Chicago Bridge and Iron (CB&I) has completed the acquisition of the Shaw Group.

The effective date of the transaction was February 14, 2013.

The combined organization brings the capabilities and experience of over 50,000 employees to the marketplace.

Even though Shaw will undergo many changes under our new company, the people remain and will provide the same level of service and dedication to clients as before.
Mercury and Air Toxics Standard (MATS) published on 2/16/2012, which became effective 60 days later. Compliance needs to be demonstrated by the 1st quarter of 2015.

Final PM limit for Filterable PM only (per EPA Method 5)

Use of the alternate SO$_2$ limit is not allowed if EGU does not have some form of FGD system and SO$_2$ CEMS installed.

Where alternate limits are designated with “or” in Table 2 Section 1 of MATS, these pollutants may be used in lieu of pollutants listed in same subsection (e.g. Total non-HAPs may be used in lieu of Filterable PM).

The Hg limit is based on a 30-day boiler operations rolling average.
Injecting chemical: EMO® chemical additives

Mercury Oxidization: \( \text{Hg}(0) \rightarrow \text{Hg}^{(2+)} \)

Mercury Absorption/Adsorption: in the existing PCD and scrubber

Injection location and temperature: Economizer outlet (> 650°F) or PCD outlet (320°F)
the X ppmv of EMO® injection rate was precisely determined by direct sample titration
Flue Gas Flow Analysis

Oxidization efficiency at the scrubber inlet:

Phase 3: \( 98\% \);
Phase 2: \( 88\% \);
Phase 1: \( 80\% \);

- Air Velocity: \( 60 \text{ ft/sec} \)
- Air Temperature: \( 650 \text{ °F} \)
- Liquid Inject Temp: \( 80 \text{ °F} \)

<table>
<thead>
<tr>
<th>Droplet Diameter (micron)</th>
<th>Evaporation Distance (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>120</td>
<td>14.1</td>
</tr>
<tr>
<td>65</td>
<td>4.8</td>
</tr>
<tr>
<td>38</td>
<td>1.2</td>
</tr>
</tbody>
</table>

* Estimated Sauter Mean Droplet Diameters Flow
Droplet Diameters – US Measures Swirl-Air Nozzle
32740-4 or 32163-2
Reference Unit 1 Testing Arrangement

- 220 MW, ESP only, 100% PRB

- **EMO™ Injection**

- **PAC/Trona Injection**

- **Hg Measurement - Speciated M30B**
  - **Vapor Halogen Measurement - EPA M26A**
  - **PMs Measurement - EPA M5**

- **Coal/Fly Ash/**

- **Stack**

- **PC Boiler**

- **ECAN**

- **ESP**

- **IDF**

- **Stack**

- **710 ± 25°F (320°C)**

- **330 ± 25°F (180°C)**

- **330 ± 25°F (180°C)**
## Reference Unit 1 Hg Data Overview

<table>
<thead>
<tr>
<th>Date</th>
<th>Unit Load</th>
<th>Max. Hg From PRB</th>
<th>EMO™ Injection Rate</th>
<th>PAC Injection Rate</th>
<th>Trona Injection Rate</th>
<th>Stack Hg</th>
<th>Stack Hg</th>
<th>Hg Oxidization at Stack</th>
<th>Overall Hg Removal</th>
<th>NOx</th>
<th>Opacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm/dd/yy</td>
<td>(MW)</td>
<td>(lb/TBtu)</td>
<td>(ppmvd)</td>
<td>lb/mmacf</td>
<td>lb/Hr</td>
<td>(lb/TBtu)</td>
<td>(lb/GWh)</td>
<td>(%)</td>
<td>(%)</td>
<td>(lb/MMBtu)</td>
<td>(%)</td>
</tr>
<tr>
<td>5/27/12</td>
<td>236</td>
<td>7.8</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>7.50</td>
<td>0.07317</td>
<td>3.8%</td>
<td>3.8%</td>
<td>0.044</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>235</td>
<td>7.8</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>7.90</td>
<td>0.07707</td>
<td>6.4%</td>
<td>-1.3%</td>
<td>0.042</td>
<td>4.5</td>
</tr>
<tr>
<td>6/7/12</td>
<td>234</td>
<td>7.8</td>
<td>4.4</td>
<td>0</td>
<td>0</td>
<td>1.49</td>
<td>0.01457</td>
<td>97.4%</td>
<td>80.9%</td>
<td>0.043</td>
<td>4.2</td>
</tr>
<tr>
<td></td>
<td>237</td>
<td>7.8</td>
<td>6.5</td>
<td>0</td>
<td>0</td>
<td>1.16</td>
<td>0.01136</td>
<td>97.7%</td>
<td>85.1%</td>
<td>0.045</td>
<td>3.4</td>
</tr>
<tr>
<td>6/8/12</td>
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<td>7.8</td>
<td>5.5</td>
<td>0</td>
<td>1200</td>
<td>3.66</td>
<td>0.03570</td>
<td>91.7%</td>
<td>53.1%</td>
<td>0.045</td>
<td>3.6</td>
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<tr>
<td>6/8/12</td>
<td>235</td>
<td>7.8</td>
<td>10.0</td>
<td>2</td>
<td>1200</td>
<td>0.60</td>
<td>0.00585</td>
<td>99.0%</td>
<td>92.3%</td>
<td>0.045</td>
<td>3.5</td>
</tr>
</tbody>
</table>

