APPENDIX A

BGC - LURGI PERFORMANCE WITH WESTERN COAL

Western sub-bituminous coals of the type assumed in this study should be nearly ideal feedstocks for the BGC/Lurgi gasification, by virtue of their low, usually alkaline ash, high reactivity and high volatile content. However, such coals have not been available at the Westfield BGC Pilot plant. Test results are available for several bituminous coals and for Scottish Francis Coal, a sub-bituminous coal having properties shown in Table A-1.

The operability of a slagging moving bed gasifier with high moisture western coal has been amply demonstrated in DOE sponsored tests of the Grand Forks Slagger (Reference 37). Slag flow problems have been encountered in limited testing with sub-bituminous coals. However, tests have been limited in number and optimization of operational parameters has not been attempted. Steam and oxygen flows used have been those which proved successful with lignite.

The most successful and extensive testing of the Grand Forks Slagger has been with Indian Head Lignite. In terms of proximate and ultimate analysis, this coal is very similar to the Wyoming Sub-bituminous coal assumed in this study. The close similarity is evident from a comparison of coal properties presented in Table A-1. Results of Grand Forks Slagger tests cannot be used directly as an approximation of BGC Lurgi performance because detailed heat and material balance data are not available. Also, the small diameter of the slagger must necessarily result in greater heat losses than could

TABLE A-1

COAL PROPERTIES

	WYOMING SUB-BITUMINOUS	SCOTTISH FRANCIS	INDIAN HEAD LIGNITE
PROXIMATE % BY WEIGHT			
Moisture	28.0	7.6	30.15
Ash	5.1	5.2	6.75
Volatile Matter	33.1	32.5	28.45
Fixed Carbon	33.8	54.7	34.70
Fixed Carbon/# DAF Coal	.51	.63	.55
ULTIMATE (DAF) % BY WEIGHT			
Carbon	74.45	83.0	71.78
Hydrogen	5.10	5.5	4.67
Sulfur	.45	.5	1.18
Nitrogen	.75	1.4	.95
Oxygen	19.25	9.2	21.40

be achieved in a larger scale unit. The lower efficiency resulting from the heat loss would cause an increase in oxygen requirements and an increase in CO_2 production, relative to a full scale unit operating at similar reaction temperatures.

In lieu of test data, the performance of the BGC gasifier with the assumed Wyoming sub-bituminous coal has been approximated based on BGC performance with Francis Coal, and dry bottom Lurgi performance with the assumed Western coal. Moving bed gasification has been considered as a two step process, e.g., devolatilization followed by steam/oxygen reaction of the remaining fixed carbon. Base case dry bottom Lurgi performance has been used as a basis for estimating the tars, oils, phenols and naphtha produced by devolatilization, while BGC data with Francis coal have been used as the basis for the composition of gaseous outputs.

The following specific assumptions were used.

1. Total carbon conversion of the BGC is assumed to be similar to the dry bottom Lurgi.
2. Since tars, oils, and phenols are produced by devolatilization, it is assumed that their production in the BGC would be the same or with the dry bottom Lurgi. If overall carbon conversion is similar, then total carbon in CH_4, C_2H_4, CO plus CO_2 will be the same as in the dry bottom Lurgi.
3. The mole percentage of CH_4, C_2H_4, CO and CO_2 produced by the BGC with Western coal are assumed to be the same as produced by the BGC with Francis Coal.

4. Steam required, as a percentage of fixed carbon, is assumed to be the same as required with Francis Coal.

5. The oxygen requirement is determined by stoichiometry assuming that the H_2/CO ratio has the value of 0.5 which typifies the BGC gasifier.

Application of these assumptions yields the estimate of BGC performance with Western coal shown in Table A-2. Base case dry ash Lurgi performance with the assumed Wyoming coal, and BGC performance with Francis Coal are shown for reference.

TABLE A-2

GASIFIER PERFORMANCE DATA

	Dry Bottom Lurgi Western Coal		BGC/Lurgi Francis Coal		BGC/Lurgi Western Coal	
	Mole %	#/#Coal(DAF)	Mole %	#/#Coal(DAF)	Mole %	#/#Coal (DAF)
OUTPUT						
CO_2	17.5	1.166	2.4	.106	2.0	.095
CO	11.1	.473	50.6	1.418	43.9	1.291
CH_4	6.7	.162	6.0	.096	5.2	.088
CH_4/C_2H_6	.4	.13	.4	.012	.3	.011
H_2	23.0	.070	25.5	.051	22.0	.046
H_2O	41.1	1.119	10.6	.191	26.3	.497
Misc. Gases	.4	.013	4.4*	.123	.3	.012
Total Bases					100%	
Tar/Oil/Phenols/Naptha	.097			.060		.097
Total Output						
Ash	.089			.060		.089
Total #/#DAF Coal	3.203			2.117		2.227
INPUT						
Oxygen #/#DAF	.360			.564*		.394
Steam #/#DAF	1.337			.406		.327
Coal as Received #/#DAF	1.507			1.147		1.507
Total	3.203			2.117		2.227

*O_2 is 90% purity, vs. 99% for other cases

APPENDIX B

PROCESS DETAILS FOR COMBINATION OF ADVANCED GASIFIERS WITH FISCHER-TROPSCH SYNTHESIS

1.0 COMPUTATION OF PRODUCT OUTPUT FROM ADVANCED GASIFIER/SYNTHOL SYNTHESIS PLANTS

1.1 Mixed Output Cases

Product output from plants employing advanced gasifiers and Synthol synthesis have been scaled from yields achieved in the SASOL-US Base Case. Synthesis gas from the advanced gasifiers is first shifted to the H_2/CO ratio of 2.54 required by the Synthol reactor. It is then assumed that the yield of each product per mole of H_2 + CO in the synthesis gas will be the same as was yielded in the SASOL-US Base Case.

The analysis is thus the straightforward application of a scaling factor. However, care must be taken to assure that only products which are produced from synthesis are scaled. SNG derived from methane, ethane and ethylene in the gasifier output, and gasoline derived from naphtha must be separately accounted for by subtracting them from the Base Case output before the scaling factor is applied. Appropriate values for gasifier derived SNG and gasifier naphtha are then added where applicable.

Table B-1 shows the computation of the output from the BGC/ Synthol plant using the above described methodology. Similar computations were made to determine the product yield from Texaco/ Synthol and SK/Synthol plants.

TABLE B-1

COMPUTATION OF OUTPUT PRODUCTS FOR
BGC/SYNTHOL COMBINATION, MIXED OUTPUT CASE

PRODUCT	SASOL-US OUTPUTS* MIXED OUTPUT CASE MMBtu			SYNTHESIS OUTPUT RATIO**	BGC/SYNTHOL OUTPUTS*** MIXED OUTPUT CASE MMBtu		
	TOTAL OUTPUT	FROM GASIFIER	FROM SYNTHESIS		FROM SYNTHESIS	FROM GASIFIER	TOTAL OUTPUT
SNG	7,243	4,966	2,277	1.446	3,292	2,889	6,180
GASOLINE	2,842	316	2,526	1.446	3,652	334	4,006
C_3	176		176	1.446	254		254
C_4	26		26	1.446	38		38
DIESEL	514		514	1.446	743		743
FUEL OIL	147		147	1.446	213		213
ALCOHOL	290		290	1.446	419		419
TOTAL	11,238	5,282	5,956	1.446	8,611	3,233	11,854

*Syngas Feed = 18.5 CO + 47 H_2 = 65.5 M lb moles

**Ratio of Synthesis Products = 94.7/65.5 = 1.446

***Synthesis Gas Feed = 26.8 CO + 68.1 H_2 = 94.7 M lb-moles

1.2 All Liquid Output Cases

Liquid yields for all liquid plants were computed by assuming that 61 percent of the HHV of the SNG in the mixed product plant is recovered as synthesized liquid products in an all liquid plant.

Using values from Table B-1, the MMBtu/hr (HHV) of liquid products (i.e., C_3^+) produced from synthesis gas in the BGC/Synthol mixed output plant is given by:

$$11{,}854 \text{ (Total)} - 6{,}180 \text{ (SNG)} - 344 \text{ (Naphtha)} = 5{,}330 \text{ MMBtu}$$

If 61 percent of the energy in the SNG is recovered in additional products then synthesis products in the all liquid case are:

$$5{,}330 + .61 \times 6{,}180 = 9{,}100 \text{ MMBtu/hr}$$

Products from synthesis in the all liquid case are thus determined by multiplying the liquid product from synthesis in the mixed output case by the factor 10,373/8,611. The naphtha from the gasifier is then added to give the total gasoline yield.

2.0 ADVANCED GASIFIERS - ADVANCED SYNTHESIS COMBINATIONS: BGC-KOLBEL SYSTEM

A complete analysis is given for this case only; other Kolbel coupled systems were analyzed by scaling from this case. Total number of lb moles of synthesis gas from BGC gasifier = 96,160/hr. This is equivalent to 34,539,710 SCF (359.19 SCF/lb mole). This is equivalent to 978,055 Nm^3 of feed synthesis gas to the Kolbel F-T units.

Table B-2 shows the raw F-T product yields in lbs/hr calculated from the data given in reference (25).

Conversion at the first pass is H_2 = 86 percent and CO = 91 percent. For recycle off gas from first pass is shifted to give 0.67 ratio and sent through the Kolbel unit again. Conversion of recycled gas is again taken to be H_2 = 86 percent and CO = 91 percent. Feed of recycle gas total = 10,580 lb moles/hr = 107,610 Nm^3/hr.

