North Refineries Company
Republic of Iraq

Preparatory Survey
on
Baiji Refinery Upgrading Project

Final Report

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JAPAN INTERNATIONAL COOPERATION AGENCY

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General

The Ministry of Oil (MOO) and North Refinery Company (NRC) of Republic of Iraq, has a plan for upgrading the Baiji Refinery (the Project) through additional construction of Fluid Catalytic Cracking (FCC) Complex for the purpose of immediate improvement of the expected future imbalance between demands and supplies of oil products for public consumption in the region.
According to the request of MOO for the Japanese Official Development Assistance (ODA) loan for implementation of the Project, Japan International Cooperation Agency (JICA) had entrusted Japan Oil Engineering Co., Ltd. (JOE), as the competent consultant (the Consultant) to conduct the Preparatory Survey (the Survey) for verification of necessity and validity of the Project as well as the development of practical basic project plan including conceptual design of the facilities and feasibility Survey as the first step of formality for the loan. Together with JOE, Chiyoda Corporation, a world-wide leading engineering company which constructed the Baiji Refinery in 1983, will perform part of the Study as the member of the Consultant.

This Report presents the result of the Survey, which demonstrates the selected optimum process scheme options for the intended FCC complex, applicable project execution and operations scheme, project feasibility and environmental and social considerations for the Project.

Executive Summary

The Ministry of Oil (MOO) and North Refinery Company (NRC) of Republic of Iraq, has a plan for upgrading the Baiji Refinery (the Project) through additional construction of Fluid Catalytic Cracking (FCC) Complex for the purpose of immediate improvement of the expected future imbalance between demands and supplies of oil products for public consumption in the region.
As requested by MOO/NRC for the realization of the Project under the Japanese Official Development Assistance (ODA) loan, Japan International Cooperation Agency (JICA) appointed Japan Oil Engineering Co., Ltd (JOE) (the Consultant) to conduct the preparatory survey (the Survey) for the Baiji Refinery Upgrading Project; and Chiyoda Corporation (Chiyoda) as the in charge party for the portions concerning for process and economics in the Study.

1. Introduction

MOO/NRC will initiate a project for the upgrading of Baiji Refinery, a grass-root refinery built in 1978, located in the district of Baiji/ Salahuddin province in the northern region of the country by installation of FCC Complex in order to achieve the goals as follows.

GOAL 1: Improving the domestic supply-demand balance of liquid products such as gasoline, diesel, kerosene

GOAL 2: Improving technology in the refinery sector in Iraq by applying a state-of-the-art process

GOAL 3: Supplying the international levels of high quality oil products such as low sulfur gasoline (less than 10 ppm) and diesel (less than 50 ppm) that complied with the international standards for the mitigation of environmental pollutions arising from public consumption of the fuels in the regions

GOAL 4: Improving the national and regional economy through minimizing Iraq’s foreign allocation outflow being caused by the importation of the gasoline and diesel and activation of the local economy by employment of local people

The FCC Complex proposed by MOO/NRC consists of the main and auxiliary processing units, utilities and related offsite facilities such as intermediate product tanks and others to be constructed within the battery limit of the Baiji Refinery. The Project requires interface alignment between the existing facilities and the FCC Complex on the following interactive aspects: coordination of feedstock supply system, products transfer system, control/ data communication system, etc. and modification/ addition of existing related facilities including products storage tanks, blending system, loading facility, etc.

The FCC Complex shall have the capacity to produce the following high quality petroleum products at least:

- 28,300BPSD of FCC gasoline with RON 90-91, less than 10ppm of sulfur content
- 5,400BPSD of diesel oil, less than 50ppm of sulfur content
- Others: fuel oil mix, LPG, naphtha, sulfur, etc.

The main feed stocks for the FCC Complex i.e. Reduced Crude (RCR), Vacuum Residue (VR), Vacuum Gas Oil (VGO), Lube Surplus, will be supplied from the existing Baiji Refinery.

For eliminating the residue (asphalt and pitch/coke) produced in the refinery for environmental preservation, the proposed FCC Complex shall include the Gasification process in the process configuration. The simplified block diagram of the existing Baiji Refinery and the proposed FCC Complex is shown in Figure 1.

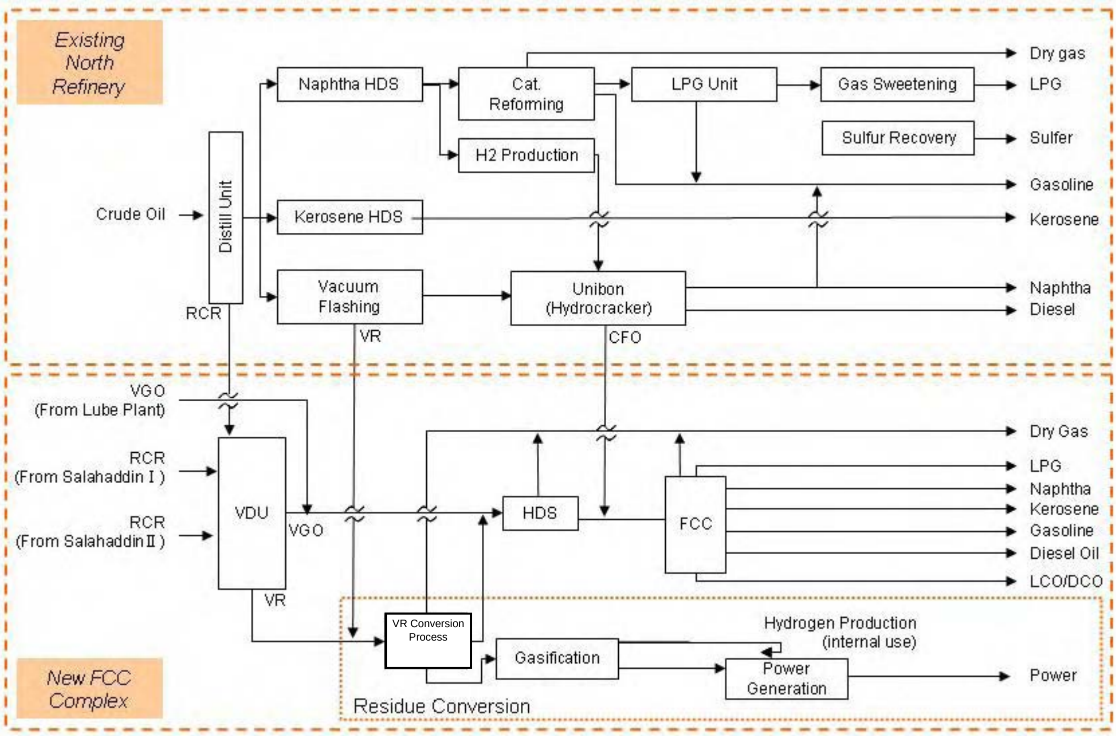

Figure 1 Simplified Block Flow Diagram

Accordingly, the most optimum configuration of main processing units composing the FCC Complex shall be selected among the following optional cases.

Case 1	VDU + HDS + RFCC + SDA + Gasification
Case 2	VDU+ HDS + FCC + Eureka + Gasification
Reference case	VDU+ HDS + FCC + Delayed Coker + Gasification

2. Choosing the most suitable FCC process for Baiji Refinery

2.1 General

The current production capacity of the existing Baiji Refinery remains at 65%, mainly due to the lack of hydrogen and frequent, unplanned shutdowns caused by an unstable power supply.
It is essential that sufficient, stable and reliable supplies of main utilities such as electrical power, industrial water and fuels from the certain internal/ external resources are secured to sustain continuous and safe operation of the FCC Complex. In addition, consumers of not only the main products, but also by-products i.e. sulfur, heavy residue, coke, and etc. should be guaranteed to ensure that the operation of the FCC Complex is a commercial success.

2.2 General Philosophy of the FCC Complex

Taking the above mentioned situation into account, and the future supply/ demand of oil products in Iraq, the following philosophy was adopted in the design of the FCC complex:

1) Combination with gasification
    - clean as well as efficient operation
    - self-sufficient and flexible operation by supplying:
        - hydrogen to the existing hydrocracker
        - clean syngas energy to the existing fuel gas users, residue upgrading and gasoline production
2) Lower sulfur content product: Euro 5 will be applied for finished product of gasoline and diesel oil. This will provide low exhaust emissions which will contribute to a clean environment in Iraq.
3) VGO FCC is preferred since it is more efficient than Residue FCC (RFCC) on the product selectivity.

2.3 Process Case Definition

In the Survey, following process combination were considered.

1) RFCC + SDA + Gasification
2) FCC + Eureka (solid pitch) + Gasification
3) FCC + Eureka (liquid pitch) + Gasification (For reference)
4) FCC +Delayed coker + Gasification (For reference)

Study case	SDA	Eureka	Delayed Coker	DAO HDS	Distillate HT	FCC		Gasification	
						VGO FCC	RFCC	Liquid	Solid
SDA case	x	-	-	x	-	-	x	x	-
Eureka case (Solid pitch)	-	x	-	-	x	x	-	-	x
Reference cases									
Eureka case (Liquid pitch)	-	x	-	-	x	x	-	x	-
Delayed coker case	-	-	x	-	x	x	-	-	x

Figure 2-1: Study Cases Definition

Note 1: The pre-screening of the thermal cracking process was done by both MOO/NRC and the Consultant at the early stage of the Survey. Other thermal cracking process, such as Flexicoker was omitted during pre-screening of the Survey due to the low calorie syngas is produced and no possibility of hydrogen production is expected.

Note 2: While Eureka (Liquid pitch) + Gasification case is expected to be the most economical, as shown in the following sections, this combination application is currently in the confirmation phase. Thus, this case only incorporated as a reference in the Survey report.

Note 3: Delayed coker case was requested by MOO/NRC as a reference in the 2nd meeting held in July 2009.

2.4 Product Properties

The product yield of three (3) cases, a combination of FCC + residue conversion processes (SDA, Eureka, and Delayed Coker) + heavy end gasification, were studied during the Survey. Figure 2-1 below shows the product yield of FCC + residue conversion process + gasification. The findings are as follows;

- Eureka case brings the highest liquid yield (shown as A) and also produces the largest amount of diesel and gasoline. (B)
- SDA case has the highest LPG yield (C) but the quality of diesel and gasoline is inferior to

that of the thermal cracking processes (Eureka case and delayed coker case) (D)

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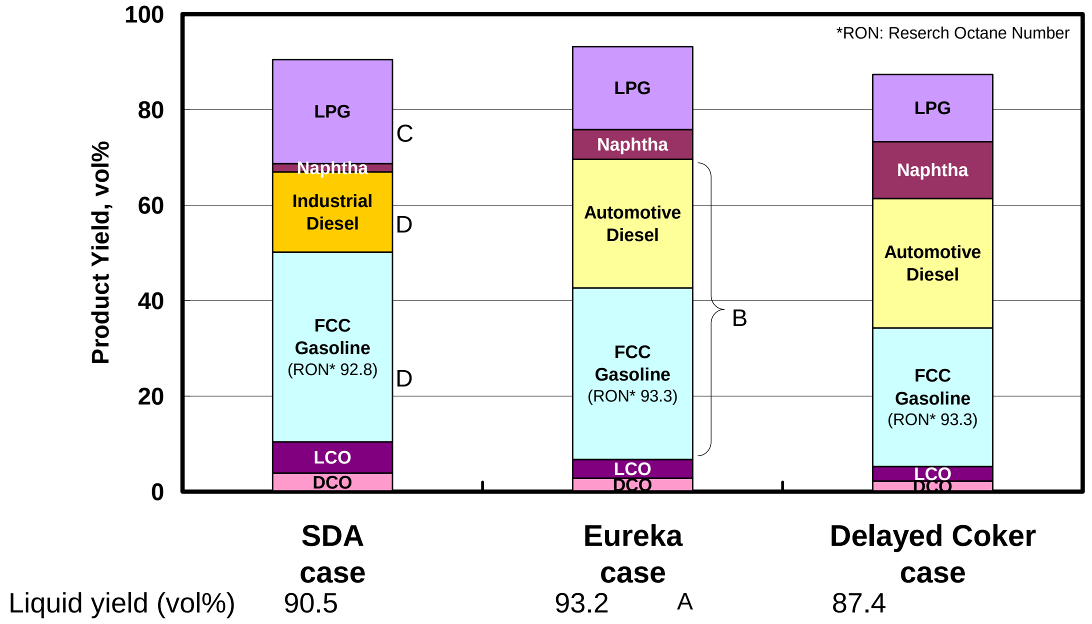

Figure 2-2 Liquid Product Yield: FCC + Residue conversion + Gasification

3. Cost Estimation of the FCC Complex

The following premises were provided for the cost estimation of FCC Complex.

1) The accuracy of cost estimation is in the range of +/- 30%
2) Project duration is assumed to be 55 months (FEED 15 months + EPC 40 months)
3) Equipment and materials are to be purchased on worldwide procurement network
4) Items excluded from the cost estimates are:
   - Land acquisition cost and any related fees
   - Taxes and duties
   - Fee for regulatory permissions
   - Charging cost of feedstock residues from the existing facilities to the FCC complex
   - Security Cost

3.1 Total Investment Cost for the Project

(unit: mmUSD)

	SDA	Eureka	Delayed Coker[1]
Process	1,450	1,390	1,420
Utility	210	210	200
Offsite	220	230	230
CAPEX	1,880	1,830	1,850
Owner's cost	245	243	242

[1] For Reference

3.2 Operating Cost (OPEX) for the Project

(unit: mmUSD/year)

	SDA	Eureka	Delayed Coker[1]
OPEX	86.0	81.3	81.4

[1] For Reference

4. Economic Evaluation

Economics were evaluated during the Survey for three (3) cases which is the combination of FCC and residue conversion processes (SDA, Eureka, and Delayed Coker) with heavy end gasification.

4.1 Basic Assumption

For the analysis of economic considerations and social justification for the Project, the following terms were applied.

- Project period 40 years
  (Repayment 30 years after 10 years of grace period)
- Depreciation 10 years straight line
- Debt/ Equity ratio 85/15
- Interest rate 0.65%

- Prices for Products

Unit: USD/bbl

	Domestic prices	International prices
Crude Oil	1.6	60.0
RCR	7.2	38.9
VR	8.1	31.4

- Products

	Domestic prices		International prices	
	USD/ton	Relative to gasoline price	USD/ton	Relative to gasoline price
LPG	0.059	140%	36.8	54%
Gasoline	0.042	100%	67.7	100%
Diesel	0.021	50%	74.7	110%
Fuel oil	0.042	100%	46.9	69%

Refineries are principally designed to maximize liquid products such as kerosene, gasoline, diesel and etc. and gain as much profit from these value added products. However, in the current domestic price structure condition in Iraq, it was observed that the price of LPG is high and the diesel price is low as shown above, which is very rare condition in refinery operation.

The domestic oil product market in Iraq is expected to be stabilized with the expanding capacity of refining oil products. On the other hand, a large amount of LPG (more than enough to balance the shortage of domestic supply) will be produced from the associated gas in Iraq due to the results of Round 1 and 2 Production Contracts. Therefore, Iraq domestic pricing structure could be reevaluated and adjusted to be proportional to the International prices configuration.

4.2 Economic considerations

For the analysis of economic considerations for the Project, domestic prices were applied for the feedstock and oil products. The result shows negative values on ROI which means subsidies from the Iraq Government are required.

Cases	SDA case	Eureka case	Delayed coker case
ROI (%)	-12.0	-12.5	-12.9

Subsidy to write-off deficit (Unit: million USD/ year)

During grace period	65.3	74.8	83.0
After grace period	140.7	148.5	157.2

SDA case shows rather better ROI (but still in negative) and require smaller subsidies than other cases. Since the current domestic prices are structured to favor the refinery to produce larger amount of LPG, SDA case seems to be better than other cases (also refer Figure 5-2). The economic evaluation based on the political pricing structure does not solely reflect the economical justification of the Project.

4.3 Social Justification

For the analysis of social justification for Iraq, international prices (Arabian Gulf Coast basis) for feedstock and product were applied.

Cases	SDA case	Eureka case	Delayed coker case
EIRR on Investment (%)	11.9	16.2	14.1

Eureka case has the highest economic performance amongst other residue conversion cases as shown above. This means that;

- Eureka case is more viable than other residue conversion cases.
- Realization of the Project is economically justified, since the Project will contribute to Iraq by reducing liquid product import from neighboring countries.

4.4 Sensitivity analysis

- Facility cost and feed/ product prices largely affect EIRR and FIRR, compared with OPEX.
- A higher syngas price will bring more advantages to Eureka + gasification case. Although 1 USD/mmBTU is used in this analysis for the price of syngas, the price of natural gas would increase in the future as the demand for clean gas in Iraq increases due to the rapid growth in the consumption of electric power.

- SDA + gasification case depends on the fluctuation of gasoline and LPG prices more than in the other cases.

5. Project Execution

5.1 "Most Preferable and Capable Contractor"

Because of the large magnitude of the investment, the FEED/EPC contractor, who will execute and lead the Project to a successful completion as the prime engineering contractor, should be well-experienced in the implementation of projects which has similar size and nature. It should have a thorough understanding of the Project requirements and should be able to work, and form a mutual trusting relationship among the stakeholders. The "Most preferable and capable contractors" should obtain the following qualifications;

- Project execution planning capacity
- Technical capability
- Project manpower availability
- Corporate quality systems
- Safety systems and safety records
- Corporate financial reliability

Preferably contractors should have;

- experiences in the selected process
- experiences in the existing plant
- knowledge with interface with existing plant for tie-in study

The above mentioned items should be evaluated prior to proceeding with any further bidding steps.

5.2 Fast-track Schedule

The project execution consists of two (2) major phases.

i) Front-End Engineering Design (FEED)

ii) Engineering, Procurement and Construction (EPC)

Given that attainment of transparency, the Consultant strongly recommends that all activities should be undertaken by a single contractor from the following reasons;

- High and consistent quality of the FCC Complex design
- Seamless implementation of FEED and a smooth transition to and execution of EPC
- Time saving by shortening the duration of the Project implementation
- Cost effectiveness

Typical schedules for the Project have been prepared as attached for better understanding of single contract, which consider all aspects of the works described in the previous chapters. The Consultant estimated FEED activities of the Project was 15 months and 40 months for EPC phase. However, if an EPC bidding phase is adopted, it normally takes 9 to 10 months (sometimes one year) before EPC activities can commence, after FEED activities have been completed, for bid document preparation.

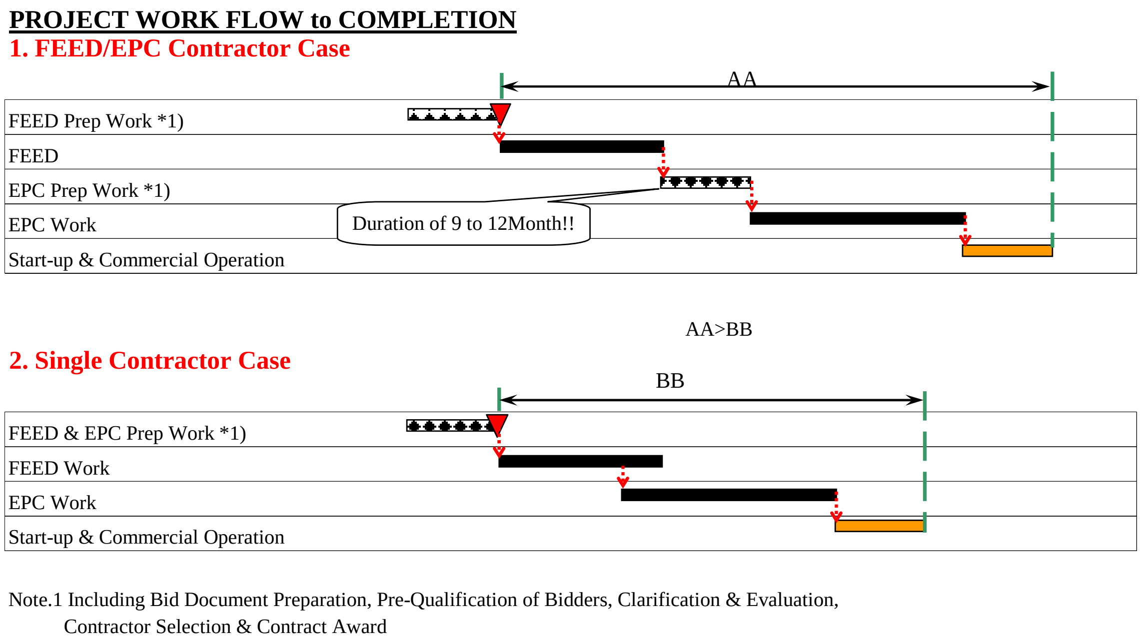

Figure 5-1 Project Work Flow to Completion

5.3 Execution Scheme

For execution of the project, the Project Office (PO) will be established in the NRC under MOO. The PO will be responsible in engaging the contracts with process licensors, FEED contractor and EPC contractor for execution of the project in the respective phases.

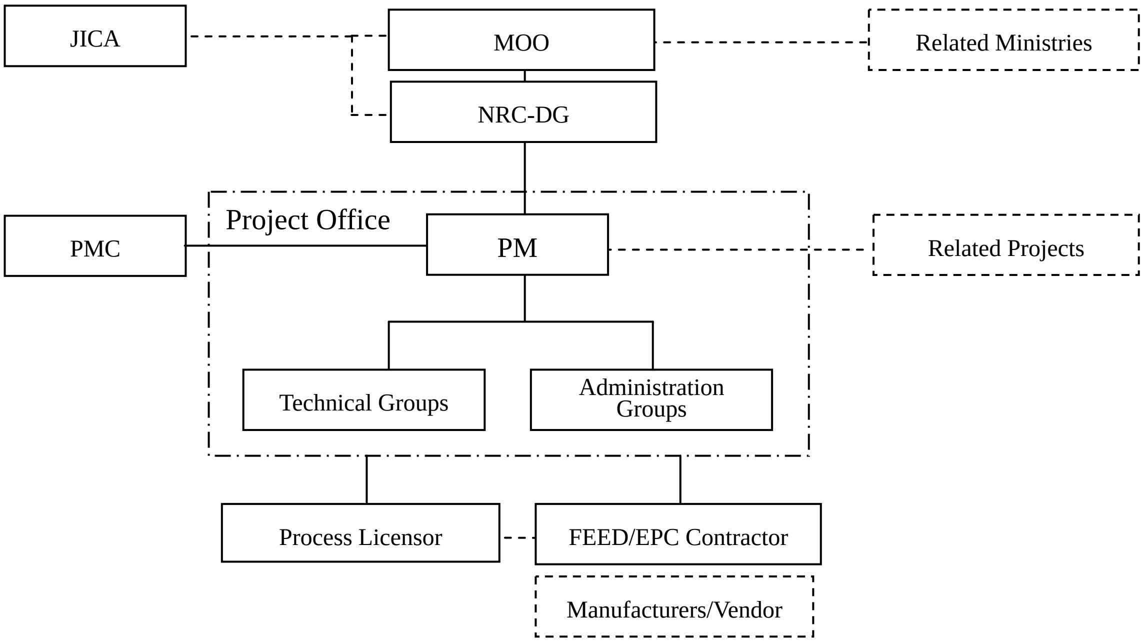

Figure 5-2 General Project Organization

NRC will employ a qualified and experienced consulting firm for project management consultancy (PMC) during the FEED and EPC phase respectively to render the necessary support and assistance to the PO to ensure successful completion of the project as planned. PMC is responsible for the necessary coordination between NRC and JICA, lender of ODA Loan.

The PO consists of the technical groups in charge of Onsite and Offsite facilities, HSE group, material procurement, quality assurance/quality control (QA/QC) group as well as administration group necessary for managing the project operation including budget control.

5.4 Technology Transfer

The proposed FCC Complex will be comprised of new technical elements such as refining processes and equipment, control system and operating procedures, which have not been adopted in the Iraqi refineries yet. The project will provide the comprehensive technology transfer plan aiming to improve the project management skills and the technical skills for engineering, construction, operation and maintenance of MOO/NRC.
In order to ensure the sustainable stable operation of the new facilities without interruption due

to human error or defective operation manner, it is essential to enhance especially the operation technology of Baiji Refinery for the new process units.

6. Finance Arrangement

It is considered that the schemes of the Yen Loan (JICA ODA Loan) and the own finance by MOO are viable for the Project.

Considering the current circumstances surrounding Iraq and its financial situation, it seems that there is a high possibility that there will be a request for a Yen loan. However, considering the huge amount of the total project cost and the amount of Yen loan allocated to the other projects in Iraq, it is unsure whether the Japanese government will allocate a Yen loan for the whole of the project cost at one time.

In this regard, a viable option would be to divide the project into several phases. Also, a combination of a Yen loan and MOO/NRC's own finance would be another way to finance the Project, but this depends very much on the price of crude oil and the situation surrounding the country's national budget. The financing for the project have to be further discussed and studied.

7. Environmental and Social Considerations

7.1 Environmental and Social Policy for the Project

MOO/ NRC state that a firm Health, Safety and Environment (HSE) policy for the Project should comprise as follows.

- *HSE protections are prioritized in the business activities.*
- *Accidents and injuries to personnel are preventable and unacceptable.*
- *Everyone is responsible for their own and their colleagues' safety at work.*

The Project complies with the environmental standards and/or discharge limits set by the relevant laws and regulations of Iraq. Where numerical standards have not been specified by the Iraqi legislation, the guidelines of the international organization such as World Bank Group/ IFC, WHO, etc. and/or best practice should be referred or applied to the project. In addition, JICA/JBIC Environmental and Social Guideline shall be applied seriously to the project to be implemented using ODA loan of JICA.

7.2 Preliminary Environmental and Social Impact Assessment

The preliminary EIA exercise carried out in this study concludes that the potential environmental and social impacts of the project activities are expected to be mitigated properly in compliance with the requirements of the relevant laws and standards in Iraq and the applicable international guidelines through implementation of the environmental and social measures discussed in the study. The EIA suggests the issues to be executed and further assessment of the potential environmental and social impacts in the subsequent FEED phase of the project as follows.

- Detailed identification of the project based on the project and facilities plans defined by the basic engineering of the project
- Collection of further environmental and social baseline data for proper impact assessment of the project
- Introduction of the numerical modeling studies for quantitative assessment of the impacts of gas emissions, wastewater discharges as well as noise emissions to the sensitive areas including the potential cumulative impacts of such environmental aspects
- Execution of the formal EIA in the subsequent FEED phase for re-assessment of the environmental impacts according to the findings of the above investigation and studies and proper feed-back of the EIA results to the engineering and design of the facilities

7.3 Environmental Management System

The EIA also suggest improving the HSE management system for upgraded Baiji Refinery in accordance with the practical international standards to assure that the HSE policy of MOO/ NRC is implemented properly in the operations of the refinery. The HSE plans to be developed in the subsequent phase of the project include :

- HSE and social plans for protection and mitigation of the potential impacts of the project,
- Environmental monitoring plans aiming to demonstrate compliance with the requirements, assess the environmental impacts of the project and evaluate the effectiveness of the measures undertaken, and
- Incident management plan (IMP) for response to the unexpected accidental events such as fire, explosion, toxic gas release, oil spill, injury and fatality of personnel.

8. Conclusion and Recommendations

8.1 Conclusion

(1) Necessity and Validity of the Project

The project is considered to be valid and reasonable with the major merits such as improvement of supply-demand balance of oil products, reduction of national expenditures for importing the oil products from foreign countries, the creation of new job opportunities and businesses in the region, improvement of technology in the refinery sector and environmental effects through supply of high quality (low sulfur content) vehicle fuels, which is fully expected to contribute effectively for the achievement of the national development strategy for refinery sector in Iraq.

(2) Technical and Economic Consideration for FCC Complex

Eureka case is advantageous to the aspects of products properties, CAPEX and OPEX compared to SDA and Delayed Coker cases.
The economic evaluation (domestic price base) shows that SDA case is rather better ROI (but still in negative) and requires smaller governmental subsidies for operations than other cases. However, the economic evaluation (international price base) shows that EIRR of Eureka case is more viable than other cases.

(3) Project Execution

The project execution consists of two (2) major phases, i.e. FEED, EPC phases. The Consultant estimated the FEED activities of the Project at 15 months and 40 months for EPC phase. In addition, it will normally take 9 to 10 months (sometimes one year) for tendering for EPC contractor after FEED.
The Project Office (PO) responsible for execution of the project will be established in the NRC under MOO. NRC will employ a qualified and experienced consulting firm for project management consultancy (PMC) during the FEED and EPC phase respectively to render the necessary support and assistance to the PO to ensure successful completion of the project as planned.

(4) Technology Transfer

The project will provide the comprehensive technology transfer plan aiming to improve the project management skills and the technical skills for engineering, construction, operation and maintenance of MOO/NRC. It is essential to enhance especially the operation technology of Baiji Refinery for the new process units to ensure the sustainable stable operation of the new facilities without interruption due to human error or defective operation manner.

(5) Environmental and Social Considerations

The environmental and social consideration for the project will be implemented properly in accordance with the relevant laws and standards in Iraq as well as applicable international guidelines to fully accomplish the HSE policy of MOO/NRC.
The preliminary EIA exercise carried out in this study concludes that the potential environmental and social impacts of the project are expected to be mitigated properly in compliance with the requirements of the relevant laws in Iraq and the applicable international guidelines through implementation of the environmental and social measures discussed in the study.

8.2 Recommendations

(1) Phases Implementation of the Project

The study estimated the CAPEX at approximately $2 billion or more in total. Considering financing capacity of JICA's ODA Loan for one single project, MOO may provide its own budget for a part of CAPEX of the project. The practicable implementation scheme (a single or multiple phases) of the project shall be discussed seriously for the realization of the project considering the finance plan of MOO, operational capability of NRC, products demand and supply (production) plan and operability of the refinery.

(2) Self-sufficient for Utility

Through introduction of the gasification plant and gas turbine power generation units, the proposed FCC Complex aims to be self-sufficient for the utilities i.e. H_2, fuel gas, steam and water as well as power, to ensure sustainable operation of the process facilities.
For introduction of the gasification plant in the FCC Complex, it is required to discuss

sufficiently the several issues to ensure the stable operations of the entire refineries, i.e. H_2 and power supply plans in whole Baiji Refinery, operability and reliability of the new gasification process, available consumers of the excessive syngas (low heat value), stable feed of the raw material, optimum capacity and numbers of trains of gasification process, costs and effects as well as potential operational risks

(3) Treatment of By-products

If the certain demands/ markets of the asphalt/ pitch are available in Iraq or neighboring countries, the by-product could be sold or exported as "Product" without any treatment. The capacity of the gasification plant could be optimized in accordance with the demands of the asphalt/ pitch in the markets. The feasible treatment solutions including consumption of the coke/ pitch in Iraq shall be investigated seriously in the subsequent phase of the project.

(4) Technology Transfer

In addition to the engineering, design of the facilities and project management skills, sufficient operational technology transfer to NRC for the new process units is essential to ensure the stable and safe operation of the new FCC Complex. Furthermore, the continuous supports and training for the operation of the new plant during the necessary period by the EPC contractor and/or licensor(s) shall be included in the technology transfer plan to be applied after commissioning of FCC Complex.

(5) Environmental and Social Considerations

The formal EIA shall be executed in the subsequent FEED phase of the project for further assessment of the potential environmental and social impacts based on the results of the basic engineering of the facilities and the detailed environmental and social baseline survey.
It is also suggested to improve or develop the HSE management system for the operation of the upgraded Baiji Refinery including HSE and social plans, monitoring plan and incident management plans in accordance with the international guidelines and practices.

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ABBREVIATIONS

AACE	Association for Advancement of Cost Estimation
AFC	Air Fin Cooler
AGR	Acid Gas Removal
ALARP	As Low As Reasonably Practicable
ANSI	American National Standard Institute
API	American Petroleum Institute
API gravity	Gravity with American Petroleum Institute method
AR	Atmospheric Residue
ASME	American Society Of Mechanical Engineers
ASTM	American Standard For Testing And Materials
Ar	Argon
B.L.	Battery Limit
BBL	Barrel
BEDD	Basic Engineering Design Data
BFW	Boiler Feed Water
BPA	Bottom Pumparound
BPD	Barrel Per Day
BPSD	Barrel Per Standard Day
C.F.O.	Hydrocracker unconverted oil from North refinery
C1	Methane
C2	Ethane
C3	Propane
C4	Buntanes
$C4^-$	Hydrocarbon lighter than Butane
C5	Pentanes
CAPEX	Capital Expenditure
CCGHT	Catalytic Cracker Gasoline Hydrotreating
CCR	Conradson Carbon Residue
CH4	Methane
CHO	Cracked Heavy Oil
CLO	Cracked Light Oil from Eureka or Clarified Oil from FCC
CMS	Contract Master Schedule
CO	Carbon Monoxide
CO_2	Carbon Dioxide
COS	Carbonyl Sulfide
CPA	Coalition Provisional Authority of Iraq
CaCO3	Limestone

CaSO4 2H2O	Gypsum
DAO	Deasphalted Oil
DCO	Decanted Oil from FCC
DCS	Distributed Control System
DSCR	Debt Service Coverage Ratio
EHS	Environment, Health And Safety
EIA	Environment Impact Assessment
EIRR	Economic Internal Rate of Return
EMP	Environment Monitoring Plan
EP	End point
EPA	US Environment Protection Agency
EPC	Engineering, Procurement and Construction
EPIC	Environmental Protection and Improvement Council of Iraq
ESD	Emergency Shut-Down
F.O.	Fuel Oil
FCC	Fluid Catalytic Cracking
FCF	Free Cash Flow
FEED	Front End Engineering and Design
FGD	Flue Gas Desulfurization
FIRR	Financial Internal Rate of Return
GA	General Arrangement Drawing
GHG	Green House Gas
GTCC	Gas Turbine Combined Cycle
GTG	Gas Turbine Generator
H/C ratio	The ratio of Hydrogen to Carbon
H_2	Hydrogen/ Hydrogen molecule
H_2S	Hydrogen Sulfide
HAZID	Hazard Identification
HAZOP	Hazard and Operability
HC	Hydrocarbon
HC	Hydrocracking
HCCG	Heavy Catalytic Cracking Gasoline
HCO	Heavy Cycle Oil
HDS	Hydro De-Sulfur Unit/ Hydrodesulfurization
HDU	Hydro De-Sulfur Unit
HHPS	High High Pressure Steam
HP	High Pressure
HPS	High Pressure Steam
HPU	Hydrogen Production Unit

HRSG	Heat Recovery Steam Generator
HSE	Health, Safety and Environment
HSE-MS	HSE management system
HT	Hydrotreater/ Hydrotreating
IA	Impractical Application
IBP	Initial Boiling Point
ID	Iraqi Dinar
IFC	International Finance Corporation
IIF	Incident and Injury Free
IMF	International Monetary Fund
IMP	Incident Management Plan
IPIECA	International Petroleum Industries Environment Conservation Association
IRR	Internal Rate of Return
ISA	Industry Standard Architecture
ISO	International Standard Organization
IT	Information Technology
JBIC	Japan Bank For International Cooperation
JICA	Japan International Cooperation Agency
JMCTI	Japan Machinery Center for Trade and Investment
JOE	Japan Oil Engineering Co. Ltd.
K.O. drum	Knock-out drum
LCCG	Light Catalytic Cracking Gasoline
LCO	Light Cycle Oil
LLI	Long Lead Item
LOSPE	Loss Prevention
LP	Low Pressure
LPG	Liquid Petroleum Gas
LPGHG	Unsaturated LPG Hydrogenation
LPS	Low Pressure Steam
LV%	Liquid Volume percentage
Ltr	Litter
M^3/hr	Cubic meters per hour
MARPOL	International Convention for the Prevention of Pollution from Ships
MC	Mechanical Completion
MHF	Material Handling Facility
MMscfd	Million Standard Cubic Feet
MOE	Ministry Of Electricity
MOEn	Ministry Of Environment
MOH	Ministry Of Health

MOO	Ministry of Oil
MPA	Medium Pumparound
MPS	Medium Pressure Steam
MRC	Midland Refineries Company
Mid-Dist	Middle Distillate
N_2	Nitrogen/ Nitrogen molecule
NACE	National Association Of Corrosion Engineers
NEC	National Electrical Code
NFPA	National Fire Protection Association
NGOs	Non-Governmental Organizations
NOC	North Oil Company
NO_X	Nitrogen Oxide(S)
NRC	North Refineries Company
Ni	Nickel
Nm3	Normal cubic meters
O_2	Oxygen/ Oxygen molecule
ODA	Official Development Assistance
OGP	International Association Of Oil & Gas Producers
OJT	On the Job Training
OPEC	Organization of Petroleum Exporting Countries
OPEX	Operating Expenditure
OSHA	US Occupational Safety And Health Administration
P&ID	Piping and Instrument Diagram
PCI	Plant Cost Index
PCS	Pitch Combustion System
PFD	Process Flow Diagram
PM	Particle Matter
PM	Project Manager
PMC	Project Management Consultancy
PMC	Pre-Mechanical Completion
PO	Project Office
PPE	Persona Protective Equipment
PR	Proven technology
PSV	Pressure Safety Valve
QA/QC	Quality Assurance and Quality Control
R&D	Research and Development
RCR	Reduced Crude (Atmospheric Residue)
RFCC	Residue Fluid Catalytic Cracking
ROE	Rate of Return on Equity

ROI	Rate of Return on Investment
RON	Research Octane Number
ROPME	Regional Organization for the Protection on the Marine Environment
ROW	Right Of Way
S	Sulfur
SDA	Solvent Deasphalting
SDR	Salahuddin Refinery
SDR I &II	Salahaddin I & II refineries
SDU	Solvent De-Asphalt Unit
SHU	Selective Hydrogenation Unit
SIL	Safety Integrity Level
SOC	South Refineries Company
SO_X	Sulfuric Oxide(s)
SR	Straight Run
SRC	South Refineries Company
SRU	Sulfur Recovery Unit
SSPC	Society For Protective Coatings
STG	Steam Turbine Generator
SWS	Sour Water Stripper
Scfd	Standard cubic feet per day
Sub-Con	Sub Contractor
Syngas	Synthesis Gas
TIC	Total Investment Cost
TPA	Top Pumparound
TSF	Temporary Site Facility
Tcf	Trillion cubic feet
Tons/D	Tons per Day
UD	Technology Under Development
UN	United Nation
US$	United State Dollar
V	Vanadium
VDU	Vacuum Distillation Unit
VGO	Vacuum Gas Oil
VM	Volatile Matter
VOCs	Volatile Organic Compounds
VR	Vacuum Residue
VRT	Vacuum Residue Treater
WB	World Bank
WBS	Work Breakdown Structure

WHB	Waste Heat Boiler
WHO	World Health Organization
WMP	Waste Management Plan
Wt%	Weight percentage
dB(A)/dBA	Decibel (Scale A)
kV	Kilo-Volt
m^3/d	Cubic meter par day
m3/hr	Cubic meters per hour
mmUSD	Million U.S. Dollar
mmscfd	Million standard cubic feet per day
p.a.	per annual
ppm	Part per million

Chapter 1 Introduction

1.1 Background of the Project

The Ministry of Oil (MOO) of Republic of Iraq has a plan to substantially phase up the production capacity of crude from approximately 2 million Barrel per Day (BPD) to 6 million BPD within the next 10 years, and for achieving the target, MOO estimate over US$20 billion of additional investment in the renovation and upgrading of the infrastructures of oil production, transportation, export and other related facilities.

With respect to the refinery sector in Iraq, there are 14 existing refineries managed by the 3 national refining companies that are operable currently. The design capacities of each refinery are shown in the bellow table.

Table 1.1-1 Refining Capacity in Iraq

(Unit: BPSD)

Refinery	Design Capacity
North Refineries Company (NRC)	
- Baiji North	170,000
- Baiji Salahuddin 1 & 2	140,000
- Kirkuk	30,000
- Senitah	30,000
- Haditha	16,000
- Kisik	10,000
- Quarayah	14,000
Midland Refineries Company (MRC)	
- Dourah	110,000
- Samawa	10,000
- Najaf	20,000
- Dewania	10,000
South Refineries Company (SRC)	
- Basrah	180,000
- Nassiriya	30,000
- Maysan	10,000
Toal	780,000

Source: NRC and MOO, as of 2007

However, due to the repeated previous conflicts in the region and aging of the facilities, the production capacity of each refinery have seriously declined and the operation rate of the plants have lowered to 50-75% in average in spite of dedicated recovery efforts.

In such circumstances of the refineries, and the favorable recovery of the domestic economy after the conflicts, the gaps of demand and supply of oil products for public use have become significant in the country. MOO estimates the gaps of supplies and demands of Gasoline and Kerosene/ Diesel in 2009 to be approximately -39,900BPD (6,350m3/day) and -40,900BPD (6,505m3/day) respectively and foresees further increased gaps in the future.

The government spends US$2.4 billion for importation of oil products from foreign countries for filling up the gaps, and spends another US$7.1 billion to US$7.6 billion as subsidies for the consumer price annually. (Source: National Development Strategy 2007-2010)

Table 1.1-2 Supply-Demand Forecast of Major Oil products

(Unit: BPD)

Products	Year	2009	2010	2011	2012	2013	2014	2015
Gasoline	Supply	73,300	78,000	101,000	126,800	133,100	138,400	156,600
	Demand	113,200	128,900	144,700	157,200	166,700	166,700	176,100
	Balance	-39,900	-50,900	-43,700	-30,400	-33,600	-28,300	-19,500
Kerosene & Diesel	Supply	141,500	222,600	269,700	287,400	284,300	306,100	306,100
	Demand	182,400	228,000	273,600	308,200	308,200	308,200	310,100
	Balance	-40,900	-5,400	-3,900	-20,800	-23,900	-2,100	-4,000
Fuel Oil	Supply	182,100	255,100	321,100	345,400	349,200	369,600	336,900
	Demand	75,500	160,400	225,200	311,300	315,700	315,700	315,700
	Balance	106,600	94,700	95,900	34,100	33,500	53,900	21,200

(Unit: m^3/d)

Products	Year	2009	2010	2011	2012	2013	2014	2015
Gasoline	Supply	11,650	12,400	16,060	20,167	21,167	22,000	24,900
	Demand	18,000	20,500	23,000	25,000	26,500	26,500	28,000
	Balance	-6,350	-8,100	-6,940	-4,833	-5,333	-4,500	-3,100
Kerosene & Diesel	Supply	22,495	35,395	42,875	45,704	45,204	48,662	48,662
	Demand	29,000	36,250	43,500	49,010	49,010	49,010	49,300
	Balance	-6,505	-855	-625	-3,306	-3,806	-348	-638
Fuel Oil	Supply	28,960	40,560	51,060	54,920	55,520	58,770	53,570
	Demand	12,000	25,500	35,800	49,500	50,200	50,200	50,200
	Balance	16,960	15,060	15,260	5,420	5,320	8,570	3,370

Source: NRC (August 09, 2009)

According to the above situation, immediate increase of production capacity of the refineries is required to improve the current and future supply/demand balance of the oil products in the country. MOO established an improvement plan for future supply-demand balance of major oil products by 2015. (Refer to Table 1.1-2 Supply-Demand Forecast of Major Oil Products.)
In order to achieve the target, MOO has planned more than 10 various projects for improving the oil product balances through;

(1) Upgrading of refinery process for higher yield of light products (gasoline, kerosene, diesel)
(2) Rehabilitation of the existing refinery facilities, and
(3) Construction of new refinery plant.

MOO prioritizes the upgrading projects of the largest refineries in the country i.e. Basrah Refinery in southern region, Baiji Refinery in northern region and Daura Refinery in central region. Baiji Refinery has the largest capacity among these refineries and the upgrading by introduction of new FCC Complex is expected to contribute largely for the improvement of oil product supplies in the region.

In addition to such upgrading projects of the existing refineries, MOO also plans/proposes to build new refineries according to the development strategy for increasing the refining capacity in the next decade as follows.

Table 1.1-3 Planned New Refineries in Iraq

(Unit: BPSD)

Refinery	Capacity
Nassiriyah	300,000
Karbala	140,000
Kirkuk	150,000
Maysa	150,000

Source: NRC, June 2009

1.2 Objectives of the Study

1.2.1 Project Description

The Ministry of Oil (MOO) will initiate a project for the upgrading of Baiji Refinery, a grass-root refinery built in 1978, located in the district of Baiji/ Salahuddin province in the northern region of the country by installation of FCC Complex in order to increase such oil products as gasoline and diesel which could add product value further in the region. The FCC Complex proposed by MOO consists of the main and auxiliary processing units, utilities and related offsite facilities such as intermediate product tanks and others.

The main feed stock (Reduced crude: RCR) to the proposed FCC Complex is to be supplied from the existing refinery. The FCC Complex aims to produce high quality products such as approximately 28,300BPSD of FCC gasoline with RON 90-91 and less than 10ppm of sulfur content, diesel oil, fuel oil mix, LPG and other by-products.

1.2.2 Terms of Reference of the Study

In order to develop the practicable facilities and project plan, verify the project validity and assess the feasibility properly, the Study includes the following specific items based on practical study procedure for the Project in accordance with practical JICA standard procedure.

1. Confirmation of Necessity and Validity of the Project
2. Conceptual Design of FCC Complex
3. Development of Project Execution Plan
4. Project Cost Estimation (CAPEX and OPEX)
5. Discussion of the project phase and scheme
6. Evaluation of Project Feasibility
7. Environmental and Social Consideration
8. Conclusion and Recommendations

1.2.3 Extent of the Study

The FCC Complex will consist of the main and auxiliary processing units, utility and related offsite facilities to be constructed within the battery limit of the Baiji Refinery. The Project requires interface alignment between the existing facilities and the FCC Complex on the following interactive aspects: coordination of feedstock supply system, products transfer system, control/ data communication system, etc. and modification/ addition of existing related facilities including products storage tanks, blending system, loading facility, etc.
In addition, for sustainable and sound operation of the FCC Complex, it is essential to ensure sufficient and stable supplies of main utilities such as electrical power, industrial water and fuels from the certain internal/ external resources.

Further, off-takers of not only the main products, but also by-products i.e. sulfur, heavy fuel mix, coke, etc. shall be guaranteed to ensure the commercial operation of the FCC Complex.

In the above context, the extent of the Study primarily covers the entire facilities including the FCC Complex and all other related facilities, utility system/ infrastructure and other aspects for operations as follows.

- New FCC Complex
- Interface between the FCC Complex and existing refineries (Feedstock supply system, product transfer system, control/ data communication system, etc.)
- Existing related facilities (Modification/ addition of products storage tanks, blending system, metering and loading system)
- Internal and external utility system (power, industrial water, fuels, etc.)
- Storage and loading facilities
- Marketing of the products and by-products
- Infrastructures related to the project and operations

1.3 General Study Basis/ Conditions

1.3.1 Process and Facilities Design

The study basis provides basic information and data necessary to develop the intended conceptual design of the FCC Complex and the project execution plan as well as other studies which should be defined clearly in the initial phase of the activities. The study basis should indicate the applicable study/ design conditions for the FCC Complex.

(1) Extent of FCC Complex

The FCC Complex shall consist of the following facilities to be constructed within the battery limit of the Baiji Refinery.

- Main and auxiliary processing units
- Utility facilities (electric power, industrial water, fuel supplies, etc.)
- Related offsite facilities (storage, loading system, etc.)
- Interface between the FCC Complex and the existing refinery

(2) Specification of FCC Complex

The FCC Complex shall have the capacity to produce the following high quality petroleum products at least:

- 28,300BPSD of FCC gasoline with RON 90-91, less than 10ppm of sulfur content
- 5,400BPSD of diesel oil, less than 50ppm of sulfur content
- Others: fuel oil mix, LPG, naphtha, etc.

(3) Feed stock

The main feed stocks for the FCC Complex to be supplied from the existing Baiji Refinery are to be as follows.

- Reduced Crude (RCR) : 36,500BPSD
- Vacuum Residue (VR) : 30,420BPSD
- Vacuum Gas Oil (VGO) : 3,380BPSD
- Lube Surplus : 5,650BPSD

(4) Process configuration

The most optimum configuration of main processing units composing the FCC Complex shall be selected among the following optional cases.

Case 1 VDU + HDS + FCC + SDA + Gasification
Case 2 VDU+ HDS + FCC + Eureka + Gasification
➢ VDU+ HDS + FCC + Coker + Gasification (for reference)

(5) Operation and control method

The operation of the FCC Complex shall be integrated with the existing Baiji Refinery. The related offsite facilities i.e. storage tanks, blending system, loading system, etc. shall be utilized commonly upon necessary modification.
Process and operation of the FCC Complex shall be secured by the independent computerized control system with necessary data communication with the existing Baiji Refinery.

(6) Location

The FCC Complex shall be located ay the location designated within the boundary of the Baiji Refinery, in Salahuddin province, Republic Iraq.

(7) Applicable laws, regulations, standards, etc.

The FCC Complex and other related facilities shall be designed, constructed and operated properly in accordance with the following.

- Relevant laws, regulations, standards in Iraq
- Technical standards practically applied to the oil sector (i.e. API, SAME, ANSI, ASTM, NEC, ISA, NFPA, SSPC, NACE, etc.)
- International guidelines and practices for refinery

1.3.2 Project Execution Plan

The project execution phases are to be categorized into FEED phase, engineering, procurement and construction (EPC) phase and operation/maintenance (O&M) phase subsequently to this feasibility study (FS).
The project execution plans for each phase of the project are to be developed in consideration of the following items.

- Organization of the project owner (NRC) for project promotion
- Recommended international FEED/EPC contractors
- Recommended international/ local subcontractors
- Any other constraints and/or essential requirements for project execution

An overall project schedule is to be developed considering the following external factors.

- International market movement
- Local conditions for construction (site conditions, infrastructure, security situation, etc.)
- Interactions with other related projects

1.3.3 Project Cost Estimation

The project cost estimation in this phase is to be made in serious consideration to the following subjects.

- Market price movement of plant materials and equipment in Japan and the world
- Local procurement potentiality and price movement in Iraq

Accuracy of the cost estimation is to be followed using the applicable guidance of international Recommended Practice provided by The Association for Advancement of Cost Estimation (AACE).

1.3.4 Financing Study

Following two (2) financing schemes are to be studied.

- Japanese Yen credit loan (JICA ODA loan)
- Own finance by Owner (MOO/NRC)

1.3.5 Project Execution Scheme

For successful completion of the Project, suitable project execution scheme is to be discussed in accordance with the following information provided by the Iraqi Study Team.

- Technical capability of the project owner (MOO/NRC) i.e. organization/ resources, experiences of similar project, technical background, etc.
- Financial capability i.e. financing plan for the project amount, budgeting, responsible body and the source of fund for the related infrastructure, procurement, etc.

1.3.5 Project Feasibility

The feasibility of the project is to be verified in the following manners.

- Calculation of Internal Rate of Return (IRR)
  The financial evaluation is to be made on ODA basis and own-investment basis using the domestic and international prices for both scenarios.
  Calculation criteria for IRR are to be discussed in detail in Chapter 7.
- Evaluation of qualitative project effects i.e.
  - Increase of direct/ indirect employment opportunities of local community

- Activation of the related industries and economy in the region
- Improvement of supply and demand balances of oil products in Iraq
- Technical development of refinery sector in Iraq
- Improvement of air quality in the region by increasing high quality oil projects

1.3.5 Environmental and Social Considerations

Environmental and social considerations including personnel health and safety of the project are to be discussed properly in accordance with the following requirements.

- Relevant laws, regulations, standards of the Iraq
- International convention, treaties, agreements ratified by the government
- JICA/JBIC environmental guideline
- World Bank group/ International Finance Corporation (IFC) standards and guidelines

1.4 Method and Procedure of the Study

1.4.1 Organization for Implementation

1.4.1.1 General Implementation Scheme

The general scheme for implementation of the study is shown below.

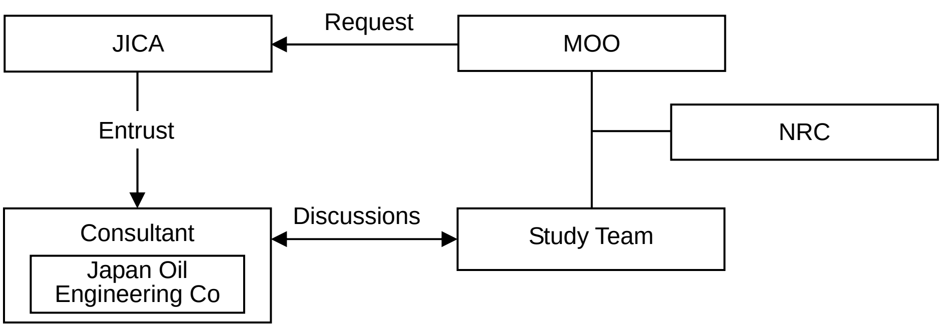


Figure 1.4.1-1 General study scheme

Based on the request of MOO, the originator of the Project, for Japanese ODA loan for the project implementation, JICA, the governmental ODA agency and the executer of the Study, entrusted Japan Oil Engineering Co. Ltd. (JOE) as the Consultant to conduct the Study.
JOE organized a consultant team for execution of the Study, collaborated with the competent

engineers of Chiyoda Corporation, a world-wide leading engineering company.
MOO organized a study team composed of project members of MOO and North Refinery Company (NRC), the project owner.
The information and data necessary for developing the study were provided by Iraqi study team.
The Study has been developed by the Consultant properly through discussion, interaction and collaboration with Iraqi study team.

1.4.1.2 Organization of the Iraqi Study Team

The Iraqi study team was composed of engineers and experts of related boards of NRC, i.e. processing, engineering power and utility, technical, inspection and follow-up, financial and administration. The team was headed by the director general and/or the director general deputy of NRC with assistance of the expert of MOO.

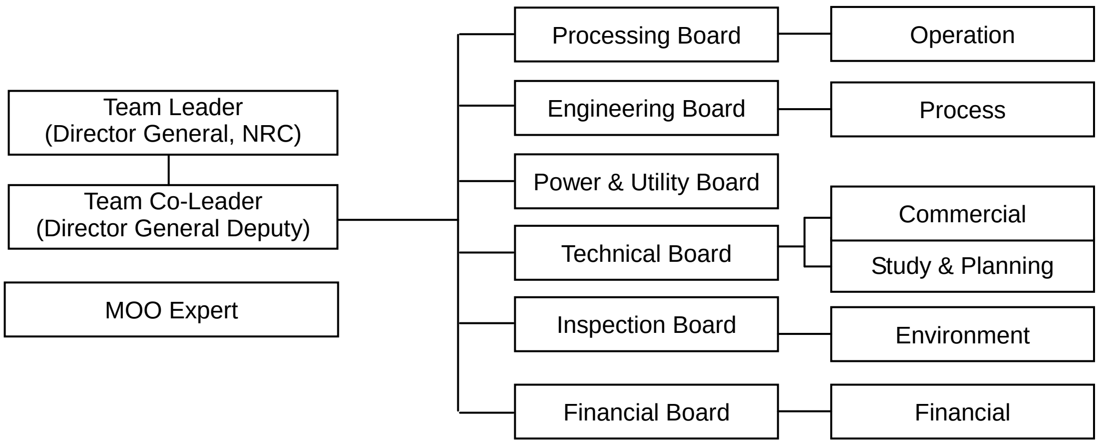


Figure 1.4.1-2 Iraqi study team

1.4.1.3 Organization of the Consultant

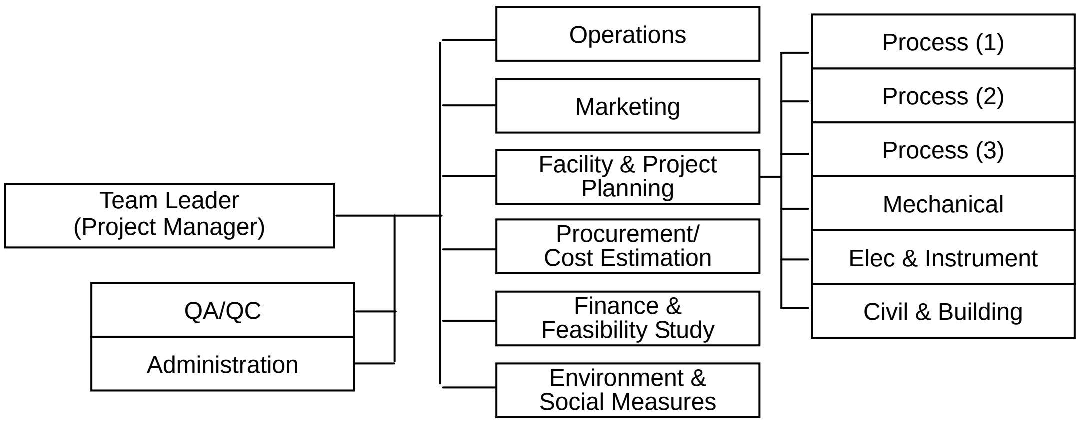


Figure 1.4.1-3 Organization of the Consultant

The consultant team was composed of the engineers and specialists of JOE and Chiyoda Corporation. The consultant team includes the disciplines of operation, marketing, process and facility design, procurement and cost estimation, finance and feasibility, and environment according to the terms of reference of the study.

1.4.2 Study Procedure

To achieve the objective, the study consists of eight (8) terms of reference described in the clause 1.2.2. The study was conducted dedicatedly by the study groups of each discipline of the Consultant team in accordance with the procedure shown in Figure 1.4.2.

1.4.3 Schedule

The general work schedule of the study conducted is presented in the bar chart in Figure 1.4.3.

1.4.4 Information and Data

All information and data required for developing the study basis were provided by Iraqi study team to the Consultant prior to commencement of the study and the 1st study meeting held in the earliest stage. For the insufficient or unclear information given by the Iraqi study team, the suitable assumptions were defined through discussion between both parties.

1.4.5 Study Activities and Work Places

The respective study group of the Consultant carried out all the engineering study at their main offices in Japan. The study meetings for discussions between the both parties were held and/or scheduled as follows.

- 1st study meeting April 06-09, 2009 at Amman, Jordan
- 2nd study meeting July 21-29, 2009 at Tokyo, Japan
- 3rd study meeting December, 2009 at Amman, Jordan

Figure 1.4.2 Study procedure

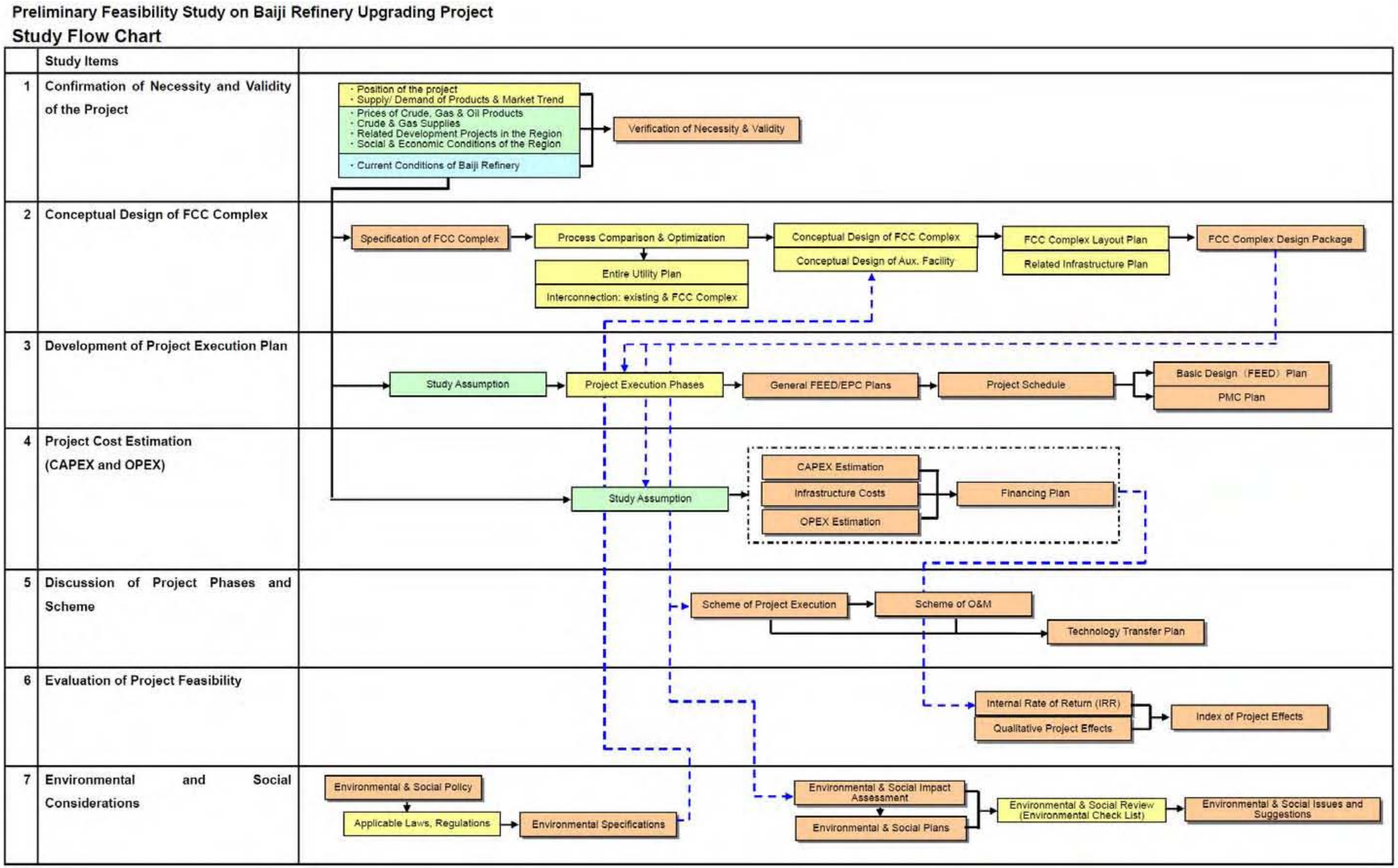


Figure 1.4.3 Study Work Schedule

	Description	2009										2010	
		Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb
1	**Preparatory Work**												
2	**Study**												
2.1	Confirmation of Necessity and Validity of the Project												
2.2	Conceptual design of FCC Complex												
2.3	Development of Project Execution Plan												
2.4	Project Cost Estimation (CAPEX and OPEX)												
2.5	Discussion of the Project Phase and Scheme												
2.6	Evaluation of Project Feasibility												
2.7	Environmental and Social Consideration												
3	**Study Meetings**												
3.1	1st Study Meeting												
3.2	2nd Study Meeting												
3.3	3rd Study Meeting												
4	**Deliverables**												
4.1	Inception Report												
4.2	Interim Report												
4.3	Draft Final Report												
4.4	Final Report												

Chapter 2 Confirmation of Necessity and Validity of the Project

2.1 Situation of the Project

The proposed upgrading project for Baiji Refinery is situated on one of the major development projects of the refinery sector in Iraq, and is aiming to be a successful achievement of the new national development strategy through possible effects associated with implementation of the project.

(1) Improvement of supply-demand balance of the oil products

As mentioned in the previous clause 1.1, Ministry of Oil (MOO) in Iraq has established an improvement plan for the supply-demand balance of the major oil products i.e. gasoline, kerosene and diesel for public use by 2015.
For achieving such target successfully, MOO gave priority to the upgrading projects of the existing major refineries in the country through introduction of modern process providing high yield of light products over the alternative solutions including construction of new refinery plants.

According to the above strategy, MOO has already launched an upgrading project in Basrah Refinery (design capacity: 180,000 BPSD) in the southern region of the country through introduction of Fluid Catalytic Cracking (FCC) process. Subsequently to Basrah Refinery, MOO will initiate the upgrading project of Baiji Refinery (design capacity: 310,000 BPSD in total) in the northern region through introduction of the similar process as second tangible plan.
The Basrah Refinery upgrading project will have an FCC unit with 30,000 BPSD of capacity and Baiji Refinery upgrading project plans to install a larger FCC unit with 51,500 BPSD of capacity. After completion of both projects, the expected increased supplies of gasoline, which is the major oil product, from each refinery will be the figures as follows.

Table 2.1 Contribution of Upgrading Projects (as of 2015)

(Unit: BPD)

Products	Basrah Refinery	**Baiji Refinery**	Total	Supply Increase Plan*
Gasoline	18,500	**28,300**	46,800	83,300

* Production/Supply to be increased from 2009 by 2015

Both upgrading projects will share of 57% in the gasoline supplies to be increased within the targeted period and Baiji Refinery will contribute approximately 34% for the targeted supply increase of gasoline in the country.

Accordingly, the proposed upgrading projects will contribute in achieving the improvement of the supply-demand balance of the major oil products in the southern and northern regions of Iraq. The Baiji Refinery Upgrading Project is highly expected being at the certain position as one of the most important projects for recovery and further development of the refinery sector in Iraq.

(2) Modernization of Refineries in Iraq

The FCC Complex to be newly introduced by the projects comprises of FCC unit and other associated process units. These production facilities and equipment will be designed, constructed and operated by employing the latest technologies and philosophy in the world, which the refineries in Iraq have not experienced before.

The upgrading projects, as a model case for modernization, also aim to promote the new technologies already recognized worldwide in refineries in Iraq including technical and career developments of the engineering and operational personnel of the refinery sector in Iraq.

(3) Environmental Effects

The proposed FCC Complex of both projects will supply the high quality oil products such as low sulfur gasoline (less than 10 ppm) and diesel (less than 50 ppm) that complied with the international standards, and which have not been available in Iraq so far. Broad distribution of these high quality oil products in the country will contribute for the mitigation of environmental pollutions arising from public consumption of the fuels in the regions.

(4) Social and Economic Effects

The increased domestic production of oil products by the earliest completion of the upgrading project will contribute to deduct the large current national expenditures on the importation of gasoline and diesel from foreign countries for filling up the supply-demand gaps and governmental subsidies for the consumer prices of such products.

In addition, the upgrading project of Baiji Refinery will provide certain employment opportunities in the region directly and indirectly.

In the construction phase, the project will require large numbers of construction personnel including technically qualified and non-qualified personnel. These work forces will be hired from the project region through contractors/subcontractors and/or local vendors. In operation phase after completion of the construction, the refinery will need to organize operational and maintenance personnel for the new facilities installed additionally in the refinery.

It is largely expected that the project will activate the regional economy through employment of local people directly and indirectly as well as procurement of the construction and operational services and materials from the local markets.
Accordingly, the activated local economy will bring prosperity and improvement of the life and livelihood of the people of the region generally.

2.2 Supply and Demand of Oil Products

With progress of the reconstruction projects and recovery of the domestic economy, demand of automobile fuel such as gasoline, diesel oil, and oil products for consumer use such as kerosene and LPG have rapidly been increasing. This tendency will continue in the future. Meanwhile, capability of refineries declined due to the repeated previous conflicts, destruction in the war, aging of the facilities, delay of rehabilitation/modernization in the following sanction, and lack of maintenance. Under the circumstances, the gaps of demands and supplies of oil products for public use have become significant in the country.

MOO estimates the gaps of demands and supplies of gasoline and Kerosene/ Diesel in 2009 to be approximately -39,900BPD (6,350m3/day) and -40,900BPD (6,505m3/day) respectively and foresees further increased gaps in the future. For improvement of the situation, Government of Iraq formed National Development Strategy aiming reinforcement of the economy foundation including development of oil sector (development of oil field, production increase and modernization of the refineries). The government spends US$2.4 billion for importation of oil products from foreign countries for filling up the gaps, and spends another US$7.1 billion to US$7.6 billion as subsidies for the consumer price annually. (Source: National Development Strategy 2007-2010)

This project is to construct FCC Complex in Baiji Refinery, the largest refinery in Iraq, located in the northern region consisting of Fluid Catalytic Cracking (FCC), related processing units and utilities. The purpose of FCC Complex is to increase oil products as gasoline and diesel oil which could add value to the products.

2.2.1 Demand (market) trends of oil products: gasoline, kerosene, diesel, fuel oil

MOO established an improvement plan for future supply-demand balance of major oil products by 2015. Based on the information/data provided by MOO, supply-demand forecast of major oil products, such as gasoline, kerosene & diesel, and fuel oil, in Iraq are summarized in the Table 2.2.1-1 and Figures 2.2.1-1 to 2.2.1-3 as follows.

Table 2.2.1-1 Supply-Demand Forecast of Major Oil Products

(Unit: BPD)

Products	Year	2009	2010	2011	2012	2013	2014	2015
Gasoline	Supply	73,300	78,000	101,000	126,800	133,100	138,400	156,600
	Demand	113,200	128,900	144,700	157,200	166,700	166,700	176,100
Kerosene, Diesel	Supply	141,500	222,600	269,700	287,400	284,300	306,100	306,100
	Demand	182,400	228,000	273,600	308,200	308,200	308,200	310,100
Fuel Oil	Supply	182,100	255,100	321,100	345,400	349,200	369,600	336,900
	Demand	75,500	160,400	225,200	311,300	315,700	315,700	315,700

(Unit: m3/d)

Products	Year	2009	2010	2011	2012	2013	2014	2015
Gasoline	Supply	11,650	12,400	16,060	20,167	21,167	22,000	24,900
	Demand	18,000	20,500	23,000	25,000	26,500	26,500	28,000
Kerosene, Diesel	Supply	22,495	35,395	42,875	45,704	45,204	48,662	48,662
	Demand	29,000	36,250	43,500	49,010	49,010	49,010	49,300
Fuel Oil	Supply	28,960	40,560	51,060	54,920	55,520	58,770	53,570
	Demand	12,000	25,500	35,800	49,500	50,200	50,200	50,200

Source: NRC (August 09, 2009)

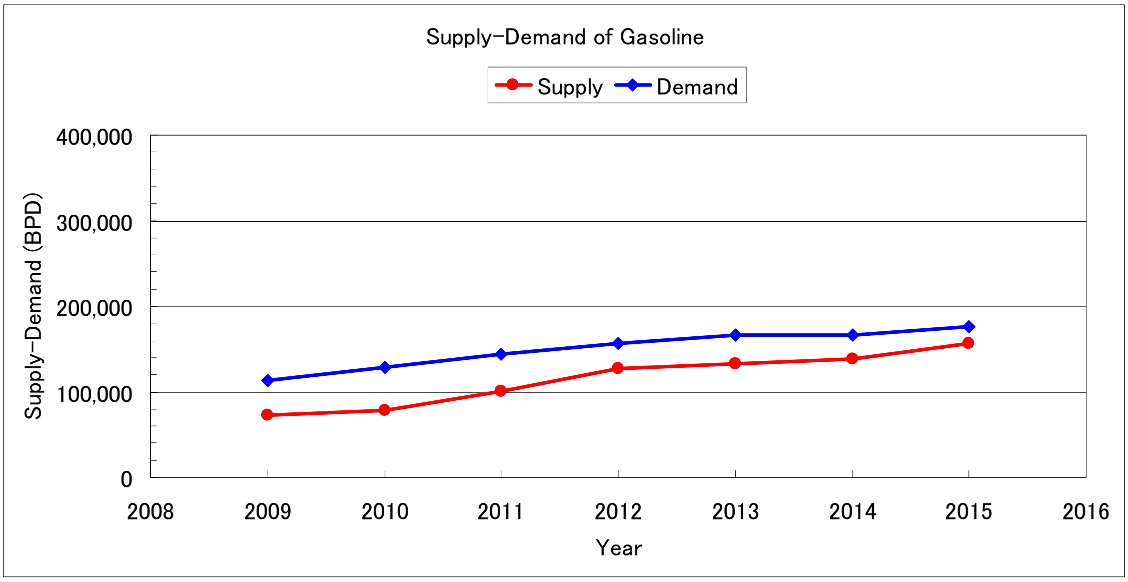


Figure 2.2.1-1 Supply-Demand of Gasoline

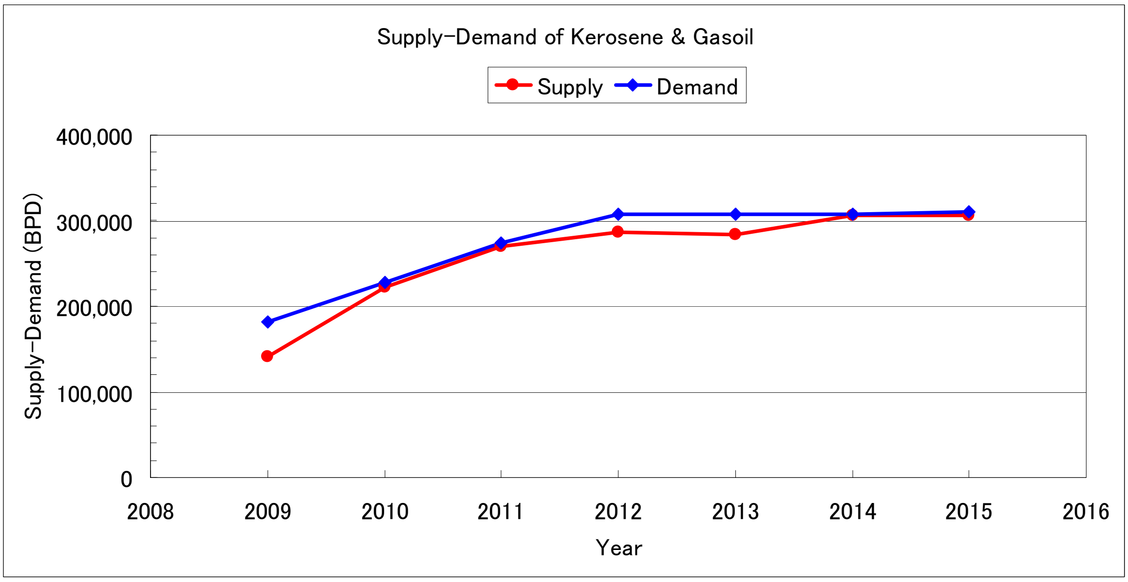


Figure 2.2.1-2 Supply-Demand of Kerosene & Diesel

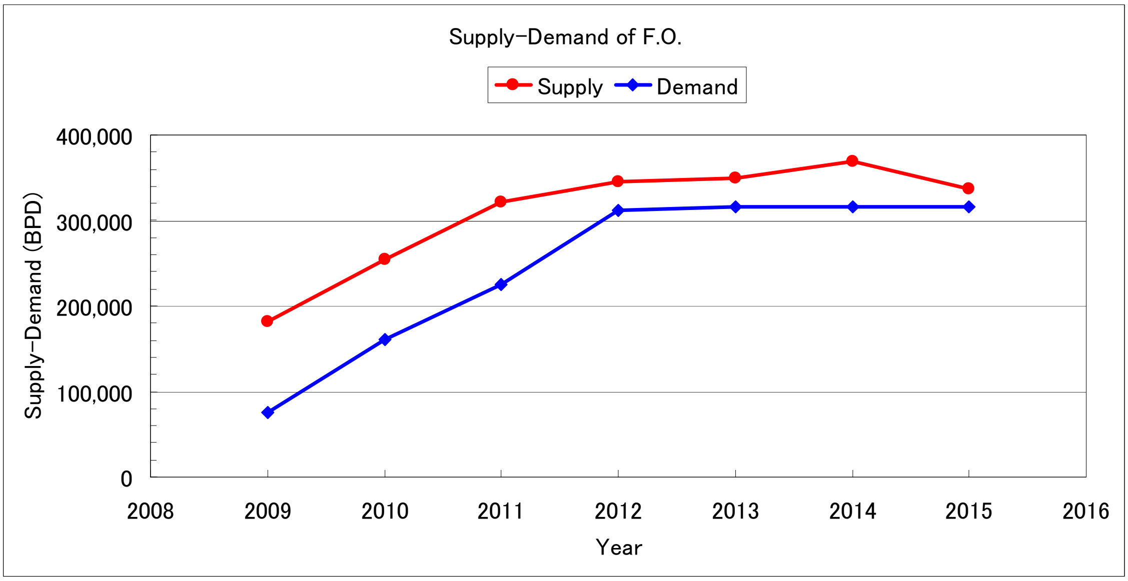


Figure 2.2.1-3 Supply-Demand of fuel oil

The large increase of fuel oil demand is mainly due to the increase of power plant capacity of Ministry of Electricity (MOE). MOE has a plan to increase diesel power plant capacity up to 999MW and thermal power plant capacity up to 15,270MW by 2015.

2.2.2 Supply-demand balance of oil products (including future exportation)

Based on the information/data provided by MOO, supply-demand balance of major oil products in Iraq are summarized in the Table 2.2.2-1 and Figure 2.2.2-1 as follows.

Table 2.2.2-1 Supply-Demand Balance of Major Oil Products

(Unit: BPD)

Products	Year	2009	2010	2011	2012	2013	2014	2015
Gasoline	Balance	-39,900	-50,900	-43,700	-30,400	-33,600	-28,300	-19,500
Kerosene, Diesel	Balance	-40,900	-5,400	-3,900	-20,800	-23,900	-2,100	-4,000
Fuel Oil	Balance	+106,600	+94,700	+95,900	+34,100	+33,500	+53,900	+21,200

(Unit: m^3/d)

Products	Year	2009	2010	2011	2012	2013	2014	2015
Gasoline	Balance	-6,350	-8,100	-6,940	-4,833	-5,333	-4,500	-3,100
Kerosene, Diesel	Balance	-6,505	-855	-625	-3,306	-3,806	-348	-638
Fuel Oil	Balance	+16,960	+15,060	+15,260	+5,420	+5,320	+8,570	+3,370

Source: NRC (August 09, 2009)

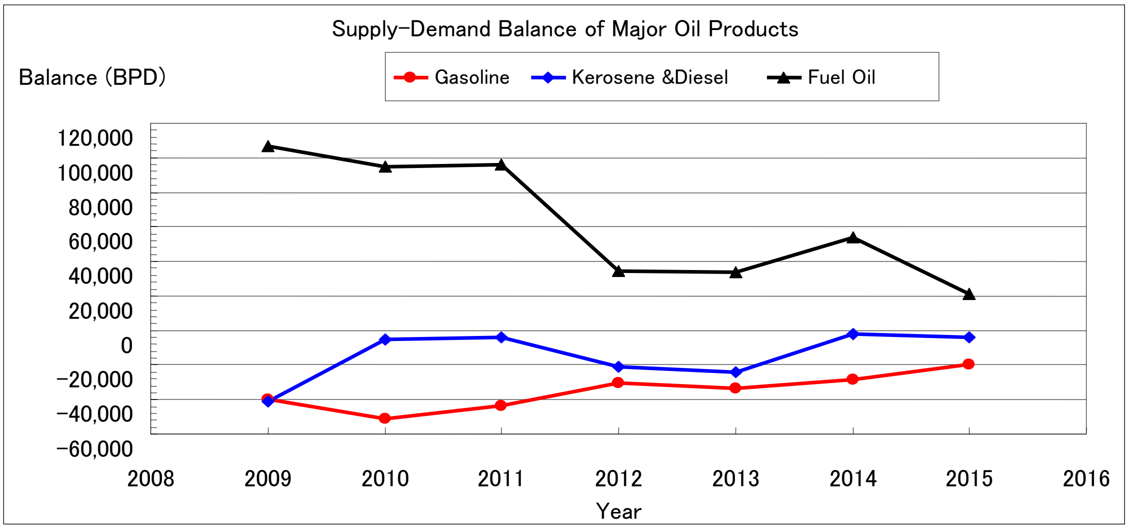


Figure 2.2.2-1 Supply-Demand Balance of Major Oil Products

The shortage of gasoline and kerosene in the country will be mostly solved by the year 2014, though still 20 kBPD gasoline is under the demand, mainly due to implementation of more than 10 various projects (refer to Section 2.2.4) for improving the oil product balances through;

(1) Upgrading of refinery process for higher yield of light products (gasoline, kerosene, diesel)
(2) Rehabilitation of the existing refinery facilities, and
(3) Construction of new refinery plant.

