reduced by blending asphalt or improved asphalt with low-coking coal prior to coking. This technology is increasingly arousing interest in the industry. There are various processes for producing coke from asphalt-containing feeds. They demand different properties from asphalt. In general, less volatile SDA asphalt containing a large amount of asphaltene can be regarded as a material more suitable for coke production than straight asphalt. This field of asphalt use is much promising, because large consumption can be expected once the technology is commercialized.

3.1.16 Operability

The solvent deasphalting process entirely consists of physical steps of mixing, extracting, evaporating, stripping, and heat-exchanging. It does not involve any complicated chemical reactions. The process can be operated by a combination of a temperature of 350°C or lower and a pressure of 35 kg/cm^2G or lower. It does not include any high-temperature or high-pressure section where operation is difficult to handle.

Furthermore, deasphalting can be run simply by microadjusting the operating temperature of the extractor, while checking on the properties of DAO and asphalt. Workup sections such as the solvent recovery section undergoes little change, once operating conditions have been set.

For these reasons, the SDA process can be highly evaluated as one of the processes easily capable of highly stable operations. The process units can be run smoothly at a yearly operating rate of more than 90%. During the initial period of operation, though, there may be some troubles caused by the lack of experience on the part of operators. As examples of conceivable troubles, there may be mentioned the clogging of SDA asphalt line, of solvent vapor line caused by bubbling in the asphalt stripper, of heating furnaces caused by asphalt coking, or of other instruments and lines caused by asphalt solidification.

Coking will occur if asphalt treatment temperature is raised above the predetermined level, or bubbles will occur if it is too low. It is thus essential to handle asphalt of a designated softening point at a predetermined temperature. Care should be taken for asphalt-transport lines, because if they are insufficiently heated, asphlt will solidify inside the lines. Causes of all these troubles are known, and we have troubleshooting measures established for them. Most of troubles can be avoided by careful attention. Asphalt may sometimes happen to flood in the extractor. This trouble can be completely prevented, as long as the extractor is run at predetermined levels of flow rate and temperature.

3.1.17 Process Scheme Variations

A general description was given in sub-section 3.1.13 as to a possibility of developing a variety of refining schemes by a combination of solvent deasphalting with other processes. In the sub-section, there will be described a possibility of a few upgrading schemes by way of solvent deasphalting, with a view to using them for the upgrading of Orinoco heavy crude.

We cannot deny a possibility of using such an upgrading process as thermal cracking (e.g., GO thermal cracking) or catalytic cracking in combination with solvent deasphalting. However, we will confine ourselves here to consider a combination of solvent deasphalting and hydrodesulfurization as a base case and additionally, to take up a combination thereof with hydrocracking. Solvent deasphalting can be used with, as its feeds, atmospheric and vacuum residues, and with the crude oils from which light fractions have to be removed to such an extent that solvent recovery may not be adversely affected. If light fractions exist in the feed exessively, a limit is inevitably set for the solvent ratio which can be lowered in solvent deasphalting. Furthermore, selectivity in demetalization also drops. For these reasons, we have decided to select either atmospheric or vacuum residue as the deasphalting feed from a practical point of view. Several upgrading schemes can be worked out by the selection of a solvent deasphalting feed and the use of a combination of solvent deasphalting with hydrodesulfurization or hydrocracking. Three major upgrading schemes and their features are as follows (See Fig. 3.2):

(1) AR SDA – HDS scheme

This is the simplest upgrading scheme. Atmospheric residue DAO has lower quality than does a vacuum residue DAO/VGO mixture. If the former DAO requires a high level of refining, the HDS unit has to bear a large burden with a resultant aggravated economics. This scheme therefore is suitable for a relatively less severe level of refining. The economics and product quality available in this scheme will be taken up in the next section, together with the description of an alternative case. As other variations of this scheme, there may be conceivable the HDS treatment of gas oil alone or further hydrocracking of a part of the product obtained by hydrodesulfurization of a GO/AR DAO mixture.

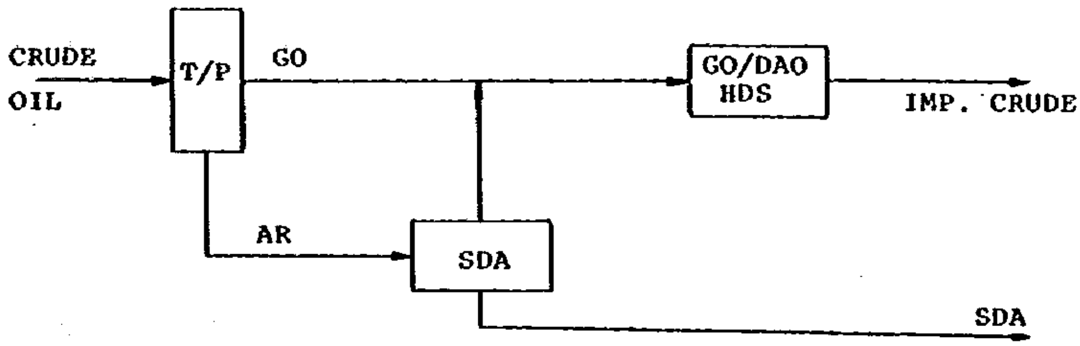
(2) VR SDA – HDS scheme

This is the most standard upgrading scheme for solvent deasphalting. A VGO/DAO mixture has suitable properties for deep hydrodesulfurization. This scheme will be described in details in the next section as the base case. As a process, this scheme is simpler than a case where gas oil is simulataneously treated by the VGO/DAO HDS unit, but separate treatment is more economic than the simultaneous treatment if a high level of desulfurization is required.

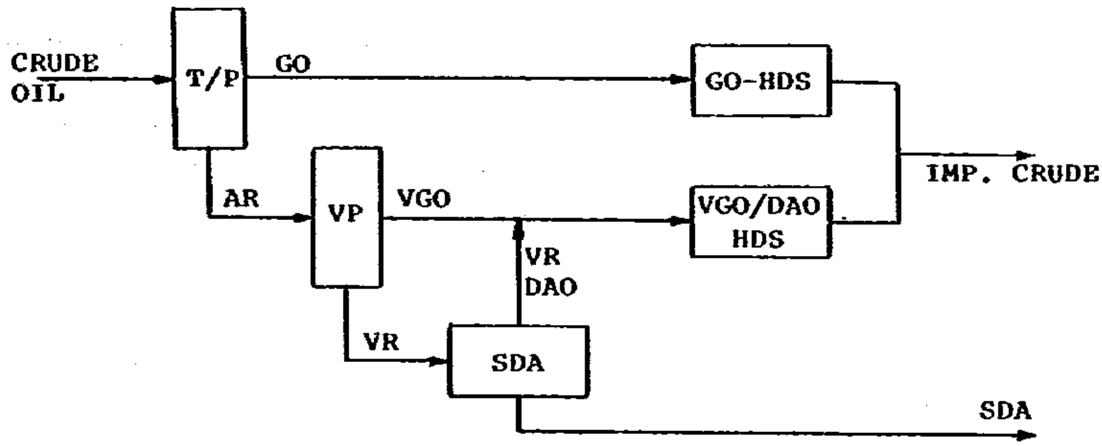
(3) VR SDA – HDS /HC scheme

The scheme is much more complicated than the above two schemes, but it gives

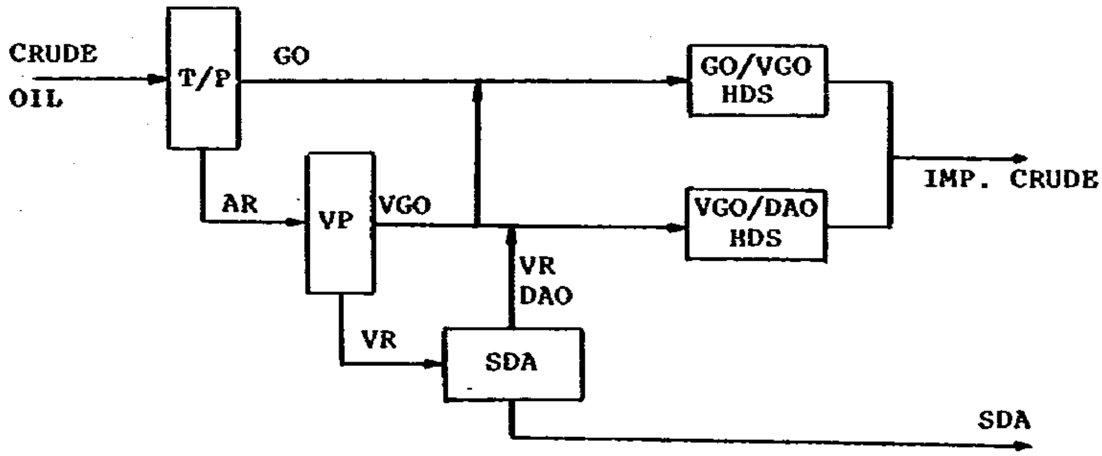
(1) AR SDA-HDS Scheme



(2) VR SDA-HDS Scheme



(3) VR SDA-HDS/HC Scheme



T/P: Atmospheric Distillation Unit

VP : Vacuum Flashing Unit

SDA: Solvent Deasphalting Unit

HDS: Hydrodesulfurization Unit

ORINOCO HEAVY OIL UPGRADING PROJECT

TYPICAL UPGRADING SCHEME BY SDA ROUTE

FIG. 3.2

higher flexibility in product yields and quality. This scheme is considered as the one to be adopted by a refinery located near its market where oil products are directly connected between the refinery and the market.

3.1.18 Future Prospect of Technical Development

As already described in some place or another in this chapter, the low solvent deasphalting technology we have developed is a remarkable improvement in process economics over conventional types of deasphalting, We have now found a possibility that our process may be even greatly improved in both of its economics and refineng level. We have thus decided to tackle again the R & D work for our process.

It has been decided that the Japanese Government would give subsidies to private companies to make them develop various substitute petroleum production technologies under a 7-year plan covering the 1980-1986 period. Maruzen Oil, with its experiences in a solvent deasphalting process of its own, decided to take part in this national project, and has already been awarded a subsidy for the development of a technology for upgrading heavy crude oils, such as Orinoco heavy crude and tar sand oil. Our R & D work shall cover the following range:

(1) To establish an improved solvent deasphalting technology inculding pretreatment.
(2) To establish a technology for hydrotreating deasphalted oil.
(3) To develop a technology for utilizing deasphalted oil.

The Orinoco oil belt development will be under way on a step-by-step basis over a long period. In our understanding this feasibility study is made for a Phase-I project. In preparing this report, we have resorted to our already developed M-DS process, but we are determined to commence on further R & D work, with a view to making an outstanding improvement in our M-DS process, giving priority to the technology for upgrading heavy crude oils. In this sense, we will be ready to make other more improved technical proposals during various stages of the long-term Orinoco heavy crude development project promoted by the Venezuelan Government.

3.2 PROCESS SCHEME FOR IMPROVED CRUDE OIL PRODUCTION

3.2.1 Introduction

Characteristics of the Orinoco heavy crude oil are low API gravity, high boiling point, high viscosity, high metal content and high sulfur content. While the definition of heavy crude oil is not clear, crudes having gravity less than 20 API degrees were called "heavy crude oil" at the International conference on the Future of Heavy Curde and Tar Sands held at Canad a in June 1973.

The heavy crude oil, in addition to difficulty in tis transportation by pipeline because of high viscosity, has high contents of high boiling point fractions; therefore, the yield does not meet with the general demand pattern. Also, sulfur and metal contents are high.

Accordingly, it is difficult to process heavy oil at a refinery having general refining processes. The Orinoco heavy crude oil, which has all the characteristics mentioned above is considered to be upgraded in order to raises its marketability at the crude market.

Among processes and combinations of process for upgrading the Orinoco heavy crude oil, an upgrading scheme based on a solvent deasphalting process which is described in Section 3.1 has been studied.

Supporting this study are accumulated research and development work for the M-DS process having superiority ineconomics, technology of hydroprocessing of deasphalted oil, and research and development on combustion of SDA asphalt.

In the study, as a base case priority is given to the M-DS process and hydrodesulfurization schem which satisfies the requirements suggested by the Venezuelan authorities. In addition to that, as an alternate case, a study has been made of a processing scheme satisfing such basic requirements as production of the improved oil which can be transported by pipeline and can be processed at the conventional refinery. The alternate schemes is an economical way of using the M-DS process.

3.2.2 Objective

The objective of the study is to plan an upgrading refinery based on a process scheme combining the M-DS process and the hydrodesulfurization processes which produces 125,000 BPSD of improved crude and supplies electric power required for crude oil production on the basis of self-sufficiency of utility in the refinery. Also, a study is made to a process scheme having superiority in economics, although the improved oil of the scheme can not satisfy the target qualities suggested by the Venezuelan authorities.

3.2.3 Summary

Process scheme for upgrading the Orinoco heavy oil based on the combination of the M-DS and hydrodesulfurization process is studied.

As a result, the scheme based on the M-DS unit processing vacuum residue and the deep HDS unit processing VGO/DAO which satisfies the target qualities of the improved crude oil is proposed as a base case.

The scheme is comparatively simple. The deep HDS unit for the deep desulfurization is similar to the atmospheric residue desulfurization process which has been operated in Japan on the level of 0.3 percent sulfur of product.

The improved crude oil which scarcely contains metal and sulfur is used as feed oil for FCC and hydrocracking processes without feed treating. Raw crude oil of 151,055 BPSD and natural gas of 850,000 Nm^3/D are required to produce the improved crude oil of 125,000 BPSD. As a by-product, asphalt of 25,543 BPSD is produced.

Meanwhile a simple process scheme is also studied as an alternate case. Although the product obtained by this alternate scheme can not satisfy the target qualities of the improved crude oil, its viscosity is low enough for pipeline transportation and it can be easily processed at conventional refinery.

The alternate process scheme simply consists of three main processes such as atmospheric crude distillation, the M-DS and GO/DAO desulfurization units. Metal content of GO/DAO is somewhat high, however, severity of desulfurization is lower than that of direct desulfurization unit which produces oil of 1.0 weight % sulfur.

The raw crude oil requirement of the alternate case is slightly greater, compared with that of the base case, because the incerease of volume in the upgrading is less. Production of by-product asphalt increases at about 3 percent corresponding to the increase of raw crude oil throughput.

Investment requirement for on-site, natural gas requirement for hydrogen generation, and energy requirement are 84%, 40% and 72.5% of those for the base case, respectively.

3.2.4 Bases of Study

Bases of the study are described in Chapter 3 of volume I. The feed oil is a mixed crude of Cogollar IX and Cerro Negro crudes. And analysis data are shown in 3.2.5 (1).

In addition to the requirements of API degree of 25 ~ 28 and max sulfur content of 1.0 weight percent, the following data are assumed as target properties of the improved crude oil.

Target Yields of Improved Crude Oil

Distill. Range, °F	Yield, Vol. %
C4/375	10~25
375/650	25 min.
650/1000	40 mix.
1000+	25 max.

Target Properties of Distilled Fractions

Distill. Range. °F			Qualities	
C4/375	S	wt%	0.05	max.
	N	ppm	2	max.
375/650	S	wt%	0.2	max.
	Cetane No		40	min.
650/1000	S	wt%	0.5	max.
	N	wt%	0.10	
	CCR	wt%	0.7	
	Aniline pt.	°F	(to be estimated)	
1000+	S	wt%	1.25	max.

An for the study on alternate case, target qualities other than sulfur content are not taken into account.

3.2.5 Results of Study

Among the two cases of the base case and the alternative case, only the base case will be described in this sub-section. As for the alternative case, analytical results will be described in 3.2.6 Discussion, where the alternative case is discussed in comparison with the base case.

(1) Feed stock

This study is conducted, using analytical data on the properties of raw crude oil (Cogollar IX – Cerro Negro crude) (Table 3.3). From long year of research and development on the solvent deasphalting, we have established the relationship between the properties of feedstock and the yields and proerties of deasphalted oil and asphalt, as well as the relationship between the conditions of solvent deasphalting and the properties and yields of feedstock and products. Among others, the n-heptane asphaltene content is the most fundamental property of crude oil and a key factor to determine the yields of products. This n-heptane insoluble asphaltene content is not included in the raw crude oil assay which has been given to us as the base of study.

Therefore, the asphaltene content is estimated by means of a method described below. The estimated value is then used to evaluate the data on the solvent deasphalting of Cogollar-IX/Cerro Negro crude. The asphaltene content merely indicates a semiquantitative relationship that the higher the Conradson carbon residue, the more increased level of the asphaltene content tends to occur. However, it can

Table 3.3 Properties of Crude Oil (Cogollar IX-Cerro Negro Crude Oil)

Properties		Crude Oil	Gas	Naphtha	Gas Oil	Reduced Crude	VGO	Vac. Residue
Yield								
on Crude	Vol.%	100	0.17	0.83	14.12	84.88	27.66	57.22
"	Wt.%	100	0.10	0.64	12.61	86.60	26.58	60.02
on Reduced	Vol.%	–	–	–	–	100	32.59	67.41
Crude	Wt.%	–	–	–	–	100	30.69	69.31
°API		8.5	–	36.9	24.9	5.4	14.2	1.8
Sp.Gr.	15/4°C	1.0101	–	0.8398	0.9042	1.0330	0.9706	1.0609
S	%	3.67		0.65	2.17	4.04	3.28	4.32
CCR	%	13.3				17.6	0.20	25.7
N	%	0.57			0.001	0.59	0.19	0.82
V	ppm	392				484	<0.9	654
Ni	ppm	84				120	<0.2	162
V+Ni	ppm	476				604	<1.1	818
Fe	ppm	9				12	<0.4	18
Visocisity								
@100°F	cst	(66,000)		1.39	5.65			
@210°F	cst	(230)		0.72	1.7	2,945	150	
@300°F	cst					164		2,891
Pour Point	°F	-90			-90	+120<		+120<
Asphaltene	%*							
(n-C_7 insol)		9.0				10.39		15.00

* Estimation

Table 3.4 Crude Sample Analysis

Properties		Crude Oil	Naphtha	Gas Oil	Reduced Crude	Vac. Residue*
Cut Point	°C		20 ~ 205	205 ~343	343+	
Yield	Vol%	100.0	1.0	15.9	83.1	60.2
on Crude	Wt%	100.0	0.8	14.2	85.0	63.3
Sp. Gr.	15/4°C	1.0199	0.8335	0.9080	1.0353	1.0514
S	Wt%	3.87	0.56	2.25	4.12	4.26
CCR	Wt%	16.9	–	–	20.4	24.5
N	Wt%	0.48	–	0.065	0.56	0.76
V	ppm	310	–	–	410	480
Ni	ppm	120	–	–	130	170
N+Ni	ppm	430	–	–	540	650
Fe		59	–	–	67	85
Na		1,100	–	–	1,000	1,500
Ash		0.246	–	–	0.264	0.357
Vis.	cst @100°C	449.8	–	–	3,739	–
Anil. Pt	°C	–	–	43.2	–	–
Asphaltene ($n-C_7$)	Wt%	11.9	–	–	13.3	16.7

* Prepared by film evaporator under vacuum.

be regarded that between similar crude oils, the asphaltene content is approximately in proportion to the carbon residue content. The asphaltene content of Cogollar-IX/Cerro Negro crude is thus estimated on the assumption that this crude gives the same ratio of the asphaltene to Conradson carbon residue as in the separately supplied crude oil sample (Table 3.4). Table 3.3 gives the asphaltene content estimated on the above assumption.

As stated above, the data on solvent deasphalting of Cogollar-IX/Cerro Negro crude are evaluated on the basis of afore-mentioned correlations in which the asphaltene is the key factor. In order to modify the estimates and make the evaluation more accurate, the solvent deasphalting was conducted under a variety of conditions, using a residue from the Orinoco heavy crude oil sample.

Cogollar-IX/Cerro Negro crude highly resembles with the separately supplied crude oil sample in their yields of respective fractions and the analytical properties, but their asphaltene contents are found to be different to an extent as much as 30%. Although any difference in the asphaltene content has a direct impact on the deasphalting data, the correlations already established from our abundant data makes it easy to evaluate the deasphalting data in spite of the changes in crude oil properties.

(2) Process scheme

Fig. 3.3 shows the upgrading process scheme of the base case.

Raw crude oil mixed with diluent LGO is processed to yield gas, naphtha, LGO, HGO and atmospheric residue in an atmospheric crude distillation unit.

The gas together with offgases from GO-HDS and VGO/DAO-HDS is, after being treated in an acid gas treating unit, used as fuel for a hydrogen generation plant.

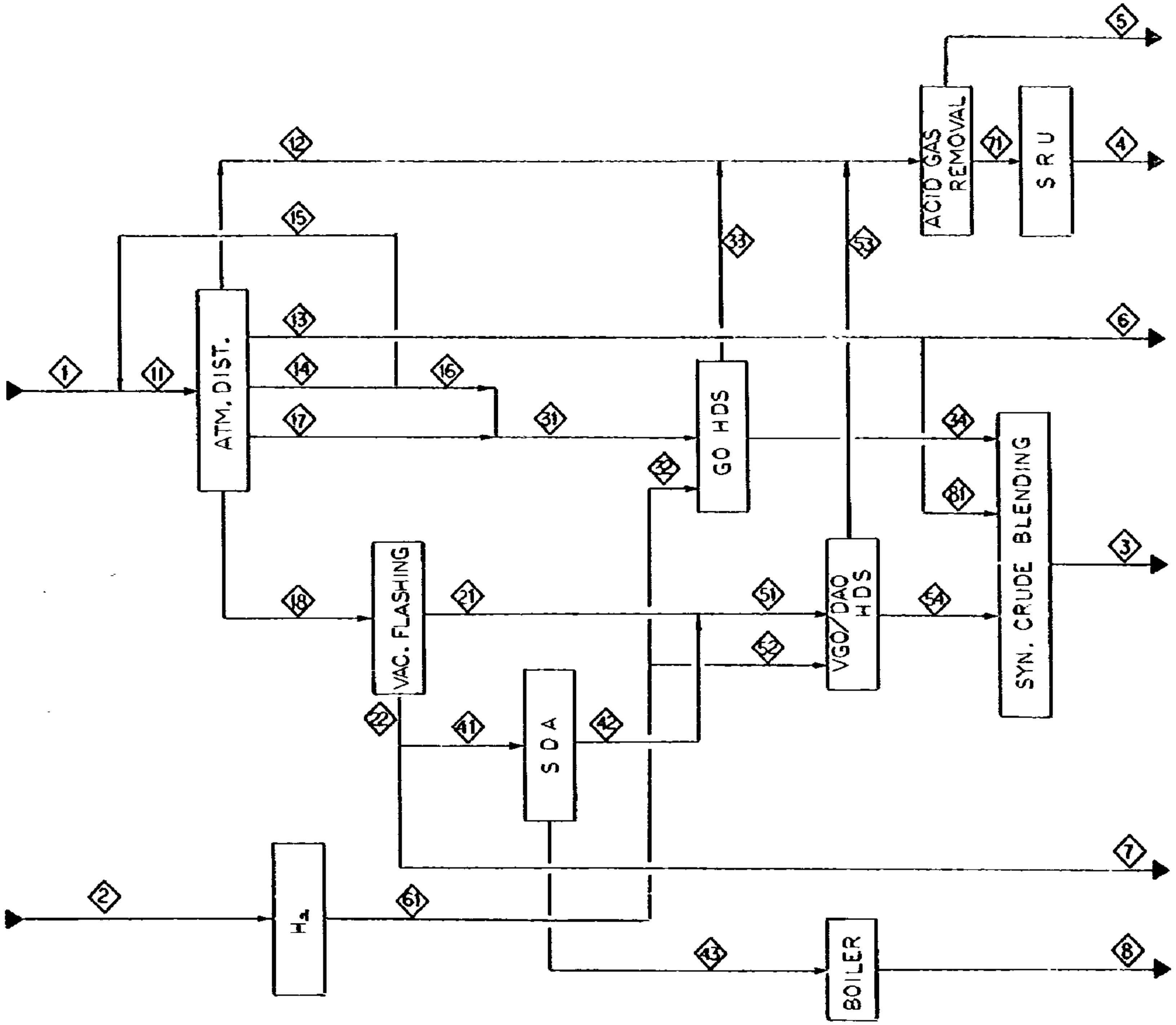
Most of the naphtha is used as fuel for the hydrogen plant, and the rest is mixed with the improved crude oil.

Most of the LGO is recycled to the crude production field as diluent and the rest together with the HGO is treated in GO-HDS unit and is used as component of the improved crude oil.

The atmospheric residue is separated into VGO and vacuum residue in a vacuum flashing unit.

A part of the vacuum residue is used as the refinery fuel and the rest is sent to the M-DS unit.

The SDA asphalt produced in the M-DS unit is directly sent to boiler and the DAO together with the VGO is desulfurized and hydrocracked in the VGO/DAO HDS unit. Thus, the improved crude consists of the straight run naphtha and the desulfurized oils of GO-HDS and VGO/DAO-HDS unit.



MATERIAL BALANCE (MOR)

STREAM NO.	STREAM NAME	FLOW RATE BPSD4)	FLOW RATE TON/D	GRAVITY °API	SULFUR WT%	SULFUR TON/D
	FEED					
1	Raw Crude	151,055	24,302	8.5	3.67	906.5
2	Natural Gas	(850)	-	-	-	-
	PRODUCT					
3	Sync. Crude	125,000	17,849	26.1	0.05	9.2
	BY-PRODUCT					
4	Sulfur	-	561	-	99.5	558.0
5	Fuel Gas 5), 6)	(657)	446	-	-	-
6	Fuel Naphtha 6)	876	117	37.2	0.65	0.8
7	Fuel Oil	5,166	876	1.8	4.32	37.9
8	Steam					
	INTER STREAM					
11	Atm. Dist. Feed	196,372	30,535	13.2	3.21	978.8
12	Off Gas	(17)	38	-	-	-
13	Naphtha	1,133	151	37.2	0.65	1.0
14	LGO (Total)	51,676	7,108	32.0	1.16	82.4
15	LGO (Dilute)	45,317	6,233	32.0	1.16	72.3
16	LGO (Net)	6,359	875	32.0	1.16	10.1
17	HGO	15,015	2,187	23.0	2.43	53.1
18	Atm. Residue	128,246	21,051	5.6	4.00	842.3
21	VGO	41,797	6,454	14.2	3.28	211.7
22	Vac. Residue	86,449	14,597	1.8	4.32	630.6
31	Gas Oil	21,374	3,062	25.5	2.06	63.2
32	H_2 Gas 1)	(230)	21	-	-	-
33	Off Gas 5)	(92)	106	-	-	58.7
34	HT Gas Oil	21,435	2,986	30.0	0.15	4.5
41	SDA Feed	81,283	13,721	1,8	4.32	592.7
42	DAO	55,740	8,958	8.5	3.52	315.3
43	SDA Asphalt	25,543	4,763	-10.6	5.82	277.4
51	VGO/DAO	97,537	15,411	10.8	3.42	527.0
52	H_2 Gas	(3,120)	281	-	-	-
53	Off Gas	(971)	920	-	-	522.5
54	HDS Oil	103,308	14,829	25.2	0.03	4.5
61	H_2 Gas(Total) 1)	(3,350)	302	-	-	-
71	Acid Gas	(406)	618	-	-	581.2
81	Naphtha	257	34	37.2	0.65	0.2

Note:

1) As Pure H_2
2) As Removed H_2S
3) As Recovered Sulfur
4) (   ) 10^3 Nm^3/D
5) Incl. Solution H_2, and C_1 contained in H_2 Gas
(Make-up H_2 Gas Composition : H_2 95 wt%, C_1 5 Vol%)
6) to be used for H_2 Plant Furnaces
7) to be used for Furnaces, except H_2 Plant Furnaces

ORINOCO HEAVY OIL UPGRADING PROJECT

BLOCK FLOW DIAGRAM OF M-DS CASE

FIG. 3.3

(3) Overall material balance

Overall material balance and the estimated properties of the improved oil are shown below. Also, the upgrading process scheme is shown in Fig. 3.3.

Overall Material Balance

Raw material	
Raw crude oil	151,055 BPSD
Natural gas	850,000 Nm^3/SD
Product	
Improved crude oil	125,000 BPSD
By-product	
Sulfur	558 Ton/SD
Asphalt	4,763 Ton/SD

Estimated Properties of Improved Crude Oil

		Improved Crude Oil	Yield and Properties of Fractions 1	2	3	4
Boiling Point,	°F		C5/375	375/650	650/1000	1000+
Yield,	Vol.%	100.0	9.5	34.0	33.5	23.0
Gravity,	°API	26.1				
Sulfur,	Wt%	0.05	< 0.01	0.08	0.02	0.03
Nitrogen,	Wt%	0.08	< 1 ppm		0.003	
Cetane No.				45		
Con. Carbon,	Wt%	0.13			0.05	
Aniline Point,	°F				130	
Asphaltene,	Wt%	Nil				
Metal						
V/Ni/Fe,	Wppm	0.1/0.2/Nil				
Viscosity,						
@100°F	cst.	22.0				
@210°F,	cst.	4.0				

Data on feed and products inspections of the process units are shown in the following table:

Table 3.5 Feed and Product Inspection of Atmospheric Distillation Unit
Table 3.6 Feed and Product Inspection of Vacuum Flashing Unit
Table 3.7 Feed and Product Inspection of GO HDS Unit

Table 3.5 Feed and Product Inspection of Process Unit

Process name : Atmospheric Distillation Unit

Basis : Cogollar IX/Cerro-Negro Crude Oil

(1) Estimated Yield

Feed

	vol.%	EPSD	wt%	Ton/SD
Raw crude	100.0	151,055	100.00	24,302
LGO (Diluent)	30.0	45,317	25.66	6,233
Total	130.0	196,372	125.66	30,535

Products

	vol.%	EPSD	wt%	Ton/SD
Off gas	0.20	302	0.16	38
Naphtha	0.75	1,133	0.62	151
LGO (net)	4.21	6,359	3.58	875
LGO (diluent)	30.00	45,317	25.66	6,233
HGO	9.94	15,015	9.02	2,187
Reduced Crude	84.90	128,246	86.62	21,051
Total	130.00	196,372	125.66	30,535

(2) Estimated Properties

		Raw Crude	Diluent LGO	Mixed Crude	Naphtha	LGO	HGO	R.C.
Gravity,	°API	8.5	32.0	13.3	37.2	32.0	23.0	5.6
Sulfur,	Wt%	3.67	1.16	3.16	0.65	1.16	2.43	4.0
Nitrogen,	"	0.57		0.45			0.002	0.59
CCR,	"	13.3		10.6				17.6
Metal,								
V,	Wtppm	392		312				484
Ni,	"	84		67				120
Fe,	"	9		7				12
Pour Point,	°F	60	<-100			<-100	<-75	>120
Viscosity								
@100°F,	cst	66,000	2.25	1,450		2.25	8.00	
@210°F,	"	230	0.99	30		0.99	2.05	2,945
@300°F,	"							164
Nominal Cut.,	°F				C5/380	380/510	510/650	650+

Table 3.6 Feed and Product Inspections of Process Unit

Process Name : Vacuum Flashing Unit
Basis : Cogollar IX/Cerro-Negro Crude Oil
(650°F+ Reduced Crude)

(1) Estimated Yield

Feed

	vol%	BPSD	wt%	Ton/SD
Reduced Crude	100	128,246	100.0	21,051

Product

	vol%	BPSD	wt%	Ton/SD
LVGO	6.47	8,298	5.97	1,255
HVGO	26.12	33,499	24.72	5,199
Total VGO	32.59	41,797	30.69	6,454
Vac. Residue	67.41	86,449	69.31	14,597
Total	100.00	128,246	100.0	21,051

(2) Estimated Properties

		Reduced Crude	LVGO	HVGO	Total VGO	Vacuum Residue
Gravity,	°API	5.6	16.9	13.5	14.2	1.8
Sulfur,	wt%	4.0	3.24	3.29	3.28	4.32
Nitrogen,	"	0.59			0.19	0.82
CCR,	"	17.6	0.07	0.23	0.20	25.7
Metal						
V,	wtppm	484			<0.9	654
Ni,	"	120			<0.2	162
Fe,	"	12			<0.4	18
Pour Point,	°F	>120			20	>120
Viscosity						
@210°F,	cst	2,945			15.0	
@300°F,	"	164				2,891
Nominal Cut,	°F	650+	650/720	720/995	650/995	995+

Table 3.7 Feed and Product Inspections of Process Unit

Process name : GO HDS Unit
Basis : Cogollar IX/Cerro-Negro Crude Oil
(380-650°F S.R. Gas Oil)

(1) Estimated Yields @MOR

Feed

	vol%	BPSD	wt%	Ton/SD
Feed Oil				
LGO	29.75	6,359	28.58	875
HGO	70.25	15,015	71.42	2,187
Total Gas Oil	100.00	21,374	100.00	3,062
Hydrogen (Chemical)	(353 SCF/BBL)		0.62	19
Total	100.00	21,374	100.62	3,081

Product

	vol%	BPSD	wt%	Ton/SD
H_2S			2.04	62.5
C1			0.05	1.5
C2			0.16	4.9
C3			0.33	10.1
C4			0.52	16.0
C5 + Product	100.29	21,435	97.52	2,986
Total	100.29	21,435	100.62	3,081

(2) Estimated Properties @MOR

		LGO	HGO	Total Gas Oil	C5 + Liquid
Gravity,	°API	32.0	23.0	25.5	30.0
Sulfur,	wt%	1.16	1.43	2.06	0.15
Nitrogen,	"		0.002		
Pour Point,	°F	<-100	<-75		
Viscosity					
@100°F,	cst	2.25	8.00		
@210°F,	"	0.99	2.05		
Nominal Cut,	°F	380/510	510/650	380/650	C5+

Table 3.8 Feed and Product Inspections of Process Unit

Process Name : Solvent Deasphalting Unit

Basis : Cogollar IX/Cerro-Negro Crude Oil
(955°F+ Vacuum Residue)

(1) Estimated Yields

Feed

	vol%	BPSD	wt%	Ton/SD
Vacuum Residue	100.0	81,283	100.0	13,721

Product

	vol%	BPSD	wt%	Ton/SD
DAO	68.57	55,740	65.3	8,958
Asphalt	31,43	25,543	34.7	4,763
Total	100.00	81,283	100.0	13,721

(2) Estimated Properties

		Feed	pro Product	
		Vacuum Residue	DAO	Asphalt
Gravity	°API	1.8	8.5	-10.6
Sp. Gr. 15/14°C	–	1.062	1.0108	1.1706
Sulfur,	wt%	4.32	3.52	5.82
Nitrogen,	"	0.82	0.418	1.58
CCR,	"	25.7	9.07	57.0
Asphaltene,	"			43.3
Metal				
V,	wtppm	654	107.9	1,683
Ni,	"	162	39.3	393
Fe,	"	18		
Pour Point,	°F	>120		
R & B Softening P't,	°C			162
Viscosity				
@210°F,	cst		700	
@250°F,	"			4,000 cp. (250°C)
@300°F,	"	2,890	69	500 cp. (300°C)
Nominal Cut,	°F	995+		

Table 3.9 Feed and Product Inspections of Process Unit

Process Name : VGO/DAO HDS Unit
Basis : Cogollar IX/Cerro-Negro Crude Oil
(650-995°F SR VGO Plus Deasphalted Oil)

(1) Estimated Yields @MDR

Feed

	Vol%	BPSD	wt%	Ton/SD
Feed Oil				
VGO	42.85	41,797	41.87	6,453
DAO	57.15	55,740	58.13	8,958
Total Feed Oil	100.00	97,537	100.00	15,411
Hydrogen (Chemical)	(1,030 SCF/BBL)		1.66	225
Total	100.00	97,537	101.66	15,666

Product

	Vol%	BPSD	wt%	Ton/SD
H_2S			3.60	555
NH_3			0.39	61
C1			0.26	41
C2			0.41	64
C3			0.37	58
C4			0.37	58
C5+ Product	105.92	103,308	96.26	14,829
Total	105.92	103,308	101.66	15,666

(2) Estimated Propertiles @MOR

		VGO	DAO	Total Feed	C5+Liquid
Gravity,	°API	14.2	8.5	10.8	25.0
Sulfur,	wt%	3.28	3.52	3.42	0.03
Nitrogen,	"	0.19	0.418	0.33	0.011
CCR,	"	0.20	9.07	5.49	0.16
Metal-V,	wtppm	<0.9	107.9	64.3	0.3
--Ni,	"	<0.2	39.3	23.4	0.1
--Fe,	"	<0.4			
Viscosity					
@100°F,	cst			6,500	26.8
@210°F,	cst	15.0	700	90	4.6
TBF Dist					
IBF/5,	°F			650/700	100/260
10/30,	"			740/905	375/590
50,	"				740
70/90,	"			/	975/
95/EP,	"			/	/

Table 3.8 Feed and Product Inspection of M-DS Unit

Table 3.9 Feed and Product Inspection of VGO/DAO HDS Unit

(4) Process Description

Outline of the M-DS, VGO/DAO hydrodesulfurization and gas oil (GO) hydrodesulfurization units are described.

