B. Methanol from Subbituminous Coal

There are two original studies available which investigated the technical and economic feasibility of producing methanol from subbituminous coals. These studies are:

1. "Methanol from Coal: An Adaptation from the Past," Bailey, Davy McKee Corp., 1979.[6]

2. "Research Guidance Studies to Assess Gasoline from Coal by Methanol-to-Gasoline and Sasol-Type Fischer-Tropsch Technologies, Schreiner, Mobil Research and Development Corp., August, 1978.[7]

The Davy McKee study investigated the use of a Davy McKee fluidized bed gasifier, which is a modified Winkler gasifier which has not been demonstrated on a commercial scale. ICI technology was used for methanol synthesis. The Mobil study utilized BGC Lurgi technology for gasification and Lurgi methanol synthesis.

Depth of Design: Neither study seems to have been based on a high level of engineering design. However, since the Davy McKee study utilized modified Winkler/ICI technology and since Davy McKee has designed and built commercial processes using Winkler and ICI technology, their study is probably based on processing and cost correlations associated with plants they have constructed. For the Mobil study, process information was based on either published or licensor data, while investment estimates were principally derived from in-house data. For offsite units vendor quotes were used where obtainable.

Ultimate Analyses of Subbituminous Coal Feedstocks: Ultimate analyses for the subbituminous coals are presented in Table 14. The higher and lower heating values are also shown. Both coals are from Wyoming and have very similar compositions.

Material Balance and Efficiencies: Feedstock and product rates for both studies are presented in Table 15. Methanol and coal are presented on both a short ton per calendar day (tpd) and an energy basis. The Davy McKee study produces 100 percent methanol while the Mobil study produces about 48 percent methanol, 50 percent SNG, and 2 percent naptha. Sulfur, ammonia and coal fines are produced as by-products from the Mobil study. Coal fines are also produced since the Lurgi gasifier cannot process them. By-products were not reported for the Davy McKee study, but are produced; therefore, for economic purposes the sulfur and ammonia yields from the other study were assumed for it.

Product qualities for the Davy McKee study are not reported, but product qualities for the Mobil case are presented in Table 16. The methanol is 99.66 percent pure, but it is still considered to be of fuel grade quality. The SNG is about 96 percent

Table 14

Ultimate Analysis of Subbituminous Coal Feedstocks

Study:	Davy McKee[6]	Mobil[7]
Coal Type:	Wyoming	Wyoming
HHV, Dry, Btu/lb	11,818	11,818
LHV, Dry, Btu/lb	10,963	10,963
Ultimate Analysis of Dry Coal, Wt %		
C	69.2	70.8
H	4.7	4.9
O	17.9	18.3
N	0.7	0.7
S	0.4	0.4
Ash	7.1	5.1
Total	100	100
Wt % Moisture (as recieved)	28	28

Table 15

Methanol from Subbituminous Coal:
Feedstock and Product Rates
(50,000 FOEB/CD of Product)

	Davy McKee[6]	Mobil[7]
Mass Basis		
Feedstock		
Dry Coal, tpd	26,820	19,063
Product		
Methanol, tpd	15,227	7,270
Synthetic Natural		
Gas, mscf/CD	-	150
Naptha, bbl/CD	-	1,351
By-products, tpd		
Sulfur	-	63
Ammonia	-	103
Coal Fines	-	1,501
Energy Basis, mBtu/CD, (HHV)		
Feedstocks		
Coal	639,918	450,563
Electricity	3,448	1,198
Products		
Fuel Grade Methanol	295,000	141,388
Synthetic Natural Gas	-	146,588
Naptha	-	7,024
Coal Fines	-	-
Thermal Efficiency, %	45.9	65.3

Table 16

Methanol from Subbituminous Coal: Product Qualities

Davy McKee[6]

The quality of the fuel grade methanol was not reported in the Davy McKee study.

Mobil[7]

1. SNG

Composition	Weight %
Hydrogen	1.7
Methane	95.9
Carbon Dioxide	0.5
Inerts (N_2 and Ar)	1.9
	100.00

HHV: 975 Btu/scf
LHV: 878 Btu/scf

2. Methanol

	Weight %
CH_3OH	99.66
Light Boiling Compounds	0.12
Heavy Boiling Compounds	0.07
Water	0.15

3. Naptha

	Weight %
Gravity, °API	43.5
(R+M)/2 (unleaded)	88.8
Reid Vapor Pressure, lb.	3.5

methane. The naptha product has an octane ((R+M)/2) of 88.8, and is a suitable gasoline blending stock.

