

## ENHANCED MERCURY COLLECTION USING THE INDIGO AGGLOMERATOR

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### **ABSTRACT**

Recent regulations in the US require Mercury emission control on coal fired power stations. Mercury is considered a major health hazard because it concentrates in the food chain and, in particular, may result in very high concentrations in some fish. The Indigo Agglomerator enhances Mercury collection by increasing the interaction between the Mercury, in the form of elemental or ionic molecules contained in the gas stream, and the adsorbent, either injected Activated Carbon or using the LOI from the combustion process. Initial tests have shown a factor of four enhancement of the Mercury removal when an Indigo Agglomerator is installed in front of an electrostatic precipitator. This is in compliance with the long term EPA requirements in the US.

## **INTRODUCTION**

Mercury is a toxic, persistent pollutant that accumulates in the food chain. Mercury in the air is a global problem. While fossil fuel-fired power plants are the largest remaining source of human-generated mercury emissions in the United States, they contribute only a small amount (about 1 percent) of total annual Mercury emissions worldwide.

On March 15, 2005, the United States EPA issued the Clean Air Mercury Rule to permanently cap and reduce mercury emissions from coal-fired power plants for the first time ever. This rule makes the United States the first country in the world to regulate mercury emissions from utilities. The Clean Air Mercury Rule will significantly reduce Mercury emissions from coal-fired power plants -- the largest remaining sources of mercury emissions in the country. When fully implemented, these rules will reduce utility emissions of mercury from 48 tons a year to 15 tons, a reduction of nearly 70 percent. A number of U.S. states have enacted or plan to enact regulations to require even greater reductions in Mercury emissions; many require a 90% reduction.

### **Mercury Emissions - A Global Problem**

Mercury emitted from coal-fired power plants comes from mercury in coal, which is released when the coal is burned. Coal-fired power plants emit mercury in three different forms: oxidized mercury (likely to deposit locally); elemental mercury, which travels hundreds and thousands of miles before depositing to land and water; and mercury that is in particulate form. Because mercury can be transported thousands of miles in the atmosphere, and because many types of fish are caught and sold globally, effective exposure reduction will require reductions in global emissions.

Concentrations of mercury in the air are usually low. However, atmospheric mercury falls to Earth through rain, snow and dry deposition and enters lakes, rivers and estuaries. Once there, it can transform into, methylmercury, and can build up in fish tissue. We are exposed to methylmercury primarily by eating contaminated fish. Because the developing fetus is the most sensitive to the toxic effects of methylmercury, women of childbearing age are regarded as the population of greatest concern. Children who are exposed to methylmercury before birth may be at increased risk of poor performance on neurobehavioral tasks, such as those measuring attention, fine motor function, language skills, visual-spatial abilities and verbal memory. More information is available at <http://www.chem.unep.ch/mercury/Report/Key-findings.htm>.

