EARLY ENTRANCE COPRODUCTION PLANT

PHASE II

Task 4.0: DESIGN BASIS UPDATE

Reporting Period: January 2001 – May 2003

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Disclaimer

Abstract

The 1999 U. S. Department of Energy (DOE) award to Texaco Energy Systems Inc. (presently Texaco Energy Systems LLC, a subsidiary of ChevronTexaco) was made to provide a Preliminary Engineering Design of an Early Entrance Coproduction Plant (EECP). Since the award presentation, work has been undertaken to achieve an economical concept design that makes strides toward the DOE Vision 21 goal. The objective of the EECP is to convert coal and/or petroleum coke to electric power plus transportation fuels, chemicals and useful utilities such as steam. The use of petroleum coke was added as a fuel to reduce the cost of feedstock and also to increase the probability of commercial implementation of the EECP concept. This objective has been pursued in a three phase effort through the partnership of the DOE with prime contractor Texaco Energy Systems LLC and subcontractors General Electric (GE), Praxair, and Kellogg Brown and Root (KBR). ChevronTexaco is providing gasification technology and Rentech's Fischer-Tropsch technology that has been developed for non-natural gas feed sources. GE is providing gas turbine technology for the combustion of low energy content gas. Praxair is providing air separation technology, and KBR is providing engineering to integrate the facility.

The objective of Phase I was to determine the feasibility and define the concept for the EECP located at a specific site; develop a Research, Development, and Testing (RD&T) Plan to mitigate technical risks and barriers; and prepare a Preliminary Project Financing Plan. The objective of Phase II is to implement the work as outlined in the Phase I RD&T Plan to enhance the development and commercial acceptance of coproduction technology. The objective of Phase III is to develop an engineering design package and a financing and testing plan for an EECP located at a specific site.

Phase I Preliminary Concept Report was completed in 2000. The Phase I Preliminary Concept Report was prepared based on making assumptions for the basis of design for various technologies that are part of the EECP concept. The Phase I Preliminary Concept Report was approved by the DOE in May 2001. The Phase I work identified technical and economic risks and critical research, development, and testing that would improve the probability of the technical and economic success of the EECP. The Project Management Plan (Task 1) for Phase II was approved by the DOE in 2001. The results of RD&T efforts for Phase II are expected to improve the quality of assumptions made in Phase I for basis of design for the EECP concept. The RD&T work plan (Task 2 and 3) for Phase II has been completed. As the RD&T work conducted during Phase II concluded, it became evident that sufficient, but not necessarily complete, technical information and data would be available to begin Phase III - Basic Engineering Design. Also due to the merger of Chevron and Texaco, the proposed refinery site for the EECP was not available. It became apparent that some additional technical development work would be needed to correctly apply the technology at a specific site.

The objective of Task 4 of Phase II is to update the concept basis of design produced during Phase I. As part of this task, items that will require design basis changes and are not site dependent have been identified. The team has qualitatively identified the efforts to incorporate the impacts of changes on EECP concept. The design basis has been modified to incorporate those changes. The design basis changes for those components of EECP that are site and feedstock dependent will be done as part of Phase III, once the site has been selected.

Table of Contents

The Contractor can not confirm the authenticity of the information contained herein since this report is being submitted under the DOE requirement that the electronic files must be submitted without being write-protected.

List of Graphical Material

Figures

None

Schematics

Table

Executive Summary

The 1999 U. S. Department of Energy (DOE) award to Texaco Energy Systems Inc. (presently Texaco Energy Systems LLC, a subsidiary of ChevronTexaco) was made to provide a Preliminary Engineering Design of an Early Entrance Coproduction Plant (EECP). Since the award presentation, work has been undertaken to achieve an economical design concept that makes strides toward the DOE Vision 21 goal. The objective of the EECP is to convert coal and/or petroleum coke to electric power plus transportation fuels, chemicals, and useful utilities such as steam. The petroleum coke was added as a fuel to reduce the cost of feedstock and also to increase the probability of commercial implementation of the EECP concept. This objective has been pursued in a three phase effort through the partnership of the DOE with prime contractor Texaco Energy Systems LLC and subcontractors General Electric (GE), Praxair, and Kellogg Brown and Root (KBR). ChevronTexaco is providing gasification technology and Rentech's Fischer-Tropsch technology that has been developed for non-natural gas feed sources. GE is providing gas turbine technology for the combustion of low energy content gas. Praxair is providing air separation technology and KBR is providing engineering to integrate the facility.

