Final Technical Report

Project Title: Green Power Initiative

Award Number: EE0000404

Recipient: Patrick Barry Butler, University of Iowa, Iowa City, IA 52242

Project Location: Oakdale Research Park, University of Iowa, Iowa City, IA 52242

Project Period: October 1, 2009 to December 31, 2012

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Executive Summary:

National energy policy supports the gathering of more detailed and authoritative data on the introduction of renewable bio-based fuels into new and existing district energy systems via the application of biomass gasification. The University of Iowa developed a biomass-fueled, university-scale steam generation system based on biomass gasification technologies. The system serves as a state-of-the-art research and educational facility in the emerging application of gasification in steam generation. The facility, which includes a smaller down-draft gasifier and a larger multi-stage biomass boiler, was designed to operate primarily on wood-based fuels, but has provisions for testing other biomass fuel sources produced within a 100-mile radius, providing enough flexibility to meet the fluctuating local supply of biomass from industry and Midwest agriculture. The equipment was installed in an existing, staffed facility. The down-draft gasifier unit is operated by College of Engineering staff and students, under the direct technical supervision of qualified Utilities plant staff.

The Green Power Initiative also includes a substantial, innovative educational component. In addition to an onsite, graduate-level research program in biomass fuels, the investigators have integrated undergraduate and graduate level teaching – through classroom studies and experiential learning – and applied research into a biomass-based, university-scale, functioning power plant. University of Iowa is unique in that it currently has multiple renewable energy technologies deployed, including significant biomass combustion (oat hulls) at its Main Power

Plant and a new reciprocating engine based renewable district energy system. This project complements and supports the national energy policy and State of Iowa initiatives in ethanol and biodiesel. Byproducts of ethanol and biodiesel processes (distiller grains) as well as industry residues (oat hulls, wood chips, construction and demolition waste), farm related material (seed corn and soybean seed), and poplar trees for cleaning up ground water are logical feed stocks for gasification.

Comparison of actual and proposed accomplishments:

All proposed activities were completed.

Project activities:

Task A - Design and development of biomass boiler system

Task A - Planned Activities:

A.ML.1 - Completion of engineering designs
A.ML.2 - Installation of boiler and research gasifier into existing utilities plant
A.ML.3 - Completion of instrumentation and controls

Task A - Accomplishments:

Q3-FY10: Draft air construction permits for the project were received on June 4, 2010. The project could not proceed, without significant risk, until we were certain it could be permitted by the Iowa Department of Natural Resources (DNR). The final air construction permit for this project was issued by the Iowa DNR on June 22, 2010. The boiler manufacturer has provided guarantees that the emission rates listed in the permit would be met. Advanced design work continued to define the installation of the biomass boiler, research gasifier, and fuel handling system. The purchase order was issued to Global Energy for the Hurst boiler and its associated systems. Detailed shop drawings were procured from the biomass boiler vendor (Hurst Boiler and Welding Company).

Q4-FY10: Design work continued to define the installation of the biomass boiler, fuel handling and storage system as well as the research gasifier with its fuel storage/handling system. Detailed Global Energy Systems (GES) & Ag Bio Power drawings were review by the College of Engineering, Facilities Management and the project engineer (Shive–Hattery) in support of the design effort.

Q1-FY11: Design work defining the installation of the biomass boiler, fuel handling & storage system as well as the research gasifier with its fuel storage/handling system was completed. Pre-bid activity took place with good contractor interest in support of a 1/13/2011 scheduled public bid opening date. Additional equipment payments were made this quarter to GES and Ag Bio Power respectively with successful submission of shop drawings.

Q2-FY11: The project was successfully bid and awarded. Existing boiler #1 was shut down, decommissioned and all asbestos abated in preparation for demolition. Demolition and new boiler installation contractor was mobilized and initiated construction of temporary detour road and construction site perimeter fencing.

Q3-FY11: Demolition of boiler #1 and roof were completed. Removal of an existing concrete floor and roof of old coal bunker was completed in order to begin foundation work for wood chip (biomass fuel) delivery, storage and handling. The manufacture of biomass boiler components was completed at the Hurst factory and the first shipments of boiler parts were received on site.

