Performance Impacts of Primary Air

Electric Power 2018

Nashville, TN

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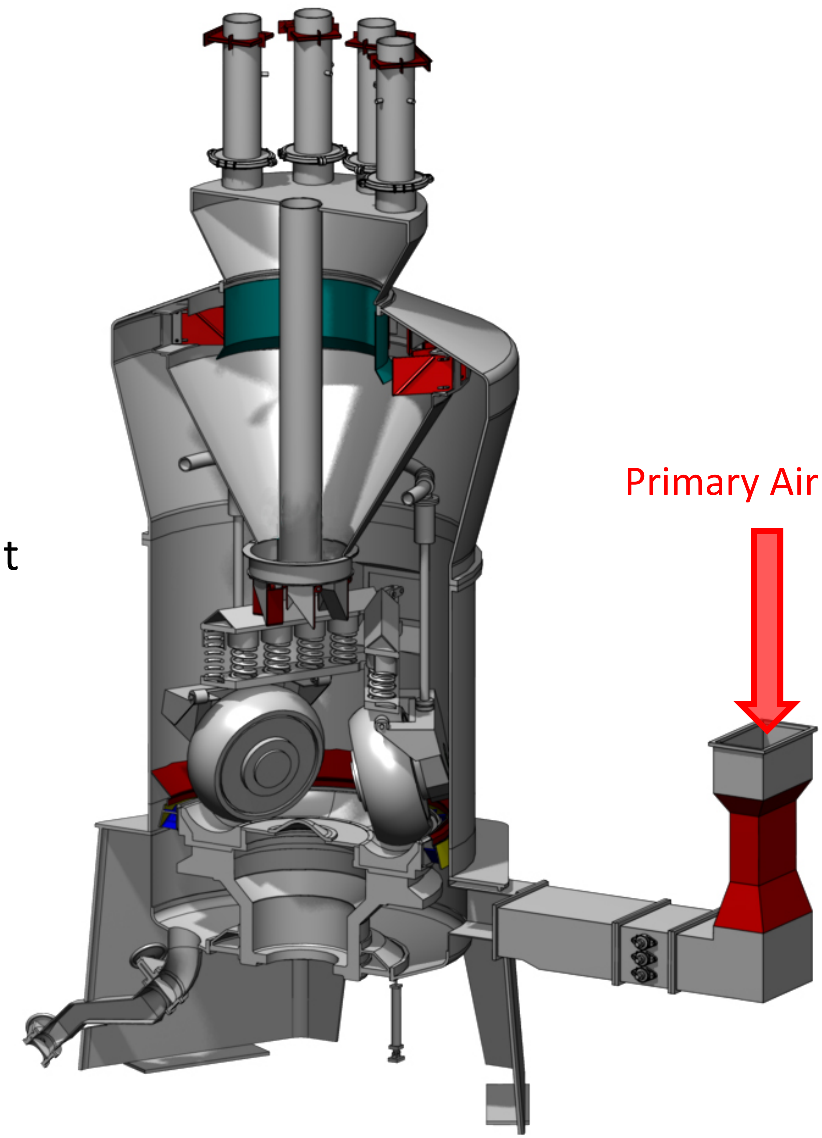
Primary Air

- What is primary air on a pulverized coal boiler?
  - Primary air is air that is heated by the air heater and is used to dry and convey pulverized coal to the boiler
  - 15%-20% of the total air supplied to the boiler is typically primary air
  - Primary air can impact pulverizer performance, reliability, emissions and heat rate



Primary Air Impacts

- Effects of high primary air
  - Increased NO_X and CO
  - Increased secondary combustion
  - Increased FEGT’s
  - Increased spray flows
  - Increased LOI’s
  - Increased slagging
  - Increased erosion
  - Decreased fuel fineness
  - Larger fuel imbalances
  - Detached flames
  - Improved boiler response
  - Decreased heat rate

Primary Air Impacts

- Effects of too little primary air
  - Increased coal rejects
  - Low fuel line velocities
  - Inability to achieve desired mill outlet temperature
  - Coal layout in the horizontal piping
  - Increased probability of fuel line plugging/fires
  - Increased probability of mill puffs
  - Lack of boiler response

Primary Air Measurement

- Most common primary air flow measurement devices
  - Pitot tubes
  - Venturis

Measurement and Control

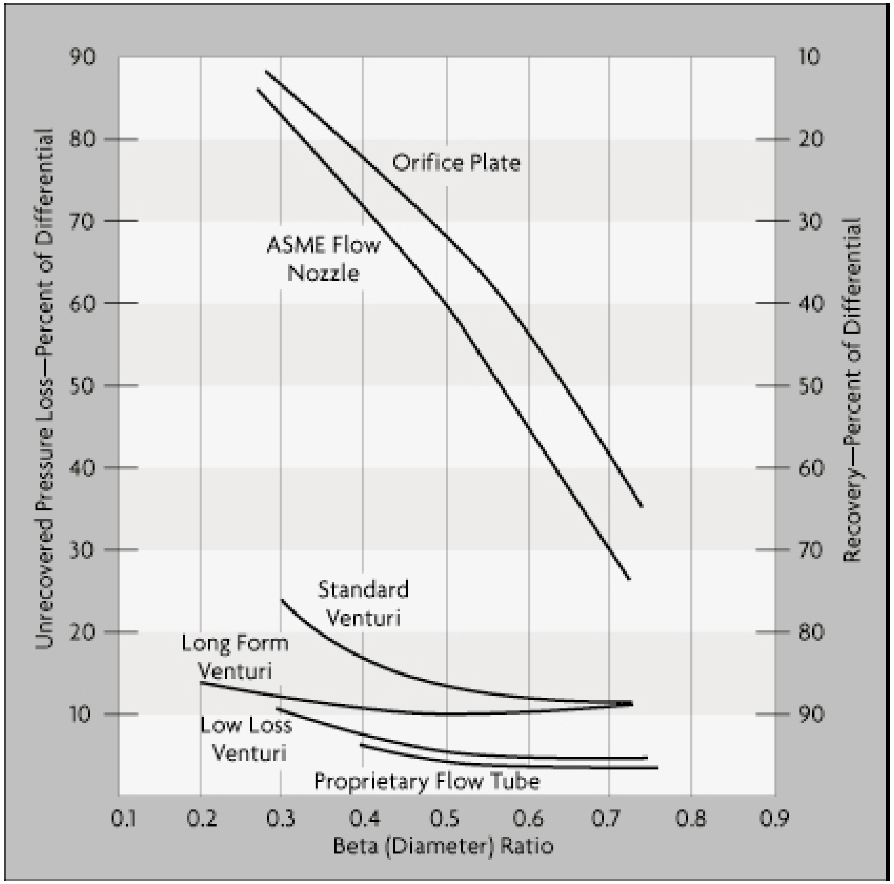
Common Low DP Airflow Measurement System Claims:

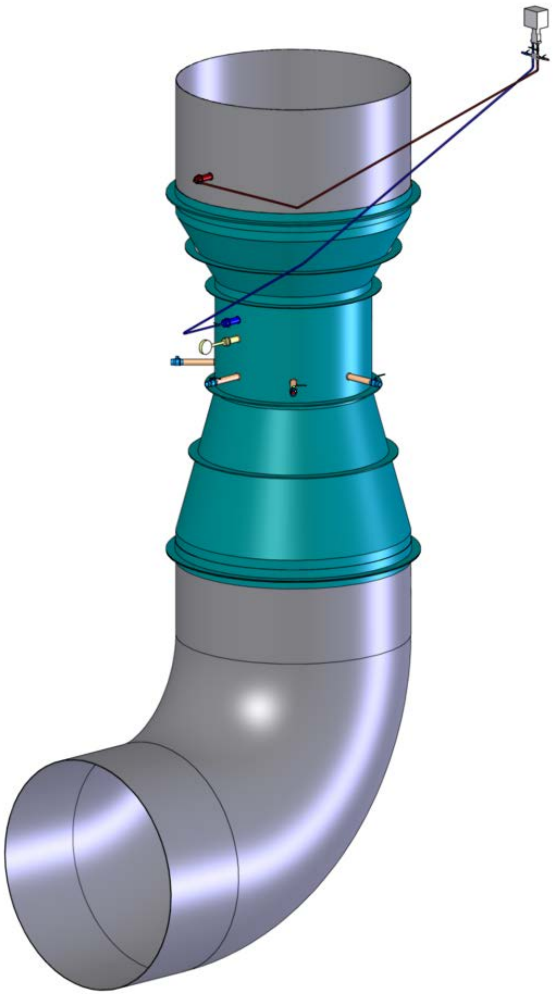
- Add one pair of sensors per existing duct (air or gas)
  - No calibration
  - No drift
  - No pressure drop
  - No maintenance
- Absolutely linear measurement characteristics
- Installations applicable for all duct dimensions in a wide velocity range
- Easy retrofit into existing ducts
- Not affected by particulate in gas stream

Storm's experience suggests the need for calibrated and proven flow elements with periodic testing to confirm accuracy

Common Misconceptions of Venturis

- Too much pressure drop
- Need a long straight run to ensure accuracy





Measurement and Control

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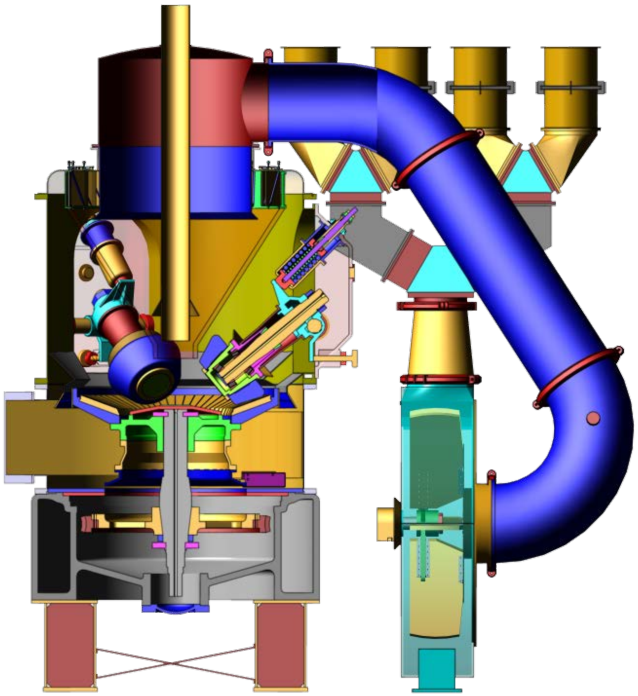
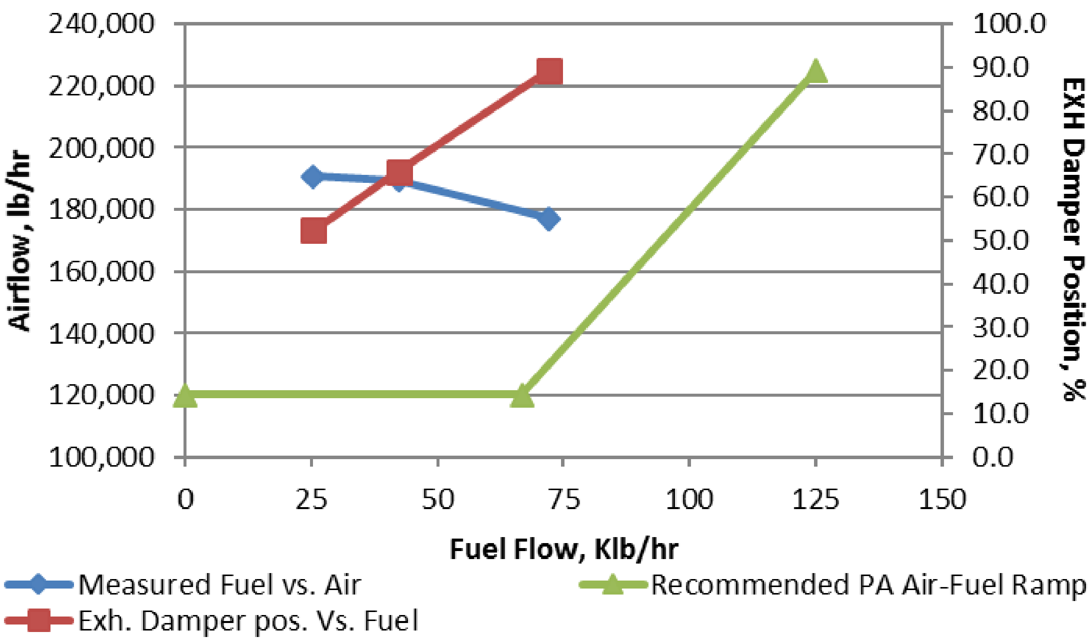
- Most suction mills have no primary air flow measurement
- Exhauster dampers control the suction and primary air to the mill
- Air/fuel ratios are often found extremely outside the recommended range





Why Hot "K" Calibrations instead of Cold?

Simply, the density of cold air is different from hot air …

This can lead to a significant variance in given velocity while having a similar mass flow rate. Therefore, when characterizing differential measuring flow elements like Venturis, Pitot tubes or Airfoils, the characterization of the **Differential vs. Flow will change for a given temperature.** Hence, the K-factor will vary. Because of this, we prefer to conduct Hot " K " airflow calibrations that use typical operational air or gas density when developing an average K factor/Curve