- Baseline Hg emission at the Stack, 7.73 lb/TBtu on average, with above 95% Hg (0)
- EMO was observed to produce above 96.5% Hg oxidation efficiency, improved from 5%
- EMO was observed to produce above 83.5% overall Hg removal efficiency
- Combined with Trona, EMO still produced Hg oxidation rat 91.7% Hg oxidation efficiency, overall Hg removal efficiency decreased down to 53.1%
- Combined with Trona/PAC, EMO produced Hg oxidation rat 99.0% Hg oxidation efficiency, overall Hg removal efficiency was determined at 92.3%
Reference Unit 2 Testing Arrangement

- 190 MW, SCR +ESP +FGD, 100% Bituminous

EMO\textsuperscript{®} Injection

Hg/Halogen/PMs Measurements applying speciated EPA Method 30B, M5/202, M26A at Stack

Hg Measurements applying speciated EPA Method 30B at FGD inlet

Coal/Fly Ash/FGD Slurry Sampling

- 350 ± 25°F (180°C)
- 650 ± 25°F (320°C)
- 120 ± 5°F (50°C)
- 650 ± 25°F (320°C)
The optimal EMO® rate was further reduced down to 3.2 ppmv.

Baseline Hg oxidization efficiency at the FGD inlet: 72.1%; Baseline overall Hg removal efficiency: 77.7%

Stack Hg (0): 1.32 lb/TBtu, Hg (T): 1.32 lb/TBtu

EMO® optimal at 3.2 ppmv: Hg oxidization efficiency at the FGD inlet: 96.8%; Overall Hg removal: 88.6%:

Stack Hg (0): 0.71 lb/TBtu, Hg (T): 0.76 lb/TBtu
Hg content in coal was observed to vary between 5.9 and 6.8 lb/TBtu

Hg re-emission was observed during the baseline testing:
FGD inlet Hg(0): 0.89 lb/TBtu; Stack Hg (0): 1.32 lb/TBtu

At the Optimal EMO® at 3.2 ppmv, Hg Reemission was observed to improve

FGD inlet Hg(0): 0.21 lb/TBtu; Stack Hg (0): 0.71 lb/TBtu

<table>
<thead>
<tr>
<th>Date</th>
<th>End Time</th>
<th>Unit Load</th>
<th>Max. Hg in Coal</th>
<th>EMO Injection Rate</th>
<th>FGD inlet Hg (0)</th>
<th>FGD inlet Total Hg</th>
<th>ESP Hg Removal</th>
<th>Hg Oxidization FGD Inlet</th>
<th>Stack Hg (0)</th>
<th>Stack Total Hg</th>
<th>Overall System Hg Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>8/16/12</td>
<td>12:30</td>
<td>191.0</td>
<td>5.9</td>
<td>0</td>
<td>0.84</td>
<td>4.30</td>
<td>27.3%</td>
<td>85.9%</td>
<td>1.15</td>
<td>1.15</td>
<td>80.5%</td>
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<tr>
<td></td>
<td>14:35</td>
<td>190.9</td>
<td>5.9</td>
<td>0</td>
<td>0.94</td>
<td>3.99</td>
<td>32.4%</td>
<td>58.3%</td>
<td>1.49</td>
<td>1.49</td>
<td>74.8%</td>
</tr>
<tr>
<td>8/17/12</td>
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<td>6.5</td>
<td>3.8</td>
<td>0.44</td>
<td>2.66</td>
<td>58.7%</td>
<td>93.2%</td>
<td>0.58</td>
<td>0.58</td>
<td>91.0%</td>
</tr>
<tr>
<td></td>
<td>15:00</td>
<td>191.0</td>
<td>6.5</td>
<td>7.4</td>
<td>0.00</td>
<td>3.16</td>
<td>51.0%</td>
<td>100.0%</td>
<td>0.64</td>
<td>0.72</td>
<td>88.8%</td>
</tr>
<tr>
<td></td>
<td>17:30</td>
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<td>6.5</td>
<td>9.8</td>
<td>0.00</td>
<td>3.13</td>
<td>51.5%</td>
<td>100.0%</td>
<td>0.61</td>
<td>0.71</td>
<td>89.0%</td>
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<td>8/18/12</td>
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<td>3.72</td>
<td>45.2%</td>
<td>98.5%</td>
<td>0.81</td>
<td>0.89</td>
<td>86.8%</td>
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<tr>
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<td>15:00</td>
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<td>2.9</td>
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<td>3.83</td>
<td>43.5%</td>
<td>98.6%</td>
<td>0.75</td>
<td>0.81</td>
<td>88.0%</td>
</tr>
</tbody>
</table>
Fly Ash Analysis and other MATS Compliance

- None of the fly ash sample failed the National TCLP requirements on the metals.

