries, respectively. There is a need for forecasting the price of the following products shown in the figures.

	Bangchak	TORC	Specific gravity	Viscosity cst@50°C	Viscosity Factor (VF)
Long Residue[1]	o	o	0.956	275	36.06
H/F Gas Oil	o	o	0.859		
LVGO	o	o	0.902	7.5	21.87
V/B Naphtha	o		0.740	-	
FCC Feedstock		o	0.896	40	30.03
T/C Feedstock		o	1.019	30,000	44.89
Fuel Oil A	o		0.969	230	35.59
Fuel Oil B		o	0.994	230	35.59
Asphalt	o	o	1.041	-	
Sulphur	o	o			
Wax	o	o	0.855	36	

(1) The price of long residuce is calculated from various types of fuel oil in Thailand, using viscosity factor. As an example, calculation is shown as of April, 1983.

The long residue price will be calculated as follows:

5,822.1Baht/kl - 61.8Baht/kl.VF x 36.06(VF) x 0.956(S.G)
= 3,691.6Baht/kl

PREREQUISITE FOR CALCULATING THE CORRELATION EQUATION

Kind of fuel oil	Specific gravity	Viscosity cst@50°C	Ex-Refinery Cost (Baht/kl)
FO 600"	0.941	80	3,930.4
FO1200"	0.955	155	3,795.5
FO1500"	0.958	180	3,751.8
FO2000"	0.962	230	3,707.1
FO2500"	0.966	280	3,660.6

(2) The H/F (Hydrofinishing) Gas Oil price is assumed the same as LVGO (Light Vacuum Gas Oil) price, because both are treated together and small in quantity.

(3) LVGO (Light Vacuum Gas Oil) price has been fixed at the mean value of HSD (High Speed Diesel) and LSD (Low Speed Diesel) prices. Taking the 1983 price, the LVGO price will be as follows:

(5,228.8Baht/kl + 5,111.3Baht/kl) / 2 = 5,170Baht/kl

(4) The V/B (Visbreaking) naphtha price is calculated as follows based on octane values of premium and regular gasolines.

	Octane value	Ex-Refinery Cost (Baht/kl)
Premium Gasoline	94.6	5,322
Regular Gasoline	82.6	4,859
Difference	12.0	463
V/B Naphtha	68.0	4,295.7[1)]

Note: 1) $4,859 - 463 \times \left(\frac{82.6-68}{12}\right) = 4,295.7$

(5) The FCC feedstock price has been obtained from gas oil and long residue prices, using viscosity.

	Specific gravity	Viscosity cst@50°C	Viscosity Factor (VF)	Ex-Refinery Cost (Baht/kl)
Gas Oil	0.860	3.95	17.42	5,228.8
Long Residue (A.L.)	0.956	275.0	36.06	3,691.5

6,412.3Baht/kl - 78.9Baht/kl.VF x 30.03(VF) x 0.896(S.G.)
= 4,289.3Baht/kl

(6) T/C (Thermal Cracking) feedstock price is calculated from fuel oil prices as in the case of long residue.

5,822.1Baht/kl - 61.8Baht/kl.VF x 44.89(VF) x 1.019(S.G.)
= 2,995.2Baht/kl

(7) As in the case of long residue, the Fuel Oil A (Bangchak) price is calculated from viscosity and prices of fuel oils as follows. Specific gravity of Fuel Oil A is assumed at 0.969 and viscosity factor at 35.59.

5,822.1Baht/kl - 61.8Baht/kl.VF x 35.59(VF) x 0.969(S.G.)
= 3,690.8Baht/kl

(8) The Fuel Oil B (Sri Racha) price is calculated as follows:

5,822.1Baht/kl - 61.8Baht/kl.VF x 35.59(VF) x 0.994(S.G.)
= 3,635.8Baht/kl

(9) The ex-refinery price of bitumen (3,508.5 Baht/kl) has been adopted as the asphalt price.

(10) The sulphur price is a result of the on-the-spot survey, adopted US$150/t CIF Bangkok in 1983.

(11) The paraffin wax price is assumed to be US$580/t, CIF Bangkok in 1984.

4-3 The Lubricating and Base Oil Prices

With regard to the lubricating oil and base oil prices, CIF Bangkok price was obtained from Thai import statistics, FOB Singapore price from Singapore export statistics, the base oil price (FOB) in Singapore from Platt's Oilgram Price Report, and CIF Bangkok price from blenders' questionnaire. Each price is influenced by the crude oil price variations. (See ANNEX II-2.)

