CO-FIRING EUCALYPTUS BIOMASS WITH PULVERIZED COAL

Lakeland Electric & Water
McIntosh Power Plant
Unit 3

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The McBurney Corporation
Norcross, GA
November 1998

219287-2

Introduction

Lakeland Electric & Water is investigating co-firing biomass with coal in existing coal fired units. This technique involves the direct injection of shredded wood fiber material into a pulverized coal fired furnace. Biomass was shredded to the consistency of fine mulch and blown into the furnace through existing refuse fuel injection ports. Coal and wood handling processing are separate. The McIntosh Plant has the unique benefit that the original system was designed to fire 10% (heat input basis) refuse derived fuel. It includes an existing solid waste processing facility and fuel transport system.

On August 26, 1998, tests were conducted at Lakeland's McIntosh Plant to test the biomass co-firing concept. Approximately 125 tons of shredded whole Eucalyptus trees were acquired from a local supplier. Tests were conducted by Lakeland Electric, co-firing this unit with a combination wood and coal. During a single continuous performance test, plant data was collected to evaluate the effect of co-firing the wood fuel.

In these tests, a co-firing level approaching 5% by heating value was achieved at full load. Average wood consumption rate during the test was about 21 tons/hour. Comprehensive stack tests were performed to determine the effect of co-firing wood compared to the same load on coal only. Results of the stack test are included in this report.

Boiler efficiency was lower with wood co-firing, due predominantly to fuel moisture and increased excess air associated with the wood fuel injection. With wood co-firing, boiler efficiency was reduced from baseline condition (100% coal blend) by approximately one boiler efficiency percentage point.

The test period was short for establishing effects on operations and maintenance. However, for the six hour test duration unusual slagging or fouling of the furnace was not noted.

This report presents the results of this test

Objectives

The objectives of this test were:

1. Determine if the existing refuse injection system is suitable for direct injecting shredded wood waste.
2. Evaluate the system performance when co-firing wood waste compared to 100% coal firing.
3. Obtain stack emissions data with and without the co-firing:

Fuel Analyses

Wood fuel samples were taken and ultimate analysis and heating value were determined by lab analysis. Copies of the lab results are attached. Following is a table of these analyses:

		Eucalyptus	Coal/Pet Coke
Carbon	(% wt.)	24.91	74.24
Hydrogen	(% wt.)	2.73	4.57
Oxygen	(% wt.)	19.81	5.33
Nitrogen	(% wt.)	0.11	1.43
Sulfur	(% wt.)	0.04	2.14
Ash	(% wt.)	0.94	7.45
Moisture	(% wt.)	51.46	4.83
Higher Heating Value	(Btu/lb)	4,238	13,305

Stack Test Results

Three hour stack tests were run for each of the firing conditions. The test data is attached to this report. A summary of the results is as follows:

		Coal Only	Co-Firing
NO_X	ppmv, dry basis	249.4	238.6
	lbs/MMBtu	0.504	0.481
SO_2	ppmv, dry basis	199.6	248.7
	lbs/MMBtu	0.561	0.697
PM	grams/DSCF	0.00009	0.00011
	lbs/MMBtu	0.0035	0.0040

Effect on Boiler Efficiency

The boiler efficiency decreased by about 1% when coal heat input was replaced by biomass. Following is a summary of the approximated heat losses:

		Coal Only	Co-Firing
Dry Gas	(%)	5.61	5.74
H_2 & H_2O in Fuel	(%)	3.94	4.76
Moisture in Air	(%)	0.15	0.15
Unburned Carbon	(%)	0.50	0.50
Radiation	(%)	0.16	0.16
Total Heat Loss	(%)	10.37	11.32
Boiler Efficiency	(%)	89.63	88.68

Fuel Handling

The existing fuel transport system handled the wood waste without problems. The plant personnel commented that the feed rate was extremely stable compared to refuse derived fuel.

Conclusions

Based upon tests conducted at the McIntosh Plant, the following conclusions can be made:

1. Wood was successfully co-fired by direct injection into the furnace. Co-firing levels approaching 5% by heating value were achieved with the plant at full load.

2. Wood consumption rate with the existing system was about 21 tons/hour.

3. With co-firing the stack emissions indicated a reduction in NOX and an increase in SO2 and particulate. However, due to the low percentage heat input from biomass these results are not conclusive. The nitrogen, sulfur and ash content of eucalyptus fuel was lower than the coal on an as fired basis.

