Worldwide Pollution Control Association

IL Regional Technical Seminar
August 3-4, 2010

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An Unbiased Comparison of FGD Technologies: Wet, Spray Dry and CDS

WPCA Conference
August 2010

Brandy Johnson
Manager, FGD Project Development
Agenda

- Introduction to FGD Technologies
- Wet FGD
- Spray Dry Absorber (SDA)
- Circulating Fluidized Bed FGD
- Compare and Contrast Technologies
- Summary
Agenda

Introduction to FGD Technologies

- Wet FGD
- Spray Dry Absorber (SDA)
- Circulating Fluidized Bed FGD

Compare and Contrast Technologies

Summary
FGD Questions

- Regulations
- Availability of Absorbents
- Schedule Requirements
- Permit Requirements
- Byproduct and Waste Water Permitting
- Technology Preferences
- Design Fuel and Fuel Flexibility
Flue Gas Desulfurization and Acid Gas Control

Spray Dry FGD System
- Up to 95% SO₂ removal
- Lower sulfur fuels
- Typically <1.5% sulfur coal
- Dry product for landfill
- Uses lime

Wet FGD
- Up to 98+% SO₂ removal
- High sulfur fuels (>1.5%)
- More fuel flexibility
- Marketable byproduct
- Typically uses limestone

Circulating Dry Scrubber
- Up to 98+% SO₂ removal
- Higher sulfur fuels (>1.5%)
- More fuel flexibility
- Dry product for landfill
- Uses lime which is hydrated on site

Dry Sorbent Injection
- Usually lime or sodium based
- Injected before particulate control device
- Used for SO₂, SO₃, HCl control
Agenda

Introduction to FGD Technologies

Wet FGD

Spray Dry Absorber (SDA)

Circulating Fluidized Bed FGD

Compare and Contrast Technologies

Summary
Typical Wet FGD Configuration

- Construction Services
- SO$_2$ Scrubber
- Fabric Filter
- SO$_3$ and Mercury
- SCR
- Boiler
- Coal Pulverizers
Characteristics of Wet FGD Systems

- Coal sulfur levels of 0.2 to 8%
- Inlet SO₂ ranges from 200 - 6500 ppmv
- Removal efficiencies up to 99%
- 98% removal typically required today
- Installed on ~ 60% exist US coal boilers
- Mature technology
- One tower per boiler or boilers, up to 1300 MW
- Added benefit: ability to remove oxidized mercury
Scrubber with One Tray
### Advantages and Disadvantages of Wet FGD

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>High removal efficiency with any coal</td>
<td>Sampling of multiple points in process required to understand chemistry</td>
</tr>
<tr>
<td>High reagent utilization</td>
<td>Typically requires wastewater treatment</td>
</tr>
<tr>
<td>Excellent fuel flexibility</td>
<td>Alloys or coatings required for chloride protection</td>
</tr>
<tr>
<td>Mature product</td>
<td>High water usage</td>
</tr>
<tr>
<td></td>
<td>Wet stack required</td>
</tr>
</tbody>
</table>
Agenda

- Introduction to FGD Technologies
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- Summary
Typical SDA Configuration

- Coal Pulverizers
- Boiler
- SCR
- Dry Scrubber
- Fabric Filter
Flue Gas Distribution

Roof Gas Disperser

Central Gas Disperser

60 / 40 Split
Process Flow Sheet and Control Basics

SO₂ Emission Setpoint

Absorber Outlet Temperature Setpoint

TCs

SO₂ Monitor

Recycle Slurry Solids Setpoint

Density Monitor

Recycle – gravity return individually for each SDA

Lime – pressurized loop to feed multiple SDAs

Lime

H₂O

H₂O

Slaker Temperature Setpoint

Recycle – gravity return individually for each SDA

FF / ESP

Lime – pressurized loop to feed multiple SDAs

Recycle

Solids

Recycle Slurry Solids Setpoint

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# Advantages and Disadvantages of SDA

