Wet FGD System Overview and Operation

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WPCA Wet FGD Seminar
Power Gen International
December 1, 2008
Agenda

• Introduction

• Major Process Equipment

• Balance of Plant Equipment

• Controls

• Summary
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- Major Process Equipment
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- Summary
Absorber Island
Absorber Designs

Open Spray Tower

Fountain Tower

Tray Tower

Jet Bubbling Reactor

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Absorber Unit Operations

Unit Operations

- Inlet – gas distribution, humidification
- Spray zone – gas/liquid contact
- Mist eliminator zone – liquid/gas separation
- Reaction tank – oxidation, dissolution, crystallization

Design Goals

- Lowest lifecycle cost
  - Capital
  - O&M
- High reliability
Absorber Inlet

- Highly corrosive environment
  - $\text{SO}_3$ condensation
  - Deposits/splash-back
- Design/construction
  - Solid 3/16” thick C-276
  - 10° slope toward absorber
  - Extends 10-15 ft. from shell
  - Internal overhead deflector and side shields
  - Test ports and emergency quench nozzles
  - Gas velocity – 3,000-3,600 ft/min
Absorber Shell

Flared-Side

Straight-Side
Contact Zone

- Multiple spray levels with dedicated pumps allows efficient turndown
- Gas velocity – 13-14 ft/sec

- Spray flow
  - Typical afternoon thunderstorm – 1-2 in/hr
  - Spray tower – 10 ft/min
Contact Zone

- Design Approach
  - Intimate gas/liquid contact
  - No gas sneakage
- Multiple spray stages depending on SO₂ inlet and removal efficiency
- Overall spray coverage (>200% at 3-feet) and nozzle distribution to provide even distribution and prevent gas sneakage.
- Wall rings to prevent gas sneakage near side walls.
- Pressure drop vs. pumping power trade-off
Spray Nozzles

- Multiple counter-current spray stages
- Nozzle type
  - Top stage—single orifice hollow cone
  - Lower stages—dual orifice hollow cone
- Sauter mean droplet diameter of ~2,000 micron at 8 psig
- Silicon carbide construction
Mist Eliminator

- Two stages of vertical-flow chevron vanes
- Construction
  - Polypropylene
  - Polysulfone
  - FRP
  - Alloy/stainless steel
Mist Eliminator Operation

Gas Flow

Carryover

Gas Velocity (ft/sec)

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Mist Eliminator Wash System

- Fresh water wash on intermittent basis
  - First stage washed from below (1.5 gpm/ft\(^2\)) and above (0.75 gpm/ft\(^2\))
  - Second stage washed from below (0.75 gpm/ft\(^2\))

- Construction
  - Piping – FRP, polypropylene, alloy/SS
  - Nozzles – polypropylene, alloy/SS
Absorber Recycle Pumps

- Typical size: 50,000-75,000 gpm at 55-85 TDH
- Pump Efficiency: 87-90+%  
- 1,000-2,500 hp
- Horizontal, centrifugal
- Rubber lined casing
- Impeller
  - Hard metal
  - Rubber-covered
Reaction Tank

- Integral to absorber
- Functions
  - Limestone dissolution
  - Oxidation
  - Gypsum crystallization
- Design considerations
  - Solids and liquid residence time
  - Foaming/freeboard
- Side entry agitators with air lances
Materials of Construction

Shell
- Rubber-lined carbon steel
- Flakeglass-lined carbon steel
- Stainless steel (317LMN)
- Duplex stainless steel (2205, 255)
- Nickel-based alloy
- Roll-clad alloy
- Lined concrete (tile, polypropylene)

External Spray Piping
- FRP
- Rubber-lined carbon steel
- SS/alloy

Mist Eliminators
- FRP
- Polypropylene
- Polysulfone
- SS/alloy

Headers
- Rubber-lined carbon steel
- FRP
- Stainless steel (317LMN)
- Duplex stainless steel (2205, 255)
- Nickel-based alloy

