Recent Experiences Tuning SCR Systems

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ABSTRACT
An important step in starting up an SCR system is tuning the AIG to obtain uniform NH$_3$/NO$_x$ ratios across the catalyst. In addition, it is also of interest to assess the velocity distribution across the catalyst surface. FERCo utilizes a technique involving NO$_x$ measurements alone at the catalyst exit to characterize the NH$_3$/NO$_x$ distribution across the catalyst surface. This involves making outlet NO$_x$ measurements with the ammonia turned off, then again with the ammonia injection set to give a modest level of NO$_x$ reduction (i.e., 50 – 60%).

A novel approach has also been developed using catalyst outlet NO$_x$ measurements to determine the velocity distribution across the catalyst.

These measurements are streamlined using FERCo’s MCDA (Multipoint-Multigas-Combustion Diagnostic Analyzer) analyzer with AIG tuning usually completed in nominally three days. Examples are presented for both boiler and gas turbine SCR systems.

INTRODUCTION
SCR (Selective Catalytic Reduction) is a key post-combustion NO$_x$ control technology that has become the method of choice by utilities to comply with increasingly stringent NO$_x$ regulations. Over 100 GW of SCR are expected to be installed in the U.S. Many of these SCR systems are being designed for high NO$_x$ reduction efficiencies of over 90% while minimizing NH$_3$ slip to below 2 ppm. In coal-fired boilers, high NH$_3$ slip has an adverse impact on cold-end equipment located downstream of the SCR reactor. The concerns include deposition, plugging and potential corrosion. On natural gas-fired units, NH$_3$ slip is primarily a regulatory issue.

The parameters that are important in achieving the concomitant requirements of high NO$_x$ reduction and low NH$_3$ slip are a uniform velocity distribution at the ammonia injection grid (AIG) and catalyst inlet, a uniform NO$_x$ distribution at the AIG, and a uniform temperature and NH$_3$/NO$_x$ ratio distribution at the catalyst inlet. Uniform velocity, NO$_x$ and temperature distribution are achieved by optimizing the ductwork design by the use of turning vanes, baffles, and perforated plates. Uniform NO$_x$ distribution at the AIG facilitates achieving a more uniform NH$_3$/NO$_x$ ratio at the catalyst. Uniform temperature distribution maintains uniform activity at high load and minimizes the deposition of ammonium bisulfate at low loads.

Of these parameters, the one that has the largest impact on achieving high levels of NO$_x$ reduction with low NH$_3$ slip is the NH$_3$/NO$_x$ ratio distribution at the catalyst surface. Large local variations in NH$_3$/NO$_x$ distribution result in NH$_3$ slip as NH$_3$/NO$_x$ ratios greater than unity mean that there are local areas of excess ammonia that pass through the catalyst unreacted.
The impact of NH$_3$/NO$_x$ ratio maldistributions on SCR performance is depicted for coal- and gas-fired units in Figures 1a and 1b, respectively. The figures were derived using FERCo’s SCR process model for SCR performance prediction for a typical coal and gas unit SCR operating at the following conditions:

<table>
<thead>
<tr>
<th></th>
<th>Coal</th>
<th>Nat Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space velocity, hr$^{-1}$</td>
<td>3200</td>
<td>12,000</td>
</tr>
<tr>
<td>Catalyst pitch, mm</td>
<td>7.7</td>
<td>3.3</td>
</tr>
<tr>
<td>Catalyst area, m$^2$/m$^3$</td>
<td>479</td>
<td>1,030</td>
</tr>
<tr>
<td>Initial NO$_x$ level, lb/10$^6$ Btu</td>
<td>0.3</td>
<td>0.15</td>
</tr>
<tr>
<td>Velocity Maldistribution, RMS%</td>
<td>10</td>
<td>10</td>
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</tbody>
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Figure 1. Effect of NH$_3$/NO$_x$ Maldistributions on SCR Performance

Figures 1a and 1b show the importance of the NH$_3$/NO$_x$ distribution on performance. For overall NO$_x$ reductions of 90% or more, the NH$_3$/NO$_x$ distribution becomes extremely important. For the coal-fired case shown in Figure 1a, if the NH$_3$ slip must be below 2 ppm to prevent air heater deposition and plugging, the maximum NO$_x$ reduction achievable is nominally 93% even with an NH$_3$/NO$_x$ maldistribution approaching 2%. If lower NO$_x$ reductions, on the order of 85%, are required, a much larger NH$_3$/NO$_x$ maldistribution can be tolerated. For instance, at 85% NO$_x$ reduction, the difference in NH$_3$ slip between 2% and 8% NH$_3$/NO$_x$ nonuniformity is only 0.5 ppm, with the absolute NH$_3$ slip level being less than 1.0 ppm.

