BASELINE DESIGN/ECONOMICS FOR ADVANCED FISCHER-TROPSCH TECHNOLOGY. QUARTERLY REPORT, OCTOBER--DECEMBER 1994

DEPARTMENT OF ENERGY, PITTSBURGH, PA.
PITTSBURGH ENERGY TECHNOLOGY CENTER

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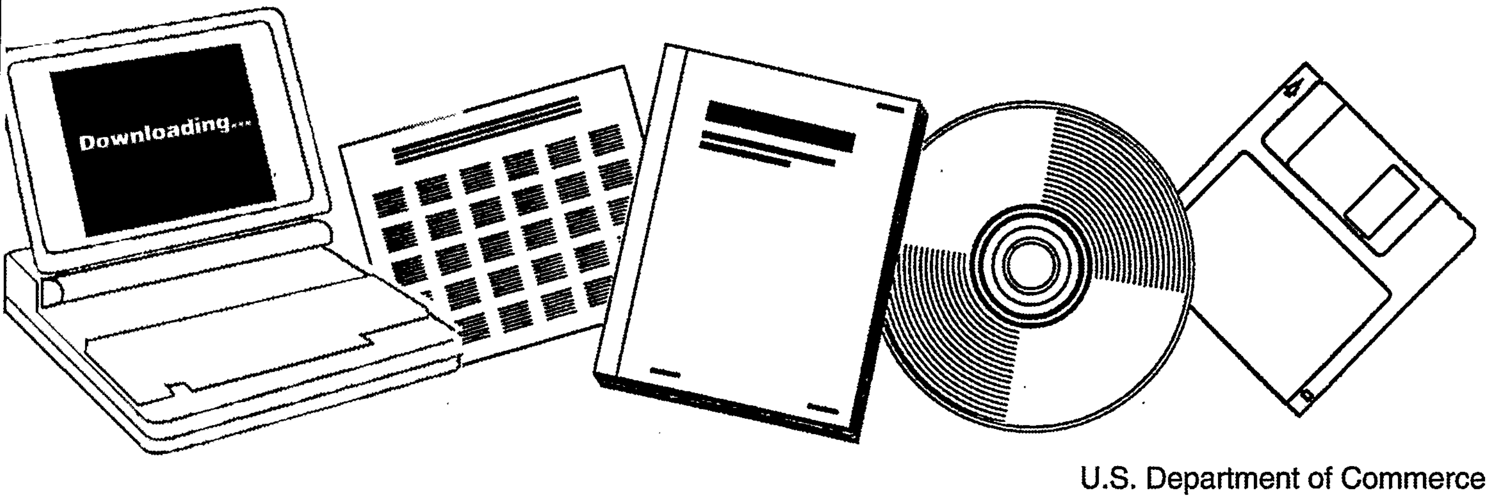

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U.S. Department of Energy
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Baseline Design/Economics
for
Advanced Fischer-Tropsch Technology

Contract No. DE-AC22-91PC90027

Quarterly Report

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Section 1

Introduction and Summary

This report is Bechtel's ninth quarterly technical progress report and covers the period of October through December, 1993.

1.1 INTRODUCTION

Bechtel, with Amoco as the main subcontractor, initiated a study on September 26, 1991, for the U.S. Department of Energy's (DOE's) Pittsburgh Energy Technology Center (PETC) to develop a baseline design and computer model for advanced Fischer-Tropsch (F-T) technology. This 24-month study, with an approved budget of $2.3 million, is being performed under DOE Contract Number DE-AC22-91PC90027.

The objectives of the study are to:

- o Develop a baseline design and two alternative designs for indirect liquefaction using advanced F-T technology. The baseline design uses Illinois No. 6 Eastern Coal and conventional refining. There is an alternative refining case using ZSM-5 treatment of the vapor stream from the slurry F-T reactor and an alternative coal case using Western coal from the Powder River Basin.
- o Prepare the capital and operating costs for the baseline design and the alternatives. Individual plant costs for the alternative cases will be prorated on capacity, wherever possible, from the baseline case.
- o Develop a process flowsheet simulation (PFS) model.

The baseline design, the economic analysis and computer model will be major research planning tools that PETC will use to plan, guide and evaluate its ongoing and future research and commercialization programs relating to indirect coal liquefaction for the manufacture of synthetic liquid fuels from coal.

The study has been divided into seven major tasks:

- o **Task 1:** Establish the baseline design and alternatives.
- o Task 2: Evaluate baseline and alternative economics.
- o Task 3: Develop engineering design criteria.
- o Task 4: Develop a process flowsheet simulation (PFS) model.
- o Task 5: Perform sensitivity studies using the PFS model.

- o Task 6: Document the PFS model and develop a DOE training session on its use.
- o Task 7: Perform project management, technical coordination and other miscellaneous support functions.

1.2 SUMMARY

During the reporting period, work progressed on Tasks 1, 4 and 7. This report covers work done during the period and consists of four sections:

- o Introduction and Summary.
- o Task 1 - Baseline Design and Alternatives.
- o Task 4 - Process Flowsheet Simulation (PFS) Model.
- o Project Management and Staffing Report.

Completed work on Task 1, during the period of this report, consisted primarily of 1) completing and reporting the Alternate (ZSM-5) Refining Case design, and 2) finalizing the Western Coal Case design, material and utility balances, equipment and cost estimates. Preliminary economic analyses on the Baseline Design and the Alternate Cases were performed and results compared.

Under Task 4, some of the individual plant models were revised and enhanced. In additional to the Baseline Design, a complete ASPEN process flowsheet simulation model for both the Alternate (ZSM-5) Refining Case as well as the Western Coal Case were developed.

Under Task 7, cost and schedule control was the primary activity.

Task 1 - Alternate (ZSM-5) Refining Case

Work progressed during this quarter consisted mainly of 1) completing and reporting the Alternate (ZSM-5) Refining Case design, and 2) finalizing the Western Coal Case design, material and utility balances, equipment and cost estimates. Preliminary economic analyses on the Baseline Design and the Alternate Cases were performed and results compared.

2.1 ALTERNATE (ZSM-5) REFINING CASE DESIGN

In summary, the Alternative Refining Case has the same design basis as the Baseline Case, except that a ZSM-5 reactor is close-coupled to the Fischer-Tropsch reactor, taking the vapor stream from that reactor and converting olefins, paraffins above C_7 and oxygenates to isoolefins, isoparaffins, naphthenes and aromatics. This eliminates a number of upgrading steps in the baseline design including catalytic naphtha reforming, C5/C6 isomerization, naphtha hydrotreating and distillate hydrotreating. Alkylation and C4 isomerization are still required but the yield of alkylate is increased and the requirement for imported n-butane is reduced. The liquid wax stream from the F-T reactor is handled in the same manner as in the baseline design, by mild hydrocracking of the wax.

The distillate fraction still has the same quality as in the baseline case. The naphtha produced is a blend of $C_3/C_4/C_5$ alkylate, ZSM-5 naphtha and hydrocracker naphtha. The ZSM-5 naphtha and the alkylate are superior products meeting gasoline specifications. The hydrocracker naphtha is low in octane but should make a good feedstock for a standard refinery catalytic reformer. As in the baseline design, all products are essentially free of S, N and O containing compounds.

Following baseline design premises, the steam generated from waste heat recovery and the fuel gas produced are used to generate a major portion of the in-plant power requirement. The only plant inputs are coal, power, n-butane, raw water, catalysts and chemicals. The plant will comply with all applicable environmental, safety and health regulations.

A summary of the major feed and product streams to the plant are given below. The Baseline Case is also shown for comparison:

	Baseline Case	Alternative Refining Case
Inputs		
ROM Coal*		
MLbs/hr	1693.57	1693.57
Tons/day	20323	20323
Power - MW	50.0	42.5
n-Butane		
MLbs/hr	26.5	7.5
BPSD	3119	882
Raw Water		
MLbs/hr	5,018	5,018
gpm	10,042	10,042
Outputs		
C_3 LPG		
MLbs/hr	14.22	18.58
BPSD	1921	2505
Naphtha		
MLbs/hr	251.44	314.64
BPSD	23915	30288
Distillate		
MLbs/hr	278.21	191.51
BPSD	24655	16857
Sulfur - MLbs/hr	46.69	46.69
Slag - MLbs/hr	187.03	187.03

*Coal as received (8.6 wt% water)
Catalyst and chemicals requirements are not indicated but are roughly comparable with ZSM-5 catalyst taking the place of reforming, hydrotreating and isomerization catalysts.

