CLEAN AS A WHISTLE

Steve Houghton, Groome Industrial Service Group, USA, looks at the benefits of online selective catalytic reduction catalyst cleaning.

The advantages of a clean selective catalytic reduction (SCR) catalyst are multifaceted. Since the conversion of nitrogen oxide (NO_X) is not driven by the catalyst alone, but by a tuned balance between the SCR and ammonia injection grid (AIG), there are many variables to consider when troubleshooting an issue of any magnitude.

The primary factors to consider when pushing for peak performance are: backpressure (dP), NO_X conversion, and ammonia slip.

dP

The effect of a dirty catalyst differs between systems with either catalyst in a production process stream, or in a power generation exhaust gas path such as a cogeneration unit, although both have a negative impact. It is very common in both old and new units to have a liner plate come loose. When this happens upstream of the catalyst bed, the insulation fibres will mask the face of the catalyst. Enough masking will cause increased restriction of the gas path flow, resulting in unfavourable backpressure. The backpressure results in reduced revenue opportunities in a production gas path application as well as reduced megawatt output in a power generation application.

NO_X conversion

A catalyst can be fouled in many ways. Many times an upset causes refractory to liberate, causing debris to migrate downstream and deposit both on the face of the catalyst and throughout the depth of the catalyst itself. It is important to note that an inch of space inside of a SCR catalyst has the surface area of an American football field. The unseen 'blockage' of vanadium conversion sites will temporarily deactivate the catalyst where these sites do not see flow from the gas path.

Ammonia slip

Proper NO_X conversion is driven by precise ammonia distribution through the catalyst. This is hindered when the gas path is restricted for ammonia, and the ammonia takes the path of least resistance to the nearest unmasked area. In these hot spots, unreacted ammonia will pass through the catalyst. Excess ammonia passing through any fin tubes can result in ammonia salt deposits, or simply emit out the stack. This process has negative effects on other systems such as the fin tube heat exchange rate and backpressure implications, as well as ammonia permitting which varies in different areas.

With this trio of factors considered, it is hard to argue that a dirty or mismanaged SCR catalyst is acceptable at any plant.

The largest obstacle is timing. Sometimes it is necessary to clean a catalyst, but there may be years remaining until planned work and the operator may not be able to afford to stop production just to clean. Online cleaning is a proven way to get this done, but it is crucial to consider certain variables.

Disadvantages of traditional offline cleaning

The traditional approach to cleaning is effective and proven. Yet there is one enormous downside: production efforts are greatly and inevitably hampered by the fact that the unit needs to be off and cooled for access.

The best-case scenario when shutting down is that the unit cools in half a shift, a crew gains access to clean in two day/night shifts, and so the unit is down for a total of two days. However, the actual impact on production is likely to be greater than that time indicates.

Determining the issue

While a picture is worth a thousand words, it does not always give the whole story. That said, it is important to understand what is causing the issue prior to cleaning. A popular first step in the diagnosis process is to utilise a high temperature camera and lance set up. While this method is effective, it is also limited.

As long as the clarity of the image provided is acceptable, one can determine what the surface level contaminant is and, just as importantly, how much masking has occurred. But this image capture is the extent of the camera's benefit.

Depending on port access and location along with catalyst size and camera lance length, it is common that a camera cannot access 100% of the catalyst bed. The images will serve to provide a quality sample population of image data to consider. While this is completely acceptable, it is worth noting that one should not expect any additional information from the camera and should prepare to move onto another method to determine the root cause.

In the event of an upset where the catalyst has seen masking or fouling, an image alone cannot determine where the catalyst is performing (or not performing). It is noteworthy to point out that a camera is also limited to taking images of the surface only. Any refractory dust in the catalyst cross-section cannot be viewed. Another tool or system that plants utilise to augment SCR performance is a permanent sampling grid (PSG).

This system is a network of stainless steel tubing installed on the downstream side of a SCR catalyst. Each run of tubes has a port that coordinates with a manifold on the outside of the unit. This gives a plant the ability to zone its catalyst and determine which areas are getting too much ammonia, as well as which areas are not getting enough. Most routinely, this system is used to tune the AIG and enable equal distribution across the SCR for optimised NO_X conversion. With a PSG installed, a plant can both tune optimally and diagnose what sections of the catalyst have potentially blocked conversion sites. Since the catalyst can be both masked on the face or fouled within the channels, the data gained from a PSG helps to provide more targeted data.

