VOLUME V

LOCATION

V LOCATION

1. Oil Refinery Location (El Rancho)

1.1 Natural Conditions

(1) Meteorology

The weather of El Rancho is tropical. The annual rainfall is about 800 mm, which is not so different from that of Guatemala City, but both temperature and humidity are high in El Rancho.

Table V-1 shows for example the meteorological data of 1981 by the Morazan Meteorological Station about 15 km away from El Rancho. It happened that 1981 had much rainfall, with an average annual rainfall of about 800 mm.

(2) Topography and Geology

El Rancho, a candidate site for oil refinery, is in El Progreso Department. It is situated in the neighborhood of a trifurcated point formed by Road CA9, the main trunk road connecting the Pacific with Atlantic coast and National Highway 17 from Coban, about 80 km northeast of capital Guatemala City and about 200 km southwest of Puerto Barrios, a port town in the Atlantic coast.

It is in a valley of about 280 m above the sea in the midstream of River Motagua that flows into the Atlantic Ocean, with the stratum of the whole neighborhood mainly consisting of sediments.

Table V-1 Meteorological Data in El Progreso (1981)

		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Atmospheric Temp. (°C)	Av. Max.	31.5	32.9	36.2	35.8	37.7	33.5	32.1	33.5	33.6	33.0	32.7	33.2	33.8
	Av.	24.5	26.0	29.0	28.7	30.5	27.7	27.1	27.7	27.7	26.9	25.6	26.3	27.3
	Av. Min.	15.6	17.0	19.7	19.6	20.7	21.3	20.6	21.5	21.5	21.3	17.4	18.7	19.6
Relative Humidity (%)	Max.	99	93	92	90	96	98	97	98	97	98	98	97	99
	Av.	64	58	52	53	54	72	73	72	71	74	65	64	64
	Min.	28	27	17	22	25	43	52	44	42	50	36	30	17
Total Rainfall (mm)		2.4	1.8	9.6	8.3	168.6	266.9	174.9	253.9	185.7	253.4	3.0	11.3	1339.8
No. of Rainy Days		3	3	4	4	11	23	18	16	21	22	2	4	131

Maximum Rainfall (mm) (from 1973 thru. 1982)	in 1 hr.	57.6	Rec'd in Mar. 3, 1978
	in 24 hrs.	97.2	Rec'd in Oct. 18, 1975

Source: Data obtained from INSIVUMEH

1.2 Social and Economic Environments

(1) Population and Labor

El Rancho belongs to San Agustin City of El Progreso Department, and its area and population are shown in Table V-2.

Table V-2 Area and Population of El Rancho, etc.

	Area (km^2)	Population	Density of Population ($No./km^2$)
El Progreso Dept.	1,922	81,100	42
San Agustin City	253	19,300	76
El Rancho	Approx. 18	Approx. 3,000	Approx. 17

Source: Hearing from mayor of the city

The unemployment rate of this area is as high as about 20%. There is plenty of labor supply, but majority of available workers are operators of simple machines, automobile drivers and simple workforces, still less engineers and skilled labor are available.

(2) Industries

The industry of San Agustin City is a primary industry, mainly consisting of agriculture such as Tobacco plantation, etc. As a major secondary industry, a large scale paper mill is being constructed in El Rancho to utilize local forestry resources. There are some small-scale lumber and leather mills, while the industry which affects employment is extremely scarce.

1.3 Utilities and Infrastructure

(1) Water

River Motagua, a main river in Guatemala, flows through the neighborhood of the candidate site of oil refinery, which the plant water will be taken from. The underground water level is about 7 to 8 m deep, and is easily available.

(2) Electricity

A power transmission line (69 KV, 60 Hz) of INDE (Instituto Nacional de Electrificación) runs through the neighborhood. However, power failure occurs frequently and reliability of power supply is low.

(3) Communication media (telephone)

A telephone line, controlled by GUATEL, the stateowned telephone organization, runs along National Highway CA9 in the neighborhood of the candidate site of oil refinery, and can be led in from it.

Major districts in Guatemala are connected with Guatemala City by microwave network, and telecommunications among major districts are possible.

(4) Road

The candiate site of oil refinery faces CA9, the major trunk road of Guatemala, connecting Puerto Barrios on the Atlantic coast through Guatemala City with San Jose on the Pacific coast, and its traffic condition is good.

(5) Educational and medical facilities

As educational facilities in this area there are one elementray school and 20 auxiliary elementary schools, to which about 8,000 children are attending, and two junior high schools to which about 400 children are attending.

No educational facilities higher than junior high school, such as high school, college, vocational training schools, exist in this district.

(6) Public fire-fighting facilities

There is no fire-fighting facility, including fireengine, for a public use.

1.4 Selection of Location of Plant Site

Two sites of El Rancho and Puerto Santo Tomas de Castilla on the Atlantic coast were proposed for the oil refinery. The results of comparison are shown in Table V-3.

Table V-3 Selection of Site

(Unit: US$ million/y)

	El Rancho	Sto. T. Castilla
Annual Expenses Related to Equipment*	67	44
Annual Expenses Related to transportation	13	52
Total	80	96

* Depreciation 10%, Insurance 1%, Interest 4% and maintenance 3% are assumed.

As shown in the table above, El Rancho has been selected as first step, because it is more advantageous in view of the total of the expenses related to equipment and product transportation than Puerto Santo Tomas de Castilla.

Further study has been conducted on several area within El Rancho district. The areas on which a field survey has been conducted are as follows:

- o Area A : Southside of Motagua river
- o Area B : Between CA9 and Route No. 4
- o Area C : Neighborhood of the furcated point of CA9 and Route 17

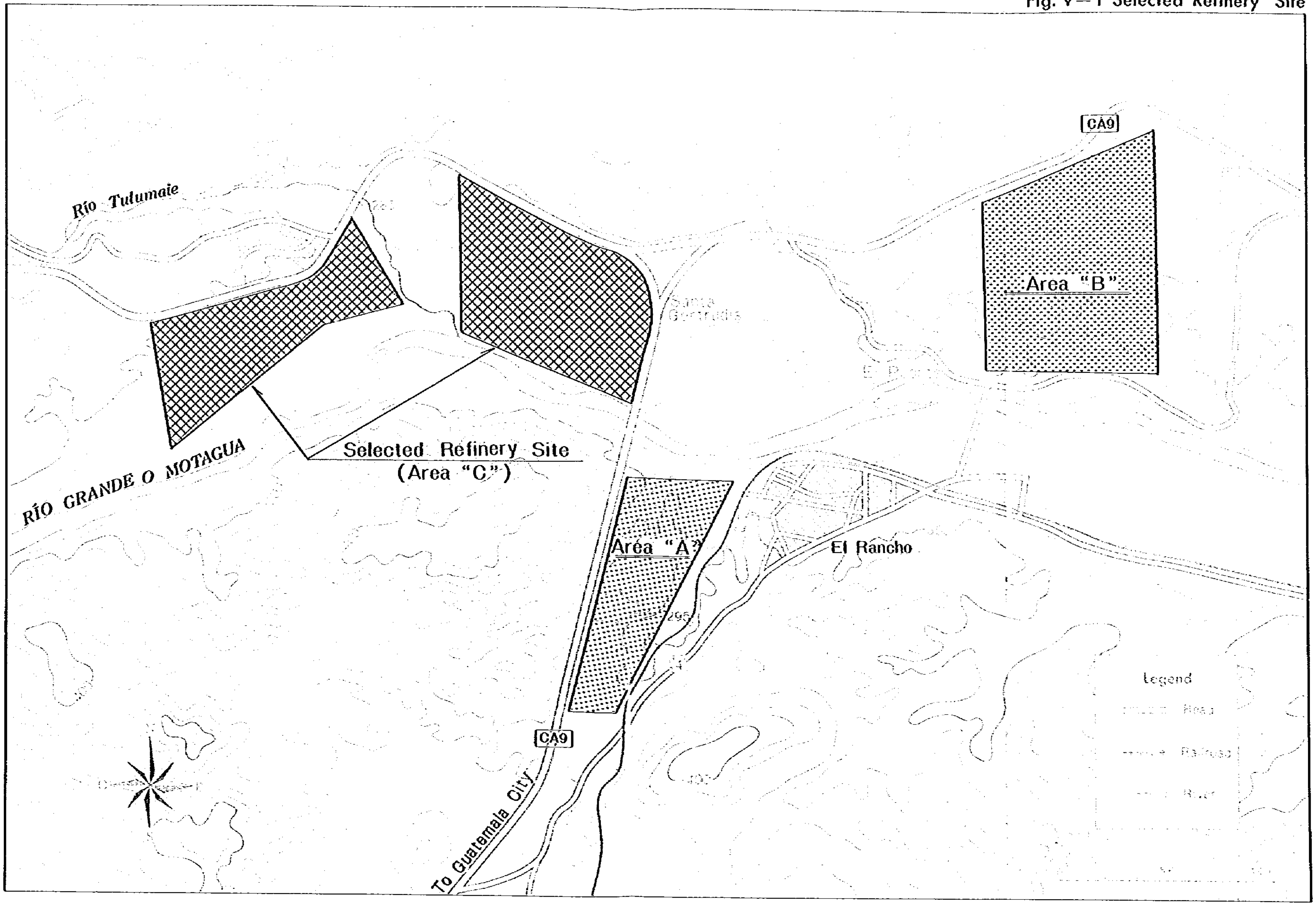
All these three areas are closely located along Motagua river and National Highway CA9. Accordingly, they are under almost same conditions in water-taking, carrying-in of heavy mechinery for construction, and costs of transportation of products.

Therefore, study has been made on geology and topography, cost of site preparation, and available size of land on these three areas.

Table V-4 Location of Oil Refinery

	Area A	Area B	Area C
Geology Topography	Sandy soil Gentle slope	Rocky soil Steep slope	Sandy soil Farm land
Cost of Land Development	Expensive	Expensive	Cheap
Available Land Size ($10^3 m^2$)	325	712	985
Overall Evaluation			○

Fig. V—1 Selected Refinery Site



As shown in Table V-4, Areas A and B are on the slope, requiring a large amount of expenses to prepare a plant site. Furthermore, the necessary land size for the oil refinery is about 980,000 m², which only Area C can provide.

For the reasons above stated, Area C has been selected as the site for the oil refinery.

Fig. V-1 shows Areas A, B and C.

2. Location of Crude Oil Terminal (Puerto Santo Tomas de Castilla)

2.1 Natural Conditions

(1) Meteorology

The weather of Puerto Santo Tomas de Castilla is tropical. The temperature and humidity are both high. With an annual rainfall of 3000 to 4000 mm, this area has the largest rainfall in the country.

Table V-5 shows the meteorological data of 1981 in Puerto Barrios that is close to Santo Tomas de Castilla.

(2) Topography and geology

Puerto Santo Tomas de Castilla is one of the main foreign trade ports facing the Caribbean Sea, as well as Puerto Barrios. It is situated at the eastern end of CA9, the trunk road of Guatemala, being a very important position in foreign trade and transportation in Guatemala.

Since this area is low and marshy, the ground is weak. The stratum mainly consists of sediments.

Table V-5 Meteorological Data in Puerto Barrios (1981)

		Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual
Atmospheric Temp. (°C)	Av. Max.	25.6	27.2	30.6	30.0	32.4	31.8	30.5	31.2	30.7	29.8	28.9	27.3	29.7
	Av.	20.9	22.2	24.9	25.1	26.8	26.7	27.1	27.4	27.1	26.3	24.7	23.8	25.2
	Av. Min.	16.9	18.7	20.5	26.2	22.2	22.5	21.6	22.3	22.1	21.8	19.7	19.3	21.1
Relative Humidity (%)	Max.	100	100	98	97	100	97	97	98	98	98	97	N.A	100
	Av.	88	91	84	87	95	87	83	81	83	85	80	N.A	86
	Min.	46	36	37	48	47	55	68	62	52	65	57	N.A	36
Total Rainfall (mm)		179.9	546.1	157.3	179.7	44.6	342.8	320.0	270.0	326.3	428.2	185.2	693.7	3,673.8
No. of Rainy Days		14	19	7	20	8	24	26	21	22	26	18	16	221

Maximum Rainfall (mm) (from 1973 thru. 1982)	in 1 hr.	67.6	Rec'd in Dec. 4, 1981
	in 24 hrs.	334.0	Rec'd in Nov. 13, 1981

Source: Data obtained from INSIVUMEH

2.2 Social and Economical Environments

(1) Population and labor

Puerto Sando Tomas de Castilla belongs to Izabal Department. Its area and population are shown in Table V-6.

Table V-6 Area and Population of Puerto Santo Tomas de Castilla

	Area (km^2)	Population	Density of Population ($No./km^2$)
Puerto Santo Tomas de Castilla	12	10,000	83

Source: Hearing from mayor of the city

Labor supply in this area is abundant. Employing automobile drivers and office clerks is easy. However, much cannot be expected on labor of high quality such as engineers and/or skilled workers.

(2) Industries

With a 30-year history of being a foreign trade port, Puerto Santo Tomas de Castilla has a number of firms on cargo handling, transportation and warehousing related to port business activities as major industry. In other fields, there are only a few small soft-dring bottlers and lumber mills.

Guatcal has an oil refinery here, but its operation stopped in the latter half of 1975. The facility has since then been used only for their storage terminal of imported petroleum products.

2.3 Utilities and Infrastructure

(1) Water

Wells are main source for plant water. The level of underground water is about 5 m deep.

(2) Electricity

Electricity is available from INDE (Instituto Nacional de Electrificación). However, power failure occurs frequently and reliability of power supply is low.

(3) Communication media (telephone)

A telephone line can be led in from the lines of Guatel (state-owned telephone organization).

(4) Road

CA9, the trunk road of Guatemala, connects Puerto Santo Tomas de Castilla through Guatemala City with San Jose on the Pacific coast. The traffic condition is good.

(5) Educational facilities

There are 11 elementary schools in Puerto Barrios, a near-by city, with 418 children attending schools. However, there is no educational facility for higher education. Higher education is being given in Guatemala City only.

(6) Medical facilities

There are four national and municipal hospitals in Puerto Barrios, with the total number of beds in these hospitals amounting to 940.

An Ambulance is available.

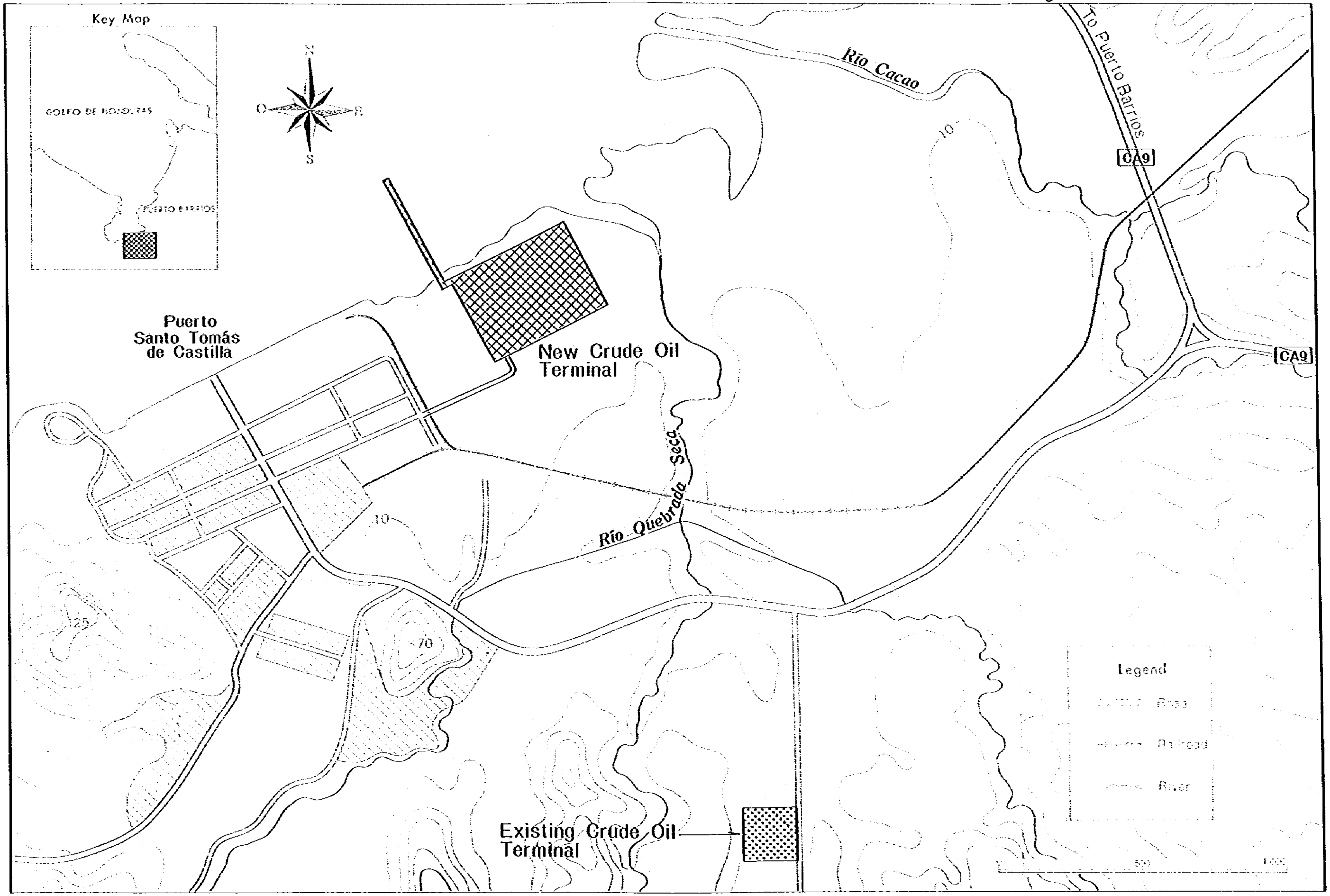
(7) Public fire-fighting facilities

Puerto Barrios has two fire-fighting automobiles.

2.4 Selection of Location

Two sites of Puerto Santo Tomas de Castilla and San Francisco del Mar were proposed for the crude oil terminal. During the field survey, Puerto Santo Tomas de Castilla was selected by comparing a site with the other on infrastructure. The reason for the selection is that the candidate site in Santo Tomas de Castilla is adjacent to the existing port facilities and is of a flat land not being used at present, as shown in Fig. V-2. The site has a large, sufficient space with surrounding infrastructure well established. Furthermore, since it is close to the existing crude oil terminal, it is conveniently located for a crude oil terminal and operation of pipeline as well.

Fig. V—2 Selected Terminal Site



3. Selection of Pipeline Route

Thus, El Rancho and Puerto Santo Tomas de Castilla have been selected as candidate sites for the oil refinery and crude oil terminal.

The pipeline to connect a site with the other is to be laid in the valley opened by Motagua river.

The geographic conditions of this area are as follow: This is a valley opened by Motagua river which starts at the neighborhood of Chichicastenango (about 2000 m above the sea) and flows into the Honduras Bay. As shown in Fig. V-3, National Highway CA9 and a railroad run along the river. National Highway CA9 is located along the mountain foot close to Lake Izabal, while River Motagua meanders very much and crosses with the railroad in the neighborhood of Los Amates. The elevation of El Rancho where the oil refinery is proposed to be built is about 280 m.

A pipeline is generally buried under the ground for security reason and also in order to reduce influences of external forces, temperature change, wind, rain, fire, etc. MEM also hinting at the underground method, the pipeline has been assumed to be installed underground as a precondition.

Then, the following three routes have been picked up along the valley of Motagua river as possible candidates:

- o Route 1 : Along National Highway CA9
- o Route 2 : Along the railroad
- o Route 3 : Along Motagua river

Study has been conducted by comparing the above three routes from the viewpoints of construction cost and easiness of the operation and maintenance. The study results are shown in Table V-7.

Table V-7 Selection of Pipeline Route

	Route 1	Route 2	Route 3
Construction Cost	Cheap	Expensive	Expensive
Operation and Maintenance	o	x	x
Overall Evaluation	o		

Generally speaking, in order to keep the contruction cost of a pipeline at a low level, it is necessary to select a site easy in construction and making the pipeline distance (beeline) shortest. There is no much difference among these three routes in the distance of pipeline. However, from the viewpoint of easiness of construction, Route 1 is most advantageous and its construction cost is lowest since access roads must be constructed in the cases of Route 2 and Route 3.

Locational conditions that are essential from the point of view of operation and maintenance are that, in addition to convenience on daily operation and maintenance, counter-measures can be quickly taken in case of emergency. Route 1 is most advantageous from this viewpoint, too.

For all these reasons, Route 1 running along National Highway CA9 has been selected as the optimum route for the pipeline.

Fig. V-4 shows the elevation of the pipeline route from the crude oil terminal to the oil refinery.

Fig. V-3 Pipeline Route

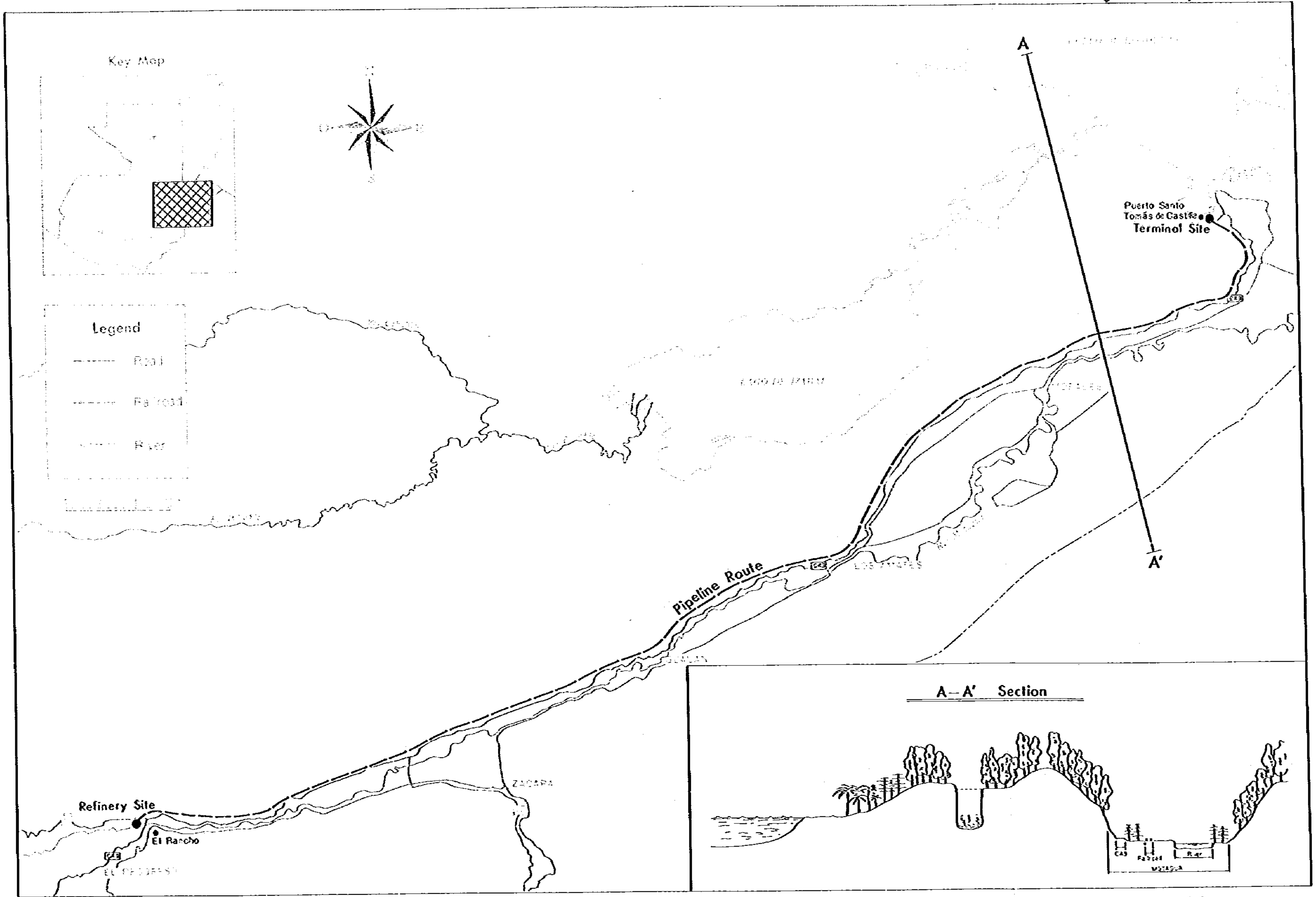
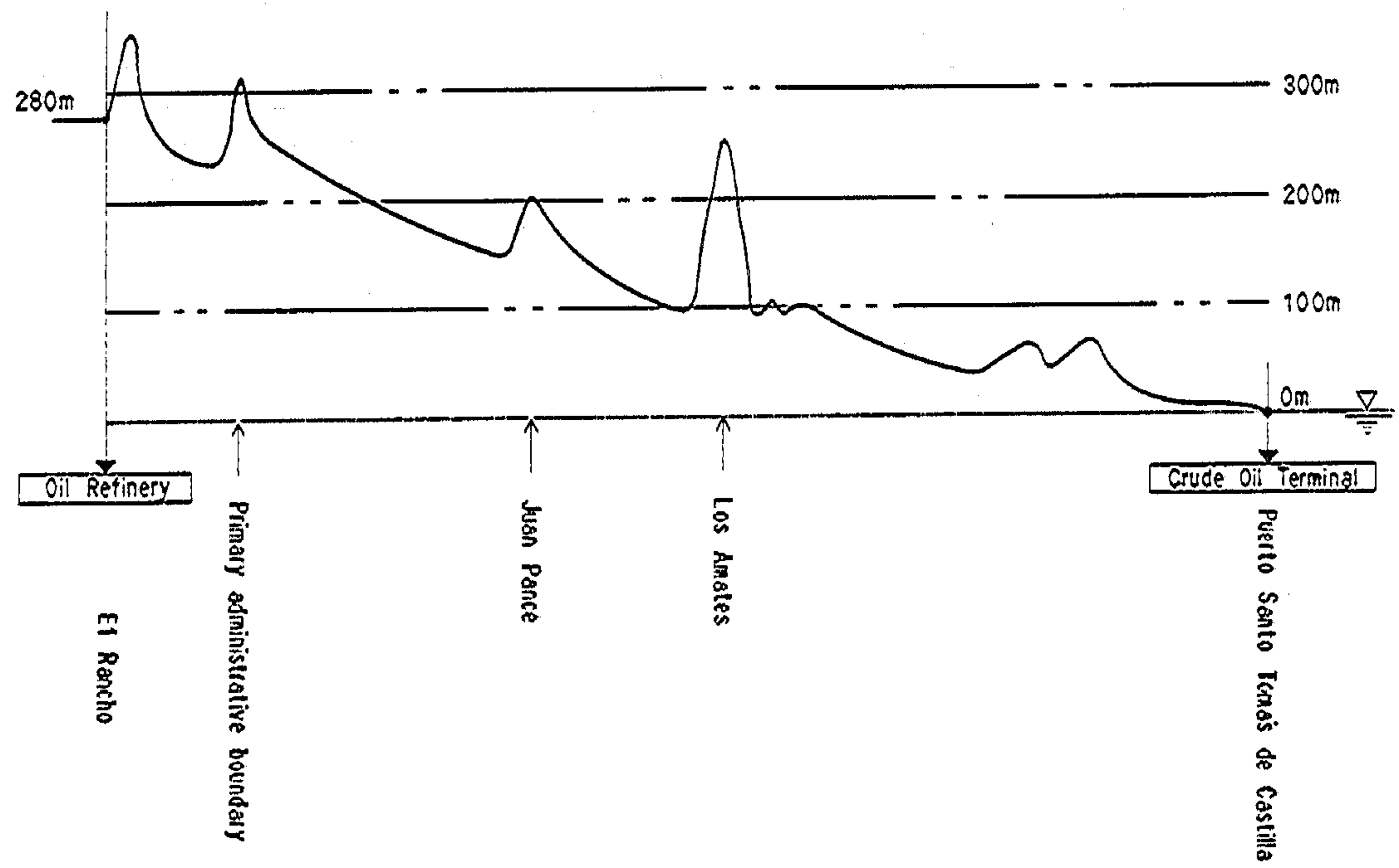