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The design basis changes for those components of the EECP that are site and feedstock dependent will be done as part of Phase III, once the site has been selected. Heat and material balances, equipment sizing, process flow sketches, process descriptions, utility/catalyst/chemical summaries, plot plan, emission and effluent summary, cost estimate, and proforma calculations have not been done in this task. Instead, these activities will be done during Phase III, if a new site is selected.

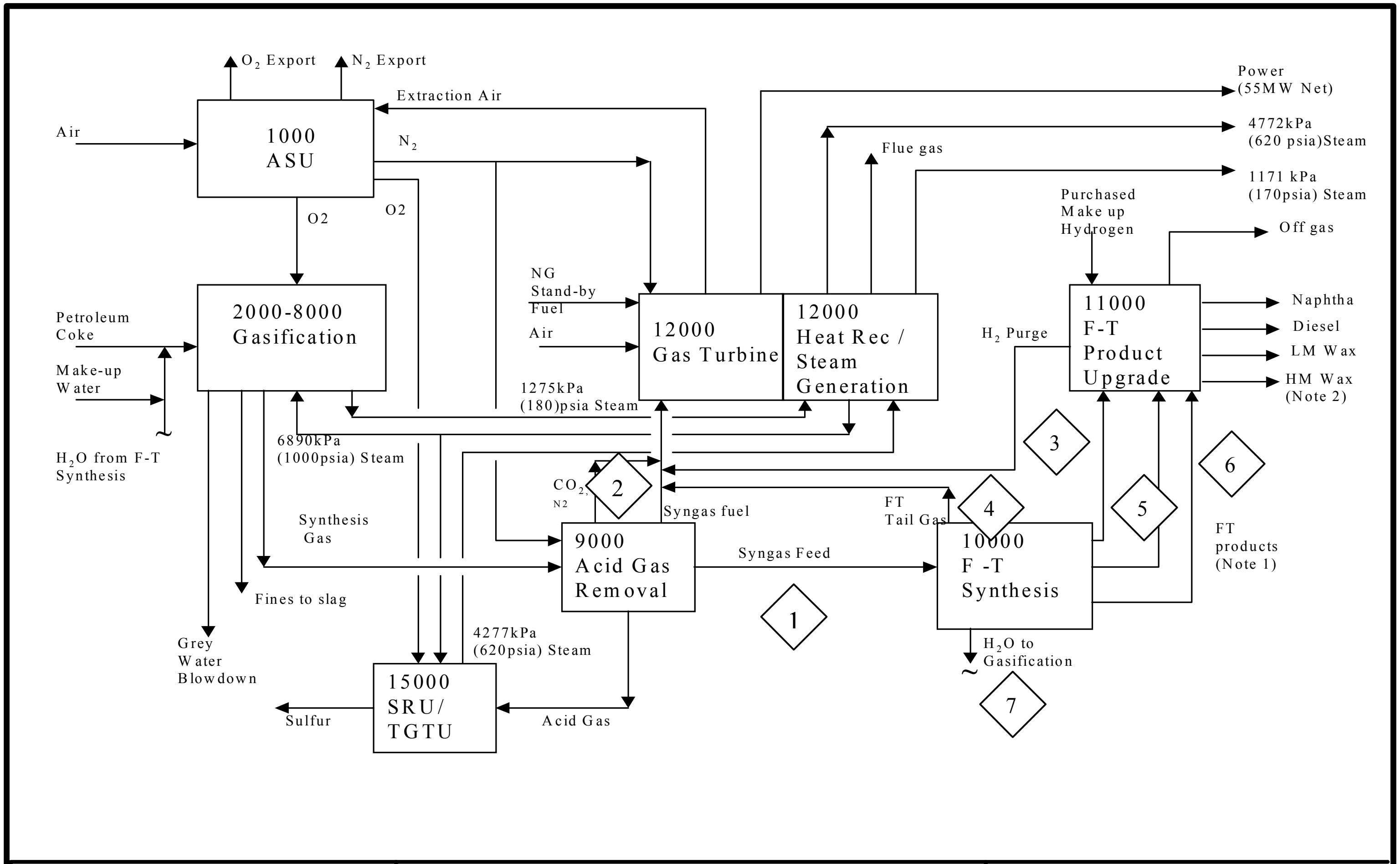
Background

The overall objective of this project is the three phase development of an Early Entrance Coproduction Plant (EECP) which uses petroleum coke and/or coal to produce at least one product from at least two of the following three categories: (1) electric power (or heat), (2) fuels, and (3) chemicals. The objective of Phase I was to determine the feasibility and define the concept for the EECP located at a specific site; develop a Research, Development, and Testing (RD&T) Plan for implementation in Phase II; and prepare a Preliminary Project Financing Plan. The objective of Phase II is to implement the work as outlined in the Phase I RD&T Plan to enhance the development and commercial acceptance of coproduction technology. The objective of Phase III is to develop an engineering design package and a financing and testing plan for an EECP located at a specific site. The project's intended result is to provide the necessary technical, economic, and environmental information needed by industry to move the EECP forward to detailed design, construction, and operation.

