C. Substitute Natural Gas-From-Coal (MWK Dwg. P3356-D)

A block flow diagram for the substitute natural gas (SNG)-from coal process is given in the cited drawing. The process may be divided into three steps:

- Coal Gasification and Raw Gas Purification
- Methane Synthesis
- Synthesis Gas Compression

1. Coal Gasification and Raw Gas Purification

This step is identical to the one in the gasoline-from-coal process which is described previously. The only difference from the gasoline-from-coal plant design is the addition of a shift conversion area which is designed to produce hydrogen by the "water gas shift" reaction:

$$CO + H_2O = CO_2 + H_2$$

Approximately one-half of the total crude gas from the gasifiers is subjected to shift conversion; the remainder is bypassed directly to the gas cooling area. The ratio of the two gas streams will be adjusted to achieve the desired H_2:CO ratio for proper feed to the methanation unit. Crude gas feed to the shift conversion area is quenched and washed first. The washed gas is heated in a series of heat exchangers before entering the first shift reactor where the bulk of carbon monoxide is catalytically converted to equivalent amount of hydrogen and carbon-dioxide. The first stage hot effluent is cooled in counter-current exchange with the feed gas before entering the second shift reactor where further conversion of carbon monoxide will take place. Effluent gas from the second shift reactor is cooled by indirect exchange with the feed gas before leaving the shift conversion unit.

2. Methane Synthesis

The methanation step converts low Btu synthesis gas to methane rich high Btu gas by the following overall chemical reactions:

$$CO + 3H_2 = CH_4 + H_2O$$

$$CO_2 + 4H_2 = CH_4 + 2H_2O$$

Both of these reactions are highly exothermic and the heat released is used to heat the incoming feed gas as well as for steam generation in waste heat boilers. Hot feed gas, after indirect exchange with the product gas, is passed through a sulfur guard reactor to remove last traces of impurities before entering the synthesis loop. The synthesis loop consists of a methanator, waste heat boilers and a recycle compressor. Feed gas composition to the methanator will be set by combining the fresh feed gas stream with the gas stream circulated by the recycle compressor. Reaction heat from the methanator is removed in the high and low pressure waste heat boilers. Product gas from the synthesis loop is cooled in a feed/recycle product heat exchanger and further cooled in a final product cooler to ambient temperature. Condensed water is removed in a product-condensate separator.

3. Synthesis Gas Compression

Synthesis gas from the methanation area is compressed by a steam driven centrifugal compressor from 225 psia to 600 psia. The compressed gas is cooled to 90°F and sent to gas purification for final acid gas removal and dehydration. Gas from the gas purification area is returned to the second stage centrifugal compressor where it is boosted to pipeline pressure.

