SOUTHERN RESEARCH

INSTITUTE

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

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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)
  - Oxygen tank and skid, simulations, safety, and eng. support.
- 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

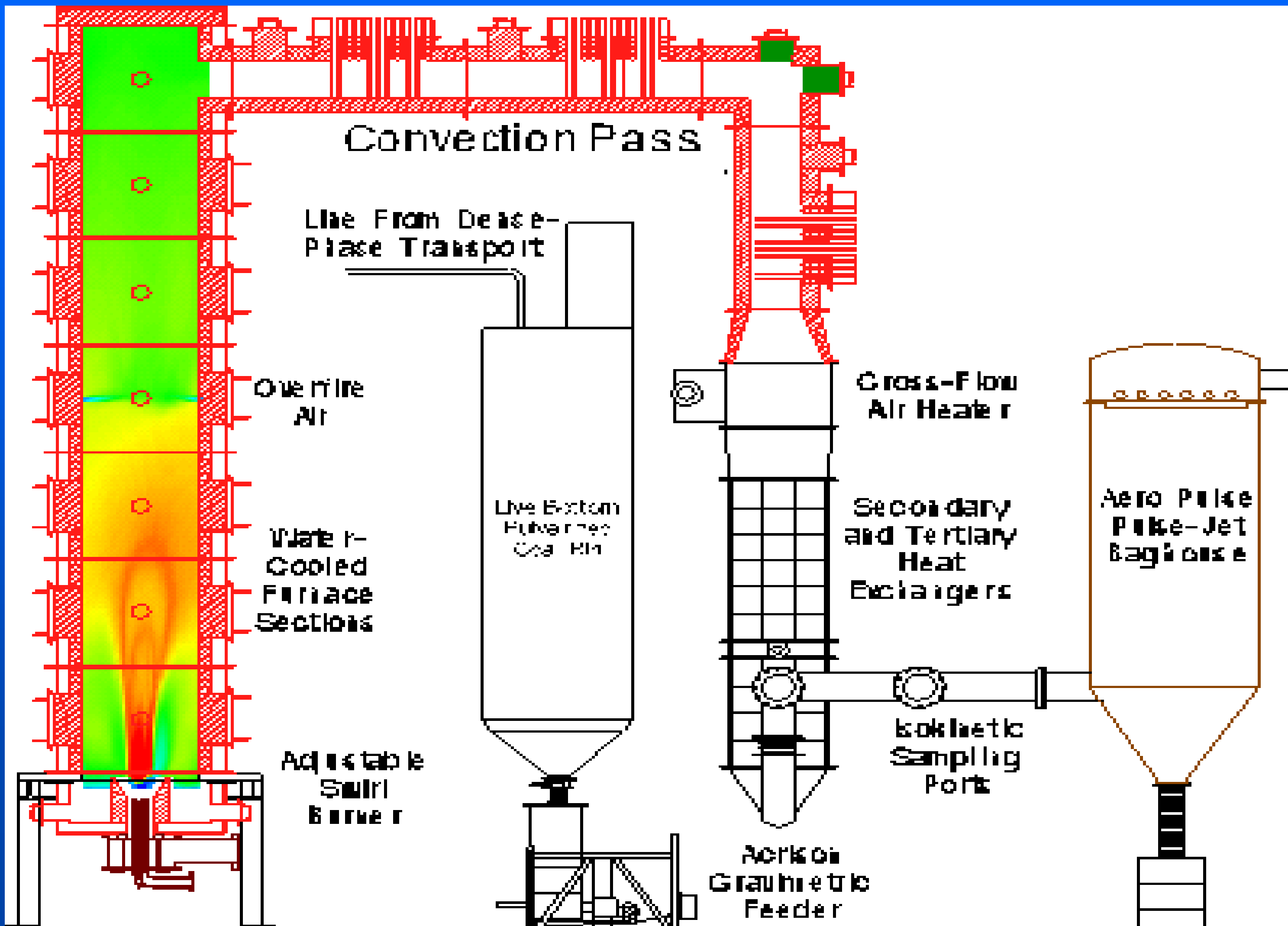
- The objective of this project is to investigate, develop, optimize, and model oxygen-fired CO_2 recycle technology for coal-fired utility boilers by retrofitting the existing Southern Company/Southern Research 1 MW pilot-scale test facility, utilizing an advanced oxy-fired coal burner, measuring the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

Fundamental Science Driving this Oxy-Fired Technology

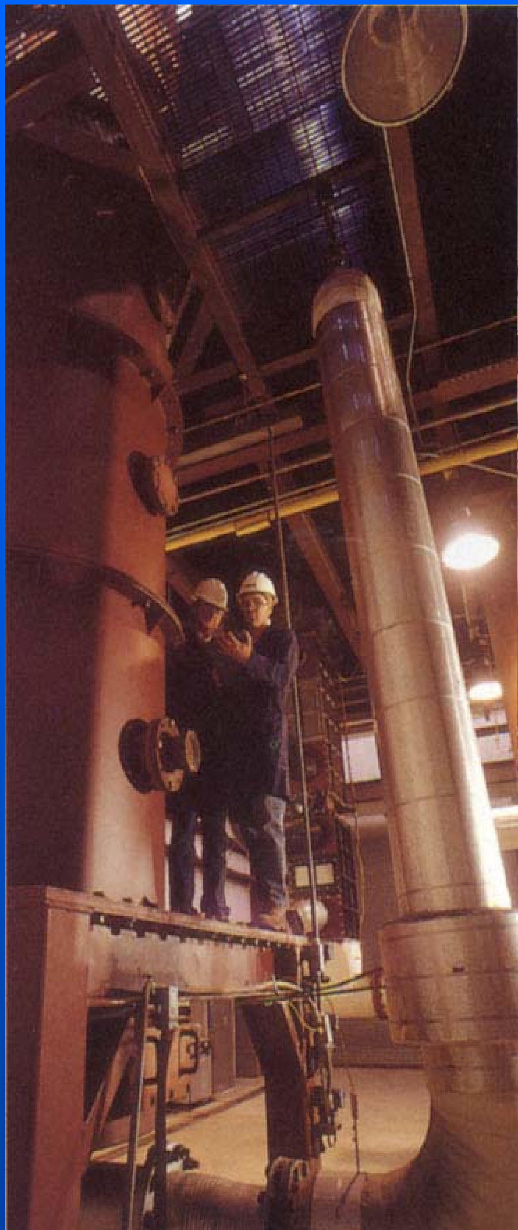
- ~75% of Coal-Fired Flue Gas is N_2
- Oxy-Fired Flue Gas is ~1/4 the Volume
- Flue-gas recycle is required for existing plants
  - To avoid excessive flame temperatures
  - Maintain flow and heat-transfer requirements in the furnace and convective sections.
- Advanced Oxygen Burners
  - Allow the flame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

