Electric Power April 10 - 13, 2017

19th Annual ELECTRIC POWER CONFERENCE + EXHIBITION

"Improving Boiler Throttle Response and AGC Control by Addressing the Inputs":

Author:
Mr. Danny Storm
Senior Consultant
Storm Technologies, Inc.
PO Box 429
Albemarle, NC 28002

Co-Author:
Mr. Aaron Steinhilber
Engineering Principal
NIPSCO Generation
2723 East 1500 North
Wheatfield, Indiana 46392

SERVICE QUALITY RESULTS STORM

NIPSCO

Project Outline and Goals:

NIPSCO Schahfer Unit 17 Details:

- 361 Net Mw
- Alstom/GE Corner Fired Unit
- Sub-Critical Boiler
- Six (6) 803 Suction Pulverizers
- SOFA and COFA
- PRB Fuel

Challenges:

- Unit 17 unable to operate in Automatic Generation Control (AGC) for several years.
- Unit load changes unresponsive and requiring 12-15 minutes to achieve a load change.
- Boiler pressure swings as much as 150 PSIG or more and unable to maintain steady pressure with load changes.

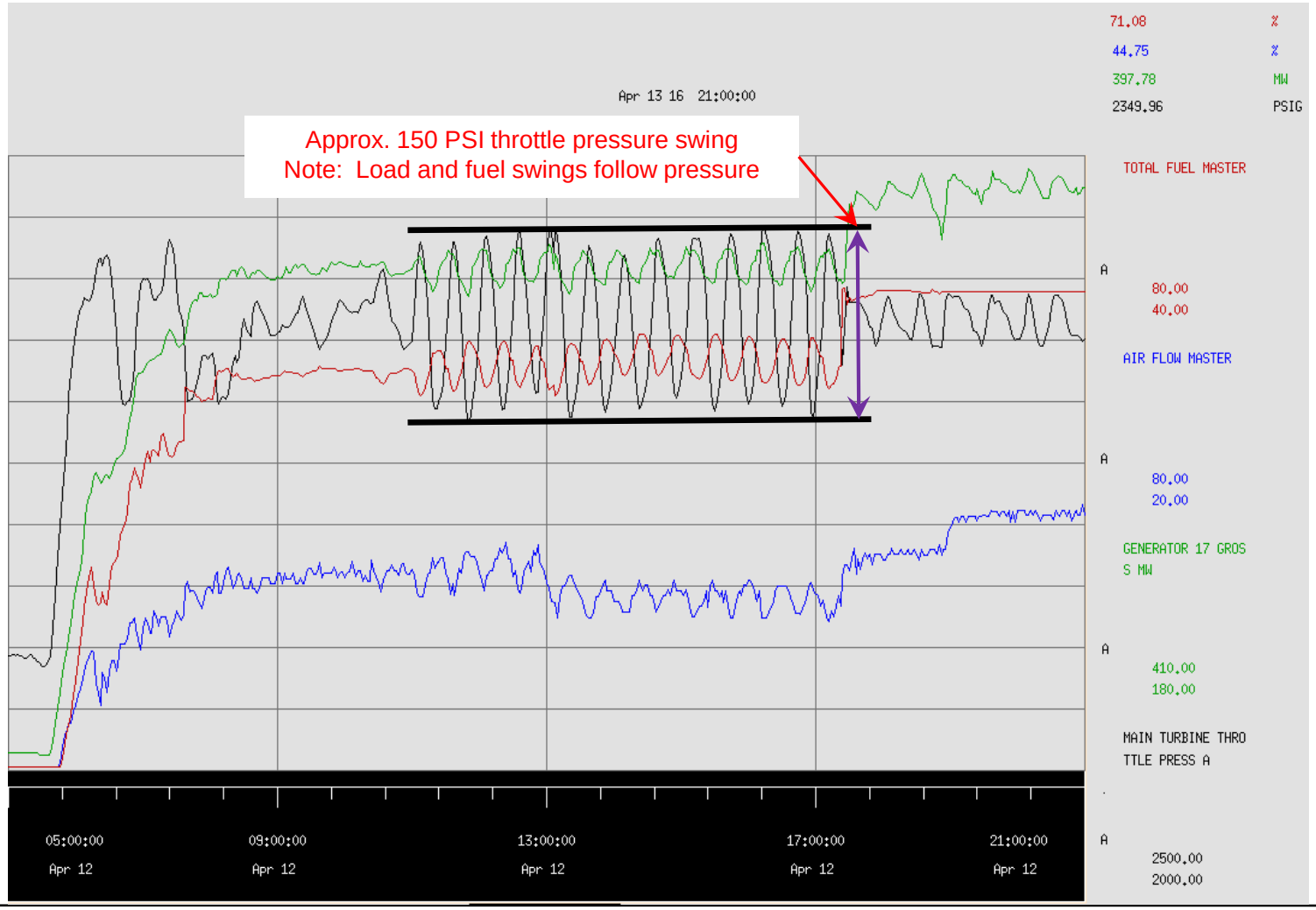
Goals:

- Ability to Operate Unit 17 in AGC Operation
- Achieve Optimum NOx and Combustion
- Develop Operating Curves across Load Range
- Maintain Acceptable Carbon In Ash (LOI)
- Address Fan Limitations and additional Operational Concerns with Operator Awareness
- Long Term Action Plan and Goals

Load Change (Pre-Tuning):

