Appendix C

Technical Performance: LEI Bio-Burner 500 Biomass Heating System

A summary of preliminary technical performance findings by the Farm Manure-to-Energy Initiative

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1. The Technology

After several years of research and development, in August of 2015, LEI Products adapted the LEI Bio-Burner 500, originally installed on Riverhill Farm in 2012 for use with woody biomass, so that the unit could be fueled with poultry litter. The Bio-Burner 500 is a fixed-grate combustion boiler system packaged unit that consists of three main components: the feed handling equipment, combustion unit and boiler, and emissions abatement technology.

The feed handling equipment consists of a large cylindrical hopper that uses a sweep arm and augers to convey the feedstock into the combustion chamber (Figure 1). The hopper's fuel feedrate modulates according to the combustion control system and will automatically increase or decrease the fuel feedrate as needed.

The hopper is designed to handle a wide variety of biomass feedstocks by preventing bridging, a common problem with biomass. The fuel is augered into the combustion chamber where it falls onto a hot combustion grate and is mechanically stirred. A propane-fired burner is used to pre-heat the combustion chamber to start the combustion of the fuel. A stir arm keeps the fuel moving, exposing it to hot surfaces and combustion air. Combustion air enters into the chamber at the grate surface and swirls around the combustion chamber, creating turbulence needed for combustion. The combustion chamber and passage to the heat exchanger are refractory lined, which keeps the combustion chamber hot enough to sustain combustion.

Hot flue gases from the combustion chamber flow through an integrated double-pass boiler into the emissions control system, which includes a cyclone followed by a wet scrubber.

This unit has four points for ash removal:

1. The combustion grate has a notch on the outer edge that allows the ash to fall into a trough where an auger will continuously remove the ash.
2. The boiler tubes are vertical and have turbulators inside the tubes that must be manually moved to keep the boiler tubes clean.
3. The ash falls to the bottom where a push arm is manually operated to move the ash into an auger for removal.
4. Any ash removed by the cyclone can be removed manually with an auger.

The boiler is designed to heat water to a set temperature controlled by a system controller. LEI Products provides the heating system without heat delivery components. How the hot water is utilized is up to the end user. The Bio-Burner 500 reviewed in this report sent the hot water to a heated radiant concrete floor in the brooding house. Pancake-style propane heaters are also used in the brooder house.

The emissions controls use cyclones followed by a wet scrubber designed to reduce particulate matter and opacity. The flue gases pass through a cylinder housing rotating vanes. These vanes rotate through a liquid bath of water and glycerin. As the vanes rotate through the liquid bath, they deposit captured particulate matter and coat themselves with

new liquid. Once the vanes exit the liquid and rotate through the flue gas stream, the wet vanes pick up particulate matter and rotate back through the bath. This process is continuous.

The flue gases are cooled to below 140^0F and the heat is removed by an external heat exchanger. Heat from the exchanger is not used on site and is discharged to the atmosphere. The purpose of cooling the flue gases is to make the capture of particulate matter and condensable particulate matter more effective. High flue gas temperature would result in evaporation of the wet scrubber liquid, interfering with performance. After the emissions control system, the resulting flue gases go through a blower and up the flue stack, venting to the atmosphere.

With respect to routine operations and maintenance, the liquid bath requires fresh liquid to be added to maintain the correct level of fluid. The wet scrubber will also require periodic flushing to remove the captured particulate matter. Additionally, the farmer must fill the hopper, manually clean the boiler tubes, and manually empty the ash.

A system controller allows the system to be almost fully automated. Adjustments and monitoring can take place remotely.

LEI Products offers this system in different sizes, ranging from 100,000 to 500,000 Btu/hr output. The unit evaluated is rated for 500,000 Btu/hr output. Initially designed for use with woody biomass fuels, this system has been used on the farm with wood chips for the past three years.

Based on design research conducted using poultry litter as a fuel over the past two years, LEI Products recently modified this unit to be fueled by poultry litter instead of wood chips. This is the first unit in the field to use poultry litter as a fuel. The modifications focused on material handling and, in particular, the higher ash production expected with poultry litter compared to woody biomass. Wood has an ash content of 1-3% by weight. Poultry litter has an ash content of 10-20% by weight. Additional ash removing augers were installed to increase the rate of ash removal from the combustion chamber, where most of the ash is produced. The gear motors on the material handling augers were upgraded to three-phase motors with stronger gearboxes. A stand-alone, skid-mounted wet scrubber was added to remove particulate matter from the flue gases. The wet scrubber requires electricity for operation. No changes were made to the combustion chamber, but the boiler received a different type of cleaning mechanism to help keep the tubes clean from particulate matter deposits.

