Quarterly Technical Progress Report – Phase I

COOPERATIVE AGREEMENT
DE-FC26-00NT40899

Calla Energy Biomass Cofiring Project

July 2003

CONTRACTOR NAME
Gas Technology Institute
1700 South Mount Prospect Road
Des Plaines, IL 60018-1804

PERIOD OF PERFORMANCE
From: April 1, 2003
To: June 31, 2003

CONTRACT PERIOD
From: September 25, 2000
To: September 30, 2003

ABSTRACT

The Calla Energy Biomass Project, to be located in Estill County, Kentucky is to be conducted in two phases. The objective of Phase I is to evaluate the technical and economic feasibility of cofiring biomass-based gasification fuel-gas in a power generation boiler. Waste coal fines are to be evaluated as the cofired fuel. The project is based on the use of commercially available technology for feeding and gas cleanup that would be suitable for deployment in municipal, large industrial and utility applications. Define a combustion system for the biomass gasification-based fuel-gas capable of stable, low-NOx combustion over the full range of gaseous fuel mixtures, with low carbon monoxide emissions and turndown capabilities suitable for large-scale power generation applications.

The objective for Phase II is to design, install and demonstrate the combined gasification and combustion system in a large-scale, long-term cofiring operation to promote acceptance and utilization of indirect biomass cofiring technology for large-scale power generation applications.

GTI received supplemental authorization A002 from DOE for additional work to be performed under Phase I that will further extend the performance period until the end of February 2003. The additional scope of work is for GTI to develop the gasification characteristics of selected feedstock for the project. To conduct this work, GTI assembles an existing “mini-bench” unit to perform the gasification tests. The results of the test will be used to confirm or if necessary update the process design completed in Phase Task 1

During this Performance Period work efforts focused on conducting tests of biomass feedstock samples on the 2” mini-bench gasifier. The gasification tests were completed. The GTI U-GAS model was used to check some of the early test results against the model predictions. Additional modeling will be completed to further verify the model predictions and actual results.

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INTRODUCTION

The Gas Technology Institute, GTI, has assembled a team to perform this project. The team includes Calla Energy Partners, who is providing cost sharing resources. Calla is a developer of energy projects, and plans to generate steam and electricity from the completed facility in an industrial park to be located in Estill County Kentucky. Biomass in the form of saw dust and wood chips shall be acquired from lumber mills located in the region. Coal waste from the impoundment ponds at the site is planned as the cofiring fuel.

GTI shall work with CARBONA and NEXANT to develop a design for a complete gasification facility capable of delivering low-Btu fuel gas, LCV, to a boiler to be provided by Calla. GTI shall also design a dual-fuel natural gas/LCV gas burner to provide clean, high-efficiency combustion to be installed in Calla's boiler.

EXECUTIVE SUMMARY

Contract Objectives

This project is to be conducted in two phases. The objective of Phase I is to evaluate the technical and economic feasibility of cofiring biomass-based gasification fuel-gas in a power generation boiler. Waste coal fines are to be evaluated as the cofired fuel. The project is based on the use of commercially available technology for feeding and gas cleanup that would be suitable for deployment in municipal, large industrial and utility applications. Define a combustion system for the biomass gasification-based fuel-gas capable of stable, low-NOx combustion over the full range of gaseous fuel mixtures, with low carbon monoxide emissions and turndown capabilities suitable for large-scale power generation applications. The design of the gasifier will be confirmed with mini-bench scale testing of the fuels selected for the project.

The objective for Phase II is to design, install and demonstrate the combined gasification and combustion system in a large-scale, long-term cofiring operation to promote acceptance and utilization of indirect biomass cofiring technology for large-scale power generation applications.

Current Activities

During this Performance Period work efforts focused on conducting tests of biomass feedstock samples on the 2" mini-bench gasifier. The gasification tests were completed toward the end of June. The GTI U-GAS model was used to check some of the early test results against the model predictions. Current activities include additional U-GAS modeling and refinement of the individual run data for the purposes of mass and energy balance closure.

