METHANOL PRODUCTION FROM EUCALYPTUS WOOD CHIPS

Attachment VII

**Feasibility Study Eucalyptus to 1000-STPD Methanol
Plant in South Central Florida
Davy McKee Corporation's Final Engineering Report**

June 1982

MASTER

**Prepared by
Biomass Energy Systems, Inc.
Lakeland, Florida**

**For the
U.S. Department of Energy
Office of Alcohol Fuels
Under Grant No. DE-FG07-80RA50316**

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METHANOL PRODUCTION FROM
EUCALYPTUS WOOD CHIPS

Working Document 7

Feasibility Study Eucalyptus to 1000-STPD Methanol
Plant in South Central Florida -
Davy McKee Corporation's Final Engineering Report

Principal Investigator:
Henry H. Fishkind

June 1982

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Prepared by
Biomass Energy Systems, Inc.
1337 Gary Road
Lakeland, Florida

For the
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FEASIBILITY STUDY EUCALYPTUS TO 1000
STPD METHANOL PLANT IN SOUTH CENTRAL
FLORIDA--DAVY McKEE CORPORATION'S
FINAL ENGINEERING REPORT

BIOMASS ENERGY SYSTEMS INC.
1337 GARY RD. LAKE LAND, FL. (813) 688-2868
"HARVESTING RENEWABLE ENERGY RESOURCES NOW"

BIOMASS ENERGY SYSTEMS, INC.
STUDY FOR PRODUCTION OF METHANOL FROM EUCALYPTUS
IN SOUTH CENTRAL FLORIDA

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Davy McKee

ENGINEERS AND CONSTRUCTORS

August 31, 1981

Biomass Energy Systems Inc.
1337 Gary Road
Lakeland, Florida 33801

Attention: Dr. Henry H. Fishkind
Vice President

Subject: Eucalyptus to Methanol
Feasibility Study

Reference: Letter of Authorization, Dr. H. H. Fishkind
to W. J. Williams, Dated March 27, 1981

Dear Dr. Fishkind:

Davy McKee is pleased to submit DMCL 2585, dated August 1981. This document, entitled "Feasibility Study - Eucalyptus to 1000 STPD Methanol Plant in South Central Florida", constitutes the final report on the subject study.

We appreciate the opportunity to provide Biomass Energy Systems with these preliminary basic process, technical and economic factors for the production of methanol via gasification of Florida eucalyptus. We look forward with great interest to working with BESI in the continuing development of your eucalyptus to methanol project.

Very truly yours,

Elmore M. Peloubet
Study Manager

METHANOL FROM EUCALYPTUS WOOD

INTRODUCTION

This study has been prepared by DM International Inc., Houston, Texas, to demonstrate the technical feasibility of producing methanol from wood, and to provide sufficient cost data to allow an assessment of the economic viability.

It is assumed that the plant is a grass roots facility located in South-Central Florida. The plant will have ready access to rail for product shipping and roads for employee commuting and wood delivery. The capacity of the plant is 1000 STPD of fuel grade methanol, equal to 100 million U.S. gallons per year based on 330 days of operation.

Methanol is produced in many areas of the world from natural gas, light hydrocarbons, fuel oil or coal. These facilities differ in that various processes are used to convert the feedstock into synthesis gas, a mixture of carbon monoxide, carbon dioxide and hydrogen, from which methanol is synthesized. Once a pure synthesis gas with the proper ratio of constituents is obtained, these facilities have methanol synthesis and distillation sections which are nearly identical and manufacture a methanol product of similar specification.

The BESI facility is comparable to these previously constructed methanol plants in many ways, except the feedstock is wood. Fuel grade methanol plants have not yet been built using wood feedstocks, although demonstration work is presently proceeding in Brazil to produce methanol from wood. The BESI process design incorporates commercially available technologies, including Davy fixed bed gasification, Texaco partial oxidation and the Davy/ICI version of ICI low pressure methanol synthesis. The BESI plant capacity is well within the parameters of experience. The wood gasification section represents the one element which creates a somewhat higher risk for this process relative to conventional methanol plants designed to use only natural gas feed stocks. However the Davy fixed bed gasifier has been proven reliable in previous commercial installations. The preliminary plant design includes customary overdesign for viable operation at nominal capacity.

Gasification

The BESI facility includes Davy fixed bed units to generate synthesis gas from eucalyptus wood using steam and oxygen. Davy has extensive experience on coal or coke feedstocks in fixed bed gasifiers and has, in fact, installed over 1,000 units in commercial facilities. Additionally, Davy has considerable experience in biomass gasification and has built over twenty air blown, single stage, fixed bed gasifiers for low BTU gas production from biomass feedstocks. A list of Davy biomass gasifiers is found on page 1-8 and indicates the variety of feedstocks which have been gasified. The Mozambique Industrial Gasifier continues to be in operation and the CESP Gasifier should be operational in 1982.

INTRODUCTION (continued)

Gasification (continued)

Feedstock properties cause biomass gasification units to differ somewhat from coal or coke units. The feedstock is dried and devolatilized, or distilled, in the upper section of the gasifier with upflowing hot gases. This eliminates the requirement for feedstock drying prior to gasification in a separate unit and, thus, the process is simplified and is more efficient. Since biomass feedstocks have a greater drying and devolatilization requirement than do coal or coke, a longer gasifier residence time is required. Also, biomass feedstocks have a lower density than do coal or coke. The combination of higher residence time and lower density with biomass feedstock increases the hold-up volume requirement, or size, of the gasifier.

The largest biomass gasifier built to date by Davy operated on wood feedstock and began operation in India in 1947. The six air fed, fixed bed gasifiers had 11 foot diameter grates and 12 foot diameter upper sections. Each unit handled about 55 tons per day of logs as received, most of which were about 18 inches in length. Operators were required to manually clear ashes from the units. The plant proved to be reliable, flexible and easy to operate. The facility operated for about 15 years.

The BESI plant includes seven oxygen fed, fixed bed, Davy gasifiers for normal operation and one gasifier as spare. A general arrangement drawing of the gasifier is presented in Section 5. Each gasifier has a 13 foot diameter grate and a 20 foot diameter upper section. The size and design is similar to the gasifier being provided by Davy for Brazil's demonstration program, which will operate on eucalyptus wood logs.

The gasifier design for the BESI project reflects the following modifications from earlier Davy biomass gasifier experience:

- o A modest gasifier size scale-up from the Indian design; the grate size, however, has been used successfully by Davy previously with coke feedstock.
- o The injection of oxygen and steam, rather than air. Oxygen must be used, insofar as the inert nitrogen from air injection is deleterious to the methanol synthesis. Steam is added with the oxygen to control the gasifier operating temperature. Davy has experience with coal-fed units using oxygen and no special problems should arise in the gasification of wood with oxygen.
- o The incorporation of modern technology and mechanical equipment to automate the wood feeding and ash removal systems. This equipment, although not previously used with wood, will be comparable to equipment used for coal handling and should not present problems.

Davy will have additional experience, in Brazil, with a similar gasifier using wood feedstocks prior to start-up of operation in Florida. The Brazilian start-up should provide experience which will improve future start-up operations.

INTRODUCTION (continued)

Partial Oxidation

The BESI facility includes Texaco partial oxidation units to generate additional synthesis gas from tars and oils, which are collected as a by-product from the wood gasification, and from purge gas, which is purged from the methanol synthesis loop. Texaco began non-catalytic partial oxidation development in 1945, and since 1953 has offered the process throughout the world as an energy efficient technology for synthesis gas production. The process is suitable for the gasification of either hydrocarbon liquids, which are pumpable below 600°F, or hydrocarbon gases. The process generally operates with temperatures in the 2,000 to 3,000°F range and with pressures in the 300 to 1,200 psig range (the BESI unit will operate a bit below 500 psig). More than 75 plants have been built in 22 countries since the first Texaco units came onstream in 1955. Most of the facilities have been associated with the manufacture of ammonia, methanol and oxo-chemicals. Commercial units have gasified such diverse materials as natural gas, natural gas liquids, crude oil, naphtha, light fuel oil, heavy fuel oil and asphalt.

Gas Treating

The gas treating processes in the BESI plant are designed to eliminate components which would be deleterious to the methanol synthesis and to produce a gas with the correct ratio of carbon oxides and hydrogen for methanol synthesis. The required operations, including hydrogenation, water gas shift, acid gas removal by the Benfield Process and desulfurization using zinc oxide, have been selected both due to suitability for this application and due to well proven performance in other commercial facilities. For example, the Benfield Process is the most economic acid gas removal process for this application, particularly in view of the negligible sulfur content in the inlet gas and of the carbon dioxide level required for methanol synthesis. The Benfield process with the Low Heat features, which are included in BESI unit, has been used in over 30 plants and has the following advantages:

- o Low steam consumption
- o Low capital cost
- o Simple flowsheet
- o Low solution make-up
- o Well proven in many applications

Methanol Synthesis

Methanol was first commercially produced before the turn of the century by the destructive distillation of wood - hence its common name, wood alcohol. However, methanol was not produced in large quantities until the advent of processes which form methanol from synthesis gas, a mixture of hydrogen and carbon oxides, at pressures in the 4,000 to 6,000 psig range and using catalysts composed of zinc and chrome compounds.

INTRODUCTION (continued)

Methanol Synthesis (continued)

Today's modern processes use more active catalysts and operate at lower temperatures and pressures. These low pressure processes reduce feedstock and energy requirements and substantially improve capital costs when compared to the older high pressure processes. All facilities built in recent times use low pressure technology, and some high pressure facilities have been converted to low pressure technology.

The BESI facility uses the ICI Low Pressure Methanol Synthesis Process. The unique feature of the process is the synthesis step utilizing a copper-based catalyst which was specially developed to give good yields of methanol at low temperatures. The high activity of the catalyst allows the synthesis reaction to be carried out at pressures as low as 750 psig and is the key to the process economy. The process was first commercialized in 1966 by ICI in a 330 short ton per day facility in Billingham, England and has since become the predominant technology for methanol production, now accounting for about 70% of the world's capacity. Methanol facilities based on the ICI technology have excellent operating records and have demonstrated output capacities in excess of nameplate capacities. Davy either designed and/or constructed about two-thirds of capacity in plants which use the ICI Low Pressure Methanol Synthesis Process; these Davy plants represent about half of the world's total methanol capacity. A list of ICI Low Pressure Methanol plants in operation and under construction is presented on page 1-9.

Feasibility Study Test Work

Previous experience allows characterization of the biomass feedstock by means of laboratory distillation and analytical testing. Results from the test work are sufficient to calculate the composition or quantity of gaseous products, the tar and oil by-product, the aqueous liquor and the ash which result from gasification; to ascertain the feedstock, oxygen and utility requirements; and to prepare the other information which is normally included in a preliminary process design.

Due to the short time available for completion of this study it was not feasible to wait for completion of analytical testing before beginning process design. It was agreed to proceed with process design based on our previous eucalyptus gasification design for Brazil. The design basis presented in Section 3 summarizes the eucalyptus test results for Brazil. The Florida eucalyptus test results obtained near the end of this study are presented in the appendix along with an evaluation of any significant differences and their expected effect on plant design.

Commercial Plant Design Test Work

The test work, which has been completed during the course of the feasibility study and is presented in the appendix, has determined the major chemical and physical properties of eucalyptus wood feedstock and, therefore, has provided a basis upon which to prepare a preliminary process design and a feasibility study. However, further testing must be completed before actual plant design is undertaken. This eucalyptus wood has not

INTRODUCTION (continued)

Commercial Plant Design Test Work (continued)

been gasified yet and, thus, the feedstock's behavior in the gasifier environment must be further defined. Other information is also required for the final design of the commercial facility. Three sets of work are recommended to allow the design basis for the commercial plant to be established.

- o Test gasification of eucalyptus wood
- o Test gasification of tars and oils
- o Characterization of aqueous liquor waste stream

Eucalyptus wood feedstock will be gasified in a pilot scale, fixed bed unit with steam and oxygen and with other conditions simulating the commercial scale operation. Two existing experimental gasifiers sized at one foot and three foot diameter are available for testing wood gasification. The pilot gasification will provide information on the eucalyptus wood feedstock's effect on the mechanical operation of the gasifier. Such potential problems as gas channeling or excessive pressure drop due to the feedstock's swelling, bridging or disintegrating tendencies will be detected. While not expected, the absence of such potential problems must be confirmed. Based upon ash fusion tests, an easy-to-handle, powdery, free flowing ash is expected, rather than a hard-to-handle, clinkered ash. The gasification tests should confirm these properties. Accurate yields of gasification products will also be provided by the pilot operation and will be used to confirm or adjust the current yields, determined by the Gray-King distillation. Thus, the pilot gasification will identify potential mechanical problems and will provide other information for the design of the commercial facility. The commercial size gasifier presently being built in Brazil will probably provide useful design data for this plant. In the course of the pilot gasification, large volumes of tars/oils and aqueous liquor, each a distinct phase, will be generated and both will be submitted for more comprehensive testing as described below.

