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CONF-780891--1

INSTITUTE OF GAS TECHNOLOGY

MASTER

SNG FROM PEAT
BY THE PEATGAS PROCESS

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Paper Presented at

FIFTH ANNUAL INTERNATIONAL CONFERENCE
ON COAL GASIFICATION, LIQUEFACTION, AND
CONVERSION TO ELECTRICITY

Pittsburgh, Pennsylvania

August 1-3, 1978

IGT
EDUCATION · RESEARCH

3424 SOUTH STATE STREET
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SNG FROM PEAT BY THE PEATGAS PROCESS

ABSTRACT

The total energy content of U.S. peat resources is estimated to be equivalent to 1440 quads or over 240 billion barrels of oil. Generally, peat deposits are located in areas with no other fossil fuel resources. Therefore, for those areas, it represents a very important energy resource. The areas with large peat deposits also have plentiful water supplies, so the local water resources can easily afford conversion of peat to substitute natural gas.

Under the joint sponsorship of the U.S. Department of Energy and the Minnesota Gas Company, the Institute of Gas Technology has developed the PEATGAS process for the conversion of peat to substitute natural gas having a heating value of about 960 Btu per SCF. The heart of the process consists of a two-stage PEATGAS reactor incorporating a cocurrent, dilute-phase entrained-flow hydrogasification stage followed by a fluidized-bed char gasification stage using steam and oxygen. The overall thermal efficiency of the process is calculated to be 67% for a 250 billion Btu per day SNG plant using a 50% moisture content Minnesota peat. About 78% of the total methane produced in the plant is made in the gasifier itself. Therefore, only about 22% of the methane is made by catalytic methanation. The by-products yield on a daily basis from a 250 billion Btu per day SNG plant is estimated to be 136,030 gallons benzene, 6,680 barrels fuel oil, 565 tons anhydrous ammonia, and 52 long tons sulfur. The total fuel output of such a plant is about 309 billion Btu per day.

INTRODUCTION

Peat may be considered a geologically young coal (1). It has been extensively used in Europe and Russia for years as a source of fuel and chemicals. Russia, with the largest peat reserves in the world, has an annual peat production capacity of over 200 million tons of air-dried peat. In Russia, electric power plants as large as 730 MW (2) are fired with peat. However, the United States, with the second largest peat resources in the world, does not use peat commercially as a source of energy.

The total energy contained in the U.S. peat resources is estimated to be about 1440 quads (10^{15} Btu), or equivalent to over 240 billion barrels of oil (3). The location of peat resources and their potential to help meet the U.S. need for clean fuels have been previously presented (4,5). The areas with large peat deposits also have plentiful water supplies, therefore, the local water resources can easily afford the conversion of peat to SNG.

The United States has recently recognized the potential of peat as a significant energy resource. In July 1976, the Institute of Gas Technology (IGT) started working on a peat gasification program jointly funded by the U.S. Department of Energy (DOE) and the Minnesota Gas Company (Minnegasco). The objective of this program is to obtain peat gasification data in laboratory-scale and in process development units (PDU), and to evaluate the economics of converting peat into substitute natural gas (SNG). Details of the laboratory-scale as well as the PDU-scale test results are presented elsewhere (6,7,8,9,10). Based on the experimental results a preferred reactor configuration (named PEATGAS) has been selected for converting peat to SNG. The economics of converting peat to SNG by the PEATGAS process is being evaluated.

This paper highlights the gasification characteristics of peat and discusses the process design for converting peat to SNG by the PEATGAS process.

PEAT GASIFICATION CHARACTERISTICS

The results of peat hydrogasification tests show that in a short residence time of about 5 seconds, 4 times as much carbon is converted directly to light hydrocarbon gases (primarily methane and ethane) as is converted during lignite hydrogasification under similar conditions as shown in Figure 1. Therefore, peat is an exceptionally good raw material for production of SNG. The results also show that the effect of increasing hydrogen partial pressure above 4 atms

