Mercury Control Challenge for Industrial Boiler MACT Affected Facilities

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Introduction

On February 26, 2004, the National Emission Standard for Hazardous Air Pollutants (NESHAP) for industrial, commercial, and institutional boilers and process heaters was finalized by the U.S. Environmental Protection Agency (EPA). This rule, also known as the Industrial Boiler MACT rule, limited the emissions of certain hazardous air pollutants (HAPs), including mercury. The mercury emission limit for existing, large (boiler heat input greater than 10 MMBtu/hr), coal-fired boilers was set at 9.0 lb/TBtu.

On June 8, 2007, the U.S. Court of Appeals D.C. Circuit Court issued a decision to vacate the Industrial Boiler MACT rule. The EPA is currently re-developing the rule and it is anticipated that a draft of the new rule will be issued in the second half of 2009 or early 2010. It is widely anticipated that the emission limits contained in the new rule will be significantly stricter than the original rule. Specifically, the new mercury emission limit for existing, large, coal-fired boilers may be as low as 1.0 or 2.0 lb/TBtu, which will require very high removal efficiencies for many facilities.

It is generally believed that coal-fired boilers equipped with fabric filters and supplemented with relatively low levels of sorbent injection (3 lb/MMacf or less) are capable of achieving a high level of mercury removal; greater than 80 percent. This belief is based largely on experience from coal-fired electric utility boilers. The vast majority of full-scale mercury testing conducted in the last decade has been on electric utility coal-fired boilers in which the flue gas temperature is generally less than 325 °F. Furthermore, the vast majority of these tests have been conducted on units in which the particulate control device is an electrostatic precipitator. Relatively few tests have been conducted on fabric filters because of the relatively good mercury control observed inherently and with sorbent injection and the relatively low flue gas temperature. However, industrial boilers present a unique challenge because the flue gas temperature entering the particulate control device is typically well above 350 °F, which makes mercury removal more difficult, even with sorbents.

This article will present a case history that demonstrates some key differences between utility and industrial coal-fired boiler applications and why the expected new mercury emission limit for the Industrial Boiler MACT will represent a significant challenge for many coal-fired industrial boilers.

Facility Background

The industrial facility cited in this paper includes two coal-fired boilers. Through testing and a feasibility study between 2003 and 2006, the facility determined that sorbent injection ahead of the fabric filter on each boiler would be required to achieve compliance with the mercury limit contained

in the original Industrial Boiler MACT rule. Therefore, in January 2007, the facility embarked upon a full-scale test program on one of the boilers to evaluate the effectiveness of sorbent injection for mercury removal. The results of the testing were intended to provide direction to the facility for implementation of permanent sorbent injection systems for Industrial Boiler MACT compliance.

The facility burns eastern bituminous coal with a nominal heating value of 12,500 Btu/lb and a sulfur content of less than 1.0 percent. The mercury concentration in the coal typically ranges between 3.0 and 9.0 lb/TBtu. The chlorine concentration in the coal is nominally 1,000 ppm. The boiler is an overfeed stoker boiler equipped with a pulse-jet fabric filter, conservatively sized with a 3.4 net air-to-cloth ratio and six compartments. The filter bags are 16 feet long, 6 inch diameter, and composed of 16 oz/yd^2 woven fiberglass, with 10% Teflon B finish. The typical full load flue gas temperature entering the fabric filter is 375 °F. The Sulfur Trioxide (SO_3) concentration in the flue gas entering the fabric filter is estimated to be between 10 to 20 ppm.

The challenge facing the facility was to demonstrate what level of mercury removal could be achieved with sorbent injection ahead of a fabric filter with relatively high flue gas temperature and moderate levels of SO_3 present in the flue gas.

Test Program Description

The sorbent injection testing was conducted over a two-week period in January 2007. A total of 23 test runs were conducted to evaluate the effectiveness of three different sorbents at varying sorbent injection rates. Each test run was approximately 90 minutes in duration. The three sorbents tested were: Norit Americas Darco Hg, which was selected as the low cost sorbent; Sorbent Technologies B-PAC, which was selected for high temperature performance; and a B-PAC/lime mix, which was selected to mitigate the potential effects of SO_3 "blinding". The B-PAC/lime mixture was 30 percent (by weight) B-PAC and 70 percent lime.

Mercury emissions were measured at the inlet and outlet of the fabric filter using the Appendix K sorbent trap method. SO_3 emissions were measured at the outlet of the baghouse on some runs using EPA Method 8A. Coal samples from each day's testing were analyzed for proximate analysis, ultimate analysis, and mercury concentration. Fly ash samples from each day's testing were analyzed for mercury concentration, SO_3 concentration, and loss on ignition (LOI). Boiler operating parameters were recorded during the test runs.