Technical Approach Changes

None

EXPERIMENTAL
Project Tasks

Task 1.0 Phase I - Feasibility Study

The objective of Phase I is to evaluate the major technical and economic factors determining project viability and to define the specific fuel sources, fuel handling requirements, gasification system and combustion system configurations necessary to insure a successful biomass cofiring demonstration. This objective will be accomplished through the following tasks:

Task 0.0. NEPA Information
Calla Energy Partners will provide reports and documentation deemed necessary for DOE to prepare a NEPA review of the project. This information shall describe all anticipated environmental impacts of the proposed project. The NEPA review and approval process shall be completed by DOE before Phase II is initiated.

Task 1.1. Feedstock Evaluation
In this task, GTI and Calla shall identify and fully characterize the available economically viable biomass fuel resources for the plant. Approximately 1000 tons per day of sawdust is know to be available from 3 sawmills within eleven miles of the plant site. Fuel supply and transportation contracts will be negotiated during Phase I to insure adequate primary and backup feedstock supplies for the plant. In negotiating any contracts, realization will be made that the project may end at the completion of the feasibility study and not proceed further. Based on the fuels identified, gasifier sizing, feed handling, feed preparation and gasifier feed system requirements will be defined for the process simulation modeling and the conceptual plant design.

Task 1.2. Process Simulation and Combustion System CFD Modeling
Based on the range of feedstocks identified in Task 1.1, the GTI Team shall perform process modeling to evaluate and optimize plant configuration, reliability and efficiency. GTI will use its proprietary gasification model to develop gasifier heat and material balances, perform gasifier sizing calculations, predict product fuel gas compositions, and define process input and output flow ranges for each feedstock identified and mixtures thereof. NEXANT shall use APEN simulation to model the remaining plant systems and components under consideration using information developed under previous and on-going studies for the US Department of Energy (DOE) to the extent possible, providing a consistent basis of information and methodologies with previous DOE efforts. GTI will use the Fluent Computational Fluid Dynamics software to perform modeling calculations for the FIR low-NOx LCV gas burner design. Fluent modeling has been developed specifically for, and used extensively in, the FIR burner development work by GTI to date.

Task 1.3. Conceptual Plant Design
Based on the feedstock and design configuration modeling results from Tasks 1.1 and 1.2, the GTI team shall develop detailed flow sheets with heat and material balances, performance estimates, and total plant capital cost estimates for the design cases agreed upon. This information will form the basis for the technoeconomic study conducted in Task 1.4.

At the beginning of the conceptual design task, Calla Energy Partners shall prepare a project permitting study identifying all federal, state and local permits required for the entire project through demonstration operations. This study will include a listing of all likely actions necessary to satisfy each permitting requirement, an approximate average time required to obtain the permit based on local experience with similar projects, the likely cost to the project, and the suggested project team member to be responsible for obtaining the permit.

Task 1.4. Technoeconomic Analysis
The capital costs at the total plant cost (IPC) level shall be determined including equipment, materials, labor, indirect construction costs, engineering, and contingencies. Operation and maintenance cost values will be determine on a first-year basis and subsequently levelized on the basis of a 20-year plant book life to form a part of the economic analysis. Quantities for major consumables such s fuels and sorbent will be taken from the technology-specific heat and material balance diagrams developed for each plant application. Other consumables will be evaluated on the basis of the quantity required using reference data. Operation costs are determined on the basis of the number of operators. Maintenance costs are evaluated on the basis of requirements for each major plant section. The capital and operating cost results for each plant case are combined with plant performance in the comprehensive evaluation of the COE. Details of the plant design definition, capital cost estimate, operations and maintenance cost estimate and economic analysis will be reported as follows:

- Plant Design
- Process Flow Sheets (heat and material balances)
- Performance Summary Table
- Overall efficiency and net plant heat rate (HHV basis)
- Summary Capital Estimate including detailed Code of Accounts
- Summary of production costs with details of the following sub-accounts: Fixed O&M, Variable O&M, Consumables, By-product Credit, and Fuel
- COE based on 15-year private sector financing based on 90% capacity factor

Task 1.5. Project Management – Phase I
Project review meetings shall be conducted as required. A topical report shall be prepared at the completion of Phase I that describes the findings of the study. A GO/NO-GO decision on Phase II must be received from DOE before initiation of detailed design and construction.