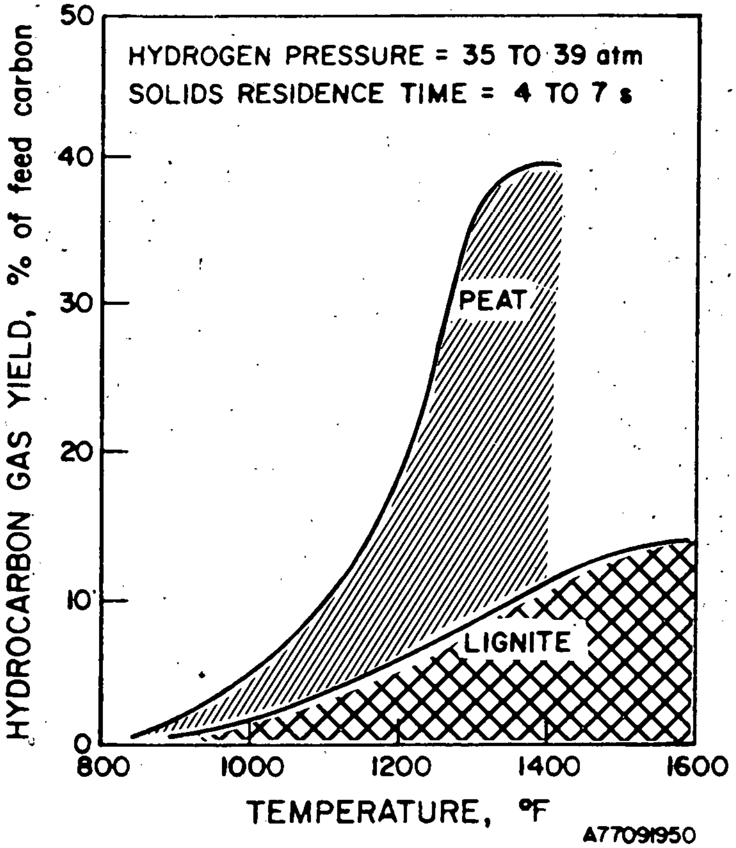

Figure 1. EFFECT OF TEMPERATURE ON THE CARBON CONVERTED TO HYDROCARBON GASES DURING HYDROGASIFICATION OF PEAT AND LIGNITE

