PENNSTATE

Feasibility Analysis for Installing a Circulating Fluidized Bed Boiler for Cofiring Multiple Biofuels and Other Wastes with Coal at Penn State University

Fourth Quarterly Technical Progress Report for the Period 03/15/2001 to 06/14/2001

By

Bruce G. Miller and Sharon Falcone Miller
The Energy Institute;

Robert Cooper, Douglas Donovan, John Gaudlip,
Matthew Lapinsky, and William Serencsits
Office of Physical Plant; and

Neil Raskin and Dale Lamke
Foster Wheeler Energy Services, Inc.

July 13, 2001

Work Performed Under Grant No. DE-FG26-00NT40809

For
U.S. Department of Energy
National Energy Technology Laboratory
P.O. Box 10940
Pittsburgh, Pennsylvania 15236

By
The Energy Institute
The Pennsylvania State University
C211 Coal Utilization Laboratory
University Park, Pennsylvania 16802

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DISCLAIMER

EXECUTIVE SUMMARY

The Pennsylvania State University, under contract to the U.S. Department of Energy, National Energy Technology Laboratory is performing a feasibility analysis on installing a state-of-the-art circulating fluidized bed boiler and ceramic filter emission control device at Penn State's University Park campus for cofiring multiple biofuels and other wastes with coal, and developing a test program to evaluate cofiring multiple biofuels and coal-based feedstocks.

The objective of the project is being accomplished using a team that includes personnel from Penn State's Energy Institute, Office of Physical Plant, and College of Agricultural Sciences, Foster Wheeler Energy Services, Inc., Parsons Energy and Chemicals Group, Inc., and Cofiring Alternatives.

During this reporting period, work focused on completing the biofuel characterization and the design of the conceptual fluidized bed system.

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1.0 Introduction

The Pennsylvania State University, under contract to the U.S. Department of Energy (DOE), National Energy Technology Laboratory (NETL) is performing a feasibility analysis on installing a state-of-the-art circulating fluidized bed (CFB) boiler and ceramic filter emission control device at Penn State's University Park campus for cofiring multiple biofuels and other wastes with coal, and developing a test program to evaluate cofiring multiple biofuels and coal-based feedstocks. Penn State currently operates an aging stoker-fired steam plant at its University Park campus and has spent considerable resources over the last ten to fifteen years investigating boiler replacements and performing life extension studies. This effort, in combination with a variety of agricultural and other wastes generated at the agricultural-based university and the surrounding rural community, has led Penn State to assemble a team of fluidized bed and cofiring experts to assess the feasibility of installing a CFB boiler for cofiring biomass and other wastes along with coal-based fuels.

The objective of the project is being accomplished using a team that includes personnel from Penn State's Energy Institute, Office of Physical Plant, and College of Agricultural Sciences, Foster Wheeler Energy Services, Inc., Parsons Energy and Chemicals Group, Inc., and Cofiring Alternatives.

The CFB boiler system that is being considered in the feasibility analysis is unique in that it:

1) is of compact versus traditional design;
2) includes modules to evaluate ceramic filters, along with fabric filters, for particulate matter control (recent work at Penn State has shown that ceramic filters have potential advantages regarding fine particulate matter and trace elements, i.e., mercury removal);
3) contains an advanced instrumentation package including temperature and pressure sensors, deposition and slagging probes, heat flux meters, and corrosion/ erosion panels;
4) contains multi-fuel capabilities (making it a versatile test site for industry and government studies); and
5) is a commercial facility in a rural, agricultural setting that contains an engineering and agricultural-based university.

The state-of-the-art CFB boiler and ceramic filter device allows the University the opportunity to do the following:

- to more economically supply heat to the University Park Campus;
- to reduce the amount of air-borne pollutants (i.e., NO_x, SO_2, particulate matter, and potentially trace elements), thus helping to reduce the overall emissions from the University's central heating plant;
- to reduce the amount of agricultural and other waste products produced by the University that must be disposed;
- to help reduce the amount of CO_2 (a greenhouse gas) emissions by combusting waste biofuels; and

- to ultimately serve as a large-scale (commercial demonstration size) test facility for federally- and other outside source-funded research and development projects related to cofiring of biofuels with coal and other coal refuse.

The feasibility analysis assesses: the economics of producing steam; the economics of off-sets such as utilizing multiple biomass and other wastes (i.e., sewage sludge); the value of a unique CFB test facility to perform research for industry, such as Foster Wheeler, and government agencies, such as the DOE; the environmental aspects of the CFB boiler; and the availability of funding from multiple sources including University, state, and federal sources. The feasibility study will also include developing a multiple-year program to test biofuels as the boiler system will be unique in that it will be heavily instrumented and will be able to handle multiple fuels.

1.1 Penn State's Steam Plants

Penn State University, Office of Physical Plant (OPP) currently operates a coal-fired central steam plant at the University Park Campus. The installed coal-fired capacity is 450,000 lb/h (pph) steam generated by four vibra-grate stoker boilers at 250 psig/540°F, which are used as baseload units. Additional steam generating capacity is available with gas or oil fire in three other boilers, totaling 260,000 pph. Electricity is also produced, as a by-product, with a maximum installed generating capacity of 6,500 kW. Currently at peak operation, which occurs when classes are in session and winter conditions experienced, 420,000 pph of steam are required. Steam requirements during the summer are 125,000 pph while approximately 200,000 pph of steam is required during the spring/fall.