Since the Fischer-Tropsch reactor is run at 50 wt% wax yield in both cases, the difference in yields is due entirely to the conversion of F-T distillate to naphtha and the upgrading of the naphtha in the ZSM-5 reactor. Both these reactions produce some light ends and this in turn increases the yield of C_3LPG and alkylate.

The overall configuration of the Alternate (ZSM-5) Refining Case, block flow diagrams, process flow diagrams, a detailed description of the Plant 201 design, its basis and considerations, and the overall material balance were reported in the last Quarterly. Of the remaining information, the overall plant utility balance summary, steam flow distribution, and catalyst & chemical requirements are given in Table 2-1, Figure 2-1 and Table 2-2 respectively.

2.2 WESTERN COAL CASE

The details of the Area 100 (Syngas Production) design for the Western Coal Case was presented in the fifth (October-December' 93) quarterly report. Design basis and considerations, PFD and process description, and material balance for all plants within Area 100 were reported.

In addition to the difference in Area 100 design, the Western Coal Case contrasts to the Baseline Case design in that it requires a zero-discharge water treatment system to conserve raw water usage. This is discussed in some detail in the following section.

2.2.1 Plant W32 (Offsite) - Raw, Cooling and Potable Water

The principal source of raw water for the Western coal plant is ground (well) water, with an estimated compositon shown in Table 2-3. Plant W32 was designed to maintain zero-discharge. Based on the total plant water requirements, estimated blowdowns from both Plant W32 (i.e, cooling tower and deminerization system) and Plant W31 (steam and power generation), the vendor recommended a system consisted of a vapor compression, falling film Brine Concentrator in series with a forced circulation Crystallizer unit. Two parallel trains are needed, each handling approximately 700 gpm.

With this zero-discharge system, the Brine Concentrator will recover approximately 90% of the total blowdown water. The Crystallizer will recover an additional 84% of the remaining liquid for an overall 98% water recovery. The distillate is to be returned to the cooling tower as part of the make-up water. The remaining water is discharged with the solids in the form of entrained moisture.

Table 2-1
Raw Water Data for Design

Property	Gillettee, Wyoming, Ground Water
pH	8.4
Calcium, ppm	3.2
Sodium. ppm	534
Potassium, ppm	3.0
Barium, ppm	<0.5
Iron, ppm	<0.05
Chloride, ppm	46
Sulfate, ppm	28
Silica, ppm	18
Total Dissolved Solids, ppm	1,170

Design Basis: Cooling Water System:

One conventional, wooden cross flow, splash fill and mechanically induced-draft cooling tower is provided.

The cooling tower is designed to supply the 3700 MMBTU/hr (including a 12% contingency) cooling requirements of the process plants and offsites. An objective of incorporating a zero-discharge system to the design is to minimize the use of imported water for cooling tower makeup. This results in maximizing the reuse of treated process waste water, as cooling tower makeup. The rest of the makeup water is supplied with clarified water. The total makeup requirement is 6438 GPM; 5240 GPM of which is clarified water and the remaining is treated process water water from Plant 34.

The cooling tower capacity is as follows:

Duty	=	3700 MMBTU/Hr
Inlet Temperature	=	115°F
Outlet Temperature	=	87°F
Circulation Rate	=	219,600 GPM
Water Evaporation Loss	=	0.1% x Delta T Ave.
Drift Loss	=	0.1%
Blowdown	=	9 Cycles

The cooling water system is designed to supply water at a temperature of 87°F.

The climatic conditions used for the cooling tower design are:

- Atmospheric press = 14.3 psig
- Air Temperatures
  - Inlet Temperature = -6 to 95°F
  - Wet Bulb Temperature = 78°F
  - Dry Bulb Temperature = 95°F at 45% Relative Humidity

Design Basis: Raw Water Treatment:

The raw water treament design is the same as the Baseline case design, except for capacity. The raw water treatment consists of:

- Clarification of water
- Gravity filtration
- Potable water chlorinator
- Demineralization

Clarified water is used for cooling tower makeup, fire fighting and utilities.

A package potable water system is used to treat water used for drinking, food preparation and sanitary facilities. This water has been clarified and filtered.

Boiler feed water has been clarified, filtered and demineralized.

Overall flow of raw, clarified and potable water is illustrated on Flow Diagram, Figure 2-2. The water clarification system is designed to treat approximately 6,800 GPM of raw water. The filtration system is designed for 1,136 GPM, demineralization for 1,032 GPM and potable water for 100 GPM water feed.

Table 2-1 (1)

Illinois No. 6 Coal - Alternative Upgrading
Utility Summary

Plant No	Plant Description	Load BHP	Power kW	Steam, M lb/hr 900 Psig/1000 °F Produced	900 Psig/1000 °F Consumed	600 Psig/650 °F Produced	600 Psig/650 °F Consumed	600 Psig/Sat'd Produced	600 Psig/Sat'd Consumed
	Area 100								
101	Coal Receiving/Storage	2055	1703						
102	Coal Drying/Grinding	28840	23905						
103	Shell Gasification	53076	44000	2268		261			
104	COS Hydro./LT Gas Cool	2656	2201						
105	Sour Water Stripping	54	45						
106	Acid Gas Removal	2546	2108						
107	Sulfur Recovery/TGT	1796	1489					127	36
108	Sulfur Polishing	0	0						
109	Syngas Wet Scrubbing	120	99						
110	Air Separation	480	400		2195				
	Subtotal:	91623	75950	2268	2195	261	0	127	36
	Area 200								
201	F-T Synthesis	8327	6885				16		
202	CO2 Removal	9558	7922						
203	Dehydration/Compress	0	0				9		
204	Hydrocarbon Recovery	1230	1020				70		
205	Hydrogen Recovery	11	8						
206	Autothermal Reforming	0	0						125
	Subtotal:	19126	15835	0	0	0	95	0	125
	Area 300								
301	Wax Hydrocracking	2505	2024				67		
302	Distillate Hydrotreating	[redacted]							
303	Naphtha Hydrotreating								
304	Catalytic Reforming								
305	C4 Isomerization	231	182				2		
306	C5/C6 Isomerization	[redacted]							
307	C3/C4/C5 Alkylation	9743	7651				20		
308	Saturated Gas Plant	112	88				9		
	Subtotal:	12591	9945	0	0	0	98	0	0
	Offsites								
19	Relief and Blowdown	23	19		73		68	34	
20	Tankage	87	72						
21	Intercon. Piping System	0	0						
22	Product Shipping	1617	1270						
23	Tank Car/Truck Loading	39	32						
24	Coal Refuse/Ash Disposal	60	50						
25	Cat./Chem. Handling	60	50						
31	Steam and Power Gener.	-90670	-71200						
32	Raw/Cooling/Pot. Water	891	700						
33	Fire Protection System	53	44						
34	Sewage/Effl. Treatment	6234	4895						
35	Instrument/Plant Air	3685	2894						
36	Purge/Flush Oil System	0	0						
37	Solid Waste Management	59	49						
40	General Site	0	0						
41	Buildings	3428	2692						
42	Telecommunications	16	13						
Other	Miscellaneous	2710	2128						
	Subtotal	-71708	-56292	0	73	0	68	34	0
TOTAL		51632	45438	2268	2268	261	261	161	161

( ) Indicates Production

Table 2-1 (2)

