SCR CATALYST PERFORMANCE UNDER SEVERE OPERATION CONDITIONS

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Abstract

Selective Catalytic Reduction (SCR) technology has been applied to a wide variety of applications since the late 1970s. Flue gas generated from refinery off gas combustion to natural gas-, oil-, and coal-fired units has been treated with SCR. More recent applications include reduction of NOx emissions generated from orimulsion-fired boilers, diesel engines, process gas streams, i.e., nitric acid plants, calcining ovens, and gas turbines firing landfill and/or digester gas.

At the heart of the SCR system is the catalyst. Each application mentioned above has unique design parameters. Therefore, a thorough understanding of catalyst behavior as it relates to the operating parameters is necessary, i.e., deactivation mechanisms, effect of sulfur content, load swings, ash loading, efficiency requirements, effect of maldistribution, etc.

This paper helps the reader understand the importance of properly defining and evaluation design parameters to achieve the most cost-effective design and to assure reliable operation. Basic relationships are presented to assess the impact of multiple design parameters. In addition, we site a number of specific examples demonstrating our experience with design and application of homogeneous honeycomb catalyst. Cases include (1) a high dust arrangement SCR designed for a cyclone boiler firing high sulfur fuel, and requiring high NOx removal efficiency, and ash re-circulation (2) an dust, high flue gas flow velocity, in-duct arrangement, and (5) a high efficiency in-duct utility boiler application.

Introduction

Selective Catalytic Reduction (SCR) is recognized worldwide as the most effective NOx control technology for utility boilers and combustion turbines when substantial NOx reduction of 50% to 95% is required. In addition to its proven high performance, it is also an economically viable solution, with current fully burdened installed costs, in the United States, estimated at between $20/kW to $30/kW for natural gas and $40/kW to $70/kW for coal unit retrofits. The technology has even given some utilities the capability to achieve lower heat rates by allowing optimization of burner operation and reduction or omission of flue gas re-circulation, further adding to its cost effectiveness.

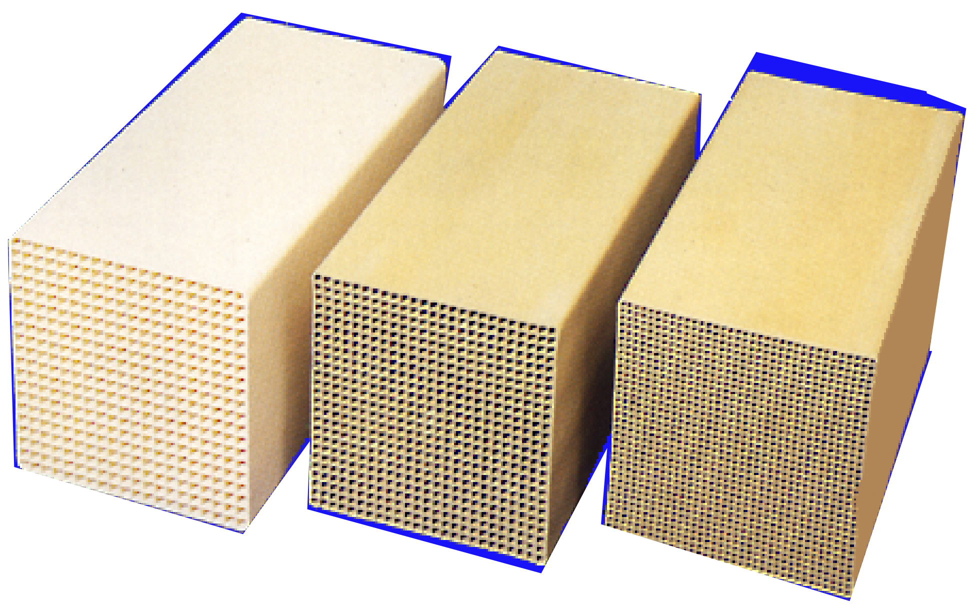


Figure 1

The capability of SCR to meet and exceed performance expectations economically start in the design phase. Cormetech draws upon the vast experience database of Mitsubishi Heavy Industries (MHI) and its licensees, the extrusion and materials know-how of Corning, and the catalyst technology of Mitsubishi Chemical Company (MCC) to provide the most effective product to the market.

This paper presents design techniques used to assure SCR performance, both catalyst and system, under severe operating condition. The definition of "severe" as it relates to this paper is, a condition, or set of conditions, which extend beyond basic performance requirements, and significantly impacts SCR catalyst and/or system design.

First, a brief review of the SCR reaction mechanism including undesired side reactions in presented. Second, parameters that must be evaluated in order to assure successful SCR implementation during the design phase are presented in a tabular form. This is followed by a discussion on post implementation, or life analysis tools used to assure continued successful operation and provide valuable information on catalyst replacement or addition options. Finally, specific case examples are outlined to demonstrate the impact of various parameters on the initial SCR system design.

Background

The governing chemical reactions that occur in the presence of the SCR catalyst, NOx reduction and SO_2 oxidation are presented below. The primary NOx reactions are listed in equations [1-3].

The catalytic reaction can take place over a wide temperature range ($300^0F – 1100^0F$) with typical applications between ($500^0F – 800^0F$). Low operating temperatures are not suitable to applications with sulfur or extremely high NOx due to the potential formulation changes must be made for high temperature applications to reduce the potential for ammonia oxidation and catalyst sintering.

$$NO + NO_2 + 2NH_3 \xrightarrow{\text{Catalyst}} 2N_2 + 3H_2O \quad [1]$$

$$4NO + 4NH_3 + O_2 \xrightarrow{\text{Catalyst}} 4N_2 + 6H_2O \quad [2]$$

$$6NO_2 + 8NH_3 \xrightarrow{\text{Catalyst}} 7N_2 + 12H_2O \quad [3]$$

Oxidation of sulfur dioxide (SO_2) to sulfur trioxide (SO_3) also occurs on the catalyst.

