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National Renewable Energy Laboratory
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The objective of the Biomass to Methanol Systems Analysis Project (BF15.3436) is the determination of the most economically optimum combination of unit operations which will make the production of methanol from biomass competitive with or more economic than traditional processes with conventional fossil fuel feedstocks. One step in this process is the development of integrated methanol production simulation models. This report summarizes the development of simulation models for methanol production based upon the Institute of Gas Technology (IGT) "Renugas" gasifier and the Battelle Columbus Laboratory (BCL) gasifier. The IGT "Renugas" gasifier is a high-pressure, oxygen-blown, fluid-bed gasifier which has been operated at the 10 ton per day (TPD) pilot plant scale of operation on a number of biomass feeds and the BCL gasifier is a low pressure indirectly heated gasifier which has also been operated at the 10-TPD scale. This report discusses methanol production technology, the IGT and BCL gasifiers, analysis of IGT and BCL gasifier data for gasification of wood, methanol production material and energy balance simulations, and one case study based upon each of the gasifiers.

The IGT model was used to perform a simulation for the Hawaii Natural Energy Institute (HNEI), assuming IGT's experiment 13-G as input data. The simulation indicated that approximately 100.5 million gallons of methanol per year can be produced from 2,000 d tons per day (dTPD) of bagasse with an IGT gasifier operating at 1526 °F and 319 psia. The BCL model was used to simulate and BCL gasifier/methanol synthesis system. The gasifier simulation included operation at 1675 °F, 20 psia, and a quench step. The simulation indicated that approximately 110.5 million gallons per year of methanol could be produced.

An addendum to this report will be issued by the end of the first quarter of 1992, in which the results of IGT gasifier operation at 1800 °F, and BCL gasifier operation with hot gas conditioning are shown.

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Technology Description

The thermochemical production of methanol from biomass involves the production of a synthesis gas rich in hydrogen and carbon monoxide which is then catalytically converted into methanol. Production of the synthesis gas is accomplished by thermal gasification.

The unit operations involved in methanol production from biomass are divided into the following major areas: 1) feed preparation, 2) gasification, 3) synthesis gas modification, and 4) methanol synthesis and purification. In order to understand the need for these processing steps a brief discussion of the chemistry of methanol production is required. Wood will be used as a typical biomass feedstock. Wood is a complex mixture (Graboski and Bain 1979) of organic compounds and polymers. The major types of compounds are lignin and carbohydrates (cellulose and hemicellulose) whose ratios and resulting properties are species dependent. Lignin, the cementing agent for cellulose is a complex polymer of phenylpropane units. Cellulose is a polymer formed from d(+)-glucose while the hemicellulose polymer is based on hexose and pentose sugars. Wood has low ash, nitrogen, and sulfur contents. In order to estimate yields during gasification the complex material must be reduced to a simplified chemical formula, such as $CH_{1.4}O_{0.6}$. Elements such as sulfur and nitrogen are typically present in very small amounts and do not need to be considered in terms of overall chemistry.

The combustion of wood can be ideally represented by:

$$CH_{1.4}O_{0.6} + 1.05\ O_2 \;\; \text{---->} \;\; CO_2 + 0.7\ H_2O \qquad (1)$$

Oxygen blown gasification can be thought of as incomplete combustion or partial oxidation. Gasification using a minimum amount of oxygen can be represented by:

$$CH_{1.4}O_{0.6} + 0.2\ O_2 \;\; \text{---->} \;\; CO + 0.7\ H_2 \qquad (2)$$

In cases where no oxygen is used an "ideal" gasification reaction can be represented by:

$$CH_{1.4}O_{0.6} \quad \text{---->} \quad 0.6\ CO + 0.4\ C + 0.7\ H_2 \qquad (3)$$

This pyrolysis reaction is endothermic and heat is needed to make the reaction proceed. This heat is provided by the oxidation reactions shown above or by indirect heat transfer. While these ideal reactions are simple, actual gasification is more complex and intermediate compounds such as tars and methane are formed which must be further processed before the synthesis gas can be used to produce methanol.

Methanol is formed catalytically by the following reaction:

$$CO + 2\ H_2 \quad \text{<--->} \quad CH_3OH \qquad (4)$$

It can be seen that two molecules of hydrogen are required for each molecule of carbon monoxide. Gasification may produce a gas with a hydrogen to carbon monoxide ratio as low as one-half. In this case water is added and some of the carbon monoxide is used to produce hydrogen by the catalytic shift conversion reaction:

$$CO + H_2O \quad \text{---->} \quad CO_2 + H_2 \qquad (5)$$

The methanol synthesis reaction is an equilibrium reaction and does not proceed to completion. In order to obtain economic yields unreacted gas is recycled to the synthesis reactor. While not detrimental to process chemistry, inert gases such as methane must be purged from the system, resulting in loss of yield and an economic penalty. Concentrations of methane larger than one or two percent typically result in unacceptable economic penalties. Therefore, synthesis gases containing high levels of methane are steam reformed prior to methanol synthesis. The primary catalytic reforming reaction is:

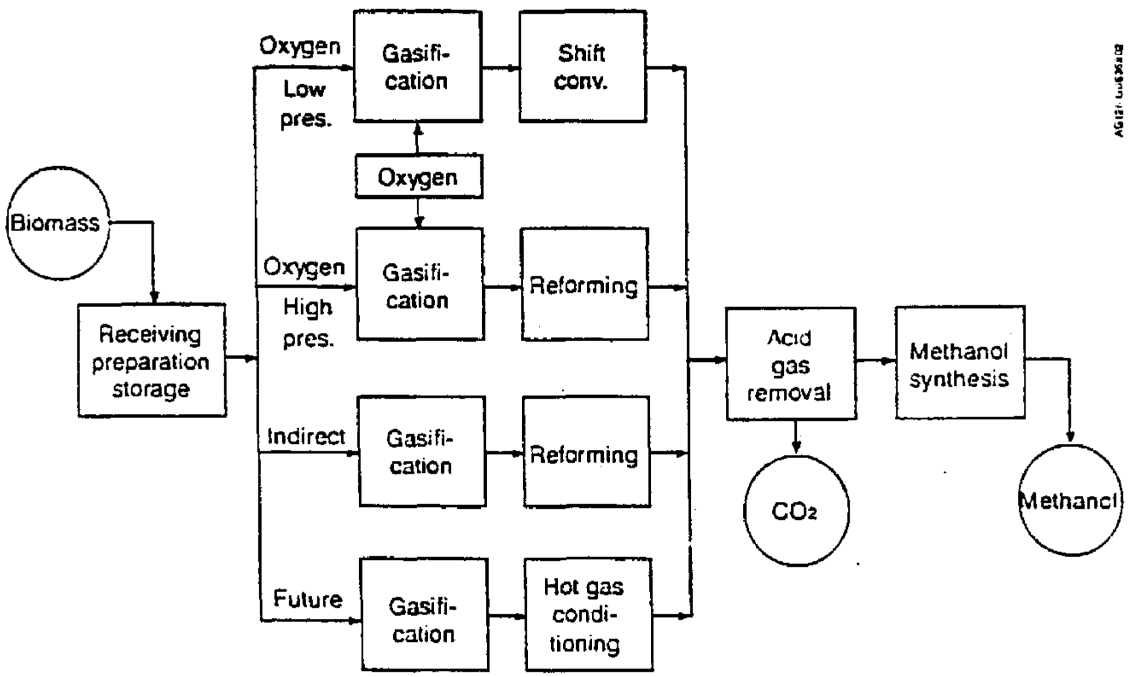
$$CH_4 + H_2O \quad \text{---->} \quad CO + 3\ H_2 \qquad (6)$$

In addition the shift conversion reaction shown above also occurs in the reformer.

Carbon dioxide also reacts with hydrogen to produce methanol, but consumes more hydrogen per mole of methanol formed than when using carbon monoxide. Most of the carbon dioxide is therefore removed from the synthesis gas prior to methanol synthesis.

With this knowledge of chemistry as a basis the unit operations can be discussed. Figure 1 shows the major routes for production of methanol from biomass on a simplified basis. These routes differ primarily in the type of gasification process chosen.

Thermochemical Routes to Methanol from Biomass



The feed preparation section of a biomass to methanol process involves wood storage and handling, size reduction, and drying. Size reduction is process specific. Drying is performed to minimize feed degradation during storage and to optimize the overall process energy balance. Drying to 10% to 15% moisture content is accomplished using waste process heat. This waste heat may come from various unit operations in an integrated methanol production facility. For a system with an indirect gasifier, this waste heat comes from hot flue gases produced during char combustion. For a direct oxidative gasifier system the waste heat comes from reformer furnace flue gases. The heat required to dry biomass from 50% moisture to 10% moisture represents about 10% of the heating value of the biomass.

Gasifiers can be divided into three major classes: 1) air gasifiers, 2) oxygen gasifiers, and 3) indirect gasifiers. This classification is based primarily upon the method of supplying the heat necessary to drive the endothermic pyrolysis reactions, the carbon-steam reaction and the carbon-carbon dioxide reaction. Gasification is an old technology for converting coal and biomass into a gas which can be used in various technical processes. Coal gasification is commercial technology used to produce substitute natural gas (Great Plains), gasoline and diesel fuel (Sasol), and methanol (Tennessee Eastman as an intermediate in acetic anhydride production and SASOL as an intermediate in formaldehyde production). Biomass gasification was used in Europe during World War II to supply energy for transportation, electricity and heat.

Biomass gasification has not been commercially developed in this country because of the abundant supplies of natural gas, petroleum, and coal. Because of the differences between coal and biomass, coal gasifiers are not directly usable for biomass gasification. Differences in reactivity (with biomass being more reactive) change required operating temperatures, pressures, and residence times. Difference in density between coal and biomass requires modification of the solids feeding systems. The ancillary facilities, such as utilities and waste treatment can be applied to biomass gasification except that biomass gasifiers do not require as extensive clean up for sulfur or nitrogen derived compound emissions as do coal gasifiers because of the low sulfur and nitrogen content of wood. A number of gasifiers are being developed in this country, in Canada,in

Europe, and in other countries to process biomass. Because of the high reactivity of biomass they are typically operated at lower temperatures than are coal gasifiers. To date, gasifier development has concentrated on production of low and medium BTU gas for use in electrical generation and as a substitute natural gas. Development has not been specific for methanol production.

Air gasifiers use the oxygen in air to provide process heat. A portion of the feed is burned, and the heat of combustion is used to gasify the remaining feed. The nitrogen present in air acts as a diluent in methanol production and leads to unattractive economics. Air gasification product can be used for electricity generation, and for ammonia synthesis.

In order to reduce the amount of inert gas in the gasifier product stream relatively pure oxygen can be used in place of air. While the use of oxygen will produce a gas suitable for downstream synthesis gas processing, oxygen is expensive and accounts for a large percentage of plant capital and operating costs. For example, oxygen costs $40 to $60 dollars per ton, and is typically used at the rate of 0.25 to 0.35 ton oxygen per ton of biomass in oxygen gasification. This translates to a cost of $10 to $21 per ton of biomass processed.

Oxygen gasifiers are operated at both low and high pressure. A low pressure oxygen (LPO) gasifer presently being evaluated for biomass gasification is the Koppers-Totzek (K-T) gasifier. The K-T gasifier (Probstein and Hicks 1982, Chem Systems 1990) is an entrained flow gasifier whose operation requires that the biomass be ground very fine, minus 30 mesh (minus ca. 0.02 inches). The required comminution adds appreciably to feed preparation costs. Operation at low pressure in the presence of oxygen produces little methane and tars. The hydrogen to carbon monoxide ratio is less than one, comparable that of indirect gasifiers. The Union Carbide Corporation Purox (Keenan 1977) process has been developed for municipal solid waste gasification. The hydrogen to carbon monoxide ratio in the produced gas is also less than one.

High pressure oxygen (HPO) gasifiers are being developed to improve on the economics of LPO gasifiers. Typically these gasifiers are fluid bed gasifiers which are fed fairly large wood chips, e.g. minus 2 inches. Oxygen and steam are injected near or at the bottom of the reactor and react with the wood, char and synthesis gas. Fluid bed reactors have the advantage of good mixing of the feed solids, uniform bed temperature, and rapid equilibrium between solids and gases. However, operation at high pressure favors the formation of methane. Operation at high pressure reduces gasifier capital cost and downstream compression costs, but downstream processing to remove or reform tars and methane adds appreciably to capital and operating costs. The Winkler and Institute of Gas Technology (IGT) gasifiers are representative of HPO fluid bed gasifiers. The Texaco gasifier is a representative HPO entrained flow gasifier. The Winkler and Texaco gasifiers have been developed for coal. The IGT gasifier (Evans et al 1988) is designed for biomass operation and has been operated at the twelve ton per day scale.

Indirect (IND) gasifiers produce a solid carbon-rich char, see equation 3, which is reacted with air in a separate combustor to provide process heat. This heat is transferred to the gasifier by circulation of hot inert solids, or by indirect heat transfer through the walls of the gasifier or through the walls of heat exchange tubes. IND gasifiers typically produce a synthesis gas rich in carbon monoxide, and with low carbon dioxide levels. In order to produce sufficient char to provide all the heat necessary for gasification these gasifiers are normally operated at relatively low temperatures, 1300 to 1600 °F. At these temperatures synthesis gas yields are reduced and methane concentration is high. The addition of a catalyst may improve the hydrogen to carbon monoxide ratio substantially. Downstream reforming is required for methanol synthesis. Operation of developmental reactors has been directed to production of medium BTU gas, not toward methanol synthesis gas production. The Battelle-Columbus Laboratory (BCL) gasifier (Feldmann et al, 1988) and the University of Missouri-Rolla (UMR) gasifier (Flanigan et al 1988) are typical of IND gasifiers developed for biomass processing. Both of these gasifiers have been operated at the pilot scale.

The synthesis gas exiting the gasifier contains small amounts of tar and char which must be removed prior to downstream catalytic conversion operations. Typically, gasification systems use scrubbers to remove tars. While efficient in contaminant removal scrubbers produce a dirty water stream which must be further processed. An alternative to scrubbing is hot gas cleanup. In coal gasification systems operated at high temperature tar removal is generally not required, and hot gas cleanup is directed toward removal of sulfur compounds. Hot gas cleanup systems are being developed for biomass gasifiers in Europe. The Studsvik MINO process (Rensfelt and Ekstrom 1989) in Sweden includes a catalytic tar conversion operation and has been operated at a pilot scale. In France the Cruesot Loire system (Philip 1986) uses a thermal tar conversion reactor. Research is ongoing in the United States in the area of hot gas cleanup for biomass gasifiers, but large pilot operations have not been undertaken to date.

All unit operations downstream of the gas cleanup operation are commercial technology, although potentially improved technologies are being investigated. Steam-methane and steam-naphtha reformers are the primary method of production of hydrogen by the petroleum industry and have been operated for many years. Likewise, shift conversion reactors have been operated commercially for many years as a part of steam-reformer systems. In 1989 approximately 7,345 million gallons of methanol production capacity existed worldwide (Crocco 1989) using thermal conversion operations. Eighty-six percent of this production capacity uses steam-reforming operations followed by catalytic methanol synthesis. The primary commercial methanol synthesis processes are licensed by ICI and Lurgi.

A liquid phase methanol synthesis concept is being investigated by Brookhaven National Laboratory (Mahajan etal 1989) in which a novel liquid phase catalyst is used to catalytically convert synthesis gas to methanol at low temperature (ca. 110-130 °C) and low pressure (ca. 180-360 psia). Single pass conversions of 90 percent of the limiting reactant, typically CO, with high selectivity, over 95 percent, to methanol have been reported. Another liquid phase methanol process is under development by Air Products and Chem Systems (Studer etal 1989) in which a solid catalysts is suspended in an organic solvent. The process has been tested at the PDU scale, up to 12 TPD of methanol production, for extended periods of time on CO rich gases. Thermal efficiencies are reported to be 90-94 % for the synthesis step. These single pass methanol synthesis processes will most probably be best utilized in conjunction with syngas generation processes producing low methane content syngas, or in a combined process where the unreacted methanol synthesis gas is used for electricity generation.

Technical development efforts for production of methanol from biomass are concentrated in the area of gasification. As stated before these efforts are primarily directed toward production of medium BTU gas for electrical generation or for fuel use and not for synthesis gas production. However, results obtained are directly applicable to gasification for methanol production. Gasification systems are being developed in the United States, in Canada, and in Europe. This discussion will concentrate on biomass gasifiers being developed in the United States.

Five gasifier systems are actively being developed in the United States for biomass gasification. These systems are listed below:

- Battelle Columbus Laboratories (BCL)
- Institute of Gas Technology (IGT)
- Manufacturing and Technology Conversion International Incorporated (MTCI)
- Syngas, Inc. (SGI)
- University of Missouri-Rolla (UMR)

BCL Gasifier

The BCL gasifier system (Feldmann et.al., 1988) is a dual bed IND gasifier system operated in an entrained flow mode. Heat for gasification is supplied by hot sand recirculating between a separate combustion vessel and the gasifier. Residual char remaining after gasification of the wood provides the fuel for the gasifier. The system has been operated at a 25 ton per day scale in pilot plant operation. The gasifier produces a synthesis gas with a low hydrogen to carbon ratio, high methane content and some tars. For methanol production the tars will have to be removed and the methane reformed to produce a suitable synthesis gas. The pilot system has been operated under conditions giving energy self sufficiency on a gasifier stand alone basis. It is possible that higher temperature operations are possible in an integrated plant where a portion of purge gases from the methanol synthesis loop can be used to make up shortfalls in heat available from char combustion. At higher temperatures tar yield and methane content will both be reduced.

IGT Gasifier

The IGT gasifier (Evans et.al., 1988) is a HPO gasifier operated in the fluid bed mode. Oxygen and steam are introduced near the bottom of the fluid bed reactor. Oxygen reacts with a portion of the feed and gasification products to supply the heat required for gasification. The system is designed to produce a medium BTU gas from biomass at moderate temperatures, 1400° to 1800°F and high pressures, 100 to 350 psia. The IGT gasifier has been operated at a 12 tons per day scale. The product gas is high in methane and contains some tars. For methanol production tars will have to be removed and the gas reformed to reduce the methane concentration.

MTCI Gasifier

The MTCI gasifier (MTCI 1990) is an IND gasifier operated in the fluid bed mode at moderate temperatures, ca. 1200° to 1300°F and atmospheric pressure. Heat for the gasification reaction is supplied indirectly through heat exchange tubes placed in the fluid bed. A pulse combustion system is used to increase the rate of heat transfer from the combustion flue gas to the fluid bed. To date natural gas has been used as the fuel for combustion, but a portion of the produced gas would probably be used for commercial operations. In addition to the high heat transfer rate, operation of the system is characterized by the use of a catalytic fluidization solid which results in product gases having high hydrogen to carbon monoxide ratios. As for the previous gasifiers the product gas contains methane and tars and will require cleanup and reforming in commercial operations. Only limited pilot runs have been performed at a 0.4 ton per day scale. For methanol production tars will have to removed, and the gas reformed to produce a suitable synthesis gas, assuming operation at conditions comparable pilot operation conditions.

SGI Gasifier

The SGI gasifier (Reed et. al., 1988) is a stratified downdraft gasifier which can be operated using air or oxygen as a LPO or HPO gasifier. The system has been operated on a limited basis as a HPO gasifier at the 24 ton per day scale. Original development of the gasifier was performed by the Solar Energy Research Institute from 1981 to 1985. The technology was licensed to SynGas, Inc., in the mid 80's for commercial development. The unit operates as a moving bed gasifier with co-current flow of oxygen or air in a downward direction. The design produces a minimum of tars. The system is designed to produce a low to medium BTU fuel gas containing a low hydrogen to CO ratio, some methane, and some tars.

UMR Gasifier

The UMR gasifier (Flanigan et.al., 1988) is an IND gasifier operated as a fluid bed reactor with heat supplied via heat exchanger tubes internal to the bed. Heat is supplied by high temperature combustion flue gas. In pilot operations natural gas has been used for combustion fuel, but in commercial operation char or a portion of gasifier product gas would be used. The system has been operated at the 3.6 short ton per day scale at relatively low temperatures. Operation at low temperatures gives higher char and tar yields and lower gas yields than the other gasifiers under development. Temperature may be limited by maximum indirect heat transfer rates. The gas will have to be reformed and tar destruction will be required to make a suitable synthesis gas feed. Because of operation at low temperature the tar production in this gasifier is an order of magnitude larger than in the other gasifiers. Higher temperature or catal bed operation of the system would produce a product stream similar to that of MTCI gasifier.

To summarize technology status, a number of gasifiers are under development which have the potential to produce a synthesis gas suitable for methanol synthesis. These gasifiers are operating in the 4 to 25 ton per day scale. All systems under development are designed to produce a low to medium BTU fuel gas. None of the systems have been operated on an integrated process basis to determine operating parameters necessary for maximum methanol production. All downstream synthesis gas operations are commercial technology in which operating conditions and yields are known.

Analysis of IGT Biomass Gasification Data

The objective of modeling the IGT gasification experimental data was to put the gasifier yield data in a form which could be used as input information in the ASPEN material and energy balance simulation. The experimental data were taken from the 1988 IGT report to Pacific Northwest Laboratories (Evans et.al., 1988). The following procedure was used convert the experimental data:

1. The experimental gasifier results given by Evans were input into a Lotus Spreadsheet. The data are given in Appendix 1.

2. The experimental yield was modified to force a 100% material balance. The modified data are given in Appendix 1.

3. Yields and gas compositions were correlated using linear least squares fits as polynomial functions of temperature. The least squares results are given in Appendix 2. A summary of gasifier conditions, feed properties, and yield correlations is given in Appendix 3.

4. The yield correlation were then used to generate ASPEN input data. The gasifier reactor model used to represent the gasifier in the ASPEN simulation is a R-YIELD reactor in which a chemical reactor is simulated by specifying component yields. This type of reactor is used when reaction stoichiometry and kinetics are unknown but yields distribution data or correlations are available. The ASPEN input data are shown in Appendix 4.

ASPEN Model for the IGT Gasifier System

The IGT gasifier based system simulated for this study is given by Figure 2. The major process components simulated were:

1. Feed dryer

2. Gasifier with no quench

3. Preformer: This reactor operates much like a naphtha preformer where higher hydrocarbons are converted to methane. The preformer was simulated as a stoichiometric reactor

4. Reformer: In the reformer methane reacts with steam to produce hydrogen and carbon monoxide. This reactor was modelled as a RGIBBS reactor, assuming equilibrium based upon minimization of Gibbs Free Energy. The reactions included in the simulation were the steam reforming reaction, the water gas shift reaction, and the CO decomposition reaction to form carbon and carbon dioxide. A steam reforming lack of equilibrium was assumed by using a minus 15 °F approach temperature for the steam reforming reaction.

5. Acid gas removal and recycle: This module is not rigorously modelled in this present simulation. The product stream is cooled and separation is forced by the simulation program. This module should be changed in the future to simulate a Benfield or Catacarb unit. A portion of the recovered carbon dioxide is recycled to the preformer.

6. The methanol compressor is modelled as a centrifugal compressor.

7. Methanol synthesis: The methanol synthesis is simulated as an equilibrium reactor. The reactions used are the methanol reaction and the water gas shift reaction.

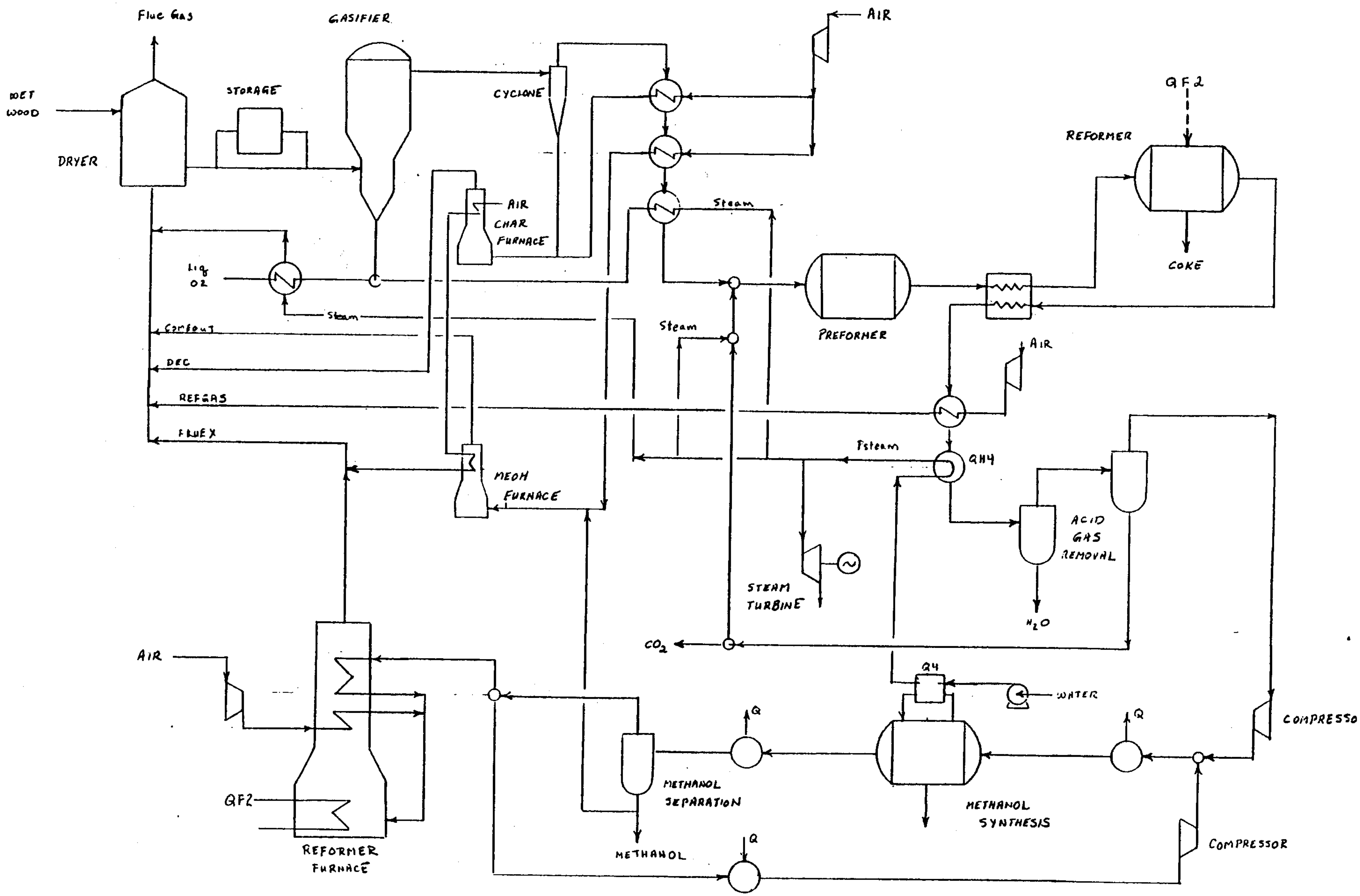


FIGURE 2
METHANOL SYNTHESIS
USING IGT GASIFIER

8. Methanol recovery is simulated by cooling the methanol reactor product stream, and performing a flash calculation. The raw methanol stream is removed. Methanol purification is not simulated. A portion of the remaining gas is recycled to the methanol reactor, and the rest is sent to the reformer furnace.

9. Reformer furnace: Methanol synthesis purge gas is burned using a stoichiometric reactor. The assumed approach temperature between furnace flue gas and reformer exit temperature is 100 °F. The flue gas from the reformer furnace is used to raise process steam, then fed to the dryer.

10. Steam Generation: Water is heated using the heat given off in the methanol synthesis reaction, and in cooling excess water from the acid gas removal operation. The amount of excess steam is dependent upon heat recovery in the acid gas plant. Future changes in the simulation will improve the accuracy of this value, and affect the amount of electricity required.

11. Electricity Generation: Excess steam is fed to a steam turbine for production of process electricity.

A listing of the simulation program is given in Appendix 5:

IGT Case Study

The IGT simulation model was used to perform a simulation for the Hawaii Natural Energy Institute (HNEI). For this case study HNEI requested that IGT's experiment 13-G be used as input data. Therefore, the data from this experiment were normalized to ASPEN input form. The normalization procedure is given in Appendix 6. The preliminary analysis is given below. In summary, the simulation indicates that approximately 100.5 million gallons of methanol per year can be produced from bagasse using a 2000 dTPD IGT gasifier operating at 1526°F, and 319 psia. This production rate compares to 101.5 million gallons per year predicted by Chem Systems (Chem Systems, 1990) for the same gasifier operating at 1800°F and 500 psia.

Basis: 2000 dTPD Feed
Feed Analysis defined per Hawaii System A data

I. System Configuration:
- a. Feed dryer
- b. Gasifier with no quench
- c. Preformer
- d. Reformer
- e. Acid gas removal
- f. Compression
- g. Methanol Synthesis
- h. Purge Gas Combustion (Reformer heat input)

II. Feed:

Total	1.333E+09 lb/yr	HHV = 0.1439E+10 Btu/hr
Carbon	0.6387E+09 lb/yr	

III. Product Streams:

A. Methanol:
Overall
2582.411 lbmol/hr = 100.45 MM gal/yr = 0.66196E+09 lb/yr
49.65 % of dry wood
HHV = 64,290 Btu/lb = 0.8072E+09 Btu/hr = 56.10 %
Carbon
0.2481E+09 = 38.84 % of carbon in

B. Carbon Dioxide
Overall 0.89894E+09 lb/yr
Carbon 0.24534E+09 lb/yr = 38.41 %

IV. Carbon Balance Check

	lb/yr	%

Methanol	0.2481E+09	38.8	
CO2	0.8453E+09	38.4	
Flue Gas	0.1234E+09	19.3	
Assoc. MeOH	0.0236E+09	3.7	(Assoc. CO, CO2, CH4)

Total		100.2	

V. UNIT OPERATIONS

A. Dryer

T = 220°F

Qd = 0.008876E+09 Btu/hr = 0.62 %
Qwg = 0.03265E+09 Btu/hr = 2.27 %
Qcond = 0.2295E+09 Btu/hr = 15.95 %

B. Storage

Not used in this case

C. Gasifier

T = 1526°F, P = 319.1 psia

Qg = 0.0303E+09 Btu/hr = 2.11 % +2.7 % IGT correction = 4.81 %

D. Solid Separation

Ash = 0.0014E+09 = 0.10 %

E. Air Compressors

Air 1	3916 lbmol/hr	
Air 2	50	
Airx	6000	
Refgas1	4000	
Ambair	5500	833.11 hp

	19466 lbmol/hr	

Total air compressor horsepower:

(19466/5500) * (833) = 2948 hp ≈ 3000 hp

Cost estimate

Reference: Garrett, D.E., Chemical Engineering Economics, using figure on page 271

Use 3 compressors, 1000 hp ea, 150 psia rating,
Add 1 compressor as spare

Purchase Price = $60,000 (1987)
Module factor = 2.6
No. units = 4

Installed Cost (1987$) = 60,000 * 2.6 * 4 = $624,000

F. Reformer Loop

1. Inlet Conditions

T = 1261°F
P = 319.1 psia
Steam Added = 6200 lbmole/hr

2. Preformer - Converts non-methane hydrocarbons

T = 1196°F

3. Preheater

Tout = 1404°F
Q = 0.04773E+09 Btu/hr
A = 1595 ft^2

4. Reformer

T = 1600°F
P = 319.1 psia
Q = -0.1744E+09 Btu/hr

Gas Composition

Comp	Mole %	Mole % Dry
H2	26.38	47.39
CO	12.29	22.08
CO2	16.68	29.96
H2O	44.33	---
CH4	0.31	0.56
H2/CO	2.15	

5. CO2 recycle

Product/Recycle = 2553/1258 = 2.03

G. Methanol Synthesis

1. Compressor 2

Pin = 319 psia
Pout = 750 psia

Tin = 300°F
Tout = 514°F
η = 0.95
Hp = 6248 ≈ 6250

Cost estimate:

Reference: Garrett, D.E., Chemical Engineering Economics, from figure on page 272

Use 3 compressors (2 + 1 spare) rated at 3200 hp ea

Base Cost (1987$) = $650,000
Number = 3
Module factor = 2.6
Stainless steel = 2.5
Pressure factor = 0.9495

Cost ($1987) = 3 * 650,000 * 2.6 * 2.5 * .9495
= 12.04 MM $

This cost compares to 7.6 MM$ in Chem Systems report for Pin = 500 psia.