Illinois No. 6 Coal - Alternative Upgrading
Utility Summary

Plant No.	Plant Description	Steam, M lb/hr 360 Psig/600 °F Produced	Steam, M lb/hr 360 Psig/600 °F Consumed	360 Psig/Sat'd Produced	360 Psig/Sat'd Consumed	Steam, M lb/hr 150 Psig/Sat'd Produced	150 Psig/Sat'd Consumed	50 Psig/Sat'd Produced	50 Psig/Sat'd Consumed
	Area 100								
101	Coal Receiving/Storage								
102	Coal Drying/Grinding								
103	Shell Gasification								
104	COS Hydro./L.T Gas Cool								49
105	Sour Water Stripping								9
106	Acid Gas Removal								318
107	Sulfur Recovery/TGT							116	277
108	Sulfur Polishing								
109	Syngas Wet Scrubbing								
110	Air Separation						16	818	
	Subtotal:	0	0	0	0	0	16	934	853
	Area 200								
201	F-T Synthesis			3273		24		4	
202	CO2 Removal		442					442	3174
203	Dehydration/Compress		258					258	
204	Hydrocarbon Recovery		381		51			384	31
205	Hydrogen Recovery		32					32	
206	Autothermal Reforming							1	
	Subtotal:	0	1091	3273	51	24	0	1121	3205
	Area 300								
301	Wax Hydrocracking		208					223	29
302	Distillate Hydrotreating	[redacted]							
303	Naphtha Hydrotreating								
304	Catalytic Reforming								
305	C4 Isomerization						0	2	20
306	C5/C6 Isomerization	[redacted]							
307	C3/C4/C5 Alkylation							5	56
308	Saturated Gas Plant							2	
	Subtotal:	0	208	0	0	0	0	232	105
	Offsites								
19	Relief and Blowdown			107			8	8	
20	Tankage								
21	Intercon. Piping System								
22	Product Shipping								
23	Tank Car/Truck Loading								
24	Coal Refuse/Ash Disposal								
25	Cat./Chem. Handling								
31	Steam and Power Gener.	3329	1723		3329			1450	
32	Raw/Cooling/Pot. Water		307					307	
33	Fire Protection System								
34	Sewage/Lfill Treatment								
35	Instrument/Plant Air								
36	Purge/Flush Oil System								
37	Solid Waste Management								
40	General Site								
41	Buildings								
42	Telecommunications								
Other	Miscellaneous								89
	Subtotal:	3329	2030	107	3329	0	8	1765	89
TOTAL		3329	3329	3380	3380	24	24	4052	4052

(-) indicates Production

Table 2-1 (3)

Illinois No. 6 Coal - Alternative Upgrading

Utility Summary

Plant No.	Plant Description	Condensate Mlb/hr	Water: BFW Mlb/hr	Water: Process Mlb/hr	Water: C W Circ GPM	Cooling, MMBtu/hr: Air	Cooling, MMBtu/hr: Water	Fuel, MMBtu/hr Total Fired
	Area 100							
101	Coal Receiving/Storage							
102	Coal Drying/Grinding							210.00
103	Shell Gasification		2555		87200		1221	
104	COS Hydro./LT Gas Cool	-49			5868	327	82	
105	Sour Water Stripping	-9			271	6	4	
106	Acid Gas Removal	-318			18132		254	
107	Sulfur Recovery/TGT	-305	242		2125		30	131.00
108	Sulfur Polishing							68.80
109	Syngas Wet Scrubbing				206	8	3	
110	Air Separation	-1392			59659		835	
	Subtotal:	-2073	2797	0	173481	341	2429	409.80
	Area 200							
201	F-T Synthesis	-12	3405	119	2092	285	29	6.60
202	CO2 Removal	-3174			35714	2446	500	
203	Dehydration/Compress	-7			1987		28	
204	Hydrocarbon Recovery	-97		11	3862	149	107	39.00
205	Hydrogen Recovery				251		3	
206	Autothermal Reforming	-2						
	Subtotal:	-3292	3405	130	43906	2880	687	45.60
	Area 300							
301	Wax Hydrocracking	-52			223	375	3	91.00
302	Distillate Hydrotreating	[redacted]						
303	Naphtha Hydrotreating	[redacted]						
304	Catalytic Reforming	[redacted]						
305	C4 Isomerization	-20			18	20	0	0.00
306	C5/C6 Isomerization	[redacted]						
307	C3/C4/C5 Alkylation	-80		21	1410	121	20	
308	Saturated Gas Plant	-5			1146	4	16	10.00
	Subtotal:	-157	0	21	2797	520	39	101.00
	Offsites							
19	Relief and Blowdown							
20	Tankage							
21	Intercon. Piping System							
22	Product Shipping							
23	Tank Car/Truck Loading							
24	Coal Refuse/Ash Disposal							
25	Cat./Chem. Handling							
31	Steam and Power Gener.	-273			14700		206	352.00
32	Raw/Cooling/Pot. Water							
33	Fire Protection System							
34	Sewage/Effl. Treatment							
35	Instrument/Plant Air							
36	Purge/Flush Oil System							
37	Solid Waste Management							
40	General Site							
41	Buildings							
42	Telecommunications							
Other	Miscellaneous	-39						
	Subtotal:	-362	0	0	14700	0	206	352
TOTAL		-5884	6202	151	234884	3741	3341	908.40

(-) indicates Production

Table 2-2

Overall Catalyst and Chemical Requirements
Illinois No. 6 Coal Alternative Upgrading Case

Catalyst	Plant	Initial Requirement	Annual Consumption
Area 100			
COS hydrolysis (C53-2-01)	104A	35,296 cft	11,765 cft/yr
Caustic, 25 wt%			5,546 lb/hr
Sulfuric acid, 25 wt%	105A		6,032 lb/hr
Amine soln (UCARSOL)	106A	142,600 lb	47,500 lb/yr
Activated carbon		8,500 lb	17,000 lb/yr
Claus (Kaiser S-201)*	107A	12,780 cft	2,556 cft/yr
SCOT catalyst*		4,520 cft	904 cft/yr
2" SS Pall rings*		1740 cft	580 cft/yr
MDEA*		347 lbl	35 gal/d
Sulfur polishing (ZnO)	108A	26,288 cft	5,535 cft/yr
Caustic, 25 wt%	109A		4,974 lb/hr
Area 200			
FT Ppt. Fe-catalyst	201A	2,302,869 lb	11,514 lb/d
ZSM5 catalyst	201A	285,500 lb	100,000 lb/d
MDEA for CO2 removal	202A	1,211,580 lb	302,895 lb/yr
Molecular sieve	203A	160,000 lb	0
Reformer, C14-2	206A	2,825 cu ft	565 cft/yr
Area 300			
UOP LPHC Catalyst	301A	233,700 lb	33,400 lb/yr
3A Molec. Sieve	305A	1,250 lb	250 lb/yr
Englehard Isom. Catalyst		3,400 lb	690 lb/yr
1" Raschig Rings Pack		60 ft3	0 ft3/yr
Carbon Tetrachloride		3,400 lb	410 lb/yr
Caustic		70 lb	40 lb/yr
KOH		250 lb	2 lb/yr
H2SO4 (98.5 wt%)	307A	1,060 ton	43,100 ton/yr
Caustic (100% NaOH)		6,170 lb	361,300 lb/yr
Offsite			
Alum	32A	19,000 lbs	2,900 lb/d
Polymer		6,000 lbs	1,100 lb/d
98% H2SO4		9,000 gals	9,900 lb/d
50% NaOH		19,000 gals	24,4000 lb/d
Chlorine	34A	2,000 lbs	350 lb/d
Polymer		3,000 lbs	450 lb/d
PAC		6,000 lbs	2,000 lb/d