In the commercial facility, the tars and oils are further gasified in the Texaco Partial Oxidation Process to produce additional synthesis gas. While the analytical information developed on the tars and oils is sufficient to prepare a preliminary design for the partial oxidation unit, a sample of tars and oils will be submitted to Texaco for pilot partial oxidation at their Montebello test facility. The process design for the partial oxidation of the tars and oils will be provided by Texaco based upon this test gasification.

The aqueous liquor contains a very high organic concentration and cannot be cleaned up by normal waste water treating methods. In the preliminary process design for the commercial plant, the aqueous liquor is treated in two stages. First the liquor is processed through flash evaporation and rectification to recover part of the organic content to feed to the partial oxidation unit for additional synthesis gas. Then the waste liquor is treated by a biological process, with the majority of organics removed and

INTRODUCTION (continued)

Commercial Plant Design Test Work (continued)

a sludge generated. Although the steps for cleaning this waste water are well defined in concept, some additional analyses and bench scale pilot testing will be done on the aqueous liquor to establish the final process design parameters.

The above test work should confirm the present design, but the possibility exists both of unexpected findings and of schedule delay. A period of three months should be allowed before process design can begin.

The test work which has been completed to date has indicated that the raw synthesis gas will have several impurities, which are potential poisons to the sensitive methanol synthesis catalyst. Consequently, the preliminary process design includes steps to eliminate the compounds. Although not currently proposed, it is possible that ICI will require tests, prior to extending process guarantees, to determine the level of detrimental trace impurities, such as cyanides, ammonia and unsaturates. These and other similar compounds, if present and if not treated, can reduce the life or damage the catalyst and, subsequently can cause lost production until the catalyst is replaced. Generally, if problems arise in a plant, the analysis of catalyst allows the identification of the poison and then steps can be taken to improve or remedy the situation.

In principal, many biomass materials can be gasified with successful results. However, each feedstock has unique properties which affect the feeding of the material to the gasifier, the passage of the material through the gasifier, the passage of gas up through the material in the gasifier, the properties and quantity of the ash, the composition of the generated synthesis gas, and the characteristics and yield of tars and oils.

These and other differences do not necessarily imply that other potential feedstocks are any less suitable for gasification than eucalyptus wood. In practice, though, other potential biomass materials could be screened using a systematic series of analytical tests and, then, batches of alternative feedstocks or moderate amounts of alternative feedstocks blended with eucalyptus wood could be tried in the facility without undue process risk. By gradually extending the period or increasing the blend proportion and by a careful monitoring and technical evaluation of the facility's operation, the program would identify those materials, and amounts thereof, which are technically compatible with the plant's design.

Safety

The BESI facility has all the characteristics of similar operations dealing with oxygen, flammable synthesis gases and high pressure synthesis operations. None of the operations are considered unsafe, but require trained personnel, a well designed plant and adequate operating and maintenance techniques to attain good operating records.

INTRODUCTION (continued)

Conclusions

The foregoing discussion presents previous commercial experience, identifies the extent to which technology or equipment will be used in a previously commercially unproven service and outlines the test work required to increase the certainty of the design; all of which are intended to provide an indication of the technical feasibility of the BESI methanol-from-wood facility. The technology and the equipment have, in general, been successfully used in other commercial facilities, however, both the particular service and the collective combination are unique and thus technical risks do exist. These risks can be more accurately defined and can be minimized by good planning, additional testing, proper design, engineering and construction by experienced professionals and careful plant operation by a trained staff. Although the BESI plant will be a unique combination, there is much previous operating experience in other similar plants to demonstrate the individual steps and support the technical viability of this process.

DAVY BIOMASS GASIFIERS

<u>Client & Location</u>	<u>Feedstock</u>	<u>Number Gasifiers</u>	<u>Contract Award</u>
E. Matarazzo & Co. <u>San Paulo, Brazil</u>	Cotton Seed Husks	3	1934
Magadi Soda Works <u>Kenya</u>	Wood Logs	1	1934
East African Management Board <u>Kenya</u>	-	1	1943
Soares Irmoas <u>Portugal</u>	Olive Refuse	2	1945
Fertilizers and Chemicals Travancore Ltd. <u>India</u>	Wood Logs	6	1945
Kafrel Zayat Co., Ltd <u>Alexandria</u>	Cotton Seed Husks	1	1946
St. Kitts Electric Light Dept. <u>West Indies</u>	Sugar Cane Refuse	1	1947
Ceylon Government Prisons Dept. <u>Colombo</u>	-	1	1947
Fabricas Triumpho <u>Portugal</u>	Wood Blocks and Chips	1	1948
Mahalakshi Sugar Mills Co., Ltd. <u>India</u>	Bagasse	1	1948
Mozambique Industrial S/A <u>Portuguese East Africa</u>	Cotton Seed Husks	1	1951
Henry Rogers, Sons & Co., Ltd. <u>South Brazil</u>	-	1	1951
Monapo <u>Mozambique</u>	Cotton Seed Husks	1	1965
CESP <u>Brazil</u>	Wood Logs	1	1980

ICI LOW PRESSURE METHANOL PLANTS

Company	Country	Capacity STPD
ICI	United Kingdom	330
Taesung Lumber	South Korea	165
Georgia Pacific	USA	1,000
Monsanto	USA	1,000
Chang Chun Petrochemical	Taiwan	130
Nishi Nihon	Japan	1,100
ICI	United Kingdom	1,210
Celanese	USA	2,200
Elf	West Germany	880
Almer	Algeria	370
Methanol Chemie Nederland	Holland	1,100
Kuhlmann	France	660
Metanor	Brazil	165
Alberta Gas Chemicals	Canada	1,230 (2x615)
IPRAN	Rumania	660
CNCIE	China	330
Cepsa	Spain	660
Taesung Methanol	South Korea	1,100
National Methanol	Libya	1,100
African Explosives and Chemical	South Africa	55
Higashi Nihon	Japan	880
Methanor	Holland	1,100
Methanor	Holland	1,100

ICI LOW PRESSURE METHANOL PLANTS (continued)

<u>Company</u>	<u>Country</u>	<u>Capacity STPD</u>
Techmashimport	USSR	2,750
Techmashimport	USSR	2,750
Borden	USA	1,900
Sabic/Celanese/Texas Eastern	Saudi Arabia	2,200
Gujarat State Fertilizer	India	65
MSK	Yugoslavia	660
China Petrochemical Development	Taiwan	310
Ocelot	Canada	1,320
Alberta Gas Chemicals	Canada	1,320
GPI	Bahrain	1,100
Petrocorp	New Zealand	1,340
Pemex	Mexico	2,750
NEC	Trinidad	1,320
ARCO	USA	2,000
Air Products	USA	490
Celanese	Canada	2,200
NZSCF	New Zealand	4,850 (2x2,425)

PROJECT SCOPE

The objective of this study is to provide information to review the engineering and economic viability of producing methanol from eucalyptus wood.

To meet this objective, the following was developed to define the project:

1. The plant complex is a grass roots facility encompassing necessary process and offsite units. The plant location is South-Central Florida.

The complex includes the following process units:

- o Wood Feed and Fuel Storage and Handling
- o Gasification and Gas Cleaning
- o Liquor Treatment
- o Booster Compression and Hydrogenation
- o High Temperature Shift
- o Acid Gas Removal
- o Methanol Synthesis
- o Methanol Distillation
- o Partial Oxidation

The complex includes the following support facilities:

- o Air Separation
- o Boiler and steam distribution system
- o Condensate and boiler feed water system
- o Cooling tower and cooling water distribution
- o Raw water treatment
- o Flare system
- o Waste water treatment
- o Firewater and sewer system
- o Nitrogen, plant air, fuel gas distribution systems
- o Electrical substation
- o Intermediate and product methanol storage and product methanol loadout

PROJECT SCOPE (continued)

1. (continued)

General plant facilities include maintenance shop, warehouse, guard-house, parking areas, roads, fences, interconnecting piping and racks, and truck loading.

2. Design philosophy includes sparing of one complete gasification and gas cleaning unit, sparing of small motor driven pumps and sparing of high maintenance equipment. The plant consists of one train with the capacity to produce 1000 tons per day of methanol. Offsite units are capable of handling the requirements of the 1000 tons per day methanol train. Feedstock for the plant will be eucalyptus wood and will be delivered to the plant as logs.
3. Well water will be pumped to the plant site for treatment before being used.
4. Major equipment drivers will be high pressure steam turbines. Other drivers will be electric motors. Steam will be generated by firing chipped eucalyptus crowns and fuel gas generated within the plant.
5. This facility will be designed to meet or exceed current federal, state and local pollution regulations for air, water and solids.

DESIGN BASIS

1. The plant complex is a grass roots facility to be located in South-Central Florida.
2. Plant complex capacity is 1000 STPD of fuel grade methanol.
3. Double trains are assumed for the compression section and a single train is assumed for the shift and synthesis section.
4. Site Climatic Conditions
 - a) Design Dry Bulb Temperature, Max. 95°F
Design Dry Bulb Temperature, Min. 32°F
 - b) Design Wet Bulb Temperature 80°F
 - c) Average Barometric Pressure 30.05 in Hg
 - d) Elevation, Ft. 144
5. Criteria for Utility and Offsite Systems
 - a) Well Water - Assumed to be available at complex battery limits.
 - b) Boiler Feedwater - BFW will be deionized for 2.0% blowdown in the complex.
 - c) Oxygen - Available from air separation plant in the complex. Oxygen will be delivered at 30 psig, 500 psig and 99.5 vol % purity.
 - d) Nitrogen - Available from air separation plant in the complex.
 - e) Potable Water - Available from complex offsite raw water treating plant.
 - f) Cooling Water - Supplied from recirculating mechanical draft cooling towers. Make up cooling water will come from well water supply.

Supply Temperature: 90°F Maximum
Return Temperature: 110°F Maximum
 - g) Fire Water - Available from complex offsites.
 - h) Electric Power - Assumed to be available at complex battery limits.

Drivers Less than 150 HP: 480V, 3 ph, 60 Hz
Drivers More than 150 HP: 4160V, 3 ph, 60 Hz

DESIGN BASIS (continued)

5. Criteria for Utility and Offsite Systems (continued)

- i) Steam - Generated in boilers at 1500 psig, 880°F.
Plant complex steam levels:

1500 psig, 880°F
500 psig, 720°F
30 psig, Sat.

- j) Fuels - internally generated fuel gases
- chipped eucalyptus crowns

- k) Instrument and Plant Air - Nitrogen available from air separation plant,

6. Feedstock Analysis (Assumed Brazilian eucalyptus experience)

TEST	RESULT
1. Material, as received	
A. Weight, kg	--
B. Bulk Density (lb/ft ³)	20
C. Mill (60-72 Mesh)	--
2. Milled Wood	
A. Proximate Analysis, wt%	
(1) Loss at 110°C (as received)	32.50
(2) Volatile Matter (dry)	84.48
(3) Fixed Carbon (dry)	14.95
(4) Ash (dry)	0.57
B. Ultimate Analysis, wt%, dry basis	
(1) Carbon	50.03
(2) Hydrogen	5.98
(3) Nitrogen	0.12
(4) Sulfur	<0.05
(5) Oxygen (Diff)	43.30
(6) Ash	0.57
C. Heating Value, BTU/lb	
(1) Gross	8268
(2) Net	7702
D. Gray-King Distillation	
(1) Dry Gas (SCF/lb ODW)	3.399
(2) Aqueous Condensate (lb/lb ODW)	0.4060
(3) Organic Condensate (lb/lb ODW)	0.1036
(4) Charcoal (lb/lb ODW)	0.2521
3. Charcoal, from 2D	
A. Proximate Analysis, wt%	
(1) Loss at 110°C	--
(2) Volatile Matter	4.98
(3) Fixed Carbon	92.64
(4) Ash	2.38

DESIGN BASIS (continued)

6. Feedstock Analysis (Assumed) (continued)

TEST	RESULT
3. Charcoal, from 2D (continued)	
B. Ultimate Analysis, wt% dry basis	
(1) Carbon	96.21
(2) Hydrogen	0.51
(3) Nitrogen	0.19
(4) Sulfur	0.03
(5) Oxygen (Diff)	0.68
(6) Ash	2.38
4. Tar/Oil, from large retort	
A. Retorting (wt%)	
Inputs	
(1) Dry Wood	100.00
(2) Wood Moisture	48.15
(3) Undecomposed Steam	11.44
Outputs	
(4) Tar/Oil	4.46
(5) Liquor	91.95
(6) Charcoal	28.86
(7) Gas By Difference	34.32
B. Ultimate Analysis, wt%	
(1) Carbon	67.69
(2) Hydrogen	7.29
(3) Nitrogen	0.11
(4) Sulfur	0.04
(5) Oxygen (Diff)	24.87
(6) Ash	-
C. Water, wt%, by K.F.	11.25
D. Specific Gravity	1.10
E. Heating Value, BTU/lb	
(1) Gross	12460
(2) Net	11770
5. Ash, from large retort charcoal	
A. Fusion Temperature (reducing) (°F)	
(1) Initial Deformation Temperature	2584
(2) Softening Temperature	2602
(3) Half Fused Temperature	2620
(4) Fusion Temperature	2667
B. Trace Elements (wt%)	
Chlorine - Cl	0.007
Nickel - Ni	<0.002
Iron - Fe	0.007
Vanadium - V	<0.005
Silicon - Si	0.01

