

URBAN WOOD/COAL CO-FIRING IN THE NIOSH BOILERPLANT

QUARTERLY TECHNICAL PROGRESS REPORT

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ABSTRACT

During the third quarter, the experimental portion of the project was carried out. Three one-day tests using wood/coal blends of 33% wood by volume (both construction wood and demolition wood) were conducted at the NIOSH Boiler Plant (NBP). Blends using hammermilled wood were operationally successful and can form the basis of Phase II. Emissions of SO₂ and NO_x decreased and that of CO increased when compared with combusting coal alone. Mercury emissions were measured and the mathematical modeling of mercury speciation reactions continued, yielding many interesting results. Material and energy balances for the test periods at the NBP, as well as at the Bellefield Boiler Plant, were prepared. Steps were taken to remove severe constraints from the Pennsylvania Switchgrass Energy and Conservation Project and to organize the supplying of landfill gas to the Bruceton federal complex. Two presentations were made to meetings of the Electric Power Research Institute and the National Energy Technology Laboratory.

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INTRODUCTION

This third quarterly technical progress report describes work done during the third three-month period of the University of Pittsburgh's project on "Urban Wood/Coal Co-firing in the NIOSH Boilerplant."

This report describes the activities of the project team during the reporting period. The principal work has focused upon experimentation (field work), environmental issues, wood supply, plant operations, analysis (including modeling of mercury speciation), reporting and outside contacts.

EXECUTIVE SUMMARY

During the third quarter, the experimental portion of the project was carried out and work continued on environmental issues, wood supply, plant operations, analysis and reporting. Several outside contacts were made.

EXPERIMENTAL

In early April six truckloads of wood/coal blends were delivered to the NIOSH Boiler Plant (NBP) – one truckload of a 20% construction wood by volume/80% coal blend and five truckloads of a 33% wood by volume/67% coal blend. Two of the 33% blends contained construction wood and three contained demolition wood. The load from each truck was fed to the NBP bunker and thence to the boiler. The 20% blend and the first of the 33% blends with construction wood utilized tub-ground wood. This material did not flow well through the receiving grill, nor through the spreaders. However, the third 33% blend with construction wood and the three 33% blends with demolition wood, all with hammermilled wood, flowed well through the receiving grill and the spreaders.

Emissions monitoring during combustion, using the blends, showed decreases in SO₂ and NO_x, and increases in CO and particulates to the baghouse, when compared with combusting coal alone. Mercury levels increased by over 200% when the blends with construction wood were combusted, but they decreased by 14% when the blends with demolition wood were combusted, when compared with combusting coal alone.

RESULTS AND DISCUSSION

Environmental Issues

J. A. Rutter Company (JARC) and Emery Tree Service (ETS) are considering establishing urban waste recycling facilities that would provide properly sized wood for producing a commercial wood/coal blend for the stoker boiler market in Pittsburgh.

Wood Supply

Wood/coal blends were prepared at Three Rivers Terminal and delivered to NBP.

Plant Operations

The plant superintendent expressed satisfaction with the blends containing hammermilled wood, supplied by ETS. The project team met with staff of NIOSH to discuss details of Phase II and begin work toward commercial operation using a 33% wood/67% coal (by volume) blend at the NBP.

Analysis

The project team performed energy balances on four test periods at the NBP and four test periods at the Bellefield Boiler Plant (BBP). Results of literature surveys and mathematical modeling of mercury speciation are: (1) mercury speciation at the NBP are similar to those at the Big Bend Boilerplant, (2) the concentration of atomic chlorine decreases significantly as temperature decreases, and (3) the concentration of moisture, CO and NO significantly affects the concentration of atomic chlorine.

Reporting

A six-paper symposium was organized on “Cofiring or Coprocessing Coal and Biomass” to be presented at the 222nd National Meeting of the American Chemical Society (ACS) in August 2001. Two presentations were made to meetings of the Electric Power Research Institute and the National Energy Technology Laboratory.

Outside Contacts

The U.S. Department of Agriculture (USDA) stipulated over a dozen criteria for the Pennsylvania Switchgrass Energy and Conservation Project (PSECP. Three of these criteria effectively disallow the project. Changes to these three criteria, to make the project viable, have been drafted and will be formally submitted to the USDA. Preliminary discussions on the PSECP were held with various key companies and agencies about initiating the project.

Discussions were initiated on a project to deliver landfill gas to the Bruceton site.

Members of the project team attended meetings of the Upgraded Coal Interest Group (UCIG) and the Biomass Interest Group (BIG) of the Electric Power Research Institute (EPRI), and of PennFuture.

Plan for the Next Quarter

During the fourth quarter from June 30 through September 30, 2001, planning will continue for Phase II at the NBP. A commercial source of wood will be sought. The process of adjusting the coal contract and air permits to allow a 33% wood/coal blend to be combusted at the NBP will begin.

The analysis of the data from the demonstrations at the NBP and the BBP will continue, leading to preparation of the final reports on both projects.

Work will continue on the modeling of mercury speciation, on the development of the PSECP, and on the acquisition of LFG by the Bruceton site.

The session on “Cofiring or Coprocessing Coal and Biomass” will be conducted at the 222nd National Meeting of the American Chemical Society (ACS) in August 2001.

EXPERIMENTAL

Wood/coal co-firing in this project was conducted at the NIOSH (National Institute of Occupational Safety and Health) Boiler Plant (NBP) during the period of April 5 through April 13. NBP supplies steam for the district heating system that serves the federal site in southern Allegheny County, Pennsylvania, housing NIOSH's Bruceton Research Center, the National Energy Technology Laboratory (NETL) of the U.S. Department of Energy (USDOE), and the Pittsburgh Mine Safety and Health Administration Technology Center of the U.S. Department of Labor. The boilerplant contains a spreader stoker with a capacity of 55,000 pounds of steam per hour using Eastern Kentucky compliance coal. It is configured with an overfire air system to reburn larger flyash particles that settle out in an expansion vessel above the boiler and are reinjected into the boiler by the stream of overfire air. The smaller flyash particles pass through the economizer and are collected in a baghouse.

Urban wood wastes used were (1) pallets collected from numerous sources by J. A. Rutter Company (JARC) of Monroeville, PA, (2) trim-ends of framing lumber, mixed with about 30% plywood and particleboard, collected at a condominium construction site being developed by Thompson Properties in a northern suburb of Pittsburgh and delivered to JARC, (3) trim-ends up to several feet long from Seven D Corporation, a wood truss manufacturer in Tyrone, PA, delivered to Emery Tree Service (ETS) of Indianola, PA and (4) roof joists, removed from the demolition of one of the buildings at the Arlington Heights Housing Project on the South Side of the City of Pittsburgh and delivered to both JARC and ETS. JARC tub-ground the wood passing through its processing plant, while ETS hammer-milled the trim-ends and roof joists it received. All of the wood for use at NBP was delivered to Three Rivers Terminal (TRT) in Belle Vernon, PA, where it was blended with coal and loaded into triaxel trucks for delivery to the boilerplant, as described in the subsection on "Wood Supply".

A truck-load of 20% construction/pallet wood ground by JARC/80% coal (by volume) blend was the first to be delivered to the NBP on the morning of April 5. The 20% blend needed a little encouragement to get through the delivery grill. When it was successfully fed through the grill at the NBP, a truck-load of 33% construction/pallet wood ground by JARC/67% coal (by volume) blend was delivered. The 33% blend needed a lot of encouragement to get through the delivery grill. However, Wayne Miller, the plant superintendent, approved using a 33% blend for the tests on April 10-13. He based this on the plan to use the construction wood, milled by ETS, and the demolition wood, both that milled by ETS and that ground by JARC. The wood to be used on April 10-13 had less fines and fewer larger pieces than the wood used in the blends delivered on April 5, and were expected to blend and flow better.

