gases are disposed of along with flue gas via power plant stacks. Section 1100 includes the treatment of water for the make-up to the boilers, aeration and blow-down. Cooling water inventory and circulation to the coolers requiring water cooling are provided by section 1700, which includes chlorination and blowdown. Makeup to this section is from section 1600, Water Treatment, where water is collected from various parts of the plant. For example, one stream to section 1600 is from section 1400, Effluent Water Treatment, where foul process condensate is purified by activated sludge waste water treating.

b. PROCESS CONSIDERATIONS

It should be noted that a SASOL-type plant as presented in this report is a plant representative of a twenty-year old technology. Improvements in this technology have been made by SASOL principally to suite their needs for fuels and chemicals. Over the years these needs have changed as new products, (e.g., pipeline gas, ammonia, ethylene, synthetic rubber, etc.) were added to the list manufactured from the raw material feeds, viz., coal, water and air. SASOL's continued study of processes in their complex has doubtless given much fundamental information that would be a real asset to a designer tailoring a coal-to-gasoline facility twenty or more years after the original design was committed. For circumstances plausible for such a plant, changes could be called for in the synthesis catalyst manufacturing, leading to a modified product spectrum to suit economic or other circumstances for the projected plant. Optimization of any such design would require information that is unlikely to be found from any source other than SASOL. Lacking access to SASOL's proprietary information for possible attempts at optimization of the facilities described in this report, the present coal-to-gasoline plant can be presented only on the basis of the twenty-year old technology with some minor updating modifications made public by SASOL in the intervening years.

It is significant that the major process steps of the SASOL plant have been proven to be compatible members of the complex and that the complex is amply proven successful for the manufacture of gasoline from coal. It follows that each major process unit is amply proven successful for its intended service.

Sections 200 and 1000 employ the Lurgi pressure gasification process developed by Lurgi Gesellschaft fuer Waermetechnik of Frankfurt, Germany. This process was selected for SASOL in the belief, now confirmed by both pilot plant and later commercial application, that this process and the South African coal were suited for each other. For the present study there is every reason to believe that the same suitability exists for the process and the Western coal chosen. Of course there are other gasification processes that might be used if properties of the coal contemplated were not suited for large-scale pressure gasification by the Lurgi process. Advantages or disadvantages of such processes could only be assessed from a complete knowledge of the coal properties plus possibly some actual test gasification work. Conceivably a coal in question would be handled most economically if pretreated to destroy possibly caking tendencies, or coked to recover byproducts of attractive sales value and then gasified by some process best suited for the product coke.

Gasification by the Lurgi process leads to the production of coal tars, oils, naphthas and phenols, that may or may not have attractive values, and also leads to the formation of methane in the gaseous product. The methane content of the fuel gas is an asset as it gives the fuel gas a higher heating value; however, for the synthesis gas methane is a liability as it requires catalytic splitting with oxygen and steam to supply the reactants needed in the Fischer-Tropsch synthesis. Conceivably a proper choice of gasifiers would involve a low pressure process for synthesis gas production and a pressure gasifier (e.g., Lurgi) for fuel gas production. On the other hand, the Lurgi gasifier with its excellent record at SASOL is not easily replaced at this time by less experienced processes unless it is not at all suited to the coal contemplated.

Gas purification is an important process step in the SASOL-type gasoline-from-coal plant. The Rectisol process first used commercially at SASOL has been an outstanding success and its performance has been phenonenal. In this single continuously-operating process, the wide-cut mixture of gases and vapors is freed of resin formers and objectionable sulfur compounds to mere trace proportions (less than 0.1 ppm total sulfur) while being separated from most of the carbon dioxide contained at about 30% concentration in the raw gas from the gasifiers. Extreme high purity is a requirement of the gas feeding to the iron catalyst of the synthesis, the same as it is for the iron catalyst of ammonia synthesis. This high purity is achieved in an absorber/stripper process in which the lean oil is a refrigerated polar solvent, e.g., methanol. For the present plant design a departure from the SASOL Rectisol design was made to achieve a more concentrated H_2S stream for sulfur recovery and a nearly sulfur-free stream for discharge to atmosphere. This departure involved the use of nitrogen from the oxygen plant for stripping of foul methanol. This is according to a variation of the Rectisol process proposed by Gesellschaft fuer Linde's Eismaschinen, Hoellriegelskreuth, Germany, developers of the Rectisol process.

Conversion of light hydrocarbons into Fischer-Tropsch reactants (H_2 + CO) is another important operation in the SASOL-type plant. The procedure whereby unwanted light hydrocarbons and methane are converted into reactants is a Kellogg development employing high temperature reforming of the hydrocarbons in a steam atmosphere, oxygen being used to supply the endothermic reaction heat. This is a regenerative process in which the reaction feed streams are heated by the reaction product stream. Unconverted steam is condensed as the product gas is cooled to cooling water temperature. This condensate is sent for treatment preparing it for reuse in steam raising. Methane splitting in this plant, as at SASOL, is accomplished in a fixed-bed catalytic reactor. The composition of the synthesis feed gas is adjusted in this reforming operation by proper choice of oxygen and steam rates corresponding to the inlet gas composition and rate.

