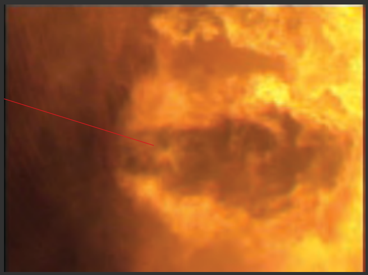
REINHOLD ENVIRONMENTAL Ltd.

2014 NOx-Combustion Round Table
& Expo Presentations

February 10 & 11, 2014, in Charlotte, NC / Hosted by Duke Energy



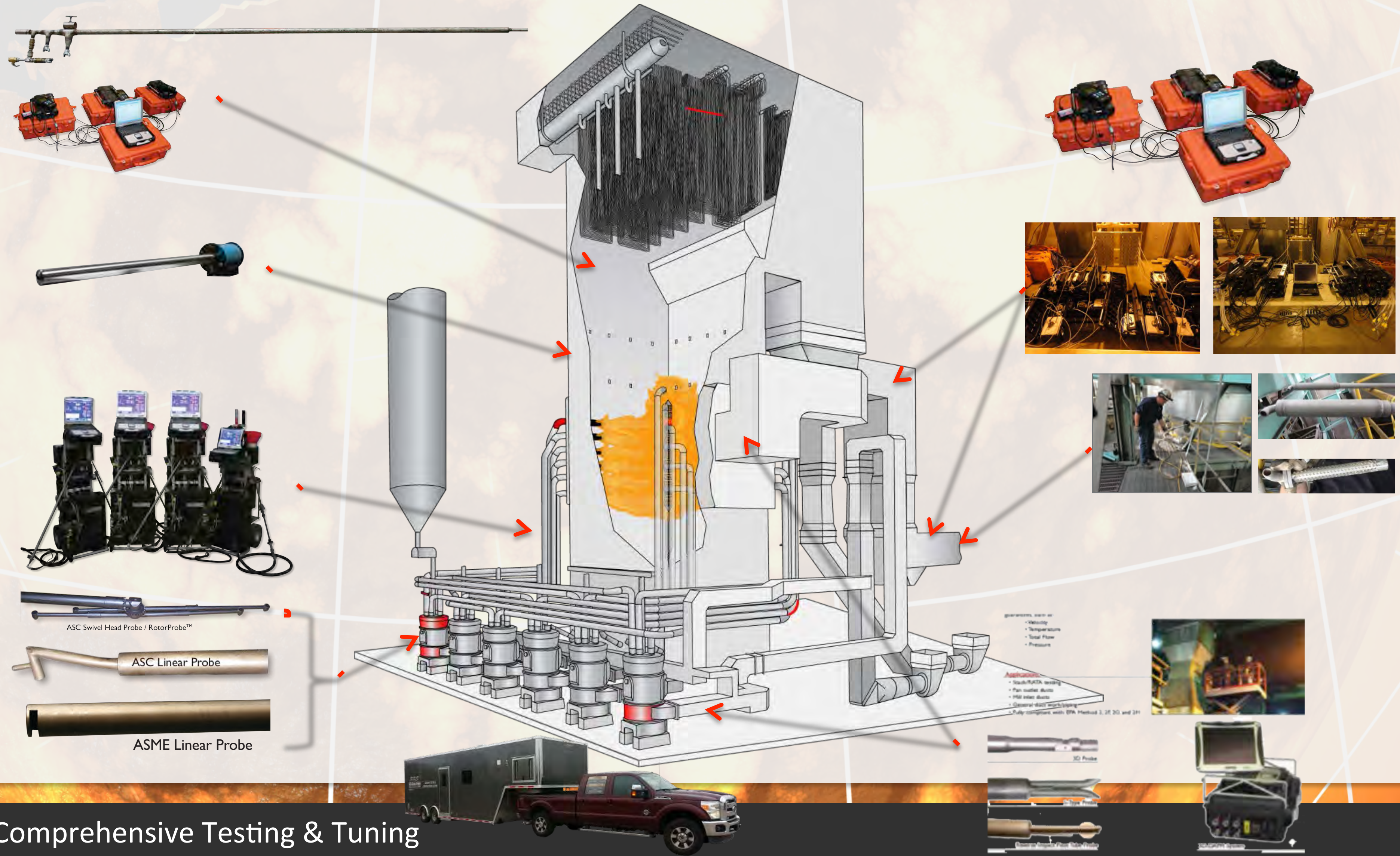

2014 NO_X Combustion / PCUG Conference

Comprehensive Boiler Testing and Tuning Approach for a 550 Mw Corner Fired PC Boiler

Daric Moenter, AES US Services, LLC
Sammy Tuzenew, SAS Global Corporation

February 10th 2014

Testing Locations



Issues

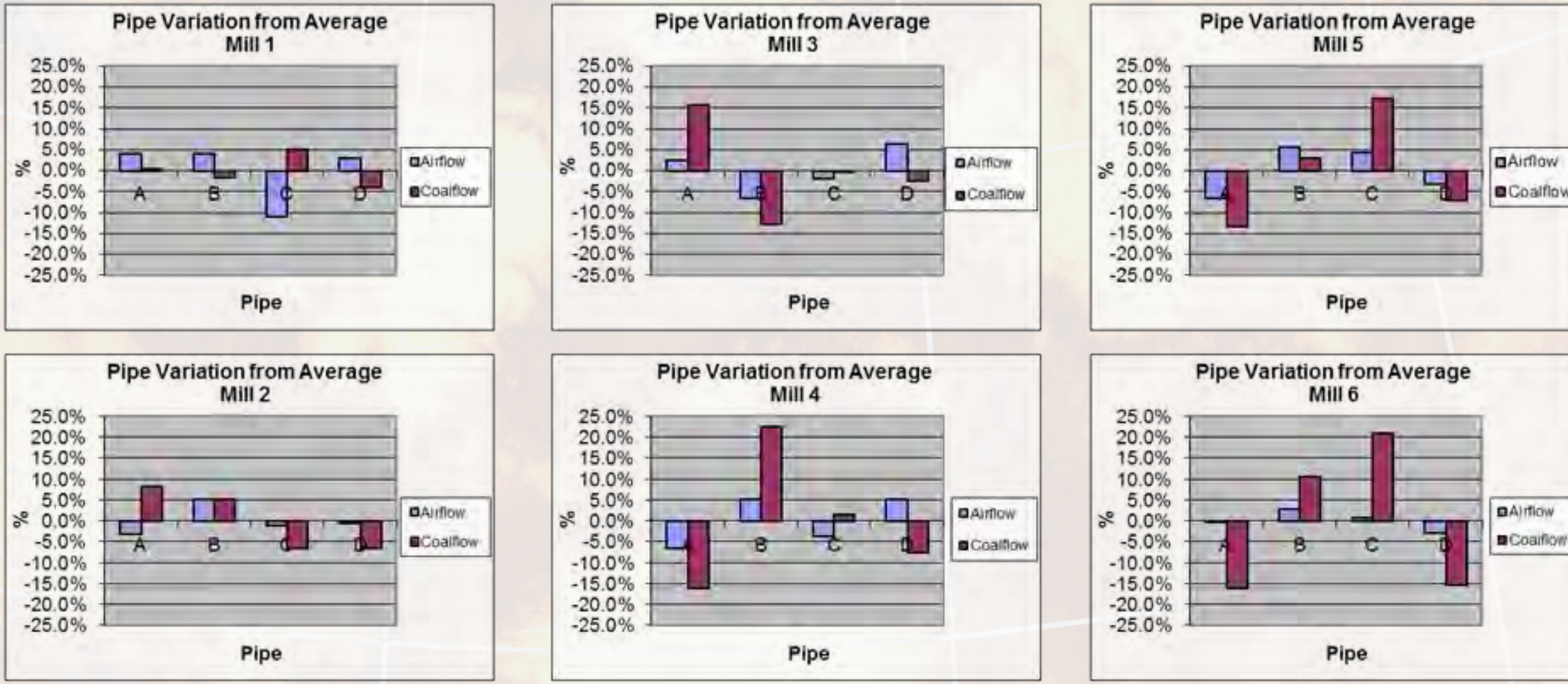
- Forced Outages to de slag the boiler
  (4 forced outages in 9 month period)
- Poor Combustion & Increase LOI's
  (LOI's increased from 2% to 6%)
  (split and unbalanced steam temps SH/RH)
- Unable to Sell Flyash
  (Forced to land fill verse selling)
- De-Rated Load (Megawatts)
  (Derated ~ 21 Mw or 4%)

