ESP and Fabric Filter Considerations for Meeting Environmental Regulations: IED, LCP and WI BREF

Theme: 8 - Combustion and Steam Plant Technology
Session: 7 - Reducing Emissions in Flue Gases

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## Introduction

### Current & Pending Environmental Regulations

<table>
<thead>
<tr>
<th>Major Regulation</th>
<th>PM Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial Emissions Directive (IED)</td>
<td>10 – 20 mg/Nm³ (dry, 6% O₂)</td>
</tr>
<tr>
<td>BAT (Best Available Techniques) Reference Document (BREF) for Large Combustion Plants (LCP)¹</td>
<td>2 – 16 mg/Nm³ (dry, 6% O₂)</td>
</tr>
<tr>
<td>BAT (Best Available Techniques) Reference Document (BREF) for Waste Incineration (WI)¹</td>
<td>1 – 20 mg/Nm³ (dry, 11% O₂)</td>
</tr>
</tbody>
</table>

1. Preliminary draft

#### Options for Compliance:

- Upgrade existing equipment
- Install new equipment
- Combination of technologies
Particulate matter (PM) control is central to any multi-component AQCS:

PM control technology selection will affect the approach to mercury and other acid gases. Co-benefits:
- Hg capture in particulate form
- Hg absorbed and collected with powdered activated carbon
- Acid gas control by collecting dry flue gas desulfurization (FGD) sorbents
Choosing the Best Combination of Technology
Cost & Schedule

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DSI &amp; ACI with Existing PM Control</strong></td>
<td>Low Capital Investment</td>
</tr>
<tr>
<td></td>
<td>Minimal Footprint Impact</td>
</tr>
<tr>
<td><strong>Add-On / Upgrade PM Control Device + DSI &amp; ACI</strong></td>
<td>Upgrade or Replace Aging ESP</td>
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<tr>
<td></td>
<td>Polishing FF Downstream of ESP</td>
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<tr>
<td></td>
<td>Improved PM Collection &amp; Sorbent Consumption</td>
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<tr>
<td><strong>Add-On / Dry FGD System</strong></td>
<td>Improved Acid Gas Control</td>
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<tr>
<td></td>
<td>Decreased Sorbent Consumption</td>
</tr>
<tr>
<td></td>
<td>Dry Disposal</td>
</tr>
<tr>
<td><strong>Add-On Wet FGD System</strong></td>
<td>Typically Multi-Product AQCS Train</td>
</tr>
<tr>
<td></td>
<td>High Acid Gas Control</td>
</tr>
<tr>
<td></td>
<td>Gypsum Byproduct</td>
</tr>
</tbody>
</table>

Increased Cost & Schedule
Electrostatic Precipitator (ESP) Design Considerations

► Advantages:
  ► Can operate at high temperature
  ► Better suited for sticky fly ash
  ► Low maintenance
  ► Low pressure drop

► Disadvantages:
  ► Sensitive to fly ash resistivity
  ► High power consumption
  ► Uneconomic below 10 mg/Nm³

Hammer Rapped Rigid Discharge Electrode (HaRDE) Dry ESP
Electrostatic Precipitator (ESP) Design Considerations

- Key Performance Considerations:
  - Specific collection area (SCA)
  - Flue gas velocity
  - ESP geometry / arrangement
  - Fly ash properties
  - Site-specific layout and construction constraints
- Equipment design
  - TR’s
  - Rapping
  - Electrodes

Variable Intensity Gravity Rapped (VIGR) Dry ESP
# Electrostatic Precipitator (ESP) Upgrade Options

<table>
<thead>
<tr>
<th>Minor Upgrades Requires Minor Outage</th>
<th>Major Upgrades Requires Major Outage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low-Ripple Power Supplies</td>
<td>Modernize Internals (Wide Plate Spacing, Wires to RDE’s)</td>
</tr>
<tr>
<td>Modernization of Control Scheme</td>
<td>Optimize Field Length / Additional Field</td>
</tr>
<tr>
<td>Increased Sectionalization</td>
<td>Increased Field Height</td>
</tr>
<tr>
<td>CFD Modeling / Flow Distribution</td>
<td>New ESP in Parallel / Series</td>
</tr>
<tr>
<td>Pre-Conditioning</td>
<td>New FF in Series or ESP-to-PJFF Conversion</td>
</tr>
</tbody>
</table>
Fabric Filter
Design Considerations

► Advantages:
  ► Low PM emissions
  ► Less dependent upon consistent operating parameters (wide fuel mix)
  ► Increased sorbent utilization
    ► Mercury (Hg)
    ► Acid gases (SO₂, HCl, HF, etc.)