DESIGN BASIS (continued)

6. Feedstock Analysis (Assumed) (continued)

TEST		RESULT
5. Ash, from large retort charcoal (continued)		
C. Major Elements (wt%)		
(1) Silicon - (as SiO ₂)		5.19
(2) Aluminum - (as Al ₂ O ₃)		1.80
(3) Iron - as Fe ₂ O ₃		2.64
(4) Titanium - (as TiO ₂)		<1.25
(5) Phosphorus - (as P ₂ O ₅)		6.60
(6) Calcium - (as CaO)		26.0
(7) Sodium - (as Na ₂ O)		5.91
(8) Potassium - (as K ₂ O)		23.0
(9) Manganese - (as MnO)		0.69
(10) Magnesium - (as MgO)		9.09
(11) Nickel - Ni		<0.25
(12) Vanadium - V		<0.25
6. Liquor, from large retort		
A. COD (wt%)		15.8
B. BOD (wt%)		7.4
C. Phenols (PPM)		163
D. Ultimate Analysis, wt%		
(1) Carbon		5.46
(2) Hydrogen		10.85
(3) Nitrogen		0.02
(4) Sulfur		<0.01
(5) Oxygen (Diff)		83.67
(6) Ash		-
E. Specific Gravity		1.01
F. Acid Index (mg KOH/gm)		97.6
G. pH		2.2
7. Gas, from Gray-King (2D) (volume %)		
A. CO ₂		34.13
B. CO		25.82
C. H ₂		20.58
D. CH ₄		16.80
E. N ₂		1.44
F. (CH ₂) _x		1.23
Gas, from large retort (4)		
H. H ₂ S (by lead acetate)		not detectable
8. Distilled Liquor from large retort		
A. Yield (wt%)		
(1) Organics		6.8
(2) Aqueous		93.2
B. Aqueous		
(1) COD (wt%)		6.2
(2) BOD (wt%)		3.0
(3) Phenols (PPM)		163
(4) pH		2.2
(5) Acid index (mg KOH/gm)		64

7. Catalysts and Chemicals

Catalysts and chemicals to be available at complex battery limits.

8. Products from Complex

<u>Fuel Grade Methanol Quality</u>	<u>Wt. %</u>
Methanol	99.0
Higher Alcohols	0.25
Water	0.75
	<u>100.0</u>

9. Wood and Product Handling and Storage

a) Wood

Wood will be delivered to the complex. Forty-day inactive storage and seven-day active storage will be provided for long wood. Storage for cut wood will be equivalent to 115 days usage.

b) Methanol

Storage capacity is 30 days production available at complex load-out facilities for shipment by rail or truck.

10. Codes and Regulations

The plant is to be designed to meet applicable local and national environmental regulations.

PROCESS DESCRIPTION

General

The complex is capable of using eucalyptus wood to generate synthesis gas for production of fuel grade methanol, via the ICI (Imperial Chemical Industries, Ltd) low-pressure methanol process. The following are the major process and offsites units.

Area 101 - Wood Feed and Fuel Storage and Handling

Area 102 - Gasification and Gas Cleanup

Area 103 - Liquor Treatment

Area 104 - Raw Gas Compression and Hydrogenation

Area 105 - High Temperature Shift

Area 106 - Acid Gas Removal

Area 107 - Guard Beds and Make Up Gas Compression

Area 108 - Methanol Synthesis

Area 109 - Methanol Distillation

Area 110 - Partial Oxidation

Area 111 - Air Separation

Area 112 - Boiler and Boiler Feedwater System

Area 113 - Raw Water Treating and Cooling Water

Area 114 - Waste Water Treating

Area 115 - Miscellaneous Facilities

Reference should be made to the Process Flow Diagrams (7018-00-PA101 to PA116), the Block Flow Diagram (7018-00-PA117), the Plot Plan (7018-00-PC-001), and to the Equipment List while reading the following description of the process.

The plant incorporates Davy fixed bed gasifiers and the Davy/ICI version of the ICI LP Methanol Process. Davy wood gasification technology is based on over 50 years of experience in the design of fixed bed gasifiers. These gasifiers have operated on coal, coke, wood and a variety of biomass and vegetable refuse feedstocks. While there are differences between feedstocks, the gasifiers all have certain things in common.

PROCESS DESCRIPTION (continued)

General (continued)

One of these is the grate necessary for introduction of the blast and for removal of the ash. Another is the manner in which the feedstock is devolatilized such that the final stage involves gasification of charcoal above the grate.

The ICI Low Pressure Methanol Process was introduced over 10 years ago and Davy was the first licensee. Since then, Davy has engineered the major part of the world's new methanol capacity. The present design includes numerous features, particularly those providing high efficiency through heat recovery, which Davy has developed in recent years. Plants have been designed ranging in capacity from 150 tons per day to 2,750 tons per day of methanol. The capacity of the present plant, though large enough to be economic, is well within the parameters of experience. Following is a description of the major process and offsite units required for the complex.

Summary

Eucalyptus logs are cut into billets ten inches long by eight inch maximum diameter. The billets are fed to fixed-bed gasifiers where reaction with oxygen and steam yields a stream of crude synthesis gas consisting mainly of hydrogen, carbon monoxide, carbon dioxide and water vapor along with some hydrocarbons, tars and oils, and water-soluble organics. Ash is discharged from the gasifiers for disposal. The hot gas from the gasifiers is cooled and scrubbed with recirculating quench water. Tar and oil is separated from the water and fed, together with oxygen, to a partial oxidation gasifier to generate additional synthesis gas. The water-soluble hydrocarbons are eliminated from the system in a purge stream of the scrubbing water which is sent to liquor treatment for recovery of organics. The clean raw gas is compressed to intermediate pressure, catalytically hydrogenated, and then partially shifted in the high temperature shift unit to achieve the required ratio of carbon oxides and hydrogen for synthesis of methanol. After passing through a Benfield acid gas removal unit for elimination of the required amount of carbon dioxide, the gas is further compressed and sent to methanol synthesis. Crude liquid methanol product from synthesis goes to the distillation unit for water removal and then to product storage.

Purge gas from the methanol synthesis unit is rich in methane. A portion of the purge gas is sent to the partial oxidation unit for production of additional synthesis gas, while the remainder of the purge gas is used as plant fuel for generating steam. Flash gas from the synthesis unit and off-gas from distillation also are used as fuel.

All waste water streams are treated to render them suitable for discharge. The purge stream of gasifier quench/scrubbing water after organics recovery is subjected to conventional biological treatment. All other waste water streams are sent to conventional neutralization and settling facilities before discharge.

Detailed descriptions of the various units within the plant are presented below.

PROCESS DESCRIPTION (continued)

Area 101 Wood Feed and Fuel Storage and Handling

Long wood logs are received by truck, unloaded by crane or mobile unit and transferred to either the long wood storage area or the long wood slasher decks where they are cut into 8 ft. lengths. Conveyors then transfer the logs to the short wood slasher decks for further cutting into 10 inch billets. Billets are discharged from the short wood slasher decks onto the wood feed bunker conveyors or the cut wood storage pile conveyor as determined by level indicators in the gasifier feed bunkers. Wood is fed to the gasifiers from the wood feed bunker by means of conveyors. A belt-weigh scale will count and record the wood feed rate to the gasifiers. All sawdust and wood waste from the slashing operation is collected and transferred to the crown chip storage pile to be used as boiler fuel.

Crown chips for boiler fuel are received by truck and unloaded by a hydraulically operated truck dumper. Chips are discharged onto grade elevation, a bulldozer with chip moving blades clears the area for the next dump and pushes the chips to the receiving conveyor. Chips are then screened, shredded as required, and transferred to the crown chip storage pile. An under-the-pile conveyor reclaims and discharges the chips onto the boiler feed conveyors to maintain the required level at the boiler feed bunker.

Area 102 Gasification and Gas Clean-up

Billets are conveyed to the wood feed hoppers located above the gasifiers. These hoppers hold charges of wood which are dumped intermittently into the lock hoppers of the gasifiers. Probes periodically sample the level of the wood bed in the gasifier and actuate the dumping of the feed hoppers. The wood has a residence time in the gasifiers on the order of 8 hours when operating at design rates. The general arrangement of the gasifier is shown in Section 5.

The gasifiers are carbon steel vessels which are water jacketed in the lower part and refractory lined in the upper part. A mixture of steam and oxygen is fed into the bottom of the gasifier and is distributed throughout the entire bed of the gasifier by means of a conical, eccentric, rotating grate. This grate serves also to remove ash from the bottom of the gasifier. The biomass undergoes drying and devolatilization as it passes down through the gasifier and is transformed into charcoal before entering the gasification zone. In the gasification zone the charcoal reacts with the upflowing gas from the combustion zone to yield primarily hydrogen, carbon monoxide, and carbon dioxide. The sensible heat in the hot gases leaving the gasification zone provides the heat for distillation of tars, oils, volatile matter, and water from the wood as it passes through the gasifier bed. This distillation cools the gas so that the gas stream leaves the gasifier at approximately 500°F. This temperature is dependent upon the quantity of water in the wood and the combustion zone temperature maintained. The unreacted charcoal from the gasification zone enters the combustion zone, located just above the ash grate, where it reacts with the incoming oxygen and steam. Combustion zone temperature is maintained at approximately 2100°F. Ash from the combustion zone enters the ash zone.

PROCESS DESCRIPTION (continued)

Area 102 Gasification and Gas Clean-up (continued)

Ash is removed continuously from the bottom of the gasifier by the action of the rotating, eccentric grate and falls in the ash lock hoppers. Since wood fuel has low ash content the gasification units are designed to add an artificial ash to ensure proper control of ash removal and to maintain an ash bed over the grate. This ash bed serves to protect the grate from the high temperatures of the combustion zone. The ash lock hoppers are discharged periodically onto a conveyor which feeds a screen. Fines from the screen, primarily wood ash, fall into a hopper for collection and are transferred to battery limits for disposal. The artificial ash from the screen is conveyed by a bucket elevator to an ash recycle hopper located above the gasifier. Recycled ash is fed to the wood feed hopper on top of the wood charge.

The hot gases from the gasifier pass through a short horizontal section of refractory-lined pipe to a downcomer spray chamber. The pressure at the exit of the gasifier will be slightly positive to minimize leakage. The gas is quenched in the downcomer spray chamber by contact with sprays of cooled scrubbing water. The gases then enter the Lymn washer for scrubbing to remove most of the tars and oils in the gas. The Lymn washer is a baffled scrubber in which the scrubbing water is sprayed in at the top and countercurrently contacts the upward flowing gas. The gas leaves the Lymn washer at a temperature of about 110°F. The gas then flows through a seal tank which serves as an entrainment separator and then to a fan to increase the gas pressure. From the fan, the gas passes through an electrostatic precipitator for final tar removal before compression.

Drains from downcomer spray chambers, Lymn washers, seal tanks, and electrostatic precipitators combine and flow in an open channel to a tar-water separator. Here the tars are separated and are pumped to the partial oxidation area. The water is pumped through a plate-and-frame exchanger for cooling to remove the heat picked up from the gases. The cooled water then goes to a surge tank, from which it is pumped to the gas washing system. A small blowdown is taken from the pump discharge to the liquor treatment area.

Liquor Treatment

The liquor purge from the scrubbing water stream in the gas cleaning section contains a significant quantity of organics (about 20% weight). These organics include a wide range of oxygenated compounds from light, volatile materials such as acetone and methanol to non-volatile tars. To separate these organics from the water in the purge stream, a system is utilized which incorporates distillation, evaporation, and gravity separation. The efficiency of recovery of the organics is expected to be 50% with this system.

The liquor purge stream is pumped from the storage tank to the first stage of a triple-effect evaporation system. Before arriving at the first effect, the stream is heated by passing through two plate-and-frame exchangers. In these exchangers waste heat is recovered from the condensate from the heating coils of the first and second effects of the evaporator.

PROCESS DESCRIPTION (continued)

Liquor Treatment

The vapors from the first effect evaporator are sent to a distillation column and the bottoms from the column are returned to the first effect evaporator. This effect of the evaporator operates at conditions of about 5 psig and 230°F. The heavy tars and organics separate readily by gravity when the light organics, which had been holding the heavy organics in solution, are removed. Accordingly, the evaporator is equipped with a boot to permit the removal of heavy tars which separate. The heating medium for this effect is the overhead from the second effect evaporator.

