BIOMASS-FUELED, SMALL-SCALE, INTEGRATED-GASIFIER, GAS-TURBINE POWER PLANT: PROGRESS REPORT ON THE PHASE 2 DEVELOPMENT

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ABSTRACT

Cratech, Inc. is progressing with a three-phase effort to develop a family of small-scale (1 to 20 MWe) biomass-fueled power plants. The biomass power plant concept envisioned is an air-blown pressurized fluidized-bed gasifier followed by a dry hot gas cleanup system with the resulting clean hot gas injected into the combustion chamber of a gas-turbine engine.

Phase 1 was the design, construction, and operation of the pressurized feed system, gasification system, and hot gas cleanup of a slipstream. Phase 2 is the design and construction of an upgraded gasification system based on the Phase 1 results. It also includes a full-flow hot gas cleanup filter based on the slipstream filter of Phase 1. This system is capable of providing pressurized hot clean gas for fueling a gas-turbine engine. Phase 3 is the modification of a gas-turbine engine to operate on the fuel produced by the Phase 2 system. A small gas-turbine-generator package has been procured and will provide for economical fuel system and combustor modification, and subsequent testing. When the Phase 2 and 3 systems are complete and tested, they will be integrated to form a complete small-scale biomass power system which will undergo performance testing.

This paper reports the latest efforts to complete development of Phase 2. A general overview of the process and performance of the system will be presented.

Keywords: Pressurized feed system, pressurized gasification, gas turbine, gas cleaning, low calorific gas

INTRODUCTION

Cratech, Inc. is progressing with a three-phase effort to develop a family of small-scale (1 to 20 MWe) biomass-fueled power plants. The biomass power plant concept envisioned is an air-blown pressurized fluidized-bed gasifier followed by a dry hot gas cleanup system with the resulting clean hot gas injected into the combustion chamber of a gas-turbine engine.

The effort has been undertaken to develop and demonstrate:

< reliable and commercially competitive power generation from a technology that has not yet been demonstrated at this scale,

< a non-polluting energy source using renewable fuel without a net increase in greenhouses gas emissions, and

< an environmental and economical alternative to landfilling or open-burning biomass residues to provide or supplement power for government installations, industrial sites, rural cooperatives, small municipalities, and regions of developing countries.

Phase 1 was the design, construction, and operation of the pressurized feed system, gasification system, and hot gas cleanup of a slipstream. The Phase 1 system was operated at a feed rate of 0.5 metric ton per hour (mtph) [0.55 ton per hour (tph)] and 2 atmospheres (atm) (202 kPa). Phase 1 is complete. (Craig 1996)

Phase 2 is the design and construction of a new gasification system based on the Phase 1 results. The Phase 2 system has been upgraded to a feed rate of 1 mtph (1.1 tph) and a design operating pressure of 12 atm (1216 kPa). It also includes a full-flow hot gas cleanup filter based on the slipstream filter of Phase 1. The Phase 2 biomass feed metering system is now gravimetric rather than volumetric. This system is capable of providing pressurized hot clean gas for fueling a gas-turbine engine.

Phase 3 is the modification of a gas-turbine engine to operate on the fuel produced by the Phase 2 system. A small gas-turbine engine was procured for this effort. The gas turbine is a Solar Spartan rated at 225 kWe with a pressure ratio of 4.0 that will provide for economical fuel system and combustor modification, and subsequent testing. A modified combustor for this turbine has been designed (Craig and Purvis 1998). Assembly of the total low calorific value (LCV), gas-fueled, turbine package is in progress. When the Phase 2 and 3 systems are complete and tested, they will be integrated to form a complete small-scale biomass power system which will undergo performance testing.