Pulverizer Diagnostic Testing

- Dirty Airflow Balance
  (Wet & Dry air determination)
- Fuel Distribution
  (Wet & Dry air determination)
- Air / Fuel Ratios
- Fuel Fineness Levels
  (Wet & Dry air determination)
- Airflow Accuracies
  (measured verse indicated)
- Fuel Flow Recovery
  (measured verse indicated)

Pulverizer Diagnostic Testing

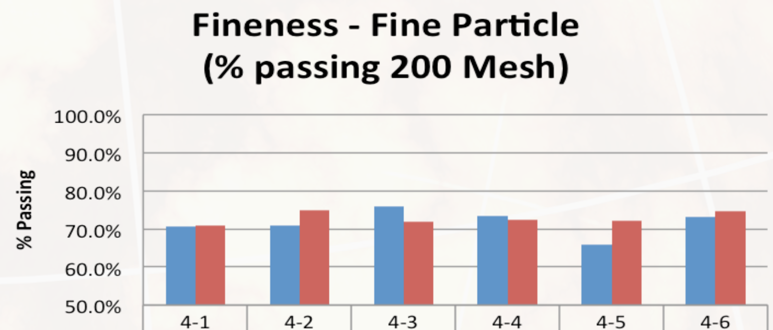
Dirty Air & Fuel Flow Distribution



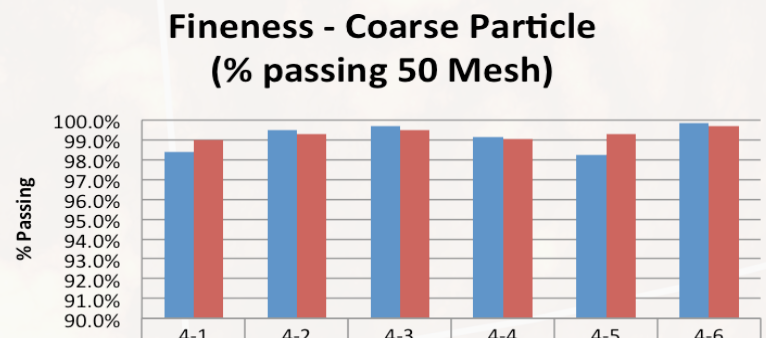
Knowing the fuel and airflow distribution for each pulverizer is used to guide tuning efforts to the Fuel Air, Aux Air, CCOFA and SOFA curves. Summing up the air and fuel flows for each corner helps identify which corners need more combustion / secondary air.

Pulverizer Diagnostic Testing

Fuel Fineness Levels



	4-1	4-2	4-3	4-4	4-5	4-6
As Found	70.6%	71.0%	76.0%	73.4%	66.0%	73.1%
As Left	71.0%	74.9%	71.8%	72.4%	72.2%	74.7%



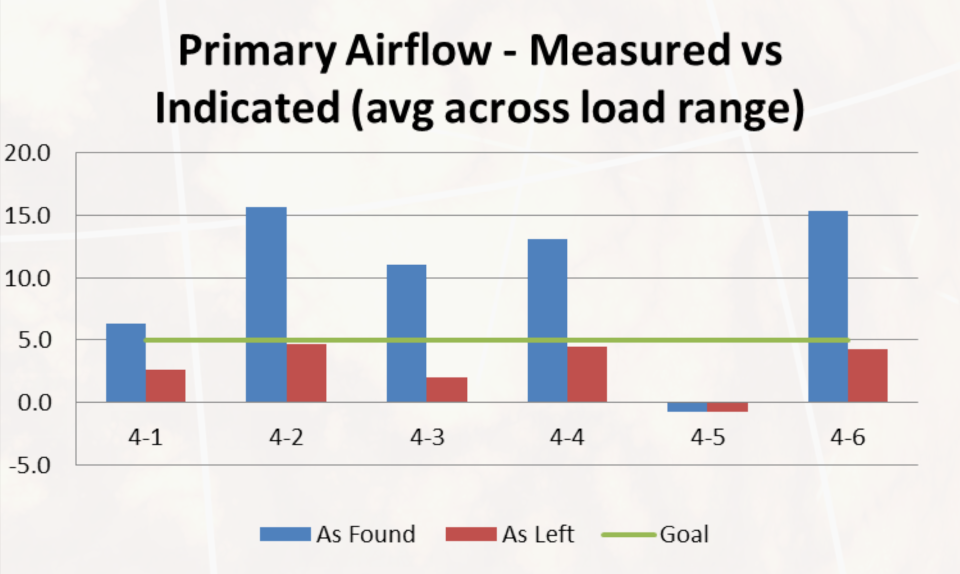
	4-1	4-2	4-3	4-4	4-5	4-6
As Found	98.4%	99.5%	99.7%	99.1%	98.2%	99.8%
As Left	99.0%	99.3%	99.5%	99.0%	99.3%	99.7%

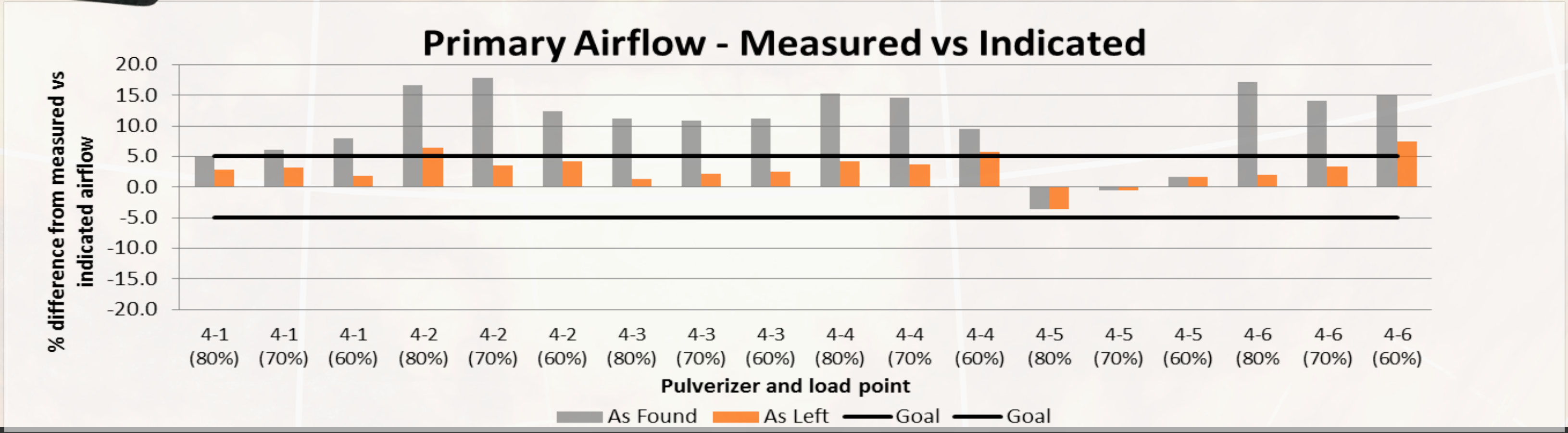
Fuel Fineness Levels were improved by re setting the roll to ring clearances and via classifier blade adjustments. 4-5 Mill was historically a bad performer for fineness levels. 4-5 and 4-6 mills supplies fuel to the top elevation burners with the least amount of residence time. 4-6 is typically out of service and used as a spare mill.

