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Texas Commission on Environmental Quality
New Technology Research & Development (NTRD) Program
Monthly Project Status Report

Title: FEEDLOT BIOMASS: A REBURN FUEL FOR “MAXIMUM NO_X” REDUCTION IN COAL-FIRED POWER PLANTS

Contract Number: TCEQ Grant # 582-5-65591 0015

PROJECT Start Date: 3/31/2005 End Date: 12/31/2006

Grantee: Texas Engineering Experiment Station, Texas A&M University

Date Submitted: June 09, 2006

Report for the Monthly period:
Starting Date: May 1, 2006 **Ending Date:** May 31, 2006

Section I. Accomplishments (*Please provide a bulleted list of project accomplishments as well as a description of their importance to the project.)*

The overall objectives of the project are i) to develop a retrofit technology of using processed low-ash feedlot biomass (FB) as reburn fuel for potential reduction of the NOx in coal-fired power plants by 80-90% and ii) determine the possible capture of Hg for low rank coals, reduction of CO_2 and other benefits of using animal wastes (alternately known as feedlot biomass, FB) as fuels.

In this report, the task lists are summarized and the progress/accomplishments for each task are reported. Tasks are indicated in bold letters

Task 1: Fuel Characteristics of lignite, sub-bituminous coal, raw manure (RM), and partially composted manure (PC)

2.1. Task Statement: The PERFORMING PARTY will analyze the fuel characteristics of raw manure (RM), and partially composted manure (PC).

2.1.1 The following four groups of FB will be selected: HA-RM (high-ash raw manure from Conventional lots), LA-RM (low-ash raw manure), HA-PC (high-ash PC), and LA-PC (low-ash PC). The LA-RM includes those collected from ash paved feedlots (25% ash) near Amarillo, TX and dairy farms (15-20% ash) located near Waco, TX. The conventional soil surface HA-FB will be obtained from the feed yards near Amarillo, Texas, while the LA-FB will be obtained from the Texas Agricultural Experiment Station (USDA-ARS Experimental Feedyard at Bushland, TX. Partially composted Dairy Biomass (DB) will be obtained from Dairy farms around Waco, TX. All fuel including FB and DB will be dried and ground, and shipped from Amarillo to TAMU facility at College Station, TX and DOE Pilot Facility at Pittsburgh, PA; Wyoming and Lignite coal will be ground and shipped to TAMU and DOE Pilot Facility, Pittsburgh.

<u>**Progress To date:**</u>

1. Most of the task has been completed except for shipping PC-FB to pilot scale facility.

2.1.1.1 All samples will be tested for moisture and ash content by the PERFORMING PARTY at the TAES/ARS Research and Production Laboratory at Bushland, Texas. Ultimate analyses including the heating values will be performed on all fuel samples. Ash analyses will also be performed on all the four types of FB fuels (including elements like Na, Fe, K, P, S and others) in order to interpret whether any variation in these elements amongst all the four types affect the pyrolysis, reburning, and fouling processes.

Progress To date:

This task is completed

2.1.1.2. Fundamental pyrolysis and ignition studies will be performed by the PERFORMING PARTY on all the four types of FB to generate data on kinetics of pyrolysis because of its relevance to reburn mechanism. Pyrolysis and ignition behavior studies will be performed for HA-RM, LA-RM, HA-PC, LA-PC and Coal: FB blends using Thermo Gravimetric Analyses (TGA).

Progress to date

Task 1 is 100% complete and a report has been submitted to TCEQ

2.1.2. Schedule: The PERFORMING PARTY shall complete this task within 13 months of the signed Notice to Proceed Date or May 1, 2006 as issued by TCEQ.

Completed

2.1.3. Deliverables: The PERFORMING PARTY shall submit a detailed written report to the TCEQ upon completion of this task, to include but not limited to a summary of the analyst of the fuel characteristics of raw manure and partially composted manure.

A report has been submitted to TCEQ

Task 2: Small Scale Reburn Experiments for NOx reduction

2.2. Task Statement: The PERFORMING PARTY will perform small scale reburn studies with fuels listed in Task 1 as reburn fuels except DB, RM and their blends. The conventional TAMU co-fired boiler burner facility will be used for the studies.