Inlet
- C-276
Limestone Grinding System

- REAGENT SILO
- CLASSIFIER
- BALL MILL
- BALL MILL RECYCLE TANK
- REAGENT FEED TANK
- TO ABSORBER
- FROM MW TANK
Limestone Preparation

- Limestone grinding
  - Horizontal/vertical wet ball mills
  - On-site vs. off-site preparation
- Product ground to 90-95% < 44 μ; 30% solids
- Rubber-lined with hardened steel balls
Pre-Ground Limestone Injection

• Dry, pre-ground limestone feed options
  − Pneumatic injection into reaction tank below slurry level
  − Pre-slurry in small tank

• Advantages
  − Low capital cost (i.e. no ball mills, auxiliary equipment, buildings, etc.)
  − Less equipment to maintain

• Disadvantages
  − Higher delivered cost

• Lifecycle cost evaluation on case-by-case basis
Dewatering Island
Primary Dewatering

- Initial solid/liquid separation step
  - Feed: 15-20% TSS
  - Underflow: 50-55% TSS
  - Overflow: 3-5% TSS

- Overflow enriched with CaCO₃ due to particle size difference; improved reagent utilization

- Steel casing with rubber, urethane, and ceramic internals
Secondary Dewatering

- Horizontal belt filter
  - 8-10% moisture in gypsum
  - Optimal for cake washing

- Rotary drum filter
  - 10-15% moisture
  - Smaller footprint

- Other options
  - Gypsum stacking
  - Centrifuge
  - Thickener
Wallboard Gypsum

• Typical specification:
  - >95% $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$
  - <0.5–1.0% $\text{CaSO}_3 \cdot \frac{1}{2}\text{H}_2\text{O}$
  - <100 ppm Cl
  - <10% moisture
  - pH 6–8
  - 30–40µ MMD

• Requires:
  - High purity limestone (95–96%)
  - High efficiency ESP/FF
  - 99+% oxidation
  - Belt filter
  - Cake washing
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Limestone Delivery/Storage

- Truck, rail, or barge delivery
- $\frac{3}{4}$" x 0" (20 x 0 mm) crushed limestone
- Outdoor long-term storage feasible in most areas
- Indoor/covered storage in harsh/wet climates
Limestone Silo

- Provide buffer between limestone pile and ball mill operation
- 16-24 hr capacity
- Carbon steel construction with polymer or stainless steel hopper lining
- Vibrating bottom/mechanical activation
- Vent filter for fugitive dust control
Gypsum Storage/Handling

- Covered storage options
  - Direct discharge to bunker/manual reclaim
  - Convey to dome/manual reclaim
  - Convey to building or silo/automated reclaim

- Open pile
  - Feasible
  - Possible issues: moisture, fugitive dust, leaching

- Selection depends on:
  - On-site storage requirement
  - Gypsum contract
Fan Arrangement – Retrofit

STACK

ELECTROSTATIC PRECIPITATOR

ID FAN
Fan Arrangement – Retrofit

STACK

ABSORBER

ELECTROSTATIC PRECIPITATOR

ID FAN

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Fan Arrangement – Retrofit

ELECTROSTATIC PRECIPITATOR

STACK

ABSORBER

ID FAN

BOOSTER FAN

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• Purge stream required to control chlorides/inert solid for wallboard gypsum

• Purge stream treatment strategy is site-specific; depends on:
  − Discharge limits
  − Receiving body
  − FGD process design
  − Fuel, limestone, make-up water

• Treatment options:
  − Direct discharge
  − Volume reduction (evaporation, …)
  − Physical/chemical treatment
    • Suspended solids
    • pH adjustment
    • Heavy metals removal
    • COD removal
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WFGD Controls

- Distributed Control Systems
  - Overview
  - Redundancy
- Primary WFGD Control Loops & Instrumentation
  - Absorber Area
  - Flue Gas System
WFGD Control Systems

- Distributed Control Systems (DCS)
  - Control and automation of WFGD processes and components
  - Interface with remaining power plant controls
  - Monitor key process parameters
  - Process trends, reports, historical data logging