H_2	4,242 lb moles/hr	=	3,651	+	594
CO	6,335 lb moles/hr	=	5,765	+	570
TOTAL	10,580 lb moles/hr		Converted		Unconverted

In addition to products obtained from Kolbel synthesis, the BGC gasifier produces the following primary products:

CH_4	7,490 lb moles/hr	120,139 lbs/hr
C_2H_4	26 lb moles/hr	729 lbs/hr
C_2H_6	341 lb moles/hr	10,270 lbs/hr

TABLE B-2

RAW F-T PRODUCT YIELDS
(lbs/hr)

	LBS/SCF x 10^{-4} FROM REFERENCE (25)	LBS/HR		
		FIRST PASS	RECYCLE	TOTAL
Methane + Ethane	3.6	12,291	1,352	13,643[1]
C_2H_4	3.9	13,584	1,495	15,079
C_3	25.2	86,897	9,561	96,458[2]
C_4	5.7	19,622	2,159	21,781[3]
50-180°C Fraction	59.6	205,921	22,656	228,577
180-220°C	4.4	15,309	1,684	16,993
220-320°C	6.7	23,072	2,538	25,610
>320°C	2.1	7,116	783	7,899
Alcohols	1.9	6,469	712	7,181
TOTAL				433,221

[1]8,732 lbs/hr is methane/4,881 lbs/hr is ethane.

[2]77,166 is C_3^-/19,292 C_3 (ie., 80% olefin)

[3]16,336 is C_4^-/5,445 C_4 (i.e., 75% olefin)

Other gasifier products like tars, oils and phenols are sent to raise steam. The naphtha from the gasifier, 17,300 lb/hr, is hydrotreated and blended with the other gasoline producing streams.

2.1 Kolbel Unit Energetics

Energy in synthesis gas IN:

	Lb Moles/Hr	MMBtu/Hr (HHV)
H_2	38,510	4,743
CO	57,650	7,019
TOTAL	95,160	11,762

Energy in Kolbel F-T products OUT: (MMBtu/hr HHV)

CH_4	208
C_2H_6	109
C_2H_4	326
C_3	1,624 + 418
C_4	341 + 116
40-180°C 180-220°C	4,954
220-320°C	518
>320°C	157
Alcohols	98
TOTAL	8,869
Unconverted CO + H_2	142
	9,011

Efficiency on converted syngas to F-T products = 75.4%.

Energy in Primary gasifier products:

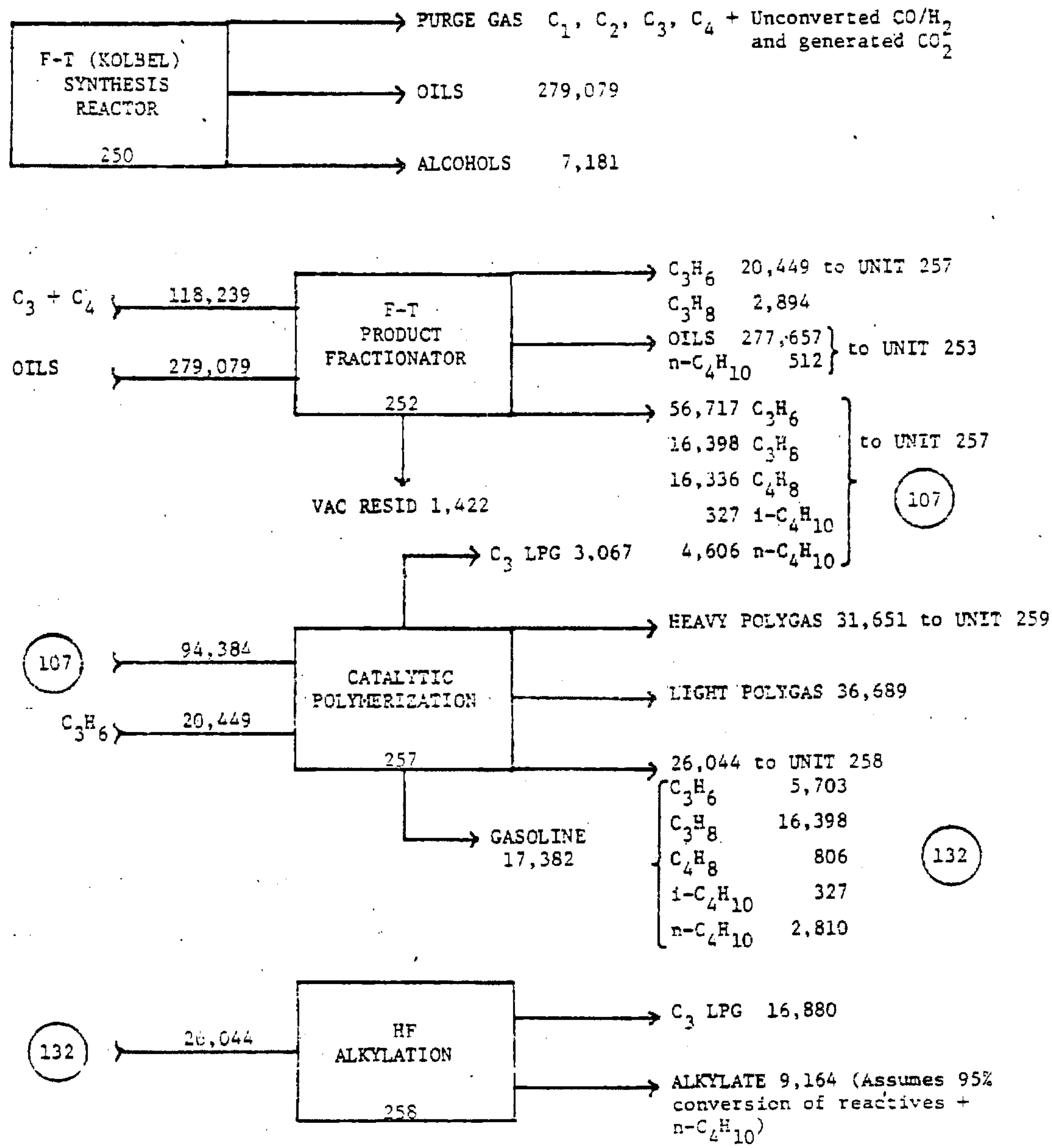
CH_4 and C_2 hydrocarbons = 3,113 MMBtu/hr (HHV)

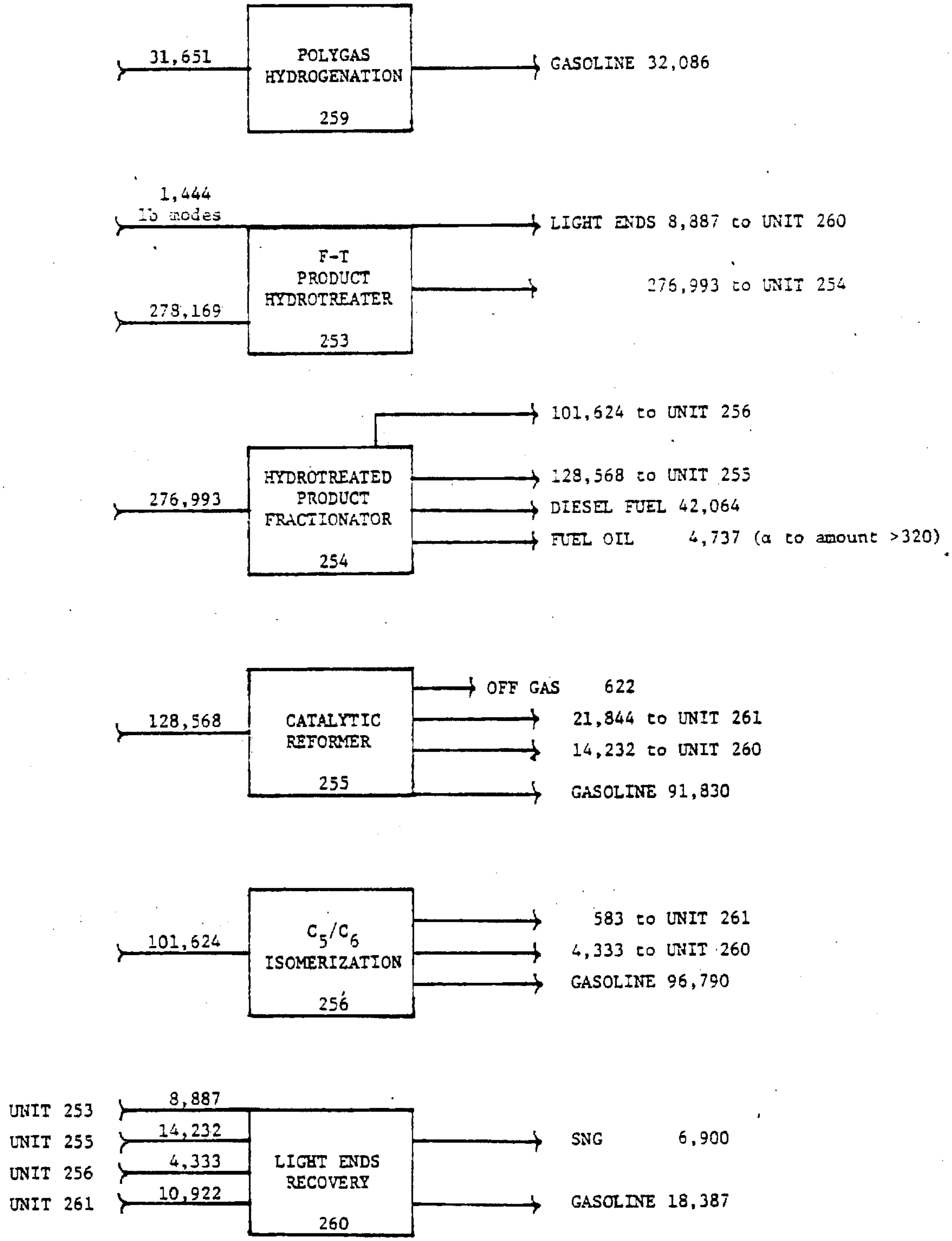
2.2 Downstream Processing (Upgrading) of Raw Kolbel Products

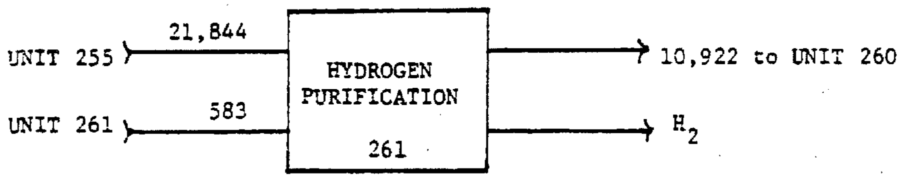
The refining of the raw F-T products generated from the Kolbel unit is described below. As far as possible the refining scheme used was identical to the scheme used in the MRDC report (1). Because of considerable differences in the product distribution the details of flows to each unit have been given.