Fig. V-4 Undulations of Pipeline Route



VOLUME VI

BASIC PLAN FOR FACILITIES

VI BASIC PLAN FOR FACILITIES

1. Major Preconditions on Basic Plan for Facilities

1.1 Scope of Basic Plan for Facilities

The scope of basic plan for the new refinery is as follows.

(1) Refinery

Falling within the scope of study inside the refinery site are process units as on-site facilities, electric power and steam generators, and cooling water facility as utility facilities, feedstock and products storage tanks, loading and shipping facilities, offices and control rooms as off-site facilities, fire engines and various fire fighting facilities as security facilities and further waste water treatment facility, etc., as environemntal protection facilities.

Also included in the scope of study are access road (from the main road to the refinery), water intake piping and sewer as facilities outside the refinery site.

(2) Crude oil terminal

Included in the scope of study on facilities for the crude oil terminal are crude oil storage tanks, security facilities such as water storage tanks and fire fighting facilities, office and control room as off-site facilities and diesel electric power generators, etc., as utility facilities.

(3) Pipeline

In addition to materials and equipment for pipeline, booster stations (including diesel electric power generators and pumps) are included in the scope of study for the pipeline connecting the refinery with the terminal.

1.2 Major Preconditions on Basic Plan for Facilities

As major preconditions to determine the basis of design for the oil refinery, crude oil terminal and pipeline, related laws and regulations, structural design standards, kinds of crude oil, specifications of petroleum products, etc., have been assumed as follow;

1.2.1 Related laws, regulations and standards

The conceptual design has been conducted in accordance with the laws, regulations and standards of the United States of America and Japan, as listed below.

(1) Civil engineering and architecture

Uniform Building Code
ANSI A58.1

(2) Boilers and pressure vessels

American Society for Mechanical Engineers, or the equivalent

(3) Rotating machines

Japanese Industrial Standards (JIS) or the equivalent

(4) Electrical equipment

National Electrical Manufacturers Association or the equivalent

(5) Instrument

Instrument Society of America or the equivalent

(6) Fire fighting facility

National Fire Protection Association or the equivalent

(7) Materials

American Society for Testing and Materials, or Japanese Industrial Standards (JIS), or the equivalent

(8) Environmental protection and security facilities

Japanese related laws and regulations

1.2.2 Structural design standards

The structure design shall conform with the standards of the United States of America or Japan, while the basis of design with regard to seismic factor and wind pressure has been assumed as follows:

(1) Seismic force

The following formula has been used in accordance with the dynamic aseismatic design standards of the Uniform Building Code:

V = ZIKCSW

V: Total lateral force or shear at the base (seismic force)

Z: Numerical coefficient dependent upon zone. Since Guatemala is subject to frequent earthquakes, this coefficient has been set at 1.0, the largest.

I: Occupancy importance factor of buildings or other structures

K: Numerical coefficient dependent upon structural system of buildings or other structures

C: $C = 1/15\sqrt{T}$ T is fundamental elastic period of vibration

S: Numerical coefficient for site-structure resonance

W: Total dead load

(2) Wind pressure

The following values have been used in accordance with the Japan Petroleum Institute Standards:

$120\sqrt[4]{H}$	kg/m^2	in case of structure being higher than 16 m
$60\sqrt{H}$	kg/m^2	in case of structure being equal to or lower than 16 m.

1.2.3 Kinds of crude oil

As described in 1.2 Curde oil production of III CRUDE OIL, recoverable Guatemalan crude oil reserves are estimated to be about 40 million bbl. Assuming that with petroleum exploration activated by the new petroleum law, its recoverable oil reserves would increase to twice as much, they would amount to about 80 million bbl, resulting in 4 million bbl/y, divided by the project life of 20 years.

About 10,000 bbl/d are obtained, further divided by annual operating days of 330 (d/y). Therefore, crude oil shortage must be filled by import. Study has been conducted, first of all, on Maya crude oil produced in Mexico, in compliance with MEM's suggestion. However, Maya crude oil is extremely heavy crude oil and does not match with demands for petroleum products. On the other hand, it could not be said, at present, that proven technologies to crack such heavy crude oil have been established. For the reasons above stated, both Maya and Isthmus crude oil of Mexican original as well have been assumed to be used as feedstock at blending ratio of 50 to 50.

Accordingly, the kinds and quantity of crude oil to be used for the project life of 20 years as average are as follow:

Guatemalan crude oil: 10,000 bbl/d

Maya and Isthmus
crude oil : 50% each for balance

However, as far as preconditions on basic plan for facilities are concerned, it is quite possible, for a short period, that only Guatemalan oil is used, or that only Maya and Isthmus crude oil are used at blending ratio of 50 to 50. Accordingly, the oil refinery and related facilities have been so designed as to be operable in following either case, A or B;

Case A:	Guatemalan crude oil	100%
Case B:	Maya and Isthmus crude oil	50% each

1.2.4 Natural conditions

Data on natural conditions like temperature, rainfall, etc. are necessary to design facilities. As described in V LOCATION, the locations of the oil refinery and crude oil terminal were determined at El Rancho and Puerto Santo Tomas de Castilla, respectively. Natural conditions for these areas are shown in Table VI-1. The data are summarized results of hearings on meteorological data for the period of 1973 through 1982 from INSIVUMEH in charge of meteorology in Guatemala.

Table VI-1 Natural Conditions

Items	Unit	El Rancho	P.S.T. Castilla
Temperature Max.	°C	40	42
Ave.	°C	27.5	25.5
Min.	°C	9.0	20.5
Relative Humidity	%	30 - 90	60 - 90
Rainfall			
Max. in 1 hour	mm/h	58	68
Max. in 24 hours	mm/d	97	330

(Source: INSIVUMEH)

1.2.5 Bearing capacity of the soil

Data on the strength of ground, that is, bearing capacity of the soil are necessary to design facilities.

Since boring data were not available during the field survey for site areas at El Rancho and Puerto Santo Tomas de Castilla, the bearing capacity of the soil has been estimated out of the results measured by means of a "portable cone" brought in for the field survey. The results are shown in Table IV-2.

Table VI-2 Bearing Capacity of the Soil

(Unit: t/m^2)

El Rancho	P.S.T. Castilla
15	3

(Source: Study team's estimate)

1.3 Specifications of Petroleum Products

Table VI-3 compares specifications of petroleum products in accordance with the Guatemalan standards, JIS and ASTM for each kind of product. The specifications of petroleum products to be adopted in the proposed oil refinery are basically in accordance with the Guatemalan standards.

Although the Guatemalan specifications of petroleum products almost conform with ASTM, their own specifications are partially incorporated, some of which seem not necessarily practical. Accordingly, some of the Guatemalan specifications have been revised through consultation with

MEM as follow, while those of various foreign countries being referred to:

(1) Gasoline

The Guatemalan specifications specify specific gravity for gasoline. There is no such case internationally except Guatemala. Beside, it is not necessary from a functional point of view to specify specific gravity for gasoline, while such specification restrict process selection for the oil refinery. The deletion of this specification proposed by the study team has been basically agreed to and accepted by MEM.

(2) Jet Fuels

The Guatemalan specifications for jet fuels almost conform with ASTM except a few.

Guatemala specifies combustion properties with smoke point only, which is considered very strict, compared with international standards such as ASTM and IP which stipulate that only either one of (1) smoke point, (2) luminometer number or (3) smoke point and naphthalenes content shall be satisfied. Since the smoke point of Guatemalan crude oil is not so high, a smoke point improvement unit must be installed to make jet fuels. The study team proposed to MEM to accept the same specifications as ASTM with regard to combustion properties and MEM agreed to it.

Table VI-3 Product Specification

(1) Specification for Liquefied Petroleum Gas

	Guatemala	JIS (Grade 2-2)	ASTM (Grade P-B Mixtures)
Specific Gravity, (60/60°F)	0.500-0.560	-	Report
, (15/4°C)	-	0.50-0.63	-
Sulfur Content, grains/100ft³	15 max.	-	15 max.
, wt.%	-	0.02 max	-
Copper Strip Corrosion 1hr at 100°F	2 max.	-	No. 1 max.
Vapor pressure at 100°F	210 max.	(225 max.)	200 max. or (1167-1880x Sp. Gravity)
Volatile Residue; evaporated temperature, 95%, °F	36 max.	-	36 max.
or			
pentane and heavier, max. vol.%	-	-	2.0
Free Water Content	none	none	none
Propane Content, vol.%	40 - 70	-	-
Propane & Propylene Content, vol.%	-	50-90	-
Butane & Butylene Content, vol.%	-	<50	-

(2) Specification for Automotive Gasoline

	Guatemala	JIS	ASTM
Color	Red/Orange	Orange	
Sulfur, wt.%	<0.15	-	<0.15
Copper Strip Corrosion 3hrs at 50°C	1 max.	1 max.	1 max.
Existent Gum mg/100ml	4.0 max.	5 max.	5 max.
Oxidation Stability	240 min.	-	240 min.
Reid Vapor Pressure, psi	10 max.	6.4-11.4	9-15 max.
Anti-knock Index			
RON	87/95	85/95	-
(RON+MON)/2	-	-	87/89/93
Lead Content, g/U.S. gal	3.17 max.	1.1 max.	4.2 max.
API Gravity, 60°F	(58 min)* (-)**	-	-
Doctor Test	Negative	-	-
Mercaptan Sulfur, wt.%	0.005 max.	-	-
ASTM Dist., °C			
10%	65 max.	70 max.	50-70 max.
50%	77 min.		77 min.
50%	118 max.	125 max.	110-121 max.
90%	190 max.	180 max.	185-190 max.
97%	-	205 max.	
End Point	221 max.	-	225 max.
Dist. Residue, vol.%	2.0 max.	2.0 max.	2 max.

*/** Revised through consultation with MEM.

(3) Specification for Kerosene

	Guatemala	JIS	ASTM
API Gravity, 60°F	50 max.	-	-
Flash Point, °C	38 min.	40 min.	38 min.
Saybolt Color	+16 min.	+25 min.	+16 min.
Sulfur, wt.%	0.1 max.	0.015 max.	0.04 max.
Smoke Point, mm	19 min.	23 min.	-
Viscosity at 40°C, cSt	1.0 min.	-	1.0 min.
	1.9 max.	-	1.9 max.
Copper Strip Corposion 3hrs at 50°C	No.3 max.	No.1 max.	No.3 max.
ASTM Dist., °C			
10%	205 max.	-	205 max.
97%	-	270 max.	-
End Point	300 max.	-	300 max.

(4) Specification for Jet Fuels

	Guatemala	JIS (Grade-1)	ASTM (Grade-Jet A-1)
API Gravity, 60°F	39-51	39-51	37-51
Flash Point, °C	38 min.	38 min.	38 min.
Viscosity, cSt at -34.4°C	-	15 max.	-
at -20°C	-	-	8 max.
at -1 °C	15 max.	-	-
Saybolt Color	21 min.		
Sulfur, wt.%	0.2 max.	0.3 max.	0.3 max.
Doctor Test	negative	-	-
Copper Strip Corrosion 2hrs at 100°C	1b max.	1 max.	No. 1 max.
Existent Gum, mg/100ml	7 max.	7 max.	7 max.
Freezing point, °C	-47 max.	-50 max.	-47 max.
Combustion Properties			
(1) Luminometer no.	(-)* (45 min.)**	45 min.	45 min.
or (2) Smoke Point, mm	25 min.	25 min.	25 min.
or (3) Smoke Point, mm	(-)* (20 min.)**	20 min.	20 min.
and Naphthalenes, vol.%	(-)* (3 max.)**	3 max.	3 max.
Net Heat of Combustion, Btu/lb or	-	18,400 min.	18,400 min.
Aniline-Gravity Product	5,250 min.	5,250 min.	5,250 min.
Aromatics, vol.%	22 max.	20 max.	20 max.
Olefines, vol.%	5 max.	5 max.	-

	Guatemala	JIS (Grade-1)	ASTM (Grade-Jet A-1)
ASTM Dist., °C			
10%	204.4 max.	204 max.	204.4 max.
20%	-	report	-
50%	-	232 max.	report
90%	-	report	report
End Point	288 max.	287.5 max.	300 max.
Residue %	1.5 max.	1.5 max.	1.5 max.
Loss %	1.5 max.	1.5 max.	1.5 max.

*/** Revised through consultation with MEM.

(5) Specification for Gas Oils

	Guatemala	JIS (Grade-2)	ASTM (Grade-No. 2-D)
Water and Sediment, vol.%	0.05 max.	-	0.05 max.
API Gravity, 60°F	30 min.	-	-
Flash Point, °C	52 min.	50 min.	52 min.
Viscosity cSt at 100°F	1.93-4.28	-	-
at 30°C	-	2.5 min.	-
at 40°C	-	-	1.9-4.1
Pour Point, °C	-7 max.	-10 max.	
Sulfur, wt.%	0.5 max.	0.5 max.	0.5 max.
Copper Strip Corrosion 3hrs at 50°C	No. 3 max.	-	No. 3 max.
Cetane Index	45 min.	45 min.	40 min.
Conradson Carbon Residue on 10% Residuum, wt.%	0.35 max.	0.10 max.	0.35 max.
Ash Weight, wt.%	0.01 max.	-	0.01 max.
Neutralization No. mg KOH/g	0.5 max.	-	-
ASTM Dist. °C, 90% min.	282	-	282
max.	338	350 max.	338

(6) Specification for Fuel Oils

	Guatemala	JIS (Grade - No. 3-1)	ASTM (Grade - No. 6)
Water, vol.%	0.75 max.	0.5 max.	-
API Gravity, 60°F	12 min.	-	-
Flash Point, °C	60 min.	70 min.	60 min.
Viscosity, (SSU at 122°F	45-300)*	-	-
(SSF at 122°F	45-300)**		
cSt at 50°C	-	<250	92-638
Pour Point, °C	-1	-	-
Ash Weight, wt.%	0.1 max.	0.1 max.	-
Sulfur, wt.%	3.0 max.	3.5 max.	-
Sediment by Extraction	0.5 max.	-	-
Water & Sediment, vol.%	-	-	2.0 max.

*/** Revised through consultation with MEM.

2. Oil Refinery

Basic plans on facilities for the oil refinery are established based on demands forecast for petroleum products in Guatemala described in IV and major preconditions on basic plan for facilities described in VI.

2.1 Capacity of the Oil Refinery

In order to determine crude processing capacity of the new refinery, several cases are prepared first of all, with demands forecast for petroleum products and processing capacity of the existing refinery of Texas Petroleum Co. in Guatemala taken into account.

Then, study will follow on each case from the viewpoints of export-import of petroleum products and basic flow patterns (component processes) to determine refinery capacity.

(1) Cases of refinery capacity

When calculating the crude processing capacity of a refinery from demands forecast for petroleum products, about 7% must be added to cover the quantity of crude oil that the refinery consumes by itself as fuel plus refining loss. TEXCO's existing refinery in Guatemala has no crude oil reformer like FCC unit, it is at present being operated at about 11,000 bbl/d while its processing capacity is 17,000 bbl/d.

Assuming, in this study, that the current operation load of TEXACO's refinery would last, the capacity of the new refinery has been calculated by deducting such 11,000 bbl/d from the crude processing capacity obtained from demands forecast. The results are shown in Table VI-4.

Table VI-4 Calculation of New Refinery Capacity

(Unit: bbl/d)

	1989	1990	1991
Demands for petroleum products	44,500	46,600	49,000
Crude processing capacity	47,600	49,900	52,400
Quantity of crude oil being processed by TEXCO's refinery	-11,000	-11,000	-11,000
Calculated crude processing capacity of new refinery	35,400	38,900	41,400

From Table VI-4, the following two cases are conceivable for the capacity of the new oil refinery:

Case A 40,000 bbl/d
Case B 45,000 bbl/d

The operation load of the new oil refinery has been set at as follows based on conference with MEM:

Starting year 70%
Second year 90%
From third year on 100%

Therefore, capacities of the new oil refinery with the operation load taken into consideration for Case A and Case B are compared in Table VI-5 below with calculated crude processing capacities shown in Table VI-4.

Table VI-5 Processing Capacities Based on Operation Load

(Unit: bbl/d)

	1989	1990	1991
Calculated crude processing capacity of new refinery	35,400	38,900	41,400
Case A (40,000 bbl/d)	28,000	36,000	40,000
Difference from calculated capacity	-7,400	-2,900	-1,400
Case B (45,000 bbl/d)	31,500	40,500	45,000
Difference from calculated capacity	-3,900	+1,600	+3,600

Difference values in negative in Table VI-5 mean that petroleum products equivalent to its processing capacity must be imported, while difference values in positive mean that petroleum products equivalent to its processing capacity must be exported or that the operation load of the oil refinery must be lowered.

(2) Study from the viewpoint of export-import

MEM has basic policy of not exporting petroleum products of the new oil refinery. On the other hand, export of petroleum products should not be taken into account from an economical point of view, since El Rancho, the proposed site for the oil refinery, is located about 200 km away from the Atlantic Coast, and besides, facilities for export must be added.

It would not be preferable also from an economical point of view that operation load will have to be lowered from 1990, if Case B (45,000 bbl/d) is selected.

On the other hand, there is no problem in importing petroleum products. Since petroleum products are being imported even now.

As a result of above studies, the capacity of the new oil refinery should be 40,000 bbl/d (Case A).

(3) Study from the viewpoint of basic flow pattern

Planning a refinery composed of processes which satisfy whole demands for petroleum products bears technical and economical problems. Especially, when consideration is given to the fact that Guatemalan crude oil and the blend of Mexican Maya with Isthmas crude oil are both heavy while demands for petroleum products in Guatemala lean relatively toward light fraction products, it is inevitable that there are some discrepancies between the product mix of the oil refinery and demands for petroleum products.

One of ways to straighten out such discrepancies is to export excessive products and to import short products.

However, since it seems difficult to export products out of new oil refinery as mentioned earlier, the capacity of the new oil refinery should be smaller than 40,000 bbl/d from the viewpoint of composition of processes.

For the reasons as described so far, the crude processing capacity of the oil refinery has been decided to be 40,000 bbl/d.

2.2 Study on Basic Flow Patterns (Component Processes)

Basic flow patterns are studied for the refinery capacity of 40,000 bbl/d, as studied in Clause 2.1. In studying on basic flow patterns, despite studying on the basis of analysis data of crude oil as a precondition for the study, as described in III CRUDE OIL, a little adjustment has been made with regard to cut ranges so as to match the yield of each fraction with demands pattern of Guatemala.

As described in Chapter 1 of this volume, the crude oil to be processed by this oil refinery is Guatemalan crude oil or 50% : 50% blend of Mexican Maya and Isthmas crude oil, both of which are heavy crude oil having high sulfur contents and high viscosity on API scale of about 27 degrees.

On the other hand, because of Guatemalan demands for products leaning toward light fractions, with gasoline and gas oil accounting for more than 60% of the total demand, a cracking unit must be introduced to crack heavy crude and obtain light fractions.

Therefore, on the basis of combination of various cracking processes now under commercial operation all over the world, several cases for basic flow patterns have been set up and the basic flow pattern to be adopted for this oil refinery has been finally fixed upon comparing these cases.

2.2.1 Heavy crude cracking process

Selection of a cracking unit is the most basic and important point in planning flow patterns of the new oil refinery.

Cracking processes are generally classified as follow:

- o Thermal cracking
- o Catalytic cracking
- o Catalytic hydrocracking
- o Gasification

Features, merits and demerits of each cracking process are explained in the following.

(1) Thermal cracking

Thermal cracking process is classified into visbreaking and coking process.

o Visbreaking

Visbreaking is a process by which thermal cracking is gently conducted under a liquid phase. This process, due to reduced viscosity of vacuum residue, saves kerosene and gas oil fractions used to control the viscosity of the fuel oil and raises indirectly the yield of middle distillate. Since the visbreaker does not cost much both in construction and operation does not generate by-products like cokes, a number of visbreakers have been installed mainly in European countries.

o Coking

Tjere are two types of cokers available; a semi-continuous type of delayed coker consisting of furnaces and cokes drums and a completely continuous type of fluid-coker consisting of fluidized bed reactors burners, both types of which are operating especially in the United

States. Since costs of construction and operation of a coker are relatively low and its cracking effect is high, coking is a very effective process if the coke as by-product is salable.

Generally speaking, however, thermally cracked oil is not stable and requires highly advanced hydration to improve properties. Therefore, there are many examples of thermal crackers combined with hydrocrackers as after-processing equipment.

(2) Catalytic cracking

Compared with thermal cracking, catalytic cracking has a merit of indicating a good stability with only a simple processing, generating a high yield of gasoline with a high enough octane number and with diolefines not contained.

A catalytic cracker is originally installed to produce mainly gasoline from vacuum gas oil fraction, but the yield of light cycle oil fraction can be raised, while that of gasoline being lowered, by applying milder operating conditions and selecting suitable catalysts.