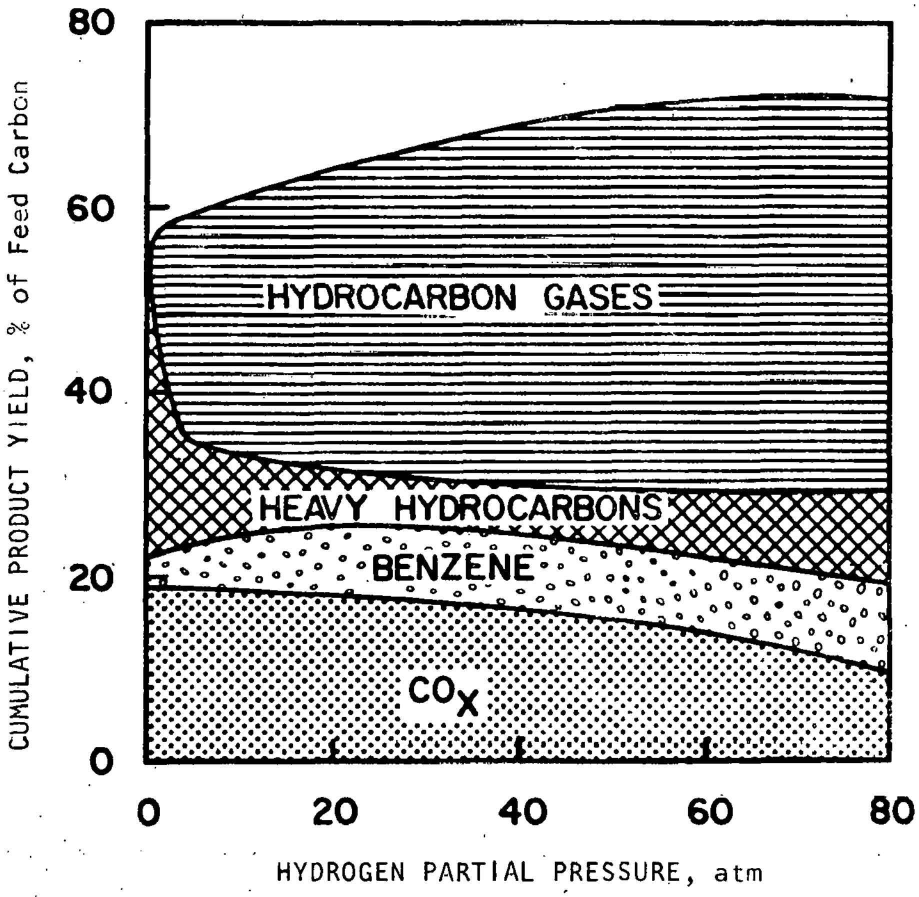

Figure 2. EFFECT OF HYDROGEN PARTIAL PRESSURE ON PRODUCT YIELDS OBTAINED DURING PEAT GASIFICATION

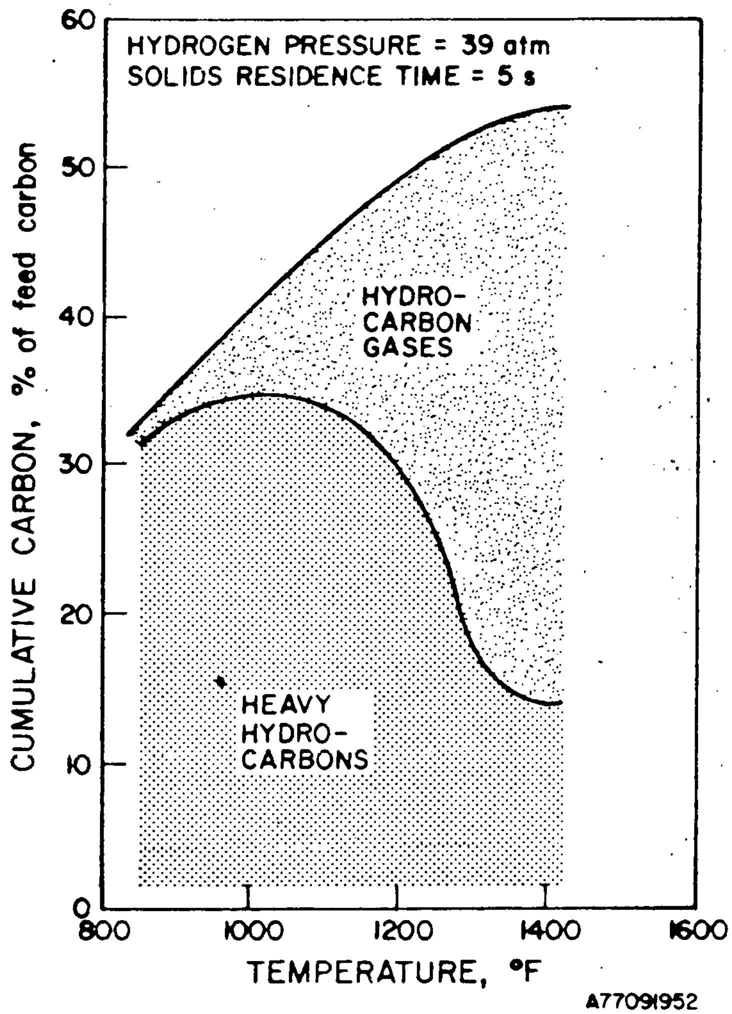

Figure 3. EFFECT OF TEMPERATURE ON THE GAS AND OIL YIELDS OBTAINED DURING PEAT HYDROGASIFICATION

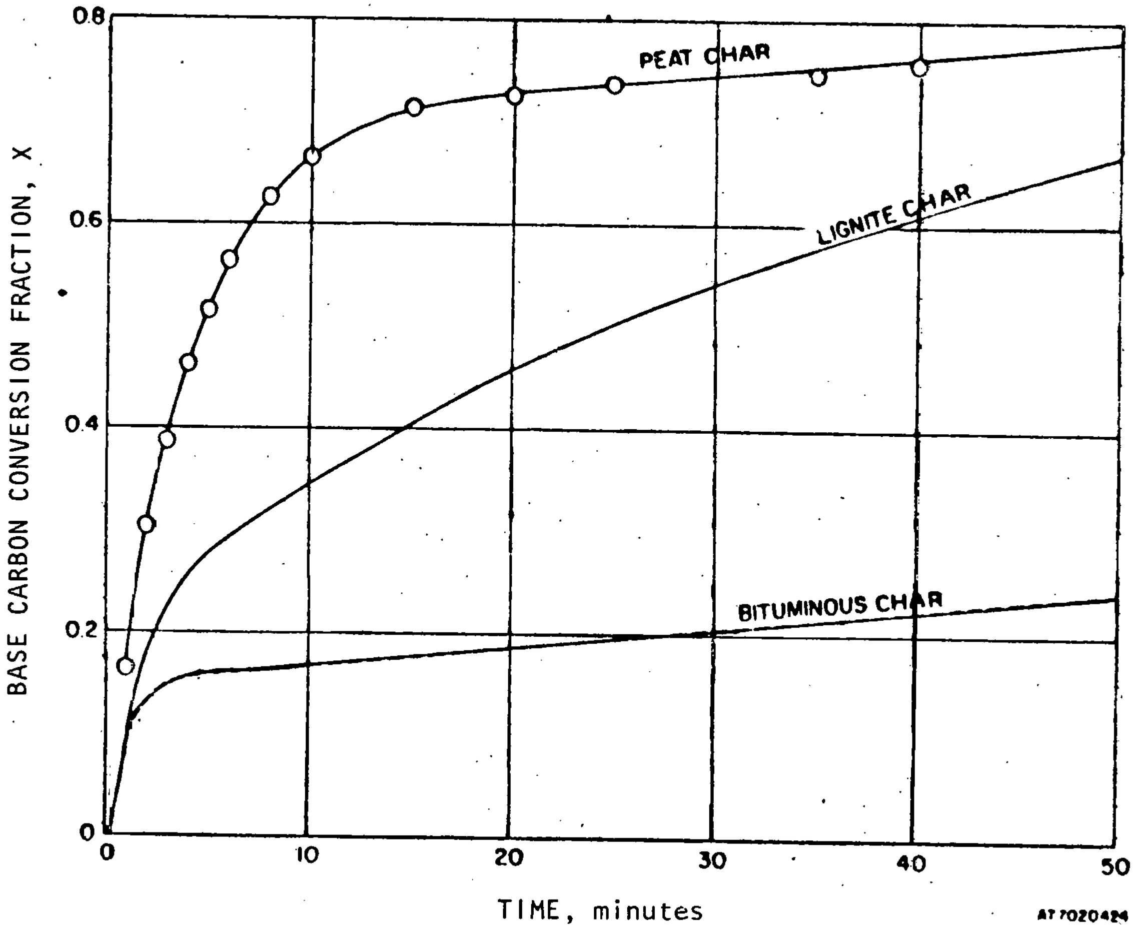

Figure 4. COMPARISON OF CARBON CONVERSIONS FOR PEAT, LIGNITE, AND BITUMINOUS COAL DURING GASIFICATION WITH A STEAM-HYDROGEN (50 mol % H_2) MIXTURE AT 1500°F AND 500 PSIG

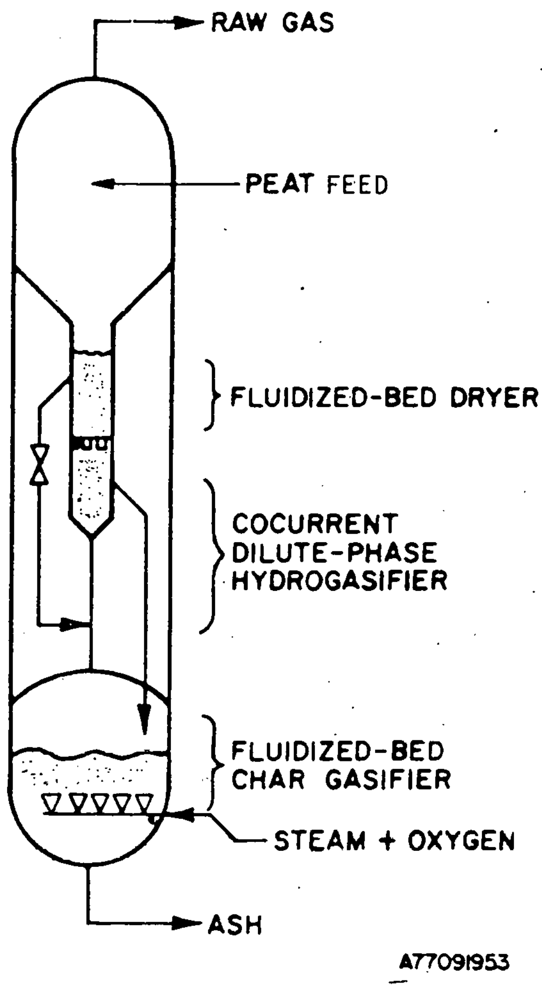

Figure 5. SCHEMATIC DIAGRAM OF THE PEATGAS REACTOR

As stated previously, a major portion of the light hydrocarbon gases during peat hydrogasification come from the secondary hydrogenation of the hydrocarbon liquids produced during primary devolatilization. The yield of hydrocarbon gases could vary from 10% to 27% of the feed carbon depending upon the operating conditions and gas-solids contacting during hydrogasification. In comparison, the yield of light hydrocarbon gases from lignite and bituminous coal hydrogasification could vary from only 6% to 10% of the feed carbon, respectively. The cocurrent dilute-phase gas-solid contacting selected for the entrained-flow hydrogasification stage of the PEATGAS reactor is preferred, because countercurrent contacting would lead to increased production of tars and phenols, and a dense-phase carbon bed would promote cracking of the hydrocarbon liquids to coke, and thus reduce light hydrocarbon gas yield.

For the production of SNG the preferred operating pressure range for the PEATGAS reactor is between 200 and 500 psig. Lower pressures promote oil and decrease methane yield. Higher pressures, as pointed out earlier, do not increase methane production significantly, but do lead to costly equipment. The preferred operating temperature range for the hydrogasifier is between 1400° and 1600°F. Lower temperatures reduce methane and increase oil yield whereas higher temperatures promote cracking to form coke and reduce both oil and methane yields. The preferred operating temperature range for the steam-oxygen char gasification zone is between 1700° and 1900°F. Lower temperatures increase the steam required because the hydrogasification section requires a certain amount of heat and more steam is required to carry this heat if the char gasifier is operated at lower temperatures. Higher temperatures cause cracking of oil in the hydrogasification section. Therefore, the clagging gasifiers which require temperatures in excess of 2600°F for making synthesis gas are not preferred for the production of SNG from peat.