Energy Systems Associates (ESA) set up equipment for flue gas monitoring on April 5. Also, staff from NETL (Sean Plasinski, Philip Goldberg, and David Delmastro), and from NIOSH (Nathan Campus and Barbara Heirendt) visited the boilerplant during the day on April 5 to observe the delivery of the blends and discuss the project.

The wood/coal blends were burned over the next forty-eight hours (April 5-7). The 20% blend posed no problems, but the 33% blend required considerable prodding to get through one of the three stokers into the boiler.

On April 9 two truck-loads of fuel were blended, each containing 33% by volume of biomass and 67% by volume of coal. The first truck-load contained construction wood milled by ETS. The second one contained demolition wood milled by ETS. The first blend, containing construction wood, was immediately delivered to the boilerplant. It passed through the receiving grill with very little assistance being required.

ESA began monitoring the flue gas (five gases, particulates, and mercury) at 6:00 a.m. on April 10. At seven a.m. the feed was switched from coal to the blend with construction wood. The load on the boiler was about 30%. The weather that day was in a record warm period and the outside temperature at 7:00 a.m. was about 53 degrees Fahrenheit. This load continued throughout the test period (April 10-13). ESA continued monitoring until 1:40 p.m. The blend burned well in the boiler. One of the Graduate Student Researchers, Hongming Li, began to collect data and the other, Jun Wang, observed the flue gas analysis.

When the 33% construction wood blend was completely burned, the feed to the boiler was switched back to coal. ESA again monitored the flue gas from coal-only operation from 6:00 a.m. to 12:40 p.m. on April 11.

On April 11, the second truck-load of blend, containing 33% demolition wood, was delivered. It passed through the receiving grill with essentially no assistance being required. The ETS-milled wood will serve as the basic specification for the wood for commercial blends in the future. This blend was introduced to the boiler early on the morning of April 12. ESA resumed monitoring the flue gas at 5:45 a.m. and continued until 3:05 p.m. The boiler resumed operation on coal only when the blend was completely burned.

The remaining wood, milled by ETS, was blended at about 30% by volume wood, delivered in two loads to the boilerplant, and used as an alternate fuel until it was depleted. The remaining wood, ground by JARC, was abandoned in place at TRT.

RESULTS AND DISCUSSION

ENVIRONMENTAL ASPECTS

Variances to Permits

During the second quarter of this project a letter was sent by the University, on behalf of the NIOSH Boiler Plant (NBP), to Sandra T. Etzel, Chief, Engineering Section, Air Quality Program, Allegheny County Health Department (ACHD), requesting an R&D variance to the boilerplant's operating permit for the project. Shortly before the start of operations at the NBP, the ACHD provided verbal approval to proceed with the demonstration.

Also during the second quarter of this project, the Pennsylvania Department of Environmental Protection (PADEP) notified both J. A. Rutter Company (JARC) and Emery Tree Service (ETS) that oral extensions of the "permit by rule" at both companies had been granted for this project.

Emissions Monitoring

Energy Systems Associates (ESA) installed a gas analyzer, connected to two sample ports: (1) in the economizer outlet (before the baghouse) and (2) in the stack inlet (after the baghouse). During an analysis, a stream of the gas being sampled was continuously withdrawn through the sample port using multiple stainless steel probes, and then conditioned with a sintered metal filter and ice-bath to remove particulates and moisture before the process gas analyzer. The analyzer obtained measurements of CO, CO₂ and SO₂ by non-dispersive infrared analysis, NO_x by chemiluminescence, and O₂ using electrochemical cells. EPA methods employed included Methods 3A, 6C, 7E and 10.

ESA also made two other installations for emissions monitoring. First, at the exit from the economizer it installed equipment to collect particulate samples, using EPA Method 17. And second, it installed equipment to conduct the Ontario Hydro Method for sampling for elemental, oxidized and particle-bound mercury, also at the economizer outlet.

A series of thirteen tests was performed at the NBP to compare stack emissions from baseline coal operation to co-firing with wood. The tests were conducted at available loads over three days. On April 10 four tests were conducted. Three of these tests (N1/Hg, N2 and N3) were co-firing with construction wood and one (N1) was with coal alone. On April 11 four tests (N4, N5, N6 and N7) were conducted with coal only. On April 12 five tests (N8, N9, N10, N11 and N12) were conducted with demolition wood co-firing. During each test gaseous data was collected at the stack inlet. During

select tests (N1, N3, N6 and N9) particulate sampling was conducted at the economizer exit to determine loading. Testing for elemental, oxidized, and particle-bound mercury was also conducted at the economizer outlet on four occasions (Tests N1/Hg, N7, N10 and N12); the results for one test (N10) should be used for total mercury only since particulate contaminated the entire sampling train due to a filter failure.

Several weeks after concluding the demonstration testing, ESA provided results of the testing. A thorough evaluation of these results will be presented in the final report. Here are the general observations made by ESA. Table 1 summarizes the absolute gaseous and particulate emissions and the change in those emissions for the combustion of pure coal and the co-firing of construction wood with coal on April 10. Table 2 provides a similar summary for the combustion of pure coal on April 11 and the co-firing of demolition wood with coal on April 12.

**Table 1. Emissions Comparison with Co-firing of Construction Wood (ESA)
(Emission values in lbs/MMBtu unless otherwise indicated)**

	NO _x	SO ₂	Particulate	CO (ppm)
Coal	0.420	0.951	2.32	650
Wood/Coal	0.403	0.852	2.89	660

**Table 2. Emissions Comparison with Co-firing of Demolition Wood (ESA)
(Emission values in lbs/MMBtu unless otherwise indicated)**

	NO _x	SO ₂	Particulate	CO (ppm)
Coal	0.429	0.916	2.30	871
Wood/Coal	0.398	0.861	2.95	1194

Table 3 on the following page provides the mercury data collected by ESA, using EPA Method 17.

Public Interactions

On May 29 the Department of Chemical and Petroleum Engineering was a finalist for the 2001 Three Rivers Environmental Award in the category of Higher Education. The work of four departmental faculty members was included in the citation. One of the four faculty members cited was Prof. Cobb for his wood/coal co-firing projects, including this one.

Future Permitting

On May 4, following the completion of the demonstration, the project team attended a meeting at the PADEP's Pittsburgh Office with members of PADEP's and ACHD's air and solid waste staffs. Following a review of the demonstrations at both the NBP and the Bellefield Boiler Plant (BBP), the attendees discussed how approximately

30,000 tons/year of construction/demolition (C/D) wood could be provided to the energy market in Pittsburgh. The principal concern expressed by the regulators was the quality control of the composition of the wood delivered to the boiler-plants. If JARC and ETS wish to satisfy a market for fuel from C/D wood, they will each need a Municipal Waste Processing Permit. JARC has already received the application form for this permit and ETS will have to obtain one also. ACHD can provide assistance in filling them out. Six to nine months are required to obtain the permit, once the application is filed. It was also noted that any boiler-plant wishing to switch to a fuel containing C/D wood must receive a construction air permit, a temporary operating air permit and a permanent air permit. During the period covered by the temporary operating air permit, compliance testing is required.

