ENHANCED MERCURY CONTROL BY MANAGING SCR SYSTEMS FOR MERCURY AND NOx

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ABSTRACT

The ability of SCR catalysts to oxidize mercury is an integral aspect of the mercury control strategy for many utilities. To help maximize the SCR mercury oxidation effect, two general catalyst management scenarios were developed. The first strategy generally applies to facilities which must aggressively maximize mercury oxidation through the SCR and requires that the final catalyst layer be managed separately from the upper layers, essentially acting as a mercury oxidation catalyst under conditions of very low ammonia. The second, less aggressive strategy, relies on the concept of “excess potential” where a predetermined amount of reactor potential is maintained over and above that required for deNOx purposes. As a result, there will always be some portion of catalyst that operates at very low ammonia slip, helping to improve mercury oxidation across the SCR. Both strategies have fine-tuning parameters which allow them to be tailored to the specific application.

INTRODUCTION

The ability of SCR catalysts to oxidize mercury is well documented and is an integral aspect of the mercury control strategy for many utilities. SCR mercury oxidation can be beneficial for facilities which rely on co-benefits for their primary mercury control, as well as for facilities which have dedicated mercury control technologies, such as sorbent injection. Much work has been done by the industry to understand the effects of factors such as fuel, flue gas composition, and SCR operating conditions on mercury oxidation across SCR catalysts. However, it is clear that some of the most important factors for mercury oxidation relate to the catalyst itself, i.e. the total catalyst volume/reactor potential, chemical formulation, physical characteristics, and age of the catalyst. Many catalyst manufacturers have attempted to maximize oxidation through advanced catalyst designs. These designs are relatively new to the industry, and as such have a limited field performance record. In any event, information as a whole indicates that catalyst management will be a critical factor in achieving maximum mercury oxidation over the long term for any particular facility. The following discussions outline some of the primary considerations in developing a catalyst management strategy to maximize mercury oxidation and propose several general catalyst management scenarios. In addition, industry data are provided as an example of the effect of various parameters on SCR catalyst mercury oxidation, and the implications of these effects for catalyst management. Example full-scale data showing the effect that catalyst management events can have on emissions are also included.

GOVERNING ASSUMPTIONS FOR CATALYST MANGEMENT STRATEGIES

There are a number of assumptions which govern to some degree the development of any catalyst management strategy. These may differ according to the particular facility in question, and therefore only general management guidelines can be developed for an SCR fleet as a whole. The actual implemented catalyst management strategy for any particular unit must necessarily take into account the goals, limitations, and practical aspects of that operating unit. In any event, the general governing assumptions for the proposed catalyst management strategies for mercury control are as follows.

Practical Limitations Clearly there are practical limits associated with maximizing mercury oxidation across SCR facilities. Maximum catalyst volume, outage availability, maximum frequency of catalyst replacement or additions, catalyst costs, etc. are all practical limitations which impact the analysis. Thus, the focus of the current analysis is to develop catalyst management strategies which can reasonably be achieved for most operating units.

Qualitative Analysis The approach of the effort is to qualitatively maximize mercury oxidation across the SCR (or at least improve the oxidation to an acceptable level for the application) considering the practical limitations of catalyst management. Predicting the exact level of mercury oxidation for any specific facility, given a set of operating conditions and fuel, is difficult. So, the approach is to develop a strategy to qualitatively improve the mercury oxidation through catalyst management, but not necessarily predict exactly what the mercury oxidation level will be.

Halogen Level The halogen content of the coals currently fired by the domestic utility industry varies greatly, from extremely low levels associated with sub-bituminous PRB coals (and other low-halogen bituminous fuels) to high-halogen eastern bituminous coals. However, the proposed catalyst management strategies focus on conditions of moderate to high halogens. This is because it is assumed that fuels deficient in native halogens will be augmented with halogen injection to improve overall mercury oxidation performance.

SCR Focus The focus of the analysis is limited to SCR catalyst mercury oxidation behavior and catalyst management, with the goal of optimizing mercury oxidation across the SCR according to the needs of the specific application. Of course, mercury oxidation and capture behavior downstream of the SCR for any particular facility heavily influences the final mercury emissions, so those factors cannot be ignored when applying catalyst management strategies. Those factors include parameters such as temperature, ESP or baghouse behavior, and scrubber behavior. In essence, these factors help to set the demand for mercury oxidation, and in turn this governs catalyst management.

EFFECTS OF OPERATING PARAMETERS ON MERCURY OXIDATION

A number of parameters strongly affect mercury oxidation across SCRs and as a result are important considerations that must be included in the development of catalyst management strategies. In particular, the ammonia profile and halogen level have important implications for catalyst management, and are addressed in the following discussions.

Effect of Ammonia

In terms of catalyst management for mercury control, the effect of ammonia is a critical consideration. This is because most catalyst management activities strongly affect the ammonia profile within the SCR reactor, which in turn strongly affects mercury oxidation. In general, ammonia has a suppressive effect on mercury oxidation, but the magnitude of that effect is influenced by other parameters, such as the halogen conditions. As a result, ammonia effects must be considered in light of other operational parameters.

The prevailing theory is that ammonia competes for active sites which influence mercury oxidation, and as a result when ammonia levels increase, fewer and fewer active sites are available for mercury oxidation. The active sites associated with mercury oxidation are thought to be related to the formation of halogen complexes, and thus a halogen influence is present. In a practical sense, it is this competition between ammonia and halogens that in large part governs catalyst behavior with respect to mercury. Figure 1 shows mercury speciation at the SCR outlet for tests performed at Gulf Power's Mercury Research Center[1] (MRC) for 4 different catalysts, two at low chlorine conditions (50 ppmv), and two at high chlorine conditions (100-120 ppmv). All of the catalysts were relatively new at the time of testing. At the low chorine conditions, the level of oxidized mercury at the outlet of the reactor is significantly impacted by increasing the deNOx level (ammonia), from a high of near 90% with no ammonia present, to roughly 70% oxidized mercury at 90% deNOx. At higher levels of chlorine (100-120 ppmv), however, there appears to be less ammonia sensitivity, with the oxidation decreasing much more moderately across the deNOx range. These data imply that higher levels of halogens can to some degree mitigate the adverse effects of ammonia.[2]