Although the H_2/CO ratio of the synthesis feed leaving the methane splitter is essentially the ratio at which these reactants are consumed in the synthesis reactions, the ratio prevailing in the reactor is much higher. The reactor H_2/CO ratio is made higher by the internal recycle of the synthesis cycle, this gas being a light tail gas from the synthesis. The mixture of feed and internal recycle is fed to the high velocity fluid catalytic reactor especially developed by Kellogg for the highly exothermic Fischer-Tropsch reaction. The mixed stream, only slightly preheated above cooling water temperature, contacts hot fluid iron catalyst descending a standpipe leg of a catalyst loop circuit and becomes heated to a kindling temperature at which the reactions begin. This mixture of catalyst and reacting gases rises vertically through the reactor leg of the catalyst loop circuit, transferring reaction heat to an external cooling medium through surfaces built into the reactor leg. Although there is considerable shrinkage of the gas volume through reaction, and a corresponding reduction in velocity, the mixture travels completely through the vertical reactor and over an inverted U-bend to the separator vessel in which the catalyst disengages from the gas stream to complete the loop via the bottom-connected standpipe leg. The product distribution obtained in this reaction is dependent on the catalyst type and activity as well as on the outlet temperature and the reactor temperature profile. The high velocity fluid reactor puts the important variables in easy control of the operator.

Heat removed from the reacting stream traversing the reactor is used to raise steam at about 175 psig which in term is used in turbine drives for compressors, e.g., internal recycle compressors. Hot gas separated from the catalyst flows to an oil scrubber in which cooling and condensation is effected through direct contact with circulating oil, dumping heat to boiler feed water for boilers in the synthesis section. The oil circulation circuit is followed by a water circulation circuit that, through direct contact with the reactor gases and vapors, effects further cooling and condensation of reactor products. Tail gas following these condensation stages is split four ways: 1) a large stream of internal recycle; 2) a net stream that is to be subsequently processed into light gas for external recycle; 3) a purge stream which is used as fuel in steam and power generation section; and 4) a heavy hydrocarbon stream feeding product separators.

Bottoms of the oil scrubber contain catalyst fines washed down in the condensation process; these bottoms are returned to the catalyst circulation. Just above the catalyst settling zone of the scrubber, a heavy oil is decanted and sent from the unit as a separate stream for further processing. Light oil separated by gravity from the water circulation circuit is first water washed to remove water soluble chemicals and then sent from the unit for further processing. Tail gas is similarly water washed and then sent on to the product recovery area. Aqueous streams condensed from the reactor product join the wash water streams and become the feed to the Chemical Recovery section 700.

Heavy oil decanted above the catalyst settling zone of the synthesis unit oil scrubber enters section 600, Product Recovery, where it is flashed to remove its very heavy components. The lighter fractions of this oil join the lighter oil of the synthesis production and together the mixture undergoes vapor phase catalytic clay treatment for the removal of oil soluble chemicals and mild catalytic cracking of the synthetic crude molecules. The catalyst is regenerated in the usual way by burning off carbon with a mixture of air and nitrogen.

Synthesis tail gas from section 500, Synthesis, is passed directly to the absorber of the section 600, Product Recovery. Lean oil stripped in the lean oil distillation tower preferentially absorbs the heavier fractions of the gas and only a small amount of the lighter unwanted fractions. The unwanted fractions are partly purged from the system to remove the inerts (e.g., N_2 and Ar brought in with coal and oxygen) and mostly returned to the Methane Splitter, Section 400, for conversion to CO and H_2 for the synthesis. Absorbed components become feed for the catalytic polymerization unit which, under high pressure and in the presence of a catalyst, unites unsaturated molecules to form high octane gasoline molecules. Some excess of stripped molecules over those consumed by polymerization are liquefied and transfered to LPG storage for eventual marketing. Part of the cat poly feed is generated in the clay treating of the synthetic oil.

A fractionator separates the liquids recovered from clay treating and cat poly into gasoline, diesel oil and furnace, or waxy, oil.

The aqueous stream from section 500, Synthesis, is treated in section 700, Chemical Recovery, for the recovery of alcohols and ketones. The first separation is made to dispose of the acids and the bulk of the water. This mixture is sent to the activated sludge treatment unit in section 1400. Overhead product of the first separation is rich in alcohols and ketones and this stream is separated into two main streams in the following distillation tower. Both of these streams are processed further in a system of eight distillation towers and two hydrogenation reactors to yield ethyl alcohol, propyl alcohol, a stream of heavier alcohols and a mixture of ketones as intermediate products. The heavier alcohols are simply distilled to yield butyl alcohol, pentyl alcohol and a small residue of heavier alcohols, used as fuel. The mixture of ketones is first caustic treated then distilled to recover acetone and MEK (methylethyl ketone).

Ethyl alcohol is blended with the gasoline product for the octane benefits it supplies. All other products of section 700 are pumped to storage in the offsites. Section 600 products are pumped to storage also with the gasoline getting the treatment and/or additives it may require for marketing, e.g., color addition, inhibitor addition.

Sulfurous gases from sections 300, Gas Purification, and 1000, Fuel Gas Manufacture, become feed to the section 1500, Sulfur Recovery Unit, which, employing a Stretford solution, recovers the sulfur of H_2S as solid sulfur. The waste gas is vented through stacks. Air for the oxidation is supplied by a compressor incorporated in section 1500.

The steam and power section, 1100, is visualized in a location close to air separation, section 900. Large compressors of the air separation plant could thus be driven by gas turbines exhausting into the firebox of boilers and steam superheaters of section 1100. Steam systems have not been sketched for the plant and for the section 1100 in particular. It is very likely that steam generation, unlike steam generation at SASOL, will be at high pressure, e.g., 1500 psig. Superheated steam at this pressure likely will be sent to topping turbines for the generation of electrical power for the plant. Exhaust of these turbines will supply the process steam for gasification in sections 200 and 1000. Low level steam generated in section 500 will doubtless find use for turbine drives within the section, probably supplemented with the process steam level established by the gasifiers. Still lower level steam generated in waste heat boilers of the gasification plant probably will supply boiler feed water deaeration needs, reboiler duties, space heating requirements, etc. Condensates will be collected in separate tanks according to whether they are expected to be always clean or whether possibly contaminated by gases or liquids reaching the condensates, possibly through equipment leaks.