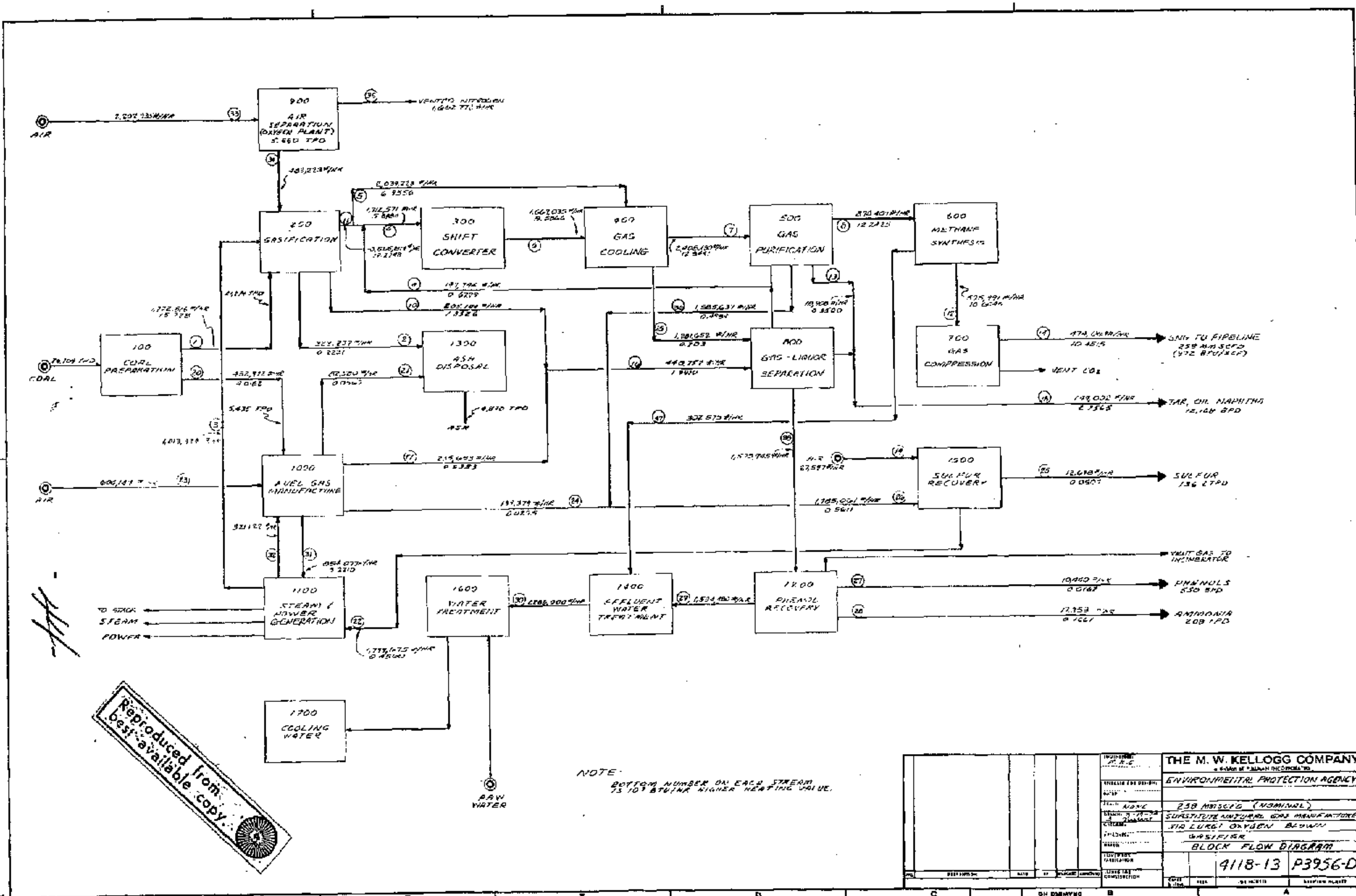
AIR
COAL
RAW WATER
100 COAL PREPARATION
900 AIR SEPARATION (OXYGEN PLANT)
VENTED NITROGEN
250 GASIFICATION
300 SHIFT CONVERTER
400 GAS COOLING
500 GAS PURIFICATION
600 METHANE SYNTHESIS
700 GAS COMPRESSION
800 GAS-LIQUOR SEPARATION
1000 FUEL GAS MANUFACTURE
1100 STEAM & POWER GENERATION
1200 PHENOL RECOVERY
1300 ASH DISPOSAL
1400 EFFLUENT WATER TREATMENT
1500 SULFUR RECOVERY
1600 WATER TREATMENT
1700 COOLING WATER
ASH
TO STACK
STEAM
POWER
VENT CO2
SNG TO PIPELINE
TAR, OIL, NAPHTHA
SULFUR
TAIL GAS TO INCINERATOR
PHENOLS
AMMONIA
NOTE:
BOTTOM NUMBER ON EACH STREAM IS 10⁹ BTU/HR HIGHER HEATING VALUE.
THE M. W. KELLOGG COMPANY
ENVIRONMENTAL PROTECTION AGENCY
250 MMSCFD (NOMINAL)
SUBSTITUTE NATURAL GAS MANUFACTURE
VIA LURGI OXYGEN BLOWN GASIFIER
BLOCK FLOW DIAGRAM
4118-13
P3956-D

TABLE 11

THE M. W. KELLOGG COMPANY
A DIVISION OF PULLMAN INCORPORATED

DESCRIPTION MATERIAL & ENERGY FLOW (SNG) CUSTOMER EPA DATE 3/14/74 BY FC

JOB NO. 4118-13

DESCRIPTION	COAL TO GAS	ASH TO POND	STEAM AND BFW TO GAS	RAW GAS TO SHIFT	RAW GAS TO COOLING	CONVERTER GAS	RANGE GAS TO RECTISOL	METHANE SYN. FEED	RECYCLE FEED TO SHIFT	GAS LIQUOR EFFLUENT	RAW GAS. FROM GAS.	GAS PRODUCT TO COMPRESS.	NAPHTHA TO STORE
STREAM	1	2	3	4	5	6	7	8	9	10	11	12	13
	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH
CO_2				14,011	17,516	21,330	38,011	4,687	2,528		29,092	2,700	
H_2S				155	199	155	346	-	32		322	-	
C_2H_4				194	255	194	449	208	46		403	-	
CO				9,478	11,056	2,159	13,215	12,935	854		19,680	34.0	
H_2				18,816	21,913	26,135	48,048	47,588	1,661		39,068	212	
CH_4				5,377	6,421	5,377	11,798	11,678	635		11,164	27,604	
C_2H_6				296	371	296	667	311	53		614	-	
N_2 + AR				155	181	155	336	329	14		322	329	
O_2				-	-		-	-	-		-	-	
TOTAL DRY GAS				48,482	57,912	55,802	112,870	77,735	5,824		100,664	30,879	
MOL. WT.				21.27	21.78	20.85	21.14	11.30	26.31		21.27	18.60	
DRY GAS #/HR				1,031,218	1,261,323	1,163,470	2,386,072	878,407	153,233		2,141,121	574,350	
	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR
H_2O	292,315		1,813,924	638,378	731,646	478,169	3,150	-	44,561	114,650	1,325,463	1,641	-
COAL (DAF)	1,173,846	16,577		-	-	-	-	-	-	-	-	-	-
ASH	306,655	306,655		-	-	-	-	-	-	-	-	-	-
TAR, OIL NAPHTHA				40,811	43,925	27,397	18,908	-	-	69,631	84,737	-	18,908
PHENOLS				2,164	2,329	-	-	-	-	7,850	4,493	-	-
SULFUR				-	-	-	-	-	-	13,010	-	-	-
AMMONIA				-	-	-	-	-	-	-	-	-	-
TOTAL #/HR	1,772,816	323,232	1,813,924	1,712,571	2,039,223	1,669,035	2,408,130	878,407	197,794	205,141	3,535,814	575,991	18,908
HHV, 10^9 Btu	15.728	0.2221	-	5.8880	6.9556	5.8866	12.8491	12.2425	0.6229	1.3526	12.2248	10.6045	0.3500
MMSCFD (DRY)	-	-	-	441.6	528.3	508.2	1027.9	708	53.0	-	916.86	281.2	-
HHV (BTU/SCF DRY)	-	-	-	320	316	278	300	415	282	-	320	905	-

