Biomass Cogasification at Polk Power Station

Final Technical Report

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Author: John McDaniel

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Tampa Electric Company

702 N. Franklin St.

Tampa FL 33601

Attn: Mark Hornick

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ABSTRACT

Part of a closed loop biomass crop was recently harvested to produce electricity in Tampa Electric's Polk Power Station Unit #1. No technical impediments to incorporating a small percentage of biomass into Polk Power Station's fuel mix were identified. Appropriate dedicated storage and handling equipment would be required for routine biomass use.

BIOMASS TEST AT POLK POWER STATION UNIT #1 IGCC

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INTRODUCTION

Polk Unit #1 is an integrated gasification combined cycle (IGCC) power plant. IGCC is a new approach to generating electricity cleanly from solid fuels such as coal, petroleum coke, and now biomass.

The purpose of this experiment was to demonstrate the Polk Unit #1 could process biomass as a fraction of its fuel without an adverse impact on availability and plant performance. The biomass chosen for the test was part of a crop of closed loop Eucalyptus trees.

EXECUTIVE SUMMARY

Polk Unit #1 is an integrated gasification combined cycle (IGCC) power plant. IGCC is a new approach to generating electricity cleanly from solid fuels such as coal, petroleum coke, and now biomass. Solid fuel is first ground into a water slurry which is pumped into the gasifier. There it is converted at over 2400°F into a high pressure combustible gas from which pollutants such as particulates and sulfur compounds are easily removed. The clean gas then fuels a combined cycle consisting of a combustion turbine plus a steam turbine. The combustion turbine operates much like a jet engine to produce electricity. The steam turbine produces additional electricity from the system's waste heat, making the combined cycle the most efficient way to produce electricity on a large commercial scale.

Polk Unit #1 IGCC's normal fuel is a blend of coal and petroleum coke, the solid residue from crude oil refining. The fresh fuel is mixed with a pumped slurry of recycled unconverted solids and finely ground in rod mills until 98% of the particles are less then 12 mesh in size. The resulting slurry is then double-screened to prevent it from plugging the suction of the main pump which delivers it to the gasifier.

One reason for conducting the test was to confirm that the biomass could be converted into fuel gas in the gasifier. This was not much of a concern. The main reason for the test was to determine that the fuel handling system could accommodate the biomass which has physical characteristics quite different than those of the fuel for which the system was designed. The fuel handling system is not well suited to softer fibrous biomass.

Closed loop biomass is an environmentally beneficial fuel for power production. Eucalyptus has been identified as a potentially suitable plant due to its relatively rapid growth rate. Common Purpose, Inc. had planted a Eucalyptus grove on land provided by the Tampa Port Authority for this purpose. Part of this grove (approximately 60 trees or 10% of the total crop) was made available for the test.

60 of the 5-year-old trees were harvested for the test in approximately 1 day. The harvest yielded almost 9 tons of fuel. The logs were reduced to splintered wood in one pass through a commercial hammer mill which required another day's work. However, these splinters were too large to pass through the pumps and piping of the gasification plant. The fuel was determined to be fine enough after 4 more passes through the mill and a trommel screen, which took an additional day.

The fuel was transported to the gasification plant site and loaded into 1 cubic meter bottom dump tote bins. These were emptied into stirred tanks which contained the unconverted carbon slurry being recycled to the rod mills. This was done at a steady rate over and 8 hour period, making the biomass feed rate approximately 1 ton/hour or about 1½ % (wt) of the plant's fuel.

The test was relatively uneventful. The only incident occurred late in the test when three larger wood chips plugged the suction of the pump used to deliver the recycled solids and biomass to the mills. The pluggage was quickly cleared. The biomass was converted easily into syngas fuel in the gasifier.

Key findings from the test were as follows:

1) The biomass harvesting and preparation were cumbersome and expensive. This was as expected since this was a one-time test.

2) Fuel feeding and handling in the plant were very labor intensive. Despite this, some unacceptably large fragments made their way into the system and caused some problems. A dedicated automated feed system with better protection against over-size material would be required for commercial utilization of biomass at Polk.