- None of the Method 5 runs were observed to fail the MATS PM compliance limit of 0.03 lb/MMBtu: The stack FPM was improved by 37.8% at the Optimal EMO® at 3.2 ppmv.

- None of the Method 26A runs were observed to fail the MATS HCl compliance limit of 0.002 lb/MMBtu.

- The material cost for continuous EMO® injection at 3.2 ppmv for this reference unit is estimated at $438K per year.
Reference Unit 3 Testing Arrangement

- 440 MW, ESP + FGD, 100% Lignite

- 630 ± 25°F
- 710 ± 25°F
- 330 ± 25°F
- 160 ± 5°F

- Hg Measurement - Speciated M30B
- HCl Measurement - EPA M26A
- PM Measurement - EPA M5

- EMO® Injection

- Coal/Fly Ash/FGD Slurry Sampling/Analysis

- Stack

- Boiler

- **Optimal EMO® Rate:** 6.5 ppmv
- **MATS Hg Limit:** 4.0 lb/TBtu
- **Phase I Optimal EMO® Hg(T) Average:** 3.7 lb/TBtu
- **Overall Hg Removal Efficiency:** 75%
- **Hg Oxidization Efficiency:** 80%

Hg content in coal varied between 15.1 and 22.4 lb/TBtu, averaged at 18.0 lb/TBtu.

MATS Hg Limit: 4.0 lb/TBtu

Optimal EMO® Rate: 6.5 ppmv
EMO® Phase II Overview (5/22/2012 – 6/12/2012)

- Hg content in coal varied between **26.6** and **54.1** lb/TBtu, averaged at **33.7** lb/TBtu, Phase 1: **18.0** lb/TBtu

- MATS Hg Limit: **4.0** lb/TBtu

- Phase II - 1 Optimal EMO® Hg(T): **3.9** lb/TBtu

- Optimal EMO® Rate: **13.5** ppmv

- Overall Hg Oxidization Efficiency: **91%**

- Overall Hg Removal Efficiency: **88%**

- Stack Total Hg Oxidization Efficiency: **91%**

- Overall Hg Removal Efficiency: **88%**

EMO® Injection Concentration (ppmvd)
The cost estimates for the first 3 non-EMO™ injection options were based on Hg Content in coal ~20 lb/TBtu. None of them demonstrated MATS compliance!
EMO’s Co-benefit for Reducing ABS across APH

**Ammonium bisulfate**
- Molecular formula: \((\text{NH}_4)\text{HSO}_4\)
- Molar mass: 115.11 g/mol
- Appearance: White solid
- Density: 1.78 g/cm³
- Melting point: 147 °C, 420 K
- Solubility in water: Very soluble
- Solubility in other solvents: Soluble in methanol, insoluble in acetone

**Ammonium bromide**
- Molecular formula: \(\text{NH}_2\text{Br}\)
- Molar mass: 97.94 g/mol
- Appearance: White powder, hygroscopic
- Density: 2.429 g/cm³
- Melting point: 452 °C, 726 K
- Solubility in water: 60.6 g/100 mL (0 °C), 78.3 g/100 mL (25 °C), 145 g/100 mL (100 °C)
- Refractive index \(\left(\eta_D\right)\): 1.712
Ammonia (NH₃) content of fly ash increased concurrent with EMO injections. At 12.4 ppmv of EMO injection, the NH₃ in the fly ash was observed to increase by 200%.
As EMO™ increased, the total NH3 in ash increased, Baseline: 28 ppm; EMO Optimal: 97 ppm; increased by 246%
Blending 260 ppm of Ca(Br)$_2$ blending in coal requires 57 lb/hr Ca(Br)$_2$ (110 lb/hr of 52% Ca(Br)$_2$ solution). This equates to 0.28 lb-mol of Ca(Br)$_2$, which generates 0.56 lb-mol available Br material in flue gas in the form of Br$_2$ or HBr.

For 3.3 ppmv EMO™ injection at 195 MW gross generation, it would require 23.1 lb/hr of HBr injection (48 lb/hr of 48% HBr solution). This equates to 0.29 lb-mol of HBr, which generates 0.29 lb-mol available Br in flue gas.

Hence applying Ca(Br)$_2$ could put approximately 50% of the Br material to waste (0.29 lb-mol vs. 0.56 lb-mol),

the difference in annual cost is approximately $120K for a 200 MW unit

HBr is a more effective material promoting Hg oxidization
Observations & Recommendations

► EMO® Injection successfully demonstrated Hg compliance to MATS >90% plus stack Hg oxidization efficiency), for Lignite, Bituminous, & Sub-Bituminous

► EMO® has been repeatedly observed to Improve Hg re-emission across the scrubber with a means of precise control

► EMO® injection does not create impact for the fly ash beneficial use/disposal (No metal leaching issues observed)

► EMO reduced ABS formation across the APH to prevent plugging issues – AS a means of neutralizing the NH3 slip to prevent the APH plugging

► EMO® was proven to be ~70% more cost-effective than PAC injection and ~50% more cost-effective than other fuel halogen additives, such as Ca(Br2)
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