# SURFACE AREA, VOLUME, MASS, AND DENSITY DISTRIBUTIONS FOR SIZED BIOMASS PARTICLES

R. Sampath, C. S. Brown, M. Byars*, G. Saha*,
G. Brobby*, and E. R. Monazam**

Morehouse College, Atlanta, GA
*Student Assistants
** Subcontractor: REM Engineering Services, Morgantown, WV

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## OUTLINE

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## INTRODUCTION

• Biomass is composed of woody materials.

• An estimate of the amount of biomass available in the U.S. for conversion to fuels is 2 billion tons per year.

• The conversion of 20% of this material can meet roughly 10% of the U.S. annual energy needs.

- Co-firing biomass and coal has been identified as a promising way of reducing net carbon dioxide emissions with minimum modifications in existing technologies.

- The shape and density for coal particles have been characterized and detailed data including surface area, volume, mass, and density distributions for several coal samples are now available for use in coal combustion models.

- In this project, scientists in the Department of Physics and Dual Degree Engineering at Morehouse, and REM Engineering Services proposed to characterize the shape, mass, and density of biomass particles to provide detailed data similar to that available for coal.

# OBJECTIVES

The specific objectives of this project are:

1)Apply unique measurement systems to characterize external surface area, volume, mass, and density for a statistically significant number of individual biomass particles (20 particles) in the size range of 100 to 200 μm.,

2) Obtain mean mass per particle of the biomass sample tested in Objective (1) by independent mass measurements of several thousand particles using a particle weighing and counting technique, and

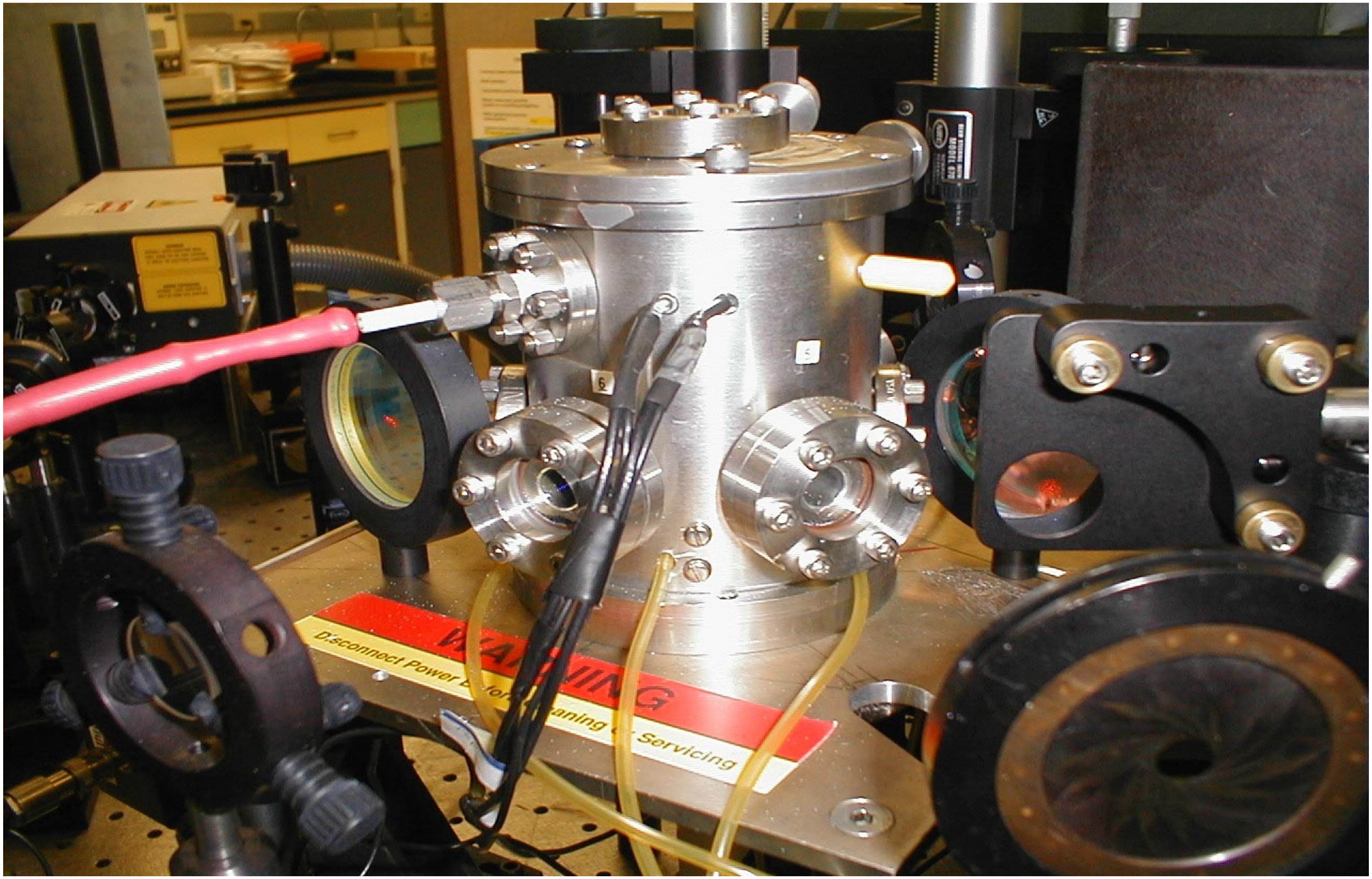
3) Correlate biomass shape, density, and mass distributions with previously published information obtained from similar research for coal particles for use in blends of coal/biomass feeds in combustion modeling.