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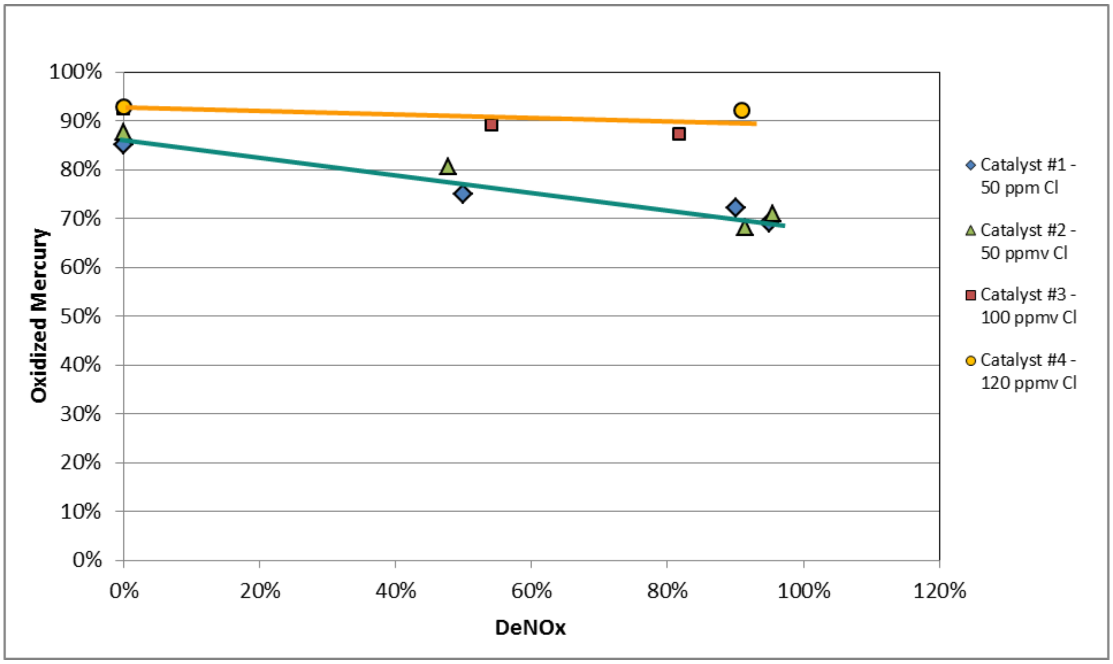
[1] This facility is located at Gulf Power's Plant Crist. The referenced project was funded jointly by EPRI and Southern Company.

[2] It should be cautioned that the presented data are just one example of the ammonia effect. These data should only be viewed qualitatively, as the actual level of oxidized mercury is a function of many factors, and will therefore vary considerably from facility to facility.

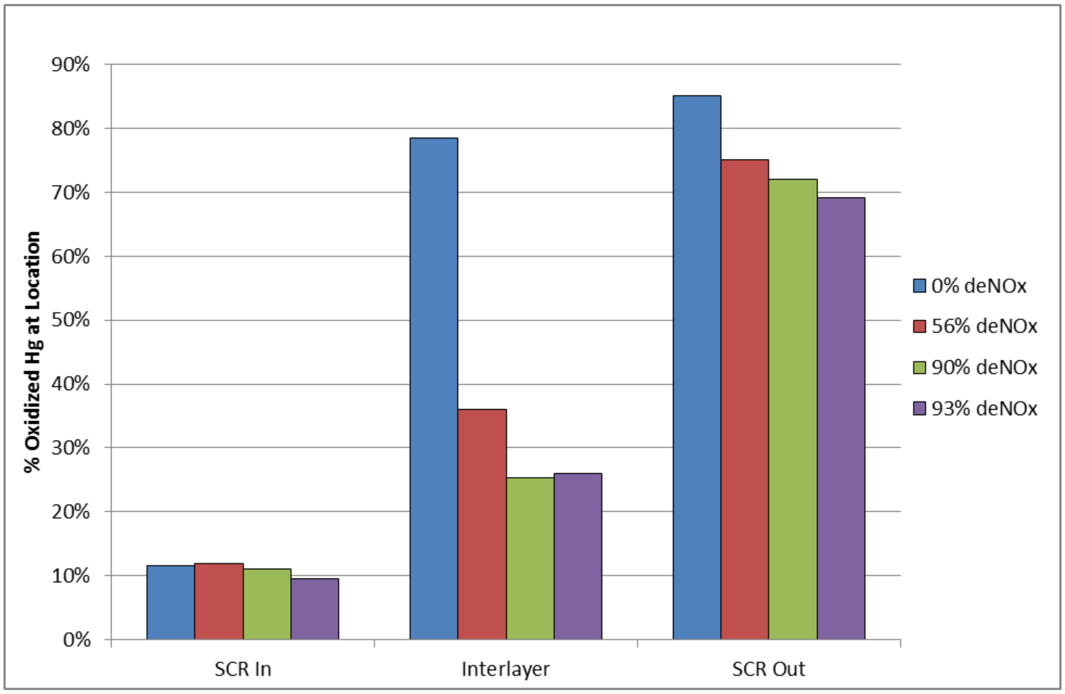
Figure 1: Effect of Ammonia on Absolute Mercury Speciation – SCR Outlet



To better understand the effects of ammonia on mercury oxidation and its relation to catalyst management, it is important to understand both the ammonia and mercury oxidation behavior of the SCR/catalyst on a layer-by-layer basis. Interlayer data for a honeycomb catalyst at the MRC, in which three (3) catalyst layers were present, are available showing the effects of various levels of deNOx on the system. These data are shown in Figure 2 giving the absolute mercury speciation at the reactor inlet, interlayer location (after the first two catalyst layers), and at the reactor outlet. Note that the data were all acquired at a moderately high level of chlorine (60 ppmv), design flow rate, and 700 ^{o}F.

