Reinhold Environmental Ltd.

2010 NOx-Combustion Round Table & Expo Presentation

February 8 & 9, 2010 Chattanooga, TN

An Innovative Approach to Improved Pulverized Coal Delivery and Combustion Optimization

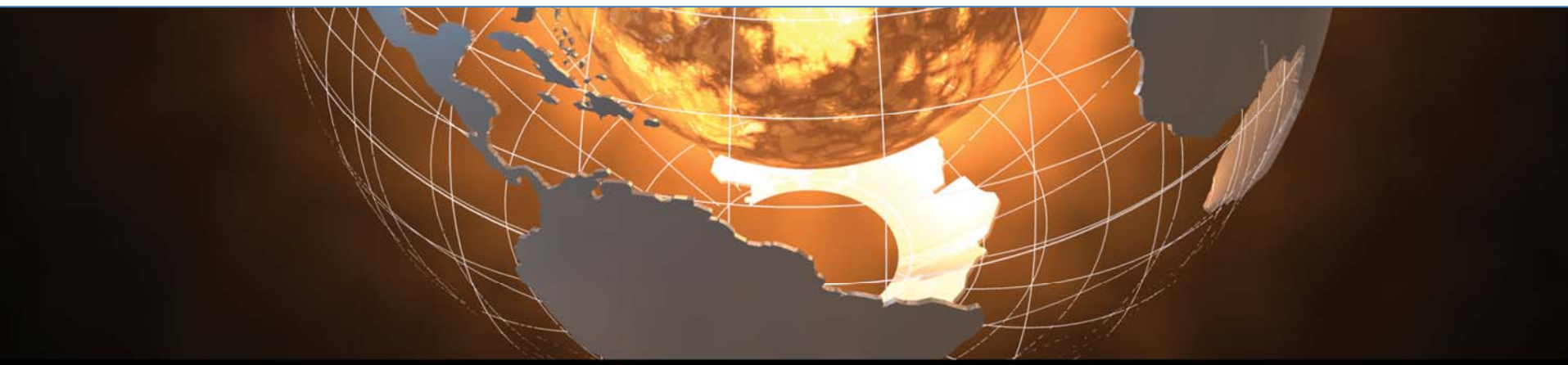
Presented at the 2010 Reinhold NO_X-Combustion Conference
February 9, 2010 • Chattanooga, TN

David Head: Xcel Energy / Alan Jensen: MIC-USA / David Billings: SAS Global

What Was Done:

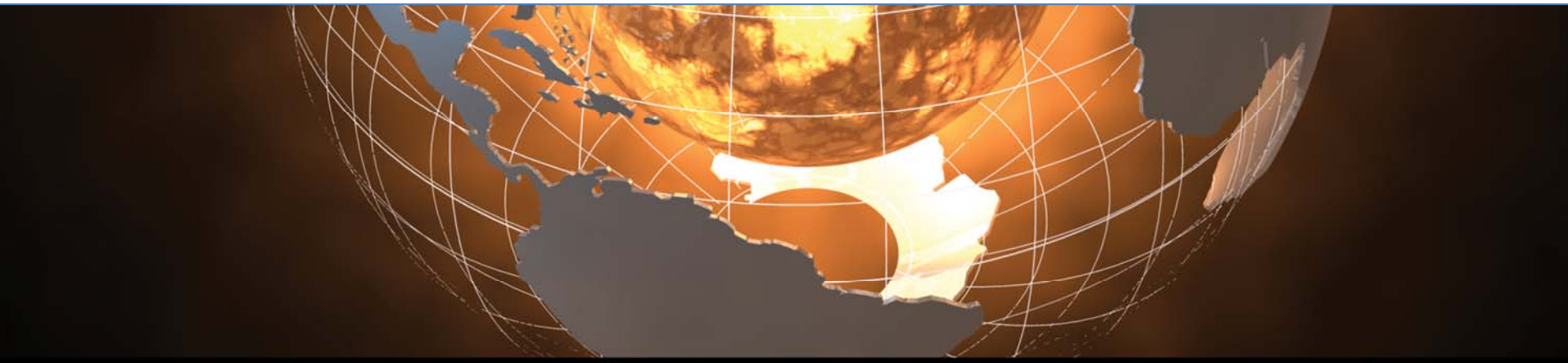
The mechanical and control changes made to Tolk Units 1 & 2 have allowed them to meet emission targets and defer installation of Low NO_X Burners.

- Grind the coal correctly
- Distribute the pulverized coal uniformly
- Test, check and compare the results
- Control and optimize the combustion process continually
- Coal Flow Measurement and Balancing



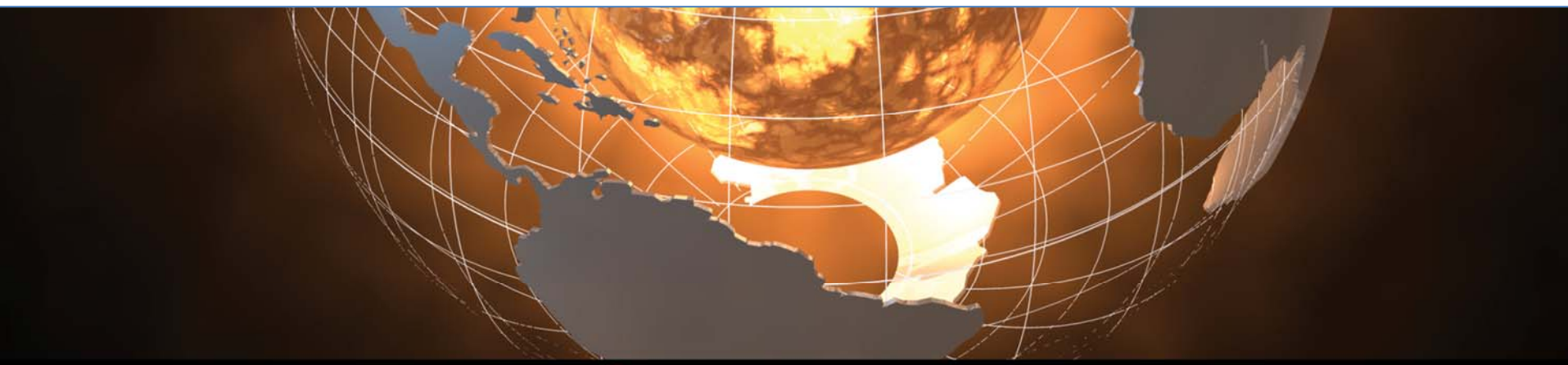
Result:

A $10 Million project was deferred six to nine years.



