8-5 Naphthenic Lube Oil

Naphthenic lube oil, produced from naphthenic crude, is used for services which indispensably require naphthenic lube oil, and is not used as substitute for paraffinic lube oil. However it is used for services which do not need high VI (Viscosity Index).

Naphthenic lube oil, used for the purpose of utilizing the characteristics of naphthenic lube oil, is used as transformer oil, refrigerator oil, rubber extender oil, etc.

Naphthenic crude, which has a low pour point, does not need dewaxing and gives a low manufacturing cost. However, the production of naphthenic crude suited for manufacturing naphthenic lube oil being decreasing, the price of naphthenic lube oil is not lower than paraffinic lube oil and the price of naphthenic lube oil which needs a special treatment is higher than paraffinic lube oil.

Table II-38 indicates free world naphthenic lube oil demand and Table II-39 indicates free world capacity for naphthenic lube oil.

Because the lube oil study for Thailand does not include naphthenic lube oil, it is required to be imported.

8-6 Used Lube Oil Re-refining

Many countries have used lube oil re-refining plants. The reasons are anticipated lube oil shortage in future, their intention of saving crude oils, and their consideration of solving environmental problems due to disposal of used lube oils.

However, it is very difficult to collect used lube oils and so government support is desirable. In Italy the collection cost is added to new lube oil prices.

Unless the characteristics of re-refined lube oils meet the specification of new lube oils, they do not only lower the efficiency of engines but also cause their corrosion and frequent replacement of their parts. So far as we know from the investigation conducted by the consultant in Thailand, the quality of recycle lube oils in Thailand is very inferior. Therefore, the current re-refining operation should be stopped without delay and used lube oils should be re-refined on a full scale after they are collected and conveyed to one or several places. Depending on the quality of used lube oils and the type of re-refining process, the full-scale re-refining becomes feasible at its capacity of 300 bbl/day and higher, and the capacity of 500 to 1,000 bbl/day is desirable. In Indonesia there were 10 re-refining plants of the same level as in Thailand, and Indonesian Government ordered to stop the re-refining last year.

A typical re-refining process for used lube oils is shown in Figure II-9.

In Japan there is one full-scale re-refining plant for motor oil. Other several plants are of conventional process and the re-refined oils are used not for engines but for others.

Table II-1 LUBRICATING OIL, BASE OIL AND ADDITIVE:
IMPORT, EXPORT, PRODUCTION AND CONSUMPTION PAST RECORD (1)

	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Lubricating Oil ($10^3 \ell$)											
Import	86,424	98,570	62,885	78,393	68,232	64,045	54,514	29,190	31,132	43,624	70,544
Export	2,262	2,247	1,173	1,151	739	42	12	36	117	13	30
Consumption	84,162	96,323	61,712	77,242	67,493	64,003	54,502	29,154	31,015	43,611	70,514
Hydraulic Brake Fluid ($10^3 \ell$)											
Import	62	21	609	-	74	4	22	22	0.16	7	0
Export	31	34	28	25	32	39	81	210	81	67	14
Consumption	31	Δ 13	581	Δ 25	42	Δ 35	Δ 59	Δ 188	Δ 81	Δ 60	Δ 14
Basic Oil ($10^3 \ell$)											
Import	-	-	-	-	96,894	71,696	106,797	32,029	137,843	95,292	91,056
Export	-	-	-	-	-	-	66	18	-	-	60
Consumption	-	-	-	-	96,894	71,696	106,731	32,011	137,843	95,292	90,996
Lubricants Bunter ($10^3 \ell$)											
Import	2,450	-	-	-	14	-	-	-	-	-	-
Export	-	2	-	-	1,045	1	-	-	-	-	-
Consumption	2,450	Δ 2	-	-	13	Δ 1	-	-	-	-	-
Other Non-Lubricating Oil ($10^3 \ell$)											
Import	57,022	1) 34,413	50,293	66,498	11,415	26,345	24,041	21,854	10,765	14,327	33,228
Export	46	447	3	2	-	3	0.200	-	-	0.003	-
Consumption	56,976	33,966	50,290	66,496	11,415	26,342	24,041	21,854	10,765	14,327	33,228
Lubricating Grease (10^3 Kg)											
Import	0,693	3,148	1,269	1,020	1,952	1,866	1,825	1,787	1,643	1,218	1,728
Export	38	45	19	31	39	7	0.213	3	0.855	51	118
Consumption	0,655	3,103	1,250	989	1,913	1,859	1,825	1,784	1,642	1,167	1,610

Table II-1 LUBRICATING OIL, BASE OIL AND ADDITIVE:
IMPORT, EXPORT, PRODUCTION AND CONSUMPTION PAST RECORD (2)

Rubber Extender (10^3Kg)											
Import	249	129	95	169	273	228	217	311	280	217	261
Export	-	-	-	0.3	-	0.380	-	1.3	1	0.665	0.763
Consumption	249	129	95	169	273	228	217	310	279	216	260
Lubricating Preparation Consist of Mixture of Oils or Fats (10^3Kg)											
Import	376	615	360	417	793	863	806	420	525	436	962
Export	-	-	-	-	0.220	-	-	-	-	-	-
Consumption	376	615	360	417	793	863	806	420	525	436	962
Oxidation Inhibitors (10^3Kg)											
Import	223	25	30	52	55	45	95	1,018	28	30	26
Export	-	-	-	6	-	-	100	382	154	432	284
Consumption	223	25	30	46	55	45	Δ 5	636	Δ 126	Δ 402	Δ 258
Viscosity Improvers (10^3Kg)											
Import	597	2,018	1,071	1,237	4,164	5,813	8,367	5,855	6,950	6,457	5,947
Export	-	-	-	-	6	-	-	3	-	-	2
Consumption	597	2,018	1,071	1,237	4,158	5,813	8,367	5,852	6,950	6,457	5,945
Anticorrosive Preparation Other Prepared Additives For Mineral Oils (10^3Kg)											
Import	3,500	4,221	4,266	5,687	4,351	4,104	3,896	3,951	4,032	1,236	2,569
Export	5	-	-	1	-	-	-	-	0.089	-	-
Consumption	3,495	4,221	4,266	5,686	4,351	4,104	3,896	3,951	4,032	1,236	2,569

Source: FOREIGN TRADE STATISTICS OF THAILAND, issued by Department of Customs

Note: 1) Other Non-Lubricating Oil in 1974 in the statistics supposed to be mistaken, that 308,855 x 10^3ℓ is including Kuwait, Qatar and Saudi Arabia crude import. Because these contries do not produce lubricating oils, and import quantity is very big.

Table II-2 REQUIRED BASE OIL BY EACH YEAR FROM 1973 TO 1983

	Condition	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Lubricating Oil 10^3lit	Additives 8%[1]	84,162	96,323	61,712	77,242	67,493	64,003	54,502	29,154	31,015	43,611	70,514
As Base Oil 10^3lit		77,429	88,617	56,775	71,063	62,094	58,883	50,142	26,822	28,534	40,122	64,873
Other Non-Lube Oil 10^3lit		56,976	33,966	50,290	66,496	11,415	26,342	24,041	21,854	10,765	14,327	33,228
As Base Oil 10^3lit		51,976	28,966	45,290	61,496	5,708	13,171	12,021	10,927	5,383	7,164	16,614
Lubricating Grease 10^3lit	Base Oil Content 70 wt0/6[3]	8,655	3,103	1,250	989	1,913	1,859	1,825	1,784	1,642	1,167	1,610
As Base Oil 10^3lit		6,854	2,457	990	783	1,515	1,472	1,445	1,413	1,300	924	1,275
Lube Oil Mixture 1^3lit	s.g. 0.884 Base Oil Content 70 wt0/6[4]	376	615	360	417	793	863	806	420	525	436	962
As Base Oil 10^3lit		298	487	285	330	628	683	638	333	416	345	762
Total (A) As Base Oil 10^3lit		136,557	120,527	103,340	133,672	69,945	74,209	64,246	39,495	35,633	48,555	83,524
Imported Base Oil 10^3lit (B)		-	-	-	-	96,894	71,696	106,731	132,011	137,843	95,292	90,996
(A) + (B) 10^3lit		136,557	120,527	103,340	133,672	166,839	145,905	170,977	171,506	173,476	143,847	174,520
Percentage (A)		100	100	100	100	41.9	50.8	37.6	23.0	20.5	33.8	47.9
Percentage (B)						58.1	49.4	52.4	77.0	79.5	66.2	52.1

Notes: 1) 8 vol% additives in lubricating oil is assumed.

2) Contents of non-lubricating oil are not clear, therefore we assume 5,000 Kl/y of non-lubricating is not petroleum products till 1976, and one half of non-lubricating is assumed to be not petroleum products.

3) Base oil content is grease is assumed 70 wt%.

4) Base oil content is lube oil mixture is assumed to be 70 wt%.

5) Specific gravity of Lube oil mixture and, Lubricating grease is assumed 0.884.

Table II-3 QUANTITY OF ENGINE OIL FOR VEHICLES

	Distance[1] covered Km (A) Km/Veh/Year	Interval of[2] Oil Exchange (B) Km	Frequency of Oil Exchange (A/B) Fr/Year	Capacity of[3] Oil Pan (C) l/Veh	Quantity of Oil (A/B)x(C)=(D) l/Veh/Year	Oil[4] Replenishment (E) l/Veh/Km	Quantity of Oil (A)x(E)=(F) l/Veh/Year	Quantity of Oil (D)+(F)=(G) l/Veh/Year	No. of[5] Registered Vehicle (H) 1,000 Veh	Total Quantity of Oil (G)x(H) Kl/Year
1983										
Heavy truck	80,000	5,000	16.0	15	240.0	0.0009	72.0	312.0	65.3	20,374
Small truck	100,000	5,000	20.0	4	80.0	0.0009	90.0	170.0	437.0	74,290
Bus	65,000	5,000	13.0	19	247.0	0.0026	169.0	416.0	30.0	12,480
Taxi	120,000	5,000	24.0	4	96.0	0.0009	108.0	204.0	15.0	3,060
Passenger car	16,000	3,500	4.6	4	18.4	0.00032	5.1	23.5	464.8	10,923
Motor cycle	12,000	10,000	1.2	1.2	1.4	0.0003	3.6	5.0	1,130.6	5,653
Tricycle	80,000				167.4*1				9.0	1,506
Grand Total										128,286
1993										
Heavy truck	80,000	6,500[6]	12.3	15	184.5	0.0006[7]	48.0	233.4	133.0	31,042
Small truck	100,000	6,500	15.4	4	61.6	0.0006	60.0	121.6	889.7	108,188
Bus	65,000	7,000	9.3	19	176.7	0.0017	110.5	287.2	30.0	8,616
Taxi	120,000	7,000	17.1	4	68.4	0.0006	72.0	140.4	15.0	2,106
Passenger car	16,000	5,000	3.2	4	12.8	0.00021	3.4	16.2	819.6	13,278
Motor cycle	12,000	10,000	1.2	1.2	1.4	0.0003	3.6	5.0	2,342.7	11,714
Tricycle	80,000	-			167.4*1				9.0	1,506
Grand Total										176,450

*1 : Gasoline and oil mixture is used for tricycle and Kilometers per litre of mixture is 23.9
Gasoline and oil are in the ratio of twenty to one.

$$80,000 Km/Veh/Year \div 23.9 Km/l \times \frac{1}{20} = 167.4 l/Veh/Year$$

Source: 1) NEA DATA excepting small truck which is revised by consultant 2) Site survey 3) Japanese experience
4) Site Survey and consultant's experience 5) NEA 6) Japanese experience 7) 4) x 2/3

Table II-4 QUANTITY OF GEAR OIL FOR VEHICLES

	Capacity of Gear Box[1)] (A) l/Veh	Frequency of Oil Exchange[1)] (B) Fr/Year	No of Registered Vehicles (C) 1,000 Veh	Quantity of Oil (A)x(B)x(C) Kl/Year
1983				
Heavy Truck	15.0	1	65.3	980.0
Small Truck	3.6	1	437.0	1,573.2
Bus	10.5	1	30.0	315.0
Taxi	3.1	1	15.0	46.5
Passenger Car	3.1	0.5	464.8	720.4
Tatal				3,635.1
1993				
Heavy Truck	15.0	1	133.0	1,995.0
Small Truck	3.6	1	889.7	3,202.9
Bus	10.5	1	30.0	315.0
Taxi	3.1	1	15.0	46.5
Passenger Car	3.1	0.5	819.6	1,270.4
Tatal				6,829.8

Source: 1) Japanese experience

Table II-5 LUBRICATING OIL CONSUMPTION FOR INDUSTRY

Item	Lube Oil Consumption (kl)							
	1983				1993			
	Engine Oil	Industrial Oil	Grease	Total	Engine Oil	Industrial Oil	Grease	Total
Transportation	1,829.5	504.6	0.32	2,334.4	3,273.0	442.2	0.18	3,715.4
Agriculture Fishery Forest Cold Storage	12,873.1	6,660.0	-	19,533.1	20,447.1	11,871.0	-	32,318.1
Construction	403.0	1,210.0	-	1,613.0	793.0	2,380.0	-	3,173.0
Electric Power Generation	257.0	298.0	-	555.0	257.0	550.0	-	807.0
Manufacturing	531.1	3,124.2	300.6	3,955.9	841.2	5,281.7	547.7	6,670.6
New Project	0.0	0.0	0.0	0.0	242.0	1,184.46	34.47	1,460.93
Lube Oil	15,893.7	11,796.8	300.92	27,991.4	25,853.3	21,709.4	582.3	48,145.0
as Base Oil	14,622.0	10,853.0	238.0	25,713.0	23,785.0	19,973.0	461.0	44,219.0

Table II - 6 BASE OIL PATTERN CALCULATED FROM ANSWER FOR QUESTIONNAIRE TO LUBE BLENDER

Imported Base Oil		Base Oil to be manufactured(Kl)				
Kind	Quantity (kl)	60N	150N	300N	500N	150BS
60N	12,637	12,637				
150N	6,980		6,980			
300N	7,960			7,960		
500N	5,540				5,540	
600N	35,923				31,073	4,850
650N	43,404				34,723	8,681
700N	2,615				1,988	627
150BS	17,279					17,279
Tatal	132,338	12,637	6,980	7,960	73,324	31,437
(Vol%)	100.0	9.6	5.3	6.0	55.4	23.7

Table II-7 DEMAND OF GASOLINE AND DIESEL OIL

Table II-7-1 PAST CONSUMPTION OF GASOLINE AND DIESEL OIL FOR TRANSPORTATION AND COMMUNICATION

(Unit: million litre)

	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
Gasoline	1,496	1,640	1,831	2,035	2,140	2,093	2,001	1,854	1,790	
Diesel Oil	1,214	1,248	1,599	1,740	1,870	2,111	1,943	2,227	2,070	
LPG	-	-	-	0	0	75	33	82	205	
Total	2,710	2,888	3,430	3,775	4,010	4,279	3,977	4,163	4,065	4,382

Souce: Oil & Thailand 1977 - 1982

Table II-7-2 DEMAND FORECAST OF GASOLINE AND DIESEL OIL FOR TRANSPORTATION AND COMMUNICATION (CALCULATED TO EMP CASE 1)

(Unit: million liter)

	1986	1991	1996	2001	1993*	1993/1983
Gasoline	1,965	3,110	4,425	5,692		
Diesel oil	2,909	3,616	4,924	6,751		
LPG for transp.	615	433	488	985		
Total	5,489	7,159	9,837	13,428	8,129	1,855

* Estimated by Consultant

Table II-8 GDPR GROWTH RATE ESTIMATED BY MACRO-ECONOMIC MODEL,

Table II-8-1 PAST GROWTH IN REAL TERM AT 1972

(Unit: Million of Baht)

	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979
VAG	48.3	50.5	50.0	56.2	57.0	62.1	65.9	65.5	72.5	71.4
VNAG	101.8	106.0	114.6	123.9	133.0	141.4	155.3	171.6	188.6	205.5
VMAN	23.3	25.2	27.9	31.6	34.4	36.8	42.5	48.1	52.5	57.8
GDPR	150.1	157.1	164.6	180.1	190.0	203.5	221.2	237.2	261.1	276.9

Table II-8-2 ESTIMATED GDPR AS OF 1972

(Unit: Million of Baht)

	1982	1983	1984	1985	1986	1987	1988	1989
GDPR	324,290	343,512	363,584	385,698	410,386	436,469	463,998	494,102
VAGR	77,784	80,340	82,471	85,740	89,133	92,053	95,083	98,227
VNAGR	246,506	263,173	281,113	299,959	321,253	344,416	368,915	395,876
VMANR	68,224	72,683	77,813	83,052	89,245	95,860	102,808	110,600

	1990	1991	1991/1982	Growth rate	1993	1993/1983
GDPR	526,700	561,647				
VAGR	101,490	104,877				
VNAGR	425,210	456,770				
VMANR	119,071	128,150	1.8784	1.0726	147,433	2.0284

GDPR Gross Domestic Production in real term (1972)

VAGR Value added of Agriculture in real term (1972)

VNAGR Value added of Non Agriculture in real term (1972)

VMANR Value added of Manufacturing in real term (1972)

Table II-9 GROWTH RATE BY MACRO-ECONOMIC MODEL

	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
GDPR (%)	4.183	5.928	5.843	6.082	6.401	6.356	6.309	6.488	6.597	6.635

Mean growth rate between 1982-1986 5.69%

Mean growth rate between 1989-1991 6.48%

For the study of EMP model run, the following growth rates are assumed.

	1982-1986	1987-1991	1992-2001	1993/1983
GDP Growth rate (%)	6.0	6.5	6.5	1.851

Table II-10 PETROLEUM PRODUCT THAI EX-REFINRY PRICES (1975-1983)

(Unit: US$/kl)

Year	Arab Light	Premium Gasoline	Regular Gasoline	JP4	JP1	Kerosene	HSD	LSD	FO600"	FO1200"	FO1500"	FO2000"	FO2500"	Bitumen *1
1975	71.20	104.6	92.8	87.3	96.9	93.1	86.9	82.0	68.9	66.9	66.3	-	-	64.7
1976	72.39	112.0	100.1	93.7	102.9	99.7	95.8	90.7	74.9	72.5	71.8	-	-	64.7
1977	77.99	116.9	104.8	97.8	105.2	102.6	100.3	96.3	78.6	76.6	75.9	-	-	64.6
1978	79.88	119.1	107.4	100.3	108.0	105.6	103.5	101.5	82.0	80.0	79.4	-	-	64.6
1979	108.56	157.8	147.5	-	-	146.9	141.0	139.2	108.3	104.5	103.3	-	-	97.1
1980	180.39	244.0	232.2	-	-	252.1	240.0	235.5	169.5	162.2	159.8	-	-	145.9
1981	204.42	265.1	248.2	-	-	275.6	262.8	257.8	205.9	200.0	198.0	197.0	195.0	203.9
1982	213.85	267.5	247.3	-	-	283.8	271.0	267.0	195.9	187.9	185.3	182.8	180.1	180.8
1983	187.50	239.8	219.6	-	-	253.4	238.1	233.5	176.7	170.3	168.2	165.5	163.3	170.3

Source: Table AII-2-5

Notes: 1. Yearly average prices of petroleum products calculated based on NEA data (Baht/lit. or Baht/kg) by using the exchange rate and weight of each period during the constant price.

*1 Specific Gravity of Bitumen = 1.1

Table II-11 PROJECTED PETROLEUM PRODUCT PRICES IN THAILAND (1984 - 2010) (1)

(Unit: US$/kl)

Year	Arab Light FOB Ras Tanura		Thai Ex-Refinery Price										
	US$/BBL	US$/kl	Premium Gasoline	Regular Gasoline	Kerosene	HSD	LSD	FO600"	FO1200"	FO1500"	FO2000"	FO2500"	*1 Bitumen
1984	29.00	182.4	237.8	221.2	246.5	234.6	230.3	174.3	167.9	165.9	163.9	161.9	165.7
1985	29.00	182.4	237.8	221.2	246.5	234.6	230.3	174.3	167.9	165.9	163.9	161.9	165.7
1986	29.00	182.4	237.8	221.2	246.5	234.6	230.3	174.3	167.9	165.9	163.9	161.9	165.7
1987	31.47	197.9	255.7	238.4	267.7	254.5	250.2	188.5	181.6	179.3	177.2	174.9	179.4
1988	34.14	214.7	275.0	256.9	290.5	276.1	271.7	203.9	196.3	193.8	191.5	189.1	194.1
1989	37.04	233.0	296.0	277.0	315.3	299.5	295.0	220.6	212.3	209.5	207.0	204.4	210.1
1990	40.19	252.8	318.9	298.8	342.3	324.9	320.3	238.7	229.7	226.7	224.0	221.2	227.5
1991	43.61	274.3	343.6	322.5	371.6	352.6	347.8	258.4	248.5	245.2	242.3	239.2	246.3
1992	47.31	297.6	370.5	348.2	403.2	382.4	377.6	279.7	268.9	265.3	262.1	258.9	266.7
1993	51.33	322.9	399.6	376.1	437.6	414.9	409.9	302.8	291.1	287.2	283.8	280.2	288.9
1994	55.70	350.3	431.3	406.4	475.0	450.2	445.0	328.0	315.2	310.9	307.2	303.3	313.0
1995	60.43	380.1	465.5	439.2	515.5	488.4	483.1	355.2	341.3	336.6	332.6	328.4	339.1
1996	65.57	412.4	502.8	474.9	559.5	529.9	524.4	384.8	369.6	364.5	360.2	355.6	367.4
1997	71.14	447.5	543.1	513.5	607.1	574.9	569.2	416.9	400.4	394.8	390.1	385.2	398.2
1998	77.19	485.5	587.0	555.4	658.9	623.7	617.8	451.7	433.7	427.7	422.6	417.3	431.5
1999	83.75	526.8	634.5	600.9	715.0	676.7	670.6	489.5	469.9	463.3	457.8	452.0	467.7
2000	90.87	571.6	686.1	650.3	776.0	734.2	727.8	530.5	509.2	502.0	496.0	489.8	507.0
2001	98.59	620.1	742.0	703.9	842.0	796.5	789.9	575.0	551.7	543.9	537.4	530.7	549.5
2002	106.97	672.8	802.8	762.0	913.8	864.2	857.3	623.2	598.0	589.5	582.5	575.2	595.8
2003	116.07	730.1	868.7	825.1	991.6	937.7	930.5	675.6	648.2	638.9	631.3	623.4	646.0
2004	125.93	792.1	940.2	893.5	1,076.0	1,017.3	1,009.8	732.4	702.5	692.5	684.2	675.7	700.3
2005	136.64	859.4	1,017.8	967.7	1,167.6	1,103.8	1,095.9	794.1	761.6	750.6	741.7	732.4	759.4
2006	148.25	932.5	1,101.9	1,048.3	1,267.0	1,197.5	1,189.2	860.9	825.6	813.7	804.0	793.9	823.4
2007	160.85	1,011.7	1,193.2	1,135.7	1,374.8	1,299.3	1,290.6	933.5	895.1	882.2	871.7	860.8	892.9
2008	174.52	1,097.7	1,292.3	1,230.5	1,491.8	1,409.7	1,400.5	1,012.2	970.5	956.4	945.0	933.2	968.3
2009	189.36	1,191.0	1,399.8	1,333.4	1,618.8	1,529.5	1,519.8	1,097.6	1,052.4	1,037.1	1,024.7	1,011.9	1,050.2
2010	205.45	1,292.2	1,516.4	1,445.0	1,756.5	1,659.4	1,649.2	1,190.3	1,141.1	1,124.5	1,111.1	1,097.2	1,138.9

Note: *1 Calculated by using equation of FO1200" and Bitumen price in 1975.