Table 3. Mercury Emissions

Test Number	Fuel	Flowrate (dscfm)	Duration (hours)	Mercury Concentration (µg)			
				Particle Bound	Oxidized	Elemental	Total
N1(Hg)	Const'n Wood/Coal	8,600	2.0	1.129	0.813	4.217	6.16
N7	Coal	6,400	2.0	0.822	0.319	0.246	1.39
N10	Demol'n Wood/Coal	7,600	2.0	0.757	0.265	0.212	1.23
N12	Demol'n Wood/Coal	7,600	2.0	0.760	0.146	0.265	1.17

WOOD SUPPLY

Collection, Grinding and Stockpiling

During the first quarter JARC had ground approximately 40 tons of pallet waste (35 tons) and construction waste (5 tons from Thompson Properties, consisting of trim-ends of framing lumber, mixed with about 30% plywood and particleboard). The entire 40 tons of BioGrind Wood Chips had been delivered to Mon Valley Transportation Company (MVTC) in Glassport, PA. During the second quarter JARC had relocated a portion of this material for use at the NBP to the TRT.

During the first quarter two truck loads of construction wood (roof truss trim-ends from Seven D Corporation) had been delivered to ETS. During the second quarter 23 ETS had milled this wood and placed the milled product in rolloffs. One of the rolloffs had been delivered to the TRT for use in this project.

During the second quarter four roll-offs had been filled with roof joists, removed from the demolition of one of the buildings at the Arlington Heights Housing Project on the South Side of the City of Pittsburgh. Two had been delivered to JARC and two to ETS. Both companies had immediately ground the demolition wood and delivered the product to TRT.

Blending

On April 5 the staff of TRT blended two truck-loads by building a pile for each truckload on the ground, using a front-loader, and turning it over twice. Both blends were prepared from the construction/pallet wood ground by JARC. The first truck-load was a 20% wood/80% coal (by volume) blend. The second truck-load was a 33% wood/67% coal (by volume) blend. Both truck-loads were delivered to the NBP that day. Trucks used for delivery were 25-ton tri-axle dump trucks.

On April 9 the staff of TRT blended two more truck-loads using the same technique. The first truck-load contained construction wood milled by ETS. The second one contained demolition wood milled by ETS. Both truck-loads were 33% wood/67% coal (by volume) blends. The first truck-load was delivered to the NBP that day. The second truck-load was delivered to the NBP on April 11.

On April 18 the remaining wood, milled by ETS, was blended at about 30% by volume wood, delivered in two loads to the boilerplant, and used as an alternate fuel until it was depleted. The remaining wood, ground by JARC, was abandoned in place at TRT.

Samples were collected of the following: tub-ground construction/pallet wood supplied by JARC, hammer-milled construction wood supplied by ETS, hammer-milled demolition wood supplied by ETS, the 33% ETS-milled construction wood blend, and the 33% ETS-milled demolition wood blend delivered to the NBP. They will be submitted to Geochemical Testing, of Somerset, PA. The following analyses will be requested: proximate, ultimate, heating value, ash fusion temperatures, and ash elemental. Results of these analyses will be presented in the final report.

Commercial Supply

Following the experimental period the project team discussed the direction in which ETS and JARC plan to go in providing an urban waste wood product meeting specifications for the stoker boiler co-firing market and the solid waste regulations of the Commonwealth of Pennsylvania.

ETS has no current plans to enter into this business in Pittsburgh. However, it is involved in it to a certain extent in another community and is open to considering it in this area.

JARC continues to give serious consideration to establishing an urban waste recycling operation at its plant in Monroeville. If it decides to do so, it would accept construction and demolition debris at its plant where the debris would be separated into a number of product streams, such as aggregate, brick, metal, gypsum and wood. Remnant material not fitting into these products would be disposed to landfill. Major issues that JARC must address in deciding to proceed are (1) product specifications, (2) processing to meet those specifications, (3) procedures to meet regulations, (4) permitting, (5) bonding and (6) economics.

PLANT OPERATIONS

General Commercial Issues for Resolution

The NBP superintendent expressed satisfaction with the blends containing hammer-milled wood, supplied by ETS. However, the blends, containing tub-ground wood supplied by JARC, was unacceptable. JARC must adjust its grinding operation to provide acceptable material.

In general, quality control of the blend, both physically and chemically, will be a major element for the viability of commercial operation using wood/coal blends.

Discussions with NIOSH and Others about Phase II

In May preliminary discussions were held with the broker holding the current sales contract for coal to the NBP. He is open to modifying the contract to provide wood/coal blends in place of some or all of the pure coal currently specified.

On June 13 the project team met with Rick Althaus and Barbara Heirendt at the NIOSH Bruceton Research Center to discuss Phase II. The project team described the results of Phase I. It noted that the NBP superintendent approves Phase II, provided the wood/coal blend meets the basic specifications of the hammer-milled wood, supplied by ETS. The steps leading to commercialization at the NBP were discussed:

- identify the businesses needed to provide the wood/coal blend to the NBP, including wood collector (recycler), wood miller, and fuel broker; the recycler and miller may be the same entity;
- establish the organization of the team and the funding for the project;

- determine the role of the Federal Energy Management Program (FEMP) and the Biomass and Alternative Methane Fuels (BAMF) Program;
- reopen and adjust the NIOSH fuel purchase contract;
- establish the contractual arrangements for the businesses and NIOSH to begin commercial operation;
- obtain the permits for the recycler, the miller and the NBP.

The project team also described the potential for landfill gas to be transported to the NBP. It reviewed the visits to the South Hills Landfill, exploration of a pipeline from the landfill to the federal site, the interest of the NBP in utilizing landfill gas, and the role of the FEMP and the BAMF Program. The NIOSH staff reiterated their interest in principle in utilizing both wood/biomass blends and landfill gas at the NBP. They agreed to examine the current fuel contract for the NBP and report the flexibility they find for reopening it. The project team agreed to continue to discuss the project with potential members of the business network.

ANALYSIS

The clearances for the two Graduate Student Researchers, Hongming Li and Jun Wang, to visit NETL and the boilerplant were received. Mr. Li's clearance was especially important, as he was the principal collector of data during the experiments at the NBP and his master's thesis will form the basis of the final report of Phase I.

Material and Energy Balances at NBP and BBP

Mr. Li has continued analysis of the data acquired during testing on Boiler #1 at the Bellefield Boiler Plant (BBP) and has begun analysis of the data acquired during the testing at the NBP. Prior to the tests at both plants, he developed detailed generic material and energy balances for coal firing in Boiler #1 of the BBP, using data from that unit. He also developed a list of data to be collected during each test at the NBP to enable material and energy balances to be calculated for the NBP.

He tested his analytical approach on two compliance tests, conducted on Boilers #3 and #5 at BBP in early March. For each test, he calculated a flue gas composition and the flow rate from data that he had obtained from the BBP (key values of which are shown in Table 4 in the following box). Mr. Li then performed a heat balance. The results of the heat balances are shown in Table 5, following the box.