Pulverizer Diagnostic Testing

Primary Airflow Traverses

The measured primary airflow were determined and calibrations performed accordingly. Accurately measured and controlled input such as air is critical to combustion performance and A/F Ratios.



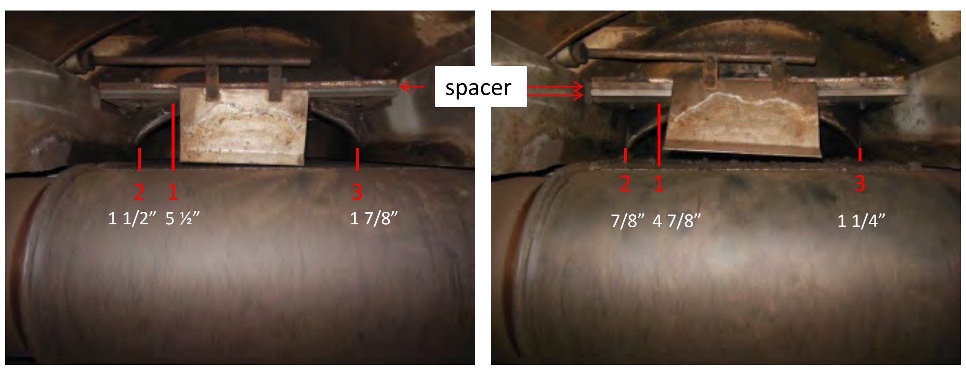


Pulverizer Diagnostic Testing

Flue Flow Recovery

The measured fuel flow was determined and calibrations performed accordingly. Note this particular plant is equipped with volumetric feeders and not gravimetric feeders. Correcting measured verse indicated fuel flows required feeder inspections and a mechanical change to the spacer as shown below.

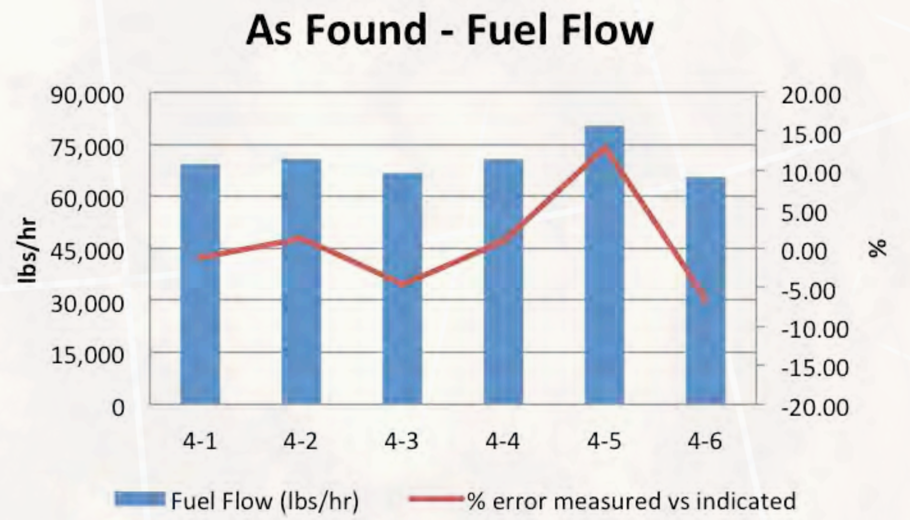
4-5 mill was operating ~10,000 lbs/hr more coal flow than the other mills. Once reason for sub standard fineness levels found on this mill.

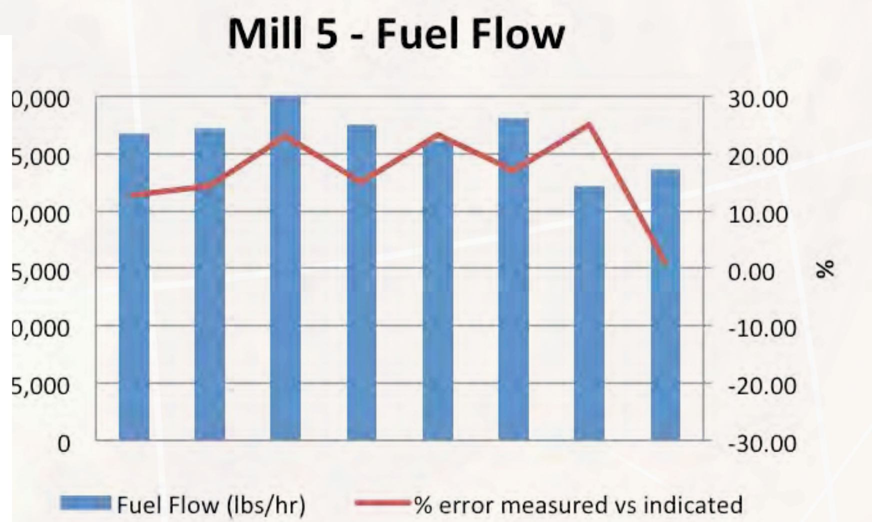


4-5 “As Found”

4-5 “As Left”

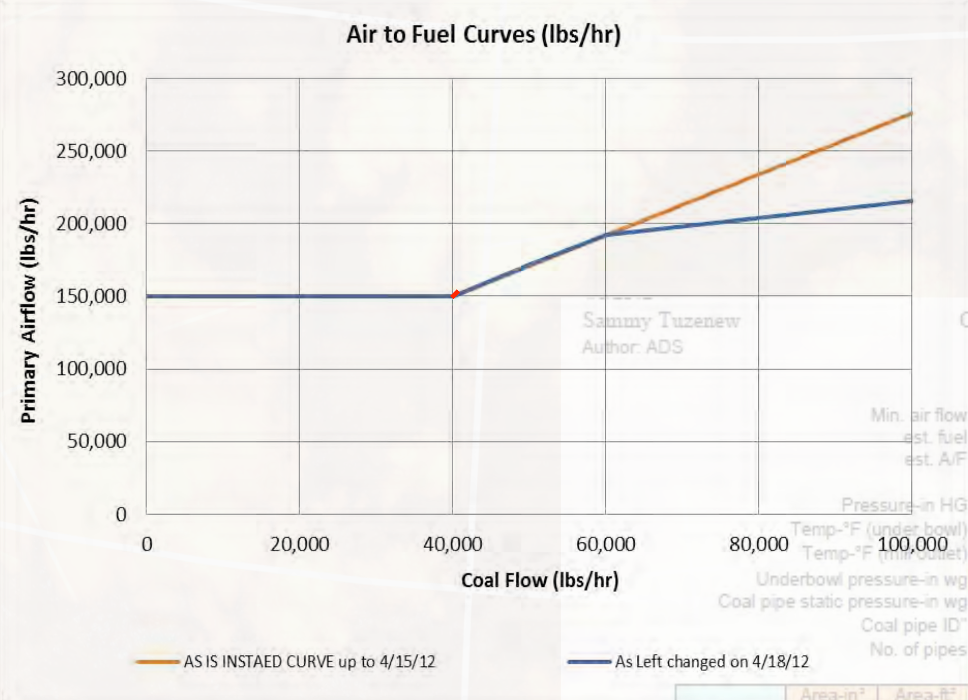
Notes: One (1) 3/8” spacer removed and two (2) ½” spacer added on 4-5 mill.





Air To Fuel Curves

A/F ratios & curves are directly impacted by the pulverizer's throat sizing. Operating with higher than desired A/F ratios impact combustion performance and heat rate.