Example #1 (Cold Air)

$$T = 50°\text{F};\ S_p = 50''\text{W.C.};\ \text{B}_p = 29.5''Hg$$

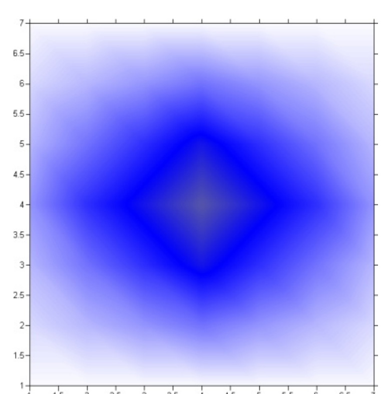
$$\delta = \frac{460 + 70°\text{F}}{460 + T} * \frac{B_p + \frac{S_p}{13.6}}{29.92''Hg} * .075\frac{lbs}{ft^3}$$

$$\delta = .0864\frac{lbs}{ft^3}$$

$$W = 100{,}000\frac{lbs}{hr};\ A = 5ft^2;\ \delta = .0864\frac{lbs}{ft^3}$$

$$V\left(\frac{ft}{min}\right) = \frac{W}{A * 60\frac{min}{hr} * \delta}$$

$$V = 3858\frac{ft}{min}$$



Example #2 (Hot Air)

$$T = 600°\text{F};\ S_p = 50''\text{W.C.};\ \text{B}_p = 29.5''Hg$$

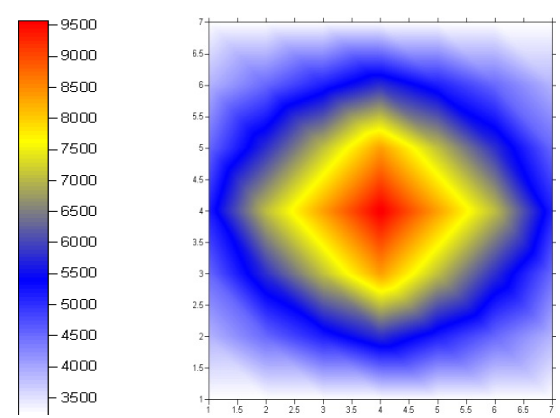
$$\delta = \frac{460 + 70°\text{F}}{460 + T} * \frac{B_p + \frac{S_p}{13.6}}{29.92''Hg} * .075\frac{lbs}{ft^3}$$

$$\delta = .029\frac{lbs}{ft^3}$$

$$W = 100{,}000\frac{lbs}{hr};\ A = 5ft^2;\ \delta = .029\frac{lbs}{ft^3}$$

$$V\left(\frac{ft}{min}\right) = \frac{W}{A * 60\frac{min}{hr} * \delta}$$

$$V = 11{,}494\frac{ft}{min}$$

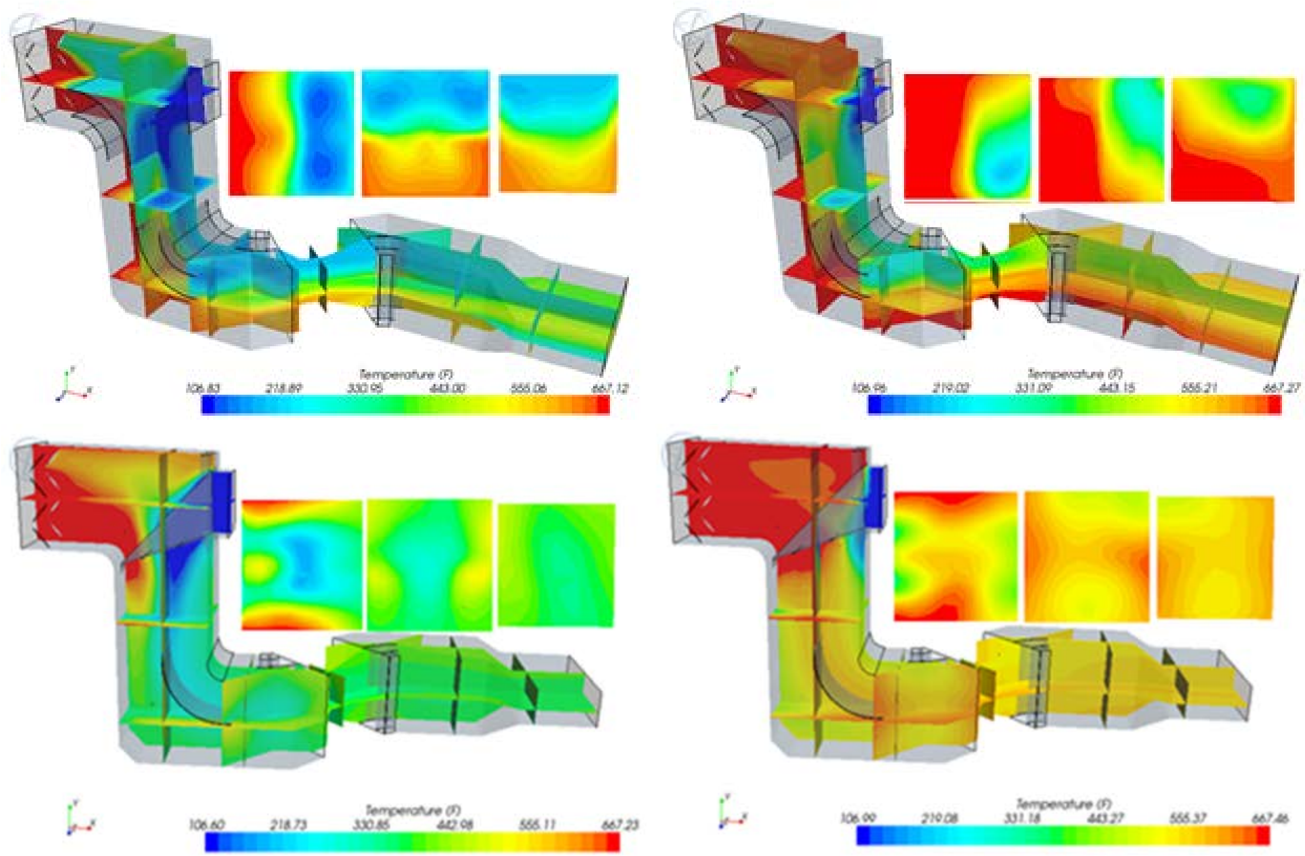


The importance of Hot “K” Calibrations instead of Cold

- Cold “K” calibrations in this case provided repeatable results where as hot testing did not due to major stratifications in temperature
- Normal operation of the mills without hot “K” calibration testing could have been a safety & reliability hazard