(a) M-DS unit

Please refer to Fig. 3.4 Simplified Process Flow Scheme of M-DS unit.

Vacuum residue as a feed oil is fed to the upper part of an extractor by a feed pump. Meanwhile solvent is fed to the bottom part of the extractor by a solvent charge pump from a No.1 solvent drum. Mixture of asphalt and solvent is drawn from the extractor bottom. Mixture of DAO and solvent drawn from the extractor overhead is heated up by a DAO solution heater and sent to a HP DAO solution flash drum.

The flash drum liquid is heat-exchanged with the flash drum vapor which is condensed and sent to the No.1 solvent drum.

Liquid from an LPHT DAO solution flash drum is heated up by steam and is sent to an LPHT DAO solution flash drum where the solvent is recovered as vapor. The solvent vapor from the LPLT DAO flash drum is condensed and sent to a No.2 solvent drum. DAO containing a small amount of solvent is stripped by steam at a DAO stripper, where the DAO is drawn from the stripper bottom.

The mixture of asphalt and solvent from the extractor bottom is heated up by an asphalt heater and sent to an asphalt drum where most of the solvent is recovered. Asphalt containing a small amount of solvent is steam-stripped at an asphalt stripper of which bottom is the M-DS asphalt.

Mixtures of the solvent and steam coming from the DAO stripper and the asphalt stripper are condensed by a solvent gas cooler. The entrained oil and the condensed water are drawn off by a slop oil and a foul water pump, respectively. The solvent vapor, after being condensed by a No.3 solvent condenser is sent to the No.2 sovent drum by a No.1 solvent circulation pump.

(b) VGO/DAO HDS unit

Please refer to Fig. 3.5 Simplified Process Flow Scheme of VGO/DAO HDS Unit.

Feed oil pumped up by a reactor charge pump, after mixed with hydrogen, is sent to a reactor with heated up by a reactor effluent and a reactor charge heater.

The reactor is of the fixed bed type consisting of multiple layers of catalyst.

Temperature in the reactor is controlled by introducing a part of recycle gas as quench gas.

The feed oil flowing downwards in the catalyst beds is hydrocracked, and also sulfur and nitrogen compounds are converted to hydrogen sulfide (H_2S) and ammonia (NH_3).

The reactor effluent, after cooled by a heat exchanger, is sent to a HP hot flash drum where vapor and liquid are separated. The vapor from the HP hot flash drum is further cooled and sent to a HP cold flash drum. The HP cold flash drum gas, after counter-contacting with an amine solution at a recycle gas scrubber to remove hydrogen sulfide, is sent to the reactor together with make-up hydrogen.

Water is injected at the condenser inlet to prevent solidification of ammonium hydrosulfide (NH_4SH) which causes fouling and plugging in the equipment. The HP cold flash drum liquid, after separating an off gas at an LP separator, is sent with the HP hot flash drum liquid to a product stabilizer for adjusting the vapor pressure of product oil. Off gases from the product stabilizer and the LP separator are used as fuel for the hydrogen plant after being treated at an acid gas removal unit.

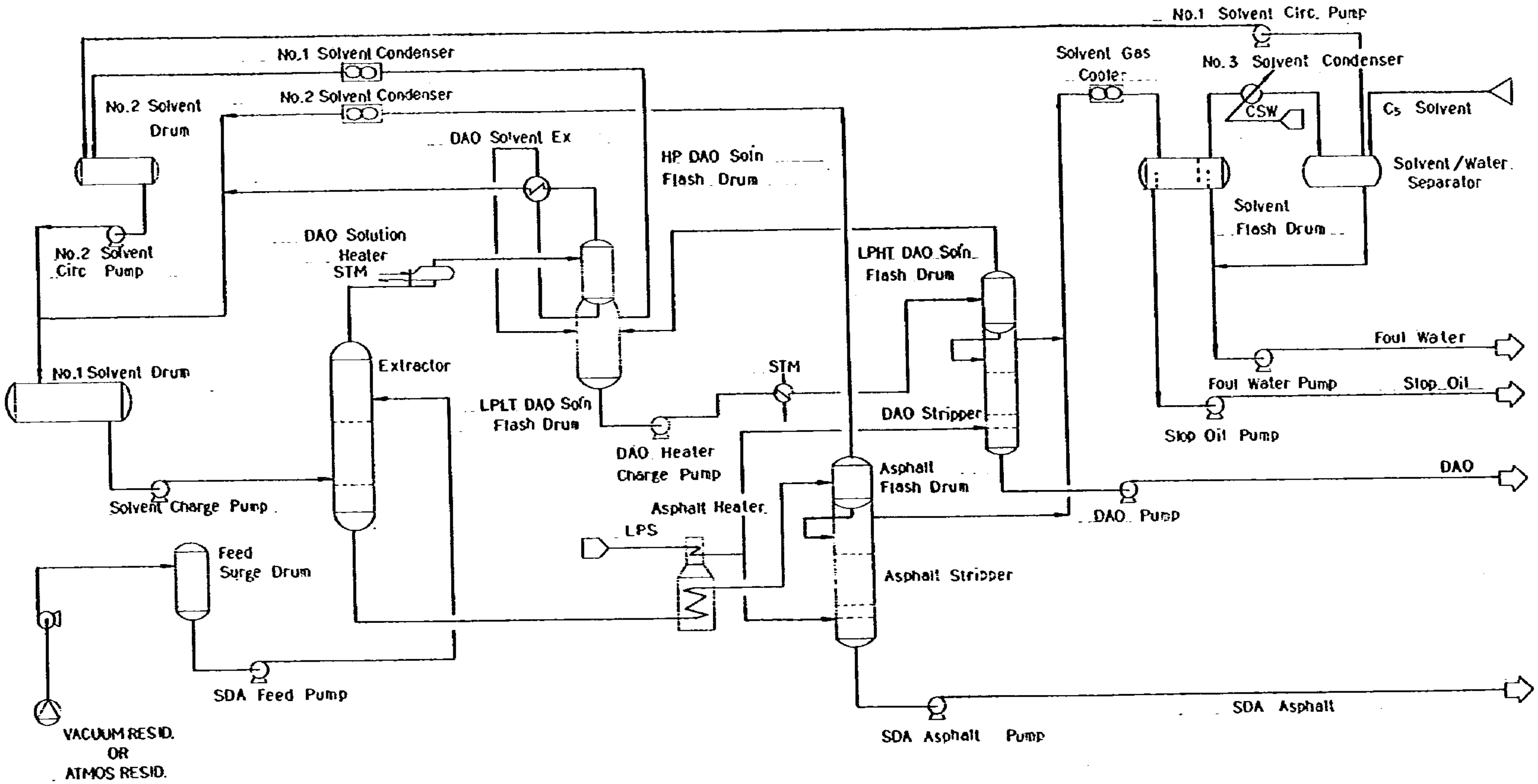
(c) GO HDS Unit

Please refer to Fig. 3.6 Simplified Process Flow Scheme of GO HDS unit. Feed oil pumped up by a reactor charge pump, after being mixed with hydrogen, is sent to a reactor with heated up by a reactor effluent and a reactor charge heater.

The reactor is of the fixed bed type containing desulfurization catalyst. Sulfur and nitrogen compounds are mostly converted to hydrogen sulfide and ammonia while the feed oil passes down the catalyst beds.

The reactor effluent, after being cooled by a heat exchanger and condenser, is sent to a HP separator. The HP separator gas is compressed by a recycle gas compressor and sent to the reactor together with hydrogen gas sent by a make-up gas compressor.

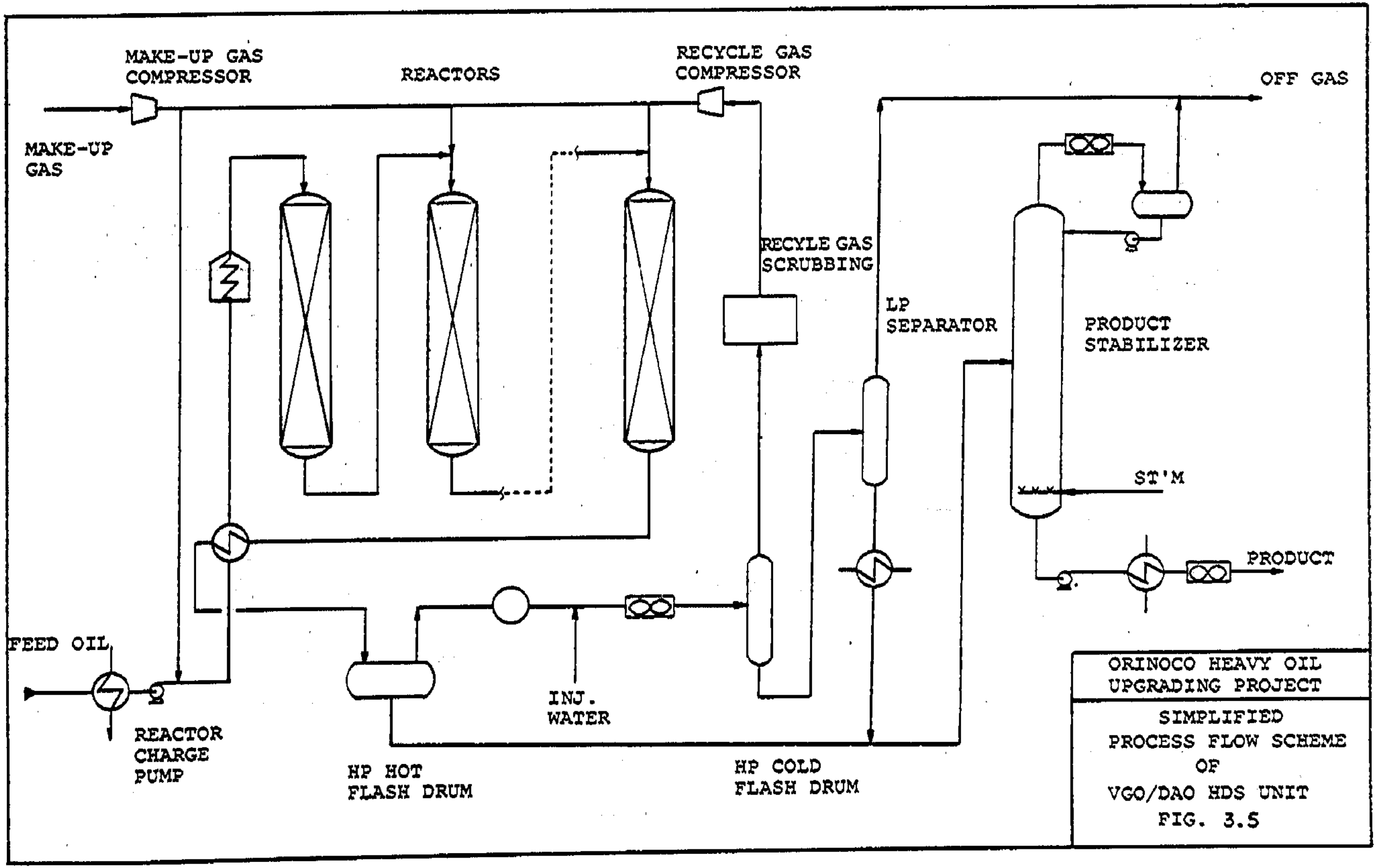
Water is injected at the condenser inlet to prevent solidification of ammonium hydrosulfide, formed by hydrogen sulfide and ammonia, which causes fouling and plugging in the equipment. The HP separator liquid, after separating an off gas at an LP separator, is sent to a product stabilizer for adjusting the vapor pressure of product oil. Off gases from the product stabilizer and the LP separator are used as fuel for hydrogen plant after treated at an acid gas removal unit.



ORINOCO HEAVY OIL UPGRADING PROJECT

PROCESS FLOW DIAGRAM OF M-DS PROCESS

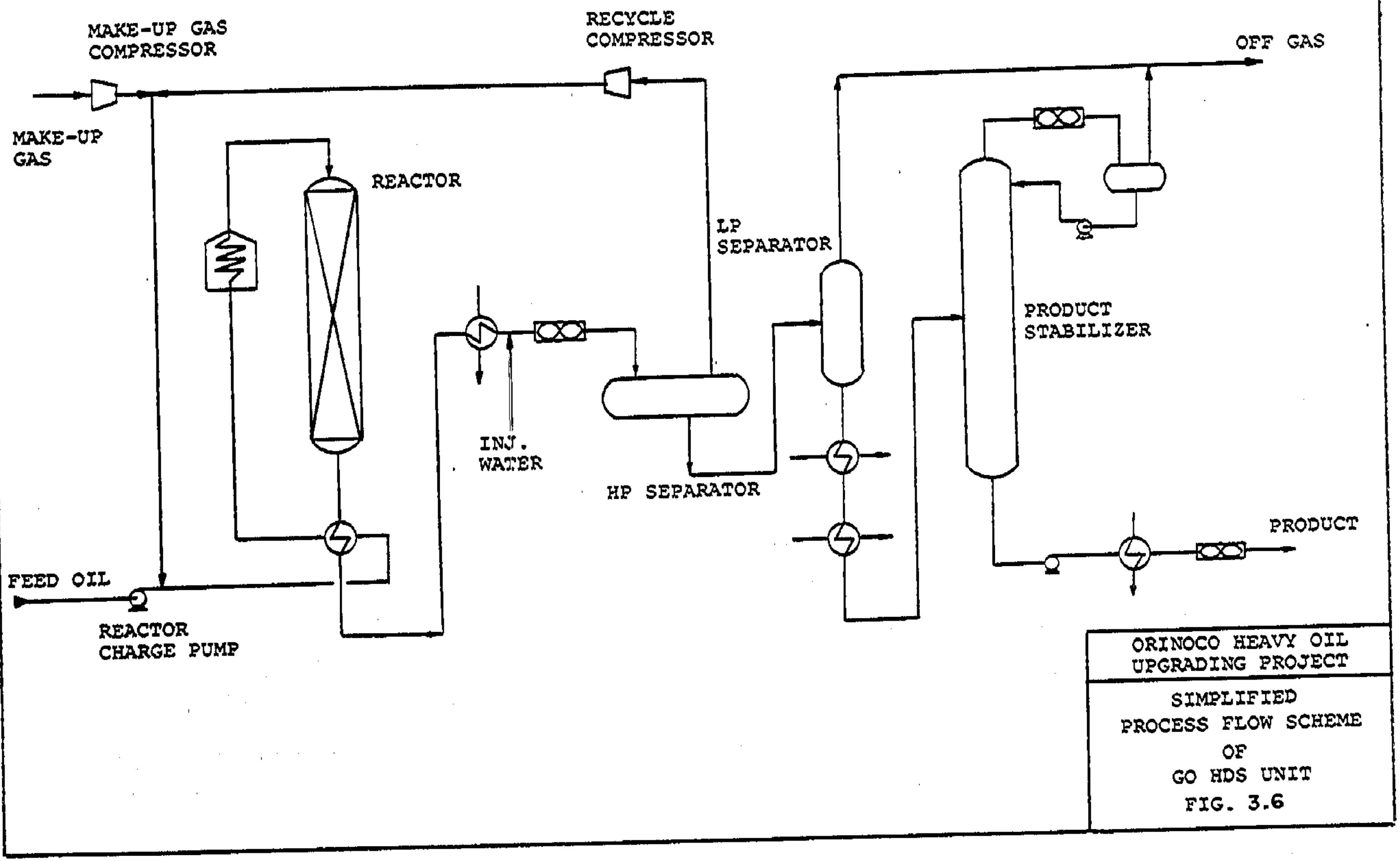
FIG. 3. 4



ORINOCO HEAVY OIL UPGRADING PROJECT

SIMPLIFIED PROCESS FLOW SCHEME OF VGO/DAO HDS UNIT

FIG. 3.5



ORINOCO HEAVY OIL
UPGRADING PROJECT

SIMPLIFIED
PROCESS FLOW SCHEME
OF
GO HDS UNIT
FIG. 3.6

Table 3.10 Estimated Utility Requirements

(M-DS Case)

	Capacity	Elec.	Steam Ton/H			Water Ton/H						Fuel	
	BPSD	KW	40KG 400°C	15KG 270°C	3.5KG sat.	BFW	cond.	Process water	Foul water	Loss water	Cooling water	x10⁶ kcal/H Gas	x10⁶ kcal/H Oil
Atm. Distillation	196,372	1,650	20.1	19.7	-20.1			65.1	-84.8		717		104.1
Vacuum Flashing	128,246	1,570	6.6		-6.6	47.9			-47.9		4,080		104.1
GO HDS	21,374	1,900		2.1		(6) 4.1			-5.3		680		15.4
M-DS	81,283	6,580	22.6	90.8	12.4		-113.4		-12.4		260		19.0
VGO/DAO HDS	97,537	23,580		34.7	14.1	(6) 100.0	-34.7		-117.7		4,350		99.0
Hydrogen Plant	(1) 3,820	3,510		-36.7		226.6	7.1		-120.0	-77.0	880	(4) 229.9	(5) 50.0
Acid Gas Removal	(2) 618	630		5.5	93.4		-98.9				1,490		
Sulfur Recovery	(3) 558	2,100			-56.1	78.5				-22.4	20		
Total		41,520	49.3	116.1	37.1	457.1	-239.9	65.1	-388.1	-99.4	12,477	229.9	391.6

Note: Negative figures indicate quantity made.

(1) $x10^3$ Nm^3/D as H_2

(2) Ton/D as H_2S

(3) Ton/D as sulfur

(4) Refinery off gas shall be used as fuel gas

(5) S.R. Naphtha shall be used as fuel oil

(6) Stripped water which is treated by Foul Water Stripping Unit will be normally used instead of BFW

(5) Estimated utility requirements

Table 3.10 shows a summary of estimated utility requirements.

(6) Estimated operating requirements

Operating labors, maintenance and repairs, plant overhead etc. will be estimated separately.

(7) Catalyst and chemicals

Initial inventory and yearly consumption of the catalyst and chemicals are shown in the Table 3.11.

Table 3.11 Catalyst and Chemical Costs

Process Unit	Total Capacity	Initial Cost 10^6 Japanese Yen	Operating Cost 10^6 Japanese Yen
No.1 Hydrotreating	21,350 BPSD	85.2	16.5
VGO/DAO Hydro-desulfurization	97,350 BPSD	4,861.1	4,704.5
M-DS	81,150 BPSD	192.0	108.6
H_2-Plant	3.82 MM Nm^3/D as H_2	525.7	172.6
Acid Gas Removal	620 Ton/D as H_2S	22.0	–
Sulfur Recovery	560 Ton/D as S	34.4	8.7
Total		5,720.4	5,010.9

(8) Process waste

Quantity and properties of waste water from each process units are shown in Table 3.12. Waste water from GO HDS unit and VGO/DAO HDS unit can be reused as injection water to the above HDS units after being treated by foul water stripping unit.

(9) Process area

Required plot areas of M-DS process, GO HDS unit and VGO/DAO HDS unit are estimated as 15,000 m^2, 10,000 m^2 and 24,000 m^2, respectively.

Table 3.12 Process Waste Water

Process	Atmos. Dist. Unit		Vacuum Flash Unit	GO HDS Unit	SDA Unit	VGO/DAO HDS Unit	Total	H_2 Plant[1)]
Plant Capacity	196,372 BPSD		128,246 BPSD	21,374 BPSD	81,283 BPSD	97,537 BPSD		3,820 x 10^3 Nm^3/D
Waste Water	Desalt. Water	OH Cond.						
Quantity, Ton/D	65.1	19.7	47.9	5.3	12.4	117.7	268.1	120.0
Properties								
pH								
COD , mg/1	200	200	30					
Oil "	100	100	20					
SS "								
BOD "								
H_2S "	400	1,000	150		38,000		19,400	
NH_3 "	100	350	100		18,000		9,200	
Phenol "	4	30						
Sulfide "								
Other "								

Note: 1) to be used as make-up water of cooling tower after degassing.

Table 3.13 Main Equipment Lists

Process	Service	Q'ty	Dimension (I.D. x T-T Length) mm	Material	Weight Each Ton	Weight Total Ton
GO HDS Unit	Reactor	2	2,600φ x 7,000H	Low-alloy Steel	79	158
VGO/DAO HDS Unit	Reactor	20	4,400φ x 14,000H	Low-alloy Steel	512	10,240
SDA Unit	Extractor	10	4,100φ x 23,000H	Carbon Steel	250	2,500
	Asphalt Stripper	2	4,500φ x 12,000H	Carbon Steel	61	122
	Solvent Drum	4	4,400φ x 11,000L	Carbon Steel	95	190
	Asphalt Flash Drum	2	5,000φ x 7,500H	Carbon Steel	100	200

(10) Main equipment list

As information for construction and equipment transportaiton planning, Table 3.13 shows main equipment including reactors, tower and vessels which have diameters of 4,000 mm and larger, and their weights, dimensions and materials.

(11) Construction costs

The construction costs of process units estimated based on the following bases are shown in Table 3.14.

- Construction site: Chiba, Japan
- Cost base as of mid. 1980 and no escalation included.
- Construciton cost includes material, labor, design and engineering fee and constructor's overhead and expenses.

Table 3.14 Construction Costs of Process Units

Process Units	Capacity	No.s	Construction Cost (10^6 Japanese Yen)
Atm. Distillation	98,186 BPSD	2	9,020
Vacuum Flashing	64,123 BPSD	2	6,444
GO Hydrotreating	10,687 BPSD	2	3,030
VGO/DAO Hydro-desulfurization	48,769 BPSD	2	42,000
M-DS	40,642 BPSD	2	12,500
Hydrogen Plant	1.91 MM Nm^3/D as H_2	2	13,388
Acid Gas Removal	309 Ton/D as H_2S	2	2,364
Sulfur Recovery and Solidification	279 Ton/D as S	2	3,221
Total			91,967

Note:

(1) Location: Chiba, Japan

(2) As of mid. 1980 and no escalation included.

3.2.6 Discussion

A base case is described for a refinery producing synthetic crude oil of improved quality from Orinoco heavy crude oil through the process steps including the solvent deasphalting of vacuum residue and a high level of hydrodesulfurization of deasphalted oil. In this subsection, there will be described some fundamental aspects affecting the base case and the details of an alternative case, i.e., a scheme comprising the steps of atmospheric residue deasphalting and desulfurization.

Availability of a high yield of synthetic crude oil is the most desirable condition in upgrading heavy crude oil. The primary factor to determine the yield of synthetic crude oil is the yield of deasphalted oil (or aspahlt) obtained from the solvent deasphalting process. Unlike the pretreatment of thermal cracking, such as coking, the solvent deasphalting process can considerably change the yield of the reject (asphalt in the case of deasphalting) which contains high concentrations of impurities originally existing in the heavy crude oil. If, however, the yield of deasphalted oil is raised to a high level, the oil tends to have lower quality for the most cases, and upgrading would become difficult.

Another, more critical factor is the flowing property of by-produced asphalt, which is aggravated concurrently with the decrease in asphalt yield. Lower flowability makes asphalt difficult to handle and use in liquid form, thereby adversely affecting stable operation of the solvent deasphalting unit. The newly developed solvent deasphalting unit is specially designed to treat smoothly the mixture of viscous asphalt and a solvent. Therefore, difficulty in handling and using of the low fluidity asphalt rather causes asphalt yield to be limited. As regards the transport of highly viscous liquids at high temperatures through pipes in process units, there is industrially known a case of such transport at a temperature of 250°C. Asphalt having a viscosity sufficient to flow through pipes at 250°C or below can be burnt, according to our judgment, in those boilers using an internal-mixing and high-temperature-steam- atomizing type of burners, as describeds later. An asphalt yield has been set in this study on the premises that asphalt has a viscosity of several thousand cp. at 250°C (a softening point of about 170°C).

A heavy oil desulfurization process has been assumed as the process for upgrading and desulfurizing deasphalted oil. The first heavy oil desulfurization unit was constructed in 1967 in Japan. Similar units with a total capacity of about 400,000 b/d are now in operation throughout the country. This process is already one of basic oil-refining means in Japan. As for the performance of this unit, it is a common practice to reduce the sulfur content of Arabian Light atmospheric residue down to 0.3% or even 0.1%, using this unit. This study therefore assumes a desulfurization unit capable of direct disulfurization to a level of 0.3 to 0.1% (in terms of Arabina Light atmospheric residue). Standard properties of 1% or less sulfur and 25°API or higher are imposed on the synthetic crude oil in this feasibility study. Solvent deasphalting increases the API gravity, but this desulfurization step is required to raise the API gravity by as much as 15°API (or decrease the density by as much as about 0.1), in order to reach the level of 25°API. In step with this increase in API gravity, it is necessary to reduce the sulfur content of product to a level as low as 0.05%. Since deasphalted oil is free of asphaltene fraction which is quite difficult to desulfurize, the desulfurization of deasphalted oil has a higher reaction rate than that of residues. The difference in reaction rates can be remarkable if a deep desulfurization is to be carried out.

Whether the reaction rate is high or low, inevitable deterioration of the catalyst takes place, due to the deposition of metals existing in the desulfurization feed on the catalyst surfaces and the coke deposition which occurs in the deep desulfurization. In the case of a unit capable of direct desulfurization to a 0.3 to 0.1% level using a non-regenerated catalyst which is replaced at an interval of 11 months, it is necessary to restrict the metal content of deasphalted oil and the coke-forming tendency at or below certain limits, to enable the unit to go on with the high level of desulfurization.

Meanwhile, the quality of deasphalted oil is greatly affected by asphalt yields, crude oil cut point (whether the feed is atmospheric residue or vacuum residue), and solvent deasphalting conditions (expecially, the solvent ratio). Asphalt yield affects the quality of deasphalted oil, but more improtantly, it affects the economics of the entire project. For this reason, asphalt yield should be kept at a minimum level that does not cause difficulty in handling asphalt, as long as the quality aspect is not a crucial factor.

As regards the effects of the cut point of solvent deasphalting feeds on the quality of deasphalted oil, Table 3.20 gives a comparison of atmospheric residue with vacuum residue. The comparison indicates that better quality results from vacuum residue deasphalting, although the data is affected to some extent by different solvent ratios. The deasphalted oils derived from both residues were analyzed for the possibility of upgrading them into synthetic crude oil having such properties as defined for the heavy oil desulfurization process. It has been revealed that the deasphalted oil from vacuum residue can be passed through the direct desulfurization unit of a 0.1% class operating on a non-regenerated catalyst replacement interval of 11 months, whereas the deasphalted oil from atmospheric residue calls for the catalyst and reactor several folds as large as those required by vacuum residue. Therefore, this study basically stands on the vacuum residue deasphalting route. As described above, if the necessary desulfurization level can be low, the gap between two residues rapidly becomes narrow, and there may be a case where the other route of atmospheric residue deasphalting happens to be superior from an overall economic point of view, depending on the desulfurization level.

The effect of solvent ratio on the quality of deasphalted oil is also a factor which cannot be neglected. But when the solvent ratio is raised to a level higher than the level at which such deasphalted oil as shown in Table 3.8 can be obtained, the deasphalting cost increases sharply, yet the improved quality of deasphalted oil generally causes the desulfurization cost to go down only slightly. Thus, the increased solvent ratio does not necessarily improves the overall economics of a deasphalting/desulfurizing combination. It has been decided from the foregoing discussion that the base case of Orinoco heavy oil upgrading project should use a combination of solvent deasphalting of vacuum residue and direct desulfurization process of a 0.1% sulfur class. Synthetic crude oil obtained from this scheme has quite excellent quality, as compared with the products from other routes. The composition of those crude oils coming from thermal cracking routes tends to be rich in aromatics, due to severe thermal treatment. On the other hand, the solvent deasphalting process provides a synthetic crude oil having properties quite usuful as the feed to catalytic cracking and hydrocracking steps, because:

(1) Condensed polycyclic aromatics exist in less amounts in deasphalted oil, owing to the solvent selectivity in favor of paraffinic hydrocarbons;

(2) In addition to (1), a high level of hydrotreating permits complete decomposition and removal of sulfur-, nitrogen- and heavy-metallic compounds; and at the same time,

(3) The polycyclic aromatics remaining in deasphalted oil are hydrogenated and converted to naphtenes.

As far as quantitiative properties, such as ligh fraction content of synthetic crude oil, is concerned, the solvent deasphalting scheme goes behind other cracking schemes. Nevertheless, when it is compared with other schemes over the entire refining steps ranging from synthetic crude oil to individual oil products, the deasphalting scheme exhibits its full advantages.

3.2.7 Alternate Case

Apart from the afore-mentioned base case planned to produce the crude oil capable of meeting standards, an alternative case, wherein Orinoco heavy crude oil is upgraded by a simpler scheme of combined solvent deasphalting and desulfurization, is studied. The study of an alternative case was motivated by a question: Is it necessary to upgrade the raw crude oil to such high levels of refined products as obtained in the base case? The synthetic crude oil to be produced is simply a raw material for further refining up to products having properties that can meet the requirements of the final demand structure. It seems that upgrading should be confirmed to the steps of:

(1) Lowering the viscosity of the highly viscous heavy crude oil to a pipelinable level.
(2) Decreasing the high concentrations of impurities, particularly the heavy metal contents, at least such levels that enable the ordinary refinery to treat them; and
(3) At the same time, decreasing the sulfur content to a moderate level.

In our impression, it looks possible that such a simpler scheme may rather be more adequate as a solvent deasphalting scheme and more beneficial to the Republic of Venezuela than the base case.

Adopted as the alternative case is a combination of solvent deasphalting of atmospheric residue and relatively moderate desulfurization of a GO/DAO mixture. As shown in Table 3.15, the deasphalted oil based on atmospheric residue is removed of metals to an extent of 60% or more of their contents of the atmospheric residue feed, but it still contains high levels of metals as a feed to a desulfurization unit. However, because it does not contain asphaltene which makes the rate of desulfurization reaction to slow down and causes the deterioration of catalyst due to coke deposit of on catalyst. It can be processed through the direct desulfurization unit of a 1% class operating on a non-regenerated catalyst replacement interval of 11 months (Refer to Table 3.16).