For natural gas-fired units, the allowable NH$_3$ slip will typically be in the range of 5 to 10 ppm and is determined primarily by a regulatory limit. At 5 ppm NH$_3$ slip, a maldistribution of 8 to 10% can be tolerated while still achieving 90% NO$_x$ reduction. At an NH$_3$ slip limit of 10 ppm, much larger maldistributions can be tolerated, see Figure 1b.

The emphasis on achieving uniform NH$_3$/NO$_x$ ratios across the catalyst points to the importance of the ammonia injection grid (AIG) as part of the SCR system. It is the AIG that is used to adjust the distribution of the ammonia flow across the duct commensurate with the inlet NO$_x$ distribution to achieve the required NH$_3$/NO$_x$ distribution. For this reason AIGs should be designed with the flexibility to bias ammonia flow in zones across both dimensions of the duct.
even when static mixers are utilized. Although ductwork design is optimized to achieve a uniform velocity distribution at the AIG inlet, the actual NO\textsubscript{x} distribution may not be uniform due to the unit’s boiler and combustion design and operating characteristics. Thus, AIG tuning is one of the key startup activities of an SCR installation.

FERCo has been actively involved in tuning SCR systems and has developed an approach using instrumentation and techniques that allow the NH\textsubscript{3}/NO\textsubscript{x} distribution to be measured by making only NO\textsubscript{x} measurements at the catalyst exit. FERCo has recently investigated the use of a similar technique to determine the velocity profile at the catalyst.

**SCR TUNING APPROACH**

**NH\textsubscript{3}/NO\textsubscript{x} Distribution**

Given an adjustable AIG, the primary measurement for optimizing SCR performance is the NH\textsubscript{3}/NO\textsubscript{x} distribution. The NH\textsubscript{3}/NO\textsubscript{x} distribution can be determined by making only NO\textsubscript{x} measurements at the exit of the last layer of catalyst.

The basis of the approach is that when NH\textsubscript{3} is injected, it either reacts with NO\textsubscript{x} across the catalyst, or it is emitted as NH\textsubscript{3} slip. This leads to the simple mass (or mole) balance:

\[
\text{NH}_3\text{in}_i = (\text{NO}_x\text{in}_i - \text{NO}_x\text{out}_i) + \text{NH}_3\text{slip}_i \quad \text{(Eqn. 1)}
\]

At modest NO\textsubscript{x} reduction levels, the NH\textsubscript{3} slip in the above equation will be zero even with large NH\textsubscript{3}/NO\textsubscript{x} maldistributions. With zero NH\textsubscript{3} slip the above equation becomes:

\[
\text{NH}_3\text{in}_i = (\text{NO}_x\text{in}_i - \text{NO}_x\text{out}_i) \quad \text{(Eqn. 2)}
\]

And the local NH\textsubscript{3}/NO\textsubscript{x} ratio at point i on the catalyst can be calculated as

\[
\left(\frac{\text{NH}_3}{\text{NO}_x}\right)_i = \left(1 - \frac{\text{NO}_x\text{out}_i}{\text{NO}_x\text{in}_i}\right) \quad \text{(Eqn. 3)}
\]

The above relationship holds for each local region of the catalyst. To balance the ammonia injection grid, or to determine the NH\textsubscript{3}/NO\textsubscript{x} distribution across the catalyst, the following steps are required:

1. Obtain a profile of the SCR inlet NO\textsubscript{x} concentrations. This can be done either by a) measuring NO\textsubscript{x} immediately upstream of the catalyst bed, or b) turning off the NH\textsubscript{3} and measuring NO\textsubscript{x} immediately downstream of the catalyst.

2. Turn on the NH\textsubscript{3} in order to achieve a modest overall NO\textsubscript{x} reduction (50-60%). At this level of NO\textsubscript{x} reduction, even if there are large maldistributions in NH\textsubscript{3}, there should be little or no local NH\textsubscript{3} slip.