The first two prices, which are based on trade statistics, serve only the checking purpose because it is difficult to evaluate the price by quality. Also, the price obtained from blenders' questionnaire was taken at one point in 1983, and we have decided to use those prices for the cheking

and supplementary purposes to Platt's Oilgram Price Report. Since Platt's Oilgram Price Report includes only FOB price of 150N, 500N and 150BS, the price for 60N was obtained from blenders' questionnaire, by seeking price ratio between 60N and 150N. Also, the price for 300N was obtained by using viscosity factor of 150N and 500N.

Shown in Table II-13 are past record of base oil prices as well as Arabian Light price published in Platt's Oilgram Price Report.

Shown in Table II-14 are CIF Thailand base oil price by adding the ocean freight cost to the FOB Singapore price.

Import prices in 1983 obtained from blenders are as follows, these figures are slightly higher than the above calculated figure based on Platt's Oilgram Price Report.

150 N		500 N		150 BS		60 N	
Baht/ lit.	US$/kl	Baht/ lit.	US$/kl	Baht/ lit.	US$/kl	Baht/ lit.	US$/kl
(Low) 8.136	353.0	8.730	378.7[1]	10.857	471.0	7.940	344.5
(High) 8.394	364.2	9.170	397.8[1]	10.932	474.3	8.120	352.3
Mean	358.6		388.3		472.7		348.4

Note: 1) US$378.7/kl is for LVI and US$397.8/kl is for HVI650.

Table II-14 shows the price forecast up to 2010, including the price of 300N estimated from the price of 150N and 500N.

Chapter 5 The Oil Refining Industry in Thailand

5-1 Demand and Supply of Petroleum Products in Thailand

Production, imports and consumption of petroleum products in Thailand during the 1979-1982 period are shown in Table II-15. The shortage of the refining capacity has made Thailand a petroleum product importing country, except low speed diesel oil. In 1982, natural gas was supplied in an amount of 47,446MMSCF, and as a result consumption of fuel oil significantly dropped. And yet, 630,000 kl of fuel oil was imported.

Despite the imports of all petroleum products, production of petroleum products declined in 1980, and even now failed to return to the 1979 level. Chief reason is the decreased production of the Bangchak refinery.

With regard to the demand forecast for petroleum products in Thailand, NEA attempted several forecasts using EMP. One of the forecasts is shown in Table II-16. Premise of the forecast is:

(1) The GDPR growth rate for the 1982-1986 period is assumed at 6.0%, and that for the 1987-2001 period at 6.5%.

(2) The increase rate of the real price of crude oil is assumed at -0.5% (The current price remain unchanged) during the 1982-1986 period, and at 2.5% during the 1987-2001 period.

(3) Natural gas production in 1986 is assumed at 410MMSCFD and that in 1991 is assumed at 650MMSCFD. (Simple division of 48,738 trillion cal. by 252Kcal/SCF 365d/y obtains 530MMSCFD.)

Since natural gas production after 1991 is assumed unrestricted, natural gas production in 1996 is calculated 91,886 trillion cal (1,000MMSCFD). Shown in Table II-17 are the forecasts with unit changed from caloric into liter (BPCD). The forecast for natural gas involved many unkown

factors, and it is reasonable to forecast that production in 1991 will continue as it is. The figures in the brackets of 1996 and 2001 columns of Table II-17 have been obtained assuming that natural gas production in 1991 will continue until 1996 and 2001.

The official capacity of Thai refineries totals 176,000 barrels per day, broken down into 65,000 barrels for TORC, 65,000 barrels for Bangchak, 45,000 barrels for Esso, and 1,000 barrels for FANG. As pointed out above, Thailand's total refining capacity is considered 161,000 barrels per day, because the capacity of Bangchak was decreased to about 50,000 barrels per day.

The shortage of the refining capacity is expected to become even greater in the future, demand for intermediates is relatively high, and fuel oil consumption is declining as a result of the growing production of natural gas, newly creating a need for changing production pattern of petroleum products. At present, debottlenecking of Esso is under way, and the TORC's expansion program Phase 1 (installation of the hydrocracking process) and 2 (installation of the topper) have been already approved. For Bangchak, rationalization of the existing facilities as well as the expansion program is also under consideration.