Fig. 3.7 shows a block flow diagram and material balance for the alternative case. In the material balance no consideration is given to refinery fuel, except for the H_2 plant fuel (naphtha and by-produced gases), thus a stringent comparison with the base case is difficult. A quick comparison of both case for their material balance and fuel oil consumption indicates that the quantity of raw crude oil required to produce 125,000

Table 3.15 Feed and Product Inspections of M-DS Unit (Alternate Case)

Basis: Cogollar IX/Cerro Negro Crude Oil (Reduces Crude)

(1) Estimated Yields

Feed

	vol%	BPSD	wt%	T/D
Reduced Crude	100.0	128,871	100.0	21,167

Product

	vol%	BPSD	wt%	T/D
DAO	78.78	101,518	76.22	16,132
Asphalt	21.22	27,353	23.78	5,035
Total	100.0	128,871	100.0	21,167

(2) Estimated Properties

		Reduced Crude	DAO	Asphalt
Gravity	°API	5.1	10.0	
Sp. Gr. 15/4°C		1.0353	0.9994	1.1576
Sulfur	wt%	4.12	3.54	5.60
Nitrogen	"	0.56	0.375	1.28
CCR	"	20.4	6.36	53.5
Asphaltene	"	13.3	0.00	43.3
Metal				
V	ppm	410	142.8	1,578
Ni	"	130	50.5	343
Fe	"	67	–	
Pour Point	°F			
R & B Softening	Pt °F			323.6
Viscosity				
@300°F	cst		240	
@300°F	"	3,739 @100°C	32	–
@250°C	cp		–	2,800
@300°C	"		–	380

Table 3.16 Feed and Product Inspection of Process Unit

Process Name: GO/AR DAO HDS Unit (Alternate Case)

(1) Estimated Yields

Feed

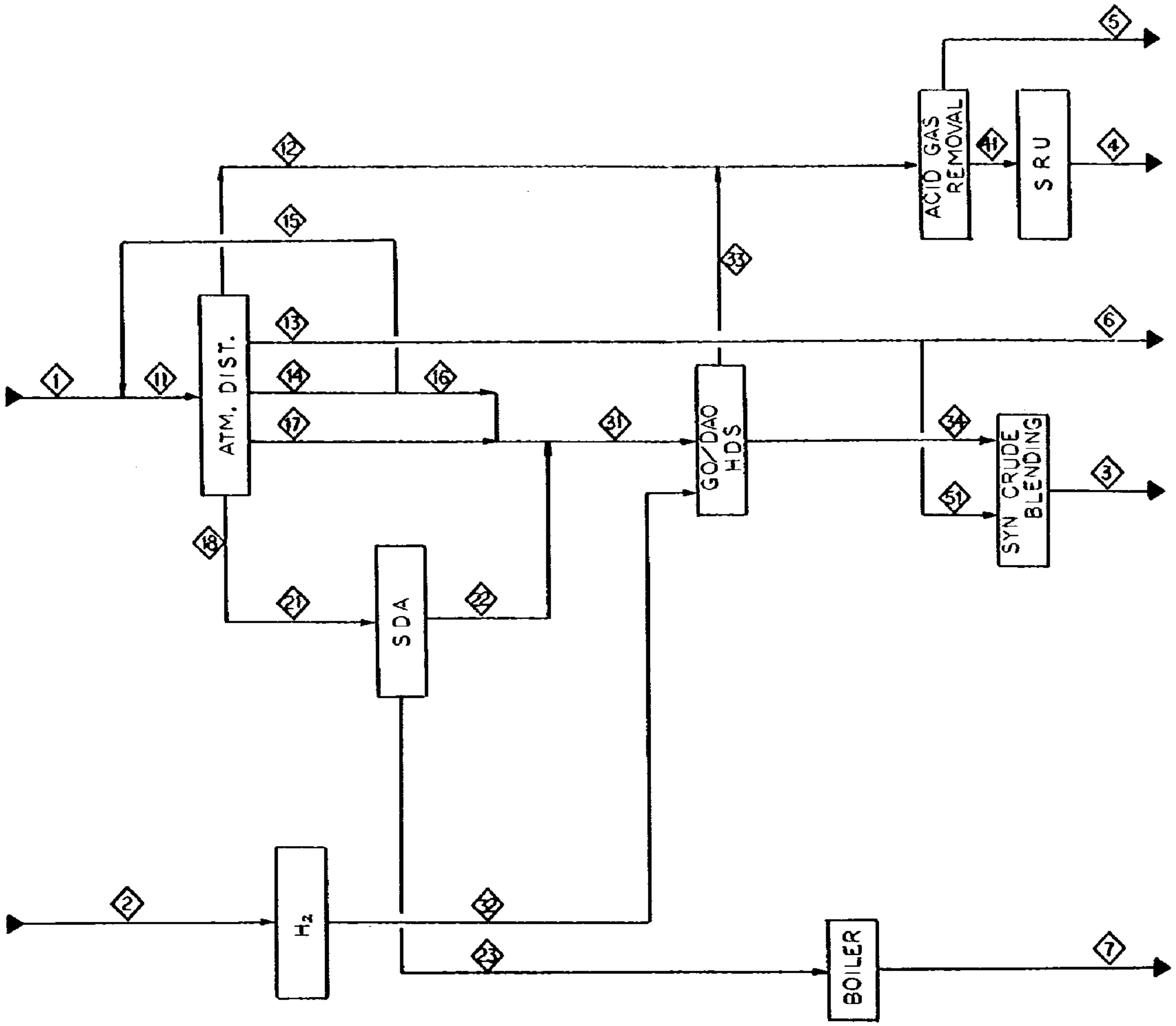
	vol%	BPSD	wt%	T/D
GO	17.46	21,478	16.01	3,076
AR DAO	82.54	101,518	83.99	16,132
Hydrogen (chemical)	(390 SCF/BBL)		0.68	131
Total	100.00	122,996	100.68	19,339

Product

	vol%	BPSD	wt%	T/D
H_2S			2.49	478
NH_3			0.12	23
C1			0.08	15
C2			0.13	25
C3			0.12	23
C4			0.12	23
C5 + Product	100.95	124,164	97.62	18,751
Total	100.95	124,164	100.68	19,339

(2) Estimated Properties @MOR

		GO	AR DAO	Total Feed	C5+ Liquid
Gravity	°API	24.9	10.0	15.2	17.1
Sulfur	"	2.17	3.54	3.32	1.00
Nitrogen	"	0.001	0.375	0.315	0.219
CCR	"		6.36	5.34	2.33
Metal					
V	ppm	–	142.8	119.9	10.2
Ni	"	–	50.5	42.4	5.0
Fe	"	–	–	–	–
Viscosity					
@100°F	cst	5.65	(50,000)	3,600	700
@210°F	"	1.70	240	67	29.1
TBP Dist					
TBP/5				407/504	100/430
10/30				572/785	515/637
50				982	930
70/90				–/–	–/–
95/EP				–/–	–/–



MATERIAL BALANCE (MOR)

STREAM NO.	STREAM NAME	FLOW RATE BPSD 4)	FLOW RATE TON/D	GRAVITY °API	SULFUR WT%	SULFUR TON/D
	FEED					
1	Raw Crude	151,791	24,435	8.5	3.67	917.6
2	Natural Gas	(360)				
	PRODUCT					
3	Syn. Crude	125,000	18,849	17.7	1.0	187.7
	BY-PRODUCT					
4	Sulfur 3)	-	432	-	99.5	430.0
5	Fuel Gas 4)	(306)	192	-	-	-
6	Fuel Naphtha 5)	303	40	37.2	0.15	0.3
7	Steam					
	INTER STREAM					
11	Atm.Dist.Feed	197,328	30,678	13.2	3.21	990.3
12	Off Gas	(18)	4)	-	-	-
13	Naphtha	1,138	152	37.2	0.65	1.0
14	LGO (Total)	51,937	7,142	32.0	1.16	82.9
15	LGO (Diluto)	45,537	6,263	32.0	1.16	72.7
16	LGO (Net)	6,390	879	32.0	1.16	10.2
17	HGO	15,088	2,197	23.0	2.43	53.4
18	Alen Residue	128,871	21,167	5.5	4.03	853.0
21	SDA Feed	128,871	21,167	5.5	4.03	853.0
22	DAO	101,513	16,132	10.1	3.54	571.1
23	SDA Asphalt	27,353	5,035	-9.3	5.60	282.0
31	GO/DAO	122,996	19,208	12.6	3.31	634.7
32	H_2 Gas 1)	(1,420)	128	-	-	-
33	Off Gas 5)	(602)	630	-	-	447.7
34	HDS Oil	124,165	18,737	17.1	1.00	187.0
41	Acid Gas 2)	(314)	478	-	-	447.7
51	Naphtha	835	112	37.2	0.65	0.7

Note:

1) As pure H_2

2) As removed H_2S

3) As removed Sulfur

4) ( ) 10^3 Nm^3/D

5) Incl. Solution H_2, and C_1 contained in H_2S
(Make-up H_2 gas composition; H_2 95 vol%,
C_1 5 vol%)

6) To be used for H_2 plant furnaces

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BLOCK FLOW DIAGRAM OF M-DS CASE ALTERNATE CASE

FIG. 3.7

BPSD of synthetic crude oil is somewhat larger in the alternative case than in the base case. This is mainly because of a small rise in API gravity (a low volume increase) in the alternative case.

In the meantime, when process unit construction cost is compared between the alternative case (Table 3.17) and the base case, it is estimated that the total cost for the alternative case is 83% of that for the base case.

Table 3.17 Construction Costs of Process Units

Process Unit	Capacity	No.s	Construction Cost (10^6 Japanese Yen)
Atm. Distillation	98,664 BPSD	2	9,046
M-DS Unit	64,436 BPSD	2	18,000
GO/DAO Hydro-desulfurization	61,498 GPSD	2	36,000
Hydrogen Plant	0.82 MM Nm^3/D as H_2	2	8,060
Acid Gas Removal	239 Ton/D as H_2S	2	2,020
Sulfur Recovery and Solidification	216 Ton/D as S	2	2,763
Total			75,889

By comparing construction costs of individual units, it is found that a higher cost of a large-scale deasphalting unit to be installed with the use of the atmospheric residue deasphalting route can be roughly offset by the cost of vacuum flashing unit which is indispensable for the vacuum residue deasphalting route. As a result, the difference in the process unit construction cost between both schemes is based on the difference in the costs of desulfurization-related units, such as GO HDS, VGO/DAO HDS and H_2 plant. In the deasphalting scheme, therefore, a key factor having a large impact on the process unit construction cost is the level of upgrading which affects the desulfurization severity.

The estimated utility requirements are also compared between the alternative case and the base case (Table 3.18). It is found that the fuel consumption in the alternative case is as low as about 60% of the fuel consumption in the base case. This reduction in fuel consumption corresponds to 3,800 BPSD of fuel oil. Of this quantity, about 2,500 BPSD is consumed in the form of naphtha and fuel oil. Such a form of fuel consumption serves to make up the defect of a low volume yield increase observed in the upgrading step of the alternative case, and thereby serves to reduce the crude oil requirement.

Table 3.18 Estimated Utility Requirements

(M-DS Alternate Case)

Process Unit	Capacity	Elec.	Steam Ton/H			Water Ton/H						Fuel x10^6 kcal/H	
	BPSD	KW	49KG 400°C	15KG 270°C	3.5KG sat.	BFW	cond.	Process water	Foul water	Loss water	Cooling water	Gas	Oil
Atm. Distillation (6)	193,728	1,660	20.2	19.8	-20.2			65.4	-85.2		708		104.6
M-DS	128,871	8,260	24.1	101.0	19.6		-125.1		-19.6		470		21.8
GO/DAO HDS	122,996	20,130		40.9	17.8	(7) 38.2	40.9		-53.9		5,440		125.0
Hydrogen Plant	(1) 1,640	1,490		-15.5		96.0	3.0		-50.8	-32.6	370	(4) 101.3	(5) 17.2
Acid Gas Removal	(2) 478	490		4.3	72.2		-76.5				1,150		
Sulfur Recovery	(3) 432	1,630			-43.4	60.8				-17.4	20		
Total		33,660	44.3	150.5	46.0	195.0	-157.7	65.4	-209.5	-50.0	8,158	101.3	268.6

Note: Negative figures indicate quantity made.

(1) x10^3 Nm^3/D as H_2

(2) Ton/D as H_2S

(3) Ton/D as sulfur

(4) Refinery off gas shall be used as fuel gas

(5) S.R. Naphtha shall be used as fuel oil

(6) Initial chemical inventory
Solvent (iC_5 50 LV%/n-C_5 50 LV%): 1800 Ton

(7) Stripped water which is treated by Foul Water Stripping Unit will be normally used instead of BFW

A primary cause of decrease fuel consumption in the alternative case is the elimination of vacuum flashing step, which accounts for about 40% of the total fuel reduction. The second cause is the small scale of hydrodesulfurization step, particularly the hydrogen plant,which accounts for about 60% of the total reduction in fuel consumption.

As obvious from the foregoing, in the case of heavy oil upgrading by means of a solvent deasphalting scheme, the upgrading level to be set is the most important factor decisively affecting the construction cost and the utility cost. This level should be determined by taking a quality/price relationship of synthetic crude oil into consideration.

Table 3.19 gives properties of synthetic crude oil obtained in the alternative case. The sulfur content of synthetic crude oil is set at 1.0%. As regards the API gravity rise and the light fraction content, the synthetic crude oil available in the alternative case fails to reach the target. Lowered viscosity of synthetic crude oil makes it easy to handle. The synthetic crude oil of the alternative case, unlike that of the base case, is not of such high quality as can be fed to FCC directly. Yet it is cleaner than any other crude oils, and has common properties permitting easy upgrading by means of a catalytic process. Orinoco heavy oil upgrading schemes based on the solvent deasphalting process have been discussed above. In principle, the base case is recommended as scheme of producing synthetic crude oil having such properties that can meet the target qualities of product. As obvious from the comparison with the alternative case, though, the cost of upgrading by the deasphalting process is significantly affected by the level of upgrading. This level should therefore be carefully determined after studies have been made on the relationship between upgrading level and refining cost, and on the quality/price relationship of synthetic crude oil.

Table 3.19 Estimated Properties of Syn. Crude by Reduced Crude Deasphalting Route

(1) Estimated Yields

	vol%	BPSD	wt%	T/D
Naphtha	0.7	835	0.6	112
C5+ Product	99.3	124,165	99.4	18,737
Total	100.0	125,000	100.0	18,849

(2) Estimated Properties

		Naphtha	C5+ Product	Syn.Crude
Gravity	°API	38.2	17.1	17.2
Sp. Gr. 15/4°C	wt%	0.8335	0.9517	0.9510
Sulfur	wt%	0.56	1.00	1.00
Nitrogen	"		0.219	0.217
CCR	"		2.33	2.30
Asphaltene	"		0.00	0.00
Metals				
V	ppm		10.2	10.2
Ni	"		5.0	5.0
Viscosity				
@100°F	cst		700	660
@210°F	"		29.1	28
Distil.				
IBP/5%	°F		100/430	100/428
10/30	"		515/637	515/635
50	"		930	930
70/90	"		–/–	–/–
95/EP	"		–/–	–/–

Table 3.20 Yield and Properties of DAO and Asphalt

Case Feed Stock		Base Case Vac Resid.		Alternate Case Atmos. Resid.	
Yield*					
DAO	Vol.%	68.57	(39.24)	78.78	(66.87)
	Wt.%	65.33	(39.21)	76.22	(66.01)
Asphalt	Vol.%	31.43	(17.98)	21.22	(18.01)
	Wt.%	34.67	(20.81)	23.78	(20.59)
DAO Properties					
Sp. Gr.	15/4°C	1.0108		0.9994	
Vis @210°F	cst	700		240	
@300°F	cst	69		32	
Sulfur	W%	3.52		3.54	
Nitrogen	W%	0.418		0.375	
Nickel	ppm	39.3		50.5	
Vanadium	ppm	107.9		142.8	
Asphaltene (C7)	W%	0.00		0.00	
Con. Carbon	W%	9.07		6.36	
Asphalt Properties					
Sp. Gr.	15/4°C	1.1706		1.1576	
R & B Soft. Pt	°C	162		162	
Sulfur	W%	5.82		5.60	
Nitrogen	W%	1.58		1.28	
Nickel	ppm	393		343	
Vanadium	ppm	1,683		1,578	
Asphaltene (C7)	W%	43.3		43.3	
Con. Carbon	W%	57.0		53.5	
Vis. @250°C	cp	4,000		2,800	
@300°C	cp	500		380	

Note * ( ) Crude Basis

3.3 UTILIZATION OF BY-PRODUCT

If a solvent deasphalting scheme is used to upgrade Orinoco heavy crude, SDA asphalt is the by-product. It is requested that the by-product is used as fuel for the steam- and power-generating boiler.

The SDA asphalt is more viscous than ordinary fuel oil used in boilers, and contains quite high levels of heavy metals which adversely affect steam super-heaters. Therefore, those boilers using SDA adphalt as their fuel call for special care.

Items of concerns about the combustion of SDA asphalt by boiler mostly relate to the handling of highly viscous fuel at a high temperature, and particularly to its pulverization. These concerns can be eliminated fundamentally by the following 4 types of combusion:

(1) Fluidized-bed combustion.
(2) Pulverized fuel combusion.
(3) Low-viscosity oil cutback.
(4) High-temperature atomizing combusition.

These alternative burning methods are compared with one another in Sub-section 3.3.10 for their respective merits and demerits. In our conclusion, the high-temperature atomization type of combustion is most advantageous. This feasibility study thus recommends this type for the boiler combustion of the SDA asphalt of Orinoco heavy crude.

3.3.1 By-product

Table 3.21 gives the products and properties of Orinoco SDA asphalt obtained from our upgrading scheme.

3.3.2 Transportation Facility

SDA asphalt given in Table 3.21 is a solid at normal temperature. The temperatures required to handle it in the liquid form are, e.g., 250°C or higher for storage (5,000 cst or less), about 300°C for flowing in pipe (500 cst or less) and 360°C or higher for atomization (100 cst or less). All these temperature levels are significantly higher than required for ordinary fuel oil handling.

It is not only difficult to maintain a large fuel tank at a temperature of 250°C or higher, but also such a high temperature is dangerous from a safety point of view, because a gaseous explosive mixture will be formed on the liquid surface. What is more, an even greater difficulty lies in heating asphalt at or above 360°C for atomization. Heat conducting surfaces, when partially heated, will cause coking or corrosion by hydrogen sulfide. Electric heaters are used for ordinary boiler fuel system, but they can never be used in this case for the above reasons.

In order to eliminate the afore-mentioned difficulties and smoothly burn the liquid form of highly viscous SDA asphalt at the boiler, we suggest a fuel piping system to be operated in the following manner:

Table 3.21 Quantities and Properties of SDA Asphalt
Cogollar IX/Cerro Negro Crude Oil Syn. Crude 125,000 BPSD

		SDA Asphalt	
		Base Case (Vac. Residue Feed)	Alternate Case (Reduced Crude Feed)
SDA Asphalt			
BPSD		25,543	27,353
Ton/SD		4,763	5,035
Properties			
Sp. Gr.	15/4°C	1.1706	1.1576
Sulfur	wt%	5.82	5.60
Nitrogen	"	1.58	1.28
CCR	"	57.0	53.5
Asphaltene	"	43.3	43.3
V	ppm	1,683	1,578
Ni	ppm	393	343
R & B Softening	Pt°C	162	162
Viscosity			
250°C	cp	4,000	2,800
300°C	cp	500	380

(1) Asphalt is directly sent from the bottom of the SDA asphalt stripper to the burners at about 340°C, by passing through a hot oil jacketed pipe kept at about 300°C, without passing asphalt through any intermediate tank or service tank.

(2) Successful atomization is accomplished at the burners, not by indirect heating, but by direct heating, wherein steam of 500°C generated at the boiler is fed to the burners of an internal mixing type to allow the steam heat to bring asphalt up to an atomizing viscosity and to promote atomization by steam.
When the deasphalting unit is directly connected to the boiler, the operation of boiler is directly affected by the operation of deasphalting unit. In those cases where the deasphalting unit is at rest during maintenance or where asphalt production runs short and fails to meet the necessary load level required by the boiler, any deficient quantity of fuel is supplemented alternatively by either vacuum residue or atmospheric residue, to immediately back up the fuel supply. Fuel piping is thus designed, taking this into consideration.

Therefore, the tank of an alternative vacuum residue (or atmospheric residue) fuel shall perform a controlling function, instead of installing an intermediate tank of SDA asphalt, if asphalt production is less than a necessary quantity of steam.

When the deasphalting unit is started up or shut down, the asphalt produced during such a period is not fed to the boiler, but is mixed with deasphalted oil, and the mixture is sent to the vacuum residue tank.

Steam of 500°C is used for heating of SDA asphalt inside the burners and subsequent asphalt atomization. Its requirement for these purposes is 15 tons/hr., which accounts for about 15% of the total fuel consumption. Since an ordinary steam requirement for atomization in the boiler is about 10% of the total fuel consumption (even 5% in a new model of burners), the asphalt combustion used in this study seems to have somewhat lower thermal efficiency than ordinary cases.

As regards the burning characteristics of SDA asphalt, it has been confirmed from our burner atomizing/burning tests with a small test burning furnace that this asphalt would give the same state of combustion as do ordinary fuel oils, as long as the asphalt is heated to a viscosity of ordinary fuel oil suitable for atomization and is burned with burners of good mixing with combustion air.

3.3.3 Boiler Plant

(1) Outline

A single-drum radiant type natural circulation boiler having water wall of a membrane type is used.

By-product asphalt from the upgrading refinery used as main fuel is atomized by burner located on the front and rear walls of the furnace.

In consideration of the combustion of the fuel having a high viscosity and high vanadium content, the furnace is designed to a large capacity enough to lower the temperature of flue gas at the furnace outlet.

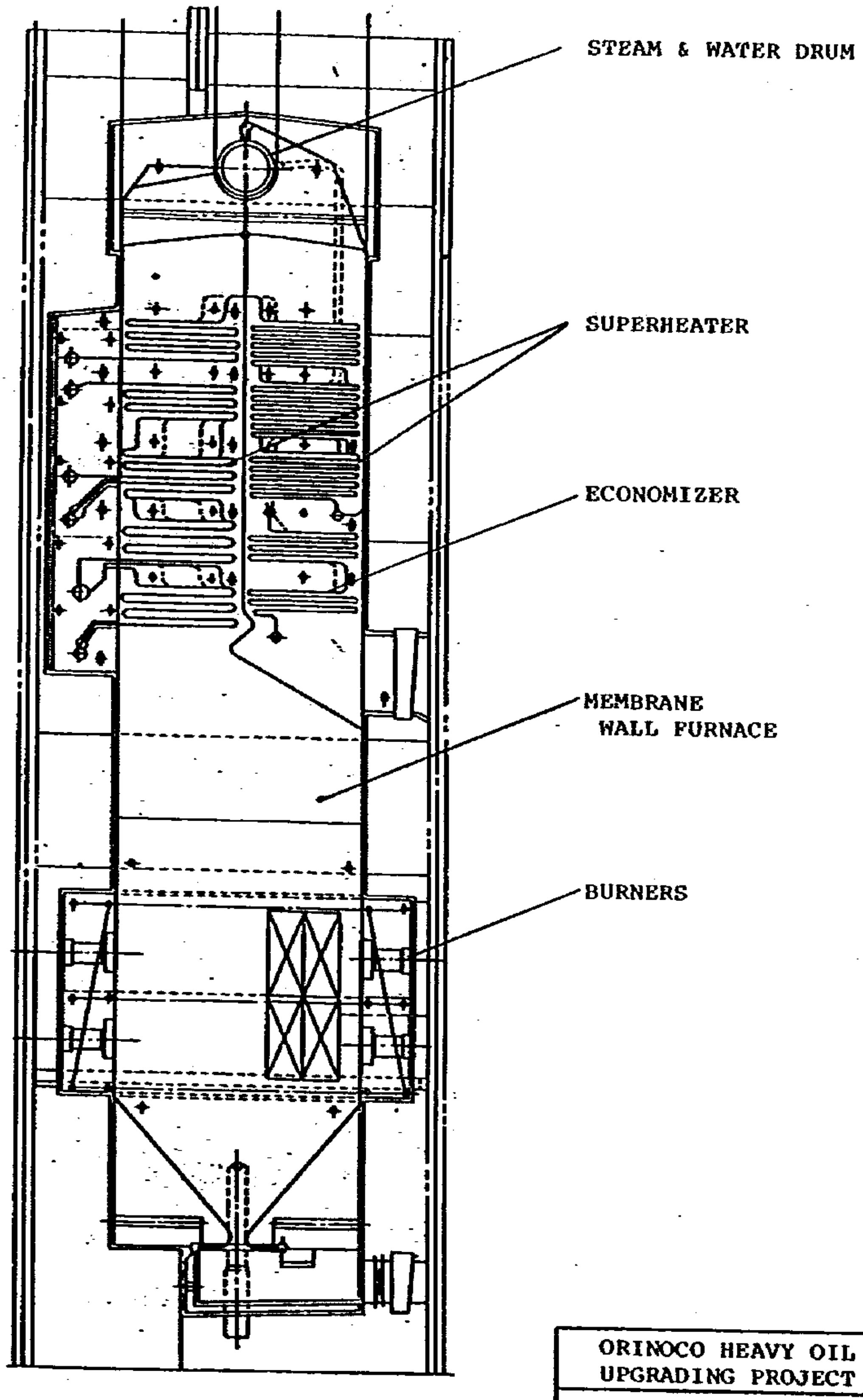
Horizontal multi-loop type superheaters, located at the furnace outlet section, superheats the saturated steam coming from the steam drum up to 500°C.

By dividing the superheaters into primary and secondary ones and installing a spray type attemperator between them, steam is controlled at a constant for the operating load range of 70 to 100%.

Horizontal multi-loop type economizer is located downstream of the superheater.

A gas air heater and a steam air heater are installed. The gas air heater is of a rotary type, divided into low- and high-temperature heating elements.

The low temperature heating element of a basket type is adopted to make its replacement easy. The steam air heater, located between the gas air heater and forced draft fan, raises the metal surface temperature of the gas air heater to a high tem-



ORINOCO HEAVY OIL UPGRADING PROJECT

GENERAL ARRANGEMENT OF BOILER

FIG. 3.8

perature enough to prevent corrosion.

Two forced draft fans and two induced draft fans are installed for air supply. The boiler, on the whole, is of a pressurized type.

The induced draft fans serve to compensate any pressure drop caused by such subsequent processes as the flue gas desulfurization and so on. It is attempted to economize auxiliary power.

Internal mixing steam atomizing type burners are located on the front and rear walls of the furnace. High temperature steam of 500°C is used for atomizing and heating to lower the viscosity of asphalt. The high-temperature air coming from the air heater is swirled by air register to give a good contact with atomized asphalt resulting stable combustion. An electrostatic precipitator is adopted to collect soot in the flue gas.

As regards control devices, combustion, boiler feed water, steam superheater are all planned to go into full automatic operation during normal operation.

Three feed water pumps, each having 50% capacity, are provided.

(2) General specifications of major equipment

General specifications of major equipment based on the following steam generation are described.

Quantity : 1,300 Ton/H

Steam conditions

Pressure : 100 Kg/cm^2G

Temperature : 500°C

(a) Boilers

Type : Single drum radiant type natural circulation boiler

Number : 3 units

Max. capacity : 650 Ton/H (each)

Steam condition

Pressure : 100 kg/cm^2G

Temperature : 500°C

Feed water temperature : 190°C

Air supply : Forced draft and induced draft fan

Structure : Refer to Fig. 3.8

(b) Burners

Type : Internal mixing steam atomizing type

Number : 12/unit

Location : Front and rear walls

(c) Air fans

Forced draft fans

Type : Turbo fan
Number : 2/unit
Operating conditions : 7,000 m^3/min. x 725 mm Aq. x 20°C

Induced draft fans

Type : Plate fan
Number : 2/unit
Operating conditins : 12,000 m^3/min. x 500 mm Aq. x 225°C

(d) Feed Water Pumps

Type : Multi stage barrel type
Number : 3/unit
Operating conditions : 340 Ton/H x 110 kg/cm^2G x 130°C

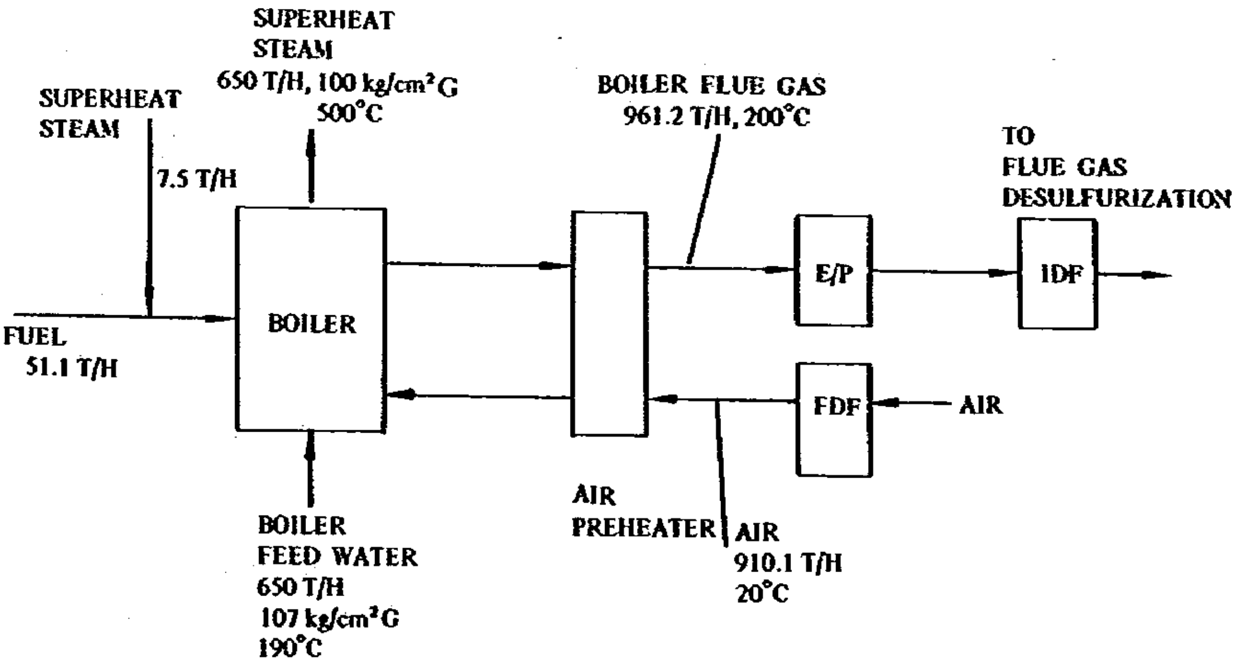
(e) Precipitators

Type : Horizontal gas flow type electrostatic precipitator
Number : 2/unit
Gas rate : 740,000 Nm^3/H
Gas temperature : 200°C
Efficiency : 98%

General arrangement of boiler is shown in Fig. 3.8.

3.3.4 Material Balance

Material balance for each boiler is shown below.



3.3.5 Combustion Characteristics and Performance of Boilers

The asphalt by-produced in the upgrading refinery is heavier and more viscous than conventional fuel oil and asphalt. It is solid at normal temperature.

In order to use this asphalt as boiler fuel, it is either fed in a solid phase or it is heated and fed in a liquid phase. The latter feeding method is studied.

Although a viscosity of about 40 cst is preferred for atomizing in the case of conventional boiler burners, it is very difficult to lower the viscosity of the by-product asphalt below 40 cst.

In the study, therefore, it is planned to raise the asphalt temperature as high, and decrease its viscosity as low, as possible for optimum atomization.

Instead of using an electric heater which may cause some coking trouble as a result of partial superheating, high-temperature steam is directly injected into the pipe at a point just upstream of the internal mixing type burners.

Since the atomized particles of asphalt are larger than those of conventional fuel oil, the following measures are taken:

- High temperature air (300°C or higher) is used.
- Swirl is given at the burner to obtain satisfactory mixing of fuel with air.
- Furnace is designed to have a capacity as large as possible to prevent fouling of the heating surface.

The atomizing steam requirement for two boilers is approximately 15 Ton/H, which accounts for 15 percent of the total boiler fuel. Since the atomizing steam requirement of conventional boiler is approximately 10 percent of the boiler fuel consumption (5% is the latest experience), efficiency of this method is a little lower, but with no impact.

In case of feeding asphalt in the solid phase, a combustion system similar to that of anthracite containing low volatile matter is required.

This, in turn, requires a larger furnace capacity, and additional equipment such as pulverizer and dryer.

What is more, boiler efficiency is reduced due to an increase in unburnt material. Therefore, a combustion system based on the feeding in liquid phase should be desirably used.

Because of high sulfur and vanadium contents of asphalt, due consideration should be paid to high-temperature corrosion caused by vanadium and low-temperature corrosion caused by sulfur in the superheater.

In order to avoid the high-temperature corrosion in the superheater tubes, the following countermeasures are required to lower the skin temperature of the tubes:

- Outlet of steam (high temperature) is arranged in the low-temperature gas section and inlet of steam is arranged in high-temperature gas section.
- The gas temperature is lowered by adopting a large furnace colume.
- A high steam velocity in the tube is used.

- The superheater is designed to avoid radiant heat from the furnace.

However, as the vanadium content of asphalt is very high, some extent of corrosion is inevitable and replacement of a part of tubes will be required during the scheduled maintenance.

As for the low-temperature corrosion prevention, the following countermeasures are required:

- A high feed water temperature (190°C) is planned, in order to keep a high skin temperature of economizer tubes.
- Corrosion-resisting material is used for the low temperature element of the gas air heater. Also, the basket type element is used for its easy replacement.
- Skin temperature of the element is kept above dew point by installing a steam air heater which raises the inlet temperature of the gas air heater.

3.3.6 Boiler Waste

(1) Normal operation (650 T/H x 2)

Blowdown water	: 13 Ton/h (Max. 40 Ton/H)
Soot from electrostatic precipitator	: 50 Ton/D

(2) Wastewater from the hydraulic tests

At time of scheduled maintenance (per year per boiler)	: about 150 Ton

(3) Wastewater from air heater washing

(per 3 months per boiler)	: about 300 Ton

3.3.7 Utility

Utility requirements for operating two boilers (650 Ton/H x 2) are:

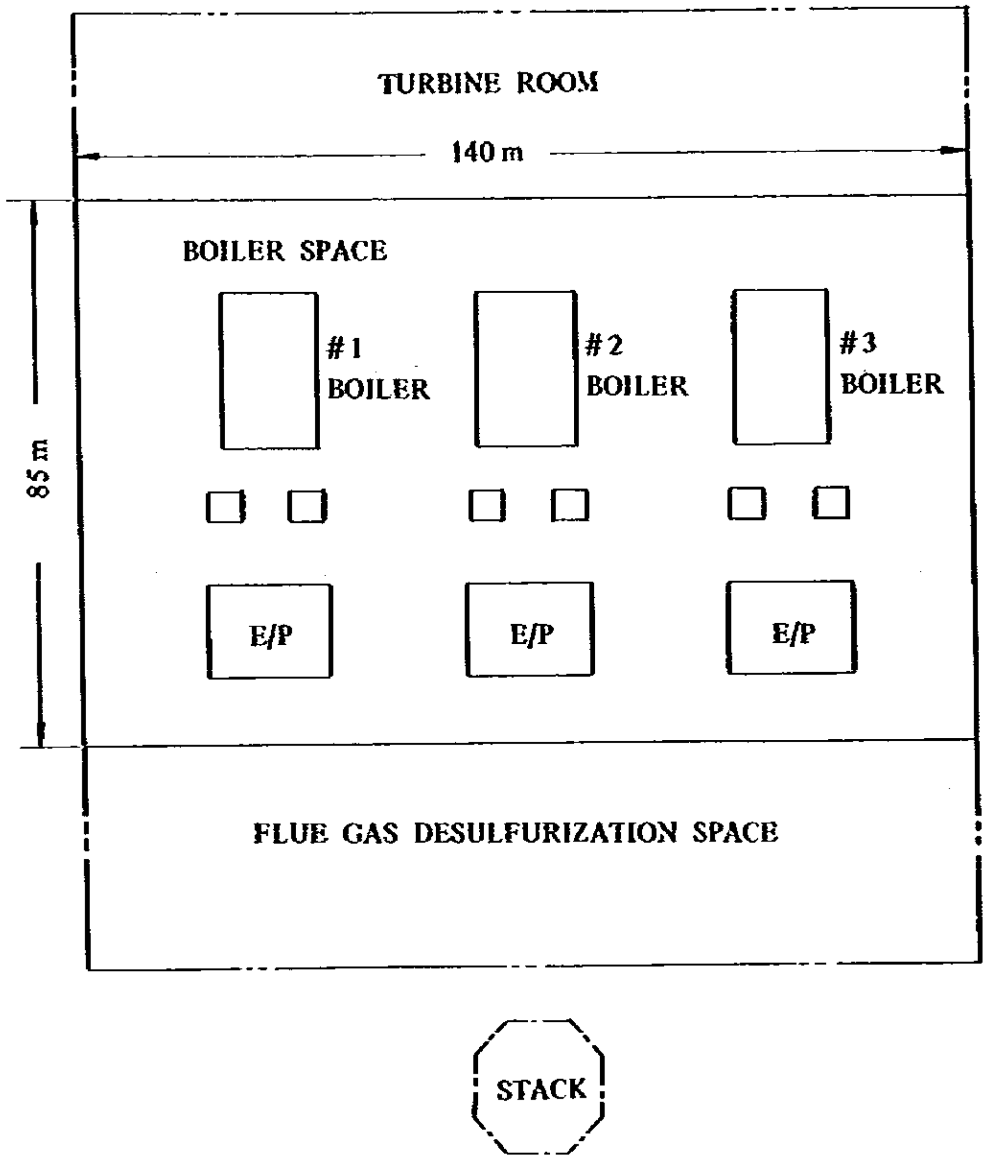
Electric power	15,000 KW
Steam, 100 kg/cm²G, 500°C	15 Ton/H
Boiler feed water	1,313 Ton/H
Blowdown water	−13 Ton/H
Cooling water	20 Ton/H
Fuel (Net)	958 MM Kcal/H

3.3.8 Estimated Investment

An estimated investment cost for the above boiler plant (650 T/H x 3 units including one spare) is 22,500 million Japanese Yen as of July, 1980 based on construction at Chiba, Japan.

3.3.9 Required Facility Area

Required facility area is shown below.



3.3.10 Alternative Methods of Asphalt Combustion

We recommend the high-temperature atomizing type of combustion as the most appropriate system for burning SDA asphalt at the boiler. As alternatives, we will outline the following three types of combustion.

(1) Fluidized-bed combustion

Boilers of the fluidized-bed burning type can maintain a good burning state even when using, as its fuel, a liquid having much larger particle size than used in ordinary boilers, or a flaky solid fuel.

Therefore, the properties of SDA asphalt, such as high viscosity and high softening point, are not considered to be any problems for use in this type of boilers.
Although we have no experience now in a large-scale commercial boiler of the fluidized-bed burning type, we expect that a technology will be established by the second half of 1980s for such a boiler. In our opinion, this type of boilers should be combined with M-DS for a potential combustion system of the future.