## EXPERIMENTS

Measurement of Particle External Surface Area and Volume

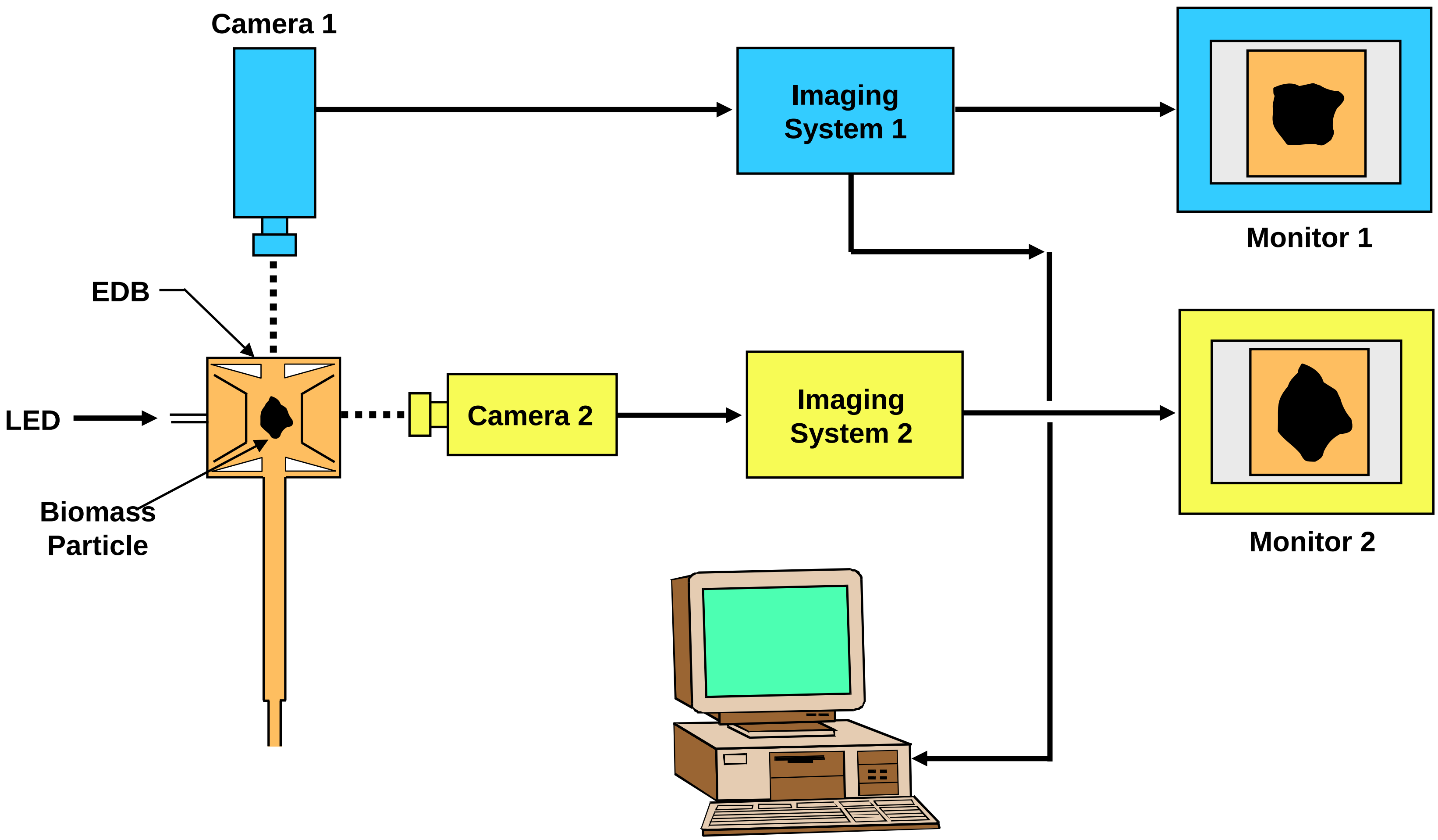
• Individual biomass particle was levitated in an electrodynamic balance (EDB).

