Circulating Dry Scrubbers (CDS)

Webinar Presentation
2012 Mid-Atlantic Regional Air Management Association
SO₂/HCl Control Technology
July 19, 2012

ONE SOURCE • ONE PURPOSE • MANY SOLUTIONS

Babcock Power

www.BabcockPower.com
Agenda

A. U.S. EPA Standards & Rules
B. Circulating Dry Scrubbers
   - Technology
   - Experience
   - Performance
C. Summary
Agenda

A. U.S. EPA Standards & Rules

B. Circulating Dry scrubbers
   -Technology
   -Experience
   -Performance

C. Summary
U.S. EPA Standard & Rules

1970 Clean Air Act
- Cross State Air Pollution Rule (CSAPR)
- Mercury and Air Toxic Standards (MATS)
- New Source Review Program
Cross State Air Pollution Rules

- $\text{SO}_2$ contributes to PM2.5, NOx contributes to Ozone
- 27 upwind states must meet state by state allocations
- EPA has developed database of power stations and required reductions of $\text{SO}_2$ and NOx
# Mercury & Air Toxic Standards

<table>
<thead>
<tr>
<th>EGU Subcategory</th>
<th>Filterable Particulate Matter</th>
<th>Hydrogen Chloride</th>
<th>Mercury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing coal firing not low rank virgin coal*</td>
<td>0.030 lb/E06 Btu (0.30 lb/MWh)</td>
<td>0.0020 lb/E06 Btu (0.020 lb/MWh)</td>
<td>1.2 lb/E12 Btu (0.013 lb/GWh)</td>
</tr>
<tr>
<td>New coal firing not low rank virgin coal*</td>
<td>0.007 lb/MWh</td>
<td>0.40 lb/GWh</td>
<td>0.0002 lb/GWh</td>
</tr>
</tbody>
</table>

* >8300 Btu/lb Moist and mineral matter free

\[
1 \text{ lb/E06 Btu} = \frac{1 \text{ lb}}{1,000,000 \text{ Btu}} = \frac{1}{10,000} \text{ lb/kWh} = \frac{1}{1,000} \text{ lb/MWh} = 0.01 \text{ lb/MWh}
\]

\[
1 \text{ lb/E12 Btu} = \frac{1 \text{ lb}}{1 \times 10^{12} \text{ Btu}} = \frac{1}{10,000} \text{ lb/kWh} = 10 \text{ lb/MWh}
\]
New Source Review Program

- $\text{SO}_2$, NOx, CO, Particulate, HAPS, Green House Gases
- Best Available Control Technology
- PM, PM2.5, PM10, Condensable PM
  - Condensables measured using Method 202 mostly affecting PM2.5
  - Proposed revision: Condensables not included in PM, but in PM2.5 & PM10.
Agenda

A. U.S. EPA Standards & Rules

B. Circulating Dry Scrubbers
   - Technology
   - Experience
   - Performance

C. Summary
Emissions Summary

SO₂  95 – 98 %
SO₃  95 – 99 %
HCl  95 – 99 %
HF   95 – 99 %
Mercury  90 – 95 %

Reduces Condensables

Coals up to 6 lbs of SO₂/E06Btu
SO₂ down to 0.03 lb/E06Btu
CHEMISTRY

\[ SO_2 + Ca(OH)_2 \rightarrow CaSO_3 + H_2O \]
\[ SO_2 + \frac{1}{2}O_2 + Ca(OH)_2 \rightarrow CaSO_4 + H_2O \]
\[ SO_3 + Ca(OH)_2 \rightarrow CaSO_4 + H_2O \]
\[ 2HCl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O \]
\[ 2HF + Ca(OH)_2 \rightarrow CaF_2 + 2H_2O \]
Process

Circulating Dry Scrubbers

Diagram showing the process of reagent preparation, flue gas cleaning, and byproduct handling. The diagram includes steps such as hydrated lime silo, reactor, fabric filter, air slide, stack, and byproduct silo.
Circulating Dry Scrubbers