3. Obtain a reduced-NO\textsubscript{x} profile at the catalyst exit.
4. Calculate the local NH₃/NOₓ ratio using Equation 3 above and the data from the inlet NOₓ and reduced-NOₓ on profiles (since in the above equation, NH₃slip = 0).

5. Tune the AIG to obtain a uniform NH₃/NOₓ distribution.

6. Increase the total NH₃ flow to reduce the outlet NOₓ to the required level, within the allowable NH₃ slip limit.

**Impact of NH₃ Slip on Tuning Procedure Validity**

The tuning procedure outline above is based on the requirement that there be no NH₃ slip at modest NOₓ reduction levels (50-60%). It is of interest to examine the validity of the tuning procedure if the zero NH₃ slip requirement was not met and there was NH₃ slip present.

SCR process model calculations were made for a typical coal-fired SCR condition. In this calculation, a random number generator was used to generate NH₃/NOₓ distributions across a catalyst surface with varying degrees of nonuniformity (characterized by the standard deviation) ranging from 3.5% to 14%. Local NOₓ reduction and ammonia slip values were then calculated for each of the randomly generated NH₃/NOₓ distributions. These calculations were made for a NOₓ removal of 85% and velocity nonuniformity of 10%.

The local NH₃/NOₓ ratios were calculated using the local NOₓ reductions and the equations discussed above with the assumption of zero local NH₃ slip. The actual NH₃/NOₓ nonuniformity versus that recovered using the technique assuming zero NH₃ slip is given in Figure 2. At the 8.6% Std. Dev. case, the local NH₃ slip was 2.4 ppm. Even with 2.4 ppm NH₃ slip, which for most coal-fired applications represents end of life, the calculated distribution of 7.8%, is fairly close to the actual distribution of 8.6% input to the model. At higher ammonia slips, the assumption of zero slip begins to introduce large errors in the calculated NH₃/NOₓ distribution.

**Figure 2.** Calculated NH₃/NOₓ Distribution vs. Input NH₃/NOₓ Distribution
The slip sensitivity analysis illustrates that the tuning procedure assuming zero slip is valid at modest NO\textsubscript{x} reduction levels even if there is some NH\textsubscript{3} slip present. It also illustrates that for installations for which ammonia slip at the design NO\textsubscript{x} reduction is very low (1 or 2 ppm), the outlet NO\textsubscript{x} measurement with NH\textsubscript{3} on (Step 2 in the tuning procedure) can be performed at the design NO\textsubscript{x} reduction condition instead of the 50-60% reduction condition. A similar analysis could be conducted for a natural gas-fired SCR to ascertain how much NH\textsubscript{3} slip can be tolerated and still yield valid NH\textsubscript{3}/NO\textsubscript{x} distribution.

**Impacts of Velocity Maldistribution on Tuning Procedure Validity**

The tuning approach discussed above calculates local NH\textsubscript{3}/NO\textsubscript{x} ratios from measurements of baseline NO\textsubscript{x} and modestly reduced NO\textsubscript{x} (with zero ammonia slip) conditions. Since NO\textsubscript{x} reduction is also a function of space velocity as well as NH\textsubscript{3}/NO\textsubscript{x} ratio, the question arises whether the measured reduced-NO\textsubscript{x} distribution manifests the effect solely of local NH\textsubscript{3}/NO\textsubscript{x} variations or also of local space velocity variations. If the outlet NO\textsubscript{x} variation includes the effect of local space velocity variation, then the accuracy of the tuning procedure may be affected since the AIG is being tuned without accounting for these local variations in space velocity.

Figure 3 shows the dependence of NH\textsubscript{3}/NO\textsubscript{x} distribution on velocity maldistribution (both characterized by the standard deviation). As with the previous calculations, a random number generator was used to generate velocity distributions across a catalyst surface with varying degrees of nonuniformity ranging from 4% to 35% standard deviation. Local NO\textsubscript{x} reduction and ammonia slip were then calculated for each of the randomly generated velocity distributions assuming a uniform NH\textsubscript{3}/NO\textsubscript{x} ratio of 10.8% for a gas unit and 5% for a coal unit. The plot in Figure 3 shows that NH\textsubscript{3}/NO\textsubscript{x} distribution calculated from the above equations is insensitive to large variations in velocity (space velocity) approaching 35%, and that the accuracy of the tuning approach is not affected by local space velocity variations.

