COMBUSTION OPTIMIZATION AND CO-FIRING OF STOKER-FIRED BOILERS

Daniel D. Hill, P.E.
Detroit Stoker Company
Monroe, Michigan, USA
About DSC Products & Services

• Solid Fuel Combustion Systems
• Combustion Air Systems
• Solid Fuel Feeding/Metering Systems
• Rotary Seal Feeders/Double Flap Airlocks
• Low NOx Gas/Oil Burners
• Aftermarket Parts & Consulting Services
• Domestic Construction Services
• Engineering Studies
  – CFD Analysis for Air Systems and Furnace Design
  – Pilot Scale Testing
ABSTRACT

To evolve with environmental and economic factors, users of existing coal-fired boilers are finding renewed operating flexibility by implementing co-firing of various fuels into their operations. Co-firing of local waste materials, and in some cases engineered fuels, has become commonplace in the United States and likewise world-wide.

Woody biomass fuels continue to be a mainstay in many co-fired boilers however opportunity fuels such as agricultural wastes have proven to be another valuable source. These range from the familiar bagasse to others lesser known such as corn stover and spent distillery grains, for example, which have been successfully co-fired. Engineered fuel products, often extruded as pellets, are also growing in popularity. Torrefied wood, RDF, and sludge pellets for example; as they offer a unique combination of benefits in a co-firing scenario.

Generally speaking, these existing boilers are often capable of co-firing 5%-10% thermal input with limited equipment additions and no major boiler modifications. As co-firing increases however, evaluations are necessary to evaluate acceptability of the combustion chamber & grate components, fuel feeding system(s), combustion air system, combustion controls, boiler cleaning & ash handling systems, environmental control equipment, and the steam generating system. These efforts will largely determine the limiting factors as well as additional capital equipment required to satisfactorily increase co-firing.

The proceeding presentation will then discuss several of these potential fuel sources and proven means to co-fire them successfully. Additionally, several fuel and combustion related systems outlined above as requiring further evaluation will be briefly reviewed and commented on.
Biomass and Refuse Opportunity Fuels
Co-Firing (Biomass) Feasibility Questions

- Infrastructure to collect and transport?
- Long term availability and cost escalation?
- Competing interest or users?
- Additional processing on-site?
- On-site storage requirements?
- Permitting?
- Emissions?
- Capital Investments Necessary?
## Taking a Closer Look at the Fuel…

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkali Metals in Ash***</td>
<td>Lowers ash fusion temps increasing fouling on refractory, furnace walls, SH tubes, and grate. Co-Firing fuels can have an eutectic effect further lowering ash fusion temperatures</td>
</tr>
<tr>
<td>Chlorine</td>
<td>High temp corrosion on SH tubes / low temp corrosion in presence of high moisture – agricultural wastes, litters, and some pellets</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Corrosion / Increased dew points – generally low in biomass</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>Fuel bound NOx for emissions consideration – shows up in agricultural wastes</td>
</tr>
</tbody>
</table>
Alkali Content Effects on Slagging and Fouling

- Alkali (sum of Potassium and Sodium Compounds)
  - $K_2O \& Na_2O$
- Alkali have an eutectic effect on melting point of mixtures, particularly $SiO_2$
- Fouling/Slagging index often assists in initial identification of potential issues

$$\frac{\text{Lb alkali}}{\text{MMBtu}} = \frac{1 \times 10^6 \text{ Btu}}{\text{Btu/lb (dry)}} \times \% \text{ Ash} \times \% \text{ Alkali of Ash}$$
Fouling / Slagging Index

- ≤ 0.4 = Low Risk
- 0.4 – 0.8 = Slagging Likely
- ≥ 0.8 = High Probability

<table>
<thead>
<tr>
<th>Material</th>
<th>Ash %</th>
<th>K2O%</th>
<th>Na2O%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wood/Bark</td>
<td>0.3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bagasse</td>
<td>0.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corn Stover</td>
<td>1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chicken Litter</td>
<td>2.7</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

©2014 Detroit Stoker Company. All Rights Reserved
Volumetric Considerations per Unit of Energy

- Bituminous Coal
- Wood Pellets – 1.8x
- Hogged Wood – 6.7x
- Bagasse – 9.8x
Potential Co-Firing Problems Spots in Existing Coal Feed System

(When mixing fuels and using a single feed system)

- Receiving Hopper Feeder
- Infeed Conveyors
- Bucket Elevators
- Weight Scales
- Coal Chutes
Coal & Biomass Arrangement

136 mT/hr
64 bar
510ºC
Coal / High Density Fuel Distributor

Detroit Underthrow Coal Distributor

©2014 Detroit Stoker Company. All Rights Reserved
Biomass / Low Density Fuel Distributors

Detroit Air Swept Distributor Spout
Multiple Fuel Arrangement

130 mT/hr
116 bar
540ºC
Pulverized Coal & Biomass Arrangement

150 mT/hr
114 bar
540°C
Combination Fuel Distributor

Detroit Combination Distributor
Dust Burners

- Dust is pneumatically introduced through the center combustion tube
- Natural Gas ring header for additional input (if desired)
- Continuous gas or oil pilot
Grate System Considerations

- Ability to slow down grate speed to maintain protective ash bed
- Grate metallurgy to support higher operating temperatures
- Grate internal seals and grate-boiler seals in good condition to minimize tramp air and promote even air distribution
FD and ID Fans

• FD Fan needs to be evaluated to confirm sufficient primary combustion air may be provided

• ID Fan needs to be evaluated to confirm furnace draft can be maintained at increased flue gas density and mass flow rates

• NOTE: Tramp air throughout the boiler and high excess air for combustion can be detrimental here
Overfire Air System (OFA)

• Provides turbulence and mixing of:
  – Suspended fuel particles
  – Above bed volatiles
• Staged air provides:
  – Reduced thermal NO \textit{x}
  – Reduced flame length
Overfire Air System (OFA)

- 1940’s-1980’s OFA as percentage of total combustion air was typically 12%-20%
- Today’s designs call for 30%-35% for improved combustion efficiency and emissions

- Introducing biomass fuels higher in fines and volatile matter content increase above grate suspension firing therefore additional OFA is required.
- By comparison, today’s biomass boilers often use 50% OFA
Boiler Capability

• Numerical modeling iterations using original design data, current operating data, and future cases. Possible outcomes may include:
  – De-rating boiler due to volumetric/absorption limitations
  – Superheater metal and steam temperatures
  – ΔP’s / Velocities
  – Higher moisture fuels will increase dewpoint temperatures
Fly Ash Handling

• Typically fly ash on coal-fired boilers is pneumatically conveyed
• When firing biomass hot embers can and will remain smoldering after dropping out of the flue gas stream
• Explosion panels and inert gas blanketing on the silo is required
• Baghouses will need to be evaluated for similar concerns