2008 ACERC Overview

Overview of Combustion Related Projects, Facilities, Technologies

ACERC Mission Statement

Develop advanced combustion technology through fundamental engineering research and educational programs aimed at the solution of critical national problems.

Method:

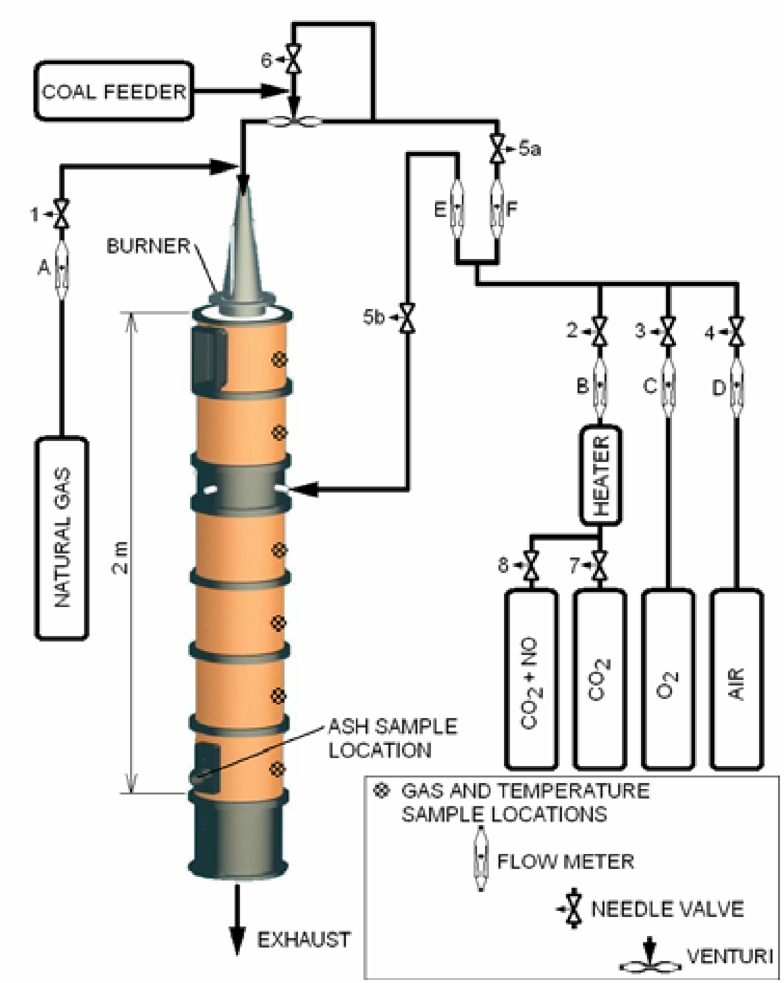
- Identify knowledge, technologies or ideas needed to solve key problems in applied combustion
- Partner with Industry and Government
- Educate students to contribute who will seek careers in the applied combustion industry

Review Current Projects, Facilities and Technologies

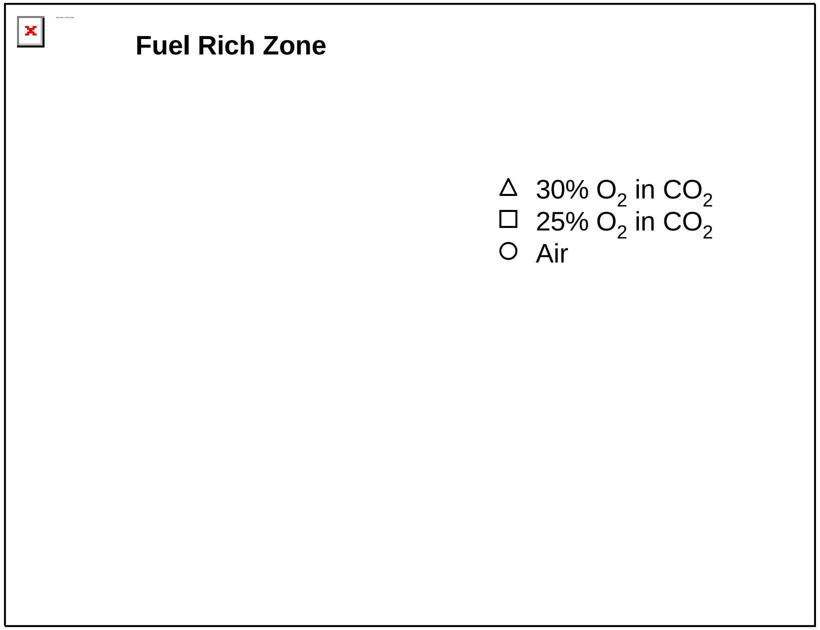
Current ACERC Projects

- Oxy-combustion: Nitrogen evolution (Tree, Fletcher Baxter)
- Deposition on turbine blades (Fletcher)
- Soot formation from coal (Fletcher)
- Ash deposition on boiler tubes (Baxter, Tree, Maynes)
- Ash deposit properties (conductivity and emittance) measurements (Baxter, Maynes, Jones)
- Co-firing of coal and biomass, modeling and detailed measurements of near burner region. (Baxter, Tree)
- SCR Catalyst reactivity (Baxter, Bartholemew)
- Solid Particle Combustion Measurements and Modeling. Particle levitation (Baxter)
- Biomass ash in concrete (Baxter)
- Kinetics of Kerogen (Fletcher)

Oxy-fuel Combustion - Nitrogen Evolution

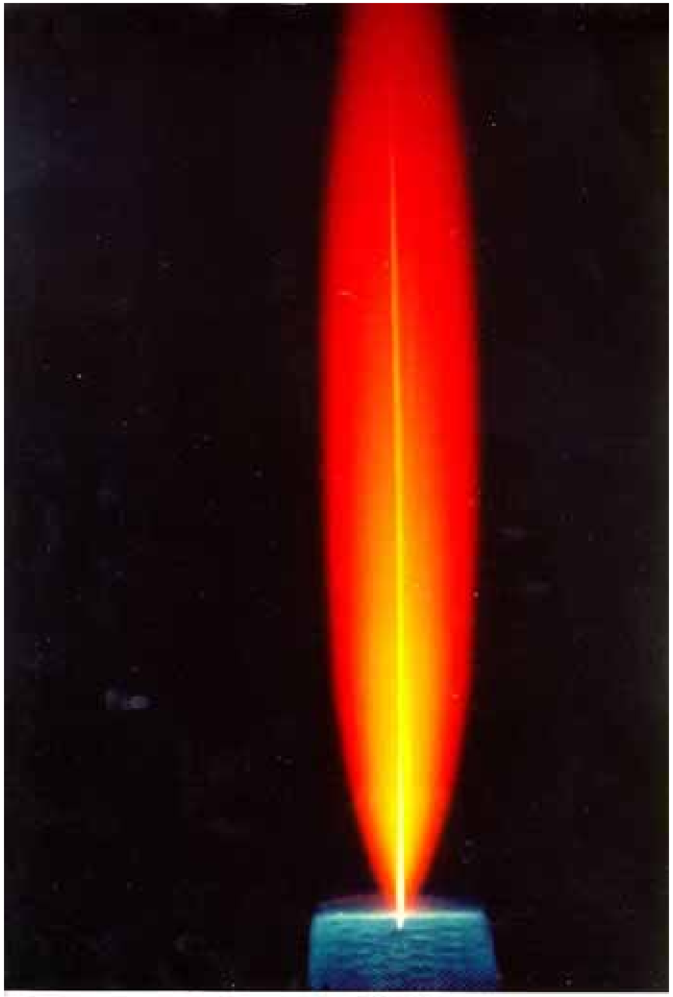


Unheated Multi-fuel Reactor

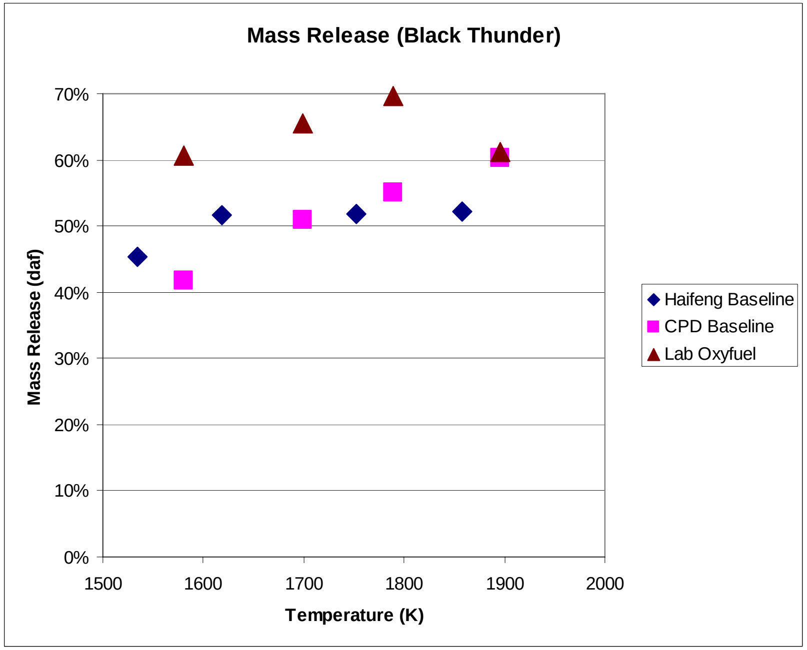


- **Both Oxy-fuel cases produce lower NO_x**
- **Similar NO_x formation but higher NO_x destruction in Oxy-fuel**
- **Gas phase kinetic model predicts same NO_x destruction**
- **Reduction of NO_x with char and increased CO suspected**