Although the present total steam generating capacity is 710,000 pph, the University prefers not to operate the gas- and oil-fired boilers because the price of the natural gas and fuel oil is significantly higher than that of the coal. Ideally, the University would like to fire only coal and have sufficient coal firing capability to allow for one coal-fired boiler to be down without impacting steam production or forcing the operation of a gas/oil-fired boiler.

The four stoker-fired boilers at Penn State are all between 33 and 40 years old. When the units were installed (1961 to 1968), the projected life of a typical unit was expected to be approximately 40 years. Since that time, the life of the steam generating units has been reevaluated based on changing technology, economic, and regulatory factors. Life extension studies on many plants have now indicated that economic lives up to 50 to 60 years may be possible depending on the levels of maintenance, type of operation of the units, the cost of competing units, and other parameters related to these factors. Despite this, the University is exploring the possibility of installing a CFB boiler to cofire biomass and other waste streams with coal because of the following benefits:

1) Waste stream utilization. The CFB boiler would be multi-fuel capable with coal being the primary fuel and supplemented with waste streams. Waste stream disposal costs would be eliminated. For example, sewage sludge is currently landfilled at a cost of $47/ton.
2) Lower overall fuel costs. This includes using a lower grade coal including bituminous coal refuse (i.e., gob), growing grasses or crops on University land and cofiring in the boiler, accepting biomass and other wastes from the municipality, and being a test site for industry (e.g., Foster Wheeler) to conduct various fuel tests where the test fuel would be used in place of fuels purchased by the University.
3) Higher efficiency boilers.
4) Lower boiler emissions.
5) Possible alternative to spreading manure on fields and the associated odor problem.
6) Potential external funding source for a boiler replacement project. A recent energy assessment for Penn State showed that a coal-fired cogeneration plant was not economically feasible. However, OPP is reconsidering a boiler replacement because there is the possibility that some of the funding may come from other sources, e.g., industrial sponsorship, state and federal agencies.
7) Research component. By being a test site for industry (e.g., Foster Wheeler), not only would there be a decrease in fuel costs but there is the possibility that other operating costs such as labor could be reduced when industry-funded testing occurs.

Penn State's seven boilers are housed at two locations on campus as shown in Figure 1. The four coal-fired boilers and one small natural gas and oil-fired boiler are located at the West Campus Steam Plant (WCSP). There is not any room for installing additional boilers at this location. Two 100,000 pph of steam boilers, designed for natural gas and No. 2 fuel oil, are located at the East Campus Steam Plant (ECSP). This facility is used for peaking purposes. This location has been identified for future boiler expansion. At this time, OPP is interested in installing a CFB boiler with 200,000 pph of steam capacity at the ECSP. This size of a boiler could be installed without extensive upgrades to the current steam, water, and condensate return infrastructure. Final selection of the boiler size will be determined as part of the feasibility study.

1.2 Project Outline

The work consists of gathering design-related information, collecting and analyzing representative biofuels, coal, and coal refuse samples, developing a conceptual CFB boiler system design, developing a preliminary three-year test program and associated budget, determining the system design/test program economics, and performing the feasibility study. The work is being performed via the following tasks:

