



# Pilot Evaluation of the Impact of Chloride on SCR Mercury Oxidation—The Effect of Coal Blending

## Abstract

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A study has been completed that investigated the effect of blending PRB coal with an Eastern bituminous coal on the speciation of Hg across an SCR catalyst. In this project, a pilot-scale coal combustor equipped with an SCR reactor for NO<sub>x</sub> control was used for evaluating the effect of coal blending on improving Hg oxidation across an SCR catalyst. Several parameters such as the ratio of PRB/bituminous coal blend and the concentrations of hydrogen halides (HCl, HBr, and HF) and halogens (Cl<sub>2</sub> and Br<sub>2</sub>) in the flue gas were evaluated to determine their effects on the oxidation of Hg<sup>0</sup> under typical SCR NO<sub>x</sub> emission control conditions. The goal of the current study was to examine the oxidation of mercury using blends ranging from 10% PRB to 40% PRB with the balance being Eastern bituminous coal, and compare those results to mercury oxidation when firing pure bituminous and pure PRB fuel.

## Experimental Apparatus and Approach

The multi-pollutant control research facility (MPCRF), located at EPA's Research Triangle Park campus, was used for the PRB and bituminous coal blending speciation tests. The MPCRF is a 4 MM Btu/hr multi-fuel furnace that can fire pulverized coal, fuel oil, or natural gas. A schematic of the facility is shown in Figure 1. The facility consists of the combustor, a series of heat exchangers to simulate the convective section, a selective catalytic reduction (SCR) unit, a fabric filter, and a lime slurry wet scrubber. The MPCRF is equipped with two sets of continuous emissions monitors (CEMs) for measuring different flue gas species including sulfur dioxide (SO<sub>2</sub>), nitrogen oxide (NO<sub>x</sub>), carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), and oxygen (O<sub>2</sub>). These measurements were taken at the inlet to the SCR and prior to the inlet of the baghouse. NO<sub>x</sub> measurements were taken at the inlet and outlet of the SCR to determine the NO<sub>x</sub> reduction efficiency.

A low-sulfur PRB coal from the North Antelope seam located in Wyoming was used as the baseline coal in these tests. A medium sulfur Eastern bituminous coal (Pittsburgh #8) was used to increase the amount of chlorine in the fuel blends. The effect of the SCR unit on Hg speciation was tested at four different PRB/bituminous blending ratios, 60%/40%, 70%/30%, 80%/20%, and 90%/10%. Along with the two baseline tests of 100% PRB and 100% of bituminous, as well as one repeated blend test, a total of 7 tests were conducted for this study.