How It Was Done:

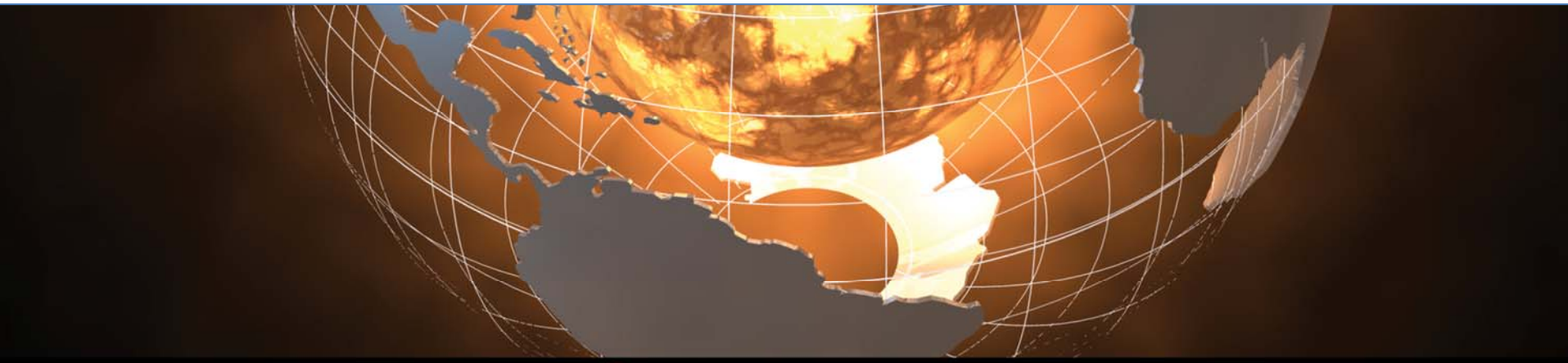
- Mill Upgrades
- SAS Patented In-Line Diffuser Installation
- Diagnostic testing
- Implementing test results
- Coal flow distribution
- Coal flow balance control



Mill Upgrades:

Why Needed

- Mill had excessive wear on coal side parts (deflectors, vane wheel, classifier)
- Uneven air flow distribution was causing erosion leading to increased maintenance
- Previous upgrades had not lasted



Mill Upgrades:

Vane Wheel replaced with SAS Global Patented Rotating Vane Wheel

Mill Upgrades:

Deflectors replaced with SAS Patented Deflectors with Cast 15-3 Liners

Mill Upgrades:

Classifier Linkage Upgraded to SAS Global Linkage

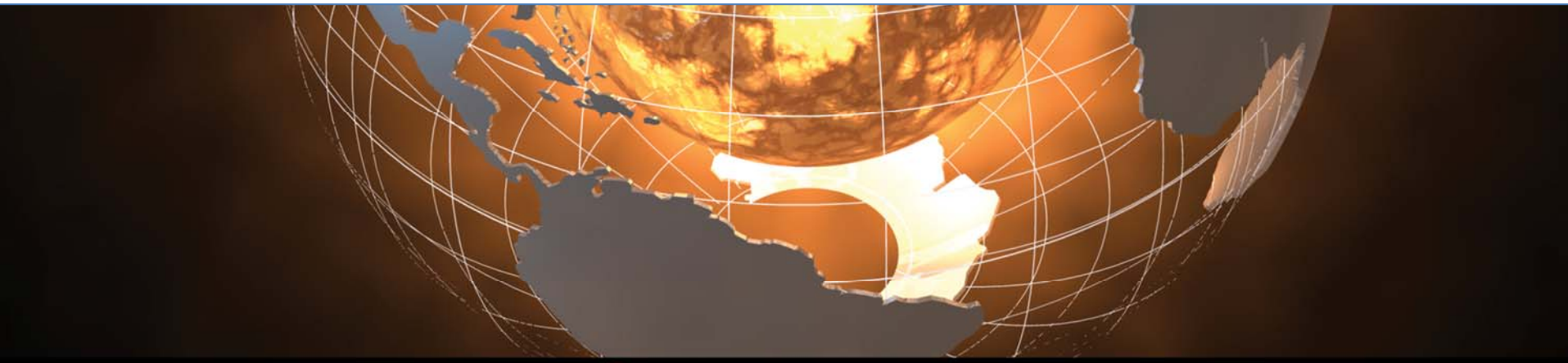
Mill Upgrades:

SAS Global Patented Multi-Outlet Diffuser Installed

The SAS Multi-Outlet Diffuser system mixes the pulverized coal and air into a homogeneous mixture as it exits the upper turret and enters the individual fuel pipes. A significant improvement in air to fuel ratio between all the fuel piping now allows for the proper usage of an orificing system, if needed, to match the fuel pipe velocities.

Non-uniform Pulverizer Coal Flow Causes:

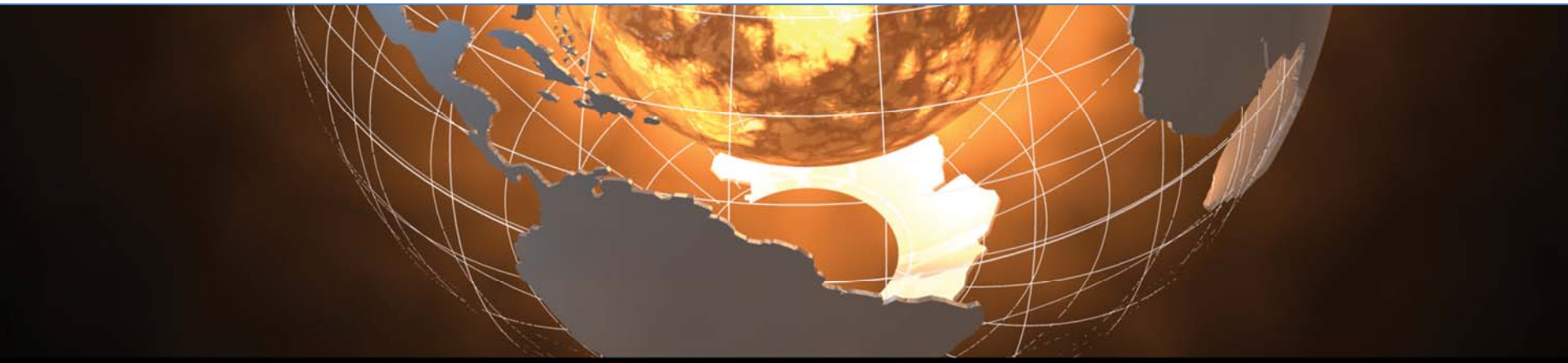
- Poor combustion
- Higher emissions
- Furnace and backend imbalances
- Slagging and fouling
- Increased opacity
- Reduced availability



SAS Patented In-Line Diffusers Installed

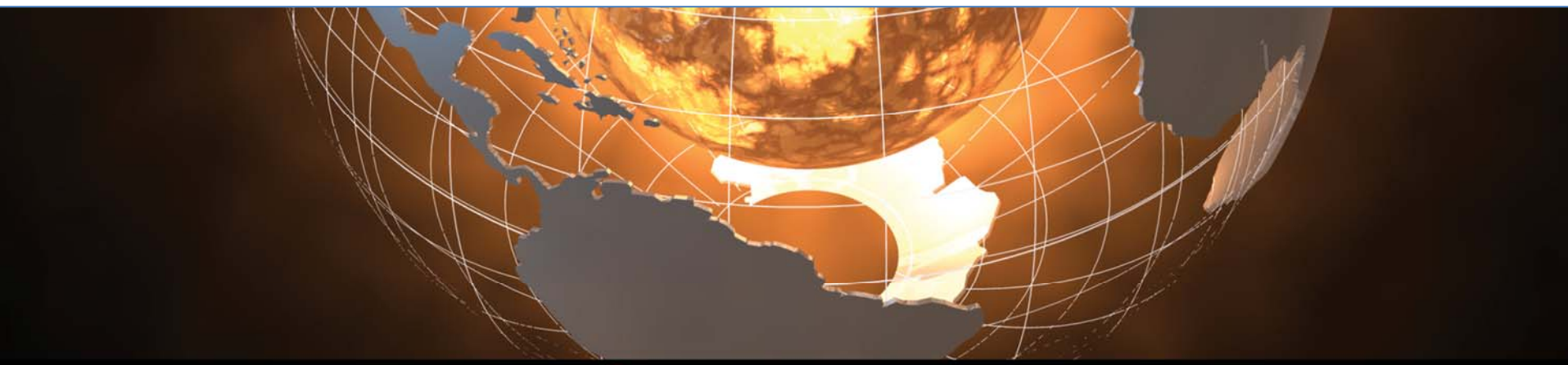
Factors That Influence Combustion

- Fuel Flow Deviations (Pipe-Pipe, Elevation-Elevation and Corner-Corner)
- Airflow Deviations (Same as for Fuel)
- Fuel Variability
- Equipment Design Parameters (Boiler, Mills, Etc.)



