CLOSED-LOOP BIOMASS CO-FIRING

**Quarterly Technical Progress Report
for the Period April-June 2000**

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Results Summary

- Effort was focused on completing preparation of biomass and coal fuels for the pilot scale tests to be performed at Sandia National Laboratory in Livermore, CA
- Planting configurations were finalized for the large-scale demonstration. Specifications of the drip tubing to accommodate for row lengths and field slope were determined
- Another solid fuel feeder calibration test was performed for one of the feeders on Boiler 2 at the Puunene factory using bagasse as the solid fuel

Progress Discussion

Task 0, General and Administrative

Payment was received for the first billing invoice made by HC&S on this project.

There was some confusion at first whether or not the second quarterly reports were received by the DOE Golden Reports Control Center by the required deadline. Later follow-up showed that DOE had received the reports before the deadline, but the report had been forwarded late to the Reports Control Center once the report was received at Golden.

Task 1, Analyze Data from Small Plot Harvests

No activity occurred for this task as it was completed during the last quarter. Variety B52298 has been chosen for large-scale planting because of its high fiber percentage and its upright nature during time of harvest.

Task 2, Large-Scale Planting of High-Fiber Cane Variety

The planting configurations for the forage harvest and conventional one-year cane harvest areas were finalized during this quarter. These configurations are shown schematically in Attachment A. The row configuration for the forage harvest area will allow harvesting 4 cane rows in one forage harvester pass. The row configuration for the one-year cane harvester area will allow harvest of 2 cane rows in one conventional cane harvester pass. The plant population for the forage harvest area will be higher at the time of harvest with 17,424 linear feet of cane line per acre compared to 11,616 linear feet of cane line per acre for the area designated for one-year cane harvest. Both of these planting configurations will provide a higher plant density compared to the conventional planting method for commercial cane that gives 9,680 linear feet of cane line per acre. It should also be possible to harvest 4 cane rows at once with the forage harvester in the area designated for one-year cane harvest for observation trials. These configurations should allow for all in-field equipment to operate in these areas without running over any cane lines. The drip irrigation tubing for each of these planting configurations has been specified to give an irrigation water application rate of 15 gpm per acre during irrigation rounds.

Large-scale planting of the 40-acre area has been delayed because of the ongoing drought at HC&S and also because seed plots of the high-fiber cane variety are not yet mature enough for yielding sufficient seed material for the large-scale planting.

Task 3, Pilot-Scale Testing of Fuel Blends

Preparation of the biomass fuel treatments was completed during this quarter for the pilot scale tests. The biomass treatments were air-dried and ground to a particle size that could be accepted by the Multi-Fuel Combustion (MFC) Facility at Sandia National Laboratory. The HC&S "Cuba" mill was used to perform de-watering for some of the biomass treatments. It was discovered that 4 passes through the Cuba mill reduced moisture at or below 50%. A coal sample was also obtained and shipped to Consol Inc. in Pennsylvania to pulverize for the pilot scale tests. What follows is a description of the pilot scale biomass fuel preparation methodology and some initial results as reported by Scott Turn of the Hawaii Natural Energy Institute. Selected photos of these trials are provided in Attachment B.

Biomass Fuel Preparation for Pilot Tests

Equipment

Shakedown testing of the Cuba mill tandem was completed in April. As reported during the last quarter, the mechanisms used to adjust the pressure on the top mill roll were nonfunctional during initial testing efforts performed in March. These problems were corrected in April and subsequent tests determined that the wet basis moisture content of samples of cane variety B52298 could be reduced to a nominal value of 50% by passing them through the mill tandem four times. Feed chutes that were designed for the milling tandem were fabricated and tested as well. Two of the fuel treatment processes included in the pilot scale test matrix required a leaching step and cylindrical, expanded-metal baskets (559 mm diameter, 457 mm height) lined with 100 mesh stainless steel wire cloth were fabricated for this purpose. The baskets fit inside 208 L polyethylene drums containing the leach water. Photos of biomass being prepared by the Cuba mill and of the leaching setup are shown in Attachment B.

Methods

Cane variety B52298 was processed during the month of May for the pilot scale tests at Sandia National Laboratories Combustion Research Facility. Four different treatments were prepared as outlined in Table 1. The first column in Table 1 contains treatment acronyms/names indicating the applied process. The second column indicates the initial material used in the treatment preparation. The remaining column headings contain unit operations in the order in which they were applied to the treatments. An "x" in a cell of the table indicates that the unit operation was included in the treatment for that row. Whole cane was harvested by hand from the test plots at HC&S. Material for the stripped cane treatment was produced by removing (by hand) the leaves and top of the harvested whole cane, leaving only the stalk or cane. All treatments were passed through a John Deere Model 34 forage harvester to reduce the particle size.

Table 1. Summary of treatment processes for cane variety B52298 fuel lots for pilot scale testing in the pilot-scale, multi-fuel combustor tests.