(2) Pulverized solids combustion

A system of pulverizing coal and burning coal and burning fine coal in a continuous manner is an established technology having a long history. The lower the asphalt yield in solvent deasphalting, the higher the asphalt softening point will rise.
Asphalt is then more easily handled in the solid form, rather than in the liquid form. Indeed, we have flaked tons of asphalt having a softening point as high as 140°C, obtained by treating a Middle East crude residue at a low solvent ratio, using a solvent deasphlting pilot plant. We thereby could have confirmed that asphalt can be pulverized in the same manner as in coal pulverization. There was no sign that powdery asphalt may undergo solidifying and lumping after a long period of storage, although we still have to make sure of its behavior when a large stock-pile of asphalt is consolidated under the storage condition.

If asphalt having a high softening point is pulverized, it is necessary to have a series of solids and power handling facilities of a large scale in such steps as molten asphalt flaking, flake asphalt pulverization, and storage of powdery asphalt in silos. Heat recovery from a high-temperature asphalt is difficult in the flaking step.
In spite of some afore-mentioned problems, the combustion of pulverized SDA asphalt is considered highly practicable, as the system is organized by existing technologies only.

(3) Asphalt cutback with a low-viscosity oil

Asphalt having a high softening point is cut back with a low-viscosity oil (GO, VGO) to bring asphalt to a low viscosity level sufficient to use it in the boilers. If a low softening asphalt is produced by deasphalting, the cutback method is more advantageous in giving a higher yield of asphalt at the same level of viscosity than the deasphalting step only.
Calculations were attempted on a case where SDA asphalt having a softening point of 170°C is cut back with VGO to such a viscosity level that can be handled at a storage temperature of 150°C and an atomizing temperature of 250°C, which are considered as the upper limits in the practice of engineering.
The following table shows a comparison of a cutback with a vacuum residue having a similar viscosity.

	SDA 65 wt.% VGO 35 wt.%	Vacuum residue, 100%
Product rate, wt.% (vol.%), Based on crude oil	32.02 (29.74)	60.02 (57.22)
Viscosity, 150°C, cs	5,000	2,500
250°C, cs	25	18

As seen in the above table, the cutback method is more advantageous in its yield of light oils than simple operations of distillation. On the other hand, boiler fuel is produced by this method in an amount more than 50% as much as in the case where asphalt alone is burnt. Another disadvantage is that VGO, an important base material for synthetic crude, has to be burnt as a component of boiler fuel.

This case therefore should be considered mainly as a means for purging asphalt pipings at the time of process shutdown.

CHAPTER 4 DETAILED DESCRIPTION OF UTILITY AND OFFSITE FACILITIES

This chapter outlines the utility and offsite facilities which are required for smooth operations of the processes described in Chapters 1, 2 and 3. Boiler facilities are described in Chapter 7, UTILIZATION OF BY-PRODUCT.

4.1 UTILITY AND OFFSITE FACILITIES

4.1.1 General

Utility and offsite facilities are planned in order to operate smoothly the on-site processes for the Orinoco heavy oil upgrading project and the boiler facilities using by-product as a fuel.

The facilities are planned individually for the following three cases.

Fluid coker case
Eureka case
M-DS case

The main items of utility and offsite facilities are as follows:

(1) Utility facilities

Steam generation and distribution system
Power generation and distribution system
Water treating system
Pure water system
Condensate treating system
Potable water system
Cooling water system
Fuel system
Air system
Inert gas system

(2) Offsite facilities

Storage system
Loading and receiving system
Waste water treating system
Flue gas desulfurization system (for boiler flue gas)
Fire fighting system
Control system
Communication system

Lighting system
Earth system
Flare and blowdown system
Roads and fences
Buildings
Administration office
Maintenance shop
Warehouse
Laboratory
Power house
Substation
Firehouse
Locker room & rest house
Gatehouse
Clinic
Cafeteria
Others

4.1.2 Design Criteria

In discussing the utility and offsite facilities, the following design criteria are set up.

(1) Design criteria of utility

The utilities which are generated and used within the refinery are based on the following criteria.

(a) Electricity

Service	kw Range	V	Phase	Hz
	Below 3/4 kw	110	1	60
Motor	1 kw – 100 kw	440	3	60
	Above 101 kw	2,400	3	60
Lighting		110	1	60
Instrument		110	1	60

(b) Steam

Supply base

	Pressure Kg/cm^2G	Temperature °C
Ultra high pressure steam	100	500
High pressure steam	50	405
Medium pressure steam	16	275
Low Pressure steam	4	165

(c) Raw water

Raw water is transported from the river Orinoco via pipeline and adequate quantities of raw water are delivered at the fence of the refinery. The raw water has enough pressure to enter the flocculation and sedimentation sections of the water treating system.

The raw water is treated and used as cooling water, industrial water, fire extinguishing water, potable water and boiler feed water. Quality of the raw water is based on the following analysis data.

Name of river water	Orinoco river water
Water intake	Casa Bombas
Date	August 27, 1975
Company	Sidor
pH	6.6
Conductivity	18
Temperature	26°C
Saturated pH (80°F)	9.8
Analysis data	
Calcium	6 ppm (12.34%)
Magnesium	2 ppm (4.11%)
Potassium	16.3 ppm (33.53%)
Bicarbonate	6 ppm (12.34%)
Sulphate	10 ppm (20.57%)
Chloride	5.3 ppm (10.90%)
Nitrate	3 ppm (6.17%)
Turbidity	14 JTU
Total dissolved solids	9.6 ppm
Suspended solids	225 mg/ℓ
Hardness	8
Total alkalinity	6

Total iron	2.4 ppm Fe
Manganese	Nil ppm Mn
Dissolved silica	6.8 ppm SiO_2
Total silica	14.4 ppm SiO_2
Nitride	Nil ppm NO_2
Permanganate value	13.7 ppm O_2
Carbon dioxide	7 ppm CO_2
Dissolved oxygen	6.7 ppm O_2
Oil	15 mg/ℓ

(d) Pure water

Raw water is fed to the pure water system after treated by the water treating system.

Quality of the pure water is set as follows:

pH	8.8 – 9.0
Total Hardness ($CaCO_3$)	0 ppm
Dissolved Oxygen	Max 0.007 ppm
Oil	0 ppm

(e) Air and inert gas

	Instrument air	Plant air	Inert gas
Pressure, Kg/cm^2G	6	6	6
Oil Free (Yes or No)	Yes	Yes	Yes
Water Free (Yes or No)	Yes	–	–
Temperature, °C	40	40	35
Dew Point, °C	-10	–	–
Purity N_2, %	–	–	99.8

(f) Fuel

Fuel used in the refinery is based on the following conditions.

Services	Source of Fuel
Process Heater	Vacuum residue is mainly used and off gas and naphtha are used for hydrogen plant.
Boiler for the Refinery	Heavy by-product and, if necessary, supplemental fuel.
(Boiler for Oil Field)	(Excess fuel gas in the refinery is delivered to oil field.)

(g) Natural gas

Natural gas is fed to the hydrogen plant.

Properties of natural gas are as follows:

Composition	
C_1	93.1 mol%
C_2	1.9 mol%
C_3+	1.3 mol%
CO_2	3.7 mol%
Total	100.0 mol%
H_2S	60 ppm
RSH & COS	10 ppm
Supply Pressure	500 psig

(2) Design criteria of offsites

The main design criteria of the offsite facilities are as follows:

(a) Storage system

The following storage capacities are set up.

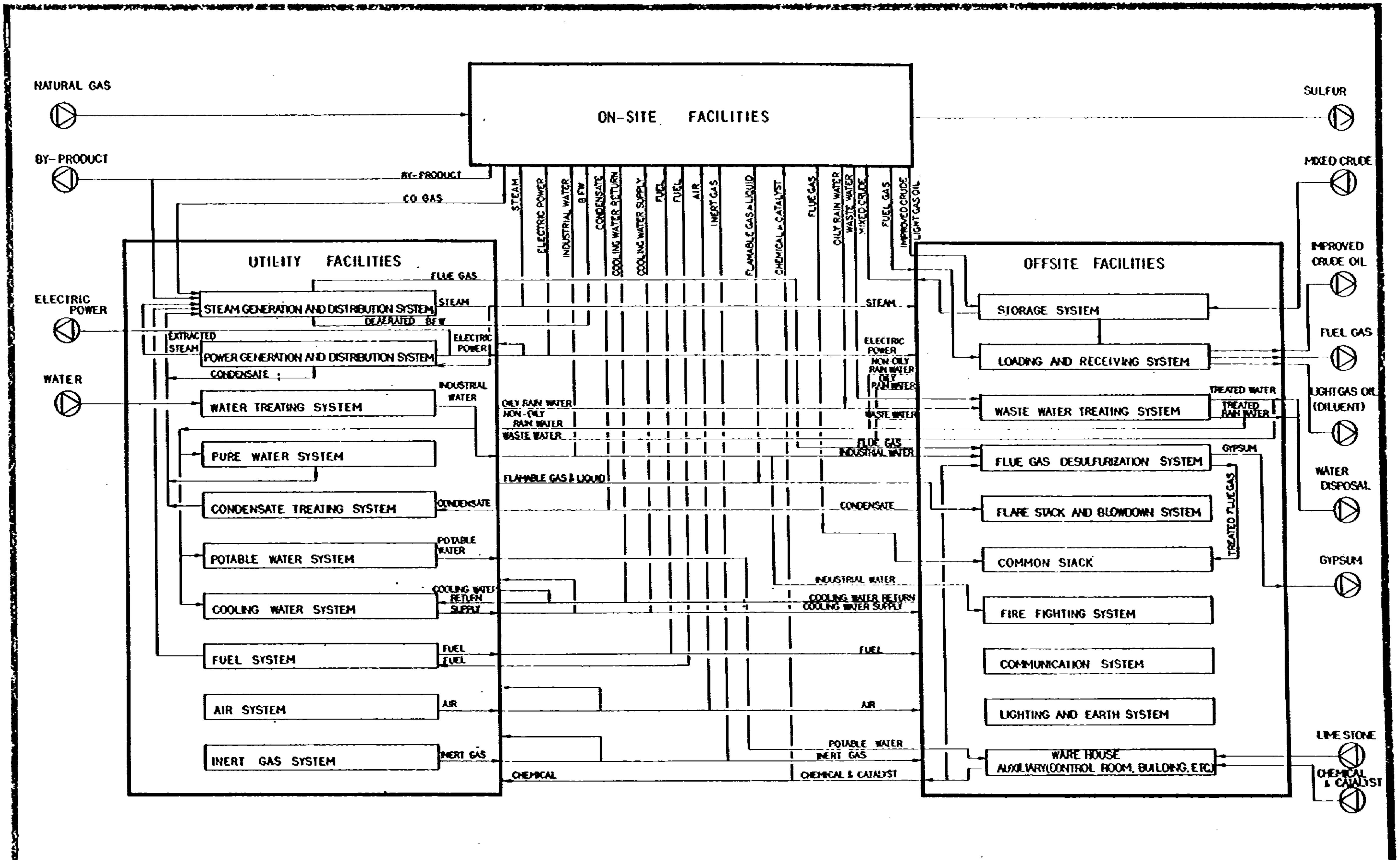
Item	Storage Capacity
Raw Materials	
Mixed Crude Oil	30 stream days
Natural Gas	No
Raw Water	1 stream day
Limestone	30 stream days
Catalysts and Chemicals	
Catalysts	Only for replacement
Chemicals	60 stream days

Item	Storage Capacity
Intermediates	
Straight Run Naphtha	3.5 stream days (minimum quantity for continuous operation)
Gas Oil	Ditto
Vacuum Gas Oil	Ditto
Vacuum Residue	Ditto
Intermediate of Each Process Unit, etc.	Ditto
Products	
Improved Crude Oil	7 stream days
Diluent Light Gas Oil	7 stream days
By-product (Coke, Pitch, Asphalt)	Minimum quantity for continuous boiler operation
Sulfur	7 stream days
Gypsum	7 stream days

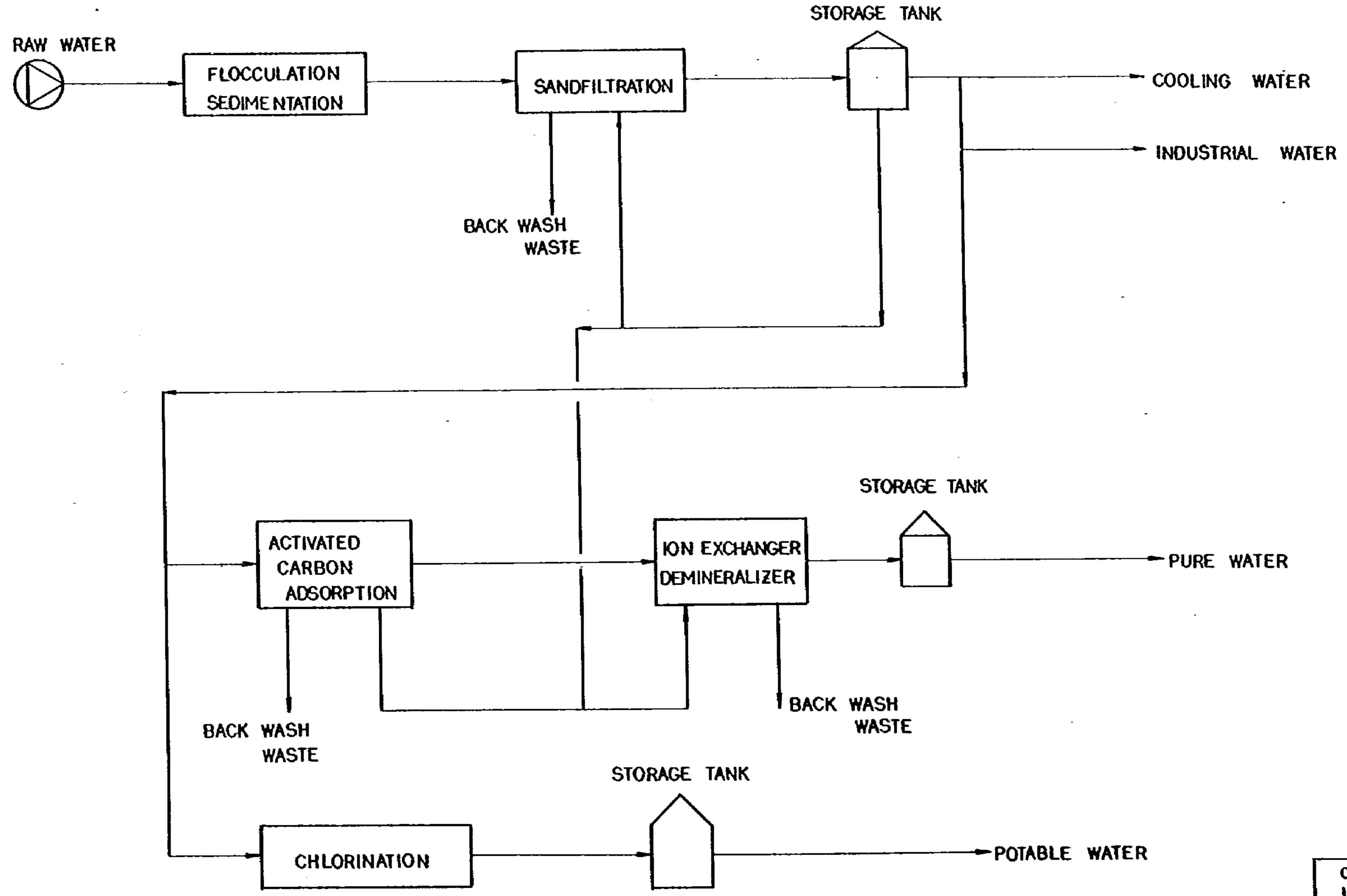
(b) Loading and receiving system

Loading and receiving are done under the following conditions.

Item	Loading and Receiving Conditions
Raw Materials	
Mixed Crude Oil	Supplied at enough pressure to enter the mixed crude tank.
Natural Gas	Supplied at a pressure of 500 psig.
Raw Water	Supplied at enough pressure to enter the flocculation, sedimentation system
Limestone	Supplied at suitable particle size to store in the silo.
Catalysts and Chemicals	Supplied at suitable conditions for storage
Product Improved Crude	Transported at a pressure of 40 kg/cm^2G.
Diluent	Transported at a pressure of 10 kg/cm^2G.
Offgas	Transported at a pressure of 10 kg/cm^2A.
By-product	Stored in minimum quantities with no loading system
Sulfur	No loading system
Gypsum	No loading system



ORINOCO HEAVY OIL UPGRADING PROJECT
BLOCK FLOW DIAGRAM OF UTILITY & OFFSITE FACILITIES
FIG. 4.1



ORINOCO HEAVY OIL UPGRADING PROJECT

BLOCK FLOW DIAGRAM OF WATER SYSTEM

FIG. 4.2

(c) Waste water treating system

It is important to plan the total waste water treating system covering not only the refinery site but also the crude oil production field.

Therefore, at the refinery site, the waste water treating system is installed to remove NH_3, H_2S and oil only from the refinery waste water. The properties of the treated waste water are planned to satisfy the following conditions.

Item	Conditions
pH	5.8 – 8.6
NH_3	Max. 30 ppm
H_2S	Max. 5 ppm
SS	Max. 30 ppm
Oil	Max. 10 ppm

(d) Flue gas desulfurization system

Flue gas desulfurization system is installed to treat the flue gas coming out of the boilers, which use CO gas and/or by-product as fuel. The rate of desulfurization is planned to be 90%.

The desulfurization is a wet method, and SO_2 in the flue gas is recovered as gypsum.

4.1.3 Description of Utility and Offsite Facilities

Block flow diagram of utility and offsite facilities is shown in Fig. 4.1

Each system is described below.

(1) Utility facilities

(a) Steam generation and distribution system

Steam generation system is described in Chapters 1, 2 and 3.

The systems are designed to generate steam efficiently throughout the year. The systems cover the steam requirements for the normal operation and reduced operation of the processes. Also the systems provide the steam requirements for generation of electric power required for the refinery and crude oil production field.

The water deionized by a pure water system is delivered to a deaerator for removing dissolved oxygen. The deaerated water is pressurized by feed water pumps and sent to boiler drums through boiler feed water heater.

Steams generated at the steam generator and extracted from the steam turbine for electric power generator, after adjustment of supply pressure, are distributed to on-site, utility and offsite facilities.

(b) Electric power generator and distribution system

The system, consisting of such major equipment as main generators and start-up generator, generates electric power which is supplied to the refinery and oil production field.

The power generators are driven by steam turbines of extracting-condensing type.

Through the unit, a part of ultra high pressure steam (100 kg/cm²G, 500°C) fed to the unit as motive steam is extracted at 50 kg/cm²G, 405°C as high pressure steam, 16 kg/cm²G, 280°C as medium pressure steam and 4 kg/cm²G, 165°C as low pressure steam to be supplied to other facilities.

(c) Water treating system

Raw water is river water transported from the River Orinoco via pipeline.

Raw water is treated by flocculation, sedimentation and sandfilter and stored in industrial water tanks. The stored water is used, either as it is or after being treated dependent on required quality as cooling water, boiler feed water, industrial water, potable water and fire fighting water. Block flow diagram of the water system is shown in Fig. 4.2.

(d) Pure water system

Boiler feed water is produced by treating the industrial water through activated carbon adsorption, decarbonator and cation and anion exchanger.

The object of treating by activated carbon adsorption system is to remove the oily content in raw water.

(e) Condensate treating system

Condensate from reboilers and heaters of the refinery is treated by polisher and reused as boiler feed water. Condensate from the surface condensers for the steam turbines is reused as boiler feed water without treating.

(f) Potable water system

The treated water by flocculation, sedimentation is sterilized by chlorine and delivered as potable water.

The system consists of chlorinator, tank and elevated tank.

(g) Cooling water system

The system recools cooling water to the specified temperature and circulates the cooled water. The treated water by flocculation, sedimentation is used as make-up water.

The system consists of such major equipment as cooling tower, cooling water pumps and chemical adding device.

Cooling water used in each facility is returned to the top of the cooling tower through cooling water return line. The returned water is recooled by contacting with air in falling down into the water basins at the bottom. After being supplied with make-up water (same quantity as loss caused by evaporation, entrainment and blowdown), the recooled water is pumped to each facility and recirculated in the refinery.

Design basis for cooling towers are as follows:

Inlet Temperature	43.3°C
Outlet Temperature	32.2°C
Wet-bulb Temperature	27.2°C
Concentration ratio	5.0

(h) Fuel system

This system receives fuel gas and fuel oil produced in the refinery and supplies them to steam boilers, process furnaces, etc.

The fuel oil system consists of such major equipment as fuel oil tank, pumps, filter and heater for lowering viscosity of fuel oil.

Minimum temperature is set up at 20°C for design of transportation of vacuum residue and asphalt.

(i) Air system

The system supplies required air for instruments and miscellaneous use.

The system consists of such major equipment as air compressor, air surge drum and air dryers.

Air is taken into the air compressor from an inlet equipped with a filter and a silencer. After being compressed by multi-stage compression, it is fed to the air surge drum through the after cooler.

From the air surge drum, the air for instruments is led to the air dryer for drying to the specified dew point and sent to pneumatic control equipment.

(j) Inert gas system

The system generates and supplies nitrogen gas to be used for sealing, purging and maintenance required for the refinery.

The system consists of such major equipment as a compressor, a cooler and a refrigerator for cooling the compressed air, an adsorber for removing moisture, a heat exchanger and an expansion turbine for further cooling, a liquefier for liquefying compressed air, a rectifying column for separating the liquefied air into waste air and nitrogen of required purity, and an evaporator for gasifying the liquid nitrogen.

(2) Offsite Facilities

(a) Storage system

The system consists of various tanks for the following purposes.

- Mixed Crude Oil Tanks : Storage for stable supply of mixed crude.

- Intermediate Tanks : Intermediate storage required for operation and maintenance of process units.
- Product Tanks : Storage of final products
- Other Service Tanks : Storage of refinery fuel oil, slop oil

(b) Loading and receiving system

The system satisfies the criteria of loading and receiving system described in para. 4.1.2 (1).

The loading system consists of such major equipment as loading pumps of improved crude oil and diluent, a compressor (in case excess off gas is generated), pipelines limited in the refinery and flow control system.

(c) Waste water treating system

Waste water from the refinery is classified into four groups; ① on-site waste water containing H_2S, NH_3 and oil, ② utility and offsite waste water, ③ oily rain water from the process paved area and tank yard and ④ non-oily rain water.

The waste water is collected individually according to its group and sent to the waste water treating system through the sewerage system.

On-site waste water, separated from other waste water, is treated by waste water stripper system to remove the dissolved NH_3 and H_2S and further treated by CPI oil separator to separate oil.

Treatment is not required for waste water from utility and offsite fasilities, except sanitary sewage which is treated with the cesspool. Treated on-site waste water and untreated utility and offsite waste water are mixed and discharged outside the refinery. Oily rain water is treated by CPI oil separator and is discharged outside the refinery.

(d) Flue gas desulfurization system

The system treats the flue gas coming out of the boilers to remove SO_2 as gypsum.

Firstly, flue gas goes to the scrubber for removing dust, then passes into an absorbing column where SO_2 in the gas is recovered as calcium sulfite while the gas is contacting with a calcium-containing solution.

The calcium sulfite is sent to an oxidizer in a slurry state, where calcium sulfite is oxidized to gypsum. Gypsum-containing slurry is treated by a solid-liquid separator to separate gypsum.

(e) Flare and blowdown system

The system disposes of vapors and liquids discharged by various pressure-relieving devices such as safety valves, rupture disks, pressure-control valves, and furnace emergency blowdown valves. The system consists of such major equipment as flare holder, blowdown drum, knockout drum and smokeless type flare stack.

(f) Common stack

Flue gas from the process furnaces and the flue gas desulfurization system is sent to the common stack and vented into the air.

(g) Fire fighting system

The system is provided in order to prevent the outbreak of a fire and to minimize damage in the event of a fire or explosion.

The system consists of three parts, i.e.:

- First-aid fire fighting system using portable fire extinguishers.
- Water fire fighting system of water, loop lines and hydrants and fixed or semi-fixed type foam fire fighting system for tankage.
- Fire alarm system.

(h) Control system

To operate the refinery safely, efficiently and economically, the operating conditions should be continuously monitored and controlled.

Reports of operating conditions are used for analyzing operating characteristics and for management purpose such as market planning.

The system consists of three control rooms for on-site, utility and offsite facilities.

(i) Communication system

The system consists of the following two systems:

- Private automatic branch exchange system

  As to calling from inside the refinery to the outside, local calls are conducted by means of dialing, and other calls are made through the exchange operation.

- Paging system

  The system is for broadcasting and communication necessitated in the course of refinery operation, and consists of the amplification facilities, power supply facilities, speakers for paging, and handset station for communication.

(j) Lighting system

- Yard lighting

  Lighting facilities necessary for nighttime operation are provided in the on-site and utility area and trankage area.

- Road lighting

  Installation of lighting facilities (at intervals of approximately 40 m, and approximately 400 W per spot) necessary for the safe movement of vehicles is being planned.

(k) Auxiliary

In addition to the above-described systems, the following systems are installed in the refinery.

- Road and Fence

– Building	No.s	Floor Area, m^2
Administration Office	1	3,000
Maintenance Shop	1	2,000
Warehouse	3	2,000
Laboratory	1	500
Engineering Office	1	1,000
Control Room	3	2,000
Powerhouse	2	4,000
Substation	20	4,000
Firehouse	1	500
Cafeteria	1	500
Clinic	1	300
Rest House	2	200
Gatehouse	2	100

4.2 UTILITY AND OFFSITE FACILITIES FOR THE FLUID COKER CASE

4.2.1 General

This section refers to the results of study for the utility and offsite facilities of Fluid Coker case based on the above-mentioned design criteria, and the construction cost of the facilities.

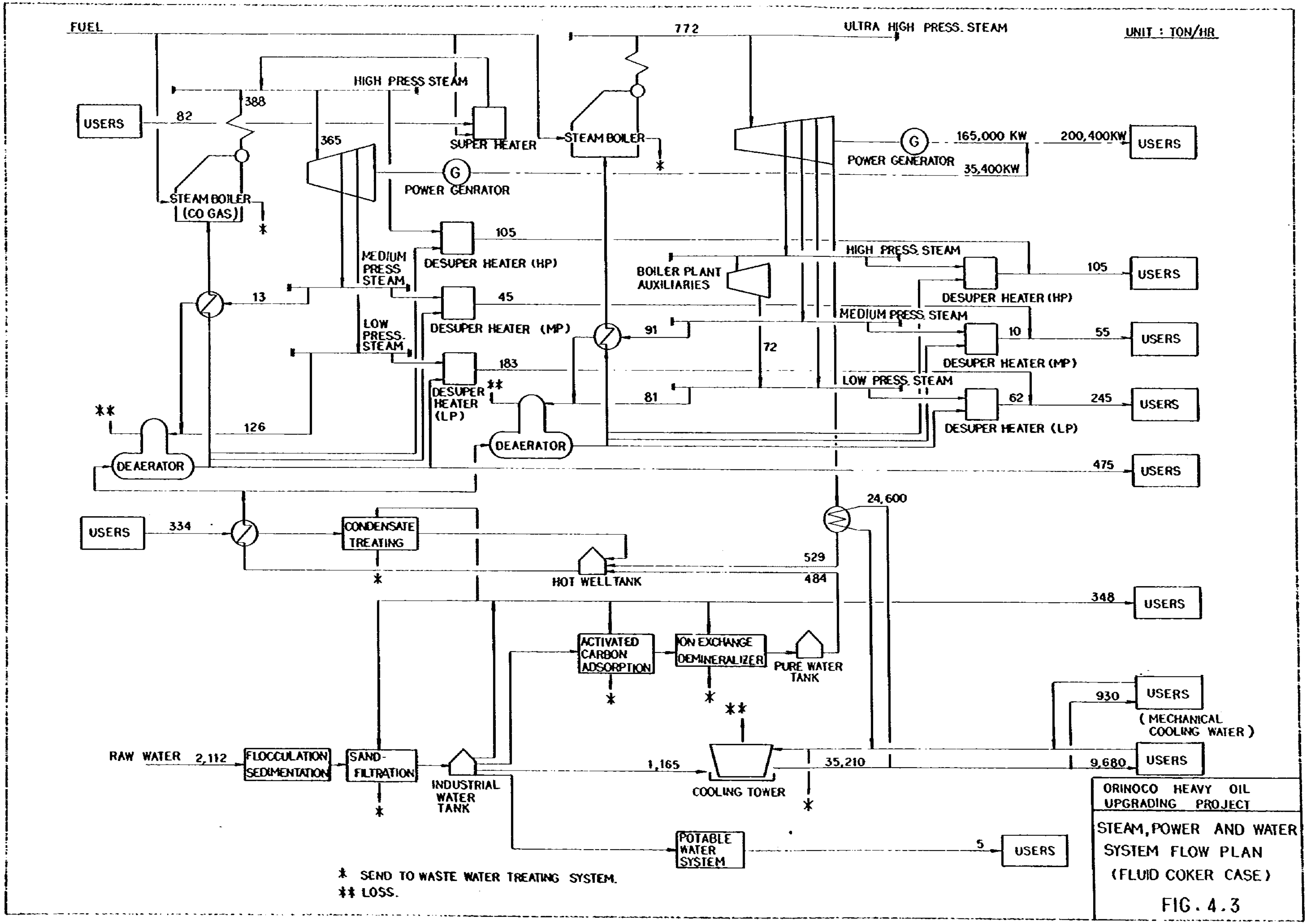
4.2.2 Results

(1) Utility facilities

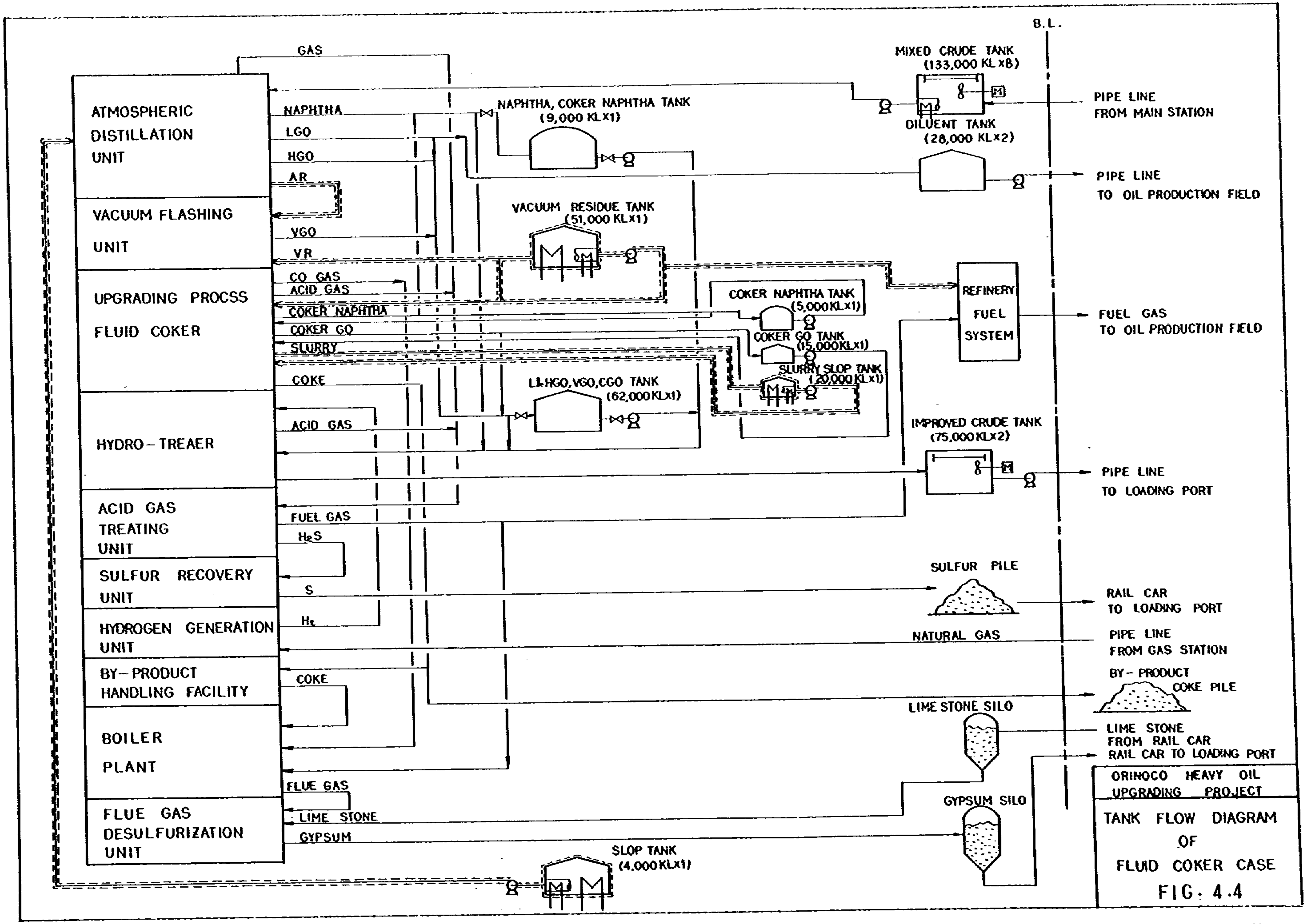
Based on the information on the utility requirements of the Fluid coker case, total utility requirements of the refinery are determined.

And the electric power requirements of the crude oil production field are calculated to be 126.2 MW, because 150 MW of electricity is required for 170,000 BPCD of crude oil production and Fluid coker case requires 158,160 BPSD of crude oil production.

$$\frac{150}{170{,}000} \times 158{,}160 \times \frac{330}{365} = 126.2\ (\text{MW})$$



FUEL
772
ULTRA HIGH PRESS. STEAM
UNIT : TON/HR
HIGH PRESS STEAM
388
USERS
82
SUPER HEATER
STEAM BOILER
365
POWER GENRATOR
G
165,000 KW
200,400KW
USERS
POWER GENERATOR
35,400KW
STEAM BOILER
(CO GAS)
105
DESUPER HEATER (HP)
MEDIUM PRESS STEAM
13
45
DESUPER HEATER (MP)
LOW PRESS. STEAM
183
DESUPER HEATER (LP)
**
126
DEAERATOR
BOILER PLANT AUXILIARIES
HIGH PRESS. STEAM
105
DESUPER HEATER (HP)
91
MEDIUM PRESS. STEAM
72
10
55
DESUPER HEATER (MP)
LOW PRESS. STEAM
81
62
245
DESUPER HEATER (LP)
475
24,600
USERS
334
CONDENSATE TREATING
HOT WELL TANK
529
484
348
ACTIVATED CARBON ADSORPTION
ION EXCHANGE DEMINERALIZER
PURE WATER TANK
930
(MECHANICAL COOLING WATER)
RAW WATER
2,112
FLOCCULATION SEDIMENTATION
SAND-FILTRATION
INDUSTRIAL WATER TANK
1,165
COOLING TOWER
35,210
9,680
POTABLE WATER SYSTEM
5
* SEND TO WASTE WATER TREATING SYSTEM.
** LOSS.
ORINOCO HEAVY OIL UPGRADING PROJECT
STEAM, POWER AND WATER SYSTEM FLOW PLAN (FLUID COKER CASE)
FIG. 4.3



B.L.
GAS
ATMOSPHERIC DISTILLATION UNIT
NAPHTHA
LGO
HGO
AR
VACUUM FLASHING UNIT
VGO
VR
UPGRADING PROCSS FLUID COKER
CO GAS
ACID GAS
COKER NAPHTHA
COKER GO
SLURRY
COKE
HYDRO-TREAER
ACID GAS
ACID GAS TREATING UNIT
FUEL GAS
H2S
SULFUR RECOVERY UNIT
S
HYDROGEN GENERATION UNIT
H2
BY-PRODUCT HANDLING FACILITY
COKE
BOILER PLANT
FLUE GAS
FLUE GAS DESULFURIZATION UNIT
LIME STONE
GYPSUM
MIXED CRUDE TANK (133,000 KL×8)
NAPHTHA, COKER NAPHTHA TANK (9,000 KL×1)
DILUENT TANK (28,000 KL×2)
PIPE LINE FROM MAIN STATION
PIPE LINE TO OIL PRODUCTION FIELD
VACUUM RESIDUE TANK (51,000 KL×1)
COKER NAPHTHA TANK (5,000KL×1)
COKER GO TANK (15,000KL×1)
SLURRY SLOP TANK (20,000KL×1)
REFINERY FUEL SYSTEM
FUEL GAS TO OIL PRODUCTION FIELD
LI-HGO,VGO,CGO TANK (62,000KL×1)
IMPROVED CRUDE TANK (75,000KL×2)
PIPE LINE TO LOADING PORT
SULFUR PILE
RAIL CAR TO LOADING PORT
NATURAL GAS
PIPE LINE FROM GAS STATION
BY-PRODUCT COKE PILE
LIME STONE SILO
LIME STONE FROM RAIL CAR
RAIL CAR TO LOADING PORT
GYPSUM SILO
SLOP TANK (4,000KL×1)
ORINOCO HEAVY OIL UPGRADING PROJECT
TANK FLOW DIAGRAM OF FLUID COKER CASE

FIG. 4.4

Utility balance is shown in Table 4.1 and Fig. 4.3.

