Conversion of Existing Coal-Fired Boilers to Natural Gas-Firing

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Overview

• Market Drivers for Conversion
• Boiler Performance Impacts
  – Furnace Performance (FEGT and Radiant Absorption)
  – Convective Performance
  – Steam Temperatures
  – Boiler Efficiency
• Unit Performance Impacts
  – Net Heat Rate
• Operations/Maintenance Impacts
Conversion of Existing Coal-Fired Boilers

Natural Gas Prices and Market Forces

• Energy Information Administration’s Annual Energy Outlook shows gas prices below $5 / MMBtu through 2025 and under $8 / MMBtu through 2040.
  – Depends on a number of economic factors
  – Projections based on Henry Hub spot prices
  – EIA estimates approx. 48 GW of coal-fired generation to retire by 2020
  – An estimated 6,900 MW of capacity planned for gas conversion.
Conversion of Existing Coal-Fired Boilers

Market Analysis

• Growing Environmental Regulations Driving Retirements
  – More than 48 GW of coal-fired generation expected to retire by 2020
• Estimated that almost 13 GW could be converted to gas (<400 MW)
  – Capital investment ≥ 400 $ / kW for AQCS Compliance
  – Approx. 6-8 GW with pipeline cost < $200 / kW showing real potential for conversion.
## Conversion of Existing Coal-Fired Boilers

### Babcock Power Services (Riley) Experience

<table>
<thead>
<tr>
<th>Customer</th>
<th>Station Name</th>
<th>Unit #</th>
<th>State</th>
<th>OEM</th>
<th>Fuel (Original)</th>
<th>MW</th>
<th>Steam Flow (pph)</th>
<th>Oper. Temp (F)</th>
<th>Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeastern Utilities</td>
<td>Middletown</td>
<td>2</td>
<td>CT</td>
<td>CE</td>
<td>Oil</td>
<td>370</td>
<td>800,000</td>
<td>1,005</td>
<td>NG Conversion</td>
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<tr>
<td>Jacksonville Electric Authority</td>
<td>Northside Gen Station</td>
<td>3</td>
<td>FL</td>
<td>Riley</td>
<td>Oil</td>
<td>518</td>
<td>3,548,000</td>
<td>1,005</td>
<td>NG conversion, low NOx, add OFA, upgrade HTSH, add stringer supports</td>
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<tr>
<td>Arizona Electric Power</td>
<td>Apache</td>
<td>1</td>
<td>AZ</td>
<td>Riley</td>
<td>Coal</td>
<td>204</td>
<td>1,355,000</td>
<td>1,005</td>
<td>NG conversion, co-fire</td>
</tr>
<tr>
<td>AEP</td>
<td>Conesville</td>
<td>3</td>
<td>OH</td>
<td>Riley</td>
<td>Coal</td>
<td>160</td>
<td>1,240,000</td>
<td>1,005</td>
<td>NG conversion</td>
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<tr>
<td>Canal Electric</td>
<td>Canal</td>
<td>2</td>
<td>MA</td>
<td>B&amp;W</td>
<td>Oil</td>
<td>560</td>
<td>4,000,000</td>
<td>1,005</td>
<td>NG conversion, low NOx retrofit</td>
</tr>
<tr>
<td>Syracuse University</td>
<td>Syracuse</td>
<td></td>
<td>NY</td>
<td>PC</td>
<td></td>
<td>18</td>
<td>180,000</td>
<td>750</td>
<td>NG Conversion, Remove PC</td>
</tr>
<tr>
<td>Univ of Iowa</td>
<td>Main Power Plant</td>
<td>Blr 10</td>
<td>Iowa</td>
<td>Riley</td>
<td>Stoker coal</td>
<td>27</td>
<td>170,000</td>
<td>760</td>
<td>Convert to 100% NG</td>
</tr>
<tr>
<td>Invista</td>
<td>Canden</td>
<td>1</td>
<td>SC</td>
<td>Riley</td>
<td>Stoker coal</td>
<td>20</td>
<td>200,000</td>
<td>800</td>
<td>Stoker coal to 100% NG</td>
</tr>
<tr>
<td>NRG Energy</td>
<td>Big Cajun II</td>
<td>2</td>
<td>LA</td>
<td>Riley</td>
<td>Turbo - Coal</td>
<td>600</td>
<td>4,300,000</td>
<td>1,005</td>
<td>NG Conversion</td>
</tr>
</tbody>
</table>
Conversion of Existing Coal-Fired Boilers

Fuel Delivery System

• Natural Gas and Supply
  – Supply pipeline to the plant
    • Metering Station
    • Pressure Reducing Station
  – Required supply Pressures to the burners is approximately 25-50 psig.
  – Main burners supply as well as ignitor supply if necessary.
    • Includes dedicated flow control valve trains to supply each individual unit’s fuel
    • All must be NFPA compliant

• Required a hazardous area classification analysis for potential required upgrades of existing infrastructure due to new fuel.
Conversion of Existing Coal-Fired Boilers

Firing System Considerations

• Existing Firing Configuration
  – Tangentially-Fired
  – Wall-Fired
  – Turbo-Fired

• Natural Gas-Firing Goals
  – 100% Gas-Firing Only
  – Co-Firing
  – Dual-Fuel Capability

Retractable main gas gun
Dual Fuel “Smart” Scanners
CCV® Coal Nozzle
# Conversion of Existing Coal-Fired Boilers