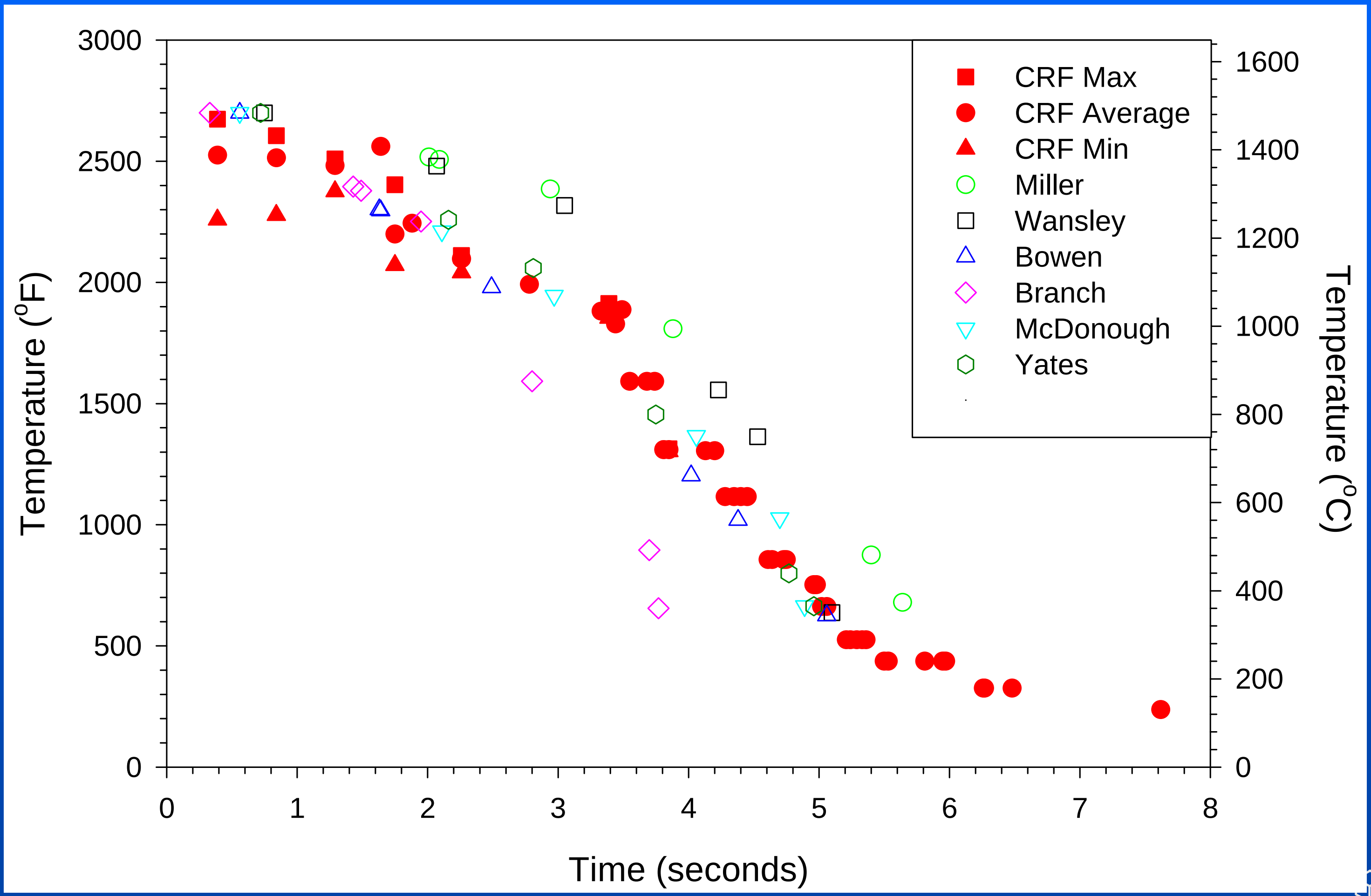


Furnace & LNB

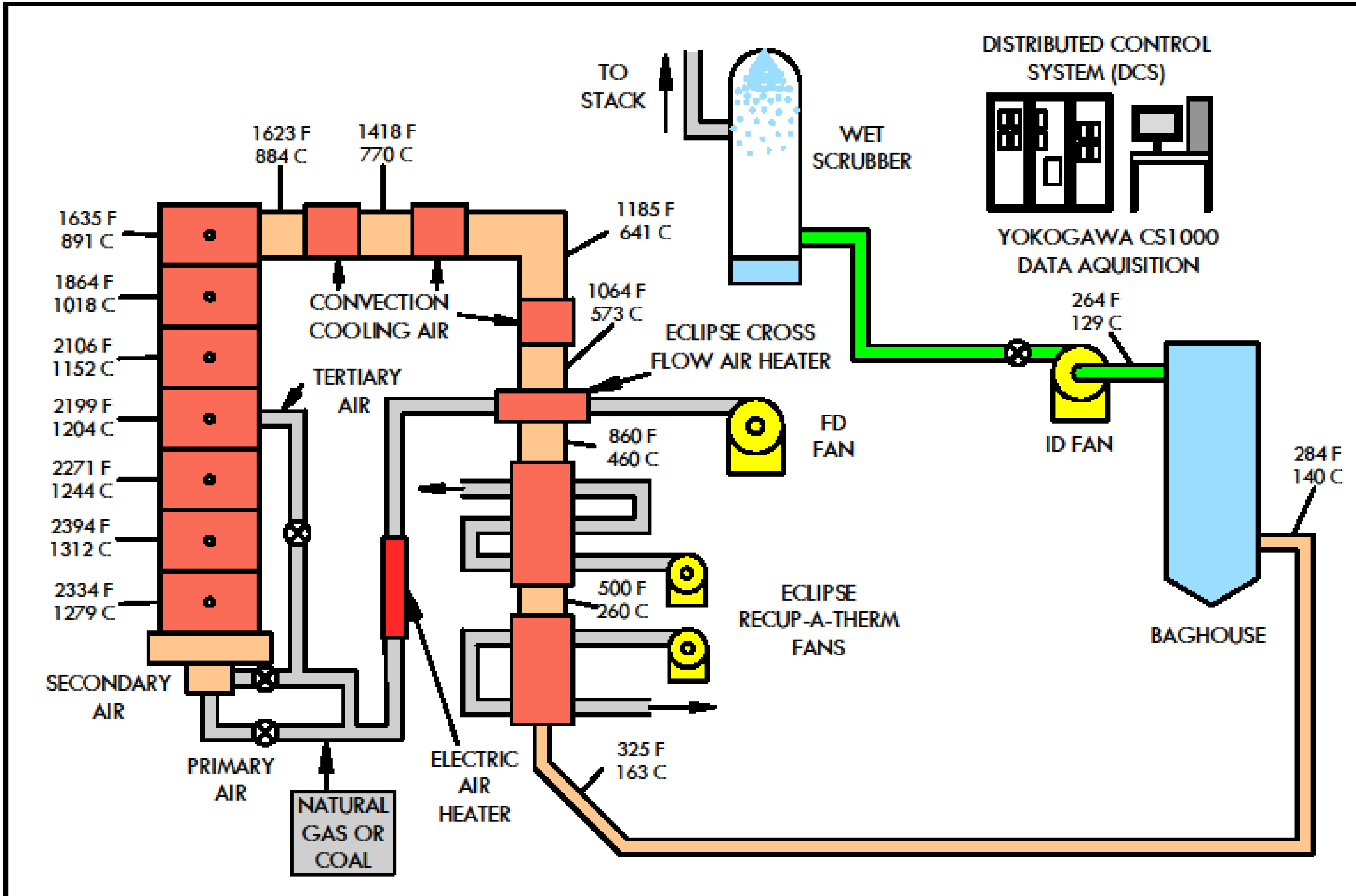
Control Room

Center Furnace Section