It is possible that this plant could be redesigned for a more interesting array of products from coal at a much reduced plant cost. The prospects would be dependent upon the product array sought and newer technology available than were at hand for the SASOL plant design. This newer technology may possibly exist with SASOL at the present or could result from the aims of research and development that may need to be undertaken. It is clear that the Methane Splitting could, for example, be eliminated if the desired product array included a reasonably high Btu gas. The external recycle would go to fuel gas. Conceivably the Lurgi gas issuing from the gasifiers could be reformed catalytically with oxygen addition at temperatures high enough to convert the tars, phenols, oils and methane to the reactants CO and H_2. Considerable savings would be made if this step could be taken. Of course, the incentive would depend on possible sales values of phenols and coal tar products.

Depending on product array desired, the catalyst may be profitably altered with possible changes in amount or kind of catalyst modifiers. Presumably there is knowledge and experience to guide steps that may be taken to this end development.

Considerable savings could doubtless be made if coal fines could be fired directly to the power plant and expensive stack gas cleaning were not a requirement for the power plant.

Tie-ins with other industries may have some interesting prospects for a gasoline-from-coal plant. Gases from a refinery handling natural crude possibly could be processed with gases from a synthesis plant to a mutual advantage. Gases or liquids from a steel mill might be exchanged with products of the synthesis to a mutual advantage. It should be remembered that the products of the synthesis are remarkably free of many troublesome contaminants, e.g., metals, sulfur. The probable octane of the gasoline from the subject plant is about 86 research. If octane levels were important, the scope of operations would probably have to be increased to include isomerization and alkylation.

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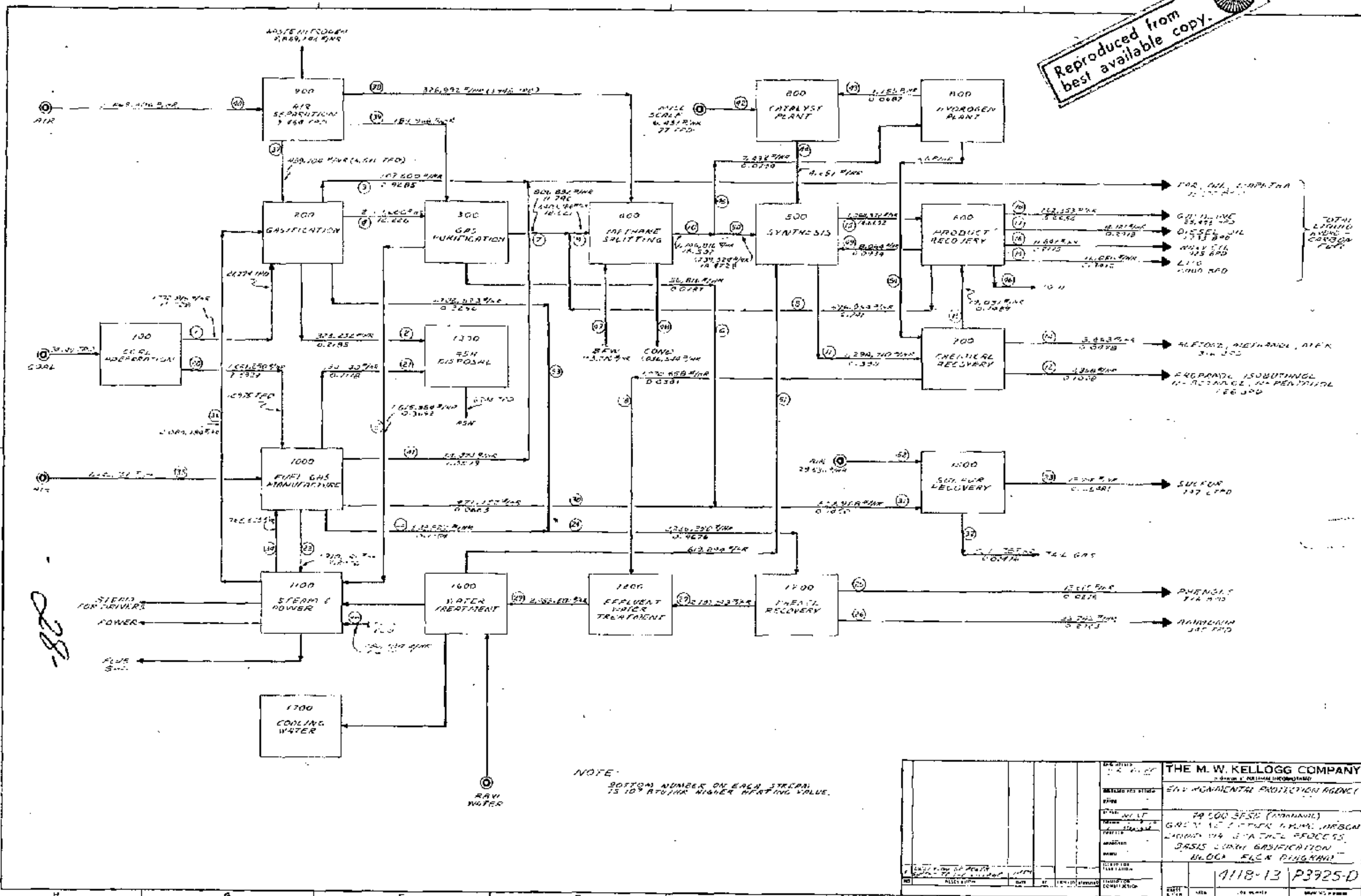


NOTE:
BOTTOM NUMBER ON EACH STREAM IS 10⁹ BTU/HR HIGHER HEATING VALUE.