## Burner Ignitor Systems

<table>
<thead>
<tr>
<th>Classification</th>
<th>Class I</th>
<th>Class III</th>
<th>Class III Special</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ignition of Main Burner</td>
<td>Ignite or support</td>
<td>Small ignitor for gas and oil burners under prescribed light-off conditions</td>
<td>Provides direct spark ignition to ignite main burner</td>
</tr>
<tr>
<td>Heat Input</td>
<td>&gt;10% burner heat input</td>
<td>&lt; 4% burner heat input</td>
<td>Only spark for ignition</td>
</tr>
<tr>
<td>Continuous Operation</td>
<td>Yes</td>
<td>Not permissible</td>
<td>No</td>
</tr>
<tr>
<td>Extended Operating Range</td>
<td>Support combustion of the main flames</td>
<td>Cannot be used to support ignition or extend the turndown range</td>
<td>Cannot be used to support ignition or extend the turndown range</td>
</tr>
<tr>
<td>Flame Detection</td>
<td>One detector to prove either the ignitor or main flame.</td>
<td>One detector required for main burner and ignitor</td>
<td>Only require main flame detector</td>
</tr>
<tr>
<td>Master Fuel Trip (MFT) Requirement</td>
<td>Does not require MFT Requires 1-minute delay before restart</td>
<td>Does not require MFT Requires 1-minute delay before restart</td>
<td>Failure of first burner to light requires MFT</td>
</tr>
</tbody>
</table>
Conversion of Existing Coal-Fired Boilers

Furnace Performance Considerations

- **Furnace Exit Gas Temperature (FEGT)**
  - Flame Characteristics
  - Furnace Cleanliness
- **Radiant Absorption**
  - Same as above
- **Circulation**
  - Change in absorption profile
  - Generally not a large impact

![Graph showing Furnace Exit Gas Temperature vs. Furnace Area Heat Release]

- Bituminous Coal
- Bituminous Coal - Severe Slagging
- Bituminous Coal - Low Slagging
- PRB Coal
- Natural Gas
Flame Characteristics

- Flame Radiation will depend on many things:
  - Temperature
  - Composition – excess air, particles, moisture, etc.

Natural Gas Flame
\[ T_{\text{flame}} \sim 3,200 \text{ – 3,500 [F]} \]

Low NO\textsubscript{x} Coal Flame
\[ T_{\text{flame}} \sim 3,000 \text{ – 3,300 [F]} \]
Changes in Gas Flows

- At 8% XSA, natural gas-firing will result in approx. 16% less flue gas than bituminous and approx. 20% less flue gas than PRB coal.
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Convective Heat Transfer

- Due to changes in radiant absorption and gas temperature and flow, heat transfer in convection sections will typically decrease.
- FGR is one way to increase the convection by increasing gas flow.
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Flue Gas Recirculation (FGR)

- Flue gas can be recirculated through the furnace bottom, or through the burners.
  - Temperature Control vs \( \text{NO}_x \) Control
- Recirculation can be via dedicated FRG fans, or the existing FD fans with IFGR.
  - Induced Flue Gas Recirculation (IFGR) is limited by FD fan capacity
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Boiler Efficiency Changes

- Highly dependent on existing fuel characteristics
- In general, a decrease in boiler efficiency of more than 5% can occur.
- 1:1 change in unit heat rate with change in boiler efficiency

η = 89.45%
η = 84.27%
η = 83.79%

(-5.7% Δη from Bit.)
(-0.5% Δη from PRB)
Conversion of Existing Coal-Fired Boilers

Unit Net Heat Rate

• Boiler efficiency is a 1:1 inverse relationship to unit heat rate.
  – 1% decrease in boiler efficiency is a 1% increase in heat rate.
• Steam temperature will effect heat rate also.
• Gas Firing results in a net decrease of auxiliary power
  – Mill power
  – I.D. Fan Power
  – $SO_x$ Removal Systems
Conversion of Existing Coal-Fired Boilers

Flue Gas Emissions Effects

• Natural Gas-Firing Produces:
  – No SO\textsubscript{x} emissions
  – Virtually no PM
  – ~1/3 the NO\textsubscript{x} emissions of coal
  – 50-80% less CO\textsubscript{2} than coal

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Conversion of Existing Coal-Fired Boilers

Operational Flexibility

• Dual Fuel
  – Natural Gas and Coal
  – CCV Dual Fuel Technology
  – Provides Operational Flexibility

• Ability to run 100% coal AND natural gas
  – Can improve economic profile of the unit by optimizing the fuel for economics and emissions

Retractable main gas gun
Dual Fuel “Smart” Scanners
CCV® Coal Nozzle
# LNB Dual Fuel Burner Emissions Capability

Indicative NO$_x$ & CO emissions w/ VS III™ burners & OFA

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Emissions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NO$_x$ (lb/mmbtu)</td>
</tr>
<tr>
<td>Bituminous Coal</td>
<td>0.27 – 0.32</td>
</tr>
<tr>
<td>PRB Coal</td>
<td>0.17 – 0.20</td>
</tr>
<tr>
<td>Natural Gas</td>
<td>0.22 – 0.30</td>
</tr>
<tr>
<td>Natural Gas w/ FGR</td>
<td>0.09 – 0.15</td>
</tr>
</tbody>
</table>

**CCV® Coal Nozzle**

**Retractable Main Gas Gun**
Conversion of Existing Coal-Fired Boilers

Operations/Maintenance Changes (cont.)

- GADS Statistics on boiler tube leaks reveals that gas-fired generation experiences ~83% less generation losses than their coal-fired counterparts.
- No ash in natural gas eliminates the numerous adverse impacts that ash has on boiler operation and performance.
  - Cost of ash-related impacts in coal-fired generation is estimated to be on the order of hundreds of millions of dollars
- Fuel quality can be highly variable for coal-fired boilers leading the many operational and performance impacts
  - Natural gas is very consistent in quality and therefore doesn’t present these same challenges