The data show that in absence of ammonia (0% deNOx), most of the total amount of mercury oxidation that occurs is accomplished by the first two layers of catalyst. In this case, it appears that a maximum equilibrium level of ammonia is being reached, and that the first two layers of catalyst are sufficient for this to occur, since little additional oxidation occurs across the final layer. However, as ammonia is introduced (represented by the 56%, 90%, and 93% deNOx conditions), oxidation across the first two layers of catalyst is immediately suppressed. This demonstrates the important role that ammonia plays in practical mercury oxidation analyses for SCR systems. This effect is emphasized even more if the data are analyzed as the percentage of available elemental mercury that is oxidized across each layer. In that case, the final layer of catalyst has a dramatically higher rate of oxidation of available elemental mercury, demonstrating the strong inhibiting effect of ammonia.

Figure 2: **Effect of Ammonia on Absolute Mercury Speciation**



In addition to the deNOx reaction itself, the ammonia profile within the SCR reactor is affected by a number of factors. These include unit load, burner configuration, mills in service, catalyst and/or AIG plugging, flue gas conditions (temperature, etc.) and distributions, and the operational deNOx set point. These will in turn all affect mercury oxidation. These factors are inherently linked to catalyst management and should be considered under any scenario which seeks to maximize mercury oxidation. ***In short, the reactor should be operated optimally to insure that the level of ammonia is minimized throughout the reactor, and in turn the mercury oxidation is maximized.***

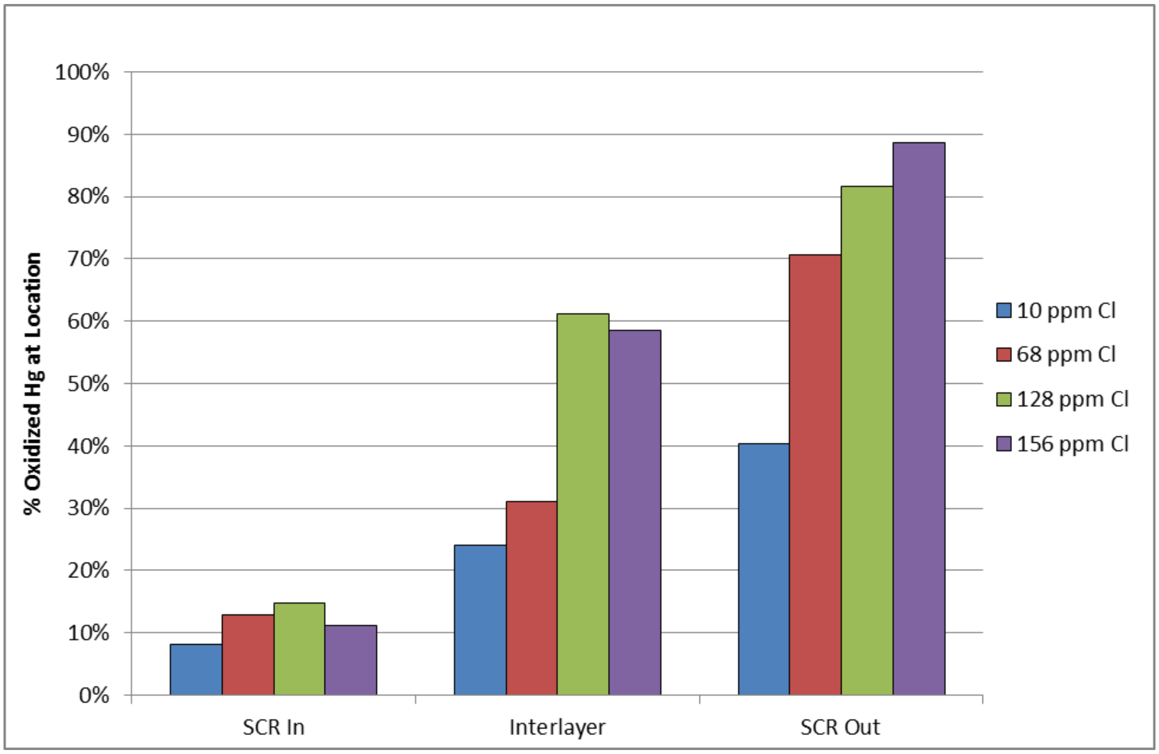
Effect of Halogens

Flue gas halogen levels are of course known to strongly affect mercury oxidation with respect to SCR catalysts. This phenomenon will affect how catalyst management should be conducted for a particular facility. Specifically, two general halogen effects must be considered with respect to catalyst management; 1) how the halogen concentration impacts the overall level of mercury oxidation, 2) how the halogen level affects the relative contribution of the various catalyst layers with respect to mercury oxidation.

Figure 3 shows the percent oxidized mercury at the SCR inlet, interlayer, and outlet for a single honeycomb catalyst using MRC data. The particular reactor design had three catalyst layers, with the interlayer tests performed after the second layer of catalyst. The presented data were all taken at design conditions (design flow rate, 90% deNOx, and 700 °F).

The data show that on an absolute speciation basis, the first two layers do contribute to the overall level of mercury oxidation, but considering that the interlayer includes the effects of 2 layers, then it is clear that there is a suppression of oxidation where the ammonia is higher (as discussed previously). This appears to be especially true for the moderate chlorine data (68 ppmv), where the level of oxidized mercury improves markedly between the interlayer and the outlet locations. At high levels of chlorine (≥128 ppmv) the large amount of chlorine appears to overcome to some degree the adverse effect of ammonia – this can be seen on the interlayer data where the 128 and 156 ppmv chlorine data show a rather dramatic increase over the lower chlorine conditions. In this case, about 70% of the overall level of oxidation is accomplished by the first two layers. This gives the impression that each layer is contributing about the same to the overall level of oxidation, at least in terms of absolute numbers. However, this impression can be seen as somewhat skewed if the available elemental mercury is considered. In that case, considering only the oxidation of available mercury, it is clear that the lower layers of catalyst are much more active for mercury oxidation. Note that at the very low chlorine condition (10 ppmv), oxidation is suppressed throughout the system, in keeping with industry experience with halogen-deficient coals, such as PRB, low-chlorine eastern bituminous, and South American coals.