Combustion Optimization Testing

- SAS Global Combustion Optimization Group performed diagnostic testing for two weeks
- Testing done at full load, static conditions
- Utilized back pass emissions grid to evaluate combustion process improvement results

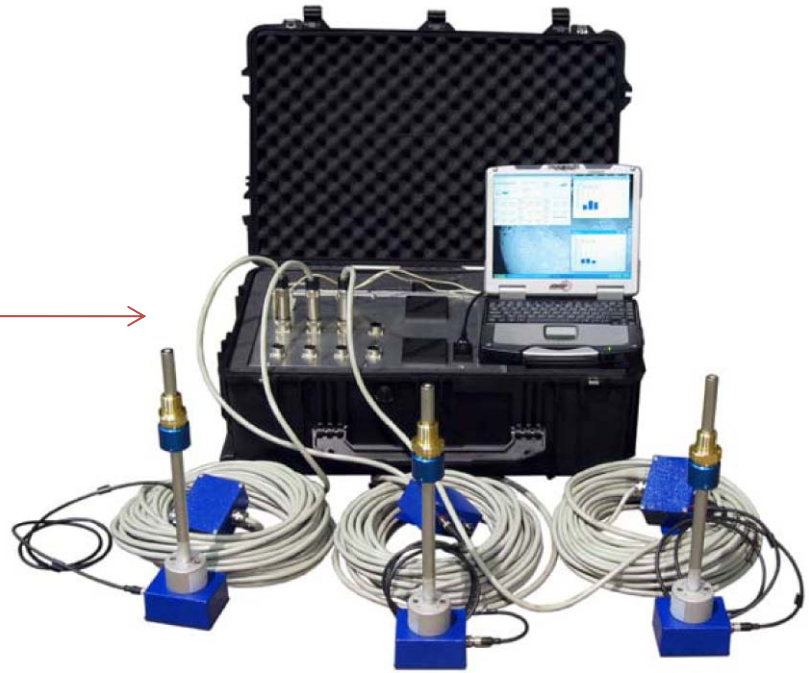


Combustion Optimization Testing

Utilized both RotoProbe™ extractive and MIC *One*™ mobile microwave mass flow testing to evaluate coal flow balance.

- Actual sample weight recovery must be compared with expected values to validate measurement accuracy

MIC *One* Portable Coal Flow Measurement System



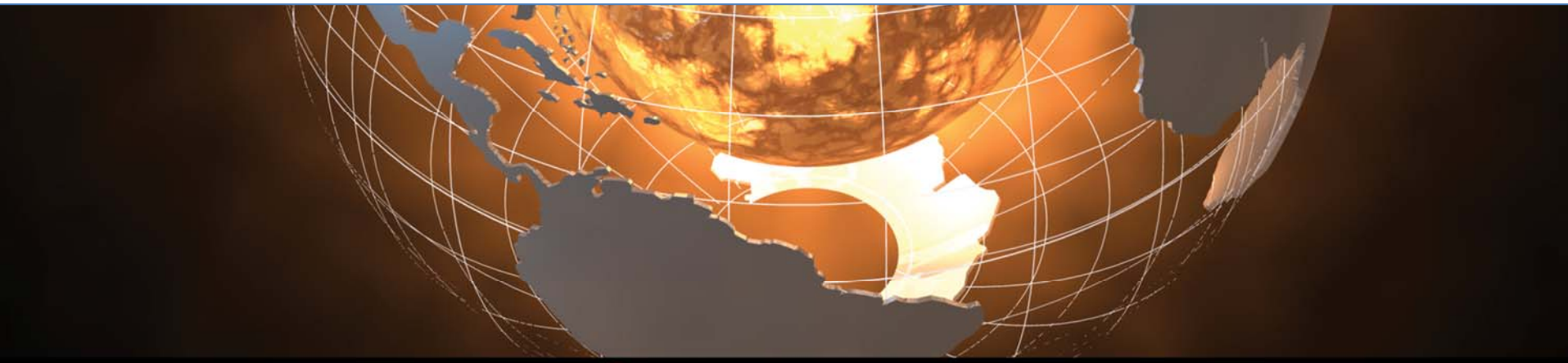
Balance Data: *Example of measured fuel balance of the boiler*

Corner 1	Corner 2	Corner 3	Corner 4
-25.7	25.0	-5.0	5.6

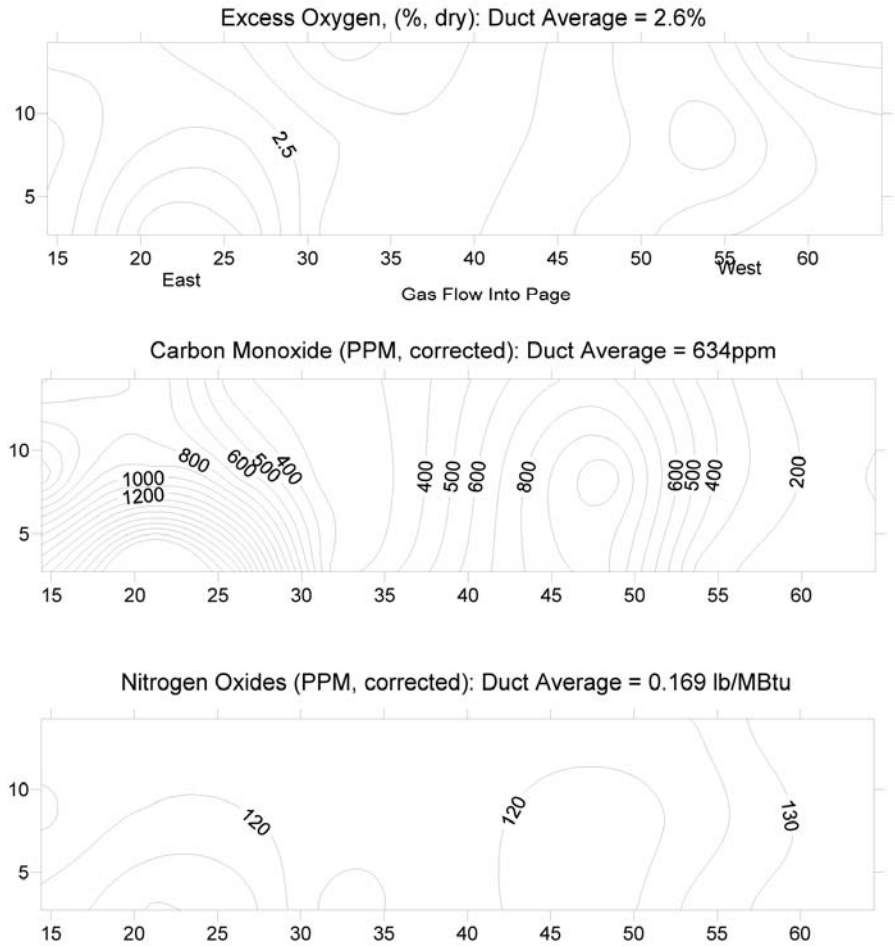
	Mill	Corner 1	Corner 2	Corner 3	Corner 4
PA	A	N/A	N/A	N/A	N/A
Fuel	A	N/A	N/A	N/A	N/A
PA	B	8.3	-0.2	-13.3	5.2
Fuel	B	3.9	1.5	-11.3	5.9
PA	C	-11.2	1.3	3.2	6.7
Fuel	C	-9.6	15.2	0.1	-5.8
PA	D	-7.7	3.5	0.5	3.8
Fuel	D	-23.3	12.9	0.1	10.3
PA	E	0.9	2.4	-2.7	-0.6
Fuel	E	4.4	-11.1	7.7	-1.0
PA	F	-2.8	-1.4	5.0	-0.8
Fuel	F	-1.1	6.5	-1.6	-3.8

