MERCURY EMISSIONS CONTROLS FOR CEMENT PRODUCTION

MARAMA/ICAC Control Technology Workshop
May 18-19, 2011
Baltimore, MD

Presented by:

Peter Paone
Manager of Pyroprocessing Technology
FLSmidth Inc.
Agenda

- Latest NESHAP limits
- Challenges faced in reducing Hg emissions
- Recent developments of control technology
  - Mercury roaster
  - Gas Suspension Absorber (GSA)
## Final NESHAP Rules – Normal Operation

National Emissions Standards for Hazardous Air Pollutants

<table>
<thead>
<tr>
<th></th>
<th>Existing Source</th>
<th>New Source (Started construction after 6 May 2009)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>55 lbs/million ST clinker</td>
<td>21 lbs/million ST clinker</td>
</tr>
<tr>
<td>THC (or Organic HAP*)</td>
<td>24 ppmvd @ 7% O$_2$ (9 ppmvd @ 7% O$_2$)</td>
<td>24 ppmvd @ 7% O$_2$ (9 ppmvd @ 7% O$_2$)</td>
</tr>
<tr>
<td>HCl</td>
<td>3 ppmvd @ 7% O$_2$</td>
<td>3 ppmvd @ 7% O$_2$</td>
</tr>
<tr>
<td>PM (Dust)</td>
<td>0.04 lbs/ST clinker</td>
<td>0.01 lbs/ST clinker</td>
</tr>
<tr>
<td>Effective Date</td>
<td>3 years from Enactment September 2013</td>
<td>Start-up or Enactment (Whichever is Later)</td>
</tr>
</tbody>
</table>

*Organic HAP includes formaldehyde, benzene, toluene, styrene, (m-, p-, o-) xylene, acetaldehyde, naphthalene
## Final NESHAP Rule – Start-up and Shutdown

**National Emissions Standards for Hazardous Air Pollutants**

<table>
<thead>
<tr>
<th></th>
<th>Existing Source</th>
<th>New Source (Started construction after 6 May 2009)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>10 µg/DSCM</td>
<td>4 µg/DSCM</td>
</tr>
<tr>
<td>THC (or Organic HAP*)</td>
<td>24 ppmdv (9 ppmdv)</td>
<td>24 ppmdv (9 ppmdv)</td>
</tr>
<tr>
<td>HCl</td>
<td>3 ppmdv</td>
<td>3 ppmdv</td>
</tr>
<tr>
<td>PM (Dust)</td>
<td>0.004 gr/DSCF ~10 mg/DNm³</td>
<td>0.0008 gr/DSCF ~2.0 mg/DNm³</td>
</tr>
<tr>
<td>Effective Date</td>
<td>3 years from Enactment September 2013</td>
<td>Start-up or Enactment (Whichever is Later)</td>
</tr>
</tbody>
</table>

*Organic HAP includes formaldehyde, benzene, toluene, styrene, (m-, p-, o-) xylene, acetaldehyde, naphthalene*
Kiln Emission Estimates

Source: Florida DEP Presentation

The information contained or referenced in this presentation is confidential and proprietary to FLSmidth and is protected by copyright or trade secret laws.

Kiln Number

Best 12% by EPA ranking

U.S. Kilns

Kiln Number

Pounds (lb) of Hg per million tons of clinker

10000

1000

100

10

43

Best 12%

One Source
Modern Preheater System

- Coal/Coke Mill
- Preheater with Calciner
- Raw Mill
- 2-Support Kiln
- Cross-bar Cooler
- Cooler Vent
- Cement Mill

The information contained or referenced in this presentation is confidential and proprietary to FLSmidth and is protected by copyright or trade secret laws.
Compound Operation
Direct Operation
Example Stack Mercury Emissions Profile
**Agenda**

- Latest NESHAP limits
- Challenges faced in reducing Hg emissions
- Recent developments of control technology
  - Mercury roaster
  - Gas Suspension Absorber (GSA)
R&D Goals for Mercury Control

- Research efforts by FLSmidth identified limitations of existing technology

- Mercury research group was tasked with finding “a better way”

- Goals of new concept:
  - High levels of mercury control
  - Lower installation costs than ACI or wet scrubbers
  - Lower operating costs than ACI or wet scrubbers
  - Smaller footprint for easier layout in existing facilities

- Result: 2 US Patents issued and 4 patents pending on mercury control technologies
FLSmidth Mercury Roaster
Pilot Testing

- Testing performed in FLSmidth laboratory proved concept
- Over 95% of mercury removed from baghouse dust
- Allows for up to 75% mercury emission reduction based on mercury cycle simulations
  - Reduction rate depends on mercury capture rate in the main filter
FLSmidth applied for a patent on the Mercury Roaster process in 2008

US Patent #7,794,524 issued September 2010

Additional patents pending related to the concept, including combinations of the Mercury Roaster with other technologies for enhanced Hg control
FLSmidth Mercury Roaster

