FINAL REPORT

Feedstock Efficiency Tests with a small Pickup-mounted Down Draft Gasifier

Wayne Keith and David Bransby

July 10, 2010

Objective

The objective of this study was to determine composition and performance of synthesis gas from gasification of selected alternative feedstocks being tested for co-firing in the Lafarge Roberta Cement kiln at Calera, Alabama, using a small down draft gasifier mounted on a pickup.

Procedure

Different feedstock mixtures were tested in a small biomass gasifier mounted on a Dodge Dakota pickup (Figure 1). Wood was used as the primary feedstock, then tested with mixtures containing 80% wood and 20% of broiler litter, switchgrass and plastic (Figures 2, 3 and 4) on an as-is weight basis. Gasoline was used as a reference point. The following steps were taken for each feedstock combination:

1) Modifications were made to the pickup so that the gas tank could be drained completely dry, and to the gasifier so samples of the syngas could be easiliy drawn for analysis.
2) Prior to the gasifier tests, the pickup was driven on 2 gallons of gasoline to provide a point of reference. The gas tank was completely drained to be sure that the 2 gallons of gasoline were accurately measured (Figure 5)
3) Feedstocks were accurately weighed on a medical scale (Figure 6) and loaded into the gasifier (Figure 7), being sure the mixture was spread as evenly as possible from top to bottom.
4) Feedstocks were sub-sampled for composition analysis, including ultimate and proximate analyses, and ash fusion temperature, at the Alabama Power Analytical Lab, Calera, AL.
5) Performance of each feedstock combination was determined by driving the pickup on the NCAT test track (Figure 8) at 50-55 mph till the fuel was completely used up. Exact time and distance and weather conditions were recorded.
6) Approximately every thirty minutes after starting the performance test for each gasifier feedstock, the pickup was stopped to measure composition of the synthesis gas (% hydrogen, carbon monoxide, methane, carbon dioxide and oxygen; Figures 9, 10, 11 and 12) being produced, with a gas analyzer. This resulted in 4 readings per feedstock.
7) Efficiency for each feedstock was calculated by determining the distance traveled per unit of energy.

Figure 1. Pick-up mounted down draft gasifier.

Figure 2. Switchgrass cubes and wood samples.

Figure 3. Broiler litter pellets

Figure 4. Plastic bags rolled into tight rolls

Fogure 5. Draining the gas tank prior to the gas test.

