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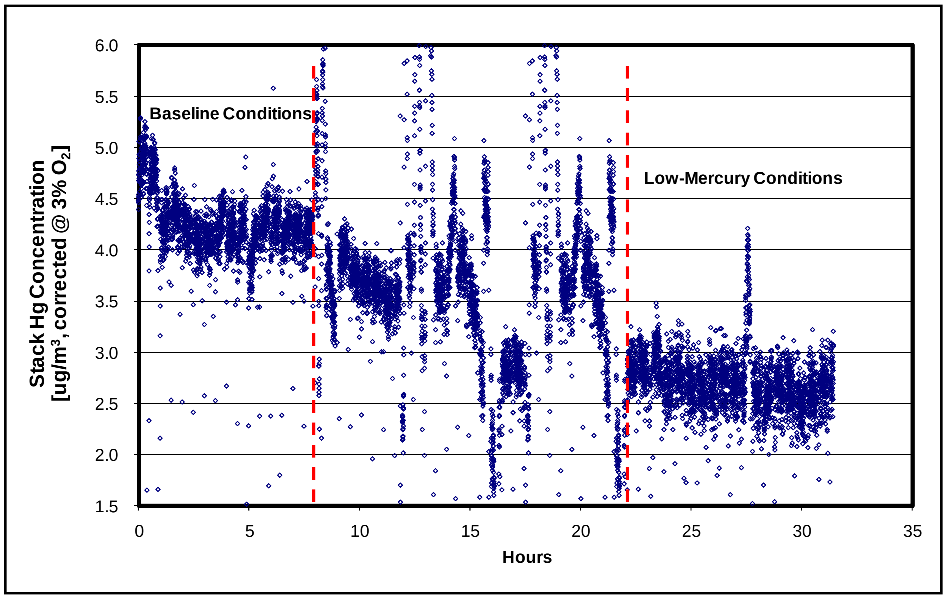
CONTROLLING MERCURY EMISSIONS FROM COAL-FIRED POWER PLANTS

The control of mercury emissions is an important issue facing the coal-fired power industry. Mercury emissions are impacted by factors including coal composition, the type of environmental control equipment installed on the unit, boiler operating conditions, and fly ash characteristics. Some mercury is collected naturally in ESP's and baghouses, and for units with SCR's and wet FGD's, some mercury is also captured in wet scrubbers. Nevertheless, at some units, additional mercury capture will be needed to comply with emissions regulations. A research team from the Energy Research Center, led by Dr. Carlos Romero, has been carrying out investigations in three different areas of mercury emissions control: (i) boiler optimization, (ii) mercury sorbents and (iii) FGD scrubber additives.

Romero explains "At combustion temperatures, Hg is present as elemental vapor. However, due to processes which occur naturally in the boiler, by the time the flue gas reaches the back end of the boiler, some of the Hg is present in an oxidized gaseous state and some as particulate bound Hg. While elemental Hg is extremely difficult to capture, oxidized Hg is more readily adsorbed by fly ash, and thus it can be removed in scrubbers, electrostatic precipitators and fabric filters."

"Published data indicate that chlorine concentration is the single most important variable with respect to influencing Hg oxidation and removal in coal-fired boilers. However, computer simulations performed at the ERC and field test results obtained by the Lehigh team show that selection of proper boiler operating settings can also play a significant role."



Boiler Optimization Results on Mercury Emissions from a 160 MW Wall-Fired Unit with PRB Coal.

Boiler Optimization. "Over the past six years, we have carried out full-scale tests at five pulverized coal-fired boilers to determine the extent to which Hg oxidation and capture can be influenced by modifying boiler control settings. The units tested have generating capacities of 110, 160, 250, 650 and 805 MW. Control parameters in the combustion system, air preheater, electrostatic precipitator, and flue gas desulphurization system were used to impact mercury emissions. The benefit of "low-mercury" operation was quantified, considering the trade-off between mercury reduction and other emissions (NO_x, CO and opacity), the level of unburned carbon in the fly ash, and unit thermal efficiency. The field test results indicated stack mercury emissions reductions ranging from approximately 30 to 70 percent were obtained by optimizing boiler operations. The degree of Hg capture was found to depend on coal type and on unit design. In general, reductions in Hg emissions were accompanied by reductions in NO_x emissions and a modest increase in unit heat rate. The figure on the first page illustrates results of boiler optimization on stack mercury emissions reduction at a 160 MW, wall-fired unit that fires PRB coal. Optimized burner and overfire air (OFA) registers, boiler combustion settings, air preheater (APH) operation, and sootblowing practices resulted in a reduction in mercury emissions from baseline levels of the order of 35 percent. This reduction in mercury emissions was accompanied by a co-benefit reduction in NO_x emissions of the order of 20 percent.