2. Htr 5 (Recycle Preheat - to eliminate condensation in recycle compressor) Q = -0.0038E+09 Btu/hr

3. Recycle Compressor; 30 HP

4. Htr 6 (Used to Balance compressor preheat)

   Q = .00456E+09 Btu/hr

   0.00456 > 0.00381 O.K.

5. Methanol Synthesis

   T = 445°F, P = 750 psia
   Q = 0.1144E+09 Btu/hr
   Note: Q + Agas Cooler Q used for steam production

6. Product Cooling Q = 0.0825E+09 Btu/hr = 5.73 %
   Not used in present case

7. MeOH Separation

   Q = 0.000408E+09 = 0.03 %

   Raw Product Liquid Composition

Comp	lbmol/hr	Mole %

H_2	3.11	0.10
CO	1.33	0.005
CO_2	242.11	8.36
H_2O	63.04	2.17
CH_4	2.71	0.009
MeOH	2582.42	89.21

8. Recycle/Purge = 4360/2147 = 2.03

H. Reformer Combustor (Furnace)

1. Air Compressor - shown earlier in section II-E as ambair compressor.

2. Air Preheater
   Q = 0.0443E+09 Btu/hr
   A = 472 ft^2

3. Feed Gas Preheater
   Q = 0.0111E+09
   A = 169 ft^2

4. Combustor

   T = 1743 °F > 1700 °F (Assumed 100 °F approach in reformer furnace.

   Excess Heat = 0.002667E+09 Btu/hr = 0.18 %

I. Steam Balance

1. Generated 18,650 lbmol/hr at 319.1 psia, 902.1°F.

2. Steam G - 5365.9 lb-mol/hr
   Steam - 6200 lb-mol/hr
   Steam02 - 1800 lb-mol/hr
   Steam2 - 5284 lb-mol/hr

J. Steam Turbine

Inlet: T = 900.9°F
P = 319.1 psia
G = 5284 lb-mol/hr
Exit: T = 213.1°F
P = 15.0 psia

Electricity = 0.02987E+09 Btu/hr = 2.08 %
= 8.75 MW
Generator Loss = 0.0016E+09 Btu/hr = 0.11 %
Steam Condensation = 7.30 %

K. Preliminary Electrical

Water Pump	118.4	Hp
Air Comp	3000	
MeOH Comp	6250	
Recycle Comp	30	

Subtotal	9398.4	Hp = 7 MW

Dryer/Conveyer/Feeder
Acid Gas
Misc

L. Energy Balance

Methanol	56.10
Dryer	0.62
Wet Gas	2.27
Condense 1	15.95
Gasifier	4.81
Ash	0.10
Water	4.06
MeOH Cool	5.73
W Turb	2.08
Gen. Loss	0.11
Comb Excess	0.05
Steam Cond	7.30

	99.31

Gas Composition, Major Streams

Comp \ Stream	Gasifier Product	Preformer Feed	Preformer Product	Reformer Product	Methanol Feed	Methanol Product	Recycle Gas
H2	17.11	11.22	12.81	26.38	66.38	50.13	72.39
CO	8.75	5.74	7.10	12.28	24.16	7.71	11.13
CO2	21.37	19.82	19.41	16.68	5.98	11.52	12.92
H2O	43.33	57.02	54.49	44.33	1.87	0.67	0.00
CH4	8.43	5.53	6.15	0.31	1.56	2.42	0.09
C2H4	0.01	0.01					
C2H6	0.62	0.41					
MEOH							
C6H6	0.1600	0.1100					
C6H6O	0.0080	0.0054					
C7H8O	0.1600	0.1000					
C10H8	0.0070	0.0045					
C14H10	0.0050	0.0033					
lb-mole/hr	14221	21680	22130	24700	14570	9400	4359
T, deg F	1526	1261	1196	1600	445	445	32
P, psia	319	319	319	319	750	750	740
H, Btu/lb-mole	-74330	-86480	-84730	-66910	-21450	-45420	-28740
H/C	1.95	1.95	1.8	2.15	2.75	6.5	6.5

Analysis of BCL Biomass Gasification Data

The objective of modelling the BCL gasification data was to put the gasifier yield data in a form which could be input into the ASPEN process simulator. The experimental data were taken from the 1988 BCL report to Pacific Northwest Laboratories (Feldmann etal, 1988). The following procedure was used to convert the experimental data:

1. The experimental results were input into a Lotus Spreadsheet and normalized to force a 100 % material balance. The data are given in appendix 7.

2. Yields and gas compositions were correlated using linear least squares fits as polynomial function of temperature. The least squares results are given in Appendix 8. A summary of gasifier conditions, feed properties, and yield correlations is given in Appendix 9.

3. The yields correlations were then used to generate ASPEN input data. These input data a given in Appendix 10.

ASPEN Model for the BCL Gasifier

The BCL gasifier based system simulated for this study is given by Figures 3 and 4. The major process componenetsa simulated were:

1. Feed dryer

2. Gasifier with quench. The gasifier was modelled as a RYield reactor. The hot sand heating system was simulated by sand heating loop and char/tar/methanol combustion loop. Heat requirements were satidfied, but the hot sand stream was not actually mixed with the gasifier stream. A recycle gas stream was simulated in the same manner.

3. Reformer Compressor

4. Preformer/Reformer: The modules was simulated in the same manner as for the IGT case.

5. Acid gas removal and recycle: This module was simulated in the same manner as for the IGT case.

6. Methanol compressor: This module was simulated as three stage centrifugal compressor with intercooling.

7. Methanol synthesi/recovery: Theses modules were simulated in the same manner as for the IGT case.

8. Reformer furnace: This module was simulated in the same manner as for the IGT case.

9. Steam Generation: This module was simulated in the same manner as in the IGT case.

10. Electricity Generation: There was no electricity generation in this simulation.

A listing of the simulation program is given in Appendix 11:

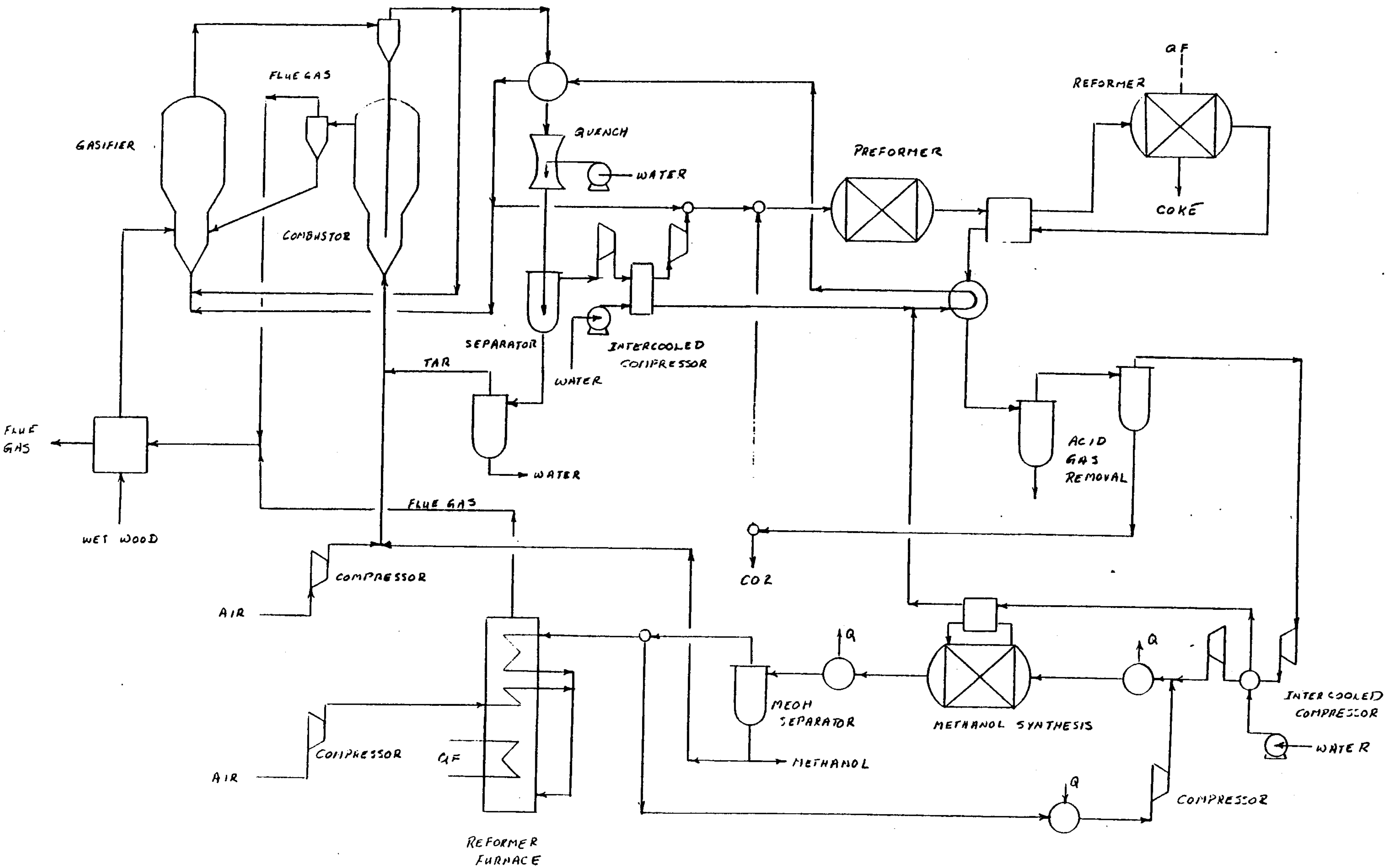


FIGURE 3: METHANOL SYNTHESIS USING BCL GASIFIER

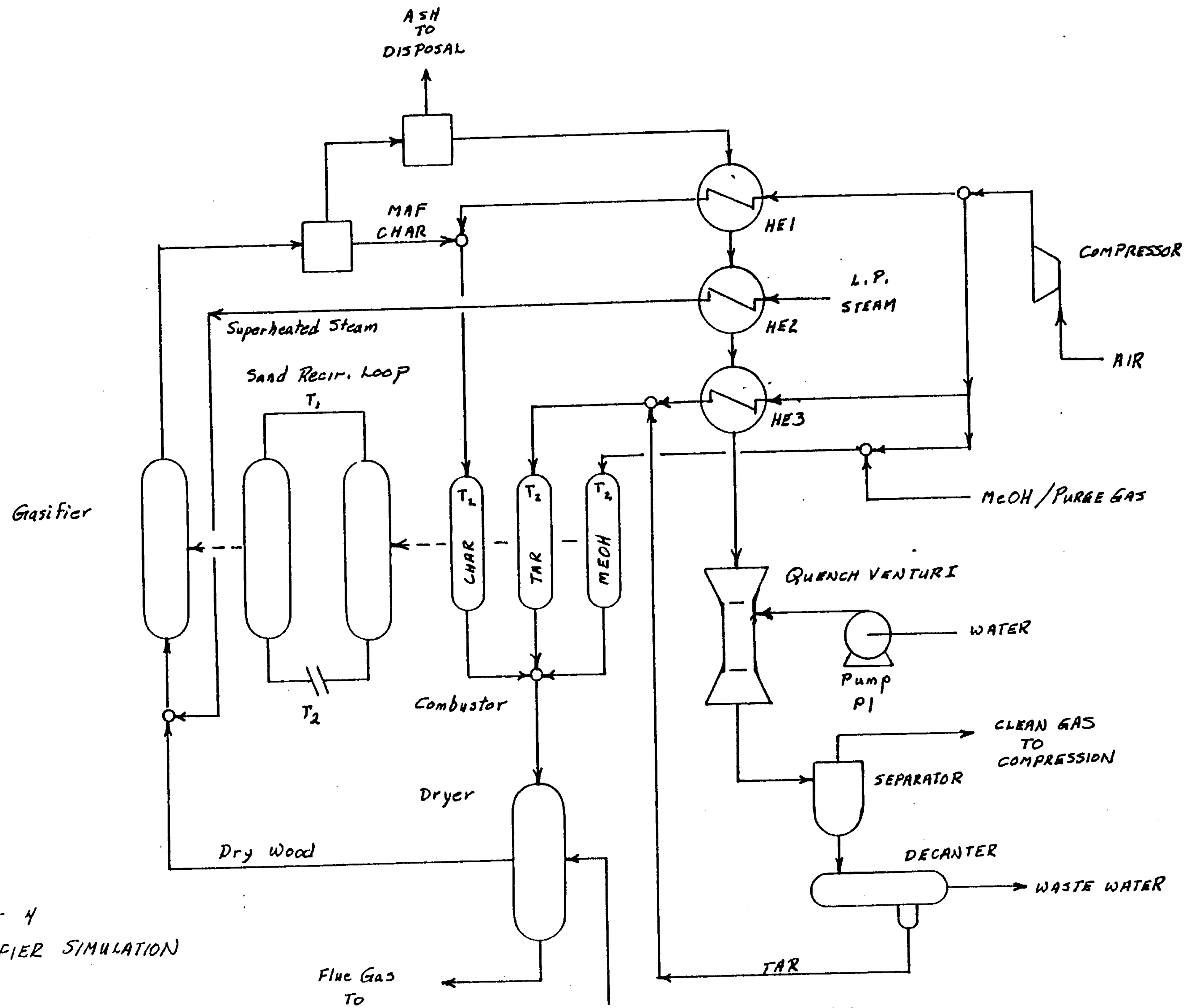


FIGURE 4
BCL GASIFIER SIMULATION

Battelle Columbus Case Study

The BCL simulation model was used to perform a simulation of base condition yields in which the raw gas leaving the gasifier was quenched and tars removed before entering the reformer train. The preliminary analysis is given below. In summary, the simulation indicates that 110.5 million gallons of methanol per year can be produced from 2000 dTPD wood. This production rate compares with 123.8 million gallons per year estimated in 1990. The differences are caused primarily by a more detailed study of dryer and steam generation heat requirements which have indicated that a larger purge gas stream from the methanol synthesis loop is required to meet process heat duty.

I. System Configuration

a. Dryer
b. Gasifier with quench and product gas recycle
c. Combustor
d. Reformer Compressor
e. Preformer
f. Reformer
g. Acid gas removal
f. Methanol synthesis compressor
g. Methanol synthesis
h. Reformer furnace

II. Feed

Total 1.333E+09 lb/yr   HHV = 1.437E+10 Btu/hr
Carbon = 0.6784E+09 lb.yr

III. Product

A. Methanol
2840 lbmol/hr = 110.5 MM gal/yr = 0.7281E+09 lb/yr
54.6 % of dry wood
HHV = 64,290 Btu/gal = 0.8878E+09 Btu/hr = 61.78 %
Carbon = 0.2729E+09 lb/hr = 40.23 %

B. Carbon Dioxide
Overall = 0.4966E+09 lb/yr
Carbon = 0.1355E+09 lb/yr

IV. Carbon Balance Check

		lb/yr		%
Methanol	=	0.2729E+09	=	40.23
Carbon Dioxide	=	0.1355E+09	=	19.97

Reformer Flue Gas = 0.0633E+09 = 9.33
Combustor Flue Gas = 0.1899E+09 = 27.85
Assoc. MeOH = 0.0232E+09 = 3.43

100.81

The difference is caused by small lack of closure in gasifier carbon balance.

V. Dryer

Temperature = 220°F
Pressure = 14.7 psia
Q_D = 0.00225E+09 Btu/hr = 0.16 %

VI. Gasifier

Temperature = 1675°F
Pressure = 20 psia
Gasifier Feed:
- Dry wood = 166,667 lb/hr
- Moisture = 16,973 lb/hr
- Steam = 66,360 lb/hr (1000°F, 25 psia)
- Hot solids = 6,000,000 lb/hr (1975°F)
- Solids/wood = 36 lb/lb
- Recycle Gas = 103,300 lb/hr (1675°F)

Quench
- Temperature = 100°F
- Pressure = 20 psia
- Water treatment rate = 310,000 gph = 5,168 gpm

VII. Combustor

Circulation Material - SiO_2
Heat capacity = 0.2 Btu/lb/°F
Circulation Rate = 6,000,000 lb/hr
Combustion feeds:
- MAF char = 25,435 lb/hr
- Tar = 1,541 lb/hr
- Methanol = 801 lb/hr
- Air = 285,447 lb/hr
- Compressor Requirements, 25 psia, 2,677 hp

Compressor Cost estimate
- Reference: Garrett, D.E., Chemical Engineering Economics, using figure on page 271
- 4 - 900 hp compressors (3 + 1 spare)
- Purchase Price = $59,000 (1987$)
- Module factor = 2.6
- No. Units = 4
- Installed Cost = 59,000 * 2.6 * 4 = $613,600

VIII. Reformer Compressor

Modelled as a 4 stage centrifugal compressor with intercooling.

Exit Temperature = 267.6°F
Exit Pressure = 200 psia
Intercooler Temperature drop = 75°F
Efficiency = 95 %
Cooling Required = 0.1223E+08 Btu/hr
Work Required = 8,393.53 Hp
Compressor Cost Estimate

Reference: Garrett, D.E., Chemical Engineering Economics, using figure on page 272
4 - 2800 hp compressors (3 + 1 spare)
Purchase Price = $600,000 (1987$)
Module factor = 2.6
Stainless Steel = 2.5
Pressure factor = 0.7485
No. Units = 4
Installed Cost = 600,000*2.6*2.5*.7485*4
= $11,676,000

IX. Reformer Loop

A. Inlet Conditions
Temperature = 267.6°F
Pressure = 200 psia
Steam Added = 8,000 lbmol/hr

B. Preformer - Converts non-methane hydrocarbons
Temperature = 1000°F

C. Preheater
Temperature Out = 1571°F
Q = 0.0937E+09 Btu/hr
A = 16,152 ft^2

D. Reformer
Temperature = 1600°
Pressure = 200 psia
Q = -0.1112E+09 Btu/hr

Gas Composition

Comp	Mole %	Mole % dry
H2	34.04	50.24
CO	18.79	27.73
CO2	14.38	21.22
H2O	32.24	---
CH4	0.55	0.81

E. CO_2 Recycle

Product/Recycle = 1410/1154 = 1.22

X. Methanol Recycle

A. Methanol Compressor

Pin = 200 psia
Pout = 750 psia
Tin = 425°F
Tout = 714.4°F
Efficiency = 0.95
Modelled as 3 stage centrifugal compressor with intercooling.
Work Required = 11,727.3 Hp
Heat Removed = 0.007599E+09 Btu/hr

Cost Estimate:

Reference: Garrett, D.E., Chemical Engineering Economics, using figure on page 272
No. Comp = 4 (3 + 1 spare) @ 3940 Hp ea
Base Cost (1987 $) = $605,000
Module Factor = 2.6
Stainless Steel = 2.5
Pressure factor = 0.9495
Cost = 605,000*4*2.6*2.5*0.9495 = $14,935,600

B. Heater 5 (Recycle Preheat - to eliminate condensation in recycle compressor) Q = 0.002901E+09 Btu/hr

C. Recycle Compressor: 22.3 Hp

D. Htr 6 (Used to balance compressor preheat)
Q = 0.01326E+09 Btu/hr > .002901E+09 (ok)

E. Methanol Synthesis
Temperature = 445°
Pressure = 750 psia
Q = -0.1282E+09 Btu/hr
Q used for steam production

F. Product Cooling Q = 0.0826E+09 Btu/hr
Not used in present case

G. Methanol Separation
Q = 0.0003882E+09 Btu/hr
Raw Product Liquid Composition

Comp	lbmole/hr	Mole %
H2	2.82	0.09
CO	3.09	0.10
CO2	233.45	7.46
H2O	18.41	0.58
CH4	5.28	0.16
MEOH	2865.25	91.59

H. Recycle/Purge = 3247/1599 = 2.03

XI. Reformer Combustor

A. Air Compressor
Work Required = 832.3 Hp
Air Rate = 5500 lb-mole/hr
Exit Temperature = 135.1°F
Pressure = 20 psia
Cost
Reference: Garrett, D.E., Chemical Engineering Economics, using figure on page 271
No. Units = 3 (2+ 1 spare)
Base Cost = $46,000 (1987 $)
Module factor = 2.6
Cost = 46,000 * 2.6 * 3 = $358,800

B. Air Preheater
Q = 0.04198E+09 Btu/hr
A = 425 ft^2

C. Feed Gas Preheater
Q = 0.005309E+09 Btu/hr
A = 55.4 ft^2

D. Combustor

T = 1730°F > 1700°F (Assumed 100°F approach temperature in reformer furnace.)
Excess heat = 0.001752E+09 Btu/hr

XII. Steam Generation

11,750 lb-mol/hr at 1036°F, 200 psia

Steam Required:

Gasifier:	3,684 lbmol/hr
Reformer:	8,000 lbmol/hr
Total:	11,684 lbmol/hr

XIII. Preliminary Electrical

Quench Pump	17.61 Hp
Steam Gen Pump	47.60
Gasifier Air Compressors	2,677
Reformer Compressor	8,394
Methanol Compressor	11,727
Reformer Air Compressor	832
Subtotal	23,695 Hp = 17.7 MW

To Be added:

- Dryer/Conveyer/Feeder
- Acid Gas
- Misc

Gas Composition, Major Streams

Comp\Stream	Gasifier Product	Preformer Feed	Preformer Product	Reformer Product	Methanol Feed	Methanol Product	MeOH Recycle Gas
H2	15.93	11.01	12.51	34.03	60.55	35.76	58.79
CO	24.89	17.20	18.78	18.78	31.25	14.21	23.32
CO2	7.16	12.12	11.91	14.37	3.73	9.99	11.62
H2O	40.30	51.64	48.83	32.24	2.20	0.23	0.01
CH4	8.80	6.09	7.94	0.55	2.21	3.81	6.16
C2H2	0.26	0.17					
C2H4	2.30	1.59					
C2H6	0.10	0.07					
C3H6	0.11	0.08					
C3H8							
MEOH					0.02	35.98	0.09
C6H6	0.06	0.00					
C10H8	0.04						
C14H10	0.03						
Lb-mole/hr	11125	16093	16384	18779	13707	7974	1599
T, deg F	1675	813	1000	1600	445	445	32
P, psia	20	200	200	200	750	750	740
H, Btu/lb-mole	-52973	-77542	-74467	-54061	-21578	-53171	-33244
H/C	0.64	0.64	0.67	1.81	1.94	2.51	2.52

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APPENDIX 1

IGT GASIFIER DATA

Reference: Evans, R. J., etal, "Development of Biomass Gasification to Produce Substitute Fuels", IGT for PNL, March 1988.

27-Dec-91

Wood Type:
- WMC = Wisconsin Maple wood chips
- PWC = Pennsylvania whole wood chips
  90 red oak, rest chestnut, aspen black birch
- WWC = Wisconsin whole wood chips
  34 % maple, 33.5 % red oak, 19.6 % birch, 12.9 % pine and brush

Item \ Test	GT-1	GT-2	GT-4	GT-5	GT-6	GT-8
Gasifier Conditions						
Temperature, deg F	1500	1650	1800	1390	1500	1510
Pressure, psia	323.7	323.7	308.7	308.7	311.7	308.7
Wet Feed Rate, lb/hr	813.4	690.6	731.9	724.3	693.5	750.4
Moisture, wt %	8.35	9.50	9.70	10.47	10.72	11.15
Oxygen, lb/lb WW	0.21	0.25	0.34	0.17	0.24	0.22
Steam, lb/lb WW	0.79	0.71	0.60	0.77	0.86	0.65
Oxygen, lb/lbBDW	0.23	0.28	0.38	0.19	0.27	0.25
Steam, lb/lb BDW	0.86	0.78	0.66	0.86	0.96	0.73
Total H20, lb/lb BDW	0.953	0.890	0.772	0.977	1.083	0.857
Prod Gas, SCF/hr	33,446	27,154	31,218	27,662	31,155	30,371
Gas Superficial Vel, ft/s	2.20	1.93	2.49	1.80	2.13	2.11
Feed						
Type	WMC	WMC	WMC	WMC	WMC	WMC
Size	Chips	Chips	Chips	Chips	Chips	Chips
Proximate Analysis						
Moisture, wt %	8.35	9.50	9.70	10.47	10.72	11.15
Volatile Matter	77.23	76.26	76.10	75.45	75.24	74.87
Ash	0.45	0.44	0.44	0.44	0.44	0.44
Fixed Carbon (by diff)	13.97	13.79	13.76	13.64	13.61	13.54
Total	100.00	100.00	100.00	100.00	100.00	100.00
Ultimate Analysis						
Ash, wt % dry	1.40	0.50	0.50	0.50	0.50	0.50
Carbon	48.84	49.54	49.54	49.54	49.54	49.54
Hydrogen	6.10	6.11	6.11	6.11	6.11	6.11
Sulfur	0.00	0.02	0.02	0.02	0.02	0.02
Nitrogen	0.00	0.10	0.10	0.10	0.10	0.10
Oxygen (by diff)	43.66	43.73	43.73	43.73	43.73	43.73
Total	100.00	100.00	100.00	100.00	100.00	100.00
HHV, BTU/lb	8371	8476	8476	8476	8476	8476
Yield, Forced closure						
Gas, wt % of C	88.22	92.20	94.23	82.26	88.20	90.52
Tar/Oil, wt % of C	3.79	2.20	0.59	4.99	3.80	2.18
Char, wt % of C	7.99	5.60	5.18	12.75	8.00	7.30
Tar/oil, wt % maf feed	2.20	1.27	0.33	2.85	2.19	1.34

Item \ Test	GT-1	GT-2	GT-4	GT-5	GT-6	GT-8
Char, wt % (maf)	3.96	2.76	2.54	6.32	3.93	3.64
Gas Yield, Calc wt %	119.3	123.3	133.4	108.2	118.4	119.0
Gas C Yield, wt %	91.7	90.9	97.9	81.0	89.5	90.6
Dry Gas, SCF/lb BDW	17.97	18.58	20.91	15.68	17.06	17.73
Wet Gas, SCF/lb BDW	37.17	36.62	37.43	36.20	39.92	35.49
Gas Composition, As Reported						
H2, mole %	10.58	11.82	13.58	9.62	8.08	9.97
CO	6.09	6.38	9.92	4.07	5.36	6.63
CO2	15.63	17.15	15.49	15.92	13.98	15.04
CH4	7.39	7.39	5.29	6.20	5.95	6.78
C2H4	0.10	0.00	0.00	0.10	0.08	0.19
C2H6	0.27	0.03	0.00	0.84	0.45	0.31
C3H8	0.00	0.00	0.00	0.02	0.00	0.00
C6H6	0.08	0.29	0.00	0.21	0.12	0.21
N2	17.08	15.42	16.23	14.93	15.17	17.45
H2O	42.78	41.52	34.96	48.09	45.44	39.00
AR	0.00	0.00	4.53	0.00	5.37	4.42
	-----	-----	-----	-----	-----	-----
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00
Vol, SCF/lb WW	41.12	39.32	42.65	38.19	44.92	40.47
Vol, SCF/lb BDW	44.87	43.45	47.23	42.66	50.31	45.55
Gas Comp, inert free, C6H6 free						
H2, mole %	12.77	14.02	17.14	11.34	10.18	12.80
CO	7.35	7.57	12.52	4.80	6.76	8.51
CO2	18.87	20.35	19.55	18.76	17.62	19.30
CH4	8.92	8.77	6.68	7.31	7.50	8.70
C2H4	0.12	0.00	0.00	0.12	0.10	0.24
C2H6	0.33	0.04	0.00	0.99	0.57	0.40
C3H8	0.00	0.00	0.00	0.02	0.00	0.00
H2O	51.64	49.26	44.12	56.67	57.27	50.05
	-----	-----	-----	-----	-----	-----
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00
Ave Mol Wt, lb/lb mole	21.49	21.65	21.47	21.55	21.57	21.74
HHV, KJ/g mole	143.53	140.12	143.86	128.65	125.27	147.77
, BTU/SCF (@ 60 deg F)	172.05	167.96	172.44	154.22	150.16	177.14

Item \ Test	GT-1	GT-2	GT-4	GT-5	GT-6	GT-8
Gas Comp, dry/ inert free						
H2, mole %	26.41	27.64	30.67	26.16	23.83	25.62
CO	15.20	14.92	22.40	11.07	15.81	17.03
CO2	39.02	40.10	34.98	43.30	41.24	38.64
CH4	18.45	17.28	11.95	16.86	17.55	17.42
C2H4	0.25	0.00	0.00	0.27	0.24	0.49
C2H6	0.67	0.07	0.00	2.28	1.33	0.80
C3H8	0.00	0.00	0.00	0.05	0.00	0.00
	-----	-----	-----	-----	-----	-----
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00
Ave Mol Wt, lb/lb mole	25.19	25.18	24.21	26.17	26.34	25.47
HHV, KJ/g mole	296.80	276.15	257.43	296.91	293.19	295.85
, BTU/SCF (@ 60 deg F)	355.78	331.02	308.59	355.91	351.45	354.64
Mol C/mol Gas	0.745	0.724	0.693	0.765	0.777	0.757
H2/CO	1.74	1.85	1.37	2.36	1.51	1.50
(H2*3CH4)/(CO+CH4)	2.43	2.47	1.94	2.75	2.29	2.26
(H2-CO2)/(CO+CO2)	-0.23	-0.23	-0.08	-0.32	-0.31	-0.23
Gas Double Check						
H2, lb/hr	18.7	16.9	22.4	14.0	13.3	16.0
CO	150.5	128.0	228.8	83.2	123.4	148.8
CO2	606.9	540.7	561.4	511.3	505.7	530.3
CH4	104.3	84.7	69.7	72.4	78.3	86.9
C2H4	2.5	0.0	0.0	2.0	1.8	4.3
C2H6	7.1	0.6	0.0	18.4	11.1	7.5
C3H8	0.0	0.0	0.0	0.6	0.0	0.0
C6H6	5.5	16.2	0.0	12.0	7.7	13.1
N2	422.0	309.3	374.3	305.1	349.2	391.5
H2O	679.6	535.5	518.3	631.8	672.4	562.5
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Total	1997.1	1631.9	1774.9	1650.8	1762.9	1760.9
H2, mole/hr	9.276	8.383	11.111	6.944	6.597	7.937
CO	5.373	4.570	8.169	2.970	4.406	5.312
CO2	13.790	12.286	12.756	11.618	11.491	12.050
CH4	6.502	5.281	4.345	4.514	4.882	5.418
C2H4	0.089	0.000	0.000	0.071	0.064	0.153
C2H6	0.236	0.020	0.000	0.612	0.369	0.249