Oxy-fuel Pyrolysis in FFB

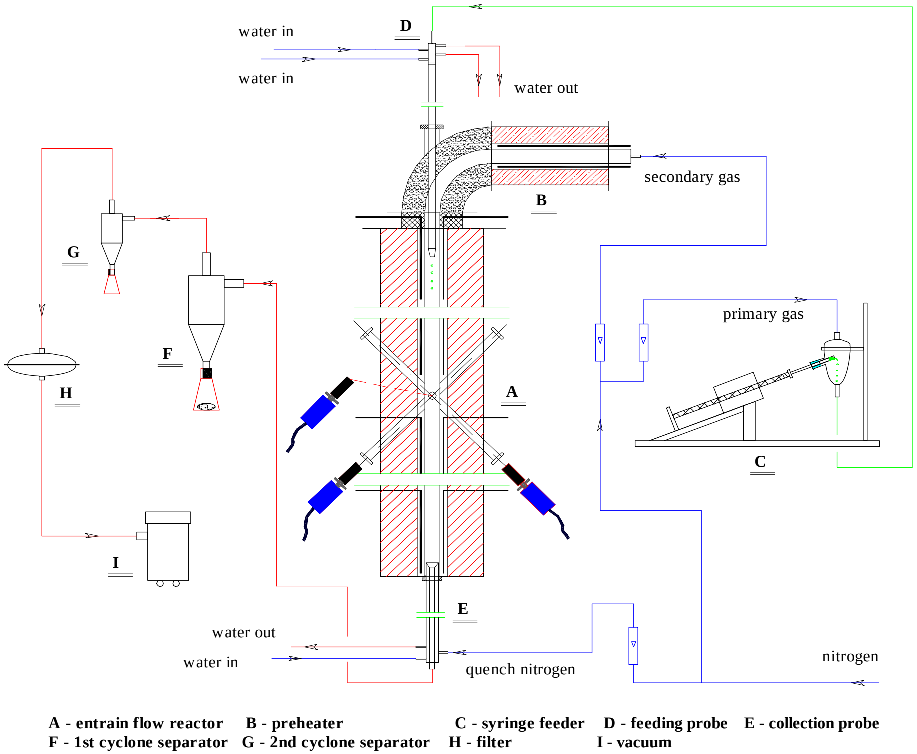


Fuel-Rich Flat-Flame Burner



- **Oxy-fuel condition formed by replacing N_2 with CO_2**
- **High gas temperatures (1600-1900 K)**
- **Hv bituminous coals showed similar mass and N release behavior in air-fired and oxy-fired environments**
- **Difference found in sub-bituminous coals**
  - **Possible CO_2 gasification**

Particle Combustion – Shape Effects

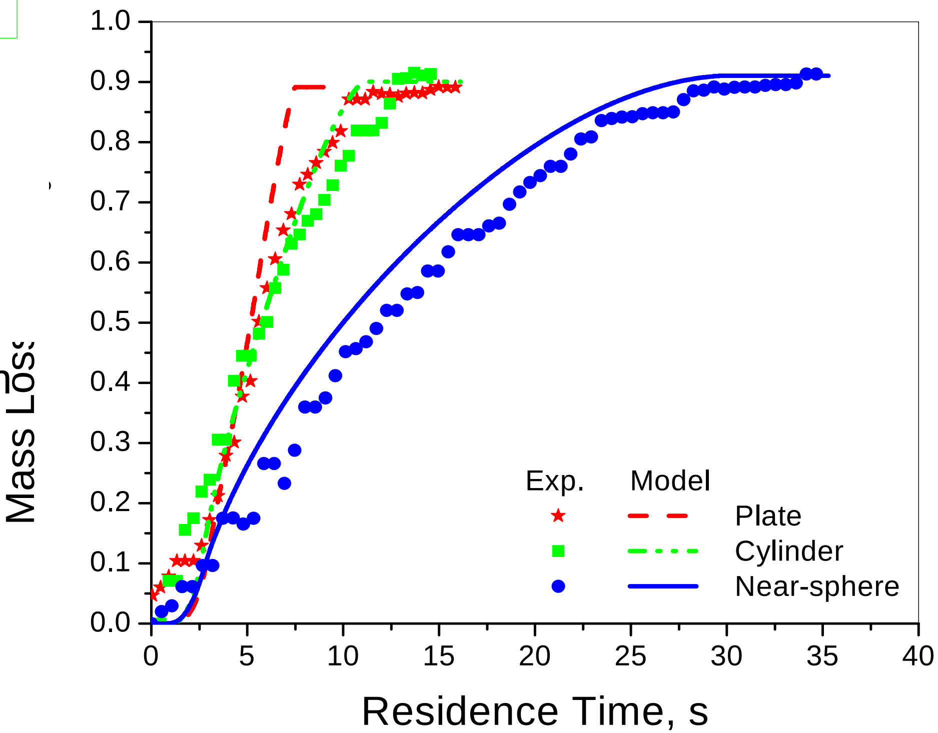


New 3-D Particle Reactor

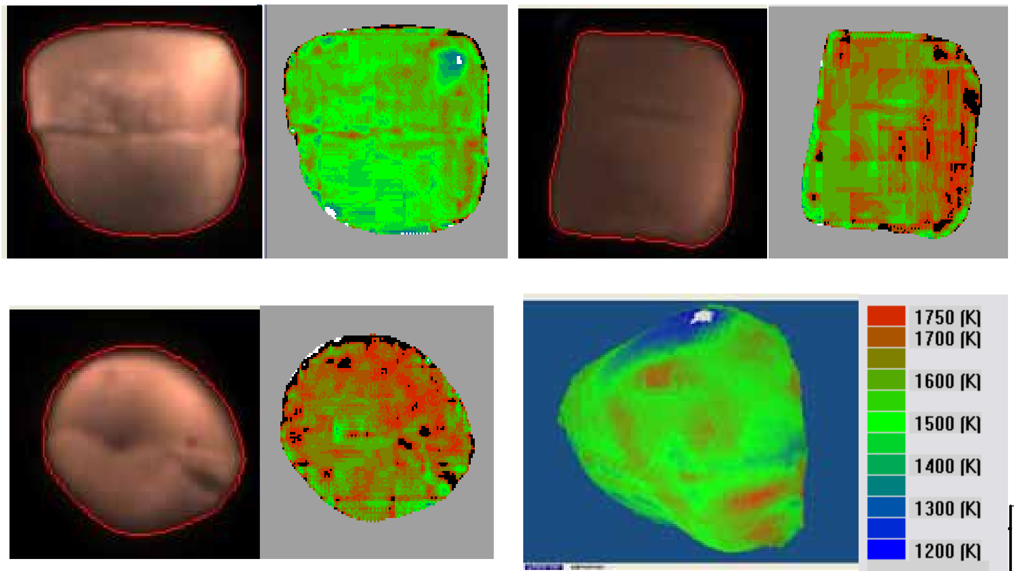
- Allows 3-D shape reconstruction from 3 orthogonal images
- Provides spatial resolution on surface and time resolution
- Separate reactor provides spatial (radial) resolution.

Particle Shape Substantially Impacts Conversion

- Spherical assumption represents extreme case and produces poor results (except for spheres)
- Most biomass and many other particles aspherical
- Model accommodates any surface area/mass ratio (any shape)
- Total reaction time +/- factor of 3 compared to simple models