Table 4. Operating Data during Compliance Tests at BBP

	<u>Boiler #3</u>	<u>Boiler #5</u>	
Steam flow (lb/hr)	80,000	73,700	
Coal flow (lb/hr)	6,164	5,704	
Gas flow (ft ³ /hr)	27,000	18,900	
Percent excess air	7.1	7.2	
<u>Coal Analysis (%)</u>		<u>Natural Gas Analysis (%)</u>	
C	74	CH ₄	74
H	5	C ₂ H ₆	11
O	8	CO ₂	2
N	2	N ₂	13
S	2		
Ash	6	<u>Steam Properties</u>	
H ₂ O	3	P	175 psi
		T	370 F

Table 5. Energy Balances during Compliance Tests at BBP

	<u>Boiler #3*</u>	<u>Boiler #5*</u>
Input	1.13	1.00
Steam	0.81	0.74
Loss to Stack	0.13	0.14
Unaccounted	0.19	0.12

* All values in 10⁸ Btu/hr

In early May Mr. Li made a preliminary energy balance for Boiler #1, operating on coal alone during the cofiring experimental period at the BBP. This calculation was based upon the same analyses for coal and natural gas and the same steam properties as the prior calculations during the compliance testing of Boilers #3 and 5 of the BBP (as shown in the box above). The following data was obtained from the plant:

Table 6. Operating Data during Coal-Only Period at BBP

Steam flow (lb/hr)	53,900
Estimated coal flow (lb/hr)	3,888
Gas flow (ft ³ /hr)	17,000

The energy balance for Boiler #1 of the BBP was calculated to be (in 10^8 Btu/hr):

Table 7. Energy Balances during Coal-Only Period at BBP

Input	0.69
Steam	0.74
Loss to stack	0.19
Unaccounted	-0.24

This energy balance was the one provided in the fourth (and final) quarterly report on the BBP demonstration, conducted under Award No. DE-FG26-00NT40808. Mr. Li's further analysis of the data from the BBP demonstration will be reported in this and future quarterly reports of the NIOSH demonstration.

In late May Mr. Li revised the energy balance for Boiler #1, operating on coal alone, and prepared three additional energy balances. The four balance periods he examined are –

- (1) “Run 1+2” on April 3 from 10:25 a.m. through 1:27 p.m., operating on coal only at high load;
- (2) “Run 3+4” on April 3 from 4:07 p.m. through 7:05 p.m., operating on coal only at low load;
- (3) “Run 6” on April 4 from 1:55 p.m. through 3:12 p.m., operating on a 40% wood/coal blend (by volume) at high load;
- (4) “Run 7” on April 4 from 4:32 p.m. through 5:43 p.m., operating on a 40% wood/coal blend (by volume) at low load.

These calculations were based upon the same analyses for coal and the same steam properties as the prior calculations during the compliance testing of Boilers #3 and 5 of the BBP (as shown in the box above). However, the natural gas analysis was adjusted to: CH₄ – 72.9%; C₂H₆ – 25.9%; and CO₂ – 1.2%. In addition, the analysis of the wood/coal blend was estimated to be: C – 43%; H – 5 %; O – 38%; ash – 4%; and H₂O – 10%. The following data was obtained from the plant:

Table 8. Operating Data during Tests at BBP

	<u>Run 1+2</u>	<u>Run 3+4</u>	<u>Run 6</u>	<u>Run 7</u>
Steam flow (lb/hr)	53,900	36,500	54,000	36,900
Estimated coal flow (lb/hr)	4,171	3,068	3,265	1,784

Estimated wood flow (lb/hr)			458	250
Gas flow (ft ³ /hr)	17,000	11,800	18,650	11,300
Percent excess air	92.8	162	93.4	146
Percent material balance error		5.3	9.1	9.2
8.6				

The energy balances were calculated to be (in 10⁸ Btu/hr):

Table 9. Energy Balances during Tests at BBP

	<u>Run 1+2</u>	<u>Run 3+4</u>	<u>Run 6</u>	<u>Run 7</u>
Input	0.754	1.30	0.73	0.49
Steam	0.535	0.004	0.54	0.37
Loss to stack	0.177	0.16	0.17	0.11
Unaccounted	0.042	1.14	0.02	0.01

The energy balance for “Run 3+4” is obviously incorrect and will be examined closely to find the error. The other three appear reasonable.

In mid-June Mr. Li prepared four energy balances for the NBP. The four balance periods he examined were –

- (1) “Run N1” on April 10 from 6:00 a.m. through 7:00 a.m., operating on coal only;
- (2) “Run N(2+3)” on April 10 from 10:25 a.m. through 1:40 p.m., operating on a 33% blend (by volume) of construction wood and coal;
- (3) “Run N(4+5+6)” on April 11 from 6:00 a.m. through 10:25 a.m., operating on coal only;
- (4) “Run N(8+9)” on April 12 from 5:45 a.m. through 8:15 a.m., operating on a 33% blend (by volume) of demolition wood and coal.

These calculations were based upon the following analyses for coal and wood/coal blends:

Table 10. Estimated Wood and Coal Analyses during Tests at NBP

<u>Coal (%)</u>	<u>Wood (%)</u>
-----------------	-----------------

C	75	43
H	5	5
O	8	38
N	2	
S	1	
Ash	6	4
H ₂ O	3	10

Steam properties were 100 psi and 328 F. The following data was obtained from the plant:

Table 10. Operating Data during Tests at NBP

	<u>Run N1</u>	<u>Run N(2+3)</u>	<u>Run N(4+5+6)</u>	<u>Run (8+9)</u>
Steam flow (lb/hr)	17,200	15,800	15,825	16,133
Estimated coal flow (lb/hr)	1,536	1,246	1,481	1,293
Estimated wood flow (lb/hr)		144		269
Percent excess air	199	235	247	245
Percent material balance error		0.3	0.4	0.4
	0.5			

The energy balances were calculated to be (in 10⁸ Btu/hr):

Table 11. Energy Balances during Tests at NBP

	<u>Run N1</u>	<u>Run N(2+3)</u>	<u>Run N(4+5+6)</u>	<u>Run (8+9)</u>
Input	0.205	0.180	0.198	0.198
Steam	0.171	0.156	0.157	0.160
Loss to stack	0.035	0.036	0.040	0.024
Unaccounted	-0.001	-0.012	0.001	0.014

In June Mr. Li began writing his master's thesis, which will form the basis of the final report of Phase I of both this project and the demonstration at the BBP.

Mercury Speciation

Mr. Wang has continued an examination of the complex chemistry of chlorine and trace elements within coal-fired boilers. He is focusing on the speciation of mercury, for which ESA analyzed during the demonstration at NBP. Here is a brief report of his findings during the third quarter.

In early April Mr. Wang prepared a preprint for a presentation of his mercury modeling results, using CHEMKIN, up to that point in time at the 222nd National Meeting of the American Chemical Society (ACS) in August 2001. (See the discussion of the organization of the session in which this paper will be presented in the section below on “Reports and Presentations.”) Mr. Wang provided a copy of the preprint to Dr. Joseph Helble at the University of Connecticut, Dr. Connie Senior at PSI Corporation and Dr. Adel Sarofim at the University of Utah.

Mr. Wang’s principal accomplishment through May 1 in using CHEMKIN was the validation of published data in the literature [R. N. Sliger et al., *Fuel Processing Technology*, 65-66 (2000) 423-438] (Ref. 1) on the equilibrium concentration of the chlorine atom in two different flue gases at high temperatures (1173 K):

Flue Gas 1: O₂ – 7.43%; CO₂ – 6.15%; H₂O – 12.3%; HCl – 300 ppm

Flue Gas 2: O₂ – 10%; N₂ – 90%; HCl – 300 ppm

Table 12. Equilibrium Concentration of Chlorine Atoms in Flue Gases at 1173 K

	<u>Literature Data (ppm)</u>	<u>Values Predicted by CHEMKIN (ppm)</u>
Flue Gas 1	0.54	0.5413
Flue Gas 2	21	20.96

In early May, Mr. Wang discovered in the data from the mercury speciation tests, in response to the mercury speciation emission information collection request (ICR) by the U.S. Environmental Protection Agency (EPA), the speciation of mercury in one coal-fired stoker boiler at the Big Bend Boilerplant. This plant reported that 20.9% of the mercury that it emitted during the test period, was HgO. This is exactly the same percentage reported by ESA at the NBP during Test Number N7, when the NBP was also burning coal only.