THE M. W. KELLOGG COMPANY
ENVIRONMENTAL PROTECTION AGENCY
BLOCK FLOW DIAGRAM
4118-13 P3925-D

TABLE 9 MATERIAL & ENERGY BALANCE

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

DESCRIPTION COAL-BASED SYNTHOL PLANT

CUSTOMER EPA

DATE

BY HBG

JOB NO. 4118-13

	COAL FEED	GASIF. ASH	GASIF. TON	RAW SYN. GAS	RECT. FUEL GAS	RECT. H_2S	PURIF. SYN GAS	RECYCLE GAS TO SYNTHOL	FEED TO METHANOL SPLIT	METHANE SPLITTER PROD.	SYNTHOL SOLVENTS	HVY ALCOHOLS	ETHANOL
	1	2	3	4	5	6	7	8	9	10	11	12	13
	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR
Moisture	292,304												
DAF Coal	1,173,856	6,576											
Ash	306,656	306,656											
#/HR	1,772,816	323,232	107,600	2,169,600	1,515,98	36,816	806,832	596,954	1,403,766	1,746,816	1,298,710	7,358	17,031
HHV Btu/HR x 10^9	15.47	0.2185	2.8285	12.2260	0.369	0.0787	11.780	6.741	18.521	18.502	0.3911	0.1008	0.1489
Tar			69,632										
Tar-Oil Naphtha			37,968										
Water													
Phenols											1,265,20		
Acids													
NH_3											5,45		
Sulfur													
LPG													
Gasoline													
Diesel Oil													
Waxy Oil													
Acetone													
Methanol											2,650		
Propanol											343		
Isobutanol											4,832	4,832	
n-Butanol											546	546	
MEK											1,606	1,606	
nPentanol											670		
Ethanol											374	374	
											17,031		17,031
	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH
CO_2				31,731.0	29,742.[illegible]	587.4	1401.6	5,315.2	6716.8	10,320.0			
H_2S				320.0		320.0	-	-	-	-			
COS						1.0	-	-	-	-			
C_2H_4				372.8	176.[illegible]		196.8	766.4	963.2	-			
CO				16,030.4	56.[illegible]		15,974.4	752.0	16,726.4	30,832.0			
H_2				39,988.4	65.[illegible]		39,923.2	17,426.8	57,352.0	93,744.0			
CH_4				12,176.0	201.[illegible]		11,974.4	9401.6	2[illegible],376.0	8,256.0			
C_2H_6				542.4	248.[illegible]		294.4	382.4	676.8	-			
N_2				417.6	6786.[illegible]	1.0	414.4	3963.2	4377.6	2,512.0			
Ar										592.0			
C_3H_6								192.0	192.0	-			
C_3H_8										-			
C_4H_8										-			
C_4H_{10}										-			
H_2Ov								67.2	67.2	380.0			
Light Oil													
Heavy Oil													
MPH Total				101,579.2	37,276.2	909.3	70,179.2	38,268.8	106,448.0	147,136.0			

COOA 11 11-64

TABLE 9 CONT.

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

DESCRIPTION COAL-BASED SYNTHOL PLANT

CUSTOMER

DATE

BY HBG

JOB NO. 4118-13

	LIGHT SOLVENTS	SYNTHOL PROD.	WAXY OIL	DIESEL OIL	GASOLINE	LPG	COAL TO FUEL GAS GEN.	ASH FROM F.G. GEN.	LOW BTU F.G.	GAS LIQUOR	FEED TO PHENOSO.	PHENOLS	AMMONIA
	14	15	16	17	18	19	20	21	22	23	24	25	26
	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR
Moisture							178,278						
DAF Coal							715,941	10,110					
Ash							187,031	187,030					
#/HR	3,663	1,068,572	11,847	15,121	262,353	16,056	1,081,250	197,140	1,910,181	523,827	2,226,350	13,665	28,742
HHV Btu/HR x 10^9	0.0478	14.6692	0.2175	0.2913	5.2654	0.3412	9.5929	0.1118	7.2906	0.1354	0.4676	0.0218	0.2763
Tar													
Tar-Oil Naphtha													
Water										523,827**	2,183,942		
Phenols											13,665	13,665	
Acids													
NH_3											28,743		28,743
Sulfur													
LPG						16,056							
Gasoline					245,322								
Diesel Oil				15,121									
Waxy Oil			11,847										
Acetone	2,650												
Methanol	343												
n-Butanol													
MEK	670												
nPentanol													
Ethanol					17,031								
	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH
CO_2		6720.0							4,394.8				
H_2S									18.8				
COS													
C_2H_4		1024.0							245.2				
CO		976.0							16,500.0				
H_2		22,080.0							21,682.3				
CH_4		11,936.0							5,627.2				
C_2H_6		608.0							369.2				
N_2		4304.0							39,038.5				
Ar		512.0											
C_3H_6		1280.0											
C_3H_8		208.0											
C_4H_8		672.0											
C_4H_{10}		96.0											
C5±		336.0											
C6.5±		160.0											
H_2Ov		160.0											
Light Oil		1404.8											
Heavy Oil		51.2											
MPH Total		52,688.0							87876.9	** Gas Liquor			

TABLE 9 CONT.

