SCR Catalyst Layer Addition Specification and Management

The 13th Sulfur Dioxide, Nitrogen Oxide, Mercury and Fine Particle Pollution Control Technology & Management International Exchange Conference

Wuhan, Hubei Province, China
June 27-30, 2009

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Abstract

In the near future, many Chinese utilities will need to consider Selective Catalytic Reduction (SCR) catalyst layer addition for the first time. The specifications and guarantees associated with catalyst layer additions are different from the initial catalyst installation and the process presents some unique challenges. Based on extensive experience with catalyst layer additions and replacements, Cormetech, Inc. recommends some proven strategies for the management of SCR catalyst layer additions.

Background

Cormetech supplied the catalyst for the first coal-fired SCR project in China in 2005 (Songyu Unit 3). In the subsequent years, SCR technology has been rapidly adopted in China. SCR is frequently required on new coal-fired boilers and some existing boilers in heavily populated areas have been retrofitted with SCR as well. There are now approximately 30 GW of coal-fired SCR generation capacity in operation in China.

SCR catalyst is designed to provide a level of performance for a specified period of time, typically 8000 – 24000 hours. Once the SCR catalyst has reached the end of the design life, catalyst layer addition or replacement is required in order for the SCR to maintain performance. As a result, many Chinese utilities will soon need to consider catalyst addition. The first catalyst layer addition and future layer replacements present unique challenges and opportunities to owners and catalyst suppliers. Based on extensive experience, Cormetech can recommend some proven strategies for the specification and management of SCR catalyst layer additions.

Most coal-fired SCR designs incorporate multiple layers of catalyst. There are two main reasons for this:

The primary reason for multiple layer SCR designs is to provide flexibility in managing the life of the SCR catalyst and the performance of the SCR system. Even in cases where a single layer of catalyst can meet the initial performance requirements, a coal-fired SCR reactor design should include provisions for at least one additional layer.

Secondly, the initial catalyst volume requirements for coal-fired SCR applications typically exceed the catalyst volume that can be manufactured in a single layer. However, this is not always the case, particularly for some projects with low deNO_x efficiency requirements.

The most typical coal-fired SCR reactor arrangement consists of two initial layers plus one future layer (2 + 1). This arrangement is shown in Figure 1. Less common potential catalyst layer arrangements (1 + 1, 1 + 2, 2 + 2, and 3 + 1) are illustrated in Figure 2.

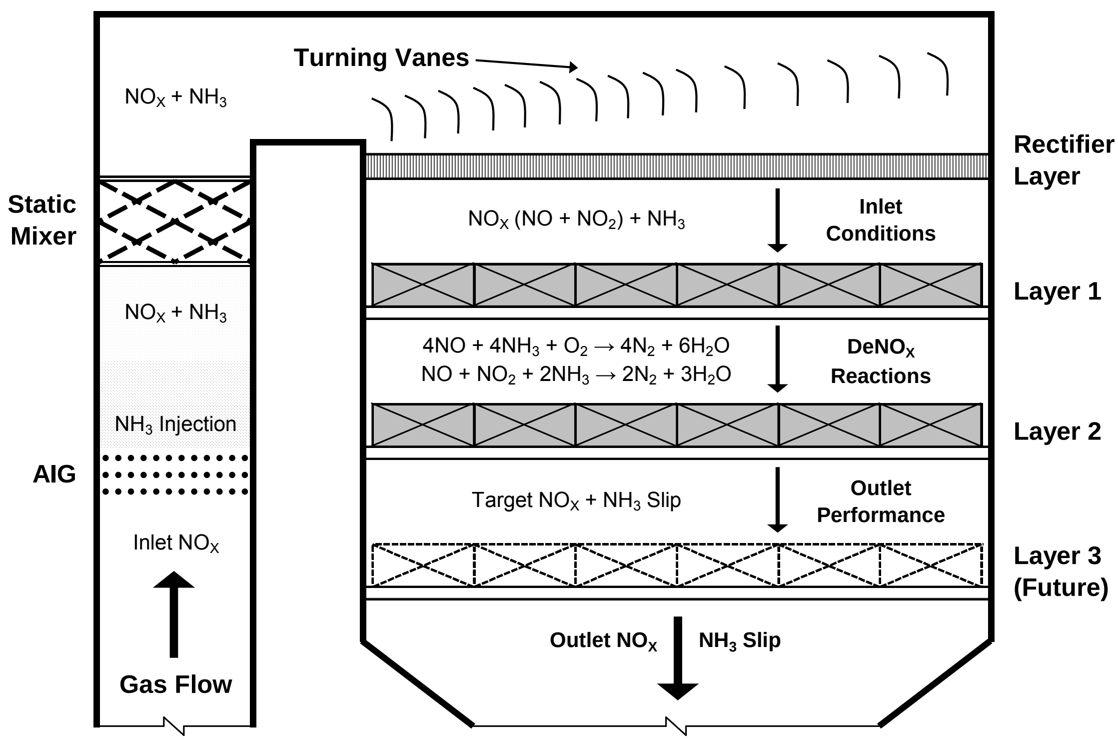

Figure 1. Typical SCR Reactor Arrangement (2+1 Layer)