The thermal efficiencies (based on higher heating values) for the Davy McKee and Mobil cases are 45.9 and 65.3 percent, respectively. This is a very significant difference. The Davy McKee efficiency is a bit lower than the lowest efficiency reported for methanol from bituminous coals (49.3 percent) in Table 9. However, the efficiency for the Mobil case is significantly greater than any of the efficiencies reported for methanol from bituminous coals. One reason for this high efficiency is that the raw syngas from the Lurgi gasifier is high in methane content and the simple isolation of this as product is more efficient than converting it to carbon monoxide and hydrogen and then to methanol. Less processing of the raw syngas is required, and, therefore, a greater efficiency is the result.

Economics: Both studies have been placed on a consistent economic basis as discussed in a previous report.[10a] Table 17 presents the investment costs broken down as much as possible into individual process unit costs. An inspection of Table 17 shows that the total instantaneous investments are $1.84 billion for the Davy McKee case and $2.26 billion for the Mobil case.

Operating costs are presented in Table 18. The difference in operating cost between both cases is mainly due to annual coal feedstock cost differences which primarily is a function of process efficiency. As noted earlier, by-product credit for Case 1 is based on the ammonia and sulfur yields of Case 2.

Table 19 and 20 present economic summaries and product costs when using capital charge rates of 11.5 and 30 percent. The methanol product cost for the Davy McKee case ranges from $6.16-10.26/mBtu while the average product costs for the Mobil case range from $6.34-$11.24, depending on the capital charge rate. In addition to average product costs, Tables 19 and 20 present product costs for the methanol, SNG, and gasoline produced in Mobil study which are based on the product value technique discussed in another report.[10a]

It is possible that the capital cost from the Mobil study is more accurate than that from the Davy McKee study; the reason for this is that the original Davy McKee Plant has to be scaled up significantly whereas the other was much closer to the selected 50,000 FOEB/CD. Therefore, the Mobil study's costs will be used in preference.

C. Methanol from Lignite

The following two original studies investigated the technical feasibility of producing methanol from lignite:

Table 17

Methanol from Subbituminous Coals: Capital Cost Summary
Millions of First Quarter 1981 Dollars

	Davy McKee[6]	Mobil[7]
Technology		
Gasification/Methanol Synthesis	Modified Winkler/ICI	Lurgi/ Lurgi
Investment Costs		
Coal Preparation and Handling	87	-
Gasification and Gas Cleaning	98	-
Shift Conversion	36	-
Acid Gas, Sulfur Recovery, Sulfur Guard	175	-
Syngas Compression	66	-
Total: Coal Preparation, Gasification, Processing	462	628
SNG Production	N/A	38
Methanol Synthesis and Distillation	153	102
Oxygen Production	262	161
Offsites and Product Storage	302	451
Infrastructure	17	67
Engineering and Design	119	184
Environmental Studies, etc.	-	3
Other Project Costs	284	331
Contingency	240	295
Total Instantaneous Plant Investment	1840	2260

Table 18

Methanol from Subbituminous Coal: Operating Cost Summary
(Millions of First Quarter 1981 Dollars Per Year)

	Davy McKee[6]	Mobil[7] Case 2
Technology		
Gasification/Methanol Synthesis	Modified Winkler	Lurgi/Lurgi
Raw Materals		
Coal	231	173
Catalysts and Chemicals	8.4	6.9
Utilities		
Power	4.7	2.1
Water	–	–
Labor and Related		
Labor	32.5	49.0
Supplies	33.3	29.0
Capital Related		
Administration and General Overhead	39.4	31.4
Local Taxes and Insurance	59.2	62.6
Interest on Working Capital	7.9	9.8
Gross Annual Operating Cost	416.4	366
By-product Credit	(9.3)	(18.3)
Net Annual Operating Costs	407	348

Table 19

Economic Summary of Methanol from
Subbituminous Coal, CCR = 11.5 Percent
(Millions of First Quarter 1981 Dollars)

