

# **MERCURY MEASUREMENT RESULTS FROM THREE EDISON MISSION ELECTRIC POWER PLANTS**

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# MERCURY MEASUREMENT RESULTS FROM THREE EDISON MISSION ENERGY ELECTRIC POWER PLANTS

## ABSTRACT

As a result of the December 2000 decision by the U.S. Environmental Protection Agency (EPA) to regulate mercury from coal-fired electric generation plants, many utilities have stepped up measures to control mercury emissions. To ensure that the most effective and economical control technologies are used, it is essential that mercury chemistry is understood in relationship to plant configuration and coal type. To this end, mercury sampling was conducted at four Edison Mission Energy (EME) boilers to help develop a projection of mercury emissions for all of the U.S. coal-fired power stations owned by the organization. Different variables included the type of control device (regular and hot-side electrostatic precipitators (ESPs), flue gas desulfurization units [FGDs], and selective catalytic reduction [SCR] units) and different coals or blends.

Testing at these sites showed results for the following measures:

- There was a clear difference between a 100% washed eastern bituminous and the medium-sulfur eastern bituminous-washed bituminous blend at two units, indicating that coal washing may have a beneficial effect on mercury speciation.
- It appears that for plants firing eastern bituminous coals, the presence of an SCR unit does increase mercury oxidation compared to the condition without SCR.
- If a plant is firing an eastern bituminous coal and has an SCR followed by an FGD system, a plant can expect to obtain 80%–90% mercury removal. The data are unclear as to the results when a PRB coal is fired.
- It is believed that, under all cases, a hot-side ESP is going to result in less mercury removal compared to a cold-side ESP. The only mercury typically collected by an ESP is that which is particulate-bound. At the temperatures at which a hot-side ESP operates, Hg<sub>p</sub> simply does not form.

Based upon the results of the sampling completed under this project, further testing should be conducted at the unit burning PRB coal to first validate these results and then to correlate these results to coal chemistry and/or plant configurations and operation. Secondly, in order to more accurately extrapolate results of this project to the entire fleet of plants owned by EME, it is recommended that ultimate and proximate analyses be done for the coal burned at each facility. Using this information with coal and fly ash analysis from each of EME's units and its respective configuration, data will be entered into the relational mercury-modeling database developed by the Energy & Environmental Research Center to arrive at an estimate of the total mercury inventory for EME.

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# MERCURY MEASUREMENT RESULTS FROM THREE EDISON MISSION ELECTRIC POWER PLANTS

## 1.0 INTRODUCTION

According to the most recent data, coal combustion by electric utilities is a large source of anthropogenic mercury emissions in the United States, accounting for 45 tons/yr of total point-source mercury emissions (1). In December 2000, the U.S. Environmental Protection Agency (EPA) issued an intent to regulate mercury from coal-fired utility boilers (2). As a result, many research and development organizations are striving to develop effective and economical mercury emission control technologies for coal-fired utility boilers (1–6).

Mercury emissions from coal-fired boilers can be empirically classified, based on the capabilities of currently available analytical methods, into three main forms: elemental mercury ( $\text{Hg}^0$ ), oxidized mercury ( $\text{Hg}^{2+}$ ), and particle-bound mercury ( $\text{Hg}_p$ ). Total mercury concentrations in coal combustion flue gas typically range from 3 to 15  $\mu\text{g}/\text{m}^3$ ; however,  $\text{Hg}^0$ ,  $\text{Hg}^{2+}$ , and  $\text{Hg}_p$  concentrations are much more variable, depending on coal composition and combustion conditions (7).

During combustion, mercury that is chemically bound in the coal is liberated as gas-phase  $\text{Hg}^0$ . However, depending on the coal type, a significant fraction of the  $\text{Hg}^0$  can be oxidized to  $\text{Hg}^{2+}$  as well as become associated with the fly ash particles in the postcombustion environment of a coal-fired boiler. Relative to  $\text{Hg}^0$ ,  $\text{Hg}^{2+}$  and  $\text{Hg}_p$  are generally more effectively captured in conventional pollution control systems such as wet scrubbers, fabric filters, and electrostatic precipitators (ESPs) (3, 4, 6, 8). Therefore, understanding the mercury chemistry in relationship to plant configuration and coal type is critical to developing sound mercury control strategies.

The mercury-sampling activities performed in this study were designed to help develop a projection of mercury emissions for all of the U.S. coal-fired power stations owned by Edison Mission Energy (EME). A variety of plant configurations and coals types were tested.

Mercury measurements were carried out using the Ontario Hydro (OH) mercury speciation method and mercury semicontinuous (or near-real-time) emission monitors (SCEMs). Speciated mercury sampling was carried out at the inlet and outlet of the ESPs for both units and at the stack (after the flue gas desulfurization [FGD] unit) on Unit 3. In addition, hopper ash samples were collected from the ESPs to help verify the concentration of particulate-bound mercury.

## 2.0 PROJECT GOAL AND OBJECTIVES

The goal of the program was to collect the information and measurements necessary to help develop an estimation of mercury inventories for EME coal-fired plants. Specific objectives of the sampling program were as follows:

- Determine the impact of SCR operation on mercury speciation and emissions.
- Determine the impact of an ESP on mercury speciation and emissions.
- Determine the difference between fuel types on mercury speciation and emissions.
- Based on the results from the sampling activities, develop logical predictions for other facilities with similar characteristics.

### **3.0 SAMPLING ACTIVITIES AT HOMER CITY**

The Homer City facility was chosen as a representative of an EME site that fires an eastern bituminous coal and has a selective catalytic reduction (SCR) unit to reduce NO<sub>x</sub> (nitrogen oxide) emissions. Two units were tested at Homer City, Units 1 and 3. The primary difference between the two units was that Unit 3 had a wet scrubber for FGD. In addition, the coal fired in these two units was somewhat different.

#### **3.1 Site Description**

The Homer City facility, located in southwestern Pennsylvania, is an 1884-MW coal-fired generating facility. Units 1 and 3 have net operating capacities of 614 and 650 MW, respectively. The Unit 1 boiler has been retrofitted with a Foster Wheeler dual-air register and internal flame staged low-NO<sub>x</sub> burners and has a separate overfire air system. The Unit 3 boiler was originally built with the first-generation Babcock & Wilcox (B&W) low-NO<sub>x</sub> burners, which met the Phase I Clean Air Act standards. A separate Riley Corporation overfire air system was installed in 1995 to further reduce NO<sub>x</sub> emissions. An emission control retrofit project was completed in 2001, prior to sampling activities. This latest retrofit added SCR systems to both Units 1 and 3 and an FGD system to Unit 3. Both units have ESPs for particulate collection.

To reduce sulfur, the coal fired at Homer City is supplied by a coal-washing facility. As stated above, during the sampling period, different eastern bituminous coals were fired in the two units. 100% of the fuel burned in Unit 1 was a washed bituminous coal, which met sulfur compliance specifications. Unit 3, however, burned a 70–30 blend of a medium-sulfur eastern bituminous coal and a washed coal.

Figure 3-1 shows a schematic of the Unit 1 boiler, ESP, and stack, including sample points. Figure 3-2 shows a similar schematic of Unit 3, including the FGD. Key parameters for the units during the sampling period include the following:

- Unit capacities:
  - Unit 1 – 660 MW gross
  - Unit 3 – 692 MW gross

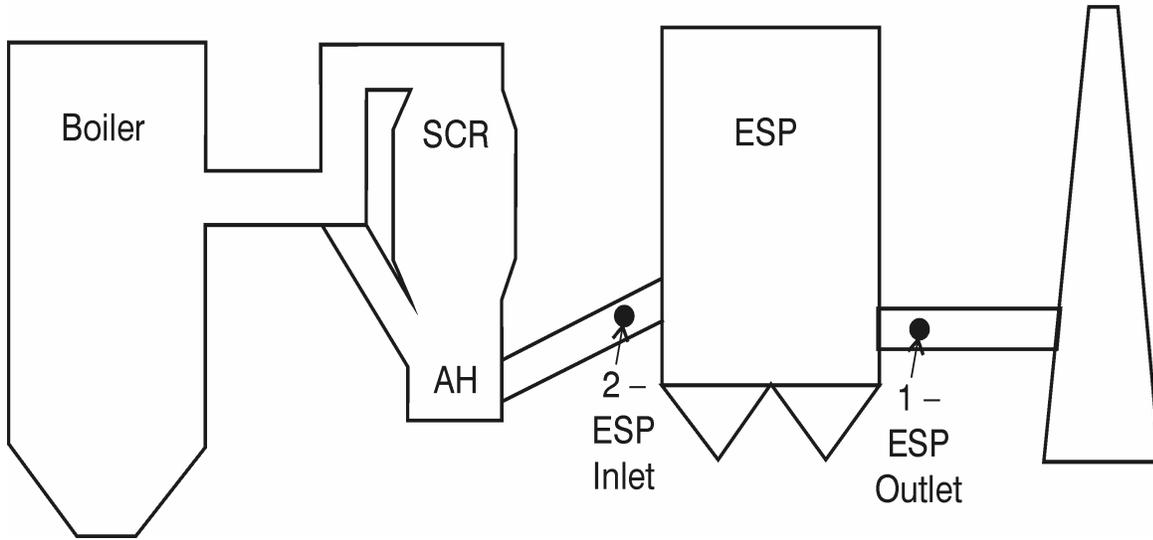


Figure 3-1. Schematic of Unit 1, Homer City.

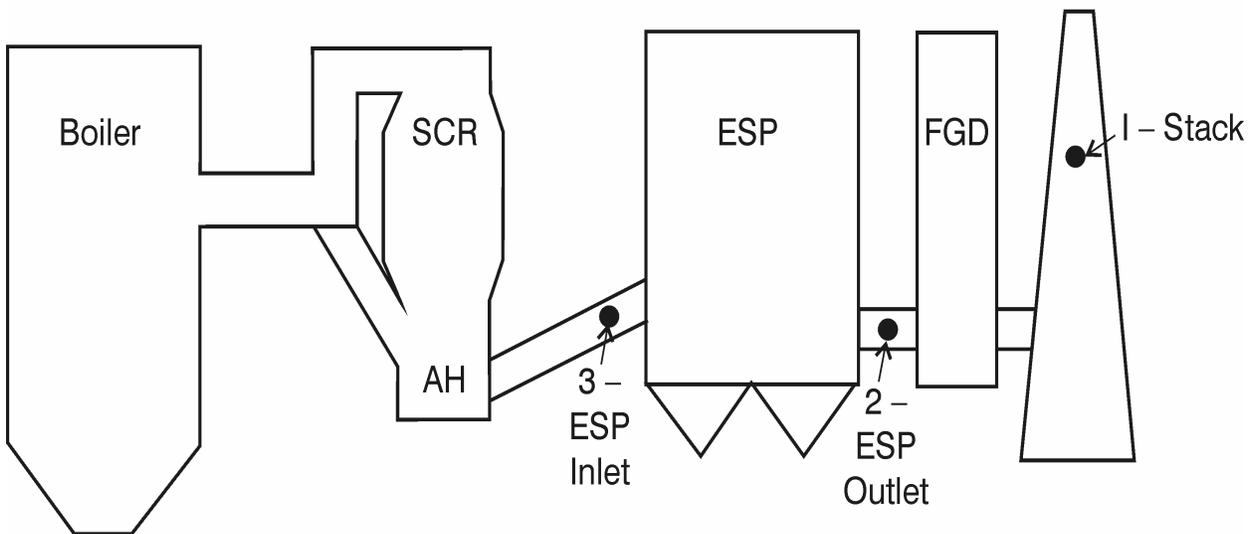


Figure 3-2. Schematic of Unit 3, Homer City.

- Fuel types:
  - Unit 1 – washed eastern bituminous coal
  - Unit 3 – 70–30 blend of eastern bituminous coal and washed coal
- SO<sub>2</sub> controls:
  - Unit 1 – none
  - Unit 3 – wet FGD unit
- Particulate controls:
  - ESP (both units)
- NO<sub>x</sub> controls:
  - SCR (both units)

### **3.2 Sampling Approach**

Testing conducted at EME’s Homer City facility took place November 5–17, 2001. Because of unforeseen problems during that time frame, it was necessary to alter the test schedule from the original plan. Although the schedule was changed to work around unit downtime, these changes did not affect the number of samples or the test matrix. Three days were used to sample Unit 1, and 4 days were used to sample Unit 3. The test matrix, shown in Table 3-1, consisted of three test conditions for each unit. The test conditions were as follows:

- Under normal SCR operating conditions (baseline)
- With the ammonia injection to the SCR turned off
- With the SCR bypassed

For Unit 1, two locations were used to obtain flue gas samples for measuring mercury speciation using the OH mercury speciation method and Hg SCEMs. The two sampling locations chosen were the ESP inlet and outlet. The ESP outlet location was also used to obtain samples for SO<sub>3</sub> and chlorides. For Unit 3, because of the presence of the FGD system, three sampling locations were chosen for sampling using the OH method:

- Inlet to the ESP
- ESP outlet (prior to the FGD unit)
- Stack

Because of difficulties operating Hg SCEMs at a wet location (a stack following an FGD unit), they were located at the ESP inlet and outlet. As was the case for Unit 1, the ESP outlet location was used to obtain samples for SO<sub>3</sub> and chlorides. Table 3-1 shows the flue gas samples that were collected and analyzed for the program. Fuel samples were collected at the coal feeders ahead of the boiler. ESP hopper ash samples were collected from the hoppers during flue gas-sampling activities.