The proposed EECP facility will coproduce electric power and steam for export and internal consumption, finished high-melt wax, finished low-melt wax, Fischer-Tropsch (F-T) diesel, F-T naphtha, elemental sulfur, and consume approximately 1,120 metric tons per day (1,235 short tons per day) of petroleum coke. During Phase I, the Motiva Port Arthur Refinery site was chosen for the EECP. The refinery site offered a ready source of petroleum coke as a feedstock. However, as a result of the merger between Texaco and Chevron, this site is no longer available.

EECP Concept

As shown in Schematic 1, Petroleum coke is ground, mixed with water and pumped as thick slurry to the Gasification Unit. This coke slurry is mixed with high-pressure oxygen from the Air Separation Unit (ASU) and a small quantity of high-pressure steam in a specially designed feed injector mounted on the gasifier. The resulting reactions take place very rapidly to produce synthesis gas, also known as syngas, which is composed primarily of hydrogen (H_2), carbon monoxide (CO), water vapor (H_2O), and carbon dioxide (CO_2) with small amounts of hydrogen sulfide (H_2S), methane, argon, nitrogen, and carbonyl sulfide. The raw syngas is scrubbed with water to remove solids, cooled, and then forwarded to the Acid Gas Removal Unit (AGR), where the stream is split. One portion of the stream is treated in the AGR to remove CO_2 and H_2S and then forwarded to the F-T Synthesis Unit. The other portion is treated in the AGR to remove the bulk of H_2S with minimal CO_2 removal and then forwarded as fuel to the GE frame 6FA gas turbine. In the AGR solvent regeneration step, high pressure nitrogen from the ASU is used as a stripping agent to release CO_2. The resulting CO_2 and nitrogen mixture and the bulk of the nitrogen are also sent to the gas turbine, which results in increased power production and reduced nitrogen oxides emissions.



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NOTES:

1. Includes Light, Medium and Heavy FT Liquid product streams
2. LM = Low Melt
   HM = High Melt

DOE EARLY ENTRANCE COPRODUCTION PLANT
PORT ARTHUR REFINERY

OVERALL BLOCK FLOW DIAGRAM

DRAWN JSA	DATE 10/10/00	DOE AWARD NUMBER: DE-FC-99FT40658	REV.
DESIGNER	DATE	SUBCONTRACTOR PROJECT NO: 9202	0
CHECKED	DATE	TASK NO: 4.1.2	
APPROVED	DATE	DRAWING NO: KBR-P-BFD-0001	

Schematic 1 – EECP Concept

Overall, approximately 75% of the sweetened syngas is sent to the gas turbine as fuel. The remaining 25% is first passed through a zinc oxide (ZnO) bed arrangement to remove the remaining traces of sulfur and then forwarded to the F-T Synthesis Unit. In the F-T reactor, CO and H_2 react, aided by an iron-based catalyst, to form mainly heavy straight-chain hydrocarbons. Since the reactions are highly exothermic, cooling coils are placed inside the reactor to remove the heat released by the reactions. Three hydrocarbon product streams, heavy F-T liquid, medium F-T liquid, and light F-T liquid are sent to the F-T Product Upgrading Unit (F-TPU) while F-T water, a reaction byproduct, is returned to the Gasification Unit and either injected into the gasifier or used in the petroleum coke slurry. The F-T tail gas and AGR off gas are sent to the gas turbine as fuel to increase electrical power production by 11%.

In the F-TPU, the three F-T liquids are combined and processed as a single feed. In the presence of a hydrotreating catalyst, H_2 reacts slightly exothermally with the feed to produce saturated hydrocarbons, water, and some hydrocracked light ends. The resulting four liquid product streams are naphtha, diesel, low-melt wax, and high-melt wax and leave the EECP facility via tank truck.

The power block consists of a GE PG6101 (6FA) 60 Hz heavy-duty gas turbine generator and is integrated with a two-pressure level heat recovery steam generator (HRSG) and a non-condensing steam turbine generator. The system is designed to supply a portion of the compressed air feed to the ASU, process steam to the refinery, and electrical power for export and use within the EECP facility. The gas turbine has a dual fuel supply system with natural gas as the start-up and backup fuel, and a mixture of syngas from the gasifier, offgas from the AGR Unit, and tail gas from the F-T Synthesis Unit as the primary fuel. Nitrogen gas for injection is supplied by the ASU for nitrogen oxide (NOx) abatement, power augmentation, and the fuel purge system.

