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Predicting the impact of SO₃ on mercury removal by carbon sorbents

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Abstract

This paper introduces a combined homogeneous and heterogeneous SO₃ production mechanism to quantify the interference of SO₃ on the capture of Hg by unburned carbon (UBC) and activated carbon sorbents in flue gas from coal-fired power plants. This mechanism was validated against measurements at different locations along the gas cleaning systems at fourteen power plants representing the entire range of coal-S, furnace stoichiometry, and gas cleaning conditions found in commercial applications.

The SO₃ production mechanism was then integrated into previously validated Hg transformation mechanisms to account for inhibition of Hg oxidation and removal due to SO₃ condensation on fly ash, UBC and activated carbon. This analysis was subsequently used to interpret Hg removals for more than two dozen test measurements at Daniel and the Mercury Research Center. These tests included different coal blends, ACI concentrations, conventional and brominated activated carbons, and SO₃ concentrations. The simulations clearly identified the tests affected by SO₃ interference and predicted the Hg removal by ACI to within 15% of the test measurements for 22 of the 27 tests at these two sites.

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1. Introduction

Activated carbon injection (ACI) into flue gas is currently the most important strategy for Hg capture in utility gas cleaning systems, especially for Hg capture from plants firing low rank coals which have inherently low concentrations of Cl. Several tests reported in NETL's Phase II Hg field-testing database indicated that SO₃ in the flue gas, either from the conversion of inherent SO₂ or from the addition of SO₃ as a flue gas conditioning agent, significantly diminishes Hg

capture by activated carbon sorbents. The testing did not demonstrate that a threshold SO₃ concentration determined whether or not SO₃ interference would come into play. Compounding matters, measurements of SO₃ concentrations are subject to large uncertainties and are almost never reported with Hg speciation in field-tests. Consequently, we developed a mechanism for SO₃ production and integrated it into reaction mechanisms for Hg transformations to quantify the inhibitory effect of SO₃ on Hg capture by unburned carbon (UBC) and ACI. This paper evaluates the simulation results with a suite of SO₃ measurements along full-scale cleaning systems, and with measured Hg removals in ACI applications at several power plants.

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2. Reaction mechanisms

2.1. SO_3 production mechanism

The mechanism for SO_2 oxidation describes the production of SO_3 from the furnace convective passes through the particle collection device (PCD) and consists of a collection of homogeneous and heterogeneous reaction mechanisms for distinct segments of a utility gas cleaning system. Sulfur dioxide begins to oxidize in the gas phase as flue gas moves through the convective passes. For this stage, we use the elementary reaction mechanism with 134 reactions involving 30 species reported by Yilmaz et al. [1] with no modifications to any of the rate parameters. The SO_3 production mechanism can shift to a heterogeneous mechanism on flyash while flue gas moves through the final superheaters and the economizer. Since the contribution from this stage has been related to the Fe content of flyash, we developed a closed-form analytical expression for the heterogeneous rate from the lab tests of Jorgensen et al. on SO_2 oxidation over Fe_2O_3 [2]. This rate depends on the concentrations of SO_2 and O_2 in the flue gas, as well as the mass fraction of Fe_2O_3 in the flyash. However, this heterogeneous contribution is very small unless both the ash content and the pyrite fraction are exceptional.

A second heterogeneous mechanism oxidizes SO_2 into SO_3 along SCR catalysts. We developed the rate for this stage from the mechanism reported by Svachula et al. [3], which has already been validated with extensive lab-scale data and used to accurately predict SO_3 production from full-scale utility SCRs. This heterogeneous rate depends on the concentrations of SO_2 and O_2 , as expected. It also depends on the concentrations of moisture, NH_3 , and NO , because both moisture and NH_3 inhibit SO_2 oxidation, whereas NO promotes it. Since NH_3 is always the deficient reactant in utility de NO_x applications, the SO_2 oxidation rate accelerates while the NH_3 concentration decays along the SCR catalyst, and becomes fastest through the trailing section of monolith.