Figure 6. Weighing wood in plastic bags prior to loading into gasifier

Figure 7. Loading wood into the gasifier

Figure 8, Driving the pickup on the NCAT test track

Figure 9. Tube taking syngas sample from gasifier

Figure 10. Gas analyzer

Figure 11. Readings on gas analyzer

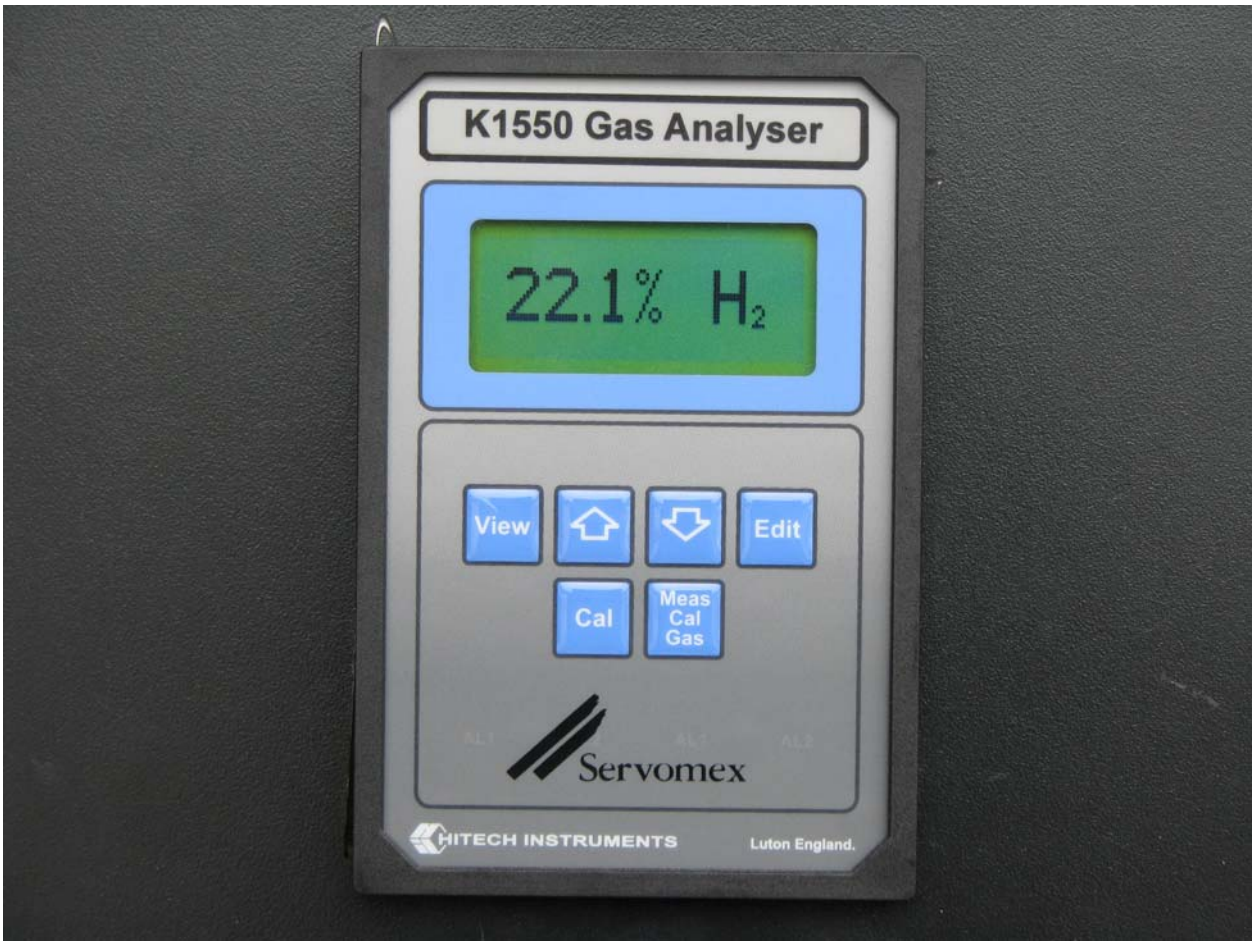

Figure 12. Hydrogen reading on gas analyzer.

Results and Discussion

Feedstock test data, including time of test, syngas composition and distance traveled, are presented in Table 1, and weather data are presented in Table 2. Of particular interest, is that the tests with gasoline and wood + plastic were conducted in cloudy weather with no rain, but the other feedstocks were tested under extended severe thunderstorm conditions with almost constant extremely heavy rain (Figure 13). This, together with the fact that no stops were made with the gasoline test, as opposed to 4 stops with each gasifier feedstock, resulted in the gasifier tests incurring a disadvantage relative to gasoline.

Table 1. Syngas, Mileage and Weather Records May 29, 2010

1) Gasoline: 2 gal – 41.9 miles Time 9:00 – 10:00

2) 50 lb of wood Time: 10:00 – 12:00

Reading	Miles	H%	CO%	CO2%	CH4%	O%
1	9.0	14.7	20.99	7.09	0.74	0.76
2	27.5	20.0	18.82	8.50	1.56	1.30
3	39.6	22.2	19.38	9.30	1.74	1.03
4	50.0	20.5	18.92	9.80	1.74	0.82
Total/mean	65.0					

3) 40 lb of wood, 10 lb switchgrass Time: 12:00 – 14:00

Reading	Miles	H%	CO%	CO2%	CH4%	O%
1	10.3	18.4	22.41	6.20	0.71	1.01
2	27.5	18.9	14.46	9.10	1.47	1.58
3	39.6	22.9	15.89	11.4	3.14	0.74
4	48.4	18.2	15.51	9.20	1.13	1.04
Total	58.0					