The distillation column operates at near-atmospheric pressure and 150°F at the top. The light organics recovered will have a water content of about 10%. The column is a plate-type column with special trays to prevent the buildup of tar on the trays. The overhead from the column is condensed using a water-cooled exchanger. The condensate flows to a surge drum, from which the column reflux pump takes suction. The product stream is pumped to the tar/oil storage tank, while the reflux stream is returned to the column. The bottoms from the column are returned to the evaporator first effect by the column bottoms pump.

All effects of the evaporation are similar in that they are kettle-type exchangers. Each is similarly equipped with a boot to drain any heavy organics which may settle by gravity. The second effect operates at conditions of about 285°F and 41 psig with heat supplied by the overhead from the third effect. The third effect operates at conditions of 355°F and about 130 psig. The heating medium for the third effect is supplied by 500 psig steam. The bottoms from the third stage are pumped to the tar/oil storage tank.

The product streams from this area include the light organics, the settled tars and heavy organics from the evaporators, and the bottoms from the third effect of evaporation.

The overhead condensate from the second and third effects of the evaporation section flows to the heavy organic separator. Any heavy organics which separate are pumped to product cooling and storage by the heavy organic pump. The water which remains is the effluent stream from the system and is pumped by the effluent pump to waste water treating.

The product streams from all areas are combined and pass through the product cooler for cooling by interchange with cooling water. The cooled product then flows to the tar/organic storage tank in the partial oxidation area.

Area 104 - Raw Gas Compression and Hydrogenation

Clean raw gas from the electrostatic precipitators in the gasification area is compressed from near atmospheric pressure to 410 psig in a multistage centrifugal booster compressor. Interstage coolers condense water vapor as well as cool the raw gas. The gas is then passed over a bed of hydrogenation catalyst to hydrogenate trace quantities of olefins to the corre-

PROCESS DESCRIPTION (continued)

Area 104 - Raw Gas Compression and Hydrogenation (continued)

sponding paraffins using the hydrogen in the gas stream. Traces of oxygen are also removed in this step. A pressure of 410 psig was selected to match the pressure level requirements of the Benfield and partial oxidation units. This pressure is well within the normal operating range of these units. The raw gas compressor is driven by a combination extraction condensing turbine. The 30 psig steam extracted from the turbine is sent to the low pressure steam header.

Area 105 - High Temperature Shift

From the hydrogenation step the raw gas stream is split into two parts. The portion of the gas stream which is to be sent to the shift reactor is heated and saturated with water vapor in the saturator vessel, which contains a packed bed for contacting the gas with hot recirculating water heated by process streams in the shift area.

The temperature of the saturated outlet gas is controlled at a level which will maintain the water vapor content at 1.1 mole of water per mole of dry gas, the optimum ratio for the shift reaction. Demineralized make-up water is supplied to the saturator and a blowdown stream is sent to waste water treating. The remaining portion of the gas stream bypasses the saturator and shift converter.

The purpose of the shift conversion step is to adjust the ratio of carbon monoxide to hydrogen according to the exothermic reaction:

An exit carbon monoxide content of 19.3 vol % (dry gas) was selected as the required concentration for downstream methanol synthesis. This shift is accomplished by a one-stage conversion reactor. Additional gas from the partial oxidation unit is combined with the remaining raw gas from the saturator as feed to the high temperature shift unit.

The gas leaving the shift reactor is cooled by preheating the shift feed gas to 600°F and by heating part of the recirculating saturator water. The shifted gases are cooled to 200°F by reboiling the regenerator in the acid gas removal area and heating makeup demineralized water.

The shifted gas is then combined with the bypassed gas from gasification and sent to the acid gas removal area. The mixed shifted gas and by-passed gas will give a stoichiometric ratio of carbon oxides to hydrogen for the methanol synthesis unit.

Area 106 - Acid Gas Removal

The Benfield process has been selected for acid gas removal. Its purpose is to remove a portion of the carbon dioxide present in the gas which feeds the methanol synthesis unit. The Benfield process is a chemical

PROCESS DESCRIPTION (continued)

Area 106 - Acid Gas Removal (continued)

absorption system using potassium carbonate solution, activated with DEA and inhibited with potassium vanadate.

The carbon dioxide tends to form carbonic acid in water.

Carbonic acid undergoes a reversible chemical absorption reaction with the potassium carbonate solution to form potassium bicarbonate:

Potassium bicarbonate will decompose on heating to carbon dioxide and potassium carbonate, driving off absorbed carbon dioxide and regenerating the absorption solution.

After cooling, gas from the high temperature shift enters the absorber column where it is scrubbed by potassium carbonate solution at about 220°F. Scrubbed gas passes from the top of the scrubber and becomes synthesis make up gas. The solution is regenerated by reboiling at reduced pressure in a regenerator column.

Area 107 - Guard Beds and Make Up Gas Compression

Gas from the Benfield absorber is preheated in the make up gas preheater and enters the first guard bed, a packed vessel containing a chloride removal absorbent. Gas from the chloride guard bed is sent to the sulfur guard beds containing zinc oxide.

The zinc oxide is impregnated with a special catalyst which hydrolyzes carbonyl sulfide to hydrogen sulfide. Hydrogen sulfide reacts with zinc oxide to form zinc sulfide and water. Gas passing from the sulfur guard beds is now essentially free of chloride and sulfur compounds. Trace quantities of chlorides and sulfur compounds will poison the methanol synthesis catalyst and decrease efficiency and productivity.

The gas from the guard beds is cooled by preheating guard bed feed and by interchange with cooling water. The gas is then compressed to 1200 psig in a two stage centrifugal compressor. The turbine driver on the make up gas compressor is a combination extraction-condensing unit. The extraction steam goes to the medium pressure steam header for use in liquor treatment and partial oxidation.

Area 108 - Methanol Synthesis

The make up synthesis gas from the make up gas compressor enters the methanol synthesis loop at the inlet of the circulator where it mixes with unconverted recycle gas. The circulator is a single-stage centrifugal compressor which circulates the gases around the synthesis loop. The mixture of unconverted recycle gas and make up gas is preheated by exchange

PROCESS DESCRIPTION (continued)

Area 108 - Methanol Synthesis (continued)

with converter effluent. The feed gas stream is then divided and the portion going to the top of the converter is heated to reaction temperature by exchange with hot converter effluent. The other portion of the gas enters the converter at various points to control reaction temperature. The methanol synthesis converter is a pressure vessel containing a single bed of catalyst. Temperature of the exothermic reaction is controlled by injecting cooler gas at appropriate levels into the catalyst bed, using internal distributors. These distributors provide excellent gas mixing.

The converter effluent is split for better heat recovery. One part is cooled by exchange with that portion of feed gas going to the top of the converter, while the balance is used to heat boiler feed water. These two gas streams are then recombined and further cooled by exchange with the total gas stream from the circulator and by cooling water before entering the methanol separator. The separator is a knockout vessel with demister pad which separates crude liquid methanol product from recycle gas. The crude methanol collected in the separator is flashed to a let-down vessel and then sent to distillation or to intermediate storage. The flashed gas then goes to the plant fuel system.

The non-reactive components of the make up gas, including methane, are purged from the synthesis loop between the separator and the point of make up gas addition. Part of this purge gas is burned in the offsites area as fuel, while the remainder is sent to the partial oxidation unit for production of additional synthesis gas.

The synthesis loop contains a start-up heater which serves to heat circulating gases at start-up, provides heat for catalyst reduction, and is also used during plant emergencies to maintain the temperature in the converter.

Area 109 - Methanol Distillation

Crude methanol is purified by distillation to eliminate light ends and to eliminate water. For fuel grade methanol, a one column distillation system is used to produce the product purity required. Crude feed from the methanol synthesis unit or from intermediate storage is fed to the refining column. The purpose of the refining column is to remove the water from the crude methanol. It also allows a purge of light ends. The product methanol is withdrawn from the top of the refining column, condensed and then cooled in the product methanol cooler prior to passing to storage. Off-gas from the refining column is compressed and utilized in the plant fuel system. Caustic soda solution is metered into the column below the feed tray to control pH. The bottoms of the refining column, which is essentially water, are pumped to the process condensate surge drum.

Area 110 - Partial Oxidation

In the partial oxidation unit a portion of the purge gas from the methanol synthesis loop is mixed with tars and oils from the wood gasifiers and

PROCESS DESCRIPTION (continued)

Area 110 - Partial Oxidation (continued)

organics recovered from the liquor treatment area. These streams are heated and mixed with steam and oxygen and then fed to the water cooled burner of the Texaco partial oxidation reactor.

The partial combustion reaction is carried out at a pressure of 450 psig in a refractory lined reactor. The hot gases are then quenched by recirculating water. The quench serves to cool and saturate the gases with water as well as to scrub residual particles of soot from the gas.

The quench water is supplied from various sources of process condensate as well as demineralized water. A blowdown stream of water containing soot is sent to waste water treating.

Area 111 - Air Separation

Air from the atmosphere is filtered and then compressed in a three-stage compressor. Water cooling is used for inter-stage and after-stage cooling. The compressed air at 110°F enters the air separation plant cold box. In the cold box, final separation produces oxygen vapor, and a nearly pure "waste nitrogen".

The 99.5% pure oxygen at 1 psig and about 100°F is then compressed in a centrifugal machine. About half of the oxygen is sent to the gasifiers at 50 psig and the remainder is further compressed in a four-stage reciprocating machine and sent to the partial oxidation units at 500 psig.

Two days storage of liquid oxygen is provided. A very small slip-stream of 99.5% pure liquid oxygen from the cold box is diverted from the heat exchanger to the storage tank. This tank is a horizontal double-wall vessel with a vacuum annular space filled with perlite insulation. It operates at the suction pressure of the oxygen compressor, about 1 psig, so that boil-off can be compressed and used. High head and low head pumps are provided, together with steam-heated oxygen vaporizers, so that high pressure oxygen vapor may be supplied to the partial oxidation unit and low pressure vapor to the gasifiers when the air separation unit is out of service.

Area 112 - Boiler and Boiler Feedwater System

This area includes boiler feed water preparation, condensate handling, steam generation in a fuel gas/wood chip fired boiler, and fuel handling facilities.

Boiler feed water consists of returned condensate plus demineralized make-up water, both of which are deaerated to eliminate oxygen.

Condensate from process heat exchangers is collected in condensate drums and pumped to the demineralizer in raw water treating for polishing. The combined polished condensate and demineralized water are then preheated with hot shifted synthesis gas before going to the deaerator. Chemicals

PROCESS DESCRIPTION (continued)

Area 112 - Boiler and Boiler Feedwater System (continued)

are injected into the boiler feed water to control scale and corrosion. A low head pump furnishes feed water to the gasifier jackets. A high pressure pump supplies boiler feed water to the boiler feedwater heater where it is heated by exchange with the methanol synthesis loop before being sent to the boiler.

The package boiler generates 1500 psig superheated steam and consists of an air preheater, economizer, boiler and fire-box, induced draft and forced draft fans, stack, burners for firing fuels, and a burner control system.

Plant fuel gas consists of that portion of the purge gas from the methanol synthesis loop which is not fed to partial oxidation, flash gas from the letdown vessel in the synthesis area, and compressed light ends purge gas from the distillation area. Gases from these sources are collected in a fuel gas drum in the boiler area; most of the gas is burned in the boiler, while some goes to the pilots of the high pressure and low pressure flares.

Chipped crowns from fuel storage and handling are conveyed to the boiler feed bunker. The chips are hydraulically reclaimed and fed to the boiler. Excess reclaim is recycled to the bunker.

Area 113 - Raw Water Treating and Cooling Water

Well water is pumped to the raw water storage tank which has a nominal capacity of ten hours storage. Water is then pumped to the demineralizer package and activated carbon filter. Make up water also flows to the cooling tower to replace water lost to evaporation, drift and blowdown.

The demineralization package produces water suitable for use in the high pressure steam boilers. Demineralized water is stored in a lined tank, from which a low head pump supplies make up boiler feed water to the deaerator and a high pressure pump furnishes demineralized water to process users. Potable water is obtained by taking a slip stream from the raw water, passing it through activated carbon beds, chlorinating it, and storing it in an atmospheric tank. From the tank it is pumped to distribution headers.

Two firewater pumps each take suction from the raw water storage tank. Two jockey pumps also take suction from the tank and maintain a pressure of approximately 150 psig in the firewater header at all times. The firewater system serves as a source of plant utility water.

The entire plant cooling load is handled by a cooling tower with a total recirculation capacity of 90,000 gpm, cooling this water to 90°F which represents a 10°F approach to the assumed design wet bulb temperature of 80°F at the site. Four vertical circulation pumps are provided with turbine drivers. A spare motor driven pump is also included. Make up water is fed to the cooling tower basin and a cooling water blowdown stream is sent to waste water treatment.

