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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 NOX" 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: February 09, 2006

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

<u>Progress To date:</u>

All fuel properties have been determined; this task is complete. A rough draft of report has been prepared. 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. 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

All pyrolysis and ignition experiments were completed and the data has been analyzed. Task 1 is 98% complete. A rough draft of report has been prepared. Final reporting is in its final review.

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.

Progress to date
Progress is on schedule

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

Yet to be performed

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 25% 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, but a rental unit was obtained and experiments are being conducted with the rental. 20% of experiments have been completed. Results based on 20 % of experiments reveal excellent NOx reduction with Low Ash PC biomass performing better than high ash PC biomass.

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

20% of experiments have been completed. Results based on 20 % of experiments reveal better reduction for task 2.2.1.2 compared to results under Task 2.2.1.1

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

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

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

This task is behind our schedule due to reasons mentioned in previous month's report. Hg equipment was received in December. The method of mercury measurement (elemental and oxidized mercury) was developed. Currently in the process of procuring chemical reagents and additional setup required to run the small-scale test to detect mercury in stack gas. Task is 10% 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.

Progress to date

Yet to be performed. Task 3 will begin when 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

The Zero Dimensional Reburn Model (ZDRM) is continuing. The base code takes in consideration only one type of fuel and uniformly sized fuel particles. The Saturn Mean diameter (SMD) has been calculated to be 47 and 69 microns for FB-A and FB-B. A graphical interface has been developed but is not complete. The verification code with the experimental data will be done as soon as data is available.

In addition a single coal particle for Hg emission has been developed. Currently the single coal particle uses a single reaction mechanism as give below.

$$Hg + 2HCl \rightarrow HgCl_2 + H_2$$

The simulations were carried out at two different temperatures by changing the concentration of chlorine present in coal at fixed mercury concentration. Thus the effect of chlorine concentration on oxidation of mercury oxidation can be studied. The results showed mercury oxidation increases with chlorine concentration but mercury oxidized by chlorine is very small. The conclusion drawn from the results is that the single reaction mechanism used does not properly model the oxidation reaction.

The three step reaction mechanism was coded.

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

Simulations were carried out for various concentrations of mercury in coal. Effect of kinetic rates on mercury oxidation is also studied. This is done by changing the pre-exponential factor and the activation energy of the chemical reactions. 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 35% 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

A spread sheet program has been developed. Research has been conducted on the limitations of SNCR and SCR for coal fired power plants. Some minor discussion of the maximum radius of the economical use for feedlot biomass as a reburn fuel is still required. A comparison of SNCR and SCR to using FB as a reburn fuel is yet to be conducted.

Computations for CO_2 savings and ash production were calculated assuming a complete combustion model. For example, in using a 90:10 blend of coal and high ash raw feedlot manure (HAFB-Raw) instead of coal alone, CO_2 production may be cut by 7%, but ash production increases by 78%. Other calculations for different blend ratios and different feedlot manures were also computed.

Task 5 is 85% 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:** None **Task 2:** None **Task 3:** None **Task 4:** Some coding problems cause delays. **Task 5:** None
Proposed Solution(s) *(Please report any possible solution(s) to the problem(s) that were considered/encountered)*	**Tasks 2 and 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 and 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: Complete all reporting.

Task 2: Complete 75% of NO_x reburn experiments. Finish the assembly of the new furnace. The construction of Hg reactor is planned to be finished by end of Feb 2006.

Task 3: Efforts will be made to contact pilot facilities to set up a time when experiments can be conducted

Task 4: Complete an additional 20% of the code.

As mentioned in the previous month report, we planned to implement a three step mercury oxidation reaction. Three step reactions are being considered as the single step oxidation reaction did not favor in mercury oxidation in a major way.

The code has been modified to implement the three step reactions. Simulations are being carried out for various concentrations of mercury in coal at different temperatures.

Simulations are also being carried out by changing the order of the reaction with respect to mercury in a single step reaction. This is being done to study the effect of the mercury concentration on the mercury oxidation. Post processing will be done when all the simulations are carried out.

Task 5: Finish Computing CO_2 savings; Continue to research the limitations of SNCR and SCR for coal fire power plants. Compare NOx reductions and cost of SNCR and SCR to those obtained or predicted from using feedlot biomass (FB) as a reburn fuel. Complete reporting for task 5.

Date: **2/10/06**

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