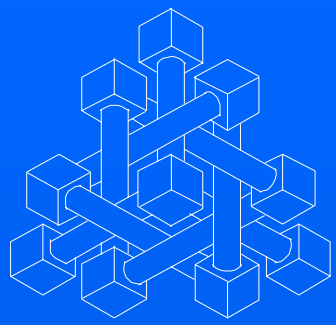


SOUTHERN RESEARCH

INSTITUTE

Oxy-Fired CO_2 Recycle for Application to Direct CO_2 Capture from Coal-Fired Power Plants

Thomas K. Gale, Power Systems Research Group

Southern Research Institute

- Leading contract research organization developing technology in Life Sciences, Engineering, Energy, and the Environment
- Not-For-Profit 501 (c) (3)
- More than 550 employees
- Corporate headquarters located in Birmingham, Alabama
- Power Systems and Environmental Research (PSER) Depart.
  - Presence at the Power Systems Development Facility (PSDF)
  - Hot-Gas Cleanup, Multi-Component Syngas-Treatment (MCST) System
  - Pilot-Scale and Laboratory-Scale Combustion Facilities
  - Catalyst Development and Testing Laboratories
  - Biomass Fuel Studies, combustion, gasification, milling, etc.
  - Pollution Control Solution Provider
    - Direct Mercury Oxidation Technologies for Hg Emission Mitigation
    - Electrostatic Precipitator, Baghouse, Scrubber Evaluations
    - SCR Studies, Analytical Services, and Measurements

Funding

- National Energy Technology Laboratory (NETL)
  - **$864,000.00**
- Southern Research Institute
  - $150,000.00
- DTE Energy
  - $75,000.00
- MAXON Corporation
  - $35,000.00
- BOC Gases (*Linde* Gas)
  - $109,000.00
- DOOSAN Babcock Energy Limited
  - $100,000.00
- Southern Company
  - $37,000.00
- **Total Funding**
  - **1,370,000.00**

Project Performance Dates

- Finished Retrofit Preliminary Design: January 2007
- Finished Detailed Retrofit Design: October 2008
- Finished Physical Retrofit, including duct work, fans, oxygen tank, computer system, valves, switches, wiring, and burner: March 2009
- Finish Programming and BMS Panel Construction , Programming, and wiring: May 20, 2009.
- Shakedown Test: Last week in May, 2009
- Performance of Test Matrix Complete June 2009
- Modeling Runs Complete by September 2009
- Final Report October 2009

Project Participants

- National Energy Technology Laboratory (NETL)
  - Management of the project
- Southern Research Institute
  - Overall technical coordination, pilot-scale testing, reporting.
- DTE Energy
  - Engineering support / preparation for demonstration in future.
- MAXON Corporation
  - Burner design, manufacture, and testing, and technical support
- BOC Gases (*Linde* Gas)
  - Provided an oxygen skid, safety training, and will run the CFD model
- Reaction Engineering International (REI)
  - CFD model modification for the pilot facility.
- CORR Systems
  - Design of recycle loop, modifications, and control systems
- DOOSAN Babcock Energy Limited
  - Support CRF retrofit, technical support, and provide recommendations
- Southern Company
  - Supporting the testing effort in the Southern Company/Southern Research pilot-scale facility

Overall Project Objectives

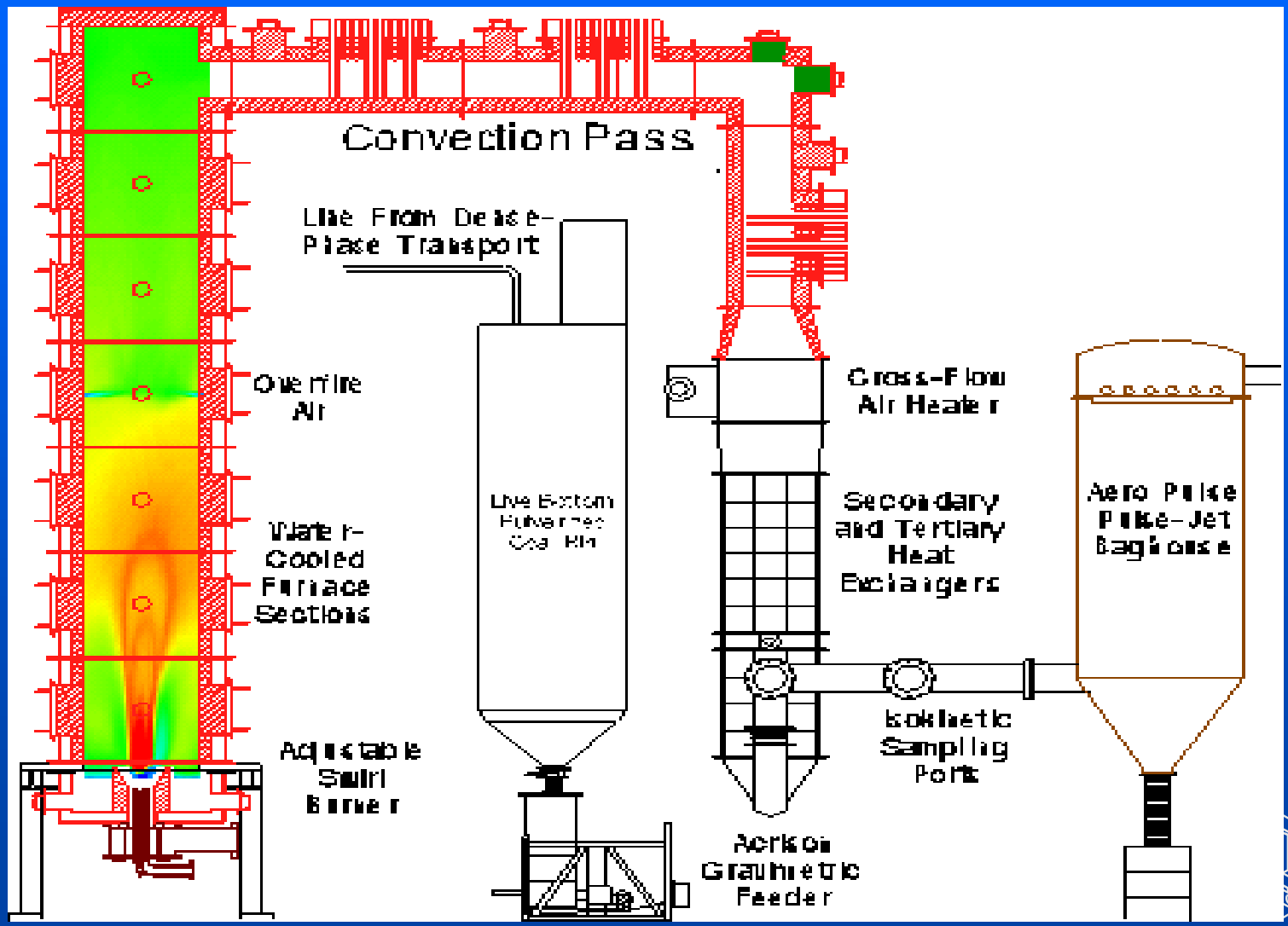
The objectives of this project are to investigate, develop, optimize, and model oxygen-fired CO_2 recycle technology for coal-fired utility boilers by retrofitting the existing Southern Company/Southern Research 1 MW pilot-scale test facility, utilizing an advanced oxy-fired coal burner, measuring the operation and output responses to adjustable operating parameters, and comparing these responses with CFD modeling results.