Table II-11 PROJECTED PETROLEUM PRODUCT PRICES IN THAILAND (1984 - 2010) (2)

(Unit: US$/kl)

Year	Thai Ex-Refinery									CIF Bangkok	
	Long Residue	H/F Gas Oil	LVGO	V/B Naphtha	FCC Feedstock	T/C Feedstock	Fuel Oil-A	Fuel Oil-B	Asphalt	Sulphur	Paraffin Wax
1984	163.2	232.5	232.5	201.0	190.2	132.5	163.2	160.7	165.7	157.5	580.0
1985	163.2	232.5	232.5	201.0	190.2	132.5	163.2	160.7	165.7	165.4	609.0
1986	163.2	232.5	232.5	201.0	190.2	132.5	163.2	160.7	165.7	173.6	639.5
1987	176.4	252.4	252.4	217.4	205.7	143.1	176.4	173.8	179.4	184.1	677.8
1988	190.7	273.9	273.9	234.9	222.5	154.7	190.6	187.8	194.1	195.1	718.5
1989	206.2	297.3	297.3	253.9	240.7	167.2	206.1	203.0	210.1	206.8	761.6
1990	223.0	322.6	322.6	274.3	260.5	181.0	223.0	219.7	227.5	219.2	807.3
1991	241.3	350.2	350.2	296.8	282.0	195.7	241.2	237.6	246.3	232.4	855.7
1992	261.1	380.0	380.0	321.1	305.2	211.8	261.0	257.1	266.7	246.3	907.1
1993	282.6	412.4	412.4	347.5	330.4	229.3	282.5	278.3	288.9	261.1	961.5
1994	305.9	447.6	447.6	376.1	358.0	248.2	305.9	301.3	313.0	276.8	1,019.2
1995	331.2	485.8	485.8	407.2	387.6	268.7	331.1	326.2	339.1	293.4	1,080.3
1996	358.7	527.2	527.2	441.0	419.9	291.0	358.6	353.3	367.4	311.0	1,145.2
1997	388.4	572.1	572.1	477.5	455.0	315.2	388.4	382.6	398.2	329.6	1,213.9
1998	420.8	620.8	620.8	517.0	492.9	341.4	420.7	414.5	431.5	349.4	1,286.7
1999	455.8	673.7	673.7	560.0	534.2	369.8	455.8	449.0	467.7	370.4	1,363.9
2000	493.9	731.0	731.0	606.7	578.9	400.8	493.8	486.5	507.0	392.6	1,445.7
2001	535.2	793.2	793.2	657.5	627.5	434.2	535.1	527.1	549.5	416.1	1,532.5
2002	580.0	860.8	860.8	712.4	680.1	470.6	579.9	571.3	595.8	441.1	1,624.4
2003	628.6	934.1	934.1	772.1	737.3	510.1	628.5	619.2	646.0	467.6	1,721.9
2004	681.3	1,013.6	1,013.6	836.7	799.3	552.9	681.2	671.0	700.3	495.6	1,825.2
2005	738.6	1,099.9	1,099.9	906.7	866.6	599.3	738.4	727.4	759.4	525.4	1,934.7
2006	800.6	1,193.4	1,193.4	983.1	939.5	649.6	800.5	788.5	823.4	556.9	2,050.8
2007	868.0	1,295.0	1,295.0	1,065.7	1,018.7	704.3	867.8	854.9	892.9	590.3	2,173.9
2008	941.0	1,405.1	1,405.1	1,155.3	1,104.6	763.6	940.9	926.8	968.3	625.7	2,304.3
2009	1,020.4	1,524.7	1,524.7	1,252.6	1,197.8	828.0	1,020.2	1,005.0	1,050.2	663.3	2,442.5
2010	1,106.4	1,654.3	1,654.3	1,358.1	1,299.0	897.8	1,106.2	1,089.7	1,138.9	703.1	2,589.1

Table II-12 RATIO OF PETROLUEM PRODUCT PRICES TO ARABIAN LIGHT FOB PRICE (1975 - 2010)

Year	Arab Lt. (US$/kl)	Premium Gasoline	Regular Gasoline	Kerosene	HSD	LSD	PO600*	PO1200*	PO1500*	PO2000*	PO2500*	Bitumen
1975	71.20	1.4691	1.3034	1.3076	1.2205	1.1517	0.9677	0.9396	0.9312			0.9087
1976	72.39	1.5472	1.3828	1.3773	1.3234	1.2529	1.0347	1.0015	0.9918			0.8938
1977	77.99	1.4989	1.3438	1.3156	1.2861	1.2348	1.0078	0.9822	0.9732			0.8283
1978	79.88	1.4910	1.3445	1.3220	1.2957	1.2707	1.0265	1.0015	0.9940			0.8087
1979	108.56	1.4536	1.3587	1.3532	1.2988	1.2822	0.9976	0.9626	0.9515			0.8944
1980	180.39	1.3526	1.2872	1.3975	1.3305	1.3055	0.9396	0.8992	0.8859			0.8088
1981	204.42	1.2968	1.2142	1.3482	1.2856	1.2611	1.0072	0.9784	0.9686			0.9975
1982	213.85	1.2509	1.1564	1.3271	1.2672	1.2485	0.9161	0.8787	0.8665			0.8455
1983	187.50	1.2789	1.1712	1.3515	1.2699	1.2453	0.9424	0.9083	0.8971			0.9083
1984	182.4	1.3037	1.2127	1.3514	1.2862	1.2626	0.9556	0.9205	0.9095	0.8986	0.8876	0.9084
1985	182.4	1.3037	1.2127	1.3514	1.2862	1.2626	0.9556	0.9205	0.9095	0.8986	0.8876	0.9084
1986	182.4	1.3037	1.2127	1.3514	1.2862	1.2626	0.9556	0.9205	0.9095	0.8986	0.8876	0.9084
1987	197.9	1.2921	1.2046	1.3527	1.2860	1.2643	0.9525	0.9176	0.9060	0.8954	0.8838	0.9065
1988	214.7	1.2809	1.1966	1.3531	1.2860	1.2655	0.9497	0.9143	0.9027	0.8919	0.8808	0.9041
1989	233.0	1.2704	1.1888	1.3532	1.2854	1.2661	0.9468	0.9112	0.8991	0.8884	0.8773	0.9017
1990	252.8	1.2615	1.1820	1.3540	1.2852	1.2670	0.9442	0.9086	0.8968	0.8861	0.8750	0.8999
1991	274.3	1.2526	1.1757	1.3547	1.2855	1.2680	0.9420	0.9059	0.8939	0.8833	0.8720	0.8979
1992	297.6	1.2450	1.1700	1.3548	1.2849	1.2688	0.9399	0.9036	0.8915	0.8807	0.8700	0.8962
1993	322.9	1.2375	1.1648	1.3552	1.2849	1.2694	0.9378	0.9015	0.8894	0.8789	0.8678	0.8947
1994	350.3	1.2312	1.1601	1.3560	1.2852	1.2703	0.9363	0.8998	0.8875	0.8770	0.8658	0.8935
1995	380.1	1.2247	1.1555	1.3562	1.2849	1.2710	0.9345	0.8979	0.8856	0.8750	0.8640	0.8921
1996	412.4	1.2192	1.1516	1.3567	1.2849	1.2716	0.9331	0.8962	0.8839	0.8734	0.8623	0.8909
1997	447.5	1.2136	1.1475	1.3566	1.2847	1.2720	0.9316	0.8947	0.8822	0.8717	0.8608	0.8898
1998	485.5	1.2091	1.1440	1.3572	1.2847	1.2725	0.9304	0.8933	0.8809	0.8704	0.8595	0.8888
1999	526.8	1.2044	1.1407	1.3573	1.2845	1.2730	0.9292	0.8920	0.8795	0.8690	0.8580	0.8878
2000	571.6	1.2003	1.1377	1.3576	1.2845	1.2733	0.9281	0.8908	0.8782	0.8677	0.8569	0.8870
2001	620.1	1.1966	1.1351	1.3578	1.2845	1.2738	0.9273	0.8897	0.8771	0.8666	0.8558	0.8861
2002	672.8	1.1932	1.1326	1.3582	1.2845	1.2742	0.9263	0.8888	0.8762	0.8658	0.8549	0.8856
2003	730.1	1.1898	1.1301	1.3582	1.2843	1.2745	0.9254	0.8878	0.8751	0.8647	0.8539	0.8848
2004	792.1	1.1870	1.1280	1.3584	1.2843	1.2748	0.9246	0.8869	0.8743	0.8638	0.8530	0.8841
2005	859.4	1.1843	1.1260	1.3586	1.2844	1.2752	0.9240	0.8862	0.8734	0.8630	0.8522	0.8836
2006	932.5	1.1817	1.1242	1.3587	1.2842	1.2753	0.9232	0.8854	0.8726	0.8622	0.8514	0.8830
2007	1,011.7	1.1794	1.1226	1.3589	1.2843	1.2757	0.9227	0.8847	0.8720	0.8616	0.8508	0.8826
2008	1,097.7	1.1773	1.1210	1.3590	1.2842	1.2758	0.9221	0.8841	0.8713	0.8609	0.8501	0.8821
2009	1,191.0	1.1753	1.1196	1.3592	1.2842	1.2761	0.9216	0.8836	0.8708	0.8604	0.8496	0.8813
2010	1,292.2	1.1735	1.1182	1.3593	1.2842	1.2763	0.9211	0.8831	0.8702	0.8599	0.8491	0.8814

Sources: Table II-10, Table II-11 (1)

Table II-13 BASE OIL PRICES/FOB SINGAPORE (1979 - 1984)

Year	Date	Arab Light (US$/kl)	150N US$/kl	150N Ratio	500N US$/kl	500N Ratio	150BS US$/kl	150BS Ratio
1979	Jan.1	83.90	189.6	2.259	200.1	2.385	235.8	2.810
1979	Jul.1	113.21	227.9	2.013	241.1	2.130	276.8	2.445
1980	Jan.1	163.53	297.9	1.821	313.1	1.915	351.4	2.149
1980	Jul.1	176.11	354.0	2.010	396.3	2.250	446.5	2.535
1981	Jan.1	201.27	372.5	1.850	418.1	2.077	472.9	2.350
1981	Jul.1	201.27	392.3	1.949	443.2	2.202	505.3	2.511
1982	Jan.1	213.85	376.5	1.760	428.7	2.005	492.1	2.301
1982	Jul.1	213.85	359.3	1.680	411.5	1.924	474.2	2.217
1983	Jan.1	213.85	352.7	1.649	402.2	1.881	465.0	2.174
1983	Jul.1	182.40	340.8	1.868	390.4	2.140	453.1	2.484
1984	Jan.1	182.40	340.8	1.868	390.4	2.140	453.1	2.484

Source: Platt's Oilgram Price Report

Table II-14 PROJECTED BASE OIL PRICES/CIF THAILAND (1984 - 2010)

(Unit: US$/kl)

Year	Arab Lt. (US$/kl)	60N	150N	300N	500N	150BS
1984	182.40	339.1	348.6	368.9	390.1	445.1
1985	182.40	339.1	348.6	368.9	390.1	445.1
1986	182.40	339.1	348.6	368.9	390.1	445.1
1987	197.94	361.5	371.8	396.1	418.9	477.7
1988	214.73	385.9	396.8	425.4	449.9	512.7
1989	232.97	412.3	424.0	457.3	483.6	550.9
1990	252.78	441.1	453.5	492.0	520.3	592.3
1991	274.29	472.1	485.5	529.5	560.0	637.2
1992	297.57	505.9	520.1	570.1	602.9	685.7
1993	322.85	542.3	557.6	614.2	649.7	738.5
1994	350.34	582.1	598.5	662.2	700.4	795.8
1995	380.09	625.0	642.6	714.0	755.1	857.8
1996	412.42	671.5	690.6	770.2	814.7	925.2
1997	447.45	722.0	742.4	831.2	879.2	998.1
1998	485.50	776.8	798.7	897.3	949.2	1,077.2
1999	526.76	836.1	859.8	969.1	1,025.1	1,163.0
2000	571.55	900.5	926.1	1,047.0	1,107.5	1,256.2
2001	620.10	970.3	997.8	1,131.3	1,196.7	1,357.1
2002	672.81	1,046.9	1,075.7	1,222.8	1,293.5	1,466.6
2003	730.05	1,128.1	1,160.2	1,322.0	1,398.6	1,585.5
2004	792.06	1,217.1	1,251.7	1,429.6	1,512.4	1,714.2
2005	859.42	1,313.6	1,351.0	1,546.3	1,636.0	1,854.0
2006	932.45	1,418.4	1,458.6	1,672.9	1,769.9	2,005.4
2007	1,011.70	1,531.9	1,575.4	1,810.1	1,915.2	2,169.8
2008	1,097.68	1,655.0	1,702.1	1,958.9	2,072.7	2,348.0
2009	1,191.02	1,788.5	1,839.4	2,120.4	2,243.5	2,541.3
2010	1,292.22	1,933.2	1,988.3	2,295.5	2,428.9	2,751.0

Sources: Table AII-2-10, Table AII-2-11

Table II-15 REFINERY PRODUCTION, IMPORTS AND CONSUMPTION OF PETROLEUM PRODUCTS

(Unit: 10^6 LITRES)

Items	Years	High Speed Diesel	Low Speed Diesel	Regular Gasoline	Premium Gasoline	Fuel Oil	Kerosene	Jet Fuel	L.P.G.	Total
Refinery Production 1/	1979	2,617.485	154.387	1,035.137	1,082.021	3,488.082	318.920	782.314	250.893	9,729.239
	1980	2,683.066	110.974	950.136	877.678	2,514.321	292.712	776.803	231.940	8,437.630
	1981	2,658.111	93.183	985.250	837.145	2,626.390	353.228	925.093	243.574	8,721.974
	1982	2,771.413	73.525	1,214.153	767.893	2,368.696	360.514	948.635	193.544	8,698.373
Imports 2/	1979	1,625.011	14.106	45.940	161.377	1,394.846	4.619	103.121	77.714	3,426.742
	1980	1,577.494	2.723	140.127	321.474	2,200.233	7.602	182.015	134.817	4,566.485
	1981	1,175.965	—	38.575	240.405	1,312.617	38.073	82.784	231.321	3,119.740
	1982	1,164.973	—	3.869	15.959	631.919	67.412	104.961	425.536	2,414.629
Consumption 3/	1979	4,164.855	133.263	896.918	1,464.504	3,993.846	312.068	869.400	369.153	12,204.007
	1980	4,019.207	90.443	1,005.553	1,243.085	4,721.183	290.213	944.612	354.381	12.668.677
	1981	3,964.356	65.325	983.089	1,107.627	4,143.077	388.591	926.518	449.907	12,028.490
	1982	3,879.792	51.173	1,322.828	692.303	2,996.768	387.689	1,081.421	600.821	11,012.795
Statistical Differences	1979	77.641	35.230	184.167	(221.106)	889.082	11.471	25.195	(40.546)	951.974
	1980	241.353	23.254	84.710	(43.933)	(6.629)	10.101	14.206	12.376	335.438
	1981	(130.280)	27.858	40.736	(30.077)	(204.070)	2.710	81.359	24.988	(186.776)
	1982	56.594	22.352	(104.806)	91.549	3.847	40.237	(27.825)	18.259	100.207

Sources: 1/ Excise Department
2/ Customs Department
3/ Oil Companies

Note: Fuel Oil Imports and Consumption Include Shengli Crude Oil.

Table II-16 ENERGY DEMAND TABLE

(Unit: 10^{12} CAL)

Products	1986 Industry (Non Elec.)	1986 Electricity	1986 Total	1991 Industry	1991 Electricity	1991 Total	1996 Industry	1996 Electricity	1996 Total	2001 Industry	2001 Electricity	2001 Total
LPG	10,055.1	-	10,055	10,913.3	-	10,913	15,237.9	-	15,238	22,839.9	-	22,839.9
GASOLINE												
(GASOLINE)	-	-	-	188.7	-	189	699.8	-	700	1,174.7	-	1,175
(PKEM)	5,464.3	-	5,464	4,475.4	-	4,475	4,834.3	-	4,834	5,298.6	-	5,299
(REG.)	11,630.0	-	11,630	22,115.3	-	22,115	32,490.5	-	22,491	42,466.0	-	42,466
DIESEL												
(HS)	37,653.3	237	38,079	47,291.9	152	47,633	63,032.1	874	64,095	85,287.9	874	86,353
(LS)	188.5			189.0			109.8			190.6		
JET FUEL	10,824.2	-	10,824	13,931.1	-	13,931	18,053.1	-	18,053	23,401.1	-	23,401
KEROSENE	1,598.7	-	1,599	1,686.1	-	1,686	1,306.9	-	1,307	1,892.2	-	1,892
FUEL OIL	23,875.5	531	24,408	28,692.9	1,959	30,652	26,017.2	77	26,094	38,828.2	59	38,887
GAS MIX (NG)	4,268.8	29,965	34,234	5,320.8	43,155	48,738	14,830.9	75,424	(69,242)	19,319.3	44,647	(56,192)
(GAS)	-			262.4			1,630.6		91,886	2,076.6		66,043
									(48,738)			(48,738)
ELEC												
(IND)	229.2			181.9			366.8			333.5		
(LV)	14,708.8	4,603	22,729	21,330.5	5,162	31,297	29,984.4	6,869	43,863	40,976.9	10,153	61,088
(MV)	3,187.7			4,621.5			1,643.1			9,624.4		
HEAT MIX (IND)	1,258.6	-	1,259	991.9	-	992	1,464.3	-	1,464	1,271.7	-	1,272
COAL MIX REV	2,140.1	16,441	18,581	7,374.3	27,151	34,525	10,870.7	27,051	37,922	9,800.3	98,547	108,348
OTHER MIX	113.7	-	114	3,330	-	333	1,035.0	-	1,035	3,549.4	1,302	4,851
TRAD EN	64,360.1	1,644	66,004	70,711.5	1,261	72,073	74,428.2	1,008	75,436	78,290.1	763	79,053
HVY RES DATE	1,634.0	-	1,634	1,794.0	-	1,794	1,969.0	-	1,969	2,162.0	-	2,162
FEED STOCK	2,008.0	-	2,008	8,098.5	-	8,099	22,510.1	-	22,510	26,485.1	-	26,485
TOTAL	195,198.1	53,419	248,617	250,503.4	79,421	329,924	327,594.1	111,841	439,435	415,268.0	156,818	572,809

Notes: 1. ( ) Case when N.G. production remain 650 MMSCFD after 1991
2. Rev 2/21/84
3. Date 2/20/84
4. Case EMPI

Table II-17 DEMAND FOR PETROLEUM PRODUCTS DERIVED FROM EMP

(Unit: 10^6 LITRES (BPCD))

	1982 (Actual Consumption)	1986	1991	1996	2001
LPG	600.821	1,581.527	1,716.480	2,396.749	3,592.449
		(27,250)	(29,580)	(41,300)	(61,900)
GASOLINE	2,015.131	2,035.485	3,188.735	4,527.804	5,827.578
		(35,070)	(54,950)	(78,020)	(100,410)
KEROSENE +JET FUEL	1,469.110	1,427.845	1,797.619	2,234.913	2,918.540
		(24,600)	(30,970)	(38,510)	(50,290)
DIESEL	3,930.965	4,063.494	5,083.022	6,839.718	9,214.918
		(70,000)	(87,590)	(117,850)	(158,780)
FUEL OIL	2,996.768	2,484.022	3,119.479	2,655.608	3,957.562
		(42,800)	(53,750)	(45,760)	(68,190)
				<7,046.815>	<5,718.705>
				(121,420)	(98,540)
BITUMEN	123.685	158.641	174.175	191.165	290.903
		(27,730)	(3,000)	(3,290)	(3,620)
TOTAL	11,136.480	11,758.666	15,067.880	18,803.812	25,719.820
	(191,889)	(202,610)	(259,670)	(324,000)	(443,170)
				<23,195.019>	<27,367.298>
				(399,660)	(472,280)

Note: < > is the case where natural gas production remains at 650 MMSCFD even after 1991 through 2001.