4. Boiler efficiency decreased with wood co-firing.

5. The shredded eucalyptus trees flowed easily through the existing system.

6. Unusual slagging or fouling was not noted in the short course of this test.

7. Particles of unburned wood were present to some degree on the dump grate. Combustion of these unburned particles can be completed prior to dumping the grate.

Acknowledgments

This study was partially funded by the U.S. Department of Energy with funds from the Southeastern Regional Biomass Energy Program (SERBEP). SERBEP is administered for the U.S. Department of Energy by the Tennessee Valley Authority.

The success of this test is a result of the active participation and support of the following individuals: Jerry Burse, Tommy Dixon, Ed Colter, Billy Haywood, Dr. Alex Green and Steve Segrest. In addition, plant operators were instrumental in ensuring the safe and stable operation of the plant.

PHOTO 1
Eucalyptus Chips As Received on Tipping Floor

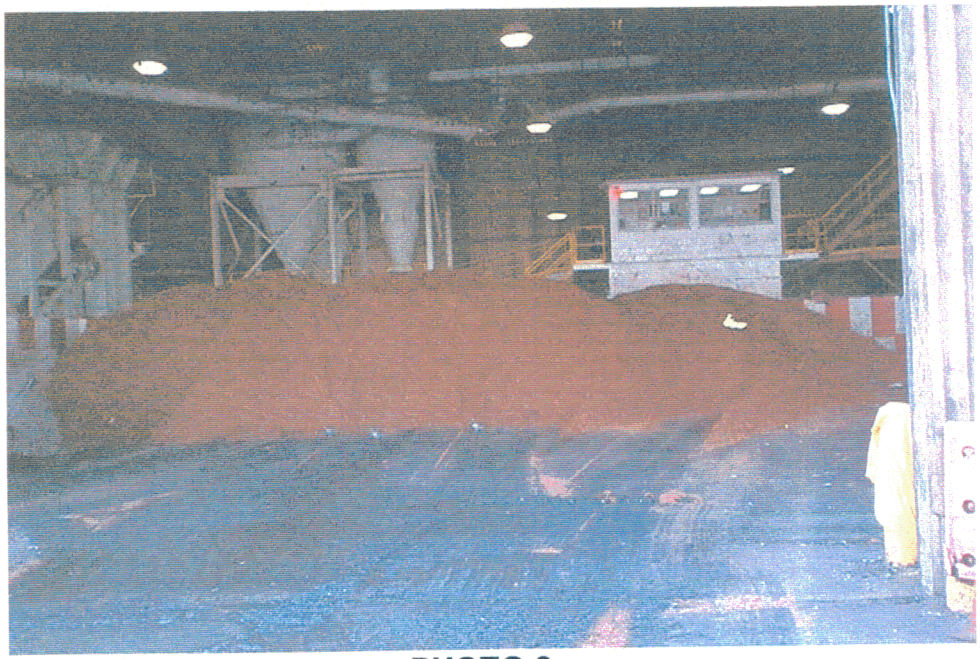

PHOTO 2
Eucalyptus Chip Pile Prepared for Firing

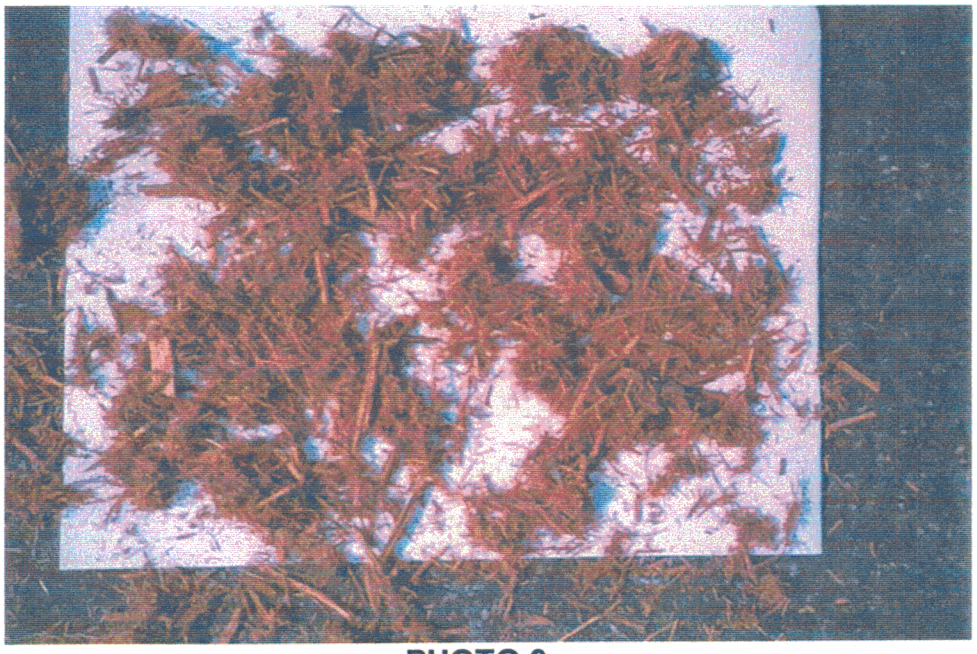

PHOTO 3
Closeup View of Eucalyptus Chips

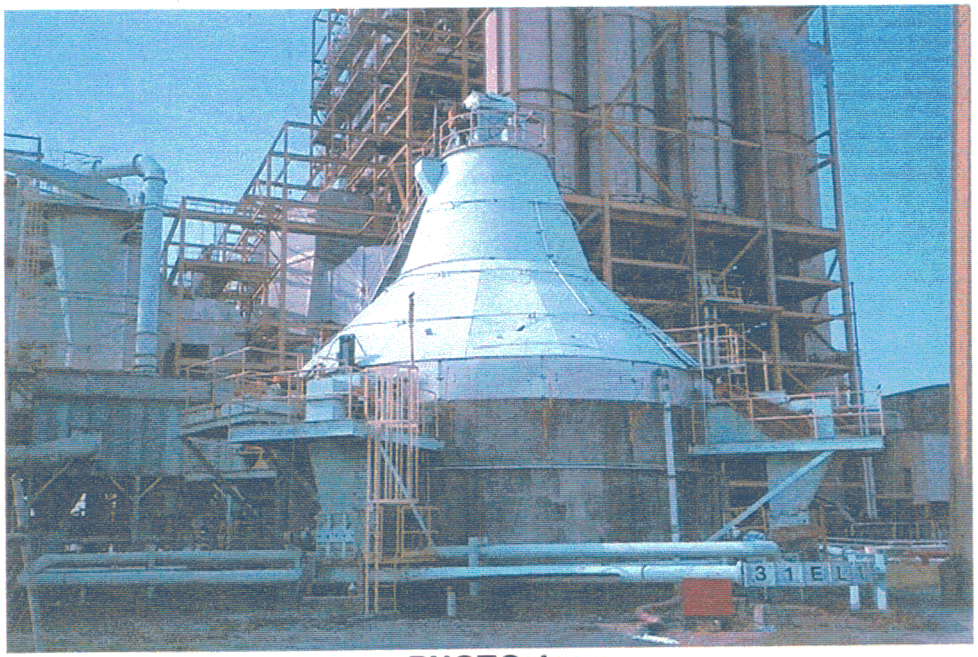

PHOTO 4
Atlas Storage Bin with Drag Chain Discharge Conveyors and Pneumatic Transport Lines

PHOTO 5
Baghouse for Dust Suppression System and Pneumatic Transport Pipes

PHOTO 6
Center Cone and Fuel Sweep Inside Atlas Fuel Storage Bin

PHOTO 7
Atlas Bin Floor Opening to Discharge Drag Chain
with Fuel Sweep Approaching Opening

PHOTO 8
End View of 1 of 4 Drag Chain Discharge Conveyors
from Atlas Fuel Storage Bin