$$SO_2 + ½ O_2 \xrightarrow{\text{Catalyst}} SO_3 \quad [4]$$

The formation of SO_3 can lead to problems in downstream equipment due to corrosion and/or plugging when combined with excess ammonia slip. Equations [5-6] show the reactions for ammonium sulfate and bisulfate respectively. The formation of these slats is highly dependent upon the concentration of each constituent; therefore, each component is a key design parameter for the system.

$$2NH_3 + SO_3 + H_2O \xrightarrow{\text{Catalyst}} (NH_4)_2 SO_4 \quad [5]$$

$$NH_3 + SO_3 + H_2O \xrightarrow{\text{Catalyst}} (NH_4) HSO_4 \quad [6]$$

Figures 2 and 3 illustrate the basic SCR system layouts for gas turbines and fossil fuel fired boilers. For reference; NH3 is the location of the ammonia injection grid (AIG); SCR is the location of the selective catalytic reduction reactor housing which contains the catalyst; ESP –electro-static precipitator; FGD –flue gas desulfurization; SH – superheater; HP, IP, LP evap- high, intermediate, and low pressure evaporator.

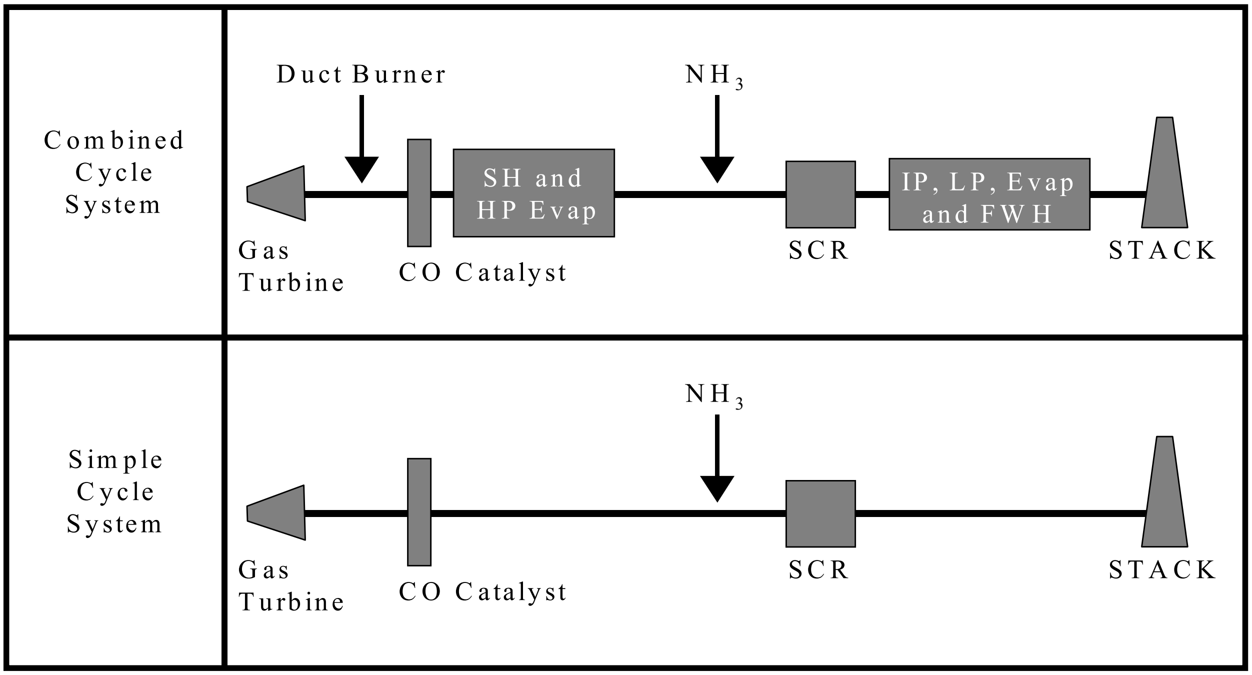


Figure 2
Gas Turbine SCR Arrangements

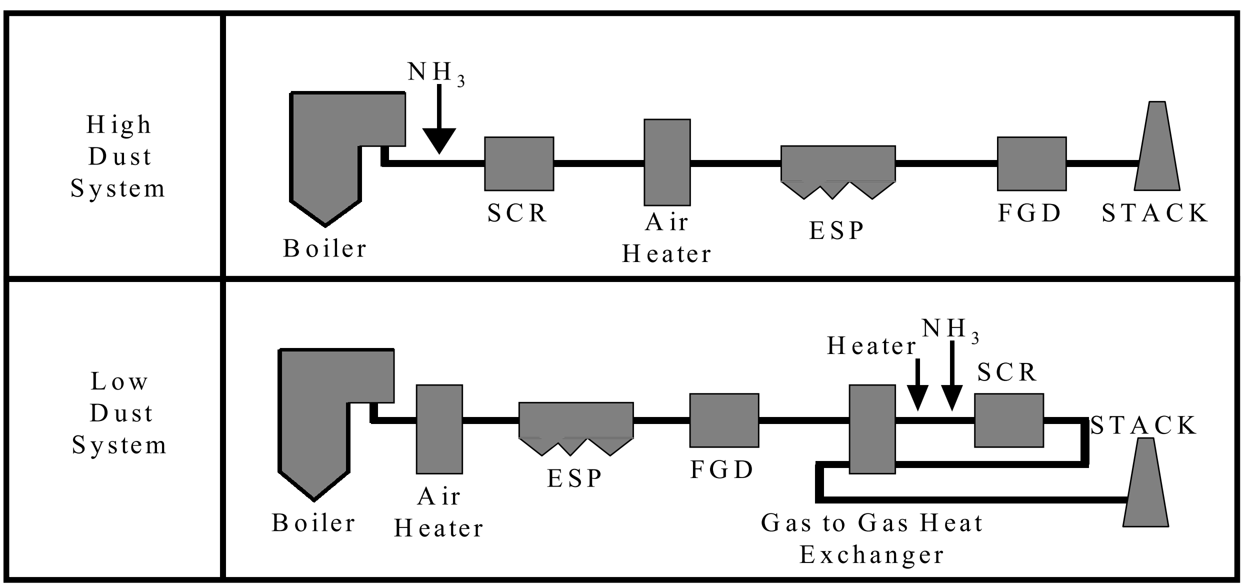


Figure 3
Boiler SCR Arrangements

System Evaluation

Design Phase- Parameter Assessment

A number of components may cause poor system performance if not properly addressed during the designed phase of a project. Components include specific catalyst poisons contained in the fuel, reactor and flue design, ammonia distribution/control, and operation methods. See reference 1 for more detailed information on catalyst poisoning mechanisms.