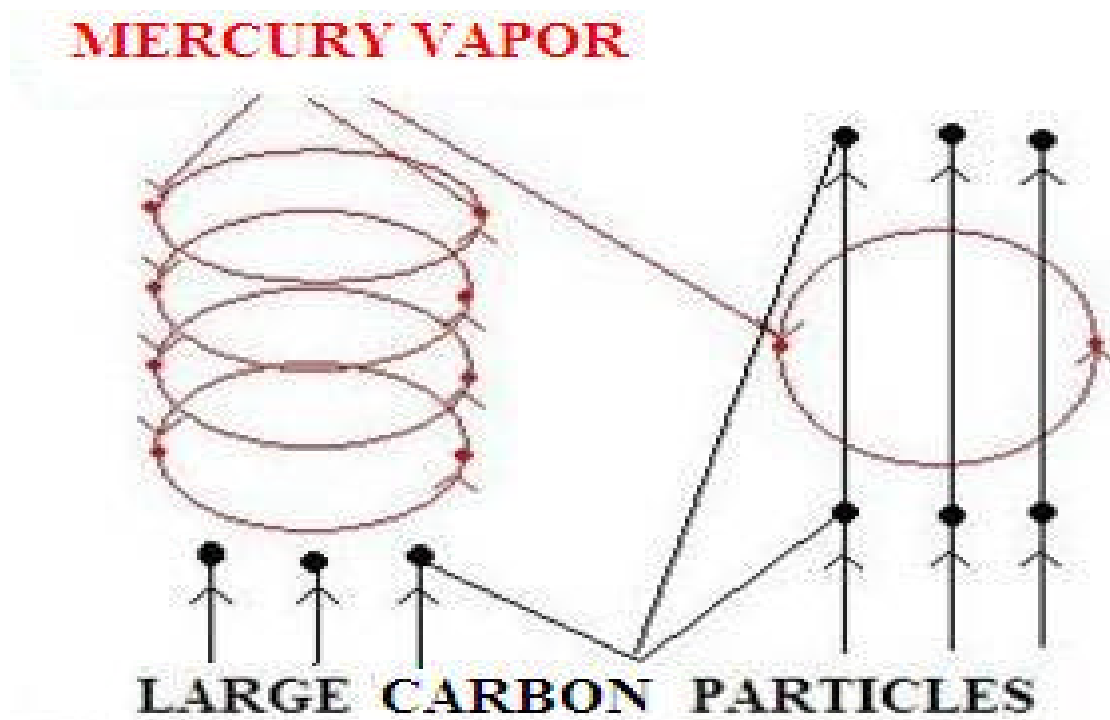
Environmental protection agencies around the world are looking at the Mercury problem and developing strategies to regulate the emission of Mercury to the atmosphere. The United States is the first country to regulate Mercury emissions but others will soon follow their lead, Mercury emission control from coal fired power stations will be the focus for future regulation in many countries. The EU are currently reviewing the effects of current EU law on Mercury emissions, providing information to support further Mercury emission cuts in Member States and studying the implications of additional control of releases from coal burning power stations.

Power stations with electrostatic precipitators generally collect between 20% and 50% of the Mercury in the coal, depending upon the coal properties and, in particular, the level of un-burnt carbon in the form of soot emitted from the boiler. As the level of un-burnt carbon increases more Mercury is adsorbed by the carbon and the Mercury emissions will be reduced. Mercury removal can be increased up to about 70% by adding Activated Carbon to

the exhaust gas following the Air-heater; Mercury is effectively adsorbed by carbon at low temperatures, generally below 160°C. Removal efficiencies of 90%, as requires in some U.S. states, are difficult to achieve with an electrostatic precipitator, even using Activated Carbon injection.

### THE INDIGO AGGLOMERATOR SOLUTION

The Indigo Agglomerator enhances the rate that Mercury is adsorbed by the carbon because the intense mixing generated in the Indigo Agglomerator increased the interaction between the Mercury and the carbon particles. This intense mixing generates micro-turbulences that entrain the Mercury vapor but have insufficient energy to entrain the large carbon particles. Thus there is a significant increase in the interaction between the Mercury and the carbon particles, as depicted in Figure 1, resulting in an increased rate of Mercury take-up by the carbon particles, whether they are un-burnt carbon from the coal combustion or injected Activated Carbon.



*Figure 1- Increased Mercury-carbon interaction*

### Test Results at Watson Power Station

A single set of Mercury tests at full load were carried out at the Mississippi Power's Plant Watson on Indigo Agglomerator trial installation on Unit 4 in January, 2004. The plant was burning Columbian CMC coal, which had a LOI level of between 9% and 16% and NO sorbent, such as Activated Carbon, was injected. The CMC coal was selected because it normally produced a high level of LOI, which is the prime Mercury sorbent produced by the combustion process. Coal ash samples taken from the three electrostatic precipitator ash hoppers during the Mercury tests were analyzed and the un-burnt carbon measurements are given in Table 1.

Table 1 – Percentage un-burnt carbon measured in each electrostatic precipitator hopper

	Front Hopper	Middle Hopper	Rear Hopper
A Side Hoppers	8.7%	9.7%	14.3%
B Side Hoppers	7.0%	13.6%	23.0%

Much of the un-burnt carbon from this coal is in the form of soot, very fine carbon particles formed from the incomplete combustion of heavy hydrocarbons (oils) in the coal. The soot, being very fine particles, is mainly collected in the rear of the electrostatic precipitator, as can be seen from Table 1. The Indigo Agglomerator increases the electrostatic precipitator fine particle collection efficiency, hence the higher carbon found in the rear hoppers on B Side. The lower carbon level in the front hopper indicates a lower un-burnt carbon level on B Side and therefore one would expect less Mercury removal.