Table II-18 CRUDE OIL TOPPING CAPACITY

(Unit: 1,000 BPCD)

Year / Refinery	1983	84	85	86	87	88	89	90	91	Remarks
MOR	55	55	60	65	65	65	65	65	65	Rehabilitation of TORC in 1985 Phase I in 1987, II in 1990. Debottlenecking of ESSO in 1986
TORC	65	65	66	66	77.7	77.7	77.7	120	120	
ESSO	48	48	55	63	63	63	63	63	63	
TOTAL	168	168	181	194	205.7	205.7	205.7	248	248	

- Base Data = EMP Scenario 1
- Capacity for 1987 = NEA's information on TORC's Phase I Capacity and Energy Pricing Studies (Nov. 1983)

Table II-19 REFINERY UNIT CAPACITIES IN 1987 AND 1991

Refinery / Feed & Product	IN 1987*(1)				IN 1991			
	MOR	TORC	ESSO	(BPCD) TOTAL	MOR	TORC	ESSO	(BPCD) TOTAL
CRUDE	65,000	77,650	63,000	205,650	65,000	120,000	63,000	248,000
+ LONG RESIDUE (PRODUCTS)		+21,400		+21,400				
LPG	1,500	1,610	2,700	5,810	1,500	4,700	2,700	8,900
GASOLINE	13,400	20,880	11,400	43,630	13,400	30,400	11,400	55,200
KEROSENE + JET FUEL	6,500	17,650	7,900	32,050	6,500	18,600	7,900	33,000
DIESEL	18,300	39,380	19,000	76,680	18,300	54,000	19,000	91,300
FUEL OIL	22,700	13,950	18,400	55,050	22,700	13,000	18,400	54,100
BITUMEN	-	760	1,900	2,660	-	800	1,900	2,700
TOTAL	62,400	94,230	61,300	227,930	62,400	121,500	61,300	255,200

*(1) NEA's information on TORC's Phase I Capacity and Energy Pricing Studies (P. 349, Nov. 1983)

Table II-20 DEMAND/SUPPLY BALANCE OF PETROLEUM PRODUCTS

BPCD

YEAR / PRODUCTS	1987			1991			1996	
	DEMAND	SUPPLY	BALANCE	DEMAND	SUPPLY	BALANCE	DEMAND	BALANCE
LPG	27,720	5,810	(-)21,910	29,580	8,900	(-)20,680	41,300	(-)32,400
					<5,810>	<(-)23,760>		<(-)35,490>
GASOLINE	39,050	43,630	4,580	54,950	55,200	250	78,020	(-)22,820
					<43,630>	<(-)11,120>		<(-)34,390>
KEROSENE	25,870	32,050	6,180	30,970	33,000	2,030	38,510	(-)5,570
+ JET FUEL					<32,050>	<1,080>		<(-)6,520>
DIESEL	73,530	76,680	3,150	87,590	91,300	3,710	117,850	(-)26,550
					<76,680>	<(-)10,910>		<(-)41,170>
FUEL OIL	45,710	55,050	9,340	53,750	54,100	350	45,760	8,340
					<55,050>	<1,300>	<121,420>	<9,290>
BITUMEN	2,780	2,660	(-)120	3,000	2,700	(-)300	3,290	(-)590
					<2,660>	<(-)340>		<(-)630>
TOTAL	214,660	215,880	1,220	259,840	245,200	(-)14,640		
					<215,880>	<(-)44,500>		

Supply Production Capacity in Refineries

(-): denotes deficits which should be compensated by import or from other source(s).

Figure in <> shows the case where Phase II Project of TORC is not realized.

Table II-21 VARIOUS TYPES OF CRUDE OIL IMPORTED BY SOURCES AND REFINED BY LOCAL REFINERIES 1982

Items	TORC		[illegible]		ESSO		Total	
	10^6 Litres	10^6 Baht	10^6 Litres	10^6 Baht	10^6 Litres	10^6 Baht	10^6 Litres	10^6 Baht
1. Saudi Arabia								
Arabian Light Crude Oil			3,543.5	19,473.9	428.5	2,123.0	3,972.0	21,596.9
Arabian Natural Petroleum Crude Oil	174.0	876.0	109.5	549.8		-	283.5	1,425.8
Arabian Medium Crude Oil					43.6	239.7	43.6	239.7
Arabian Light Berry Natural Petroleum Crude Oil	106.2	549.9					106.2	549.9
Tailored Arabian Berry Crude Oil					106.2	543.5	106.2	543.5
Tailored Arabian Light Crude Oil					910.1	4,532.0	910.1	4,532.0
Tailored Arabian Light Berry Crude Oil					181.8	912.9	181.8	912.9
Sub Total	280.2	1,416.9	3,653.0	20,023.7	1,676.2	8,356.1	5,609.4	29,736.7
2. Malaysia								
Miri Light Crude Oil	71.6	378.0					71.6	378.0
Miri Natural Petroleum Crude Oil	364.2	1,886.7	151.6	779.8			515.8	2,666.5
Tembungo Crude Oil					229.9	1,194.3	229.9	1,194.3
Tapis Blend Crude Oil					512.2	2,770.9	512.2	2,770.9
Labuan Crude Oil	82.2	421.7					82.2	421.7
Sub Total	518.0	2,686.4	151.6	779.8	742.1	3,965.2	1,411.7	7,431.4
3. Qatar								
Qatar Natural Petroleum Crude Oil	474.0	2,444.4					474.0	2,444.4
Qatar Crude Oil	211.8	1,085.5					211.8	1,085.5
Sub Total	685.8	3,529.9					685.8	3,529.9
4. Brunei								
Seria Natural Petroleum Crude Oil	413.0	2,093.8					413.0	2,093.8
Champion Crude Oil					34.0	169.8	34.0	169.8
Sub Total	413.0	2,093.8			34.0	169.8	447.0	2,263.6
5. China								
Shengli Crude Oil			115.5	543.4			115.5	543.4
Sub Total			115.5	543.4			115.5	543.4
6. Dubai								
Dubai Natural Petroleum Crude Oil	103.0	516.9					103.0	516.9
Sub Total	103.0	516.9					103.0	516.9
7. Oman								
Oman Natural Petroleum Crude Oil	105.2	543.9					105.2	543.9
Sub Total	105.2	543.9					105.2	543.9
8. United Arab Emirates								
Zakum Crude Oil					65.2	342.1	65.2	342.1
Sub Total					65.2	342.1	65.2	342.1
Grand Total	2,105.2	10,797.8	3,920.1	21,351.9	2,517.5	12,833.2	8,542.7	44,972.9

Source: Department of Customs

Table II-22 PRODUCTION FORECAST FOR MAJOR CRUDE OIL IN THE FREE WORLD

(Unit: 1,000 B/D)

	1978	1985	1990	Index in 1990 (1978=100)
Berri	578	500- 600	550- 600	95-104
Arabian Light	5,472	5,335- 6,050	5,350- 6,000	98-110
Arabian Medium	968	1,700- 1,910	2,110- 2,370	218-245
Arabian Heavy	1,479	2,165- 2,440	2,690- 3,030	182-205
Sub-total	3,497	9,700-11,000	10,700-12,000	126-141
Iranian Light	2,000	1,125- 1,800	1,125- 1,400	56- 70
Iranian Heavy	2,123	1,375- 2,200	1,375- 2,100	65- 99
Sub-total	4,123	2,500- 4,000	2,500- 3,500	61-85
Khafji	463	550	550	119
Kuwait	2,364	2,100	2,100	89
Basrah Light	2,909	3,500- 4,400	3,950- 4,850	136-167
Basrah Heavy	295	370- 470	420- 520	142-176
Murban	1,961	2,100	2,100	107
Middle East Total(A)	20,612	20,820-24,620	22,320-25,620	108-124
Attaka	654	725	725	111
Seria	170	180	220	129
Minas	1,271	1,345	1,355	107
South Asia Total(B)	2,095	2,250	2,300	110
Total(A+B)	22,708	23,070-26,870	24,620-27,920	108-123
Other Free World Total	24,383	30,450	32,680	134
Free World Total	47,091	53,520-57,320	57,300-60,600	122-129
(OPEC)	(30,062)	(30,000-33,800)	(31,500-34,800)	(105-116)
(Non-OPEC)	(17,029)	(23,520)	(25,800)	(152)

Source: The Institute of Energy Economics (Japan), 1980

Table II-23 PARAFFIN WAX IMPORTED (CIF VALUES)

Petroleum Products	1975		1976		1977		1978		1979		1980		1981		1982	
	10^3 Litres	10^3 Baht	10^3 Litres	10^3 Baht	10^3 Litres	10^3 Baht	10^3 Litres	10^3 Baht	10^3 Litres	10^3 Baht	10^3 Litres	10^3 Baht	10^3 Litres	10^3 Baht	10^3 Litres	10^3 Baht
Paraffin Wax	6,205	29,278	7,178	33,429	8,839	61,923	8,800	74,540	10,362	112,745	6,984	115,997	9,524	153,067	7,448	96,508
Other Mineral Wax	231	1,989	400	4,132	435	4,431	405	5,573	468	6,392	141	3,945	466	9,210	343	6,987
Petroleum Bitumen	1,241	3,477	1,317	3,622	1,283	4,189	2,028	6,848	2,498	9,575	1,826	9,787	718	5,826	375	3,281

Table II-24 LUBE OIL BLENDERS IN THAILAND

Lube Oil Blenders	Nominal Production Capacity (ML)	Operation hour	Note
Esso	78	12 hr x 300 d/y	Operating and oil refinery and gasoline stations
SHELL	64	7 hr x 240 d/y	Operating and oil refinery and gasoline stations
CALTEX	58	8 hr x 286 d/y	Operating gasoline stations
MOBIL	16	8 hr x 300 d/y	Importing base oil from Australia and no gasoline station
Asia Oil	16	N.A.	Importing base oil from China, supplying lube oil to Chinese dealers and PTT, no gasoline stations
PENNZOIL	N.A.	N.A.	Importing base oil from China, gasoline stations
CASTROL	N.A.	N.A.	Purchasing production from mainly Shell

Note: These blenders are importing not only base oils but lubricating oils.

Table II-25 PAST AND PROJECT FREE WORLD ENERGY AND LUBE DEMAND

	1965	1970	1975	1980	1985	1990	1995	2000
Total Energy Demand 10^9 (Bbl/year) (Equivalent Oil)								
J.L. Helm 1)	20.7	27.4	31.1	35.2	40.3	45.6	51.6	58.4
Growth Rate 2)		5.77	2.57	2.50	2.74	2.50	2.50	2.50
L.E.G. 3)				35.2	36.6	40.5	45.4	50.8
Growth Rate 4)					0.78	2.05	2.29	2.29
H.E.G. 5)				35.2	39.1	44.1	49.8	56.2
Growth Rate 6)					2.11	2.45	2.45	2.45
% Lube Oil Demant 7)/ Total Energy Demant	0.56	0.51	0.47	0.50	0.49	0.48	0.48	0.48
Toal Lube Oil Demand 10^6 Bbl/year								
J.L. Helm 8)	115	140	145	175.6	195.7	221.1	247.7	280.0
L.E.G. 9)				175.6	177.7	187.5	217.9	243.8
H.E.G. 10)				175.6	189.8	204.2	239	269.8

Note:
1) 1965-1990: Source: J.L. Helm, Sun Oil Products Co., the 4th International Conference on Used Oil Recovery and Reuse
1995, 2000: Estimated by the consultant (used growth rate 1985/1990)
2) Annual growth of energy demand
3) Total energy demand in case of high GNP growth rate
4) Annual high growth rate of GNP by Shell International Petroleum Co.
5) Total energy demand in case of high GNP growth rate
6) Annual low growth rate of GNP by Shell International Petroleum Co.
7) % Lube demand to total energy demand
8) Lube Oil demand, J.L. Helm data revised by consultant
9) Total lube oil demand in case of low GNP growth rate
10) Total lube oil demand in case of high GNP growth rate
11) Supplus and deficit capacity, when lube oil supply of 1995 and 2000 is as same as its of 1990
12) Source: Table II-29

Table II-26 RESULTS AND FORECAST OF NET GDP (GROSS DOMESTIC PRODUCT) GROWTH RATE

	1960 -73	1973 -79	1980 -85	1985-95	
				High	Low
Advanced industrial countries	4.9	2.8	1.9	4.3	2.5
Developing countries	6.3	5.2	2.8	5.5	4.7
Lower income countries					
Asia Africa	5.9	5.2	5.8	5.3	4.6
Oil-import-medium-income countries					
Ind. products export countries	6.7	5.8	1.6	6.3	5.2
Other countries	5.3	4.3	1.9	4.3	3.8
Oil export countries	6.9	4.9	2.4	5.4	4.7

Note: From World Bank "The 1984 World Development Report"

TABLE II-27 PROJECTED FREE WORLD BASE LUBE DEMAND

(Unit: million Bbl/year)

Region	1980	1985	1990	Growth Rate 1980/1985	Growth Rate 1980/1990
North America (Ex. US)	9.4	11.3	13.2	3.8	3.5
United States	62.4	66.2	69.9	1.2	1.1
Carib. & Cent. America	1.3	1.3	1.9	0	3.9
South America	10.1	12.0	13.9	3.5	3.2
Western Europe	47.2	53.5	60.0	2.5	2.4
Middle East	8.2	10.7	13.2	5.5	4.9
Africa	7.6	8.2	9.5	1.5	2.3
Asia/Australia (Ex. Japan)	15.5	19.7	25.7	4.9	5.2
	29.4	32.5	39.5	2.0	6.1
Japan	13.9	12.8	13.8	-1.6	0
Total	175.6	195.7	221.1		

Note: Base data: J.L. Helm, Sun Petroleum Products Co.
Original data is presented to the 4th International Conference on Used Oil Recovery and Reuse, Oct. 1, 1981, after that be revised last year.
The consultant revises Asia/Australia demand by Mitsubishi Oil Co.'s data and International Energy Annual Data.

TABLE II-28 ASIA/AUSTRALIA LUBE OIL DEMAND

(Unit: million Bbl/year)

	1980	1981	1982	1985	1986	1990
Australia	2.9	2.9	2.9		4.0	
Bangladesh	0.2	0.2	0.2		0.2	
Burma	0.2	0.2	0.2		0.2	
China	0.4	0	0		0.4	
Hong Kong	0	0.35	0.35		0.4	
India	3.7	3.7	3.9		5.1	
Indonesia	0.7	1.1	1.1		1.5	
Korea North						
Korea South	1.5	1.5	1.3		1.6	
Malaysia	0.7	0.7	0.6		0.7	
New Zealand		0	0			
Pakistan	0.4	0.7	0.9		1.3	
Philippines	1.5	1.5	1.5		1.8	
Singapore	0.4	0.35	0.5		0.5	
Sri Lanka	0.1	0.1	0.1		0.2	
Taiwan	1.5	1.5	1.3		1.5	
Thailand	1.1	1.1	1.0		1.2	
Vietnam		0			0	
Other	0.2	0	0.35		0.4	
Sub-total	15.5	15.9	16.2	19.7	21.0	25.7
Japan	13.9	13.9	12.3	12.8	13.0	13.8
Grand Total	29.4	29.8	28.5	32.5	34.0	39.5

Note: 1988-1981: The consultant revises International Energy Annual Data

1982 and 1986: The consultant revises Mitsubishi Oil Company's Data by International Energy Annual Data

1) Lube oil demand of 1985 is estimated by growth rate (1982/1986).

2) Lube oil demand of 1990 is estimated by growth rate (1980/1986).

Table II-29 FREE WORLD BASE OIL
SUPPLY 1980 - 1990

(Unit: million Bbl/year)

Region	1980 Supply	1985 Supply	1990 Supply
North America (ex. U.S.A.)	11.3[1)]	11.9	13.9
U.S.	73.0	76.1	65.2
Carib. & Center. America	8.1	10.0	11.0
South America	8.5	11.0	13.0
Western Europe	49.6	50.1	50.1
Middle East	5.0	10.5	18.4[2)]
Africa	5.1[1)]	8.1	11.5
Asia/Australia	33.1	35.7	37.7
Total Supply[3)]	193.7	213.4	220.8

Note: Base data is J.L. Helm, Sun Petroleum Products Co., but the consultant revises.

1) Source: International Energy Annual

2) Revised by Table II-28

3) Source: Table II-27

U.S. Supply of Helm's data is 73.0 xmillion Bbl/year, but output of International Energy Annual is 65.0 x million Bbl/year, due to some of U.S. lube plans shutdown owing to superannuate.

Table II-30 CAPACITY FORECAST OF SAUDI ARABIAN PLANTS

Company	New Capacity (million Bbl/year)	Location	Completion Date
Petromin-Ashland	1.83	Yanbu	1984
Petromin/Chevron/Texaco	4.38	Jubail	1985
Petromin/Mobil	0.51	Jidoah[1)]	1985
	0.33	Riyadh[1)]	1985
Petromin/Shell	1.39	Jubail	Under Study
Petromin/Apicorp	1.46	Yanbu or Rabigh	Under Study
Total New Capacity	9.96		
Existing Capacity	0.73		
Total	10.63		

Note: 1) Existing capacity expansion

Total Petromin/Mobil Capacity will be increased to 1.57 x million Bbl/year, thus existing capacity is 0.73 million Bbl/year.

Source: Japanese Company

Table II-31 INCREMENT CAPACITY OF LUBE OIL PLANTS AS OF JUNE 1984

(Unit: 1,000 Bbl/year)

	Complete	Under Construction	Engineering	Planning	Total of Each Country
U.S.	3,103(84)				6,644
	(add)694(84)				
	2,847				
Brazil			(Re)Cap.N.A.		N.A.
Colombia		(add)949(84)			949
Equador				Cap.N.A.	N.A.
Mexico			4,298		4,298
Venezuela			(to)840[420]		420
Portugal	(Ex)Cap.N.A.				N.A.
Scotland				350(85)	350
Greece		(to)220[110]			110
Yogoslavia				1,050	1,050
Egypt			Cap.N.A.		N.A.
Iran		(Ex)588	1,400(87)		3,388
			1,400(87)		
Iraq		700(84)	1,750(85)		2,450
Saudi Arabia			4,380(87)		4,380
			Cap.N.A.		N.A.
Japan	1,095				1,095
Pakistan		(add)700(84)			700
South Korea				4,954	4,954
Australia			(add)308		308
Indonesia	1,225				1,225
Total	8,964+	3,047	13,956+	6,354+	Total 32,321+

Note: (add) Increment of capacity added
(Ex) Expansion
(86) Last two number of year of estimated construction completion e.g. 1986
(to) Total capacity after construction, therefore 1/2 of capacity is increment capacity to be assumed
(Re) Revamping

Source: Hydrocarbon Processing, HPI Construction Baxscore February 1984 and June 1984

Table II-32 FREE WORLD LUBE OIL (INCLUDING GREASE) OUTPUT, IMPORT, EXPORT, APPARENT CONSUMPTION 1980

(Unit: 1,000 Bbl/day)

Region & Country	Output	Import	Export	Consumption	Remarks
North America					
U.S.	178 (65.0)	7 (2.6)	23 (8.4)	159 (58.0)	
Other	31 (11.3)	7 (2.6)	0	39 (14.2)	
Total	209 (76.3)	14 (5.1)	24 (8.8)	198 (72.3)	
Cent. America	(8)	(1.1)	(5.5)	(4.4)	
South America	(11.3)	(2.1)	(1.8)	(10.2)	
Western Europe	136 (49.6)	68 (24.8)	73 (26.6)	124 (45.3)	
Middle East	7 (2.6)	6 (2.2)	3 (1.1)	9 (3.3)	
Africa	14 (5.1)	10 (3.7)	2 (0.7)	23 (8.4)	
Far East & Ocenia					(e): Denotes less than one-half the unit of measure or zero
Australia	11 (4.0)	1 (0.4)	4 (1.5)	8 (2.9)	
Bangladesh					
China	0			1 (0.4)	
Hong Kong		1 (0.4)		1 (0.4)	
India	8 (2.9)	3 (1.1)		11 (4.0)	
Indonesia	1 (0.4)	2 (0.7)	1 (0.4)	2 (0.7)	
Japan	41 (15.0)	3 (1.1)		38 (13.9)	
Korea North	0 (0)				
Korea South	4 (1.5)			4 (1.5)	
Malaysia	0	3 (1.1)		2 (0.7)	
New Zealand	0			0	
Pakistan	2 (0.7)			1 (0.4)	
Philippines	0	(e)		(e)	
Singapore	12 (4.4)	(e)	11 (4.0)	1 (0.4)	
Sri Lanka					
Taiwan	10 (3.7)	2 (0.7)		10 (3.7)	
Thailand	0	1 (0.4)		1 (0.4)	
Vietnam					
Other	(e)	1 (0.4)	8 (2.9)	1 (0.4)	
Total	90 (32.9)	16 (5.3)	24 (8.8)	81 (29.6)	
World Total	507(185.1)	123(44.9)	146(53.3)	475(173.4)	

Note : ( ) million Bbl/year

Source: International Energy Annual

Table II-33 WORLD-WIDE LUBE DEMAND AND SUPPLY FORECAST

(Unit: Million Bbl/y)

	1980	1985	1990	1995	2000
Lube Oil Supply	193.7	213.4	220.1	220.1	220.1
Lube Oil Demand					
1) J.L.Helm	175.6	195.7	221.1	247.7	280.0
2) GDP High Growth	175.6	189.8	204.2	239.0	269.8
3) GDP Low Growth	175.6	177.7	187.5	217.9	243.8
Surplus					
1) J.L.Helm	18.1	17.7	△1.0	△27.6	△59.9
2) GDP High Growth	18.1	23.6	15.9	△18.9	△49.7
3) GDP Low Growth	18.1	35.7	32.6	2.2	△23.7

Table II-34 FREE WORLD BASE OIL
SUPPLY - DEMAND BALANCE 1980-1990

(Unit: million Bbl/year)

Region	1980 Supply	1980 Demand	1980 Excess & Deficit	1985 Supply	1985 Demand	1985 Excess & Deficit	1990 Supply	1990 Demand	1990 Excess & Deficit
North America (Ex. US)	11.3 1)	9.4	1.9	11.9	11.3	0.6	13.9	13.2	0.7
U.S.	73.0	62.4	10.6	76.1	66.2	9.9	65.2	69.9	-4.7
Carib. & Cent America	8.1	1.3	6.8	10.0	1.3	8.7	11.0	1.9	9.1
South America	8.5	10.1	-1.6	11.0	12.0	-1.0	13.0	13.9	-0.9
Western Europe	49.6	47.2	2.4	50.1	53.5	-3.4	50.1	60.0	-9.9
Middle East	5.0	8.2	-3.2	10.5	10.7	-0.2	18.4 2)	13.2	5.2
Africa	5.1 1)	7.6	-2.5	8.1	8.2	-0.1	11.5	9.5	2.0
Asia/Australia	33.1	29.4	3.7	35.7	32.5	3.2	37.7	39.5	-1.8
Total Supply 3)	193.7			213.4			220.8		
Total Demand		175.6			195.7			221.1	
Surplus			18.1			17.7			-0.3

Note: Base data is J.L. Helm, Sun Petroleum Products Co., but the consultant revises.