Table 1 below provides each evaluation parameter and a brief description of the potential impact on catalyst and/or system components. Many parameters have interrelated impacts on design. In some cases, one or a few of these conditions may be severe enough to provide a unique challenge and govern the design. Cormetech has, through both its internal and external resources, i.e., large customer base with over 120 applications and provide an optimized design.

The information provided in the table is separated into related category topics by the reference symbols. The reference symbol is utilized during the case study discussions in order to assist the reader. Where the evaluation parameter is specific to a type of application, a designator is used, i.e. boiler (Blr), gas turbine (GT).

Table 1

Reference Symbol	**Evaluation Parameter**	**Potential Impact**
F_{AN}	Fuel Analysis, including trace elements and firing duration: ♦ Primary ♦ Secondary ♦ Duct Burner (GT)	• Catalyst formulation • Catalyst volume • Catalyst Management • Monitoring plan
F_{AD}	Fuel Additives	• Catalyst volume • Catalyst Management • Monitoring plan
FG_{AN}	Fuel gas analysis	• Catalyst volume • Catalyst Management • Monitoring plan
A_{AN}	Ash Analysis, including trace elements	• Catalyst volume • Catalyst management • Monitoring plan

Table 1 (continued)

Reference Symbol	**Evaluation Parameter**	**Potential Impact**
A_I A_H	Ash Loading & Characteristics ♦ Handling Method re-circulation, disposal, recycle	• Catalyst pitch • Catalyst volume • Catalyst management • Ammonia slip • Downstream equipment design • Sootblower requirements
C_{SOxL}	SO_3 and SO_2 vs. Load	• Catalyst formulation • Catalyst volume • Catalyst management • Economizer bypass (Blr) • Downstream equipment design • Ammonia slip
C_{NOL}	NOx vs. Load	• Catalyst volume • Economizer bypass (Blr) • Water or stream injection rate (GT)
T_L	Temperature vs. Load	• Catalyst volume • Economizer bypass (Blr) • Catalyst management
η_{NOx}	Removal efficiency	• Catalyst volume • Ammonia injection grid (AIG) design requirements
NH_{3S}	Ammonia slip	• Catalyst volume • APH design (Blr) • Ash Handling (Blr)
B_F	Boiler firing method	• NOx content • SO_3 content • Ash characteristics
ΔP	Pressure loss	• Fan or turbine capacity • Catalyst reactor design • Boiler and/or ESP reinforcement (Blr) • Catalyst pitch • Catalyst management

Table 1 (continued)

Reference Symbols	Evaluation Parameter	Potential Impact
D_α D_F D_T	Distribution Criteria ♦ NH_3:NOx ♦ Flow ♦ Temperature	• Catalyst volume • AIG Design • Reactor and flue design
O_{LS} O_{CF} O_{BF}	Systems Operation ♦ Load swing ♦ Capacity factor ♦ % Time on Backup fuel	• Catalyst volume • Catalyst pitch • Life management plan • Control logic • Catalyst management systems inspection
R_S R_T	Regulations ♦ Seasonal reduction requirements ♦ ERC or allowance trading environment	• NOx reduction requirements • Catalyst volume • Systems capacity • SCR bypass (BIr)
SC	Site Conditions (1) ♦ Multiple boiler ♦ Back-end arrangement ♦ Foundation ♦ Electrical	• NOx reduction requirements • Catalyst volume • Reactors geometry • Type of reagent • Reagent vaporization methods

(1) Site conditions can impact many segments of the design. The items is shown in this table to make the reader aware to make the reader aware of some of the potential impact and is mot meant to be all inclusive.

Operations Phase – Performance Assessment Tools

Once the catalyst and systems have been designed and installed, the next phase of assuring continued satisfactory performance through system and catalyst monitoring. This includes analysis of field data and catalyst sample analysis.

The table provided in attachment 1 shows the field data necessary to assist in the evaluation of the SCR system performance. Data must be measured at regular intervals and under consistent and repeatable operating conditions. The purpose of measuring the field data is to understand the interaction between the system and the catalyst. When utilizing field data to assess performance potential, a thorough understanding of the relative accuracy for each of the measured points and their respective impact is extremely important.

Since the catalyst activity decreases overtime due to factor such as poisoning, surface masking, or thermal degradation, catalyst testing should be performed. Testing catalyst sample provides specific information on the condition of the catalyst relative to expectations set during design. Specific catalyst testing plans, including physical and chemical property test, are especially important where expected deactivation was the governing factor of the design. The information is also used in conjunction with the field data to assess overall system performance. For example, if catalyst testing shows a low degree of degradation but overall system performance is poor, further in the case of high conversion efficiency design where ammonia distribution is a governing factor.

In addition to system assessment, catalyst testing provides vital in formation to the owner regarding the remaining useful life of the catalyst. This information can be used to devise the most efficient catalyst management plan as it relates to catalyst volume and know plant outage schedules.

Ultimately, all catalyst deactivation data obtained is correlated to various parameters such as fuel type, operation hour, temperature, etc. and applied to new project during the design phase.

Case Studies

The following case studies are presented to show the procedure or method of analysis performed during the proposal, design, and operation phase of the project. Case study one (1) details all aspect of the analysis, while cases two (2) through five (5) concentrate on specific areas. Cases two (2) and three (3) relate the importance of evaluating and understanding fuel constituent and impact on catalyst and downstream equipment design.