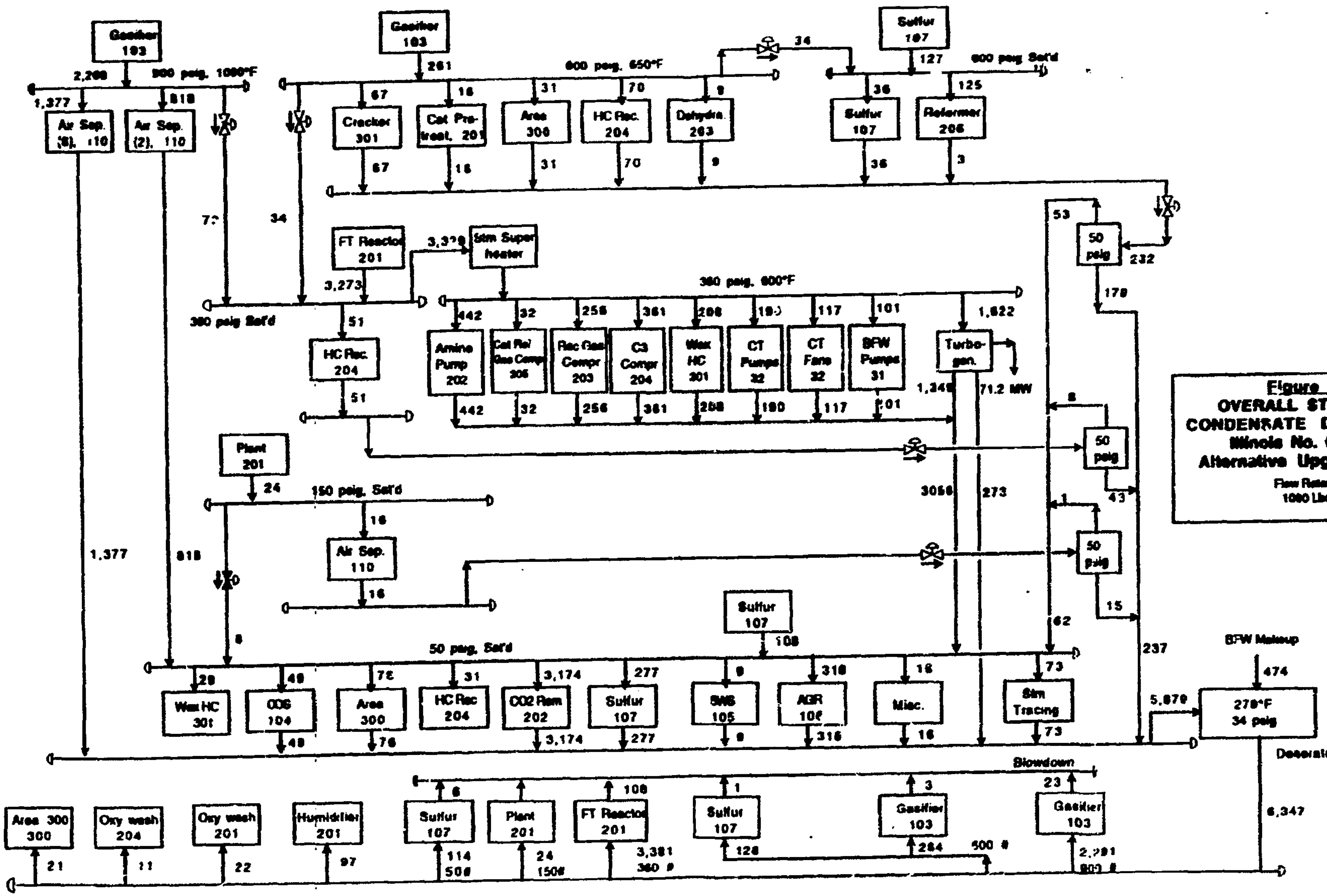

Figure 2-1
OVERALL STEAM AND CONDENSATE DISTRIBUTION
Illinois No. 6 Coal - Alternative Upgrading Case
Flow Rates Are 1000 Lbs/Hr

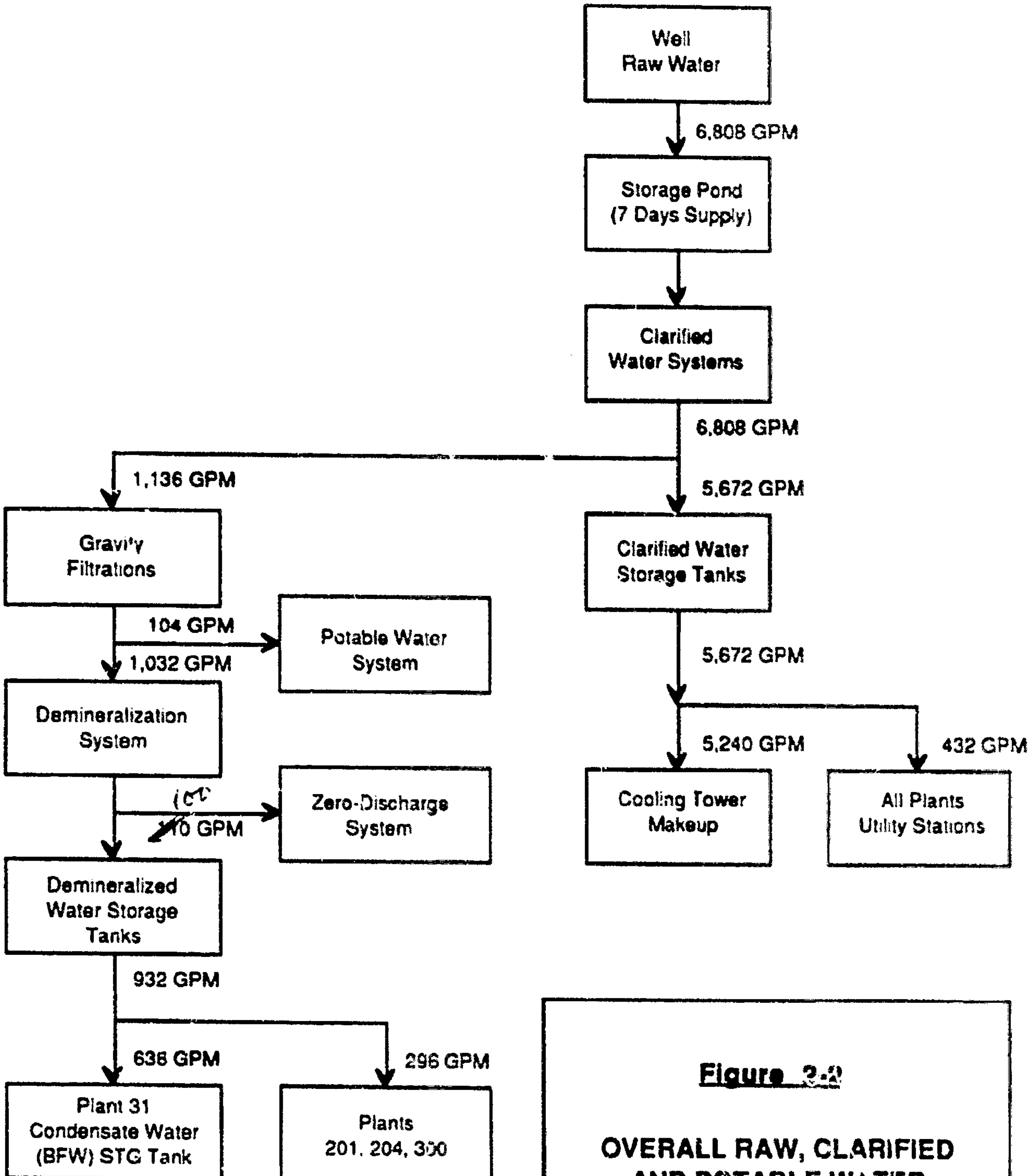

Figure 2-2

OVERALL RAW, CLARIFIED AND POTABLE WATER DISTRIBUTION (WYOMING COAL)

Note: Flows are for normal operation

Section 3
Task 4 - Simulation Model Development

Previous quarterly progress reports described the development of ASPEN process simulation models for each of the individual plants in the indirect coal liquefaction complex and their integration into a complete process simulation model for the baseline design case. During this quarter, some of the individual plant models were enhanced, and two additional complete ASPEN process simulation models were developed for the alternate refining case using ZSM-5 catalyst and for the Western coal case.

3.1 ENHANCEMENTS TO THE PLANT 201 FISCHER-TROPSCH SYNTHESIS REACTOR MODEL

The Fortran user block model for Plant 201, the Fischer-Tropsch synthesis plant, is the most sophisticated of all the Fortran user block models. This block model consists of thirteen Fortran subroutines. It models the Fischer-Tropsch reactions, predicts the yields, and predicts the utilities consumptions and productions for the entire Fischer-Tropsch plant.