(a) Steam generation and distribution system

The system consists of two kinds of boilers, ultra high pressure steam boiler and high pressure steam boiler.

Steam generation and power generation system, which consists of high pressure steam boiler as main equipment, supplies steam and electricity to on-site facilities. Two of high pressure steam boilers are provided in accordance with two trains of on-site facilities. High pressure steam boiler uses by-product CO gas from Fluid coker case and refinery offgas as supplemental fuel. This high pressure steam boiler has no stand-by, because its operation and maintenance schedule is considered to be the same as that of on-site facilities.

Meanwhile, the steam generation and power generation system, which consists of ultra high pressure steam boilers as main equipment, supplies steam and electricity to the utility facilities, offsite facilities and crude oil production field.

Ultra high pressure steam boiler uses by-product coke from Fluid coker process as main fuel and refinery off gas as supplemental fuel. Four ultra high pressure steam boilers (one is for stand-by) are provided.

Each pressure level of steam header is used in common for ultra high pressure steam boiler and for high pressure steam boiler, and one stand-by ultra high pressure steam boiler supplies required steam to the header for high pressure steam boiler in case of an accident of high pressure steam boiler.

(b) Electric power generation system

Two steam turbines and electric power generators (each has a capacity of 18,000 KW) supply electric power to the on-site facilities. There is no stand-by, and the operation and maintenance is scheduled the same as that for the on-site facilities.

Another four steam turbines and electric power generators (each has a capacity of 55,000 KW) are provided and three supply electric power to the utility facilities, offsite facilities and crude oil production field and one is for stand-by.

Steam turbine

- 18,000 KW

  Type: Single stage extracting-back pressure type

  Supplied steam conditions (at turbine inlet)

pressure	:	50 kg/cm²G
temperature	:	405°C

Table 4.1 Utility Balance of Fluid Coker Case

	Elec.	Steam						Water								Fuel	
	Power	UHP	HP	HP (Sat)	MP	LP	LOSS	BFW	Cond.	Pure Water	Indu. Water	Raw Water	Foul Water	C.W.	M.C.W.	Cons.	Gen.
	KW						T/H							T/H		MM Kcal/H	
1. On-Site Facilities	32,840	0	105	-82	45	183	-160	475	-272	0	68	0	-362	9,220	250	386	-2,623
2. Offsite Facilities	7,100	0	0	0	10	62	-15	0	-62	0	5	0	0	0	13	0	0
3. Utility Facilities																	
• Steam Gene. System																	
(CO Boiler)	2,220	0	-470	82	13	126	-4	-477	272	462	0	0	-4	0	8	298	0
(By-Pro. Utilization) (*1)	16,070	-772	72	0	91	9	-104	-1	591	22	280	0	-188	190	128	559	0
• Power Gene. System																	
(CO Boiler)	-35,400	0	365	0	-58	-309	0	2	0	0	0	0	0	0	86	0	0
(By-Pro. Utilization)	-165,000	772	-72	0	-101	-71	0	1	-529	0	0	0	0	24,600	400	0	0
• Water Systems (*2)	1,100	0	0	0	0	0	0	0	0	-484	-1,518	2,112	-110	0	13	3	0
• Cooling Water System	11,300	0	0	0	0	0	-1,024	0	0	0	1,165	0	-141	-34,280	-904	0	0
• Other Utility System (*3)	1,240	0	0	0	0	0	0	0	0	0	0	0	0	270	6	0	0
	-128,530	0	0	0	0	0	-1,807	0	0	0	0	2,112	-805	0	0	1,246	-2,623

(*1) Include Flue Gas Desulfurization Unit

(*2) Include Water Treating System, Pure Water System Etc.

(*3) Include Air System, Inert Gas System etc.

\+ Indicates Quantity Used

\- Indicates Quantity Made

Table 4.2 General Definition of Utility Facilities
(Fluid Coker Case)

Item	Capacity per Unit	Q'ty	Note
1. Steam Generation System			
Ultra High Pressure Steam	260 T/H	4	One unit for stand-by
High Pressure Steam	200 T/H	2	
2. Power Generation System			
by Ultra High Pressure Steam	55,000 KW	4	One unit for stand-by
by High Pressure Steam	18,000 KW	2	
3. Water Treating System	2,120 T/H	1	
4. Pure Water System	250 T/H	3	One unit for stand-by
5. Condensate Treating System	170 T/H	2	
6. Potable Water System	5 T/H	1	
7. Cooling Water System	18,000 T/H	2	
8. Fuel System			
Fuel Gas	400 x 10^6 kcal/H	1	
Vacuum Residue	220 x 10^6 kcal/H	1	
9. Air System	1,800 Nm^3/H	3	One unit for stand-by
10. Inert Gas System	350 Nm^3/H	2	

Extracting conditions

pressure : 16 kg/cm^{2}G

temperature : 285°C (assumed)

Discharge conditions

pressure : 4 kg/cm^{2}G

temperature : 178°C (assumed)

– 55,000 KW

Type: Three stage extracting-condensing type

Supplied steam conditions (at turbine inlet)

pressure : 100 kg/cm^{2}G

temperature : 500°C

Extracting conditions

pressure	: 50 kg/cm^{2}G	16 kg/cm^{2}G	4 kg/cm^{2}G
temperature	: 405°C (assumed)	280°C (")	165°C (")

Generator

Capacity	:	18,000 KW x 2 units
		55,000 KW x 4 units
Voltage	:	13.8 KV

General definitions of utility facilities for the Fluid coker case are given in Table 4.2.

(2) Offsite facilities

(a) Storage system

Tank flow of offsite facilities for the Fluid coker case is shown in Fig. 4.4. A list of feed tanks, intermediate tanks, product tanks, etc. is shown in Table 4.3.

(b) Waste water treating system

The quantity of waste water from on-site facilities is 362 T/H. This waste water contains NH_3, H_2S and oil, and is treated by the stripper and then treated by CPI oil separator. The treated waste water is mixed with the waste water from utility and offsite facilities and discharged outside the refinery. The properties of discharged water are as follows:

(excluding rain water)

Flow Rate	805 T/H
H_2S	2 ppm
NH_3	13 ppm
COD	171 ppm
Oil	5 ppm
SS	20 ppm
pH	6 – 8

Oily rain water treated by CPI oil separator is mixed with non-oily rain water and discharged outside the refinery.

(c) Flue gas desulfurization system

Capacity	1.6×10^6 Nm^3/H (Flue gas)
Rate of Desulfurization	90%
Product Gypsum	28.0 T/H
Limestone Consumption	16.4 T/H
H_2SO_4 Consumption	3.0 T/H (As 98% H_2SO_4)

Table 4.3 Tank List (Fluid Coker Case)

Fluid	Flow Rate BPSD	Flow Rate Kl/D	Storage Days	Net Storage Capacity Kl	Tank Capacity Kl	No. of Tanks	Total Tank Capacity Kl	Remarks
Mixed Crude Oil	205,588	32,688	30	980,640	133,000	8	1,064,000	FR, Mixer, Suction Heater
Light Gas Oil (Diluent)	47,428	7,541	7	52,787	28,000	2	56,000	CR.
Vacuum Residue	87,117	13,852	3.5	48,482	51,000	1	51,000	Insulation CR, Heater, Suction Heater
Coker Naphtha					5,000	1	5,000	DR.
Coker Gas Oil					15,000	1	15,000	CR.
Slurry Slop Oil					20,000	1	20,000	Insulation CR, Heater, Suction Heater
Naphtha, CN	14,844	2,360	3.5	8,260	9,000	1	9,000	DR.
L. & H.G.O., VGO, CGO	106,942	17,004	3.5	59,514	62,000	1	62,000	CR.
Slop Oil					4,000	1	4,000	Insulation CR, Heater, Suction Heater
Improved Crude Oil	125,000	19,875	7	139,125	75,000	2	150,000	FR, Mixer
Total							1,436,000	

Note FR: Floating Roof Tank
CR: Cone Roof Tank
DR: Dome Roof Tank

(3) Construction cost of utility and offsite facilities for fluid coker case

Construction costs of utility and offsite facilities based on the following bases are shown in Table 4.4 and 4.5, respectively.

- Construction site: Chiba, Japan
- Cost base as of the middle of 1980 and no escalation included.
- Construction cost includes cost of materials, labor cost, costs of design and engineering, and contractor expenses.

4.3 UTILITY AND OFFSITE FACILITIES FOR THE EUREKA CASE

4.3.1 General

This section refers to the results of study for utility and offsite facilities of the Eureka case based on the above-mentioned design criteria, and the construction cost of the facilities.

4.3.2 Results

(1) Utility facilities

Based on information on the utility requirements of the Eureka case, total utility requirements of the refinery are determined.

And the electric power requirements of the crude oil production field are calculated to be 126.6 MW, because 150 MW of electricity is required for 170,000 BPCD of crude oil production and the Eureka case calls for 158,710 BPSD of crude oil production.

$$\frac{150}{170,000} \times 158,710 \times \frac{330}{365} = 126.6 \text{ (MW)}$$

Utility balance is shown in Table 4.6 and Fig. 4.5.

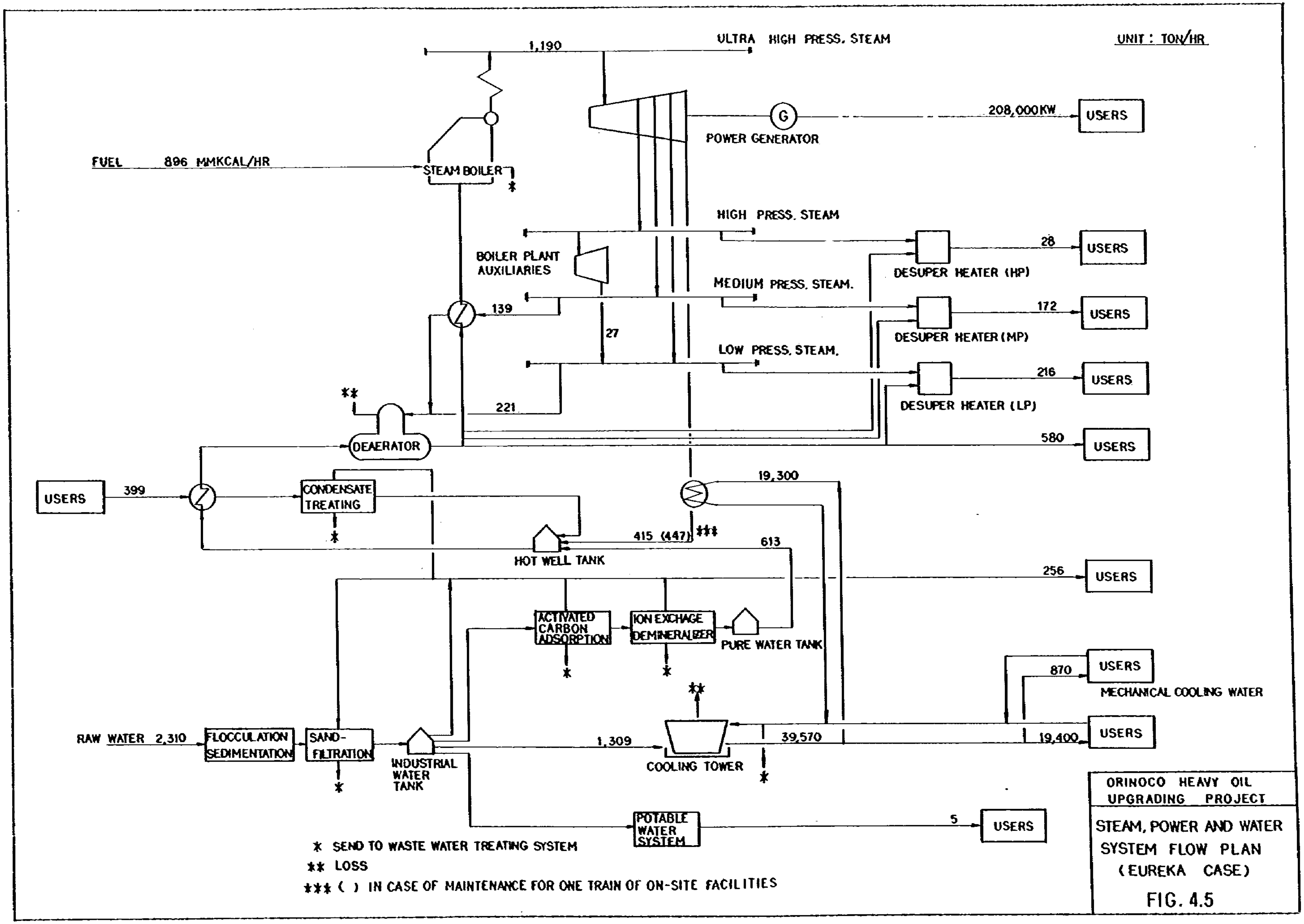
(a) Steam generation and distribution system

This system consists of such major equipment as ultra high pressure steam boiler.

Six ultra high pressure steam boilers are provided and five supply steam for the required facilities in the refinery and one is for stand-by. Generated steam is also used for electric power generation required for the refinery and the crude oil production field.

Each of ultra high pressure steam boiler is set at same capacity in consideration of conformity.

The ultra high pressure steam boiler uses by-product pitch from Eureka process as fuel.



ORINOCO HEAVY OIL UPGRADING PROJECT

STEAM, POWER AND WATER SYSTEM FLOW PLAN (EUREKA CASE)

FIG. 4.5

Table 4.4 Construction Cost of Utility Facilities
(Fluid Coker Case)

Item	Capacity	10^6 Japanese Yen
Steam Generation & Distribution System	260 T/H x 4, 200 T/H x 2	19,238
Power Generation & Distribution System	55,000KW x 4, 18,000KW x 2	18,545
Water Treating System (Including Potable Water System)	2,120 T/H	944
Pure Water System	250 T/H x 3	2,815
Condensate Treating System	170 T/H x 2	305
Cooling Water System	18,000 T/H x 2	2,442
Fuel System		89
Air System	1,800 Nm^3/H x 3	181
Inert Gas System	350 Nm^3/H x 2	505
Total		45,064

Table 4.5 Construction Cost of Offsite Facilities
(Fluid Coker Case)

Item	10^6 Japanese Yen
Storage System (Total Tankage 1,436,000 Kl)	14,142
Loading and Receiving System	628
Waste Water Treating	1,940
Flue Gas Desulfurization System	5,022
Fire Fighting System	
Control System Communication System Lighting and Earth System Flare and Blow Down System Common Stack Auxiliary	8,987
Total	30,719

During the maintenance of one train of on-site facilities, only four boilers are operated.

(b) Electric power generation system

The system consists of six of steam turbines and electric power generators (each has a capacity of 46,000 KW) and five supply electric power to the refinery facilities and to the crude oil production field and one for stand-by.

Steam Trubine

Type: Three stage extracting-condensing type x 6 units

Supplied steam conditions (at turbine inlet)

pressure	: 100 kg/cm^2G		
temperature	: 500°C		
Extracting conditions			
pressure	: 50kg/cm^2G	16kg/cm^2G	4kg/cm^2G
temperature	: 405°C (assumed)	280°C (")	165°C (")

Generator

Capacity	: 46,000 KW x 6 unit
Voltage	: 13.8 KV

General definitions of utility facilities of the Eureka case are given in Table 4.7.

(2) Offsite facilities

(a) Storage system

Tank flow of offsite facilities for the Eureka case is shown in Fig. 4.6.

A list of feed tanks, intermediate tanks, product tanks, etc. is shown in Table 4.8.

(b) Waste water treating system

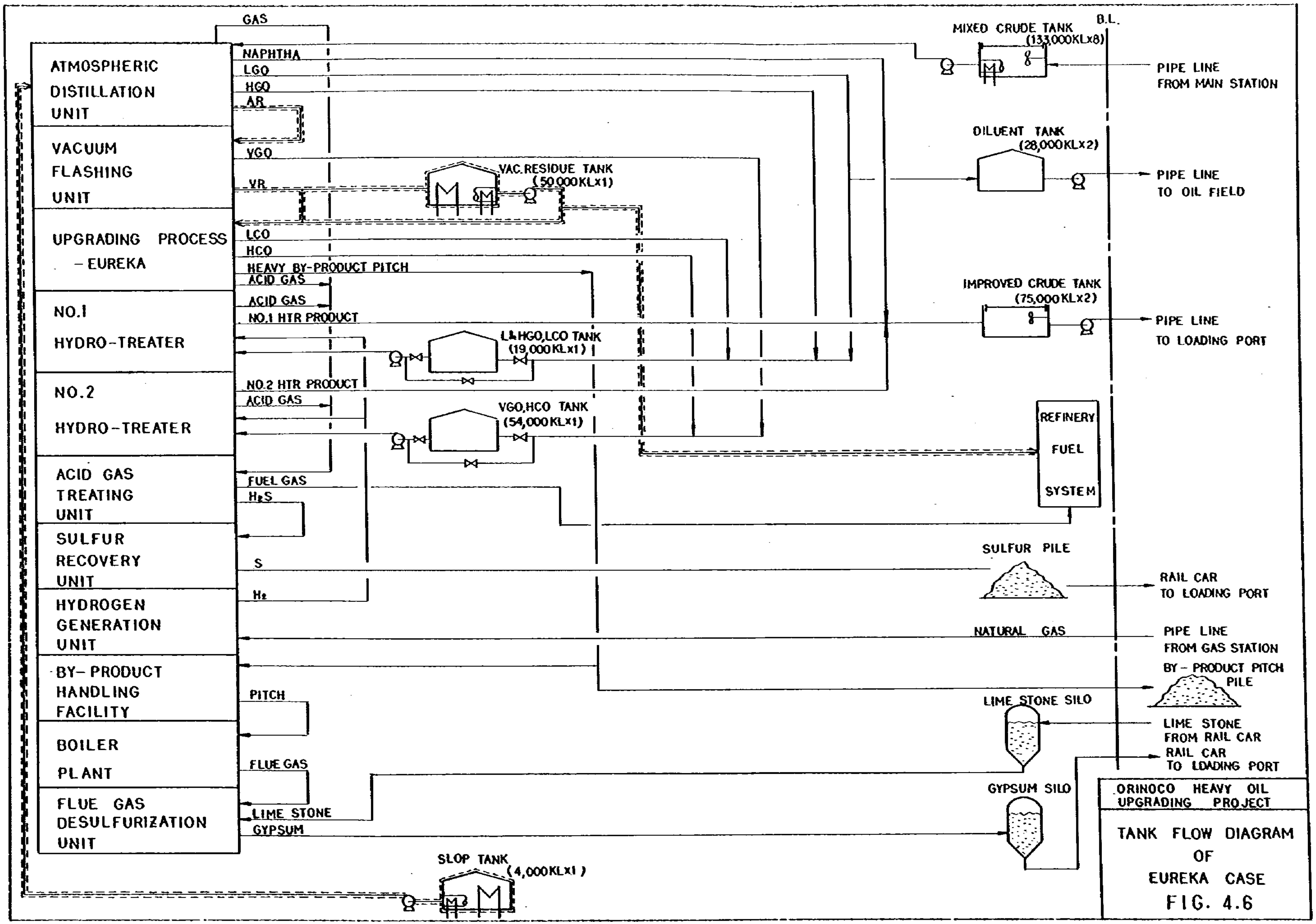
The quantity of waste water from on-site facilities except the Eureka process is 277 T/H. This waste water containes NH_3, H_2S and oil, and is treated by the stripper and, after mixing with the waste water from the Eureka process, is treated by the CPI oil separator.

The treated waste water is mixed with the waste water from utility and offsite facilities and discharged outside the refinery.

The properties of discharged water are as follows:

(excluding rain water)

Flow Rate	915 T/H
H_2S	4 ppm
NH_3	22 ppm



ORINOCO HEAVY OIL UPGRADING PROJECT

TANK FLOW DIAGRAM OF EUREKA CASE

FIG. 4.6

Table 4.6 Utility Balance of Eureka Case

	Elec.	Steam						Water						Cooling Water		Fuel	
	Power	UHP	HP	HP (Sat)	MP	LP	LOSS	BFW	Cond.	Pure Water	Indu. Water	Raw Water	Foul Water	C.W.	M.C.W.	Cons.	Gen.
	KW						T/H							T/H		MM Kcal/H	
1. On-Site Facilities	33,660	0	28	0	160	154	130	580	-335	0	71	0	-528	18,980	284	718	-2,698
2. Offsite Facilities	4,300	0	0	0	12	62	-15	0	-64	0	5	0	0	0	10	0	0
3. Utility Facilities				0													
· Steam Generation (*1)	27,900	-1,190	27	0	139	194	-100	-581	814	613	185	0	-101	130	23	896	0
· Power Generation	-208,000	1,190	-55	0	-311	-410	0	1	-415	0	0	0	0	19,300	500	0	0
· Water System (*2)	1,200	0	0	0	0	0	0	0	0	-613	-1,570	2,310	-127	0	15	4	0
· Cooling Water System	12,550	0	0	0	0	0	-1,150	0	0	0	1,309	0	-159	-38,700	-838	0	0
· Other Utility System (*3)	1,240	0	0	0	0	0	0	0	0	0	0	0	0	290	6	0	0
	-127,150	0	0	0	0	0	-1,395	0	0	0	0	2,310	-915	0	0	1,618	-2,698

(*1) Include Flue Gas Desulfurization Unit

(*2) Include Water Treating System, Pure Water System etc.

(*3) Include Air System, Inert Gas System etc.

+ Indicates Quantity Used

– Indicates Quantity Made

COD	208 ppm
Oil	6 ppm
SS	16 ppm
pH	6 – 8

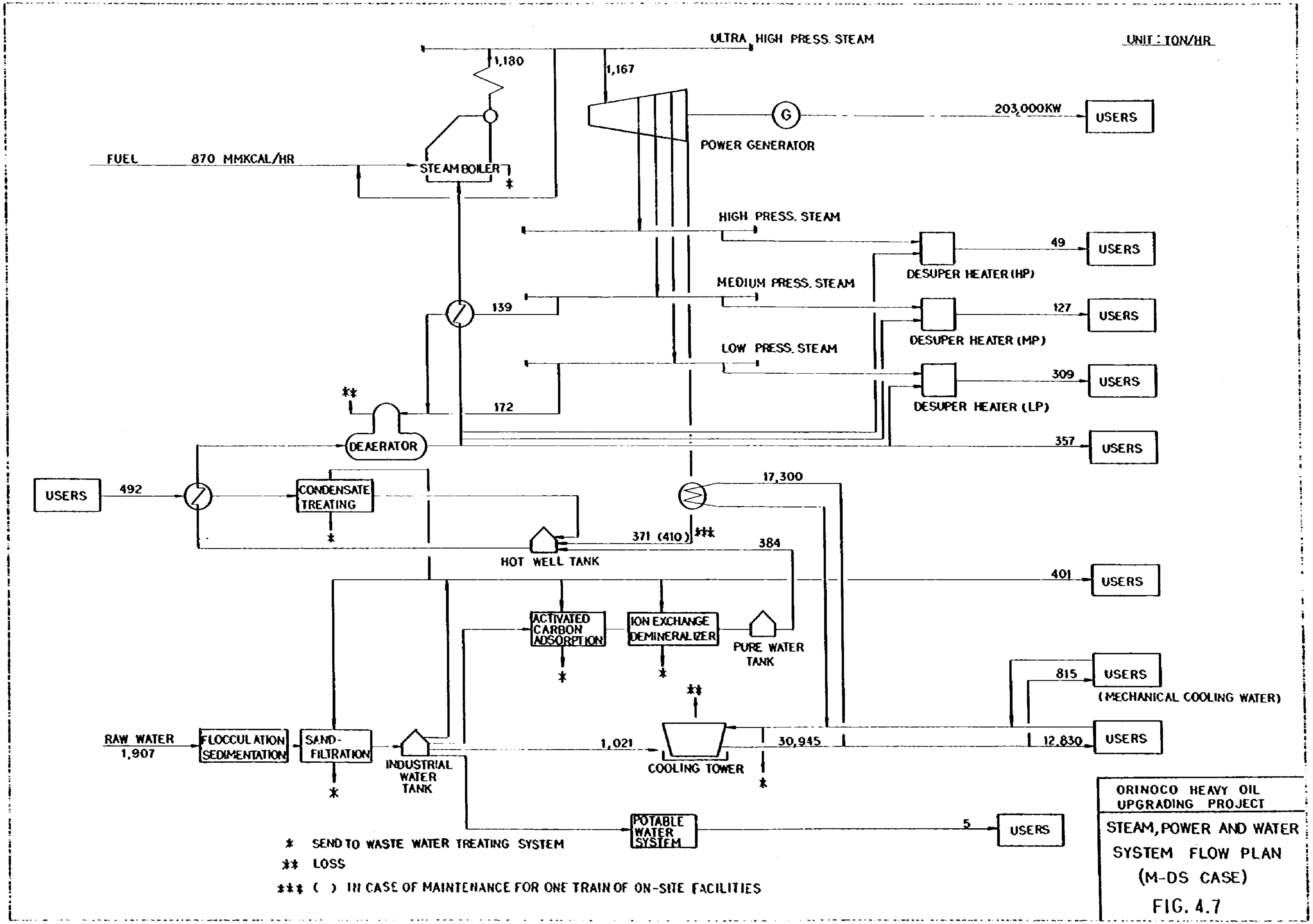
Oily rain water treated by the CPI oil separator is mixed with non-oily rain water and discharged outside the refinery.

(c) Flue gas desulfurization system

Capacity	1.3×10^6 Nm^3/H (Flue gas)
Rate of Desulfurization	90%
Product Gypsum	20.8 T/H
Limestone Consumption	12.1 T/H
H_2SO_4 Consumption	1.9 T/H (as 98% H_2SO_4)

Table 4.7 General Definition of Utility Facilities (Eureka Case)

Item	Capacity per Unit	Q'ty	Note
1. Steam Generation System			
Ultra High Pressure Steam	240 T/H	6	One unit for stand-by
2. Power Generation System			
by Ultra High Pressure Steam	46,000 KW	6	One unit for stand-by
by High Pressure Steam	—	—	
3. Water Treating System	2,310 T/H	1	
4. Pure Water System	310 T/H	3	One unit for stand-by
5. Condensate Treating System	200 T/H	2	
6. Potable Water System	5 T/H	1	
7. Cooling Water System	20,000 T/H	2	
8. Fuel System			
Fuel Gas	308×10^6 kcal/H	1	
Vacuum Residue	410×10^6 kcal/H	1	
9. Air System	2,000 Nm^3/H	3	One unit for stand-by
10. Inert Gas System	350 Nm^3/H	2	



ORINOCO HEAVY OIL UPGRADING PROJECT

STEAM, POWER AND WATER SYSTEM FLOW PLAN (M-DS CASE)

FIG. 4.7

Table 4.8 Tank List (Eureka Case)

Fluid	Flow Rate BPSD	Flow Rate Kl/D	Storage Days	Net Storage Capacity Kl	Tank Capacity Kl	No. of Tanks	Total Tank Capacity Kl	Remarks
Mixed Crude Oil	206,323	32,805	30	984,150	133,000	8	1,064,000	FR, Mixer, Suction Heater
Light Gas Oil (Diluent)	47,613	7,570	7	52,990	28,000	2	56,000	CR.
Vacuum Residue	84,656	13,460	3.5	47,110	50,000	1	50,000	Insulation CR. Heater, Suction Heater
L. & H. GO, LCO	32,139	5,110	3.5	17,885	19,000	1	19,000	CR.
VGO, HCO	91,671	14,576	3.5	51,016	54,000	1	54,000	CR.
Slop Oil					4,000	1	4,000	Insulation CR. Heater, Suction Heater
Improved Crude Oil	125,000	19,875	7	139,125	75,000	2	150,000	FR, Mixer
Total							1,397,000	

Note FR: Floating Roof Tank
CR: Cone Roof Tank

(3) Construction cost of utility and offsite facilities for the Eureka process case

Construction costs of utility and offsite facilities based on the following bases are shown in Table 4.9 and 4.10, respectively.

- Construction site: Chiba, Japan
- Cost base as of the middle of 1980 and no escalation included.
- Construction cost includes cost of materials, labor cost, cost of design and engineering, and contractor expenses.

4.4 UTILITY AND OFFSITE FACILITIES FOR THE M-DS CASE

4.4.1 General

This section refers to the results of study for utility and offsite facilities of the M-DS case based on the above-mentioned design criteria, and the construction cost of the facilities.

4.4.2 Results

(1) Utility facilities

Based on information on the utility requirements of the M-DS case, the total utility requirements of the refinery is determined.

And the electric power requirements of the crude oil production field are calculated to be 120.5 MW, because 150 MW of electricity is required for 170,000 BPCD of crude oil production and M-DS case requires 151,055 BPSD of crude oil production.

$$\frac{150}{170{,}000} \times 151{,}055 \times \frac{330}{365} = 120.5\ (\text{MW})$$

Utility balance is shown in Table 4.11 and Fig. 4.7.

(a) Steam generation and distribution system

The system consists of such major equipment as ultra high pressure steam boiler.

Six ultra high pressure steam boilers are provided and five supply steam for the specific facilities in the refinery and one is for stand-by. Generated steam is also used for electric power generation required for the refinery and the crude oil production field. Each of ultra high pressure steam boiler is set at the same capacity in consideration of conformity. The ultra high pressure steam boiler uses by-product asphalt from M-DS process as fuel.

During the maintenance of one train of on-site facilities, four are operated.

(b) Electric power generation system

The system consists of six steam turbines and electric power generators (each

Table 4.9 Construction Cost of Utility Facilities
(Eureka Case)

Item	Capacity	10^6 Japanese Yen
Steam Generation & Distribution System	240 T/H x 6	23,757
Power Generation & Distribution System	46,000KW x 6	20,530
Water Treating System (Including Potable Water System)	2,310 T/H	1,024
Pure Water System	310 T/H x 3	3,367
Condensate Treating System	200 T/H x 2	331
Cooling Water System	20,000 T/H x 2	2,707
Fuel System		116
Air System	2,000 Nm^3/H x 3	192
Inert Gas System	350 Nm^3/H x 2	505
Total		52,529

Table 4.10 Construction Cost of Offsite Facilities
(Eureka Case)

Item	10^6 Japanese Yen
Storage System (Total Tankage 1,397,000 Kl)	13,697
Loading and Receiving System	260
Waste Water Treating System	1,659
Flue Gas Desulfurization System	4,527
Fire Fighting System Control System Communication System Lighting and Earth System Flare Stack and Blow Down System Common Stack Auxiliary	9,044
Total	29,187

Table 4.11 Utility Balance of M-DS Case

	Elec.	Steam						Water						Cooling Water		Fuel	
	Power	UHP	HP	HP (Sat)	MP	LP	LOSS	BFW	Cond.	Pure Water	Indu. Water	Raw Water	Foul Water	C.W.	M.C.W.	Cons.	Gen.
	KW						T/H							T/H		MM Kcal/H	
1. On-Site Facilities	42,880	0	49	0	116	252	-124	357	-433	0	168	0	-385	12,380	254	624	-2,485
2. Offsite Facilities	4,300	0	0	0	11	57	-14	0	-59	0	5	0	0	0	9	0	0
3. Utility Facilities																	
· Steam Generation (*1)	22,200	-1,167	0	0	139	172	-102	-357	863	384	233	0	-165	170	18	870	0
· Power Generation	-203,000	1,167	-49	0	-266	-481	0	0	-371	0	0	0	0	17,300	490	0	0
· Water Systems (*2)	1,000	0	0	0	0	0	0	0	0	-384	-1,427	1,907	-96	0	13	2	0
· Cooling Water System	10,000	0	0	0	0	0	-897	0	0	0	1,021	0	-124	-30,130	-790	0	0
· Other Utility Systems (*3)	1,200	0	0	0	0	0	0	0	0	0	0	0	0	280	6	0	0
	-121,420	0	0	0	0	0	-1,137	0	0	0	0	1,907	-770	0	0	1,496	-2,485

(*1) Include Flue Gas Desulfurization Unit

(*2) Include Water Treating System, Pure Water System etc.

(*3) Include Air System, Inert Gas System etc.

\+ Indicates Quantity Used

\- Indicates Quantity Made

has a capacity of 44,000 KW) and five supply electric power to the refinery facilities and to the crude oil production field and one is for stand-by.

Steam Turbine

Type: Three stage extracting-condensing type x 6 units

Supplied steam conditions (at turbine inlet)

pressure	: 100 kg/cm^2G		
temperature	: 500°C		
Extracting conditions			
pressure	: 50 kg/cm^2G	16 kg/cm^2G	4 kg/cm^2G
temperature	: 405°C (assumed)	280°C(")	165°C(")

Generator

Capacity	: 44,000 KW x 6 units
Voltage	: 13.8 KV

General definitions of utility facilities of the M-DS case are given in Table 4.12.

(2) Offsite facilities

(a) Storage system

Tank flow of offsite facilities for the M-DS case is shown in Fig. 4.8.

A list of feed tanks, intermediate tanks, product tanks, etc. is given in Table 4.13.

(b) Waste water treating system

The quantity of waste water from on-site facilities is 385 T/H. This waste water contains NH_3, H_2S and oil, and is treated by the stripper and further by the CPI oil separator.

The treated waste water is mixed with the waste water from utility and offsite facilities and discharged outside the refinery.