Case four (4) details the impact of high velocity dust laden environment, included catalyst and fan requirements. Case (5) illustrates the impact of flow, ammonia, and temperature distribution on the effective catalyst life.

Case study 1: Coal Fired Cyclone Boiler

This case study utilizes a high arrangement SCR designed for cyclone boiler with high sulfur fuel, high NOx removal efficiency, and re-circulation to demonstrate the use of the design tools on parameters described above. Data for each evaluation parameter is provided in Table 2.

Designed Data Table 2

Reference symbol	Evaluation Parameter	Value
F_{AN}	Fuel Analysis	
	Sulfur , % wt.	2.8 - 3.3
	As, ppm	5
	Ni, ppm	20
	Cr, ppm	30
	Cl, ppm	500
F_{AN}	Fuel Additive	limestone (2% by wt. of fuel)
FG_{AN}	Fuel Gas Analysis	
	Flow Rate, lb/hr	5,400,000
	NO_x, ppm	1500
	O_2 , % vol.	2.5
	H_2O, % vol.	5.0
	SO_2 ppm (max)	1800
	SO_3 ppm (max)	36
A_{AN}	Ash analysis, % wt	
	SiO_2	50
	As_2O_3	20
	Fe_2O_3	3
	CaO (Free / Amorphous)	1.5 / 1.5
	MgO	1
	TiO_2	0.5
	MnO	0.1
	V_2O_5	0.03
	Na_2O	0.05
A_{AN}	Ash analysis, % wt (continued)	
	K_2O	1
	P_2O_6	0.3
A_H	Ash recirculation, %	100
A_L	Ash loading , mg/Nm^3	10,000
C_{SOXL}	SO_2 and So_3 vs. load	flat
C_{NOXL}	NO_x vs. load	linear (min =1000 ppm)

Design Data Table 2 (continued)

Reference Symbol	Evaluation Parameter	Value
T_L	Temperature vs. load	linear (min = 600^0F)
ηNO_x	NO_x removal efficiency	90%
NH_{3S}	Ammonia slip, ppm	2
B_F	Boiler Firing Method	Cyclone
ΔP	Pressure loss	5" w.g. for system
	Distribution Criteria	
D_α	$NH_3:NO_X$	± 5% RMS
D_F	Flow	± 15% RMS
D_T	Temperature	± ^{0}F absolute
	System Operation	
O_{LS}	Load Swings	Base loaded
O_{LS}	Min. operating load	50%
O_{CF}	Capacity Factor	0.75
R	Regulations	Year round reduction is required
SC	Site Condition	
	Air preheater type	Ljungstrom
	Retrofit difficulty	Moderate

Catalyst Design

The required base catalyst surface area is determined as a function of gas constituents (FG_{AN}), design efficiency (η_{NOx}), and operating temperature (T_L) .

Design ammonia slip is set at 2 ppm based of the SO2 content (FG_{AN}) and ash handling method (A_H). The initial cost impact of designing with 2ppm vs. 5 ppm ammonia slip is estimated at 5-10 % of the total capital and includes catalyst and reactor alterations.

Adjustments to the required base surface area performed based on the design distribution criteria ($D\alpha$ $D_{F,}$ D_T). The impact of flow maldistribution on a high dust design are twofold. Poorly distributed flow increased the potential for catalyst erosion and plugging through proper system design and catalyst erosion and plugged through proper system design and catalyst erosion and plugging through proper system design and catalyst edge hardening (figure 4). The second area of impact concern meeting the required performance and achieving the longest possible catalyst life . Further discussion regarding this item is detailed under case study 5.

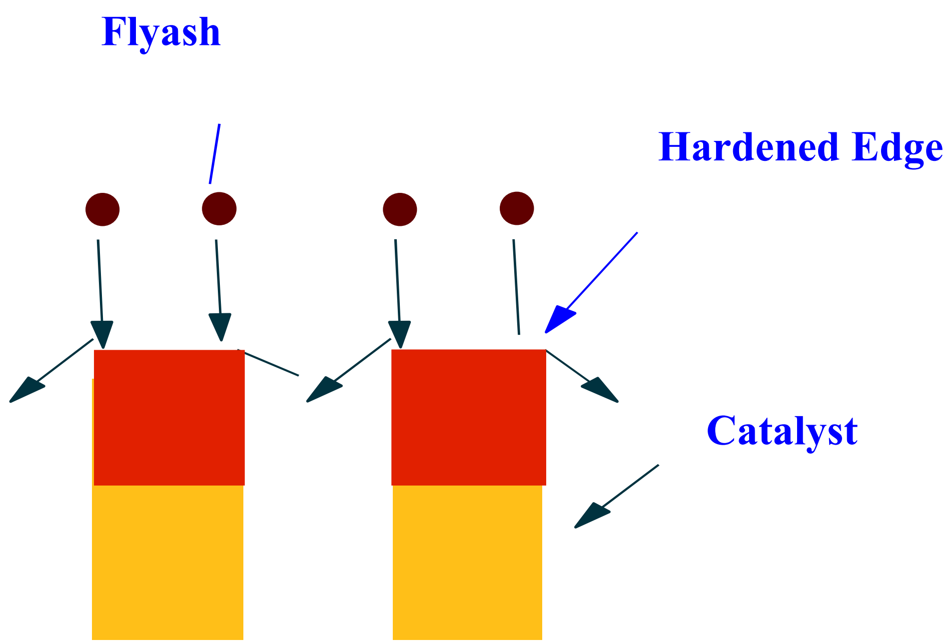


Figure 4

Erosion Resistant Edge Hardened Catalyst

Once the base catalyst surface area is set, the next step in determining the required catalyst volume for an application can be taken. The fuel analysis (F_{AN}), fuel additives (F_{AD}), ash analysis (A_{AN}), ash load (A_L), and evaluation of the effect of ash recirculation are performed. The designer utilizes historical database information, laboratory and field test results to determine expected catalyst deactivation rates.