In the case of fluid catalytic cracking, are used only asphaltene-free distillates which are produced by vacuum distillation, propane deasphalting of vacuum residue, or cracked by coker or visbreaker, because asphaltenes contained in the residue cause to increase the coke generation, thus raising the temperature of the regenerator, and besides, metal impurities (especially vanadium, nickel, iron, copper, etc.) contained there in act as catalyst poison, causing to deteriorate the activity and selectivity of catalysts and ultimately to lower the gasoline yield.

However, now that catalysts resistant against metal poisoning have been recently developed, atmospheric residue with low sulfur or desulfurized residue is being actively tried to be used as feedstocks of fluid catalytic cracker.

(3) Catalytic hydrocracking

The feed oil if cracked under high temperature and high pressure in hydrogen stream using a catalyst, and much attention is being paid to catalytic hydrocracking in place of catalytic cracking. Features of catalytic hydrocracking are as follow:

- o Ability of processing various feedstocks

  The feed can be selected from naphtha, kerosene, gas oil, deasphalted oil or vacuum residue in accordance with the purpose and desulfurization and cracking can concur.

- o Free control of product yield

  Since the yield of cracked oil (from LPG to kerosene, gas oil, desulfurized fuel oil) can be controlled in a wide range by changing cracking conditions. The production can be flexibly matched with the market demand.

- o High liquid yield

  The refinery loss caused by generation of dry gas is kept to the minimum and the yield of liquid product to feedstocks is as high as 110 to 120%.

o High quality of product

Since desulfurization concurs with cracking, the product contains rather small amount of sulfur and no desulfurization unit needs be installed. Since the light gasoline contains much of isoparaffin, the octane number is high and it can be used as blend stock for gasoline without further processing. Since the heavy gasoline contains much of naphtene, it can be easily converted by reforming to high octane number gasoline. Kerosene and gas oil superior in smoke point, cetane number and pour point are obtainable.

On the other hand, different from hydrodesulfurization of kerosene and gas oil, hydrocracking requires a large quantity of hydrogen and the costs of consturction and operation are relatively high, since hydrogen produced as by-product from the reformer is not enough and, therefore, a hydrogen production unit is additionally installed.

The following describes cases of applying hydrocracking to distillate and residue.

1) Distillate hydrocracking

Hydrocracking using distillate that does not contain asphaltene like vacuum gas oil or deasphalted oil produces a good quality of cracked product and has a high flexibility in controlling the yield of products. It is an optimum process when the target is limited to the increase of production of kerosene or gas oil. However, the costs of construction and operation are high, since the process requires severe operating conditions.

2) Residue hydrocracking

Since hydrocracking of residue cracks the polycyclic aromatics consisting of huge asphaltene molecules contained in the residue, it requires very severe conditions on reaction. Also, it involves an essential problem of the catalyst life being extremely short because the residue contains a large amount of metal like nickel and vanadium. There are two types of process which are actually operating: one is ebullated-bed type and the other is fixed-bed type. The latter leaves much to be desired in improvement of the catalyst life.

The ebullated-bed type reactor has the following features:

- o The catalyst can be replaced or added during operation, so that the catalyst activity can be maintained constant. This type is very effective when processing inferior feed oil having a large amount of metal.

- o Since the feed oil, catalyst and hydrogen are blended extremely well in the reactor, the reaction temperature is uniform, resulting in constant product yield and properties.

- o Because of an ebullated bed, solids do not accumulate, while small catalyst particles can be used in this process, since pressure drop is out of the question.

Because of these features, residue containing asphaltene can be processed in the ebullated-bed type of hydrocracking.

(4) Gasification

There are two processes representing gasification: flexicoking and partial oxidation. When a feed for hydrocracking is produced using solvent deasphalting or coking, how to dispose of the ultra-heavy residue like pitch and cokes is a headache, but partial oxidation of the residue is one of effective solutions. However, since production of hydrogen by partial oxidation necessitates an oxygen plant, the construction cost becomes high. At present, the cost by this process is much higher than that by steam reforming, but it is an effective process for a bottomless refinery which will be constructed in the future.

The flexicoking process, the fluid coker combined with the gasification unit, to gasify generated coke continuously generates a large amount of low heating value gas instead of coke. This process is very effective, if generated gas is salable.

2.2.2 Setting-up of cases for basic flow patterns

The following three cases have been set up in applying the various cracking processes as explained in the previous section to this oil refinery:

Case A: Combination of coker with fluid catalytic cracking

The process flow chart in case of processing Guatemalan crude oil is shown in Fig. VI-1, while that in case of processing Mexican Maya and Isthmas crude oil is shown in Fig. VI-2.

Case B: Combination of residue hydrocracking with fluid catalytic cracking

The process flow chart in case of processing Guatemalan crude oil is shown in Fig. VI-3, while that in case of processing Mexican Maya and Isthmas crude oil is shown in Fig. VI-4.

Case C: Combination of residue hydrocracking with vacuum gas oil hydrocracking

The process flow chart in case of processing Guatemalan crude oil is shown in Fig. VI-5, while that in case of processing Mexican Maya and Isthmas crude oil is shown in Fig. VI-6.

The features, merits and demerits of each case are described in the following:

(1) Case A: Combination of coker with fluid catalytic cracking

After the bottom fraction from the distillation unit has been vacuum distillated, the vacuum distillated residue is processed by the coker. The heavy coker gas oil are hydrotreated, mixed with gas oil from the vacuum distillation unit, and then treated by fluid catalytic cracking (FCC).

The advantage of Case A is low costs of the construction and operation of the units, while it has such shortcomings as that the operation load must be kept to a low level because of unbalance on the demand and supply of gasoline, that is, production exceeds demand, and also inferior gasoline quality, that is, with high sulfur contents and a low octane number because of coker gasoline from the coker being mixed. Besides, about 500 t/d of coke produced as by-product from the coker, resulting in fuel equivalent to fuel oil, are very difficult to market, in Guatemala, while their export is not practical because of the transportation cost since El Rancho is located about 200 km away from the Atlantic Coast.

(2) Case B: Combination of residue hydrocracking with fluid catalytic cracking

The bottom fraction from the crude distillation is vacuum distillated and the distillated residue is processed by ebullated-bed hydrocracking unit (EB). The vacuum distillated gas oil from EB after having been mixed with gas oil from the vacuum distillation unit, is processed by the fluid catalytic cracking unit (FCC). The advantages of Case B are that the product pattern well matches the products demand, except for the shortage of gas oil and that there is no quality problem on the products.

A shortcoming of Case B is high costs of the construction and operation.

(3) Case C: Combination of residue hydrocracking with vacuum gas oil hydrocracking

The bottom fraction from the crude distillation unit is vacuum distillated and the vacuum distillated residue is processed by the ebullated-bed hydrocracking unit (EB). After the vacuum gas oil from EB has been mixed with gas oil from the vacuum distillation unit, it is processed by the fixed-bed hydrocracking unit (FB).

Case C has the advantage of producing more gas oil than Cases A or B, with production fairly close ot the demand.

The shortcomings of Case C are that the production of kerosene exceeds the demand considerably, while gasoline becomes substantially short, and that the construction and operation costs are very high.

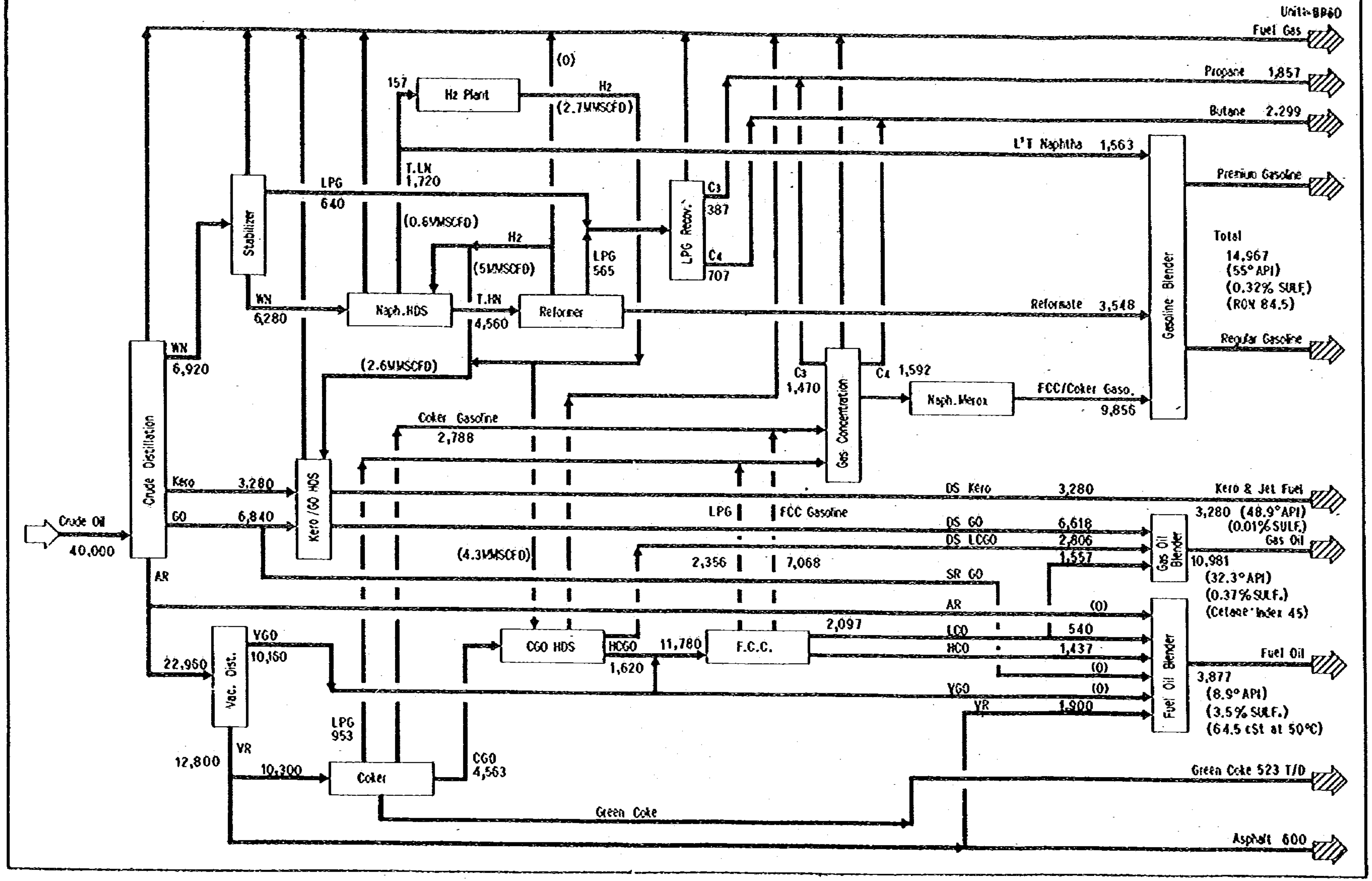
The merits and demerits of Cases A, B and C, as described in the above, are summarized in Table VI-6 below.

Table VI-6 Comparison of Flow Pattern Cases

	Case A Coker + FCC	Case B EB + FCC	Case C EB + FB
Relation with product demand	Gasoline becomes excessive. Gas oil production is close to demand.	Good balance on production and demand except that gas oil becomes short largely.	Kerosene becomes excessive and gasoline becomes short.
Product quality	Problem on gasoline quality	No particular problem	No particular problem
Construction & operation cost	Cheap	Fairly high	Very high
Others	Problem of disposing by-product coke		
Overall evaluation		○	

As summarized in Table VI-6, Case B, the combination of ebullated-bed hydrocracking unit (EB) with fluid catalytic cracking unit (FCC) is considered to be the best from the overall viewpoint, and has been decided to be the basic flow pattern of this oil refinery.

Fig. VI-1 Process Flow Scheme Case A
(Coker-FCC Crude: Coban, Blend)



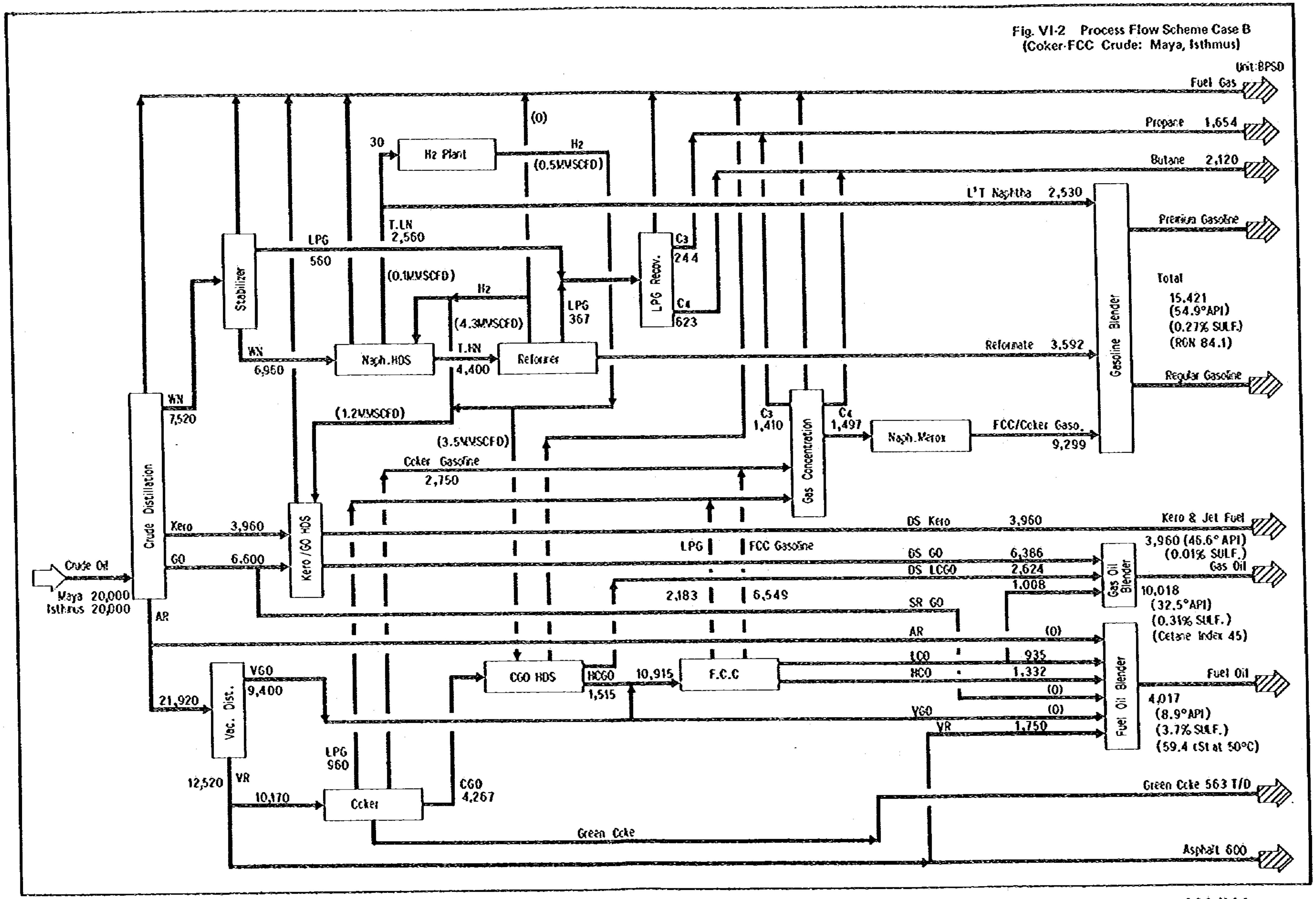


Fig. VI-2 Process Flow Scheme Case B
(Coker-FCC Crude: Maya, Isthmus)
Unit:BPSD
Fuel Gas
Propane 1,654
Butane 2,120
L'T Naphtha 2,530
Premium Gasoline
Total
15,421
(54.9°API)
(0.27% SULF.)
(RON 84.1)
Regular Gasoline
Reformate 3,592
FCC/Coker Gaso.
9,299
H2 Plant
30
(0)
H2
(0.5MMSCFD)
T.LN
2,560
LPG
560
Stabilizer
(0.1MMSCFD)
H2
(4.3MMSCFD)
LPG
367
LPG Recov.
C3
244
C4
623
WN
6,960
Naph.HDS
T.HN
4,400
Reformer
Gasoline Blender
WN
7,520
(1.2MMSCFD)
(3.5MMSCFD)
C3
1,410
C4
1,497
Gas Concentration
Naph.Merox
Coker Gasoline
2,750
Crude Distillation
Kero 3,960
GO 6,600
Kero/GO HDS
DS Kero 3,960
Kero & Jet Fuel
3,960 (46.6°API)
(0.01% SULF.)
LPG
FCC Gasoline
DS GO 6,386
DS LCGO 2,624
1,008
Gas Oil Blender
Gas Oil
10,018
(32.5°API)
(0.31% SULF.)
(Cetane Index 45)
2,183
6,549
Crude Oil
Maya 20,000
Isthmus 20,000
AR
SR GO
AR (0)
LCO 935
HCO 1,332
(0)
VGO (0)
VR 1,750
Fuel Oil Blender
Fuel Oil
4,017
(8.9°API)
(3.7% SULF.)
(59.4 cSt at 50°C)
CGO HDS
HCGO
1,515
10,915
F.C.C
Vac. Dist.
VGO
9,400
21,920
LPG
960
12,520
VR
10,170
Coker
CGO
4,267
Green Coke
Green Coke 563 T/D
Asphalt 600

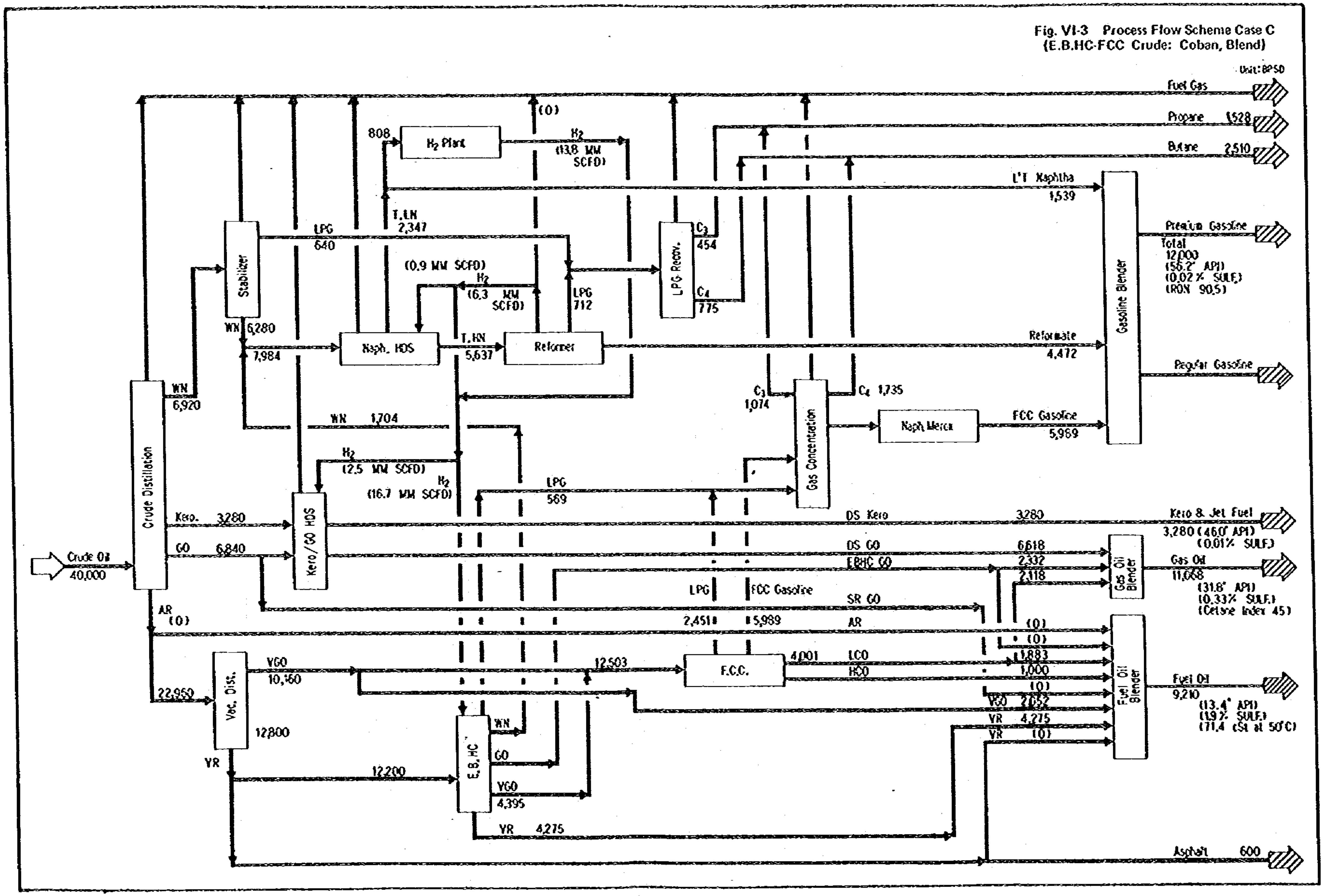


Fig. VI-3 Process Flow Scheme Case C
(E.B.HC-FCC Crude: Coban, Blend)

Fig. VI-4 Process Flow Scheme Case D
(E.B.HC-FCC Crude: Maya, Ishmus)

