

LEHIGH ENERGY UPDATE

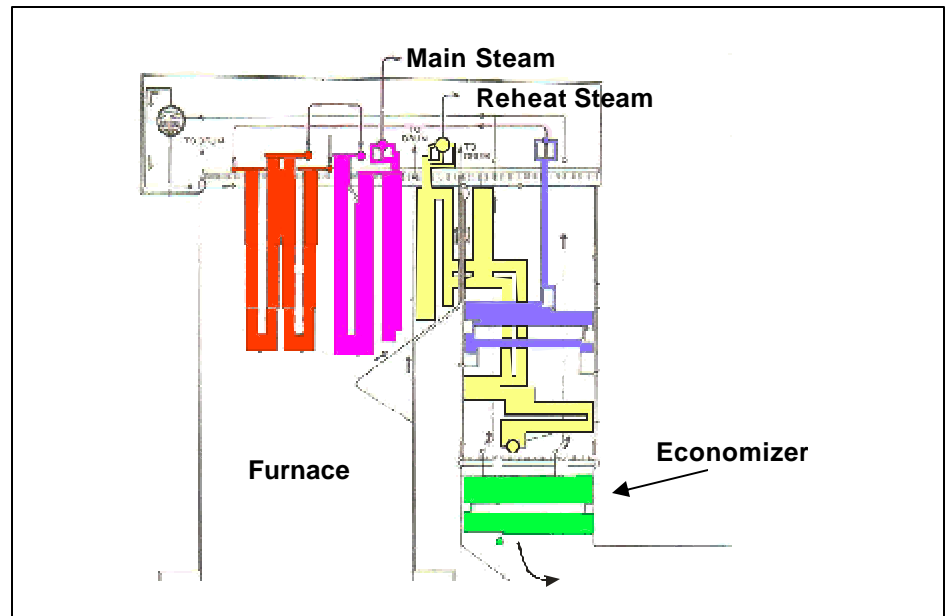


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MODELING SO₃ FORMATION PROCESSES IN COAL-FIRED BOILERS

Visible sulfuric acid plumes, due to formation of sulfur trioxide (SO₃) within the boiler, have become a major issue for some coal fired power plants. The presence of these plumes has led to an industry-wide effort to develop techniques to reduce SO₃ emissions, typically through injection of alkali reagents in the boiler to convert the gas-phase SO₃ to solid sulfate compounds. While it is recognized that SO₃ is formed in the boiler by oxidation of SO₂, there are several SO₃ formation and depletion mechanisms which contribute to the process, with very little information available on which of these are most important. A research team from the Energy Research Center has developed a boiler heat transfer and chemical kinetic computer modeling tool which is helping to clarify how boiler design, boiler operating conditions and fuel properties control the SO₃ formation process. Funded by the Electric Power Research Institute, this project involves Edward Levy, Carlos Romero, Zheng Yao, Harun Bilirgen and Hugo Caram from Lehigh University and Harvey Stenger, from the University at Buffalo (SUNY).

Levy explains, "The flue gas concentration of SO₃ in the economizer gas exit duct or at the SCR inlet, in the case of boilers with an SCR, is typically in the range of a few ppm to 40 ppm. The actual percentage of SO₂ which is converted to SO₃ is very much site specific, as is illustrated by the data in the table, which shows measured SO₃ concentrations in the economizer gas exit ducts of three coal-fired boilers. All are pulverized coal-fired, all burned Eastern coals with 2 to 3 percent sulfur, all have full load capacities in the 600 to 700 MW



Arrangement of Boiler Heat Transfer Sections of Boiler Modeled for SO₃ Generation.

range, and none was equipped with an SCR. The measured full load SO₃ concentrations, which covered the range from 1 to 24 ppm, point out the difficulty of estimating SO₃ solely from data on fuel sulfur content or on SO₂ emissions.

In fact, boiler design and operating conditions and fuel properties all affect the quantity of SO₃ which is produced. Examples of important variables include fuel sulfur content and fly ash composition, oxygen levels in the flue gas, design of the various boiler heat transfer sections and their arrangement in the boiler, and temperature distribution and residence time of the flue gas through the boiler."