**Table 3-1. Sampling Test Matrix Completed at Homer City**

Condition	Unit	Date	Sample Location – Method Start Times				
			ESP Inlet OH	ESP Outlet OH	Stack OH	ESP Outlet Chlorides	ESP Outlet SO <sub>3</sub>
Baseline	1	11/06/01					14:45
Baseline	1	11/07/01				9:31	13:25
SCR w/No NH <sub>3</sub>	1	11/08/01	13:45	13:40			
Baseline	1	11/09/01				8:36	
SCR Bypassed	1	11/10/01	11:30	11:32			
SCR Bypassed	1	11/10/01	14:00	14:00			
Baseline	1	11/15/01	9:32	9:35			16:10
Baseline	1	11/15/01	13:30	13:33			
Baseline	3	11/13/01	11:45	11:30	15:37		
Baseline	3	11/14/01	9:40	9:50	11:25	14:38	12:59
SCR w/No NH <sub>3</sub>	3	11/16/01	9:35	9:40		12:12	
Bypass	3	11/17/01	9:27	9:50			

### 3.3 Process Operating Conditions

The load conditions during testing for Units 1 and 3 are shown in Table 3-2. During the time frame scheduled for sampling, problems occurred with the boilers that resulted in load variations. In fact, during the last day of testing on Unit 3, there was a severe change in load. Tables 3-3 and 3-4 present the flue gas information for Units 1 and 3, respectively. The ESP collection efficiency was measured to be >99.5% for Unit 1 and >99.9% for Unit 3.

### 3.4 Homer City Results

#### 3.4.1 Coal Analysis Results

As stated in Section 3.1, Homer City burned different coals in each unit during the sampling period. In Unit 1, 100% of the fuel burned was a washed bituminous coal. Unit 3 fired a 70–30 blend of a medium-sulfur eastern bituminous coal (unwashed) and a washed redundant

**Table 3-2. Plant Load Conditions During Sampling at Homer City**

Day	Date	Unit	Load, MW	Comments
3	11/8/01	1	640	Normal
4	11/9/01	1	640	Normal
5	11/10/01	1	540	Low load
8	11/15/01	1	540	Increasing from 450 to 600 MW
6	11/13/01	3	700	Normal
7	11/14/01	3	700	Normal
9	11/16/01	3	700	Normal
10	11/17/01	3	450	Decreasing from 450 to 100 MW

**Table 3-3. Auxiliary Flue Gas Data, Homer City Unit 1**

<b>Sampling Location</b>	<b>Date</b>	<b>Moisture, %</b>	<b>Dust Loading, grains/dscf</b>	<b>ESP Efficiency, %</b>	<b>O<sub>2</sub>, %</b>	<b>CO<sub>2</sub>, %</b>	<b>Temperature, °F</b>
ESP Inlet	11/08/01	9.9	4.8282		4.3	15.1	319
ESP Outlet	11/08/01	7.1	0.0698	98.55	5.8	13.4	313
ESP Inlet	11/10/01	7.4	2.8706		4.4	15.0	312
ESP Outlet	11/10/01	8.2	0.0004	99.98	6.5	13.0	300
ESP Inlet	11/10/01	7.2	2.2042		5.2	14.3	323
ESP Outlet	11/10/01	6.6	0.0006	99.97	6.6	13.0	300
ESP Inlet	11/15/01	7.2	4.8763		5.0	14.4	312
ESP Outlet	11/15/01	7.1	0.0091	99.81	7.7	12.0	300
ESP Inlet	11/15/01	7.8	3.5248		5.0	14.4	319
ESP Outlet	11/15/01	7.8	0.0090	99.74	6.7	12.9	300

<sup>1</sup> O<sub>2</sub> concentration at the specified sampling point.

**Table 3-4. Auxiliary Flue Gas Data, Homer City Unit 3**

<b>Sampling Location</b>	<b>Date</b>	<b>Moisture, %</b>	<b>Dust Loading, grains/dscf</b>	<b>ESP Efficiency, %</b>	<b>O<sub>2</sub>,<sup>1</sup> %</b>	<b>CO<sub>2</sub>, %</b>	<b>Temperature, °F</b>
ESP Inlet	11/13/01	7.3	6.9363		5.1	14.3	289
ESP Outlet	11/13/01	6.4	0.0013	99.98	6.8	12.6	295
Stack	11/13/01	11.2	0.0007		8.4	11.4	121
ESP Inlet	11/14/01	7.4	5.4026		5.3	14.2	300
ESP Outlet	11/14/01	6.3	0.0027	99.95	7.0	12.5	294
Stack	11/14/01	11.7	0.0006		8.4	11.4	122
ESP Inlet	11/16/01	8.5	3.7588		4.6	14.7	302
ESP Outlet	11/16/01	6.5	0.0030	99.92	6.9	12.5	295
ESP Inlet	11/17/01	8.2	7.2864		6.3	13.5	292
ESP Outlet	11/17/01	8.5	0.0022	99.97	9.1	10.4	286

<sup>1</sup> O<sub>2</sub> concentration at the specified sampling point.

eastern bituminous coal (different than the first coal). The analysis of each of the coals is shown in Table 3-5. There were clear differences between the two fuels. As expected, the ash and sulfur content of the 100% washed coal was lower than the blended coal. Also, the mercury concentration of the blended coal was significantly higher than the washed coal. The chloride concentration was about the same for the two coals.

**Table 3-5. Analysis of Coal Collected at Homer City, as received**

<b>Date:</b>	<b>11/8/01</b>	<b>11/9/01</b>	<b>11/13/01</b>	<b>11/14/01</b>	<b>11/15/01</b>	<b>11/16/01</b>
<b>Day:</b>	<b>3</b>	<b>4</b>	<b>6</b>	<b>7</b>	<b>8</b>	<b>9</b>
<b>Unit:</b>	<b>1</b>	<b>1</b>	<b>3</b>	<b>3</b>	<b>3</b>	<b>3</b>
Mercury, µg/g (dry)	0.168	0.153	0.439	0.465	0.409	0.461
Mercury, lb/TBtu	12.5	11.7	37.1	42.4	34.5	38.6
Chloride, µg/g (dry)	1300	1350	1250	1350	1350	997
<i>Proximate Analysis</i>						
Moisture, wt%	1.3	1.4	1.0	0.8	0.8	1.0
Volatile Matter, wt%	34.4	31.8	24.3	23.8	27.1	23.4
Fixed Carbon, wt%	55.7	57.0	55.4	53.7	52.2	55.9
Ash, wt%	8.6	9.8	19.3	21.7	19.9	19.7
<i>Ultimate Analysis</i>						
Hydrogen*, wt%	4.9	4.8	4.0	3.9	4.2	4.0
Carbon, wt%	75.8	75.1	66.9	66.5	67.9	67.5
Nitrogen, wt%	1.6	1.5	1.3	1.2	1.3	1.3
Sulfur, wt%	1.7	1.6	3.2	3.3	2.9	2.6
Oxygen, wt% (by diff.)	7.4	7.3	5.3	3.4	3.8	4.9
Heating Value, Btu/lb	13,219	12,852	11,727	10,885	11,776	11,834
F <sub>d</sub> , dscf/10 <sup>6</sup> Btu	9957	10,111	9941	10,705	10,135	9907

\* Includes hydrogen as water.

### 3.4.2 Flue Gas OH Method Mercury Results

The OH method results for Unit 1 are summarized in Figure 3-3 and compiled in Tables 3-6 and 3-7. For Unit 1, average total mercury concentration at the inlet to the ESP was almost the same for the three test conditions: 15.8, 16.3, and 16.7 µg/Nm<sup>3</sup>. The mercury speciation at the inlet is very similar in all three, with a small increase in Hg<sup>2+</sup> either when the SCR was bypassed or without NH<sub>3</sub>. However, at the ESP inlet sampling location, a very high concentration of particulate-bound mercury was measured. It is clear that the fly ash generated is very reactive toward mercury. The particulate-bound mercury measurement reflects a bias that occurs when the filter prior to the OH train builds up with this reactive ash. This is evident because the ESP was shown to remove only a small portion of the particulate-bound mercury measured at the ESP inlet.

The overall average mercury removal is 22.1% when the SCR is operated normally. When the NH<sub>3</sub> is turned off to the SCR, the average ESP mercury removal efficiency is 36.2%. When the SCR is bypassed entirely, a much higher percentage of the measured particulate-bound mercury at the ESP inlet is removed by the ESP. The overall mercury removal efficiency averaged 77.8%. The difference between the test conditions may be a result of changes in flue gas chemistry that occur as a result of SCR and also, potentially, from the coal being washed.

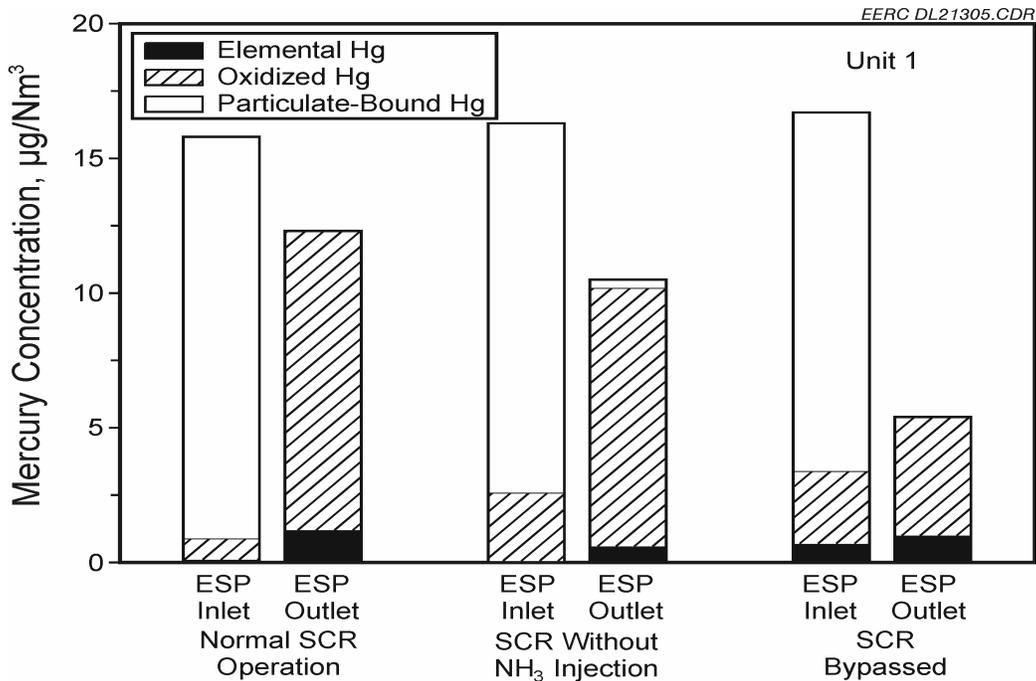


Figure 3-3. Mercury-sampling results for Homer City Unit 1.

**Table 3-6. OH Method Mercury Data for Homer City Unit 1<sup>a</sup>**

	SCR		SCR Without NH <sub>3</sub>		SCR Bypassed	
	11/15/01		11/8/01		11/10/01	
<i>Run 1</i>	ESP Inlet, µg/Nm <sup>3</sup>	ESP Outlet, µg/Nm <sup>3</sup>	ESP Inlet, µg/Nm <sup>3</sup>	ESP Outlet, µg/Nm <sup>3</sup>	ESP Inlet, µg/Nm <sup>3</sup>	ESP Outlet, µg/Nm <sup>3</sup>
Hg <sub>p</sub>	14.8	0.04	13.7	0.27	14.9	0.02
Hg <sup>2+</sup>	0.7	12.2	2.6	9.6	0.8	4.4
Hg <sup>0</sup>	0.0	1.4	0.0	0.6	0.3	1.9
Hg <sup>Total</sup>	15.6	13.6	16.3	10.4	16.0	6.3
<i>Run 2</i>	11/15/01		11/10/01		11/10/01	
	ESP Inlet, µg/Nm <sup>3</sup>	ESP Outlet, µg/Nm <sup>3</sup>	ESP Inlet, µg/Nm <sup>3</sup>	ESP Outlet, µg/Nm <sup>3</sup>	ESP Inlet, µg/Nm <sup>3</sup>	ESP Outlet, µg/Nm <sup>3</sup>
Hg <sub>p</sub>	15.0	0.04			11.7	0.02
Hg <sup>2+</sup>	1.0	10.0			4.5	1.0
Hg <sup>0</sup>	0.1	1.0			1.2	0.1
Hg <sup>Total</sup>	16.0	11.0			17.4	1.1
<i>Average</i>	ESP Inlet, µg/Nm <sup>3</sup>	ESP Outlet, µg/Nm <sup>3</sup>	ESP Inlet, µg/Nm <sup>3</sup>	ESP Outlet, µg/Nm <sup>3</sup>	ESP Inlet, µg/Nm <sup>3</sup>	ESP Outlet, µg/Nm <sup>3</sup>
Hg <sub>p</sub>	14.9	0.0	13.7	0.3	13.3	0.0
Hg <sup>2+</sup>	0.8	11.1	2.6	9.6	2.7	2.7
Hg <sup>0</sup>	0.1	1.2	0.0	0.6	0.7	1.0
Hg <sup>Total</sup>	15.8	12.3	16.3	10.4	16.7	3.7
Hg <sup>Total</sup> , lb/TBtu	11.6	9.0	11.9	7.6	12.2	2.7

<sup>a</sup> All concentrations are reported on a dry, 3% O<sub>2</sub> basis.

**Table 3-7. Average Mercury Speciation for Homer City Unit 1, on a percentage basis**

Mercury Species	SCR		SCR Without NH <sub>3</sub>		SCR Bypassed	
	ESP Inlet, %	ESP Outlet, %	ESP Inlet, %	ESP Outlet, %	ESP Inlet, %	ESP Outlet, %
Hg <sub>p</sub>	94.3	0.0	84.0	2.9	79.6	0.0
Hg <sup>2+</sup>	5.1	90.2	16.0	92.3	16.2	73.0
Hg <sup>0</sup>	0.6	9.8	0.0	5.8	4.2	27.0

For Unit 3, the results are summarized in Figure 3-4 and compiled in Tables 3-8 and 3-9. As was indicated by the much higher average coal mercury concentration of 0.443 µg/g for Unit 3 compared to 0.161 µg/g for Unit 1, the measured mercury in the flue gas was much higher as well. The concentrations at the ESP inlet were 44.3, 40.8, and 40.6 µg/Nm<sup>3</sup>. The measured mercury speciation was also quite different than that measured at Unit 1. This can be seen by comparing the average mercury speciation for the two units, as shown in Tables 3-7 and 3-9. As stated earlier, one of the differences between the coals burned in Units 1 and 3 is the percentage of washed coal. It is possible that coal washing results in chemical changes that may affect the mercury speciation.