In mid-May Mr. Wang used CHEMKIN to evaluate the effect of changes in concentration of H₂O, CO and NO on the concentration of chlorine atoms in flue gas in the economizer at lower temperatures (866K). The flue gas composition was: O₂ – 7.63%; CO₂ – 6.15%; HCl – 53%; N₂ – 86.22%. Here are key results of his parametric study.

Table 13. Equilibrium Concentration of Chlorine Atoms in Flue Gases at 866 K

<u>Moisture (%)</u>	<u>CO (ppm)</u>	<u>NO (ppm)</u>	<u>Chlorine Atom (ppb)</u>
0.043	150	150	8.45

0.093	150	150	6.06
0.063	100	0	4.77
0.063	200	0	3.58
0.063	100	150	5.62
0.063	200	150	8.92

Note the dramatic drop in the concentrations of the chlorine atom in this table from those at higher temperatures (1173 K) in Table 11.

In late May Mr. Wang examined the concentration of chlorine atom expected in flue gases from the combustion of three different coals at an even lower temperature (838 K).

Table 14. Equilibrium Concentration of Chlorine Atoms in Flue Gases from Three Coals.

	<u>Pittsburgh</u>	<u>Illinois</u>	<u>Wyodak</u>
Cl in coal (ppmw)	980	340	550
HCl in flue gas (ppmv)	62	24	49
H ₂ O in flue gas (vol %)	5.69	6.51	11.13
Chlorine atom (ppb)	0.786	0.295	0.467

The concentration of NO and CO in these flue gases was set at 1270 ppm and 1 ppm respectively. At a more realistic concentration for NO and CO of 200 ppm and 100 ppm respectively, the concentration of chlorine atom rises to 2.67 ppb in flue gas from Pittsburgh coal, which is about twice the concentration of mercury in the flue gas (1.263). If methane is added to this flue gas, the concentration of chlorine atom increases to 6.27 ppb.

Having recognized the theoretical importance of flue gas temperature and composition on the concentration of the chlorine atom and the role of the chlorine atom in mercury oxidation, Mr. Wang began considering how to explore this experimentally. He developed a design for an experimental apparatus, utilizing a quartz reactor, and discussed his design with the school's chief technician and with Professor Radisav Vidic of the Civil and Environmental Engineering Department, who is conducting a project on mercury removal from flue gas.

The preapplication to NETL's Solicitation No. DE-PS26-01NT41048, "Development of Technologies and Capabilities for Developing Coal and Gas Energy Resources," entitled "Mercury Oxidation in the Post-Combustion Zone of Pulverized Coal Boilers," submitted in Area of Interest #1, "Power Systems Advanced Research," on March 29, was rejected by NETL on June 8. Dr. Benjamin Breen of ESA, with whom the preapplication was prepared, plans to discuss the project, described in the preapplication, with the combustion research group of the USEPA at Research Triangle Park. Mr. Wang plans to join him in this discussion.

In late June Mr. Wang spoke with Francis Lau, Director of Gasification at the Gas Technology Institute (GTI), about his study of mercury speciation. Mr. Lau invited Mr. Wang to visit GTI in Chicago in August to discuss mutual interests.

REPORTS AND PRESENTATIONS

In April and May Dr. Cobb, the project's Principal Investigator, and Dr. Sean Plasynski of NETL organized a six-paper symposium on "Cofiring or Coprocessing Coal and Biomass" to be presented at the 222nd National Meeting of the American Chemical Society (ACS) in August 2001. They solicited papers principally from the Biomass Interest Group and the Upgraded Coal Interest Group of EPRI. Key topics listed in the solicitation were:

1. Preparation and firing of biomass and coal separately fed to boilers from individual storage bunkers.
2. Preparation and firing of blends manufactured from biomass and coal for delivery to boilers.
3. Preparation and firing of pellets (or other types of particles), manufactured from biomass and coal for delivery to the boiler.
4. Preparation and firing of blends containing opportunity fuels in addition to biomass and coal.

Dr. Cobb served as secondary coauthor of two papers, one from Cofiring Alternatives and the other from CQ Inc., whose primary authors were unable to participate in person in the symposium. The six papers that will be presented in the symposium are:

1. Joseph Battista and James Cobb, "Biomass Cofiring in the United States: A Survey of Past Tests."
2. Sean Plasynski, "DOE's Biomass Cofiring Program: Overview."
3. Wiles Elder, Gene Geiger and James Cobb, "Wood/Coal Cofiring to Stoker Boilers in Pittsburgh."
4. Jun Wang, Wiles Elder and James Cobb, "Study of Mercury Oxidation in the Post-Combustion Zones of Coal Boilers."
5. Yoshiki Sato, et al., "Production of Upgraded Solid Fuel and Chemicals from Low Rank Coal with Biomass."

6. James Cobb and David Akers, “Coprocesed Fuel Pellets from Coal, Biomass and Waste.”

Members of the project team gave brief presentations of their work on the project at the Roundtable that was part of the meeting of the Upgraded Coal Interest Group (UCIG) of the Electric Power Research Institute (EPRI) on May 10 and 11 at NETL.

Dr. Cobb gave a formal presentation on this project, along with others that it is conducting, at the EPRI Biomass Interest Group (BIG) meeting on June 7 and 8 in Washington, D.C.

Dr. Cobb gave another formal presentation on this project, along with the project at the BBP, at the Biomass Cofiring Project Review Meeting, which was held at NETL on June 21 and 22.

Dr. Cobb, Dr. Geiger and Mr. Elder submitted an abstract for a paper on “Urban Wood/Coal Cofiring in Pittsburgh-Area Stoker Boilerplants” to the Fifth Biomass Conference of the Americas. The abstract was accepted in mid-April by the conference organizers.

OUTSIDE CONTACTS

Pennsylvania Switchgrass Energy and Conservation Project (PSECP)

Late in the first quarter of the project, the University submitted an application for the PSECP, to the Director of the Pennsylvania State Farm Service Agency (FSA). The proposal was in response to Notice CRP-378, “Reviewing and Recommending Applications for Biomass Pilot Projects,” issued by the U.S. Department of Agriculture (USDA). Late in the second quarter of the project, the USDA announced its approval of four CRP biomass pilot projects, including the PSECP. The other three projects are operated by local Resource Conservation and Development Agencies of the USDA. The PSECP is the only one being operated by a university (and a university without a school of agriculture or Land Grant status).

The project team learned in early April that Union Vale Coal Company has established switchgrass on some of its reclaimed surface mine lands and is interested in providing switchgrass to boilerplants that are members of the Anthracite Regional Independent Power Producers Association (ARIPPA) in conjunction with the PSECP.

On April 17 the Principal Investigator spoke at length with David Tillman and Neal Raskin of Foster Wheeler about switchgrass cofiring in fluid bed boilers. Mr. Tillman advised that in general switchgrass is difficult to feed to boilers and it can contain sizeable amounts of alkali, which can lead to significant slagging problems.