Item \ Test	GT-1	GT-2	GT-4	GT-5	GT-6	GT-8
C3H8	0.000	0.000	0.000	0.014	0.000	0.000
C6H6	0.070	0.207	0.000	0.154	0.099	0.168
N2	15.061	11.039	13.358	10.889	12.463	13.972
H2O	37.722	29.724	28.769	35.069	37.322	31.222
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Total	88.120	71.509	78.508	72.854	77.692	76.481
lb bdw/hr	745.5	625	660.9	648.5	619.2	666.7
Vol, SCF/ lb bdw	44.85	43.41	45.07	42.62	47.60	43.52
N2 Free vol	38.09	38.62	39.05	37.98	41.67	37.44
N2,C6H6 Free vol	38.06	38.53	39.05	37.92	41.62	37.37
Dry Gas Vol	21.14	25.62	26.08	22.97	23.86	23.78
H2, mole %	10.53	11.72	14.15	9.53	8.49	10.38
CO	6.10	6.39	10.40	4.08	5.67	6.95
CO2	15.65	17.18	16.25	15.95	14.79	15.75
CH4	7.38	7.38	5.53	6.20	6.28	7.08
C2H4	0.10	0.00	0.00	0.10	0.08	0.20
C2H6	0.27	0.03	0.00	0.84	0.48	0.33
C3H8	0.00	0.00	0.00	0.02	0.00	0.00
C6H6	0.08	0.29	0.00	0.21	0.13	0.22
N2	17.09	15.44	17.02	14.95	16.04	18.27
H2O	42.81	41.57	36.64	48.14	48.04	40.82
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TOTAL	100.00	100.00	100.00	100.00	100.00	100.00
Wet Gas						
H2, mole %	12.71	13.91	17.05	11.23	10.13	12.73
CO	7.36	7.58	12.54	4.81	6.76	8.52
CO2	18.89	20.39	19.58	18.80	17.64	19.33
CH4	8.91	8.76	6.67	7.30	7.50	8.69
C2H4	0.12	0.00	0.00	0.12	0.10	0.25
C2H6	0.32	0.03	0.00	0.99	0.57	0.40
C3H8	0.00	0.00	0.00	0.02	0.00	0.00
H2O	51.68	49.32	44.16	56.73	57.30	50.08
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	100.00	100.00	100.00	100.00	100.00	100.00

Item \ Test	GT-9	GT-10	GT-11	GT-16	GT-13	GT-14
Gasifier Conditions						
Temperature, deg F	1500	1465	1500	1450	1520	1510
Pressure, psia	314.7	104.7	296.7	314.7	323.7	344.7
Wet Feed Rate, lb/hr	765.9	399.5	1029.7	768.6	742.1	826.9
Moisture, wt %	12.44	12.08	10.02	7.71	9.58	15.02
Oxygen, lb/lb WW	0.21	0.23	0.20	0.22	0.23	0.18
Steam, lb/lb WW	0.50	0.62	0.48	0.74	0.53	0.00
Oxygen, lb/lbBDW	0.24	0.26	0.22	0.24	0.25	0.21
Steam, lb/lb BDW	0.57	0.71	0.53	0.80	0.59	0.00
Total H2O, lb/lb BDW	0.713	0.843	0.645	0.885	0.692	0.177
Prod Gas, SCF/hr	25,103	17,918	34,407	30,164	27,220	27,772
Gas Superficial Vel, ft/s	1.70	3.59	2.47	1.99	1.81	1.73
Feed						
Type	WMC	WMC	WMC	WMC	PWC	PWC
Size	Chips	Chips	Chips	Chips	Chips	Chips
Proximate Analysis						
Moisture, wt %	12.44	12.08	10.02	7.71	9.58	15.02
Volatile Matter	73.79	74.09	75.83	77.77	74.61	70.13
Ash	0.43	0.43	0.44	0.45	0.85	0.80
Fixed Carbon (by diff)	13.34	13.40	13.71	14.06	14.96	14.06
Total	100.00	100.00	100.00	100.00	100.00	100.00
Ultimate Analysis						
Ash, wt % dry	0.50	0.50	0.50	0.50	0.94	0.94
Carbon	49.54	49.54	49.54	49.54	48.51	48.51
Hydrogen	6.11	6.11	6.11	6.11	6.17	6.17
Sulfur	0.02	0.02	0.02	0.02	0.04	0.04
Nitrogen	0.10	0.10	0.10	0.10	0.12	0.12
Oxygen (by diff)	43.73	43.73	43.73	43.73	44.22	44.22
Total	100.00	100.00	100.00	100.00	100.00	100.00
HHV, BTU/lb	8476	8476	8476	8476	8330	8330
Yield, Forced closure						
Gas, wt % of C	88.49	95.35	87.38	90.18	89.92	85.99
Tar/Oil, wt % of C	3.47	0.63	4.42	4.12	0.02	6.09
Char, wt % of C	8.05	4.02	8.20	5.70	10.07	7.92
Tar/oil, wt % maf feed	1.84	0.34	2.34	2.10	0.87	3.20

Item \ Test	GT-9	GT-10	GT-11	GT-16	GT-13	GT-14
Char, wt % (maf)	4.06	2.03	4.11	2.75	4.95	3.95
Gas Yield, Calc wt %	113.0	113.4	108.8	113.4	118.9	95.7
Gas C Yield, wt %	86.7	88.4	85.1	85.0	90.1	76.9
Dry Gas, SCF/lb BDW	16.21	16.50	16.14	16.76	18.47	12.98
Wet Gas, SCF/lb BDW	31.50	34.90	30.29	35.89	32.68	18.73
Gas Composition, As Reported						
H2, mole %	9.81	7.52	10.37	10.52	13.84	5.60
CO	7.05	7.24	9.39	6.09	7.08	7.20
CO2	17.64	11.89	15.61	15.89	17.28	13.26
CH4	7.96	4.87	7.30	6.17	6.82	5.83
C2H4	0.27	0.45	0.27	0.12	0.01	0.36
C2H6	0.56	0.37	0.54	0.61	0.51	0.60
C3H8	0.00	0.01	0.00	0.00	0.00	0.00
C6H6	0.44	0.60	0.43	0.34	0.14	0.84
N2	8.64	22.85	11.71	15.28	13.16	46.37
H2O	40.84	36.06	38.11	44.98	35.02	14.53
AR	6.79	8.14	6.27	0.00	6.14	5.41
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TOTAL	100.00	100.00	100.00	100.00	100.00	100.00
Vol, SCF/lb WW	32.78	44.85	33.41	39.25	36.68	33.59
Vol, SCF/lb BDW	37.44	51.01	37.13	42.53	40.57	39.53
Gas Comp, inert free, C6H6 free						
H2, mole %	11.66	10.99	12.71	12.47	17.18	11.82
CO	8.38	10.58	11.51	7.22	8.79	15.20
CO2	20.97	17.38	19.13	18.83	21.45	27.99
CH4	9.46	7.12	8.95	7.31	8.47	12.30
C2H4	0.32	0.66	0.33	0.14	0.01	0.76
C2H6	0.67	0.54	0.66	0.72	0.63	1.27
C3H8	0.00	0.01	0.00	0.00	0.00	0.00
H2O	48.54	52.71	46.71	53.31	43.47	30.67
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TOTAL	100.00	100.00	100.00	100.00	100.00	100.0C
Ave Mol Wt, lb/lb mole	22.36	21.83	22.04	21.59	21.63	24.90
HHV, KJ/g mole	156.20	142.80	163.56	134.45	159.41	216.82
, BTU/SCF (@ 60 deg F)	187.24	171.17	196.06	161.17	191.08	259.91

Item \ Test	GT-9	GT-10	GT-11	GT-16	GT-13	GT-14
Gas Comp, dry/ inert free						
H2, mole %	22.66	23.25	23.85	26.70	30.39	17.05
CO	16.29	22.38	21.60	15.46	15.55	21.92
CO2	40.75	36.75	35.90	40.33	37.94	40.37
CH4	18.39	15.05	16.79	15.66	14.98	17.75
C2H4	0.62	1.39	0.62	0.30	0.02	1.10
C2H6	1.29	1.14	1.24	1.55	1.12	1.83
C3H8	0.00	0.03	0.00	0.00	0.00	0.00
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TOTAL	100.00	100.00	100.00	100.00	100.00	100.00
Ave Mol Wt, lb/lb mole	26.47	26.08	25.57	25.68	24.41	27.95
HHV, KJ/g mole	303.56	301.97	306.92	287.95	281.99	312.73
, BTU/SCF (@ 60 deg F)	363.88	361.97	367.90	345.16	338.02	374.87
Mol C/mol Gas	0.793	0.794	0.780	0.752	0.708	0.859
H2/CO	1.39	1.04	1.10	1.73	1.95	0.78
(H2*3CH4)/(CO+CH4)	2.24	1.83	1.93	2.37	2.47	1.77
(H2-CO2)/(CO+CO2)	-0.32	-0.23	-0.21	-0.24	-0.14	-0.37
Gas Double Check						
H2, lb/hr	13.0	7.1	18.8	16.7	19.9	8.2
CO	130.7	95.8	238.7	135.7	142.4	147.7
CO2	514.1	247.3	623.5	556.5	546.1	427.5
CH4	84.4	36.8	106.0	78.6	78.4	68.4
C2H4	5.0	6.0	6.9	2.7	0.2	7.4
C2H6	11.1	5.2	14.7	14.6	11.0	13.2
C3H8	0.0	0.2	0.0	0.0	0.0	0.0
C6H6	22.7	22.1	30.4	21.1	7.8	48.0
N2	160.2	302.5	297.7	340.5	264.6	951.4
H2O	486.9	306.9	622.8	644.4	452.7	191.7
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Total	1428.1	1029.9	1959.5	1810.8	1523.1	1863.5
H2, mole/hr	6.448	3.522	9.325	8.284	9.871	4.067
CO	4.666	3.420	8.522	4.845	5.084	5.273
CO2	11.681	5.619	14.167	12.645	12.409	9.714
CH4	5.262	2.294	6.608	4.900	4.888	4.264
C2H4	0.178	0.214	0.246	0.096	0.007	0.264
C2H6	0.369	0.173	0.489	0.486	0.366	0.439

Item \ Test	GT-9	GT-10	GT-11	GT-16	GT-13	GT-14
C3H8	0.000	0.005	0.000	0.000	0.000	0.000
C6H6	0.291	0.283	0.389	0.270	0.100	0.615
N2	5.717	10.796	10.625	12.152	9.443	33.954
H2O	27.026	17.035	34.569	35.768	25.128	10.641
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Total	61.639	43.360	84.941	79.446	67.295	69.231
lb bdw/hr *	670.6	351.2	926.5	709.3	671	702.7
Vol, SCF/ lb bdw	34.87	46.84	34.78	42.49	38.05	37.38
N2 Free vol	32.88	41.79	31.09	37.33	34.46	24.69
N2,C6H6 Free vol	32.78	41.65	30.95	37.22	34.42	24.46
Dry Gas Vol	23.35	33.67	18.93	22.02	24.86	20.48
H2, mole %	10.46	8.12	10.98	10.43	14.67	5.88
CO	7.57	7.89	10.03	6.10	7.55	7.62
CO2	18.95	12.96	16.68	15.92	18.44	14.03
CH4	8.54	5.29	7.78	6.17	7.26	6.16
C2H4	0.29	0.49	0.29	0.12	0.01	0.38
C2H6	0.60	0.40	0.58	0.61	0.54	0.63
C3H8	0.00	0.01	0.00	0.00	0.00	0.00
C6H6	0.47	0.65	0.46	0.34	0.15	0.89
N2	9.28	24.90	12.51	15.30	14.03	49.05
H2O	43.85	39.29	40.70	45.02	37.34	15.37
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TOTAL	100.00	100.00	100.00	100.00	100.00	100.00
Wet Gas						
H2, mole %	11.59	10.91	12.61	12.36	17.09	11.73
CO	8.39	10.59	11.53	7.23	8.80	15.21
CO2	21.00	17.41	19.16	18.87	21.49	28.02
CH4	9.46	7.11	8.94	7.31	8.46	12.30
C2H4	0.32	0.66	0.33	0.14	0.01	0.76
C2H6	0.66	0.54	0.66	0.72	0.63	1.27
C3H8	0.00	0.01	0.00	0.00	0.00	0.00
H2O	48.58	52.77	46.76	53.37	43.51	30.70
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	100.00	100.00	100.00	100.00	100.00	100.00

Item \ Test	GT-15	GT-17	T12-1	T12-2	T30-1a	T30-1b
Gasifier Conditions						
Temperature, deg F	1520	1530	1530	1500	1538	1562
Pressure, psia	320.7	320.7	314.7	116.7	323.7	323.7
Wet Feed Rate, lb/hr	673.4	648.8	643.9	352.9	427.5	748
Moisture, wt %	14.47	26.74	4.94	7.72	10.80	10.80
Oxygen, lb/lb WW	0.25	0.33	0.25	0.26	0.26	0.23
Steam, lb/lb WW	0.41	0.46	0.61	0.69	1.18	0.63
Oxygen, lb/lbBDW	0.29	0.45	0.26	0.28	0.29	0.26
Steam, lb/lb BDW	0.48	0.63	0.64	0.75	1.32	0.71
Total H2O, lb/lb BDW	0.649	0.993	0.694	0.831	1.444	0.827
Prod Gas, SCF/hr	28,271	33,016	24,603	15,693	23,003	27,695
Gas Superficial Vel, ft/s	1.90	2.23	1.69	2.87	1.55	1.88
Feed						
Type	PWC	PWC	WWC	WWC	WWC	WWC
Size	Chips	Chips	Chips	Chips	Chips	Chips
Proximate Analysis						
Moisture, wt %	14.47	26.74	4.94	7.72	10.80	10.80
Volatile Matter	70.58	60.45	79.39	77.07	74.50	74.50
Ash	0.80	0.69	0.77	0.75	0.72	0.72
Fixed Carbon (by diff)	14.15	12.12	14.90	14.46	13.98	13.98
Total	100.00	100.00	100.00	100.00	100.00	100.00
Ultimate Analysis						
Ash, wt % dry	0.94	0.94	0.82	0.82	0.82	0.82
Carbon	48.51	48.51	48.40	48.40	48.40	48.40
Hydrogen	6.17	6.17	6.31	6.31	6.31	6.31
Sulfur	0.04	0.04	0.03	0.03	0.03	0.03
Nitrogen	0.12	0.12	0.21	0.21	0.21	0.21
Oxygen (by diff)	44.22	44.22	44.23	44.23	44.23	44.23
Total	100.00	100.00	100.00	100.00	100.00	100.00
HHV, BTU/lb	8330	8330	8389	8389	8389	8389
Yield, Forced closure						
Gas, wt % of C	90.24	96.68	90.18	87.37	92.95	93.79
Tar/Oil, wt % of C	4.28	0.00	5.46	5.33	3.07	2.98
Char, wt % of C	5.48	3.32	4.36	7.30	3.98	3.23
Tar/oil, wt % maf feed	2.26	0.00	2.97	2.88	1.61	1.57

Item \ Test	GT-15	GT-17	T12-1	T12-2	T30-1a	T30-1b
Char, wt % (maf)	2.75	1.65	2.17	3.62	1.98	1.62
Gas Yield, Calc wt %	112.4	136.1	119.2	107.2	129.7	115.5
Gas C Yield, wt %	86.5	97.8	91.5	87.5	94.5	85.9
Dry Gas, SCF/lb BDW	16.31	19.35	17.98	14.91	20.11	17.44
Wet Gas, SCF/lb BDW	31.04	41.00	32.38	34.75	48.98	34.71
Gas Composition, As Reported						
H_2, mole %	8.14	7.96	12.05	5.90	10.88	12.30
CO	6.89	3.99	8.00	7.72	3.59	5.58
CO_2	12.93	13.42	17.06	11.52	13.86	17.32
CH_4	4.79	3.95	7.37	4.58	4.79	6.56
C_2H_4	0.20	0.00	0.03	0.65	0.04	0.04
C_2H_6	0.27	0.09	0.22	0.56	0.17	0.20
C_3H_8	0.00	0.00	0.00	0.01	0.00	0.00
C_6H_6	0.49	0.17	0.27	0.24	0.18	0.81
N_2	28.24	37.53	19.18	27.64	18.63	15.59
H_2O	30.03	32.89	35.82	41.18	47.86	41.60
AR	8.02	0.00	0.00	0.00	0.00	0.00
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00
Vol, SCF/lb WW	41.98	48.21	38.21	44.47	53.81	37.03
Vol, SCF/lb BDW	49.08	65.81	40.20	48.19	60.33	41.51
Gas Comp, inert free, C_6H_6 free						
H_2, mole %	12.87	12.78	14.96	8.18	13.40	14.71
CO	10.89	6.40	9.93	10.70	4.42	6.67
CO_2	20.44	21.54	21.18	15.97	17.07	20.72
CH_4	7.57	6.34	9.15	6.35	5.90	7.85
C_2H_4	0.32	0.00	0.04	0.90	0.05	0.05
C_2H_6	0.43	0.14	0.27	0.78	0.21	0.24
C_3H_8	0.00	0.00	0.00	0.01	0.00	0.00
H_2O	47.48	52.79	44.47	57.10	58.95	49.76
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00
Ave Mol Wt, lb/lb mole	22.29	22.10	21.98	21.99	20.66	21.59
HHV, KJ/g mole	146.16	113.35	157.12	135.36	107.31	135.22
, BTU/SCF (@ 60 deg F)	175.21	135.88	188.34	162.25	128.63	162.09

Item \ Test	GT-15	GT-17	T12-1	T12-2	T30-1a	T30-1b
Gas Comp, dry/ inert free						
H2, mole %	24.50	27.07	26.94	19.07	32.64	29.29
CO	20.74	13.57	17.89	24.95	10.77	13.29
CO2	38.92	45.63	38.14	37.23	41.58	41.24
CH4	14.42	13.43	16.48	14.80	14.37	15.62
C2H4	0.60	0.00	0.07	2.10	0.12	0.10
C2H6	0.81	0.31	0.49	1.81	0.51	0.48
C3H8	0.00	0.00	0.00	0.03	0.00	0.00
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TOTAL	100.00	100.00	100.00	100.00	100.00	100.00
Ave Mol Wt, lb/lb mole	26.16	26.67	25.15	27.28	24.47	25.14
HHV, KJ/g mole	278.29	240.12	282.94	315.51	261.40	269.15
, BTU/SCF (@ 60 deg F)	333.59	287.83	339.16	378.20	313.34	322.63
Mol C/mol Gas	0.769	0.732	0.736	0.849	0.680	0.713
H2/CO	1.18	1.99	1.51	0.76	3.03	2.20
(H2*3CH4)/(CO+CH4)	1.93	2.49	2.22	1.60	3.01	2.63
(H2-CO2)/(CO+CO2)	-0.24	-0.31	-0.20	-0.29	-0.17	-0.22
Gas Double Check						
H2, lb/hr	12.1	13.9	15.6	4.9	13.2	18.0
CO	143.9	97.3	145.4	89.5	61.0	114.2
CO2	424.4	514.4	487.3	209.9	370.1	556.9
CH4	57.2	55.1	76.5	30.3	46.5	76.7
C2H4	4.2	0.0	0.5	7.5	0.7	0.8
C2H6	6.0	2.4	4.3	7.0	3.1	4.4
C3H8	0.0	0.0	0.0	0.2	0.0	0.0
C6H6	28.5	11.6	13.7	7.8	8.5	46.2
N2	589.8	915.4	348.6	320.5	316.6	319.0
H2O	403.2	515.7	418.6	306.9	522.9	547.2
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Total	1669.3	2125.8	1510.5	984.5	1342.6	1683.4
H2, mole/hr	6.002	6.895	7.738	2.431	6.548	8.929
CO	5.137	3.474	5.191	3.195	2.178	4.077
CO2	9.643	11.688	11.072	4.769	8.409	12.654
CH4	3.566	3.435	4.769	1.889	2.899	4.782
C2H4	0.150	0.000	0.018	0.267	0.025	0.029
C2H6	0.200	0.080	0.143	0.233	0.103	0.146

Item \ Test	GT-15	GT-17	T12-1	T12-2	T30-1a	T30-1b
C3H8	0.000	0.000	0.000	0.005	0.000	0.000
C6H6	0.365	0.149	0.175	0.100	0.109	0.591
N2	21.049	32.670	12.441	11.438	11.299	11.385
H2O	22.380	28.625	23.235	17.035	29.024	30.373
	------	------	------	------	------	------
Total	68.492	87.014	64.783	41.362	60.594	72.965
lb bdw/hr	576	501.7	612.1	325.7	381.3	667.2
Vol, SCF/ lb bdw	45.11	65.80	40.15	48.18	60.29	41.49
N2 Free vol	35.62	44.31	35.16	42.67	53.48	36.77
N2,C6H6 Free vol	35.45	44.21	35.09	42.62	53.41	36.52
Dry Gas Vol	25.36	25.37	25.76	34.41	35.91	23.92
H2, mole %	8.76	7.92	11.94	5.88	10.81	12.24
CO	7.50	3.99	8.01	7.73	3.59	5.59
CO2	14.08	13.43	17.09	11.53	13.88	17.34
CH4	5.21	3.95	7.36	4.57	4.78	6.55
C2H4	0.22	0.00	0.03	0.65	0.04	0.04
C2H6	0.29	0.09	0.22	0.56	0.17	0.20
C3H8	0.00	0.00	0.00	0.01	0.00	0.00
C6H6	0.53	0.17	0.27	0.24	0.18	0.81
N2	30.73	37.54	19.20	27.65	18.65	15.60
H2O	32.68	32.90	35.87	41.18	47.90	41.63
	------	------	------	------	------	------
TOTAL	100.00	100.00	100.00	100.00	100.00	100.00
Wet Gas						
H2, mole %	12.75	12.72	14.83	8.15	13.31	14.64
CO	10.91	6.41	9.95	10.71	4.43	6.68
CO2	20.48	21.57	21.23	15.99	17.10	20.75
CH4	7.57	6.34	9.14	6.33	5.89	7.84
C2H4	0.32	0.00	0.03	0.90	0.05	0.05
C2H6	0.42	0.15	0.27	0.78	0.21	0.24
C3H8	0.00	0.00	0.00	0.02	0.00	0.00
H2O	47.54	52.82	44.54	57.12	59.01	49.80
	-----	-----	-----	-----	-----	-----
	100.00	100.00	100.00	100.00	100.00	100.00

Item \ Test	T12-3a	T12-3b	T12-4a	T12-4b
Gasifier Conditions				
Temperature, deg F	1672	1413	1509	1516
Pressure, psia	317.7	317.7	83.7	98.7
Wet Feed Rate, lb/hr	708.1	708.1	375.4	375.4
Moisture, wt %	9.14	9.14	8.98	9.59
Oxygen, lb/lb WW	0.26	0.18	0.27	0.28
Steam, lb/lb WW	0.69	0.68	0.72	0.73
Oxygen, lb/lbBDW	0.29	0.20	0.30	0.31
Steam, lb/lb BDW	0.76	0.75	0.79	0.81
Total H2O, lb/lb BDW	0.860	0.849	0.890	0.914
Prod Gas, SCF/hr	27,472	25,373	16,813	17,439
Gas Superficial Vel, ft/s	2.01	1.63	4.31	3.8
Feed				
Type	WWC	WWC	WWC	WWC
Size	Chips	Chips	Chips	Chips
Proximate Analysis				
Moisture, wt %	9.14	9.14	8.98	9.59
Volatile Matter	75.89	75.89	76.02	75.51
Ash	0.74	0.74	0.74	0.73
Fixed Carbon (by diff)	14.24	14.24	14.26	14.17
Total	100.00	100.00	100.00	100.00
Ultimate Analysis				
Ash, wt % dry	0.82	0.82	0.82	0.82
Carbon	48.40	48.40	48.40	48.40
Hydrogen	6.31	6.31	6.31	6.31
Sulfur	0.03	0.03	0.03	0.03
Nitrogen	0.21	0.21	0.21	0.21
Oxygen (by diff)	44.23	44.23	44.23	44.23
Total	100.00	100.00	100.00	
HHV, BTU/lb	8389	8389	8389	8389
Yield, Forced closure				
Gas, wt % of C	96.12	87.14	91.78	93.22
Tar/Oil, wt % of C	2.16	6.72	5.12	4.74
Char, wt % of C	1.72	6.14	3.10	2.04
Tar/oil, wt % maf feed	1.13	3.54	2.73	2.51

Item \ Test	T12-3a	T12-3b	T12-4a	T12-4b
Char, wt % (maf)	0.86	3.09	1.57	1.04
Gas Yield, Calc wt %	125.7	105.2	111.4	115.1
Gas C Yield, wt %	95.3	83.5	88.8	91.5
Dry Gas, SCF/lb BDW	19.20	14.98	16.04	16.61
Wet Gas, SCF/lb BDW	36.40	33.24	36.28	37.15
Gas Composition, As Reported				
H2, mole %	12.69	8.55	7.49	7.38
CO	7.22	5.59	7.79	7.59
CO2	17.42	15.72	11.98	11.93
CH4	7.60	6.95	4.32	4.61
C2H4	0.00	0.28	0.65	0.50
C2H6	0.02	0.90	0.35	0.30
C3H8	0.00	0.00	0.01	0.01
C6H6	0.41	0.57	0.47	0.40
N2	14.34	15.13	25.80	27.29
H2O	40.30	46.31	41.14	39.99
AR	0.00	0.00	0.00	0.00
	-----	-----	-----	-----
TOTAL	100.00	100.00	100.00	100.00
Vol, SCF/lb WW	38.80	35.83	44.79	46.45
Vol, SCF/lb BDW	42.70	39.43	49.21	51.38
Gas Comp, inert free, C6H6 free				
H2, mole %	14.89	10.14	10.16	10.21
CO	8.47	6.63	10.57	10.50
CO2	20.43	18.65	16.25	16.50
CH4	8.91	8.24	5.86	6.38
C2H4	0.00	0.33	0.88	0.69
C2H6	0.02	1.07	0.47	0.41
C3H8	0.00	0.00	0.01	0.01
H2O	47.27	54.93	55.80	55.30
	-----	-----	-----	-----
TOTAL	100.00	100.00	100.00	100.00
Ave Mol Wt, lb/lb mole	21.62	21.90	21.70	21.72
HHV, KJ/g mole	146.26	142.50	131.25	132.18
, BTU/SCF (@ 60 deg F)	175.32	170.82	157.33	158.44

Item \ Test	T12-3a	T12-3b	T12-4a	T12-4b
Gas Comp, dry/ inert free				
H2, mole %	28.23	22.51	22.98	22.83
CO	16.06	14.71	23.90	23.48
CO2	38.75	41.38	36.76	36.91
CH4	16.91	18.29	13.26	14.26
C2H4	0.00	0.74	1.99	1.55
C2H6	0.04	2.37	1.07	0.93
C3H8	0.00	0.00	0.03	0.03
	-----	-----	-----	-----
TOTAL	100.00	100.00	100.00	100.00
Ave Mol Wt, lb/lb mole	24.85	26.64	26.36	26.30
HHV, KJ/g mole	277.39	316.22	296.93	295.72
, BTU/SCF (@ 60 deg F)	332.51	379.05	355.93	354.48
Mol C/mol Gas	0.718	0.806	0.801	0.797
H2/CO	1.76	1.53	0.96	0.97
(H2*3CH4)/(CO+CH4)	2.39	2.34	1.69	1.74
(H2-CO2)/(CO+CO2)	-0.19	-0.34	-0.23	-0.23
Gas Double Check				
H2, lb/hr	18.4	11.4	6.6	6.8
CO	146.5	104.8	96.8	97.8
CO2	555.6	463.1	233.8	241.5
CH4	88.1	74.4	30.7	33.9
C2H4	0.0	5.2	8.1	6.4
C2H6	0.4	18.1	4.7	4.1
C3H8	0.0	0.0	0.2	0.2
C6H6	23.2	29.8	16.3	14.4
N2	291.0	283.6	320.5	351.6
H2O	525.8	558.0	328.5	331.2
	-----	-----	-----	-----
Total	1649.0	1548.4	1046.2	1087.9
H2, mole/hr	9.127	5.655	3.274	3.373
CO	5.230	3.742	3.456	3.492
CO2	12.624	10.523	5.312	5.487
CH4	5.493	4.638	1.914	2.113
C2H4	0.000	0.185	0.289	0.228
C2H6	0.013	0.602	0.156	0.136

Item \ Test	T12-3a	T12-3b	T12-4a	T12-4b
C3H8	0.000	0.000	0.005	0.005
C6H6	0.297	0.382	0.209	0.184
N2	10.385	10.121	11.438	12.548
H2O	29.185	30.972	18.234	18.384
	------	------	------	------
Total	72.355	66.820	44.286	45.951
lb bdw/hr	643.4	643.4	341.7	339.4
Vol, SCF/ lb bdw	42.67	39.40	49.17	51.37
N2 Free vol	38.24	35.41	43.55	44.92
N2,C6H6 Free vol	38.11	35.26	43.45	44.83
Dry Gas Vol	25.66	23.06	34.48	35.38
H2, mole %	12.61	8.46	7.39	7.34
CO	7.23	5.60	7.80	7.60
CO2	17.45	15.75	12.00	11.94
CH4	7.59	6.94	4.32	4.60
C2H4	0.00	0.28	0.65	0.50
C2H6	0.02	0.90	0.35	0.30
C3H8	0.00	0.00	0.01	0.01
C6H6	0.41	0.57	0.47	0.40
N2	14.35	15.15	25.83	27.31
H2O	40.34	46.35	41.17	40.01
	------	------	------	------
TOTAL	100.00	100.00	100.00	100.00
Wet Gas				
H2, mole %	14.80	10.04	10.03	10.15
CO	8.48	6.64	10.59	10.51
CO2	20.47	18.68	16.28	16.52
CH4	8.91	8.24	5.86	6.36
C2H4	0.00	0.33	0.88	0.69
C2H6	0.02	1.07	0.48	0.41
C3H8	0.00	0.00	0.01	0.01
H2O	47.32	55.00	55.86	55.34
	-----	-----	-----	-----
	100.00	100.00	100.00	100.00

APPENDIX 2

LEAST SQUARES FIT OF IGT GASIFIER VARIABLES

I. Hydrogen

Regression Output:

Constant		-1.3528E+01
Std Err of Y Est		1.9229E+00
R Squared		4.0984E-01
No. of Observations		2.0000E+01
Degrees of Freedom		1.7000E+01
X Coefficient(s)	1.7467E-02	-2.6444E-07
Std Err of Coef.	1.1374E-01	3.5693E-05
t Value	0.153573727	-0.00740873
	0.151262835	0.007299769
t Probability	0.439884279	0.497087863
F Value	5.902804634	
	0.111111111	
	0.013071895	
	2.278572097	
F Probability	0.011346303	

II. CO

Regression Output:

Constant		-3.6349E+01
Std Err of Y Est		1.9910E+00
R Squared		1.7282E-01
No. of Observations		2.0000E+01
Degrees of Freedom		1.7000E+01
X Coefficient(s)	4.8316E-02	-1.2257E-05
Std Err of Coef.	1.1776E-01	3.6957E-05
t Value	0.410289657	-0.33166456
	0.403258929	0.326259783
t Probability	0.343378747	0.372113796
F Value	1.775929734	
	0.111111111	
	0.013071895	
	0.847891091	
F Probability	0.198249442	

III. CO2

Regression Output:

Constant		-5.1963E+01
Std Err of Y Est		1.7287E+00
R Squared		1.1919E-01
No. of Observations		2.0000E+01
Degrees of Freedom		1.7000E+01
X Coefficient(s)	8.4609E-02	-2.4793E-05
Std Err of Coef.	1.0225E-01	3.2089E-05
t Value	0.827472113	-0.7726484
	0.807215849	0.754689185
t Probability	0.209771196	0.225217863
F Value	1.150177777	
	0.111111111	
	0.013071895	
	0.409678427	
F Probability	0.341020	

IV. CH4

Regression Output:

Constant		-4.3123E+01
Std Err of Y Est		1.1366E+00
R Squared		5.0808E-02
No. of Observations		2.0000E+01
Degrees of Freedom		1.7000E+01
X Coefficient(s)	6.4007E-02	-2.0016E-05
Std Err of Coef.	6.7229E-02	2.1098E-05
t Value	0.952071729	-0.94868564
	0.925810784	0.922603153
t Probability	0.177272269	0.178107135
F Value	0.454980481	
	0.111111111	
	0.013071895	
	-0.37599196	
F Probability	0.646529332	