• Volume and surface area were obtained by rotating particle and recording image data for successive video fields as a function of rotation angle using a side view video imaging system.



**NETL's Electrodynamic Balance Facility**
**to Levitate and Characterize Single Particles**

# Video Based Imaging Systems Used to Characterize Particle Areas and Volumes



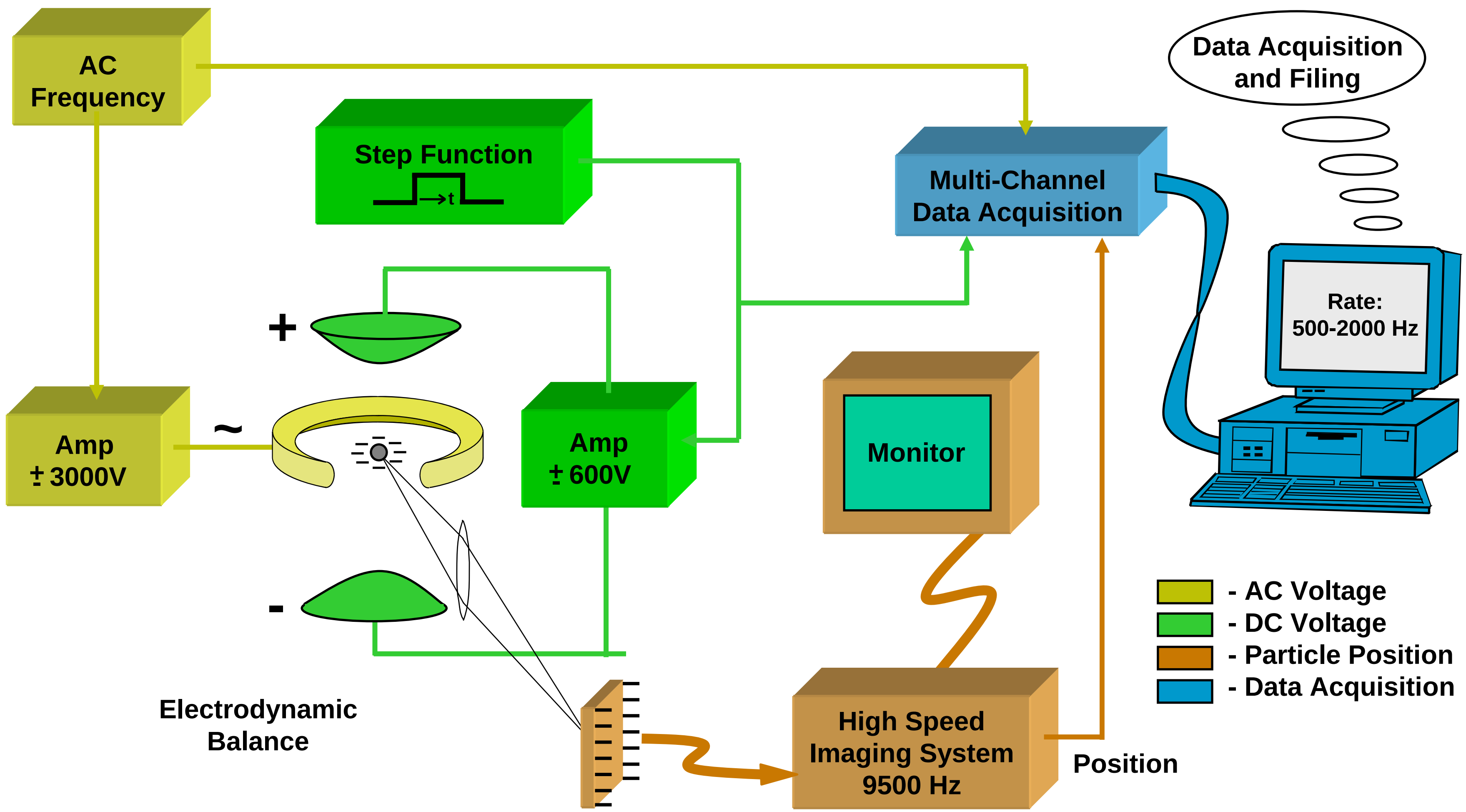
## Measurement of Particle Drag coefficient/mass ($C_d$/m) ratio