Figure 3: Mercury Oxidation at SCR Outlet vs. Chlorine – Pilot Data



As the above discussions make clear, halogens influence the mercury oxidation reaction kinetics. This in turn influences how best to manage catalyst to maximize mercury oxidation. Further, the optimum management strategy may differ depending on the halogen environment. For example, facilities operating with very high halogen levels may not be as sensitive to catalyst characteristics as facilities operating with lower levels of halogens, and as a result may not require as aggressive catalyst management activities to maintain the required level of mercury oxidation. Further, the data imply that due to the ammonia suppression effect, especially under halogen-limited conditions, that the activity of the final layer of catalyst may have a disproportionately large effect on the mercury oxidation for the reactor as a whole. Overall, interlayer data helps considerably to understand how catalyst should be managed to optimize mercury oxidation. In turn, this type of data also helps to understand the implications of halogen level on the appropriate management strategy.

CATALYST MANAGEMENT STRATEGIES

Based on the bulk of the data currently available, two catalyst management strategies for mercury control were developed. These strategies are general in nature, however, such that the actual catalyst management plan for any particular facility would need to be tailored to meet certain specific characteristics of the facility. The two management strategies differ mainly in the degree of aggressiveness with which they approach maximizing SCR mercury oxidation. Catalyst management Strategy A is the more aggressive approach that would generally be applied to facilities that have a high demand on mercury oxidation through the SCR. In other words, these facilities would rely heavily on SCR oxidation for mercury control and must maintain the highest SCR oxidation rate reasonably possible. Strategy B is a less stringent approach and would generally be applied to facilities normally having relatively high levels of native halogens, and in general are able to achieve the required mercury removal levels under most operating conditions. Generally these facilities would seek to maintain mercury oxidation consistently, and with some level of margin, through catalyst management. Each of these strategies is discussed in detail below.

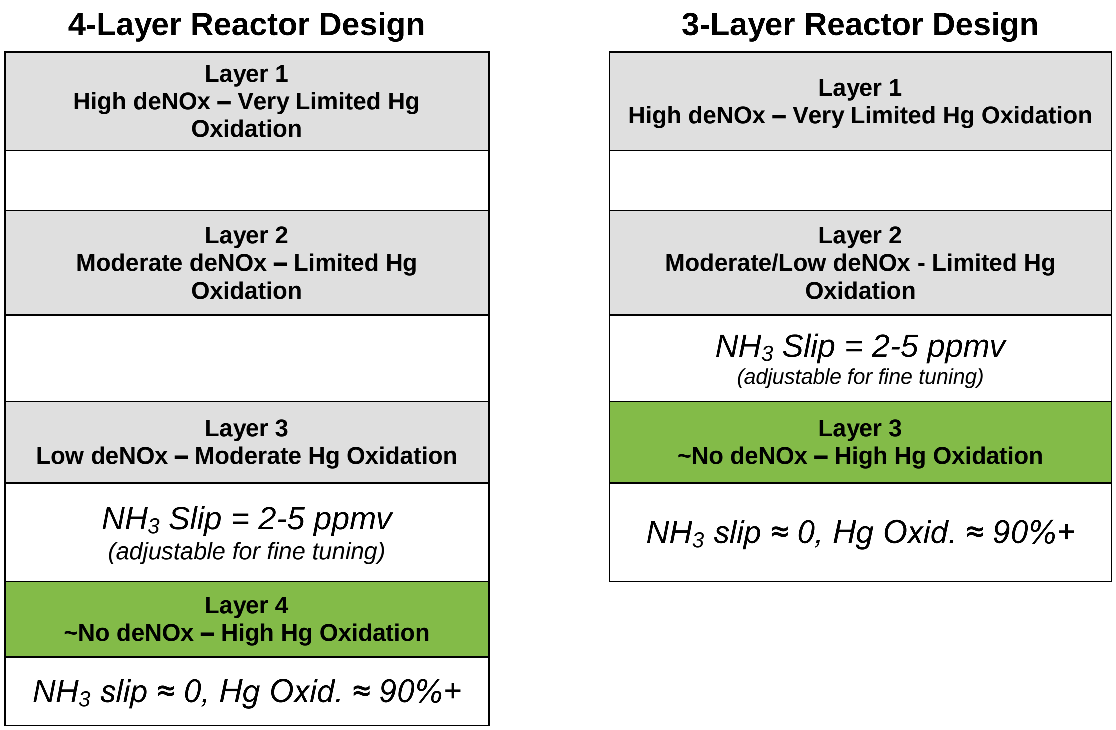
Strategy A

Strategy A, being the more aggressive strategy, generally applies to facilities for which mercury capture is marginal, and as a result rather aggressive strategies are in order to minimize mercury emissions. This results in a high demand on the catalyst for mercury oxidation. Often these facilities are halogen-limited, and in a halogen-limited environment, mercury oxidation by the catalyst is heavily influenced by ammonia concentrations, with the bulk of the oxidation occurring across the last catalyst layer where ammonia is presumably very low. These facilities may employ halogen injection to enhance mercury oxidation. In this case, the catalyst management strategy would be implemented in tandem with halogen injection to help maximize mercury oxidation while minimizing the halogen injection rate (helping to alleviate reagent usage as well as adverse balance-of-plant effects). Under strategy A, the last layer of catalyst would be managed principally as a mercury oxidation catalyst, where the ammonia levels would be very low (generally <5 ppmv at the inlet). As a result, the contribution to deNOx by this layer would be minimal. This strategy would therefore require that the upper layers of catalyst be managed to achieve the required levels of deNOx, with an ammonia slip exiting these layers of typically under 5 ppmv. This slip limit, however, could be adjusted according to the level of aggressiveness required (i.e. fine-tuned for the application). For instance, in a very aggressive approach, the upper layers of catalyst would be managed as if no additional catalyst were present, usually resulting in an ammonia slip limit of <2 ppmv at the exit of these layers. This would result in very low ammonia entering the final catalyst layer, which would then perform much of the mercury oxidation. For a 3+1 reactor configuration, the scenario would manage the first three catalyst layers as the deNOx portion of the reactor, without regard to the presence of a fourth catalyst layer, while the fourth layer operated as a mercury oxidation catalyst only, contributing very little to the overall deNOx. Similarly, in a 2+1 arrangement, the first 2 layers of catalyst would be used for deNOx, while the third would be used primarily for mercury oxidation. If the same slip requirements were used at the inlet to the last catalyst layer, a 3-layer reactor design would generally represent a more difficult and aggressive management approach than a 4-layer design, since for the 3-layer design, 33% of the total available catalyst would be used for mercury oxidation and thus unavailable for deNOx, while in a 4-layer design, only 25% of the catalyst would be removed from deNOx service. In any event, the allowable ammonia level at the inlet to the final mercury oxidation catalyst layer could be fine-tuned to the application. As a result, it is likely that for a 3-layer design, the allowable slip entering the final layer would be somewhat higher than with a 4-layer design.

