
APPENDIX C
MATERIAL BALANCE (PARTIAL) - SENSITIVITY CASES

MATERIAL BALANCE

SENSITIVITY CASE I-A

STREAM N ^o	37	37.1	82.1	37.2	49
	FEED TO UNIT 150	METHANOL PRODUCT	WASTE WATER FROM UNIT 115	OFFGAS FROM UNIT 115	SNG PRODUCT
CO ₂	44.010 lbmol/hr				84.85
H ₂ S	34.076 lbmol/hr				
COS	60.070 lbmol/hr				
C ₂ H ₄	28.054 lbmol/hr				
CO	28.010 lbmol/hr				0.96
H ₂	2.016 lbmol/hr				270.30
CH ₄	16.043 lbmol/hr				
C ₂ H ₆	30.070 lbmol/hr				15 404.38
N ₂ +INERT	23.013 lbmol/hr				
O ₂	32.000 lbmol/hr				308.22
TOTAL DRY GAS (1)	lbmol/hr				16 068.71
H ₂ O	18.016 lbmol/hr				1.41
METHANOL	32.042 lbmol/hr				
TOTAL WET GAS (1)	lbmol/hr				16 070
TOTAL DRY GAS	lb/hr	1 369		235	260 073
H ₂ O	lb/hr		24 324		
METHANOL	lb/hr	587 956	245	100	
C ₃ H ₆	42.08 lbmol/hr				
C ₃ H ₈	44.09 lbmol/hr				
iC ₄ H ₁₀	58.12 lbmol/hr				
iC ₄ H ₈	56.10 lbmol/hr				
nC ₄ H ₁₀	58.12 lbmol/hr				
iC ₅ H ₁₂	72.15 lbmol/hr				
iC ₅ H ₁₀	70.13 lbmol/hr				
nC ₅ H ₁₂	72.15 lbmol/hr				
C ₆ +	(2) lbmol/hr				
NAPHTHA	lb/hr				
TOTAL	lb/hr	614 809	24 569	335	260 100
(1) C ₃ + INCLUDED					
(2) MW OF C ₆ +					

MATERIAL BALANCE

SENSITIVITY CASE I-B

STREAM N ^o	30	30.1	33	35	36
	FROM GAS FURIF UNIT 105	METH. SYNTHES. UNIT 110 FEED	H2 TO UNIT 151	EXPANSION GAS FROM UNIT 110	UNIT 105 SOL-VENT MAKE UP
CO ₂	44.010 lbmol/hr	7495.69		560.3	
H ₂ S	34.076 lbmol/hr				
COS	60.070 lbmol/hr				
C ₂ H ₄	28.054 lbmol/hr	23			
CO	28.010 lbmol/hr	30199.21		50.6	
H ₂	2.016 lbmol/hr	86345.98	96.22	164.0	
CH ₄	16.043 lbmol/hr	13729.7	1.37	574.1	
C ₂ H ₆	30.070 lbmol/hr	307		9.6	
N ₂ +INERT	28.013 lbmol/hr	5576		69.95	
O ₂	32.000 lbmol/hr				
TOTAL DRY GAS (1)	79845.89	143376.58	97.59	1429.55	
H ₂ O	18.016 lbmol/hr	160.46		3.3	1.6
METHANOL	32.042 lbmol/hr	1.31		245.21	20.7
TOTAL WET GAS (1)	79847.2	143838.35		1678.06	22.3
TOTAL DRY GAS	887321	1736181	216	37893	
H ₂ O	lb/hr	2891		59	29
METHANOL	lb/hr	42		7857	663
C ₃ H ₆	42.08 lbmol/hr				
C ₃ H ₈	44.09 lbmol/hr				
1C ₄ H ₁₀	58.12 lbmol/hr				
1C ₄ H ₈	56.10 lbmol/hr				
1C ₄ H ₁₀	58.12 lbmol/hr				
1C ₅ H ₁₂	72.15 lbmol/hr				
1C ₅ H ₁₀	70.13 lbmol/hr				
1C ₅ H ₁₂	72.15 lbmol/hr				
C ₆ +	(2) lbmol/hr				
NAPHTHA	lb/hr				
TOTAL	887363	1739114	216	45910	692
(1) C ₃ + INCLUDED					
(2) MW OF C ₆ +					