Once the SO_3 has been produced as a vapor species, it may condense within the air preheater (APH) depending on the acid dew point of the flue gas. In the calculations, we evaluate dew points from the APH inlet through the PCDs with a dew point correlation [4] and the assigned flue gas composition. As soon as the gas temperature falls below a dew point, sufficient SO_3 is condensed onto flyash to reduce the dew point to the local gas temperature. These incremental condensations occur while the flue gas moves through the APH and into the PCD, provided that the dew point exceeds the local gas temperature. Otherwise, no SO_3 condenses to interfere with Hg adsorption. In the heterogeneous mechanism for Hg/Cl chemistry, the population of carbon sites

that can be chlorinated and therefore participate in adsorption of both elemental Hg (Hg^0) and oxidized Hg (Hg^{2+}) is reduced in proportion to the amount of condensed SO_3 . When the condensate completely covers the chlorinated site population, the interference reaches the saturation limit for monolayer SO_3 coverage.

2.2. Hg transformation mechanism

According to the established phenomenology for Hg transformations via Cl chemistry, suspended UBC is chlorinated while flue gas moves through the back-end heat exchangers, and Hg^0 oxidizes on the chlorinated sites at faster rates for progressively greater Cl levels in the flue gas. This stage of the in-flight heterogeneous chemistry is limited by the Hg^0 adsorption rate, so Hg^{2+} is produced but there is little accumulation of Hg on UBC particles in the back-end section. Generally, Hg^0 oxidizes even faster along SCR catalysts than on UBC if the Cl levels are moderate or higher, although the oxidation rates are affected by the catalyst formulation and several SCR operating conditions [5]. Downstream of the SCR, the chemistry shifts back to the in-flight mechanism on UBC which, in turn, shifts to desorption control when the flue gas is cooled by the APH. In this regime, adsorbed Hg species accumulate on UBC as particulate Hg (HgP) and are ultimately recovered in PCDs along with flyash. What little chemistry occurs at the low temperatures of PCDs perturbs the proportions of Hg^0 , Hg^{2+} , and HgP until enough UBC has been removed from the flue gas to quench the chemistry completely. Nearly all the Hg^{2+} vapors will be dissolved and retained in the FGD wastewater, while the Hg^0 vapors pass into the smokestack.

This phenomenology has been implemented with a 168-step homogeneous mechanism and a 6-step heterogeneous mechanism for Hg/Cl chemistry [6], and was recently expanded for Hg/Cl/Br chemistry [7]. The basic heterogeneous Cl mechanism was independently validated with Hg transformation data on whole coal-derived flue gas with suspended flyash and UBC first at lab-scale [8]; then at pilot-scale [9]; then with a field-test database that represents more than 50 field-tests in various full-scale gas cleaning configurations [6]. At this point it has been used to interpret over 100 sets of Hg speciation data from full-scale field-tests, including nearly all the tests in the Phase I and II NETL Hg testing program [10].

3. Validation of the simulation results

3.1. Validation of the SO_3 production mechanism

To validate the predictions from the SO_3 production mechanism, a database of SO_3

concentrations in coal-derived flue gas was compiled from literature including NETL field-tests on Hg speciation and/or SO₃ control. It comprises 14 test measurements from 13 full-scale cleaning systems. Of the 14 tests, 12 tests were on units firing bituminous coals and one test each was on a unit firing a subbituminous coal and a subbituminous/bituminous blend. Ten tests included an SCR in the gas cleaning system, of which five tests reported SO₃ concentrations at both the SCR inlet and outlet while three and two tests, respectively, reported SO₃ concentrations at only the SCR outlet and only SCR inlet. Three of the eight tests which reported a measured SO₃ concentration at the SCR outlet did not satisfy the input data requirements for modeling SO₃ production across an SCR. For these three tests, the predicted SO₃ was compared with the measured value only at the SCR inlet. For the tests that did not involve an SCR, two tests each reported SO₃ concentrations at the economizer outlet/APH inlet and APH outlet/ESP inlet. Test measurements beyond the ESP inlet were not used for validation purposes.

The SO₃ database covers the full range of coal-S (from 0.4 to 4.8 daf wt.%) and furnace stoichiometry in commercial power plants. Note, however, that in most cases test-specific coal properties including coal-S were not available and the calculations therefore used nominal values. Some tests at the sites which had test-specific coal-S measurements were discarded because the measured SO₃ concentrations either fell below the detection limit or were deemed too low by the testing teams. The economizer O₂ varied from 2.1% to 4.2% with most cases between 3.3% and 3.7%. Two independent tests at one site reported SO₃ concentrations at the SCR inlet for economizer O₂ levels of 2.1% and 3.5%. The effect of O₂ on SO₃ formation factors into our simulations of these tests. No economizer O₂ levels were reported for tests C-S1, C-S2 and C-S3. These tests were simulated at an O₂ level of 3% because the measurements were normalized to this level.