Last quarter, an improved version of the slurry bed reactor sizing model that is documented in the final report of the "Slurry Reactor Design Studies" project (DOE project De-AC22-890PC867) was converted to Fortran code and integrated into the ASPEN Fortran user block model for Plant 201. The conversion of this spreadsheet model to Fortran was not simple because the calculation procedure involves several nested calculation loops. When these calculations are requested, the sizes of the Fischer-Tropsch slurry bed reactors will be calculated and reported.

This quarter, the slurry bed reactor sizing model was enhanced to predict the weight and ISBL field cost of the slurry bed reactors from their calculated size. The reactor cost is estimated using standard estimating techniques that convert to a constant cost per pound.

The Fischer-Tropsch slurry bed reactor sizing model allows the study of the effects of feed rate, feed composition, conversion, pressure, inlet gas velocity, catalyst concentration, catalyst makeup rate, and relative catalyst activity on the size and cost of the slurry bed reactors. Thus, this reactor sizing and costing model requires the following eight input parameters.

1. Number of parallel slurry bed Fischer-Tropsch reactors per plant train
2. Fischer-Tropsch slurry bed inlet gas velocity in cm/sec
3. Fischer-Tropsch catalyst concentration in the slurry in wt %
4. Fischer-Tropsch catalyst makeup rate in percent of catalyst inventory per day

5. Temperature of the steam generated in the tubes of the Fischer-Tropsch slurry bed reactor
6. Pressure of the steam generated in the tubes of the Fischer-Tropsch slurry bed reactor
7. Weight of the reference Fischer-Tropsch slurry bed reactor for the ISBL reactor cost calculation
8. ISBL cost of the reference Fischer-Tropsch slurry bed reactor

Table 3-1 is the complete four page plant summary report that the model generates for Plant 201. The second page shows a brief summary of the results of the above slurry bed reactor sizing and costing calculations. Additional and more detailed results of the reactor sizing calculations are given in the standard ASPEN history file.

Additional code was developed and added to the Fortran user block model for Plant 201 to estimate the sizes of the major pieces of equipment in the entire Fischer-Tropsch synthesis plant for the baseline design case as a function of capacity. The number and sizes of the various pieces of equipment are estimated based on a characteristic flow rate in the various plant sections. For instance, the syngas humidifier is sized based on the total entering syngas flow rate, and the vapor coolers are sized based on the gas flow rate leaving the Fischer-Tropsch reactors. Thus, this procedure allows the equipment size predictions to be responsive both to the plant capacity and Fischer-Tropsch reactor performance. The third and fourth pages of Figure 3-1 shows the equipment list that the model generates for the baseline design case.

The Fortran user block model for the Fischer-Tropsch slurry reactor is responsive to the following process variable effects

1. Selectivity expressed as wax yield
2. Conversion per pass as specified by hydrogen conversion
3. H_2/CO ratio
4. Inlet gas rate
5. Inlet gas composition
6. Inlet gas velocity
7. Catalyst concentration
8. Fischer-Tropsch catalyst activity
9. Fischer-Tropsch catalyst life
10. Pressure (w/o any Fischer-Tropsch catalyst effects)

Because it would be difficult and time consuming to study the responses of this model to many variables within the complete model of the entire coal liquefaction complex, a separate ASPEN input file for the Plant 201 Fischer-Tropsch slurry bed reactor model was developed. This input file is a derivative of one that was used to develop the Plant 201 Fortran user block model, and it executes only the Fortran user block model for the Plant 201 Fischer-Tropsch slurry bed reactors. Consequently, it runs much faster than the model for the entire coal liquefaction complex. It contains conditions representative of the baseline design case. However, it is easy to modify to study other conditions. Also, the use of this input file will facilitate the development of future model revisions and enhancements.

3.2 DEVELOPMENT OF AN ASPEN PROCESS SIMULATION MODEL FOR THE ALTERNATE REFINING CASE

Last quarter, a separate process simulation model was developed for Area 300 of the alternate refining case where the Fischer-Tropsch reactor vapors are upgraded by passing them through a reactor containing ZSM-5 oligomerization catalyst. In this quarter, this model was integrated with the Area 100 and Area 200 models to produce an ASPEN process simulation model for the complete alternate refining case.

In the alternate refining configuration, all of the overhead vapor from the slurry phase Fischer-Tropsch reactor is passed directly to a second stage, fixed bed reactor containing ZSM-5 catalyst where olefins, oxygenates and heavy paraffins are converted to a mixture of isoparaffins, isoolefins, naphthenes and aromatics. All of the oxygen atoms in the oxygenates are converted to water. The C5+ portion of this product is a quality gasoline and the light ends are converted to gasoline by alkylation. The wax fraction is hydrocracked to produce naphtha and distillate.

As a result of the improved gasoline quality, the configuration of the Area 300 refining section for the alternate refining case is different. It contains only the following four plants.

1. Plant 301, the Wax Hydrocracking Plant
2. Plant 305, the C4 Isomerization Plant
3. Plant 307, the C3/C4/C5 Alkylation Plant
4. Plant 308, the Saturated Gas Plant.

The distillate hydrotreating, naphtha hydrotreating, naphtha reforming, and C5/C6 isomerization plants have been eliminated. This configuration produces more butanes than are consumed by the alkylation unit. These extra butanes are now sold, in contrast to the baseline design case which was short of butanes and had to purchase them.

the syngas preparation area, and the Fischer-Tropsch loop to generate a model for the complete alternate refining case. Besides passing the Fischer-Tropsch reactor effluent vapor stream through the ZSM-5 reactor, several other modifications were required. The most significant of these were:

1. Revising the hydrocarbon recovery system in Plant 204 to one that is better suited for the revised product refining system.
2. Removing the recycle stream between Areas 200 and 300 because there is no naphtha reformer hydrogen rich gas stream to feed the hydrogen recovery plant since the naphtha reformer plant has been eliminated.
3. Adjusting the makeup steam and oxygen stream flow rates to Plants 201 and 206 for improved performance.
4. Developing a revised inline Fortran block that summarizes the calculations and writes the management summary report for this case.
5. Adjusting the utilities plant and other OSBL plant parameters for this case to match the detailed design values.

Except for the above modifications, the ASPEN process simulation model for the alternate refining case using ZSM-5 oligomerization catalyst is similar to that of the baseline design case. It runs slightly faster because four plants and one recycle loop have been removed.

Table 3-2 contains the management summary report which summarizes the entire model results for the alternate refining case on a single page. A summary of the major plant input and output streams is given at the top of the page. The middle section of the page provides a summary of the individual plants. This includes the number of operating and spare plants, the number of dedicated operators, the ISBL field cost, and the total installed plant cost. The total installed plant cost includes an apportioned amount for the OSBL cost, home office cost, fees and contingency. The total number of operators, foremen and maintenance workers are given at the bottom of the page.

3.3 DEVELOPMENT OF AN ASPEN PROCESS SIMULATION MODEL FOR THE WESTERN COAL CASE

A process simulation model was developed for an alternate Western coal case which will process Powder River Basin coal. The plant is located at a mine mouth site near Gillette, Wyoming. The as-received Powder River Basin coal contains much more moisture (31.0 wt%) than the Illinois No. 6 coal (8.6 wt%) used for the baseline design case. On a moisture free basis, it contains less ash (8.7 vs. 11.5 wt%), less sulfur (0.6 vs. 3.2 wt%), and more oxygen (17.2 vs. 8.0 wt%) than the baseline design Illinois No. 6 coal. As a result of these differences in coal properties, a different design had to be developed for the Area 100, the syngas production area, of the plant.

The design of the syngas production area for the alternate Western coal case required that Plant 106 be a Rectisol acid gas removal plant instead of the amine based plant used for the baseline design case. Furthermore, because of the lower sulfur content of the coal, Plant 104, the syngas treating and cooling plant, was eliminated. Figure 3-1 shows the ASPEN block flow diagram for the syngas production area for the alternate Western coal design case. In addition to the changes to the overall configuration of Area 100, some other design changes were made such as the feed coal to the gasifier was dried to 8 wt% moisture compared to the 2 wt% moisture level used for the baseline design case. In order to produce about the same amount of liquid products, nine Shell gasifiers were required for the Western coal case compared to eight for the baseline design case.