The Praxair ASU is designed as a single train elevated pressure unit. Its primary duty is to provide oxygen to the gasifier and Sulfur Recovery Unit (SRU), and all of the EECP's requirements for nitrogen and instrument and compressed air. ASU nitrogen product applications within the EECP include its use as a stripping agent in the AGR Unit, as diluents in the gas turbine where its mass flow helps increase power production and reduce NOx emissions, and as an inert gas for purging and blanketing. The gas turbine, in return for diluent nitrogen, supplies approximately 25% of the air feed to the ASU, which helps reduce the size of the ASU's air compressor, hence oxygen supply cost.

Acid gases from the AGR, as well as sour water stripper (SWS) off gas from the Gasification Unit, are first routed to knockout drums as they enter the Claus SRU. After entrained liquid is removed in these drums, the acid gas is preheated and fed along with the SWS gas, oxygen, and air to a burner. In the thermal reactor, the H_2S, a portion of which has been combusted to sulfur dioxide (SO_2), starts to recombine with the SO_2 to form elemental sulfur. The reaction mixture then passes through a boiler to remove heat while generating steam. The sulfur-laden gas is sent to the first pass of the primary sulfur condenser in which all sulfur is condensed. The gas is next preheated before entering the first catalytic bed in which more H_2S and SO_2 are converted to sulfur. The sulfur is removed in the second pass of the primary sulfur condenser, and the gas goes through a reheat, catalytic reaction, and condensing stage two more times before leaving the SRU as a tail gas. The molten sulfur from all four condensing stages is sent to the sulfur pit, from which product is transported off site by tank truck.

The tail gas from the SRU is preheated and reacted with hydrogen in a catalytic reactor to convert unreacted SO_2 back to H_2S. The reactor effluent is cooled while generating steam before entering a quench tower for further cooling. A slip stream of the quench tower bottoms is filtered and sent along with the condensate from the SRU knockout drums to the SWS. H2S is removed from the quenched tail gas in an absorber by lean methyldiethanolamine (MDEA) solvent from the AGR Unit, and the tail gas from the absorber is thermally oxidized and vented to the atmosphere. The rich MDEA solvent returns to the AGR Unit to be regenerated in the stripper.

Design Basis Update

A Phase I Preliminary Concept was completed in 2000. The Phase I Preliminary Concept Report was prepared based on making assumptions for the basis of design for various technologies [such as Air Separation Unit (ASU), Gasification Unit, Acid Gas Removal (AGR), Sulfur Recovery Unit (SRU), Tail Gas Treating Unit (TGTU), Fischer-Tropsch Synthesis (F-T), F-T Product Upgrading (F-TPU), Gas Turbine (GT), Steam System, Off-sites] that are part of the EECP concept. The basis of design for Phase I was included in Section 3.0 - TECHNICAL ASSESSMENT OF SUBSYSTEMS, Phase I Preliminary Concept Report. The Phase I Preliminary Concept Report was approved by the DOE in May 2001[1]. The Phase I work identified technical and economic risks and critical research, development, and testing that would improve the probability of technical and economic success of the EECP. The Project Management Plan (Task 1) for Phase II was approved by the DOE in 2001. The results of RD&T efforts for Phase II would improve the quality of assumptions made in Phase I for the basis of design for the EECP concept. The RD&T work plan (Task 2 and 3) for Phase II has been completed.

As the RD&T work conducted during Phase II concluded, it became evident that sufficient, but not necessarily complete, technical information and data would be available to begin Phase III - Basic Engineering Design. Also due to the merger of Chevron and Texaco, the proposed refinery site for the EECP was not available. It became apparent that some additional technical development work would be needed to correctly apply the technology at a specific site.

The objective of Task 4 of Phase II is to update the concept basis of design produced during Phase I. As part of this task, technologies that will require design basis changes and are not site dependent have been identified as Fischer Tropsch Synthesis and Fischer Tropsch Product Upgrading. The design basis for both above technologies has been modified to incorporate those changes.

The design basis changes for those components of the EECP that are site and feedstock dependent have been identified as the Gasification Unit and its associated units such as ASU, AGR, SRU, TGTU, GT, and steam system. The update to the design basis for these units will be done as part of Phase III, once the site has been selected.

As outlined in the Project Management Plan for Phase II, heat and material balances, equipment sizing, process flow sketches, process descriptions, utility/catalyst/ chemical summaries, plot plan, emission and effluent summary, cost estimate, and proforma calculations have not be done in this task. Instead, these activities will be done during Phase III, if a new site is selected.