Compared to gas- or oil-fired units, coal-fired SCR units require relatively high catalyst volumes due to the characteristics of certain Chinese coals and the expectation of certain performance requirements. The initial catalyst requirements for SCR projects in China are likely to increase as $deNO_x$ requirements become more stringent in the future.

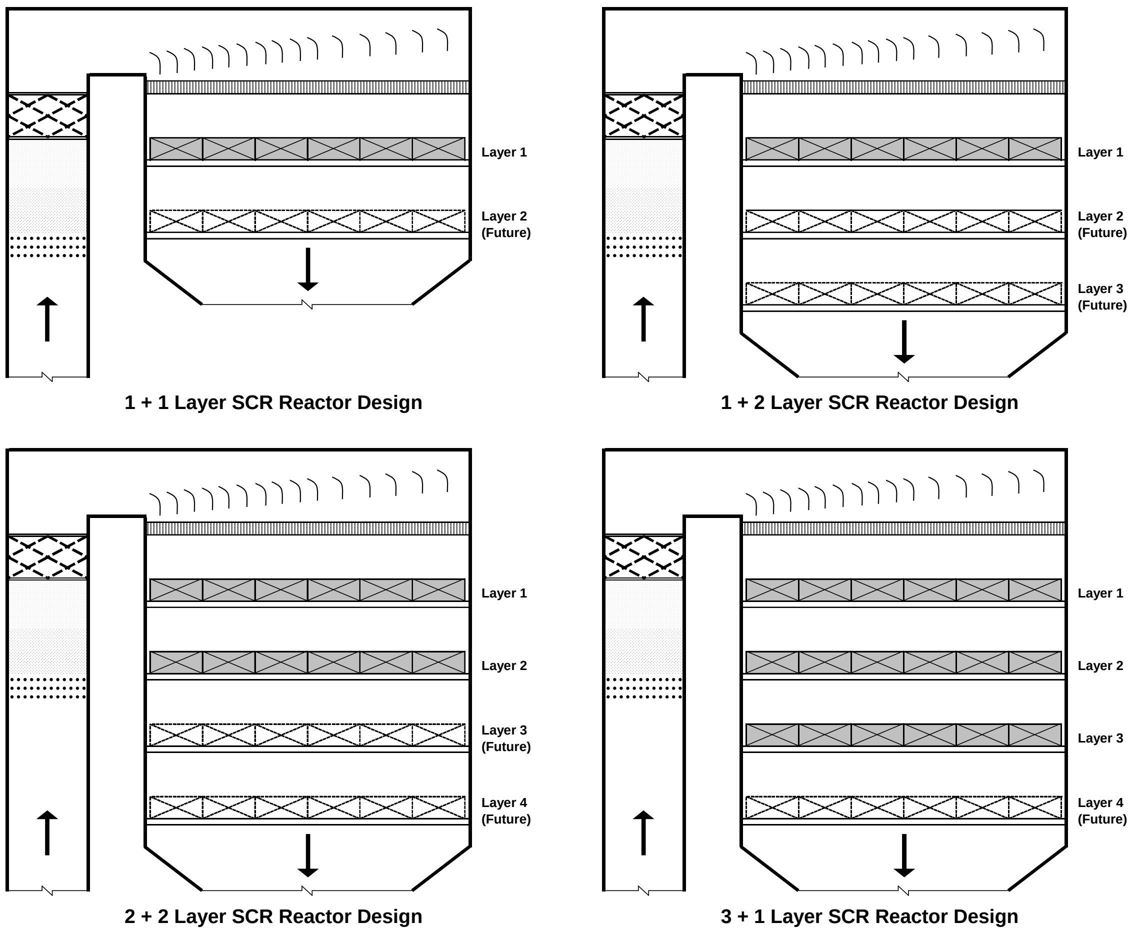

Figure 2. Alternate SCR Reactor Arrangements

Once the combustion gases begin to flow through the SCR, the catalyst will begin to deactivate. Over time, the catalytic potential will decrease and eventually fail to provide the required $deNO_x$ performance. The rate of catalyst deactivation is dependent on the fuel that is fired in the boiler. The deactivation rates for different coals can vary widely, and can be relatively severe in some cases. The catalyst supplier will consider the coal and ash analysis provided by the customer during the design phase and account for the expected deactivation rate during the guarantee period.