Figure 4 shows Strategy A in a graphical manner, where the relative contribution to deNOx or mercury oxidation is shown. Clearly, the upper layers perform the majority of the deNOx, but exhibit limited mercury oxidation, while the lower layers contribute more to mercury oxidation, but contribute proportionately less to the deNOx. The final catalyst layer in both cases operates at very low slip/inlet ammonia and therefore has a negligible contribution to deNOx, but a very high contribution to mercury oxidation. As a result, these final layers act principally as mercury oxidation catalysts. As mentioned, the catalyst management strategy can be tailored according to the application by adjusting the allowable ammonia entering the last catalyst layer. The most aggressive approach would be to limit the slip entering the last catalyst layer to 2 ppmv, basically the normal slip limit for a commercial SCR. In a slightly less stringent approach, the slip entering the last layer could be allowed to increase marginally above 2 ppmv. However, much higher levels of slip would adversely impact mercury oxidation. It is also important to remember that many factors in addition to the catalyst affect the ammonia profile within the reactor, so the reactor should be operated in an optimal manner in terms of cleanliness, inlet distributions, etc. The presence of a relatively high overall reactor potential should not be allowed to reduce the focus on good system optimization. ***In short, the SCR as a whole must be operated as if the final layer of catalyst were not available for deNOx purposes.***

Other fine-tuning options (in addition to varying the allowable ammonia entering the final layer) include the halogen injection level (if equipped), and the frequency of replacement of the final catalyst layer (essentially the minimum activity that is maintained for this layer). These various fine-tuning parameters give considerable flexibility to the catalyst management strategy, and allow the aggressiveness of the overall approach to be tailored to the application. In addition, there would be the option of using advanced catalyst in place of conventional catalyst. At present, it is unclear what differential improvement in mercury oxidation could be realized from the use of advanced catalyst. And, while advanced catalyst would likely be most appropriate for the final catalyst layer, it is conceivable that advanced catalyst could be utilized throughout the reactor for maximum mercury oxidation.

Figure 4: Strategy A – Catalyst Layout and Reaction Participation



In terms of detailed catalyst management activities related to the replacement of various catalyst layers, the final catalyst layer must be managed completely separately from the above layers.[3] In essence the upper catalyst layers are managed as the deNOx portion of the reactor, while the final catalyst layer is managed as the mercury oxidation portion of the reactor. Figure 5 shows the catalyst management strategy graphically in the typical manner. However, there are two activity/potential profiles. The upper potential profile represents the upper deNOx portion of the reactor where catalyst layer replacements result in a step change in potential, followed by a period of gradual deactivation. Accompanying this profile is the slip profile, shown at the top, essentially showing a slip response opposite of the activity. The minimum activity is set such that a maximum slip

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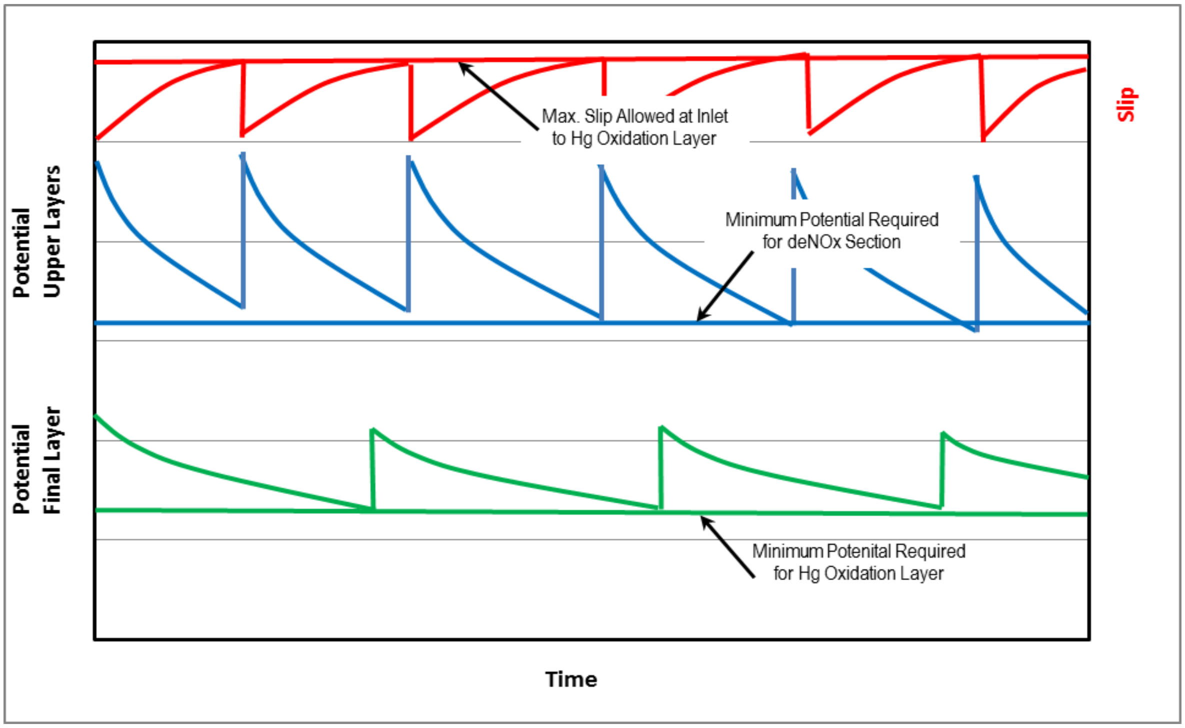
[3] Other than possibly taking advantage of logistics, etc. associated with combining work on the final catalyst layer with work on above layers. For instance, if the catalyst management plan for the deNOx portion of the reactor called for a layer replacement, and a required final-layer replacement was near, both might be replaced at the same time.

is not exceeded. Note that this slip value is the slip entering the final layer of catalyst, rather than exiting the final layer of catalyst as would normally be the case. The second potential profile (shown at the bottom of the plot) shows the potential of the final catalyst layer, which is managed for mercury oxidation.