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

DESCRIPTION COAL-BASED SYNTHOL PLANT

CUSTOMER EPA

DATE

BY HBG

JOB NO. 4118-13

	WATER FROM PHENOSOL-VAN	ACID WATER FROM 700	TREATED WATER	HOT CARB. H_2S	H_2S TO SRU	SRU TAIL GAS	SULFUR	STEAM TO F.G. GEN.	AIR TO F.G. GEN	STEAM TO GASIFIER	O_2 TO GASIF.	O_2 TO METH. SPLIT	N_2 TO RECT.
	27	28	29	30	31	32	33	34	35	36	37	38	39
	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR
Moisture													
DAF Coal													
Ash													
#/HR	2,224,983	1,270,658	2,485,581	471,152	507,968	524,628	13,757	766,605	1,442,051	2,089,984	459,704	328,992	189,968
HHV Btu/HR x 10^9	-	0.0341	-	0.0663	0.1450	0.02496	0.05481	-	-	-	-	-	-
Tar													
Tar-Oil Naphtha													
Water	2,224,983	1,265,205	2,485,581					766,605	9,038	2,089,984			
Phenols													
Acids		5,453											
NH_3													
Sulfur							13,757						
LPG													
Gasoline													
Diesel Oil													
Waxy Oil													
Acetone													
Methanol													
n-Butanol													
MEK													
nPentanol													
Ethanol													
	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH
CO_2				10,468.8	10,860.4	11,101.5							
H_2S				192.2	452.3	22.6							
COS					0.8	0.8							
C_2H_4				2.1		2.1							
CO				34.8		34.8							
H_2				54.4		54.4							
CH_4				13.8		13.8							
C_2H_6				2.1		2.1							
N_2				91.4	93.6	902.1			38666.2		792.4	185.6	6784.5
Ar												20.8	
C_3H_6													
C_3H_8													
C_4H_8													
C_4H_{10}													
C5±													
C6.5±													
H_2Ov						429.7		42,589	502.1	116,110.2			
Light Oil													
Heavy Oil													
O_2									10344.5		13,660.0	10,092.8	
MPH Total				10,856.0	11,407.1	12563.5		42,589	49512.1	116,110.2	14,452.4	10,299.2	6784.5

TABLE 9 CONT.

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

JOB NO. 4118-13

DESCRIPTION COAL-BASED SYNTHOL PLANT

CUSTOMER EPA

DATE

BY HBG

	AIR TO O_2 PLANT	F.G. GEN TON	MILL-SCALE	H_2 TO CAT PLANT	CAT. TO SYNTHOL	SYN. GAS TO H_2 PLANT	PURGE GAS	BFW TO METH. SPLIT	METH. SPLIT COND.	GAS RECYCLE TO SYN.	SYNTHOL FEED	WATER TO SYNTHOL	AIR TO SRU
	40	41	42	43	44	45	46	47	48	49	50	51	52
	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR
Moisture													
DAF Coal													
Ash													
#/HR	3,868,406	54,474	6,437	1155.2	4,651	7,492	150,784	953,776	1,036,544	8,064	1,739,324	619,894	29,536
HHV Btu/HR x 10^9	-	1.0519	-	0.0687	-	0.0794	1.675	-	-	0.0934	18.428	-	-
Tar		54,474											
Tar-Oil Naphtha													
Water								953,776	1,036,544			619,894	
Phenols													
Acids													
NH_3													
Sulfur													
LPG													
Gasoline													
Diesel Oil													
Waxy Oil													
Acetone													
Methanol													
n-Butanol													
Air													29,536
Millscale			6,437										
Catalyst					4,651								
	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH
CO_2						44.3	1332.8			72.0	10,275.7		
H_2S						-				-			
COS										-			
C_2H_4							193.6			4.8			
CO						132.2	212.8			11.3	30,699.8		
H_2				534.4		402.1	4412.8			238.4	93,341.9		
CH_4				5.4		35.4	2404.8			129.6	8,220.6		
C_2H_6							97.6			3.2			
N_2	101,669.0					10.8	852.3			46.4	2,501.2		
Ar	119.7					2.5	107.2			6.4	589.5		
C_3H_6							48.0			1.6			
C_3H_8													
C_4H_8													
C_4H_{10}													
C5+													
C6.5±													
H_2Ov	7742.0						19.2			11.2	876.2		
Light Oil													
Heavy Oil													
O_2	26,976.3					3.3							
MPH Total	136,507.0			539.8		631.1	9681.6			528.0	147,504.9		

TABLE 9 CONT.

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

JOB NO. 4118-13

DESCRIPTION COAL-BASED SYNTHOL PLANT

CUSTOMER EPA

DATE

BY HBG

	GAS LIQUOR FROM GASIF	H_2 TO SECT. 700
	53	54
	#/HR	#/HR
Moisture		
DAF Coal		
Ash		
#/HR	1,702,523	56
HHV Btu/HR x 10^9	0.3256	
Tar		
Tar-Oil Naphtha		
Water	1,675,006	
Phenols	8867	
Acids		
NH_3	18,650	
Sulfur		
LPG		
Gasoline		
Diesel Oil		
Waxy Oil		
Acetone		
Methanol		
n-Butanol		
MEK		
Millscale		
Catalyst		
	MPH	MPH
CO_2		
H_2S		
COS		
C_2H_4		
CO		
H_2		26
CH_4		0.3
C_2H_6		
N_2		
Ar		
C_3H_6		
C_3H_8		
C_4H_8		
C_4H_{10}		
C5 ±		
C6.5±		
H_2Ov		
Light Oil		
Heavy Oil		
O_2		
MPH Total		26.3

B. Methanol-From-Coal (MWK Dwg. P3355-D)

A block flow diagram for the methanol-from-coal process is given in the cited drawing. The process may be divided into three steps:

- Coal Gasification and Raw Gas Purification
- Synthesis Gas Preparation
- Methanol Synthesis and Purification

1. Coal Gasification and Raw Gas Purification

This step is identical to the one in the gasoline-from-coal plant.