Pre Mixing Plates

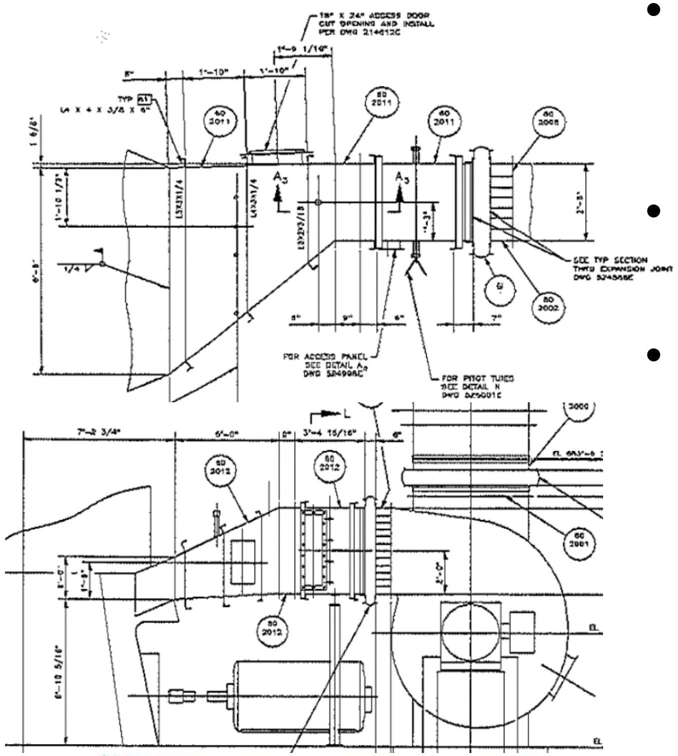
Post Mixing Plates

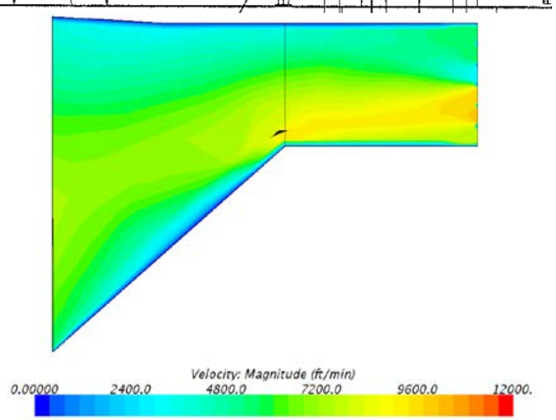


Optimizing Primary Air

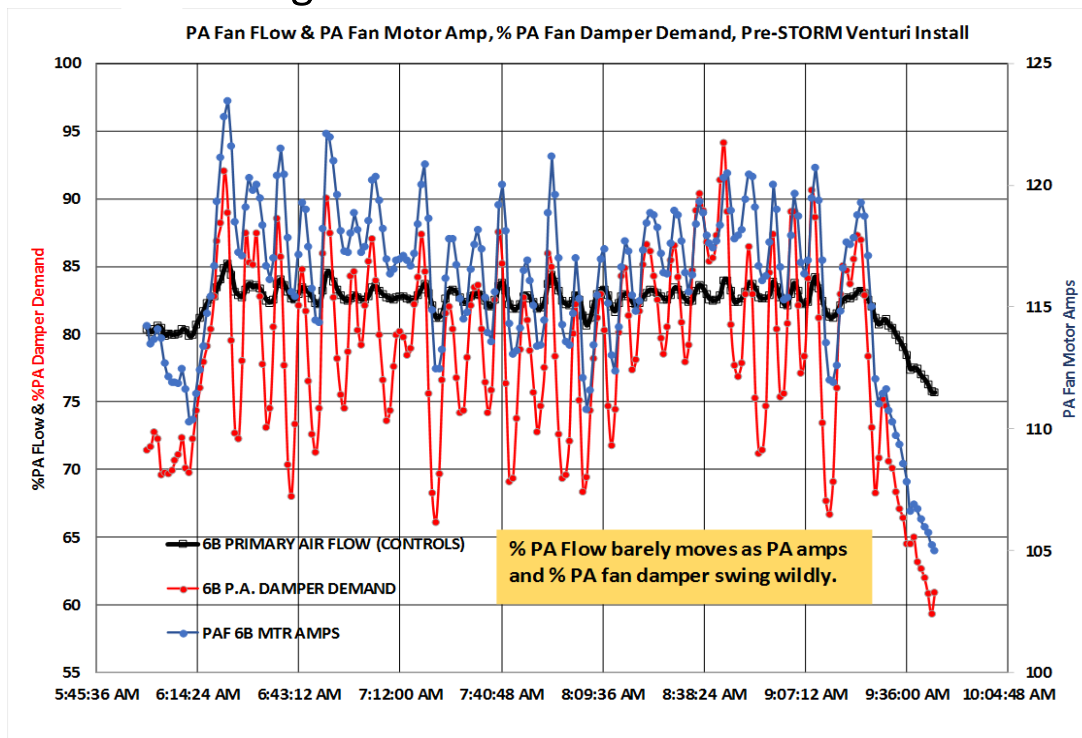
- Primary air flow should be accurately measured and controlled to within ±3% of the field measured value
- Primary air flow should operate on the recommended air/fuel ramp when above minimum airflow
- Minimum airflow in the fuel lines should be set to allow for no less than 3,300 ft/min velocities
- Hot "K" calibration testing should be completed on an annual basis

Field Proven Results: Case #1

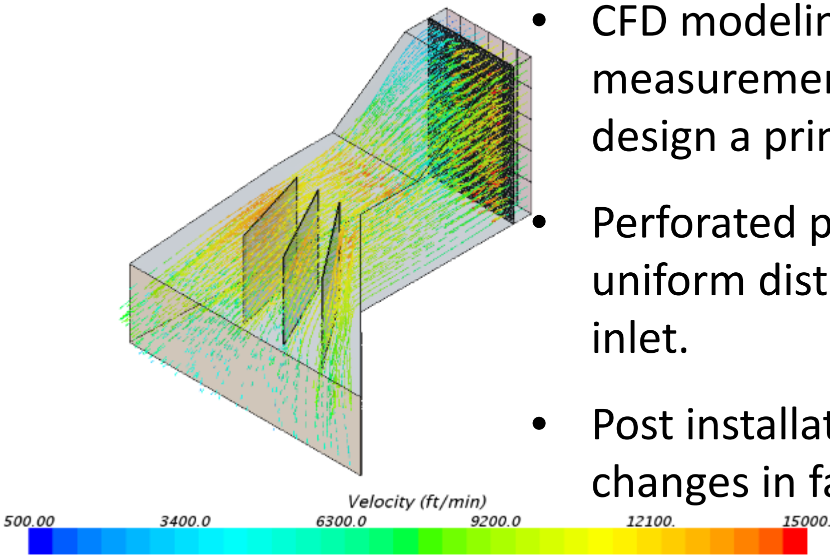




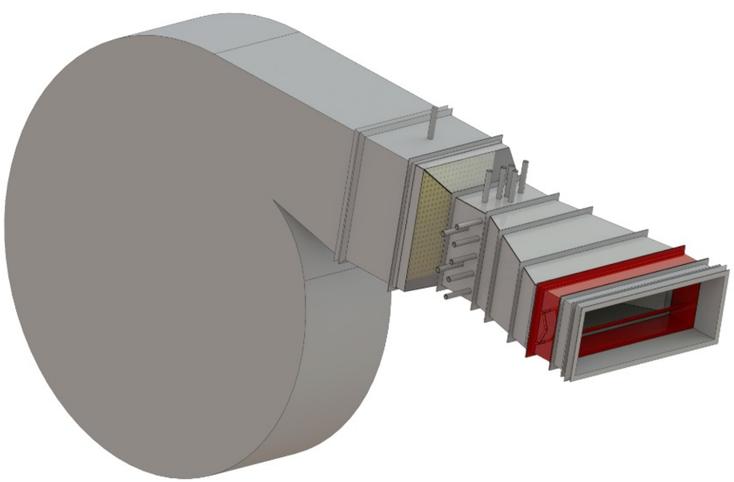
- Poor primary air measurement and control plagued the plant with throttle pressure swings, fuel line fires and poor pulverizer performance
- Pitot tube array located at the discharge of the PA fan did not accurately measure flow.
- PA fan amps and damper changes resulted in nearly no indicated change in PA flow