PHOTO 9
Top View of Drag Chain Discharge
While Conveying Eucalyptus Chips

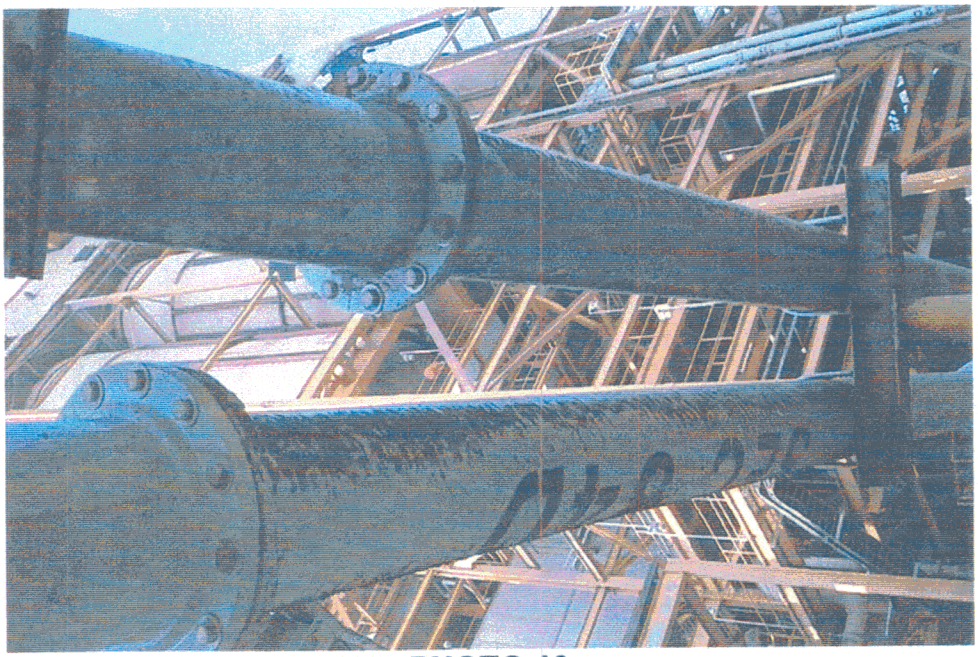

PHOTO 10
Fuel Transport Pipes

PHOTO 11
Fuel Transport Pipes

PHOTO 12
1 of 4 Rotary Air Locks Between
Drag Chain Discharge and
Fuel Transport Pipe