2. Synthesis Gas Preparation

Feed gas introduced into the methanol synthesis loop must contain the correct proportions of carbon monoxide, carbon dioxide and hydrogen according to the following overall reactions:

$$CO + 2H_2 = CH_3OH$$

$$CO_2 + 3H_2 = CH_3OH + H_2O$$

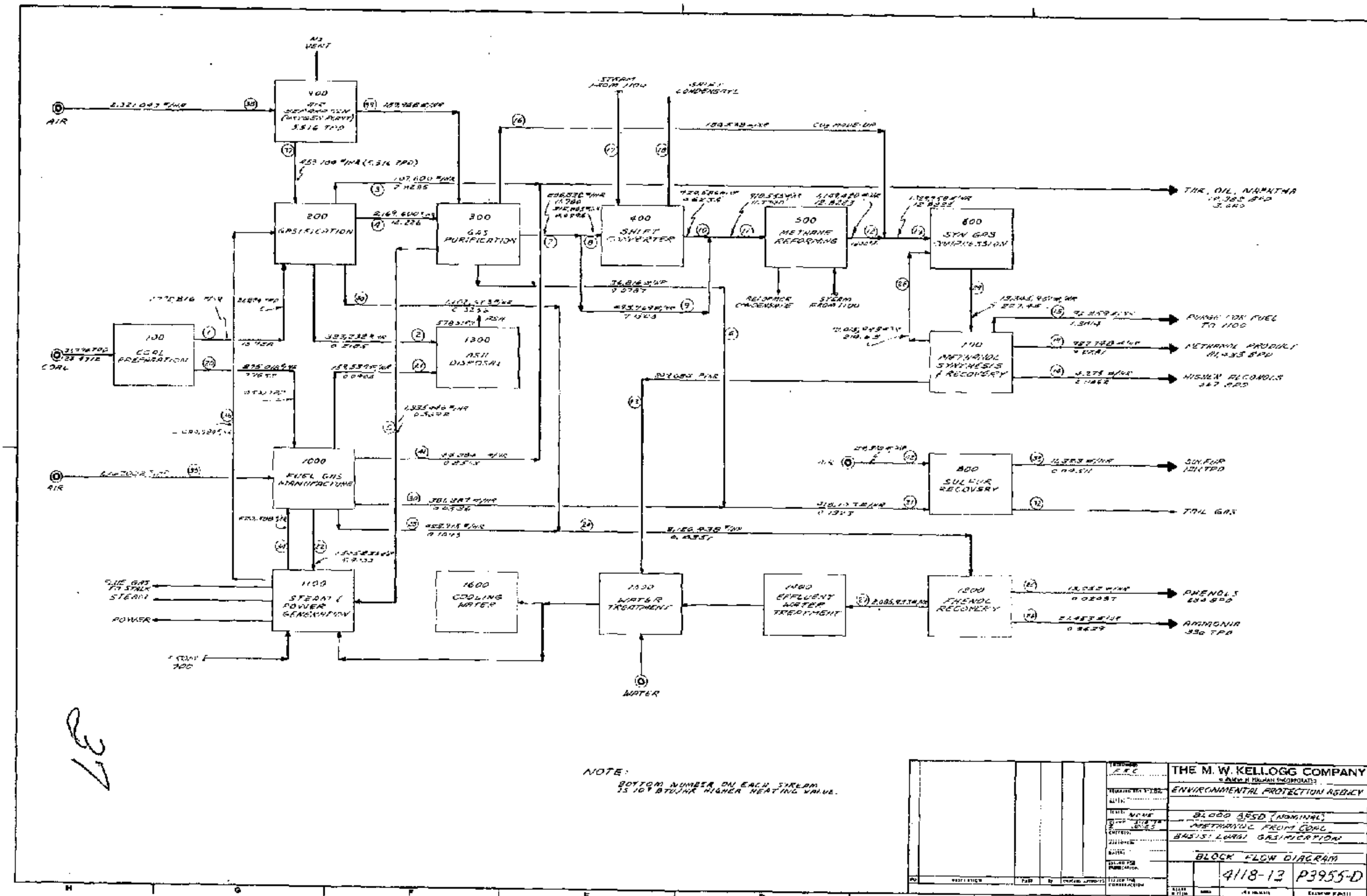
Synthesis gas composition will be adjusted by shift reaction and steam reforming. Raw synthesis gas from the purification section contains methane which is an unwanted component in the synthesis feed. The methane and other light hydrocarbon produced are split into hydrogen and carbon oxides by steam reforming. However, due to the relatively high concentration of carbon monoxide in the raw synthesis gas, carbon may be formed by disproportionation and deposit on the reforming catalyst surface and render the catalyst inactive. Part of the synthesis gas is sent to shift conversion and the remainder is by-passed. In the shift reaction carbon monoxide reacts with steam to form equivalent amounts of carbon dioxide and hydrogen. The shift reaction is exothermic and the shift effluent is cooled against boiler feed water. Water condensed in the cooling of the gas is separated and the cooled gas is then sent to the methane reforming unit. Steam reforming of methane is highly endothermic and heat is required as input to the reformer. Reformer effluent exits at about 1600°F, is cooled against the incoming feed and also used to boil feed water. The final synthesis gas is adjusted to the composition desired by a carbon dioxide make-up stream from the Rectisol unit.

