# Temperature, Velocity and Species Profile Measurements for Reburning in a Pulverized, Entrained Flow, Coal Combustor

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One of the most widely used methods for the production of electricity is pulverized coal combustion. Recently, technologies such as low $NO_x$ burners (LNBs), reburning and advanced reburning are being implemented to reduce emissions and maintain efficiency. Although these are proven technologies in the laboratory, the engineering of these ideas on full scale boilers is expensive and financially risky. The collection of detailed experimental data which improves our understanding of these processes and provides an opportunity to validate existing comprehensive models of coal combustion can reduce the uncertainty of these important pollution reducing technologies. The objective of this work is to obtain detailed combustion measurements of pulverized coal flames which implement reburning and advanced reburning in order to test the accuracy of comprehensive combustion models. The comprehensive data may also lead to new insights into reburning and advanced reburning which could improve understanding and ability for implementation.

Initial work focused on obtaining a comprehensive baseline data set containing detailed axial and radial measurements of major gas species, temperature and velocity at three different swirl conditions (0, 0.5 and 1.5). The LDA velocity data for the baseline condition are fairly unique as only one other data set has been published where temperature and species have been included with the velocity. This data set also contains detailed velocity measurements of the burner inlet which can be used to describe boundary conditions. The data has been compiled in spreadsheet format for distribution to any interested parties. The data has also been submitted for journal publication and is in review. To date, the data has been distributed to several research groups in industry and academia.

NO measurements of the effluent gases with reburning have been obtained investigating the effect of location (residence time), reburning zone stoichiometric ratio, and reburning injector momentum. The data showed a maximum reduction in NO of 70 % was possible. NO reduction increased as stoichiometric ratios in the reburning zone decreased reaching a maximum reduction at 0.78 after which further increases in reburning fuel had no effect. Increased residence time was found to increase reburning up to approximately 200 ms after which further increases in residence time had little effect. The highest reductions in NO occurred when the reburning fuel was injected just below the point where carbon burnout was nearly complete and NO concentrations were the highest.

A detailed map of species and temperature have been obtained for reburning at 1.5 swirl and effluent measurements of reburning have been obtained at 0.5 swirl. Detailed measurements of the velocity have not yet been obtained with reburning. Current objectives are to obtain detailed reburning data at 0.5 and 1.5 swirl but not zero swirl.

Effluent measurements have been obtained of NO for the coal flame with advanced reburning. In this process, ammonia was injected immediately downstream of the reburning zone. The effluent measurements have investigated the effect of reburning zone stoichiometric ratio and ammonia nitrogen to NO nitrogen ratio (Nitrogen Stoichiometric Ratio or NSR.) on effluent NO.

Figure 1 shows preliminary results of NO reduction achieved with reburning alone and reburning followed by ammonia injection or advanced reburning. At low stoichiometric

ratios, reburning alone achieved an NO reduction of approximately 70% with no additional benefit when advanced reburning was added. As the reburning zone became leaner, reburning alone became less effective but the ammonia more than compensated to produce greater than 90% reduction in NO at 1.05 stoichiometric ratio. The stoichiometric ratio has an uncertainty of 5% for this data do to uncertainties in the coal feed rate, therefore, it is uncertain whether large NO reductions are occurring under lean conditions with the ammonia injection. More data will be sought to verify this current observation by measuring the NO reduction under leaner conditions and by attempting to lower the uncertainty of the stoichiometric ratio measurement.