2.2.1 The PERFORMING PARTY shall modify the facility for reburn experiments. These modifications include 1) allow two different reburn injection schemes to enable better mixing with NOx laden streams; 2) Install a single- or double pass water tube heat exchanger just before the water quench system to cool the gases and study the fouling behavior; and 3) Install an air assisted injector system for injection of Hg Acetate solution to simulate Hg emission on the primary burn zone. Due to size of TAMU reactor and safety and health issues involved in injecting pure Hg, Texas lignite coal with known Hg content will be fired through reburn ports to create Hg emission and then blended with FB in various proportions in order to study the effect of FB (i.e. amount of Cl in FB) on reduction of elemental Hg emission. For the following experiments, the NOx from the main burner will be reduced to maintain at 100-400 ppm. Gas temperatures in the reburn zone, and species concentration at exhaust will be measured. Process variables will include co-fired heat input, and reburn zone stoichiometric ratio (SR). Pulverized Wyoming and Texas Lignite Coal will be used as the baseline main fuel. Parameters to be monitored as key performance indicators include emissions of NOx, SO2, CO, and CO2 and ash analyses (loss-on-ignition). The TGA analyses of FB determined from Task 1 will be used in interpreting the test data. Tests will be performed with fan type injectors to spread the FB throughout the cross section and at an upward angle in order to improve mixing and provide more residence time for

NOx reduction. The mixing time scale will be determined by measuring the O2% when air is injected in the main burner while N2 is injected through the reburn nozzle...

Progress to date

Most of NOx and fouling related modifications have been completed.

For the fouling behavior three single-pass air tubes were installed, and experiments have been performed. Ash deposited on the surface of each tube is collected for analysis. Ash deposition becomes thicker and thicker from the top tube to the bottom tube. Since an experiment lasts at least 8 hours, burning HA-PC can completely clogged the burner; cleaning of the burner is regularly required. It is very hard to brake because it is inside of reactor. So far, preliminary results of the fouling study show unsteady heat transfer; however, they tend to decrease over time which is the expected behavior. Fouling study is only 20% completed.

2.2.1.1. The PERFORMING PARTY will investigate the effect of reburn zone equivalence-ratio for Texas Lignite, LA-PC, and blends of Texas lignite and LA-PC.

Progress to date

Mr. Paul Goughnour has written MS thesis and recently defended his thesis. The thesis includes results of Task 2.2.1.1. The thesis is under revision and a condensed form of thesis will form first part of Report under Task 2.

2.2.1.2. The PERFORMING PARTY will use N_2 and air mixture in the reburn nozzle in order to simulate the exhaust gas recirculation (EGR) for injection of reburn fuel.

Mr. Paul Goughnour has written MS thesis and recently defended his thesis. The thesis includes results of Task 2.2.1.2

2.2.1.3. The PERFORMING PARTY will study the fouling potential, associated with FB as reburn fuel. During the combustion experiments, the PERFORMING PARTY will measure the water inlet temperature and exit temperature to determine the degree of ash deposition. The ash will be scraped off and sent for analyses.

Progress to date

1. Heat exchanger tubes were added to the furnace and fouling experiments are expected to start in May. Data generated were not meaningful due to location of Thermocouples inside the heat exchanger.
2. Some delays occurred due to the fracture of the natural gas burner.

2.2.1.4. The PERFORMING PARTY will conduct experiments for Hg Capture. Trace amounts of Hg acetate solution will be injected to simulate the Hg vapor in flue gases. The FB will be injected through reburn ports. Hg capture will be studied with and without the presence of heat exchangers. An Automatic Mercury Analyzer will be used for measurements of Hg (Hg0, Hg+2) emissions.

Progress to date

Mercury Analyzer

Progress: Conducted experiments with 100% TX lignite coal during April, and estimated the total, elemental and oxidized mercury levels in the flue gases using the wet chemistry method and Mercury instrument (Ducon). Unfortunately mercury instrument broke down and has been sent back to the manufacturer for servicing. The unit has been sent for repair; it will take another 2-3 weeks before the unit is returned to the facility.