The surplus of the products can be exported to the outside of the country to acquire foreign currency. The production of fuel oil can be controlled by the new refineries and newly installed/proposed FCC Complex to get more gasoline and kerosene.

2.2.3 By-Products

a. Current by-products

Current by-products of Baiji refinery are LPG, asphalt and sulfur. By construction of the proposed FCC Complex, coke will be newly produced as by-products and production of sulfur will increase.

b. Supply-demand

Construction of sulfuric acid plant of 20 ton/day capacity has been planned and tendered in Iraq. This new plant would be one of the potential customers of sulfur.
On the one hand, coke can be used as fuel of boiler. In case to construct a private power plant in FCC complex, coke could be one of the options of fuel. Furthermore, coke can be gasified by the introduction of new gasification process and the generated gas can be used as fuel for multi-purposes.

2.2.4 Development plans of MOO: upgrading, rehabilitation, new refineries

As is well known, MOO's development plan of oil/gas field by introducing foreign investors is ongoing. The followings are MOO's other plans for production increase of crude oil, oil products and natural gas.

- Drilling of new production wells to cover the reduction of production in the existing oil/gas fields.
- Increasing investment in associated gas project to increase production of gas to use it in power generation, and reduce the burning/flaring of gas to reach production up to 3500 MMscfd at the end of 2014.
- Increasing the refining capacities up to design capacities of 1.5 million BPD and improving the quality of products to protect the environment and safety by enlarging and developing the existing big refineries, also building new refineries with recent technologies.
- Increasing storage capacities for crude oil, 1 million BBL for North and 3.5 million BBL for South to cover five days production.

2.3 Prices of Crude, Gas and Oil Products: Pricing System of Iraq

2.3.1 Prices of Crude and Gas supplied from NOC

Purchase price of the crude oil from North Oil Company is as follows, which are decided by MOO.

- Crude oil $1.610 / BBL (Distribution Co. price).

2.3.2 Wholesale prices of oil products: decided by MOO

Prices of oil products coming out from Baiji Refinery are as follows.

- Gasoline $0.042 / Ltr.
- Kerosene $0.021 / Ltr.
- Diesel $0.021 / Ltr.
- Fuel oil $0.042 / Ltr.
- LPG $0.059 / Ltr.

Costs in transporting products from refinery to market are as follows.

- Cost of Transportation for Gasoline / Diesel / Kerosene / LPG
  ID 55 (for each m^3/km)
- Cost of Transportation for Crude Oil
  ID 100 (for each 1000 m^3/km)

Wholesale prices of the oil products/by-products from Baiji Refinery are as follows.
(Local Governmental Products Price sold to people in the station.)

- Gasoline ID 400 / Ltr.
- Kerosene ID 150 / Ltr.
- Diesel ID 400 / Ltr.
- Fuel oil ID 250 / Ltr.
- LPG ID 334 / Ltr.

2.3.3 Domestic retail prices of oil products

Domestic retail prices of the oil products/by-products in local market are controlled by the subsidies of MOO as follows.

- Gasoline ID 700 / Ltr.
- Diesel ID 650 / Ltr.

2.4 Crude and Gas Supplies

2.4.1 Crude and Gas Production of Iraq (including development plans)

Current and future plan of the crude and gas production of Iraq are shown in the Table 2.4.1-1.

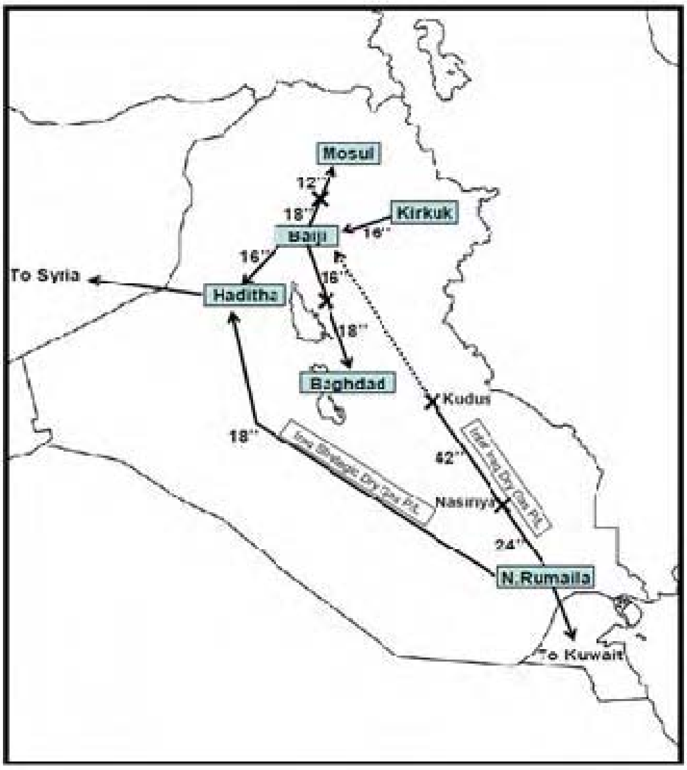
Table 2.4.1-1 Crude and Gas Production of Iraq

	2009	2010	2011	2012	2013	2014	2015
Crude (1000 BPD)	2,600	2,700	2,900	3,300	3,800	4,400	6,000
Gas (MMscfd)	1,400	1,450	1,800	2,300	2,900	3,600	7,000

Source: NRC (April 21, 2009)

2.4.2 Crude and Gas Supply System (pipeline network, current conditions, availability)

NOC has been supplying crude oil and associated gas of Kirkuk oil field to Baiji Refinery via pipelines. The main gas and oil pipelines in Iraq are shown in Figure 2.4.2-1 and Figure 2.4.2-2, respectively. (Source: MOO)



Remarks, X: Changing points of pipe diameter.
Dotted Line: Under construction

Figure 2.4.2-1 Map of Dry Gas Pipeline

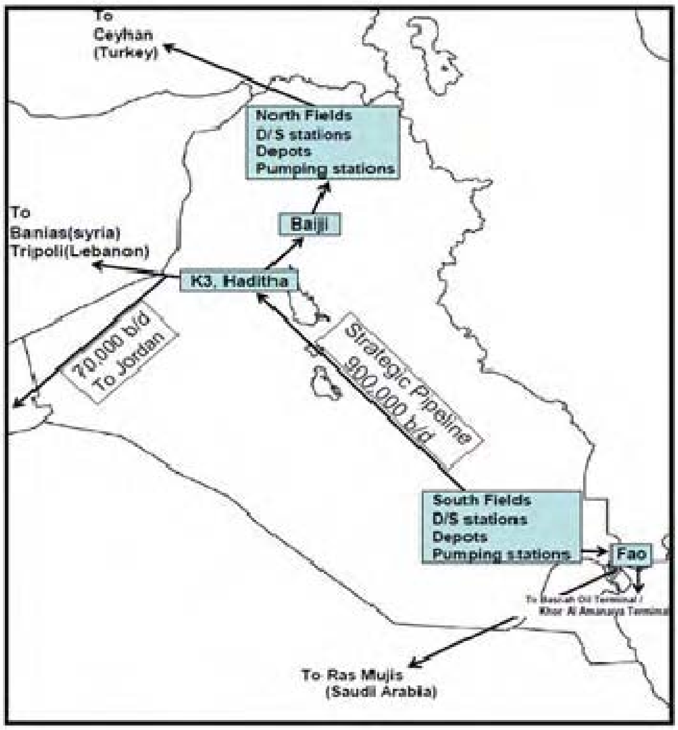


Figure 2.4.2-2 Map of Oil Pipeline

2.4.3 Capability of steady crude and gas supplies to Baiji refinery

The production/supply record of crude oil/gas of NOC is shown in the Table 2.4.3-1.

Table 2.4.3-1 Production/Supply Record of Crude Oil/Gas of NOC

	Jun. 2008	Aug. 2008	Sep. 2008	Oct. 2008	Nov. 2008	Dec. 2008	Jan. 2009	Mar. 2009
Oil Production (1000 BPD)	606	586	586	581	606	598	638	667
Oil Supply to Refineries (1000 BPD)	257	263	211	251	274	236	231	215
Associated Gas Prod. (MMscfd)	240	260	285	267	252	339	361	439

(Source: MOO)

As shown in the Table 2.4.3-1, NOC supplied sufficient crude oil/gas to refineries. The proven reserve of Kirkuk oil field is about 1 billion barrel which is equivalent to about 15 years consumption of Baiji Refinery. Also Kirkuk is one of the 1st bidding round projects for development and is planned to be developed by introduction of foreign investors. NOC is expected to continue to supply sufficient crude oil/gas to Baiji Refinery in the future.

2.5 Related Development Projects

2.5.1 Upgrading projects: Basrah, Baiji, Doura, etc.

The ongoing/planned two (2) upgrading projects in NRC other than Baiji refinery based on the master plan for reconstruction and development of refinery sector in Iraq are shown below.

- Basrah Refinery FCCU project
- Doura Refinery (upgrading)

2.5.2 Rehabilitation of domestic refineries

The ongoing/planned rehabilitation projects in NRC other than Baiji refinery are shown bellow.

- Isomerization in Baiji (Mechanical Completion in end of 2009)
- Blowing Asphalt in Qaiyarah (10,000 BPSD)

- Packaged units in Qaiyarah (10,000BPSD X 2)
- Packaged unit in Kasik (10,000 BPSD)

2.5.3 New refinery Projects

Table 2.5.3-1 shows the planned new refinery projects based on the master plan for reconstruction and development of refinery sector in Iraq.

Table 2.5.3-1 Ongoing/planned new refinery projects in Iraq

(Unit: BPSD)

Refinery	Capacity
Nassiriyah	300,000
Karbala	140,000
Kirkuk	150,000
Maysa	150,000

Source: NRC, June 2009

2.5.4 Power Supply

Based on the master plan of MOE as of 2008, additional power generation capacity increase of 3,855 MW by 6 new projects is planned in North region.

2.5.5 Others: chemical, cement, etc

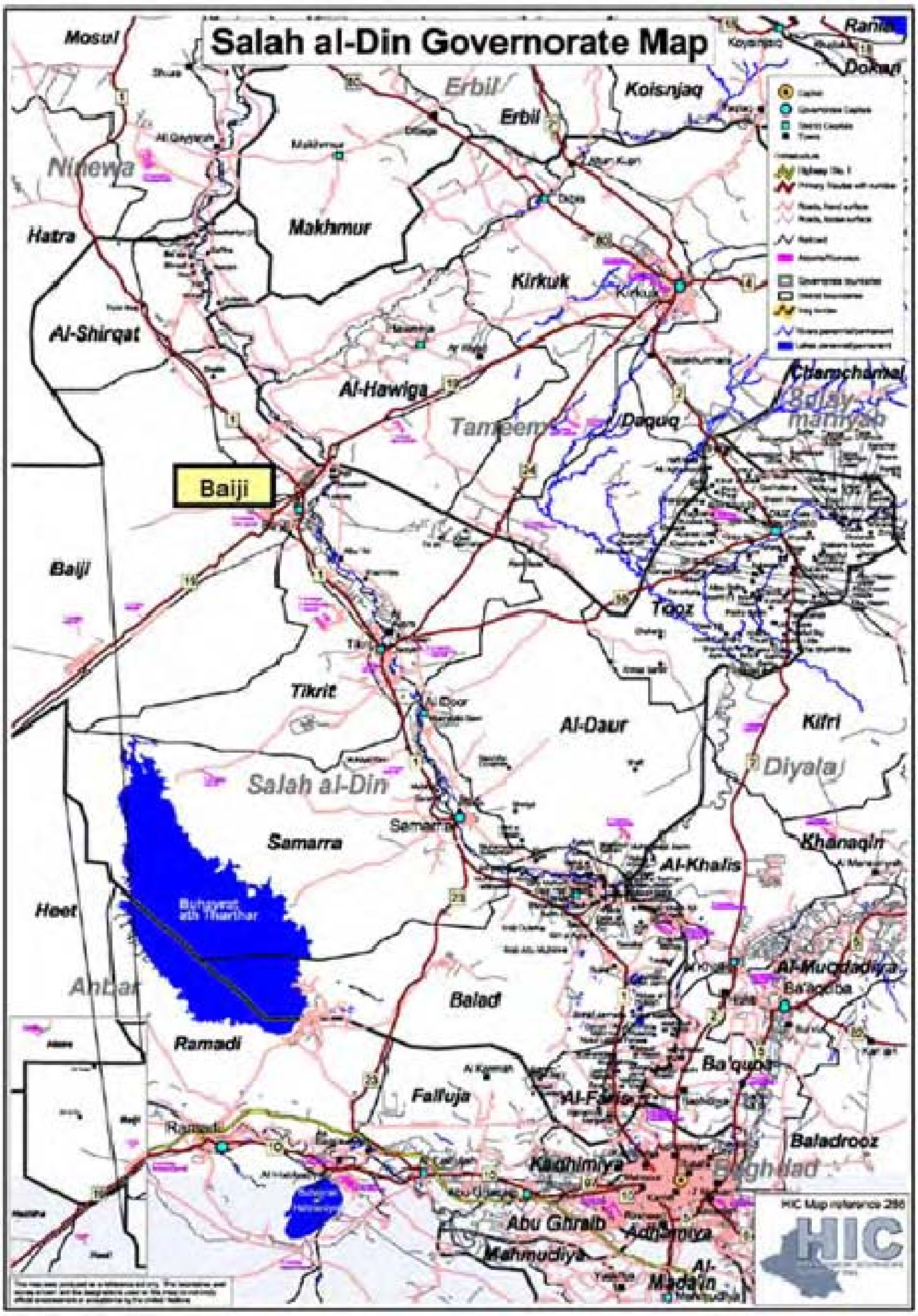
The Ministry of Industry and Minerals has a plan to develop the chemical and cement industry by mobilization of private resources. Several rehabilitation/new construction projects including the rehabilitation of Baiji Fertilizer plant are under development in the Northern Region.

2.6 Social and Economic Conditions of the Region

2.6.1 Salahuddin Province

Baiji Refinery is located in Baiji City, the 3rd largest city of Salahuddin province, central north of Iraq. Salahuddin province is abundant in agricultural resources, and has about 1.1 million populations and about 616 thousand labor forces. The area of the province is about 29,000

square kilometers and surrounded by other Iraqi provinces. The capital city is Tikrit.
The national roads and railways are running through the province. Tigris River is also running through the center of the province.



Source: United Nations Assistance Mission for Iraq

Figure 2.6.1-1 Map of Salahuddin Province

2.6.2 Baiji city

Baiji is located in the northwest of Salahuddin province, and is located near the junction of two of Iraq's main national rail lines as well as two primary road routes. Its population is about 200 thousand.

2.6.3 Industries

The main industry of the province is agriculture (livestock) and oil refining. 44% of the workforce in the province is employed in the agricultural sector, which is the highest percentage among all 18 provinces. In the province, a huge number of grape vines, apple trees, and citrus trees are under cultivation.
In addition to Baiji refinery, Baiji has large power plant and urea fertilizer plant. Further concentration of petrochemical industry is expected around Baiji city using these infrastructures and the existing plants.

Also tourism has a potential in the province since there are many ancient monuments with transportation convenience like Samarra. Samarra is one of Iraq's major historic places. Its ruins extend for hundred of square kilometers along the Tigris River. The province contains several important Muslim shrines and mosques.

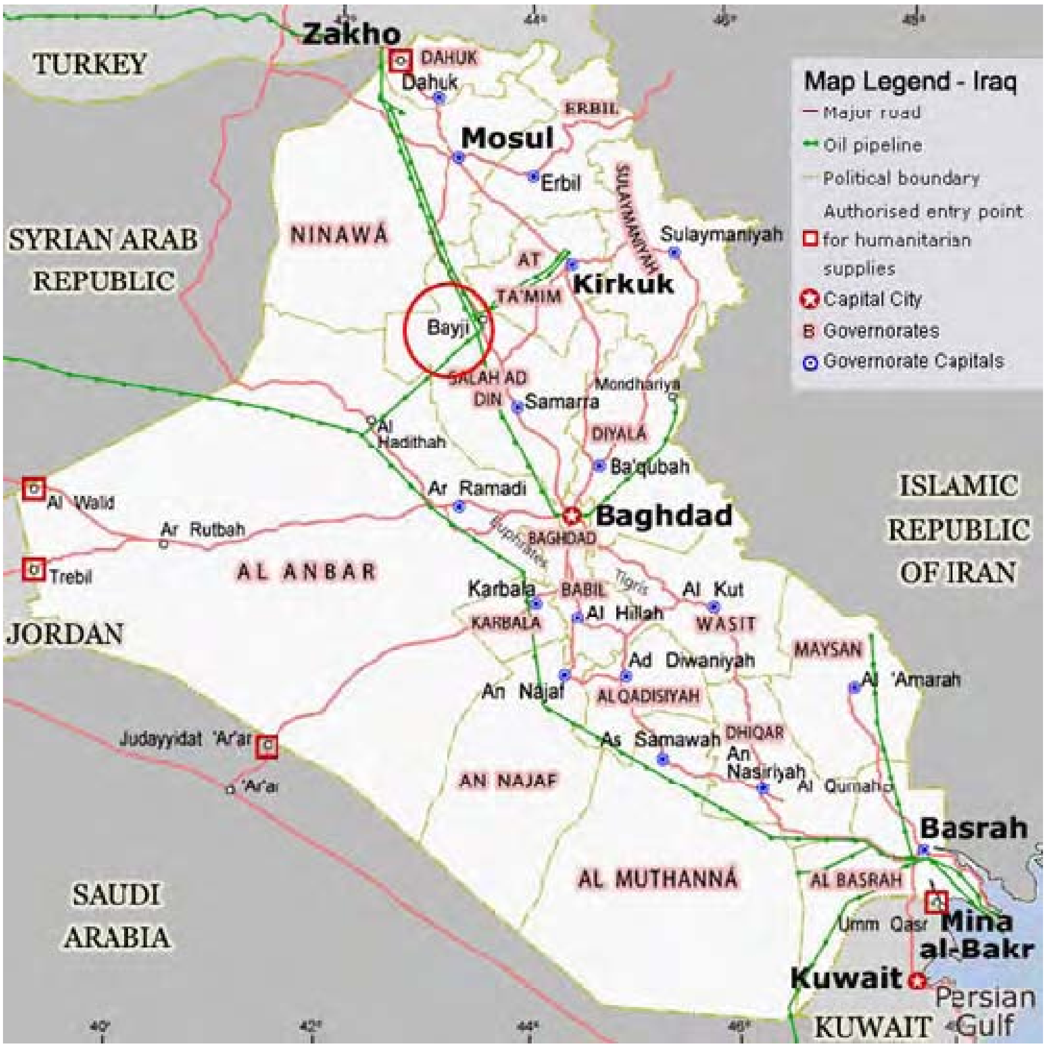
2.6.4 Infrastructures: roads, railways, water supply, etc.

According to MOO information, conditions of the infrastructure of Baiji Refinery are described as follows.

(1) Roads and railways

Networks of the main roads and railways of Iraq are shown in Figures 2.6.4-1 and 2.6.4-2.
One of the main roads leading to north from Baghdad heads to Samarra and Tikrit, and also passing Baiji on the way to Mosul. From Tikrit, a primary road heads northeast to Kirkuk. A main road also crosses the province at Baiji, running northeast to Kirkuk and southwest to Haditha in Al Anbar province and on the Al-Qaim border crossing with Syria. Major north-south rail line in Iraq passes through the province with service from Baghdad to Mosul via Tikrit.

Baiji is located on the main road from Bagdad to Mosul. It is good for transportation of the oil products and materials/equipment for construction of FCC complex. Also Baiji is the junction of the national railway.



Source: the United Nations Office of the Iraq Program

Figure 2.6.4-1 Road Map in Iraq

Source: Wikipedia

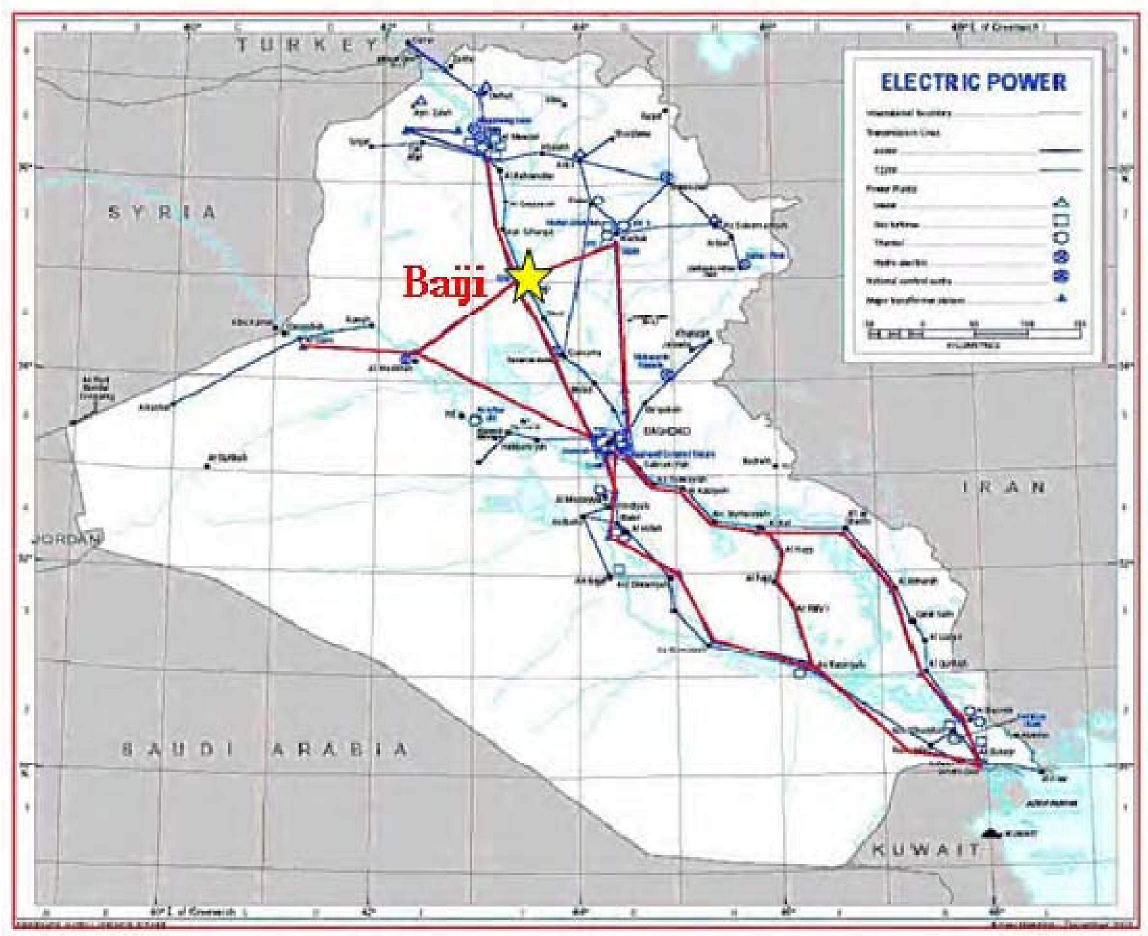
Figure 2.6.4-2 Iraqi Railway Network

(2) Industrial Water Supply

Industrial water supply is not available around Baiji Refinery. The required water for Baiji Refinery is taken from the Tigris River and waste water is discharged in the lower course of the river. Construction of new facilities for water intake which enable water intake required for the whole Baiji Refinery including the proposed FCC Complex is anticipated.

(3) Electricity

The capacity of electricity supplied by MOE to Baiji Refinery is 85 MW. MOE can increase it up to 110 MW. The power system network of Iraq is shown in Figure 2.6.4-3.



Source: MOO

Figure 2.6.4-3 Power System Network of Iraq

The backbone power system of Iraq consists of 400 kV, 132 kV transmission line network, and the 400 kV transmission line is forming a loop power system. As this 400 kV transmission line forming the loop, compared to that of radially-arranged, the supply reliability is higher at the failure of the power system.

2.7 Current Condition of Baiji Refinery

Existing refineries and operations

There are 14 existing refineries in Iraq. There are three (3) national oil refinery companies that were established in 1997 managing those refineries; the North Refineries Company (NRC), Midland Refineries Companies (MRC) and South Refineries Company (SRC).

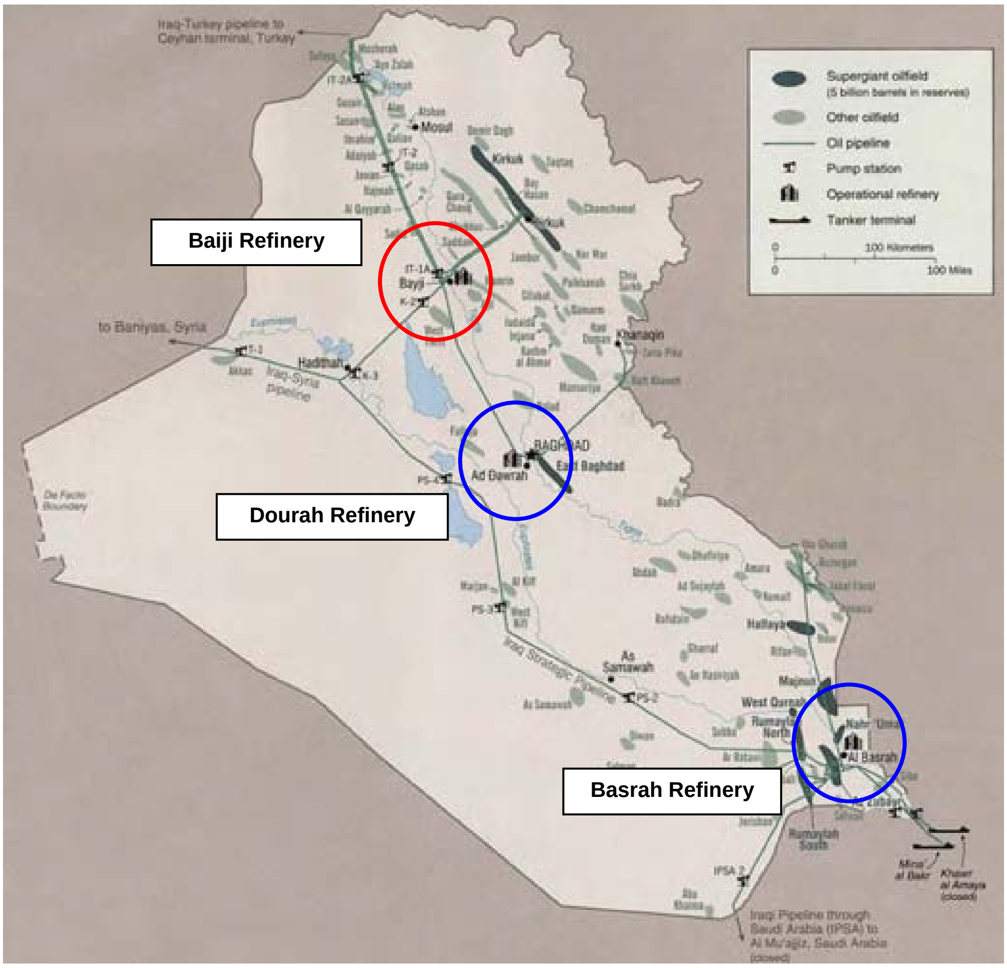


Figure 2.7-1 Refineries in Iraq

Baiji Refinery, constructed as a grass-roots refinery in 1978, is located in Baiji city, Salahuddin province, in the northern district of the country. The refinery consists of Baiji North and Baiji Salahuddin 1 & 2Refinery plants (SDR I&II), with a total combined design capacity of 310,000 BPD which are the largest refineries in Iraq.

Table 2.7 -1 Refineries in Iraq

Refinery	Design Capacity (BPSD)
North Refineries Company (NRC)	
- **Baiji Refinery**	
- Baiji North	**170,000**
- **- Baiji SDR I& II**	**70,000 each**
- Kirkuk	30,000
- Senitah	30,000
- Haditha	16,000
- Kisik	10,000
- Quarayah	14,000
Midland Refineries Company (MRC)	
- Dourah	110,000
- Samawa	10,000
- Najaf	20,000
- Dewania	10,000
South Refineries Company (SRC)	
- Basrah	180,000
- Nassiriya	30,000
- Maysan	10,000
Total	**780,000**

Source : Google

Figure 2.7-2 Baiji Refinery-General View

The refinery plants in the existing Baiji Refinery consist of the following main processing units.

Table 2.7-2 Processing Units in Baiji Refinery

Processing Unit	Design Capacity (BSPD)
Baiji North	150,000
Crude Distillation Unit	150,000
Naphtha HDS Unit	41,000
Platforming Unit	22,000
Kerosene HDS Unit	28,000
LGO HDS unit	31,000
Vacuum Distillation Unit	65,000
Hydrocracking Unit	38,000
Baiji Salahuddin 1	
Crude Distillation Unit	70,000
Light Distillate HDS Unit	29,000
Gas Oil HDS Unit	12,000
Catalytic Reforming Unit	8,000
LPG Recovery Unit	540 Tons/D
Baiji Salahuddin 2	
Crude Distillation Unit	70,000
Light Distillate HDS Unit	29,000
Gas Oil HDS Unit	12,000
Catalytic Reforming Unit	16,500

Figure 2.7-3 Baiji Refinery (1)

In addition to the processing units, the Baiji Refinery has auxiliary facilities including storage tanks for the crude and products, loading systems for the products, utility systems such as steam generation, a cooling water system, instrument and plant air systems, power receiving and distribution system, etc.


Figure 2.7-4 Baiji Refinery (2)

Figure 2.7-5 Control Room

The production capacities of the Baiji Refinery for the main oil products are shown as below. The current operation rate of the refinery plants fluctuates between 65-80% due to an unstable power supply and frequent unplanned partial shutdown of the facilities.

Table 2.7-3 Capacity of Main Oil Products

Products	Capacity (BSPD)
Gasoline	60,700
Kerosene	49,000
Gas Oil (Diesel)	58,600
Fuel Oil	124,100
LPG	540 Tons/D

The products are delivered to the domestic market by tanker trucks and railway.

Figure 2.7-6 Tanker Loading System

Crude, the feed stock of the Baiji Refinery, is supplied from the Kirkuk oil fields through the existing pipeline network in the region and the 132kV and 400kV power supply for operation is currently taken from the regional grid. The existing power supply capacity to the refinery is 110MW/h and the current power consumption of the refinery is 85MW/h.

The refinery, being reliant upon an external source of electricity, is however susceptible to the occurrence of possible breakdowns in the aging power generation plants and transmission system, which occasionally causes power outages and, consequently, interruption to the stable operation of the facilities.

The water required for operation of the facilities is taken from the sub-stream of Tigris River which is routed to the east side of the refinery site. The water intake system supplies the water to the cooling water system, boiler feed water system, fire water system, etc. of the refinery.

Figure 2.7-7 Baiji Power Station

Whilst the existing refineries will supply residue feedstocks to the new proximate FCC complex, the current conditions are as described above and, therefore, the following operating premises of the existing refineries are assumed for the study.

North refinery:	Crude oil of 170,000 BPSD is charged to North refinery, and Hydrocracker operates at 65% turn down. The hydrogen manufacturing plant is not in operation due to technical reasons. It is assumed in this study that new FCC complex will supply hydrogen to the hydrocracker in a quantity equivalent to the nominal capacity of the existing hydrogen plant.
SDR I & II refinery:	140,000 BPSD of crude oil is charged to SDR I & II refineries.
Lube Plant:	RCR (atmospheric residue) of 16,000 BPSD is charged to produce lube stocks.

Infrastructure relating to the new project

It has been assumed, as a premise of the study, that the existing fresh water supply system will be re-established. The first reason is that, as the current intake point from the Tigris River is located at a downstream of and near to a cooling water outfall from a power station, the intake water temperature is relatively high and not appropriate for use in refineries, which have a problem in utilizing high temperature fresh water. The second reason is that the existing river water intake facilities and transfer pipeline to the refineries are in a very poor physical condition. In conclusion, a new intake facilities and pipeline have been incorporated into the study to fulfill the demand of the existing facilities and new FCC complex.

Transportation of Oil Products

The main means of transportation of major oil products from the Baiji Refinery are Tanker Car and Railway. Current transportation volume is shown in Table 2.7.3-1.

Table 2.7.3-1 Current Transportation Volume

	Tanker Car	Railway
Gasoline	2911M^3/day	1000M^3/day
Kerosene	2159M^3/day	1000M^3/day
Gas Oil	6135M^3/day	1000M^3/day
Fuel Oil	12307M^3/day	2000M^3/day

Source: NRC (April 21, 2009)

400-500 ton/day of LPG is shipped by pipeline and 600ton/day of asphalt is shipped by truck. No sulfur is currently being shipped.

2.8 Verification of Necessity and Validity of the Project

Demand of consumer oil products such as gasoline and diesel is expected to continue to increase in the future in Iraq. Improvement and development of refineries is one of the issues urgently to be solved. The proposed project matches the current situation of oil products in Iraq.

From the several view points of availability of feedstock/fuel, conditions of infrastructure, and contribution to the region through economic and social aspects, it could be concluded that the proposed Baiji FCC Complex project is considered to be valid and reasonable with the following major merits.

- Improvement of supply-demand balance of the oil products i.e. gasoline and diesel for the public use in the region
- Reduction of national expenditures for importing the oil products from foreign countries due to gaps of supply-demand in Iraq
- Social and economic effects by the creation of new job opportunities and businesses in the region
- Improvement of technology in the refinery sector in Iraq through the introduction of modern and up to date technology into the project
- Environmental effects through supply of high quality (low sulfur content) vehicle fuels

Thus, this project is fully expected to contribute effectively for the achievement of the national development strategy for refinery sector in Iraq.

Chapter 3 Conceptual Design of FCC Complex

3.1 Specification of FCC Complex

3.1.1 Feedstock properties and flow rates

FCC Complex receives five (5) kinds of feedstock from the existing North Refinery, Salahaddin I & II (SDR I&II) and the Lube plant, which are identified in Table 3.1-1.

Note: The flow rate and property of RCR were confirmed by NRC and the Consultant during the second meeting held at Tokyo, Japan from 21-30 July, 2009.

RCR flow rate and property were calculated from the flow rates and properties of VGO and VR, as presented in Figure 3.1-1, 3.1-2 and 3.1-3, which had previously been provided by NRC. Although RCR streams come from North Refinery and SDR I&II, it was assumed that all RCR streams would have the same properties.

As a result, the flow rates and properties of VR and VGO streams, after processing RCR in the new VDU of FCC Complex, are defined in Table 3.1-2.

3.1.2 Product quality specifications

The complex will have the following key specifications for the products.

LPG	Saturated C3/C4 mixed LPG	
FCC gasoline	Sulfur content:	Less than 10 ppm
	RON[1] :	90 to 91
Diesel	Sulfur content:	Less than 50 ppm
Residual fuel oil	Sulfur content:	High sulfur fuel oil production is not suitable from an environmental point of view. Please refer Section 3.2.2.3 for more detail.

3.2 Conceptual Design of FCC Complex (Comparison and Optimization)

3.2.1 Overview of FCC application

FCC process is applied to increase motor gasoline production with a better octane quality. The

[1] RON: Research Octane Number

most fundamental FCC is applied by cracking Vacuum Gas Oil (VGO) as shown in Figure 3.2-1. This application can be justified in a specific market where there is a demand for the residual fuel oil within the country. However in the majority of developed markets, residual fuel oil has been superseded in the electric power sector by gas power generation and, thus, Vacuum Residue (VR) fraction is required for a further cracking process to produce valuable products. VR produced in Baiji Refinery contains so much heavy metal and high CCR as to charge it directly to FCC unit and, therefore, the configuration should incorporate residue conversion as describe below.

3.2.2 Basic understanding on residue conversion scheme

3.2.2.1 Necessity of residue conversion

Residue conversion is one of key considerations for upgrading oil refineries to accommodate following market changes, which will be predicted in the near future of Iraq;

1) Natural gas prevails in the power generation market due to its higher efficiency of power generation and reduced environmental impact. As a result, the use of residual fuel oil declines, which consequently means lower demand and price reduction.
2) The demand for motor gasoline and middle distillates increases.
3) The high price level of crude oil, predicted to remain at high level in the future, has the effect of widening the price spread between light and heavy products. This justifies residue conversion economically.

3.2.2.2 Advantages and recent issues on carbon rejection type technology

Past studies and investigations have indicated that carbon rejection type technology is the most practical and economical among the various residue conversion technologies available today. Referring to Figure 3.2-1, discussion may be concentrated on the VR processing scheme.

As for the residue hydroprocessing scheme, VR property in Baiji Refinery is too heavy for the Residue HT/HC + RFCC scheme, as demonstrated in Figure 3.2-2. Thus, this scheme has been considered to be inappropriate for this project. Therefore, MOO/NRC and the Consultant selected Solvent Deasphalting (SDA), Eureka, and the cokers of Delayed Coker and Flexicoker / Fluidcoker for the carbon rejection scheme as the preliminary screening.

The disposal of the rejected carbon (heavy end products such as petroleum coke, pitch and asphaltene) became a focal issue in developing the project, from the following reasons;

1) The calorie content of heavy ends is too much to be totally balanced inside the upgraded complex and/or refinery and, therefore, a large amount of heavy ends have to be exported outside as excess.
2) Heavy end produced from residue conversion contains a high sulfur content (7 - 8 wt% sulfur), which is difficult to be sold in the market as a commodity. The high content of SOx is emitted when the heavy ends is burned in the power generation sector outside the refinery. It will results in severe environmental pollution.
3) Although not limited to carbon rejection type technology, a large amount of hydrogen is essential for residue conversion. It is, therefore, highly advisable that a source of hydrogen should be developed to maximize petroleum products in quantity and quality and to improve "energy self-sufficiency".

3.2.2.3 Gasification drastically improves self-sufficiency

Low value residue can be gasified to provide hydrogen, which improves the self-sufficiency in utilization of material, and this kind of residue conversion complex would consume around half of the syngas to generate hydrogen, as shown below. Around 20-30% of the syngas is used as energy for utilities, whether or not gasification is employed in the complex. However, about 70-80% of the syngas is exported from the complex where gasification is not used, which is reduced to the level of 20-30% when gasification is employed. As presented below, the targeted self-sufficiency of the complex could be drastically improved.

Heavy end used	Gasification	Non-Gasification
for hydrogen production	45-55%	0%
for utility energy source	20-30%	20-30%
for export	20-30%	70-80%
Total	100%	100%

Further, through a gas turbine combined cycle system which would be installed outside the complex, syngas from the gasification is almost as clean and of equivalent or higher efficiency in power generation source as natural gas.

In case that heavy ends will be exported to the end user like power generation sector, Flue gas desulfurization (FGD: SOx scrubbing) is inevitable for environmental protection. Figures on sulfur compounds from this complex are presented below. Large amounts of limestone and gypsum need to be charged and produced, and the logistics of obtaining and transporting such commodities should be considered in this alternative.

Sulfur in SOx emission	= around 225 ton/d	as S
Limestone charged to the scrubbing	= around 700 ton/d	as $CaCO_3$
Gypsum produced from the scrubbing	= around 1,200 ton/d	as $CaSO_4\ 2H_2O$

The FGD would preferably be installed in a centralized single power station to avoid environmental pollution. Distributing the high sulfur heavy end to several power stations is less efficient and more costly.

3.2.2.4 More appropriate heavy end for gasification

The heavy end from residue conversion is routed to the gasification. In general, condensed heavy end with a low ratio of hydrogen to carbon, and low volatility, causes technical difficulties in the gasification reaction. Excessively condensed heavy ends, a fully carbonized material (such as the cases with delayed coke and fluid coke), does not easily react in gasification. It is for this reason that “shot coke” from a delayed coker with the gasification scheme is not technically feasible.

Feedstock to Gasification

Heavy ends	SDA asphalt	Eureka pitch		Delayed coke[1]	
				Sponge	Shot
Phase	Liquid	Liquid[1, 2]	Solid[2]	Solid	Solid
H/C ratio[3]	High---Low				
Volatility	High---Low				
Pulverization	-	-	Easy/Fragile	Hard	Very hard
Volume required for burning[4]	-	120%	120%	200%	>200%

Application of combination with gasification:

1 For Reference
2 Liquid and solid pitches from Eureka have the same H/C ratio and volatility.
3 Hydrogen to Carbon ratio
4 Volume required for supplemental firing and/or gasification. Residual fuel oil requires 100% volume of the boiler, Eureka pitch requires only 120%, but delayed coke needs 200% or more.

Efficiency	High---Low				
Syngas	Large---Small				
Hydrogen	Large---Small				
Status of application	Proven Technology	Under Development	Proven Technology	Under Development	Impractical Application

3.2.3 Case definition for the study

Table 3.2-1 presents definition for the following study cases.

1) RFCC + SDA + Gasification
2) FCC + Eureka (solid pitch) + Gasification
3) FCC + Eureka (Liquid pitch) + Gasification (For reference)
4) FCC + Delayed coker (Sponge coke) + Gasification (For reference)

Note:

(a) The pre-screening of the thermal cracking process was carried out both by the MOO/NRC and the Consultant at the early stage in the Survey. Other thermal cracking processes, such as Flexicoker, were omitted during pre-screening of the feasibility study due to the low calorific value of the syngas produced and there being no possibility of hydrogen production.

(b) Eureka (liquid pitch) case is shown as a reference in this final report of the Survey, since it is currently in the confirmation stage with R&D.

(c) In general, the delayed coker is able to produce a higher yield when the “shot coke” mode is chosen. However, as shown in Section 3.2.2.4, “shot coke” is too hard to pulverize and impractical for use in the gasification application. Thus, a relatively mild condition (“sponge coke” mode) was applied for FCC + Delayed coker + Gasification.

3.2.4 Product yield of residue conversion process

1) C5 plus liquid (from naphtha to VGO) yield

Figure 3.2-3 presents the weight yield of products from SDA, Eureka and delayed coker. One of the most important considerations in residue conversion is how to maximize a weight yield of C5 plus liquid (from naphtha to VGO), because a high yield of those products means that residue is efficiently being converted to distillate liquid products. In this aspect, Eureka case indicates the highest yield and the most efficient technology among the three (3) residue conversion processes considered. While the SDA case indicates a yield of Deasphalted Oil (DAO), it is not a fair comparison since the DAO is not a distillate fraction but a part of VR fraction without asphaltene. DAO requires further severe processing due to it containing large molecules.

2) VGO yield

VGO fraction is largely contained in Eureka compared to the delayed coker. One of Eureka's features, the thermal cracking reaction, is a non-selective reaction and has a low reaction velocity (around one tenth) in VGO cracking compared with VR cracking; VGO cracking should be subjected to secondary selective catalytic cracking to obtain the desired products.

3) Difficulty in burning and gasifying coke

To maximize the liquid product yield, a "shot coke" mode is recommended but it has the disadvantage of having the property of coke. "Shot coke" is too hard to be pulverized into a sufficiently fine particle size for efficient burning. As a result, it requires larger size of fire box for burning and gasifying. "Shot coke" is not feasible with the gasification application. In order to achieve gasification, the delayed coker scheme has to use a "sponge coke" mode, which is not as hard as "shot coke". To operate delayed coker in "sponge coke" mode, the coke yield has to be increased and, consequently, the product liquid yield will be further decreased. A volatile matter (VM) contained in the coke is also a key parameter as well as the coke hardness. Even with "sponge coke" mode, coke is low in the VM and, basically, the delayed coker scheme is unable to increase the VM to a level sufficient for burning and gasifying; a special design consideration would be required in the gasification.

3.2.5 Processing Configuration

Simplified block flow diagram for the study cases are shown in figures hereinafter.

1) Figure 3.2-4: RFCC + SDA + Gasification
2) Figure 3.2-5: FCC + Eureka (solid pitch) + Gasification
3) Figure 3.2-6: FCC + Eureka (Liquid pitch) + Gasification (For reference)
4) Figure 3.2-7: FCC + Delayed coker (Sponge coke) + Gasification (For reference)

Material balances for the study cases are shown in tables hereinafter.

5) Table 3.2-2: Charges and Products around FCC Complex
6) Table 3.2-3: Fuel Energy Balance around FCC Complex
7) Table 3.2-4: Capacity of Process Facility
8) Table 3.2-5: Product Properties

3.2.5.1 Solvent deasphalting (SDA) scheme

The solvent deasphalting process separates VR into DAO and asphaltene by using solvents such as C3, C4 and C5. Figure 3.2-8 shows the estimated properties of DAO depending on the type of solvent used. Since asphaltene molecules contain a high proportion of metals, CCR, sulfur and nitrogen, which deteriorate catalyst performance in the downstream processing, the asphaltene molecule is rejected by the SDA to mitigate the deactivation of the downstream catalysts.

Since the downstream processing of the SDA is made firstly by hydroprocessing, the deactivation of such hydroprocessing catalyst becomes a focal point of discussion. Since vanadium and nickel strongly affect catalyst life and replacement cost, sufficient capacity for metal deposition on the catalyst should be provided in the design. Further, deactivation of the hydroprocessing catalyst by coke, which is caused also by large aromatics molecules and CCR molecules, has to be seriously considered. It is necessary to raise the hydrogen partial pressure to cope with the coke deactivation of the catalyst as well as to increase the catalyst volume. Since the coke deactivation is very delicate and not easy to be correctly quantified, a robust and tough design is strongly recommended for reactor pressure and space velocity.

DAO and VGO blended feedstock is presented in Table 3.2-6. The lift (yield) of DAO in this case is designed at a mild cut with C4 solvent, so as to be able to take a mild hydrotreating. The hydrotreating is estimated to be designed at a pressure of 110 Barg. However, the SDA case can further squeeze the asphaltene yield with larger DAO yield by utilizing C5 solvent. In this severe case, the DAO hydrotreating requires around 180 to 200 Barg pressure. The latter case requires a more robust design for heavier crude processing, and maximizes the liquid yield of product. In conclusion, the economic results for the both mild and severe cases have been confirmed to be at a similar level to each other, although the investment cost is different.

The mild case has been selected as the SDA case for the Survey.

The primary key features on this SDA scheme are;

a) The SDA unit itself is relatively cheap, but provides only separation without cracking.
b) Cracking is made by DAO hydroprocessing and/or catalytic cracking at a high cost.
c) SDA asphaltene is a liquid product, which can be directly charged to gasification.

Note: Direct charge of DAO to FCC

Direct charge means charging DAO without hydroprocessing from the SDA to FCC, the purpose of which is to reduce the cost by eliminating high cost hydroprocessing. Hydroprocessing is carried out to reduce contents of CCR, nitrogen and sulfur in the feedstock to FCC. However, since the CCR, nitrogen and sulfur are distributed in broader sizes of molecules than for metals, they are brought to FCC still having a relatively high content even after SDA processing. CCR strongly affects the heat balance and size of regenerator in FCC, nitrogen causes temporary deactivation of cracking catalyst performance, and sulfur leads to a high content of SOx in the regenerator flue gas. To prevent these situations from occurring, the lift (yield) of DAO is lowered in SDA design. Even so, however, SOx emission has to be removed by installing a flue gas desulfurization scrubber, charged with limestone and producing gypsum on FCC flue gas stream. Taking the above aspects into consideration, the direct charge of DAO to FCC scheme is not recommended.

3.2.5.2 Eureka scheme

Eureka is one of the residue thermal cracking technologies, which are usually evaluated as the most economical process category. Among residue thermal cracking technologies, Eureka has following unique advantages.

1) Mild thermal cracking condition depresses over-cracking
   a) C1 to C4 gas yield is minimized in thermal cracking processes and C5 plus liquid product yield is maximized, as presented in Figure 3.2-3.
   b) Eureka thermal cracking is controlled to minimize over-cracking of cracked materials, thus VGO fraction is large and the product of each fraction contains less condensed heavy material. Such VGO fraction can be selectively converted to valuable products via catalytic cracking and hydrocracking.

2) Small yield of pitch (heavy end) even at moderate thermal cracking
   a) Steam injection and immediate stripping after thermal cracking also squeezes the yield of pitch (heavy end) to a level similar to the coke yielded in the delayed coker “shot coke” mode, but makes the pitch much more homogeneous. As a result, the pitch can be produced and exported in a liquid phase with a stable condition. Pitch is evaluated not as coke, but is more comparable to liquid oil due to its high hydrogen to carbon ratio with high in volatile matter, which facilitates burning in boilers and gasifiers. The simplicity of burning pitch serves to reduce the size of the boiler. Whereas residual fuel oil requires 100% of the volume of the boiler, Eureka pitch requires only 120%, as against delayed coke which needs 200% or more.
   b) Eureka’s shorter cycle length in a batch operation reduces the reactor size to nearly one- tenth (1/10) of that required for the delayed coker, which in turn reduces the cost.

c) Since Eureka pitch more fragile than delayed coke, the solid pitch pulverizer is smaller and much simpler and the pulverized pitch has a smaller particle size than that of petroleum coke.

3) Advanced design in thermal cracking

a) Since batch operation is limited only to the reactor section, the prior and post processes of reactors can be maintained in continuous operation. Therefore, the operation is easily controlled and stable.

b) Eureka unit is environmentally clean because it is a liquid pitch operation which has a closed system.

c) There have been continuous technological advances and improvements which have resulted in the current design being the most up-to-date among the residue thermal cracking technologies.

4) Pitch to gasification

a) The pitch is continuously drawn off in a liquid phase from the reactor system and sent to pitch solidification system (flaker). After the pitch is pulverized into fine particles with a simple attrition type mill, the powdered pitch is transported pneumatically to burners in the gasifiers. The technology of the pulverization and transportation system has been proven in the existing Pitch Combustion System (PCS) in the Fuji Oil refinery. The fine particle size and highly volatility of the pitch provides the existing boiler with a stable firing similar to that of residual fuel oil burning.

b) As an alternative, the liquid pitch can be diluted with FCC bottom oil to meet the viscosity specification on the gasifier burner and charged directly to gasifier. This system was a conceptual design and numerous tests have been carried out in Fuji Oil refinery and at the R&D center of Chiyoda.

c) While the marketing of FCC bottom oil is usually difficult due to its high aromatic nature, liquid pitch gasification consumes FCC bottom oil. Whereas the amount of energy exported in the liquid pitch case is larger than in the solid pitch case, it is due to dilution with DCO..

d) It should be noted that the facility cost for the solid gasification case is relatively more expensive than for liquid gasification. Therefore an economic evaluation has been incorporated in the final conclusion.

Eureka has significant technical and commercial advantages over other thermal cracking technologies, which makes a combination of Eureka process with gasification the most favorable option available from the residue conversion competitors.

The commercial Eureka process has been operating in Fuji Oil Company's plant in Japan for more than 30 years and, during its history, several aspects of its technology have been constantly improved in pursuit of a more economical, energy efficient and stable operation. Now with its fully matured technology, it has been proven to be exceptionally reliable.

3.2.5.3 Delayed coker scheme (For Reference)

Delayed coke is a deeply condensed material obtained through repetitive cracking, including over-cracking of cracked materials. As a result, the carbon to hydrogen ratio and the properties of the VM of coke and pitch differ.

	H/C ratio	VM
	wt/wt	wt%
Eureka pitch	15	40
Sponge coke[1]	18	12 -13
Shot coke[2]	25	9 - 10

[1] To be adjusted for application with gasification

[2] To aim at minimum coke yield

Such hydrogen/carbon ratios with the VM affect the performance of burning and gasification. In other words, the delayed coker condenses heavy end too deeply to enable it to be efficiently gasified, which leads to the conclusion that a combination of delayed coker and gasification is less attractive.

3.3 Utility balance of study cases

Table 3.2-7, 3.2-8, 3.2-9 and 3.2-10 present Utility Balance in FCC Complex.

The concepts of the utility design will be described later in Section 3.6.

3.4 Interconnections between FCC Complex and existing facilities

As the basic philosophy when designing FCC Complex is that self-sufficiency within the complex should be maximized, the following interconnections should be considered in the design with the existing facilities and outside refinery.

Feedstocks:

1) RCR: Atmospheric residue from North refinery and SDR I&II
2) VR: Vacuum residue from vacuum unit of North refinery
3) VGO: Vacuum gas oil from vacuum unit of North refinery
4) C.F.O: Hydrocracker unconverted oil from North refinery
5) Lube surplus: Stock from lube plant

Note: It is anticipated that the feedstocks will be sent from the existing storage facilities.

Products:

1) LPG: Routed to the existing shipping facility
2) Naphtha: Routed to the existing naphtha shipping facility
3) Diesel: Routed to the existing shipping facility
4) FCC gasoline: Routed to the existing motor gasoline blending facility
5) LCO: Routed to the existing diesel hydrotreater via storage
6) DCO: Routed to the existing fuel oil shipping facility
7) Sulfur: Stored in a new silo and shipped as bulk material
8) Export syngas: Routed to the B.L. and connected to a new gas turbine combined cycle power station outside the complex, which will be installed by power generation sector.

Hydrogen:

1) To the existing facility: 70 mmscfd of high purity hydrogen will be routed to the existing facility.

Utility:

1) River water: An intake facility will be installed on the River Tigris and a pipeline routed from there to the complex at 4,000 m3/hr. The flow rate is assumed also to cover consumption of the existing intake facility and the power station.

3.5 Process Description

A description of the process facilities is provided in this section.

A simplified Process Flow Diagram for following unit, and the overall block flow, is shown in Appendix-3.5. A list of major equipment for the SDA case and Eureka case are as attached in Appendix 3.5-1 & 3.5-2.

3.5.1 SDA Process

Solvent deasphalting occurs at subcritical conditions; supercritical conditions are used in solvent recovery. When the solvent's critical point is exceeded, the solubility of the DAO in the solvent greatly diminishes and two phases are formed.

The steps in the process are：

Fresh feedstock is mixed with recycled solvent to reduce viscosity and is then fed to the Asphaltene Separator where additional recycled solvent is counter-currently contacted with the feed at an "elevated temperature", but below the critical temperature of the solvent, and at a pressure above the critical pressure of the solvent. The solvent-to-feed ratio is high (7.4-8:1), which maximizes the deasphalted oil yield and quality. The fraction containing the asphaltene separates from the solution, is withdrawn from the bottom of the contractor and is heated.

- Steam-stripping of the asphaltene stream will recover solvent, which is condensed and recycled, and the asphaltene product (less than 0.05 wt％) leaves the unit for blending or further processing.
- Oil dissolved in the solvent leaves the top of the Asphaltene Separator. The stream is heated to above the solvent's critical point, first by exchange with hot recycled solvent from the Separator and then by a heater. The heater has generally been a hot oil type, which uses about half the fuel consumed in the SDA unit. Recently, direct-fired heaters with flue gas recirculation have been proposed as having a lower capital cost and higher energy efficiency.
- The DAO is separated from the solvent in the Separator, under supercritical conditions, where the solubility of the DAO in the solvent is greatly reduced. The separation is energy-efficient because the heat input is less than the latent heat of vaporization of the solvent. The low energy cost allows the use of high solvent-to-feed ratios in the Asphaltene Separator. Supercritical solvent leaves overhead and is cooled to sub-critical temperature by exchange with the rich solvent in the heat exchanger. A cooler, usually an air-cooled exchanger, further cools the solvent.
- The DAO flows from the bottom of the Separator and is steam-stripped (to less than 0.05 wt% solvent). The recovered solvent is combined with solvent recovered from the Asphaltene Stripper, condensed and recycled.

DAO yield and quality are functions of the solvent used and the operating conditions of the Asphaltene Separator. The efficiency of the DAO Separator is critical to minimizing solvent make-up.

New separator technology has reduced solvent boil-away (test of DAO entrainment in solvent) from a high of 4 LV％ (liquid volume %) to less than 0.4 LV％. DAO quality was equal to or better than that obtained with the earlier design.

3.5.2 Vacuum residue thermal cracking unit ("Eureka")

The Eureka process is a residue thermal cracking process which produces higher yields of cracked oil and lower yields of cracked gas / pitch than other commercially-available thermal cracking processes. Cracked oil is easily desulfurized by conventional HDS technology and all the cracked gas is consumed internally as fuel for furnaces.

Pitch is not only used as a boiler and gasification fuel but also as a binder for coking coal in the steel industry. In FCC Complex project, the pitch is pulverized and charged into the gasification unit.

As an alternative, liquid pitch is diluted appropriately to meet the viscosity specification on the gasifier burner and charged directly to gasifier. A major feature of the process of liquid feed case is that it initiates a reaction in a homogeneous liquid state, thereby avoiding problems with coking and solid handling. Thus, the combination of such technologies is likely to become a future standard by providing a new paradigm in the field of residue conversion.

Reaction Section

Feedstock is heated up to 280 ^{o}C by HP steam from the gasifier syngas cooler and again heated up to 340 ^{o}C in the preheater. It then enters the bottom of the fractionator, where it is mixed with recycled heavy fractions of cracked oil refluxed down in the fractionator.

After that, the mixture of feedstock and recycled oil is pumped and fed to a cracking heater, where the temperature reaches approximately 490 ^{o}C.

The effluent from the cracking heater flows through an automatically operated switching valve into one of the two swing reactors. A continuous flow is maintained at the cracking heater outlet but the reaction in the reactor is carried out semi-batch wise.

The reactors operate at a temperature of 430-440 ^{o}C under a pressure of 0.3-0.4 BarG and are cycled every 3 hours, which consists of feed charging time, soaking time, quenching time, blow-down time and standby time. The heat required for cracking reaction is mainly brought in by the effluent from the cracking heater and additional heat is provided by super heated steam, which is blown into the reactor bottom to make up reaction heat and to strip out the cracked oil.

Both cracking and poly-condensation take place in the reactor. During the reaction, the cracked

products and injected steam are withdrawn from the top of the reactor into the fractionator.
The extent of this reaction is measured by the softening point of the pitch. When the softening reaches a specified value, the remaining reaction mixtures (pitch) are quenched with water to stop the reaction.
Pitch is withdrawn from the reactor by gravity into the stabilizer located just beneath the reactor. The stabilizer serves as a buffer drum between the batch operation of the reactor and the continuous operation of the downstream equipment. A small amount of steam is injected into the stabilizer to strip out the tar fraction. The pitch is appropriately diluted and transferred continuously to the gasification unit.
All pipes, valves and pumps for the pitch service are provided with a jacket of circulating hot oil to ensure the fluidity of the pitch by maintaining the correct temperature.

Fractionation Section

The fractionator is operated at a temperature of 113 ^{o}C at the top and 340 ^{o}C at the bottom with a pressure of 0.1 BarG at the top. Cracked gas and cracked product oil drawn from the reactor are continuously fed to the fractionator and separated into cracked gas, cracked light oil (CLO) and cracked heavy oil (CHO).
The light fraction of the cracked product oil and steam are cooled and condensed at an overhead condenser, then enters the reflux drum where it is separated into cracked gas, cracked light oil and condensed water.
Non-condensable cracked gas is compressed to 4.9 BarG and sent to the desulfurization unit. Desulfurized cracked gas is consumed as fuel to heat the furnaces in the Eureka process.
The major part of the condensed cracked light oil is refluxed to the fractionator to separate the C_4- components through the CLO absorber and the remainder is fed to the CLO stabilizer and then sent to the product tank.
Cracked heavy oil is drawn as a side stream from the middle of the fractionator and, after being cooled, is sent to the HDS unit. A part of the cracked heavy oil is refluxed to the lower part of the fractionator, in order to remove a small amount of entrained residue in the cracked product oil vapor.

Steam System

A large amount of heat from the cracked product oil vapor is recovered from the middle part of the fractionator by generating 9.8 BarG steam. Most of generated steam is utilized as injection steam at the reactor.

Three heating furnaces - the preheater, the cracking heater, and the steam superheater - are operated in the Eureka process. Heat from the flue gas from these furnaces is recovered by generating 19.6 BarG steam.

3.5.3 Hydrodesulfuring Unit (HDS)

Feedstock for the HDS comprises strait run (SR) VGO, VGO components from Lube plant, Cracked oil (or DAO), which is charged first into the reactor sections.

Diene Reactor Section

The CLO from the charge pump is combined with recycled hydrogen from the recycle gas compressor. The combined liquid and gas feed is preheated by an exchanger with reactor effluent and then proceeds to the diene saturation reactor. The purpose of this reactor is to saturate the majority of the diolefins in the thermal cracked oil before the material is sent to the HDS reactors. Since the saturation reaction is made in a liquid phase of the feedstock, the reaction condition is much milder than that experienced in downstream HDS.

The saturated product contains no more diene molecules which polymerizes in downstream HDS.

HDS Reactor Section

The SR VGO, CHO (or DAO) and VGO component from the lube plant are pumped up by a high pressure feed charge pump and charged into the reactor.

The feed stream is combined with the diene reactor effluent and the recycle gas before going to the feed / reactor-effluent exchangers (Eureka case). The combined stream passes through the shell side of the feed / reactor-effluent exchangers, where it exchanges heat with the stream leaving the reactor. After the feed / reactor-effluent exchangers, the stream is sent to the reactor feed furnace, where it is further heated to the desired reactor inlet temperature. After that the stream is charged into the top of the reactor through an inlet distributor.

The operating pressure of the reactor is about 80 BarG (130 BarG for SDA case) and the operating temperature within the range of 350 to 400^{o}C. The first stage and second stage reactors have several individual catalyst beds separated by quench gas distributors, a catalyst support grid, and a vapor/liquid re-distributor tray. The reactor effluent flows through the tube side of the feed / reactor-effluent exchangers where heat is transferred to the combined feed stream.

The reactor effluent is sent to the hot separator and the bottom liquid is sent to the product stripper, while the vapor is sent to the cold separator through the reactor effluent air cooler.

Before entering the air cooler, wash water is injected into the reactor effluent to remove ammonium hydro-sulfide from the system. The separated sour water is sent to the sour water stripper facilities.

After removing H2S in the amine scrubber, the gas from the cold separator is compressed by the recycle gas compressor. Lean amine comes from the amine regeneration section and rich amine is returned to the amine regeneration section.

A part of recycle gas is used as a quench gas. The make-up gas is a high purity hydrogen rich gas coming from a hydrogen converted section in gasification unit and it is injected into the compressed recycle gas stream.

Product stripper section

The liquid from the hot separator and cold separator are charged into the product stripper and is separated into sour off gas, unstabilized naphtha, diesel and VGO.

Sour off gas and naphtha are separated in the stripper overhead separator. Sour off gas is sent to the sour water stripper facilities, and unstabilized naphtha is sent to the LPG recovery unit. Diesel is cooled down by a heat exchanger and/or cooler and run down to the product storage tank. VGO from the bottom of product stripper is cooled down by a heat exchanger and/or cooler and is run down to the product storage tank.

3.5.4 FCC (RFCC) Process

This section describes both FCC and RFCC Process. FCC (Fluid Catalytic Cracking) is one of popular process to obtain motor gasoline. A powdery catalyst that flows like a fluid is mixed with the feedstock for cracking reaction. RFCC (Resid FCC), a type of FCC process unit, is usually chosen when more severe reaction condition is required due to the feedstock property.

Reactor-Regenerator Section

The Reactor-Regenerator Section is the process section where the charge stock is cracked in the Reactor side and the spent catalyst is regenerated in the Regenerator side for recirculating back to the reactor. Another commonly used name to identify this process section is Catalyst Section.

Reactor

A simplified flow diagram of the reactor-regenerator section is provided in Appendix-1.

Hot regenerated catalyst from the regenerator and acceleration media, which is a mixture of steam and sponge gas from the Gas Concentration unit, meets at the bottom of the riser. All streams are contained and well mixed in the Mixing Chamber. The acceleration media fluidizes, lifts and accelerates the catalyst mixture prior to feed injection, establishing a medium density, plug flow catalyst profile.

Further up the riser, fresh feed and steam are injected through multiple feed distributors arranged symmetrically around the riser. The hot catalyst vaporizes the fresh feed and provides the heat for reaction. The reaction vapors carry the catalyst upward through the riser.

At the top of the riser the catalyst is quickly separated from the reaction products. The reaction products pass through a secondary separation stage of cyclones and then to the Main Fractionation Section. Spent catalyst passes through the cyclone diplegs directly into a Spent Catalyst Stripper, where counter-current steam is injected to strip the volatile hydrocarbons from the catalyst. The stream of stripped spent catalyst flows on level control, down through the spent catalyst standpipe to the combustor to be regenerated.

Regenerator

Spent catalyst enters from the Spent Catalyst Stripper via the spent catalyst standpipe to the lower section of the regenerator section, which is called the Combustor. Spent catalyst, process air from the main air blower and hot regenerated catalyst recirculated from the upper vessel are mixed in the combustor to burn the coke off of the spent catalyst. The hydraulic conditions in the combustor create very good radial mixing of both air and catalyst. Complete combustion of coke to CO_2 is accomplished in a medium-density, plug-flow regime in the Combustor by using excess air. The recycle of hot catalyst raises the combustor temperature to promote thermal combustion of CO to CO_2, eliminating the need for CO promotor additives. The catalyst and combustion gases flow up an internal riser and exit via a multiple-arm distributor. All coke has been completely burned in the Combustor at this point. So, mostly a very uniform temperature is achieved at all points in the upper regenerator vessel. The regenerated catalyst falls into a dense bed of catalyst at the bottom of the upper vessel which maintains a surge volume of catalyst.

A portion of the regenerated catalyst is recirculated via the recirculating catalyst standpipe from the cone section of the upper vessel down to the bottom of the combustor. The hot catalyst, typically at 1320-1365ºF (715-740°C), controls the temperature and density in the combustor and provides the heat needed to promote the combustion of coke completely to CO_2.

On its main path, the regenerated catalyst from the upper vessel flows via the regenerated catalyst stand pipe to the bottom of the reactor riser, completing the catalyst circuit. The reactor temperature is controlled by regulating the amount of regenerated catalyst that returns to the bottom of the riser through a slide valve.

Process air required for regeneration is supplied on flow-control from the main air blower. An anti-surge control system protects the blower from damage. Blower discharge air flows through a direct-fired air heater before entering the regenerator. This heater is used only during start-up period to heat the catalyst inventory of the unit.

The flue gas leaving the regenerator passes through sets of two-stage cyclones which remove entrained catalyst particles. After leaving the regenerator vessel, the gas passes through the flue gas slide valve which controls the reactor-regenerator differential pressure and then through an orifice chamber, which controls the back pressure. Excess heat is recovered in a steam generator. At the end of the regenerator section the flue gas is discharged to the atmosphere through a stack.

If necessary, a catalyst cooler to cool the circulating catalyst, an electrostatic precipitator or a third stage separator to remove catalyst fines from he flue gas, and a power recovery unit can be included to recover power from the flue gas as part of overall design.

Catalyst is added and withdrawn from the regenerator side as required to maintain activity and equilibrium metals content of the circulating catalyst. Fresh catalyst is introduced into the circulating catalyst system from a catalyst storage hopper. A second hopper is provided for storage of equilibrium catalyst withdrawn from the circulating system.

Main Fractionation Section

The schematic flow diagram of the main fractionation section is provided in Appendix-3.5 Reaction products are directed from the reactor to the Main Fractionation Column where light gasoline and gaseous, olefin-rich products are taken overhead and routed to the gas concentration unit. Both heavy naphtha and light cycle oil (LCO) are recovered as sidecuts and used in the gas concentration unit for heat exchange. The net products of heavy naphtha and LCO are stripped before sending to storage. The heavy naphtha can serve as a swing cut, to be blended with gasoline in the maximum gasoline and maximum LPG/Olefins mode, or with LCO in maximum distillate mode. Heavy cycle oil (HCO) is also withdrawn as a pump-around sidecut, sent to the Gas Concentration Unit as heating medium, and returned to the main column.

Clarified oil (CLO) from the main column bottom is cooled by producing steam and by exchanging heat with fresh feed. Net CLO product is cooled before sending to storage. In many cases, suspended solids in the CLO are reduced by either filtration or hydraulic cyclones.

Due to the low pressure of the main column, the overhead gas contains a significant amount of heavy material and the overhead liquid product contains light material. Both of these streams are sent to the Gas Concentration Unit for high pressure re-contacting and separation.

<u>Gas Concentration Unit</u>

The schematic flow diagram of the Gas Concentration Unit is provided in Appendix-3.5. Gas from the main column overhead receiver is compressed and combined with primary absorber bottoms and stripper overhead gas. The combined stream is cooled and sent to the High Pressure Receiver. Gas from this receiver is routed to the Primary Absorber where it is contacted by the unstabilized gasoline from the main column overhead receiver and a small recycle stream of debutanizer bottoms. Primary absorber off-gas is directed to a Secondary or Sponge Absorber, where a circulating stream of LCO from the main column is used as absorption oil. The sponge gas, containing C2 and lighter material (C2 minus) is directed to gas treating, which optionally may be included as part of this section.

Liquid from the High Pressure Receiver is preheated by the debutanizer bottoms and sent to the Stripper. The Stripper is reboiled first by heat exchange with debutanized gasoline and secondly, by heat exchange with the circulating LCO stream from the main column. The net stripper bottoms are preheated by circulating heavy naphtha from the main column and sent to the Debutanizer.

An olefin-rich C3/C4 stream is recovered from the debutanizer overhead and is usually sent to an amine treater, for H2S removal followed by further treating for mercaptan removal in an extractive mercaptan caustic wash process. The treated C3/C4 olefin-rich product will be sent to a splitter column to separate C3 and C4 for use in downstream units.

Stabilized gasoline from the debutanizer bottoms is usually sent to mercaptan treating outside the battery limits of the unit.

3.5.5 Gasification Process

<u>Gasifier / Syngas Effluent Cooler / Soot Removal</u>

The non-catalytic partial oxidation of hydrocarbons takes place in a refractory-lined gasification reactor. A syngas effluent cooler is used to recover heat from the very hot syngas and to generate high-pressure saturated steam.

The gasifier itself is a refractory lined vessel. The gasification burner is designed to ensure proper atomization of highly viscous fuel and an intimate mixing of the fuel with the oxygen, which is important for efficient performance.

Steam, used as moderator, is added to the gasifier via the burner. The term "partial oxidation" is used to describe the net effect of various reactions:

$$2\ CH_n + O_2 \rightarrow 2\ CO + n\ H_2$$

Depending on the composition of the feedstock the raw syngas contains small quantities of CO_2,

CH_4, H_2S, N_2, Ar, etc. In addition a small amount of soot is also present.

The hot reactor effluent enters a syngas effluent cooler, in which high heat transfer rates are achieved and maintained. The syngas is cooled down in a coiled evaporator section from approx. 1320 °C to 350 °C. Saturated steam, which is exported, is produced at a pressure typically around 80 bar. Secondary heat recovery takes place in a boiler feed water economiser.
The gasification facility is designed with five (5) parallel strings and, usually, all the strings are in operation at any one time. This concept allows a very high availability to be achieved, which is often required by downstream process installations. The residue is run down into a common feed vessel. The feedstock is supplied to the gasifier using reciprocating feed pumps, one for each string, and gasification takes place at a typical pressure of about 65 bar; the temperature of the syngas entering the syngas cooler is approx. 1320 °C.
When partial oxidation of hydrocarbons occurs, the product gas contains a certain amount of free carbon (soot). The soot particles, together with the ash components contained in the feed, are removed from the gas in two stages. This system consists of a quench pipe and soot separator followed by a packed tower, the soot scrubber. In the quench pipe, a direct water spray removes more than 95% of the soot. In the scrubber the gas is washed in a counter-current flowing in a packed bed and a circulation system is employed using a circulating pump and an air cooler. After leaving the scrubber, the gas has a residual soot content of less than 1 mg/Nm^3. Excess water from the scrubber bottom is recycled via a filter to the quench pipe. The soot formed in the gasifier is thus removed from the system with the process condensate as soot slurry via the bottom outlet of the soot separators and is routed to a common soot slurry system for further processing.

<u>Soot slurry processing / waste water stripping</u>

The soot slurry ex gasification is let down to low pressure in a common slurry flash vessel to flash off dissolved syngas components like H_2, CO and acid gas, which are routed via the waste water stripper to the refinery sulphur recovery unit (SRU) .
The flashed soot slurry is cooled down in slurry coolers to a temperature that is acceptable for the downstream filters, and flows to the filter feed vessel. In case of shutdown of the filtration units, the flashed soot slurry can be routed to an escape tank to provide temporary hold-up. Carbon slurry filtration takes place in a membrane filter press system, which is optimized for each particular situation, with most of the filtrate from the press being collected in the filtrate vessel and recycled via the filtrate pumps to the scrubbers. The excess, including the flushing water intake in the filtration units, flows to the wastewater stripper. The wastewater stripper receives water filtrate from the slurry filter presses and the flash gas from the soot slurry flash

vessel. The column is equipped with a reflux pump and reflux cooler. The stripped water is sent to the battery limits by means of an effluent pump and passes the effluent through a cooler prior to bio-treatment (outside battery limit).

The filter cake has a typical particle size of 2 cm (maximum of about 5 cm), a temperature of 50-60°C and a solids content of 18 %wt. Depending on the local situation, the filter cake can be sent to a material handling facility (MHF) unit for further processing to a saleable Ni/V ash (optional solution).

Waste Water Treatment

In view of the trace components present, the effluent water from the wastewater stripper should be further processed in the wastewater treatment facilities, outside battery limit.

3.5.6 Hydrogen production unit

Sour shift section

Syngas from the soot scrubber is charged into the saturator in a sour conversion system.

Saturator

Steam is required for the CO shift reaction, which is introduced in two ways. In the first step, the synthesis gas with a temperature of 120 deg.C comes into direct contact with the hot process condensate recycled from the desaturator. The process condensate is then vaporized and taken into the synthesis gas until the saturated condition. In the second step, the MP (middle pressure) steam is introduced externally.

Sour CO Shift

Sulfur resistant shift catalyst has a high and stable activity for conversion of carbon monoxide in gases that contain sulfur and is suitable for plants based on partial oxidation of heavy oil or coal. The shift reaction going on in the sour shift converter

$$CO + H_2O \rightleftarrows CO_2 + H_2 + heat$$

will only proceed in contact with a catalyst.

Carbonyl sulphide present in the feed gas will be converted according to the following reaction

$$COS + H_2O \rightleftarrows CO_2 + H_2S + heat$$

Desaturator

The desaturator is installed downstream of the 3rd sour CO shift converter, the process condensate is separated via the desaturator and the process condensate circulation between the

Desaturator and Saturator is established.

Sour converted syngas is introduced into the acid gas removal section.

Acid Gas Removal Section

The H_2S and CO_2 contained in the sour syngas coming from the desaturator are removed in the acid gas removal (AGR) unit. The detail process description is as follows.

Feed gas from the desaturator is cooled through a feed/product gas exchanger and is sent to the H2S absorber. The gas flows upward through packed beds where it comes into contact with chilled loaded solvent entering at the top of the tower. The loaded solvent is laden with CO_2 from the CO_2 absorber, which improves the selectivity of the solvent for H2S absorption. The contact between the gas phase and liquid phase is enhanced as they each pass through the packed beds, where primarily H_2S, COS, and some CO_2 and other gases such as hydrogen, are transferred from the gas phase to the liquid phase. The treated gas passes through de-entrainment devices at the top of the packed beds and tower. The solvent stream from the H_2S absorber collects in the bottom of the tower and is called rich solvent as it is loaded with H_2S and CO_2. The rich solvent is pumped to the lean / rich exchanger, where the temperature is increased through the exchange with the lean solvent from the bottom of the H2S stripper.

The treated gas exits the top of the H_2S absorber and is sent to the CO_2 absorber, but a portion also needs to be sent directly to the steam superheater / generator. The gas in the CO_2 absorber flows upward through packed beds where it comes into contact with chilled lean solvent entering at the top of the tower, and chilled semi-lean solvent entering near the top of the tower. The contact between the gas phase and liquid phase is enhanced as they each pass through the packed beds, where primarily CO_2, and some H_2S, COS, hydrogen, and other gases are transferred from the gas phase to the liquid phase. The treated gas passes through de-entrainment devices at the top of the packed beds to minimize the solvent carry over. The treated gas then exits the top of the CO_2 absorber and is sent to the methanator via the feed /product gas exchanger.

The solvent from the CO_2 absorber collects in the bottom of the tower. The loaded solvent is split and sent either to the H_2S absorber after chilling or sent to four successive flash drums to partially regenerate a portion of the solvent by removing CO_2.

The first flash drum is the CO_2 recycle flash drum where H_2, CO_2, and some dissolved and entrained gas are transferred to the gas phase by a reduction in pressure. The separated gas is returned to the CO_2 absorber via the CO_2 recycle compressor. This recycle minimizes the loss of valuable gases from the treated gas stream and controls the overall CO2 purity from the CO_2 flash section.

The solvent from the CO_2 recycle flash drum is then sent to the CO_2 LP (low pressure) flash drum, which operates at 0.2 BarG, to flash off some of the CO_2. The solvent then flows to the CO_2 vacuum drum which operates at (-0.8) BarG. This final flash operates at a vacuum which maximizes regeneration and helps minimize solvent circulation. The flash regenerated semi-lean solvent is returned to the CO_2 absorber after being chilled. The CO_2 product gases from the CO_2 flash drums exit the unit battery limits.

The rich solvent from the H_2S absorber is pumped to the lean/rich exchanger where it is heated by exchange with the lean solvent from the H_2S stripper, which is cooled. The lean/rich exchanger reduces the duties of the Lean Solvent Chiller and the H_2S Stripper Reboiler. The heated rich solvent stream proceeds to the H_2S Concentrator, while the lean solvent is sent to the Lean Solvent Chiller.

