



EERC

Energy & Environmental Research Center

UNIVERSITY OF NORTH DAKOTA

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December 21, 2011

Mr. Timothy Edman
Manager, Regulatory Administration
Xcel Energy, Inc.
414 Nicollet Mall
Minneapolis, MN 55401

Dear Mr. Edman:

Subject: Revised Milestone 7 Progress Report Entitled “Indirect Liquefaction of Wood Waste for Remote Power Generation Fuel”; Contract No. RD3-66; EERC Fund 9968

Enclosed please find the Revised Milestone 7 report which has been modified to reflect Mark Ritter’s comments in his e-mails of December 13 and December 20, 2011, and a telephone conversation with him on December 21. If you have any questions, please contact me by phone at (701) 777-5159 or by e-mail at jhurley@undeerc.org.

Sincerely,

John P. Hurley
Senior Research Advisor

JPH/bjr

Enclosure

c/enc: Mark Ritter, Xcel Energy, Inc.



Energy & Environmental Research Center, University of North Dakota
15 North 23rd Street, Stop 9018
Grand Forks, ND 58202-9018

Project Title: Indirect Liquefaction of Wood Waste for Remote Power Generation Fuel
Contract Number: RD3-66 Milestone Number: 7 Report Date: December 21, 2011

Principal Investigator: John Hurley Contract Contact: Tobe Larson

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Congressional District: Not Applicable

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MILESTONE REPORT

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Executive Summary

Under RD3-66, the University of North Dakota Energy & Environmental Research Center (EERC) is testing a mobile system for converting wet wood into methanol for use in power generation at remote, off-grid sites. During this milestone period, the EERC tested the mobile indirect liquefaction system (MILS) to determine its methanol production rates as the system is currently designed, to produce enough methanol for testing in a fuel cell reformer, and to determine variations in operation due to the use of different wood types.

Two different wood types, chipped hybrid poplar and chipped ash, were tested. Moisture contents varied from 27% to 50%, which is far too wet for use in most commercial gasifier designs that can only handle partially dried wood. However, the MILS gasifier is specially designed to handle wood with this level of moisture and operated well except for problems associated with operating the system in subfreezing temperatures, indicating that more insulation of critical components is required for winter operation. The syngases produced from these two softwoods had compositions that were not significantly different from each other. However, it is expected that syngas produced from hardwoods or coniferous trees may vary more substantially.

Syngas from the gasifier was fed to a methanol reactor whereby the methanol production rate was approximately 10 to 20 gallons per ton of biomass. Production rates were only about ½ of what was expected with the gas composition provided by the gasifier, primarily because the gas flow rate was only ½ of what was expected as a result of the underperforming syngas blower. Approximately 12 gallons of methanol was produced for testing by IdaTech, LLB, of Bend, Oregon, in a fuel cell reformer. The liquid produced contains 89% methanol, which is of relatively high purity for a gas-to-liquid process. However, a precipitate formed in the methanol, which will require filtering before reformer testing.

Technical Progress

System Design:

Figure 1 shows the general 3-D design of the MILS. The sizing of the gasifier, heat exchangers, and gas cleanup components is such that the system extends beyond the trailer roof height and so requires assembly in the field.

The indirect liquefaction process begins with the gasifier toward the rear of the trailer from which the gas will flow through a set of heat exchangers and wet scrubbers to clean it. After this stage, the gas is ducted toward the middle of the trailer, where it goes through another cleaning process and then to the compressor. The compressor pressurizes the gas to 900 psi, and then the gas flows through the gas-to-liquid reactor system. The control area is at the front of the trailer, shown by the enclosed box on the upper trailer. A picture of the MILS system is shown in Figure 2.