V. C2H4

Regression Output:

Constant		2.0095E+00
Std Err of Y Est		2.8460E-01
R Squared		1.2421E-01
No. of Observations		2.0000E+01
Degrees of Freedom		1.8000E+01
X Coefficient(s)	-1.1442E-03	
Std Err of Coef.	7.1612E-04	
t Value	-1.59778852	
	1.522536506	
t Probability	0.063937262	
F Value	2.552928155	
	0.222222222	
	0.012345679	
	1.154218815	
F Probability	0.124205188	

V1. C2H6

Regression Output:

Constant		2.6517E+01
Std Err of Y Est		1.3753E-01
R Squared		8.1572E-01
No. of Observations		2.0000E+01
Degrees of Freedom		1.7000E+01
X Coefficient(s)	-3.0323E-02	8.6568E-06
Std Err of Coef.	8.1347E-03	2.5529E-06
t Value	-3.72755965	3.390956626
	3.09446958	2.888209082
t Probability	0.000985775	0.001937095
F Value	37.62440422	
	0.111111111	
	0.013071895	
	4.75231605	
F Probability	1.0337E-06	

VII. C3H8

Regression Output:

Constant		4.9248E-02
Std Err of Y Est		6.8449E-03
R Squared		1.4156E-01
No. of Observations		2.0000E+01
Degrees of Freedom		1.8000E+01
X Coefficient(s)	-2.9673E-05	
Std Err of Coef.	1.7223E-05	
t Value	-1.72285127	
	1.632937739	
t Probability	0.051241018	

VIII. H20

Regression Output:

Constant		2.2154E+02
Std Err of Y Est		3.8295E+00
R Squared		3.4412E-01
No. of Observations		2.0000E+01
Degrees of Freedom		1.7000E+01
X Coefficient(s)	-1.8940E-01	5.0717E-05
Std Err of Coef.	2.2650E-01	7.1083E-05
t Value	-0.83621181	0.713482906
	0.81557067	0.69778619
t Probability	0.207372995	0.242655542
F Value	4.459693009	
	0.111111111	
	0.013071895	
	1.919489163	
F Probability	0.027461344	

IX. Tar

Regression Output:

Constant		2.2739E+01
Std Err of Y Est		6.7970E-01
R Squared		4.3102E-01
No. of Observations		2.0000E+01
Degrees of Freedom		1.7000E+01
X Coefficient(s)	-2.0584E-02	4.5476E-06
Std Err of Coef.	4.0202E-02	1.2617E-05
t Value	-0.51201629	0.360446762
	0.502552864	0.354469465
t Probability	0.307639255	0.361493418
F Value	6.439100545	
	0.111111111	
	0.013071895	
	2.392352073	
F Probability	0.008370372	

X. Char

Regression Output:

Constant		1.2722E+01
Std Err of Y Est		1.2802E+00
R Squared		1.7921E-01
No. of Observations		2.0000E+01
Degrees of Freedom		1.8000E+01
X Coefficient(s)	-6.3858E-03	
Std Err of Coef.	3.2212E-03	
t Value	-1.98241538	
	1.856189302	
t Probability	0.03171339	

XI. Dry Gas

Regression Output:

Constant		0.0000E+00
Std Err of Y Est		4.8097E+00
R Squared		9.0780E-03
No. of Observations		2.0000E+01
Degrees of Freedom		1.8000E+01
X Coefficient(s)	3.0627E-02	-8.8818E-06
Std Err of Coef.	1.1270E-02	7.3156E-06
t Value	2.717485525	-1.21409508
	2.44104567	1.173450083
t Probability	0.00732236	0.120307621
F Value	0.164900645	
	0.222222222	
	0.012345679	
	-0.49619202	
F Probability	0.690104404	

XII. Wet Gas

Regression Output:

Constant		0.0000E+00
Std Err of Y Est		3.9164E+00
R Squared		7.3226E-03
No. of Observations		2.0000E+01
Degrees of Freedom		1.8000E+01
X Coefficient(s)	4.5549E-02	-1.3377E-05
Std Err of Coef.	9.1773E-03	5.9570E-06
t Value	4.963198082	-2.24559468
	3.771229671	2.073913012
t Probability	0.000081352	0.019043819
F Value	0.132778899	
	0.222222222	
	0.012345679	
	-0.57618809	
F Probability	0.717735648	

APPENDIX 3

IGT Gasifier - Conditions and Correlations

Gasifier Conditions

Temp	1390-1800	deg F
Press	84-345	psia
H2O		
Feed	5-27	wt %
Steam	0-1.32	lb/ lb BDW
Oxygen	0.19 - 0.45	lb/ lb BDW
Feed Rate	375-1030	wet lb/hr
H2O total	0.841 +/- 0.115	lb/lb BDW

Average Feed Composition

Proximate

M, %	10.87
VM	74.60
A	0.61
FC	13.92

Ultimate, dry			MW	Moles	N	w
A, %	0.70	use silica	60.09	0.0116	0.003	0.17
C	48.94		12.01	4.0749	1.000	12.01
H	6.19		1.008	6.1409	1.507	1.52
S	0.03		32.06	0.0009	0.000	0.01
N	0.14		14.01	0.0100	0.002	0.03
O	44.00		16	2.7500	0.675	10.80
HHV, BTU/lb	8416					24.54

Correlations

Variable	Units	Independent Variable	Units	A	B	C
Dry Gas	wt %	Temp	deg F	-2.3134E+02	3.8070E-01	-9.9300E-05
Carbon conv to	wt %	Temp	deg F	-1.6987E+02	2.9376E-01	-8.0899E-05
Gas Volume	scf/lb BDW	Temp	deg F	0.0000E+00	3.0627E-02	-8.8818E-06
Char Yield	wt %(maf/maf)	Temp	deg F	1.2772E+01	-6.3860E-03	0.0000E+00
Tar/oil yield	wt % (maf)	Temp	deg F	2.2739E+01	-2.0584E-02	4.5476E-06
H2	mole %	Temp	deg F	-1.3528E+01	1.7460E-02	-2.6444E-07
CO	mole %	Temp	deg F	-3.6349E+01	4.8316E-02	-1.2257E-05
CO2	mole %	Temp	deg F	-5.1963E+01	8.4609E-02	-2.4793E-05
H2O	mole %	Temp	deg F	2.2154E+02	-1.8940E-01	5.0717E-05
CH4	mole %	Temp	deg F	-4.3123E+01	6.4007E-02	-2.0016E-05
C2H4	mole %	Temp	deg F	2.0095E+00	-1.1442E-03	0.0000E+00
C2H6	mole %	Temp	deg F	2.6517E+01	-3.0323E-02	8.6568E-06
C3H8	mole %	Temp	deg F	4.9250E-02	-2.9673E-05	0.0000E+00

APPENDIX 4

ASPEN INPUT DATA - IGT GASIFIER

Temperature		MW	1400	1450	1500	1550	1600	1650	1700	1750	1800
Steam	lb/hr	18.016	140,166.667	140,166.667	140,166.667	140,166.667	140,166.667	140,166.667	140,166.667	140,166.667	140,166.667
Oxygen	lb/hr	31.9988	36,138.333	38,117.500	40,096.667	42,075.833	44,055.000	46,034.167	48,013.333	49,992.500	51,971.667
H2	lb/hr	2.0158	3,195.131	3,468.716	3,750.140	4,040.455	4,340.918	4,653.034	4,978.265	5,318.881	5,678.002
CO	lb/hr	28.01055	31,041.374	34,064.700	36,908.209	39,577.625	42,078.301	44,415.580	46,591.764	48,613.809	50,492.668
CH4	lb/hr	16.04275	17,743.797	18,686.065	19,419.220	19,940.709	20,246.813	20,332.578	20,190.205	19,812.221	19,190.204
C2H4	lb/hr	28.0539	1,743.222	1,505.895	1,268.112	1,028.705	786.580	540.649	289.740	32.636	0.000
C2H6	lb/hr	30.0697	4,731.149	3,452.768	2,365.675	1,468.567	762.119	248.769	0.000	0.000	0.000
C3H8	lb/hr	44.09665	51.813	42.045	32.228	22.316	12.263	2.024	0.000	0.000	0.000
CO2	lb/hr	44.00995	120,058.896	125,348.700	130,043.414	134,140.526	137,637.150	140,529.900	142,804.512	144,459.194	145,499.570
H2O	lb/hr	18.016	153,217.469	148,368.805	144,267.373	140,913.981	138,309.090	136,452.887	135,284.957	134,828.561	135,092.552
Char	lb/hr		6,431.017	5,895.099	5,359.181	4,823.263	4,287.345	3,751.427	3,215.509	2,679.590	2,143.672
Benzene	lb/hr	78.1143	1,189.449	1,029.510	879.112	738.255	606.939	485.163	372.929	270.235	177.083
Naphthalene	lb/hr	128.1747	1,189.449	1,029.510	879.112	738.255	606.939	485.163	372.929	270.235	177.083
Anthracene	lb/hr	178.2351	1,189.449	1,029.510	879.112	738.255	606.939	485.163	372.929	270.235	177.083
o-cresol	lb/hr	108.14065	1,189.449	1,029.510	879.112	738.255	606.939	485.163	372.929	270.235	177.083
In	lb/hr		342,971.667	344,950.833	346,930.000	348,909.167	350,888.333	352,867.500	354,846.667	356,825.833	358,805.000
Out	lb/hr		342,971.667	344,950.833	346,930.000	348,909.167	350,888.333	352,867.500	354,846.667	356,825.833	358,805.000
Diff	lb/hr		(0.000)	0.000	(0.000)	0.000	0.000	(0.000)	0.000	0.000	0.000
Steam											
as steam	lb/hr		119840.55	119840.55	119840.55	119840.55	119840.55	119840.55	119840.55	119840.55	119840.55
as moisture	lb/hr		20326.12	20326.12	20326.12	20326.12	20326.12	20326.12	20326.12	20326.12	20326.12

For Ryield Reactor

		1400	1450	1500	1550	1600
Temp						
Feed		1129.365	1191.217	1253.068	1314.919	1376.770
Oxygen	lb-mole/hr	6651.896	6651.896	6651.896	6651.896	6651.896
Steam	lb-mole/hr	186992.782	186992.782	186992.782	186992.782	186992.782
10.87% M Feed	lb/hr					
Oxygen	lb/hr	36139.689	38118.929	40098.170	42077.411	44056.652
Steam	lb/hr	119840.551	119840.551	119840.551	119840.551	119840.551
10.87% M Feed	lb/hr	186992.782	186992.782	186992.782	186992.782	186992.782
Total	lb/hr	342973.022	344952.263	346931.504	348910.745	350889.985
Yield						
H2	lb/lb feed	9.3160E-03	1.0056E-02	1.0809E-02	1.1580E-02	1.2371E-02
CO		9.0507E-02	9.8752E-02	1.0638E-01	1.1343E-01	1.1992E-01
CH4		5.1735E-02	5.4170E-02	5.5974E-02	5.7151E-02	5.7701E-02
C2H4		5.0827E-03	4.3655E-03	3.6552E-03	2.9483E-03	2.2417E-03
C2H6		1.3795E-02	1.0009E-02	6.8189E-03	4.2090E-03	2.1720E-03
C3H8		1.5107E-04	1.2189E-04	9.2894E-05	6.3958E-05	3.4948E-05
CO2		3.5005E-01	3.6338E-01	3.7484E-01	3.8446E-01	3.9225E-01
H2O		4.4673E-01	4.3011E-01	4.1584E-01	4.0387E-01	3.9417E-01
Char		1.8751E-02	1.7090E-02	1.5447E-02	1.3824E-02	1.2218E-02
Benzene		3.4681E-03	2.9845E-03	2.5340E-03	2.1159E-03	1.7297E-03
Naphthalene		3.4681E-03	2.9845E-03	2.5340E-03	2.1159E-03	1.7297E-03
Anthracene		3.4681E-03	2.9845E-03	2.5340E-03	2.1159E-03	1.7297E-03
o-cresol		3.4681E-03	2.9845E-03	2.5340E-03	2.1159E-03	1.7297E-03
Total		1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00

		1650	1700	1750	1800
Temp					
Feed		1438.622	1500.473	1562.324	1624.175
Oxygen	lb-mole/hr	6651.896	6651.896	6651.896	6651.896
Steam	lb-mole/hr	186992.782	186992.782	186992.782	186992.782
10.87% M Feed	lb/hr				
Oxygen	lb/hr	46035.893	48015.134	49994.375	51973.616
Steam	lb/hr	119840.551	119840.551	119840.551	119840.551
10.87% M Feed	lb/hr	186992.782	186992.782	186992.782	186992.782
Total	lb/hr	352869.226	354848.467	356827.708	358806.949
Yield					
H2	lb/lb feed	1.3186E-02	1.4029E-02	1.4906E-02	1.5825E-02
CO		1.2587E-01	1.3130E-01	1.3624E-01	1.4072E-01
CH4		5.7621E-02	5.6898E-02	5.5523E-02	5.3483E-02
C2H4		1.5322E-03	8.1652E-04	9.1462E-05	0.0000E+00
C2H6		7.0499E-04	0.0000E+00	0.0000E+00	0.0000E+00
C3H8		5.7360E-06	0.0000E+00	0.0000E+00	0.0000E+00
CO2		3.9825E-01	4.0244E-01	4.0484E-01	4.0551E-01
H2O		3.8670E-01	3.8125E-01	3.7785E-01	3.7650E-01
Char		1.0631E-02	9.0616E-03	7.5095E-03	5.9744E-03
Benzene		1.3749E-03	1.0510E-03	7.5733E-04	4.9353E-04
Naphthalene		1.3749E-03	1.0510E-03	7.5733E-04	4.9353E-04
Anthracene		1.3749E-03	1.0510E-03	7.5733E-04	4.9353E-04
o-cresol		1.3749E-03	1.0510E-03	7.5733E-04	4.9353E-04
Total		1.0000E+00	9.9999E-01	9.9999E-01	9.9999E-01

For Wwood at 50 % M	166666.667	
Total H2O	146340.551	8122.810
H2O	20326.115	
as M	186992.782	
Wwood		

APPENDIX 5

```
TITLE  'GASIFIER - REFORMER - METHANOL SYNTHESIS - HNEI CASE A'
;GASIFIER - RYIELD MODEL
;REFORMER - EQUILIBRIUM MODEL. METHANOL - EQUILIBRIUM MODEL
;UPDATED: DECEMBER 5, 1991
;
IN-UNITS   ENG
OUT-UNITS  SI TEMPERATURE = C  PRESSURE = BAR
;
HISTORY  MSG-LEVEL  PROPERTIES=4  SIMULATION=4 STREAMS=4 SYSTEM=4
;
RUN-CONTROL      MAX-TIME=600
SIM-OPTIONS      SIZE-RESULTS = 0
;
STREAM-REPORT
     STREAMS ALL
     FLOW-FRAC  MIXED   BASES = MOLE MOLE-FRAC
     INTENSIVE-PROPS  MIXED  PROPS=TEMP PRES MW ENTH DENS BASE =MOLE
     FLOW-FRAC CISOLID  BASES = MASS
     INTENSIVE-PROPS CISOLID  PROPS=TEMP PRES ENTH DENS BASE=MASS
     FLOW-FRAC NCPSD    BASES = MASS
     INTENSIVE-PROPS NCPSD  PROPS=TEMP PRES ENTH DENS  BASE=MASS
;
;************    COMPONENTS AND PROPERTIES   ******************************
;
PROPERTIES    SYSOPO / SYSOP3R  LOOP2
;
COMPONENTS
  H2          H2          /
  CO          CO          /
  CO2         CO2         /
  H2O         H2O         /
  CH4         METHANE     /
  C2H2        ACETYLENE   /
  C2H4        ETHYLENE    /
  C2H6        ETHANE      /
  C3H6-2      PROPYLENE   /
  C3H8        C3H8        /
  MEOH        CH4O        /
  O2          O2          /
  N2          N2          /
  AR          AR          /
  C6H6        C6H6        /   ;  Benzene
  C6H6O       C6H6O       /   ;  Phenol
  C10H8       C10H8       /   ;  Naphthalene
  C14H10-1    C14H10-1    /   ;  Anthracene
  C7H8O-4     C7H8O-4     /   ;  O-cresol
  C           C           /
  O2SI        O2SI        /
  CHAR                    /
  WOOD
;
ALIAS
```

```
  H2          H2          /
  CO          CO          /
  CO2         CO2         /
  H2O         H2O         /
  CH4         CH4         /
  C2H2        C2H2        /
  C2H4        C2H4        /
  C2H6        C2H6        /
  C3H6-2      C3H6-2      /
  C3H8        C3H8        /
  MEOH        CH4O        /
  O2          O2          /
  N2          N2          /
  AR          AR          /
  C6H6        C6H6        /
  C6H6O       C6H6O       /
  C10H8       C10H8       /
  C14H10-1    C14H10-1    /
  C7H8O-4     C7H8O-4     /
  C           C           /
  O2SI        O2SI        /
  CHAR                    /
  WOOD
;
Attr-Comps CHAR     Proxanal Ultanal Sulfanal Coalmisc Genanal
Attr-Comps WOOD     Proxanal Ultanal Sulfanal Coalmisc Genanal
;
Prop-Sources
   Global  ASPENPCD  Comps= CH4 H2 H2O CO2 CO O2 C6H6 C2H2 C2H4 AR  &
                            C2H6 C3H6-2 C3H8 C6H6O C7H8O-4 N2 MEOH &
   Global  DIPPR     Comps= C10H8 C14H10-1 C O2SI
;
Nc-props  wood  enthalpy  hcjlboie  /  density  dnstygen
Nc-props  char  enthalpy  hcjlboie  /  density  dnstygen
;
Prop-data
   comp-list                 wood     char
      cval  dengen  1   1     440     1000
;
Prop-data
   Prop-List     BOIEC
;                        C          H           S       O       N       BIAS
      Pval  Wood     154.8761   122.50632    0.0     0.0     0.0      0.0
      Pval  Char     154.8761   122.50632    0.0     0.0     0.0      0.0
;
Prop-Data
   Prop-List  MW  /  SPGR  / DHSFRM /  DGSFRM / VSPOLY / CPSP01
   PVAL    C  12.01115 / 2.2 / 0.   / 0.  / 0.0053 0.0 0.0 0.0 0.0 0.0 3000. /&
              1.7154e+4 4.268 0.0 0.0 -2.786e+8 0.0 3000.0
   Pval O2SI  60.086 / 2.2 / 0. / 0. / .02726 0. 0. 0. 0. 0. 3000. / &
              37713 0. 0. 0. 0. 0. 3000.
;
```

```
;**********************    FLOWSHEET    *************************************
;
;
FLOWSHEET  DRY
    CHNG        IN = FLUE4                          OUT = FLUEX
    CHNGF       IN = REFGAS                         OUT = GASREF
    DRYER       IN = WWOOD DEC COMOUT FLUEX GASREF ADDAIR sto2A &
                                                    OUT = WETGAS  DWOOD      QDRYER
    STORE       IN = DWOOD                          OUT = DWOOD2             QSTORE
    WGCHECK     IN = WETGAS                         OUT = COOLGAS            QWG
FLOWSHEET  GASFER
    O2HEAT      IN = STEAMO2 OXY                    OUT = STO2A   OXY2
    FEEDMIX     IN = STEAMG2 DWOOD2 OXY2            OUT = FEEDG
    GASIFIER    IN = FEEDG                          OUT = GPROD              QGAS
    SOLSEP      IN = GPROD                          OUT = SOLID1  GAS1
    SOLSP2      IN = GAS1                           OUT = SOLID2  GAS1B
    HEAT1       IN = GAS1B    AIR1                  OUT = GAS1C   AIR1B
    CHCOMP2     IN = AIR2                           OUT = AIR3               WCHAR
    HEAT2       IN = GAS1C    AIR3                  OUT = GAS1D   AIR3A
    CM          IN = SOLID1   AIR1B                 OUT = DECFD
    CDECOMP     IN = DECFD                          OUT = DEC                Qdec
    AMIX        IN = AIRX QDEC  Qmeth               OUT = ADDAIR
    CMIX        IN = AIR3A    METH                  OUT = COMIN
    COMBUST     IN = COMIN                          OUT = COMOUT             Qmeth
    HEAT3       IN = GAS1D    STEAMG                OUT = GAS1E   STEAMG2
FLOWSHEET  LOOP1
    Change      IN = GAS1E                          Out = Gasc
    INLET       IN = Gasc  STEAM RCO2               OUT = CFEED
    REAC1       IN = CFEED                          OUT = FEED2
    HTR2        IN = HPROD    FEED2                 OUT = HPROD2  Refin
    REFORM      IN = Refin                          OUT = HPROD   COKE       QH3
    HTR3        IN = HPROD2   REFGAS1               OUT = AGAS    REFGAS
    HTR3A       IN = AGAS                           OUT = AGAS1              QH4
    H2OCOND     IN = AGAS1                          OUT = AGAS2   WWATER
    WCOOL       IN = WWATER                         OUT = WATOUT             qwat
    Q1SEP       IN = QWAT                           OUT = QWAT1   QWAT2
    CO2COND     IN = AGAS2                          OUT = CGAS    LIQ
    CO2SEP      IN = LIQ                            OUT = PCO2    RCO2
FLOWSHEET  LOOP2
    Change2     In = Cgas                           Out = Cgas2
    COMP2       IN = Cgas2                          OUT = GAS4               W1
    HTR5        IN = RECYCLE                        OUT = RECYCLE2           QH5
    COMP3       IN = RECYCLE2                       OUT = GAS4A              W1A
    MIXM        IN = GAS4     GAS4A                 OUT = GAS4B
    HTR6        IN = GAS4B                          OUT = GAS5               Q3
    MEOH        IN = GAS5                           OUT = GASM    LIQM       Q4
    COOL        IN = GASM                           OUT = GASM2              Q5
    CONDENSE    IN = GASM2                          OUT = Gasrl   METHANOL   Q6
    MSPLIT      IN = GASR1                          OUT = PURGE   RECYCLE
FLOWSHEET COMBUST
    AIRCOMP     IN = AMBAIR                         OUT = COMAIR             WAIR1
    HCOM1       IN = FLUE2    COMAIR                OUT = FLUE3   COMAIR2
    HCOM2       IN = FLUE3    PURGE                 OUT = FLUE4   PURGEH
```

```
    MCOMB       IN = COMAIR2  PURGEH       OUT = COMGAS
    ADCOMB      IN = COMGAS QH3            OUT = FLUEGAS
FLOWSHEET CHECK
    PUMP1       IN = WATER                 OUT = WATER2             WP1
    WHTR1       IN = WATER2 Q3  Q4 QWAT1   OUT = WATER3
    WHTR2       IN = WATER3 QH4 QFL2       OUT = Psteam
    STEAMSEP    IN = PSTEAM                OUT = PSTEAM2   PSTEAM3
    TURBINE     IN = PSTEAM2               OUT = PSTEAM4            WTURB
    STCOOL      IN = PSTEAM4               OUT = COOLH2O            QH2O
    REFCOOL     IN = FLUEgas               OUT = FLUE2              QFL2
;
;************   STREAM SPECIFICATIONS   **********************************
;
;
Def-Subs-Attr  PSD  PSD
   in-units  Length = MU
   intervals  10
   size-limits  0/4/5/6.4/8/10.1/12.7/16/20.2/32/50.8
;
Def-Stream-Class Mixcinc
   Definition Substreams=Mixed Cisolid Ncpsd
;
Def-Streams Mixcinc Dry Gasfer/mixcisld Loop1/Conven Loop2
;
Def-Streams HEAT QH4 QH5 Q3 Q4 Q5 Q6 QDRYER QSTORE QGAS Qdec Qmeth &
    QH3  QFL2 QWG QH2O qwat QWAT1 QWAT2
;
DEF-STREAMS WORK  W1  W1A WAIR1  WP1 Wchar WTURB
;
STREAM  STEAM
    Substream  Mixed  TEMP =900  PRES = 319.088  MOLE-FLOW = 6200
    MOLE-FRAC  H2O  1.00

Stream SteamG
    Substream  Mixed  Temp = 900  Pres = 319.088  Mass-flow = 96666.666
    Mass-frac  H2O  1.00
;
Stream Steam02 Mixed  Temp= 900 Pres = 319.088 Mole-flow = 1800
    Mole-frac H2O  1.00
;
Stream Oxy
   Substream Mixed Temp = -300 Pres = 319.088 Mass-flow = 41666.666
   Mole-frac O2 1.0
;
Stream water
    Substream  Mixed  Temp = 60 P=25 Mole-flow= 18650
    Mole-frac H2O  1.00
;
Stream Refgas1
    Substream Mixed  Temp = 80 Pres=25 Mole-flow = 4000
    Mole-frac O2 0.21 / N2 0.79
;
Stream Ambair
```

```
   Substream  Mixed  Temp=80 Pres=14.696 Mole-flow = 5500
   Mole-frac  O2  0.21  / N2  0.79
;
Stream Air1
   Substream  Mixed  Temp=80 Pres = 14.696 Mass-flow=100
   Mass-frac  O2 0.2329 / N2 0.7671
;
Stream Air2
   Substream  Mixed  Temp = 80 Pres = 14.696 Mole-flow = 50
   Mole-frac  O2 0.21 / N2 0.79
;
Stream Airx
    Substream  Mixed  Temp = 80 Pres = 14.696 Mole-flow =6000
    Mole-frac O2 0.21 / N2 0.79
;
Stream Meth
   Substream  Mixed  Temp = 80 Pres = 14.696 Mole-flow =0.01
   Mole-frac  MEOH  1.0
;
Stream Wwood  Mixed  Temp=80  Pres=14.696  Mass-flow= 150905.294
    Mass-flow H2O  150905.294
    Substream NCPSD  Temp=80  Pres=14.696  Mass-flow=186428.038
    Mass-flow Wood   186428.038  / Char 1e-10
    Subs-attr PSD Frac=0.593 0.001 0.011 0.026 0.033 0.04 0.052 &
                     0.072 0.140 0.032
    Comp-Attr Wood  Proxanal (10.60 14.8 82.1 3.1)/
                    Ultanal  (3.1 47.9 6.2 0.60 0.0 0.01 42.19)/
                    Sulfanal (0.004 0.003 0.003)/
                    Coalmisc (8628. 0.0 0.0 0.0 0.0)/
                    Genanal  (100.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0)
    Comp-Attr Char  Proxanal (0.0 80.0 20.0 0.0)/
                    Ultanal  (0.0 93.68 6.0 0.0 0.0 0.05 0.27)/
                    Sulfanal (.02 .02 .01)/
                    Coalmisc (15244 0.0 0.0 0.0 0.0)/
                    Genanal  (100.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0)
;
;**************  Blocks  ****************************************************
;
;
Block Chng Clchng
;
Block Chngf Clchng
;
Block Dryer Flash2
   Param Temp = 220  Pres = 14.696  maxit = 100
;
Block Store Heater
   Param Temp=220
;
Block WGCHECK Heater
   Param Temp = 80 V=1
;
```

```
Block O2Heat Heatx
   Param Opt=2 Flowdir=0 Tcold=600
;
Block Feedmix  Mixer
   Param Pres=319.088
;
Block Gasifier Ryield
   Properties Option=SYSOPO
   Param Temp=1526  Pres=319.088
   Massyield Ssid = Mixed    Comp = H2        Val=1.51109E-02/
             Ssid = Mixed    Comp = CO        Val=1.07374E-01/
             Ssid = Mixed    Comp = CO2       Val=4.11858E-01/
             Ssid = Mixed    Comp = CH4       Val=5.92536E-02/
             Ssid = Mixed    Comp = C2H2      Val=0.0000E-00/
             Ssid = Mixed    Comp = C2H4      Val=1.22623E-04/
             Ssid = Mixed    Comp = C2H6      Val=8.28036E-03/
             Ssid = Mixed    Comp = C3H6-2    Val=0.0000E-00/
             Ssid = Mixed    Comp = C3H8      Val=0.0000E-00/
             Ssid = Mixed    Comp = C6H6      Val=5.80442E-03/
             Ssid = Mixed    Comp = C6H6O     Val=6.59455E-03/
             Ssid = Mixed    Comp = C10H8     Val=3.87915E-04/
             Ssid = Mixed    Comp = C14H10-1  Val=3.87915E-04/
             Ssid = Mixed    Comp = C7H8O-4   Val=3.87915E-04/
             Ssid = Mixed    Comp = H2O       Val=3.41829E-01/
             Ssid = Cisolid  Comp = O2SI      Val=1.53194E-02/
             Ssid = Ncpsd    Comp = Char      Val=2.72938E-02/
             Ssid = Ncpsd    Comp = Wood      Val=0.0
;
Block Solsep Sep2
   Frac   Subs=Ncpsd    Stream=Solid1  Comp=Char      Frac=1.0/
          Subs=Mixed    Stream=Gas1    Comp=C14H10-1  Frac=0.9995
   Flash-specs Gas1 Pres=319.088
;
Block Solsp2 Sep2
   Frac   Subs=Cisolid  Stream=Solid2  Comp=O2SI     Frac=1.0 /
          Subs=Mixed    Stream=Gas1b   Comp=C14H10-1 Frac=0.9995
   Flash-specs Gas1b Pres=319.088
;
Block Heat1 Heatx
   Param  Option=1  Fdir=0  Thot=1490
;
Block Chcomp2 Compr
   Param  Type = 1  Pres = 25  EP = 0.90
;
Block Heat2 Heatx
   Param Opt=1 Fdir=0 Thot=1489.9
;
Block Heat3  Heatx
   param  opt = 1 Fdir=0  Thot = 1489
;
Block CM  Mixer
;
```

```
Block Cdecomp Ryield
   Param Pres = 25 Temp=2000
   Massyield  Ssid = Mixed  Comp=CO2    Val = 0.249712543/
              Ssid = Mixed  Comp=H2O    Val = 0.039009473/
              Ssid = Mixed  Comp=N2     Val = 0.711277984
;
Block Amix Mixer
;
Block Cmix Mixer
;
Block Combust Rstoic
   Param Pres = 20 Maxit = 500 T = 2000
   Stoich  1  Mixed  MEOH -1 / O2 -1.5  / CO2 1  / H2O 2
   Conv    1  Mixed  MEOH 1.0
;
Block Change Clchng
;
Block Inlet MIXER
     PARAM   PRES = 319.088
;
BLOCK  REAC1  RSTOIC
     PARAM  PRES = 319.088
     STOICH  1  MIXED  C2H2      -1   / H2O -1  / CO 1 / CH4 1
     STOICH  2  MIXED  C2H4      -1   / H2O -1  / CO 1 / CH4 1 / H2 1
     STOICH  3  MIXED  C2H6      -1   / H2O -1  / CO 1 / CH4 1 / H2 2
     STOICH  4  MIXED  C3H6-2    -1   / H2O -1  / CO 1 / CH4 2
     STOICH  5  MIXED  C6H6      -1   / H2O -3  / CO 3 / CH4 3
     STOICH  6  MIXED  C10H8     -1   / H2O -10 / CO 10 / H2 14
     STOICH  7  MIXED  C14H10-1  -1   / H2O -14 / CO 14 / H2 19
     STOICH  8  MIXED  MEOH      -1   / H2   2  / CO 1
     STOICH  9  MIXED  C6H6O     -1   / H2O -5  / CO 6  / H2 8
     STOICH 10  MIXED  C7H8O-4   -1   / H2O -6  / CO 7  / H2 10
     CONV  1  MIXED  C2H2       1.00
     CONV  2  MIXED  C2H4       1.00
     CONV  3  MIXED  C2H6       1.00
     CONV  4  MIXED  C3H6-2     1.00
     CONV  5  MIXED  C6H6       1.00
     CONV  6  MIXED  C10H8      1.00
     CONV  7  MIXED  C14H10-1   1.00
     CONV  8  MIXED  MEOH       1.00
     CONV  9  MIXED  C6H6O      1.00
     CONV 10  MIXED  C7H8O-4    1.00
;
Block Htr2 Heatx
   Param Opt=1 Fdir=0 Thot=1400
;
BLOCK REFORM RGIBBS
     PARAM  TEMP = 1600. PRES = 319.088 maxit=500 nr=3
     PROD  H2 1 / CO 1 / H2O 1 / CH4 1 / CO2 1 / C 0
;     STOI   1  CO2 -1    / H2  -1 / H2O 1 / CO 1
;     STOI   2  CO  -2    / C 1    / CO2 1
;     STOI   3  CH4 -1    / H2O -1 / CO 1  / H2 3
```

```
;     DELT   3   -15.
;
Block Htr3 HeatX
   Param Opt=1 Fdir=0 Thot=1300
;
Block Htr3A Heater
   Param Temp=450
;
BLOCK  H2OCOND  Sep2
   Frac Subs=Mixed Stream=Agas2 Comp=H2 CO CO2 CH4 H2O FRAC=1.0 1.0 1.0 1.0 &
             0.025/
        Subs=Mixed Stream=Wwater Comp=H2 CO CO2 CH4 H2O Frac=0.0 0.0 0.0 &
             0.0 0.975
   Flash-Specs  Agas2  Temp=450 P=319.088  Maxit = 300 Tol=0.001 V=1/
                Wwater Temp=450 P=319.088  Maxit = 300 Tol=0.001 V=1
;
Block Wcool Heater
   Param Temp = 80
;
Block Q1sep Fsplit
   Frac Qwat1  0.75 /  Qwat2  0.25
;
BLOCK  CO2COND  Sep2
   Frac Subs=Mixed Stream=Cgas Comp=H2 CO CH4 H2O CO2 FRAC=1.0 1.0 1.0 1.0 &
             0.075/
        Subs=Mixed Stream=Liq Comp=CO2 Frac=0.925
   Flash-Specs  Cgas   Temp=450 P=319.088/
                Liq    Temp=450 P=319.088
;
Block CO2SEP Fsplit
   Frac PCO2 0.67 / RCO2  0.33
;
Block Change2 Clchng
;
BLOCK  COMP2  COMPR
     PARAM  TYPE = 1  PRES = 750  EP = 0.95
;
Block HTR5 Heater
     Param Temp=150
;
BLOCK COMP3 COMPR
     PARAM  TYPE = 1  PRES = 750   EP=0.95
;
BLOCK  HTR6  HEATER
     PARAM  TEMP = 445  PRES =750
;
BLOCK  MEOH  Rgibbs
     PARAM  TEMP = 445  PRES =750 NR=3 IDEL = 1  Maxit=500
     Prod CO 1 / H2O 1 / MEOH 1 / CO2 1 / H2 1 / CH4 1
     STOI  1  CO  -1 / H2 -2 / MEOH 1
     STOI  2  CO2 -1 / H2 -1 / CO   1 / H2O 1
     STOI  3  CO  -1 / H2 -3 / CH4  1 / H2O 1
```

```
    EXSP  3  0.1E-30
    DELT  1  +10.0
;
Block Cool Heater
    Param Temp=35
;
BLOCK  CONDENSE  FLASH2
    PARAM  TEMP = 32  PRES = 740
;
BLOCK MSPLIT  FSPLIT
    FRAC  PURGE 0.33 / RECYCLE  0.67
    Param npk=1 kph=1
;
BLOCK  MIXM  MIXER
    PARAM  KPH = 1
;
Block Aircomp Compr
   Param Type = 1  Pres=20  EP=0.90
;
Block Hcom1 Heatx
   Param Opt=1 Fdir=0 Thot=1000
;
Block Hcom2 Heatx
   Param Opt=1 Fdir=0 Thot=900 DPC=20
;
Block Mcomb  Mixer
   Param Pres=20 Maxit = 500  Tol=0.001 NPK=1 kph=1
;
Block Adcomb Rstoic
   Param Pres=20 Maxit=500 Test=1800 Tol=0.001
   Stoich 1  Mixed  CO -1   / O2 -0.5 / CO2 1
   Stoich 2  Mixed  CH4 -1  / O2 -2   / CO2 1 / H2O 2
   Stoich 3  Mixed  MEOH -1 / O2 -1.5 / CO2 1 / H2O 2
   Stoich 4  Mixed  H2 -1   / O2 -0.5 / H2O 1
   Conv   1  Mixed  CO         1.00
   Conv   2  Mixed  CH4        1.00
   Conv   3  Mixed  MEOH       1.00
   Conv   4  Mixed  H2         1.00
;
Block Refcool Heater
   Param Temp=1700
;
Block Pump1 Pump
   Param Pres=319.088 Type=1 Eff=0.9
;
Block Whtr1 Heater
;
Block Whtr2 Heater
;
Block Steamsep Fsplit
   Mole-flow Psteam2  5284.1
   Def-key ID=1  Subs=Mixed Comp=H2O
```

```
;
Block Turbine Compr
   Param Type=3 Pres = 15.0 ES = 9.95
;
Block Stcool Heater
   Param Temp = 80
;
;******************   Design Specifications    ****************************
;
;******************    Fortran Blocks    ***********************************
Fortran  Set-Air
   Properties  Sysop0
   Define FA  Mass-flow  Stream=Solid1  Substream=Ncpsd  Comp=Char
   Define FB  Mass-flow  Stream=Air1    Substream=Mixed  Comp=O2
   Define FC  Mass-flow  Stream=Air1    Substream=Mixed  Comp=N2
F       FB = 2.968741*FA
F       FC = 9.777148*FA
   Flash-specs  Air1  Kode=2  Temp=80  Pres=25
   Execute after solsep
```