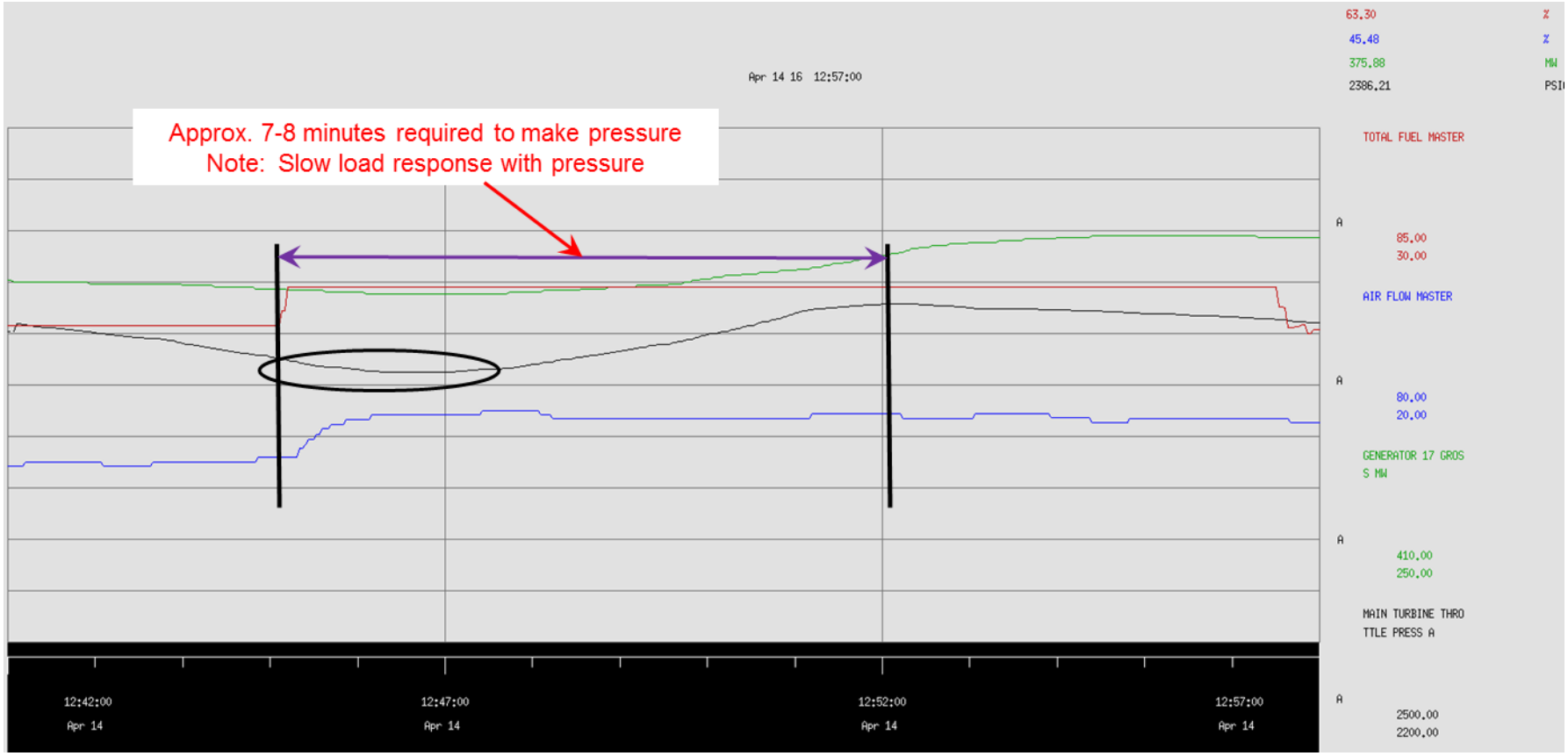
19th Annual ELECTRIC POWER CONFERENCE + EXHIBITION

Load Test: No Pulverizer Tuning



Example Load Test (Pre-Tuning):

Mill #1 Load Test: Pulverizer increased to review response



Note: Each pulverizer responded different and varied some were as much as 12-15 minutes to achieve pressure.

Identifying Opportunities

Challenges:

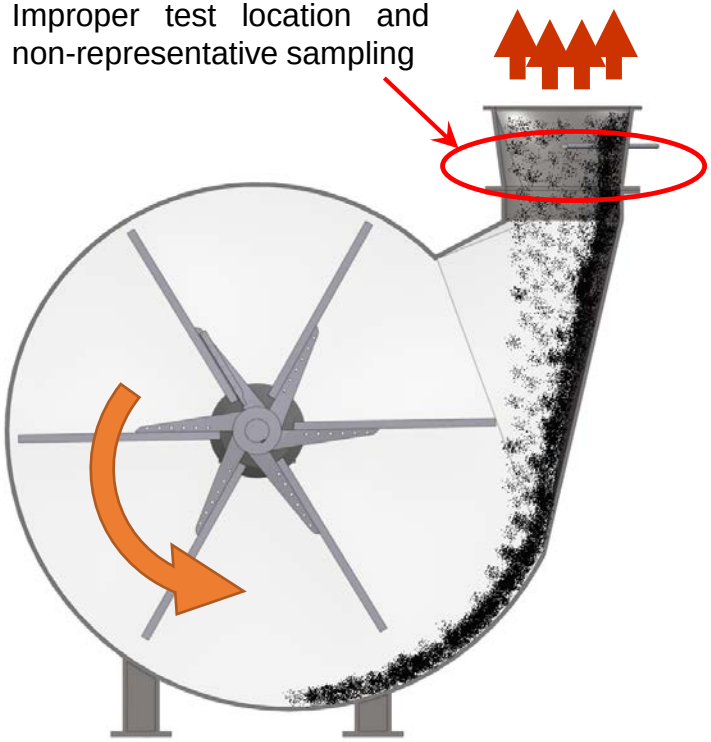
- Unit 17 has had considerable control tuning to get to the previous response and control. Unable to operate in “AGC” mode which could impact dispatch.
- Load ramp and control impacts on NOx control and Combustion.
- Slow response resulted in 150+ PSIG swings in pressure and load swings impacting airflow, temperatures, emissions, etc.

Identifying Cause:

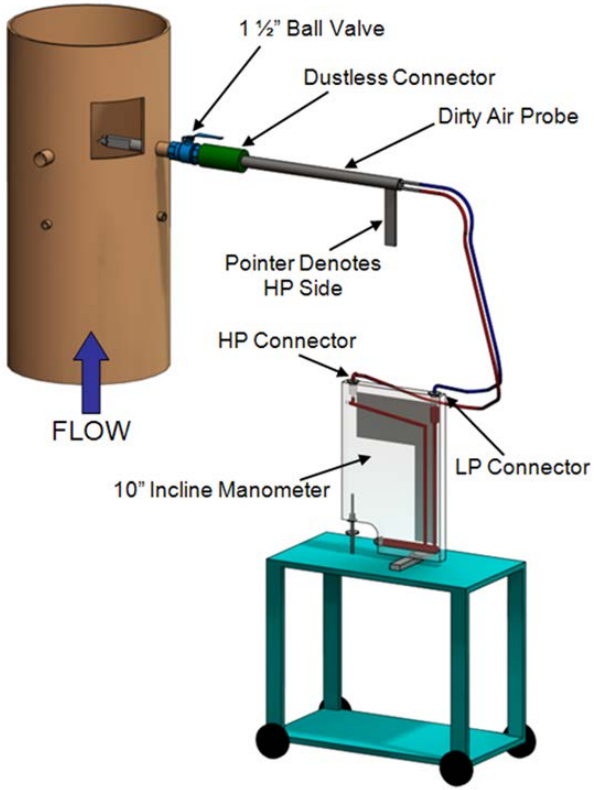
- Measuring the Inputs.
  - Past testing at the plant noted No change or minimal change in airflow across the load range of pulverizers as fuel flow increased and this was addressed again by characterizing exhauster curves.
    - Note the following data indicating flow across the pulverizer load range