	Davy McKee	Mobil
Total Instantaneous Plant Investment	1,840	2,260
Total Adjusted Capital Investment	2,087	2,563
Start-up Cost*	131	163
Pre-paid Royalties	10**	25
Total Capital Investment	2,228	2,751
Initial Catalyst and Chemicals and Working Capital***	131	163
Total Capital Requirement	2,359	2,914
Annual Capital Charge	256	335
Annual Operating Costs	407	348
Total Annual Charge	663	683
Product Cost		
$/FOEB of Product****	36.33	37.43
$/mBtu of Product	6.16	6.34
Methanol, $/mBtu	6.16	7.04
SNG, $/mBtu	-	5.63
Gasoline, $/mBtu	-	7.04

* Start-up cost = 6.3 percent of Total Adjusted Capital Investment.

** Royalties were assumed equal to $10 million unless reported by study.

*** Working Capital and Initial Catalyst and Chemical = 6.3 percent of Total Adjusted Capital Investment.

**** One FOEB = 5.9 mBtu.

Table 20

Economic Summary of Methanol from
Subbituminous Coal, CCR = 30 Percent
(Millions of First Quarter 1981 Dollars)

	Davy McKee	Mobil
Total Instantaneous Plant Investment	1,840	2,260
Total Adjusted Capital Investment	2,053	2,522
Start-up Cost	131	163
Pre-paid Royalties	10	25
Total Capital Investment	2,194	2,710
Working Capital	131	163
Total Capital Requirement	2,325	2,873
Annual Capital Charge	698	862
Annual Operating Costs	407	348
Total Annual Charge	1,105	1,210
Product Cost		
$/FOEB of Product*	60.55	66.30
$/mBtu of Product	10.26	11.24
Methanol, $/mBtu	10.26	12.48
SNG, $/mBtu	-	9.98
Gasoline, $mBtu	-	12.48

* One FOEB = 5.9 mBtu.

1. Production of Methanol from Lignite, prepared by Wentworth Brothers Incorporated (WBI), and C.F. Braun and Company for EPRI.[9]

2. Lignite-to-Methanol, an Engineering Evaluation of Winkler Gasification and ICI Methanol Synthesis Route, prepared by Davy McKee International, Inc.[8]

Both these studies represent approximately the same amount of engineering design. The WBI/C.F. Braun study uses Texaco gasification and WBI methanol synthesis technology. Three cases from this study are presented. Case 1 was prepared by WBI and was designed based on a 55 percent lignite/45 percent water slurry concentration. Gasification of a lignite concentration this high has not been commercially demonstrated. Case 2 represents a C.F. Braun modification of the WBI design still using the 55 percent slurry concentration. Since the 55 percent lignite slurry concentration has not been commercially demonstrated, C.F. Braun also analyzed a methanol from lignite case based on a 43 percent lignite slurry concentration which has been successfully gasified (Case 3).

The DMI study is based on Winkler gasification and ICI methanol synthesis. Both of these technologies have been commercially proven.

Ultimate Analysis of Lignite: All four cases were based on the same lignite, and the ultimate analysis for this lignite is presented in Table 21. Gasifier yields and oxygen requirements for all four cases are based on this analysis.

Material Balance and Efficiencies: Feedstock and product rates for each case are presented in Table 22. Methanol and lignite are presented on both a short ton per calender day (tpd) and an energy basis. The methanol produced is of fuel grade quality, even though in Cases 1, 2, and 3 the methanol product rates are reported on a dry equivalent basis. All rates are based on 50,000 FOEB/CD of liquid products. Sulfur is the only by-product reported in Table 22.

Thermal efficiencies vary from 43.9 percent for Case 3 to 51.2 percent for Case 1. The 43.9 percent efficiency results from the low lignite concentration in the slurry. The vaporization of the additional water in lower lignite concentration slurries consumes energy in the gasifier and produces larger quantities of synthesis gas. The result is a lower thermal efficiency and an increase of the capacities of all process units except methanol synthesis.