1) Source : International Energy Annual
2) Revised by Table II-28
3) Source : Table II-27

U.S. Supply of Helm's data is 73.0 x million Bbl/year, but output of International Energy Annual is 65.0 million Bbl/year; due to some of U.S. lube plans shutdown owing to superannuate.

Table II-35 ASIA/AUSTRALIA LUBE OIL SUPPLY AND DEMAND FORECAST

(Unit: million Bbl/year)

	1982			1986		
	Supply	Demand	Defference	Supply	Demand	Defference
Australia	3.7	2.9	0.8	4.55	4.0	0.55
India	3.2	3.9	-0.7	3.6	5.1	-1.5
Pakistan	0.6	0.9	-0.3	1.3	1.3	0
Bangladesh	-	0.2	-0.2	-	0.2	-0.2
Sri Lanka	-	0.1	-0.1	-	0.2	-0.2
Burma	-	0.2	-0.2	-	0.2	-0.2
Thailand	-	1.0	-1.0	-	1.2	-1.2
Malaysia	-	0.6	-0.6	-	0.7	-0.7
Singapore	4.9	0.5	4.4	4.9	0.5	4.4
Indonesia	0.6	1.1	-0.5	1.2	1.5	-0.3
Hong Kong	-	0.35	-0.35	-	0.4	-0.4
Philippines	1.4	1.5	-0.1	1.4	1.8	-0.4
South Korea	1.5	1.3	0.2	1.45	1.6	-0.15
Taiwan	1.6	1.3	0.3	1.6	1.5	0.1
China	N.A.	0		N.A.	0.4	-0.4
Other	-	0.35	-0.35	-	0.4	-0.4
Sub-total	17.5	16.2	1.3	20.0	21.0	-1.0
Japan	17.0	12.3	4.7	17.0	13.0	3.9
Total	34.5	28.5	6.0	37.0	34.0	2.9

Source: Revised Mitsubishi Oil Co.

Table II-36 ESTIMATED DEMAND FOR SYNTHETIC LUBRICANTS IN THE U.S.A.

Cagegories	Major end use	Millions of Galions		
		1980	1985	1990
Synthesized Hydrocarbons (PAO & DAB)	Automotive Crankcase Oils Gear Oils	9	18	30
Organic Esters (Polyol, (Poly & Dibasic Acids)	Jet Engine Lubes	12	16	23
Other(Phosphate Esters, Halogenated Hydrocarbons, etc.)	Fire-Resistant Fluids	29	33	37
Total				
% of Total Finished Oil Volumes		50 2	67 2.5	90 3

Notes: PAO=Poly-alphaolefins (Hydrogenation)
DAB=Di-alkylbenzene

Source: R.e. Sager, Hydrocarbon Processing, July, 1981

Table II-37 SYNLUBES HELP SLOVE ENERGY, OPERATIONAL AND ENVIRONMENTAL PROBLEMS

Problems	Results	Syniubes benefits
Less crude imports, high prices	Fuel economy demand; small engines	Energy-conserving lubes; less friction by low vis, high VI
Shortage of good light neutrals	Wide temperature base oils; higher prices	Consistent, low volatility lubes
Stressed equipment service	Wide temperature extremees; high speeds and severe loads	Low temperature fluidity; high temperature stability
Air pollution	Low-emissions standards	Low volatility of low vis lubes

Source: M Campen, D.F. Kendrick and A.D. Markin Hydrocarbon Processing, Feb., 1982

Table II-38 FREE WORLD ESTIMATED NAPHTHENIC LUBE OIL DEMAND

	1980		1985		1990	
Country/Region	MMbbl	%	MMbbl	%	MMbbl	%
U.S.A.	13.3	56.7	13.2	55.6	13.0	54.1
W. Europe	4.2	17.9	4.1	17.3	4.1	17.1
Canada	0.5	2.3	0.5	2.3	0.5	2.3
Africa	0.6	2.6	0.7	2.9	0.9	3.7
Far East	2.9	12.4	3.1	13.1	3.3	13.7
Latin America	1.9	8.1	2.1	8.8	2.2	9.1
Naphthenics	23.4	100.0	23.7	100.0	24.0	100.0
Paraffinics	135.4		156.7		181.5	
Total Luboils	158.8		180.4		205.5	
% Naphthenics	14.8		13.2		11.7	

Source: J.G. Maraquez Hydrocarbon Processing, Feb. 1982

Table II-39 ESTIMATED FREE WORLD CAPACITY[6)] FOR NAPHTHENIC LUBE OILS

Country/Region	Yearly capacity, MMbbl		
Production	1980	1985	1990
U.S.A.	16.8	16.1	15.2
W. Europe	5.6	5.2	5.0
Canada	0.4	0.2	--
Far East	3.3	3.2	3.2
Latin America	2.9	3.4	3.6
Total	29.0	28.1	27.0
Potential			
U.S.A.	16.8	17.8	19.0
W. Europe	5.6	6.0	7.0
Canada	0.4	0.2	0.3
Far East	3.3	5.0	6.0
Latin America	2.9	3.2	5.5
Total	29.0	32.2	37.8

Source: J.G. Maraquez, Hydrocarbon Processing, Feb. 1982

Figure II-1 A DISTRIBUTION AND SALES MECHANISM FOR THE LUBRICATING OIL AND BASE OIL IN THE KINGDOM OF THAILAND (AS OF DEC. 1982)

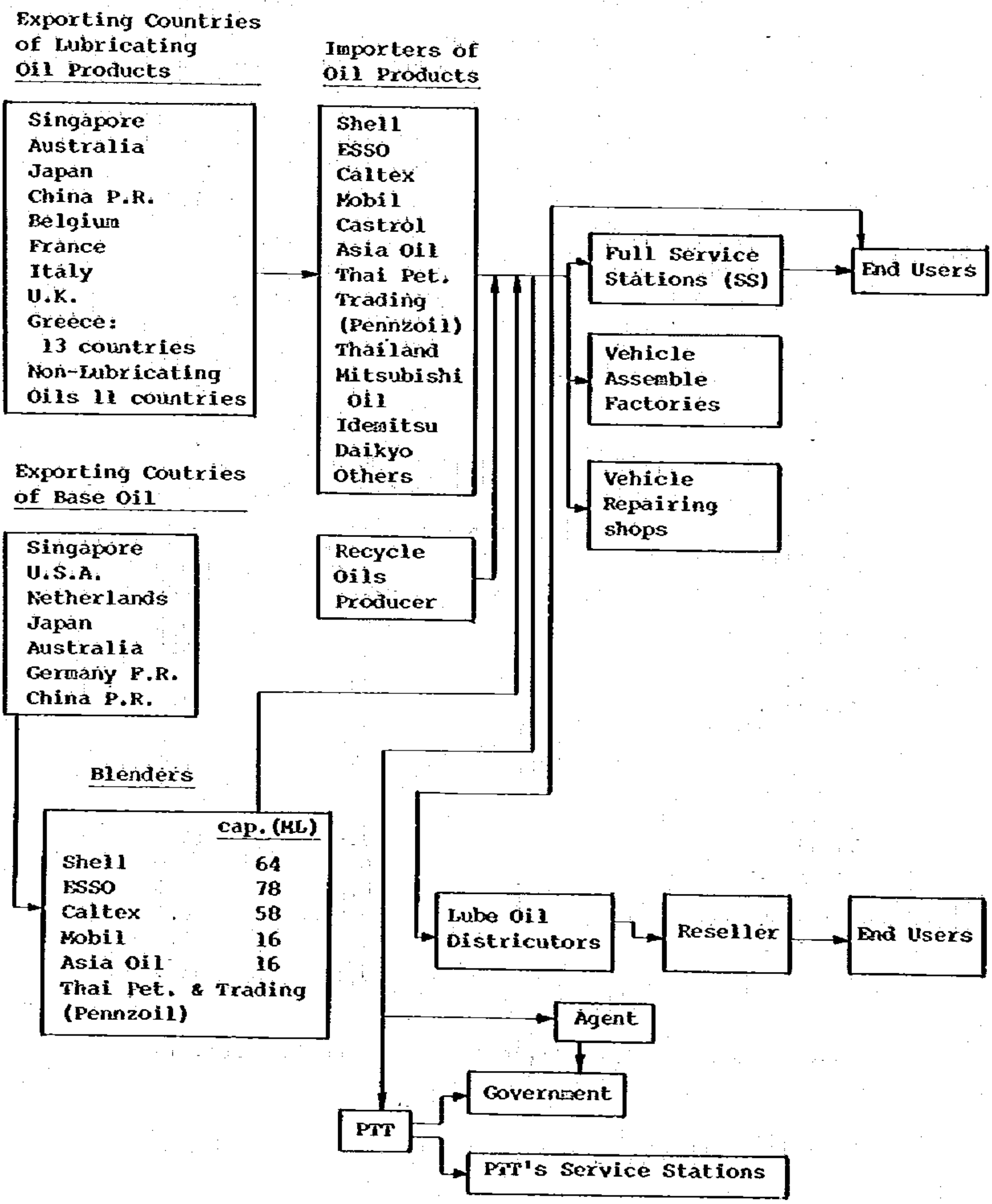


Figure II-2 CRUDE OIL PRICE FORECAST

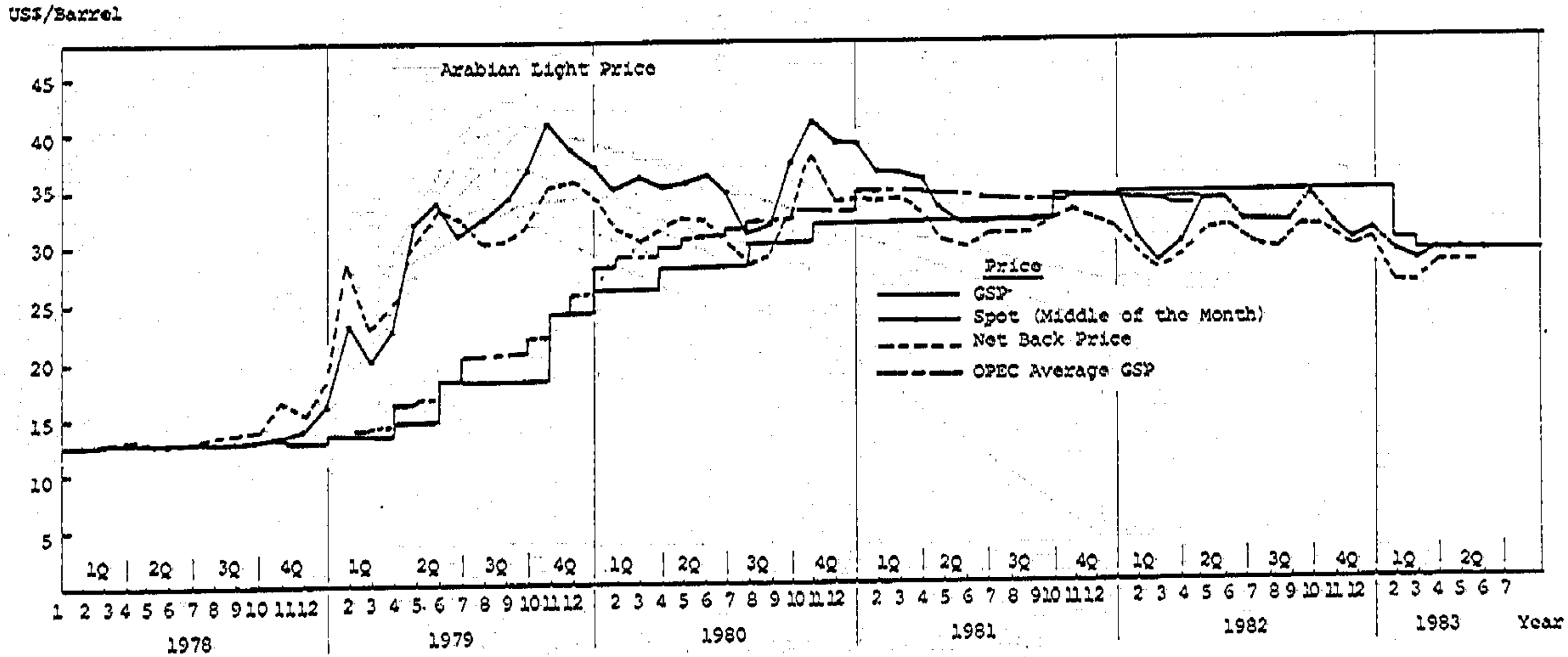


Figure II-3 CHARACTERISTIC OF CRUDE OIL PRICE

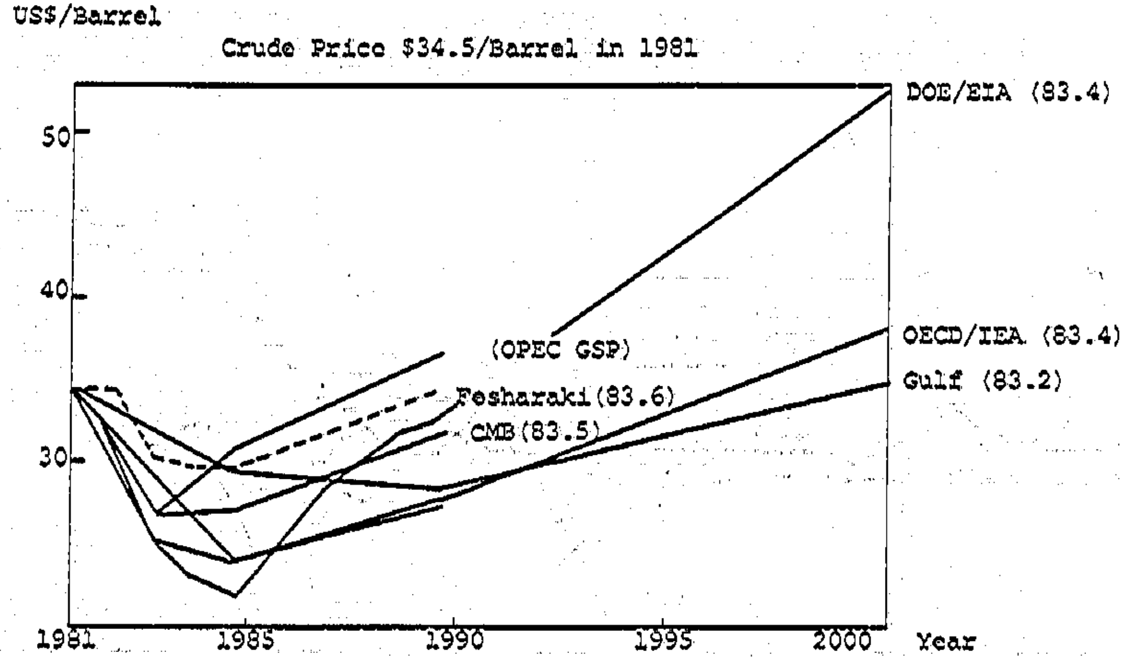


Figure II-4 SALABLE PRODUCTS FROM LUBE COMPLEX
(BANGCHAK CASE)

(Unit: BPCD)

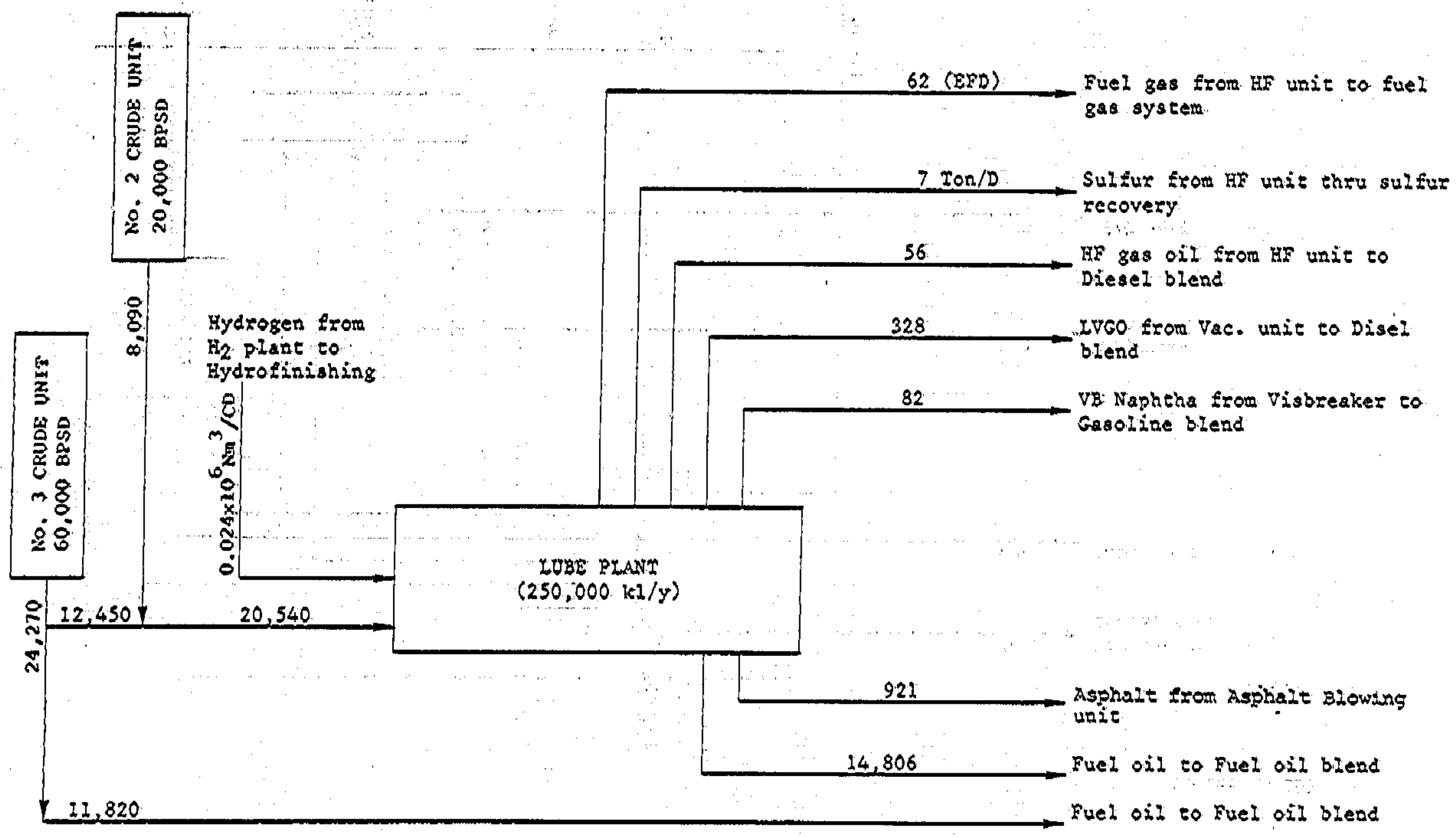


Figure II-5 SALABLE PRODUCTS FROM LUBE COMPLEX
(SRI RACHA CASE)

(Unit: BPCD)