LIQUIDS TRAIN

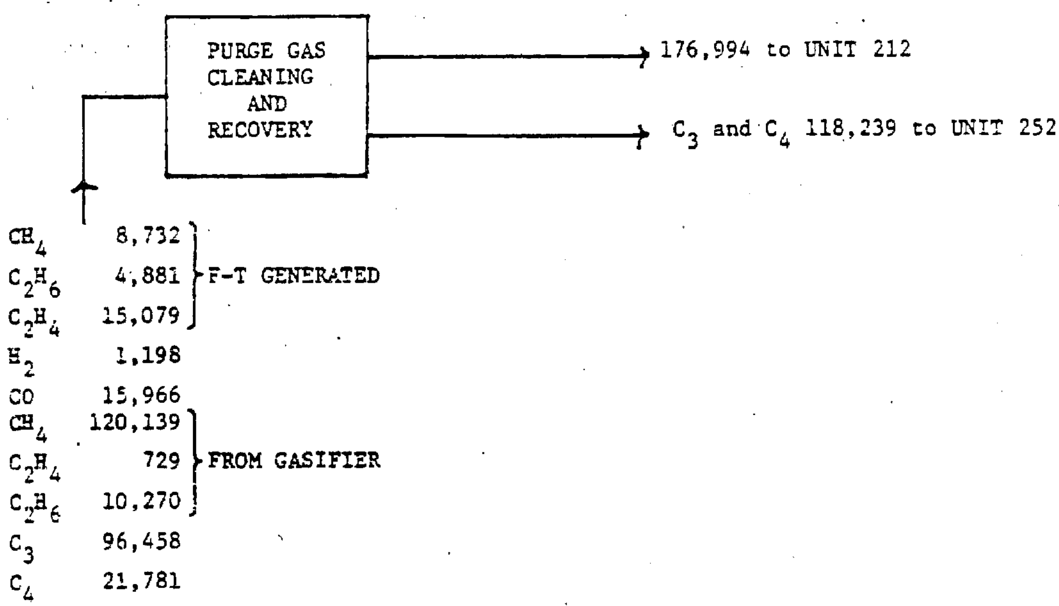
(All Flow Numbers are in lbs/hr)

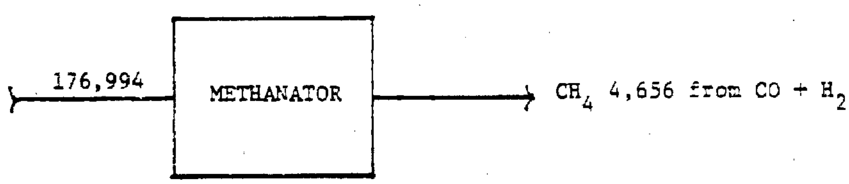



31,651
POLYGAS HYDROGENATION
259
GASOLINE 32,086
1,444
lb moles
LIGHT ENDS 8,887 to UNIT 260
F-T PRODUCT HYDROTREATER
253
278,169
276,993 to UNIT 254
101,624 to UNIT 256
276,993
HYDROTREATED PRODUCT FRACTIONATOR
254
128,568 to UNIT 255
DIESEL FUEL 42,064
FUEL OIL 4,737 (α to amount >320)
128,568
CATALYTIC REFORMER
255
OFF GAS 622
21,844 to UNIT 261
14,232 to UNIT 260
GASOLINE 91,830
101,624
C_5/C_6 ISOMERIZATION
256
583 to UNIT 261
4,333 to UNIT 260
GASOLINE 96,790
UNIT 253
8,887
UNIT 255
14,232
UNIT 256
4,333
UNIT 261
10,922
LIGHT ENDS RECOVERY
260
SNG 6,900
GASOLINE 18,387


UNIT 255
21,844
UNIT 261
583
HYDROGEN
PURIFICATION
261
10,922 to UNIT 260
H_2

SNG TRAIN:


PURGE GAS
CLEANING
AND
RECOVERY
176,994 to UNIT 212
C_3 and C_4 118,239 to UNIT 252
CH_4 8,732
C_2H_6 4,881
C_2H_4 15,079
F-T GENERATED
H_2 1,198
CO 15,966
CH_4 120,139
C_2H_4 729
C_2H_6 10,270
FROM GASIFIER
C_3 96,458
C_4 21,781


176,994
METHANATOR
CH_4 4,656 from CO + H_2

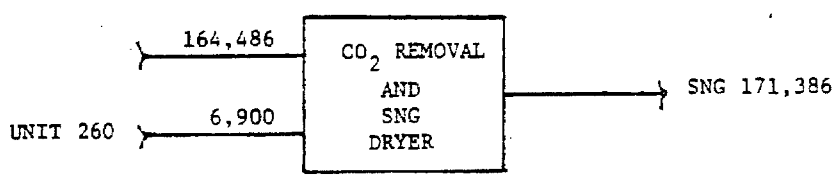

164,486
UNIT 260
6,900
CO_2 REMOVAL
AND
SNG
DRYER
SNG 171,386

TABLE B-3

TOTAL PRODUCTS FROM DOWNSTREAM PROCESSING

		LBS/HR	MM Btu/Hr (HHV)
GASOLINE:	Gasifier Naphtha	16,886	348
	Alkylate	9,164	
	Polygas	32,086	
	Light Polygas	36,689	
	Reformate	91,830	
	Isomerate	114,172	
	Light Ends	18,387	
	TOTAL	319,214	6,439
C_3 LPG	Unit 252	2,894	
	Alkylation	16,880	
	Unit 257	3,067	
	TOTAL	22,841	490
SNG		164,486	
	Unit 260	6,900	
	TOTAL	171,386	3,937
DIESEL		42,064	851
FUEL OIL		4,737	94
ALCOHOLS		7,181	98
	TOTAL		11,909

This table is represented schematically in Figure B-1 which shows the flows in lbs/hr to the downstream processing units.

Conversion of the flows in Table B-3 above to SCF and barrels per stream day is shown in Table VII-3 in Section 7.1.

2.3 BGC-Kolbel: All Liquid Output Case

The HHV thermal value in MMBtu/hr of liquid products (i.e., C_3^+) produced from F-T synthesis is given by

$$11,909 - 3,937 = 7,972 - \text{gasifier naphtha}$$

$$= 7,927 - 348 = 7,624 \text{ MMBtu/hr}$$

If 61 percent of the thermal energy in the reformed SNG is available in the synthesized liquids then

energy from reforming SNG = 0.61 x 3,937 = 2,402 MMBtu/hr

Total energy now in liquid products = 2,402 + 7,624 = 10,026 MMBtu/hr

Thus multiplication factor for all liquids case is 10,026/7,624 = 1.315. Using this factor as a multiplier for the yields in Table VII-3 will give the products expected for a plant producing an all-liquids output. For the gasoline yield, the gasifier naphtha contribution of 1,627 B/SD is first subtracted before multiplication by the factor and then added to the result. The result of this is shown in Table VII-4.

2.4 Texaco-Kolbel System

The gasification products from the Texaco gasifier require clean up but no shift. Total lb moles/hr are given below.

H_2	50,100
CO	73,675
CH_4	150
TOTAL	123,925

Total lb moles/hr of synthesis gas = 123,775

From the BGC case we had a total of 96,160 lb moles/hr

∴ multiplier is 123,775/96,160 = 1.287.

To determine the final, refined product spectrum from the Texaco-Kolbel combination, the F-T generated products from the BGC-Kolbel case are multiplied by the factor 1.287. Thus, for a mixed output case we have:

		MMBtu/Hr
[1] SNG	51,805 + 2,400 lbs/hr = 29.78 MMSCF/D	1,245
[2] GASOLINE	37,507 B/SD	7,850
[3] C_3 LPG	3,970 B/SD	631
[3] DIESEL	4,918 B/SD	1,095
[3] FUEL OIL	512 B/SD	121
[3] ALCOHOL	795 B/SD	126
		11,068

[1] The BGC gasifier generated C_1 and C_2 hydrocarbons are subtracted before using the factor and the small amount of Texaco gasifier generated C_1 is added.

[2] The gasoline number used for scaling is 29,139 B/SD which is the total minus the BGC gasifier generated naphtha contribution.