Particle Combustion – Size Effects

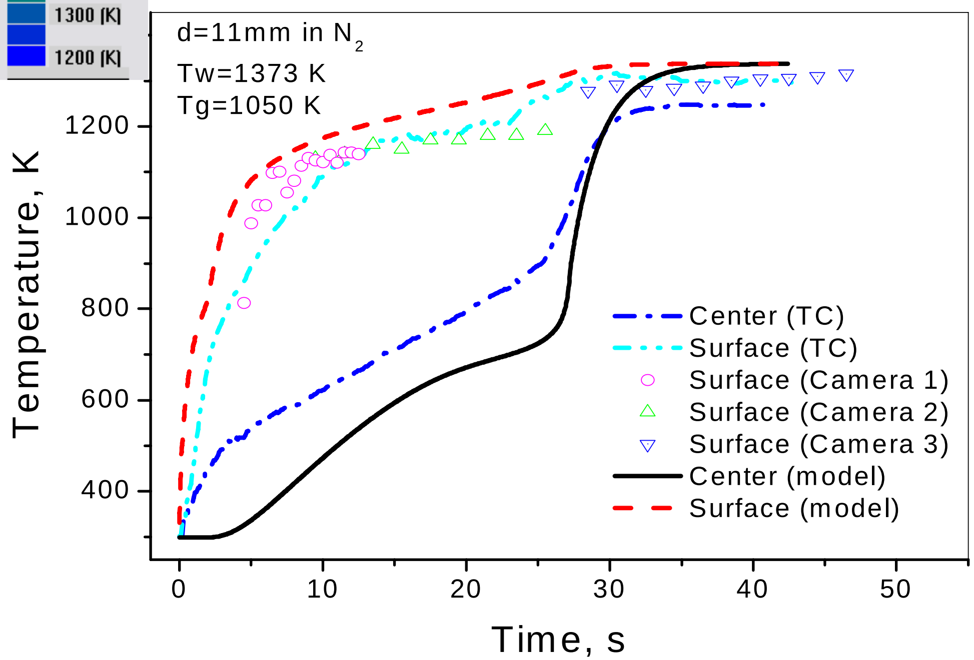


Pixel-by-pixel Temperature Measurement

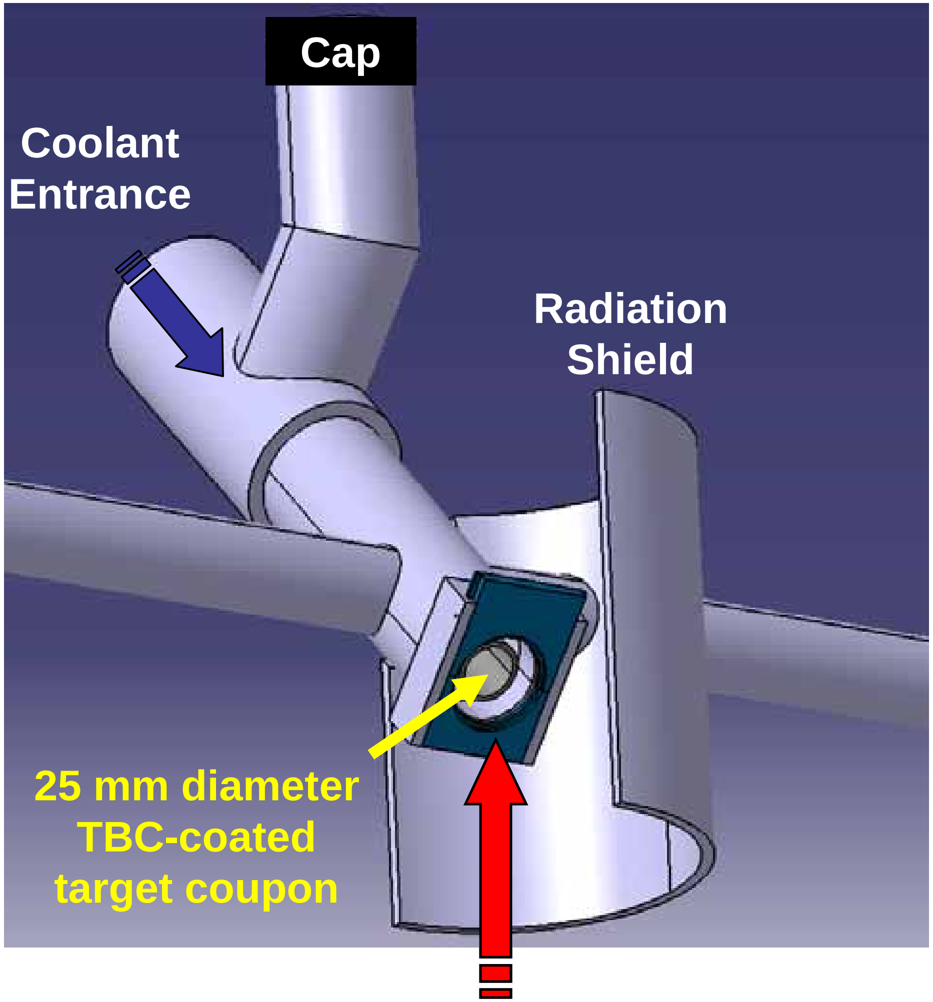
- Substantial surface temperature differences on biomass particles
- Data indicate leading and trailing edge temperatures and hence reaction rates differ
- Differences decrease with decreasing size

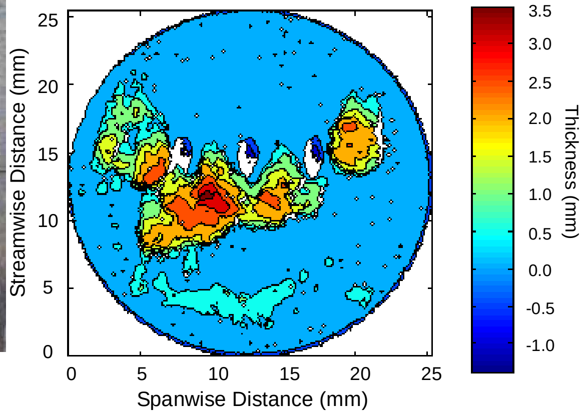
Temporal and Spatial Temperature Resolution

- Large radial temperature gradients measured and predicted in biomass particles
- Substantial surface temperature differences on biomass particles
- Models predict details of radial but not surface temperature differences.



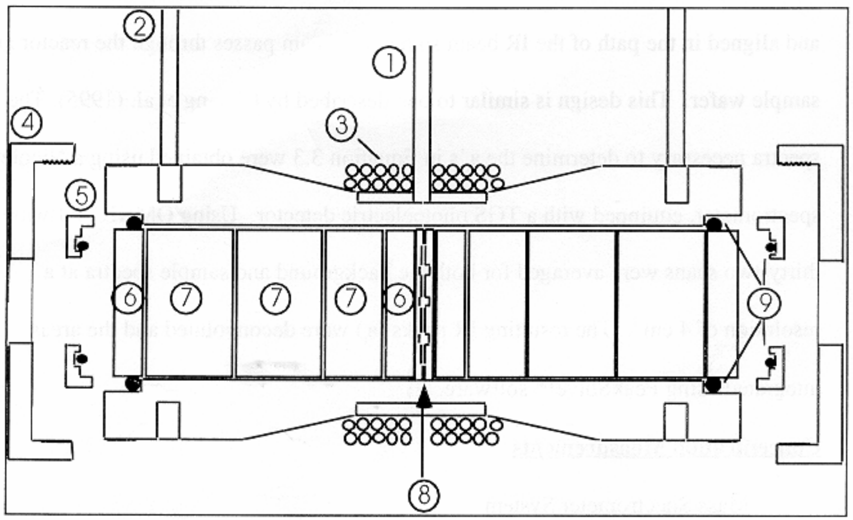
Synfuel Deposits on Gas Turbine Blades





- Small amounts of particles (< 5μm) pass through filters in IGCC system
- Particles hit 1st stage vanes and rotors at Mach 0.25
  - appreciable deposits in 1-2 years
- Lab reproduces deposition in 1-4 hours
- Configurations include:
  - Backside impingement cooling
  - Film cooling holes

Biomass Influence on SCR Performance

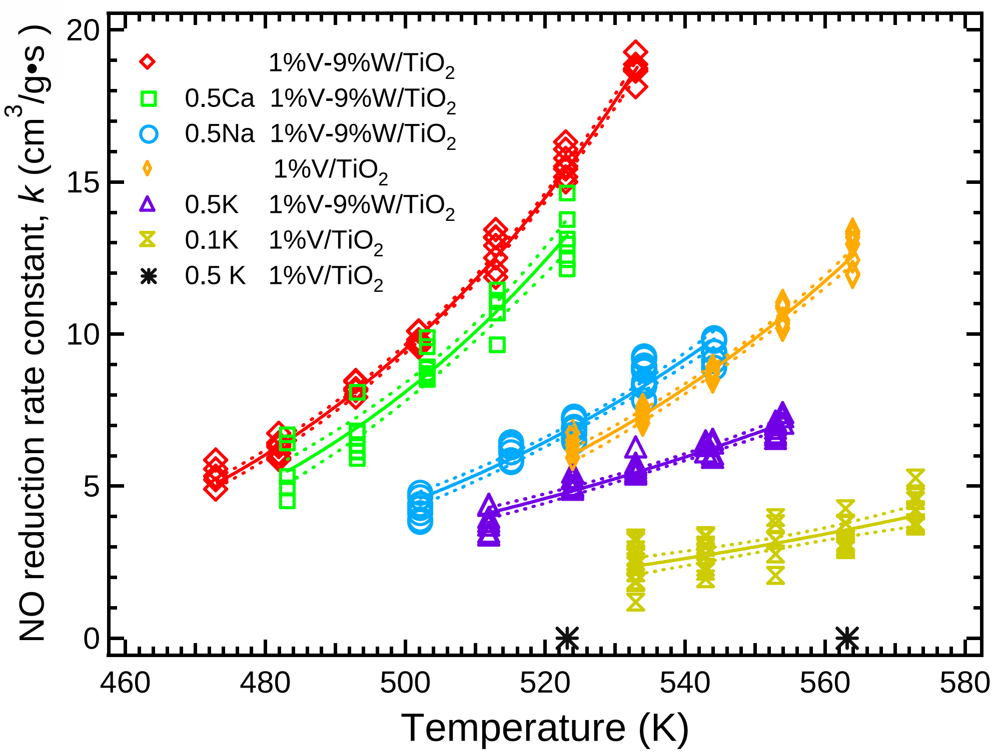


In Situ FTIR Surface Spectroscopy Lab

- Quantifies surface species and coverage
- Couples with mass spectrometer to provide mechanistic and rate data
- Complements systems for analyzing commercially exposed systems