Last, and perhaps most important, is dP. Many plants have data but do not use it optimally. If one has the minute or hourly-average run data logged from a continuous emission monitoring system (CEMS), it is possible to plot the data points, which a plant can then examine to determine if other factors or plant processes may be involved.

Important variables to know

Every unit has unique design features and running parameters, and understanding these variables is key to designing a proper cleaning plan.

First, knowing the catalyst original equipment manufacturer (OEM) is beneficial. There are a few different types of SCR construction. In addition to the catalyst itself, these manufacturers' system designs vary and are prone to collect contaminants in different areas. Upfront knowledge enables a contractor to clean quickly and more effectively.

Second, catalyst bed dimensions are an important factor to understand.

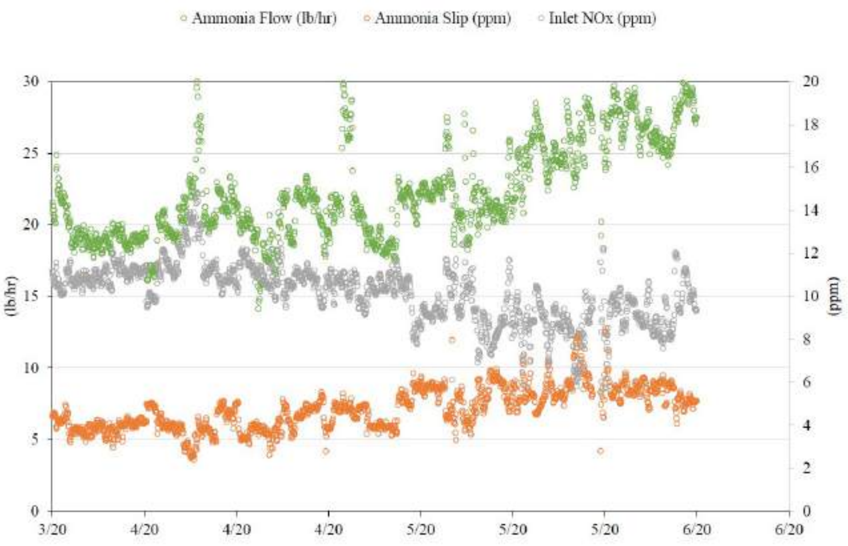

Figure 1. Relation of increased ammonia flow to ammonia slip.

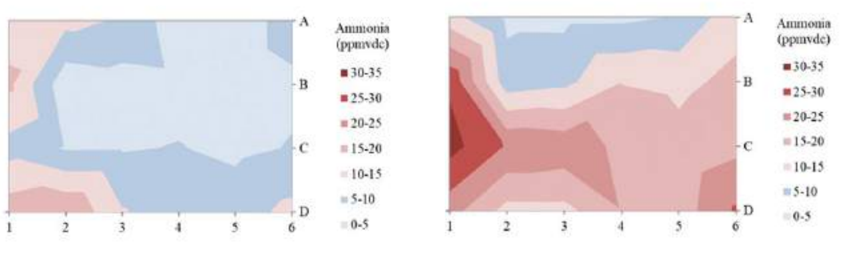

Figure 2. Mapping of AIG flow and slip. If it is known that ammonia flow is balanced and there are slip hot spots, there may be a blockage.

Width and height are needed to determine necessary lance and hose length. An oft-overlooked factor is catalyst depth. Cleaning design for vacuum pull and equipment needed must be carefully considered to maximise the vacuum while protecting the integrity of the catalyst itself.

Third, flue gas temperature is a required data point to factor in necessary safety protocols for escaping flue gas as well as transferred heat to cleaning equipment. Standard gas path temperatures range from 500˚F to 800˚F. Flue gas flow rate and pressure at the SCR must also be understood to design proper vacuum pressure.

And finally, there are multiple access factors to contemplate including: catalyst orientation (vertical or horizontal), top or side access, port sizes, number of ports, port orientation, and port distance to the catalyst face. Understanding this last set of factors will assist in designing a system to access the highest percentage of a catalyst for optimal system performance.

Additional points related to crew safety specifically include: planned operator change-out, gas monitors, high temperature personal protective equipment (PPE), heat reflective PPE, tie-off access, number of tie-offs, tool lanyards, and more.

