

Evaluating Mercury Control Technologies for Coal Power Plants

Coal fired power plants may be able to achieve mercury reductions of 90 percent or more as a co-benefit of existing pollution control devices already used by the plant.*



Controls designed to remove other pollutants can remove a substantial amount of mercury under certain conditions. For example, the combination of a wet scrubber (FGD designed to remove sulfur dioxide) and selective catalytic reduction (SCR designed to remove nitrogen oxides) have demonstrated mercury removal rates of 70 to 90 percent or more from plants burning high-sulfur bituminous coal. Other measures are available aimed at controlling mercury specifically, including chemical additives, such as calcium bromide, which can be used by itself or in combination with activated carbon.¹

Capital Investment and Operational Costs of Mercury Control Technologies

Mercury controls are relatively inexpensive compared to conventional air pollution control devices such as wet scrubbers or nitrogen oxides controls.² The least expensive technology for controlling mercury is bromine salt additives, however, these require a scrubber. Table 1 summarizes the costs of available controls including the capital investment and operational cost.

Table 1: Cost of Controls

Control Technology	Average Cost per Boiler, Million dollars, 2008 (range)	Capital cost (\$/kW)	Operating Costs ³
Activate Carbon Injection Systems ⁴	\$1 (up to \$6.2) ⁵	\$5-\$15	\$674,000 ⁶ ; moderate
Fabric Filter and Carbon Injection (mercury control) ⁷	\$15.8 (\$12.7 - \$24.5)	\$120 - \$150	Moderate
Oxidation catalysts with ESP & FGD ⁸		\$2-\$4	Low
Bromine additives with ESP w/FGD or SCR w/FGD ⁹		\$1 - \$2	Low to Moderate

Source: GAO-10-47, October 2009; NESCAUM, 2010; UNEP POG, July 2010.

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Optimizing Mercury Control Technologies

Mercury control levels vary across existing pollution controls and there are measures to implement that will optimize each technology. Table 2 presents the levels and recommends improvements for each scenario.¹⁰ In each case, careful monitoring of mercury in the exiting flue gas will be required to ensure sufficient mercury control and to determine whether further controls, such as activated carbon or additives are necessary.

Table 2: Optimizing Mercury Control

Existing Control Equipment Configuration	Average Percent of Mercury Control based on coal type (Bituminous/Sub-bituminous/Lignite)	Options for Further Mercury Control and Notes
Electrostatic Precipitator (ESP)	36/ 9/ 1	<ul style="list-style-type: none"> • Add Activated Carbon Injection (ACI) and/or bromine additive • Fine tune ESP operation • Increase the amount of PM-bound mercury in flue gas (e.g., by coal blending or addition of oxidants)
Fabric Filter (FF) ¹¹	90/ 72/ NT	<ul style="list-style-type: none"> • Optimize bag cleaning cycle • May require ACI depending on amount and characteristics of fly ash and unburned carbon (UBC)
ESP + Wet Scrubber ¹²	81/ 10/ 48	<ul style="list-style-type: none"> • Optimize the amount of oxidized mercury in flue gas through coal blending or addition of oxidants • Prevent/control Re-emission of elemental mercury
FF + Spray Dryer	98/ 25/ 2	<ul style="list-style-type: none"> • Optimize bag cleaning cycle • ACI may be required for low rank coal
FF + Wet Scrubbers	98/ NT/ NT	<ul style="list-style-type: none"> • Optimize mercury oxidation by FF • Prevent/control elemental mercury re-emission • Optimize SO₂ control
Selective Catalytic Reduction (SCR) + ESP	1 – 87%	<ul style="list-style-type: none"> • Optimize the amount of oxidized mercury in flue gas through coal blending or addition of oxidants • Fine tune ESP operation • ACI and/or additives may be required
SCR + ESP + Wet scrubbers	44 – 90%	<ul style="list-style-type: none"> • Optimize the amount of oxidized mercury in flue gas through coal blending or addition of oxidants • Prevent/control re-emission of mercury • Fine tune ESP operation • Optimize SO₂ control

Source: UNEP POG, July 2010; Institute of Clean Air Companies

NT = Not tested

When flue gas monitoring shows that existing pollution control equipment cannot sufficiently control mercury, adding ACI is the most reliable technology. ACI systems can easily be retrofitted onto existing power plants. The footprint is small, consisting mainly of a storage silo for powdered activated carbon (PAC). The carbon is metered out of the silo through a blower into the flue gas before it enters a particulate control device, such as an ESP.¹³ In order to significantly improve mercury capture rates, brominated carbon is used for most plants burning poor quality coals.¹⁴ Test data indicate that brominated ACI is *unlikely* to increase toxic dioxin emissions.¹⁵

Levels of Mercury Controls at Existing Plants Around the Globe

Information from a number of countries confirms the variety of options available to achieve substantial reductions in mercury emissions.