2.2.2. Schedule: The PERFORMING PARTY shall complete this task within eleven sixteen months of the signed Notice to Proceed Date (or 8/1/06) as issued by TCEQ.

2.2.3. Deliverables: The PERFORMING PARTY shall submit a detailed written report to the TCEQ upon completion of this task, to include but not limited to a summary of the test results from the reburn studies. These results include the monitored emissions of NOx, SO_2, CO, and CO_2 and ash analyses as well as the results from the Mercury Analyzer.

Progress to date

The MS thesis of Mr. Paul Goughnour is under revision and a condensed form of thesis will form NOx part of Report under Task 2.

Task 2 is 60 % completed.

Task 3: Pilot scale test at the 500,000 BTU/hr DOE-NETL facilities to verify the small-scale test data on NOx reduction and Hg capture and obtain optimum conditions.

2.3. Task Statement: The pilot plant at the Combustion and Environmental Research Facility (CERF) will bused for testing LA-RM and LA-PC fuels and measuring the NOx emissions. The PERFORMING PARTY will also obtain the optimum operating conditions and appropriate injector configuration.

2.3.1. Schedule: The PERFORMING PARTY shall complete this task within nine months 19 months from NTP (or 11/1/06) of the signed Notice to Proceed Date as issued by TCEQ

2.3.2. Deliverables: The PERFORMING PARTY shall submit a detailed written report to the TCEQ upon completion of this task, to include but not limited to a summary of the pilot scale test and results of the NOx emissions.

Progress to date

1. The vendor for the pilot scale facility indicated availability only in Fall 2006. Request was made to TCEQ to extend the contract from June 30, 2006 to Dec 31, 2006. It has been approved. The PIs plan to visit the Vendor in June 29-300, 2006 to discuss possible pilot scale experiments in Fall 2006.

Task 4: Reburn modeling to predict NOx capture by biomass fuels.

2.4. Task Statement: The PERFORMING PARTY will create a model for characterizing reburn performance with coal, FB and coal: FB blends in predicting NOx and as well as Hg control performance. This task will be conducted primarily using zero Dimensional reburn code with characteristic mixing time scale concept. The simplified model will provide directions for improvement of NOx capture and assist in developing the test matrix.

2.4.1. Schedule: The PERFORMING PARTY shall complete this task within 12 months 16 months (or 8/1/06) of the signed Notice to Proceed Date as issued by TCEQ.

2.4.2. Deliverables: The PERFORMING PARTY shall submit a detailed written report to the TCEQ upon completion of this task, to include but not limited to a summary of the modeling.

Progress to date

NOx

1. In the last month, the work was concerned with sensitivity analysis of the NO_x reduction with different chemical kinetics.
2. Different reburn conditions were analyzed
3. The work on the preparation of the final report has continued.

Hg

1. Much work has been done on the mercury reactions to understand the direction and identify reactions which are most important for Hg modeling. The knowledge of the evolution of chlorine is especially critical as the mercury oxidation relies on the presence of atomic chlorine to take place.
2. More work still needs to be performed since the results look too optimistic when compared with the experimental data from literature.
3. A better accuracy in mercury and chlorine content in the fuel are necessary and fuel samples will be mailed to have those measurements.

Task 4 is 80% complete.

Task 5: Perform the economics of the use of FB as reburn fuel in coal fired power plants and cost of NOx reduction compared to other technologies.

2.5. Task Statement: The PERFORMING PARTY will conduct an economic analysis for all four biomass fuels listed in Task 1.

2.5.1.1. The following will be calculated: 1) required coal and reburn fuel firing rate, 2) the ash production, 3) the dollar and CO_2 savings in using feedlot biomass, and 4) maximum radius of economical use of feedlot biomass.