Q1-FY12: Installation of the biomass boiler and all support systems was completed. This included completion of a new biomass receiving building with wood chip storage/handling (as well as the actual receipt of wood chip biomass fuel). The gasifier installation was also completed. The start-up of the biomass boiler on both natural gas and wood chip biomass was accomplished with extended boiler run time completed on the gas burner. Limited boiler run time on biomass was achieved, delaying the gasifier start-up and commissioning.

Q2-FY12: Piping, electrical and control connections to the installed boiler, wood chip storage and handling system, and bag house were completed along with build-out of a new biomass receiving building. The boiler and auxiliary equipment (including biomass fuel handling and storage) were commissioned with system start-up completed. Initial continuous equipment operation was interrupted by a premature failure of a gear box and drag chain within the boiler fuel conveying system.

Q4/Q4-FY12: Gasifier refractory repair was completed. During subsequent extended gasifier operation, the radar based fuel level indicator malfunctioned. Research on a laser based replacement was complete and a new unit was ordered.

Q1-FY13: A mechanically-based fuel level indicator was installed. Since then, the gasifier has, and continues to, operate normally.

Task B – Curriculum Development

Task B - Planned Activities:

B.ML.1 - Completion of educational materials.
B.ML.2 - Completion of educational programs.

Task B – Accomplishments:

Q3-FY11: Data for the more common biomass fuel materials existent in Iowa was collected. A course framework was partially developed.

Q2-FY12: Material from the testing and commissioning process was collected for use in the course. The materials include photos and descriptions of all activities, particularly situations where issues arose and had to be rectified.

Q3-FY12: All materials were collected except for the experimental data from the gasifier itself. The educational program was still being developed as the gasifier operational details were unavailable.

Q4-FY12: All materials were prepared including photos and descriptions of all activities. The educational program was completed and was scheduled to be presented on Nov. 16, 2012 during the short course.

Q1-FY13: The educational program was completed and the short course took place on November 16, 2012. The attendees were very positive about what they learned and the educational program was successful.

Task C – Operational testing, evaluation and modeling

Task C - Planned Activities:

C.ML.1 - Completion of research test matrix.
C.ML.2 - Dissemination of research results.

Task C – Accomplishments:

Q4-FY10: Research focused on whole kernal corn and paper sludge. Several sizes of untreated crushed corn were tested. A schematic of the laboratory test configuration used in this work is shown in Figure 1. Preliminary blueprints for both the Ag Bio gasifier and the material handling system were developed. Fill drawing were completed for the Ag Bio system and 95% complete drawings for all construction and equipment required for materials storage, transport, and metering, as well as the ash removal hardware. New features included a new exterior corn storage bin, details of the ash removal system, and a start on specifying the dust control system. Aspen software was configured and work started on a biomass tutorial. A Fluent model was also started. Work continued on the operations document describing the rules and guidelines. Work was started on a commissioning plan as it requires joint operation of the Ag Bio system with the Hurst boiler system.