Sammy Tuzenew
Author: ADS

CE - 903 (AES IPL - PETE # 4)

Min. air flow	lbs/hr	147,350
est. fuel	lbm/hr	81,861
est. A/F	ratio	1.8/1

Pressure-in HG		29.9	Density-lb/ft³
Temp-°F (under bowl)		375	0.049961
Temp-°F (mill outlet)		150	0.065687
Underbowl pressure-in wg	est	20.00	
Coal pipe static pressure-in wg		3.00	
Coal pipe ID"		21.25	
No. of pipes		4	

Pipe Air-flow lbs/hr

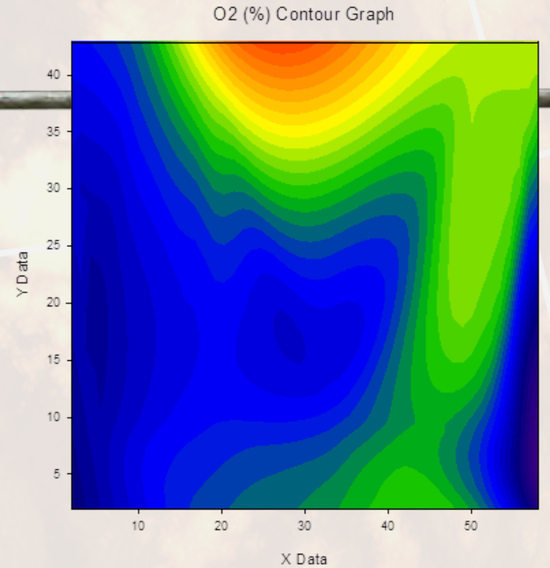
		147350	162000	198000	216000
Ave pipe vel-ft/min		3795	4172	5100	5563
Ave pipe vel-ft/sec		63	70	85	93
Velocity @ pipe bias-%	-14.0	3264	3588	4386	4784

Air-flow lbs/hr

	Area-in²	Area-ft²	130000	140000	147350	150000	162000	170000	180000	198000	216000
OEM VANE	1462.3	10.155	4270	4599	4840	4927	5322	5584	5913	6504	7096
CFM (under bowl)			43367	46703	49155	50039	54043	56711	60047	66052	72057

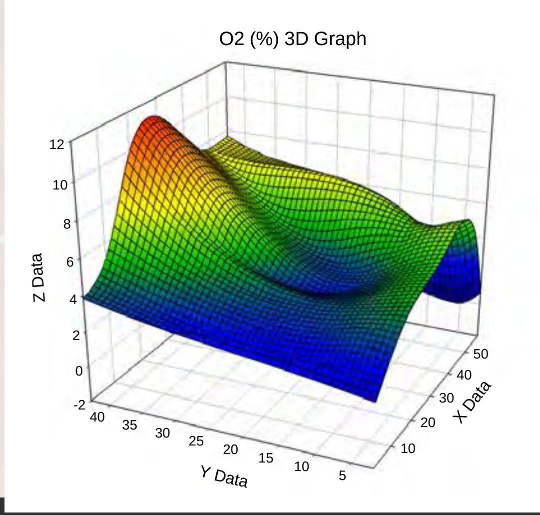
Flue Gas Testing

Upper Furnace



Upper Furnace Flue gas testing is performed with water cooled probes. The High Velocity Thermocouple (HVT) probe was designed for measuring Furnace Exit Gas Temperatures (FEGTs) and if equipped can be used to measure the flue gas profiles in order to perform the mapping of Temperature, O2, CO and NOX profiles.

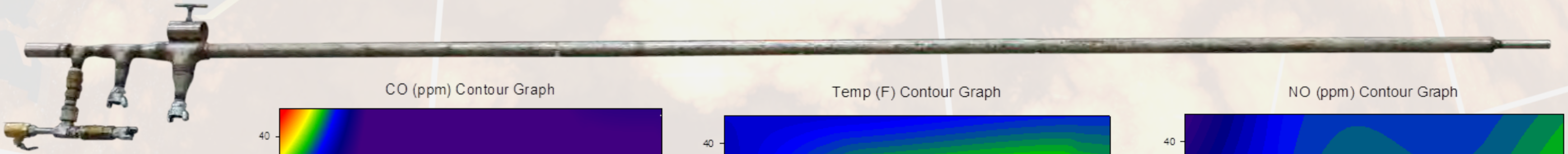
HVT traverses are very useful when diagnosing and performing tuning efforts. The testing is very labor intensive and typically used to base line upper furnace profiles. Periodic test runs during tuning efforts are normally performed on a limited basis. And ideally performed for pre and post tuning efforts in most cases.

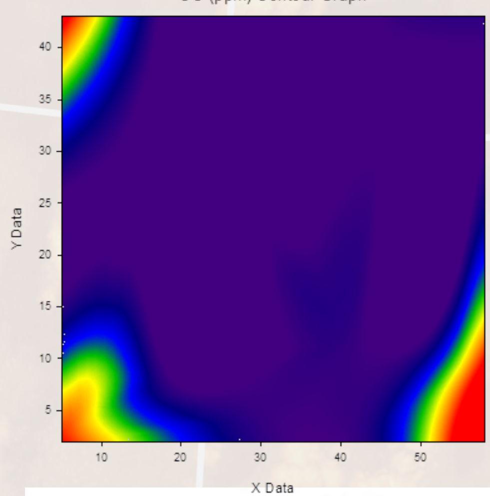


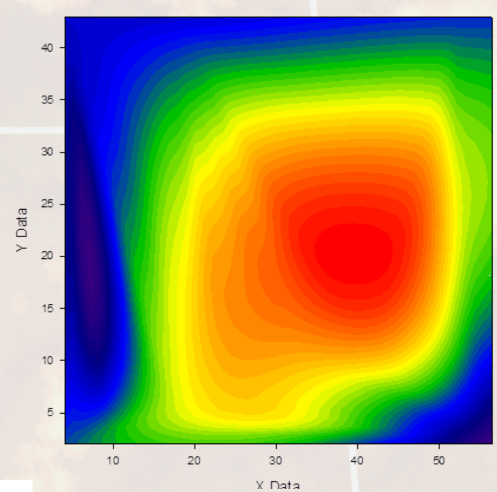
Flue gas mapping and testing at the economizer exit plane guides the majority of the boiler tuning results.

