CHARACTERIZATION OF COAL AND BIOMASS FUEL BLENDS

David E. Prinzing
Kermit P. Hellem
W. John McVey

Foster Wheeler Environmental Corporation
2525 Natomas Park Drive, Suite 250
Sacramento, CA 95833-2900

Keywords: Fuel Characterization, Fuel Blending, Energy Generation

ABSTRACT

The cofiring of biofuels with coal in existing boilers presents significant potential benefits to electric power generators. The practice has been shown to reduce SO_2 and NO_x emissions, reduce fuel costs at some locations, and provide support to industrial customers from the forest products industry. One of the technical uncertainties associated with cofiring involves the characterization of the biomass and the coal, both separately and as fuel blends. Foster Wheeler Environmental Corporation has evaluated the practice of cofiring biomass with coal for the Electric Power Research Institute and the Tennessee Valley Authority. This paper reviews the characterization requirements and presents the analytical results for a number of coals and biomass wastes, focusing largely on the impact of fuel blending on ash fusibility and viscosity. Also, the consequences of these characteristics on the performance of pulverized coal and cyclone boilers is reviewed.

INTRODUCTION

Foster Wheeler Environmental Corporation has been evaluating the practice of cofiring waste wood residues with coal at existing Tennessee Valley Authority (TVA) power plants for the Electric Power Research Institute (EPRI) and TVA. This work has been directed toward specific TVA power plants at cofiring levels up to 15 percent on a heat input basis. The following benefits can be expected from such a cofiring program:

(1) A cost-effective program for reducing emissions of sulfur dioxide (SO_2) and oxides of nitrogen (NO_x);

(2) A cost-effective strategy for reducing fossil fuel based carbon dioxide (CO_2) emissions in concert with the global climate challenge of reducing the generation of greenhouse gases;

(3) Potentially reduced cost of fuel to coal-fired power plants, improving their economics and consequent capacity utilization;

(4) Increased support for the forest products industry in solving waste disposal problems.

The information presented here is focused specifically on cofiring waste wood residues with coal at the Allen Fossil Plant in Memphis, Tennessee and the Kingston Fossil Plant near Knoxville, Tennessee. The Allen Fossil Plant is equipped with three 265 MW cyclone boilers and has undergone parametric cofiring tests at low and moderate percentages of wood waste. The Kingston Fossil Plant is equipped with nine tangentially-fired pulverized coal boilers, four single furnace units rated at 136 MW_e each, and five twin furnace units rated at 200 MW_e each. The Kingston Fossil Plant has completed parametric testing of cofiring sawmill residues at low levels.

One of the technical uncertainties associated with wood cofiring lies in understanding the locally available fuels, with emphasis both on physical characteristics (particle size, specific gravity, and moisture content) and on fuel chemistry (proximate and ultimate analyses, higher heating value, and ash chemistry).

CHARACTERISTICS OF LOCALLY AVAILABLE FUELS AND FUEL BLENDS

To characterize the locally available waste wood residues, over 25 potential wood fuel suppliers (including both sawmills and manufacturing facilities) in each of the Memphis and Knoxville areas were selected and sampled in the fall of 1993. Repeat sampling of ten of the sources from each area was completed in the spring of 1994. The sources of wood were characterized, including process flow diagrams for the processes that generated the wood waste. Wood samples were prepared and sent to a fuels laboratory for determination of the proximate analysis, ultimate analysis, calorific value, ash elemental analysis, and ash fusibility characteristics. Also, samples of coal from the Allen and Kingston Fossil Plants were sent to the laboratory for the same analyses. For the Allen Fossil Plant, blends of coal and wood were prepared on a dry weight basis at four levels (5, 10, 20, and 30 weight percent wood; these correspond to heat inputs of about 2.5, 5, 10, and 15 percent respectively). These samples also were sent to the laboratory for analysis. Particle size distributions for each wood fuel source were determined using a sieve analysis.

The direct result of this work is the detailed characterization of the various fuels and fuel blends. For both the Allen and Kingston Fossil Plants, these include the baseline coals, the locally available waste wood fuels, and blends of the coal and wood at various levels. The baseline coal and average wood fuel characteristics fell within expected ranges for these kinds of fuels. With regard to the variability in fuel characteristics for the wood fuels sampled, it was found that the statistical confidence intervals were relatively small. Consequently, it is expected that the average values presented are representative of the waste wood fuels available from these sources, and that relatively little variation from these values is expected. Such a stable, well-defined fuel characterization helps reduce the uncertainties associated with cofiring wood in coal-fired boilers. Tables 1 and 2 provide summary data concerning these analytical results.