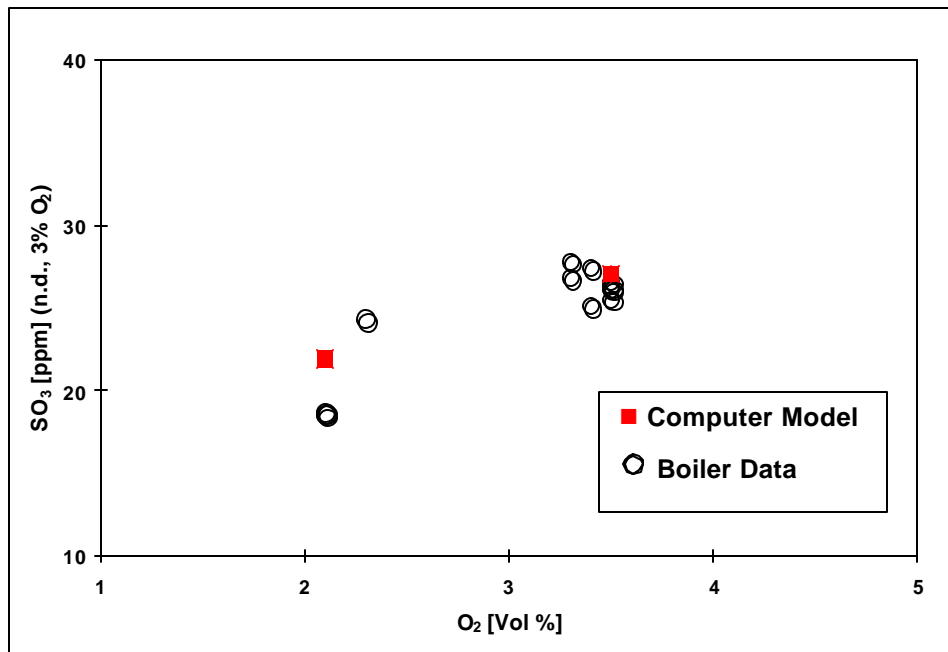
Stenger adds, "We've developed a chemical kinetic model of the boiler which treats the boiler as a chemical reactor for the formation of SO₃ from oxygen and SO₂. The model includes SO₃ formation reactions within the flue gas, between the flue gas and iron

oxide contained in the fly ash, and between the flue gas and the oxide scale layer on the tube wall. Alkali compounds contained in the fly ash cause a reduction of SO₃ concentration, and these reactions were modeled as well."

Zheng continues, "We then obtained boiler design data for a 600 MW pulverized coal boiler which fires an Eastern bituminous coal. After calculating the flue gas and tube wall temperature profiles, we used our computer model to predict the SO₃ concentrations at the SCR inlet for various boiler operating conditions and compared the predicted SO₃ values to measured values. We found the baseline predicted and measured SO₃ concentrations were in very, very close agreement. In addition, both the predicted and measured values followed the same trends as the excess air level was reduced and as the boiler sootblowers were activated. Now we

Measured SO₃ Concentrations in Economizer Gas Exit Ducts of Three Coal-Fired Boilers

Pulverized Coal-Fired; 2 – 3% Sulfur Coal			
Unit	SO ₃ (ppm)	Unit Load (MW)	O ₂ (%) at Economizer Gas Exit
A	1 to 2.5	585	2 to 4
B	20	640	--
C	21 to 24	700	4 to 5



Variation of SO₃ Concentration at SCR Inlet. Effect of O₂ Variations.

need to determine if our model will also give good results for boilers of other designs and for other fuels.”

Romero adds, “To carry out the validation process for the SO₃ code, we plan to use the code to model boilers of various designs, operating conditions and fuel and ash properties. But in order to do this, we will need to obtain access to other boilers so that we can test our model. EPRI has agreed to arrange for one of its contractors to make SO₃ measurements at various locations within the boilers and the Lehigh team will use its computer code to predict the SO₃ concentrations at those locations. The comparisons between our predictions and the measured values will either confirm the validity of the mechanisms included in our model or provide guidance on how to alter them. The host utilities will be asked to furnish detailed design data on the boiler

heat transfer sections and standard boiler operating data collected while the SO₃ is being measured.

Once the code has been validated and we are convinced it gives correct results, we will be in a position to use it to explore potential options for reducing SO₃ concentrations from boilers. We know from the calculations we’ve performed so far that some of the factors which contribute to high concentrations of SO₃ are heavy fly ash accumulation on convective pass heat exchangers and a fuel ash with high iron and low alkali content. But it is possible other factors, such as secondary superheater design or level of CO concentration in the furnace and convective pass might also have an impact on SO₃ formation. We plan to use our software to explore these and other potential SO₃ reduction possibilities.” ■