THE M. W. KELLOGG COMPANY
A DIVISION OF PULLMAN INCORPORATED

TABLE 11 CONT'D.

DESCRIPTION MATERIAL & ENERGY BALANCE, (SNG)

CUSTOMER EPA

DATE 3/14/74
BY FC

JOB NO. 4118-13

DESCRIPTION	SNG TO PIPELINE	GAS LIQUOR TO SEPARATION	TAR, OIL TO SEPERATOR	GAS LIQUOR FROM FUEL	TAR, OIL NAPHTHA	AIR TO CLAUS PLANT	COAL TO FUEL GAS SECT.	ASH TO POND	CLAUS PLANT TAIL GAS	COMP. AIR TO GAS	ACID GAS TO CLAUS PLANT	SULFUR BYPRODUCT	FEED TO CLAUS
STREAM	14	15	16	17	18	19	20	21	22	23	24	25	26
	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH
CO_2	569	901							38,659		4,385		39,659
H_2S	-	8							**25		80		421
C_2H_4	-	-							209		1		209
CO	34	4							76		15		76
H_2	212	1							84		23		84
CH_4	27,192	-							264		6		263
C_2H_6	-	-							323		1		323
N_2 + AR	329.0	-				750			801	16,434	38		41
O_2						200			-	4,369	-		-
TOTAL DRY GAS	28,336	914				950			41,439	20,803	4,549.0		41,076
MOL. WT.	16.73	43.69				28.86			43.21	28.86	43.40		43.41
DRY GAS #/HR	474,069	39,935				27,424			1,790,587	600,360	197,427		1,783,109
	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR
H_2O	-	1,206,665	320,882	206,232		173	74,681		9,088	3,787	1,952		1,952
COAL (DAF)	-	-	-				299,896	4,235	-	-	-		-
ASH	-	-	-				78,345	78,345	-	-	-		-
TAR, OIL, NAPHTHA	-	37,975	92,119	22,488	149,002		-	-	-	-	-		-
PHENOLS	-	-	10,440	2,590			-	-	-	-	-		-
SULFUR	-	-	17,353	4,344			-	-	-	-	-	12,698	-
AMMONIA	-	-	-				-	-	-	-	-		-
TOTAL, #/HR	474,069	1,281,652	440,794	235,653	149,002	27,597	452,922	82,580	1,799,675	604,147	199,379	12,698	1,785,061
HHV 10^9 Btu	10.4531	0.703	1.9910	0.6383	2.7565	-	4.0182	0.0567	0.4560	-	0.0275	0.0507	0.5611
MMSCFD (DRY)	258.1	-	-	-	-	-	-	-	377.4	-	41.48	-	374.1
HHV (BTU/SCF DRY)	972	-	-	-	-	-	-	-		-		-	
LT/D									29		15.9	136	36

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TABLE 11 CONT'D.