PROCESS DESIGN

A block flow diagram for production of 250 billion Btu per day of SNG from peat is shown in Figure 6. The reason for selecting this plant size is that it has been used in the past for evaluating various coal gasification processes. The basic flow scheme is very similar to a coal gasification plant. Fifty percent moisture content peat is received into the plant. After grinding and screening to -10+100 mesh, peat is transferred to lockhoppers used for feeding the peat into the high pressure PEATGAS reactor at 500 psig. With peat, the

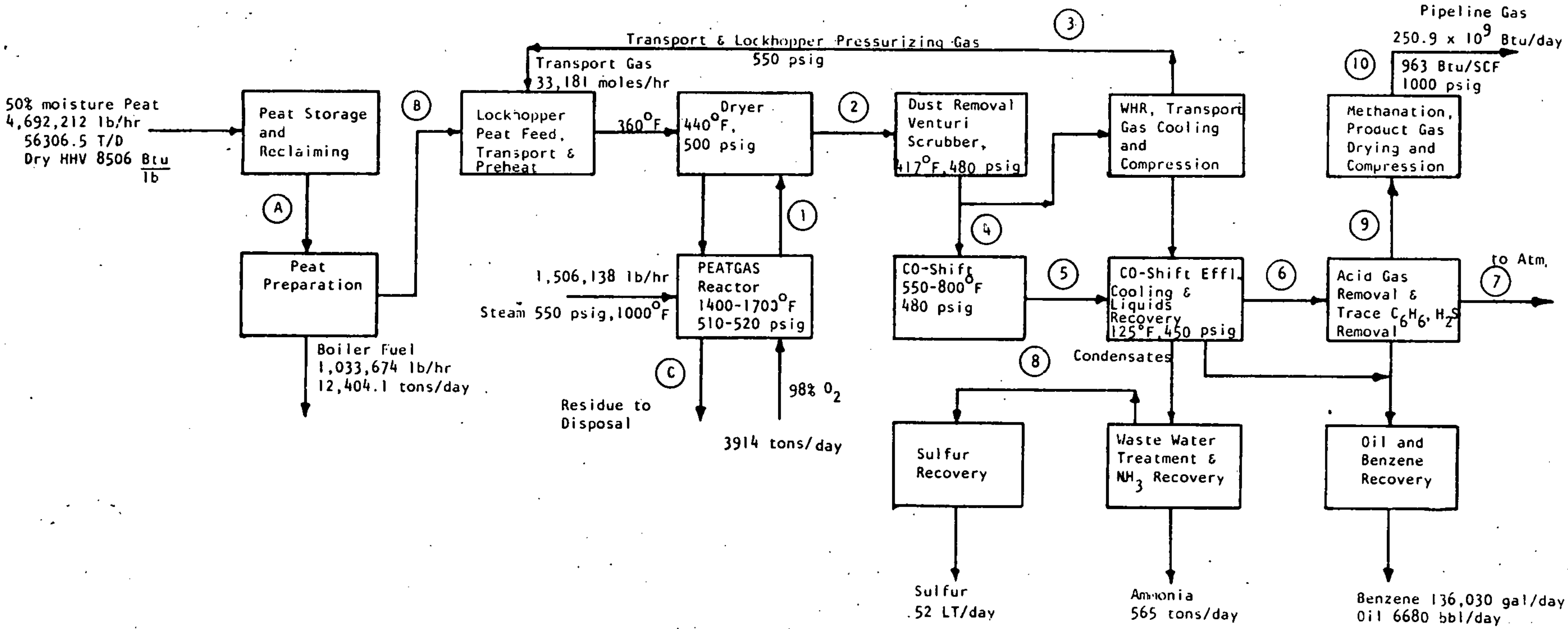

Figure 6. BLOCK FLOW DIAGRAM FOR PEAT TO SNG PLANT PRODUCING 250.9 X 10^9 Btu/Day SNG BY IGT'S PEATGAS PROCESS

COMPOSITION OF SOLID STREAMS

Stream No.	(A)		(B)		(C)	
Stream Name	RAW PEAT		PROCESS PEAT		CHARGASIFIER RESIDUE	
Component	lb/hr	wt%	lb/hr	wt%	lb/hr	wt%
C	1,170,649	49.90	912,760	49.90	9,128	3.97
H	119,416	5.09	93,109	5.09	3,671	1.60
N	64,174	2.73	50,037	2.73	10,534	4.58
S	6,251	0.27	4,874	0.27	-	-
O	720,519	30.71	561,792	30.71	-	-
Ash	265,097	11.30	206,697	11.30	206,697	89.85
Subtotal Dry	2,346,106	100.00	1,829,269	100.00	230,030	100.00
Moisture (50%)	2,346,106		1,829,269		-	
TOTAL	4,692,212		3,658,538		230,030	
Tons/Day	56306.5		43,902.4		2760.4	

