PENNSTATE

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

Sixth Quarterly Technical Progress Report for the Period 09/15/2001 to 12/14/2001

By

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The Energy Institute;

Robert Cooper, Douglas Donovan, John Gaudlip,
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Office of Physical Plant; and

Neil Raskin
Foster Wheeler Energy Services, Inc.

January 18, 2002

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
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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 performing the design of the conceptual fluidized bed system and determining the system economics.

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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 airborne 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 multiyear 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:

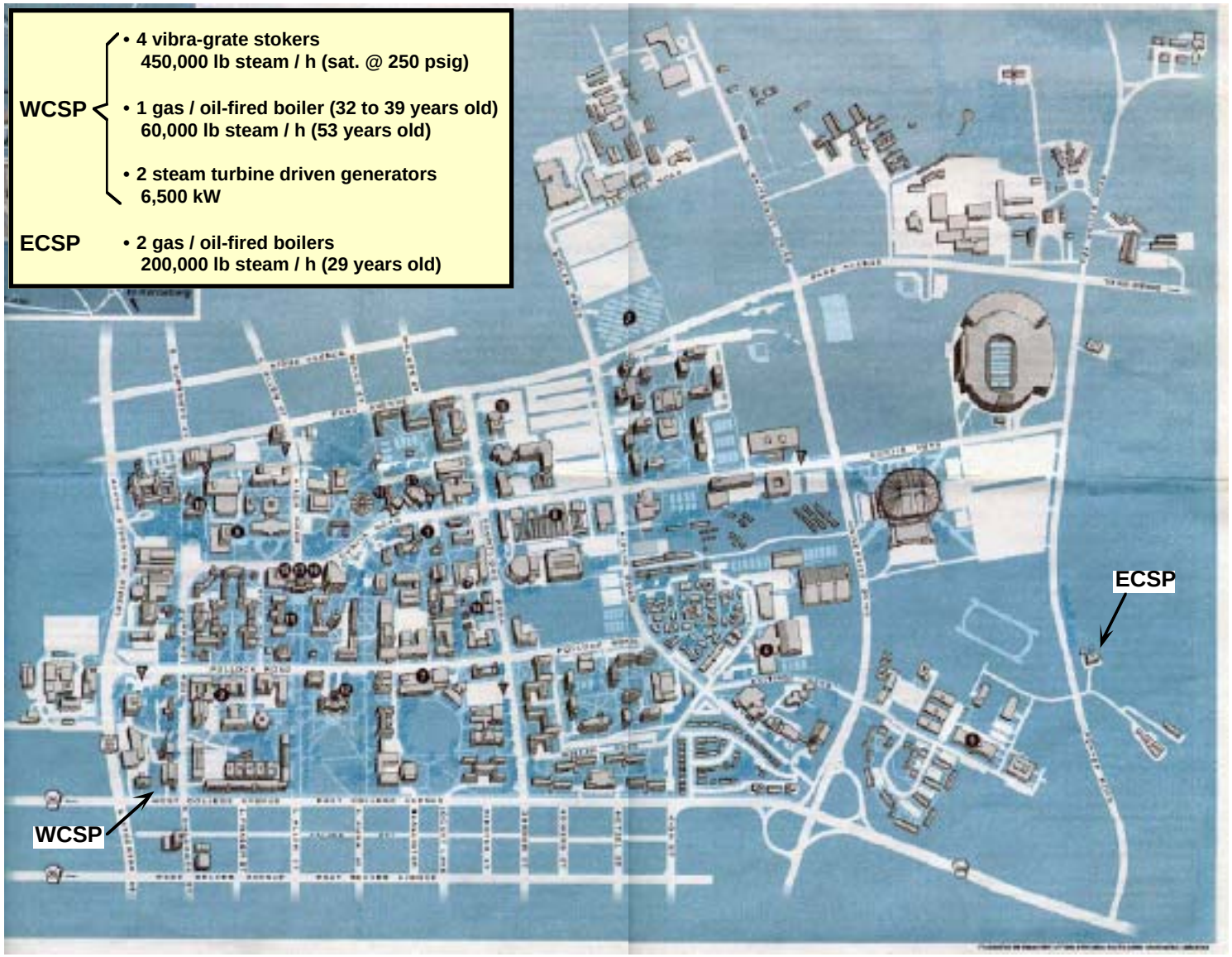


Figure 1. PENN STATE'S WEST CAMPUS AND EAST CAMPUS STEAM PLANTS

- 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.