Treatment Name	Initial Material	Forage Chopped	Initial Cuba Milling (4 passes)	Leaching	Second Cuba Milling (4 passes)
WC-U	whole cane	x			
WC-M	whole cane	x	x		
WC-MLM	whole cane	x	x	x	x
SC-MLM	stripped cane	x	x	x	x
WC – whole cane					
SC – stripped cane					
U – unprocessed					
M – milled four times through the Cuba mill					
L – leached using tap water at a 10:1 weight ratio (nominal) of water to fiber.					

Approximately 125 kg of whole cane were forage chopped and air dried to equilibrium moisture to produce treatment WC-U. Air-drying was accomplished by placing the material in ~75 mm layer on plastic tarps on a cement pad covered by a pole supported roof (see photo in Attachment B). The treatments were covered with light plastic mesh to prevent losses due to wind and to provide protection against outside dust contamination. The material layer was turned over daily in order to promote uniform drying. This same air-drying process was used for all other treatments listed in Table 1.

The remaining treatments shown in Table 1 required additional processing. The Cuba mill and its operation were described in the last quarterly report. As noted above, earlier tests determined that fresh material passed through the Cuba mill four times was reduced to a moisture content of ~50% wet basis, the moisture content normally produced by mills in sugar factories. Fiber and expressed juice streams from the milling process were collected and weighed after each pass. Duplicate samples of the streams were collected on a selective basis. Sample processing and analysis are described below. Bulk density measurements (ASTM Standard Method E-872) were made after each pass through the mill for some of the treatments (see photo in Attachment B). The WC-M treatment was passed through the Cuba mill four times and then air-dried.

The remaining two treatments (WC-MLM and SC-MLM) were initially milled and then leached in ~15 kg batches, the weight being determined by the amount of material which would fit into the leaching baskets (described above). The polyethylene drums were filled with 75 L of tap water and a basket containing 15 kg of milled material was lowered into the drum. The moisture content of the material which had been milled four times was assumed to be 50% (wet basis) yielding a tap water to dry fiber ratio of ~10. Subsequent analysis of sample moisture contents determined that this assumption was well justified (see below). At the 10:1 ratio, the fiber sample was completely re-hydrated, with water present in excess. The fiber in the basket was agitated in the leach water for roughly one minute and then the basket was raised out of the water and allowed to drain into the drum for about five minutes. The water remaining in the drum (free leachate) and the saturated biomass were subsequently weighed and the free leachate sampled. The saturated, leached biomass was again passed through the Cuba mill four times and the juice and fiber streams were sampled and bulk density measured as before. The resulting fuel lots, WC-MLM and SC-MLM, were air dried as described above.

When the four fuel treatments were air dried to equilibrium moisture content, each was recovered from the drying area, placed in plastic bags, and boxed. All treatments were subsequently ground to pass through a 1 mm screen using a Wiley mill. After milling, approximately 30 to 35 kg of each treatment were shipped by HC&S to Dr. Larry Baxter at Sandia National Laboratories for testing in the MFC.

Sample Analyses

Biomass samples were oven dried and moisture content determined using gravimetric methods. Results for the samples of the WC-MLM and SC-MLM treatments taken during processing are shown in Figure 1. Note that whole cane initially has lower moisture content (69%) than the stripped cane (75%) because of the inclusion of lower moisture content leaf and top material. The moisture content of all treatments was reduced with each successive pass, albeit with decreasing marginal reduction. As expected, all treatments were reduced to less than 50% moisture content (wet basis) after the fourth pass through the Cuba mill. The stripped cane data show that the second milling after leaching and re-hydration (sixth pass overall) reduced the moisture content to less than 50%.

Figure 2 shows the wet bulk density of forage chopped whole cane (WC-MLM) and stripped cane (SC-MLM) as measured after each pass through the Cuba mill during processing. The stripped cane bulk density was initially 419 kg m⁻³ whereas the whole cane material was substantially lower at 275 kg m⁻³. Changes in bulk density may result from a reduction in the material's true density or from changes in particle size and, consequently, the void volume. Wet bulk density follows the same general pattern as the decreasing moisture content trend, and exhibits smaller incremental reductions with each successive milling.

Figure 3 presents the dry bulk densities calculated from the wet bulk density (Figure 2) and corresponding moisture content data (Figure 1). The dry bulk density for fresh whole cane increases from 86 to 97 kg m⁻³

over the first four passes through the Cuba mill, indicating that additional particle size reduction is occurring during the milling process. Dry bulk density of stripped cane is initially greater than 100 kg m^{-3} but after the second milling remains relatively constant between 95 and 98 kg m^{-3} . After leaching, one milling returns the dry bulk density of stripped cane to the same range of 95 to 98 kg m^{-3} .

The potassium ion concentration of all juice, leachate, and tap water samples was measured using an ion selective electrode (ISE). Figure 4 shows the percentage (mass) of the total potassium removed in the liquid streams for each individual liquid stream generated in the whole cane and stripped cane leached treatments, WC-MLM and SC-MLM. Recall that a liquid stream was generated from each mill pass. Potassium from the free leachate was included in the K sum and its contribution is represented by the bar in Figure 4 labeled with an "L" in the legend. Note that roughly 65% and 75% of the total K was removed in the four millings prior to the leaching step for the WC-MLM and SC-MLM treatments, respectively, indicating that leaching provides more incremental reduction to the whole cane material.