Test Results and Discussion

The test results are summarized in Table 1. A graph summarizing the mercury removal efficiency across the fabric filter versus the sorbent injection rate for all of the test runs is presented in Figure 1.

In general, the mercury removal across the fabric filter was much less than expected. It is believed that the primary cause of the poor mercury removal performance was the relatively high flue gas temperature, which limited the performance of the sorbents more than expected. Secondary factors contributing to the poor performance may be the higher-than-expected SO_3 concentrations in the flue gas and the unexpectedly poor mercury removal capability of the LOI in the ash. These issues are discussed further below.

- Mercury removal across the fabric filter was expected to be between 45 and 55 percent at sorbent injection rates between 2.0 and 4.0 lb/MMacf. This expectation was based on budgetary proposals received from sorbent injection system suppliers during a 2005 feasibility study and from previous budgetary proposals received on similar projects. The quoted injection rates were higher than typical injection rates for utility fabric filter applications, which typically operate closer to 300 °F, to account for the higher flue gas temperature of this application.

- Mercury removal does appear to generally increase with increasing sorbent injection rate, as expected, but the injection rate curve is very flat when compared to the typically steep injection rate curves for coal-fired utility boilers utilizing

Table 1. Sorbent Injection Test Results Summary

Note: Negative mercury removal values indicate a higher mercury concentration measured at the stack than measured in the coal or prior to the fabric filter (FF).

Run ID	Coal Data Hg lb/TBtu	Boiler Load pph	Sorbent	Sorbent Injection Rate lb/hr	Sorbent Injection Rate lb/MMacf	Lime Portion	FF Inlet Hg Emissions lb/TBtu	FF Outlet Hg Emissions lb/TBtu	Mercury Removal Efficiency Coal-to-FF %	Across FF %	Coal-to-Stack %
Baseline	5.20	135,000	None	0	0		7.50	6.79	-44%	9%	-31%
Run-1	4.47	133,000	Darco Hg	14.4	2.1		5.08	5.76	-13%	-13%	-29%
Run-2	4.47	135,000	Darco Hg	14.4	2.1		6.13	6.07	-37%	1%	-36%
Run-3	4.47	135,000	Darco Hg	40	5.8		5.33	3.61	-19%	32%	19%
Run-4	4.47	139,000	Darco Hg	40	5.8		6.35	4.46	-42%	30%	0%
Run-5	6.03	138,000	B-PAC	14.4	2.1		7.35	5.59	-22%	24%	7%
Run-6	6.03	136,000	B-PAC	23	3.3		5.63	5.21	7%	7%	14%
Run-7	6.03	137,000	B-PAC	23	3.3		5.64	5.11	6%	10%	15%
Run-8	5.25	158,000	B-PAC	23	3.5		7.97	5.78	-52%	27%	-10%
Run-9	5.25	158,000	B-PAC	31.5	4.7		4.67	5.21	11%	-12%	1%
Run-10	5.25	148,000	B-PAC	57	8.6		7.43	3.85	-41%	48%	27%
				Total lb/hr	B-PAC Portion lb/MMacf	Lime Portion lb/hr					
Run-11	4.39	147,000	B-PAC/lime	18	0.7	13	3.47	3.86	21%	-11%	12%
Run-12	4.39	145,000	B-PAC/lime	18	0.7	13	2.68	2.68	39%	0%	39%
Run-13	4.39	145,000	B-PAC/lime	18	1.4	26	2.19	1.65	50%	25%	63%
Run-14	4.39	159,000	NONE	baseline	0		2.66	2.75	39%	-4%	37%
					B-PAC Portion lb/MMacf	Lime Portion lb/hr					
Run-15	5.51	161,000	B-PAC/lime	9	0.4	6.3	3.34	3.05	39%	9%	45%
Run-16	5.51	163,000	B-PAC	10	1.3		3.31	2.97	40%	10%	46%
Run-17	5.51	160,000	B-PAC	20	2.7		3.11	2.93	43%	6%	47%
Run-18	6.59	159,000	B-APC	54	6.9		2.79	1.98	58%	29%	70%
Run-19	6.59	145,000	NONE	baseline	0		3.05	3.25	54%	-6%	51%
Run-20	6.59	145,000	NONE	baseline	0		2.66	2.03	60%	24%	69%
Run-21	5.13	146,000	Darco Hg	27	3.5		2.46	1.58	52%	36%	69%
Run-22	5.13	140,000	Darco Hg	27	3.5		1.82	1.27	65%	30%	75%

fabric filters. Typical injection rate curves for coal-fired utility fabric filters have a very steep slope at low injection rates (1.0 to 5.0 lb/MMacf) and then flatten out at higher injection rates.

