LEHIGH ENERGY UPDATE

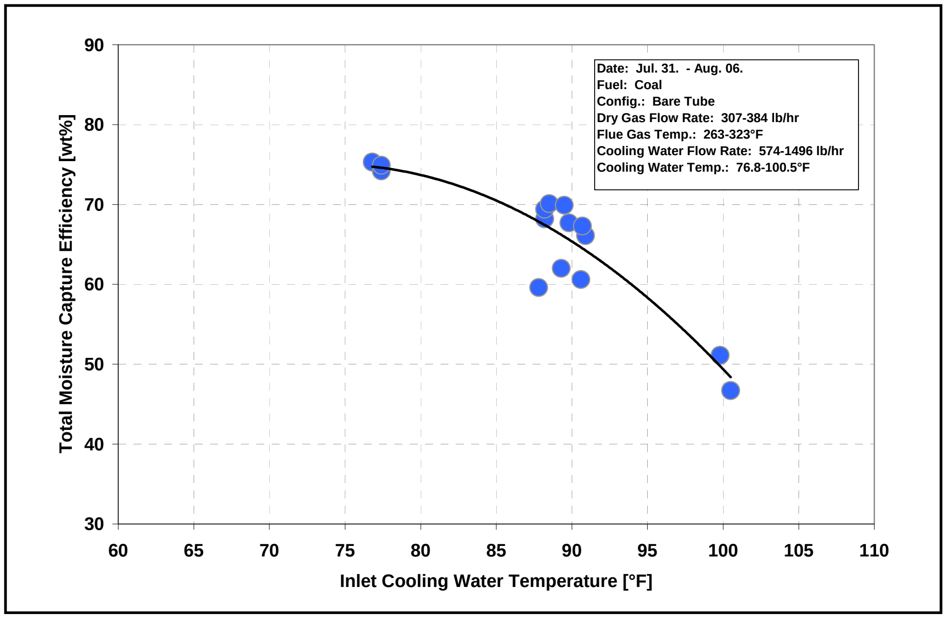
January 2008, Vol. 26, No. 1

CAPTURING WATER AND ACID VAPORS FROM BOILER FLUE GAS

Coal-fired power plants have traditionally operated with stack temperatures in the 300°F range to minimize fouling and corrosion problems due to sulfuric acid condensation and to provide a buoyancy force to assist in the transport of flue gas up the stack. However, there would also be significant incentives to cooling the flue gas to temperatures below the water vapor and acid dew points, provided the acid corrosion problems can be overcome in a cost-effective way. A team of Energy Research Center researchers, led by Edward Levy, has been developing heat exchanger concepts for this application, which they believe will provide substantial benefits for coal-fired power plants.

In addition to Levy, the project team includes Harun Bilirgen, Nenad Sarunac, Hugo Caram, Christopher Samuelson, Kwangkook Jeong, Michael Kessen and Christopher Whitcomb. Funding for the program is provided by NETL-DOE, Alstom Power Inc. and the Pennsylvania Infrastructure Technology Alliance.

According to Levy, "After decades of relatively stable regulatory requirements and a predictable operating environment, U.S. coal-based electric generation companies are beginning to be confronted with new requirements which are threatening to affect the operating profitability of their coal-fired units. For example, some power generation companies are having difficulties finding sufficient quantities of fresh water for power plant cooling. Some have had to inject alkali sorbents in their boilers to control emissions of sulfuric acid. New regulations governing control of mercury emissions are beginning to be implemented in some parts of the country, necessitating installation of new equipment, in some cases in



The weight percent of water vapor condensed in the heat exchangers depends on inlet cooling water temperature and initial moisture content of the flue gas. These results are for flue gas obtained by burning a high moisture coal.

combination with sorbent injection for mercury control. And looming ahead is the prospect that existing coal-fired units might have to be retrofitted with expensive technologies to reduce CO_2 emissions.

Benefits of Reducing Flue Gas Temperature. Use of heat exchangers to cool the flue gas and separate the acids and water vapor from the flue gas would help to solve the problems mentioned above. The condensed water vapor would provide a source of water for use in power plant cooling; recovered latent and sensible heat from the flue gas could be used to reduce unit heat rate and thereby reduce CO_2 emissions; condensation of acid in a controlled manner would reduce the flue gas acid content and provide environmental, operational and maintenance benefits; the reduced flue gas temperature would promote increased mercury removal; and the availability of low temperature flue gas with reduced acid and water vapor content would reduce the costs of capturing CO_2 at the back end of the boiler."

Test Apparatus and Results. Bilirgen continues, "Up to now, much of the focus of our project has been on designing, fabricating and testing heat exchangers, some designed specifically to capture sulfuric acid and others for condensation of water vapor and hydrochloric and nitric acid vapors from flue gas. The heat exchangers are connected in series to make it possible to separate the high temperature region where sulfuric acid condenses from lower temperatures where water vapor and hydrochloric acid and nitric acid vapors condense. By using this approach, we've been able to optimize the design of the heat exchangers, with some designed specifically to capture sulfuric acid and others to handle water vapor and the lower temperature acids."