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mature product</td>
<td>Limited to lower sulfur coals</td>
</tr>
<tr>
<td>Recycle usage lowers lime consumption</td>
<td>Increased dry byproduct to dispose</td>
</tr>
<tr>
<td>Simple chemistry checks – solids in slurry</td>
<td>Byproduct disposal requires care</td>
</tr>
<tr>
<td>Carbon steel construction</td>
<td>Fairly high quality water required for slaking</td>
</tr>
<tr>
<td>Low water usage</td>
<td></td>
</tr>
<tr>
<td>No wastewater treatment</td>
<td></td>
</tr>
<tr>
<td>No wet stack required</td>
<td></td>
</tr>
</tbody>
</table>
Agenda

Introduction to FGD Technologies

Wet FGD

Spray Dry Absorber (SDA)

Circulating Fluidized Bed FGD

Compare and Contrast Technologies

Summary
Typical CDS Arrangement

- Stack
- Absorbent Silo
- Fabric Filter
- CDS
- Product Silo
- Clean Gas Duct
- Raw Gas Duct
- Flue Gas Dampers
- ID-Fan
- Clean Gas Recirculation
Typical Process Overview

- Raw gas
- Silo
- SO2
- Water
- Absorbent
- CDS
- Filter
- Product recirculation
- Product discharge to silo
- Stack
- Clean gas
- Δp
- ID Fan

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CFD Modeling of Arrangements
Venturis

Top view

Bottom view
Water Injection

- Lower water consumption than wet systems
- No saturation of clean gas
- High pressure injection (~600 psi)
- Low quality water can be used
- Water feed control independent from sorbent feed
## Advantages and Disadvantages of CDS

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water evaporation independent of sorbent feed rate</td>
<td>Higher pressure drop</td>
</tr>
<tr>
<td>Carbon steel construction</td>
<td>High pressure feedwater pumps required</td>
</tr>
<tr>
<td>Small footprint / compact plant arrangement</td>
<td>Byproduct transport requires care</td>
</tr>
<tr>
<td>No wastewater</td>
<td>Elevated baghouse</td>
</tr>
<tr>
<td>No wet stack required</td>
<td></td>
</tr>
</tbody>
</table>
Agenda

Introduction to FGD Technologies

Wet FGD

Spray Dry Absorber (SDA)

Circulating Fluidized Bed FGD

Compare and Contrast Technologies

Summary
# Absorber Configurations

<table>
<thead>
<tr>
<th></th>
<th>Wet</th>
<th>SDA</th>
<th>CDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet/Dry Interface</td>
<td>Inlet quench</td>
<td>Absorber</td>
<td>Absorber</td>
</tr>
<tr>
<td>Size Constraints</td>
<td>~1000</td>
<td>~300 atomizer</td>
<td>~400 bed stability</td>
</tr>
<tr>
<td>Largest single tower (MW) Limitations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># Absorbers / Unit</td>
<td>Single</td>
<td>Multiple</td>
<td>Multiple</td>
</tr>
<tr>
<td>Slurry pH</td>
<td>5 - 6</td>
<td>11 - 12</td>
<td>N/A</td>
</tr>
<tr>
<td>Chlorides</td>
<td>High</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Flue Gas</td>
<td>Saturated</td>
<td>Above Saturation</td>
<td>Above Saturation</td>
</tr>
</tbody>
</table>
# Material of Construction

<table>
<thead>
<tr>
<th>Material</th>
<th>Wet</th>
<th>SDA</th>
<th>CDS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absorber Tower</td>
<td>Alloy Tile</td>
<td>Carbon Steel</td>
<td>Carbon Steel</td>
</tr>
<tr>
<td></td>
<td>Fiberglass</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nozzles / Atomizers</td>
<td>Ceramic</td>
<td>Alloy / Ceramic</td>
<td>CS venturis/ceramic water</td>
</tr>
<tr>
<td>Flues</td>
<td>Lined</td>
<td>Carbon Steel Coatings</td>
<td>Carbon Steel Coatings</td>
</tr>
</tbody>
</table>
# Reagents