- Particle $C_d$/m ratio was determined based on measurements of particle trajectory in the EDB.

- Single particle was balanced in the EDB and a step change was applied to the EDB endcap voltage, stimulating a dynamic response of the particle from its balance position. The resulting transient motion of the particle was measured using a high-speed diode array imaging system which provided an analog output indicating particle position along the EDB center axis.

- A force balance model referred to as the Particle Dynamic Model (PDM) was used to simulate the particle trajectory in the EDB. The only unknown in the force balance was particle $C_{d/}$m which was determined by matching the model output with the measurements.

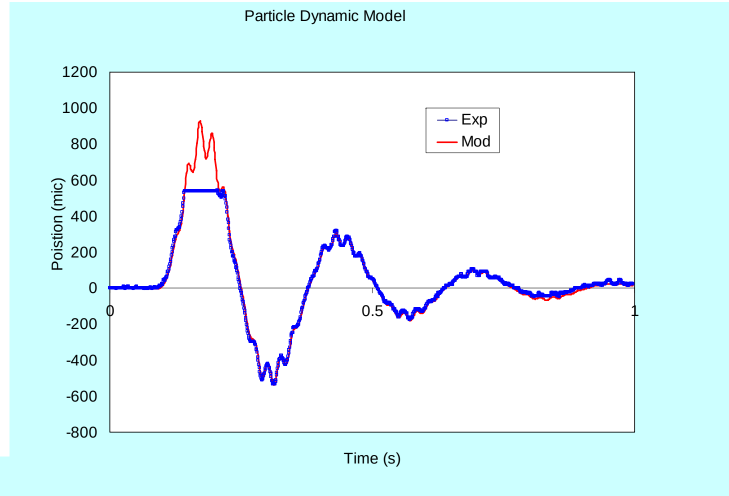
# Electrodynamic Balance with Diode Array Detection and Data Acquisition Systems for Tracking Particle Motion in the Balance

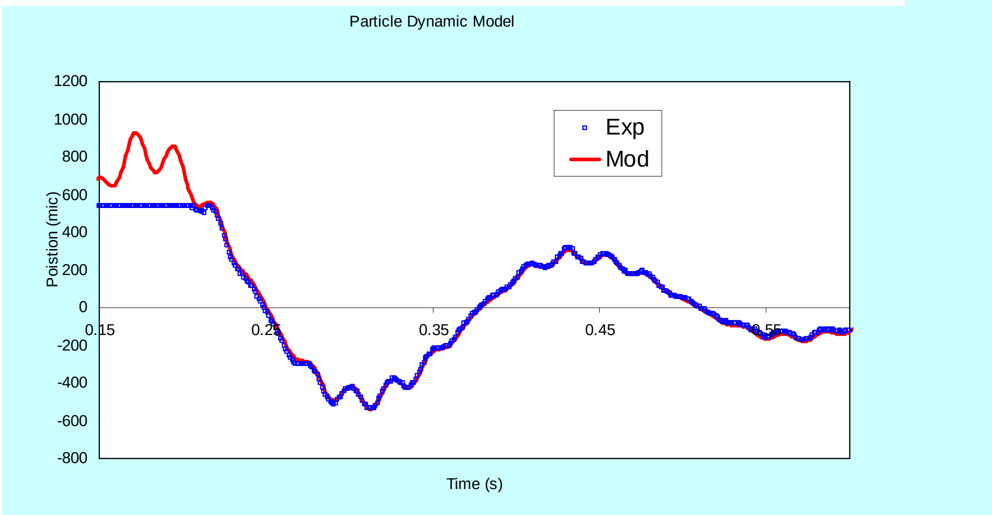


# Drag/mass measurement

- Force balance model
  - $F_{ac}$, $F_{dc}$,$F_g$, $F_{dg}$
- Balance condition

  $$F_{dc} = F_g$$
- $F_{ac}$ is function of geometry (known)