Ion strength adjuster solution required for chloride ISE measurements is back ordered and Cl^- measurements will be made in the next several weeks. Preparation is currently under way to perform corroborating measurements of K and Ca, Mg, Na, Fe, P, and Si on selected samples using inductively coupled plasma/atomic emission spectroscopy. Selective measurement of Cl and S using high performance liquid chromatography is also scheduled.

Analysis of the particle size distribution of oven dried samples of the WC-MLM and SC-MLM treatments taken after each of the eight mill passes is currently being performed using standard sieve analysis and will be included in the next quarterly report.

Figure 1. Moisture content of forage chopped whole cane and stripped cane as a function of the number of passes through the Cuba mill. Both materials were leached and re-hydrated between the fourth and fifth mill passes.

Figure 2. Wet bulk density of whole cane and stripped cane as a function of the number of passes through the Cuba mill. Both materials were leached and rehydrated between the fourth and fifth mill passes.

Figure 3. Dry bulk density of whole cane and stripped cane as a function of the number of passes through the Cuba mill. Both materials were leached and rehydrated between the fourth and fifth mill passes.

Figure 4. Distribution of potassium measured in expressed liquids and free leachate as a percentage of the total potassium recovered from whole cane and stripped cane treatments. Both materials were leached and re-hydrated between the fourth and fifth mill passes.

Task 4. Procuring Harvest Equipment

Discussions with field operations personnel at HC&S revealed that the conventional one-year cane harvesters that will be available during the time the co-firing demonstration is expected to be conducted will most likely be the CAMECO® cane combine harvester and the CLAAS Ventor model cane harvester. Also available will be the CLAAS models 1400-3000 cane harvesters that are used normally for cutting seed cane. The CLAAS Ventor harvester is not suitable for harvesting whole cane as it depends on the trash extracting equipment to facilitate material throughput.

The John Deere model 9610 forage harvester operating at the former Pioneer Mill Co. on Maui to harvest alfalfa was not observed during this quarter. Plans are to observe this machine and a CLAAS Jaguar model forage harvester operate during the next quarter.

Task 5. Perform Harvest and Co-Firing Trials for Full-Scale Demonstration

Another bagasse feeder calibration test was performed during this quarter. This test was performed April 22 using one of the feeders on Boiler 2 at the Puunene power plant. Results were provided in the previous quarter on a bagasse feeder calibration test performed March 7 using one of the feeders on Boiler 1 at the Puunene power plant. However, the tests performed on March 7 were not conducted over a wide enough range of operating speeds to develop a relationship with some confidence between feeder operating speed (RPM) and fuel feed rate (lbs/hr).

The results obtained from the April 22 calibration test are presented in Figure 5. The moisture determined for the bagasse fuel averaged 45.4% and was very similar to the March 7 testing. The average amount of bagasse fuel per revolution of feeder was determined to be 32.8 lbs per revolution. Results from the March 7 test gave a result of 34.2 lbs per revolution. Compared to coal fuel, bagasse fuel is more variable in terms of providing a consistent feed rate to the boiler.

Figure 5. Feed rates for bagasse fuel for varying feeder speed settings.

Upcoming Quarter Events

Task 2, Large-Scale Planting of High-Fiber Cane Variety

- Prepare field 415 for large-scale planting
- Plant field 415 in high-fiber cane variety B52298

Task 3, Pilot-Scale Testing of Fuel Blends

- Perform pilot-scale testing on prepared fuels at the MFC facility at SNL

Task 4, Procuring Harvest Equipment

- Observe forage harvest equipment operating in alfalfa forage harvest operation on Maui
- Observe forage harvest equipment operating in corn forage harvest operation in California

Task 5, Perform Harvest and Co-Firing Trials for Full-Scale Demonstration

- Install feeder counters on all bagasse and coal feeders on boilers at Puunene power plant

ATTACHMENT A

Planting Configurations for High Fiber Cane

FORAGE HARVESTER

SEED ROWS 20" APART IN 4-ROW BED
TUBING IN 40" x 80" SPACING, 60" AVG. SPACING

LIN FT TUBE/AC: 8,712'

LIN FT CANE/AC: 17,424'

SCALE: 1" = 9.5'

ONE-YEAR CANE HARVESTER

SEED ROWS 30" APART SERVED

BY TUBING ON 7.5' CENTERS, 90" SPACING

LIN. FT. TUBE/AC: 5,808'

LIN FT. CANE
PER ACRE: 16,616'

SCALE: 1" = 9.5'

ATTACHMENT B

Selected Photos of Biomass Fuel Preparation for Pilot-Scale Tests

Photo 1. Fiber cane biomass processed by Cuba mill

Photo 2. Leaching equipment setup

Photo 3. Bulk density determination

Photo 4. Air-drying of biomass fuel treatments