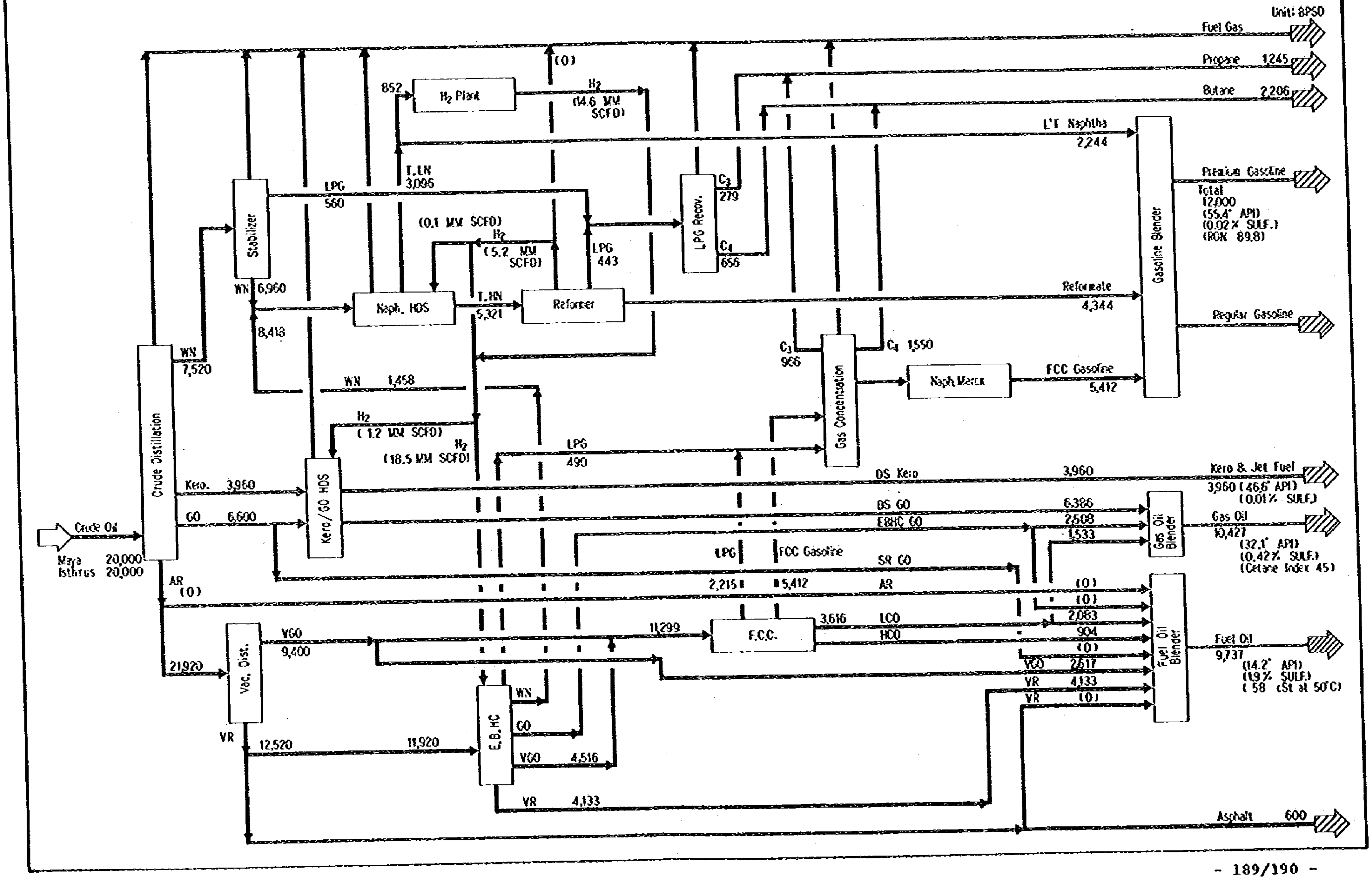
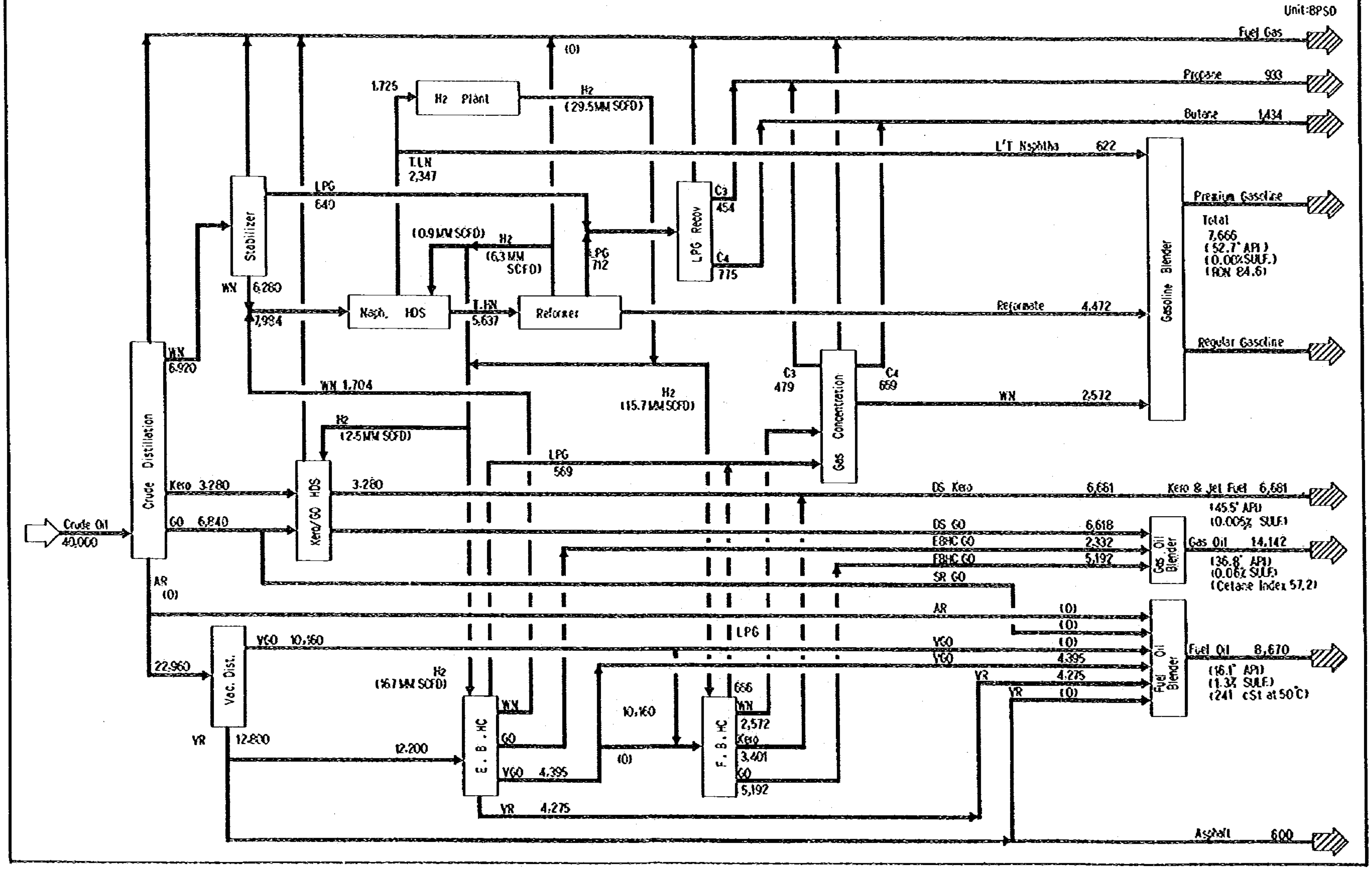


Fig. VI-5 Process Flow Scheme Case E
(E.B.HC-F.B.HC Crude: Coban, Blend)



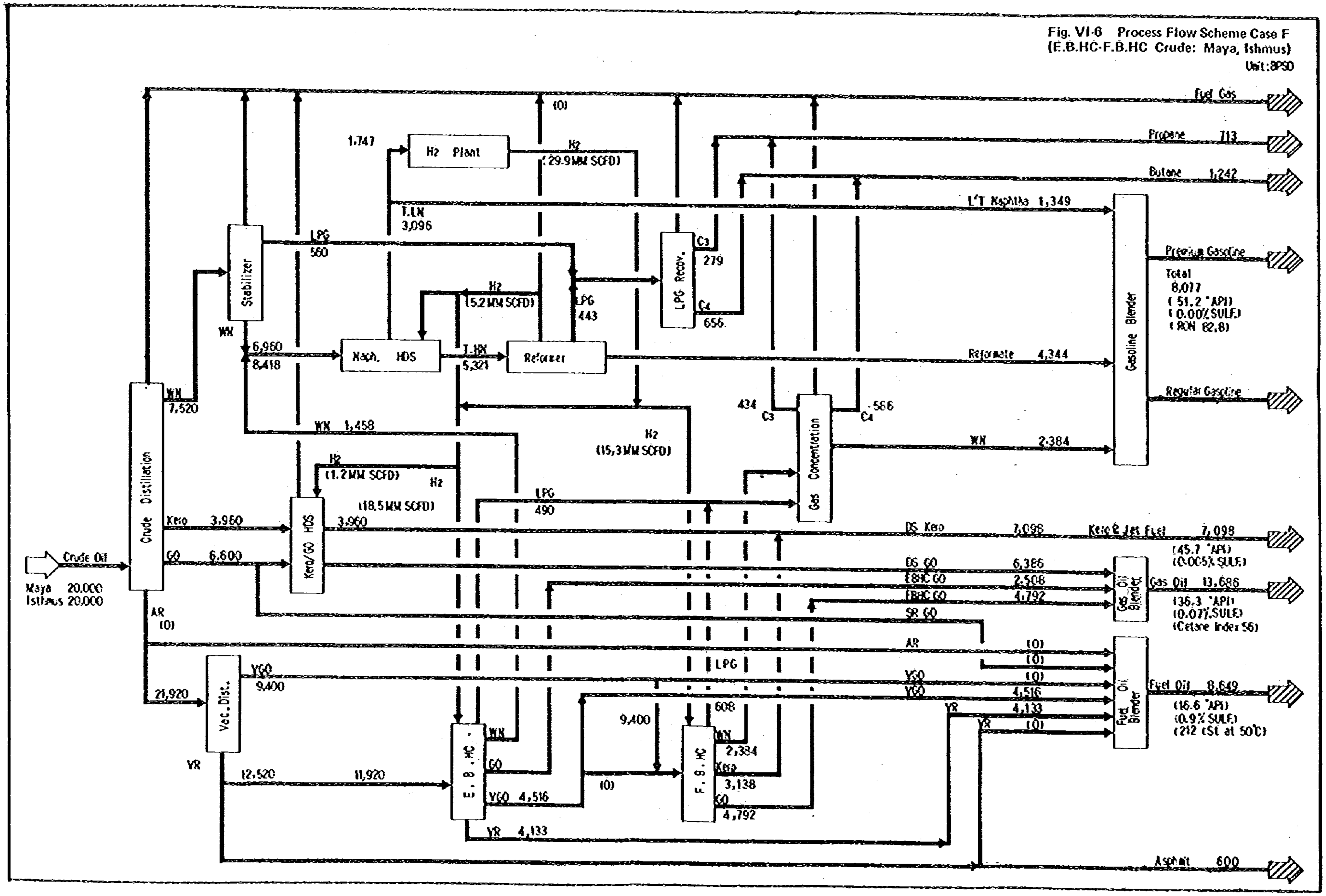


Fig. VI-6 Process Flow Scheme Case F
(E.B.HC-F.B.HC Crude: Maya, Ishmus)
Unit:BPSD
Fuel Gas
Propane 713
Butane 1,242
H2 Plant
1,747
H2
(29.9MM SCFD)
(0)
L'T Naphtha 1,349
T.LN
3,096
Stabilizer
LPG
560
LPG Recov.
C3
279
C4
656
H2
(5.2MM SCFD)
LPG
443
Premium Gasoline
Total
8,077
(51.2 °API)
(0.00% SULF.)
(RON 82.8)
Gasoline Blender
Naph. HDS
Reformer
6,960
8,418
T.HN
5,321
Reformate 4,344
Regular Gasoline
WN
7,520
434
C3
C4
586
WN 1,458
H2
(15.3MM SCFD)
Gas Concentration
WN 2,384
H2
(1.2MM SCFD)
H2
(18.5MM SCFD)
LPG
490
Crude Distillation
Kero 3,960
Kero/GO HDS
3,960
DS Kero 7,098
Kero & Jet Fuel 7,098
(45.7 °API)
(0.005% SULF.)
Crude Oil
Maya 20,000
Isthmus 20,000
GO 6,600
DS GO 6,386
EBHC GO 2,508
FBHC GO 4,792
SR GO
Gas Oil Blender
Gas Oil 13,686
(36.3 °API)
(0.07% SULF.)
(Cetane Index 56)
AR
(0)
AR (0)
(0)
VGO
9,400
VGO (0)
VGO 4,516
VR 4,133
VR (0)
Fuel Oil Blender
Fuel Oil 8,649
(16.6 °API)
(0.9% SULF.)
(212 cSt at 50°C)
21,920
Vac. Dist.
VR
12,520
11,920
E.B.HC
WN
GO
VGO 4,516
VR 4,133
9,400
(0)
LPG
608
F.B.HC
WN
2,384
Kero
3,138
GO
4,792
Asphalt 600

2.3 Process Selection

On the basis of the basic flow patterns as described in the preceding clause, first, described is the service factor which is commonly applicable to each process and then the processes adopted for the oil refinery are described in the sequence of the flow shown in Fig. VI-3 and Fig. VI-4.

2.3.1 Service factor

Although the service factor that is necessary to determine the equipment capacity can be set at a high level because of abundant experiences in Japan and operation experiences of the existing oil refinery in Guatemala, the service factor has been set at 0.90, or 330 operating days a year, in view of the fact that this will be the first introduction of modern equipment requiring experiences to maintain and manage them properly.

2.3.2 Distillation unit

A crude distillation unit is installed to separate the crude oil into the following fractions:

Whole range straight run naphtha
Kerosene
Gas oil
Topped crude oil

The crude distillation unit is provided with a desalter to remove salt and water contained in the crude oil, and also a stabilizer to recover LPG as a product.

A vacuum distillation unit is installed to produce the feed for a cracking unit and asphalt, treating the crude distillation residue and separating into vacuum gas oil and vacuum residue. The vacuum gas oil is mainly used as the feed for a fluid catalytic cracking unit, part of it being blended with heavy fuel oil.

The majority of vacuum residue is used as the feed for an ebullated-bed hydrocracking unit, with only part of it shipped as asphalt.

2.3.3 Desulfurization unit

A desulfurization unit is indispensable to this oil refinery since the crude oil to be processed contains much sulfur. Each fraction is desulfurized in the following methods.

(1) LPG

Since LPG from the crude distillation unit and fluid catalyticcracking unit contains comparatively much sulfur, a desulfurization unit is necessary to produce LPG that satisfies the product specifications. LPG is desulfurized in one of the following three methods:

- o Caustic washing
- o Removal of hydrogen sulfide with MEA (Monoethanolamine) and mercaptane by the MEROX unit
- o Processing of LPG blended with naphtha by a hydrodesulfurization unit

As a result of technical and economical reviews of these methods and also taking into consideration that the Guatemalan crude oil generates a large amount of hydrogen sulfide when heated, the MEA/MEROX process has been selected, consuming only a small amount of caustic soda and leaving only little problem on the spent caustic.

(2) Light and heavy naphtha fractions

The light and heavy naphtha fractions from the crude distillation unit and ebullated-bed hydrocracking unit are first processed by a naphtha hydrodesulfurization unit, separating into light naphtha and heavy naphtha. The latter is used as the feed for the catalytic reforming unit, while part of the former is used as the feed for the hydrogen production unit with the other part blended with gasoline.

A high grade of refining of heavy naphtha to remove sulfur, nitrogen compounds and metals contained in it is necessary, in order to process heavy naphtha by the catalytic reforming unit. The heavy naphtha is pretreated by a hydrodesulfurization unit, while light naphtha is to be processed by a hydrodesulfurization unit since Gautemalan crude oil contains a large amount of sulfur, although light naphtha is normally not required to be hydrotreated.

(3) Kerosene and gas oil fractions

The sulfur contained in kerosene and gas oil fractions is removed by a hydrodesulfurization unit in order to satisfy the product specifications. A desulfurization unit for kerosene and gas oil is separately installed to desulfurize kerosene and gas oil alternately.

(4) Cracked gasoline

A MEROX unit is installed to sweeten the cracked gasoline obtained from the fluid catalytic cracking unit.

2.3.4 Catalytic reforming unit

A catalytic reforming unit is installed to raise the octane number of heavy naphtha obtained from the crude distillation unit and ebullated-bed hydrocracking unit up to the level of being usable for gasoline production.

Hydrogen gas, a by-product from the catalytic reforming unit, can be effectively used as the hydrogen gas consumed by the hydrodesulfurization unit and hydrocracking unit. However, this is not enough and a hydrogen gas production unit must be installed separately.

2.3.5 Cracking unit

As described in detail in Clause 2.2 Flow pattern, in order to match the yields of petroleum products of the oil refinery with the demand structure of Guatemala as closely as possible, a fluid catalytic cracking unit and ebullated-bed hydrocracking unit are installed.

The fluid catalytic cracking unit cracks the vacuum gas oil from the vacuum distillation unit and ebullated-bed hydrocracking unit to produce LPG, gasoline, light cycle oil and heavy cycle oil. LPG, along with the LPG from the hydrocracking unit, desulfurized, while C3 and C4 being recovered, by a gas concentration unit. Naphtha fraction, after C5+ fraction having been recovered from the gas by a gas concentration unit, is treated by a MEROX unit and used for gasoline blending. Light and heavy cycle oils are used for blending with heavy fuel oil since they are rich in aromatics and the cetane number is low. However, the light cycle oil is to be blended with gas oil as much as possible within the limit of gas oil specifications.

On the other hand, the ebullated-bed hydrocracking unit cracks the vacuum residue from the vacuum distillation unit. LPG obtained is separated into C3 and C4 by a gas concentration unit, while light and heavy naphtha fractions (whole range naphtha), having been mixed with whole range straight run naphtha from the crude distillation unit, are desulfurized by the naphtha hydrodesulfurization unit and separated into light naphtha and heavy naphtha. The latter, after its octane number having been raised by a catalytic reforming unit, is used for gasoline production. The gas oil fraction is used without further treatment for blending with gas oil. The vacuum gas oil fraction is used as the feed for a fluid catalytic cracking unit, while the vacuum residue fraction, being mixed with other fractions, is used for fuel oil production.

2.3.6 Hydrogen gas production unit

In this oil refinery, since a large volume of hydrogen gas is consumed by two hydrodesulfurization units and a hydrocracking unit, hydrogen gas produced as a by-product from the catalytic reforming unit is not enough. In order to fill the gap, a hydrogen gas production unit will be installed. A hydrogen gas production unit using light naphtha as the feed, of which construction cost is low, seems to fit in well with the proposed oil refinery, since the fluid catalytic cracking unit has a large capacity and accordingly high margins in the gasoline production.

2.4 Designed Processing Capacity and Production of Each Unit

2.4.1 Designed processing capacity of each unit

The following lists up the designed processing capacity of each unit described in Clause 2.3. The unit of capacity is Barrel Per Stream Day (BPSD).

o Crude distillation unit (including gasoline stabilizer)		40,000 BPSD
o Naphtha hydrodesulfurization unit		8,500 BPSD
o Catalytic reforming unit		5,700 BPSD
o Kerosene/gas oil hydrodesulfurization unit		10,600 BPSD
o Vacuum distillation unit		23,000 BPSD
o Fluid catalytic cracking unit		12,500 BPSD
o Ebullated-bed hydrocracking unit		12,200 BPSD
o LPG recovery unit		1,400 BPSD
o Gas concentration unit	LPG	3,100 BPSD
	Naphtha	7,500 BPSD
o Naphtha MEROX unit		7,500 BPSD
o Hydrogen gas production unit		16×10^6 ft^3/d
o Waste water treatment unit		32 t/d

(Note 1) The gas concentration unit and the naphtha MEROX unit have been so designed as to be able to meet the maximum requirement in processing capacity, even in case the fluid catalytic cracking unit operates on the maximum yield of gasoline.

(Note 2) The waste water treatment unit treats toxic materials like hydrogen sulfide, ammonia, etc. generating from the crude distillation unit, vacuum distillation unit, hydrogen desulfurization unit and hydrogen cracking unit.

2.4.2 Quantity of crude oil to be processed and products

As described in Chapter 1, the average quantity of crude oil used by the oil refinery for the project life of 20 years as follows:

Guatemalan crude oil	10,000 bbl/d

Shortage to be filled by 50% each of Maya and Isthmas crude oil

Therefore, when the refinery capacity is set at 40,000 bbl/d, the quantity of crude oil to be processed is as follows:

Guatemalan crude oil	10,000 bbl/d
Mexican Maya crude oil	15,000 bbl/d
Mexican Isthmas oil	15,000 bbl/d

The quantity of products in this case is outlined in the following. These figures on products will be used as the basic case of financial analysis of the oil refinery.

Quantity of products

LPG	759×10^3 bbl/y
Premium gasoline	$1,980 \times 10^3$ bbl/y
Regular gasoline	$1,980 \times 10^3$ bbl/y
Kerosene, Jet fuel oil	$1,251 \times 10^3$ bbl/y
Gas oil	$3,494 \times 10^3$ bbl/y
Fuel oil	$2,671 \times 10^3$ bbl/y
Asphalt	198×10^3 bbl/y

2.5 Preconditions on Basic Plan for Off-site Facilities

Preconditions on basic plan for off-site facilities are described as follow:

2.5.1 Tankage

The major basis of design for tanks is as follows;

(1) Method to determine the tank capacity

The tank capacity has been determined by the following formula:

$$Q = V \times D \times 1/W$$

Q: Required capacity of tank (kl)
V: Quantity of product (kl) or feed oil consumption (kl/operating day)
D: Number of storage days (d)
W: Working factor

Working factors have been decided as follow in consideration of a dead space of 2.0 m as a total of top and bottom in case of a cone roof and dome roof tank and a dead space of 3.5 m in case of floating roof tank;

Cone or dome roof tank; W = 0.8
Floating roof tank; W = 0.7

(2) Number of storage days and number of tanks

1) Crude oil tank

Since the crude oil terminal has the capacity to store crude oil for 30-days operation, the storage capacity of crude oil in the refinery has been set at about 10-days production. The minimum number of tanks is six, assuming that three kinds of crude oil will be used.

2) Intermediate tank

An intermediate tank will be installed, as a rule, for each unit, and the number of storage days is 15 days in consideration of emergency shutdown. The feed is supplied directly from the upperstream unit to the catalytic reforming unit in principle, however, a tank will be installed to secure the feed for start-up. The number of storage days for this tank is seven.

The number of storage days for intermediate tanks for the kerosene and gas oil hydrodesulfurization unit have been increased, since kerosene and gas oil are processed alternately. The number of intermediate tanks is not less than two for each kind of oil.

3) Component tank

Number of storage days	;	15 days
Number of tanks	;	not less than two for each component

4) Product tank

In consideration of the shutdown period of the units and that the product tanks are the terminal point for direct delivery to sonsumers, the number of tanks is at least two for each product.

5) Additionally, two slop tanks (for light slop oil and heavy slop oil, 2,000 kl each) for startup and one home fuel oil tank (residue oil, 2,000 kl) will be installed.

(3) Legal regulations

The following specifications are in accordance with the Fire Fighting and Fire Prevention law of Japan and National Fire Protection Association (NFPA) regulations of USA with regard to petroleum tanks.

- o Tank height — Not more than 22 m
- o Distance between tanks — Not more than tank diameter or height, whichever is larger
- o Fire dike capacity — Not smaller than 110% of the maximum tank capacity

(4) Type of tank

o LPG	Spherical tank
o Crude	Floating roof tank
o Naphtha and gasoline	ditto
o Kerosene	Cone roof tank
o Gas oil	ditto
o Fuel oil (including residual oil)	ditto
o Asphalt	

However, the charge tank to the hydrodesulfurization unit among the intermediate tanks is of dome roof type for prevention of fouling and provided with the inner float device inside.

2.5.2 Product blender

A product blender is necessary for gasoline, gas oil and fuel oil, and the major design specifications are as follow:

(1) Operation time

Number of operating days a year:	240 days
Operating hours:	8 h/d

(2) Blender capacity and blending ratio

1) Gasoline blender

o Blender capacity 360 kl/h

o Blending ratio (Typical)

Light gasoline	19%
Reformate	36%
Cracked gasoline	45%

Additionally, lead and coloring agent blending equipment is provided with to control the octane number and coloring (red/orange) by blending lead with coloring agent. The premium and regular gasoline being blended to make products, the blending ratio of each type is designed with a margin of about 50%.

2) Gas oil blender

o Blender capacity 330 kl/h

o Blending ratio (Typical)

Desulfurized gas oil	61%
Catalytic cracked light gas oil	25%
Hydrocracked gas oil	14%

The blending ratio of each type is designed with a margin of 20%.

3) Fuel oil blender

- o Blender capacity 290 kl/h

- o Blending ratio (Typical)

Catalytic cracked light gas oil (Light molecular)	21.4%
Catalytic cracked light gas oil (Heavy molecular)	9.3%
Vacuum gas oil	26.9%
Hydrocracked vacuum residue	42.4%

The blending ratio of each type is designed with a margin of 20%.

2.5.3 Shipping facility

Except asphalt, all products are shipped by lorry to the delivery points. Asphalt, being filled in drums, is shipped by trucks.

(1) Shipping conditions

o	Shipping time	8 h/d x 300 d/y
o	Lorry capacity	20 kl
	LPG	20 m^3
	Asphalt drum	200 kg

o Lorry turnover Once a day

Assuming that the distance is 80 km/one way, 4 hours outward bound and 2 hours homeward bouhd.

o Loading speed

White oil (gasoline, kerosene, gas oil, jet fuel)	120 kl/h
Fuel oil	80 kl/h
LPG	60 kl/h
Asphalt	40 drums/h

The lorry for white oil can be bottom-loaded and its loading speed is 120 kl/h.

2.5.4 Utility facilities

The capacities of utility facilities are determined on the basis of the following estimated utilities consumption:

Utility item	Estimated consumption
Electricity	15,600 kw
Make-up water	294 t/h
Cooling water	7,910 t/h
Steam	192 t/h
Fuel	196×10^6 kcal/h

With as much waste heat recovery as possible of about 70 t/h counted on, the steam which will have to be generated by the boiler is about 122 t/h. Based on necessary amounts of utilities outlined in the above, the capacity of each utility facility has been determined with addition of some margins as follows;

Facility name		Capacity
Water intake and water treating facility		320 t/h
Cooling water facility		9,500 t/h
Boiler		65 t/h x 3
Generator		9 MW x 3
Boiler feed water facility		1,560 t/d
Condensate recovery facility		120 t/h
Air compressor		4,000 Nm^3/h
Nitrogen gas generator	Total	1,000 Nm^3/h
	Gas	920 Nm^3/h
	Liquid	80 Nm^3/h
Home fuel oil facility	Liquid fuel	40 kl/h
	Gas fuel	20 t/h

2.6 Security and Environmental Protection Measures

Since an oil refinery because of its nature always stores and processes a large amount of inflammable oil, constant attention must be paid to the safety and security. Also, since there is the possibility of an oil refinery becoming a source of pollution because of toxic materials that are generated during the operation, prevention of the pollution is essential.

(1) Security measures

Because of the limit on the site, the oil refinery is located separately from the shipping terminal. In order to assure the security, both the refinery and shipping terminal are surrounded by fences, preventing third parties from entering the premises, while security men patrolling within the premises.

In the event of a fire breaking out, the security men are organized into the fire squad to fight a fire.