Both Poisons and Enhancers in Flue Gas

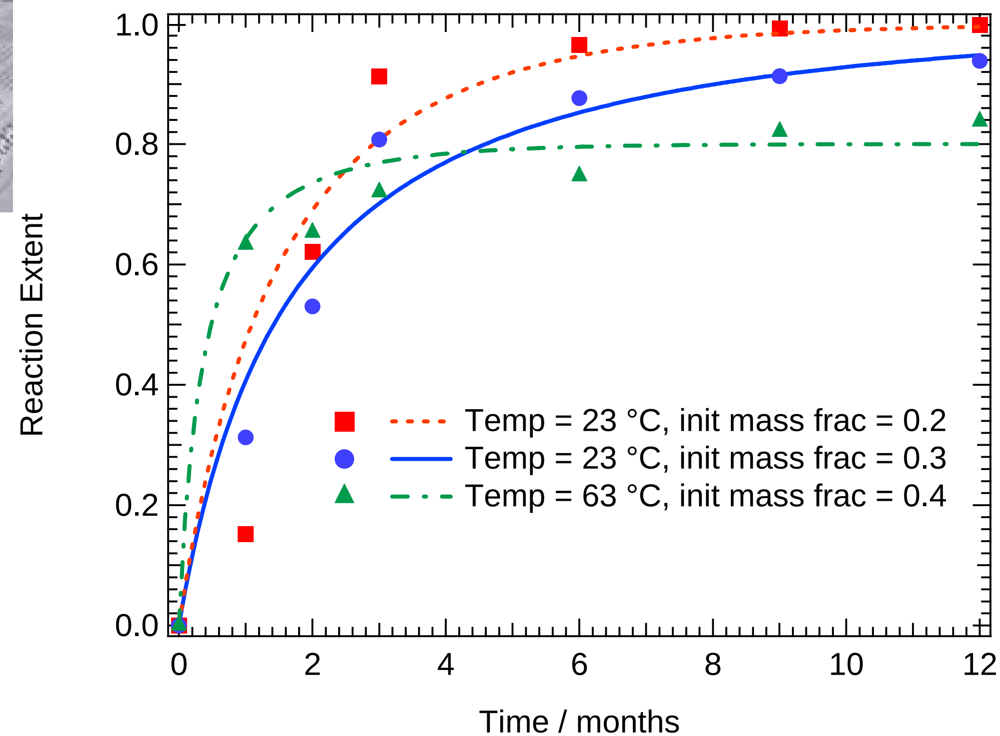
- Catalyst sulfation uniformly results in increased activity
- Alkali metals strong poisons
- Mechanistic information uncovered
- Quantitative model of poisoning impacts



Biomass & Coal Fly Ash Behavior in Concrete

New Laboratory Facilities for Concrete Analyses

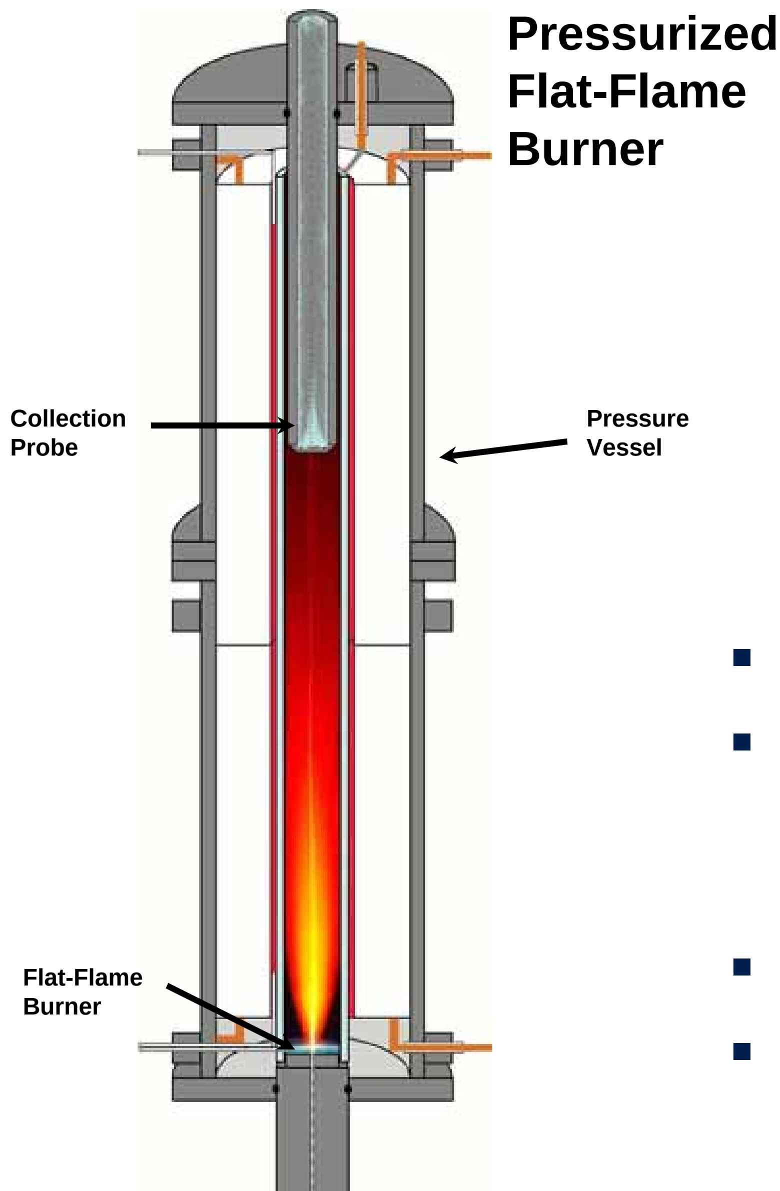
- Quantifies traditional concrete performance (ASTM)
- Quantifies pozzolanic reaction rates
- Quantifies alkali-silica reactions

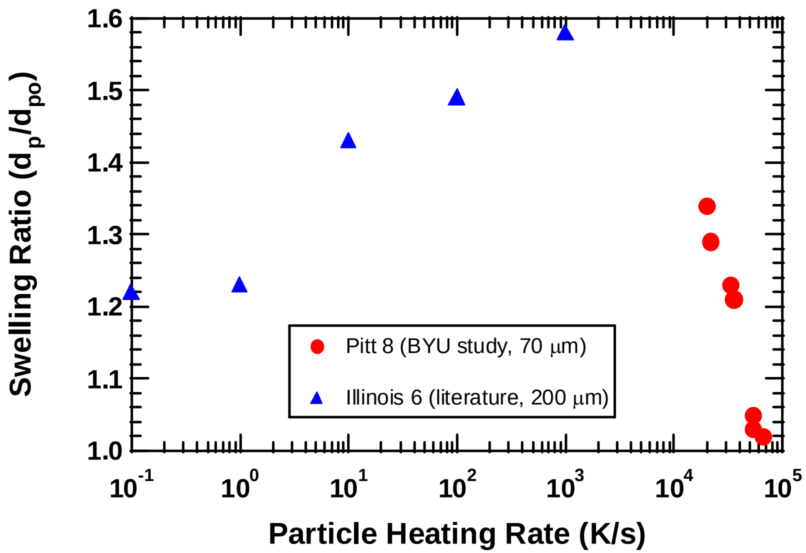


Comprehensive Data and Models

- Biomass fly ash performance changes comparable to coal fly ash
- Biomass fly ash pozzolanic reaction changes comparable to or better than coal and much better than no fly ash
- Biomass fly ash ASR changes comparable to or better than coal and much better than no fly ash
- Actively working with ASTM on standards

Coal Gasification Kinetics & Soot Formation





- Residence times of 12-500 ms
- 6-inch ID Vessel capable of 30 atm
  - All required systems proven at pressures of up to 15 atm
- Heating rates of up to ~10^5 K
- Temperatures to 1500 K

Pyrolysis Kinetics of Kerogen (Oil Shale)

