DEVELOPING SCR TECHNOLOGY OPTIONS FOR MERCURY OXIDATION IN WESTERN FUELS

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Project Description

The project will evaluate the ability of selective catalytic reduction (SCR) catalysts to oxidize mercury. The EERC study will include both currently used SCR catalysts and new SCR catalysts formulated to enhance mercury oxidation, as well as the use of additives to enhance oxidation. The first catalyst to be tested will be an existing formulation that Haldor Topsoe currently manufactures. A second set of tests will be conducted on several new formulations developed in cooperation with Haldor Topsoe. The catalyst will be tested in flue gas compositions similar to what is found in plants burning Powder River Basin (PRB) and lignite coals and will be varied accordingly. The use of oxidation additives to promote the formation of oxidized mercury to levels of those seen for eastern coals will also be a primary emphasis.

Goal

The primary goal is to demonstrate that high concentrations of elemental mercury in certain flue gases can be catalytically oxidized to yield greater than 85% oxidized mercury. This would allow for removal in existing and future scrubbers and enhance the capture of mercury on low-cost sorbents for unscrubbed systems. Specific objectives include the following:

- Identify the primary component(s) in SCR catalysts that contribute to mercury oxidation
- Quantify the effects of various oxidants on mercury oxidation across SCR catalysts
- Evaluate the effects of temperature (650° and 350°F)
- Evaluate the effects of ammonia

Rationale

There is an increasing recognition of the need for mercury control technologies specifically targeted toward plants burning western U.S. coals which emit predominantly elemental mercury. Laboratory and field tests indicate that western coals pose unique challenges in meeting future mercury control requirements. Recent field data have shown that while significant oxidation of elemental mercury occurs across SCR systems for certain applications, there are also applications where no conversion is measured (1, 2). In four utility tests (three sites) with eastern bituminous coals, the elemental mercury levels averaged 63% upstream of the SCR and 26% downstream. For a single utility site burning PRB coal, the elemental mercury went from 92% to 82% across the SCR. These data indicate that the mercury in low-rank western coals may be more difficult to oxidize, and one of the likely causes is low chlorine levels in these coals.

Roughly two-thirds of the Texas and North Dakota lignite-fired generation capacity is currently equipped with either wet or dry scrubbers. In addition, enactment of the Clear Skies Act or other multipollutant bills would increase the likelihood of new SCR and scrubber installations. For these units, the best-case scenario is development of a cost-effective mercury oxidation technology to allow removal in the scrubbers. Additionally, for plants burning low-sulfur PRB coals, increasing the level of mercury oxidation will enhance the effectiveness of sorbent injection systems.

Approach

The research will be completed in two tasks to be performed in the EERC's mercury laboratory. A standard concentration of 15 $\mu g/Nm^3$ of elemental mercury will be used in the flue gas.

Task 1 – Evaluation of Flue Gas Additives and Temperature

Task 1 will quantify the effects of several variables on the performance of a typical commercially available SCR catalyst in oxidizing elemental mercury. A baseline flue gas composition which simulates that from a low-rank western coal will be used, and the bench-scale system will be modified to enable catalyst testing. The flue gas composition will be fairly typical of that from most western coals in terms of low HCl and SO_2 concentrations. The most critical variables will be the type and quantity of mercury oxidants. Candidate oxidants for addition to the gas stream include HCl, other chlorine species, other halogen species, and acid gases. Another important variable is the flue gas temperature at the catalyst. Tests will be performed at both 350° and 650°F to determine the effectiveness of the catalyst at a lower temperature where the equilibrium further favors the oxidized forms of mercury. Other researchers have performed limited experiments that show improved oxidation at lower temperatures. In addition, the effect of ammonia will be evaluated at 650°F to determine if there are any effects as reported by others (1–7). The impact of ammonia reported by others has been mixed, varying from a negative effect to no effect. Limited testing with ammonia addition will be performed to identify any effects with the baseline SCR catalyst.

Table 1 below contains the test plan for the flue gas concentrations to be tested under this task. An inlet mercury concentration of 12 $\mu g/Nm^3$ will be used. The catalyst will be standard catalyst provided by Haldor Topsoe. The baseline flue gas will be representative of a utility burning a low-rank fuel. Components such as HCl, NO, and SO_3 will be varied as noted in Table 1.

The testing will be completed on an existing bench-scale laboratory with the addition of an SCR chamber. The reactor chamber is approximately 1.5 inches square and 14 inches long. The reactor will be housed in an oven that will be maintained at the appropriate temperature as describe in the research plan. Enough tubing will be coiled in the oven to ensure that gases will be at the appropriate temperature 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 the appropriate temperature. The level of oxidized and elemental mercury will be monitored at the inlet and the outlet of the SCR chamber. The catalyst will be allowed to condition at

