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Gasification of Alternative Fuels to Convert Waste Materials to Energy Phase Two

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MILESTONE THREE REPORT

Executive Summary

This project is the next demonstrative step of gasification technology that was initially tested in a previous Excel Renewable Energy Fund project. To achieve the primary goal of this project, a gasifier has been installed at P & J Products to convert turkey litter, flock mortalities, and/or various other locally available biomass materials, separately or combined, to energy. When complete the project will demonstrate a complete gasification system, a small micro-turbine that will generate electricity, and the auxiliary equipment determined to best meet the heat and power needs of the industry partner and the fuel. Milestone Three is the keystone of the project as it includes installation and commissioning of the gasification technology and auxiliary equipment.

The majority of the work for Milestone Three was completed in two phases. The initial phase, the installation of the gasification system itself, was finished in March 2009. Due to the long lead times for the heat exchanger and other logistic issues, the installation of the energy application equipment was not finalized until March of 2010. The installation and commissioning of the system now facilitates the ability to collect commercial data on the operation of the gasifier. This required data is necessary for analysis for the balance of heat and power, assessment of the economic benefits, and to validate (or disprove) the assumptions made regarding the project and the technology.

The following tasks were included in this Milestone and have been completed:

Task #11 - Fabricate gasification system, prepare site, and purchase other equipment if needed (heat exchanger, power generation equipment)

Task #12 - Transport equipment to site and install and commission system

Task #13 - Train operators and operate system to ensure system is functioning properly

Technical Progress

The gasification system was installed in March of 2009. This included pouring a 30-foot by 50-foot concrete pad, and providing electrical service and propane feed to the edge of the pad. The electrical service was a single phase 200-amp service. Additional components of the system include:

- Walking floor feed bin
- Hydraulic ram feed system
- Primary gasification unit – 36 square feet of reaction floor designed to process up to 12 tons per day of turkey litter – including walking floor bottom to remove ash from unit
- Refractory lined transition ducting from the gasifier to the oxidizer
- Thermal Oxidizer
- Refractory lined stack
- Three air fans and various air ducting
- Hydraulic power pack
- Motor Control Center including PLC system and variable frequency drive controls on many components
- Roto-phase system to convert single phase power to 3-phase
- Step up transformer to increase voltage from 240 volts to 480 volts
- Remote access feature
- Ash auger to take material away from the gasifier
- Propane start up burner for the gasifier and modulating propane oxidizer burner to prevent smoking during start up and during operation when fuel quality may become too poor to operate alone and stay within operating parameters

This system was installed and commissioned in March of 2009. The unit was operated successfully for two days and initial training was completed. There is a need to line the floor of the gasifier with inert material before the initial operation, so a mixture of ash from other operations and sand from P & J Farms was used; thus no biochar samples were taken from the initial operation.

Due to the long lead times for the heat exchanger, and other logistic issues, the installation of the energy application equipment was not completed until March of 2010. The completion of this system included:

- Refractory lined drop out box – attached between the bottom of the stack and the heat exchanger to remove particulate prior to hot oil tubes.
- Hot air to hot oil heat exchanger designed to convert between 2 and 3 MMBTU/hr. of energy to hot oil operating at up to 425 degrees.
- Induced draft fan
- Hood and ducting to connect the exhaust from the heat exchanger back into the stack
- Hot oil pump and tank
- Fan coil to receive hot oil and deliver hot air to turkey house – system is designed to provide 10,000 CFM to the house, and increase air temperature from -10 degrees to 90 degrees.
- Hot oil piping and controls to distribute and monitor oil flows.
- Air ducting from the fan coil to inside of the barn to supply the hot air into the barn.

The system was designed and installed with a variety of features. The oil flow is controlled by manual valves which will be changed to electronic valves when additional applications are added later. The oil pump is a fixed flow pump, so a constant supply of oil is flowing through the system. The fan supplying the air to the barn is a single phase unit and is totally separate from the gasification power system. This was done so that during warmer periods, the fan could be used to supply cooling air to the barn without the gasification system operating.

The system was operated for two days to cure the refractory of the new components and to operate and test the system. In addition to simply commissioning the system, operating data and parameters were collected. Initial results from operation were:

- The fan was operated while the oil temperatures were well below designed operating temperatures. While oil temperatures were at 240 degrees, the fan was able to produce hot air that was 70 degrees above ambient temperature, so the heat transfer is very good and easy to maintain.
- The hot oil inlet and outlet temperatures were monitored with thermal couples in the pipe and their ability to measure the temperature was excellent.
- The oil system has the ability to bypass the fan coil and simply circulate hot oil directly to the tank. At times when heating is required during the night and morning hours, but not during the middle of the day, the gasifier can continue to operate and the oil simply be bypassed. This is needed if the fan is either required to supply cooling air or if it is shut off. When it is off and the oil is circulating through the fan coil, it does produce significant heat.
- The initial system control has been designed to have the barn temperature communicate to the hot oil temperature probe. The hot oil probe will control the fan speed of the induced draft fan, which will ramp up or down to provide the required energy. The Inducacool fan operates on pressure inside of the gasifier, so it compensates to keep the gasifier running smoothly. During commissioning, the hot oil temperature was set to operate at 250 degrees. The fans modulated to control that temperature and regardless of energy output from the gasifier, the temperature was constantly maintained within 25 degrees of the set temperature.

- The system was operated long enough to purge the gasifier of the initial material that lined the floor and the start of good biochar was produced. Both fuel and biochar samples were taken for lab analysis.

P & J Commissioning and Training

During the commissioning of the system, John Zimmerman was given training on the operation of the system and the detailed operating manual was reviewed. John was given a copy of the manual to study to further assist him in operations. The initial operating parameters were established – both on how to run the system, and how the system monitored and controlled the atmosphere in the barn. The initial concept of air distribution and control has been established, but there may be several variations before the final configuration is identified.

