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FUNDAMENTAL STUDY OF SCR IMPACT ON MERCURY SPECIATION

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Project Description

Previous testing conducted by the EERC to evaluate the impact of selective catalytic reduction (SCR) on mercury speciation included 4 weeks of pilot-scale testing and full-scale sampling at six different power plants. The results from these studies indicated that the impact is coal-specific. It is speculated that SO_2/SO_3 and HCl/Cl_2 concentrations play a pivotal role. Bench-scale tests using a fixed-bed system will be conducted to help determine the effects of these gases. A full-factorial design is being used to evaluate the independent variables, which include the reactor (none, SCR), presence of acid gases (HCl and SO_2/SO_3), fly ash type, and residence time. The presence of ammonia will depend on reactor mode.

Goal

The goal of this project is to determine the factors that have the potential to alter mercury speciation when SCR technologies are used. The specific objective is to determine the effects of the different variables: flue gas chemistry, fly ash type, and residence time on mercury speciation.

Rationale

Many utilities, in anticipation of pending regulations impacting air emissions and to help achieve ozone attainment, are planning to install SCR reactors. SCR units achieve lower NO_x emissions by reducing NO_x to N_2 and H_2O . Generally, ammonia is the reducing gas, and the system is operated at a temperature of 343°C (650°F). The catalyst most commonly used to promote this reaction is vanadium–titanium metal oxide ($\text{V}_2\text{O}_5/\text{WO}_3\text{--TiO}_2$). Bench-, pilot-, and full-scale testing by the EERC and others has shown that metal oxides, including V_2O_5 and TiO_2 , promote the formation of oxidized mercury (Hg^{2+}) and particulate-bound mercury under some conditions [1, 2]. Therefore, it seemed probable that the SCR process would improve mercury control efficiencies by promoting the formation of Hg^{2+} and/or particulate-bound mercury formation rather than elemental mercury (Hg^0).

The EERC, with funding from the U.S. Department of Energy, EPRI, the U.S. Environmental Protection Agency, and Ontario Power Generation, first conducted 4 weeks of pilot-scale testing followed by full-scale field sampling to evaluate whether or not this is the case. The pilot-scale tests were conducted using four different coals: three bituminous coals and one Powder River Basin subbituminous coal. However, the results were inconclusive, as it appears that the impact may well be coal-specific [3].

The field sampling studies were conducted at six different power plants. Four of the plants had SCR units to reduce NO_x emissions, one plant injected ammonia and SO₃ as conditioning agents to improve electrostatic precipitator (ESP) performance, and the sixth plant injected urea as part of a selective noncatalytic reduction (SNCR) system. The results showed that SCR did increase Hg²⁺ at two of the SCR facilities but not at the other two. It did not appear that SNCR or ammonia/SO₃ had much of an effect. Although these tests clearly show that mercury speciation can be changed by a variety of factors and speculation is that SO₂/SO₃ and HCl/Cl₂ concentration may play a pivotal role, many questions remain. To answer the questions posed by these tests, it became clear that bench-scale testing was needed using a full-factorial design to isolate the effects of various variables, including flue gas chemistry, fly ash type, and residence time.

Approach

To evaluate the effects of independent variables, a full-factorial experimental design will be used to test the reactor (none or SCR), the presence of acid gases (HCl and SO₂/SO₃), fly ash type, and residence time. The presence of ammonia concentration will be dictated by the mode of operation. The expected gas concentrations to be used to simulate flue gases are shown in Table 1.

Table 1. Simulated Gas Concentrations

Baseline Gases	
CO ₂	10%
O ₂	6%
NO/NO ₂	600/30 ppm
H ₂ O (v)	8%
Hg ⁰	20 : g/m ³
N ₂	Balance
Variable Gases	
SO ₂ /SO ₃	2000/50 ppm
HCl	50 ppm
NH ₃	600 ppm with SCR

Bench-scale tests will be conducted using a modification to an existing bench-scale test system. This test rig was designed so that almost any gas can be added to the system, including both elemental and HgCl₂ vapor. A schematic of the bench-scale system is shown in Figure 1.

The primary modification being made to the existing bench-scale system is the installation of a small SCR reactor. The catalyst bed is packed with a catalyst developed by Cormetech, the same catalyst installed in the EERC pilot-scale SCR unit. The reactor is housed in an oven maintained at 343°C (650°F). Enough tubing is coiled in the oven to ensure that gases will be at 343°C (650°F) prior to entering the reactor.

For tests when the SCR reactor is bypassed, the flue gas will still pass through the oven and be heated to 343°C (650°F). To double the residence time, the gas will pass through an empty chamber (also heated to 343°C [650°F]) upstream of the SCR reactor.