EXPERIMENTAL

The closed loop biomass crop is a 600-tree eucalyptus grove planted in 1996 by Common Purpose, Inc., on land provided by the Tampa Port Authority. 10% of the crop was harvested in late December 2001 (Figure 1). The felled trees were cut into 4-foot logs (Figure 2. These were processed through a portable commercial hammer mill and trommel screen. After 5 passes through the mill and screen, the trees were reduced to 8.8 tons of material with the consistency of coarse sawdust (Figure 3). The particles needed to be this fine to avoid plugging the pumps and screens in the power plant's fuel slurry feed system.

FIGURE 1-Biomass Crop – Eucalyptus Grove
(Processing Equipment in Foreground)

FIGURE 2-Eucalyptus Logs **FIGURE 3-Eucalyptus Fuel After 5th Pass**

The fuel was transported by special closed trailer to Polk Power Station located in the southwest corner of Polk County. A slag bin that usually holds the non-combustible residual mineral matter from coal gasification had been thoroughly cleaned to receive the biomass and serve as the staging area. Expensive automated solids handling and feeding equipment that would be used for long term commercial operation was not installed for the brief test. Instead, the biomass was manually loaded into 22 tote sacks which held an average of 800 lb each (Figure 4). The totes were emptied over an 8½ hour test period into a stirred tank which supplies some of the water and recycled fines to the plant's coal/water slurry preparation system (1) (Figure 5).

FIGURE 4-Loading Tote Sacks **FIGURE 5-Emptying Totes Into Tank**

The test went very smoothly. The biomass comprised 1.2% of the plant's fuel during the 8½ hours it was being fed. Plant performance during the biomass test was statistically indistinguishable from operation on the plant's base fuel, a blend of coals and petroleum coke. The biomass yielded 860 kW (7700 kWh total) of electricity during the test period based on the relative heating values and flow rates of the biomass and base fuel. Overall test results are summarized in Table 1 below.

TABLE 1 - Biomass Test Overall Results

	Base Fuel	Biomass	Total/Average
Fuel Feed Rate (Lb/Hr As Received)	164,840	1,945	166,786
Moisture Content (Wt %)	7.82%	46.8%	8.27%
Higher Heating Value (BTU/ Lb As Received)	13,322	4,424	13,218
Higher Heating Value (MMBTU/Hr)	2196	8.6	2205
Net Power Production (kW)	219,640	860	220,500

There was only 1 minor incident during the test. Despite the extreme care taken to exclude all oversized material during biomass preparation, 3 wood chips did find their way into the 21st tote (Figure 6). These plugged the suction to one of the pumps in the slurry feed system. The chips were easily removed in a few minutes without any interruption to gasification or power production. A commercial biomass feed system could be easily configured to prevent this from recurring.

FIGURE 6-Oversized Fuel

From the positive test results, we conclude there is no technical impediment to incorporating small percentages of biomass into the Polk Power Station IGCC fuel mix. The biomass feeding method used for the test was obviously very labor intensive. Dedicated receiving, storage, handling, and feeding systems would be required for practical routine biomass gasification.

Figure 1 on the following page is a block flow diagram of the Polk Power Station IGCC syngas fuel production system. Table 2 shows the overall mass balance across this system. Tables 3 and 4 provide compositions and elemental balances for major constituents (C, H, S, N, O, Ash) of all the individual streams.

Table 5 presents the detailed analysis of the biomass and of the coal/petroleum coke blend, the plant's normal feedstock. Other documentation of the test such as the log of the biomass feed rate and certified truck scale tickets of the biomass delivery to the plant are available upon request.