Showing Overfire Air Ports

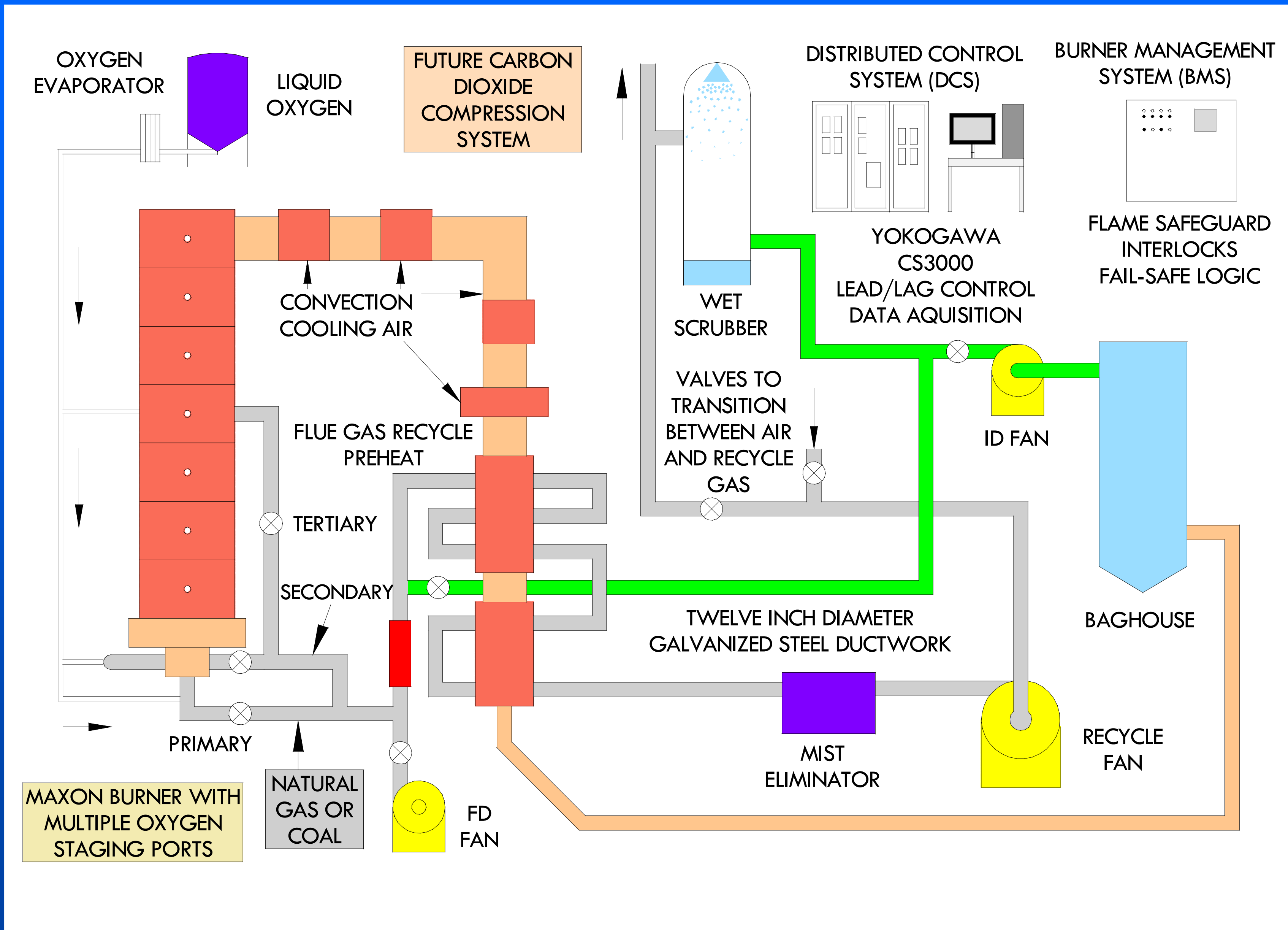
Temperature/Time Profile of the Combustion Research Facility