Revenue opportunities

There are really only three options that a plant has when it is forced to run at reduced capacity due to SCR catalyst issues, with years left until the next turnaround. And the level of risk varies.

A plant's first option is to run at 50% capacity until the next turnaround and assume that 50% capacity is the maximum before permit levels are exceeded. The upside here is that no expenditures are made, while the obvious (and costly) downside is that revenue will also run at 50% until the issue is fixed. There is an imminent breakeven here that will depend on variables such as time, capacity, permit levels, and revenue.

The second option frequently explored is to complete a traditional or offline cleaning. This requires plant shutdown of all production equipment in line with the emissions system, with additional time needed to allow the unit to cool down enough for access. Assuming a cleaning can be completed in two shifts (this depends on unit size and access), the plant has lost production capability and any associated revenue for three days or more.

If these two scenarios are not acceptable, a plant does have the option to clean online while the unit is running. In this case, revenue can still be realised while a crew removes contaminants from the catalyst so that the plant can run back within permit levels or at an acceptable dP level. The return on this is also dependent on many variables at the plant. For argument's sake, return on investment (ROI) is often realised between 30 and 60 days, but sometimes in as little as 5 – 10 days. If the next turnaround is any further than 60 days out, online cleaning is sensible in most cases.

Determining effectiveness

It is commonplace for a plant to rely on images to determine the effectiveness of a cleaning. Additionally, sometimes a review of the contents of the vacuum system is requested. These tests are merely evidence that some work was done, and are not an indicator that the intended result was accomplished. A camera, for example, can illustrate what was removed from a sample section of the catalyst face, but it is impossible to determine how much of the fouling within the catalyst channels was cleaned based on camera images. A plant needs concrete evidence to support the ROI of a project to determine whether or not the unit can perform to expectations.

When calculating key performance indicators (KPIs), it is essential to provide a contractor with run data and a goal of what required conversion, slip, or dP improvement is. The length of time it will take to receive measurable results will depend on the systems that a plant has to measure these KPIs. It is preferable to select a KPI that a plant can report on quickly so the proper number of shifts can be allocated to a cleaning crew. This is a win-win for the plant, since one can determine the goal has been accomplished and no additional or unnecessary expenses were incurred from the cleaning contractor.

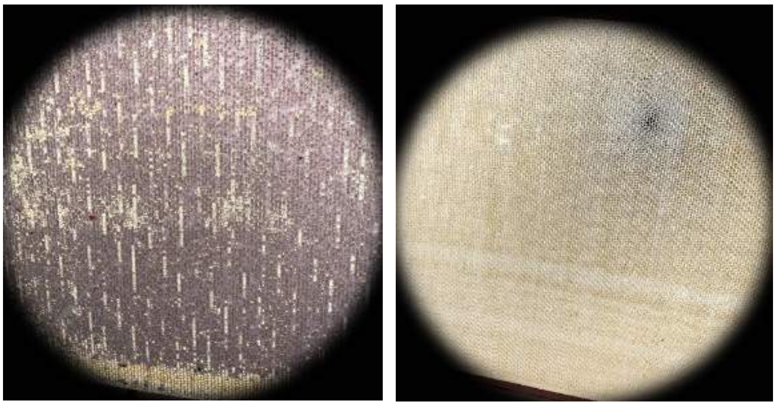

Figure 3. Before (left) and after (right) online cleaning.

Case study: online cleaning delivering a ROI

Groome Industrial recently completed the cleaning of a SCR at an ethylene plant within the US.

Cleaning of the SCR took place online, so the refinery experienced no downtime. Nearly 50% of the catalyst was dirty, and in these conditions the plant was generating US$300 000 in daily revenue. Once the thorough online cleaning was completed, the plant increased its daily revenue by 90% to almost US$570 000. The plant realised a positive ROI on this project within just nine days. After the cleaning, the plant was able to run well within both its ammonia slip and NO_x permit, due to even ammonia distribution through the catalyst.

Conclusion

Catalyst protection is the most important factor when selecting a cleaning method. It can be tempting to ask a contractor to clean at any cost when poor SCR performance is resulting in poor plant performance, but it is essential that a contractor uses the right tools as well as a well thought-out cleaning design for each project.