Economics: Table 23 presents all of the investment costs broken down into individual process units. These costs are based on a plant size of 50,000 FOEB/CD of product. An inspection of

Table 21

Ultimate Analysis of Lignite Feedstock

Heating Values	
HHV, dry, Btu/lb	10,179
HHV, wet, Btu/lb	9,765
LHV, approximated, dry, Btu/lb	6,460
Ultimate Analysis, Dry Coal, Wt%	
C	58.98
H	4.55
O	19.05
N	0.77
S	1.40
Ash	15.25
Total	100.00
Wt.% Moisture (as received)	35

Table 22

Methanol from Lignite: Feedstock and Product Rates
(Normalized to 50,000 FOEB/CD of Product)

Study:	WBI[9] Case 1	C.F. Braun[9] Case 2	C.F. Braun[9] Case 3	Davy McKee[8]
Mass Basis				
Feedstocks				
Lignite, tpd (wet)	44,250	44,596	52,071	48,171
Products				
Methanol (tpd)	15,063*	15,063*	15,063*	15,226
By-Products				
Electricity, energy equivalent per day	8,756	10,107	13,721	-
Sulfur, tpd	324	324	384	312
Energy Basis, mBtu/CD, (HHV)				
Feedstocks				
Lignite	571,705	576,172	671,982	622,363
Products				
Methanol	295,000	295,000	295,000	295,000
Thermal Efficiency, %	51.6	51.2	43.9	47.4

* Methanol on a dry equivalent basis.

Table 23

Methanol from Lignite: Capital Cost Summary
(Millions of First Quarter 1981 Dollars)

Study:	WBI[9] Case 1	C.F. Braun[9] Case 2	Case 3	Davy McKee[8]
Technology				
Gasification/Methanol Synthesis	Texaco/ WBI	Texaco/ WBI	Texaco/ WBI	Winkler/ ICI
Slurry Concentration, %	55	55	43	N/A
Plant Investment Costs				
Lignite Storage and Preparation	41.1	43.5	49.3	114.2
Syngas Generation, Gas Adjustment, and Purification	637.8	779.4	932.8	—
Gasification, Compression and Shift Conversion	—	—	—	278
Acid Gas Removal, Chlorideand Sulfur Guard, Compression	—	—	—	368.7
Methanol Synthesis, Distillation and Hydrogen Recovery	—	—	—	—
Methanol Synthesis	155.7	164.7	164.7	—
Gas Desulfurization, and Sulfur Recovery	23.0	24.4	27.5	35
Air Separation	457.2	483.6	677	—
Utility System	285.96	314.0	314	—
Utilities and Offsites	—	—	—	661.1
General Facilities	154.6	96.0	122.9	
Engineering Fees, Home Office Cost, and License Fees	91.4	92	92.5	225.8
Contingency	263	286	331	219
Total Instantaneous Plant Investment	2110	2283	2628	1901

Table 23 shows that the plant investment estimates vary from $1.90-2.63 billion. Cases 1, 2, and 3 are based on the same technology. Case 1 was prepared by WBI; whereas Case 2 is C.F. Braun's analysis of the WBI design. Both are based on the same lignite slurry concentration (55 percent).

Braun evaluated the capital costs for adjustments they thought necessary to appraise the WBI work. The necessary adjustments were the addition of one spare gasifier/exchanger set per train and operation with the start-up boiler continuously on the line thus increasing export power. This equipment was added as insurance to maintain production levels and to provide flexibility to the complex. Thus, Case 2 is more conservative; its capital cost is $170 million more than that for Case 1. It must be noted that to obtain a 55 percent slurry concentration, feed pretreatment is necessary and the cost of pretreatment equipment was not included in either of the estimates.

The instantaneous investment for the C.F. Braun case which utilizes the 43 percent lignite slurry concentration is $2.63 billion, which is $350-500 million more than the Case 1 and 2 investments, respectively. This higher investment results from increased capacities of all process units (except methanol synthesis) needed to accomodate the larger amounts of water (and steam) present with the 43 percent lignite slurry.

The total instantaneous investment for the Davy McKee case is $1.901 billion. This case is based on Winkler/ICI technology.

Operating costs are presented in Table 24. Net annual operating costs range from $237 million for Case 1 to $380 million for Case 3. Reasons for the low operating cost estimates for Case 1 are that: 1) general and administration cost have not been included, 2) 1 percent of the total instantaneous plant investment was used for property taxes and insurance as opposed to 2.5 percent for the other studies, and 3) labor costs were reported to be less than those for the other studies.