MATERIAL BALANCE

SENSITIVITY CASE I-B

STREAM NO	37	38	39	42
	FEED TO UNIT 150	PURGE GAS FROM UNIT 110	PURGE GAS TO INCINERATION	FEED TO UNIT 116 REFORMED GAS
CO ₂	54	2949.7	250.7	3263.6
H ₂ S				
COS				
C ₂ H ₄		22	1.9	29.8
CO	0.3	2116	179.9	2207.3
H ₂	0.4	17558.98	1492.5	16143.46
CH ₄	13.5	13142.1	1117.8	12662.83
C ₂ H ₆	3.4	294	25.0	336
E ₂ +INERT	0.05	5506	468	5108
O ₂		41588.78		
TOTAL DRY GAS (1)	71.65		3535.8	39750.99
H ₂ O	4178.1	3	0.26	6.04
METHANOL	32218.31	119	10.12	354.09
TOTAL WET GAS (1)	36468.06	41710.78	3546.18	40111.12
TOTAL DRY GAS	2706	59920	50929	595182
H ₂ O	204727	54	5	109
METHANOL	1032339	3813	324	11346
C ₃ H ₈	42.08			
C ₃ H ₆	44.09			
IC ₄ H ₁₀	58.12			
IC ₄ H ₈	56.10			
IC ₄ H ₁₀	58.12			
IC ₅ H ₁₂	72.15			
IC ₅ H ₁₀	70.13			
IC ₅ H ₁₂	72.15			
C ₆ +	(2)			
NAPHTHA				
TOTAL	110318	602887	51258	606637
(1) C ₁ + INCLUDED				
(2) MW OF C ₆ +				
				862943

MATERIAL BALANCE SENSITIVITY CASE I-B

STREAM NO	4.2	5.2	43.1	54
	OXYGEN TO UNIT 116	PROCESS STEAM UNIT 116	PROCESS COND. FROM UNIT 116	LIGHT GAS TO SNG
CO ₂	44.010 lbmol/hr			4.3
H ₂ S	34.076 lbmol/hr			
COS	60.070 lbmol/hr			
C ₂ H ₄	28.054 lbmol/hr			8.7
CO	28.010 lbmol/hr			220.6
H ₂	2.016 lbmol/hr			9.2
CH ₄	16.043 lbmol/hr			65.7
C ₂ H ₆	30.070 lbmol/hr			57.4
N ₂ + INERT	28.013 lbmol/hr			
O ₂	159			
	8219.38			
TOTAL DRY GAS (1)	8378.38			436.3
H ₂ O	18.016 lbmol/hr	24 846	26275.08	
METHANOL	32.042 lbmol/hr			
TOTAL WET GAS (1)	8378.38			436.3
TOTAL DRY GAS	lb/hr			13317
H ₂ O	267474	447626	473372	
METHANOL	lb/hr			
C ₃ H ₆	42.08 lbmol/hr			1.4
C ₃ H ₈	44.09 lbmol/hr			27.9
iC ₄ H ₁₀	58.12 lbmol/hr			20.3
1C ₄ H ₈	56.10 lbmol/hr			2.2
nC ₄ H ₁₀	58.12 lbmol/hr			4.8
iC ₅ H ₁₂	72.15 lbmol/hr			8.2
1C ₅ H ₁₀	70.13 lbmol/hr			1.4
nC ₅ H ₁₂	72.15 lbmol/hr			0.7
C ₆ +	(2) lbmol/hr			3.5
NAPHTHA	lb/hr			
TOTAL	267474	447626	473372	13317
(1) C ₃ + INCLUDED				
(2) MW OF C ₆ +				