Polk Power Station IGCC Syngas Fuel Production System

FIGURE 7-Block Flow Diagram

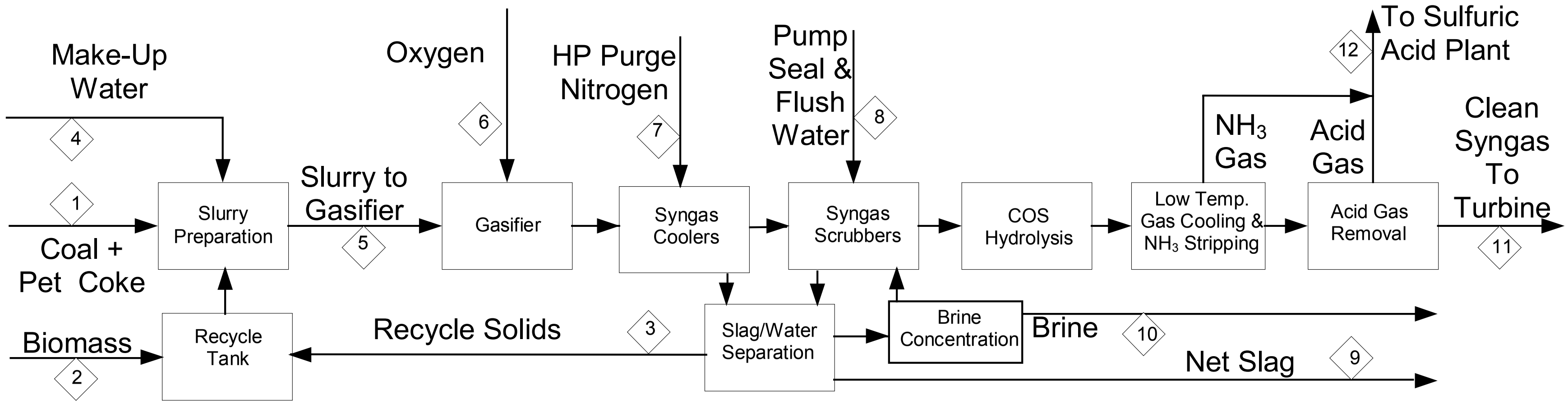

TABLE 2 – Overall Mass Balance During Biomass Test

Input (Feed) Streams		
Stream Number	Stream Description	Flow (KPPH)
1	Coal / Petroleum Coke Blend	164.84
2	Biomass	1.95
4	Make-Up Water To Slurry	16.50
6	Oxygen To Gasifier	166.94
7	High Pressure Purge/Sootblowing N_2	11.07
8	Pump Seal/Instrument Flush Water	19.49
TOTAL SYSTEM INPUT STREAMS		**380.79**

Product (Output) Streams		
Stream Number	Stream Description	Flow (KPPH)
9	Slag	17.36
10	Brine	.02
11	Clean Syngas To Combustion Turbine	337.78
12	Acid and NH_3 Gas To Sulfuric Acid Plant	25.62
TOTAL SYSTEM OUTPUT STREAMS		**380.78**

Key Internal Streams		
5	Slurry To Gasifier	264.40
3	Recycle Solids To Slurry Preparation	81.12

TABLE 3 – Slurry Preparation Area Stream Flows and Compositions

Stream Number		1	1	2		3	4	5
	Units	COKE + COAL (Lab)	COKE + COAL (Calculated)	BIOMASS	COMBINED FRESH FUELS	RECYCLE SOLIDS	MAKE-UP WATER	SLURRY TO GASIFIER
COMPOSITION								
C	Wt % Dry	82.88	82.24	49.18	82.02	66.26		80.68
H	"	4.50	4.71	5.78	4.71	0.29		4.34
N	"	1.85	1.83	0.24	1.81	0.95		1.74
S	"	2.99	3.15	0.06	3.13	2.31		3.06
O	"	3.53	3.67	39.42	3.92	0.00		3.58
ASH	"	4.25	4.40	5.32	4.41	30.19		6.60
TOTAL	"	100.00	100.00	100.00	100.00	100.00		100.00
SUBTOTAL FLOW	KPPH DRY	151.950	151.950	1.035	152.985	14.196		167.181
H2O	Wt % AR	7.82	7.82	46.8	8.27	82.50		36.77
H2O	KPPH	12.891	12.891	0.910	13.801	66.924	16.496	97.220
TOTAL FLOW	KPPH AR	164.841	164.841	1.945	166.786	81.120		264.401
MASS FLOW								
C	Dry Lb/Hr	125936	124962	509	125471	9406		134877
H	"	6838	7150	60	7210	41		7251
N	"	2811	2774	2	2777	135		2911
S	"	4543	4791	1	4791	328		5119
O	"	5364	5582	408	5990	0		5990
ASH	"	6458	6691	55	6746	4286		11031
Ar	"	0	0	0	0	0		0
SUBTOTAL-Dry Solids	"	151950	151950	1035	152985	14196		167181
WATER / MOISTURE	"	12891	12891	910	13801	66924	16496	97220
TOTAL	"	164841	164841	1945	166786	81120		264401
HEAT CONTENT								
Calculated HHV	BTU/Lb (Dry)	14491	14511	8419	14470	9698		14065
Measured HHV	BTU/Lb (Dry)	14435		8213		9811		13990
Balance HHV	BTU/Lb (Dry)	14452	14452	8315	14411	9701		14011
Balance HHV	BTU/Lb (AR)	13322	13322	4424	13218	1698		
Balance HHV	MMBTU/Hr	2196	2196	8.60	2205	138		2342