The properties of discharged water are as follows:

(excluding rain water)

Flow Rate	770 T/H
H_2S	3 ppm
NH_3	19 ppm
COD	187 ppm
Oil	5 ppm
SS	22 ppm
pH	6 – 8

Table 4.12 General Definition of Utility Facilities

(M-DS Case)

Item	Capacity per Unit	Q'ty	Note
1. Steam Generation System			
Ultra High Pressure Steam	240 T/H	6	One unit for stand-by
2. Power Generation System			
by Ultra High Pressure Steam	44,000 KW	6	One unit for stand-by
by High Pressure Steam	—	—	
3. Water Treating System	1,910 T/H	1	
4. Pure Water System	200 T/H	3	One unit for stand-by
5. Condensate Treating System	250 T/H	2	
6. Potable Water System	5 T/H	1	
7. Cooling Water System	15,500 T/H	2	
8. Fuel System			
Fuel Gas	230×10^6 kcal/H	1	
Naphtha	50×10^6 kcal/H	1	
Vacuum Residue	344×10^6 kcal/H	1	
9. Air System	1,900 Nm^3/H	3	One unit for stand-by
10. Inert Gas System	350 Nm^3/H	2	

Oily rain water treated by the CPI oil separator is mixed with non-oily rain water and discharged outside the refinery.

(c) Flue gas desulfurization system

Capacity	1.2×10^6 Nm^3/H (Flue gas)
Rate of Desulfurization	90%
Product Gypsum	24.8 T/H
Limestone Consumption	14.4 T/H
H_2SO_4 Consumption	2.3 T/H (as 98% H_2SO_4)

(3) Construction cost of utility and offsite facilities for the M-DS case

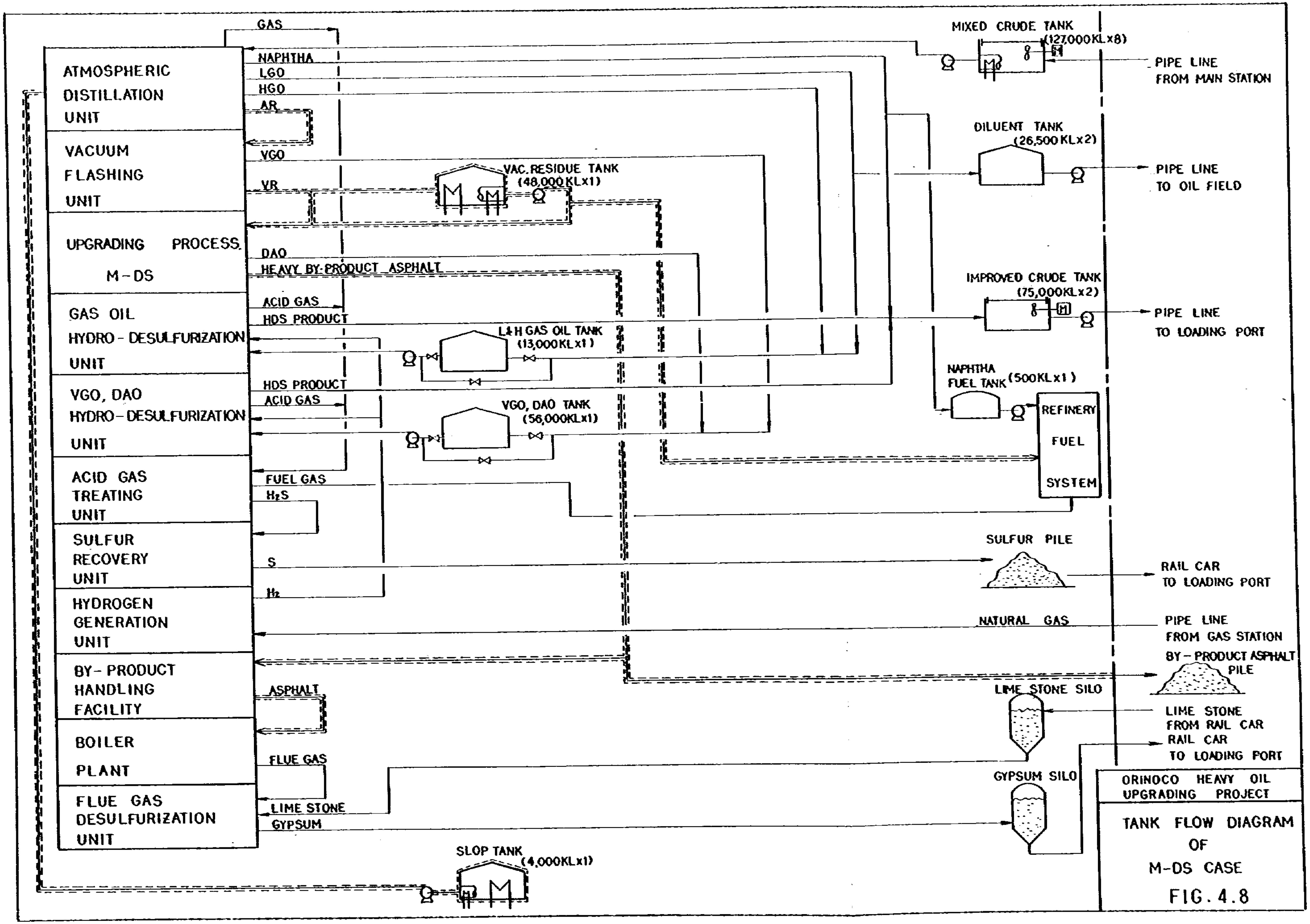
Construction cost of utility and offsite facilities based on the following bases are shown in Table 4.14 and 4.15.

- Construction site: Chiba, Japan
- Cost base as of the middle of 1980 and no escalation included.
- Construction cost includes cost of materials, labor cost, cost of design and engineering, and contractor expenses.

Table 4.13 Tank List (M-DS Case)

Fluid	Flow Rate		Storage	Net Storage Capacity	Tank Capacity	No. of	Total Tank Capacity	Remarks
	BPSD	Kl/D	Days	Kl	Kl	Tanks	Kl	
Mixed Crude Oil	196,372	31,223	30	936,690	127,000	8	1,016,000	FR, Mixer, Suction Heater
Light Gas Oil	45,317	7,205	7	50,435	26,500	2	53,000	CR.
L. & H. Gas Oil	21,374	3,398	3.5	11,893	13,000	1	13,000	CR.
VGO & DAO	97,537	15,508	3.5	54,278	56,000	1	56,000	CR.
Vacuum Residue	81,283	12,924	3.5	45,234	48,000	1	48,000	Insulation CR, Heater, Suction Heater
Refinery Fuel (Naphtha)	876	139	3.5	487	500	1	500	DR.
Slop Oil					4,000	1	4,000	Insulation CR, Heater, Suction Heater
Improved Crude Oil	125,000	19,875	7	139,125	75,000	2	150,000	FR, Mixer
Total							1,340,500	

Note FR: Floating Roof Tank
CR: Cone Roof Tank
DR: Dome Roof Tank



ATMOSPHERIC DISTILLATION UNIT
VACUUM FLASHING UNIT
UPGRADING PROCESS M-DS
GAS OIL HYDRO-DESULFURIZATION UNIT
VGO, DAO HYDRO-DESULFURIZATION UNIT
ACID GAS TREATING UNIT
SULFUR RECOVERY UNIT
HYDROGEN GENERATION UNIT
BY-PRODUCT HANDLING FACILITY
BOILER PLANT
FLUE GAS DESULFURIZATION UNIT
GAS
NAPHTHA
LGO
HGO
AR
VGO
VR
DAO
HEAVY BY-PRODUCT ASPHALT
ACID GAS
HDS PRODUCT
HDS PRODUCT
ACID GAS
FUEL GAS
H2S
S
H2
ASPHALT
FLUE GAS
LIME STONE
GYPSUM
MIXED CRUDE TANK (127,000KLx8)
PIPE LINE FROM MAIN STATION
DILUENT TANK (26,500KLx2)
PIPE LINE TO OIL FIELD
VAC. RESIDUE TANK (48,000KLx1)
IMPROVED CRUDE TANK (75,000KLx2)
PIPE LINE TO LOADING PORT
L&H GAS OIL TANK (13,000KLx1)
NAPHTHA FUEL TANK (500KLx1)
REFINERY FUEL SYSTEM
VGO, DAO TANK (56,000KLx1)
SULFUR PILE
RAIL CAR TO LOADING PORT
NATURAL GAS
PIPE LINE FROM GAS STATION
BY-PRODUCT ASPHALT PILE
LIME STONE SILO
LIME STONE FROM RAIL CAR
RAIL CAR TO LOADING PORT
GYPSUM SILO
SLOP TANK (4,000KLx1)
ORINOCO HEAVY OIL UPGRADING PROJECT
TANK FLOW DIAGRAM OF M-DS CASE

FIG. 4.8

Table 4.14 Construction Cost of Utility Facilities
(M-DS Case)

Item	Capacity	10^6 Japanese Yen
Steam Generation & Distribution System	240 T/H x 6	20,192
Power Generation & Distribution System	44,000KW x 6	19,450
Water Treating System (Including Potable Water System)	1,910 T/H	856
Pure Water System	200 T/H x 3	2,460
Condensate Treating System	250 T/H x 2	318
Cooling Water System	15,500 T/H x 2	2,113
Fuel System		108
Air System	1,900 Nm^3/H x 3	186
Inert Gas System	350 Nm^3/H x 2	505
Total		46,188

Table 4.15 Construction Cost of Offsite Facilities
(M-DS Case)

Item	10^6 Japanese Yen
Storage System (Total Tankage 1,340,500 Kl)	13,209
Loading and Receiving System	263
Waste Water Treating System	2,017
Flue Gas Desulfurization System	4,323
Fire Fighting System Control System Communication System Lighting and Earth System Flare Stack and Blow Down System Common Stack Auxiliary	8,724
Total	28,536

CHAPTER 5 ANALYSIS OF CRUDE SAMPLE

The receiving and treating results of the sample crude oil which was supplied by the Venezuelan side for the study basis are as follows:

5.1 RECEIVING OF CRUDE SAMPLE

5.1.1 Request to Venezuelan Authority

The first survey team requested the supply of a crude sample in the meeting on October 3, 1979 and the request was accepted by the Venezuelan authority in the "Record of Discussions".

5.1.2 Delay in Crude Sample Shipment

It was scheduled to transport to Japan the crude sample by tanker in mid. November 1979. However, the following official telegram was received from MEM on October 26, 1979:

"As result of trouble of oil well to produce sample crude, the sample crude is not prepared yet. The detail information will be notified again."

Therefore, the shipment of the crude sample was postponed to the end of December.

5.1.3 Tanker's Schedule

The transportation of the sample crude oil was undertaken by captain of the U.S.S.R. tanker "LUKHOVITSY" which shipped the feedstock of lube oil from Venezuela to Japan.

December 21, 1979	Departure from Cardon, Venezuela
January 25, 1980	Arrival at Iwakuni, Japan

5.1.4 Customs Clearance and Receipt

The customs clearance of the sample crude oil was done at Iwakuni port.

A total of 5 drums of sample oil were received.

5.1.5 Dehydration and Distillation of Crude Sample

After dehydration, atmospheric distillation and vacuum distillation of the sample crude oil, dehydrated crude oil and vacuum residue were distributed to three (3) groups for crude analysis and sample oil of upgrading processes.

The distribution had been completed by the end of February 1980.

The sample crude oils of five drums had different water content and the sample crude oil was dehydrated from average nine (9) percent to 0.2 percent.

5.1.6 Utilization of Analysis Result for Preliminary Study

As a result of the delay in sample crude arrival, the analysis result of the sample crude was not utilized in the preliminary study.

5.2 CRUDE ANALYSIS

Typical analysis data on the sample crude oil are as follows:

5.2.1 Test method of Orinoco Crude Oil

(1) Distillation method of crude oil

The crude oil was distilled as follows by ASTM-D-2892 type distillation unit:

Sample Name	W–N	LGO	LVGO	HVGO	VGO	AR	VR
Cut temp. (°C)	IBP ~205	205 ~343	343 ~455	455 ~500	343 ~500	343+	500+
Vacuum (mmHg)	100	10	1	0.35	1~0.35		
Reflux Ratio	5:1	5:1	1:1	1:1	1:1		

(2) Test method of crude oil and distillates

Test items and test method of crude oil and distillates are as follows:

Test item	Test method	Test item	Test method
Specific gravity	JIS-K-2249	Kinematic	JIS-K-2283
Distillation	JIS-K-2254	Viscosity	IP-230/69
	ASTM-D-1160	Cetane Number	JIS-K-22045.7
Sulfur content	JIS-K-2541	Con. Carbon	JIS-K-2270
Nitrogen content	JIS-K-2609	Flash point	JIS-K-2265
Water content	JIS-K-2275	Smoke point	JIS-K-2537
Water & sediment	JIS-K-2603	Ash	JIS-K-2272
Salt content	JIS-K-2604	Total acidity	JIS-K-2502
Anilin point	JIS-K-2256	Metal	JPI
Pour point	JIS-K-2269	FIA	JIS-K-2536

(3) Sample crude oil

Cerro Negro Crude Oil

5.2.2. Test Result of Orinoco Crude Oil

The test result of Orinoco crude oil is shown in Table 5.1.

5.2.3 Comparison of Analysis Results

The main property comparisons of crude oil, atmospheric residue and vacuum residue between analysis result of sample oil and crude assay of Cogollar IX-Cerro Negro crude mixture prepared by LAGOVEN are shown in Table 5.2.

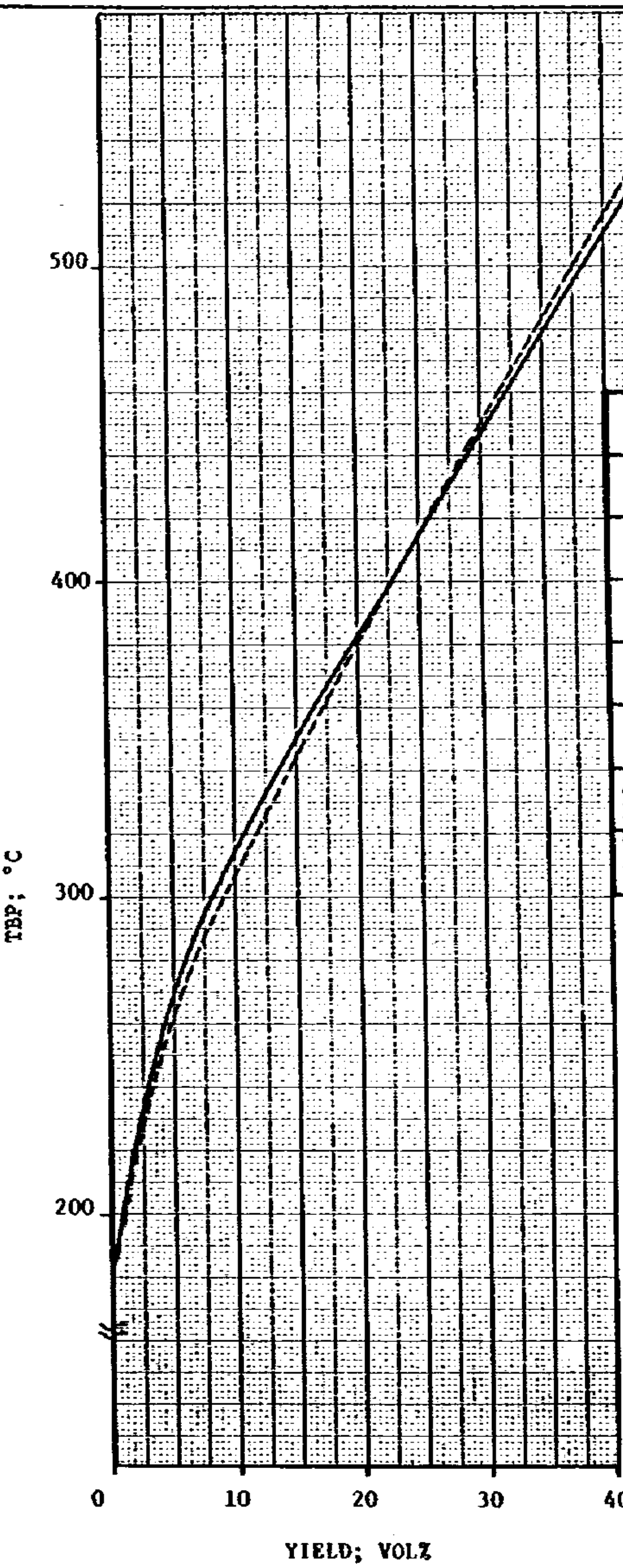
The differences of both main property are not so big and both data may be used as typical crude data for Cerro Negro area.

Therefore, LAGOVEN's crude assay which had more detailed analysis data was selected as study basis. The above mentioned was confirmed by the Venezuelan side during the second survey.

Table 5.1 Test Result of Orinoco Crude Oil

Sample Name	W-N	LGO	AR	LVGO	HVGO	VGO	VR	Crude
Cut Range (°C)	IBP 205	205 343	343+	343 455	455 500	343 500	500+	
Yield (Vol%)	0.8	13.0	86.2	17.6	7.3	24.9	61.3	
Sp. Gr. (15/4°C)	0.8423	0,9030	1.038	0.9558	0.9800	0.9626	1.062	1.019
IBP	157.0	233.0	361	348	435	354	470	241
5%	172.5	244.5	383	362	450	368	494 (1%)	298
10%	176.0	251.0	406	370	454	375	506 (2%)	334
20%	180.0	258.0	448	378	458	380	516 (3%)	398
30%	184.0	267.5	485	388	461	400	524 (4%)	456
40%	188.0	275.5	500	396	464	414		508
50%	192.0	283.0	(35%)	404	468	427		
60%	195.5	291.0		414	473	439		
70%	199.0	299.0		422	478	451		
80%	203.5	307.5		435	483	461		
90%	209.0	319.5		445	495	474		
95%	214.0	332.0		454	505	488		
97%	217.0	343.5		462	515	498		
EP	220.0	348.5		476	524	506		
T|R/L	98.0 | 1.0/1.0	98.0 | 1.5/0.5	35.0 | 65.0	98.0 | 2.0	98.0 | 2.0	98.0 | 2.0	4.0 | 96.0	40.0 | 60
Sulfur (wt%)	0.67	2.02	3.96	3.27	3.29	3.27	4.21	3.75
Nitrogen (wt%)			0.65	0.16	0.32	0.20	0.73	0.58
(wtppm)	0.9	130						
Water (vol%)								Trace
BS & W								0.70
Aniline Point (°C)	45.0	44.1		43.5	53.5	48.3		
Vis,								
30°C (cst)	1.534	6.251						
50°C (cst)	1.798	3.675		47.37	505.4	80.64	(155°C)	
75°C (cst)	(@20°C)						1789	2,468/2,579
98.9°C (cst)			2858	7.093	26.74	9.711	609.5	505.2/519.8
Pour Point (°C)		−50⊖	+52.5	−20.0	+5.0	−10.0	(175°C)	+27.5
Cetane Index		33						
CCR (wt%)			20.6	0.05	0.62	0.17	29.5	18.0
Flash Point (°C)								120
Smoke Point (mm)	18.5							
Component P, N	83.3							
vol% O	0.7							
A	16.0							
Ash (550°C) wt%			0.482			0.002	0.784	0.474
(750°C) wt%			0.460				0.609	0.451
Metal								
Fe (wtppm)			30			0.1−	55	30
Ni (wtppm)			110			0.1−	160	110
Na (wtppm)			850			0.1−	1190	840
V (wtppm)			480			0.1−	660	420
T Acid Number (mg KOH/g)								3.09
Salt Content (ppm/PTB)								3,200/1,210

TBP curve of Orinoco crude oil is shown in Fig. 5.1.



CUT RANGE (%)		YIELD (VOL%) SAMPLE	ASSAY
WN	IBP ~ 205	(0 ~0.8) 0.8	(0.2~1.0) 0.8
GO	205 ~ 343	(0.8~13.8) 13.0	(1.0~15.1) 14.1
LVGO	343 ~ 455	(13.8~31.4) 17.6	(15.1~30.6) 15.5
HVGO	455 ~ 535	(31.4~44) 12.6	(30.6~42.8) 12.2
VGO	343 ~ 535	(13.8~44) 30.2	(15.1~42.8) 27.7
ATM. RESIDUE	343+	86.2	84.9
VAC. RESIDUE	535+	56.0	57.2

———: SAMPLE (Cerro Negro Crude)

-------: ASSAY prepared by LAGOVEN (Cogollar 1X-Cerro Negro Crude)

ORINOCO HEAVY OIL UPGRADING PROJECT

TBP CURVE OF ORINOCO CRUDE OIL

FIG. 5.1

Table 5.2 Comparison of Main Analysis Data

ANALYSIS

SAMPLE	CUT.PT.	TEST*	Sp. Gr. (15.4°C)	Sulfur wt%	CCR wppm	V wppm	Ni wppm	Ash wt%	Na wppm	Asphaltene wt%
	–	A	1.019	3.75	18.1	420	110	0.451	840	–
Crude Oil	–	B	1.0199	3.87	17.0	310	120	0.246	1,100	–
	–	ASSAY	1.011	3.67	13.3	392	84	–	–	–
Atmospheric	650°F+	A	1,038	3.96	20.60	480	110	0.46	850	–
Residue	650°F+	B	1,0353	4.12	20.40	410	130	0.264	1,002	13.3
	650°F+	ASSAY	1.034	4.04	17.6	484	120	–	–	–
	930°F+	A	1.062	4.21	29.50	660	160	0.609	1,190	–
	950°F+	B	1.0514	4.26	–	–	170	0.357	1,500	–
Vacuum Residue	830°F+	C	1.045	4.14	22.79	559	148	0.3	1,190	–
	995°F+	ASSAY	1.062	4.32	25.7	654	162	–	–	–
	950°F+	ASSAY	1.058	4.26	23.6	616	153	–	–	–
	851°F+	ASSAY	1.049	4.17	20.5	546	135	–	–	–

* A, B, C : Testers
ASSAY : LAGOVEN'S ASSAY

CHAPTER 6 SURVEY REPORT

6.1 FIRST SURVEY REPORT

6.1.1 Introduction

The first survey was undertaken on October 1979 by the team of JICA to accomplish the following objectives:

(1) To confirm basic prerequisities

(2) To obtain crude samples

(3) To discuss preliminary T/R

The survey was arranged and assisted in full by the Embassy of Japan in Venezuela, especially Mr. Yutaka Nomura, Ambassador, Mr. Katsuhiko Tsunoda, Councilor and Mr. Hiroshi Mitsukawa, First Secretary.

This report includes the following:

List members of the first survey team

Survey synopsis

Survey results

6.1.2 Members of the First Survey Team

(1) First survey team

Mr. Sen'ichi HIROSE	Project Manager (Chief of the Team)	Consultant to JICA
Mr. Toshio IBI	Policy in Technical Cooperation	Deputy Director Development Division Petroleum Department Agency of Natural Resources and Energy MITI
Dr. Koji UKEGAWA	Petroleum Refinery Engineering	Senior Scientific Officer National Research Institute for Pollution and Resources, MITI
Mr. Hideo YASUKI	Coordination	Deputy Director Industrial Survey Division, JICA

Mr. Yasuhisa HOSOYA	Petroleum Refinery Engineering	Consultant to JICA (Mechanical Engineer)
Mr. Terutada TSUKAGOSHI	Petroleum Refinery Engineering	Consultant to JICA (Chemical Engineer)

(2) Attendants from Embassy of Japan to conferences with Venezuelan authorities

Mr. Katsuhiko TSUNODA, Councilor
Mr. Hiroshi MITSUKAWA, First Secretary

(3) Attendant from PDVSA to Orinoco Field

Dr. Edison Perozo, Petroleum Engineering Manager, Orinoco Oil Belt

(4) Venezuelan attendants to the conferences are listed in the attached "Record of Discussions".
(Attachment – 2)

6.1.3 Survey Synopsis

(1) September 30 (Sunday)
Departure from Tokyo, stay in New York

(2) October 1 (Monday)
Departure from New York, Arrival at Caracas
16:00 – 19:00 Schedule meeting with Mr. H. Mitsukawa and team meeting

(3) October 2 (Tuesday)
10:15 – 12:05 Meeting with Mr. Y. Nomura, Ambassador, Mr. K. Tsunoda, Councilor and Mr. H. Mitsukawa, First Secretary at the Embassy of Japan and team meeting
14:00 – 19:00 Team meeting

(4) October 3 (Wednesday)
10:10 – 12:10 Conference with Ministry of Energy and Mines (MEM)
15:00 – 17:00 Conference with PDVSA
17:30 – 18:00 Team meeting

(5) October 4 (Thursday)
10:00 – 12:00 Conference with PDVSA
14:45 – 16:10 Conference with LAGOVEN
16:30 – 17:00 Interim report to the Embassy of Japan

(6) October 5 (Friday)
9:00 – 13:00 Conference with INTEVEP
15:30 – 18:00 Team meeting

(7) October 6 (Saturday)

8:30 – 12:30 Team meeting and study of information

(8) October 7 (Sunday)

8:30 – 10:00 Preparation of Record of Discussions

(9) October 8 (Monday)

8:00 – 9:15 Departure from Caracas and arrival at Morichal

9:15 – 14:30 Field survey of Orinoco oil belt
(Cerro Negro, Morichal & Jobo)

14:30 – 17:15 Departure from Morichal and arrival at Caracas

(10) October 9 (Tuesday)

10:00 – 12:00 Meeting with Embassy of Japan

14:00 – 17:00 Team meeting

(11) October 10 (Wednesday)

9:00 – 12:00 Team meeting

14:20 – 15:05 Final conference with MEM
Signing and exchange of Record of Discussions

15:45 – 16:15 Report to the Embassy of Japan

16:15 – 16:30 Team meeting

(12) October 11 (Thursday)

Departure from Caracas, stay in New York

(13) October 12 (Friday)

Departure from New York

(14) October 13 (Saturday)

Arrival at Tokyo

6.1.4 Survey Results

The first survey team discussed with Venezuelan side based on "JICA-1 and JICA-2" contained in ATTACHMENT-1.

The results of discussions and survey are as follows:

(1) Record of Discussions

The result of the first survey is summarized in the attached "Record of Discussions" and signed and exchanged between MEM and the team.
(Refer to ATTACHMENT-2)

(2) Data given by MEM

(a) Crude analysis data

Cogollar IX-Cerro Negro Crude Mixture (Refer ATTACHMENT-3)
Pilon Crude

Morichal Crude

ATTACHMENT-3 was used as study basis

(b) The heavy oil industry in Venezuela

(c) Investigation y desarrolla del procesamiento de las crudos pesados de la faja petrolifera del Orinoco

(d) Faja petrolifera del Orinoco cronograma de proyectos pilotos

(e) Planification primer modulo faja petrolifera del Orinoco

(f) Faja petrolifera del Orinoco

(3) Data given by the Embassy of Japan

(a) Guide of Caracas

(b) Introduction of Venezuela

6.2 SECOND SURVEY REPORT

6.2.1 Introduction

The second survey was undertaken by the team of JICA to accomplish the following objectives on May 1980 after completion of preliminary study.

(1) To report the result of the preliminary study

(2) To confirm the additional basic conditions for the feasibility study

(3) To confirm the basic conditions for the economic study on the feasibility study

(4) To collect information and data on construction planning for the feasibility study

The survey was arranged and assisted in full by the Embassy of Japan in Venezuela, especially Mr. Katsuhiko Tsunoda, Minister and Mr. Hiroshi Yoshida, First Secretary.

This report includes the following:

List of members of the second survey team

Survey synopsis

Survey results

6.2.2 Members of the Second Survey Team

(1) Second survey team

Mr. Sen'ichi HIROSE	Project Manager (Chief of the Team)	Consultant to JICA
Mr. Kei'ichi GOTOH	Policy in Technical Cooperation	Deputy Director Development Division Petroleum Department Agency of Natural

		Resources and Energy, MITI
Dr. Koji UKEGAWA	Petroleum Refinery Engineering	Senior Scientific Officer National Research Institute for Pollution and Resources, MITI
Mr. Hideo YASUKI	Coordination	Deputy Director Industrial Survey Division, JICA
Mr. Yasuhisa HOSOYA	Petroleum Refinery Engineering	Consultant to JICA (Mechanical Engineer)
Mr. Terutada TSUKAGOSHI	Petroleum Refinery Engineering	Consultant to JICA (Chemical Engineer)
Mr. Isao USUI	Cost Estimation	Consultant to JICA (Cost Engineer)
Mr. Akimasa IIMURA	Construction Planning	Consultant to JICA (Civil Engineer)

(2) Attendants from the Embassy of Japan to conferences with Venezuelan authorities

Mr. Katsuhiko Tsunoda, Minister
Mr. Hiroshi Yoshida, First Secretary

(3) The survey team was organized by two groups as Group A and Group B.

Group A organized by Messrs. Hirose, Gotoh, Ukegawa, Yasuki, Hosoya and Tsukagoshi accomplished items (1), (2) and (3) in the above 6.2.1 and Group B organized by Messrs. Hirose, Usui, Iimura and Hosoya accomplished item (4) in the above 6.2.1

(4) Venezuelan attendants to the conferences are listed in the attached "Record of Discussions" (Attachment 5)

6.2.3 Survey Synopsis

(1) Group A and Group B

(a) May 3 (Saturday)

Departure from Tokyo (18:45) PA800
Arrival at New york (18:15)

(b) May 4 (Sunday)

Departure from New York (9:45) PA217

Arrival at Caracas (14:15)

17:20 – 18:10 Schedule meeting with Mr. H. Yoshida and team meeting

(c) May 5 (Monday)

8:30 – 12:00 Team meeting

14:00 – 16:00 Meeting with Mr. K. Tsunoda, Minister and Mr. H. Yoshida, First Secretary

Group A

(a) May 6 (Tuesday)

9:00 – 12:00 Team meeting

14:30 – 17:00 Conference with Ministry of Energy and Mines (MEM)

17:30 – 19:00 Team meeting

(b) May 7 (Wednesday)

9:00 – 12:00 Conference with MEM, PDVSA, INTEVEP and LAGOVEN at PDVSA office

14:20 – 15:20 Conference at PDVSA (continue)

15:30 – 18:40 Team meeting

(c) May 8 (Thursday)

9:00 – 11:00 Team meeting

11:45 – 16:10 Conference with MEM, PDVSA, INTEVEP and LAGOVEN at LAGOVEN office

17:20 – 18:00 Interim report to the Embassy of Japan

19:00 – 3:00 Preperation of Record of Discussions

(d) May 9 (Friday)

7:30 – 11:20 Team meeting (Study of R/D)

15:00 – 16:00 Conference with PDVSA

14:00 – 18:10 Typing of R/D

(e) May 10 (Saturday)

8:00 – 16:00 Typing of R/D

17:00 – 18:30 Checking of R/D

(f) May 11 (Sunday)

9:00 – 13:00 Copy of R/D

15:30 – 16:00 Booking of R/D

(g) May 12 (Monday)

10:00 – 11:20 Final conference with MEM and PDVSA

Signing and exchange of Record of Discussions

14:00 – 16:00 Team meeting

(h) May 13 (Tuesday)

9:00 – 16:00 Study of Information and Team Meeting

(i) May 14 (Wednesday)

Departure from Caracas (9:30) PA218

Arrival at New York (14:15)

(j) May 15 (Thursday)

Departure from New York (11:00) PA801

(k) May 16 (Friday)

Arrival at Tokyo (18:10)

(3) Group B

(a) May 6		(Tuesday) Caracas
	10:00 – 12:00	Taihei Dengyo (Construction company)
	14:45 – 16:00	Fujita Gumi (Construction company) Survey of material, labor & construction cost
	16:30 – 18:00	INELECTRA (Engineering company) Survey of design laws and regulations and design capacity
(b) May 7		(Wednesday) Caracas
	9:00 – 10:30	RIVACO (Construction company) Survey of material, labor & construction cost
	11:00 – 12:00	Data and schedule arrangement
	15:20 – 16:00	SADE (Construction company) Survey of material & labor cost
(c) May 8		(Thursday)
	Caracas (7:45)	Ciudad Bolivar (8:45) by AVENSA
	10:30 – 13:30	Survey of Job Site by helicopter
	14:00 – 18:00	Ciudad Bolivar Pto. Ordaz by Car survey of road (width, curve, bridge, slope, forest etc.)
(d) May 9		(Friday) Pto. Ordaz
	8:00 – 18:00	Pto. Ordaz – Sidor – Harbor (VANDAM) Survey of port facilities and road for material/equipment transportation survey of factory facilities and capacity
(e) May 10		(Saturday)
	7:00 – 18:00	Pto. Ordaz – Pto. La Cruz Survey of road by car
(f) May 11		(Sunday) Pto. La Cruz Holiday
(g) May 12		(Monday) Pto. La Cruz
	8:00 – 18:00	Pto. La Guanta – La Encruci Jada – TRAVEN Survey of road between Pto. La Guanta and La Encruci Jada Survey of inland transportation cost

(h) May 13	(Tuesday) Caracas
8:00 – 12:00	Data arrangement
14:00 – 18:00	Pto. Guaraguao – Pto. La Guanta – Barcelona Survey of port facilities and road for equipment/material transportation
19:25 – 20:00	Barcelona Caracas by Aeropostal
(i) May 14	(Wednesday) Caracas
9:30 – 12:00	Arrangement of data and schedule
14:00 – 16:00	Nihon Yusen (Shipping company) etc. Survey of harbor, import procedures and customs clearance Survey of design data books
(j) May 15	(Thursday)
9:45 – 10:45	Caracas – Maracaibo by Aeropostal
14:00 – 17:00	AFCA (Manufacturing company Survey of factory facilities & capacity
18:50 – 19:50	Maracaibo – Caracas by Aeropostal
(k) May 16	(Friday) Caracas
9:00 – 12:00	Preparation of survey report
14:00 – 15:00	Fujita Gumi (Construction company) Survey of material, labor & construction cost
15:30 – 17:00	Survey of tax, insurance & other fees
(l) May 17	(Saturday) Caracas
9:00 – 12:00	Preparation of survey report
14:00 – 18:00	Survey of equipment, furniture for office and housing Survey of foods
(m) May 18	(Sunday) Caracas Holiday
(n) May 19	(Monday) Caracas
7:00 – 20:00	VANDAM & IMOSA (Manufacturing company) Survey of factory facilities & capacity. Preparation of survey report
(o) May 20	(Tuesday) Caracas
9:00 – 10:30	The Embassy of Japan Report of Group B's survey result
11:00 – 11:30	SADE (Construction company) Survey of material & labor cost
12:00 – 13:00	VANDAM (Manufacturing company) Survey of factory facilities & capacity

14:00 – 14:30	SADE (Construction company)
	Survey of material & labor cost
15:00 – 16:00	Final summary of survey
16:30 – 18:00	RIVACO (Construction company)
	Survey of material, labor & construction cost
(p) May 21	(Wednesday)
9:30 – 14:15	Caracas-New York by PA218
(q) May 22	(Thursday)
11:00	Departure from New York by PA801
(r) May 23	(Friday)
13:35	Arrival at Tokyo

6.2.4 Survey Results

The second survey team discussed with Venezuelan side and surveyed based on "JICA-1 and JICA-2" contained in ATTACHMENT-4.

The results of discussions and survey are as follows:

(1) Record of discussions

The result of the second survey by Group A is summarized in the attached "Record of Discussions" and signed and exchanged between MEM and the team. (Refer to ATTACHMENT-5).

(2) Site survey items

Among the results of the second on-the-spot survey, those obtained by Group B are not attached to this report, but those results are fully incorporated in the report by reference in studying the feasibility of an upgrading refinery. This second survey includes the following items.

(a) Equipment and materials

Various plants have been erected in Venezuela during the latest decade. As far as the number of construction equipment and materials is concerned, most of the materials seem to be available from domestic production, but their delivery poses a problem. Those items unavailable from domestic production include steel plant, large steel materials, equipment, equipment of special materials, machinery, instruments, special electric appliances, fillers, etc.