High Mercury Control Achieved with Activated Carbon

New Hampshire, USA

The Bridgeport Harbor Station in New Hampshire operates a 403 MW sub-bituminous coal fueled conventional boiler built in the 1960s. It is equipped with a cold side Electrostatic precipitator without flue gas conditioning installed in 1968; a pulse fabric filter and activated carbon injection were added in 2008. The mercury capture rate is greater than 90 percent.

Michigan, USA

The Presque Isle Station in Michigan operates a mix of fuels in its conventional boilers. Several boilers use a mix of bituminous coal and petroleum coke, and are equipped with cold side ESPs; these achieve a 60 to 66 percent mercury removal rate. Other boilers at this plant (units 7-9, 270 MW) burn Powder River Basin sub-bituminous coal and are equipped with hot side ESPs but achieve virtually no mercury reduction at all without specialized mercury controls. These units were equipped with a TOXECON™ carbon injection and fabric filter system that achieves a roughly 90 percent mercury removal rate. The TOXECON™ baghouse was installed after the hot-side ESPs. The system performs best with a brominated carbon (DARCO® Hg-LH at 0.5-3lb/MMacf).¹⁶

Mercury Control Possible with Particulate Controls

Russia

The Kashirskaya Power Plant outside of Moscow has three 300 MW coal boilers with ESPs and wet ash removal. Mercury removal rates of 74 percent have been measured.

Mercury Control Possible with Wet Scrubbers

Slovenia

One of the major thermal power plants, which supplies one third of the power in Slovenia, reports a mercury capture rate approaching 90% with wet FGD. The high mercury removal rates for the five lignite fueled boilers outfitted with ESPs is attributed to oxygen in the scrubber that oxidizes the mercury.

Texas, USA

The Monticello station in Texas burns lignite and sub-bituminous coal in several conventional boilers and has a cold side ESP and a wet FGD on one of the major boilers (#3, 593 MW). Baseline mercury removal rates were roughly 36 percent. The use of halogen additives including calcium chloride and calcium bromide reduced mercury by up to 92 percent (CaBr₂ having been the most effective at very high injection rates of 332 ppmw). Catalysts were also tested on this unit downstream of the ESP, producing mercury reductions of up to 87 percent. The Palladium catalyst was the most successful.

China

Numerous studies have documented mercury removal rates from existing air pollution controls on power plants in China. Removal efficiencies vary greatly: ESPs removed from 4.6% to 98.6% (Average, 22%);¹⁷ Wet FGDs removed 7.3% to 75%; FFs removed 2% to 85%; SCR/ESP/WFGD removed 73% to 93%. The most common scenario, ESPs plus FGD, removes 70% of mercury on average, but FFs and SCR should improve mercury removal; they are expected to be widely installed from 2010 to 2020. Large ranges in mercury removal efficiencies among existing air pollution controls suggest that halogen additives or other chemical treatments may be useful in boosting mercury removal rates.

NO_x Controls Can Enhance Mercury Removal

New Jersey, USA

The Logan Generating Plant in New Jersey operates a 242 MW bituminous fueled conventional boiler, which is equipped with a baghouse, spray dryer and SCR (all installed in 1994). It achieves a 97 percent mercury reduction without any specialized mercury controls.

South Korea

Thermal power plants in Korea report mercury control of 68 percent to 91 percent from some plants with certain high efficiency air pollution controls including SCR, CS-ESP, and wet FGD. One bituminous fueled plant (500 MW) with just ESP and wet FGD, however, reports a 95 percent mercury removal rate.

Massachusetts, USA

The Salem Harbor Station in Massachusetts operates several bituminous fueled conventional boilers equipped with ESP and Selective noncatalytic reduction achieving a roughly 90 percent mercury reduction without any specialized mercury controls.¹⁸

Netherlands

Fairly high mercury removal rates are reported for certain combinations of existing air pollution controls on coal fired power plants: around 50 percent for ESPs alone; around 75% for ESPs with wet scrubbers; and up to 90 percent for SCR with ESPs and wet scrubbers.

It should be noted that simply having multi-pollutant air pollution control devices in place does not ensure mercury control. For example, the Wygen station in Wyoming has two boilers burning sub-bituminous fuel (91 and 96 MW) equipped with pulse fabric filters, spray dryers and SCR. Mercury removal rates are very low: 5 to 33 percent.

Monitoring, preferably continuous emissions monitoring should be used to evaluate the level of mercury control at any given plant. Where controls are inadequate, additional measures must be required.