Fundamental Science Driving Oxy-Fired Technology

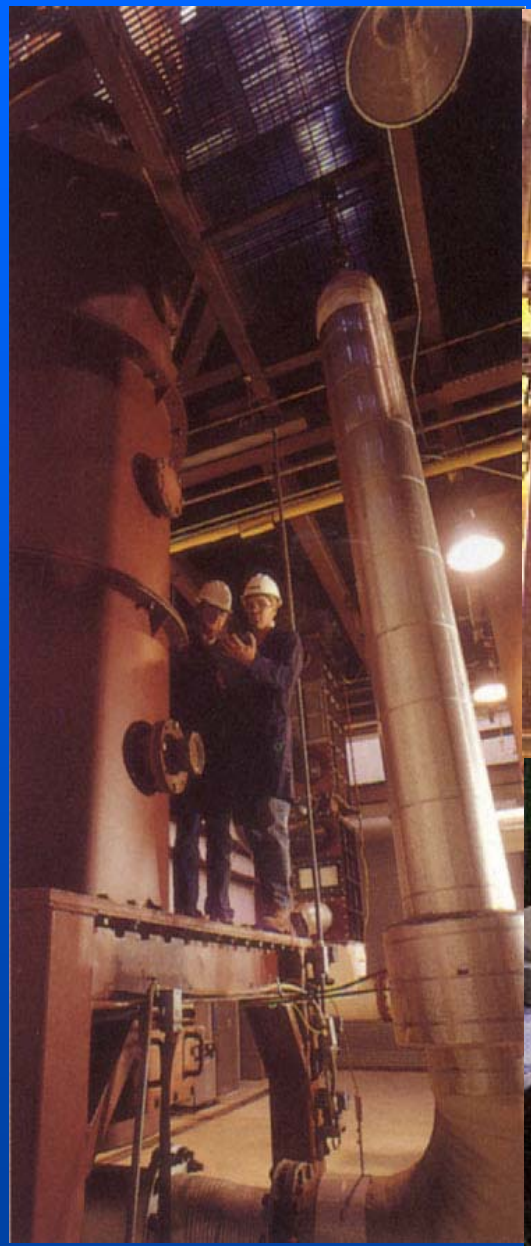
- ~75% of Coal-Fired Flue Gas is N_2
- Oxy-Fired Flue Gas is ~1/4 the Volume
- Flue-gas recycle is required for existing plants
  - To avoid excessive flame temperatures
  - Maintain flow and heat-transfer requirements in the furnace and convective sections.
- Advanced Oxygen Burners
  - Allow the flame shape and heat release to be controlled.
  - Provide a stable attached flame.

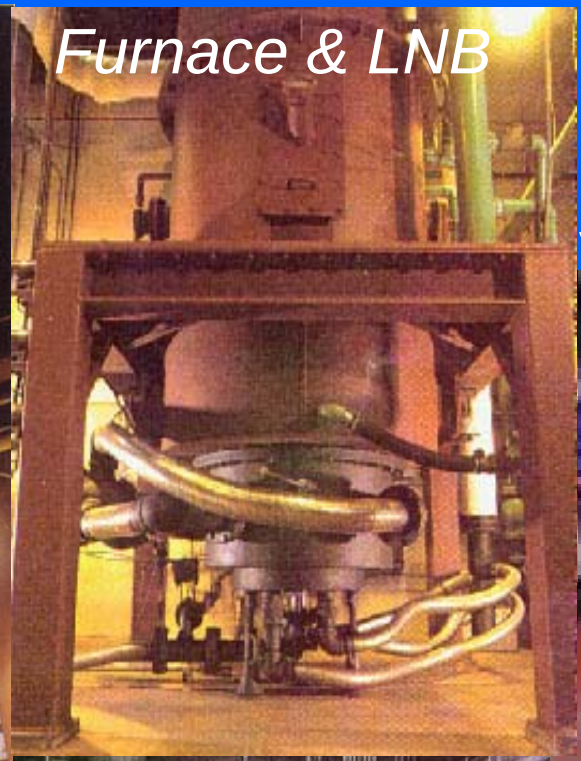
How the Innovative Oxy-Burner Design Works