A simulation of the test case at Gavin appears in Fig. 1 showing the predicted formation of SO₃ from the furnace through the APH. Gavin fires a bituminous coal with 4.8 daf wt% S at a furnace stoichiometry that gives 3.5% O₂ at the economizer. Since flue gas temperatures were reported only from the economizer outlet onwards, the calculations impose our default thermal history for the upstream sections. SO₂ begins to oxidize in the convective passes, and continues to oxidize into the economizer. The SO₃ concentration increases through the back-end heat exchangers, but reaches a plateau near the economizer inlet, well-upstream of the SCR inlet. Along the SCR catalyst, SO₂ oxidizes at the fastest rate of all to double the SO₃ concentration. The predicted SO₃ concentrations at the SCR inlet and outlet

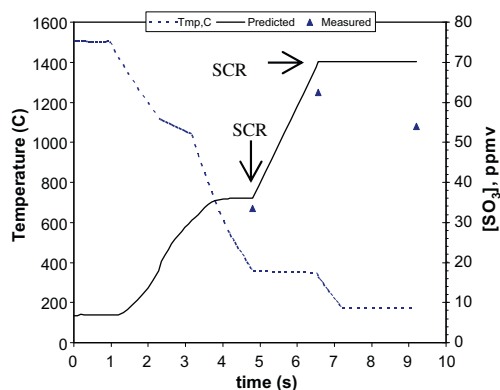


Fig. 1. Predicted SO₃ concentration along the gas cleaning system at Gavin compared with measured values (▲) on a wet basis at the actual O₂ level. The thermal history appears as the dashed line segments.

of 36 and 72 ppmv compare well with the measured values of 33.5 and 62.4 ppmv, respectively. There are no channels for SO₃ production downstream of the SCR so the flue gas SO₃ level remains constant until the flue gas reaches the acid gas dew point. For this cleaning system, the flue gas temperature was always above the calculated acid dew point of 153.4 °C. The reason for the drop in the measured SO₃ concentration at the APH outlet is therefore unclear.

The predicted SO₃ concentrations for all cases in the SO₃ validation database are compared with measured values in Fig. 2. Five cases with predictions across SCRs from four vendors appear on the left side. At present, an identical set of SO₂ oxidation rate parameters is used for the different vendors. Vendor-specific parameter sets, similar to the sets we use for Hg⁰ oxidation, will be specified as additional datasets become available. The predicted SO₃ concentrations match the measured values at all sites except S5 and, perhaps, RPS. All the predicted concentrations at SCR inlets are accurate. The predicted enhancement of SO₃ across SCRs is accurate for all sites except S5, where it was over-predicted. And the SO₃ levels at the three ESP inlets are also accurate. The measurements at L-S1 indicate a 29.3% reduction in SO₃ as the economizer O₂ was reduced from 3.5% to 2.1%, versus a predicted reduction of 29.4%.

Minor discrepancies at C-S1 and C-S2 are attributed to the omission of economizer O₂ levels in the test report which, as seen in L-S1O1 v. L-S1O2, can account for several ppm of SO₃. The only major discrepancy in the validation is at S5 where the predicted SO₃ concentration of 49 ppm at SCR inlet is significantly higher than the comparable data for a coal-S level of 4.4 daf wt% and an SCR in the gas cleaning configuration. By comparison, the measured SO₃ at S5 is inconsistent with