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.

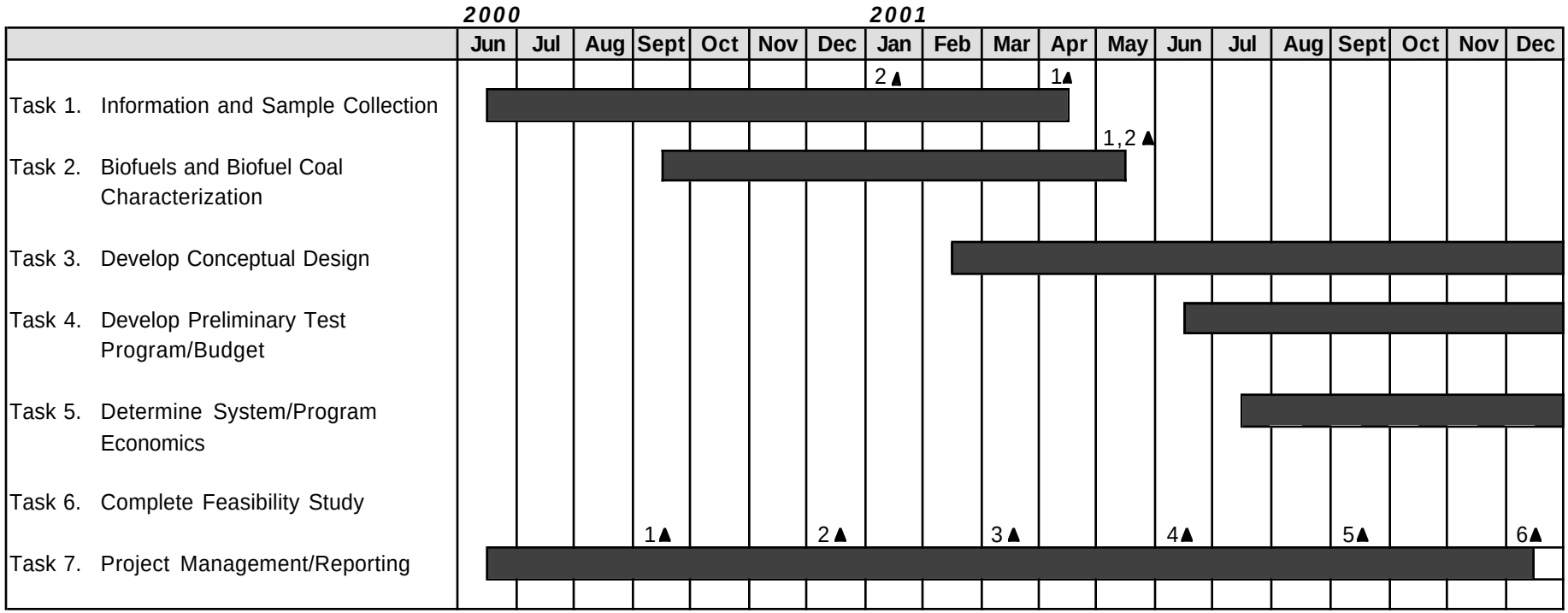
Task 4. *Develop Preliminary Test Program/Budget*: A multiyear test program will be designed and costed to use the state-of-the-art CFB boiler system for investigating a range of issues when cofiring multiple biofuels and possibly other waste materials. Penn State will develop the preliminary test program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