THE M. W. KELLOGG COMPANY
A DIVISION OF PULLMAN INCORPORATED

DESCRIPTION MATERIAL & ENERGY BALANCE, (SNG) CUSTOMER EPA DATE 3/14/74 BY FC

JOB NO. 4118-13

DESCRIPTION	PHENOLS BYPRODUCT	AMMONIA BYPRODUCT	H_2O EFFLUENT FROM PHENSOLVAN	TO WATER TREATMENT	LOW BTU GAS	STEAM TO AIR GASIF	AIR TO O_2 PLANT	O_2 TO GASIFIER	N_2 VENT	ACID GAS TO CLAUS	WATER CONDENSATE	FEED TO PHENOSOLVAN	
STREAM	27	28	29	30	31	32	33	34	35	36	37	38	
	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	
CO_2					1,841					35,274			
H_2S					8					341			
C_2H_4					103					208			
CO					6,012					61			
H_2					9,084					61			
CH_4					2,357					257			
C_2H_6					155					322			
N_2 + AR					16,353		58,427	301	58,126	13			
O_2							15,239	14,740	499	-			
TOTAL DRY GAS					36,811		73,666	15,041	58,625	36,527			
MOL. WT.					21.64		28.82	32.06	28	43.41			
DRY GAS #/HR					796,600		2,123,571	482,223	1,641,500	1,585,637			
	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR
H_2O		-	1,534,480	1,285,000	46,353	321,122	79,364		11,272		302,575	1,534,480	
COAL (DAF)					-	-					-	-	
ASH					-	-					-		
TAR, OIL, NAPHTHA					**11,123	-					-	-	
PHENOLS	10,440				-	-					-	10,440	
SULFUR	-				-	-					-	-	
AMMONIA	-	17,353			-	-					-	17,353	
TOTAL, #/HR	10,440	17,353	1,534,480	1,285,000	854,077	321,122	2,202,935	482,223	1,652,772	1,585,637	302,575	1,562,273	
HHV, 10^9 Btu	0.0167	0.1667	-	-	3.2210	-	-	-	-	0.4948	-	0.1886	
MMSCFD (DRY)	-	-	-	-	336.4	-	-	-	-	332.6	-	-	
							-	-	-	36.	-	-	
HHV (BTU/SCF DRY)	-	-	-	-	229.8	-							
LT/D													

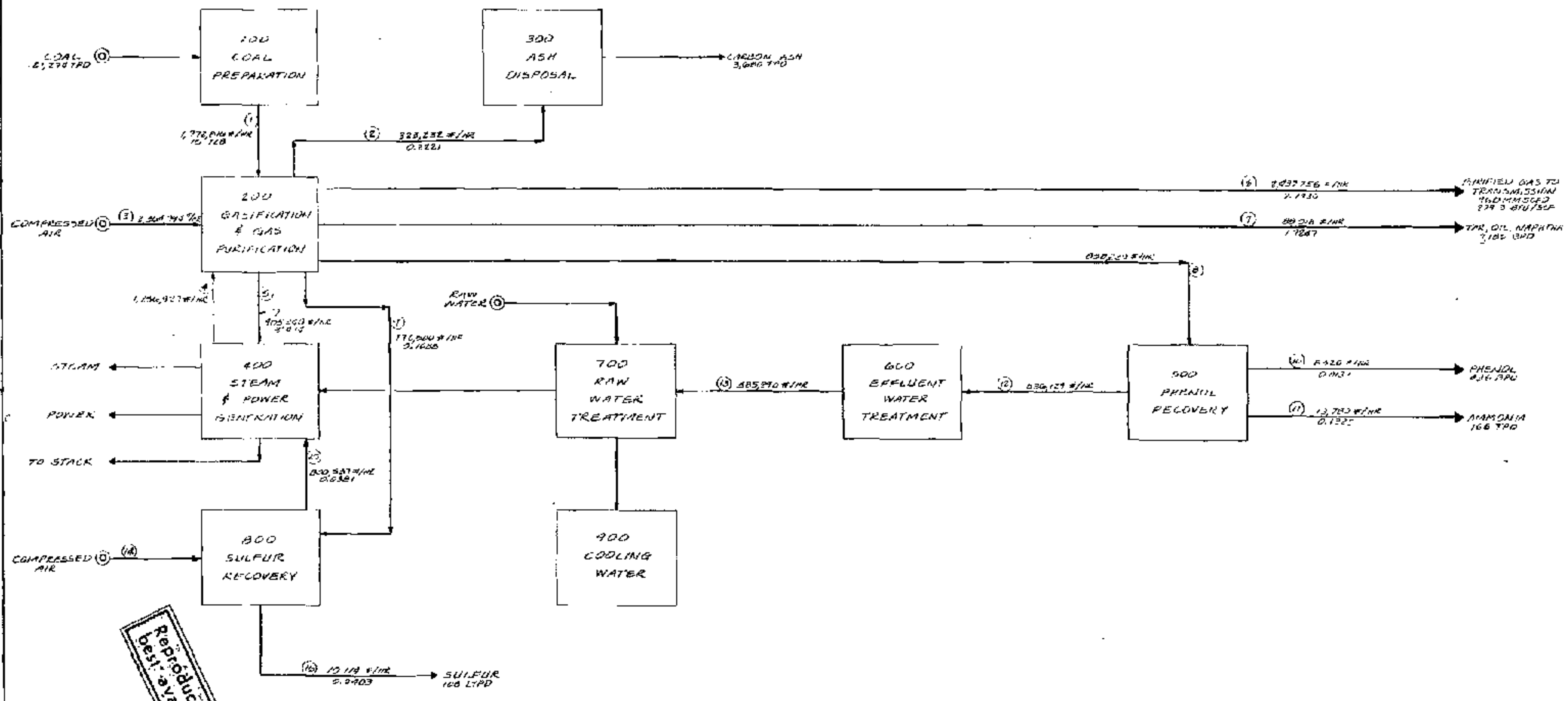
**IN GAS STREAM

D. Low Btu Gas-From-Coal (MWK Dwg. P3357-D)

A block flow diagram for the low Btu gas-from-coal process is given in the cited drawing. The air blown gasification process is adopted from Lurgi's design.