[3] These numbers are scaled directly from the BGC-Kolbel case using the lb moles of synthesis gas factor.

2.5 Texaco-Kolbel: All Liquids Case

Total thermal value of liquid products is 11,068 - 1,265 = 9,823 MM Btu/hr

Energy from reforming SNG = 0.61 x 1,245 = 759.5 MM Btu/hr

Total energy in liquid products after reforming = 10,582.5

Thus multiplier for all liquids case is 10,582.5/9,823 = 1.077

Using this factor as a multiplier for the yields obtained above, we have the product spectrum shown in Table VII-8 in the text.

2.6 Shell-Koppers/Kolbel System

The gasification products from the Shell-Koppers gasifier are:

	CO	91,700 lb moles/hr
	H_2	44,020 lb moles/hr
TOTAL		135,720 lb moles/hr

The synthesis gas produced has a H_2/CO ratio of 0.48

For compatibility with the data from Kölbel a ratio of 0.67 is required. After shift the total number of moles is constant and H_2 = 54,451 and CO = 81,269 lb moles/hr. No methane or gasifier naphtha is produced.

Multiplier factor is 135,720/96,160 = 1.41.

For mixed output the product spectrum is:

SNG	31.21 MMSCF/D		1,305 MMBtu/hr
GASOLINE	41,127 B/SD		8,608
C_3 LPG	4,353 B/SD		692
DIESEL	5,393 B/SD		1,201
FUEL OIL	562 B/SD		133
ALCOHOLS	872 B/SD		138
		TOTAL	12,077 MMBtu/hr

For the All-Liquid output case we have:

12,077 - 1305 = 10,772 MMBtu/hr in liquid products

1,305 x 0.61 =	796	MMBtu/hr for reforming SNG
TOTAL	11,568	MMBtu/hr total Btu's in liquid products in all liquid output case

∴ factor = 11,568/10,772 = 1.074

Multiplying by this factor in the Table above gives the product spectrum shown in Table VII-7 in the text.

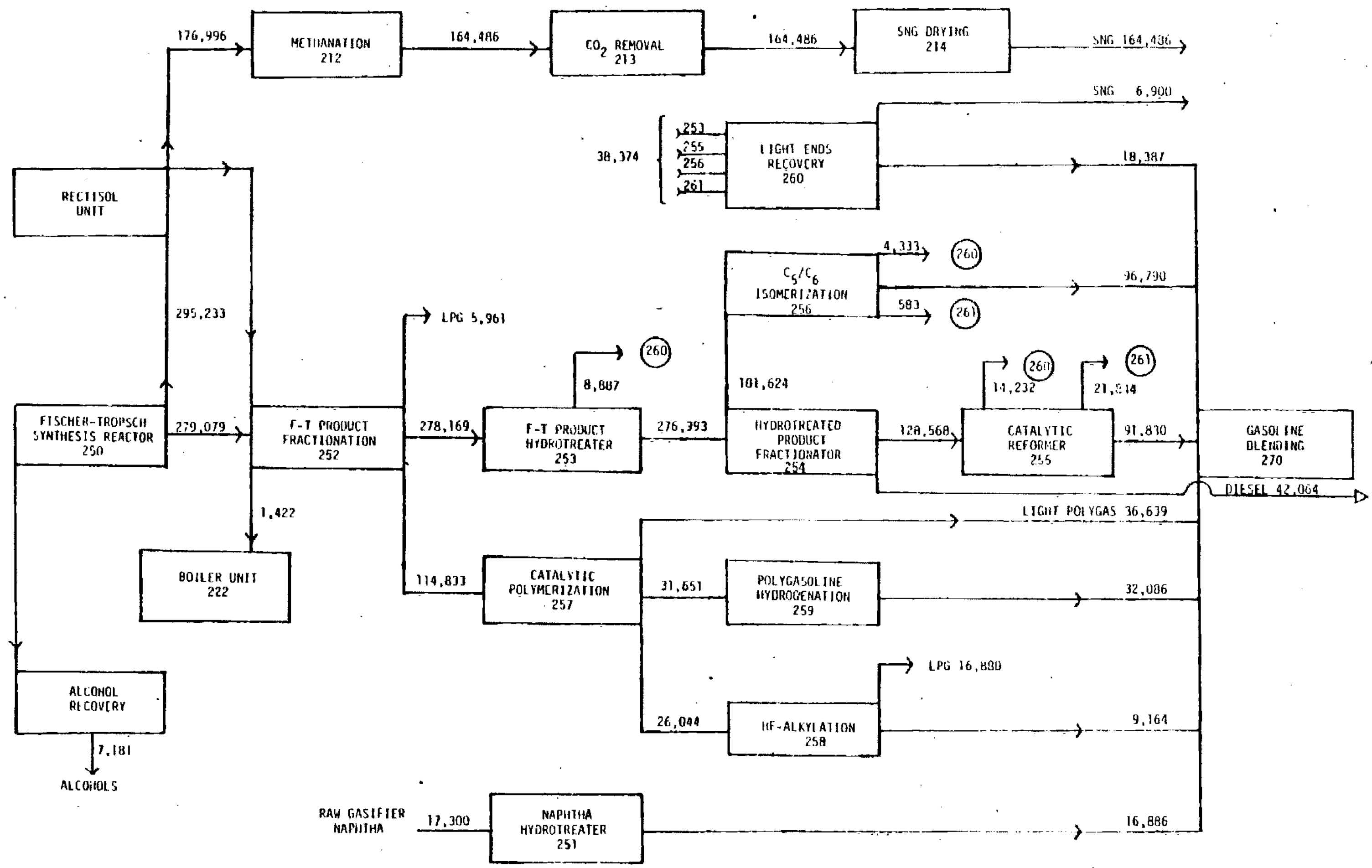


FIGURE B-1
F-T DOWNSTREAM PROCESSING (BGC-KOLBEL)
(UNITS LBS/HR)

APPENDIX C

PLANT CONSTRUCTION COST ANALYSIS

The unit by unit cost analysis prepared by MRDC for the SASOL-U.S. Base Case presented in Reference 1 has been used as the primary basis for estimates of the contruction cost of the revised indirect liquefaction plant considered in this study. The methodology used is described below.

1. Establish a flow diagram for the revised plant.

2. Determine the required capacity for each process unit which is common between the revised plant and the Base Case.

3. Adjust the construction cost of each unit based on unit capacity using a .7 exponential scaling factor. For example:

$$\text{Revised Cost} = \text{Base Case Cost} \left(\frac{\text{Revised Capacity}}{\text{Base Case Capacity}}\right)^{0.7}$$

4. Obtain best available data from the literature and/or vendor sources for units in the revised plant which are not common to the base case. Adjust these data to 1977 $ where applicable. Total construction cost for each revised plant is computed as the sum of unit costs plus certain miscellaneous items common to all plants. Capital cost is assumed to exceed construction cost by a factor of 1.59 as in the base case.

Tables C-1 through C-7 show the detailed computation for each revised plant considered in this study. The basis of unit cost data from sources other than Reference 1, and other pertinent details are provided in descriptive notes to the tables.

TABLE C-1
SASOL-U.S. BASE CASE

SASOL-U.S.		MIXED OUTPUT		ALL-LIQUID		
UNIT	DESCRIPTION	CAPACITY	COST $ MM	CAPACITY	NOTE	COST $ MM
COAL AND ASH HANDLING			71.4		1	71.4
228	Coal Handling	27.8 M T/D				
229	Ash Handling	1.4 M T/D				
	Coal Dryer	N.A.				
	Slurry Preparation	N.A.				
SYNTHESIS GAS PREPARATION			331.6		1	331.6
201	Gasifiers	1,901 M lb/hr	200.7			
202	Raw Gas Shift	36 M lb moles	12.8			
203	Raw Gas Cooling	156 M lb moles	13.3			
204	Shifted Gas Cooling	36 M lb moles	6.0			
205	Gas Purification	116 M lb moles	71.7			
241	Refrigeration	(For unit 205)	27.1			
BY-PRODUCT RECOVERY			110.4		1	110.4
206	Sulfur Recovery	35 M lb moles CO_2	59.0			
207	Gas/Liquor Separation	55 M lb moles H_2O	18.6			
208	Phenol Recovery	85 M lb moles H_2O	14.0			
209	Ammonia Recovery	85 M lb moles H_2O	18.8			
GASIFIER NAPHTHA TREATMENT			12.5		1	12.5
211	Hydrogen Recovery	1.1 M lb moles	8.7			
251	Naphtha Hydrotreating	15,922 lb/hr	3.7			
SYNTHESIS			104.1		2	157.1
250	Synthol Reactors	4,696 MM Btu/hr	76.4	10,752 MM Btu/hr	2	109.1
271	Catalyst Preparation	30 T/D	27.7	65.7 T/D	2	48.0
SNG PREPARATION OR REFORMING			24.3			40.7
212	Methanation	173.3 MM SCF/D	12.0			
213	CO_2 Removal	Total SNG	9.2			
214	Drying and Compression	Output	3.1			
116	Autothermal Reformer	N.A.			3	40.7
F-T LIQUID PRODUCT RECOVERY AND UPGRADE		(18,093 B/D Liquid Fuels)	92.1	39,695 B/D Liquids	2	159.6
210	Hydrocarbon Recovery	534 M lb/hr Flow	19.4			
252	F-T Product Fract.	275 M lb/hr	14.5			
253	Product Hydrotreating	124 M lb/hr	6.6			
254	Hyd. Product Fract.	123 M lb/hr	3.8			
255	Catalytic Reforming	47 M lb/hr	7.3			
256	C_5/C_6 Isomerization	37 M lb/hr	5.3			
257	Cat. Polymerization	53 M lb/hr	4.1			
258	HF Alkylation	10 M lb/hr	2.2			
259	Poly Gasoline Hydro.	20 M lb/hr	2.4			
260	Light Ends Recovery	8 M lb/hr	2.2			
261	H_2 Purification	2.2 M lb/hr	2.7			
262	Alcohol Recovery	1,629 B/D	11.0			
270	Gasoline Blending	13,580 B/D	2.0			
237	Storage	α to Total Liquids	8.6			
x205	Rectisol					
OFFSITES AND MISC.			429.7			499.4
221	Oxygen Plant	458 M lb/hr	110.1	702 M lb/hr	2	148.5
222-223	Boiler, Main Superheater	3111 M lb/hr steam	146.6			
225-226	Stack Precip. Cleanup					
224	LP and MP Superheater		1.6			
231	BFW Preparation		20.6	3,519 lb/hr		
232	CW Make-up		.5			
233	CW Towers		23.3			
236	Blow-down Facilities		2.7			
	(Subtotal for Steam Plant)		195.3		2,4	212.9
235	Waste Water Treatment	2.1 MM lb/hr	26.3	2.53 MM lb/hr	2	30.0
234	Power Generation		10.6		1	10.6
238	Interconnecting Piping		20.4		1	20.4
	Infrastructure		46.4		1	46.4
	Other Misc.		30.6		1	30.6
		TOTAL	1,186.1			