The Fischer-Tropsch synthesis loop and product refining areas (Areas 200 and 300) for the alternate Western coal case are identical to those of the baseline design case. However, this is not the case in the OSBL plants. This plant has been designed to use a minimal amount of fresh water and be a zero discharge facility. As a result the waste water treatment plant has been significantly redesigned to reuse all the water. The only water losses are through evaporation and that which leaves with the slag.

Because this plant is located in a remote location near Gillette, Wyoming which has different labor and construction costs, the ISBL costs of all the individual plants are different than those of the baseline design. These cost differences prevented combining the process simulation model for the alternate Western coal case with that for the baseline design case into a single ASPEN input file.

The physical properties and components sections of the alternate Western coal case and the baseline design case models are identical. Area 100, the syngas preparation area, contains most of the changes. Many block models have the letter W added to the end of their name to indicate they are for the alternate Western coal case and contain different parameters than the corresponding model for the baseline design case. Except for the removal of block P104F, the Fortran user block model for the syngas treating and cooling plant, the renaming of ASPEN class changer block P104C1 to P109C, and the use of nitrogen rather than water in Plant 106, the alternate Western coal block flow diagram in Figure 3-3 is the same as that for the baseline design case. However, the model parameters in all the blocks ending with W are different than those for the baseline design case.

The Fischer-Tropsch synthesis loop and product refining areas (Areas 200 and 300) for the alternate Western coal case are identical to those of the baseline design case which has been previously described.

The inline Fortran block which controls the final summarizing calculations for this model has to be revised to contain the appropriate parameters for this case. This Fortran block was renamed SUMWEST to avoid confusion with similar blocks for the other two models since it contains specific parameters for the Western coal case.

All cost parameters for all the process blocks are different to reflect the different construction costs in Wyoming compared to southern Illinois. The OSBL costs also reflect the effects of minimizing fresh water usage and making this a zero discharge plant.

Table 3-3 contains the management summary report which summarizes the entire model results for the Western coal case on a single page. A summary of the major plant input and output streams is given at the top of the page. The middle section of the page provides a summary of the individual plants. This includes the number of operating and spare plants, the number of dedicated operators, the ISBL field cost, and the total installed plant cost. The total installed plant cost includes an apportioned amount for the OSBL cost, home office cost, fees and contingency. The total number of operators, foremen and maintenance workers are given at the bottom of the page.

3.4 GENERAL MODEL REVISIONS AND CLEANUP

As the two additional process simulation models for the alternate refining case and the Western coal case were developed, several minor revisions were made to the process simulation model for the baseline design case. In general, these revisions were made to maintain consistency between all the models and to allow greater flexibility.

For instance, the model for Plant 307, the C3/C4/C5 alkylation plant, was changed from a feed basis to a total alkylate product stream basis. This change was made to allow the model to better account for the difference between the baseline design case and the alternate refining case.

Also, the process simulation models were revised to predict the catalyst and chemicals consumptions as a function of capacity. Previously, the catalyst and chemical consumption calculations were contained in the LOTUS spreadsheet economics model which would only adjust these costs to reflect capacity differences. Now that these calculations are contained in the process simulation models and transferred to the economics spreadsheet via the transfer file, the significantly lower catalyst and chemical costs for the Western coal case are adequately represented.

Finally, all three ASPEN process simulation models were tuned to the latest utility balances and cost estimates. These adjustments were necessary because of a redesign of the waste water treatment plant and an associated cost reduction.

Table 3-1

Plant 201 Summary Report for the Baseline Design Case

PLANT 201 - SUMMARY REPORT
FISCHER-TROPSCH SYNTHESIS REACTORS

REACTOR COMPONENT FLOW RATES, MLBS/HR COMPONENT	INLET	OUTLET	MOLE WT	AVERAGE BP, F	API GRAVITY
H2	94.230	27.817			
N2	96.363	96.363			
O2	.000	.000			
CO	2831.798	371.356			
CO2	260.405	2377.346			
H2O	199.741	40.142			
CH4	7.412	22.830			
C2H4	.000	11.024			
C2H6	.000	2.954			
C3H6	.000	14.671			
C3H8	.000	2.713			
IC4H8	.000	.764			
NC4H8	.000	14.502			
IC4H10	.000	.198			
NC4H10	.000	3.756			
C5H10	.000	14.833			
NC5H12	.000	4.578			
IC5H12	.000	.508			
C6H12	.000	14.776			
NC6H14	.000	4.539			
IC6H14	.000	.504			
C7H14	.000	13.339			
C7H16	.000	5.834			
C8H16	.000	12.650			
C8H18	.000	5.519			
C9H18	.000	11.807			
C9H20	.000	5.141			
C10H20	.000	10.883			
C10H22	.000	4.731			
C11H22	.000	9.930			
C11H24	.000	4.311			
C12H24	.000	8.985			
C12H26	.000	3.897			
C13H26	.000	8.073			
C13H28	.000	3.498			
C14H28	.000	7.211			
C14H30	.000	3.122			
C15H30	.000	6.407			
C15H32	.000	2.772			
C16H32	.000	5.668			
C16H34	.000	2.451			
C17H34	.000	4.994			
C17H36	.000	2.158			
C18H36	.000	4.385			
C18H38	.000	1.894			
C19H38	.000	3.838			
C19H40	.000	1.658			
WAX	.000	284.757	617.819	1032.0	38.65
OXVAP	.000	2.221	50.921		
OXHC	.000	14.360	86.240		
OXH2O	.000	7.283	45.556		
TOTAL	3489.950	3489.950			
TEMPERATURE, F	362.7	487.6			
PRESSURE, PSIA	325.0	304.0			

Table 3-1 (2)

PLANT 201 - SUMMARY REPORT
FISCHER-TROPSCH SYNTHESIS REACTORS
(CONTINUED)

F-T REACTOR CONVERSIONS:

HYDROGEN CONVERSION	70.48
CARBON MONOXIDE CONVERSION	86.89
SYNGAS CONVERSION	81.70

FISCHER-TROPSCH SLURRY BED REACTOR DESIGN

NUMBER OF F-T PLANT TRAINS =	8
NUMBER OF F-T REACTORS/TRAIN =	3

THE FOLLOWING VALUES ARE FOR 1 OF 24 OPERATING F-T SLURRY BED REACTORS.

AVERAGE REACTOR TEMPERATURE, F	487.6
AVERAGE REACTOR PRESSURE, PSIA	315.0
REACTOR INSIDE DIAMETER, FT	16.35
EXPANDED SLURRY BED HEIGHT ABOVE BOTTOM TANGENT LINE, FT	51.79
SUPERFICIAL GAS VELOCITY, CM/SEC	10.000
RELATIVE CATALYST ACTIVITY	1.000
CATALYST LOADING, MLBS	94.820
CATALYST CONCENTRATION, WT%	22.5
NUMBER OF STEAM TUBES	1458.
TOTAL REACTOR WEIGHT, MLBS	620.726
ISBL REACTOR COST, MM$	2.070

COMPLETE REACTOR DESIGN INFORMATION IS GIVEN IN THE HISTORY FILE.

PLANT UTILITIES CONSUMPTIONS

POWER, KW	4042.
900 PSIG/1000 F STEAM, MLBS/HR	.0
360 PSIG/440 F STEAM, MLBS/HR	-3272.8
600 PSIG/650 F STEAM, MLBS/HR	16.0
600 PSIG SATD STEAM, MLBS/HR	.0
150 PSIG SATD STEAM, MLBS/HR	.0
50 PSIG SATD STEAM, MLBS/HR	-4.0
PLANT FUEL, MM BTUS/HR	5.00
COOLING WATER, MGAL/HR	125.51
PROCESS WATER, MGAL/HR	14.29
NITROGEN, MM SCF/HR OF N2	.00
TOTAL PLANT OPERATORS/DAY	43.0

PLANT COSTING INFORMATION

TOTAL NUMBER OF DUPLICATE TRAINS	8
MAXIMUM SIZE, MM SCF/HR	8.053
MINIMUM SIZE, MM SCF/HR	2.690

	TOTAL	FIRST	SUBSEQUENT
CAPACITY, MM SCF/HR	64.040	8.005	8.005
PLANT ISBL FIELD COST, MM$	173.693	21.712	21.712

Table 3-1 (3)

EQUIPMENT SUMMARY
Plant 201 - Fischer-Tropsch Synthesis Plant

This plant has 8 parallel trains with 3 F-T slurry reactors/train.