► Disadvantages:
  ► Consumable filter bags
  ► High pressure drop
Fabric Filter Design Considerations

► Key Performance Considerations:
  ► Air-to-cloth ratio
  ► Filter bag material
  ► Pulse cleaning frequency
  ► Equipment design
    ► Pulse cleaning equipment (valves, headers, blow pipes)
    ► Gas flow distribution
    ► Controls

High Pressure Jet III Pulse Jet Fabric Filter (PJFF)
## Fabric Filter Upgrade Options

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<tr>
<th>Minor Upgrades Requires Minor Outage</th>
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<tbody>
<tr>
<td>Upgrade Filter Media</td>
<td>Change to Jet VIP Cleaning System to Reduce Cleaning Frequency</td>
</tr>
<tr>
<td>CFD Modeling / Flow Distribution</td>
<td>Increase Cloth Area (Increase Bag Length, Add Compartments, etc.)</td>
</tr>
<tr>
<td>Reduce Air In-Leakage</td>
<td>New Polishing FF in Series</td>
</tr>
</tbody>
</table>
Fabric Filter
Polishing FF Downstream of ESP

► High A/C Ratio:
  ▶ Lower costs than “full burden” FF

► Preserve ash sales from ESP

► Performance:
  ▶ Low PM emissions
  ▶ High utilization of ACI and DSI sorbents

► Special Considerations:
  ▶ Gas flow distribution
  ▶ Bag length

4 x 818 MW Coal-Fired Boilers – U.S.
Fabric Filter
ESP-to-PJFF Conversion

- Low-Cost Method to Realize Benefits of PJFF Technology

- Size and Condition of Existing Equipment Critical
  - ESP casing and hoppers
  - ID fan capacity

- Tie-In Outage:
  - Maximize ground assembly
  - Install in large pieces
Electrostatic Precipitator
Wet ESP

► Target pollutants:
  ► Sub-micron particulate
  ► Metals
  ► Condensed acids

► Final polishing device:
  ► Opacity reduction

► Retrofit potential:
  ► Small footprint
  ► Low pressure drop
  ► Minimal impact to water system

2 x 800 MW Coal-Fired Boiler – U.S.
## Case Study
### U.S. MATS Compliance

- City of Fremont, Nebraska
- Lon D. Wright Unit 8
- 90 MW (gross) PC boiler
- Powder River Basin (PRB) coal

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Emissions$^1$</th>
<th>MATS Limits$^1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO$_2$</td>
<td>1900 mg/Nm$^3$</td>
<td>300 mg/Nm$^3$</td>
</tr>
<tr>
<td>HCl</td>
<td>12.4 mg/Nm$^3$</td>
<td>3.1 mg/Nm$^3$</td>
</tr>
<tr>
<td>PM</td>
<td>250 mg/Nm$^3$</td>
<td>47 mg/Nm$^3$</td>
</tr>
<tr>
<td>Hg</td>
<td>16 $\mu$g/Nm$^3$</td>
<td>1.9 $\mu$g/Nm$^3$</td>
</tr>
</tbody>
</table>

$^1$ Values are approximate. MATS regulatory units are lb/MMBtu
Case Study
U.S. MATS Compliance

Existing:
- Boiler
- Hot-Side ESP
- Stack

Retrofit:
- Activated Carbon Injection (ACI)
- Spray Dryer Absorber (SDA)
- Pulse Jet Fabric Filter (PJFF)
Case Study
U.S. MATS Compliance

► Start-up: Nov. 2015

► Emissions are within all MATS limits

► PJFF cleaning system has cleaned at a rate of approximately 7 – 24 pulses / bag / day:
  ► Depending on operating conditions of the upstream ESP (on vs. off)
  ► Very low cleaning frequency
  ► Will help extend filter bag life
Summary

► ESP’s and fabric filters are both proven and reliable technologies.

► Each technology has advantages, disadvantages, and a wide range of design considerations.

► Recent MATS and Boiler MACT project experience and lessons learned in the U.S. will provide a roadmap for success.
  ► Low level PM
  ► Mercury (Hg)
Questions?

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