TABLE C-2
BGC GASIFICATION/SYNTHOL SYNTHESIS

SASOL-U.S., MIXED OUTPUT				BGC/SYNTHOL					
				MIXED OUTPUT			ALL-LIQUID		
UNIT	DESCRIPTION	CAPACITY	COST $ MM	CAPACITY	NOTE	COST $ MM	CAPACITY	NOTE	COST $ MM
COAL AND ASH HANDLING			71.4		1	71.4		1	71.4
228	Coal Handling	27.8 M T/D							
229	Ash Handling	1.4 M T/D							
	Coal Dryer	N.A.							
	Slurry Preparation	N.A.							
SYNTHESIS GAS PREPARATION			331.6			258.3		8	258.3
201	Gasifiers	1,901 M lb/hr	200.7	2,070 M lb/hr	5	100.4			
202	Raw Gas Shift	36 M lb moles	12.8	159 M lb moles	6	30.0			
203	Raw Gas Cooling	156 M lb moles	13.3	NA					
204	Shifted Gas Cooling	36 M lb moles	6.0	159 M lb moles	7	13.5			
205	Gas Purification	116 M lb moles	71.7	143.5 M lb moles	2	83.0			
241	Refrigeration	(For unit 205)	27.1		2	31.4			
BY-PRODUCT RECOVERY			110.4			80.3		8	80.3
206	Sulfur Recovery	35 M lb moles CO_2	59.0	40 M lb moles	2	64.8			
207	Gas/Liquor Separation	55 M lb moles H_2O	18.6	15.5 M lb moles	2	5.6			
208	Phenol Recovery	35 M lb moles H_2O	14.0	15.5 M lb moles	2	4.2			
209	Ammonia Recovery	85 M lb moles H_2O	18.9	15.5 M lb moles	2	5.7			
GASIFIER NAPHTHA TREATMENT			12.5	1,630 B/D	2	13.3		8	13.3
211	Hydrogen Recovery	1.1 M lb moles	8.7						
251	Naphtha Hydrotreating	15,922 lb/hr	3.7						
SYNTHESIS			104.1			134.9			201.3
250	Synthol Reactors	4,896 MM Btu/hr	76.4	7,092 MM Btu/hr	2	99.0	12,559 MM Btu/hr		147.7
271	Catalyst Preparation	30 T/D	27.7	43.5 T/D	2	35.9	77 T/D		53.6
SNG PREPARATION OR REFORMING			24.3		2	21.7			36.5
212	Methanation	173.3 MM SCF/D	12.0	147.9 MM SCF/D					
213	CO_2 Removal	Total SNG	9.2	Total SNG					
214	Drying and Compression	Output	3.1	Output					
116	Autothermal Reformer	NA		NA				3	36.5
F-T LIQUID PRODUCT RECOVERY AND UPGRADE		(18,093 B/D Liquid Fuels)	92.1	26,217 B/D	2	119.4	44,751 B/D	2	173.6
210	Hydrocarbon Recovery	534 M lb/hr Flow	19.4						
252	F-T Product Fract.	275 M lb/hr	14.5						
253	Product Hydrotreating	124 M lb/hr	6.6						
254	Hyd. Product Fract.	123 M lb/hr	3.8						
255	Catalytic Reforming	47 M lb/hr	7.3						
256	C_5/C_6 Isomerization	37 M lb/hr	5.3						
257	Cat. Polymerization	53 M lb/hr	4.1						
258	HF Alkylation	10 M lb/hr	2.2						
259	Poly Gasoline Hydro.	20 M lb/hr	2.4						
260	Light Ends Recovery	8 M lb/hr	2.2						
261	H_2 Purification	2.2 M lb/hr	2.7						
262	Alcohol Recovery	1,829 B/D	11.0						
270	Gasoline Blending	13,580 B/D	2.0						
237	Storage	σ to Total Liquids	8.6						
x205	Rectisol								
OFFSITES AND MISC.			429.7			405.0			454.7
221	Oxygen Plant	458 M lb/hr	110.1	545 M lb/hr	2	124.3	750 M lb/hr	2	155.5
222-223	Boiler, Main Superheater	3111 M lb/hr steam	146.6	2,264 M lb/hr			2,612 M lb/hr		
225-226	Stack Precip. Cleanup								
224	LP and MP Superheater		1.6						
231	BFW Preparation		20.6		2,4	156.4		2,4	172.8
232	CW Make-up		.5						
233	CW Towers		23.3						
236	Blow-down Facilities		2.7						
	(Subtotal for Steam Plant = 195.3)								
235	Waste Water Treatment	2.1 MM lb/hr	26.3	1.06 MM lb/hr	2	16.3	1.26 MM lb/hr	2	18.4
234	Power Generation		10.6		1	10.6		1	10.6
238	Interconnecting Piping		20.4		1	20.4		1	20.4
	Infrastructure		46.4		1	46.4		1	46.4
	Other Misc.		30.6		1	30.6		1	30.6
		TOTAL	1,186.1			1,104.3			1,289.4

TABLE C-3
TEXACO GASIFICATION SYNTHOL SYNTHESIS

SASOL - U.S., MIXED OUTPUT				TEXACO - SYNTHOL					
				MIXED OUTPUT			ALL-LIQUID		
UNIT	DESCRIPTION	CAPACITY	COST $ MM	CAPACITY	NOTE	COST $ MM	CAPACITY	NOTE	COST $ MM
COAL AND ASH HANDLING			71.4			95.2			95.2
228	Coal Handling	27.8 M T/D	65.6	25.5 M T/D	2	68.4	25.5 T/D	2	68.4
229	Ash Handling	1.4 M T/D	5.8	inc. in cooler			inc. in cooler		
	Coal Dryer	N.A.		27.8 T/D	9	20.0	27.8 T/D	9	20.0
	Slurry Preparation	N.A.			10	6.8		10	6.8
SYNTHESIS GAS PREPARATION			331.6			299.8			299.8
201	Gasifiers	1,901 M lb/hr	200.7		11	53.0		11	53.0
202	Raw Gas Shift	36 M lb moles	12.8	184 M lb moles	6	30.0	184 M lb moles	6	30.0
203	Raw Gas Cooling	156 M lb moles	13.3		11	67.0		11	67.0
204	Shifted Gas Cooling	36 M lb moles	6.0	184 M lb moles	7	14.9	164 M lb moles	7	14.9
205	Gas Purification	116 M lb moles	71.7	181 M lb moles	2	97.9	181 M lb moles	2	97.9
241	Refrigeration	(For unit 205)	27.1			37.0			37.0
BY-PRODUCT RECOVERY			110.4			75.6			75.6
206	Sulfur Recovery	35 M lb moles CO_2	59.0	44 M lb moles	2	69.3	44 M lb moles	2	69.3
207	Gas/Liquor Separation	55 M lb moles H_2O	18.6	NA			NA		
208	Phenol Recovery	85 M lb moles H_2O	14.0	NA			NA		
209	Ammonia Recovery	85 M lb moles H_2O	18.8	18 M lb moles H_2O	2	6.3	18 M lb moles		6.3
GASIFIER NAPHTHA			12.5	NA			NA		
211	Hydrogen Recovery	1.1 M lb moles	8.7						
251	Naphtha Hydrotreating	15,922 lb/hr	3.7						
SYNTHESIS			104.1			136.1			203.3
250	Synthol Reactors	4,896 MM Btu/hr	76.4	9,253 MM Btu/hr	2	97.7	12,737 MM Btu/hr		149.2
271	Catalyst Preparation	30 T/D	27.7			38.4	78.1 T/D		54.1
SNC PREPARATION OR REFORMING			24.3		2	16.8			23.2
212	Methanation	173.2 MM SCF/D	12.0	102.8 MM SCF/D					
213	CO_2 Removal	Total SNG	9.2	Total SNG					
214	Drying and Compression	Output	3.1	Output					
116	Autothermal Reformer	N.A.		NA				3 c	23.2
F-T LIQUID PRODUCT RECOVERY AND UPGRADE		(18,093 b/D Liquid Fuels)	92.1	34,182 B/SD	2	143.8	47,061 B/SD		179.8
210	Hydrocarbon Recovery	534 M lb/hr Flow	19.4						
252	F-T Product Fract.	275 M lb/hr	14.5						
253	Product Hydrotreating	124 M lb/hr	6.6						
254	Hyd. Product Fract.	123 M lb/hr	3.8						
255	Catalytic Reforming	47 M lb/hr	17.3						
256	C_5/C_6 Isomerization	37 M lb/hr	5.3						
257	Cat. Polymerization	53 M lb/hr	4.1						
258	HF Alkylation	10 M lb/hr	2.2						
259	Poly Gasoline Hydro.	20 M lb/hr	2.4						
260	Light Ends Recovery	8 M lb/hr	2.2						
261	H_2 Purification	2.2 M lb/hr	2.7						
262	Alcohol Recovery	1,829 B/D	11.0						
270	Gasoline Blending	13,380 B/D	2.0						
237	Storage	σ to Total Liquids	8.6						
x205	Rectisol								
OFFSITES AND MISC.			429.7			399.5			408.5
221	Oxygen Plant	456 M lb/hr	110.1	1,296 M lb/hr	2	228.0	1,442 M lb/hr	2	245.7
222-223 225-226	Boiler, Main Superheater Stack Precip. Cleanup	3111 M lb/hr steam	146.6						
224	LP and MP Superheater		1.6		1	1.6		1	1.6
231	BFW Preparation		20.6	3,070 M lb/hr	1	20.6		1	20.6
232	CW Make-up		.5	Plant Fired	1	.5		1	.5
233	CW Towers		23.3	by Gas Cooler	1	23.3		1	23.3
236	Blow-down Facilities		2.7		1	2.7		1	2.7
	(Subtotal for Steam Plant)		195.3						
235	Waste Water Treatment	2.1 MM lb/hr	26.3	256 M lb/hr	12	6.1	502 M lb/hr	12	9.7
234	Power Generation		10.6		1	10.6			10.6
238	Interconnecting Piping		20.4		1	20.4			20.4
	Infrastructure		46.4		1	46.4			46.4
	Other Misc.		30.6		1	30.6			30.6
		TOTAL	1,185.1			1,167.1			1,289.0