- Although the data is very scattered, it appears that the Darco Hg sorbent performed better than the B-PAC sorbent or the B-PAC/lime sorbent. However, the B-PAC portion of the B-PAC/lime sorbent was injected at lower rates than the Darco Hg or straight B-PAC. The overall curve for the B-PAC/lime sorbent appears to show more potential that the other two sorbents.

- Fabric filter outlet SO_3 concentration was measured at 21 ppm for the baseline condition (no sorbent injection), which was higher than expected. If the SO_3 concentration is this high at the fabric filter inlet, then it is likely negatively affecting the PAC performance. Full-scale testing on utility coal-fired boilers has suggested that SO_3 concentrations as low as 5 to 10 ppm can negatively affect PAC performance. SO_3 and mercury are both competing for adsorption sites on the PAC particle and the SO_3 is preferentially adsorbed.

- Fabric filter outlet SO_3 concentrations during the sorbent injection runs were between 5 and 8 ppm, confirming that the PAC injection is likely adsorbing and reducing the SO_3 concentration in the flue gas.

- It is difficult to determine from the data if the lime portion of B-PAC/lime sorbent mixture effectively reduced the SO_3 and minimizing the blinding of the B-PAC. Due to limitations during the testing, the B-PAC/lime injection rate was below the target injection rate of 47 lb/hr. As a result, the lime injection rate utilized during Run-11, -12, and -15 may not have been adequate

enough for significant SO_3 reduction. The lime portion of the mix was injected at stoichiometric ratios (moles of lime / moles of SO_3 removed, as estimated by Burns & McDonnell) between 0.8 and 1.6 and the mercury removal efficiency was no higher than 9 percent during these runs. In general, a stoichiometric ratio of approximately 2.0 is required to achieve 50% SO_3 reduction.

- There are varying opinions among sorbent injection suppliers on whether or not co-injection of carbon and lime is effective. One supplier believes the lime must be injected separate from, and upstream of, the carbon injection. Therefore, it is possible with co-injection, even at higher lime injection rates, that the potential for SO_3 blinding of the sorbent may not be reduced or eliminated.

- It is generally believed that high levels of LOI in the fly ash can serve to increase the inherent mercury removal across a fabric filter. This belief is based on experiences from coal-fired utility boilers. However, testing at this facility indicated that despite LOI concentrations in the fly ash typically at 30 percent or greater, it provided no significant mercury removal. It is believed that the lack of mercury removal at this facility was due to the extremely low surface area ash (characteristic of stoker boilers) compared to that of utility boilers. This provides another example of utility coal-fired boiler experience not translating well to industrial coal-fired boiler applications.

- There is limited full-scale testing of sorbent injection ahead of baghouses to compare against the test results from this facility. As of early 2007, there have been four (4) full-scale tests conducted in the U.S. on utility baghouses all of which were at flue gas temperatures near 300 °F. Figure 2 summarizes this utility testing data (blue and red symbols on the graph). We are aware of one full-scale test conducted on an industrial boiler baghouse at the DuPont Washington Works facility at which the flue gas temperature was 350 °F. The results of this sorbent injection test are also shown in Figure 2 by overlaying the test data (green symbols on the graph) with the utility data. Finally, the test data from the industrial facility discussed in this article are also overlaid on Figure 2 (refer to the yellow, pink, and blue trend lines).

- Sorbent injection suppliers have always maintained that the performance of carbon based sorbents is significantly affected above 350 °F. The comparison of the test data in Figure 2 supports this belief and is further evidence that the relatively poor mercury removal performance