Notes: Calculated HHV is by the Mason Formula. Difference between “Lab” and “Calculated” Coke+Coal composition is within sampling and analytical accuracy range.

TABLE 4 – Gasification System Stream Flows and Compositions

		GASIFICATION SYSTEM INPUTS					GASIFICATION SYSTEM OUTPUTS					
STREAM NUMBER		5	6	7	8		9	3	10	11	12	
	UNITS	SLURRY TO GASIFIER	OXYGEN	HP PURGE NITROGEN	SEAL & FLUSH WATER	TOTAL SYSTEM INPUT	SLAG	RECYCLE SOLIDS	BRINE (NH4Cl)	CLEAN SYNGAS	ACID GASES	TOTAL SYSTEM OUTPUT
GAS STREAMS												
CO	VOL %		0.00	0.00						44.72	2.06	
H2	VOL %		0.00	0.00						36.02	0.52	
CH4	VOL %		0.00	0.00						0.02	0.02	
CO2	VOL %		0.00	0.00						15.01	66.42	
N2	VOL %		1.08	99.99						3.33	0.00	
Ar	VOL %		2.01	0.00						0.65	0.00	
H2O	VOL %		0.00	0.00						0.21	5.26	
H2S	VOL %		0.00	0.00						0.01	21.02	
COS	VOL %		0.00	0.00						0.01	0.06	
NH3	VOL %		0.00	0.00						0.00	4.62	
O2	VOL %		96.90	0.01						0.00	0.01	
TOTAL	VOL %		100.00	100.00						100.00	100.00	
MOLECULAR WT	LB/MOLE		32.12	28.02						21.10	38.76	
FLOW	KSCFH		1972.6	149.9						6075.5	250.9	
SOLID AND LIQUID STREAMS												
C	WT %	80.68					42.37	66.26				
H	WT %	4.34					0.31	0.29	7.49			
N	WT %	1.74					0.44	0.95	26.22			
S	WT %	3.06					1.47	2.31				
O	WT %	3.58					0	0.00				
ASH	WT %	6.60					55.41	30.19	66.29			
TOTAL	WT %	100.00					100.00	100.00	100.00			
DRY FLOW	KPPH	167.181					12.149	14.196	0.021			
H2O	WT %	36.77					30	82.50				
H2O FLOW	KPPH	97.220			19.489		5.207	66.924				
TOTAL FLOW	KPPH	264.401					17.356	81.120				
ELEMENTAL FLOWS / BALANCE:												
C	LB/HR	134877	0	0		134877	5148	9406		114880	5443	134877
H	LB/HR	18130	0	0	2181	20311	620	7530	2	11709	450	20311
N	LB/HR	2911	1580	11066		15558	53	135	6	14936	428	15558
S	LB/HR	5119	0	0		5119	179	328		144	4469	5119
O	LB/HR	92331	161177	1	17308	270817	4624	59435		191926	14832	270817
ASH	LB/HR	11031	0	0		11031	6732	4286	14	0	0	11031
Ar	LB/HR	0	4184	0		4184				4184	0	4184
TOTAL	LB/HR	264401	166941	11067	19489	461898	17356	81120	21	337779	25623	461898