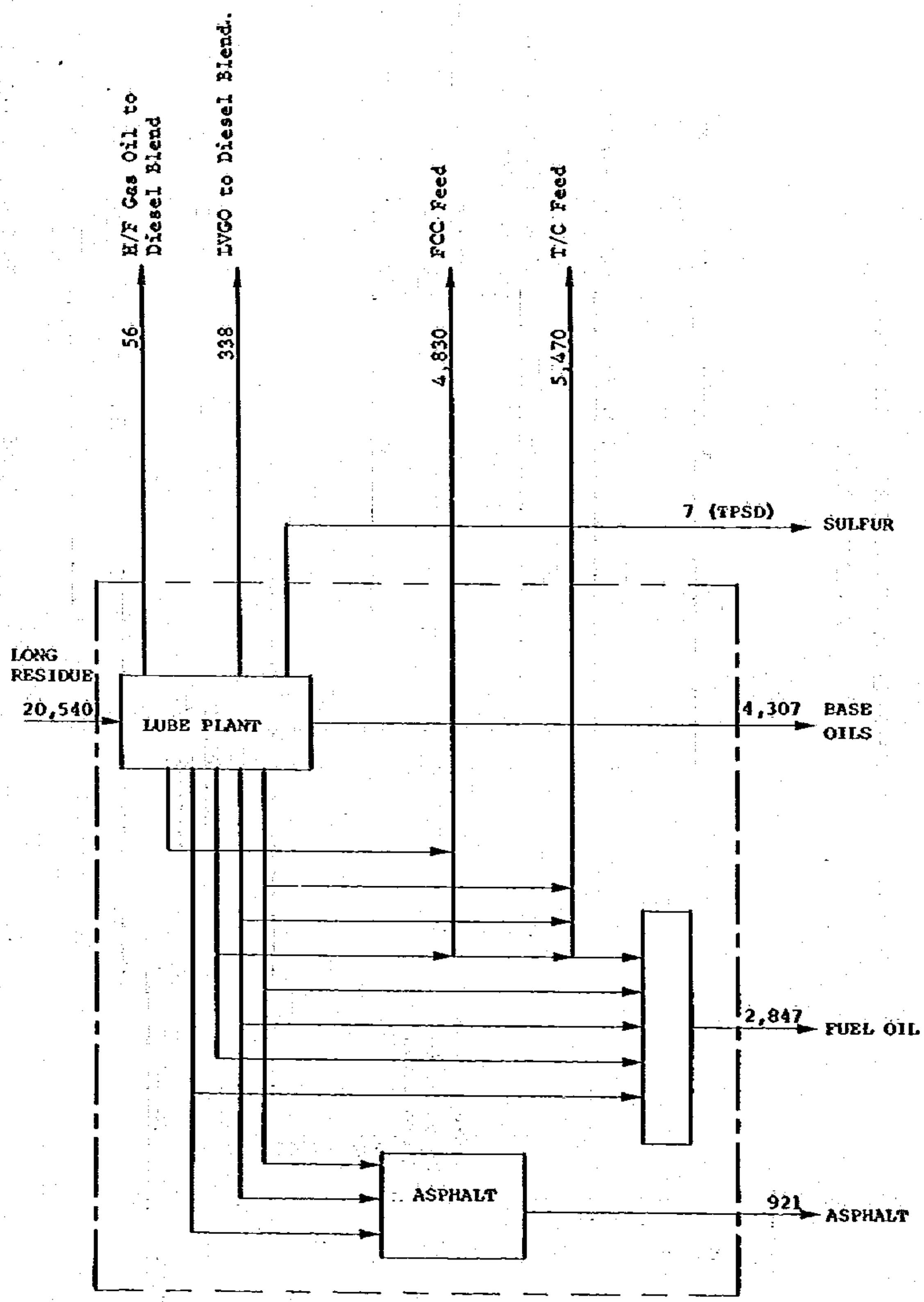
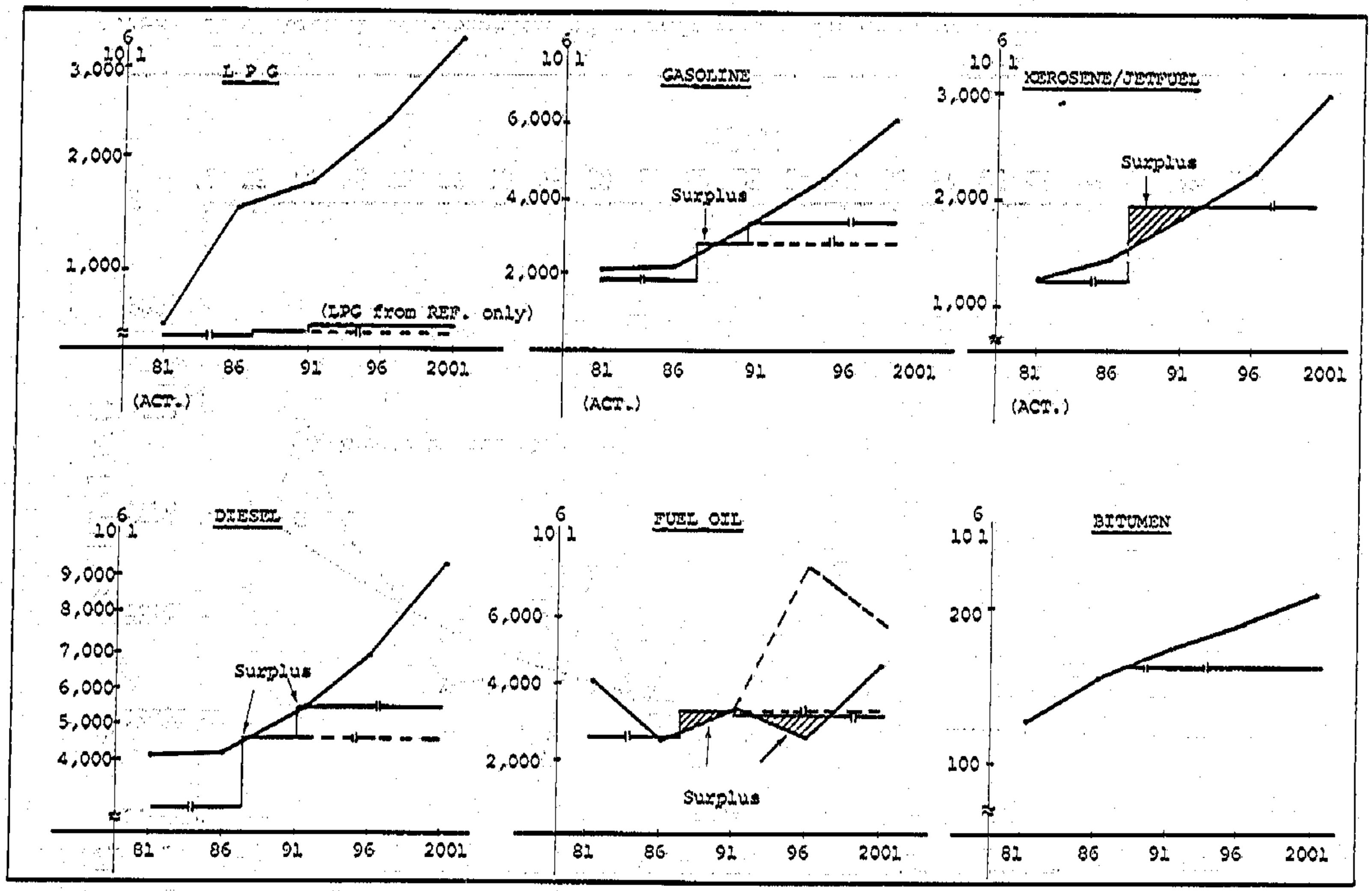
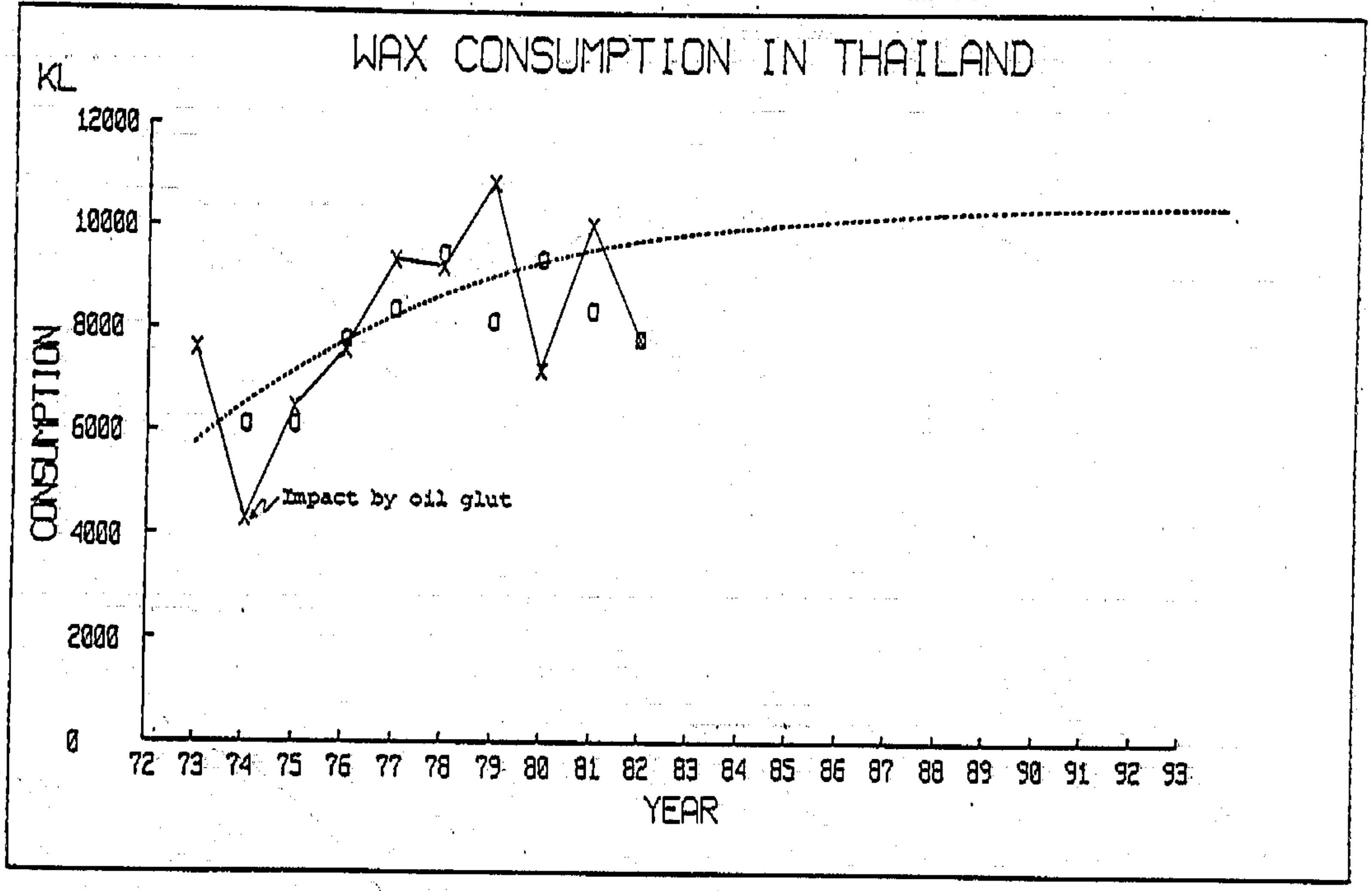


Figure II-6 DEMAND/SUPPLY FORECAST FOR PETROLEUM PRODUCTS



— Demand
---- Demand with projection of no increase in Natural Gas Production after 1991 (650MMSCFD)
— Supply from Domestic Refinery
---- Supply without TOFC's Phase-II Project

Figure II-7 WAX CONSUMPTION IN THAILAND



Notes: 1. X Actual consumption of paraffin wax in each year

2. O Average consumption per year of three(3) consecutive year

Figure II-8 MAP FOR LUBRICATING OIL FACTORIES IN BANGKOK AREA

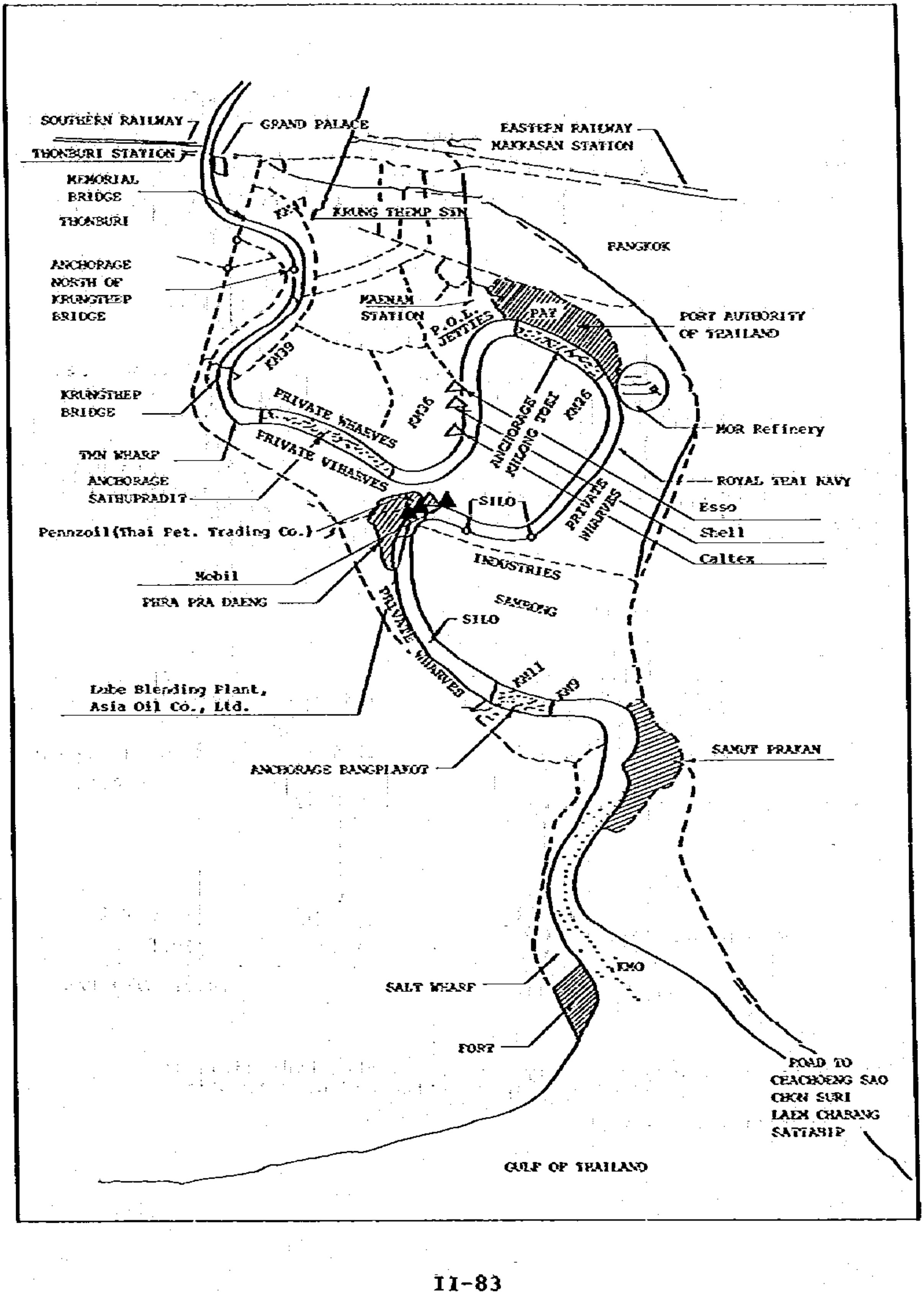
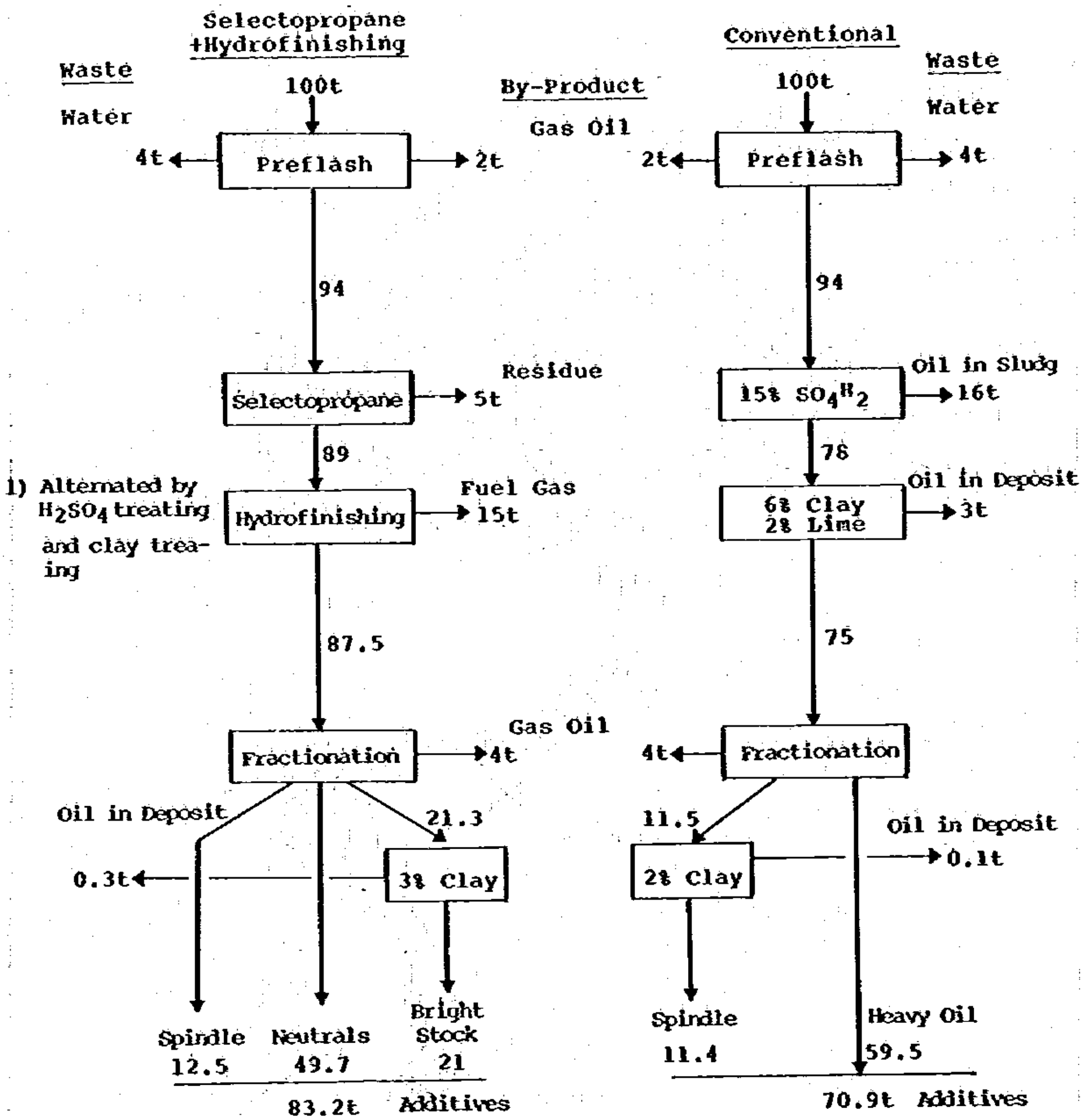


Figure II-9 USED LUBE OILS REREFINING COMPARATIVE YIELDS



Note: 1) Hydrogen is very expensive, thus hydrofinishing alternated by acid treating and clay treating

Source: ELF Bulletin

Part III

BASE SCHEME OF THE PROJECT

Part III BASE SCHEME OF THE PROJECT

Chapter 1 Basic Considerations

1-1 Selection of Crude Oil

In order to choose crude oil for producing lube base oils, it is necessary to consider suitability of the crude in terms of product yield and product quality of the base oils as well as its availability. Crude selection would affect the plant investment cost and plant operating cost as well.

(1) Availability of Crude Oil

Crude oil is generally divided in two categories; one is paraffinic crudes and the other is naphtenic crudes.

Paraffinic crudes which account for about 85% of total crude supply are found world-wide in the Persian Gulf, North Africa and Texas in U.S.

Naphtenic crudes which are suitable for lube oil are mainly distributed in U.S. Gulf Coast, California, Venezuela and in the region of the Caribbean Sea, i.e. Netherlands Antilles and Trinidad, however their production capacity are tending a decline and will become scarce of the supply in the near future.

According to the consultant's investigation, Arabian Light, Basrah Light, Kirkuk, Kuwait, Murban, and Qatar Marine Crude are most widely used for producing base oils among those produced in the Middle East.

As pointed out in the "Thailand Additional Refinery Capacity Study Report" prepared by UNICO International and submitted to NEA in September, 1981, Arabian Light ranked first in Thailand in view of availability, followed by Kuwait and Qatar Marine, taking account of the potential reserve and stable supply. In Japan, Arabian Light Crude is also most extensively used.

(2) Evaluation of Crude Oil for Production of Base Oil

There are two basic types of lubricating oil in the world, i.e. naphtenic and paraffinic.

The naphtenic lubes produced from naphtenic crudes have such physical properties as low wax content, very good low temperature fluidity, high specific gravity, low viscosity index (VI) and high cyclic hydrocarbon/aromatic content.

They may enjoy 35 - 40% lube base stock yield compared with around 10% of paraffinic crudes.

Although naphtenic lubes may have some advantages over paraffinic lubes in quality of low temperature characteristics, solubility characteristics with elastomeric polymers, etc., its low VI characteristic is considered to be an inherent weak point of naphtenic lubes for most applications.

It is difficult to obtain viscosity index of 90 and higher in the case of naphtenic lubes.