4) 40 lb wood, 10 lb broiler litter Time: 14:00 – 16:00

Reading	Miles	H%	CO%	CO2%	CH4%	O%
1	10.4	19.3	14.30	9.81	3.09	0.92
2	27.6	24.6	22.90	7.33	2.52	0.89
3	39.7	22.2	16.04	10.2	1.92	0.79
4	50.2	5.83	22.36	4.82	0.06	0.70
Total	50.2					

5) 40 lb wood, 10 lb plastic Time:16:00 – 18:00

Reading	Miles	H%	CO%	CO2%	CH4%	O%
1	10.4	13.3	13.21	9.50	5.15	1.44
2	27.6	17.9	17.02	6.53	2.72	2.82
3	39.7	15.9	17.00	4.84	2.61	4.43
4	50.1	14.5	15.43	4.64	1.66	4.85
Total	69.9					

Table 2. Hourly Weather Data for Opelika obtained from the Weather Channel

Time	Description	Temp ^{0}F	Dew pt ^{0}F	Humidity%	Pressure	Wind
09:30	Cloudy	74	68	82	29.87	E 7mph
10:30	Cloudy	75	69	80	29.87	ESE 5mph
11:30	Cloudy	78	70	76	29.88	ESE 7 mph
12:30	Thunder Heavy Rain	81	70	70	29.87	SE 8 mph
13:30	Thunder Heavy Rain	78	70	70	29.86	E 8 mph
14:30	Thunder Heavy Rain	75	69	82	29.85	NE 8 mph
15:30	Light Rain	68	68	100	29.86	WNW 7 mph
16:30	Cloudy	69	67	95	29.85	NE 6 mph

Figure 13: Torrential rain during the gasifier tests – the pickup can barely be seen just to the left of the road signs

Figure 14. Equipment was placed in a large overhang, facilitating continuation of the tests even though it rained most of the day

Based on data in APPENDIX 1, Alabama Power Lab analyses (except for moisture content, which was not representative of these samples, and which was therefore determined separately at Auburn University) data presented in Table 3 was generated. It is concluded from these results that the gasifier was more efficient than gasoline. In particular, efficiency of wood was 37% higher than that of gasoline (231.6 miles per million Btu for wood, compared to 168.6 miles per million Btu for gasoline).

Table 3. Energy efficiency of different fuels based on distance traveled per unit of energy

Fuel	Total Btu Fuel	Total Mileage	Moisture %	Miles/gal gas equivalent	Miles/MMBtu
Gasoline	248,524	41.9	---	20.95	168.6
Wood	280,600	65.0	15.60	28.78	231.6
Wood + Broiler Litter	272,038	50.2	14.28	22.93	184.5
Wood + Switchgrass	298,050	58.0	14.56	24.18	194.6
Wood + Plastic	383,317	69.9	12.80	22.65	182.4

APPENDIX 1

Alabama Power
General Test Laboratory
P.O. Box 2641
Birmingham, Alabama 35291
(205) 664 - 6032 or 6171
FAX (205) 664-1654

CERTIFICATE OF ANALYSIS

TO: Mr. David Bransby
bransdi@auburn.edu
202 Funchess Hall Auburn Univ.
Dept. of Agronomy & Soils