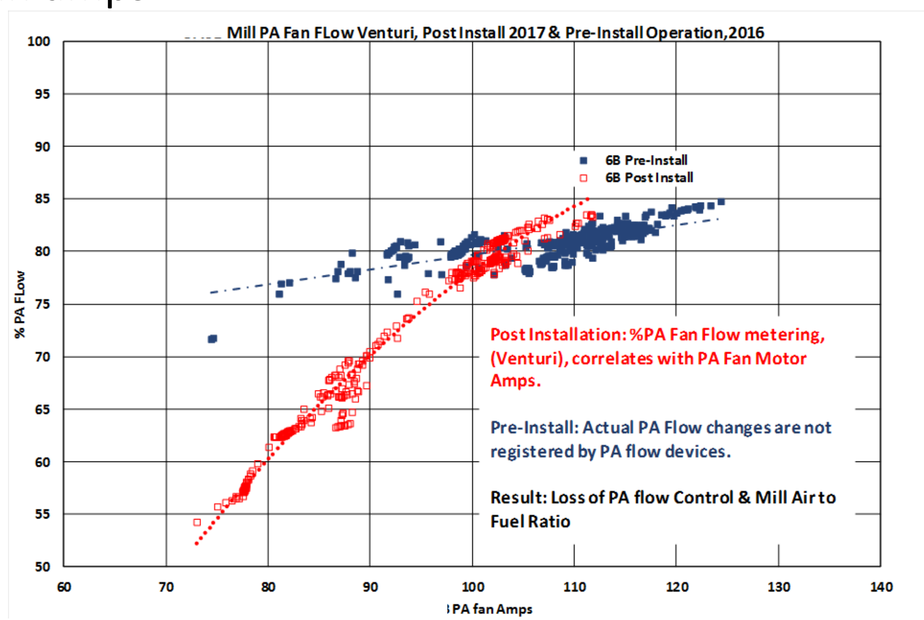


Field Proven Results: Case #1



- CFD modeling was utilized in conjunction with field measurements across the full load range of the pulverizer to design a primary air venturi.
- Perforated plate and turning vanes installed to provide more uniform distribution of air through the venturi and at the mill inlet.
- Post installation: PA flow is much more responsive (red) to changes in fan amps





Field Proven Results: Case #2

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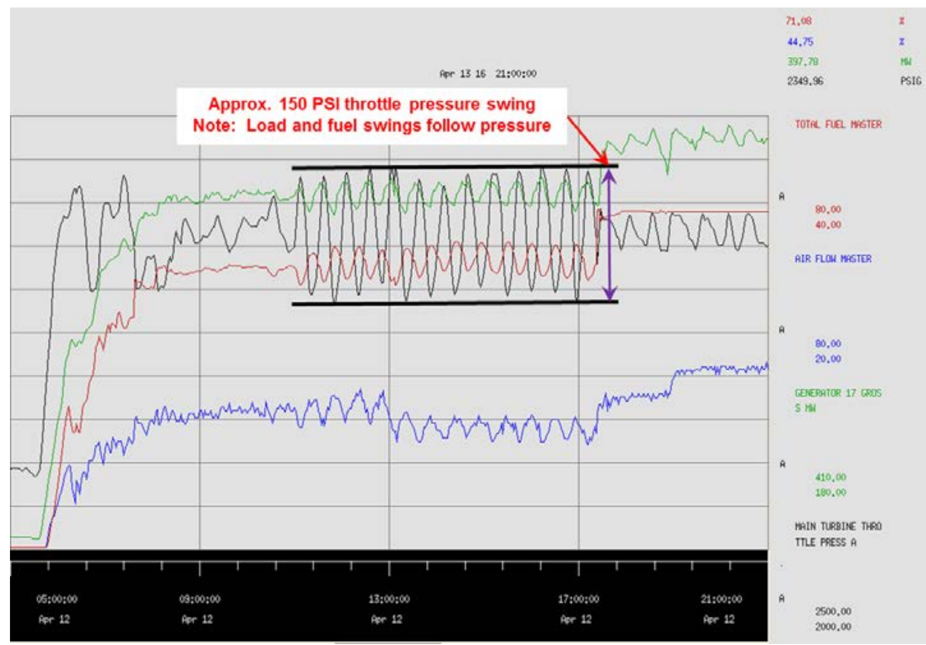
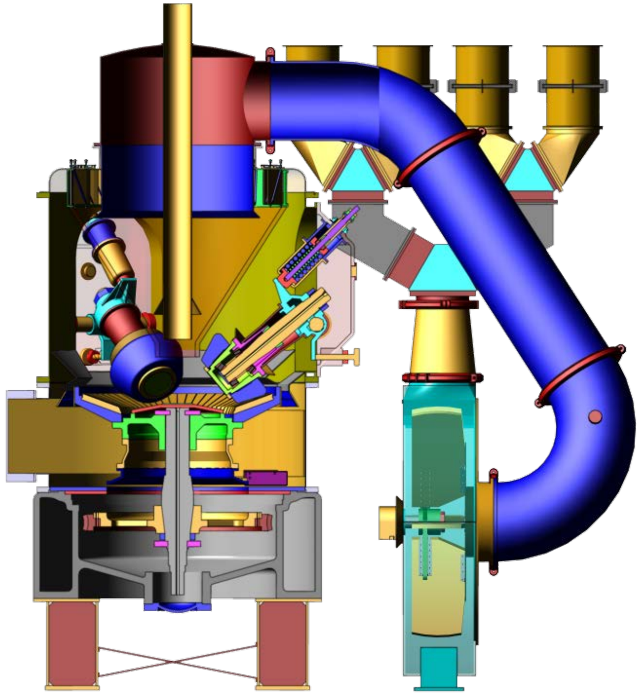
- The boiler had historically been unable to operate in AGC due to large throttle pressure swings
- Field testing on the RS 803 pulverizers in 2013 found unresponsive primary air flow with respect to changes in feeder speed
- Unresponsive pulverizers = unresponsive load changes and boiler stability