Although the total mercury concentrations are higher than average for Unit 3 (typically eastern bituminous coals average 8–15 µg/Nm<sup>3</sup>), the mercury speciation is similar, with a high percentage of Hg<sup>2+</sup>. Again, as was the case for Unit 1, based on the total mercury concentrations at the outlet of the ESP, it appears that the particulate-bound mercury measured at the ESP inlet is a function of the bias of the filter used in the OH method. For all three conditions, the ESP

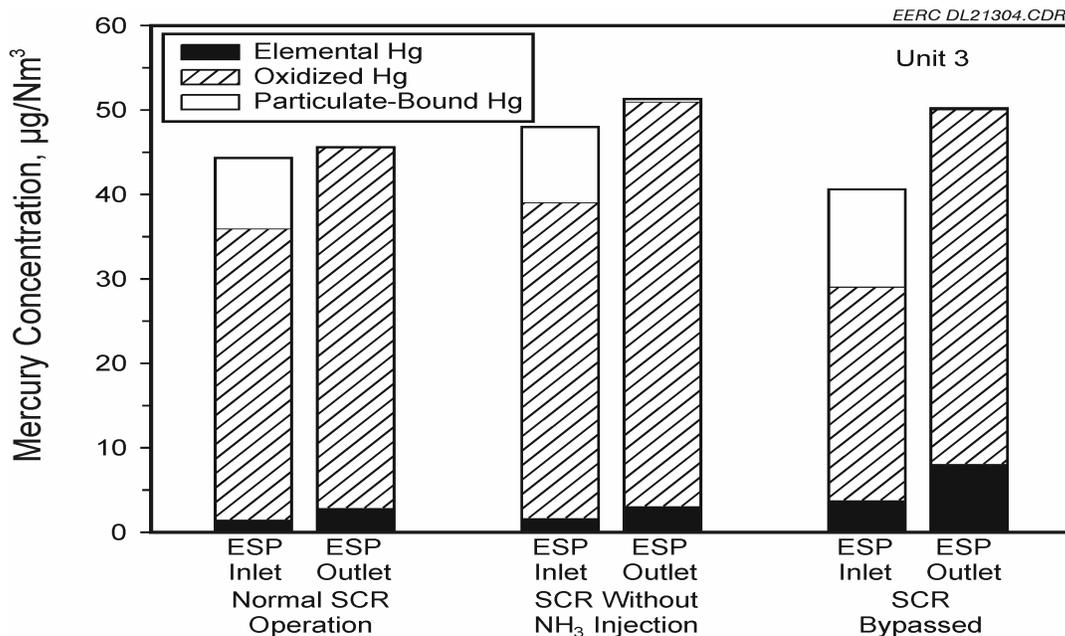


Figure 3-4. Mercury sampling results for Homer City Unit 3.

**Table 3-8. OH Method Mercury Data for Homer City Unit 3<sup>a</sup>**

	SCR			SCR Without NH <sub>3</sub>		SCR Bypassed	
<i>Run 1</i>	11/13/01			11/16/01		11/17/01	
	ESP Inlet, μg/Nm <sup>3</sup>	ESP Outlet, μg/Nm <sup>3</sup>	Stack, μg/Nm <sup>3</sup>	ESP Inlet, μg/Nm <sup>3</sup>	ESP Outlet, μg/Nm <sup>3</sup>	ESP Inlet, μg/Nm <sup>3</sup>	ESP Outlet, μg/Nm <sup>3</sup>
Hg <sub>p</sub>	9.7	0.01	0.01	8.9	0.01	11.5	0.08
Hg <sup>2+</sup>	29.7	38.4	0.2	37.4	47.9	25.3	42.0
Hg <sup>0</sup>	1.8	3.4	0.7	1.7	3.1	3.8	8.1
Hg <sub>Total</sub>	41.2	41.8	0.9	48.0	50.9	40.6	50.1
<i>Run 2</i>	11/14/01						
	ESP Inlet, μg/Nm <sup>3</sup>	ESP Outlet, μg/Nm <sup>3</sup>	Stack, μg/Nm <sup>3</sup>				
Hg <sub>p</sub>	6.9	0.01	0.01				
Hg <sup>2+</sup>	39.3	47.1	0.3				
Hg <sup>0</sup>	1.1	2.5	0.8				
Hg <sub>Total</sub>	47.3	49.6	1.0				
<i>Average</i>	ESP Inlet, μg/Nm <sup>3</sup>	ESP Outlet, μg/Nm <sup>3</sup>	Stack, μg/Nm <sup>3</sup>	ESP Inlet, μg/Nm <sup>3</sup>	ESP Outlet, μg/Nm <sup>3</sup>	ESP Inlet, μg/Nm <sup>3</sup>	ESP Outlet, μg/Nm <sup>3</sup>
Hg <sub>p</sub>	8.3	0.0	0.0	8.9	0.0	11.5	0.1
Hg <sup>2+</sup>	34.5	42.7	0.2	37.4	47.9	25.3	42.0
Hg <sup>0</sup>	1.5	2.9	0.8	1.7	3.1	3.8	8.1
Hg <sub>Total</sub>	44.3	45.7	1.0	48.0	50.9	40.6	50.1
Hg <sup>Total</sup> , lb/TBtu	32.8	33.9	0.7	35.6	37.8	30.1	37.1

<sup>a</sup> All concentrations are reported on a dry, 3% O<sub>2</sub> basis.

**Table 3-9. Average Mercury Speciation for Homer City Unit 3, on a percentage basis**

	SCR			SCR Without NH <sub>3</sub>		SCR Bypassed	
<b>Mercury Species</b>	<b>ESP Inlet, %</b>	<b>ESP Outlet, %</b>	<b>Stack</b>	<b>ESP Inlet</b>	<b>ESP Outlet</b>	<b>ESP Inlet</b>	<b>ESP Outlet</b>
Hg <sub>p</sub>	18.7	0.0	0.0	18.5	0.0	28.3	0.2
Hg <sup>2+</sup>	77.9	93.4	20.0	77.9	94.1	62.3	83.8
Hg <sup>0</sup>	3.4	6.3	80.0	3.5	6.1	9.4	16.2

inlet and outlet total mercury concentrations are essentially the same. However, it appears that SCR results in a small increase in oxidation. Work is currently ongoing at a number of power plants evaluating the effect of SCR on mercury speciation (9, 10). It appears that for plants firing eastern bituminous coals, the presence of an SCR unit does increase mercury oxidation compared to the condition without SCR. Even though the coal fired in Unit 3 generated a high concentration of mercury in the flue gas, because Unit 3 has an FGD, the mercury removal efficiency across the FGD was also very high, 97.7%.

### **3.4.3 Flue Gas Hg SCEM Results**

The Hg SCEM results are shown in Figures 3-5 through 3-8 (it should be noted that Hg SCEM data only provide gas-phase mercury concentrations). Although there was variability in the data, the Hg SCEM results show reasonable agreement with the OH method data. For Unit 1, ESP inlet and outlet data are essentially the same, except on Day 10, when the SCR unit was bypassed. For the Day 10 test condition, the vapor-phase mercury concentration decreased from about 8  $\mu\text{g}/\text{m}^3$  to about 4  $\mu\text{g}/\text{m}^3$  at the ESP outlet (the Hg SCEM data are at the actual  $\text{O}_2$  concentration and are not corrected to 3%  $\text{O}_2$ ). This decrease corresponds to the decrease shown in Figure 3-3. For Unit 3, there was also substantial variability in the data; however, there is again good agreement with the OH method data for vapor-phase mercury. As was shown in Figure 3-5, there was little difference between the ESP inlet and outlet mercury concentrations.

### **3.4.4 ESP Ash Results**

The ESP hopper ash results collected from the ESP of both Units 1 and 3 are shown in Table 3-10. The inlet hopper location is the first field, and the outlet is the last field. As expected, the mercury concentration is greater in the last field because of increased surface area as a result of the smaller particle-size distribution. Also, the loss on ignition (LOI) is substantially higher in the last field. However, the amount of ash as a percentage of the total ash collected by the ESP is much smaller in the later fields compared to the first field.

A comparison of hopper ash mercury concentrations (0.55 and 0.38  $\mu\text{g}/\text{g}$  for Units 1 and 3, respectively) and the concentration of mercury on the filter of the OH sampling from the ESP inlet location (1.6 and 0.6  $\mu\text{g}/\text{g}$  for Units 1 and 3, respectively) reveals the bias of the OH method when a highly reactive ash is generated. The ash collected on the OH filter adsorbs more mercury than what is collected by the ESP. Work is ongoing to develop sampling probes that help minimize the contact between the ash and the flue gas (10).

### **3.4.5 Mercury Mass Balance**

A mercury mass balance is determined by comparing the concentration of mercury in sources entering the plant to the concentration of mercury in sources being emitted from the plant. For Unit 1, the mercury enters the plant via the coal and exits the plant primarily with the ESP hopper ash and as emissions to the atmosphere. For Unit 3, a mass balance is more complicated because of the presence of the FGD system. The primary source of mercury to Unit 3 is still the coal feed, but a small amount of mercury also enters the system through the FGD lime slurry. The exit streams for the mercury are the ESP hopper ash, the FGD sludge, and emissions to the atmosphere. It was never the intention of this project to complete a rigorous mass balance; therefore, only coal and ash samples were taken, and flue gas mercury was measured primarily at the ESP inlet and outlet, with stack mercury measurements made only for Unit 3. Also, the mercury being collected in the ESP hopper ash varied as the test conditions were changed.

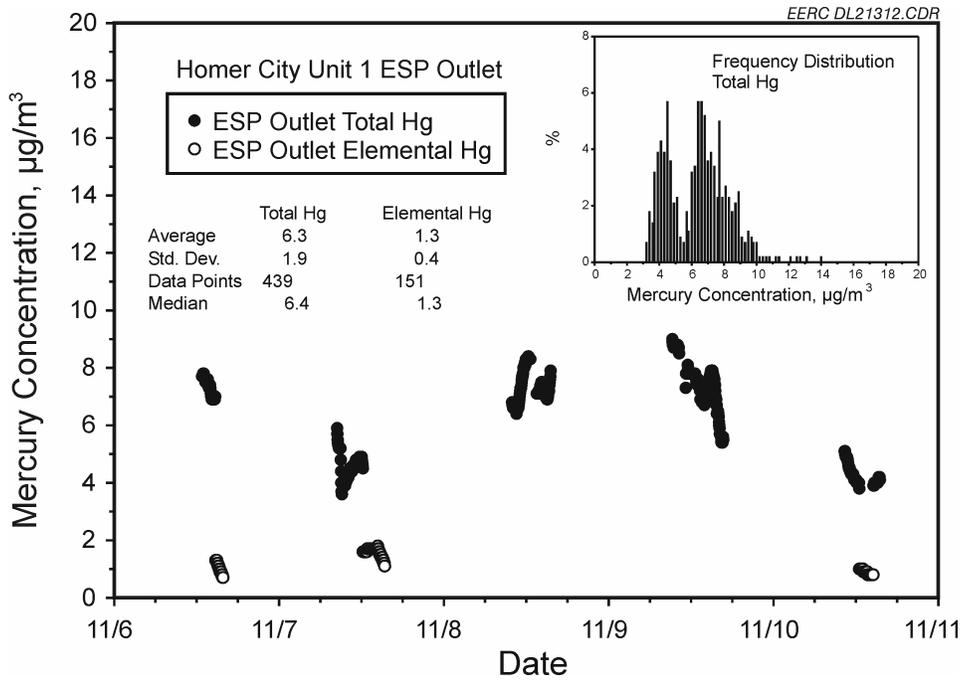


Figure 3-5. Hg SCEM ESP outlet data for Unit 1.

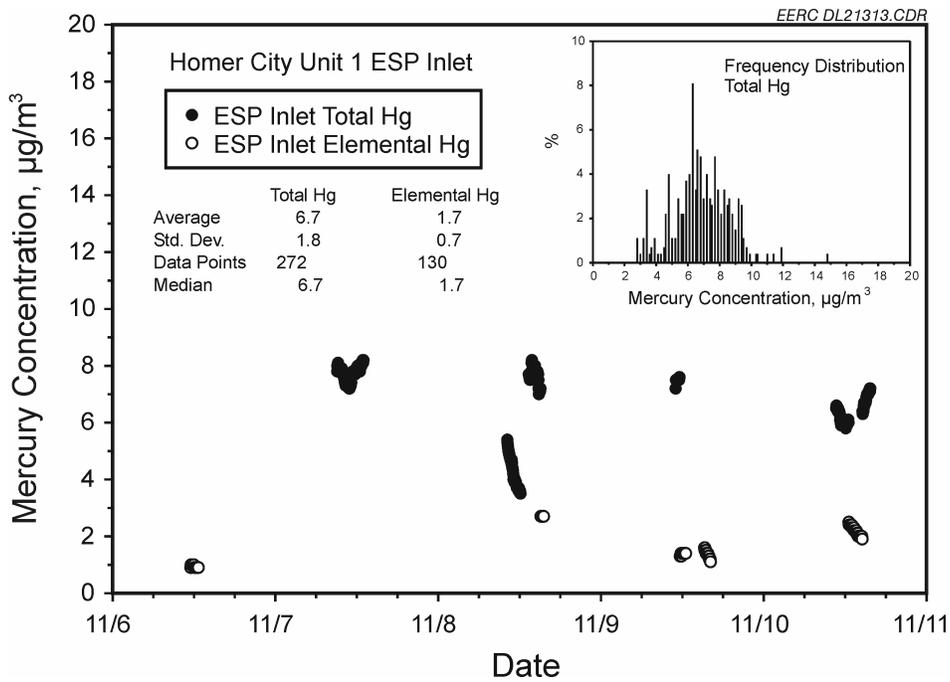


Figure 3-6. Hg SCEM ESP inlet data for Unit 1.