Proper Test Locations:

Improper test location and non-representative sampling

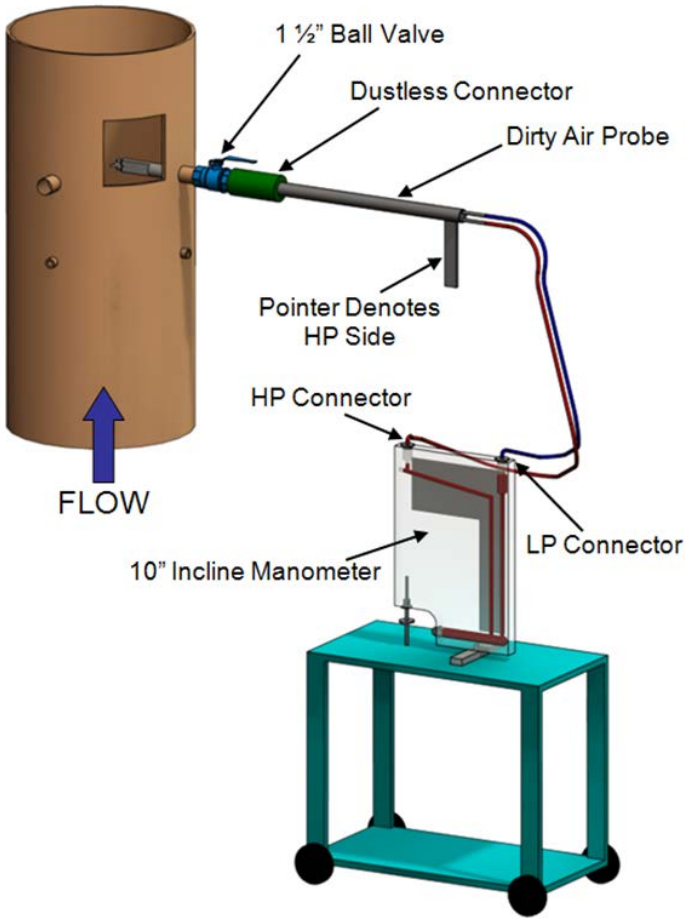


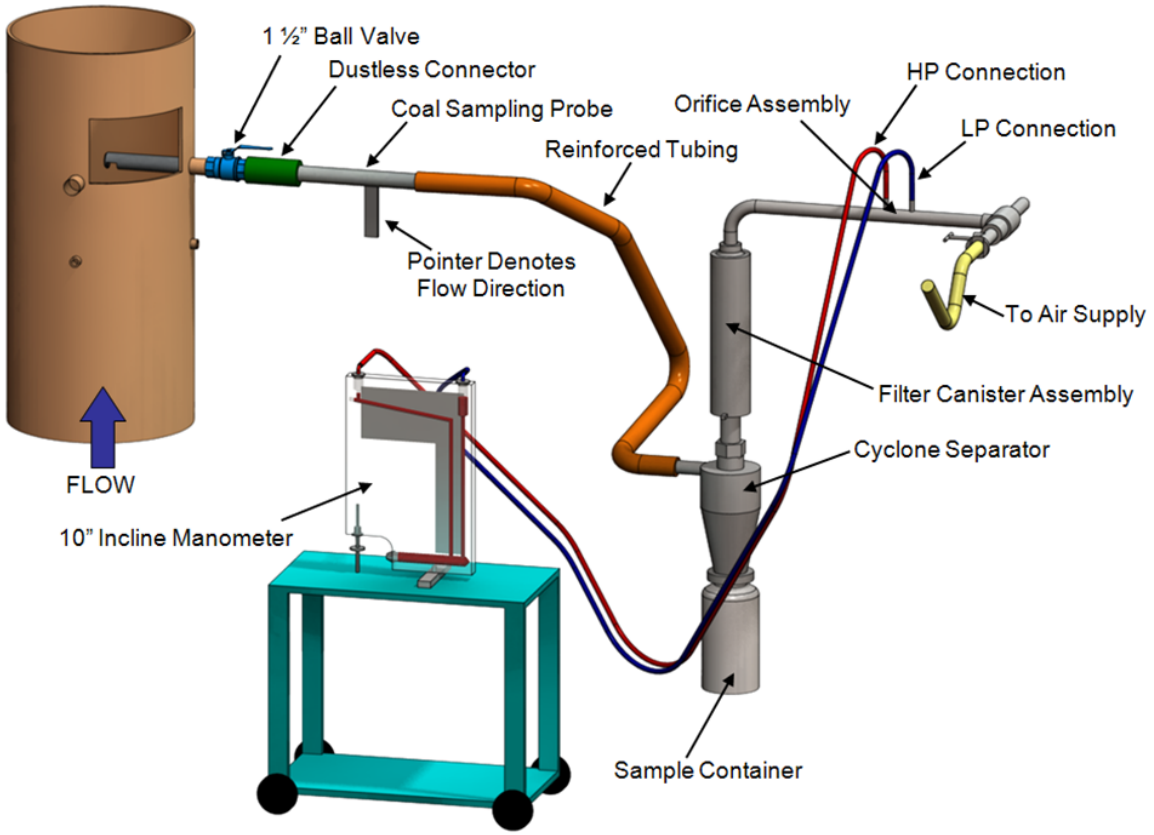
Stratification and separation of fine and coarse particles due to centrifugal force.



Dirty air velocities must be measured in each fuel line to establish proper sampling rate (ΔP) for the isokinetic sampler and to determine airflow in each fuel line. The dirty air probe is a field proven device, which allows the measurement of airflow in a dust-laden environment with a minimum of probe stoppage.

Testing Method Utilized:





Identifying Opportunities

"A" Pulverizer Test Summary

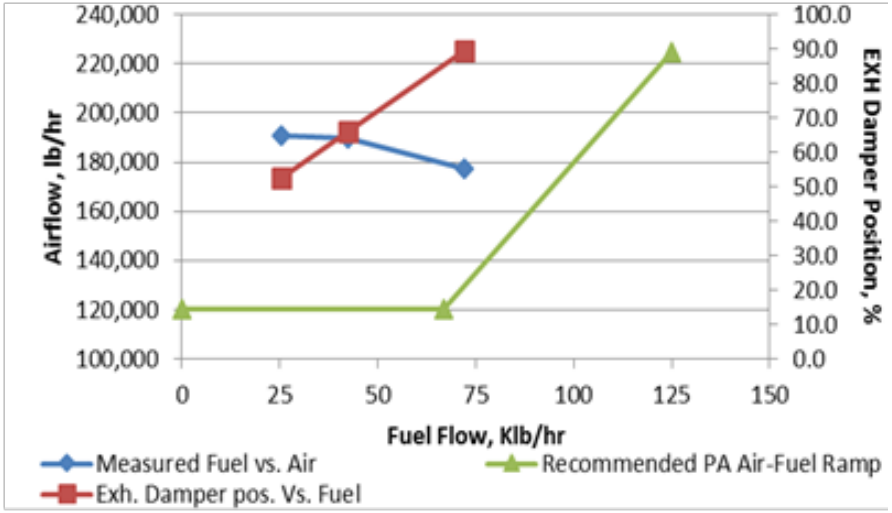
	30% Feeder	50% Feeder	85% Feeder
Indicated Coal Flow	25,500	42,300	72,000
Measured Coal Flow	24,424	41,034	73,176
Measured Airflow Flow	191,802	189,234	179,799
Average Measured Veloicty	6,134	6,052	5,724
Exhauster Damper Postion	52.4	66	89.8