PROCESS DESCRIPTION (continued)

Area 113 - Raw Water Treating and Cooling Water (continued)

An automated chemical injection package adds chemicals to control pH, scale, corrosion and algae in the cooling water system. A non-chromate type of corrosion inhibitor is used in order to avoid the necessity for difficult and expensive treatment which would otherwise be required to recover chromate from the blowdown stream and prevent contamination of the effluent. A small slip stream from the discharge of the circulating pumps is filtered and returned to the cooling tower basin.

Area 114 - Waste Water Treating

The blowdown stream of quench/scrubbing water from the gasifiers is subjected to conventional biological treatment in a two-stage system of trickling filter and activated sludge aeration tank. Approximately 300 gpm of treated water overflows to the river, while the underflow of biological sludge from the clarifiers is sent to disposal outside the plant.

All other liquid waste water streams from the plant are treated in a neutralizing basin before being allowed to overflow to the river. These streams include the waste water from the partial oxidation reactors, blowdown from the cooling towers, condensate from the booster compressor, backwash and underflow from raw water treating, blowdown from the boiler and boiler ash wash water. These streams, amounting to approximately 1000 gpm, enter a mixing section of the neutralizing basin where lime solution is added. A recirculation pump takes suction from the mixing section and pumps the mixture over a divider into the main settling portion of the neutralizing basin. Recirculating liquid flows back under the bottom of the divider to the mixing section. Clarified water overflows another divider to a clear water section of the basin. Approximately 300 gpm are pumped to the boiler ash wash systems while the remaining 700 gpm overflows to effluent. Solids which accumulate on the bottom of the basin are removed for disposal.

No limitations for water use or disposal were stated as the design basis of this plant. High capital and operating costs preclude consideration of further treatment to render the water effluent suitable for recycle within the plant. However, the water effluent is suitable for discharge to the local environment.

Area 116 - Miscellaneous Facilities

Product and Intermediate Storage

Thirty days of finished product storage of fuel grade methanol is provided. Truck loading facilities and methanol loading pumps capable of loading at three times the rated plant capacity are also included.

Intermediate storage is provided for twelve hours production of crude methanol from the synthesis unit, from which crude methanol can be pumped to distillation.

PROCESS DESCRIPTION (continued)

Area 116 - Miscellaneous Facilities (continued)

Instrument Air System

An instrument air package is provided. The package includes a compressor discharging at 100 psig with inter-and-after coolers, and a surge/separator drum. An electrically regenerated drier is used to dry the air before it enters the air receiver.

Flare System

The largest quantity of gas which would be released from high pressure sources to the flare would result from failure of the make up gas compressor. Accordingly, a 20 inch diameter high pressure flare stack 175 feet tall is provided to handle the entire quantity of synthesis gas. An 8 inch diameter low pressure flare is provided to handle discharges from various low pressure sources in the plant. It is installed alongside the high pressure flare; a common support system is used for both flares. It is not necessary to size the low pressure flare to handle the large flow coming from the gasifiers, since the emergency shutdown system will be designed to immediately close off oxygen, steam and air flows to the gasifiers in the event of power failure or other emergencies.

Nitrogen System

Nitrogen from the air separation unit is compressed and sent to the nitrogen surge drum where it is kept at 100 psig for use as plant nitrogen.

DRAWING LIST

Process Flow Diagrams

7018-00-PA-101	Area 101, Wood Feed and Boiler Fuel Handling
7018-00-PA-102	Area 102, Gasification and Gas Cleanup
7018-00-PA-103	Area 103, Liquor Treatment
7018-00-PA-104	Area 104, Raw Gas Compression & Hydrogenation
7018-00-PA-105	Area 105, High Temperature Shift
7018-00-PA-106	Area 106, Acid Gas Removal
7018-00-PA-107	Area 107, Guard Beds & Make-Up Gas Compression
7018-00-PA-108	Area 108, Methanol Synthesis
7018-00-PA-109	Area 109, Methanol Distillation
7018-00-PA-110	Area 110, Partial Oxidation of Purge Gas, Tars & Oils
7018-00-PA-111	Area 111, Air Separation
7018-00-PA-112	Area 112, Boiler & BFW System
7018-00-PA-113	Area 113, Raw Water Treating & Cooling Water System
7018-00-PA-114	Area 114, Waste Water Treating
7018-00-PA-115	Area 115, Utility Distribution Balance Sheet Fuel Gas & Cooling Water Balances
7018-00-PA-116	Area 116, Steam Generation Balance

Block Flow Diagram

7018-00-PA-117

General Arrangement

5-7018-VE-001 Davy Fixed Bed Gasifier

Conceptual Plot Plan

7018-00-PC-001

102-1895
EVAPORATOR
FEED PREHEATER

102-1896
EVAPORATOR
FEED HEATER

102-1680
EVAPORATOR
FIRST EFFECT

102-1687
EVAPORATOR
SECOND EFFECT

102-1688
EVAPORATOR
THIRD EFFECT

102-1180A,B
RECOVERED
TAR PUMP

102-2280
HEAVY ORGANICS
SEPARATION

102-1182A,B
DISTILLATION
WASTE WATER
PUMP

102-1682
COLUMN DISTILLATION
CONDENSER

102-2282
RECOIL
ACCUMULATOR

102-1186A,B
FIRST
EVAPORATOR
TRANSFER PUMP

102-1187A,B
SECOND
EVAPORATOR
TRANSFER PUMP

102-1181A,B
HEAVY ORGANICS
PUMP

102-1184A,B
COLUMN BOTTOMS
PUMP

102-2281
LIGHT ORGANICS
STRIPPED COLUMN

102-1183A,B
COLUMN REFLUX
PUMP

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FUEL DISTRIBUTION

The diagram illustrates the fuel distribution system. It features several input streams on the left: PURGE GAS (2825#/HR), FLASH GAS (2125#/HR), LIGHT END PURGE (1598#/HR), and BWG GAS (NORMALLY NO FLOW FR. BOOSTER COMPRESSORS 104-1303). These streams enter a vertical cylindrical vessel labeled 112-2287 FUEL GAS DRUM. A line labeled 500#/HR exits the top of the drum and splits to feed a START-UP SHIFT GAS HEATER (105-1501) and a HP & LP FLARES (115-1502, 115-1503). A line labeled 6055#/HR exits the side of the drum and feeds a BOILER (112-2510). A line labeled 114,000#/HR exits the bottom of the drum and feeds the same BOILER. A line labeled 100-1113 METHANOL TRANSFER PUMP feeds the BOILER. A line labeled 109-2409 METHANOL PRODUCT STORAGE TANK feeds the pump. A line labeled NORMALLY NO FLOW FOR START-UP ONLY connects the tank to the pump. A line labeled CROWN CHIPS feeds the BOILER. A line labeled NORMALLY NO FLOW connects the START-UP SHIFT GAS HEATER to the HP & LP FLARES.

COOLING WATER DISTRIBUTION

EVAP. LOSS = 1800 GPM
DRIFT LOSS = 100 GPM

112-1855

COOLING WATER MAKE-UP
2500 GPM

110°F

110°F

110°F

110°F

110°F

110°F

110°F

115°F

50000 GPM

23000 GPM

27000 GPM

110°F

110°F

110°F

110°F

110°F

110°F

110°F

110-2134
COOLING TOWER
CIRCULATION PUMP

INSTRUMENT AIR
1000 GPM

AIR SEPARATION
PLANT
8800 GPM

PUMP & COMP.
SEAL COOLING
1000 GPM

NITROGEN
COMPRESSOR
COOLING
1000 GPM

POX
COOLING
400 GPM

SURFACE
CONDENSERS
11000 GPM

LIQUOR TREATING
5700 GPM

ACID GAS
REMOVAL COOLING
15400 GPM

SULFUR CLARIFIER
1800 GPM

METHANOL
18000 GPM

COMPRESSION
6700 GPM

GASIFICATION
21800 GPM

[illegible]

STREAM NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
DESCRIPTION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	STEAM TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD AND OILS TO GASIFICATION	WOOD AND OILS CLEAN-UP TO GASIFICATION	WOOD AND OILS TO GASIFICATION	WOOD AND OILS TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION	WOOD TO GASIFICATION
FLOW RATE - GPM	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
FLOW RATE - LB/H	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	
COMPONENTS	WOOD	WOOD	STEAM	WOOD	WOOD	WOOD AND OILS	WOOD AND OILS CLEAN-UP	WOOD AND OILS	WOOD AND OILS	WOOD	WOOD	WOOD	WOOD	WOOD	WOOD	WOOD	WOOD	WOOD	WOOD	WOOD	WOOD	WOOD	WOOD	WOOD	WOOD	WOOD	WOOD	WOOD	WOOD	WOOD	WOOD	WOOD

<div style="text-align: center;">5-18</div>										<div style="text-align: center;"> Davy McKee Corp. ENGINEERS AND CONSTRUCTORS BLOCK FLOW DIAGRAM BEST WOOD TO METHANOL PROJECT BIONASS ENERGY SYSTEMS INC. </div>									
REV DATE DESCRIPTION _____ _____ _____										REV DATE DESCRIPTION _____ _____ _____									
DRAWN CHECKED APPROVED _____ _____ _____										DRAWN CHECKED APPROVED _____ _____ _____									
NONE										7018-00-PA-117

METHANOL FROM EUCALYPTUS WOOD

SINGLE LINE EQUIPMENT LIST

The methanol-from-wood facility includes the following major equipment items:

Area 101 - Wood Feed and Fuel Storage and Handling

<u>Item</u>	<u>No. Required</u>	<u>Description</u>
101-1001	2	Long Wood Slasher
101-1002	4	Short Wood Slasher
101-1003	1	Crown Chip Shredder
101-1401	1	Disc Screen
101-1402	1	Magnetic Separator
101-1801	8	Wood Weigh Feeder
101-1802	2	Truck Scale
101-1901	1	Log Unloader
101-1902	1	Log Crane
101-1903	1	Crown Chip Dozer
101-1904	1	Crown Chip Truck Dumper
101-1905	1	Front-End Loader
101-1906	15	Miscellaneous Monorail, Trolley and Hoist
101-1907	2	Hydraulic Log Aligner Arms
101-2101	1	Long Wood Slasher Discharge Conveyor
101-2102	4	Short Wood Slasher Feed Conveyor
101-2103	3	Short Wood Distribution Conveyor
101-2104	4	Short Wood Slasher Discharge Conveyor
101-2105	4	Wood Bunker Feed Conveyor
101-2106	1	Cut Wood Collection Conveyor
101-2107	4	Gasifier Feed Conveyor Number 1
101-2108	4	Gasifier Feed Conveyor Number 2
101-2109	1	Cut Wood Pile Conveyor
101-2110	4	Hydraulic Live Bottom Reclaimer
101-2111	1	Crown Chip Receiving Conveyor
101-2112	1	Shredder Discharge Conveyor
101-2113	1	Crown Chip Storage Conveyor
101-2114	1	Crown Chip Reclaimer
101-2115	1	Reclaimer Discharge Conveyor
101-2116	1	Boiler Feed Conveyor Number 1
101-2117	1	Boiler Feed Conveyor Number 2
101-2301	4	Wood Feed Bunker
101-2503	1	Slasher Saw Maintenance Equipment
101-2506	1	Sawdust Collection System

Area 102 - Gasification and Gas Cleanup

<u>Item</u>	<u>No. Required</u>	<u>Description</u>
102-1101	7+9 *	Tar Pump
102-1102	7+9	Scrubbing Water Pump
102-1103	1+1	Purge Liquor Pump
102-1301	2	Start-up Air Blower
102-1302	7+1	Gas Blower
102-1403	2	Ash Screen
102-1601	7+1	Scrubbing Water Cooler
102-1701	7+1	Lynn Washer
102-1702	7+1	Downcomer Spray Chamber
102-1703	2	Electrostatic Precipitator
102-2118	8	Ash Conveyor
102-2119	2	Ash Collecting Conveyor
102-2120	2	Ash Bucket Elevator
102-2121	2	Ash Distribution Conveyor
102-2122	8	Ash Vibrating Feeder
102-2302	7+1	Seal Tank
102-2303	7+1	Ash Feed Hopper
102-2304	2	Ash Storage Silo
102-2305	2	Ash Receiver
102-2306	7+1	Wood Feed Hopper
102-2307	7+1	Tar/Water Separator
102-2308	1	Purge Liquor Storage Tank
102-2501	7+1	Gasifier
102-2518	1	Ash Conveyor System

Area 103 - Liquor Treatment

103-1180	1+1	Recovered Tar Pump
103-1181	1+1	Heavy Organics Pump
103-1182	1+1	Gasification Wastewater Pump
103-1183	1+1	Column Reflux Pump
103-1184	1+1	Column Bottoms Pump
103-1186	1+1	First Evaporator Transfer Pump
103-1187	1+1	Second Evaporator Transfer Pump
103-1680	1	Evaporator First Effect
103-1682	1	Column Overhead Condenser
103-1685	1	Evaporator Feed Preheater
103-1686	1	Evaporator Feed Heater
103-1687	1	Evaporator Second Effect
103-1688	1	Evaporator Third Effect