The paraffinic lubes produced from paraffinic crudes generally have the physical properties of high VI, high wax content, low aromatic content and low specific gravity.

In the case of paraffinic lubes dewaxing process is indispensable to reduce wax content and produce good low temperature flow characteristics.

Among paraffinic crudes there are only limited number of suitable crudes for lube oil production, for example, some paraffinic crudes such as Sumatran Light and Iranian Heavy are not adequate. The former is of much wax content, and less heavy fractions such as 150 brightstock, and the latter is of much aromatic fractions and only yields small quantity of base oil.

In Thailand where climate is hot, high viscosity lube base stocks such as 500 neutral and 150 bright stock are in large demand. Therefore, the crudes from which heavy base oils cannot be produced are not desirable for Thailand.

Evaluation of crude oil indicates that Phet crude is not suitable for the production of heavy base oils. Approximate volume of each typical crude necessary for the production of 100,000 kl of base oils per annum, taking account of Thailand's domestic demand pattern, is shown below.

Type of Crude	Volume of Crude (BCD)	Yield of Base Oil (Vol.% on Crude)
Arabian Light	17,200	10.0
Basrah Light	17,200	10.0
Daqing (China)	17,200	10.0
Qatar Marine	17,600	9.8
Kuwait	19,900	8.7
Murban	21,200	8.1
Iranian Heavy	31,300	5.5
Sumatran Light	32,200	5.4
Phet (Thailand)	64,400	2.7

(3) Assessment of By-products (Asphalt, Wax)

Whether or not valuable by-products can be produced is one of important factors of choosing crude oil.

From Arabian Light and Qatar Marine, asphalt and wax can be obtained, but asphalt from Sumatran Light has low softening point and ductility of as low as zero, and, owing to this fact, fails to meet the specification.

Naphthen-base crudes almost lack in wax content, and also the asphalt produced from them has poor quality of low softening point.

(4) Views from Plant Investment and Operating Cost for Base Oil Production

The yield of base oil fractions greatly affects the plant investment and operating cost.

For instance, the worse is the potential raffinates' yield in the solvent refining unit due to the processed crude oil, the larger quantity of solvent must be used together with the larger solvent recovery system, and the larger extraction tower is needed, hence it will result in the higher investment cost and the higher operating cost as well.

From the above view points it is necessary to choose the crude oil which can accomplish as much higher yield rate of base oils as possible.

(5) Desirable Crude for Base Oil Production

From the aforementioned discussions it is concluded that Arabian Light Crude is the most desirable crude for Thailand in terms of proximity of crude transportation, availability of the crude, suitability for the required specifications of Thai base oil production and high products yield which should result in less capital and less operating cost.

1-2 Product Selection and Production Rate

(1) Lube Base Oils

As for selection of suitable grades of base oils and determination of the plant capacity it is important to investigate demand/supply, demand pattern and marketability of lube oils in Thailand.

The present status of demand and supply of lube oil in Thailand are described in Part II, based on the market survey. The demand forecast of base oils in Thailand is also discussed therein.

The total production rate of base oils for the plant is determined 250,000 kl per annum on the basis of the forecasted demand in 1993, when full production of the plant is scheduled to be attained with reasonable time span necessary for the realization of the project.

The product yields are determined to meet the demand and its pattern in Thailand, that consists of five grades classified viscosity-wise.

The planned base oil production rate of each grade is determined as follows:

Base Oil Products	Production Rate (kl/year)	Volume Ratio (%)
60 Neutral Oil	23,900	9.6
150 Neutral Oil	13,300	5.3
300 Neutral Oil	14,900	6.0
500 Neutral Oil	138,600	55.4
Bright Stock Oil	59,300	23.7
Total	250,000	100.0

(2) By-products

Generally speaking, in the lube base oil manufacturing, total yield of the base oil products is normally fallen between 15 to 25 volume percent of feedstock (Long Residue).

Therefore, an effective utilization or marketability of remaining 75 to 85% of intermediate products and by-products of the plant is one of the important factors affecting the economics of the lube base oil project.

In this respect, the following potential salable products are to be produced from the plant as final by-products:

. Fuel Oil (2000" grade)
. Bunker Fuel Oil
. Asphalt (paving grade)
. Wax (food grade)
. Sulphur

Of those, the production rates of asphalt and wax are determined as 1,000 BPSD and 250 BPSD respectively to make up for the forecasted deficit of domestic supply in Thailand in 1993.

Some intermidiate products are designed to be blended into the final fuel products unless otherwise it is planned to be delivered to the existing refinery.

Especially in the Sri Racha case, effective use of the catalytic cracking unit and the thermal cracking unit in TORC refinery is taken into account.

1-3 Product Specification

(1) Grade of Base Oils

Based on the replies to the Consultant's questionnaire from the lube oil blending companies and the result of market survey of the end users together with the import records of Thailand, five (5) grades of base oils, 60N, 150N, 300N, 500N and 150BS are selected as basic base stocks from the plant.

(2) Product Specification of Base Oils

The specifications of base oils established for this study are summarized in Table III-1. In setting up the specifications, the following data sources are taken into consideration:

a. Answers from base oil importers of Thailand on the questionnaires
b. Actual records of Japanese base oil exporter to Thailand
c. Typical specifications acceptable in the world-wide market
d. The standard of the Ministry of Commerce

Among the specifications for lube base oils, viscosity index (VI), sulfur content and pour point are most important characteristics.

As for VI, it can be said that base oils having higher than 95 VI are becoming common in the international market while base oils having lower than 85 VI are being become limited for use in the market especially rare for the use of automobiles.

As for sulfur content, most of base oils are being imported to Thailand with the specification of low sulfur content, i.e. less than 0.3% and 0.5% for neutral oils and bright stocks respectively.

As for pour point, max. -10°C is specified commonly for base oils, and this value is considered suitable for the specification of lube oils in Thailand.

The specification of flash point of base oils seems rather high comparing that of lube oil products in MOC's specification, however, it is necessary to have higher flash point for base oil than that for lube products, because flash point of base oil is often lowered when blended with additives having low flash point.

Flash pooint for base oil is basically governed by the fractionation and stripping at the vacuum distillation unit. Even in the case when feedstock of the vacuum distillation unit, long residue, contains light component having low flash point, flash point of base oil can be kept within specification with good operating conditions at the vacuum distillation unit without any additional investment and operation costs.

(3) Specification of By-products

The specifications of by-products such as fuel oil, blown asphalt and hard wax are shown in Table III-2.

Fuel Oil

Considering the demand of fuel oil being produced in Thailand at present and the quality of blending components which will be output from the base oil plant, 2000" grade of fuel oil or bunker fuel oil are planned to be produced.

Asphalt (Blown Asphalt)

The specifications which are determined based on the typical standards such as ASTM and JIS are shown in Table III-2. Among others the important properties of paving grade asphalt are penetration and softening point.

As for penetration, 40/60 grade is specified in consideration of tropical temperature although 80/100 penetration is specified in Thailand instead.

Hard Wax

The FDA (Food and Drug Administration of the U.S.) grade specification is assumed as shown in Table III-2 so as to meet the demand in the foodstaff industry in Thailand to be used for packing and wrapping papers of foodstuff, etc. as well as the materials for candles, polish, water proofing and so on.

As for melting point, ordinary grades of 140P and 150P are selected taking account of the actual import records of wax quality in Thailand.

1-4 Processing Scheme of Lube Base Oil Production

As the basic configuration of refining scheme of lube base oil production, either of the following two types is recognized to be adopted by ordinary base oil producers:

- Conventional Scheme
- Hydrotreating Scheme

1-4-1 Conventional Scheme

General configuration of conventional scheme

Simplified typical block flow diagram of this type of scheme is shown in Figure III-1. This type of scheme is typical and traditional, which is implemented in the majority of worldwide base oil manufacturing plants.

As shown in Figure III-1, all the processes except the hydrofinishing process are kind of separation processes in which the mixture of compounds in the feedstock will be separated into more than two products, and each separated product contains narrow range of similar compounds in terms of physical and chemical properties.

The first step of the scheme is the vacuum distillation which divides the feed stock (long residue) into several components such as, waxy distillates and vacuum residue. In the vacuum unit the waxy distillates are rectified into the components of a relatively narrow range of boiling points.

The next process is the propane deasphalting which removes resins and asphaltenes from the vacuum residue. The vacuum residue is divided into two products, one containing almost all the resins and asphaltenes, called PDA asphalt, the other containing compounds chemically similar to those of the waxy distillates but of higher boiling point. This material called deasphalted oil is refined in the same way as the waxy distillates described hereafter.

The next process in the sequence is the solvent extraction. In this process, most of aromatic compounds contained in the feedstock, namely, waxy distillates and deasphalted oil, are extracted as a by-product called extract, and remaining waxy raffinates which are, desirable components for lube base oils, are to be processed in further refining.

The next process is the hydrofinishing. In the hydrofinishing, the waxy raffinates are mildly hydrotreated so as to refine the oil and remove impurities such as sulfur, etc. The most obvious benefits are stabilization and decolorizing of the base oil.

The final process in the sequence is the solvent dewaxing. This process produces two products, one is a by-product called slack wax which is almost complete paraffins, and the other is a low pour point dewaxed oil. It can be said this dewaxed oil is the base oil itself.

Elimination of the hydrofinishing unit

For quality of lube base oils, stability, color and sulfur content are important properties considered. Instability and dull color are mainly due to existence of such impurities as sulfur/nitrogen/oxygen compound, etc. as well as aromatic and naphthenic hydrocarbons in base oils.

In the planned scheme of the sutdy, the hydrofinishing unit is added to meet the specification of sulfur content (0.3 or 0.5 wt%) as well as to decolor and improve oxidation/color stability of base oils.

Among the conventional routes, there are two major trends in the world. One is American and Japanese way which includes a hydrofinishing unit aiming at the above mentioned objectives and the other in an European way being adopted mainly by SHELL which has no such unit although in the latter case the sulfur content cannot be reduced as low as 0.3 - 0.5 wt%. In the case without a hydrofinishing unit, they have to cut each distillate in very narrow boiling range, so that the vacuum distillation unit should become more sophisticated as described below, comparing with the conventional route.

- Larger number of trays (two towers)
- Higher vacuum level (lower pressure)
- More side cuts (swing cut is normally drawn off between each distillate)

This is because the narrow cut distillation are required to improve selectivity of removing aromatics and other impurities as extract in the following solvent extraction unit.

Nevertheless the operating conditions of the solvent extraction unit should become more severe than those in the case with a hydrofinishing unit.

The choice, whether it adopts hydrofinishing or not, mainly depends upon the policy of process owner or refiner in terms of product quality especially sulfur content and stability. Regarding stability of the base oil to be used for automotive oil, it can be improved by special additives, while industrial oils such as turbine oil, etc., still require hydrotreatment.

1-4-2 Hydrotreating Scheme

Simplified typical block flow diagram of this type of scheme is shown in Figure III-2. The primary objective of the hydrotreating scheme is production of high quality and high viscosity index lube base oils.

As shown in Figure III-2, in the hydrotreating scheme the solvent extraction process adopted in the conventional scheme is replaced by the hydrotreating process. However, the objectives and functions of other processes in this scheme are the same as those in the conventional scheme.

In the hydrotreating process, in which chemical reaction with hydrogen is taken place, aromatics hydrogenation, hydrocracking and isomerization occur at the same time, and that results in the elimination of impurities such as sulfur, oxygen and nitrogen, the production of base oils of higher viscosity index (VI), and also in the improvement of relative stability to degradation. The hydrotreated product has 100 - 125 VI for general feedstocks and as high as 130 - 135 VI for selected feeds. The advantages and disadvantages of the hydrotreating scheme compared with the conventional scheme are described as follows:

Advantages

1) Ability to produce high quality base oils from crude oils generally accepted as suitable for lube oil production and to produce base oils from the crude oils previously deemed unsuitable for lube oil production.

2) Flexibility in design to meet product yield/pattern and required quality of base oils and in operation by alteration of process severity.

3) Higher yields of base oils, because of chemical conversion into useful base oils from the constituents which, otherwise, have to be removed in the solvent refining unit of the conventional scheme.

4) Production of by-products of higher value such as naphtha and gas oil.

Disadvantages

1) Higher capital investment for construction of the plant due to operating under severe conditions.

2) Higher operating cost due to consumption of a lot of hydrogen required, despite lower energy cost.

3) Less experience in commercial operation. This comes mainly from such a reason as extremely high viscosity index is not required so far.

4) Increase in undesirable waxes that have to be removed in the dewaxing step, because of the chemical conversion that produces more paraffinic compounds including wax components.

5) Question of compatibility of hydrotreated base oils with additives which are used at present for the solvent extracted base oils.

1-4-3 Selection of Processing Scheme

As mentioned above, the hydrotreating scheme has some definite advantages over the conventional (solvent extraction) scheme when the quality of available crude is unsuitable for lube base oil production or higher VI base oils of which VI's over 100 are required, since the hydrotreating process is highly flexible and can produce required components of base oils from less desirable components of hydrocarbons.

However, from the standpoint of initial investment and refining cost, the hydrotreating scheme is highly cost intensive, therefore, the incremental cost for the hydrotreating is harder to justify compared with the conventional scheme where suitable quality crudes for lube base oil production is available.

The conventional solvent extraction, in other words, is more economical than the hydrotreating in order to manufacture the base oils of which specification requires current level of viscosity index provided that the refiner is to use suitable crudes.

Taking account of the circumstances of the Project where, Arabian Light Crude, which is considered one of the most suitable crudes for lube oil production, is available as the feedstock for the Plant, the conventional scheme should be applied for production of base oils of which viscosity indexes are not so high (max. 100).

Regardless of qualitative or quantitative investigations, it is hard to say which is better choice between solvent refining and hydrotreating, because it is not always possible to obtain the same base oil quality and also it is difficult to assess the value of the inherent flexibility of hydrotreating.

Nevertheless, studies by some consultants, in the past, signify that solvent extraction will remain as an economical choice if the crudes which have high extraction yields remain available.

One example of economic comparison between conventional scheme and hydrotreating scheme for Kuwait Crude is shown in Table III-3. The major points in the table are described as follows:

	Conventional	Hydrotreating
Required Feedstock	Base	20-25% less
Plant Cost	Base	20-30% higher
Refining Cost	Base	15-25% higher

As shown in the above example of economic comparison, the refining cost of base oils in hydrotreating scheme is estimated roughly 20% higher than that in conventional scheme. In the case of Arabian Light Crude, the difference of that cost will become more significant. Based on the discussions described above, it is recommended that the conventional scheme shall be studied as a base scheme for the Project.

1-5 Component Processes for Lube Base Oil Refining

This section describes the outline of each process unit which composes the selected conventional scheme of lube base oil refining, and also discusses the reason why it is selected for this study among candidate processes.

The selected processes suitable for each function of the scheme are as follows:

- Vacuum Distillation
  for separation of waxy distillates from feed long residue to produce neutral oils

- Propane Deasphalting
  for separation of deasphalted oil from vacuum residue to produce bright stocks

- Furfural Extraction
  for improvement of viscosity index and stability of base oils

- Hydrofinishing
  for improvement of color and stability of base oils

- MEK Dewaxing
  for removal of waxes to produce low pour point base oils

1-5-1 Vacuum Distillation

The vacuum distillation is the first process in refining lube base oil, where the feed long residue is separated into several waxy distillates and vacuum residue.

The major properties of waxy distillates to be controlled by vacuum distillation are viscosity, flash point and carbon residue.

In the conventional scheme which has no cracking process, the viscosity of base oil, which is the most important physical property for lubricant, is originally determined by the viscosity of the distillate.

In addition to the viscosity of waxy distillate, the sharp separation between the vacuum residue and the heavy waxy distillate is also one of the most important objectives of the vacuum distillation.

Asphaltenes which should be concentrated in the vacuum residue, entrained into the lube oil fraction as impurities, have bad effects for operation of all downstream units, e.g. dark color and low yield of raffinates, high coke laydown in the hydrofinishing, difficulties in filtration, etc.

1-5-2 Propane Deasphalting

The vacuum residue which composes components of the highest boiling fractions, contains resins and asphaltenes which must be removed in order to produce base oils of acceptable specifications. However, distillation process cannot be applied to this purpose, since the heavier fractions will be thermally cracked.

The removal of asphaltenes by use of liquid hydrocarbon solvents such as propane and butane is a well established process.

In the selected process, liquid propane is used as a solvent to extract the deasphalted oil (DAO) from the feed vacuum residue, leaving the resins and asphaltenes as the PDA asphalt.

Propane deasphalting process has been widely used in the lubricant industry to produce bright stock from vacuum residue.

Propane is the solvent most selective for deasphalting, which has different selectivity characteristics with different temperature ranges. At low temperatures from -40°C to 20°C, it does not dissolve paraffins whereas at higher temperatures from 50°C to 80°C, paraffins are well soluble in propane together with the aromatics and resin precipitates.

At its critical temperature (97°C) propane does not dissolve hydro carbons of any kind. By reason of these characteristics, propane could be used as a solvent selective for extracting DAO from vacuum residue to become the prospective products by adjusting propane to oil ratio and extraction temperature.

The key properties of deasphalted oil which is to be processed in the same manner as the waxy distillates in the following processes are viscosity, carbon residue, metal content and asphaltenes.

Since the propane deasphalting process with high solvent ratio consumes much energy in the solvent recovery section, an effective heat recovery using double-effect system is considered in the planned scheme for aiming at energy conservation.

The use of supercritical conditions in the solvent recovery system from the deasphalted oil has recently demonstrated in such modern processes as Demex (UOP) and Rose (Kerr-McGee) in which utility savings are considerable in certain applications.

1-5-3 Furfural Extraction

Aromatic compounds and other constituents which are detrimental to quality of lube base oil shall be removed in the solvent extraction by use of a selective solvent. The removal of these components results in improvement of viscosity index, color, thermal and oxidation stability, inhibitor response ability with base oils.

The typical solvents used for commercial extraction processes are furfural, phenol, Duo-sol (mixture of propane, cresol and phenol), liquid sulfur dioxide and NMP (N-methyl-2-pyrrolidone).

Among applicable solvents above, furfural and NMP are the most preferable ones from viewpoints of adaptability to different types of feedstocks, selectivity, stability and toxicity.

Furfural is at present the most widely used solvent for the solvent refining process in base oil manufacturing industry. The major advantages using furfural are abundant commercial experience, availability, low toxicity, better selectivity on lube stocks at relatively low solvent to oil ratio and reasonable cost of the solvent.

NMP has recently emerged as a competitive solvent to furfural. The major advantage of NMP over furfural is that NMP will generally require lower solvent to oil ratio on account of stronger solvent selectivity, which results in reduction of solvent dosage and lower energy consumption for the solvent recovery. Nevertheless, NMP has disadvantages in its cost, scarce experience, and limited availability . In addition, due to the high boiling point and non-azeotropic nature of NMP, certain difficulties may be raised for the production of very light lube stocks.

Upon comparison of furfural and NMP described above, the furfural extraction is selected as a solvent refining process for this study and disregarded NMP especially due to higher cost and limited availability of NMP, moreover, superiority in energy savings is not so significant compared with the case of using good quality crude.

1-5-4 Hydrofinishing

The hydrofinishing is the catalytic reaction of lube base oils with hydrogen. This hydrogen treatment results in improvement of color and oxidation/thermal stability in the finished oil by reducing the level of trace contaminants such as sulfur/oxygen/nitrogen compounds. The position of the hydrofinishing unit in the process scheme will be decided in consideration of the charge stock properties and specifications of base oil products.

On the selected scheme, the hydrofinishing unit is placed before the dewaxing process to ensure that the product's pour point meets the specification, because a part of feedstocks to the hydrofinishing unit could be cracked to paraffin waxes if severe operation is taken place so as to meet low sulfur specification like in this project.

However, the hydrofinishing unit is scarcely positioned behind MEK dewaxing unit. In the latter case the capacity of hydrofinishing unit can be smaller than that of the former case, but the haze (cloud) on lube base oil might occur and the filtering temperature must be lower by about 3 degree C in order to compensate the pour point increase through the hydrofinishing unit.

1-5-5 MEK Dewaxing

Lube base oils with high viscosity index are highly paraffinic and thus are made from the stocks which contain appreciable quantities of dissolved wax resulting in high pour point base oils.

The process for removing this high pour point constituents is called dewaxing.

As a dewaxing process, two different technologies, i.e. solvent dewaxing or catalytic dewaxing, can be employed.

In a solvent dewaxing process, precipitated waxes in the solvent are filtrated and produced as a by-product slack wax.

On the other hand, in a catalytic dewaxing process, paraffins are selectively cracked into LPG and naphtha without wax production.

In solvent dewaxing, one of the desirable features of a good solvent is low wax solubility at filtration temperature as well as high solvent power to the oil. This property is best achieved by the use of a dual solvent consisting of an aromatic component and a ketone.

MEK dewaxing is the most widely used solvent dewaxing process today, using a mixture of methyl-ethyl-ketone and toluene as solvents.

Catalytic dewaxing process is of a simple fixed bed reactor system operated at relatively mild conditions similar to those of the distillate hydrodesulfurization processes.

Catalytic dewaxing process has the following advantages over solvent dewaxing process which come mainly from its simplicity.

. lower investment cost
. lower operating costs of utilities and lower operating personnel costs
. higher by-products value
. equivalent or higher dewaxed oil yields
. less plot area

However, viscosity indexes, of dewaxed oils obtained by catalytic dewaxing are lower than those of solvent dewaxed oils.