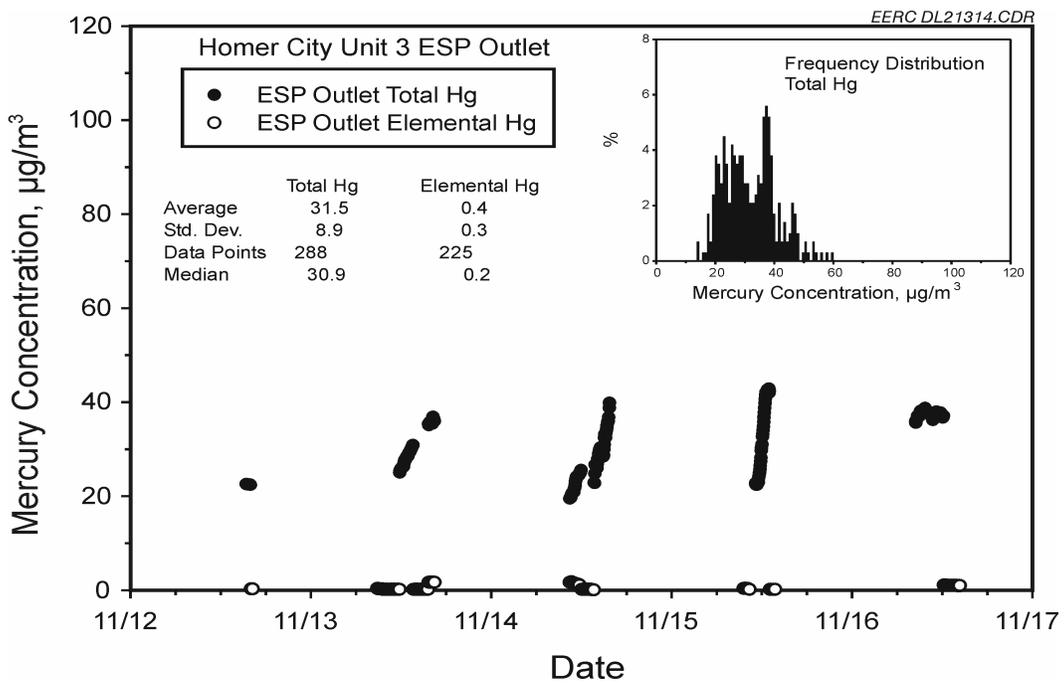


Figure 3-7. Hg SCEM ESP outlet data for Unit 3.

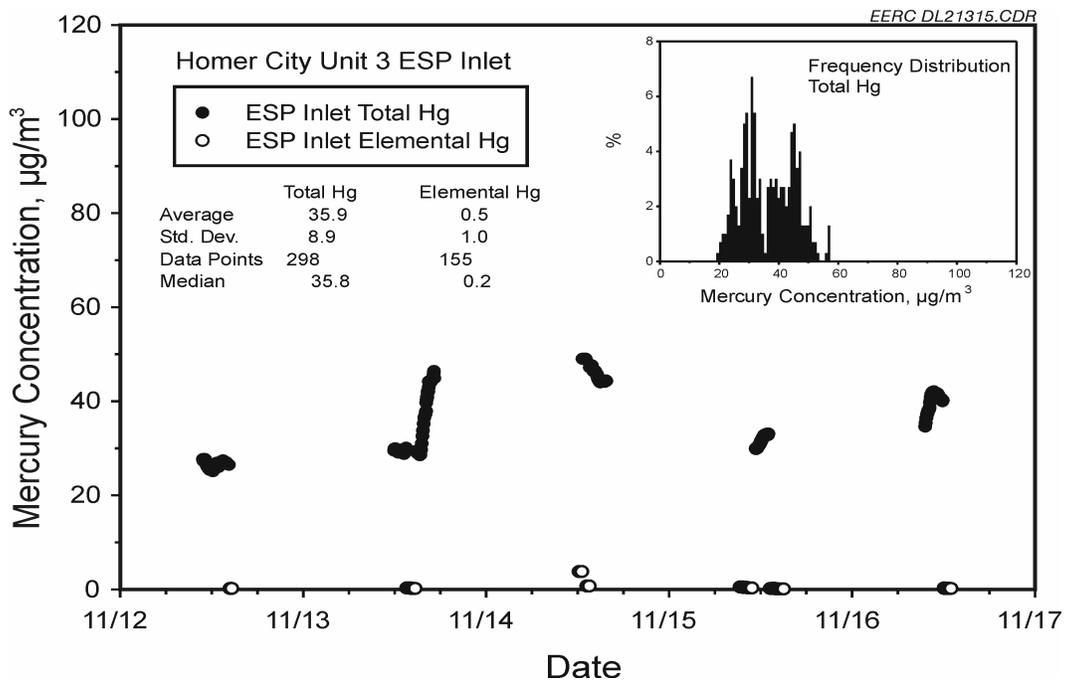


Figure 3-8. Hg SCEM ESP inlet data for Unit 3.

**Table 3-10. Mercury and LOI Analysis of ESP Hopper Ash Collected at Homer City**

Unit	Hopper Location		Inlet		Outlet	
	Condition	Day	Hg, $\mu\text{g/g}$	LOI, %	Hg, $\mu\text{g/g}$	LOI, %
1	SCR w/no NH <sub>3</sub>	3	0.31	9.2	0.81	18.6
1	SCR	8	0.79	10.4	2.60	26.6
1	SCR	8	0.26	6.5	0.93	18.8
3	SCR	6	0.17	9.9	0.92	16.7
3	SCR	7	0.41	5.6	0.94	17.0
3	SCR w/no NH <sub>3</sub>	9	0.25	6.7	0.94	17.0

Using the average  $F_d$  factors and the heating value of the coal, the expected flue gas mercury concentration can be calculated based on the coal mercury concentrations (Table 3-5). For Unit 1, the calculated mercury concentration is 19.6  $\mu\text{g}/\text{Nm}^3$  compared to the measured 16.4  $\mu\text{g}/\text{Nm}^3$ . For Unit 3, the calculated value is 60.4  $\mu\text{g}/\text{Nm}^3$ , compared to an average measured value of 46.6  $\mu\text{g}/\text{Nm}^3$ . The measured versus expected values are then 83.4% and 77.1% for Units 1 and 3, respectively. Although a little on the low side, these are reasonable.

### 3.4.6 Chlorides and SO<sub>3</sub> Concentrations

Table 3-11 shows the SO<sub>3</sub> and chloride measurements made for Units 1 and 3. As expected, the SO<sub>3</sub> concentrations are related to the sulfur concentration in the coal. Unit 3 had a higher sulfur concentration than Unit 1 and a corresponding higher SO<sub>3</sub> concentration. The chloride concentrations in the flue gas are what would be expected, based on the coal chloride concentration.

**Table 3-11. Flue Gas SO<sub>3</sub> Concentrations at the ESP Outlet Location**

Unit	Condition	SO <sub>3</sub> , ppm	Total Chlorides, ppm
1	SCR	<0.3	107
1	SCR	<0.3	100
1	SCR	0.9	—
3	SCR	7.2	98
3	SCR	—	68

## 3.5 General Observations for Homer City

### 3.5.1 Unit 1

- The ash produced is very reactive, i.e., sorbs mercury.
- 22% of the mercury was removed across the ESP with the SCR on-line.

- 78% of the mercury was apparently removed across the ESP when the SCR is bypassed. It appears that with the SCR bypassed, more mercury is particulate-bound than when the SCR is on-line.
- Although the data were variable, there appeared to be an increase in mercury oxidation as a result of the SCR. In comparing the ESP outlet mercury concentrations, both with the SCR unit and with the SCR bypassed, the  $\text{Hg}^{2+}$  increased from 73.0% without the SCR to 93.4% with the SCR.
- Operating the SCR without  $\text{NH}_3$  injection gave mercury speciation results similar to when the SCR was operated normally.
- Average emissions of mercury at the stack were 9.0 lb/TBtu with SCR bypassed and 2.7 lb/TBtu with SCR in service.

### 3.5.2 Unit 3

- The ash produced is reactive, i.e., sorbs mercury.
- There was only minimal mercury removal across the ESP for all three test conditions.
- For all test conditions, the mercury at the ESP outlet is predominantly  $\text{Hg}^{2+}$  >90% when the SCR is on-line.
- Based on the stack measurements, the wet FGD was very effective at removing the mercury; 97.7% of the mercury was removed across the FGD with the SCR on-line.
- There appeared to be a small increase in mercury oxidation as a result of SCR. Comparing the ESP outlet mercury concentrations, both with SCR and with SCR bypassed, the  $\text{Hg}^{2+}$  increased from 83.8% to 93.4%.
- There was minimal effect on mercury speciation as a result of operating the SCR without  $\text{NH}_3$  injection.
- Average mercury emissions at the stack were 0.7 lb/TBtu with SCR.

## 4.0 SAMPLING ACTIVITIES AT JOLIET

The Joliet facility, located in northern Illinois, was chosen as representative of an EME site that fires a Powder River Basin (PRB) subbituminous coal.

### 4.1 Site Description

Figure 4-1 shows a schematic of the Unit 7 boiler, ESP, and stack including sample points. Key parameters for the unit include the following:

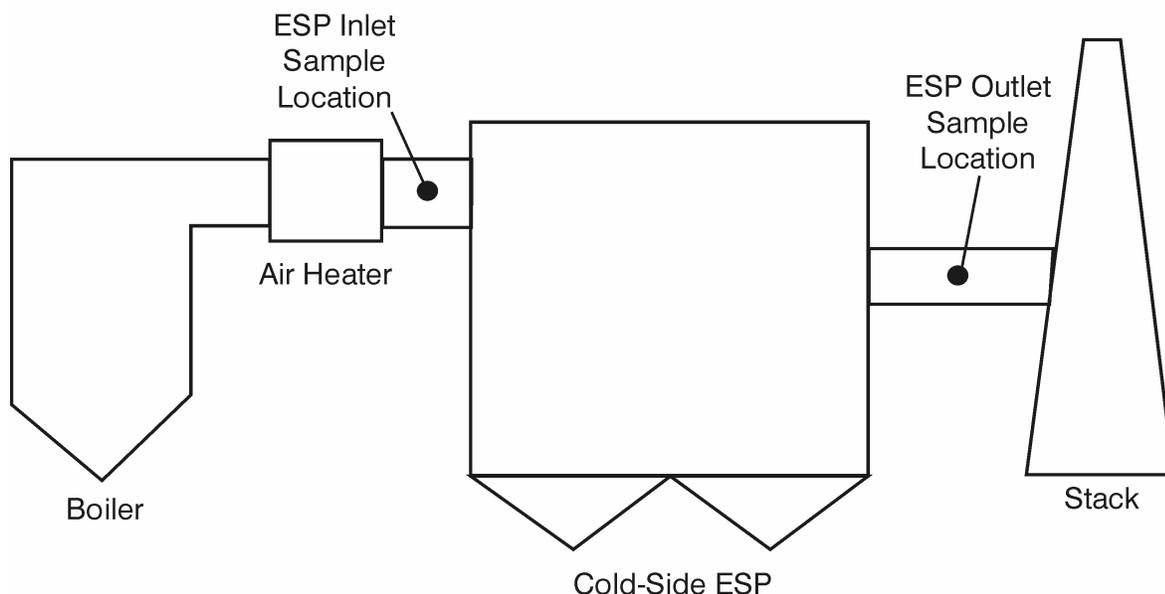


Figure 4-1. Schematic of Joliet Unit 7 power facility.

- Unit capacity: 531 MW gross
- Boiler type: pulverized coal (pc)-fired
- Fuel type: PRB subbituminous coal
- SO<sub>2</sub> control: none (low-sulfur coal)
- Particulate control: ESP
- NO<sub>x</sub> control: low-NO<sub>x</sub> burners

#### 4.2 Sampling Approach

Testing conducted at EME’s Joliet facility took place March 13–14, 2002, on Unit 7. Sampling was done at two locations, the ESP inlet and outlet, using the OH method and Hg SCEMs. The test matrix is shown in Table 4-1.

**Table 4-1. Sampling Test Matrix Completed at Joliet Power Plant**

Date	Day	Sample Location – Sampling Start Times		
		ESP Inlet	ESP Outlet	ESP Inlet
		OH	OH	SO <sub>3</sub>
3/13/2002	1	11:04	11:05	15:20
3/14/2002	2	14:00	14:00	11:18

### 4.3 Process Operating Conditions

The load conditions, as demonstrated in Figure 4-2, by the coal feed were relatively constant during the sampling periods (from about 08:00 to 18:00). However, the load did decrease each night. Table 4-2 presents the auxiliary flue gas information for Unit 7 for the 2 days of sampling.

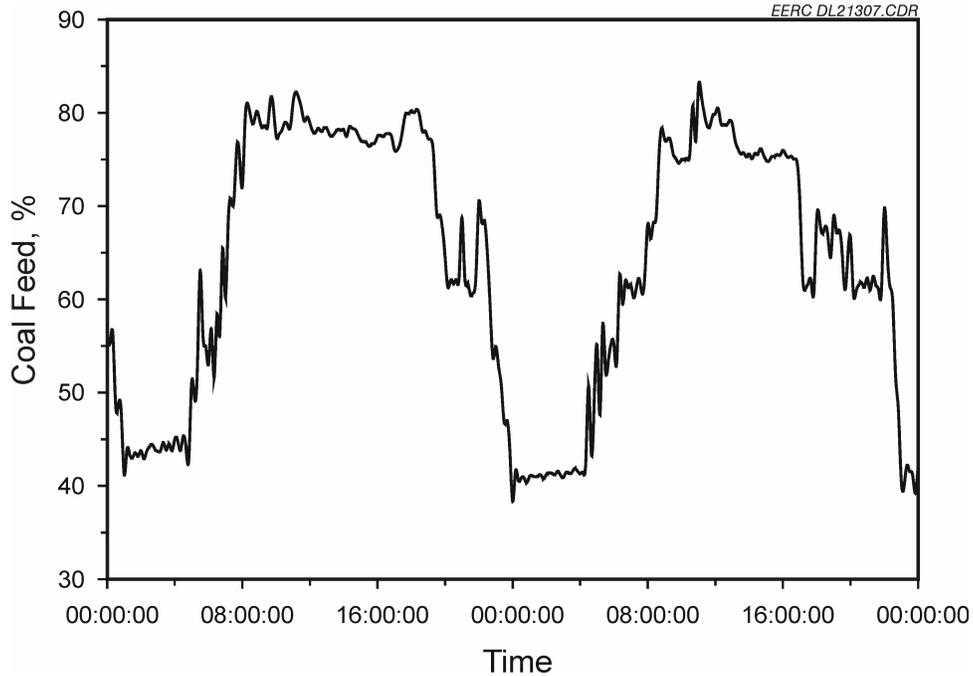


Figure 4-2. Plant load variability based on coal feed for Joliet Unit 7.

