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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

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

Date Submitted: March 10, 2006

Report for the Monthly period:
Starting Date: February 1, 2006 **Ending Date:** February 28, 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 is reported

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>

All the necessary fuels HA-RM, LA-RM, HA-PC, LA-PC, Wyoming Subbituminous coal, and Texas Lignite coal have been collected, dried and ground. They have been shipped to TAMU facility at College Station, TX. A pilot plant has not been selected and hence fuel samples have not yet been shipped to a 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:

All the fuels HA-RM, LA-RM, HA-PC and LA-PC have tested for moisture and ash content. Ultimate analyses including the heating values have been performed (typically 3 samples for each fuel) on HA-RM, LA-RM, HA-PC, LA-PC, Wyoming coal and Lignite coal. Various heat value and emissions calculations were conducted for the two types of coal and compared to results of DB and FB obtained earlier. *This task has been completed and a report on Fuel Characteristics has been prepared*.

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

In order to model the processes for cofiring and reburn and understand the basic mechanisms governing the ignition behavior and NOx reduction with FB, fundamental experiments have been conducted to generate data on pyrolysis and ignition characteristics of FB and coal. Experiments were conducted in a Thermogravimetric Analyzer / Differential Thermal Analyzer (TGA/DTA) in both N_2 and air for coal, FB and coal/FB blends. In the past, Using the parallel reaction model, devolatilization kinetic constants were obtained by curve fitting the mass traces for pure pyrolysis of FB. TGA traces were obtained for HA-PC and LA-PC. When the experiments were repeated in air, coal exhibited a distinct mass loss trace different than N2, which is then used to interpret the ignition behavior. When the experiments were repeated for FB in air the trace was very similar to the N2 trace indicating no group ignition behavior for FB. All pyrolysis and ignition experiments were completed and the data has been analyzed. Task 1 is 100% complete.

2.1.2. Schedule: The PERFORMING PARTY shall complete this task within 8 months of the signed Notice to Proceed Date as issued by TCEQ.

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.

Progress to date

The report has undergone final revisions and is ready for submittal 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-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. For the following experiments, the NOx from the main burner will be reduced to 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). Texas Lignite Coal will be used as the baseline main fuel. Parameters to be monitored as key performance indicators include emissions of NOx, SO_2, CO, and CO_2 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 O_2% when air is injected in the main burner while N_2 is injected through the reburn nozzle.

Progress to date

The facility has been modified for reburn tests. 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. Task 2 is 35% complete.

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

The gas analyzer that was previously holding up experiments was never repaired due to age of equipment and difficulty of updating the equipment; but a rental unit was obtained and experiments are being conducted with the rental unit. 75% of experiments have been completed. A new unit has been ordered using funds from DOE contract.

2.2.1.2. The PERFORMING PARTY will use N2 and air mixture in the reburn nozzle in order to simulate the exhaust gas recirculation (EGR) for injection of reburn fuel.

Progress to date

75% of experiments have been completed and extensive reburn data has been obtained on HAPC, LAPC, blends of Lignite coal: HAPC and Lignite coal: LAPC. In order to check whether the extreme reductions of NOx are possible, calculations are being performed to check whether enough urea is being released by FB injected as reburn fuel.

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

Yet to be performed; a PhD student has been assigned for the task.

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

Yet to be performed; currently there is only one reactor; construction of a dedicated second reactor is behind schedule. Current existing reactor which is being used for NOx will be used once NOx experiments are completed to get preliminary data.

2.2.2. Schedule: The PERFORMING PARTY shall complete this task within 11 months of the signed Notice to Proceed Date 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.

<u>Progress to date</u>

Hg equipment was received in December. The method of mercury measurement (elemental and oxidized mercury) was developed. Ambient elemental Hg was measured to be 1.8 $\mu g/m^3$ (= 0.18 ppb) . OSHA (Occupational Safety and Health Administration) sets the ceiling limit as 100 $\mu g/m^3$ (10 ppb) for work place exposure. Currently in the process of procuring chemical reagents, and additional setup (impinger train) required to run the small-scale test to detect both elemental and oxidized mercury in stack gas. Task is 25% 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 9 months 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.

<u>Progress to date</u>

Yet to be performed. Task 3 will begin when Hg part of results from Task 2 are obtained. Task 3 is 1% complete.

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 11 months 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

In the past month the development of the code has proceeded as follows: The code that considers the size distribution of the fuel has been added and debugged successfully. The comparison of the numerical results with the experimental results has just started. Modeling on Zero Dimension reburn process is continuing.