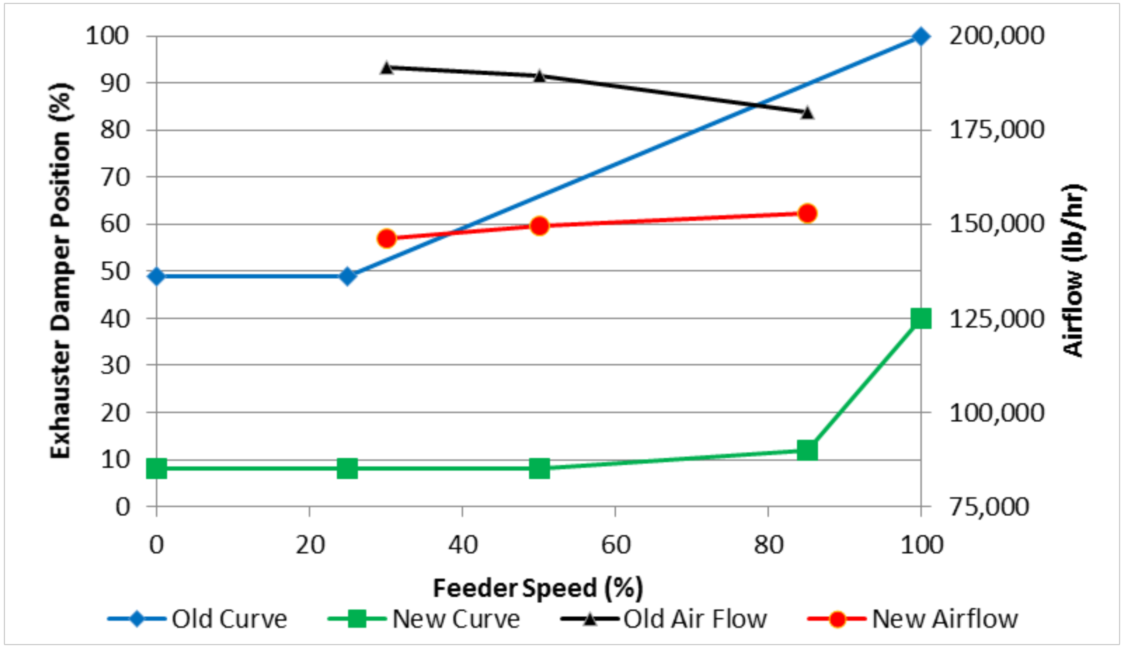


Note: Each pulverizer responded different and varied some were as much as 12-15 minutes to achieve pressure.

Field Proven Results: Case #2

- Recharacterizing the exhauster vs. feeder curves for each pulverizer improved boiler stability
- Each pulverizer was tested and exhauster curves varied from mill to mill
- Unit is able to operate in AGC following improved primary air flow control
- Airflow kickers were installed in the control logic to open exhauster damper momentarily during load changes





Field Proven Results: Case #2

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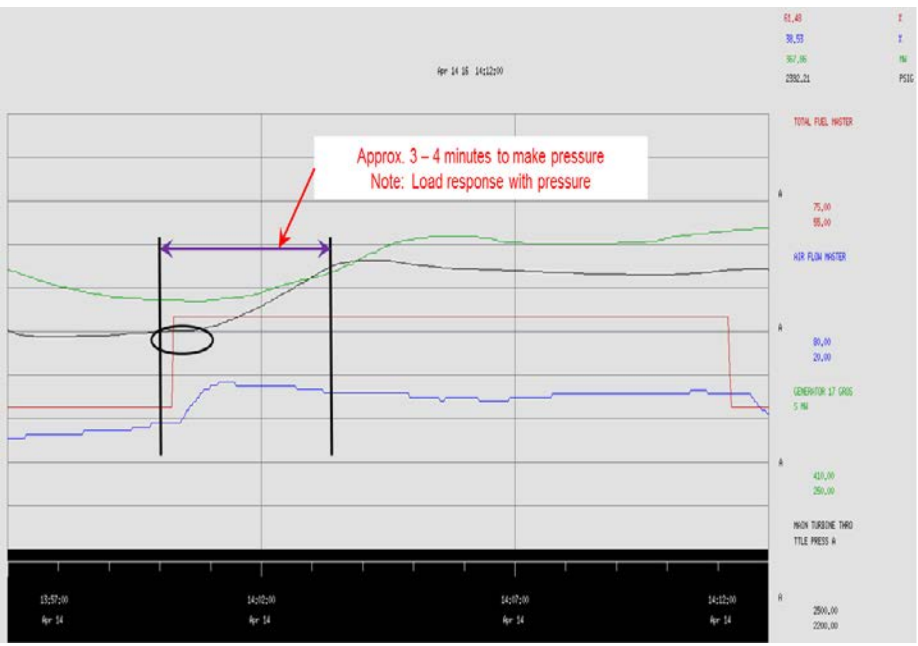
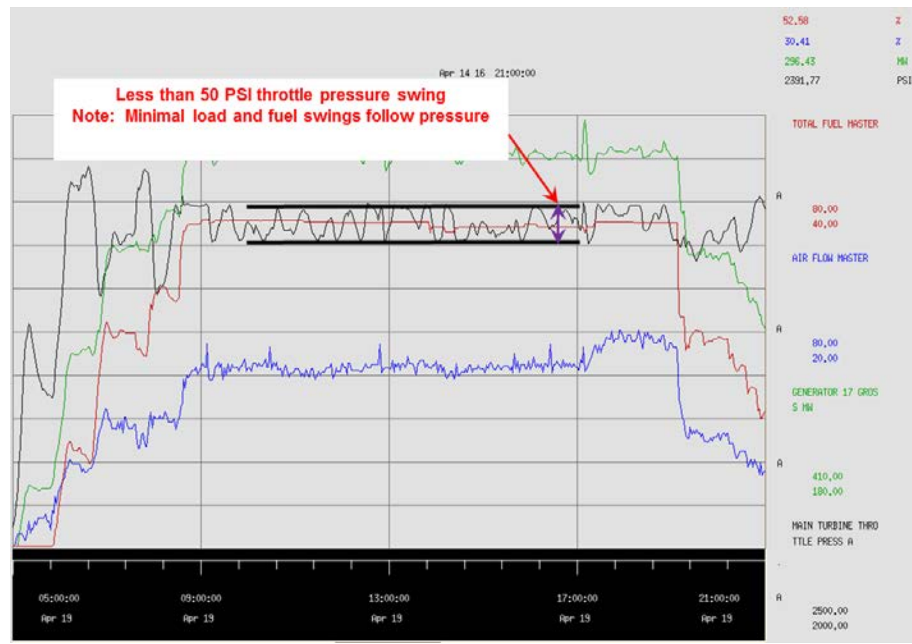
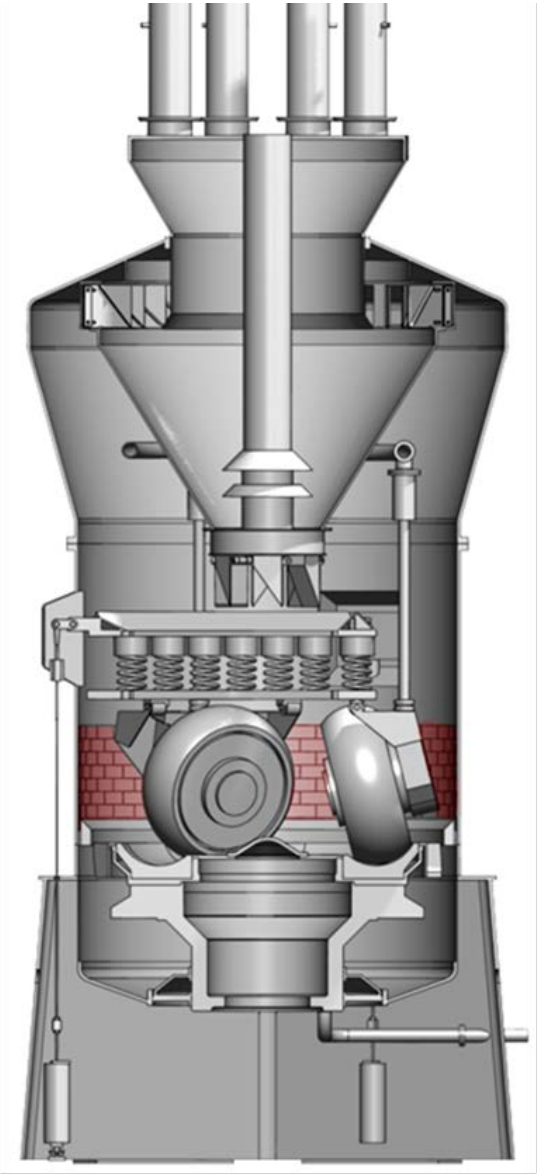
- Recharacterizing the exhauster vs. feeder curves for each pulverizer improved boiler stability
- **Remember each pulverizer was tested and exhauster curves varied from mill to mill**
- Unit is able to operated in AGC following improved primary air flow control