3. Methanol Synthesis and Purification

Synthesis gas, containing hydrogen, carbon monoxide, carbon dioxide and small amounts of nitrogen, argon and methane, flows to the suction of the two-stage centrifugal feed compressor. The compressor is driven by a steam turbine using high pressure superheated steam. Fresh synthesis gas is compressed to about 1370 psig in two stages with intercooling between stages. Following cooling and separation of condensate, the compressed synthesis feed gas joins synthesis loop recycle gas containing about 0.3 percent methanol vapor. The combined stream is then compressed by a single-stage, turbine-driven centrifugal compressor to about 1485 psig and delivered to the methanol converter. Prior to entering the converter, a major portion of the feed flows to the interchanger which preheats the gas by exchange with the hot methanol converter effluent. The two overall reactions occuring in the converter are those associated with the combination of hydrogen and carbon monoxide to form methanol and the reaction of hydrogen and carbon dioxide to form carbon monoxide and water. Other side reactions involve the formation of dimethyl ether, ketones and higher alcohols. The hot effluent is cooled by the interchanger and again by water-cooled exchanger to 100°F thus condensing out the crude methanol product. The vapor/liquid stream then flows to the catchpot for separation of vapor from liquid. Disengaged vapor, containing unreacted hydrogen, carbon monoxide, carbon dioxide, methanol vapor, water and dimethylether flows to recycle compressor suction where it is combined with fresh feed make-up gas. Prior to compression, a proportion of the recycle gas is vented continuously to the fuel system to control the concentrations of methane, nitrogen and argon in the synthesis loop. These components would otherwise build up in the system and reduce the effective synthesis pressure, which would be reflected by lower methanol conversion per pass and reduced production capacity. Purge gas is delivered to the fuel gas system for power and steam generation.

Crude methanol from the catchpot, containing methanol, water and various impurities, flows to flash drums where the stream is flashed at 50 psig for removing the bulk of gas dissolved in the stream. Flash gas from this pressure reduction step also flows to the fuel system. Liquid from flash drums flow to the crude methanol storage tank.

Purification of methanol is accomplished in a two-tower distillation facility. The fractionation system consists of a topping column whose primary purpose is to remove light-end impurities such as dimethyl ether, ketones and aldehydes and a refining column to remove the heavy ends including ethanol and other higher alcohols from the methanol product. It should be noted that a two tower purification system may not be necessary for "fuel grade" methanol in which case the investment and operating cost would be reduced slightly.



AIR
COAL
AIR
WATER
N2 VENT
900 AIR SEPARATION (OXYGEN PLANT) 3,516 TPD
100 COAL PREPARATION
200 GASIFICATION
300 GAS PURIFICATION
400 SHIFT CONVERTER
500 METHANE REFORMING
600 SYN GAS COMPRESSION
700 METHANOL SYNTHESIS & RECOVERY
800 SULFUR RECOVERY
1000 FUEL GAS MANUFACTURE
1100 STEAM & POWER GENERATION
1300 ASH DISPOSAL
1400 EFFLUENT WATER TREATMENT
1500 WATER TREATMENT
1600 COOLING WATER
1800 PHENOL RECOVERY
STEAM FROM 1100
SHIFT CONDENSATE
CO2 MAKE-UP
REFORMER CONDENSATE
STEAM FROM 1100
TAR, OIL, NAPHTHA
PURGE GAS FUEL TO 1100
METHANOL PRODUCT
HIGHER ALCOHOLS
SULFUR
TAIL GAS
PHENOLS
AMMONIA
FLUE GAS TO STACK
STEAM
POWER
NOTE:
BOTTOM NUMBER ON EACH STREAM IS 10⁹ BTU/HR HIGHER HEATING VALUE.
THE M. W. KELLOGG COMPANY
ENVIRONMENTAL PROTECTION AGENCY
METHANOL FROM COAL
BASIS: LURGI GASIFICATION
BLOCK FLOW DIAGRAM
4118-13
P3955-D
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TABLE 10

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

DESCRIPTION 11338 TPD METHANOL-FROM-COAL MATERIAL BALANCE CUSTOMER EPA

DATE 3/5/74 BY FC

EST NO. 10F4 JOB NO. 4118-13

DESCRIPTION	COAL FEED	GASIF. ASH	TAR, OIL NAPHTHA	RAW SYN. GAS	RECT. FUEL GAS	RECT. H_2S GAS	PURIF. SYN. GAS	SHIFT CONV. FEED	SHIFT CONV. BY-PASS	SHIFT CONV. EXIT	FEED TO REFORMER	EXIT FROM REFORMER	SYN. G. TO COM-PRESSOR
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				31,731.0	25,640.2	587.4	1,401.6	550.8	850.8	6,514.1	7,364.9	10,401.7	14,503.7
H_2S				320.0	–	320.0	–	–	–	–	–	–	–
COS					–	1.0	–	–	–	–	–	–	–
C_2H_4				372.8	176.0		196.8	77.3	119.5	77.1	196.9	–	–
CO				16,030.4	56.0		15,974.4	6,277.9	9,696.5	312.5	10,009.0	16,971.9	16,971.9
H_2				39,988.4	65.6		39,923.2	15,689.8	24,233.4	21,654.4	45,887.8	78,229.3	78,229.3
CH_4				12,176.0	201.6		11,974.4	4,705.9	7,268.5	4,705.0	11,973.5	2,957.0	2,957.6
C_2H_6				542.4	248.0		294.4	115.7	178.7	115.7	294.4	–	–
N_2				417.6	6,787.7	1.0	414.4	162.9	251.5	162.9	414.4	414.4	414.4
AR													
C_3H_6													
H_2O (v)													
O_2													
CH_3OH													
BuOH, DME, ETC.													
TOTAL MPH				101,579.2	33,174.2	909.3	70,179.2	27,580.4	42,598.8	33,526.0	76,140.6	108,974.6	113,076.9
	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR
TAR, OIL, NAPHTHA			107,600										
WATER													
PHENOLS													
AMMONIA													
SULFUR													
ASH	306,656												
D.A.F. COAL	1,173,856	6,576											
MOISTURE	292,304	306,656											
TOTAL #/HR	1,772,816	323,232	107,600	2,169,600	1,335,446	36,816	806,832	312,863	493,969	424,586	918,555	1,149,420	1,329,958
HHV 10^9 BTU/HR	15.7280	0.2185	2.8285	12.226	0.3692	0.0787	11.7800	4.6295	7.1505	4.6235	11.7740	12.8223	12.8223

CODA 11-71-64

TABLE 10 CONT.