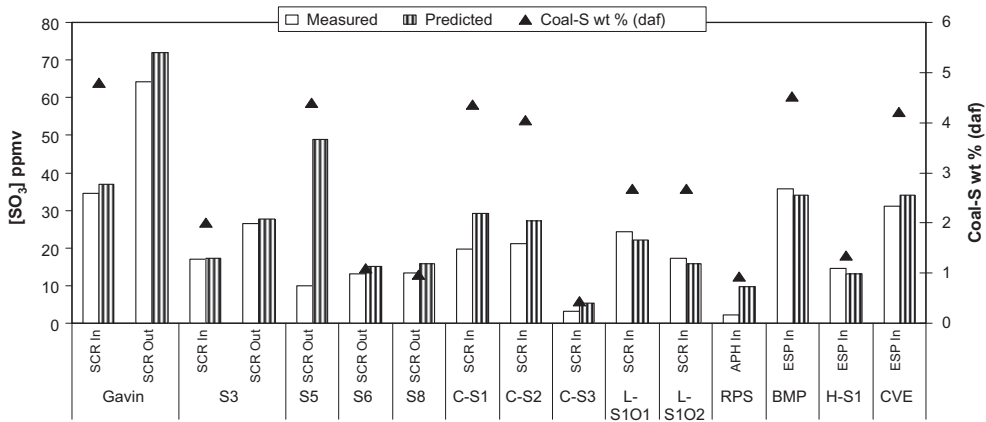


Fig. 2. Measured (open bars) and predicted (hatched bars) SO_3 concentrations at various sampling locations on a wet basis corrected to 3% O_2 . Coal-S values (\blacktriangle) in daf wt% are indicated on the right axis.

the remainder of the tests with similar or lower coal-S that report much higher levels of SO_3 than this measured value of 10 ppm. We strongly suspect that the measured value is erroneously low. When the test results at S5 are omitted, the correlation coefficient (R) for the predicted SO_3 concentration at the different sampling locations is 0.97.

3.2. SO_3 Interference on Hg capture by ACI

In full-scale gas cleaning systems it is almost never possible to standardize fuel quality throughout test campaigns as short as even several days, because coal-Cl variations are independent of all other coal properties. Gas cleaning conditions must also change to respond to variations in load and NO_x emissions, among many other factors. To contend with this inherent variability, we simulate each individual test based on the coal quality and gas cleaning conditions in effect while the Hg speciation data was recorded, to the extent possible. The following kinds of input data are required: the fuel properties consist of the proximate and ultimate analyses expanded with the Hg- and Cl-contents. A nominal flue gas composition is assigned with an equilibrium calculation from the fuel properties, fuel feedrate or furnace rating and load, and an economizer O_2 level. A continuous thermal history is constructed from the temperatures recorded at all Hg sampling locations; temperatures and transit times upstream of the measurement positions are almost always assigned from default specifications. UBC characteristics are assigned from LOI measurements and coal quality, and are also evaluated as a continuous function of residence time along the gas cleaning system. The flyash loading is determined by subtracting away the bottom ash, and expressed as a suspension loading in the whole flue gas. LOI is first used to estimate

UBC, then added to the flyash loading. As the flue gas cools, the suspension loading and therefore the UBC surface area per unit volume increases continuously. Conversely, UBC and flyash are eliminated at the PCDs, according to specified collection efficiencies. Ammonia is injected at the residence time for the SCR inlet. Mercury sorbents are processed the same way. Hence, all the necessary gas cleaning conditions are specified as continuous functions of residence time along the entire gas cleaning system.

The sets of differential equations associated with the elementary reaction mechanisms are solved as one-dimensional initial value problems in transit time, beginning with the equilibrium flue gas composition at the furnace exit. Each simulation of a full-scale gas cleaning system takes several seconds on a mobile workstation operating at 2.9 GHz.

Daniel Unit 1 is a T-fired furnace with an ESP-only cleaning configuration. The plant fires a 60/40 or 80/20 blend of bituminous/subbituminous coals with the blends having average coal-Cl of approximately 100 and 430 daf ppmw, respectively. Only an average inherent LOI of 3.2% was reported. Test-specific coal-Cl were not available for any of the ACI tests. The measured baseline Hg removal at this site was approximately 5% when firing the 60/40 blend. No baseline removal for the 80/20 blend was reported. The calculated baseline SO_3 concentrations at Daniel were 7 and 9 ppmv, respectively, for 60/40 and 80/20 coal blends and no measured SO_3 concentrations were reported. Darco Hg was injected upstream of the ESP at concentrations of 3, 5 and 9 lb/MMacf. Tests at Daniel evaluated SO_3 interference on Darco Hg performance by addition of 6 ppmv SO_3 upstream of the ESP in all cases involving the 60/40 blend and in select cases involving the 80/20 blend. For the Darco Hg-LH (brominated

activated carbon) tests, SO_3 was injected upstream of the ESP at a concentration of 6 ppmv in cases involving the 80/20 blend, and at 3 and 6 ppmv for the 60/40 blend. Hg speciation measurements were not reported for any of the ACI tests. The calculated acid dew point of approximately 137°C is greater than the temperatures across the ESP. The reported nominal temperatures at the ESP inlet and outlet were 137 and 121°C , and 141 and 130°C for the 60/40 and the 80/20 blends, respectively.