TABLE C-4
SHELL KOPPERS GASIFICATION SYNTHESIS

SASOL-U.S., MIXED OUTPUT				SHELL KOPPERS/SYNTHOL					
				MIXED PRODUCT			ALL-LIQUID		
UNIT	DESCRIPTION	CAPACITY	COST $ MM	CAPACITY	NOTE	COST $ MM	CAPACITY	NOTE	COST $ MM
COAL AND ASH HANDLING			71.4			89.0			89.0
228	Coal Handling	27.8 M T/D	55.6	29.9 M T/D	2	69.0	29.9 M T/D	2	69.0
229	Ash Handling	1.4 M T/D		inc. in cooler			inc. in cooler		
	Coal Dryer	N.A.				20.0			20.0
	Slurry Preparation	N.A.							
SYNTHESIS GAS PREPARATION			331.6			307.7			307.7
201	Gasifiers	1,901 M lb/hr	200.7		21	53.0		21	53.0
202	Raw Gas Shift	36 M lb moles	12.8	174.6 M lb moles	6	30.0		6	30.0
203	Raw Gas Cooling	156 M lb moles	13.3		21	67.0		21	67.0
204	Shifted Gas Cooling	36 M lb moles	6.0	214		16.6	214		16.6
205	Gas Purification	116 M lb moles	71.7	193		102.4	193		102.4
241	Refrigeration	(For unit 205)	27.1			38.7			38.7
BY-PRODUCT RECOVERY			110.4			90.1			90.1
206	Sulfur Recovery	35 M lb moles CO_2	59.0	57 M lb moles		83.0			83.0
207	Gas/Liquor Separation	55 M lb moles H_2O	16.6	NA					
208	Phenol Recovery	85 M lb moles H_2O	14.0	NA					
209	Ammonia Recovery	85 M lb moles H_2O	18.8	21 M lb moles/hr		7.1	21 M lb moles/hr		7.1
GASIFIER NAPHTHA			12.5	NA			NA		
211	Hydrogen Recovery	1.1 M lb moles	8.7						
251	Naphtha Hydrotreating	15,922 lb/hr	3.7						
SYNTHESIS			104.1			173.4			216.8
250	Synthol Reactors	4,896 MM Btu/hr	76.4	10,148 MMBtu/hr		127.3	13,964 MMBtu/hr		159.1
271	Catalyst Preparation	30 T/D	27.7	62		46.1	85.6		57.7
SNG PREPARATION OR REFORMING			24.3			18.0			30.1
212	Methanation	173.3 MM SCF/D	12.0	112.3 MSF/Day					
213	CO_2 Removal	Total SNG	9.2						
214	Drying and Compression	Output	3.1					3	30.1
116	Autothermal Reformer	N.A.							
F-T LIQUID PRODUCT RECOVERY AND UPGRADE		(18,093 B/D Liquid Fuels)	92.1	37,489 B/D		153.5	51,586 B/D		191.8
210	Hydrocarbon Recovery	534 M lb/hr Flow	19.4						
252	F-T Product Fract.	275 M lb/hr.	14.5						
253	Product Hydrotreating	124 M lb/hr	6.6						
254	Hyd. Product Fract.	123 M lb/hr	3.8						
255	Catalytic Reforming	47 M lb/hr	7.3						
256	C_5/C_6 Isomerization	37 M lb/hr	5.3						
257	Cat. Polymerization	53 M lb/hr	4.1						
258	HF Alkylation	10 M lb/hr	2.2						
259	Poly Gasoline Hydro.	20 M lb/hr	2.4						
260	Light Ends Recovery	8 M lb/hr	2.2						
261	H_2 Purification	2.2 M lb/hr	2.7						
262	Alcohol Recovery	1,829 B/D	11.0						
270	Gasoline Blending	13,580 B/D	2.0						
237	Storage	α to Total Liquids	8.6						
x205	Rectisol								
OFFSITES AND MISC.			429.7			399.7			421.7
221	Oxygen Plant	458 M lb/hr	110.1	1284	2	226.6	1,443	2	245.7
222-223	Boiler, Main Superheater	3111 M lb/hr steam	146.6						
225-226	Stack Precip. Cleanup								
224	LP and HP Superheater		1.6		1	1.6			1.6
231	BFW Preparation		20.6		1	20.6			20.6
232	CW Make-up		.5		1	.5			.5
233	CW Towers		23.3		1	23.3			23.3
236	Blow-down Facilities		2.7		1	2.7			2.7
	(Subtotal for Steam Plant)		195.3						
235	Waste Water Treatment	2.1 MM lb/hr	26.3	1.07		16.4	1.35		19.3
234	Power Generation		10.6		1	10.6		1	10.6
238	Interconnecting Piping		20.4		1	20.4		1	20.4
	Infrastructure		46.4		1	46.4		1	46.4
	Other Misc.		30.6		1	30.6		1	30.6
		TOTAL	1,186.1			1,231.4			1,347.2