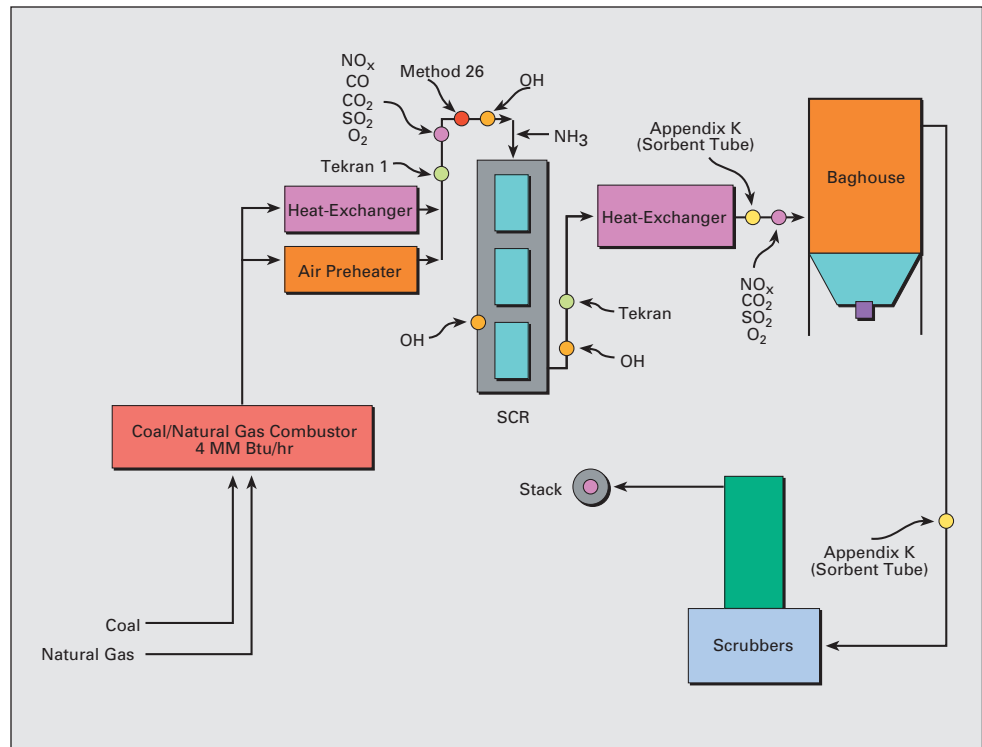


Figure 1. Schematic of Multi-Pollutant Control Research Facility showing the sampling locations.

**The primary speciated mercury measurement was made using the Ontario Hydro (OH) method.**

The SCR unit consists of three full length sections of honeycomb SCR catalyst elements (each section containing nine honeycomb catalyst elements of 1327 mm length and 150 mm square cross-section). The catalyst that was used in this system was manufactured by Cormetech. This catalyst was used for 3 ozone seasons at a coal-fired power plant that burned low sulfur Eastern bituminous fuel. The catalyst was removed from the full-scale unit because there was approximately 30% blockage of the catalyst channels. The catalyst was reconditioned to about 5% blockage.

Several sampling locations were used during these tests and are noted in Figure 1. The primary speciated mercury measurement was made using the Ontario Hydro (OH) method. The method was modified in that an in-stack filter was used in place of the standard hot box filter. Two OH impinger trains per day were pulled at the inlet and outlet of the SCR unit with a total sampling time of approximately 1.5 hours per train.

Halogen measurements were taken at the inlet of the SCR once per test condition using Method 26. Sorbent tubes were used to obtain total mercury concentrations at the inlet and outlet of the baghouse. Sorbent tube measurements at the inlet to the baghouse were biased due to the flyash buildup in the front section of the tube and the results are not reported.

The operating conditions for the tests are shown in Table 1. The SCR inlet temperature ranged from a high of 740 °F to a lower limit of 700 °F. The SCR outlet temperature was roughly 60-70 °F lower than the inlet temperature due to heat loss across the catalyst section, and ranged from 630 to 670 °F. The SCR inlet NO<sub>x</sub> concentration ranged from 530

Table 1. Operating conditions for tests.

PRB/BIT Ratio	SCR Inlet					SCR Outlet				
	NO <sub>x</sub> ppm	SO <sub>2</sub> ppm	CO <sub>2</sub> %	O <sub>2</sub> %	Temperature °F	NO <sub>x</sub> ppm	SO <sub>2</sub> ppm	CO <sub>2</sub> %	O <sub>2</sub> %	Temperature °F
100% Bit	625	990	14.7	5.1	725	65	988	14.4	5.0	660
65%/35%	570	457	13.7	6.7	700	28	432	13.5	6.6	630
70%/30%	575	421	14.6	5.4	720	42	400	14.2	5.6	660
74%/26%	530	365	14.1	6.2	740	32	349	14.2	5.6	670
79%/21%	545	263	14.3	5.9	710	13	175	13.6	6.3	650
91%/9%	530	169	13.5	6.8	730	10	77	13.1	7.1	665
100% PRB	580	153	15.8	4.7	725	48	126	15.1	5.0	665

to 625 ppm, with a greater than 90% reduction in NO<sub>x</sub> achieved across the SCR. Sulfur dioxide ranged from a high of 990 ppm for the 100% bituminous test to 153 ppm for the 100% PRB test. Excess oxygen concentrations in the flue gas were in the 5-6 % range.