The measured and predicted Hg removals (as percentages of the total Hg inventories) for the Darco Hg cases are compared in Fig. 3a. The tests labeled as DSU1PHG1–3 fired the 60/40 blend while the rest fired the 80/20 blend. The suffixes ‘a’ and ‘b’ in the 80/20 blend test labels (DSU1PHG4–6) represent 0 and 6 ppmv added SO_3 , respectively. Six ppmv SO_3 was added in all three tests with the 60/40 blend (DSU1PHG1). For the Darco Hg-LH injection tests in Fig. 3b, all tests fired the 60/40 blend except DSU1PLH4a–b, which fired the 80/20 blend. For several tests, the

ACI injection location was shifted upstream to extend the residence time for Hg capture.

For the Darco Hg tests with the 60/40 blend (DSU1PHG1–3), the predicted Hg removals are within 5% of the measured values. The measured Hg removals increased from 10 to 29% while the predicted values increased from 9% to 32% as the ACI concentrations were increased from 3 to 9 lb/MMacf. With no SO_3 interference, the simulated Hg removals would have increased from 28% to 38% as the ACI concentration were increased from 3 to 9 lb/MMacf, which is 10–20% greater than measured values.

For the Darco Hg tests involving the 80/20 blend (DSU1PHG4–6) with and without added SO_3 , the predicted Hg removals are within 10% of the measured values for four of the six cases. The extent of inhibition of Hg capture by ACI due to SO_3 is accurately predicted at all ACI concentrations while the actual removals are over-predicted by at least 15% for the highest ACI concentration of 9 lb/MMacf. Whereas the measured extents of SO_3 interference hardly change with ACI concentration in this range, the predictions show progressively less interference for increasing ACI concentrations.

For the cases involving Darco Hg-LH in Fig. 3b, the predictions are accurate for all cases except two tests involving the 80/20 blend (DSU1PLH4a–b). Although the predictions show the inhibitory effect of SO_3 for these tests, the predicted Hg removals are significantly greater than the measurements. This discrepancy can only be explained if the actual operating temperatures were lower than the nominal values by at least 10 degrees, which would promote stronger inhibition by SO_3 . The predicted extents of Hg removal were within approximately 10% of the measured values for all the remaining tests. The simulations accurately predict the extent of inhibition of SO_3 on Hg capture by Darco Hg-LH at all three ACI concentrations and three added SO_3 concentrations for the 60/40 blend. Hg removals at tests DSU1PLH11–3, where the sorbent injection location was shifted upstream, are also predicted within 15% by accounting for the additional sorbent residence time in the flue gas in the simulations.

At comparable flue gas conditions, the brominated Darco Hg-LH removed 6, 9% and 27% more Hg than the untreated Darco Hg at injection concentrations of 3, 5 and 9 lb/MMacf, respectively, in the presence of 6 ppmv added SO_3 . The predictions at Daniel clearly show the accuracy of the mechanisms to predict SO_3 inhibition of Hg capture by ACI because the predictions are within 10% of the measurements for seven of the nine tests involving Darco Hg and for nine of the thirteen involving Darco Hg-LH. The correlation coefficient for the predicted removals for all tests at Daniel except two Darco Hg-LH tests with the 80/20 blend was 0.93 with a std. dev. of 8.7%

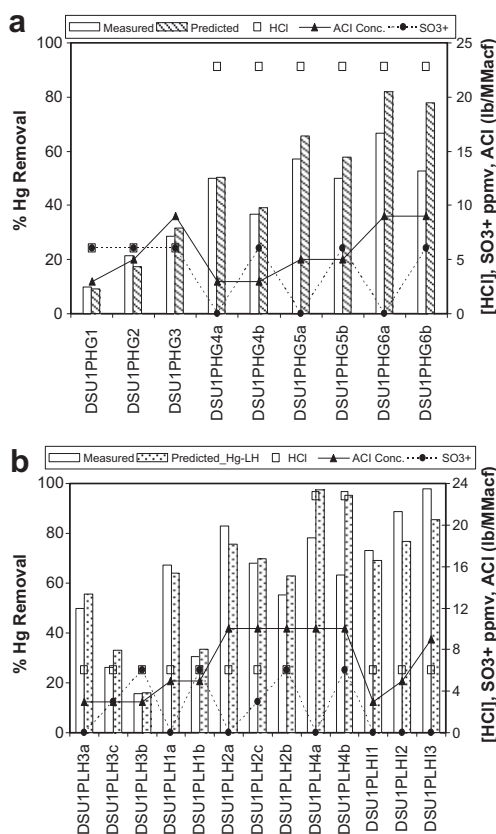


Fig. 3. Comparison of measured and predicted Hg removals (%) for (a) Darco Hg and (b) brominated Darco Hg-LH ACI tests at Daniel. SO_3+ represents additional SO_3 added to the baseline flue gas.

of the Hg inventory, which is well within the measurement uncertainties.

