



BioDiesel Test on an Alstom GT 11N

Preamble:

On August 15th, 2006, Hopewell Cogeneration Facility conducted a test burn of Bio Diesel in GT1, an Alstom 11NM combustion turbine located at the Hopewell, Virginia site. This report will document the results of this test, to determine the feasibility of this renewable fuel as a permanent supply option.

The main objectives of the test were as follows:

1. Determine the combustion capability of a 25% bio diesel mixture in #2 fuel oil.
2. Identify the effect on combustor pulsations and other variables using this fuel mixture.
3. Identify the effect on NOx or other emissions.
4. Identify any changes in turbine performance or power output.

Pre-Test Preparation

Several activities proceeded the test date, the most noteworthy of which are described below.

Bio Diesel Lab Testing

In June 22, 2006, a sample of 100% bio diesel was obtained from a local supplier, Virginia BioDiesel Refinery, LLC, located in the town of West Point, Virginia. Several lab tests were conducted over a four (4) week period, both on samples of pure biodiesel and on mixtures of #2 fuel oil in varying proportions, in order to determine the physical properties of the fuel and mixtures.

1. *Mixability.* A sample representative of 25% bio diesel was poured into a fuel oil sample. No agitation was applied during the mixing process. The two fuels combined readily, and no settling of either fuel could be observed (Note: bio diesel is light brown in color, while #2 fuel oil is dyed red, see Appendix A).

The mixture was then placed in storage for a 4-week period, and no settlement or separation of either fuel was observed. The mixture of 25/75% bio diesel to fuel oil appeared stable and permanent.

2. *Solidification.* A sample of 100% pure bio diesel was cooled down to determine the potential to solidify at low temperatures. Solidification of this sample began at 25 degF.

A sample of 75/25% bio diesel to fuel oil was then cooled down to 16.9 degF, before solidification began to occur. Another sample of 50/50% mixture was cooled to 7.7 degF before solidification began. No solidification or crystallization of a 25/75% bio diesel to fuel oil was experienced at this temperature.

In all cases where solidification was evident, full liquefaction occurred as soon as the samples were warmed up. There was also no separation of fuels during this process.

Fuel System Modifications

Modifications to the fuel piping in the fuel unloading building was designed to permit direct transfer of the fuel mixture from trucks to the combustion turbines, bypassing the fuel oil tanks to avoid contamination. Fuel was pumped from the truck through the fuel unloading pump, to the suction of the fuel forwarding pump. This pump then delivered the fuel directly to the combustion turbine.

Coordination with Third Parties

Personnel from the combustion turbine OEM, Alstom Power, were invited to participate in the pre-planning phase and during the test as observers. Data on bio diesel properties were supplied to their engineering sections, and no objections were identified on the fuel mixture to be tested.

The local environmental regulators, Virginia Department of Environmental Quality (VADEQ), provided approval to conduct the test using a non-permitted fuel. HCF enjoys a positive relationship with this local regulator who cooperated fully with the request, recognizing the potential to displace fossil fuel with a renewable source.

HCF personnel have operated and maintained the facility in an exceptional manner, consistent with industry recognized best management practices. In August 2005, the plant was recognized by the VADEQ as an Exemplary Environmental Enterprise, and was awarded E3 status under their Environmental Excellence award program. Finally, in January 2006, the Hopewell and Prince George Chamber of Commerce further recognized this accomplishment, and presented the plant with the 2005 award for Progressive Business Practices.