Combustion Research Facility



Combustion Research Facility



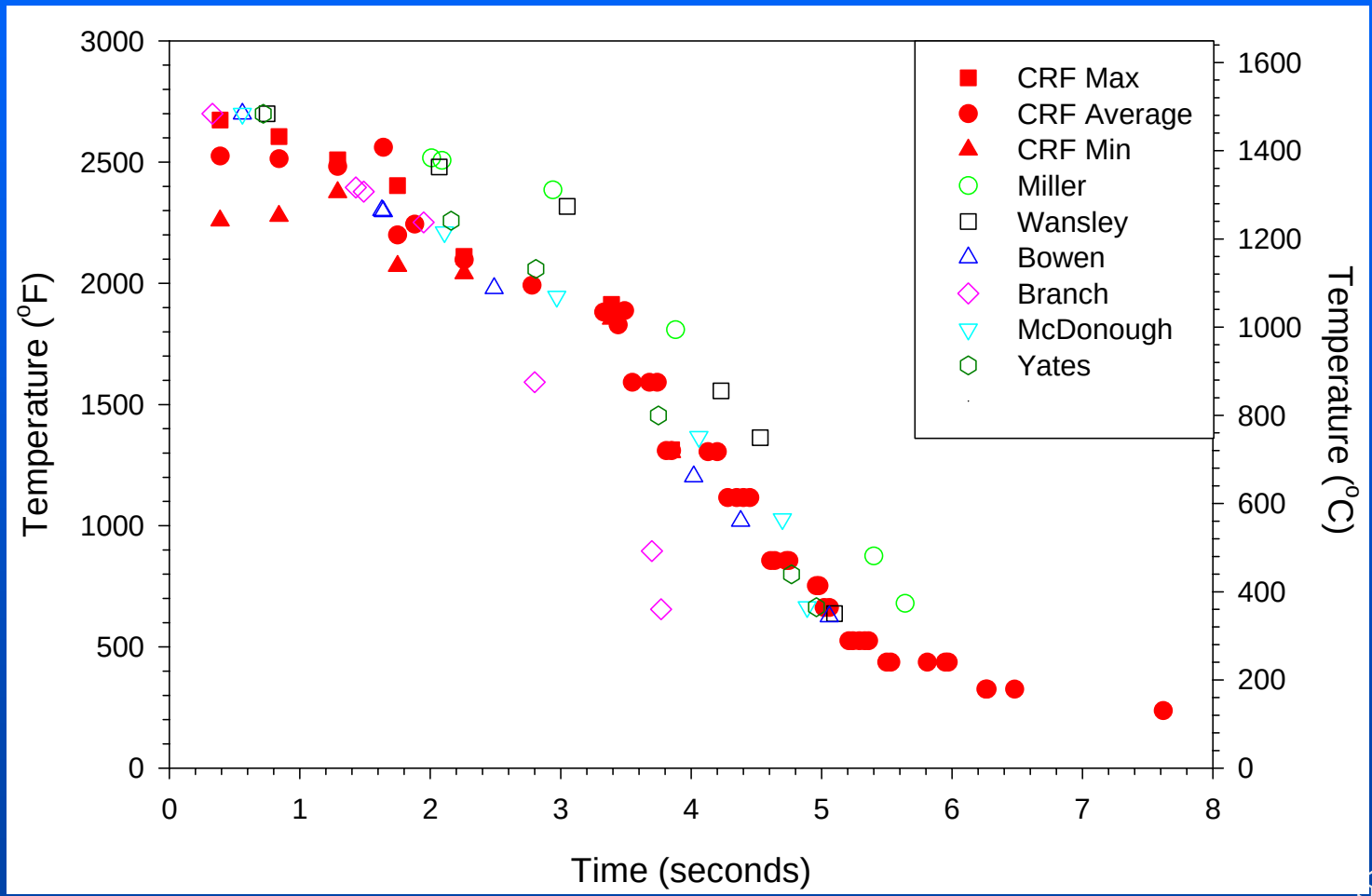


Furnace & LNB

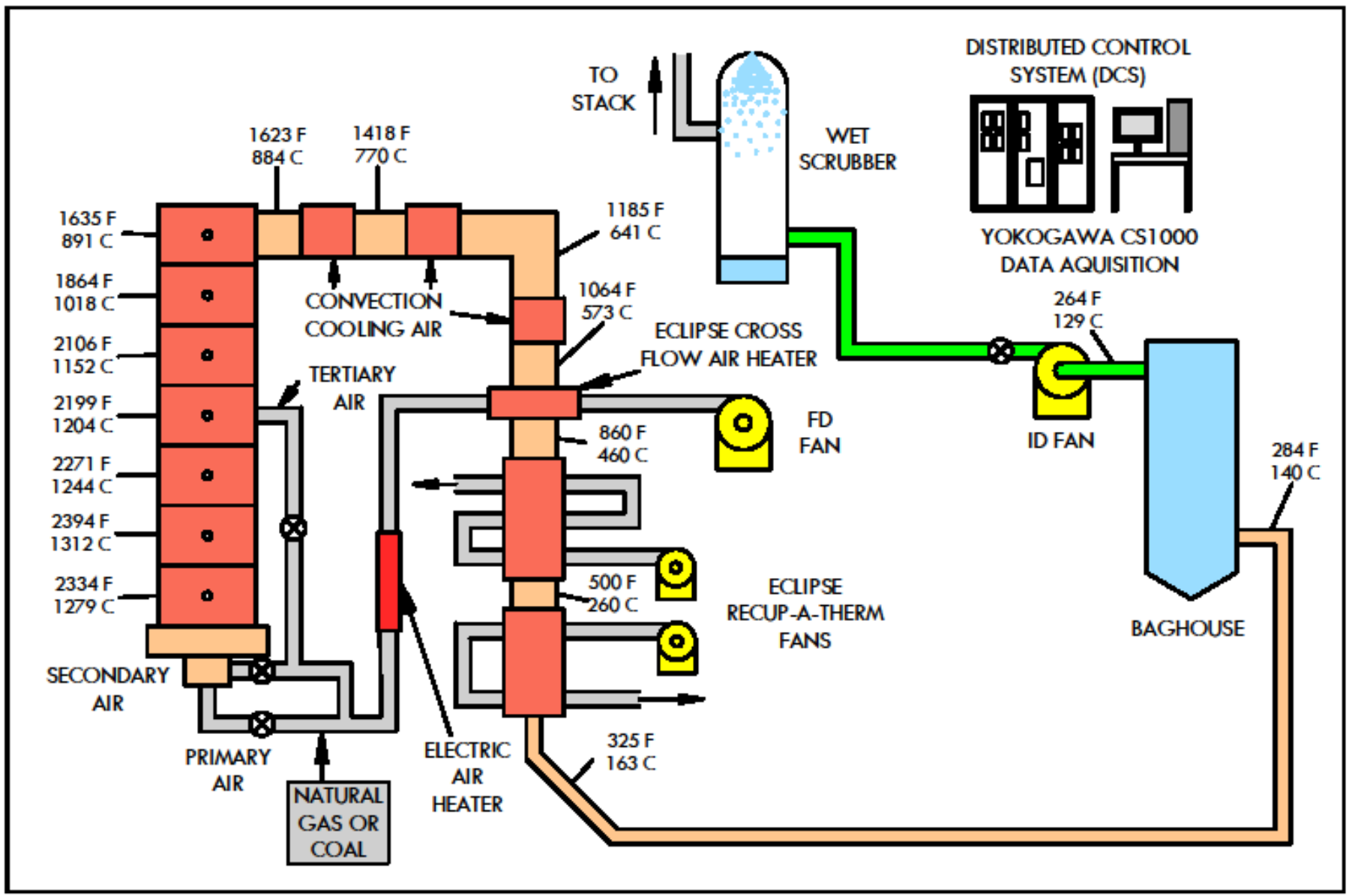