SYSTEM DESCRIPTION

Referring to Figure 1, the biomass is loaded into the live-bottom bulk biomass feeder. The biomass is transported through a fan-driven pneumatic conveying system and an inlet valve into one of two identical biomass pressurization vessels (BPVs), only one

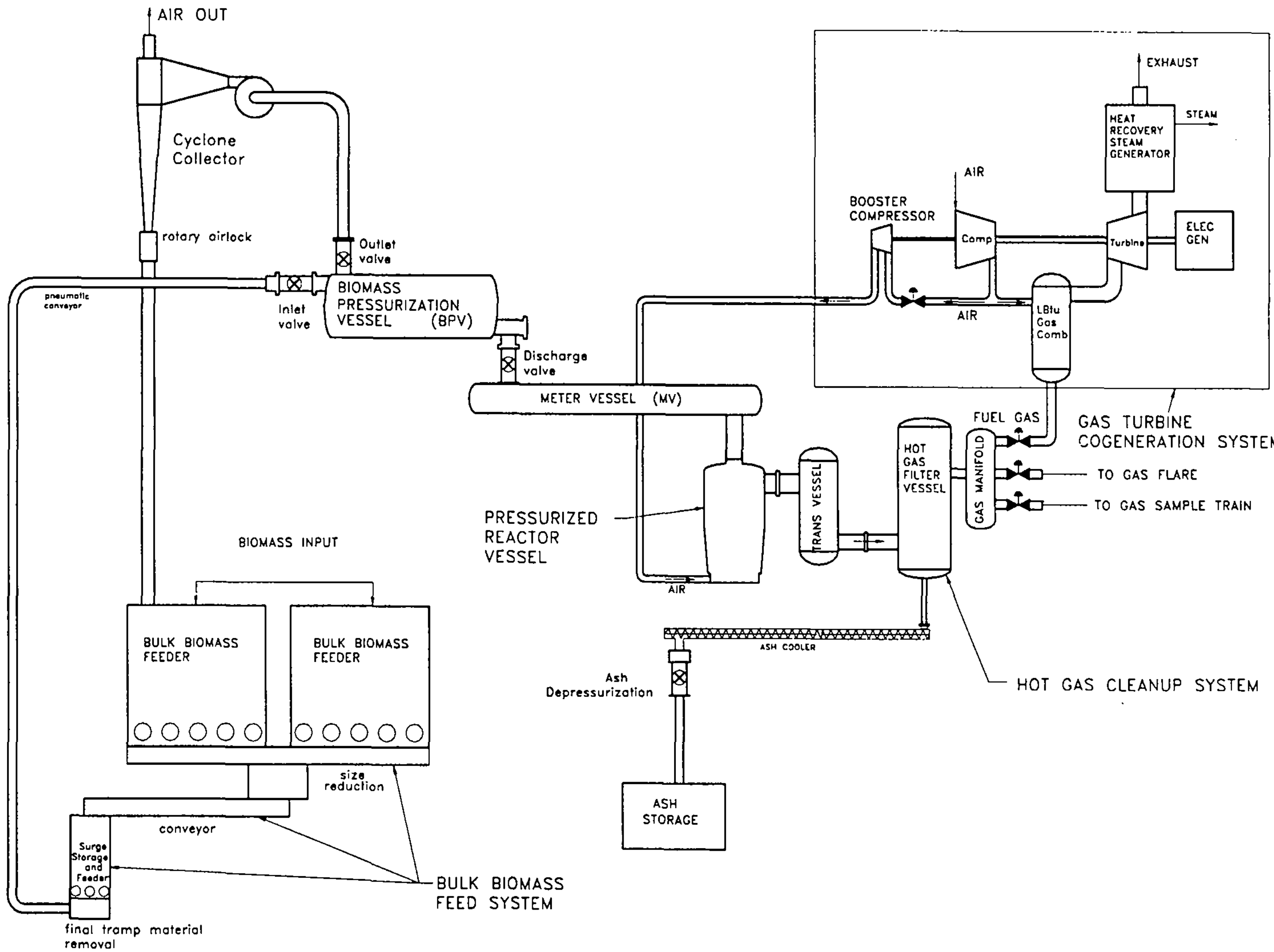

Figure 1. System Diagram

BPV is shown in Figure 1. The biomass drops out of the airstream and settles into the BPV. The air exits through a valve. When the BPV is filled with biomass, the inlet and exhaust valves close and the BPV is pressurized with air. When the pressure between the BPV and the meter vessel (MV) is equalized, the discharge valve opens and supplies the meter vessel with biomass. The MV is under constant pressure and gravimetrically feeds biomass to the reactor vessel at a set rate. When the level of biomass in the BPV reaches its low level, the discharge valve closes and biomass is supplied through the other BPV and discharge valve, which completes its fill and pressurization cycle while the other BPV is emptying. The empty BPV depressurizes and begins its fill cycle again.