Reactors and Vessels

Item No.	Equipment Description	No.	Length (T-T, ft)	Diameter (ID, ft)
201C-1	Syngas Humidifier	1	13.0	11.7
201C-2	Steam Drum	25	30.5	10.0
201C-3	Fischer-Torpsch Slurry Reactor	25	*	*
201C-4	Hydroclone Underflow Drum	25	8.0	3.0
201C-5	Shutdown Wax/Catalyst Storage	3	35.5	17.7
201C-6	F-T Vapor 3-Phase Separator	8	30.0	10.0
201C-7	Vapor Oxygenates Wash Column	8	44.7	6.5
201C-8	High Temp F-T Liquid Separator	8	11.5	3.5
201C-9	Low Temp F-T Liquid Separator	8	7.5	2.5
201C-10	F-T Liquid Intermediate Storage	8	15.0	5.0
201C-11	Catalyst Pretreator	1	25.0	12.0
201C-12	Pretreated Catalyst Feed Tank	1	25.0	12.0
201C-13	Catalyst Pretreater OH KO Drum	1	8.0	4.0
201C-14	Catalyst Recycle Interm Mix Tank	2	14.0	7.0
201C-15	Spent Catalyst Wash Tank	1	8.0	4.0

* See the results of the detailed F-T slurry reactor calculations.

Heat Exchangers

Item No.	Equipment Description	No.	Duty (MM BTU/hr)	Type of Exchanger
201E-1	Used Catalyst/Wax Slurry Heater	3	14.3	Shell & Tube
201E-2	F-T Vapor Trim Cooler	8	2.7	Shell & Tube
201E-3	F-T Vapor Air Cooler	8	35.7	Air-Fin
201E-4	Low Temp Separator Feed Cooler	8	.2	Shell & Tube
201E-5	Wax Heater	1	13.6	Shell & Tube
201E-6	Catalyst Pretreater OH Cooler	1	7.5	Shell & Tube
201E-7	Pretreater Feed/Effluent Exchngr	1	5.7	Shell & Tube

Fired Heaters

Item No.	Equipment Description	No.	Duty (MM BTU/hr)
201F-1	Pretreater Circulation Ga[illegible]er	1	4.8

Table 3-1 (4)

EQUIPMENT SUMMARY (Continued)
Plant 201 - Fischer-Tropsch Synthesis Plant

This plant has 8 parallel trains with 3 F-T slurry reactors/train.

Compressors

Item No.	Equipment Description	No.	Flow Rate (ACFM)	Brake Horsepower
201K-1	Pretreater Circulation Gas Compr	1	1390.	450.

Pumps

Item No.	Equipment Description	No.	Flow Rate (GPM)	Brake Horsepower
201G-1	Humidifier Water	2	280.0	7.0
201G-2	F-T Reactor Boiler Feed Water	50	3266.8	136.0
201G-3	Hydroclone Underflow	50	7.0	2.0
201G-4	Catalyst/Wax Slurry Transfer	16	225.0	18.5
201G-5	Wax Transfer	6	225.0	8.3
201G-6	F-T Liquid Separator Bottoms	16	1.0	.5
201G-7	F-T Wax Filter Feed	16	155.0	15.0
201G-8	Wax Pretreater Feed	2	200.0	38.9
201G-9	Pretreater Liquid	2	10.0	10.0
201G-10	Makeup Catalyst Feed	2	80.0	22.6
201G-11	Oxygenates Water Wash Column	2	30.0	3.4
201G-12	Catalyst Recycle Slurry	4	200.0	48.0
201G-13	Spent Catalyst Slurry	2	43.0	3.0

Special Equipment

Item No.	Equipment Description	No.	Comments
201T-1	Cyclone Separator	25	2.0 ft ID x 3.5 ft T-T
201T-2	Hydroclone	25	56.0 GPM
201T-4	Wax Filters	16	120.0 GPM
201T-5	Makeup Cat Feed Hopper Baghouse	1	30.0 sq ft Cloth Area
201T-6	Makeup Catalyst Feed Hopper	1	22.0 ft ID x 44.0 ft
201T-7	Catalyst Pretreater Baghouse	1	30.0 sq ft Cloth Area
201T-8	Spent Catalyst Filter	2	39.0 GPM
201T-9	Holo-Flite Drier System	1	3699.8 Lbs/hr

The above is based on a proration of the baseline plant design. For either very small or very large capacity plants, the user may wish to adjust the number of spare items or the amount of parallel capacity in some plant sections.

Table 3-2

Management Summary Report for the Alternate Refining Case

MANAGEMENT SUMMARY REPORT

MAJOR INPUT AND OUTPUT STREAMS

INPUT	MLBS/HR	TONS/DAY	
ROM COAL*	1547.933	18575.	
NATURAL GAS, MM SCF/HR			.000
ELECTRIC POWER, MEGA-WH/SD			1089.343
RAW WATER MAKE-UP, MM GAL/SD			14.460

OUTPUT	MLBS/HR	TONS/DAY	BBL/DAY
PROPANE	18.579	223.	2509.
BUTANES	7.529	90.	886.
GASOLINE	314.959	3780.	30317.
DIESEL	191.096	2293.	16820.
REFUSE*	.000	0.	
SLAG*	187.033	2244.	
SULFUR	46.689	560.	
TOTAL	765.886	9191.	50533.

* THESE STREAM FLOW RATES ARE ON A DRY BASIS.
NEGATIVE PRODUCT FLOWS DESIGNATE PURCHASED MATERIAL.

ISBL FIELD AND TOTAL INSTALLED COSTS (INCLUDING OSBL COSTS)

PLANT	NUMBER OF PLANTS OPERATING	SPARES	PLANT COST, MM$, ISBL	TOTAL	DEDICATED OPERATORS
101	1	0	42.020	64.114	12
102	5	1	101.223	154.441	17
103	8	1	702.910	1072.499	183
104	8	0	38.000	57.980	8
105	1	0	3.220	4.913	0
106	4	0	18.660	28.471	9
107	2	1	43.340	66.128	13
108	8	0	23.710	36.177	0
109	8	0	7.580	11.566	8
110	8	0	326.372	497.978	8
201	8	0	172.347	262.966	43
202A	8	0	16.809	25.648	0
202B	8	0	124.570	190.069	8
203	4	0	17.811	27.176	4
204	4	0	53.611	81.799	4
205	4	0	34.862	53.192	4
206	4	0	21.027	32.083	4
207	8	0	23.256	35.484	0
301	1	0	43.947	67.054	10
305	1	0	3.265	4.982	4
307	1	0	40.517	61.821	10
308	1	0	5.088	7.763	4
TOTAL			1864.142	2844.304	353

CATALYST AND CHEMICALS, MM$/YEAR 31.070

DEDICATED PLANT OPERATORS	353
EXTRA OPERATORS, FOREMEN AND MAINTENANCE WORKERS	671
TOTAL	1024

Table 3-3

Management Summary Report for the Western Coal Case

MANAGEMENT SUMMARY REPORT

MAJOR INPUT AND OUTPUT STREAMS

INPUT	MLBS/HR	TONS/DAY	
ROM COAL*	1649.072	19789.	
NATURAL GAS, MM SCF/HR			.000
ELECTRIC POWER, MEGA-WH/SD			2009.605
RAW WATER MAKE-UP, MM GAL/SD			9.804

OUTPUT	MLBS/HR	TONS/DAY	BBL/DAY
PROPANE	14.131	170.	1909.
BUTANES	-26.426	-317.	-3110.
GASOLINE	249.862	2998.	23764.
DIESEL	276.026	3312.	24461.
REFUSE*	.000	0.	
SLAG*	145.584	1747.	
SULFUR	9.029	108.	
TOTAL	668.206	8018.	47024.

