May 12, 2021

Extended Low Load Boiler Operation to Improve Performance and Economics of an Existing Coal Fired Power Plant

2021 Spring Review Meeting

DOE/NETL – GE Steam Cooperative Agreement No. DE-FE0031546

Extended Low Load Boiler Operation to Improve Performance and Economics of an Existing Coal Fired Power Plant

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Extended Low Load Boiler Operation to Improve Performance and Economics of an Existing Coal Fired Power Plant

Agenda

Background

Plant Low Load Dynamic Simulation Study

Low Load Pulverizer Tests
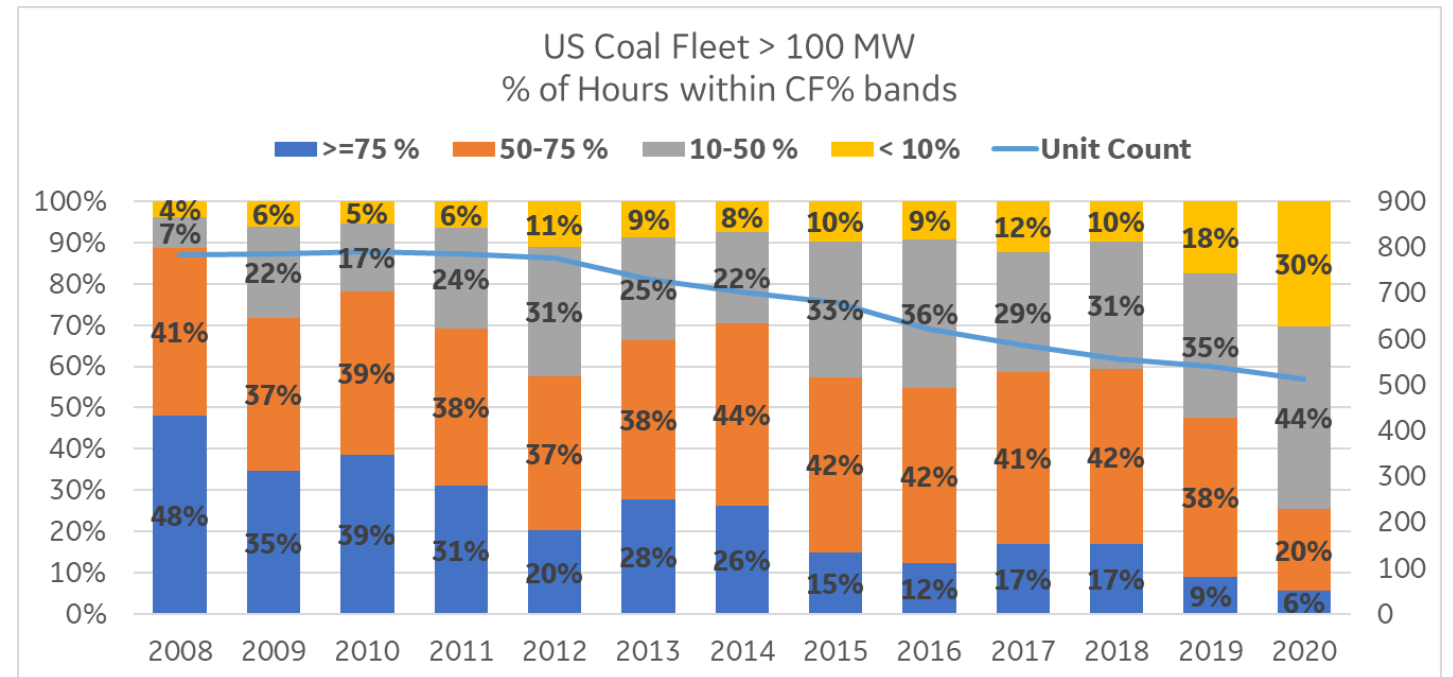
Low Load Combustion Tests

Field Test

Low Load Boiler Operation Background

- Increasing load from renewables, low natural gas price, and a flat load demand has caused many base load coal plants to become cycling plants.

- Dispatching of fossil-fueled power plants has changed to require increased flexibly.
  - More unit starts
  - Higher ramp rates
  - Increased layup status
  - Lower minimum loads

Historical Operation from 2008 through 1H20

US Coal Fleet > 100 MW
% of Hours within CF% bands

Legend: >=75 % | 50-75 % | 10-50 % | < 10 % | Unit Count

Year	>=75 %	50-75 %	10-50 %	< 10 %
2008	48%	41%	7%	4%
2009	35%	37%	22%	6%
2010	39%	39%	17%	5%
2011	31%	38%	24%	6%
2012	20%	37%	31%	11%
2013	28%	38%	25%	9%
2014	26%	44%	22%	8%
2015	15%	42%	33%	10%
2016	12%	42%	36%	9%
2017	17%	41%	29%	12%
2018	17%	42%	31%	10%
2019	9%	38%	35%	18%
2020	6%	20%	44%	30%