## Results

**Halogen measurements were taken at the inlet of the SCR once per test condition using Method 26.**

Mercury concentration data from the coal blending tests are shown in Table 2. Elemental mercury, oxidized mercury, and total mercury are shown at the SCR inlet and SCR outlet. Two OH sampling trains were pulled during each test day. No particulate-bound mercury was detected as the temperature of the in-stack filter was above 600 °F. Mercury speciation results are shown in

Table 2. OH Results from Coal Blending Tests.

PRB/BIT Ratio	SCR Inlet				SCR Outlet			
	Hg <sup>0</sup> μg/m <sup>3</sup>	Hg <sup>2+</sup> μg/m <sup>3</sup>	Hg <sup>T</sup> μg/m <sup>3</sup>	Ox Hg <sup>2+</sup> %	Hg <sup>0</sup> μg/m <sup>3</sup>	Hg <sup>2+</sup> μg/m <sup>3</sup>	Hg <sup>T</sup> μg/m <sup>3</sup>	Ox Hg <sup>2+</sup> %
100% Bit - Sample 1	8.99	3.64	12.63	28.8	2.22	10.34	12.55	82.3
100% Bit - Sample 2	9.64	3.36	13.01	25.9	2.10	12.23	14.33	85.3
65%/35% - Sample 1	5.86	1.12	6.98	16.0	2.87	4.68	7.55	61.9
65%/35% - Sample 2	6.56	0.72	7.28	9.8	3.10	4.95	8.05	61.5
70%/30% - Sample 1	7.70	2.03	9.74	20.9	4.62	5.26	9.88	53.3
70%/30% - Sample 2	5.09	1.71	6.80	25.2	3.07	4.03	7.10	56.8
74%/26% - Sample 1	4.73	1.11	5.83	19.0	2.80	3.13	5.93	52.7
74%/26% - Sample 2*	8.38	0.36	8.74	4.1	7.08	1.23	8.31	14.8
79%/21% - Sample 1	6.36	0.32	6.68	4.8	5.50	0.52	6.02	8.7
79%/21% - Sample 2	5.51	0.46	5.97	7.6	3.98	1.89	5.87	32.2
91%/9% - Sample 1	5.09	0.23	5.32	4.3	4.28	1.04	5.31	19.5
91%/9% - Sample 2	5.23	0.27	5.50	4.9	3.71	0.94	4.65	20.2
100% PRB - Sample 1	5.52	0.37	5.90	6.4	6.36	0.15	6.51	2.2
100% PRB - Sample 2	5.89	0.40	6.30	6.4	5.89	0.21	6.10	3.4

\*This run has been omitted from the data set due to facility problems during the test.