* 7+9 indicates 7 operating plus 9 spares

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Area 103 - Liquor Treatment (continued)

<u>Item</u>	<u>No. Required</u>	<u>Description</u>
103-2280	1	Heavy Organics Separator
103-2281	1	Light Organics Stripping Column
103-2282	1	Reflux Accumulator

Area 104 - Raw Gas Compression and Hydrogenation

104-1150	1+1	RG Compressor Turbine Condensate Pump
104-1303	2	Raw Gas Compressor
104-1602	2	First Stage RG Compressor Intercooler
104-1603	2	Second Stage RG Compressor Intercooler
104-1604	2	Third Stage RG Compressor Intercooler
104-1605	2	RG Compressor Bypass Cooler
104-2201	2	Feed RG Compressor Knockout Drum
104-2202	2	First Stage RG Compressor Knockout Drum
104-2203	2	Second Stage RG Compressor Knockout Drum
104-2204	2	Third Stage RG Compressor Knockout Drum
104-2206	1	Hydrogenation Reactor

Area 105 - High Temperature Shift

105-1105	1+1	Saturator Circulating Pump
105-1501	1	Start-up Shift Gas Heater
105-1609	1	Saturator Water Heater
105-1611	1	Demineralized Water Heater
105-1612	1	Shift Gas Preheater
105-2207	1	Synthesis Gas Knockout Drum Number 1
105-2208	1	Synthesis Gas Knockout Drum Number 2
105-2222	1	Saturator
105-2223	1	Shift Reactor

Area 106 - Acid Gas Removal

106-1117	1+1	Lean Solution Pump
106-1120	1+1	Reflux Pump
106-1637	1	Regenerator Reboiler #1
106-1638	1	Regenerator Reboiler #2
106-1639	1	Acid Gas Cooler
106-2226	1	Absorber
106-2228	1	Acid Gas Condensate Separator
106-2229	1	Regenerator

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Area 107 - Guard Beds and Make Up Gas Compression

<u>Item</u>	<u>No. Required</u>	<u>Description</u>
107-1146	1+1	Process Condensate Pump
107-1153	1+1	Make Up Gas Compressor Turbine Condensate Pump
107-1304	1	Make Up Gas Compressor
107-1613	1	Make Up Gas Preheater
107-1614	1	Make Up Gas Trim Heater
107-1657	1	Make Up Gas Trim Cooler
107-1658	1	Make Up Gas Compressor Intercooler
107-1659	1	Make Up Gas Compressor Aftercooler
107-2209	1	Process Condensate Surge Drum
107-2210	1	Chloride Guard Bed
107-2211	1	Sulfur Guard Bed
107-2253	1	Make Up Gas Compressor Feed Separator
107-2254	1	Make Up Gas Compressor Intercooler Separator
107-2255	1	Make Up Gas Compressor Aftercooler Separator

Area 108 - Methanol Synthesis

108-1154	1+1	Circulator Turbine Condensate Pump
108-1305	1	Circulator
108-1412	1+1	High Pressure Methanol Filter
108-1413	1+1	Low Pressure Methanol Filter
108-1613	1	Boiler Feed Water Preheater
108-1615	1	Cold Shell Interchanger
108-1616	1	Loop Startup Heater
108-1617	1	Warm Shell Interchanger
108-1620	1	Crude Methanol Condenser
108-2212	1	Methanol Converter
108-2213	1	Methanol Separator
108-2214	1	Letdown Vessel

Area 109 - Methanol Distillation

109-1112	1+1	Refining Column Reflux Pump
109-1113	1+1	Refining Column Bottoms Pump
109-1115	1+1	Methanol Transfer Pump
109-1116	1+1	Crude Methanol Pump
109-1306	1	Light Ends Purge Compressor

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Area 109 - Methanol Distillation (continued)

<u>Item</u>	<u>No. Required</u>	<u>Description</u>
109-1625	1	Refining Column Condenser
109-1626	1	Refining Column Vent Condenser
109-1627	1	Product Methanol Cooler
109-1629	1	Refining Column Reboiler
109-2216	1	Refining Column
109-2219	1	Refining Column Reflux Drum
109-2309	1	Methanol Product Storage Tank
109-2311	1	Crude Methanol Storage Tank
109-2514	1	Caustic Dosing Set

Area 110 - Partial Oxidation

110-1124	1+1	Tar/Oil Circulation Feed Pump
110-1125	2+1	Quench Water Circulation Pump
110-1126	2+1	Tar/Oil Booster Feed Pump
110-1144	2+2	Burner Coolant Pump
110-1649	2	Tar/Oil Feed Heater
110-1651	1	Waste Water Cooler
110-1652	2	Purge Gas Heater
110-1653	2	Burner Coolant Cooler
110-1654	2	Make Up Quench Water Heater
110-1706	2	Venturi Scrubber
110-2240	2	Partial Oxidation Reactor
110-2241	2	Scrubber Column
110-2317	1	Tar/Oil Storage Tank
110-2325	1	Burner Coolant Tank
110-2516	2+2	Pox Process Burner
110-2517	2	Pox Start Up Burner

Area 111 - Air Separation

111-1123	1+1	Low Pressure Oxygen Pump
111-1141	1+1	High Pressure Oxygen Pump
111-1656	1	Low Pressure Oxygen Vaporizer
111-1657	1	High Pressure Oxygen Vaporizer
111-2312	3	Liquid Oxygen Storage Tank
111-2505	1	Air Separation Plant

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Area 112 - Boiler and Boiler Feed Water System

<u>Item</u>	<u>No. Required</u>	<u>Description</u>
112-1135	1+1	Low Pressure BFW Pump
112-1136	1+1	High Pressure BFW Pump
112-1142	1+1	Low Pressure Condensate Pump
112-1151	1+1	HP BFW Pump Turbine Condensate Pump
112-1506	1	Steam Desuperheater
112-2245	1	Boiler Blowdown Flash Drum
112-2246	1	Deaerator
112-2247	1	Fuel Gas Drum
112-2250	1	Low Pressure Condensate Drum
112-2510	1	Fired Boiler
112-2511	1	Boiler Feed Water Dosing Set
112-2515	1	Boiler Feed Bunker

Area 113 - Raw Water Treating and Cooling Water

113-1127	1+1	Well Water Pump
113-1128	2+1	Firewater Pump
113-1129	1+1	Firewater Jockey Pump
113-1130	1+1	Demineralizer Feed Pump
113-1132	1+1	LP Demineralized Water Pump
113-1133	1+1	Potable Water Pump
113-1134	4+1	Cooling Tower Circulation Pump
113-1140	1+1	High Pressure Demineralized Water
113-1152	1+1	CT Pump Turbine Condensate Pump
113-1405	1+1	Activated Carbon Filter
113-1406	1+1	Cooling Tower Sidestream Filter
113-1655	1	Cooling Tower
113-2318	1	Demineralized Water Storage Tank
113-2319	1	Potable Water Storage Tank
113-2320	1	Raw Water Storage Tank
113-2508	1	Demineralization Package
113-2509	1	Cooling Tower Treatment Set
113-2520	1	Potable Water Chlorinator

Area 114 - Waste Water Treating

114-1122	1+1	Neutralization Basin Circulating Pump
114-1137	1+1	Boiler Ash Wash Pump
114-1138	1+1	Decanted Water Pump
114-1139	1+1	Boiler Ash Sludge Pump
114-2316	1	Neutralizing Basin
114-2323	1	Boiler Ash Slurry Settling Basin

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Area 114 - Waste Water Treating (continued)

114-2504	1	Biological Treatment
114-2519	1	Lime Slaker

Area 115 - Miscellaneous Facilities

<u>Item</u>	<u>No. Required</u>	<u>Description</u>
115-1502	1	High Pressure Flare
115-1503	1	Low Pressure Flare
115-2249	1	Nitrogen Surge Drum
115-2512	2	Tank Truck/Tank Car Loading System
115-2513	1	Instrument Air Package

METHANOL FROM EUCALYPTUS WOOD

RAW MATERIALS AND UTILITIES SUMMARY

A. RAW MATERIALS AND UTILITIES IMPORTED

	<u>Consumption</u>	<u>Consumption Per Ton of Methanol</u>
1. <u>Eucalyptus Wood</u> (Dry Basis)		
Feedstock	1995 TPD	2.00 Ton
Fuel	1052 TPD	1.05 Ton
2. <u>Well Water</u>	2800 GPM	4032 Gal.
3. <u>Electrical Power</u>	21,500 KW	516 KWH
4. <u>Air</u>	3303 TPD	3.3 Ton

B. PRODUCTS AND UTILITIES EXPORTED

	<u>Production</u>	<u>Production Per Ton of Methanol</u>
1. <u>Fuel Grade Methanol</u>	1000 TPD	
2. <u>Treated Waste Water</u>	1050 GPM	1512 Gal.
3. <u>Gasifier Ash</u>	12.2 TPD	0.012 Ton
4. <u>Boiler Ash Water Sludge</u> (Dry)	5.6 TPD	0.006 Ton
5. <u>Biological Sludge</u> (Dry)	163 TPD	0.163 Ton
6. <u>Carbon Waste</u>	2.6 TPD	0.003 Ton
⑦. <u>Carbon Dioxide</u>	1881 TPD	1.88 Ton

C. CATALYSTS AND CHEMICALS

	<u>Requirements Cubic Feet</u>	<u>Expected Life Years</u>	<u>Cost Per Ton of Methanol</u>
1. <u>Catalyst Charge</u>			
Hydrogenation	850	2-5	\$ 0.87
CO Shift	585	3-5	0.05
Chloride Guard	660	2-5	0.06
Zinc Oxide	1700	2-3	0.26
Copper → Methanol Synthesis	Confidential	2-5	1.41

C. CATALYSTS AND CHEMICALS (continued)

	Requirements Cubic Feet	Expected Life Years	Cost Per Ton of Methanol
2. <u>Water Treating</u>			
Sand for Cooling Water Filters	570	5-10	<0.001
Activated Carbon for Potable Water Filters	28	1	0.003
Demineralization Caton Bed	566	3-5	0.03
Demineralization Weak Anion Bed	210	2-3	0.06
Demineralization Strong Anion Bed	210	2-3	0.06
3. <u>Distillation</u>	<u>Consumption lb per day</u>	<u>Cost Per Ton of Methanol</u>	
Caustic, NaOH (100% Basis)	20	\$ 0.004	
4. <u>Water Treating</u>			
Lime	126,000	2.02	
Chlorine	250	0.02	
5. <u>Demineralization</u>			
Acid, H ₂ SO ₄ (100% Basis)	2800	0.11	
Caustic, NaOH (100% Basis)	1133	0.20	
6. <u>Boiler Chemicals</u>			
Scale Inhibitor	5.00	0.006	
Oxygen Scavenger	0.45	0.002	
Corrosion Inhibitor	2.26	0.009	
Dispersant	10.00	0.015	
7. <u>Cooling Tower</u>			
Corrosion Control	630	0.39	
Dispersant	90	0.03	
Algae Control	750	0.05	

It should be noted that all water treating chemical requirements are calculated based on typical quality of water. The amounts of chemicals and types of treatment are subject to change depending upon final water analysis.

METHANOL FROM WOOD MANPOWER REQUIREMENTS

The methanol-from-wood facility is estimated to require the following manpower:

Operating Labor - Wood Storage and Handling

- Basis: Assume
- o Unloading - one 10 hour shift, six days per week
 - o Wood processing - two shifts, seven days per week
 - o Wood feeding - three shifts, seven days per week

	<u>Weekday Shifts</u>			<u>Weekend/ Holiday Shifts</u>
	<u>1st</u>	<u>2nd</u>	<u>3rd</u>	
Operators	12	11	3	7
Foremen	<u>2</u>	<u>2</u>	<u>1</u>	<u>2</u>
Manpower	14	13	4	9

110,400 manhours per year
1,920 hours per year per employee
58 hourly employees

Operating Labor - Process Areas

Basis: Assume manpower is required 24 hours per day, 345 days per year.

	<u>Weekday Shifts</u>			<u>Weekend/ Holiday Shifts</u>
	<u>1st</u>	<u>2nd</u>	<u>3rd</u>	
Operators	12	12	12	12
Foremen	<u>2</u>	<u>2</u>	<u>2</u>	<u>2</u>
Manpower	14	14	14	14

115,920 manhours per year
1,920 hours per year per employee
61 hourly employees

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Maintenance Labor

Basis: Assume manpower is required 24 hours per day, 345 days per year.