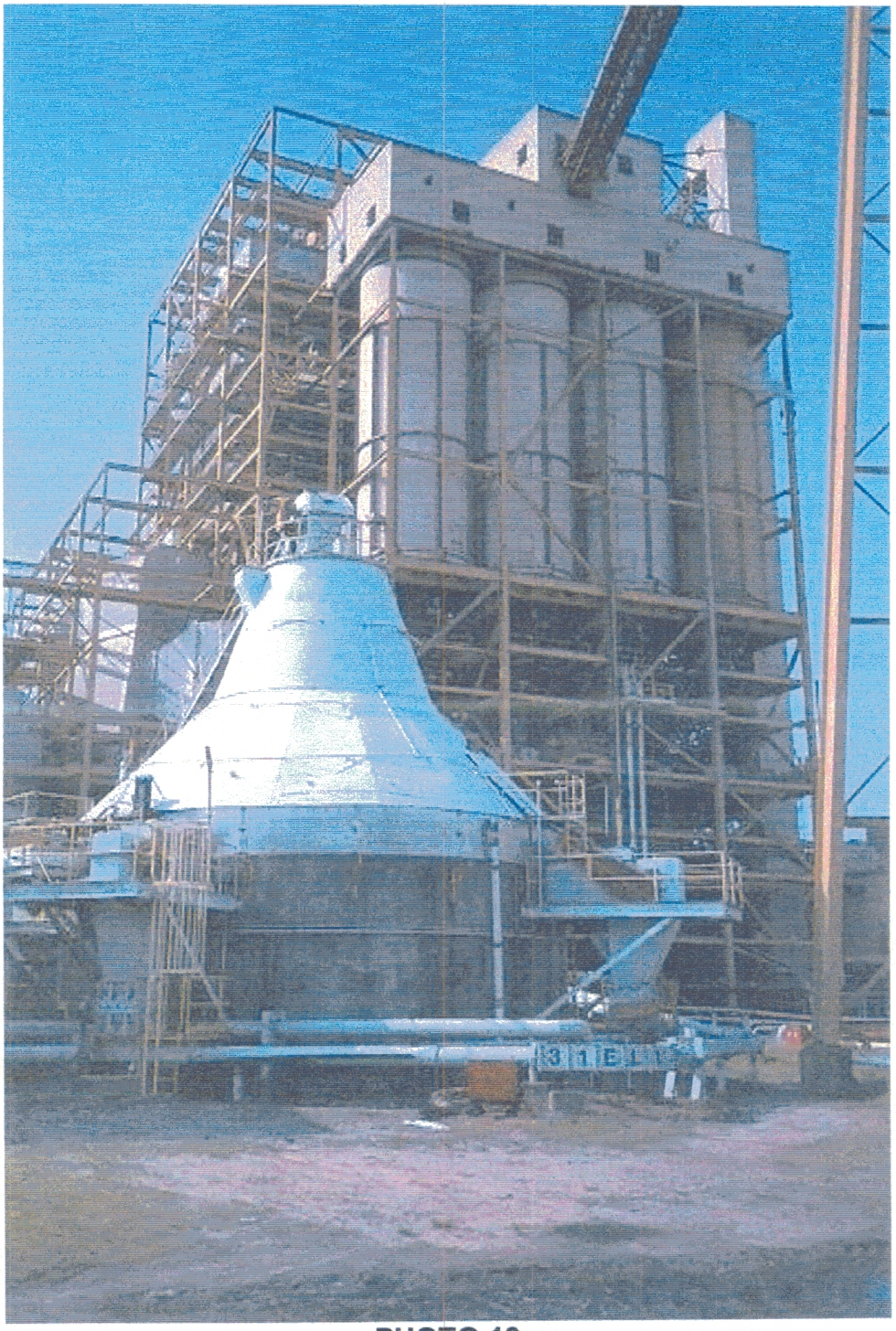

PHOTO 13
Atlas Fuel Storage Bin
Coal Silos and Boiler in Background

COAL AND BIOMASS CO-FIRING DATA

Boiler Duty Data	Units	14:29	15:29	16:29	17:29	18:29	Average
Main Steam Temp @ Blr	(^{0}F)	*Single Data Point Available*					**1007.4**
Econ Water Inlet Temp	(^{0}F)	355.5	355.9	356.4	355.9	355.4	**355.8**
31 PSH Outlet Temperature	(^{0}F)	835.3	846.1	848.9	838.5	838.9	**841.5**
32 PSH Outlet Temperature	(^{0}F)	850.1	862.9	865.9	851.9	851.9	**856.5**
31 1rst DES Steam Out Temperature	(^{0}F)	732.1	733.7	733.2	734.3	736.6	**734.0**
32 1rst DES Steam Out Temperature	(^{0}F)	715.6	716.7	715.6	716.2	716.5	**716.1**
31 Platen SH Out Temp.	(^{0}F)	813.0	814.4	814.1	812.9	814.6	**813.8**
32 Platen SH Out Temp.	(^{0}F)	813.2	814.5	814.1	813.2	814.9	**814.0**
Hot Reheat Stm Temp	(^{0}F)	*Single Data Point Available*					**1122.0**
Cold RH Attemp In Temp	(^{0}F)	665.7	668.4	668.7	666.1	666.7	**667.1**
Cold RH Attemp Out Temp	(^{0}F)	647	634.2	630.5	642.9	648.3	**640.6**
RH Spray Water Temp	(^{0}F)	*Single Data Point Available*					**408.0**
Main Stm Flow	(Klbh)	2215.2	2210.5	2210.6	2208.7	2209.3	**2210.9**
31 2 ST Attemp Flow	(Klbh)	26.6	30.4	30.5	23.6	24.3	**27.1**
32 2 ST Attemp Flow	(Klbh)	22.8	26.2	25.6	18	18.3	**22.2**
31 1 ST Attemp Flow	(Klbh)	141.2	148.1	152.1	141.1	141.6	**144.8**
32 1 ST Attemp Flow	(Klbh)	116.1	122.0	125.9	115.4	113.4	**118.6**
Reheat Attemp Flow	(Klbh)	19.9	47.1	53.9	26.4	20.8	**33.6**