Footnotes

- * Based on US EPA data. For example, about one-third of boilers that currently fall under state mercury regulations in the USA are relying on existing pollution controls to meet their mercury reduction requirements. This is achievable particularly for boilers using high quality bituminous coals that employ a fabric filter. Boilers using poor grades of coal with high levels of mercury, low levels of chlorine and high ash content can be expected to emit more mercury in all pollution control scenarios.
- ¹ At least one major ACI system has been up and running since 2005. Additional mercury controls include the following: Energy efficiency improvements could contribute very modest mercury reductions of up to seven percent. Coal washing can remove up to 30 percent of mercury by mass and may provide additional benefits such as reduced ash content, but can vary widely depending on coal type. Chemical treatments of coal, such as the K-fuel process, can reduce mercury emissions by up to 70 percent. Coal blending and switching can reduce mercury emissions by up to 80 percent. Several multi-pollutant control technologies appear to be promising yet may require more demonstration experience before they are commercially viable.
- ² Average costs of ACI are roughly \$1 million compared to wet scrubbers and NOx controls at \$86 million and \$66 million.
- ³ Qualitative information based on UNEP POG, July 2010, page 69.
- ⁴ Total cost to purchase and install ACI reflects the cost of the sorbent injection equipment, associated mercury emissions monitoring system, and associated engineering and consulting services.
- ⁵ The Institute of Clean Air Companies estimates roughly \$1 million as the average cost of ACI. This is much lower than the cost reported in the GAO study, however, this study included the earliest adopters of this technology when the initial cost was likely significantly higher.
- ⁶ The operating cost of ACI is almost entirely the cost of the sorbent itself. Annual costs at 18 boilers ranged from \$76,500 to \$2.4 million.
- ⁷ These estimates are for 5 boilers that installed the controls for mercury. Five other boilers installed ACI with a fabric filter designed to control for other pollutants; the average cost of the ACI for those boilers was \$2.9 million and for the monitoring systems, \$0.5 million. The average cost for the FFs was \$84 million and for the engineering studies, \$11 million. One combination ACI-FF, known as TOXECON™, is designed to preserve the quality of fly ash so that it can be sold.
- ⁸ Mercury removal rates for 3 different catalysts were all 73%; coal type was lignite, lignite/SB or SB.
- ⁹ Less bromine is required when paired with SCR, which helps oxidize mercury, therefore lowering the cost.
- ¹⁰ Note that mercury speciation affects selection of appropriate mercury control strategies: Whether mercury is in an elemental form (Hg₀), oxidized form (Hg₂⁺) or particulate form (HgP) determines which mercury controls are effective, since the oxidized and particulate forms are more easily removed. Parameters affecting mercury speciation in the flue gas include: coal composition (chlorine content and ash composition), combustion system operation (how much carbon is left unburned in the ash), and the temperature and residence time of the exhaust gas in a PM control device.
- ¹¹ Fabric Filters can assist with mercury control and provide additional benefits of reducing acid gases, metals and capturing fly ash. FFs are more effective at reducing mercury than ESPs and are increasingly being installed to reduce PM emissions and other pollutants, but currently less than 20 % of boilers have them.
- ¹² Wet scrubbers refer to Flue Gas Desulfurization (FGD). Mercury is not likely to leach from fly ash and FGD gypsum; however, it can leach from wet FGD sludge. Therefore the sludge presents a risk in handling and disposal. Re-emission of elemental mercury from FGDs is another concern but can be controlled effectively through the use of chemical additives to oxidize the mercury in the flue gas.
- ¹³ Note that PM controls are always necessary to re-capture the used carbon once it adsorbs mercury from the flue gas.
- ¹⁴ There are certain situations where ACI can be less effective than expected. Three factors can compromise the success of ACI in controlling mercury: Sulfur trioxide interference, use of hot-side ESPs and use of lignite or low grade coals. None of these issues are common in the US. All of these issues can be overcome through the use of alternative flue gas conditioners, careful calibration of SCR systems, alkali-based sorbents, coal blending, heat resistant sorbents, fabric filters and boiler additives.
- ¹⁵ This is likely due to a number of factors: PAC is used in some cases as a control for dioxins and furans, which adsorb onto the carbon; dioxins and furans are already at very low levels in coal combustion flue gas; and the bromine on the activated carbon is very tightly bound and therefore would not be available for dioxin formation.
- ¹⁶ Performance is also best with greater durations between bag cleaning likely due to the fact that unburned carbon in the fly ash and activated carbon have more residence time to remove mercury.
- ¹⁷ High mercury removal rates were on CFB boilers.
- ¹⁸ Boiler 1 is 81 MW; boiler 3 reported in EPA's 1999 ICR but the size is unknown.

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