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

DESCRIPTION 11338 TPD METHANOL FROM COAL

CUSTOMER EPA

DATE 3/5/74
BY FC

JOB NO. 4115-13

DESCRIPTION	HIGHER ALCOHOLS	PURGE FOR FUEL GAS	PURE CO_2 MAKEUP	STEAM TO SHIFT	STEAM CONDENSATE	METHANOL PRODUCT	COAL TO FUEL GAS GEN.	ASH FROM FUEL GAS GEN	FUEL GAS TO STEAM & POWER GEN.	GASGAS LIQUOR	FEED TO PHENOSOLVAN	PHENOLS BYPRODUCT	AMMONIA BYPRODUCT
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		521.4	4,102.0						3,574.8				
H_2S		–							15.3				
COS		–							–				
C_2H_4		–							199.4				
CO		212.0							13,421.2				
H_2		3,173.8							17,637.5				
CH_4		2,903.3							4,577.2				
C_2H_6		–							300.3				
N_2		413.9							31,754.4				
AR		–											
C_3H_6		–											
H_2O (V)		9.5		7,533.0	1,567.8								
O_2		–											
CH_3OH		73.1				28,956.0							
BuOH, DME, ETC.	67.5	5.8											
TOTAL MPH	67.5	7,313.0	4,102.0	7,533.0	1,567.8	28,956.0			71,490.1				
	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR
TAR, OIL, NAPHTHA													
WATER										410,927	2,085,933		
PHENOLS										4185.0	13,052	13052.0	
AMMONIA										8803.0	27,453		27,453
SULFUR													
ASH							151357.6	151357.6					
DAF COAL							579386.0	8181.7					
MOISTURE							144,273.8						
TOTAL #/HR	4,275	96,258.8	180,537.8	135,745.	28,251.8	927,748.3	875,018	159,539	1,545,835	423,915	2,126,438	13,052	27,453
HHV 10^9 BTU/HR	0.0562	1.3814	..	–	–	9.2281	7.7632	0.0905	5.9000	0.0536	0.4351	0.02087	0.2639

TABLE 10 CONT.

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

DESCRIPTION 11338 TPD METHANOL FROM COAL

CUSTOMER EPA

DATE 3/5/74
BY TC

JOB NO. 4118-13

DESCRIPTION	WATER FROM PHENOSOLVAN	SYN. GAS RECYCLE	INLET TO METHANOL SYNTHESIS	HOT H_2S	H_2S TO SULFUR PLANT	TAIL GAS TO STACK	SULFUR BYPRODUCT	STEAM TO FUEL GAS MFG.	COMP. AIR TO FUEL GAS GEN.	STEAM TO GASIF.	O_2 TO GASIFIER	COMP. AIR TO OXYGEN PLANT	N2 TO RECTISOL PLANT
STREAM	27	28	29	30	31	32	33	34	35	36	37	38	39
	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH
		–											
CO_2		45,937.0	60,440.7	8,472.1	9,053.5	9,137.5							
H_2S		–	–	155.5	475.5	18.6							
COS		–	–	–	1.0	1.0							
C_2H_4		–	–	1.7	1.7	1.8							
CO		31,836.8	48,808.7	28.2	28.2	29.1							
H_2		486,126.8	564,356.1	44.0	44.0	45.4							
CH_4		392,276.7	395,234.3	11.1	11.1	11.5							
C_2H_6		–	–	1.7	1.7	1.8							
N_2		61,577.9	61,992.3	74.1	75.1	742.5			31291.2		792.4	61001.4	6785.4
AR												71.8	
C_3H_6		–	–	–									
H_2O (V)		340.0	340.0	–				34,427.7	406.3	116,110.2		4645.2	
O_2		–	–	–					8371.5		13,660.0	16185.8	
CH_3OH		2,913.0	2,913.0	–									
BuOH, DME, ETC.		216.5	216.5	–									
TOTAL MPH		1,021,224	1134301.6	8786.7	9696.0	9989.2		34,427.7	40,069.2	116,110.2	14452.4	81,904.2	6785.4
	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR	#/HR
TAR, OIL, NAPHTHA													
WATER	2,125,133												
PHENOLS													
AMMONIA							11,323						
SULFUR													
ASH													
DAF COAL													
MOISTURE													
TOTAL #/HR	2,125,133	12,015,993	13,345,951	381,287	418,103	431,816	11,323	620,388	1,167,002	2,089,984	459,704	2,321,043	189,968
HHV 10^9 BTU/HR	–	214.6311	227.4534	0.0536	0.1323	0.02055	0.04511	–	–	–	–	–	–

TABLE 10 CONT.

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

DATE 3/5/73 PAGE NO. 4 OF 4
BY FC JOB NO. 4118-13

DESCRIPTION 11338 TPD METHANOL FROM COAL CUSTOMER EPA

DESCRIPTION	GAS LIQUOR FROM GASIFICATION	TAR, OIL NAPHTHA FROM FUEL GAS	AIR TO SULFUR PLANT	PROCESS WATER RECOVERED									
STREAM	40	41	42	43									
	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH	MPH
CO_2													
H_2S													
COS													
C_2H_4													
CO													
H_2													
CH_4													
C_2H_6													
N_2			} 660										
AR			}										
C_3H_6													
H_2O (V)													
O_2			175.4										
CH_3OH													
BuOH, DME, ETC.													
TOTAL MPH			835.4										
TAR, OIL, NAPHTHA		44,084											
WATER	1,675,006			249,684									
PHENOLS	8867.												
AMMONIA	18,650												
SULFUR													
ASH													
DAF COAL													
MOISTURE													
TOTAL #/HR	1,702,523	44,084	24,310	249,684									
HHV 10^9 BTU/HR	0.3256	0.8513	-	-									

COOA 11 11-64