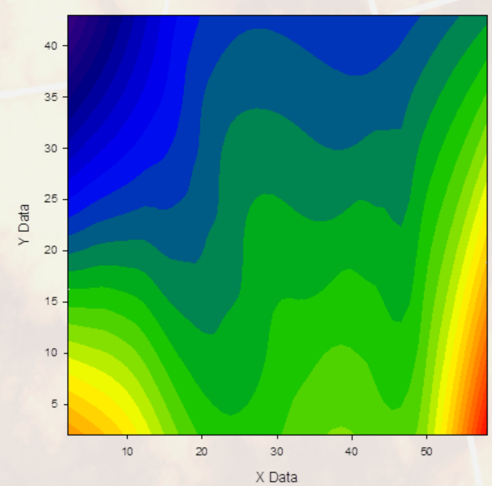
Flue Gas Testing

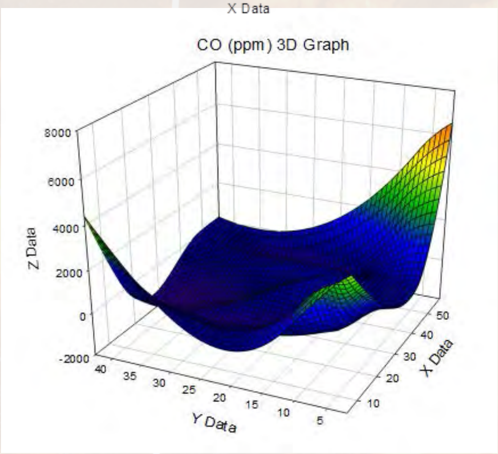
Upper Furnace

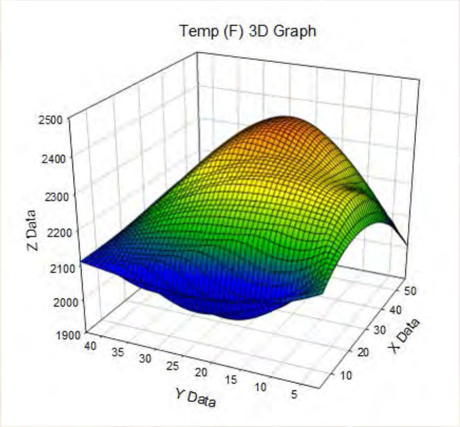


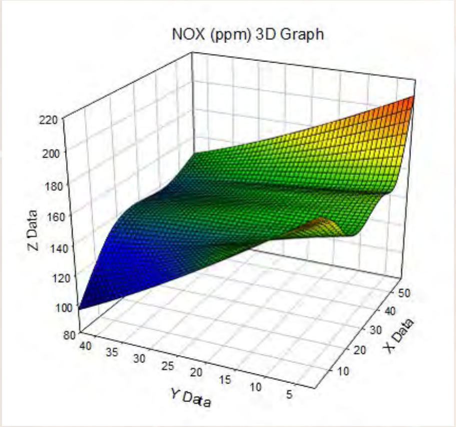






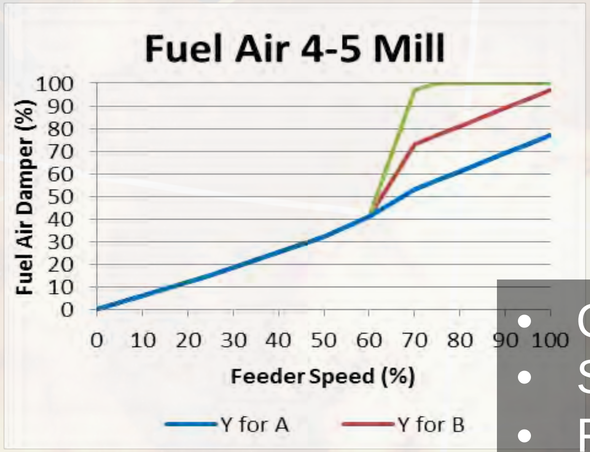


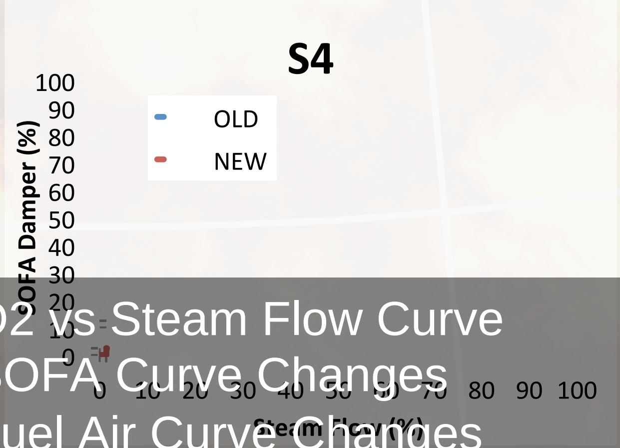


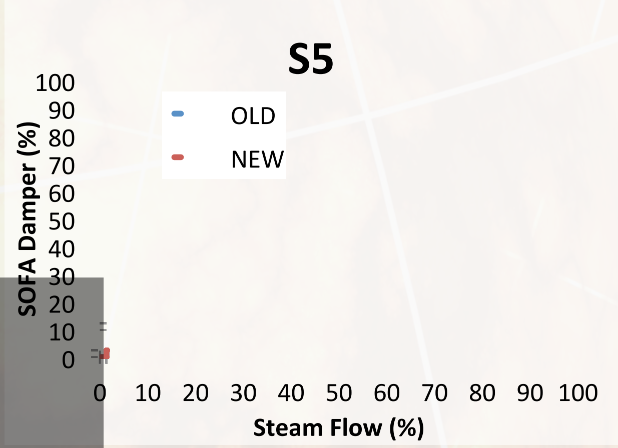


Boiler Tuning

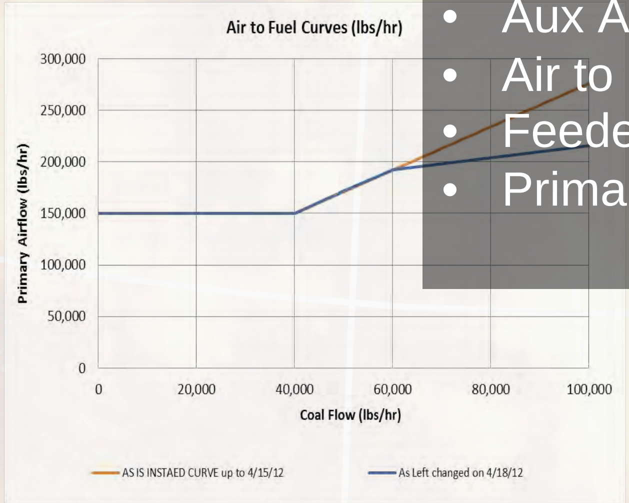
Tuning Changes

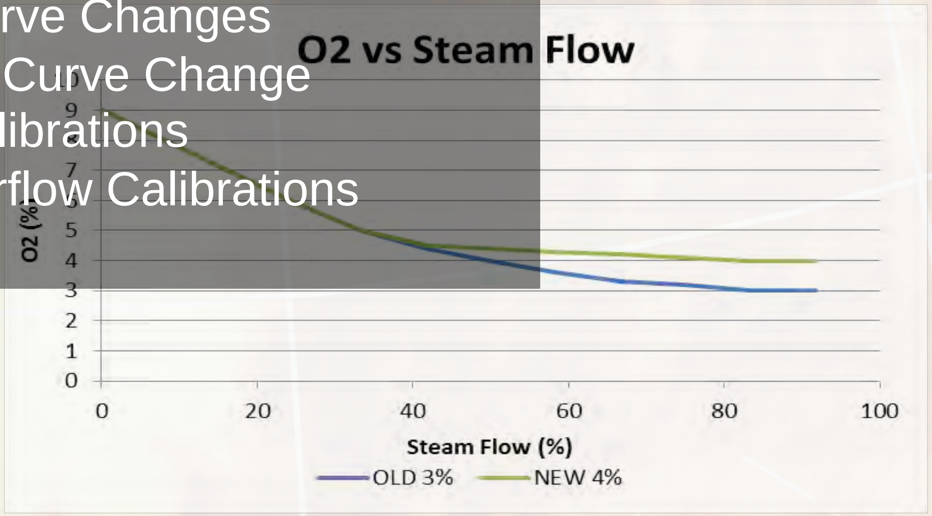






- O2 vs Steam Flow Curve
- SOFA Curve Changes
- Fuel Air Curve Changes
- Aux Air Curve Changes
- Air to Fuel Curve Change
- Feeder Calibrations
- Primary Airflow Calibrations