Figure 1. The silver cylinder with the wooden "A" frame cover is the litter storage hopper. It has a sweep arm that feeds the litter into an auger that meters the litter into the combustion chamber.

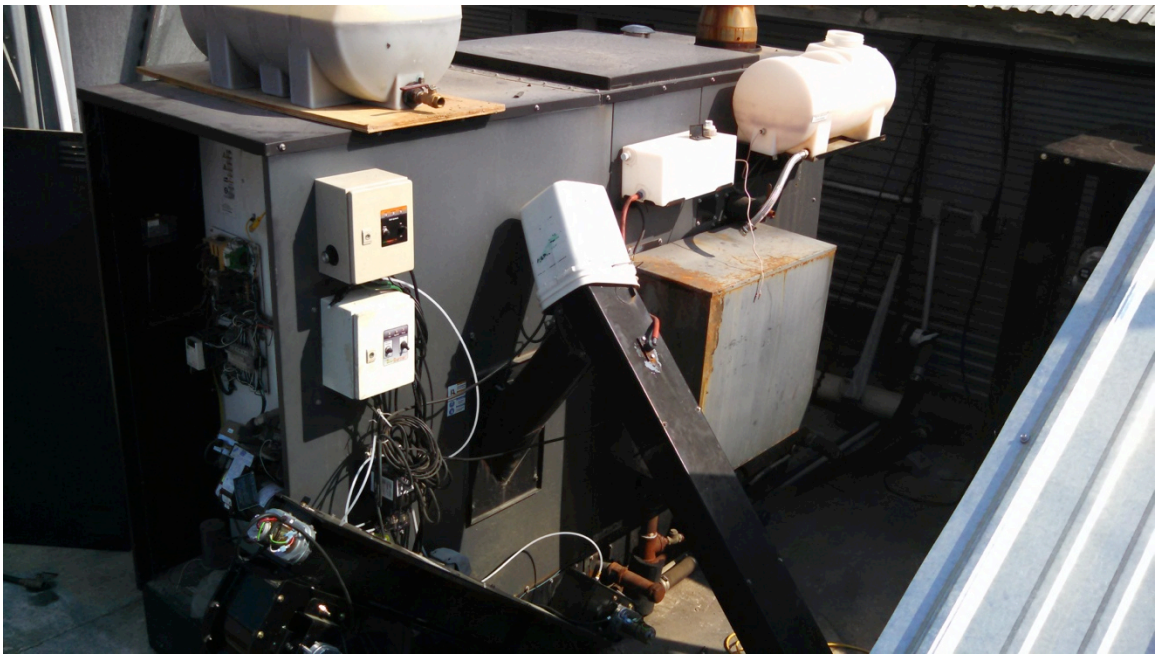

Figure 2. The rectangular tube in the middle of the picture is an auger that is metering the litter into the combustion chamber from the litter storage unit that is to the left of the picture.

Figure 3. This is the entire system without the scrubber. It is capable of sitting outside without a shelter as long as the litter and ash bins are covered.

Figure 4. This is the wet scrubber before it was connected to the exhaust of the combustion unit.

2. The Farm

Glenn Rodes, owner of Riverhill Farm in Port Republic, Virginia, grows eight flocks of 35,000 turkeys or 280,000 turkeys per year for Cargill. Turkeys spent the first five weeks on the farm in a brooding house and are then moved to the farm's four poultry grow-out houses for an additional eight weeks. The turkey brooding house has a high heat demand compared to traditional turkey housing for larger birds. In addition to the 0.5 MBtu/hour rated Bio-Burner 500, the house propane heating system (88, 48 inch Sibley Convention Brooder stoves, at 31,000 Btu each) supplies about 0.5 MBtu/hour (Figure 5).

The brooder house litter is cleaned out between each flock and litter is replaced with new bedding (soft wood shavings, mostly pine). Over all, including poultry litter from the brooder house and the four grow-out houses, the Riverhill Farm poultry operation produces 1,600 tons of poultry litter per year. According to the farm's nutrient management plan recommendations, almost all of the poultry litter is exported off the farm (via a poultry litter broker). Much of the litter is transported to the Rocky Mount area of Virginia, a nutrient-deficient region outside of the Chesapeake Bay watershed. Energy value of the litter is 4030 Btu/lb and moisture content is 24.4% (see Appendix E for details on methods used for collection and analysis).

Riverhill Farm also has 500 acres of cropland, which produces corn, soybeans, alfalfa, hay, barley, and canola.

Figure 5. Brooder house with newly placed poults.

3. Objectives and Methods

Because installation of this system occurred in the last year of the project (August 2015), technical performance data is primarily limited to Mr. Rodes' previous experience fueling the unit with wood chips. The system is permitted under a Biomass Research Permit, which allows for use of the system for data collection purposes (for example, air emissions testing), but not for routine use. Once the research permit has been reviewed and finalized by the permitting agency, the system will begin operation using poultry litter as a fuel, allowing for additional performance evaluation.