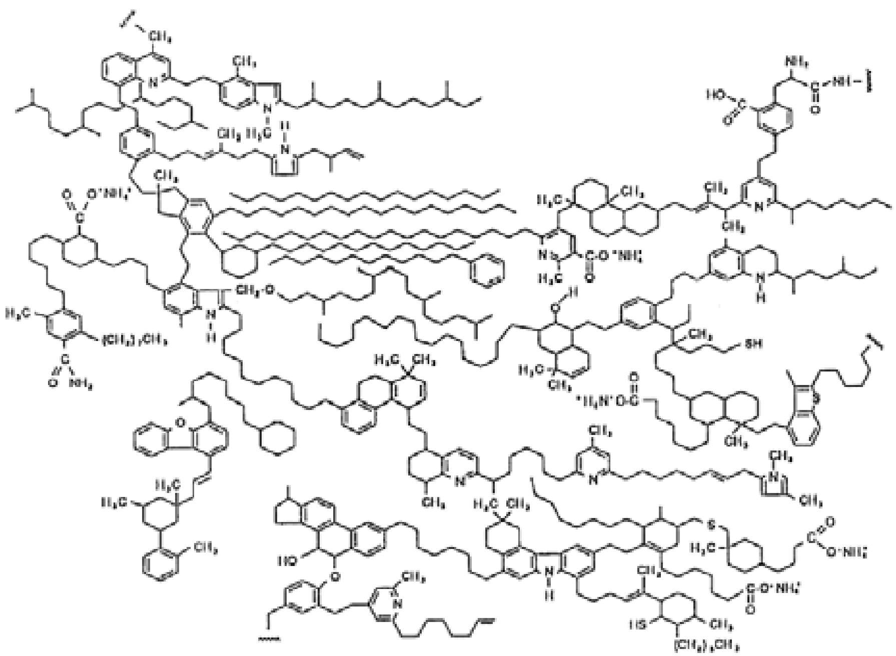
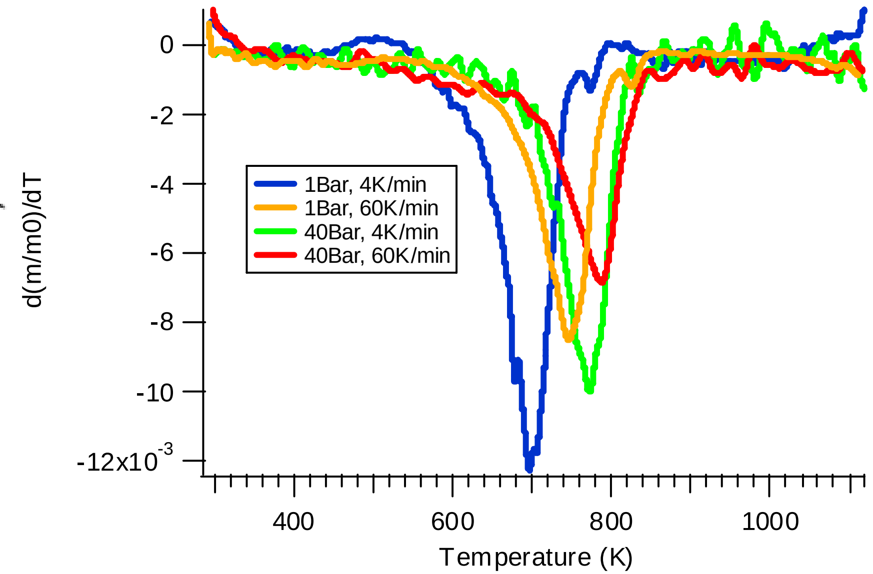
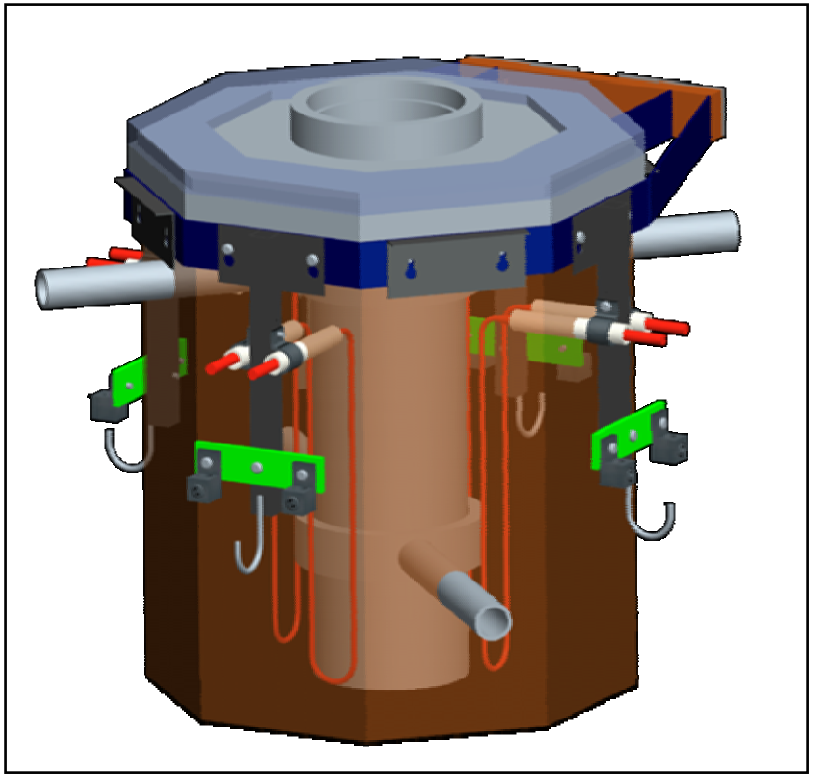


Figure 1. Siskin's model of organic material in Green River Oil Sale.*

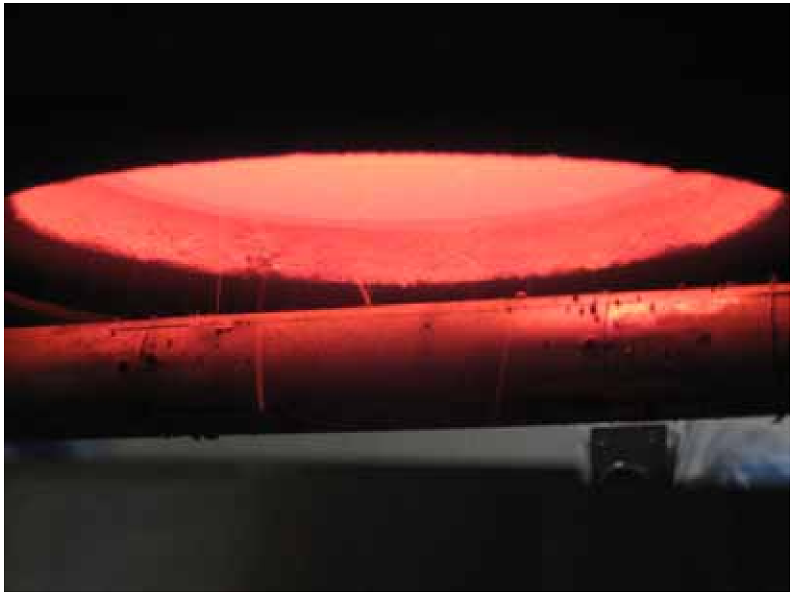


- **Pressurized TGA pyrolysis**
  - **Up to 100 bar, 1200°C**
  - **4 to 60 K/min**
- **Kinetics of kerogen and bitumen pyrolysis**
- **FTIR analysis of gases**
- **Obtaining GCMS system**

Ash Deposition Rate and Properties



One of Seven Sections in the Heated Multi-fuel Reactor

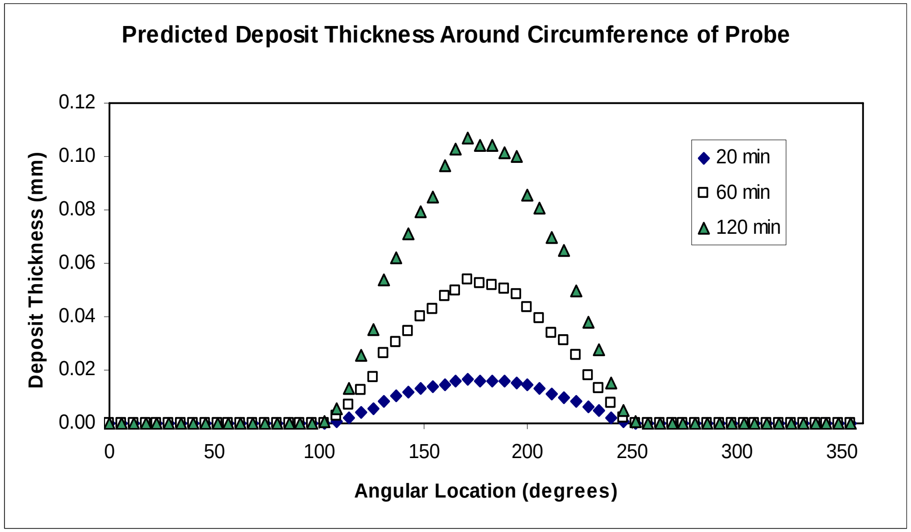


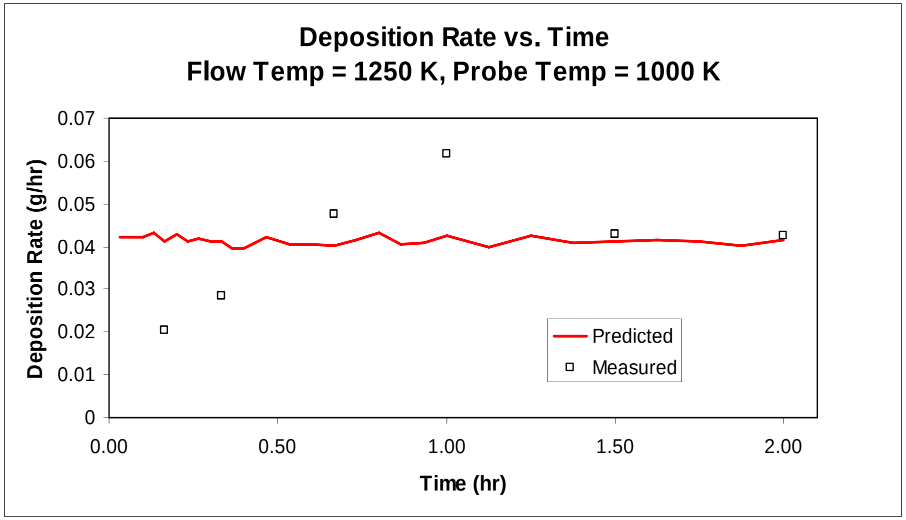
Deposition tube collecting deposit at reactor outlet

Measuring

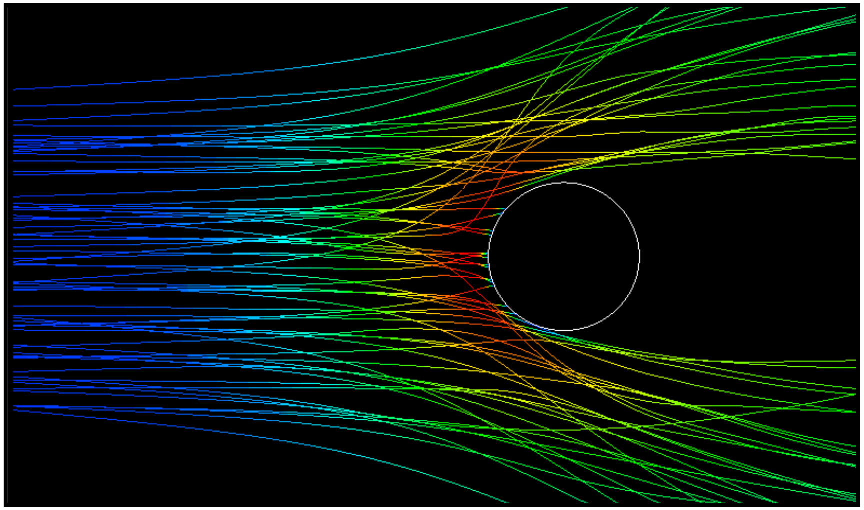
- Deposition rate (mass)
- Deposit emittance (FTIR)
- Tube surface temperature
- Deposit surface temperature
- Heat flux and thermal conductivity