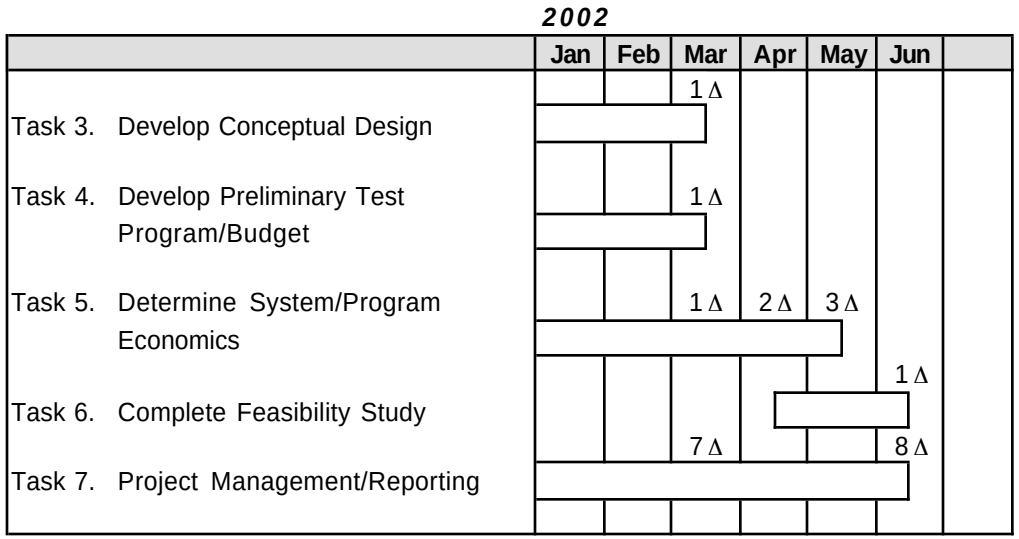


Figure 2. MILESTONE SCHEDULE

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	03/15/02	
Task 4, No. 1	Develop preliminary task program/budget	03/15/02	
Task 5, No. 1	Determine capital cost	03/15/02	
Task 5, No. 2	Determine operating costs	04/15/02	
Task 5, No. 3	Assess availability of funding	05/15/02	
Task 6, No. 1	Complete feasibility study	06/14/02	
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	10/12/01
Task 7, No. 6	Prepare program/project management and technical report 6	12/15/01	01/18/02
Task 7, No. 7	Prepare program/project management and technical report 7	03/14/02	
Task 7, No. 8	Prepare program/project management and technical report 8; prepare final report	06/14/02	

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., 2001a)

3.0 Task 2. Biofuels and Biofuel/Coal Characterization

Task 2 has been completed. The biofuel analyses, contained in previous quarterly reports (Miller et al., 2000; Miller et al., 2001a), 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. Chemical fractionation analysis 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 results from the spectrochemical and chemical fractionation analyses can be found in Miller et al. (2001b).

4.0 Task 3. Develop Conceptual Design

During this reporting period, work continued on developing the conceptual design. The following work was performed during the last three months:

- Revised the boiler island structural steel arrangement;
- Determined the column loading for the revised arrangement;
- Changed the fuel feeders from air-swept chutes to screw type;
- Updated the P&I drawings; and
- Began the design basis write-ups for the final report.

5.0 Task 4. Develop Preliminary Test Program/Budget

The preliminary test program was prepared during the last reporting period. The budget is being finalized and will be completed during the next quarter.

6.0 Task 5. Determine System/Program Economics

Work in Task 5 continued during this reporting period. Foster Wheeler is preparing the system costs. The results will be incorporated into the feasibility study.

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

Technical reporting was performed per the contractual requirements. In addition, work started on the final report.

9.0 Next Quarterly Activities

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

- Finalize the P&I drawings;
- Finalize the plant electrical load list;
- Finalize the plant input/output (I/O) list;
- Complete the conceptual design;
- Complete the cost estimate; and
- Continue the final report preparation.

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, 2001a, 72 pages.

Miller, B.G., S. Falcone Miller, R. Cooper, D. Donovan, J. Gaudlip, M. Lapinsky, W. Serencsits, N. Raskin, and D. Lamke, "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," Prepared for the U.S. Department of Energy National Energy Technology Laboratory, Pittsburgh, Pennsylvania, DE-FG26-00NT40809, July 13, 2001b, 22 pages.

11.0 Acknowledgements

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