Fischer-Tropsch Synthesis Design Basis Update

The Fischer-Tropsch (F-T) Synthesis Section Design Basis has been revised based on the information ascertained from the development work carried out since Phase I. The body of work used in the revision of the design basis includes both Phase II RD&T and efforts outside the scope of the EECP. The updated design basis is presented below.

The Fischer-Tropsch (F-T) Synthesis section is designed to convert Synthesis Gas (syngas) produced in the Gasification section to liquid hydrocarbons using Rentech technology. The syngas is produced in the Gasification section by gasifying petroleum coke. Part of the syngas after H_2S removal is received in the F-T Synthesis section. The syngas will be first treated with zinc oxide to remove the remaining H_2S and then sent to the F-T Reactor. The F-T Reactor is a slurry bubble column reactor. The F-T liquid products from the F-T Synthesis section are sent to the Product Upgrading section for further treatment. The F-T Catalyst Handling section maintains the reactor catalyst activity by daily adding and removing catalyst.

Phase II RD&T improved the design basis from the Phase I Preliminary Concept and reduced the overall risk to the EECP. The F-T related portions (Synthesis and Product Upgrading) of the EECP concept contained the most uncertainty. Phase II testing helped reduce the uncertainty of the EECP Concept. Testing reduced the uncertainty of the liquid yield of the F-T Synthesis design basis and showed that all three of the F-T feed streams (light, medium, and heavy) can not be co-mingled and hydrotreated a single reactor.

Battery Limit Conditions

Tables 1-1 through 1-3 summarize feed, product, and effluent streams in relation to the F-T Synthesis plant. **Tables 1-1 through 1-3 have not changed from the original Phase I Preliminary Concept Report.**

Table 1-1
Feed Streams Entering F-T Synthesis Plant

Feeds	From	Pressure, kPa (psia)	Temperature, K (°F)
F-T Syngas Feed	AGR (Stream 1*)	3737 (542)	322 (120)
GT Syngas Feed	AGR (Stream 2*)	2206 (320)	307 (93)
High Pressure purge gas	FTPU (Stream 3*)	12,617 (1830)	322 (120)
F-T Fresh Catalyst	Offsite		

*see Schematic 1

Table 1-2
Products Streams Leaving F-T Synthesis Plant

Products	From	Destination	Pressure, kPa (psia)	Temperature, K (°F)
GT Syngas Feed	Preheater (Stream 4*)	Gas Turbine	2413 (350)	478 (400)
F-T Light Liquid	Cold Separator (Stream 5*)	Product Upgrading	2661 (386)	322 (120)
F-T Medium Liquid	Hot Separator (Stream 5*)	Product Upgrading	2723 (395)	355 (180)
F-T Wax	Filtered Wax Pump (Stream 6*)	Product Upgrading	621 (90)	538 (509)
430 psia Steam	Combined Gas Preheater	Offsite	2965 (430)	505 (450)

*see Schematic 1

Table 1-3
Effluent Streams

Effluent	From	Destination	Pressure, kPa (psia)	Temperature K (°F)
F-T Water/Alcohol	F-T Water Pump (Stream 7*)	Gasification	5170 (750)	344 (160)
1st Wax Surge Drum Offgas	1st Wax Surge Drum	Offsite	207 (30)	538 (509)
2nd Wax Surge Drum Offgas	2nd Wax Surge Drum	Offsite	138 (20)	
Water Surge Drum Offgas	Water Surge Drum	Offsite		
F-T Catalyst Fines	Wax Filtration System, FT Water Surge Drum	Offsite		
F-T Spent Catalyst	Wax Filtration System	Offsite		

*see Schematic 1

Syngas

Characteristics of the syngas feed are listed in Table 2-1. Since a new EECP site has not been identified, Table 2-1 have not been changed.

Table 2-1 Feed Gas Composition (Stream 1*)

Components	Mole Percent
Hydrogen (H_2)	40.32
Carbon Monoxide (CO)	53.20
Carbon Dioxide (CO_2)	3.88
Water (H_2O)	0.19
Methane (CH_4)	0.07
Argon (Ar) & Nitrogen (N_2)	2.34
Hydrogen Sulfide (H_2S) (ppmv)	10
Temperature, K (°F)	322 (120)
Pressure, kPa (psia)	3737 (542)
Total Flow Rate, kgmol/hr (MPH)	1159 (2555)
Total Flow Rate, Nm^3/hr (MMSCFD)	25,980 (23.27)
Total Flow Rate, kg/hr (lb/hr)	20,999 (46,303)
H_2 + CO Flow Rate, Nm^3/hr (MMSCFD)	24,290 (21.76)
H_2:CO ratio	0.76

*see Schematic 1

Zinc Oxide Bed Design Basis

Table 3-1 summarizes the design basis requirements that will help reduce total sulfur level to less than 0.1 ppmv. This table has not changed from the Phase I Preliminary Concept.