The characteristics of coal and wood fuel blends can be seen largely as arithmetic averages of the characteristics of the two fuels. The more interesting exception to this generalization lies in the fusibility characteristics of the ash resulting from the fuel blends. A significant eutectic was present in the ash from the blends, reducing the ash fusion temperatures to levels below that of either fuel by itself. These results are depicted graphically as polynomial regressions of measured data in Figure 1.

CONSEQUENCES FOR PULVERIZED COAL AND CYCLONE BOILERS

The issues of fuel characterization impact fuel handling, combustion, and ash management. From the perspective of fuel handling, the fine particle sizes obtained in the samples demonstrated that the fossil stations could avoid elaborate wood particle size reduction systems. Significant percentages of wood at <1/4", <1/8", and 1/16" document the fact that the materials handling system can consist of screens and magnets for pulverizer and boiler protection. Also, the materials handling system could include a wood fuel dryer, if desired. Extensive investments in hammer mills and related equipment can be avoided by procurement practices. Further, the wood moisture contents will likely be on the order of 40 to 50 percent, based upon the experience of the sampling teams in the field.

The characterizations of the fuel lead to assessments of their impact on boiler performance at cofiring levels of 10-15 percent (heat input basis). Such characterizations lead to the conclusion that, at operating conditions currently associated with the Allen and Kingston facilities, there would be no significant deleterious impact on boiler efficiency or net station heat rate. Similarly, there is no significant impact on flame temperatures.

Of more consequence is the impact on ash chemistry and the behavior of non-combustibles, particularly as it relates to the cyclones.

The reduction in the ash fusion temperatures associated with fuel blends is consistent with the fact that the base/acid ratio is increased relative to that of the coal used at the Allen Fossil Plant, and decreased relative to that of the wood available in the Memphis area. The resulting base/acid ratio associated with the blends approaches 1.0 from both "pure fuel" directions.

This analysis does not, and can not address the impact of fuel blending on the final ash consideration: the salability of flyash as a pozzolanic material, or the sale of slag for such products as roofing granules. Those questions can only be addressed by significant additional testing of the cofiring process.

In conclusion, the fuel characterization studies demonstrated the significant potential associated with cofiring. The wood fuels available to Allen and Kingston Fossil Plants are not unusual, and contain no significant problems.

ACKNOWLEDGMENTS

This is to acknowledge support for the program from the Electric Power Research Institute and the Tennessee Valley Authority.