The rich solvent and desorbed vapors from the Lean/Rich Exchanger are routed to the H2S Concentrator, where some CO_2, dissolved and entrained gases are stripped using a slipstream of sweet syngas product. In the H2S Concentrator, compounds such as CO_2, H_2, and CO are transferred from the liquid phase to the gas phase. Hydrogen sulfide has a high solubility in solvent, and as such, has more of a tendency than most other gases to stay in the liquid phase. The gas exiting the H_2S Concentrator is primarily composed of CO_2, N_2, CO, and some H_2S. The gas stream is combined with the flash gas from the H_2S Flash Drum. The combined stream is cooled, compressed and recycled to the inlet of the H_2S Absorber.

The partially regenerated solvent from the H_2S Concentrator is sent to a H_2S Flash Drum where more of the non-H_2S components are flashed off, cooled, compressed and combined with the H2S Concentrator off gas stream for recycling. The solvent from the H_2S Flash Drum flows to the H_2S Stripper where the primary solvent regeneration occurs. The remaining H_2S, CO_2, N_2 and other compounds are transferred from the liquid phase to the gas phase by contact with the steam generated in the H_2S Stripper Reboiler. The rich solvent from the H_2S Concentrator enters the Stripper about two-thirds up the column, just above the stripping section. After some residual flashing due to de-pressurization, the solvent passes through a flashing feed liquid distributor, and then flows down the packed bed in the stripping section releasing H_2S, COS,

CO_2 and other components after contact with the steam generated in the Stripper Reboiler.

The steam and liberated gases exit the packed section of the stripper, and then flow upward through a demister and into the trayed section of the column. In the trayed section, the rising gas is contacted with counter-current flowing reflux water to cool and partially condense the hot overhead vapor, as well as reduce solvent entrainment. The overhead stream passes through a de-entrainment device and exits the top of the column.

The overhead gas then passes through the Reflux Condenser in order to condense and recover a portion of the overhead steam. The liquid and vapor phases are separated in the Reflux Drum. The H2S-rich acid gas exits the unit battery limits, and the liquid is returned to the trayed section of the H2S Stripper, via the Reflux Pump.

The H2S Stripper Reboiler generates steam from the solvent via heat exchange with saturated low-pressure steam. Live steam injection into the Stripper is not used to avoid diluting the solvent and to avoid water balance problems. Solvent for the reboiler is collected in a trap-out tray located below the bottom packed section in the H_2S Stripper. The resulting steam generated in the reboiler re-enters the bottom of the H_2S Stripper below the trap-out tray and travels up the column, stripping the acid gas from the down-flowing solvent. The total stripping heat duty of the reboiler is determined by the sensible heat requirement of the solvent, the stripper overhead steam requirement, the heat necessary to transfer H_2S, CO_2 and other dissolved gasses from the solvent, and the heat required to vaporize the water absorbed from the feed gas.

The lean solvent from the H2S Stripper is then sent to the hot side of the Lean / Rich Exchanger via the Lean Solvent Pump. The temperature of the lean solvent is further reduced in the Lean Solvent Cooler and Chiller, and then returned to the top of the CO_2 Absorber.

Methanation Section

CO and CO_2 are converted to methane via Methanator.

In the Methanator the chemical reactions are as follows:

$$CO + 3H_2 \rightleftharpoons CH_4 + H_2O + heat$$
$$CO_2 + 4H_2 \rightleftharpoons CH_4 + 2H_2O + heat$$

Downstream the Methanator the gas normally contains less than 10 ppmv CO + CO_2. The temperature rise through the Methanator will be about 110°C.

At upstream of the Methanator, Sulfur Guard removes sulfur compounds (which exist at exit of Acid Gas Removal Unit) which become poisonous for methanation catalyst.

3.5.7 Amine regeneration unit

The combined rich amine solution is sent to Rich Amine Flash Drum, where the dissolved and entrained hydrocarbons in the rich amine are flashed off at low pressure (1 BarG).The released gas in Rich Amine Flash Drum is scrubbed with the lean amine in a scrubbing section. The rich amine is settled to separate the dissolved liquid hydrocarbons from it. The liquid hydrocarbon is sent to Slop Tank. The rich amine is pumped from Rich Amine Flash Drum and heat-exchanged in Rich-Lean Amine Exchanger with the lean amine solution from Regenerator and is fed to Regenerator.

The rich amine solution enters at 101 ^{o}C /1.1 BarG where H2S and traces of light hydrocarbons are stripped. The overhead vapors (121 ^{o}C /1.1 BarG) from Regenerator are cooled (60 ^{o}C /0.9 BarG) by Regenerator Overhead Condenser where the most of water vapor is condensed. The condensed water is separated from the acid gas vapor in Regenerator Reflux Drum. Acid Gas flows to Sulfur Recovery Unit.

The lean amine solution leaving Regenerator bottom (127 oC /1.3 BarG) is directed to Regenerator Reboiler, where it is heated and reboiled to produce stripping steam at 121 oC. Desuperheated LP steam is utilized as heating medium for Reboiler to keep the max tube skin at desired temperature. The lean amine solution from Regenerator flows through Amine Exchanger to Amine Storage Tank (60 oC /0.2 BarG). The lean amine solution is supplied from Amine Storage Tank through Lean Amine Trim Cooler to the lean amine solution users by Lean Amine Circulation Pump.

To remove solid particles and other degradation products, a part of the lean amine solution is branched downstream of Amine Solid Filter and passed through Amine Carbon Filter of mechanical cartridge type.

3.5.8 Sulfur recovery unit

The sulfur recovery process, which is known as the Claus process, is based upon the partial combustion of hydrogen sulfide with a ratio controlled flow of air which is automatically maintained in the correct quantity for the complete oxidation of all hydrocarbons, ammonia and hydrogen cyanide present in the acid gas feed and to obtain as H_2S/SO_2 ratio of 2 in the downstream part of the unit.

$$H_2S + 3/2\ O_2 = SO_2 + H_2O + 520\ \text{kJ/mol}\ H_2S$$

The major percentage of the residual H2S combines with the SO_2 to form sulfur, according to the equilibrium reaction

$$2\ H_2S + SO_2 \rightleftharpoons 3\ S + 2\ H_2O + \text{heat}$$

Sulfur is formed in vapor phase in Combustion Chamber.

The primary function of Waste Heat Boiler is to remove the major portion of heat generated in the combustion chamber.
The secondary function of the Waste Heat Boiler is to utilize its heat to produce medium pressure steam.

The gas flows into the First Sulfur Condenser, in which the sulfur vapor is condensed. The process gas leaving the first sulfur condenser still contains a considerable part of its H_2S and SO_2, therefore the essential function of the following equipment is to shift the equilibrium by adopting a low reaction temperature, thus removing the sulfur as soon as it is formed.

Conversion to sulfur is by catalytic process in subsequent reactors containing special synthetic alumina catalysts.
Before entering the First Reactor, the process gas flow is heated by steam.
In the First Reactor, the reaction between the H_2S and SO_2 recommences until equilibrium is reached.

The effluent gas from the first reactor passes to the Second Sulfur Condenser, where the sulfur is condensed. In order to achieve the required sulfur recovery rate, the process gas is passed to two other reactor stages and super Claus reactor. A sulfur coalescer is installed downstream of the Fifth Sulfur Condenser to separate entrained sulfur mist.

The sulfur condensed and separated in the Sulfur Condensers and the sulfur coalescer is drained via Sulfur Locks to the Sulfur Pit.

The process gas (tail gas) leaving the sulfur coalescer still contains an amount of H_2S, which is considered to be dangerous if released directly to the atmosphere. Therefore the gas is incinerated, which means that residual hydrogen sulfide and sulfur vapor are converted to sulfur dioxide in the presence of oxygen. At the outlet of the incinerator the converted gas steam is quenched by means of air before it is released via the stack to the atmosphere.

3.5.9 Sour water stripper unit

The combined sour water is fed to Feed Degasser, in which the entrained hydrocarbon is separated. Off gas from Feed Degasser is fed to Sulfur Recovery Unit Incinerator.

The sour water is pumped from Sour Water Feed Tank by Sour Water Stripper Feed Pumps to Sour Water Stripper through Feed/Bottom Exchanger where it exchanges heat with the hot stripped water from Sour Water Stripper. The stripper feed temperature is so selected as to prevent evaporation of the sour water downstream of the Feed/Bottom Exchanger. While the sour water flows downward in the column, it is heated by upward flowing generated vapor and is stripped of H_2S, NH_3 and other impurities. The required vapor is generated in Sour Water Stripper Reboiler by low pressure steam.

The hot stripped water collected at the bottom of the stripper is drawn off by Sour Water Stripper Bottoms Pump and passes through Feed/Bottom Exchanger and Stripped Water Cooler successively, to be cooled to its design rundown temperature. The stripper Top Section is cooled by Sour Water Pumparound Cooler.

The sour gas composed mainly of H2S, NH3 and water vapor is preferably sent to the Sulfur Recovery Unit.

3.6 Utility and Off-sites

3.6.1. Basis of Utilities and Off-sites

All utilities are self-supported in FCC Complex without raw water (from river water intake) For FCC Complex fuel gas, synthesis gas and cracked gas, which is generated in FCC Complex, are consumed as furnace fuel in FCC Complex itself and no imported fuel is realized. Excess clean fuel gas is exported to outside of FCC Complex.

The gasification process generates a large amount of heat energy due to a partial oxidation of residue feed. Other processes can utilize the energy with the heat integration with the gasification. A part of high pressure steam generated from the gasification is utilized in a feed preheating and in process steam, then remaining steam is super-heated and supplied to gasifyer and other process, i.e. sour shift reactor as process reaction steam.

3.6.2. Capacity of Utilities

The capacities of utility facilities are presented in Table 3.6-1
Description of Utilities and Off-sites facilities are explained as follows.

3.6.3. Gas turbine generator and HRSG

77 BarG saturated steam is generated in a synthesis gas cooling in the gasification unit. The saturated steam remained after consumed in other process is charged to HRSG for super heating. Synthesis gas from gasification is fed to gas turbine generator for electric power demand of FCC Complex. The exhaust heat is recovered by HRSG and to generate two kinds of superheat steam of 77 BarG. The 77 BarG steam is charged to Sour shift reactor and remained steam is charged to STG. The STG produce electric power, HPS, MPS and LSP for FCC Complex demand. For start-up operation in order to utilize power and steam from the existing facilities, a power grid and steam piping connection is provided between the existing plants.

3.6.4. Demineralization and BFW (Boiler Feed Water) treatment unit

Industrial water from river water intake is charged to the demineralized water system. A deaeration is designed for the recovered steam condensate and the demineralized water to prepare the BFW charged to the HRSG of gas turbine. A polishing section is provided for the recovered condensate upstream of the deaeration.

3.6.5. Cooling water system and River water intake

An intake facility will be installed on the River Tigris and a pipeline routed from there to the complex at 4,000 m3/hr. The flow rate is assumed also to cover consumption of the existing intake facility and the power station.. River water is charged to the demineralization unit and cooling water make-up (as industrial water). A recirculated fresh cooling water system is provided assuming a 11^{o}C temperature rise in the return cooling water.

3.6.6. Offsite Facilities

Storage facility (Tank)

The following tanks are assumed to be already in the existing facilities

- HDS charge tank (Lube surplus + VGO#02)
- AR (RCR) tank
- VR (VR#02) tank
- Hydrocracker unconverted oil (CFO) tank

Storage planning is summarized in Table 3.6-2, 3 and 4.
Storage capacities of each tank are assumed as follows;

LPG tank	6 days
Naphtha tank	6 days
Diesel tank	6 days
FCC gasoline tank	6 days
LCO tank	6 days
Solid sulfur silo	6 days
Diluent tank	1 day
Cracked slop tank	8 hours
Hot slop tank	8 hours
Cracked slops	8 hours

Flare system

A dedicated flare system is located in FCC Complex. The capacity of the flare system is controlled mainly by the flare load at depressuring of the high pressure section of the HDS.

Others

A dedicated effluent treatment system is located in FCC Complex.
A dedicated fire fighting system is designed in FCC Complex.
Solid sulfur and petcoke are operated by sulfur and coke handling systems.

3.7 General Layout Plan

The general plant layouts will be developed based on FCC complex conceptual design, which covers both process units and utility/offsite facilities as follows:

Appendix 3.7-1 shows an overall picture of North Refinery in Baiji photographed by a commercial satellite especially for the feasibility study.

The most preferable and suitable location for the huge FCC complex facilities will then be decided at True-North-West opened space, i.e. Drawing-North, which is currently occupied by the existing flare stack and flare-header piping for the Baiji Refinery. The location is shown in Appendix 3.7-2.

The following plant layouts will be developed for the SDA+Gasification Case and the Eureka+Gasification Case assuming that re-location of the existing flare is conducted in a timely manner before construction works for FCC complex facilities commence. Although the Consultant has tentatively decided that new location for the existing flare should be just north of the perimeter of the existing plants, the final location and the procedures for re-construction of the existing flare stack will be determined during engineering work in the FEED phase.

A new waste water treatment facility will be located at south end of the proposed area because the treated water needs to be discharged into the Tigris river, which runs to the south of the refineries. (Refer to the photo-picture).

(1) RFCC + SDA+ gasification Scheme

Facilities	Approximate Required Area,m2	Remarks
Process Units	354,200	
Utility Facilities	52,800	includes Oily WWT at south end
Offsite Facility	70,000	
Flare Stack area	49,900	
Buildings area	16,300	includes Control Room and Electrical Substation
Total	543,200	

Appendix 3.7-3 shows overall plant location for SDA+ Gasification Case.

(2) FCC + Eureka + gasification Scheme

A plant area requirement is assumed to be almost same as for the SDA Case, although the dedicated plant location is slightly different.

Appendix 3.7-4 shows overall plant location of EUREKA + Gasification Case.

3.8 Related Infrastructure Plan

The project plans the facility to supply fresh water to FCC Complex, which will be introduced from the Tigris River. The intake point at the river is located around 7 km from the complex and the water is transported through a pipeline to the complex.
The capacity of facility is designed with a flow rate of 4,000 m3/hr.

3.9 Scope of the Project

Table 3.9-1 presents the process, utility and offsite facilities in FCC Complex.
Feedstocks from the existing facilities are pumped up at the existing storage tank area and transported to the complex through interconnecting piping of this project.
The product oils are stored in tankage facilities in the complex and transported to the existing units, blending and shipping facilities. Therefore, the complex has no shipping facilities for the products.

A part of the hydrogen is consumed in the complex and the remaining part is sent to the existing hydrocracker.
The clean synthesis gas (clean syngas) after the acid gas removal of raw syngas is sent to the gas turbine generators in the utility facility of the complex and also to a new gas turbine combined cycle (GTCC) power station, which is installed outside the complex. The clean syngas piping is connected with a transfer pipeline at a tie-in point of the complex fence. It is assumed in the study that the new power station with the GTCC would be installed adjacent to the complex.

Table 3.1-1 Feedstock to FCC complex

		RCR 1)	VR	VGO	C.F.O 2)	Lube surplus
Flow rate	bpsd	36,500	30,420	3,380	5,270	5,650
Specific gravity	15.5/4 degC	0.9622 1)	1.0109	0.9094	0.8313	0.8800
API gravity	degree	15.6 1)	8.5	24.1	38.7	29.3
Viscosity	cSt @50 degC		5100	28		16
	cSt @100 degC				2.92	4.4
Sulfur	wt%	4.02 1)	4.99	2.85	50ppm	2.50
CCR	wt%	10.55 1)	19.16	0.18	0.0	0.17
Nitrogen	wtppm		4900	1000		378
Pour Point	degC		51	30	18	21
Flash Point	degC		3.2	182	158	160
Asphaltenes	wt%		3.92	<0.01		
Nickel	wtppm	23 1)	31-54	<0.3		<1
Vanadium	wtppm	44 1)	70-90.5	<0.3		<1
Ash content	wt%		0.0343			
Distillation	degC					
IBP					248	
50					398	
98.5					478	
EP						

Note: 1) RCR stands for atmospheric residue in Crude distillation unit.
2) C.F.O stands for unconverted oil of Hydrocracking unit.

Figure 3.1-1 Fuel Oil Balance provided by NRC

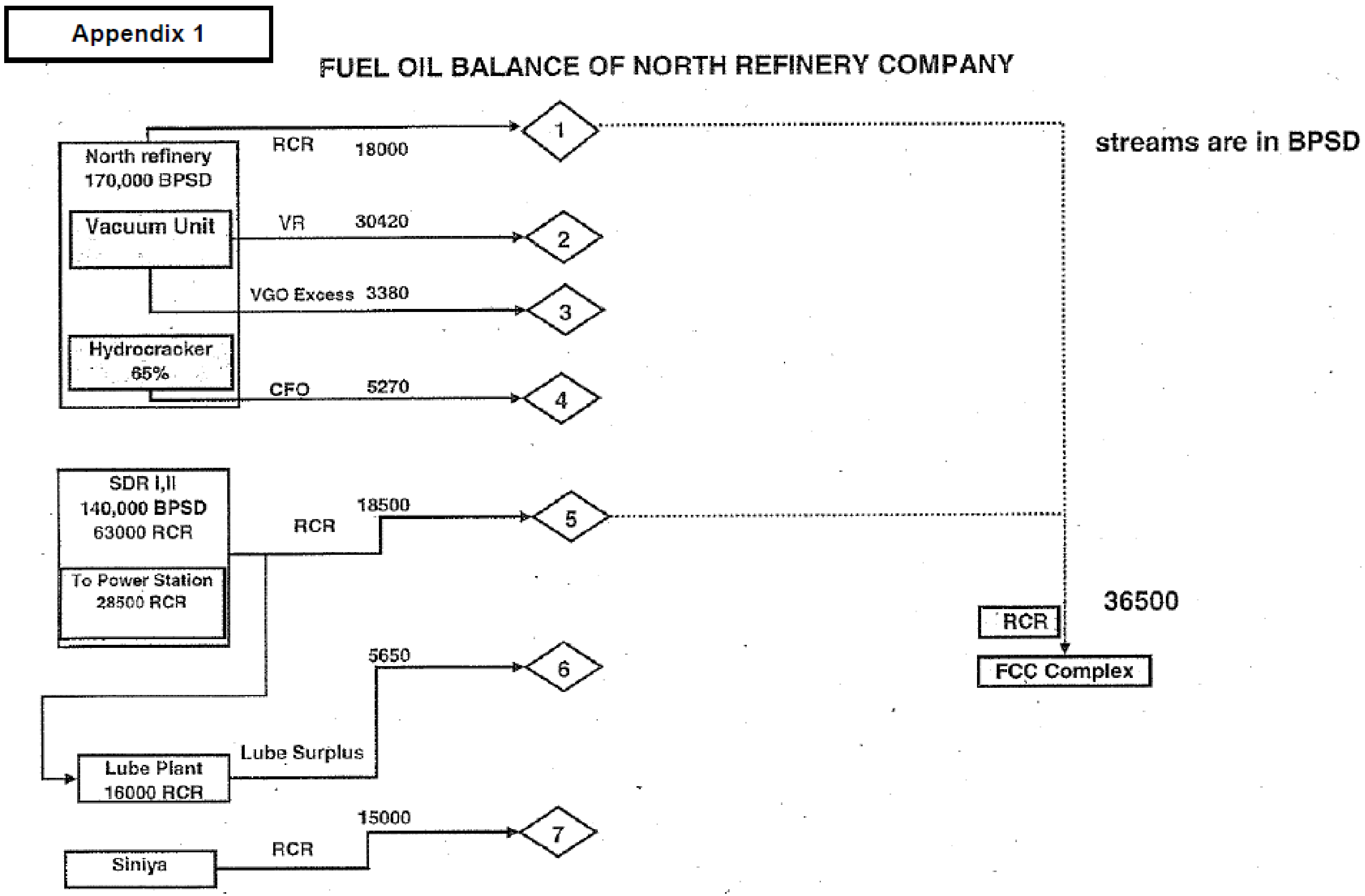


Figure 3.1-2 Pre-study Balance of FCC complex, provided by NRC

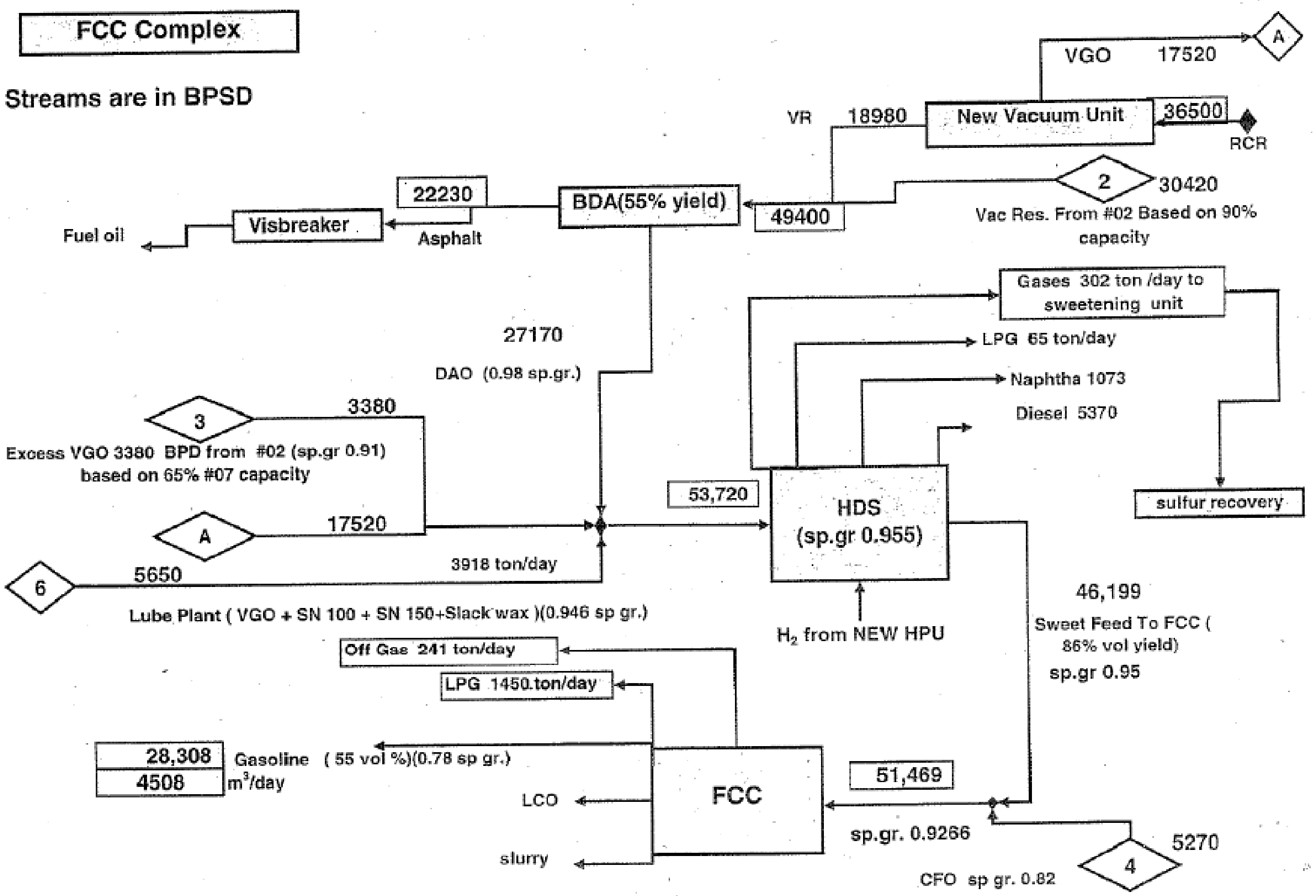


Figure 3.1-3 Feed Properties, provided by NRC

ITEM	TEST	RCR NR 1987	RCR NR 2009	VGO #02 23/11/1987	VR #02	VR الدهون
1.	SP. GRAVITY @15.6 C°	0.9576-0.9614	0.9563	0.9094	1.0109	
2.	VISCOSITY @ 100 C°	28.6-37.0	24.51			1282
3.	F.P. C°	192-280	208	182	3.2	
4.	VISCOSITY @ 50.0 C°	379		28	5100	
5.	SULPHUR CONTENT wt% ASTM D-1266	4.2-4.37		2.85	4.99	
6.	CARBON RESIDUE (RAMS) wt% ASTM D-524	6.8-7.1		0.18	19.16	
7.	ASPHALTENES wt% IP-143	1.58		<0.01	3.92	
8.	P.P. C°	+18		+30	+51	
9.	V CONTENT PPM	31.0-50.0		<0.3	70 – 90.5	
10.	Ni CONTENT PPM	14.0-27.0		<0.3	31-54	
11.	Na CONTENT PPM	22			19.8 - 40	
12.	ASH CONTENT wt%	0.0072 - 0.03			0.0343	
13.	CALORIFIC VALUE (GROSS) KCAL/Kg	10553.9				
14.	CALORIFIC VALUE KCAL/Kg	10333.9-10450			10200	
15.	NET					
16.	ASTM DISTILLATION I.B.P C° C° C° C° C° C° C° C° C° C° C° TOTAL DISTILATE TOTAL RESIDUE	ASTM D-1160				

Table 3.1-2 Feedstock to FCC complex after processing RCR in New VDU

		VR 1)	VGO 2)	C.F.O	Lube surplus
Flow rate	bpsd	49,400	20,900	5,270	5,650
Specific gravity	15.5/4 degC	1.0109	0.9094	0.8313	0.8800
API gravity	degree	8.5	24.1	38.7	29.3
Viscosity	cSt @50 degC	5100	28	-	16
	cSt @100 degC	-	-	2.92	4.4
Sulfur	wt%	4.99	2.85	50ppm	2.50
CCR	wt%	19.16	0.18	0.0	0.17
Nitrogen	wtppm	4900	1000	-	378
Pour Point	degC	51	30	18	21
Flash Point	degC	3.2	182	158	160
Asphaltenes	wt%	3.92	<0.01	-	-
Nickel	wtppm	31-54	<0.3	-	<1
Vanadium	wtppm	70-90.5	<0.3	-	<1
Ash content	wt%	0.0343	-	-	-
Distillation	degC				
IBP		-	-	248	-
50		-	-	398	-
98.5		-	-	478	-
EP		-	-	-	-

Note: 1) Including VR from new Vacuum distillation (VDU) processing RCR.
2) Including VGO from new Vacuum distillation (VDU) processing RCR.

Figure 3.2-1 Overview for Selecting FCC Scheme to Expand Motor Gasoline Production

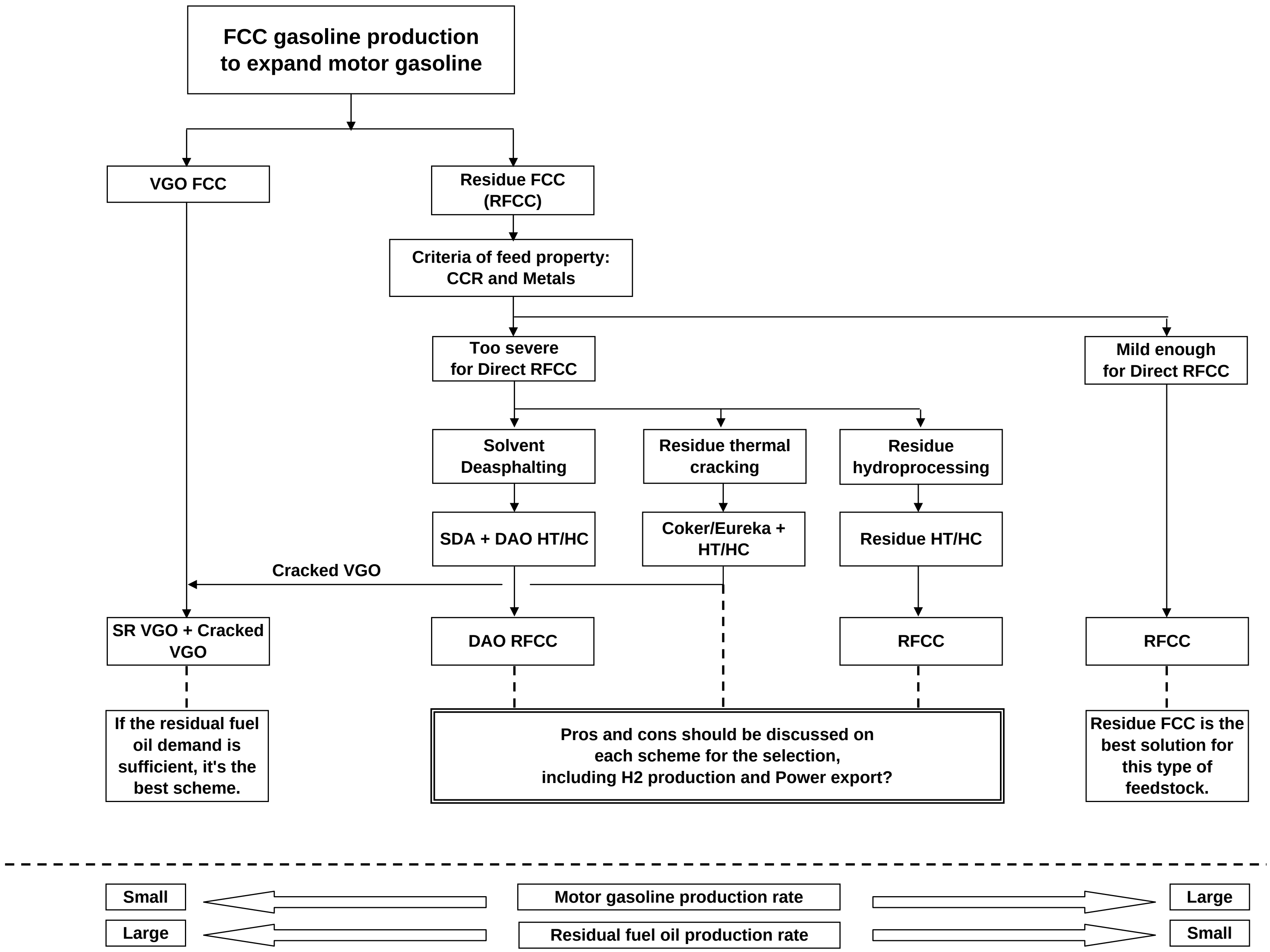


Figure 3.2-2 Appropriate Area for FCC Application, and NRC Residue

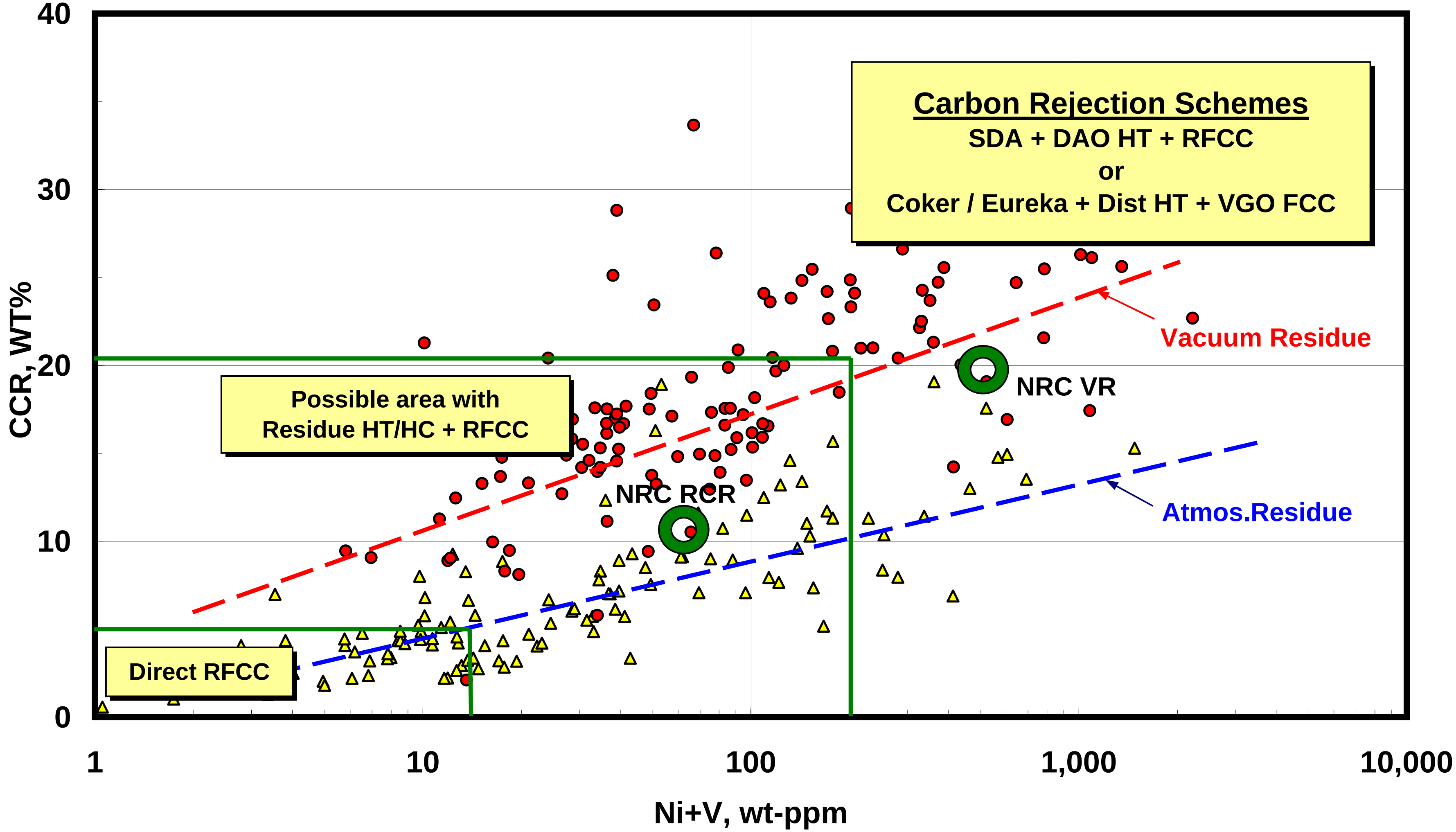


Table 3.2-1 Case Definition for the study

Study case	SDA	Eureka	Delayed Coker	DAO HDS	Distillate HT	FCC		Gasification	
						VGO FCC	RFCC	Liquid	Solid
SDA case	X	-	-	X	-	-	X	X	-
Eureka case (Solid pitch)	-	X	-	-	X	X	-	-	X
Reference cases									
Eureka case (Liquid pitch)	-	X	-	-	X	X	-	X	-
Delayed coker case	-	-	X	-	X	X	-	-	X

Figure 3.2-3 Product Yield of SDA, Eureka and Delayed Coker

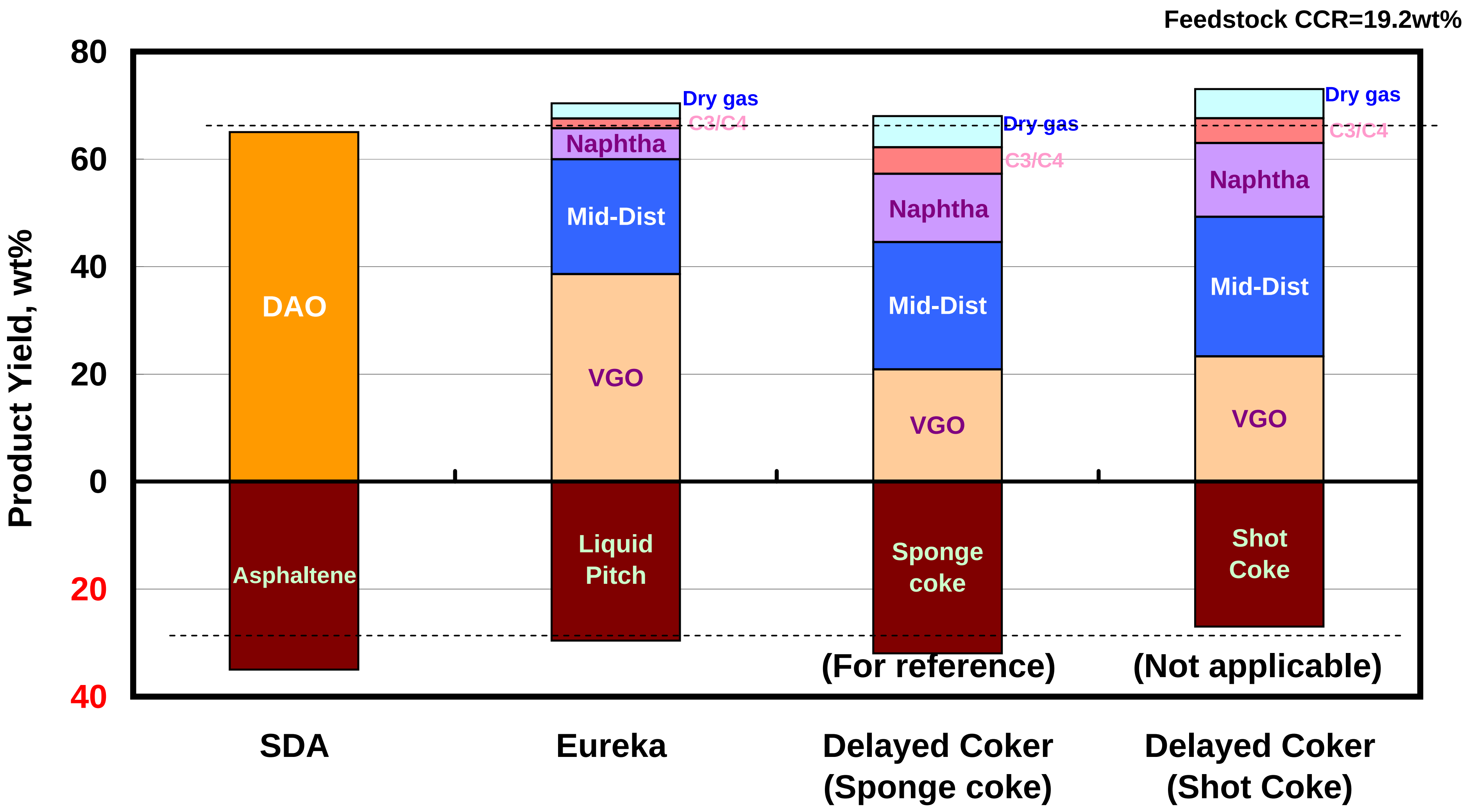
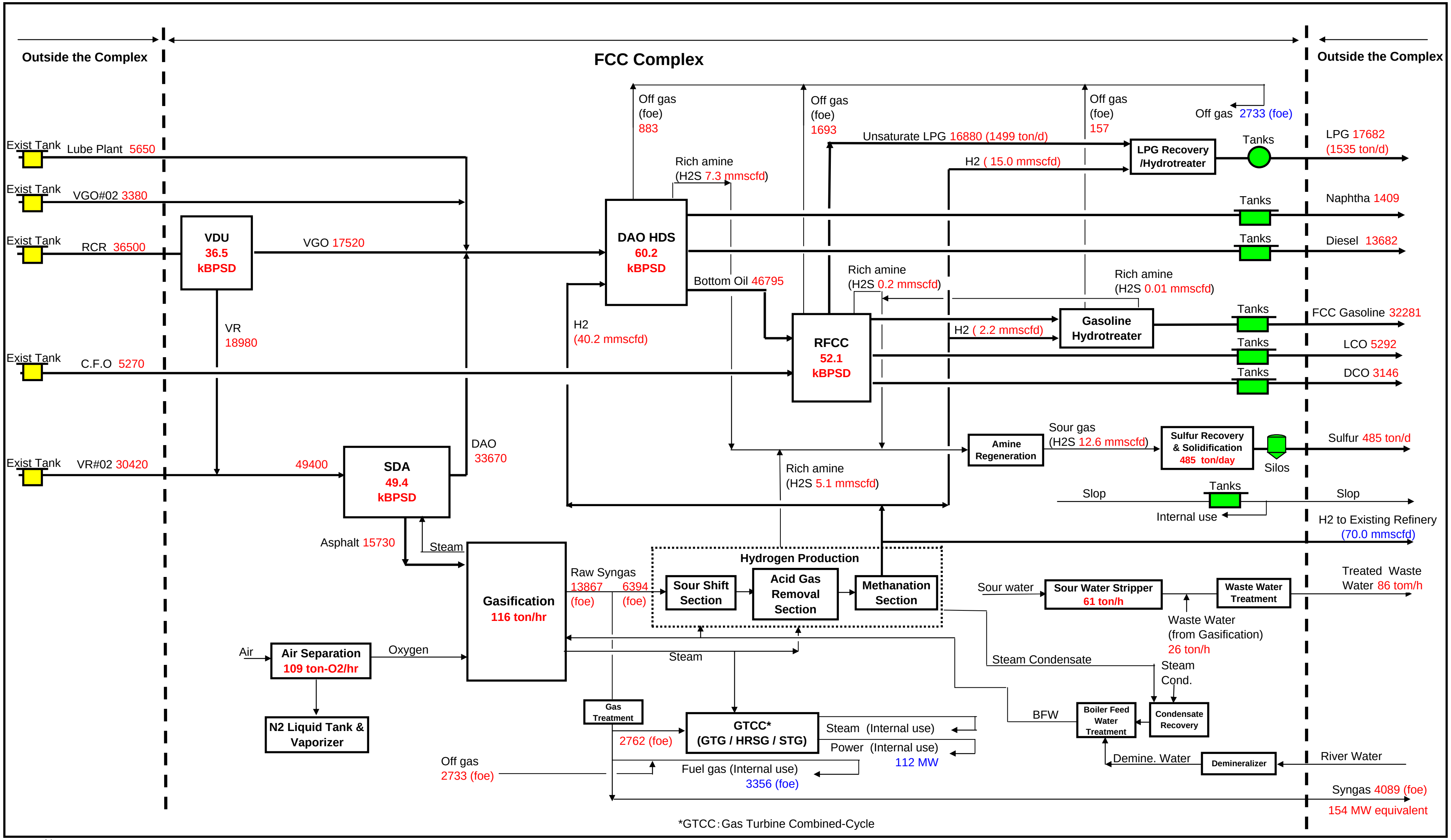
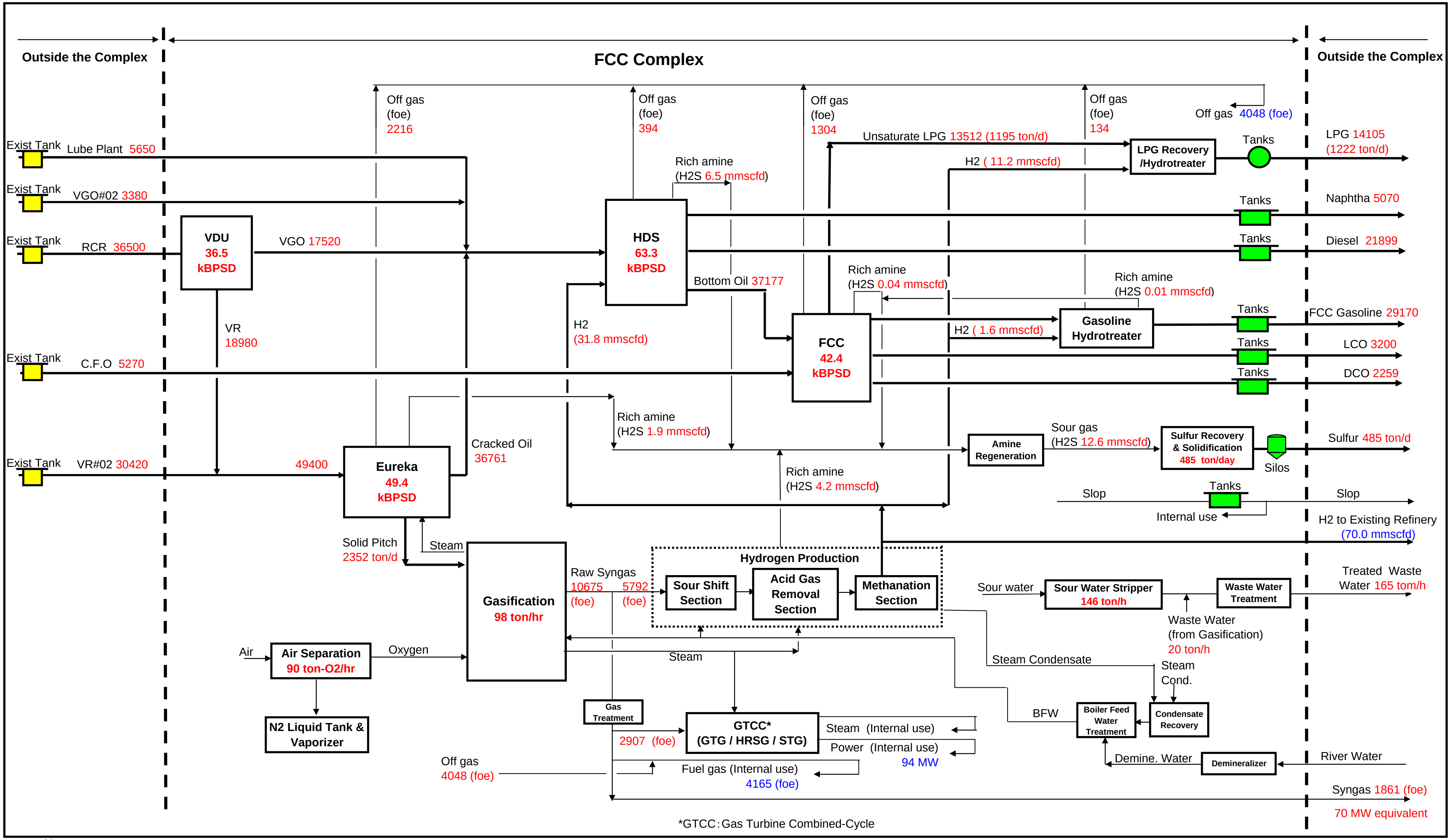


Figure 3.2-4 Simplified Block Flow Diagram: SDA Case



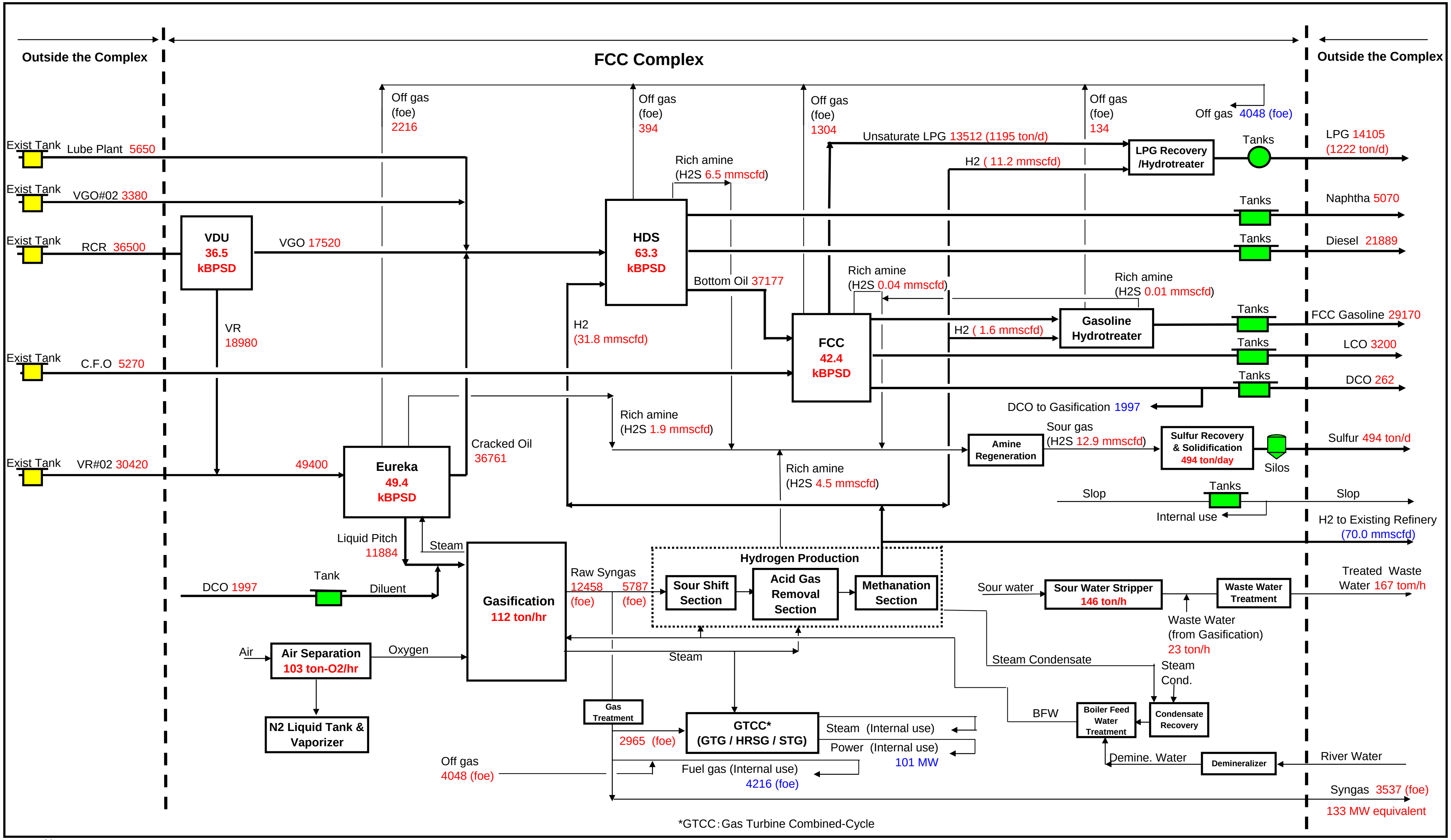
Note :
1) Figures, indicated in the above block flow diagram, are showing their flow rate [BPSD], unless otherwise indicated.

Figure 3.2-5 Simplified Block Flow Diagram: Eureka Case (Eureka + Solid Gasification)



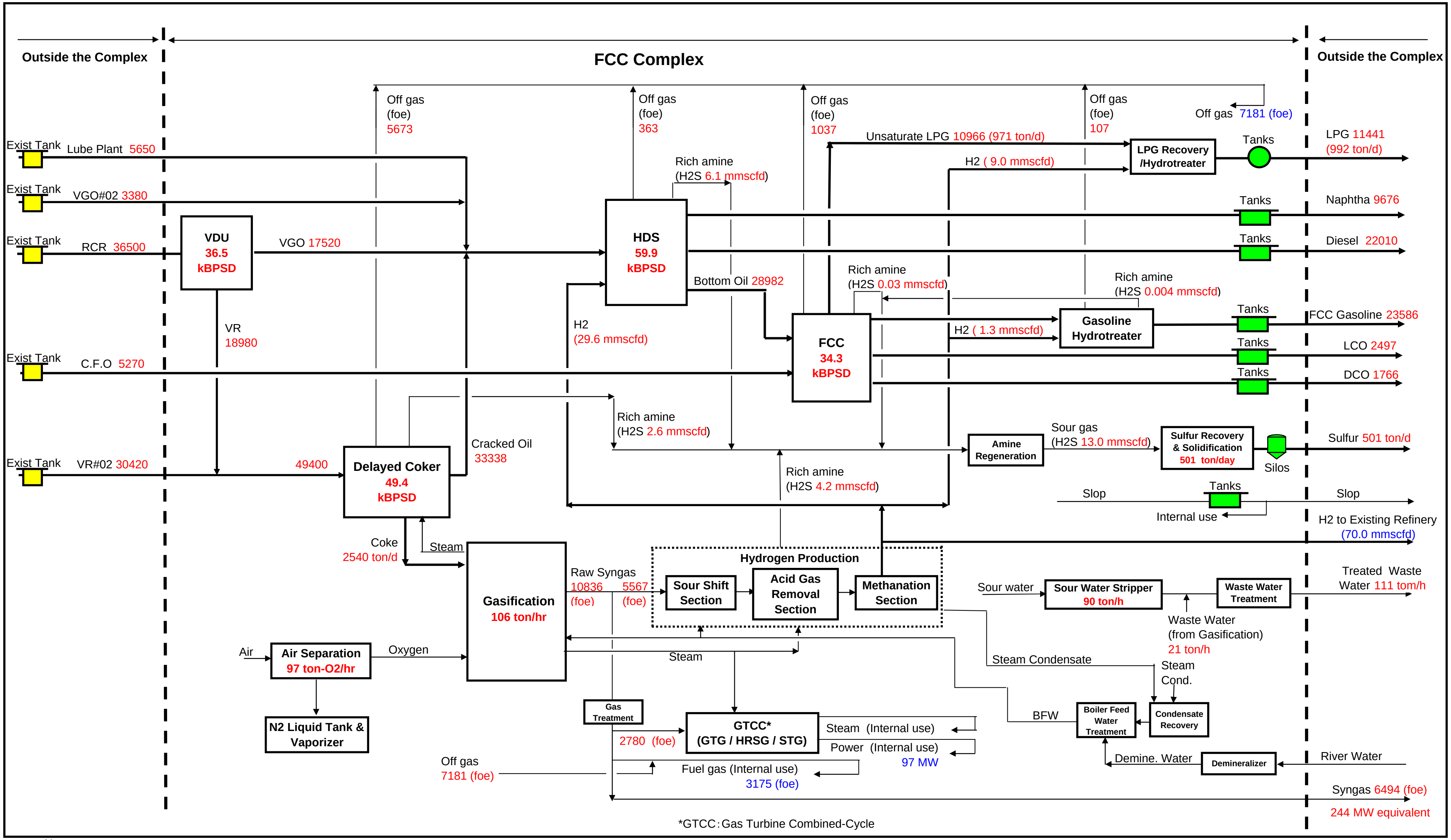
Note :
1) Figures, indicated in the above block flow diagram, are showing their flow rate [BPSD], unless otherwise indicated.

Figure 3.2-6 Simplified Block Flow Diagram: Eureka Case (Eureka + Liquid Gasification) (For Reference)



Note :
1) Figures, indicated in the above block flow diagram, are showing their flow rate [BPSD], unless otherwise indicated.

Figure 3.2-7 Simplified Block Flow Diagram: Delayed Coker Case (Delayed Coker+ Solid Gasification) (For Reference)



Note :
1) Figures, indicated in the above block flow diagram, are showing their flow rate [BPSD], unless otherwise indicated.

Table 3.2-2 Charges and Products around FCC Complex

		SDA		Eureka Solid Gasification		Eureka Case Liquid Gasification (For Reference)		Delayed Coker (For Reference)		Remarks
			Vol%		Vol%		Vol%		Vol%	
Charge										
RCR	bpsd	36,500	44.9	36,500	44.9	36,500	44.9	36,500	44.9	
VGO#02	bpsd	3,380	4.2	3,380	4.2	3,380	4.2	3,380	4.2	
VR#02	bpsd	30,420	37.5	30,420	37.5	30,420	37.5	30,420	37.5	
Lube Surplus	bpsd	5,650	7.0	5,650	7.0	5,650	7.0	5,650	7.0	
C.F.O	bpsd	5,270	6.5	5,270	6.5	5,270	6.5	5,270	6.5	
Total	bpsd	81,220	100.0	81,220	100.0	81,220	100.0	81,220	100.0	
Product										
LPG	ton/d	1,535	-	1,222	-	1,222	-	992	-	
	bpsd	17,682	21.8	14,105	17.4	14,105	17.4	11,441	14.1	
Naphtha	bpsd	1,409	1.7	5,070	6.2	5,070	6.2	9,676	11.9	
Diesel	bpsd	13,682	16.8	21,899	27.0	21,899	27.0	22,010	27.1	
FCC Gasoline	bpsd	32,281	39.7	29,170	35.9	29,170	35.9	23,585	29.0	
LCO	bpsd	5,292	6.5	3,200	3.9	3,200	3.9	2,497	3.1	
DCO (for Heavy Oil)	bpsd	3,146	3.9	2,259	2.8	262	0.3	1,766	2.2	
Sulfur	ton/d	485	-	485	-	494	-	501	-	
Export Syngas (foe)	bpsd-foe*	4,089	-	1,861	-	3,537	-	6,496	-	
	MW equivalent	154	-	70	-	133	-	244	-	Power generation outside complex
H2	mmscfd	70	-	70	-	70	-	70	-	To Existing Refinery
LPG + C5+ liquid Total	bpsd	73,492	90.5	75,703	93.2	73,706	90.7	70,975	87.4	
C5+ liquid Total	bpsd	55,810	68.7	61,598	75.8	59,339	73.1	59,534	73.3	

*foe(Fuel Oil Equivalent): 9,776 kcal/kg

Table 3.2-3 Fuel Energy Balance around FCC Complex

(unit: mmkcal/h)

	SDA Case	Eureka (Solid Gasification)	Eureka (Liquid Gasification) (For Reference)	Delayed Coker (For Reference)	Remarks
Fuel production					
Off gas	170	252	252	446	
Syngas	465	304	415	328	excluding syngas for H2
Total	635	555	666	774	
Fuel consmption	-380	-440	-446	-370	Internal use
Export Fuel to outside Complex					
Syngas	254	116	220	404	
	(154MW)	(70MW)	(133MW)	(244MW)	Electric power equivalent to syngas, assuming Gas turbine combined cyele.

Table 3.2-4 Capacity of Process Facility

		SDA	Eureka (Solid pitch)	Eureka (Liquid pitch) (Reference)	Delayed Coker (Reference)	Remarks
VDU	kbpsd	36.5	36.5	36.5	36.5	
SDA	kbpsd	49.4				
Eureka	kbpsd		49.4	49.4		
Delayed coker	kbpsd				49.4	
Gasification_Liquid	ton/h	116		112		
Gasification_Solid	ton/h		98		106	
H2 manufacturing from syngas	mmscfd	127	115	115	110	
DAO HDS	kbpsd	60.2				
HDS	kbpsd		63.3	63.3	59.9	
RFCC	kbpsd	52.1				
FCC	kbpsd		42.4	42.4	34.3	
Gasoline HT	kbpsd	32.3	29.2	29.2	23.6	
Amine regenerator/Sulfur recovery	ton/d	485	485	494	501	
Sour Water Stripper	ton/h	61	146	146	90	

Table 3.2-5 Product Properties

		Specification	SDA	Eureka (Solid Gasification)	Eureka (Liquid Gasification) (For Reference)	Delayed Coker (For Reference)	Remarks
Mixed LPG							
C3/C4	wt%/wt%	-	41/59	43/57	43/57	43/57	
Olefins	-	-	<0.5%	<0.5%	<0.5%	<0.5%	While hydrotreating is envisaged, but olefins content is tentative figure.
Naphtha							
Specific gravity	d60/60F	-	0.735	0.731	0.731	0.731	
Sulfur	ppm	-	45	<5	<5	<5	
Diesel							
Specific gravity	d60/60F	-	0.835	0.835	0.835	0.835	
Sulfur	ppm	<50	50	18	18	18	
FCC Gasoline							
Specific gravity	d60/60F	-	0.734	0.732	0.732	0.732	
Sulfur	ppm	<10	<10	<10	<10	<10	
RON	-	>90-91	92.8	93.3	93.3	93.3	
LCO							
Specific gravity	d60/60F	-	0.959	0.955	0.955	0.947	
Sulfur	wt%	-	0.37	0.11	0.11	0.17	
Nitrogen	ppm	-	480	333	335	371	
Viscosity@50deg.C	cSt	-	3-4	3-4	3-4	3-4	
DCO							
Specific gravity	d60/60F	-	1.084	1.083	1.083	1.081	
Sulfur	wt%	-	1.07	0.31	0.31	0.39	
Nitrogen	ppm	-	740	522	522	572	
Viscosity@50deg.C	cSt	-	80-100	80-100	80-100	80-100	

Figure 3.2-8 Estimated Properties of DAO from NRC VR

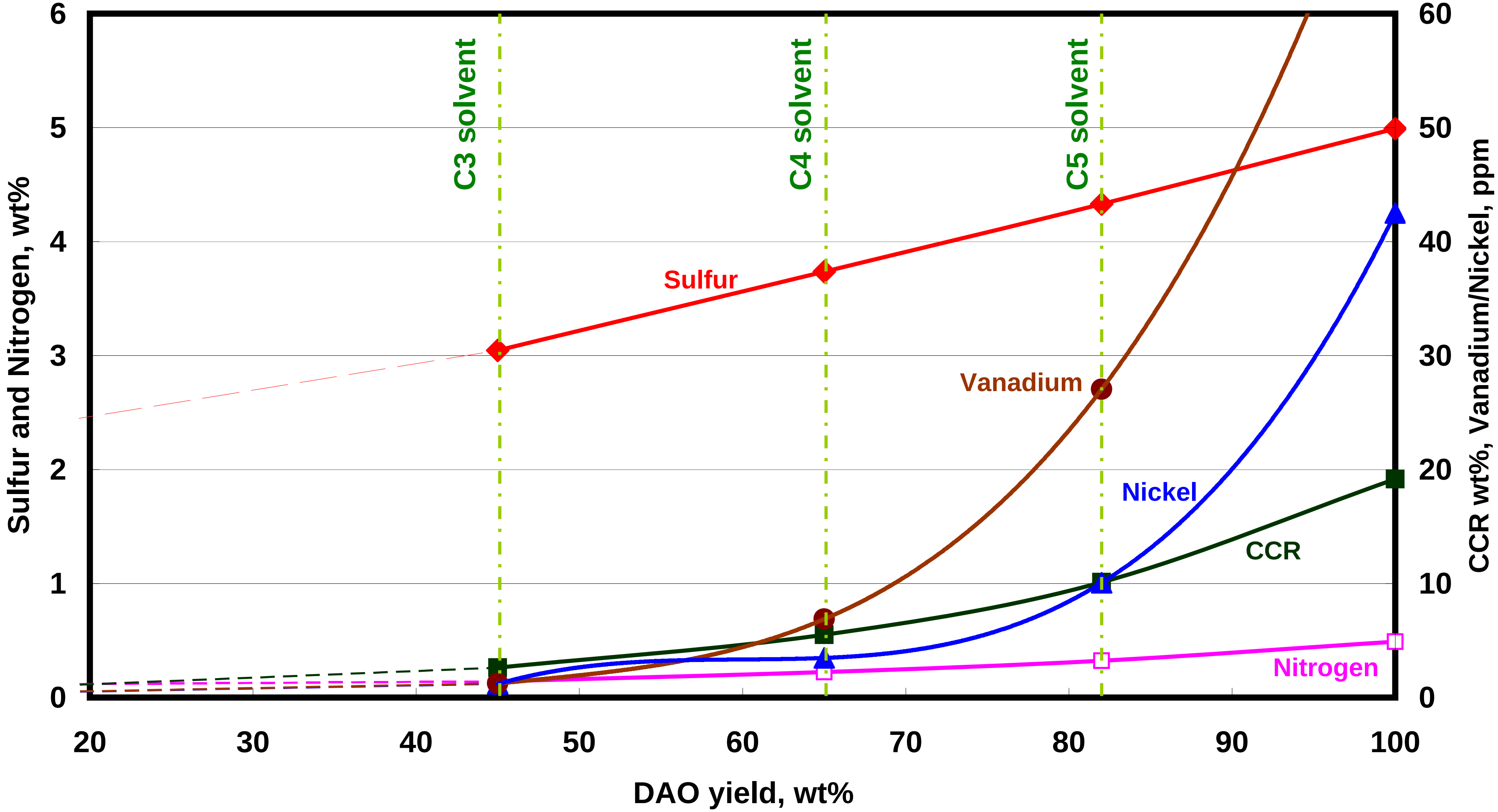


Table 3.2-6 Feedstock Definition to HDS unit

		SDA	Eureka (Solid Gasification)	Eureka (Liquid Gasification) (For Reference)	Delayed Coker (For Reference)
Charge rate					
	ton/hr	374	376	376	348
	kbpd	60.2	63.3	63.3	59.9
Property					
Specific gravity	d15/4˚C	0.9384	0.8971	0.8971	0.8778
Sulfur	wt%	3.33	2.81	2.81	2.87
Nitrogen	wt ppm	1,657	1,598	1,598	1,570
Vanadium	wt ppm	<4.2	-	-	-
Nickel	wt ppm	<2.2	-	-	-
Conradson carbon residue	wt%	3.2	-	-	-
Viscosity @50˚C	cSt	107	-	-	-
Viscosity @100˚C	cSt	14	-	-	-

Table 3.2-7 Utility Balance: SDA Case

Sections	Electric power	Fuel firing		Steam				Condensate	BFW	Cooling Water	Industrial Water	Demine. Water	Sour Water	Treated Water
				HHPS	HPS	MPS	LPS							
	MW	mmkcal/hr	foe-bbl/d	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr
Process area														
VDU	0.8	32.2	518			10.9	1.4			680			-11.3	
SDA	4.3	57.3	921			0.0	11.1						-11.1	
Gasification_Liquid	67.1			-225.3		13.1	10.5	-26.5	299.3		9.5			-25.9
H2 Manufacturing from Syngas	8.9			51.9		42.9	20.8		16.3	3799	17.3		-0.9	
DAO HDS	4.7	44.8	720		25.8		-24.6		10.1	233			-10.1	
RFCC	3.8	37.5	603			18.6	10.3	-1.5		1190			-26.0	
Gasoline HT	1.7	2.8	44		5.2	32.3		-43.5		186				
LPG Recovery	14.4					-3.5		-27.9		3134				
Amine regenerator/Sulfur recovery	2.2	11.3	181			-48.0	25.6	27.5		407			-1.5	
Sour Water Stripper	0.1	1.5	24				15.0	-15.0		217			60.9	-60.3
Fuel gas header		-380.4	-6,118											
Utility area														
Steam turbine generator	-46.5			311.4	-31.0	-66.2	-127.1	-87.1		4024				
Gas turbine generator/HRSG	-65.3	193.1	3106	-138.0					139.4					
Demineralizer	0.1										245.8	-234.0		
Deaeration	0.2						57.0	174.0	-465.1			234.0		
Cooling water system	3.5									-13868	346.7			
Industrial water intake	0.1													
Balance closure	0	0	0	0	0	0	0	0	0	0	619	0	0	-86

Table 3.2-8 Utility Balance: Eureka Case (Solid Gasification)

Sections	Electric power	Fuel firing		Steam				Conden sate	BFW	Cooling Water	Industrial Water	Demine. Water	Sour Water	Treated Water
				HHPS	HPS	MPS	LPS							
	MW	mmkcal/hr	foe-bbl/d	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr
Process area														
VDU	0.8	32.2	518			10.9	1.4			680			-11.3	
Eureka	6.4	121.4	1,953	50.6			-8.7	-51.2	110.8	4262			-100.7	
Gasification_Solid	51.1			-171.7		9.8	9.3	-19.9	234.1		10.3			-19.8
H2 Manufacturing from Syngas	8.1			47.0		38.8	18.8		14.7	3441	15.7		-0.8	
HDS	4.9	47.0	757		27.1		-25.8		10.6	245			-10.6	
FCC	3.1	30.5	491			15.2	8.4	-1.2		970			-21.2	
Gasoline HT	1.6	2.5	40		4.7	29.2		-39.3		168				
LPG Recovery	11.4					-2.8		-22.3		2495				
Amine regenerator/Sulfur recovery	2.2	11.3	181			-48.1	25.6	27.5		407			-1.5	
Sour Water Stripper	0.3	3.6	58				36.1	-36.1		520			146.1	-144.7
Fuel gas header		-439.7	-7,072											
Utility area														
Steam turbine generator	-25.0			219.3	-31.8	-53.0	-124.8	-9.8		450				
Gas turbine generator/HRSG	-68.7	191.1	3074	-145.2					146.7					
Demineralizer	0.1										320.6	-305.3		
Deaeration	0.2						59.7	152.1	-517.1			305.3		
Cooling water system	3.4									-13638	341.0			
Industrial water intake	0.1													
Balance closure	0	0	0	0	0	0	0	0	0	0	686	0	0	-165

Table 3.2-9 Utility Balance: Eureka Case (Liquid Gasification) (For Reference)

Sections	Electric power	Fuel firing		Steam				Condensate	BFW	Cooling Water	Industrial Water	Demine. Water	Sour Water	Treated Water
				HHPS	HPS	MPS	LPS							
	MW	mmkcal/hr	foe-bbl/d	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr
Process area														
VDU	0.8	32.2	518			10.9	1.4			680			-11.3	
Eureka	6.4	121.4	1,953	50.6			-8.7	-51.2	110.8	4262			-100.7	
Gasification_Liquid	58.4			-196.4		11.3	10.6	-22.8	267.8		11.8			-22.7
H2 Manufacturing from Syngas	8.0			47.0		38.8	18.8		14.8	3438	15.6		-0.8	
HDS	4.9	47.0	757		27.1		-25.8		10.6	245			-10.6	
FCC	3.1	30.5	491			15.2	8.4	-1.2		970			-21.2	
Gasoline HT	1.6	2.5	40		4.7	29.2		-39.3		168				
LPG Recovery	11.4					-2.8		-22.3		2495				
Amine regenerator/Sulfur recovery	2.2	11.5	184			-49.0	26.1	28.0		414			-1.5	
Sour Water Stripper	0.3	3.6	58				36.2	-36.2		520			146.2	-144.7
Fuel gas header		-446.4	-7,181											
Utility area														
Steam turbine generator	-31.3			247.0	-31.8	-53.5	-131.4	-30.3		1399				
Gas turbine generator/HRSG	-70.1	197.7	3179	-148.1					149.6					
Demineralizer	0.1										329.9	-314.2		
Deaeration	0.2						64.5	175.0	-553.7			314.2		
Cooling water system	3.7									-14592	364.8			
Industrial water intake	0.2													
Balance closure	0	0	0	0	0	0	0	0	0	0	722	0	0	-167

Table 3.2-10 Utility Balance: Delayed Coker Case (For Reference)

Sections	Electric power	Fuel firing		Steam				Conden sate	BFW	Cooling Water	Industrial Water	Demine. Water	Sour Water	Treated Water
				HHPS	HPS	MPS	LPS							
	MW	mmkcal/hr	foe-bbl/d	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr	ton/hr
Process area														
VDU	0.8	32.2	518			10.9	1.4			680			-11.3	
Delayed Coker	10.7	62.5	1,005		54.1	1.9		-66.5	29.2	2820	36.2		-49.3	
Gasification_Solid	55.2			-185.4		10.6	10.0	-21.5	252.9		11.1			-21.4
H2 Manufacturing from Syngas	7.7			45.2		37.3	18.1		14.2	3308	15.0		-0.8	
HDS	4.6	44.5	716		25.6		-24.4		10.0	232			-10.0	
FCC	2.5	24.7	397			12.3	6.8	-1.0		783			-17.1	
Gasoline HT	1.3	2.0	32		3.8	23.6		-31.8		136				
LPG Recovery	9.3					-2.3		-18.0		2025				
Amine regenerator/Sulfur recovery	2.2	11.6	186			-49.5	26.4	28.4		419			-1.5	
Sour Water Stripper	0.2	2.3	36				22.3	-22.3		321			90.1	-89.2
Fuel gas header		-370.2	-5,954											
Utility area														
Steam turbine generator	-32.5			279.1	-83.5	-44.7	-110.6	-40.3		1859				
Gas turbine generator/HRSG	-65.7	190.5	3064	-138.9					140.3					
Demineralizer	0.0										234.8	-223.6		
Deaeration	0.2						50.2	172.8	-446.6			223.6		
Cooling water system	3.2									-12582	314.5			
Industrial water intake	0.1													
Balance closure	0	0	0	0	0	0	0	0	0	0	604	0	0	-111

Table 3.6-1 Capacity of Utility Facility

		SDA	Eureka (Solid Gasification)	Eureka (Liquid Gasification) (For Reference)	Delayed Coker (For Reference)	Remarks
Gas turbine generator	MW	24 X 3	24 X 3	24 X 3	24 X 3	
HRSG	ton/h	55 X 3	55 X 3	57 X 3	55 X 3	
Steam turbine generator	MW	25 X 2	15 X 2	18 X 2	18 X 2	
Demineralizer	ton/h	240 X 1	310 X 1	320 X 1	240 X 1	
Cooling water system (⊿T=11deg.C)	ton/h	15,000 X 1	15,000 X 1	16,000 X 1	14,000 X 1	
Fresh Water Treatment	ton/h	750 X 1	830 X 1	870 X 1	870 X 1	

Table 3.6-2 List of Storage; SDA Case

Service	Existing or New	Type of storage	Number of unit	Installed tankage: Inside diameter, m	x	Installed tankage: Height, m	Installed tankage: Gross capacity, k-m3	Installed tankage: Net woring capacity, k-m3	Total capacity: Gross capacity, k-m3	Total capacity: Net woring capacity, k-m3	Strage Time, days	Remarks
I. Existing storage utilized for the FCC Complex (Use of existing storage should be discussed on next stage.)												
HDS charge tank (Lube surplus + VGO#02)	Existing	Cone roof	1	-		-	-	1.4	-	1.4	1.0	Insuration & heating
AR (RCR) tank	Existing	Cone roof	1	-		-	-	5.8	-	5.8	1.0	Insuration & heating
VR (VR#02) tank	Existing	Cone roof	1	-		-	-	4.8	-	4.8	1.0	Insuration & heating
Hydrocracker unconverted oil (CFO) tank	Existing	Cone roof	1	-		-	-	0.8	-	0.8	1.0	Insuration & heating
II. Newly installed storage												
LPG tank	New	Spherical	2	26.2		-	9.4	8.4	18.7	16.9	6.0	
Naphtha tank	New	Floating roof	2	8.2	x	14.0	0.7	0.7	1.5	1.3	6.0	
Diesel tank	New	Cone roof	2	21.8	x	19.5	7.3	6.5	14.5	13.1	6.0	
FCC Gasoline Tank	New	Floating roof	2	33.4	x	19.5	17.1	15.4	34.2	30.8	6.0	
LCO tank	New	Cone roof	2	15.4	x	15.0	2.8	2.5	5.6	5.0	6.0	
DCO tank	New	Cone roof	2	11.9	x	15.0	1.7	1.5	3.3	3.0	6.0	
Solid sulfur silo	New	Silo for pelletized sulfur	2	8.5	x	15.0	0.8	0.8	1.7	1.5	6.0	
Cracked slops	New	Cone roof	1	12.8	x	17.0	2.2	2.0	2.2	2.0	0.3	
Hot slops	New	Cone roof	1	16.4	x	17.0	3.6	3.2	3.6	3.2	0.3	Insuration & heating

Table 3.6-3 List of Storage; Eureka Case

Service	Existing or New	Type of storage	Number of unit	Installed tankage: Inside diameter, m	x	Height, m	Gross capacity, k-m3	Net woring capacity, k-m3	Total capacity: Gross capacity, k-m3	Net woring capacity, k-m3	Strage Time, days	Remarks
I. Existing storage utilized for the FCC Complex (Use of existing storage should be discussed on next stage.)												
HDS charge tank (Lube surplus + VGO#02)	Existing	Cone roof	1	-		-	-	1.4	-	1.4	1.0	Insuration & heating
AR (RCR) tank	Existing	Cone roof	1	-		-	-	5.8	-	5.8	1.0	Insuration & heating
VR (VR#02) tank	Existing	Cone roof	1	-		-	-	4.8	-	4.8	1.0	Insuration & heating
Hydrocracker unconverted oil (CFO) tank	Existing	Cone roof	1	-		-	-	0.8	-	0.8	1.0	Insuration & heating
II. Newly installed storage												
LPG tank	New	Spherical	2	24.3		-	7.5	6.7	14.9	13.5	6.0	
Naphtha tank	New	Floating roof	2	15.6	x	14.0	2.7	2.4	5.4	4.8	6.0	
Diesel tank	New	Cone roof	2	27.5	x	19.5	11.6	10.4	23.2	20.9	6.0	
FCC Gasoline Tank	New	Floating roof	2	31.8	x	19.5	15.5	13.9	30.9	27.8	6.0	
LCO tank	New	Cone roof	2	13.4	x	12.0	1.7	1.5	3.4	3.1	6.0	
DCO tank (Solid Gasification)	New	Cone roof	2	10.3	x	14.4	1.2	0.8	2.4	1.5	6.0	
DCO tank (Liquid Gasification)	New	Cone roof	2	5.0	x	7.0	0.1	0.0	0.3	0.0	6.0	In case of Liquid Gasification (For reference)
Solid sulfur silo	New	Silo for pelletized sulfur	2	9.5	x	12.0	0.9	0.8	1.7	1.5	6.0	
Diluent Tank (Liquid Gasification)	New	Cone roof	1	6.1	x	12.0	0.4	0.3	0.4	0.3	1.0	In case of Liquid Gasification (For reference)
Cracked slops	New	Cone roof	1	12.8	x	17.0	2.2	2.0	2.2	2.0	0.3	
Hot slops	New	Cone roof	1	16.4	x	17.0	3.6	3.2	3.6	3.2	0.3	Insuration & heating

Table 3.6-4 List of Storage; Coker Case (For Reference)

Service	Existing or New	Type of storage	Number of unit	Installed tankage					Total capacity		Strage Time, days	Remarks
				Inside diameter, m	x	Height, m	Gross capacity, k-m3	Net woring capacity, k-m3	Gross capacity, k-m3	Net woring capacity, k-m3		
I. Existing storage utilized for the FCC Complex (Use of existing storage should be discussed on next stage.)												
HDS charge tank (Lube surplus + VGO#02)	Existing	Cone roof	1	-		-	-	1.4	-	1.4	1.0	Insuration & heating
AR (RCR) tank	Existing	Cone roof	1	-		-	-	5.8	-	5.8	1.0	Insuration & heating
VR (VR#02) tank	Existing	Cone roof	1	-		-	-	4.8	-	4.8	1.0	Insuration & heating
Hydrocracker unconverted oil (CFO) tank	Existing	Cone roof	1	-		-	-	0.8	-	0.8	1.0	Insuration & heating
II. Newly installed storage												
LPG tank	New	Spherical	2	22.6		-	6.1	5.5	12.1	10.9	6.0	
Naphtha tank	New	Floating roof	2	19.0	x	18.0	5.1	4.6	10.3	9.2	6.0	
Diesel tank	New	Cone roof	2	28.7	x	18.0	11.7	10.5	23.3	21.0	6.0	
FCC Gasoline Tank	New	Floating roof	2	28.6	x	19.5	12.5	11.2	25.0	22.5	6.0	
LCO tank	New	Cone roof	2	11.8	x	12.0	1.3	1.2	2.6	2.4	6.0	
DCO tank	New	Cone roof	2	10.0	x	12.0	0.9	0.8	1.9	1.7	6.0	
Solid sulfur silo	New	Silo for pelletized sulfur	2	8.6	x	15.0	0.9	0.8	1.7	1.6	6.0	
Cracked slops	New	Cone roof	1	12.8	x	17.0	2.2	2.0	2.2	2.0	0.3	
Hot slops	New	Cone roof	1	16.4	x	17.0	3.6	3.2	3.6	3.2	0.3	Insuration & heating

Table 3.8-1 Facility in the FCC Complex

Facilities		
Process facility		
	Vacuum distillation	
	Vacuum residue processing	
		SDA or Eureka or Delayed coker
	Residue (Asphaltene or Pitch or Coke) Gasification	
	H2 manufacturing from syngas	
	Acid gas removal from syngas	
	Distillate HDS or DAO HDS	
	VGO FCC or Residue FCC	
	Gasoline Hydrotreater	
	Amine regenerator/Sulfur recovery	
	Sour Water Stripper	
Utility facility		
	Gas trubine generators	
	HRSG (Heat recovery steam generator)	
	Steam turbine generators	
	Demineralization unit	
	Cooling water system	
	Fresh water treatment system	
Offisite facility		
	Storage facility	
	Flare system	
	Fire fighting system	
	Solid sulfur and Coke handling facilities	
	Waste water treatment system	

Chapter 4 Development of Project Execution Plan

This Chapter describes the proposed project execution plan of the Project.