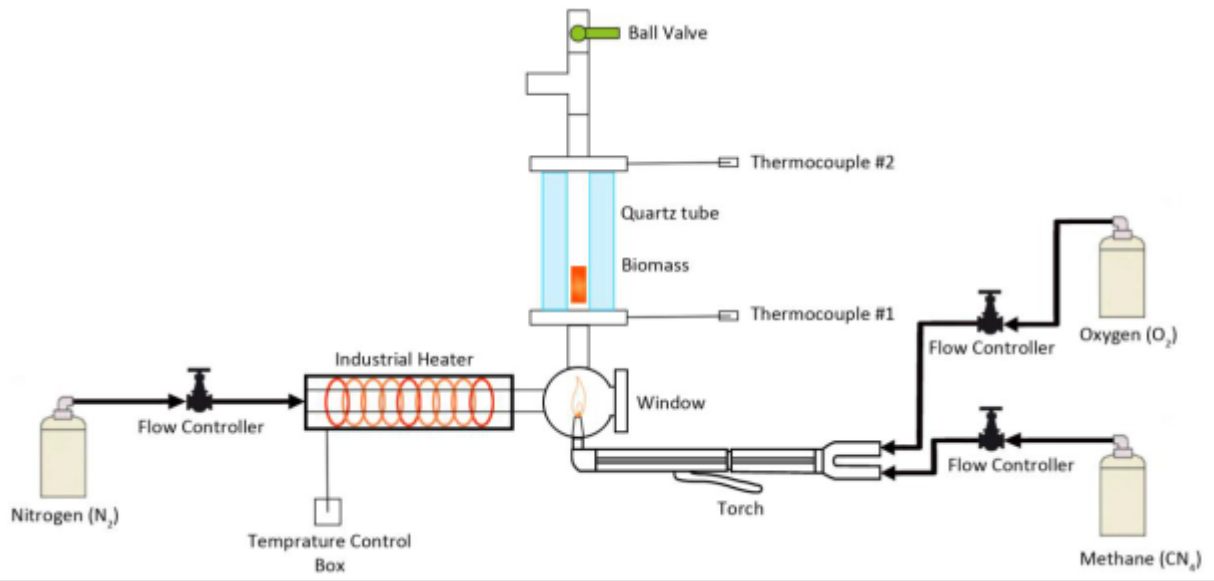

Figure 1. Schematic of laboratory testing arrangement for biomass testing.

Q1-FY11: Wood chips, particularly pine, were assessed as a potential fuel. This is the fuel that the Hurst Boiler is expected to begin operation with. Design development was completed and the project went out for bid. A combined Aspen and Fluent model was generated of the gasifier fire tube. Preliminary work on constructing the chemistry model for seed corn combustion was initiated. The operations document describing the rules and guidelines was expanded. Work continued on the commissioning plan.

Q2-FY11: A Fluent model of the Ag Bio gasifier was constructed and various operating conditions were investigated. The results showed that the system is sensitive to air flow and fuel bed porosity, and that these need to be tuned to avoid oscillating internal conditions that would reduce efficiency. Review of the Ag Bio control scheme continued.

Q3-FY11: Locally available paper sludge was tested as a potential fuel. With over 67,000 tons per year available, this low-cost material was viewed as an appealing option. As available, it contains 47% water, resulting in low system efficiency. Drying the material was considered a possibility. The fabricated gasifier was inspected and several variances from design were noted. These were being corrected and installation on-site was expected at the start of the next quarter. A commissioning plan for gasifier operation was completed.

Q1-FY12: Installation of research gasifier was completed. Control software was partly completed. Planning for short course dissemination commenced. Prof. Ratner presented on the project for Iowa State University and Ames Power Plant personnel.

Q2-FY12: Direct control software was completed and tested and automatic control software was debugged. Planning for short course dissemination continued.

Q3-FY12: System was declared complete and ready for testing. Short course was scheduled for September 2012 to disseminate results. Lab-based results were presented last quarter generated discussions with external parties.

Q4-FY12: Testing was completed. Short course was scheduled for November 16, 2012 to disseminate results.

Q1-FY13: Results were disseminated during the short course on November 16, 2012.

Products developed under award:

Publications / Presentations:

Presentation at the 123rd and the 124th Annual Meetings of the Iowa Academy of Science and at the 2012 meeting of the Central States Section of the Combustion Institute. Continuing presentation of the results as expected at the Joint US Sections Meeting of the Combustion Institute in May 2013.

Muilenburg, M., Shi, Y., and Ratner, A., "Computational Modeling of the Combustion and Gasification Zones in a Downdraft Gasifier," *ASME Proceedings*, Vol. 4, paper#IMECE2011-64009, pp. 151-158, 2011.

Shi, Y., Gong, Z., Ratner, A., and Emadi, M., "Gas Evolution of Biomass in Gasification and Pyrolysis," *Central States Section Meeting of the Combustion Institute*, paper 12S-54, Dayton, OH, April 22-24, 2012.

Gong, Z., Shi, Y., Ratner, A., and Emadi, M., "Gas Evolution of Corn from Biomass Gasification," *Central States Section Meeting of the Combustion Institute*, paper 12S-53, Dayton, OH, April 22-24, 2012.

Patents: None to date.

Protected PII:

The report does not contain any Protected PII.