Control Room

Center Furnace Section Showing Overfire Air Ports

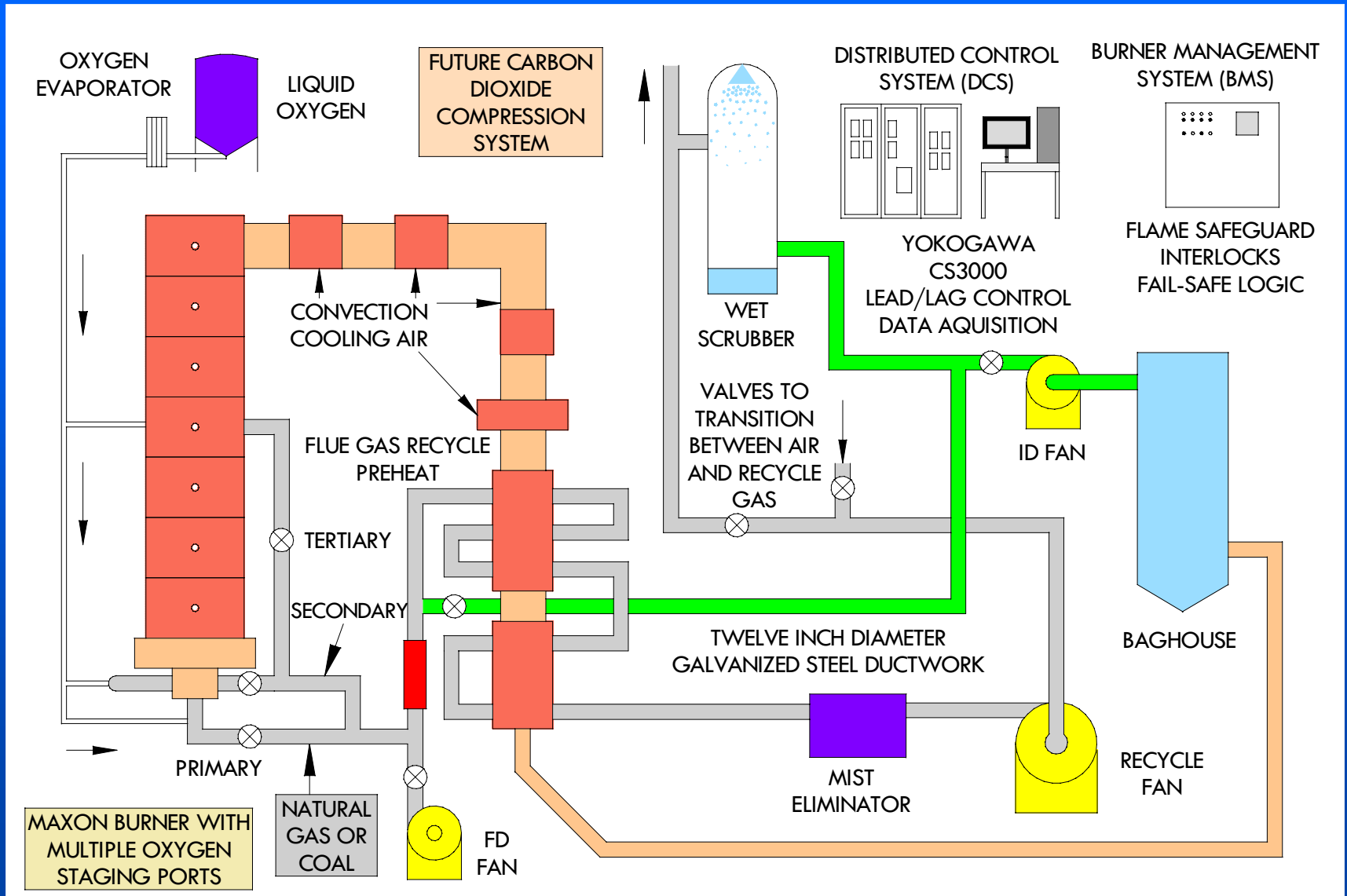
Temperature/Time Profile of the Combustion Research Facility



