Wet & Dry Scrubbers

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Dry FGD/DSI Topics

**DRY FGD**
Technology Variations
Technology Description
  - Reagent Handling and Preparation
  - Absorber System
  - Baghouse System
  - Waste Recycle System
  - Flue Gas System
Dry FGD Technology Suppliers
Dry FGD/DSI Topics

- **DRY SORBENT INJECTION (DSI)**
- DSI vs. Other FGD Options
- Types of Sorbent
- Trona vs. SBC
- Current Industry Trends
DRY FGD
Technology Variations

Dry Scrubbers

Spray Dryer Absorber (SDA)
  Rotary Atomizer
  Dual-Fluid Nozzle

Circulating Dry Scrubber (CDS)
  Fluidized Bed FGD
  NID DS

Dry Sorbent Injection (DSI)
Dry FGD – Rotary Atomizer
Dry FGD – Dual Fluid Nozzle
Dry FGD – Circulating Dry Scrubber
Dry Sorbent Injection (DSI)
Dry FGD

Spray Dry Flue Gas Desulphurization (FGD)

Circulating Dry Scrubber (CDS) or Circulating Fluidized Bed (CFB) Scrubber

NIDS
  A subset of CDS

Dry Alkali Injection for SO$_2$ control
Commonality Between Dry Systems (SDA and CDS)

All Systems Require a Particulate Collection Device downstream of the absorber – preferably a baghouse but could use an ESP.

Both use a lime derivative – \( \text{Ca(OH)}_2 \) as the reagent:
- Spray Dryer uses it wet in a slurry
- CDS uses semi-dry hydrate & adds water separately

Both have limited module sizes:
- SDA = 450 MW
- CDS = 400 MW operating, up to 490 MW
- NID = 75 MW/module, multiple modules compose a system
Commonality Between Dry Systems

Because both systems stay at least 30°F above the dew point, both use carbon steel as the primary material of construction.

Because both systems stay at least 30°F above the dew point, the existing chimney can be re-used in a retrofit.

Both systems recycle large amounts of baghouse catch back to the absorber to improve lime usage.

Both produce a sulfite-sulfate mixed material that must be landfilled.

Can be used in low grade concrete aggregate when mixed with fly ash.
Dry FGD Chemistry

Coal Sulfur forms gaseous $SO_2$ & $SO_3$

Lime is received as CaO (pebble lime)
(3/4” x 0” for Dry FGD or CDS, 1/8” x 0” for NID)

Lime is slaked/hydrated as follows:
CaO + H$_2$O $\rightarrow$ Ca(OH)$_2$

In the absorber, SO$_2$ is captured as:
Ca(OH)$_2$ + SO$_2$ $\rightarrow$ CaSO$_3$$\cdot$$\frac{1}{2}$H$_2$O + 1/2 H$_2$O (70-75%)
Ca(OH)$_2$ + SO$_2$ + H$_2$O + 1/2O$_2$ $\rightarrow$ CaSO$_4$$\cdot$2H$_2$O (25-30%)

In a CDS absorber, CO$_2$ is captured as:
Ca(OH)$_2$ + CO$_2$ $\rightarrow$ CaCO$_3$ + H$_2$O
Stoichiometric ratio

Stoichiometric Ratio often referred to as the Ca/S ratio

Actual moles of calcium/theoretical amount of calcium required for the moles of SO$_2$ collected

For wet FGD it is expressed as a ratio to the SO$_2$ collected.

Typical values would be 1.03 to 1.05

Dry system suppliers express their usage on the basis of the inlet SO$_2$ not the SO$_2$ collected like the wet systems.

Typical values would be 1.1 to 1.4 for PRB Coal for 95% Efficiency
Spray Droplet Chemistry

Slurry droplet drying time is a function of the flue gas temperature at the SDA inlet.

- Higher the temperature, lower the residence time to dry the droplet.
- Typically 1-4 seconds is needed to dry the largest droplet.

Drying time is also a function of chlorides and recycle amount.

- Higher the CaCl₂, higher the residence time needed to dry the slurry droplet which can increase the amount of SO₂ capture.
- The lower the amount of fly ash in the recycle, the higher the residence time needed to dry a slurry droplet.
Spray Dryer Absorber
Dual-Fluid Nozzles Versus Rotary Atomization Spray Dryers

Footprint Is Smaller For Dual-Fluid Spray Dryer Than For Rotary Atomizer Spray Dryer

Removal of One Dual-Fluid Nozzle (Out of 40) For Maintenance Has Less Of An Effect On Emissions Than One Rotary Atomizer (Out Of 2 [B&W] or 6 [Alstom])

Spare Atomizer Costs -
- B&W - $675,000 (1 atomizer per vessel)
- Alstom - $250,000 (3 atomizers per vessel)
- Siemens - $18,000 (20 nozzles per vessel)

Maintenance Times -
- Dual-fluid Nozzles - ~12 – 15 man-hours/week
- Rotary Atomizers - ~20 – 30 man-hours/week
Dual-Fluid Nozzles Versus Rotary Atomization Spray Dryers

Costs Between Dual-Fluid & Rotary Atomizer FGD Systems About Equal

Energy Consumption Between The Two Technologies Is About The Same

More Rotary Atomizer FGD Systems In Service Than Dual-Fluid Nozzles
Rotary Atomizer

For utility sized systems many atomizers are mechanical, rotary atomizers.