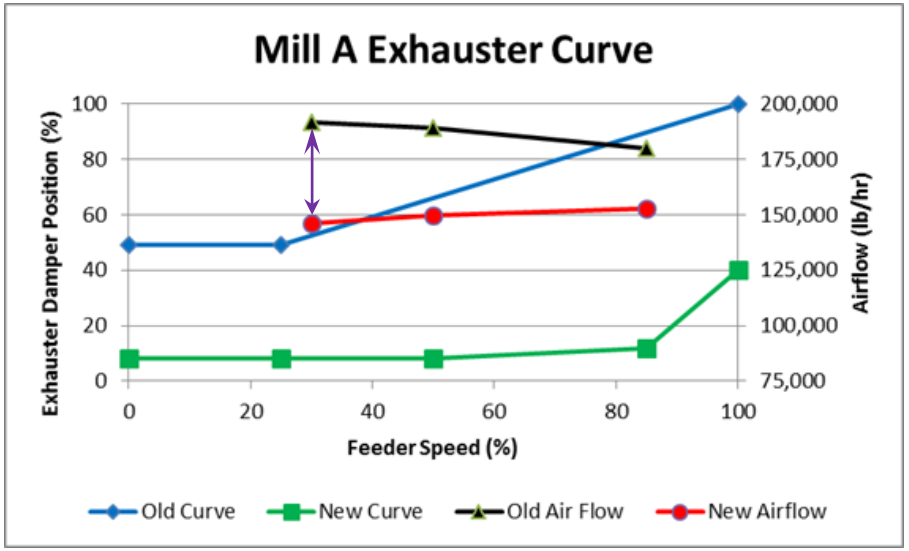
Notes:

- Airflow reduces from 30% feeder to 85% feeder (damper increases from 52 - 90%)
- Typical exhauster curve “As Found” Pre-Tuning
- Past testing at the plant noted No change in air/fuel ratio of pulverizers and this was addressed again by characterizing exhauster curves.

Solutions:

- As previously noted and shown below, airflow decreased with load increase
- Total primary air curve was reduced by approximately 20% (depending on exhauster)
  - Maintaining flow greater than required minimum airflow (Approx. 120,000 lb/hr)
- Controls were adjusted with a anticipatory signal or “Kicker” with load increase





Pre vs Post Tuning Curves:

Mill A	Old Exhauster Curve			New Exhauster Curve		
	Test 1	Test 2	Test 3	Test 7	Test 6	Test 5
Feeder Speed	30%	50%	85%	30%	50%	85%
Exhaust Damper Postion	52%	66%	90%	8%	8%	12%
Dirty Airflow Total (Lbs./Hr.)	191,802	189,234	179,799	152,859	149,414	146,295
Fuel Flow Total (Lbs./Hr.)	24,424	41,034	73,176	24,888	42,985	81,030
Air/Fuel Ratio (#air/#fuel)	7.85	4.61	2.46	6.14	3.48	1.81

Notes:

- Some exhausters were closed to 5% open (limited to 5% as minimum)
  - Continued to have airflow greater than minimum required for 3300 FPM
- Although air curve was relatively flat the control “kicker” would allow for increase of flow, which would carry more fuel to the furnace improving response time.
- Note Air/Fuel ratio of Old vs. New – This will impact performance and optimization

Pre vs Post Tuning Curves:

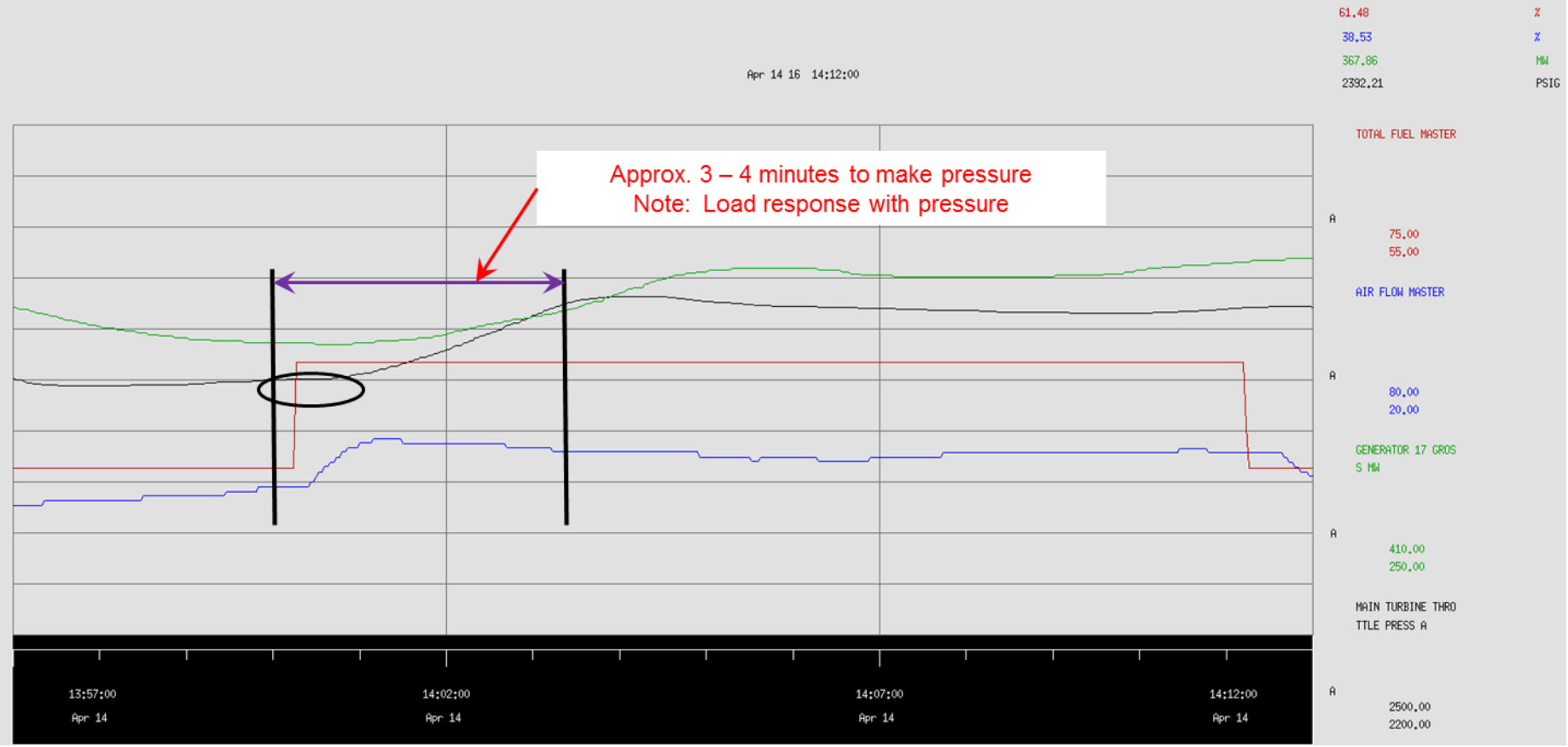
Mill B	Old Exhauster Curve			New Exhauster Curve		
	Test 1	Test 2	Test 3	Test 5	Test 6	Test 8
Feeder Speed	30%	50%	85%	30%	50%	85%
Exhaust Damper Postion	35%	53%	86%	15%	15%	25%
Dirty Airflow Total (Lbs./Hr.)	180,560	187,237	180,267	147,343	145,455	148,536
Fuel Flow Total (Lbs./Hr.)	24,927	43,042	75,623	26,375	45,486	75,642
Air/Fuel Ratio (#air/#fuel)	7.24	4.35	2.38	5.59	3.20	1.96