Combustion Uniformity Measurements

- Location: Economizer Exit/Air Heater Inlet, Pulverizer Piping, PA Inlet Ducts
- Equipment: Combustion Analyzers and Flyash LOI Machine, MIC, RotorProbe, ACFM



Example Data Plot for a Back Pass Data: Goal was to dissolve the heavy concentrations



SAS Global recommended the following control system settings for combustion and emissions optimization

OFA Tilts = +10 degrees

Wind box to Furnace Delta Pressure = 4.5 in H2O

No Mill Bias Remaining

Aux Air Dampers in Auto

Excess Oxygen Level = 2.1%

Burner Tilts = 0 Degrees

AA Dampers = 50%

“A” FA Dampers = 50%

Corner 4 DE and EF Dampers at 45%

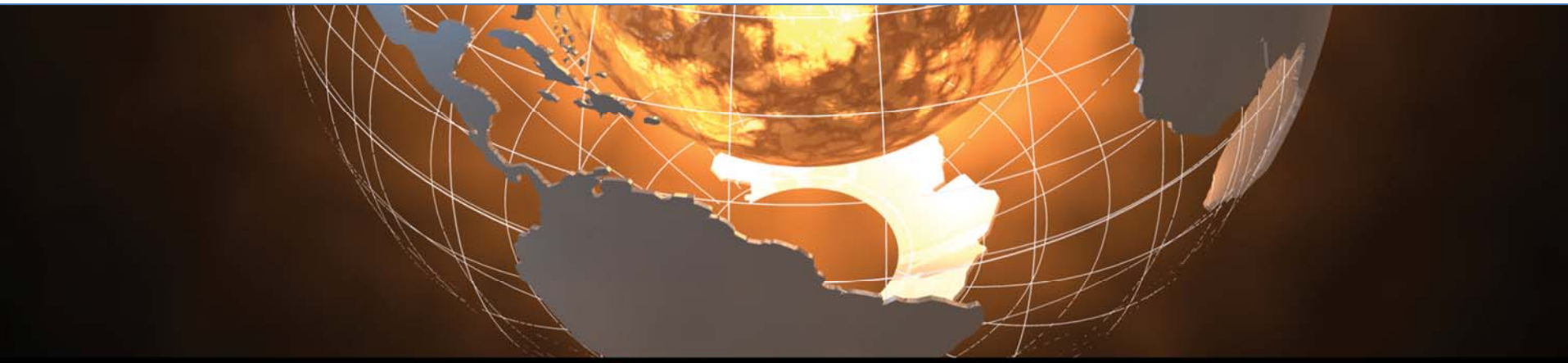
1B and 2B FA Dampers = 45%

Remaining FA Dampers = 100%

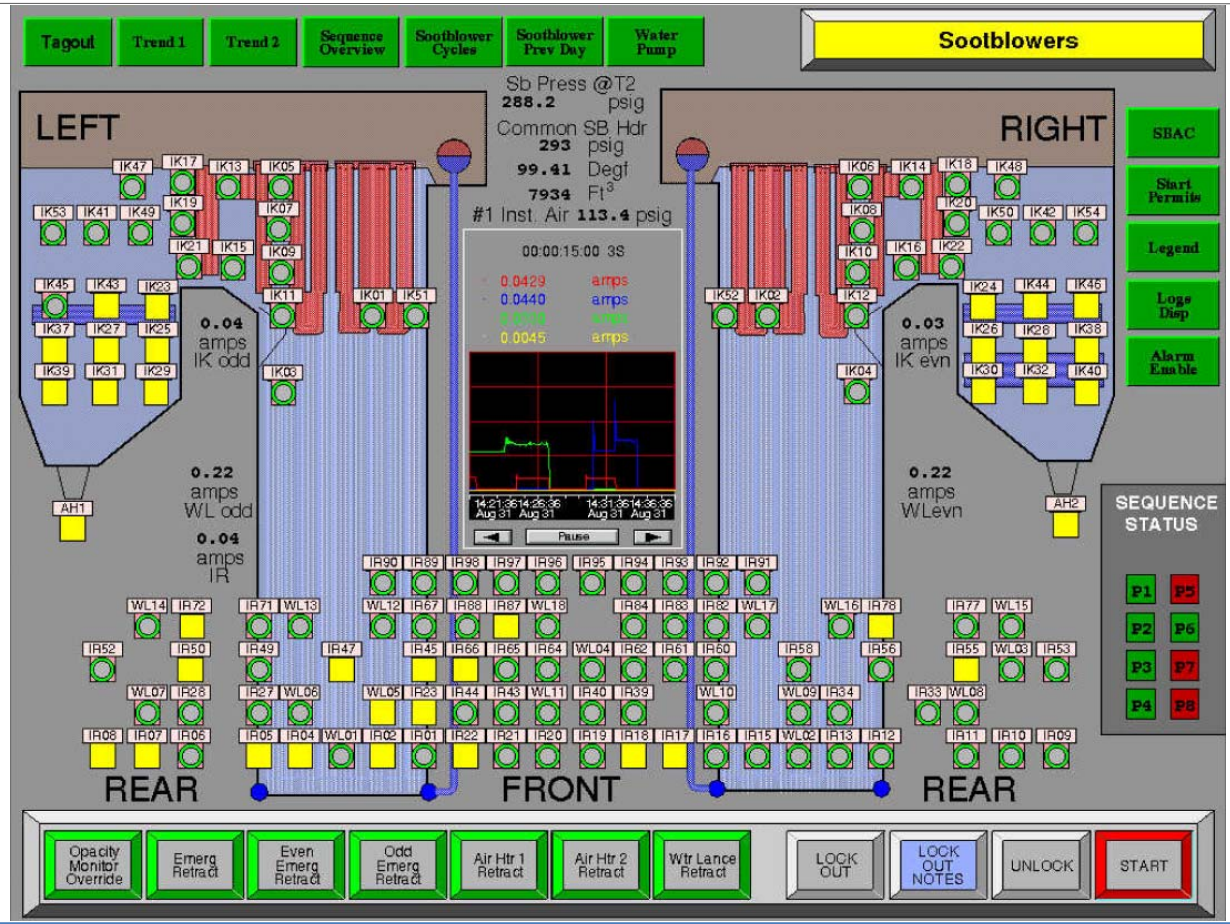
Implementing Test Results

Burner Tilts to Horizontal

- Tilt high limit ramps from 100% (15 degrees up) to 50% (horizontal) as load increases from 440 MW to 540 MW
- Drives tilts to horizontal as load increases, and will drive lower if temperature dictates
- Vary the time between IR blowers (wall blowers) to drive tilts toward horizontal