**Table 4-2. Auxiliary Flue Gas Data During Sampling at the Joliet Power Plant**

Sample Location	Date	Moisture, %	Dust, grains/dscf	Collection Efficiency, %	O <sub>2</sub> , %	Stack CO <sub>2</sub> , %	ESP Temp., °F
ESP Inlet	3/13/2002	11.7	1.2605		4.8	14.6	269
ESP Outlet	3/13/2002	10.9	0.0226	98.21	5.0	14.4	265
ESP Inlet	3/14/2002	11.6	1.2224		5.2	14.3	273
ESP Outlet	3/14/2002	11.1	0.0249	97.96	4.9	14.5	268

### 4.4 Results for Joliet

#### 4.4.1 Coal Analysis Results

As stated in Section 4.1, Joliet burns a PRB subbituminous coal. Two coal samples were taken during the sampling period. The results are shown in Table 4-3. The mercury was nearly twice as high in the first sample as the second sample. Based on previous experience and the

**Table 4-3. Analysis of Coal Collected at Joliet, as received**

<b>Date:</b>	<b>3/13/2002</b>	<b>3/14/2002</b>
Mercury, $\mu\text{g/g}$ (dry)	0.118	0.066
Mercury, lb/TBtu	10.0	5.6
Chloride, $\mu\text{g/g}$ (dry)	28.8	41.8
<i>Proximate Analysis</i>		
Moisture, %	29.7	29.7
Volatile Matter, %	33.7	33.1
Fixed Carbon, %	31.5	33.1
Ash, %	5.1	4.1
<i>Ultimate Analysis</i>		
Hydrogen, % <sup>a</sup>	6.7	6.5
Carbon, %	47.6	47.4
Nitrogen, %	0.8	0.7
Sulfur, %	0.4	0.2
Oxygen, % (by diff.)	39.5	41.1
Heating Value, Btu/lb	8263	8238
F <sub>d</sub> , dscf/10 <sup>6</sup> Btu	9609	9394

<sup>a</sup>Includes water hydrogen.

information collection request (ICR) data, 0.118  $\mu\text{g/g}$  is much higher than would be typical of PRB coals; 0.066  $\mu\text{g/g}$  is much more in the range of what would be expected and, as will be discussed in Section 5, is similar to the PRB fired at the Will County Station. The OH sampling results indicate that the concentration was much closer to the second sample than the first. Although very low for both coal samples, the chloride content was higher on the second day. All other analyses for the two coal samples are similar.

#### **4.4.2 Flue Gas OH Method Mercury Results**

The OH mercury results are shown graphically in Figure 4-3. As can be seen at the ESP inlet location, almost all of the mercury is particulate-bound, 94.6%. Based on this result, it would be expected that the ESP would then remove 90% to 95% of the total mercury. However, the OH results show that only 78% of the mercury is removed by the ESP. As was discussed in Section 3, the difference between the two percentages is the amount of particulate-bound mercury that was measured as a result of the filter prior to the OH sampling train. The mercury adsorbed by the OH filter was  $\text{Hg}^0$ , as shown by an increase in  $\text{Hg}^0$  about 2.5  $\mu\text{g}/\text{Nm}^3$  higher at the ESP outlet compared to the ESP inlet. The  $\text{Hg}^{2+}$  concentration was the same at each location. This being said, 78% removal of mercury across an ESP is unusual for a PRB coal based on the ICR data.

#### **4.4.3 Flue Gas Hg SCEM Results**

The Hg SCEM results are shown in Figures 4-4 and 4-5. Although there was variability in the data, the Hg SCEM results show reasonable agreement with the OH method data. Because of

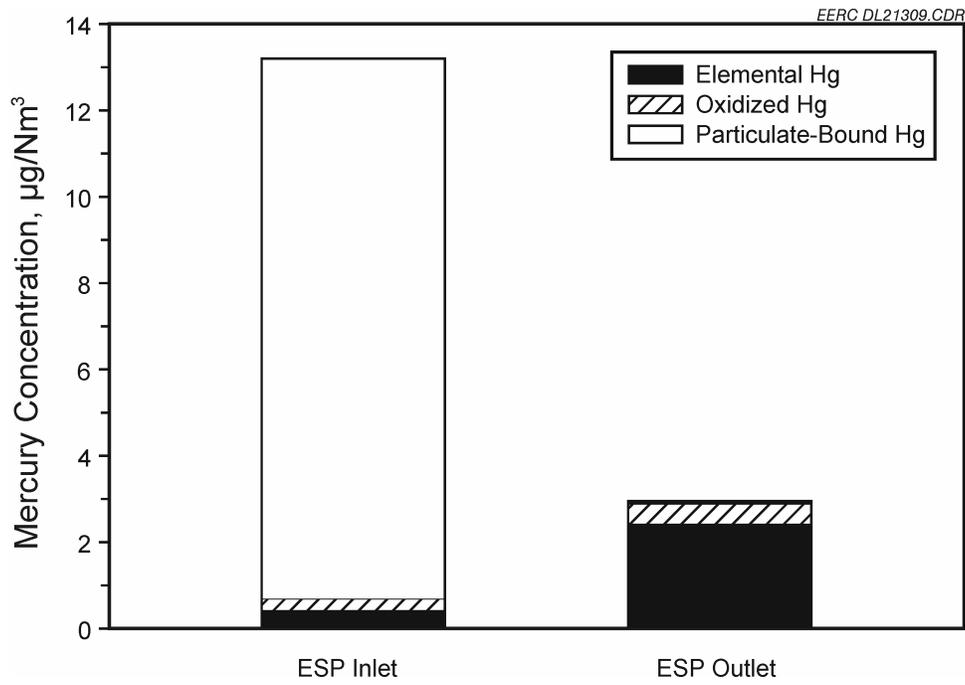


Figure 4-3. Mercury sampling results for Joliet Unit 7.

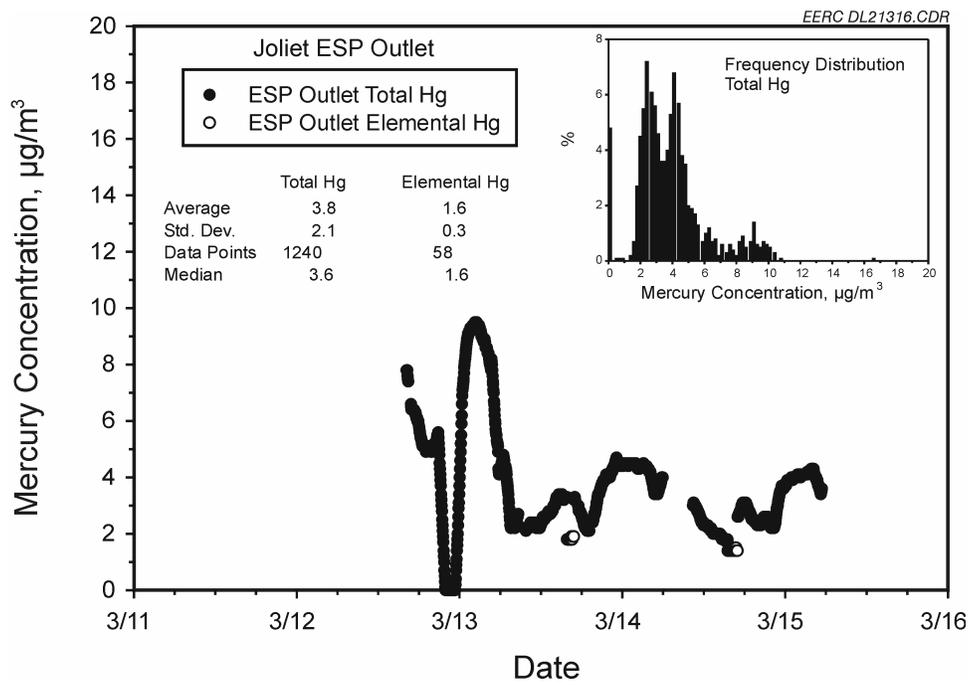


Figure 4-4. Hg SCEM ESP outlet data for Joliet Unit 7.

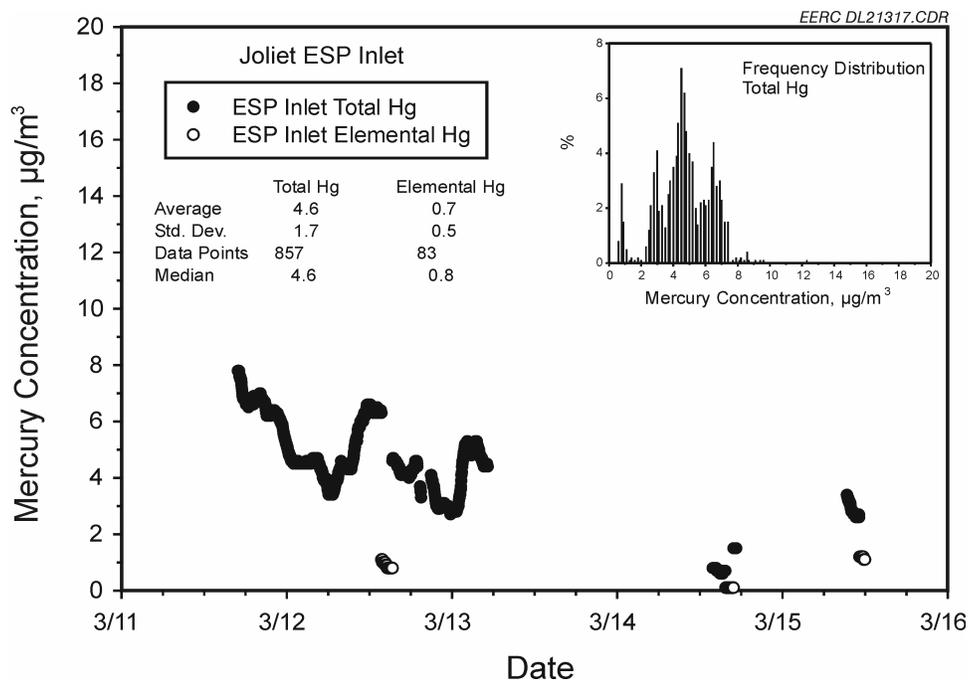


Figure 4-5. Hg SCEM ESP inlet data for Joliet Unit 7.

the adsorptive nature of the fly ash, it was difficult to operate the Hg SCEM at the ESP inlet. An attempt was made to reduce the effect of the particulate removal filter located prior to the Hg SCEM by turning the nozzle away from the gas stream and sampling nonisokinetically. In this way, some useful data were obtained. The results showed that 90% of the data for the total mercury concentration was between 3.5 and 6.0  $\mu\text{g}/\text{Nm}^3$  (the data generated during the initial instrument start-up period is not included in this average). This compares to an average total gas-phase mercury concentration of 0.7  $\mu\text{g}/\text{Nm}^3$  using the OH method, again, clearly showing the problems associated with the sampling filter of the OH method when a reactive fly ash is generated.

From Table 4-4, comparing the ESP inlet and outlet mercury concentrations, it would be expected that the true  $\text{Hg}^0$  at the ESP inlet be about 2.5  $\mu\text{g}/\text{Nm}^3$ . The Hg SCEM data at the ESP inlet location support this conclusion. The Hg SCEM showed the  $\text{Hg}^0$  concentration was between 1.5 and 2.0  $\mu\text{g}/\text{Nm}^3$ , after correcting for oxygen.

At the ESP outlet location, 90% of the Hg SCEM data was between 2.0 and 5.5  $\mu\text{g}/\text{Nm}^3$  with an average close to 3.0  $\mu\text{g}/\text{Nm}^3$ . This is in very good agreement with the OH method, which showed an average total mercury concentration at the ESP outlet of 2.9  $\mu\text{g}/\text{Nm}^3$ . Both the OH method and Hg SCEM data show the total gas-phase mercury to be mostly  $\text{Hg}^0$ .

**Table 4-4. Ontario Hydro Mercury Results for Joliet Unit 7**

	3/13/2002	3/13/2002	3/14/2002	3/14/2002
Hg Species	ESP Inlet, µg/Nm <sup>3</sup>	ESP Outlet, µg/Nm <sup>3</sup>	ESP Inlet, µg/Nm <sup>3</sup>	ESP Outlet, µg/Nm <sup>3</sup>
Hg <sub>p</sub>	12.7	0.06	12.3	0.03
Hg <sup>2+</sup>	0.2	0.2	0.4	0.8
Hg <sup>0</sup>	0.2	2.4	0.6	2.3
Hg <sup>Total</sup>	13.1	2.7	13.3	3.2
<i>Average OH Results</i>				
Hg Species	ESP Inlet, µg/Nm <sup>3</sup>	ESP Inlet, %	ESP Outlet, µg/Nm <sup>3</sup>	ESP Outlet, %
Hg <sub>p</sub>	12.5	94.7	0.05	1.7
Hg <sup>2+</sup>	0.3	2.2	0.5	16.9
Hg <sup>0</sup>	0.4	3.1	2.4	81.4
Hg <sup>Total</sup>	13.2	100.0	2.9	100.0
Hg <sup>Total</sup> , lb/TBtu	9.1	100.0	2.2	100.0

\* All results are reported on a dry, 3% O<sub>2</sub> basis.