Debottlenecking of Esso is in progress now, But TORC's Phase I has been delayed due to disagreement on conditions for loan facilitation. But from the increasing demand for petroleum products and the structural change in Thailand, those programs are considered certain to be carried out sooner or later. Phase 2 involving the construction of topper is expected to start by 1990. (The alternative steps are being studied when Phase 2 is not realized.)

The improvement measures have been suggested to Bangchak by the World Bank, and the establishment of a new company is taking shape. But this is not counted among future plans because the concrete plan for facilities is not submitted yet. Table II-18 indicates the crude oil topping capacity for each refinery. The configuration will be described later in the base oil plant designing conditions, because it is related with the base oil plant process.

Table II-19 shows refinery capacities for each petroleum product.

Shown in Table II-20 is the demand/supply predictions for petroleum products in Thailand. Figure II-6 is the same predictions shown by a diagram.

In this table, the natural gas forecast in 1996 is given at 91,886 trillion cal. (about 1,000MMSCFD) and that in 2001 at 66,043 trillion cal. (about 718MMSCFD), since the production forecast for natural gas after 1991 is assumed to be obtained unrestrictedly.

Figures in the brackets of Table II-20 indicate the demand/supply balance when the topper construction in Phase 2 is not realized for TORC.

When TORC's Phase 2 is added, the petroleum product demand in 1991 is almost met, but in 1996 petroleum products will once again be in short supply, except fuel oil.

Since long residue is raw materials for the base oil plant, demand and supply of fuel oil have an important effects on economical viability of fuel oil of the base oil plant. When the demand/supply balance is studied, the following three factors will exercise great influence:

(1) One is the supply capacity of natural gas. Almost all of natural gas are used as a substitute fuel for fuel oil. Assuming that the natural gas production in 1996 and 2001 is on the same level as in 1991, demand for fuel oil in 1996 and 2001 is increased by 75,660 BPCD and 30,350 BPCD, respectively.

(2) Another is the trend of fuel oil cracking units. Since natural gas is abundantly produced in Thailand, fuel oil declines in consumption and become oversupplied. Therefore, cracking fuel oil to produce middle distillate will be a natural choice for Thailand. TORC's Phase 1 is the case in point. If Phase 1 alone is carried out, TORC requires 21,400 BPCD of long residue in addition to 77,650 BPCD of crude oil as raw materials as shown in Table II-19. (If

Phase 2 is realized, the increase in toppers will tide over the shortage of fuel oil.)

(3) The fuel oil forecast is most important for assessing demand/supply balance.

If the fuel oil demand forecast is correct, and if the hydrocracking plant, which TORC planned to construct in Phase 1, is not built, fuel oil will have an additional excess of 21,400 BPCD in 1991. If topper is additionally constructed to cover the shortage of petroleum products as planned in TORC's Phase 2, the surplus of fuel oil will become even greater.

This shows the necessity of choosing between the two --either exporting fuel oil or building a fuel oil cracking plant. In this sense, the price of fuel oil should be competitive level with that as FOB price Singapore.

5-2 Present and Future of Crude Oil Imports in Thailand

Table II-21 shows crude oil imported by Thai refineries in 1982, as broken down by types. Out of total crude oil importation of 8,542,700 kl, excluding 1,974,200 kl which is imported 1,411,700 kl from Malaysia, 447,000 kl from Brunei and 115,500 kl from China, 6,568,500 kl (77%) is imported from Middle East. In particular, 5,609,400 kl of importation from Saudi Arabia represents 66 percent of total importation, and 3,972,000 kl or 46 percent thereof is Arabian Light crude oil.

Arabian Light is imported by the Bangchak refinery in an amount of 65,000 barrel a day based on the long-term contract (efffective until the end of this year) which it signed with Saudi Arabia. Of the total imports, 15,000 to 20,000 barrels a day are passed on to TORC.

Types of the future crude oil imports are largely affected by availability of crude oil, demand structure of petroleum products in Thailand, the price of crude oil by types, and diversification of import sources for stable supply.