Objective: To reduce total sulfur level to less than 0.1 vppm

Table 3-1
Design Basis for Zinc Oxide Bed

Catalyst Description	2.8-4.75 mm spherical granules
Catalyst Life per bed, months	3 (basis 20 vppm sulfur feed)
Gas Flow Space Velocity, 1/hr	2500
Temperature, K (°F)	511 (460)
Pressure, kPa (psia)	3309 (480)
Number of beds	2 beds in Lead/Lag Configuration
Volume of ZnO per bed	9.1 m^3 (320 ft^3)
Budgetary Cost	\$14,800 (\$ 420/ ft^3)

Fischer-Tropsch Synethesis Reactor Yields

Table 4-1 shows the yield from the F-T Synthesis reactor and the Phase I Preliminary Concept in parentheses.

Table 4-1
F-T Synthesis Reactor Yields
(Phase I Preliminary Concept Yields)

Total Flow from F-T Reactor	586 (580) kgmol/hr	1292 (1279) lbmol/hr
Total Flow from F-T Reactor	20,999 (21,008) kg/hr	46,303 (46,315) lb/hr
Light F-T Liquids (Stream 5*)	14 (38) kg/hr	31.26 (84.8) lb/hr
Medium F-T Liquids (Stream 5*)	356 (781) kg/hr	784 (1722) lb/hr
Heavy F-T Liquids (Stream 6*)	3311 (2628) kg/hr	7301 (5793) lb/hr
F-T Water (Stream 7*)	1877 (1711) kg/hr	4138 (3905) lb/hr
F-T Tailgas (Stream 4*)	15,339 (15,750) kg/hr	33,822 (34,722) lb/hr
Steam Generation from Internal cooling tubes	25,394 (25,079) kg/hr	55,994 (56,859) lb/hr

*see Schematic 1

Fischer-Tropsch Catalyst Properties

The F-T catalyst properties are as follows:

Fresh Unactivated Catalyst

Catalyst type:	Iron-based catalyst

Catalyst Activation

There is no change in the proprietary Rentech F-T catalyst activation procedure from the Phase I Preliminary Concept. Before the fresh catalyst is introduced into the reactor it has to be activated by converting from its oxide state into the active or chemically state. Activation is done by pretreating the catalyst with syngas. Activation of the initial charge to the reactor is done in situ or in the reactor vessel itself as part of the startup. Activation of daily fresh catalyst addition is carried out ex-situ in a separate vessel. The procedure calls for heating the slurry to 478 K (400°F) using syngas. Heating from 478 to 555 K (400 to 540°F) should be done with an inert gas like CO_2. Once the catalyst is heated to 555 K (540°F), syngas can be used for the rest of the activation time.

Fischer Tropsch Product Upgrading Design Basis Update

The Fischer-Tropsch Product Upgrading (F-TPU) Section Design Basis has been revised based on the information ascertained from the development work carried out since Phase I. The body of work used in the revision of the design basis includes Phase II RD&T. The updated design basis is presented below.

The Fischer-Tropsch Product Upgrading section is designed to convert liquid products produced in the Fischer-Tropsch Synthesis section into finished products based on Bechtel's Wax Hy-Finishing^{SM} technology. The Phase I conceptual studies were done based on the assumption that all the three liquid products from the F-T synthesis section (F-T Light, F-T Medium and F-T Heavy) stream will be co-mingled and hydrotreated in a single reactor. However, due to difficulties experienced during the pilot plant runs (see Topical Report Task 2.5 – Product Upgrading), it was decided to hydrotreat only the F-T Heavy stream. The design basis is modified to reflect that change. Processing conditions and reactor yields are based on research and literature data in conjunction with compositional data provided with the feed.

The impact of this change will be that the F-T naphtha and F-T diesel that would be present in the F-T Light and F-T Medium stream will not be hydrotreated. Since these streams are very small quantities and contain very little wax, they can be blended with existing refinery streams.

Feedstock and Product Properties

The Fischer-Tropsch Product Upgrading Unit is designed to process wax feedstock, which is a product from the Fischer-Tropsch Synthesis Unit. The feed is identified as F-T Heavy, representing a specific boiling range liquid from the synthesis unit. The F-T Heavy feed is pumped from a synthesis unit day tank. Physical properties of the feed are shown in Table 5.1.

The boiling range of the feedstock indicates that one major product will be produced from the F-TPU namely high melt wax product. Product specifications are included in Table 5.2.