4.1 General Conditions for Execution Plan Development

4.1.1 FEED/EPC contractor's selection

A reference list, attached hereto as Table 4.1-1, has been prepared and it contains candidate of FEED/EPC engineering contractors with the following qualifications;

- Project execution planning capacity
- Technical capability
- Project manpower availability
- Corporate quality systems
- Safety systems and safety records
- Corporate financial reliability
- Preferably contractors having;
  - experiences in the selected process
  - experiences in the existing plant
  - knowledge with interface with existing plant for tie-in study

The above mentioned items should be evaluated prior to proceeding with any further bidding steps. Because of the large magnitude of the investment, FEED/EPC contractor, who executes and leads the Project to a successful completion as the prime engineering contractor, should be well-experienced in the implementation of projects of a similar size and nature. It should have a thorough understanding of the Project requirements and should be able to work, and form a mutual trusting relationship among the stakeholders.

4.1.2 Local Contractor Selection

The Consultant has only limited information on potential local contractors due to difficulties in obtaining information in Iraq. MOO/NRC has kindly provided the Consultant with the list of several companies that have been engaged by and worked with MOO/NRC in the Baiji Refinery as maintenance contractors (see Table 4.1-2 attached). The Consultant also received confirmation from MOO/NRC that these companies have excellent capabilities, which has been well-proven in their performance of maintenance and construction works. Such information could be helpful and worthwhile.

As a reference, the Consultant has prepared a list of internationally capable prime and/or second (if any) construction contractors in Table 4.1-3.

4.2 General Project Execution Schemes and Phase

The Project execution consists of two (2) major phases.

i) Front-End Engineering Design (FEED)

ii) Engineering, Procurement and Construction (EPC)

Given that attainment of transparency, the Consultant strongly recommends that all activities should be undertaken by a single contractor from the following reasons;

- High and consistent quality of the FCC Complex design
- Seamless implementation of FEED and a smooth transition to and execution of EPC
- Time saving by shortening the duration of the Project implementation
- Cost effectiveness

The discussion held during the second meeting between MOO/NRC and the Consultant covered the following.

- A single FEED/EPC contractor could provide a comprehensive and effective transfer of engineering and design technology. The FCC complex has complicated process systems with many interfaces that require in-depth consideration, therefore obtaining the design integrity and consistency concepts approach throughout FEED and EPC phases is important.
- Separate FEED and EPC phases, with different contractors, would require duplication of some activities in the period from start of design to completion of construction works (See Chapter 4.6), as well as EPC contractor having to go through a learning curve before its design work can begin in earnest.
- The former of above two items will consequently contribute to a cost reduction on the Project. Attaining a high quality of design in the early phase will avoid the requirement for re-works to be undertaken and minimize design changes which would reflect to EPC cost. Also, a fast track execution schedule would facilitate earlier production, with all the benefits that would bring to the Iraqi economy.

4.3 Front End Engineering Design (FEED)

FEED should be conducted to obtain basic engineering and design information, which would be based on the recommended process scheme considered in the Survey. Further detailed technical information would be developed during FEED phase, especially for equipment and package facilities comprising the units dedicated for the FCC complex. FEED work activities and deliverables are as summarized in Table 4.3-1 attached.

A key element required for FEED contractor is the efficiency of its execution planning. Execution planning should be comprehensive and flawless since any defects in FEED work will impact on the Project quality in EPC phase.
The following will be considered during FEED phase with a view to efficient Project execution.

1) Identifying of LLIs (Long Lead Items)

   Equipment engineering and design performed in the early stage of a project helps procurement activities, particularly those for equipment with a long-lead delivery time. Firm specifications shown in requisitions can be distributed to potential equipment vendors, which will provide them with sufficient time to prepare their quotations. In return, FEED contractor is able to determine more accurate EPC schedule and duration by investigation of delivery periods, availability of materials or potential issues may arise during manufacturing.

2) Critical Path Analysis

   Critical procurement or any activities of concern should be highlighted by including them on the critical path in FEED work schedule. MOO/NRC and FEED contractor will establish an expected level 3 or 4 EPC schedule based on the most updated market information around the world obtained through FEED contractor's survey and investigation.

   The critical path analysis method with a detailed networked schedule is conducted to prevent any foreseeable potential obstacles from arising during execution of EPC. MOO/NRC and FEED contractor will identify and prioritize EPC activities.

   Resource availability is also an important constraint during execution of EPC. Loading of relevant resources and their availability can be verified through the critical path analysis.

3) Health, Safety and Environment (HSE) Approach

   MOO/NRC and FEED contractor should not ignore environmental impact assessment and other related activities. Among the governmental regulations on social affairs in any country, those related to environmental impact are very important and should be properly assessed with quantitative figures taken off through the early engineering work and summarized in a report for authority approval. The following HSE activities will be addressed during FEED work:

- Preliminary Risk Register
- Environmental Aspect and Impact Register
- Preliminary Environmental Protection Plan
- Preliminary Project HSE Plan
- HAZID Study
- Preliminary Environmental Impact Assessment (EIA)

4) Design Quality

Design quality is other important aspect of FEED work, which should be as comprehensive as possible in order to avoid any re-works and to minimize design changes in the future EPC engineering phase. A low quality of design deliverables from FEED will affect EPC schedule and, consequently, the overall quality of the Project. Therefore, the Consultant suggests that MOO/NRC should select an international prime FEED/ EPC contractor capable for delivering a high quality design and with the extensive experience in such activities.

5) Budget Cost Estimate

A more precise and detailed budget cost estimate of the Total Investment Cost (TIC) for EPC phase can be achieved on the basis of the quality and amount of accurate information obtained through FEED phase.

6) Other activities/ constraints

FEED contractor, as a minimum requirement, should prepare and issue the deliverables as described as above. In addition, it is imperative that the following constraints should be addressed during FEED.

i) Logistical impediments of inland transportation

Currently the Consultant has limited information on local transportation, ports for unloading, available routes and other factors related to local logistics. This will be addressed and plans will be proposed during FEED activities.

ii) Geotechnical deterioration or collapse of the existing equipment foundations:
Collapse of the existing equipment foundations, mainly in Salahaddin Refinery areas, were discussed during the third meeting held in Amman in December 2009. The Consultant recommended that further investigation, including undertaking a site survey, should be addressed during FEED phase in order to judge if there are any impact on the planned area for FCC complex facility for further unpredictable collapses.

4.4 Engineering Procurement and Construction (EPC)

The Project will enter into the detailed engineering/design step, in which FEED information is further developed into proper and firm specifications to purchase the equipments/ materials. The engineering activities during EPC phase will spread into all areas, not only for the process units but also the utility and offsite facilities. Features of the facilities, specifications and the activities to be undertaken are also fixed during this phase. EPC work activities are as summarized in Table 4.4-1. Several important points in execution are described hereunder.

1) Engineering phase
All the necessary works will be performed in accordance with the critical path schedule that was pre-determined during FEED phase.

HSE
EPC contractor will be required to incorporate the HSE requirements correctly into design, including the initial detail engineering phase, through the construction phase to the pre-commissioning and commissioning phases. As well as HSE matters, it is also mandatory that ergonomics should be afforded full consideration in the design and engineering of such a huge project. Only a high quality EPC contractor, with past proven experience on similar projects, will be able to execute the above described engineering work properly.

Early Completion of HAZOP/ SIL Studies
The HAZOP study and SIL study should be undertaken, and operability matters resolved, at such a time when the effects of the outcome of the meeting can be implemented into the Project quality matters and the schedule. It is therefore essential that this study should be carried out as early as possible and reflects to the design.

Early Design Freeze

In order to maintain the Project schedule, particularly the construction activities at the site, an early design freeze is required to avoid unnecessary engineering manpower due to prolonged duration of design/engineering activities.

For the efficient and effective use of engineering manpower, MOO/NRC and EPC contractor should understand that design freeze needs to be established at a reasonable and early stage and effectively coordinated in accordance with critical path analysis of EPC schedule.

2) Procurement phase

International procurement from major countries such as Japan, East Asia, Europe and United States, will be considered for the Project for both dedicated equipment and construction bulk materials. EPC contractor should therefore be required to have a global knowledge for procurement of equipment/ bulk materials as well as having experience from similar past activities, vendor information such as shop fabrication availability, material procurement capability and shop inspection ability. The contractor should also have a thorough working knowledge of international codes and standards that assure product quality.

Procurement plans should be developed prior to commencement of the activities covering purchasing, inspection & quality control and procurement management related to all the materials and equipment needed for the Project. A typical procurement organization is shown below:

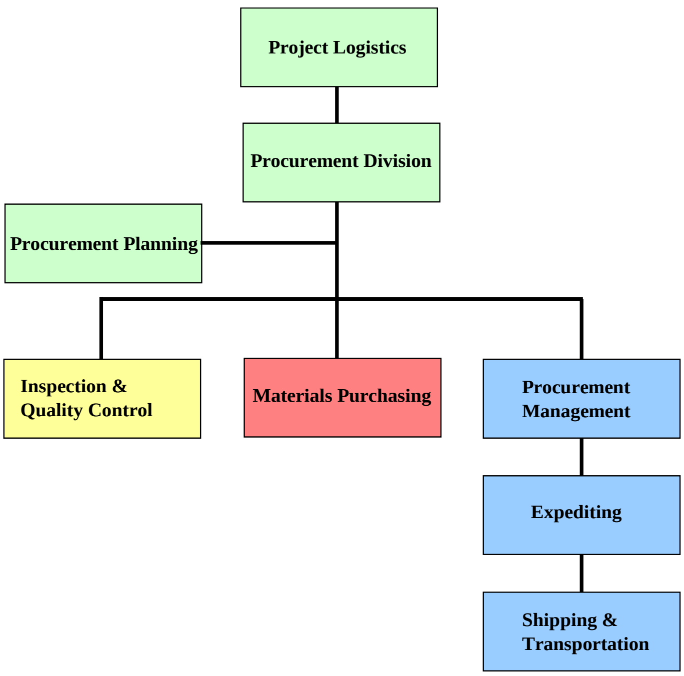


Figure 4.4-1 A typical procurement organization

In order to manage the status of purchased equipment/materials from placing the purchase order up to its erection at site, a sophisticated management system is normally used, which has a function to alert procurement personnel and prevent any material shortage that may impacts on EPC schedule.

<u>Logistics and Custom Clearance</u>

As it is expected that huge volumes of cargo will arrive at site for the Project, advance planning of offloading facilities is important so that imported equipment and materials can be received on time to meet the construction schedule. This will apply not only for delivery of cargos of Project equipment, but also EPC contractor's, or their subcontractors' own construction equipment and/or construction materials.

In order to develop an appropriate unloading plan, EPC contractor should, at an early stage in EPC phase, investigate the situation in existing ports that are suitable for the Project logistics and be fully aware of Iraqi regulations, including those related to custom clearance.

3) Construction Activities

<u>Temporary Facilities Area</u>

A vast lay-down area will be required for the temporary storage area and stockpiling of bulk materials and equipment. In addition, a camp for the construction labor force will also be required for construction activities. Although the final requirements will come from EPC contractor when they made a volumetric estimation of total plant construction materials, a preliminary estimation should be made available during FEED phase.

<u>Constructability Study</u>

Constructability studies should be carried out during the early EPC phase, where the following should be properly addressed:

- Construction Sequence
- Heavy Transportation
- Heavy Lifting with Rigging Study

Recent trends in construction show that the following construction methods are becoming more and more preferable as they provide higher efficiency compared with orthodox methods such as "prefabrication" and "pre-casting". Furthermore, these methods can contribute to safe construction because of being able to reduce the number of activities and, therefore, the work force at the construction site:

- Modularization
- Pre-Assembly
- Full Dress-up
- Auto-Welding

EPC contractor should recognize that optimized construction productivity is an important factor affecting construction progress which can decide whether or not a certain construction method is deployed.
In addition, the Consultant suggests that the following factors also greatly assist in optimizing productivity:

Factor - Site Conditions

- Early Completion of TSF (Temporary Site Facilities)
- IIF (Incident and Injury Free at the Job Site)
- PMC (Pre-Mechanical Completion) Oriented Construction Schedule
- Clean Work Field Conditions
- Maximize Utilization of Efficient Construction Methods (above)

4.5 Project Management Plan

MOO/NRC will establish the Project Office (PO) in the organization of the company, which will be responsible for management of the Project execution.

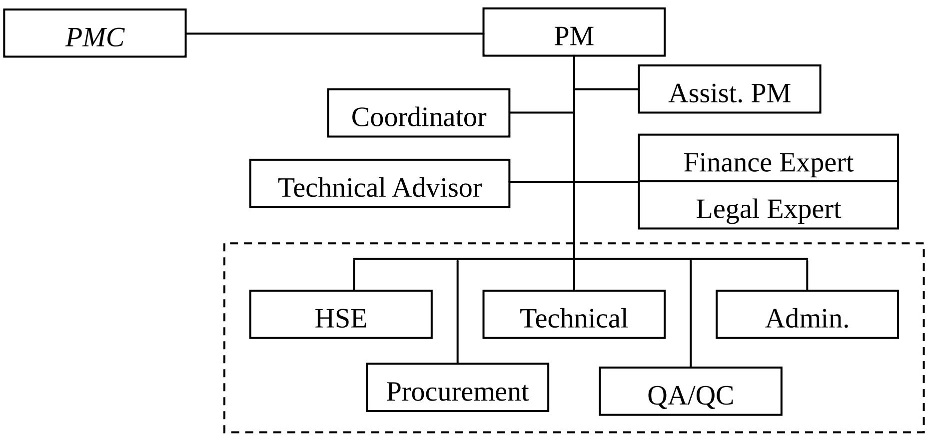


Figure 4.5-1 Project Management Scheme

The PO will consist of the technical groups in charge of Onsite and Offsite facilities, the HSE group, material procurement, quality assurance/quality control (QA/QC) group as well as administration group necessary for management of the project operation.

The technical groups will be responsible for the technical aspects of the project including engineering and design of the facilities and supervision of the performance of the contractor(s) in FEED and EPC phases. The QA/QC group will be responsible for the quality management for the deliverables/goods furnished by the contractor(s) and its (their) workmanship. Third-party inspectors will be employed to support the QA/QC group. An independent HSE group will be provided in the PO for implementation of the HSE and social considerations of the project.

The PO will be headed by the Project Manager, with the support of an assistant PM and a coordinator, who will be fully responsible for the management of the entire project execution and performance including schedule and budget for the project. On technical aspects, a technical advisor supports the PM along with the technical groups. On financial and legal issues, each expert will be nominated to assist the PM.

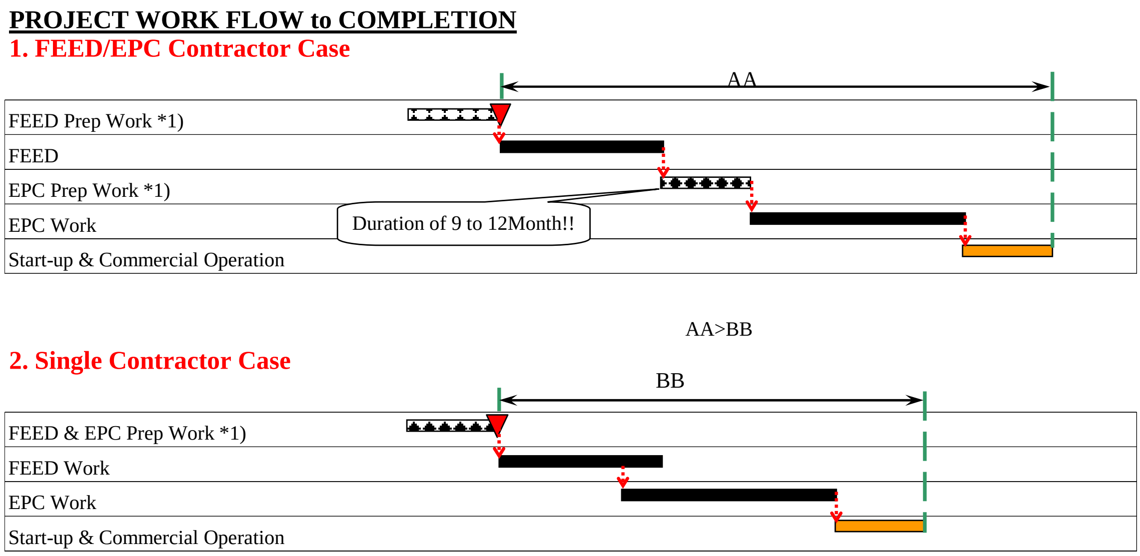
Further, MOO/NRC may employ a qualified, experienced and fair consulting firm for project management consultancy (PMC) during both FEED phase and EPC phase to render the necessary support and assistance to the PO. The responsibilities of the PMC will include the services as follows.

- Supervision of the Contractors
- Review and evaluation of the project documents provided by the Contractors and Process Licensers
- Technical support to MOO/NRC for the interfacing and related facilities
- Coordination with MOO/NRC and the contractor(s)
- Technology transfer to NRC project personnel
- Review of sub-contract, if necessary
- Other technical supports for the project management
- Japan ODA support

The proposed “Terms of Reference for PMC work” is attached at the end of this chapter.

4.6 Project Schedule

Typical schedules for the Project have been prepared as attached for better understanding of single contract, which consider all aspects of the works described in the previous chapters. The Consultant estimated FEED activities of the Project would be 15 months and 40 months for EPC phase. However, if an EPC bidding phase is adopted, normally take 9 to 10 months (sometimes one year) before EPC activities can commence, after FEED activities have been completed, for bid document preparation.



Note.1 Including Bid Document Preparation, Pre-Qualification of Bidders, Clarification & Evaluation, Contractor Selection & Contract Award

Figure 4.6-1 Project Work Flow to Completion

The Consultant recommended that a FEED contractor should be selected who, as a single contractor, can execute licensor selection and EPC work; and that the successful bidder should implement both FEED and EPC work as mentioned in Chapter 4.2.Should the Consultant's recommendation be accepted, MOO/NRC would be able to reduce the schedule, from implementation of FEED to completion of EPC, by about 9 to 12 months, consequently, save on total investment cost. MOO/NRC is able to recognize total project duration "BB" shorter than "AA" in the Figure 4.6-1.

（FEED and EPC schedules are shown in more detail in Figures 4.6-2 and 4.6-3）

For efficient Project execution, the following subjects will need to be considered specifically in

EPC engineering phase:

1) Licensor Engineering

One of important key drivers for efficient schedule control in both FEED work and EPC work is good and smooth coordination with licensors and the gathering of technical information provided through the licensor engineering. A timely information exchange on technical deliverables along with the schedule should be strictly adhered to.

2) Early Procurement

Recently, project owners have identified and defined long-lead items as a part of the early design freeze and early procurement items, depending on the period of delivery proposed by equipment vendors.

If the specifications for long lead items are firmly defined, and the status is “ready for placing order” during FEED phase, MOO/NRC can initiate procurement prior to the commencement of EPC phase so that the purchase orders for those items can be assigned from MOO/NRC to EPC contractor in the early part of EPC phase. The philosophy relating to long-lead items are outlined in chapter 4.3 1) and such items will be identified in the critical path of the Project schedule. A green bar in the attached EPC schedule is typically shown for early procurement activity of the equipment.

Table 4.1-1

International FEED/EPC Contractors

	Contractors		Notes
	BECHTEL	USA	
	CB&I LUMMUS	USA	
	CHIYODA	Japan	
	FLOUR	USA	
	FOSTER WHEELER	Britain	
	JACOBS ENGINEERING	USA	
	JGC	Japan	
	KBR	USA	
	LURGI GmbH	German	
	PETROFAC	Britain	
	SAIPEM	Italia	
	SHAW	USA	
	TECNICAS REUNIDAS	Spain	
	TECHNIP	France	
	TOYO ENGINEERING	Japan	
	WORLEY PERSONS	Australia	

Table 4.1-2

Local Subcontractors

Governmental Sub-Contractors Worked in NRC

Company Name	Ministry belonged to	Specialization	e-mail
Al-Saad State Company	Ministry of Re-building and Housing	All Specializations for Industrial & oil Projects	Saad_st_comp@yahoo.com Jassim_mutlak@yahoo.com
Al-Faw State Company	Ministry of Re-building and Housing	All Specializations for for Industrial & oil Projects	iqcfaweg@yahoo.com
Al-Hater State Company	Ministry of Industry and Minerals	Mechanical – Civil for Industrial Projects	alhaterco@yahoo.com ahmed_rathin@yahoo.com
General System Company	Ministry of Industry and Minerals	Instrumentations	dgoffice@gsc-iraq.com
SCOP	Ministry Of Oil	All Specializations for Industrial Projects	Scop_iraq@yahoo.com Scop_nod@yahoo.com

Private Sub-Contractors Worked in NRC

Al-Rafidain Company	Private Sector	Oil Projects	roscojordan@gmail.com
Al-Marjal Company	Private Sector	Mechanical – Electrical	
Al-Muutasem Company	Private Sector	Instrumentations	salemkhomar@yahoo.com.ae mutasum2000@yahoo.com

Table 4.1-3

International Construction Contractors

	Contractors	Company Origin	Notes
	AL-RUSHID Co.	Saudi Arabia	
	CONSOLIDATED CONTRACTORS INTERNATIONAL Co.	Greek	
	CTCI	Taiwan	
	M.S. AL-SWAIDI INDUSTRIAL SERVICES Co.	Saudi Arabia	
	NASSER AL HAJRI Corp.	Saudi Arabia	
	TEFKEN CONSTRUCTION and INSTALLATION Co.	Turkish	
	DODSAL	India	
	HYUNDAI	Korea	
	DAEWOO	Korea	

Table 4.3-1

Terms of Reference for FEED WORK of FCC Complex Project

	Terms of References	Descriptions	
1	**Project Objectives and Definitions**		
2	**Scope of Work**		
2.1	**Applicable Codes and Standards**		
2.2	**General Specifications Development**	Piping General Specifications	
		Project Specifications for Painting and Insulation	
		Earth Works General Specifications	
		Access and Internal Road General Plans	
		Welding General Specifications	
		General Specifications for Building and Structure	
		General Specifications for Static Equipment	
		General Specifications for Rotating Equipment	
		General Specifications for Electrical Power System	
		General Specifications for Instrumentation	
		General Specifications for Automation Control	
		General Specifications for Telecommunication	
		General Specifications for Cathodic Protection	
2.3	**Design Criteria/Philosophies Development**		
2.4	**General Arrangement Drawings Development**	GA for Main Structures	
		GA for Piping Routing	
		GA for Electrical Substations	
		Tpical Drawing for Cathodic Protection	
2.5	**BEDD**		
2.6	**HSE**		
	Environmental Protection Plan		
	Safety and Firefighting		
	Loss Prevention Plan		
	HAZID/HAZOP/SIL Study		
	Waste Management Plan		
	HSE Plan		
2.7	**Licensor Interfaces**		
	Design Basis for Licensed Units		
	Licensor Inquiry		
	Licensor Bid Tabulation		
	Licensor Evaluation		
	Licensor Selection		
	PFDs		
	Utility Consumption Summary		
	Material Selection Diagram		
	Preliminary Plot Plan		

	Terms of References	Descriptions	
	Preliminary Flare Load Summary		
	Equipment List		
	P&IDs		
	Cause and Effect Matrix		
	Process Data Sheet		
	Control Valves & PSVs Data Sheet		
	Process Design Package		
2.8	Process Engineering		
	Process Description		
	Material and Heat Balance		
	PFDs		
	Utility Consumption Summary		
	Material Selection Diagram		
	Electrical Load Summary		
	Flare Load Summary		
	Critical Equipment List		
	P&IDs		
	Cause and Effect Matrix		
	Process Data Sheet		
	Control Valves & PSVs Data Sheet		
	Process Data Sheet		
	Catalysts and Chemicals Summary		
2.9	Discipline Engineering-Piping		
	Plot Plan		
	Line List		
	Piping Class		
	Utilities and Interconnecting P&IDs		
	Preliminary Routing Study		
2.10	Discipline Engineering-Civil		
	Geotechnical and Topological Study		
	Plot Plan for Foundations		
	Drainage Plan		
	Sanitary System Plan		
	Building Design		
2.11	Discipline Engineering-Static Equipment		
	Heat Exchangers Thermal Design		
	Mechanical Sketch for Equipment	Engineering Drawings	
	Fired Heaters and Incinerators Design		
	Critical Items List		
	Equipment Summary		
	Requisitions for Critical Items		
2.12	Discipline Engineering-Rotating Equipment		
	Critical Items List		
	Requisitions for Critical Items		

	Terms of References	Descriptions	
2.13	Discipline Engineering-Package Equipment Critical Items List Requisitions for Critical Items		
2.14	Discipline Engineering-Electrical Single Line Diagram Layout of Substation Equipment Preliminary Power System Study Electrical Load Summary Electrical Equipment List Main Cable Layout Technical Specifications for Critical Equipment Technical Specifications for Cathodic System Critical Items List Requisitions for Critical Items		
2.15	Discipline Engineering-Automation Instrument and Telecomm. Instrument List Technical Specifications for Control & Safety System Technical Specifications fo r Control, On-Off & PSVs Technical Specifications for On-Line Analyzer Telecomm. System Specs. and Block Diagram Main Cable Routing and Equipment Plot Plan Control Room and Satelite Room Layout Critical Items List Requisitions for Critical Items		
3	FEED Schedule		
4	FEED Work Execution Philosophy and Plan		
5	Deliverables List		
6	Deliverables as Attachments		

	Terms of References	Descriptions	
2.13	Discipline Engineering-Package Equipment Critical Items List Requisitions for Critical Items		
2.14	Discipline Engineering-Electrical Single Line Diagram Layout of Substation Equipment Preliminary Power System Study Electrical Load Summary Electrical Equipment List Main Cable Layout Technical Specifications for Critical Equipment Technical Specifications for Cathodic System Critical Items List Requisitions for Critical Items		
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3	FEED Schedule		
4	FEED Work Execution Philosophy and Plan		
5	Deliverables List		
6	Deliverables as Attachments		

Table 4.4-1

Major Activities of EPC Works

	Major Work Activities	Descriptions	
1	<u>Project Bases</u>	to be clearly defined	☑Site Location with Site Report ☑Project Scope ☑Production Unit Capacities ☑Utility & Offsite Facilities Requirements ☑Project Master Schedule ☑Applicable Codes, Standards and General Specifications ☑Environmental Protection Plan
2	<u>Engineering Phase</u>		
2.1	Project Execution Plans	Project Management Procedures Contracting Strategy Project Organization Project WBS Project IT and Control Plan Project Procurement Plan Project Schedule Project Manning Schedule Approved Vendor list System Turn-Over Procedure	 if any
2.2	Site Survey		
2.3	BEDD-Basic Engineering Design Data		
2.4	Basic Engineering		
2.5	Detailed Engineering		
2.6	HAZOP/SIL Study		
2.7	Value Engineering		
2.8	Materials Take-off		
2.9	Requisitions Preparation		
2.10	Constructability Study		
2.11	Lifting Plan		
3	<u>Procurement Phase</u>		
3.1	Request for Quotation		
3.2	Bid Tabulation		
3.3	Bid Evaluation		
3.4	Procurements		
3.5	Procurement Expediting		
3.6	Procurement Qulaity Control - Vendor Shop Inspection		

Figure 4.6-2 FEED Schedule for Baiji Refinery FCC Complex Project

ID	タスク名
1	**1. Project Milestones**
2	Contract Award
3	Kickoff Meeting
4	FEED Planning
5	Licensor Selection
6	EPC Bid Document Preparation (Optional)
7	
8	
9	**2. Common**
10	General Specifications
11	Project Management Procedures
12	HSE
13	LOSPE
14	Quality
15	Procurement Planning
16	Construction Planning
17	
18	
19	**3. FEED Activities**
20	Licensor Interfaces
21	Plot Plan
22	PFDs
23	P&IDs
24	Process Data Sheets
25	Disciplines Engineering
26	
27	Material Selection
28	Flare Load Calculation
29	Early Procurement Information
30	
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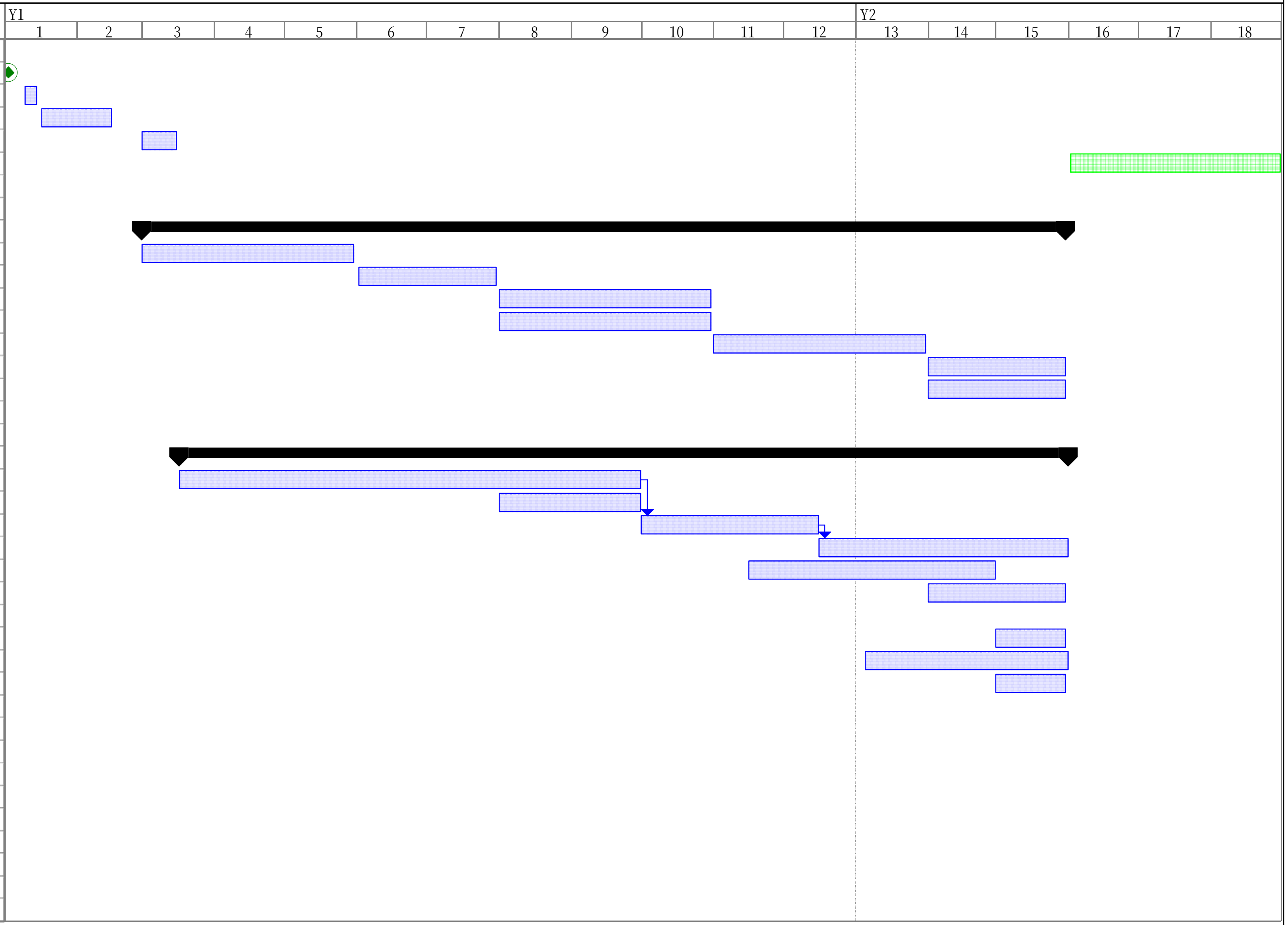


Figure 4.6-3 EPC Schedule for Baiji Refinery FCC Complex Project

For Reference

Baiji Refinery Upgrading Project

Project Management Consultancy Work
In FEED Phase

TERMS OF REFERENCE

Table of Contents

TERMS OF REFERENCE

1. Introduction

The Ministry of Oil (MOO) and North Refinery Company (NRC) intend to build a new Fluid Catalytic Cracking unit (FCC) and related facilities at the Baiji Refinery as Baiji Refinery Upgrading Project (the Project) to produce mainly gasoline as well as byproducts for domestic use.

The Project is to be partially financed under ODA (Official Development Assistance), loan sharing between Japan's government through Japan International Cooperation Agency (JICA) and the Government of Republic of Iraq.

MOO/NRC intend to execute the Front-End Engineering Design (FEED) through selected FEED Contractor (the Contractor) in engineering phase of the Project, prior to construction of the plant. MOO/NRC will be responsible in selecting the suitable process licensers of FCC process and other relevant processes with assistance of the Contractor in the earliest stage of the FEED work.
MOO/NRC require that a qualified and experienced consulting firm for project management consultancy or so called FEED Review CONSULTANT (the CONSULTANT) be employed during the FEED stage of the Project.

2. General Terms of Reference

2.1 Objectives

The CONSULTANT shall carry out, in accordance with the Contract, all necessary technical and administrative services for project management including technical support on MOO/NRC, recommendations and suggestions for engineering development, coordination with MOO/NRC and the Contractor to ensure that the completion of FEED work of the Project be a success.
MOO/NRC is to require a qualified and experienced CONSULTANT which shall undertake the assistance of project management of MOO/NRC including the following services:

- Supervision of the Contractor
- Review and evaluation of the project documents provided by the Contractor and Process Licensers
- Technical support on MOO/NRC for the interfacing and related facilities

- Coordination with MOO/NRC and the Contractor
- Technology transfer to MOO/NRC project personnel
- Review of sub-contract, if necessary

The CONSULTANT shall, for the duration of the work, assign the necessary competent personnel and other resources required to realize the objectives of this Contract.

2.2 Responsibilities of the CONSULTANT

(1) The CONSULTANT shall exercise its work with reasonable skill, care, diligence, accuracy, and completeness.
(2) The CONSULTANT shall well understand the contents and basic information of the Project including the contracts between MOO/NRC and the Contractor.
(3) The CONSULTANT shall act as a faithful adviser to MOO/NRC. MOO/NRC may, however, delegate to the CONSULTANT more or less authority to act on its behalf, from full responsibility to make final decisions to that of advisor to MOO/NRC with little authority to make decisions.
(4) The CONSULTANT shall coordinate the interfacing facilities such as the existing and on-going other projects (MOO/NRC portion) to guarantee that the implementation of the Project is done economically and efficiently in accordance with time schedules.
(5) The CONSULTANT shall advise MOO/NRC for additional works deemed necessary that will satisfy the completion requirement of MOO/NRC and JICA.
(6) In the case of a difference of opinion between the MOO/NRC and the CONSULTANT on any important matters, MOO/NRC shall allow the CONSULTANT to submit to MOO/NRC a written report for further discussion before any irreversible steps are taken in the matter.

3. Scope of CONSULTANT's Work

The scope of the CONSULTANT's work shall include, but not limited to, the following:

3.1 Supervision of FEED Work

The CONSULTANT shall review and supervise key component of the FEED works which includes, but not limited to, as follows:

- Engineering Quality:
  The CONSULTANT shall review the engineering outputs submitted from the Contractor, and supervise to maintain its quality to higher and acceptable level.
- Documentation Control:
  The CONSULTANT shall control all project documents related to the engineering and studies issued by the Contractor and MOO/NRC.
- FEED Work Schedule:
  The CONSULTANT shall review the overall and breakdown FEED work schedule (Project Implementation Schedule) proposed by the Contractor and confirm the compliance with the project schedule specified.
- Breakdown Schedule for FEED Work:
  The CONSULTANT shall review and confirm the Breakdown Schedule for FEED Work and provide any modifications that the CONSULTANT would result in a more effective and efficient schedule.
- Contract Master Schedule (CMS):
  The CONSULTANT shall prepare the overall Contract Master Schedule (CMS) indicating all the major activities and critical milestones based on the schedule prepared by the Contractor.
- Manpower Schedule:
  The CONSULTANT shall review and confirm the overall manpower schedule of the Contractor within the framework of MOO/NRC's approved CMS.
- Evaluation of the Contractor's claims and preparation of recommended course of action to be considered by MOO/NRC.
- Anticipation and assessment of delays, penalty and liquidated damages, if any, and preparation of recommendation to MOO/NRC.

3.2 Project Document Review and Evaluation

The CONSULTANT shall review and evaluate the engineering documents developed by the Contractor and the Process Licensers (FCC and the others) and provide MOO/NRC with adequate advice, comments and recommendation upon its review and evaluation results.

(1) The engineering documents which subject for review and evaluation are, but not limited to, as follows:

- Basic Engineering Design Data
- Process Design Package
- Basic Design Package
- Cost Estimation
- EPC Project Execution Plan
- EPC Tender Document Package
- Other related documents

In addition to the above, the CONSULTANT shall also review the engineering documents for interfaces in the existing facilities and related offsite facilities which are to be provided by MOO/NRC. The CONSULTANT shall also assist MOO/NRC in the design work, if requested. Further, the CONSULTANT shall coordinate all the necessary interfaces between all parties to ensure successful completion of the Project is achieved.

(2) The CONSULTANT shall review the following study reports provided by the Contractor.

- F/S review report
- Process and operations safety analysis
- Environmental Impact Assessment (EIA)
- Value engineering

3.3 Technical Support for MOO/NRC

The CONSULTANT shall coordinate appropriate interface with the related onsite and offsite facility as well as utility supplies.
The CONSULTANT shall review the related engineering documents provided by the Contractor such as tie-in points and verify the proper arrangements of the existing facilities to be tied-in. The CONSULTANT shall assist MOO/NRC for the necessary engineering work for the interfaces on the existing facility.

The CONSULTANT shall also review the utility balance between demands of the new FCC plant and available utility supplies from the existing and/or upgraded utility system. In addition, the CONSULTANT shall assist MOO/NRC to coordinate the necessary engineering for the utility supply of the Project.

3.4 Coordination between the Project and Other Projects

The CONSULTANT shall review the other on-going and planned project plans in the same refinery plant, and provide the necessary technical coordination such as project site, schedule, utility supply, etc. if they can be interacted mutually. MOO/NRC will furnish the CONSULTANT with the necessary information for its study.

3.5 Technology Transfer

Technical transfer to MOO/NRC's project personnel is one of the objectives of the CONSULTANT. The intended technical transfer program of MOO/NRC in the respective phases of the project lifecycle shall be prepared by the CONSULTANT. The CONSULTANT shall transfer its international level of the project execution technologies to the assigned MOO/NRC's project members. The technologies to be transferred in this phase are, but not limited to, as follows.

- Project management practice
- Engineering and facilities design technology
- Facilities safety analysis methods (HAZID, HAZOP, etc.)
- Environmental impact assessment and protective considerations
- Project integrity assessment method
- Execution procedure for the subsequent phase (EPC) of the Project

MOO/NRC will dispatch the selected project members from the project management office (PMO) and the North Refinery Company (NRC) to the main work place of the CONSULTANT. The technology transfer shall be made through their participations in the actual works of the CONSULTANT (on the job training: OJT) and lectures by the CONSULTANT during the project period. Therefore, the CONSULTANT is requested to prepare sufficient work spaces including furnishings, office equipment, etc. necessary for the work of the MOO/NRC's personnel. The costs for overseas travels and local transportation, accommodations and meals, etc. for the program will be covered at MOO/NRC's expense.

MOO/NRC will inform the CONSULTANT of the project members to be assigned for the program later. The CONSULTANT shall propose an effective technical transfer program to achieve the objectives to MOO/NRC at the earliest stage of the Project.

4. Project Schedule

The CONSULTANT shall commence and complete the work in accordance with the implementation schedule of the FEED works and the CONSULTANT’s work.
The CONSULTANT shall submit the overall project schedule showing the breakdown schedule and manpower allocation schedule for the works in accordance with the expected FEED activities proposed by the Contractor before the date specified by MOO/NRC after the effective date of the contract.

The CONSULTANT shall provide monthly and weekly work schedules indicating all planned activities for the following month and week during the Project.

5. Execution Procedure

5.1 Organization and Project Staffs

The CONSULTANT shall provide a capable and responsible project organization for execution of the Project consisting of the project managing staffs, professional consultants/engineers of relevant fields to the Project such as, but not limited to, technical, safety and environment, procurement, project tenders, contract, etc.

And the CONSULTANT shall provide a site office team in the organization at the site office in Baiji or nearby country for facilitation of communication and coordination with MOO/NRC project members in Baiji.

The CONSULTANT shall execute a contract with local consultant firm in Iraq, who can access and visit the site for collection of accurate information of the site and related existing facilities, witness of the site survey to be conducted by the Contractor and close communication to MOO/NRC project member at site, if needed.

The CONSULTANT shall estimate and propose a sufficient manning plan at his main work place and the site office for successful completion of the Project in accordance with the responsibility and scope of the work specified in this document.

5.2 Project Management, Control and Administration

The CONSULTANT shall manage, execute, and administer all project related activities to ensure satisfactory performance, and completion of the Work shall be in conformance with the Contract.

In order to ensure that all Work is performed to fully meet the quality, schedule, and other requirements of the Contract, the CONSULTANT shall have an efficient management organization fully supported by effective systems and procedures.

The CONSULTANT shall timely provide necessary information for appropriate decision making of MOO/NRC and JICA, which include, but not limited to, the following activities:

- A kick-off meeting to discuss the overall work schedule, project organization, project execution procedure, etc.
- Regular meetings including monthly/quarterly meetings to discuss the progress of the work, work schedule, and problems encountered and foreseen. In addition, additional meetings when occasion arises.
- Monitoring and review of the procedures and activities of the Contractor.
- Provision of the related information necessary for management, coordination, and administration of the Project.
- Advice to MOO/NRC on the progress and performance to resolve potential problems and to avoid change orders and stand-by costs.
- Management and control of the administrative and engineering documents issued by the Contractor and received from all parties.
- Collection and grasp of the necessary information of other projects and interface facilities in the same refinery related to the Project.
- Dispatch of competent staffs to the site to support the supervisory staff of MOO/NRC for solving technical issues related to interface facilities, if any.
- Dispatch of competent staffs to the Contractor to coordinate or solve the serious technical issues on behalf of MOO/NRC, if necessary.

- Establishing, administering, and assuring of security and safety requirements at all work places for its staff.
- Training of the assigned MOO/NRC members for the engineering and project management skills.

5.3 Document Control

The CONSULTANT shall be responsible for the control of all project documents related to the engineering and studies issued by the Contractor and MOO/NRC to ensure successful completion of the Project. The CONSULTANT shall conduct necessary activities, including but not limited to:

- Finalization of the documentation plan proposed by the Contractor including definition of the documents, number of copies, distribution.
- Provision of a list of the documents and information that are necessary for the engineering and study works of the Contractor.
- Registering of the documents and recording of all receipts and issues.
- Maintaining the record of document status and revisions up to date.
- Monitoring and grasp of the status of all the documentation.
- Taking necessary action to the Contractor and/or MOO/NRC at appropriate timing without delay.

The followings are necessary activities and procedures in order to follow the applicable document control system for the Project.

- Issue of the FEED documents from the Contractor to MOO/NRC and the CONSULTANT in accordance with the document control plan.
- Review of the documents by MOO/NRC and the CONSULTANT.
- Advising by the CONSULTANT based on the review results as necessary information for MOO/NRC's decision making for approval or non-approval.
- Return of the approved document from MOO/NRC to the Contractor through the CONSULTANT. If not approved, the documents shall be returned with comments.

Details of the document control procedure including the required period for document review and the documents subject to MOO/NRC's approval will be finalized in the earliest stage of the Project.

5.4 Reporting

The CONSULTANT shall prepare work reports providing all necessary information for MOO/NRC's project management within the scope of consultancy work as follows.

- Weekly/Monthly/Quarterly progress reports
- Interim Technical Review Report
- Final Technical Review Report

The format and contents of the reports must be approved by MOO/NRC. The quarterly, interim and final reports should be submitted to JICA through MOO/NRC.

In addition to the above regular reports, the CONSULTANT shall submit an occasional report to MOO/NRC for the issues of technical and management aspects of the Project to be discussed with the Contractor and/or MOO/NRC, upon necessary.

5.5 Work Place

The CONSULTANT may work mainly in its home office, but the CONSULTANT shall set up its site engineering office preferably in Baiji or in a nearby country for close coordination and contact with MOO/NRC.

The CONSULTANT shall organize a capable site office team consisting of sufficient number of project management, administrative, and consultant staffs throughout the project period. The site office shall have sufficient space and rooms for both the CONSULTANT and MOO/NRC's project staffs with necessary equipment for office operations. The CONSULTANT shall cover all operational cost for consultation activities in the offices.

In addition to the above offices, the CONSULTANT shall work at the work place of the Contractor for the meetings, witness, and review of the works, when required.
Further more, the CONSULTANT shall visit the project site for the investigation of the interfacing facilities of the related existing plants using its sub-contractor, if needed.

Chapter 5 Project Costs Estimation

5.1 Assumption

The following premises were established for cost estimation purposes.

1) Location of plant erection site for the cost estimates
   The plant erection site is at Baiji, Iraq.

2) Plant cost index
   Plant erection cost is greatly affected by the general status of the economy and the situation of supply and demand. Such situation may be considered and reflected into the estimation of plant erection cost by using the Plant Cost Index (PCI). The plant cost index, issued by Japan Machinery Center for Trade and Investment (JMCTI) in October 2009, is presented in Figure 5.1-1, in which a general PCI figure is shown as well as the Consultant's in-house data for petroleum refineries.

3) Cost estimation method
   Plant erection costs for process, utility and offsite facilities, and the owner's costs, have been estimated based on Consultant's past experience and the costs of various projects maintained in the Consultant's comprehensive database, which includes the costs of facilities erection, split into various categories of facility. Capacities, design conditions as well as geographical region of site are also taken into consideration in the estimates. The cost of the utility facilities has been estimated as a lump-sum cost including the overall system of utility supply as well as respective cost of units. The owner's cost is to be regarded as a "typical" estimate which, depending on various factors could change.

4) Accuracy of cost estimates
   The accuracy cost is estimation is in the range of +/- 30%.

5) Duration of the Project
   A Project is based on duration of 55 months (FEED 15 months + EPC 40 months) as defined in Chapter 4.6

6) Procurement
   Equipment and materials are to be purchased worldwide procurement network.

7) Owner’s Cost

The owner’s cost includes the following items, plus a 10% contingency.

- Studies and investigation
- Technology license fee
- Licensor design packages
- Basic engineering contracts
- Project management contracts
- Laboratory, maintenance and mobile equipment
- Initial catalysts
- Spare parts
- Pre-startup and startup expenses

8) Items excluded from the cost estimates

- Land acquisition cost and any related fees
- Taxes and duties
- Fee for regulatory permissions
- Charging cost of feedstock residues from the existing facilities to the FCC complex
- Security Cost

5.2 Project Cost (CAPEX)

The facility cost is any cost to be charged to installation of facilities, regardless of the types of investment. Table 5.1-1 presents the Total Investment Cost for this FCC complex project (Mid. 2009 base). Physical contingency is excluded.

5.3 Disbursement Schedule on Facility and Owner’s Costs during Construction Period

The following schedule shows the typical pattern for disbursement of facility and owner’s costs during construction.

- First year: 1.2%
- Second year: 17.8%
- Third year: 37.0%
- Fourth year: 28.0%
- Fifth year: 16.0%

5.4 Operating Cost (OPEX)

The operating cost is summarized in Table 5.1-2.
The operating cost is estimated on the following bases.

- Maintenance cost: 3.0% p.a. on facility cost
- Insurance: 0.2% p.a. on facility cost
- Operating supply cost: 0.25% p.a. on facility cost
- Number of employee and man power allocation is presented in Table 5.1-3, 5.1-4 and 5.1-5.
- Payroll burden: 1,000 USD/month/person
- Overheads: 700 USD/month/person

5.5 Study of Financing Plan

In general, the following financing schemes are viable for this kind of project.

- Own finance by MOO
- Yen Loan (JICA ODA Loan)
- Export / Import Loan from Japan Bank for International Cooperation (JBIC)
- Commercial Loan / Bond
- Loan from other countries / International organization (except Asian Development Bank)

Considering the current situation in Iraq, it will take some time before the conditions precedent to obtaining an Export / Import Loan from JBIC (Japan Bank for International Cooperation) can be met. Furthermore, as a result of the turmoil in finance market from sub-prime crisis, the same can be said of commercial loans / bonds.
It has been reported that Iraqi Government is negotiating with the International Monetary Fund (IMF) for billions of dollars in new loans. At the International Donors' Conference on the Reconstruction of Iraq held in Madrid on 24 October 2003, the participating countries and international organizations had announced the overall pledges and indicative pledges amounting to more than US$33 billion dollars (equivalent to €28 billion) in grants and loans. At present, most of them have already been allocated and there have been no additional announcement of any further substantial loans.

5.5.1 Own Finance

Iraq is undoubtedly one of the most naturally resource-rich countries in the world, with its proven oil reserves at 115 billion barrels, the third largest in the world, and its proven natural gas reserves at 110 trillion cubic feet (Tcf), the tenth largest in the world.
The 1st and 2nd round tender for oil / gas field development was conducted by MOO in June and December 2009. A total of 10 projects have reached agreement, however, there are still many challenges ahead before the realization of the projects and actual stable production.

On the other hand, the recent turmoil in the financial market and the decline in crude oil prices have seriously affected Iraq's national finances. The Iraqi government reduced the 2009 national budget drastically and many projects have been postponed. In addition to the loan from the IMF, the Iraqi government is planning to issue short term national bonds to make up for the shortfall of revenue. Although Iraq government increased the national budget of 2010 reflecting the gradual recovery of oil price, budget for new project is still very tight.

5.5.2 Yen Loan (JICA ODA Loan)

As mentioned in the above, partially because of the financial crisis in recent years, it could take some time before any other financial support becomes available. Meanwhile, the Japanese government announced a US$5 billion of support measures for the reconstruction of Iraq including a US$3.5 billion Yen loan. Furthermore, both governments have agreed to extend the Yen loan to the following 15 projects that totals US$3.28 billion.

- Samarah Bridges and Roads Construction Project
- Al-Mussaib Thermal Power Plant Rehabilitation Project
- Irrigation Sector Loan
- Port Sector Rehabilitation Project
- Electricity Sector Reconstruction Project
- Engineering Services for Basrah Refinery Upgrading Project
- Crude Oil Export Facility Reconstruction Project
- Khor Al-Zubair Fertilizer Plant Rehabilitation Project
- Electricity Sector Rehabilitation Project in Kurdistan Region
- Basrah Water Supply Improvement Project
- Bagdad Sewerage Facilities Improvement Project (Engineering Services)

- Water Supply Improvement Project
- Al-Akkaz Power Plant Construction Project
- Water Sector Loan Project in Mid-Western Iraq
- Deralok Hydropower Plant Construction Project

This preparatory survey (preliminary feasibility study) was carried out at the request of Iraqi government based on the application of Yen Loan to the project. Considering the current circumstances surrounding Iraq and its financial situation, it seems that there is a high possibility that there will be a request for a Yen loan. However, considering the huge amount of the total project cost and the amount of Yen loan allocated to the other projects in Iraq, it is unsure whether the Japanese government will allocate a Yen loan for the whole of the project cost at one time. In this regard, a viable option would be to divide the project into several phases. Also, a combination of a Yen loan and MOO/NRC's own finance would be another way to finance the Project, but this depends very much on the price of crude oil and the situation surrounding the country's national budget. An example of finance scheme is shown in the Table 5.5.2-1.

Table 5.5.2-1 Project Financial Scheme

Scope	FEED Phase	EPC Phase
1. FCC Complex	ODA	ODA*
2. Interfaces	ODA	MOO
3. Aux. Facilities	ODA	MOO
4. Utility Supply	ODA	MOO
5. Infrastructure	Other Ministries	Other Ministries
6. PMC	ODA	ODA
7. Tech. Transfer	ODA	ODA

*To be discussed whether one loan or being divided to several phases.

Current standard terms and conditions for Yen loan for the projects in Iraq are shown in the Table 5.5.2-2.
Since Iraq is considered as a lower middle income country, and the Project will contribute to the reconstruction of Iraq, Preferential Terms (Standard) would be applied.

Table 5.5.2-2 Standard Terms and Conditions of Yen Loan (effective from April 1, 2009)

	Condition for Procurement	Interest Rate (% p.a.)	Repayment Period (Year)	Grace Period (Year)
General Terms (Standard)	Untied	1.4	30	10
General Terms (Option 1)	Untied	0.8	20	6
General Terms (Option 2)	Untied	0.7	15	5
Preferential Terms (Standard)	Untied	0.65	40	10
Preferential Terms (Option 1)	Untied	0.55	30	10
Preferential Terms (Option 2)	Untied	0.50	20	6
Preferential Terms (Option 3)	Untied	0.40	15	5
STEP (Standard)	Prime Contractor is tied to Japanese firm.	0.2	40	10
STEP (Option 1)	Prime Contractor is tied to Japanese firm.	0.1	30	10

Source: JICA http://www.jica.go.jp/english/operations/schemes/oda_loans/standard/

5.5.3 Potential finance source for the related infrastructure projects

Many related infrastructure projects shown below have been planned around the Baiji Refinery, most of which are currently "Own finance". However, as mentioned above, the government budget is greatly affected by the price of crude oil that financing of those planned projects have to be further discussed and studied.

Table 5.5.3 Planned Related Infrastructure Projects

Project	Owner	Finance source
Projects in NRC other than Baiji Refinery	NRC	Own finance
Power plant	MOE	Own finance
Power plant (in Baiji Refinery)	NRC	Own finance or Yen loan as part of this project
Water intake facilities for Tigris River	NRC	Own finance
Rehabilitation of fertilizer factory	Ministry of Industry and Minerals	Own finance
Roads	Salahuddin province or Ministry of Transport	Own finance

Figure 5.1-1 Cost Escalation on Plant Erection

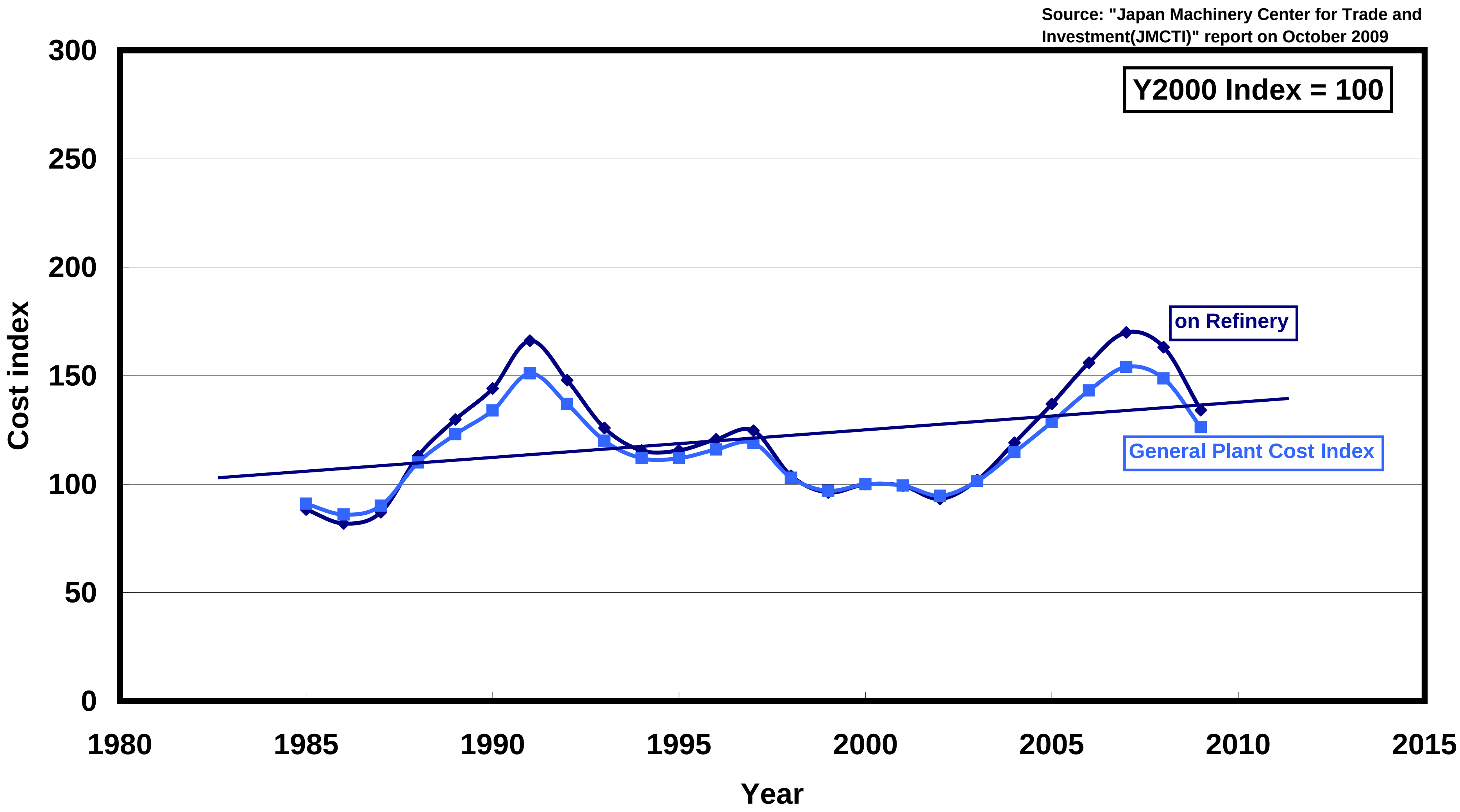


Table 5.1-1a Total Investment Cost: Facility Cost: Mid-East location Mid. 2009 Base (Unit: mmUSD)

	SDA	Eureka Solid Gasf.	Eureka Liquid Gasf. (For reference)	Delayed Coker (For reference)	Remarks
Process					
VDU	56	56	56	56	
SDA	120				
Eureka		243	243		
Delayed coker				279	
Liquid Gasification	393		384		Including H2 Purification & Gas Treatment
Solid Gasification		480		521	ditto
DAO HDS	376				
Distillate HDS		180	180	173	
RFCC	310				Including LPG Recovery
FCC		228	228	199	ditto
Gasoline HT	58	54	54	47	
Amine regenerator/Sulfur recovery	122	123	123	124	
Sour Water Stripper	16	28	28	21	
Process Total Rounded	**1,450**	**1,390**	**1,300**	**1,420**	
Utility					
Utility System Total Rounded	**210**	**210**	**210**	**200**	
including					
Gas turbine generators					
HSG					
Steam turbine generators					
Demineralization unit					
Cooling water system					
Fresh water treatment system					
Offsite					
Site preparation and road	17	17	17	17	
Control room and communication	19	19	19	19	
Effluent reatment (WWT and Flare)	17	22	22	19	
Fire fighting	10	10	10	10	
Sulphur and coke handling	19	25	19	25	
Tankage	47	45	45	42	
Interconnecting	35	35	35	35	
Substation and buildings	49	49	49	49	Excludhing control room and substations
River water intake and pipeline	12	12	12	12	
Offsite Total Rounded	**220**	**230**	**230**	**230**	
Facility Cost Total	**1,880**	**1,830**	**1,740**	**1,850**	

Table 5.1-1b Total Investment Cost: Owner's Cost (Unit, mmUSD)

	SDA	Eureka Solid Gasf.	Eureka Liquid Gasf. (For reference)	Delayed Coker (For reference)	Remarks
Technology license fee and design package	45	45	46	44	
Initial catalyst	21	22	22	21	
Laboratory and maintenance equipment	10	10	10	10	
Spare parts	28	27	26	28	1.5% on Facility cost
Project Management Contracts	67	67	67	67	
Basic Engneering Contracts	15	15	15	15	
Studies and investigation	0.2	0.2	0.2	0.2	
Prestartup and startup expense	29	29	29	29	
Cash on hand	7	7	6	7	One month of operating cost
Contingency	22	22	22	22	10%
Total owner's cost	245	245	243	242	

Table 5.1-2 Operating Cost (OPEX)

	SDA	Eureka Solid Gasification	Eureka Liquid Gasification (For reference)	Delayed Coker (For reference)	Remarks
	mmUSD/yr	mmUSD/yr	mmUSD/yr	mmUSD/yr	
Variable operating cost					
Catalyst & Chemicals	12.3	8.9	8.9	8.4	Including Value-Added Tax 18%.
Total variable operating cost	12.3	8.9	8.9	8.4	
Fixed operating cost					
Maintenance	56	55	52	55	3% p.a. on facility cost
Insurance	3.8	3.7	3.5	3.7	0.2% p.a. on facility cost
Operating supply	4.7	4.6	4.3	4.6	0.25% p.a. on facility cost
Payroll burden	5.2	5.4	5.4	5.4	1,000 USD/month/person
Number of employee	431	449	449	449	Details are specified in Table 5.1-3 to 5.1-5
Overhead	3.6	3.8	3.8	3.8	700 USD/month/person
Total fixed operating cost	73.7	72.4	69.1	73.0	
Total operating cost	86.0	81.3	78.0	81.4	

Table 5.1-3 Man Power Allocation on the FCC complex: SDA case

	Div. Manage	Sec. Manage	Secretary	Supervisor	Day Operato	Shift Leade	Shift Board Mar	Shift Field Operator A	B	C	Total
Operation Div.		1	1								
VDU				1		1	1	1	1	1	
SDA				1		1	1	1	1	1	
Gasification				1		1	1	2	2	4	
Gas treatment & H2 manuf.							1	1	1	2	
HDS				1		1	1	1	2	2	
Amine regenerator/Sulfur recovery								1	1	1	
Sour Water Stripper								1	1	1	
FCC/Gasoline HT/LPG Recovery				1		1	1	3	3	3	
Utility & Offsite				1							
Power							1	1	1		
Tank					2	1		1			
LPG bottl., Sulf. Solid.					3						
Waste Water					2		1	1			
Sub Total		1	1	6	7	6*	9*	14*	15*	21*	267
Technical Services Div.				Super Int.	Engineer	Technical					
	1	1	2								
Process											
VDU & SDA				1	1	3					
HDS				1	2	2					
FCC				1	2	2					
Gasification				1	2	2					
Design					1	3					
Laboratory				1	4	10					
Sub Total	1	1	2	5	12	22					43
Maintenance Div.		1	1	Super Int.	Engineer	Technical					
Contract			1	1							
Inspection/Repaire											
Equipment/Pipe				1	3	6					
Machine				1	3	6					
Electrical Eq.				1	2	3					
Instrument				1	3	6					
Field					3	10					
Ware House				1	1						
Sub Total		1	2	6	15	31					55
Enviroment/Safety *		1	1	Super Int.	Engineer	Technical					
Emvironment				1	1	1					
Safety(Fire Fight)				1	2	2		8*			
Sub Total		1	1	2	3	3		36			46
General Services **		1	1	Super Int.	Officer	Staff					
Account				1	2	2					
Shipping				1	1	1					
Purchase					1	1					
Personell				1	3	4					
Sub Total		1	1	3	7	8					20
Total											431

**: These functions could be co-worked with existing organization members. But these personell number corresponds to self-organized enterprise.

Table 5.1-4 Man Power Allocation on the FCC complex: Eureka case

	Div. Manager	Sec. Manager	Secretary	Supervisor	Day Operator	Shift Leader	Shift Board Man	Shift Field Operator A	B	C	Total
Operation Div.		1	1								
VDU				1		1	1	1	1	1	
Eureka				1		1	1	1	2	4	
Gasification				1		1	1	2	2	4	
Gas treatment & H2 manuf.							1	1	1	2	
HDS				1		1	1	1	2	2	
Amine regenerator/Sulfur recovery								1	1	1	
Sour Water Stripper								1	1	1	
FCC/Gasoline HT/LPG Recovery				1		1	1	3	3	3	
Utility & Offsite				1							
Power							1	1	1		
Tank					2	1		1			
LPG bottl., Sulf. Solid.					3						
Waste Water					2		1	1			
Sub Total		1	1	6	7	6*	9*	14*	15*	21*	285
Technical Services Div.				Super Int.	Engineer	Technical					
	1	1	2								
Process											
VDU & Eureka				1	1	3					
HDS				1	2	2					
FCC				1	2	2					
Gasification				1	2	2					
Design					1	3					
Laboratory				1	4	10					
Sub Total	1	1	2	5	12	22					43
Maintenance Div.		1	1	Super Int.	Engineer	Technical					
Contract			1	1							
Inspection/Repaire											
Equipment/Pipe				1	3	6					
Machine				1	3	6					
Electrical Eq.				1	2	3					
Instrument				1	3	6					
Field					3	10					
Ware House				1	1						
Sub Total		1	2	6	15	31					55
Enviroment/Safety *		1	1	Super Int.	Engineer	Technical					
Emvironment				1	1	1					
Safety(Fire Fight)				1	2	2		8*			
Sub Total		1	1	2	3	3		36			46
General Services **		1	1	Super Int.	Officer	Staff					
Account				1	2	2					
Shipping				1	1	1					
Purchase					1	1					
Personell				1	3	4					
Sub Total		1	1	3	7	8					20
Total											449

**: These functions could be co-worked with existing organization members. But these personell number corresponds to self-organized enterprise.

Table 5.1-5 Man Power Allocation on the FCC complex: Delayed coker case (For Reference)

	Div. Manager	Sec. Manager	Secretary	Supervisor	Day Operator	Shift Leader	Shift Board Man	Shift Field Operator			Total
								A	B	C	
Operation Div.		1	1								
VDU				1		1	1	1	1	1	
Coker				1		1	1	1	2	4	
Gasification											
Gas treatment & H2 manuf.							1	1	1	2	
HDS				1		1	1	1	2	2	
Amine regenerator/Sulfur recovery								1	1	1	
Sour Water Stripper								1	1	1	
FCC/Gasoline HT/LPG Recovery				1		1	1	3	3	3	
Utility & Offsite				1							
Power							1	1	1		
Tank					2	1		1			
LPG bottl., Sulf. Solid.					3						
Waste Water					2		1	1			
Sub Total		1	1	6	7	6*	9*	14*	15*	21*	285
Technical Services Div.				Super Int.	Engineer	Technical					
	1	1	2								
Process											
VDU & Coker				1	1	3					
HDS				1	2	2					
FCC				1	2	2					
Gasification				1	2	2					
Design					1	3					
Laboratory				1	4	10					
Sub Total	1	1	2	5	12	22					43
Maintenance Div.		1	1	Super Int.	Engineer	Technical					
Contract			1	1							
Inspection/Repaire											
Equipment/Pipe				1	3	6					
Machine				1	3	6					
Electrical Eq.				1	2	3					
Instrument				1	3	6					
Field					3	10					
Ware House				1	1						
Sub Total		1	2	6	15	31					55
Enviroment/Safety *		1	1	Super Int.	Engineer	Technical					
Emvironment				1	1	1					
Safety(Fire Fight)				1	2	2		8*			
Sub Total		1	1	2	3	3		36			46
General Services **		1	1	Super Int.	Officer	Staff					
Account				1	2	2					
Shipping				1	1	1					
Purchase					1	1					
Personell				1	3	4					
Sub Total		1	1	3	7	8					20
Total											449

**: These functions could be co-worked with existing organization members. But these personell number corresponds to self-organized enterprise.

Table 5.1-6 Catalyst and Chemical Consumption

	SDA		Eureka Solid Gasification		Eureka Liquid Gasification (For Reference)		Delayed Coker (For Reference)		Remarks
	Initial fill mmUS$	Consumption mmUS$/yr	Initial fill mmUS$	Consumption mmUS$/yr	Initial fill mmUS$	Consumption mmUS$/yr	Initial fill mmUS$	Consumption mmUS$/yr	
SDA	-	0.1	-	-	-	-	-	-	Solvent
Eureka	-	-	-	0.1	-	0.1	-	-	Anitfoam agent + Hot oil
Coker	-	-	-	-	-	-	-	0.3	Antifoam agent
Gas Treatment	0.03	-	0.03	-	0.03	-	0.03	-	Catalyst
H2 manufacturing from syngas	9.3	2.3	9.3	2.3	9.4	2.3	9.3	2.3	Catalyst
HDS on DAO and Dist	9.8	4.9	10.3	2.6	10.3	2.6	9.7	2.4	Catalyst
FCC	0.8	2.8	0.7	2.2	0.7	2.2	0.5	1.8	Catalyst
Gasoline HT	1.0	0.3	0.9	0.2	0.9	0.2	0.8	0.2	Catalyst & Chemicals
Amine regenerator	0.01	-	0.01	-	0.01	-	0.01	-	Chemicals
Sulfur recovery	0.5	0.1	0.5	0.1	0.5	0.1	0.5	0.1	Catalyst
Total	21.5	10.4	21.7	7.6	21.8	7.5	20.8	7.2	

Chapter 6 Project Phase and Scheme

The project is categorized into 3 phases such as FEED, EPC and Operation phases. The effective and functional schemes to implement the project were discussed between MOO/NRC and the Consultant as follows.

6.1 MOO and NRC

For discussing the suitable project scheme, it is essential to understand the present schemes of MOO and NRC for the operation and general projects as well as the competence/ capability to implement and manage the project properly.

6.1.1 Organization of MOO and NRC

(1) MOO

The organization of MOO is outlined in Figure 6.1.1-1. MOO consists of 5 divisions under the minister of MOO that are: upstream, downstream, distribution, oil marketing and development & training. These divisions are headed by the respective deputy minister in charge of the division. NRC is one of the national entities for operations of the downstream division.
All the construction and upgrading projects for refineries are implemented by each refinery company under the management of the downstream division of MOO.

(2) NRC organization

The operational organization of NRC is shown in Figure 6.1.1-2. NRC is headed by the Director General (DG) of the company. NRC has 7 operation Boards under GM, i.e. 6 technical boards and finance/administration board and each board has several departments responsible to the tasks related to operation of the refinery.
The Baiji refinery is not a unified organization, but comprised of several refinery entities i.e. North Refinery Department, Salahuddin-1 Refinery Department, Salahuddin-2 Refinery Department, and Lube Oil Refinery Department in the Processing Board of NRC.

6.1.2 Experiences of Projects

(1) Project experience of Baiji refinery

Baiji refinery has the following experience of projects.

Table 6.1.2 Project Experience of Baiji Refinery

Project	Capacity	Year of Completion	EPC contractor
Salahuddin-1	70,000 BPSD	1978	Chemoprojekt
Salahuddin-2	70,000 BPSD	1984	Chemoprojekt
North Refinery	150,000 BPSD	1982	Chiyoda
Lube Plant	15,850 BPSD	1989	Technip
Isomerization	20,000 BPSD	1Q 2009*	Chemoprojekt

* Mechanical Completion

The Baiji Refinery was completed as a grass-root refinery in the region through the construction projects in 1970s-1980s. Since completion of the refineries, Baiji Refinery has experienced no major project for expansion or modernization of the plants with application of advance technologies introduced practically by the refinery sector in the world at the time.
The Isomerization Project is the only opportunity where advanced process was introduced to the refinery, but which is extremely smaller in scale compared to FCC Complex project.

(2) Project Execution Scheme for Isomerization Project

Since the Isomerization project is a smaller and simple project, no special organization for the project such as project office was established in NRC. The works related to the project were executed by the respective responsible boards/ departments of NRC.

6.1.3 Technical Background

NRC has been operating the Baiji Refinery and other refineries in the region for more than 30 years. Baiji Refinery is composed of 3 refinery plants, which consists of several conventional processing units described in the clause 2.7 of Chapter 2.

(1) Process

The proposed FCC Complex consists of several kinds of process units including the same or similar conventional process to the existing refinery plants and the new process units for Baiji Refinery which NRC has not experienced so far. The outline is shown below.

Table 6.1.3-1 Processes in FCC Complex and Baiji Refinery

Proposed Process in FCC Complex	Existing Process in Baiji Refinery	Remarks
VDU	✓	
SDA	✓*	*Lube Plant (Propane extraction)
Eureka*	-	*Thermal Cracker
Gasification	-	
DAO/VGO HDS	✓	
RFCC/FCC	-	
SRU etc	✓	

Note ✓ : Same or similar process

Eureka (thermal cracker), Gasification and RFCC/FCC are completely new processes for Baiji refinery.

(2) Facilities Design

NRC has been denied of opportunities for introduction of the latest technology for the refinery sector in the last few decades unfortunately. The facilities and equipment being composed the FCC Complex will be designed and fabricated by the latest technology and best industrial practices in accordance with the philosophy to ensure the safe, stable and feasible operation.
NRC has a firm intention to introduce such advanced technology and practices for engineering and design to the project through the dedicated technology transfer program.

(3) Control System

Older Salahuddin-1 and North plants are operated with the conventional panel control system. On the other hand, the operations of Salahuddin-2 and Lube plant are already equipped and controlled with computerized Distributed Control System (DCS) system. The similar modern control system is also introduced to the new Isomerization plant.
Thus, Baiji Refinery is well familiar and knowledgeable with the modernized control systems for facilities operation.

(4) Operation and Maintenance

Unplanned shut down days of Baiji Refinery in 2008 are as follows. The data shows that the rate of operation (except the scheduled shut down) is somewhat lower as compared to the internationally accepted level of 95%.

Table 6.1.3-2 Unplanned Shut down days of Baiji Refinery

Plant	Salahuddin-1/2 Refinery		North Refinery	
Distillation	52 days	85.2%	149 days	59.3%
Naphtha HDS	78 days	78.7%	50 days	86.4%
Kerosene HDS			47 days	87.2%
Cathartic reforming	39 days	89.4%	38 days	89.7%
LPG	27 days	92.7%	48 days	86.9%
Gas sweetening	—	—	34 days	90.8%

Source: NRC (17 March 2009)
Percentage figure : Operational rate

The causes of the unplanned shutdown of the plant include unstable power supply from the regional grid and unexpected defects or malfunction of the equipment due to aging and the shortage of spare parts of the equipment and so on.

6.2 Project Organization

6.2.1 General Project Organization

The Project Office (PO) will be established in the NRC. The PO is supervised by the Director General (DG) of NRC under MOO. The PO headed by the Project Manager (PM) will consist of technical groups and administration groups. The PO will be responsible in engaging the contracts with process licensors, FEED contractor and EPC contractor for execution of the project in the respective phases.

NRC will employ a qualified and experienced consulting firm for project management consultancy (PMC) during the FEED and EPC phase respectively to render the necessary support and assistance to the PO to ensure successful completion of the project as planned. PMC is responsible for the necessary coordination between NRC and JICA, lender of ODA Loan.

The PM coordinates the related projects of NRC and MOO coordinates the issues concerned to the other ministries adequately upon necessity.

General organization for execution of the project is shown in Figure 6.2.1-1.

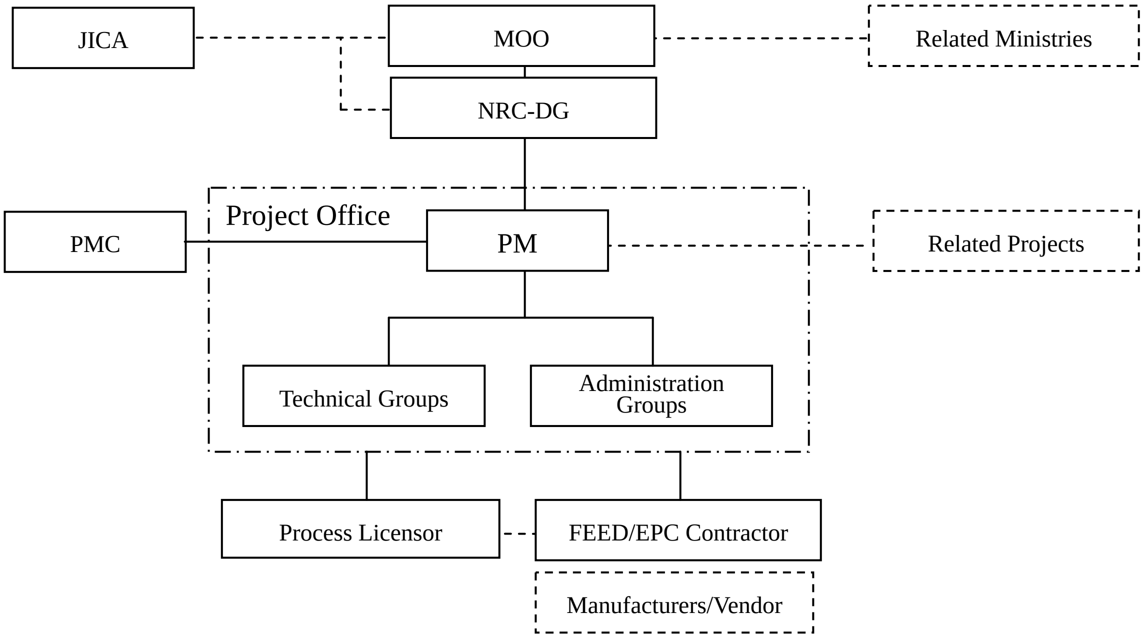


Figure 6.2.1 General Project Organization

6.2.2 Project Office (PO)

The Project Office will be established in the Project Board of NRC. The project team will be organized with the staffs of Planning Project Department, Design Department and Field Execution Department in the same board and the other related boards such as Technical, Engineering, Inspection/Follow-up Board. Processing and Powerhouse/ Utility Board will provide the necessary information to the project team.

The PO consists of the technical groups in charge of Onsite and Offsite facilities, HSE group, material procurement, quality assurance/quality control (QA/QC) group as well as administration group necessary for managing the project operation including budget control.
The technical groups are responsible for the technical aspects including engineering and design of the facilities and supervision of the performance of the contractors in FEED and EPC phases. The QA/QC group is responsible for the quality management for the deliverables/goods furnished by the contractors and the workmanships of the contractors. The 3rd party inspectors will be employed to provide support to the QA/QC group. The independent HSE group is provided in the PO for implementation of the HSE and social considerations of the project.

The PO is headed by the Project Manager with support of an assistant PM and a coordinator, who is fully responsible for the management of the entire project execution and performance including schedule and budget for the project.