Bio Diesel Test Details

Date of Test:	August 15, 2006
Start of Test:	12:12
End of Test:	15:54

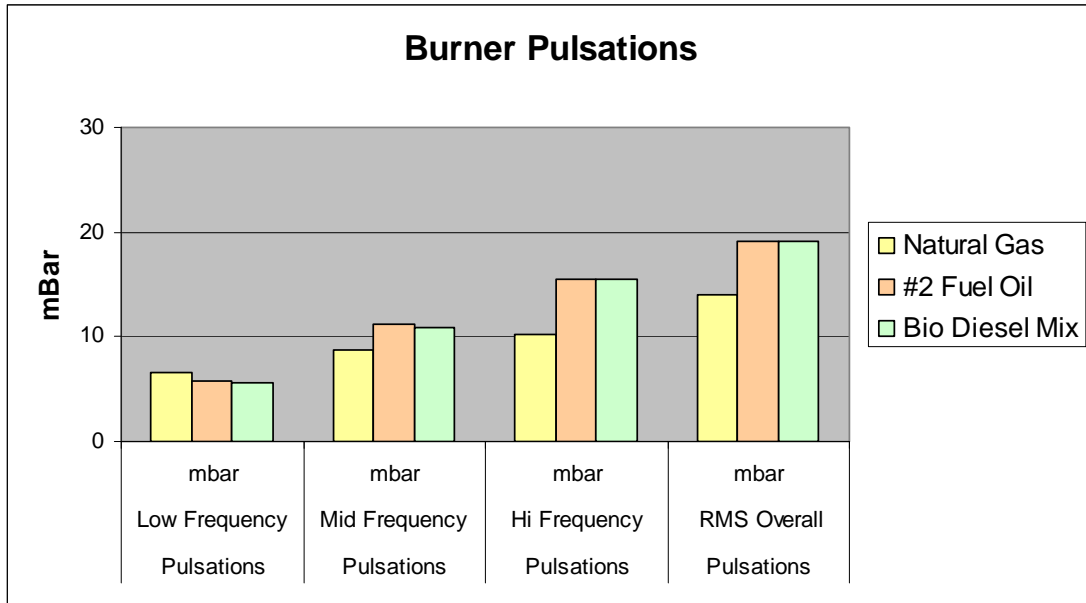
Approximately 8000 gallons of bio diesel was picked up from the refinery on August 14th, divided evenly between four (4) trucks. Each truck was then filled with #2 fuel oil, resulting in approximately 7,500 gals of the 25/75% fuel mixture. Each truck load represented one hour of full load operation on one combustion turbine. Due to operational issues, only 3 trucks participated in the test burn. The test schedule was as follows:

- On August 15th, the plant was dispatched to full load at 10:00 by the local utility.
- At 11:00 GT1 was switched from natural gas to #2 fuel oil. The unit was operated for approximately one hour to collect data and achieve steady state.
- At 12:12 GT1 was switched to the bio diesel mixture, by manual manipulation of valves within the piping modification system in the fuel unloading building.
- The test continued until about 14:28 when the GT1 was shifted back to one hundred percent #2 fuel oil.
- The unit ran until 15:54 of this fuel and was then shifted back to natural gas.

Test Results and Conclusion

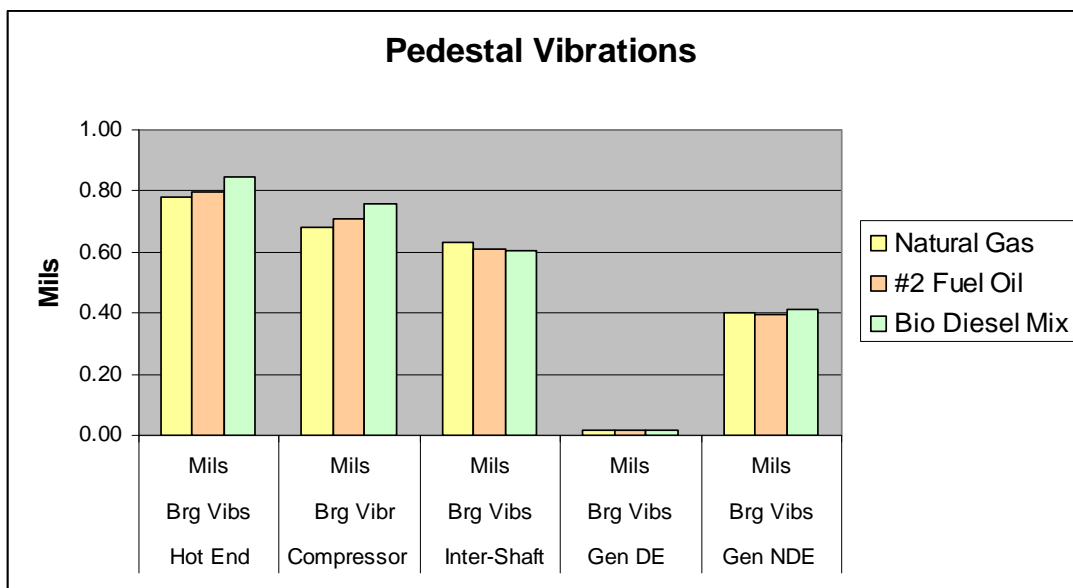
Operational data collected by the facility's DCS and the Alstom turbine monitoring system ("GMS") was analyzed to determine the effect of the fuel mix on the turbine's performance, combustion process and exhaust emissions. The following results were noted:

Burner Pulsations



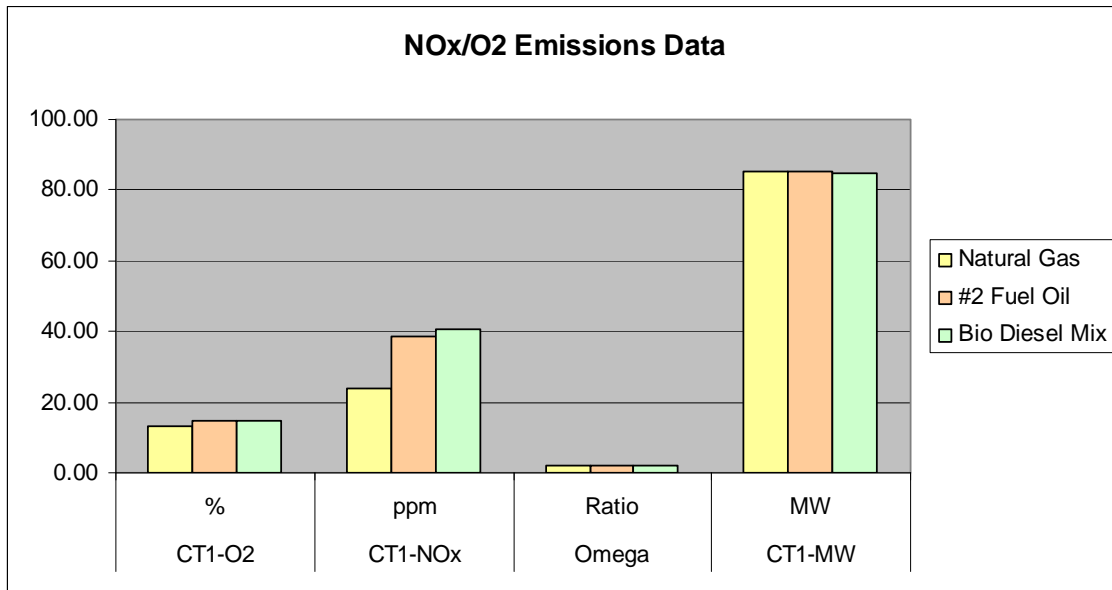
There was no significant increase in combustion chamber pulsations when the unit was switched to the bio diesel/fuel oil mix. As the chart above indicated, RMS overall pulsations are equal on the fuel mix and pure #2 fuel oil. The step change between natural gas and liquid fuel is expected.