Ash Deposition Rate and Properties





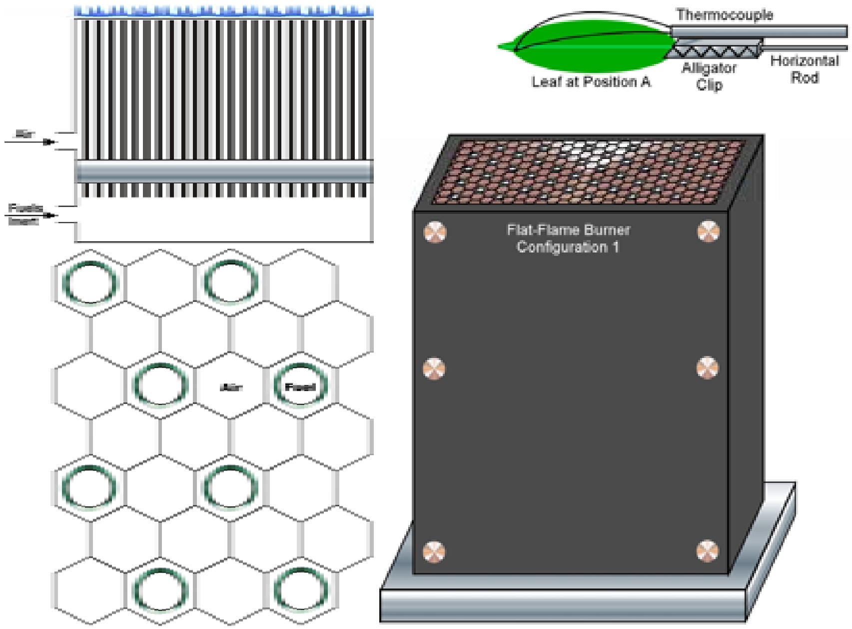
Deposit thickness and deposition rate

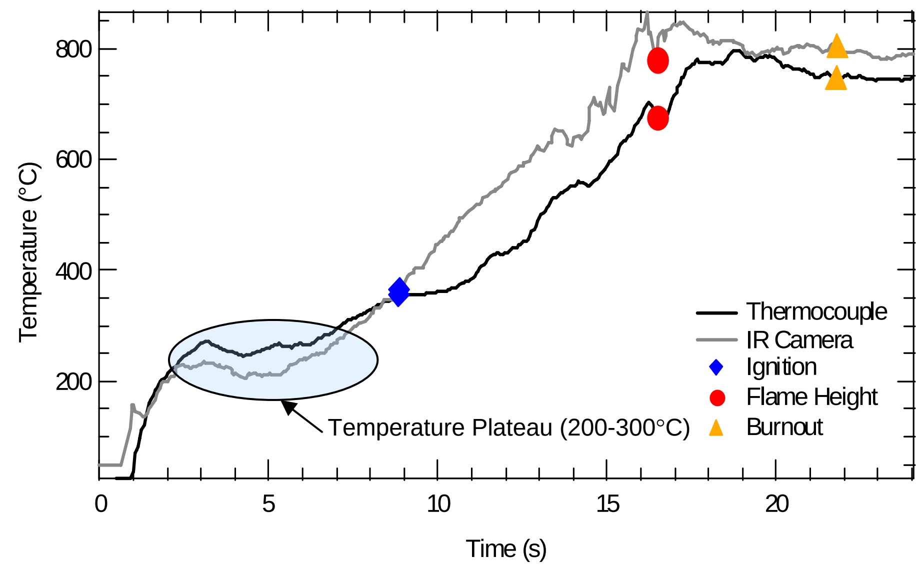


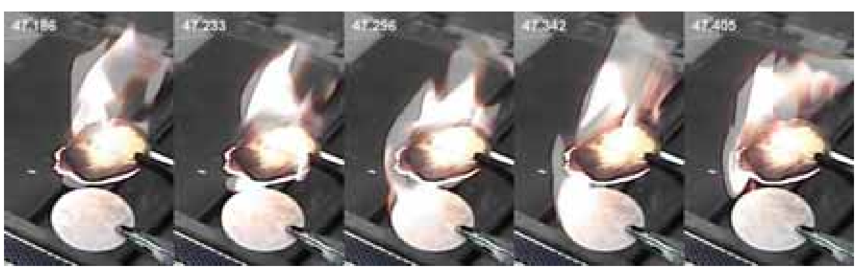
Model of Particle Trajectories and Deposition Rate

- Particle capture model based on particle energy and surface energy absorption (Lokare and Baxter)
- Random walk model comparison of deposition rate
- Deposition rate measurements as a function of time.

Combustion Characteristics of Live Foliage

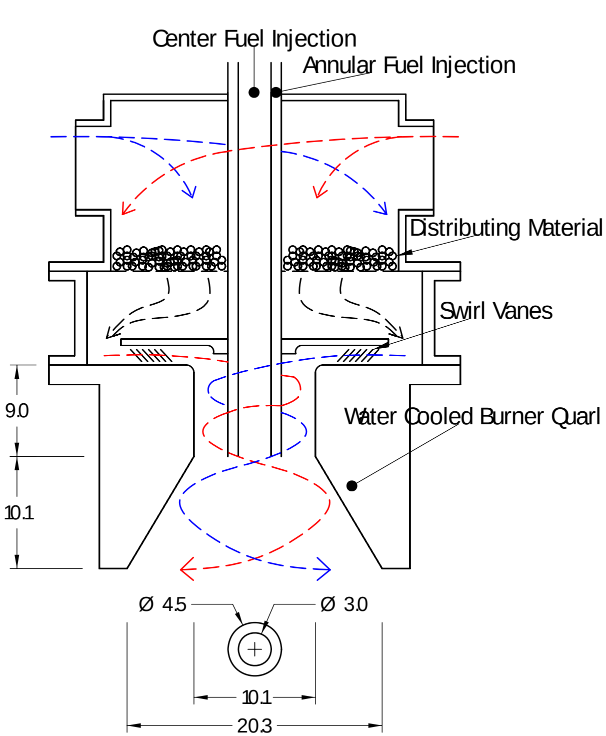






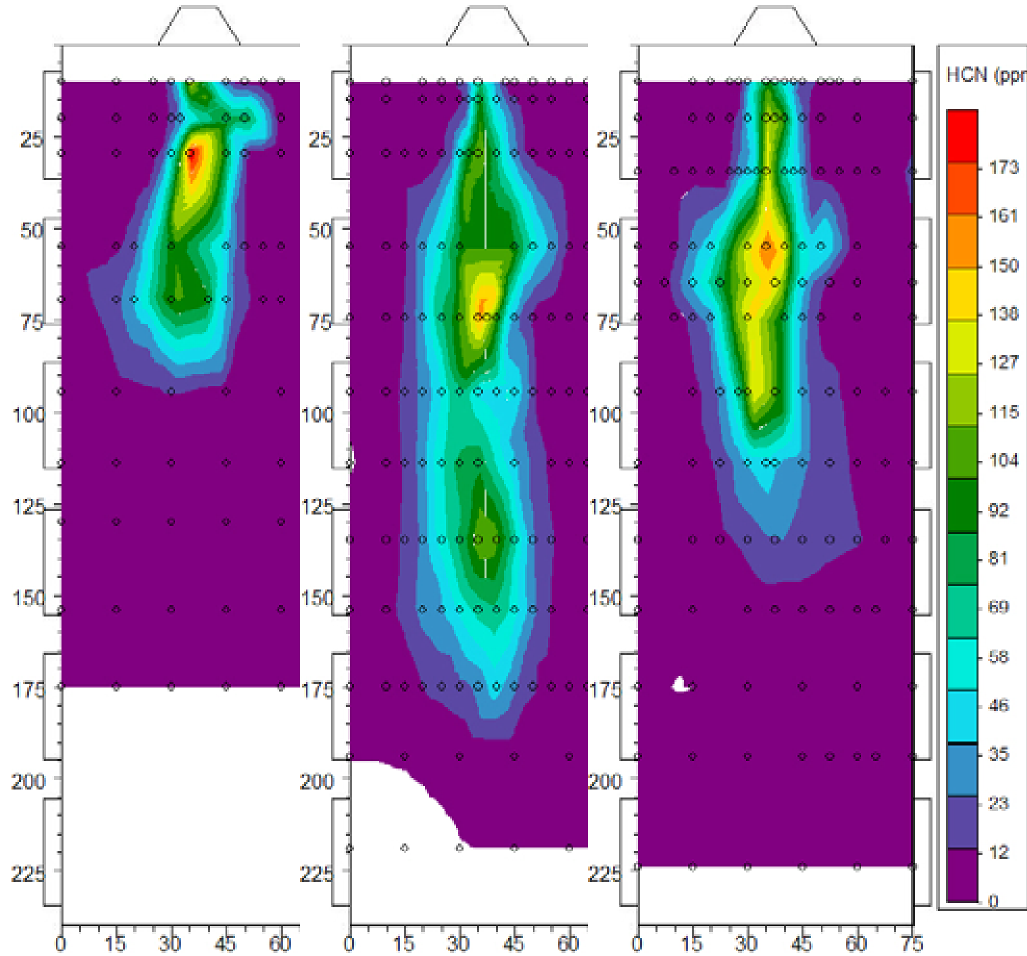
- **Flat Flame burner on wheels**
- **1200 K, 10 mol% O_2**
- **Leaf suspended on balance**
- **Imbedded thermocouple**
- **IR camera**
- **Obtaining GCMS system**
- **Studying effects of:**
  - **Moisture content**
  - **Leaf-to-leaf fire spread**
  - **Species from UT, CA, and FL**