<table>
<thead>
<tr>
<th></th>
<th>Wet</th>
<th>SDA</th>
<th>CDS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stoichiometry</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><a href="https://via.placeholder.com/576x756">image</a></td>
<td><a href="https://via.placeholder.com/576x756">image</a></td>
<td><a href="https://via.placeholder.com/576x756">image</a></td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>Limestone (CaCO₃)</td>
<td>Lime (CaO) Fly Ash</td>
<td>Lime (CaO) Fly Ash</td>
</tr>
<tr>
<td></td>
<td>Lime Sodium</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Typical Cost</strong></td>
<td>$5 - 25/ton</td>
<td>$60 - 120/ton</td>
<td>$60 – 120/ton</td>
</tr>
<tr>
<td><strong>Preparation</strong></td>
<td>Wet grinding</td>
<td>Grinding Slaking</td>
<td>Hydration</td>
</tr>
</tbody>
</table>
# By-Product Streams

<table>
<thead>
<tr>
<th></th>
<th>Wet</th>
<th>SDA</th>
<th>CDS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solids Composition</strong></td>
<td>CaSO₄</td>
<td>Fly ash</td>
<td>Fly ash</td>
</tr>
<tr>
<td></td>
<td></td>
<td>CaSO₃, CaSO₄, CaCl₂</td>
<td>CaSO₃, CaSO₄, CaCl₂</td>
</tr>
<tr>
<td><strong>Beneficial Uses</strong></td>
<td>Gypsum Wall-board, Cement additive</td>
<td>Aggregate Mine reclaim, Cement</td>
<td>Aggregate Mine reclaim, Cement</td>
</tr>
<tr>
<td><strong>Landfill</strong></td>
<td>Dry / pond</td>
<td>Dry</td>
<td>Dry</td>
</tr>
<tr>
<td><strong>Water</strong></td>
<td>Treatment</td>
<td>None</td>
<td>None</td>
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# Economics

<table>
<thead>
<tr>
<th></th>
<th>Wet</th>
<th>SDA</th>
<th>CDS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Capital Costs</strong></td>
<td>🚀🚀</td>
<td>👇</td>
<td>🚀</td>
</tr>
<tr>
<td><strong>Reagent Usage</strong></td>
<td>👇</td>
<td>🚀Apollo</td>
<td>🚀Apollo</td>
</tr>
<tr>
<td><strong>Power Usage</strong></td>
<td>🚀Apollo</td>
<td>👇</td>
<td>🚀Apollo</td>
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</tbody>
</table>
## Lifecycle Economics

<table>
<thead>
<tr>
<th></th>
<th>Wet</th>
<th>SDA</th>
<th>CDS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Eastern Mid-High</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfur Fuel with</td>
<td>![↑][↑]</td>
<td>Typically N/A</td>
<td>![↓]</td>
</tr>
<tr>
<td>high removal</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>requirements,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;~400MW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Eastern Mid-High</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfur Fuel with</td>
<td>![↓]</td>
<td>Typically N/A</td>
<td>![↑][↑]</td>
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<tr>
<td>&gt;~400MW</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Western Fuels</strong></td>
<td>![↑][↑]</td>
<td>![↓]</td>
<td>![↑]</td>
</tr>
</tbody>
</table>
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## Summary of Wet, Spray Dry and CDS FGD

<table>
<thead>
<tr>
<th>Wet FGD</th>
<th>Spray Dryer</th>
<th>CDS</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Typically, the lower lifecycle cost for larger units burning high S coal and requiring high SO$_2$ removal</em></td>
<td><em>Typically, the lowest lifecycle costs if required SO$_2$ removal is achievable</em></td>
<td><em>Typically, the lower lifecycle cost for smaller units burning high S coal and requiring high SO$_2$ removal</em></td>
</tr>
</tbody>
</table>
Thank You.