The combination of comparatively high catalyst volumes and significant deactivation potential for coal-fired SCR applications should encourage utilities to maximize the value of their investments in SCR catalyst. Effective utilization of layer additions and catalyst management techniques can help utilities achieve this goal.

Catalyst Management

Proper catalyst management enables the owner to optimize the value and performance of the SCR catalyst over the life of the SCR system. A catalyst management plan is a useful tool for understanding the expected catalyst performance and planning for activities such as catalyst layer addition, replacement, or regeneration. Figure 3 provides a typical catalyst management plan.

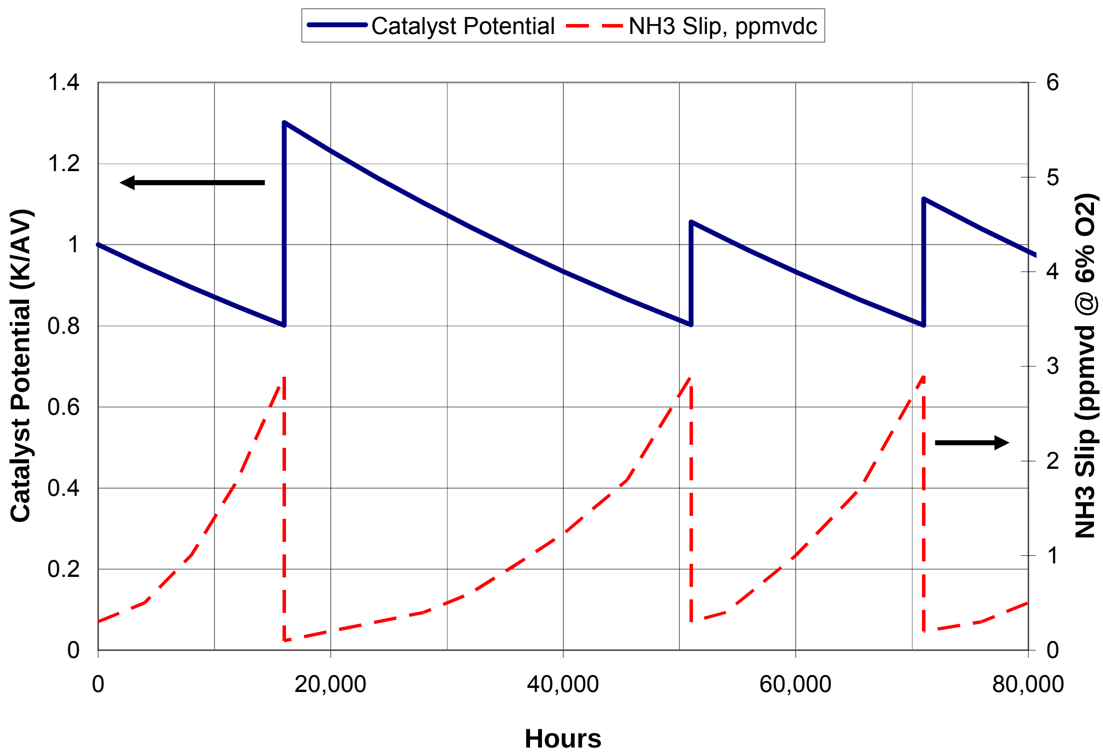

Figure 3. Catalyst Management Plan 16,000 Hour Design Life (2 + 1 Layer)

The left axis of the management plan represents the relative catalyst potential, which starts with a value of 1.0 and decreases over time based on the deactivation rate of the catalyst. The deactivation rate depends on the characteristics of the coals that are fired in the boiler.

The right axis of the management plan represents the NH_3 slip. The NH_3 slip typically starts at a very low level and increases gradually as the catalyst deactivates. The NH_3 slip will reach the design limit when the catalyst has deactivated to the minimum acceptable potential. This should also coincide with the design life of the catalyst.

It is at this point, where the NH_3 slip reaches the design limit and the catalyst activity approaches the minimum performance threshold the management plan calls for the addition of a catalyst layer. Upon adding the layer, the catalyst potential increases significantly and the NH_3 slip returns to a low level. After the SCR catalyst layer addition, the cycle of catalyst deactivation continues and when the catalyst potential reaches the minimum acceptable level again, the first catalyst layer replacement should occur. Catalyst layer replacements continue throughout the life of the SCR system.

