Summary

INTEGRATING PHYSICAL COLD FLOW MODELING AND PROCESS MODELING TO IMPROVE THE SCR DESIGN PROCESS*

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INTRODUCTION

To meet more stringent NO_x emission regulations, the utility industry is moving in a direction of utilizing Selective Catalytic Reduction (SCR), in addition to combustion modifications, as a way of achieving compliance. At the same time, efforts are being made to reduce costs by exploring "in-duct" SCR arrangements. "In-duct" SCR arrangements incorporate the SCR reactor basically along the existing flue gas path from the economizer to the air preheater.

In the extreme, there would be no changes to the ductwork for an "in-duct" SCR and the catalyst inserted within the existing ductwork, so-called "true in-duct SCR." True in-duct systems are likely to be most applicable when used in conjunction with other NO_x controls (e.g., low NO_x burners, SNCR, air preheater catalyst) where the SCR NO_x reduction requirement is reduced to the range of 60-80%. In many cases, "in-duct" arrangements will involve enlarging the ductwork to lower velocities in order to accommodate a larger volume of catalyst and reduce pressure drop. This "in-duct" concept is contrasted to a more traditional retrofit approach associated with Japanese or German SCR installations, where a large separate SCR reactor is built with fairly extensive ductwork changes to route the flue gas to and from the SCR reactor.

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While the “in-duct” arrangement can potentially reduce retrofit costs, it also poses greater challenges to the designer. In addition to the type and amount of catalyst, the process designer must also address velocity and NH_3/NO_x uniformity across the catalyst face. In the traditional separate SCR reactor approach, there is usually sufficient ductwork to allow a uniform velocity to be generated at the ammonia injection grid. A uniform velocity profile at the ammonia injection grid greatly simplifies the ammonia/NO_x mixing process. Likewise, with the separate SCR reactor, there will be sufficient space to design ductwork expansions and turning vanes to meet velocity uniformity requirements at the catalyst face. As a consequence, previous design approaches specified criteria such as the standard deviation in the velocity profile, or NH_3/NO_x profile, at the catalyst face. If these criteria are met, then the SCR system will perform as designed.

With an “in-duct” arrangement, it may not be possible to: (1) provide a uniform velocity at the ammonia injection grid, or (2) accommodate traditional design guidelines in terms of duct expansion angles, etc. As a consequence, it will be more difficult, if not impossible in some instances, to meet traditional criteria in terms of a velocity uniformity and/or NH_3/NO_x uniformity at the catalyst face. However, this does not mean that an “in-duct” arrangement should be discarded as a viable approach. Rather, it points to the need to develop better engineering design tools to assess the performance of these systems.

This presentation describes a new methodology to support the design of SCR systems. The method integrates the results of cold flow modeling with an SCR process model to quantitatively account for site-specific conditions. The paper will describe the methodology and show how the methodology was used to design a true “in-duct” SCR.

SCR PROCESS DESIGN METHODOLOGY

Physical cold flow modeling has been used previously during the design of SCR systems. In most cases, the cold flow modeling has focused on developing uniform velocities at the catalyst face and/or at the plane of the ammonia injection grid, and reducing pressure drop. In some instances, tracer gas techniques have been used to simulate the ammonia injection process. To provide more input to the SCR design process, a methodology has been developed that integrates cold flow modeling results along with a model of the SCR process to predict performance for a given specific configuration.

The process model integrates: (1) the cold flow velocity distributions, which define local variations in space velocity, (2) tracer gas results which define local variations in NH_3/NO_x ratio, and (3) ideal catalyst performance data (i.e., NO_x removal and NH_3 slip versus NH_3/NO_x and space velocity with uniform velocity and NH_3/NO_x profiles) to calculate overall NO_x removal and NH_3 slip for a given catalyst and NH_3 injection configuration. This is compared to the ideal case of completely uniform velocity and

NH_3/NO_x. The model also estimates the pressure drop across the catalyst. The basic methodology was validated at the PG&E/EPRI ASCR Pilot Plant**.