	<u>Weekday Shifts</u>			<u>Weekend/ Holiday Shifts</u>
	<u>1st</u>	<u>2nd</u>	<u>3rd</u>	
Labor/Craftsmen	12	8	4	5
Foremen	<u>2</u>	<u>1</u>	<u>1</u>	<u>1</u>
Manpower	14	9	5	6

77,280 manhours per year
1,920 hours per year per employee
41 hourly employees

Overhead Personnel

Plant Manager	1
Assistant Plant Manager	1
Plant/Maintenance Engineers	8
Purchasers/Marketers	3
Chemists	2
Technicians	5
Clericals	3
Guards	<u>5</u>
Salaried Employees	26

Total Employees: 186

CAPITAL AND OPERATING REQUIREMENTS

Cost Estimate

The total installed cost for the plant is estimated as follows:

<u>Process Unit (Area)</u>	<u>Installed Cost (\$000)</u>
Wood Storage and Handling (101)	20,900
Wood Gasification, Gas Clean Up, and Liquor Treatment (102/103)	64,100
Partial Oxidation (110)	6,800
Gas Treating and Compression (104/105/106/107)	60,500
Methanol Synthesis (108)	19,100
Methanol Distillation (109)	6,550
Air Separation (111)	19,600
Offsites, Storage and Buildings (112/113/114/115)	52,450
Total Installed Cost:	250,000

This estimate is an order-of-magnitude estimate including all installation, indirects, engineering and contracting costs and process and engineering fee and license charges. The estimate is conditioned on the following:

Specifically excluded from the estimate are land costs, working capital and start-up costs.

The estimate was developed for second quarter 1981 with no escalation on material or wage rates.

No soil stabilization or site preparation is required. (A graded level site is assumed.)

All utilities and feedstocks will be delivered to the battery limits at the conditions and quantities defined in Section 3 (Design Basis).

No construction camp is necessary due to plant's proximity to established communities.

CAPITAL AND OPERATING REQUIREMENTS (continued)

The items listed below have also been excluded from this estimate:

- Piling
- Railroad Spur
- Water Well
- Spare Parts
- Operator Training
- Cost of Investment Capital
- Regulatory Licenses, Permits, etc.
- Taxes and Insurance
- Administration Building and other non-process buildings
- Catalysts

Operating Requirements

Labor

The following is the estimated operating labor required based on a four-shift rotation:

Hourly personnel	160
Salaried personnel	<u>26</u>
Total employees	186

Catalyst and Chemicals Required

Catalyst and chemicals are estimated to cost approximately \$5.66/ton of methanol produced over the life of the plant (\$1981). ~~Actual costs will occur at the time of catalyst replacement.~~

Maintenance

→ Maintenance is estimated at 2-1/2% - 3% per year of Total Installed Cost, including labor and materials.

Escalation

Using a projection from the Nelson Refinery Index, the cost of a 1000 ton per day plant is estimated at \$650,000,000 if delayed five years from mid 1981.

Plant Cost versus Plant Size

An order of magnitude estimate for a 500 ton per day methanol plant of identical scope to the base case was also estimated.

Total Installed Cost: \$145,000,000

21% per year
cost increase is BS

APPENDIX 1

SOUTHWEST RESEARCH INSTITUTE

POST OFFICE DRAWER 28510 · 6220 CULEBRA ROAD · SAN ANTONIO, TEXAS 78284 · (512) 884-5111

ENERGY SYSTEMS RESEARCH DIVISION

TELEX: 767367

TWX: 910-871-1084

15 July 1981
File: 05-6267-001

DM International
Attn: Kerry Rock
6161 Savoy Drive
P.O. Box 36444
Houston, TX 77036

RE: BESI PN 7018

Dear Sir:

As we have discussed by phone, several analyses have required reruns and updates. The tables of data previously submitted have been corrected and updated as noted:

<u>Table</u>	<u>Corrected Items</u>
III	Lead Acetate Test COD, BOD, Phenols Acidity Data
IV	Fusion Temp. Atmosphere Data Headings
V	Recovery, wt Aq, Fr.1
VI	COD, BOD, Phenols Acidity Data

We have initiated a repeat run of the ash fusion temperature in reducing atmosphere as requested. We will forward the data in about two weeks, when complete. If you have any questions please contact us.

Best Regards,

Frank M. Newman

Frank M. Newman
Manager
Chemistry Laboratories

FMN/rsh

TABLE I
ANALYTICAL REPORT
EUCALYPTUS WOOD

<u>Analysis</u>	<u>Stems</u>	<u>Crowns</u>
Material, as received		
Weight, kg	102	55
Bulk Density, kg/m ³	366	282
Loss at 110°C, wt%	50.7	13.5
Milled wood, dry basis		
<u>Proximate Analysis, wt%</u>		
Volatile Matter	83.63	79.83
Fixed Carbon	14.43	15.53
Ash	1.94	4.64
<u>Ultimate Analysis, wt%</u>		
Carbon	48.47	47.23
Hydrogen	6.07	5.72
Nitrogen	0.60	1.69
Sulfur	<0.05	<0.03
Oxygen (Diff)	42.88	40.31
Ash	1.96	5.03
<u>Heating Value, Btu/lb</u>		
Gross	8185	8025
Net	7630	7503

TABLE II
ANALYTICAL REPORT
EUCALYPTUS WOOD - STEMS
GRAY-KING DISTILLATION

<u>Analysis</u>			
<u>Dry Basis</u>	<u>wt, g</u>	<u>wt%</u>	<u>lbs/metric ton</u>
<u>Initial Wood Change</u>	<u>8.10</u>		
Charcoal	2.20	27.2	600
Tar/Oil/Liquor	3.90	48.1	1061
Gas	1.97	24.3	536
<u>Total Recovery</u>	<u>8.07</u>	<u>99.6</u>	<u>2197</u>

<u>Gases</u>	<u>Air Free Norm. %</u>
CO	27.4
CO ₂	24.2
H ₂	26.7
CH ₄	14.7
O ₂	0.0
N ₂	0.9
(CH ₂) _x	6.1

<u>Gas Volume</u>	<u>at 29.10 in. Hg and 75°F, cm³ 2000</u>	<u>at STP, cm³ 1788</u>	<u>SCF/metric ton 7804</u>
-------------------	--	--	--------------------------------

<u>Charcoal</u>	
<u>Proximate Analysis, wt%</u>	
Volatile Matter	5.56
Fixed Carbon	87.70
Ash	6.74

<u>Ultimate Analysis, wt%</u>	
Carbon	89.97
Hydrogen	0.66
Nitrogen	0.66
Sulfur	< 0.09
Oxygen (Diff)	2.23
Ash	6.43

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TABLE III
ANALYTICAL REPORT
EUCALYPTUS WOOD - STEMS
LARGE SCALE RETORT

<u>Charge</u>	<u>wt, g</u>	<u>wt%</u>
Wood Chips	2623	67
H ₂ O Added	1263	33
<u>Total</u>	<u>3886</u>	<u>100</u>
 <u>Products</u>		
Charcoal	815.5	26.9
Liquor	2120	69.9
<u>Tar/Oil</u>	<u>96</u>	<u>3.2</u>
<u>Total</u>	<u>3031.5</u>	<u>100.0</u>
 Lead Acetate Test on Gases - Negative; Sensitivity 1 ppm		
<u>Product Analysis</u>	<u>Tar/Oil</u>	<u>Liquor</u>
COD, %	---	12.8
BOD, %	---	5.7
Phenols, ppm	---	1940±20
 <u>Ultimate Analysis, wt%</u>		
Carbon	69.26	4.92
Hydrogen	7.26	10.70
Nitrogen	0.31	0.06
Sulfur	<0.08	< 0.05
Oxygen (Diff)	22.68	84.22
Ash	0.50	0.10
 Specific Gravity at 75°F	1.092	1.007
 Water, wt% by KF	6.27	---
 Heating Value, Btu/lb		
Gross	12947	---
Net	12285	---
 Acidity		
pH	---	3.2
Total, wt% acetic acid		3.2

TABLE IV
ANALYTICAL REPORT
EUCALYPTUS WOOD - STEMS

LARGE RETORT CHARCOAL ASH

<u>Fusion Temperature (Oxidizing)</u>	<u>°F</u>
IDT	> 2800
ST	> 2800
HT	> 2800
FT	> 2800
<u>Major Elements</u>	<u>wt%</u>
SiO ₂	1.15
Al ₂ O ₃	4.22
Fe ₂ O ₃	0.21
TiO ₂	N/D
CaO	49.50
MgO	0.80
Na ₂ O	1.84
K ₂ O	5.80
Li ₂ O	0.06
P ₂ O ₅	12.71
SO ₄	2.24
CO ₃	14.22
<u>Trace Elements, (HNO₃ Soluble)</u>	<u>ug/g</u>
Ag	< 0.08
As	< 1.8
Be	< 0.03
Cd	0.11
Cr	30
Cu	74
Fe	865
Hg	0.002
Mn	1700
Ni	24
Pb	6
Se	< 3.7
Sb	< 1.0
Tl	0.04
Zn	488

TABLE V
ANALYTICAL RETORT
EUCALYPTUS WOOD - STEMS
DISTILLATION OF LIQUOR/TAR/OIL FROM LARGE REPORT

Sample Charge, g 1757.5
Water Added, g 255.0
Total Charge, g 2012.5

Column Packed to 50 cm Height With Nichrome Helipak							
Gas Bag Attached to Head Vent				12 June 1981		P = 737.2 mm Hg	
Time	Temperature, °C			Fraction No.	Fraction wt, g	Gas Bag No.	Reflux Ratio
	Pot Liq.	Pot Vap.	Head Vap.				
11:35 a	25.2		22.5			1	Total
12:00 n	49.0		22.7				
12:20 p	72.2		22.7				
12:40 p	88.1		22.8			2	
12:56 p	96.9		53.6		Vapors appear in head		
12:58 p	97.1		62.8	1	Condensate collected		4:1
1:15 p	98.3		84.7	1			
1:20 p	98.6		89.8	1	23.3		
1:25 p	98.8		85.2	2		3	1:1
1:45 p	99.3		97.4				
2:35 p	100.4		99.4				
3:00 p	100.7		99.7				
3:30 p	100.9		99.9				
4:00 p	101.5		99.9				
4:30 p	104		99.9				
4:40 p	106.4		100.0		Removed 981 g distillate & lost 1 gas		
5:05 p	116.4		99.9		added to Bag No. 3 measurement		
5:20 p	88.0	101.6	99.9				
5:40 p	88.0	127.9	100.0				
6:00 p	88.5	140.5	100.0				
6:20 p	89.0	169.4	100.0				
6:30 p	91.6	185.0	100.1		Removed 706 g distillate		

Recovery

Fract. No.	Wt, g	Wt%	Wt Org, g	Wt Aq, g	
1	23.3	1.16	23.3		
2	1687	83.8	4.7	1682.3	All organics combined
Pot Res.	238	11.8	70.8	151.1	for Table VI
Hang-up	73.8	3.67	3.5	70.3	

Bag No.	Volume at 29.3 in. Hg and 77°F, cm ³	
1		2990
2		2990
3		1620

TABLE VI
 ANALYTICAL REPORT
 EUCALYPTUS WOOD - STEMS
 DISTILLED TAR/OIL/LIQUOR FROM LARGE RETORT

<u>Analysis</u>	<u>Light Distillate, Distilled Oil & Pot Tar</u>	<u>Distilled Aqueous</u>	<u>Pot Res. Aqueous</u>
COD, %	---	5.3	---
BOD, %	---	4.0	---
Phenols, ppm	---	2272±22	---
<u>Ultimate Analysis, wt%</u>			
Carbon	54.75	2.32	21.61
Hydrogen	8.06	11.09	9.34
Nitrogen	0.28	<0.01	0.24
Sulfur	0.03	<0.01	0.02
Oxygen (Diff)	36.28	86.59	68.79
Ash	0.60	0.0	0.0
Specific Gravity	1.083	0.995	1.084
<u>Acidity</u>			
pH		2.9	
Total, wt% acetic acid		1.4	

SOUTHWEST RESEARCH INSTITUTE

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ENERGY SYSTEMS RESEARCH DIVISION

TELEX: 767357

TWX: 910-671-1084

14 August 1981
File: 05-6267-001

DM International
Attn: Kerry Rock
6161 Savoy Drive
P.O. Box 36444
Houston, Texas 77036

RE: BESI PN 7018

Dear Sir:

As you requested, we have rerun the ash fusion temperatures in reducing atmosphere and have separated the liquor from the Tar/Oil obtained from the Gray-King Distillation so that % C and H could be determined. The data are reported in the attached supplemental table. If you have any questions, please contact us.

Best Regards,

Frank M. Newman

Frank M. Newman
Manager
Chemistry Laboratories

FMN/cag
Encl: 1

SAN ANTONIO, TEXAS
WITH OFFICES IN HOUSTON, TEXAS, AND WASHINGTON, D.C.

DMI-BESI
PN 7018
05-6267-001

SUPPLEMENTAL
ANALYTICAL REPORT

EUCALYPTUS WOOD - STEMS

LARGE RETORT CHARCOAL ASH

<u>Fusion Temperature (Reducing)</u>	<u>°F</u>
IDT	>2800
ST	>2800
HT	>2800
FT	>2800

Gray-King Distillation

	<u>Liquor</u>	<u>Tar/Oil</u>
Carbon, wt%	22.99	48.77
Hydrogen, wt%	9.24	7.92

APPENDIX 2

EVALUATION OF ACTUAL FLORIDA VS ASSUMED BRAZILIAN EUCALYPTUS WOOD COMPOSITION

The analytical results from Appendix 1 have been rearranged and are presented in Table I for a side by side comparison of assumed and actual values. In some cases the units or form of presentation have been changed to facilitate comparison. Comments will be made where a significant deviation between results exists. At the end of this Appendix an analysis of the effects of any differences on plant capital and operating cost will be presented.