Notes:

- Note curve difference from previous example (damper range 15-25% vs 8-12%).
  - There is no primary air indication, which will be discussed later

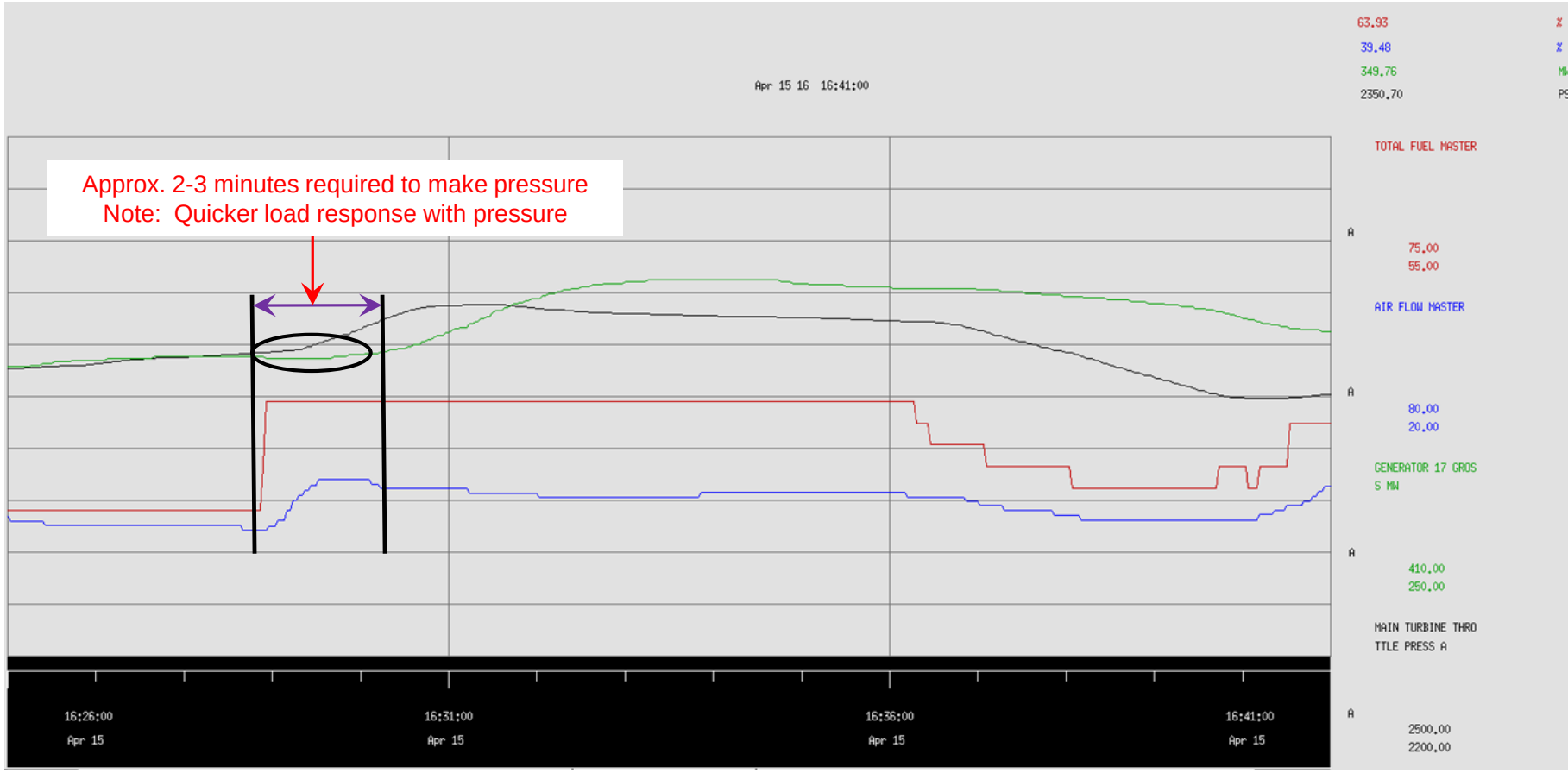
Example Load Test (Post-Tuning):

Mill 1 Load Test: Pulverizer increased 20% to review response



Example Load Test (Post-Tuning):

Mill 2 Load Test: Pulverizer increased 20% to review response



Note: All Mills were verified with similar responses and results.