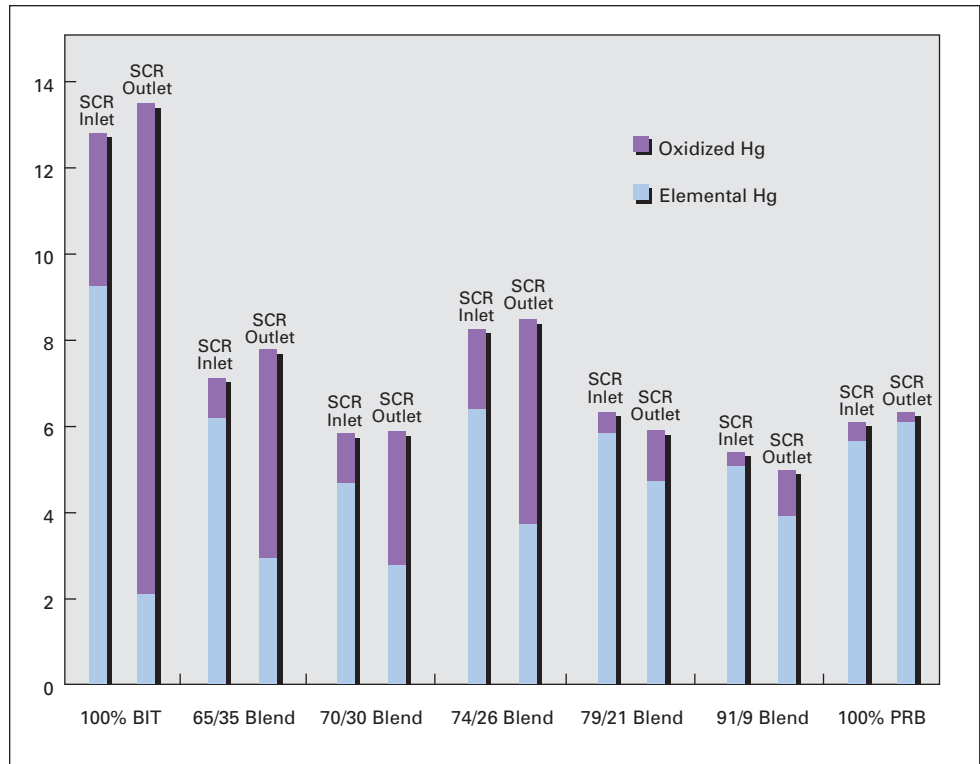


Figure 2. Mercury speciation results for different coal blend combinations.

**Oxidation of Hg is highly dependent on the halogen concentration in the flue gas.**

Figure 2. The amount of oxidized Hg is shown as an average of the two runs for each coal blend at the SCR inlet and outlet. The percentage of oxidized Hg is higher at the SCR inlet than at the SCR outlet for all of the test cases except for the 100% PRB run where the inlet and outlet oxidized concentrations were similar.

The percent oxidized mercury for the SCR inlet and SCR outlet is shown in Figure 3. The SCR inlet Hg oxidation is highest for the 100% bituminous coal run at about 27.3%. At the SCR outlet the Hg oxidation increases to 84%. The net increase in Hg oxidation across the SCR unit decreases with a corresponding decrease in bituminous coal. The net oxidation across the SCR for the PRB coal is slightly negative. It is clear that a higher degree of oxidation is obtained with the higher rank bituminous coal and corresponding higher chlorine content. An abrupt drop occurs when reducing bituminous blend fraction from 70% PRB/30% bituminous to 80% PRB/20% bituminous. The amount of  $Hg^{2+}$  was near 55% for the 70/30 blend and drops to 20% for the 80/20 blend. Similar lower  $Hg^{2+}$  results were obtained for the 90/10 blend tests.

Oxidation of Hg is highly dependent on the halogen concentration in the flue gas. Nearly all of the chlorine in the coal is converted into hydrogen chloride (HCl). Bituminous coal had the highest Cl concentration which translated into an HCl concentration of 60.8 ppm at the SCR inlet, while PRB had the lowest fuel Cl concentration which translates into an HCl concentration of below 5 ppm at the SCR inlet. Bromine and hydrogen bromide (HBr) were not detected in the flue gas at the SCR inlet, while hydrogen fluoride (HF) was present in concentrations of less than 5 ppm. It is therefore expected that the primary Hg oxidant is HCl. There is an excel-