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

Oxygen Tank and Evaporator

Stack Recycle Takeoff and Fan

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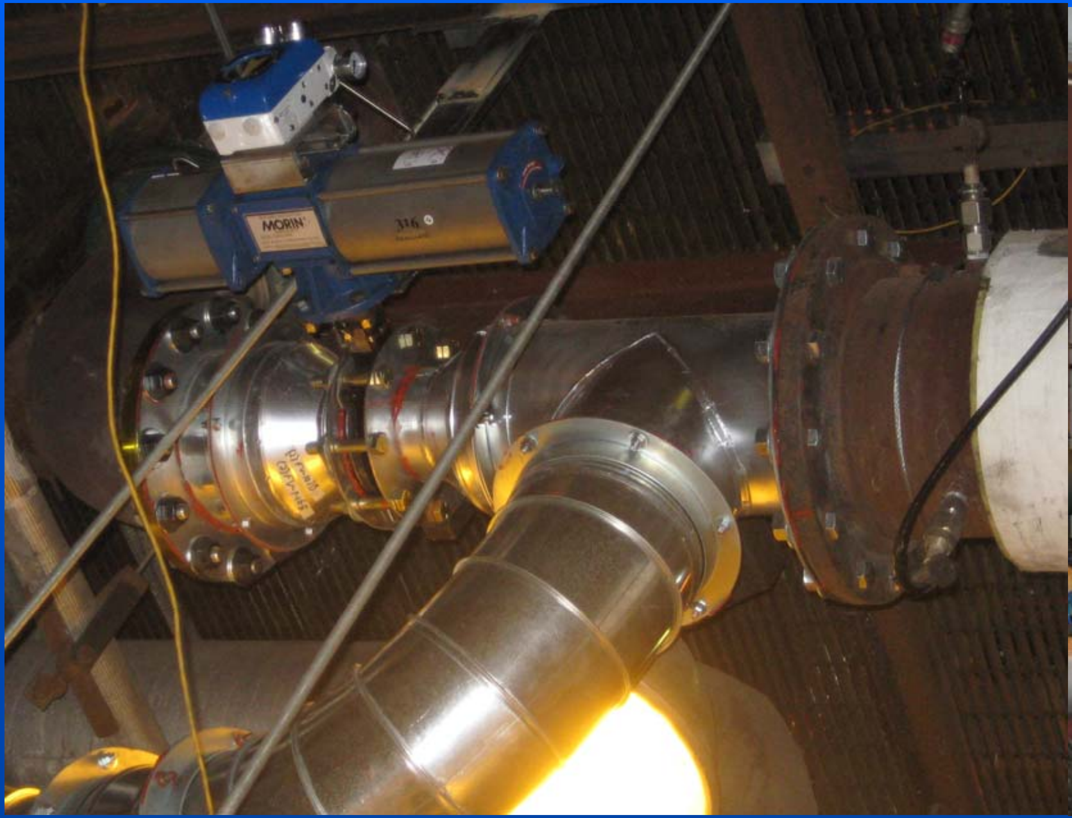
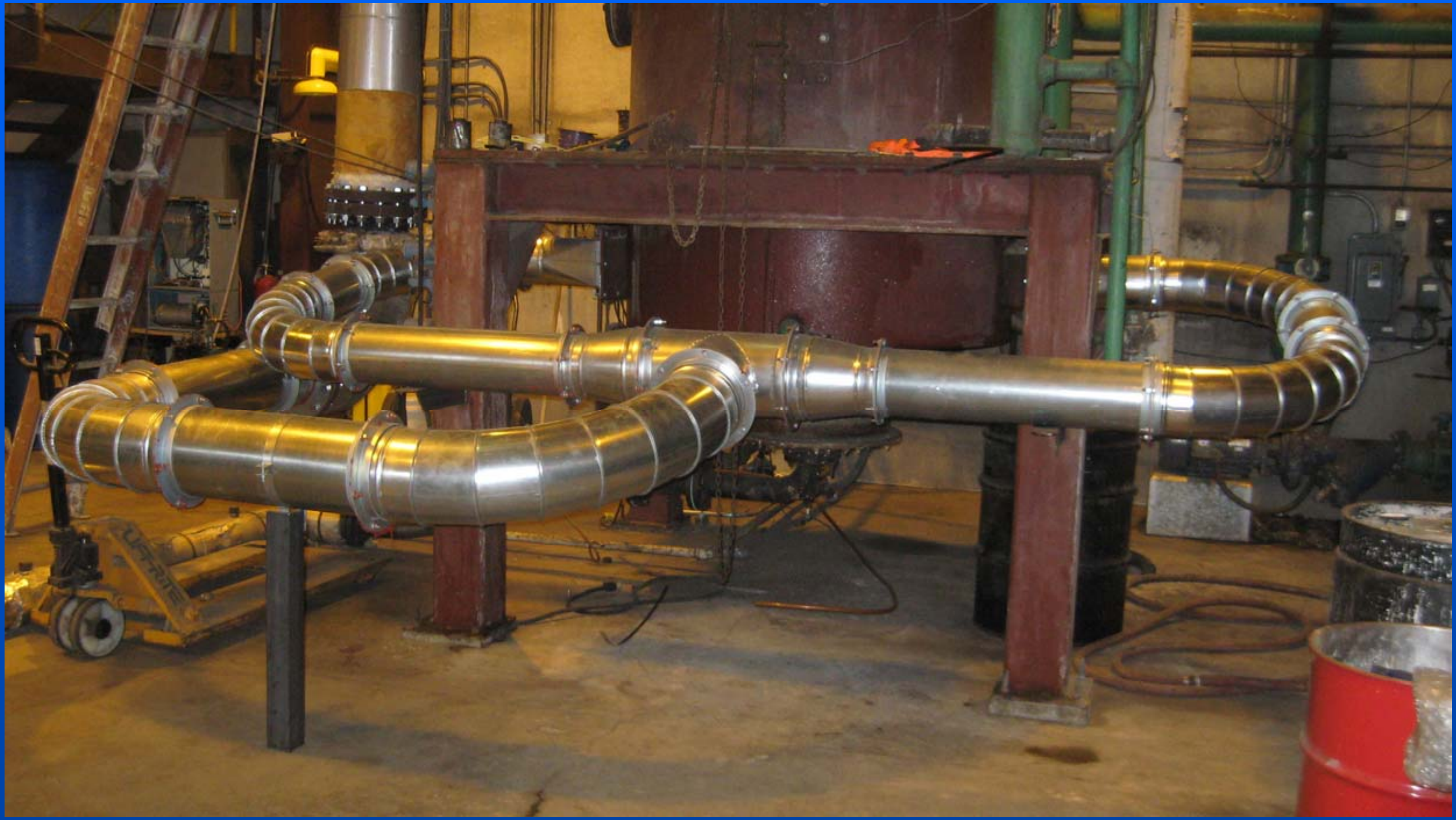
Recycle Reheat Ducting