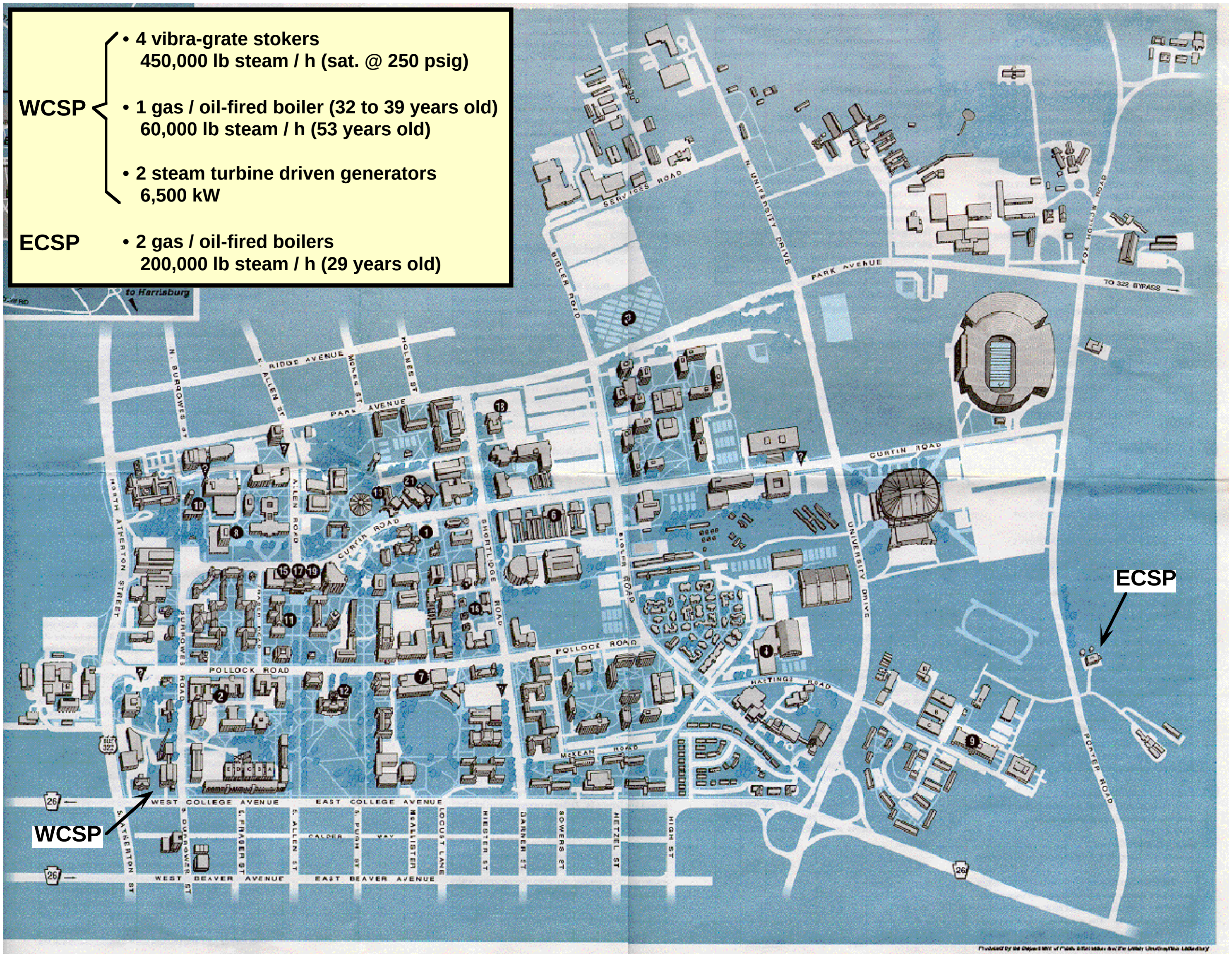

Figure 1. PENN STATE'S WEST CAMPUS AND EAST CAMPUS STEAM PLANTS

- Task 1. Information and Sample Collection
- Task 2. Biofuels and Biofuel/Coal Characterization
- Task 3. Develop Conceptual Design
- Task 4. Develop Preliminary Test Program/Budget
- Task 5. Determine System/Program Economics
- Task 6. Complete Feasibility Study
- Task 7. Project Management/Reporting

A summary of the activities being performed in each task includes:

Task 1. *Information and Sample Collection*: System requirements and infrastructure information will be assembled by Penn State and provided to Foster Wheeler. In addition, representative samples of biofuel and coal will be collected by Penn State and Cofiring Alternatives.

Task 2. *Characterize Biofuels and Biofuel/Coal Combinations*: Penn State will characterize the samples collected in Task 1 and Foster Wheeler will use the analyses for assessing issues such as materials handling, deposition, and emissions.

Task 3. *Develop Conceptual Design*: A CFB boiler system will be designed to address the multiple project objectives. Foster Wheeler will perform the conceptual design with input from Penn State and Cofiring Alternatives.

Task 4. *Develop Preliminary Test Program/Budget*: A three-year test program will be designed and costed to use the state-of-the-art CFB boiler system for investigating a range of issues when cofiring multiple biofuels and possibly other waste materials. Penn State will develop the preliminary test program with consultation from Foster Wheeler and Cofiring Alternatives.

Task 5. *Determine System/Program Economics*: Capital and operating costs will be determined. In addition, the availability of funding for the system and test program will be assessed.

Task 6. *Complete Feasibility Study*: The feasibility study will be completed by incorporating the results from each of the tasks.

Task 7. *Project Management/Reporting*: The project will be managed and reported per DOE's contractual requirements. Reporting will include the quarterly program/project management and technical progress reports, and a final report.

The status of Tasks 1 through 7 is presented in Sections 2.0 through 8.0, respectively. Activities planned for the next quarterly period are listed in Section 9.0. References and acknowledgments are contained in Sections 10.0 and 11.0, respectively. The project schedule is given in Figure 2, with a description of the milestones contained in Table 1.