Table 5-1
Fischer-Tropsch Product Upgrading Unit Feed Properties

	F-T Heavy (Stream 6*)
Specific Gravity @ 60°F	0.86
API Gravity @ 60°F	32.5
Density @ 15°C, kg/m^3	863
Sulfur, Wt%	<3.0 ppm
Total Nitrogen, ppmw	<3.0
Total Paraffins, Wt%	Not determined
Total Olefins, Wt%	Not determined
Naphthenes, Wt%	Not determined
Aromatics, Wt%	Not determined
Oxygenates, Wt%	Not determined

Table 5.1 (continued)		
Light Ends Analysis, Wt%	Not determined	
Distillation (D86)	K	°F
1, vol % off	593	(608.2)
5	664	(735.4)
10	691	(784.2)
30	747	(884.1)
50	875	(1115.8)
70	N/a	N/a
90	N/a	N/a
95	N/a	N/a
98	N/a	N/a

*see Schematic 1

Table 5-2
Food-Grade Wax Specifications

(Finished Food-Grade Wax)		
Property	ASTM Test Method	Specification
Nominal Boiling Range, °K (°F)	ASTM D-1160	
IBP	@ 760 mm Hg	644.3 (700)
Color, Saybolt, Minimum	D-156	+30
Oxygenates, Wt% Maximum	TES Special	0.5
Oil Content, Wt% Maximum	D-721	0.5
Olefins, Wt% Maximum	TES Special	0.5
Odor, Maximum	D-1833	2.0
Sulfur Content, ppmw, Maximum	D-2622	1
FDA UV, Maximum	CFR 121.11565, Step B, Step A,	Pass
	280-280 nm, Maximum	0.150
	290-299 nm, Maximum	0.120
	300-359 nm, Maximum	0.080
	360-400 nm, Maximum	0.020
Melting Point, K (°F), Minimum	D-87 and/or D-127	337.6 (148)

Table 5.2 (continued)		
Metals, Iron, ppmw, Maximum	TES Specified	1
Penetration	D-1321	73 (*)
Density @ 60°F	D-70	836 (*)
Viscosity, SUS @ 210°F	D-88	Solid
Congealing Point, K (°F)	D-938	366 (93) (*)
Peroxide Number	D-1832	Not Reported

* before stripping

Feed Rates and Process Yields

The Fischer-Tropsch Product Upgrading Unit is designed to continuously process the F-T heavy wax feed from the F-T synthesis section.

Process yields resulting from pilot testing are shown in Table 6.1.

Table 6-1
Process Yields of End of Run Feeds

	Weight %	**Phase I Preliminary Concept Weight %**
Hydrogen Sulfide	0.00	0.00
Water	1.66	0.92
Ammonia	0.00	0.00
C_1	4.63	0.00
C_2	0.09	0.25
C_3	0.16	0.11
C_4's	0.15	0.23
C_5's	0.11	0.50
C_6+	0.43	24.09
Wax	93.93	74.33
Total	97.53	100.43

Hydrogen Makeup gas

High purity hydrogen makeup gas is available as required. Typical gas composition feeding the F-TPU is shown in Table 7.1. There is no change in the purity of the makeup gas from the Phase I Preliminary Concept.

Table 7-1
Typical F-T Hydrogen Feed Gas

Hydrogen	93.00	Mole %
C_1	6.78	Mole %
C_2	30	ppm
Carbon Monoxide	1	ppm
Oxygen	1	ppm
Nitrogen & Argon	350	ppm
Water	1800	ppm

Unit Design Basis

Service Factor

The Fischer-Tropsch Product Upgrading Unit is designed to run continuously with a service factor of 93% or 340 days of operation per year.

Design Considerations

(a) The F-TPU based on Bechtel Wax Hy-Finishing^{SM} technology is to be designed and fabricated maximizing modular construction in order to conserve plot space and reduce field construction time.

(b) Wax products will meet all specifications for final saleable products.

(c) The study will consider all offsite facilities that are solely required as a result of including the F-TPU in the EECP project. These items include feed, intermediate and product tankage, transfer pumps, and loading facilities.

Site Conditions

The basic site conditions are assumed to be the same as the Phase I Preliminary Concept since a new EECP site has not been identified.

Plant Location

To be determined.

Typical Meteorological and Plant Data

The meteorological and plant data used in the updated basis of design is the same as the Phase I Preliminary Concept (shown in Table 8.1) since a new EECP site has not been identified.