**Figure 3.** Effect of Velocity Maldistribution on the Measured NH\textsubscript{3}/NO\textsubscript{x} Distribution
Test Equipment and Instrumentation

To determine NH$_3$/NO$_x$ or velocity distribution at the catalyst inlet, point-to-point NO$_x$ measurements at the catalyst exit are needed. Depending on the size of the SCR reactor, it is not uncommon for a reactor to have a 36- to 48-probe grid at the catalyst exit, or 96 probes for the entire SCR system if it is a two-reactor design. At a measurement rate of 2 to 3 minutes per point, it will require between 1.5 to 2.5 hours per reactor, or 3 – 5 hours to obtain a complete NO$_x$ profile.

In order to simplify these point-to-point measurements, FERCo has developed an NO/O$_2$/CO monitoring system that is capable of simultaneously monitoring the NO, O$_2$, and CO levels for up to twelve separate sample points in the economizer exit duct or SCR exit. This analyzer system allows the SCR profiles to be characterized in a matter of minutes, as opposed to hours. Data from twelve sample lines is taken every 10 seconds and a contour plot of O$_2$, NO, and CO is shown in “real time” on a computer screen. Figure 4 shows a general arrangement of this system.

**Figure 4.** FERCo’s Multipoint-Multigas Combustion Diagnostic Analyzer

The Multipoint-Multigas Combustion Diagnostic Analyzer (MCDA) is installed in FERCo’s mobile laboratories which are configured to routinely handle up to 48 sample lines. A valve panel containing 12 five-way valves is used to successively sample from 12 of 48 probes. With this system, a 48-point profile can be obtained in about 30 minutes, and a large two reactor SCR system can be completely characterized in nominally one hour. This is roughly one-fifth of the time required if the points are measured one at a time. The MCDA is used in conjunction with an extractive continuous emissions monitoring (CEM) package, also contained in FERCo’s mobile lab. This provides a means to validate the NO$_x$ measurements made by the MCDA.

FERCo has also developed a simplified version of the MCDA that has the same capability as the system described above. However, rather than monitoring twelve separate sample points simultaneously, it monitors two sample points simultaneously. The twelve sample points are monitored sequentially in sets of two using a specially designed and computer controlled rotary
valve. While the data collection rate is a little slower than the 12-point MCDA this system has greater portability and lower testing costs.

**AIG OPTIMIZATION EXAMPLE CASES**

FERCo has been successful in applying the approach described in this paper to tune the ammonia injection grids on both boiler and gas turbine SCR systems. Results from some of these tuning efforts using this technique are described below.

**A 230 MW Natural Gas-Fired Boiler**

A 230 MW tangentially fired gas-fired boiler was retrofitted with an SCR system. Results of the AIG tuning are shown below in Figure 5. Figure 5a shows the baseline test of the as-found condition with no ammonia injection. With the addition of enough ammonia flow to reduce NOx emissions about 70% (with all valves set for equal ammonia flow), the NOx and NH3/NOx profiles of Figures 5b and 5c were achieved. The variation in NH3/NOx distribution had a standard deviation of 9.7%.

**Figure 5. 230 MW Natural Gas-Fired Boiler**

Figure 5d shows the optimized NH3/NOx profile after nominally four AIG valve adjustments. The standard deviation was 4.1%, reduced from 9.7%. The NH3 slips were measured and found to be well within the allowable limit of 10 ppm, in fact the NH3 slip was less than 2 ppm.

**14 MW Gas Turbine with Waste Heat Recovery Boiler**
The AIG of an SCR system on a 14 MW gas turbine (with a waste heat recovery boiler) was tuned. The standard deviation for the as-found condition was 14.7%. At the completion of the tuning effort, the standard deviation was reduced to 6.5%. The corresponding NH$_3$/NO$_x$ distribution profiles are shown in Figure 6. While the uniformity was significantly better than the target RMS of 10%, a maldistribution still remains in the center of the duct. This is due to the AIG design that only had two adjustable zones across the duct width. With two zones it was not possible to deal with a high NH$_3$/NO$_x$ region in the center of the duct.