The reactor vessel contains a pressurized fluid bed. The reactor receiving the metered biomass is supplied air from an air compressor. The fuel and air mix and react in the fluid bed at a maximum temperature of 760 °C. The product of the reaction is a combustible fuel gas laden with ash particles. The gas flows through a transition vessel into the high-temperature gas filter vessel. The filter vessel separates the ash from the gas. The ash falls to the bottom of the filter vessel, and the cleaned gas flows upward into the gas distribution manifold. The ash continues to flow downward into an ash cooler. Heat is removed from the ash until its temperature reaches approximately 65°C. The ash exits the cooler, then flows through a depressurization system. The ash is then conveyed to a short-term storage hopper. The clean gas is directed from the gas distribution manifold to a gas flare, a gas sampling train, and/or the gas-turbine.

SYSTEM PERFORMANCE

The Phase 2 gasification system design is complete and construction is complete except for the hot gas filtration system, which is 95% complete. Shakedown testing of the system, bypassing the high-temperature gas filter, has begun. Four shakedown runs ranged from 30 minutes to 2 hours in duration and yielded valuable data. The operators have tested, and are continuing to test, the system to refine the process control programming and to vary operating parameters for optimizing performance of the gasification system. These runs also identified wiring/hardware integrity issues.

Run 1: This 30-minute run was terminated due to a feed system programming error.

Run 2: The load cell signal of the gravimetric feed system was lost. The signal loss caused the biomass metering system to shut down after 80 minutes.

Run 3: This 110-minute run was terminated due to a feed system programming error.

Run 4. During this 120-minute run, steady-state operation of the gasifier was achieved. This achievement was the result of identifying the optimum operating parameters that allowed for controlling the gasifier. During the steady state operation , the average bed temperature in the gasifier was held at 760 +/- 2 °C. Most major programming errors were apparently corrected. This run was terminated when an electrical connection to a valve limit switch failed, triggering a shutdown. Figure 2 shows the performance of run 4.