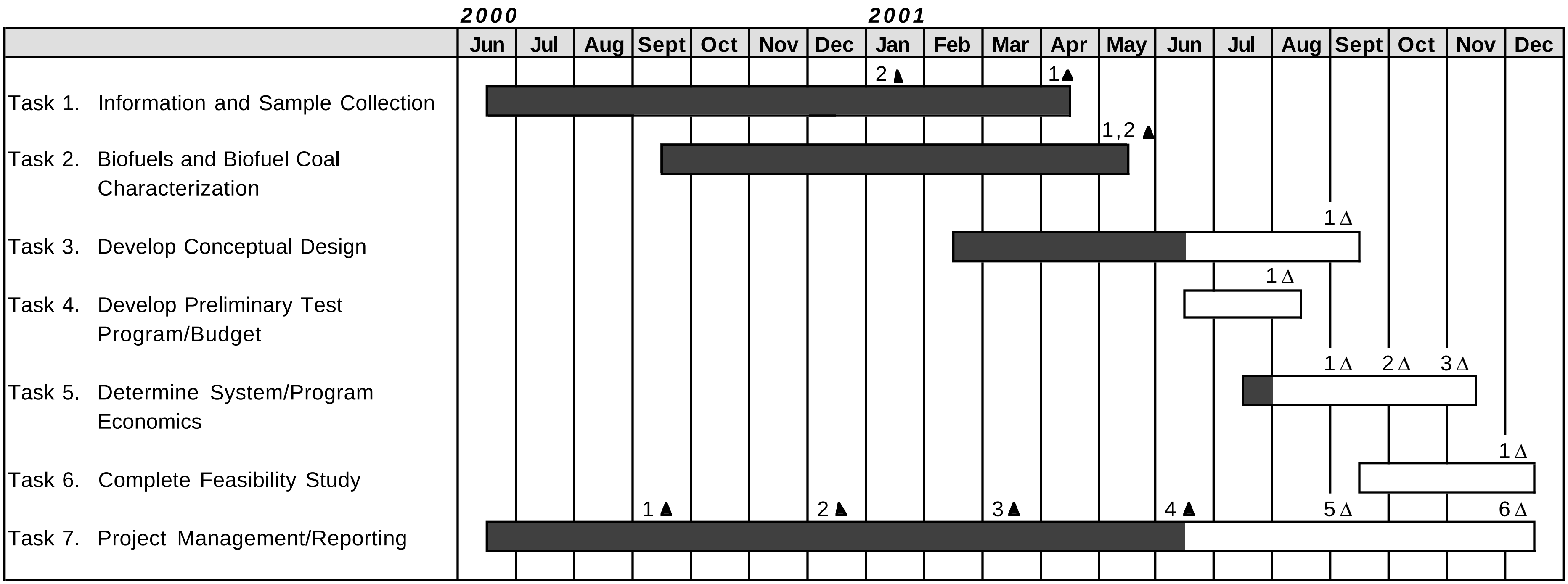

Figure 2. MILESTONE SCHEDULE

Table 1. Description of Milestones

Milestone	Description	Planned Completion Date	Actual Completion Date
Task 1, No. 1	Assemble system requirements and infrastructure information	04/15/01	04/15/01
Task 1, No. 2	Collect representative biofuel and coal samples	11/15/00	01/15/01
Task 2, No. 1	Complete characterization of biofuel samples	05/15/01	05/15/01
Task 2, No. 2	Complete characterization of biofuel/coal samples	05/15/01	05/15/01
Task 3, No. 1	Complete conceptual design	09/15/01	
Task 4, No. 1	Develop preliminary task program/budget	08/15/01	
Task 5, No. 1	Determine capital cost	09/15/01	
Task 5, No. 2	Determine operating costs	10/15/01	
Task 5, No. 3	Assess availability of funding	11/15/01	
Task 6, No. 1	Complete feasibility study	12/15/01	
Task 7, No. 1	Prepare program/project management and technical report 1	09/15/00	10/15/00
Task 7, No. 2	Prepare program/project management and technical report 2	12/15/00	12/15/00
Task 7, No. 3	Prepare program/project management and technical report 3	03/15/01	03/30/01
Task 7, No. 4	Prepare program/project management and technical report 4	06/15/01	07/13/01
Task 7, No. 5	Prepare program/project management and technical report 5	09/15/01	
Task 7, No. 6	Prepare program/project management and technical report 6; prepare final report	12/14/01	

2.0 Task 1. Information and Sample Collection

Task 1 has been completed. System requirements and infrastructure information were assembled and provided to Foster Wheeler. This information is currently being used to develop the conceptual design. Representative samples of biofuels were collected by Penn State. Specifics on the samples collected were previously reported (Miller and Jawdy, 2000; Miller et al., 2000). Cofiring Alternatives completed a resource assessment of sawmills and secondary wood processors with wood wastes available for marketing as well as other potential biomass feedstocks for the CFB (Miller et al., 2000; Miller et al., 2001)

3.0 Task 2. Biofuels and Biofuel/Coal Characterization

Analysis of the coal ashes, sewage sludge, and biofuels was completed during this reporting period. The biofuel analyses, contained in a previous quarterly report (Miller et al., 2000) consisted of:

1) Proximate analysis;
2) Ultimate analysis;
3) Higher heating value;
4) Bulk density (where appropriate);
5) Chlorine content (where appropriate); and
6) Rheological characteristics (where appropriate).

In addition, the bulk chemical analysis of the biofuel ashes, stoker bottom and fly ash, and sewage sludge ash was determined. The results are shown in Table 2.

Chemical fractionation analysis, originally not planned as part of this project but added later, was performed on the following samples to determine the mode of occurrence of major and minor elements:

1) Pine shavings;
2) Red oak shavings;
3) Dairy tie-stall manure;
4) Dairy free-stall manure;
5) Miscellaneous manure (mixture of various small-quantity manure streams that are collected at a central storage barn);
6) Sewage sludge;
7) Sheep manure;
8) Reed Canary grass;
9) Bottom ash; and
10) Fly ash.