Progress to date

1. The Computations were completed for coal and reburn fuel firing rates, CO2 savings, and ash production.
2. The fueling rates of raw high-ash feedlot biomass (HAFB-Raw), partially composted high-ash FB (HAFB-PC), raw low-ash FB (LAFB-Raw), and partially composted low-ash FB (LAFB-PC) were compared.
3. The moisture and ash percentages of LAFB-Raw and LAFB-PC were found to be very similar, and hence there is virtually no difference in fueling rate. Moreover, HAFB-PC fueling rates are only slightly different to those of HAFB-Raw. Hence, it may be deduced that choosing between a high-ash fuel and a low-ash fuel has more of an effect on reburn fueling rates than the choice between utilizing raw or partially composted FB.
4. Carbon dioxide (CO2) savings depend on the percentage of the total required heat release the reburn fuel meets. Only CO2 released from non-renewable sources, such as coal, is counted because it adds to the net CO2 loading on the environment. Therefore, less coal firing rates due to energy release from biomass means greater savings on CO2 emissions.
5. Ash production increases with HAFB, however, lower heat values of high-ash biomass fuels require higher coal firing rates for equal biomass fueling to meet heat rate requirements. Therefore, there may be a tradeoff between CO2 savings and ash production when deciding between firing HAFB and LAFB.

6. More detailed calculations and analysis will be included in the Task 5 report.

Estimated 99% complete

2.5.1.2. The PERFORMING PARTY will conduct an analysis of the benefits and limitations of using Selective Non Catalytic Reduction and Catalytic Reduction for NOx reductions.

Progress to date

1. For nominal base case values, it was found that retrofitting a low-ash, FB reburn system in a coal plant that currently uses SCR for NOx reduction would have a NPV of $11.8 million and a simple payback of 2 years and 4 months.
2. Sensitivity analysis of the NPV of such a retrofit project indicate that increased percent NOx reduction from the biomass, increased CO2 penalties, increased coal cost, lower distances between plant and feedlot, and lower biomass transportation costs are all favorable to the value of a FB reburn system retrofit on a coal-firing unit that currently uses SCR for NOx reduction.
3. When looking at the specific NOx reduction cost, it was found that for equal operation times, SCR is more cost effective at $5.80/lb NOx to that of low-ash FB reburning at $6.74/lb NOx. Selective non-catalytic reduction (SNCR) seems to be the poorest option with a specific NOx reduction cost of $14.26. However, SNCR requires the lowest investment cost, which may make it favorable to smaller plants (<200 MW).
4. Additional research was conducted on current Texas coal-fired plants in order to produce real world economic comparisons for NO_x reduction.
5. This information will be used to approximate NO_x and dollar savings for some actual coal-fired units in Texas.

More detailed calculations and analyses will be included in the Task 5 report.

Estimated 90% complete

2.5.2. Schedule: The PERFORMING PARTY shall complete this task within Twelve months 16 months (or 8/1/06) to reflect changes in deadlines for tasks 2 and 4.of the signed Notice to Proceed Date as issued by TCEQ

2.5.3. Deliverables: The PERFORMING PARTY shall submit a detailed written report to the TCEQ upon completion of this task, to include but not limited to a summary of the economic analysis including the benefit analysis of using Selective Non-Catalytic Reduction and Catalytic Reduction for NOx reductions.

Progress to date

Task 5 is 90% complete

Indicate which part of the Grant Activities as defined in the grant agreement, the above accomplishments are related to:

Current status and progress on all tasks are reported

Section II: Problems/Solutions

<table>
<tr><td>Problem(s) Identified

(Please report anticipated or unanticipated problem(s) encountered and its effect on the progress of the project)</td><td>Task 1:
None
Task 2:
Problems with newly acquired Mercury equipment are causing delays.
<u>New Reactor</u>: A new vertical reactor was planned and constructed for injecting solid fuels at two locations: main fuel at the top of the burner which will produce NOx and Hg and reburn fuel downstream of main burner for reducing NOx and Hg. The frame for the new reactor for Hg studies is complete and refractory was cast for the furnace. Work was done to prepare the new furnace for experiments. Fuel feeders were received and are installed. Flow meters were received and are being installed and calibrated. The natural gas burner remains to be installed. However due to more delay in completing the set up, this reactor will not be used for TCEQ experiments; they will be used for the DOE-NREL projects.
Recently acquired Hg instrument is under repair

Task 3:
None
Task 4:
None
Task 5:
None</td></tr>
<tr><td>Proposed Solution(s)

(Please report any possible solution(s) to the problem(s) that were considered/encountered)</td><td>Tasks 2
Keep working to obtain needed equipment repairs. The old reactor is being used with revised contract task.