Foster Wheeler has observed straw cofiring in Denmark and has designed switchgrass feed systems for several U.S. boilerplants. Processing of switchgrass as a feed to boilers can be significant and expensive. The feed to fluid bed boilers from switchgrass should be ½ inch by ¼ inch and should have good control on long spears. Mr. Raskin noted that Foster Wheeler performs aftermarket engineering for four ARIPPA boilerplants, including several that have expressed an interest in the PSECP.

Dr. Geiger and Mr. Elder attended the April meeting of ARIPPA in Pottsville, PA on April 24. Also attending were David Bingaman of the PADA, Joseph Sherrick of the PADEP and Neal Raskin of Foster Wheeler. The ARIPPA members from eight of the twelve plants of the Association were briefed on the PSECP, the interest of the PADA in growing switchgrass in Pennsylvania, and the willingness of the PADEP to consider assisting the PSECP in monitoring air emissions during cofiring tests at ARIPPA boilerplants. Following the meeting, Donald Martin, the President of ARIPPA, suggested that he would speak further with Mr. Bingaman and Mr. Raskin and also with those who have cofiring switchgrass to pulverized coal boilers in other states about their experiences, problems they have encountered, and their vision for the future. Mr. Elder will provide Mr. Martin with several key articles about switchgrass and cofiring of it.

On May 3 the USDA sent a memorandum to the Pennsylvania FSA Office, giving the criteria that must be met for all producers participating in the PSECP:

- “1. CRP acreage must be plants to an approved permanent cover.
- “2. No acreage subject to a CRP contract may be harvested more than once every other year.
- “3. No portion of the biomass harvested from CRP acreage is used for any commercial purpose other that energy production from biomass.
- “4. No wetland, or acreage of any type enrolled in a partial field conservation practice, is harvested.
- “5. CRP participant agree to a 25 percent payment reduction for the acreage harvested.
- “6. CRP participants shall not convert existing approved cover to a different cover to become eligible to participate in the approved biomass pilot project. Existing approved covers shall not be converted to monoculture covers.
- “7. Land devoted to field windbreaks, waterways, shallow water areas for wildlife, contour grass strips, shelter belts, living snow fences, permanent vegetation to reduce salinity, salt tolerant vegetative cover, filter strips, riparian buffers, wetland restoration, and cross wind traps strips is not eligible for the biomass pilot project.

“8. Land within an approved public wellhead protection area not to exceed a radius of 2,000 feet from an approved public wellhead is not eligible for the biomass project.

“9. Land with an erodibility index of more than 15 is not eligible for the biomass pilot project.

“10. Land within 180 feet of a stream or other waterbody is not eligible for the biomass pilot project.

“11. Land considered a wetland under 7 CFR part 12 is not eligible for the biomass pilot project.

“12. All other eligibility criteria of the CRP must be met.

“13. Enrollment in the CRP under continuous signup criteria for participation in a biomass pilot project is not authorized.

“The State office must ensure that: (1) not more than 25 percent of the total acreage enrolled in the CRP, in any crop reporting district, is harvested in any 1 year; (2) acres approved for a biomass pilot project will reduce the amount of acres available for research projects on a acre-for-acre basis; and (3) the Dominion Center for Environment and Energy is informed of the approval and the required criteria.”

In reviewing the thirteen criteria, Mr. Bingaman determined that Criterion 9 is so severe that no CRP land in Pennsylvania qualifies for the PSECP. In addition, Criteria 6 and 10 are very restrictive and make the PSECP much more difficult than apparently necessary. For example, Mr. Stickle’s Monona Farms has an average erodibility index of 33, which makes it unavailable for the PSECP under Criterion 9. The project team began working with PADA to prepare a formal request for adjustments to these three criteria. On June 28 Mr. Bingaman wrote a letter to the USDA Natural Resource Conservation Service (NRCS), outlining his concerns with these three criteria. J Here are extracts from his letter that deal with them.

“Criteria number six seems to prevent the change of Conservation Reserve Program (CRP) acres to biomass crops from any existing cover. We feel that to increase acres of biomass crops such as switchgrass we need to be able to enroll existing acres and to change existing ground covers to switchgrass. It is the role of the NRCS field offices to determine where a suitable change is appropriate in terms of soil loss prevention and environmental protection. In the case of switchgrass seeding can be done using a no till system that will not result in soil erosion. Where appropriate switchgrass blends could be suggested by NRCS to prevent monoculture populations. . . .

“When planted with a nurse crop biomass crops like switchgrass are designed to replace row crops on erodible soils thus providing an acceptable alternative for the landowner, game manager and agency personnel alike. An erodibility index of fifteen

will severely limit the ability of the Pennsylvania program to demonstrate the viability of biomass crops. When properly integrated into a farm (land) conservation plan much higher erodibility indexes (30+) can be safely converted to biomass crops such as switchgrass without causing soil loss (meet T).

“The 180 foot buffer along streams is unacceptable because of the significant acreage it eliminates from program participation. With 80,000 miles of streams a very significant portion of the overall agricultural (and state) acreage falls within these distances. When you add productive cropland (not considered for CRP) to forest land and developed areas little land area remains since 60% of PA is forested. A buffer needs to be established based on scientific criteria in order to provide a sensible solution to prevent soil loss, protect the environment and still provide for a biomass program.”

The project team will meet with PAFSA on July 13 to draft the request.

The project team has begun to organize two demonstrations: (1) a demonstration of the production of switchgrass and (2) a demonstration of switchgrass cofiring at a fluid-bed boiler in Pennsylvania. In early June, Mr. Stickle spoke with Ernst Seed Company and Partners for Wildlife about establishing several acres of switchgrass on CRP land at one or more farms in west-central Pennsylvania, including Monona Farms. He also has investigated the equipment and project details for custom harvesting the switchgrass, preparing it for use in a boilerplant and transporting it to the plant. Mr. Stickle will meet with Mr. Ernst on July 3 to discuss their collaboration further.

At Mr. Raskin’s suggestion, also in early June, Mr. Elder sent preliminary information about the PSECP and its interest in a demonstration to the Glatfelter papermill in Spring Grove, Pennsylvania. On June 18, Dr. Cobb, Dr. Geiger, Mr. Elder and Mr. Stickle visited with Joel Morrison, Executive Director of the West Penn Power Sustainable Energy Fund (WPPSEF), at the Energy Institute of the Pennsylvania State University (PSU). Mr. Morrison described the procedure for seeking funds from WPPSEF and directed the team to its webpage, <http://www.wppsef.org>.

The project team has also begun to prepare a proposal for submission in response to Request for Proposal No. 34-12396-91, “Improvement of the Production Capacity for Switchgrass as an Energy Crop,” issued by the Bioenergy Feedstock Development Program of Oak Ridge National Laboratory. As a potential subcontractor, it is assisting Matt A. Sanderson, Research agronomist of the Pasture Systems and Watershed Management Research Unit (PSWMRU) USDA-ARS, University Park, PA, in preparing his proposal in response to the same RFP. On June 18 Dr. Cobb, Dr. Geiger, Mr. Elder and Mr. Stickle met with Mr. Sanderson at his office at the PSWMRU. Mr. Sanderson offered to provide assistance to the Pitt team within the framework of Pitt’s proposal and to include Monona Farms as a test site in his proposal. He also provided a contact in the Agricultural Economics Department of PSU’s Agricultural School as a potential subcontractor for the Pitt proposal. In following up on Mr. Sanderson’s suggestion, the project team will be working with Prof. Jason Harper, who will develop a subcontract

proposal for the Pitt project. Mr. Elder will visit Prof. Harper on July 6 to initiate discussion with him. Mr. Sanderson visited Monona Farms on June 27.