The chemical fractionation process, which is being used to distinguish different types of inorganic matter in the fuel according to their solubility in different solvents, has been completed for the samples. A detailed description of the chemical fractionation

Table 2. Spectrochemical Analysis of Feedstock Ashes

	Fly Ash	Bottom Ash	Dairy Tie Stall	Dairy Free Stall	Misc. Manure	Reed Canary Grass	Sewage Sludge	Red Oak	Pine Shavings	Sheep Manure
LOI (900°C)	27.4	27.7	92.4	86.7	50.1	95.1	53.0	62.4	52.9	21.7
Al_2O_3	32.8	30.8	2.26	0.96	1.34	1.66	6.21	3.04	13.4	3.08
BaO	0.24	0.18	0.02	0.02	0.01	0.05	0.05	0.24	0.15	0.05
CaO	2.36	1.48	23.3	6.38	3.44	9.57	37.7	45.7	8.75	12.8
Fe_2O_3	10.7	10.4	1.37	1.29	0.93	1.47	4.39	4.69	5.94	1.95
K_2O	1.82	1.62	10.7	6.75	1.77	18.1	1.18	6.10	4.94	23.4
MgO	1.55	0.55	8.91	2.65	1.06	5.29	3.67	4.92	3.35	5.74
MnO	0.01	0.02	0.14	0.17	0.03	0.11	0.07	3.49	0.49	0.17
Na_2O	0.44	0.32	7.04	1.32	0.88	2.34	0.40	1.39	1.38	4.64
P_2O_5	2.14	0.34	14.7	2.90	2.54	13.8	2.30	2.80	1.44	9.21
SiO_2	46.8	53.0	26.0	75.0	84.8	43.0	35.6	18.7	57.2	29.3
SrO	0.28	0.20	0.14	0.04	0.01	0.02	0.12	0.10	0.05	0.03
TiO_2	1.22	1.57	0.11	0.10	0.14	0.11	0.59	0.26	0.80	0.20
SO_3	0.14	0.09	5.08	2.06	1.20	4.99	2.43	- - -	1.16	5.52
Total	100.6	100.6	99.8	99.6	98.2	100.5	94.7	91.3	99.10	96.1

procedure is given in Appendix A. A schematic representation of the method is shown in Figure 3.

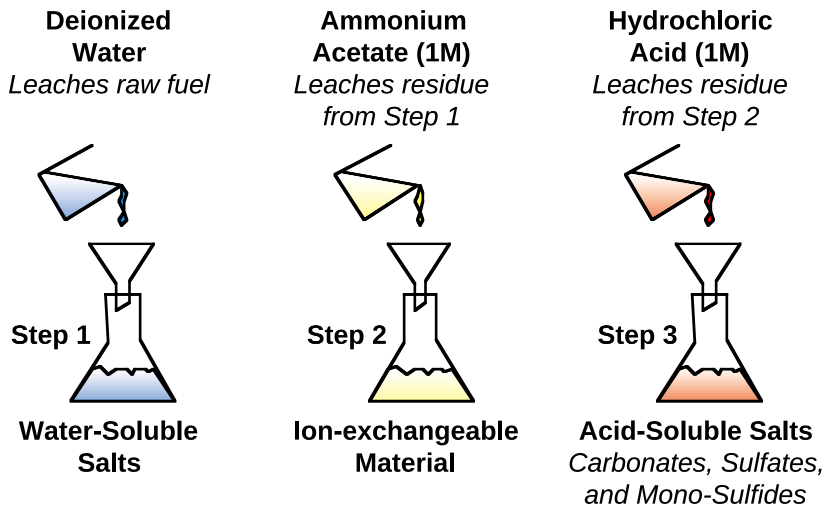

Figure 3. SCHEMATIC REPRESENTATION OF THE CHEMICAL FRACTIONATION METHOD

In the first step of leaching, water was used to remove trace elements that are water soluble. This consists primarily of water-soluble salts. The leachate and a portion of the residue from this step were analyzed for trace elements.

The remainder of the residue from Step 1 was subjected to a second leaching step using ammonium acetate to remove trace elements that are bound loosely to organic matter, e.g., ion-exchangeable materials. Again, the leachate and a portion of the residue from this step were analyzed for trace elements.

The final leaching step used hydrochloric acid to remove trace element-bearing minerals that exist as acid-soluble salts such as carbonates, sulfates, mono-sulfide minerals, and simple oxides. Again, the leachate and a portion of the residue from this step were analyzed for trace elements.

The analytical results are being used as input for global equilibrium calculations. Due to the voluminous nature of the results, the data are still being interpreted and will be presented in a paper at the Fifth Biomass Conference of the Americas in September 2001.

4.0 Task 3. Develop Conceptual Design

During this reporting period, work continued on developing the conceptual design. The following work has been completed or is in progress:

- Completed preliminary plant arrangement;
- Finalized equipment requirements with suppliers for the ash handling and fuel(s) feed systems;
- Completed preliminary P&IDs;
- Initiated plant electric load list; and
- Initiated plant input/ output (I/O) list.

5.0 Task 4. Develop Preliminary Test Program/Budget

No work was performed in Task 4 during this reporting period.

6.0 Task 5. Determine System/Program Economics

Work in Task 5 started during this reporting period. Equipment and erection cost estimates were initiated as part of the conceptual design.

7.0 Task 6. Complete Feasibility Study

No work was performed in Task 6 during this reporting period.

8.0 Task 7. Project Management/Reporting

During this reporting period, a meeting was held at the Pennsylvania Department of Environmental Protection's Williamsport office on April 2, 2001 to discuss permitting issues (i.e., air, water, and solids). This was attended by Penn State, Foster Wheeler, and Parsons Energy and Chemicals Group, Inc.. In addition, technical reporting was performed per the contractual requirements.