Operating costs for Case 3 are expected to be higher than those for Case 1 and 2 because of its higher capital investment and higher feedrate of lignite.

Cases 1 and 2 are based on the same technology and lignite slurry concentration. Since Case 2 is a further analysis of Case 1 and is more conservative, it is expected that the operating and capital cost for Case 2 are more representative. Therefore, Case 2 will be used in preference to Case 1 for developing methanol product costs.

Tables 25 and 26 present economic summaries of methanol costs for capital charge rates of 11.5 and 30 percent. For the lower capital charge rate, product costs vary from $5.70 to $6.92/mBtu.

Table 24

Methanol from Lignite: Operating Cost Summary
(Millions of First Quarter 1981 Dollars Per Year)

	WBI[9] Case 1	C.F. Braun[9] Case 2	Case 3	Davy McKee[10]
Technology				
Gasification/Methanol Synthesis	Texaco/ WBI	Texaco/ WBI	Texaco/ WBI	Winkler/ ICI
Slurry Concentration, %	55	55	43	N/A
Annual Operating Costs				
Raw Materials				
Coal	160.7	160.7	190	175.7
Fuel	—	12.2	—	—
Catalysts and Chemicals	3.6	3.6	3.6	17.9
Utilities				
Water	—	—	—	0.2
Labor and Related	24.5			
Operating	—	11.2	11.2	19.9
Maintenance	—	37.9	45.4	18.4
Administration and Support	—	14.7	16.9	11.5
Capital Related				
Ash Disposal	2.1	2.1	2.5	2.4
Maintenance Materials	52.8	46.3	58.1	27.9
General and Administration	—	24.9	30	25.1
Property Taxes and Insurance	21.1	52.8	65.7	47.5
Interest on Working Capital	8.9	9.6	11.0	8.0
Gross Annual Operating Cost	273.7	376	434.4	354.5
By-product Credit				
Sulfur	(5.8)	(5.8)	(6.9)	(5.7)
Electric Power Export, (3.5¢/kw-hr)	(30.5)	(35.2)	(47.8)	—
Net Annual Operating Cost	237	335	380	349

Table 25

Economic Summary of Methanol from
Lignite, CCR = 11.5 Percent
(Millions of First Quarter 1981 Dollars)

	WBI	C.F. Braun		
	Case 1	Case 2	Case 3	Davy McKee
Total Instantaneous Plant Investment	2,110	2,283	2,628	1,901
Total Adjusted Capital Investment	2,393	2,589	2,980	2,156
Start-up Cost	148	160	184	133
Pre-paid Royalties	10	10	10	10
Total Capital Investment	2,551	2,759	3,174	2,299
Working Capital	148	160	184	133
Total Capital Requirement	2,699	2,919	3,358	2,432
Annual Capital Charge	293	317	365	264
Total Annual Charge	530.5	652	745	613
Product Cost				
$/FOEB of Methanol*	29.07	35.73	40.83	33.61
$/mBtu of Methanol	4.93	6.06	6.92	5.70

* One FOEB = 5.9 mBtu.

Table 26

Economic Summary of Methanol
from Lignite, CCR = 30%
(Millions of First Quarter 1981 Dollars)

	WBI Case 1	C.F. Braun Case 2	C.F. Braun Case 3	Davy McKee
Total Instantaneous Plant Investment	2,110	2,283	2,628	1,901
Total Adjusted Capital Investment	2,355	2,548	2,933	2,122
Start-up Cost	148	160	184	133
Pre-paid Royalties	10	10	10	10
Total Capital Investment	2,513	2,718	3,127	2,265
Working Capital	148	160	184	133
Total Capital Requirement	2,661	2,878	3,311	2,398
Annual Capital Charge	754	815	938	680
Annual Operating Costs	237	335	380	349
Total Annual Charge	992	1,150	1,318	1,029
Product Cost				
$/FOEB of Methanol*	54.36	63.01	72.23	56.38
$/mBtu of Methanol	9.21	10.68	12.24	9.56

* One FOEB = 5.9 mBtu.