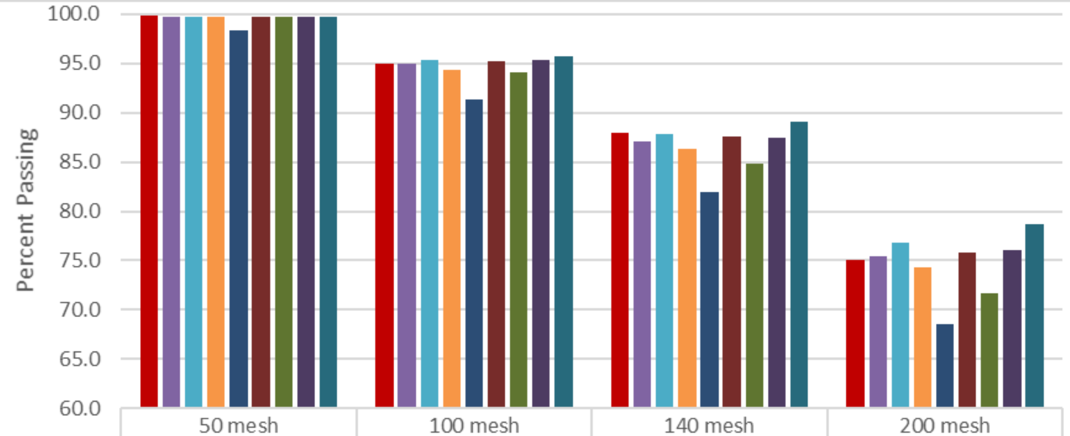




Field Proven Results: Case #3



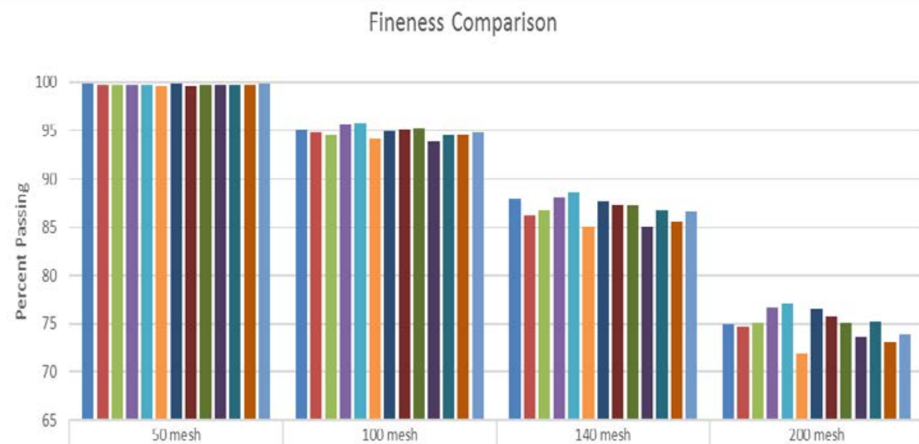
- Pulverizer performance has been monitored at the facility consistently since 2008
- Primary air flow is accurately measured, controlled and field checked on an annual basis
- Mill outlet temperatures were operating around 128 deg. F in early 2016



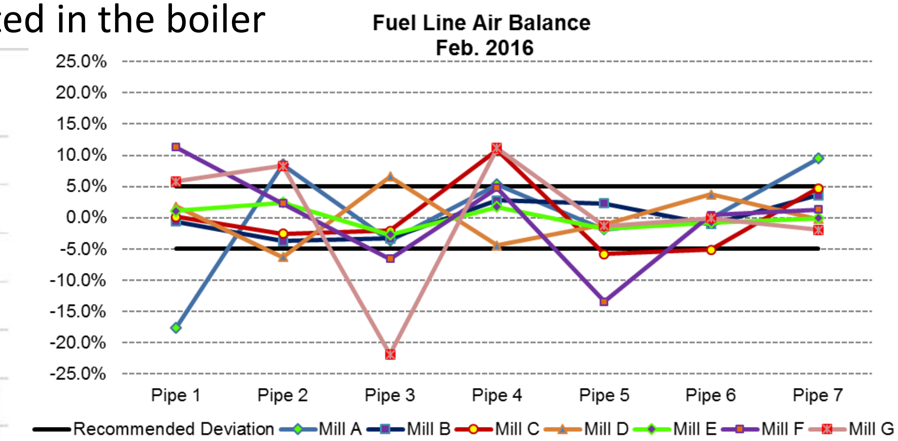
	50 mesh	100 mesh	140 mesh	200 mesh
Recommended	99.9	95.0	88.0	75.0
Jan 2012	99.7	94.9	87.1	75.5
April 2013	99.7	95.3	87.8	76.8
Nov 2013	99.8	94.4	86.3	74.3
April 2014	98.4	91.3	82.0	68.6
May 2014	99.8	95.3	87.6	75.8
June 2015	99.8	94.2	84.9	71.7
Feb 2016	99.7	95.3	87.5	76.1
Dec 2016	99.7	95.8	89.1	78.7

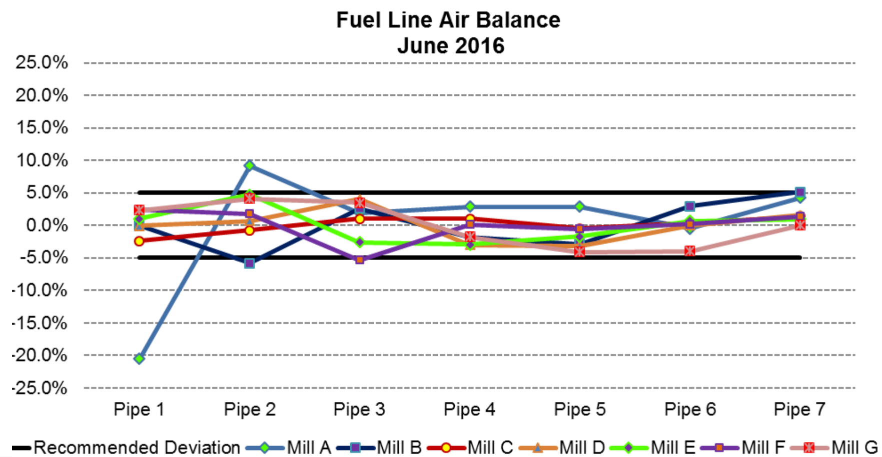
Field Proven Results: Case #3

- Lower than desired mill outlet temperatures impact performance by
  - Utilizing higher amounts of tempering air (stealth heat rate penalty)
  - Negatively impacting pulverizer fineness
  - Increased fuel moisture required to be evaporated in the boiler