Comparison of Analyses

1. The higher actual bulk density is caused by the higher moisture content of the as received sample. It is expected that the actual bulk density would be the same as assumed at the same moisture content.
2. The actual moisture analysis of the as received sample is considerably higher than the assumed value. However, the wood storage yard will have capacity for four months storage. The drying which takes place in storage is expected to produce an average moisture content equivalent to the assumed level.

The actual sample has a much higher ash content than assumed. This may be an artifact of contamination by dirt during harvesting but has been treated as real here. There should be no ill effects upon the gasification.

When compared on an ash free basis the actual heating value is slightly higher than that assumed.

The Gray-King distillation indicates yields of gas, aqueous and organic condensates and charcoal. These yields along with analyses of each fraction are used to predict synthesis gas production and gasifier design requirements. The Gray-King distillation indicates slightly lower actual aqueous condensate than assumed. This is reflected in higher yields of gas and charcoal.

3. The lower actual fixed carbon content of the charcoal is caused by higher actual ash content. When adjusted for moisture absorbed by the sample from air (loss at 110°F), the actual fixed carbon yield is slightly higher than assumed. This applies as well to the ultimate analysis.
4. The retort procedure produces larger samples of liquids and charcoal than the Gray-King. These samples are required for additional analyses.

Comparison of Analyses (continued)

4. (continued)

The yields from the retort closely follow the results from the Gray-King. The lower actual mass yield of gas from the retort is mostly due to its lower molecular weight (lower CO₂ content).

The actual tar/oil has a slightly higher organic content as indicated by the ultimate analysis, water content and heating values.

5. The test for fusion temperature indicates that all stages of fusion are above 2800°F. This result shows that there should be no problems with slagging of ash in the bottom of the gasifier where temperatures approach 2100°F.

The analysis of trace and major elements of the ash is useful in determining the eventual disposition of the material (landfill, fertilizer etc.). The trace elements are only those soluble in nitric acid and therefore there may be some difference between elements which show up in both trace and major analyses. The lower actual values of sodium and potassium support the higher fusion temperatures discussed above.

6. The lower actual COD indicates a slightly lower content of soluble organics in the liquor from the large retort. This observation is confirmed by the lower actual values of BOD and carbon by ultimate analysis.

Actual phenols are much higher than assumed. Duplicate analyses were conducted to confirm this result.

The actual acid index was much lower than assumed. This result is supported by the measurement of a higher actual pH.

7. The actual analysis of gas from the Gray-King distillation indicates a higher CO plus H₂ content than assumed. The heavier than methane hydrocarbons are also higher while CO₂ content is significantly lower than that assumed. The actual gas is also lower in molecular weight.
8. The liquor from the large retort is distilled in a fractional distillation to simulate the separation which takes place in the liquor treatment area. The various fractions are analyzed and combined to represent the aqueous and organic product streams.

The actual organics recovery is lower than that assumed. This again agrees with the analyses in Section 6 except that the efficiency of organics recovery is not as high as assumed. The lower organics recovery shows up as a higher than assumed BOD in the combined aqueous effluent.

The actual distilled aqueous stream has much higher phenols and lower acid content than assumed just as in the raw liquor.

Evaluation of Analytical Differences

Preliminary calculations were performed to evaluate the effects of different analyses upon plant capital and operating cost. The wood feed rate used is identical to that shown as feed to the gasifiers in the Block Flow Diagram presented in the body of the report.

Since carbon monoxide and hydrogen are the reactants for methanol and are interchangeable by the shift reaction, the sum of these two components will be used to predict the methanol product potential of each feedstock. In the table below the carbon monoxide content of various streams within the plant are tabulated for assumed and actual feedstock.

Source of CO plus H ₂	<u>lb mols CO + H₂</u> <u>hr</u>		
	Assumed	Actual	Actual Adjusted
Wood gas	5512	5815	5751
POX of purge gas	434	879	869
POX of tar/oil	2346	1724	1705
Purge to fuel gas	<u>- 84</u>	<u>-119</u>	<u>-117</u>
Total	8208	8299	8208

The actual total of CO + H₂ is about 1.1% higher than the assumed value so the third column (actual adjusted) was added to reflect the same CO + H₂ production rate and lower wood feed rate. Although adjustment to equivalent total CO plus H₂ does not imply exactly the same methanol production, it is close enough for the purpose of this comparison.

As can be seen, the wood gas contains about the same amount of CO plus H₂ in both cases. The actual gas volume will be slightly lower due to higher CO plus H₂ concentration than the assumed wood gas. Therefore the gas cleaning and raw gas compression equipment will be slightly smaller.

The actual CO plus H₂ from partial oxidation of purge gas is almost double the assumed value. This reflects the higher content of methane and heavier hydrocarbons in the wood gas which must be purged from the methanol synthesis circulation loop. As a result the circulator would be slightly smaller and the purge gas to fuel would be approximately doubled.

The actual CO plus H₂ from partial oxidation of tars and oils is about 27% lower than assumed. This is confirmed by the lower amounts of organic condensate and lower soluble organics recovered from the liquor as discussed previously. The total amount of CO plus H₂ produced from both purge gas and tars/oil is within 10% of assumed and actual values so there should be only minor changes required in partial oxidation equipment.

Evaluation of Analytical Differences (continued)

Other minor effects of differences in analyses are as follows:

1. Higher actual ash content will increase ash production by a factor of about 3.4 and ash handling equipment capacity should be increased accordingly.
2. The higher values of BOD and phenols in the distilled aqueous stream indicate the need for more waste water treating capacity. The capital cost for the waste water treatment area will increase by approximately 30%. Due to lower neutralization requirements the lime usage is reduced by 80%.

In summary all of the effects of differences in analysis between actual and assumed are very small. Minor increases in capital in some areas will tend to be offset by decreases in other areas. Changes in operating cost are mainly decreases reflected in lower wood and lime consumption. Overall, any differences are well within the order of magnitude (± 25%) accuracy of this estimate.

TABLE I

Feedstock Analysis

<u>TEST</u>		<u>ASSUMED</u>	<u>ACTUAL</u>
1.	Material, as received		
A.	Weight, kg	—	102
B.	Bulk Density (lb/ft ³)	20	23
C.	Mill (60-72 Mesh)	—	—
2.	Milled Wood		
A.	Proximate Analysis, wt%		
	(1) Loss at 110°C (as received)	32.50	50.70
	(2) Volatile Matter (dry)	84.48	83.63
	(3) Fixed Carbon (dry)	14.95	14.43
	(4) Ash (dry)	0.57	1.94
B.	Ultimate Analysis, wt%, dry basis		
	(1) Carbon	50.03	48.47
	(2) Hydrogen	5.98	6.07
	(3) Nitrogen	0.12	0.60
	(4) Sulfur	<0.05	<0.05
	(5) Oxygen (Diff)	43.30	42.88
	(6) Ash	0.57	1.96
C.	Heating Value, BTU/lb		
	(1) Gross	8268	8185
	(2) Net	7702	7630
D.	Gray-King Distillation		
	(1) Dry Gas (SCF/lb ODW)	3.399	3.741
	(2) Aqueous Condensate (lb/lb ODW)	0.4060	0.3720
	(3) Organic Condensate (lb/lb ODW)	0.1036	0.1090
	(4) Charcoal (lb/lb ODW)	0.2521	0.2720
3.	Charcoal, from 2D		
A.	Proximate Analysis, wt%		
	(1) Loss at 110°C	—	—
	(2) Volatile Matter	4.98	5.56
	(3) Fixed Carbon	92.64	87.70
	(4) Ash	2.38	6.74
B.	Ultimate Analysis, wt% dry basis		
	(1) Carbon	96.21	89.97
	(2) Hydrogen	0.51	0.66
	(3) Nitrogen	0.19	0.66
	(4) Sulfur	0.03	<0.09
	(5) Oxygen (Diff)	0.68	2.23
	(6) Ash	2.38	6.43
4.	Tar/Oil, from large retort		
A.	Retorting (wt%)		
	Inputs		
	(1) Dry Wood	100.00	100.00
	(2) Wood Moisture	48.15	48.15
	(3) Undecomposed Steam	11.44	11.74

TABLE I
(continued)Feedstock Analysis (continued)

<u>TEST</u>		<u>ASSUMED</u>	<u>ACTUAL</u>
4.	Tar/Oil, from large retort (continued)		
A.	Retorting (wt%) (continued)		
	Outputs		
	(4) Tar/Oil	4.46	3.67
	(5) Liquor	91.95	92.57
	(6) Charcoal	28.86	31.09
	(7) Gas By Difference	34.32	32.56
B.	Ultimate Analysis, wt%		
	(1) Carbon	67.69	69.26
	(2) Hydrogen	7.29	7.26
	(3) Nitrogen	0.11	0.31
	(4) Sulfur	0.04	<0.08
	(5) Oxygen (Diff)	24.87	22.68
	(6) Ash	-	0.50
C.	Water, wt%, by K.F.	11.25	6.27
D.	Specific Gravity	1.10	1.09
E.	Heating Value, BTU/lb		
	(1) Gross	12460	12947
	(2) Net	11770	12285
5.	Ash, from large retort charcoal		
A.	Fusion Temperature (reducing) (°F)		
	(1) Initial Deformation Temperature	2584	>2800
	(2) Softening Temperature	2602	>2800
	(3) Half Fused Temperature	2620	>2800
	(4) Fusion Temperature	2667	>2800
B.	Trace Elements (wt%)		
	Chlorine - Cl	0.007	-
	Nickel - Ni	<0.002	< .002
	Iron - Fe	0.007	.087
	Vanadium - V	<0.005	-
	Silicon - Si	0.01	-
	Silver - Ag	-	<0.000008
	Arsenic - As	-	<0.00018
	Beryllium - Be	-	<0.000003
	Cadmium - Cd	-	0.000011
	Chromium - Cr	-	0.0030
	Copper - Cu	-	0.0074
	Mercury - Hg	-	<0.0000002
	Manganese - Mn	-	0.17
	Lead - Pb	-	0.0006
	Selenium - Se	-	<0.00037
	Antimony - Sb	-	<0.0001
	Thallium - Tl	-	0.000004
	Zinc - Zn	-	0.049

TABLE I
(continued)

Feedstock Analysis (continued)

TEST	ASSUMED	ACTUAL
5. Ash, from large retort charcoal (continued)		
C. Major Elements (wt%)		
(1) Silicon - (as SiO ₂)	5.19	1.15
(2) Aluminum - (as Al ₂ O ₃)	1.80	4.22
(3) Iron - as Fe ₂ O ₃)	2.64	0.21
(4) Titanium - (as TiO ₂)	<1.25	ND
(5) Phosphorus - (as P ₂ O ₅)	6.60	12.71
(6) Calcium - (as CaO)	26.0	49.50
(7) Sodium - (as Na ₂ O)	5.91	1.84
(8) Potassium - (as K ₂ O)	23.0	5.80
(9) Manganese - (as MnO)	0.69	-
(10) Magnesium - (as MgO)	9.09	0.80
(11) Nickel - Ni	<0.25	-
(12) Vanadium - V	<0.25	-
6. Liquor, from large retort		
A. COD (wt%)	15.8	12.8
B. BOD (wt%)	7.4	5.7
C. Phenols (PPM)	163	1920
D. Ultimate Analysis, wt%		
(1) Carbon	5.46	4.92
(2) Hydrogen	10.85	10.70
(3) Nitrogen	0.02	0.06
(4) Sulfur	<0.01	<0.05
(5) Oxygen (Diff)	83.67	84.22
(6) Ash	-	0.10
E. Specific Gravity	1.01	1.01
F. Acid Index (mg KOH/gm)	97.6	29.7
G. pH	2.2	3.2
7. Gas, from Gray-King (2D) (volume %)		
A. CO ₂	34.13	27.4
B. CO	25.82	24.2
C. H ₂	20.58	26.7
D. CH ₄	16.80	14.7
E. N ₂	1.44	0.9
F. (CH ₂) _x	1.23	6.1
Gas, from large retort (4)		
H. H ₂ S (by lead acetate) (PPM)	<1	<1
8. Distilled Liquor from large retort		
A. Yield (wt%)		
(1) Organics	6.8	5.1
(2) Aqueous	93.2	94.9
B. Aqueous		
(1) COD (wt%)	6.2	5.3
(2) BOD (wt%)	3.0	4.0
(3) Phenols (PPM)	163	2250
(4) pH	2.2	2.9
(5) Acid index (mg KOH/gm)	64	13.0