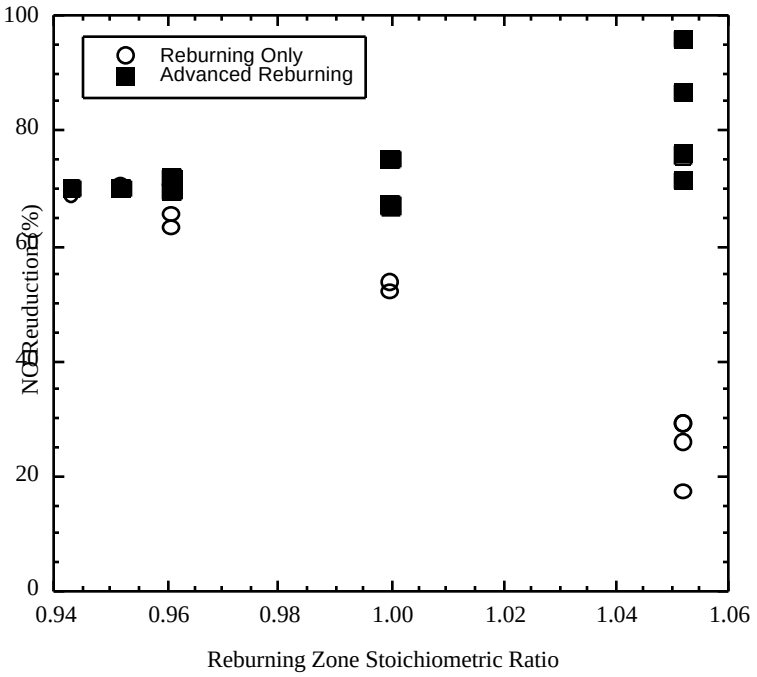


Figure 1. NO reduction achieved with reburning alone and with advanced reburning as a function of reburning zone equivalence ratio.

The four data points in Figure 1 for advanced reburning at 1.05 stoichiometric ratio were obtained at three different NSR values. The highest NO reduction occurred at an NSR of 2.5 and the lowest at an NSR of 1. The data indicates that increased NSR increases NO reduction but values greater than 2.0 have been shown to cause considerable ammonia slip. This data suggests that approximately 90% reduction in NO can be achieved at an NSR of 2.0

# List of Articles, Presentations and Students

## Publications

1. Pickett, L.M., Jackson, R.E. and Tree D.R. (1998) "LDA Measurements in a Pulverized Coal Flame at Thre Swirl Ratios," Submitted to Combustion Science and Technology, March 1998.

2. Nazeer, W.A., Pickett, L.M. and Tree D.R. (1998) "In-Situ Species, Temperature and Velocity Measurements in a Pulverized Coal Flame," Submitted to Combustion and Science Technology, March 1998.

## Presentations

1. Tree, D.R., Haneberg, A., Pickett, L.M. Nazeer, W (1998) "In-Situ Species and Temperature Measurements of Pulverized Coal Flames with Reburning and Advanced Reburning," ACERC Annual Conference, March 25, 1998.

2. Pickett, L.M., Jackson, R.E. and Tree, D.R. (1997) "LDA, Gas Species and Temperature in a Pulverized Coal Flame," Western States Section, Comb. Inst., Spring 1997.

3. Jackson, R.E., Pickett, L.M., and Tree, D.R. (1997) "Comprehensive Combustion Code Predictions of the Flow Field for Pulverized Coal Combustion," Western States Section, The Combustion Institute, Spring 1997.

4. Nazeer, W.A., Jackson, R.E. and Tree, D.R. (1997) "Detailed Species and Temerpature Measurements in a Pulverized Cola Flame with Natural Gas Reburning," Western States Section, The Combustion Institute, Fall 1998.

5. Tree, D.R., Haneberg, A., Pickett, L.M. Nazeer, W. "Velocity, Soot and Reburning Measurements in a Pulverized Coal Reactor," ACERC Annual Conference, March 13, 1997.

## Students

1. Lyle M. Picket, Masters of Science in Mechanical Engineering, December 1996, Thesis Title: *Velocity Measurements in a Pulverized Coal Flame Using Laser Doppler Anemonetry.*

2. Waseem Nazeer, Masters of Science in a Mechanical Engineering, December 1997, Thesis Title: *Species and Temperature Measurements in a Pulverized Coal, Controlled Profile Reactor with Natural Gas Reburning.*

3. Adam Clark, Master of Science in Mechanical Engineering, Anticipated, August of 1998.

4. Robert Jackson, Doctor of Philosophy, Ph.D. in Mechanical Engineering, Anticipated December of 1998.