#### 4.4.4 ESP Ash Results

The ESP hopper ash results are shown in Table 4-5. Under the “ID” column, inlet refers to the first field and outlet is the last field. As expected, the mercury concentration is greater at the outlet field because of increased surface area as a result of the smaller particle-size distribution.

It has been speculated that the adsorptive capability of a given ash for mercury is related to the carbon content of the ash. This clearly is not the case for this PRB fly ash. Based on the mercury measurement, the fly ash readily adsorbs mercury even though LOI values are very low. It is possible that the difference in flue gas chemistry (i.e., SO<sub>2</sub>/SO<sub>3</sub> and chlorides) between the two ranks of coal may result in a fly ash and/or carbon that behave very differently toward mercury.

#### 4.4.5 Mercury Mass Balance

A mercury mass balance is determined by comparing the concentration of mercury in sources entering the plant to the concentration of mercury in sources being emitted from the plant.

**Table 4-5. Hopper Ash Mercury and LOI**

Day	Date	ID	Hg, µg/g	LOI, %
1	3/13/2002	Inlet	0.63	0.15
1	3/13/2002	Outlet	1.75	0.39
2	3/14/2002	Inlet	0.38	0.20
2	3/14/2002	Outlet	1.35	0.56

For Joliet, the mercury enters the plant via the coal. Mercury exits the plant primarily with the ESP hopper ash and as an emission to the atmosphere. The mercury concentration in the fly ash is high but not nearly what would be expected based on OH sampling, which showed 78% capture of the mercury by the fly ash. Using the average dust loading values shown in Table 4-2 and average mercury concentration in the ash of 1.0 µg/g from Table 4-5, the mercury concentration equivalent in the flue gas is 2.8 µg/Nm<sup>3</sup> compared to the 10.2 µg/Nm<sup>3</sup> that would be necessary to complete a mass balance. The difference is most likely due to the extreme difficulty in obtaining representative ash samples from ESPs.

Using the average F<sub>d</sub> factors and the heating value of the coal, the expected flue gas mercury concentration can be calculated based on the coal mercury concentrations (Table 4-3). Based on the first coal analysis of 0.118 µg/g, the expected mercury concentration would be 23.3 and 13.7 µg/Nm<sup>3</sup> based on the second coal analysis of 0.066 µg/g. Using the first coal mercury concentration, the measured versus calculated mercury concentration is only 56.7%. However, if the second coal mercury concentration is used, the measured versus calculated mercury is 96.3%, which is excellent.

#### 4.4.6 SO<sub>3</sub> Concentrations

As shown in Table 4-6, the SO<sub>3</sub> concentrations are very low, as would be expected from firing a low-sulfur PRB coal.

**Table 4-6. Flue Gas SO<sub>3</sub>**

<b>Sample Location</b>	<b>SO<sub>3</sub>, ppm<sup>a</sup></b>
ESP Inlet	0.47
ESP Inlet	<0.4

<sup>a</sup>At-stack moisture and % O<sub>2</sub>.

#### 4.5 General Observations for Joliet

- The ash produced at Joliet is very reactive, i.e., sorbs mercury.
- 78% of the mercury generated is removed across the ESP.
- The mercury measured at the ESP outlet was 83% Hg<sup>0</sup>.
- Average mercury emissions at the stack were 2.2 lb/TBtu.

### 5.0 SAMPLING ACTIVITIES AT THE WILL COUNTY POWER PLANT

The Will County Power Plant was chosen to represent those plants utilizing a hot-side ESP for particulate control (see Figure 5-1).

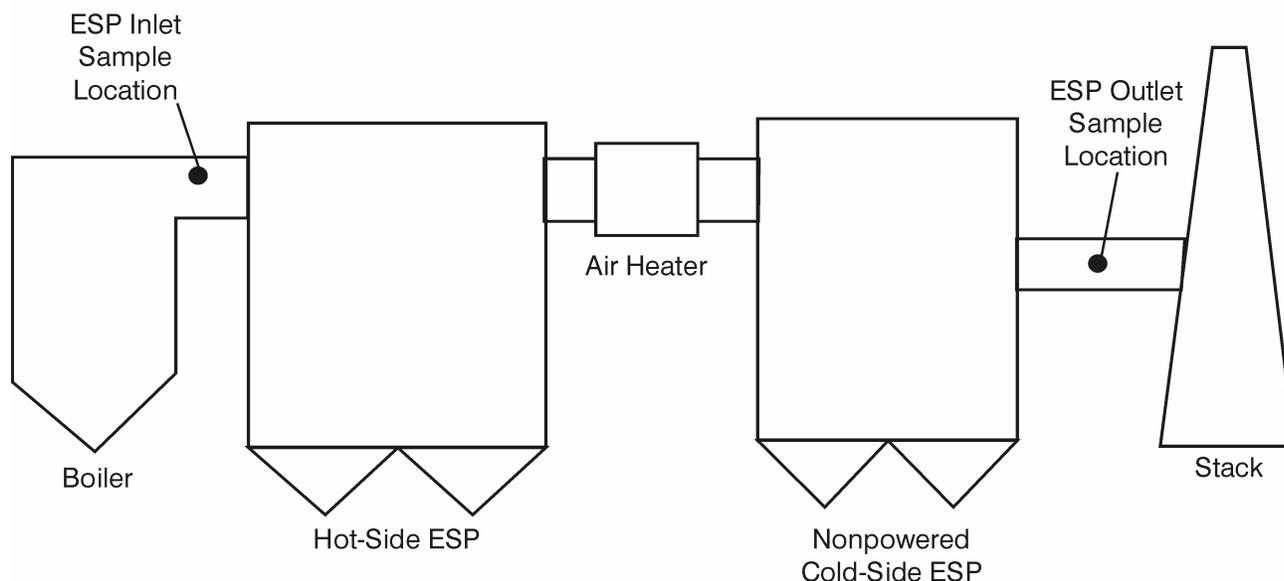


Figure 5-1. Schematic of Unit 3 Will County Power Plant.

## 5.1 Site Description

The Will County facility, located in northern Illinois, is a 1092-MW coal-fired generating facility. Sampling was completed on Unit 3, which has a gross operating capacity of 278 MW. The Unit 3 boiler is equipped with low-NO<sub>x</sub> burners and a hot-side ESP for particulate collection. There is also in series with the hot-side ESP an older and smaller cold-side ESP, but this unit is not powered up. The facility burns a PRB subbituminous coal for sulfur compliance. Key parameters for the unit include the following:

- Unit capacity: 278 MW gross
- Boiler type: pc-fired
- Fuel type: PRB subbituminous coal
- SO<sub>2</sub> control: none (compliance coal)
- Particulate control: hot-side ESP
- NO<sub>x</sub> control: low-NO<sub>x</sub> burners

## 5.2 Sampling Approach

Testing conducted at EME's Will County facility took place March 5–7, 2002. Sampling using the OH method was completed at three locations as follows:

- Inlet to the hot-side ESP
- Hot-side ESP outlet
- Stack

The ESP inlet location was also used to obtain samples for SO<sub>3</sub>. Table 5-1 shows the test matrix for the flue gas samples that were collected and analyzed for the program. Hg SCEMs were used to obtain gas-phase speciated mercury emissions data at the ESP inlet and stack locations. Fuel samples were collected at the coal feeders ahead of the boiler. Hot-side ESP ash samples were collected from the hoppers during flue gas-sampling activities.

### 5.3 Process Operating Conditions

There was substantial variation in plant load during the sampling periods. This resulted in variability in the temperature of the hot-side ESP as well. The variability is shown in Figure 5-2. Although the mercury results are reasonably consistent, these changes in plant operating conditions may have some effect on the results. The auxiliary flue gas data collected are shown for each sample point in Table 5-2.

**Table 5-1. Sampling Test Matrix Completed at Will County Power Plant**

Date	Day	Sample Location – Sampling Start Times			
		ESP Inlet OH	ESP Outlet OH	Stack OH	ESP Inlet SO <sub>3</sub>
3/5/2002	1		15:30		
3/6/2002	2	13:17	9:47	13:10	
3/7/2002	3	10:52		10:50	
3/7/2002	3	13:35			

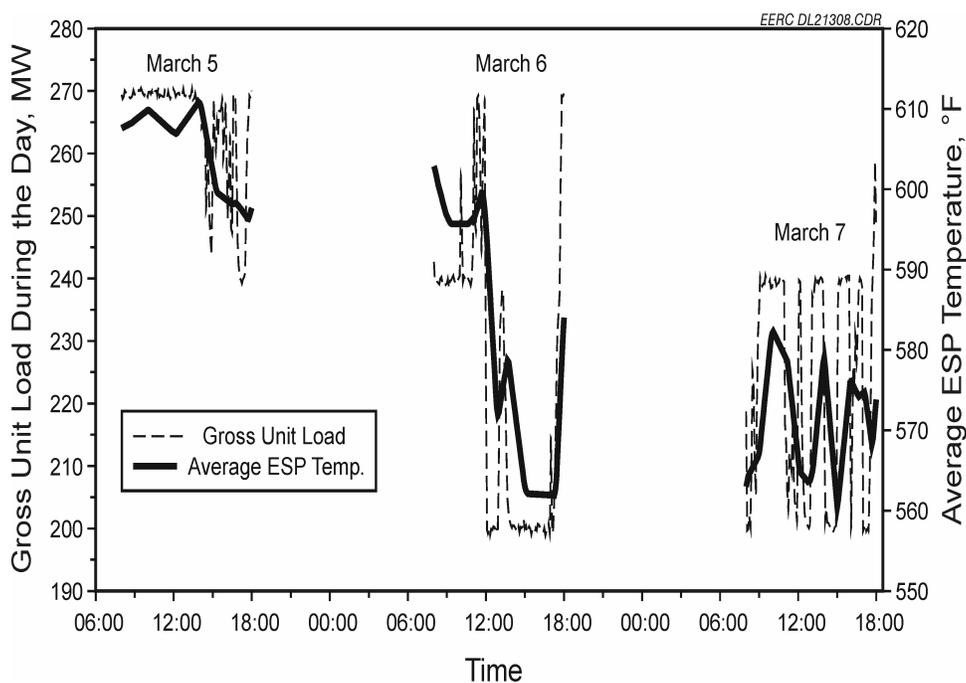


Figure 5-2. Plant load and hot-side ESP temperature variability for Will County Unit 3.

**Table 5-2. Auxiliary Flue Gas Data for Will County Power Plant**

Sample ID	Date	Moisture, % <sup>a</sup>	Dust, grains/dscf <sup>a</sup>	Efficiency, %	O <sub>2</sub> , %	CO <sub>2</sub> , %
D1 ESP Out	3/5/2002	12.4	NA		4.1	15.2
D2 ESP In	3/6/2002	12.7	1.4173		4.1	15.2
D2 ESP Out	3/6/2002	10.8	NA		3.3	16.0
D2 Stack	3/6/2002	9.1	0.0139	99.02	7.3	12.4
D3-1 ESP In	3/7/2002	12.5	1.9841		3.3	16.0
D3-2 ESP In	3/7/2002	12.7	2.5629		3.9	15.4
D3-1 Stack	3/7/2002	9.4	0.0126	99.36	7.7	12.0

<sup>a</sup> Calculated at the actual O<sub>2</sub> values.

## 5.4 Results for Will County

### 5.4.1 Coal Analysis Results

As stated in Section 4.1, Will County burns a PRB subbituminous coal. Two coal samples were taken during the sampling period. The results are shown in Table 5-3. The mercury was a bit higher in the first sample compared to the second sample. However, based on the ICR results, both samples have mercury concentrations that are typical of a PRB coal. As is typical of PRB coals, the chlorides and sulfur were very low. In general, the two coal samples were very similar, based on the ultimate–proximate analyses.

### 5.4.2 Flue Gas OH Method Mercury Results

The flue gas mercury results using the OH method are shown in Table 5-4 and graphically in Figure 5-3. Although, as was shown in Figure 5-2, the plant load varied substantially during each test period, the mercury results are remarkably consistent. As would be expected for a plant utilizing a hot-side ESP for particulate control, there was little, if any, Hg<sub>p</sub>, and there was no mercury removal across the hot-side ESP. However, there does appear to be a change in mercury speciation across the ESP. Figure 5-2 shows a higher concentration of Hg<sup>2+</sup> with a corresponding decrease in Hg<sup>0</sup> at the ESP outlet compared to the ESP inlet. Although there was little if any removal across the hot-side ESP, there was an overall 17% mercury removal between the hot-side ESP inlet location and stack. The removal is all Hg<sup>2+</sup>, as the Hg<sup>0</sup> remained the same. This small decrease in mercury may be a result of mercury disposition on the walls or ash deposits in the nonpowered and noninsulated old ESP.

### 5.4.3 Hg SCEM Results

The Hg SCEM results are very consistent with the OH results, as shown in Figures 5-4 and 5-5. The difference is at the stack, where the Hg SCEM shows an Hg<sup>0</sup> concentration of 3 µg/Nm<sup>3</sup> compared to 5.4 µg/Nm<sup>3</sup> using the OH method.

**Table 5-3. Analysis of Coal Samples Collected at Will County Power Plant, as-received**

Date	3/6/2002	3/7/2002
Mercury, µg/g (dry)	0.076	0.055
Mercury, lb/TBtu	6.4	4.7
Chloride, µg/g (dry)	36.0	49.1
<b>Proximate Analysis</b>		
Moisture, %	29.1	29.3
Volatile Matter, %	33.6	33.1
Fixed Carbon, %	33.4	34.0
Ash, %	4.0	3.6
<b>Ultimate Analysis</b>		
Hydrogen, % <sup>a</sup>	6.6	6.6
Carbon, %	48.2	48.8
Nitrogen, %	0.7	0.7
Sulfur, %	0.2	0.2
Oxygen, % (by diff.)	40.4	40.1
Heating Value, Btu/lb	8410	8367
F <sub>d</sub> , dscf/10 <sup>6</sup> Btu	9422	9611

<sup>a</sup> Includes hydrogen as water.