Based on high sulfur oil experience, as well as results of the DOE clean coal demonstration project performed at Gulf Power's Plant Crist, the effect of high fuel sulfur was addressed. The Plant Crist application burned a high sulfur coal and tested our catalyst in a high and low dust arrangement for over 10,000 and 6,000 hours, respectively. The measure results showed that the deactivation rate was well within expected limits and in fact showed that the deactivation was well within expected limits and in fact surpassed expectation (see figure 5). Figure 6 shows a typical catalyst management plan based on prediction degradation data for a cyclone boiler with 100% ash recirculation.

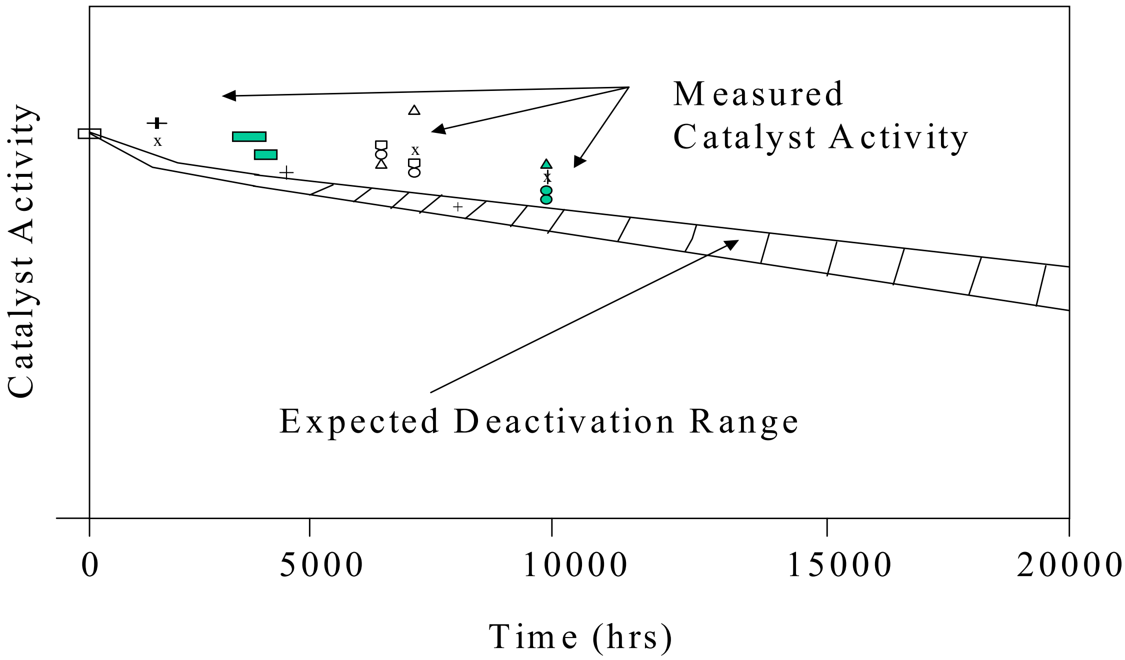


Figure 5
Plant Crist High Sulfur Coal Demonstration
Catalyst Degradation Data

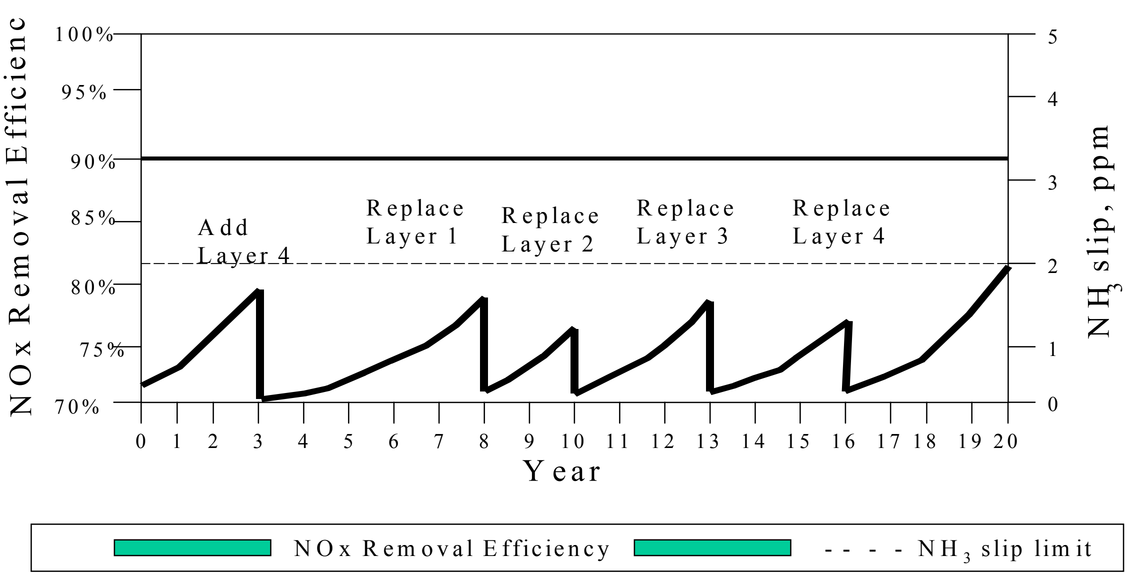


Figure 6
Typical Catalyst Management for Cyclone Boiler 100% ash Recircualtion

The design sensitivity to the use of ash recirculation and fuel additive can be significant. In this case 100% ash recirculation was implemented and a limestone fuel additive was used. The addition of limestone to the fuel effectively mitigates much of the potential catalyst deactivation caused by arsenic poisoning. Free CaO in the limestone reacts with gaseous arsenic to form a solid, $Ca_3(AsO_4)_2$ which does not poison the catalyst. Figure 7 shows the impact of Limestone injection on the gaseous arsenic content for multiple boilers. The decrease in the relative rate of catalyst deactivation results in a cost saving directly for the reactor. The total catalyst cost savings, of course, must be measured against the cost for the limestone addition. In this case, limestone addition was a viable countermeasure.