APPENDIX 6

HAWAII MATERIAL BALANCE INFORMATION

Feed: Bagasse

Proximate Analysis, Dry

VM, %	82.1
FC	14.8
Ash	3.1

	100.0

Ultimate Analysis

	Dry	MAF
C, %	47.90	49.43
H	6.20	6.40
N	0.60	0.62
S	0.01	0.01
O	42.19	43.54
Ash	3.10	
	-----	-----
	100.00	100.00

Heating Value

Given	19,100 kJ/kg	
Corr.	19,021 kJ/kg	(NREL CORRELATION)

Process Information

	System A	System B
Conditions		
Temperature, C	830	750
F	1526	1382
Pressure, Bars	22	10
, psia	319.1	145.0
Steam/Feed, lb/lb	0.58	1.2
Oxygen/Feed, lb/lb	0.25	0.00
Feed Moisture, % wet	10.60	5.00

Product Composition	System A	System B
Char Composition		
C, %	60.00 *	87.4
H	3.84 *	5.6
O	0.21 *	0.3
Ash	35.95 *	6.7
Tar Composition		
C, %	69.2	69.2
H	6.7	6.7
O	24.1	24.1
Gas Composition		
H2	17.15	33.46
CO	8.77	9.03
CO2	21.41	15.84
CH4	8.45	4.96
C2H4	0.01	0.00
C2H6	0.63	0.00
C3H8	0.00	0.00
C6H6	0.17	0.00
H2O	43.41 *	36.71
	-----	-----
	100.00	100.00
Yield Structure		
Gas (m3/kg bagasse)	1.05	1.68
(ft3/lb bagasse)	37.076	59.322
Carbon Conversion, %		
To Gas	87.415 *	75.0
To Char	10.401 *	25.0
To Liquid	2.184 *	0.0
	100.000	

* = changed from original data

System A Analysis

Basis:

Feed:	83,333.333	lb/hr
Temp:	1526	deg F
Press:	319.088	psia

System Input:

Dry Bagasse, lb/hr		83,333.333
Carbon, lb/hr		39,916.667
Hydrogen		5,166.667
Nitrogen		500.000
Sulfur		8.333
Oxygen		35,158.333
Ash		2,583.333

	Check	83,333.333
Moisture, lb/hr		9,880.686
H (MW=1.0079)		1,105.593
O (MW=15.9994)		8,775.093
Steam, lb/hr		48,333.333
H (MW=1.0079)		5,408.229
O (MW=15.9994)		42,925.104
Oxygen, lb/hr		20,833.333
Total In, lb/hr		162,380.685
C		39,916.667
H		11,680.489
N		500.000
S		8.333
O		107,691.863
Ash		2,583.333

	Check	162,380.685

System Output

Gas	Comp	MW	Mole %	wt	wt %	C	H	O
	H2	2.01580	17.15	34.5710	1.5912	0.0000	34.5710	0.0000
	CO	28.01055	8.77	245.6525	11.3069	105.3378	0.0000	140.3147
	CO2	44.00995	21.41	942.2530	43.3702	257.1587	0.0000	685.0943
	CH4	16.04275	8.45	135.5612	6.2396	101.4942	34.0670	0.0000
	C2H4	28.05390	0.01	0.2805	0.0129	0.2402	0.0403	0.0000
	C2H6	30.06970	0.63	18.9439	0.8720	15.1340	3.8099	0.0000
	C3H8	44.09665	0.00	0.0000	0.0000	0.0000	0.0000	0.0000
	C6H6	78.11430	0.17	13.2794	0.6112	12.2514	1.0281	0.0000
	H2O	18.01520	43.41	782.0398	35.9959	0.0000	87.5059	694.5340
			-----	-----	-----	-----	-----	-----
			100.0000	2172.5815	100.0000	491.6164	161.0221	1519.9430

MW		21.726 lb/lbmol
wt % C		22.628
wt % H		7.412
wt % O		69.960
	check	100.000

Product Yield, based on carbon conversion

	Total	Carbon	Hydrogen	Oxygen
Gas	154,201.985	34,893.154	11,428.767	107,880.064
Char	6,919.554	4,151.732	265.711	14.531
Tar	1,259.798	871.780	84.406	303.611
	---------	-----	-----	-----
Out	162,381.337	39,916.667	11,778.885	108,198.206
Error, %	0.000	(0.000)	0.842	0.470

Char Yield, based on ash and char comp
7,185.906 lb/hr

Gas Yield , based on vol and MW

186,989.401	ST=	32 deg F
176,914.179	ST=	60 deg F
173,573.336	ST=	70 deg F

Tar Composition

Component	MW	wt %	wt	lb C	lb H	lb H
C10H8	128.1747	5	640.874	600.558	40.316	0.000
C14H100	178.2351	5	891.176	840.781	50.395	0.000
C7H80	108.14065	5	540.703	420.390	40.316	79.997
C6H60	95.0742	85	8,081.307	6,125.687	514.029	1,441.592
		--------	--------	--------	--------	--------
		100.000	10,154.059	7,987.415	645.056	1,521.589

	ANALYSIS	MODEL
WT % C	69.2	78.66
WT % H	6.7	6.35
WT % O	24.1	14.99

Reported Tar Analysis must contain water. It is much different than reported IGT analyses

Case A
IGT input file, oxygen case

Feed

Dry feed	83,333.333	
Moisture 1	9,880.686	Associated water to gasifier
Steam	48,333.333	
Oxygen	20,833.333	

Total	162,380.685	

Dryer Moisture 73,452.647 Associated water removed in dryer

Product Component	lb/hr	lb/lb gasifier feed
H2	2,453.723	1.51109E-02
CO	17,435.529	1.07374E-01
CO2	66,877.716	4.11858E-01
CH4	9,621.647	5.92536E-02
C2H4	19.912	1.22623E-04
C2H6	1,344.570	8.28036E-03
C3H8	0.000	0.00000E+00
C6H6	942.526	5.80442E-03
H2O	55,506.362	3.41829E-01
C10H8	62.990	3.87915E-04
C14H10O	62.990	3.87915E-04
C7H8O	62.990	3.87915E-04
C6H6O	1,070.828	6.59455E-03
Char	6,919.554	4.26132E-02
	------	------
Total	162,381.337	1.00000E+00

Case A
Air input file

Basis: air at 80 deg F, 14.696 psia, 20 % RH

Air Composition

Component	MW	Mole %	wt	wt %
Oxygen	31.9988	20.66	661.095	22.94
Nitrogen	28.0134	77.01	2,157.312	74.87
Argon	39.948	0.92	36.752	1.28
CO2	44.00995	0.03	1.320	0.05
H2O	18.0152	1.38	24.861	0.86
			-----	-----
			2,881.341	100.00

Feed

Dry feed	83,333.333	
Moisture 1	9,880.686	Associated water to gasifier
Steam	48,333.333	
Air		
Oxygen	20,833.333	
Nitrogen	67,984.154	
Argon	1,158.184	
CO2	41.607	
H2O	783.453	

Total	232,348.084	
Moisture 2	73,452.647	Associated water removed in dryer

Product	lb/hr	lb/lb gasifier feed
H2	2,453.723	1.05605E-02
CO	17,435.529	7.50406E-02
CO2	66,919.323	2.88013E-01
CH4	9,621.647	4.14105E-02
C2H4	19.912	8.56975E-05
C2H6	1,344.570	5.78688E-03
C3H8	0.000	0.00000E+00
C6H6	942.526	4.05653E-03
H2O	56,289.815	2.42265E-01
C10H8	62.990	2.71101E-04
C14H10O	62.990	2.71101E-04
C7H8O	62.990	2.71101E-04
C6H6O	1,070.828	4.60872E-03
N2	67,984.154	2.92596E-01
Ar	1,158.184	4.98469E-03
Char	6,919.554	2.97810E-02
	------	------
Total	232,348.735	1.00000E+00

APPENDIX 7

BCL Gasifier Data

Item/Test		71	74	75	76	77	78	79	80	81	82
Gasifier Conditions	*										
Temperature, deg F	*	1280	1504	1562	1359	1466	1382	1445	1470	1548	1429
Pressure, psig	*	3.8	6.2	8.2	8.4	7.8	7.0	5.8	5.2	5.0	6.8
Moisture, wt %	*	14.42	15.69	6.88	9.00	9.00	10.79	10.00	10.00	8.12	8.12
Wet Wood Rate, lb/hr	*	486	588	700	916	777	1046	786	580	408	782
Dry wood Rate, lb/hr	*	416	496	652	834	707	933	707	522	375	719
Nitrogen Rate, lb/hr	*	139	173	315	169	204	218	160	160	160	152
Steam Rate, lb/hr	*	389	404	401	461	415	371	406	412	413	437
Steam Rate, lb/lb BDW	*	0.935	0.815	0.615	0.553	0.587	0.398	0.574	0.789	1.101	0.608
Total H2O Rate, lb/lb BDW	*	1.103	1.000	0.689	0.651	0.686	0.519	0.686	0.900	1.189	0.695
Total H2O, lb/lb MAF wood	*	1.135	1.012	0.693	0.659	0.694	0.530	0.688	0.908	1.195	0.698
Total H2O, SCF/lb MAF wood	*	23.896	21.318	14.595	13.870	14.614	11.151	14.499	19.128	25.158	14.710
Feed	*										
Type	*	Red Oak	Red Oak	Red Oak	Red Oak	Red Oak	Red Oak	Bir+Map	Bir+Map	Bir+Map	Bir+Map
Size	*	chips	chips	chips	chips	chips	chips	chips	chips	chips	chips
Proximate Analysis	*										
Volatile Matter, wt % dry	*	81.07	70.42	82.82	83.38	83.38	80.47	83.99	84.48	83.63	83.30
Ash	*	2.76	1.21	0.63	1.14	1.14	2.03	0.36	0.87	0.44	0.44
Fixed Carbon	*	16.17	28.37	16.55	15.48	15.48	17.50	15.65	14.65	15.93	15.93
Proximate Analysis	*										
Moisture, wt %	*	14.42	15.69	6.88	9.00	9.00	10.79	10.00	10.00	8.12	8.12
Volatile Matter	*	69.38	59.37	77.12	75.88	75.88	71.79	75.59	76.03	76.84	76.54
Ash	*	2.36	1.02	0.59	1.04	1.04	1.81	0.32	0.78	0.40	0.40
Fixed Carbon	*	13.84	23.92	15.41	14.09	14.09	15.61	14.09	13.19	14.64	14.64
Ultimate Analysis	*										
Ash, wt % dry	*	2.76	1.21	0.63	1.14	1.14	2.03	0.36	0.87	0.44	0.44
Carbon	*	49.34	57.75	50.08	49.77	49.77	49.50	49.85	50.14	51.13	51.13
Hydrogen	*	5.93	5.58	6.05	5.99	5.99	5.86	6.12	6.10	5.73	5.73
Nitrogen	*	0.07	0.44	0.21	0.20	0.20	0.25	0.10	0.03	0.14	0.14
Chlorine	*	0.03	0.03	0.08	0.02	0.02	0.03	0.03	0.03	0.02	0.02
Sulfur	*	0.13	0.87	0.00	0.00	0.00	0.01	0.08	0.03	0.03	0.03
Oxygen (diff)	*	41.74	34.12	42.95	42.88	42.88	42.32	43.46	42.80	42.51	42.51

Item/Test	71	74	75	76	77	78	79	80	81	82
Product Gas										
Rate, SCF/lb MAF	7.66	10.74	13.94	8.50	10.84	9.94	10.25	10.59	11.08	9.82
Rate, SCF/ lb BDW	7.45	10.61	13.85	8.40	10.72	9.74	10.21	10.50	11.03	9.78
Dry N2 Free Comp										
H2, mole %	13.25	20.59	20.51	14.66	18.15	14.94	17.20	20.81	23.79	19.36
CO	49.52	43.98	43.80	49.18	46.27	49.13	48.15	44.17	41.91	45.23
CO2	16.32	14.24	17.08	14.39	13.93	14.21	12.75	14.78	15.42	14.57
CH4	16.10	15.90	14.41	16.59	16.30	16.47	16.38	15.36	14.42	15.83
C2H2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
C2H4	3.81	4.80	3.94	4.18	4.63	4.30	4.78	4.28	4.15	4.31
C2H6	1.00	0.49	0.26	1.00	0.72	0.95	0.74	0.60	0.31	0.70
	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
MW, lb/lbmole	25.273	23.046	23.694	24.539	23.587	24.451	23.636	23.142	22.576	23.431
HHV, Btu/lb mole	167,980.25	172,079.84	159,299.31	173,419.53	173,909.87	173,636.13	176,380.20	168,097.18	162,677.77	170,256.79
HHV, Btu/lb	6,646.70	7,466.86	6,723.13	7,067.12	7,373.04	7,101.47	7,462.25	7,263.83	7,205.81	7,266.36
HHV, Btu/SCF @ 60 deg F	442.75	453.56	419.87	457.09	458.38	457.66	464.89	443.06	428.78	448.75
C, lb/lbmole	10.9974	10.1734	10.0521	10.8725	10.4737	10.8473	10.6082	10.0978	9.6894	10.2875
C, lb/lb gas	0.4351	0.4414	0.4242	0.4431	0.4440	0.4436	0.4488	0.4363	0.4292	0.4391
C, lb/SCF	0.0290	0.0268	0.0265	0.0287	0.0276	0.0286	0.0280	0.0266	0.0255	0.0271
C, lb/lb MAF wood	0.2220	0.2880	0.3693	0.2436	0.2992	0.2842	0.2866	0.2819	0.2830	0.2663
C Conv to Gas, %	43.7590	49.2647	73.2849	48.3842	59.4410	56.2467	57.2847	55.7244	55.0996	51.8484
H, lb/lb mole	1.1303	1.2792	1.1690	1.1934	1.2532	1.1960	1.2446	1.2476	1.2470	1.2446
H, lb/lb gas	0.0447	0.0555	0.0493	0.0486	0.0531	0.0489	0.0527	0.0539	0.0552	0.0531
H, lb/SCF	0.0030	0.0034	0.0031	0.0031	0.0033	0.0032	0.0033	0.0033	0.0033	0.0033
H, lb/lb MAF wood	0.0228	0.0362	0.0430	0.0267	0.0358	0.0313	0.0336	0.0348	0.0364	0.0322
H Conv to Gas, wt %	37.4196	64.1111	70.5449	44.1250	59.0955	52.3849	54.7423	56.5903	63.2747	55.9704
Tar Estimate										
Yield, lb/lb maf feed	0.0204	0.0159	0.0148	0.0188	0.0167	0.0184	0.0171	0.0166	0.0150	0.0174
Eq Tar=0.046-.00002*Temp										
Comp										
C3H6, LB/lb maf wood	0.0051	0.00398	0.00369	0.004705	0.00417	0.00459	0.004275	0.00415	0.00376	0.004355
C6H6	0.0051	0.00398	0.00369	0.004705	0.00417	0.00459	0.004275	0.00415	0.00376	0.004355
C10H8	0.0051	0.00398	0.00369	0.004705	0.00417	0.00459	0.004275	0.00415	0.00376	0.004355
C14H10	0.0051	0.00398	0.00369	0.004705	0.00417	0.00459	0.004275	0.00415	0.00376	0.004355
lb C/lb maf wood	0.0147	0.0115	0.0107	0.0136	0.0120	0.0133	0.0123	0.0120	0.0109	0.0126
lb H/lb maf wood	0.0057	0.0044	0.0041	0.0052	0.0046	0.0051	0.0048	0.0046	0.0042	0.0048
lb C/lb dry wood	0.0143	0.0114	0.0106	0.0134	0.0119	0.0130	0.0123	0.0119	0.0108	0.0125
lb H/lb dry wood	0.0055	0.0044	0.0041	0.0052	0.0046	0.0050	0.0047	0.0046	0.0042	0.0048

Item/Test		71	74	75	76	77	78	79	80	81	82
Basis: 1 lb dry wood											
Char estimate, Let C=86, H=4, O=10 wt % MAF											
lb Ash	*	0.0276	0.0121	0.0063	0.0114	0.0114	0.0203	0.0036	0.0087	0.0044	0.0044
lb C	*										
In	*	0.4934	0.5775	0.5008	0.4977	0.4977	0.4950	0.4985	0.5014	0.5113	0.5113
Out in Gas	*	0.2159	0.2845	0.3670	0.2408	0.2958	0.2784	0.2856	0.2794	0.2817	0.2651
Out in Tar	*	0.0143	0.0114	0.0106	0.0134	0.0119	0.0130	0.0123	0.0119	0.0108	0.0125
Out in Char	*	0.2632	0.2816	0.1232	0.2435	0.1900	0.2036	0.2006	0.2101	0.2188	0.2337
	*										
H in char	*	0.0188	0.0201	0.0088	0.0174	0.0136	0.0145	0.0143	0.0150	0.0156	0.0167
H in gas	*	0.0222	0.0358	0.0427	0.0264	0.0354	0.0307	0.0335	0.0345	0.0363	0.0321
H in tar	*	0.0055	0.0044	0.0041	0.0052	0.0046	0.0050	0.0047	0.0046	0.0042	0.0048
H In	*	0.1828	0.1677	0.1376	0.1328	0.1367	0.1166	0.1380	0.1617	0.1904	0.1351
H in Steam	*	0.1363	0.1074	0.0820	0.0838	0.0831	0.0664	0.0854	0.1076	0.1343	0.0815
lb H2O	*	1.2177	0.9601	0.7328	0.7485	0.7427	0.5935	0.7631	0.9620	1.2005	0.7286
	*										
Lb in	*										
Dry Wood	*	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Water	*	1.1034	1.0000	0.6887	0.6511	0.6860	0.5188	0.6860	0.9004	1.1893	0.6954
	*										
lb Out	*										
Gas	*	0.4962	0.6445	0.8651	0.5435	0.6662	0.6276	0.6363	0.6403	0.6564	0.6038
Tar	*	0.0198	0.0157	0.0147	0.0186	0.0165	0.0180	0.0170	0.0165	0.0150	0.0173
Char	*	0.3372	0.3434	0.1512	0.2978	0.2349	0.2598	0.2396	0.2559	0.2618	0.2793
H2O	*	1.2177	0.9601	0.7328	0.7485	0.7427	0.5935	0.7631	0.9620	1.2005	0.7286
Closure	*	98.46	98.19	104.45	97.42	98.48	98.69	98.22	98.65	97.46	96.09
Water Conversion %	*	-10.37	3.99	-6.41	-14.97	-8.27	-14.40	-11.24	-6.84	-0.94	-4.77
Water Conver., lb/lb dry wood	*	-0.1144	0.0399	-0.0442	-0.0975	-0.0567	-0.0747	-0.0771	-0.0616	-0.0112	-0.0332

Item/Test		83	84	85	86	87	88	89	90	91	92
Gasifier Conditions	*										
Temperature, deg F	*	1465	1395	1422	1451	1408	1436	1371	1436	1374	1388
Pressure, psig	*	4.4	4.1	3.4	2.6	2.6	2.4	2.8	2.7	3.6	4.1
Moisture, wt %	*	12.37	3.65	10.00	2.00	4.70	3.70	15.00	5.50	10.00	10.00
Wet Wood Rate, lb/hr	*	457	418	397	425	425	413	348	420	275	275
Dry wood Rate, lb/hr	*	400	403	357	417	405	398	296	397	248	248
Nitrogen Rate, lb/hr	*	119	105	226	221	222	86	101	124	124	124
Steam Rate, lb/hr	*	430	432	467	447	422	426	436	419	429	434
Steam Rate, lb/lb BDW	*	1.075	1.072	1.308	1.072	1.042	1.070	1.473	1.055	1.730	1.750
Total H2O Rate, lb/lb BDW	*	1.218	1.109	1.420	1.091	1.091	1.108	1.649	1.113	1.839	1.859
Total H2O, lb/lb MAF wood	*	1.225	1.115	1.427	1.101	1.098	1.115	1.662	1.124	1.851	1.871
Total H2O, SCF/lb MAF wood	*	25.803	23.477	30.047	23.190	23.125	23.479	35.004	23.682	38.984	39.412
Feed	*										
Type	*	Bir+Map	Bir+Map	Bir+Map	Hard Chips	Hard Chips	Hard Chips	Hard Chips	Hard Chips	Hard Chips	S Oak
Size	*	chips	chips	chips	chips	chips	chips	chips	chips	chips	chips
Proximate Analysis	*										
Volatile Matter, wt % dry	*	84.42	84.50	84.09	83.41	84.16	85.65	83.47	84.33	85.07	85.07
Ash	*	0.63	0.50	0.46	0.91	0.61	0.61	0.81	0.99	0.67	0.67
Fixed Carbon	*	14.95	15.00	15.45	15.66	15.23	13.74	15.72	14.68	14.26	14.26
Proximate Analysis	*										
Moisture, wt %	*	12.37	3.65	10.00	2.00	4.70	3.70	15.00	5.50	10.00	10.00
Volatile Matter	*	73.98	81.42	75.68	81.74	80.20	82.48	70.95	79.69	76.56	76.56
Ash	*	0.55	0.48	0.41	0.89	0.58	0.59	0.69	0.94	0.60	0.60
Fixed Carbon	*	13.10	14.45	13.91	15.35	14.51	13.23	13.36	13.87	12.83	12.83
Ultimate Analysis	*										
Ash, wt % dry	*	0.63	0.50	0.46	0.91	0.61	0.61	0.81	0.99	0.67	0.67
Carbon	*	50.95	50.37	50.41	49.63	40.12	49.63	49.84	49.69	49.81	49.81
Hydrogen	*	5.70	5.88	6.13	6.00	6.23	6.42	5.30	6.33	6.05	6.05
Nitrogen	*	0.13	0.19	0.39	0.31	0.13	0.16	0.16	0.13	0.11	0.11
Chlorine	*	0.02	0.03	0.03	0.03	0.03	0.06	0.02	0.02	0.02	0.02
Sulfur	*	0.02	0.00	0.00	0.00	0.03	0.04	0.00	0.00	0.01	0.01
Oxygen (diff)	*	42.55	43.03	42.58	43.12	52.85	43.08	43.87	42.84	43.33	43.33

Item/Test	83	84	85	86	87	88	89	90	91	92
Product Gas										
Rate, SCF/lb MAF	8.97	10.96	8.24	10.72	10.30	10.28	10.21	10.04	9.98	9.75
Rate, SCF/ lb BDW	8.91	10.91	8.20	10.62	10.24	10.22	10.13	9.94	9.91	9.68
Dry N2 Free Comp										
H2, mole %	20.92	19.81	19.19	18.41	16.65	18.54	18.21	20.47	19.38	20.04
CO	42.57	42.23	43.61	46.46	47.38	45.36	44.51	43.51	43.80	43.01
CO2	15.30	16.11	14.82	12.65	13.26	13.62	15.04	14.27	14.95	14.92
CH4	15.91	15.75	17.13	17.06	17.01	16.65	16.61	16.12	16.42	16.58
C2H2	0.00	0.00	0.00	0.00	0.00	0.28	0.23	0.27	0.24	0.24
C2H4	4.88	4.83	4.48	4.79	4.89	4.83	4.53	4.65	4.41	4.51
C2H6	0.42	1.27	0.77	0.63	0.81	0.72	0.87	0.71	0.80	0.70
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	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
MW, lb/lbmole	23.127	23.582	23.361	23.222	23.787	23.389	23.711	23.055	23.413	23.216
HHV, Btu/lb mole	170,824.08	173,830.25	174,553.95	177,736.95	178,315.86	177,401.01	174,714.40	174,277.93	173,419.49	173,817.92
HHV, Btu/lb	7,386.34	7,371.39	7,472.04	7,653.77	7,496.37	7,584.82	7,368.60	7,559.36	7,406.92	7,487.10
HHV, Btu/SCF @ 60 deg F	450.25	458.17	460.08	468.47	469.99	467.58	460.50	459.35	457.09	458.14
C, lb/lbmole	10.1350	10.3644	10.3368	10.4509	10.6959	10.4845	10.5001	10.2287	10.3380	10.2587
C, lb/lb gas	0.4382	0.4395	0.4425	0.4500	0.4497	0.4483	0.4428	0.4437	0.4415	0.4419
C, lb/SCF	0.0267	0.0273	0.0272	0.0275	0.0282	0.0276	0.0277	0.0270	0.0272	0.0270
C, lb/lb MAF wood	0.2396	0.2994	0.2245	0.2953	0.2904	0.2841	0.2826	0.2707	0.2719	0.2636
C Conv to Gas, %	46.7337	59.1438	44.3299	58.9572	71.9350	56.8910	56.2359	53.9345	54.2292	52.5732
H, lb/lb mole	1.2853	1.3058	1.3046	1.2901	1.2675	1.2889	1.2766	1.2984	1.2837	1.3014
H, lb/lb gas	0.0556	0.0554	0.0558	0.0556	0.0533	0.0551	0.0538	0.0563	0.0548	0.0561
H, lb/SCF	0.0034	0.0034	0.0034	0.0034	0.0033	0.0034	0.0034	0.0034	0.0034	0.0034
H, lb/lb MAF wood	0.0304	0.0377	0.0283	0.0365	0.0344	0.0349	0.0344	0.0344	0.0338	0.0334
H Conv to Gas, wt %	52.9750	63.8333	46.0101	60.2010	54.8977	54.0659	64.2950	53.7418	55.4382	54.9090
Tar Estimate										
Yield, lb/lb maf feed	0.0167	0.0181	0.0176	0.0170	0.0178	0.0173	0.0186	0.0173	0.0185	0.0182
Eq Tar=0.046-.00002*Temp										
Comp										
C3H6, LB/lb maf wood	0.004175	0.004525	0.00439	0.004245	0.00446	0.00432	0.004645	0.00432	0.00463	0.00456
C6H6	0.004175	0.004525	0.00439	0.004245	0.00446	0.00432	0.004645	0.00432	0.00463	0.00456
C10H8	0.004175	0.004525	0.00439	0.004245	0.00446	0.00432	0.004645	0.00432	0.00463	0.00456
C14H10	0.004175	0.004525	0.00439	0.004245	0.00446	0.00432	0.004645	0.00432	0.00463	0.00456
lb C/lb maf wood	0.0121	0.0131	0.0127	0.0123	0.0129	0.0125	0.0134	0.0125	0.0134	0.0132
lb H/lb maf wood	0.0046	0.0050	0.0049	0.0047	0.0050	0.0048	0.0052	0.0048	0.0051	0.0051
lb C/lb dry wood	0.0120	0.0130	0.0126	0.0121	0.0128	0.0124	0.0133	0.0124	0.0133	0.0131
lb H/lb dry wood	0.0046	0.0050	0.0049	0.0047	0.0049	0.0048	0.0051	0.0048	0.0051	0.0050