**Table 5-4. Ontario Hydro Method Mercury Data for Will County Power Plant<sup>a</sup>**

	3/6/2002	3/7/2002	3/7/2002	3/5/2002	3/6/2002	3/6/2002	3/7/2002
Hg species	ESP Inlet, µg/Nm <sup>3</sup>	ESP Inlet, µg/Nm <sup>3</sup>	ESP Inlet, µg/Nm <sup>3</sup>	ESP Outlet, µg/Nm <sup>3</sup>	ESP Outlet, µg/Nm <sup>3</sup>	Stack, µg/Nm <sup>3</sup>	Stack, µg/Nm <sup>3</sup>
Hg <sub>p</sub>	0.10	0.04	0.04	<0.01	<0.01	0.01	<0.01
Hg <sup>2+</sup>	0.4	1.0	1.1	2.4	2.4	0.5	0.6
Hg <sup>0</sup>	6.8	5.9	6.1	5.0	4.7	5.5	5.4
Hg <sup>Total</sup>	7.3	7.0	7.2	7.4	7.1	6.0	6.0
<b>Average OH Results</b>							
	ESP Inlet, µg/Nm <sup>3</sup>	ESP Inlet, %	ESP Outlet, µg/Nm <sup>3</sup>	ESP Outlet, %	Stack, µg/Nm <sup>3</sup>	Stack, %	
Hg <sup>p</sup>	0.04	0.6	<0.1	0	0.01	0.1	
Hg <sup>2+</sup>	1.1	15.4	2.4	33.3	0.6	10.1	
Hg <sup>0</sup>	6.0	84.0	4.8	66.7	5.4	89.8	
Hg <sup>Total</sup>	7.1	100	7.2	100	6.0	100	
Hg <sup>Total</sup> , lb/TBtu	4.9	100	5.0	100	4.2	100	

<sup>a</sup> Dry at 3% O<sub>2</sub>.

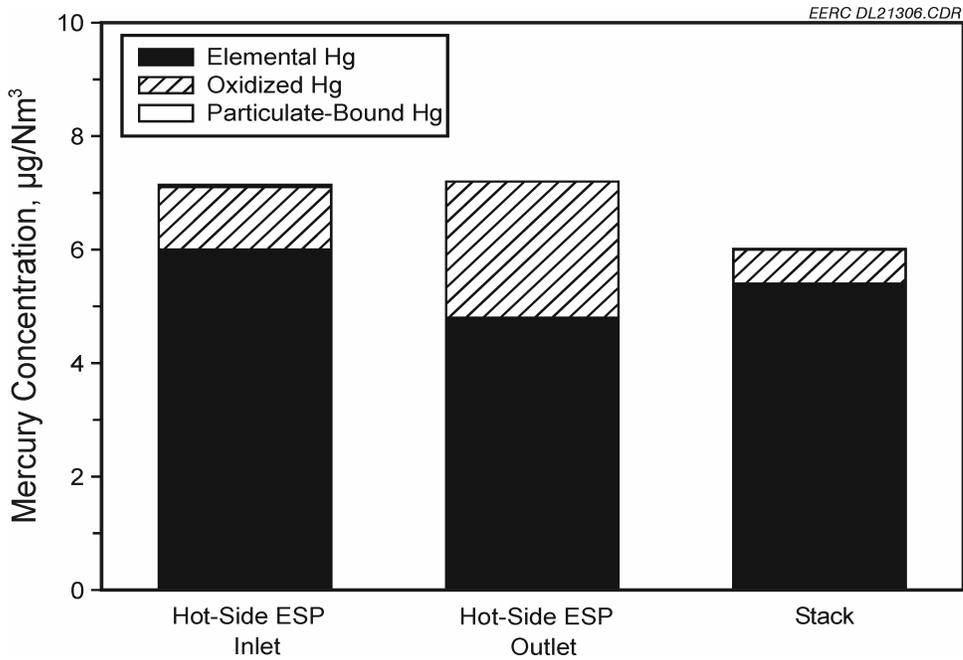


Figure 5-3. Mercury-sampling results for Will County Unit 3.

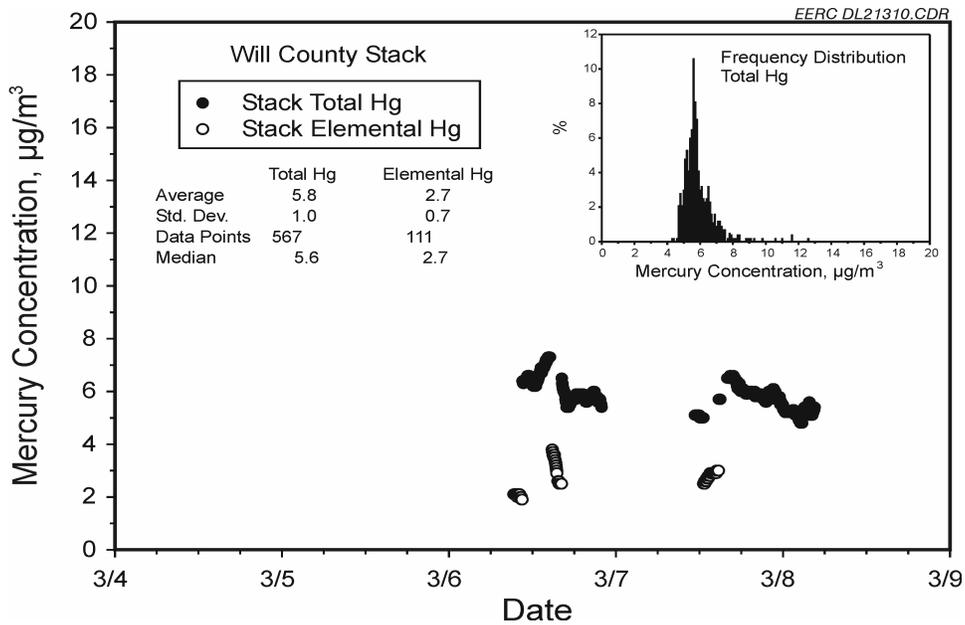


Figure 5-4. Hg SCEM results at the ESP stack for Will County Unit 3.

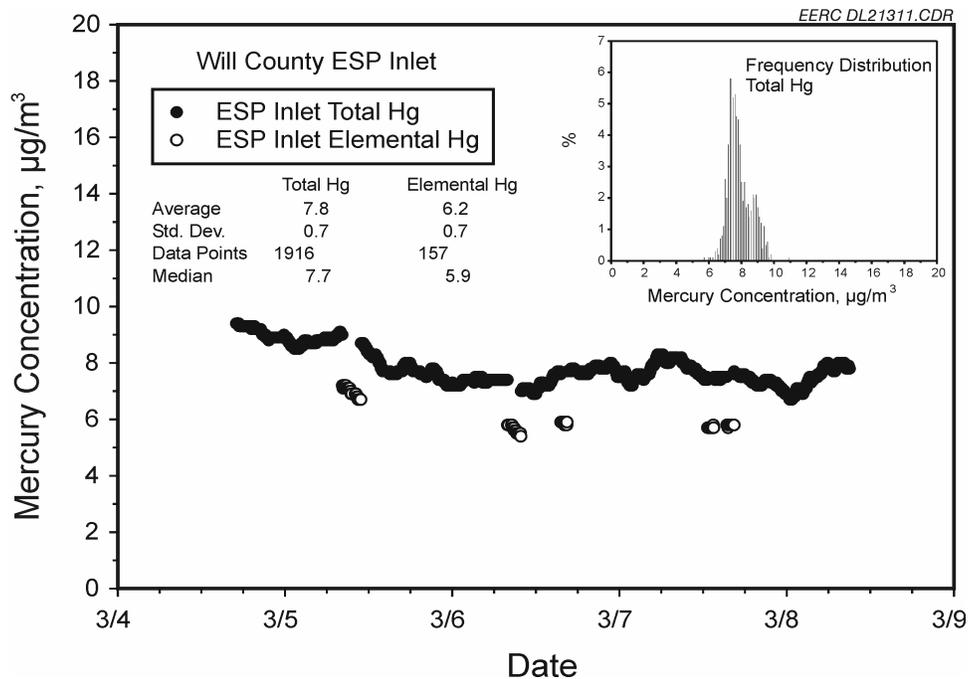


Figure 5-5. Hg SCSEM results at the ESP inlet for Will County Unit 3.

#### 5.4.4 Hot-Side ESP Ash Results

The ESP hopper ash results are shown in Table 5-5. As expected based on the OH mercury concentration and the temperature of the ESP, almost no mercury is captured by the hot-side ESP. The percent LOI, as shown in Table 5-5, is also very low. The LOI values at Will County are very similar to those obtained at Joliet.

**Table 5-5. Hopper Ash Mercury and LOI Collected at the Will County Power Plant**

Date	Hopper ID	Hg, µg/g	LOI, %
3/6/2002	B3	0.010	0.35
3/6/2002	B7	0.003	0.33
3/7/2002	B3	0.007	0.59
3/7/2002	B7	0.006	0.38

#### 5.4.5 Mercury Mass Balance

A mercury mass balance is determined by comparing the concentration of mercury in sources entering the plant to the concentration of mercury in sources being emitted from the plant. For Will County, the mercury enters the plant via the coal. Mercury exits the plant primarily with the ESP hopper ash and as an emission to the atmosphere. It was not the object of this project to complete a rigorous mass balance. Although there was little if any mercury measured in the hot-side ESP ash, there was a decrease in flue gas moisture between the hot-side

ESP and the stack. Therefore, there must be some mercury deposited in the older nonpowered cold-side ESP. It was not possible to obtain any representative ash sample from this unit.

Using the average  $F_d$  factors and the heating value of the coal, the expected flue gas mercury concentration can be calculated based on the coal mercury concentrations (Table 4-3). Based on coal mercury analyses of 0.076 and 0.055  $\mu\text{g/g}$ , the expected mercury concentration would be 11.0 and 8.0  $\mu\text{g/Nm}^3$ , respectively. Comparing the expected to the measured mercury concentration in the flue gas gives a calculated balance of 66.4% and 90.0%.

#### 5.4.6 $\text{SO}_3$ Concentrations

As shown in Table 5-6, the  $\text{SO}_3$  concentrations are very low, as would be expected from firing a low-sulfur PRB coal.

**Table 5-6. Flue Gas  $\text{SO}_3$  at Will County Power Plant**

Date	Sample Location	$\text{SO}_3$ Conc., ppm <sup>a</sup>
3/6/02	ESP Inlet	0.90
3/7/02	ESP Inlet	<0.4

<sup>a</sup>At actual stack moisture and  $\text{O}_2$ .

### 5.5 General Observations for Will County

- There appears to be somewhat of a change in speciation across the hot-side ESP as the percentage of  $\text{Hg}^{2+}$  in the flue gas increases from 15.4% to 33.3% with a corresponding decrease in  $\text{Hg}^0$ .
- There is a 17% removal in mercury based on the hot-side ESP inlet mercury concentration compared to the stack mercury concentration. However, no mercury was captured across the hot-side ESP. The 17% decrease is most likely a result of mercury deposition on the surfaces of the older nonpowered ESP.
- The mercury removed between the hot-side ESP and stack is  $\text{Hg}^{2+}$ . The concentration of the  $\text{Hg}^0$  does not decrease, but the  $\text{Hg}^{2+}$  decreases from 2.4 to 0.6  $\mu\text{g/Nm}^3$ .
- 89.8% of the mercury being emitted at Will County is  $\text{Hg}^0$ .
- Average mercury emissions at the stack were 4.2 lb/TBtu.

## 6.0 QUALITY ASSURANCE/QUALITY CONTROL

The Energy & Environmental Research Center (EERC) is committed to delivering consistent and high-quality research that meets its clients' needs and expectations. In order to ensure that the goals of this project are realized, an organizationwide quality management system

(QMS), authorized and supported by EERC managers, is in effect and governs all programs within the organization. The EERC established and formalized a QMS and quality control (QC) procedures in August 1988. *The Quality Manual* defines the requirements and the organizational responsibilities for each major element of the QMS and references the supporting documents needed to provide a comprehensive program. Compliance with this manual and its supporting documents assures that the EERC adequately fulfills governmental and private clients' requirements relating to quality and compliance with applicable regulations, codes, and protocols. This project was required to follow the Quality Manual, project-specific quality assurance (QA) procedures, and all revisions. The EERC Quality Assurance Manager implements and oversees all aspects of QA/QC for all research, development, and demonstration projects and reviewed the QA/QC components of this project. The project manager is responsible for ensuring that project-specific QA/QC protocols are followed.

To ascertain data quality obtained during the sampling program, it was intended that the following procedures be used:

- Process operating data were to be examined to ensure that the OH sampling took place during steady, representative plant operation.
- Sampling and analysis protocols were to be reviewed to ascertain how the data compared with other data generated using standard protocols.
- The type and quantity of QA samples were to be reviewed to qualitatively determine the confidence that can be placed in the results.
- The QA/QC data results then were to be compared with data quality indicators to qualitatively determine the validity of the data in terms of variability and accuracy.

### **6.1 Process Data Evaluation**

Plant operating data were examined during and after the test program to determine if operation was stable and representative during the OH sampling periods. Scatter or significant trends in relevant process variables can indicate periods of nonrepresentative unit operation. Data scatter is useful for identifying periods of operational difficulty; data trends indicate periods when steady-state operation has not been achieved. Because of some plant requirements, not all samples were taken during steady-state operations. At both Homer City and Will County, the plant load varied during the test program. At Will County, it did not appear to have a negative impact on data quality; however, at Homer City, the data were more variable than what has typically been the case.

### **6.2 Sampling Quality Control Evaluation**

An evaluation of the measurement data quality is based on QC data obtained during sampling and analysis. Generally, the type of QC information obtained pertains to measurement precision, accuracy, and blank effects, determined by collecting various types of replicate, spiked, and blank samples. The specific characteristics evaluated depend on the type of QC

checks performed. For example, if problems with contamination occur, blank samples can be prepared at different stages in the sampling and analysis process to isolate the source of a blank effect. Similarly, replicate samples may be generated at different stages to isolate and measure the sources of variability. Table 6-1 summarizes the QA/QC measures used and the characteristic information obtained for this project.