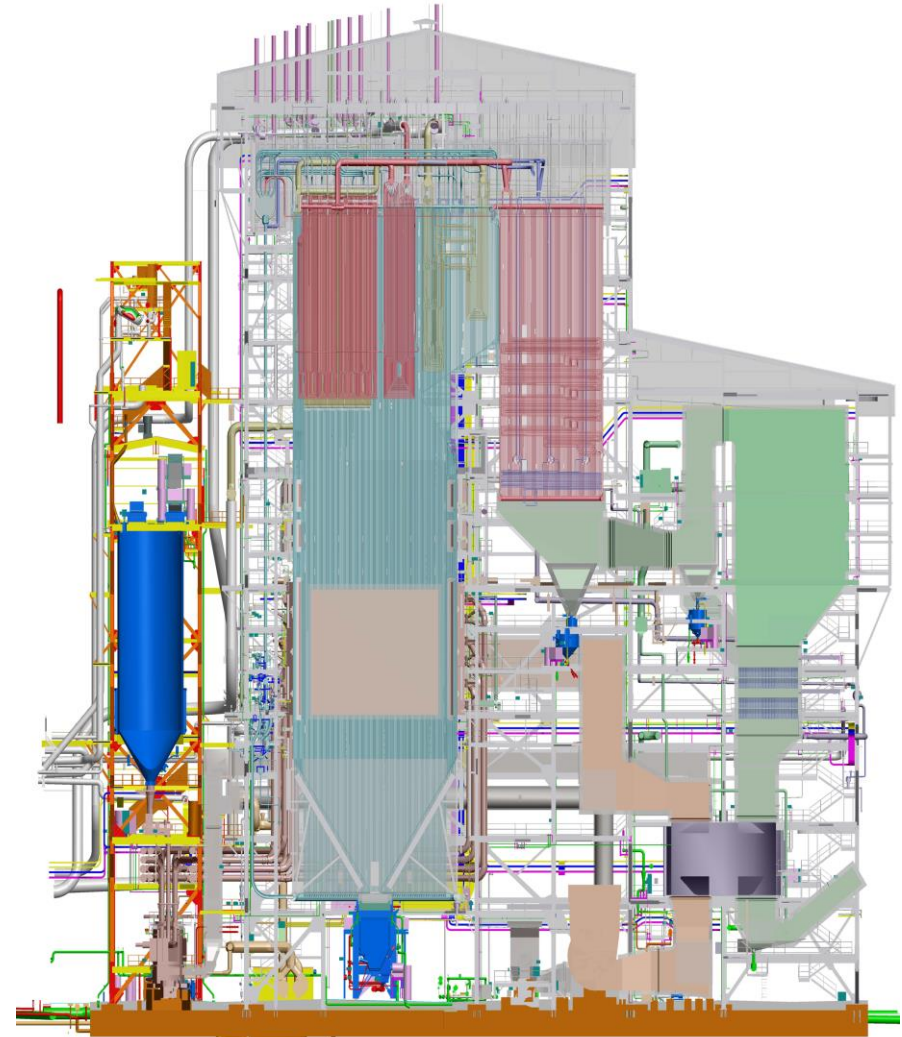# Low Load Boiler Operation Background

Definition - Low Load :

The minimum output level achievable without requiring support fuel and without compromising safety, reliability, emissions, or equipment.

Focus Areas:

Pulverizer, Main Burner Zone, Steam and Gas temperature control

Constraints:

Minimal capital cost solutions
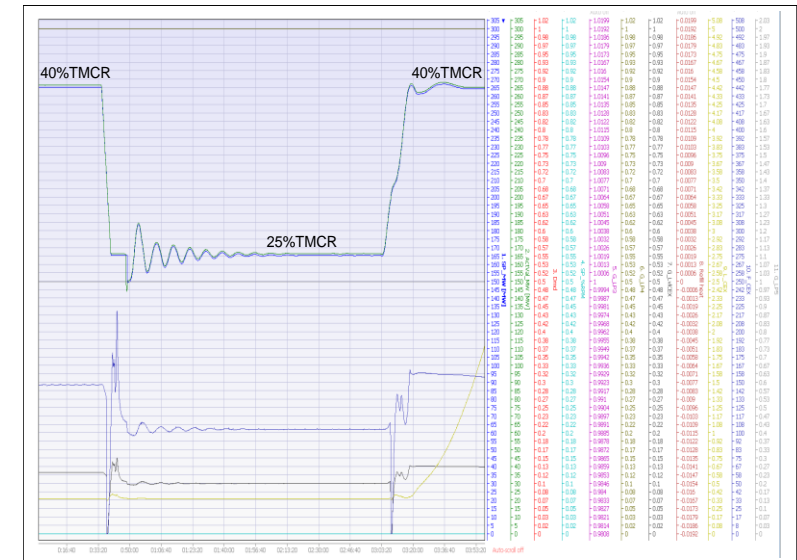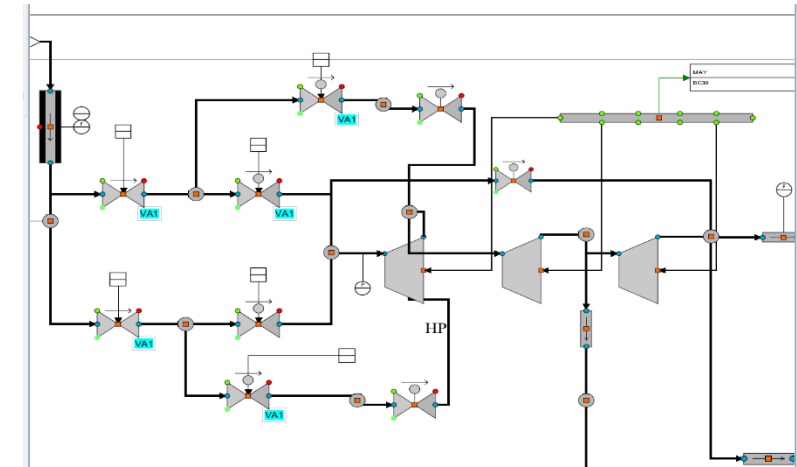
Low Load Boiler Operation Objectives