Item/Test	83	84	85	86	87	88	89	90	91	92
Basis: 1 lb dry wood										
Char estimate, Let C=86, H=4, O=										
lb Ash	0.0063	0.0050	0.0046	0.0091	0.0061	0.0061	0.0081	0.0099	0.0067	0.0067
lb C										
In	0.5095	0.5037	0.5041	0.4963	0.4012	0.4963	0.4984	0.4969	0.4981	0.4981
Out in Gas	0.2381	0.2979	0.2235	0.2926	0.2886	0.2823	0.2803	0.2680	0.2701	0.2619
Out in Tar	0.0120	0.0130	0.0126	0.0121	0.0128	0.0124	0.0133	0.0124	0.0133	0.0131
Out in Char	0.2594	0.1928	0.2680	0.1915	0.0998	0.2016	0.2048	0.2165	0.2147	0.2232
H in char	0.0185	0.0138	0.0191	0.0137	0.0071	0.0144	0.0146	0.0155	0.0153	0.0159
H in gas	0.0302	0.0375	0.0282	0.0361	0.0342	0.0347	0.0341	0.0340	0.0335	0.0332
H in tar	0.0046	0.0050	0.0049	0.0047	0.0049	0.0048	0.0051	0.0048	0.0051	0.0050
H In	0.1932	0.1829	0.2202	0.1821	0.1844	0.1882	0.2375	0.1879	0.2662	0.2685
H in Steam	0.1399	0.1266	0.1680	0.1276	0.1382	0.1343	0.1836	0.1336	0.2123	0.2143
lb H2O	1.2502	1.1314	1.5014	1.1405	1.2347	1.2003	1.6412	1.1943	1.8969	1.9152
Lb In										
Dry Wood	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Water	1.2175	1.1092	1.4202	1.0911	1.0914	1.1080	1.6486	1.1134	1.8387	1.8589
Lb Out										
Gas	0.5433	0.6778	0.5050	0.6502	0.6418	0.6299	0.6329	0.6041	0.6117	0.5926
Tar	0.0166	0.0180	0.0175	0.0168	0.0177	0.0172	0.0184	0.0171	0.0184	0.0181
Char	0.3115	0.2318	0.3199	0.2345	0.1235	0.2432	0.2491	0.2647	0.2593	0.2692
H2O	1.2502	1.1314	1.5014	1.1405	1.2347	1.2003	1.6412	1.1943	1.8969	1.9152
Closure	95.68	97.62	96.85	97.65	96.48	99.17	95.96	98.43	98.15	97.77
Water Conversion %	-2.69	-2.00	-5.72	-4.52	-13.14	-8.32	0.45	-7.27	-3.16	-3.03
Water Conver., lb/lb dry wood	-0.0327	-0.0222	-0.0813	-0.0493	-0.1434	-0.0922	0.0074	-0.0809	-0.0582	-0.0563

Item/Test		93	94	101	102	103	104	105	106	107	109
.Gasifier Conditions	*										
.Temperature, deg F	*	1290	1328	1623	1512	1507	1651	1627	1544	1650	1500
.Pressure, psig	*	3.4	3.2	7.0	5.6	5.6	3.4	6.0	3.8	4.8	3.8
.Moisture, wt %	*	40.00	35.00	5.50	4.42	5.74	4.59	4.59	4.00	5.00	3.00
.Wet Wood Rate, lb/hr	*	340	518	450	390	370	420	424	306	357	312.5
.Dry wood Rate, lb/hr	*	204	337	425	373	349	401	405	294	339	303
.Nitrogen Rate, lb/hr	*	128	62	108	134	107	99	0	4	93	113
.Steam Rate, lb/hr	*	430	417	468	432	407	447	372	449	439	345
.Steam Rate, lb/lb BDW	*	2.108	1.237	1.101	1.158	1.166	1.115	0.919	1.527	1.295	1.139
.Total H2O Rate, lb/lb BDW	*	2.775	1.774	1.160	1.204	1.226	1.162	0.965	1.568	1.348	1.170
.Total H2O, lb/lb MAF wood	*	2.793	1.785	1.174	1.211	1.242	1.167	0.970	1.579	1.355	1.206
.Total H2O, SCF/lb MAF wood	*	58.813	37.585	24.729	25.501	26.157	24.584	20.424	33.245	28.539	25.402
.Feed	*										
.Type	*	S Oak	Sawdust	Sawdust	Hard	Hard	Hard	Hard	Hard	Hard	hog
.Size	*	chips	powder	powder	chips	chips	chips	chips	chips	chips	chips
.Ultimate Analysis	*										
. Volatile Matter, wt % dry	*	81.92	80.65	83.80	85.20	84.20	85.60	85.60	85.26	85.37	70.29
. Ash	*	0.65	0.57	1.21	0.59	1.26	0.45	0.45	0.67	0.52	3.00
. Fixed Carbon	*	17.43	18.78	14.99	14.21	14.54	13.95	13.95	14.07	14.11	12.82
.Proximate Analysis	*										
. Moisture, wt %	*	40.00	35.00	5.50	4.42	5.74	4.59	4.59	4.00	5.00	3.00
. Volatile Matter	*	49.15	52.42	79.19	81.43	79.37	81.67	81.67	81.85	81.10	68.18
. Ash	*	0.39	0.37	1.14	0.56	1.19	0.43	0.43	0.64	0.49	2.91
. Fixed Carbon	*	10.46	12.21	14.17	13.58	13.71	13.31	13.31	13.51	13.40	12.44
.Ultimate Analysis	*										
. Ash, wt % dry	*	0.65	0.57	1.21	0.59	1.26	0.45	0.45	0.67	0.52	3.00
. Carbon	*	53.92	53.11	50.22	50.50	50.37	51.30	51.30	50.82	50.84	45.36
. Hydrogen	*	6.53	6.50	5.90	5.93	6.00	6.12	6.12	6.08	6.07	5.63
. Nitrogen	*	0.21	0.18	0.06	0.18	0.19	0.11	0.11	0.14	0.22	0.18
. Chlorine	*	0.04	0.04	0.02	0.01	0.01	0.03	0.03	0.03	0.03	0.03
. Sulfur	*	0.04	0.03	0.09	0.01	0.02	0.10	0.10	0.20	0.40	0.02
. Oxygen (diff)	*	38.61	39.57	42.50	42.78	42.15	41.89	41.89	42.06	41.92	45.78

Item/Test	93	94	101	102	103	104	105	106	107	109
Product Gas										
Rate, SCF/lb MAF	8.82	6.31	14.45	12.02	11.78	13.83	14.57	12.99	14.93	9.96
Rate, SCF/ lb BDW	8.76	6.27	14.28	11.95	11.63	13.77	14.50	12.90	14.85	9.66
Dry N2 Free Comp										
H2, mole %	14.16	16.81	24.58	21.90	20.87	24.87	25.48	22.47	26.39	21.54
CO	51.75	50.92	40.75	41.96	42.72	41.05	40.21	43.17	41.09	48.38
CO2	12.02	10.53	13.21	13.99	14.02	13.70	13.41	12.54	12.55	9.07
CH4	16.26	15.61	16.75	16.74	16.86	15.61	16.45	16.65	15.65	15.19
C2H2	0.00	0.25	0.37	0.29	0.35	0.57	0.40	0.34	0.49	0.27
C2H4	4.74	4.96	4.06	4.60	4.71	4.09	3.84	4.47	3.69	4.96
C2H6	1.07	0.92	0.28	0.52	0.47	0.11	0.21	0.36	0.14	0.59
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	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
MW, lb/lbmole	24.331	23.474	21.730	22.560	22.816	21.862	21.562	22.186	21.280	22.053
HHV, Btu/lb mole	178,535.45	180,020.76	172,478.48	175,057.09	175,843.09	168,996.57	170,142.73	175,303.26	168,393.20	179,033.91
HHV, Btu/lb	7,337.81	7,669.10	7,937.28	7,759.78	7,707.15	7,730.09	7,890.86	7,901.58	7,913.10	8,118.18
HHV, Btu/SCF @ 60 deg F	470.57	474.49	454.61	461.41	463.48	445.43	448.45	462.05	443.84	471.89
C, lb/lbmole	11.0082	10.7284	9.6245	10.0305	10.1686	9.5969	9.4852	9.9332	9.3603	10.1230
C, lb/lb gas	0.4524	0.4570	0.4429	0.4446	0.4457	0.4390	0.4399	0.4477	0.4399	0.4590
C, lb/SCF	0.0290	0.0283	0.0254	0.0264	0.0268	0.0253	0.0250	0.0262	0.0247	0.0267
C, lb/lb MAF wood	0.2559	0.1784	0.3666	0.3178	0.3157	0.3498	0.3643	0.3401	0.3683	0.2657
C Conv to Gas, %	47.1527	33.4046	72.1085	62.5560	61.8916	67.8860	70.6859	66.4734	72.0746	56.8290
H, lb/lb mole	1.1968	1.2288	1.3589	1.3391	1.3258	1.3137	1.3524	1.3330	1.3300	1.2877
H, lb/lb gas	0.0492	0.0523	0.0625	0.0594	0.0581	0.0601	0.0627	0.0601	0.0625	0.0584
H, lb/SCF	0.0032	0.0032	0.0036	0.0035	0.0035	0.0035	0.0036	0.0035	0.0035	0.0034
H, lb/lb MAF wood	0.0278	0.0204	0.0518	0.0424	0.0412	0.0479	0.0519	0.0456	0.0523	0.0338
H Conv to Gas, wt %	42.3292	31.2628	86.6569	71.1204	67.7431	77.8950	84.4807	74.5649	85.7767	58.2422
Tar Estimate										
Yield, lb/lb maf feed	0.0202	0.0194	0.0135	0.0158	0.0159	0.0130	0.0135	0.0151	0.0130	0.0160
Eq Tar=0.046-.00002*Temp										
Comp										
C3H6, LB/lb maf wood	0.00505	0.00486	0.003385	0.00394	0.003965	0.003245	0.003365	0.00378	0.00325	0.004
C6H6	0.00505	0.00486	0.003385	0.00394	0.003965	0.003245	0.003365	0.00378	0.00325	0.004
C10H8	0.00505	0.00486	0.003385	0.00394	0.003965	0.003245	0.003365	0.00378	0.00325	0.004
C14H10	0.00505	0.00486	0.003385	0.00394	0.003965	0.003245	0.003365	0.00378	0.00325	0.004
lb C/lb maf wood	0.0146	0.0140	0.0098	0.0114	0.0115	0.0094	0.0097	0.0109	0.0094	0.0116
lb H/lb maf wood	0.0056	0.0054	0.0038	0.0044	0.0044	0.0036	0.0037	0.0042	0.0036	0.0044
lb C/lb dry wood	0.0145	0.0140	0.0097	0.0113	0.0113	0.0093	0.0097	0.0108	0.0093	0.0112
lb H/lb dry wood	0.0056	0.0054	0.0037	0.0044	0.0044	0.0036	0.0037	0.0042	0.0036	0.0043

Item/Test		93	94	101	102	103	104	105	106	107	109
Basis: 1 lb dry wood											
Char estimate, Let C=86, H=4, O=											
lb Ash	*	0.0065	0.0057	0.0121	0.0059	0.0126	0.0045	0.0045	0.0067	0.0052	0.0300
lb C	*										
In	*	0.5392	0.5311	0.5022	0.5050	0.5037	0.5130	0.5130	0.5082	0.5084	0.4536
Out in Gas	*	0.2542	0.1774	0.3621	0.3159	0.3117	0.3483	0.3626	0.3378	0.3664	0.2578
Out in Tar	*	0.0145	0.0140	0.0097	0.0113	0.0113	0.0093	0.0097	0.0108	0.0093	0.0112
Out in Char	*	0.2705	0.3397	0.1304	0.1778	0.1806	0.1554	0.1407	0.1595	0.1326	0.1846
	*										
H in char	*	0.0193	0.0243	0.0093	0.0127	0.0129	0.0111	0.0101	0.0114	0.0095	0.0132
H in gas	*	0.0276	0.0203	0.0511	0.0422	0.0406	0.0477	0.0517	0.0453	0.0521	0.0328
H in tar	*	0.0056	0.0054	0.0037	0.0044	0.0044	0.0036	0.0037	0.0042	0.0036	0.0043
H In	*	0.3758	0.2636	0.1888	0.1940	0.1972	0.1912	0.1692	0.2363	0.2115	0.1872
H in Steam	*	0.3232	0.2136	0.1246	0.1348	0.1393	0.1289	0.1037	0.1753	0.1464	0.1369
lb H2O	*	2.8885	1.9089	1.1139	1.2044	1.2451	1.1517	0.9272	1.5671	1.3084	1.2237
	*										
Lb In	*										
Dry Wood	*	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Water	*	2.7745	1.7745	1.1600	1.2038	1.2264	1.1621	0.9654	1.5680	1.3481	1.1700
	*										
Lb Out	*										
Gas	*	0.5619	0.3882	0.8176	0.7105	0.6995	0.7933	0.8243	0.7545	0.8331	0.5616
Tar	*	0.0201	0.0193	0.0134	0.0157	0.0157	0.0129	0.0134	0.0150	0.0129	0.0155
Char	*	0.3247	0.4054	0.1655	0.2151	0.2251	0.1873	0.1700	0.1944	0.1612	0.2472
H2O	*	2.8885	1.9089	1.1139	1.2044	1.2451	1.1517	0.9272	1.5671	1.3084	1.2237
Closure	*	100.55	98.10	97.70	97.36	98.16	99.22	98.45	98.56	98.62	94.38
Water Conversion %	*	-4.11	-7.57	3.98	-0.05	-1.53	0.90	3.96	0.06	2.94	-4.59
Water Conver., lb/lb dry wood	*	-0.1140	-0.1344	0.0461	-0.0006	-0.0187	0.0104	0.0382	0.0010	0.0396	-0.0537

Item/Test	110	111	112	117	118	119	120	121	122	123
Gasifier Conditions										
Temperature, deg F	1579	1350	1313	1725	1609	1684	1610	1553	1765	1512
Pressure, psig	3.6	6.2	6.2	5.2	6.2	5.2	6.8	14.4	6.0	10.4
Moisture, wt %	9.70	5.00	5.00	7.80	7.80	0.82	5.82	5.82	0.00	4.40
Wet Wood Rate, lb/hr	407.5	1207	1405	270.3	1239	434.8	1362.3	1988.4	497.9	1897
Dry wood Rate, lb/hr	368	1147	1335	249	1142	431	1283	1873	498	1814
Nitrogen Rate, lb/hr	101	109	109	96	0	102	0	0	0	0
Steam Rate, lb/hr	331	346	346	370	374	367	378	423	110	34
Steam Rate, lb/lb BDW	0.899	0.302	0.259	1.486	0.327	0.852	0.295	0.226	0.221	0.019
Total H2O Rate, lb/lb BDW	1.007	0.354	0.312	1.571	0.412	0.860	0.356	0.287	0.221	0.064
Total H2O, lb/lb MAF wood	1.008	0.356	0.313	1.577	0.414	0.861	0.357	0.288	0.222	0.065
Total H2O, SCF/lb MAF wood	21.231	7.487	6.592	33.202	8.714	18.131	7.512	6.058	4.668	1.364
Feed										
Type	pine	pine	pine	pine	pine	pine	pine	pine	pine	pine
Size	chips	chips	chips	chips	chips	chips	chips	chips	chips	chips
Proximate Analysis										
Volatile Matter, wt % dry	85.04	84.34	84.34	84.79	84.79	85.35	85.35	85.35	84.27	84.27
Ash	0.13	0.44	0.44	0.32	0.32	0.07	0.07	0.07	0.44	0.44
Fixed Carbon	14.83	15.22	15.22	14.89	14.89	14.58	14.58	14.58	15.29	15.29
Proximate Analysis										
Moisture, wt %	9.70	5.00	5.00	7.80	7.80	0.82	5.82	5.82	0.00	4.40
Volatile Matter	76.79	80.12	80.12	78.18	78.18	84.65	80.38	80.38	84.27	80.56
Ash	0.12	0.42	0.42	0.30	0.30	0.07	0.07	0.07	0.44	0.42
Fixed Carbon	13.39	14.46	14.46	13.73	13.73	14.46	13.73	13.73	15.29	14.62
Ultimate Analysis										
Ash, wt % dry	0.13	0.44	0.44	0.32	0.32	0.07	0.07	0.07	0.44	0.44
Carbon	51.27	52.44	52.44	52.55	52.55	52.89	52.89	52.89	52.02	52.02
Hydrogen	6.19	6.36	6.36	6.42	6.42	6.29	6.29	6.29	6.13	6.13
Nitrogen	0.13	0.14	0.14	0.14	0.14	0.18	0.18	0.18	0.23	0.23
Chlorine	0.02	0.01	0.01	0.01	0.01	0.03	0.03	0.03	0.01	0.01
Sulfur	0.13	0.27	0.27	0.24	0.24	0.02	0.02	0.02	0.01	0.01
Oxygen (diff)	42.13	40.34	40.34	40.32	40.32	40.52	40.52	40.52	41.16	41.16

Item/Test	110	111	112	117	118	119	120	121	122	123
Product Gas										
Rate, SCF/lb MAF	13.03	9.65	9.35	16.14	12.99	14.43	14.53	11.78	15.25	10.95
Rate, SCF/ lb BDW	13.01	9.61	9.31	16.09	12.95	14.42	14.52	11.77	15.18	10.90
Dry N2 Free Comp										
H2, mole %	22.99	16.18	15.20	27.97	20.96	24.66	20.23	18.46	26.96	17.10
CO	46.43	49.46	50.72	43.29	47.69	46.67	48.71	49.41	46.34	50.63
CO2	9.62	12.43	12.30	10.46	9.30	9.03	9.16	9.56	8.50	9.65
CH4	14.99	16.05	15.86	14.12	15.92	14.85	15.78	16.24	14.37	16.48
C2H2	0.41	0.17	0.18	0.50	0.26	0.45	0.23	0.17	0.34	0.14
C2H4	5.22	4.60	4.20	3.66	5.43	4.18	5.60	5.30	3.03	4.84
C2H6	0.34	1.35	1.54	0.00	0.44	0.16	0.53	0.86	0.46	1.16
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	100.00	100.24	100.00	100.00	100.00	100.00	100.24	100.00	100.00	100.00
MW, lb/lbmole	21.781	23.966	24.159	20.715	22.151	21.264	22.405	22.814	20.647	23.160
HHV, Btu/lb mole	178,361.52	179,406.51	177,911.28	166,089.73	182,065.71	172,877.09	183,340.82	183,835.63	167,884.14	183,620.70
HHV, Btu/lb	8,188.98	7,485.85	7,364.16	8,017.76	8,219.31	8,130.04	8,183.09	8,057.84	8,131.32	7,928.27
HHV, Btu/SCF @ 60 deg F	470.11	472.87	468.93	437.77	479.88	455.66	483.24	484.54	442.50	483.98
C, lb/lbmole	9.9669	10.8317	10.8965	9.1513	10.2299	9.6245	10.3740	10.5542	9.2330	10.6947
C, lb/lb gas	0.4576	0.4520	0.4510	0.4418	0.4618	0.4526	0.4630	0.4626	0.4472	0.4618
C, lb/SCF	0.0263	0.0285	0.0287	0.0241	0.0270	0.0254	0.0273	0.0278	0.0243	0.0282
C, lb/lb MAF wood	0.3423	0.2755	0.2685	0.3893	0.3503	0.3661	0.3973	0.3277	0.3711	0.3087
C Conv to Gas, %	66.6771	52.3055	50.9829	73.8455	66.4383	69.1626	75.0651	61.9149	71.0278	59.0746
H, lb/lb mole	1.3070	1.2437	1.2119	1.2907	1.3151	1.2831	1.3064	1.2960	1.2796	1.2772
H, lb/lb gas	0.0600	0.0519	0.0502	0.0623	0.0594	0.0603	0.0583	0.0568	0.0620	0.0551
H, lb/SCF	0.0034	0.0033	0.0032	0.0034	0.0035	0.0034	0.0034	0.0034	0.0034	0.0034
H, lb/lb MAF wood	0.0449	0.0316	0.0299	0.0549	0.0450	0.0488	0.0500	0.0402	0.0514	0.0369
H Conv to Gas, wt %	72.4239	49.5211	46.7529	85.2531	69.9111	77.5283	79.4883	63.9270	83.5375	59.8692
Tar Estimate										
Yield, lb/lb maf feed	0.0144	0.0190	0.0197	0.0115	0.0138	0.0123	0.0138	0.0149	0.0107	0.0158
Eq Tar=0.046-.00002*Temp										
Comp										
C3H6, LB/lb maf wood	0.003605	0.00475	0.004935	0.002875	0.003455	0.00308	0.00345	0.003735	0.002675	0.00394
C6H6	0.003605	0.00475	0.004935	0.002875	0.003455	0.00308	0.00345	0.003735	0.002675	0.00394
C10H8	0.003605	0.00475	0.004935	0.002875	0.003455	0.00308	0.00345	0.003735	0.002675	0.00394
C14H10	0.003605	0.00475	0.004935	0.002875	0.003455	0.00308	0.00345	0.003735	0.002675	0.00394
lb C/lb maf wood	0.0104	0.0137	0.0143	0.0083	0.0100	0.0089	0.0100	0.0108	0.0077	0.0114
lb H/lb maf wood	0.0040	0.0053	0.0055	0.0032	0.0038	0.0034	0.0038	0.0042	0.0030	0.0044
lb C/lb dry wood	0.0104	0.0137	0.0142	0.0083	0.0099	0.0089	0.0100	0.0108	0.0077	0.0113
lb H/lb dry wood	0.0040	0.0053	0.0055	0.0032	0.0038	0.0034	0.0038	0.0042	0.0030	0.0044

Item/Test		110	111	112	117	118	119	120	121	122	123
Basis: 1 lb dry wood											
Char estimate, Let C=86, H=4, O=											
lb Ash	*	0.0013	0.0044	0.0044	0.0032	0.0032	0.0007	0.0007	0.0007	0.0044	0.0044
lb C	*										
In	*	0.5127	0.5244	0.5244	0.5255	0.5255	0.5289	0.5289	0.5289	0.5202	0.5202
Out in Gas	*	0.3419	0.2743	0.2674	0.3881	0.3491	0.3658	0.3970	0.3275	0.3695	0.3073
Out in Tar	*	0.0104	0.0137	0.0142	0.0083	0.0099	0.0089	0.0100	0.0108	0.0077	0.0113
Out in Char	*	0.1604	0.2365	0.2429	0.1292	0.1664	0.1542	0.1219	0.1907	0.1430	0.2016
	*										
H in char	*	0.0115	0.0169	0.0173	0.0092	0.0119	0.0110	0.0087	0.0136	0.0102	0.0144
H in gas	*	0.0448	0.0315	0.0297	0.0547	0.0449	0.0488	0.0500	0.0402	0.0512	0.0367
H in tar	*	0.0040	0.0053	0.0055	0.0032	0.0038	0.0034	0.0038	0.0042	0.0030	0.0044
H In	*	0.1746	0.1032	0.0985	0.2400	0.1103	0.1592	0.1028	0.0951	0.0860	0.0685
H in Steam	*	0.1143	0.0496	0.0459	0.1729	0.0497	0.0960	0.0402	0.0371	0.0216	0.0131
lb H2O	*	1.0211	0.4429	0.4104	1.5452	0.4446	0.8576	0.3596	0.3314	0.1931	0.1167
	*										
Lb in	*										
Dry Wood	*	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
Water	*	1.0068	0.3540	0.3116	1.5715	0.4124	0.8603	0.3564	0.2875	0.2207	0.0645
	*										
Lb Out	*										
Gas	*	0.7471	0.6069	0.5928	0.8784	0.7560	0.8082	0.8574	0.7079	0.8262	0.6655
Tar	*	0.0144	0.0189	0.0197	0.0115	0.0138	0.0123	0.0138	0.0149	0.0107	0.0157
Char	*	0.1901	0.2826	0.2901	0.1552	0.1990	0.1821	0.1441	0.2250	0.1727	0.2415
H2O	*	1.0211	0.4429	0.4104	1.5452	0.4446	0.8576	0.3596	0.3314	0.1931	0.1167
Closure	*	98.30	99.81	100.10	100.73	100.07	100.00	101.37	99.36	98.52	97.64
Water Conversion %	*	-1.42	-25.14	-31.70	1.68	-7.80	0.32	-0.90	-15.30	12.50	-80.92
Water Conver., lb/lb dry wood	*	-0.0143	-0.0890	-0.0988	0.0263	-0.0322	0.0027	-0.0032	-0.0440	0.0276	-0.0522

Item/Test		136	137	138	139	140	141	142	Avg	Std
Gasifier Conditions	*									
Temperature, deg F	*	1857	1839	1851	1316	1786	1687	1749		
Pressure, psig	*	6.3	7.6	6.7	13.1	3.6	5.2	3.8		
Moisture, wt %	*	5.92	7.71	8.01	13.67	12.30	33.85	10.00	9.2426	7.9281
Wet Wood Rate, lb/hr	*	391	429	336	2116	300	551	447		
Dry wood Rate, lb/hr	*	368	396	309	1827	263	364	402		
Nitrogen Rate, lb/hr	*	88	80	86	86	87	86	84		
Steam Rate, lb/hr	*	365	368	355	377	321	335	333		
Steam Rate, lb/lb BDW	*	0.992	0.929	1.149	0.206	1.221	0.920	0.828	0.9259	0.4474
Total H2O Rate, lb/lb BDW	*	1.054	1.013	1.236	0.365	1.361	1.434	0.940	1.0387	0.5054
Total H2O, lb/lb MAF wood	*	1.058	1.017	1.239	0.381	1.418	1.466	0.942	1.0481	0.5096
Total H2O, SCF/lb MAF wood	*	22.283	21.424	26.095	8.025	29.859	30.865	19.848	22.0740	10.7316
Feed	*									
Type	*	pine	pine	pine	sawdust	bark	hogfuel	pine		
Size	*	chips	chips	chips	Powder	chips	chips	chips		
Proximate Analysis	*									
Volatile Matter, wt % dry	*	84.39	87.08	85.70	80.45	80.23	81.02	85.70	83.44	3.17
Ash	*	0.35	0.46	0.23	4.33	3.99	2.15	0.23	0.89	0.93
Fixed Carbon	*	15.26	12.47	14.07	15.22	15.78	16.83	14.07	15.37	2.22
Proximate Analysis	*									
Moisture, wt %	*	5.92	7.71	8.01	13.67	12.30	33.85	10.00	9.24	7.93
Volatile Matter	*	79.39	80.37	78.84	69.45	70.36	53.59	77.13	75.80	7.83
Ash	*	0.33	0.42	0.21	3.74	3.50	1.42	0.21	0.79	0.81
Fixed Carbon	*	14.36	11.51	12.94	13.14	13.84	11.13	12.66	13.88	1.80
Ultimate Analysis	*									
Ash, wt % dry	*	0.35	0.46	0.23	4.33	3.99	2.15	0.23	0.89	0.93
Carbon	*	52.48	51.55	51.58	53.10	50.35	50.73	51.58	50.89	2.36
Hydrogen	*	5.99	5.98	5.78	6.04	5.83	5.71	5.78	6.04	0.26
Nitrogen	*	0.05	0.11	0.06	0.17	0.11	0.33	0.06	0.17	0.08
Chlorine	*	0.01	0.02	0.02	0.03	0.03	0.03	0.02	0.03	0.01
Sulfur	*	0.48	0.02	0.01	0.02	0.07	0.05	0.01	0.09	0.16
Oxygen (diff)	*	40.64	41.86	42.32	36.31	39.62	41.00	42.32	41.90	2.48

Item/Test	136	137	138	139	140	141	142	Avg	Std
Product Gas									
Rate, SCF/lb MAF	20.02	21.08	21.43	9.85	19.60	14.84	15.97		
Rate, SCF/ lb BDW	19.95	20.98	21.38	9.42	18.82	14.52	15.93		
Dry N2 Free Comp									
H2, mole %	35.57	33.31	33.89	13.03	30.48	32.25	27.86		
CO	39.74	41.64	42.42	54.79	40.41	36.03	45.30		
CO2	10.43	9.65	8.95	12.13	10.89	14.75	9.19		
CH4	12.54	12.93	12.80	14.74	13.43	12.33	13.83		
C2H2	0.39	0.47	0.35	0.00	1.08	0.48	0.44		
C2H4	1.33	2.00	1.59	3.63	3.25	4.16	3.38		
C2H6	0.00	0.00	0.00	1.68	0.46	0.00	0.00		
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	100.00	100.00	100.00	100.00	100.00	100.00	100.00		
MW, lb/lbmole	18.925	19.340	19.095	24.836	20.212	20.504	20.576		
HHV, Btu/lb mole	150,310.65	155,850.24	153,855.85	172,383.40	166,869.63	158,585.36	165,255.73		
HHV, Btu/lb	7,942.41	8,058.52	8,057.48	6,940.82	8,255.98	7,734.41	8,031.32		
HHV, Btu/SCF @ 60 deg F	396.18	410.78	405.52	454.36	439.83	417.99	435.57		
C, lb/lbmole	7.9454	8.3069	8.1736	11.0839	8.9255	8.6949	9.1237		
C, lb/lb gas	0.4198	0.4295	0.4281	0.4463	0.4416	0.4241	0.4434		
C, lb/SCF	0.0209	0.0219	0.0215	0.0292	0.0235	0.0229	0.0240		
C, lb/lb MAF wood	0.4193	0.4615	0.4617	0.2878	0.4611	0.3401	0.3840		
C Conv to Gas, %	79.6095	89.1214	89.3010	51.8457	87.9240	65.5988	74.2841		
H, lb/lb mole	1.2841	1.2829	1.2704	1.1049	1.3365	1.3246	1.2643		
H, lb/lb gas	0.0678	0.0663	0.0665	0.0445	0.0661	0.0646	0.0614		
H, lb/SCF	0.0034	0.0034	0.0033	0.0029	0.0035	0.0035	0.0033		
H, lb/lb MAF wood	0.0678	0.0713	0.0718	0.0287	0.0690	0.0518	0.0532		
H Conv to Gas, wt %	112.7208	118.6444	123.8576	45.4344	113.7019	88.7851	91.8614		
Tar Estimate									
Yield, lb/lb maf feed	0.0089	0.0092	0.0090	0.0197	0.0103	0.0123	0.0110		
Eq Tar=0.046-.00002*Temp									
Comp									
C3H6, LB/lb maf wood	0.002215	0.002305	0.002245	0.00492	0.00257	0.003065	0.002755		
C6H6	0.002215	0.002305	0.002245	0.00492	0.00257	0.003065	0.002755		
C10H8	0.002215	0.002305	0.002245	0.00492	0.00257	0.003065	0.002755		
C14H10	0.002215	0.002305	0.002245	0.00492	0.00257	0.003065	0.002755		
lb C/lb maf wood	0.0064	0.0067	0.0065	0.0142	0.0074	0.0089	0.0080		
lb H/lb maf wood	0.0025	0.0026	0.0025	0.0055	0.0029	0.0034	0.0031		
lb C/lb dry wood	0.0064	0.0066	0.0065	0.0136	0.0071	0.0087	0.0079		
lb H/lb dry wood	0.0025	0.0026	0.0025	0.0052	0.0027	0.0033	0.0031		

Item/Test		136	137	138	139	140	141	142	Avg	Std
Basis: 1 lb dry wood										
Char estimate, Let C=86, H=4, O=										
lb Ash	*	0.0035	0.0046	0.0023	0.0433	0.0399	0.0215	0.0023		
lb C	*									
In	*	0.5248	0.5155	0.5158	0.5310	0.5035	0.5073	0.5158		
Out in Gas	*	0.4178	0.4594	0.4606	0.2753	0.4427	0.3328	0.3832		
Out in Tar	*	0.0064	0.0066	0.0065	0.0136	0.0071	0.0087	0.0079		
Out in Char	*	0.1006	0.0495	0.0487	0.2421	0.0537	0.1659	0.1247		
	*									
H in char	*	0.0072	0.0035	0.0035	0.0173	0.0038	0.0118	0.0089		
H in gas	*	0.0675	0.0709	0.0716	0.0274	0.0663	0.0507	0.0531		
H in tar	*	0.0025	0.0026	0.0025	0.0052	0.0027	0.0033	0.0031		
H In	*	0.1779	0.1731	0.1961	0.1012	0.2106	0.2176	0.1630		
H in Steam	*	0.1007	0.0961	0.1186	0.0512	0.1377	0.1517	0.0980		
lb H2O	*	0.9001	0.8586	1.0596	0.4577	1.2310	1.3556	0.8754		
	*									
Lb in	*									
Dry Wood	*	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000		
Water	*	1.0543	1.0126	1.2362	0.3645	1.3612	1.4341	0.9403		
	*									
Lb Out	*									
Gas	*	0.9951	1.0696	1.0761	0.6169	1.0025	0.7848	0.8641		
Tar	*	0.0088	0.0092	0.0090	0.0188	0.0099	0.0120	0.0110		
Char	*	0.1219	0.0628	0.0596	0.3281	0.1030	0.2166	0.1490		
H2O	*	0.9001	0.8586	1.0596	0.4577	1.2310	1.3556	0.8754		
Closure	*	98.62	99.38	98.57	104.18	99.37	97.33	97.90	98.56	1.79
Water Conversion %	*	14.63	15.21	14.29	-25.57	9.56	5.47	6.90		
Water Conver., lb/lb dry wood	*	0.1543	0.1540	0.1766	-0.0932	0.1302	0.0785	0.0649		

APPENDIX 8

BCL LEAST SQUARES FITS

1. Dry Gas Yield, SCF/MAF lb

Regression Output:		
Constant		28.99260129
Std Err of Y Est		0.947115477
R Squared		0.938118681
No. of Observations		37
Degrees of Freedom		34
X Coefficient(s)	-0.04332509	0.000020966
Std Err of Coef.	0.020685743	6.5312E-06
t Value	-2.09444215	3.210111277
	2.015061631	2.969444219
t Probability	0.021949226	0.0014916
F Value	257.7194211	
	0.111111111	
	0.006535948	
	8.838240047	
F Probability	1.4827E-17	

2. Gas Yield, lb/lb dry wood

Regression Output:		
Constant		0.155529322
Std Err of Y Est		0.059060263
R Squared		0.872020662
No. of Observations		37
Degrees of Freedom		34
X Coefficient(s)	-0.00022057	3.7617E-07
Std Err of Coef.	0.001289922	4.0728E-07
t Value	-0.1709956	0.923630659
	0.169701795	0.91114171
t Probability	0.432622395	0.18111047
F Value	115.8339428	
	0.111111111	
	0.006535948	
	7.641883919	
F Probability	4.3112E-14	

3. Tar Yield, lb/lb dry wood

Regression Output:		
Constant		0.045494068
Std Err of Y Est		0.000118381
R Squared		0.9985358
No. of Observations		37
Degrees of Freedom		35
X Coefficient(s)	-1.9759E-05	
Std Err of Coef.	1.2789E-07	
t Value	-154.495416	
	8.29468485	
t Probability	5.6747E-16	

TABLE 7 (CONT.)