Pneumatic Valves Switch from Air to Recycle in Secondary Line



Recycle Evenly Injected on Either Side of the Burner Quarl



Transport Gas Switched to Recycle Flue Gas During Oxy-Firing

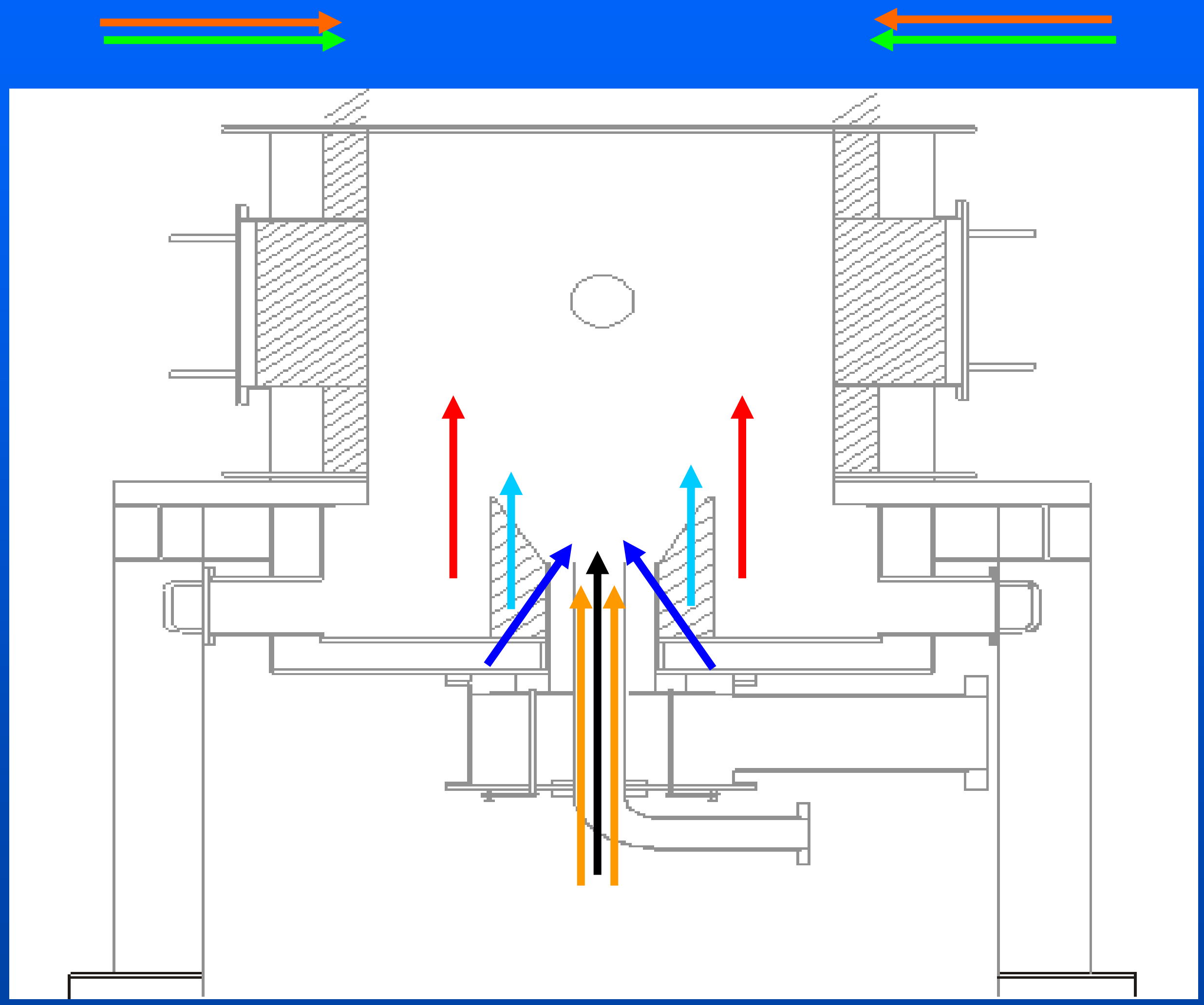
Technical & Economic Advantages of this Technology