Coal Biomass Co-firing – Nitrogen Evolution



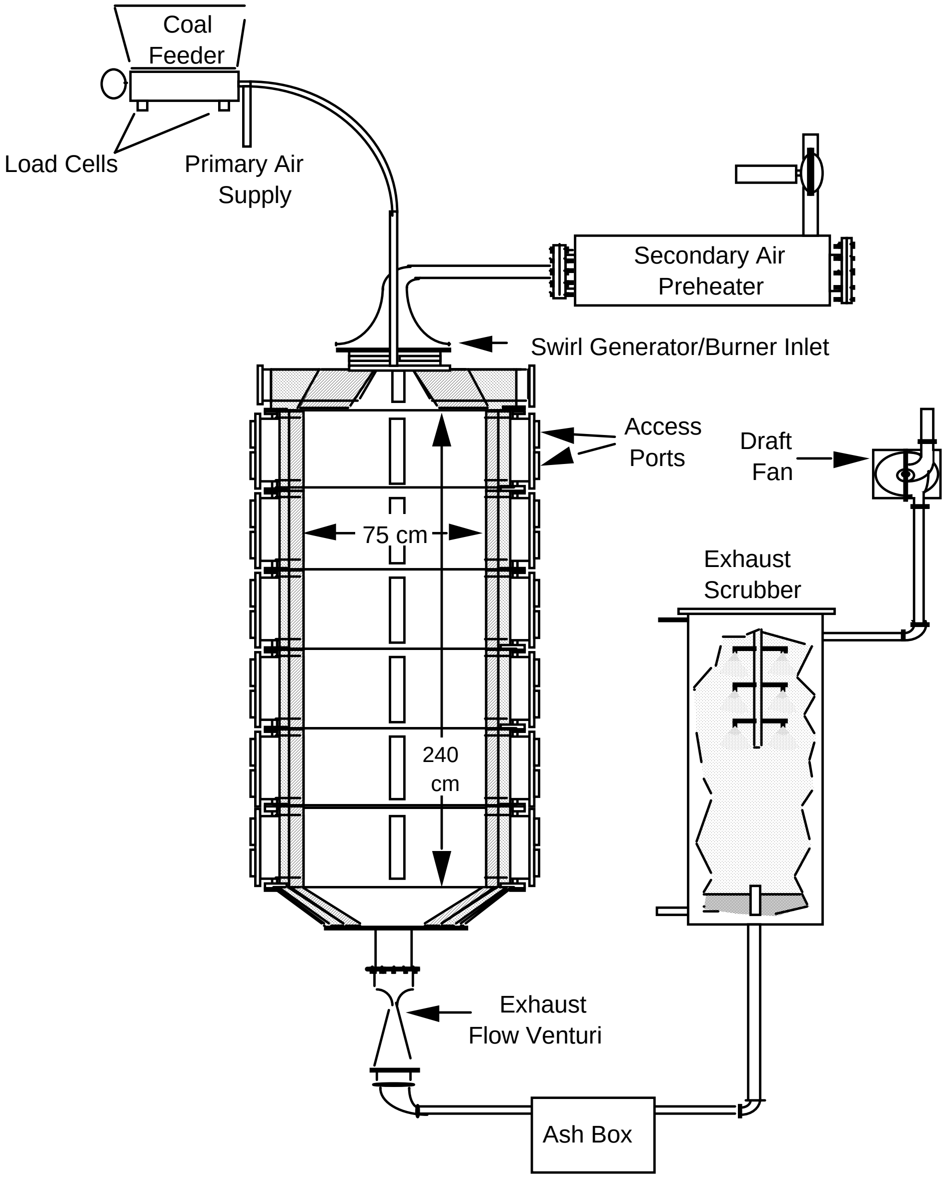
Dual Fuel Injection – Coal and Biomass (Straw and Sawdust)

- Detailed species maps including O_2, CO, CO_2, NO, NH_3, HCN, C_2H_2 were collected
- Data include coal, straw, coal/straw, fine straw, saw dust
- Comparison and discussion of modeling approach



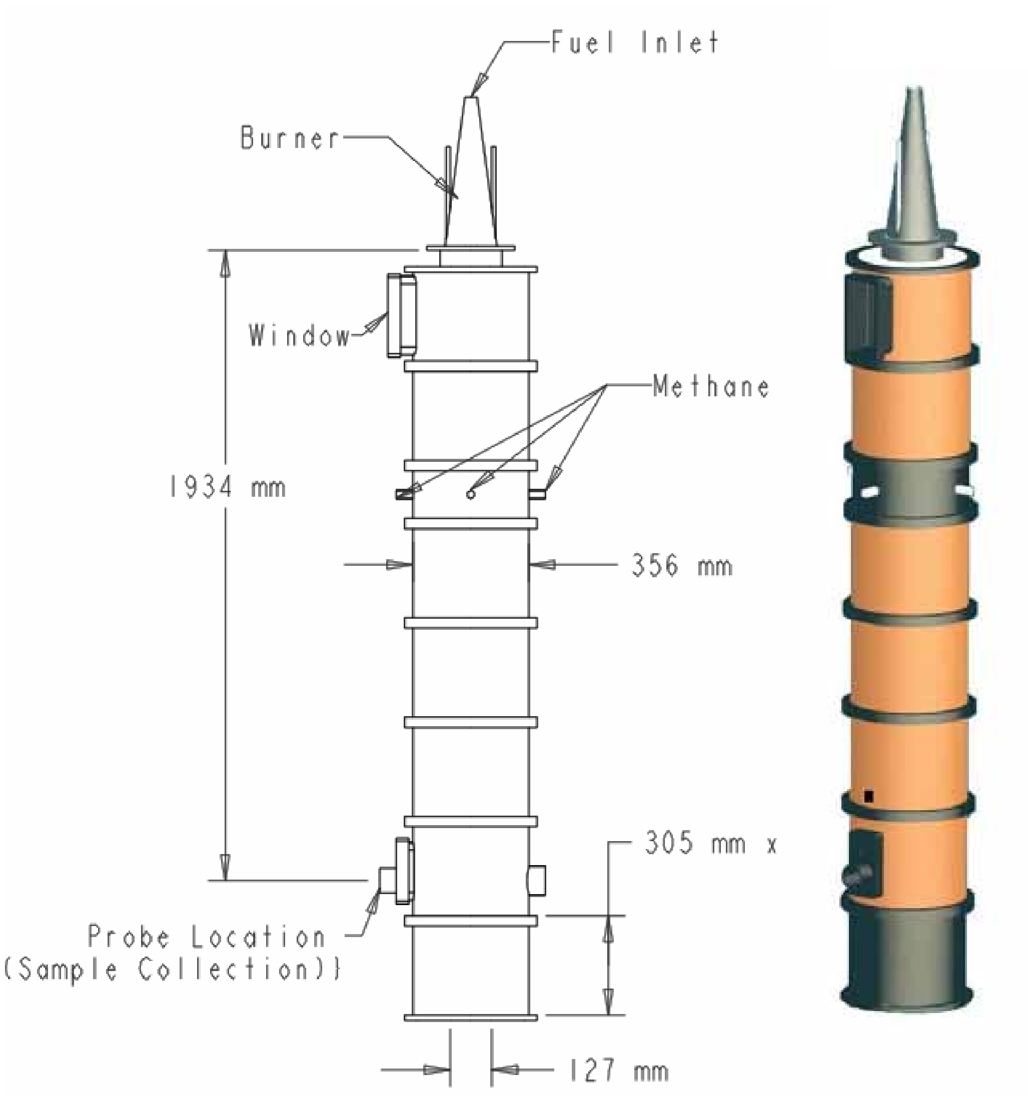
HCN maps for coal (left), straw (middle) and co-firing (left)

