An Innovative Approach to Improved Pulverized Coal Delivery and Combustion Optimization

Xcel Energy - Tolk Station

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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.
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How It Was Done:

- Mill Upgrades
- Utilization of SAS Diffusion Technology
- Non-invasive burner modifications
- Diagnostic testing
- Coal flow distribution and balance control
- Implementing and monitoring innovative recommendations
Mill Upgrades:

- Were completed to extend service life of components
- A Multi-Outlet Diffuser was included to redistribute air/fuel mixture in turret
Non-uniform Pulverizer Coal Flow Causes:

- Poor combustion (excessive coal consumption)
- Higher emissions
- Furnace and backpass imbalances
- Slagging and fouling
- Increased opacity
- Reduced availability
- Elevated Heat Rate
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After the Pulverizers are Optimized

- Adjustable Orifices are necessary for on-line fuel flow adjustments
- In-Line Diffusers are added to the burner configuration to atomize air fuel injection to furnace
SAS Global Adjustable V-Style Orifice (patent pending)
SAS Patented In-Line Diffusers Installed

T-Fired Burner Diagram

Flame without Patented In-Line Diffuser
This picture indicates premature combustion due to the segregation of coal and air. Coal roping has created an area with a high air/fuel ratio where combustion first starts to take place, and unfortunately its right at the tip of the burner nozzle. The ignition continues from the exit of the burner along the entire top of the unmixed coal and air.

Homogenous Mixture of Fuel and Air

Flame with Patented In-Line Diffuser
A homogenous mixture of fuel and air is delivered to the tangent point of the center circle of the boiler. T-Fired units are designed to mix the air and coal from all the burners in the very center of the boiler. This flame is exactly where it is supposed to be and there will never be any concerns about burning or melting the burner nozzles. Secondary air and over fire air can now be used effectively for limiting NOx formation.
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 fourteen days
• 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 mobile microwave mass flow testing to evaluate coal flow balance.

- Actual sample weight recovery must be compared with expected values to validate measurement accuracy.
Balance Data: *Example of measured fuel balance of the boiler*

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**An Innovative Approach to Improved Pulverized Coal Delivery and Combustion Optimization**
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

Excess Oxygen, (%, dry): Duct Average = 2.6%

Carbon Monoxide (PPM, corrected): Duct Average = 634ppm

Nitrogen Oxides (PPM, corrected): Duct Average = 0.169 lb/MBtu
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 tilt 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
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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
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
Backpass Testing
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 microwave 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 microwave system coal flow is balanced as necessary
Tolk Unit 1 Weekly Average:

$\text{NO}_X$ 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 emissions
• Combustion improvements also resulted in reduced coal deliveries to Tolk Station
• This results in 22,000 tons less CO₂ 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
Other SAS Global Patented Products and Services to Optimize Combustion and Performance
Never have another nozzle fail from sigma phase or thermal distortion again.
Problems with other (2) Piece Nozzles

Burner Nozzles fail by either thermal deterioration or by coal particle erosion. SAS Global's patented two piece coal nozzle is designed to overcome both of these modes of failure. Don't be fooled by other two piece designs. Other two piece designs split the outer housing into two pieces while still attaching the tip to the inner housing and splitter plates. The problem with this is two fold. First the inner and outer housings are exposed to different temperatures that cause the two to distort and in some cases rip apart. The second is when you remove the clips holding the outer sections of the housing together and can fall off (safety issue) and it is difficult to align a new replacement tip.

![Damaged by Thermal Distortion](image1.png)

![Damaged by Sigma Phase](image2.png)
SAS Global Patented (2) Piece Burner Nozzle

Complete Turnkey Burner Nozzle and Barrel Assembly

**Inner Housing**
310 Stainless Steel with multiple layers of SA1750CR Chromium Carbide Hardfacing
SA1750CR is a Chromium Carbide Overlay Plate consisting of a Hypereutectic Matrix with up to 40% chromium carbides metallurgically fused to an appropriate steel substrate. The hardness of a SA1750CR overlay is a composite of the hard chromium carbides (1750 Vickers), with that of the tough, austenitic matrix. The macro-hardness of the overlay is 55-62 Hrc, depending on the thickness of the overlay.

**Burner Barrel**
1/4” SA1750CR Chromium Carbide Hardfacing on 1/2” Carbon Steel (SA1750CR on the inside)
SA1750CR is a Chromium Carbide Overlay Plate consisting of a Hypereutectic Matrix with up to 40% Chromium Carbides metallurgically fused to an appropriate steel substrate. The hardness of a SA1750CR overlay is a composite of the hard chromium carbides (1750 Vickers), with that of the tough, austenitic matrix. The macro-hardness of the overlay is 55-62 Hrc, depending on the thickness of the overlay.