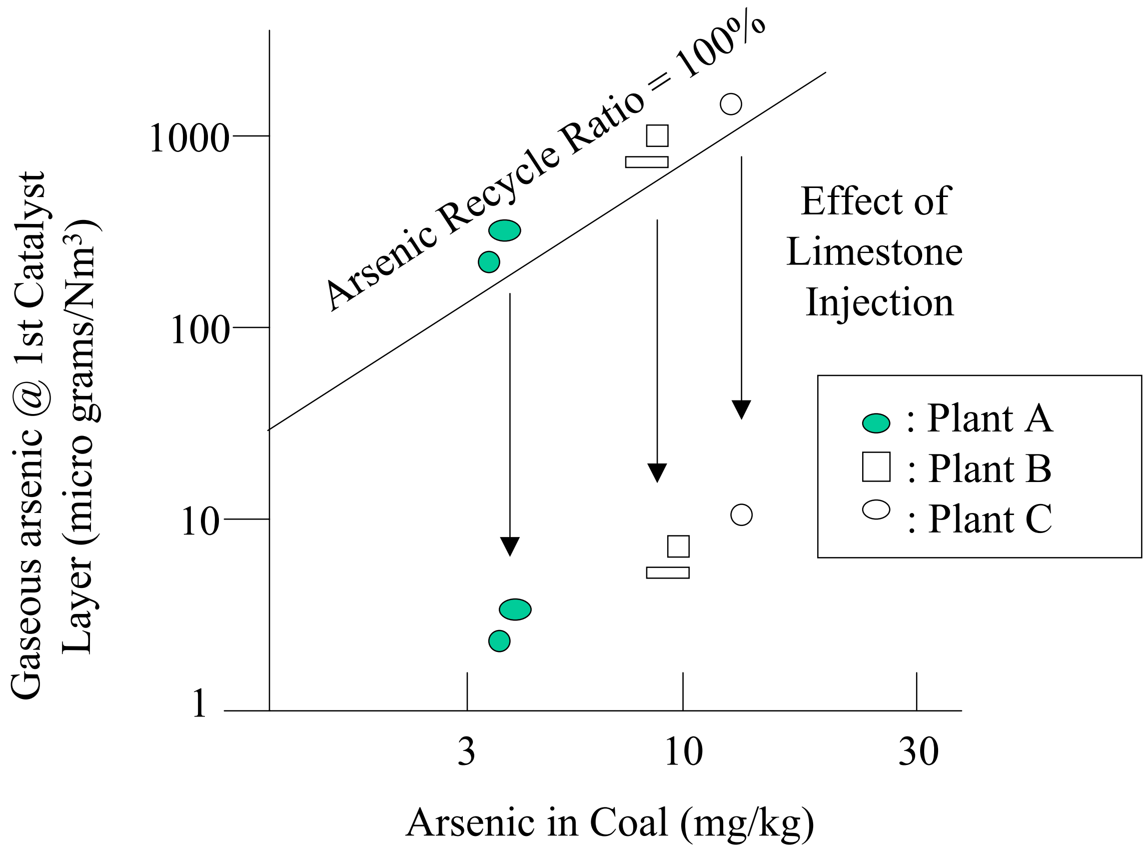


Figure 7
Effect of limestone Addition

The ash loading (A_L) and characteristics dictate the catalyst pitch. For this application a fairly standard 7.1mm pitch product was selected. Potential cost saving through use of a reduced catalyst pitch which provides higher surfaces area per unit volume is currently being investigated.

System Design

Impact to the system design are evaluated based on the distributed criteria established (D_A , D_F , D_T) ash loading (A_L), and SO_2 and SO_3 concentration (CO_{SOXL}), Pressure loss criteria (ΔP), operating temperature (T_L), regulations (R), and conditions (SC).

The ammonia injection grid design is based on the distribution criteria. For this application a thirty- six zone (36) adjustable grid was selected. A cold flow model and or a computer CFD model test will be performed prior to fabrication to assure the adequacy of the initial design.

The reactor and flue design is dictated by the site conditions, pressure loss criteria, operating temperature, distribution criteria, regulations, and ash loading. The site conditions allowed for an in-line reactor between the economizer outlet and air-preheater inlet. An economizer bypass and static mixer was required in order to maintain sufficient temperature at the catalyst to achieve the required NO_x reduction and avoid salt formation. Due to the year round NO_x reduction requirement a SCR bypass was not necessary.

Sufficient test ports were designed into the system to assure the capability for proper system tuning during plant start-up. In addition removable catalyst sample were designed into the system to allow for laboratory performance audits. The combination of field data and catalyst laboratory testing throughout the life of the plant will yield valuable information for scheduling catalyst addition and/or replacements, especially in this case where the catalyst management plan is a governing factor.

Case Study 2: Orimulsion Fired Boiler

The primary area of concern for applying SCR to a boiler fired with orimulsion fuel is associated with the high levels of two components, namely SO_3 and vanadium. Since orimulsion is relatively new fuel, there is somewhat limited full scale operating experience. Therefore the method of analysis relies heavily on the related experience of heavy oil.

The system must be designed to with stand high SO_3 concentrations. The catalyst will be designed to cost effectively manage the increase in SO_2 to SO_3 conversion that will be designed over time due to vanadium deposition and deactivation. Catalyst management may de dictated by, either a decrease in NO_x reduction performed or an increased in $SO_{2\,t}$ to SO_3 conversion.

As previously mentioned, if proper operating temperatures are maintained SO_3 does not have any detrimental effects on catalyst performance, however downstream equipment must be considered. Measure such as enameling of cold end layers may be taken in order to limit air preheater corrosion and plugging. In addition, the ash particle size distribution of orimulsion enhances the potential for ash agglomeration. The designer must take this into account when considering the catalyst formulation and cleaning method i.e. sootblower designer and frequency of operation.