The heat exchanger array is fully instrumented to measure flue gas

(Continued on Page 2)

("Boiler Flue Gas" Continued from P. 1)

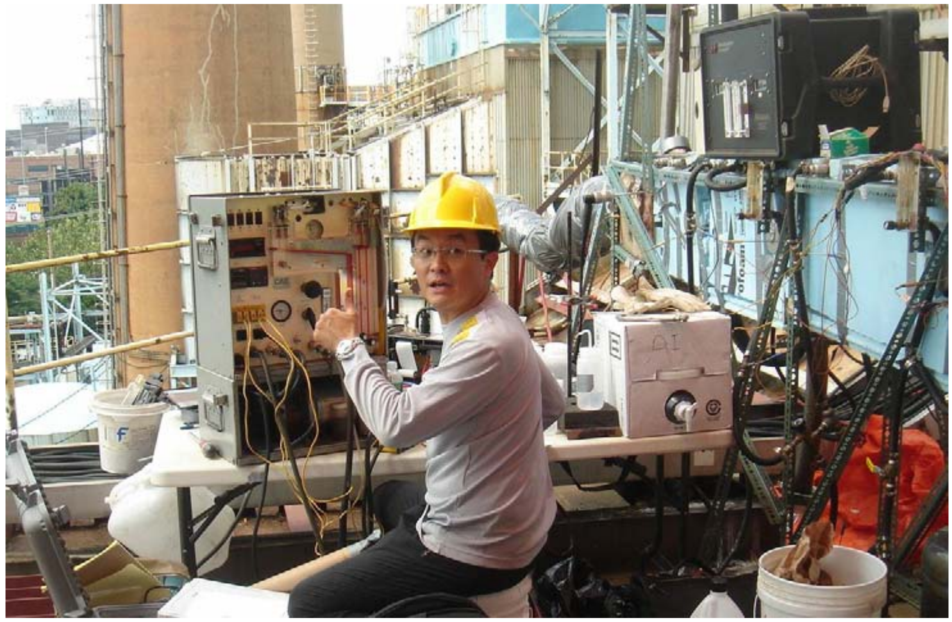
and cooling water flow rates and temperatures, flue gas water vapor content, and rate of water vapor condensation from each heat exchanger. In addition, a technique referred to as the Controlled Condensation Method is being used to measure flue gas sulfuric acid concentration.

The project team performed tests using slip streams of flue gas from both an oil and natural gas-fired boiler at Lehigh University and at a large coal-fired power plant. The data from tests at both sites very clearly show the effects of inlet cooling water temperature, flue gas flow rate and inlet water vapor moisture content on rate of water vapor condensation. The test data show that with a high moisture coal it is possible to capture approximately 50 percent of the flue gas water vapor, while operating with a flue gas discharge temperature in the 100 to 110°F range.

Typical sulfuric acid dew points are in the 240 to 300°F range, depending on flue gas sulfuric acid and water vapor concentrations. Measurements of flue gas sulfuric acid vapor show large reductions occurred in flue gas sulfuric acid concentration in the first few high-temperature heat exchangers. Laboratory analyses of condensed water from the low temperature heat exchangers indicate the presence of sulfuric, hydrochloric and nitric acids in the water condensate. Information on their concentrations will be used to select the most appropriate tube materials for the low temperature heat exchangers.

While performing tests at the coal-fired power plant, the project team also made measurements of flue gas mercury content, and these show a large beneficial effect of cooling the flue gas on mercury capture. The data show there was a 60 percent reduction in total flue gas mercury content from the inlet to the exit of the heat exchanger system.

Bilirgen adds, "The experiments have shown that the heat transfer and water vapor condensation data with flue gas from the coal-fired power plant are consistent with what we observed during testing with flue gas from firing fuel oil and natural gas. Moisture condensation capture efficiency is a strong function of inlet cooling water temperature and a much weaker function of flue gas inlet moisture content. Data on the nitrate and chloride concentrations in the condensed water indicate the expected range of concentrations of hydrochloric and nitric acids being deposited on heat exchanger tubes in the low temperature range of operation."



Tests at a coal-fired power plant showed not only good water capture efficiency, but also demonstrated the effects on acid and mercury capture.

Next Phase. Levy concludes, "The project team is now moving into the next phase of this program. We are gearing up to perform additional experiments in Spring 2008 to measure the effects of alternative heat exchanger designs on water vapor and sulfuric acid condensation patterns. We are developing computer software for modeling the heat transfer and condensation processes which occur as flue gas cools down as it flows through arrays of heat exchangers. The experimental data obtained from the pilot scale tests are being used to validate and fine-tune the computer algorithms. Once complete, the validated code will be used to design heat exchangers for full scale power plants, which is a necessary step to being able to estimate realistic costs of full scale condensing heat exchangers. We are also performing analyses of the impacts on unit heat rate of recovering sensible and latent heat from flue gas and integrating the captured thermal energy into the boiler and turbine cycles." ■

RESEARCHERS' PROFILES

- ***Harun Bilirgen*** is a Senior Research Scientist in the Energy Research Center and his research deals with performance improvement and emissions control in coal-fired power plants.
- ***Hugo Caram*** is a Professor of Chemical Engineering. His research is in the areas of mass transfer, chemical reactor design and chemical thermodynamics.
- ***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.
- ***Nenad Sarunac*** is a Principal Research Scientist and Associate Director of the Energy Research Center. His research focuses on power plant heat rate improvement, emissions control and process optimization.
- ***Christopher Samuelson*** has an MS degree in Mechanical Engineering from Lehigh University and is now employed in the power generation industry.
- ***Kwangkook Jeong, Michael Kessen, Christopher Whitcomb*** are Mechanical Engineering graduate students at the Energy Research Center.