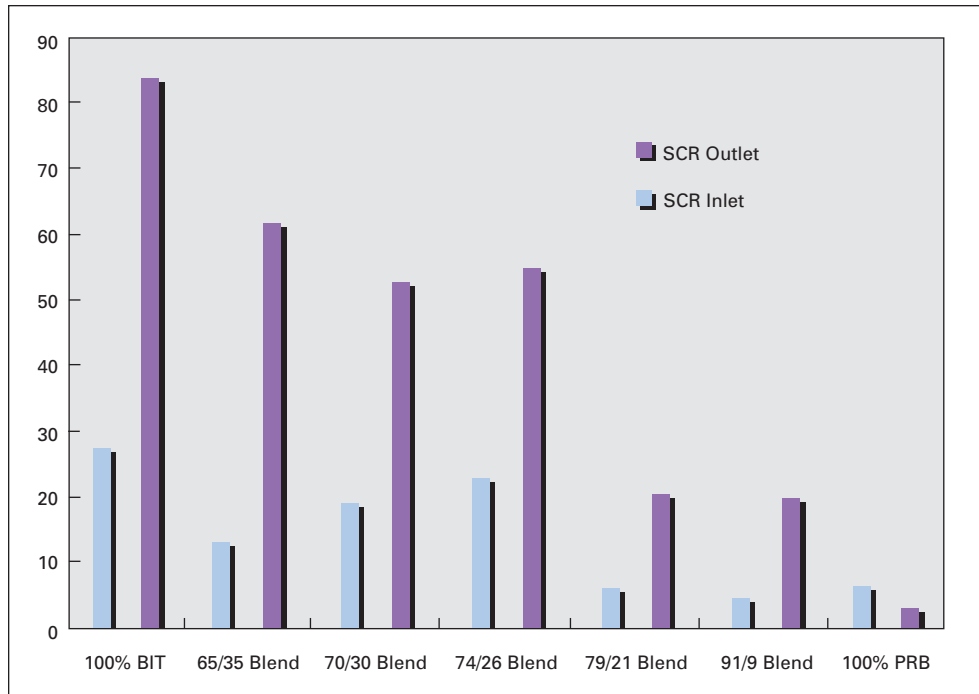


Figure 3. Percent oxidized mercury for SCR inlet and SCR outlet for different coal blend combinations.

**There is an excellent correlation for the HCl in the flue gas as a function of coal chlorine content.**

lent correlation for the HCl in the flue gas as a function of coal chlorine content, as shown in Figure 4. The one to one correlation is also shown in Figure 4 that indicates most of the chlorine is in the vapor phase and available for reacting with Hg.

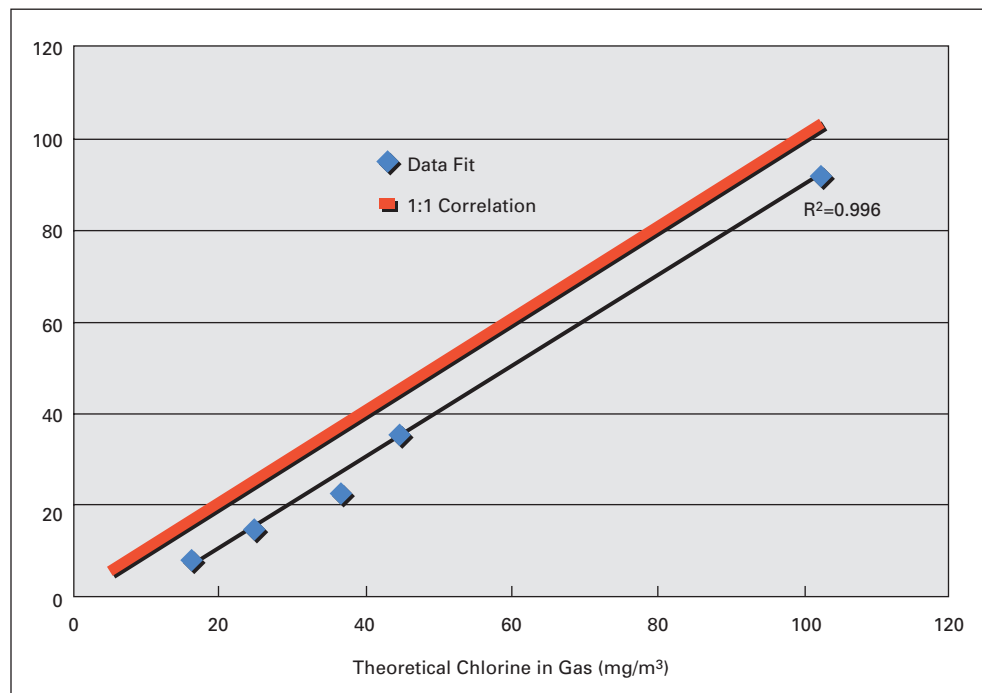


Figure 4. Gas-phase chlorine ( $HCl + Cl_2$ ) versus theoretical chlorine concentration.

**It was determined that a higher percentage of the total Hg was present as oxidized Hg at the SCR outlet as the chlorine in the coal increased.**

Mercury oxidation as a function of corresponding coal chlorine content is shown in Figure 5. From this chart one may estimate expected levels of oxidized mercury at the SCR outlet as a function of coal chlorine content. Notice the slope of the line for the SCR outlet decreases right around 250 ppm (70% PRB/30% bituminous blend). Increasing the chlorine content 3 fold from 300 ppm to 900 ppm only nets an increase of roughly 30%.