Figure 1: Ash Fusion Temperatures for Coal/Wood Fuel Blends

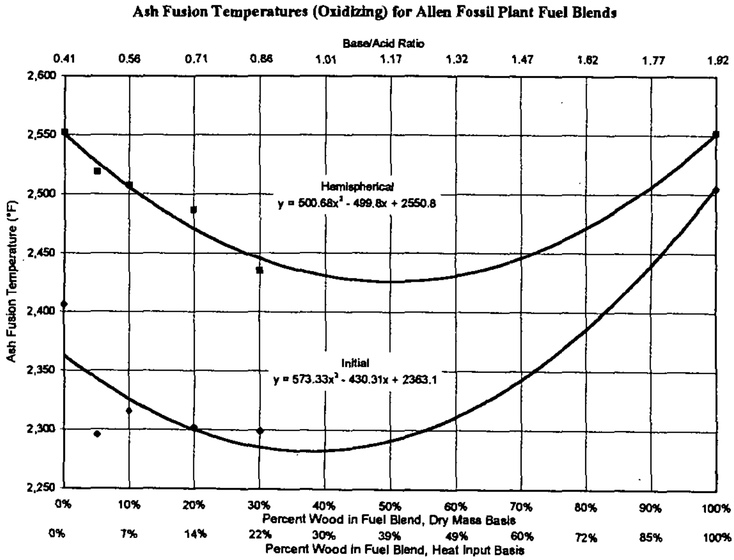

Table 1: Summary of Coal Characterizations

Parameter	Allen Coal	Kingston Coal
Proximate Analysis (wt %, as rec'd)		
Moisture	9.91	7.17
Volatile Matter	33.53	33.78
Fixed Carbon	47.73	49.06
Ash/Inerts	8.83	9.99
Ultimate Analysis (wt %, dry basis)		
Carbon	74.77	74.35
Hydrogen	5.08	5.02
Oxygen	6.32	7.19
Nitrogen	1.44	1.52
Sulfur	2.31	1.14
Chlorine	0.27	0.02
Ash/Inerts	9.81	10.76
Heating Value (Btu/lb)		
As Received	11,748	12,378
Dry Basis	13,040	13,334
Moisture/Ash Free	14,457	14,814
Ash Elemental Analysis (wt %)		
SiO_2	44.16	47.66
Al_2O_3	22.89	23.05
TiO_2	1.00	0.75
Fe_2O_3	22.86	19.08
CaO	2.16	2.37
MgO	0.47	0.93
Na_2O	0.25	0.56
K_2O	1.97	2.43
P_2O_5	0.50	0.43
SO_3^-	1.93	2.13
Undetermined	1.81	0.61
Alkali Metals (lb/MMBtu)		
CaO	0.15	0.18
MgO	0.03	0.07
Na_2O	0.02	0.04
K_2O	0.13	0.18
Ash Fusion Temperature (°F)		
Oxidizing Atmosphere		
Initial	2,406	2,481
Softening	2,545	2,528
Hemispherical	2,552	2,535
Fluid	2,565	2,553
Reducing Atmosphere		
Initial	2,082	2,081
Softening	2,273	2,300
Hemispherical	2,325	2,418
Fluid	2,429	2,444
T_{250} Temperature (°F)	2,397	2,463
Base/Acid Ratio	0.41	0.36
Slagging Index	0.94	0.40
Fouling Index	0.10	0.2

Table 2: Summary of Wood Fuel Characterizations

Parameter	Allen Wood Average	Allen Wood 95% Conf. Interval	Kingston Wood Average	Kingston Wood 95% Conf. Interval
Proximate Analysis (wt %, dry)				
Volatile Matter	84.32	0.70	84.85	0.65
Fixed Carbon	14.47	0.55	14.45	0.59
Ash/Inerts	1.21	0.47	0.70	0.16
Ultimate Analysis (wt %, dry)				
Carbon	49.24	0.21	49.81	0.31
Hydrogen	5.90	0.05	5.96	0.08
Oxygen	43.24	0.42	43.18	0.35
Nitrogen	0.39	0.27	0.32	0.21
Sulfur	0.02	0.00	0.02	0.00
Chlorine	0.01	0.01	0.01	0.01
Ash/Inerts	1.21	0.47	0.70	0.16
Heating Value (Btu/lb)				
Dry Basis	8,335	38	8,391	46
Moisture/Ash Free	8,437	34	8,450	45
Ash Elemental Analysis (wt %)				
SiO_2	22.90	5.29	17.93	4.05
Al_2O_3	4.43	1.11	4.55	1.16
TiO_2	0.46	0.48	0.78	1.04
Fe_2O_3	1.79	0.45	1.96	0.39
CaO	40.16	3.77	39.89	3.71
MgO	5.37	1.22	8.12	2.07
Na_2O	2.93	1.45	2.74	2.04
K_2O	9.48	1.78	10.33	1.81
P_2O_5	2.25	0.38	3.42	1.55
SO_3^-	2.07	0.91	2.08	0.58
Undetermined	8.16	---	8.20	---
Alkali Metals (lb/MMBtu)				
CaO	0.58	---	0.33	---
MgO	0.08	---	0.07	---
Na_2O	0.04	---	0.02	---
K_2O	0.14	---	0.09	---
Ash Fusion Temperature (°F)				
Oxidizing Atmosphere				
Initial	2,517	90	2,472	47
Softening	2,538	87	2,526	27
Hemispherical	2,541	88	2,530	22
Fluid	2,553	94	2,534	19
Reducing Atmosphere				
Initial	2,541	128	2,537	182
Softening	2,552	134	2,546	193
Hemispherical	2,558	128	2,549	191
Fluid	2,568	117	2,557	181
T_{250} Temperature (°F)	2,424	75	2,384	105
Base/Acid Ratio	2.15	---	2.71	---
Slagging Index	0.04	---	0.05	---
Fouling Index	6.30	---	7.43	---