APPLICATION TO THE DESIGN OF A TRUE "IN-DUCT" SCR

The methodology was used to perform a preliminary design for a true "in-duct" SCR for PG&E's Morro Bay Units 3 and 4. These units incorporate low NO_x burners, overfire air and FGR for NO_x control. With these combustion NO_x controls, the NO_x levels are less than 40 ppm (dry @ 3% O_2). Following the design, the PG&E/EPRI ASCR pilot plant was modified to this "in-duct" arrangement and tests conducted to validate the performance.

Figure 1 shows a cross-section of the potential AIG and catalyst arrangements. The logical location for the catalyst was at the current location of a damper just upstream of the air preheater. Similarly, the logical location for the NH_3 injection grid was either just downstream of the 90° turn, or just downstream of the FGR take-off duct.

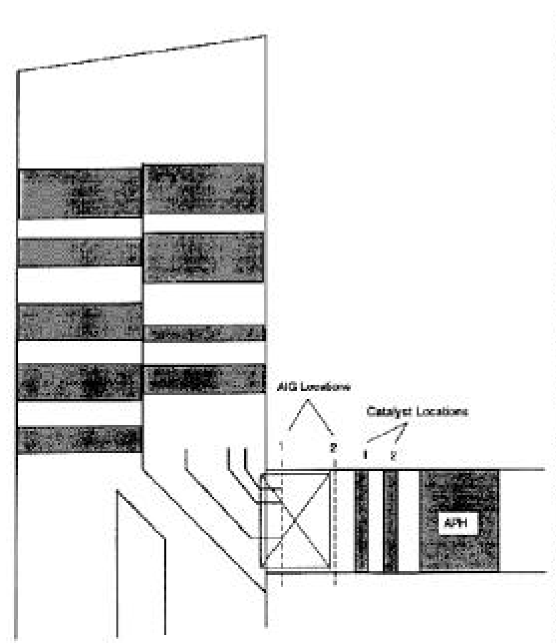

Figure 1. Side View Showing Catalyst and AIG Locations and the Turning Vanes

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**Muzio, L.J., et al., "A New Design Tool for SCR Systems, " 1995 joint EPRI/EPA Symposium on Stationary Combustion NO_x Control, Kansas City, May 1995.

The design issues that were addressed during the cold flow modeling included: (1) optimum location for the catalyst and AIG (see Figure 1); (2) the velocity uniformity at the catalyst, (3) NH_3/NO_x uniformity at the catalyst, and (4) minimizing NH_3 entrainment into the FGR stream.

One of the key design issues for this "in-duct" SCR arrangement was minimizing the amount of ammonia entrained into the FGR and carried back to the burner. Three approaches were considered: (1) locating the AIG downstream of the FGR duct (i.e., location 2 in Figure 1); (2) biasing the individual AIG injectors; and (3) using a baffle to separate the AIG from the FGR flow. Tracer gas studies eliminated approach (1) as there was a large recirculation zone that carried NH_3 from location 2 back into the FGR duct. Further, approaches (2) and (3) would only be feasible if the flue gas that entered the FGR duct was localized to the outer portions of the duct. A tracer gas test showed that, without turning vanes, the flue gas entering the FGR duct was drawn from virtually the entire width of the boiler. However, with the installation of the turning vanes, the FGR is localized to the outer edges of the duct. With the turning vanes installed, further cold flow tests showed that location (1) was the preferred location for the AIG and catalyst. Also, biasing the AIG injectors was the preferred approach to minimize NH_3 entrainment into the FGR duct while maximizing NH_3 at the catalyst face. At the biased condition the standard deviation of the velocity and NH_3/NO_x profiles at the catalyst face were 15% and 18%, respectively.

Following the cold flow study, SCR process calculations showed that with a 2.5" H_2O pressure drop limit, the "in-duct" SCR could accommodate a 3.3 mm opening catalyst with a space velocity of 35,000 hr-1 (for an initial NO_x level of 35 ppm, calculated NO_x reduction was 72% with 10 ppm NH_3 slip).