During the quarter, the project team continued to discuss funding approaches for the PSECP, considering that its authorization was not linked with any appropriation. Consideration is being given to approaching foundations, and state and federal legislatures and agencies. One specific foundation is the WPPSEF, mentioned earlier in this section. As noted in a later section, discussions have begun with PennFuture. Dr. Cobb has opened a dialog on this subject with the School of Engineering's coordinator for requests of support from foundations. Dr. Cobb has also opened a dialog with the Community and Government Relations Office of the University of Pittsburgh about approaching state and federal legislators and agencies to seek support for the PSECP.

Discussions on Urban Wood Wastes

In early March Mr. Barry had began speaking with the recycling coordinators of Allegheny and Dauphin Counties, PA about the current opportunity for local governments to develop urban waste recovery demonstrations. During this quarter, Mr. Elder continued this general area of discussion with various individuals in Allegheny County.

Landfill Gas

During this quarter Dr. Geiger and Mr. Barry began to explore a project to move cleaned landfill gas (LFG) from the South Hills Landfill, operated by Waste Management, to the NIOSH boilerplant and the NETL site in Bruceton, PA. About five miles separates the landfill from the federal site. The South Hills Landfill was identified several years ago by the Federal Energy Management Program (FEMP) as a prime site for LFG development. In that same time frame this landfill was also identified by a local LFG developer as one of three local landfills to be retrofitted with equipment to clean its gas, upgrade it to pipeline quality and feed it into the local gas distribution line. The other two landfills recently have begun producing pipeline-quality LFG, but the South Hills Landfill was finally deemed too small to be profitable for pipeline-quality LFG production. Another company studied the possibility of using LFG from this landfill for cogeneration at the NIOSH boilerplant, but found that approach also uneconomic, even with the financial incentives offered by the Biomass and Alternative Methane Fuels (BAMF) Program of the FEMP.

The Pitt project team envisions that the financial incentives offered by FEMP and BAMF could provide the financial incentives to develop a project at the South Hills Landfill and the federal site at Bruceton, given certain modifications to the project that are discussed below. From the outset it was recognized that many parties would have to participate in the definition of the project, including the landfill operator, the local gas distribution company, the NIOSH boilerplant, NETL, staff of FEMP and the BAMF

Program, a qualified FEMP/BAMF contractor, and various local consultants who could provide insight into project details.

In mid-April Dr. Cobb and Mr. Barry met with one of the local consultants to review the current local LFG activity and the opportunity for local developmental funds for the project.

Mr. Barry then spoke with two staff members at NIOSH in Bruceton who expressed interest in exploring the overfiring of LFG at the boilerplant there for NO_x control. They noted that project could become more attractive by adding LFG to the blend of fuels to be used to meet the thermal requirements of two new buildings scheduled for construction over the next several years at the federal site.

After ascertaining interest at Bruceton, Mr. Barry spoke with a staff member of Waste Management about the possibility of developing 1000 CFM of 45% methane LFG for Bruceton from the South Hills Landfill. Finding interest there, Mr. Barry laid out a route for a 5-mile pipeline along right-of-ways of Equitable Gas Company, and estimated its cost at \$200,000. He then held preliminary discussions with a staff member of Equitable Gas and with staff members of FEMP. The staff members of FEMP revealed that it was premature to consider support from that source, as BAMF contractors have not yet been selected.

Sewage Treatment Off-Gas

Mr. Barry had an extensive conversation with a staff member of the Pleasant Hills Sewage Treatment Plant, adjacent to the Bruceton site. A study has already been made there about cleaning the off-gas from secondary sewage treatment and delivering it to Bruceton for cogeneration. The Pleasant Hills plant could provide only a small amount of gas (10 CFM). In addition, the cogeneration project proved to be very expensive and its potential cash flow too small to justify its organization, planning, financing and implementation.

Ethanol

Dr. Geiger has begun an analysis of ethanol production from cellulose in order to understand how some of the switchgrass from the PSECP might eventually be directed toward this end product.

PennFuture

On May 9 Dr. Cobb and Mr. Elder traveled to Harrisburg, Pennsylvania to attend PennFuture's conference on "Getting to 10%" that discussed renewable energy in the

Commonwealth. They learned that four bills promoting various forms of renewable energy have been introduced in the Pennsylvania legislature. However, none of them relate to biomass energy. Nor was bioenergy on the conference agenda. Pennsylvania has no prominent advocate for bioenergy to bring this energy form to the legislature's attention or to the conferees at PennFuture's meetings.

EPRI Interest Groups

The entire project team, including the two graduate students (Mr. Li and Mr. Wang), attended the meeting of EPRI's UCIG at NETL on May 10 and 11. The graduate students had the opportunity during the two days to speak with many of the other attendees.

On June 7 and 8 three members of the project team attended the meeting of EPRI's BIG at EPRI's Washington office.

ADMINISTRATIVE ASPECTS

This section provides a note of special actions, the monthly highlights, and a comparison of progress with the milestone chart.

Special Actions

Thomas Stickle began working informally with the project team when it was preparing the proposal for the PSECP during the first quarter. He has continued his informal relationship since then and plans to do so in the future.

Forms for clearance for Mr. Li and Mr. Wang to visit NBP and NETL were submitted to NETL on January 31. The clearances were received in early April in time for these two Graduate Student Researchers to participate in the field work on this project. Having the clearances also allowed them to attend the EPRI UCIG meeting in early May at NETL.

Nine group meetings were held during this quarter to manage the work and discuss the activities of the program team. During these meetings, in addition to the demonstration at the NBP, the program team addressed the NETL-sponsored wood/coal cofiring demonstration at the Bellefield Boiler Plant (BBP), boiler system analysis, the evaluation of mercury speciation data, the PSECP, the landfill gas investigation, and the production of ethanol.

The Chemical and Petroleum Engineering Department was nominated for a Three Rivers Environmental Award. The BBP and NBP projects were included in the background and rationale for the award. The department was recognized as a finalist in the Higher Education Category, but did not receive an award.

Monthly Highlights

Here are the highlights of the third three-month period of the project.

March 30 – April 30, 2001

- Clearances were received for Mr. Li and Mr. Wang to visit NBP and NETL.
- Six truck-loads of wood/coal blends were prepared at TRT and delivered to the NBP.
- Four one-day test firings of wood/coal blends were conducted at the NBP.
- Emissions of SO₂, NO_x, mercury (both elemental and oxidized) and particulates were measured during two days of blend testing and one day of operation on coal alone at the NBP.
- Literature values of the concentration of chlorine atoms in flue gases simulated in the laboratory were duplicated by the modeling work being performed in this project.
- A broad-based briefing on the PSECP was provided to ARIPPA at its monthly meeting in April.
- Discussions were held with NIOSH and NETL about supplying LFG from the South Hills Landfill to the Bruceton site.
- A six-paper symposium on “Cofiring or Coprocessing Coal and Biomass” was organized for the 222nd National Meeting of the ACS to be held in August 2001.
- A preprint was prepared on mercury modeling for the 222nd National Meeting of the ACS.

April 30 – May 30, 2001

- A meeting was held with PADEP and ACHD to review the testing at the BBP and to discuss future activity there.