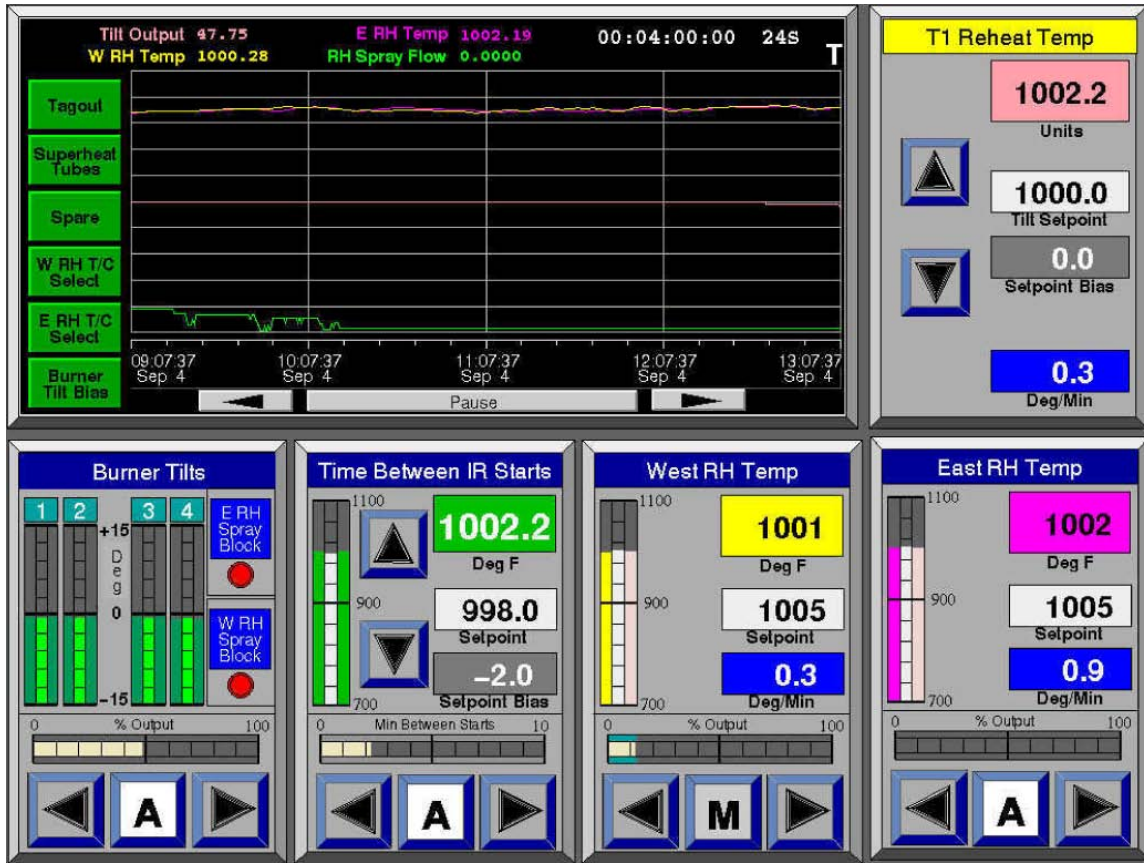


Sootblower Arrangement



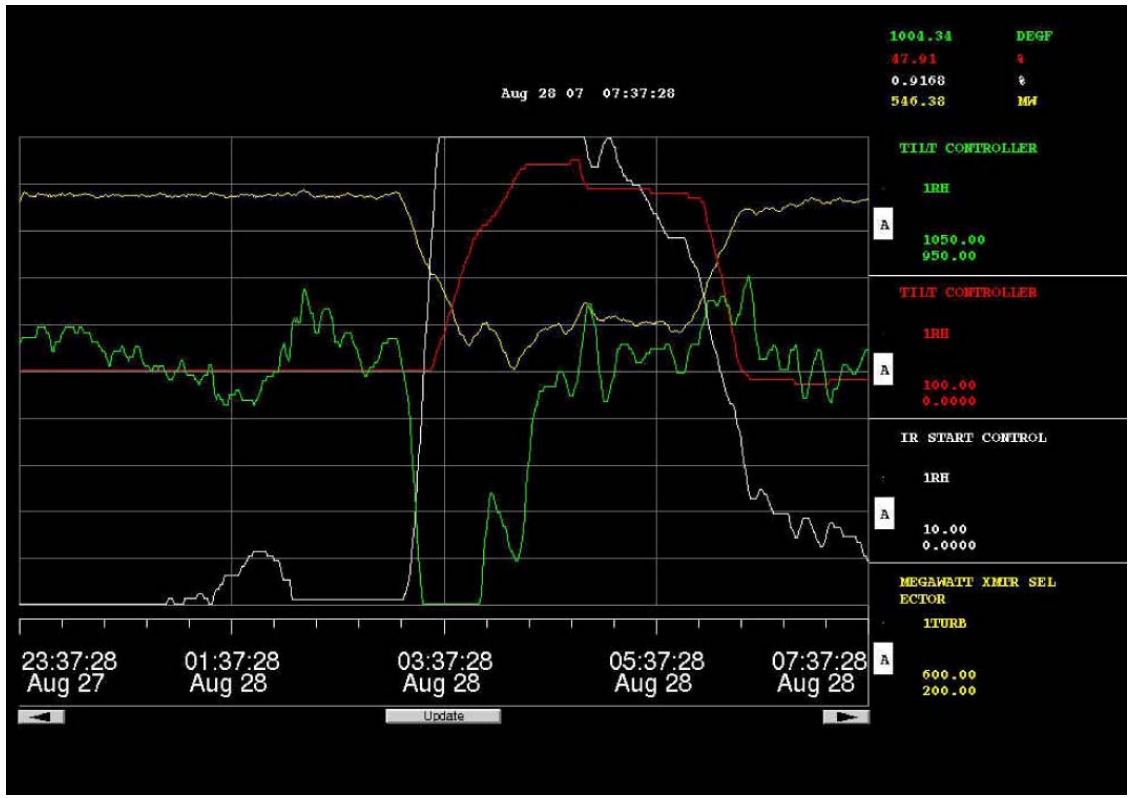
Furnace Temperature

- Tilts are at 50% - Horizontal Location
- IR Sootblower at operational setting



Tilt Controller

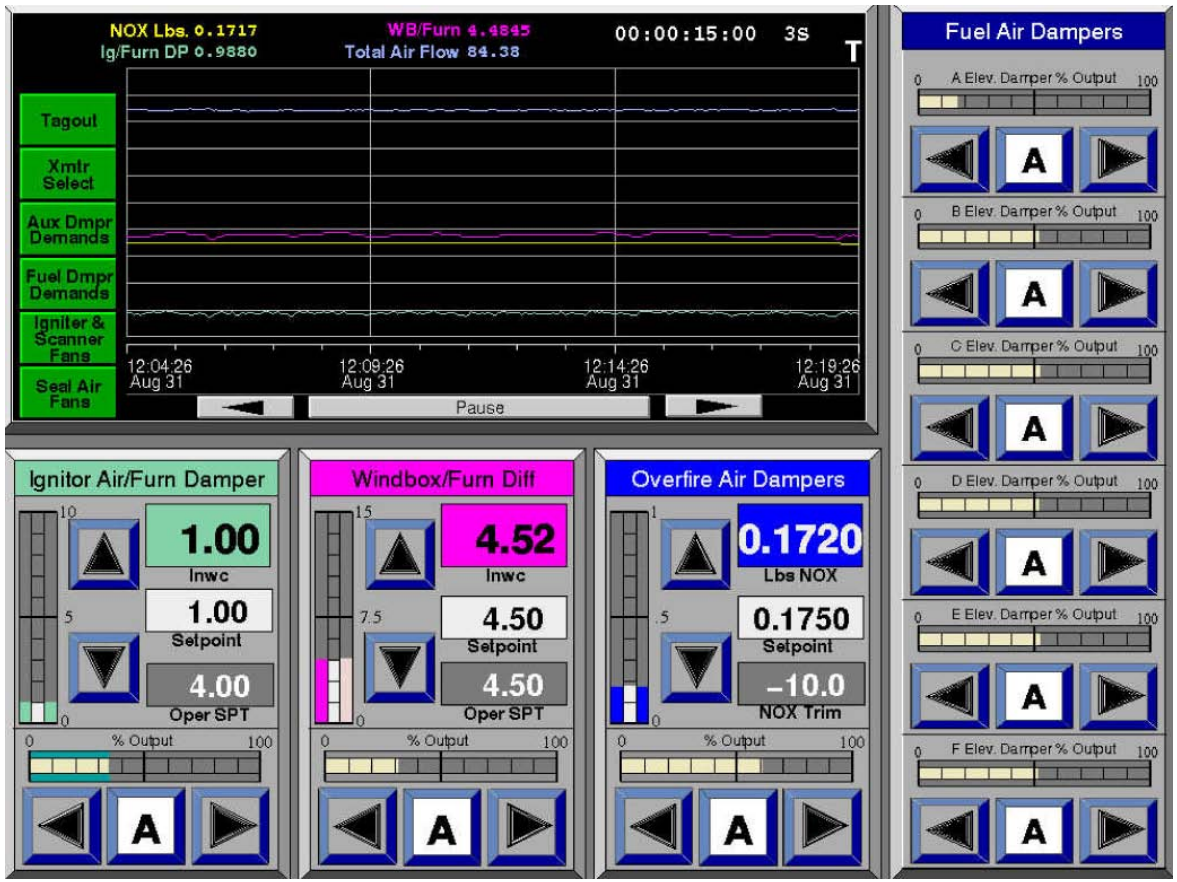
- Tilts need to stay horizontal for good emissions
- Tilts tilt up at a lower load