In addition to the above, a technical advisor, a finance expert and a legal expert are placed in the organization under PM to ensure successful implementation of the project.

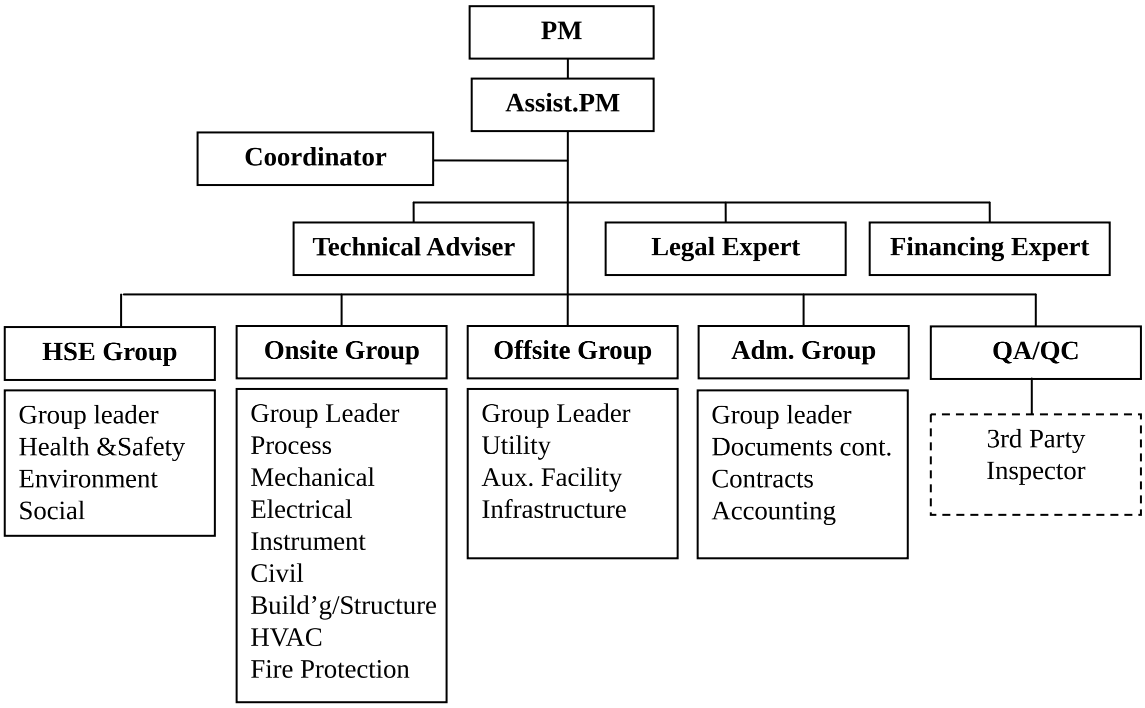


Figure 6.2.2 NRC Project Organization

6.3 Scheme of Operation and Maintenance

6.3.1 Operational Organization

Two optional operational scheme were discussed, which are

Case 1 Independent schemes for the existing plants and FCC Complex
Case 2 Integration into the existing scheme

The applicable operation scheme for the upgraded Baiji Refinery including facilities maintenance was discussed through considerations of the following issues.

- Current operation and maintenance scheme for Baiji Refinery
- Need for new operational and maintenance technology and practice for FCC Complex
- Interaction and interface of operations between the existing refineries and FCC Complex (transfer of feedstock and products, operational data and signals, etc.)
- Emergency responses and management (fire and explosion, injuries, etc.)
- Operational options: integration of both facilities or separation (independence) from the existing refinery

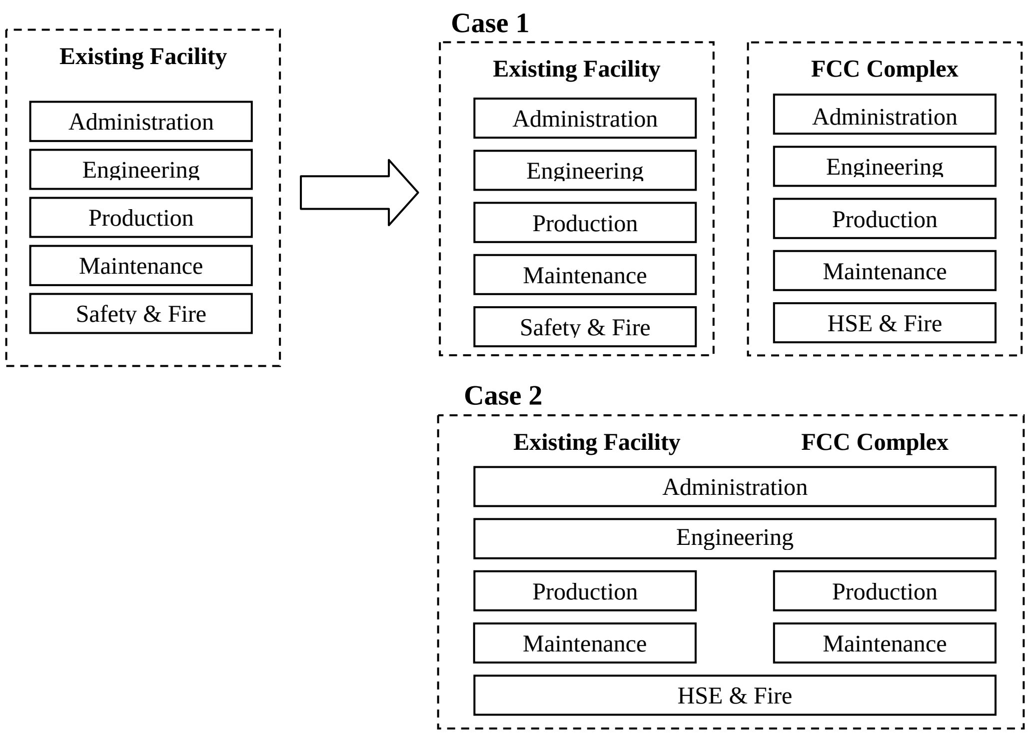


Figure 6.3-1 Scheme of Operation and Maintenance

The operation of the proposed FCC Complex will be directly linked to the entire operation of the Baiji Refinery. Therefore, Case 2 Integrated Scheme was eventually selected after discussion.

According to the general NRC organization scheme, a new operational department so called as “FCC Complex Department” will be established in the Processing Board for operation of the process facility similar to the other refineries. In addition, the new FCC Complex Utility Department will be also established in the Power house/ Utility Board.

Other departments of the operational Boards in NRC i.e. Project, Finance/Administration, Inspection/Follow-up, Technical, Engineering, will play a role as the respective tasks for the operation of the FCC Complex similar to the existing refineries.

6.3.2 Maintenance

The Engineering Board will be responsible for the facilities maintenance of the FCC Complex as practical. A maintenance group for FCC Complex will be allocated in the maintenance shop in the same plant area.
The maintenance plans for the FCC Complex composed of advanced equipment and systems will be developed properly prior to commissioning of the plant in accordance with the latest maintenance philosophy and procedures as well as the international practices. The maintenance plans for the new facilities will be integrated into the general maintenance program of the Baiji Refinery.

6.4 Technology Transfer

The proposed FCC Complex will be comprised of new technical elements such as refining processes and equipment, control system and operating procedures, which have not been adopted in the Iraqi refineries yet. The project could be completed successfully through the proper management procedures drawn out for project implementation in accordance with the international practices for the same industrial sector. The integral operations of the new facilities could be achieved by employing technically competent operational personnel.

The technology transfer aims *"to enhance the project execution technology of MOO/NRC to the international level as well as the operation and maintenance skills for the facilities newly introduced" through implementation of the project.*

6.4.1 Themes and Methods of Technology transfer

Main themes for the technology transfer required by MOO/NRC are;

- Project Management skill
- Technical skill for Engineering, Construction, Operation and Maintenance

For developing the technology transfer plan for the project, following items were discussed with both parties.

- Items and elements to be transferred
- Personnel subject to the technical transfer
- Technical back ground/ capabilities of the personnel and organization
- Goals of the technical transfer
- Schedule : FEED, EPC, Commissioning, and Operation phase
- Budget

The methods of the technology transfer applicable to the project are proposed as follows.

- On the job training (OJT) by participants in the actual job at the project office/site
- Lectures at the offices of the respective firms i.e. PMC, FEED contractor, EPC contractor, process licensor, Manufacturer/vendor, etc.
- Seminars/Workshops at the technical institutes or agents in the fields

6.4.2 Outline of Technology Transfer Plan

According to the above discussion, the outline of the technology transfer plan is proposed as follows.

Table 6.4.2-1 Technology Transfer Plan

Subject	Schedule/Project Phase			
	FEED	EPC	Commissioning	Operation
1 Project Management	✓	✓		
2 Engineering*	✓	✓		
3 Process Safety Analysis	✓			
4 Project Analysis	✓			
5 Project Execution	✓	✓		
6 Commissioning/Start-up		✓	✓	
7 Operation and Maintenance		✓	✓	✓
8 HSE	✓	✓	✓	✓
To be executed by	PMC FEED Cont. (Process licensor)	PMC EPC Cont. Process licensor Mfr/Vendor	PMC EPC Cont. Process licensor Mfr/Vendor	EPC Cont. Process licensor Mfr/Vendor

* Engineering: Process, Mechanical, Electrical, Instrument/Control, etc.

Cont. : Contractor

(1) FEED Phase

- Project/ engineering management practices i.e. technical, schedule, documentation, etc

- Skills for FEED document review
- Engineering and design procedures and practices
- Refining process and controls
- Process and control safety analysis: HAZOP (Hazard and Operability) study
- HSE management and EIA
- Tender procedure for EPC contractor and process licensor(s)

(2) EPC phase

- Project/ EPC management practices: design, procurement, construction, schedule, budget, QA/QC, etc.
- Project execution procedure and practices
- Process and control systems
- Skills for document review i.e. facility design, drawing, specification, procedure, etc.
- Material procurement procedure including trans
- Method and procedure for construction/ erection of facilities/ equipment
- Pre-commissioning procedure i.e. equipment, systems, etc.
- Operation procedure and practices
- Maintenance technology and method

(3) Commissioning phase

- Commissioning procedure and skill i.e. process units, utilities, etc.

(4) Operation phase

- Operational management method and practices
- Procedures for facility operation i.e. process units and utilities, etc.
- Process control system (DCS) operation skills
- Start up, Shut-down, Emergency shut-down procedure
- Analysis of process operation
- Maintenance skill for major equipment and systems
- Inspection skills for facilities integrity

As described in the clause 6.1.3, the FCC Complex will have new process units such as FCC/RFCC, residue conversion process, gasification plant, which NRC have not experienced so far. In order to ensure the sustainable stable operation of the new facilities without interruption due to human error or defective operation manner, it is essential to enhance especially the operation technology of Baiji Refinery for the new process units.

The comprehensive technology transfer plan is shown in Table 6.4.2-2 for reference, which includes additional OJT for improvement of operational skill at the office of the process licensor and the refinery that possesses the similar process unit(s) prior to commissioning of the FCC Complex and the continuous technical support by the process licensor or EPC contractor after commissioning.

Figure 6.1.1-1 Organization Chart of Ministry of Oil

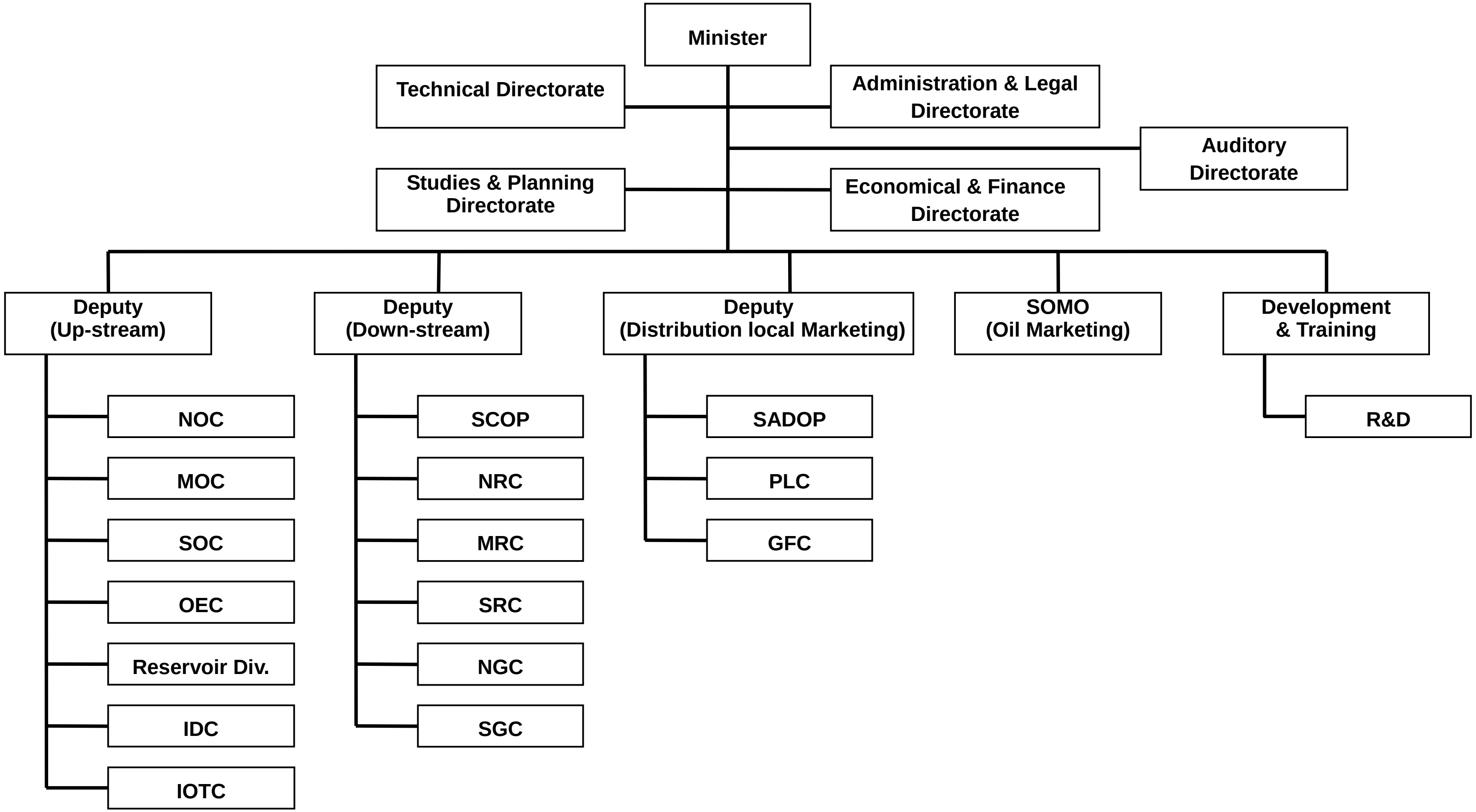


Figure 6.1.1-2 Organization Chart of North Refinery Company

Source: NRC (17 March 2009)

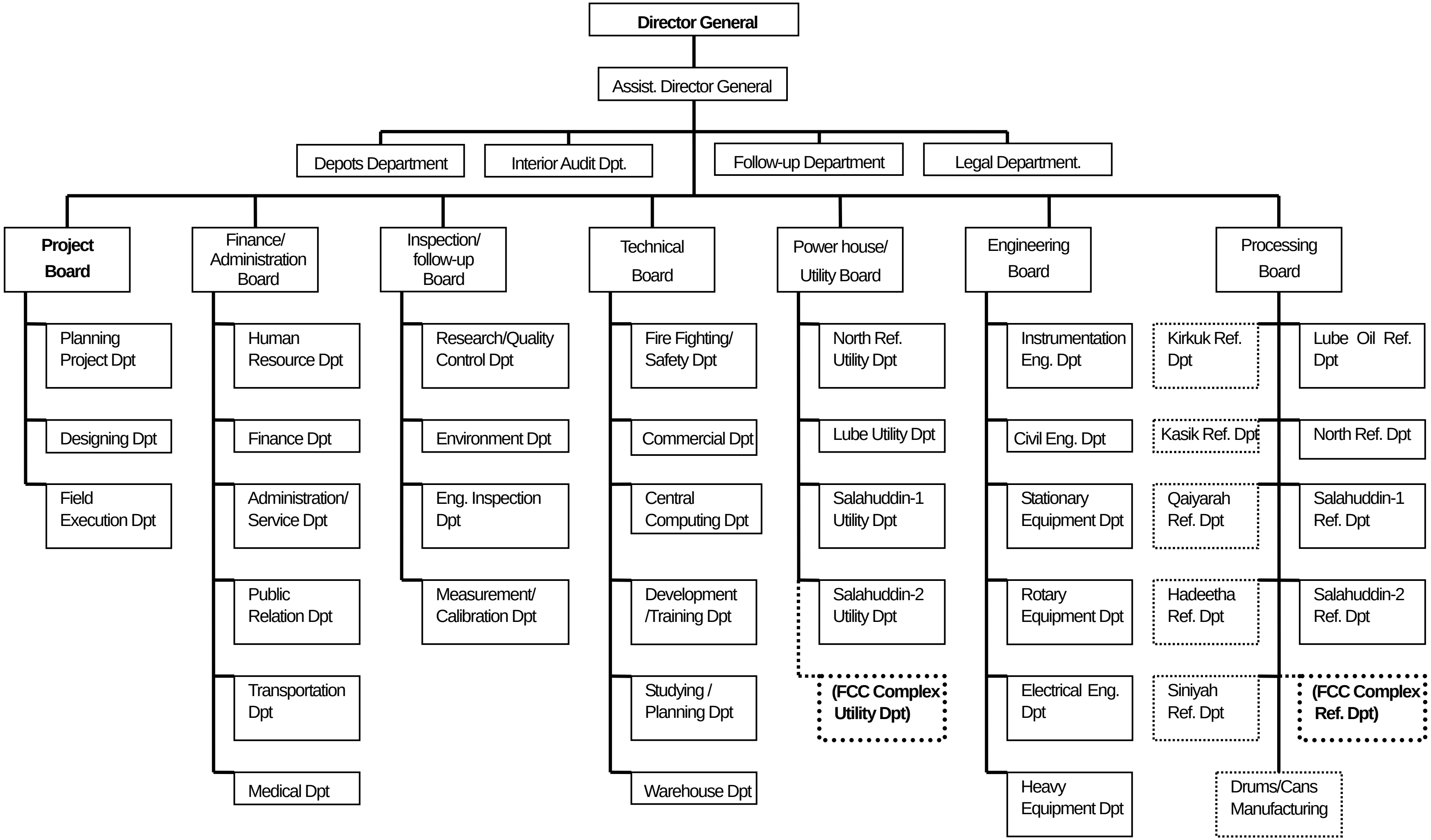


Table 6.4.2-2 Outline of Technology Transfer plan for FCC Complex (For Reference)

Subject	Item, Element	Phase				Trained by	Trainee		Period	Location	Method	Remarks
		FEED	EPC	Com	Ope		No.	Organization				
1 Project Management	Design works (Scheduling, document control, applied standard),	○	○			FEED-C/ EPC-C	2	PJ-T	6-9 month	FEED-CO	OJT	
	Construction work (Scheduling, resources , arrangement),		○			PMC or EPC-C	2+	PJ-T	Construction	FO& PS	OJT	
	Commissioning work (Scheduling, resources , arrangement, back up),			○		EPC-C & Licenser	each 2+	PJ-T/ Com Team	Commissioning	FO& PS	OJT	
	Operation work (guarantee operation etc)			○	(○)	Licensor & EPC-C	2+	Com Team/ operator	by contract	FO& PS	OJT	
2 Engineering	equipment design, Layout,	○	○			FEED-C	2	(PJ-T)	2-3 month	FEED-CO	OJT	Additional trip base
	Document check/review	○	○			PMC or FEED-C/EPC-C	2-5	PJ-T	FEED-EPC	FO	OJT	
	Technical meeting (Technical issue, criteria, countermeasures)	○	○			PMC or FEED-C/EPC-C	2+	PJ-T/Related	Periodically or Occasionally	FO	Discussion	
	Process design training	○	○			Licenser	2	(PJ-T)	Case by case (5-30 days)	Licensers- O	Lecture & training	Formal training course etc
3 Process Safety Analysis	HAZOP study	○	(○)			FEED-C	10-20	Related Dpt.	10-30 days	FO	OJT & themselves	
4 Project Analysis	Process selection study (comparing items & method)	○				PMC orFEED-C	2+	(PJ-T)	2-3 days	FO etc	Lecture	
	HSE impact assessment (consideration items etc)	○				PMC orFEED-C	2+	(PJ-T)	2-3 days	FO etc	Lecture	
5 Project Execution	Construction work (HSE management &, integrity checking etc)		○			PMC or EPC-C (HSE sect etc)	2+	(PJ-T)	Construction	FO& PS	OJT	with EPC-C etc
	Inspection of main equipment		○			EPC-C etc	1-2	(PJ-T)	Inspection timing	Manufacturing place etc	OJT (Visible and measured)	with EPC-C etc
6 Commissioning/ Start-up	Commissioning work (method and planning)		(○)	○		Licensor & EPC-C	AN	(PJ-T)	Prior to Commissioning 1-2week	FO& PS	Discussion & OJT	
7 Operation & Maintenance	Operation procedure (commissioning, upset condition etc)			○	○	Licensor & EPC-C& Mft	AN	Com Team/ operator	Several times for each shift workers (5-10 days/once)	FO& PS	Lecture & OJT	with manual
	DCS control (basic)		○			Mft	4-8	(Operator)	Mft 2-3 month	Mft office	Lecture & OJT	
	(applied)			○	○	Mft (licenser)	AN	(Operator)	Com. & Ope	FO	OJT	
	Laboratory test procedure		(○*)	○	○	licenser	2+	(QC sect)	Com. & Ope	FO	OJT	*analytical manual
	Production management (QC/volume/energy)					EPC-C/ other refinery person	2+	(Processing board)	3-5 days	FO etc	Lecture	
	Maintenance procedure (items, method etc)			(○)	○	Licensor, Mft, EPC-C	AN	(PJ-T)	5-10 days	FO etc	Lecture & OJT	Maintenance sect
	Follow-up OJT				○	Licensor Mft	AN	Operation &, maintenance dpt.	Max. 9 months	FO& PS	Lecture & OJT	Trouble shooting etc
8 HSE Management	Operational control (low NOx burner, FCC etc)			(○)	○	Licensor/EPC-C	2+	Inspection board & Operator	2-3 days	FO& PS	Lecture & OJT	

Note) Com: Commissioning, Ope: Operation, FEED-C(O): Front End Engineering and Design Contractor (Office), EPC-C(O): Engineering, Procurement and Construction Contractor (Office), OJT: On the Job Training, FO: Field Office, PS: Project Site, PJ-T: Project Team, AN: As Necessary, 2+: more than 2 persons、Mft: Manufacturer

Chapter 7 Evaluation of Project Feasibility

7.1 Internal Rate of Return (IRR)

7.1.1 Prices of feedstock and products

Table 7.1-1 shows feedstock and product prices those are basis of the calculation of internal rate of return (IRR).

Prices of feedstock (extracted from Table7.1-1) USD/bbl

	Domestic prices	International prices
Crude Oil	1.6	60.0
RCR	7.2	38.9
VR	8.1	31.4

Prices of Products (extracted from Table7.1-1)

	Domestic prices		International prices	
	USD/bbl	Relative to gasoline price	USD/bbl	Relative to gasoline price
LPG	9.4	140%	36.8	54%
Motor Gasoline	6.7	100%	67.7	100%
Diesel	3.3	50%	74.7	110%
Fuel oil	6.7	100%	46.9	69%

1) International prices

For the purpose of project viability and feasibility evaluation, the price of crude oil in the Arabian Gulf as OPEC basket crude oil price is applied as international price and 60 USD/Bbl, as agreed by MOO/NRC, is utilized for the calculation of product prices. Approximated price correlations on the major finished products, such as motor gasoline, diesel and fuel oil versus crude oil which is presented in Figure 7.1-1 to 7.1-3, are utilized to estimate at 60 USD/Bbl crude oil price.

The oil prices of feedstock, intermediates and other products are estimated from another price analysis. Figure 7.1-4 shows the relation of oil gravity (API) and prices of each product.

2) Domestic prices

Domestic prices, provided by MOO/NRC, are also presented in Table 7.1-1. The pricing structure where fuel oil is as same price as gasoline, the price of diesel is only half of that of gasoline/ fuel oil and especially LPG is double of gasoline is different from that of the ordinary refinery.

Based on these prices, a correlation of API and each product prices is provided in Figure 7.1-5. The plots based on fuel oil prices provided by MOO/NRC, where heavier oils are priced high and lighter oils are priced low, shows reverse trend as shown in Figure 7.1-4.

Another anomaly is the price of LPG, which is relatively high when compared with to the domestic Gasoline. Refineries are basically designed to maximize liquid products such as kerosene, gasoline, diesel and etc. and the process scheme should be configured to gain the maximum profit from these value added products. This phenomenon is further addressed in the subsequent section 7.1.1 4) hereinafter “Alternative adjusted domestic prices as reference case.”

3) Importance of the prices when configuring process scheme

The discussion on pricing structure is also very important from technical aspect, because the configuration for the refining process would be greatly influenced by such pricing of feedstock and products. The process configuration should be discussed and determined based upon a reasonable and stable pricing structure that would be maintained over a long period, otherwise, the development of refinery configurations would be misled. The pricing structure should reflect reasonable production costs and to obtain the development of the oil industries.

4) Alternative adjusted domestic prices (reference case)

The domestic prices, provided by MOO/NRC, figure an unusual pricing structure. With the international prices, heavier oil products have lower prices and lighter oil products have higher prices but for domestic prices show the opposite trend.

It seems that the domestic pricing structure is based not on technical theory but on some other considerations. Under such circumstances, the Project can be economically and financially justified based solely upon adjusted domestic prices.

Prices of Products: Adjusted Alternative (extracted from Table7.1-2) USD/bbl

	Domestic prices	Adjusted alternative	Arab Gulf Coast
Motor gasoline	6.7	6.7	67.7
Kerosene	3.3	3.3	75.1
Diesel	3.3	6.7	74.7
Fuel oil	6.7	3.3	46.9

Figure 7.1-5 also presents another plotted data i.e., adjusted alternative prices. Alternative domestic price is under the assumption that if MOO changes the prices of gas oil and fuel oil. By such adjustment, correlation between prices and API seems more reasonable and become closer to the configuration of normal refinery. The local government prices were provided by NRC. The alternative adjusted domestic prices are presented in Table 7.1-2.

5) Syngas price

The price of syngas is assumed to be 1 USD/mmBTU, as presented in Table 7.1-1 and 7.1-2, which has been used to calculate the revenue received for exporting syngas outside the FCC Complex. The economics of the gasification scheme is naturally affected by this syngas price and the following hydrogen prices.

6) Hydrogen price

Hydrogen will be supplied to the existing hydrocracker, the price of which is assumed to be 2 USD/mscf (0.075 USD/Nm3).

7.1.2 Premises used for evaluation of the project economics

Two (2) scenarios for determining the level of pricing of feedstock and products are considered. One is the Arab Gulf prices (International) scenario and another is domestic prices scenario (including alternative case). Furthermore, the economics are evaluated by two (2) conditions which are JICA case and commercial case, as presented in the Table 7.1-3.

In the domestic and alternative adjusted price scenario, hypothetical subsidies (which is the amount needed from Iraq Government to write-off any deficit caused by low prices of feedstock and products) have been calculated because the ROI shows negative values.
Following is the table for combination of project justification;

Purpose	Social justification		Amount of subsidies	For reference	
1) Economic evaluation	EIRR	FIRR	ROI	ROI	EIRR
2) Loan condition	JICA[1]				Commercial
3) Price of feed and product	International		Domestic	Domestic (Adjusted)	International

[1] JICA ODA condition applied for the economic calculation is described in the following page.

Conditions of JICA ODA loan and other variables applied for the economics evaluation are shown hereunder. More details are outlined in Table 7.1-3.

	Conditions	Note
Total Facility Cost (TFC)	Defined in Chapter 5	
Operating Cost	Defined in Chapter 5	
Project period	- JICA condition: 40 years after effective date of Exchange Note - Commercial condition: 20 years after commencement of operation	
Interest rate	0.65% per annual	JICA condition
Repayment	30 years after 10 years of grace period	JICA condition
Debt/Equity ratio	85 / 15	
Depreciation	10 years straight line	as per MOO/NRC instruction

Table 7.1-4 summarizes the project economics on EIRR, FIRR, and ROI.
Tables 7.1-5, 7.1-6, 7.1-7 and 7.1-7b show the results of project economics evaluation for international and domestic price cases.

7.1.3 Project economics

1) Economic IRR (EIRR): IRR on investment
EIRR is meaningful for assessing the viability of a project. Arabian Gulf prices are applied as international prices for the calculation. EIRR has been calculated on the basis of the following items which comprise both cost and benefit elements.

Elements on cost side	Element on benefit side
1. Raw material purchase cost 2. Operating cost Catalyst and chemicals costs Maintenance cost Insurance cost Operating supply cost Payroll burden Overhead 3. Depreciation 4. Income tax	1. Product sales revenue

The Arabian Gulf prices have been used as international prices to evaluate the Economic Internal Rate of Return (EIRR).

	Economic IRR (EIRR)		Project viability (Relative)
	JICA condition	Commercial condition[1]	
SDA case	11.9%	10.7%	Low
Eureka (solid) case	16.2%	15.5%	High
Eureka (liquid) case[1]	16.8%	16.2%	High
Delayed coker case[1]	14.1%	13.2%	Intermediate

[1] For Reference

The EIRR is meaningful for assessing the viability of a project. Any project with EIRR more than 10% is considered economically reasonable. Either study cases (SDA and Eureka (solid) case) indicate EIRR of above 10%, 11.9% to 16.2% with JICA condition respectively.
It is clear that Eureka case provide higher economic performance than SDA and Delayed coker cases. Furthermore, 16.2% to 16.8% of EIRR on Eureka cases with JICA condition means that the project is economically viable. For SDA case and Delayed coker case, less economically viable and, just under the marginal level to realize the project.

Also, realization of the Project is economically justified, since the Project will contribute to Iraq by reducing liquid product import from neighboring countries.

2) Financial IRR (FIRR): IRR on equity

FIRR has been calculated on the basis of the following items, which comprise both cost and benefit elements.

Elements on cost side	Element on benefit side
1. Raw material purchase cost 2. Operating cost Catalyst and chemicals costs Maintenance cost Insurance cost Operating supply cost Payroll burden Overhead 3. Depreciation 4. Income tax 5. Principal repayment 6. Interest payment	1. Product sales revenue

FIRR was calculated using the Arabian Gulf prices as international prices and JICA condition.

	Financial IRR (FIRR)
SDA case	45.8%
Eureka (solid) case	57.2%
Eureka (liquid) case[1]	58.8%
Delayed coker case[1]	51.7%

[1] For Reference

Since JICA condition and international prices provide quite a high FIRR, it is clear that JICA financing contributes to the Iraqi economy.

3) Subsidy to write-off deficit caused by low product prices

To enable NRC to pay annual operating deficit and repay JICA loan, a hypothetical subsidy has been calculated. After commencement of operation, the subsidies in the first 6 years and 7th year onward (beyond 10 years grace period) would be focal points in case of the domestic prices.

Based on domestic prices, all cases would see negative gross revenue from the purchase and sale of oil products, thus the subsidies are required from the government. SDA case, although showing a low EIRR, would require a slightly fewer amounts of subsidies than the other cases. This situation arises only because the domestic prices are structured to favor a refinery that produces larger amount of LPG.

Hypothetical subsidies (extracted from Table7.1-7/ 7.1-7b) mmUSD/yr

	Domestic prices		Adjusted alternative	
	First 6 years	In 7th year onward	First 6 years	In 7th year onward
SDA case	65.3	141.2	0.0	25.0
Eureka (solid) case	74.8	148.8	0.0	21.2
Eureka (liquid) case[1]	68.3	138.9	0.0	11.2
Delayed coker case[1]	83.0	157.5	0.0	28.8

In the case of adjusted alternative price structure, where heavier oil products have lower prices and lighter oil products have higher prices, it would be able to turn gross revenue around and make positive. However, the gross revenue is so small to pay the operating cost and to repay JICA loan and, as a result, the net revenue would falls into negative.

It seems that the domestic pricing structure is based not on technical theory but on some other considerations. Under such circumstances, the Project can be economically and financially justified based solely upon adjusted domestic prices.

Since Eureka case shows higher EIRR than that of SDA case, it would normally means that Eureka requires fewer amounts of subsidies. Special price structures often mislead the judgment.

7.1.4 Sensitivity analysis

Figures 7.1-6 to 7.1-13 present the results of the sensitivity analysis. The effects of feed and product prices have been checked as they are linked to OPEC basket prices. From this analysis, major findings are as follows.

1) Effects of facility cost, and feed/product prices on EIRR and FIRR

Both feed and product prices have a great affect on EIRR and FIRR compared with other factors.

2) Operating cost: Effect on EIRR

There are relatively small impacts on EIRR due to the operating cost.

3) Syngas price: Effect on EIRR

Although the syngas price is of 1 USD/mmBTU has been used for the economics analysis, it is supposed that the future natural gas price would increase, with the rapid growth of electric power consumption in future.

4) Gasoline and LPG prices: Effects on EIRR

It was determined that economy of SDA case more strongly dependent upon prices of gasoline and LPG than that of other cases.

7.1.5 Financial statement

The following tables show the financial statements on the basis of JICA condition and international prices.

Table 7.1-8 Profit & Loss Statement: SDA case
Table 7.1-9 Cash Flow: SDA case
Table 7.1-10 Free Cash Flow: SDA case
Table 7.1-11 Profit & Loss Statement: Eureka (solid)case
Table 7.1-12 Cash Flow: Eureka (solid) case
Table 7.1-13 Free Cash Flow: Eureka (solid) case

7.2 Qualitative project effects

The Project can qualitatively contribute to the Iraqi economy and market in the following aspects.

- FCC complex efficiently supplies motor gasoline, diesel, and LPG products, demanded in Iraq, without importing them from the international markets.
- The high EIRR means that the upgrading project is more justified than importing products from the international market.
- Upgrading of the existing refineries should be the first priority to meet the market demand. Building a new grass-roots refinery will require larger investment costs because it will require new offsite, infrastructure and so on.
- FCC Complex, by supplying hydrogen to the existing hydrocracker and clean syngas energy to the existing fuel gas for power generation, would makes the existing refinery more self-sufficient and flexible operation than current situation.

- Syngas is considered as clean as natural gas which can be taken by the power generation sector. Power generation with gas turbine combined cycle is also higher efficiency than the case with natural gas.
- High quality products improve the exhaust emissions from automobiles, with sulfur-free gasoline and low sulfur diesel.
- The Project would create employment opportunity for around 430 to 450 people.
- The Project would invigorate local economics.
- The Project would save energy resources since valuable products such as gasoline and diesel oils are produced from the residue.
- Since the modern technologies are introduced into Iraq, technological advancement effects are expected in an academic and industrial engineering fields.
- FCC complex with Eureka is robust and tough enough to convert heavier residue to light products, with expansion project for the future.

7.3 Index of project effects

MOO/NRC has established the following performance indicators and will monitor the operation of the FCC Complex after commencement of operation.

- 80% Capacity[1], with optimum specification
- 330 day/year[1] operation

[1] 80% Capacity: Designed flow rates of the feedstocks (RCR, VR#02, VGO#02, CFO, Lube surplus) to the FCC Complex derived with below conditions which were given at 1st Survey in Amman from MOO/ NRC.

Salahuddin I	65%	(330-day operation/year base)
Salahuddin II	73%	(ditto)
North Refinery	82%	(ditto)
Weighted %-Capacity	75.7%	(ditto)

Table 7.1-1 Prices on Feedstocks and Products

	Arab Gulf Coast		Domestic Ministry price			Remarks
	USD/Bbl	USD/ton	USD/Ltr	USD/Bbl	USD/ton	
Crude						
OPEC basket price	60.0	431	-	-	-	30 degree API
NRC Crude Oil	-	-	0.010	1.6	12	Provided by NRC
Feedstock						
RCR	38.9	253	0.045	7.2	47	
VR	31.4	192	0.051	8.1	50	
VGO	51.4	356	0.035	5.6	39	
Lube CFO	59.4	440	0.025	4.0	30	
Intermediate products						
FCC gasoline	68.9	556	0.042	6.7	54	
SR Naphtha	57.2	479	0.021	3.3	28	
SR kerosene	71.5	590	0.021	3.3	26	
SR LGO	71.1	526	0.021	3.3	25	
LCO	44.0	289	0.044	7.0	46	
DCO	10.0	58	0.002	0.3	52	
Syngas(foe)	5.9	39	0.037	5.9	39	Equivalent to 1 USD/mmBTU
H2	2.0	USD/mscf		2.0	USD/mscf	
Finished products						
Mixed LPG	36.8	421	0.059	9.4	104	Domestic price is provided by NRC
Naphtha	60.8	510	0.021	3.3	28	
Motor gasoline	67.7	546	0.042	6.7	54	Domestic price is provided by NRC
Jet/Kerosene	75.1	590	0.021	3.3	26	ditto
Diesel	74.7	559	0.021	3.3	25	ditto
180cSt HSFO	46.9	310	0.042	6.7	44	ditto
Sulfur	-	0	-	-	0	

Note) Data source:

Arab Gulf Coast prices are based on information from Oil Market Intelligence.

Domestic prices are provided by NRC.

Figure 7.1-1 Motor Gasoline Prices in Arab Gulf Coast

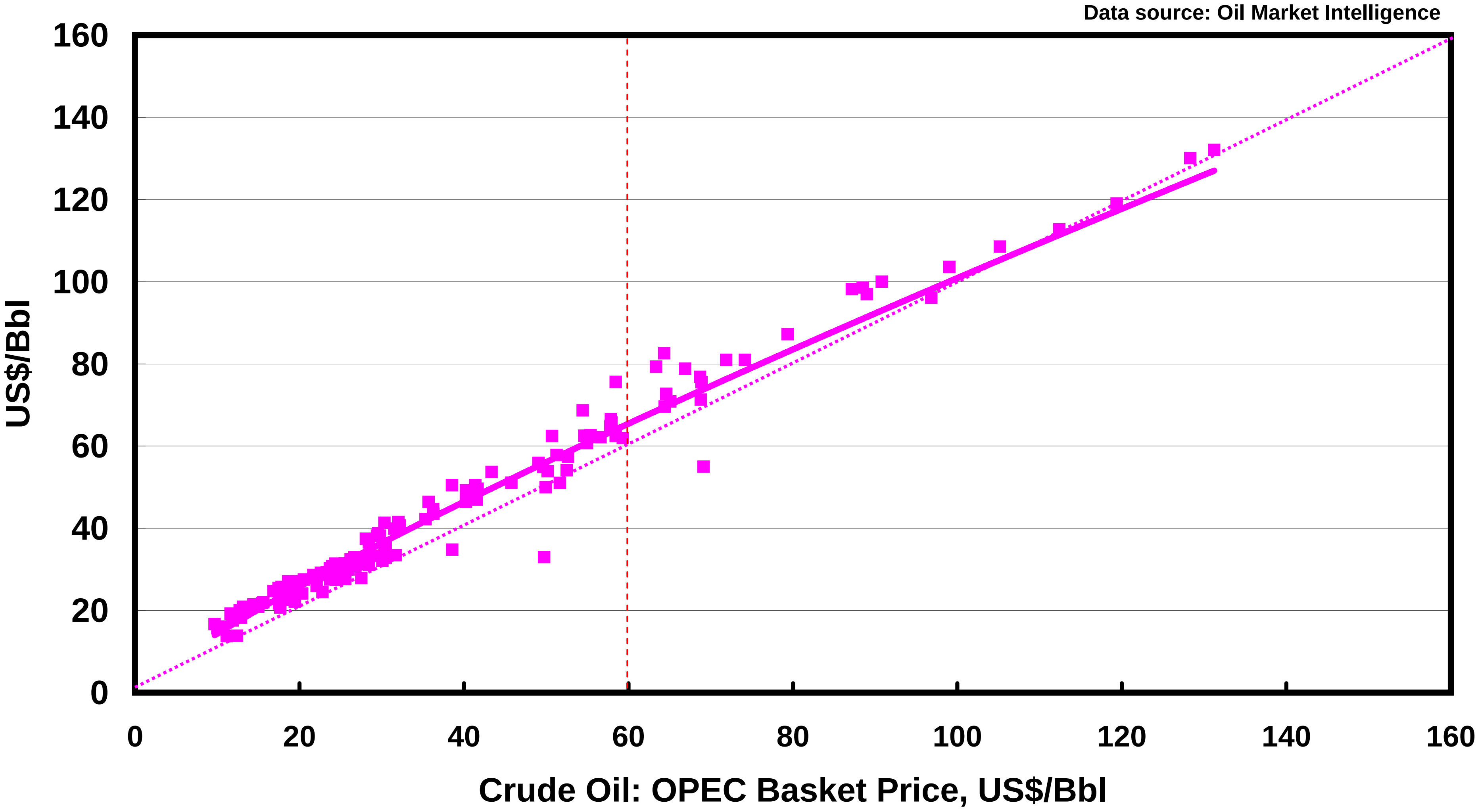


Figure 7.1-2 Diesel Oil Price in Arab Gulf Coast

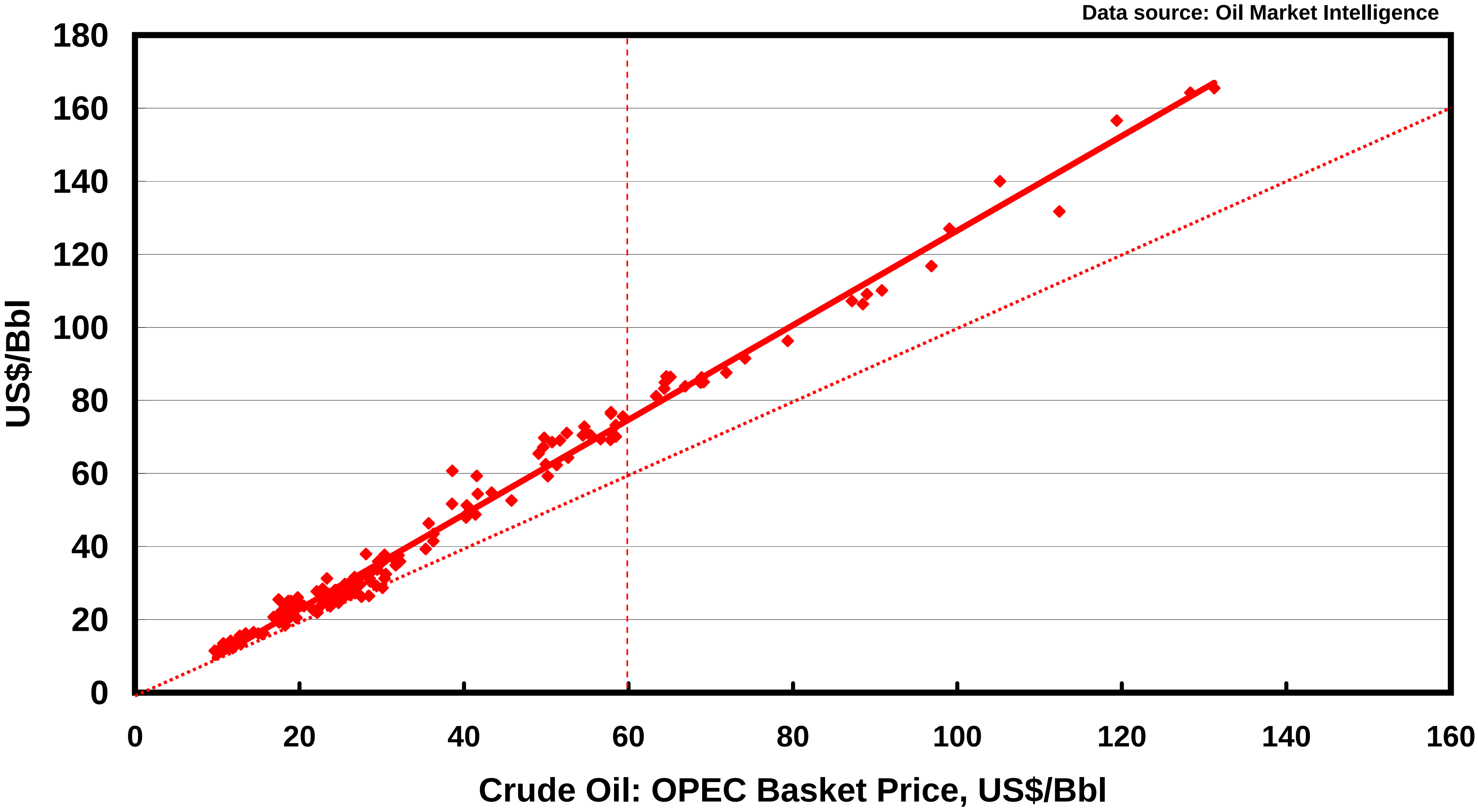


Figure 7.1-3 180cSt High Sulfur Fuel Oil Price in Arab Gulf Coast

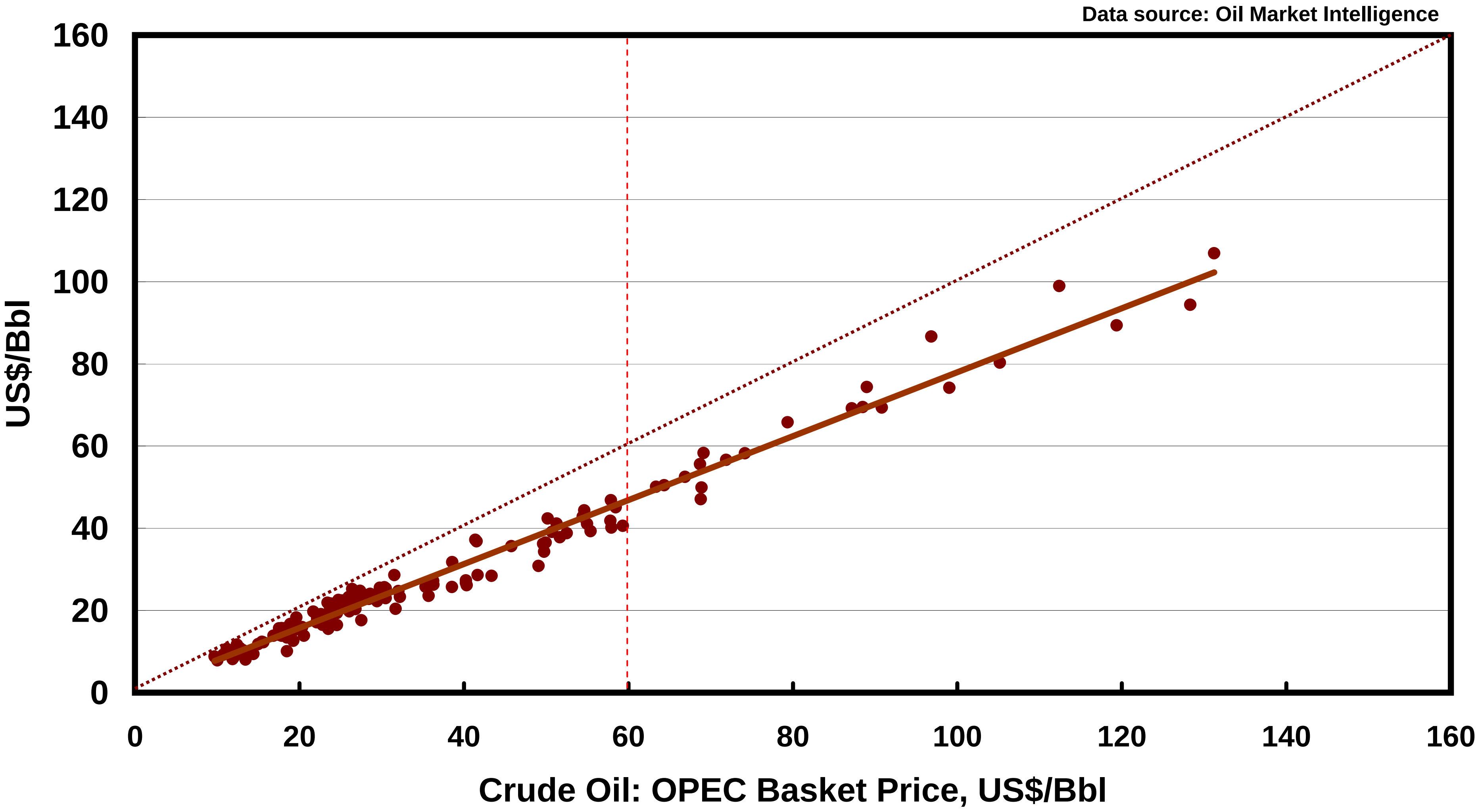


Figure 7.1-4 Prices of Liquid Products on Arab Gulf Coast Basis

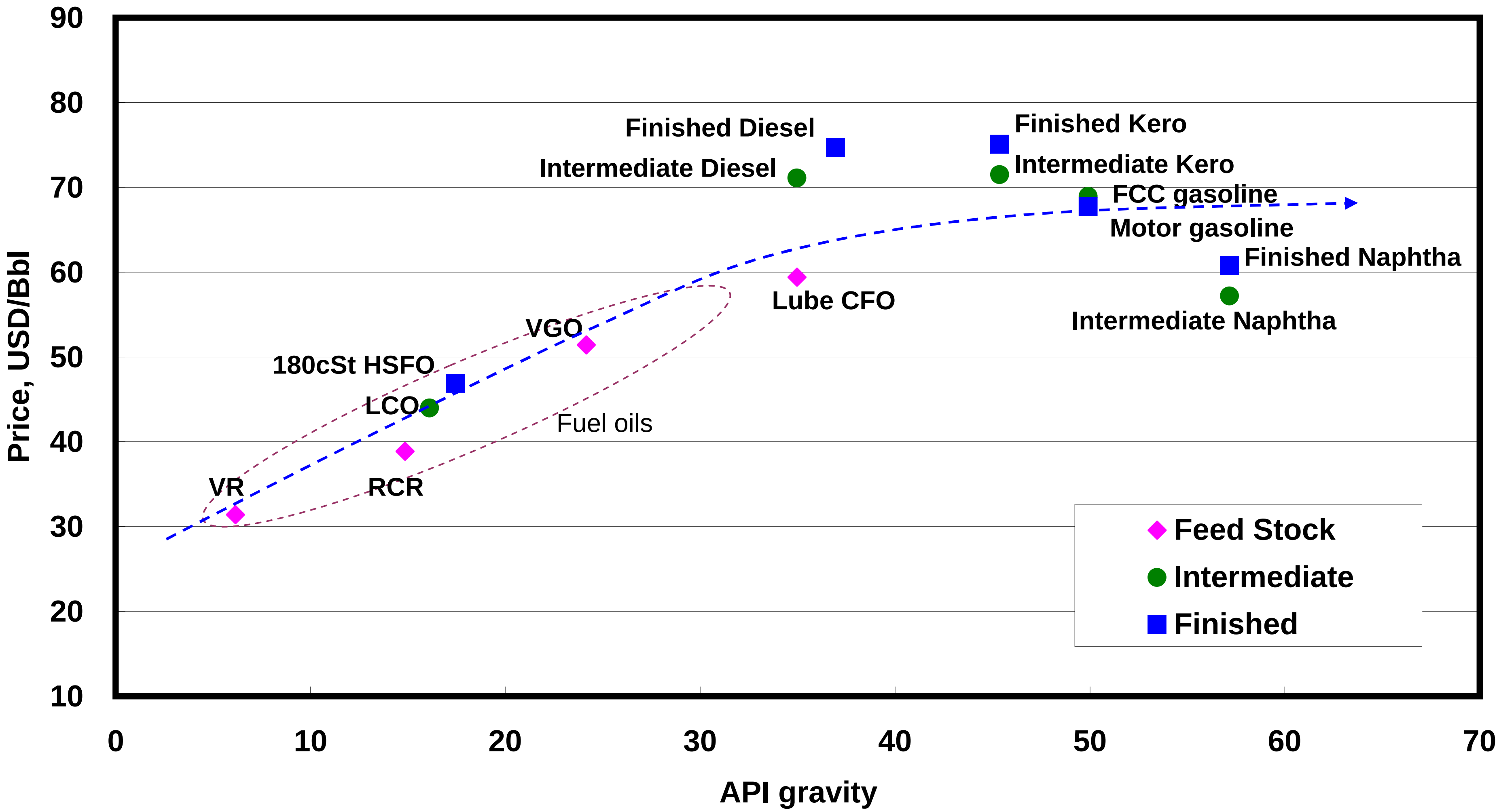


Figure 7.1-5 Prices of Liquid Products on Domestic Basis: Originals and Adjusted

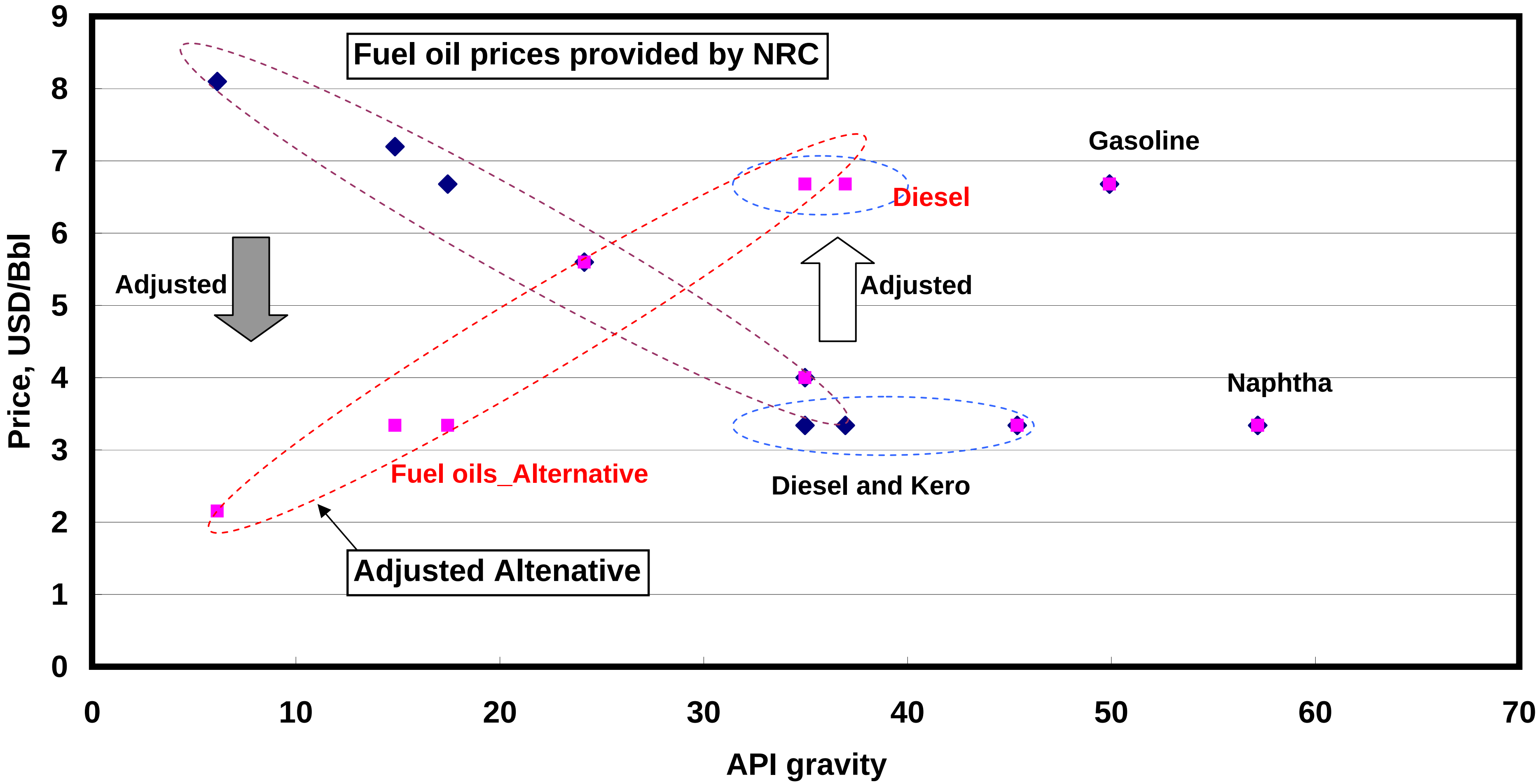


Table 7.1-2 Prices on Feedstocks and Products: Alternative on Domestic Prices

	Arab Gulf Coast (International)		Domestic: Ministry price		Domestic: Adjusted Alternative (for reference)		Remarks
	USD/Bbl	USD/ton	USD/Bbl	USD/ton	USD/Bbl	USD/ton	
Crude							
OPEC basket price	60.0	431	-	-	-	-	30 degree API
NRC Crude Oil	-	-	1.6	12	1.6	12	
Feedstock							
RCR	38.9	253	7.2	47	3.3	22	
VR	31.4	192	8.1	50	2.2	13	
VGO	51.4	356	5.6	39	5.6	39	
Lube CFO	59.4	440	4.0	30	4.0	30	
Intermediate products							
FCC gasoline	68.9	556	6.7	54	6.7	54	
SR Naphtha	57.2	479	3.3	28	3.3	20	
SR kerosene	71.5	590	3.3	26	3.3	20	
SR LGO	71.1	526	3.3	25	6.7	39	
LCO	44.0	289	7.0	46	3.3	22	
DCO	10.0	58	0.3	2	0.3	2	
Syngas(foe)	5.9	39	5.9	39	5.9	39	Equivalent to 1USD/mmBTU
H2	2.0	USD/mscf	2.0	USD/mscf	2.0	USD/mscf	
Finished products							
Mixed LPG	36.8	421	9.4	104	9.4	104	
Naphtha	60.8	510	3.3	28	3.3	28	
Motor gasoline	67.7	546	6.7	54	6.7	54	
Jet/Kerosene	75.1	590	3.3	26	3.3	26	
Diesel	74.7	559	3.3	25	6.7	50	
180cSt HSFO	46.9	310	6.7	44	3.3	22	
Sulfur	-	0	-	0	-	0	

Note) Data source:
Arab Gulf Coast prices are based on information from Oil Market Intelligence.
Domestic prices are provided by NRC.

Table 7.1-3 Outline of Premises on Project Economics Evaluation

Price of Feed and Product	Arab Gulf Coast basis (International)		Domestic and domestic alternative price basis	
		(for reference)	Domestic	Adjusted alternative (for reference)
Calculation condition	JICA condition	Commercial condition	JICA condition	JICA condition
Evaluation concept	Economic justification	Economic justification	Amount of subsidies to write-off loss	Amount of subsidies to write-off loss
Economic IRR (EIRR) (IRR on investment)	X	X	-	-
Financial IRR (FIRR) (IRR on equity)	X	-	-	-
Simple ROI	-	-	X	X
Conditions				
Project period after contract of finance	40 years	20 years after commecement of operation	40 years	40 years
Repayment period	ditto	-	ditto	ditto
Grace period	Front 10 years in repayment period	-	Front 10 years in repayment period	Front 10 years in repayment period
Debt/Equity ratio	85/15	-	85/15	85/15
Interest rate	0.65%	-	0.65%	0.65%
Depreciation 1)	10 years straight-line	10 years straight-line	10 years straight-line	10 years straight-line
Income tax rate	0%	0%	0%	0%
Escalation of feed and product prices	without escalation	without escalation	without escalation	without escalation
On-stream hours and days a year	8.000hr, 333 days	8.000hr, 333 days	8.000hr, 333 days	8.000hr, 333 days
	(91.3%)	(91.3%)	(91.3%)	(91.3%)
On-stream operation				
First year	80%	80%	80%	80%
Second year and thereafter	100%	100%	100%	100%
FEED and Costruction period	55 months	55 months	55 months	55 months

Note: 1) Depreciation method of 10 years straight line is defined in the first meeting with NRC, under NRC's instruction.

Table 7.1-4 Summary of Project Economics

		Condition & Price basis	**SDA**	**Eureka Solid Gasification**	**Eureka Liquid Gasification (For Reference)**	**Delayed Coker (For reference)**
Economic IRR (EIRR) (IRR on Investiment)	%	Commercial Basis International Price	10.7	15.5	16.2	13.2
	%	JICA Basis International Price	11.9	16.2	16.8	14.1
Financial IRR (FIRR) (IRR on Equity)	%	JICA Basis International Price	45.8	57.2	58.8	51.7
Simple ROI	%	JICA Basis Domestic Price	-11.9	-12.4	-12.2	-12.8

Table 7.1-5 Project Economics: JICA Condition on International Basis

	Cost and Price USD/BBL		SDA BPSD	SDA mmUSD/yr	Eureka Solid Gasification BPSD	Eureka Solid Gasification mmUSD/yr	Eureka Liquid Gasification (For reference) BPSD	Eureka Liquid Gasification (For reference) mmUSD/yr	Delayed Coker (For reference) BPSD	Delayed Coker (For reference) mmUSD/yr	Remarks
Raw material purchases											
RCR	39		36,500	473	36,500	473	36,500	473	36,500	473	
VGO#02	51		3,380	58	3,380	58	3,380	58	3,380	58	
VR#02	31		30,420	318	30,420	318	30,420	318	30,420	318	
Lube Surplus	59		5,650	112	5,650	112	5,650	112	5,650	112	
C.F.O	59		5,270	104	5,270	104	5,270	104	5,270	104	
Total raw material purchases				1,066		1,066		1,066		1,066	(1)
Product sales											
LPG	37		17,682	217	14,105	173	14,105	173	11,441	140	
Naphtha	61		1,409	29	5,070	103	5,070	103	9,676	196	
Diesel	75		13,682	341	21,899	545	21,899	545	22,010	548	
FCC Gasoline	69		32,281	742	29,170	670	29,170	670	23,585	542	
LCO	44		5,292	78	3,200	47	3,200	47	2,497	37	
DCO	10		3,146	10	2,259	8	262	1	1,766	6	
Sulfur	0		485	0	485	0	494	0	501	0	
Syngas (foe)	6		4,089	8	1,861	4	3,537	7	6,496	13	
H2	2	USD/mscf	70	47	70	47	70	47	70	47	
Total product sales				1,471		1,596		1,593		1,528	(2)
Gross revenue				405		530		527		463	(3)=(2)-(1)
Operating cost				86.0		81.3		78.0		81.4	(4)
Net revenue				319		449		449		381	(5)=(3)-(4)
Depreciation - 10 years straight-line method				188		183		174		185	(6)
Taxable income				131		266		275		196	(7)=(5)-(6)
Income tax				0		0				0	(8)=(7)x(9)
Income tax rate			0%		0%		0%		0%		(9)
Profit				131		266		275		196	(10)=(7)-(8)
Cash flow				319		449		449		381	(11)=(5)-(8)
Economic IRR (EIRR) (IRR on investment)				11.9%		16.2%		16.8%		14.1%	Project period: 40 years
Financial IRR (FIRR) (IRR on equity)				45.8%		5720.4%		58.8%		51.7%	Project period: 40 years
Net present value				527		1,819		1,934		1,158	mmUSD
@Discount rate =	10%										

Table 7.1-6 Project Economics: Commercial Condition on International Basis

	Cost and Price USD/BBL		SDA BPSD	SDA mmUSD/yr	Eureka Solid Gasification BPSD	Eureka Solid Gasification mmUSD/yr	Eureka Liquid Gasification (For reference) BPSD	Eureka Liquid Gasification (For reference) mmUSD/yr	Delayed Coker (For reference) BPSD	Delayed Coker (For reference) mmUSD/yr	Remarks
Raw material purchases											
RCR	39		36,500	473	36,500	473	36,500	473	36,500	473	
VGO#02	51		3,380	58	3,380	58	3,380	58	3,380	58	
VR#02	31		30,420	318	30,420	318	30,420	318	30,420	318	
Lube Surplus	59		5,650	112	5,650	112	5,650	112	5,650	112	
C.F.O	59		5,270	104	5,270	104	5,270	104	5,270	104	
Total raw material purchases				1,066		1,066		1,066		1,066	(1)
Product sales											
LPG	37		17,682	217	14,105	173	14,105	173	11,441	140	
Naphtha	61		1,409	29	5,070	103	5,070	103	9,676	196	
Diesel	75		13,682	341	21,899	545	21,899	545	22,010	548	
FCC Gasoline	69		32,281	742	29,170	670	29,170	670	23,585	542	
LCO	44		5,292	78	3,200	47	3,200	47	2,497	37	
DCO	10		3,146	10	2,259	8	262	1	1,766	6	
Sulfur	0		485	0	485	0	494	0	501	0	
Syngas (foe)	6		4,089	8	1,861	4	3,537	7	6,496	13	
H2	2	USD/mscf	70	47	70	47	70	47	70	47	
Total product sales				1,471		1,596		1,593		1,528	(2)
Gross revenue				405		530		527		463	(3)=(2)-(1)
Operating cost				86.0		81.3		78.0		81.4	
Net revenue				319		449		449		381	(5)=(3)-(4)
Depreciation - 10 years straight-line method				188		183		174		185	(6)
Taxable income				131		266		275		196	(7)=(5)-(6)
Income tax				0		0				0	(8)=(7)x(9)
Income tax rate			0%		0%		0%		0%		(9)
Profit				131		266		275		196	(10)=(7)-(8)
Cash flow				319		449		449		381	(11)=(5)-(8)
Economic IRR (EIRR) (IRR on investment)				10.7%		15.5%		16.2%		13.2%	Project period: 20years
Net present value @Discount rate = 10%				156		1,296		1,411		715	mmUSD

Table 7.1-7 Project Economics: JICA Condition on Domestic Basis

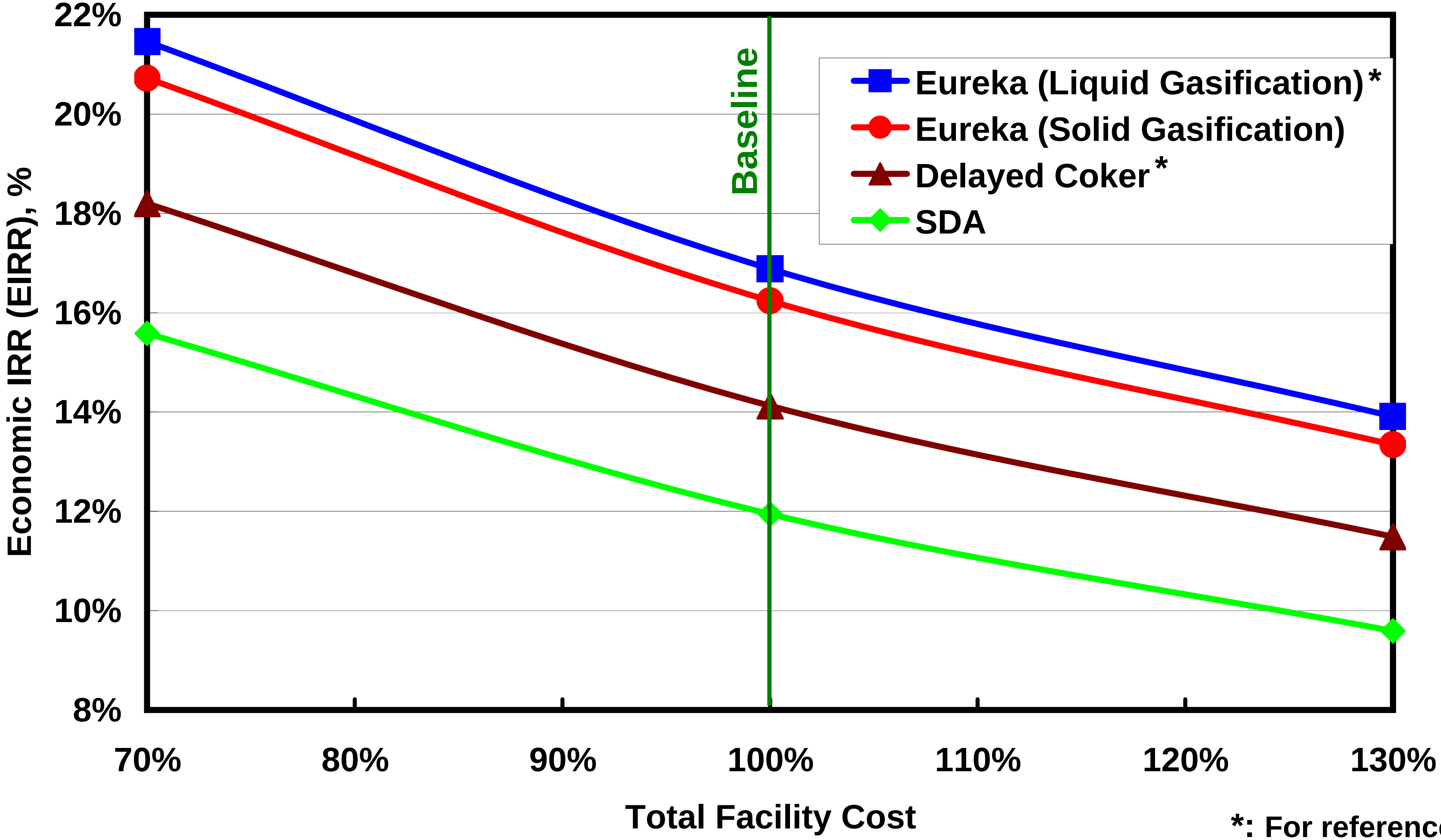
	Cost and Price USD/BBL		SDA BPSD	SDA mmUSD/yr	Eureka Solid Gasification BPSD	Eureka Solid Gasification mmUSD/yr	Eureka Liquid Gasification (For reference) BPSD	Eureka Liquid Gasification (For reference) mmUSD/yr	Delayed Coker (For reference) BPSD	Delayed Coker (For reference) mmUSD/yr	Remarks
Raw material purchases											
RCR	7		36,500	88	36,500	88	36,500	88	36,500	88	
VGO#02	6		3,380	6	3,380	6	3,380	6	3,380	6	
VR#02	8		30,420	82	30,420	82	30,420	82	30,420	82	
Lube Surplus	4		5,650	8	5,650	8	5,650	8	5,650	8	
C.F.O	4		5,270	7	5,270	7	5,270	7	5,270	7	
Total raw material purchases				191		191		191		191	(1)
Product sales											
LPG	9		17,682	55	14,105	44	14,105	44	11,441	36	
Naphtha	3		1,409	2	5,070	6	5,070	6	9,676	11	
Diesel	3		13,682	15	21,899	24	21,899	24	22,010	24	
FCC Gasoline	7		32,281	72	29,170	65	29,170	65	23,585	52	
LCO	7		5,292	12	3,200	7	3,200	7	2,497	6	
DCO	0		3,146	0	2,259	0	262	0	1,766	0	
Sulfur	0		485	0	485	0	494	0	501	0	
Syngas (foe)	6		4,089	8	1,861	4	3,537	7	6,496	13	
H2	2	USD/mscf	70	47	70	47	70	47	70	47	
Total product sales				211		197		200		189	(2)

	SDA In first 6 years mmUSD/yr	SDA In 7th year mmUSD/yr	Eureka Solid Gasification In first 6 years mmUSD/yr	Eureka Solid Gasification In 7th year mmUSD/yr	Eureka Liquid Gasification In first 6 years mmUSD/yr	Eureka Liquid Gasification In 7th year mmUSD/yr	Delayed Coker In first 6 years mmUSD/yr	Delayed Coker In 7th year mmUSD/yr	Remarks
Gross revenue	21	21	6	6	10	10	-2	-2	(3)=(2)-(1)
Operating cost	86.0	86.0	81.3	81.3	78.0	78.0	81.4	81.4	
Repayment	0.0	75.9	0.0	74.0	0.0	70.5	0.0	74.5	(5)
Subsidies	65.3	141.2	74.8	148.8	68.3	138.9	83.0	157.5	(6)
Net revenue	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	(7)=(3)-(4)-(5)+(6)
Simple ROI without Subsidies		-11.9%		-12.4%		-12.2%		-12.8%	

Table 7.1-7b Project Economics: JICA Condition on Domestic-Alt

	Cost and Price USD/BBL		SDA		Eureka Solid Gasification		Eureka Liquid Gasification (For reference)		Delayed Coker (For reference)		Remarks
			BPSD	mmUSD/yr	BPSD	mmUSD/yr	BPSD	mmUSD/yr	BPSD	mmUSD/yr	
Raw material purchases											
RCR	3		36,500	41	36,500	41	36,500	41	36,500	41	
VGO#02	6		3,380	6	3,380	6	3,380	6	3,380	6	
VR#02	2		30,420	22	30,420	22	30,420	22	30,420	22	
Lube Surplus	4		5,650	8	5,650	8	5,650	8	5,650	8	
C.F.O	4		5,270	7	5,270	7	5,270	7	5,270	7	
Total raw material purchases				83		83		83		83	(1)
Product sales											
LPG	9		17,682	55	14,105	44	14,105	44	11,441	36	
Naphtha	3		1,409	2	5,070	6	5,070	6	9,676	11	
Diesel	7		13,682	30	21,899	49	21,899	49	22,010	49	
FCC Gasoline	7		32,281	72	29,170	65	29,170	65	23,585	52	
LCO	3		5,292	6	3,200	4	3,200	4	2,497	3	
DCO	0		3,146	0	2,259	0	262	0	1,766	0	
Sulfur	0		485	0	485	0	494	0	501	0	
Syngas (foe)	6		4,089	8	1,861	4	3,537	7	6,496	13	
H2	2	USD/mscf	70	47	70	47	70	47	70	47	
Total product sales				220		218		221		210	(2)
			In first 6 years	**In 7th year**	**In first 6 years**	**In 7th year**	**In first 6 years**	**In 7th year**	**In first 6 years**	**In 7th year**	
			mmUSD/yr	mmUSD/yr	mmUSD/yr	mmUSD/yr	mmUSD/yr	mmUSD/yr	mmUSD/yr	mmUSD/yr	
Gross revenue			137	137	134	134	137	137	127	127	(3)=(2)-(1)
Operating cost			86.0	86.0	81.3	81.3	78.0	78.0	81.4	81.4	
Repayment			0.0	75.8	0.0	74.0	0.0	70.5	0.0	74.5	(5)
Subsidies			0.0	25.0	0.0	21.2	0.0	11.2	0.0	28.8	(6)
Net revenue			50.7	0.0	52.8	0.0	59.3	0.0	45.7	0.0	(7)=(3)-(4)-(5)+(6)
Simple ROI without Subsidies				-6.5%		-6.3%		-5.8%		-6.7%	