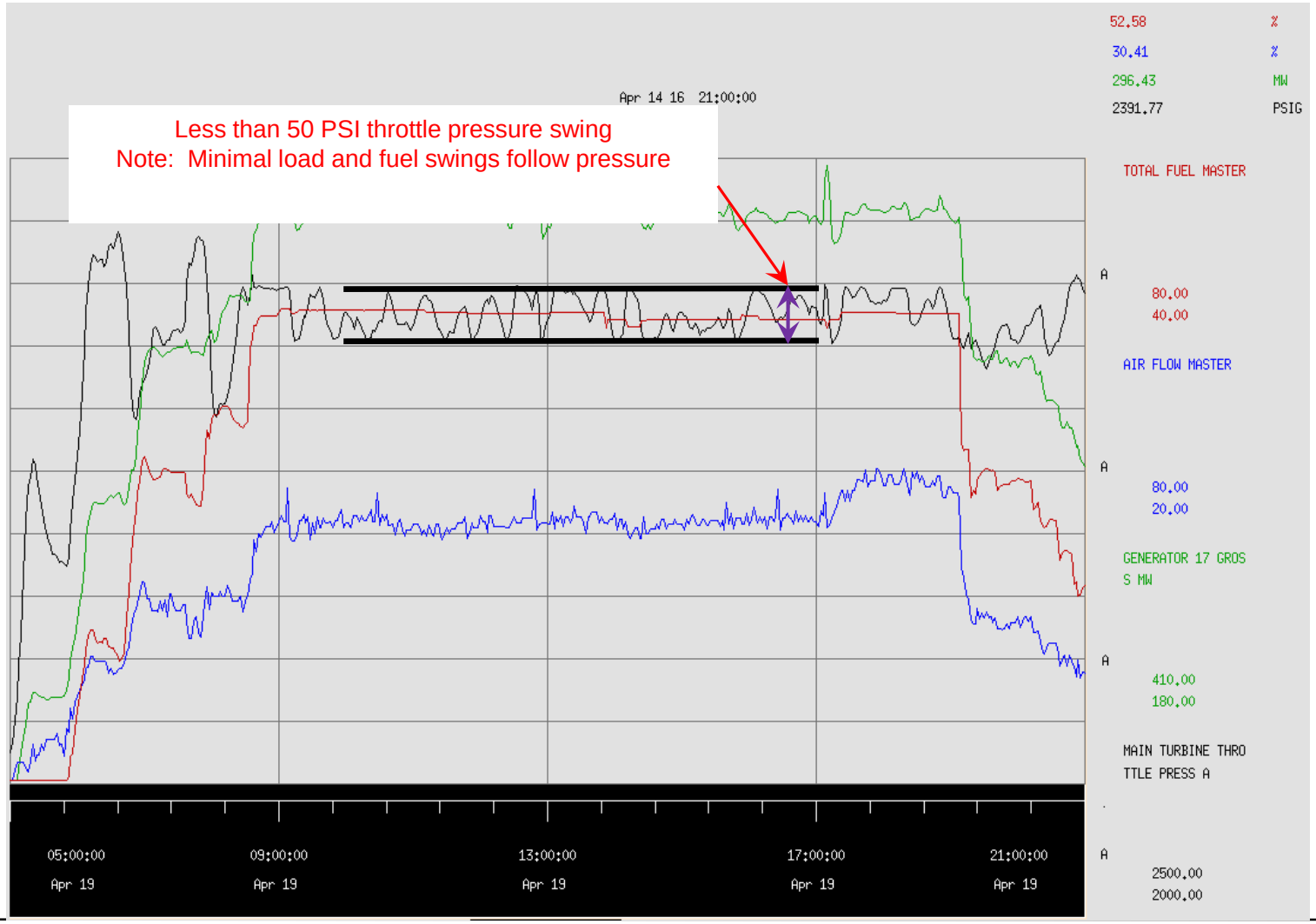
Unit Load Post Tuning Data:

Summary:

- Testing was completed on all six (6) 803 RS Pulverizers
  - New curves implemented on all mills.
  - Fineness adjusted based on test results for performance. Several issues noted on pulverizer performance.
  - “Kicker” increases exhauster in auto control to maximum air flow for given time and backs off with change in load.
- Aux air and fuel air dampers were tuned to improve wind box control and NOx by staging of the fuel and air.
- Note the following data for “AGC” Control of Unit 17 post pulverizer tuning.

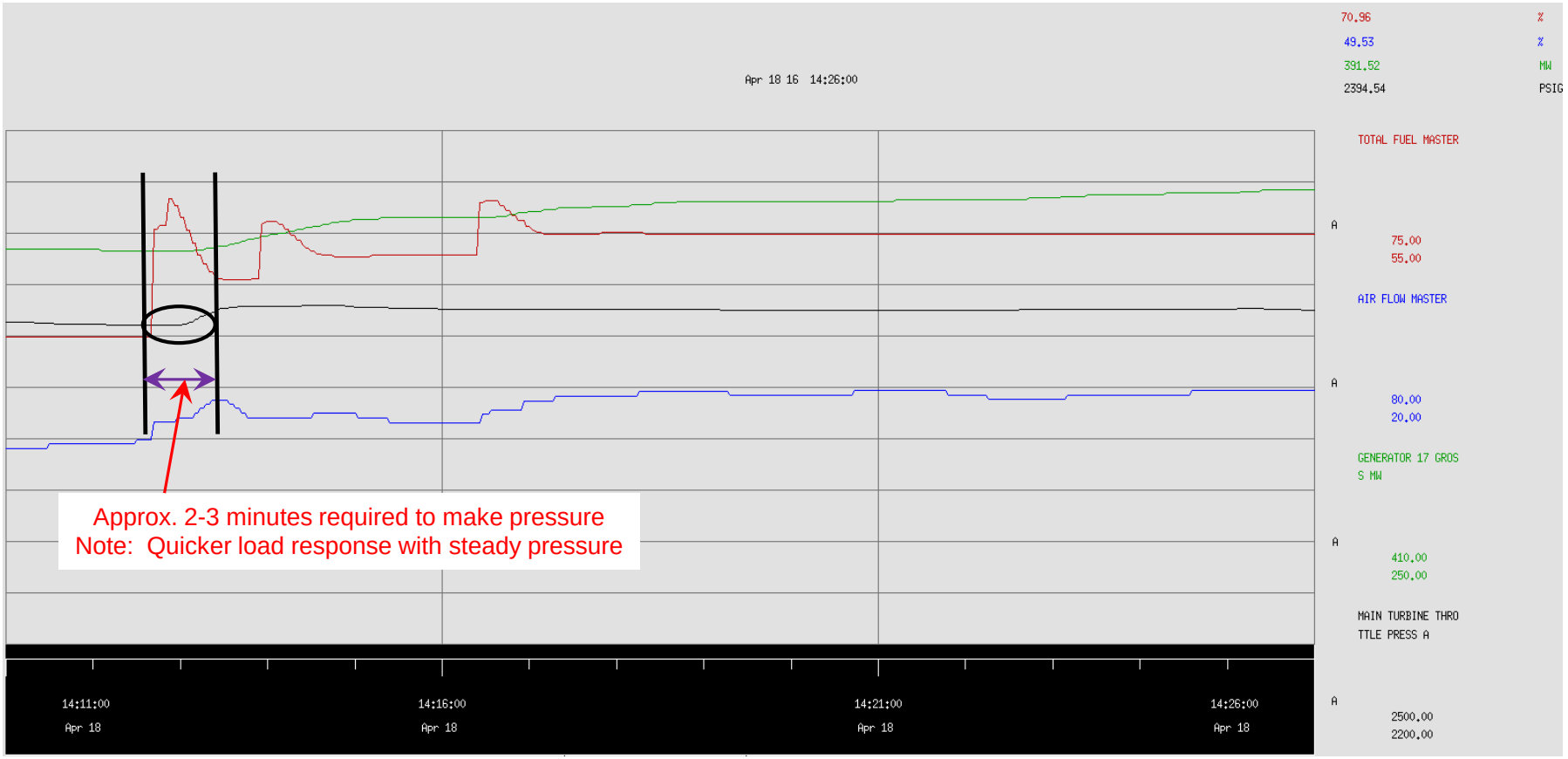
Load Change (Post-Tuning all Mills):