Thailand has been depending upon the Middle East and Asian countries for crude oil imports. The geography of Thailand indicates that this trend will remain unchanged. From the diversification point of view, it may be better to import crude oil from Asian suppliers. However, as shown in Table II-22, Asian countries produce a total of less than 2.5 million barrels a day, constituting 4 or 5% of the total free world production. Such being the case, Thailand must continue to depend upon the Middle East for the greater part of crude oil imports. Demand for petroleum products in Thailand is shown in Table II-17. The demand ratio of fuel oil and bitumen to total products was or will be 28% in 1982, 22.5% in 1986, 21.9% in 1991 and 15% in 1996, all showing the low levels. On the other hand, the high demand ratio of Diesel oil is the special demand structure of petroleum products in Thailand. Therefore, it is suited to Thailand to import crude oil whose fuel oil production ratio is low (light crude oil). But this must be studied from the viewpoint of price difference between the light and heavy crude oil. In principle, price difference is regarded the world over as cost difference to produce petroleum products that meet demand. But when the processed facilities of fuel oil of the refinery are insufficient, the price difference of the light and heavy crude oil becomes greater than cost difference.

During the past year or two, the price of the light crude oil was relatively higher than that of the heavy crude oil. But as the fuel oil processing facilities are increasing, the difference of crude oil price began narrowing. On the spot market where the price difference between Arabian Light and Arabian Heavy once stood at US$3.00, it is now narrowing to US$1.00.

The difference of the official price of OPEC nations is still higher than the spot price, partly due to their internal problem. But sooner or later the OPEC price will follow the spot price. If not so, it will be difficult to market the light crude oil.

It is profitable for advanced nations in terms of cost to turn the fuel oil to light and middle distillates, because they have many existing facilities and their cost of equipment is relatively low. Cost difference in

advanced nations is lower than that of nations where new construction expenses are high.

All those factors considered, and from the future price difference between the light and heavy crude oil, it will be profitable for Thailand to import the light crude oil. From the above explanations, it is expected that Thailand will keep higher import ratio of Arabian Light.

Chapter 6 Demand Forecast for Paraffin Wax and Bitumen

6-1 Demand Forecast for Paraffin Wax

Currently in Thailand no paraffin wax is produced and its demand is all met by import. The export quantity being small, it is omitted in this forecast.

The actual import quantity of paraffin wax from 1975 to 1982 is shown in Table II-23, Figure II-7 shows a graph of this change. The demand for paraffin wax in 1993 can be forecasted as 10,000 t/y from the figure (forecast based on regression formula indicates 9,000 t/y but its correlation factor is low as 0.058).

The main use of paraffin wax is as follows:

1. Candle

   Several perecent of stearic acid is added to paraffin wax.
   Use: lightening

2. Paraffin Processing Paper

   Use: dampproof, waterproof, dust prevention, agriculture for protection of noxious insect of fruits, keeping warm for seeding of rearing and cultivating, etc.

3. Waterproof Corrugated Cardboard

   Use: packaging material for frozen meat, frozen fish, vegetables, fruits, machine and tool, etc.

4. Blend Wax

Mixture of paraffin wax with micro wax, ethylene-vinyl acetate copolymer, polyolefin, etc.

Use: paraffin paper, waterproof corrugated cardboard, paper cup, carton for frozen food, carton for butter, etc.

5. Electrical Insulating Material

Use: surface coating of conductor and cable.

6. Use for rubber

Age resister for rubber, and internal lubricant for mixing rubber.

7. Chlorinated Paraffin

Use: extreme pressure additives, cutting oil (metal working), plasticizers for vinyl chloride resins, blending materials for synthetic resins and gum, and soft detergents.

8. Others

Use: match, raw material for crayon, ink, textile industry, leather, polishing (wax for automobile, etc.), food model, pottery manufacture, cosmetics, etc.

In Thailand the main use of unfinished paraffine wax is for candles and refined paraffin is used for paraffin processing papers.

6-2 Demand Forecast for Bitumen

Currently, TORC and Esso produce bitumen and also export it.

(Unit: kl)

	Production	Import	Export
1975		1,241	1,712
1976		1,317	1,105
1977		1,283	3,490
1978	151,689	2,028	3,288
1979	122,507	2,498	1,178
1980	114,655	1,826	1,061
1981	135,680	718	438
1982	123,685	375	1,170

NEA's Energy Master Plan forecasts the demand for bitumen to be 174,000 kl in 1991 and 191,000 kl in 1996 (Table II-17), and from these volumes the demand in 1993 was estimated at 180,971 kl (3,118 BPCD).

On the other hand, the estimated production in future is 2,660 BPCD (154,356 kl/y) in 1987 and 2,700 BPCD (156,677 kl/y) in and after 1991 (TORC: 800 BPCD, Esso 1,900 BPCD) (Table II-19). Therefore, shortage in 1993 will be 420 BPCD.