ACERC Combustion Facilities



Burner Flow Reactor – Realistic burner fluid flow, 25 kg/hr coal

ACERC Combustion Facilities



Premixed MFR

Premixed down-fired, 150mm diameter

2m length

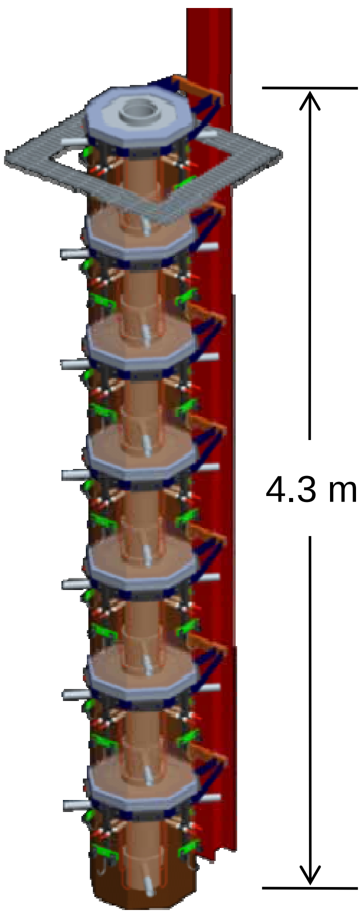
Unheated

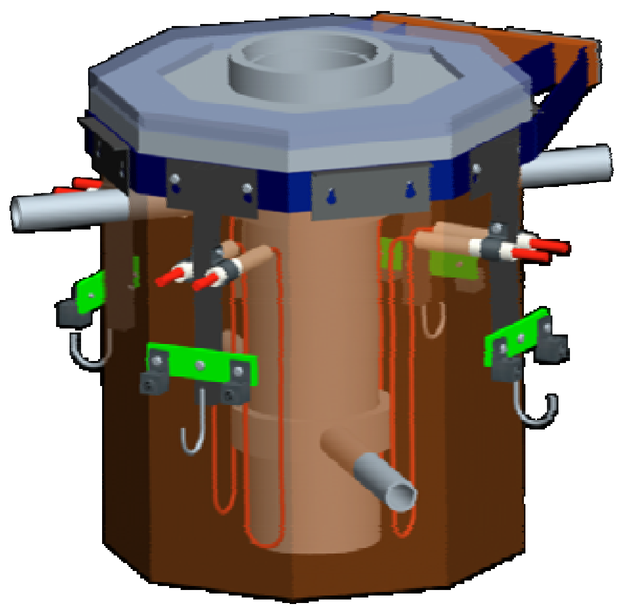
1 kg/hr coal feed

1 Sec residence time

ACERC Combustion Facilities

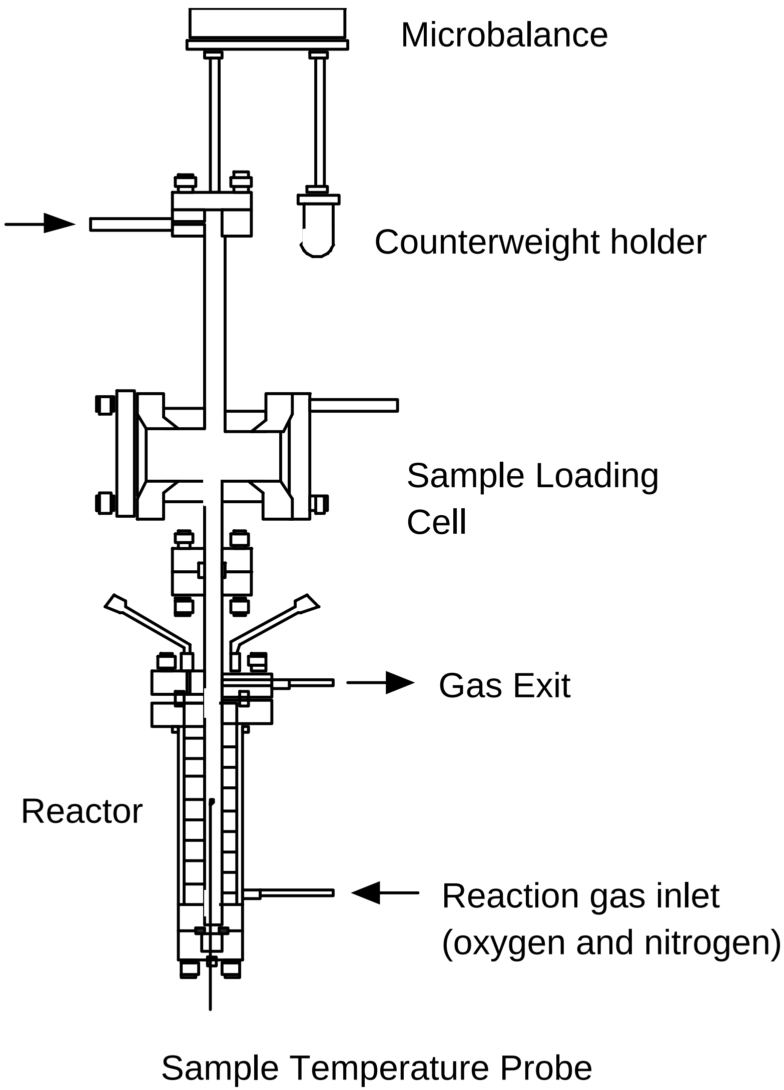
- Multi Fuel Reactor – Down-fired, Heated walls, 150 mm diameter, 4.3 m length, 1-2 kg/hr





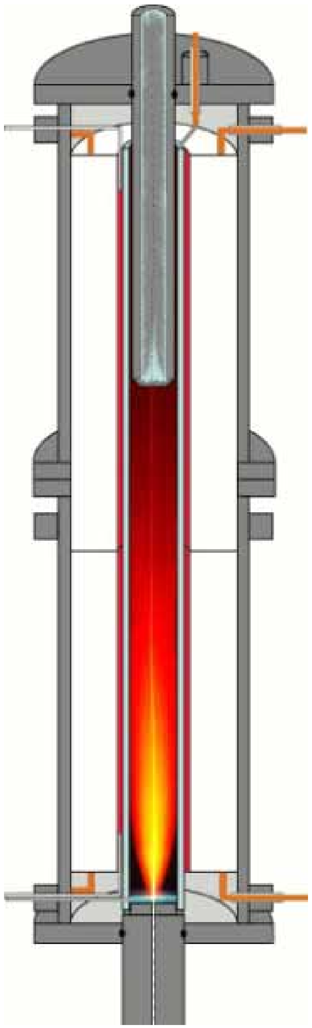
ACERC Combustion Facilities

High Pressure TGA



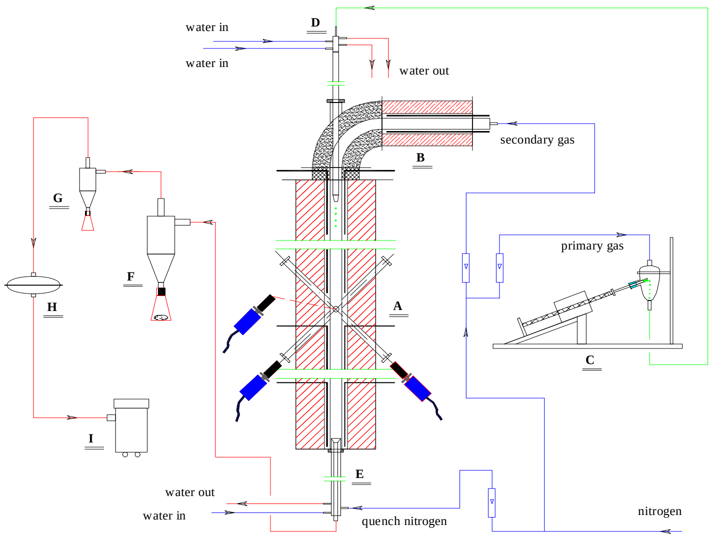
ACERC Combustion Facilities

High Pressure Flat Flame Burner

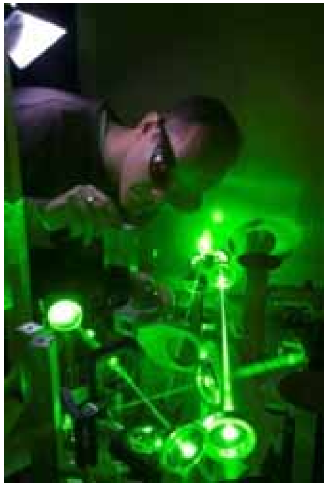


- Orthogonal View Reactor – 1.8 m length, heated walls
- Flat Flame Burner – Cooled collection probe, FTIR analysis
- High Pressure Flat Flame Burner
- High Pressure FTIR –
- High Pressure TGA –
- Particle deposition burner –
- Gas analyzers, Air compressor, Coal Pulverizer, FTIR, SEMs
- Chemistry Lab

Orthogonal View Reactor



Laser Particle Levitation



Technologies

Current Technologies and Tools Under Development

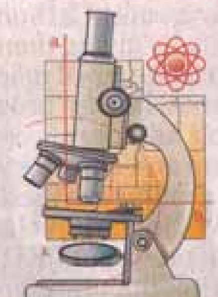
- The CPD Model
- Oxy-fuel Kinetic Model with Modified CPD
- Chemical Fractionation for inorganic materials
- 3-D Imaging of particles during combustion
- RGB Two-color pyrometry
- In-situ ash thermal properties

Current Technologies and Tools Under Development

Science targets coal impact

Y. professor working to reduce carbon footprint and warming

By Joe Bauman
Deseret Morning News



UTAH SCIENTIFIC

Brigham Young University scientist Larry Baxter concedes that carbon sequestration will make electricity more expensive and power plants less efficient. Yet because of global warming concerns, the technology may be required. If it is, he may have developed better sequestration technology.

In addition, he and his team at the Provo university have improved coal gasification techniques, another way to reduce humanity's carbon footprint. A professor of chemical engineering at BYU, he earlier worked with Sandia National Laboratories.

Interest in both sequestration and coal gasification stems from concern about global warming. Burning carbon fossil fuels, particularly coal, releases a tremendous amount of carbon dioxide pollution, the "greenhouse gas" most blamed for global warming. Also, the pollution itself is harmful, with or without warming.

JAREN WILKEY, BYU

Brigham Young University scientist Larry Baxter, shown at the school's lab in early February, may have developed better sequestration technology.

Please see **COAL** *on B2*

ACERC Invitation

- We welcome new projects and collaborations
- We hope to partner with industry and government to identify and solve key research issues
- Our goal is to produce:

1. Useful new information (publications)
2. Bright and well prepared students

Thank You