Total Mercury trap sampling in triplicate was performed by the Southern Research Institute at the Air-heater Outlet, the Indigo Agglomerator Outlet and the Electrostatic Precipitator Outlet on B Side and at the Air Heater Outlet and Electrostatic Precipitator Outlet on A Side. The Mercury Traps and Plugs or Pre-filters, used to trap particulate prior to the Mercury Trap, were sent to Frontier Science for analysis. The coal was also analyzed and was found to contain Mercury equivalent to 4.5ug/m<sup>3</sup> at the Air-heater Outlet. The sample point locations are shown in Figure 2.

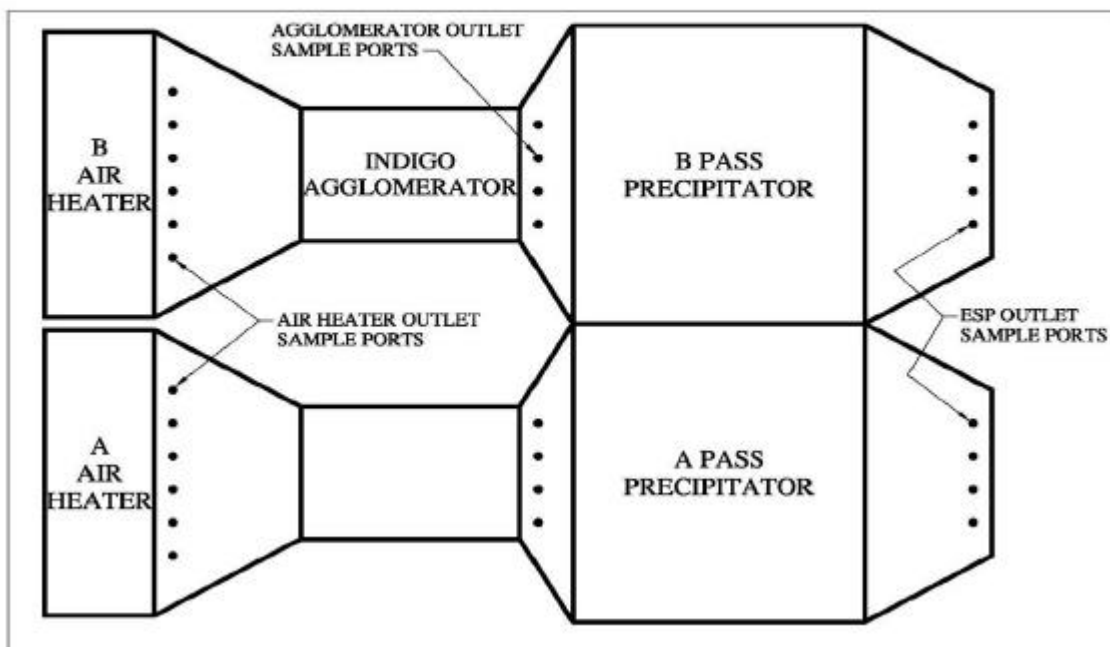


Figure 2 – Mercury sample points

Three separate samples were taken at the A Side Air-heater Outlet concurrently with four samples at the A Side electrostatic precipitator outlet on the 27<sup>th</sup> January, 2004. Six samples were taken at the B Side Air-heater Outlet, three concurrently with the three at the Indigo Agglomerator Outlet and three concurrently with three at the A Side electrostatic precipitator

outlet on the 28<sup>th</sup> January, 2004. The 19 sealed Mercury Traps along with the Plugs or Pre-filters were sent to Frontier Science for analysis. The Total Mercury results measured by Frontier Science, as supplied by the Southern Research Institute, are given in Table 2.