4. Char Yield, lb/lb dry wood

Regression Output:

Constant		0.755025269
Std Err of Y Est		0.046192661
R Squared		0.654807013
No. of Observations		37
Degrees of Freedom		34
X Coefficient(s)	-0.00030212	-3.1178E-08
Std Err of Coef.	0.001008884	3.1854E-07
t Value	-0.29946257	-0.0978786
	0.29706482	0.097152064
t Probability	0.383208421	0.461302946
F Value	32.24781398	
	0.111111111	
	0.006535948	
	5.388529103	
F Probability	3.8988E-08	

5. H2, mole %

Regression Output:

Constant		17.9961
Std Err of Y Est		1.5945
R Squared		0.9178
No. of Observations		37.0000
Degrees of Freedom		34.0000
X Coefficient(s)	-0.02644794	0.00001893
Std Err of Coef.	0.034824711	0.000010995
t Value	-0.7594591	1.721579457
	0.750697843	1.67285326
t Probability	0.226417374	0.047178091
F Value	189.8141747	
	0.111111111	
	0.006535948	
	8.407872216	
F Probability	2.6612E-16	

6. CO, mole %

Regression Output:

Constant		133.4594
Std Err of Y Est		2.4738
R Squared		0.3974
No. of Observations		37.0000
Degrees of Freedom		34.0000
X Coefficient(s)	-0.10290149	0.000028792
Std Err of Coef.	0.054029627	0.000017059
t Value	-1.9045382	1.687769178
	1.842043231	1.641333522
t Probability	0.032734507	0.050364078
F Value	11.21026844	
	0.111111111	
	0.006535948	
	3.51363458	
F Probability	0.000221109	

7. CO_2, mole %

Regression Output:

Constant		-9.5251
Std Err of Y Est		1.8040
R Squared		0.4174
No. of Observations		37.0000
Degrees of Freedom		34.0000
X Coefficient(s)	0.037888569	-1.4927E-05
Std Err of Coef.	0.039401634	0.000012441
t Value	0.961598939	-1.19987957
	0.948103907	1.178645015
t Probability	0.171538376	0.119269716
F Value	12.17966128	
	0.111111111	
	0.006535948	
	3.654061653	
F Probability	0.000129184	

8. CH_4, mole %

Regression Output:

Constant		-13.8203
Std Err of Y Est		0.7822
R Squared		0.6933
No. of Observations		37.0000
Degrees of Freedom		34.0000
X Coefficient(s)	0.044178788	-1.6167E-05
Std Err of Coef.	0.0170848	5.3943E-06
t Value	2.585853318	-2.99706996
	2.449242287	2.796085158
t Probability	0.007157811	0.002586159
F Value	38.43244924	
	0.111111111	
	0.006535948	
	5.708786026	
F Probability	6.6430E-09	

9. C_2H_2, mole %

Regression Output:

Constant		-4.31140373
Std Err of Y Est		0.056156337
R Squared		0.716618516
No. of Observations		22
Degrees of Freedom		19
X Coefficient(s)	0.005449933	-1.5610E-06
Std Err of Coef.	0.001564876	4.8968E-07
t Value	3.482660609	-3.18792205
	2.992308924	2.794416185
t Probability	0.001384292	0.002599547
F Value	24.02371458	
	0.111111111	
	0.011695906	
	4.291022394	
F Probability	8.9728E-06	

10. C2H4, mole %

Regression Output:		
Constant		-38.2576352
Std Err of Y Est		0.322371315
R Squared		0.876167713
No. of Observations		37
Degrees of Freedom		34
X Coefficient(s)	0.058434712	-1.9868E-05
Std Err of Coef.	0.007040842	2.2231E-06
t Value	8.299392915	-8.93736877
	5.806651565	6.016020731
t Probability	3.8117E-09	1.1365E-09
F Value	120.2824517	
	0.111111111	
	0.006535948	
	7.703145134	
F Probability	2.8817E-14	

11. C2H6, mole %

Regression Output:		
Constant		11.11368612
Std Err of Y Est		0.134430177
R Squared		0.852017036
No. of Observations		37
Degrees of Freedom		34
X Coefficient(s)	-0.01166677	3.0640E-06
Std Err of Coef.	0.00293606	9.2702E-07
t Value	-3.97361304	3.305165152
	3.553365071	3.04535283
t Probability	0.000190275	0.001161968
F Value	97.87808856	
	0.111111111	
	0.006535948	
	7.363029758	
F Probability	2.6634E-13	

12. H2O Conv, %

Regression Output:		
Constant		0.289594752
Std Err of Y Est		0.032742674
R Squared		0.841575638
No. of Observations		47
Degrees of Freedom		44
X Coefficient(s)	-8.9048E-04	4.3384E-07
Std Err of Coef.	5.8863E-04	1.8809E-07
t Value	-1.5128183	2.306574776
	1.485035998	2.227133353
t Probability	0.068767037	0.012969253
F Value	116.8675309	
	0.111111111	
	0.005050505	
	8.237266254	
F Probability	8.3280E-16	

APPENDIX 9

FEED ANALYSIS AND YIELD CORRELATIONS

Feed		
Proximate Analysis		
Volatile Matter, wt % dry	83.44	
Ash	0.89	
Fixed Carbon	15.37	
Proximate Analysis		
Moisture, wt %	9.24	
Volatile Matter	75.80	
Ash	0.79	
Fixed Carbon	13.88	
Ultimate Analysis	Dry	MAF
Ash, wt % dry	0.89	
Carbon	50.89	51.35
Hydrogen	6.04	6.10
Nitrogen	0.17	0.17
Chlorine	0.03	0.03
Sulfur	0.09	0.09
Oxygen (diff)	41.90	42.28
HHV, Btu/lb		
IGT	8,726	
Boie	8,539	
New	8,608	
Total Water, lb/lb dry wood	0.500	
Feed Moisture, %	9.243	
Feed Moisture, lb/lb dry wood	0.102	
Steam, lb/lb dry wood	0.398	
Total feed, lb/lb dry wood	1.500	
Plant Size, dTPD	2000	
Dry wood rate, lb/hr	166,666.667	
Moisture, lb/hr	16,972.993	
Steam, lb/hr	66,360.340	
Total, lb/hr	250,000.000	

Variable	Units	A	B	C
H2O Conversion	lb/lb Dry wood	2.8959E-01	-8.9048E-04	4.3384E-07
Dry Gas	SCF/lb MAF wood	2.8993E+01	-4.3325E-02	2.0966E-05
Gas	lb/lb dry wood	1.5553E-01	-2.2057E-04	3.7617E-07
Tar	lb/lb dry wood	4.5494E-02	-1.9759E-05	
Char	lb/ln dry wood	7.5503E-01	-3.0212E-04	-3.1178E-08
H2	mole %	1.7996E+01	-2.6448E-02	1.8930E-05
CO	mole %	1.3346E+02	-1.0290E-01	2.8792E-05
CO2	mole %	-9.5251E+00	3.7889E-02	-1.4927E-05
CH4	mole %	-1.3820E+01	4.4179E-02	-1.6167E-05
C2H2	mole %	-4.3114E+00	5.4499E-03	-1.5610E-06
C2H4	mole %	-3.8258E+01	5.8435E-02	-1.9868E-05
C2H6	mole %	1.1114E+01	-1.1667E-02	3.0640E-06

$$X = A + BT + CT^2$$

APPENDIX 10

ASPEN INPUT FILE: BCL RECYCLE CASE

	1300	1325	1350	1375	1400
H2, lb/lb total feed	4.3388E-03	4.7025E-03	5.0966E-03	5.5234E-03	5.9853E-03
CO	1.8679E-01	1.9242E-01	1.9830E-01	2.0447E-01	2.1092E-01
CO2	8.8040E-02	9.1789E-02	9.5561E-02	9.9345E-02	1.0313E-01
CH4	3.6046E-02	3.7766E-02	3.9513E-02	4.1285E-02	4.3078E-02
C2H2	4.8608E-04	6.3477E-04	7.8808E-04	9.4574E-04	1.1074E-03
C2H4	1.5982E-02	1.7335E-02	1.8669E-02	1.9976E-02	2.1246E-02
C2H6	4.6650E-03	4.4820E-03	4.2899E-03	4.0892E-03	3.8805E-03
C3H6	3.3012E-03	3.2189E-03	3.1366E-03	3.0542E-03	2.9719E-03
C6H6	3.3012E-03	3.2189E-03	3.1366E-03	3.0542E-03	2.9719E-03
C10H8	3.3012E-03	3.2189E-03	3.1366E-03	3.0542E-03	2.9719E-03
C14H10	3.3012E-03	3.2189E-03	3.1366E-03	3.0542E-03	2.9719E-03
H2O	4.4407E-01	4.3801E-01	4.3167E-01	4.2505E-01	4.1813E-01
Ash	5.9191E-03	5.9191E-03	5.9191E-03	5.9191E-03	5.9191E-03
Char, MAF	2.0046E-01	1.9406E-01	1.8764E-01	1.8119E-01	1.7471E-01
Total	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00

	1300	1325	1350	1375	1400
H2, moles/lb feed	2.1524E-03	2.3328E-03	2.5283E-03	2.7400E-03	2.9692E-03
CO	6.6684E-03	6.8695E-03	7.0796E-03	7.2996E-03	7.5302E-03
CO2	2.0005E-03	2.0856E-03	2.1713E-03	2.2573E-03	2.3433E-03
CH4	2.2469E-03	2.3541E-03	2.4630E-03	2.5734E-03	2.6852E-03
C2H2	1.8668E-05	2.4378E-05	3.0266E-05	3.6321E-05	4.2532E-05
C2H4	5.6969E-04	6.1790E-04	6.6547E-04	7.1207E-04	7.5734E-04
C2H6	1.5517E-04	1.4908E-04	1.4269E-04	1.3602E-04	1.2908E-04
C3H6	8.4523E-05	8.2415E-05	8.0307E-05	7.8199E-05	7.6091E-05
C6H6	4.2261E-05	4.1207E-05	4.0153E-05	3.9099E-05	3.8046E-05
C10H8	3.1094E-05	3.0319E-05	2.9543E-05	2.8768E-05	2.7992E-05
C14H10	1.8522E-05	1.8060E-05	1.7598E-05	1.7136E-05	1.6674E-05
H2O	2.4650E-02	2.4314E-02	2.3962E-02	2.3594E-02	2.3210E-02
	--------	--------	--------	--------	--------
	3.8638E-02	3.8919E-02	3.9210E-02	3.9512E-02	3.9826E-02

	1300	1325	1350	1375	1400
H2, mole %	5.57	5.99	6.45	6.93	7.46
CO	17.26	17.65	18.06	18.47	18.91
CO2	5.18	5.36	5.54	5.71	5.88
CH4	5.82	6.05	6.28	6.51	6.74
C2H2	0.05	0.06	0.08	0.09	0.11
C2H4	1.47	1.59	1.70	1.80	1.90
C2H6	0.40	0.38	0.36	0.34	0.32
C3H6	0.22	0.21	0.20	0.20	0.19
C6H6	0.11	0.11	0.10	0.10	0.10
C10H8	0.08	0.08	0.08	0.07	0.07
C14H10	0.05	0.05	0.04	0.04	0.04
H2O	63.80	62.47	61.11	59.71	58.28
	-------	-------	-------	-------	-------
	100.00	100.00	100.00	100.00	100.00

Recycle Gas, Assume C6+removed, Sat with H2O at 20 psia, 100 deg F

	1300	1325	1350	1375	1400
MF	0.36	0.37	0.39	0.40	0.42
Dry Gas					
H2, mole %	15.49	16.07	16.68	17.31	17.96
CO	47.99	47.32	46.70	46.10	45.55
CO2	14.40	14.37	14.32	14.26	14.17
CH4	16.17	16.22	16.25	16.25	16.24
C2H2	0.13	0.17	0.20	0.23	0.26
C2H4	4.10	4.26	4.39	4.50	4.58
C2H6	1.12	1.03	0.94	0.86	0.78
C3H6	0.61	0.57	0.53	0.49	0.46
Total	100.00	100.00	100.00	100.00	100.00

p* H2O at 100 deg F =	0.9487				
f H2O	0.047435				
Sat Gas Analysis					
H2, mole %	14.75	15.31	15.89	16.48	17.11
CO	45.71	45.08	44.48	43.92	43.39
CO2	13.71	13.69	13.64	13.58	13.50
CH4	15.40	15.45	15.47	15.48	15.47
C2H2	0.13	0.16	0.19	0.22	0.25
C2H4	3.91	4.05	4.18	4.28	4.36
C2H6	1.06	0.98	0.90	0.82	0.74
C3H6	0.58	0.54	0.50	0.47	0.44
H2O	4.74	4.74	4.74	4.74	4.74
	-----	-----	-----	-----	-----
Total	100.00	100.00	100.00	100.00	100.00

	1425	1450	1475	1500	1525
H2, lb/lb total feed	6.4850E-03	7.0252E-03	7.6089E-03	8.2394E-03	8.9202E-03
CO	2.1770E-01	2.2483E-01	2.3233E-01	2.4025E-01	2.4860E-01
CO2	1.0690E-01	1.1065E-01	1.1436E-01	1.1802E-01	1.2160E-01
CH4	4.4890E-02	4.6714E-02	4.8549E-02	5.0388E-02	5.2227E-02
C2H2	1.2728E-03	1.4415E-03	1.6130E-03	1.7868E-03	1.9624E-03
C2H4	2.2468E-02	2.3629E-02	2.4717E-02	2.5718E-02	2.6615E-02
C2H6	3.6645E-03	3.4421E-03	3.2140E-03	2.9813E-03	2.7452E-03
C3H6	2.8896E-03	2.8072E-03	2.7249E-03	2.6426E-03	2.5603E-03
C6H6	2.8896E-03	2.8072E-03	2.7249E-03	2.6426E-03	2.5603E-03
C10H8	2.8896E-03	2.8072E-03	2.7249E-03	2.6426E-03	2.5603E-03
C14H10	2.8896E-03	2.8072E-03	2.7249E-03	2.6426E-03	2.5603E-03
H2O	4.1093E-01	4.0344E-01	3.9566E-01	3.8760E-01	3.7924E-01
Ash	5.9191E-03	5.9191E-03	5.9191E-03	5.9191E-03	5.9191E-03
Char, MAF	1.6821E-01	1.6168E-01	1.5512E-01	1.4854E-01	1.4193E-01
Total	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00
H2, moles/lb feed	3.2171E-03	3.4851E-03	3.7746E-03	4.0874E-03	4.4251E-03
CO	7.7722E-03	8.0266E-03	8.2945E-03	8.5769E-03	8.8751E-03
CO2	2.4291E-03	2.5143E-03	2.5985E-03	2.6816E-03	2.7629E-03
CH4	2.7981E-03	2.9119E-03	3.0262E-03	3.1409E-03	3.2555E-03
C2H2	4.8883E-05	5.5360E-05	6.1946E-05	6.8622E-05	7.5365E-05
C2H4	8.0088E-04	8.4228E-04	8.8106E-04	9.1672E-04	9.4871E-04
C2H6	1.2189E-04	1.1449E-04	1.0691E-04	9.9167E-05	9.1312E-05
C3H6	7.3983E-05	7.1875E-05	6.9767E-05	6.7659E-05	6.5551E-05
C6H6	3.6992E-05	3.5938E-05	3.4884E-05	3.3830E-05	3.2776E-05
C10H8	2.7217E-05	2.6441E-05	2.5666E-05	2.4891E-05	2.4115E-05
C14H10	1.6212E-05	1.5750E-05	1.5288E-05	1.4826E-05	1.4364E-05
H2O	2.2810E-02	2.2394E-02	2.1963E-02	2.1515E-02	2.1051E-02
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	4.0153E-02	4.0494E-02	4.0852E-02	4.1227E-02	4.1622E-02
H2, mole %	8.01	8.61	9.24	9.91	10.63
CO	19.36	19.82	20.30	20.80	21.32
CO2	6.05	6.21	6.36	6.50	6.64
CH4	6.97	7.19	7.41	7.62	7.82
C2H2	0.12	0.14	0.15	0.17	0.18
C2H4	1.99	2.08	2.16	2.22	2.28
C2H6	0.30	0.28	0.26	0.24	0.22
C3H6	0.18	0.18	0.17	0.16	0.16
C6H6	0.09	0.09	0.09	0.08	0.08
C10H8	0.07	0.07	0.06	0.06	0.06
C14H10	0.04	0.04	0.04	0.04	0.03
H2O	56.81	55.30	53.76	52.19	50.58
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	100.00	100.00	100.00	100.00	100.00

Recycle Gas

	1425	1450	1475	1500	1525
MF	0.43	0.45	0.46	0.48	0.49
Dry Gas					
H2, mole %	18.64	19.34	20.06	20.81	21.59
CO	45.02	44.54	44.09	43.67	43.29
CO2	14.07	13.95	13.81	13.65	13.48
CH4	16.21	16.16	16.09	15.99	15.88
C2H2	0.28	0.31	0.33	0.35	0.37
C2H4	4.64	4.67	4.68	4.67	4.63
C2H6	0.71	0.64	0.57	0.50	0.45
C3H6	0.43	0.40	0.37	0.34	0.32
Total	100.00	100.00	100.00	100.00	100.00
Sat Gas Analysis					
H2, mole %	17.75	18.42	19.11	19.83	20.56
CO	42.89	42.43	42.00	41.60	41.24
CO2	13.40	13.29	13.16	13.01	12.84
CH4	15.44	15.39	15.32	15.23	15.13
C2H2	0.27	0.29	0.31	0.33	0.35
C2H4	4.42	4.45	4.46	4.45	4.41
C2H6	0.67	0.61	0.54	0.48	0.42
C3H6	0.41	0.38	0.35	0.33	0.30
H2O	4.74	4.74	4.74	4.74	4.74
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Total	100.00	100.00	100.00	100.00	100.00

	1550	1575	1600	1625	1650
H2, lb/lb total feed	9.6550E-03	1.0448E-02	1.1303E-02	1.2226E-02	1.3220E-02
CO	2.5743E-01	2.6678E-01	2.7669E-01	2.8721E-01	2.9839E-01
CO2	1.2509E-01	1.2846E-01	1.3171E-01	1.3479E-01	1.3769E-01
CH4	5.4059E-02	5.5879E-02	5.7680E-02	5.9455E-02	6.1195E-02
C2H2	2.1391E-03	2.3163E-03	2.4932E-03	2.6690E-03	2.8428E-03
C2H4	2.7392E-02	2.8031E-02	2.8512E-02	2.8812E-02	2.8909E-02
C2H6	2.5068E-03	2.2677E-03	2.0294E-03	1.7935E-03	1.5622E-03
C3H6	2.4779E-03	2.3956E-03	2.3133E-03	2.2309E-03	2.1486E-03
C6H6	2.4779E-03	2.3956E-03	2.3133E-03	2.2309E-03	2.1486E-03
C10H8	2.4779E-03	2.3956E-03	2.3133E-03	2.2309E-03	2.1486E-03
C14H10	2.4779E-03	2.3956E-03	2.3133E-03	2.2309E-03	2.1486E-03
H2O	3.7060E-01	3.6168E-01	3.5246E-01	3.4296E-01	3.3317E-01
Ash	5.9191E-03	5.9191E-03	5.9191E-03	5.9191E-03	5.9191E-03
Char, MAF	1.3530E-01	1.2864E-01	1.2196E-01	1.1524E-01	1.0851E-01
Total	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00
H2, moles/lb feed	4.7897E-03	5.1830E-03	5.6073E-03	6.0649E-03	6.5583E-03
CO	9.1904E-03	9.5241E-03	9.8780E-03	1.0254E-02	1.0653E-02
CO2	2.8422E-03	2.9190E-03	2.9926E-03	3.0627E-03	3.1286E-03
CH4	3.3697E-03	3.4831E-03	3.5954E-03	3.7060E-03	3.8145E-03
C2H2	8.2152E-05	8.8958E-05	9.5752E-05	1.0250E-04	1.0918E-04
C2H4	9.7642E-04	9.9919E-04	1.0163E-03	1.0270E-03	1.0305E-03
C2H6	8.3384E-05	7.5430E-05	6.7502E-05	5.9658E-05	5.1962E-05
C3H6	6.3443E-05	6.1336E-05	5.9228E-05	5.7120E-05	5.5012E-05
C6H6	3.1722E-05	3.0668E-05	2.9614E-05	2.8560E-05	2.7506E-05
C10H8	2.3340E-05	2.2564E-05	2.1789E-05	2.1013E-05	2.0238E-05
C14H10	1.3903E-05	1.3441E-05	1.2979E-05	1.2517E-05	1.2055E-05
H2O	2.0572E-02	2.0076E-02	1.9565E-02	1.9037E-02	1.8494E-02
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	4.2038E-02	4.2477E-02	4.2941E-02	4.3433E-02	4.3954E-02
H2, mole %	11.39	12.20	13.06	13.96	14.92
CO	21.86	22.42	23.00	23.61	24.24
CO2	6.76	6.87	6.97	7.05	7.12
CH4	8.02	8.20	8.37	8.53	8.68
C2H2	0.20	0.21	0.22	0.24	0.25
C2H4	2.32	2.35	2.37	2.36	2.34
C2H6	0.20	0.18	0.16	0.14	0.12
C3H6	0.15	0.14	0.14	0.13	0.13
C6H6	0.08	0.07	0.07	0.07	0.06
C10H8	0.06	0.05	0.05	0.05	0.05
C14H10	0.03	0.03	0.03	0.03	0.03
H2O	48.94	47.26	45.56	43.83	42.07
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	100.00	100.00	100.00	100.00	100.00

	1550	1575	1600	1625	1650
Recycle gas					
MF	0.51	0.53	0.54	0.56	0.58
Dry Gas					
H2, mole %	22.38	23.21	24.05	24.92	25.82
CO	42.95	42.64	42.37	42.14	41.94
CO2	13.28	13.07	12.84	12.59	12.32
CH4	15.75	15.60	15.42	15.23	15.02
C2H2	0.38	0.40	0.41	0.42	0.43
C2H4	4.56	4.47	4.36	4.22	4.06
C2H6	0.39	0.34	0.29	0.25	0.20
C3H6	0.30	0.27	0.25	0.23	0.22
Total	100.00	100.00	100.00	100.00	100.00
Sat Gas Analysis					
H2, mole %	21.32	22.11	22.91	23.74	24.59
CO	40.91	40.62	40.36	40.14	39.95
CO2	12.65	12.45	12.23	11.99	11.73
CH4	15.00	14.86	14.69	14.51	14.30
C2H2	0.37	0.38	0.39	0.40	0.41
C2H4	4.35	4.26	4.15	4.02	3.86
C2H6	0.37	0.32	0.28	0.23	0.19
C3H6	0.28	0.26	0.24	0.22	0.21
H2O	4.74	4.74	4.74	4.74	4.74
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Total	100.00	100.00	100.00	100.00	100.00

	1675	1700	1725	1750	1775
H_2, lb/lb total feed	1.4293E-02	1.5449E-02	1.6696E-02	1.8041E-02	1.9491E-02
CO	3.1029E-01	3.2297E-01	3.3650E-01	3.5096E-01	3.6641E-01
CO_2	1.4038E-01	1.4282E-01	1.4498E-01	1.4683E-01	1.4832E-01
CH_4	6.2892E-02	6.4537E-02	6.6118E-02	6.7624E-02	6.9043E-02
C_2H_2	3.0135E-03	3.1800E-03	3.3412E-03	3.4956E-03	3.6418E-03
C_2H_4	2.8776E-02	2.8384E-02	2.7704E-02	2.6700E-02	2.5336E-02
C_2H_6	1.3374E-03	1.1215E-03	9.1710E-04	7.2710E-04	5.5464E-04
C_3H_6	2.0663E-03	1.9839E-03	1.9016E-03	1.8193E-03	1.7370E-03
C_6H_6	2.0663E-03	1.9839E-03	1.9016E-03	1.8193E-03	1.7370E-03
$C_{10}H_8$	2.0663E-03	1.9839E-03	1.9016E-03	1.8193E-03	1.7370E-03
$C_{14}H_{10}$	2.0663E-03	1.9839E-03	1.9016E-03	1.8193E-03	1.7370E-03
H_2O	3.2309E-01	3.1273E-01	3.0207E-01	2.9113E-01	2.7991E-01
Ash	5.9191E-03	5.9191E-03	5.9191E-03	5.9191E-03	5.9191E-03
Char, MAF	1.0174E-01	9.4955E-02	8.8139E-02	8.1298E-02	7.4431E-02
Total	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00	1.0000E+00
H_2, moles/lb feed	7.0904E-03	7.6641E-03	8.2827E-03	8.9497E-03	9.6690E-03
CO	1.1078E-02	1.1530E-02	1.2013E-02	1.2529E-02	1.3081E-02
CO_2	3.1897E-03	3.2451E-03	3.2943E-03	3.3363E-03	3.3701E-03
CH_4	3.9203E-03	4.0228E-03	4.1213E-03	4.2152E-03	4.3037E-03
C_2H_2	1.1573E-04	1.2213E-04	1.2832E-04	1.3425E-04	1.3987E-04
C_2H_4	1.0257E-03	1.0118E-03	9.8751E-04	9.5174E-04	9.0312E-04
C_2H_6	4.4484E-05	3.7303E-05	3.0505E-05	2.4185E-05	1.8449E-05
C_3H_6	5.2904E-05	5.0796E-05	4.8688E-05	4.6580E-05	4.4472E-05
C_6H_6	2.6452E-05	2.5398E-05	2.4344E-05	2.3290E-05	2.2236E-05
$C_{10}H_8$	1.9462E-05	1.8687E-05	1.7911E-05	1.7136E-05	1.6360E-05
$C_{14}H_{10}$	1.1593E-05	1.1131E-05	1.0669E-05	1.0207E-05	9.7453E-06
H_2O	1.7934E-02	1.7359E-02	1.6768E-02	1.6160E-02	1.5537E-02
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	4.4509E-02	4.5099E-02	4.5727E-02	4.6398E-02	4.7115E-02
H_2, mole %	15.93	16.99	18.11	19.29	20.52
CO	24.89	25.57	26.27	27.00	27.76
CO_2	7.17	7.20	7.20	7.19	7.15
CH_4	8.81	8.92	9.01	9.08	9.13
C_2H_2	0.26	0.27	0.28	0.29	0.30
C_2H_4	2.30	2.24	2.16	2.05	1.92
C_2H_6	0.10	0.08	0.07	0.05	0.04
C_3H_6	0.12	0.11	0.11	0.10	0.09
C_6H_6	0.06	0.06	0.05	0.05	0.05
$C_{10}H_8$	0.04	0.04	0.04	0.04	0.03
$C_{14}H_{10}$	0.03	0.02	0.02	0.02	0.02
H_2O	40.29	38.49	36.67	34.83	32.98
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	100.00	100.00	100.00	100.00	100.00

Recycle Gas

	1675	1700	1725	1750	1775
MF	0.60	0.61	0.63	0.65	0.67
Dry Gas					
H2, mole %	26.74	27.68	28.65	29.65	30.67
CO	41.78	41.65	41.56	41.51	41.49
CO2	12.03	11.72	11.40	11.05	10.69
CH4	14.78	14.53	14.26	13.96	13.65
C2H2	0.44	0.44	0.44	0.44	0.44
C2H4	3.87	3.65	3.42	3.15	2.86
C2H6	0.17	0.13	0.11	0.08	0.06
C3H6	0.20	0.18	0.17	0.15	0.14
Total	100.00	100.00	100.00	100.00	100.00
Sat Gas Analysis					
H2, mole %	25.47	26.37	27.29	28.24	29.21
CO	39.79	39.67	39.59	39.54	39.52
CO2	11.46	11.17	10.86	10.53	10.18
CH4	14.08	13.84	13.58	13.30	13.00
C2H2	0.42	0.42	0.42	0.42	0.42
C2H4	3.68	3.48	3.25	3.00	2.73
C2H6	0.16	0.13	0.10	0.08	0.06
C3H6	0.19	0.17	0.16	0.15	0.13
H2O	4.74	4.74	4.74	4.74	4.74
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Total	100.00	100.00	100.00	100.00	100.00