- 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 and maximum heat transfer for a given boiler type and plant configuration.
- New Plants: Advanced Thermodynamic Cycles can recover some of the energy penalty.

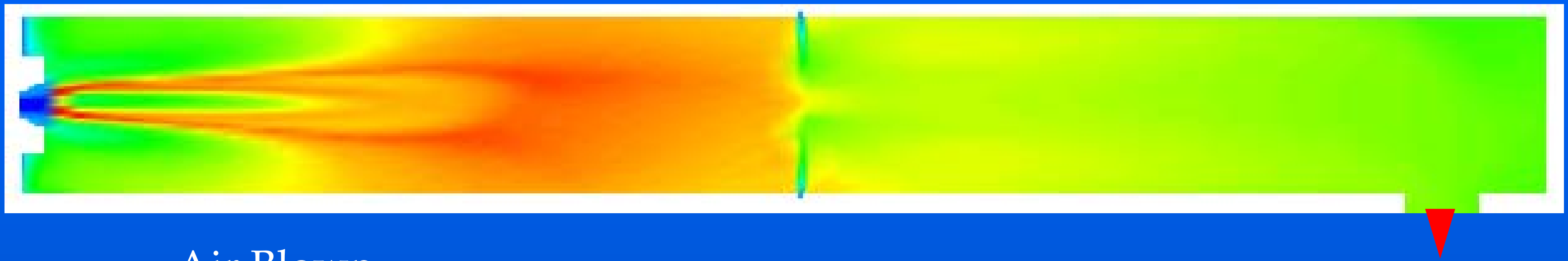
Technical & Economic Challenges

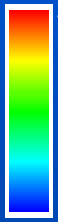
- Cost of retrofit is significant for existing plants.
- Energy penalty to produce oxygen is about 25%.
- Additional energy penalties come from purification of CO_2 and compression and sequestration.
- Concern about corrosion of low-temperature ductwork and equipment.