Although most of the results looked reasonable, the total Mercury in the B Side Air-heater Outlet Traps (0.79ug/m<sup>3</sup>) was very low compared to that expected based on the coal analysis (4.5ug/m<sup>3</sup>) and the A Side Air-heater Outlet analysis results (4.25ug/m<sup>3</sup>). After consideration, it was thought likely that the Mercury may have been trapped by the LOI carbon particles captured in the Plugs or Pre-filters. After some weeks it was decided to have Frontier Science analyze the Plugs or Pre-filters to determine the level of Mercury present. This was found to be very high on B Side and lifted the Total Mercury concentration at the Air-heater Outlet from 0.79ug/m<sup>3</sup> to 2.64ug/m<sup>3</sup>, there was more than twice the Mercury in the Plug or Pre-filter than there was in the actual Mercury Trap. The main variation was at the B Side Air-heater Outlet and the Indigo Agglomerator Outlet, the variation in the other results was quite small, as little Mercury was found in the Plug or Pre-filter. This data shows a 65.5% reduction in Mercury emission on B Side with the Indigo Agglomerator compared to a 20.6% reduction across the electrostatic precipitator on A Side. This is a 70% improvement in Mercury removal on B Side electrostatic precipitator with the Indigo Agglomerator compared to the A Side electrostatic precipitator.

There is still a large difference in the Mercury concentration at the B Side Air-heater Outlet (2.64ug/m<sup>3</sup>) compared to A Side Air-heater Outlet and the coal data (4.5ug/m<sup>3</sup>). Because the Plugs or Pre-filters were not stored in sealed containers during the period between the sampling and the analysis, some weeks later, it is certain that some of the Mercury in the Plugs or Pre-filters would have escaped, since Mercury will evaporate at normal temperatures. By assuming a similar percentage loss from all Plugs or Pre-filters, the Plugs or Pre-filters Mercury can be adjusted until both A Side and B Side Air-heater Outlets are about the same. This indicated that the loss of Mercury from the Plugs or Pre-filters was about 54%, which is reasonable given the extended time between sampling and analysis. As shown in Table 3, the reduction in Mercury emission on B Side with the Indigo Agglomerator is 78% compared to a 16% reduction across the electrostatic precipitator on A Side. This is an 80% improvement in Mercury removal on B Side electrostatic precipitator with the Indigo Agglomerator compared to the A Side electrostatic precipitator.

The effect of Mercury adsorption by the carbon caught in the per-filter was very small at the electrostatic precipitator outlet. If the inlet Mercury concentration was the same, the collection trap measurements at the electrostatic precipitator outlet show almost a 75% improvement in Mercury removal on B Side electrostatic precipitator (0.82mg/m<sup>3</sup>) with the Indigo Agglomerator compared to the A Side electrostatic precipitator (3.2mg/m<sup>3</sup>). The Mercury emissions from the A Side electrostatic precipitator are four times that emitted from the B Side electrostatic precipitator equipped with an Indigo Agglomerator. The results are almost the same if the Mercury adsorbed in the per-filter is included. This shows a significant reduction in Mercury emissions from the B Side electrostatic precipitator even though the un-burnt carbon level in the front hopper is lower, which should indicate a lower level of Mercury adsorption as there is less un-burnt carbon to adsorb the mercury.

## CONCLUSION

Despite problems with the Mercury measurement and analysis at the B side Air-heater Outlet and the Indigo Agglomerator Outlet sample points, the test data measured at both electrostatic precipitator outlets was consistent and reliable, since the LOI levels were much lower and the Mercury caught by the Plug or Pre-filter was minimal. The Mercury emissions were much lower, 0.9 ug/m<sup>3</sup> to 1.0ug/m<sup>3</sup>, on B Side with the Indigo Agglomerator compared to A Side

with just the electrostatic precipitator, 3.6ug/m<sup>3</sup> to 4.0ug/m<sup>3</sup>. **This indicates a consistent 75% reduction in Mercury emissions with the Indigo Agglomerator installed.** The data shows a removal efficiency of between 65% and 79% with the Indigo Agglomerator and the electrostatic precipitator compared to 16% to 21% with the electrostatic precipitator alone. **This indicates a huge 300% to 500% increase in Mercury emissions from the A Side electrostatic precipitator, without the Indigo Agglomerator installed, compared the B Side electrostatic precipitator, with an Indigo Agglomerator installed at the inlet.**