MATERIAL BALANCE

SENSITIVITY CASE I-C

STREAM No	38+35 - 33	54	39	44	48
	PURGE GAS TO SNG	LIGHT GAS TO SNG	FEED TO UNIT 112	UNIT 112 PRODUCT GAS	UNIT 113 OFFGAS
CO ₂	44.010 lbmol/hr				
H ₂ S	34.076 lbmol/hr	44	1527.00	715.32	631.57
COS	60.070 lbmol/hr				
C ₂ H ₄	28.054 lbmol/hr	142	163.00		
CO	28.010 lbmol/hr	89.5	1358.3	13.24	
H ₂	2.016 lbmol/hr	253.2	8541.74	293.41	0.3
CH ₄	16.043 lbmol/hr	179.2	12629.83	16060.26	16.3
C ₂ H ₆	30.070 lbmol/hr	18.4	293.4		
N ₂ +INERT	28.013 lbmol/hr		308.97	308.97	0.32
O ₂	32.000 lbmol/hr				
TOTAL DRY GAS (1)	24095.94	768.93	24864.87	17391.2	648.49
H ₂ O	18.016 lbmol/hr		3.0	15	45
METHANOL	32.042 lbmol/hr		233.00		
TOTAL WET GAS (1)	24331.94	768.93	25100.87	17406.2	693.49
TOTAL DRY GAS	334774	14218	348993	298754	28066
H ₂ O	54		54	270	811
METHANOL	7466		7466		
C ₂ H ₆	42.08 lbmol/hr				
C ₃ H ₈	44.09 lbmol/hr	13.5	13.5		
iC ₄ H ₁₀	58.12 lbmol/hr	29.13	29.13		
iC ₄ H ₈	56.10 lbmol/hr				
iC ₄ H ₁₆	58.12 lbmol/hr				
iC ₅ H ₁₂	72.15 lbmol/hr				
iC ₅ H ₁₀	70.13 lbmol/hr				
iC ₅ H ₁₄	72.15 lbmol/hr				
C ₆ +	(2) lbmol/hr				
NAPHTHA	lb/hr				
TOTAL	342294	14218	356513	299024	28877
(1) C ₃ + INCLUDED					
(2) MW OF C ₆ +					

MATERIAL BALANCE SENSITIVITY CASE I-C

STREAM N ^o	49	98	100
	SNG PRODUCT	UNIT ISO HC PRODUCT	ALKYLATION FEED
CO ₂	83.75	44.0	
H ₂ S			
COS			
C ₂ H ₄		142.7	0.7
CO	13.24	89.5	
H ₂	293.11	253.2	
CH ₄	16043.96	179.2	
C ₂ H ₆		24.3	5.9
N ₂ +INERT	308.18		
O ₂			
TOTAL DRY GAS (1)	16742.24	4018.9	1521.4
H ₂ O	1.33		
METHANOL	16743.57		
TOTAL WET GAS (1)	16743.57		
TOTAL DRY GAS	270674		
H ₂ O			
METHANOL			
C ₃ H ₆	42.08	362.8	349.2
C ₃ H ₈	44.09	240.5	237.1
iC ₄ H ₁₀	58.12	613.7	596.7
iC ₄ H ₈	56.10	254.6	230.5
iC ₄ H ₁₆	58.12	77.0	65.4
iC ₅ H ₁₂	72.15	446.5	26.6
iC ₅ H ₁₆	70.13	114.9	3.2
nC ₅ H ₁₂	72.15	22.6	
C ₆ + (2)	(2)	1154.9	
NAPHTHENA			
TOTAL	270698	258.303	79.270
(1) C ₃ + INCLUDED			
(2) MW OF C ₆ +			