- Advantages
  - Smaller footprint than wet scrubber or ACI
  - Lower cost than wet scrubber or ACI
  - Uses less water than wet scrubbing, less sorbent than ACI
  - Can be used in conjunction with other methods (ACI, semi-dry scrubbers) for enhanced Hg reduction and reduction in waste streams
  - Re-uses filter dust for additional mercury capture
  - Reduces the mercury cycle in the system
  - Can also be used for single components (e.g. flyash)
    - Implications for concrete as well as cement
Recent Mercury Roaster Developments

Kingston, TN Power Plant - Ash Slide in Dec 2008
-Recent discussion of developing Mercury Roaster for treating coal combustion residues
# Mercury Roaster Results with Flyash

<table>
<thead>
<tr>
<th>Sample</th>
<th>Hg (ppb) Before Roaster</th>
<th>Hg (ppb) After Roaster</th>
<th>% Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1</td>
<td>380</td>
<td>&lt;1</td>
<td>&gt;99.7%</td>
</tr>
<tr>
<td>Sample 2</td>
<td>260</td>
<td>8</td>
<td>96.9%</td>
</tr>
</tbody>
</table>
Agenda

- Latest NESHAP limits
- Challenges faced in reducing Hg emissions
- Recent developments of control technology
  - Mercury roaster
  - Gas Suspension Absorber (GSA)
Semi-Dry Scrubbing - Gas Suspension Absorber (GSA)
GSA – Gas Suspension Absorber

- Originally designed for HCl mitigation in WtE boilers and incinerators
- 50 Installations
- Dry or semi-dry
- Recirculation of sorbent reduces molar ratio

<table>
<thead>
<tr>
<th>Component</th>
<th>Guaranteed removal %</th>
<th>Achieved removal %</th>
</tr>
</thead>
<tbody>
<tr>
<td>SO₂</td>
<td>95.0</td>
<td>99.1</td>
</tr>
<tr>
<td>HCl</td>
<td>95.0</td>
<td>&gt;99.9</td>
</tr>
<tr>
<td>HF</td>
<td>95.0</td>
<td>&gt;99.9</td>
</tr>
<tr>
<td>Dust</td>
<td>99.6</td>
<td>99.8</td>
</tr>
</tbody>
</table>

Table 2: Removal efficiencies for the flue gas treatment plant at LKAB in Kiruna
Semi-dry Scrubber Location

Preheater string 2

Preheater string 1

Cond. Tower 1

GSA

ESP

Bag filter

To Raw Mill

To Coal Mills

To Stack

The information contained or referenced in this presentation is confidential and proprietary to FLSmidth and is protected by copyright or trade secret laws.
# Test Results – SO₂ + HCl

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet Gas Flow</td>
<td>153,775 Nm³/h wet</td>
</tr>
<tr>
<td>Inlet Gas Temp.</td>
<td>163 °C</td>
</tr>
<tr>
<td>Outlet Gas Temp.</td>
<td>88 °C</td>
</tr>
<tr>
<td>Outlet O₂</td>
<td>9% Vol. dry</td>
</tr>
<tr>
<td>Lime to SO₂ ratio</td>
<td>1.2</td>
</tr>
</tbody>
</table>
## Test Results – SO₂

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet SO₂</td>
<td>405 mg/Nm³ dry</td>
</tr>
<tr>
<td>Outlet SO₂</td>
<td>10.8 mg/Nm³ dry</td>
</tr>
<tr>
<td>Lime Usage</td>
<td>74 kg/hr</td>
</tr>
</tbody>
</table>

97.3% reduction
# Test Results – HCl

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet HCl</td>
<td>34 mg/Nm³ dry</td>
</tr>
<tr>
<td>Outlet HCl</td>
<td>1.6 mg/Nm³ dry</td>
</tr>
<tr>
<td>Outlet HCl</td>
<td>1.2 ppmd @ 7% O₂</td>
</tr>
</tbody>
</table>

95.2% reduction
### Test Results - Mercury

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Trials 1, 2, 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inlet Gas Flow</td>
<td>Nm³/h wet</td>
<td>162,500</td>
</tr>
<tr>
<td>Inlet Gas Temp.</td>
<td>°C</td>
<td>161</td>
</tr>
<tr>
<td>Stack Gas Temp.</td>
<td>°C</td>
<td>85</td>
</tr>
</tbody>
</table>
# Test Results - Mercury

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>Trial 1</th>
<th>Trial 2</th>
<th>Trial 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inlet Hg</strong></td>
<td>µg/Nm³ dry</td>
<td>2.01</td>
<td>22.8</td>
<td>6.38</td>
</tr>
<tr>
<td><strong>Stack Hg</strong></td>
<td>µg/Nm³ dry</td>
<td>0.14</td>
<td>0.66</td>
<td>0.71</td>
</tr>
<tr>
<td><strong>% Hg reduction</strong></td>
<td></td>
<td>93.0%</td>
<td>97.1%</td>
<td>88.9%</td>
</tr>
</tbody>
</table>

**93.0% average reduction**
Summary

- Meeting the new NESHAP limits can be challenging for cement plants, but some demonstrated technologies are available.
- There is no “One size fits all” approach.
- Selecting the correct solution requires knowledge of the issues at any one plant.
Thank you for your attention