	1800	1825	1850
H2, lb/lb total feed	2.1055E-02	2.2742E-02	2.4562E-02
CO	3.8296E-01	4.0069E-01	4.1973E-01
CO2	1.4941E-01	1.5005E-01	1.5018E-01
CH4	7.0362E-02	7.1564E-02	7.2633E-02
C2H2	3.7782E-03	3.9029E-03	4.0139E-03
C2H4	2.3571E-02	2.1361E-02	1.8656E-02
C2H6	4.0320E-04	2.7665E-04	1.7925E-04
C3H6	1.6546E-03	1.5723E-03	1.4900E-03
C6H6	1.6546E-03	1.5723E-03	1.4900E-03
C10H8	1.6546E-03	1.5723E-03	1.4900E-03
C14H10	1.6546E-03	1.5723E-03	1.4900E-03
H2O	2.6839E-01	2.5659E-01	2.4450E-01
Ash	5.9191E-03	5.9191E-03	5.9191E-03
Char, MAF	6.7538E-02	6.0619E-02	5.3674E-02
Total	1.0000E+00	1.0000E+00	1.0000E+00

H2, moles/lb feed	1.0445E-02	1.1282E-02	1.2185E-02
CO	1.3672E-02	1.4305E-02	1.4985E-02
CO2	3.3949E-03	3.4094E-03	3.4124E-03
CH4	4.3859E-03	4.4608E-03	4.5274E-03
C2H2	1.4510E-04	1.4989E-04	1.5415E-04
C2H4	8.4022E-04	7.6143E-04	6.6500E-04
C2H6	1.3411E-05	9.2020E-06	5.9625E-06
C3H6	4.2364E-05	4.0256E-05	3.8148E-05
C6H6	2.1182E-05	2.0128E-05	1.9074E-05
C10H8	1.5585E-05	1.4809E-05	1.4034E-05
C14H10	9.2834E-06	8.8215E-06	8.3596E-06
H2O	1.4898E-02	1.4243E-02	1.3572E-02
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	4.7883E-02	4.8704E-02	4.9586E-02

H2, mole %	21.81	23.16	24.57
CO	28.55	29.37	30.22
CO2	7.09	7.00	6.88
CH4	9.16	9.16	9.13
C2H2	0.30	0.31	0.31
C2H4	1.75	1.56	1.34
C2H6	0.03	0.02	0.01
C3H6	0.09	0.08	0.08
C6H6	0.04	0.04	0.04
C10H8	0.03	0.03	0.03
C14H10	0.02	0.02	0.02
H2O	31.11	29.24	27.37
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	100.00	100.00	100.00

Recycle Gas

	1800	1825	1850
MF	0.69	0.71	0.73
Dry Gas			
H2, mole %	31.71	32.78	33.87
CO	41.51	41.56	41.66
CO2	10.31	9.91	9.49
CH4	13.32	12.96	12.59
C2H2	0.44	0.44	0.43
C2H4	2.55	2.21	1.85
C2H6	0.04	0.03	0.02
C3H6	0.13	0.12	0.11
Total	100.00	100.00	100.00
Sat Gas Analysis			
H2, mole %	30.21	31.22	32.27
CO	39.54	39.59	39.68
CO2	9.82	9.44	9.04
CH4	12.68	12.35	11.99
C2H2	0.42	0.41	0.41
C2H4	2.43	2.11	1.76
C2H6	0.04	0.03	0.02
C3H6	0.12	0.11	0.10
H2O	4.74	4.74	4.74
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Total	100.00	100.00	100.00

APPENDIX 11

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NEW
TITLE  'INDIRECT GASIFIER - REFORMER - METHANOL SYNTHESIS '
;GASIFIER - BATTELLE COLUMBUS - RYIELD MODEL
;Low steam case
;REFORMER - EQUILIBRIUM MODEL. METHANOL - EQUILIBRIUM MODEL
;VERSION 2 - SAND RECYCLE, STEAM GENERATION
;UPDATED: November 4, 1991
;
IN-UNITS   ENG
OUT-UNITS  ENG
;
HISTORY  MSG-LEVEL  PROPERTIES=4  SIMULATION=4 STREAMS=4 SYSTEM=4
;
RUN-CONTROL      MAX-TIME=600
SIM-OPTIONS      SIZE-RESULTS = 0
;
STREAM-REPORT
     STREAMS ALL
     FLOW-FRAC  MIXED  BASES  = MOLE MOLE-FRAC
     INTENSIVE-PROPS  MIXED  PROPS=TEMP PRES MW ENTH DENS BASE =MOLE
     FLOW-FRAC CISOLID  BASES =  MASS
     INTENSIVE-PROPS CISOLID  PROPS=TEMP PRES ENTH DENS BASE=MASS
     FLOW-FRAC NCPSD  BASES   =  MASS
     INTENSIVE-PROPS NCPSD  PROPS=TEMP PRES ENTH DENS  BASE=MASS
;
;************    COMPONENTS AND PROPERTIES   *******************************
;
PROPERTIES    SYSOPO / SYSOP3R  LOOP2
;
COMPONENTS
  H2          H2          /
  CO          CO          /
  CO2         CO2         /
  H2O         H2O         /
  CH4         METHANE     /
  C2H2        ACETYLENE   /
  C2H4        ETHYLENE    /
  C2H6        ETHANE      /
  C3H6-2      PROPYLENE   /
  MEOH        CH4O        /
  O2          O2          /
  N2          N2          /
  C6H6        C6H6        /   ;  Benzene
  C10H8       C10H8       /   ;  Naphthalene
  C14H10-1    C14H10-1    /   ;  Anthracene
  C           C           /
  O2SI        O2SI        /
  CHAR                    /
  WOOD
;
ALIAS
  H2          H2          /
```

```
CO           CO           /
CO2          CO2          /
H2O          H2O          /
CH4          CH4          /
C2H2         C2H2         /
C2H4         C2H4         /
C2H6         C2H6         /
C3H6-2       C3H6-2       /
MEOH         CH4O         /
O2           O2           /
N2           N2           /
C6H6         C6H6         /
C10H8        C10H8        /
C14H10-1     C14H10-1     /
C            C            /
O2SI         O2SI         /
CHAR                      /
WOOD
;
Attr-Comps CHAR    Proxanal Ultanal Sulfanal Coalmisc Genanal
Attr-Comps WOOD    Proxanal Ultanal Sulfanal Coalmisc Genanal
;
Prop-Sources
   Global  ASPENPCD  Comps= CH4 H2 H2O CO2 CO O2 C6H6 C2H2 C2H4  &
                            C2H6 C3H6-2 N2 MEOH &
   Global  DIPPR     Comps= C10H8 C14H10-1 C O2SI
;
Nc-props  wood  enthalpy  hcjlboie  /  density  dnstygen
Nc-props  char  enthalpy  hcjlboie  /  density  dnstygen
;
Prop-data
   comp-list                   wood     char
      cval  dengen  1   1       440     1000
;
Prop-data
   Prop-List     BOIEC
                        C           H           S      O      N      BIAS
;
      Pval  Wood     154.8761    122.50632    0.0    0.0    0.0     0.0
      Pval  Char     154.8761    122.50632    0.0    0.0    0.0     0.0
;
Prop-Data
   Prop-List  MW  /  SPGR  / DHSFRM /  DGSFRM / VSPOLY / CPSP01
   PVAL   C  12.01115 / 2.2 / 0.   / 0.  / 0.0053 0.0 0.0 0.0 0.0 0.0 3000. /&
               1.7154e+4 4.268 0.0 0.0 -2.786e+8 0.0 3000.0
   Pval O2SI   60.086 / 2.2 / 0. / 0. / .02726 0. 0. 0. 0. 0. 3000. / &
               37713 0. 0. 0. 0. 0. 3000.
;
;**********************    FLOWSHEET    **************************************
;
;
FLOWSHEET  DRY
     DRYER        IN = WWOOD DRYGAS QNET  OUT = WETGAS  DWOOD        QDRYER
     STORE        IN = DWOOD              OUT = DWOOD2               QSTORE
```

```
FLOWSHEET  GASFER
    FEEDMIX     IN = STEAMG2  DWOOD2    OUT = FEEDG
    GASIFIER    IN = FEEDG              OUT = GPROD                  QGAS
    SOLSEP      IN = GPROD              OUT = SOLID1   GAS1
    SOLSP2      IN = GAS1               OUT = SOLID2   GAS1B
    HEAT1       IN = GAS1B    AIR1      OUT = GAS1C    AIR1A
    HEAT2       IN = GAS1C    STEAMG    OUT = GAS1D    STEAMG2
    HEAT3       IN = GAS1D    AIRT      OUT = GAS1E    AIRT2
    PUMPA       IN = CWATER             OUT = CWATER2                WPA
    HEAT3A      IN = GAS1E              OUT = GAS1F                  QHT3A
    HEAT4       IN = GAS1F              OUT = GAS1G                  QHT4
    AQUENCH     IN = GAS1G    CWATER2   OUT = scrub
    AHTR        IN = SCRUB              OUT = SCRUB2                 Qscrub
    AQSEP       IN = SCRUB2             OUT = GAS      LIQUOR        QSEP
    AQSEP2      IN = LIQUOR             OUT = WASTE    TARS
    AQSEP3      IN = WASTE              OUT = SGAS     WASTE2
    GASMIX1     IN = GAS      SGAS      OUT = SUMGAS
    RGHTX       IN = RCG3     RCG1      OUT = RCG4     RCG2
    RGCOMP      IN = RCG                OUT = RCG1                   WCRCG
    RGHEAT      IN = RCG2               OUT = RCG3                   QRCG
    RPUMP       IN = RGWAT              OUT = RGWAT2                 WPRCG
    RQUENCH     IN = RCG4     RGWAT2    OUT = RCG5
    RGHTR       IN = RCG5               OUT = RCG6                   QRCG3
    RGSEP       IN = RCG6               OUT = RCG7     RCGLIQ
    GASHT       IN = QGAS     QRCG      OUT =                        QGASFER
FLOWSHEET HOTSAND
    HSAND       IN = SAND1    QGASFER   OUT = SAND2                  QSAND1
    CSAND       IN = SAND2              OUT = SAND3                  QSAND2
    CHCOMP      IN = AIR2               OUT = AIR3                   WCHAR
    CM          IN = SOLID1   AIR1A     OUT = DECFD
    CDECOMP     IN = DECFD              OUT = DEC                    Qdec
    CMIX        IN = AIR3 METH  qht3a   OUT = COMIN
    COMBUST     IN = COMIN              OUT = COMOUT                 Qmeth
    CHCOM2      IN = AIRTAR             OUT = AIRT                   WAIRT
    MIXTAR      IN = AIRT2    TARS      OUT = TARC
    COMTAR      IN = TARC               OUT = TARP                   QTAR
    SUMGAS      IN = DEC  COMOUT TARP   OUT = DRYGAS
    SUMQ1       IN = QDEC QMETH  QTAR   OUT =                        QCHAR
FLOWSHEET  LOOP1
    Change      IN = SUMGAS             Out = Gasc
    COMP1       IN = GASC               OUT = HPGAS  WC1 WC1A WC1B WC1C &
                                                     QC1 QC2 QC3
    INLET       IN = HPGAS STEAM RCO2   OUT = CFEED
    HTR         IN = HPROD2   CFEED     OUT = HPROD3   FEED1
    REAC1       IN = FEED1              OUT = FEED2                  QF
    HTR2        IN = HPROD    FEED2     OUT = HPROD2   Refin
    REFORM      IN = Refin              OUT = HPROD    COKE          QH3
    HTR3        IN = HPROD3             OUT = AGAS                   QH4
    H2OCOND     IN = AGAS               OUT = AGAS2    WWATER
    HWCOOL      IN = AGAS2              OUT = AGAS2A                 QHW
    QHWSEP      IN = QHW                OUT = QHW1     QHW2
    CO2COND     IN = AGAS2A             OUT = CGAS     LIQ
```

```
  CO2SEP      IN = LIQ                          OUT = PCO2    RCO2
FLOWSHEET  LOOP2
  Change2     In = Cgas                         Out = Cgas2
  HTR4        IN = CGAS2                        OUT = RGAS                  QH
  COMP2       IN = RGAS                         OUT = GAS4 W1 W1A W1B QC5  QC6
  HTR5        IN = RECYCLE                      OUT = RECYCLE2              QH5
  COMP3       IN = RECYCLE2                     OUT = GAS4A                 WLA
  MIXM        IN = GAS4      GAS4A              OUT = GAS4B
  HTR6        IN = GAS4B                        OUT = GAS5                  Q3
  MEOH        IN = GAS5                         OUT = GASM     LIQM         Q4
  COOL        IN = GASM                         OUT = GASM2                 Q5
  CONDENSE    IN = GASM2                        OUT = Gasrl    METHANOL     Q6
  MSPLIT      IN = GASR1                        OUT = PURGE    RECYCLE
FLOWSHEET COMBUST
  AIRCOMP     IN = AMBAIR                       OUT = COMAIR                WAIR1
  HCOM1       IN = FLUE2     COMAIR             OUT = FLUE3    COMAIR2
  HCOM2       IN = FLUE3     PURGE              OUT = FLUE4    PURGEH
  MCOMB       IN = COMAIR2   PURGEH             OUT = COMGAS
  ADCOMB      IN = COMGAS QH3 QF                OUT = FLUEGAS
FLOWSHEET CHECK
  PUMP1       IN = WATER                        OUT = WATER2                WP1
  SUMQ2       IN = QC1 QC2 QC3 QC5 QC6 QHT4 QHW1 &
                                                OUT = QSUM

  WHTR1       IN = WATER2 QSUM                  OUT = WATER3
  WHTR2       IN = WATER3 Q4 QFLUE QH4   OUT = Psteam
  REFCOOL     IN = FLUEgas                      OUT = FLUE2                 QFL2
  REFCOOL2    IN = FLUE4                        OUT = FLUE5                 QFLUE
;
;************    STREAM SPECIFICATIONS   **********************************
;
;
Def-Subs-Attr  PSD  PSD
  in-units  Length = MU
  intervals  10
  size-limits  0/4/5/6.4/8/10.1/12.7/16/20.2/32/50.8
;
Def-Stream-Class Mixcinc
  Definition Substreams=Mixed Cisolid Ncpsd
;
Def-Streams Mixcinc Dry Gasfer Hotsand/mixcisld Loopl/Conven Loop2
;
Def-Streams HEAT QH QH4 QH5 Q3 Q4 Q5 Q6 QDRYER QSTORE QGAS Qdec Qmeth &
    QH3 QSEP Qscrub QF QFL2 QSAND1 QSAND2 Qchar QC1 QC2 QC3 QC5 Qht3a &
    QC6 Qtar Qflue QRCG QRCG3 QGASFER Qht4 Qhw Qhw1 Qhw2 QSUM Qchar
;
DEF-STREAMS WORK W1 WLA WC1 WAIR1 WP1 Wchar Wairt WPA WC1A WC1B WC1C &
    W1A W1B WCRCG WPRCG
;
STREAM  STEAM
    Substream  Mixed  TEMP =1000  PRES = 300  MOLE-FLOW = 8000
    MOLE-FRAC  H2O  1.00

Stream SteamG
```

```
    Substream  Mixed  Temp = 1000  Pres = 25   Mass-flow = 66360.340
    Mass-frac  H2O  1.00
;
Stream Cwater
    Substream  Mixed  Temp=50 P=14.7 Mole-flow=10000
    Mole-frac  H2O  1.00
;
Stream water
    Substream  Mixed  Temp = 50 P=25 Mole-flow= 11750
    Mole-frac H2O  1.00
;
Stream Ambair
   Substream  Mixed  Temp=80 Pres=14.7 Mole-flow = 5500
   Mole-frac  O2  0.21  / N2  0.79
;
Stream Air1
   Substream  Mixed  Temp=80 Pres = 25 Mass-flow=100
   Mass-frac  O2 0.2329 / N2 0.7671
;
Stream Air2
   Substream  Mixed  Temp = 80 Pres = 14.7 Mole-flow = 200
   Mole-frac  O2 0.21 / N2 0.79
;
Stream Meth
   Substream  Mixed  Temp = 80 Pres = 14.7 Mole-flow =25
   Mole-frac  MEOH  1.0
;
Stream Airtar
   Substream  Mixed  Temp = 80 Pres=14.7 Mole-flow = 1250
   Mole-frac  O2 0.21/ N2 0.79
;
Stream RCG
   Substream Mixed  Temp=100 Pres=20 Mole-flow = 4900.0
   Mole-frac H2 0.2547 / CO 0.3979 / CO2 0.1146 / CH4 0.1408 / &
             C2H2 0.0042 / C2H4 0.0368 / C2H6 0.0016 / &
             C3H6-2 0.0019 / H2O 0.0474
;
Stream Rgwat
   Substream Mixed Temp = 50 P = 14.696 Mole-flow = 1000
   Mole-frac H2O 1.0
;
Stream Wwood  Mixed  Temp=80  Pres=14.7  Mass-flow= 149693.674
    Mass-flow H2O  149693.674
    Substream NCPSD  Temp=80  Pres=14.7  Mass-flow=183639.660
    Mass-flow Wood   183639.660       / Char 1e-10
    Subs-attr PSD Frac=0.593 0.001 0.011 0.026 0.033 0.04 0.052 &
                     0.072 0.140 0.032
    Comp-Attr Wood  Proxanal (9.24 15.37 83.44 0.89)/
                    Ultanal  (0.89 50.89 6.04 0.17 0.03 0.09 41.90)/
                    Sulfanal (0.03 0.03 0.03)/
                    Coalmisc (8539. 0.0 0.0 0.0 0.0)/
                    Genanal  (100.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0)
```

```
   Comp-Attr Char  Proxanal (0.0 80.0 20.0 0.0)/
                   Ultanal  (0.0 86.0 4.0 0.0 0.0 0.03 9.97)/
                   Sulfanal (.01 .01 .01)/
                   Coalmisc (14336. 0.0 0.0 0.0 0.0)/
                   Genanal  (100.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0 0.0)

;
Stream Sandl
   Substream Mixed   Temp=1975 P=25 Mole-flow=0.01
   Mole-frac N2 1.00
   Substream Cisolid Temp=1975 P=25 Mass-flow=6E+6
   Mass-frac  O2SI  1.00
;
;**************  Blocks  **************************************************
;
;
Block Dryer Flash2
   Param Temp = 220  Pres = 14.7  maxit = 100
;
Block Store Heater
   Param Temp=220
;
Block Feedmix  Mixer
   Param Pres=20
;
Block Gasifier Ryield
   Properties Option=SYSOPO
   Param Temp=1675  Pres=20
   Massyield Ssid = Mixed    Comp = H2         Val=1.4293E-02/
             Ssid = Mixed    Comp = CO         Val=3.1029E-01/
             Ssid = Mixed    Comp = CO2        Val=1.4038E-01/
             Ssid = Mixed    Comp = CH4        Val=6.2892E-02/
             Ssid = Mixed    Comp = C2H2       Val=3.0135E-03/
             Ssid = Mixed    Comp = C2H4       Val=2.8776E-02/
             Ssid = Mixed    Comp = C2H6       Val=1.3374e-03/
             Ssid = Mixed    Comp = C3H6-2     Val=2.0663E-03/
             Ssid = Mixed    Comp = C6H6       Val=2.0663E-03/
             Ssid = Mixed    Comp = C10H8      Val=2.0663E-03/
             Ssid = Mixed    Comp = C14H10-1   Val=2.0663E-03/
             Ssid = Mixed    Comp = H2O        Val=3.2309E-01/
             Ssid = Cisolid  Comp = O2SI       Val=5.9191E-03/
             Ssid = Ncpsd    Comp = Char       Val=1.0174E-01/
             Ssid = Ncpsd    Comp = Wood       Val=0.0
;
Block Solsep Sep2
   Frac    Subs=Ncpsd    Stream=Solid1  Comp=Char       Frac=1.0/
           Subs=Mixed    Stream=Gas1    Comp=C14H10-1   Frac=0.995
   Flash-specs Gas1 Pres=20
;
Block Solsp2 Sep2
   Frac    Subs=Cisolid  Stream=Solid2  Comp=O2SI      Frac=1.0 /
           Subs=Mixed    Stream=Gas1b   Comp=C14H10-1  Frac=0.995
   Flash-specs Gas1b Pres=20
;
```

```
Block Heat1 Heatx
   Param  Option=1  Fdir=0  Thot=1100
;
Block Heat2 Heatx
   Param  Option=1 Fdir=0 Thot=1075
;
Block Heat3 Heatx
   Param  Option=1 Fdir=0 Thot=1025
;
Block Heat3A Heater
   Param Temp=1010
;
Block Heat4 Heater
   Param Temp = 600
;
Block PumpA Pump
   Param Pres=20 Type=1 Eff=0.9
;
Block AQuench mixer
;
Block Ahtr Heater
   Param  Temp = 100
;
Block AQsep Flash2
   Param Pres=20 Temp=100
;
Block Aqsep2  Sep2
   Frac  Subs=Mixed  Stream=Tars  Comp=C6H6 C10H8 C14H10-1 Frac=1.0 1.0 1.0/
         Subs=Mixed  Stream=Waste Comp= H2 CO CO2 CH4 C2H2 C2H4 C2H6 C3H6-2 &
                     H2O  Frac= 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0
;
Block Aqsep3  Sep2
   Frac  Subs=Mixed Stream=Sgas  Comp= H2 CO CO2 CH4 C2H2 C2H4 C2H6 C3H6-2 &
                    FRAC = 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0/
         Subs=Mixed Stream=Waste2 Comp=H2O Frac=1.0
;
Block Gasmix1 Mixer
;
Block Change Clchng
;
Block Rghtx Heatx
   Param Opt=1 Fdir=0 Thot=400
;
Block Rgcomp Compr
   Param Type=1 Pres=25 EP=0.85
;
Block Rgheat Heater
   Param Temp=1675
;
Block Rpump Pump
   Param Type=1 Pres=20 Eff=0.90
;
```

```
Block Rquench Mixer
   Param Pres=20
;
Block Rghtr Heater
   Param Temp=300
;
Block Rgsep Flash2
   Param Pres=345 Temp=200
;
Block Gasht Mixer
;
Block Hsand Heater
   Param Temp=1675 Pres=25
;
Block Csand Heater
   Param Temp=1975 Pres=25
;
Block Chcomp Compr
   Param  Type = 1  Pres = 25  EP = 0.90
;
Block CM  Mixer
;
Block Cdecomp Ryield
   Param Pres = 25 Temp=2075
   Massyield  Ssid = Mixed  Comp=CO2    Val = 0.267717/
              Ssid = Mixed  Comp=H2O    Val = 0.030371/
              Ssid = Mixed  Comp=N2     Val = 0.701912
;
Block Cmix Mixer
;
Block Combust Rstoic
   Param Pres = 20 Maxit = 500 T = 2075
   Stoich  1  Mixed  MEOH -1 / O2 -1.5  / CO2 1  / H2O 2
   Conv    1  Mixed  MEOH 1.0
;
Block Chcom2 Compr
   Param Type=1 Pres=25 EP=0.90
;
Block MixTar Mixer
;
Block Comtar Rstoic
   Param  Temp=2075 Pres=25
   Stoich  1   Mixed C6H6      -1 / O2   -7.5   / CO2  6   / H2O  3
   Stoich  2   Mixed C10H8     -1 / O2   -12    / CO2  10  / H2O  4
   Stoich  3   Mixed C14H10-1  -1 / O2   -16.5  / CO2  14  / H2O  5
   Conv  1  Mixed  C6H6         1.0
   Conv  2  Mixed  C10H8        1.0
   Conv  3  Mixed  C14H10-1     1.0
;
Block Sumgas Mixer
;
Block SumQ1 Mixer
```

```
;
Block Compl Mcomp
    Specs Nstage=4 Pfinal=200
    Param  kode=0 Type=1 EP=0.95  DELT=75
;
Block Inlet MIXER
;
BLOCK  HTR  Heatx
   Param Opt=1 Fdir=0 Thot=900
;
BLOCK  REAC1  RSTOIC
     PARAM  TEMP = 1000
     STOICH  1  MIXED  C2H2      -1   / H20 -1  / CO 1 / CH4 1
     STOICH  2  MIXED  C2H4      -1   / H20 -1  / CO 1 / CH4 1 / H2 1
     STOICH  3  MIXED  C2H6      -1   / H20 -1  / CO 1 / CH4 1 / H2 2
     STOICH  4  MIXED  C3H6-2    -1   / H20 -1  / CO 1 / CH4 2
     STOICH  5  MIXED  C6H6      -1   / H20 -3  / CO 3 / CH4 3
     STOICH  6  MIXED  C10H8     -1   / H20 -10 / CO 10 / H2 14
     STOICH  7  MIXED  C14H10-1 -1    / H20 -14 / CO 14 / H2 19
     STOICH  8  MIXED  MEOH      -1   / H2   2  / CO 1
     CONV  1  MIXED  C2H2       1.00
     CONV  2  MIXED  C2H4       1.00
     CONV  3  MIXED  C2H6       1.00
     CONV  4  MIXED  C3H6-2     1.00
     CONV  5  MIXED  C6H6       1.00
     CONV  6  MIXED  C10H8      1.00
     CONV  7  MIXED  C14H10-1   1.00
     CONV  8  MIXED  MEOH       1.00
;
Block Htr2 Heatx
   Param Opt=1 Fdir=0 Thot=1050
;
BLOCK REFORM RGIBBS
     PARAM  TEMP = 1600. maxit=500 nat=4
     PROD  H2 1 / CO 1 / H20 1 / CH4 1 / CO2 1 / C 0
;     STOI   1  CO2 -1    / H2  -1 / H20 1 / CO 1
;     STOI   2  CO  -2    / C 1    / CO2 1
;     STOI   3  CH4 -1    / H20 -1 / CO 1  / H2 3
;     DELT   3   -15.
;
Block Htr3 Heater
   Param Temp=425
;
BLOCK  H2OCOND  Sep2
   Frac Subs=Mixed Stream=Agas2 Comp=H2 CO CO2 CH4 H2O FRAC=1.0 1.0 1.0 1.0 &
          0.05/
        Subs=Mixed Stream=Wwater Comp=H2 CO CO2 CH4 H2O Frac=0.0 0.0 0.0 &
          0.0 0.95
;    Flash-Specs  Agas2  Temp=425 P=200  Maxit = 300 Tol=0.001/
;                 Wwater Temp=425 P=200  Maxit=300 Tol=0.001
;
Block Hwcool Heater
```

```
   Param Temp = 80
;
Block Qhwsep Fsplit
   Frac Qhw1 0.75 / Qhw2 0.25
;
BLOCK  CO2COND  Sep2
   Frac Subs=Mixed Stream=Cgas Comp=H2 CO CH4 H2O CO2 FRAC=1.0 1.0 1.0 1.0 &
           0.05/
        Subs=Mixed Stream=Liq Comp=CO2 Frac=0.95
   Flash-Specs  Cgas  Temp=425 P=200/
                Liq   Temp=425 P=200
;
Block CO2SEP Fsplit
   Frac PCO2 0.55 / RCO2  0.45
;
Block Change2 Clchng
;
BLOCK  HTR4  HEATER
     PARAM  TEMP = 425  PRES = 200
;
BLOCK  COMP2  MCOMP
     SPECS  NSTAGE=3 PFINAL=750
     PARAM  KODE=0 TYPE = 1 EP = 0.95  DELT=50
;
Block HTR5 Heater
     Param Temp=150
;
BLOCK COMP3 COMPR
     PARAM  TYPE = 1  PRES = 750   EP=0.95
;
BLOCK  HTR6  HEATER
     PARAM  TEMP = 445  PRES =750
;
BLOCK  MEOH  Requil
     PARAM  TEMP = 445  PRES =750 NR=3 Mxol=600 Mxil=600
     STOI  1  CO  -1 0/ H2 -2 0/ MEOH 1 0
     STOI  2  CO2 -1 0/ H2 -1 0/ CO   1 0/ H2O 1  0
     STOI  3  CO  -1 0/ H2 -3 0/ CH4  1 0/ H2O 1  0
     EXSP  3  0.1E-08
     DELT  1  +0.0001
;
Block Cool Heater
     Param Temp=35
;
BLOCK  CONDENSE  FLASH2
     PARAM  TEMP = 32  PRES = 740
;
BLOCK MSPLIT  FSPLIT
     FRAC  PURGE 0.3300 / RECYCLE  0.6700
     Param npk=1 kph=1
;
BLOCK  MIXM  MIXER
```

```
     PARAM  KPH = 1
;
Block Aircomp Compr
   Param Type = 1  Pres=20  EP=0.90
;
Block Hcom1 Heatx
   Param Opt=1 Fdir=0 Thot=950
;
Block Hcom2 Heatx
   Param Opt=1 Fdir=0 Thot=850 DPC=20
;
Block Mcomb  Mixer
   Param Pres=20 Maxit = 500  Tol=0.001 NPK=1 kph=1
;
Block Adcomb Rstoic
   Param Pres=20 Maxit=500 Test=1800 Tol=0.001
   Stoich 1  Mixed  CO -1   / O2 -0.5 / CO2 1
   Stoich 2  Mixed  CH4 -1  / O2 -2   / CO2 1 / H2O 2
   Stoich 3  Mixed  MEOH -1 / O2 -1.5 / CO2 1 / H2O 2
   Stoich 4  Mixed  H2 -1   / O2 -0.5 / H2O 1
   Conv   1  Mixed  CO         1.00
   Conv   2  Mixed  CH4        1.00
   Conv   3  Mixed  MEOH       1.00
   Conv   4  Mixed  H2         1.00
;
Block Refcool Heater
   Param Temp=1700
;
Block Refcool2 Heater
   Param Temp=250
;
Block Pump1 Pump
   Param Pres=200 Type=1 Eff=0.9
;
Block Sumq2 Mixer
;
Block Whtr1 Heater
;
Block Whtr2 Heater
;
;******************   Design Specifications    ******************************
;
Design-spec Three
   Define C  Strm-attr-var Stream=Qscrub Attribute=Heat Variable=Duty
   Spec C to 0
   Tol-spec 50
   Vary Stream-var  Stream=Cwater Variable=mole-flow
   Limits 0  1E+06
;
Design-spec RG
   Define R Strm-attr-var Stream=Qrcg3 Attribute=Heat Variable=Duty
   Spec R to 0
```

```
   Tol-spec 100
   Vary Stream-var Stream=Rgwat Variable=Mole-flow
   Limits 0 0.1e+07
;
;******************    Fortran Blocks    ***********************************
Fortran  Set-Air
   Properties  Sysop0
   Define FA  Mass-flow  Stream=Solid1  Substream=Ncpsd  Comp=Char
   Define FB  Mass-flow  Stream=Air1    Substream=Mixed  Comp=O2
   Define FC  Mass-flow  Stream=Air1    Substream=Mixed  Comp=N2
F       FB = 2.5085984*FA
F       FC = 8.2617314*FA
   Flash-specs  Air1  Kode=2  Temp=80  Pres=25
   Execute after solsep
;
```

REPORT DOCUMENTATION PAGE

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The objective of the Biomass to Methanol Systems Analysis Project is the determination of the most economically optimum combination of unit operations which will make the production of methanol from biomass competitive with or more economic than traditional processes with conventional fossil fuel feedstocks. This report summarizes the development of simulation models for methanol production based upon the Institute of Gas Technology (IGT) "Renugas" gasifier and the Battelle Columbus Laboratory (BCL) gasifier. This report discusses methanol production technology, the IGT and BCL gasifiers, analysis of gasifier data for gasification of wood, methanol production material and energy balance simulations, and one case study based upon each of the gasifiers.

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