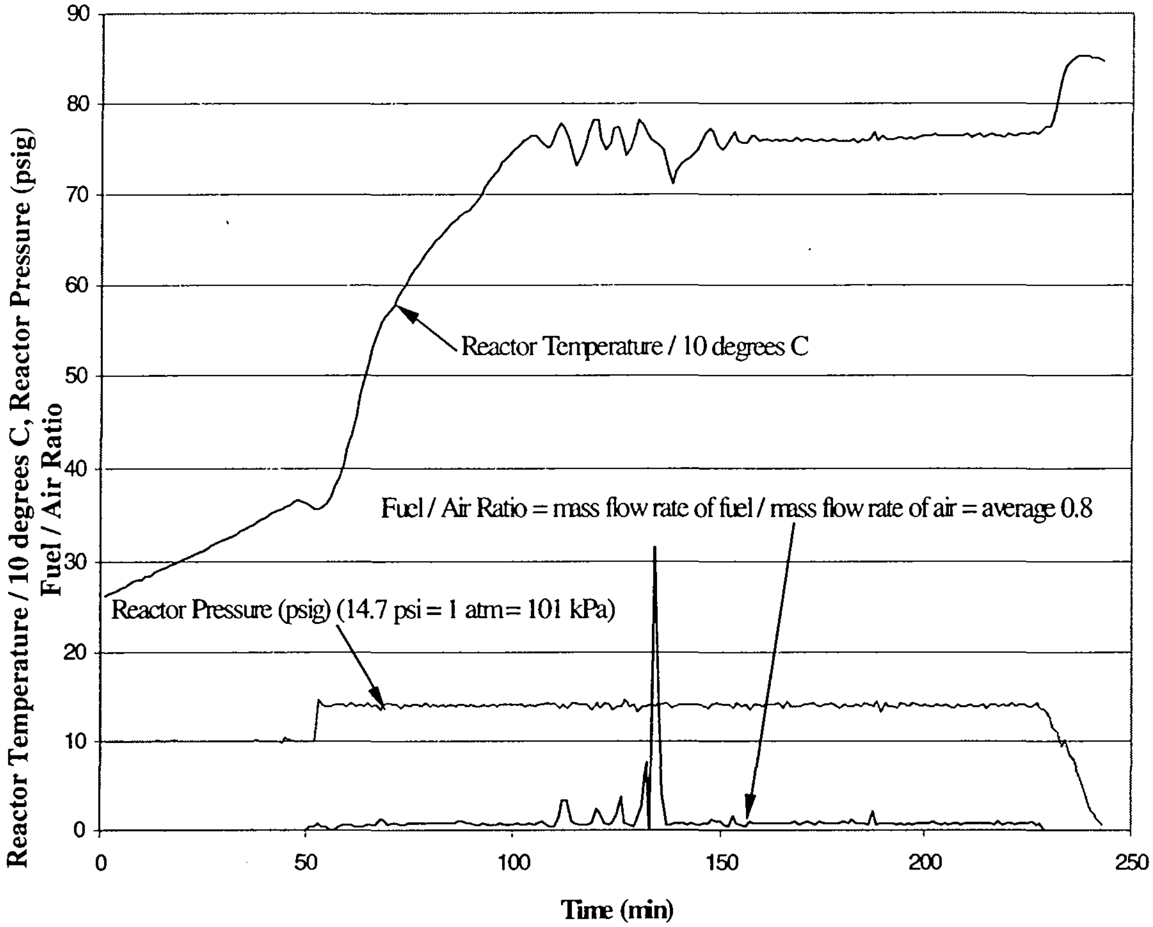

Figure 2. Performance of Phase 2 System During Run 4 (06/05/2000)

With the success of defining the operating parameters that allow for steady state operation of the gasifier, it was decided to proceed with bringing the hot gas filtration subsystem online. Some additional piping and programming are required, and testing with the hot gas filtration subsystem was scheduled to begin in August 2000.

DESCRIPTION OF SAMPLING

Gas will be analyzed to determine the molar composition and concentration of reactant products, particulate concentration, and alkali content. From the manifold, on the outlet side of the high-temperature gas filter vessel, gas can be diverted to the gas sampling train. The gas sampling train has been designed and fabricated to provide ports for the connection of gas sampling equipment. The train is installed on a portable table for the convenience of connecting and disconnecting the train and gas sampling equipment from the manifold.

The sampling equipment consists of an EPA Method 5 and Method 29 train, a gas chromatograph, and analyzers for carbon dioxide (CO_2), nitrogen oxides (NO_x), and oxygen (O_2). The EPA Method 5 train will collect particulate for analysis. The EPA

Method 29 train (the multiple metals train) will be used to collect samples for analysis of alkalis. A Hewlett Packard 5890 Series II Gas Chromatograph (GC) has been configured to measure the molar concentrations of hydrogen (H_2), nitrogen (N_2), carbon monoxide (CO), methane (CH_4), and CO_2.

When Cratech is satisfied with the operation and performance of the gasification system, including the high-temperature gas filtration subsystem, sampling will begin.

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NRMRL-RTP-P-548

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA/600/A-00/106	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Biomass-fueled, Small-scale, Integrated-gasifier, Gas-turbine Power Plant: Progress Report on the Phase 2 Development		5. REPORT DATE
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Carol R. Purvis (EPA) and Joe D. Craig (Cratech)		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Cratech, Inc. P.O. Box 70 Tahoka, TX 79373		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO. EPA PR 0C-R219-NASA
12. SPONSORING AGENCY NAME AND ADDRESS **EPA, Office of Research and Development Air Pollution Prevention and Control Division Research Triangle Park, NC 27711**		13. TYPE OF REPORT AND PERIOD COVERED Published paper; 4-8/00
		14. SPONSORING AGENCY CODE EPA/600/13

15. SUPPLEMENTARY NOTES APPCD project officer is Carol R. Purvis, Mail Drop 63, 919/541-7519. For presentation at Bioenergy 2000 Conference, 10/17/00, Buffalo, NY.

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17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Pollution	Pollution Control	13B
Fuels	Stationary Sources	21D
Biomass	Gas Cleaning	06C
Gasification	Low-calorific Gas	13H, 07A
Gas Turbine Power Generation		10A
Gas Turbines		13G

18. DISTRIBUTION STATEMENT **Release to Public**	19. SECURITY CLASS *(This Report)* Unclassified	21. NO. OF PAGES 6
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (9-73)