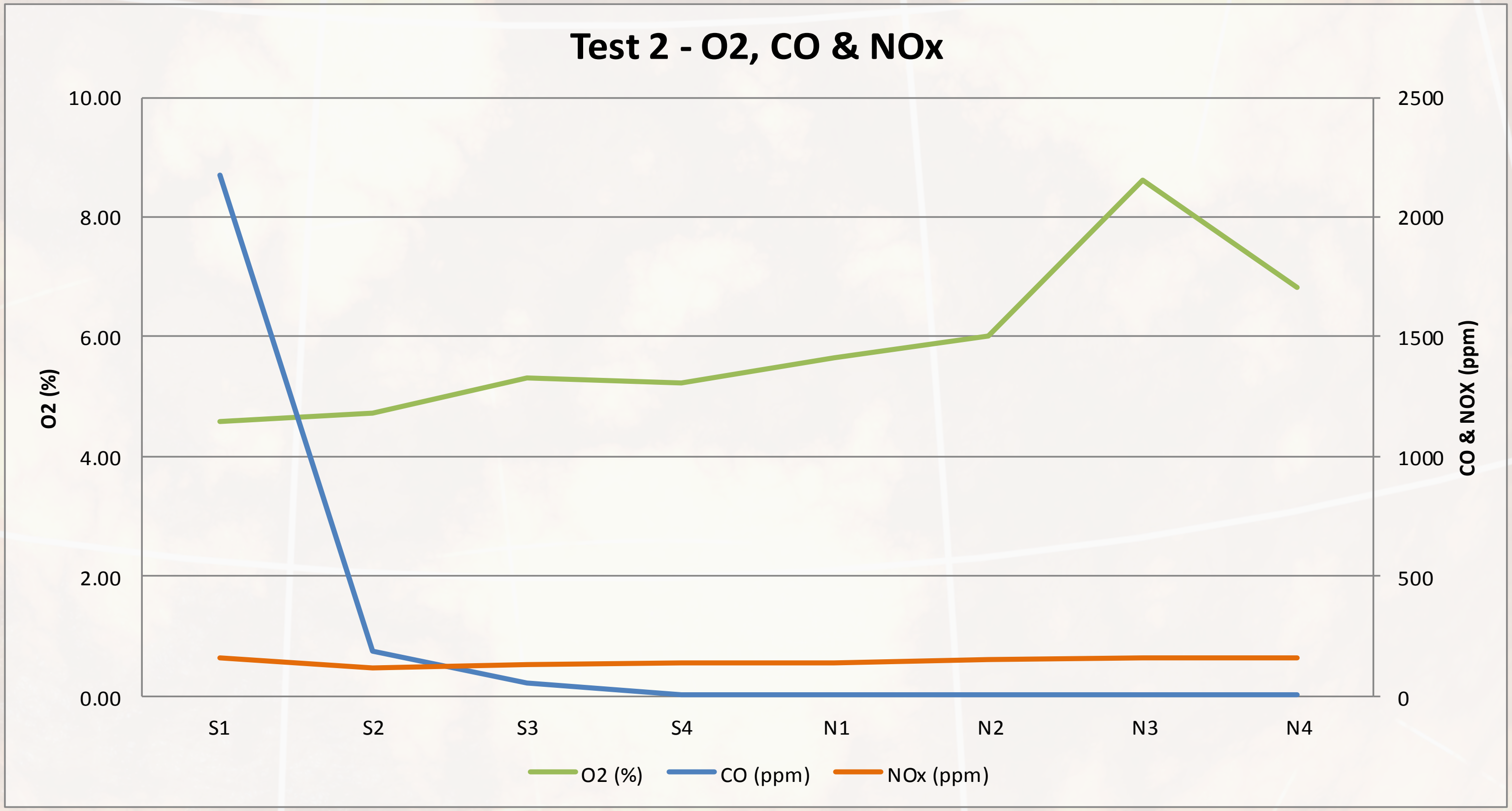




Boiler Tuning

Tuning Results

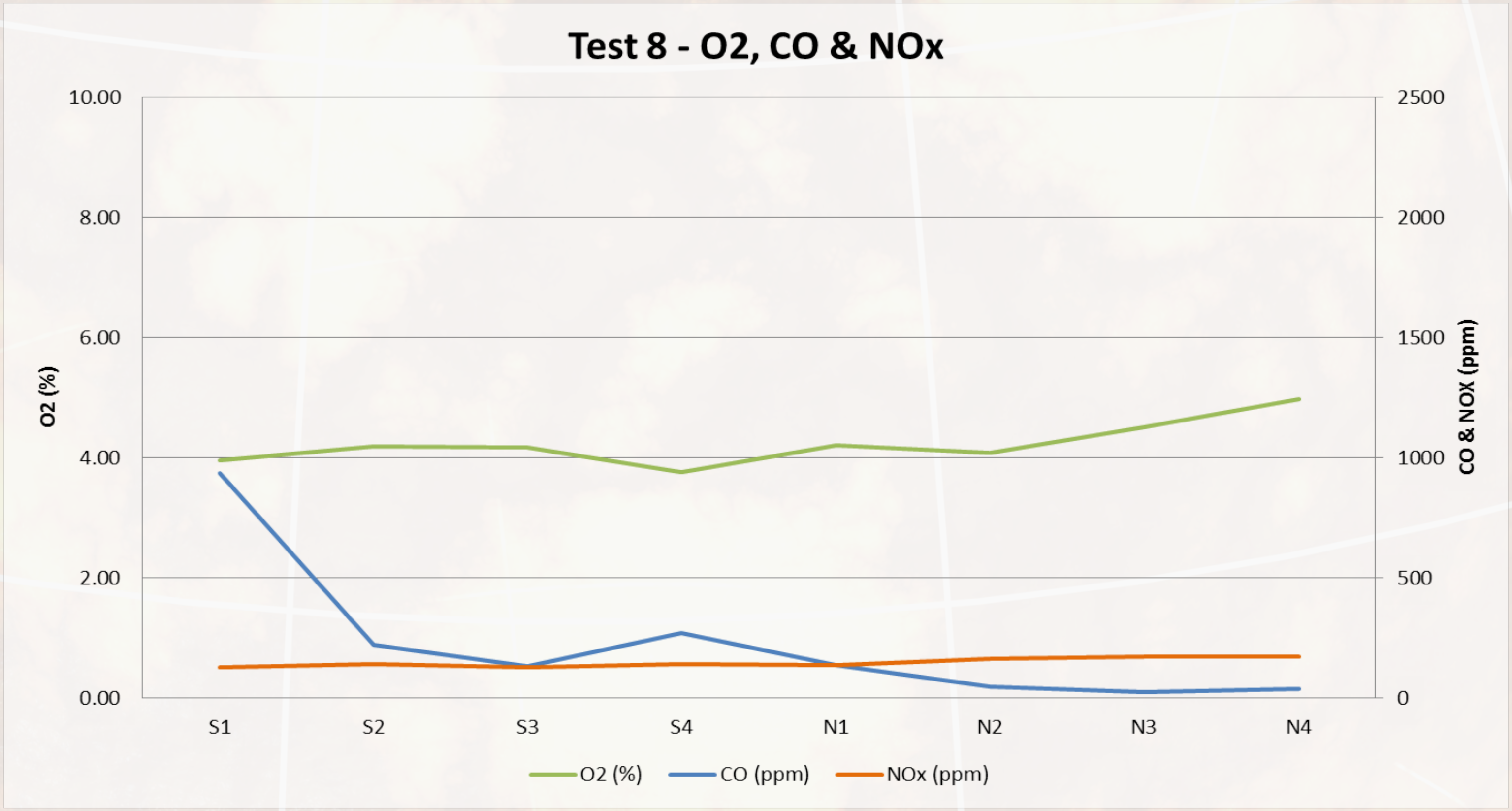
Tuning efforts were performed based on the economizer exit flue gas profiles for O_2, CO & NO_x. Both the north and south duct were equipped with multipoint probes. Each duct had 4 probes with 3 sampling points each for a representative test grid. The data here shows the average readings measured for each port. The CO profiles, as shown with the blue line, shows CO levels greater than 2,000 ppm.