- Identify **control methods** for **steam and gas temperature regulation** at low load

- Investigate **Sensors and Analytics** for **monitoring pulverizer operation** at lower loads to **maintain/optimize coal distribution, mill outlet temperature, and fineness**.

- Investigate **flame monitoring** techniques that quantify **local and global flame stability**. Classify **burner to burner fuel-air balance** to compensate with fuel or air distribution biases.

- Develop **conceptual design** of new **sensors and algorithms** required for full scale low load field test.

- Validate the **pulverizer / boiler control system** to **extend the minimum load** operating point in a **safe and reliable manner** on an existing full-scale utility boiler.

Dynamic Simulations of Low Load Plant Modeling for Low Load

- Established a boiler model calibrated for low load (25%TMCR) and integrated with the plant cycle model

- Calibrated plant level model using the plant cycle thermal balance calculation data for 25%TMCR

- Tuned control loops for load change simulations

- Studied unit control system with load ramp simulations between low load (25-30%TMCR) to higher load levels (40-50%TMCR)
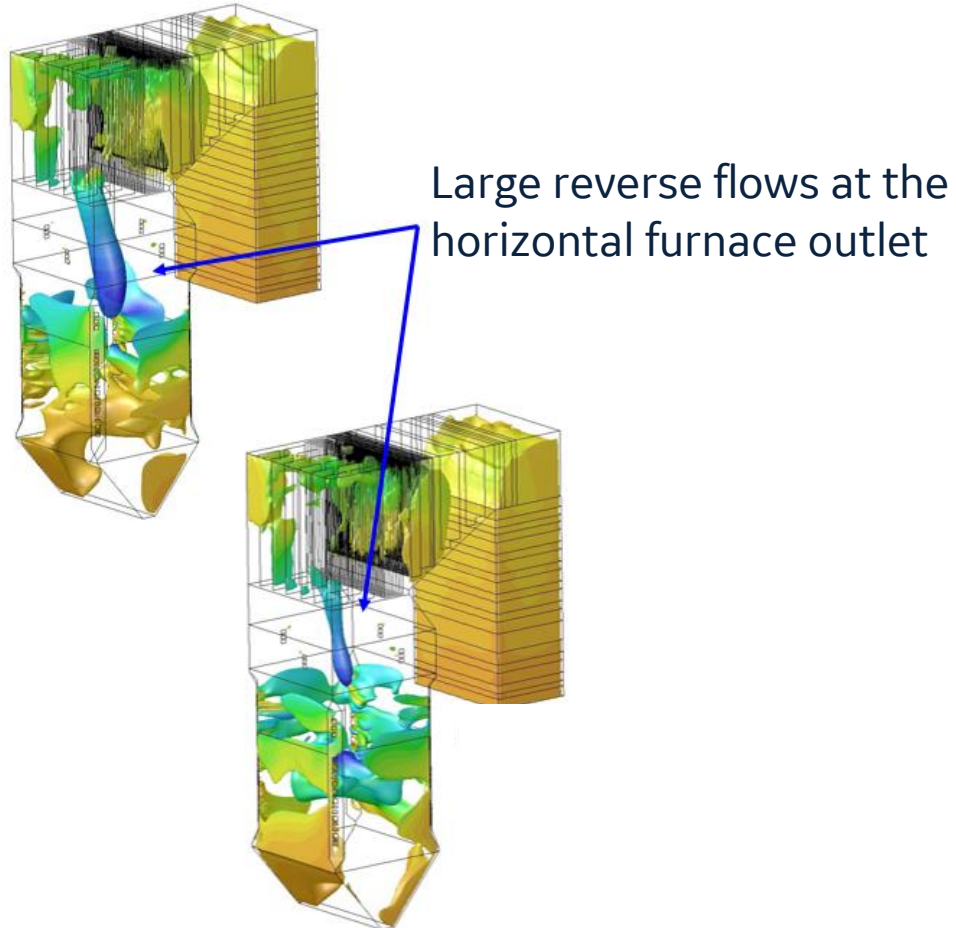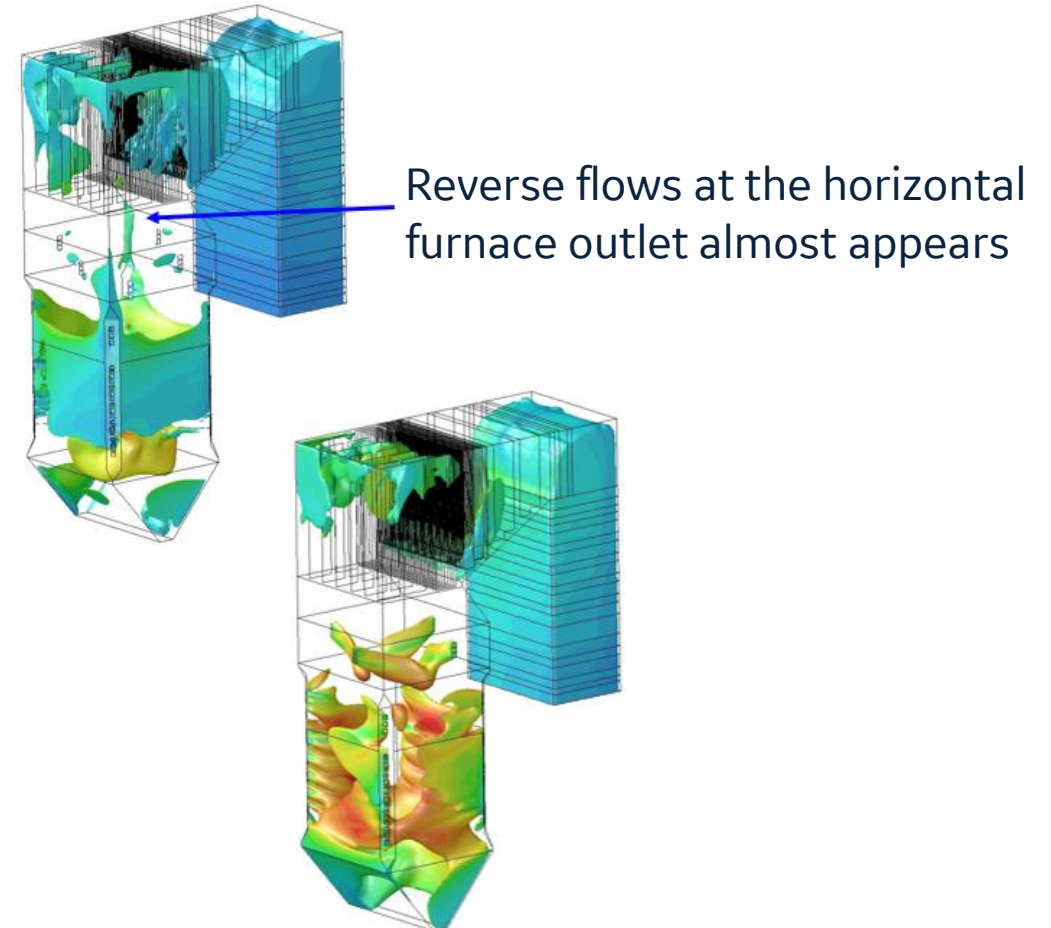
Dynamic Simulations of Low Load
CFD Low-Load Simulation