Unit Load Test: After Pulverizer Tuning



Load Response (Post-Tuning all Mills):

Unit Load Response Test: All mills post tuning completed



Recommendation and Summary

Additional Goals:

- Continued “AGC” Control and Operation
- Continued NOx strategy and tuning
  - Pulverizer Performance
- Performance Optimization and Heat Rate Impacts
- Obtain Maximum Reliability and Availability for Competitive Generation

Recommendations:

- Address Inputs and Fundamentals
  - Pulverizer Airflow Management
  - Fineness/Distribution of the pulverizers
  - Burner Tilts, Aux/Fuel Air Damper Operation
  - Staging and Manage Air/Fuel to boiler

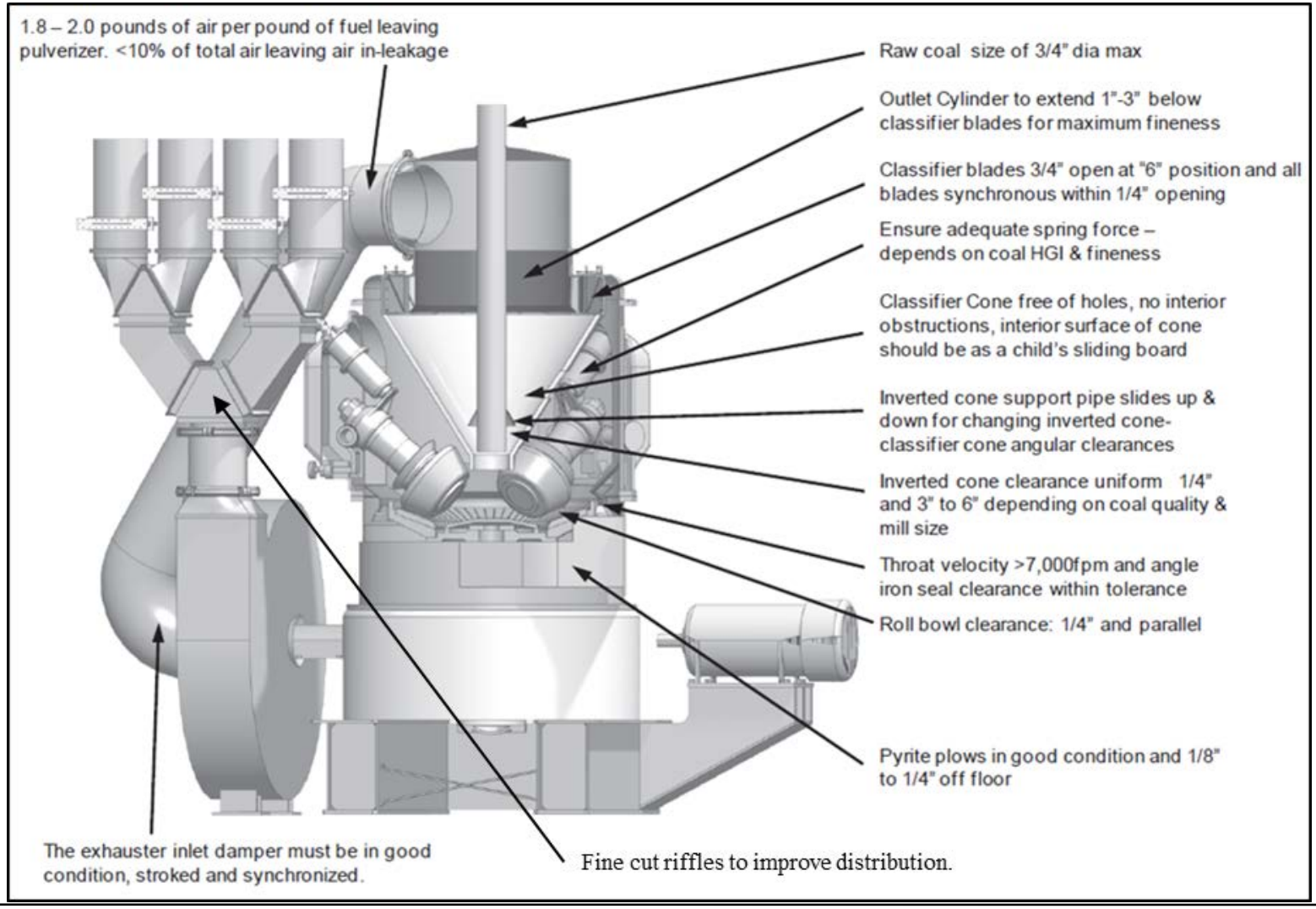
STORM®

Specialists in Combustion and Power

Thirteen Essentials of Optimum Combustion for Low NO_x Burners

1. Furnace exit must be oxidizing preferably, 3%.
2. Fuel lines balanced to each burner by "Clean Air" test ±2% or better.
3. Fuel lines balanced by "Dirty Air" test, using a Dirty Air Velocity Probe, to ±5% or better.
4. Fuel lines balanced in fuel flow to ±10% or better.
5. Fuel line fineness shall be 75% or more passing a 200 mesh screen. 50 mesh particles shall be less than 0.1%.
6. Primary airflow shall be accurately measured & controlled to ±3% accuracy.
7. Overfire air shall be accurately measured & controlled to ±3% accuracy.
8. Primary air/fuel ratio shall be accurately controlled when above minimum.
9. Fuel line minimum velocities shall be 3,300 fpm.
10. Mechanical tolerances of burners and dampers shall be ±1/4" or better.
11. Secondary air distribution to burners should be within ±5% to ±10%.
12. Fuel feed to the pulverizers should be smooth during load changes and measured and controlled as accurately as possible. Load cell equipped gravimetric feeders are preferred.
13. Fuel feed quality and size should be consistent. Consistent raw coal sizing of feed to pulverizers is a good start.