In the generalized scenario as shown, catalyst management events on the upper deNOx portion of the reactor occur more frequently than is the case for the final layer (accomplishing primarily the mercury oxidization). This may not necessarily be the case, since the required frequently of replacement of the final catalyst layer is unclear at present (the exact deactivation rate for this catalyst position is site and catalyst specific). The replacement frequency of this layer will also depend on the required aggressiveness of the specific management scenario, and therefore may vary greatly in practice. In any event, it is clear than under catalyst management Strategy A, two distinct and relatively independent catalyst management efforts will be in place; one for the deNOx portion of the reactor, and one for the mercury oxidation portion of the rector (the final layer). Also note that certain "pinch-points" may be present for the combination of the two management efforts. These occur when both the catalyst potential for deNOx (the upper portion of the reactor), and the catalyst potential for mercury oxidation (the final catalyst layer) are both near their end of life. This results in a case where the ammonia level is at its maximum entering the final catalyst layer, and the oxidation potential across the final layer is at a minimum. One of these pinch-points is represented in the figure as the first management event for the final layer of catalyst, which roughly coincides with the second management event for the upper portion of the reactor. In practice, it may be desirable to manage the two sections of the reactor in such a way as to avoid these pinch-points.

Figure 5: Strategy A – Generalized Long-Term Catalyst Management Profile



Strategy B

Catalyst management Strategy B is a more straightforward strategy, and is a less aggressive strategy as compared to Strategy A. This strategy generally applies to facilities which have reasonably high levels of mercury oxidation, and low emissions levels. As a result, the oxidation demand on the SCR is not as high as would be the case for facilities utilizing Strategy A. Often facilities using Strategy B would have high native halogen levels that allow the catalyst to achieve mercury oxidation more easily under higher ammonia conditions, and as a result this relaxes to some degree the demands on the catalyst.[4] Under this strategy, the entire reactor is managed as a whole, but it is managed in such a way as to insure that there is enough catalyst operating in a low ammonia environment to accomplish the necessary level of mercury oxidation. In a sense the strategy relies on the concept of "excess potential" which would be defined as additional deNOx potential over and above that necessary required to provide the required deNOx for the facility within the prescribed slip limits. For instance, in this strategy a facility may require a minimum reactor potential of 5.0 to maintain its deNOx and ammonia slip specifications, but it may be determined that an additional potential of 1.0 (the excess potential) is needed, giving an overall minimum required potential of 6.0. This insures that a sufficient portion of catalyst is operating at low ammonia slip (presumably less than 2 ppmv for most facilities) to accomplish the necessary mercury oxidation. The real need for this additional potential only manifests near the catalyst end of life, just prior to a catalyst management event. Note that the principal fine-tuning parameter for this catalyst strategy is the amount of excess potential that is deemed necessary for the particular application.

The scenario does not make a distinction as to the required potential of any particular catalyst layer, thus the reactor potential as a whole is managed. Note that currently there is not enough data to estimate the advantages of using advanced catalysts as opposed to conventional catalysts, especially as a function of location. However, it is assumed that advanced catalysts would be at least as good as conventional in all reactor locations, and it is reasonable to assume that they may provide some incremental improvement over conventional catalysts. This incremental improvement may differ according to the layer in which the advanced catalyst is present – for instance it may have more impact on the final layer than on the first, but this information is not known currently. Similarly, the relative effects of exchanging an initial layer of catalyst with fresh conventional catalyst, as compared to the exchange of the final layer are not known. This shortfall in information supports the approach of managing the reactor as a whole without distinction as to layer. Future findings, however, may shed light on the issue, and refinements to the management strategy could conceivably be made which differentiated the use of advanced catalyst as opposed to conventional catalyst, as well as the management of the catalyst on a layer-by-layer basis.