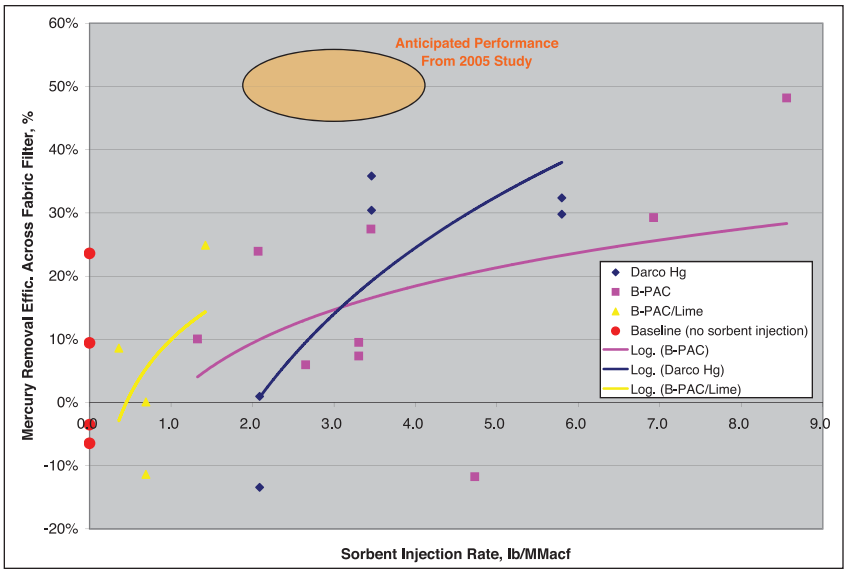

Figure 1. *Mercury removal efficiency across the fabric filter vs. sorbent injection rate.*

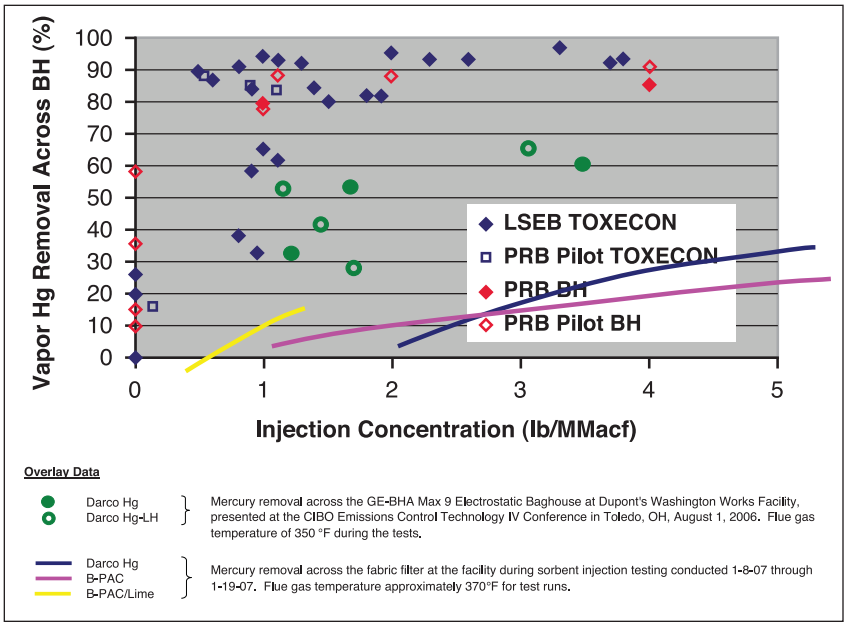

Figure 2. *Overlay of facility's sorbent injection test results against other full-scale baghouse sorbent injection tests.*
Source: Mercury control from power plants, Figure 6, R. Change, presented at the EPRI Mega Symposium, Baltimore, MD August 28, 2006.
Note: This data is believed to be at flue gas temperatures less than 325° F.

of the testing at this facility may be largely the result of the higher flue gas temperatures, which were typically near 370 °F.

Conclusions

An industrial coal-fired boiler facility conducted a test program to evaluate the effectiveness of sorbent injection on mercury removal ahead of a fabric filter with an inlet flue gas temperature of 375 °F. The results of the sorbent injection testing are essentially inconclusive relative to providing the facility with enough data upon which to base the design and implementation of permanent sorbent injection system(s). The mercury removal performance of the sorbents was significantly less than expected. The data suggests that 50 percent mercury removal across a baghouse with flue gas temperatures at or above 375 °F and containing moderate levels of SO_3 may be very difficult to achieve with activated carbon sorbent injection alone.

The challenge many coal-fired industrial facilities may face is the implementation of additional measures beyond sorbent injection to achieve high levels of mercury removal that will likely be required by the upcoming new Industrial Boiler MACT rule. To counter the negative effects of high flue gas temperature on mercury removal with sorbents, it may be necessary to retrofit additional boiler heat transfer surface or spray cooling of the flue gas upstream of the baghouse. Furthermore, to counter the negative effect of moderate or high SO_3 levels in the flue gas on mercury removal, it may be necessary to also inject sorbents, such as trona or hydrated lime, to reduce the SO_3 concentrations in the flue gas. **em**

References

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