According to our judgement from our surveys, it is likely that, except for high-pressure vessels (50mm or more in wall thickness), most of shelled vessels (towers, heat exchangers, and tanks) can be manufactured domestically.

Since, therefore, domestic suppliers are given priority, it will take much time and labor to get a permission for import. (We were told that in the case of government projects, import permission can be stipulated in the agreements; in that case, import poses no problem.) As regards the items of controlled imports, a tariffs list is in publication.

(b) Food

With exceptions of miso and soy sauce (There are imported items, but their quantities are the problem.), most of other foodstuffs used in the Japanese cooking are available. (Japanese immigrants settled in Valencia produce agricultural products of the types used by Japanese.)

(c) Office and residential furnishings

Most of these items are available.

(d) Labor

It is reported that both of regular employment rate and work efficiency are low, because skilled workers are less in number and laborers are strongly protected under a labor agreement.

The legal minimum wage system is an established system in this country. Care should be taken to the government alternation (in every 5 years), for wages tend to be raised to a large extent at each time of alternation.

In the case of a big project, it seems necessary for the contractor to set up a training center to train those who are employed for the construction work, and at the same time, to work out some measures, including higher wages, so that they won't leave their jobs.

Restriction in the number of foreign workers:

	Foreigners	Natives
Number	1	4
Salaries (total)	1	4

(Foreign workers are mostly those who come from Caribbean Sea countries, as well as from Central and Latin America.)

(e) Construction equipment

Rental costs are very high, because they are calculated on the basis of complete depreciation in about 10 months. In the case of a big project, domestic purchases or imports (low import tariffs) of new equipment are considered as a better choice.

(f) Rough estimates of individual costs for construction work

- Civil and foundation work.
- Building work.
- Steel structure work.

- Electrical work.
- Instrumentation work.
- Piping work.
- Tank work.
- Thermal insulation work.
- Painting work.
- Temporary facility work.

We could not make little survey on these items because of insufficient data on estimates, time limit, and such situations in which the project is only at the stage of feasibility study and in which every construction company is now very busy.

(g) Project expenses

Formalities for entry of foreigners, and for permissions of their stay and employment, can be gone through at the central government offices in the capital. Formalities concerning other matters can be completed locally.

Taxes in connection with the project can be largely grouped into personal income tax and corporate tax (tax out of profits). Care should be taken to the corporate tax, because cost standards pose a problem, depending upon the type of contract.

(h) Customs clearance and inland transportation

- customs clearance:

  It is reported that only document check is required for the Pto. Ordaz, but material inspection is required for the Pto. La Cruz.

  Detailed information is not available.

- Inland transportation:

  The largest cargo size is estimated at 3,000 mmϕ x 30,000 mm L x 80 tons under the limitation posed by bridge(s), road bends, and over-bridge(s).

  The upgrading project calls for huge volumes of cargo and a lot of large-size equipment. It involves the use of land as wide as 4 concession areas. For these reasons, it is considered appropriate to construct an unloading wharf used exclusively for the refinery on the north side of Orinoco River.

(i) Accomodation facilities

The upgrading project requires that about 3,500 people will be engaged in construction work during the peak period even the upgrading refinery in the LAGOVEN area only. Therefore, accommodation facilities near the site are a necessity.

CHAPTER 7 COMBUSTION OF HEAVY BY-PRODUCT

In the course of upgrading the Orinoco heavy oil, large quantities of such heavy by-products as fluid coke, pitch from the Eureka process, asphalt from the M-DS process are produced.

Meanwhile, large amounts of electric power are required for the production of raw crude oil.

Taking these factors into consideration, it would be effective to use the heavy by-products as boiler fuel. However the by-products are solid or liquid having very high viscosity and high pour point, therefore, due consideration should be given to the combusion system utilizing these by-products.

Three groups of Japan, who have studied the upgrading process schemes, have also studied utilization of the by-products in Chapters 1, 2 and 3.

However, we (JICA) have made a basic review on the combustion method in consideration of its importance.

7.1 SAMPLE

There are various heavy petroleum products such as straight asphalt, solvent deasphalted (SDA) asphalt, Eureka pitch and coke.

Fig. 7.1 shows general tendency of softening points and oil contents of the heavy petroleum products.

Of these, straight asphalt can be burned by conventional entrainment type combustion by raising its temperature.

We selected the following two samples for analysis of general properties and burning tests:

- SDA asphalt of about 150°C softening point and high oil content.
- Coke as a representative having low oil content.

7.1.1 Source of Sample

BDA pitch:

A butane deasphalting asphalt produced from the Middle East vacuum residue was supplied by a refining company in Japan.

Coke:

A flexicoke produced from the Middle East vacuum residue was supplied from Toa Oil Co., Ltd.

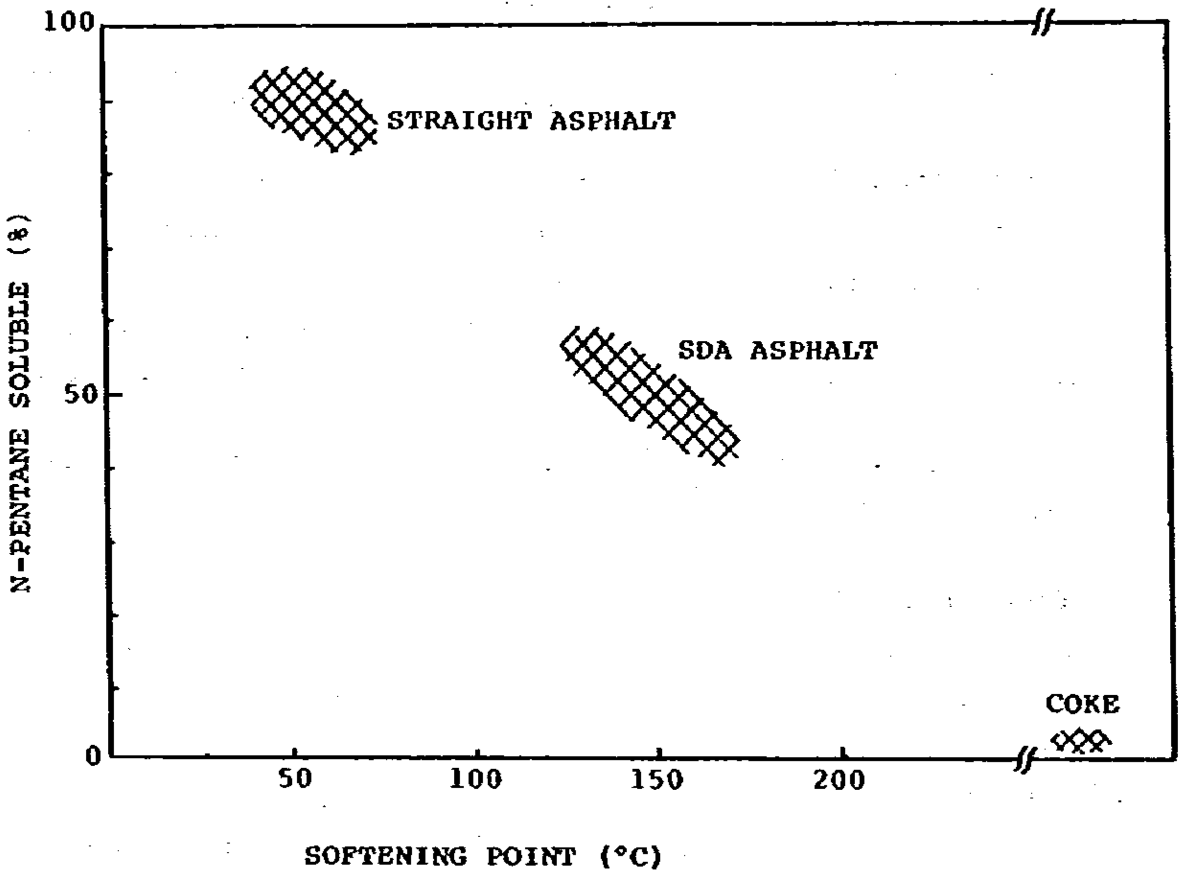
7.1.2 Analysis of General Properties

Analyses of general properties are shown in Table 7.1.

Table 7.1 Analysis of General Properties

Industrial Analysis		Flexi coke	BDA-Asphalt
Calorific Value,	Kcal/kg	7,720	9,420
Moisture	%	1.0	0.1
Fixed carbon	"	96.5	34.5
Volatile matter	"	1.2	65.3
Ash.	"	1.3	0.2
Total sulfur	"	5.7	5.8
Elemental Analysis (Dry basis)			
C	%	94.4	83.5
H	"	0.5	8.5
O	"	0.2	1.9
N	"	0.6	0.9
S	"	5.7	5.8
Ash, composition			
V	ppm	2,460	1,500
Ni	"	610	280
Fusibility of Ash			
Softening Temp.	°C	810	Impossible to measure
Deformation Temp.	"	Fused	because of small ash
Fluid Temp.	"		

FIG. 7.1 SOFTENING POINT AND N-PENTANE SOLUBLE OF HEAVY RESIDUALS



7.1.3 Test for Fuel

Ignition temperature, combustion velocity and grindability index are shown in Table 7.2.

Table 7.2 Test for Fuel

	Flexi coke	BDA-Asphalt
Ignition Temp. (°C)	870 — 920	640 — 650
Combustion Velocity	Good	Very good
Grindability (GHI)	32	Impossible to measure, as adhesive matter grows

Ignition temperature and combustion velocity versus volatile matter are shown in Fig. 7.2 and 7.3.

7.2 COMBUSTION METHOD

Described below are conceivable ways of direct burning of the by-product, without using valuable light oil as diluent for adjusting viscosity for the atomizing of fuel.

7.2.1 Pulverized Fuel Combustion

Fig. 7.4 shows a schematic diagram of pulverized fuel combustion. The by-products are pulverized to the fineness of 65 – 80 percent through 200 mesh and are sent to the furnace by air.

This type of combustion is widely used in the field of coal firing. As for the petroleum products, instances are recorded in the combustion boiler such as:

- The Delaware City Power Station

  This was the first power station designed specifically to burn fluid coke.

- The Detroit Refinery of Marathon Oil Co.

  Pulverized fluid coke and offgas or residual fuel are burned.

7.2.2 Fluidized Bed Combustion

Fig. 7.5 shows a schematic diagram of fluidized bed combustion system.

This method (FBC) is to burn fuel in the fluidized bed formulated by air and inert particles such as limestone and dolomite.

Heat transfer tubes are immersed in the fluidized bed and are also located in the free board zone.

FIG. 7.2 IGNITION TEMPERATURE

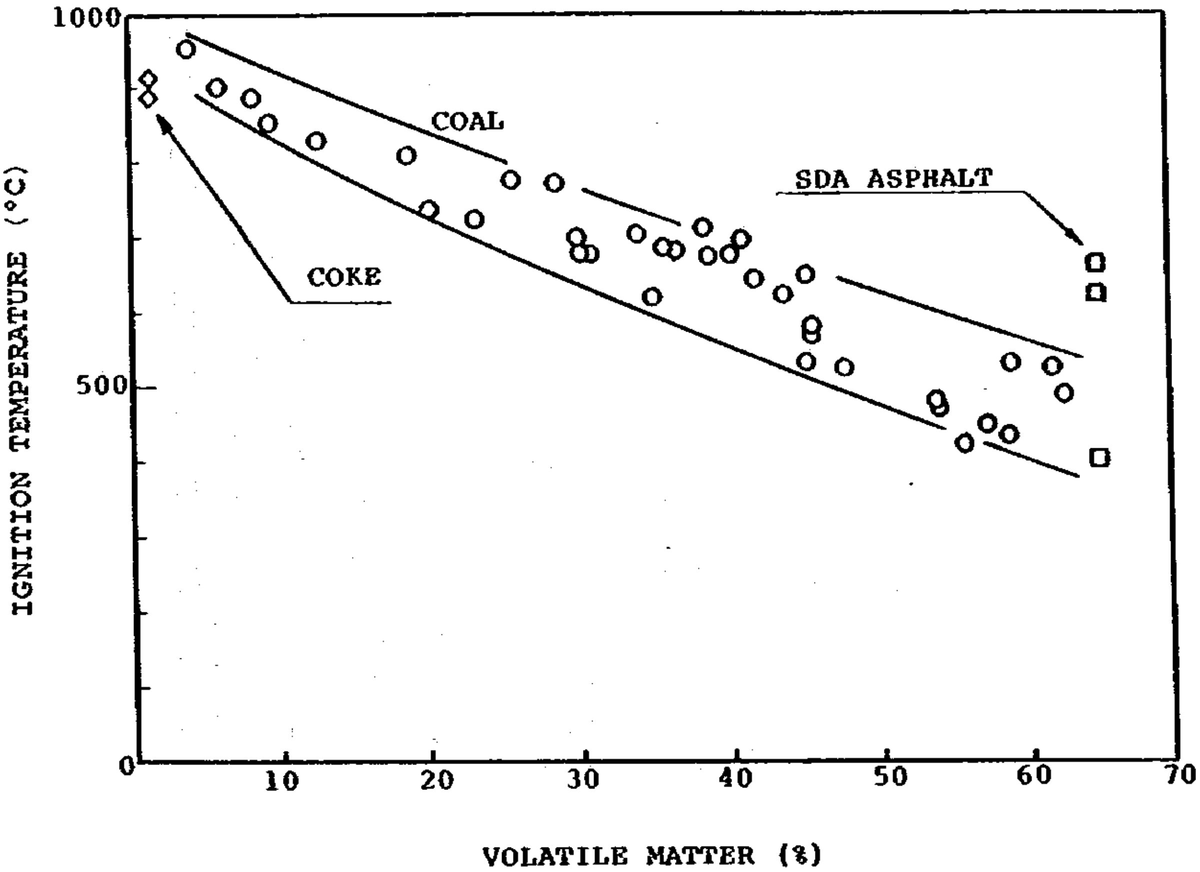
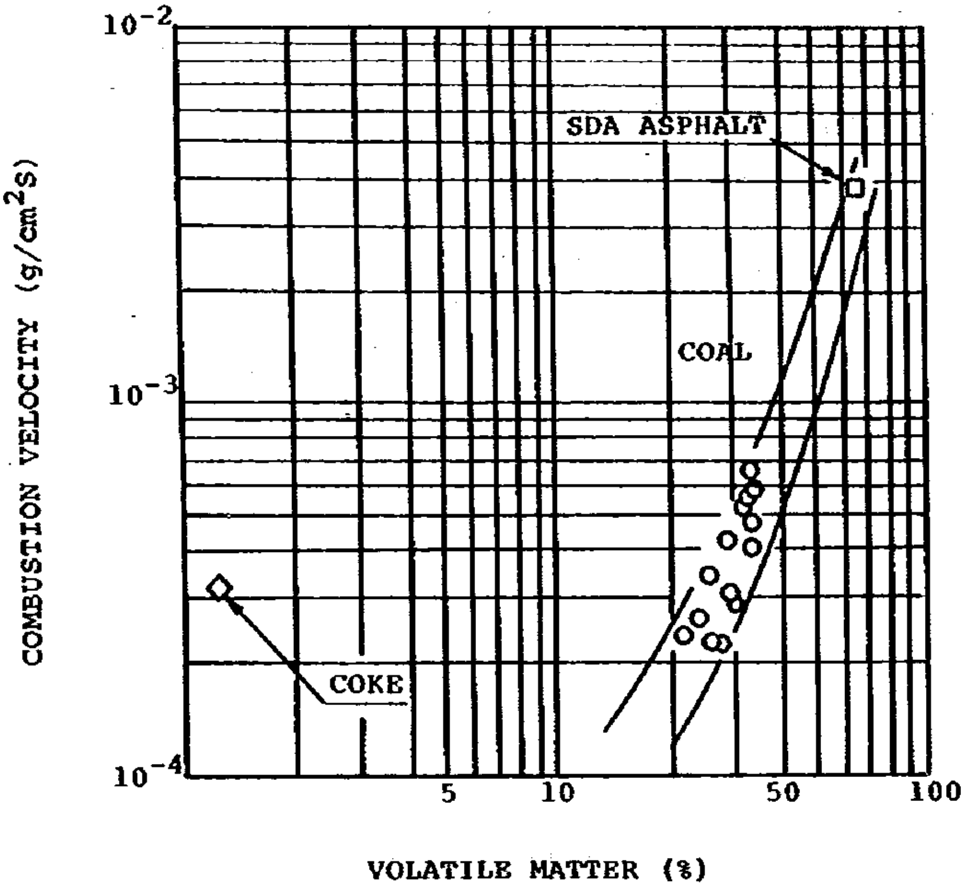


FIG. 7.3 COMBUSTION VELOCITY



Features of the method are as follows:

- Various fuels such as low-grade coal, coke, heavy petroleum product can be burned.
- Stable combustion is expected since the ratio of combustible material (fuel) is less than 2 percent of the fluidizing material.
- Lower combustion temperature (800–900°C) is applicable, therefore, lower NOx emission is expected.
- Boiler is more compact compared with the conventional (Entrainment oil fired boiler) one, because heat flux and heat transfer coefficient are large.
- Desulfurization is attained because of the function of limestone or dolomite.
- Slagging on the heat transfer tube is little, because the particle fluidizes in the bed.

The FBC is a promising technology because of its superior features described before. However, the technology is in an under development stage and boiler manufactures and research institutes are investigating and testing on pilot plants in order to realize commercial plants.

Research and development situations are:

England

NCB has started research on the coal combustion by the FBC. Recently, Babcock is conducting testing on a boiler of 20 t/h steam at Renflew, Scotland.

U.S.A.

More than 10 research and development projects are in progress. For example, a demonstration plant of 136 T/H has been operated since 1977 at Rivesville, West Virginia.

Japan

From 1960's, research work started for the purpose of burning industrial wastes, and in this field a commercial plant was realized.

In 1978, cooperative work between the Coal Technology Institute and four boiler manufacturers started and a test run of a 20 ton/h pilot plant is expected to start in 1981.

7.3 CONSIDERATION ON COMBUSTION METHOD OF BY-PRODUCTS

7.3.1 Fluid Coke

In consideration of the commercial experience of the coke combustion boiler, the combustion method of the fluid coke is pulverized coke combustion. However, in adopting this method, due consideration should be given to the following points:

(1) Ignition and combustion

Since the volatile matter content of the fluid coke is low and the ignition point is high (approximately 900°C) it is necessary to bring the temperature of particles up to, and maintain it at, ignition temperature. This can be accelerated by:

- Burners

  Burners are located downward (U-type burning). Thus high flame temperatures are maintained as a result of the close proximity of the radiation heat to the hot slag. With a number of small nozzles, the surface of the fuel exposed to radiant heat from the flame is much greater than when a single nozzle is used. The rectangular shape burner also gives a greater periphery than a circular nozzle.

- Temperature of primary air

  The temperature of the particles has to be raised to the ignition temperature, before burning can take place.

  The higher initial temperature of the particle-and-air mixture, the quicker ignition will take place.

- Supporting fuel

  In order to keep the flames stable, a supporting fuel with less than 10 percent of total heat needed will be required. Coker gas is used as the supporting fuel.

(2) Pulverizing

When the pulverized fuel combustion is used, the fuel has to be pulverized to appropriate fineness.

In the case of pulverizing the fluid coke, larger power consumption is anticipated because of its low Hardgrove grindability index. And selection of the material for the surfaces of the pulverizer where there is a high rate of wear is important.

7.3.2 BDA Asphalt

(1) Pulverized fuel combustion

Since the volatile matter is rich and the ignition point is low compared with those of the fluid coke, stable ignition and combustion are expected in the pulverized fuel combustion system.

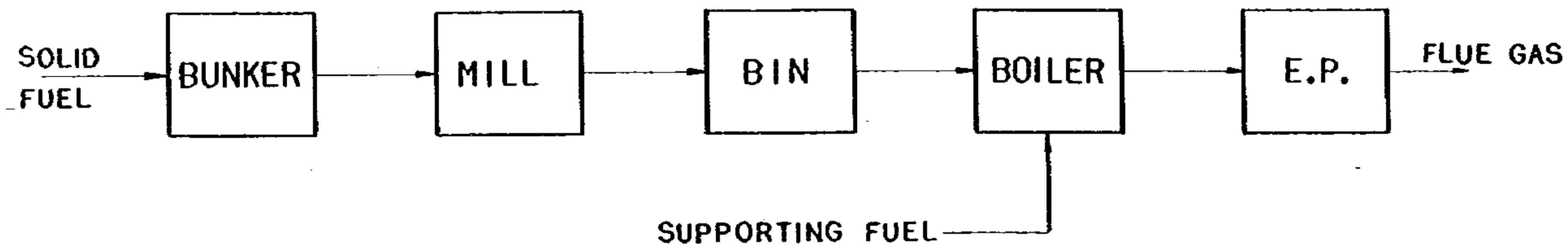
However, the softening point is not so high and the volatile matter is rich compared with those of the fluid coke. Thus, consideration should be give to avoiding making the particles become cohesive in the pulverizer and the pipe.

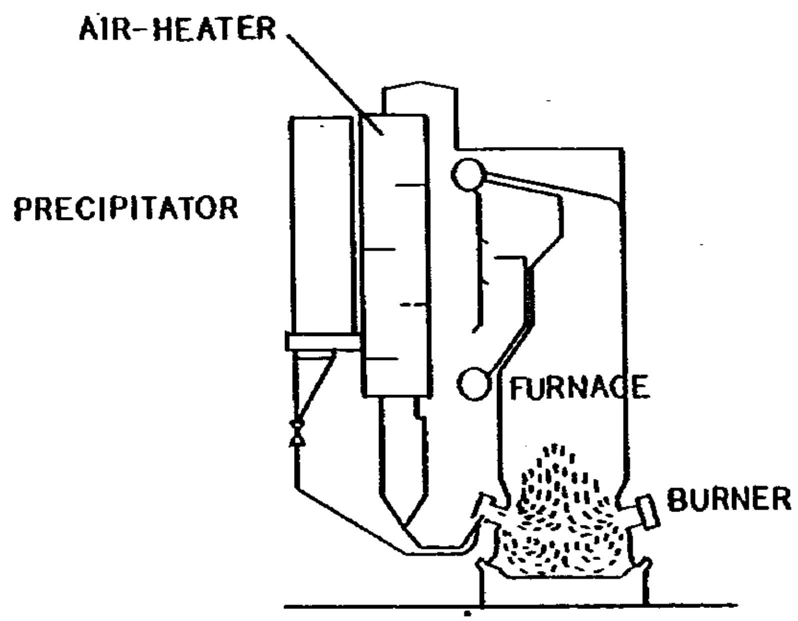
Also, solidifiation problems must be checked for storing large quantities of pulverized asphalt.

We consider that hammer type mill will be used as a pulverizer; however extensive test is required for pulverizing the SDA asphalt.

(2) Fluidized bed combustion

As for the fluidized bed combustion, two methods are considered.

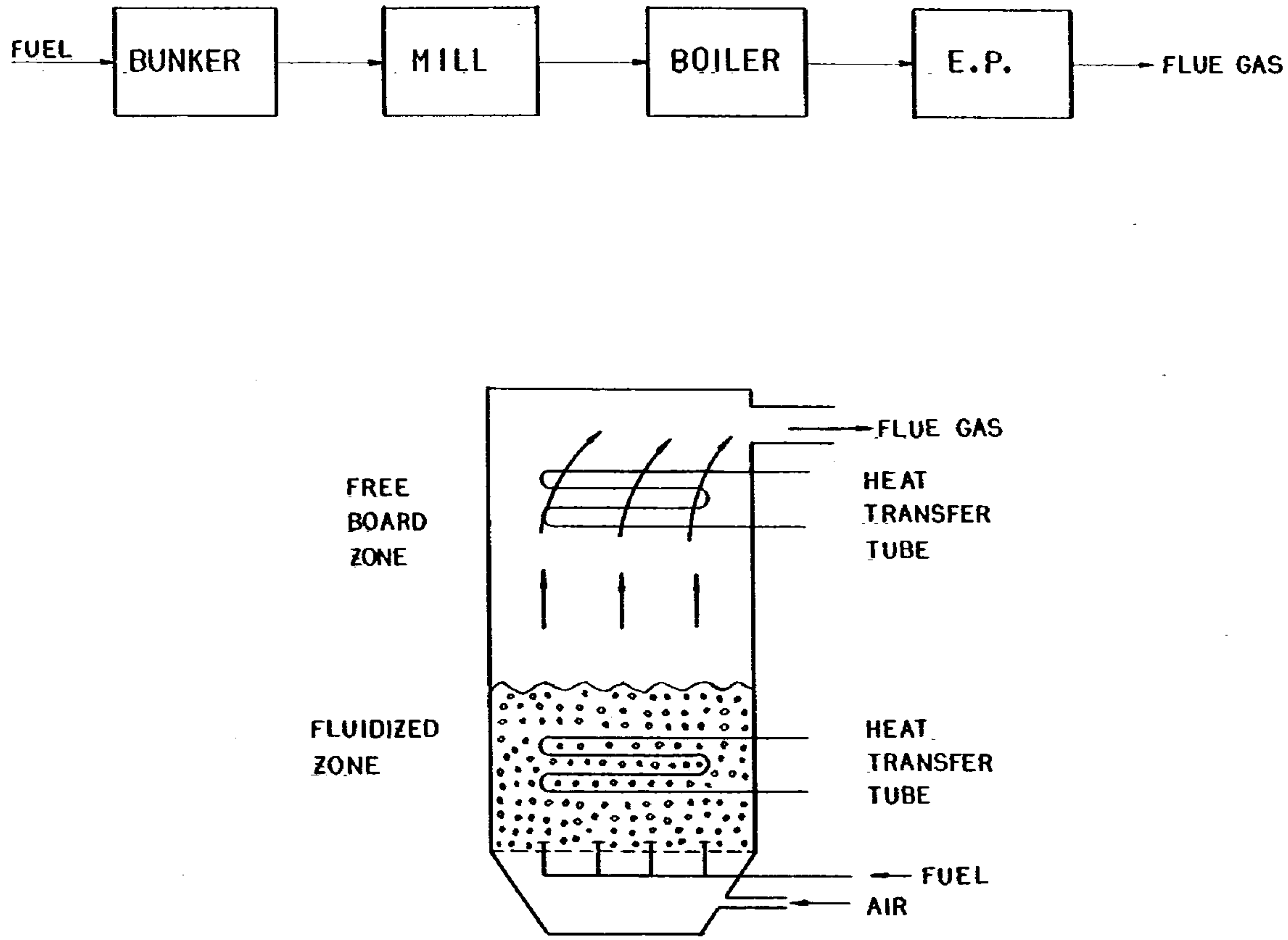




ORINOCO HEAVY OIL UPGRADING PROJECT

SYSTEM FLOW OF PULVERIZED FUEL COMBUSTION

FIG. 7.4



ORINOCO HAEVY OIL UPGRADING PROJECT

SYSTEM FLOW OF FLUIDIZED BED COMBUSTION

FIG. 7.5

(a) Liquid feed

In order to feed in the liquid phase, the by-products run down from the process must be held at high temperature of approximately 250°C. In that case, as the low-pressure steam is not effective, another heating system such as a hot oil system and so forth must be considered.

(b) Solid feed

The required particle size is 1~7 mm diameter so that milling condition is not severe compared with the pulverized fuel combustion case.

In both cases, the fluidized bed combustion is under development and there are various problems to be solved such as:

- Air ratio, bed temperature, kind of desulfurization material, Ca/S mol ratio, pressure and so forth have to be carefully reviewed in relation to desulfurization efficiency.
- Uniform combustion
  Feeder must be arranged so as to burn uniformly in the fluidized bed.
- Particle fly-over
  In the fluidized bed combustion system, the combustion efficiency is determined mainly by the fly-over of the unburnt particles. Therefore burning of the cyclone dust and carbon burn up cell must be studied.

In summary, the fluidized bed combustion will be a promising technology in the near future.

7.4 SUMMARY OF COMBUSTION OF BY-PRODUCT

Table 7.3 gives a summary showing combustion systems versus the by-products.

Though we have not conducted burning and pulverizing tests, the Eureka pitch is also included in the table based on the data and discussions with engineers of Kureha Chemical Industry Co., Ltd.

7.5 PROBLEMS ASSOCIATED WITH HIGH SULFUR AND HIGH METAL FUEL

Both fuels have sulfur content of about 5.8%, then SOx in the flue gas is about 3,500 ppm.

- If 5% of SOx is converted to SO_3, SO_3 at boiler outlet will be 170 ~ 180 ppm and the dew point will increase.
  Therefore, the following achievement is required.

Supply temperature to economizer	190°C
Flue gas temperature at outlet of air preheater	180°C

- Regarding high temperature corrosion due to high sulfur and high vanadium contents, no problem is anticipated under about 600°C of metal surface temperature.
  There is an additive injection method of Mg-hydroxide also.

Table 7.3 By-Product vs. Combustion Method

By-Product / Method		Entrainment Type Combustion	Pulverized Fuel Combustion	Fluidized Bed Combustion (FBC)
By-Product	Condition required	For oil firing, viscosity at burner is 20 ~ 30 cst usually.	Powder 65–80% through 200 mesh.	For solid, 1–7 mmφ size. For liquid, viscosity is less than 6,000 cst for pumping.
	Situation	Conventional fuel oil is burned by this method.	Coal combustion and coke combustion are existing.	Under development. Pilot plants are existing.
BDA asphalt Volatile matter > 50% Ignition point ≒ 650°C Softening point ≒ 160°C Hardgrove index		In order to use conventional fuel oil firing method, low viscosity oil is required as diluent. For direct combustion of the M-DS asphalt, Maruzen Oil Co. proposes to use an internal mixing steam atomizing type burner.	According to the test of the sample, care will be required to pulverize the BDA asphalt to fine particles.	In feature, the FBC will be used for firing BDA asphalt. In the case of feeding in solid phase, it will be possible to pulverize it to 1 ~ 7 mmφ with Hammer mill.
Eureka pitch Volatile matter 40 ~ 50% Ignition point Softening point 200°C ~ Hardgrove index 150 ~ 160		–	It will be pulverized.	In future, the pulverized pitch will be burned by the FBC.
Fluid coke Volatile matter ≒ 2% Ignition point ≒ 900°C Hardgrove index ≒ 30			Commercial boilers are operated. Harder than coal, but it is not so difficult to pulverize. Supporting fuel is required.	In future, the coke will be burned by the FBC.

(Additive rate/fuel: 1/2,000 – 1/6,000)

Generally, the additive injection method has the following effects:

To increase the melting point of ash

To decrease corrosion at high temperatures

To control the conversion of SO_2 to SO_3

To control corrosion at low temperatures

A T T A C H M E N T

ATTACHMENT-1: JICA-1 & JICA-2 (First Survey)

- JICA-1, General Description
- JICA-2, Talking Paper
- Attachment to JICA-2, Confirmation Item of Basis of Feasibility Study
- Attachment to JICA-2, Preliminary Terms of Reference

ATTACHMENT-2: Record of Discussions (First Survey)

ATTACHMENT-3: Crude Assay of Cogollar IX-Cerro Negro Crude Oil Mixture

- Ensayo de Productos Combustibles de crude Cogollar IX-Cerro Negro No.LV.5C-C.79

ATTACHMENT-4: JICA-1 & JICA-2 (Second Survey)

- JICA-1, General Description
- JICA-2, Talking Paper
- Attachment to JICA-2, The Report of Preliminary Study of Feasibility Study
- Attachment to JICA-2, Confirmation Items of Bases of Economic Study
- Attachment to JICA-2, Information and Data on Construction Planning

ATTACHMENT-5: Record of Discussions (Second Survey)

ATTACHMENT-6: Minutes of Meetings (Presentation of Draft Final Report)

THE UP-GRADING PROJECT
OF ORINOCO HEAVY OIL IN THE REPUBLIC OF VENEZUELA

--- GENERAL DESCRIPTION ---

1. Venezuelan Government's Request

(1) In April 1978, the Venezuelan Government officially requested the technical cooperation of Japan in a letter of the Minister of Energy and Mines.
The requested cooperation mainly consists in conducting studies and evaluations, from a neutral point of view, of various proposals to the Government made on an industry basis, on which the Government has difficulties in making judgements.

(2) In accordance with the request, the Japanese Government sent a preliminary survey team to Venezuela in late August 1978 to discuss how to develop the cooperation with the Venezuelan Government. At the discussion, Venezuela requested the Japanese Government to conduct a feasibility study on processes for up-grading the Orinoco heavy oil.

(3) The content of the request is as follows:

(a) Purposes of Feasibility Study

It is planned to produce the Orinoco heavy crude around 1985, for which a plant of a 100,000 - 120,000 BPSD class is expected to be built to up-grade and refine the crude. A feasibility study is to be made to judge what process could be best used for the plan, making examinations on mainly the processes proposed by three groups of Japan.

(b) Prerequisites of Feasibility Study

Properties of the Orinoco heavy crude and estimated grade of the product synthetic crude shall be presented. By-products from the up-grading shall be used to generate the steam for crude production and the energy needed for up-grading.

(c) Scope of Feasibility Study

The feasibility study excludes the survey on financing, the marketing of the synthetic crude, the infrastructure and site selection of the plant.

(d) Supply of Data

All data necessary for the feasibility study shall be provided by Venezuela.

2. Response of Japanese Government

The Japanese Government studied the approach based on the report of the preliminary survey team, and determined to conduct the feasibility study following the procedures below. In March 1979, Japan notified the Venezuelan Government of this decision via the Japanese Embassy in Venezuela, confirming the basic prerequisites and requesting the supply of crude samples. Procedures for the feasibility study are as follows:

(1) Objectives of Feasibility Study

This study is intended to make clear the respective features of the three processes proposed by three groups of Japan for the up-grading of the heavy crude to be produced in the Orinoco Heavy Crude Development Project located on the north side of the River Orinoco, and to provide the data necessary for the selection of a process adequate for the construction of a commercial plant.

(2) Scope of Feasibility Study

Technical and economic studies will be conducted with limitations to the plant facilities for the up-grading of the crude:

(3) Procedures for Execution

(a) Conduct a preliminary study based on basic prerequisites and crude samples.

(b) After deciding the terms of reference for the feasibility study, send a F/S survey team to Venezuela to hold discussions and to do a field survey.

(c) Perform work in Japan and prepare a report.