Two <u>highest</u> coal elevations in service

Two <u>lowest</u> coal elevations in service

Large reverse flows at the horizontal furnace outlet

Reverse flows at the horizontal furnace outlet almost appears

Clean Energy Center ISBF and PDF Facilities

Low Load Boiler Operation Pulverizer Tests

Sensor Selection

Supplemental sensors

- Vibration
- Journal displacement
- Humidity (Out)
- Coal Distribution (4 pipes)
- Spillage
- Motor Torque (Bowl/Classifier)
- Bowl Speed (control)
- Additions Pressure measurements
- Moisture (In)

Targeted Analytics

- Vibration (Smooth-Rough, Rumble)
- Coal Velocity/Flow
- Correlations (Humidity, Air-Fuel slip)
- Distribution versus feed rate, classifier speed, bowl speed, etc.

Low Load Boiler Operation
Pulverizer Test – Coal Distribution

Test Results

Low Feed Rates	Successful down to 5%	• Partial journal engagement • Moderate Vibration • Good fineness control • Fineness distribution degrades at very low feed rates
Coal Distribution	Good results at >50% feed rate	• Good tracking (>10%) at feed rates > 50% • Good low load performance
Humidity	Good results tracking humidity changes due to coal flow and temperature.	• Data to be compared with sample results • Investigating use as fineness indicator
Vibration	Good results monitoring general machine vibration.	• Could not establish rumble for vibration test
Spillage	Good results detecting excessive spillage at low air flow rates	