Figure 7.1-6 Sensitivity Analysis: Effect of Facility Cost on EIRR



*: For reference

Figure 7.1-7 Sensitivity Analysis: Effect of Crude & Product Price on EIRR

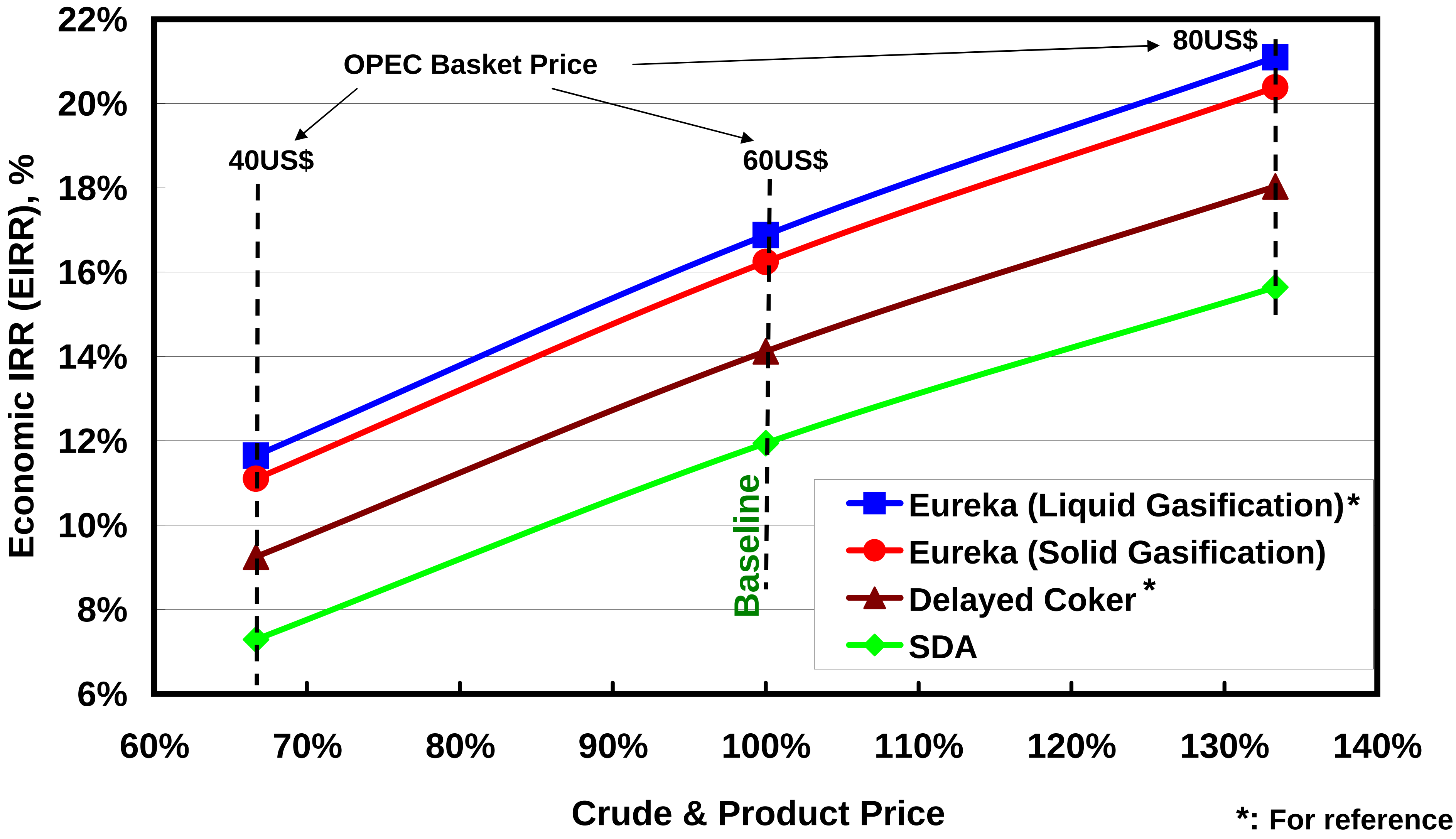


Figure 7.1-8 Sensitivity Analysis: Effect of Operating Cost on EIRR

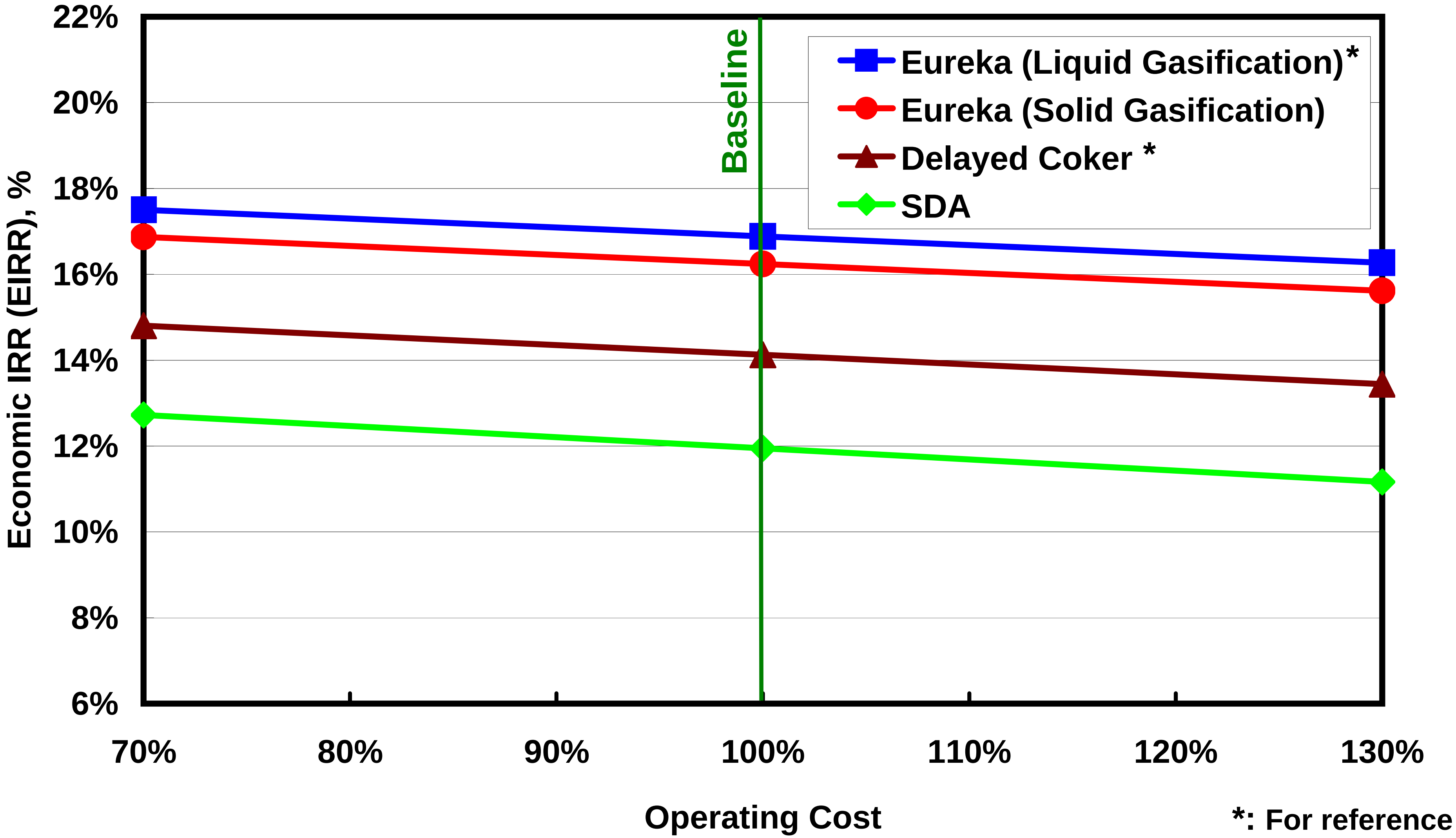
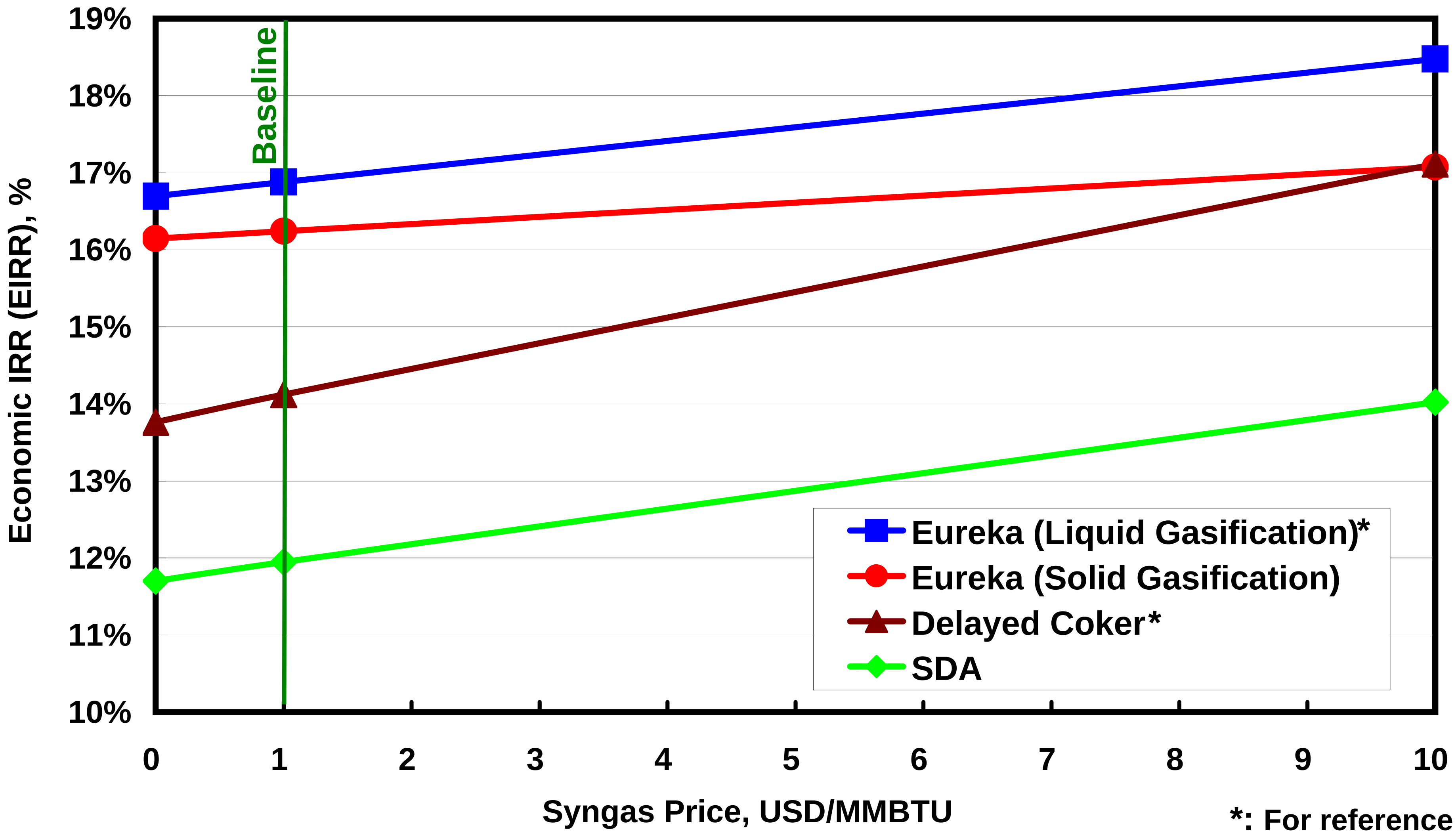
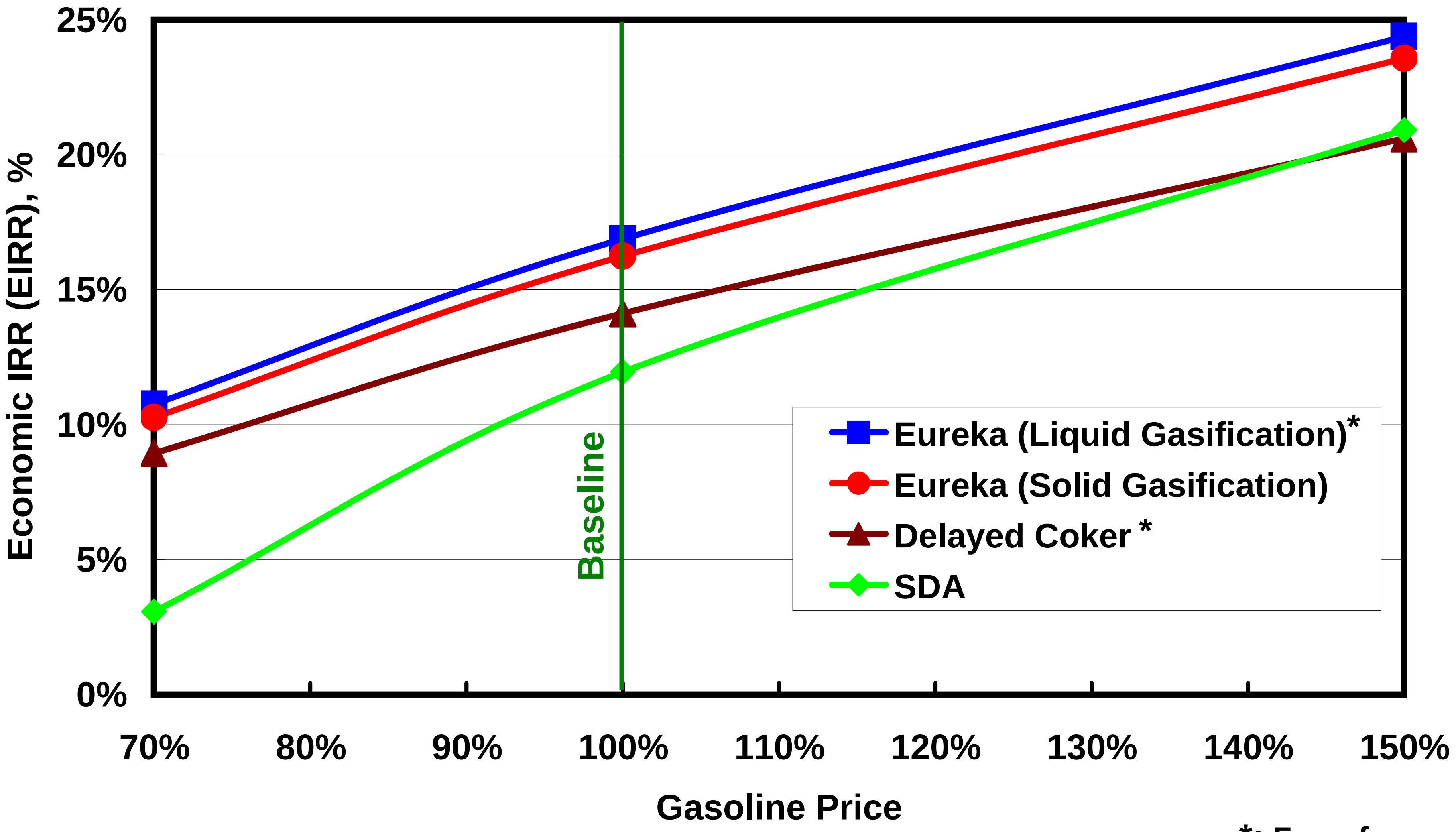


Figure 7.1-9 Sensitivity Analysis: Effect of Syngas Price on EIRR



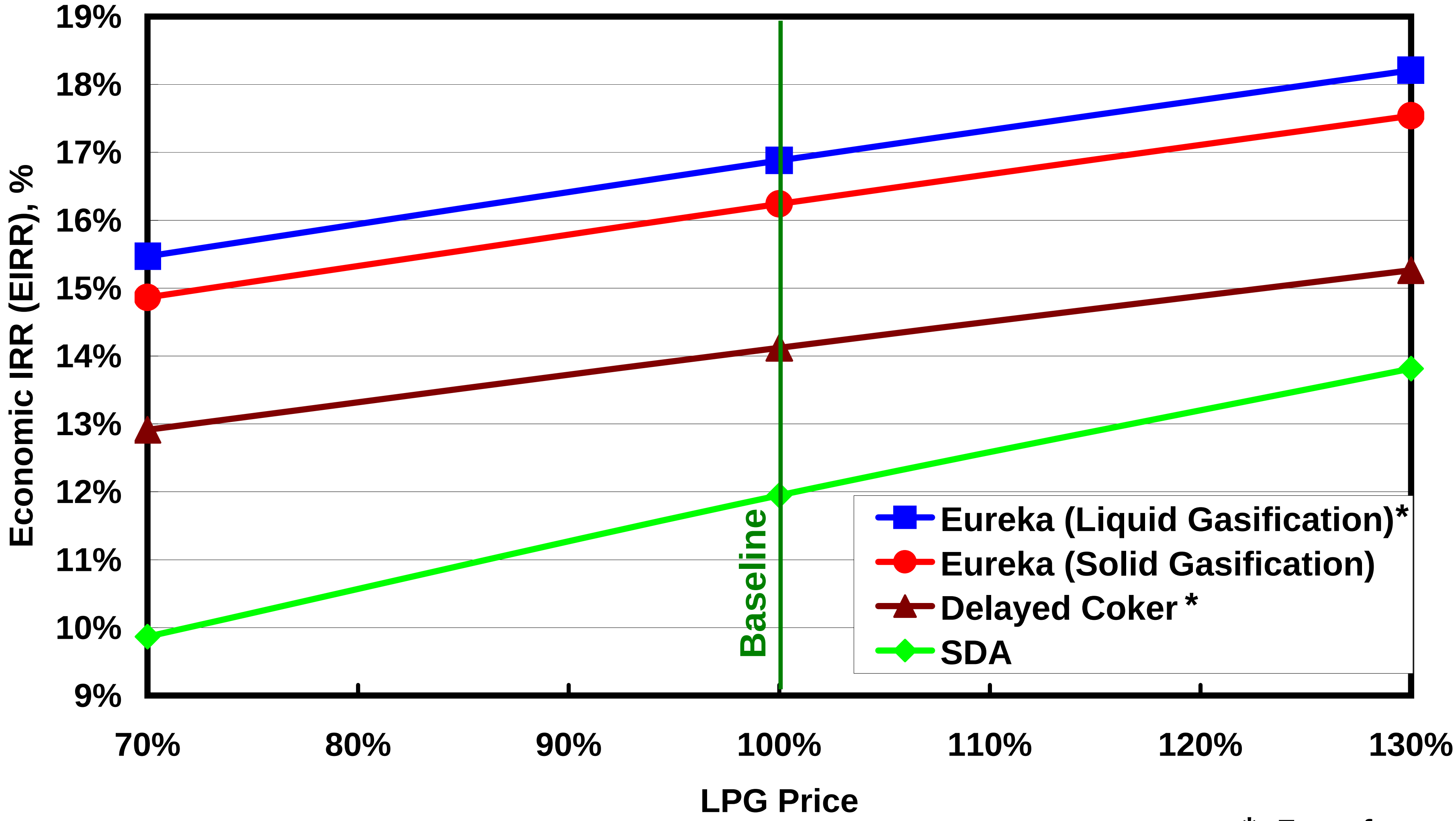
*: For reference

Figure 7.1-10 Sensitivity Analysis: Effect of Gasoline Price on EIRR



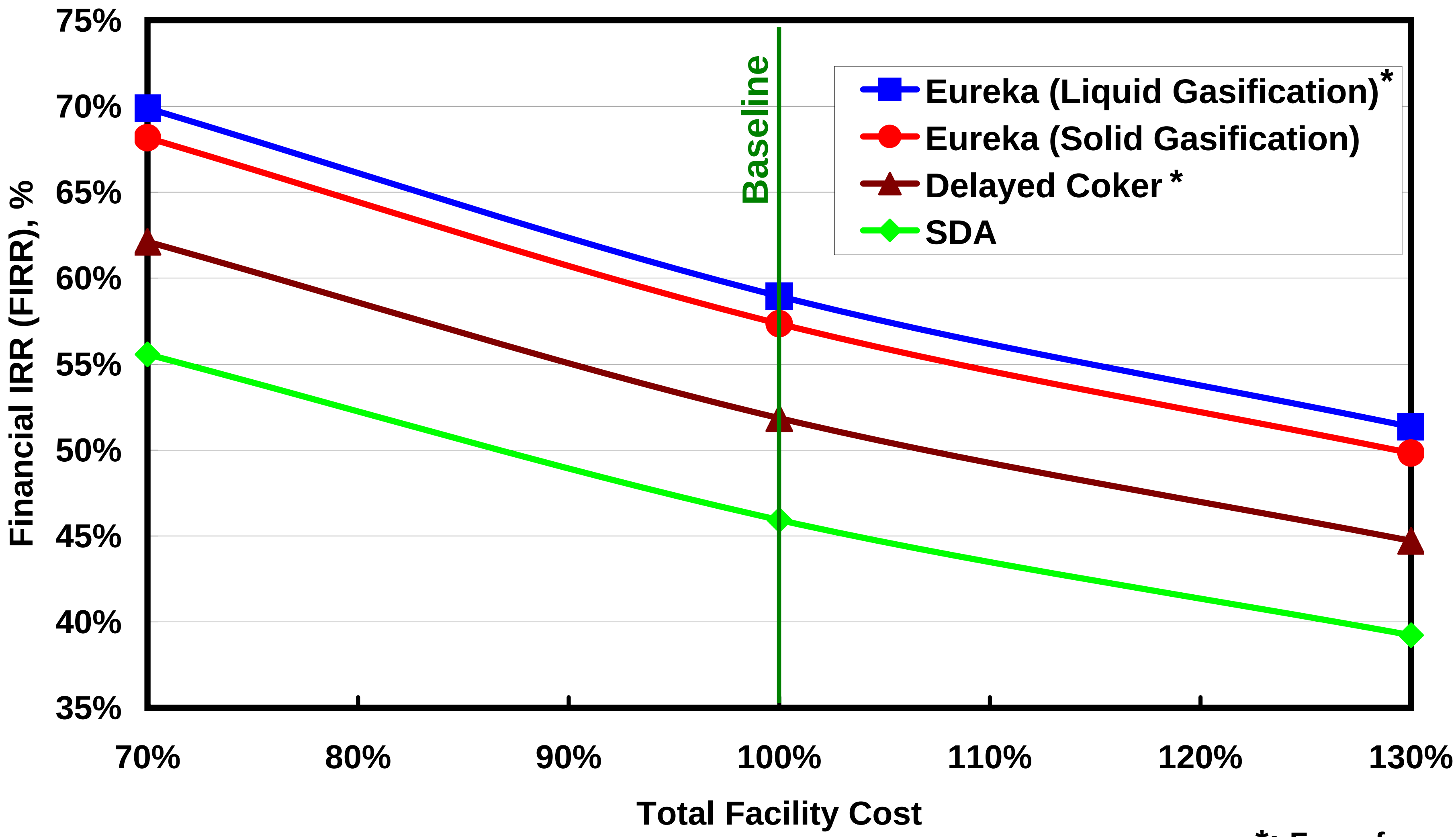
*: For reference

Figure 7.1-11 Sensitivity Analysis: Effect of LPG Price on EIRR



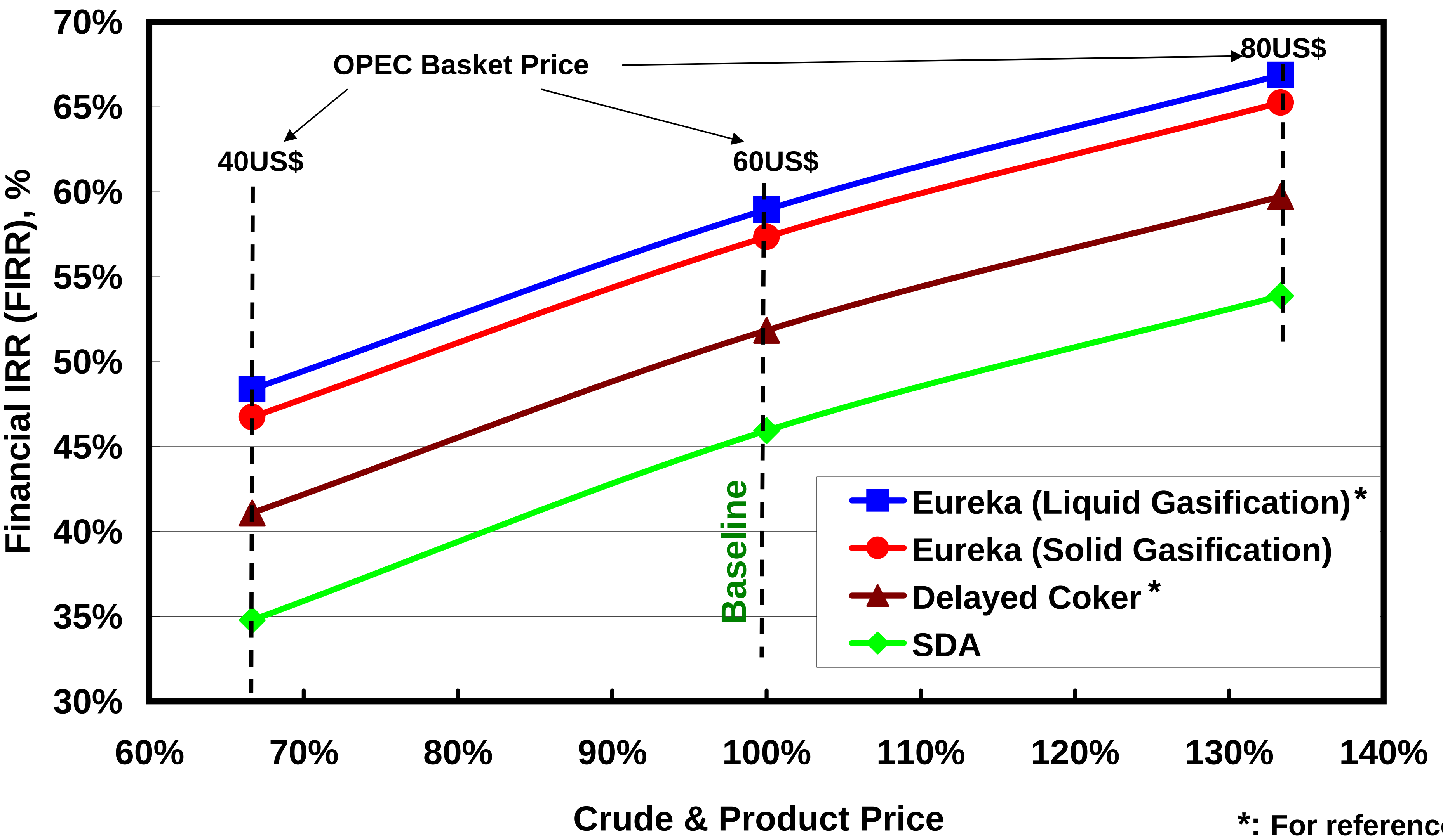
*: For reference

Figure 7.1-12 Sensitivity Analysis: Effect of Facility Cost on FIRR



*: For reference

Figure 7.1-13 Sensitivity Analysis: Effect of Crude & Product Price on FIRR



*: For reference

Table 7.1-8 Profit & Loss Statement: JICA Condition on International Basis
- SDA Case -

Year			-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11
Product sales	**mmUS$/yr**							1,176	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471
Raw material purchases	**mmUS$/yr**							853	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066
Gross income	**mmUS$/yr**							324	405	405	405	405	405	405	405	405	405	405
Utilization rate	**%**							80%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Operating cost	**mmUS$/yr**							84	86	86	86	86	86	86	86	86	86	86
Depreciation	**mmUS$/yr**							188	188	188	188	188	188	188	188	188	188	0
Interest	**mmUS$/yr**							0.0	0.0	0.0	0.0	0.0	0.0	12.3	11.9	11.5	11.0	10.6
Income before tax	**mmUS$/yr**							52	131	131	131	131	131	119	119	119	120	308
Tax	**mmUS$/yr**							0	0	0	0	0	0	0	0	0	0	0
Tax rate		0%																
Income after tax(Profit)	**mmUS$/yr**							52	131	131	131	131	131	119	119	119	120	308
Capital investment	**mmUS$**	2,151	26	378	791	604	352											
Facility cost and owner's cost	**mmUS$**	2,126	26	378	786	596	341											
Interest during construction	**mmUS$**	24	0.04	1	4	8	11											
Debt	**mmUS$**	1,832	22	322	673	515	301											
Equity	**mmUS$**	319.0	3.8	56.7	118.0	89.4	51.1											
Debt service																		
Debt	**mmUS$**	1,832	22	322	673	515	301											
Interest rate	**%**	0.65%																
Repayment period	**years**	36																
Grace period	**years**	6																
Accumulated interest during grace period	**mmUS$**		0.04	1	5	13	24	36	48	60	73	85	97					
Principal payment	**mmUS$**							0	0	0	0	0	0	63	63	63	63	63
Interest payment	**mmUS$**							0	0	0	0	0	0	12	12	11	11	11
Balance	**mmUS$**							52	131	131	131	131	131	43	44	44	45	234
Simple ROI (on Profit basis)	**%**							2.4%	6.1%	6.1%	6.1%	6.1%	6.1%	2.0%	2.0%	2.1%	2.1%	10.9%
Average Simple ROI	**%**	9.3%																

Table 7.1-8 Profit & Loss Statement: JICA Condition on International Basis
- SDA Case - Cont'd.

12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471
1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066
405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.2	9.8	9.4	9.0	8.6	8.1	7.7	7.3	6.9	6.5	6.1	5.7	5.3	4.8	4.4	4.0	3.6	3.2	2.8	2.4	2.0	1.8	1.1	0.7	0.3
309	309	310	310	310	311	311	312	312	312	313	313	314	314	314	315	315	316	316	317	317	317	318	318	319
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
309	309	310	310	310	311	311	312	312	312	313	313	314	314	314	315	315	316	316	317	317	317	318	318	319
63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63	63
10	10	9	9	9	8	8	7	7	6	6	6	5	5	4	4	4	3	3	2	2	2	1	1	0
235	236	237	237	238	239	240	241	242	242	243	244	245	246	247	247	248	249	250	251	252	252	253	254	255
10.9%	11.0%	11.0%	11.0%	11.1%	11.1%	11.2%	11.2%	11.2%	11.3%	11.3%	11.3%	11.4%	11.4%	11.5%	11.5%	11.5%	11.6%	11.6%	11.7%	11.7%	11.7%	11.8%	11.8%	11.8%

Table 7.1-9 Cash Flow: JICA Condition on International Basis
- SDA Case -

Year			-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11
Product sales	**mmUS$/yr**							1,176	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471
Raw material purchases	**mmUS$/yr**							853	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066
Gross income	**mmUS$/yr**							324	405	405	405	405	405	405	405	405	405	405
Operating cost	**mmUS$/yr**							84	86	86	86	86	86	86	86	86	86	86
Tax	**mmUS$/yr**							0	0	0	0	0	0	0	0	0	0	0
Interest	**mmUS$/yr**							0.0	0.0	0.0	0.0	0.0	0.0	12.3	11.9	11.5	11.0	10.6
Principal payment	**mmUS$/yr**							0.0	0.0	0.0	0.0	0.0	0.0	63.5	63.5	63.5	63.5	63.5
Net Cash Flow	**mmUS$/yr**		-4	-57	-118	-89	-51	240	319	319	319	319	319	243	244	244	244	245
DSCR								-	-	-	-	-	-	4.21	4.23	4.26	4.28	4.30
Minimum DSCR	**-**	4.30																
ROE								75%	100%	100%	100%	100%	100%	76%	76%	76%	77%	77%
Equity	**mmUS$**	319.0	3.8	56.7	118.0	89.4	51.1											
Equity % in total investment	**%**	15%																
Average ROE	**%**	81%																
Financial Evaluation																		
FIRR; Financioal IRR	**%**	**45.8%**																
(IRR on Equity)																		

Table 7.1-9 Cash Flow: JICA Condition on International Basis
- SDA Case - Cont'd.

	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471
	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066
	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405
	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	10.2	9.8	9.4	9.0	8.6	8.1	7.7	7.3	6.9	6.5	6.1	5.7	5.3	4.8	4.4	4.0	3.6	3.2	2.8	2.4	2.0	1.5	1.1	0.7	0.3
	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5	63.5
	245	246	246	246	247	247	248	248	249	249	249	250	250	251	251	251	252	252	253	253	253	254	254	255	255
	4.33	4.35	4.38	4.40	4.43	4.45	4.48	4.50	4.53	4.56	4.58	4.61	4.64	4.67	4.70	4.72	4.75	4.78	4.81	4.84	4.87	4.90	4.94	4.97	5.00
	77%	77%	77%	77%	77%	78%	78%	78%	78%	78%	78%	78%	78%	79%	79%	79%	79%	79%	79%	79%	79%	80%	80%	80%	80%

Table 7.1-10 Free Cash Flow: JICA Condition on International Basis
- SDA Case -

Year			-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11
Product sales	mmUS$/yr							1,176	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471
Raw material purchases	mmUS$/yr							853	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066
Gross income	mmUS$/yr							324	405	405	405	405	405	405	405	405	405	405
Operating cost	mmUS$/yr							84	86	86	86	86	86	86	86	86	86	86
Depreciation	mmUS$/yr							188	188	188	188	188	188	188	188	188	188	0
Taxable income	mmUS$/yr							52	131	131	131	131	131	131	131	131	131	319
Tax	mmUS$/yr							0	0	0	0	0	0	0	0	0	0	0
Free Cash Flow	mmUS$/yr		-26	-378	-786	-596	-341	240	319	319	319	319	319	319	319	319	319	319
Discounted Cash Flow	mmUS$/yr		-37	-503	-952	-655	-341	219	264	240	218	198	180	164	149	135	123	112
Discount rate	%	10.0%																
Cummulative Discounted Cash Flow	mmUS$/yr		-37	-540	-1,492	-2,147	-2,488	-2,270	-2,006	-1,766	-1,549	-1,351	-1,170	-1,007	-858	-723	-600	-488
Econimical Evaluation																		
EIRR; Econimical IRR (IRR on Investment)	%	11.9%																
Net Present Value	mmUS$	527																
Simple ROI(on FCF basis)	%							11.3%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%
Average Simple ROI	%	14.9%																

Table 7.1-10 Free Cash Flow: JICA Condition on International Basis
- SDA Case - Cont'd.

	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471	1,471
	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066
	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405	405
	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86	86
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319
	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319	319
	102	92	84	76	69	63	57	52	47	43	39	36	32	29	27	24	22	20	18	17	15	14	12	11	10
	-386	-294	-210	-134	-64	-1	56	108	156	199	238	274	306	335	362	386	409	429	447	464	479	492	505	516	527
	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%	15.0%

Table 7.1-11 Profit & Loss Statement: JICA Condition on International Basis
- Eureka (Solid Gasification) Case -

Year			-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11
Product sales	**mmUS$/yr**							1,277	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596
Raw material purchases	**mmUS$/yr**							853	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066
Gross income	**mmUS$/yr**							424	530	530	530	530	530	530	530	530	530	530
Utilization rate	**%**							80%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Operating cost	**mmUS$/yr**							80	81	81	81	81	81	81	81	81	81	81
Depreciation	**mmUS$/yr**							183	183	183	183	183	183	183	183	183	183	0
Interest	**mmUS$/yr**							0.0	0.0	0.0	0.0	0.0	0.0	12.0	11.6	11.2	10.8	10.4
Income before tax	**mmUS$/yr**							161	266	266	266	266	266	254	254	254	255	439
Tax	**mmUS$/yr**							0	0	0	0	0	0	0	0	0	0	0
Tax rate		0%																
Income after tax(Profit)	**mmUS$/yr**							161	266	266	266	266	266	254	254	254	255	439
Capital investment	**mmUS$**	2,101	25	370	772	590	344											
Facility cost and owner's cost	**mmUS$**	2,077	25	369	768	582	333											
Interest during construction	**mmUS$**	24	0.03	1	4	8	11											
Debt	**mmUS$**	1,790	21	314	657	503	294											
Equity	**mmUS$**	311.6	3.7	55.4	115.2	87.3	49.9											
Debt service																		
Debt	**mmUS$**	1,790	21	314	657	503	294											
Interest rate	**%**	0.65%																
Repayment period	**years**	36																
Grace period	**years**	6																
Accumulated interest during grace period	**mmUS$**		0.03	1	5	13	24	35	47	59	71	83	95					
Principal payment	**mmUS$**							0	0	0	0	0	0	62	62	62	62	62
Interest payment	**mmUS$**							0	0	0	0	0	0	12	12	11	11	10
Balance	**mmUS$**							161	266	266	266	266	266	180	180	181	182	366
Simple ROI (on Profit basis)	**%**							7.7%	12.6%	12.6%	12.6%	12.6%	12.6%	8.5%	8.6%	8.6%	8.7%	17.4%
Average Simple ROI	**%**	16.4%																

Table 7.1-11 Profit & Loss Statement: JICA Condition on International Basis
- Eureka (Solid Gasification) Case - Cont'd.

12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596
1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066
530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530
100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.0	9.6	9.2	8.8	8.4	8.0	7.6	7.2	6.8	6.3	5.9	5.5	5.1	4.7	4.3	3.9	3.5	3.1	2.7	2.3	1.9	1.7	1.1	0.7	0.3
439	439	440	440	441	441	441	442	442	443	443	443	444	444	445	445	445	446	446	447	447	447	448	448	449
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
439	439	440	440	441	441	441	442	442	443	443	443	444	444	445	445	445	446	446	447	447	447	448	448	449
62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62	62
10	10	9	9	8	8	8	7	7	6	6	6	5	5	4	4	4	3	3	2	2	2	1	1	0
367	368	369	369	370	371	372	373	373	374	375	376	377	377	378	379	380	381	381	382	383	384	385	385	386
17.5%	17.5%	17.5%	17.6%	17.6%	17.7%	17.7%	17.7%	17.8%	17.8%	17.8%	17.9%	17.9%	18.0%	18.0%	18.0%	18.1%	18.1%	18.2%	18.2%	18.2%	18.3%	18.3%	18.3%	18.4%

Table 7.1-12 Cash Flow: JICA Condition on International Basis
- Eureka (Solid Gasification) Case -

Year			-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11
Product sales	**mmUS$/yr**							1,277	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596
Raw material purchases	**mmUS$/yr**							853	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066
Gross income	**mmUS$/yr**							424	530	530	530	530	530	530	530	530	530	530
Operating cost	**mmUS$/yr**							80	81	81	81	81	81	81	81	81	81	81
Tax	**mmUS$/yr**							0	0	0	0	0	0	0	0	0	0	0
Interest	**mmUS$/yr**							0.0	0.0	0.0	0.0	0.0	0.0	12.0	11.6	11.2	10.8	10.4
Principal payment	**mmUS$/yr**							0.0	0.0	0.0	0.0	0.0	0.0	62.0	62.0	62.0	62.0	62.0
Net Cash Flow	**mmUS$/yr**		-4	-55	-115	-87	-50	345	449	449	449	449	449	375	375	376	376	377
DSCR								-	-	-	-	-	-	6.07	6.10	6.13	6.17	6.20
Minimum DSCR	**-**	6.20																
ROE								111%	144%	144%	144%	144%	144%	120%	120%	121%	121%	121%
Equity	**mmUS$**	311.6	3.7	55.4	115.2	87.3	49.9											
Equity % in total investment	**%**	15%																
Average ROE	**%**	127%																
<u>Financial Evaluation</u>																		
FIRR; Financioal IRR	**%**	**57.2%**																
(IRR on Equity)																		

Table 7.1-12 Cash Flow: JICA Condition on International Basis
- Eureka (Solid Gasification) Case - Cont'd.

12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596
1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066
530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530
81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10.0	9.6	9.2	8.8	8.4	8.0	7.6	7.2	6.8	6.3	5.9	5.5	5.1	4.7	4.3	3.9	3.5	3.1	2.7	2.3	1.9	1.5	1.1	0.7	0.3
62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0
377	377	378	378	379	379	379	380	380	381	381	381	382	382	383	383	383	384	384	385	385	385	386	386	387
6.24	6.27	6.31	6.34	6.38	6.41	6.45	6.49	6.53	6.57	6.61	6.64	6.68	6.72	6.77	6.81	6.85	6.89	6.93	6.98	7.02	7.07	7.11	7.16	7.20
121%	121%	121%	121%	121%	122%	122%	122%	122%	122%	122%	122%	123%	123%	123%	123%	123%	123%	123%	123%	124%	124%	124%	124%	124%

Table 7.1-13 Free Cash Flow: JICA Condition on International Basis
- Eureka (Solid Gasification) Case -

Year			-4	-3	-2	-1	0	1	2	3	4	5	6	7	8	9	10	11
Product sales	mmUS$/yr							1,277	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596
Raw material purchases	mmUS$/yr							853	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066
Gross income	mmUS$/yr							424	530	530	530	530	530	530	530	530	530	530
Operating cost	mmUS$/yr							80	81	81	81	81	81	81	81	81	81	81
Depreciation	mmUS$/yr							183	183	183	183	183	183	183	183	183	183	0
Taxable income	mmUS$/yr							161	266	266	266	266	266	266	266	266	266	449
Tax	mmUS$/yr							0	0	0	0	0	0	0	0	0	0	0
Free Cash Flow	mmUS$/yr		-25	-369	-768	-582	-333	345	449	449	449	449	449	449	449	449	449	449
Discounted Cash Flow	mmUS$/yr		-37	-491	-930	-640	-333	313	371	337	307	279	253	230	209	190	173	157
Discount rate	%	10.0%																
Cummulative Discounted Cash Flow	mmUS$/yr		-37	-528	-1,457	-2,098	-2,431	-2,117	-1,746	-1,409	-1,102	-824	-570	-340	-131	60	233	390
Econimical Evaluation																		
EIRR; Econimical IRR	%	16.2%																
(IRR on Investment)																		
Net Present Value	mmUS$	1819																
Simple ROI(on FCF basis)	%							16.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%
Average Simple ROI	%	19.3%																

Table 7.1-13 Free Cash Flow: JICA Condition on International Basis
- Eureka (Solid Gasification) Case - Cont'd.

12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596	1,596
1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066	1,066
530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530	530
81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81	81
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
449	449	449	449	449	449	449	449	449	449	449	449	449	449	449	449	449	449	449	449	449	449	449	449	449
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
449	449	449	449	449	449	449	449	449	449	449	449	449	449	449	449	449	449	449	449	449	449	449	449	449
143	130	118	107	98	89	81	73	67	61	55	50	46	41	38	34	31	28	26	23	21	19	18	16	15
533	663	782	889	987	1,076	1,156	1,230	1,296	1,357	1,412	1,462	1,508	1,549	1,587	1,621	1,652	1,681	1,707	1,730	1,751	1,770	1,788	1,804	1,819
21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%	21.6%

Chapter 8 Environmental and Social Considerations

8.1 Environmental and Social Policy for the Project

8.1.1 Environmental and Social Policy

MOO/ NRC state that a firm Health, Safety and Environment (HSE) policy for the Project should comprise as follows.

- *HSE protections are prioritized in the business activities.*
- *Accidents and injuries to personnel are preventable and unacceptable.*
- *Everyone is responsible for their own and their colleagues' safety at work.*

The environmental and social study aims to provide appropriate environmental and social considerations including countermeasures to be undertaken throughout the project's life-cycle i.e. construction, operation and decommissioning/ disposal phases. The study includes necessary discussions that could suitably prevent or minimize the impacts of the project on the environment as well as local communities in and adjacent to the project site.
In order to achieve the above goal, the both study teams agreed that the study is to be carried out taking into consideration of the following strategy for the Project.

- *To comply with the relevant laws, standards and regulations of Iraq*
- *To fully introduce the applicable international standards, guideline and practices to the project*
- *To ensure that environment, personnel health, safety (HSE) and social aspects are considered in the study*
- *To apply the feasible Best Available Technology for the prevention or mitigation of the impacts*
- *To contribute to the sustainable development of the region and the country*

8.1.2 Legislative Framework to be applied

The Iraqi environmental standards will be applied basically to the Project. The following legislative framework including the laws in Iraq and other effective international conventions and agreements related to the environment are to be applied.

【National Laws and Regulations】

- System of Rivers and Other Water Resources Protection (Include of 45 Pollutants) Law No. 25 (1967)
- Environment wildlife Law (1971)
- Protection and Improvement of Environment Law No. 79 (1986)
- Act No. 71 promulgating the Labor Code of 27 July 1987 (LC)
- Public Health (Drinking Water Provision, Sanitation and Environmental Monitoring) Law No. 89 (1981)
- Modified Law of Environmental Protection and Improvement No. 3 (1997) and No.73 (2001)
- Radiation Control Law
- Coalition Provisional Authority (CPA) Order No. 44 (2003)
- Relevant laws, regulation and standards enacted by Ministry of Environment (MOEn) and other related ministries
- Environmental quality standards approved by Environmental Protection and Improvement Council (EPIC)

【International/Regional Conventions and Agreements】

- Convention concerning the protection of the World Cultural and Natural Heritage (1972)
- MARPOL (1973)
- Regional Organization for the Protection on the Marine Environment (ROPME) (2006)
- UN Convention on the Law of the Sea (1982)
- Montreal Protocol : under preparing
- Ramsar Convention (2008)
- Convention on Biological Diversity, 1992 (2009)
- Vienna Convention for the Protection of Ozone Layer, 1985 (2008)
- Kyoto Protocol (2008)

(Source: UNEP Iraq Institutional Capacity Assessment Report, Ministry of Environment, June 2006)

8.1.3 Environmental Standards and Guidelines to be applied to the project

The environmental and social considerations for the project shall be developed appropriately in accordance with the procedure of JICA/ JBIC Environmental Guideline so as to fulfill the condition of JICA ODA loan.

Where the item being not specified by the Iraqi legislation, or significantly lower than the international guideline value, the international environmental guidelines/ standards, i.e. World Bank Group/ International Finance Corporation (IFC), should be applied to the project in accordance with the Environmental Guideline of JICA/ JBIC.

The environmental standards and guidelines to be applied to the Project are as follows.

(1) Air Quality

Table 8.1.3-1 Ambient Air Quality

Parameter		Guideline Value (Unit: μg/m^3)
SO2	Maximum 24-hour average	Interim target 1: 125 Interim target 2: 50 Guideline: 20
	10 minutes average	500
NO2	1-year average	40
	1 hour average	200
PM_{10}	1-year average	Interim target 1: 70 Interim target 2: 50 Interim target 3: 30 Guideline: 20
	24-hour average	Interim target 1: 150 Interim target 2: 100 Interim target 3: 75 Guideline: 50
$PM_{2.5}$	1-year average	Interim target 1: 35 Interim target 2: 25 Interim target 3: 15 Guideline: 10
	24-hour average	Interim target 1: 75 Interim target 2: 50 Interim target: 37.5 Guideline: 25
Ozone	8-hour daily maximum	Interim target: 160 Guideline: 100

Source: IFC EHS General Guideline (April 2007)/ WHO Guideline

Table 8.1.3-2 Air Emissions

Pollutant	Guideline Value (Unit: mg/Nm^3)
NOx	450
SOx	150 for Sulfur recovery units 500 for other units
Particle Matter	50
Vanadium	5
Nickel	1
H_2S	10

Source: IFC EHS Guideline for Petroleum Refining (April 2007)

(2) Waste Water Quality

Table8.1.3-5 Waste Water Limitation

Pollutant	Iraqi Limitation	Guideline Value
pH	6.5 – 8.5	6 - 9
BOD	30 ppm	30 mg/L
COD	150 ppm	150 mg/L
TSS	40 ppm	30 mg/L
TDS	1500 ppm	
Oil & Grease	10 ppm	10 mg/L
Chromium (total)		0.5 mg/L
Copper		0.5 mg/L
Iron	2 ppm	3.0 mg/L
Total Cyanide		1.0 mg/L
Cadmium	0.2 ppm	
Lead	0.1 ppm	0.1 mg/L
Nickel	0.2 ppm	0.5 mg/L
Mercury	0.005 ppm	0.02 mg/L
Vanadium		1.0 mg/L
Phenol		1 mg/L
Benzene		0.05 mg/L
Sulfide	400 ppm	1 mg/L
Total Chlorine	0.7 – 1.0 ppm	
Total Nitrogen		10 mg/L
Total Phosphorus		2.0 mg/l
Temperature	Less than 33°C	Increase < 3°C

Source: Annex 18 and IFS EHS Guideline Petroleum Refining (April 2007)

(3) Noise

Table 8.1.3-6 Noise Level Guideline

Receptor	Maximum Allowable Value (Unit: dBA)	
	Daytime (07:00 - 22:00)	Nighttime (22:00 - 07:00)
Residential, institutional, educational area	55	45
Industrial, commercial area	70	70

Source: IFC EHS General Guideline (April 2007)

(4) Waste Management

- IFC EHS General Guidelines and Petroleum Refining

(5) Safety and Fire

- American Petroleum Institute (API) Standards
- National Fire Protection Agency in USA (NFPA) Regulation

(6) Emergency Response

- International Petroleum Industry Environmental Conservation Association (IPIECA) Report Series on Oil Spill (For oil spill response plans)

(7) Occupational Health and Safety

- Occupational Safety and Health Administration (OSHA) Regulations
- IFC EHS General Guideline and EHS Guideline for Petroleum Refining
- World Health Organization (WHO) standards
- United State Environmental Protection Agency (EPA) standards

8.2 Preliminary Environmental and Social Impact Assessment

The Environmental and Social Impact Assessment (EIA) is a formal and consultative process for assurance of integrity for the environmental and social considerations for the project activities. The EIA shall be implemented primarily in this study based on the environmental and social baseline information preliminarily investigated, the project activities planned conceptually, the potential effects on the respective receptors and protective or mitigation measures developed in this study.

Note that the Preliminary EIA developed in the study shall be reviewed by JICA.

8.2.1 EIA Process

The procedure and methodology of the formal EIA should be in accordance with applicable international practices. The EIA process for the project incorporates a number of key steps as shown below.

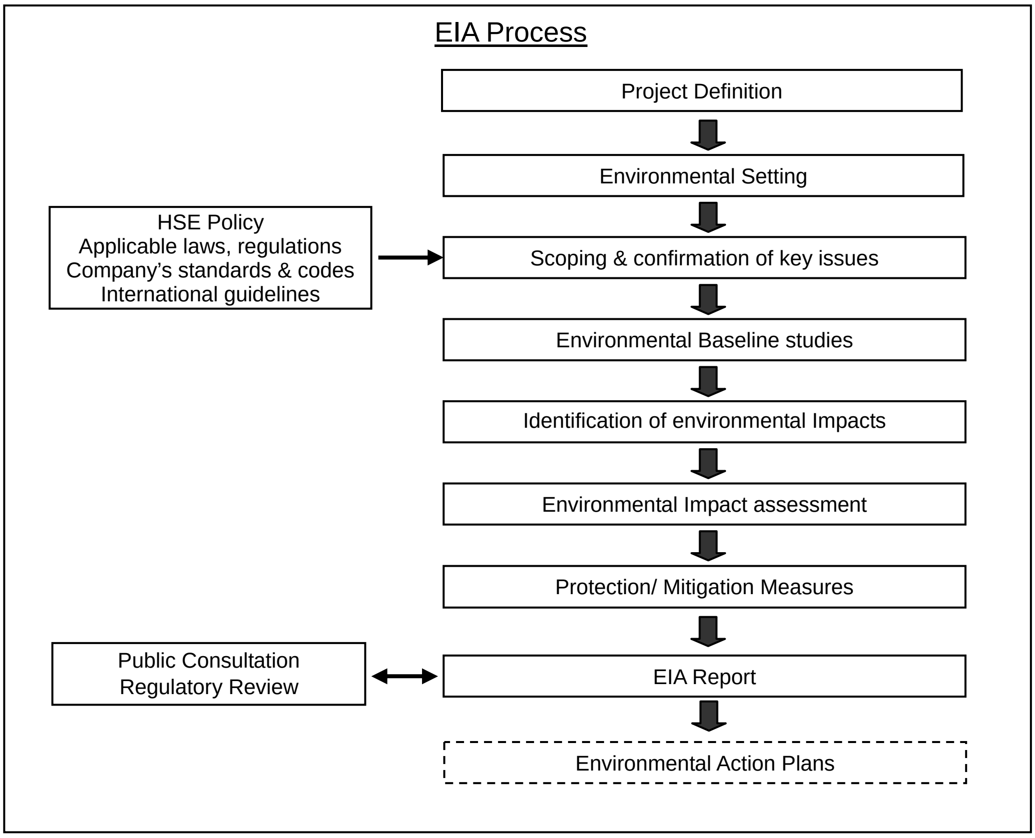


Figure 8.2.1 EIA Process

(1) The EIA process starts by defining the nature of the project primarily, i.e. type and scope of the project, facilities to be installed, locations, works involved, duration, etc.

(2) An earlier EIA process involves developing a preliminary understanding of the features of the environmental conditions surrounding the project area which is likely to be affected by the project.

(3) According to the nature of the project and features of the environment of the surrounding area, potential key environmental aspects associated with the project are recognized preliminarily. Based on above findings, the HSE policy and legal requirements to be applied to the project, a scoping exercise of key issues to be focused on HSE considerations of the project is conducted.

(4) An environmental baseline investigation for the project and surrounding areas is executed for detailed understanding of the features and characteristics of the current environmental conditions of the project area and surrounding areas through actual field survey and literature survey including scientific investigation, which covers natural and physical environment, socio-economic aspect of the communities, historical and cultural heritages, etc.

(5) According to the features and contents of the proposed project (e.g. facilities design, construction and operation methods, etc.) and the findings of the environmental baseline study, potential hazards to the environment and personnel throughout the project lifecycle, i.e. construction, operational and decommissioning/ abandonment phase are identified comprehensively.

(6) The potential hazards identified and probable impacts on the environment and personnel are assessed dedicatedly. The impact assessment is made through the studies on the potential risk of the hazards such as possibilities, affecting time duration and severities/ consequences of the impacts. Significant impacts, which require proper protection and/ or mitigation measures are revealed through this assessment study.

(7) Based on the results of the above assessment, effective protection and/ or mitigation measures for the significant impacts are developed adequately. And the protected/ mitigated impacts are re-assessed together with the effectiveness of the measures. The measures are then fed back to the project plan and subsequently reflected to the facilities design, where required.

(8) The results of the above studies are consolidated into an EIA report. The draft EIA report is disclosed and reviewed by the stakeholders, upon necessary. The final EIA report is provided incorporating comments of the authority if any and eventually submitted to the authority for approval.

(9) The EIA report proposes the effective protection and/ or mitigation measures for the potential environmental impacts associated with the project. In accordance with the result of the EIA study, the project shall develop practical action plans to ensure that the proposed protection and/ or mitigation measures will be implemented properly in the project and operation.

Throughout this procedure, suitable protection and mitigation measures for potential environmental and socio-economic aspects are developed and reflected in the design, construction and operation plans of all phases of the project.

8.2.2 Preliminary EIA Report

The preliminary EIA has been conducted in this study. The EIA report is attached to this document in a separate volume.

The result of the preliminary EIA report includes the following items.

- Executive summary
- Introduction
- Policy and legal framework
- Project description
- Environmental and social baseline
- Environmental and social Impact and mitigation measures
- Analysis of alternatives
- Environmental and social management and monitoring plan
- Conclusion and recommendations (for the items to be discussed and developed in next phase of the project)

It is assumed that the preliminary EIA report developed in this study will be subject to the primary approval of Ministry of Environment (MOEn) in accordance with the legal formality of project authorization for implementation.
MOO/NRC should take a necessary arrangement for the primary approval of MOEn for the preliminary EIA developed in the Study.

8.3 Environmental and Social Considerations

8.3.1 Baseline Conditions

An understanding of the features of the current environmental and social conditions of the project site and adjacent area is necessary in order to draw out the proper consideration of the environmental and social aspects. Being well aware of the area would contribute to the factual identification of the environmental and social resources and/or receptors that could be affected by the project and as a result will help recognize the issues to be developed properly for the protective or mitigation measures to be considered in the project plan.
The baseline conditions to be understood preliminarily consist of the following items.

(1) Physical Environmental Conditions

- Terrain and geological conditions
- Hydrology and water conditions (surface and ground water, etc.)
- Climate
- Atmospheric conditions (air quality and emission) and noise
- Water quality of Tigris River, which is the source of industrial water of the refinery
- Emission inventories of pollutants from the existing refinery

(2) Biological Conditions

- Terrestrial flora and fauna
- Biota and habitats in surface water body and marshes
- Rare, threatened and endangered species, if any

(3)Socio-economic Conditions

- Population and livelihood in the communities
- Economic activities in the region (industries, agriculture, livestock, etc.)
- Infrastructure and land use
- Historical and cultural heritages
- Landscape and visual impacts
- Stakeholders including local communities, central and regional governmental authorities, NGOs, etc.

The primary information and data of the above aspects to be utilized for the environmental and social baseline study were collected primarily through investigation of literatures or articles published by the relevant international scientific institutes as well as information and data available through the internet. In addition, the information and data provided by NRC was further applied to the study.

8.3.2 Identification and Assessment of Impacts

Based on the environmental and social sensitivities in the area and the planned project activities, the expected effects on the sensitive receptors are assessed through preliminary analysis of the potential risks arising from the project. According to the outcomes of the evaluation, appropriate protective or mitigation measures for the potential impacts shall be developed subsequently in accordance with relevant laws and regulations of Iraq and applicable international guidelines and practices.

The potential environmental and social impact aspects associated with the refinery project to be assessed and the possible causes of such impacts are described as follows.

Table 8.3.2 Environmental and Social Impacts and Causes of Refinery Project

	Potential Impacts	Possible Causes/ Sources
1	Environmental pollutions	
	(1) Air quality	• Flue gas from construction vehicles and equipment • Dusts from construction site • Flue gas from heater/furnace, boiler, engine, turbine, etc. • Flare stack • Vent and fugitive gas • Oil and gas leak/ release
	(2) Water quality	• Storm/ rain water • Industrial waste water discharge • Cooling water discharge • Oil/ chemical spill • Hazardous wastes
	(3) Wastes	• Construction works • Operation and maintenance • Office and camp (Including garbage, non-hazardous and hazardous/ toxic wastes)
	(4) Soil/ land	• Industrial waste water discharge • Oil/ chemical leak • Hazardous wastes
	(5) Noise and vibration	• Construction vehicles and equipment • Construction work • Operation of facility and equipment
	(6) Odor	• Flue gas • Flare and vent stacks • Fugitive gas • Waste water and wastes • Oil and gas leak/ release
2	Degradation of natural environment	
	(1) Ecology	• Loss or damage of habitats by construction (site clearing, reclamation, excavation, etc) • Environmental pollution • Collecting and hunting
	(2) Surface and underground water bodies	• Construction work (reclamation of river, pond, lake, wetland) • Construction of dike, water gate, dam, etc. • Extraction of river, lake water • Extraction of underground water • Discharge/release of water

	Potential Impacts	Possible Causes/ Sources
	(3) Topography and geology	• Construction work (reclamation, excavation, leveling, etc.) • Construction of canal, pond
3	Social environment	
	(1) Loss of land, property, resettlement, etc.	• Land acquisition (project site, temporary yard and road, etc.) • Restriction/ control of land use (cultivation, grazing, fishing, etc.)
	(2) Life and livelihood	• Interruption of local traffic by construction work • Traffic accident due to increased vehicles • Conflicts with migrated construction workers • Activation of local economy • Inflation of goods at local markets
	(3) Historical and cultural heritage	• Damage or loss due to construction • Restriction to access by construction work
	(4) Landscape	• Installation of large temporary facility during construction • Permanent large/ tall facility • Light and illumination
	(5) Ethnic minorities and indigenous people	• Land acquisition (project site, temporary yard and road, etc.) • Restriction/ control of land use (cultivation, grazing, fishing, etc.)
4	Personnel health and safety	
	(1) Injury and death	• Construction works • Operation and maintenance works • Accidents (fire, explosion, toxic gas leak/ release, etc.) • Interruption by 3rd party
	(2) Health	• Working conditions and environment • Living condition of office and camp (hygiene, etc.) • Inflectional disease • Foods and water

8.3.3 Environmental and Social Impact Assessment

Identification and assessment of the potential environmental and social impacts as well as personnel health and safety hazards was examined dedicatedly using an HSE and Social Impact Assessment Sheet in this study.

Table 8.3.3 HSE and Social Impact Assessment Sheet

No.	Activities/ Works		Impact Receptor																Justification & Mitigation Measures
			Physical Environment						Biological			Safety		Social					
			Atmosphere	Surface Water	Underground water	Soil	Topography	Landscape	Flora	Animals/Reptile/Fis	Birds	People	Assets	Life/ Livelihood	Land use	Local economy	Cultural heritage	Liability/ Reputation	
1	Land acquisition	FCC Complex site																	
		Auxiliary facility site (Offsite of NRC))																	
2	Site preparation	Site clearing & Civil works																	
3	Construction	Installation & erection																	
		Machines & vehicles operation																	
		Noise & vibration																	
		Construction effluent																	
		Construction wastes																	
4	Transportation	Materials & workers																	
5	Migration of workers	Construction camps																	
6	Employments	Direct & indirect																	

The HSE and Social Impact Assessment Sheets as results of the study are attached at the end of this chapter.

The project activities and possible impact aspects associated with the activities are listed in vertical columns. The potential receptors of the impacts from the project activities are also listed in a horizontal column of the sheet, which include the elements of physical and natural environment, health and safety, and social impacts in the project site and surrounding areas.

Potential impacts of the activities on each receptor are discussed and identified in the sheet primarily and the expected risk levels of the respective impacts identified are assessed subsequently.

Features of the expected impacts, justification of the assessment results and the protection and/or mitigation measures to be undertaken are described in the right column of the sheet.

8.3.4 Risk Assessment

Significance of the risk of the impact and hazard was evaluated by both severity (strength, extent and duration of the impact) and probability (frequency) of occurrence and the potential risks on the respective aspects identified in the previous step of the study are assessed qualitatively using the Risk Matrix shown below.

Table 8.3.4 Risk Matrix

			Probability				
			A	**B**	**C**	**D**	**E**
			Practically Impossible	Not Likely to Occur	Possibility of Occurring Sometime	Possibility of Isolated Incidents	Possibility of Repeated Incidents
Severity	**1**	Slight	LOW	LOW	LOW	LOW	MIDIUM
	2	Minor	LOW	LOW	MIDIUM	MIDIUM	HIGH
	3	Moderate	MIDIUM	MIDIUM	MIDIUM	HIGH	HIGH
	4	Major	MIDIUM	MIDIUM	HIGH	HIGH	HIGH

<u>Possibility Definitions</u>

A : Once in 100 or more facility lives

B : Once in 10 of facility lives

C : Once in facility life

D : 5 times in facility life

E : 25 or more times in facility life

<u>Severity Definitions</u>

Category	Impact Aspects			
	Environment	Safety & Health	Assets	Social
1	Slight effect	Slight injury or health effect	Zero or slight damage	Zero or slight impact
2	Minor effect	Minor injury or health effect	Minor damage	Minor impact
3	Local effect	Major injury or health effect	Local major damage	Considerable impact
4	Major effect	One or more fatality or permanent total disability	Major or extensive damage	Major domestic or worldwide impact

Definitions of each risk level are as follows:

- High Risk : Major Hazard, Unacceptable. Action must be taken immediately to lower the risk.
- Medium Risk : Acceptable, but must be managed at ALARP*. Risk reduction measures must be planned
- Low Risk : Acceptable without requiring further action

* ALARP : As Low As Reasonably Practicable. The residual risk shall be as low as reasonably practicable. For a risk to be ALARP, it must be possible to demonstrate that the cost involved in reducing the risk further would be grossly disproportionate to the benefit gained.

The outcomes of risk assessment for respective impact and hazards identified are indicated as "L", "M" or "H" in the Environmental and Social Impact Assessment Sheets.
Where the activity is assessed as "H" on the specific element of the receptor, effective protection or mitigation measure must be developed to reduce the risk to acceptable level.
Where assessed as "M", further mitigation measure should be re-considered to reduce the impact, if applicable.

8.3.5 Environment and Social Impacts and Mitigation Measures

The preliminary environmental impact assessment for the project has been carried out during the feasibility study in accordance with the procedure presented above. The findings of the EIA exercise such as the environment (HSE) and social impacts of the project and the proposed mitigation measures are shown in the Table 8.3.5-1, 2, 3 HSE and Social Impact Assessment Sheets attached in the end of this section. The summary is presented briefly as follows.

(1) Physical Environment

In the construction phase, the well maintained construction equipment and vehicles mobilized for the works will reduce the emissions of the pollutants in the exhaust gases. Proper dust prevention measures such as water spraying and soil control will be provided at the site. The wastewater discharged by the construction activities will be properly controlled and flowed out to the existing drainage system of the refinery.
In the operation phase, the combustion equipment such as heaters, boilers, diesel engines, flare stack, etc. in the FCC Complex will be specified to comply with the standards for the emission of the harmful substances in the flue gas required by the relevant laws and/or the international guidelines. The closed oily drain system and vent gas system designed in accordance with the international practices will reduce the fugitive VOCs from the facility into the air.
The oily wastewater and the other wastewater discharged from the process and other facilities will be collected and treated by the wastewater treatment system provided in the FCC Complex in accordance with the water quality standards specified by the NRC which complied with the relevant laws and the international guidelines. The treated water is then discharge to the Tigris River through the water canals around the refinery.

It is expected that these measures will contribute to mitigate the impact on the air quality and water quality of the area in both the construction and operation phases of the project.

The project site will be located at the designated facilities area in the existing Baiji Refinery and the nearest residential area, the most sensitive area to the noise emitted from the construction and operation of the facilities, is located at approximately 3 km south from the project site. The extensive tank farm is laid out in between the plant area and the southern boundary of the refinery, which will buffer the noise from the facilities. The project will specify the source equipment of large noise to be equipped with the proper protection devices such as silencer, enclosure, housing, etc. so as to comply with the standards of the noise in the residential area.
According to the above site location and the protective measures, the noise in the nearby residential area is expected to be mitigated to the acceptable levels.

(2) Ecology

The proposed FCC Complex will be located at the area prepared for future expansion in the boundary of the Baiji Refinery. Accordingly, the construction works including site preparation will not have direct impacts on ecology in terms of loss or damage of the wildlife habitats of the area. The proper protective measures for the gas emissions and wastewater discharges to the environment will mitigate the probable degradation of the environmental qualities of the habitats.
Therefore, it is expected that the project will not create significant impact on the ecological diversity in the region from the construction and operational activities.

(3) Socio-Economic

The major project activities such as the construction of the FCC Complex will be limited within the boundary of the existing Baiji Refinery. Therefore, the project will not need any land acquisition and the resettlement of the residents for the construction of the proposed facilities. On the other hand, the project will create a new employment opportunities in the local community and promote various related businesses and services in the region. These activities will contribute to activate the local and regional economy and improve the life and livelihood of the affected communities accordingly.
In order to mitigate the potential impact on the community, NRC will develop the suitable social management plans addressing the possible disturbances to the life and social activities of the local people arising from the project and operational activities of the refinery.

(4) Personnel Safety and Health

For assurance of the facilities safety, the international standards and practices as well as the procedure for the risk analysis recognized by the refinery sector in the world will be applied to the engineering and design of the proposed facilities. NRC will develop the safety procedure addressing the operational and maintenance works of the new facilities including the consideration for the conditions/environment of the work places, protection measures, permit to work system, training, etc. In addition, NRC will provide the incident management plan to response properly and effectively on the unexpected emergency event possibly occurred during operation of the facilities.
These considerations will contribute to mitigate the risk of the personnel safety and health associated with the project.

(5) Cumulative Impacts

The proposed FCC Complex will be operated together with the existing refinery plants in the Baiji Refinery, so that, the cumulative environmental impact derived from the entire operations of the Baiji Refinery consisting of the existing and new facilities shall be assessed adequately.
According to the environmental monitoring records of the existing Baiji Refinery, both the air quality at the boundary of the refinery and the water quality of the wastewater discharged from the refinery are well within the requirements of the relevant standards. The environmental protection measures for air emissions and water quality of the proposed FCC Complex will be developed appropriately in compliance with the applicable laws of the country and the international guidelines.

Accordingly, it is expected that the cumulative impacts of the entire operations of the refinery will also satisfy the requirements. However, it is needed to predict the possible cumulative impacts of the respective environmental aspects on the sensitive areas of the region through the use of reliable modeling exercises in the subsequent phase of the project. The environmental aspects subject to the exercises shall include air emissions, water quality and noise at least.

8.4 Environmental and Social Issues and Suggestions

The study on the environmental and social considerations was conducted preliminarily in accordance with the limited information and conditions provided by the conceptual engineering of FCC Complex and basic project plan developed in this phase. Therefore, further discussions are required for the development of more concrete environmental and social measures according to the further developed facility and project plans in the subsequent FEED phase.

Based on the outcomes of the above environmental and social studies, the Consultant will suggest the extent of further study and/ or investigation items to be made and the issues to be discussed in the facility design and project planning in the FEED phase.

(1) Environment Impact Assessment (EIA)

The preliminary EIA for the project has been drawn out preliminarily based on the project plan developed by the conceptual design of the proposed FCC Complex and the limited information and data collected by the literature investigations for the environmental and social baselines of the project region without any site survey. The potential environmental impacts derived from the project activities and operations were assessed primarily and qualitatively using such limited information so as to scope the HSE items to be focused in the subsequent phase of the project.

For further assessment of the potential impacts identified by the preliminary EIA, the items to be undertaken by the formal EIA study in the subsequent FEED phase of the project are proposed as follows.

- Detailed identification of the project based on the project and facilities plans defined by the basic engineering of the project
- Collection of further environmental and social baseline data for proper impact assessment of the project
- Introduction of the numerical modeling studies for quantitative assessment of the impacts of gas emissions, wastewater discharges as well as noise emissions to the sensitive areas including the potential cumulative impacts of such environmental aspects
- Re-assessment of the environmental impacts according to the findings of the above investigation and studies and proper feed-back of the results of the assessment to the engineering and design of the facilities

(2) Environmental Management System

The improved HSE management system (HSE-MS) for the upgraded Baiji Refinery shall be structured essentially in accordance with the international standards (ISO 14000 series for environmental management and OHSAS 18000 series for occupational health and safety management) or the equivalent practices widely introduced to the refinery sector in the world.

According to the HSE management system, NRC shall provide the plans showing below which address the HSE and social aspects assessed by the EIA exercise in the subsequent phase necessary for achieving the goals/targets in accordance with the HSE policy of NRC.

- HSE and social plans for protection and mitigation of the potential impacts of the project
- Environmental monitoring plans aiming to demonstrate compliance with the requirements, assess the environmental impacts of the project and evaluate the effectiveness of the measures undertaken
- Incident management plan (IMP) for response to the unexpected accidental events such as fire, explosion, toxic gas release, oil spill, injury and fatality of personnel.
- Other HSE related plans proposed/ recommended by the formal EIA

Table 8.3.5-1 HSE AND SOCIAL IMPACT ASSESSMENT SHEET (1 Construction Phase)

Project	Baiji Refinery Upgrading Project
Site	Baiji, Salahaldeen, Iraq
Project Phase	**Construction**

Impact Severity Categories		
High	Medium	Low
H	M	L

No.	Activities/ Works		Impact Receptor																Justification & Mitigation Measures
			Physical Environment						Biological			Safety		Social					
			Atmosphere	Surface Water	Underground water	Soil	Topography	Landscape	Flora	Animals/Reptile/Fish	Birds	People	Assets	Life/ Livelihood	Land use	Local economy	Cultural heritage	Liability/ Reputation	
1	Land acquisition	FCC Complex site	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	Since the project site is located within the existing Baiji Refinery boundary, no additional land acquisition is required.
		Auxiliary facility site (Water Intake & Transfer System)	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**L**	**L (M)**	**L**	**L**	**L**	NRC will acquire the Land for the water intake station & transfer pipeline in accordance with the relevant laws. NRC will investigate the users of the land and provide appropriate compensation for the users consulting with the authority, if any .
2	Site preparation	Site clearing & Civil works	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	**L**	Since the construction site is located in the plant area of Baiji Refinery prepared for future expansion, no large soil work will made. Accordingly, the impacts on the environment, ecology and community in the region will be mitigated satisfactorily. The contractor will comply with the HSE standards and regulations of the project seriously.
3	Construction	Installation & erection	**-**	**-**	**-**	**-**	**-**	**L**	**-**	**-**	**-**	**L**	**L**	**L**	**-**	**L**	**-**	**L**	The main works will be limited within the Baiji refinery area. The impacts on the ecology and community in the region are insignificant. Since the nearest residential area is approx. 3 km south from the site, no impact of the construction works on landscape from the local people is expected. The contractor will comply with the safety work procedure of NRC.
		Equipment & vehicles operation	**L**	**-**	**-**	**-**	**-**	**-**	**L**	**L**	**L**	**L**	**-**	**L**	**-**	**L**	**-**	**L**	The construction equipment and vehicles will be maintained in good conditions to mitigate emissions of the exhaust gases. Low impacts on the air quality and ecology in the region is expected. Operation area and time are controlled properly to mitigate the probable impacts on the local people.
		Noise & vibration	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**L**	**L**	**L**	**-**	**L**	**-**	**-**	**-**	**L**	The construction site is located in the Baiji Refinery area. The nearest residential area is approx. 3 km south from the site and the extensive tank farm is laid out in between the areas. Low noise impact on the local people and wildlife is expected. The construction workers will wear the suitable noise protection gear in compliance with the occupational safety and health procedure.

Table 8.3.5-1 HSE AND SOCIAL IMPACT ASSESSMENT SHEET (1 Construction Phase)

No.	Activities/ Works		Impact Receptor																Justification & Mitigation Measures
			Physical Environment						Biological			Safety		Social					
			Atmosphere	Surface Water	Underground water	Soil	Topography	Landscape	Flora	Animals/Reptile/Fish	Birds	People	Assets	Life/ Livelihood	Land use	Local economy	Cultural heritage	Liability/ Reputation	
		Wastewater discharge	-	L	L	L	-	-	L	L	L	-	-	-	-	-	-	L	The contractor will control the wastewater discharge in accordance with the requirements of NRC regulation and relevant laws. Such measure will mitigate the impacts on the water quality of the Tigris River and underground water as well as ecology in the region.
		Construction wastes	-	L	L	L	-	-	-	-	-	L	-	-	-	-	-	L	The construction wastes will be segregated properly according to hazardous and non-hazardous properties. The wastes are managed properly from generation to the ultimate disposal in accordance with the waste management plan (WMP) provided by the construction contractor. The WMP will be complied with the regulation of NRC and relevant laws of Iraq.
4	Transportation	Materials & workers	L	-	-	-	-	-	-	-	-	L	-	L	-	-	-	L	The construction contractor will develop the traffic management plan (TMP) consulting with the local community and related authority in the region. The TMP will specify the routes and time schedule as well as safety provisions for operation of the project vehicles.
5	Migration of workers	Construction camps	-	-	-	-	-	-	-	-	-	-	-	L	-	-	-	L	The construction contractor will prioritize to mobilize the workers from the project region. The construction camps will be located at the designated area in the boundary of Baiji Refinery to minimize the contact with the community and the appropriate camp management plan will be provided for managing the attitudes of the workers.
6	Employments	Direct & indirect	-	-	-	-	-	-	-	-	-	-	-	✓	-	✓	-	L	NRC and the construction contractor will disclose the information for recruits to the public in order to provide fair and equal job opportunities to the people in the region. The project will create a new job opportunities in the region directly and indirectly. It will contribute to improve the life/livelihood of the local people. The job period will be limited to construction phase, which is relatively short.
7	Material/Service procurements		-	-	-	-	-	-	-	-	-	-	-	✓	-	✓	-	L	The construction bulk materials and related services will be procured from local markets. It will contribute to enhance related industries and business and activate economy of the region.

Table 8.3.5-2 HSE AND SOCIAL IMPACT ASSESSMENT SHEET (2 Operation Phase)

Project	Baiji Refinery Upgrading Project
Site	Baiji, Salahaldeen, Iraq
Project Phase	**Operation**

Impact Severity Categories		
High	Medium	Low
H	M	L

No.	Activities/ Works		Impact Receptor																Justification & Mitigation Measures
			Physical Environment						Biological			Safety		Social					
			Atmosphere	Surface Water	Underground water	Soil	Topography	Landscape	Flora	Animals/Reptile/Fish	Birds	People	Assets	Life/ Livelihood	Land use	Local economy	Cultural heritage	Liability/ Reputation	
1	Facilities Commissioning		**L**	**L**	**L**							**L**	**L**					**L**	The commissioning of the new facilities will be conducted properly in accordance with the procedure including safety measures to prevent the unexpected accident.
2	Facilities operation	Operation & Maintenance activities	**L**	**L**	**L**	**L**						**L**	**L**					**L**	NRC will develop the appropriate operation and maintenance procedure including HSE measures and emergency response. The workers at the site are required to wear proper Personal Protection Equipment (PPE) in accordance with the safety work procedure of NRC. The periodical HSE training will be conducted.
		Gas emissions	**L (M)**						**L**	**L**	**L**	**L**						**L**	The combustion equipment (Furnace, heater, boiler, engines, etc.) is specified to comply with the gas emission standards of NRC. It will mitigate the potential degrading of air quality in the region including the wildlife habitats. Potential cumulative impact of the gas emissions from entire facilities of Baiji Refinery shall be assessed through a reliable gas emission modeling study in FEED phase.
		Wastewater discharges		**L (M)**	**L**	**L**			**L**	**L**	**L**	**L**						**L**	The wastewater discharged from the facilities will be treated properly by the wastewater treatment system in the refinery in compliance with the standards of NRC or relevant laws of Iraq. The treated water quality discharged to the external drainage system is monitored regularly. Such measures will contribute to prevent pollution of Tigris River, underground water as well as the environment of wildlife habitats. Potential cumulative impact of the wastewater discharges from entire facilities of Baiji Refinery shall be assessed properly in FEED phase.
		Wastes		**L**	**L**	**L**						**L**						**L**	The construction wastes will be segregated properly according to hazardous and non-hazardous properties. The wastes are managed properly from the generation to the ultimate treatment or disposal in accordance with the waste management plan (WMP) established by NRC. The WMP will be complied with the regulation of NRC and relevant laws of Iraq.

Table 8.3.5-2 HSE AND SOCIAL IMPACT ASSESSMENT SHEET (2 Operation Phase)

No.	Activities/ Works		Impact Receptor																Justification & Mitigation Measures
			Physical Environment						Biological			Safety		Social					
			Atmosphere	Surface Water	Underground water	Soil	Topography	Landscape	Flora	Animals/Reptile/Fish	Birds	People	Assets	Life/ Livelihood	Land use	Local economy	Cultural heritage	Liability/ Reputation	
		Noise & vibration								L	L	L (M)						L	The FCC Complex is located in the Baiji Refinery area. The nearest residential area is approx. 3 km south from the site and the extensive tank farm is laid out in between the areas. Low noise impact on the local people and wildlife is expected accordingly Potential cumulative impact of entire operation of Baiji Refinery shall be assessed through a noise modeling study in FEED phase. The construction workers will wear the suitable noise protection gear in compliance with the occupational safety and health procedure.
		Fuels & Chemicals		L	L	L						L						L	Hazardous material such as fuels and chemicals will be stored at the facility/equipment with secondary containment devices in accordance with the applicable regulation. It prevents to spread the hazardous liquid to outside, where spilled accidentally. NRC provides the safety procedure for storage and handling of such materials.
		Utilities consumption (Power & water)												L				L	The electric power is supplied from the regional power grid separately from public use. The FCC Complex will provide an in-house power generation plant to self-supply the power required for operation. (optional case) A new water supply system will be provided to supply the industrial water from Tigris River.
3	Accident	Fire, explosion, oil leak, gas release, etc.	L	L	L	L			L	L	L	L (M)		L (M)		L		L (M)	Incident/accident preventive measures for the facilities and operations are discussed seriously in the engineering and design phase in accordance with the international standards, guidelines and practices widely recognized by the refinery sector in the world. NRC will develop the Incident Management Plan (IMP) addressing to the possible incident/accident in the entire operation of Baiji Refinery. Since the facilities are located in the extensive boundary of the refinery, no significant direct impact of the accident on the nearby community is expected regardless of occurrence. However, a detailed risk assessment shall be made according to the possible accident scenarios in FEED phase.
4	Transportation	Materials & personnel										L		L				L	The NRC will develop the traffic management plan (TMP) consulting with the local community and related authority in the region. The TMP will specify the routes and time schedule as well as safety provisions for operation of the vehicles.

Table 8.3.5-2 HSE AND SOCIAL IMPACT ASSESSMENT SHEET (2 Operation Phase)

No.	Activities/ Works		Impact Receptor															Justification & Mitigation Measures
			Physical Environment						Biological			Safety		Social				
			Atmosphere	Surface Water	Underground water	Soil	Topography	Landscape	Flora	Animals/Reptile/Fish	Birds	People	Assets	Life/ Livelihood	Land use	Local economy	Cultural heritage	Liability/ Reputation	
5	Employment	Direct & indirect												✓		✓		**L**	NRC will disclose the information for recruits to the public in order to provide fair and equal job opportunities to the people in the region. The project will create a new job opportunities in the region directly and indirectly. It will contribute to improve the life/livelihood of the local people continuously during operation phase.
6	Material/Service procurement													✓		✓		**L**	The bulk materials for operation/ maintenance and related services will be procured from local markets. It will contribute to enhance related industries and business and activate economy of the region.