There are two kinds of bitumen: natural bitumen and petroleum bitumen. Petroleum bitumen has four kinds according to use as follows:

Straight Bitumen (Including Semi Blown Asphalt)
Blown Asphalt
Cut Back Bitumen
Bitumen Emulsion

Straight Bitumen (Including Semi Blown Asphalt)

Use: Paving (the greatest use of bitumen-used for high way and airfield run way because it is easily repaired), roofing paper anticorrosive paint, electrical insulating material and lense abrasive.

Brown Asphalt

Use: Waterproofing, moistureproofing, hot insulation, cold insulation, electrical insulation, anticorrosion, rubber mixing, bitumen varnish and bitumen tile.

1. Building material such as roof material, wall material and roofing paper.

2. Waterproofing for tunnel (including subway), building roof and basement.

3. Waterproofing and moistureproofing work in a form of cable or sheet being mixed with rubber.

4. Sealing material for opening of prefabricated concrete building.

5. Enclosing radioactive wastes from nuclear electric power stations in a block to be disposed into the deep sea.

Cut Back Bitumen (cut back with kerosene, etc.)

Use: Repairing pavement or making simple paving by sprinkling.

Bitumen Emulsion

Use: Paving at atmospheric temperature being mixed with sand and aggregate. Used mainly for repairing pavement or making simple paving.

In Thailand, straight bitumen is mainly used, but bitumen with low penetration should be produced and more bitumen paving should be used. The reason is that the bitumen paving is less expensive and that it leads to reduction of excess short residue. In Japan, bitumen with penetration of 60-80 or 80-100 has been largely used, but blown asphalt with penetration of 40-60 is now being used because of increasing car traffic including large-sized cars.

Chapter 7 Distribution and Sales Mechanism for Base Oils and Lubricating Oils

In Thailand, there are no base oil producing plants and lubricating oils are supplied through the following routes:

(1) Base oil import by blenders - Blending with additives to make lube oils - Deal in the market

(2) Lube oil import by blenders and importers - Deal in the market

(3) Re-refining of wasted lubricating oils (recycle oil) - Deal in the market by producers

While lubricating oils are sold to gasoline service stations, vehicle assembly factories and vehicle repair shops by the above supply companies, they are sold to end users by the above supply companies through lubricating oil distribution routes or directly.

However, to government enterprises, Authority of Thailand (PTT) supplies lubricating oils purchased through bid from the above supply companies.

The above distribution routes are shown in Figure II-1. This figure indicates blending capacities of blenders, main exporting countries of base oils and lubricating oils, importers of lubricating oils and etc.

The locations of blenders' plants are shown in Figure II-8. All the plants fronts on the Chasphya river, and base oils are received from 2,000 - 3,000 tonnage ships from Singapore, China, P.R., etc.

When base oil plants are constructed neighboring to three refineries and the existing blending facilities are utilized in Thailand in future, base oils will be all transported to the blending facilities by ship.

The production capacities of blenders are shown in Table II-24.

Chapter 8 Free World Lube Oil Demand and Supply Forecast

8-1 World-wide Oil Demand Forecast

In making world-wide lube oil demand forecast, two cases of using oil consumption forecast and of using energy consumption forecast are considered. However, in the former case annual oil products demand does not always reflect the actual condition of transportation fields and industries demanding lube oils because the replacement of oil products has been advanced, and therefore we forecast the lube oil demand using the relation with energy demand forecast in the latter case.

The lube oil consumption per energy unit has decreased because of (1) improvement of lube oil quality and (2) structural improvement of used machines and equipments.

Actual results of lube oil consumption per energy unit from 1965 to 1980 and its forecast after 1980 are listed below:

	1965	1970	1980	1985	after 1990
Lube oil consumption % per energy unit	0.56	0.51	0.50	0.49	0.48

(Based on Mr. J.L. Helm's Table on Energy and Lube Oil Forecast)

The world-wide energy demand forecast depends on the economic growth and energy saving efforts of each country.

Table II-25 indicates yearly lube oil demand forecast prepared based on the free world energy demand and lube oil demand forecast from 1965 to 2000 presented by Mr. J.L. Helm of Sun Oil Products Co. at the 4th International Conference on Used Oil Recovery and Reuse, and on the world GDP growth rate and energy demand forecast prepared by Shell International Petroleum Co.

