Co-firing Coal: Feedlot and Litter Biomass Fuels

Quarterly Progress Report no: 2

Grant #: **DE-FG26-00NT40810**

Project Name: *Feedlot and Litter Biomass Co-firing in Pulverized Fuel and Fixed Bed Burners*

Contractor name: Texas Engineering Experiment Station, Texas A&M University

Sponsor: US Dept of Energy, National Energy Technology Laboratory

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Report Period: 9/15/00-12/14/2000

PROGRESS

Proposed activities for quarter 2 (9/15/00-12/14/00)

1. Conduct TGA and fuel characterization studies - Task 1
2. Perform re-burn experiments. – Task 2
3. Fabricate fixed bed gasifier/combustor - Task 3.
4. Modify the 3D combustion modeling code for feedlot and litter fuels - Task 4

A. Achieved During Quarter 2 (9/15/00-12/14/00)

1. The chicken litter has been obtained from Sanderson farms in Denton, after being treated with a cyclonic dryer. The litter was then placed into steel barrels and shipped to California to be pulverized in preparation for firing. Litter samples have also been sent for ultimate/proximate laboratory analyses. - Task 1
2. Reburn-experiments have been conducted on coal, as a base case for comparison to litter biomass. Results will be reported along with litter biomass as reburn fuel in the next report - Task 2.
3. Student has not yet been hired to perform task 3. Plans are ahead to hire him or her during quarter # 3.
4. Conducted a general mixture fraction model for possible incorporation in the code (Appendix A)

C. Proposed activities for quarter 3 (12/15/01-3/14/01)

1. Conduct TGA and fuel characterization studies - Task 1
2. Continue to perform re-burn experiments. - Task 2
3. Hire the student and design the fixed bed gasifier/combustor. – Task 3
4. Modify the PCGC2 code to include thermal NOx model and do computations for parametric study for cofiring of pulverized coal and litter biomass. - Task 4

APPENDIX A: Computer Code Modifications

In order to numerically simulate cofiring of coal and biomass more accurately, multiple mixture fractions are needed to represent mass in the gas phase, which originates from different sources. For example, these mixture fractions may represent primary air stream, coal off gas, broiler litter off gas, sawdust off gas, etc. Previously, the PCGC2 code was modified from two mixture fractions to three mixture fractions. In this research, a general PDF method for arbitrary number of mixture fractions was studied and detailed formulations were developed. The Favre mean mixture fractions and variations are computed by solving corresponding governing equations along with governing equations for continuity, momentum and energy. The formulation of source terms of the governing equations for Favre mean mixture fractions were studied and general formulation were formed. To evaluate the turbulence mean properties, the PDF method was used. A Gibbs minimization method is used to calculate instantaneous equilibrium properties of gas phase including chemical composition, density, etc. The mean properties of gas phase are obtained by integration of instantaneous properties as

$$\tilde{f} = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\cdots\int_{-\infty}^{+\infty} f(h_1,h_2,...,h_N,h,p)\,P(h_1,h_2,...,h_N,h,p)\,dh_1 dh_2 ... dh_N\,dh\,dp \qquad (1)$$

Where $P(h_1,h_2,...,h_N,h,p)$ is joint PDF, $f(h_1,h_2,...,h_N,h,p)$ is instantaneous property, $h_1,h_2,...,h_N$ and are mixture fractions. The joint PDFs are too complicated to handle so assumptions must be made to simplify the above equation. The pressure fluctuation is negligibly small so we can ignore it. We further assume that $h_1,h_2,...,h_N$ are independent, hence equation (1) becomes

$$\tilde{f} = \int_{-\infty}^{+\infty}\int_{-\infty}^{+\infty}\cdots\int_{-\infty}^{+\infty} f(h_1,h_2,...,h_N,h_r,\overline{p})\,P(h_1)P(h_2)...P(h_N)\,dh_1 dh_2 ... dh_N \qquad (2)$$

Where h_r is residual enthalpy, and $P(h_i)$ are independent PDFs for h_i. Equation (2) is then decomposed so that the limits of integral are 0^+ and 1^- and intermittencies at 0 and 1 are considered. Mathematical derivation shows that the total terms after decomposition is 2^{N+1}-1. These terms are mainly intermittencies and multiple integrals up to order of N. In computation using PCGC2, most CPU time is used for calculation of mean properties using PDF methods. Increasing the number of mixture fractions from 3 to 4 will double the number of terms, increasing the order of multiple integrals from 3 to 4, introducing two additional governing equations, brings more computation to solid particle lagrangian and PSI-Cell parts, and requires more iterations to make the result converge. As a result, CPU time will increase many times. Strategies or comprises must be made to avoid CPU time out of control.