Boiler Tuning

Tuning Results

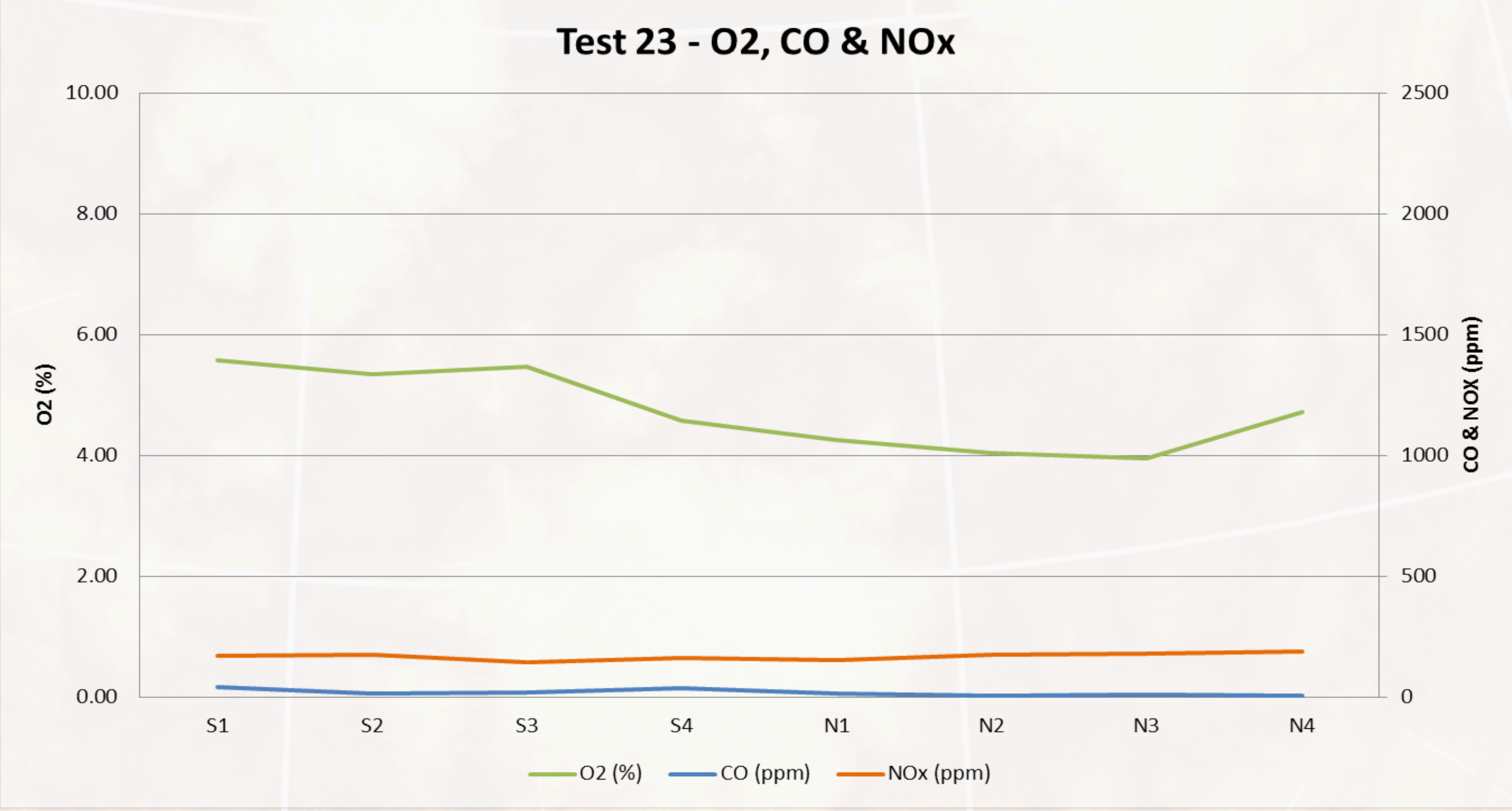
Test 8 was performed post adjustments to the air to fuel curve installed for each mill and 4-5 Feeder issues corrected. As you can see, the CO levels drop on the South side from >2,000 ppm to less than 1,000 ppm.



Boiler Tuning

Tuning Results

Test 23 shows the economizer exit flue gas profiles with CO levels significantly reduce with CO levels below 50 ppm. Tuning adjustments were made to the O2 vs Steam flow curve, damper setting changes to SOFA, Fuel Airs & Aux Airs and fuel bias on top mill.

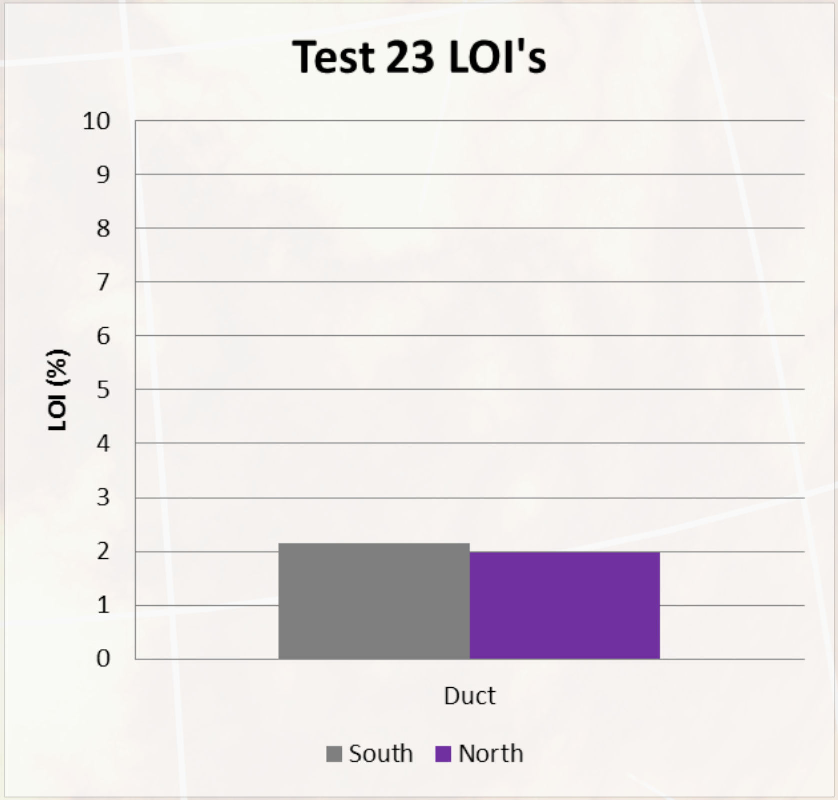


Cost Savings & Justifications

Flyash LOI Results

Table below shows the cost savings for improving LOI's from an average 4% to 2%. ***For every 1% improvement in LOI is equal to ~ 0.1% gain in boiler efficiency***

Inputs		
Ash in Fuel	9.37%	%
Initial LOI	4.00%	%
Improved LOI	2.00%	%
Initial		
Lbs of Unburned Carbon and Ash	218,128,364	Lbs
Lbs of Unburned Carbon	8,725,135	Lbs
Improved		
Lbs of Unburned Carbon and Ash	213,676,765	Lbs
Lbs of Unburned Carbon	4,273,535	Lbs
Final Calculations		
Reduction of Unburned Carbon	4,451,599	Lbs
Reduction of Coal Fired per Year	7,150,015	Lbs
Fuel Cost Savings in Reductions	**$136,561.85**	**$**



Cost Savings & Justifications

Primary Airflow

With the adjustments to the air to fuel curve only there was a cost savings as a result of parasitic power consumption on the 4-1 and 4-2 primary air fans. The savings was calculated based on the data provided Table 1. Cost savings by improving the air to fuel curve from 2.94 to 2.58 resulted in an additional savings as shown in Table 2. The reduction in primary airflow results in less energy being spent to heat up the additional airflow. This results in a heat rate improvement and fuel cost savings. Table 3 is also provided to show the potential cost savings by improving the air to fuel curve form 2.58 to 1.8. The cost savings in Table 3 will require mechanical changes to the pulverizer throats and new air to fuel curve settings.

Pre Tuning	
Cost to run PA Fan 4-1 at 537 Mw	$ 137,638.80
Cost to run PA Fan 4-2 at 537 Mw	$ 139,050.48
Post Tuning	
Cost to run PA Fan 4-1 at 558 Mw	$ 129,168.72
Cost to run PA Fan 4-2 at 558 Mw	$ 129,874.56
Cost Savings	**$ 17,646.00**

Tab. 1. PA Fan Cost Savings. Note that the cost of operating the primary air fans was less at 558 Mw.

# of Mills	5	#
As Found A/F Ratio per mill	2.94	lb/lb
Improved A/F Ratio per mill	2.58	lb/lb
Operating Cost at 2.94 A/F Ratio	$4,253,553.02	$/yr
Operating Cost at 2.58 A/F Ratio	$4,173,080.75	$/yr
Heat Rate Improvement Potenial	9.1	BTU/kwh
Heat Rate Penalty	0.15%	0.15%
Cost Savings	**$80,472.27**	**$/yr**
Cost Savings	**$16,094.45**	**$/yr/mill**

Tab. 2 Air to Fuel Curve Cost Savings. Improvement from 2.94 to 2.58 A/F Ratio.