Coal is conveyed from the coal preparation area to coal bunkers located above the coal gasifiers. Coal is fed to the gasifiers through coal locks which are pressured by a slip stream of the raw gas. Hot compressed air and process steam is mixed and introduced into the gasifiers. Ash is removed at the bottom of the gasifiers through ash locks and transported to ash disposal. Hot raw gas leaving the gasifiers is cooled by quenching with a gas liquor spray in wash coolers. Raw gas from the wash cooler is further cooled and cleaned by gas liquor in wash scrubbers. A purge stream of gas liquor is sent to the phenol recovery section. After cooling, the gas liquor is flashed to atmospheric pressure in an expansion vessel to remove dissolved gases. Coal tar is separated from the gas liquor by gravity and sent to product storage. A portion of the clarified gas liquor is recycled to the wash scrubber as make-up. The remainder is sent to phenol recovery where dissolved ammonia and phenol will be removed.

Expansion gas and coal lock vent gas are compressed and combined with the raw gas. Desulfurization of raw gas is accomplished by a hot potassium carbonate system in which hydrogen sulfide and the bulk of carbon dioxide are removed. Acid gas from the regenerator is cooled and sent to the sulfur recovery section. Part of the fuel gas produced is sent to steam and power generation section for process requirement. The remainder of the fuel gas is transmitted to pipeline as primary product.



NOTE:
BOTTOM NUMBER ON EACH STREAM IS 10^9 BTU/HR HIGHER HEATING VALUE.

THE M. W. KELLOGG COMPANY

ENVIRONMENTAL PROTECTION AGENCY

LOW BTU GAS MANUFACTURE VIA LURGI AIR BLOWN GASIFIER 960 MMSCFD (NOMINAL)

BLOCK FLOW DIAGRAM

4118-13 | P-3957-D

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TABLE 12

THE M. W. KELLOGG COMPANY
A DIVISION OF PULLMAN INCORPORATED

DESCRIPTION LOW BTU GAS MATERIAL BALANCE | CUSTOMER EPA | DATE 3/18/73 | BY FC | PAGE NO. 1 OF 2 | JOB NO. 4118-13

DESCRIPTION	COAL TO GASIFICATION	ASH TO POND	COMPRESSED AIR TO GAS	STEAM & WATER TO GAS	LOW BTU GAS FOR POWER GEN	LOW BTU GAS PRODUCT	TAR, OIL, NAPHTHA	GAS LIQUOR TO PHENOLSOLVAN	TO SULFUR RECOVERY	PHENOLS BYPRODUCT	AMMONIA BYPRODUCT	WATER EFFLUENT PHENOLSOLVAN	RECYCLE WATER
STREAM	1	2	3	4	5	6	7	8	9	10	11	12	13
	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH
CO_2					1,951	5,254			17,165				
H_2S					8	23			315				
C_2H_4					109	293			4				
CO					7,326	19,728			6				
H_2					9,628	25,928			89				
CH_4					2,298	6,729			22				
C_2H_6					164	441			4				
N_2 + AR			64,326		17,332	46,675			150				
O_2			17,101		–	–			–				
TOTAL DRY			81,427		39,017	105,069			17,755				
MOL. WT.			28.86		21.64	21.64			43.51				
TOTAL, #/HR			2,349,971		844,320	2,273,702			772,500				
	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR
H_2O	292,315				49,131	132,305		836,129				836,129	585,290
COAL (DAF)	1,173,846	16,577	14,823	1,256,927	–	–							
ASH	306,655	306,655			–	–							
TAR, OIL, NAPHTHA					11,790	31,749	88,018						
PHENOL					–	–		8,320		8,320			
SULFUR					–	–							
AMMONIA					–	–		13,780			13,780		
TOTAL #/HR	1,772,816	323,232	2,364,794	1,256,927	905,240	2,437,756	88,018	858,229	772,500	8,320	13,780	836,129	585,290
HHV 10^9 BTU	15.728	0.2221	–	–	3.414	9.1936	1.7247	–	0.1088	0.0133	0.1324	–	–
MMSCFD (DRY)	–	–	–	–	356.5	960.1	–	–					
HHV (BTU/SCF DRY)					230	230							

TABLE 12 CONT'D.

THE M. W. KELLOGG COMPANY
A DIVISION OF PULLMAN INCORPORATED

DATE 3/18/73
BY FC

JOB NO. 4118-13

DESCRIPTION LOW BTU GAS FLOW RATE

CUSTOMER EPA

DESCRIPTION	COMPRESSED AIR	TAIL GAS TO STEAM GEN.	SULFUR BYPRODUCT
STREAM	14	15	16
	MPH	MPH	MPH
CO_2		17,165	
H_2S		16	
C_2H_4		4	
CO		6	
H_2		89	
CH_4		22	
C_2H_6		4	
N_2 + AR	563	1,372	
O_2	149	-	
TOTAL DRY	712	18,678	
MOL. WT.	28.86	42.57	
TOTAL, #/HR	20,559	795,150	
	#/HR	#/HR	#/HR
H_2O	139	5,387	
COAL (DAF)			
ASH			
TAR, OIL, NAPHTHA			
PHENOL			
SULFUR			10,114
AMMONIA			
TOTAL #/HR	20,698	800,537	10,114
HHV 10^9 BTU	-	0.0381	0.0403
MMSCFD (DRY)			

CODA 11-11-64

V. Discussion of Results and Recommendations

Using the specific processes shown in this report, gasoline, methanol, substitute natural gas and low Btu gas can be manufactured from coal via a SASOL-type plant which utilizes Lurgi air- and oxygen-blown gasification processes.