Original CRF Configuration



Retrofit CRF Configuration



Main Components of the Retrofit

- MAXON Oxy-Fired Burner
- Oxygen Skid and Piping System
- DCS (Distributed Control System) Hardware Updated to Yokogawa CS3000
- New data acquisition and control system and program to modulate the flow of oxygen and recycled flue gas.
- Burner Management System
- Recycle System
  - Recycle Fan
  - Ductwork, Valves, Thermocouples, Flow Meters
- Permanent Oxygen Tank, Tank Pad, and Spill Pad
- Safety Systems
  - Procedures relative to oxygen use
  - CO_2 and CO monitors and alarms/interlocks

Technical & Economic Advantages

- Oxy-burners maintain a stable attached flame and can light off without natural-gas assist.
- The ¼ volume oxy-fired flue gas is much less expensive to purify and compress for carbon sequestration.
- Recycling dry flue gas through PRB coal pulverizers eliminates concern of pulverizer fires.
- Burners and recycle rate can be tuned to achieve low cost operation (i.e., minimize recycle) and maximum heat transfer for a given boiler type and plant configuration.
- New Plants: Advanced Thermodynamic Cycles can recover some of the energy penalty associated with air separation.

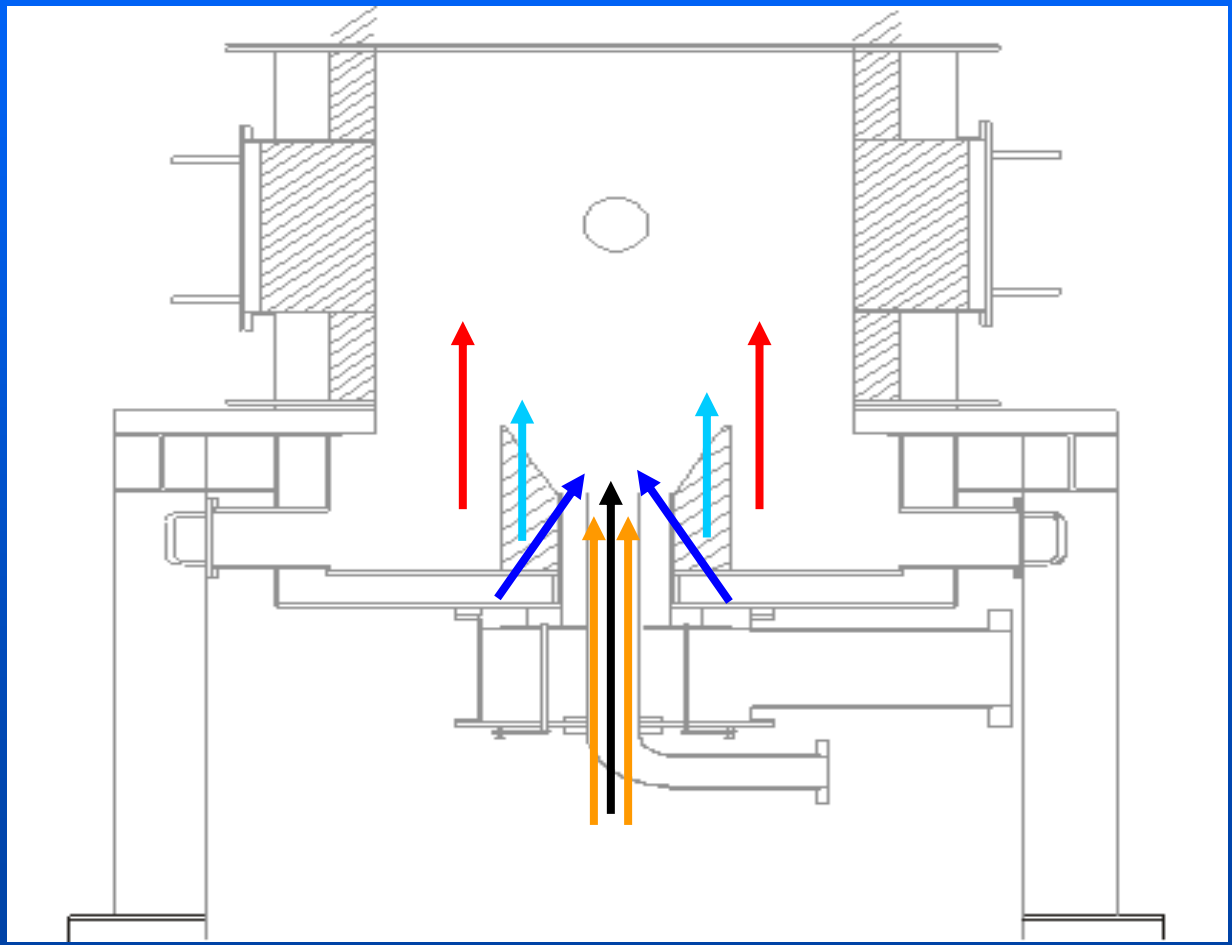
Technical & Economic Challenges

- Cost of retrofit is significant for existing plants.
- Energy penalty to produce oxygen is about 25%.
- Additional energy penalties come from purification of CO_2 and compression and sequestration.
- Concern about corrosion of low-temperature ductwork and equipment.

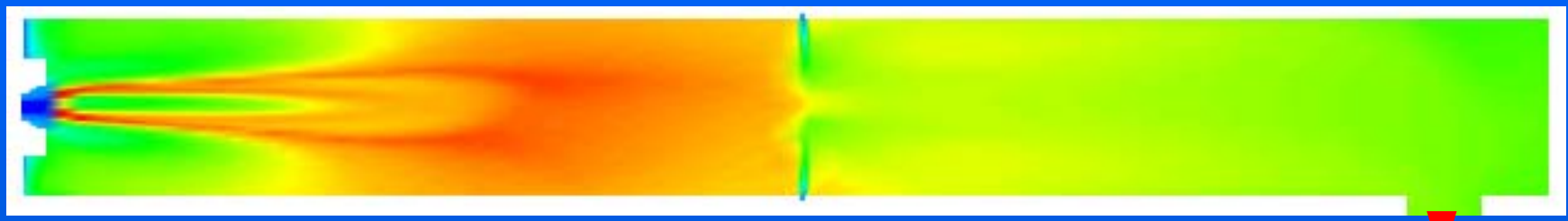
Progress and Current Status

- Physical retrofit is complete this month
- BMS Panel is the last component needed for the control system.
- Will have programming complete April 20th.
- Will perform shakedown tests end of April.
- Will complete test matrix by end of June.
- The burner has been tested and validated.
- The burner and CRF furnace have been modeled with CFD and results are favorable.