The catalyst management plan shown in Figure 3 is constructed based on the assumption that each future catalyst layer addition and replacement will provide the same catalyst potential as one original catalyst layer. This is easily seen in the impact of the first layer addition. The original relative catalyst potential is 1.0. At the end of guarantee period (16,000 hours), the catalyst potential has decreased to 0.8. This indicates that 80 percent of the original catalyst potential remains, and that 20 percent of the original catalyst potential is expected to deactivate. When the third layer of catalyst is added, the relative catalyst potential will increase to 1.3. Therefore, the relative catalyst potential of the layer addition is 0.5, which is equal to half (one layer) of the original catalyst.

It is convenient to assume that all catalyst layers will be identical when calculating the initial catalyst management plan. However, it is not necessary for a utility to keep all catalyst layers within a reactor the same. In many cases, the geometry and/or the chemistry of the catalyst layer additions and replacements will be different from the original catalyst layers.

There are several reasons for the owner to prefer a catalyst layer that is not the same as the installed catalyst:

- The utility may want to maximize the catalyst potential of the layer addition in order to meet the new performance requirements for an extended period of time. At the end of the design life for the original SCR catalyst, the performance requirements for the SCR system may be adjusted. For example, many SCR projects in China will require relatively low $deNO_x$ efficiency (60 – 75 percent) initially. However, at the time of the first layer addition, some of these projects will expect to increase $deNO_x$ efficiency to meet more stringent standards (80 – 90 percent).

- Some owners may want to minimize the additional SO_2 conversion or the pressure drop of a layer addition. This may result in selecting a lower activity catalyst, a smaller volume, or a different pitch catalyst for the layer addition. Also, product advancements may result in the utility selecting a different type of catalyst for the layer addition. In any case, the layer addition process will provide the owner and the catalyst supplier a key opportunity. Both parties can work together to evaluate the performance of the existing catalyst and design the catalyst layer addition to meet the future requirements of the system.

Catalyst Layer Addition

There are two general methods of specifying catalyst layer additions. The first approach is based on maintaining the performance of the existing SCR system and providing some associated performance guarantees. The second approach is based solely on the physical and chemical characteristics of the catalyst layer addition. In either of the catalyst specification methods, the specification should also include the information described in Table 1.

Table 1. Site Specific Information Required for Catalyst Layer Additions

Site Specific SCR System Information		
a.	Reactor drawings specific to catalyst module / support beam interface	
b.	Product feature preferences [catalyst pitch, opening size, etc.]	
c.	Operating limitations [pressure drop, SO_2 oxidation, etc.]	
d.	Coal and ash specifications	
e.	Anticipated future changes to operation or fuels	
f.	SCR process conditions	
	i.	Gas flow rate
	ii.	Temperature
	iii.	Inlet NO_X
	iv.	Inlet SO_2
	v.	Inlet SO_3
	vi.	H_2O
	vii.	O_2

Please note that when a layer of catalyst is added to the SCR system, the total pressure drop and SO_2 conversion rate will increase. The amount of increase can be controlled to some extent through the design of the catalyst layer.

System Performance Approach

In the system performance approach, the performance requirements specified are similar to those that were specified with the original SCR project (deNO_X efficiency, ammonia slip). The catalyst layer addition will be operated in conjunction with the existing installed catalyst and the effectiveness of the overall SCR system is dependent upon the joint performance of the existing catalyst and the new catalyst. This is relatively straightforward if the original (OEM) catalyst supplier will also supply the layer addition.

In order for a different (non-OEM) catalyst supplier to provide a design and offer commercial guarantees under this methodology, they must have significant knowledge related to the design of the original catalyst. It is possible that the utility does not have access to this level of design detail.

Table 2 provides a summary of information that the owner should include in the specification of catalyst layer additions when system-based performance guarantees are required. The OEM catalyst supplier will already have most of the required information based on the original design. If non-OEM catalyst suppliers are invited to bid on the catalyst layer addition, the owner will need to provide more extensive information regarding the existing catalyst design and performance. This data will allow non-OEM suppliers to calculate the catalyst potential (K/AV) and understand the rate of catalyst deactivation, ultimately allowing the supplier to offer commercial guarantees associated with the overall SCR performance.