- Local Control Panels (LCP)

- Programmable Logic Controllers (PLC)

- Main FGD Control Area
  - Dedicated WFGD Control Station
  - Centralized WFGD Control with Boiler/Power Plant
Major Control Loops - Absorber

- Reagent Feed
- pH
- Make-Up Water
- Solids / Gypsum Bleed
**pH / Reagent Feed Control**

- **Scrubbing Liquor pH**
  - Most important process variable to be controlled in WFGD $\rightarrow$ continuous, in-line monitoring, daily lab verification
  - Indication of the amount of CaCO$_3$ in scrubbing solution
  - Scrubbing liquor below desired range $\rightarrow$ lower SO$_2$ removal efficiency
  - Scrubber liquor above desired range $\rightarrow$ higher SO$_2$ removal efficiency, excess CaCO$_3$ and reduced gypsum byproduct purity

![Scrubbing Liquor pH Diagram]

5.3 – 5.8
Scrubbing Liquor pH

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pH / Reagent Feed Control
**Gypsum Bleed / Solids Control**

- **Scrubber Slurry Solids**
  - Important WFGD process variable, verified daily with laboratory samples
  - Scrubber slurry solids: gypsum, limestone, flyash, inerts
  - Numerous inputs affecting water balance and solids concentration
  - Control solids concentration within narrow range: 14-16 wt.%

- **Solids Control**
  - Solids too low: potential for gypsum scaling
  - Solids too high: increased potential for wear of equipment
  - Equipment sizing
Gypsum Solids / Density Control

Primary Dewatering Hydroclones

Return to Absorber

Secondary Dewatering

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Density Measurement

- **Nuclear Density Meters**
  - Source emits gamma radiation through process
  - Detector measures energy of radiation
  - Capable of detecting process variations within desired narrow range
  - Safe
  - Accurate
  - Simple calibration
  - Verify with laboratory analyses

Nuclear Density Meter
Density Instrumentation

PROCESS SLURRY

DENSITY METER

LOCAL DISPLAY PANEL
Level / Make-Up Water Control

Deaerator

Level Controller

Make-up water

Reaction Tank

Absorber

OX AIR

f(x)

f(x)

DENSITY

DE

DY

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Booster Fan Control

- **EXISTING STACK**
  - ID FANS
  - STACK REVERSE FLOW

- **NEW STACK**
  - ID Fan Load, Boiler MW

- **DUCT PRESSURE**
- **VANE PITCH CONTROL**
- **SPRAY TOWER ABSORBER**
- **BOOSTER FANS**

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O&M staffing varies; depends on:
- Owner staffing philosophy/practices
- Plant layout/design
- Reagent/byproduct
- Labor bargaining agreements
- Other equipment at plant
<table>
<thead>
<tr>
<th>Position Description</th>
<th>No.</th>
<th>Coverage</th>
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<tbody>
<tr>
<td>FGD Supervisor</td>
<td>1</td>
<td>1 shift, 5 days/week</td>
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<tr>
<td>FGD Operator</td>
<td>1</td>
<td>3 shifts, 7 days/week</td>
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<tr>
<td>FGD Mechanic</td>
<td>1</td>
<td>1 shift, 5 days/week</td>
</tr>
<tr>
<td>FGD Computer Tech</td>
<td>1</td>
<td>1 shift, 5 days/week</td>
</tr>
<tr>
<td>FGD Specialist</td>
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<td>1 shift, 5 days/week</td>
</tr>
<tr>
<td>FGD Material Handling</td>
<td>1</td>
<td>3 shifts, 7 days/week</td>
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## Lifecycle Cost Comparison