FW Flow	(Klbh)	1896.9	1866.4	1868.0	1903.0	1906.8	**1888.2**
Main Stm Press	(psig)	2174.2	2170.0	2170.3	2169.1	2171.0	**2170.9**
Cold RH Stm Press	(psig)	589.4	593.2	594.9	589.4	588.6	**591.1**
Hot RH Stm Press	(psig)	560.2	563.9	565.3	559.6	559.7	**561.7**
Boiler Drum Press	(psig)	2465.0	2459.4	2460.5	2460.9	2463.3	**2461.8**

COAL AND BIOMASS CO-FIRING DATA

Combustion Data	Units	14:29	15:29	16:29	17:29	18:29	Average
31 SCAH In Temp	(^{0}F)	107.7	108.3	108.8	107.9	106.3	**107.8**
32 SCAH In Temp	(^{0}F)	105.4	105.1	105.4	105.5	107.1	**105.7**
31 APH Air In Temp	(^{0}F)	112.5	106.8	106.8	112.7	104.4	**108.6**
32 APH Air In Temp	(^{0}F)	111.9	111.3	111.8	112.1	113.5	**112.1**
31 APH Air Out Temp	(^{0}F)	444.4	443.0	443.8	447.2	445.2	**444.7**
32 APH Air Out Temp	(^{0}F)	503.4	504.2	503.7	504.7	507.0	**504.6**
31 APH Gas In Temp	(^{0}F)	609.4	608.6	606.9	606.7	609.6	**608.2**
32 APH Gas In Temp	(^{0}F)	609.7	608.2	606.0	607.3	610.3	**608.3**
31 APH Gas Out Temp	(^{0}F)	276.9	273.1	275.0	279.4	273.1	**275.5**
32 APH Gas Out Temp	(^{0}F)	309.1	306.5	306.7	306.3	305.9	**306.9**
31 Boiler O2	(%)	2.6	2.6	2.6	2.6	2.6	**2.6**
32 Boiler O2	(%)	3.5	3.5	3.5	3.5	3.5	**3.5**
Total Boiler Air Flow	(Klbh)	184182	185570	185670	181921	182429	**183954**
31 Coal Flow	(Klbh)	66.6	66.0	66.0	66.0	66.4	**66.2**
32 Coal Flow	(Klbh)	65.5	64.7	65.1	64.8	65.3	**65.1**
33 Coal Flow	(Klbh)	65.2	64.5	64.5	64.5	64.9	**64.7**
34 Coal Flow	(Klbh)	66.4	65.7	65.8	65.7	66.2	**66.0**