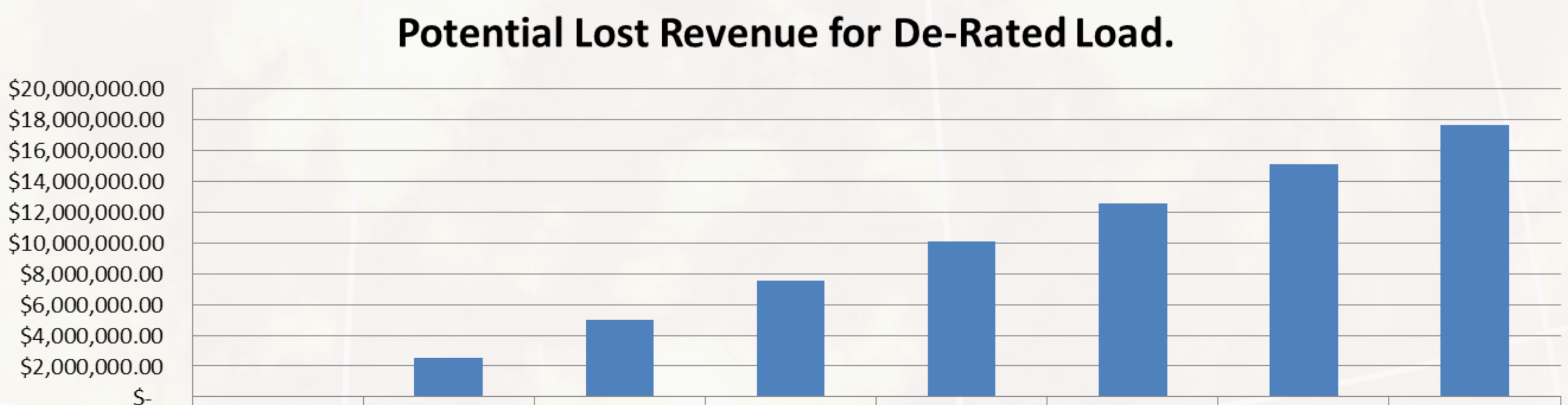
# of Mills	5	#
As Found A/F Ratio per mill	2.58	lb/lb
Improved A/F Ratio per mill	1.80	lb/lb
Operating Cost at 2.58 A/F Ratio	$4,253,553.02	$/yr
Operating Cost at 1.8 A/F Ratio	$4,079,196.18	$/yr
Heat Rate Improvement Potenial	19.7	BTU/kwh
Heat Rate Penalty	0.33%	0.33%
Cost Savings	**$174,356.84**	**$/yr**
Cost Savings	**$34,871.37**	**$/yr/mill**

Tab. 3 Air to Fuel Curve Cost Savings (Potential). Improvement from 2.58 to 1.8 A/F Ratio.

Cost Savings & Justifications

De-Rated Load and impact of power sales

Revenue for 21 megawatts was used to illustrate the potential sale of megawatts based on pricing from $25 to $200 per MW/hr. Fuel pricing, unit heat rate, fuel analysis and capacity factor are required to determine the data shown below.



	$25.00	$50.00	$75.00	$100.00	$125.00	$150.00	$175.00	$200.00
Revenue	$-	$2,520,000.0	$5,040,000.0	$7,560,000.0	$10,080,000.	$12,600,000.	$15,120,000.	$17,640,000.

Cost Savings & Justifications

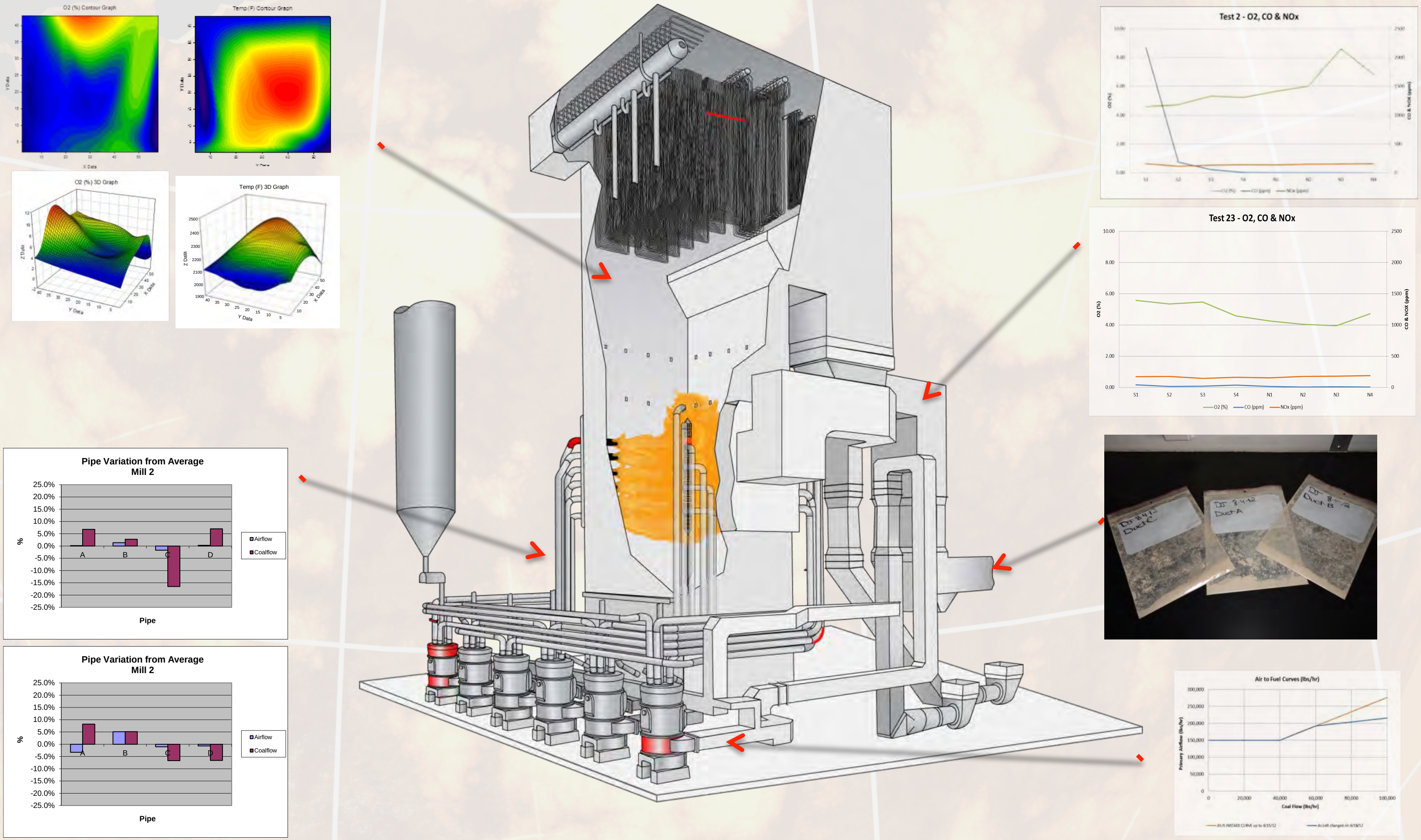
Cost Savings & Justifications Not Included

- Improvements for improved SH & RH Temperatures
- Replacement Power cost
- Cost for de-slagging boiler
- Sell of Flyash
- Reduce fuel tonnage for same Megawatts

Project Success

- Operations, Maintenance and I&C Personnel
- Engineering, Management, Plant Liaison & Consulting group
- Setting of NOx and LOI targets
- Tuning on a holistic approach
- Determining the mechanical limitations of the firing equipment
- Inspection, Testing & Tuning

Recap


O2 (%) Contour Graph
Temp (F) Contour Graph
O2 (%) 3D Graph
Temp (F) 3D Graph
Test 2 - O2, CO & NOx
Test 23 - O2, CO & NOx
Pipe Variation from Average
Mill 2
Airflow
Coalflow
Pipe
Pipe Variation from Average
Mill 2
Airflow
Coalflow
Pipe
Air to Fuel Curves (lbs/hr)
Coal Flow (lbs/hr)