**Figure 6. 14 MW Gas Turbine**

![Graph showing NH$_3$/NO$_x$ distribution for as-found and optimized conditions](image)

(a) As-found (RMS=14.7%)  
(b) Optimized (RMS=6.5%)

**600 MW Coal-Fired Boiler**

Figure 7 shows the results of tuning a large 600 MW coal unit. The SCR system has two reactors but, for illustration purposes, the results from only one reactor are shown. With all AIG valves open, the “as-found” NH$_3$/NO$_x$ distribution was quite good, exhibiting a standard deviation of 3.6 % (Figure 7a). However, a couple of valve adjustments, completed in a day, improved the distribution to a standard deviation of 2.1 %. This is also apparent in the fewer contours in Figure 7b.

**Figure 7. Tuning a Large Coal-Fired SCR**

![Graph showing NH$_3$/NO$_x$ distribution for as-found and optimized conditions](image)

(a) As-found RMS = 3.6%  
(b) Optimized RMS = 2.1%
Catalyst Velocity Distribution

Using traditional methods for measuring flue gas velocities in an SCR system can be cumbersome and problematic. Characterizing the velocity distribution at the catalyst inlet using pitot probes is difficult because of the low velocities and the long probes required to cover the entire span of the catalyst surface. An alternative method for characterizing velocity distribution, again by making NO\textsubscript{x} measurements at the catalyst exit, is described here.

At typical SCR operating conditions the NH\textsubscript{3}/NO\textsubscript{x} uniformity dominates the performance. If the NH\textsubscript{3}/NO\textsubscript{x} maldistributions can be eliminated, then in principal the NO\textsubscript{x} variations are only a function of local space velocity (or velocity effects, assuming uniform catalyst activity). As a special short-term test, the NH\textsubscript{3}/NO\textsubscript{x} maldistribution can, in essence, be eliminated. This can be done by operating the SCR for a short time at high NH\textsubscript{3}/NO\textsubscript{x} ratios (e.g., NH\textsubscript{3}/NO\textsubscript{x} ~ 1.5). At these high ratios any NH\textsubscript{3}/NO\textsubscript{x} effects should be eliminated since the NH\textsubscript{3}/NO\textsubscript{x} ratio at any point of the catalyst bed should be greater than 1.0. Thus, there should be sufficient NH\textsubscript{3} at any point on the catalyst to remove the maximum possible amount of NO\textsubscript{x} at that point.

The results of such a special test are illustrated in Figure 8. The figure shows data at the outlet of a gas turbine SCR catalyst as a function of the ammonia injection rate (20-point grid at the outlet). In this case, the NO\textsubscript{x} concentration at the inlet to the catalyst was uniform. Any variations in NO\textsubscript{x}, point-to-point, could be attributed to either NH\textsubscript{3}/NO\textsubscript{x} maldistributions, or velocity maldistributions. At the mid-range ammonia injection rates, one can see a fair amount of NO\textsubscript{x} variation point-to-point. However, as the ammonia injection rate increases, the point-to-point variation decreases. At the higher ammonia injection rates, NH\textsubscript{3}/NO\textsubscript{x} maldistributions become less important as there is already an excess of ammonia at all points and velocity maldistributions alone should account for the variations in outlet NO\textsubscript{x}. Thus, any variations in outlet NO\textsubscript{x} at these high ammonia injection rates should be attributable to velocity maldistributions. Figure 8b shows an expanded section of the high ammonia injection region in Figure 8a. As can be seen, all but three of the points have leveled off; points 17, 18, and 20 still exhibit decreasing NO\textsubscript{x} as the NH\textsubscript{3} injection rate increases. This indicates that there are still some NH\textsubscript{3}/NO\textsubscript{x} maldistributions. In any event, the data at the high injection rate, along with SCR process model calculations, can be used to calculate a velocity distribution.

Given the exit NO\textsubscript{x} levels measured at a high ammonia injection rate, the SCR process model is then used to estimate the velocities and velocity distribution. The model calculations need to be performed for the particular SCR system being tested; however as an example, Figure 9 shows how the exit NO\textsubscript{x} would vary with space velocity for typical SCR on coal- and natural gas-fired systems.