Bearing Pedestal Vibrations

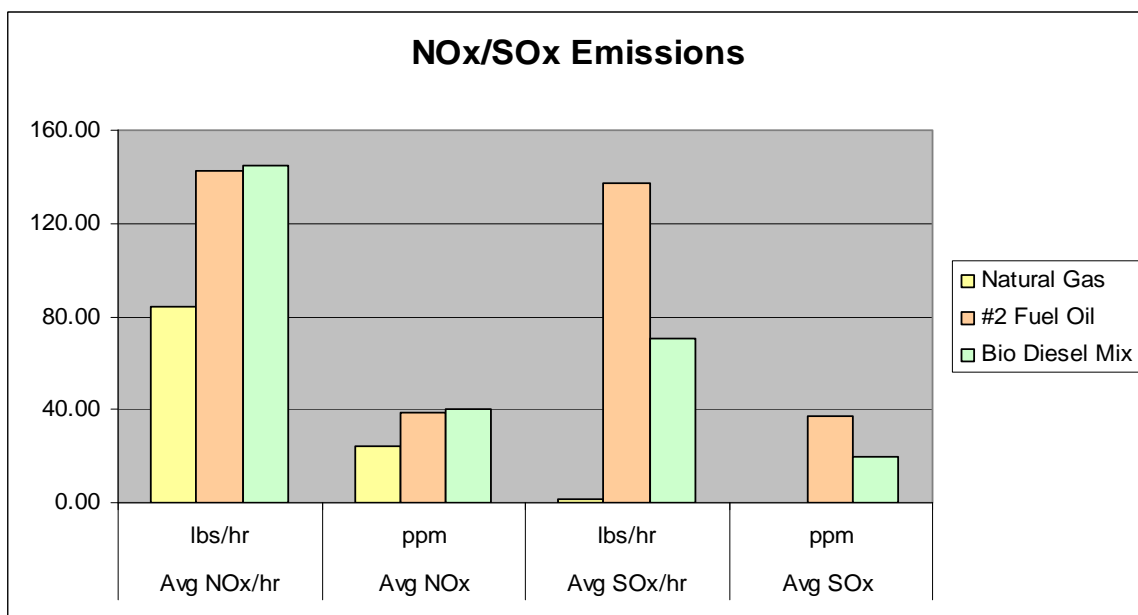


A minor increase in vibrations was observed on Bearing #1 (hot end) and Bearing #2 (compressor end) while burning the bio diesel/fuel oil mix. This increase does not affect the safety or reliability of the unit, as vibration alarm limits and trip settings are 2.1 mils and 5.3 mils respectively.

Emissions Data



There was a 11.4% increase in excess O₂ while burning #2 fuel oil vs. natural gas. This percent increase was relatively unchanged when burning the bio diesel mixture. A notable change was observed in NO_x emissions, however. The use of #2 fuel oil increases NO_x emissions 60.6% vs. burning natural gas as expected. The bio diesel fuel mix increases NO_x emissions an additional 1.9 ppm, an approximate 5% increase over #2 fuel oil emissions. It should also be noted that steam injection flow rates remained relatively constant when burning either #2 fuel oil or the bio diesel mix, as evident by similar Omega ratios.



Finally, the chart above indicated that while there is a minor 5% increase in NO_x, there is a significant decrease in SO_x while burning the bio diesel mix as compared with pure #2 fuel oil. SO_x production decreased 46.3% during the bio diesel mixture combustion, providing another environmental benefit for this renewable fuel.

Conclusion

The use of bio diesel as fuel source for the Alstom 11NM combustion turbines is a viable option. There appears to be no significant impact to unit output or heat rates, burner pulsations and rotor vibrations.

From the emissions perspective, there is a minor increase in NO_x production when burning the bio diesel mix over #2 fuel oil. There is however a significant decrease in SO_x production using bio diesel vs. pure #2 fuel oil.

The following actions are required in order to fully investigate the permanent use of this fuel at the HCF site.

1. Identify manufacturers of bio diesel who are capable of supplying the annual volumes used at the facility. For a 25% mixture, this would require 1.5 to 2 million gallons per year.
2. Favorable pricing of the product need to be negotiated to make it an economically viable option.
3. Further testing of the fuel mixture is required to ensure no long term storage issues within the plant's bulk tanks.
4. Bio diesel will have to be added to the plant's Title V permit as an alternative fuel.
5. Investigate potential environmental credits for using a substitute, renewable fuel to displace a fossil fuel.
6. Refine the logistics for trucking and mixing the bio diesel product with #2 fuel oil, as the supply chains are very different.

Appendix A: Fuel Samples



100% Bio Diesel



25% Bio Diesel Mix and 100% #2 Fuel Oil