Cost ($/MMBtu) of manufacturing such products decreases in the following manner:

Gasoline > methanol > SNG > Low Btu Gas

Incidentally, the order shown also represents the degree of flexibility of these products. Gasoline and methanol being in liquid form are less expensive for transportation and storage. Gasoline having a higher heating value is a superior product because it is the only proven and widely used automotive fuel and has a greater market demand than methanol. SNG in turn is superior to low Btu gas because it can be transported as pipeline quality gas whereas low Btu gas cannot be transported long distances and its use is therefore restricted to close-coupled plants (e.g., utility boilers).

With respect to the technology involved, gasoline-from-coal plant has been operated commercially by SASOL for more than twenty years. At present a SNG-from-coal facility using Lurgi air-and oxygen-blown gasification processes is yet to be built. Although several are in design stages, large-scale methanol from coal plants are only in planning discussion. Thus, the technology of gasoline-from-coal is ahead of the other coal conversion processes in that a commercial plant is in operation.

Methanol unquestionably can be manufactured from coal cheaper than gasoline; however, the applicability of methanol as a fuel should be explored carefully. Studies have shown that a methanol-gasoline mixture of up to 10% methanol by volume burns more efficiently than gasoline in automobiles and the emissions of unburned hydrocarbons, carbon monoxides, nitrogen oxides are reduced drastically (5). In view of the current U.S. crude shortage of about 8%, methanol can be explored as an additive to gasoline provided the conversion cost of the engine for burning gasoline-methanol mixture is insignificant. Alternatively, the best use of methanol may be to displace fuel oil and natural gas from utility and industrial boilers. The fuel oil thus displaced could be converted to gasoline.

SNG or low Btu gas can be produced cheaper than gasoline or methanol. However, either SNG or low Btu gas is basically a different form of fuel and has a different applicability than gasoline and methanol. Direct comparison of the costs should only be made after one establishes usefulness of the products as well as market demand.

It should be noted that both this report and Task 13 Preliminarly Report did not include any optimization studies because of the limited scope of the task. For example, when the desired end product is SNG or low Btu gas, Lurgi gasification technology is probably the best. For gasoline-or methanol-from-coal plant where methane is an undesirable product in the raw gas synthesis, however, the use of other gasification processes such as Kopper-Totzek gasification unit (which produces practically negligible methane) should be investigated for possible savings.

The use of fuel gas from coal gasification for steam and power generation is undesirable if low sulfur coal can be burned directly for this purpose. If high sulfur fuels are used for auxiliary steam and power generation, installation of a stack gas scrubbing unit may be required.

Production of a singular specialized product may not be the best utilization of the SASOL-type process as reflected by SASOL facility which includes the manufacture of a wide spectrum of chemicals, plastics, oil, gas and fertilizers.