The catalyst supplier's offers may include caveats associated with the condition of the original catalyst at the end of the new lifetime. For example, they may require that the K/AV of the original catalyst be ≥ X at the end of the new guarantee period. Similarly, there may be conditions associated with the rate of catalyst deactivation, which is typically considered to be same as historical. If this is not the case, coal and ash analysis data will be required in order to predict the deactivation rate and determine the performance lifetime of the system.

Table 2. System Performance Specification Data for Catalyst Layer Additions

System Performance Approach			
a.	Similar performance requirements as original procurement		
	i.	DeNO$_X$ efficiency	
	ii.	NH_3 slip	
	iii.	Catalyst life	
	iv.	Catalyst pressure drop	
	v.	SO_2 oxidation	
b.	Additional information regarding existing catalyst required for non-OEM catalyst suppliers to offer system performance guarantees		
	i.	Original catalyst volume	
	ii.	Original catalyst geometric surface area [m^2 / m^3]	
	iii.	Original catalyst activity [Ko]	
		1.	Activity test conditions [AV, Temperature, NH_3:NO_X MR]
	iv.	Original catalyst current activity [Ke]	
	v.	Age of catalyst [operating hours]	

	vi.	Reactor location of the new catalyst layer [1st, 2nd, 3rd, etc.]	
	vii.	Catalyst inlet conditions	
		1.	NH_3:NO_X [+/- %RMS]
		2.	Velocity [+/- %RMS]
		3.	Temperature [+/- °C]

Catalyst Product Specification Approach

The second approach is a product type guarantee for the single layer. The catalyst is evaluated on the basis of catalyst activity, surface area, and SO_2 oxidation rate for the single layer. The utility manages the performance associated with the integration of the new layer with the existing layers installed to assure that the $deNO_x$, ammonia slip and life goals are achieved. In this case, the utility specifies the minimum catalytic potential of the layer being procured. Typical requirements for this type of specification are provided in Table 3.

Table 3. Catalyst Product Specification Data for Catalyst Layer Additions

Catalyst Product Specification Approach			
a.	Typical catalyst specifications for the layer addition or replacement		
	i.	Catalyst pitch	
	ii.	Catalyst geometric surface area [m^2 / m^3]	
	iii.	Catalyst initial activity [Ko]	
		1.	Activity test conditions [AV, Temperature, NH_3:NO_X MR]
	iv.	Catalyst end of life activity [Ke]	
	v.	Catalyst pressure drop	
	vi.	SO_2 oxidation	
		1.	Activity test conditions [AV, Temperature, NH_3:NO_X MR]

Because the utility will be responsible for managing the integration of the layer addition and determining the expected performance, most utilities will prefer to build some experience with SCR and develop a solid understanding of catalyst characteristics and requirements before utilizing the catalyst product specification approach. If the catalyst product specification approach is selected, the catalyst supplier should typically provide the information described in Table 4 for evaluation by the owner.

Table 4. Catalyst Supplier Guarantees and Supporting Data for Product-Based Catalyst Layer Additions

Catalyst Supplier Guarantees and Supporting Data		
a.	Initial catalyst activity [Ko, $Nm^3/(h\text{-}m^2)$]	
b.	End-of-life catalyst activity [Ke, $Nm^3/(h\text{-}m^2)$]	
c.	Catalyst activity test conditions	
	i.	Temperature [°C]
	ii.	Area velocity [AV, $Nm^3/(h\text{-}m^2)$] (typically = field AV)
	iii.	NO_X
	iv.	SO_2
	v.	SO_3
	vi.	H_2O
	vii.	O_2
	viii	Molar ratio [MR, NH_3:NO_X] (typically = 1)
d.	Catalyst SO_2 conversion [%]	
e.	Catalyst SO_2 conversion test conditions	
	i.	Temperature [°C]
	ii.	Area velocity [AV, $Nm^3/(h\text{-}m^2)$] (typically = field AV)
	iii.	NO_X
	iv.	SO_2
	v.	SO_3
	vi.	H_2O
	vii.	O_2
	viii	Molar ratio [MR, NH_3:NO_X] (typically = 0, without NH_3 injection)
f.	Pressure drop guarantee [Pa per layer]	

Conclusions

The first wave of catalyst layer additions will present some unique challenges in China. Because SCR technology is relatively new in China, the utilities and some catalyst suppliers lack experience in this area. The regulatory environment is also expected to evolve and SCR performance requirements will become more stringent. This will impose difficult technical demands on many catalyst layer additions. Utilities and catalyst suppliers will need to work together closely to clearly define the performance requirements, specifications, and commercial guarantees associated with catalyst layer additions.