9.0 Next Quarterly Activities

During the next reporting period, the following will be done:

- Compete the equipment cost estimate;
- Complete the erection cost estimate;
- Finalize the plant arrangement;
- Finalize the plant P&IDs;
- Complete the plant electric load list;
- Prepare a draft report on FosterWheeler's scope of work;
- Develop a preliminary test program and budget;
- Attend and make a presentation at DOE's Project Review Meeting in Pittsburgh, Pennsylvania on June 21-22, 2001; and
- Prepare and present a manuscript at the Fifth Biomass Conference of the Americas in September 2001.

10.0 References

Miller, B.G. and C. Jawdy, “Feasibility Analysis for Installing a Circulating Fluidized Bed Boiler for Cofiring Multiple Biofuels and Other Wastes with Coal at Penn State University First Quarterly Technical Progress Report for the Period 06/15/2000 to 09/14/2000,” Prepared for the U.S. Department of Energy National Energy Technology Laboratory, Pittsburgh, Pennsylvania, DE-FG26-00NT40809, October 9, 2000, 40 pages.

Miller, B.G., S. Falcone Miller, C. Jawdy, R. Cooper, D. Donovan, and J.J. Battista, “Feasibility Analysis for Installing a Circulating Fluidized Bed Boiler for Cofiring Multiple Biofuels and Other Wastes with Coal at Penn State University Second Quarterly Technical Progress Report for the Period 09/15/2000 to 12/14/2000,” Prepared for the U.S. Department of Energy National Energy Technology Laboratory, Pittsburgh, Pennsylvania, DE-FG26-00NT40809, December 21, 2000, 95 pages.

Miller, B.G., S. Falcone Miller, R. Cooper, D. Donovan, J. Gaudlip, M. Lapinsky, W. Serencsits, N. Raskin, D. Lamke, and J.J. Battista, “Feasibility Analysis for Installing a Circulating Fluidized Bed Boiler for Cofiring Multiple Biofuels and Other Wastes with Coal at Penn State University Third Quarterly Technical Progress Report for the Period 12/15/2000 to 03/14/2001,” Prepared for the U.S. Department of Energy National Energy Technology Laboratory, Pittsburgh, Pennsylvania, DE-FG26-00NT40809, March 30, 2001, 72 pages.

11.0 Acknowledgements

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Randy Swope from Penn State’s College of Agricultural Sciences Farm services and William Lamont from the Horticulture are Department are acknowledged for their assistance in quantifying and sampling various potential feedstocks.

Mike Delallo and Francis Caracappa from Parsons Energy and Chemicals Group, Inc. are acknowledged for their assistance in the system design, costing, and permitting.

APPENDIX A. DESCRIPTION OF THE CHEMICAL FRACTIONATION PROCEDURE

Appendix A details the chemical fractionation procedure to determine the mode of occurrence of the mineral components of the biomass feedstocks, coal ashes, and sewage sludge.

Purpose: To determine the occurrence (free, organic, mineral) of the inorganic components in the fuels.

Method: Ground fuel is successively washed with water, ammonium acetate, and hydrochloric acid.

Results: Determined by analyzing both solid and liquid samples taken after each washing step. Mass balance is done to determine the amount of inorganic components lost during each step.

Steps:

1) Dry Fuel

- Fuel are completely dried at 60°C in the large Dispatch oven
- Pyrex pie plates are used for drying (metal tools/containers should be avoided so that contamination will be minimal)

2) Grind Fuel

- Dried fuel is ground to –60 mesh (<250 μm)
- Clean the crusher and pulverizer with compressed air, followed with acetone before every new fuel to be ground
- Cut up fuel if necessary (example: hay)
- Slowly feed to disc crusher
- Feed output from disc crusher to pulverizer
- If necessary, recut and refeed fuel particles that are too large to be fed until they enter the pulverizer
- Remove pulverized fuel from output bin and store in a labeled container in the Dispatch oven until fractionated

3) Clean Glassware

- All glassware and stirrers must be thoroughly cleaned before use as follows:
  clean with scrubber and water
  rinse with deionized water
  rinse with 1M HNO_3 made with deionized water
  rinse with deionized water
  dry on rack

4) Water Wash

- Weigh 120 grams of ground fuel into clean beaker (600 ml for coals, up to 2,000 ml for fluffy biomass)
- Place beaker on stir/heat plate
- Add cleaned stir bar
- Slowly add deionized water and stir with clean glass rod
- Stop adding water when all fuel is wetted and stirring well and heat to 70°C.
- Stir overnight

5) Solid/ Liquid Separation

- Quickly remove beaker from plate and pour mixture into cleaned centrifuge tubes (if the mixture is not stirring as you pour it you will get separation by density and size)
- Centrifuge
- Set up a vacuum filter with Whatman coarse paper (402) and large (1,000 ml) vacuum flask
- Pour supernatant from centrifuge tubes through vacuum filter
- Scrape out solid from centrifuge tubes into a cleaned and labeled Pyrex plate with a clean Teflon coated spatula
- Repeat until beaker is empty
- Scrape solid from Pyrex plate into vacuum filter
- Rinse centrifuge tubes and beaker into vacuum filter
- Rinse solids in vacuum filter with approximately 500 ml of deionized water
- Scrape solids from vacuum funnel back into the Pyrex plate and rinse vacuum funnel with deionized water into plate
- Stir solids thoroughly to mix fractions of different density/size
- Place a small (~15 g) sample of the solids into a sample container, being careful to take a REPRESENTATIVE sample to be submitted for analysis
- Shake up liquid in vacuum flask and put a small sample (~120 ml) in a Nalgene bottle and label to be submitted for analysis
- Measure volume of liquid remaining using a 1,000 ml graduated cylinder and discard this liquid after recording the volume