Figure 6 (cont'd). BLOCK FLOW DIAGRAM FOR PEAT TO SNG PLANT PRODUCING 250.9 X 10^9 Btu/Day SNG BY IGT'S PEATGAS PROCESS

Stream No.	①		②		③		④		⑤	
Stream Name	Gasifier Effluent		Dryer Effluent		Lock Hoppers Transport And Recycle Gas		CO-Shift Feed		CO-Shift Effluent	
Temperature, °F	1474		440		100		417		605	
Pressure, psig	510		500		550		490		475	
Component	Moles/Hr	Mole %	Moles/Hr	Mole %	Moles/Hr	Mole %	Moles/Hr	Mole %	Moles/Hr	Mole %
CO	9,910	6.81	14,128	5.04	4,228	12.74	9,898	5.04	5,896	3.00
CO_2	33,502	23.02	46,657	16.65	13,186	39.74	32,688	16.65	36,690	18.69
H_2	17,685	12.15	25,211	9.00	7,544	22.74	17,663	9.00	21,665	11.04
H_2O	61,233	42.08	162,834	58.12	65	0.20	114,082	58.12	110,080	56.08
CH_4	15,656	10.76	22,315	7.97	6,675	20.12	15,635	7.97	15,635	7.97
C_2H_6	2,766	1.90	3,945	1.41	1,182	3.56	2,763	1.41	2,763	1.41
NH_3	2,820	1.94	2,820	1.01	-	-	1,976	1.01	1,976	1.01
H_2S	152	0.10	152	0.05	-	-	106	0.05	106	0.05
N_2 + Ar	203	0.14	289	0.10	86	0.26	203	0.10	203	0.10
C_6H_6	889	0.61	1,101	0.39	213	0.64	771	0.39	771	0.39
C_6H_6O	441	0.31	443	0.16	2	-	310	0.16	310	0.16
$C_{10}H_8$	266	0.18	266	0.10	-	-	186	0.10	186	0.10
TOTAL	145,523	100.00	280,161	100.00	33,181	100.00	196,281	100.00	196,281	100.00

Stream No.	⑥		⑦		⑧		⑨		⑩	
Stream Name	Acid Gas Removal Feed		Sour Gas From Acid Gas Removal		Sulfur Plant Feed		Methanation Feed		Product Gas	
Temperature, °F	125		125		125		125		100	
Pressure, psig	450		5		5		425		1000	
Component	Moles/Hr	Mole %	Moles/Hr	Mole %	Moles/Hr	Mole %	Moles/Hr	Mole %	Moles/Hr	Mole %
CO	5,890	7.26	18	0.05	8	0.25	5,872	12.60	29	0.10
CO_2	34,729	42.84	34,263	89.78	2,702	84.12	466	1.00	421	1.47
H_2	21,653	26.71	110	0.29	16	0.50	21,543	46.24	1,095	3.82
H_2O	175	0.22	3,702	9.70	312	9.72	205	0.44	4	0.01
CH_4	15,619	19.27	62	0.16	19	0.59	15,557	33.40	26,923	93.89
C_2H_6	2,747	3.39	8	0.02	3	0.09	2,739	5.88	-	-
NH_3	trace	-	trace	-	trace	-	-	-	-	-
H_2S	trace	-	trace	-	152	4.73	-	-	-	-
N_2 + Ar	203	0.25	-	-	-	-	203	0.44	203	0.71
C_6H_6	50	0.06	-	-	-	-	-	-	-	-
C_6H_6O	-	-	-	-	-	-	-	-	-	-
$C_{10}H_8$	-	-	-	-	-	-	-	-	-	-
TOTAL	81,066	100.00	38,163	100.00	3,212	100.00	46,585	100.00	28,675	100.00

Figure 6 (cont'd). BLOCK FLOW DIAGRAM FOR PEAT TO SNG PLANT PRODUCING 250.9 X 10^9 Btu/Day SNG BY IGT'S PEATGAS PROCESS lockhopper feed system at 500 psig is preferred to a slurry feed system because in a slurry feed system, peat will have to be dried to about 10% moisture and then slurried with about 67% oil. Our preliminary evaluation indicates that the cost of drying peat from 50% to 10% moisture overweights the disadvantages of higher equipment cost and higher compression energy requirements of the lockhopper system. Peat is conveyed from the lockhoppers to the reactor using a part of the gasifier effluent gas. In the transport path from the lockhoppers to the dryer section of the reactor, the peat is preheated to 360°F using waste heat. Downstream of the PEATGAS reactor the processing steps are similar to those in a coal gasification plant for SNG production.

A typical analysis of the Minnesota peat used in the process design is shown in Table 1. This peat has a high heating value of 8500 Btu per pound on a dry basis. For the "as harvested" peat containing 50% moisture, its heating value is 4250 Btu per pound. The reactor operating conditions, selected for evaluating the preliminary economics of converting peat to SNG by the PEATGAS process, consist of 500 psig pressure, 1700°F char gasifier temperature, and 440°F peat dryer temperature. Material and energy balance calculations as well as reaction kinetic and thermodynamic considerations yield a hydrogasifier temperature of 1475°F. Based on kinetics, the residence times required in the hydrogasifier and char gasifier are only 5 seconds and 2 minutes, respectively. An overall energy distribution around the entire peat gasification complex is summarized in Figure 7. It shows that the overall thermal efficiency of the process is 67% and that of the total energy input to the peat gasification complex, 52.4% is converted to SNG and 12.2% is converted to liquid hydrocarbons (benzene and fuel oil). Figure 6 shows that 78.1% of the total methane produced in the plant is made in the gasifier and only 21.9% of the methane has to be made by catalytic methanation of carbon monoxide and hydrogen. In comparison, coal gasification processes require higher percentages, 31 to 74, of the methane to be made by the catalytic methanation as given in Table 2. Therefore, the catalytic methanation requirements for peat gasification by the PEATGAS process are 50 to 350% lower than those for gasification of western subbituminous coal, depending upon the process. High methane formation in the PEATGAS reactor favors higher overall thermal efficiency of the process.