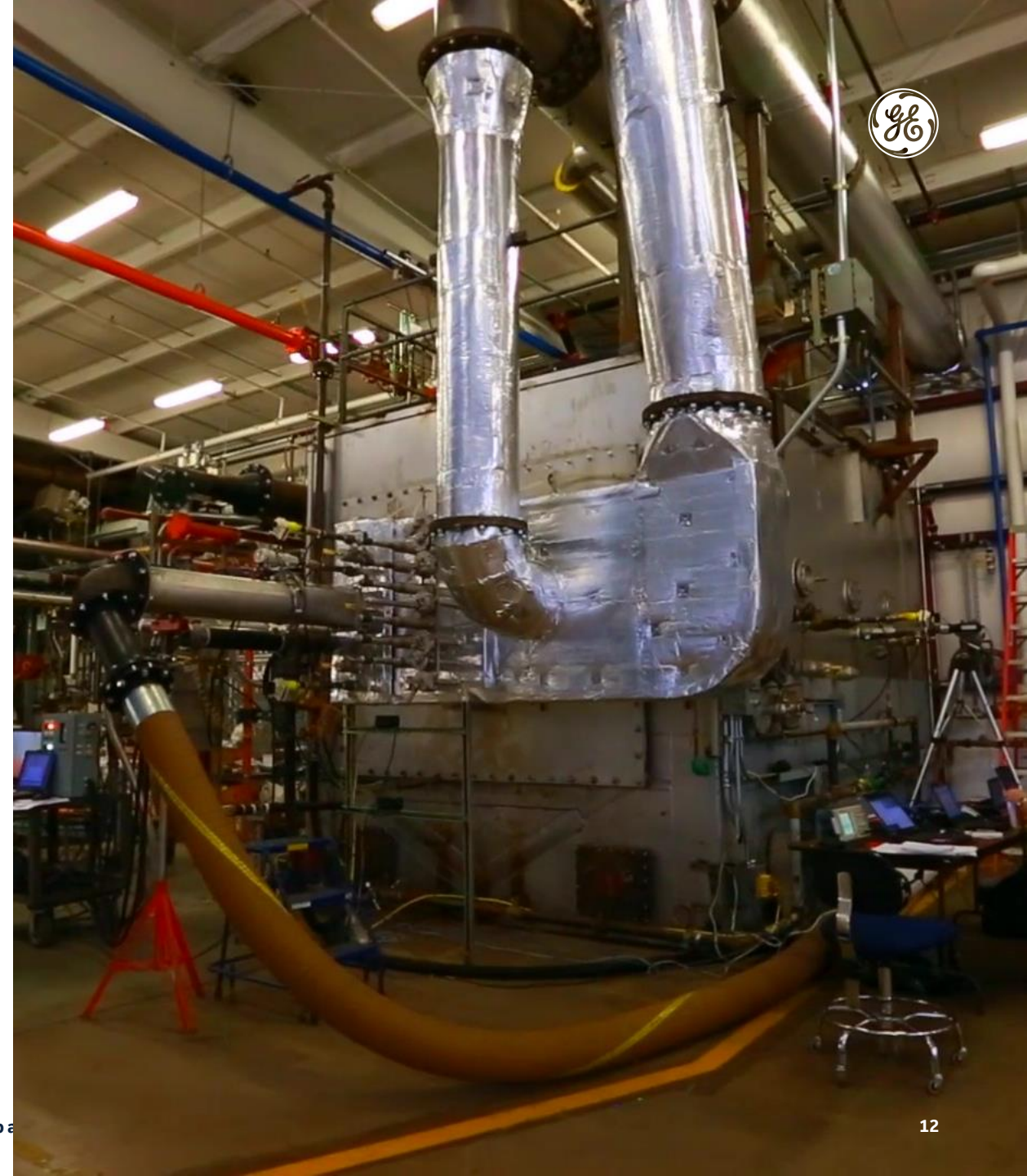# Low Load Boiler Operation
Technical Approach (Flame Stability)

Sensor Selection

Added sensors for low load burner testing

- Near furnace O2, CO, NO sensor grid

- Static / Dynamic combustion pressure

- High turndown flame scanner

- 2D Temperature furnace camera

Targeted Analytics

- Burner flame stability (local and global)
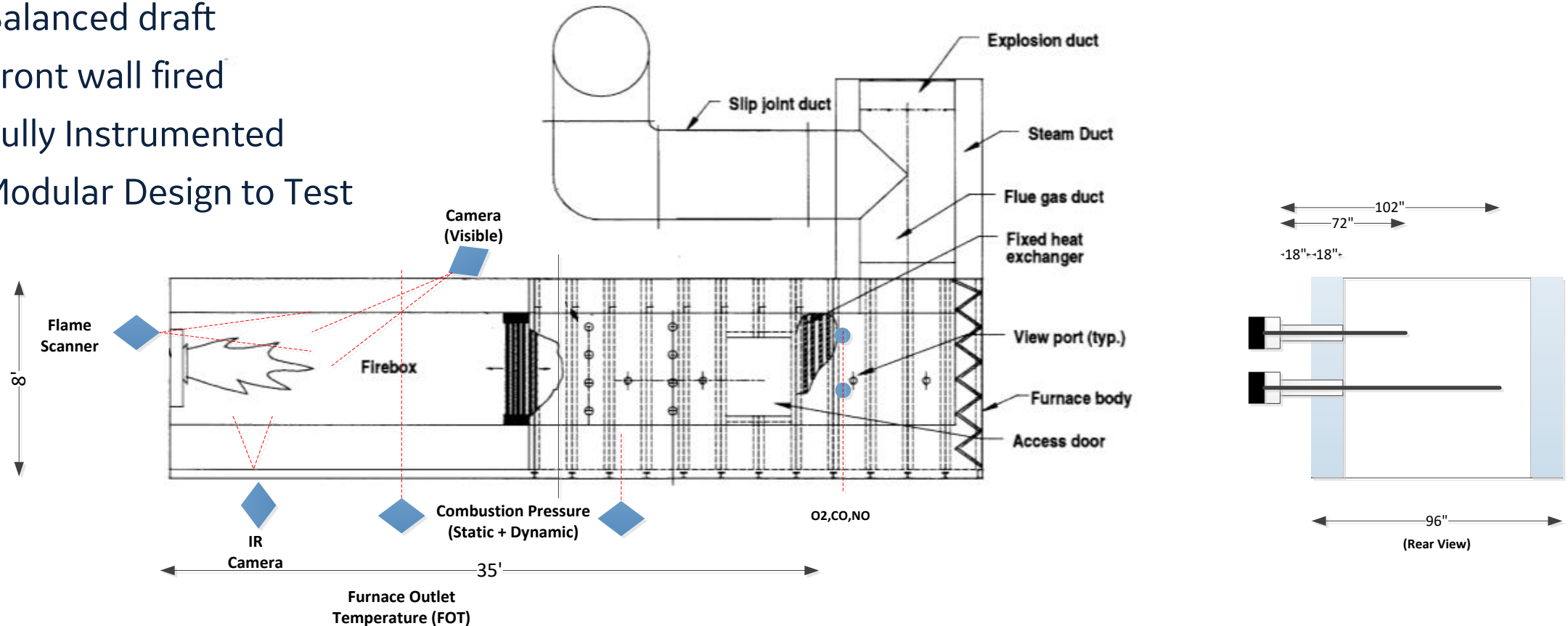
- Fuel/Air balance classification