Other tests on a 650 unit fired by Bituminous coals resulted in Hg emissions reductions of approximately 80 percent. In this case, the following parameters were investigated to enhance the "naturally-occurring" Hg capture in the unit: combinations of excess O_2 and OFA register settings, an appropriate mill out-service configuration in combination with modified dynamic classifier speed, modified APH back-end temperature, and modified ESP power levels and rapping.

FGD Scrubber Additives. A second issue related to mercury emissions control from coal-fired power plants is the transformation of absorbed ionic mercury to insoluble elemental mercury in wet FGD scrubbers, leading to elemental mercury re-emission. Wet scrubbers are known to provide the co-benefit of mercury removal, when mercury is found in the flue gas in oxidized form. Laboratory-scale experiments were performed in a simulated forced oxidation limestone scrubber. This study found that higher concentrations of sulfites, and chloride and bromide ions inhibit oxidized mercury transformation to elemental mercury, while higher concentrations of ionic mercury in the liquor, and increased scrubber temperature and pH value results in higher mercury re-emission levels. Four additives were tested to promote precipitation of ionic mercury as mercury sulfide, and they all achieved more than 90 percent reduction in elemental mercury re-entrainment.

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Mercury Sorbents. Activated carbon (PAC) injection is the most widely known technology available for mercury emissions control. This technology has evolved in terms of cost and mercury control effectiveness for a wide spectrum of coals types. Nevertheless, test evaluation and screening of different activated carbons and alternative sorbents can offer reduction in the cost of mercury compliance by sorbent injection. Dr. Romero's team collaborated with a utility company on their full-scale testing of commercially available PAC. Eight PAC's were evaluated in field tests consisting of 2-day injection trials, with the test unit operated at full load and similar consistent combustion conditions and fly ash unburned carbon levels from test to test. Mercury measurements were performed at the stack. The tested PAC's had a range of densities, particle size distributions, Iodine numbers and halogen levels. Measured mercury reduction efficiencies ranged from 54 to 93 percent, with injection levels ranging from 300 to 780 lb/hr. Four of the sorbents were found to comply with the mercury emissions target of the plant. Additional economic analysis were later performed on those four PAC's to choose the most cost-effective sorbent that comply with the mercury emissions limits and offer the least side-impact on the balance of the plant.

Data from Mercury Sorbent Injection Tests

Sorbent	Avg. Injection Rate	Lowest Hg Emissions	Hg Reduction
	(lb/hr)	(μg/Nm^3)	(%)
Baseline		1.9	
A	783	0.66	65.0
B	432	0.88	53.7
C	301	0.21	88.9
D	311	0.23	87.9
E	476	0.34	82.1
F	231	0.14	92.6
G	286	0.14	92.6
H	331	0.26	86.3

Romero concludes, "Many of the coal-fired units which are retrofitted with a combination of SCR's and wet FGD's for NO_x and SO_x control should be able to meet Hg emissions regulations without any other controls. However, some plants will find that their mercury emissions exceed the permitted levels, and in these cases, additional mercury control measures will be needed. Use of scrubber additives and optimization of boiler operating conditions are two approaches which we believe will be useful for increasing mercury capture to compliance levels in these cases. For units without SCR's or wet FGD's, the most likely remedy is sorbent injection, and in these cases, we recommend that the power generation company perform an evaluation of a range of sorbents to identify those that control mercury at the lowest costs and with the least impact of the injected sorbent on the balance of the plant."

Other members of the project team included Harun Bilirgen, Neand Sarunac, Zheng Yao and Ohmine Naruhito. ■

RESEARCHERS' PROFILES

- ***Dr. Harun Bilirgen*** is Senior Research Scientist in the Energy Research Center and his research focuses on emissions control and performance improvement of coal-fired power plants.
- ***Dr. Ian Laurenzi*** is an Assistant Professor of Chemical Engineering at Lehigh University. He has degrees in Chemistry and Chemical Engineering and is a specialist in chemical process simulation and design`.
- ***Dr. Edward Levy*** is Professor of Mechanical Engineering and Mechanics and Director of the Energy Research Center. His research deals with emissions control and performance improvement in coal-fired power plants.
- ***Ohmine Naruhito*** has degrees in Chemical Engineering and is employed by Hitachi in the Air Pollution Control Group.
- ***Dr. Carlos Romero*** is an Associate Director of the Energy Research Center. He is a specialist in combustion kinetics and emissions control.
- ***Dr. Nenad Sarunac*** is Associate Director of the Energy Research Center. His research focuses on power plant heat rate improvement, emissions control and process optimization.
- ***Austin Szatkowski*** earned a MS degree from Lehigh University in Mechanical Engineering. His MS research topic involved simulations of a coal-fired power plant with a post-combustion CO_2 capture system.
- ***M. Jeremy Walsh*** has BS and MS degrees in Mechanical Engineering from Lehigh University, and his MS research involved simulations of coal-fired power plants with carbon capture. He is now employed by Air Products & Chemicals.
- ***Zheng Yao*** is a Research Scientist in the Energy Research Center. His research deals with optimization of power plant operations.