TABLE 5 – Feedstock Analysis

	Fuel	Coal/Coke Blend	Biomass
	Units		
Total Moisture	Wt %	7.82	46.8
Ultimate Analysis			
Ash	Wt % (Dry Basis)	4.25	5.32
C	Wt % (Dry Basis)	82.88	49.18
H	Wt % (Dry Basis)	4.5	5.78
N	Wt % (Dry Basis)	1.85	0.24
S	Wt % (Dry Basis)	2.99	0.06
O	Wt % (Dry Basis)	3.53	39.42
Heating Value			
Measured HHV	BTU/Lb (Dry Basis)	14435	8213
Calculated HHV	BTU/Lb (Dry Basis)	14490	8419
Miscellaneous			
T250	Deg F	2560	2188
Chlorine	Wt % (Dry Basis in Coal)	0.02	0.07
Fluorine	Wt % (Dry Basis in Coal)	<0.01	34
Chromium	PPM (Wt) In Ash	136	85.9
Vanadium	Wt % In Ash	2.29	0.63
Nickel	ug/g dry coal	166	69
Arsenic	ug/g dry coal	2.1	1.9
Mercury	ug/g dry coal	0.03	0.02
Lead	ug/g dry coal	2.6	6.2
Beryllium	ug/g dry coal	1.3	0.49
Ash Minerals			
CrO	Wt % In Ash	0.02	0.01
V2O5	Wt % In Ash	4.08	1.12
NiO	Wt % In Ash	0.50	0.17
As2O3	Wt % In Ash	0.0065	0.0047
Hg	Wt % In Ash	0.000071	0.000037
PbO	Wt % In Ash	0.0066	0.0125
BeO	Wt % In Ash	0.0085	0.0026
SiO2	Wt % In Ash	49.21	40.7
Al2O3	Wt % In Ash	20.52	4.98
TiO2	Wt % In Ash	0.93	0.29
Fe2O3	Wt % In Ash	12.89	6.12
CaO	Wt % In Ash	3.34	22.31
MgO	Wt % In Ash	1.91	1.85
Na2O	Wt % In Ash	0.57	1.41
K2O	Wt % In Ash	2.04	3.64
P2O5	Wt % In Ash	0.16	1.44
SO3	Wt % In Ash	3.4	3.67
Sum of Determined Minerals	Wt % In Ash	99.07	87.73
Undetermined Ash Minerals	Wt % In Ash	0.93	12.27

RESULTS AND DISCUSSION

The main objective of the test was met, i.e., to demonstrate feeding of biomass to the gasification system. However, it became clear that other means must be developed to inject commercial quantities. Specifically, it required 4 men full time to feed 0.4% of the plant's fuel heating value during the 8.5 hour test. The plant's full operating staff is only 10 men. Even with this high level of manpower dedicated to the biomass, some oversized material still made its way into the system and caused problems.

The harvesting and testing demonstrated that biomass does not lend itself to size separation by screening. One promising option under consideration is to feed the woody biomass preground to nominally ½" size as a solid directly to the rod mills. This would prevent oversized chips from plugging the recycle slurry pump. Hopefully the mill would reduce any oversized chips to a size that could be accommodated by the main slurry screens and gasifier feed pump.

Another option is to concentrate on other biomass forms such as grasses. It is not unlikely that grasses may pose problems of their own such as agglomerating, and they could be accompanied by fairly sturdy weed stalks. Nevertheless, they would be less likely to plug pumps and lines than woody fuels if fed in small quantities.

Biomass fuel has very low energy density. The eucalyptus used for the test contained only 1/3 the heating value per pound at about half the bulk density of coal. Consequently, for even a modest contribution to the plant's fuel requirement, a biomass feed system would need to be quite massive, and would likely to be relatively expensive.

CONCLUSIONS

Small quantities of biomass can be used to supplement the main fuel to a base-loaded gasification combined cycle power plant. The gasifier itself is quite capable of converting modest quantities of biomass to syngas. A feed system tailored to the particular biomass fuel must be used if plant availability is to be maintained. This is particularly true of slurry-fed gasifiers such as the one at Polk Power Station. Significant quantities of biomass will be required to produce a small portion of the plant's power due to the relatively low energy density of biomass fuel. Consequently, the supplemental biomass feed system(s) could be physically almost as large as the feed system for normal solid fuel such as coal or petroleum coke.

REFERENCES

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