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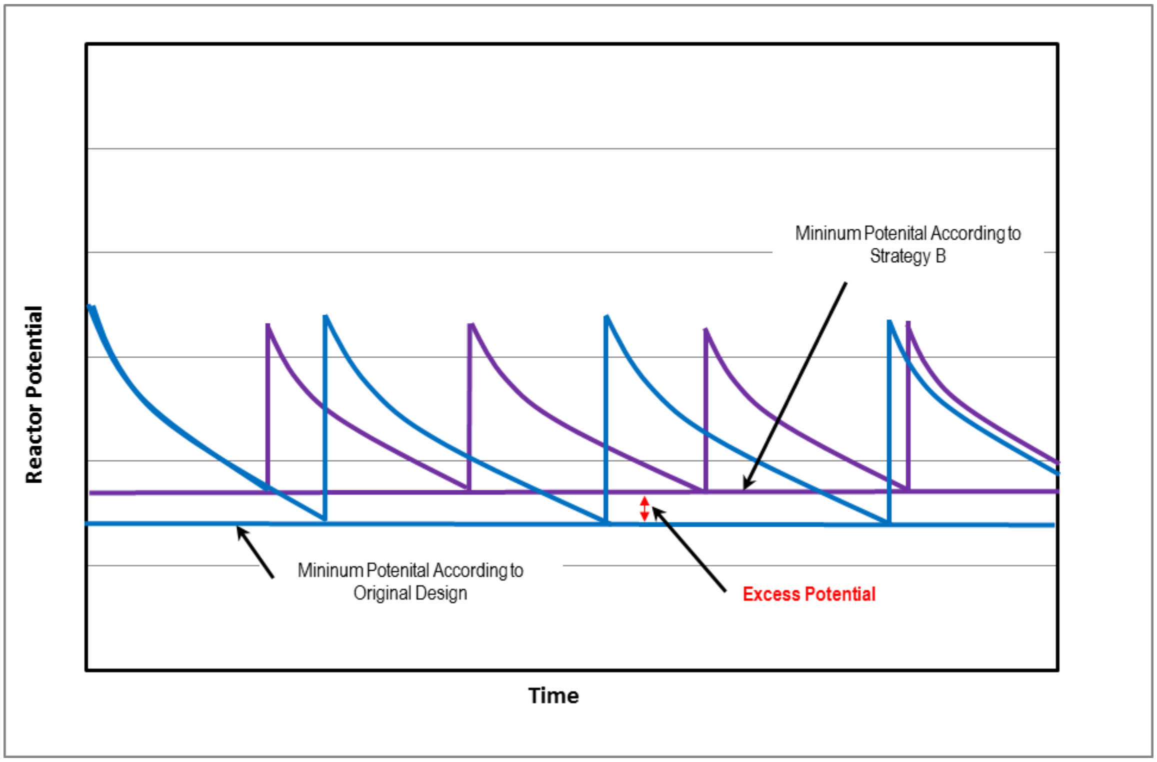
[4] Of course it is conceivable that facilities using halogen injection would opt for this less-aggressive strategy, assuming that the required levels of mercury oxidation are relatively easily met without concerns over the level of halogens injected or balance-of-plant effects.

Figure shows Strategy B graphically. Also included is an example “normal” catalyst management scenario for comparison purposes. Without the need for optimization for mercury control, the allowable minimum reactor potential is lower than is the case for Strategy B. The difference in the two potentials is the excess potential which is maintained for mercury control. The strategy results in an accelerated catalyst management scenario, where catalyst layer replacements are required more frequently to maintain a higher average overall reactor potential over the long-term. Note that additional potential may be introduced by using tighter pitch catalyst, or deeper catalyst layers, so although an accelerated replacement schedule is shown in this example, other ways of increasing the reactor potential may be available.

The strategy results in lower ammonia slip exiting the reactor, on average, than would be the case under the usual management scenario. Unless the excess potential is equivalent to a full catalyst layer, the actual specified maximum slip for the facility will be reached somewhere within the last catalyst layer. As a result, it would not be possible to measure slip directly to determine if the management strategy is actually on target in terms of slip, as could be done with Strategy A.

It is illustrative to note that in some sense Strategy A could be seen as a very aggressive version of Strategy B, where the excess potential is equivalent to an entire catalyst layer, and that excess potential is represented by advanced catalyst. The two strategies do differ fundamentally, however, in that in Strategy A the final layer of catalyst is managed completely separately from the upper layers.

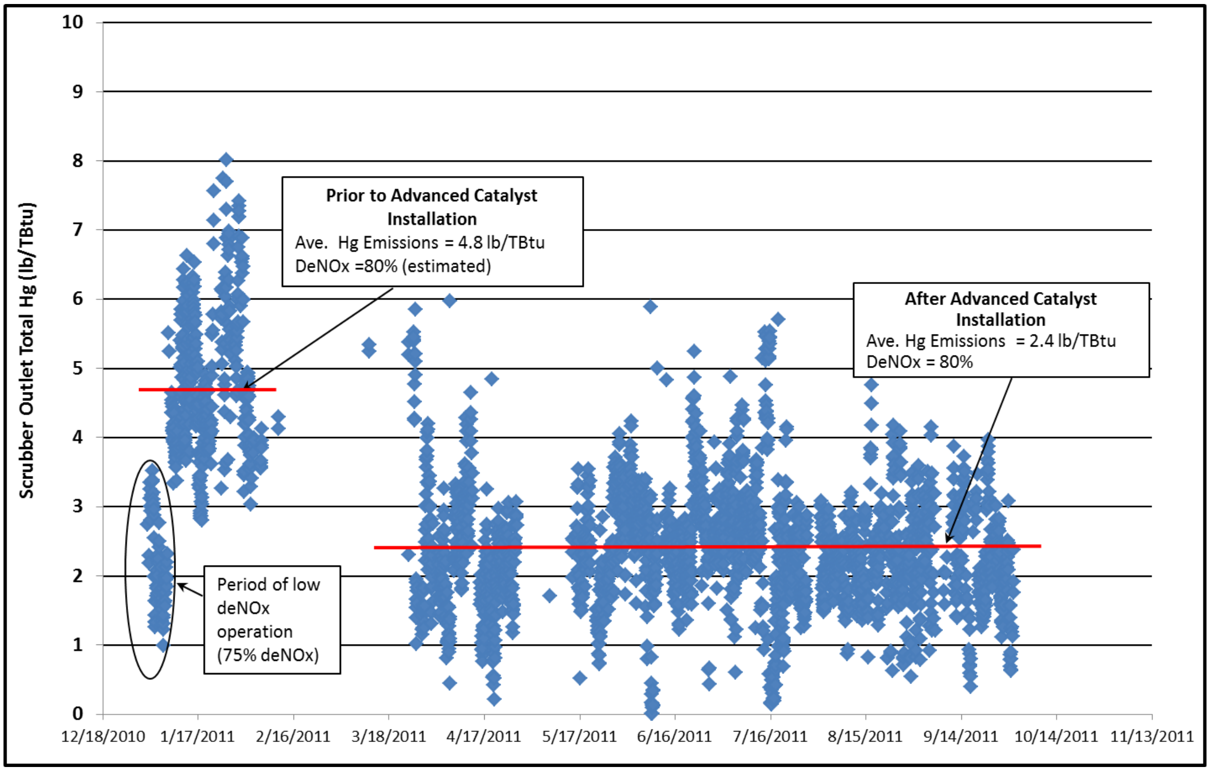
Figure 6: Strategy B – Generalized Long-Term Catalyst Management Profile



Field Data- Catalyst Management Emissions Effect

There are only limited industry field data which help to show the effect of catalyst management activities on SCR mercury oxidation, and most importantly on the resulting mercury emissions. In addition, there are virtually no data showing the long-term effects of the implementation of any particular catalyst management strategy for mercury control as compared to conventional management strategies. Certain very specific sets of data, however, do show the effects of certain catalyst management events on mercury oxidation or emissions. This information can be used to imply what results might be obtained by various catalyst management scenarios. Figure 7 shows one such example for a large commercial PRB-fired unit equipped with a cold-side ESP and wet scrubber. The example shows the effect of adding a fourth layer of advanced catalyst to the existing three layers of conventional catalyst. The effect on emissions at the scrubber outlet is shown (limited to full-load data).