Table 8-1
Meteorological and Plant Data

(a) Site Elevation:	1.1 m (3.5 ft)	above mean sea level
(b) Air Temperature:	308.2 K (95°F)	Design Dry Bulb
	300.4 K (81°F)	Design Wet Bulb
	266.5 K (20°F)	Winterizing Temperature

Typical Utilities (ISBL)

The utilities used in the updated basis of design is the same as the Phase I Preliminary Concept (shown in Table 9.1) since a new EECP site has not been identified.

Table 9-1
Utilities

	Temperature, K (°F)	Pressure, kPa (psia)
Steam Systems		
Low Pressure	Saturated	448 (65)
Medium Pressure	Saturated	1344 (195)
Condensate System	420.9 (298)	448 (65)
Cooling Water		
Supply	302.6 (85)	448 (65)
Return	316.5 (110)	379 (55)
Nitrogen	Ambient	793 (115)

Typical Battery Limit Conditions

The updated and Phase I Preliminary Concept battery limit conditions are shown in Table 10.1. The major change from the Phase I Preliminary Concept is that the F-T Light and F-T Medium streams are no longer processed in the F-TPU.

Table 10-1
Battery Limit Conditions

	Current		Phase I Preliminary Concept	
	Temperature, K (°F)	Pressure, kPa (psia)	Temperature, K (°F)	Pressure, kPa (psia)
Feeds:				
F-T Light	*N/A*	*N/A*	322 (120)	1069 (155)
F-T Medium	*N/A*	*N/A*	355 (180)	2551 (370)
F-T Heavy Normal	533 (500)	621 (90)	533 (500)	621 (90)
Minimum	422 (300)		422 (300)	
High Purity Hydrogen	311 (100)	3344 (485)	311 (100)	3344 (485)
Products:				
Stabilized Naphtha	*N/A*	*N/A*	311 (100)	241 (35)
Low Sulfur Diesel	*N/A*	*N/A*	311 (100)	448 (65)
Low-Melt Wax	394 (250)	621 (90)	394 (250)	621 (90)
High-Melt Wax	422 (300)	621 (90)	422 (300)	621 (90)
High Pressure Offgas	322 (120)	12,410 (1800)	322 (120)	12,410 (1800)
Vent Gas	322 (120)	207 (30)	322 (120)	207 (30)
Wastewater	322 (120)	448 (65)	322 (120)	448 (65)

Unit Turndown

As in the Phase I Preliminary Concept, the F-TPU Unit will be designed to operate at 60 percent of design capacity.

Conclusions

Phase II RD&T resulted in improvements to the basis of design for the F-T Synthesis and F-TPU units. The primary changes are in the F-T Synthesis Reactor yields and the decision not to send the F-T light and medium streams from the F-T Synthesis Reactor to the F-TPU unit. The updated basis of design reduces the overall project risk.

Bibliography

John Anderson, Lalit Shah, Early Entrance Coproduction Plant Phase I Preliminary Concept Report, May 2001.

List of Acronyms and Abbreviations

^oF	degrees Fahrenheit
AFDU	Alternative Fuels Development Unit
AGR	Acid Gas Removal
API	American Petroleum Institute
Ar	argon
ASTM	American Society for Testing and Materials
ASU	Air Separation Unit
CFR	Code of Federal Regulation
CH_4	methane
CO	carbon monoxide
CO_2	carbon dioxide
DOE	U.S. Department of Energy
F-T	Fischer-Tropsch
FCC	Fluid Catalytic Cracking
FDA	U.S. Food and Drug Adminstration
Ft^3	cubic feet
FTPU	Fischer-Tropsch Product Upgrading
FPS	feet per second
GE	General Electric
GT	gas turbine
H_2	hydrogen
H_2O	water
H_2S	hydrogen sulfide
Hg	mercury
Hr	hour
HRSG	heat recovery steam generator
K	Kelvin
KBR	Kellogg Brown & Root
Kg	kilogram
Kgmol/hr	kilogram mole per hour
kPa	kilo Pascal
lb	pound
lbmol	pound mole
m^3	cubic meter
MDEA	Methyldiethanolamine
MM	millimeter
MMSCFD	Million(s) Standard Cubic Feet Per Day
MPH	mole per hour
N_2	nitrogen
Nm	nanometer
Nm^3	Normal Cubic Meter
NOx	nitrogen oxide
PPMW	parts per million (weight)

PSI	pounds per square inch
PSIA	pounds per square inch - atomoshere
RFCC	Resid Fluid Catalytic Cracking
RD&T	Research, Development, and Testing
SO2	sulfur dioxide
SRU	sulfur recovery unit
SWS	sour water stripper
TES	Texaco Energy Systems LLC
TGTU	tail gas treating unit
UV	ultraviolet
wt%	weight percent
vol %	volume percent
vppm	volume-parts per million
ZnO	zinc oxide