(2) Environmental protection measures

Pollutions that an oil refinery may cause are air pollution, water pollution, offensive odor, noise and vibration. In developed countries, a strict pollution control has been legislated with regard to discharge standards, etc., and various measures to avoid pollutions are being taken. Although there are no definite discharge standards in Guatemala, the oil refinery must be planned and designed so that no pollution probelm will occur after start-up of operation.

However, El Rancho area where the oil refinery is proposed to be constructed is a very thinly populated area quite different from a densely populated area where most of refineries in developed countries are located, and there is no other industry in the area than a paper mill under construction. Accordingly, the pollution control of the refinery should naturally be different from that for developed countries with economical factors taken into consideration. The following describes the basic thought on the pollution control.

1) Air pollution

Major materials that cause air pollution are sulfur oxide and nitrogen oxide contained in the flue waste gas. Because of the location, any special measures against air pollution such as de-SOx or de-NOx plant has not been considered to this oil refinery at this moment. However, when the basic design of the new oil refinery will be executed in the future, the discharge amount of

SOx and NOx should be considered in determining the height of the stack.

2) Water pollution

Since this oil refinery will be located in the inland area and waste water from the refinery has to be discharged to River Motagua, to prevent the river from being contaminated is very important. Clean and contaminated water have to be separatedly sewered. The contaminated water is treated by a waste water stripper, API separator, activated-sludge treatment facility or coagulating sedimentation facility, while measures are to be taken to reduce the contaminated water to the maximum extent.

The target figures on the quality of treated waste water from the refinery are set as follow:

Item	Effluent quality
pH value	5.8 to 8.6
Suspended solids	30 ppm max.
BOD	20 ppm max.
COD	30 ppm max.
Oil content	5 ppm max.
Phenol	0.5 ppm max.

3) Offensive odor

The materials that cause to generate offensive odor are ammonia, hydrogen sulfide, and mercaptane. The offensive odor has been planned to be burned in the furnace or flare stack.

4) Noise and vibration

No particular measures will be taken to control noise and vibration since the oil refinery is constructed in a thinly populated area and is far enough away from private houses.

3. Crude Oil Terminal

3.1 Preconditions on Basic Plan

The following preconditions have been set up in making basic plan for the crude oil terminal.

(1) Location

As shown in Fig. V-2 in Volume V of this report, the crude oil terminal has been proposed to be constructed in the area adjacent to the existing port facilities of Puerto Santo Tomas de Castilla.

(2) Relation with the existing Guatemalan crude oil export terminal

After the start-up of operation of the new oil refinery, all crude oil produced in Guatemala will be consumed by the new oil refinery. A new pipeline will branch off at a point of the existing pipeline connecting the existing crude oil terminal with the shipping pier and lead to the new crude oil terminal. Another pipeline, therefore, will transport crude oil as far as the new oil refinery via the newly constructed crude oil terminal.

(3) Size of inbound tankers

On the basis of the size of the largest tanker that have ever arrived at the pier of Puerto Sando Tomad de Castilla in the past, size has been assumed to be 24,000 dead weight ton (DWT).

(4) Means of receiving crude oil

Crude oil will be received from crude oil tankers by means of loading arms which are provided on the sea berth of dolfin type.

(5) Specifications of crude oil tank

The capacity of a crude oil tank is 40,000 kl with margin, so that it can store crude oil from a 24,000 DWT tanker. The tank is of floating roof type which is commonly adopted for a large capacity tank.

(6) Capacity of crude oil tank

The total storage capacity of crude oil is 200,000 kl (40,000 bbl/d x 0.159 kl/bbl x 30), equivalent to 30-days operation of the new oil refinery.

(7) Quantity of crude oil to be handled annually

40,000 bbl/d x 0.159 kl/bbl x 330 = 2,098,800 kl/y

(8) Kinds of oil to be handled

Guatemalan Coban blend
Mexican Maya
Mexican Ithmas

(9) Number of days occupied by a tanker

Three days.

(10) Number of inbound tankers a year

About 88 tankers a year.

(11) Electric power supply

Diesel generators will be provided for power supply to the terminal facilities. Commercial electricity will be purchased for illumination of offices, etc.

(12) Security and fire fighting facilities

Foam fire fighting facility, fire dike and fire extinguisher will be installed in accordance with the National Fire Protection Association (NFPA) standards.

(13) Environmental protection facility

An API oil separator will be installed as waste water treatment facility.

The basic specifications of crude oil terminal are based on the maximum size of inbound tanker of 24,000 DWT, according to the information obtained from MEM, but in the execution stage, the specifications should be determined on the basis of results of a through survey on the water depth of Puerto Santo Tomas de Castilla. If the water is not deep enough, offshore receiving by mooring buoy should be studied as an alternative plan.

4. Pipeline

4.1 Preconditions on Basic Plan

(1) Section of pipeline installation

As shown in Fig. V-3 of Volume V, the pipeline will be installed from Puerto Santo Tomas de Castilla where the crude oil terminal is constructed to El Rancho where the oil refinery is constructed.

(2) Pipeline specifications

There are two ways to install a pipeline; underground piping and aboveground piping. In this project, the underground piping has been selected from the viewpoint of security, to avoid the influence of temperature changes, as well as in accordance with the indication by MEM.

(3) Preconditions on determination of pipeline diameter

Pipeline diameter has been studied on the basis of preconditions as follow;

- o Flow rate

  An allowance of 20% is added to the quantity required with the oil refinery.

  40,000 bbl/d x 120% = 48,000 bbl/d

- o Pipeline length

  The distance from Puerto Santo Tomas de Castilla to El Rancho along National Highway CA9 is 200 km. However, since detouring is unavoidable in some area, the total length has been assumed to be 220 km.

- Elevation difference

  The maximum difference of elevation between Puerto Santo Tomás de Castilla and El Rancho has been assumed to be 350 m.

- Fluid viscosity

  Since the viscosity of Guatemalan crude oil is higher than that of the blend of Mexican Maya and Isthmas crude oil, the viscosity of Guatemalan crude oil of 87.4 centistokes (cSt) has been adopted.

(4) Place of installation of booster pumps

A booster pump will be installed in two places. Therefore, the total pressure drop is shared by total three pumps; one delivery pump from the crude oil terminal and two booster pumps.

(5) Determination of pipeline diameter

Under the preconditions outlined in Item (3), the total pressure drop has been calculated on the basis of three pipeline diameters of 14, 16 and 18 inches. Since three pumps are to share the pressure drop, each pump must have the following boosting capacity:

Pipeline diameter	Total pressure drop	Required boosting capacity
14 inches	344 kg/cm²	115 kg/cm²
16 inches	195 kg/cm²	65 kg/cm²
18 inches	125 kg/cm²	43 kg/cm²

As a result of an overall evaluation of the required boosting capacity of each pump and pipeline installation cost, 16-inch size has been selected as the most economical diameter.

(6) Operation method of booster station

Unattended operation system is adopted. However, three pipeline operators are assigned to the crude oil terminal, and two out of them are to regularly patrol the pipeline every day and check up operating conditions of the booster station.

(7) Driving of booster station pump

The booster station pump is diesel engine driven.

VOLUME Ⅶ

CONCEPTUAL DESIGN

VII CONCEPTUAL DESIGN

Conceptual designs of the oil refinery, crude oil terminal and pipeline have been conducted on the basis of the basic plan for facilities described in Volume VI.

The results of conceptual design have been summarized as follow:

- o Oil refinery and crude oil terminal
  Process flow, Plot Plan and Major equipment list

- o Pipe line
  Process flow and Major equipment list

1. Oil Refinery

1.1 Process Flow

1.1.1 Process plants

The process flow of process plants is shown in Fig. VII-1 and Fig. VII-2.

(1) Crude distillation unit

Crude oil passes through the desalter to the main fractionator and is separated into to the following fractions by the difference of boiling points:

Whole range straight run naphtha
Kerosene
Gas oil
Atmospheric residue (Topped crude)

The whole range straight run naphtha from the top of the main fractionator, after LPG having been separated at the next stabilizer, is introduced into the naphtha desulfurization unit or intermediate tanks. The kerosene and gas oil fractions are side-cut from the main fractionator, and after flash point having been controlled by the side stripper, sent to the kerosene/gas oil hydrodesulfurization unit or intermediate tanks.
The topped crude oil taken out of the bottom of the main fractionator is sent to the vacuum distillation unit or intermediate tanks.

(2) Naphtha hydrodesufurization unit

The whole range straight run naphtha from the stabilizer bottom of the crude distillation unit and the whole range naphtha obtained from the ebullated-bed hydrocracking unit are blended with hydrogen and sent to the reactor, where sulfur contained in naphtha is converted to hydrogen sulfide by the action of desulfurizing catalysts. With hydrogen sulfide removed by a stripper, the treated whole range naphtha is separated into light naphtha and heavy naphtha by the splitter. The latter is sent to the catalytic reforming unit, while light naphtha is sent to the intermediate tank, which is mainly used for gasoline blending and besides partly used as the feed for the hydrogen production unit.

(3) Catalytic reforming unit

The heavy naphtha which has been desulfurized and refined by the naphtha desulfurization unit is reformed to high octane gasoline fraction in the catalytic reforming unit by the action of reforming catalyst, while hydrogen gas is being circulated in it with hydrogen and LPG by-produced.

The octane number varies by the structure of hydrocarbons that constitute the gasoline, and the following relationship is found between the octane number and structure:

- o In hydrocarbons that belongs to the same series, the lower the boiling point, the higher the octane number.

- o The octane number increases in order of paraffins, olefins, naphthenes and aromatics on hydrocarbons having the same number of carbons.

- o Isomers have a higher octane number, and the octane number increases as the molecular structure concentrates the center.

- o Among olefins, the closer double bond is to the center of molecules, the larger the octane number is.

- o Among naphthenes and aromatics, the octane number becomes smaller as the side chain is longer.

Almost all reactions to produce high octane components, except olefins, occur in the reactor of this unit and such major reactions are as follow:

- o Conversion to aromatics by dehydrogenation of naphtenes

- o Conversion to aromatics by cyclization and dehydrogenation of paraffins

- o Isomerization of paraffins
- o Hydrocracking of paraffins

Since the reaction as a whole is endothermic and the temperature drops, this unit has been so designed as to obtain reaction temperature as close as possible to the target value by reducing temperature differences among each part of catalyst beds of three reactors. Such reduction of temperature differences can be attained by reheating the fluid from each reactor by the intermediate furnace and charging it to the next reactor.

The fluid that has completed all reactions is separated into liquid and gas which mainly consists of hydrogen. The liquid is sent to the debutanizer installed at the side of this unit, where dry gas and LPG are taken out from the top and the product (reformate) which has been controlled under a predetermined vapor pressure is discharged from the bottom.

The by-produced hydrogen gas is used as make-up hydrogen for the hydrodesulfurization and hydrocracking units.

(4) Kerosene/gas oil hydrodesulfurization unit

The kerosene and gas oil fractions which have been separated by the crude distillation unit contains such impurities as organic sulfur, oxygen compounds and nitrogen compounds. Kerosene and gas oil are refined by removing such impurities through the hydrorefining unit. The kerosene and gas oil sent from the intermediate tanks or main fractionator are processed by this unit separately and alternately.

The components of this unit are basically same as those of naphtha hydrodesulfurization unit. The feed oil, having been mixed with hydrogen, is charged into the reactor, where impurities contained in the feed are converted to hydrogen sulfide, ammonia, water, etc. by the action of desulfurizing catalysts. There are various combinations of components constituting the stripping section, where hydrogen sulfide, water, etc. are removed. The combination of a steam stripper and vacuum dryer has been selected inasmuch as it is advantageous in fuel consumption. The refined product are stored in the tank, after hydrogensulfide is removed by the steam stripper and then water is removed by the vacuum dryer.

(5) Vacuum distillation unit

The atmospheric residue from the crude distillation unit is separated in the vacuum distillation unit into vacuum gas oil to be fed to the fluid catalytic cracking unit and into vacuum residue to be fed to the hydrocracking unit. The atmospheric residue is in part filled in drums shipped out as, product, straight asphalt.

The components of the vacuum distillation unit are similar to those of the crude distillation unit. Basic difference is that the vacuum distillation unit is equipped with a vacuum producing system to operate the fractionator in vacuum state so that heating temperature can be low.

(6) Fluid catalytic cracking unit

The fluid catalytic cracking unit, using vacuum gas oil as the feed, mainly produces gasoline, and generates concurrently cracked gas and cracked gas oil. The feed is first preheated by the heat exchanger, merged with the slurry oil coming from the bottom of the main fractionator, and sent to the inlet of the reactor. At the inlet, it is heated and vaporizes by contacting with the regenerated catalyst supplied from the regenerator, serves for sending the catalyst into the reactor as well. In the reactor, the catalyst and vaporized feed oil contact in the fluid phase, and cracking reaction takes place. As the cracking reaction advances, code deposits on the surface of the catalyst, reducing the activity of the catalyst. Therefore, hydrocarbons contained in the catalyst are continuously removed by steam at the stripper installed at the bottom of reactor before the catalyst is recycled to the regenerator. While regeneration air being supplied into the regenerator, the coke on the surface of the catalyst is burned off and generated in the fluid phase. The flue gas entraining the catalyst goes up to the top of the regenerator and, after catalyst particles having been separated by a cyclone, is discharged into atmosphere. The flue gas containing a large amount of carbon monoxide is effectively utilized to generate steam by a CO boiler.

The temperature of catalyst beds in the regenerator is raised to 550 to 620°C by coke burning and the regenerated catalyst is returned to the reactor, providing heat necessary for reaction. The cracked materials from the reactor, after the entrained catalyst having been separated in the cyclone at the upper part of the reactor are sent to the main fractionator bottom, being separated into gas, gasoline, light cycle oil, heavy cycle oil, etc. by refluxing slurry oil and cycle oil that have been cooled through heat exchange with the feed oil and by the steam generator.

(7) Ebullated-bed hydrocracking unit

Since the catalyst and feed oil are kept in the ebullated state by hydrogen gas and catalytic reaction occurs in the vapor-liquid mixed phase, such problems as channelling, increase of pressure drops, heterogeneous reaction temperature, etc. which crop up with conventional fixed-bed reactors, can be avoided. Since the catalyst is taken out and new catalyst is made up little by little during operation, there is no need of stopping the operation to regenerate or replace the catalyst, as needed with fixed-bed reactors.

Part of the feed oil, having been merged with cracked vacuum residue, is preheated, mixed with hydrogen gas, and then charged into the first stage of the reactor. The reactor effluent from the first stage is subject to another reaction at the second stage and then separated into vapor and liquid. The separated gas is cooled by a heat exchanger and cooler, and recycled to the reactor after condensed liquid portion has been separated. The liquid effluent from the separator is sent en masse to the fractionation section and separated into the following fractions:

- o Gas
- o Whole range hyudrocracked naphtha
- o Cracked gas oil
- o Vacuum gas oil
- o Vacuum residue

The gas is sent to the gas concentration unit to recover C3 and C4 fractions contained in the gas. The whole range hydrocracked naphtha is processed by the naphtha hydrodesulfurization unit along with the whole range straight run naphtha from the crude distillation unit. The heavy naphtha fraction is further sent to the catalytic reforming unit to raise the octane number, and then used for gasoline. The gas oil fraction is used for gas oil blending. The vacuum gas oil fraction is the feed for the fluid catalytic cracking unit. The vacuum residue in part is recycled, while the remainder is used for fuel oil blending.

(8) Gas concentration unit

The gas generated by the fluid catalytic cracking unit and ebullated-bed hydrocracking unit contains large quantities of C3 and C4 fracrtions. Since it is uneconomical to recover and separate the C3 and C4 fractions by fractionation only, the C3 and C4 fractions are dissolved into liquid by absorption and then separated and recovered by fractionation.

The compressed gas is first given countercurrent contact with the bottom oil of the debutanizer for absorption of LPG fraction contained in the gas, and then the LPG fraction is recovered by same contact with light cycle oil from the fluid catalytic cracking unit.

The bottom oil of the debutanizer which has absorbed light hydrocarbons is sent to the stripper for separation of light portion, and returns to the debutanizer. LPG fraction is obtained from the top of the debutanizer, while naphtha fraction being obtained from the bottom. The LPG fraction is sent to the LPG recovering unit, where its sulfur content is removed by MEA treater and LPG MEROX unit incorporated in the LPG recovering unit, and returns again to the gas concentration unit, where C3 and C4 are separated by the depropanizer.

The naphtha fraction in part is recycled to the absorber as absorbent, as explained above, while the remainder is sweetened in the naphtha MEROX unit and then stored in the tank as gasoline fraction.

(9) LPG recovering unit

The saturated LPG obtained from the top of the satabilizer of the crude distillation unit and unsaturated LPG obtained from the top of the debutanizer of the gas concentraction unit are treated with MEA and caustic soda respectively for removal of hydrogen sulfide and mercaptan. The MEA regenerator and caustic soda regenerator (LPG MEROX unit) will be commonly installed.

The treated saturated LPG, being merged with the LPG from the catalytic reforming unit, is distilled and separated distillation and into gas, C3 and C4 fractions by the deethanizer and depropanizer, while treated unsaturated LPG is sent back to the gas concentration unit, where C3 and C4 fractions are separated by the depropanizer.

(10) Naphtha MEROX unit

Since the cracked gasoline of which vapor pressure has been controlled by the gas concentration unit contains mercaptane, which is changed into a disulfide by the naphtha MEROX unit. It is then sent to a tank as sweet products and used for gasoline blending.

(11) Hydrogen production unit

Since large quantities of hydrogen are consumed by the hydrodesulfurization unit and hydrocracking unit in this oil refinery, the hydrogen gas by-produced from the catalytic reforming unit is by no means sufficient. In order to fill the gap, a hydrogen production unit by steam reforming of light naphtha has been planned.

The light naphtha used as the feed for this unit is hydrodesulfurized and fed to the hydrogen production unit. The naphtha, being mixed with recycling hydrogen, after sulfur contained in it has been reduced further by the naphtha treater and sulfur guard, is mixed with steam, heated in the reforming furnace, led into the catalyst tube, and catalytically reformed by externally supplied heat.

The reformed gas coming out of the reforming furnace, after heat has been recovered by the quench boiler, is sent to the CO converter consisting of two stages of high and low temperature, where CO is converted into CO_2 and H_2. The gas from the converter is sent to the CO_2 absorber to remove CO_2, and after a small amount of remaining CO and CO_2 have been converted to methane by the metanator, cooled and made product, hydrogen gas.

Fig. VII-1 Flow Diagram of Refinery (1/11)
(Crude Distillation Unit)

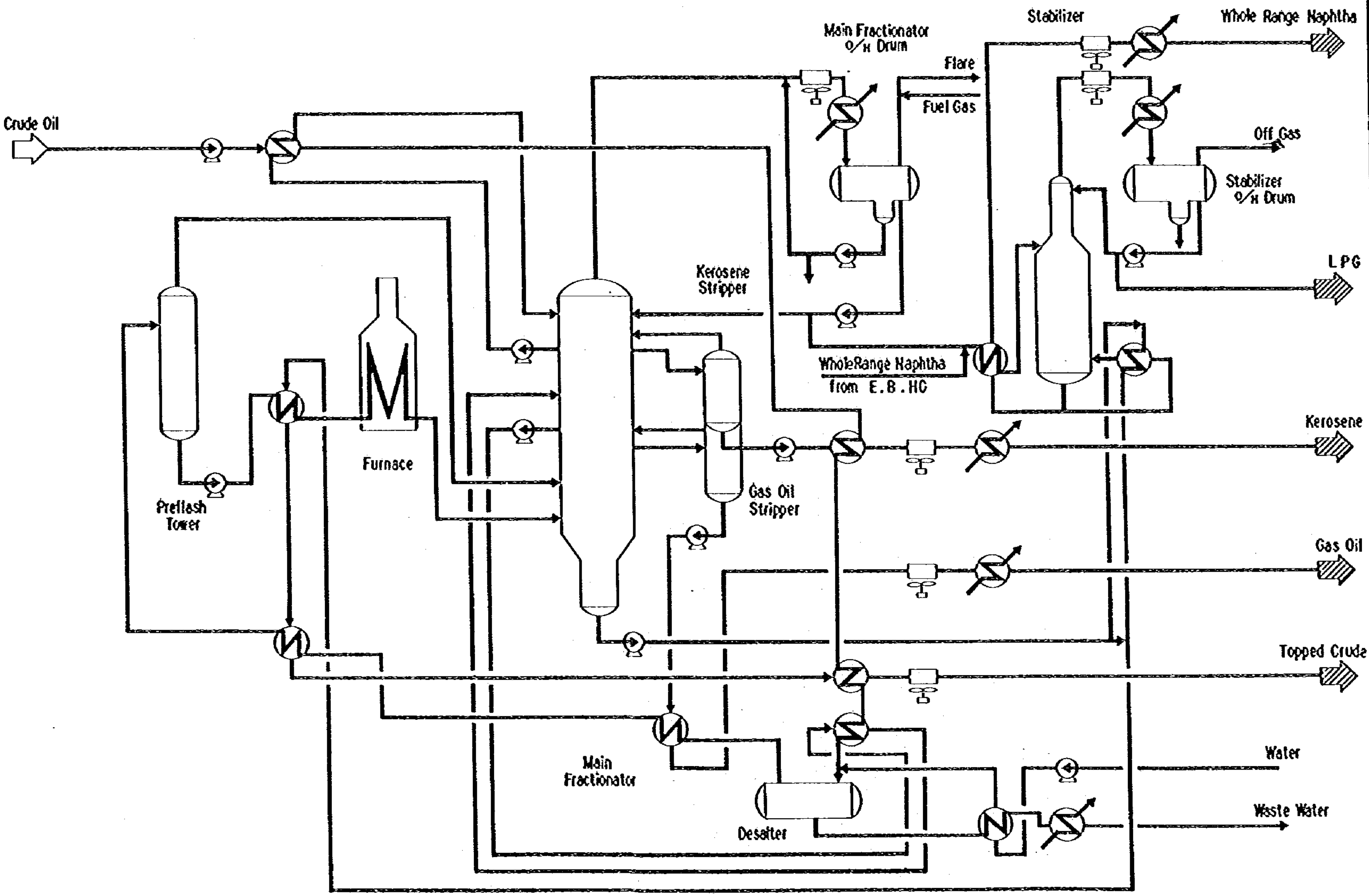
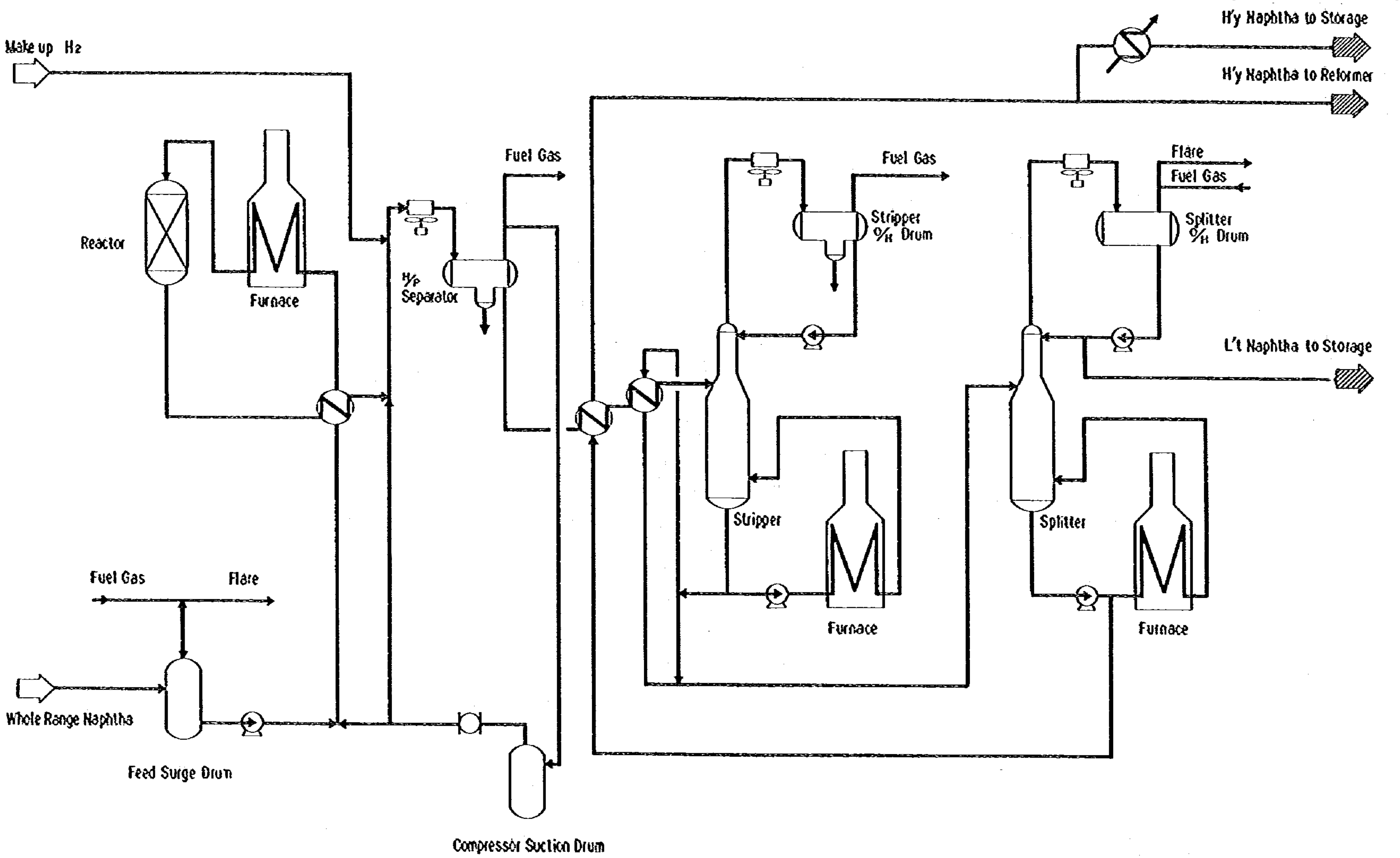