Fuel Properties:

During this milestone period, the system was initially operated with chipped hybrid poplar purchased from Dukek Logging, obtained from a site near Regal, Minnesota. Moisture contents in 1-pound samples have varied from 27% to 50%, which is far too wet for use in most commercial gasifier designs, which can only handle partially dried wood. However, the MILS gasifier is specially designed to handle wood with this level of moisture. Later in the milestone period, we switched to using chipped ash trees provided by Dwight's Tree Service of Grand Forks, North Dakota. The chipped ash trees also had a high moisture content of 36% to 43% and contained more small branch pieces, which in the past have led to some problems in feeding the wood since the branch pieces would sometimes bridge across the wood hopper at the top of the gasifier. When this happens, the bridge has to be manually knocked down.

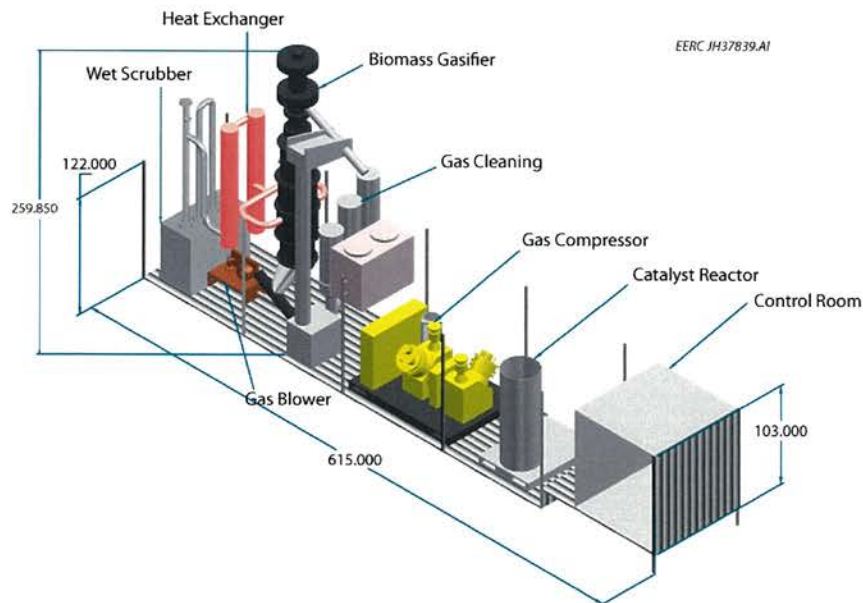


Figure 1. 3-D drawing of trailer-mounted gasification system. The trailer roof has been removed for this depiction only. Lengths are in inches.



Figure 2. The completed MILS system. The gas-to-liquid reactor is behind the trailer curtain.

System Operation:

Tests with the MILS system were run during the time period of November 21 to December 9, 2011. The gasifier was designed to handle approximately 200 pounds of wet wood per hour, but we believe, based on initial operation, that over 300 pounds of wet wood can be handled by the gasifier per hour.

In order to understand the effect of variation of biomass species on syngas and methanol production, two different biomasses were tested during this milestone period. The photographs of the test fuels are shown in Figure 3. As stated above, the moisture content of the biomass was much higher than can be handled by other gasifier designs. It was also highly variable between the two fuels, but the variation in the moisture content or biomass species had no measureable effect on the syngas composition.

The highest throughput of the biomass in the gasifier was dependent on the ability of the blower to maintain the required suction and delivery pressures. The peak throughput attained was 264 lb/h at a peak syngas production rate of 131 scfm during a methanol production test. The suction pressure required was about 75 inches of water column, while the delivery pressure developed by the blower was 10.5 psig. The effect of lowering of the ambient temperature (all tests were done at below freezing temperatures) was found to have impacted the increase in pressure drop across the packed bed, because of freezing of syngas water vapor in the bed matrix. The highest pressure drop experienced was during the coldest phase of the experiment during which the measured ambient air temperature was -15°C . The total pressure drop the blower had to overcome was 169 inches of water column. This condition resulted in reduction of syngas flow rate to as low as 83 scfm at maximum blower speed. Experiments under such conditions were suspended because of stalling of the syngas compressor as a result of attainment of lowest flow and inlet pressure limits. A total of 5900 lb of biomass was consumed during system testing during this milestone period.