The mercury modeling of the three step reaction mechanism was added to the code.

$$HCl + OH \rightarrow Cl + H2O$$
$$Hg + Cl \rightarrow HgCl$$
$$HgCl + Cl \rightarrow HgCl2$$

Three step reaction mechanisms given above are considered for mercury oxidation. Simulations were done for two different coals: Texas Lignite and Wyoming. The following parametric study is complete:

a. Effect of Concentration of Chlorine in Coal,
b. Effect of Volatile matter,
c. Effect of Coal Particle Diameter,
d. Effect of Temperature.

Some problems with the numerical code have been encountered and cause the mass fraction of certain species to go negative. Currently work is being conducted to eliminate these errors.

Task 4 is 60% 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.

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.

2.5.2. Schedule: The PERFORMING PARTY shall complete this task within 11 months 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

An Excel spreadsheet was generated to compute each subtask. A baseline case of a 90:10 blend of Texas Lignite and High Ash Raw Feedlot Biomass in a 100 MW plant was assumed along with various assumed values for other parameters such as the dollar value of ash, CO_2 emission charge, and distance between power plant and feedlot.

A sensitivity analysis was then conducted to determine how firing rates, ash production, dollar savings and CO_2 savings varied while changing each parameter.

Several general findings are as follows:

- Ash production increases with higher blend ratios due to higher ash contents in all feedlot biomass samples compared to both Texas Lignite and Wyoming Powder River Basin Coal. This is particularly true for high ash biomass
- However, due to higher combustible percentages in low ash biomass, the CO_2 savings from burning blends with low ash biomass are greater than burning blends with high ash biomass.
- If an $11/ton CO_2 charge is assumed and if the distance between the power plant and feedlot is short, then for lower blends (90:10, 80:20) CO_2 emission charges and coal delivery charges dominate over the cost of delivering biomass and the revenue from ash production.
- When considering the net cost from CO_2 emission charges, ash production, and coal and biomass delivery costs, there is little difference between burning blends of partially composted biomass and raw biomass. This is because although partially composted biomass may have lower moisture percentages, it also has slightly higher ash percentages, making the combustible percentages between the two roughly the same. Thus the required firing rates for partially composted biomass and raw biomass are approximately the same.
- There is approximately a $500,000 savings from burning blends of low ash biomass instead of high ash biomass.
- It is less also costly to burn 90:10 blends with Wyoming Powder River Basin Coal than Texas Lignite.
- Blend ratios much above 70:30 may become unfeasible due to the inability to collect required rates of biomass from local feedlots. As distances between plants and feedlots become too great, the cost of delivering biomass makes burning coal/biomass blends unprofitable compared to burning coal alone.

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

Problem(s) Identified (*Please report anticipated or unanticipated problem(s) encountered and its effect on the progress of the project)*	**Task 1:** Submission of Report on Fuel characteristics was delayed; One of the PI (Kalyan) was involved on Combustion Book Draft prior to start of TCEQ grant; he received the page proofs (about 1500 pages) in Dec 2005 which he is correcting now; further he has been working on the paper work required for the additional DOE grant in Jan and Feb 2006. The report has been prepared but needs to be checked by the PI. None **Task 2:** Problem in obtaining all required chemicals and equipment (impinger) for Mercury experiments is causing delays. **Task 3:** Awaits results from Task 2 None **Task 4:** None **Task 5:** None
Proposed Solution(s) *(Please report any possible solution(s) to the problem(s) that were considered/encountered)*	**Task 1:** Mail the book proofs by March 20; correct and submit the report on Task1 to TCEQ **Tasks 2** Keep working to obtain needed equipment **Task 3:** **Task 3:** **Task 4:** **Task 5:**

Action(s) Conducted and Results *(Please describe the action(s) taken to resolve the problem(s) and its effect)*	**Tasks 2** Contacted manufactures and other departments on campus in an effort to obtain equipment. **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)*

Next Month's Goals

Task 1: Submit Report on Fuel characteristics

Task 2: Complete 100% of NOx reburn experiments and begin final report. Finish the assembly of the new furnace.

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

Task 4: Complete the code. Calibrate the code with the experimental data in order to provide information also for different conditions.

Task 5: Complete research on limitations of SNCR and SCR for coal fire power plants (task 5.1 B). Compare NOx reductions and cost of SNCR and SCR to those obtained or predicted from using feedlot biomass (FB) as a reburn fuel. Complete report for Task 5.

K. [signature]

_____ **Date:** 3/10/06

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

Appendix A: Blank