- Material balances for four test periods at the BBP were prepared.
- The effect of flue gas composition and temperature on the concentration of chlorine atoms in flue gas were predicted by the modeling work being performed in this project.
- Criteria that must be met for all producers participating in the PSECP were received from the USDA.
- Discussions were held with Waste Management and Equitable Gas Company about supplying LFG from the South Hills Landfill to the Bruceton site.
- The Department of Chemical and Petroleum Engineering was a finalist for the 2001 Three Rivers Environmental Award in the category of Higher Education. This project was highlighted in the descriptions of the work of the finalists.
- The entire project team attended EPRI's UCIG meeting and spoke about the project at its roundtable session.
- Members of the project team attended PennFuture's conference on "Getting to 10%" in Harrisburg, PA, and discussed bioenergy informally.

May 30 – June 30, 2001

- A meeting was held with staff at NIOSH to review the testing at the NBP and to discuss Phase II of the project.
- Material balances for four test periods at the NBP were prepared.
- The preapplication, submitted in March to NETL's Solicitation No. DE-PS26-01NT41048 (Area of Interest #1) on "Mercury Oxidation in the Post-Combustion Zone of Pulverized Coal Boilers" was rejected.
- Discussions were held with FEMP about supplying LFG from the South Hills Landfill to the Bruceton site.
- Members of the project team attended a meeting of the EPRI Biomass Interest Group. A presentation was given on the University's Wood/Coal Cofiring Program.

- Members of the project team attended the Biomass Cofiring Project Review Meeting, held at NETL. A presentation was given on the University's Wood/Coal Cofiring Program.

Comparison of Progress with Milestone Chart

Task 1: This task has been completed. A request for the air quality permit R&D variance was submitted and has been approved.

Task 2: This task has been completed. JARC has modified its grinder and produced BioGrind Wood Chip from both construction and demolition wood. The resulting product appeared chunkier than previous materials, but contained a significant amount of fines. ETS has modified its mill and has processed both construction wood and demolition wood. The product appears to be of good quality.

Task 3: This task has been completed. Construction wood has been collected from Thompson Properties and Seven D Corporation. Demolition wood has been collected from the Arlington Heights Housing Project.

Task 4: This task has been completed. JARC has ground 40 tons of pallets, construction wood from Thompson Properties and delivered approximately half of it to TRT. JARC has ground 5 tons of demolition wood and delivered it to TRT. ETS has milled two truck-loads of construction wood from Square D Corporation and delivered half of it to TRT. ETS has milled two roll-offs of demolition wood and delivered it to TRT.

Task 5: This task has been completed. Six truck-loads of wood/coal blends have been prepared at TRT and delivered to the NBP.

Task 6: This task has been completed. Two one-day test periods, in which a 33% by volume blend of wood, hammermilled by ETS, with coal was fired to the NBP, have been conducted, and this blend has been approved by the plant superintendent for commercialization.

Task 7: This task has been completed. NO_x emissions were reduced by 4-7% and SO₂ emissions by 6-10%. CO emissions were increased by 2-37% and particulate loadings to the baghouse by 25-28%. Mercury emissions decreased by 14% for the blend of demolition wood and coal, but increased by 240% for the blend of construction wood and coal.

PLAN FOR THE NEXT QUARTER

During the fourth quarter from June 30 through September 30, 2001, planning will continue for Phase II at the NBP. A commercial source of wood will be sought. The process of adjusting the coal contract to allow a 33% wood/coal blend to be combusted at the NBP will begin. The process of making any necessary adjustments to the NBP air permits will begin.

The analysis of the data from the demonstrations at the NBP and the BBP will continue, leading to preparation of the final reports on both projects.

Work will continue on the modeling of mercury speciation, on the development of the PSECP, and on the acquisition of LFG by the Bruceeton site.

The session on “Cofiring or Coprocessing Coal and Biomass” will be conducted at the 222nd National Meeting of the American Chemical Society (ACS) in August 2001.

CONCLUSIONS

The field work has been successfully completed.

Four blends of wood and coal were prepared, using both construction wood and demolition wood, delivered to the NBP, and fed to the spreader stoker boiler at the plant. Feeding and firing of a blend of 33% hammermilled wood and 67% coal (by volume) was acceptable operationally and can form the basis for Phase II.

Discussion was initiated with NIOSH concerning the steps toward Phase II.

The quantity of emissions of SO₂ and NO_x were reduced by the use of wood/coal blends. The quantity of CO and particulates to the baghouse were increased.

The quantity of mercury emitted from the boilerplant was reduced when cofiring with demolition wood, but increased when cofiring with construction wood. Mercury speciation was comparable to that observed at the Big Bend Boilerplant, as reported in response to EPA's mercury speciation emission ICR. Examination of the literature and the ICR database, and use of CHEMKIN to model the course of reactions in flue gas following combustion, have shown significant trends in the formation of atomic chlorine, which is a key reactant in the oxidation of mercury.

Material and energy balances were constructed for four test periods at the NBP, as well as for four test periods at the BBP.

A session on bioenergy has been organized for the ACS national meeting in August. The NBP and BBP projects will be described in one of the six papers of this session. Two formal presentations were made in June, describing the NBP and BBP projects, one to the EPRI Biomass Interest Group and the other to NETL's Biomass Cofiring Project Review Meeting.

Several outside contacts have been made. Three unworkable constraints, placed upon the PSECP, have been identified and a request for changes is being prepared. Demonstrations and proposals are being organized to forward the work of the PSECP, which has received no funding from the USDA. An investigation into the supplying of landfill gas from the South Hills Landfill to NIOSH and NETL has begun. Two members of the project team attended the "Getting to 10%" conference of PennFuture.

REFERENCES

- [1] R. N. Sliger et al., *Fuel Processing Technology*, 65-66 (2000) 423-438.

LIST OF ACRONYMS AND ABBREVIATIONS

ACHD	Allegheny County Health Department
ACS	American Chemical Society
ARIPPA	Anthracite Regional Independent Power Producers Association
BAMF	Biomass and Alternative Methane Fuels
BBP	Bellefield Boiler Plant
BIG	Biomass Interest Group
C&D	Construction and Demolition
CFM	Cubic Feet per Minute
CFR	Code of Federal Regulations
CRP	Conservation Reserve Program
DCEE	Dominion Center for Environment and Energy
EPRI	Electric Power Research Institute
ESA	Energy Systems Associates
ETS	Emery Tree Service
FEMP	Federal Energy Management Program
FSA	Farm Service Agency
GTI	Gas Technology Institute
ICR	Information Collection Request
JARC	J. A. Rutter Company
MOU	Memorandum of Understanding
MVTC	Mon Valley Transportation Company
NBP	NIOSH Boiler Plant

NETL	National Energy Technology Laboratory
NIOSH	National Institute of Occupational Safety and Health
NRCS	National Resource Conservation Service
PADA	Pennsylvania Department of Agriculture
PADEP	Pennsylvania Department of Environmental Protection
PSECP	Pennsylvania Switchgrass Energy and Conservation Project
PSWMRU	Pasture Systems and Watershed Management Research Unit
PAFSA	Pennsylvania Farm Service Agency
PSU	Pennsylvania State University
STC	State Technical Committee
TRT	Three Rivers Terminal
UCIG	Upgraded Coal Interest Group
USDA	U.S. Department of Agriculture
USDOE	U.S. Department of Energy
USEPA	U.S. Environmental Protection Agency
WPPSEF	West Penn Power Sustainable Energy Fund