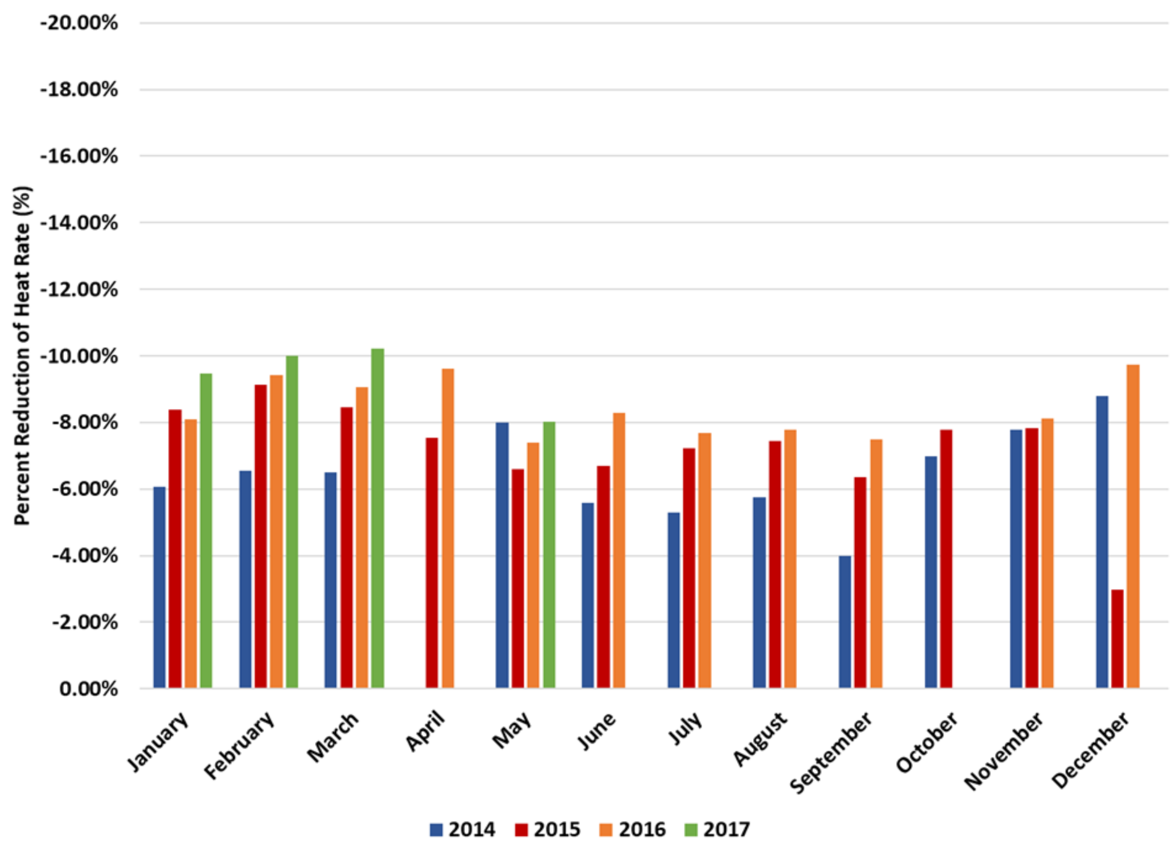
	50 mesh	100 mesh	140 mesh	200 mesh
Recommended	99.9	95	88	75
Mill A @ 128°F	99.8	94.8	86.3	74.7
Mill A @ 135°F	99.7	94.5	86.8	75.1
Mill B @ 128°F	99.8	95.7	88.0	76.7
Mill B @ 135°F	99.8	95.8	88.6	77.2
Mill C @ 128°F	99.7	94.2	85.1	71.8
Mill C @ 135°F	99.9	95.0	87.6	76.5
Mill D @ 128°F	99.7	95.2	87.3	75.7
Mill D @ 135°F	99.8	95.2	87.3	75.1
Mill E @ 128°F	99.8	93.9	85.1	73.6
Mill E @ 135°F	99.8	94.4	86.8	75.1
Mill F @ 128°F	99.7	94.6	85.6	73.0
Mill F @ 135°F	99.9	94.8	86.7	73.9





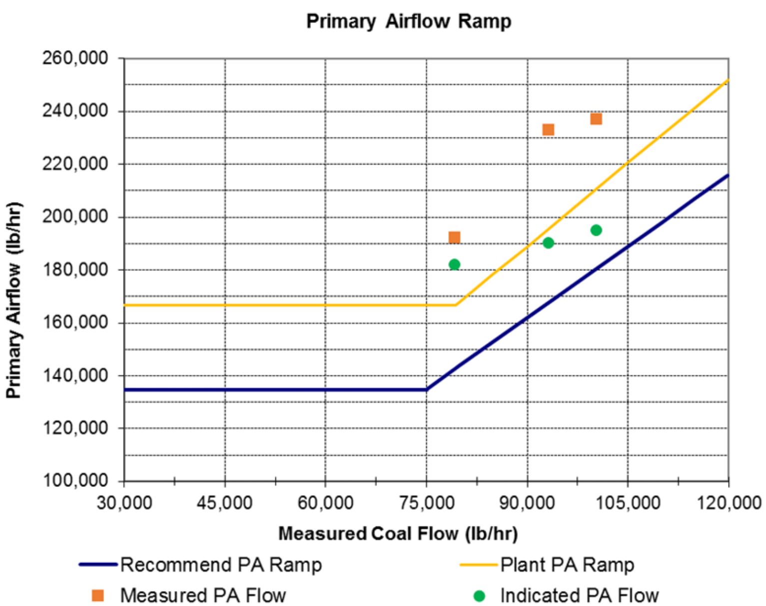
Field Proven Results: Case #3

- Lower than desired mill outlet temperatures impact performance by
  - Utilizing higher amounts of tempering air (stealth heat rate penalty)
  - On average over 100 Btu/kWhr improvement in heat rate seen following increase in mill outlet temperature set point.



Final Conclusions

- Roughly 1/5 of the total air to the boiler is primary air, but precise measurement and control of this small percentage is extremely important.
- Primary air can affect boiler response, pulverizer performance, reliability and heat rate
- Minimum primary airflow should be reviewed thoroughly to ensure fuel line and throat velocities are adequate
- Hot “K” calibrations should be completed on at least an annual basis
- Primary air flow should be accurately measured and controlled to within ±3%.



Thank You

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