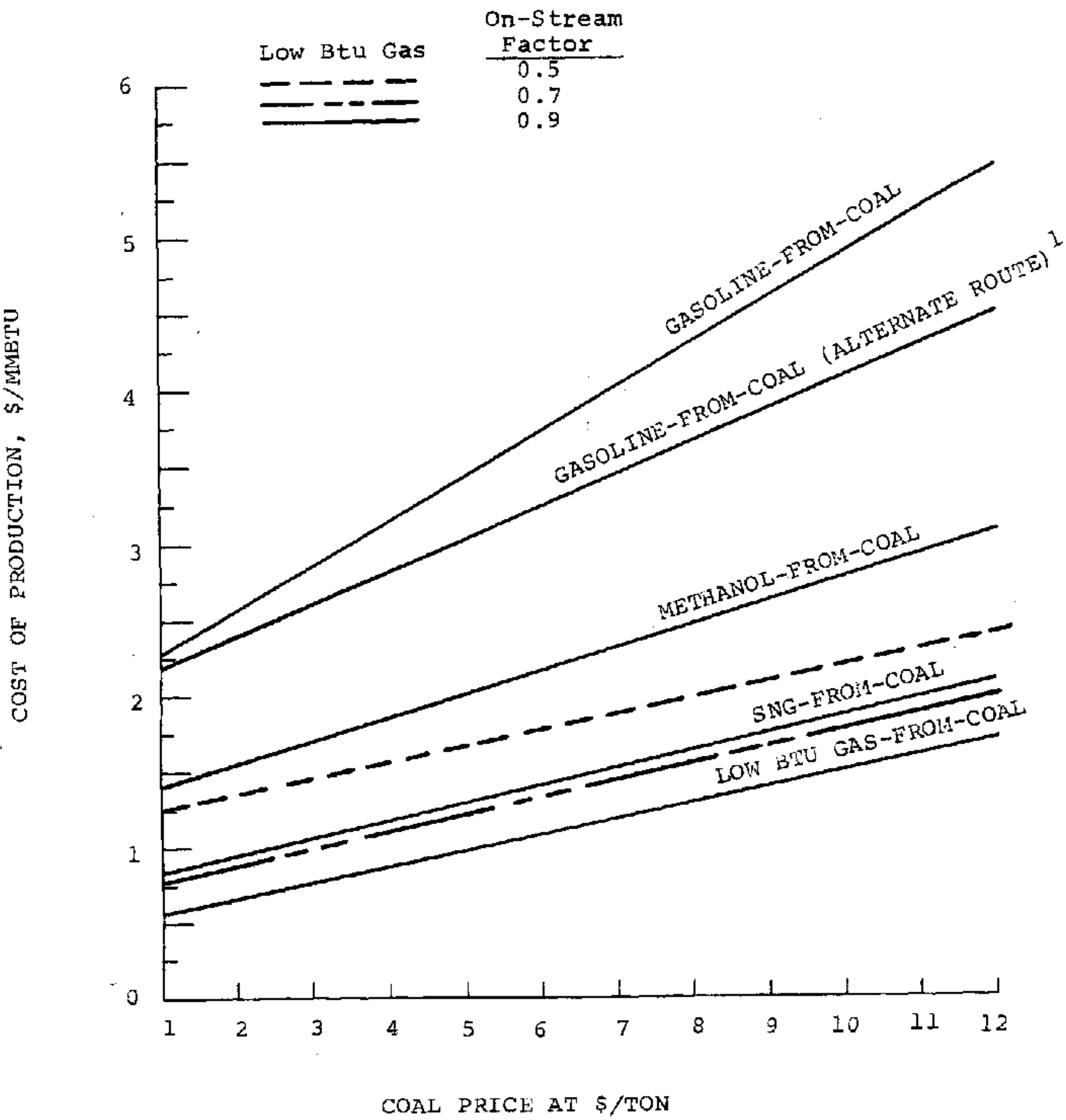
In any event, the cost of manufacturing gasoline and methanol from coal can be lowered by proper optimization of the process. The gasoline-from-coal plant via a SASOL-type process merits a much more detailed optimization study since it is the only available gasoline-from-coal technology today. Such study should include the latest operating technique of the SASOL plant as well as the Synthol process by M.W. Kellogg.

The costs presented in this report should be considered as having budget type accuracy. Also, the values presented in the appendices for coal cost, hourly wage, interest rate, etc., are assumed to be typical for a general evaluation but would need to be refined for a specific application. Figure 5 presents the cost of the products for various coal costs as well as the sensitivity of on-stream factors on the low Btu gas cost.

The basis of the modified Panhandle Eastern accounting procedure used in deriving the cost figures is given in Appendix E. This short cut method is intended to be used for the financing of utility plant and may not be appropriate for the gasoline- or methanol-from-coal plants, both of which are of chemical and refinery type operation. In the absence of a comparative accounting procedure for chemical and refinery plant, the modified Panhandle Eastern accounting procedure is used throughout the report to generate compatible production costs of gasoline and methanol. An estimated incremental increase of 1% in the fixed total capital charge will raise the unit gasoline and methanol costs by 5% (with by-product credits). For example, using a sinking fund method with a 15 year plant life, the fixed capital charge including depreciation, interim replacements, insurance, tax and cost of capital is 18.22% (6). The resulting gasoline and methanol unit costs will be $4.05/MMBtu and $2.34/MMBtu respectively, corresponding to an increase of about 30% over the previous prices derived from the modified Panhandle Eastern accounting procedure. An estimated incremental increase of 1% in the fixed total capital charge will raise the unit SNG cost by 5% and unit low Btu gas by 4% (with by-product credits). Using the same sinking fund method, the unit SNG and low Btu gas costs will be \$1.50/MMBtu and \$1.10/MMBtu respectively.

FIGURE 5: EFFECT OF COAL PRICE ON THE PRODUCTION COST OF GASOLINE, METHANOL, SNG & LOW BTU GAS

Mine-Mouth Coal Cost
On-Stream Factor = 0.9
For Gasoline, Methanol & SNG



1. Maximize gasoline production by including the conversion of tar, oil, naphtha

VI. Reference

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3. El Paso Natural Gas Company application to Federal Power Commission for Burnham Coal Gasification Complex in New Mexico, November 7, 1972.

4. "The Supply - Technical Advisory Task Force - Synthetic Gas - Coal", Final Report, April 1973.

5. Reed, T. B., and R. M. Lomer, Science, Volume 182, December 28, 1973, Number 4119.

6. "Evaluation of SO_2-Control Process", Task No. 5 Final Report, submitted to Environmental Protection Agency, Office of Air Programs, Division of Control Systems by M. W. Kellogg Co., Contract No. CPA 70-68. October 15, 1971.

7. "Steam-Electric Plant Factors", 1973 Edition, National Coal Association, Washington, D.C.

