If adopted by EPA, proposed new regulations on stack emissions will force many utilities with coal-fired boilers to reduce their NOx emissions to levels which are substantially lower than can be achieved with current low NOx burner technology. To meet these requirements, some utilities are anticipating the need to use selective catalytic reduction (SCR) for NOx control. New SCR catalysts under development at the Energy Research Center (ERC) show promise for substantially reducing the cost of using an SCR system.

Advantages of Low Temperature Operation. The selective catalytic reduction process uses a catalyst in the flue gas stream to decompose NO into N2 and O2. The ability of a catalyst to promote a particular chemical reaction is often extremely sensitive to temperature. Commercially available SCR catalysts operate in the temperature range of 600 to 750°F and as a result, they are typically located at the exit of the economizer. Most SCR catalysts require the use of ammonia to promote the conversion of NO. While these systems are quite effective at reducing NOx, they are also expensive, particularly for many retrofit applications. Some alternate designs locate the catalyst reactor downstream of the electrostatic precipitator, however, this requires the flue gas be reheated from the 300°F stack temperature to above 600°F, which increases heat rate and operating costs.

The catalysts being developed by the ERC operate in the temperature range of 250° to 300°F and, thus, are intended to be used at or near the inlet to the stack. There are several important advantages of this approach. Locating the reactor just prior to the entrance of the stack decreases the cost of the installation, particularly for retrofit applications. Potential capital savings result from the availability of more space at or near the stack than in the economizer exit gas duct, and thus better accessibility and easier installation. There will be savings in materials of construction due to lower reactor temperatures and a clean flue gas.

In addition, the outage time required for installation will be shorter because of the less complicated retrofit.

Savings related to operation will also be realized. These include less need for sootblowing and catalyst cleaning, longer catalyst life, the avoidance of reheating costs and a higher resale value for fly ash because of the lack of ammonia contamination.

The Catalyst Development Process. The ERC’s catalyst program involves faculty, staff and students from chemical engineering, chemistry and materials science and engineering. The low
temperature SCR catalyst project is under the direction of Professor Harvey Stenger from Chemical Engineering, Dr. Richard Herman, Director of the Zettlemoyer Center for Surface Chemistry, and Professor Charles Lyman, a professor from Materials Science and Engineering. The project, which has been underway since December 1996, has focused on close to a dozen different catalysts, all of which were prepared and characterized and are now being tested at Lehigh.

Catalyst development is an iterative process, typically involving catalyst preparation, characterization, testing and redesign. Herman describes the catalyst preparation process. “Catalysts come in various configurations and sizes, including powders, pellets, and monoliths. The actual catalyst components are usually incorporated onto supports by impregnation, wash coating, physical mixing prior to extrusion or a combination of these techniques.

Prior to use, catalysts are often pretreated to give them the desired surface chemical properties. Pretreatment is usually carefully conducted in known gas environments for precise amounts of time and with well controlled temperatures.”

After preparing the various catalysts to be tested, the Lehigh team characterized its catalysts to obtain information on bulk structure, chemical composition and morphology, and chemical and electronic properties. This allowed the researchers to observe the surfaces of the catalysts and understand the reactions which occur.

The catalyst group has access to a wide array of sophisticated characterization techniques to examine surface structure and chemical composition at the atomic level. This instrumentation, located in research laboratories at Lehigh, includes x-ray photoelectron spectroscopy, Auger electron spectroscopy, laser Raman spectroscopy, analytical electron microscopy, environmental scanning electron microscopy, solid-state nuclear magnetic resonance, Fourier transform infrared spectroscopy and x-ray powder diffraction.

Lyman, whose specialty is scanning electron microscopy analysis of catalysts, explains, “Characterization is typically done both before and after catalyst testing. Before testing, it is important to know if the catalyst was prepared correctly. After testing, the catalyst may be in a different chemical or physical state and thus chemical surface analysis, catalyst dispersion and surface area measurements are necessary to determine what effects the reaction conditions had on the catalyst structure. Knowing the chemical, physical and surface structure of the catalyst, both before and after testing, and correlating this information to catalyst performance allows us to determine what catalyst structures are most beneficial for the desired reaction.”

The catalysts studied by the group are being tested in two types of reaction systems. The continuous flow system uses reagent gases which are blended as desired from gas cylinders. Using the system, the catalyst can be tested in a gas stream having a composition very similar to that encountered at a power plant. More important, the gas composition can be varied to determine the effects of gas species such as O\(_2\), NO, H\(_2\)O and SO\(_2\) on catalyst performance and life. Test temperature and data collection are controlled by computer.

A second type of reactor used by the group incorporates a combustor able to produce flue gases found in coal-fired, oil-fired and gas-fired power plants and conducts the gas analysis using a Fourier transform infrared spectrometer. With this latter apparatus, the team is able to test SCR catalysts under actual flue gas conditions.

**Results to Date.** The catalyst testing phase of the project has been under way for about nine months. So far the tests on the catalysts have involved experiments to determine the effects of gas composition, temperature and length of exposure to the gas stream on catalyst performance.

The first phase of testing identified two catalysts out of the initial group which are particularly active at temperatures in the 300°F range. The preparation methods involve both ion exchange and impregnation with carefully controlled pretreating procedures. The other catalysts tested appear to be suitable only for higher temperature applications.

One of the limitations on use of catalysts in a coal-fired boiler is the effect of SO\(_2\) on catalyst performance and life. Tests with H\(_2\)O in the gas stream showed no harmful effects on either catalyst performance or life. Testing is now underway to determine the long term effects of SO\(_2\) on these catalysts and to begin the process of fine-tuning the catalyst design to maximize NO conversion while minimizing detrimental effects due to SO\(_2\) impacts.

Once the bench scale studies have been completed, the project team plans to test its catalysts in a flue gas stream at a pulverized coal-fired power plant. If the results of the laboratory and field testing are all positive, the catalysts will be licensed for commercialization to a company which specializes in SCR catalysts.

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