## Conclusions

Coal blending tests were conducted to investigate the effect of blending PRB coal with an Eastern bituminous coal on the speciation of Hg across an SCR catalyst. Tests were conducted in which 100% bituminous coal and 100% sub-bituminous PRB were fired to examine the effect on mercury oxidation. Several blends were run with bituminous coal comprising the minority fraction. It was determined that a higher percentage of the total Hg was present as oxidized Hg at the SCR outlet as the chlorine in the coal increased. The other hydrogen halides such as HBr and HF do not appear to be in appreciable concentrations to have an impact on oxidation. A blend that contained at least 35% bituminous coal was necessary to obtain an oxidized Hg concentration of 60% oxidized Hg at the SCR outlet with 100% bituminous coal producing just under 90% oxidized Hg at the SCR outlet. Very little Hg passed through the baghouse due to the high LOI of the ash. Those power plants that are equipped with SCR and wet scrubbers may have an

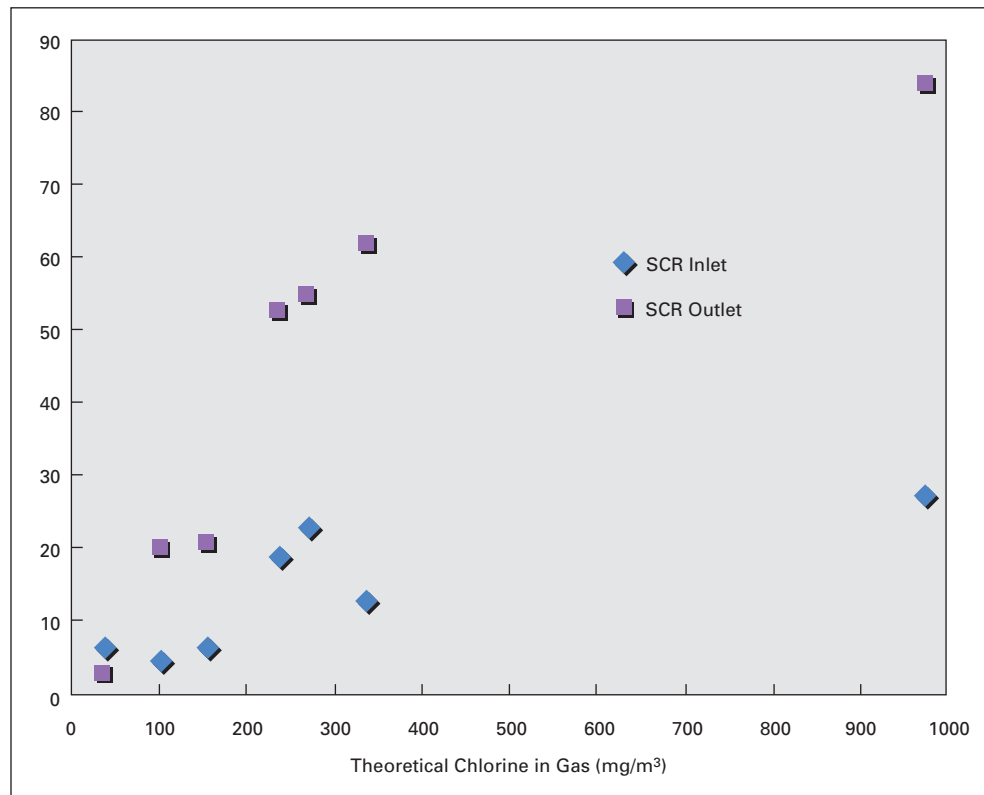


Figure 5. Mercury oxidation as a function of coal chlorine content for SCR inlet and outlet.

additional option of utilizing existing DeNO<sub>x</sub> and SO<sub>2</sub> pollution control equipment to improve mercury control by adding an additional source of chloride to the fuel through fuel blending or other means.

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