Fig. VII-2 Flow Diagram of Refinery (2/11)
(Naphtha Hydrodesulfurization Unit)



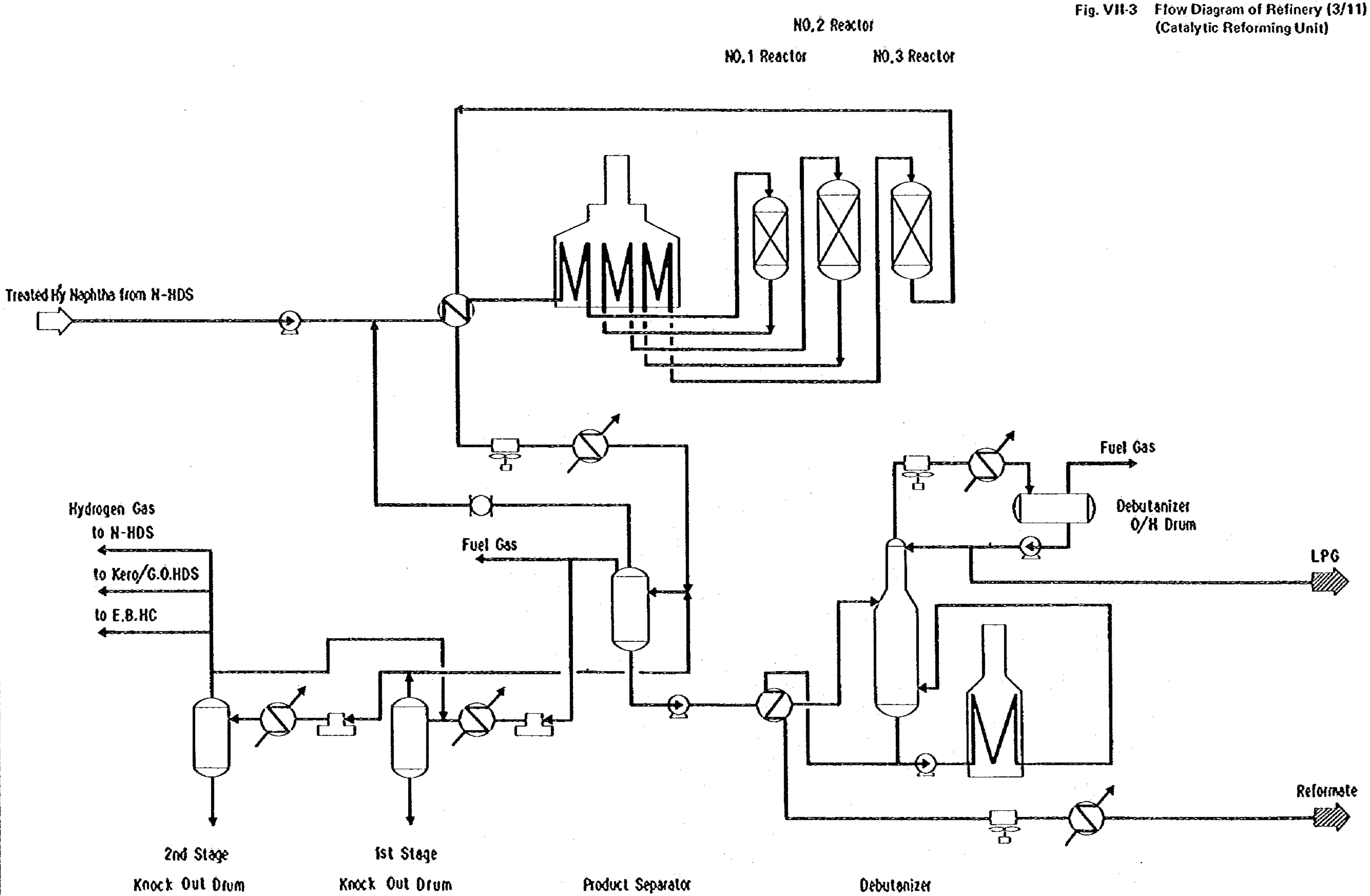


Fig. VII-3 Flow Diagram of Refinery (3/11)
(Catalytic Reforming Unit)

Fig. VII-4 Flow Diagram of Refinery (4/11)
(Kero./G.O. H.D.S Unit)

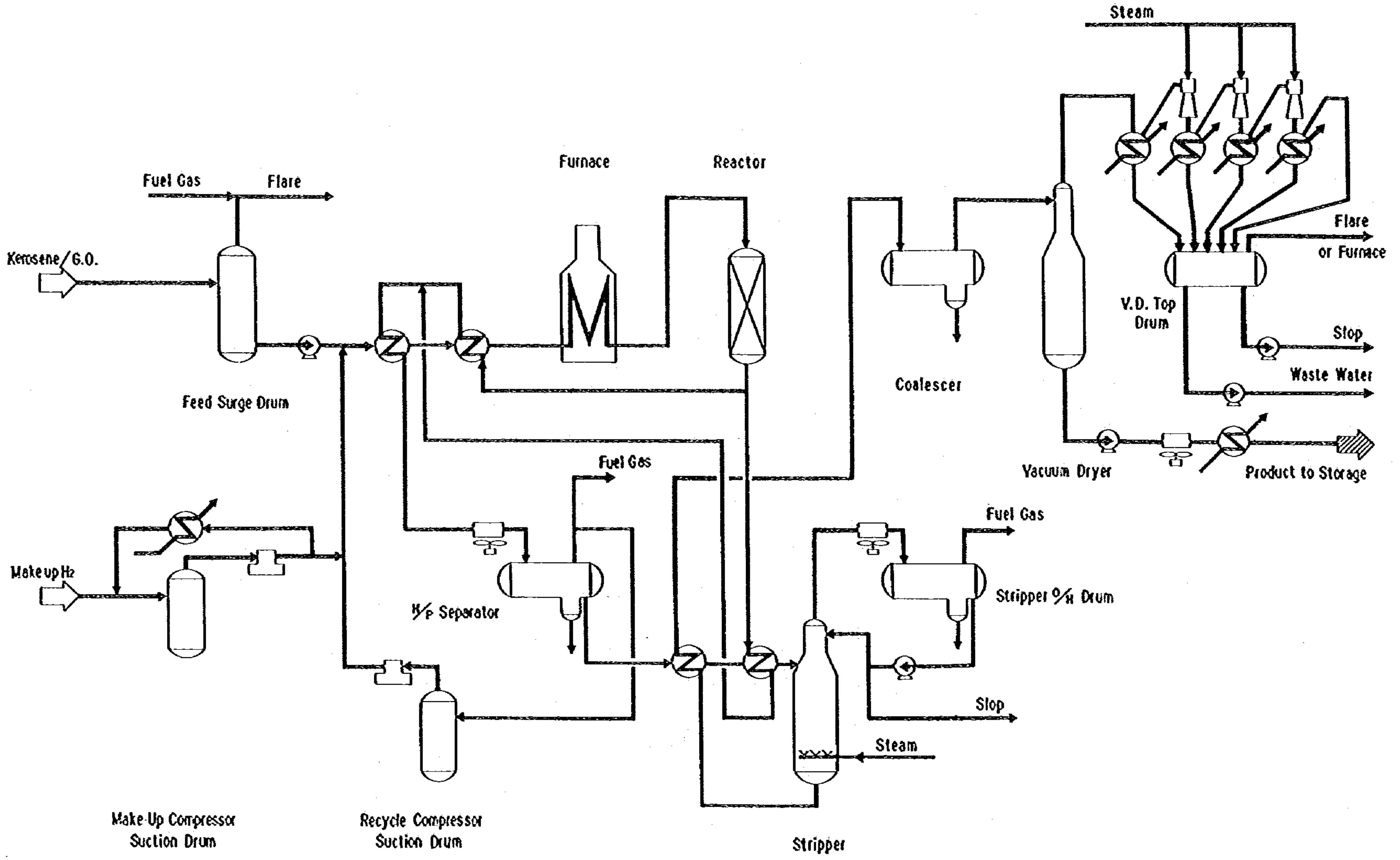


Fig. VII-5 Flow Diagram of Refinery (5/11)
(Vacuum Distillation Unit)

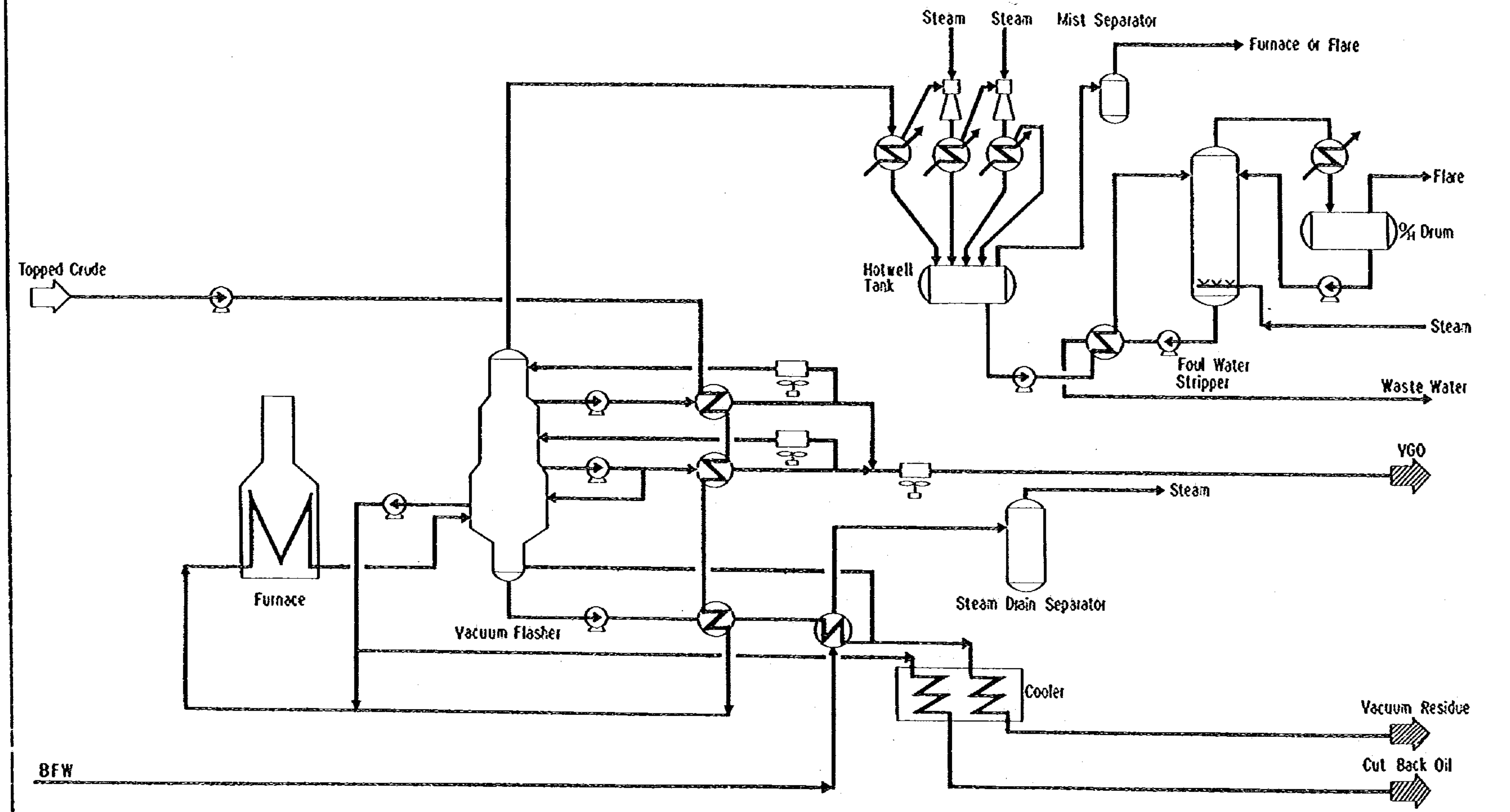


Fig. VII-6 Flow Diagram of Refinery (6/11) (FCC Unit)

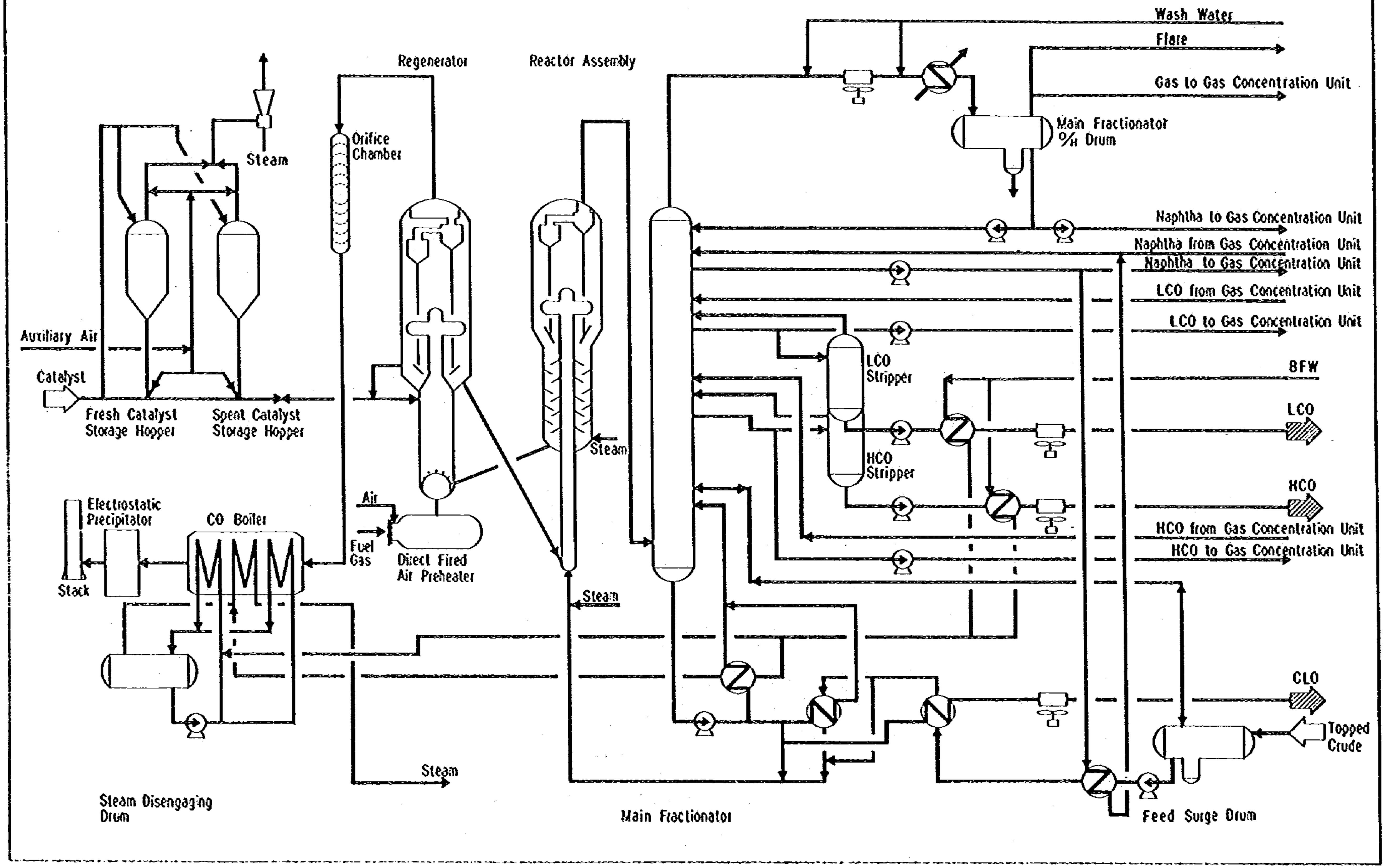


Fig. VII-7 Flow Diagram of Refinery (7/11)
(Ebullated-Bed Hydrocracking Unit)

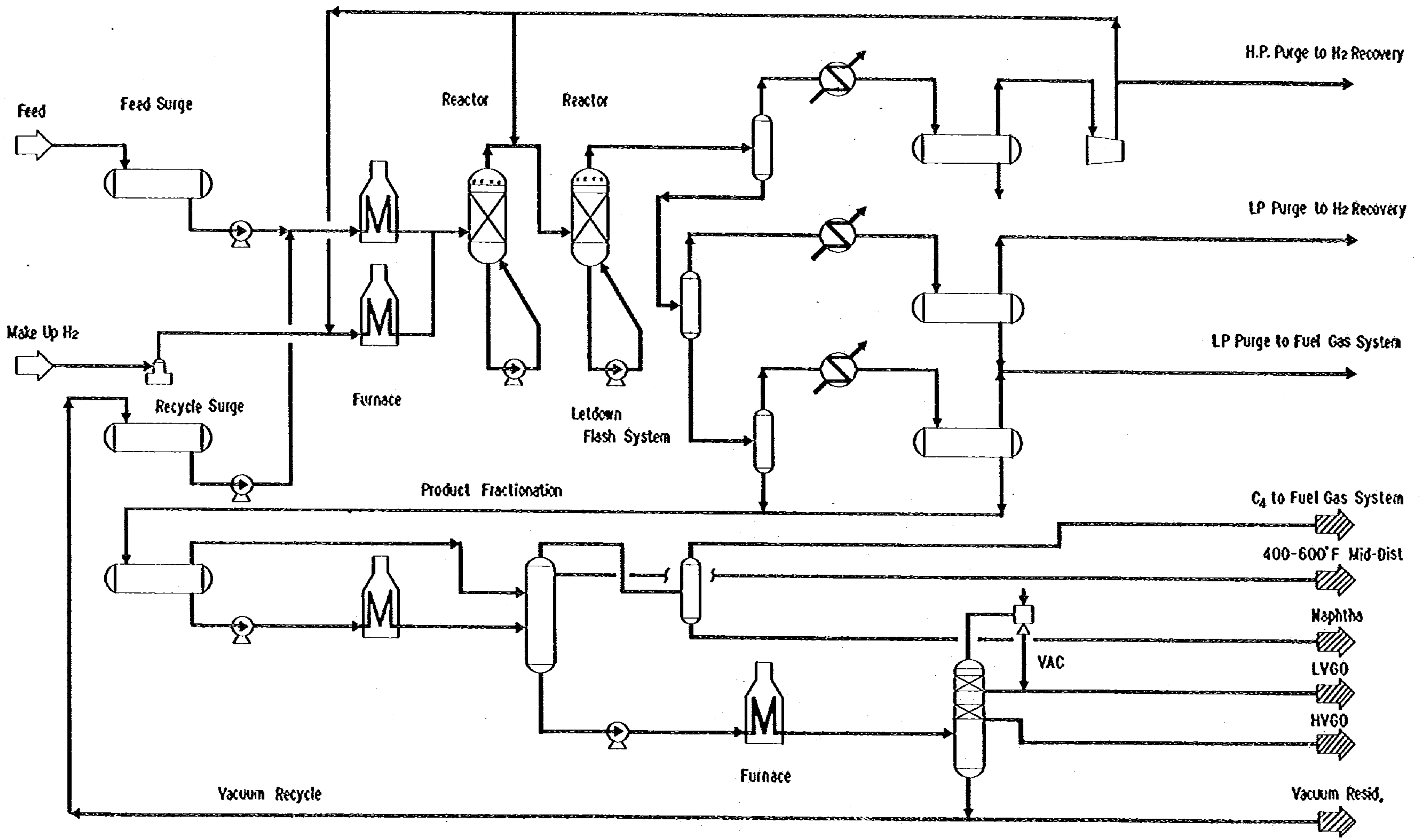


Fig. VII-8 Flow Diagram of Refinery (8/11)
(Gas Concentration Unit)

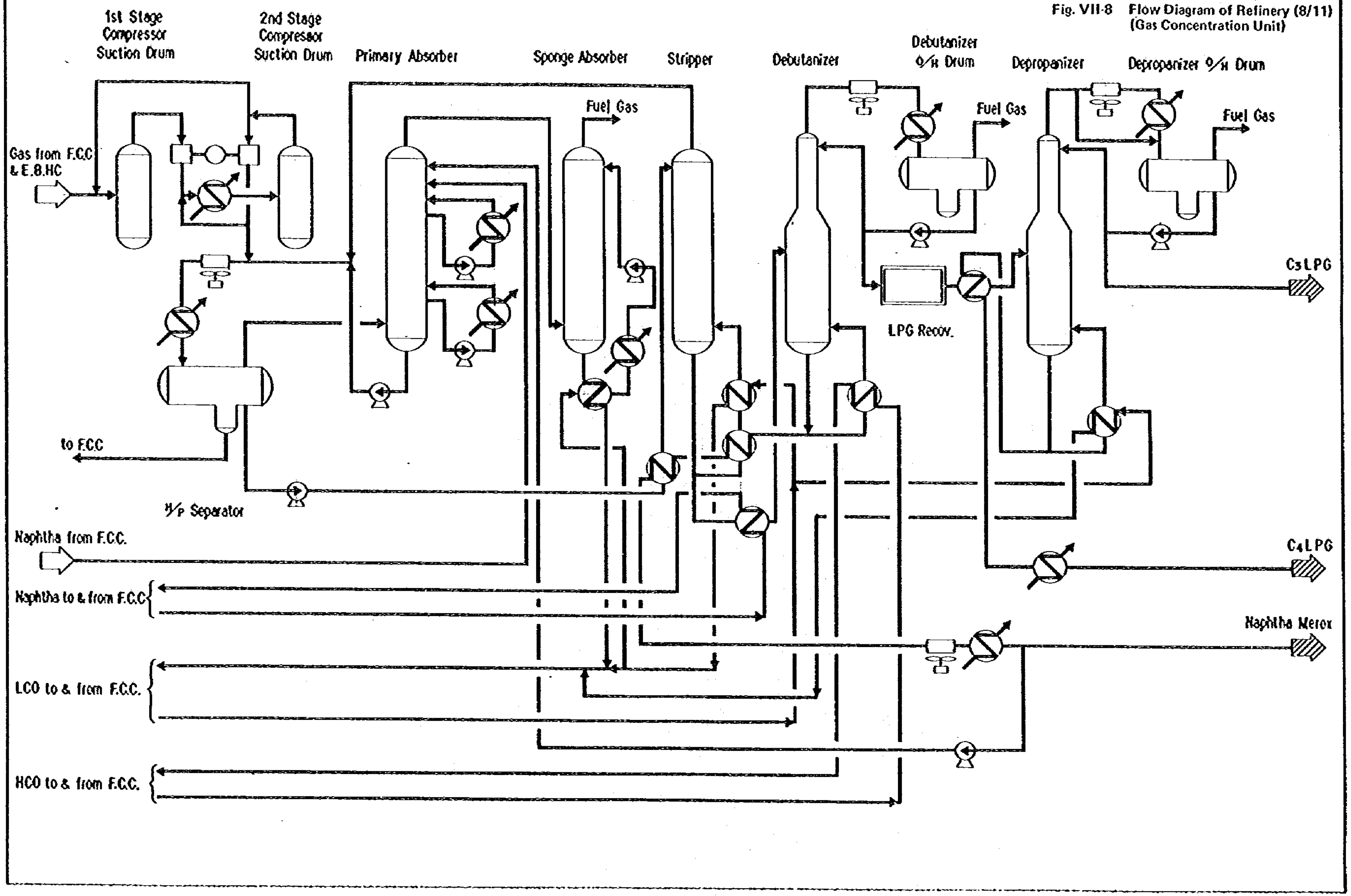


Fig. VII-9 Flow Diagram of Refinery (9/11)
(LPG Recovery Unit)