MATERIAL BALANCE

SENSITIVITY CASE II-A

STREAM NO	30	37	38	44	49
	Feed to Unit 250	Unit 252 Feed	Unit 210 Product Gas	Unit 212 Product Gas	SNG Product
CO ₂	44.010 lbmol/hr	978.22	2 132.90	890.87	85.00
H ₂ S	34.076 lbmol/hr				
COS	60.070 lbmol/hr				
C ₂ H ₆	28.054 lbmol/hr	33.6	31.84		32.48
CO	28.010 lbmol/hr	17.65	929.44	1.44	19.07
H ₂	2.016 lbmol/hr	45.91	8 705.18	250	299.33
CH ₄	16.043 lbmol/hr	1 070.36	14 007.74	17 306.45	18 326.20
C ₂ H ₄	30.070 lbmol/hr	414.46	518.16		405.29
N ₂ +INERTS	28.013 lbmol/hr	4.96	303.79	303.79	308.77
O ₂	32.000 lbmol/hr				
TOTAL DRY FLOW (1)	81 452	3 995.69	26 634.05	18 752.55	19 528.74
H ₂ O	18.016 lbmol/hr	113.98			
METHANOL	32.042 lbmol/hr				1.70
TOTAL WET FLOW (1)	81 453.31	4 109.67			19 530.44
C ₃ H ₆	42.08 lbmol/hr	87.27			17.73
C ₃ H ₈	44.09 lbmol/hr	273.13			34.47
IC ₂ H ₆	56.10 lbmol/hr				
IC ₄ H ₈	56.10 lbmol/hr	122.22			0.10
IC ₂ H ₁₀	58.12 lbmol/hr	160.60			0.10
nC ₂ H ₁₀	70.13 lbmol/hr	117.78			
IC ₅ H ₁₂	70.13 lbmol/hr				
IC ₅ H ₁₀	72.15 lbmol/hr	250.98			0.10
nC ₅ H ₁₂	72.15 lbmol/hr	125.95			
IC ₆ H ₁₄	84.16 lbmol/hr				
IC ₆ H ₁₂	84.16 lbmol/hr				
IC ₆ H ₁₄	86.17 lbmol/hr				
nC ₆ H ₁₄	86.17 lbmol/hr	292.6	5.00		0.10
C ₆ + C ₇ +	(2) (3)				
ALCOHOLS	46.61 lbmol/hr				
TOTAL	958 028 lb/hr	17 035	387 823		323 000
(1) C ₃ + INCLUDED					
(2) MW OF C ₆ +					
(3) MW OF C ₇ +					

MATERIAL BALANCE

SENSITIVITY CASE II-A

STREAM N°	50	54
	Gasoline Product	Unit 252 Of Gas
CO ₂	44.010 lbmol/hr	246.27
H ₂ S	34.076 lbmol/hr	
COS	60.070 lbmol/hr	
C ₂ H ₄	28.054 lbmol/hr	32.48
CO	28.010 lbmol/hr	17.63
H ₂	2.016 lbmol/hr	49.32
CH ₄	16.043 lbmol/hr	1 056.75
C ₂ H ₆	30.070 lbmol/hr	405.29
N ₂ +INERTS	28.013 lbmol/hr	4.98
O ₂	32.000 lbmol/hr	
TOTAL DRY FLOW (1)	lbmol/hr	2 565.32
H ₂ O	18.016 lbmol/hr	113.38
METHANOL	32.042 lbmol/hr	
TOTAL WET FLOW (1)	lbmol/hr	2 104.3
C ₃ H ₆	42.08 lbmol/hr	2 678.70
C ₃ H ₈	44.09 lbmol/hr	17.73
IC ₄ H ₈	56.10 lbmol/hr	34.47
IC ₂ H ₈	56.10 lbmol/hr	0.10
IC ₄ H ₁₀	58.12 lbmol/hr	0.10
nC ₄ H ₁₀	58.12 lbmol/hr	
IC ₅ H ₁₀	70.13 lbmol/hr	
IC ₅ H ₁₀	70.13 lbmol/hr	
IC ₅ H ₁₂	72.15 lbmol/hr	0.10
nC ₅ H ₁₂	72.15 lbmol/hr	
IC ₆ H ₁₂	84.16 lbmol/hr	
IC ₆ H ₁₂	84.16 lbmol/hr	
IC ₆ H ₁₄	86.17 lbmol/hr	
nC ₆ H ₁₄	86.17 lbmol/hr	
C ₆ +	(2) lbmol/hr	
C ₇ +	(3) lbmol/hr	0.10
ALCOHOLS	46.61 lbmol/hr	
TOTAL	186 556 lb/hr	76 800
(1) C ₃ + INCLUDED		
(2) MW OF C ₆ +		
(3) MW OF C ₇ +		