Case Study 3: Gas Turbine landfill and digester gas cofiring with natural gas

This case is similar to the orimulsion case the potential focuses on the effect of fuel constituents, however in this case the potential damage to catalyst is somewhat different and to a larger degree.

Cormetech currently has three gas turbine unites which co-fire either land fill gas or digester gas with natural gas. Catalyst has been evaluated in both turbines and duct firing of these waste fuels. The primary catalyst concern when firing landfill of digester gas is a component in the fuel which can caused severe catalyst deactivation, namely siloxanes. Siloxanes are a family of polymers commonly found in health and beauty products which find their way into general waste streams. They have been the subject of much study and concern due to their detrimental affect on both CO and NO_x catalyst deactivation. Siloxanes deposit on the surface and prevent the reactants from reaching active sites for conversion. Siloxane poisoning cannot be practically reversed. There has been some limited success in rejuvenation trails on CO catalyst.

Unlike the coal or orimulsion fired applications discussed above, the solution to fired this fuel does not lie within the catalyst or SCR system design. Instead, fuel treatment system must be employed which removes the siloxanes components. Selective elimination is not practical and successful treatment systems are in operation strip both siloxanes and other components, including VOC's. Activated carbon is needed to reach the removal levels necessary and can be either regenerated or disposed of, whichever is most suited to the specific site demands. Once cleaned, these waste fuel can be fired with little or no detriment to catalyst. The oldest units have been successfully operating approximately two and one-half years with out difficulty.

A catalyst testing plan has been developed to monitor catalyst performance and silicon levels at both sites. Testing assure that the fuel treatment system is effective and provides useful information for evaluating catalyst life potential.

Case Study 4: High velocity dust laden application

Although traditional or stand-alone SCRs are the most effective means of reducing significant quantities of NOx, some focus to "high velocity SCRs" for coal and oil fired boilers. a number of issue arise when considering this type of application; 1) pressure drop, 2) NOx removal potential, and 3) erosion potential.

Typical high velocity SCR pressure drop values range from 8-10 inches water versus typical values of 4 to 5 inches of water. Due to the increased system pressure caused by the addition of the high velocity SCR, electrostatic precipitators and furnace structure must be re-evaluated to assure structural integrity.

NOx removal potential for high velocity SCRs can vary greatly from unit to unit. Typical reduction efficiency is approximately 30% to 40% with a maximum of 50%.

For coal fired applications where ash is present catalyst erosion must be considered. Cormetech has completed a short term high velocity test (approximately 2 month duration) and is currently participating in another (approximately 18 months). Results thus far, show that catalyst erosion has been minimized through proper system design and catalyst leading edge hardening.

Case Study 5: High efficiency in-duct utility boiler application

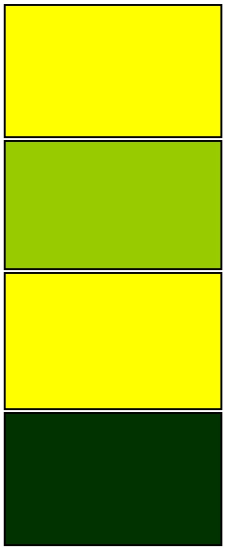
This case addresses the impact of maldistribution on a high performance SCR system installed on a large gas fired utility boiler. Three (3) components controlled much of the design for this application; 1) site condition 2) removal efficiency, and 3) distribution criteria.

The site condition presented a very tight back-end arrangement with little room for expansion. The space between the economizer exit and the stack was nearly completely occupied by the APH. The resulting SCR design required severe transition both to and from the reactor. The ammonia injection grid was placed in an area which allowed very little residence time for mixing, but did provide substantial coverage of the flue.

The removal efficiency of the units is 92.6% with a maximum ammonia slip of 10 ppmvd @ 3% O_2 after four (4) years.

The distribution criteria was set based on an iterative process which involved both Cormetech and the system supplier. A cold flow model was built and tested. Specific volume based on the performance results. Limiting factors included cost, pressure loss and space restrictions.

A simplified example of the iterative analysis and the associated impact on catalyst performance is provided graphically in figures 8 (before) and 9 (after). The figures depict the flue cross-section divided into distinct areas representing the extent of the flow, ammonia, and temperature distribution before and after modifications.

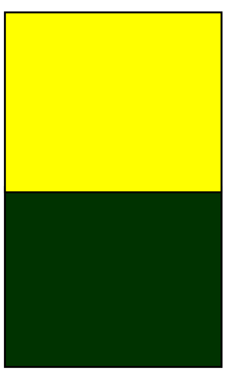


Input		Output	
Flow: Temperature: NH_3:	+30% +50^{0}F -20%	Outlet NOx: NH_3 slip:	14.6 ppmvdc 7.1 ppmvdc
Flow: Temperature: NH_3:	+15% +25^{0}F -10%	Outlet NOx: NH_3 slip:	10.0 ppmvdc 6.8 ppmvdc
Flow: Temperature: NH_3:	-15% +25^{0}F -10%	Outlet NOx: NH_3 slip:	4.5 ppmvdc 10.0 ppmvdc
Flow: Temperature: NH_3:	-30% -50^{0}F +20%	Outlet NOx: NH_3 slip:	2.6 ppmvdc 12.4 ppmvdc

Results

- Catalyst able to achieve NOx reduction from 122 to 9 ppmvdc
- However, NH_3 slip is 10 ppmvdc

Figure 8
Effect of Maldistribution on High Performance SCR (Before Modification)



Input		Output	
Flow: Temperature: NH_3:	+10% +25^{0}F -5%	Outlet NOx: NH_3 slip:	10.8 ppmvdc 5.2 ppmvdc
Flow: Temperature: NH_3:	-10% -25^{0}F +5%	Outlet NOx: NH_3 slip:	6.8 ppmvdc 5.0 ppmvdc

Results

- Catalyst achieve NOx reduction from 122 to 9ppmvdcH3
- NH_3 Slip is 2.5 ppmvdc

Figure 9
Effect of Maldistribution on High Performance SCR (After Modification)

Figure 10 shows the significance of proper distribution in terms of effective catalyst life. After only two years of operation, an improperly designed system would not be able to meet the required performance. The maldistribution effectively makes the system operate as if the catalyst was between 5 and 6 years old.