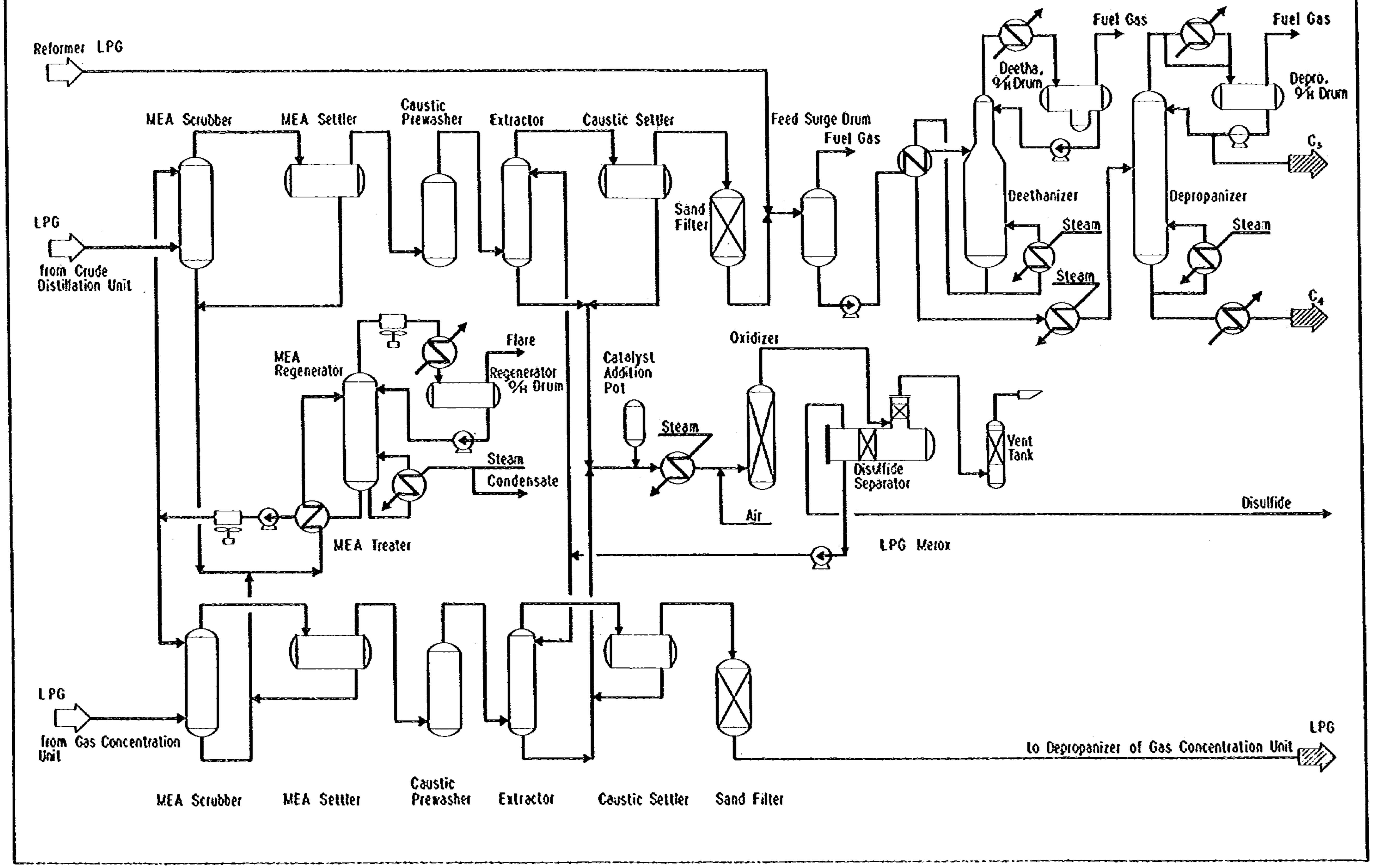


Fig. VII-10 Flow Diagram of Refinery (10/11) ((Naphtha Merox Unit)

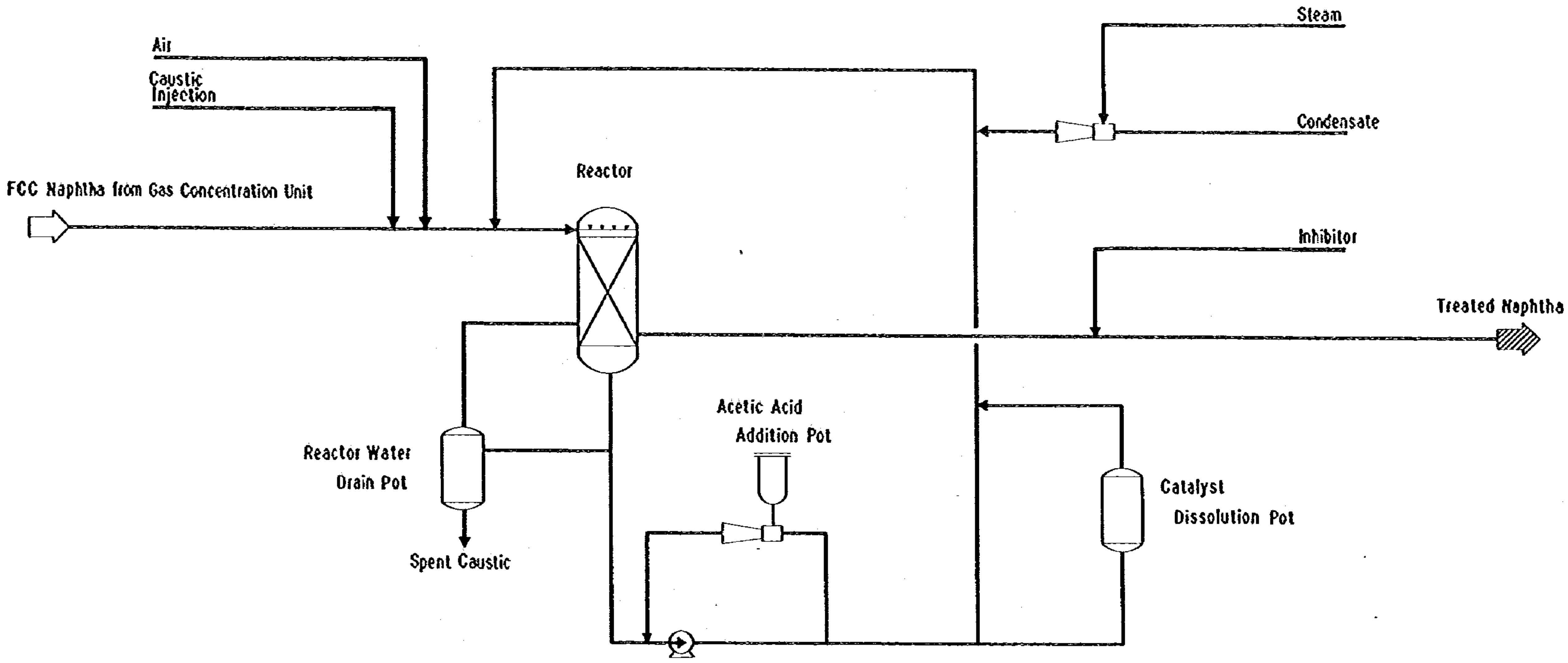
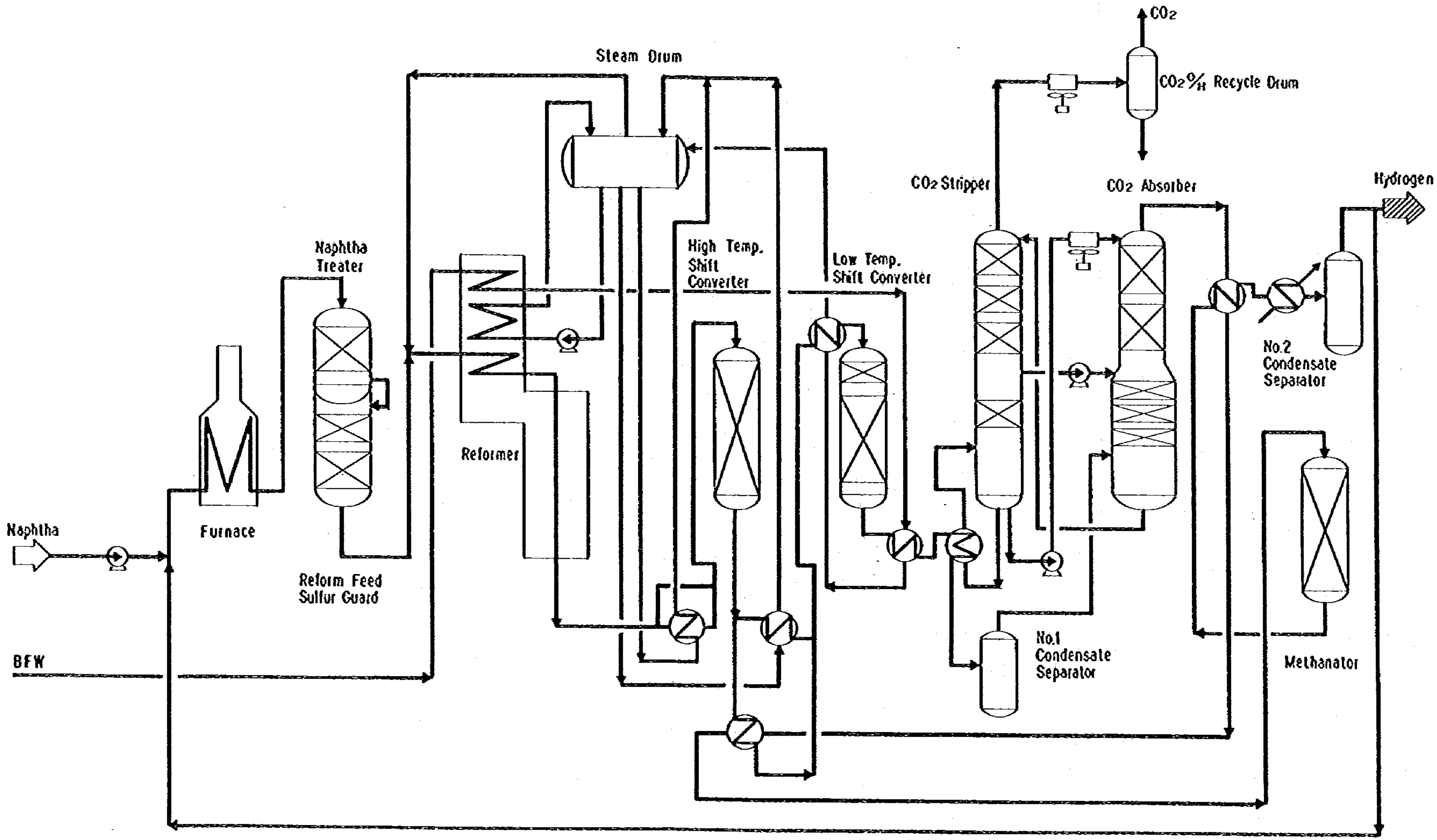


Fig. VII-11 Flow Diagram of Refinery (11/11)
(Hydrogen Production Unit)



1.1.2 Utility facility

(1) Water intake and water treatment facility

About 300 t/h of water is required for boiler feed, process, cooling and drinking water, and a total design capacity of the water facility is 320 t/h.

The water to be taken in from River Motagua flowing near the proposed site for the oil refinery is treated by coagulation and filtration for use as industrial water. The filtrated water is further treated by a demineralizing unit for use as boiler feed and process water, and in part is chlorinated for use as drinking water.

(2) Cooling tower

Since taking in too much water from River Motagua cannot be expected in the dry season and also returning too much used warm water to the river is not preferable, a circulating water cooling tower system has been adopted to minimize the quantity of water taken in from the river, along with installation as many air-cooled exchangers as possible.

The cooling water cooled by the cooling tower is supplied to each equipment by circulating pumps.
Equipment are cooled by heat exchange with cooling water. Heat exchanged warm water is led to the top of the cooling tower by self pressure force, contacts with rising, countercurrent air that is sucked in by draft fans while flowing down the tower naturally, in part evaporates, resulting in cooling down to the required temperature, flows in the water tank installed at the bottom of the cooling tower, and recirculated to machinery and equipment.

The cooling capacity is set at 9,500 t/h with 20% allowance added to the required quantity of 7,910 t/h.

An appropriate amount of industrial water is continuously supplied to supplement the evaporation and drift loss in the cooling tower and the loss of blow-down which is necessary to control the quality of cooling water. Physical and chemical troubles may occur in the circulation water while it is repeated by used, such as growth of iron bacteria and algae as well as deposits of scale and corrosion. Therefore, chemical injection units are installed to control the quality of water.

There are several types of cooling facilities available, such as, spray pond, natural draft cooling water, etc., out of which has been selected a forced draft cooling tower which is highly efficient, requires a smaller installation area and has a small drift loss.

(3) Boiler

The steam consumption by the oil refinery is estimated to be 192 t/h including the consumption by the turbine for power generation. Inasmuch as about 70 t/h steam is estimated to be generated by recovering waste heat from within the refinery, the required amount of steam to be generated by the boiler is about 122 t/h, including the self-consumption of the boiler.

A boiler is indispensable for a safe and stable operation of refinery plants, and requires periodical inspection and repair. In consideration of the above, three biolers, each having steam generating capacity of 65 t/h have been planned to be installed.

(4) Power generator

Now that the new hydraulic power station started operation, Guatemala has allowance in the power generating capacity. However, because of unreliability on a stable power supply and high power rates, it is more economical for the refinery to install its own power generation plant.

The power consumption of this oil refinery is estimated to be 15,600 KW, three power generators, each having power generating capacity of 9 MW.
Generated power is supplied to each facility through secondary substations installed within the refinery to reduce its voltage down to required voltages.

Power temporarily used for construction and initial startup of the refinery is expected to be supplied by INDE. The power receiving facility is installed so that externally supplied power is able to be used as backup power to protect the plant facilities of the refinery in the event of power failure which might occur in its own power plant.

(5) Demineralization unit

The demineralization unit is intalled to remove inorganic salts dissolved and silica contained in biler feed water.

The quality required of boiler feed water is determined, dependent on its application, operating conditions and evaporating capacity. The demineralizing unit has been so designed as to obtain the following figures on the quality of boiler feed water:

- o Electrical conductivity 1 micro MHO/cm max.
- o Silica contents (as SiO_2) 50 ppb max.

Since a major part of boiler feed water is recycled from condensates recovered from the exhaust steam of the turbines for driving power generators, process pumps and compressors, the capacity of the demineralization unit is set at net 1,560 t/d in consideration of regeneration time of ion exchange resin.

(6) Condensate recovery system

In order to reduce the quantity of water to be taken in and to decrease the capacity of water treatment facility and that of the demineralization unit, as much steam condensate as possible should be recovered and recycled within the oil refinery to be reused as boiler feed and process water. The steam condensates from turbines for power generators, high output driving turbines and steam heaters are reovered and stored in the condensate tanks installed in the utility area and recycled as boiler feed water. The amount of condensates to recover is estimated to be about 108 t/h, and the capacity of the recovery system is 120 t/h.

(7) Compressed air system

Instrument and plant air are needed as compressed air by the oil refinery. The instrument air is first compressed and cooled, and then dehumidified by a dryer to lower its dew point down to 0°C at the atmospheric pressure, and supplied to each instrument generally at 7.0 kg/cm^2G.

The estimated consumption of instrument air is about 2,000 Nm^3/h. Instrument air is supplied by the main compressor at all times or a spare compressor having the same capacity which automatically start when the pressure of instrument air drops, so that the pressure of instrument air is constantly kept at a certain level.

The plant air is used always for handling of catalysts for the fluid catalytic cracking unit, and also used for catalyst regeneration intermittently. The capacity of the compressor for plant air is 2,000 Nm^3/h x 2 sets, same as that for instrument air and in case the pressure for instrument air drops, the plant air compressors can back up, too.

(8) Home fuel system

Off-gases by-produced during crude oil refining are used with top priority for home fuel consumption and fuel shortage is generally filled by fuel having lower product value. Balancing the production and estimated demands for petroleum products in Guatemala, LPG is expected to result in excess in the new oil refinery. Therefore, an LPG vaporizer is installed to use LPG as home fuel. Further shortage is filled by home fuel oil.

The estimated fuel consumption is about 196 million Kcal/h, while the estimated off-gas by-produced from the refinery is 48 million Kcal/h. Accordingly, the calorific value to be supplied with LPG and fuel oil is estimated to be about 148 million Kcal/h.

The designed capacity for each home fuel system to cover a total consumption with these fuel is as follows:

o	LPG vaporizer	20 t/h
o	Liquid fuel facility	40 kl/h

1.1.3 Storage tanks

Planning of storage tanks is very important since the oil refinery processes a large amount of crude oil and requires a number of intermediate and products tanks because of a lot of process units and various products involved.

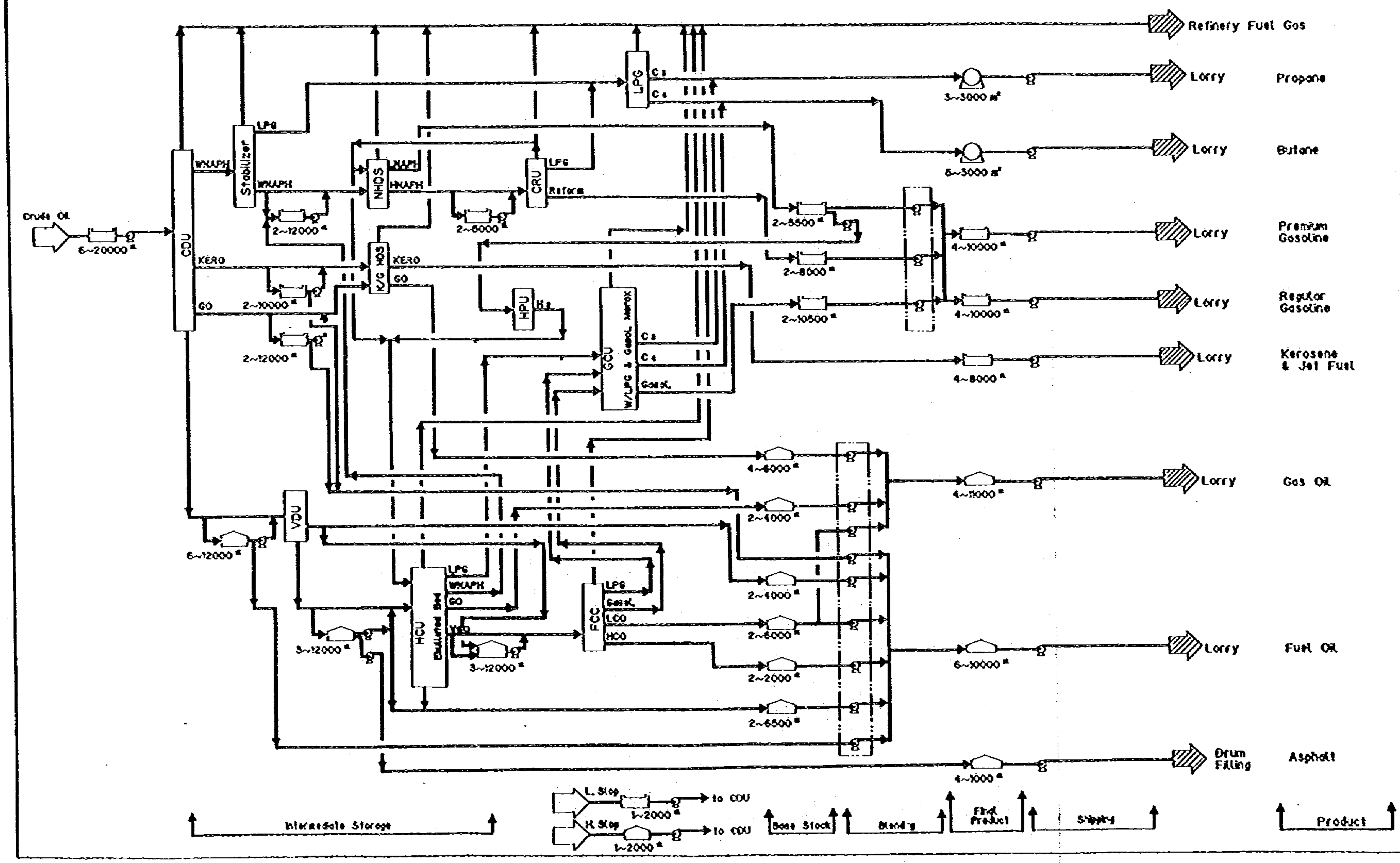
Fig. VII-12 shows the flow of storage tanks.

Crude oil is first fractionated by the crude distillation unit and then each fraction is processed by each process unit. Intermediate tanks are installed between a process unit and the next in consideration of a stable operation. Among various products from the final process, gasoline, gas oil and fuel oil are temporarily stored in base stock tanks, blended by a line blender, and then stored in final product tanks. LPG and kerosene are directly stored from the final process to final product tanks. LPG, kerosene, gasoline, gas oil and fuel oil are shipped from the final product tanks by lorry, while asphalt is filled in drums and shipped by truck.

1.1.4 Auxiliary facilities

There are the following auxiliary facilities installed in this oil refinery:

Fig. VII-12 Tank Flow Sheet at Refinery



- o Waste water treatment system
- o Blowdown and flare system
- o Fire fighting facility
- o Communication system
- o Building
- o Others

The following outlines these auxiliary facilities.

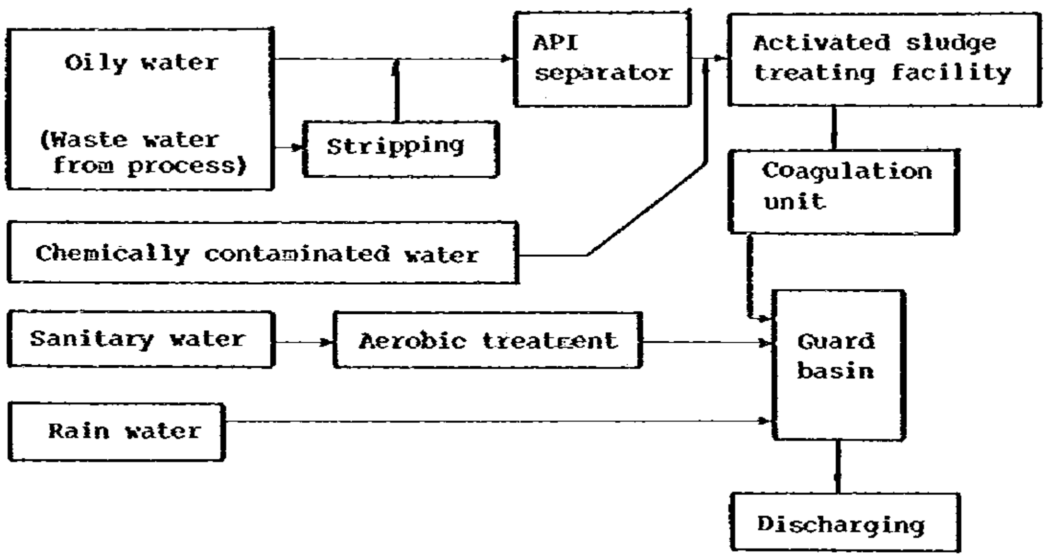
(1) Waste water treatment system

Waste water from the oil refinery can be generally classified into the following four streams:

Stream	Main source
Rain water	Street run-off Tank area and utility area run-off Building roof drain
Oily water	Process drain Tank drain Waste water from process area and shipping facilities Maintenance shop Laboratories
Chemically contaminated water	Desalter MEROX unit Waste water from ion exchange resin regeneration of demineralization unit

Sanitary water	Canteen Lavatories

Since the oil refinery is constructed in an inland area and the waste water is discharged into River Motagua, the waste water must be sufficiently treated. Therefore, the following systems have been adopted so as not to contaminate Motagua river water:



Oily water flows into the API separator and oil contained in the water is reduced to 5 to 15 ppm. Waste water from refining processes such as desalting, distillation, desulfurization and cracking contains oil, hydrogen sulfide, ammonia and phenol causing offensive odor and water contamination, as well as disturbing living activity of micro-organisms during biological treatment, except a small amount of ammonia. Therefore, in order to eliminate them, a foul water stripper (32 t/h capacity) is installed in the process area, and hydrogen sulfide, ammonia and phenol are separated from the vapor, burned off and discarded to the flare stack. The treated water from the foul water stripper is sent to the API separator.