Oxy-Burner CFD Modeling by REI

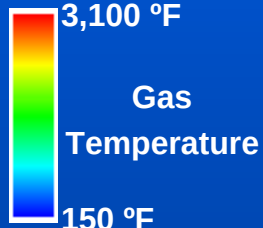


Standard Air-Blown Case

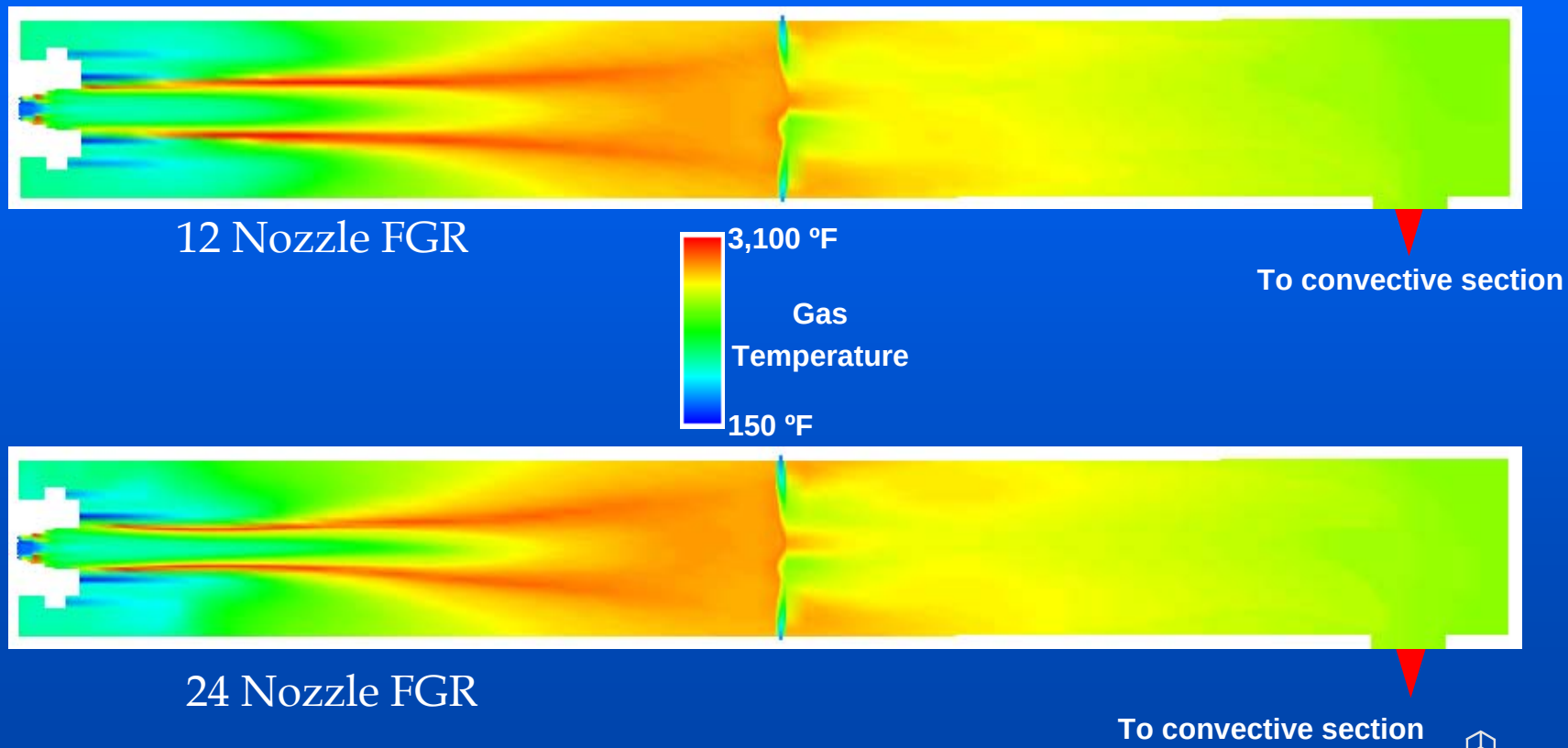


Air Blown

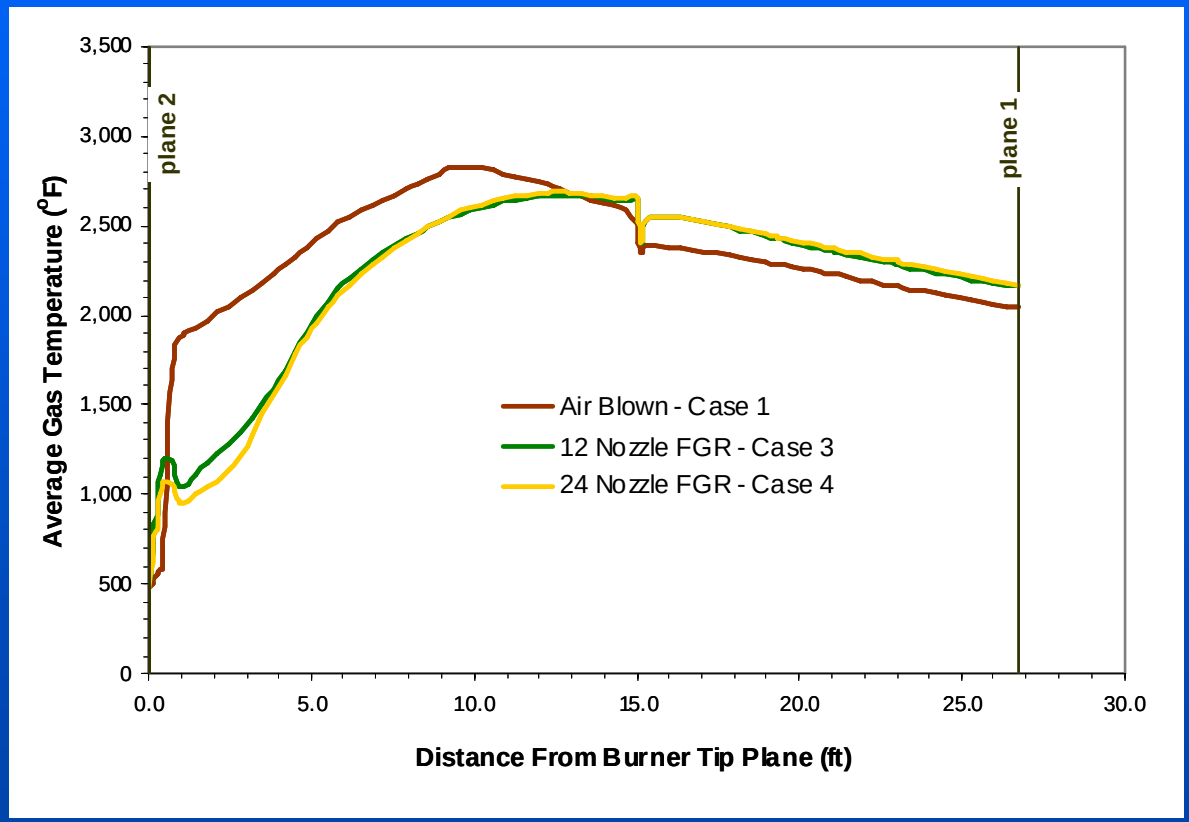
To convective section

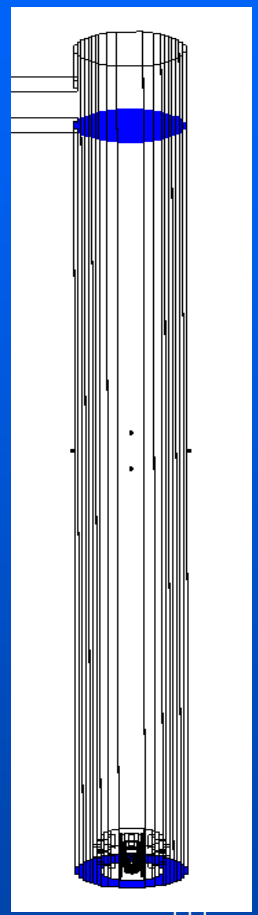


Oxy-Fired w/Flue-Gas Recycle Predictions

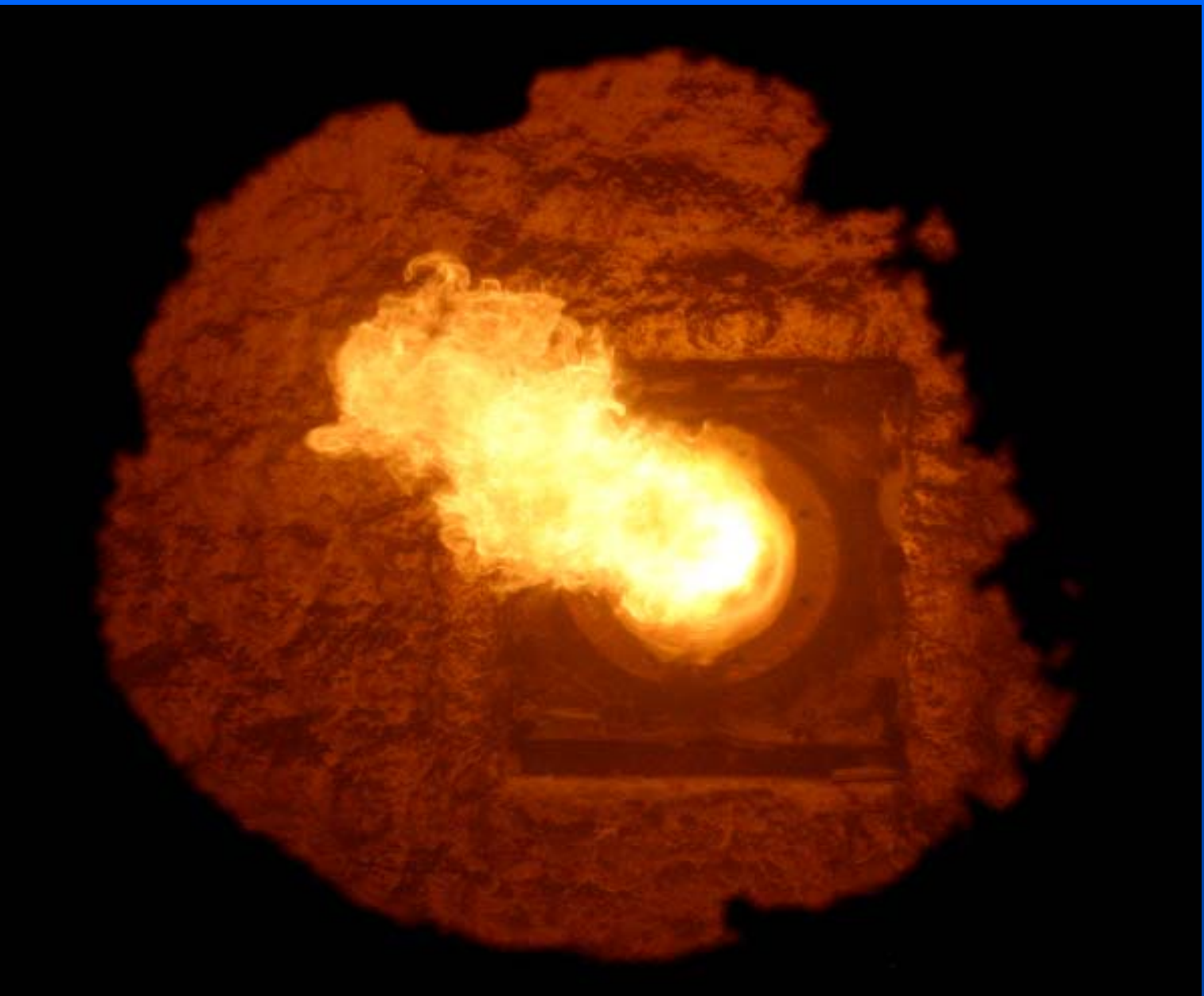


Oxy-Fired w/Flue-Gas Recycle Predictions





MAXON Burner Test Results



MAXON Burner Test Results

- Illinois Bituminous
- 2400 ^{o}F test chamber
- 3% excess O_2
- Staged oxygen prototypes
- Air conveyed = 0.3-0.4 #NOx/MM BTU
- CO_2 conveyed = 0.16-0.18 #NOx/MM BTU

MAXON Burner Test Results

- Indonesian Coal
- 2400 ^{o}F test chamber
- 3% excess oxygen
- Staged oxygen prototypes
- Air conveyed = 0.18-0.2 #NOx/MM BTU
- CO_2 conveyed = 0.08-0.1 #NOx/MM BTU

Plans for Testing

- Variables
  - Coal Type
  - Firing Configuration
    - Staging
    - Percentage of Recycle
    - Oxygen Purity
- Responses
  - Flue-Gas Composition and purity
  - Inleakage
  - Heat transfer and temperatures
  - Consistency and stability of operation
  - Apparent corrosion or acid-gas build up.

Subsequent Testing Efforts

- MAXON has developed a new oxy-fired burner that we plan to test in the facility that internally mixes the recycled flue gas with the oxygen.
- In 2009 and 2010 will be using the facility to test a technology for treating coal and compressing and purifying CO_2 exhaust at the same time.
- Looking for opportunities to work with our oxy-fired technology team to demonstrate this technology at a full-scale plant.