Task 1.6. Technology Conceptualization
GTI shall prepare a feasibility analysis of the advanced technology, based on their gasification experience. This report shall focus on the potential future opportunities of the proposed technology and other related gasification opportunities for biomass.

Task 1.7 Gasification Characterizations of Selected Feedstocks
GTI shall determine experimentally the gasification characteristics of selected feedstock for the project. To conduct this work, GTI will assemble an existing "mini-bench" unit to perform the gasification tests. The results of the test will be used to confirm or if necessary update the process design completed in Phase Task 1.3. GTI will work closely with Calla Energy Partners to identify suitable materials for testing.

Subtask –1
GTI will identify several feedstocks that are available for long term supply to Call Energy. GTI and Calla will confirm the availability of the feedstock and procure sufficient representative samples for biomass gasification tests at GTI. The samples will be analyzed for their physical and chemical properties prior to selection and procurement.

Subtask –2
GTI will assemble, pressure test, the existing mini-bench scale gasification test unit. The instrumentation and data acquisition systems will be calibrated. Test material will be dried and readied for testing.

Subtask – 3
GTI will conduct gasification tests of the selected feed materials. These will characterize the gasification temperatures, steam/feed ratio, air/feed ratio, and other key process parameters. GTI will conduct tests to optimize conversion efficiency and determine conditions that minimize oil/tar formation.

Subtask – 4
The results of Subtask 3 will be used to update GTI's gasification computer model. The results of the testing will be used to compare to the design basis used for Task 1.3 and to update the design basis if necessary.

Phase II Plant Design, Construction and Demonstration

Contingent on a decision to proceed based on the results of the Phase I feasibility study, detailed design, construction and demonstration of the biomass gasification–based fossil fuel cofiring facility will be completed in Phase II. This will be covered under a follow-on contract to this agreement.

RESULTS AND DISCUSSION

Task 0.0. NEPA Review
Completed.

Task 1.1 Feedstock Evaluation
Completed

Task 1.2. Process Simulation and Combustion System CFD Modeling
Combustion System
Completed

Gasification System
Completed

Task 1.3. Conceptual Plant Design
Completed

Task 1.4. Technoeconomic Analysis
The final topical report was completed and submitted to DOE.

Task 1.5. Project Management – Phase I
- GTI has continued to manage the work flow to keep the project on schedule.

Task 1.6. Technology Conceptualization
Task Completed

Task 1.7 Gasification Characterizations of Selected Feedstocks
Testing of the 2" unit has continued through this reporting period and is complete. The proposed test matrix from the previous quarterly report was used to determine the test conditions for individual test runs.

For a test run the feed hopper was filled with a measured amount of startup material, primarily charcoal. The unit was preheated using hot nitrogen to heat the bed and reactor. When the reactor reached a set temperature, the feed material and air were fed to the reactor. At this point the charcoal was burned to heat the reactor to gasification temperature. Once near gasification temperature the feed hopper was opened and the full batch of pelletized biomass feed was charged to the feed hopper. Roughly 6 pounds of material was put into the hopper. The conditions of the run were then set, feed rate, steam rate, and temperature. The reactor was then allowed to reach a steady state, where the feed rates and reactor temperature did not fluctuate. This usually took about 30 minutes before the reactor temperature would become steady. Once the feed rates, product gas rates, and temperature were deemed steady, the product gas was sampled. Reactor conditions of temperature, pressure, and flow rates were monitored by the data acquisition system continuously and manual recorded every ten minutes. A sample of a steady state period is included in Table 1. Another gas sample was taken before the end