Process Control

PRODUCT DISCHARGE / AIR SLIDE LEVEL CONTROL LOOP

CONTROL PARAMETERS:
- Direct control of air slide air pressure
- Level alarms to ensure proper operation
- Discharge rate maintains product level within air slide
Internal Solids Recirculation Enhances Reactions

Flue Gas and Solids Path Diagram

- Turbulent Reactor Mixing
- No Slurry Handling
- High Solids Recirculation
Circulating Dry Scrubbers

Reactivation of Reacted Sorbent

Formation of reaction products layer

1. Reaction after first pass
   - $\text{CaSO}_3 \frac{1}{2} \text{H}_2\text{O}$
   - $\text{Ca(OH)}_2$

2. Water added to surface during recirculation
   - $\text{CaSO}_3 \frac{1}{2} \text{H}_2\text{O}$
   - $\text{H}_2\text{O}$
   - $\text{Ca(OH)}_2$

3. Sulfite crystal forms, exposing fresh surfaces
   - $\text{CaSO}_3 \frac{1}{2} \text{H}_2\text{O}$
   - $\text{H}_2\text{O}$
   - $\text{Ca(OH)}_2$
Features

- Turbulent Mixing in Reactor
  - High flue gas solid contact
  - Internal reactor solid recirculation
  - No flue gas sneakage
  - High apparent reactor stoichiometry

- High Solids Circulation
  - Reactor solids rewetting
  - Secondary Removals with Fabric Filter
Features (continued)

- Water Injected Separately
  - No slurries
  - No limit on hydrated lime injection rate
  - No waste water

- Construction
  - Mild Steel
  - Modular
  - Dry Stack
Agenda

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C. Summary
Suppliers

- Graf-Wulff
- Allied Environmental
- Alstom Novel Integrated Desulfurization
- Babcock Power Environmental
  - Turbosorp® Circulating Dry Scrubber
  - Licensee to Austrian Energy & Environment For North American Coal-Fired Applications

Buecker B., Hovey, L. Circulating Dry Scrubbers: A New Wave in FGD?, Power Engineering, November 2011.
World Wide Experience

- Systems have been operating since 1994
- 60 CDS systems in Europe
  - 34 units on coal
- 14 CDS projects in China
- 24 CDS projects in the U.S.
- Five Turbosorp® CDS Coal-fired Systems Operating in the U.S.
### AES Greenidge Turbosorp®
Dresden, NY

#### Design Data

<table>
<thead>
<tr>
<th>Category</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler</td>
<td>115 MW</td>
</tr>
<tr>
<td>Fuel</td>
<td>Bituminous Coal</td>
</tr>
<tr>
<td>S-Content in Coal</td>
<td>2.9%</td>
</tr>
<tr>
<td>By-Product</td>
<td>Stabilized Product</td>
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<tr>
<td>Volume Flow</td>
<td>277,800 SCFM</td>
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<tr>
<td>SO₂ Inlet</td>
<td>2,100 ppmv</td>
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<tr>
<td>SO₂ Removal</td>
<td>&gt; 95 %</td>
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<tr>
<td>Startup</td>
<td>2006</td>
</tr>
</tbody>
</table>

![Diagram of AES Greenidge Turbosorp® facility](image)
Roquette Turbosorp®
Keokuk, Iowa

Design Data

Boiler: 80 MW CFB boiler
Fuel: Coal+ pet coke
Flue gas capacity: 210,000 SCFM
SO₂ concentration: 400 ppmv
SO₂ Removal: > 90%
Sorbent: Carryover from CFB boiler
Start-up: 2007
AES Westover Turbosorp®
Johnson City, NY

Design Data

- Boiler: 90 MW
- Fuel: Bituminous coal
- S-Content in coal: 2.2%
- By-product: Stabilized product
- Volume flow: 258,300 SCFM
- SO$_2$ inlet: 650 ppmv dry @ 6%O$_2$
- SO$_2$ removal: > 95%
- Startup: 2008
### First Light – Mount Tom Turbosorp®
Holyoke, MA