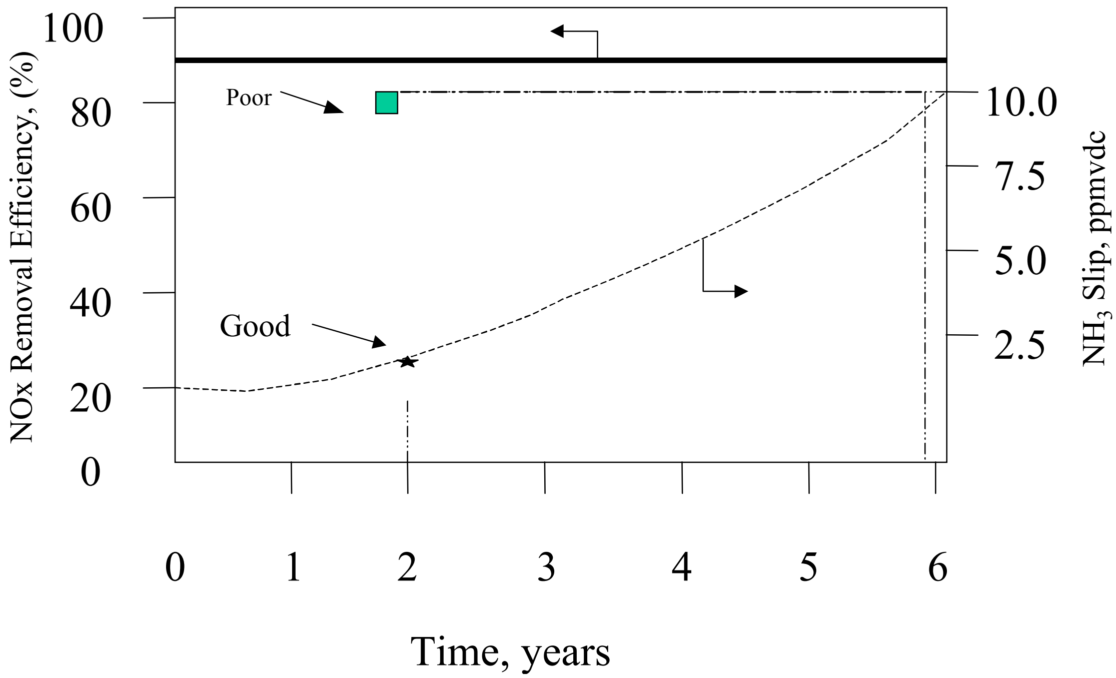


Figure 10
Effect of Maldistribution on High Performance SCR
(Effective Catalyst Life)

If this system had been a coal or oil fired boiler with significant quantities of sulfur, poor distribution would not only have caused poor NOx reduction performance, but may have also caused significant air heater plugging. Therefore, it is important to understand and account for maldistributions in order to assure a successful and reliable system.

Conclusion

Severe operating condition can be defined over a wide range of parameter including fuel types, performance requirements, and systems operating. It is important to understand which design parameters to assess and the proper evaluation techniques. Once a design is implemented it is important to retrieve and analyze data as well as perform laboratory tests on catalyst field samples. Information gained from the field and catalyst testing can be utilized to optimize future catalyst replacement or additions and provide valuable information for future designs.

Reference:

1. Optimizing SCR Catalyst Design and Performance for Coal-Fired Boilers by Pritchard et al presented at EPA/EPRI 1995 Symposium on Stationary Combination NOx Control.

ATTACHMENT 1

Purpose: As a tool for SR catalyst system performance monitoring over time

Notes:

- Use this form to record SCR operational parameter at start-up and monthly thereafter.
- It is very important to achieve consistent operating condition, preferably at or near design point, before recording data each month.
- Use this form as a master. Make copies for recording data.

Date	
Gas flow (lb./hr)	
SCR gas Flow Temperature (^{0}F)	
Inlet NOx (ppmvd) @ 15% O_2	
Outlet NOx (ppmvd) @ 15%) O_2	
O_2 (Vol. %, dry)	
H_2O (Vol. %)	
NH_3 Flow (lb./hr)[1]	
NH_3 Slip (ppmvd) @ 15% O_2	
Date of last Equipment Calibration (Analyzers, NH_3 metering pump, etc.)	
Date of last Relative Accuracy Test	
Operating Hours on Catalyst (total)	
Operating Hours on primary Fuel	
Operating Hours on Back-up Fuel	
Total Number of Stops and Starts since Catalyst Installation	
AIG Balancing Valve Positions (gauge ΔP, Zone 1,Zone 2,...)	
Catalyst Δp, in. wg	

[1]If aqueous ammonia, % solution should be recorded.
[2]Method of measurement and accuracy should be noted for all measured values, e.g., flow (boiler load signal or stack measurement ±___%,) NOx (dilution method chemiluminescence ±___%) NH_3 (chemiluminesence subtraction method or calculated ±__%, ammonia flow lb./hr ±__%), etc.
[3] Impact of instrument accuracy and repeatability must be evaluated on a case basis.
[4] This form should be completed at start –up, during all relative accuracy tests, and on a monthly basis.
[5] Month to month data correction; $NH_{3\,m}$ x ($Flow_m$ / $Flow_r$) x (ΔNOx_m / NOx_R)

Where:
$NH_{3\,C}$ =Corrected NH_3 flow
$NH_{3\,M}$ =Measure NH_3 flow
$Flow_M$ =Measure flue gas flow
$Flow_R$ =Reference flue gas flow
ΔNOx_M =(Measure Inlet NOx)- (Measure Outlet NOx)
ΔNOx_R =(Reference Inlet NOx) – (Reference Inlet NOx)

If measurements for temperature, oxygen, and water content vary greatly, additional corrections must be performed
[6] Corrected ammonia flow data should be trend charted to provide indication of performance capability.