of the steady state period. The steady state time usually ran up to about 1 hour. Due to the limited feed stock in the hopper the steady state period was kept no longer than 1 hour so that the unit did not run out of feed. If the unit was allowed to run out of feed a fire could result in the freeboard area, which could lead to sever equipment damage. To shut the unit down, feed was stopped and the air was replaced with nitrogen. The unit was allowed to cool under a nitrogen atmosphere to stop all of the gasification and combustion reactions. The next day the unit was cleaned, all of the bed material was removed, samples taken to the lab and the unit prepared for the next run.

Table 1. Raw Test Data (from steady state period)

Time	air	nitrogen	steam	Reactor Temperature (^{o}F)					Pressure	Product Flow	
	SLM	SLM	grams/min	1	2	3	4	5	psig	CFM	
15:50	28	2.4		1453	1458	1452	1450	1446	24	1.9	
16:00	28	2.2	6.1	1453	1455	1449	1450	1444	24.6	1.8	sampled
16:10	28	2.3	6.1	1450	1454	1449	1446	1443	25.4	1.8	
16:20	28	2.2	6.1	1450	1454	1448	1445	1441	26.6	1.8	
16:30	28	2.3	6.1	1448	1451	1448	1445	1442	25	1.8	
16:40	28.5	2.4	6.1	1454	1458	1456	1451	1448	25.8	1.8	sampled
16:50	28	2.4	6.2	1453	1457	1451	1448	1446	24.4	1.8	
17:00	28	2.4	6.1	1448	1449	1446	1445	1442	25.5		

As stated earlier the test conditions were chosen according to the test matrix in Table 2. The mass balances for the runs are not complete, so actual carbon to oxygen and carbon to steam ratios are not yet available. Due to the variability in the biomass flow from the screw feeder the carbon ratios may be slightly different than the set point desired. Not all of the analytical data from these runs is complete.

Table 2. Planned Test Matrix Overview

Condition	Carbona Design	Minimum	Maximum
Temperature	1562 F	1450	1650
Pressure	15 psig	12 psig	25 psig
Oxygen: Carbon	0.32 mole: mole	0.25	0.5
Steam: Carbon	0.35 mole: mole	0.2	0.6

The GTI U-GAS model was applied to some of the early test data. Table 3 shows the results of the U-GAS model as compared to the test run data. The data from the model appears to match some of the results of the tests. Further modeling will be conducted to determine the reasons for discrepancies in the results. There can be peculiarities of certain test runs that will affect test results, such as the temperature of the preheated feed gas, an interruption in biomass feed (bridging) that will have to be determined from the run logs. Once these items are determined, the model will be applied to the Calla process.

Table 3. Test Run Model Data (mol% on mf basis)

Test No.	WP-041703	U-GAS	WP-020403	U-GAS
Component				
Hydrogen	13.7%	9.6%	13.7%	13.9%
Carbon Monoxide	11.6%	12.8%	11.4%	11.8%
Carbon Dioxide	17.8%	16.9%	17.3%	15.2%
Nitrogen	50.4%	55.2%	52.4%	52.7%
Methane	4.57%	4.52%	3.35%	3.37%
Others (Argon, higher hydrocarbons)	1.93%	0.98%	1.85%	3.03%
H2S (other sulfur compounds)	161 ppm		not analyzed	

CONCLUSION

Summary Status Assessment And Forecast

Testing of the 2 inch gasification unit is complete. The ongoing work will be to complete the assessment of the data and to close material and energy balances for the individual test runs. The GTI U-GAS model will be verified using actual test data. The 2 inch unit equipment will be assessed for wear during the testing period.

Open Items

None

Future Work Plan Next Quarter:

- Analyze results of gasification tests.
- Obtain mass and energy balance closure for individual tests.
- Check U-GAS model prediction versus bench scale plant.
- Complete final topical report.