

ENHANCING MERCURY CONTROL ON COAL-FIRED BOILERS USING SCR OR OXIDATION CATALYST AND FGD

Mercury capture in existing emissions control equipment offers a cost effective mercury control option for coal-fired power plants. The co-benefit of mercury capture from coal-fired power plants varies significantly depending on the existing emissions control configuration and type of coal being burned. Different coals and control configurations produce varying amounts of the three basic forms of mercury in flue gas including elemental, oxidized, and particulate mercury. Particulate mercury will typically be captured in the particulate control device and oxidized mercury is water soluble and can therefore be captured in certain control equipment such as wet flue gas desulfurization (FGD) systems.

In order to enhance mercury capture, the elemental form of mercury can be catalytically oxidized from the elemental metallic form, Hg^0 , to the oxidized form of mercury, Hg^{+2} , and captured by a downstream FGD system. Selective catalytic reduction (SCR) catalysts or oxidation catalysts may be used for the catalytic oxidation step, followed by downstream wet or dry FGD technology to capture the oxidized mercury. High levels of oxidized mercury and total mercury capture are achieved commercially when firing bituminous coal on units equipped with SCR and FGD due to relatively high halogen levels in the coal. Enhancement of mercury capture efficiency for low-halogen coals (i.e. coals with low chloride content such as subbituminous or lignite coals) equipped with SCR and FGD can be accomplished by several methods: addition of halogen-containing compounds to the coal, co-firing higher-halogen content coals, usage of advanced SCR catalysts with improved mercury oxidation performance, or addition of a sorbent system such as activated carbon injection. Co-firing involves blending in 15 to 50 percent bituminous coal when firing low-halogen subbituminous or lignite coal types. Additives may also be used in the FGD system with all coal types to prevent the reemission of captured mercury to the flue gas.

Technology Overview

Flue gas desulfurization is a widely used post-combustion technology for controlling SO_2 emissions. FGD also captures a large percentage of oxidized mercury present in coal-fired combustion flue gas because the oxidized mercury is soluble in the calcium-containing liquid solution in the FGD. However, FGD does not effectively capture elemental mercury from the flue gas because elemental mercury is not soluble in the liquid solution. For bituminous firing, there is a medium to high level of oxidized mercury at the FGD inlet resulting in a comparable level of mercury capture. For sub-bituminous and lignite firing, the relative levels of oxidized mercury and subsequent capture are both low unless means are provided to enhance oxidation of elemental mercury as described above. Neither “wet” FGD nor “dry” FGD is effective in capturing elemental mercury. In a dry FGD unit, also known as spray dryer absorber (SDA), a calcium-containing liquid solution is sprayed into the flue gas to capture SO_2 but does not saturate the flue gas like wet FGD. For dry FGD, the subsequent

baghouse normally provides additional contact time thus effectively allowing the combined SDA/baghouse configuration to capture oxidized mercury as efficiently as wet FGD units.

Selective catalytic reduction (SCR) is a widely-employed post-combustion method for controlling NO_x emissions. Although SCR catalyst reduces NO_x, it also has the dual-function of oxidizing elemental mercury. This provides a significant co-benefit since SCR installed upstream of an FGD will result in higher overall mercury capture. An increasing number of plants are operating with SCR/FGD control combinations due to EPA regulations that require significant SO₂ and NO_x reductions from power plants. For bituminous coal firing units, 80 percent to over 90 percent overall mercury capture has been observed on a sustained basis in full-scale plant tests where SCR followed by wet FGD is employed. A large bituminous-fired plant equipped with SCR and wet FGD showed sustained high Hg capture performance over multiple ozone operating seasons. Firing of low chlorine containing subbituminous and lignite coals will require process enhancements, such as those outlined below, in order to achieve high mercury capture.

Oxidation catalysts containing precious metals have been used in a commercial demonstration for the oxidation and improved capture of mercury by downstream FGD, and may provide an alternative for units not employing SCR that are equipped with FGD. These catalysts can be installed upstream of an FGD and perform in a similar manner to SCR catalyst. Oxidation catalyst might also be installed between the SCR catalyst and the FGD to enhance the overall performance of the SCR/FGD system for mercury oxidation and capture. Greater than 90 percent mercury oxidation efficiency has been achieved firing PRB (subbituminous) and North Dakota lignite coals in slipstream tests at power plants, and 80% oxidation was observed in the 200 MW PRB demonstration¹.