- Flame emissions

Low Load Boiler Operation
Technical Approach (Flame Stability)

15 MWth Industrial Scale Burner Facility (ISBF)

- Balanced draft
- Front wall fired
- Fully Instrumented
- Modular Design to Test

Low Load Boiler Operation
Combustion Tests (Low Feed Operation) - Objectives

Low Feed Rates

- Identify operational issues at low firing rates – extend traditional limits

- Extend Turndown with operational changes (Air Flow, Air Distribution, etc.)

- Experiment with Staging Air at low firing rates

Coal Distribution

- Evaluate Coal Flow Sensors for Velocity

Sensors

- Characterize abnormal/undesirable behaviour with Sensors + Analytics

- Evaluate Flame Scanner for evaluating stability

- Evaluate Flue gas sensor (CO, O2, Temperature, NOx) for detecting flow imbalances

Low Load Boiler Operation
Combustion Tests (Low Feed Rate Operation)

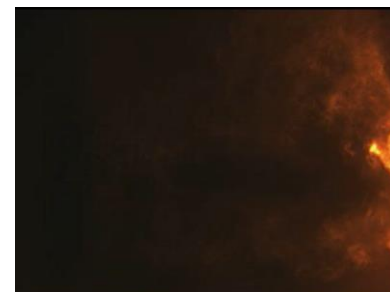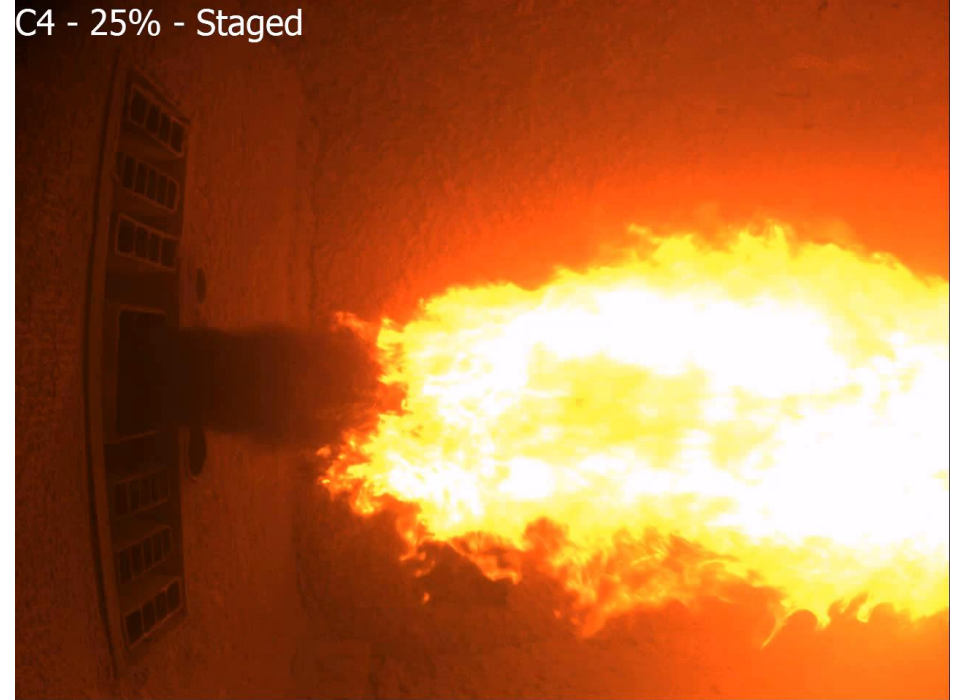**Visualization of flame attachment versus % Load**

(30% Load)