<table>
<thead>
<tr>
<th></th>
<th>High Sulfur</th>
<th>Low Sulfur</th>
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<tbody>
<tr>
<td>Total Plant Capital Cost</td>
<td>$150,000,000</td>
<td>$120,000,000</td>
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<tr>
<td></td>
<td>$/kW</td>
<td>250</td>
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<tr>
<td>Plant Capacity (per unit)</td>
<td>MWe</td>
<td>600</td>
</tr>
<tr>
<td>No. Units</td>
<td>1</td>
<td>1</td>
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<tr>
<td>Plant Capacity Factor</td>
<td>%</td>
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<tr>
<td>Equivalent Full-Load Hour</td>
<td>hr</td>
<td>7,446</td>
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<tr>
<td>Escalation Rate</td>
<td>%</td>
<td>3.0</td>
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<tr>
<td>NPV Discount Rate</td>
<td>%</td>
<td>10.0</td>
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<tr>
<td>SO2 Removal</td>
<td>%</td>
<td>98</td>
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<tr>
<td>SO2 Production Rate</td>
<td>lb/hr</td>
<td>45,000</td>
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<tr>
<td></td>
<td>lb/MM MBtu</td>
<td>7.50</td>
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<tr>
<td>ID Fan Flue Gas Flow</td>
<td>acfm</td>
<td>2,100,000</td>
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<thead>
<tr>
<th></th>
<th>High Sulfur</th>
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</tr>
</thead>
<tbody>
<tr>
<td>No. O&amp;M Personnel/Shift</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>O&amp;M Labor Rate /hr</td>
<td>50.00</td>
<td>50.00</td>
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<tr>
<td>AQCS Power kW</td>
<td>9,000</td>
<td>4,500</td>
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<tr>
<td>Fan Power Consumption kW</td>
<td>2,464</td>
<td>1,628</td>
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<tr>
<td>Total Power kW</td>
<td>11,464</td>
<td>6,128</td>
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<tr>
<td>Power Cost $/kw -hr</td>
<td>0.03</td>
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<tr>
<td>Lime stone Consumption lb/hr</td>
<td>74,709</td>
<td>19,922</td>
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<tr>
<td>Lime stone Cost $/ton</td>
<td>20.00</td>
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<tr>
<td>Gypsum Production lb/hr</td>
<td>138,618</td>
<td>36,965</td>
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<tr>
<td>Gypsum Price $/ton</td>
<td>(5.00)</td>
<td>(5.00)</td>
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<tr>
<td>Repair/Maintenance % of TPC</td>
<td>1.5</td>
<td>1.5</td>
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</table>
## Lifecycle Cost Comparison

<table>
<thead>
<tr>
<th>Technology</th>
<th>High Sulfur</th>
<th>Low Sulfur</th>
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</thead>
<tbody>
<tr>
<td>O &amp; M Labor</td>
<td>$2,190,000</td>
<td>$2,190,000</td>
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<tr>
<td>Auxiliary Power</td>
<td>$2,560,776</td>
<td>$1,368,838</td>
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<tr>
<td>Lime stone</td>
<td>$5,562,823</td>
<td>$1,483,420</td>
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<tr>
<td>W W TS Reagents</td>
<td>$1,500,000</td>
<td>$500,000</td>
</tr>
<tr>
<td>Gypsum</td>
<td>($2,580,382)</td>
<td>($688,102)</td>
</tr>
<tr>
<td>Repair/Maintenance</td>
<td>$2,250,000</td>
<td>$1,800,000</td>
</tr>
<tr>
<td>Total</td>
<td>$11,483,218</td>
<td>$6,654,156</td>
</tr>
<tr>
<td>$/MW-hr</td>
<td>2.57</td>
<td>1.49</td>
</tr>
</tbody>
</table>

**Total Plant Capital Cost**

|                | $150,000,000 | $120,000,000 |

**O & M Cost (25-Yr NPV)**

|                | $138,240,000 | $69,540,000  |

**Lifecycle Cost**

|                | $288,240,000 | $189,540,000 |
Summary

- WFGD system design is mature; operation is routine
- Major process islands
  - Absorber
  - Reagent
  - Dewatering
- Key balance of plant equipment
  - Flue gas handling
  - Material handling
  - Wastewater treatment
  - Electrical system
Questions?