The Mercury Research Center (MRC) is fed by a 5 MW flue gas slipstream from a 75 MW T-fired boiler burning either a South American coal or a blend of South American and Eastern bituminous coals. The two coals have markedly different coal-Cl levels (0.02 v. 0.32 wt%) and neither test-specific coal-Cl levels nor the coal blend ratios were reported for any test. We used average properties for a coal blend from previous testing for all 15 tests, which gave a flue gas HCl level of 115 ppmv. An average inherent LOI of 6.5%, also based on a previous test report, was used for all tests. The measured baseline Hg removal at MRC was 38%. The calculated baseline SO_3 concentration at MRC was 9.5 ppmv and no measured SO_3 concentrations were reported. Tests at MRC evaluated the Hg removals for Darco Hg ACI both in the presence and absence of SO_3 . The injected concentrations of Darco Hg varied from 2 to 6 lb/MMacf while the added SO_3 concentration in the flue gas, denoted by ‘ SO_3^+ ’, varied from 0 to 34 ppmv.

Two types of test configurations were used: (i) Series MRC0: SO_3 injected upstream of the APH and Darco Hg injected upstream of the ESP, and (ii) Series MRC1: Darco Hg injected upstream of the APH and SO_3 injected upstream of the ESP. In series MRC0, the Darco Hg concentration was fixed at 4 lb/MMacf while the added SO_3 was increased from 0 to 34 ppmv. In series MRC1, the Darco Hg concentration was varied from 2 to 6 lb/MMacf while the added SO_3 was varied from 0 to 10 ppmv. The calculated acid gas dew points varied from 134 °C for the baseline 9.5 ppmv SO_3 to 150 °C for an additional 34 ppmv SO_3 . The average ESP operating temperatures were 152 °C at the ESP inlet and 138 °C at the ESP outlet. In the simulations, SO_3 interference comes into play as soon as the flue gas temperatures fall below the acid gas dew point.

Predicted Hg removals for all tests at MRC are compared with the measured values in Fig. 4. The predictions are within approximately 10% of the measured values for twelve of the fifteen tests. The only larger discrepancies are in tests MRC1HG2, MRC1HG3 – which has the maximum discrepancy of 23% – and MRC1HG14. These errors can be attributed to the omission of test-specific Cl and LOI values. The correlation coefficient for the predicted Hg removals for all tests at MRC is 0.80 and the std. dev. is 11.2% of the Hg inventory. More important, the predicted extents of SO_3 interference on Hg removals at a constant ACI concentration are accurate for all tests in the MRC0 series, which validates the SO_3 interference mechanism. The measured and predicted Hg removals are more clearly represented as a function of added SO_3 concentration in Fig. 5. The ACI concentration during this test

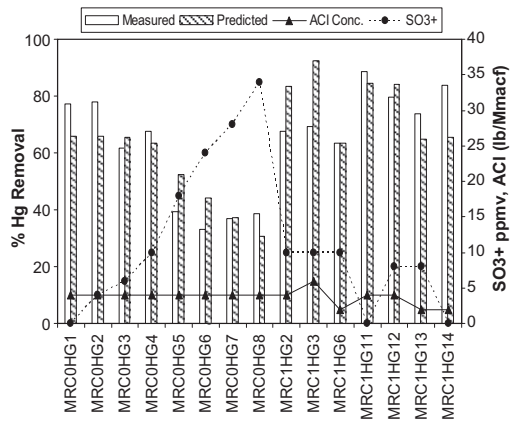


Fig. 4. Comparison of measured and predicted Hg removals (%) for Darco Hg ACI tests at MRC. SO_3^+ represents the equivalent SO_3 concentration in flue gas added to supplement the baseline concentration. The HCl concentration in all simulations was 115 ppmv.

series was 4 lb/MMacf. The predictions exhibit the unperturbed Hg removals though 10 ppm added SO_3 , then diminish for progressively greater SO_3 addition. They are accurate throughout the entire range of SO_3 additions in these tests.