Appendix A

Gasoline-From-Coal Via Synthol Process
Total Capital Requirement

		1975 M$
Total Direct & Indirect Cost of Plant (Incl. Contractor & Eng. Fees, Tax & Licenses)		505,000
Contingency		47,000
Total Plant Investment		552,000
Interest During Construction Interest Rate (9.0%) x Total Plant Investment x 1.875 years average period		93,000
Plant Start-Up Cost 40% of Operating Cost for 1/2 year		9,000
Working Capital	M$	
Coal @ $3.60/ton** (64 day supply)	7,900	
Catalyst & Chemicals (60 day supply)	1,000	
Receivables less Payable (1/24 of Annual Revenue from Gasoline @ $3.05/MMBtu)	5,200	
Total Working Capital		14,000
Total Capital Requirement		668,000

**Mine-Mouth Coal Cost.
This figure is taken from the average coal cost in New Mexico as reported by Steam-Electric Plant Factors, 1973 Edition, National Coal Association with escalation of 10% per year to 1975.

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Appendix A (Cont'd.)

Gasoline-From-Coal Via Synthol Process
Annual Operating Cost

On-stream factor = 0.9

		1975, M$/year
1.	Raw Materials	
	Coal @ $3.60/ton	40,000
2.	Purchased Utilities	
	Power	---
	Raw Water	500
3.	Labor	
	A. Operating Labor @ $8/hr	10,800
	B. Maintenance Labor (1.5% of Total Plant Investment)	8,300
	C. Supervision (0.15 of A + B)	2,900
4.	Supplies	
	A. Operating Catalyst & Chemicals	8,000
	B. Maintenance (1.5% of Total Plant Investment)	8,300
5.	Administration & General Overheads	
	60% of Total Labor Including Supervision	13,200
6.	Tax & Insurance at 2.7% of Total Plant Investment	15,000
7.	Total Operating Cost (Without By-Product Credits)	107,000

Appendix A (Cont'd.)

Gasoline-From-Coal Via Synthol Process
Annual Operating Cost

On-stream factor = 0.9

				MS/Yr.	1975, M$/Year
8.	By-Product Credits				
	A.	Tar, Oil, Naphtha	($8/Barrel)	34,770	
	B.	Phenols	($70/Ton)	3,770	
	C.	Ammonia	($50/Ton)	5,670	
	D.	Sulfur	($10/LT)	480	
	E.	Higher Alcohols	($100/Ton)	3,040	
	F.	Acetone	($150/Ton)	1,570	
	G.	M.E.K.	($200/Ton)	530	
	H.	Diesel Oil	($10.5/Barrel)	4,250	
	I.	Waxy Oil	($7.5/Barrel)	2,280	
	J.	LPG	($6.5/Barrel)	4,270	
	Total By-Product Credit			60,600	
9.	Net Operating Cost (With By-Product Credit)				46,400

Unit Costs Base Case

10. Gasoline Cost (with By-product Credits)

A.	$/MMBtu	3.05
B.	$/Barrel	15.11

11. Gasoline Cost (without By-product Credits)

A.	$/MMBtu	4.55
B.	$/Barrel	22.52

Unit Costs Alternate Case

12. Gasoline Cost (with By-product Credits)

A.	$/MMBtu	2.76
B.	$/Barrel	13.70

Appendix A (Cont'd.)

Gasoline-From-Coal Cost

For 20 year Average Price
Without Escalation (Based on
Shortcut Method on Panhandle
Eastern Accounting Procedure)**

Gasoline Cost

= (Net Operating Cost + 0.1198 x Total Capital Requirement + 0.0198 x Working Capital)/Gasoline Production

Gasoline Production

= 41.5×10^6 MMBtu/Year (8.375 MM Barrels)

$$\text{Gasoline Cost} = \frac{46.4 + 0.1198 \times 668 + 0.0198 \times 14}{41.5}$$

= \$3.05/MMBtu (with By-Product Credits)

= \$15.11/Barrel (with By-Product Credits)

$$\text{Gasoline Cost} = \frac{107 + 0.1198 \times 680 + 0.0198 \times 14}{41.5}$$

= \$4.55/MMBtu (Without By-Product Credits)

= \$22.52/Barrel (Without By-Product Credits)

**Final Report of the Supply-Technical Advisory Task Force - Synthetic Gas From Coal, April, 1973

Appendix A (Cont'd.)

Alternate Gasoline-From-Coal Cost
(By Further Processing the Tar
Oil, Naphtha to Gasoline Product)

Gasoline Production = 25495 + 13230 x 0.8 BPD

= 11.85×10^6 MM Barrel/Year

= 58.7×10^6 MMBtu/Year

Annual Operating Cost (Deletion of Tar, Oil, Naphtha By-Product Credits)

= \$81.2 Million/Year

Total Capital Required = \$552 + \$93 + \$16 + \$14 Million

= \$675 Million

$$\text{Alternate Gasoline Cost} = \frac{81.2 + 675 \times 0.1198 + \$14 \times 0.0198}{58.7}$$

= \$2.76/MMBtu (With Byproduct Credits)

= \$13.70/Barrel (With Byproduct Credits)