Table 1. PEAT COMPOSITION

Proximate Analysis (dry basis), wt%

Volatile Matter	65.0
Fixed Carbon	23.7
Ash	11.3
TOTAL	100.0

Ultimate Analysis, (dry basis), wt%

C	49.90
H	5.09
O	30.71
N	2.73
S	0.27
Ash	11.30
TOTAL	100.00

Calorific Value, Btu/lb 8506

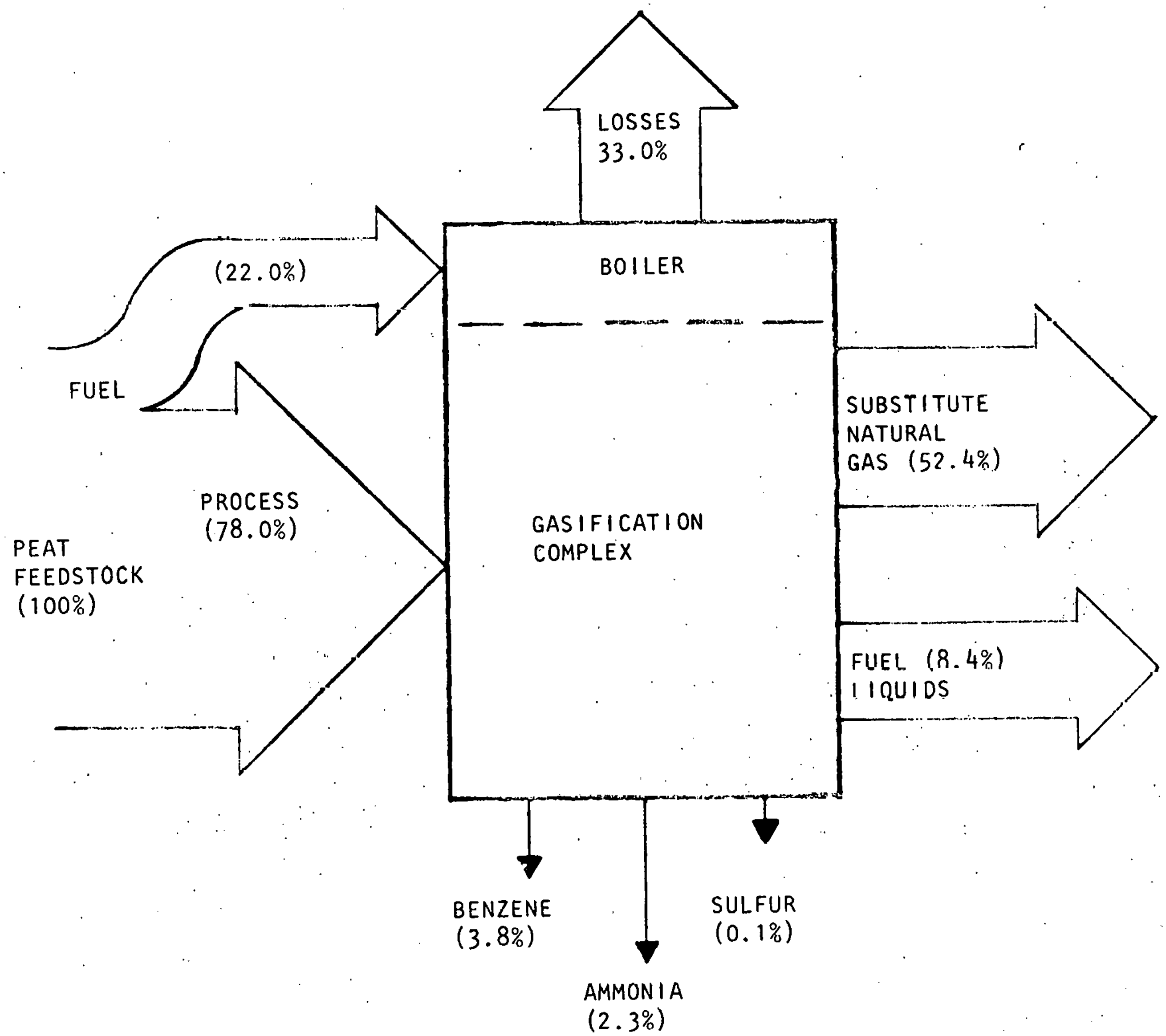

Figure 7. Energy Distribution For A Nominal 250 X 10^9 Btu/day SNG Plant Based on IGT's PEATGAS Process.