(25% Load)
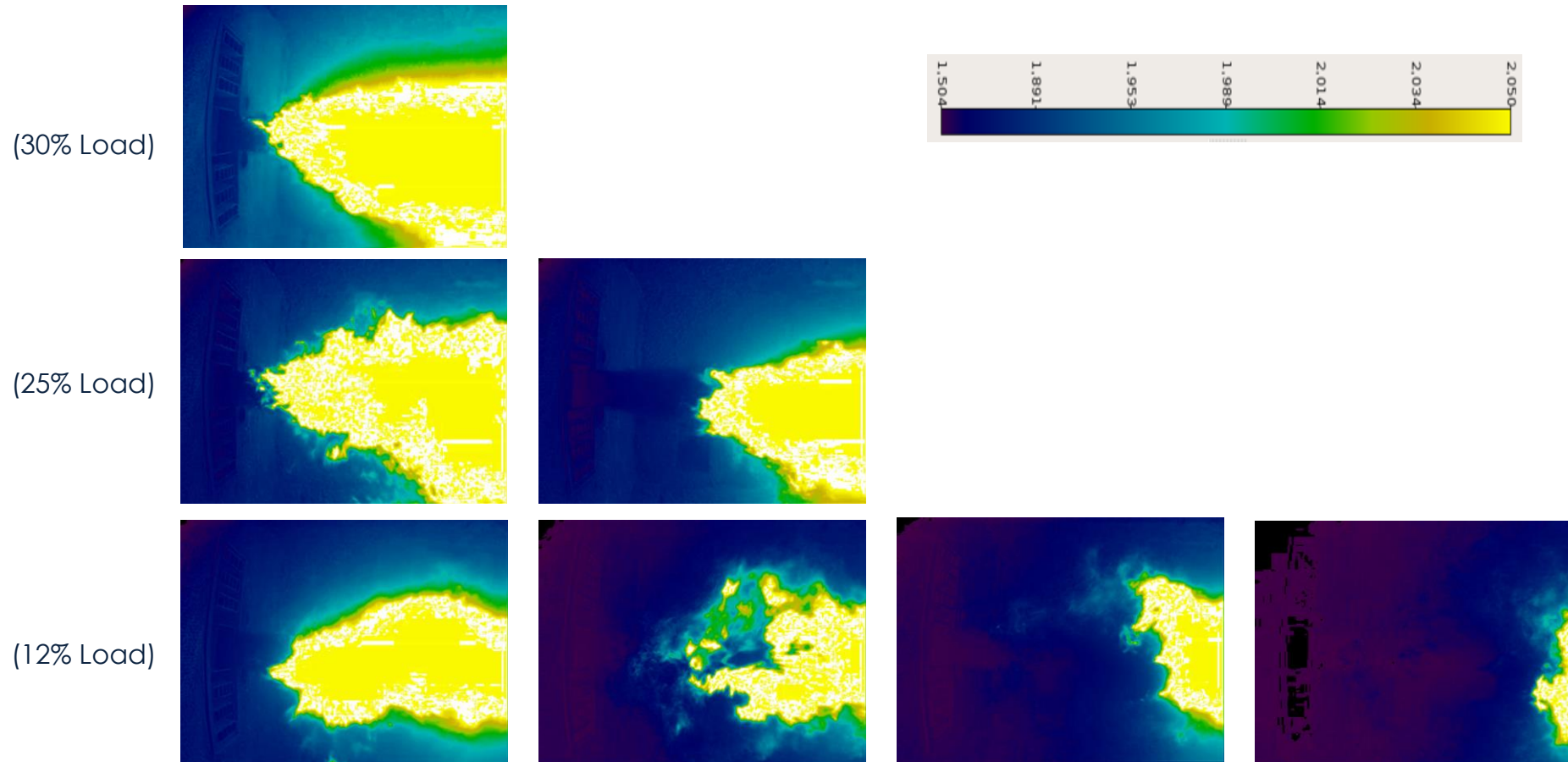
(12% Load)

C4 - 25% - Staged

Low Load Boiler Operation
Combustion Tests (Low Feed Rate Operation)

Visualization of flame attachment versus % Load

Low Load Boiler Operation
Combustion Test – Coal Distribution

Test Results

Low Feed Rates	Successful down to 15% (disclaimer - *specific to test*)	• Fuel + Aux air dampers closed • Minimum Primary Air (60fps) • Extra fine coal promote early ignition/lower NOx
Coal Velocity	Good results tracking but investigating absolute value	• Correct issue at low flows – software update
Flame Scanners	No issues detecting flame at low loads Analytics required to assess flame stability	• Investigating best features for flame stability (Phase II)
Combustion Camera	Excellent flame images	• Tremendous potential as global stability monitor
Flue gas Grid	Good NO results, CO/O2 readings were high	• Investigating high readings

Low Load Boiler Operation
Santee Cooper – Cross Generating Station

Located in Pineville, SC approximately 25 miles northwest of Charleston, SC on Lake Moultrie and next to Lake Marion