COAL FIRING DATA

Boiler Duty Data	Units	9:29	10.29	11:29	12:29	13.29	Average
Main Steam Temp @ Blr	(^{0}F)	*Single Data Point Available*					**1010.1**
Econ Water Inlet Temp	(^{0}F)	354.5	355.3	355.2	354.6	355.3	**355.0**
31 PSH Outlet Temperature	(^{0}F)	844.5	850.9	852.0	829.3	839.5	**843.2**
32 PSH Outlet Temperature	(^{0}F)	854.6	861.2	863.1	842.6	850.6	**854.4**
31 1rst DES Steam Out Temperature	(^{0}F)	736.2	734.7	731.4	724.6	726.4	**730.7**
32 1rst DES Steam Out Temperature	(^{0}F)	714.5	713.5	710.3	704.3	706.6	**709.8**
31 Platen SH Out Temp.	(^{0}F)	814.1	814.1	814.2	813.5	814.2	**814.0**
32 Platen SH Out Temp.	(^{0}F)	814.7	814.4	814.4	813.9	814.3	**814.3**
Hot Reheat Stm Temp	(^{0}F)	*Single Data Point Available*					**1122.0**
Cold RH Attemp In Temp	(^{0}F)	666.4	667.4	667.4	666.3	667.2	**666.9**
Cold RH Attemp Out Temp	(^{0}F)	649.7	641.1	638.5	651.2	640.0	**644.1**
RH Spray Water Temp	(^{0}F)	*Single Data Point Available*					**408.0**
Main Stm Flow	(Klbh)	2214.2	2215.3	2213.2	2210.6	2211.1	**2212.9**
31 2 ST Attemp Flow	(Klbh)	20	22.3	25.2	35.9	35.7	**27.8**
32 2 ST Attemp Flow	(Klbh)	18	19.7	22.2	31.4	30.8	**24.4**
31 1 ST Attemp Flow	(Klbh)	146.2	152.6	159.1	153.0	153.9	**153.0**
32 1 ST Attemp Flow	(Klbh)	119.3	126.2	132.4	121.6	127.0	**125.3**
Reheat Attemp Flow	(Klbh)	17.5	33.4	37.2	18.1	35.2	**28.3**
FW Flow	(Klbh)	1890.8	1868.7	1863.5	1878.9	1848.3	**1870.0**
Main Stm Press	(psig)	2169.2	2170.1	2169.3	2168.6	2169.2	**2169.3**
Cold RH Stm Press	(psig)	586.9	590.0	590.2	586.2	590.4	**588.7**
Hot RH Stm Press	(psig)	558.3	561.1	561.0	557.6	561.4	**559.9**
Boiler Drum Press	(psig)	2458.9	2458.6	2457.5	2456.8	2456.7	**2457.7**