Table 8.3.5-3 HSE AND SOCIAL IMPACT ASSESSMENT SHEET (3 Decommissioning/Abandonment Phase)

Project	Baiji Refinery Upgrading Project
Site	Baiji, Salahaldeen, Iraq
Project Phase	**Decommissioning/ Abandonment**

Impact Severity Categories		
High	Medium	Low
H	M	L

No.	Activities/ Works		Impact Receptor																Justification & Mitigation Measures
			Physical Environment						Biological			Safety		Social					
			Atmosphere	Surface Water	Underground water	Soil	Topography	Landscape	Flora	Animals/Reptile/Fish	Birds	People	Assets	Life/ Livelihood	Land use	Local economy	Cultural heritage	Liability/ Reputation	
1	Facilities demolition	Displacement of contents	**L**	**L**	**L**	**L**	**-**	**-**	**L**	**L**	**L**	**L**	**-**	**-**	**-**	**-**	**-**	**L**	The decommissioning plan will be established after the decommissioning schedule is decided. The methods of displacement and the procedure how to treat the contents displaced will be discussed in the plan in accordance with the laws and regulation of that time for mitigation of the possible impacts on HSE and social aspects.
		Demolition works	**L**	**L**	**L**	**L**	**-**	**-**	**-**	**-**	**-**	**L**	**-**	**-**	**-**	**-**	**-**	**L**	The works will be carried out properly in accordance with the demolition procedures including HSE measures.
		Equipment & vehicles operation	**L**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**L**	**-**	**L**	**-**	**-**	**-**	**L**	The equipment and vehicles will be maintained in good conditions to mitigate emissions of the exhaust gases. Low impacts on the air quality and ecology in the region is expected. Operation area and time are controlled properly to mitigate the probable impacts on the local people.
		Noise & vibration	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**L**	**L**	**L**	**-**	**L**	**-**	**-**	**-**	**L**	The site is located in the Baiji Refinery area. The nearest residential area is approx. 3 km south from the site and the extensive tank farm is laid out in between the areas. Low noise impact on the local people and wildlife is expected. The construction workers will wear the suitable noise protection gear in compliance with the occupational safety and health procedure.
		Wastes	**-**	**L**	**L**	**L**	**-**	**-**	**-**	**-**	**-**	**L**	**-**	**-**	**-**	**-**	**-**	**L**	The decommissioning plan will estimate the inventories of the wastes and discuss the maximum reuse or recycle of the waste materials. The other wastes will be segregated properly according to hazardous and non-hazardous properties. The wastes are managed properly from generation to the ultimate disposal in accordance with the waste management plan (WMP) provided by the construction contractor. The WMP will be complied with the regulation of NRC and relevant laws of Iraq.

Table 8.3.5-3 HSE AND SOCIAL IMPACT ASSESSMENT SHEET (3 Decommissioning/Abandonment Phase)

No.	Activities/ Works		Impact Receptor																Justification & Mitigation Measures
			Physical Environment						Biological			Safety		Social					
			Atmosphere	Surface Water	Underground water	Soil	Topography	Landscape	Flora	Animals/Reptile/Fish	Birds	People	Assets	Life/ Livelihood	Land use	Local economy	Cultural heritage	Liability/ Reputation	
2	Transportation	Materials & workers	L	-	-	-	-	-	-	-	-	L	-	L	-	-	-	L	The construction contractor will develop the traffic management plan (TMP) consulting with the local community and related authority in the region. The TMP will specify the routes and time schedule as well as safety provisions for operation of the project vehicles.
3	Site restoration		✓	✓	✓	✓	-	-	✓	✓	✓	-	-	✓	-	-	-	✓	After demolition of the facilities, the site will be restored to the previous conditions. It will cause that the environmental conditions and wildlife habitats will be improved due to termination of the emission/discharge of the pollutants into the environment.
4	End of operation	Dismissal	-	-	-	-	-	-	-	-	-	-	-	L (M)	-	L (M)	-	L (M)	According to the end of operation, the people will lose the jobs at the refinery. NRC will disclose the information regarding the end of operation in the early time after decision of the plan. NRC will also discuss the measures for the maximum continuous employment of the people or job training for re-employment to the other industries.
		No more material procurement	-	-	-	-	-	-	-	-	-	-	-	L (M)	-	L (M)	-	L (M)	According to the end of operation, the related companies will lose the business. It will associate probable decline of economy of the region. NRC will disclose the information regarding the end of operation in the early time after decision of the plan in order to prevent the sudden change of the business environment of the region.

Chapter 9 Conclusion and Recommendation

9.1 Conclusion

From the results of the studies and discussions presented in the previous chapters, the study is concluded as follows.

9.1.1 Necessity and Validity of the Project

From the several view points considered i.e. availability of feedstock and fuels, conditions of infrastructure, and contribution to the region through economic and social aspects, it could be concluded that the proposed Baiji FCC Complex project is considered to be valid and reasonable with the following major merits.

- Improvement of supply-demand balance of the oil products i.e. gasoline and diesel for the public use in the region
- Reduction of national expenditures for importing the oil products from foreign countries due to gaps of supply-demand in Iraq
- Social and economic effects by the creation of new job opportunities and businesses in the region
- Improvement of technology in the refinery sector in Iraq through the introduction of modern and up to date technologies into the refineries
- Environmental effects through supply of high quality (low sulfur content) vehicle fuels

Thus, this project is fully expected to contribute effectively for the achievement of the national development strategy for refinery sector in Iraq.

9.1.2 Technical and Economic Consideration for FCC Complex

Optimum process configuration for the FCC Complex was studied by comparison of the various characteristics of the following optional cases.

Case 1	VDU + HDS + RFCC + SDA + Gasification
Case 2	VDU+ HDS + FCC + Eureka + Gasification
Reference case	VDU+ HDS + FCC + Delayed Coker + Gasification

The findings are as follows.

(1) Product Properties

- Eureka case brings the highest liquid yield of the products and also produces the largest amount of diesel and gasoline among the 3 cases.
- SDA case has the highest LPG yield, but the quality of diesel and gasoline is inferior to that of the thermal cracking processes (Eureka case and Delayed Coker case)

(2) Investment and Operating Costs

- CAPEX of Eureka case is the lowest compared to the SDA and Delayed Coker cases.
- Owner’s cost for Eureka case is slightly lower than SDA case.
- Eureka case brings the lowest OPEX among the 3 cases.

(3) Economic Evaluation (domestic price base)

- SDA case shows rather better ROI (but still in negative) and requires smaller subsidies than other cases.
- Eureka case needs higher governmental subsidy than SDA case to write-off deficit.

(Note that the economic evaluation based on the political pricing structure does not solely reflect the economical justification of the Project.)

(4) Economic Evaluation (international price base: Arabian Gulf Coast basis)

- EIRR of Eureka case is more viable than other cases.
- The Project is economically justified, since the Project will contribute to the development of Iraq by reducing liquid product import from neighboring countries, thus saving the much needed hard currency that can be used for other advancement projects.

9.1.3 Project Execution

The project execution consists of two (2) major phases, i.e. FEED, EPC phases. The Consultant estimated the FEED activities of the Project at 15 months and 40 months for EPC phase. In addition, it will normally take 9 to 10 months (sometimes one year) for tendering for EPC contractor after FEED. However, if all activities would be undertaken by a single contractor, the project duration and cost could be saved effectively.

The Project Office (PO) will be established in the NRC under MOO. The PO will be responsible for execution of the project in the respective phases. NRC will employ a qualified and experienced consulting firm for project management consultancy (PMC) during the FEED and EPC phase respectively to render the necessary support and assistance to the PO to ensure successful completion of the project as planned. PMC is responsible for the necessary coordination between NRC and JICA, lender of ODA Loan.

9.1.4 Technology Transfer

The project will provide the comprehensive technology transfer plan aiming to improve the project management skills and the technical skills for engineering, construction, operation and maintenance of MOO/NRC. It is essential to enhance especially the operation technology of Baiji Refinery for the new process units to ensure the sustainable stable operation of the new facilities without interruption due to human error or defective operation manner.

9.1.4 Environmental and Social Considerations

The environmental and social consideration for the project will be implemented properly in accordance with the relevant laws and standards in Iraq as well as applicable international guidelines to fully accomplish the HSE policy of MOO/NRC.
The preliminary EIA exercise carried out in this study concludes that the potential environmental and social impacts of the project activities in the respective project phases are expected to be mitigated properly in compliance with the requirements of the relevant laws in Iraq and the applicable international guidelines through implementation of the environmental and social measures discussed in the study.

9.2 Recommendations

(1) Phased Implementation of the Project

The conceptual design of the FCC Complex and the study on project execution, cost estimation and feasibility of the project were conducted based on the assumption that the whole FCC Complex is constructed completely in a single phase for the minimum construction period and costs. The Study estimated the CAPEX at approximately $2 billion or more in total.
On the other hand, considering financing capacity of JICA's ODA Loan for one single project, MOO may provide its own budget for a part of CAPEX of the project.

The practicable implementation scheme (a single or multiple phases) of the project shall be discussed seriously considering the following items.

- Finance plan of MOO
- Operational capability of NRC including familiarization of the new processes
- Products demand and supply (production) plan
- Operability and redundancy of the process train

For the realization of the Project, further discussion and consideration for the following 2-phase scenario shall be made subsequently to this preparatory survey.

- FEED will be made as a single phase.
- VDU will be provided in the 2nd phase.
- HDS, FCC, SDA/Eureka, gasification plant and the other processing units will be divided into 2 phases.
- Utility facilities will be provided as a single phase principally. However, GTG with HRSG will be divided into 2 phases.
- Offsite facilities including tanks will be provided as a single phase.

(2) Self-sufficient for Utility

The proposed FCC Complex aims to be self-sufficient for the utilities i.e. H_2, fuel gas, steam and water as well as power, to ensure sustainable operation of the process facilities.
The gasification plant in FCC Complex will produce H_2 and fuel gas from the residual material (asphalt/ petroleum pitch) of SDA/ Eureka process. The gasification plant will be capable to supply H_2 to all the processing units using H_2 including the existing refinery plants and fuel gas (heat value: 2700kcal/Nm^3) for the proposed in-house gas turbine power generation units and other consumers in the refinery.
For introduction of the gasification plant in the FCC Complex, it is required to discuss the following items to ensure the stable operations of the entire refineries.

- H_2 production and supply plan in whole Baiji Refinery: individual or integration
- Power supply plan: self-sufficiency or receive from the regional grid
- Available consumers of the excessive syngas (low heat value) to power generator
- Stable feed of raw material from SDA/ Eureka
- Operability and reliability of the new gasification process

- Optimum capacity and number of trains of the gasification process
- Costs and expected effects including potential operational risks

(3) Treatment of By-Product

The proposed SDA/ Eureka unit in the FCC complex will produce a large amount of asphalt (15730bpd)/ solid pitch (2352ton/day) as by-product, but the consumers (markets) for such product in Iraq is still small so far. The purpose of the gasification plant is to convert the low marketable by-product to H_2 and fuel gas to be useful to the operation of the refinery.
In the Study, the capacity of the gasification plant was decided on the assumption that it is capable to treat the whole asphalt/ pitch produced by SDA/ Eureka. However, if the certain demands/ markets of the asphalt/ pitch are available in Iraq or neighboring countries, the by-product could be sold or exported as “Product” without any treatment. The capacity of the gasification plant could be optimized in accordance with the demands of the asphalt/ pitch in the markets.

According to the research of the international market of the petroleum coke/ pitch (1999), 40% of the total coke production (48 million tons) in the world was consumed at cement factories as fuel and raw material of cement.
According to modernization (introduction of the thermal cracking process for the residual distillate oil) of the refineries in Iraq, it is expected that the production of the petroleum coke/ pitch will be increased gradually in the future. The feasible treatment solutions including consumption of the coke/ pitch in Iraq shall be investigated seriously in the subsequent phase of the project.

(4) Technology Transfer

The FCC Complex includes several new processing units with advanced technologies, which are not yet existing in the refineries in Iraq. Therefore, in addition to the engineering, design of the facilities and project management skills, sufficient operational technology transfer to NRC for the new process units is essential to ensure the stable and safe operation of the new FCC Complex.
The technology transfer plan for the operation shall include the prior on the job training (OJT) during EPC phase at the refinery plant in Japan or other country, which possesses similar FCC plant with SDA/ Eureka process, for earlier familiarization of the facility and operation. Furthermore, the continuous supports and training for the operation of the new plant during the

necessary period by the EPC contractor and/or licensor(s) shall be included in the plan to be applied after commissioning of FCC Complex.
Such operational technology transfer plan with the schedule and the necessary budget shall be discussed further in the subsequent phase of the project accordingly.

(5) Environmental and Social Considerations

The preliminary EIA suggests that the formal EIA shall be executed in the subsequent FEED phase of the project for further assessment of the potential environmental and social impacts based on the results of the basic engineering of the facilities and the detailed environmental and social baseline survey.
It is also suggested to improve or develop the HSE management system for the operation of the upgraded Baiji Refinery including HSE and social plans, monitoring plan and incident management plans in accordance with the international guidelines and practices.

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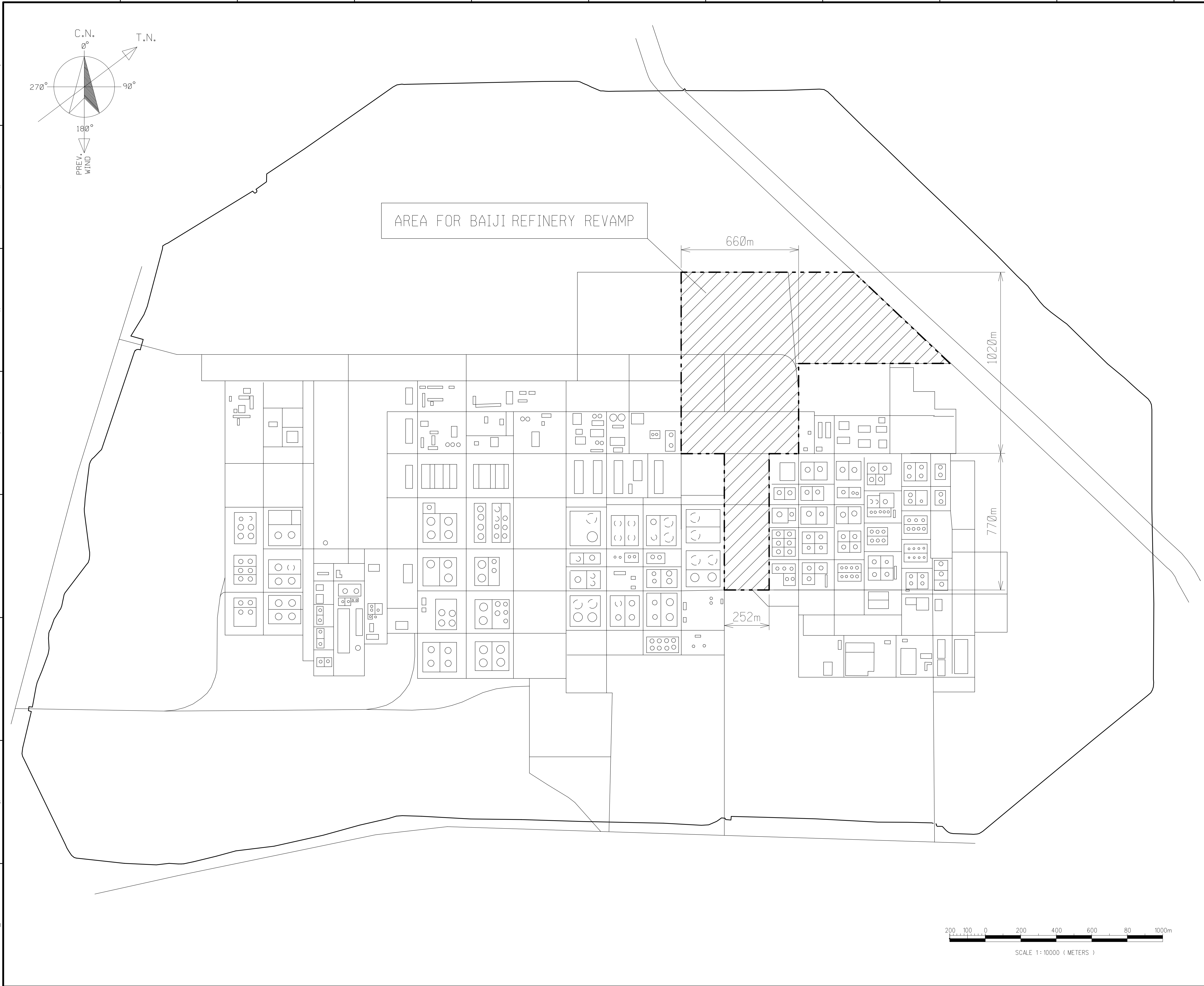
APPENDIX

Appendix 3.7-1

Overall Picture of North Refinery in Baiji, Iraq



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SITE PLAN

SCALE | JOB NO.

PROJECT | DRAWING NO. | REVISION

APPENDIX 3.7-2

WORK NO.

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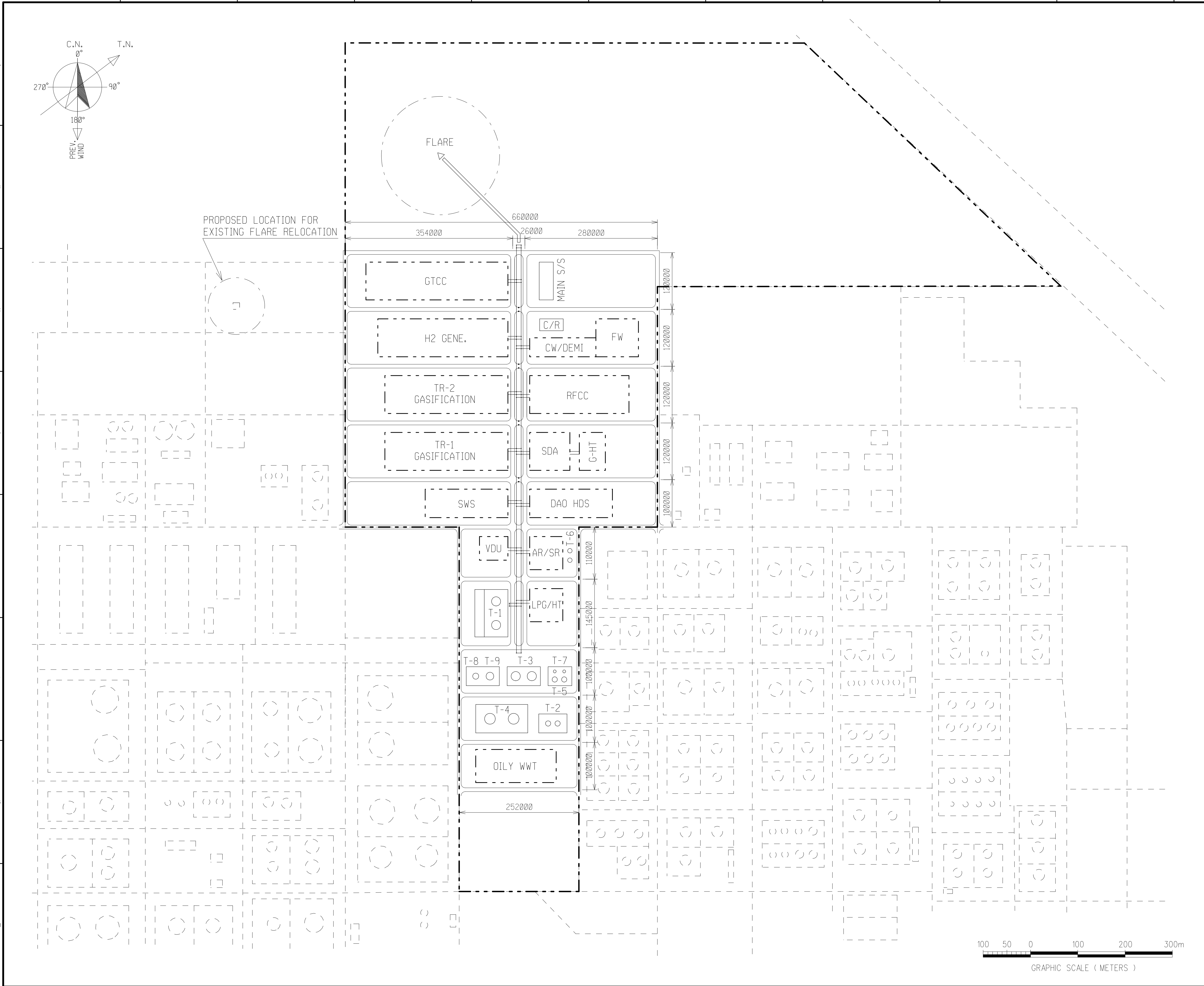

PROCESS UNIT LIST

UNIT NAME	ABBREVIATION
VDU	-
SDA	-
GASIFICATION	-
H2 GENERATION	H2 GENE.
DAO HDS	-
RFCC	-
GASOLINE HT	G-HT
LPG RECOVERY /HYDRO TREATER	LPG/HT
AMINE REGENERATOR /SULFUR RECOVERY	AR/SR
SOUR WATER STRIPPER	SWS

STORAGE LIST

MARK	QTY	SERVICE
T-1	2	LPG TANK (SPHERICAL)
T-2	2	NAPHTHA TANK (FLOATING ROOF)
T-3	2	DIESEL TANK (CONE ROOF)
T-4	2	FCC GASOLINE TANK (FLOATING ROOF)
T-5	2	LCO TANK (CONE ROOF)
T-6	2	SOLID SULFUR SILO
T-7	2	DCO TANK (CONE ROOF)
T-8	1	CRACKED SLOPS (CONE ROOF)
T-9	1	HOT SLOPS (CONE ROOF)

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JICA

TITLE
OVERALL PLOT PLAN
SDA CASE

SCALE · JOB NO. ·

PROJECT · DRAWING NO. APPENDIX 3.7-3 REVISION

WORK NO.

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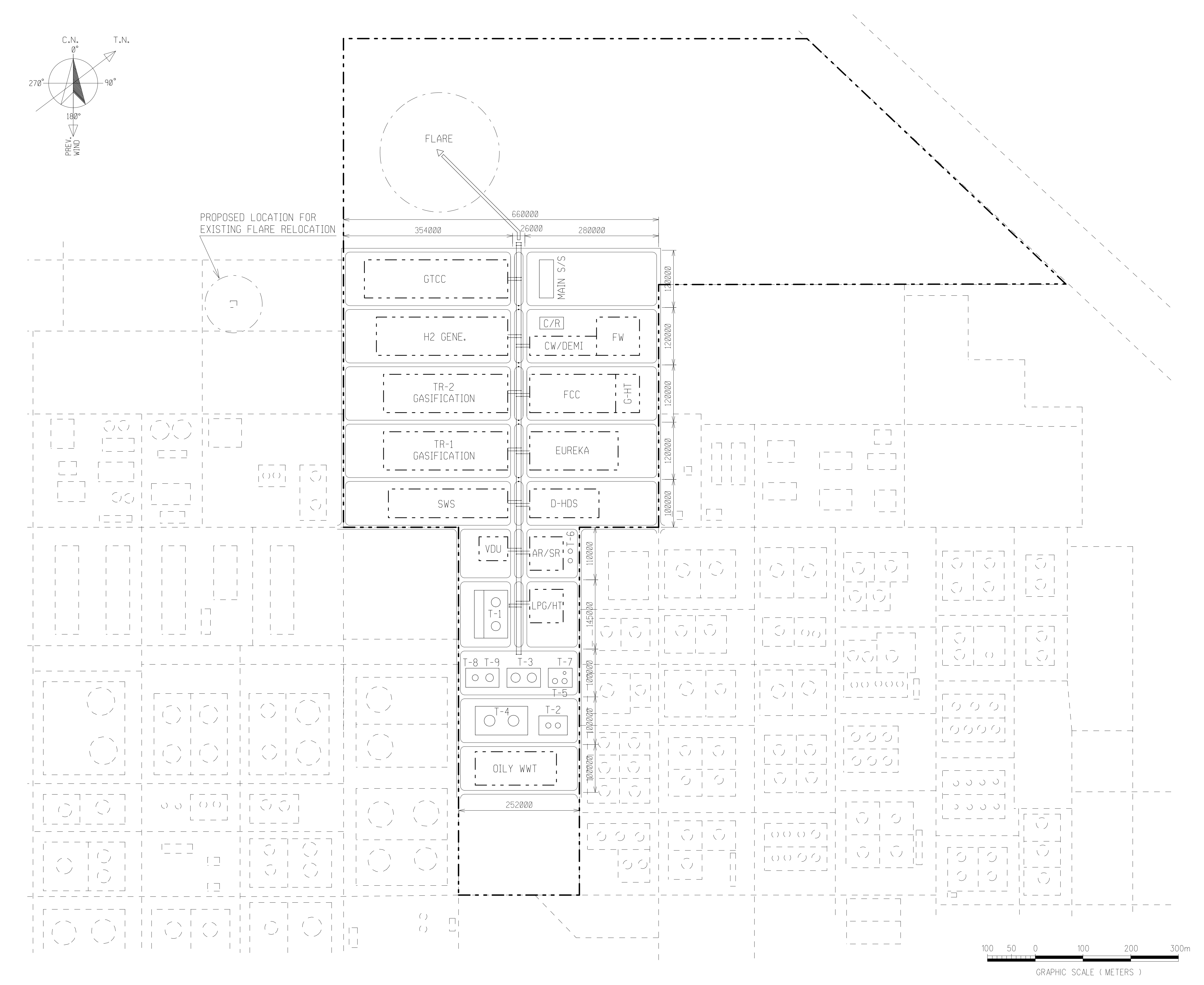

PROCESS UNIT LIST

UNIT NAME	ABBREVIATION
VDU	-
EUREKA	-
GASIFICATION	-
H2 GENERATION	H2 GENE.
DISTILLATE HDS	D-HDS
FCC	-
GASOLINE HT	G-HT
LPG RECOVERY /HYDRO TREATER	LPG/HT
AMINE REGENERATOR /SULFUR RECOVERY	AR/SR
SOUR WATER STRIPPER	SWS

STORAGE LIST

MARK	QTY	SERVICE
T-1	2	LPG TANK (SPHERICAL)
T-2	2	NAPHTHA TANK (FLOATING ROOF)
T-3	2	DIESEL TANK (CONE ROOF)
T-4	2	FCC GASOLINE TANK (FLOATING ROOF)
T-5	2	LCO TANK (CONE ROOF)
T-6	2	SOLID SULFUR SILO
T-7	1	DILUENT TANK (CONE ROOF)
T-8	1	CRACKED SLOPS (CONE ROOF)
T-9	1	HOT SLOPS (CONE ROOF)

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JICA

TITLE
OVERALL PLOT PLAN
EUREKA CASE

SCALE · JOB NO. ·

PROJECT · DRAWING NO. APPENDIX 3.7-4 REVISION

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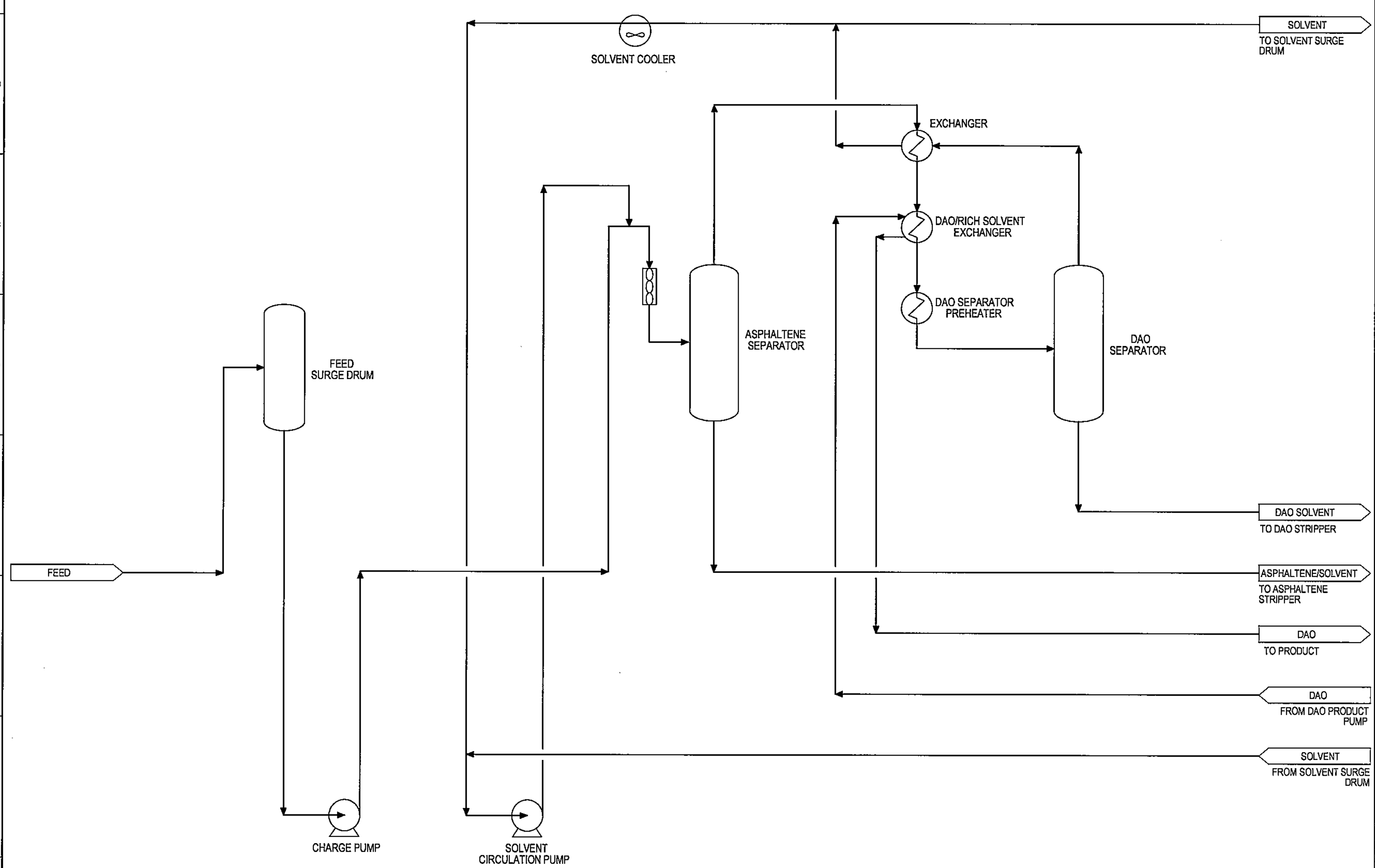

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FOR

NORTH REFINERY COMPANY

Japan International Cooperation Agency

TITLE BAIJI REFINERY UPGRADING PROJECT
SIMPLIFIED PROCESS FLOW DIAGRAM
SDA UNIT SEPARATION SECTION

SCALE | JOB NO.

PROJECT | DRAWING NO. | REVISION

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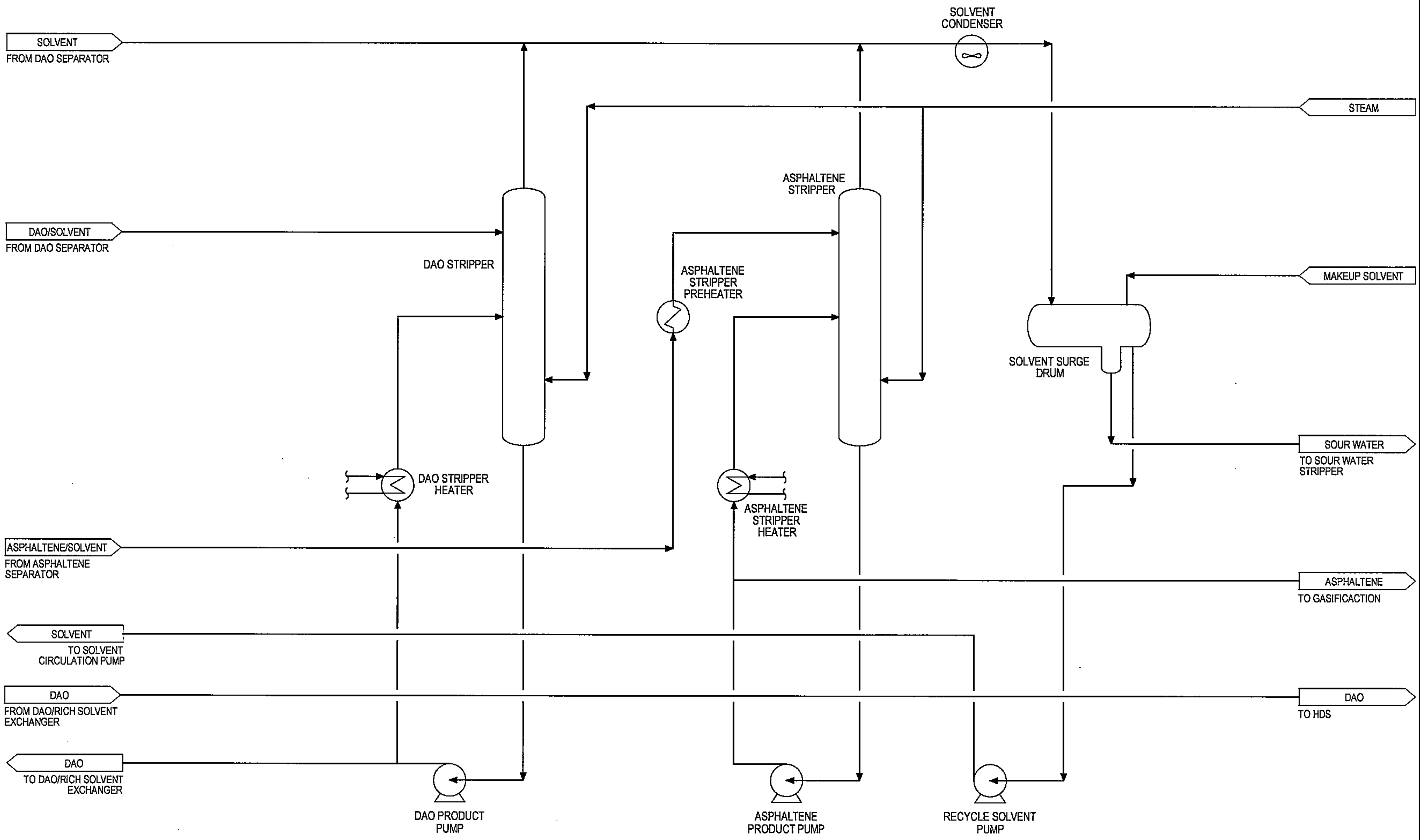

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TITLE
BAIJI REFINERY UPGRADING PROJECT
SIMPLIFIED PROCESS FLOW DIAGRAM
SDA UNIT
STRIPPER SECTION

SCALE	JOB NO.	
PROJECT	DRAWING NO.	REVISION

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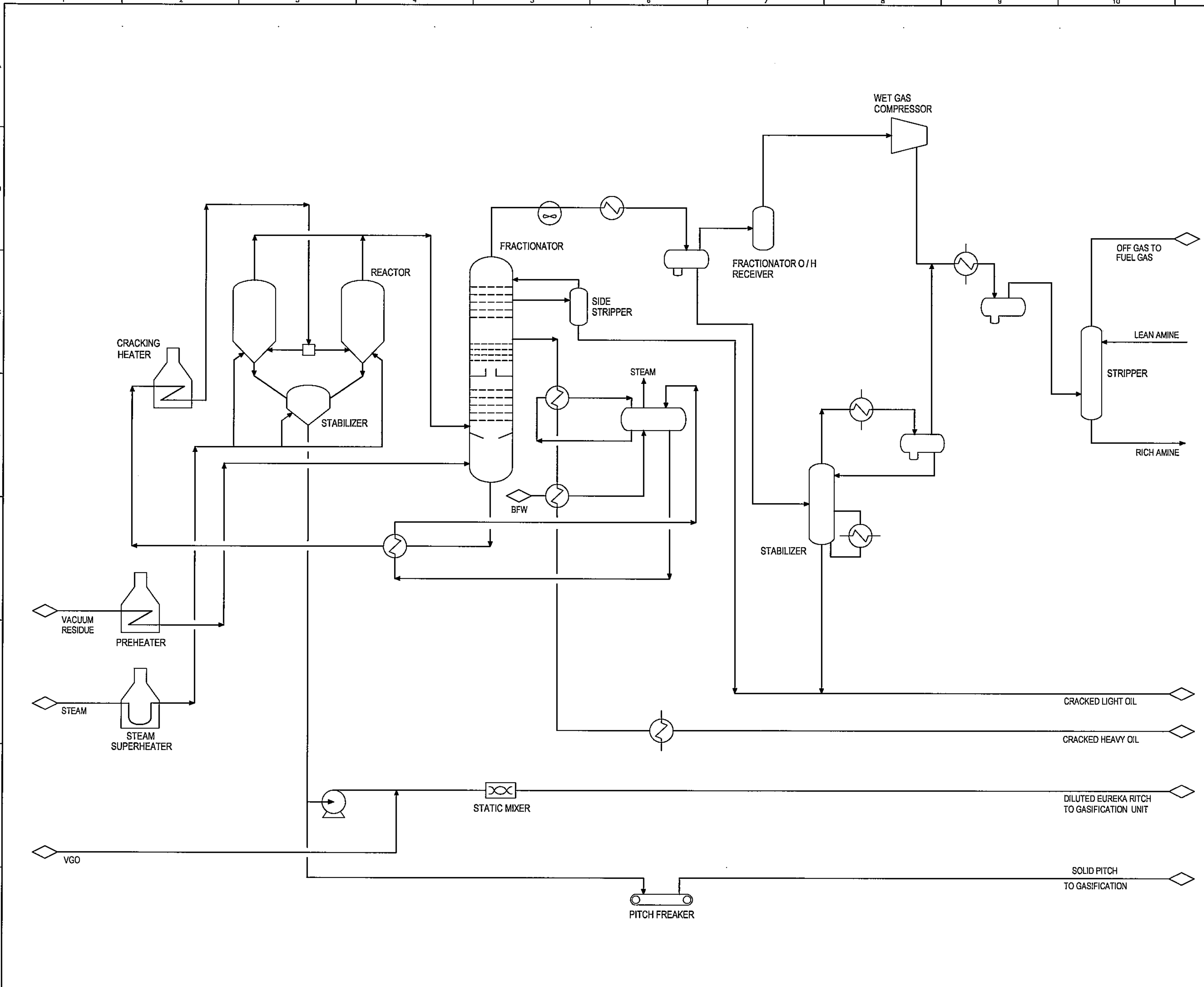

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TITLE BAIJI REFINERY UPGRADING PROJECT
SIMPLIFIED PROCESS FLOW DIAGRAM
FOR EUREKA UNIT

SCALE | JOB NO.

PROJECT | DRAWING NO. | REVISION

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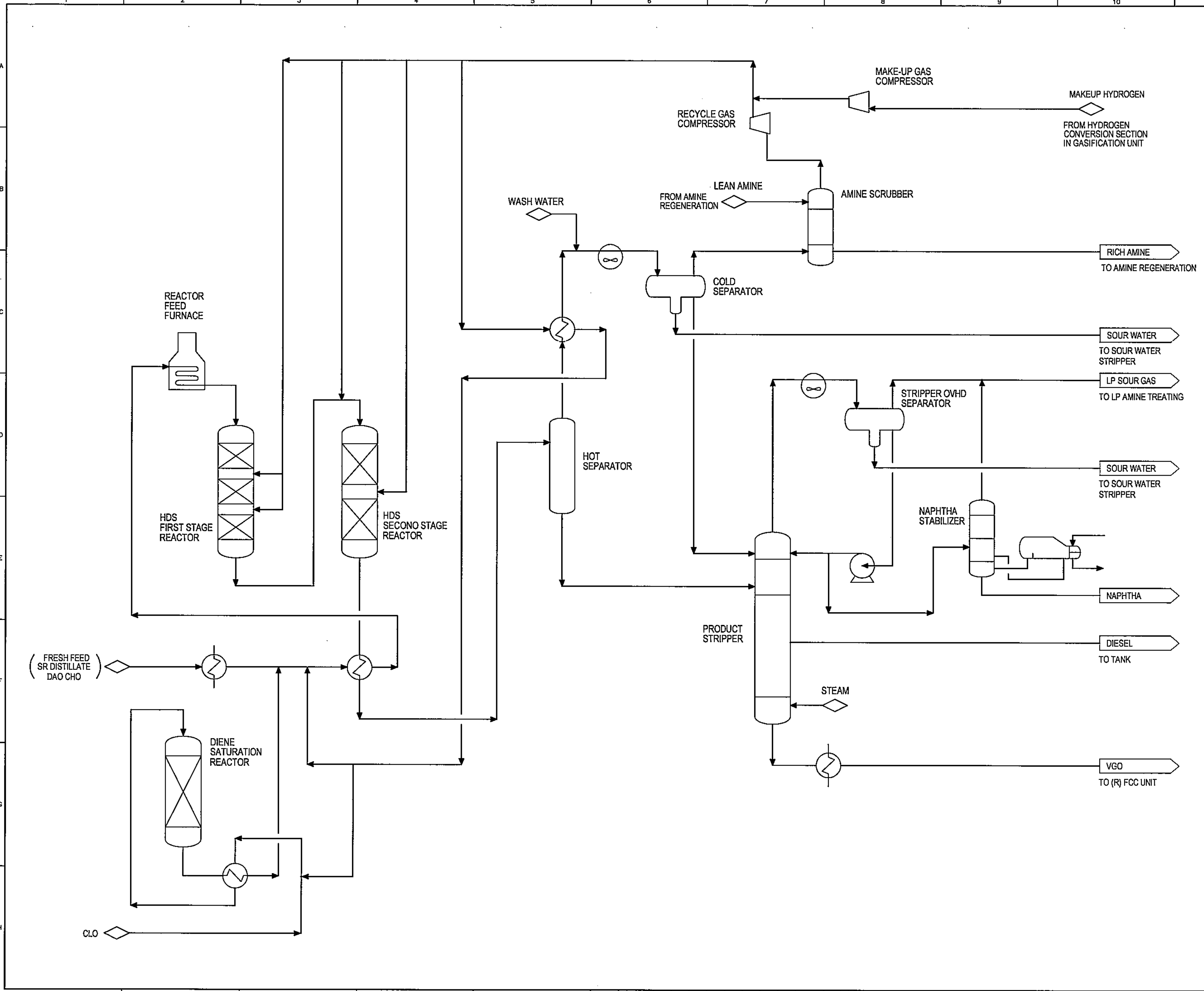

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TITLE
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SIMPLIFIED PROCESS FLOW DIAGRAM
HDS UNIT

SCALE | JOB NO.

PROJECT | DRAWING NO. | REVISION

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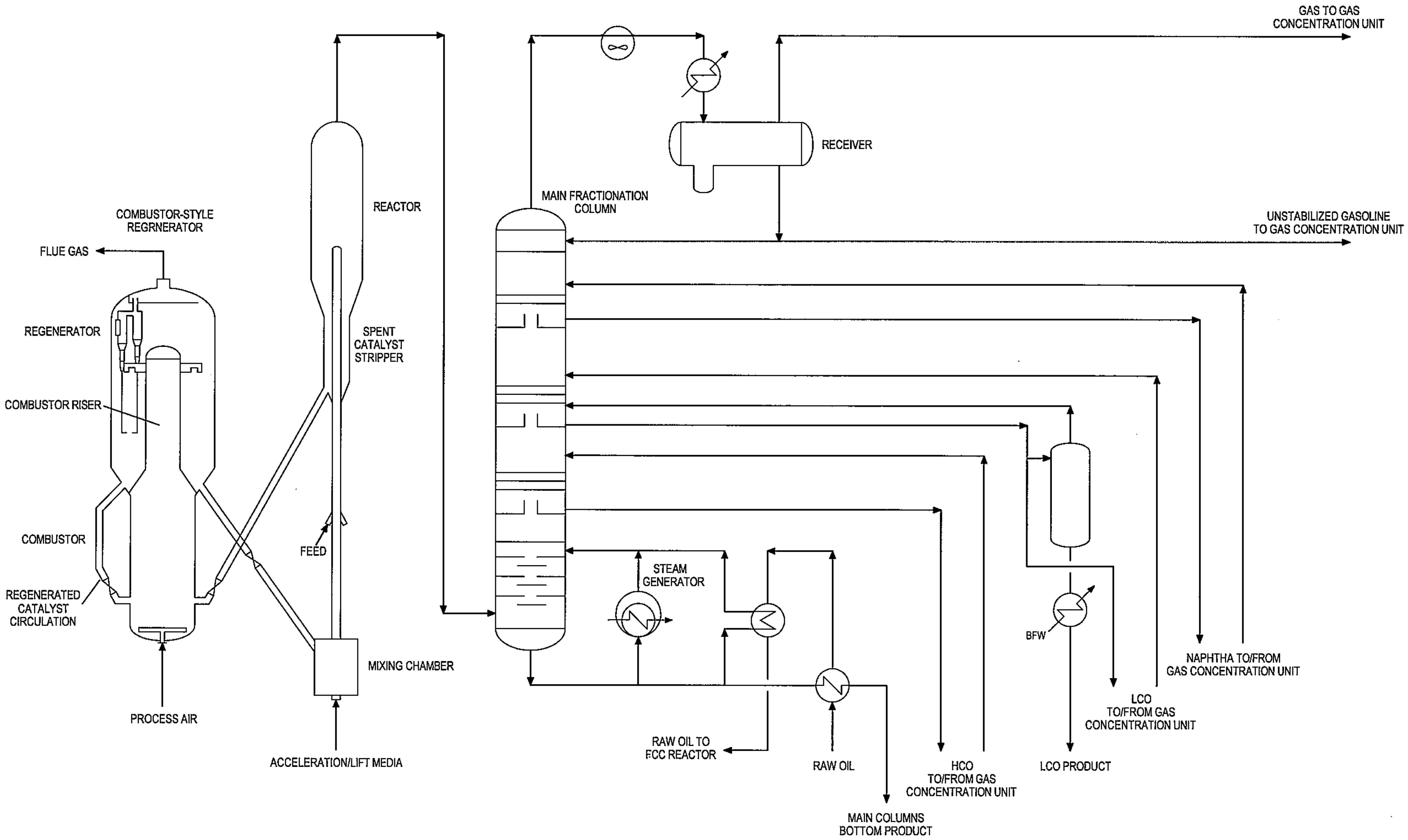

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TITLE BAIJI REFINERY UPGRADING PROJECT
SIMPLIFIED PROCESS FLOW DIAGRAM
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SCALE | JOB NO.

PROJECT | DRAWING NO. | REVISION

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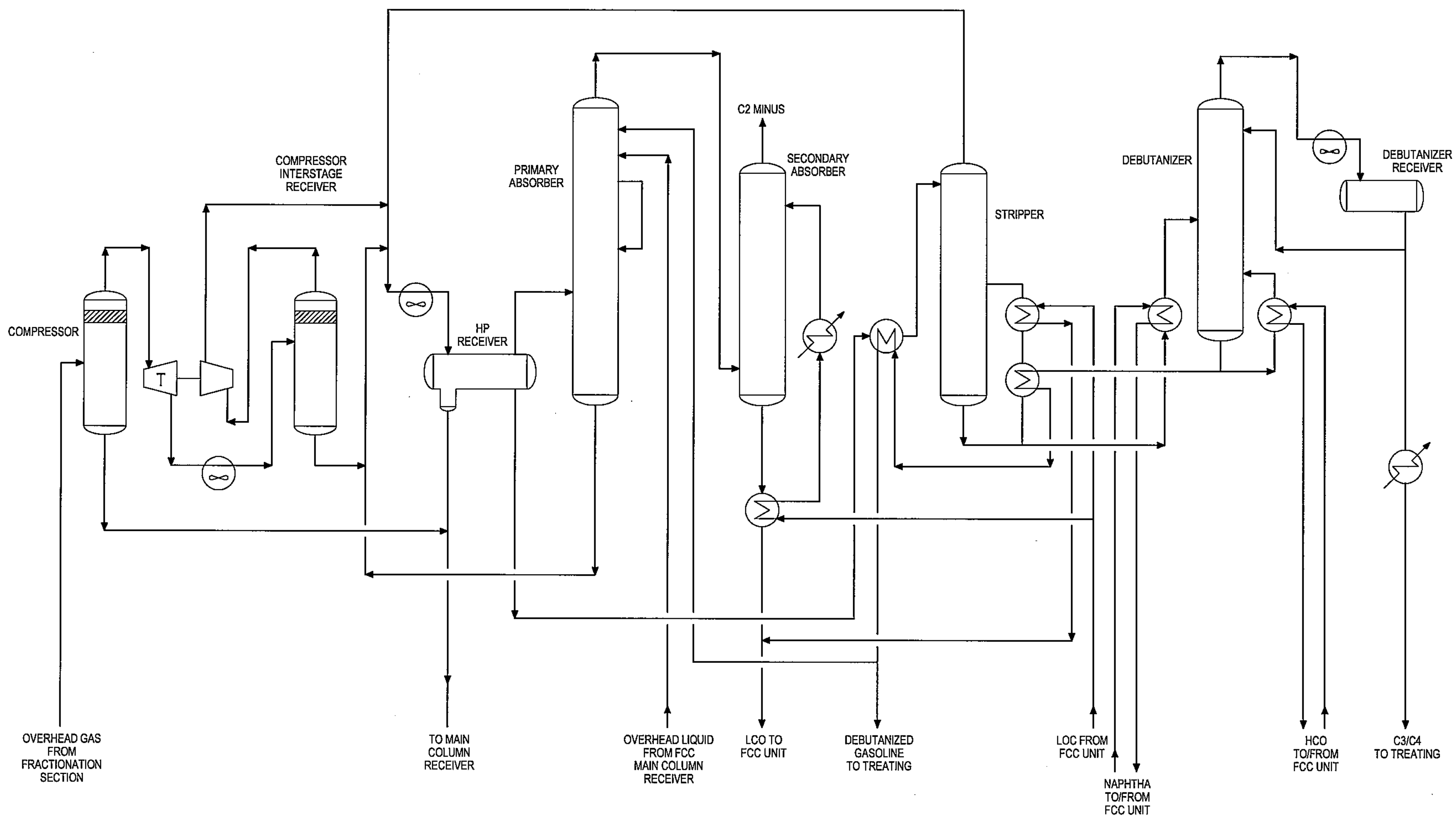

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BAIJI REFINERY UPGRADING PROJECT
SIMPLIFIED PROCESS FLOW DIAGRAM
RFCC UNIT
GAS CONCENTRATION SECTION

SCALE	JOB NO.

PROJECT	DRAWING NO.	REVISION

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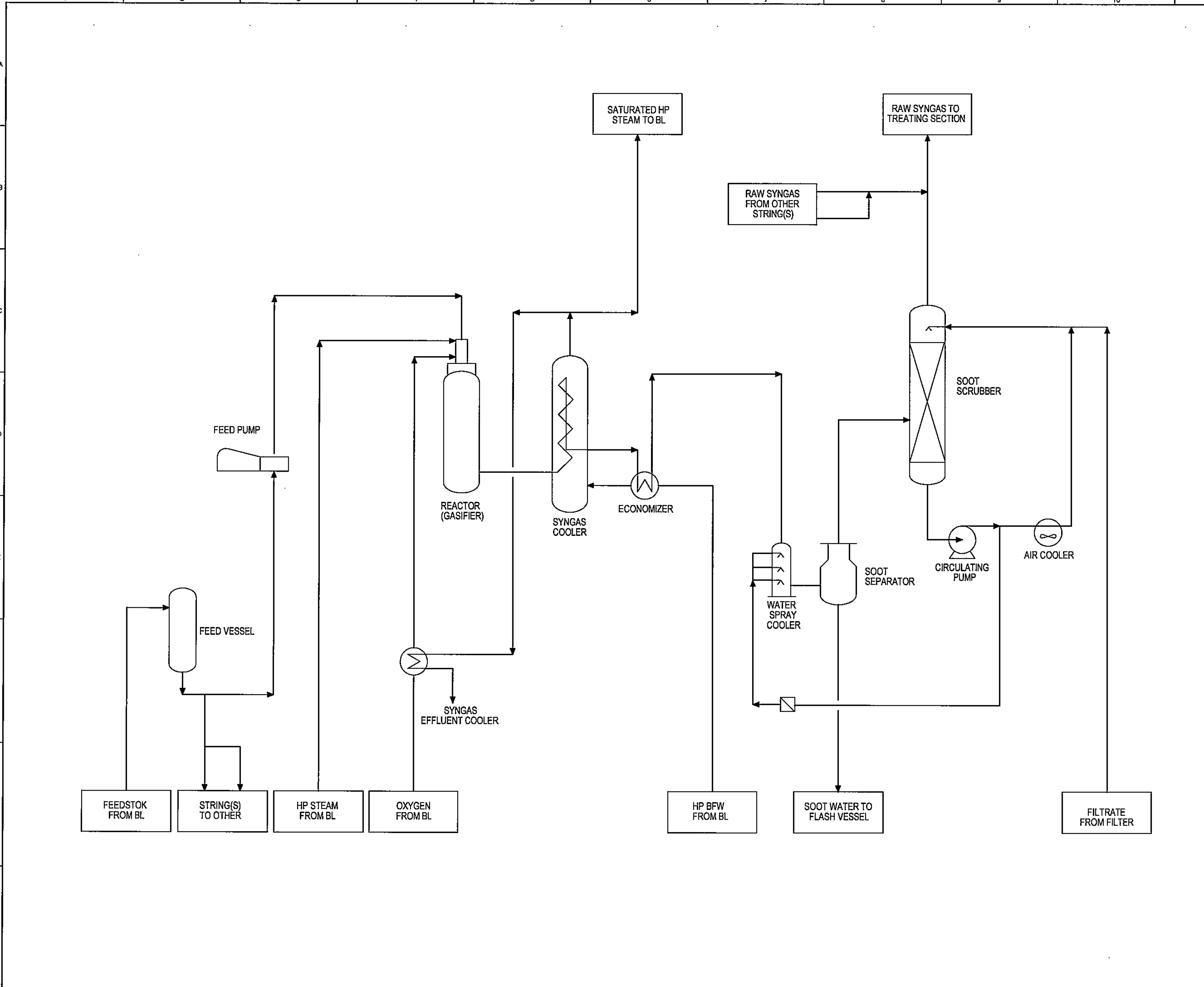

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TITLE BAIJI REFINERY UPGRADING PROJECT
SIMPLIFIED PROCESS FLOW DIAGRAM
GASIFICATION/GAS COOLING SECTION

SCALE | JOB NO.

PROJECT | DRAWING NO. | REVISION

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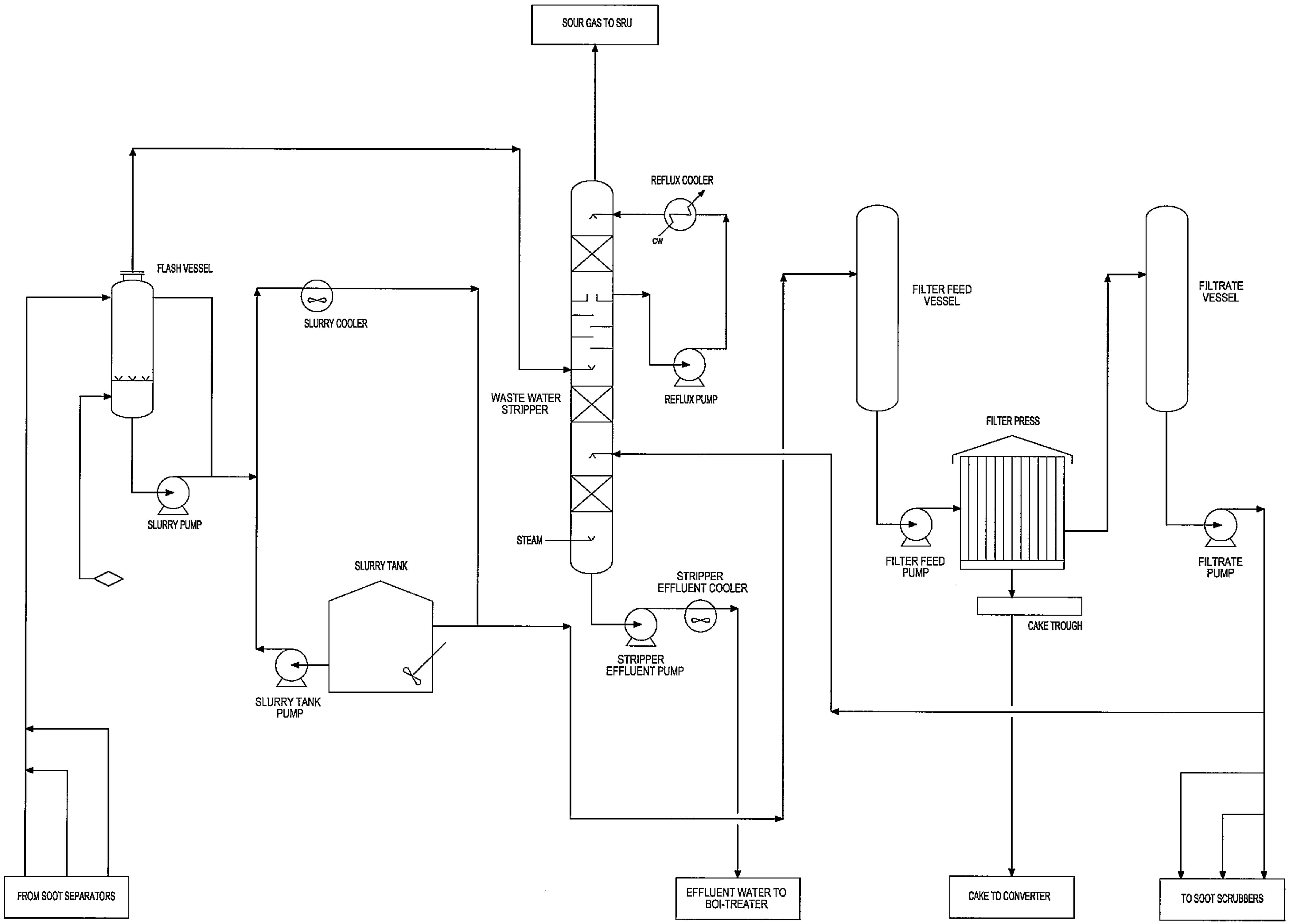

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SIMPLIFIED PROCESS FLOW DIAGRAM
SOOT AND ASH HANDLING SECTION

SCALE	JOB NO.

PROJECT	DRAWING NO.	REVISION

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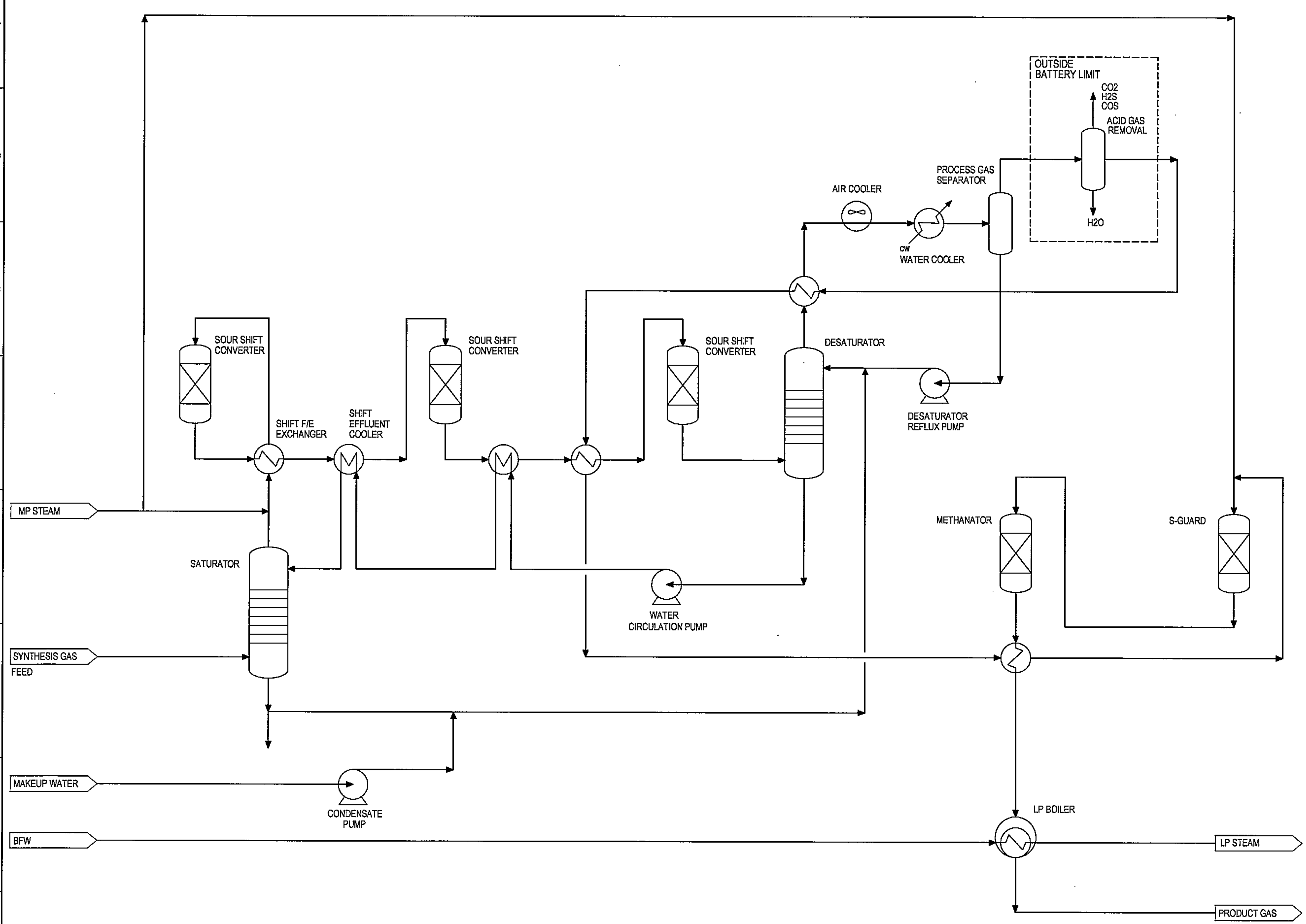

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TITLE
BAIJI REFINERY UPGRADING PROJECT
SIMPLIFIED PROCESS FLOW DIAGRAM
3 STAGE SOUR SHIFT AND METHANATION

SCALE | JOB NO.

PROJECT | DRAWING NO. | REVISION

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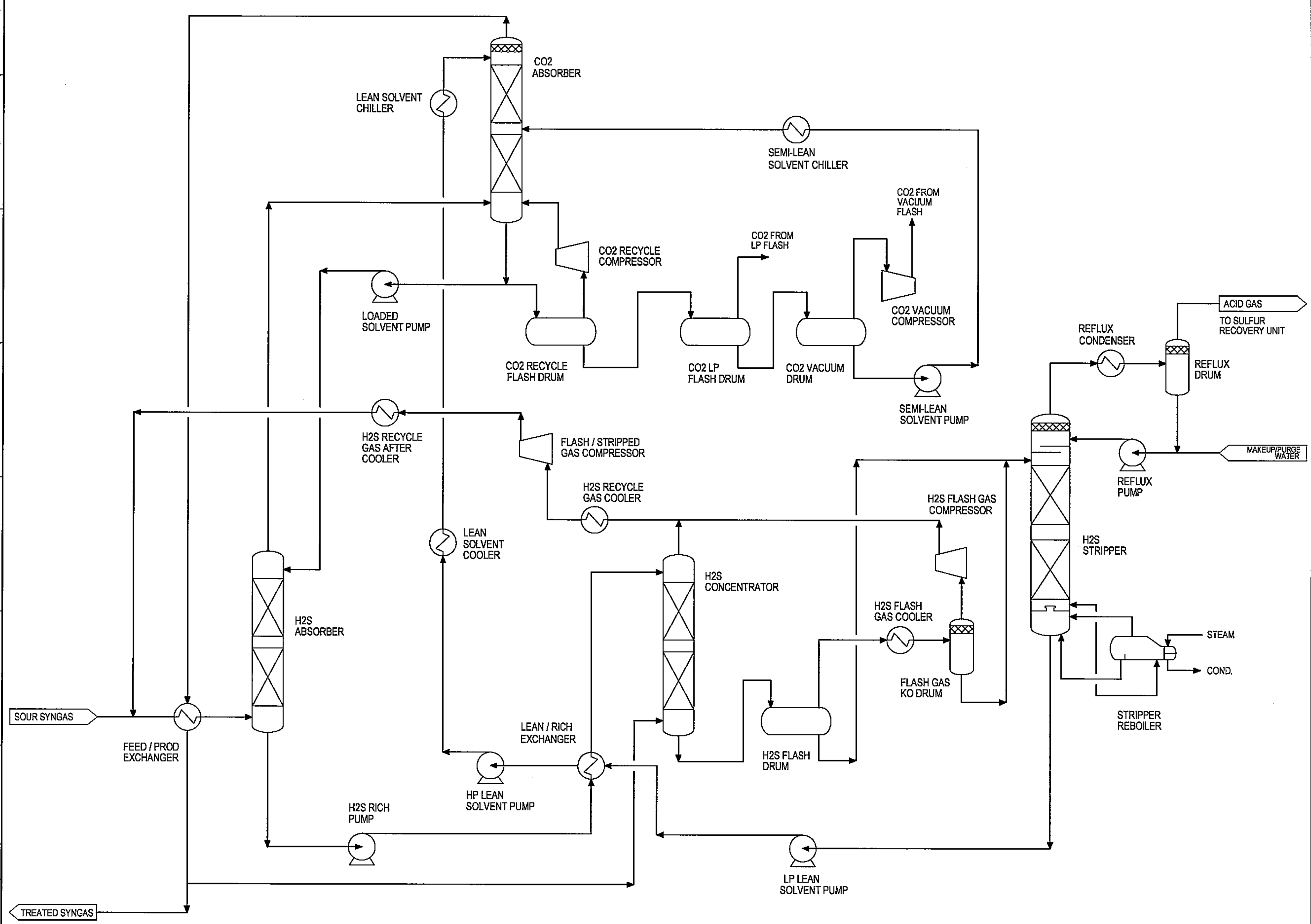

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REVISIONS

REV	DATE	APPROVED

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FOR

NORTH REFINERY COMPANY

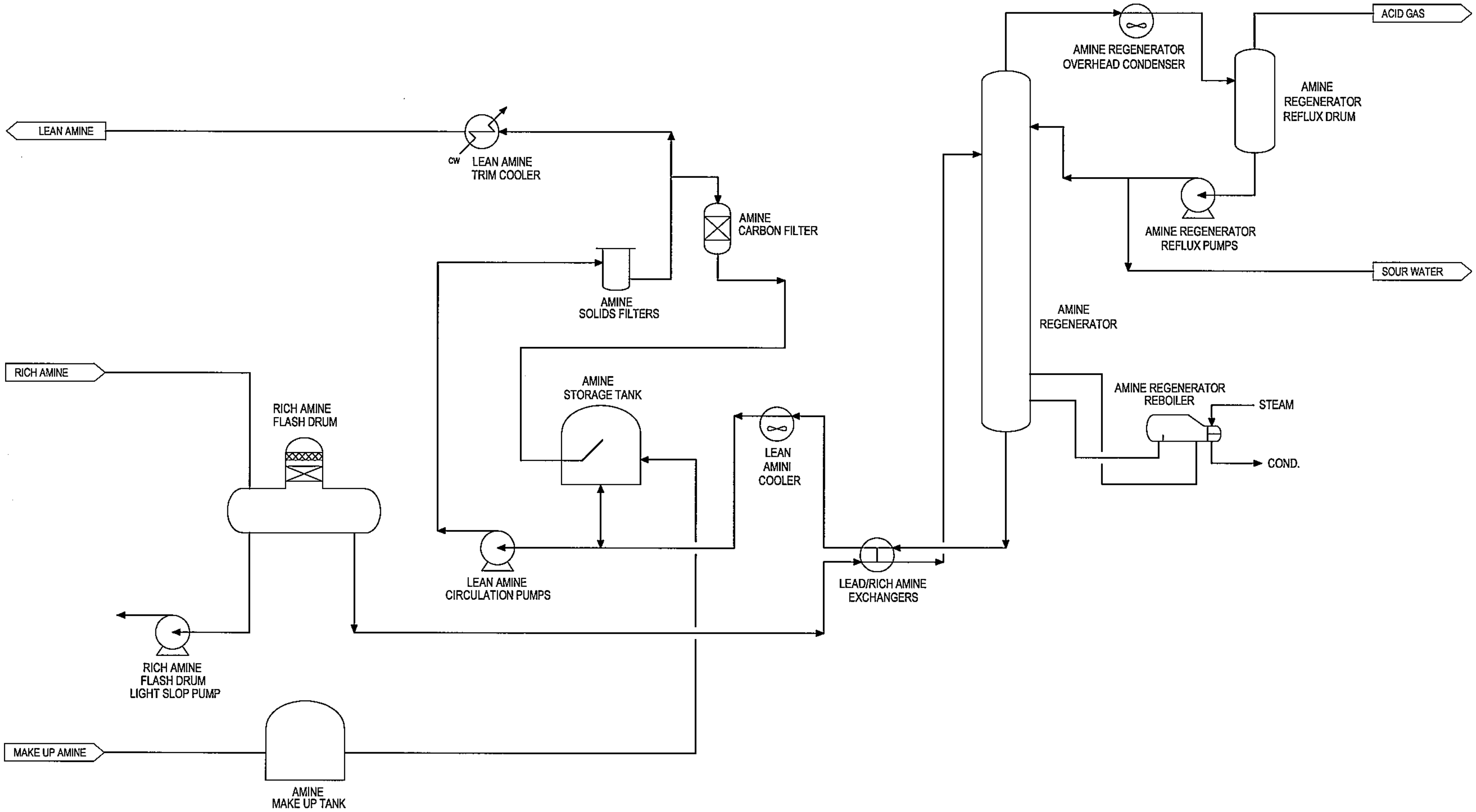
JICA Japan International Cooperation Agency

TITLE BAIJI REFINERY UPGRADING PROJECT
SIMPLIFIED PROCESS FLOW DIAGRAM
ACID GAS RECOVERY UNIT

SCALE | JOB NO.

PROJECT | DRAWING NO. | REVISION

WORK NO. PF-005



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DWG NO.	TITLE

REFERENCE DRAWINGS

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FOR

NORTH REFINERY COMPANY

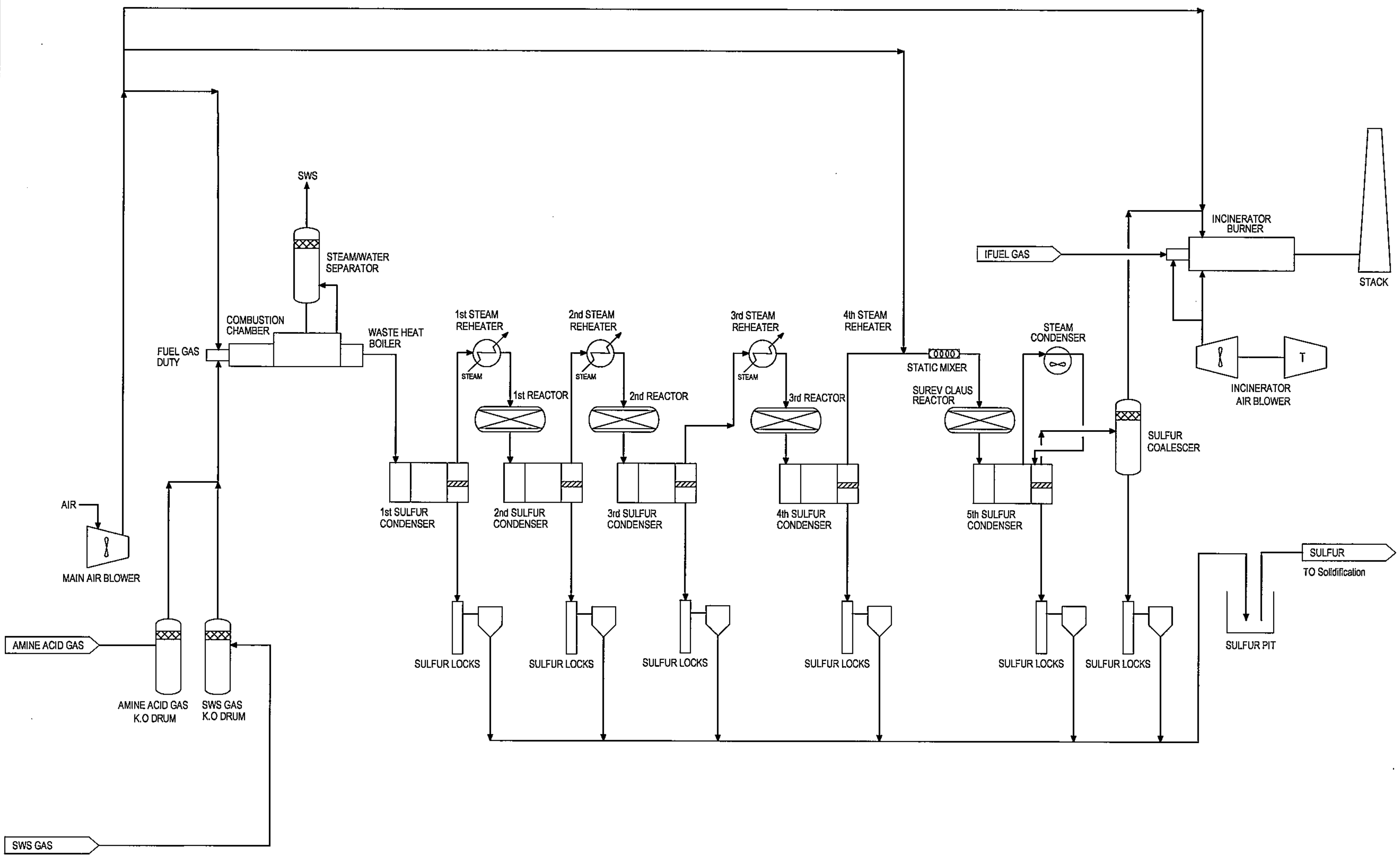
Japan International Cooperation Agency

TITLE BAIJI REFINERY UPGRADING PROJECT
SIMPLIFIED PROCESS FLOW DIAGRAM
AMINE REGENERATION UNIT

SCALE | JOB NO.

PROJECT | DRAWING NO. | REVISION

WORK NO. PF-003



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DWG NO.	TITLE

REFERENCE DRAWINGS

NO.	DESCRIPTION	BY	CHKD	APVD	DATE

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FOR

NORTH REFINERY COMPANY

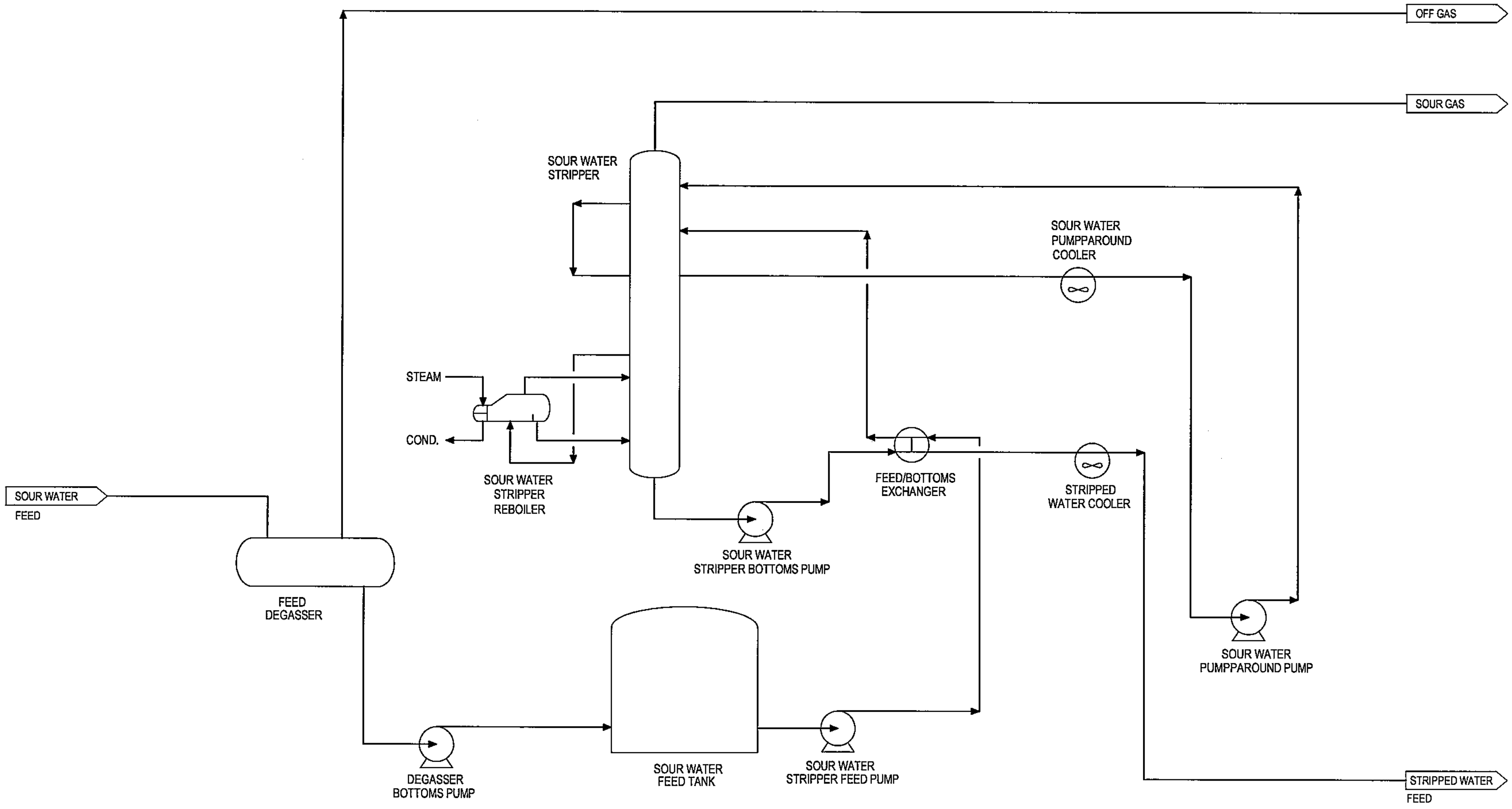
Japan International Cooperation Agency

TITLE BAIJI REFINERY UPGRADING PROJECT
SIMPLIFIED PROCESS FLOW DIAGRAM
SULFUR RECOVERY UNIT

SCALE | JOB NO.

PROJECT | DRAWING NO. | REVISION

WORK NO. PF-006



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REFERENCE DRAWINGS

NO.	DESCRIPTION	BY	CHKD	APVD	DATE

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FOR

NORTH REFINERY COMPANY

Japan International Cooperation Agency

TITLE
BAIJI REFINERY UPGRADING PROJECT
SIMPLIFIED PROCESS FLOW DIAGRAM
SOUR WATER STRIPPER UNIT

SCALE | JOB NO.