Table 2. COMPARISON OF METHANE SOURCE AND OVERALL EFFICIENCIES FOR THE PEATGAS PROCESS WITH THOSE FOR COAL GASIFICATION PROCESSES

RAW MATERIAL	PEAT	MONTANA SUBBITUMINOUS*			
PROCESS	PEATGAS	HYGAS	BI-GAS	SYNTHANE	LURGI†
Gasifier Conditions					
Pressure, psig	510	1200	1260	1000	400
No. of Stages	2	3	2	2	1
Temp. Range, °F	1475-1700	1360-1850	1600-2800	1690-1800	700-2000+
Source of Methane In Product Gas, % of Total					
Gasifier‡	78	61	26	69	48
Methanator	22	39	74	31	52
Overall Efficiency, Products as % of Coal H.H.V.	67	77	64	59	72

*Derived from "Factored Estimates for Western Coal Commercial Concepts," by C. F. Braun for ERDA, October 1976.

†Single feed.

‡Includes methane equivalent of C_2H_6 and C_2H_4, as well as CH_4, formed in the gasifier.

Figure 6 also shows that the plant requires 1,506,140 lb/hr of process steam and 3914 tons of oxygen (commercial grade, 98% purity) on a daily basis. These steam requirements are within the range of 1,016,000 and 1,670,000 lbs/hr steam requirements for an equivalent size western subbituminous coal gasification plant for SNG production as shown in Table 3. The oxygen requirements of the PEATGAS process are lower than those of the coal gasification processes, except the HYGAS process. The plant requires a total of 56,307 tons per day of "as received" peat containing 50% moisture. Of that peat, 78% is gasified and 22% is used as boiler fuel. The high moisture content of peat is used advantageously in processing downstream of the gasifier. Because the water contained in peat after vaporization stays in the gasifier effluent gases, no external steam is required for the shift reaction. The high steam content of CO-shift effluent makes it possible to use it in regenerating the acid gas removal solution, thus eliminating the requirements of stripping steam. Finally, this water is reused after treatment and thus reduces the raw makeup water requirements. The daily yield of useful byproducts from the peat-to-SNG plant are 136,030 gallons of benzene, 6680 barrels of fuel oil, 565 tons of anhydrous ammonia, and 52 long tons of sulfur. Compared to gasification plants based on a western subbituminous coal, peat gasification by the PEATGAS process produces large amounts of anhydrous ammonia and low yields of sulfur. This is because of the high nitrogen and low sulfur contents of peat. The energy content of the byproducts is 70 billion Btu. The total fuel (SNG, benzene and fuel oil) output of the plant is about 309 billion Btu per day.

CONCLUSIONS

Minnesota peat can be converted to SNG by the PEATGAS process at a plant thermal efficiency of 67%. At 500 psig operation, about 78% of the total methane produced in the plant is made within the gasifier and thus only about 22% of the methane must be made by catalytic methanation. This represents methanation requirements for peat gasification by the PEATGAS process to be 50% to 350% lower than those for western subbituminous coal gasification depending upon the gasification process. For a 250 billion Btu per day SNG plant, the daily yield of useful byproducts consists of 136,030 gallons of benzene, 6680 barrels of fuel oil, 565 tons of anhydrous ammonia and 52 long tons of sulfur. The total fuel (SNG, benzene and fuel oil) output of the plant is about 309 billion Btu per day.

TABLE 3. RAW MATERIALS AND PRODUCTS FOR NOMINAL 250 X 10^9 BTU/DAY SNG PLANT

PROCESS	PEATGAS	HYGAS	BI-GAS	SYNTHANE (SLURRY-FEED)	LURGI
Raw Material	Peat	Montana Subbituminous Coal*			
Moisture Content of Raw Material, Wt %	50	22			
Feed Requirements (Dry), tons/day					
Process	21,951.3	13,629.6	13,870.8	21,733.2	15,163.2
Fuel	6,202.0	2,337.6	3,813.6	-	3,673.2
Total	28,153.3	15,967.2	17,684.4	21,733.2	18,836.4
Oxygen (98%), tons/day	3,914.0	2,954.4	5,892.0	6,127.2	4,860.0
Steam, lb/hr	1,506,140	1,098,100	1,479,340	1,016,000	1,670,000
Process Makeup Water, gpm	2,060	1,906	2,156	2,009	2,434
BY-PRODUCTS					
Liquid Fuels, Bbl/day	9,919**	4,594	-	4,286	9,411
Ammonia, tons/day	565	88.8	92.4	86.4	140.4
Sulfur, long tons/day	52	88.9	96.4	112.5	85.7
Export Power, kW	-	-	-	128,190	-

* Coal Gasification Data for Various Processes taken from "Factored Estimates for Western Coal: Commercial Concepts Interim Report," prepared by C. F. Braun for ERDA, Oct., 1976.

** Includes benzene

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