TABLE C-5
BGC GASIFICATION/KOLBEL SYNTHESIS

SASOL-U.S., MIXED OUTPUT				BGC-KOLBEL					
				MIXED PRODUCT			ALL-LIQUID		
UNIT	DESCRIPTION	CAPACITY	COST $ MM	CAPACITY	NOTE	COST $ MM	CAPACITY	NOTE	COST $ MM
COAL AND ASH HANDLING			71.4		1	71.4		1	71.4
228	Coal Handling	27.8 M T/D							
229	Ash Handling	1.4 M T/D							
	Coal Dryer	N.A.							
	Slurry Preparation	N.A.							
SYNTHESIS GAS PREPARATION			331.6			226.5		6	226.5
201	Gasifiers	1,901 M lb/hr	200.7	2,100 M lb/hr	5	100.4			
202	Raw Gas Shift	36 M lb moles	12.8	30.6 M lb/hr	2	11.36			
203	Raw Gas Cooling	156 M lb moles	13.3	107 M lb/hr	2	10.22			
204	Shifted Gas Cooling	36 M lb moles	6.0	30.6 M lb/hr	2	5.32			
205	Gas Purification	116 M lb moles	71.7	106 M lb/hr	2	67.16			
241	Refrigeration	(For unit 205)	27.1	247.7 M lb/hr*	13	32.1			
BY-PRODUCT RECOVERY			110.4			48.4		8	48.4
206	Sulfur Recovery	35 M lb moles CO_2	59.0	10 M lb moles	2	24.56			
207	Gas/Liquor Separation	55 M lb moles H_2O	18.6	32 M lb moles	2	9.38			
208	Phenol Recovery	85 M lb moles H_2O	14.0	32 M lb moles	2	7.04			
209	Ammonia Recovery	85 M lb moles H_2O	18.8	32 M lb moles	2	9.43			
GASIFIER NAPHTHA TREATMENT			12.5		2	13.2		6	13.2
211	Hydrogen Recovery	1.1 M lb moles	8.7			3.92			
251	Naphtha Hydrotreating	15,922 lb/hr	2.7	17,300 lb/hr		9.33			
SYNTHESIS			104.1			155.7			187.5
250	Synthol Reactors	4,896 MM Btu/hr	76.4	8,319 MM Btu/hr	17	132.8	10,510 MM Btu/hr		159.6
271	Catalyst Preparation	30 T/D	27.7	23.4 T/D	14	22.9	30.4 T/D		27.9
SNG PREPARATION OR REFORMING			24.3		2	15.9			26.5
212	Methanation	[173.3 MM SCF/D	12.0	94.2 MM SCF/D					
213	CO_2 Removal	Total SNG	9.2	94.2 MM SCF/D					
214	Drying and Compression	Output	3.1	94.2 MM SCF/D					
116	Autothermal Reformer	N.A.]		NA			92.4 M SCF/D	3	26.5
F-T LIQUID PRODUCT RECOVERY AND UPGRADE		(18,093 B/D Liquid Fuels)	92.1	37,060 B/SD		146.6	48,736 B/SD	2	177.6
210	Hydrocarbon Recovery	534 M lb/hr Flow	19.4						
252	F-T Product Fract.	275 M lb/hr	14.5	397 M lb/hr	2	18.7			
253	Product Hydrotreating	124 M lb/hr	6.6	378 M lb/hr	2	11.6			
254	Hyd. Product Fract.	123 M lb/hr	3.8	277 M lb/hr	2	6.7			
255	Catalytic Reforming	47 M lb/hr	7.3	124 M lb/hr	2	14.8			
256	C_5/C_6 Isomerization	37 M lb/hr	5.3	102 M lb/hr	2	10.8			
257	Cat. Polymerization	53 M lb/hr	4.1	115 M lb/hr	2	7.1			
258	HF Alkylation	10 M lb/hr	2.2	26 M lb/hr	2	4.3			
259	Poly Gasoline Hydro.	20 M lb/hr	2.4	32 M lb/hr	2	3.3			
260	Light Ends Recovery	8 M lb/hr	2.2	38 M lb/hr	2	6.5			
261	H_2 Purification	2.2 M lb/hr	2.7		16	5.4			
262	Alcohol Recovery	1,829 B/D	11.0	618 B/D	2	5.1			
270	Gasoline Blending	15,580 B/D	2.0	30,766 B/D	2	3.5			
237	Storage	σ to Total Liquids	8.6	38,667 B/D	2	13.8			
x205	Rectisol	116 M lb moles	71.7	41,795 lb moles/hr	2	35.0			
OFFSITES AND MISC.			429.7			390.1			
221	Oxygen Plant	456 M lb/hr	110.1	553 M lb/hr	2	125.6	710 M lb/hr	2	151.6
222-223	Boiler, Main Superheater	3111 M lb/hr steam	146.6	2,033 M lb/hr			2,317 M lb/hr		
225-226	Stack Precip. Cleanup								
224	LP and MP Superheater		1.6						
231	BFW Preparation		20.6						
232	CW Make-up		.5						
233	CW Towers		23.3						
236	Blow-down Facilities		2.7						
	(Subtotal for Steam Plant = 195.3)			Subtotal		145.0	Subtotal		158.9
							563 M lb/hr	2	10.7
235	Waste Water Treatment	2.1 MM lb/hr	26.3	646 M lb/hr	2	11.5			10.6
234	Power Generation		10.6		2	10.6			
238	Interconnecting Piping		20.4						
	Infrastructure		46.4	97.4	1	97.4			
	Other Misc.		30.6					1	97.[illegible]
		TOTAL	1,186.1			1,067.9			1,180.4

TABLE C-6
TEXACO GASIFICATION/KOLBEL SYNTHESIS

SASOL-U.S., MIXED OUTPUT				TEXACO-KOLBEL, ALL LIQUIDS CASE		
UNIT	DESCRIPTION	CAPACITY	COST $ MM	CAPACITY	NOTE	COST $ MM
COAL AND ASH HANDLING			71.4		18	95.2
228	Coal Handling	27.8 M T/D				
229	Ash Handling	1.4 M T/D				
	Coal Dryer	N.A.				
	Slurry Preparation	N.A.				
SYNTHESIS GAS PREPARATION			331.6			254.9
201	Gasifiers	1,001 M lb/hr	200.7		18	53.0
202	Raw Gas Shift	36 M lb moles	12.8		19	--
203	Raw Gas Cooling	156 M lb moles	13.3		18	67.0
204	Shifted Gas Cooling	36 M lb moles	6.0		19	--
205	Gas Purification	116 M lb moles	71.7		18	97.9
241	Refrigeration	(For unit 205)	27.1		18	37.0
BY-PRODUCT RECOVERY			110.4			45.2
206	Sulfur Recovery	35 M lb moles CO_2	59.0	16.8 M lb moles CO_2	2	35.3
207	Gas/Liquor Separation	55 M lb moles H_2O	18.6	NA		
208	Phenol Recovery	85 M lb moles H_2O	14.0	NA		
209	Ammonia Recovery	85 M lb moles H_2O	18.8	34 M lb moles H_2O	2	9.9
GASIFIER NAPHTHA TREATMENT			12.5			
211	Hydrogen Recovery	1.1 M lb moles	8.7			
251	Naphtha Hydrotreating	15,922 lb/hr	3.7			
SYNTHESIS			104.1			194.7
250	Synthol Reactors	4,896 MM Btu/hr	76.4	11,408 MM Btu/hr	17	165.7
271	Catalyst Preparation	30 T/D	27.7	32 T/D	14	29.0
SNG PREPARATION OR REFORMING			24.3			
212	Methanation	[173.3 MM SCF/D	12.0			
213	CO_2 Removal	Total SNG	9.2			
214	Drying and Compression	Output	3.1			
116	Autothermal Reformer	N.A.]		29.8 MM SCF/D	3	11.9
F-T LIQUID PRODUCT RECOVERY AND UPGRADE		(18,093 B/D Liquid Fuels)	92.1	51,390 B/SD	20	184.3
210	Hydrocarbon Recovery	534 M lb/hr Flow	19.4			
252	F-T Product Fract.	275 M lb/hr	14.5			
253	Product Hydrotreating	124 M lb/hr	6.6			
254	Hyd. Product Fract.	123 M lb/hr	3.8			
255	Catalytic Reforming	47 M lb/hr	7.3			
256	C_5/C_6 Isomerization	37 M lb/hr	5.3			
257	Cat. Polymerization	53 M lb/hr	4.1			
258	HF Alkylation	10 M lb/hr	2.2			
259	Poly Gasoline Hydro.	20 M lb/hr	2.4			
260	Light Ends Recovery	8 M lb/hr	2.2			
261	H_2 Purification	2.2 M lb/hr	2.7			
262	Alcohol Recovery	1,829 B/D	11.0			
270	Gasoline Blending	13,580 B/D	2.0			
237	Storage	α to Total Liquids	8.6			
x205	Rectisol					
OFFSITES AND MISC.			429.7			379.3
221	Oxygen Plant	458 M lb/hr	110.1	1.338 M lb/hr	2	233.2
222-223 225-226	Boiler, Main Superheater Stack Precip. Cleanup	3111 M lb/hr steam	146.6			
224	LP and MP Superheater		1.6		1	1.6
231	BFW Preparation		20.6		1	20.6
232	CW Make-up		.5		1	.5
233	CW Towers		23.3		1	23.3
236	Blow-down Facilities		2.7		1	2.7
	(Subtotal for Steam Plant = 195.3)			(Subtotal 48.7)		
235	Waste Water Treatment	2.1 MM lb/hr	26.3			
234	Power Generation		10.6			10.6
238	Interconnecting Piping		20.4			20.4
	Infrastructure		46.4			46.4
	Other Misc.		30.6			30.6
		TOTAL	1,186.1			1,176.1