**Plant Watson Unit 4 Mercury Carbon Trap Test Results**

Date	Start Time	End Time	Sample ID	SRI Sample Vol (Liters)	SRI Blank Corrected (ug/m <sup>3</sup> )				Revised Averages With Plugs (ug/m <sup>3</sup> )
1/27/2004	1420	1445	WAI-1-FSTMA	15.45	4.88				
1/27/2004	1508	1540	WAI-2-FSTMA	15.40	3.80	A Side Air-heater Outlet	4.25	(ug/m <sup>3</sup> )	4.51
1/27/2004	1607	1647	WAI-3-FSTMA	15.14	4.06				
1/27/2004	1420	1446	WAO-1-FSTMA	15.02	3.58				
1/27/2004	1513	1537	WAO-2-FSTMA	15.02	3.32	A Side ELECTROSTATIC PRECIPITATOR Outlet Average	3.20	(ug/m <sup>3</sup> )	3.58
1/27/2004	1613	1632	WAO-3-FSTMA	15.04	3.02				
1/27/2004	1720	1747	WAO-4-FSTMA	15.02	2.89				
1/28/2004	803	847	WBI-1-FSTMA	15.17	1.08				
1/28/2004	913	950	WBI-2-FSTMA	15.04	0.44	B Side Air-heater Outlet	0.79	(ug/m <sup>3</sup> )	2.64
1/28/2004	1015	1103	WBI-3-FSTMA	15.16	0.84				
1/28/2004	805	836	WBO-1-FSTMA	15.03	0.74				
1/28/2004	858	930	WBO-2-FSTMA	15.08	0.83	B Side ELECTROSTATIC PRECIPITATOR Outlet Average	0.82	(ug/m <sup>3</sup> )	0.91
1/28/2004	1020	1052	WBO-3-FSTMA	15.02	0.89				
1/28/2004	1202	1247	WBI-4-FSTMA	15.28	0.50				
1/28/2004	1330	1410	WBI-5-FSTMA	15.20	0.39	B Side Air-heater Outlet	0.53	(ug/m <sup>3</sup> )	2.50
1/28/2004	1430	1510	WBI-6-FSTMA	15.35	0.72				
1/28/2004	1200	1244	WBAGO-1-STMA	15.04	0.36				
1/28/2004	1329	1408	WBAGO-2-STMA	15.03	0.66	B Side Indigo AG Outlet Average	0.51	(ug/m <sup>3</sup> )	2.08
1/28/2004	1430	1510	WBAGO-3-STMA	15.04	0.50				

**Note:** Significant problems on B side with high unburned carbon levels and loading of prefilters which had to be changed out at least once per test.

*Table 2 – Mercury test results supplied by The Southern Research Institute*

**Mercury Test Data Watson Generating Plant with LOI from CMC Coal**

	Mercury Measured in Collection Trap ug/m <sup>3</sup>	Mercury Measured in Filter and Collector ug/m <sup>3</sup>	Mercury in Filter ug/m <sup>3</sup>	Mercury in Filter with 54% Loss ug/m <sup>3</sup>	Total Mercury with 54% Loss ug/m <sup>3</sup>	Removal Efficiency %
<b>A Side Air-heater Outlet</b>	4.25	4.51	0.26	0.57	4.82	16.4%
<b>A Side ESP Outlet</b>	3.2	3.58	0.38	0.83	4.03	
<b>B Side Air-heater Outlet</b>	0.79	2.64	1.85	4.02	4.81	78.9%
<b>B Side ESP Outlet</b>	0.82	0.91	0.09	0.20	1.02	
<b>B Side Air-heater Outlet</b>	0.53	2.5	1.97	4.28	4.81	18.5%
<b>B Side Agglomerator Outlet</b>	0.51	2.08	1.57	3.41	3.92	

**NOTE - Estimate of Mercury from Coal analysis is 4.5ug/m<sup>3</sup>**

**Increased Mercury emissions from A Side electrostatic precipitator 481.4%**

**Mercury removal improvement with Agglomerator is 77.5%**

*Table 3 – Mercury measurement correction and analysis*