Customer Account :
Sample Date : 01-Jun-10

Laboratory Account BRANSBY
Received Date : 10-Jun-10

Description : Auburn Univ./Agronomy & Soils
SWITCHGR
Switchgrass

Laboratory ID Number : AP16930

Test Name	Reference	Result	
Dry Basis			
Ash, dry	ASTM D 5142	3.41	weight %
Heat of Combustion, dry	ASTM D 5865	8211	Btu/lb
Carbon, dry	ASTM D 5373	48.76	weight %
Hydrogen, dry	ASTM D 5373	5.74	weight %
Nitrogen, dry	ASTM D 5373	0.98	weight %
Oxygen, dry	ASTM D 3176	41.06	weight %
Fixed Carbon, dry	ASTM D 3172	16.43	weight %
Volatiles, dry	ASTM D 5142	80.16	weight %
Sulfur, dry	ASTM D 4239	0.05	weight %
As Received			
Moisture, Total	ASTM D 3302	15.00	weight %
Ash, as received	ASTM D 5142	2.90	weight %
Heat of Combustion, as received	ASTM D 5865	6979	Btu/lb
Carbon, as received	ASTM D 5373	41.45	weight %
Hydrogen, as received	ASTM D 5373	4.88	weight %
Nitrogen, as received	ASTM D 5373	0.83	weight %
Oxygen, as received	ASTM D 3176	34.90	weight %
Carbon Fixed, as received	ASTM D 3172	13.97	weight %
Volatiles, as received	ASTM D 5142	68.14	weight %
Sulfur, as received	ASTM D 4239	0.04	weight %
General			
Heat of Combustion, MAF	ASTM D 5865	8501	Btu/lb
Sulfur, lbs/mm Btu	ASTM D 3180	0.061	lbs/mm Btu

Comments:

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Description : Auburn Univ./Agronomy & Soils
SWITCHGR
Switchgrass

Laboratory ID Number : AP16930

Test Name	Reference	Result	
Initial deformation ash fusion,	ASTM D 1857	2090	degrees F
Softening ash fusion, Reducing	ASTM D 1857	2218	degrees F
Hemispherical ash fusion, Reduci	ASTM D 1857	2246	degrees F
Fluid ash fusion, Reducing	ASTM D 1857	2260	degrees F

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Description : Auburn Univ./Agronomy & Soils
WOOD
Wood

Laboratory ID Number : AP16931

Test Name	Reference	Result	
Dry Basis			
Ash, dry	ASTM D 5142	2.72	weight %
Heat of Combustion, dry	ASTM D 5865	7543	Btu/lb
Carbon, dry	ASTM D 5373	49.77	weight %
Hydrogen, dry	ASTM D 5373	5.03	weight %
Nitrogen, dry	ASTM D 5373	1.12	weight %
Oxygen, dry	ASTM D 3176	41.34	weight %
Fixed Carbon, dry	ASTM D 3172	18.80	weight %
Volatiles, dry	ASTM D 5142	78.48	weight %
Sulfur, dry	ASTM D 4239	0.02	weight %
As Received			
Moisture, Total	ASTM D 3302	29.08	weight %
Ash, as received	ASTM D 5142	1.93	weight %
Heat of Combustion, as received	ASTM D 5865	5349	Btu/lb
Carbon, as received	ASTM D 5373	35.30	weight %
Hydrogen, as received	ASTM D 5373	3.57	weight %
Nitrogen, as received	ASTM D 5373	0.79	weight %
Oxygen, as received	ASTM D 3176	29.32	weight %
Carbon Fixed, as received	ASTM D 3172	13.33	weight %
Volatiles, as received	ASTM D 5142	55.66	weight %
Sulfur, as received	ASTM D 4239	0.01	weight %
General			
Heat of Combustion, MAF	ASTM D 5865	7754	Btu/lb
Sulfur, lbs/mm Btu	ASTM D 3180	0.027	lbs/mm Btu

Comments:

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Description : Auburn Univ./Agronomy & Soils
WOOD
Wood

Laboratory ID Number : AP16931

Test Name	Reference	Result	
Initial deformation ash fusion,	ASTM D 1857	2674	degrees F
Softening ash fusion, Reducing	ASTM D 1857	2690	degrees F
Hemispherical ash fusion, Reduci	ASTM D 1857	2694	degrees F
Fluid ash fusion, Reducing	ASTM D 1857	2702	degrees F

Comments:

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Laboratory Account BRANSBY
Received Date : 10-Jun-10