3. <u>Dispatch of First Survey Team</u>

With regard to the confirmation of the basic prerequistites and the requested supply of the crude samples, it has been determined that the execution schedule is to be somewhat modified to accelerate the progress of the study. That is, the First Survey Team will be dispatched to Venezuela to do the following work:

(1) To confirm the basic prerequisites

(2) To obtain the crude samples

(3) To discuss the preliminary T/R which is prepared as a result of the preliminary survey

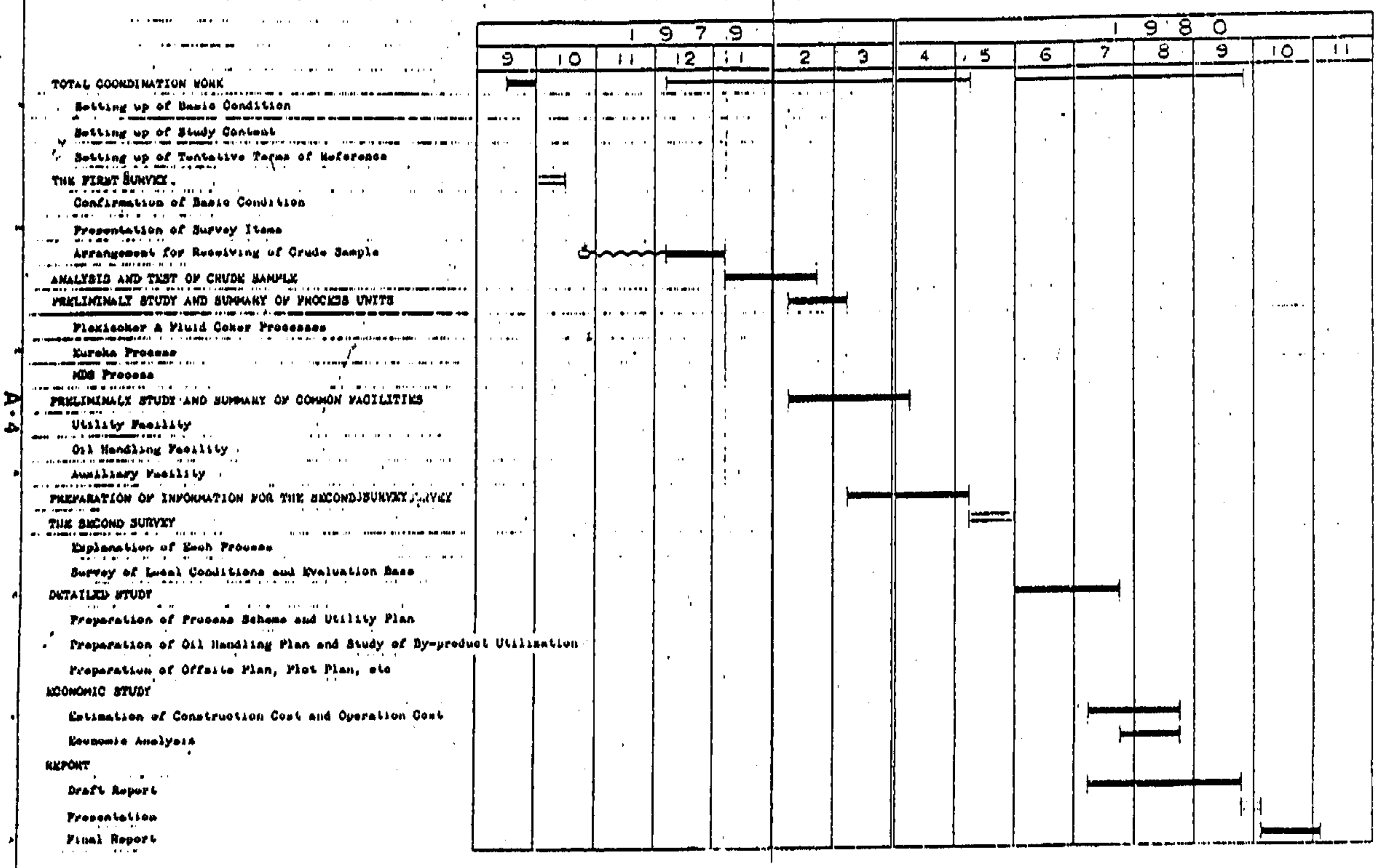
4. <u>Project Execution Shedule and Execution Manner</u>

The project execution schedule and execution manner are set as per <u>Fig. 1 attached</u>.

SCHEDULE

Fig. 1 ORINOCO HEAVY OIL UP-GRADING PROJECT

ATTACHMENT TO JICA-1



THE FIRST SURVEY TEAM
THE UP-GRADING PROJECT
OF ORINOCO HEAVY OIL IN THE REPUBLIC OF VENEZUELA

- TALKING PAPER -

1. **Objectives**

The Japanese First Survey Team sent by the Japan International Cooperation Agency (hereinafter referred to as "JICA") is expected to accomplish the following scope of work by exchanging views with the authorities concerned in the Republic of Venezuela, so as to meet the real needs of Venezuela:

(1) To clarify the contents of plans of the Venezuelan Government

(2) To confirm the basic conditions for the feasibility study

(3) To confirm the dilivery of Orinoco crude sample

(4) To discuss the preliminary T/R

(5) To visit Orinoco project site

(6) To collect relevant information and data in Venezuela

2. **Members of the First Survey Team**

The members of the JICA First Survey Team are as follows:

Name	Function	Title
Mr. Sen'ichi HIROSE	Project Manager (Chief of the Team)	Consultant to JICA
Mr. Toshio IBI	Policy in Technical Cooperation	Deputy Director Development Division Petroleum Department Agency of Natural Resources and Energy, MITI

Name	Function	Title
Dr. Koji UKEGAWA	Petroleum Refinery Engineering	Senior Scientific Officer National Research Institute for Pollution and Resources, MITI
Mr. Hideo YASUKI	Coordination	Deputy Director Industrial Survey Division JICA
Mr. Yasuhisa HOSOYA	Petroleum Refinery Engineering	Mechanical Engineer Consultant to JICA
Mr. Terutada TSUKAGOSHI	Petroleum Refinery Engineering	Chemical Engineer Consultant to JICA

Address : Japan International Cooperation Agency

P.O. Box No.216, 48th Floor
Shinjuku Mitsui Bldg.
2-1, Nishi Shinjuku, Shinjuku-ku
Tokyo, Japan

Telephone: Tokyo (03) 346-5287 ~ 9

Cable : JICAHDQ TOKYO

Telex : J22271 JICAHDQ J

3. Schedule of the First Survey

Schedule for the first survey is considered to be as indicated in the attached Fig. 2.
This tentative schedule is to be further developed and adjusted through discussions with you so as to accomplish the objectives of the survey most efficiently.
Your cooperation in this regard will be much appreciated.

4. Method of Approach by the First Survey Team

The survey team will visit government organizations and Orinoco site and exchange views on the proposed subjects with responsible officers.

Upon completion of the survey, the survey team will prepare minutes of meetings, which are to be signed and exchanged with the Venezuelan side.

5. Information Required

(1) The contents of plans of the Government of the Republic of Venezuela

a) Present status of Orinoco Oil Belt

b) Master Plan for Orinoco Development

c) Organization for Orinoco Development including upgrading plant

(2) Basis of Feasibility Study

Please refer to the attached "Confirmation Items of Basis of Feasibility Study".

(3) Delivery of Orinoco Crude Sample

Please refer to the attached "Confirmation Items of Basis of Feasibility Study".

(4) Terms of Reference for Feasibility Study

Final terms of reference will be determined after the first survey and the preliminary study. The preliminary T/R we have in mind at present is shown in the attachment.

(5) Visit to Orinoco Project Site

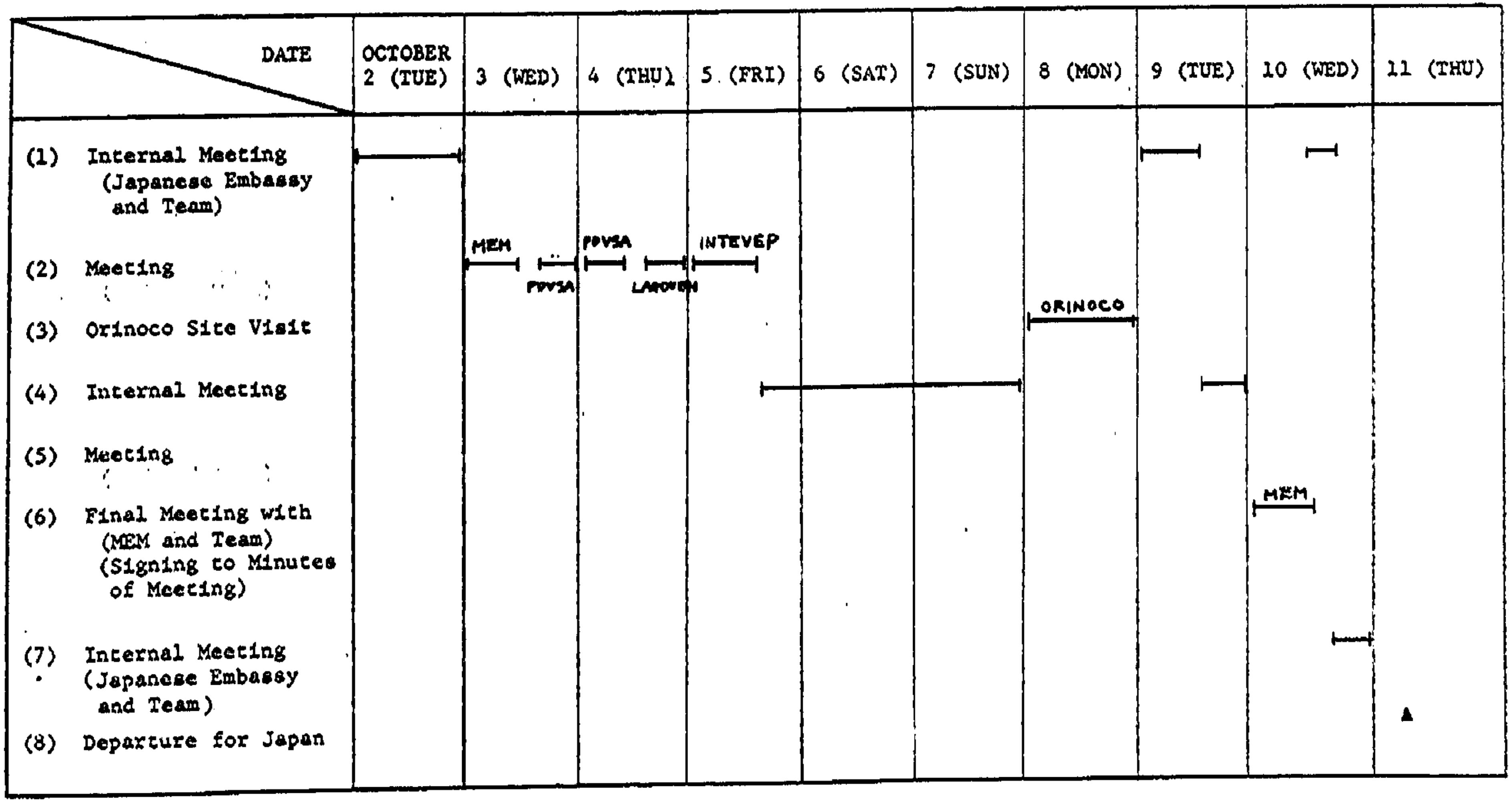
a) Schedule arrangement

b) Transportation arrangement

c) Permission and guide for Site visit

(6) Relevant Information and Data

Fig. 2 SCHEDULE OF FIRST SURVEY TEAM



ATTACHMENT TO JICA-2

THE STUDY ON
UP-GRADING OF ORINOCO HEAVY OIL
VENEZUELA
CONFIRMATION ITEMS OF BASIS
OF
FEASIBILITY STUDY

(FOR THE FIRST SURVEY TEAM)

OCTOBER, 1979

JAPAN INTERNATIONAL COOPERATION AGENCY

CONTENTS

I. EXECUTION

1. May we call "THE STUDY ON UP-GRADING OF ORINOCO HEAVY OIL" for this project?

   (a) Yes
   (b) No

2. Please submit your organization chart and the official title and name of each responsible person for Orinoco development.

   (a) Name
   (b) Adress
   (c) Telephone & Telex
   (d) Title
   (e) Person name

3. Please decide your key person for contacting and communication.

   (1) Contract General

   (2) Project General

   (3) Engineering

   (4) Financing

   (5) Marketing

   (6) Orinoco Field

   (7) Sample Oil Supply

   (a) Name
   (b) Adress
   (c) Telephone & Telex
   (d) Title
   (e) Person name

☆ 4. Please arrange and send the sample crude oil by the following conditions:

   (1) Kind of Crude Oil

   Same oil as the study base.

(2) Quantity of Sample oil

Five (5) drums (sealed)

(3) Condition of Sample Oil

Water separated oil at production site.

(4) Receiving time

arriving at Japan as early as possible, because the oil will be study base.

(5) Shipping fee

paid by Venezuela side.

(6) Consignee is JICA.

(a) Yes

(b) No

☆ 5. Transportation of Crude Oil

who is responsible person?

(1) How to arrange the crude shipping?

(a) Sampling of crude oil

(b) inland transportation from Orinoco to the port of Caracas.

(c) Shipping arrangement and loading to ocean going vessel

(2) When is expected date of crude shipping?

(a) Sampling of crude oil

(b) arriving at port

(c) Schedule of ocean going vessel (Venezuela to Yokohama)

II. PLANNING

☆ 1. PURPOSE OF UP-GRADING

Please select & mark it!

(1) Is it correct to understand that the final goal of the Orinoco heavy crude up-grading plan is to produce synthetic crude?

(a) Yes
(b) No
(Reason)

(2) What is the type of synthetic crude? ——→ Refer Fig.1

(a) Oil excluded gases
(b) Oil excluded gases & LPG
(c) Oil excluded gases LPG & Naphtha
(d) Other ( )

(3) Where is destination of synthetic crude?

(a) Export
(b) Domestic
(c) Export & Domestic

(4) What is the capacity of Orinoco heavy crude to be up-graded in this study?

(a) 100,000 BPSD feed
(b) 125,000 BPSD feed
(c) Other (BPSD feed)

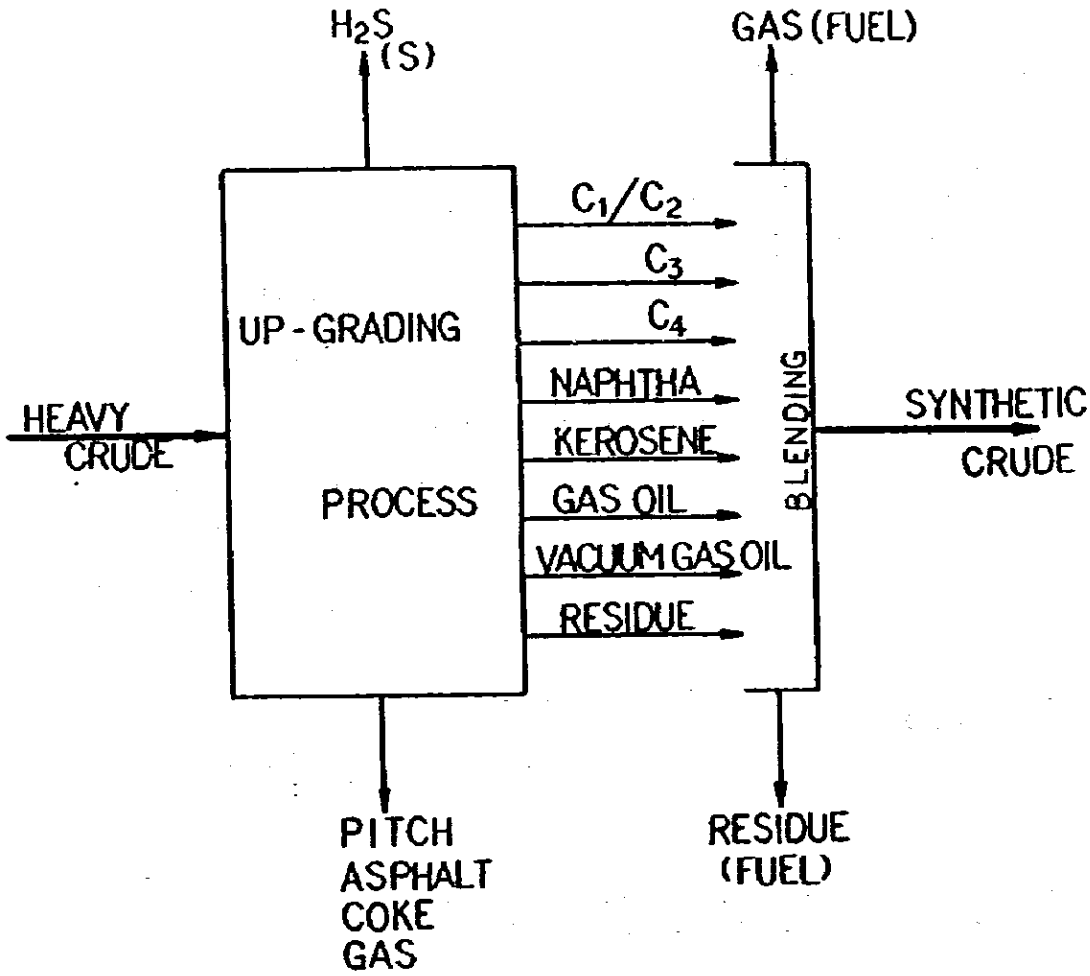
(5) Is it allowable to include residue in the synthetic crude? ——→ Refer Fig.2

(a) OK (b) No

(6) Is it necessary that the material balance is fitted between the field and the refinery? ——→ Refer Fig.3

(a) Yes (b) No

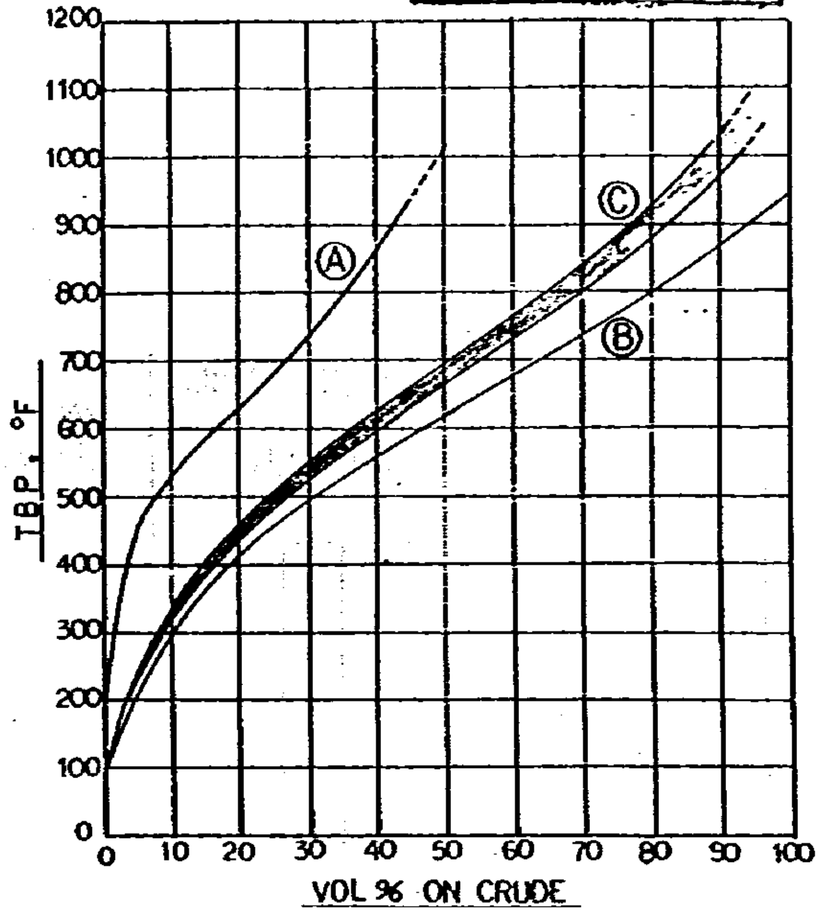
Refinery crude charge (100,000 BPSD)
= by-product from refinery
= Field boiler fuel
= Steam Generation
= Crude production for refinery crude charge (equivalent 100,000 BPSD)



TYPE OF SYNTHETIC CRUDE

FIG. 1

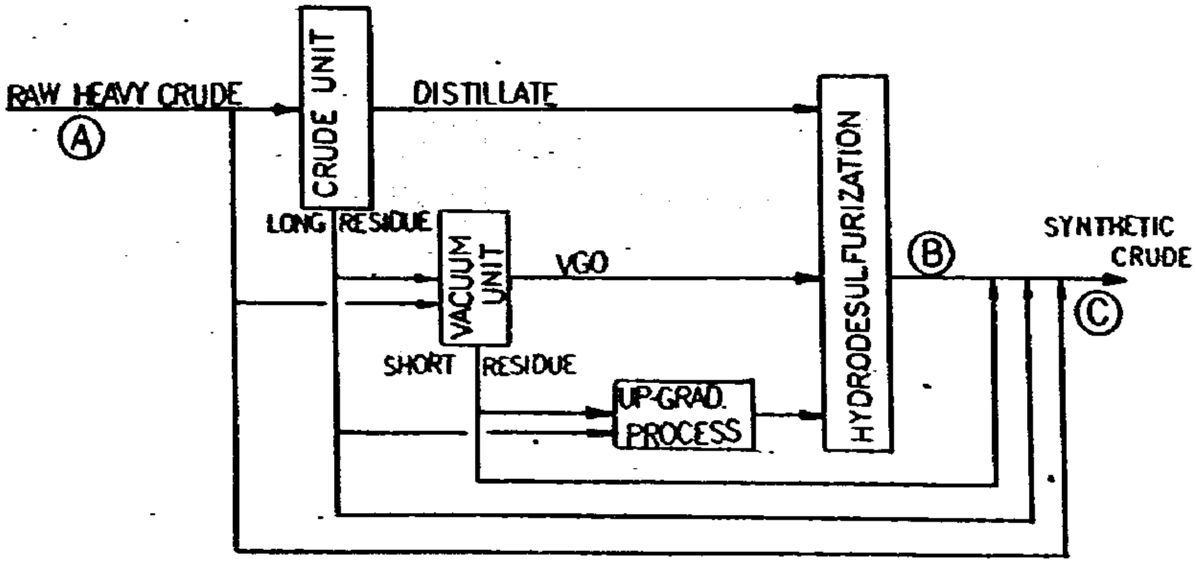
FOR REFERENCE ONLY



(A) - RAW HEAVY CRUDE ... incl. Residue

(B) - SYNTHETIC CRUDE (all up-grading) ... no residue

(C) - SYNTHETIC CRUDE (partial up-grading) ... incl. residue mixed with raw crude, long residue or short residue



SYNTHETIC CRUDE OIL FIG. 2

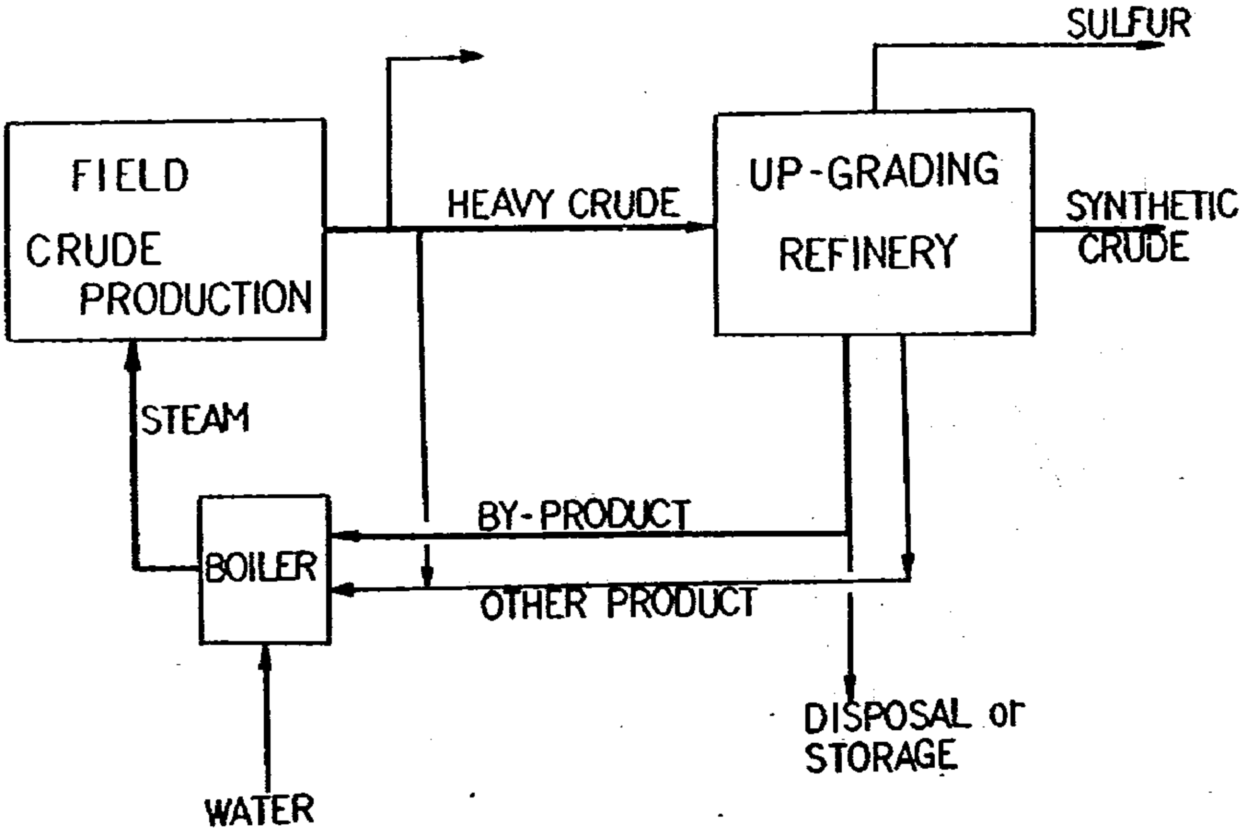


FIG.3 MATERIAL BALANCE
(FIELD & REFINERY)

(a) In case of shortage of by-product from refinery, what is used for boiler fuel?

(a) Refinery distillate
(b) Synthetic crude
(c) Raw heavy crude

(b) In case of excess of by-product from refinery, what is used for by-product?

(a) Disposal or storage of by product
(b) Production of excess crude by excess steam

☆ 2. SITE PLAN

——→ Refer Fig.4 (& Table 1)

(Please plot these places on a map.)

Please select, mark it & indicate!

(1) Where is the Orinoco heavy crude production field?

(a) Morichal
(b) Selonegro
(c) Other
(Where is it?)

(2) Where is the up-grading plant site?

(a) Morichal
(b) Selonegro
(c) Other
(Where is it?)

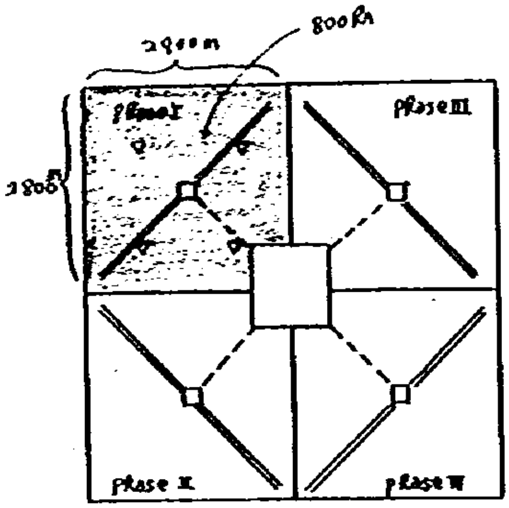
(3) How many places are considered as the up-grading plant site for 100,000 - 120,000 BPSD of Orinoco heavy crude?

(a) 1 site
(b) few sites
(Separate plant site)
(Where are they?)

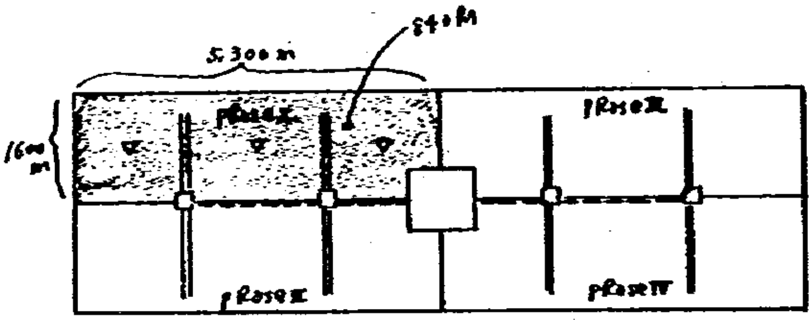
(4) Where is the injection field of steam that is produced by by-product fuels of the up-grading process?

(a) Morichal
(b) Selonegro
(c) Other
(Where is it?)

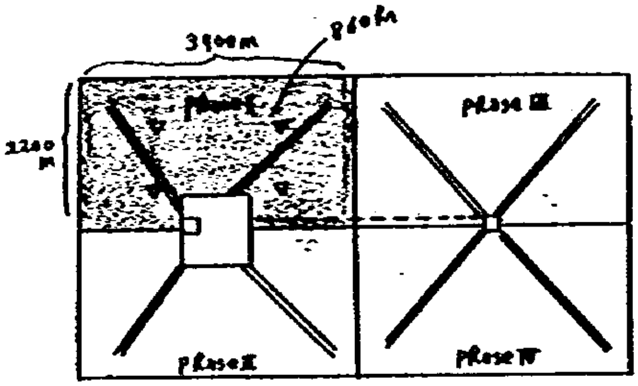
FOR REFERENCE ONLY



Boiler	1 place (each 5 years)
Steam	2 km max. Transmission
Fuel	1.6 km max. Transmission
Injection	51 wells
Production	133 wells



Boiler	2 places (each 10 years)
Steam	2.5 km max. Transmission
Fuel	3.7 km max. Transmission
Injection	52 wells
Production	141 wells



Boiler	1 place (each 10 years)
Steam	2.85 km max. Transmission
Fuel	3.9 km max. Transmission
Injection	50 wells
Production	133 wells

Phase I	1 ~ 5 year
Phase II	6 ~ 10 year
Phase III	11 ~ 15 year
Phase IV	16 ~ 20 year

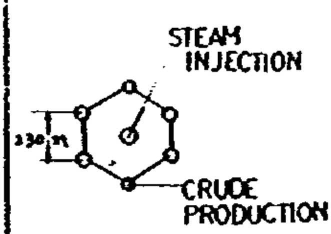
□	Refinery Site
▫	Boiler Site
═	Steam Main Transmission pipe
---	Boiler Fuel Transmission
▽	Oil Block Station

FIG.4 FIELD MODEL

TABLE-1 FIELD MODEL FOR SITE PLAN

FOR REFERENCE ONLY

		EXAMPLE	YOUR PLAN
(1)	Crude Production Rate per a well of a hexagon	300 BPOD	BPOD
(2)	Life of Well	5 years	years
(3)	Production Method	Steam Drive Method	Method
(4)	Distance between well and well	230 m	m
(5)	Refinery Site Area (one place)	1,000 m x 1,000 m	
(6)	Boiler Site Area (Movable)	250 m x 250 m	
(7)	Operation Life of Refinery	20 years	years
(8)	Injection Steam pressure at boiler	70 kg/cm^2G	kg/cm^2G
(9)	Transmission Distance of Steam (Maximum)	3,000 m	m
(10)	Refinery Charge Capacity	100,000 BPSD	BPSD
(11)	Steam Injection	6.0 BBL/steam Ton 3.0 1.5	BBL/steam Ton



(5) Where is the boiler plant site for steam injection?

(a) Morichal
(b) Selonegro
(c) Other
(Where is it?)

(6) Where is the loading port of the synthetic crude?

(a) Puelto ordaz
(b) Other
(Where is it?)

3. SCOPE OF WORK → Refer Fig.5

Please mark it!

(1) What is the scope of work for the F/S? (as hard range)

(a)	Up-grading Refinery	(a) Yes (b) No
(b)	By Products (Low-grade fuel) Storage & Transmission Facility	(a) Yes (b) No
(c)	Steam Generation Facility	(a) Yes (b) No

(2) What are the items of Study for the F/S? (as soft range)

(a)	Heavy Crude Oil Analysis/ Testing	(a) Yes (b) No
(b)	Technical Study	(a) Yes (b) No
(c)	Economic Study	(a) Yes (b) No

☆ 4. ORINOCO HEAVY CRUDE OIL

Please fill up in the blank.

(1) What is the name of Orinoco heavy crude for this F/S?

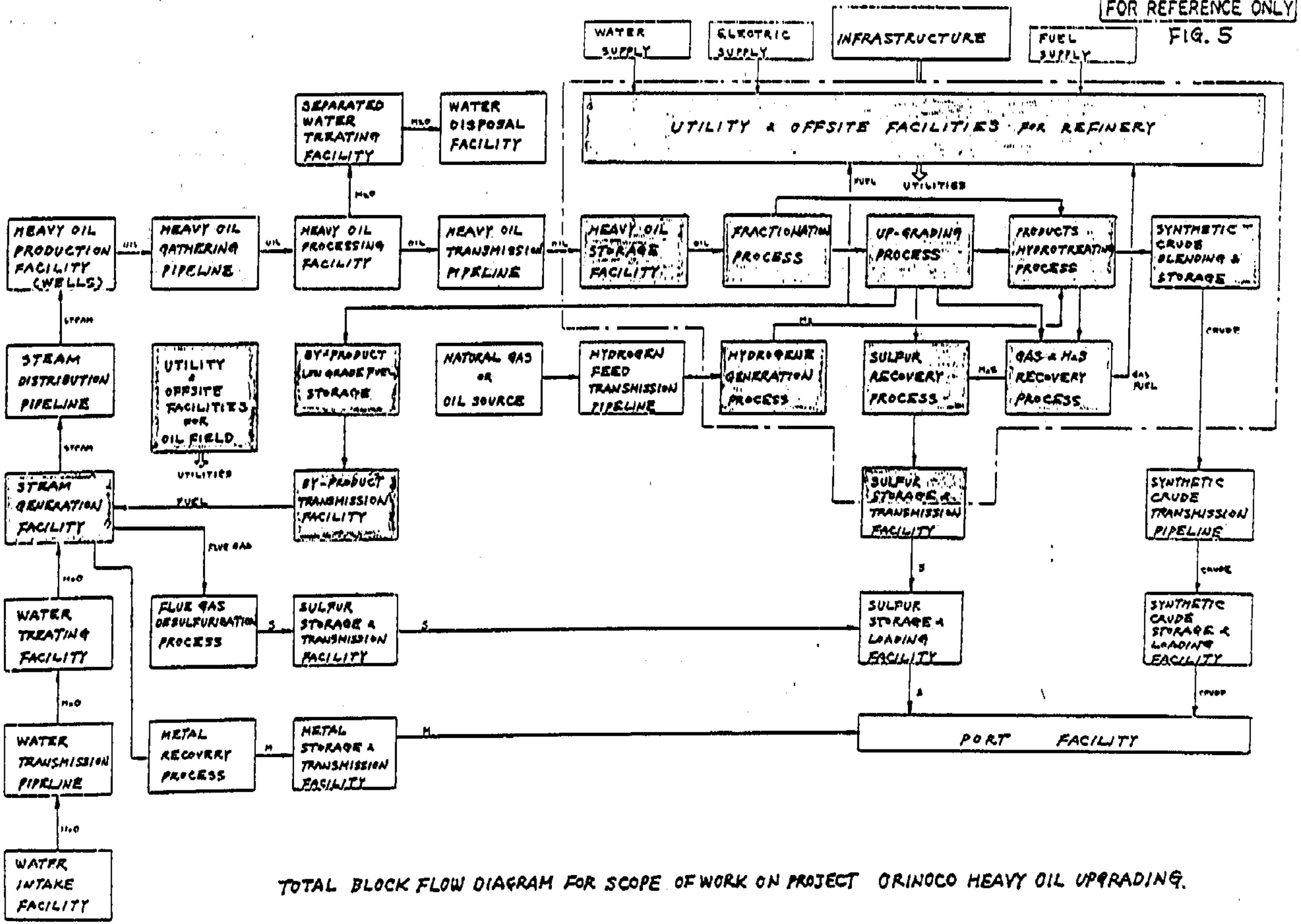
[ ] crude

(2) Where is the field of heavy crude production or proposed field of development?

[ ] field

FOR REFERENCE ONLY

FIG. 5



TOTAL BLOCK FLOW DIAGRAM FOR SCOPE OF WORK ON PROJECT ORINOCO HEAVY OIL UPGRADING.