- Tilts that move up increase emissions



Implementing Test Results

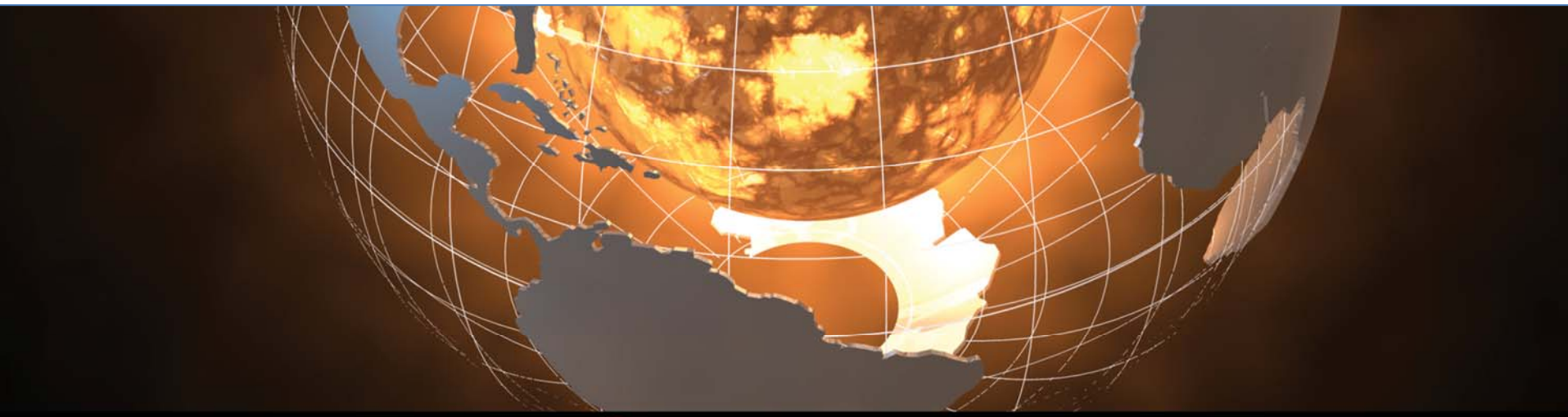
- AA and A auxiliary air control
  - Dampers are controlled by Overfire Air Damper Control when “A” mill is off
  - OFA Control uses characterizer blocks to add aux. air as follows:
    - Over fire dampers
    - AA auxiliary dampers
    - A fuel air dampers