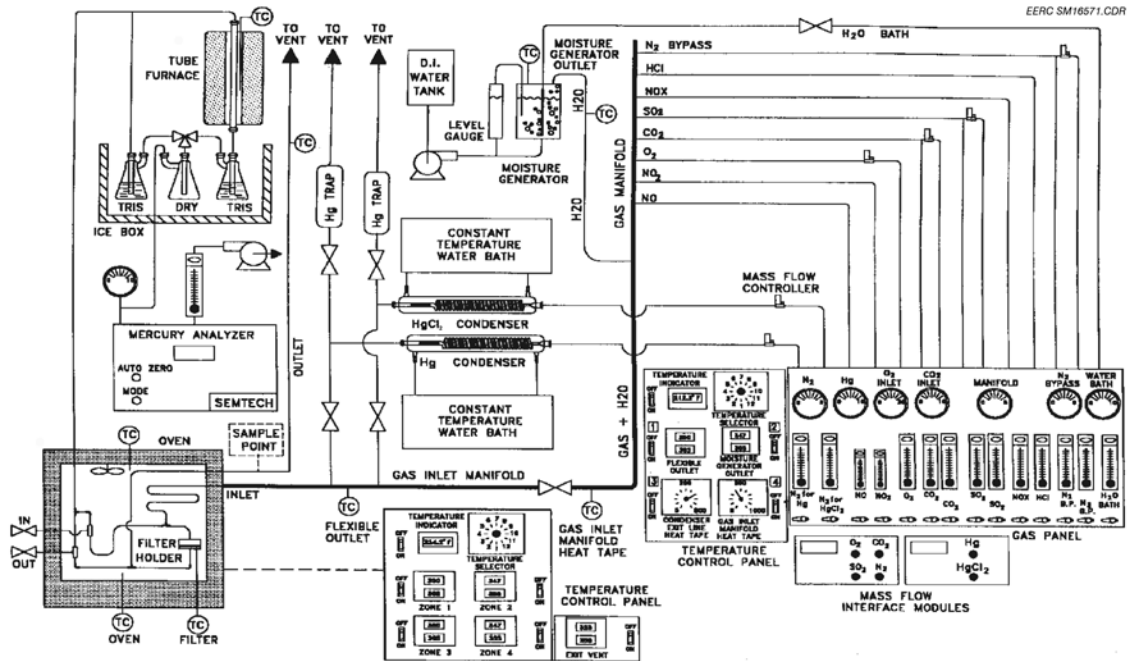


Figure 1. Schematic of the Bench-Scale System

For the tests, two different fly ashes will be used. The first will be an ash generated from combustion of a bituminous coal, and the second will be from a subbituminous coal. It is expected that the ashes will be either the baseline ESP hopper ash collected during the pilot-scale project or the fly ash collected when the SCR unit was bypassed at the full-scale facilities tested. For each of the bench-scale tests, two filter assemblies containing a fixed amount of the same fly ash will be used. The first will be located in the reactor oven (directly downstream of the SCR reactor when it is used), with the second located in another oven heated to 149°C (300°F). As shown in Table 2, 16 different tests will be completed. Each test will be replicated, totaling 32 tests.

Progress

Modifications to the existing system, as detailed above, are in progress. Parts and supplies that will be needed have been ordered. Initially, the project was planned to include a commercial sponsor. Although the sponsor may still participate at a later date, the project will proceed as defined without commercial support.

Potential Users/Technology Transfer

Although full-scale tests seem to indicate the usefulness of SCR reactors as multipollutant control devices in some circumstances, numerous factors potentially impact their effect on mercury emissions. This project seeks to isolate factors so that each variable can be statistically examined individually. As pending regulations on mercury emission levels and ambient air are introduced, utilities must be able to make a rational, informed decision as to the efficiencies of commercially available technologies, as well as system modifications that can be used to meet standards.

Table 2. Proposed Full-Factorial Test Design

Test No.	Acid Gases ¹	Increase Residence Time	Fly Ash	Reactor
1	Yes	No	Bit.	None
2	No	Yes	Bit.	None
3	Yes	Yes	Bit.	None
4	No	No	Bit.	None
5	Yes	No	Sub.	None
6	No	Yes	Sub.	None
7	Yes	Yes	Sub.	None
8	No	No	Sub.	None
9	Yes	No	Bit.	SCR
10	No	Yes	Bit.	SCR
11	Yes	Yes	Bit.	SCR
12	No	No	Bit.	SCR
13	Yes	No	Sub.	SCR
14	No	Yes	Sub.	SCR
15	Yes	Yes	Sub.	SCR
16	No	No	Sub.	SCR

¹ The sum of HCl, SO₂, and SO₃ concentrations.

References

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