6) Dry Washed Solids

- Dry solids in Pyrex plate and sample container in Dispatch oven overnight (longer if moisture remains)
- Weigh both bulk solids and sample and record weights

7) Ammonium Acetate Wash

- Repeat water wash procedure using the dried filtrate from the water wash, this time using 1M ammonium acetate made with deionized water
- Heat liquid to 70°C during the stirring phase, checking temperature with a clean thermometer clamped into place on the beaker

- Excess water must be added before you leave for the night to ensure that all the water does not evaporate
- Ammonium acetate wash must be done three times
- Keep the liquid from each washing/centrifuging/filtering step in a labeled container, and take a sample from the combined liquid after the third washing to be submitted for analysis
- Dry the solid after the third washing and remove ~15g to be submitted for analysis
- The remaining solid goes on to the hydrochloric acid step

8) Hydrochloric Acid Wash

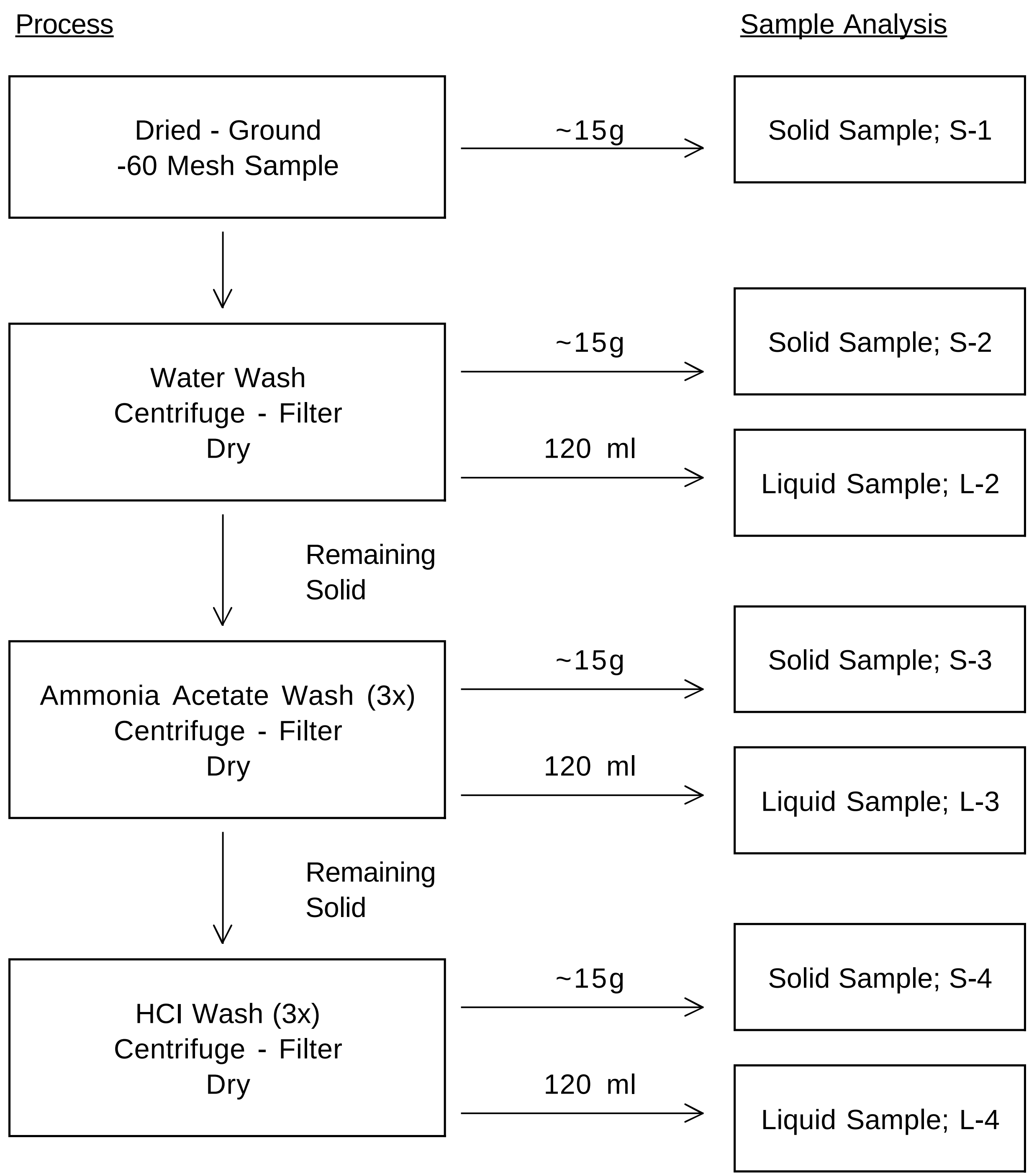
- Repeat the ammonium acetate procedure using 1M HCl rather than ammonium acetate
- Submit ~15g dried solid and 120 ml liquid for analysis

9) Refilter Liquid Samples (if necessary)

- If particulate matter can be seen settled at the bottom of your liquid sample containers, they must be refiltered
- Pass the liquid through a clean vacuum filter set up with a fine Whatman paper and pour back into sample bottle

10) Analyze Samples

- Perform Inductively Coupled Plasma (ICP) spectrometric analysis on all solid and liquid samples



Liquid Samples - add 3% nitric acid.