Neutralized waste water of ion exchange resin regeneration discharged from the demineralization unit, waste water from the desalter and spend caustic water from the MEROX unit contain chemical materials. Therefore, they are mixed with treated water from the API separator, treated by the activated sludge treating facility and coagulation unit, and discharged to River Motagua via the guard basin.

Sanitary water is decomposed by aerobic treatment and discharged to River Motagua via the guard basin.

Rain water that does not contain oil is led to the guard basin through road side ditches or underground piping and discharged to River Motagua.

(2) Blowdown and flare system

Combustible gas generated from process plants is extracted out of the plants so as to control plant pressures to predetermined levels. Most of this gas is effectively used by a furnace as fuel, while low-pressure gas and excessive gas are extracted from the system and discharged.

On the other hand, when an emergency like fire, water or power failure, occurs, the system gas is discharged in order to avoid an abnormal rise of gas pressure in the system. If the pressure still rises, a large volume of gas is discharged at a time through relief valves to protect the equipment. At the time of routine checking, internal gas must be completely discharged prior to inspection or repairing of inside.

In either case, since gas discharged is inflammable and is dangerous to discharge directly into the atmosphere, the gas is burned off in the flare stack before being discharged into the atmosphere. The gas to be burned off in the flare stack is collected in the flare header from all the process plants, after entrained mist and drain having been separated in a knock-out drum led to the burner at the top of flare stack and burned off.

(3) Fire fighting facility

An oil refinery must be equipped with sufficient fire fighting facility to be prepared for an accident since a large amount of inflammable oil is stored and processed in an oil refinery. Although there is no legal regulation for the fire fighting facility, the fire fighting facility is based on the Japanese fire fighting law and NFPA standards of USA. The fire fighting facility consists of the following three systems.

1) Water fire-fighting

The water fire fighting system has been so designed that water can be supplied from water storage tanks in the oil refinery through a loop of exclusive piping throughout the whole premises. The capacity of fire fighting water pump is determined to cover the quantity of water consumed by all fire-fighting facilities used within the same hazardous area its head is determined with a sufficient allowance provided to required tip pressure. Two sets of spare fire-fighting water pumps are installed for a case of pump failure; one is an electric motor driven pump and the other is a diesel engine driven pump for a case of power failure.

2) Foam fire-fighting

A foam fire-fighting facility extinguishes fire by the suffocating effect of foams and is the most effective fire fighting facility in case of a large scale of oil fire. A fixed type of foam fire-fighting facility is installed for each tank. The fixed type foam fire-fighting facility consists of an air foam station and fixed piping that connects the water source with foam discharge outlet. Since foams can be discharged by operating a valve only, a speedy and sure fire extinguishing effect can be expected.

3) Others

Fire extinguishers of various types are installed at required places so that any discoverer or operator at the position can take appropriate counteractions immediately in the initial stage of fire. Also, at some places, steam or water spray facilities are installed to help taking effective fire-extinguishing activities. Furthermore, fire engines and chemical fire engines are stationed in the oil refinery to secure a perfect fire-fighting system.

(4) Communication system

A telephone, paging and loud speaker system will be installed as communication facilities in the oil refinery. The public telephone lines of GUATEL are used for communication with the outside facilities, such as, crude oil terminal and booster station.

1) Telephone system

An in-house telephone network is established by installing a crossbar automatic switchboard. This telephone system is connected with the GUATEL line through a switchboard, so that communication can be made with external telephone network system. Since this telephone system is equipped with direct current power source, communication can be made for 30 minutes after power failure has occurred.

2) Paging system

An independent paging system is installed in each of the process area, utility area and off-site area for calling, commanding and paging between control rooms and fields. This system is also equipped with direct current power source, and operates for 30 minutes after the power supply has been turned off.

3) Loud speaker system

The loud speaker system is installed to broadcast correct time, chime, instructions, paging, etc. in the whole area of the refinery. In places where the above paging system has been installed, loud speakers are used commonly by this system.
Simultaneous communication and instruction to be issued in case of emergency throughout the refinery are made through this system.

(5) Buildings

Buildings in the refinery can be classified generally into buildings that are not directly related with production, such as, administration offices, welfare facilities, etc. and buildings that are directly related with production like the control rooms. When this project materializes and when designing such buildings security and labor hygiene factors must be taken into consideration.

(6) Others

Auxiliary facilities necessary for management, control and operation of the refinery are planned as follows:

- o Maintenance equipment and tools
- o Laboratory equipment
- o Protective appliances
- o First-aid appliances
- o Internal transportation

1.2 Plot Plan

About 980,000 m² is estimated to be required for the construction of the oil refinery. The refinery has been laid out on the west side of the paper mill located in El Rancho. Since a river runs through this site near the central part, splitting it into two areas, they are tentatively to be called the Western and Eastern Part respectively. The facilities laid out in each Part are shown below:

Eastern Part (about 570,000 m²)

Process plants, crude oil tanks, intermediate tanks, utility facilities, offices

Western Part (about 410,000 m^2)

Product tanks, shipping facilities

A special attention has been paid to the following points when preparing this plot plan:

(1) The site is located between Motagua river and a mountain, and there is a village near the site. Although the best way to make an ideal plot plan for the oil refinery is to secure one unit of land by scraping the mountain and detouring National highway No. 17, the above conclusion has been reached from a economic point of view.

(2) The crude oil tanks have been laid out in the Eastern Part since the part is closer to Route CA9, along which the pipeline for crude oil is proposed to be installed. Therefore, the crude oil processing plants have been laid out in the Eastern Part.

(3) Because of an areal limitation product tanks and shipping facilities have been plotted in the Western Part.

(4) When the Motagua river water increases, its basin expands. The site for the Western Part has been defined with such basin expansion taken into consideration.

The plot plans for the Eastern Part and Western Part are shown in Fig. VII-13 and Fig. VII-14, respectively.

Fig. VII-13 Plot Plan (Eastern Part)

(Area: 574,400 m²)

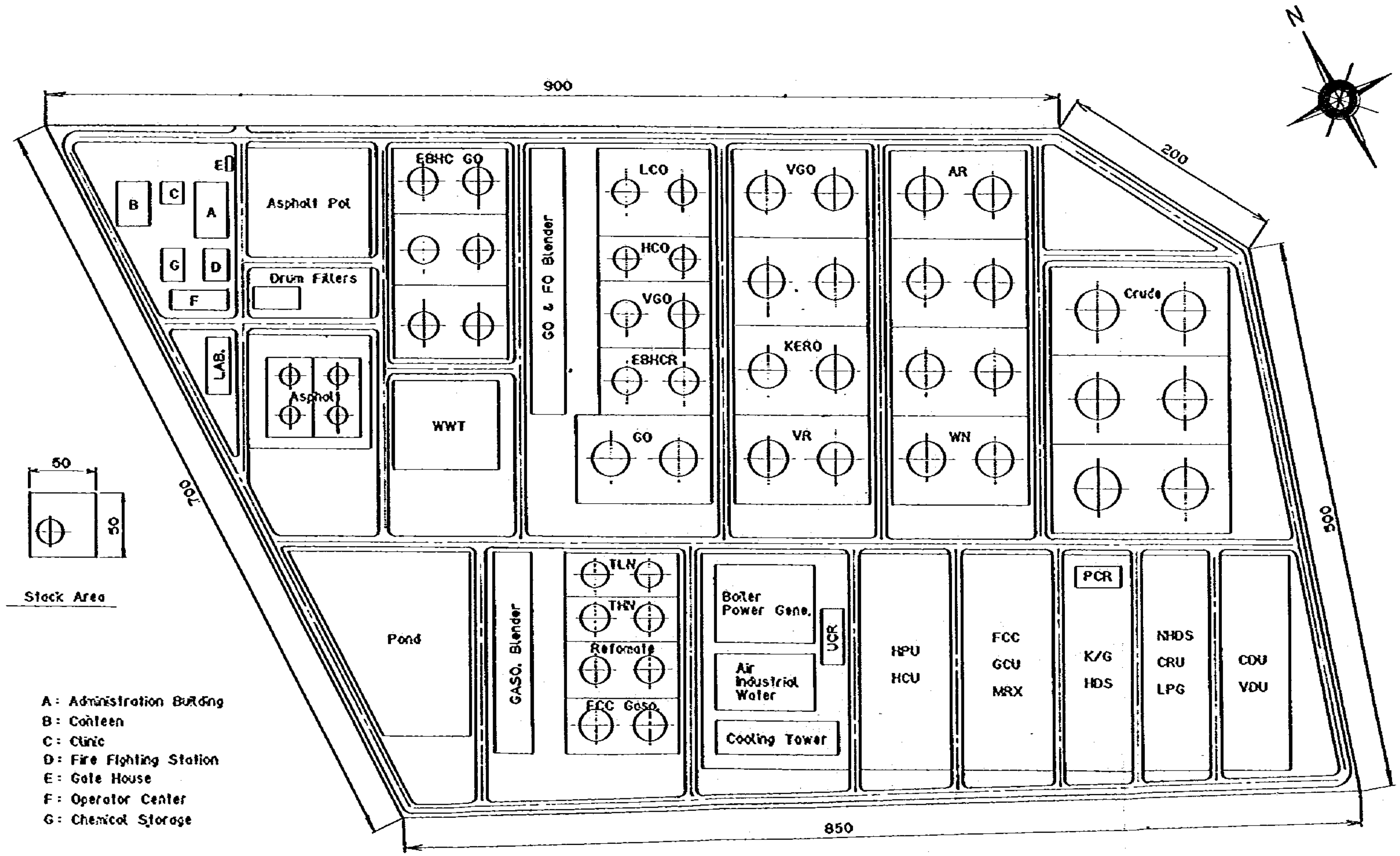
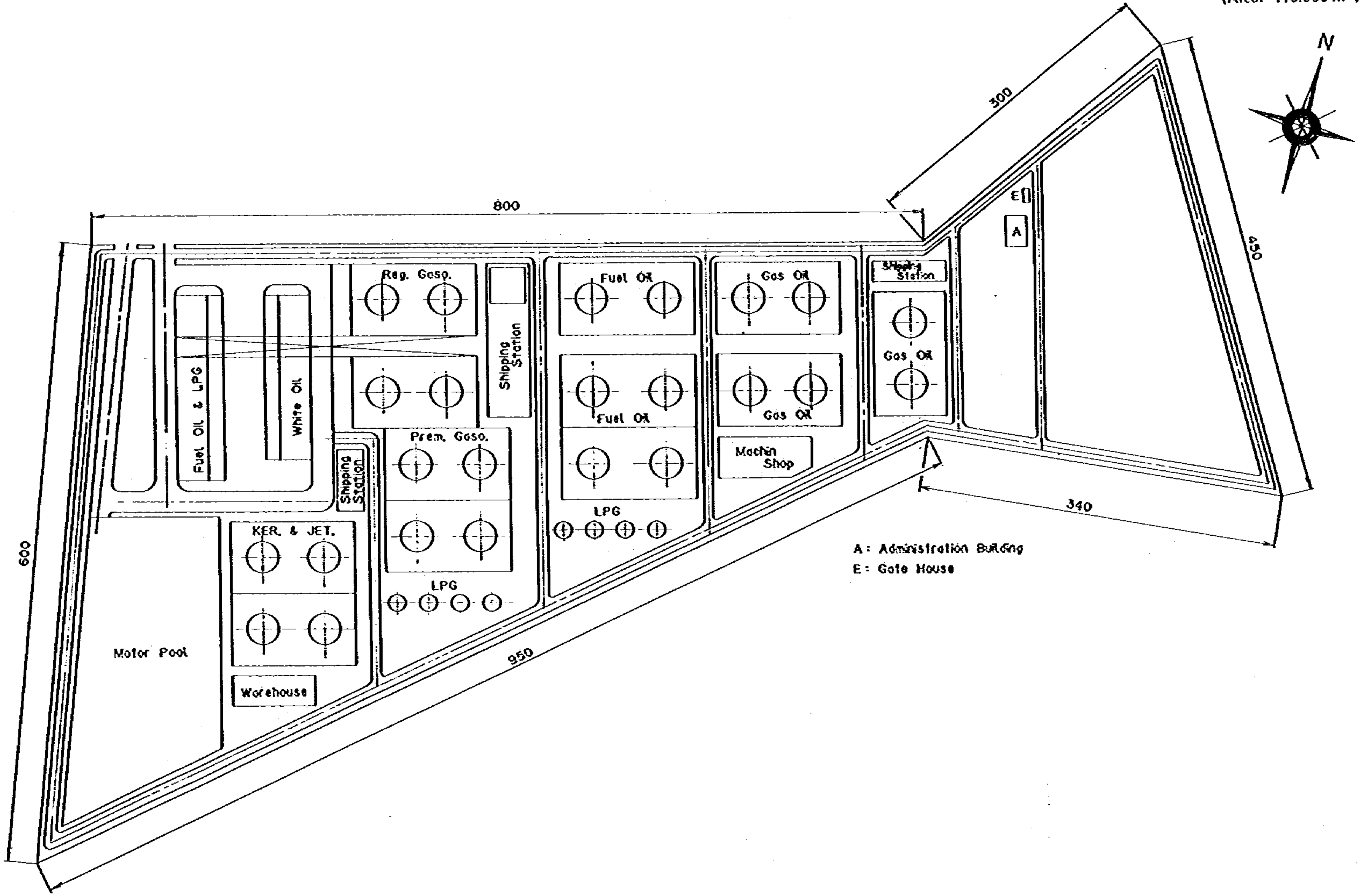


Fig. VII-14 Plot Plan (Western Part)

(Area: 410.900 m²)



1.3 List of Major Facilities

Table VII-1 shows the major facilities for the oil refinery (excluding tanks, shipping facilities and buildings).

Table VII-2 shows a list of tanks

Table VII-3 shows a list of shipping facilities.

Table VII-4 shows a list of buildings.

Table VII-1 Main Equipment List of Refinery (1/15)

[Process Unit]

Item No.	Service	Q'ty	Description	Material	Remarks
	<u>Crude Distillation Unit</u>				
1	Preflash Tower	1	Baffle Tray	C.S.	C.S.: Carbon Steel
2	Main Fractionator	1	$3,700^{I.D.} \times 38,000^{L}$ Valve Tray	C.S./Stainless Clad Steel (T.P. & Bt'm)	
3	Kerosene Stripper	1	Valve Tray	C.S.	
4	Gas Oil Stripper	1	Ditto	Ditto	
5	Stabilizer	1	Ditto	Ditto	
6	Curde Charge Heater	1		Cr-Mo Alloy Steel	
7	Vessles	11		C.S.	
8	Heat Exchangers	24	Shell & Tube Type	Ditto	
8-2	Heat Exchangers	8	Air Fin Type	Ditto	
9	Pumps	24	Centrifugal Type		
9-2		13	Reciprocating Type		

Table VII-1 Main Equipment List of Refinery (2/15)

(Process Unit)

Item No.	Service	Q'ty	Description	Material	Remarks
	Naphtha Hydrodesulfurization Unit				
1	Stripper	1	Valve Tray	C.S.	
2	Splitter	1	Ditto	Ditto	
3	Reactor Charge Heater	1		Cr-Mn Alloy Steel	
4	Stripper Reboiler	1		C.S.	
5	Splitter Reboiler	1		Ditto	
6	Reactor	1		Carbon-Mo Alloy Steel with Stainless Clad Steel	
7	Vessles	7		C.S.	
8	Heat Exchangers	12	Shell & Tube Type		
8-2		7	Air Fin Type		
9	Recycle Gas Compressor	1	Centrifugal Type		
10	Pumps	14	Ditto		
10-2		2	Reciprocating Type		

Table VII-1 Main Equipment List of Refinery (3/15)

[Process Unit]

Item No.	Service	Q'ty	Description	Material	Remarks
	Naphtha Catalytic Reforming Unit				
1	Debutanizer	1	Valve Tray	C.S.	
2	Reactor Charge Heater	1		Cr-Mo Alloy Steel	
3	No.1 Intermediate Heater	1		Ditto	
4	No.2 Intermediate Heater	1		Ditto	
5	Debutanizer Reboiler	1		C.S.	
6	No.1 Reactor	1		Cr-Mo Alloy Steel	
7	No.2 Reacotr	1		Ditto	
8	No.3 Reactor	1		Ditto	
9	Vessles	6		C.S.	
10	Heat Exchangers	11	Shell & Tube Type		
10-2		4	Air Fin Type		
11	Recycle Gas Compressor	1	Centrifugal Type		
12	Booster Compressor	2	Reciprocating Type		

Table VII-1 Main Equipment List of Refinery (4/15)

[Process Unit]

Item No.	Service	Q'ty	Description	Material	Remarks
13	Pumps	12	Centrifugal Type		
13-2		2	Reciprocating Type		
14	Steam Generator	1 set	Flue Gas Heat Recovery		
	Kerosene/Gas Oil HDS Unit				
1	Stripper	1	Valve Tray	C.S.	
2	Vacuum Dryer	1	Baffle Tray	Ditto	
3	Reactor Charge Heater	1		Stainless Steel	
4	Reactor	1		Carbon-Mo Alloy Steel with Stainless Clad Steel	
5	Vessles	9		C.S.	
6	Heat Exchangers	14	Sheel & Tube Type		
6-2		8	Air Fin Type		
7	Recycle Gas & Make up Gas Compressor	2	Reciprocating Type		
8	Pumps	10	Centrifugal Type		

Table VII-1 Main Equipment List of Refinery (5/15)

[Process Unit]

Item No.	Service	Q'ty	Description	Material	Remarks
8-2		2	Reciprocating Type		
	<u>Vacuum Distillation Unit</u>				
1	Vacuum Flasher	1	$5,300^{ID} \times 23,700^{L}$	C.S.	
			Glitsch Grid & Bubble Cap Tray	(Partly with Stainless Clad Steel)	
2	Foul Water Stripper	1	Sieve Tray	C.S. (Bt'm: Stainless Clad Steel)	
3	Vacuum Flasher Charge Heater	1		Cr-Mo Alloy Steel	
4	Vessles	4		C.S.	
5	Heat Exchangers	20	Shell & Tube Type		
5-2		2	Box Type		
5-3		8	Air Fin Type		
6	Pumps	15	Centrifugal Type		

Table VII-1 Main Equipment List of Refinery (6/15)

[Process Unit]

Item No.	Service	Q'ty	Description	Material	Remarks
	<u>Fluid Catalytic Cracking Unit</u>				
1	Main Fractionator	1	$3,400^{ID} \times 34,000^{L}$ Valve Tray	Top: C.S. with Stainless Clad Steel Bt'm: Cr-Mo Alloy Steel with Stainless Clad Steel	
2	LCO Stripper	1	Valve Tray	C.S.	
3	HCO Stripper	1	Ditto	Ditto	
4	Direct Fired Air Preheater	1		Ditto	
5	Regenerator	1		Ditto	
6	Reactor Assembly (Reactor)	1		Cr-Mo Alloy Steel with Stainless Clad Steel	
	(Stripper/Riser)			Cr-Mo Alloy Steel	
7	Vessles	13		C.S.	
7-2		1	Orifice Chamber	Stainless Steel	

Table VII-1 Main Equipment List of Refinery (7/15)

[Process Unit]

Item No.	Service	Q'ty	Description	Material	Remarks
8	Heat Exchangers	17	Shell & Tube Type		
8-2		10	Air Fin Type		
9	Air Blower	1	Centrifugal Type		
10	Pumps	29	Ditto		
10-2		3	Reciprocating Type		
11	CO Boiler	1 set			
12	Electro Static Precipitator	1 set			
	<u>Ebullated-Bed Hydrocracking Unit</u>				
	Process licensor will notify the owner of the equipment list of this Unit in detail under a secrecy agreement.				
	<u>Gas Concentration Unit</u>				
1	Primary Absorber	1	Valve Tray	C.S.	
2	Sponge Absorber	1	Ditto	Ditto	
3	Stripper	1	Ditto	Ditto	

Table VII-1 Main Equipment List of Refinery (8/15)

[Process Unit]

Item No.	Service	Q'ty	Description	Material	Remarks
4	Debutanizer	1	Valve Tray	C.S.	
5	Depropanizer	1	Ditto	Ditto	
6	Vessels			Ditto	
7	Heat Exchangers	24	Shell & Tube Type		
7-2		6	Air Fin Type		
8	Gas Compressor	2	Reciprocating Type		
9	Pumps	18	Centrifugal Type		
	<u>LPG Recovery Unit</u>				
1	MEA Scrubber	2	Packed Column (Raschig Ring)	C.S.	
2	Extractor	2	Sieve Tray	Ditto	
3	MEA Regenerator	1	Valve Tray	C.S. (Top: Stainless Clad Steel)	
4	Oxidizer	1	Packed Column (Raschig Ring)	C.S.	
5	Deethanizer	1	Valve Tray	Ditto	
6	Depropanizer	1	Ditto	Ditto	

Table VII-1 Main Equipment List of Refinery (9/15)

[Process Unit]

Item No.	Service	Q'ty	Description	Material	Remarks
7	Vessles	21		C.S.	
7-2	(MEA Regen. O/H Drum)	1		Stainless Steel	
8	Heat Exchangers	11	Shell & Tube Type		
8-2		1	Double Tube Type		
8-3		2	Air Fin Type		
9	Pumps	13	Centrifugal Type		
9-2		1	Reciprocating Type		
	<u>Naphtha Merox Unit</u>				
1	Reactor	1	Packed with Charcoal	C.S.	
2	Vessels	6		Ditto	
3	Pumps	2	Centrifugal Type		
3-2		2	Reciprocating Type		

Table VII-1 Main Equipment List of Refinery (10/15)

[Process Unit]

Item No.	Service	Q'ty	Description	Material	Remarks
	Hydrogen Production Unit				
1	CO_2 Absorber	1	Packed Column	C.S. (Bt'm: Stainless Clad Steel)	
2	CO_2 Stripper	1	Ditto	C.S. (Top: Stainless Clad Steel)	
3	Degasser	1		Top: Stainless Steel Bt'm: C.S.	
4	Naphtha Treater Header	1		Cr-Mo Alloy Steel	
5	Steam Reformer	1			
			(BFW)	C.S.	
			(Steam-Naphtha [Convection])	Cr-Mo Alloy Steel & Stainless Steel	
			(Steam-Naphtha [Radiation])	Cr-Ni Alloy Steel	
6	Naphtha Treater	1		Mn-Mo Alloy Steel	
7	Reformer Feed Sulfur Guard	1		Ditto	

Table VII-1 . Main Equipment List of Refinery (11/15)

[Process Unit]

Item No.	Service	Q'ty	Description	Material	Remarks
8	High Temperature Shift Converter	1		Mn-Mo Alloy Steel	
9	Low Temperature Shift Converter	1		C.S.	
10	Methanator	1		Mn-Mo Alloy Steel	
11	Vessels	15		C.S.	
11-2		4		Stainless Steel	
12	Heat Exchangers	12	Shell & Tube Type		
12-2		5	Air Fin Type		
13	Hydrogen Compressor	2	Reciprocating Type		
14	Pumps	19	Centrifugal Type		
14-2		3	Reciprocating Type		
	<u>Foul Water Stripping Unit</u>				
1	Stripper	1	Valve Tray	C.S. (Top: Stainless Clad Steel)	

Table VII-1 Main Equipment List of Refinery (12/15)

[Process Unit]

Item No.	Service	Q'ty	Description	Material	Remarks
2	Vesszles	2		C.S.	
3	Heat Exchangers	4	Shell & Tube Type		
3-2		1	Air Fin Type		
4	Pumps	7	Centrifugal Type		

Table VII-1 Main Equipment List of Refinery (13/15)

[Utility Facilities]

Item No.	Service	Q'ty	Description	Material	Remarks
1	Water Intake & Water Treatment	1 set	320 t/h		
2	Colling Water System	1 set	9,500 t/h		
3	Boiler	3 sets	65 t/h		
4	Power Generator	3 sets	9 MW		
5	Demineralization Unit	1 set	1,560 t/d		
6	Condensate Recovery System	1 set	120 t/h		
7	Compressed Air System	1 set	4,000 Nm^3/h		
8	Nitrogen Gas Generator	1 set	1,000 Nm^3/h (Gas 920 Nm^3/h, Liquid 80 Nm^3/h)		
9	Home Fuel System	1 set	(Fuel Oil 40 kl/h LPG 20 t/h Fuel Gas)		