The PG&E/ASCR pilot plant was modified to simulate this true "in-duct" arrangement . Pilot scale tests verified that the NH_3 entering the FGR duct could be minimized by biasing the AIG. Figure 2 shows the measured performance of the "true in-duct" pilot plant along with the model predictions. Model predictions are shown for two AIG configurations; balanced and biased. As can be seen, the comparison is quite good. An interesting point in Figure 2 is the small difference in the predicted NO_x reductions for the balanced and biased injectors. This represents a difference in NH_3/NO_x uniformity of 14% and 23%. This illustrates the need to address actual velocity and NH_3/NO_x nonuniformities in the design and not rely on rule-of-thumb design criteria

A similar design exercise for coal fired units indicates the potential for NO_x removals in the range of 30-80% depending on the initial NO_x levels and allowed pressure drop.

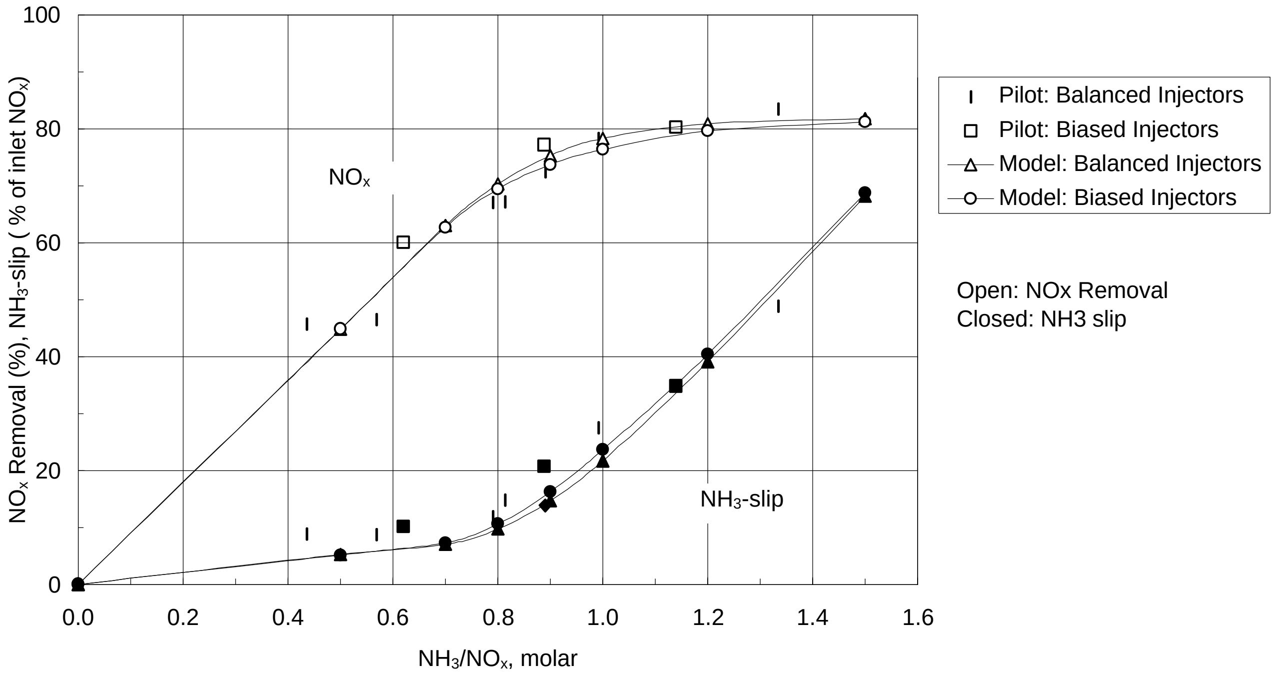

Figure 2. Comparison of the Model and Pilot-Scale
True In-duct SCR Results