Sampling precision can be estimated by comparing the results for various parameters of the replicate samples, notably velocity, moisture content, and gas composition in the stack. Sampling

**Table 6-1. Elements of the QA/QC Plan**

<b>QC Activity</b>	<b>Characteristic Measured</b>
<b><i>Precision</i></b>	
Replicate Samples Collected Over Time Under the Same Conditions	Total variability, including process or temporal, sampling, and analytical variability but not bias.
Duplicate Field Samples Collected Simultaneously	Sampling plus analytical variability at the actual sample concentrations.
Duplicate Analyses of a Single Sample	Analytical variability at the actual sample concentrations.
Media-Spiked Duplicates	Sampling plus analytical variability at an established concentration.
Laboratory Control Sample Duplicates	Analytical variability in the absence of sample matrix effects.
<b><i>Accuracy (including precision and bias)</i></b>	
Media-Spiked Samples	Analyte recovery in the sample media, indicating possible interferences and other effects. In a single sample, includes both random error (imprecision) and systematic error (bias).
Laboratory Control Samples	Analyte recovery in the absence of actual sample matrix effects. Used as an indicator of analytical control.
<b><i>Blank Effects</i></b>	
Field Blank	Total sampling plus analytical blank effect, including sampling equipment and reagents, sample transport and storage, and analytical reagents and equipment.
Reagent Blank	Blank effects from reagents used.

accuracy is usually inferred from the calibration and proper operation of the equipment and from historical validation of the methods. Field blanks are used to determine any biases that may be caused by contamination or operator errors. A field blank is defined as a complete impinger train, including all glassware and solutions, that is taken out to the field during sampling and exposed to ambient conditions. These sample trains were then taken apart and the solutions recovered and analyzed in the same manner as those sample trains used for sampling activities. If the field blank shows contamination above instrument background, steps must be taken to eliminate or reduce the contamination to below background levels. The results of the blanks can be seen in Table 6-2. In almost all cases, the field blank results were less than detection limits. For the one sample where a detectable level of mercury was measured, the concentration was low enough to be insignificant compared to the measured flue gas concentration for that mercury species.

Sample precision and accuracy estimates are based primarily on the actual sample media to document the precision and accuracy actually obtained, and the objectives serve as benchmarks for comparison. The effects of not meeting the objectives need to be considered in light of the intended use of the data. The results of the field spikes that were done as part of this project are shown in Table 6-3. As can be seen in these tables, the spike recovery was good ( $\pm 15\%$ ) for all the field spikes completed. Although blank filters are routinely analyzed for mercury to ensure there was no mercury contamination on the sample, no field filter spikes were completed for the project. However, in the laboratory, known mercury calibration standards are routinely analyzed.

**Table 6-2. Field Blanks at Each Test Site**

<b>Day</b>	<b>KCl Solution, <math>\mu\text{g}</math> 500 mL</b>	<b>H<sub>2</sub>O<sub>2</sub>/HNO<sub>3</sub> Solution, <math>\mu\text{g}</math> 250 mL</b>	<b>KMnO<sub>4</sub>/H<sub>2</sub>SO<sub>4</sub> Solution, <math>\mu\text{g}</math> 500 mL</b>
<i>Homer City</i>			
3	<0.01	<0.01	<0.01
3	<0.01	<0.01	<0.01
4	<0.01	<0.01	<0.01
5	<0.01	<0.01	<0.01
6	<0.01	<0.01	<0.01
7	<0.01	0.023	<0.01
8	<0.01	<0.01	<0.01
9	<0.01	<0.01	<0.01
<i>Joliet</i>			
1	<0.01	<0.01	<0.01
2	<0.01	<0.01	<0.01
<i>Will County</i>			
1	<0.01	<0.01	<0.01
2	<0.01	<0.01	<0.01
3	<0.01	<0.01	<0.01

**Table 6-3. Field Spike Results at Each Test Site**

Day	KCl Solution			H <sub>2</sub> O <sub>2</sub> /HNO <sub>3</sub> Solution			KMnO <sub>4</sub> /H <sub>2</sub> SO <sub>4</sub> Solution		
	Measured Value, ppb	Spike, ppb	Spike Recovery, ppb	Measured Value, ppb	Spike, ppb	Spike Recovery, ppb	Measured Value, ppb	Spike, ppb	Spike Recovery, ppb
<i>Homer City</i>									
3	5.61	5	112.2	0.82	1	82.0	4.75	5	95.0
4	5.51	5	110.2	0.87	1	87.0	4.96	5	99.2
5	5.52	5	110.4	1.08	1	108.0	5.11	5	102.2
6	5.73	5	114.6	0.81	1	81.0	4.98	5	99.6
7	5.46	5	109.2	1.10	1	110.0	5.23	5	104.6
8	11.03	10	110.3	0.98	1	98.0	5.24	5	104.8
9	10.96	10	109.6	0.92	1	92.0	4.93	5	98.6
Average			110.9			94.0			100.6
<i>Joliet</i>									
1	2.05	2	102.5	1.09	1	109.0	4.45	5	90.8
2	2.00	2	100.0	1.08	1	108.0	4.68	5	93.6
Average			101.3			108.5			92.2
<i>Will County</i>									
2	5.57	5	111.4	1.04	1	104.0	4.97	5	99.4
3	5.79	5	115.8	1.02	1	102.0	4.98	5	99.6
Average			113.6			103.0			99.5

Sampling comparability depends on the representativeness of the samples and on the use of standard methods consistently applied. All methods used for the project were standard American Society for Testing and Materials (ASTM) or EPA sampling methods. Sampling completeness is mainly a function of providing the requisite number of samples to the analytical laboratory. In most cases, this included duplicate samples.

Other specific QC procedures that were used to measure mercury in the flue gas for this project were as follows.

**Instrument Setup and Calibration.** The instrument used in the field for mercury determination was a Leeman Labs PS200 CVAA. To measure mercury, the instrument was set up for absorption at 253.7 nm with a carrier gas of nitrogen and 10% <sup>w/v</sup>. Each day the drying tube and acetate trap were replaced and the tubing checked. The rinse container was cleaned and filled with fresh solution of 10% <sup>v/v</sup> HCl. After the pump and lamp were turned on and warmed up for 45 minutes, the aperture was set to the manufacturer specifications. A four-point calibration curve was then completed using matrix-matched standards. The detector response for the given standard was then logged and compared to specifications to ensure the instrument had been properly set up. A QC standard of a known analyte concentration was analyzed immediately after the instrument was standardized in order to verify the calibration. This QC standard is prepared from a different stock than the calibration standards. It was required that the values obtained read within 5% of the true value before the instrument was used. After the initial QC standardizations were completed, standards were run every five samples to check the slope of the calibration curve. All samples were run in duplicate, and one in every ten samples was spiked to verify analyte recovery. A QC chart is maintained at the EERC to monitor the long-

term precision of the instrument. The results of these calibrations are available upon request of any EERC client.

**Presampling Preparation.** All data sheets, volumetric flasks, and petri dishes used for sample recovery were marked with preprinted labels. The liquid samples were recovered into premarked volumetric flasks and logged, then analyzed on-site. The outlet filter samples were placed in premarked petri dishes and taken back to the EERC, where they were then analyzed using mixed-acid digestion techniques. The labels contained identifying data, including date, time, run number, sample port location, and the name of the sampler.

**Glassware and Plasticware Cleaning and Storage.** All glass volumetric flasks and transfer pipets used in the preparation of analytical reagents and calibration standards were designated Class A to meet federal specifications. Prior to being used for the sampling, all glassware was washed with hot, soapy water, then rinsed with deionized water three times, soaked in 10%  $V/V$  nitric acid for a minimum of 4 hours, rinsed an additional three times with deionized water, and dried. The glassware was then stored in closed containers until it was used at the plant. All glassware cleaning solutions are periodically checked for mercury. In all cases, the measured mercury concentration was below detection limits.

**Analytical Reagents.** All acids to be used for the analysis of mercury were trace metal-grade or analytical reagent-grade. The calibration standards used for instrument calibration and the QC standards used for calibration verification were purchased commercially and certified to be accurate within  $\pm 0.5\%$  and were traceable to National Institute of Standards and Technology (NIST) standard reference materials.

## 7.0 CONCLUSIONS AND RECOMMENDATIONS

### 7.1 Conclusions

Because of problems that occurred at Homer City during sampling, the results were somewhat difficult to interpret; however, it appears that the SCR units at Homer City did result in an increase in mercury oxidation. This is consistent with the results that have been obtained at other plants firing eastern bituminous coals and that have an SCR reactor (10). In general, if a plant is firing an eastern bituminous coal and has an SCR followed by an FGD system, a plant can expect to obtain 80%–90% mercury removal.

There are substantially fewer data as to the effect of an SCR unit when a PRB coal is fired. It is intended that this year, two facilities will be tested that should help to answer this question. However, based on the ICR data, the testing conducted for this project, and testing by others, it does appear that facilities firing PRB coals are going to have a more difficult time reducing mercury emissions than those firing eastern bituminous coals. The reason for this is that a high percentage of the mercury in the flue gas is in the form of  $Hg^0$ , which is not removed by scrubbers and is difficult to remove even with carbon injection. PRBs have a very low chloride content. This is significant because it has been speculated that SCRs increase mercury oxidation by catalytically increasing the rate of reaction between  $Hg^0$  and Cl.

It is believed that, under all cases, a hot-side ESP is going to result in less mercury removal compared to a cold-side ESP. The only mercury typically collected by an ESP is that which is particulate-bound. At the temperatures at which a hot-side ESP operates, Hg<sub>p</sub> simply does not form.

## 7.2 Recommendations

Based upon the results of the sampling completed under this project, we recommend the following actions. The first is to better evaluate the results at Joliet, where the ESP appeared to remove almost 80% of the mercury emitted. This is a very high removal rate for a PRB coal. It is important to ensure that these results were not an anomaly. Further testing should be conducted to first validate these results and then to correlate these results to coal chemistry and/or plant configurations and operation.

The second recommendation is based on the stated objectives of the project: to use modeling techniques to extrapolate results of this project to the entire fleet of plants owned by EME. The quantity of mercury can be estimated based on the mercury concentration in the coal and the F<sub>d</sub> factors as provided in EPA Method 19. To do this, it is necessary to obtain the ultimate and proximate analyses of the coal burned at each facility. It is recommended that coal and fly ash samples from each of EME's units be collected and analyzed. The results of the coal and ash analyses, together with information regarding each unit's configuration, will be entered into the relational mercury-modeling database developed by the EERC to arrive at an estimate of the total mercury inventory for EME. The current database has nominally over 330,000 results from 50,000 samples collected from 100 plants, as well as bench- and pilot-scale systems. The database includes detailed information on analysis (sample type and analytical method), engineering (system type, design, and operating parameters), and material (sample type and origin) and can retrieve all samples that meet any given criteria. Using the database regression techniques and artificial intelligence, correlations will be produced by the EERC to predict mercury speciation based on fuel analysis and plant configuration.

## 8.0 REFERENCES

1. EPRI. *An Assessment of Mercury Emissions from U.S. Coal-Fired Power Plants*; EPRI Report 1000608; Oct 2000.
2. Regulatory Findings on the Emissions of Hazardous Air Pollutants from Electric Utility Steam Generating Units. *Fed. Regist.* **2000**, 65 (245), 79825–79831.
3. Carey, T.R.; Skarupa, R.C.; Hargrove, O.W. Jr. *Enhanced Control of Mercury and Other HAPs by Innovative Modifications to Wet FGD Processes*; Phase I Report for U.S. Department of Energy Contract DE-AC22-95PC95260; Aug 28, 1988.
4. Holmes, M.J.; Redinger, K.E.; Evans, A.P.; Nolan, P.S. Control of Mercury in Conventional Flue Gas Emissions Control Systems. Presented at the 4th International Conference on Managing Hazardous Air Pollutants, Washington, DC, Nov 12–14, 1997.

5. Miller, S.J.; Dunham, G.E.; Olson, E.S. Controlling Mechanisms That Determine Mercury Sorbent Effectiveness. Presented at the 92nd Annual Meeting & Exhibition of the Air & Waste Management Association, Paper 99-898, St. Louis, MO, June 1999.
6. Laudal, D.L.; Pavlish, J.H.; Galbreath, K.C.; Thompson, J.S.; Weber, G.F.; Sondreal, E.A. *Pilot-Scale Screening Evaluation of the Impact of Selective Catalytic Reduction for NO<sub>x</sub> on Mercury Speciation*; EPRI Report 1000755 for U.S. Department of Energy Cooperative Agreement DE-FC26-98FT40321; EERC Publication 2000-EERC-12-01; Energy & Environmental Research Center: Grand Forks, ND, Dec 2000.
7. ICR Reports. <http://www.epa.gov/ttn/uatw/combust/utiltox/utoxpg.html> (accessed Oct 7, 2000).
8. Hargrove, O.W. Jr.; Peterson, J.R.; Seeger, D.M.; Skarupa, R.C.; Moser, R.E. Update of EPRI Wet FGD Pilot-Scale Mercury Emissions Control Research. Presented at EPRI-DOE International Conference on Managing Hazardous and Particulate Air Pollutants, Toronto, Ontario, Canada, Aug 1995.
9. EPRI. *Power Plant Evaluation of the Effect of Selective Catalytic Reduction On Mercury*; EPRI Report 1005400 for U.S. Department Of Energy, Pittsburgh, PA, and U.S. Environmental Protection Agency, Research Triangle Park, NC, 2002.
10. Gutberlet, H.; Schlüten, A.; Lienta, A. SCR Impacts on Mercury Emissions on Coal-Fired Boilers. Presented at EPRI SCR Workshop, Memphis, TN, April 2000.
11. Sjostrom, S.; Ley, T; Anderson, G., Harrington, P. Development of a Sample Conditioning System for Reliable, Continuous Mercury Measurements in Coal-Fired Flue Gas. Presented at Air Quality III: Mercury, Trace Elements, and Particulate Matter Conference, Washington, DC, Sept 2002.

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