Oxy-Burner CFD Modeling by REI

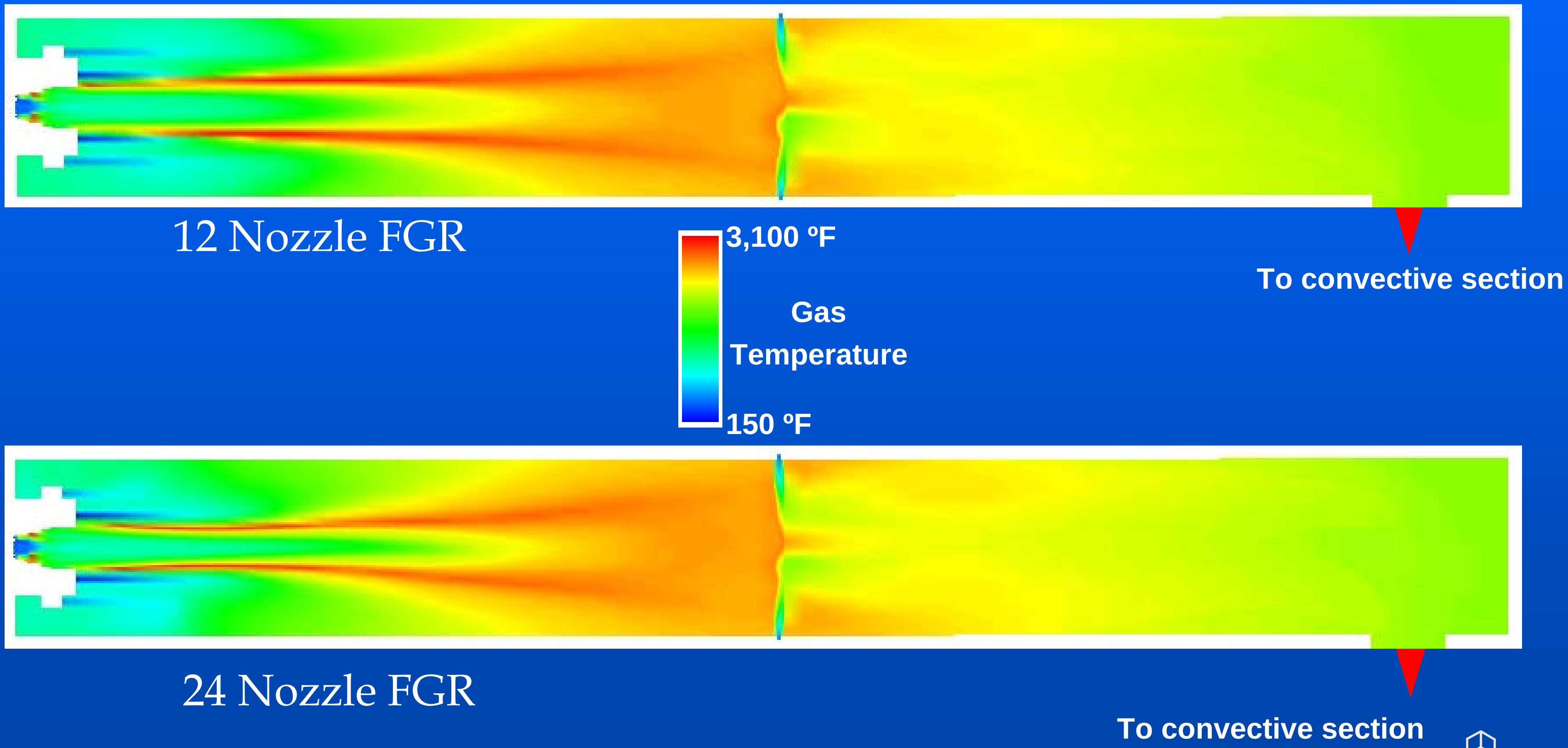


Standard Air-Blown Case





Oxy-Fired w/Flue-Gas Recycle Predictions



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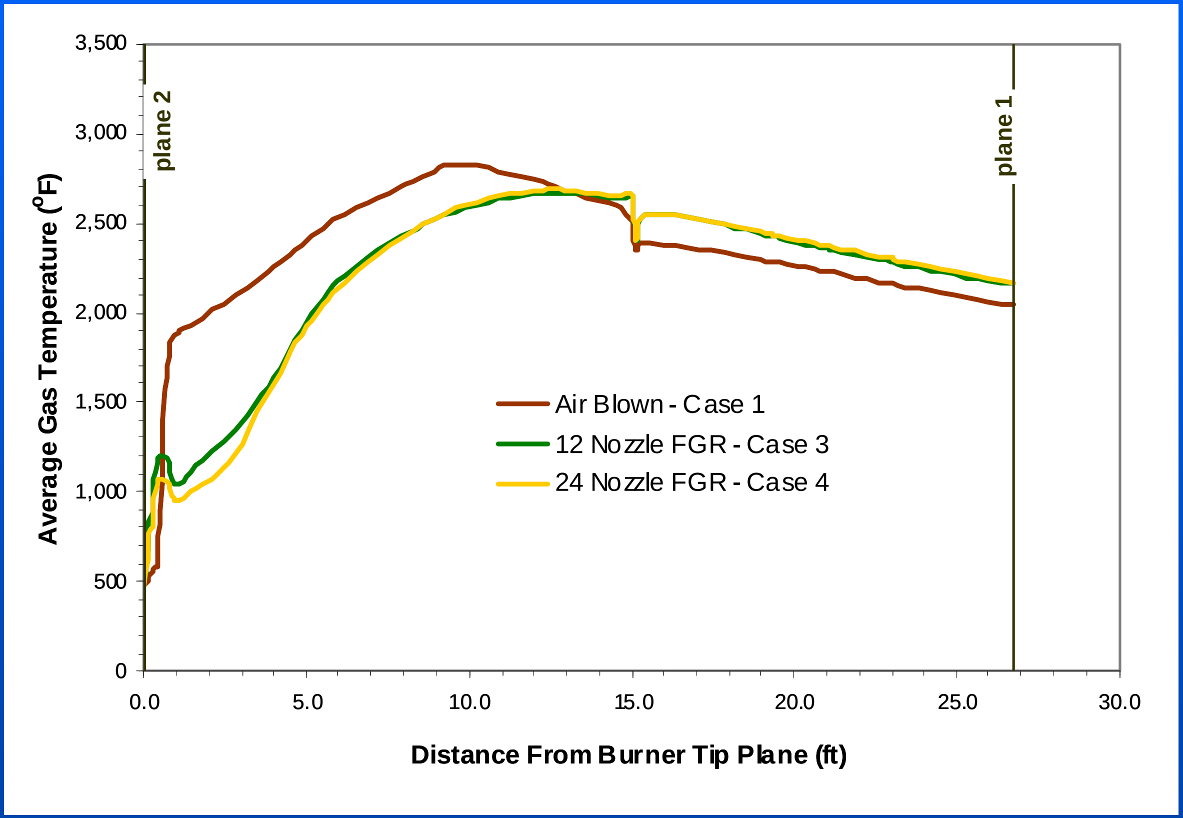
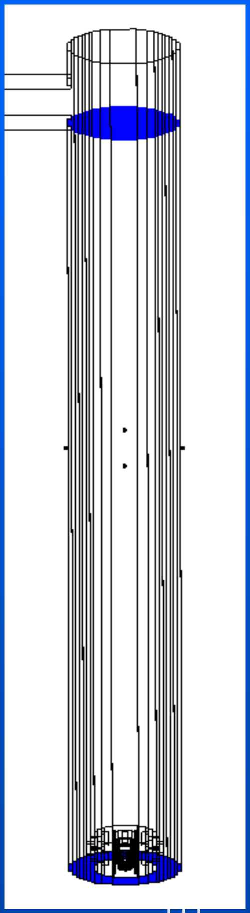
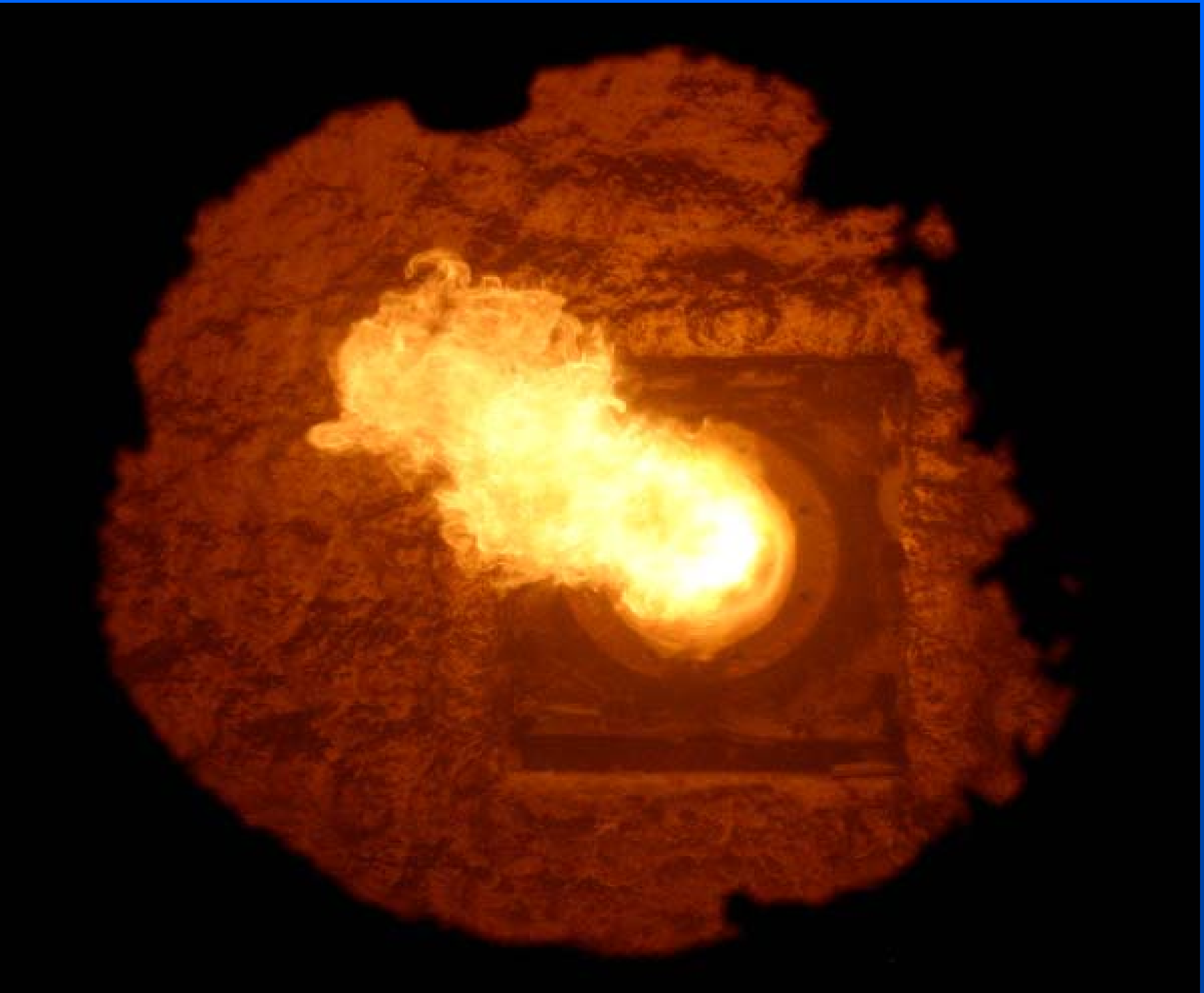


Plane 1



Plane 2

MAXON Burner Test Results



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MAXON Burner Test Results

- Illinois Bituminous
- 2400 ºF 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 ºF 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.

Coal Type

- 3 High-Volatile Eastern Bituminous Coals
  - Choctaw America – Low S, Low Chlorine HvA
  - Blacksville – Higher S, Medium Chlorine HvA
  - Galatia – Medium S, High Chlorine HvB
- PRB sub-bituminous coal – NARC
- Western Bituminous Coal
  - West Elk – Reactive, low-sulfur HvA coal

Firing Configuration

- Purity of the oxygen feed
  - 90 to 99.5%
- Amount of CO_2 recycle (+/- 20%)
- O_2 Concentration in the primary flow
- Amount of O_2 in the burner quarl tip
- Staging (O_2 concentration) through the recycle-gas ports on the sides of the burner
- Amount of Staging through the Overfire-Air Ports

Responses / Measurements

- Furnace gas-temperature profile (gas-suction pyrometry)
- Furnace and convective pass wall and tube temperatures
- Heat flux in the convection pass
- Heat flux in the furnace
- Char burnout (found from unburned carbon in the ash).
- Flue-Gas Concentrations of CO_2, CO, NO_x, SO_2, and O_2
- MKS 2030 FTIR measurements of H_2O, NH_3, H_2S, SO_3, H_2SO_4, HCl, hydrocarbons, and other organics.
- A GC monitor will be used to directly measure N_2.
- Physical Examination of deposits, metal surfaces, and tubes for relationships between firing conditions and deposition, erosion and corrosion.

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 out oxy-fired technology team to demonstrate this technology at a full-scale plant.