NO_X as a set point for Over Fire Air



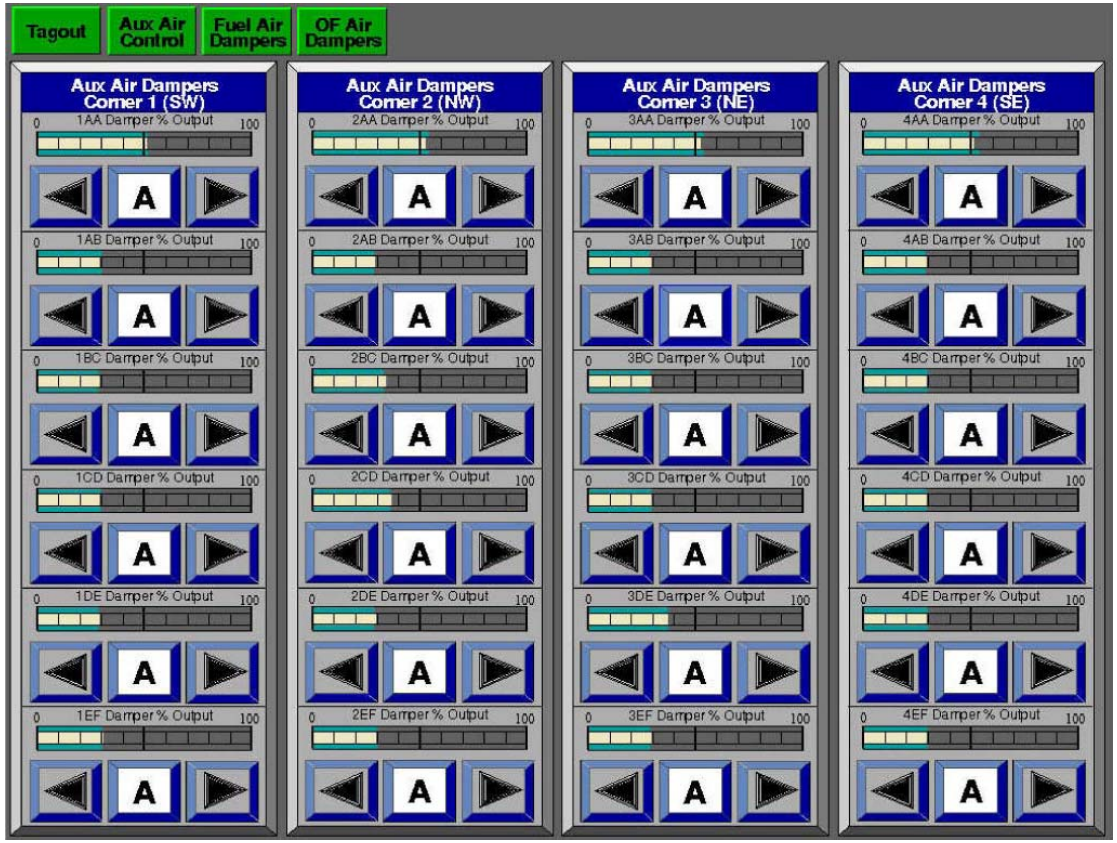
Implementing Test Results

- Individual Aux. Air Damper Bias
  - Utilized existing bias blocks to increase damper position more rapidly on the individual dampers which benefit emissions



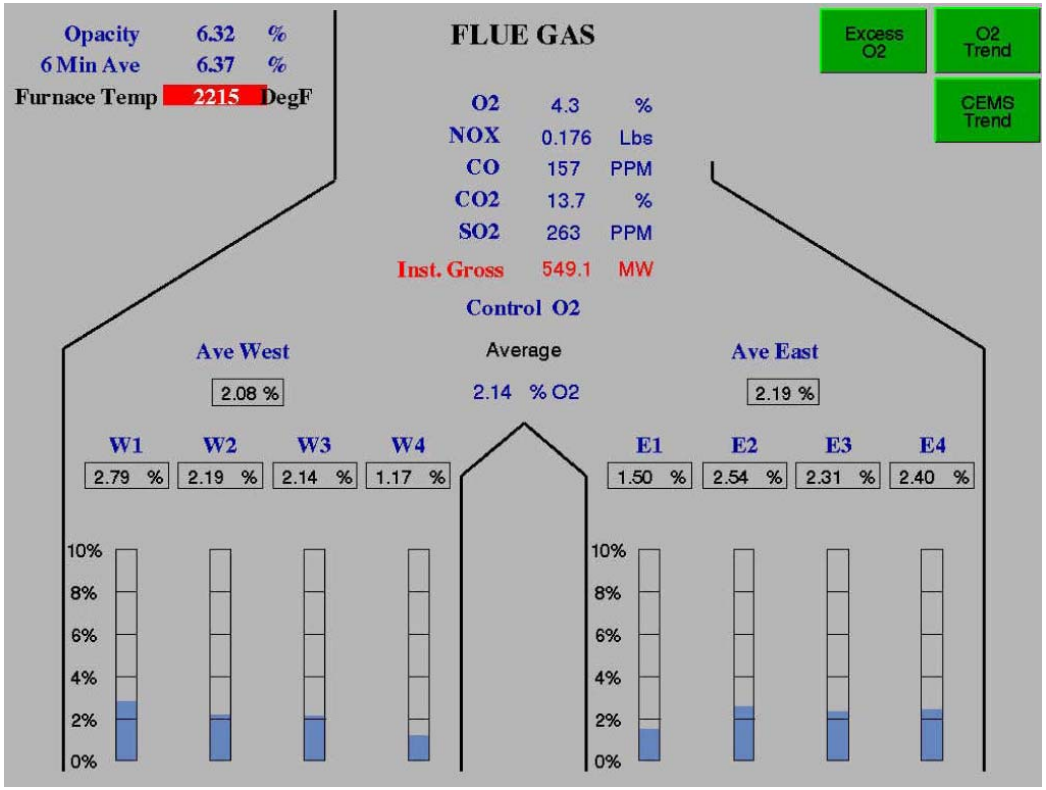
Aux. Air Dampers

- AAD use to operate by corner groups
- Now move to individually optimized combustion and emissions



