Gas-Gas Mixing Applied to SCR Systems

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In the SCR process the oxides of nitrogen are reduced with ammonia to create nitrogen and water vapor by a catalytic reaction. Ammonia has to be mixed in with the NOx laden combustion exhaust gases. The degree of conversion depends on how many NOx molecules receive NH3 molecules in the correct stochiometric ratio at the entry to the first catalyst bed. The catalyst supplier's guarantee of the percentage of NOx reduction is dependent on the inlet conditions to the catalyst.

Static Mixers are being used worldwide for over 50 years in a very wide spectrum of industrial areas and process applications; however, they are relatively new to the power generation industry.

A static mixer provides homogenization without the use of moving parts. The stationary guiding elements split the product stream into partial streams. These partial streams are then redirected inside the guiding elements in such a manner that a mixture is obtained which is homogeneous with respect to concentration and/or temperature. The path of the flow through the guiding elements is predetermined precisely. Due to the fixed manner in which these elements function, industrial applications can be designed with certainty on the basis of the result of pilot experiments.

The geometric structure of the SULZER SMV static mixer causes both small-scale mixing and by creating strong cross flows, large-scale homogenization over the pipe or duct cross-section. A mixing element consists of several corrugated plates which form partial ducts that are open on one side.

For mixing in ducts the flow is divided, deflected in different directions and sectioned off at points of intersection, where vortices move gas from one part of the duct into adjacent crossing channels. Strong eddies with intensive mixing effects are created both in the mixing element and in the empty duct downstream of the mixer.

The performance of the static mixer can be judged on the basis of a criterion of mixing quality in order to quantify its efficiency. The basic criteria for static mixers are mixing distance and pressure drop.

By using a SULZER static mixer a simple ammonia injection grid (AIG) is utilized. The simple yet very effective design of the AIG requires no adjustment valves and no field tuning.

The Mixer-AIG system offers low pressure drop, minimal ammonia slip, longer catalyst life, shorter duct length and can tolerate wide variation in inlet loadings, concentration and temperature shifts.

One case study to be discussed in the presentation is the use of static mixers at the Progress Energy (former CP&L) 385 MW Roxboro Unit #1 SCR as designed by Foster Wheeler with the use of a Cormetech catalyst. Static mixers in conjunction with simple AIG's were used during the computational flow model simulations and 1:12 scale cold flow model. We will go through steps to explain where the mixers were used and to provide results that were obtained in each stage of design as well as start up data.

Design Criteria @ Gas Flowrate of 3,552,000 lb/hr
INLET NOx: 0.50 lb/10^6 Btu OUTLET NOx: 0.08 lb/10^6 Btu
DeNOx Efficiency: 84% NOx removal
Ammonia Consumption: 563 lb/hr (anhydrous)
Ammonia slip: < 2 ppmvd

The mixer and ammonia injection grid shall meet the performance requirements listed below at all operating loads between 30% and 100%:

i. NH_3 concentration distribution at the catalyst inlet: **RMS ≤ 5%**

ii. The flue gas temperature distribution at the catalyst inlet shall be less than **± 25°F** from the mean temperature.

iii. *Mixer Pressure Drop*

The pressure drop across the mixer shall not exceed **0.94 inches w.c.** at the 100% load case.

Pressure loss guarantee shall allow for the fact that the inlet flow to the mixer will not have a completely uniform velocity profile and may contain eddy currents.

Foster Wheeler contracted the CFD study to SULZER INNOTEC and flow model study to NELS Consulting. CFD study was performed before physical model testing, to evaluate the economizer bypass design and to better determine the best mixer design and location within the SCR inlet flue.

The objective of the CFD was to determine the best point at which to connect the economizer bypass flue to the main economizer exit flue. Once established the CFD model was then used to optimize the position and design of the static mixers to achieve a temperature distribution of +/- 25°F at the catalyst inlet. The economizer bypass flues were ultimately designed with multiple flue segments at the interface point of the economizer exit flue. These segments help to generate more turbulence and better mixing of the two fluid streams.

A 1/12th scale flow model was used to determine the optimum arrangement of flow control devices needed to meet the flow, temperature and ammonia distribution within the SCR. In addition, flues and flow control devices were optimized to minimize system pressure drop and ash dropout.

A 1:12 cold flow model was performed to determine the following distributions.

Flow Distribution: Cold flow simulation utilizing ambient air was measured in the model at the point of interest. Standard pitot tubes and hot wire anemometers were used to measure the velocity field and flow angles at the catalyst inlet.

Temperature Distribution: A tracer gas was uniformly injected into the economizer bypass flues, and the concentration field was measured at the catalyst inlet. A mass transfer to heat transfer correlation was made to infer temperature distribution at the catalyst.

Ammonia Distribution: A tracer gas was uniformly injected into the 20 SULZER AIG pipes, and the concentration field was measured at the catalyst inlet.

Pressure Drop: Model pressures were measured and corrected to full-scale flow and temperature conditions.

In conclusion, upon initial plant SCR startup all criteria were met.