PROJECT | DRAWING NO. | REVISION

WORK NO. PF-002

Appendix 3.5-1

Major Equipment List for SDA Case

1 Vacuum Distillation Unit (VDU)

2 Solvent De-Asphalting Unit (SDA)

3 VGO/DAO HDS (HDS)

4 Residue Fluid Catalytic Cracking Unit (RFCC)

5 Catalytic Cracker Gasoline Hydrotreating Unit (CCGHT)

6 Unsaturated LPG Hydrogenation Unit (LPGHG)

7 Gasification Unit

8 Hydrogen Production Unit (HPU)

8.1 Sour Shift and Methanation Section
8.2 Acid Gas Removal Section

9 Amine Regeneration Unit

10 Sulfur Recovery Unit

11 Sour Water Stripping Unit

Abbreviation :

H	Horizontal
1S	One Spare
UG	underground

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: SDA Case
Major Equipment List

Vacuum Distillation Unit (VDU)

36,500 BPSD

Column

Service	No. req'd	Diameter (mm) Top /Mid/Btm	Length (mm) TL-TL Top/Bottom	Note
Vacuum Distillation Column	1	4,600/7,000 4,700	45,000	

Heat Exchanger/AFC

AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Total Duty (MW)	Note
Feed/1st Vacuum Residue Exchanger	2	ST	6.6	
Feed/2nd Vacuum Residue Exchanger	5	ST	11.8	
Feed/Vacuum BPA Exchanger	3	ST	14.1	
Feed/1st HVGO Product Exchanger	1	ST	2.4	
Feed/2nd HVGO Product Exchanger	1	ST	2.3	
Feed/3rd HVGO Product Exchanger	1	ST	2.1	
Feed/1st Vacuum MPA Exchanger	2	ST	0.9	
Feed/2ndVacuum MPA Exchanger	1	ST	1.4	
Ejector Condenser	4	ST	-	By Vendor
TPA Cooler	1	AC	3.7	IDF
MVGO Rundown Cooler	1	AC	3.1	IDF
HVGO Rundown Cooler	1	AC	1.6	IDF
XHVGO Rundown Cooler	1	AC	1.0	IDF

Furnace

Service	No. req'd	Type	Absorb. Duty (MW)	Note
Feed Preheater	1	BOX	19.6	

Pump

C: Cenrigugal, R: Reciprocating

Service	No. req'd	Type	Capacity (m3/hr)	Note
Vacuum Charge Pump	1 + 1S	C	277	
TPA/LVGO Pump	1 + 1S	C	20	
MPA/MVGO Pump	1 + 1S	C	165	
BPA/HVGO Pump	1 + 1S	C	636	
Recycle/XHVGO Pump	1 + 1S	C	25	
Vacuum Residue Pump	1 + 1S	C	210	
HC Condensate Pump	1 + 1S	C	1.5	
Overhead Water Pump	1 + 1S	C	23	

Vessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
VDU Overhead Accumulator	1	1,300	6,000	
Sour Gas K.O. Drum	1	350	1,300	

Auxiliary Equipment

Service	No. req'd	Type	Note
Ejector System	1		

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: SDA Case
Major Equipment List

Solvent De-Asphalting Umit (SDA)

49.4 Kbpsd

Column

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Asphaltene Separator	1	-	-	
DAO Separator	1	-	-	
DAO Stripper	1	3,500	13,700	
Asphaltene Stripper	1	2,300	12,200	

Heat Exchanger/AFC

AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Total Duty (MW)	Note
Exchanger	30	ST	93.2	
DAO/Rich Solvent Exchanger	2	ST	7.1	
DAO Separator Preheater	2	ST	37.6	
DAO Stripper Heater	6	ST	12.5	
Asphaltene Stripper Preheater	3	ST	7.8	
Asphaltene Stripper Heater	2	ST	2.1	
Flush Oil Heater	1	ST	3.0	
Steam Superheater	1	ST	0.7	
Solvent Cooler	1	AC	24.4	
Solvent Condenser	1	AC	31.4	

Furnace

Service	No. req'd	Type	Absorb. Duty (MW)	Note
Hot Oil Furnace	1	CYL	62.7	

Pump

C: Cenrigugal, R: Reciprocating

Service	No. req'd	Type	Capacity (m3/hr)	Note
Charge Pump	1 + 1S	C	400	
Solvent Circulation Pump	1 + 1S	C	3,820	
DAO Pump	1 + 1S	C	760	
Asphaltene Pump	1 + 1S	R	180	Rotary
Recycle Solvent Pump	1 + 1S	C	270	
Sour Water Pump	1 + 1S	C	13	
Hot Oil Circulation Pump	1 + 1S	C	2,970	
Relief K.O. Drum Pump	1 + 1S	C	38	
Flushing Oil Pump	1	C	18	

Vessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Feed Surge Drum	1	2,100	5,900	
Solvent Surge Drum	1	5,000	15,000	
Hot Oil Surge Drum	2	5,000	15,000	
Relief K.O. Drum	2	3,100	9,200	
Fuel Gas K.O. Drum	1	950	3,500	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
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Major Equipment List

HDS Unit

60.2 KBPSD

Column

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
H2S Absorber	1	2,700	17,460	
Product Stripper	1	2,500	25,760	
Product Fractionator	1	7,000	46,815	
Kerosene Stripper	1	2,300	15,700	
Diesel Stripper	1	3,600	15,400	
Heavy Diesel Stripper	1	1,400	9,100	

Heat Exchanger/AFC

AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Surface Area (m2/shell)	Note
Reactor Feed/Effluent Exchanger No.1	2	ST	678	
Reactor Feed/Effluent Exchanger No.1	2	ST	705	
Reactor Effluent/Stripper Bottoms Exchanger	4	ST	2,315	
HHPS Vapor Air Cooler	4	AC	1,292	
Product Stripper Overhead Condenser	1	AC	267	
Naphtha Recovery Air Cooler	1	AC	174	
Product Fractionator Overhead Condenser	3	AC	2,956	
Heavy Premium Diesel Pumparound MP Steam Generator	1	ST	221	
Diesel Pumparound Air Cooler	1	AC	146	
Kerosene Stripper Reboiler	1	ST	165	
Diesel Stripper Reboiler	2	ST	931	
Kerosene Air Cooler	1	AC	159	
Diesel Air Cooler	1	AC	706	
Heavy Diesel Air Cooler	1	AC	251	
Fractionator Bottoms/Feed Exchanger	1	ST	768	
Fractionator ottoms/Feed Exchanger	1	ST	375	

Furnace

Service	No. req'd	Type	Heat Duty (MW)	Note
Reactor Feed Furnace	2	BOX	5.7	
Product Fractionator Feed Furnace	1	BOX	28.9	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
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Major Equipment List

HDS Unit

60.2 KBPSD

Compressor/Pump

C: Cenrigugal, R: Reciprocating

Service	No. req'd	Type	Capacity (m3/hr)	Note
Recycle Gas Compressor	1	C	5,400 Nm3/h	
HP Hydrogen Compressor	3	R	76,000 Nm3/h	
Reactor Charge Pump	2	C	282	
2nd Stage Feed Pump	2	C	251	
Product Stripper Bottoms Pump	2	C	555	
Product Stripper Bottoms Pump	2	C	90	
Product Fractionator Bottoms Pump	2	C	644	
Fractionator Reflux Pump	2	C	741	
Heavy Premium Diesel Pumparound Pump	2	C	750	
Kerosene Stripper Bottoms Pump	2	C	68	
Diesel Stripper Bottoms Pump	2	C	611	
Heavy Diesel Stripper Bottoms Pump	2	C	126	

Reactor/Vessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
No.1 Reactor	1	2,700	8,300	D.P.=110 barg
No.2 Reactor	1	3,400	20,000	D.P.=110 barg
1st Stage Reactor	1	3,400	20,000	
2nd Stage Reactor	1	3,400	20,000	
Filtered Feed Surge Drum	1	4,300	14,300	
Hot High Pressure Separator	1	2,500	6,900	
Cold High Pressure Separator	1	2,400	4,000	
Cold Low Pressure Separator	1	1,500	5,300	
Product Stripper Reflux Drum	1	2,700	4,900	
Product Fractionator Reflux Drum	1	3,800	7,900	

MISC.

Service	No. req'd	Type	Note
Feed Filter System	1		

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Major Equipment List

Residue Fluid Catalitic Cracking Unit (RFCC) 52.1 Kbpsd

R&R, Fractionation, Vapor Recovery & Gas/LPG Treating

Column

Service	No. req'd	Diameter (mm) Top /Bottom	Length (mm) TL-TL Top/Bottom	Note
Main Fractionator	1	6,600/6,600	22,000/21,000	
Light Cycle Oil Stripper	1	850	8,000	
Primary Absorber	1	2,000	30,000	
Sponge Absorber	1	800	16,000	
Stripper	1	3,000	29,000	
Debutanizer	1	2,700/3,300	13,000/18,000	
Amine HP Absorber	1	1,300	21,700	
Amine LPG Absorber	1	2,100	19,800	
Amine Stripper	1	950/1,450	22,400	

Heat Exchanger/AFC

AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Total Heat Duty (MW)	Note
Catalyst Cooler	2	Special	175 m2 x 2	
Raw Oil/Circ. LCO Exchanger	1	ST	4.5	
Raw Oil/Fractionator Bottoms Product Exchanger	1	ST	2.2	
Raw Oil/Circ. HCO Exchanger	1	ST	9.7	
Raw Oil/Fractionator Bottoms Exchanger	1	ST	3.6	
Fractionator Bottoms Cooler	2	ST	1.6	
Fractionator Bottoms Steam Generator	2	ST	44.5	
LCO Product/BFW Exchanger	2	ST	3.8	
LCO Product Cooler	1	AC	2.4	
Fractionator Overhead Condenser	1	AC	41.9	
Fractionator Trim Condenser	1	ST	3.8	
Compressor Interstage Cooler	1	AC	4.1	
Compressor Interstage Trim Cooler	1	ST	1.5	
HP Condenser	1	AC	4.1	
HP Trim Condenser	1	ST	1.5	
Primary Absorber Lower Intercooler	1	ST	0.5	
Primary Absorber Upper Intercooler	1	ST	0.5	
Sponge Absorber Lean Oil/Rich Oil Exchanger	1	ST	1.6	
Sponge Absorber Lean Oil Cooler	1	ST	1.8	
Lean Gas Cooler	1	ST	0.7	
Stripper Feed Exchanger	1	ST	3.4	
Stripper Steam Generator	1	ST	5.8	
Debutanizer Overhead Condenser	1	AC	14.3	

Heat Exchanger/AFC — AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Total Heat Duty (MW)	Note
Debutanizer Net Overhead Condenser	1	ST	0.4	
Debutanizer LCO Reboiler	1	ST	7.2	
Debutanizer HCO Reboiler	1	ST	7.2	
Stripper Reboiler Exchanger	1	ST	5.2	
Debutanizer Bottoms Product Cooler	1	AC	3.3	
Debutanizer Bottoms Trim Cooler	1	ST	0.7	
Amine Stripper Reboiler	1	ST	3.0	
Amine Stripper Condenser	1	AC	1.6	
Lean Amine Cooler No.1	1	ST	1.1	
Lean/Rich Amine Exchanger	3	ST	2.4	
Lean Amine Cooler No.2	1	ST	0.3	

Furnace

Service	No. req'd	Type	Absorb. Duty (MW)	Note
Direct Fired Air Heater	1	BOX	38.4	
Flue Gas Steam Generator (WHB)	1	Boiler	Steam 132 ton/h	Natural Circulation

Compressor/Blower/Pump — C: Cenrigugal, R: Reciprocating

Service	No. req'd	Type	Capacity (m3/hr)	Note
(Compressor/Blower)				
Main Air Blower	1	C	332,000 Nm3/h	
Catalyst Cooler Air Compressor	1	R	8,900 Nm3/h	
Wet Gas Compressor	1	C	64,000 Nm3/h	
(Pump)				
Cat Cooler Water Circulation Pump	2 + 1S	C	2,930	
Raw Oil Pump	1 + 1S	C	343	
Main fractionator Bottoms Circ. Pump	1 + 1S	C	581	
Main fractionator Bottoms Product Pump	1 + 1S	C	24	
HCO Circulation Pump	1 + 1S	C	907	
LCO Circulation Pump	1 + 1S	C	2,570	
LCO Product Pump	1 + 1S	C	97	
Heavy Naphtha Circulation Pump	1 + 1S	C	2,085	
Sour Water Pump	1 + 1S	C	47	
Main fractionator Reflux Pump	1 + 1S	C	200	
Main Hot Oil Pump	1 + 1S	C	125	
Flushing Oil Pump	1 + 1S	C	35	
Compressor Suction Drum Pump	1 + 1S	R	7	
Compressor Interstage Condensate Pump	1 + 1S	C	53	
Water Injection Pump	1 + 1S	C	15	
HP Receiver Pump	1 + 1S	C	182	

Primary Absorber Rich Oil Pump	1 + 1S	C	214	

Compressor/Blower/Pump C: Cenrigugal, R: Reciprocating

Service	No. req'd	Type	Capacity (m3/hr)	Note
Primary Absorber Lower Intercooler Pump	1 + 1S	C	190	
Primary Absorber Upper Intercooler Pump	1 + 1S	C	182	
Sponge Absorber Lean Oil Pump	1 + 1S	C	53	
Debutanizer Overhead Pump	1 + 1S	C	347	
Debutanizer Bottoms Recycle Pump	1 + 1S	C	65	
Lean Amine Pump	1 + 1S	C	35	
Amine Stripper Reflux Pump	1 + 1S	C	3	
Wash Water Circulation Pump	1 + 1S	C	5	
Water Injection Pump	1 + 1S	R	1	
Debutanizer Bottoms Recycle Pump	1	C	5	

Reactor/RegeneratorVessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
(Reactor)				
RFCC Reactor:	1	7,500	15,300	
Disengaging System	1			
Cyclones	5	1,670		
Spent Catalyst Stripper	1	4,500	8,700	
Reactor Riser:				
External Upper Reactor Riser	1	1,680	19,400	
Internal Upper Reactor Riser	1	1,680	17,000	
Feed Injection Zone	1		3,000	
Lift Zone	1	1,230	3,100	
Catalyst Mix Chamber	1	2,900	2,900	
(Regenerator)				
Regenerator:	1	12,100/8,800	16,400	
Cyclones	7	1,870		
Regenerated Recirculation Standpipe	1	1,250		
Cooled Catalyst Standpipe	1	1,250		
Spent Catalyst Standpipe	1	1,050		
(Vessel)				
Fresh Catalyst Hopper	1	4,900	20,400	Vertical
Equillibrium Catalyst Hopper	1	6,800	20,400	Vertical
Low Metals Equillibrium Catalyst Hopper	1	4,900	20,400	Vertical
ZSM-5 Storage Hopper	1	2,500	7,600	Vertical
Catalyst Cooler Steam Disengager Drum	1	2,600	7,900	Hosizontal
3rd Stage Separator	1	5,800	5,400	Vertical
Oriffice Chamber	1	3,800	15,100	Vertical
4th Stage Separator	1	3,000	4,200	Vertical

Break Vessel	1	3,000	4,200	Vertical
Recovered Catalyst Hopper	1	2,800	10,200	Vertical

Reactor/RegeneratorVessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Fuel Gas K.O. Drum	1	700	1,600	Vertical
Raw Oil feed Surge Drum	1	4,300	9,800	Hosizontal
Main Fractionator Receiver	1	4,100	9,200	Hosizontal
Steam Generator Separator A	1	800	1,400	Vertical
Steam Generator Separator B	1	800	1,400	Vertical
Flushing Oil Receiver	1	1,200	3,600	Vertical
Compressor Suction Drum	1	4,000	5,600	Vertical
Compressor Inter Stage Suction Drum	1	2,100	5,600	Vertical
High Pressure Receiver	1	3,400	9,000	Hosizontal
Lean Gas K.O. Drum	1	800	2,600	Vertical
Debutanizer Receiver	1	2,900	7,600	Hosizontal
LPG Coaleescer Pre-Filter	1			Filter Package
LPG Coaleescer	1	1,600/2,400	3,300	Vertical
Rich Amine Flash Drum	1	1,700	5,300	Hosizontal
Amine Stripper Reflux Drum	1	1,300	3,700	Vertical
Carbon Filter	1	1,100	4,500	Vertical
Product K.O. Drum	1	1,100	2,200	Vertical
Lean Amine Post-Filter	1			Filter Package
Lean Amine Pre-Filter	1			Filter Package
Amine Sump Drum	1	2,200	2,600	Vertical
Skimming Drum	1	850	2,000	Vertical
Amine Reboiler Condensate Pot	1	1,000	2,200	Vertical
Feed Gas K.O. Drum	1	1,100	2,400	Vertical
No.1 Anti-Foamer Drum	1	6 inch	300	Vertical
No.2 Anti-Foamer Drum	1	6 inch	300	Vertical

Packaged Equipment

Service	No. req'd	Type	Capacity	Note
Power Recovery Unit	1			

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
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FCC Gasoline Hydrotreating Unit (CCGHT)

32.3 Kbpsd

Heat Exchanger/AFC

AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Total Duty (MW)	Note
HDS Feed/Effluent Exchanger	5	ST	19.9	
Separator Post Condenser	1	ST	0.3	
Stabilizer Feed/Bottoms Exchanger	2	ST	5.1	
Stabilizer Reboiler	1	ST	4.0	
Stabilizer Condenser	1	ST	0.3	
HCCG product Cooler	1	ST	0.7	
SHU Feed/Bottoms Exchanger	1	ST	3.4	
SHU Feed/Effluent Exchanger	1	ST	4.7	
SHU Preheater	1	ST	4.4	
Splitter Reboiler	1	ST	15.2	
Splitter Post Condenser	1	ST	0.3	
LCCG Product Trim Cooler	1	ST	0.3	
Splitter Condenser	1	AC	15.8	
LCCG Product Air Cooler	1	AC	2.0	
Reactor Effluent Cooler	1	AC	12.8	
HCCG Product Air Cooler	1	AC	3.0	

Furnace

Service	No. req'd	Type	Absorb. Duty (MW)	Note
Hot Oil Furnace	1	CYL	3.7	

Compressor/Pump

C: Cenrigugal, R: Reciprocating

Service	No. req'd	Type	Capacity (m3/hr)	Note
Recycle Gas Compressor	1 + 1S	R	59,000 Nm3/h	
HDS Feed Pump	1 + 1S	C	172	
Quench Pump	1 + 1S	C	17	
Stabilizer Reflux Pump	1 + 1S	C	20	
HCCG Storage Pump	1 + 1S	C	165	
SHU Feed Pump	1 + 1S	C	290	
Splitter Reflux Pump	1 + 1S	C	225	

Reactor/Vessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
SHU Reactor	1	2,200	16,700	
1st HDS Reactor	1	2,900	8,500	
2nd HDS Reactor	1	3,100	5,000	

Separator Drum	1	2,400	7,200	
Stabilizer Reflux Drum	1	1400	3,900	
Compressor K.O. Drum	1	1,200	3,000	
Surge Drum	1	3,100	9,500	
Splitter Reflux Drum	1	2,100	6,800	

Column

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Gasoline Splitter	1	3,300	32,000	
Amine Scrubber	1	1,500	16,000	
Stabilizer	1	2,200	18,000	

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LPG Hydrogenation Unit (LPG HG) 1,590 mt/d

Heat Exchanger/AFC AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Total Duty (MW)	Note
Selective Hydrogenation Startup Heater	1	ST	3.9	
Hydrogenation Feed/Effluent Exchanger	2	ST	5.2	
Feed/ Effluent Exchanger	3	ST	9.8	
Deethanizer Condenser	1	ST	5.6	
Deethanizer Reboiler	1	ST	0.9	
Deethanizer Bootoms Cooler	1	ST	5.6	

Furnace

Service	No. req'd	Type	Absorb. Duty (MW)	Note
Feed Startup Furnace	1	CYL	2.6	

Compressor/Pump C: Cenrigugal, R: Reciprocating

(*1) 1S = One standby unit

Service	No. req'd (*1)	Type	Capacity (m3/hr)	Note
Makeup Gas Compressor	1 + 1S	R	880	
LPG Feed Pump	1 + 1S	C	140	
Deethanizer Reflux Pump	1 + 1S	C	60	

Reactor/Vessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Selective Hydrogenation Reactor	1	1,600	16,700	
Hydrogenation Reactor	1	2,700	13,500	
Steam Drum	1	2,600	3,900	
Deethanizer Reflux Drum	1	4,000	5,600	
Feed Surge Drum	1	2,800	9,400	

Column

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Deethanizer	1	2,400	21,800	

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Gasification Unit

116 ton/h

Column

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Soot Scrubber	1	2,100/2,100	7400/11,400	
Waste Water Stripper	1	2,000/1,700	8900/23,700	

Heat Exchanger/AFC

AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Total Duty (MW)	Note
1st Train Oxygen Preheater	1	ST	66 m2	
1st Train Syngas Effluent Cooler	1	ST	37.5	Vertical
1st Train Economizer	1	ST	7.7	Vertical
2nd Train Soot Scrubber Air Cooler	1	AC	5.3	
2nd Train Oxygen Preheater	1	ST	66 m2	
2nd Train Syngas Effluent Cooler	1	ST	37.5	Vertical
2nd Train Economizer	1	ST	7.7	Vertical
3rd Train Soot Scrubber Air Cooler	1	AC	5.3	
3rd Train Oxygen Preheater	1	ST	66 m2	
3rd Train Syngas Effluent Cooler	1	ST	37.5	Vertical
3rd Train Economizer	1	ST	7.7	Vertical
3rd Train Soot Scrubber Air Cooler	1	AC	5.3	
4th Train Oxygen Preheater	1	ST	66 m2	
4th Train Syngas Effluent Cooler	1	ST	37.5	Vertical
4th Train Economizer	1	ST	7.7	Vertical
4th Train Soot Scrubber Air Cooler	1	AC	5.3	
5th Train Oxygen Preheater	1	ST	66 m2	
5th Train Syngas Effluent Cooler	1	ST	37.5	Vertical
5th Train Economizer	1	ST	7.7	Vertical
5th Train Soot Scrubber Air Cooler	1	AC	5.3	
Soot Water Cooler	2	AC	5.7	
Feed/Effluent Exchanger	1		1.1	Plate HE
Stripper Circulation Cooler	1	AC	5.4	
Waste Water Air Cooler	1	AC	6.9	

Ejector

Service	No. req'd	Type	Note
1st Train Stack Ejector	1		
2nd Train Stack Ejector	1		
3rd Train Stack Ejector	1		
4th Train Stack Ejector	1		
5th Train Stack Ejector	1		
Filter Press Ejector	1		

Gasification Unit

116 ton/h

Mixer

Service	No. req'd	Type	Note
1st Train Oxygen/Steam Mixer	1		
2nd Train Oxygen/Steam Mixer	1		
3rd Train Oxygen/Steam Mixer	1		
4th Train Oxygen/Steam Mixer	1		
5th Train Oxygen/Steam Mixer	1		

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Gasification Unit

116 ton/h

Pump

C: Cenrigugal, R: Reciprocating

Service	No. req'd	Type	Capacity (m3/hr)	Note
Burner Cooling Water Pump	1 + 1S	C	121	
1st Train Soot Scrubber Bottoms Pump	1 + 1S	R	193	
1st Train Soot Scrubber Circulation Pump	1 + 1S	C	176	
2nd Train Soot Scrubber Bottoms Pump	1 + 1S	R	193	
2nd Train Soot Scrubber Circulation Pump	1 + 1S	C	176	
3rd Train Soot Scrubber Bottoms Pump	1 + 1S	R	193	
3rd Train Soot Scrubber Circulation Pump	1 + 1S	C	176	
4th Train Soot Scrubber Bottoms Pump	1 + 1S	R	193	
4th Train Soot Scrubber Circulation Pump	1 + 1S	C	176	
5th Train Soot Scrubber Bottoms Pump	1 + 1S	R	193	
5th Train Soot Scrubber Circulation Pump	1 + 1S	C	176	
Soot Water Pump	1 + 1S	C	272	
Soot Water Tank Pump	1 + 1S	C	77	
Filtrate Pump	1 + 1S	C	176	
First Filter Pump	1 + 1S	C	928	
Sump Pump	1 + 1S	C	39	
WWS Feed Pump	1 + 1S	C	83	
1st Train Filtered Feed Pump	1 + 1S	Special	134	
1st Train Filter Cloth Washing Pump	1 + 1S	C	173	
1st Train Pressure Water Pump	1 + 1S	C	36	
2nd Train Filtered Feed Pump	1 + 1S	Special	134	
2nd Train Filter Cloth Washing Pump	1 + 1S	C	173	
2nd Train Pressure Water Pump	1 + 1S	C	36	
3rd Train Filtered Feed Pump	1 + 1S	Special	134	
3rd Train Filter Cloth Washing Pump	1 + 1S	C	173	
3rd Train Pressure Water Pump	1 + 1S	C	36	
4th Train Filtered Feed Pump	1 + 1S	Special	134	
4th Train Filter Cloth Washing Pump	1 + 1S	C	173	
4th Train Pressure Water Pump	1 + 1S	C	36	
5th Train Filtered Feed Pump	1 + 1S	Special	134	
5th Train Filter Cloth Washing Pump	1 + 1S	C	173	
5th Train Pressure Water Pump	1 + 1S	C	36	
Waste Water Pump	1 + 1S	C	109	
Stripper Circulation Pump	1 + 1S	C	303	

Filter

Service	No. req'd	Type	Capacity (m3/hr)	Note
1st Train Quench Water Filter	1	Basket	38	
2nd Train Quench Water Filter	1	Basket	38	
3rd Train Quench Water Filter	1	Basket	38	

Gasification Unit

116 ton/h

4th Train Quench Water Filter	1	Basket	38	
5th Train Quench Water Filter	1	Basket	38	
1st Train Filter Press	1		62	
2nd Train Filter Press	1		62	
3rd Train Filter Press	1		62	
4th Train Filter Press	1		62	
5th Train Filter Press	1		62	

Gasification Unit

116 ton/h

Fan

Service	No. req'd	Type	Capacity (Kg/hr)	Note
1st Train Filter Exhaust Fan	1		124,500	
2nd Train Filter Exhaust Fan	1		124,500	
3rd Train Filter Exhaust Fan	1		124,500	
4th Train Filter Exhaust Fan	1		124,500	
5th Train Filter Exhaust Fan	1		124,500	

Reactor

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
1st Train Gasification Reactor	1	2,700	14,600	
2nd Train Gasification Reactor	1	2,700	14,600	
3rd Train Gasification Reactor	1	2,700	14,600	
4th Train Gasification Reactor	1	2,700	14,600	
5th Train Gasification Reactor	1	2,700	14,600	

Tank

Service	No. req'd	Diameter (mm)	Height (mm)	Note
Soot Water Tank	1	29,400	21,500	

Vessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Burner Cooling Water Vessel	1	2,200	5,300	
1st Train Soot Quench Vessel	1	900	7,200	
1st Train Soot Separator	1	1,600	7,800	
1st Train Oxygen Preheater Condensate Vessel	1	650	1,900	
2nd Train Soot Quench Vessel	1	900	7,200	
2nd Train Soot Separator	1	1,600	7,800	
2nd Train Oxygen Preheater Condensate Vessel	1	650	1,900	
3rd Train Soot Quench Vessel	1	900	7,200	
3rd Train Soot Separator	1	1,600	7,800	
3rd Train Oxygen Preheater Condensate Vessel	1	650	1,900	
4th Train Soot Quench Vessel	1	900	7,200	
4th Train Soot Separator	1	1,600	7,800	
4th Train Oxygen Preheater Condensate Vessel	1	650	1,900	
5th Train Soot Quench Vessel	1	900	7,200	
5th Train Soot Separator	1	1,600	7,800	
5th Train Oxygen Preheater Condensate Vessel	1	650	1,900	
Soot Water Flash Vessel	1	6,500	11,200	
Filtrate Collecting Vessel	1	6,300	12,300	
Filtrate Feed Vessel	1	6,300	12,300	
Nitrogen Buffer Vessel	1	2,500	6,000	

Gasification Unit

116 ton/h

Water Heat-up Vessel	1	2,000	5,300	
1st Train Pressure Water Vessel	1	2,050	4,000	
2nd Train Pressure Water Vessel	1	2,050	4,000	
3rd Train Pressure Water Vessel	1	2,050	4,000	
4th Train Pressure Water Vessel	1	2,050	4,000	
5th Train Pressure Water Vessel	1	2,050	4,000	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: SDA Case
Major Equipment List

Gasification Unit

116 ton/h

Misc.

Service	No. req'd	Diameter (mm)	Length (mm)	Capacity (mt/hr)	Note
Desuperheater	1			90.0	
Oxygen Silencer	1				
Butane Vaporizer Unit	1				
Gasification Reactor Burner	1				
1st Train Auxiliary Burner	1				
1st Train Startup Silencer	1			66.2	
1st Train Heat-up Stack	1	570	30,000		
1st Train Gasification Reactor Burner	1				
2nd Train Auxiliary Burner	1				
2nd Train Startup Silencer	1			66.2	
2nd Train Heat-up Stack	1	570	30,000		
2nd Train Gasification Reactor Burner	1				
3rd Train Auxiliary Burner	1				
3rd Train Startup Silencer	1			66.2	
3rd Train Heat-up Stack	1	570	30,000		
3rd Train Gasification Reactor Burner	1				
4th Train Auxiliary Burner	1				
4th Train Startup Silencer	1			66.2	
4th Train Heat-up Stack	1	570	30,000		
4th Train Gasification Reactor Burner	1				
5th Train Auxiliary Burner	1				
5th Train Startup Silencer	1			66.2	
5th Train Heat-up Stack	1	570	30,000		
5th Train Gasification Reactor Burner	1				
Soot Water Slops Pit	1				
1st Train Cake Trough	1			98 m3	
1st Train Cake Trough	1			98 m3	
1st Train Cake Trough	1			98 m3	
1st Train Cake Trough	1			98 m3	
1st Train Cake Trough	1			98 m3	

Conveyor

Service	No. req'd	Type	Capacity (Kg/hr)	Note
Cake Trough Conveyor 1	1		25,300	
Cake Trough Conveyor 1	1		25,300	
Cake Trough Conveyor 1	1		25,300	
Cake Trough Conveyor 1	1		25,300	
Cake Trough Conveyor 1	1		25,300	
Cake Trough Conveyor 1	1		25,300	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: SDA Case
Major Equipment List

Hydrogen Production Unit (Sour-Shift And Methanation Section)

127 mmscfd

Column

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Saturator	1			
Desaturator	1			

Heat Exchanger/AFC — AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Duty (MW)	Note
Shift Feed/Effluent Exchanger 1	1	ST	4.8	
Shift Effluent Cooler 1	1	ST	28.0	
Shift Effluent Cooler 2	1	ST	5.7	
Shift Feed/Effluent Exchanger 2	1	ST	9.4	
Converted Gas Exchanger	1	ST	3.5	
Converted Gas Cooler	1	ST	24.2	
Converted Gas Trim Cooler	1	ST	5.3	
Methanation Feed/Effluent Exchanger	1	ST	4.1	
LP Boiler	1	ST	12.2	

Pump — C: Cenrigugal, S: Sump

Service	No. req'd	Type	Capacity (m3/hr)	Note
Condensate Pump	1 + 1S	S	23	
Water Circulation Pump	1 + 1S	C	260	
Desaturator Reflux Pump	1 + 1S	C		

Reactor/ Vessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note (Cat. Vol, m3)
1st Stage Sour Shift Converter	1	3,100	7,000	56
2nd Stage Sour Shift Converter	1	3,700	7,300	80
3rd Stage Sour Shift Converter	1	4,800	9,000	168
Sulfur Guard	1	4,800	3,900	92
Methanator	1	2,600	2,400	25
Process Gas Separator	1			

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: SDA Case
Major Equipment List

Hydrogen Production Unit (Acid Gas Removal Section)

127 mmscfd

Column

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
H2S Absorber	1	4,000	45,700	
H2S Concentrator	1	2,800	22,600	
CO2 Absorber	1	2,800	51,700	
H2S Stripper	1	3,700	41,500	

Heat Exchanger/AFC

AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Total Duty (MW)	Note
Lean/Rich Exchanger	1	ST	59.9	
Feed/Product Exchanger	1	ST	1.5	
Stripper Reboiler	1	ST	36.5	
H2S Flash Gas Cooler	1	AC	0.5	
H2S Recycle Gas Cooler	1	AC	4.1	
H2S Recycle Gas Compressor Cooler	1	AC	1.1	
Lean Solvent Cooler	1	AC	11.4	
Reflux Condenser	1	AC	8.3	
HIDE	1		0.1	
Lean Solvent Chiller	1	AC	14.5	
Semi-Lean Solvent Chiller	1	AC	2.4	

Compressor/Pump

C: Cenrigugal, R: Reciprocating

Service	No. req'd	Type	Capacity (m3/hr)	Note
CO2 Removal Compressor	1	C	3,700 Nm3/Hr	
H2S Flash Gas Compressor	1	C	4,500 Nm3/Hr	
Flash Stripped Gas Compressor	1	C	45,000 Nm3/Hr	
CO2 Vacuum Compressor	1	C	5,200 Nm3/Hr	
LP Lean Solvent Pump	1 + 1S	C	535	
HP Lean Solvent Pump	1 + 1S	C	470	
Reflux Pump	1 + 1S	C	9	
Semi-Lean Solvent Pump	1 + 1S	C	1,076	
Loading Solvent Pump	1 + 1S	C	544	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: SDA Case
Major Equipment List

Hydrogen Production Unit (Acid Gas Removal Section)

Vessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
CO2 Recycle Flash Drum	1	4,000	9,900	
CO2 LP Flash Drum	1	4,900	12,200	
CO2 Vacuum Flash Drum	1	4,400	11,200	
H2S Flash Drum	1	4,300	10,500	
Reflux Drum	1	1,300	3,800	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: SDA Case
Major Equipment List

Amine Regeneration Unit

485 ton/SD SRU Equivalent

Column

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Amine Regenerator	1	4,600	23,100	

Heat Exchanger/AFC

AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Surface Area (m2/shell)	Note
Amine Regenerator Reboiler	1	ST		
Amine Regenerator Overhead Condenser	1	AC		
Lean/Rich Amine Exchanger	2	ST		
Lea\n Amine Cooler	1	AC		
Lea\n Amine Trim Cooler	1	AC		

Pump

C: Cenrigugal, S: Sump

Service	No. req'd	Type	Capacity (m3/hr)	Note
Amine Regenerator Reflux Pump	1 + 1S	C	25	
Lean Amine Circulation Pump	1 + 1S	C	272	
Amine Sump Pump	1	S	29	
Rich Amine Flash Drum Light Slops Pump	1	C	2	
Amine Booster Pump	1 + 1S	C	41	
Flare K.O. Drum Pump	1	C	270	

Tank

Service	No. req'd	Type	Diameter (mm)	Height (mm)	Capacity (m3)	Note
Amine Storage Tank No.1	1	DOME	12,500	9,000	1,120	
Amine Storage Tank No.2	1	DOME	12,500	9,000	1,120	

Vessel

Service	No. req'd	Type	Diameter (mm)	Length (mm) TL-TL	Note
Rich Amine Flash Drum	1		5,600	15,200	
Amine Regenerator Reflux Drum	1		1,600	3,200	
Regenerator Condensate Pot	1		1,000	1,400	
Reboiler Steam Condensate Pot	1		800	1,400	
Flare K.O. Drum	1		4,700	12,900	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: SDA Case
Major Equipment List

Sulfur Recovery Unit

485 ton/D

Heat Exchanmger/AFC AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Surface Area (m2/shell)	Note
1st Sulfur Condenser	1	ST		
2nd Sulfur Condenser	1	ST		
3rd Sulfur Condenser	1	ST		
4th Sulfur Condenser	1	ST		
5th Sulfur Condenser	1	ST		
1st Sulfur Reheater	1	ST		
2nd Sulfur Reheater	1	ST		
3rd Sulfur Reheater	1	ST		
4th Sulfur Reheater	1	ST		
Steam Condenser	1	AC		
Waste Heat Boiler	1	ST		

Burner

Service	No. req'd	Type	Note
Main Burner	1		
Incinerator Burner	1		

Blower/Pump C: Cenrigugal, S: Sump

Service	No. req'd	Type	Capacity (m3/hr)	Note
Main Air Blower	1 + 1S	C		
Incinerator Air Blower	1 + 1S	C		
Sulfur Pump	1 + 1S	S		

Reactor/Pit

Service	No. req'd	Type	Diameter (mm)	Length (mm) TL-TL	Note
1st Reactor	1		3,500	4,200	
2nd Reactor	1		3,500	4,600	
3rd Reactor	1		3,500	4,600	
Super-Claus Reactor	1		3,500	6,300	
Sulfur Pit	1	UG/PIT		3,200	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: SDA Case
Major Equipment List

Sulfur Recovery Unit

485 ton/D

Vessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Amine Acid Gas K.O. Drum	1	1,400	3,500	
SWS Gas K.O. Drum	1	1,400	3,500	
Sulfur Coalescer	1	1,800	2,000	
Steam/Water Separator	1			

Auxiliary

Service	No. req'd	Type	Note
Combustion Chamber	1	H	
Thermal Incinerator	1	H	
Stack	1	-	
Sulfur Lock	6		
Sulfur Solidification System	1		

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: SDA Case
Major Equipment List

Sour Watre Stripper Unit

61 ton/h

Column

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Sour Water Stripper Column	1	1,400	34,350	

Heat Exchanger/AFC

AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Surface Area (m2/shell)	Note
Sour Water Stripper Reboiler	1	ST		
Feed/Bottoms Exchanger	1	ST		
Stripped Water Pump	1	AC		
Sour Water Pumparound Cooler	1	AC		

Pump

C: Cenrigugal, R: Reciprocating

Service	No. req'd	Type	Capacity (m3/hr)	Note
Degasser Bottoms Pump	1 + !S	C	49	
SWS Feed Pump	2	C	50	
SWS Bottoms Pump	2	C	53	
Sour Water Pumparound Pump	2	C	112	

Tank

Service	No. req'd	Type	Diameter (mm)	Height (mm)	Capacity (m3)
Sour Water Feed Tank	1	DOME	14,500	18,300	3,010

Vessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Feed Degasser	1	3,800	9,400	

Appendix 3.5-2

Major Equipment List for Eureka Case

1 Vacuum Distillation Unit (VDU)

2 Eureka Unit

3 VGO/Eureka Cracked Oil HDS (HDS)

4 VGO Fluid Catalytic Cracking Unit (VGOFCC)

5 Catalytic Cracker Gasoline Hydrotreating Unit (CCGHT)

6 Unsaturated LPG Hydrogenation Unit (LPGHG)

7 Gasification Unit

8 Hydrogen Production Unit (HPU)

8.1 Sour Shift and Methanation Section
8.2 Acid Gas Removal Section

9 Amine Regeneration Unit

10 Sulfur Recovery Unit

11 Sour Water Stripping Unit

Abbreviation :

H	Horizontal
1S	One Spare
UG	underground

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: Eureka Case
Major Equipment List

Vacuum Distillation Unit (VDU)

36,500 BPSD

Column

Service	No. req'd	Diameter (mm) Top /Mid/Btm	Length (mm) TL-TL Top/Bottom	Note
Vacuum Distillation Column	1	4,600/7,000 4,700	45,000	

Heat Exchanger/AFC

AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Total Duty (MW)	Note
Feed/1st Vacuum Residue Exchanger	2	ST	6.6	
Feed/2nd Vacuum Residue Exchanger	5	ST	11.8	
Feed/Vacuum BPA Exchanger	3	ST	14.1	
Feed/1st HVGO Product Exchanger	1	ST	2.4	
Feed/2nd HVGO Product Exchanger	1	ST	2.3	
Feed/3rd HVGO Product Exchanger	1	ST	2.1	
Feed/1st Vacuum MPA Exchanger	2	ST	0.9	
Feed/2ndVacuum MPA Exchanger	1	ST	1.4	
Ejector Condenser	4	ST	-	By Vendor
TPA Cooler	1	AC	3.7	IDF
MVGO Rundown Cooler	1	AC	3.1	IDF
HVGO Rundown Cooler	1	AC	1.6	IDF
XHVGO Rundown Cooler	1	AC	1.0	IDF

Furnace

Service	No. req'd	Type	Absorb. Duty (MW)	Note
Feed Preheater	1	BOX	19.6	

Pump

C: Cenrigugal, R: Reciprocating

Service	No. req'd	Type	Capacity (m3/hr)	Note
Vacuum Charge Pump	1 + 1S	C	277	
TPA/LVGO Pump	1 + 1S	C	20	
MPA/MVGO Pump	1 + 1S	C	165	
BPA/HVGO Pump	1 + 1S	C	636	
Recycle/XHVGO Pump	1 + 1S	C	25	
Vacuum Residue Pump	1 + 1S	C	210	
HC Condensate Pump	1 + 1S	C	1.5	
Overhead Water Pump	1 + 1S	C	23	

Vessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
VDU Overhead Accumulator	1	1,300	6,000	
Sour Gas K.O. Drum	1	350	1,300	

Auxiliary Equipment

Service	No. req'd	Type	Note
Ejector System	1		

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: Eureka Case
Major Equipment List

Eureka Unit

49.4 Kbpsd

Column

Service	No. req'd	Diameter (mm) Top /Bottom	Length (mm) TL-TL Top/Bottom	Note
Main Fractionator	1	7.000/8,800	14,150/14,000	
Side Stripper	1	1,100	5,300	
Naphtha Absorber	1	1,200/3,000	1,400/4,600	
CLO Stabilizer	1	1,300/1,900	12,150/2,650	
Stripper	1	1,700	21,030	
Absorber	1	1,500	22,160	
Stabilizer	1	1,900	21,630	

Heat Exchanger/AFC

AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Surface Area (m2/shell)	Note
Main Fractionator O/H Condenser	1	AC		8 Bay/Induced
Main Fractionator Trim Condenser	2	ST	1,033	
CHO Waste Heat Boiler	3	ST	1,452	
CHO No.1Cooler	3	ST	228	
CHO No.2 Cooler	3	ST	189	
Feed Preheater Recycle Cooler	1	ST	711	
CGC Aftercooler	1	ST	117	
CLO Stabilizer Feed Heater	2	ST	67	
CLO Stabilizer Condenser	1	ST	95	
CLO Stabilizer Reboiler	1	ST	363	
CLO Cooler	1	ST	164	
Stripper Reboiler	1	ST	5.3 MW	
Stabilizer Reboiler	1	ST	4.4 MW	

Furnace

Service	No. req'd	Type	Heat Duty (MW)	Note
Feed Preheater	1	BOX	25.8	
Cracking Heater	3	BOX	11.4	
Steam Superheater	1	BOX	23.1	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: Eureka Case
Major Equipment List

Eureka Unit

49.4 Kbpsd

Compressor/Pump

C: Cenrigugal, R: Reciprocating

Service	No. req'd	Type	Capacity (m3/hr)	Note
Cracked Gas Compressor	1	C	5,500 Nm3/h	
Stabilizer Side draw Pitch Pump	5	R	16	Rotary
Stabilizer Bottom Pitch Pump	5	R	16	
Gasification Feedstock Circulation Pump	1 + 1S	C	151	
Gasification 1st Train Feedstock Pump	1 + 1S	R	27	
Gasification 2nd Train Feedstock Pump	1 + 1S	R	27	
Gasification 3rd Train Feedstock Pump	1 + 1S	R	27	
Gasification 4th Train Feedstock Pump	1 + 1S	R	27	
Gasification 5th Train Feedstock Pump	1 + 1S	R	27	

Reactor/Vessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
No.1 Eureka Reactor	2	5,500	9,000	
No.2 Eureka Reactor	2	5,500	9,000	
No.3 Eureka Reactor	2	5,500	9,000	
No.4 Eureka Reactor	2	5,500	9,000	
No.5 Eureka Reactor	2	5,500	9,000	
No.1 Pitch Stabilizer	1	5,500	4,000	
No.2 Pitch Stabilizer	1	5,500	4,000	
No.3 Pitch Stabilizer	1	5,500	4,000	
No.4 Pitch Stabilizer	1	5,500	4,000	
No.5 Pitch Stabilizer	1	5,500	4,000	
Main Fractionator O/H Separator	1	1,800	3,700	
Main Fractionator Reflux Drum	1	4,300	15,900	
Steam Drum	1	2,200	7,300	
CLO Stabilizer Reflux Drum	1	1,200	2,400	
Gasification Feedstock Buffer Vessel	1	4,000	8,300	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: Eureka Case
Major Equipment List

Eureka Unit

49.4 Kbpsd

Auxiliary Equipment

Service	No. req'd	Type	Note
No.1 Reactor Agitator	2		
No.2 Reactor Agitator	2		
No.3 Reactor Agitator	2		
No.4 Reactor Agitator	2		
No.5 Reactor Agitator	2		
No.1 Pitch Stabilizer Agitator	1		
No.2 Pitch Stabilizer Agitator	1		
No.3 Pitch Stabilizer Agitator	1		
No.4 Pitch Stabilizer Agitator	1		
No.5 Pitch Stabilizer Agitator	1		
No.1 Reactor AJEC	2		
No.2 Reactor AJEC	2		
No.3 Reactor AJEC	2		
No.4 Reactor AJEC	2		
No.5 Reactor AJEC	2		
No.1 Pitch Stabilizer Coke Crasher	1		
No.2 Pitch Stabilizer Coke Crasher	1		
No.3 Pitch Stabilizer Coke Crasher	1		
No.4 Pitch Stabilizer Coke Crasher	1		
No.5 Pitch Stabilizer Coke Crasher	1		

Filter

Service	No. req'd	Type	Capacity (m3/hr)	Note
Gasification Feedstock Filter	1	Basket	91	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: Eureka Case
Major Equipment List

HDS Unit

63.3 KBPSD

Column

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
H2S Absorber	1	2,700	17,460	
Product Stripper	1	2,500	25,760	
Product Fractionator	1	7,000	46,815	
Kerosene Stripper	1	2,300	15,700	
Diesel Stripper	1	3,600	15,400	
Heavy Diesel Stripper	1	1,400	9,100	

Heat Exchanger/AFC

AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Surface Area (m2/shell)	Note
Reactor Feed/Effluent Exchanger No.1	2	ST	678	
Reactor Feed/Effluent Exchanger No.1	2	ST	705	
Reactor Effluent/Stripper Bottoms Exchanger	4	ST	2,315	
HHPS Vapor Air Cooler	4	AC	1,292	
Product Stripper Overhead Condenser	1	AC	267	
Naphtha Recovery Air Cooler	1	AC	174	
Product Fractionator Overhead Condenser	3	AC	2,956	
Heavy Premium Diesel Pumparound MP Steam Generator	1	ST	221	
Diesel Pumparound Air Cooler	1	AC	146	
Kerosene Stripper Reboiler	1	ST	165	
Diesel Stripper Reboiler	2	ST	931	
Kerosene Air Cooler	1	AC	159	
Diesel Air Cooler	1	AC	706	
Heavy Diesel Air Cooler	1	AC	251	
Fractionator Bottoms/Feed Exchanger	1	ST	768	
Fractionator ottoms/Feed Exchanger	1	ST	375	
DIENE SAT Feed/Effluent Exchanger	1	ST	1,687	

Furnace

Service	No. req'd	Type	Heat Duty (MW)	Note
Reactor Feed Furnace	2	BOX	5.7	
Product Fractionator Feed Furnace	1	BOX	28.9	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: Eureka Case
Major Equipment List

HDS Unit

63.3 KBPSD

Compressor/Pump

C: Cenrigugal, R: Reciprocating

Service	No. req'd	Type	Capacity (m3/hr)	Note
Recycle Gas Compressor	1	C	5,400 Nm3/h	
HP Hydrogen Compressor	3	R	76,000 Nm3/h	
Reactor Charge Pump	2	C	282	
2nd Stage Feed Pump	2	C	251	
Product Stripper Bottoms Pump	2	C	555	
Product Stripper Bottoms Pump	2	C	90	
Product Fractionator Bottoms Pump	2	C	644	
Fractionator Reflux Pump	2	C	741	
Heavy Premium Diesel Pumparound Pump	2	C	750	
Kerosene Stripper Bottoms Pump	2	C	68	
Diesel Stripper Bottoms Pump	2	C	611	
Heavy Diesel Stripper Bottoms Pump	2	C	126	

Reactor/Vessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
No.1 Reactor	1	2,700	8,300	D.P.=90 barg
No.2 Reactor	1	3,400	20,000	D.P.=90 barg
1st Stage Reactor	1	3,400	20,000	
2nd Stage Reactor	1	3,400	20,000	
Filtered Feed Surge Drum	1	4,300	14,300	
Hot High Pressure Separator	1	2,500	6,900	
Cold High Pressure Separator	1	2,400	4,000	
Cold Low Pressure Separator	1	1,500	5,300	
Product Stripper Reflux Drum	1	2,700	4,900	
Product Fractionator Reflux Drum	1	3,800	7,900	

MISC.

Service	No. req'd	Type	Note
Feed Filter System	1		

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: Eureka Case
Major Equipment List

VGO Fluid Catalitic Cracking Unit (VGOFCC) 42.4 Kbpsd

Column

Service	No. req'd	Diameter (mm) Top /Bottom	Length (mm) TL-TL Top/Bottom	Note
Main Fractionator	1	6,100/6,100	22,000/21,000	
Light Cycle Oil Stripper	1	800	8,000	
Primary Absorber	1	1,800	30,000	
Sponge Absorber	1	700	16,000	
Stripper	1	2,700	29,000	
Debutanizer	1	3,600/4,400	13,000/18,000	
Amine HP Absorber	1	1,150	21,700	
Amine LPG Absorber	1	1,850	19,800	
Amine Stripper	1	850/1,350	22,400	

Heat Exchanger/AFC AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Total Heat Duty (MW)	Note
Raw Oil/Circ. LCO Exchanger	1	ST	3.7	
Raw Oil/Fractionator Bottoms Product Exchanger	1	ST	1.8	
Raw Oil/Circ. HCO Exchanger	1	ST	7.9	
Raw Oil/Fractionator Bottoms Exchanger	1	ST	3.0	
Fractionator Bottoms Cooler	2	ST	1.3	
Fractionator Bottoms Steam Generator	2	ST	36.2	
LCO Product/BFW Exchanger	2	ST	3.1	
LCO Product Cooler	1	AC	2.0	
Fractionator Overhead Condenser	1	AC	34.1	
Fractionator Trim Condenser	1	ST	3.1	
Compressor Interstage Cooler	1	AC	3.2	
Compressor Interstage Trim Cooler	1	ST	1.2	
HP Condenser	1	AC	3.2	
HP Trim Condenser	1	ST	1.2	
Primary Absorber Lower Intercooler	1	ST	0.4	
Primary Absorber Upper Intercooler	1	ST	0.4	
Sponge Absorber Lean Oil/Rich Oil Exchanger	1	ST	1.3	
Sponge Absorber Lean Oil Cooler	1	ST	1.4	
Lean Gas Cooler	1	ST	0.5	
Stripper Feed Exchanger	1	ST	2.7	
Stripper Steam Generator	1	ST	4.6	
Debutanizer Overhead Condenser	1	AC	11.1	
Debutanizer Net Overhead Condenser	1	ST	0.3	

Heat Exchanger/AFC AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Total Heat Duty (MW)	Note
Debutanizer LCO Reboiler	1	ST	5.6	
Debutanizer HCO Reboiler	1	ST	5.6	
Stripper Reboiler Exchanger	1	ST	4.0	
Debutanizer Bottoms Product Cooler	1	AC	2.5	
Debutanizer Bottoms Trim Cooler	1	ST	0.5	
Amine Stripper Reboiler	1	ST	2.3	
Amine Stripper Condenser	1	AC	1.3	
Lean Amine Cooler No.1	1	ST	0.8	
Lean/Rich Amine Exchanger	3	ST	1.9	
Lean Amine Cooler No.2	1	ST	0.2	

Furnace

Service	No. req'd	Type	Absorb. Duty (MW)	Note
Direct Fired Air Heater	1	BOX	18.0	
Flue Gas Steam Generator (WHB)	1	Boiler	Steam 62 ton/h	Natural Circulation

Compressor/Blower/Pump C: Cenrigugal, R: Reciprocating

Service	No. req'd	Type	Capacity (m3/hr)	Note
(Compressor/Blower)				
Main Air Blower	1	C	156,000 Nm3/h	
Wet Gas Compressor	1	C	49,900 Nm3/h	
(Pump)				
Raw Oil Pump	1 + 1S	C	279	
Main fractionator Bottoms Circ. Pump	1 + 1S	C	474	
Main fractionator Bottoms Product Pump	1 + 1S	C	20	
HCO Circulation Pump	1 + 1S	C	739	
LCO Circulation Pump	1 + 1S	C	2,092	
LCO Product Pump	1 + 1S	C	79	
Heavy Naphtha Circulation Pump	1 + 1S	C	1,700	
Sour Water Pump	1 + 1S	C	38	
Main fractionator Reflux Pump	1 + 1S	C	164	
Main Hot Oil Pump	1 + 1S	C	102	
Flushing Oil Pump	1 + 1S	C	28	
Compressor Suction Drum Pump	1 + 1S	R	5	
Compressor Interstage Condensate Pump	1 + 1S	C	41	
Water Injection Pump	1 + 1S	C	12	
HP Receiver Pump	1 + 1S	C	300	
Primary Absorber Rich Oil Pump	1 + 1S	C	166	
Primary Absorber Lower Intercooler Pump	1 + 1S	C	148	
Primary Absorber Upper Intercooler Pump	1 + 1S	C	142	

Sponge Absorber Lean Oil Pump	1 + 1S	C	41	

Compressor/Blower/Pump C: Cenrigugal, R: Reciprocating

Service	No. req'd	Type	Capacity (m3/hr)	Note
Debutanizer Overhead Pump	1 + 1S	C	270	
Debutanizer Bottoms Recycle Pump	1 + 1S	C	51	
Lean Amine Pump	1 + 1S	C	37	
Amine Stripper Reflux Pump	1 + 1S	C	2	
Wash Water Circulation Pump	1 + 1S	C	4	
Water Injection Pump	1 + 1S	R	1	
Debutanizer Bottoms Recycle Pump	1	C	4	

Reactor/RegeneratorVessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
(Reactor)				
FCC Reactor:	1	6,800	14,200	
Disengaging System	1			
Cyclones	5	1,690		
Spent Catalyst Stripper	1	3,800	8,100	
Reactor Riser:				
External Upper Reactor Riser	1	1,500	18,400	
Internal Upper Reactor Riser	1	1,500	15,900	
Feed Injection Zone	1		3,000	
Lift Zone	1	1,140	3,100	
Catalyst Mix Chamber	1	2,600	2,600	
(Regenerator)				
Regenerator:	1	8,600/6,200	12,700	
Cyclones	7	1,280		
Regenerated Recirculation Standpipe	1	860		
Cooled Catalyst Standpipe	1	530		
Spent Catalyst Standpipe	1	720		
(Vessel)				
Fresh Catalyst Hopper	1	3,800	15,800	Vertical
Equillibrium Catalyst Hopper	1	5,300	15,800	Vertical
Low Metals Equillibrium Catalyst Hopper	1	3,800	15,800	Vertical
ZSM-5 Storage Hopper	1	1,950	5,900	Vertical
3rd Stage Separator	1	4,450	4,200	Vertical
Oriffice Chamber	1	2,450	9,800	Vertical
4th Stage Separator	1	2,350	3,300	Vertical
Break Vessel	1	2,500	3,300	Vertical
Recovered Catalyst Hopper	1	2,150	7,900	Vertical
Fuel Gas K.O. Drum	1	590	1,300	Vertical
Raw Oil feed Surge Drum	1	3,600	8,400	Hosizontal

Main Fractionator Receiver	1	3,500	7,900	Hosizontal
Steam Generator Separator A	1	600	1,100	Vertical

Reactor/RegeneratorVessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Steam Generator Separator B	1	600	1,100	Vertical
Flushing Oil Receiver	1	930	2,800	Vertical
Compressor Suction Drum	1	3,650	5,100	Vertical
Compressor Inter Stage Suction Drum	1	1,950	5,100	Vertical
High Pressure Receiver	1	3,450	9,200	Hosizontal
Lean Gas K.O. Drum	1	700	2,300	Vertical
Debutanizer Receiver	1	2,650	7,000	Hosizontal
LPG Coaleescer Pre-Filter	1			Filter Package
LPG Coaleescer	1	1,500/2,200	3,100	Vertical
Rich Amine Flash Drum	1	1,500	4,900	Hosizontal
Amine Stripper Reflux Drum	1	1,200	3,400	Vertical
Carbon Filter	1	1,000	4,100	Vertical
Product K.O. Drum	1	1,000	2,000	Vertical
Lean Amine Post-Filter	1			Filter Package
Lean Amine Pre-Filter	1			Filter Package
Amine Sump Drum	1	2,000	2,400	Vertical
Skimming Drum	1	800	1,800	Vertical
Amine Reboiler Condensate Pot	1	900	2,100	Vertical
Feed Gas K.O. Drum	1	1,100	2,200	Vertical
No.1 Anti-Foamer Drum	1	6 inch	300	Vertical
No.2 Anti-Foamer Drum	1	6 inch	300	Vertical

Packaged Equipment

Service	No. req'd	Type	Capacity	Note
Power Recovery Unit	1			

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: Eureka Case
Major Equipment List

FCC Gasoline Hydrotreating Unit (CCGHT) 29.2 Kbpsd

Heat Exchanger/AFC — AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Total Duty (MW)	Note
HDS Feed/Effluent Exchanger	5	ST	16.9	
Separator Post Condenser	1	ST	0.3	
Stabilizer Feed/Bottoms Exchanger	2	ST	4.3	
Stabilizer Reboiler	1	ST	3.4	
Stabilizer Condenser	1	ST	0.9	
HCCG product Cooler	1	ST	0.6	
SHU Feed/Bottoms Exchanger	1	ST	2.9	
SHU Feed/Effluent Exchanger	1	ST	4.0	
SHU Preheater	1	ST	3.7	
Splitter Reboiler	1	ST	12.9	
Splitter Post Condenser	1	ST	0.3	
LCCG Product Trim Cooler	1	ST	0.3	
Splitter Condenser	1	AC	13.5	
LCCG Product Air Cooler	1	AC	1.7	
Reactor Effluent Cooler	1	AC	10.9	
HCCG Product Air Cooler	1	AC	2.6	

Furnace

Service	No. req'd	Type	Absorb. Duty (MW)	Note
Hot Oil Furnace	1	CYL	3.2	

Compressor/Pump — C: Cenrigugal, R: Reciprocating

Service	No. req'd	Type	Capacity (m3/hr)	Note
Recycle Gas Compressor	1 + 1S	R	50.000 Nm3/h	
HDS Feed Pump	1 + 1S	C	150	
Quench Pump	1 + 1S	C	14	
Stabilizer Reflux Pump	1 + 1S	C	17	
HCCG Storage Pump	1 + 1S	C	140	
SHU Feed Pump	1 + 1S	C	250	
Splitter Reflux Pump	1 + 1S	C	190	

Reactor/Vessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
SHU Reactor	1	2,100	16,700	
1st HDS Reactor	1	2,700	8,500	
2nd HDS Reactor	1	2,900	5,000	

Separator Drum	1	2,300	6,800	
Stabilizer Reflux Drum	1	1300	3,700	
Compressor K.O. Drum	1	1,100	2,900	
Surge Drum	1	3,000	9,000	
Splitter Reflux Drum	1	2,000	6,400	

Column

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Gasoline Splitter	1	2,600	32,000	
Amine Scrubber	1	1,200	16,000	
Stabilizer	1	1,900	18,000	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: Eureka Case
Major Equipment List

LPG Hydrogenation Unit (LPG HG)

1,230 mt/d

Heat Exchanger/AFC

AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Total Duty (MW)	Note
Selective Hydrogenation Startup Heater	1	ST	3.1	
Hydrogenation Feed/Effluent Exchanger	2	ST	4.1	
Feed/Effluent Exchanger	3	ST	7.6	
Deethanizer Condenser	1	ST	4.4	
Deethanizer Reboiler	1	ST	0.7	
Deethanizer Bootoms Cooler	1	ST	4.3	

Furnace

Service	No. req'd	Type	Absorb. Duty (MW)	Note
Feed Startup Furnace	1	CYL	2.0	

Compressor/Pump

C: Cenrigugal, R: Reciprocating

(*1) 1S = One standby unit

Service	No. req'd (*1)	Type	Capacity (m3/hr)	Note
Makeup Gas Compressor	1 + 1S	R	690	
LPG Feed Pump	1 + 1S	C	110	
Deethanizer Reflux Pump	1 + 1S	C	47	

Reactor/Vessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Selective Hydrogenation Reactor	1	1,400	16,700	
Hydrogenation Reactor	1	2,400	13,500	
Steam Drum	1	2,400	3,600	
Deethanizer Reflux Drum	1	3,700	5,100	
Feed Surge Drum	1	2,600	8,700	

Column

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Deethanizer	1	2,100	21,800	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: Eureka Case
Major Equipment List

Gasification Unit

98 ton/h

Column

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Soot Scrubber	1	2,100/2,100	7400/11,400	
Waste Water Stripper	1	2,000/1,700	8900/23,700	

Heat Exchanger/AFC

AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Total Duty (MW)	Note
1st Train Oxygen Preheater	1	ST	55 m2	
1st Train Syngas Effluent Cooler	1	ST	31.7	Vertical
1st Train Economizer	1	ST	6.5	Vertical
2nd Train Soot Scrubber Air Cooler	1	AC	4.5	
2nd Train Oxygen Preheater	1	ST	55 m2	
2nd Train Syngas Effluent Cooler	1	ST	31.7	Vertical
2nd Train Economizer	1	ST	6.5	Vertical
3rd Train Soot Scrubber Air Cooler	1	AC	4.5	
3rd Train Oxygen Preheater	1	ST	55 m2	
3rd Train Syngas Effluent Cooler	1	ST	31.7	Vertical
3rd Train Economizer	1	ST	6.5	Vertical
3rd Train Soot Scrubber Air Cooler	1	AC	4.5	
4th Train Oxygen Preheater	1	ST	55 m2	
4th Train Syngas Effluent Cooler	1	ST	31.7	Vertical
4th Train Economizer	1	ST	6.5	Vertical
4th Train Soot Scrubber Air Cooler	1	AC	4.5	
5th Train Oxygen Preheater	1	ST	55 m2	
5th Train Syngas Effluent Cooler	1	ST	31.7	Vertical
5th Train Economizer	1	ST	6.5	Vertical
5th Train Soot Scrubber Air Cooler	1	AC	4.5	
Soot Water Cooler	2	AC	4.8	
Feed/Effluent Exchanger	1		0.9	Plate HE
Stripper Circulation Cooler	1	AC	4.6	
Waste Water Air Cooler	1	AC	5.8	

Gasification Unit

98 ton/h

Ejector

Service	No. req'd	Type	Note
1st Train Stack Ejector	1		
2nd Train Stack Ejector	1		
3rd Train Stack Ejector	1		
4th Train Stack Ejector	1		
5th Train Stack Ejector	1		
Filter Press Ejector	1		

Mixer

Service	No. req'd	Type	Note
1st Train Oxygen/Steam Mixer	1		
2nd Train Oxygen/Steam Mixer	1		
3rd Train Oxygen/Steam Mixer	1		
4th Train Oxygen/Steam Mixer	1		
5th Train Oxygen/Steam Mixer	1		

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: Eureka Case
Major Equipment List

Gasification Unit

98 ton/h

Pump

C: Cenrigugal, R: Reciprocating

Service	No. req'd	Type	Capacity (m3/hr)	Note
Burner Cooling Water Pump	1 + 1S	C	102	
1st Train Soot Scrubber Bottoms Pump	1 + 1S	R	163	
1st Train Soot Scrubber Circulation Pump	1 + 1S	C	149	
2nd Train Soot Scrubber Bottoms Pump	1 + 1S	R	163	
2nd Train Soot Scrubber Circulation Pump	1 + 1S	C	149	
3rd Train Soot Scrubber Bottoms Pump	1 + 1S	R	163	
3rd Train Soot Scrubber Circulation Pump	1 + 1S	C	149	
4th Train Soot Scrubber Bottoms Pump	1 + 1S	R	163	
4th Train Soot Scrubber Circulation Pump	1 + 1S	C	149	
5th Train Soot Scrubber Bottoms Pump	1 + 1S	R	163	
5th Train Soot Scrubber Circulation Pump	1 + 1S	C	149	
Soot Water Pump	1 + 1S	C	230	
Soot Water Tank Pump	1 + 1S	C	65	
Filtrate Pump	1 + 1S	C	149	
First Filter Pump	1 + 1S	C	784	
Sump Pump	1 + 1S	C	33	
WWS Feed Pump	1 + 1S	C	70	
1st Train Filtered Feed Pump	1 + 1S	Special	113	
1st Train Filter Cloth Washing Pump	1 + 1S	C	146	
1st Train Pressure Water Pump	1 + 1S	C	30	
2nd Train Filtered Feed Pump	1 + 1S	Special	113	
2nd Train Filter Cloth Washing Pump	1 + 1S	C	146	
2nd Train Pressure Water Pump	1 + 1S	C	30	
3rd Train Filtered Feed Pump	1 + 1S	Special	113	
3rd Train Filter Cloth Washing Pump	1 + 1S	C	146	
3rd Train Pressure Water Pump	1 + 1S	C	30	
4th Train Filtered Feed Pump	1 + 1S	Special	113	
4th Train Filter Cloth Washing Pump	1 + 1S	C	146	
4th Train Pressure Water Pump	1 + 1S	C	30	
5th Train Filtered Feed Pump	1 + 1S	Special	113	
5th Train Filter Cloth Washing Pump	1 + 1S	C	146	
5th Train Pressure Water Pump	1 + 1S	C	30	
Waste Water Pump	1 + 1S	C	92	
Stripper Circulation Pump	1 + 1S	C	256	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: Eureka Case
Major Equipment List

Gasification Unit

98 ton/h

Filter

Service	No. req'd	Type	Capacity (m3/hr)	Note
1st Train Quench Water Filter	1	Basket	32	
2nd Train Quench Water Filter	1	Basket	32	
3rd Train Quench Water Filter	1	Basket	32	
4th Train Quench Water Filter	1	Basket	32	
5th Train Quench Water Filter	1	Basket	32	
1st Train Filter Press	1		52	
2nd Train Filter Press	1		52	
3rd Train Filter Press	1		52	
4th Train Filter Press	1		52	
5th Train Filter Press	1		52	

Fan

Service	No. req'd	Type	Capacity (Kg/hr)	Note
1st Train Filter Exhaust Fan	1		105,200	
2nd Train Filter Exhaust Fan	1		105,200	
3rd Train Filter Exhaust Fan	1		105,200	
4th Train Filter Exhaust Fan	1		105,200	
5th Train Filter Exhaust Fan	1		105,200	

Reactor

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
1st Train Gasification Reactor	1	2,400	14,600	
2nd Train Gasification Reactor	1	2,400	14,600	
3rd Train Gasification Reactor	1	2,400	14,600	
4th Train Gasification Reactor	1	2,400	14,600	
5th Train Gasification Reactor	1	2,400	14,600	

Tank

Service	No. req'd	Diameter (mm)	Height (mm)	Note
Soot Water Tank	1	26,200	21,500	

Gasification Unit

98 ton/h

Vessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Burner Cooling Water Vessel	1	2,000	4,900	
1st Train Soot Quench Vessel	1	800	6,700	
1st Train Soot Separator	1	1,500	7,200	
1st Train Oxygen Preheater Condensate Vessel	1	600	1,800	
2nd Train Soot Quench Vessel	1	800	6,700	
2nd Train Soot Separator	1	1,500	7,200	
2nd Train Oxygen Preheater Condensate Vessel	1	600	1,800	
3rd Train Soot Quench Vessel	1	800	6,700	
3rd Train Soot Separator	1	1,500	7,200	
3rd Train Oxygen Preheater Condensate Vessel	1	600	1,800	
4th Train Soot Quench Vessel	1	800	6,700	
4th Train Soot Separator	1	1,500	7,200	
4th Train Oxygen Preheater Condensate Vessel	1	600	1,800	
5th Train Soot Quench Vessel	1	800	6,700	
5th Train Soot Separator	1	1,500	7,200	
5th Train Oxygen Preheater Condensate Vessel	1	600	1,800	
Soot Water Flash Vessel	1	6,000	10,400	
Filtrate Collecting Vessel	1	5,800	11,400	
Filtrate Feed Vessel	1	5,800	11,400	
Nitrogen Buffer Vessel	1	2,300	5,600	
Water Heat-up Vessel	1	1,800	4,900	
1st Train Pressure Water Vessel	1	1,900	3,700	
2nd Train Pressure Water Vessel	1	1,900	3,700	
3rd Train Pressure Water Vessel	1	1,900	3,700	
4th Train Pressure Water Vessel	1	1,900	3,700	
5th Train Pressure Water Vessel	1	1,900	3,700	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: Eureka Case
Major Equipment List

Gasification Unit

98 ton/h

Misc.

Service	No. req'd	Diameter (mm)	Length (mm)	Capacity (mt/hr)	Note
Desuperheater	1			76.3	
Oxygen Silencer	1				
Butane Vaporizer Unit	1				
Gasification Reactor Burner	1				
1st Train Auxiliary Burner	1				
1st Train Startup Silencer	1			55.9	
1st Train Heat-up Stack	1	512	30,000		
1st Train Gasification Reactor Burner	1				
2nd Train Auxiliary Burner	1				
2nd Train Startup Silencer	1			55.9	
2nd Train Heat-up Stack	1	512	30,000		
2nd Train Gasification Reactor Burner	1				
3rd Train Auxiliary Burner	1				
3rd Train Startup Silencer	1			55.9	
3rd Train Heat-up Stack	1	512	30,000		
3rd Train Gasification Reactor Burner	1				
4th Train Auxiliary Burner	1				
4th Train Startup Silencer	1			55.9	
4th Train Heat-up Stack	1	512	30,000		
4th Train Gasification Reactor Burner	1				
5th Train Auxiliary Burner	1				
5th Train Startup Silencer	1			55.9	
5th Train Heat-up Stack	1	512	30,000		
5th Train Gasification Reactor Burner	1				
Soot Water Slops Pit	1				
1st Train Cake Trough	1			83 m3	
1st Train Cake Trough	1			83 m3	
1st Train Cake Trough	1			83 m3	
1st Train Cake Trough	1			83 m3	
1st Train Cake Trough	1			83 m3	

Conveyor

Service	No. req'd	Type	Capacity (Kg/hr)	Note
Cake Trough Conveyor 1	1		21,400	
Cake Trough Conveyor 1	1		21,400	
Cake Trough Conveyor 1	1		21,400	
Cake Trough Conveyor 1	1		21,400	
Cake Trough Conveyor 1	1		21,400	
Cake Trough Conveyor 1	1		21,400	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex

Vacuum Bottoms Conversion Option: Eureka Case

Major Equipment List

Hydrogen Production Unit (Sour-Shift And Methanation Section)

115 mmscfd

Column

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Saturator	1			
Desaturator	1			

Heat Exchanger/AFC — AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Duty (MW)	Note
Shift Feed/Effluent Exchanger 1	1	ST	2.5	
Shift Effluent Cooler 1	1	ST	14.6	
Shift Effluent Cooler 2	1	ST	3.0	
Shift Feed/Effluent Exchanger 2	1	ST	4.9	
Converted Gas Exchanger	1	ST	1.8	
Converted Gas Cooler	1	ST	12.6	
Converted Gas Trim Cooler	1	ST	2.8	
Methanation Feed/Effluent Exchanger	1	ST	2.1	
LP Boiler	1	ST	6.4	

Pump — C: Cenrigugal, S: Sump

Service	No. req'd	Type	Capacity (m3/hr)	Note
Condensate Pump	1 + 1S	S	12	
Water Circulation Pump	1 + 1S	C	136	
Desaturator Reflux Pump	1 + 1S	C		

Reactor/ Vessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note (Cat. Vol, m3)
1st Stage Sour Shift Converter	1	2,500	5,500	29
2nd Stage Sour Shift Converter	1	3,000	5,800	42
3rd Stage Sour Shift Converter	1	3,800	7,200	88
Sulfur Guard	1	3,800	3,100	48
Methanator	1	2,500	2,000	15
Process Gas Separator	1			

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: Eureka Case
Major Equipment List

Hydrogen Production Unit (Acid Gas Removal Section)

115 mmscfd

Column

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
H2S Absorber	1	2,700	45,700	
H2S Concentrator	1	1,900	22,600	
CO2 Absorber	1	1,900	51,700	
H2S Stripper	1	2,500	41,500	

Heat Exchanger/AFC

AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Total Duty (MW)	Note
Lean/Rich Exchanger	1	ST	31.2	
Feed/Product Exchanger	1	ST	0.8	
Stripper Reboiler	1	ST	19.0	
H2S Flash Gas Cooler	1	AC	0.2	
H2S Recycle Gas Cooler	1	AC	2.1	
H2S Recycle Gas Compressor Cooler	1	AC	0.6	
Lean Solvent Cooler	1	AC	6.0	
Reflux Condenser	1	AC	4.3	
HIDE	1		0.1	
Lean Solvent Chiller	1	AC	7.6	
Semi-Lean Solvent Chiller	1	AC	1.2	

Compressor/Pump

C: Cenrigugal, R: Reciprocating

Service	No. req'd	Type	Capacity (m3/hr)	Note
CO2 Removal Compressor	1	C	3,300 Nm3/Hr	
H2S Flash Gas Compressor	1	C	4,000 Nm3/Hr	
Flash Stripped Gas Compressor	1	C	40,000 Nm3/Hr	
CO2 Vacuum Compressor	1	C	4,600 Nm3/Hr	
LP Lean Solvent Pump	1 + 1S	C	472	
HP Lean Solvent Pump	1 + 1S	C	415	
Reflux Pump	1 + 1S	C	8	
Semi-Lean Solvent Pump	1 + 1S	C	950	
Loading Solvent Pump	1 + 1S	C	480	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: Eureka Case
Major Equipment List

Hydrogen Production Unit (Acid Gas Removal Section)

Vessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
CO2 Recycle Flash Drum	1	3,100	7,600	
CO2 LP Flash Drum	1	3,800	9,400	
CO2 Vacuum Flash Drum	1	3,500	8,600	
H2S Flash Drum	1	3,300	8,200	
Reflux Drum	1	1,000	2,500	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: Eureka Case
Major Equipment List

Amine Regeneration Unit

485 ton/SD SRU Equivalent

Column

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Amine Regenerator	1	4,600	23,100	

Heat Exchanger/AFC — AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Surface Area (m2/shell)	Note
Amine Regenerator Reboiler	1	ST		
Amine Regenerator Overhead Condenser	1	AC		
Lean/Rich Amine Exchanger	2	ST		
Lea\n Amine Cooler	1	AC		
Lea\n Amine Trim Cooler	1	AC		

Pump — C: Cenrigugal, S: Sump

Service	No. req'd	Type	Capacity (m3/hr)	Note
Amine Regenerator Reflux Pump	1 + 1S	C	25	
Lean Amine Circulation Pump	1 + 1S	C	272	
Amine Sump Pump	1	S	29	
Rich Amine Flash Drum Light Slops Pump	1	C	2	
Amine Booster Pump	1 + 1S	C	41	
Flare K.O. Drum Pump	1	C	270	

Tank

Service	No. req'd	Type	Diameter (mm)	Height (mm)	Capacity (m3)	Note
Amine Storage Tank No.1	1	DOME	12,500	9,000	1,120	
Amine Storage Tank No.2	1	DOME	12,500	9,000	1,120	

Vessel

Service	No. req'd	Type	Diameter (mm)	Length (mm) TL-TL	Note
Rich Amine Flash Drum	1		5,600	15,200	
Amine Regenerator Reflux Drum	1		1,600	3,200	
Regenerator Condensate Pot	1		1,000	1,400	
Reboiler Steam Condensate Pot	1		800	1,400	
Flare K.O. Drum	1		4,700	12,900	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: Eureka Case
Major Equipment List

Sulfur Recovery Unit

485 ton/D

Heat Exchanmger/AFC AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Surface Area (m2/shell)	Note
1st Sulfur Condenser	1	ST		
2nd Sulfur Condenser	1	ST		
3rd Sulfur Condenser	1	ST		
4th Sulfur Condenser	1	ST		
5th Sulfur Condenser	1	ST		
1st Sulfur Reheater	1	ST		
2nd Sulfur Reheater	1	ST		
3rd Sulfur Reheater	1	ST		
4th Sulfur Reheater	1	ST		
Steam Condenser	1	AC		
Waste Heat Boiler	1	ST		

Burner

Service	No. req'd	Type	Note
Main Burner	1		
Incinerator Burner	1		

Blower/Pump C: Cenrigugal, S: Sump

Service	No. req'd	Type	Capacity (m3/hr)	Note
Main Air Blower	1 + 1S	C		
Incinerator Air Blower	1 + 1S	C		
Sulfur Pump	1 + 1S	S		

Reactor/Pit

Service	No. req'd	Type	Diameter (mm)	Length (mm) TL-TL	Note
1st Reactor	1		3,500	4,200	
2nd Reactor	1		3,500	4,600	
3rd Reactor	1		3,500	4,600	
Super-Claus Reactor	1		3,500	6,300	
Sulfur Pit	1	UG/PIT		3,200	

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: Eureka Case
Major Equipment List

Sulfur Recovery Unit

485 ton/D

Vessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Amine Acid Gas K.O. Drum	1	1,400	3,500	
SWS Gas K.O. Drum	1	1,400	3,500	
Sulfur Coalescer	1	1,800	2,000	
Steam/Water Separator	1			

Auxiliary

Service	No. req'd	Type	Note
Combustion Chamber	1	H	
Thermal Incinerator	1	H	
Stack	1	-	
Sulfur Lock	6		
Sulfur Solidification System	1		

Project : Baiji Refinery Upgrading Project - Introduction of FCC Complex
Vacuum Bottoms Conversion Option: Eureka Case
Major Equipment List

Sour Watre Stripper Unit

146 ton/h

Column

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Sour Water Stripper Column	1	2,100	34,350	

Heat Exchanger/AFC

AC: Air Fin Cooler, ST:Shell & Tube

Service	No. req'd	Type	Surface Area (m2/shell)	Note
Sour Water Stripper Reboiler	1	ST		
Feed/Bottoms Exchanger	1	ST		
Stripped Water Pump	1	AC		
Sour Water Pumparound Cooler	1	AC		

Pump

C: Cenrigugal, R: Reciprocating

Service	No. req'd	Type	Capacity (m3/hr)	Note
Degasser Bottoms Pump	1 + 1S	C	117	
SWS Feed Pump	1 + 1S	C	118	
SWS Bottoms Pump	1 + 1S	C	125	
Sour Water Pumparound Pump	1 + 1S	C	266	

Tank

Service	No. req'd	Type	Diameter (mm)	Height (mm)	Capacity (m3)
Sour Water Feed Tank	1	DOME	22,400	18,300	7,200

Vessel

Service	No. req'd	Diameter (mm)	Length (mm) TL-TL	Note
Feed Degasser	1	5,050	12,500	