The higher NH\textsubscript{3} injection rate data from Figure 8 and process model calculations for the specific SCR system (similar to Figure 9) were used to estimate the velocity distribution for the gas-turbine SCR. The results are shown in Figure 10. For this system the results indicate a velocity profile characterized by a standard deviation of 5%. The profile shows a centrally located low velocity region with somewhat higher velocities on the south side of the reactor.
Figure 8. Outlet NO\textsubscript{x} vs. Ammonia Injection Rate for Individual Probes at Catalyst Exit (20-point Grid)

(a) NO\textsubscript{x} variations due primarily to NH\textsubscript{3}/NO\textsubscript{x} maldistribution

(b) expanded view
**Figure 9.** Calculated Outlet NO$_x$ Variations as a Function of Velocity at High NH$_3$/NO$_x$ Ratios

![Graph showing calculated outlet NO$_x$ variations as a function of velocity at high NH$_3$/NO$_x$ ratios.]

**Figure 10.** Velocity Profiles for a Gas Turbine SCR

![Velocity profiles for a gas turbine SCR. The velocity distribution is shown with a normalized RMS of 5%.](image-url)
A similar analysis was done for a 600 MW coal-fired SCR system. The results of this analysis are shown in Figure 11. This was a two-reactor unit and the results shown in Figure 11 are for one reactor. Also shown in Figure 11 are the actual velocity profiles measured on the cold flow model. A couple of observations can be made from the results in Figure 11.

**Figure 11. Velocity Profiles from a Large Coal Unit**

- The estimated full-scale velocity profile exhibits a standard deviation of 3.6%, which is lower than the 5.8% from the cold flow model. This would be expected as the cold flow model velocity measurements were made at the catalyst inlet, whereas the estimated velocity profile from the NOx measurements is more indicative of the catalyst outlet.

- There are some commonalities between the two profiles. Specifically, both show low velocity regions along the left side of the reactor.

Overall, the technique for estimating the velocity profiles by measuring NOx variations at high NH3/NOx ratios appears to produce reasonable results. However, it does require that the unit be operated at high NH3/NOx ratios. This should only be done if the data can be collected in a short time period using instrumentation such as FERCo’s MCDA analyzer.
Catalyst Activity

When a catalyst vendor determines catalyst activity, NOx reduction is measured across a catalyst sample with the laboratory system operating at a high NH3/NOx ratio. The activity is calculated using an equation of the form:

\[ K = \frac{1}{A_v} \ln(1 - \Delta \text{NO}_x) \]

\( K = \) activity

\( A_v = \) area velocity

\( \Delta \text{NO}_x = \) NOx reduction across the catalyst sample with NH3/NOx > 1

A similar approach can be used to track the activity at full-scale. In fact, by making a series of local measurements the activity across the catalyst surface can be tracked. This is illustrated in Figure 12 which shows local NOx measurements as a function of NH3 injection rate for a large natural gas-fired unit with a catalyst with nominally 10 years of service. As can be seen, there are a number of local points where very little NOx reduction occurs even at the highest injection rates where the curves have flattened out. These high NOx levels cannot be explained by velocity maldistributions and suggest that there are some local regions where catalyst activity has degraded.

**Figure 12.** High NH3/NOx Operation Used to Assess Catalyst Activity
Conclusion

SCR is a key post-combustion NOx control technology that is rapidly being implemented by utilities to comply with increasingly stringent NOx regulations. The effectiveness of an SCR system is contingent on satisfying the design criteria of uniformity for velocity and NH3/NOx distribution at the catalyst inlet. The NH3/NOx ratio uniformity has a first-order effect on SCR performance, and maldistribution of NH3/NOx affects not only NOx reduction but also the extent of NH3 slip. Uniform NH3/NOx distribution is achieved at system startup by tuning the AIG; thus AIG tuning is one of the key startup activities of an SCR installation.

This paper described an approach to tune or balance AIGs by making only NOx measurements at the catalyst exit. This is done in conjunction with a multipoint multigas measurement system that simplifies and streamlines this process making it possible to completely tune an SCR system in two to three days.

An approach to estimate velocity distributions across an SCR catalyst, again using only NOx measurements at the exit of the catalyst, was also described. This basic approach was also shown to be useful in assessing in situ catalyst activity.

FERCo has used this technique successfully to tune ammonia injection grids of SCR systems on gas- and coal-fired utility boilers and on gas turbines.

Key Words:
SCR
AIG
Tuning