Figure 3. Biomass used in the experiments: a) chipped green poplar wood waste and b) city wood waste, primarily chipped ash.

For the methanol production tests, syngas was fed to the methanol reactor at a flow rate of 75 standard cubic feet per minute. A typical syngas composition would be CO 15%, H₂ 15%, CO₂ 17%, N₂ 50%, and hydrocarbons 3%. During a typical run, the concentrations of each of the gas species varied by several percent up and down because of fuel variability and the fact that the fuel is fed in batches, not continuously. The composition of the gas produced by both of the wood types tested was within this amount of variability, indicating no measureable difference in syngas composition produced by these two wood types. However, the fuels tested were both softwoods. It is expected that syngas compositions may vary more if hardwoods or coniferous woods were used.

The methanol reactor was operated at 210°C and 900 psi. The methanol production rate was approximately 10 to 20 gallons per ton of biomass for both fuels. This production rate was approximately ½ of what was predicted for this gas composition because of the syngas flow rate produced by the blower was only about ½ of what was predicted. In addition, a sample of pressurized syngas was also collected in a gas cylinder for testing the production of Fischer-Tropsch (FT) fuels during the final milestone period.

Long-term, steady-state operation of the methanol reactor has been hindered by a couple of operational issues. Occasional air leaks upstream of the reactor increased the concentration of oxygen in the syngas to 1%–2%. The oxygen vigorously reacted with the catalyst and syngas at the entrance of the methanol reactor, which caused unacceptably high temperature increases and forced reactor shutdowns. The air leaks were identified and repaired. The syngas compressor had difficulty providing consistent feed to the reactor as well because of low suction pressure faults. The root cause of the faults is an undersized blower, which pulls air through the gasifier and pressurizes the gas to the compressor. As a short-term solution to prevent the compressor from faulting, the low suction pressure limit was reduced from 5 to 1 psi.

The liquid that is produced by the system is of relatively high purity for a gas-to-liquid process. Tests show that it is 89% methanol and contains approximately 6% water, 4% simple oxygenated

organic compounds such as ethanol or dimethyl ether, and 1% aromatic compounds such as benzene and toluene. These numbers vary only about 1 actual percent between different samples, which is within the experimental error of the measuring devices. The constancy of the liquid composition is largely a factor of the catalyst used, which is very specific for methanol. Because the catalyst is so specific and because the syngases produced from the two types of wood fed were so similar, all of the methanol produced was combined in one barrel, and separate methanol samples produced from the separate types of wood feed were not analyzed.

The nonmethanol organic compounds in the liquid should not hinder the operation of a fuel cell that is fueled by it, nor would they hinder operation of a simple methanol combustor. However, additional analyses showed that the liquid also contains some inorganics, including approximately 10 ppm iron and several ppm copper, which may or may not hinder fuel cell operation by creating an ash layer on the reformer catalyst and would create a light ash within a combustor system.

The iron and copper are believed to come from the catalyst used to create the methanol and should drop in concentration with long-term use of the system. Figure 4 shows a jar of the liquid product several days after production. When the product comes out of the gas-to-liquid reactor, it is clear. But after several hours, it begins to turn a yellowish color and a precipitate forms, as seen in Figure 4, probably because of oxidation of the iron and condensation of waxes. Therefore, we intend to filter the product before sending it to IdaTech for testing in its fuel cell reformer.

Project Status

All tests of the MILS system are now complete. During the next milestone period, which will be the last for the project, we will prepare the draft final report and send it to the program monitors. In addition, we will test some of the syngas for its ability to make FT liquids that can be turned into fuels. Also, the methanol will be filtered and sent to IdaTech for testing. We will also test the filtered product for methanol content and iron content. However, the IdaTech test results will not be ready in time for the draft final report, due by December 31, although they will be ready in time for inclusion in the modified final report which will be prepared after the project teleconference review by the project monitors and the Renewable Development Fund board.



Figure 4. A jar of the liquid product several days after production showing the yellowish color and precipitate that develops in the liquid.

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