* THESE STREAM FLOW RATES ARE ON A DRY BASIS.
NEGATIVE PRODUCT FLOWS DESIGNATE PURCHASED MATERIAL..

ISBL FIELD AND TOTAL INSTALLED COSTS (INCLUDING OSBL COSTS)

	NUMBER OF PLANTS		PLANT COST, MM$,		DEDICATED
PLANT	OPERATING	SPARES	ISBL	TOTAL	OPERATORS
101	1	0	47.690	74.191	12
102	6	1	128.980	200.654	20
103	9	1	735.660	1144.465	205
105	1	0	5.370	8.354	0
106	4	0	166.000	258.246	25
107	2	1	14.980	23.304	13
108	8	0	21.610	33.619	0
109	9	0	6.620	10.299	9
110	9	0	306.550	476.899	9
201	8	0	164.520	255.943	43
202A	8	0	17.319	26.943	0
202B	8	0	111.221	173.027	8
203	4	0	15.920	24.767	4
204	4	0	47.880	74.487	4
205	4	0	42.200	65.650	4
206	4	0	18.940	29.465	4
301	1	0	40.460	62.944	10
302	1	0	13.100	20.380	4
303	1	0	6.080	9.459	4
304	1	0	29.430	45.784	10
305	1	0	6.170	9.599	4
306	1	0	6.690	10.408	4
307	1	0	33.510	52.131	10
308	1	0	5.210	8.105	4
TOTAL			1992.110	3099.122	410

CATALYST AND CHEMICALS, MM$/YEAR 21.320

DEDICATED PLANT OPERATORS	410
EXTRA OPERATORS, FOREMEN AND MAINTENANCE WORKERS	780
TOTAL	1190

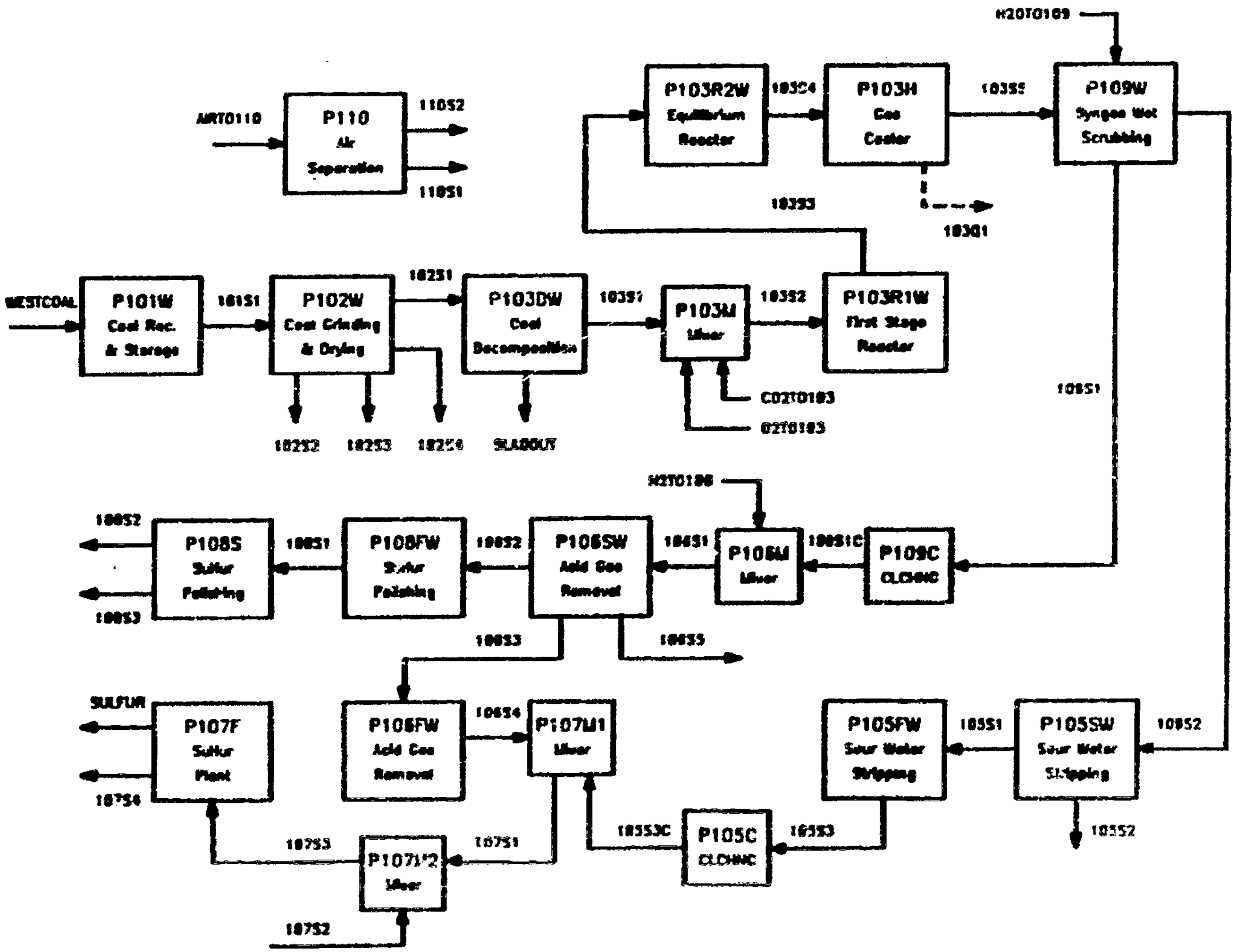

Figure 3-1

ASPEN Block Flow Diagram for Western Coal Area 100 - Singas production

Section 4

Project Management & Staffing Report

4.1 TASK 7 - PROJECT MANAGEMENT

During this reporting period, cost and schedule ccntrol was the primary activity.

4.2 KEY PERSONNEL STAFFING REPORT

The key personnel staffing report for this reporting period as required by DOE/PETC is shown below:

Name	Function	% Time Spent[(a)]
Bechtel		
Samuel S. Tam	Project Manager	25
Gerald N. Choi	Process Engineer	90
Amoco		
R.D. Kaplan	Subcontract Manager	3
S. S. Kramer	Process Model/Simulation	72

(a) Number of hours spent divided by the total available working hours in the period and expressed as a percentage.

Figure 4-1

Overall Milestone Schedule

(as of December 19, 1993)

DOE F 1332.3
(11-84)

☐ PLAN ■ STATUS REPORT

FORM APPROVED
OMB NO. 1901-1400

1. TITLE Baseline Design/Economics for Advanced Fischer-Tropsch Technology	2. REPORTING PERIOD 11/22/93 to 12/19/93	3. IDENTIFICATION NUMBER DE-AC22-91PC90027
4. PARTICIPANT NAME AND ADDRESS Bechtel Corporation, 50 Beale Street, San Francisco, CA 94105		5. START DATE 9/26/91 6. COMPLETION DATE 4/30/94

7. ELEMENT CODE	8. REPORTING ELEMENT	9. DURATION FY 93 / FY 94 (M J J A S O N D J F M A M J J A S O N D J F M A)	10. PERCENT COMPLETE a. Plan	b. Actual
Task 1	Baseline Design	① ② ③ △	100	[illegible]
Task 2	Economic Evaluation	△	100	100
Task 3	Engineering Design Criteria	△	100	100
Task 4	Process Flowsheet Simulation Model	△	100	75
Task 5	Sensitivity Studies	△	100	77
Task 6	Documentation and Training	△	85	7
Task 7	Project Management & Administration	△	100	83

△ Completion
① Second progress meeting
② Baseline case design complete
③ Baseline case equipment list transmitted to Cost Estimating

11. SIGNATURE OF PARTICIPANT'S PROJECT MANAGER AND DATE Samuel S. Tam [signature] 5/3/94

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U.S. DEPARTMENT OF COMMERCE
Technology Administration
National Technical Information Service
Springfield, VA 22161 (703) 605-6000