Process Augmentation for Mercury Capture Enhancement

The following options to increase the efficiency of mercury capture of the SCR/FGD or Oxidation Catalyst/FGD process are in various stages of development, field demonstration, or commercial utilization at a small number of units:

- (a) One technique is the addition of bromine, chlorine, or other halogens to the coal (pre-combustion), directly to the boiler (combustion), or after the boiler (post-combustion). The elemental mercury is oxidized by the halogens to form mercury halides to improve mercury capture. This approach is especially useful when firing low halogen content coals.
- (b) Another method is blending for sub-bituminous or lignite coal firing by the addition of bituminous coal with higher halogen levels. This technique can be used to improve overall mercury capture for FGD, SCR/FGD and oxidation catalyst/FGD configurations. Performance tests at a large utility plant firing a 60 percent sub-bituminous and 40 percent bituminous blend at two identical boilers (one equipped with SCR and the other

¹ “Full-scale Demonstration of Oxidation Catalyst for Enhanced Mercury Control by Wet FGD”, Mega Symposium Conference 2008.

without SCR) showed an increase in downstream oxidized mercury fraction from 63 percent without SCR to 97 percent with SCR. An unblended PRB sub-bituminous coal situation would have only achieved between 0-40 percent oxidized mercury based on full-scale data from the 1999 EPA Information Collection Request.

- (c) Addition of catalysts to specifically convert elemental mercury to oxidized mercury is another method. Options for SCR-equipped units include addition of an extra SCR catalyst layer or usage of SCR catalyst with enhanced mercury oxidation performance. Possibilities for mercury-specific oxidation catalyst include catalyst addition after (or in lieu of) the SCR catalyst layers in a hot flue gas location, or the addition of a mercury-specific oxidation catalyst in a relatively cool flue gas location (a cool location was used for the commercial demonstration). For some units firing sub-bituminous or lignite coals, SCR catalyst or potential oxidation catalyst systems may require augmentation of flue gas halogen levels.
- (d) Usage of FGD additives to avoid re-emission of captured mercury is another technique. Commercial tests have shown 0-20 percent re-emission of captured mercury from wet FGD units, and additives have shown the ability to substantially prevent this re-emission effect. Additives include various liquids, solids or gases that affect the FGD slurry chemistry.

Performance

The overall mercury capture efficiency depends on the configuration of post-combustion air pollution control equipment and coal type at a particular plant. EPA had previously developed the following estimates of co-benefit mercury capture efficiencies for some of the major plant configurations involving FGD or combined SCR/FGD (those shown are for pulverized coal fired boilers). These incidental efficiencies which were identified under EPA’s earlier ICR data collection are not optimized for mercury capture and may be optimized further.

Post-Combustion Controls			Mercury Capture Efficiency		
<i>PM</i>	<i>NO_x</i>	<i>SO₂</i>	<i>Bituminous</i>	<i>Subbituminous</i>	<i>Lignite</i>
ESP	None	Wet FGD	66%	16%	44%
ESP	None	Dry FGD	36%	35%	0%
ESP	SCR	Wet FGD	90%	66%	44%
ESP	SCR	Dry FGD	36%	35%	0%
None	None	Wet FGD	42%	30%	0%
None	None	Dry FGD	40%	15%	0%
None	SCR	Wet FGD	90%	51%	0%
None	SCR	Dry FGD	40%	15%	0%

Note: ESP is cold-side electrostatic precipitator.

Actual performance is somewhat variable and new ICR data is being obtained by EPA. As an example, a 550 MW bituminous-fired unit equipped with ESP, SCR and wet FGD resulted

in greater than 90 percent overall mercury capture in the downstream wet FGD unit. With the usage of the SCR catalyst, the oxidized fraction of mercury in the flue gas increased from 64 percent of total gaseous mercury to over 95 percent. However, caution should be taken using this data since lower mercury capture occurs at some SCR/FGD equipped units. In such cases it may be necessary to augment mercury oxidation or FGD capture efficiency using the methods described above, or alternatively add a sorbent injection system (e.g. activated carbon injection) to serve as a trim control.

Installation and Availability

Around one-third of the coal-fired capacity in the U.S. has installed FGD for SO₂ control and SCR for NO_x control. The majority of the FGD installations are wet FGD systems. A significant number of existing coal-fired power plants are currently retrofitting or planning on retrofitting their boilers with FGD and/or SCR systems, which are more suited for the low cost mercury control options previously discussed. The enhanced control approaches primarily utilize additives and catalysts that are readily available in adequate quantities for initial operation and continued operation of these control systems. The augmentation technologies being commercialized are expected to become readily available and not limited by installation manpower, equipment, or consumables.

Typical Costs

Site-specific factors result in significant variation in costs. For units that are already equipped or will be equipped with both SCR and FGD for NO_x and SO₂ control, the incremental operating costs are relatively low for SCR catalyst replacements, SCR catalyst additions/replacements, or FGD additives. FGD additives also require a relatively low capital investment for equipment. Costs for other SCR/FGD augmentation technologies are variable dependent upon site-specific factors and the technology being deployed.