**Splitter Plates**
310 Stainless Steel with multiple layers of SA1750CR Chromium Carbide Hardfacing
SA1750CR is a Chromium Carbide Overlay Plate consisting of a Hypereutectic Matrix with up to 40% Chromium Carbides metallurgically fused to an appropriate steel substrate. The hardness of a SA1750CR overlay is a composite of the hard chromium carbides (1750 Vickers), with that of the tough, austenitic matrix. The macro-hardness of the overlay is 55-62 Hrc, depending on the thickness of the overlay.

**Locking Tabs**
310 Stainless Steel

**Nozzle Tip**
310 Stainless Steel

**Cast Outer Housing**
HN or HK Stainless Steel
All 40 of the BR5 burner nozzles were replaced during the 1999 turnaround. Two nozzles from SAS Global were installed for evaluation purposes in corners 4 and 5 on A mill. The SAS nozzles differ in two aspects of their design. Firstly the leading edge of the splitter plates is overlaid with chromium carbide, which greatly extends the life of the component in this erosive service. Secondly the nozzle tip is designed to be free floating within the outer shroud. This overcomes distortion issues caused by differential expansion between the inner and outer parts of the nozzle.

The following photographs illustrate how well these upgraded burner nozzles have performed relative to the OEM nozzles after 3 years.
Case History

Figures 1 & 2 – This shows the SAS nozzle installed in 5A from the furnace side. Note that the chromium carbide leading edges of the splitter plates is still intact and that the nozzle is free from distortion. (SAS)
Case History

Figures 6 & 7 – These show the extensive wear and deformation that has occurred with the OEM nozzles on 5B.
Case History

Figure 8 – This shows the extensive wear and deformation that has occurred with the OEM nozzles on 5C.
Case History

Figure 9 – This is a close up of the cracking issue with the OEM nozzle.
Case History

Figure 10 – This is another view of 5B taken from inside the pipe. OEM
ACFM: Advanced Coal Flow Measurement

Special Features

- Fast and accurate test results
- Machine self adjusts to extract 100% Isokinetic
- All testing is computer controlled
- Fuel flows automatically moisture corrected
- Comprehensive report
- Easy to understand data format
- Rapid ROI of testing expenditure
## ACFM: Advanced Coal Flow Measurement

<table>
<thead>
<tr>
<th>Data Obtained</th>
<th>Data Reported</th>
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<tr>
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<td>• Primary air flow</td>
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<td>• Static &amp; total pressure at the measurement location</td>
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<td>• Relative humidity</td>
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<td>• Dew point</td>
<td>• Presentation of proven means to maximize optimization of your system</td>
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ACFM provides a true measure of fuel flow by calculating the moisture lost during the drying process by measuring the humidity level in the pipe.
Portable High Temperature Boiler Camera System
High Temperature Boiler Camera Services

There are many common problems that are easily identified by reviewing the real time burner footage. These problems include:

- Flame instability/detachment
- Eyebrows
- High-unburned carbon (LOI)
- Slagging
- Fuel impingement on boiler walls
- CO and O2 imbalance
- Problems adjusting secondary air and low NOx burners
High Temperature Boiler Camera Basic System

**High Temperature Camera Case Contents**
- High Temperature Camera (A)
- Portable Air Filtration and Regulator Assembly (B)
- Air Hose Connection from Filtration/Regulator to High Temperature Camera (C)
- Power Cord for High Temperature Camera to Battery Pack (D)
- Charger for Battery Pack (E)
- Battery Pack for High Temperature Camera (F)
- Back-up 120V Power Cord for High Temperature Camera (G)
- Composite Video Cable for Connecting High Temperature Camera to Video Case (H)
- Air Hose from plant air to Filtration/Regulator (I)

**Video Case Contents**
- Sony MiniDV Recorder and LCD Screen (J)
- Composite Video Cable Connection (K)
- Charger for Sony MiniDV Recorder (under recorder) (L)
High Temperature Boiler Camera Services

Example Flames with Highlighted Trouble Spots

Ignition at Burner Face

Early Ignition
High Temperature Boiler Camera Services

Example Flames with Highlighted Trouble Spots

heavy fuel concentration
High Temperature Boiler Camera Services

Example Flames with Highlighted Trouble Spots

large particle of ash
High Temperature Boiler Camera Services

Example Flames with Highlighted Trouble Spots

- Slag build-up on Tubes
- Slag build-up on Nose