According to the information obtained from a licensor of the catalytic dewaxing process, the attainable value of viscosity index of the base oils is lower than the specification set up for this study by 5 to 11 for neutral base oils and by 2 for bright stock.

In order to meet the specification, the MEK dewaxing process is selected for this study instead of the catalytic dewaxing process.

In future, however, if the specification of viscosity index, is to be relaxed, a catalytic dewaxing process will may have potentiality to become an attractive process in place of solvent dewaxing.

Process selection procedure and pros/cons of alternate processes are tabulated in ANNEX III. These tables only describe qualitative comparisons and a strict comparison including economic concept for the process selection shall normally be conducted in a basic design stage based on process licensor's information.

1-6 Existing Facilities of the Refineries and Future Plan

1-6-1 Bangchak Refinery

(1) Outline of Existing Refinery

1) Flow Scheme

The ownership of Bangchak refinery was transferred in 1981 with the termination of lease contract from the Summit Corporation (Panama) to the Defence Ministry. After that PTT has been in charge of purchasing crude oil and marketing/ distribution of petroleum products. The Bangchak refinery has the simple hydroskimming scheme as shown in Figure III-3 and the refinery has supplied fuel oil for power generation plants to EGAT (Electric Generation Authority of Thailand) as their important role ever since Summit's operation.

The product pattern of the refinery is tabulated in Table III-4 together with TORC and ESSO refineries and it shows that the fuel oil production percentage in Bangchak refinery is higher than those in two other refineries.

2) Production capacity of existing facilities

There are three crude distillation units totalling 70,000 BPSD. These design capacities are based upon processing Arabian Light Crude, and component unit capacities are given in Table III-5. At present the No. 1 crude unit is used only for processing slop oil from No. 2 and No. 3 units, and both the vacuum and bitumen units are shut down.

No. 2 and No. 3 units are processing condensate from natural gas field in the Gulf of Thailand and domestic light crude oil produced in Kamphaeng Phet mixed with Arabian Light Crude, and as a consequence, the thru-put of the units has to be reduced less than that of solely Arabian Light Crude due to some bottlenecks raised.

3) Refinery hydrogen balance

The Bangchak refinery has three hydrogen sources which are two catalytic reformers and one hydrogen manufacturing plant. Produced hydrogen is used for two hydrodesulfurization units and the remainder is mixed with refinery off gas which is burned as refinery fuel gas. The hydrogen plant is operating at about 50% load so as to produce and supply carbon dioxide to nearby beer companies and soft drink companies. Table III-6 shows refinery hydrogen balance.

(2) Expansion Plan

At present the government is planning to transfer the ownership and management of the refinery from the Defence Ministry to a new company which is to be managed and operated by a private sector.

After that, the refinery will probably obtain a loan from the world bank in order to increase the operating efficiency by rehabilitation, modernization and energy conservation.

These measures, and other expansion plans will be as follows:

1) Scrap No. 1 unit due to low efficiency

2) Increase existing capacity by debottlenecking

3) Install FCC or hydrocracking unit for the production of lighter distillates

Table III-7 shows the expansion plan of debottlenecking.

1-6-2 TORC Refinery

(1) Outline of Existing Refinery

1) Flow scheme

TORC is the largest petroleum refiner and marketer in the country selling their products exceeding 10 billion Baht per annum. Their shareholders are PTT (49%), Royal Property Bureau (2%) and other private entrepreneurs (49%).

TORC refinery's flow scheme is of cracking type as shown in Figure III-4 and the yield of fuel oil is the lowest among the refineries (Table III-4) by the adoption of cracking unit, FCC, and thermal cracker.

Basically the refinery was designed to maximize light and middle distillate production, that is, less fuel oil production.

2) Production capacity of existing facilities

TORC refinery is composed of two groups of units, that is, TORC 1 and TORC 2, the crude capacity of which is 65,000 BPSD in total.

Capacity of major units are shown in Table III-8. TORC is the sole refinery which has FCC unit in the country and has contributed to the increase of lighter distillates production. Currently the refinery is in full load operation and processes crude oil of Light Arabian, Medium Arabian, Qatar, Seria and Murban plus natural gas liquid (condensate from gas well).

(2) Expansion Plan

TORC employed Foster Wheeler (FW) as a consultant of refinery's expansion study, who conducted Phase I and Phase II expansion plan.

Phase I plan of the expansion from 65,000 to 83,500 BPSD was approved by MOI. Outline of Phase I project by FW study is as follows:

1) Installation of:
   - Hydrocracking unit (17,050 BPSD)
   - Vacuum Distillation unit (32,300 BPSD)
   - Hydrogen Plant (78 MT/SD)

2) Partial introduction of Long Residue of 26,300 BPSD for H/C feed from outside (26,300 BPSD)

   Phase II project is intended to install 65,000 BPSD crude distillation unit as TORC 3 for production of long residue to feed H/C in place of long residue from outside in the plan of Phase I. These two phase projects are shown in Table III-9.

1-6-3 ESSO Refinery

(1) Outline of Existing Refinery

1) Flow scheme

The ESSO refinery belongs to the ESSO Thailand company which is the affiliate of Exxon Corporation, and is located adjacent to TORC refinery. As shown in Figure III-5, the refinery is of a hydroskimming type similar to the Bangchak refinery.

2) Production capacity of existing facilities

The ESSO refinery consists of crude distillation, vacuum distillation, naphtha and distillates desulfurization, catalytic reforming, merox treating and bitumen unit. The capacities of those units are shown in Table III-10. The ESSO refinery has presently been operated with high efficiency and high profitability.

(2) Expansion Plan

The ESSO refinery is presently undergoing an expansion (debottlenecking) project of increasing its throughput from 52,000 BPSD to 70,000 BPSD. Table III-11 shows unit capacities before and after the completion of debottlenecking project.

1-7 Plant Location

Lube refinery is usually located near or inside existing petroleum refinery area from the viewpoint of easiness of feed oil supply, treatment of by-products and so on.

In Thailand the Banchak, TORC and ESSO refineries are conceived as candidate plant location. Since the production capacity for the project is 250,000 kl/annum, an approximate required area ranges 300,000 - 400,000 m2 with difference by cases as for the installation of process units, utilities facilities and off-site facilities.

According to the site survey and information concerned, it is judged that required area for the Plant in Bangchak and Sri Racha are physically available.

<u>Bangchak Area</u>

Most of required area for the Project is assured inside the refinery by demolishing and utilizing the present residence area of the employees. Also available area for the Project is found beyond the north boundary of the refinery, which presently belongs to PTT.

<u>Sri Racha Area</u>

According to the site survey there is no appropriate area for the Project in both refineries. In TORC even the Phase I expansion project area is prepared by demolishing the existing small tanks. It seems that the ESSO refinery also does not have room for the Project in it. However, in surroundings of both TORC and ESSO refineries, there may have enough area ranging 300,000 - 400,000 m2 for the plant although the area is not utilized now and owned by private sectors.

Chapter 2 Case Definition

The study cases for financial/economic analysis are examined from the viewpoints of:

1) Plant site
2) Operation body
3) Additional process unit

2-1 Plant Site

Generally a lube plant should be located near a existing refinery from the viewpoints of feed oil supply, by-products treating, common use of utility and offsite facilities, etc. For this study, first, the candidate sites have been investigated in the proximity of Bangchak, TORC and ESSO refineries. Regarding TORC and ESSO refineries, it is observed that there are no room of space to construct a new lube plant inside the refineries. Therefore both refineries need new areas for the Plant outside the refinery area. A common site near both refineries is considered because of proximity of each other refinery. Accordingly the following two cases are defined as the candidate sites:

CASE Bangchak: Bangchak area (inside or proximity of the refinery)
CASE Sri Racha: Proximity area of TORC and ESSO refineries

2-2 Operation Body

In compliance with type of investor or operation body, two cases are set up of "Independent" and "Expansion". "Independent case" means that a new lube oil manufacturing company is established independent of the near-by existing refinery with respect to investment, operation and management, and "Expansion case" means that the lube refinery is a new investment of the existing refinery and operated by their management or administration. In latter case the existing facilities are usually utilized to a maximum extent. On the other hand, in the case of new company establishment, the management, operation and maintenance etc. are, as a matter of course, to be provided independently from the existing refinery.

CASE A : Independent
CASE B : Expansion

2-3 Additional Process Units

Even though the operation body/investor or the plant site are different, the processing scheme of the lube base oil manufacturing, the quality/quantity of feed stock and the base oil products are basically same. Variations of the plant mainly rests with by-product production as well as treatment of intermediate products. In this study provision of a food grade wax production plant or an asphalt plant is evaluated as variation cases of the Bangchak new company. The other variation cases such as for "Expansion case" and "Sri Racha case" are abandoned from the study cases. It is because the influence of installation of the plants is same order of magnitude in terms of economics even with different plant site and/or different operation body as described in the part IV. Therefore the following tow cases are selected as variation cases; AX or AY in addition to the standard Case A.

CASE AX: Installation of wax production plant additionally
CASE AY: Withdrawing installation of asphalt production plant

2-4 Possible Case Combinations

From the discussions of the preceeding section, the following six case combinations are selected as the study cases. More explicitly Table III-12 shows details of the case definition of the six cases.

CASE Bangchak A:

The lube base oil plant is installed and operated by a newly established company. Plant site is adjacent area of the Bangchak refinery.

CASE Bangchak B:

The lube base oil plant is installed by the existing refinery and operated and managed by the expanded existing refinery organization. Most of plant areas are provided inside the refinery and partly is situated adjacent to the existing Bangchak refinery.

CASE Bangchak AX:

Plant site and operation body are the same as CASE A except that a wax production plant is attached to the base oil manufacturing plant.

CASE Bangchak AY:

Plant site and operation body are the same as CASE A except that an asphalt production plant is deleted from the standard case of the base oil plant.

CASE Sri Racha A:

Lube oil plant is installed and operated by a newly established company. Plant site is located in the proximity area of both TORC and ESSO refineries.

CASE Sri Racha B:

Lube oil plant is installed by one of the existing refineries, that is, TORC or ESSO. Operation and management are done by the refinery. Plant site is available in the proximity area of the existing refinery, same as CASE Sri Racha A.

Chapter 3 Processing Scheme

This chapter outlines the processing scheme of the planned lube base oil plant for two candidate sites; namely, Bangchak site and Sri Racha site.

3-1 Process Scheme

Block flow diagrams of the lube base oil plant with overall material balances for two sites are shown in Figure III-6 (Bangchak) and Figure III-7 (Sri Racha) respectively.

These diagrams shown are based on the cases that the new company invests for and manages the lube complex. (Bangchak-A and Sri Racha-A)

In the case of existing refinery expansion, there is no difference in the processing scheme and material balance except that a little bit of higher fuel oil yield can be gained in the expansion cases due to less requirement of refinery fuel oil which is used for steam generation for tank heating.

As shown in Figure III-6 and Figure III-7, no difference in the lube base oil processing scheme appears in both cases of Bangchak and Sri Racha locations, and only the configurations for by-products treating are slightly different, reflecting specific conditions of each site.

Moreover, to investigate the effect of wax and asphalt production on the economics of the Project, two alternate flow schemes of by-product processing are considered, taking the Bangchak case as an example which are shown in Figure III-8, and Figure III-9.

Even in these alternate cases, the flow schemes for lube base oil processing are also the same as the base case described above.

3-1-1 Base Oil Processing Scheme

The planned processing scheme of lube base oil is the same in all cases defined in Chapter 2 of this Part.

The processing scheme comprises the following five units in series;

- Vacuum Distillation Unit
- Propane Deasphalting Unit
- Furfural Extraction Unit
- Hydrofinishing Unit
- MEK Dewaxing Unit

In the units above, the vacuum distillation and the propane deasphalting unit are operated continuously while other units are operated in blocked out mode to manufacture several grades of base oil with the different operating cycle based on the demand pattern.

The long residue of Arabian Light Crude is charged to the vacuum distillation unit - this is the first process in sequence, and separated into four grades of waxy distillates, namely, 60N, 150N, 300N, 500N which are to be refined to the neutral grade base oils, and vacuum residue. Swing cut between 60N and 150N is drawn off to keep good separation and mixed with 150N and 300N surplus vacuum gas oil to be used for the fuel oil blend stock or the feed stock of FCC and TC unit.

The estimated yields and properties of distillates and vacuum residue except swing cut are summarized below:

	60N	150N	300N	500N	Vacuum Residue
Separation Temp. (°C)	360-374	402-454	454-477	477-538	538
Yield on Crude (vol.%)	2.2	7.9	3.0	6.5	16.0
Specific Gravity (15/4°C)	0.902	0.913	0.924	0.936	1.014
Sulfur (wt %)	2.0	2.4	2.6	2.8	4.0
Viscosity @100°C (CST)	2.6	5.0	8.0	14.9	600

A part of vacuum residue is fed to the propane deasphalting unit to extract the deasphalted oil by using liquid propane as a solvent, leaving PDA asphalt as by-product.

The deasphalted oil is to be used for producing bright stock base oil.

The yield and properties of the deasphalted oil and PDA asphalt for this project are estimated as follows:

		Deasphalted Oil	PDA Asphalt
Yield on Feed	(Vol %)	40.0	60.0
Specific Gravity	(15/4°C)	0.935	1.067
Sulfur	(wt %)	2.4	4.9
Viscosity @100°C	(CST)	43	30,000
Penetration	(1/10mm)	-	0
Softenning Point	(°C)	-	76

The remaining vacuum residue together with PDA asphalt is utilized as materials for production of fuel oil and asphalt described in the following section.

Four kinds of waxy distillates and one kind of deasphalted oil are fed to the furfural extraction unit to remove aromatic compounds and improve thermal and oxidation stability as well as viscosity-temperature characteristics measured by viscosity index (VI). The desired materials for base oils are separated as raffinates leaving by-products, called extracts, which composes mostly aromatic compounds.

Each grade of raffinates from the furfural extraction unit is fed to the hydrofinishing unit to produce stable and high quality base oil by hydrogeneration, where the decolorization and neutralization as well as the removal of trace contaminants such as sulfur/nitrogen compounds are accomplished.

Hydrogen required in this unit is supplied from the existing hydrogen generation facilities such as catalytic reformer and/or hydrogen manufacturing unit.

Removed sulfur as hydrogen sulfide is separated in the amine gas treater which is included in the hydrofinishing unit and then sent to the sulfur recovery unit.

The hydrofinished raffinate is next fed to MEK dewaxing unit, this is the last process in the scheme, where the wax is removed as slack wax to reduce pour point of base oil utilizing a solvent mixture of methyl-ethyl-ketone and toluene.

Each grade of dewaxed oils is rundown and stored in the respective product tank. A part of 500 neutral oil is made by blending 300N and bright stock, this is to avoid uneconomical operation of the plant.

3-1-2 By-product Processing Scheme

(1) Bangchak Case

The following by-products are produced from the lube base oil processing units;

- Vacuum residue (surplus)
- Vacuum gas oils (swing cut and surplus)

- PDA asphalt
- Extracts
- Slack waxes

Portion of vacuum residue, PDA asphalt and extracts are mixed and fed to the asphalt blowing unit to produce paving asphalt of 40/60 penetration grade.

For production of 2000" grade of fuel oil, a part of vacuum residue is sent to the visbreaker together with PDA asphalt, and the visbroken oil by thermal reaction is blended into the fuel oil.

The surplus vacuum gas oil for 60N base oil (LVGO) and cracked oils from the hydrofinishing unit and the visbreaker are sent to the existing refinery as a feedstock for upgrading or a blendstock of gas oil.

The rest of the vacuum residue, PDA asphalt, extracts, vacuum gas oils and all slack waxes are directly utilized as fuel oil blend stocks.

A part of fuel oil, of which sulfur level meets the government specification, is consumed as refinery fuel together with off-gas from the hydrofinishing unit and the visbreaker.

Removed H2S by amine washing in the hydrofinishing unit is sent to the sulfur recovery unit and then recovered as element sulfur.

Waste water released from several units are treated in the sour water stripper for removing H2S and NH3 and then sent to the waste water treatment facilities for further treating. The removed H2S and NH3 are sent to the sulfur recovery unit as well.

Wax Production Case (Bangchak - AX Case)

As shown in Figure III-8, a portion of slack waxes from the MEK dewaxing unit is utilized for producing food grade wax through the MEK deoiling unit and the wax hydrotreating unit.

The rest of the slack waxes and foots oil from the MEK deoiling unit are blended into fuel oil.

No Asphalt Production Case (Bangchak - AY Case)

In this case, as shown in Figure III-9, no paving asphalt is produced but more amounts of fuel oil than the base case is produced.

In this case, in order to produce the blended fuel oil which meets the viscosity specification of 2000" grade, a larger capacity of the visbreaker than the base case are provided.

(2) Sri Racha Case

The following by-products are produced from the lube base oil processing units;

- Vacuum residue (surplus)
- Vacuum gas oils (swing cut and surplus)
- PDA asphalt
- Extracts
- Slack waxes

Portion of vacuum residue, PDA asphalt and extracts are mixed and fed to the asphalt blowing unit to produce paving asphalt of 40/60 penetration grade.

For accomplishing efficient utilization of the upgrading unit in TORC refinery, the following components are considered to be supplied to the fluid catalytic cracking unit and the thermal cracking unit as feedstock;

To FCC

- A part of vacuum gas oil
- All slack waxes

To Thermal Cracker

- Mixture of vacuum residue, vacuum gas oil and PDA asphalt: The quality of mixture is of the level of vacuum residue

The surplus vacuum gas oil for 60N base oil (LVGO) and cracked oil from the hydrofinishing unit are also sent to the existing refinery as a feedstock for upgrading or a blendstock of gas oil.

The rest of PDA asphalt, extracts and vacuum gas oils are directly utilized as fuel oil blend stocks.

A part of fuel oil is consumed as refinery fuel together with off-gas from the hydrofinishing unit.

Removed H2S by amine washing in the hydrofinishing unit is sent to the sulfur recovery unit and recovered as element sulfur.

Waste water released from several units are treated in the sour water stripper for removing H2S and NH3 and then sent to the waste water treatment facilities for further treating.

The removed H2S and NH3 are sent to the sulfur recovery unit as well.

3-2 Product and Property

Production volume of lube base oils and by-products for each case are summarized in Table III-13. The estimated actual properties of products obtained from the lube complex are shown in Table III-14, Table III-15.

Lube Base Oil

A part of 500N oil is produced by blending of 300N and bright stock oil at the ratio of about 70/30. This is because the demand ratio of 500N on total base oils is very high, if all of 500N would be produced directly from the plant, the complex should require a larger quantity of long residue feed, that means it is very unpracticable in terms of investment cost and operating cost.

Fuel Oil

In Bangchak case, most of the by-products are blended into 2000" grade of fuel oil according to planned blending ratio described below:

Fuel Oil Blending Table
(Bangchak-A)

Components	BPCD
Vacuum Gas Oil	5,938
Vacuum Residue	742
PDA Asphalt	2,315
Visbroken Oil	1,955
Extracts	2,626
Slack Waxes	1,230
Fuel Oil	14,806*

* Including refinery fuel oil

In both cases (the base case with wax plant, and the base case without asphalt plant), the visbreaker capacity becomes larger than the base case because viscosity of fuel oil pool exceeds the specification owing to the following reasons:

With Wax Production: Reduce low viscosity stocks, i.e. slack waxes

Without Asphalt Production: Increase high viscosity stocks, i.e. Vacuum residue and PDA asphalt

In Sri Racha case, where lower sulfur components such as vacuum gas oils and slack waxes are to be supplied to the existing refinery as feedstocks of the upgrading processes i.e. FCC and thermal cracker, it is impossible to produce fuel oil which meets the specification of sulfur of 2000" grade by blending only with remaining stocks from the plant.

Therefore, in this case, 2000" grade bunker fuel is to be produced that is to keep the specification of viscosity within the range.

It could, however, produce on-spec fuel oil by means of cutting back with lower sulfur components such as desulfurized gas oil obtained from the existing refinery. In detail it may become an additional study item in further stage of the project realization.

Other Intermediate Products

Light vacuum gas oil will be blended into the diesel oil after being treated in the desulfurizing unit. Gas oil from the hydrofinishing unit will also be blended into the diesel product without any further treatment. Thermal cracked naphtha from the visbreaker will be a part of feedstock to the catalytic reformer through the naphtha hydrotreater to produce motor gasolines.

3-3 Installed Capacities of Process Units

The capacities of the process units to be installed are summarized in Table III-16. These capacities are determined by using on-stream days of 340 per annum.

The typical process flow diagram of each unit is attached in Annex III-1.

Chapter 4 Integration of Lube Base Oil Plant and Existing Refinery

4-1 Case of Bangchak Refinery

Reference is made to Figure III-10.

In the case of new lube base oil plant of the Bangchak refinery, the raw material for the plant (Long Residue, 20,540 BPCD) is supplied from the existing crude distillation units which are expected to expand after the plant rehabilitation.

Hydrogen needed for the hydrofinishing is fed from the surplus refinery hydrogen sources. The fuel oil and asphalt from the plant are sold at appropriate prices to the market. Off gas from HF unit is used for refinery fuel and small amount of LVGO (surplus vacuum distillates) is blended into diesel pool.

4-2 Case of TORC Refinery

Reference is made to Figure III-11 and 12.

For TORC case, it is assumed that the Phase I expansion will be already realized by the time when the Project for the lube plant is completed, but not for the Phase II expansion. In Figure III-11, it is shown where the by-products of the plant are treated in the existing refinery and what amount of long residue is to be imported from outside the refinery.