#### Design Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Boiler</td>
<td>155 MW</td>
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<tr>
<td>Fuel</td>
<td>Bituminous Coal</td>
</tr>
<tr>
<td>S-Content in Coal</td>
<td>1.5 %</td>
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<tr>
<td>By-Product</td>
<td>Stabilized Product</td>
</tr>
<tr>
<td>Volume Flow</td>
<td>452,950 SCFM</td>
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<tr>
<td>SO$_2$ Inlet</td>
<td>1,300 ppmv</td>
</tr>
<tr>
<td>SO$_2$ Removal</td>
<td>&gt; 95 %</td>
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<tr>
<td>Startup</td>
<td>2009</td>
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</tbody>
</table>
### Gainesville Regional Utilities
#### Deerhaven Turbosorp®
**Gainesville, FL**

#### Design Data

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Details</th>
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<tr>
<td>Boiler</td>
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<tr>
<td>Fuel</td>
<td>Bituminous Coal</td>
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<tr>
<td>S-Content in Coal</td>
<td>1.5 %</td>
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<tr>
<td>By-Product</td>
<td>Stabilized Product</td>
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<tr>
<td>Volume Flow</td>
<td>584,600 SCFM</td>
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<tr>
<td>SO$_2$ Inlet</td>
<td>1,450 ppmv</td>
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<tr>
<td>SO$_2$ Removal</td>
<td>&gt; 95 %</td>
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<tr>
<td>Startup</td>
<td>2009</td>
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Turbosorp® SO₂ Removal Compared to EPA MATS

Ake, T. et. al. Measured Particulate, HCl, and Hg Emissions from Circulating Dry Scrubbers Compared to the EPA Mercury Air Toxic Standards, To be presented at AWMA MegaSymposium, Baltimore MD, August 2012.
Turbosorp® SO₂ Emissions Compared to EPA MATS

![Graph showing SO₂ emissions comparison]

- **Inlet SO₂ (lb/E06 Btu)**
- **Stack SO₂ (lb/MWh)**

**Existing-EGU EPA MATS Limit**

**New-EGU EPA MATS Limit**

**U.S. DOE CDS Parametric Tests** *

>95% SO₂ Removal

Turbosorp® Acid Gas Removal Compared to EPA MATS

- Average SO$_2$ Removal = 96%
- Outlet measurements below detection
- Both Inlet & Outlet measurements below detection

- Existing EGU
- New EGU
- EPA MATS
- HCl
- SO$_3$
Turbosorp® HCl Emissions Compared to EPA MATS

Inlet HCl (lb/E06 Btu) vs. Stack HCl (lb/MWh)

- New-EGU EPA MATS Limit
- Existing-EGU EPA MATS Limit
- Stack HCl measurements below detection

U.S. DOE CDS Parametric Tests*
SO₂ Removal > 95%

CDS Performance

Turbosorp® PM Emission Data Compared to EPA MATS

![Bar chart showing PM emission data for existing and new EGU compared to EPA MATS standards.](chart)

- **Total PM**: Includes condensables
- **Filterable PM Limit**

<table>
<thead>
<tr>
<th>Power Station Number</th>
<th>Existing EGU</th>
<th>New EGU</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Includes condensables*
CDS Performance

Filterable Particulate Emission Data

Figure from U.S.DOE Report*

Average stack emission value shown for 59 particulate measurements for a Turbosorp® CDS.


Note logarithmic scale. One standard deviation error bar = 0.00011 lb/E06 Btu is shown.
Hg Removal Data

Average SO\textsubscript{2} Removal = 96%

- Existing EGU
- New EGU (EPA MATS)
- Performance Tests
- U.S. DOE Parametric Tests

Outlet measurements below detection limit w/ Activated Carbon (others w/o)
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C. Summary
Turbosorp® CDS removes:

- $SO_2$
- $HCl$
- $SO_3$ & $HF$
- $Hg$

Filterable Particulate
Condensable Particulate

→ No waste-water

U.S. EPA Programs:

- CSAPR
- MATS
- NSR
Boiler Tube Company of America