TITLE: Development of a Novel Radiatively/Conductively Stabilized Burner for Significant Reduction of NO_x Emissions and for Advancing the Modeling and Understanding of Pulverized Coal Combustion and Emissions

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ABSTRACT

OBJECTIVE

The primary objective of the proposed study is the rigorous modeling, analysis, experimental exploration and validation, and design recommendations for a novel radiatively-conductively stabilized combustion process for pulverized coal which, based on our prior studies with both liquid fuels and pulverized coal, holds a high promise to reduce NO_x production significantly, and has not been studied adequately yet. The unique suitability of this type of burner for the experimental study of coal particle combustion in general would also be exploited for additional fundamental studies of the highly promising radiatively/conductively stabilized combustion.

ACCOMPLISHMENTS TO DATE

We have primarily engaged in continuing our process modeling and analysis, and making preparations for the experimental work

In an attempt to study ways for reducing NO_x emissions from radiatively/conductively stabilized combustors (RCSC) for pulverized coal, our conjugate heat&mass transfer and reaction kinetics model of that combustor was improved. As compared with our previous simple three-reaction model, a global reaction model is used in this new model to simulate volatile-NO formation and destruction along with the Zeldovich mechanism for thermal NO_x., and a ten-equation kinetic mechanism suggested by the authors and their co-workers is used for

the char-NO formation process. Thirteen chemical species are now included, and the mass conservation equations for the species, taking into account mass convection and diffusion was added to the previous model. The radiative properties of the different solid and gaseous components in the combustor are expressed by simplified expressions we have developed, which give acceptable errors, yet a much faster computation than the solution of the Mie equations.

Using this numerical model, we have also studied the effects of changing combustor wall conductivity, thickness and emittance, flame location, fuel/air ratio, and fuel-air mixture preheating, on NO_x emissions. Flame location was found to have little effect (~6%) and internal wall emittance had an insignificant effect. While the concentration of these emissions was lowered by lowering the flame temperature, accomplished by increasing the excess air ratio, the overall mass of NO emitted with the thicker lower-temperature flames produced by such increases in excess air was much higher, indicating that the RCSC with its capability for producing a high temperature thin flame is much more effective for the reduction of NO emissions than some lower temperature combustion alternatives. Preheating has been found to reduce NO_x emissions, by about 14%. The turbulent modeling was improved by introducing a k-, model instead of the 3-layer one used in the current model. The model was run so far just to examine wall temperature effects on the velocity distribution, flow development, and convective heat transport between the gas and the combustor wall.

Several numerical and experimental studies were also conducted on air-propane flames (without coal) just to examine the effects of flow rate, equivalence ratio, tube thermal conductivity, and wall temperatures on the number of stable states (positions) of the flame in the combustor and on flame stability in general. Some of the main findings were (1) increasing the mass flow rate, or decreasing the equivalence ratio, or tube thermal conductivity, moves the flame axially towards the center, (2) increasing the tube length moves stable flames located downstream of the center further down along the tube.

Initial estimates have been made of the configuration needed for a commercial/industrial RCSC.

SIGNIFICANCE TO FOSSIL ENERGY PROGRAMS

The national goal expressed by the USDOE, is to reduce NO_x and SO_x emissions in coal plants by at least an order of magnitude by the year 030 , and at least by four-fold by 2005. The NO_x emissions, currently at several hundred ppm, should be reduced to single-digit levels. Using fluid fuels, the RCSC was proven in the laboratory to indeed produce NO_x at levels below 10 ppm. Using coal, our analysis and experiments conducted so far indicate that this novel approach to combustion is highly likely to reduce NO_x levels significantly.

PLANS FOR THE COMING YEAR

- to complete the modification and improvement of the RCSC model so that it represents turbulent flows, particle motion, and the reaction kinetics better
- to conduct validation experiments
- To assess several promising further improvements in the RCSC, including staged combustion, enhanced

upstream heat transfer for better preheat and flame stabilization, and NH_3 injection.

- to produce the design of an optimized configuration of a commercial/industrial version of this RCSC combustor.