Santee Cooper Corporate is located in Moncks Corner, SC about 15 miles south of Cross Station
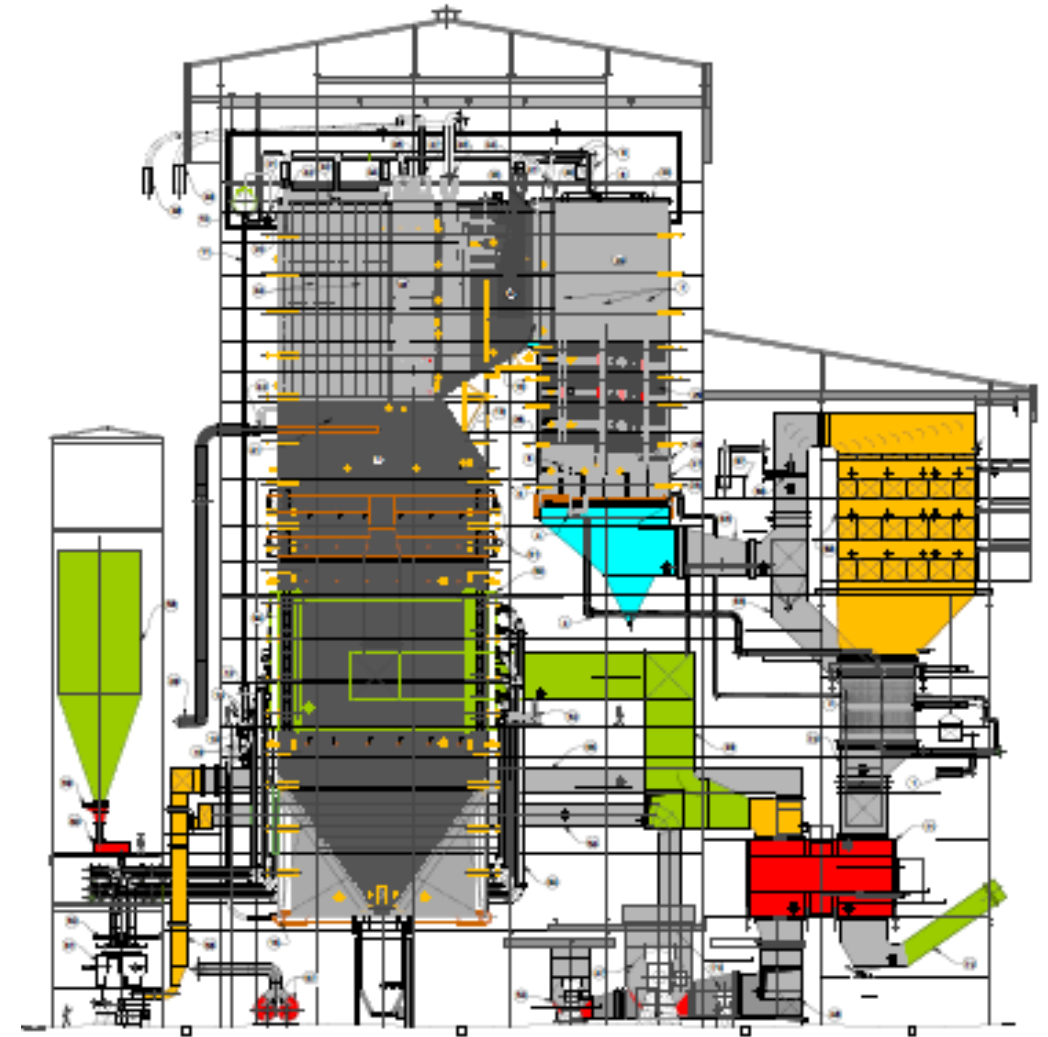
Low Load Boiler Operation
Santee Cooper – Cross Generating Station

Cross Unit 4

- Commissioned 2009
- 640 MWe subcritical 1055F / 1055F
- Tangential firing system

Low Load Boiler Operation
Field Test Program

Objectives

- Install and test the pulverizer / boiler control system on an existing full-scale utility boiler

- Extend the minimum load operating point in a safe and reliable manner

Scope

- Detailed engineering, installation, commissioning, testing on the entire coal-fired combustion system

Benefits

- Establish a reference for high turndown

- Validate for other T-Fired plants, use turndown to improve dispatchability

Low Load Boiler Operation Pulverizer and Burner Control System

Sensor	Description
Flame Scanners	Flame detection to infer fuel-air imbalances and ignition point
Secondary Air Damper Controls	Individual DCS control of each air damper
Pulverizer Sensors	Coal flow sensors, coal moisture/humidity, pulverizer spillage
Pulverizer Controls	Regulate primary air transport velocity at low load
Flue Gas CO / O_2 / Temperature	Monitor combustion / temperature pattern
Furnace Outlet Temperature	Tune models and predict slagging conditions
Fireball Monitoring	Measure fireball stability, fireball features and position, feedback for air distribution biases
Edge Analytics	Analytics for deriving flame stability, fireball stability, O2 setpoint, air distribution biases, etc. from the installed sensor mix

Low Load Boiler Operation Field Test

Status

Bulk of sensors were installed and wired during 2019 w/ exception of frame for furnace camera / furnace outlet temperature probes (frame installed Dec 2020)

Communications with sensors established (except furnace camera / FOT probes, mill bay sensors)

External contractor restrictions implemented starting Spring 2020

Low load season occurs October to April

Next Steps

Complete sensor installation / communications

Conduct a series of controlled tests at low load

Fine tune the analytics

Conduct long-term test currently scheduled starting December 2021