Figure 7: Example - Continuous Mercury Emissions Data with Catalyst Addition



Prior to Advanced Catalyst Installation
Ave. Hg Emissions = 4.8 lb/TBtu
DeNOx =80% (estimated)

After Advanced Catalyst Installation
Ave. Hg Emissions = 2.4 lb/TBtu
DeNOx = 80%

Period of low deNOx operation (75% deNOx)

The data show a period of low deNOx operation (75%) near the end of 2010, in which the emissions rate for the unit was considerably lower than after that date, when the deNOx level was raised to the normal 80% (roughly). This demonstrates the sensitivity of mercury emissions to deNOx for this unit. The period of operation from roughly January 1, 2011, to February 15, 2011, represents the baseline emissions data prior to the addition of the advanced catalyst layer in the fourth layer of the reactor. The data show an emissions rate of about 4.8 lb/TBtu. For the period after the advanced catalyst installation (beginning in mid-March), the mercury emissions are reduced substantially, to roughly half that of the prior period of operation without the advanced catalyst. This period of operation showed average emissions of 2.4 lb/TBtu, which equates to roughly 60% mercury removal. Overall, the data show the clear beneficial effect on emissions as a result of the catalyst addition. It is unclear, however, how much of the benefit is due to the utilization of advanced catalyst as opposed to what would have occurred had conventional catalyst been used. In other words, simply adding catalyst potential would be expected to produce some positive effect, so the actual benefit of using advanced catalyst as opposed to conventional catalyst cannot be quantified with this data.

SUMMARY

SCR catalyst mercury oxidation is a function of a number of factors, many of which have implications for catalyst management scenarios that seek to maximize mercury oxidation. Based on these factors, and several governing assumptions, two general mercury control strategies were developed as summarized in Table 1. Strategy A generally applies to facilities which must aggressively maximize mercury oxidation through the SCR. Often these facilities have low or moderate halogen levels and may utilize supplemental halogen injection. Strategy B is less aggressive and generally applies to facilities which seek to marginally improve or simply maintain their normal relatively high levels of mercury oxidation. This strategy would often be associated with facilities which fire high-halogen fuels. It is important to note that although facilities not requiring halogen injection may often use Strategy B, there may be specific facilities in this category where the current level of mercury capture is so low, or the perceived need for additional capture margin so high, that Strategy A is selected. Conversely, there may be cases where halogen injection is maintained at a very high level, or where catalyst management according to Strategy A is precluded, such that Strategy B is more appropriate. Thus, the particular strategy utilized for any particular facility should not immediately be assumed based on the native level of halogens, or if halogen injection will be utilized. Ultimately, the catalyst management scenario for any particular facility, and the fine-tuning options associated with that scenario, will be selected based on the perceived mercury oxidation demand for the SCR, with many factors influencing that perceived demand.

The more aggressive, high demand, approach of Strategy A requires that the final catalyst layer be managed separately from the upper layers, with the final layer operating as a mercury oxidation catalyst under very low ammonia conditions, and the upper layers operated as the deNOx portion of the reactor. The allowable slip entering the final catalyst layer, and the allowable deactivation of the final catalyst layer, are fine-tuning parameters that can be tailored to the specific unit. In addition, halogen injection can be fine-tuned in tandem with the implementation of a detailed catalyst management plan to achieve a least-cost optimal approach. Advanced catalyst is likely to be used at least in the final layer of catalyst.

Strategy B, being the less aggressive (low demand) approach, helps provides additional margin to the mercury oxidation rate to insure long-term adequate mercury removal, and to help account for operational excursions and adverse fuel conditions. The strategy treats the reactor as a single entity with excess capacity being utilized to insure the required level of mercury oxidation. The strategy can be fine-tuned by selecting the amount of excess capacity that is required, and by adjusting the halogen injection rate if this strategy is applied to units so equipped. Note that currently this scenario, as presented, does not make any layer-by-layer distinction in the catalyst management, but refinements could include a more detailed approach in terms of the differences in mercury oxidation that might occur between a first layer catalyst exchange and a final layer catalyst exchange, for instance. Additional refinements are also likely to include the comparative effects of using advanced catalyst as opposed to conventional catalyst in various reactor locations.

Table 1: Summary of Catalyst Management Strategies

Strategy	**A**	**B**
Aggressiveness	High	Moderate
General Application	Facilities that have very limited mercury oxidation under normal operation	Facilities that routinely achieve, or nearly achieve, the required mercury removal under normal operation
Halogen Level	Often low native halogen coals (PRB and domestic/foreign low-chlorine coals), with halogen supplementation required/other facilities for which demand for SCR mercury oxidation is high	Usually moderate to high-halogen coals where no halogen supplementation is required/ other facilities for which demand for SCR mercury oxidation is low or moderate
Approach	Manage final catalyst layer as a mercury oxidation catalyst with very low ammonia – upper catalyst layers managed for deNOx	Manage entire reactor as a whole using excess reactor potential to insure adequate mercury oxidation
Variables (fine tuning parameters)	1) Allowable slip entering the final catalyst layer 2) Allowable deactivation of final layer prior to replacement 3) Halogen injection rate, if utilized	1) Amount of excess potential required to meet the desired margin in mercury removal 2) Halogen injection rate, if utilized *Note: Future refinements may include the use and relative placement of advanced catalyst as a fine-tuning parameter*