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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: April 10, 2006

Report for the Monthly period:
Starting Date: March 1, 2006 **Ending Date:** March 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 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.

Progress To date:

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. However fuel samples for Pilot testing have not yet been prepared. A pilot plant has been approached; but the facilities are available only in Fall 2006; if request for extension of grant to Dec 31, 2006 is approved, fuel samples will be prepared; however they 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.

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 almost 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

Task 1 is almost 100% complete. The condensed report is based on MS thesis of Mr. Brandon Martin (in preparation). The condensed report is ready for submittal.

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. Fuel feeders were received and are being installed. Flow meters, temperature acquisition system and a natural gas burner remain to be installed.

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, but a rental unit was obtained and experiments were conducted with the rental. About 90% of NOx experiments have been completed. Effect of Reburn Zone equivalence ratio has been studied. Analysis of data and reporting remain.

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

About 90% of experiments have been completed. Analysis of data and reporting remain; they will form a part of MS thesis of Mr. Paul Goughnour

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

Heat exchanger tubes were added to the furnace and fouling experiments are expected to start in the first week April.

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

All the required chemicals and accessories required to run the experiments for mercury analysis have arrived at the lab. And an additional setup for mercury measurement was constructed to estimate both elemental and oxidized mercury in flue gas. The experiments on small scale boiler burner for mercury analysis would begin on 7th April, 2006.

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.

Progress to date

The report will be prepared once Hg part of the data is generated.

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.

Progress to date

Since the Hg data will be generated starting April 2006, the GE systems have been contacted for possible pilot scale tests within next 2 months; however GE systems have a backlog of pilot scale test and informed us that the facilities will be available only by 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 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 and for the moment the main target is to calibrate some parameters in the code that depend on the actual characteristics of the furnace. Modeling on Zero Dimension reburn process is continuing.

The single particle mercury modeling included the three step reaction mechanism.

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

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:

Effect of Concentration of Chlorine in Coal,
Effect of Volatile matter,
Effect of Coal Particle Diameter,
Effect of Temperature.

Simulations were also carried out by using coal blends for fuel. Coal and biomass were used to form the blends. The parameter in this case is the blend ratio. Two different blend ratios (80:20, 90:10) are used for simulations. The reason for using coal blends is that biomass, which has very high percentage of chlorine, results in increase of chlorine concentration in flue gases.

Task 4 is 70% 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.

Additions were made to the spread sheet discussed last month to include both the effects of blending coal with feedlot biomass and re-burning with biomass. Different combinations of reburn firing rates will be computed for different blend ratios and different biomass fuels (i.e. Texas Lignite or Wyoming Coal and High Ash Feedlot Biomass or Low Ash Feedlot Biomass).Estimated that 95% of task 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.

A literature review on the cost of SNCR and SCR was conducted. Estimated 50% of task is complete

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.

Task 5 is almost 75% 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

Problem(s) Identified (Please report anticipated or unanticipated problem(s) encountered and its effect on the progress of the project)	Task 1: A pilot scale facility has been approached in 2005; however no attempt was made for further communication with them pending small scale test data on NOx and Hg from TAMU 100,000 BTU/hr. Recently all necessary data on NOx have been obtained; but the recent contact indicated that facilities are available only in Fall 2006; if request for extension of grant to Dec 31, 2006 is approved, fuel samples will be prepared; however they have not yet been shipped to a pilot scale facility. Task 2: There was delay in getting the Hg equipments and starting experiments due to timely death of a senior PhD student responsible for Hg related tasks Task 3: The delay in Hg part of task 2 is causing delay in task 3 since small scale data is required to arrive at conditions for Hg reduction using animal wastes. Since the Hg data will be generated starting April 2006, the GE systems have been contacted for possible pilot scale tests within next 2 months; however GE systems informed us that they have a backlog of pilot scale test and the facilities will be available only in Fall 2006. 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: Request for extension of grant to Dec 31, 2006 to TCEQ Tasks 2 The order for parts for Hg experiments has been placed Task 3: 1. Request for no cost extension of grant to Dec 31, 2006; 2. Look for alternative pilot facilities. 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 manufacturers and other departments on campus in an effort to obtain equipment. All the required parts to be in place by end Task 3: Request for extension of grant to Dec 31 appears to be best solution, since the fuel preparation will require atleast 2 months. Further the GE system is known to have commercial contacts with utilities. 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: The task 1 is finished except supplying fuel samples for pilot scale tests

Task 2: Complete 100% of NOx reburn experiments and begin final report. Complete about 50 % of Hg experiments. Finish the assembly of the new furnace.

Task 3: If the request for extension of contract to Dec 31, 2006 is granted, then contact pilot facilities to set up a schedule for conducting experiments

Task 4: Complete an additional 20% of the code. Continue the validation of the code and generate data on the combustion of fuel blends.

Task 5: Complete economic studies on use 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.

_____ Date:___4/10/06_____
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