**•Model fit parameter - $C_d$/m**

**•Fit resolution $\pm$ 5%**

<u>Measurement of Particle Mass, and Density</u>

• The measured surface area and volume were used to estimate the particle drag coefficient ($C_d$) by applying Brenner's approach for deformed spheres.

• The particle mass was then separated from the $C_d/m$ ratio.

• From the mass and volume, the particle density was determined.

## Mean Mass Measurements by Gravimetric Technique

- This involved weighing and counting several thousand biomass particles.

- A paper boat was made with a grid paper and its empty weight measured using a sub- milligram balance (uncertainty ± 10 μg).

- Several thousand biomass particles were dispersed on the grid surface and the weight of the particles plus the boat was measured.

- The particles were then counted under a microscope and the mean mass per particle was calculated.


Seen here are George Brobby (an undergraduate student) and
Dr. Sampath involved in weighing several hundred biomass particles

George involved in counting several hundred biomass particles

## RESULTS TO DATE

Results of low, high, and average values for particle surface area diameter ($d_{sa}$), volume diameter ($d_v$), $C_d/m$, mass (m), and density (ρ) obtained employing the EDB system for 25 individual biomass particles are presented below.

# Shape, Mass, and Density Information for Biomass Particles

| | Surface Area Dia, $d_{sa}$ (µm) | Volume dia, $d_v$ (µm) | $C_d/m$ (1/s) | mass, m (g) | density, ρ ($g/cm^3$) |
|---|---|---|---|---|---|
| Low | 66.8 | 61.4 | 34.4 | 5.50E-08 | 0.50 |
| High | 125.9 | 117.2 | 216.5 | 5.79E-07 | 1.21 |
| Average | 96.7 | 88.2 | 107.8 | 1.83E-07 | 0.80 |

The large differences seen in $d_{sa}$, $d_v$, $C_d/m$, and ρ between low and high values of biomass particles suggest that the variability in these parameters between particles must be accounted for in the single particle modeling in order to reliably predict the energy balances for individual particles.

Result of the Direct Gravimetric method:

To date 32,133 particles were weighed and counted and the mean mass per particle for a total of 32,133 biomass particles was found to be $1.82 \times 10^{-7}$ g.

Validation of Single Particle Mass Measurement:

The mean mass of 25 individual biomass particles obtained employing the EDB system is found to be $1.83 \times 10^{-7}$ g. It should be noted that this mean mass is to within ±1% of that obtained by the gravimetric approach discussed above.

# Accomplishments To Date:

| Project Tasks | Scheduled Milestones | % Complete | (Forecasted) completion date |
|---|---|---|---|
| 1. Setting Up the Measurement Systems (Morehouse and REM) | 7/1/04 to12/31/04 | 100% | |
| 2. Calibration and Testing of the Measurement Systems (Morehouse and REM) | 1/1/05 to 6/30/05 | 100% | |
| 3. Collection of Experimental Data (Morehouse) | 7/1/05 to 6/30/06 | 100% | 12/31/06 |
| 4. Collection of Experimental Data (REM) | 7/1/05 to 9/30/06 | 100% | 12/31/06 |
| 5. Analysis of Data (Morehouse) | 10/1/05 to 6/30/07 | 85% | 7/31/07 |
| 6. Final Report (Morehouse) | 7/1/07 to 9/30/07 | 0% | 8/31/07 |

# Remaining Work

• Overall about 85% of the proposed project work has been Completed to date.

• Correlations for coal/biomass blends using biomass shape, density, and mass distributions obtained in this study with previously published information obtained by us from similar research for coal particles are being developed.

• These correlations will be useful in coal/biomass combustion modeling.

## Remaining Work …. Continued…..

•A Final Report will be developed documenting the results of all activities in Tasks 1 to 5.

• The final report will present conclusions and discuss the technical, environmental, and economic issues associated with co-firing biomass and coal to meet the goal of advanced coal utilization.

# ACKNOWLEDGMENTS

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