Description : Auburn Univ./Agronomy & Soils
BROILERL
Broiler Litter

Laboratory ID Number : AP16932

Test Name	Reference	Result	
Dry Basis			
Ash, dry	ASTM D 5142	26.56	weight %
Heat of Combustion, dry	ASTM D 5865	6325	Btu/lb
Carbon, dry	ASTM D 5373	35.36	weight %
Hydrogen, dry	ASTM D 5373	4.48	weight %
Nitrogen, dry	ASTM D 5373	3.30	weight %
Oxygen, dry	ASTM D 3176	29.48	weight %
Fixed Carbon, dry	ASTM D 3172	11.96	weight %
Volatiles, dry	ASTM D 5142	61.48	weight %
Sulfur, dry	ASTM D 4239	0.82	weight %
As Received			
Moisture, Total	ASTM D 3302	13.13	weight %
Ash, as received	ASTM D 5142	23.07	weight %
Heat of Combustion, as received	ASTM D 5865	5495	Btu/lb
Carbon, as received	ASTM D 5373	30.72	weight %
Hydrogen, as received	ASTM D 5373	3.89	weight %
Nitrogen, as received	ASTM D 5373	2.87	weight %
Oxygen, as received	ASTM D 3176	25.61	weight %
Carbon Fixed, as received	ASTM D 3172	10.39	weight %
Volatiles, as received	ASTM D 5142	53.41	weight %
Sulfur, as received	ASTM D 4239	0.71	weight %
General			
Heat of Combustion, MAF	ASTM D 5865	8612	Btu/lb
Sulfur, lbs/mm Btu	ASTM D 3180	1.296	lbs/mm Btu

Comments:

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Description : Auburn Univ./Agronomy & Soils
BROILERL
Broiler Litter

Laboratory ID Number : AP16932

Test Name	Reference	Result	
Initial deformation ash fusion,	ASTM D 1857	2104	degrees F
Softening ash fusion, Reducing	ASTM D 1857	2190	degrees F
Hemispherical ash fusion, Reduci	ASTM D 1857	2266	degrees F
Fluid ash fusion, Reducing	ASTM D 1857	2376	degrees F

Comments:

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Received Date : 10-Jun-10

Description : Auburn Univ./Agronomy & Soils
PLASTIC
Plastic

Laboratory ID Number : AP16933

Test Name	Reference	Result	
Dry Basis			
Ash, dry	ASTM D 5142	7.42	weight %
Heat of Combustion, dry	ASTM D 5865	16142	Btu/lb
Carbon, dry	ASTM D 5373	76.55	weight %
Hydrogen, dry	ASTM D 5373	12.94	weight %
Nitrogen, dry	ASTM D 5373	0.95	weight %
Oxygen, dry	ASTM D 3176	2.10	weight %
Fixed Carbon, dry	ASTM D 3172	1.31	weight %
Volatiles, dry	ASTM D 5142	91.27	weight %
Sulfur, dry	ASTM D 4239	0.04	weight %
As Received			
Moisture, Total	ASTM D 3302	0.20	weight %
Ash, as received	ASTM D 5142	7.41	weight %
Heat of Combustion, as received	ASTM D 5865	16110	Btu/lb
Carbon, as received	ASTM D 5373	76.40	weight %
Hydrogen, as received	ASTM D 5373	12.91	weight %
Nitrogen, as received	ASTM D 5373	0.95	weight %
Oxygen, as received	ASTM D 3176	2.10	weight %
Carbon Fixed, as received	ASTM D 3172	1.31	weight %
Volatiles, as received	ASTM D 5142	91.09	weight %
Sulfur, as received	ASTM D 4239	0.04	weight %
General			
Heat of Combustion, MAF	ASTM D 5865	17436	Btu/lb
Sulfur, lbs/mm Btu	ASTM D 3180	0.025	lbs/mm Btu

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Received Date : 10-Jun-10

Description : Auburn Univ./Agronomy & Soils
PLASTIC
Plastic

Laboratory ID Number : AP16933

Test Name	Reference	Result	
Initial deformation ash fusion,	ASTM D 1857	2500	degrees F
Softening ash fusion, Reducing	ASTM D 1857	2514	degrees F
Hemispherical ash fusion, Reduci	ASTM D 1857	2638	degrees F
Fluid ash fusion, Reducing	ASTM D 1857	2712	degrees F

Comments:

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