In the meantime, in addition to air emissions testing (discussed in Appendix E), determination of the Bio-Burner 500 heat output was calculated using a paddle wheel flow meter and water temperatures sensors located at the inlet and outlets of the boiler.

4. Results to Date

4.1 Reliability

The Bio-Burner 500 has been in operation on the farm using wood chips as fuel since the spring of 2012. Riverhill Farm places an average of eight flocks during the year in the brooding barn: approximately four flocks during the warmer months and four flocks during the colder months. Typically, the wood chip-fueled Bio-Burner 500 would operate continuously for 1-2 weeks for each flock during the warmer months and approximately 3-4 weeks for each flock during the colder months. This totaled approximately 20 weeks of run time during each year.

Since 2012 (while using wood chips as the primary fuel), the Bio-Burner 500 did experience some failures that were resolved quickly as indicated in table 2. According to Riverhill Farm, when used with wood chips as a fuel, the LEI Bio-Burner operates reliably with less than 5% downtime.

Table 2. Description of the failures with wood as fuel

Description of Mechanical Issue	Farmer Time to Resolve (hrs)	Recommended Next Steps
Fuel auger motors failed	2 hours to replace	DC drive gearmotors failed approximately once a year. More robust AC gearmotors with variable frequency drives (VFDs) will be installed that will be more robust.
DC transformer failed	Few hours to replace	This was used to power the DC drive gearmotors. VFDs will replace the DC system.
Touchscreen control panel	Few hours	Dead spots would develop in the screen. This has been replaced twice.
Heat exchanger tube failure	1 week for parts and 1 day for replacement	Some of the tubes rusted, potentially due to poor water quality. LEI replaced the tubes.
Thermocouple in combustion chamber failed	Few hours	A thermocouple failed and was replaced.
Fuel stir arm failed	Few hours	The original design had combustion air going through the stir arm, and the stirm arm would only last for one year. The new stir arm does not have combustion air going through it.
Fuel stir arm driveshaft failure	Several hours	New design is much easier to replace where older design was much harder and took longer.
Flue gas fan failure	Several hours	Motor failure.

4.2 Temperature and Propane Savings

The Bio-Burner 500 heat delivery system demonstrated successful integration with the farms existing propane heating systems. The brooding house uses pancake-style propane heaters to deliver heat from the top down, while the radiant floor heat delivers heat from the bottom up.

The Bio-Burner 500 heat output has been variable, but typically falls in the range of 375,000 and 400,000 Btu/hr. Mr. Rodes estimates that he saves approximately 500-800 gallons per flock during the summer months and about 2,000 gallons per flock during the winter months, or approximately 10,000 gallons during one year.

4.3 Operation and Maintenance Requirements

Mr. Rodes estimates that he spends about five minutes a day checking on the unit while it is running and about 30 minutes a week to clean the boiler tubes and remove the ash when the unit is using wood chips for fuel. Miscellaneous maintenance and repairs require about three hours a month. The hopper is filled about 2-3 times a week and it requires 10 minutes per filling. Mr. Rodes estimates these numbers will be similar when the unit is operating with poultry litter instead of wood. He suggests that the unit may need to be cleaned more frequently.

5. Discussion

Most of the system failures were associated with components that were easily replaced, such as motors and electronic parts that are prone to wearing out over time. Some of these parts have been redesigned or upgraded to increase service life.

According to Mr. Rodes, with woodchips as a fuel, the unit has been reliable to date. However, he suggests that any biomass unit requires design and maintenance. Early adopters can expect to run into problems that require design changes, as he experienced with the Bio-Burner (for example, the combustion fuel stir bar needed replacing). Overall, he's been very happy with the unit to date.

Initial research and development and initial operation on Riverhill Farm suggests that the system, with modifications as discussed, will work with poultry litter as a fuel.

However, due to the increase in ash content when used with poultry litter, the entire ash handling system will need to be modified in the future. Currently the ash removal from the combustion chamber is automated, and a larger final container for the ash will be needed. The boiler tubes and cyclone are secondary sources of ash and are currently manual. These systems could be modified to automatically empty into the main ash collection area so that there is only one source of ash for the farmer to manage. This system is ideally suited for one to two poultry houses.

6. Recommendations and Next Steps

The project team recommends the following modifications to the unit to facilitate ease of use with poultry litter as a fuel:

- Modify ash removal in the boiler tubes to automate and streamline ash removal from the system.
- The ash hopper size should be increased to accommodate the increased amount of ash.
- LEI may want to consider building a larger unit that can provide heat to multiple poultry houses.