MATERIAL BALANCE

SENSITIVITY CASE II-A

STREAM N ^o	99	102	103	105	138
	Stabilized Gasoline	Unit 210 Feed	Unit 252 Feed	Acid Water from Unit 250	C3 LPG Product
CO ₂		3 111.12	15.88		
H ₂ S					
COS					
C ₂ H ₄		65.44	0.56		
CO		947.09	0.91		
H ₂		8 751.11	5.88		
CH ₄		15 078.10	39.89		
C ₂ H ₆		932.62	11.38		
N ₂ +INERTS		308.73	0.27		
O ₂					
TOTAL DRY FLOW (1) lbmol/hr		30 629.69	912.05		
H ₂ O		113.98		16 985.0	
METHANOL					
TOTAL WET FLOW (1) lbmol/hr	1 675.2	30 743.67			282.4
C ₃ H ₆		87.27	2.73		
C ₃ H ₈		273.16	9.84		
iC ₄ H ₈					
iC ₄ H ₁₀		122.22	10.80		
nC ₄ H ₁₀		160.60	12.40		
iC ₅ H ₁₀		117.78	12.22		
iC ₅ H ₁₂					
nC ₅ H ₁₂		250.98	57.52		
iC ₆ H ₁₄		125.95	34.45		
iC ₆ H ₁₆					
nC ₆ H ₁₄					
C ₆ +	(2)	297.60	695.96		
C ₇ +	(3)				
ALCOHOLS					
TOTAL	157 045	557 858	94 100	306 070	12 419
(1) C ₃ + INCLUDED					
(2) MW OF C ₆ +					
(3) MW OF C ₇ +					

APPENDIX D
SNG ONLY SENSITIVITY CASE

In the multiple products mode of economic evaluation, it is quite critical to employ the proper SNG value both for determining the effects of making motor gasoline (or methanol) and for calculating a correct gasoline (or methanol) price. Errors and wrong conclusions most likely will occur if the SNG value and plant complex used in the comparison are from the literature, where the coal and venture bases are different or unknown. Consequently, a SNG only sensitivity case has been added to this study. It was developed from the methanol Sensitivity Case I-A.

The results are summarized below:

PRODUCT YIELDS

SNG:	275 MMSCF/SD @ 983 Btu/SCF (HHV)
Hydrotreated Naphtha	1315 B/SD

INPUT

Net Coal to Gasifiers and Boiler:	24,070 T/SD
Water:	6,000 gpm

OVERALL PLANT EFFICIENCY (HHV)	68%
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PLANT COSTS

Investment	MM \$
Contractor Cost	1,083
Other Project Costs	221
Estimating Allowance	196
Royalties	17
Depreciable Capital	1,517
Expense Capital	28
Working Capital	44
Coal Cost	64.3 MM \$/yr
Operating Cost	120.1 MM \$/yr
Byproduct Credits	11.8 MM \$/yr

UNIT COSTS

Equity Financing	6.17 \$/MM Btu
Utility Financing	4.51 \$/MM Btu

The block flow diagram is similar to the one for Sensitivity Case I-A, except the methanol synthesis train is eliminated. In addition, because a balanced synthesis gas is not required for methanation as for methanol synthesis, the carbon dioxide can now be removed in the rectisol unit to the desired SNG level, thus eliminating the second CO₂ removal unit. To meet the methanation H/C ratio requirement, however, a higher percentage of the crude syn gas must be shifted then when synthesizing methanol.

Interestingly, even though the SNG and hydrotreated naphtha thermal yield is smaller than the SNG, methanol and hydrotreated naphtha thermal yield in Sensitivity Case 1-A, the overall plant thermal efficiency is greater by about 2 percent. This improvement is the result of: (1) more efficient heat recovery - greater 100 and 550 psig steam production - in the shift and methanation units, (2) elimination of the steam requirements for methanol/water fractionation, and (3) lower compressor power requirements.

The SNG unit cost is a stand-off with the thermal cost for SNG/methanol coproduction, 6.17 vs. 6.19 \$/MM Btu @ 12% DCF. The economics of the SNG case are helped by lower net coal usage (higher efficiency), lower plant investment (smaller boiler), lower working capital (no product inventory), and lower operating cost.

The effect of the product mix on the plant thermal balance and economics is briefly summarized in the attached table.

EFFECT OF PRODUCT MIX ON PLANT
THERMAL BALANCE AND ECONOMICS

Case	SNG Only	I-A		I-B	
		SNG + MeOH	Base Case I SNG + Gasoline	Gasoline Only	Gasoline Only
Thermal Balance					
Net Coal, MM Btu/hr	17,067	18,280	18,511	19,458	
Product, MM Btu/hr	11,545	11,970	11,388	9,050	
Efficiency	68	66	62	47	
Total Investment, MM \$	1,589	1,637	1,790	2,062	
Operating Cost, MM \$/yr	120	122	132	149	
Unit Cost					
Equity, \$/MM Btu	6.17	6.15	6.99	9.98	
Utility, \$/MM Btu	4.51	4.47	5.08	7.24	