TABLE C-7
SHELL KOPPERS GASIFICATION/KOLBEL SYNTHESIS

SASOL-U.S., MIXED OUTPUT				SHELL-KOPPERS/KOLBEL					
				MIXED OUTPUT			ALL LIQUID		
UNIT	DESCRIPTION	CAPACITY	COST $ MM	CAPACITY	NOTE	COST $ MM	CAPACITY	NOTE	COST $ MM
COAL AND ASH HANDLING			71.4		22	89.0		22	89.0
228	Coal Handling	77.8 M T/D							
229	Ash Handling	1.4 M T/D							
	Coal Dryer	N.A.							
	Slurry Preparation	N.A.							
SYNTHESIS GAS PREPARATION			331.6			255.5			255.5
201	Gasifiers	1,901 M lb/hr	200.7		22	53		22	53
202	Raw Gas Shift	36 M lb moles	12.8	36 M lb moles		12.8			12.8
203	Raw Gas Cooling	156 M lb moles	13.3		21	67.0		21	67.0
204	Shifted Gas Cooling	36 M lb moles	6.0	181 M lb/moles	2	14.8		2	14.8
205	Gas Purification	116 M lb moles	71.7	132 M lb/moles	2	78.2		2	78.2
241	Refrigeration	(For Unit 205)	27.1			29.7			29.7
BY-PRODUCT RECOVERY			110.4			41.3			41.3
206	Sulfur Recovery	35 M lb moles CO_2	59.0	12.4		28.5			28.5
207	Gas/Liquor Separation	55 M lb moles H_2O	18.6	NA					
208	Phenol Recovery	85 M lb moles H_2O	14.0	NA					
209	Ammonia Recovery	85 M lb moles H_2)	18.8	49 M lb/moles		12.8			12.8
GASIFIER NAPHTHA			12.5						
211	Hydrogen Recovery	1.1 M lb moles	8.7						
251	Naphtha Hydrotreating	15,922 lb/hr	3.7						
SYNTHOL SYNTHESIS			104.1			197.4			207.3
250	Synthol Reactors	4,896 MM SCF/D	76.4	11612	17	167.8	12470	17	176.4
271	Catalyst Preparation	30 T/D	27.7	33		29.6	35		30.9
SNG PREPARATION OR REFORMING			24.3		2	7.3		3	12.2
212	Methanation	173.3 MM SCF/D	12.0	31.21 MM SCF/D					
213	CO_2 Removal	Total SNG	9.2	Total SNG					
214	Drying and Compression	Output	3.1						
216	Autothermal Reformer	N.A.							
F-T LIQUID PRODUCT RECOVERY AND UPGRADE		(18,093 B/D Liquid Fuels)	192.1	52307 B/SD	20	136.6	56173 B/SD	20	195.1
250	Hydrocarbon Recovery	534 M lb/hr Flow	19.4						
252	F-T Product Fract.	275 M lb/hr	14.5						
253	Product Hydrotreating	124 M lb/hr	6.6						
254	Hyd. Product Fract.	123 M lb/hr	3.8						
255	Catalytic Reforming	47 M lb/hr	7.3						
256	C_5/C_6 Isomerization	37 M lb/hr	5.3						
257	Cat. Polymerization	53 M lb/hr	4.1						
258	HF Alkylation	10 M lb/hr	2.2						
259	Poly Gasoline Hydro.	20 M lb/hr	2.4						
260	Light Ends Recovery	.8 M lb/hr	2.2						
261	H_2 Purification	2.2 M lb/hr	2.7						
262	Alcohol Recovery	1,829 B/D	71.0						
270	Gasoline Blending	13,580 B/D	2.0						
237	Storage	to Total Liquids	6.6						
x205	Rectisol.								
OFFSITES AND MISC.			429.7						392.1
221	Oxygen Plant	458 M. lb/hr	110.3	1284	2	226.6	1328		232.0
222-223	Boiler, Main Superheater	3111 M lb/hr steam	146.6						
225-226	Stack Precip. Cleanup								
224	LP and MP Superheater		1.6			1.6			1.6
231	BFW Preparation		20.5			20.6			20.6
232	CW Make-up		.5			.5			.5
233	CW Towers		23.3			23.3			23.3
236	Blow-down Facilities		2.7			2.7			2.7
	(Subtotal for Steam Plant)		195.3	(Subtotal = 48.7)			(Subtotal = 48.7)		
235	Waste Water Treatment	2.1 x 10^6	26.3	115 M lb/hr	23,2	3.4		23,2	3.4
224	Power Generation		10.6		1	10.6		1	10.6
238	Interconnecting Piping		20.4		1	20.4		1	20.4
	Infrastructure		46.4		1	46.4		1	46.4
	Other Misc.		30.6		1	30.6		1	30.6
		TOTAL	1,186.1			1,163.3			1,193.5

Notes to Tables
C-1 - C-7

1. Unchanged from Base Case

2. Scaled on capacity using .7 scaling factor

3. Scaled from Mobil Case 1-B (Reference 13) on which an Autothermal Reformer Costing $36.5 MM was required to reform products which produced $48.5 MM SCF/D SNG in Mobil Case 1-B

4. Capacity of all units assumed proportional to steam plant

5. The unit cost of the BGC gasifier is assumed equal to the Lurgi Dry Bottom. Fourteen BGC units (12 operating and 2 spares) are required vice 28 Lurgi (25 operating and 2 spares) in the Base Case. Alternative costing methods using Conoco (Reference 8) or Flour (Reference 7) data would have produced much lower relative costs for BGC gasification

6. Vendor estimate of construction cost of two-reactor unit handling ~180,000 lb mole/hr

7. Scaled from Base Case unit 203

8. Unchange from corresponding Mixed Product Case

9. Vendor estimate

10. Pulverization, bi-model screening and slurry preparation are assumed to add 10% to coal handling costs

11. Scaled from Flour design for EPRI (Reference 7) using .7 scale factor

12. Capacity based on waste water in access of slurry requirements.

13. Includes refrigeration for extra Rectisol unit used in liquid product recovery

14. Based on a catalyst requirement for the Kolbel reactor of 0.46 times the requirement of the Synthol reactor. (See Section 6.0)

15. Unit 210 unnecessary because of addition of extra Rectisol unit after the Kolbel F-T reactor

16. Scaled on ratio of flows to catalytic reformer since this is largest source of generated hydrogen in the refinery.

17. Scaled on base case Btu/hr to 0.7 factor with an additional 20% cost added as an estimate of the cost of a Kolbel reactor

18. Same as Texaco F-T case

19. No shift required for this case

20. Scaled from BGC-Kolbel all liquids case based on total barrels of liquids

21. Assumed equivalent to Texaco

22. Same as Shell-Koppers-Synthol case

23. Waste water generated is insufficient to meet quench requirements. Assume that 20% of quench water is slipstreamed to waste to prevent contaminant build up

This costing methodology is believed to provide a straightforward and accurate measure of the relative costs of plants considered herein. Interpretation of results based on absolute price levels should be avoided.

APPENDIX D

ANALYSIS OF PRODUCT COSTS

The MRDC Report(1) computes gasoline costs from the F-T plants on the basis of thermal product costs ($/MM Btu) and on the basis of multiple products (market basis).

In this report, all costs other than coal costs are considered proportional to construction cost, thus, for Base Case II, the value of the thermal product cost, not including coal cost, is $7.06/MM Btu (Equity 12% DCF). The cost of coal corresponding to this case is 0.72 cents/MM Btu output.

Thermal Basis costs are computed from this Base Case numbers for the cases considered in this report. The following example serves to illustrate the procedure used.

Case: BGC-Synthol Mixed Output

Thermal Basis Cost is computed as below:

7.06 x construction cost factor x HHV output factor + 0.72 x HHV factor where

$$\left.\begin{array}{ll} \text{construction cost factor} & = 1104.3/1186.1 = 0.931 \\ \text{and HHV output factor} & = 11238/11855 = 0.948 \end{array}\right\} \text{See Table IV-1}$$

= (7.06 x 0.931 x 0.948) + (0.72 x 0.948) = 6.91 $/MM Btu.

Since 8.36 gallons of F-T gasoline are equivalent to 1 MM Btu, the cost of gasoline/gallon on a thermal basis = 6.91/8.36 = 0.83 $. Total plant revenue required/hr = $\$81.918 \times 10^3$/hr.

Multiple products (market basis) costs are computed as below:

The basis used in the MRDC Report[1] for product pricing on an equity basis choses a plant gate price of \$6.17/MM Btu for SNG and C_3 LPG. For C_4 butanes an arbitrary 30¢/MM thermal value delta below gasoline was assumed.

Other assignments were:

Diesel Oil 1.70 \$/B delta

Fuel Oil 3.50 \$/B delta

Alcohols 15 cents/lb (equivalent to \$11.005/MM Btu).

These assumptions lead to the following table of simultaneous equations for the BGC-Synthol case considered here. G is the price of gasoline in \$/MM Btu.

	MM Btu/Hr	Cost/MM Btu	G	Constant
Gasoline	4005	G	4005	-
C_3	255	6.17	-	1573
C_4	38	G-0.3	38	-11
Diesel	745	0.94G-0.318	700	-237
Fuel Oil	213	0.88G-0.616	187	-131
Alcohols	417	11.005		4589
SNG	6180	6.17		38131
		Total	4930G	+43914

Since the total plant revenue is 81918 \$/hr, then G is determined by:

$$81918 = 4930G + 43914$$

$$G = 7.709 \text{ \$/MM Btu}$$

Gasoline price/gallon = 7.709/8.36 = <u>\$0.92</u>/gallon

All other cases, including liquid output cases, are computed in a similar manner to the example shown above. The results of the analyses are shown for all the cases considered in this report in Table D-1.

TABLE D-1

GASOLINE PRODUCT COSTS

	Construction Cost	HHV Output	Construction Cost Factor	HHV Factor	Capital Derived Cost	Coal Cost	$/MM Btu Total Cost	Gasoline $/Gallon Thermal Basis	1000 $/Hr	Market Basis Gasoline $/Gallon
Base Case (Mixed)	1186.1	11238	1	1	7.06	.72	7.78	.93	87.43	1.33
Base Case (All Liquid)	1382.7	8413	1.17	1.34	10.99	.96	11.95	1.43	100.54	1.51
BGC/Synthol (Mixed)	1104.3	11855	.931	.948	6.23	.68	6.91	.83	81.918	.92
BGC/Synthol (All Liquid)	1289.4	9444	1.097	1.19	9.13	.86	9.99	1.19	94.346	1.24
BGC/Kolbel (Mixed)	1067.9	11909	.900	.944	6.00	.68	6.68	.80	79.552	.84
BGC/Kolbel (All Liquid)	1180.4	10377	.995	1.083	7.61	.78	8.39	1.00	87.063	1.03
Texaco Synthol (All Liquid)	1289.0	9577	1.087	1.173	9.00	.91	9.91	1.19	94.908	1.23
Texaco/Kolbel (All Liquid)	1176.1	10583	0.9916	1.062	7.43	.82	8.25	.99	87.310	1.01
Texaco/Synthol (Mixed)	1167.1	11254	.984	.999	6.94	.77	7.71	.92	86.768	1.05
Shell Koppers/Synthol (Mixed)	1231.4	12333	1.038	.911	6.68	.70	7.38	.88	91.018	.98
Shell Koppers/Synthol (All Liquid)	1347.2	10499	1.135	.934	8.58	.83	9.41	1.13	98.795	1.16
Shell Koppers/Kolbel (Mixed)	1163.8	12077	.981	.931	6.44	.72	7.16	.86	86.471	.89
Shell Koppers/Kolbel (All Liquid)	1193.5	11568	1.006	.972	6.90	.75	7.65	.92	88.495	.94

* Coal cost is $/MMBtu of output.

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