Table 1. Test Plan for Task 1

	Chemistry Test 1	Chemistry Test 2	Chemistry Test 3	Chemistry Test 4	Chemistry Test 5	Chemistry Test 6
Velocity	5 m/s	5 m/s	5 m/s	5 m/s	5 m/s	5 m/s
O_2	6%	6%	6%	6%	6%	6%
CO_2	12%	12%	12%	12%	12%	12%
H_2O	15%	15%	15%	15%	15%	15%
SO_2	600 ppm	600 ppm	600 ppm	600 ppm	600 ppm	600 ppm
NO	120 ppm	120 ppm	120 ppm	300 ppm	120 ppm	120 ppm
HCl	1 ppm	1 ppm	10 ppm	10 ppm	1 ppm	1 ppm
NO_2	6 ppm	6 ppm	6 ppm	6 ppm	6 ppm	6 ppm
Hg^0	12 μg/Nm^3	12 μg/Nm^3	12 μg/Nm^3	12 μg/Nm^3	12 μg/Nm^3	12 μg/Nm^3
SO_3	2% of SO_2	None	None	None	2% of SO_2	2% of SO_2
NH_3	1:1 with NO_x	1:1 with NO_x	1:1 with NO_x	1:1 with NO_x	None	None
Other Halogens	TBD	TBD	TBD	TBD	TBD	TBD
Temperature	650°F	650°F	650°F	650°F	350°F	650°F
Catalyst	Baseline	Baseline	Baseline	Baseline	Baseline	Baseline

temperature for a period of 1 hour prior to feeding Hg in the system. Three additional tests will be performed upon completion of the matrix in Table 1. The conditions for the additional tests will be chosen based on the results from the first six tests.

Task 2 – Development of SCR Catalyst for Mercury Oxidation

Task 2 will identify improved catalyst formulations for oxidizing elemental mercury. The focus will be on understanding the fundamentals of the catalyst–mercury interactions and identifying the catalyst components such as Al_2O_3, TiO_2, V_2O_5, and others that are critical to mercury oxidation. Haldor Topsoe will develop and supply different catalyst formulations and provide cofunding for the testing under this task. Three new catalyst formulations can be tested. Table 2 below contains the test plan for three catalyst formulations under this task. The three formulations will be those other than the standard SCR catalyst offered by Haldor Topsoe. The standard catalyst will be tested as a baseline and will be in addition to the three tests planned below.

The flue gas concentrations will be meant to mimic those of a low-rank fuel. Approximately 12 μg/Nm^3 of elemental mercury will be added to the bench-scale system. Small amounts of ammonia will be added to mimic a full-scale SCR system. The amount of elemental and oxidized mercury before and after the SCR catalyst chamber will be measured. The catalyst will be allowed to condition at temperature for a period of 1 hour prior to feeding Hg in the system.

Progress

To date, all efforts have been directed toward securing funding and completing the confidentiality agreement with Haldor Topsoe. The agreement has been successfully executed, and the test plan above was developed.

Table 2. Test Plan for Task 2

	Topsoe Test 1	Topsoe Test 2	Topsoe Test 3
Velocity	5 m/s	5 m/s	5 m/s
O_2	6%	6%	6%
CO_2	12%	12%	12%
H_2O	15%	15%	15%
SO_2	600 ppm	600 ppm	600 ppm
NO	120 ppm	120 ppm	120 ppm
HCl	1 ppm	1 ppm	1 ppm
NO_2	6 ppm	6 ppm	6 ppm
Hg^0	12 µg/Nm^3	12 µg/Nm^3	12 µg/Nm^3
SO_3	2% of SO_2	2% of SO_2	2% of SO_2
NH_3	1:1 with NO_x	1:1 with NO_x	1:1 with NO_x
N_2	Balance	Balance	Balance
Temperature	650°F	650°F	650°F
Catalyst	Topsoe 1	Topsoe 2	Topsoe 3

Quality Assurance/Quality Control

Quality Objectives

Activities within this project are focused on advancing the knowledge of and options for mercury control via oxidation in an SCR catalyst system. The quality objective of this project is to provide appropriate data that can be examined to test the researching hypothesis. These results will be used to determine whether mercury can be effectively oxidized by improved formulations of SCR catalyst under optimum conditions of oxidant concentration(s) and temperature to serve as the basis for enhancing mercury control technologies for western U.S. coals.

Measurement/Data Acquisition

The data will be collected with a Semtech or Tekran continuous mercury monitor (CMM).

The system is calibrated using Hg^0 as the primary standard.

Assessment and Validation

The following procedures will be used to ensure data quality:

- Sampling and analytical analysis protocols will be validated by comparing test data with other data generated using standard protocols in place at the EERC.

- The type and quantity of quality assurance (QA) samples will include calibration of the CMMs, replicate tests (minimum of three), and a blank at the beginning at each day.

- The QA/quality control (QC) data results will then be compared with data quality indicators to qualitatively determine the validity of the data in terms of precision and accuracy. Only when mass balances are ±30% will the data be considered valid.

Status

The testing is scheduled to take place in January and February of 2005. The results of this study will be submitted for presentation at one national conference.

Potential Users/Technology Transfer

Potential users of this technology will be any utility that wishes to use catalyst to enhance mercury oxidation and capture, especially utilities burning western fuels (lignite and PRB) where there is a low concentration of chlorine and, therefore, very little oxidized mercury. Oxidized mercury can more easily be captured in existing pollution control devices.

References

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