COAL FIRING DATA

Combustion Data	Units	9:29	10.29	11:29	12:29	13:29	Average
31 SCAH In Temp	(^{0}F)	94.1	98.7	103.3	105.4	106.8	**101.7**
32 SCAH In Temp	(^{0}F)	97.5	100.4	102.7	104.5	106.1	**102.2**
31 APH Air In Temp	(^{0}F)	97.1	100.5	105.6	106.6	105.0	**103.0**
32 APH Air In Temp	(^{0}F)	104.2	106.9	109.2	110.7	112.8	**108.8**
31 APH Air Out Temp	(^{0}F)	437.3	437.4	437.5	443.5	437.2	**438.6**
32 APH Air Out Temp	(^{0}F)	500.9	501.2	501.9	503.5	498.9	**501.3**
31 APH Gas In Temp	(^{0}F)	608.9	607.3	607.9	610.7	605.2	**608.0**
32 APH Gas In Temp	(^{0}F)	614.3	612.2	611.7	612.4	607.1	**611.5**
31 APH Gas Out Temp	(^{0}F)	263.2	264.2	266.6	272.5	266.5	**266.6**
32 APH Gas Out Temp	(^{0}F)	303.6	303.1	307.4	311.6	298.2	**304.8**
31 Boiler O2	(%)	2.6	2.6	2.6	2.6	2.6	**2.6**
32 Boiler O2	(%)	3.5	3.5	3.5	3.5	3.5	**3.5**
Total Boiler Air Flow	(Klbh)	182756	182291	182350	182904	182527	**182566**
31 Coal Flow	(Klbh)	67.9	67.4	68.1	68.2	66.3	**67.6**
32 Coal Flow	(Klbh)	66.7	66.7	66.8	67.2	67.2	**66.9**
33 Coal Flow	(Klbh)	66.5	66.2	66.6	66.7	66.9	**66.6**
34 Coal Flow	(Klbh)	67.6	67.4	67.8	68.0	68.1	**67.8**

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April 13, 1998

CITY OF LAKELAND
3030 E. Lake Parker Dr.
Lakeland, FL 33805
Attn: Steven Parrish

Sample identification by
City of Lakeland

Kind of sample
reportad to us Petroleum Coke / Coal blend

Sample ID: 480-98

Sample taken at ------

Sample taken by ------

Date sampled March 8, 1998

Date received April 3, 1998

P.O. No. 42727

Analysis Report No. 71-64516 Page 1 of 1

ULTIMATE ANALYSIS

	As Received	Dry Basis	
% Moisture	4.83	xxxxx	
% Carbon	74.24	78.01	
% Hydrogen	4.57	4.80	
% Nitrogen	1.43	1.50	
% Sulfur	2.14	2.25	
% Ash	7.46	7.84	
% Oxygen(diff)	5.33	5.60	
	100.00	100.00	
Btu/lb	13305	13980	MAF Btu 15169
% Chlorine	0.12	0.13	
Fluorine, ug/g		68	

METHODS
Moisture: ASTM D 3302; Carbon, Hydrogen & Nitrogen: ASTM D 5373; Sulfur: ASTM D 4239 (Method C); Ash: ASTM D 3174
Oxygen: Calculated Value (Difference); Btu/lb: ASTM D 3286; Chlorine: ASTM D 4208; Fluorine: ASTM D 3761

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.

Manager, South Holland Laboratory

GENERAL TEST LABORATORY
P.O. Box 2641
BIRMINGHAM, ALABAMA 35291
(205) 664 - 6081

ALABAMA POWER
A SOUTHERN COMPANY

CERTIFICATE OF ANALYSIS

TO:

Address:

Customer Account
Sample Date : 28-Aug-98
Laboratory Account : CSDIG
Received Date : 03-Sep-98

Description : McBurney Corp. Eucalyptus Fuel

Laboratory ID Number AC24135

Test Name	Reference	Result	Units
Dry Basis			
Ash, Dry	ASTM D 5142	1.93	% By Weight
Heat of Combustion, Dry	ASTM D 5865	8730	Btu/lb
Carbon, Dry Basis	ASTM D 5373	51.32	% By Weight
Hydrogen, Dry Basis	ASTM D 5373	5.62	% By Weight
Nitrogen, Dry Basis	ASTM D 5373	0.23	% By Weight
Chlorine, Dry Basis	ASTM D 3761	499	mg/kg
Sulfur, Dry Basis	ASTM D 4239	0.08	% By Weight
As Received			
Moisture, Total	ASTM D 2013	51.46	% By Weight
Ash, As Received	ASTM D 5142	0.94	% By Weight
Heat of Combustion, As Received	ASTM D 5865	4238	Btu/lb
Carbon, As Received	ASTM D 5373	24.91	% By Weight
Hydrogen, As Received	ASTM D 5373	2.73	% By Weight
Nitrogen, As Received	ASTM D 5373	0.11	% By Weight
Chlorine, As Received	ASTM D 3761	242	mg/kg
Sulfur, As Received	ASTM D 4239	0.04	% By Weight
General			
Heat of Combustion, MAF	ASTM D 5865	8902	Btu/lb
Coal Contract Sulf - #/mmBtu	ASTM D 3180	0.092	lbs/mmBTU
Sulfur - lbs/mmBTU	ASTM D 3180	0.092	lbs/mmBTU

This Certificate states the physical and/or chemical characteristics of the sample as submitted.