Shell estimated the world GDP growth rate in two cases; high and low, and forecasted the energy demand corresponding to the rate. This

forecast of GDP growth rate is lower than the forecast of net GDP (Table II-26) of advanced industrial countries and developing countries mentioned in "The 1984 World Development Report" issued by World Bank on July 9, 1984 and Shell's higher forecast of GDP growth rate corresponds to World Bank's lower forecast. Mr. J.L. Helm's energy forecast is somewhat higher than Shell's higher forecast. Therefore, Mr. J.L. Helm's lube oil forecast may be considered to correspond to World Bank's lower economic growth.

Mr. J.L. Helm's regional lube oil demand forecast is shown in Table II-27. The demand forecasts for Asia and Australia in Table II-27 were revised based on the lube oil demand forecast for each country of Asia and Australia indicated by the Consultant in Table II-28.

8-2 World-wide Lube Oil Forecast

Table II-29 indicates Mr. J.L. Helm's lube oil supply forecast with some revision made by the Consultant.

Main points of the revision are due to considering the forecast of capacity increase of lube oil plants in future (Table II-31) including Saudi projects (Table II-30), etc.

Supply quantity was calculated as 90% of a plant capacity.

As found from Table II-31, in future, expansion of lube oil plants will decrease in number in advanced countries and increase in developing countries.

This is because lube oil plants provide a lower investment efficiency and result in environmental problems in advanced countries, and because, on the other hand, developing countries want to raise additional values of oils (oil producing countries) and have a desire to stop the import of lube oils by producing them in their countries and to save foreign currency. According to Mr. J.L. Helm, the supply capacity of the

U.S.A. in 1990 will be smaller than that in 1985. This is supposed to be due to shut down of some superannuated lube oil plants in the U.S.A.

Table II-32 indicates lube oil output, export, import and consumption by region (partly by country) in 1980. The biggest among total export 146 million bbl/year is with Western Europe and in the region import is also big. With respect to net export, the export of the U.S.A. and Singapore is conspicuous.

8-3 World-wide Lube Oil Demand and Supply Forecast

Table II-33 indicates world-wide lube oil demand and supply forecast prepared from the demand forecasted from Table II-25 and the supply from Table II-29. This table also indicates the supply forecasts in the cases of both higher GNP growth rate (lower one forecasted by World Bank) and lower growth rate made by Shell besides Mr. J.L. Helm's demand forecast, providing the comparison with supply in Table II-29. The lube oil production capacity includes only currently-definitely-planned ones and therefore it remains constant in and after 1990.

While Mr. J.L. Helm's demand forecast shows an approximate balance of demand and supply in 1990, Shell's forecast shows a between 1990 and 1995. balance between 1990 and 1995.

Judging from the fact that Shell's GDP growth rate forecast corresponds to World Bank's lower forecast, that the projected plants which were taken into calculations include new constructions planned by Iran and Iraq, and that Saudi Arabia's plan partly includes undecided plants, it is generally estimated that the demand and supply relation of lube oils of which supply is now in excess will be tight.

Table II-34 indicates demand and supply forecast by region based on Mr. J.L. Helm's demand and supply forecast.

In 1985 Western Europe already comes to the side of an excess of import and in 1990 the U.S.A. also does so partially due to the decreased

supply in the U.S.A. On the other hand, Middle East that is in the side of an excess of import in 1985 shifts to the side of an excess of export in 1990. From this table it can be expected that the excess lube oils in Caribbean Sea will be transported to the U.S.A. and part of Western Europe and that most of the excess in Middle East to Western Europe.

Table II-35 indicates demand and supply forecast in 1982 and 1986 in Asia/Australia regions. Singapore and Japan are main export countries.

8-4 Synthetic Lubricating Oil Demand

Synthetic lube oil, mainly used as automotive crank case oil (including turbo charger), aircraft engine oil (turbine oil), hydraulic oil, transformer oil, refrigerator oil and metalworking oil, is used for services which indispensably require synthetic lube oil or in which synthetic lube oil functions more efficiently. Recently, the demand of synthetic lube oil has been increasing with the advance of machines.

Estimated demand for synthetic lubricants in the U.S.A. is shown in Table II-36, and syn-lubes benefits are shown in Table II-37.

Being very expensive, synthetic lube oil is in the same use as mineral oil only when it satisfies the following condition:

(1) Its use is economical though expensive.
(2) Its use is required to meet the specification.
(3) Use in which a problem is not solved by conventional lube oil but solved only by synthetic lube oil

Because the lube oil study for Thailand does not include synthetic lube oil, it is required to be imported but its quantity is not so large.