It is difficult to compare Hg removals between the two test series at MRC because both the ACI and SO_3 concentrations were varied while the SO_3 and Darco Hg injection locations were swapped. Nevertheless, the predicted Hg removals are almost as accurate for series MRC1 as for MRC0. Parametric simulations indicated that injecting Darco Hg upstream of the APH increased the Hg removals by approximately 20%. Because the flue gas temperatures dropped below the acid gas dew point within the ESP,

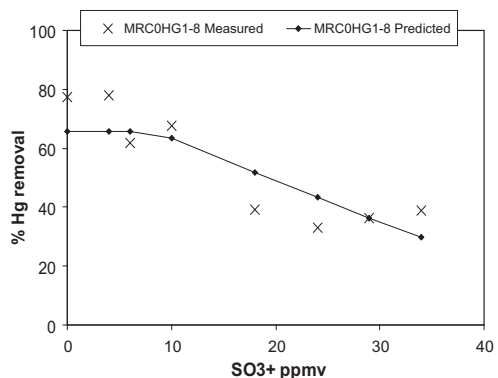


Fig. 5. Comparison of measured and predicted Hg removals (%) for the tests at MRC with variable levels of added SO_3 . In all simulations, the HCl concentration was 115 ppmv and the Darco Hg ACI concentration was 4 lb/MMacf.

the change in the SO₃ injection location did not affect the predicted Hg removals. Consequently, we attribute the additional removal, if any, achieved by injecting Darco Hg upstream of the APH to the extended sorbent residence time in the flue gas.

Due to the word limit, two other validation cases could not be presented. The predicted Hg removals from Monroe are within 2–15% of the measured values at the three higher ACI concentrations, but too high for the lowest ACI concentration, due to an over-prediction for the inherent Hg removal without ACI. Since test-specific LOI values were not reported, and since the predictions are accurate at all three higher ACI concentrations, a LOI variation could also be responsible for the poor prediction at the lowest ACI concentration. The worst performance was for Conesville, where measured removals increased from 8% to 18% whereas the predicted values increased from 80% to 88% as the ACI concentration increased from 10 to 18 lb/MMacf. These tests are especially hard to interpret because the flue gas is split into parallel PCDs and the temperatures dropped from 185 to 151 °C from the ESP inlet to the outlet on the B-side, while the temperatures on the A-side inlet and outlet were approximately 30 °C lower than the B-side. This temperature stratification meant that the B-side, where Hg was measured, operated above the calculated acid dew point while most of the A-side operated below the dew point. The test team attributed the inhibition of Hg capture by ACI to SO₃ in the flue gas, but we feel that the mechanism of inhibition in these tests remains unclear, although deeper interpretations are unwarranted due to the significant temperature stratification across the ESP.

4. Discussion

The proposed SO₃ production mechanism was validated against a literature database comprising the full range of coal-S, furnace stoichiometry, and cleaning conditions in commercial power plants. With the exception of one abnormally low test measurement, the correlation coefficient for the predicted SO₃ concentration at different sampling locations for fourteen full-scale plants is 0.97. Homogeneous oxidation along the convective passes and heterogeneous oxidation along SCR catalysts determine SO₃ concentrations into the APH, but heterogeneous oxidation on flyash is almost always unimportant.

Once the SO₃ production mechanism was integrated into our validated mechanisms for Hg transformations, the simulations correctly identified which sites in the Ph. II NETL Hg field-testing database were afflicted by SO₃ interference,

and predicted its impact on Hg removals. With the exception of tests at Conesville Unit 6, where temperature stratification across the ESP was an issue, simulations accurately predicted the effect of SO₃ on Hg removal by both conventional and brominated activated carbons at Daniel and the MRC. The predicted removals at these two sites for the different coal blends, activated carbons and SO₃ injection concentrations were within 15% of the measured values for 22 of the 27 test measurements. The proposed mechanisms clearly identify whether interference by SO₃ is important or not, as seen in the predictions of the MRC0 test series, which involve the addition of incremental amounts of SO₃ to the flue gas at a constant ACI concentration. Under these conditions, Hg removal by ACI was unaffected by less than 10 ppm of added SO₃ and, as the added SO₃ concentration reached 35 ppmv, approximately 35% inhibition is both measured and predicted.

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