Comments:

Quality Control _____ Supervision _____ Date : 9/25/98

cc:

smk/ccal

Company: The City of Lakeland, EPD
Plant: C.D. McIntosh, Jr. Power Plant
Location: Lakeland, Polk County, Florida
Technicians: LJB, DKV, RPO
Source: Unit 3, a 364 MW Steam Boiler

Preliminary Results
PM, SO2, and NOx
Unit M-3 Boimass

Test Run Designation	Normal	Biomass	Average
Date	8/26/98	8/26/98	
Start Time (24 hr. CEMS time)	10:55	15:45	18:06
Stop Time (24 hr. CEMS time)	13:18	17:52	
Unit Operational Data			
Fuel Flow (tons/hr of coal + petroleum coke)	130.93	132.94	131.94
Fuel Flow (tons/hr of refuse derived fuel)	4.08	1.31	2.70
Heat Input (MMBtu/hr, coal + coke + refuse)	3426.3	3420.2	3423.3
Unit Load (% capacity, based upon 3640 MMBtu/hr maximum	94.1	94.0	94.0
Generator Output (MW, average for the tests)	367	367	367.0
Stack Gas Sampling Data			
PM Hot/Cold Box No.	C-1	C-3	-
Dry Gas Meter Factor	0.9888	0.9888	0.9888
Atmospheric Pressure ("Hg, absolute)	29.46	29.44	29.45
Average ΔH (meter differential pressure @ orifice)	2.29	2.37	2.33
Average Meter Temperature (°R)	549.6	554.5	552.0
Sample Volume at STP, dry basis (SCF)	88.799	93.659	91.229
Moisture (% volume)	11.76	10.65	11.21
O_2 (% volume, dry basis)	8.82	8.80	8.81
CO_2 (% volume, dry basis)	10.71	10.74	10.73
Stack Velocity (ft/sec @ stack conditions)	86.15	87.56	86.86
Stack Flow, wet (kSCFM)	1158.87	1166.71	1162.79
Stack Flow, dry (SCFH)	6.14E+07	6.25E+07	6.20E+07
Sample Run Time (minutes)	120	120	120
PM Sample Nozzle Area (ft²)	0.0001917	0.0001917	0.000192
% of Isokinetic Sampling	102.7	106.2	104.4
Particulate Matter Weight Analysis			
Filter Number	**C-1**	**C-3**	
Average Tare Weight	0.3792	0.3641	0.3716
Average Final Weight	0.3831	0.3684	0.3758
Filter Weight Gain	0.0040	0.0044	0.0042
Filter Blank Number	**B-3**	**B-2**	
Average Tare Weight	0.3677	0.3677	0.3677
Average Final Weight	0.3677	0.3677	0.3677
Filter Blank Weight Gain	0.0000	0.0000	0.0000
Acetone Rinse (PM) Blank Number	**A-1**	**A-2**	
Volume (Acetone)	100	100	100.0
Average Tare Weight	97.4350	96.1587	96.7968
Average Final Weight	97.4400	96.1651	96.8025
Nozzle Weight Gain	0.0050	0.0064	0.0057
Acetone Rinse (PM) Blank Number	**A-1**	**A-2**	
Volume (Acetone)	100	100	100
Average Tare Weight	101.6676	101.6676	101.6676
Average Final Weight	101.6682	101.6682	101.6682
Acetone Blank Residue Concentration (mg/mg)	0.0000076	0.0000076	0.0000076
Particulate Matter Weight Gain			
Total Collected Blank Weight Correction (Acetone + Filter)	0.00060	0.00060	0.0006
Total Collected Sample Weight (Filter + Nozzle + Loose PM)	0.00900	0.01075	0.0099
Total Collected Particulate Matter, Blank Corrected (g)	0.00840	0.01015	0.0093
Measured Emissions			
NO_x (ppmv, dry basis)	249.4	238.6	244.0	
NO_x (lbs/MMBtu, per EPA Method 19 O_2 "F_d Factor")	0.504	0.481	0.493	0.70
SO_2 (ppmv, dry basis)	199.6	248.7	224.2	
SO_2 (lbs/MMBtu, per EPA Method 19 O_2 "F_d Factor")	0.561	0.697	0.629	1.20
PM (grams PM/DSCF flue gas)	0.00009	0.00011	0.00010	
PM (lbs/MMBtu, per EPA Method 19 O_2 "F_d Factor")	0.0035	0.0040	0.0038	0.050

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