For the Plant major portion of the raw material (Long Residue) is supplied from TORC 1 and TORC 2 crude distillation units. Among the by-products of the Plant, slack wax and VGO which is delivered from solvent dewaxing unit and vacuum distillation unit respectively, are charged to FCC unit as a feedstock so that economy of the plant should be increased to have value added by-products.

Some portion of vacuum residue, PDA asphalt and furfural extracts are supplied also to the thermal cracking unit. Small amount of HP gas oil and LVGO are to be used for diesel blending.

4-3 Case of ESSO Refinery

Concerning the integration of the Plant with the existing ESSO refinery, there are two particulars to be discussed; one is the supply of feed stock for the Plant and the other is the treatment of the intermediate by-products of the Plant.

The existing ESSO refinery after the expansion will be able to supply long residue to the Plant. If available long residue of the ESSO refinery is not sufficient, balance of the feed stock should be imported from outside sources; i.e. indeginous or overseas suppliers.

As for the treatment of the intermediate products, there are two cases to be considered; one is to supply the products to the TORC refinery and have them treated by their FCC and thermal cracker, the other case is that no intermediate by-products will be treated outside the refinery, but treated within the refinery such as for the blend stock of diesel oil or fuel oil, etc.

The former case is very resemble to the case of Banchak refinery. On the other hand, the latter case will become eventually equal to the case of TORC refinery.

Accordingly, in this study one common case is defined and studied as the Sri Racha case.

Chapter 5 Plant facilities

5-1 Basic Design Conditions

5-1-1 Codes and Standards

The plant facilities are to be designed based on the internationally accepted codes and standards in U.S.A., Europe and Japan shown in ANNEX III-3.

According to our investigation on governmental regulation of Thai, so far, it is expected that there might be no codes and standards which could make a significant impact on cost and schedule of the plant.

Design of the plant facilities such as boilers, buildings, structures, pressure vessels, plumbing, sanitary facilities, storage tanks, electrical installations safety and fire protection, etc., are regarded as being easily met with the relevant Thai regulations.

5-1-2 Consideration for Energy Conservation

In the lube base oil refining, large amount of energy is required in each process unit for heating up, evaporation, cooling and so on. Therefore, reduction of energy consumption is one of important keys giving economic advantage to the Project.

For this study, the basic design of each unit adopts modern techniques which take newer approaches for energy conservation as described below:

- In order to increase heat recovery ratio, two (2) stages evaporation system are adopted for each solvent recovery section of the propane deasphalting, the furfural extraction and the MEK dewaxing unit.

- In order to increase furnace efficiency, air preheaters are provided with fired heaters of the vacuum distillation unit, the hydrofinishing unit and the hot oil system. Also, high efficiency burners are installed for the furnaces to reduce fuel consumption.

- Steam generators are installed to utilize waste heat of highly viscous streams such as vacuum residue, PDA asphalt and blown asphalt, as well as to prevent the plugging trouble which could be occurred in the water cooling exchangers.

- Solvent multi-injection system is adopted in the MEK dewaxing unit to reduce solvent rate required, which results in saving of energy used in the solvent recovery section.

- Some sections of the vacuum distillation tower are provided with packings of low pressure drop characteristics to reduce required quantity of motive steam for ejectors.

- Efficient heat recovery is attained by the aid of advanced technology of heat exchanger arrangement.

5-1-3 Environmental Consideration

There are relatively severe control standards of waste water disposal in Thailand, whereas, currently there is no legislated air quality standard.

The Environmental Quality Standard Division of NEB is now working on preparation of draft proposal of air quality control to be enforced in near future.

As far as it is known to us at present air quality control policy of Thailand appears to aim at moderate level of control on industrial sectors as well as private sectors. The plant are to be designed taking the above into consideration. The planned approaches for pollution abatement are described in Section 5-6 of this chapter.

5-2 Study on the Plant Site

5-2-1 Selection of Plant Site

Selection of the plant site for Thai Lube Base Oil Refinery is rather limited to the neighboring places mainly in terms of supply of the long residue and up-grading of intermediate products outside refinery fence.

Supply of the feed stock for the Plant will be single source such as from MOR in Bangkok area, or TORC, or ESSO both located in Sri Racha area. It is not favorable but under unusual conditions multi-sources could be considered, e.g. imported long residue prior to TORC phase II expansion.

For this reason, a candidate plant site shall be neighboring either of the above three refineries.

Proximity of the Plant with the existing refinery will be most desirous for transportation of the long residue and intermediate products such as LVGO, V/B naphtha, and slack wax.

It is assumed that the relevant interconnecting piping between the existing refinery and a new lube base oil refinery are assumed less than three hundred meters.

It is judged from our site observation that the required acreage of total 350,000 m2 for the Plant would be available next to each refinery of MOR/TORC/ESSO, on the condition that the land owners agree to the transference of the land.

5-2-2 Current Status of Infrastructure

Current status of infrastructure in Bangchak area and Sri Racha area is described below:

Bangchak Area

This area is located southeast of Bangkok, near the Chaophya river.

The candidate site in this area is close to the road which leads to the port of PAT at a distance of 5 Km. For transportation of general goods, this road and the port of PAT can be in use.

Landing of large equipment for construction will be executed utilizing the MOR berth.

For loading of product base oils from the plant, the existing MOR's jetty can be utilized after being made appropriate improvements.

Sri Racha Area

This area is in the coastal industrial region located south of the Gulf of Thailand.

The national development program of industrialization and city planning for the Eastern Seaboard is under execution for the purpose to ease recent population concentration to the Metropolitan area and to realize the development of country in balance.

Especially, consolidation of industrial infrastructure such as construction of port, development of roads, rail ways, communication facilities and power plant are under execution at present.

In the construction stage, a long distance inland transportation of about 50 Km from the Sattahip Port is required utilizing the existing road which has been completed.

For shipping of product base oils from the Plant, the existing jetty located near the site can be in service by modifying as required.

5-2-3 Condition of Candidate Plant Sites

(1) MOR

CASE A

The candidate plant site is selected to be situated in the PTT property next to the LPG distribution depot being under construction and adjacent north boundary of the existing refinery.

Nature of terrain is lightly forested with coconut trees and other shrubs on the flat plain. Geographical nature of the land is low-land and lightly swampy with proximity to the Chaophya river.

MOR recently experienced serious flooding on their facilities, and is considering that the land should be filled up to the height of at lowest one meter from the level of the existing soil.

As a result of the site survey, the soil bearing capacity of this area is assumed at about 3 ton/m2, therefore, in principle, foundations must require piling.

22 meter long concrete piles and friction piles are to be used for heavy equipment and light equipment, respectively.

Because of high level of ground water, dewatering will be necessary during construction.

During the refinery visit severe subsidence was observed in many places especially on the buildings. It is considered mainly due to pumping of large quantities of well water utilizing for CTW, BFW, etc. In this study raw water for the various plant facilities is considered to be supplied from the Chao-Phaya river instead of well waters so as to cope with further sinking of the land.

CASE B

In this case the existing property is to be utilized to a maximum extent.

Due to the limited availability of the land within the property fence of MOR, a portion of plant facilities such as product tanks, product shipping, WWT, etc., is to be situated outside the fence.

Process units and major associated facilities are located in the present residential area of company employees, which is to be relocated to the other side of the super-highway.

(2) TORC/ESSO

CASE A

The required acreage of 350,000 m2 is to be acquired adjacent to the existing oil refinery.

Nature of terrain of the surroundings is spotted coppices with small undulations in rural area.

Soil bearing capacity is assumed to be about 15 ton/m2, so that usual spread-footing type foundations should be applied for the plant.

CASE B

The existing TORC/ESSO refinery seems to be compactly designed and insufficient room for future expansion.

Therefore, major portion of the plant facilities is considered to be newly acquired, consequently it is deemed to be little difference with CASE A above.

5-3 Major Equipment of Process Units

Process units outlined in Chapter 2 in this part need such major equipment as listed in ANNEX III-2. This section explains the equipment peculiar to the lube base oil plant.

(1) RDC (Rotating Disc Contactors)

Reference is made to Figure III-13 which shows a typical type of RDC.

The RDC of the furfural extraction unit is used to extract aromatic compounds and others from the feed oil for the unit, i.e waxy distillates or deasphalted oil, by contacting with furfural. The RDC has a number of compartments divided by stator rings, and has rotating discs supported by one rotation shaft.

The advantages of the RDC over conventional liquid-liquid contacting apparatus are:

- relatively small equipment size resulting in lower capital cost
- high flexibility
- low maintenance cost

(2) Rotary Vacuum Filter

The Rotary Vacuum Filter is used in the MEK dewaxing unit and MEK deoiling unit to separate wax from the mixture of processing oil and solvent. Figure III-14 shows a typical type of filter. Filtration takes place on the surface of rotating cylindrical drum covered with cloth. After filtration, wax on the cloth is washed with cold solvent and scraped from the cloth.

(3) Double-pipe Heat Exchanger and Double-pipe Chiller

The double-pipe heat exchanger and the double-pipe chiller are used in the MEK dewaxing unit and the MEK deoiling unit for cooling the mixture of oil and solvent. Cooling medium i.e. filtrate mixture or propane, is flowing in the outer pipes and the mixture of oil and solvent is flowing in the inner pipes. Rotating scrapers are provided in the inner pipes to take off stuck wax from inside surface of the inner pipes to secure efficiency of heat exchange and prevent from plugging.

5-4 Offsite Facilities

5-4-1 Tankage

(1) Bangchak-A Case

Reference is made to Figure III-15 of the tank flow diagram, which illustrates the planned oil handling system.

Long Residue Tank

The long residue is delivered by a pipeline from MOR to the tankage which is capable of storing enough for three days' operation of the plant.

Intermediate Tank

The vacuum distillation unit and the propane deasphalting unit are operated continuously whereas the furfural extraction unit is run by blocked out operation.

Accordingly the storage tanks for the vacuum distillates and DAO are required as intermediate tanks.

Table III-17 shows the assumed operation cycle of the furfural extraction unit, the hydrofinishing unit and the MEK dewaxing unit of which capacity the tank volumes are based upon.

The hydrofinishing unit and the MEK dewaxing unit are also run on blocked out operation. The raffinate storage tanks and the hydrofinished raffinate storage tanks are designed to have capacity of one day's storage to maintain smooth switching of operation modes.

The charge stocks for the asphalt blowing unit and the visbreaking unit are provided by blending of multiple stocks. For this purpose, seven days' storage capacity of each throughput is provided.

The storage tanks for the fuel oil blending components are designed to store seven days' capacity of the blending rate.

Product Tank

The base oil storage capacity is planned to be able to maintain smooth operation as for each operation cycle shown in Table III-17, and to blend and ship the base oils according to appropriate schedule. The planned capacity is equivalent to about 30 days' shipping volume as total.

The 50 days' shutdown is planned every two years as the turnaround maintenance. Prior to the shutdown, the blending companies in Thailand are assumed to have inventory of more than 50 days' consumption.

Blown asphalt storage is planned to have a capacity of seven days' storage for tank-lorry loading.

Heavy fuel oil storage is planned to have a capacity of two days' storage for pipeline loading.

(2) Bangchak-AX Case

The following tanks are added to the Bangchak-A case:

- the slack wax (300N grade) tanks as MEK deoiling charge tanks
- the slack wax (500N grade) tanks as MEK deoiling charge tanks
- the wax (140P grade) tanks
- the wax (150P grade) tanks

(3) Bangchak-AY Case

The following tanks are eliminated from the Bangchak-A case:

- the heavy extract tanks
- the asphalt blowing charge tanks
- the blown asphalt tanks

(4) Bangchak-B Case

Utilization of the existing tanks is assumed in the following services:

- the long residue tanks
- the blown asphalt tanks
- the heavy fuel oil tanks

Detailed investigation would be required for the utilization of the existing tanks in the further step.

(5) Sri Racha-A Case

Reference is made to Figure III-16 of the tank flow diagrams which illustrates the planned oil handling system for the Sri Racha-A case. The visbreaking charge tanks and visbreaking distillate and residue tanks are not required in this case.

(6) Sri Racha-B Case

Utilization of the existing tanks in TORC or ESSO is assumed in the following services:

- the long residue tanks
- the blown asphalt tanks
- the heavy fuel oil tanks

Detailed investigation would be required for the utilization of the existing tanks in the further step.

(7) Planned Storage Capacity

The planned tankage for each case is summarized in Table III-18, Tankage Summary. The working capacity of each tank is assumed to be 85 percent of the total tank capacity.

5-4-2 Product Loading

(1) Bangchak-A Case

Base Oil

Base oil products are shipped using one of the existing wharfs by means of 1,000 DWT barges. The five kinds of base oils, namely 60N, 150N, 300N, 500N, and bright stock are pumped from the product tanks to the wharf. Loading time to the barge is assumed to be one hour utilizing individual loading arms for each base oil product simultaneously.

Fuel Oil

Fuel oil products are being sent to the nearby power station from the existing refinery by means of a pipeline. Fuel oil products are assumed to be shipped in the same manner from the plant.

Asphalt and Sulfur

Tank lorry loading facilities are provided for asphalt and sulfur shipping.

(2) Bangchak-AX Case

Wax products are shipped by means of trucks after molding and packing.

(3) Bangchak-AY Case

Tank lorry loading facilities for asphalt shipping are eliminated from the Bangchak-A case.

(4) Bangchak-B Case

Utilization of the fuel oil and asphalt loading facilities of the existing refinery is assumed. However, a detailed investigation would be required in the further step.

(5) Sri Racha-A Case

Base Oil, Asphalt and Sulfur

The same loading system are to be installed as the Bangchak-A case.

Fuel Oil

Fuel oil products are assumed to be shipped by means of an approximately 1,000 DWT coastal tanker. Shipping would be required three times every week. Loading time to the coastal tanker is assumed to be one hour. The fuel oil products are pumped from the product tanks to the existing pier via a newly installed pipeline.

(6) Sri Racha-B Case

Utilization of the existing fuel oil and asphalt loading facilities in TORC or ESSO is assumed. However, a detailed investigation would be required in the further step.

5-4-3 Interconnecting Pipeline

The following interconnecting pipelines are to be installed to connect the lube base oil plant and each adjacent refinery, i.e. MOR, TORC or ESSO.

Interconnecting Pipeline

	Bangchak	Sri Racha
From the existing refinery to the plant	. Long Residue . Hydrogen . Propane	. Long Residue . Hydrogen . Propane
From the Plant to the existing refinery	. LVGO . HF Cracked Gas Oil . Visbreaker Naphtha	. LVGO . HF Cracked Gas Oil . FCC Feedstock . Thermal Cracker Feedstock

5-4-4 Blending

Base Oil Blending

The 500N base oil is produced by blending 300N, straight run 500N and bright stock. Blending is carried out by means of tank blending followed by further mixing and adjustment.

Fuel Oil Blending

The heavy fuel oil and the refinery fuel oil is produced by means of in-line blending followed by further mixing and adjustment in tanks. The component oils for each case are shown below.

Component Oils for Fuel Oil Blend

Bangchak Case	Sri Racha Case
. Slack Wax	
. Visbroken Distillate and Residue	
. Extracts	. Extracts
. PDA Asphalt	. PDA Asphalt
. Vacuum Residue	. Vacuum Residue
. Vacuum Gas Oil Gas Oil	. Vacuum

Asphalt Blowing Charge Blending

Asphalt blowing charge stock is produced by blending vacuum residue, PDA asphalt and extracts. Blending is carried out by means of in-line blending followed by further mixing and adjustment in tanks.

5-4-5 Wax Molding and Packing

The liquid wax is pumped from the product wax tanks to the wax molding and packing unit in order to solidify the product wax and pack the solid wax in carton boxes for shipping. The unit consists of wax molding machines, refrigeration package and packing machines. The units are required only in the case of the wax production. (Bangchak-AX Case)

5-4-6 Firefighting System

Firefighting system consists of ring header systems or loops equipped with an appropriate number of hydrants, monitors and sprinklers. Water for the firefighting is drawn from the river water intake pit for the Bangchak case and the water tank which is to be installed for the Sri Racha case. Two of firefighting pumps are rated at 500 m3/H with 100 m differential head. One of the pumps is electrically driven and the other is of diesel engine driven. Besides the above, one fire truck and required number of fire extinguishers are to be provided.

5-4-7 Waste Effluent System

Reference is made to section 5-6.

5-4-8 Flare and Blowdown System

The flare and blowdown system is provided for discharging hydrocarbon vapors discharged from various pressure relieving devices such as safety valves, pressure control valves, and emergency blowdown valves. Facilities included in the system are flare knockout drum, smokeless type flare stack of adequate diameter and height, and associated piping.

5-4-9 Building

Table III-19 shows the planned buildings with necessary floor areas calculated. The floor areas for the expansion cases are estimated one third of that of the new company cases because utilization of the existing facilities is considered to a maximum extent.

However, a detailed investigation on availability of the existing facilities would be required in the further step.

5-5 Utility Facilities

One of the important factors for the successful operation of the plant is reliable and stable supply of necessary utilities to the users. Utilities facilities are investigated and defined taking prevailing local conditions into account.

Utilities Supply Sources

The following table represents the planned utilities for the two locations, namely Bangchak and Sri Racha.

Utilities Supply Sources

Service \ Location	Bangchak	Sri Racha
. Electricity	Purchased from EGAT	Purchased from EGAT
. Raw water		
for boiler feed	Drawn from Chao-Phaya river	Drawn from Sea
for cooling tower make-up	Drawn from Chao-Phaya river	Drawn from Bang Phra reservoir
. Hydrogen	Purchased from MOR	Purchased from TORC or ESSO
. Steam	Self-supporting	Self-supporting
. Air	Self-supporting	Self-supporting
. Inert Gas	Self-supporting	Self-supporting
. Fuel	Self-supporting	Self-supporting

Electricity is assumed to be supplied from EGAT as much as required. In this regard, detailed investigation and discussion with the relevant Government's authorities are required in the further step.

Major users of raw water in the plant are boiler feed water and cooling tower make-up water. In the Bangchak case, raw water is considered to be supplied from Chao-Phaya river as described in 5.2.2 in this part, whereas in the Sri Racha case, raw water for the boiler feed is supplied from a sea water desalination unit and raw water for the cooling tower make-up is supplied from the Bang Phara reservoir. Figure III-17 and III-18 represent the water system of the above two cases.

Hydrogen is used for the hydrofinishing unit and the wax hydrotreating unit in the plant. This is assumed to be supplied from each adjacent refinery by means of interconnecting pipeline.

The steam system has two pressure levels as shown below:

- High pressure steam : 15 kg/cm2G, 250°C
- Low pressure steam : 3.5 kg/cm2G, Saturate

The air compressors are provided to supply the instrument air and the plant air as required. Inert gas generators of air separation type are provided to supply the entire plant's demand of nitrogen.

The refinery fuel system consists of the fuel oil and the fuel gas. For the fuel gas system the sweetened off gas from the amine treater is used.

Utilities Balance

Table III-20 and Table III-21 show the utilities balances of two base cases of the new company, namely the Bangchak-A case and the Sri Racha-A case. Utilities' requirements for all cases are summarized in Table III-22.

Installed Capacity

The capacities of the individual utility facilities are determined based on various operating modes of the plant taking the peak loads into account. For the new company cases, i.e. Bangchak-A case, Bangchak-AX case, Bangchak-AY case, and Sri Racha-A case, one spare unit is provided for the following major facilities as stand-by service:

- Boiler
- Desalinator
- Cooling tower
- Cooling water circulation pump
- Air compressor

On the other hand, for the expansion cases, i.e. Bangchak-B case, and Sri Racha-B case, stand-by facilities of the boilers and the air compressors are considered as a whole refinery incorporating both the existing refinery and the plant, so that the stand-by capacity of the existing refinery could be used commonly. Therefore, there are no stand-by facilities are provided additionally for the plant.

In this study, each stand-by unit of boilers and air compressors is assumed enable to be eliminated. In this regard, detailed investigation on the existing facilities would be required in the further steps.

Table III-23 lists the installed capacity of utility facilities for each case.

5-6 Environmental Control Facilities

(1) Design of Waste Effluent System

Oily wastewater characteristics from the lube base oil refinery is more complex and in plenty of quantities compared to the hydroskimming type oil refinery, while the practice in lubricating oil processing is to conserve as much solvent as possible, accordingly only small amount of solvent can be expected to be treated with the wastewater treatment system.

So as to meet the waste quality standard of 3 mg/L for oil concentration and 30 mg/L of suspended solids in discharging water from the Plant the waste effluent system is designed for the Plant to have physical treatment, chemical treatment and biological treatment which composes the following:

- CPI separator
- Chemical injection
- Activated sluge with aeration
- Clarifier and filters

More specifically, reference is made to the attached "BLOCK FLOW DIAGRAM OF WASTE EFFLUENT SYSTEM" (Figure III-19)

(2) Sources and controls of wastes of the plant

Reference is made to the attached tables "SOURCE AND CONTROL OF WASTES FROM LUBE BASE OIL REFINERY" (Table III-24)

Discussions are made in the categories of air emissions, liquid wastes and solid wastes to meet the relevant Thai environmental control laws.

For the control of air emissions the plant design is intended to keep internationally prevailing moderate tolerable level of air quality for the surroundings of the refinery i.e.

SOx - average daily one hour value of 0.1 ppm or less as ambient air quality

NOx - hourly value of 0.15 ppm or less as ambient air quality

5-7 General Plot Plan

In order to estimate the required area for the project the plant facilities and buildings are laid out preliminary.

The plant is considered as a group of general areas arranged to include; feed stock storage, intermediate storage, product storage, product shipping facility, process units, utility production units, waste water treating facilities and administrative/service buildings.