Pulverizer Recommendation Overview



NOx Optimization:

Schahfer Unit 17 Low NO_X Operating Parameters

Boiler testing/tuning completed has revealed that the following operating parameters provide ideal conditions for low NO_X firing. While operating at a net load of 340 MW or greater, the following biases have been shown to reduce NO_X production with Optimized Combustion:

O_2 Set Point Bias

- +0.20 % Bias to promote oxidizing atmosphere in the furnace (Note: it is important to watch the FD fan amps when operating on warmer days to avoid tripping the fan and adjust accordingly). The oxygen bias can be increased to raise the NO_X and decreased to lower NO_X

Windbox to Furnace Set Point Bias

- +0.20 in w.c. Bias to increase wind-box pressure and distribution from top to bottom of each corner for combustion and NOx control

Burner Tilts

- Burner tilts should be set to -2 degrees or nearly horizontal to reduce superheat and reheat sprays

Staging Aux/Fuel and OFA:

Fuel/Air Dampers

- Elevation A: 0.00 % Bias
- Elevation B: 0.00 % Bias
- Elevation C: 0.00 % Bias
- Elevation D: 0.00 % Bias
- Elevation E: 0.00 % Bias
- Elevation F: 0.00 % Bias

Auxiliary Air Dampers

- Elevation AA: -10.00 % Bias
- Elevation AB: -5.00 % Bias
- Elevation BC: -5.00 % Bias
- Elevation CD: -5.00 % Bias
- Elevation DE: +10.00 % Bias
- Elevation EF: +10.00 % Bias

SOFA Dampers

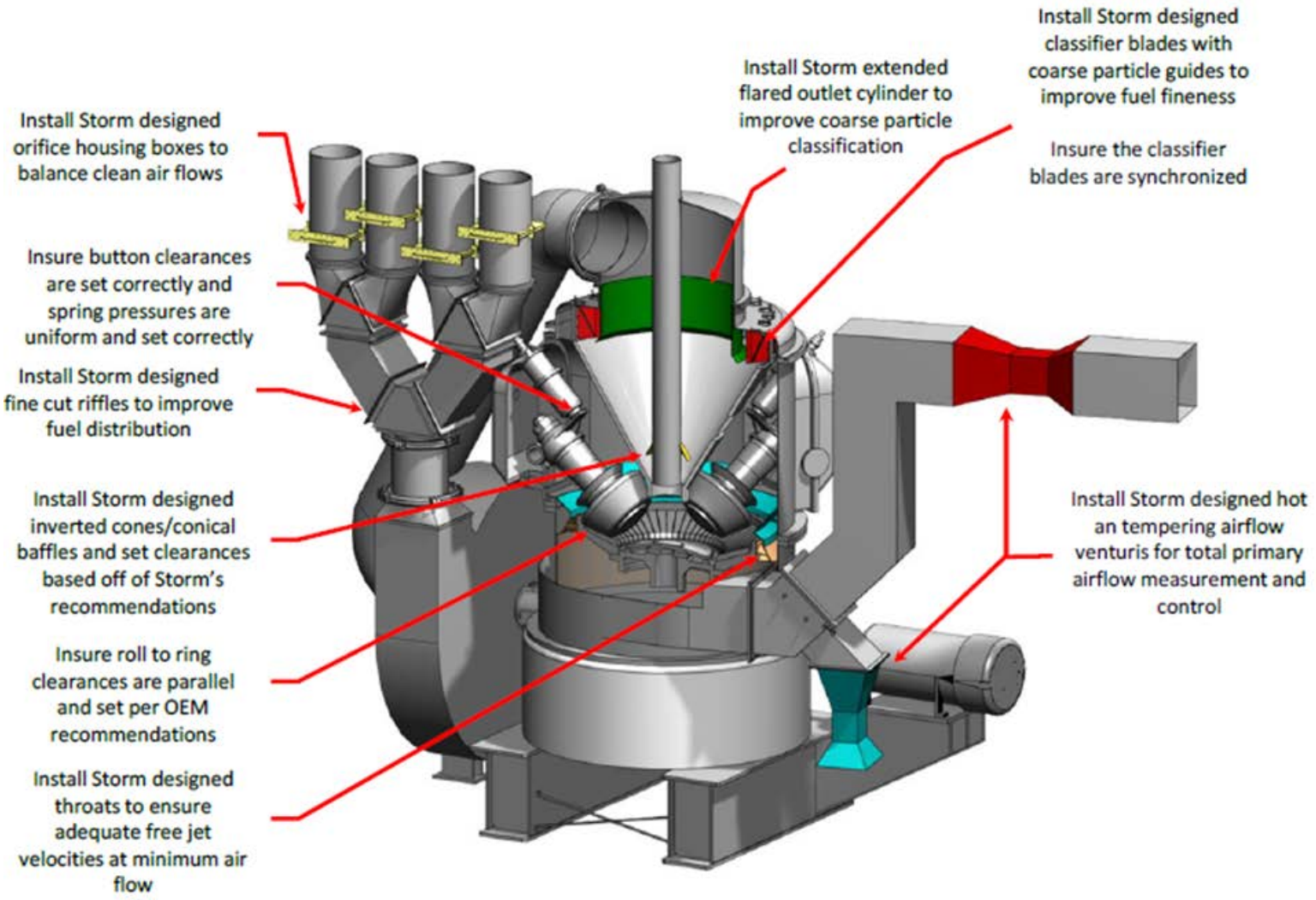
- Elevation 1: +10.00 % Bias
- Elevation 2: +10.00 % Bias
- Elevation 3: 0.00 % Bias

CCOFA Dampers

- Elevation 1: 0.00 % Bias
- Elevation 2: +5.00 % Bias
- Elevation 3: -4.00 % Bias
- Elevation 4: -20.00 % Bias

Long Term Recommendation:

19th Annual ELECTRIC POWER CONFERENCE + EXHIBITION



THANK YOU!

19th Annual ELECTRIC POWER CONFERENCE + EXHIBITION

Author:
Mr. Danny Storm
Senior Consultant
Storm Technologies, Inc.
PO Box 429
Albemarle, NC 28002

Co-Author:
Mr. Aaron Steinhilber
Engineering Principal
NIPSCO Generation
2723 East 1500 North
Wheatfield, Indiana 46392