APPENDIX B. INFORMATION PRESENTED TO THE PENNSYLVANIA DEPARTMENT OF PROTECTION ON APRIL 2, 2001

Penn State University CFB Feasibility Project

The following information/ bullets were presented to the Pennsylvania Department of Environmental Protection (DEP) on April 2, 2001. Participants included representatives from DEP, Foster Wheeler, Parsons Energy and Chemicals Group, Inc., Office of Physical Plant, and The Energy Institute.

Foster Wheeler had completed preliminary layout designs. This included both a side elevation and a plan view. The following items were discussed:

Boiler

- 200,000 lb steam/ hr Foster Wheeler Compact Circulating Fluid Bed
- Initially supplying steam to the campus at 250 psig and 540°F

Fuel Handling Systems

1) Coal/ pelletized fuel (e.g., coal/ paper sludge)
2) Biomass
  2a) Wood products
  2b) Manures
  2c) Additional system

- Receiving – enclosed
- Storage – silos/ bunkers
- Conveying
- Feed to the boiler

Limestone Handling System

- Receiving – pneumatic system
- Storage – silo
- Conveying
- Feed to the boiler

Feedwater System

- Condensate return
- Make-up
- Treatment
- Storage
- Boiler feed

Ash Handling Systems

1) Bottom Ash

- Collection
- Ash hydration
- Conveying
- Storage
- Disposal

2) Fly Ash

- Collection via fabric filter baghouse
- Recycle
- Conveying
- Storage
- Disposal

Air Emissions

Uncontrolled NO_x emissions will be 0.2 lb/ million Btu. SO_2 emissions will be 0.14 lb/ million Btu using limestone addition. Particulate emissions will be controlled at 0.04 lb/ million Btu using a fabric filter baghouse.

Potential Electric Power Generation

The plant arrangement will allow for future generation of electric power as well as room for adding a sister unit. Specifics include:

- Boiler is designed to operate at 200,000 lb steam/ hr capacity with a pressure of 950 psig and a temperature of 950°F although it will initially be operated at 250 psig and 540°F, i.e., materials of construction will be for the higher pressure and temperature.
- Feedwater system will be capable of providing water at the proper quality and pressure.
- Fuels, limestone, and ash handling systems will be designed for the larger quantities.
- The plant can be expanded to add either an extraction steam turbine (15 MW_e).or a condensing steam turbine (20 MW_e).and electric generator.
- The plant arrangement will consider the best access to the electric power transmission system.

During the meeting with DEP, several items were discussed with respect to permitting. The three main issues were air emissions (listed above), solid waste, and water. Below are the design issues with respect to the solid waste and water. Also, attached is a spreadsheet with the preliminary fuel (coal, biomass, and other wastes) feedrates that are being used in the design. Note that the bottom and fly ash from the existing stoker-fired units will also be fired in the boiler although they are not shown in the firing rate table.

Solid Waste

Ash Quantity

- 8,670 lb/ hr total
- 6,935 lb/ hr of fly ash
- 1,735 lb/ hr of bottom ash

Ash Constituents (wt. %)

• Ash from the fuel	50.8
• CaO	22.3
• $CaSO_4$	20.2
• Unburned fuel	3.6
• Inert	1.6
• $CaCO_3$	1.0
• MgO	0.5

Waste Water

- No permitting necessary for pretreatment. Water from the power plant water treatment equipment and the boiler blowdown will be collected, treated, and discharged to the University’s sewer system.
- Storm water from inside the plant boundary will be collected, treated, and discharged to the storm water channel adjacent to the plant.

Cooling Water

- Cooling water for the equipment in the plant will be provided by a closed cooling water system that will utilize the University’s sewage treatment plant effluent as a heat sink.

Fuel and Firing Rate Information

Feedstock	Maximum Firing Rate (lb/h, wet)	Maximum Thermal Input (Btu/h)	
Coal	16,667	200,000,000	
	(assuming heating value (Btu/lb) =	12,000	)
Sewage Sludge	780	475,700	
Swine Waste	715	116,777	
Dairy Manure	3,800	10,600,000	
Beef Manure	295	944,000	
		(assuming HHV=8,000 Btu/lb)	
Sheep Manure	76	290,400	
Coverd Barn Manure	336	507,800	
Reed Canary Grass	171	369,189	
Plastics	0.6	11,500	
Wood Chips/Shavings	5,700	28,400,000	

Total boiler thermal ratio =	200,000,000	Btu/h
Thermal input from all non-coal streams =	41,715,366	Btu/h
Thermal input from coal after biomass/wastes removed =	158,284,634	Btu/h
Thermal ratio of biomass/wastes-to-total =	0.21	
Thermal ratio of coal-to-total =	0.79	
Coal equivalent displaced by biomass/wastes =	3,476.28	lb/h
Total lb/h (wet) from all biomass/waste streams =	11,874	lb/h
Coal feed rate =	13,190	lb/h
Total fuel rate =	25,064	lb/h
Fuel ratio of biomass-to-total =	0.47	
Fuel ratio of coal-to-total =	0.53	