If repair can not be performed within reasonable period, a new unit will be shipped

Task 3:

Task 3:

Task 4:

Task 5:</td></tr>
</table>

Action(s) Conducted and Results *(Please describe the action(s) taken to resolve the problem(s) and its effect)*	**Tasks 2** Contacted manufacturer. They are sending replacement parts. **Task 3:** **Task 4:** **Task 5:**

Section III. **Goals and Issues for Succeeding Period**: (*Please provide a brief description of the goal(s) you hope to realize in the coming period and identify any notable challenges that can be foreseen)*

<u>Next Month's Goals</u>

Task 1: Task is complete

Task 2: Complete the final report. Finish the assembly of the new furnace. Begin fouling experiments.

Task 3: Contact pilot facilities to set up a time when experiments can be conducted

Task 4: Complete all mercury calculations with the code. Complete the NOx reduction report.

Task 5: Complete report for Task 5.

Proposal for June: A new mercury instrument is expected at the lab by end of June. In the meantime, literature survey is being carried out, as well as analyzing any improvements in the wet-chemistry or entire analysis procedure. Once the instrument is here, looking to continue with the experiments, to estimate the mercury levels (total, elemental and oxidized) in flue gases by co-firing coal with feed lot bio-mass, at 90:10, 70:30 and 50:50 ratios and at different equivalence ratios

K. Annamalai

____ **Date:** ___**6/10/06**______________________
Authorized Project Representative's Signature

NOTE: Please attach any additional information that you feel should be a part of your report or that may be required to meet the deliverable requirements for tasks completed during this reporting period.

LIST OF ACRONYMS

AB: Agricultural Biomass
AC: Activated Carbon
ACI: activated carbon injection
APCD: Air Pollution Control Devices
APH: Air Pre-heater
AW: Agricultural Wastes
ARS: Agricultural Research Station
ATP: Texas Advanced Technology Program
AWDF: Animal Waste Derived Biomass Fuels
CAFO: Concentrated Animal Feeding Operations
CAIR: Clean air Interstate Rule
CAMR: Clean Air Mercury Rule
CB: Cattle biomass
CO_2: Carbon Dioxide
DAF: Dry Ash Free

DB: Dairy Biomass
DOE: Department of Energy
DSC: Differential Scanning Calorimeter
EER: Energy and Environmental research Corp.
EGR: Exhaust Gas Recirculation
EPA: Environmental Protection Agency
ESP: electrostatic Precipitator
FB: Feedlot biomass (Cattle manure or Cattle Biomass CB)
FC: Fixed Carbon
FGD: flue gas Desulfurizer
FR: Feed Ration
GRA: Graduate Research Assistant
HA-FB-Raw: High Ash Feedlot Biomass Raw form
HA-FB-PC: High Ash Feedlot Biomass Partially Composted
HAHP: high ash/High Phosphorus feedlot biomass
HP: High Phosphorus
HHV: Higher Heating Value
HV: Heating value
LA-FB-Raw: Low Ash Feedlot Biomass
LA-FB-PC: Low Ash Feedlot Biomass Partially Composted
LALP: Low ash/Low Phosphorus feedlot biomass
LAHP: Low ash/High Phosphorus feedlot biomass
LOI: Loss on ignition or % carbon in bottom and fly ash
LP: Low Phosphorus
MAF: Moisture Ash Free, Dry Ash Free
mmBTU: million BTU
MMF: Mineral Matter Free
NETL: National Energy Technology Lab.
N2: Nitrogen
NOx: Oxides of Nitrogen
O2: Oxygen
PAC: powdered activated carbon
PCD: particulate control devices
PM: particulate matter
RM; Raw Manure
S: Sulfur
SCR: Selective catalytic reduction
SR: Stoichiometric ratio, AF/ AF_{stoich}
TAMU: Texas A&M University
TAES: Texas Agricultural Extension Service
TGA: Thermo-Gravimetric Analysis
TMPA: Texas Municipal Power Agency
TXU: Texas Utilities
USDA: US Dept of Agriculture
VM: Volatile matter