The initial system has a single thermal probe monitoring the barn temperature. This probe is tied into the probe monitoring the oil temperature. The oil temperature is controlling the fan speed on the induced draft fan, which then impacts the speed of the inducacoil fan. This process allows the fan system to control the amount of energy that is sent to the hot oil system and thus controls the barn temperature. There will be ongoing modifications of the system during the completion of Milestone 4 as data is collected. Part of the goal of that milestone is to optimize the operation of the system to provide maximum benefits with minimal fuel consumption. One interesting option that was not considered before the commissioning is the ability to operate during the day and then heat the barn during the night with the heat remaining in the system. This option probably is not available when more energy is required, but when a single barn is being supplied, and the heat needs are not extreme, it is possible that the heat remaining in the system can heat the barn throughout the night. This again requires some programming and controls modification, but that is all planned during Milestone 4.

Hot Oil System Operation

The hot oil system operation is very straight forward. The pump is a constant speed pump, so there are no fluctuations in the operation. The heat exchanger is simply a refractory lined box with multiple hot oil tubes inside that carry the oil through the hot syngas to heat the oil. The manufacturer has supplied a manual with the heat exchanger, but the majority of the information deals with curing refractory and maintenance, as the actual operation is very simple. The oil temperature is measured both on the input into the heat exchanger and in the outlet through the use of thermocouples that are inside of the pipe. The current arrangement has two circuits – the main circuit circulates the hot oil from the pump through the heat exchanger and then through the fan coil. The fan blows a constant volume (10,000 CFM) through the coil to heat the air. The alternate circuit is simply a bypass that allows the oil to bypass the fan coil and return directly to the tank. This can be used when no heat is required for the barn, but the hot oil is still warm – when the fan is turned off and oil is still circulating through the coil, it still produces heat going into the barn. The control of these circuits is done through manual shut off valves. When additional circuits are added to provide heat to a second barn, these valves will most likely be upgraded to electronically controlled valves to make control much easier. The control of the hot oil system is based on several factors:

- The flow of the hot oil through the system is constant.

- The fan speed going into the barn is constant.
- The shut off valves can be used to change the flow of the oil, but are not currently being used to maintain constant temperature control.
- The operation of the gasifier can be ramped up and down to produce different amounts of energy; however, the constant temperature control will not be done through changing the operation of the gasifier energy output – it can't react quickly enough to maintain the necessary control.

The control of the hot oil system will be done through the use of the thermocouples providing information that controls the speed of the induced draft and inducacoil fans. Both of these fans are controlled by variable frequency drives which are controlled through the programmical logic controls. The actual logic is fairly complex, but the simple steps are that there are set points established for the temperature of the hot oil. As the temperature of the oil is decreased through the heating of the air, it is reheated as it passed through the heat exchanger. The control of that heating is done by the fan control. The induced draft fan speed is increased or decreased to keep the hot oil temperature within the range of the set points that are established. As that fan speed is changed, the inducacoil fan reacts to that change. The induced draft fan is controlled by the hot oil thermocouples; the inducacoil is controlled by pressure within the gasifier. As the heat needs decrease, more energy is pulled by the inducacoil and bypassed directly up the stack. As more energy is needed, more air is pulled through the heat exchanger by the induced draft fan.

As the system continues to operate, more logic will be written to further fine tune the temperature control as more data is collected and the results from the changes are confirmed.

Additional Milestones:

The next steps are to collect operating data under Milestone 4. This data includes energy production, environmental benefits of the barn and the bird performance, and biochar quality and opportunities. The next visit is being coordinated to have the barn empty, so preheating of the barn can be done. This feature may not be as critical for this first barn, but expansion of the system to a second barn will show significant potential if the barn can be preheated to a very high temperature.

Project Status

The project is behind schedule and is within budget.

Appendix: See Attached

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Appendix 1: Photos



Gasification System



System End View



**Hot Oil System and Fan Coil
Ducted Into House**

Appendix 2: Training Agenda

Gasifier System Operation Training Outline

P & J Farms
Northfield, MN

- I. Operation of Gasifier (4/8/2009)
 - A. Feed Hopper
 - 1. Filled with a front-end loader
 - 2. Need for enclosure to reduce the windblown dust from handling
 - 3. Feedstock fed into the gasifier with a hydraulic ram
 - B. Gasifier
 - 1. Review components
 - 2. Single Point Operation/Control
 - a. Temperatures
 - b. Fan settings
 - c. Feed rates
 - 3. SCADA (Supervisory Control And Data Acquisition) control system capabilities.
 - a. Allows for computer system monitoring and controlling process
 - b. Remote operation of the system via a web interface.
 - C. Oxidizer
 - D. Ash Handling
 - 1. Ash purged from the gasifier with a hydraulic ram
 - 2. Ash handling system also needs to be installed

- II. Whole System Operation (3/28/2010)
 - A. Drop Out Box
 - 1. Refractory lined
 - 2. Slows velocity of the hot air to allow any particulate to drop out
 - B. Heat exchanger
 - 1. Refractory lined
 - 2. Hot oil transports heat to barns and electrical generator
 - 3. Exhaust heat captured and returned to stack
 - C. Heat delivery
 - 1. Hot oil used to deliver heat to barns and/or generator
 - 2. Controlled by valves and thermocouples
 - 3. Hot air distributed in barn through a perforated sock (~130°F)
 - a. Positive pressure in barn
 - b. Sock can be raised and lowered
 - i. Adjust temperature for age of birds
 - ii. Elevated to be out of the way for cleaning barn
 - c. Fan can supply cooling air in the summer
 - D. Monitoring and establishing test controls