Slurry is fed into a disc nozzle rotating at a high rate of speed.

This spins fine droplets of slurry out into the gas stream – where they dry and are captured in the baghouse.
Typical Rotary Atomizer
(1-3 Per Spray Dryer)
Dual Fluid Nozzle

Certain Manufacturers use dual fluid nozzles as an alternative to the Rotary Atomizer in SDA.

In the dual fluid nozzle lime slurry is atomized by a high pressure second fluid – predominantly compressed air to produce the fine spray needed.

Dual fluid nozzles do not have high speed rotating parts like the Rotary atomizer.

16-20 per absorber
Typical Dual Fluid Nozzle
(16-20 Per Spray Dryer)
SO₂ Absorption Continues in Baghouse

Baghouse contributes 10 to 20% of the total SO₂ removal – design SDA and FF as a system

"Clean Gas"
Dry FGD

Subsystems

- Reagent Handling and Preparation
- Absorber System
- Baghouse System
- Waste Recycle and Storage System
- Flue Gas System
Reagent Handling and Preparation
Reagent Handling and Preparation System

Lime Handling and Storage

Pneumatic Conveying to long term silos
30 days capacity factor storage
Pneumatic conveying to Preparation system

Lime Slurry Preparation system

24 hours day bin
2 x 100% slakers
20% slurry
8-16 hours slurry storage
slurry piping (loop to absorbers)
Lime Handling and Storage
Lime Unloading System
Lime Slaking/Hydration Process:

- Exothermic Hydration Process
- Operating Temperature
- Quality of Lime
  - MgO, CaCO$_3$, “Grits”
- Quality of Water ($SO_4^{2-}$, $SO_3^{2-}$)

CaO + H$_2$O $\rightarrow$ Ca(OH)$_2$
Ball Mill Slakers

- Conventional Ball Mill Slaker
- Rotating cylinder
- Steel balls create the grinding action
- Ball mills grind the grit
Ball Mill Slaker
VertiMill Slakers

- Steel balls create the grinding action
- Finer Particle Size
- Less Power Than a Ball Mill Slaker
Vertimill Slaker
Detention Slakers

- Violent Agitation – No steel balls
- Opposed Pumping Turbines
- Particle to Particle Contact = Attrition
- Grit is removed by screens that follow the slakers. Also included in recycle trains
Detention Slakers Require Grit Removal
CDS Systems Use Hydrators Instead of Slakers

- Same chemical reaction in a hydrator as a slaker
  - $\text{CaO} + \text{H}_2\text{O} \rightarrow \text{Ca(OH)}_2$
- 500 Btu’s of heat released per pound of lime slaked
  (278 kcal/kg)
- Only enough water used to hydrate the lime
- More difficult to operate than a slaker
Absorber System

- Minimum 10 Second Residence time
- Carbon Steel
- Atomizers
- Slurry mix tank
Spray Dryer

- Spray Dryer introduces a lime slurry into the hot flue gas by means of an atomizer
  - For utility sized systems atomizers are either rotary atomizers, or dual-fluid nozzles
  - With a Rotary Atomizer the slurry is fed into a disc rotating at a high rate of speed (~10,000 RPM).
  - With a Dual-fluid Nozzle compressed air mixes with the slurry at the nozzle tip
- Droplets are dispersed into the flue gas stream, reacts with the SO₂, and are dried into fine powder
Hot flue gases are often split to aid in drying the slurry

Spray dryers are generally limited to low to medium sulfur fuels by the amount of water in slurry

Exit temperatures must stay above the adiabatic saturation temperature to ensure complete drying of droplets

Temperature above saturation defined as “Approach to Saturation”
Rotary Atomizer

• Rotary Atomizer shows dispersion of slurry from disk
• Atomizers are supplied with quick disconnects – as they are changed while the Unit is on-line
  – B&W design uses one atomizer in an SDA vessel
  – Alstom design use several atomizers in a single vessel
Dual Fluid Atomizer

• Dual Fluid Atomizer shows dispersion of slurry from nozzle
• Atomizers are supplied with quick disconnects to permit on-line maintenance
• Siemens design uses 15 – 20 dual fluid nozzles in a single vessel
Dual Fluid Atomizer