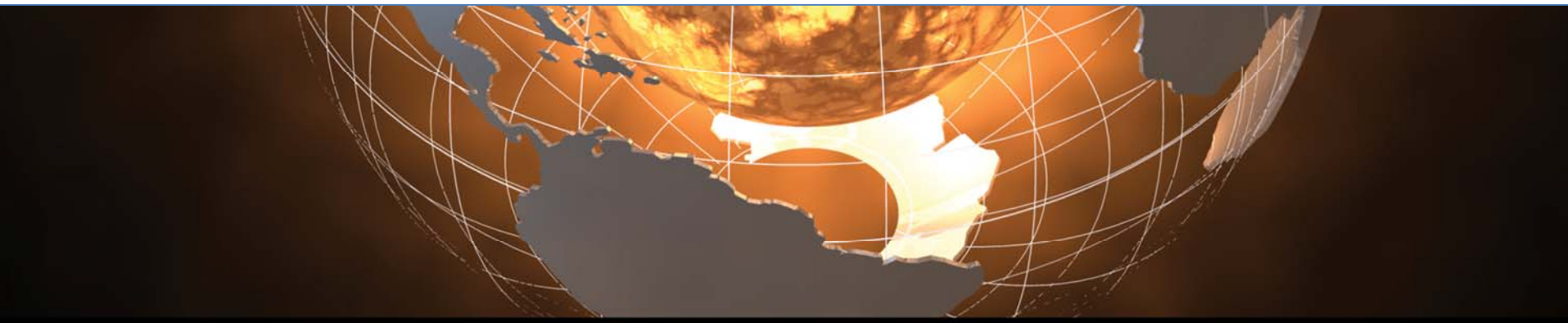
What operators can see on screen

- Improve O_2 split on furnace

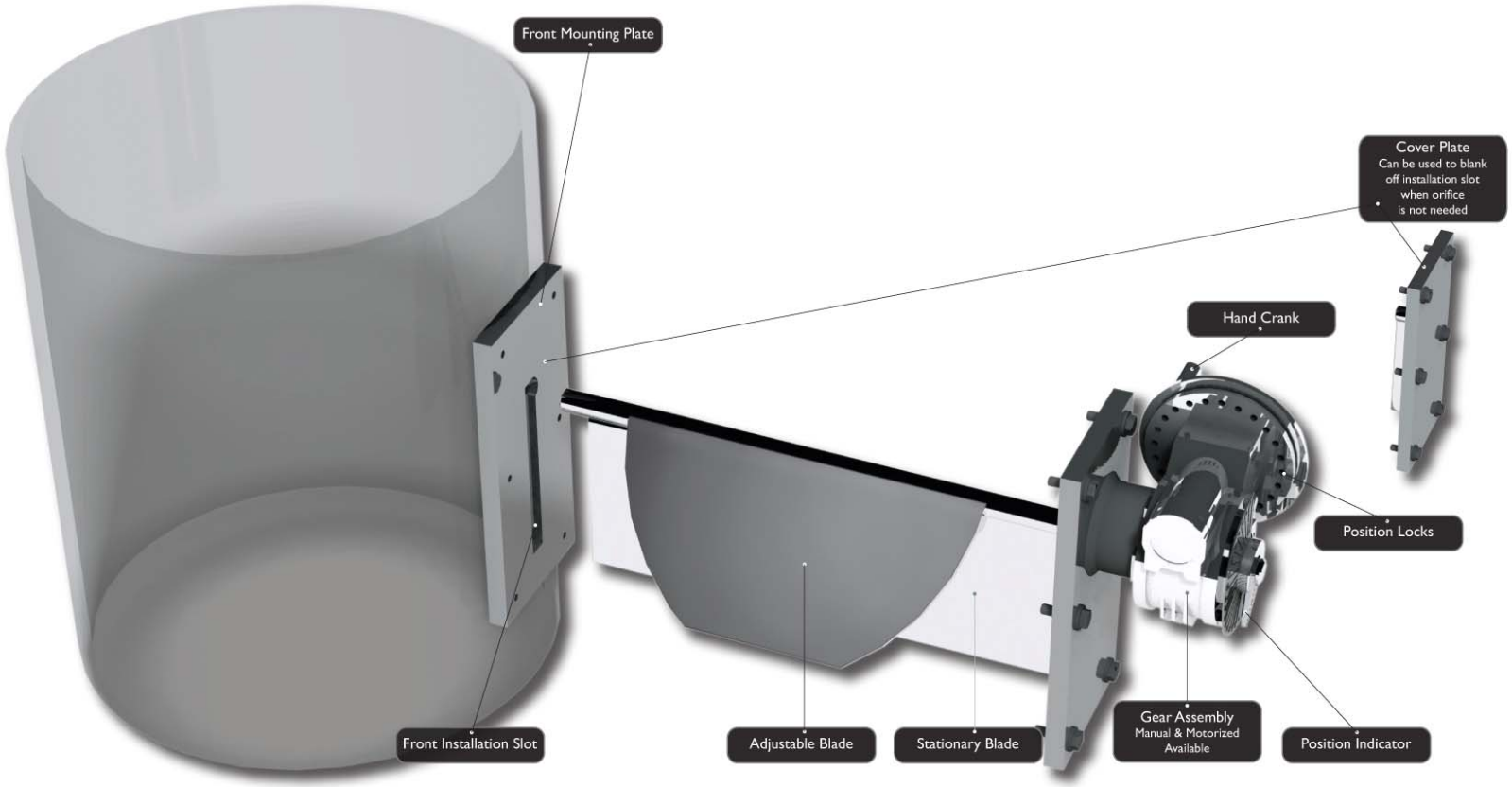


Continuous coal flow monitoring and control

- Coal flow balance monitoring and control
  - Installed MIC coal flow measurement instrumentation to measure corner to corner coal flow
  - Fixed orifices were removed and manually adjustable orifices installed
  - Based off measurements provided by the MIC system coal flow is balanced as necessary



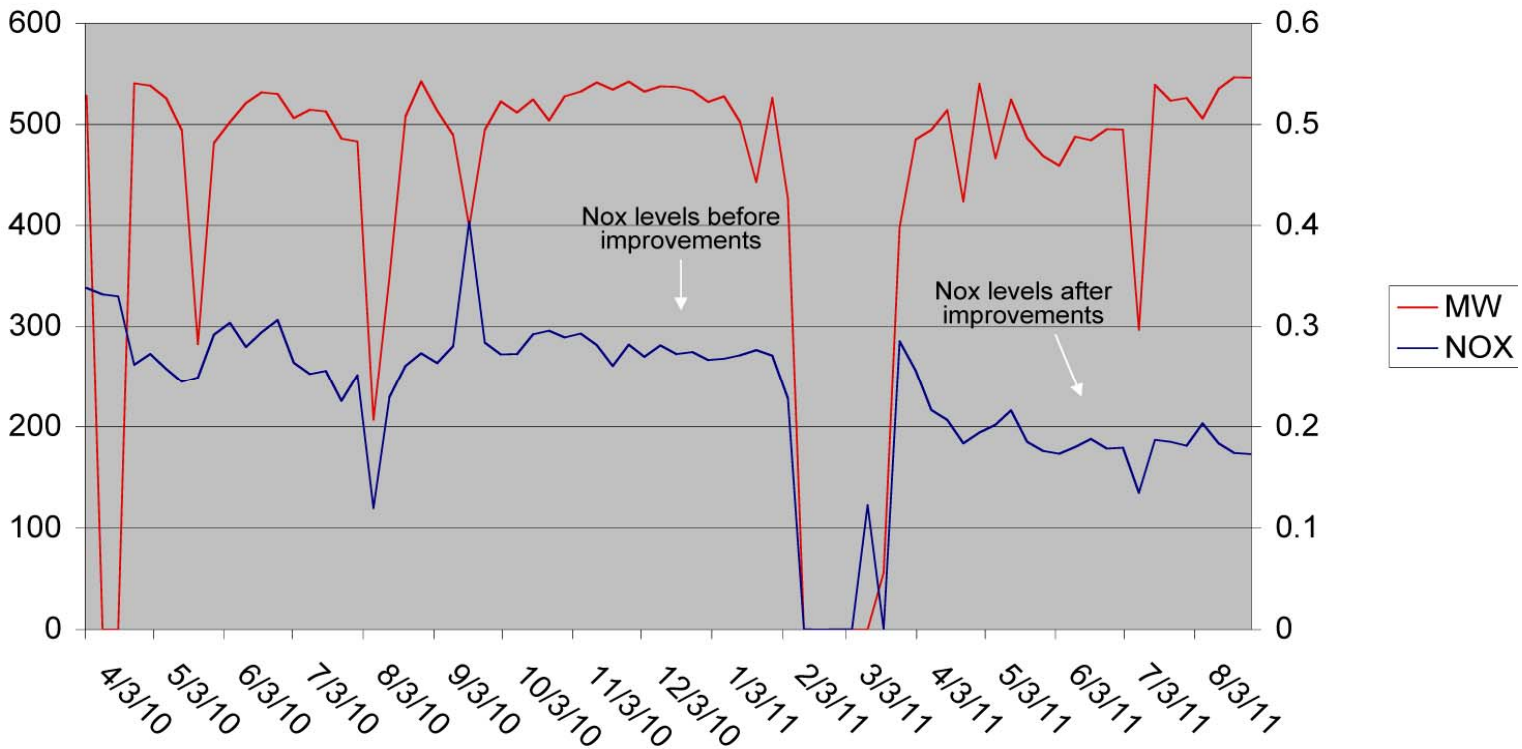
SAS Global Adjustable V-Style Orifice (patent pending)



Controlled Loop System: SAS Global V-Style Orifice (patent pending)

Tolk Unit 1 Weekly Average:

NO_X and unit load trends before and after fuel delivery system improvements



Results

Pulverized coal delivery system optimization has resulted in:

- At least a 30% reduction in NO_X emissions
- Combustion improves that reduced coal deliveries to Tolk Station by approximately one unit train per month
- This results in at 22,000 tons less CO_2 emissions

Real World

- Change in operational priority
  - Emissions on equal footing with Efficiency
  - Cultures take time to change
  - Some operators are reluctant to give control over to automated systems