16-20 per absorber
FABRIC FILTERS

Principles of Operation

- Particulate Laden Gas Passes Through A Woven Or Felted Fabric
- Forces Of Impaction, Interception, And Diffusion Separate The Particles From The Gas Stream
- As The Process Proceeds Particles Will Impinge Upon Previously Collected Particles
- The Built Up Deposit May Itself Become The Collection Medium
- Dust Is Removed From The Media
- With an SDA or CDS System the Fabric Filter Can Account for Up to 20% of the SO$_2$ removed
Waste Recycle System
Waste Recycle System

To increase lime utilization
Recycle ash day bin (8 hours)
Distance between recycle slurry tanks and atomizers should be kept short
Current trend is to minimize retention time in recycle tanks

Waste Storage Silo
Size based on amount of waste to disposal
Waste Storage Silo
Waste Recycle System

To increase lime utilization

4-8 hours storage silo
slurry mix tank
2 x 4 hours slurry storage tank
Deposits in the bottom of tank
>35% solid
3-4 day waste storage
Flue Gas System

Inlet/outlet ductwork
- Carbon Steel
- Keep Distance short between Absorber Outlet and Baghouse Inlet
- Minimize turns and direction changes

Chimney
- Top 20’ wall papered with stainless steel (acid resistant coating is the lower cost option) requiring more maintenance
  - Typically low load velocities/possibility of cold air infiltration
Circulating Dry Scrubbers (CDS) or Circulating Fluidized Bed (CFB)
Circulating Dry Scrubber System

The separate addition of water allows the CDS system to operate on somewhat higher sulfur fuels than the spray dryer technology.

CDS system is simpler in components and concept than the Spray Dryer.

Both technologies recycle large amounts of solids to help control lime consumption.

High efficiencies similar to a wet FGD are possible.

Low levels of emissions have been guaranteed in the past.

Lowest guaranteed emission - 0.040 lb/ mmBtu
Circulating Dry Scrubber

Very High Recirculation of Baghouse Solids Results in High Utilization of Lime

Internal Solids Recirculation Enhances Reactions

- lime
- active carbon
- water
- raw gas
- recirculation
- residues
- clean gas
Circulating Dry Scrubber System

The absorber is a fluidized bed of solids suspended by flue gas.

At low loads clean gas is recirculated to maintain solids suspension.

As opposed to the spray tower design CDS adds dry hydrate to the absorber.

Water is sprayed in separately in the fluidized bed to aid in collection.
Dry FGD Technology Suppliers

Semi-dry FGD

Alstom
Babcock & Wilcox
Siemens Environmental

Circulating Dry Scrubber

Alstom
Babcock & Wilcox
Foster Wheeler (Graff Wulff)
Allied Technology
Babcock Power
Hitachi
Marsulex
DSI Technology Suppliers

ADA-ES
Babcock & Wilcox
Clyde Bergemann
F L Smidth
FuelTech
Nalco-Mobotec
Nol-Tech
Schick
UCC
SO$_2$ Control – DSI

When Compared to other FGD Technologies

- Lower Capital Costs
- Higher Operating Costs for Reagent
- Smaller Footprint
- Ease of Installation (Installed in Existing Ducts)
- Only Moderate SO$_2$ Reduction (50% to 80% SO$_2$ Removal)
**SO₂ Control – DSI**

**Calcium vs. Sodium**

<table>
<thead>
<tr>
<th>Calcium</th>
<th>Sodium</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Limestone or Lime)</td>
<td>(Trona or Sodium Bicarbonate (SBC))</td>
</tr>
<tr>
<td><strong>1800°F to 2200°F Optimum for Furnace Injection</strong></td>
<td><strong>600°F to 800°F Optimum for Trona</strong></td>
</tr>
<tr>
<td></td>
<td><strong>250°F to 350°F Optimum for SBC</strong></td>
</tr>
<tr>
<td>Lime Could also be Injected After Economizer</td>
<td>Dry Injection</td>
</tr>
<tr>
<td>Some Reduced ESP Performance</td>
<td>Improved ESP Performance</td>
</tr>
<tr>
<td>Limited to ~50% SO₂ Removal</td>
<td>Up to ~80% Removal</td>
</tr>
</tbody>
</table>
SO₂ Control – DSI

Trona

SBC

Example NSR at 60% Removal (Refer to Graphs Above)

<table>
<thead>
<tr>
<th>Sorbent</th>
<th>Trona</th>
<th>SBC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capture Device</td>
<td>ESP</td>
<td>ESP</td>
</tr>
<tr>
<td>NSR</td>
<td>2.6</td>
<td>1.2</td>
</tr>
<tr>
<td>Sorbent Increase by wt.</td>
<td>3.1</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Source: Solvay Chemicals
Questions?