SCR Retrofit

Improving Performance

Presented by:
Dale K. Purdy
Business Development

Turner EnviroLogic
1140 SW 34th Avenue
Deerfield Beach, FL 33442

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Khalil M. Nasser
Sales and Marketing Manager
Anticipated catalyst replacement projects provide an opportune time to assess the performance of existing SCR units. A careful review of SCR system design should be made when the time comes to replace the catalyst especially if the catalyst is deactivating earlier than expected. In many cases premature catalyst failure is actually caused by poor design of the SCR system itself, which can be masked initially due to the fact that new catalysts normally outperform their guarantee for a period of time as they go through a “break in” stage. Effective SCR operation requires very uniform distribution of airflow and ammonia for optimal performance. Improvements can be made to both the airflow patterns and the ammonia distribution within existing SCR units that will reduce the pressure drop, improve the reduction efficiencies, reduce ammonia consumption and increase the future catalyst life. These upgrades can save money and reduce downtime.

**Burbank Water and Power’s Lake One Power Plant Improvement**

Burbank Water and Powers’ Lake One power plant began operation on July 18, 2002. Lake One is a 47-megawatt power plant located on the grounds of Burbank Water and Power. Lake One was built to help meet the City’s summer power demand. It replaces existing power plants that are as old as 25 years.

The Lake One facility uses a General Electric LM-6000 PC Sprint running on natural gas. Air emissions were originally treated with a Selective Catalytic Reduction (SCR) system supplied by Hamon Research-Cottrell using CO and NOx catalysts supplied by Englehard. Operating parameters for the system are shown in the chart below.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exhaust Temperature</td>
<td>880 F</td>
</tr>
<tr>
<td>Exhaust Flow</td>
<td>1,062,468 lb/hr (236,104 SFCM)</td>
</tr>
<tr>
<td>CO Emissions</td>
<td>50 ppm</td>
</tr>
<tr>
<td>NOx Emissions</td>
<td>35 ppm</td>
</tr>
<tr>
<td>Pressure Drop Across SCR</td>
<td>1.8 IWC</td>
</tr>
<tr>
<td>Pressure Drop Across CO catalyst</td>
<td>1.2 IWC</td>
</tr>
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</table>

**Phase I – CO Catalyst Replacement**

Very shortly after commissioning of the equipment it became apparent that Lake One was going to have difficulty meeting their permitted emissions limits, though the limits were initially achieved. The CO and NOx catalyst appeared to be degrading prematurely and was exhibiting very uneven air and ammonia distribution across the faces of the respective catalysts. This uneven flow distribution resulted in certain areas of the catalyst being over worked due to high space velocities that caused the catalyst to degrade prematurely. The uneven ammonia distribution required increasing total ammonia flow above original design in order to provide sufficient ammonia to the overloaded sections of the catalyst, which then produces excess ammonia slip rate (unreacted ammonia). As a result the facility was struggling to maintain permitted slip levels, and was using excessive quantities of ammonia, raising operating costs.
A review of the original design confirmed that the perforated plate sections provided for flow redistribution were inadequate. Contributing to the problems was a severe 68 degree angle in the transition from the turbine exhaust to the CO catalyst face. The photo below shows the SCR at Burbank Water and Power.

Since CO emissions seemed to be the most critical to maintaining permit compliance, Burbank Water and Power decided, after only one season in operation, to solicit bids to replace the CO catalyst as a first phase to correct their air emissions problems. The scope of the project included replacement of the CO catalyst, modifications to the existing system to improve air flow distribution and repair of the transition section from the turbine, which had become damaged due to thermal expansion. The project was to be done on a turnkey basis including fabrication of equipment, on-site modifications to the existing system, full project management responsibilities and installation. Burbank Water and Power required the following performance guarantees from the bidders of the project.

**CO Catalyst Replacement Project Guarantees**

- Velocity variation of flow across the CO catalyst face and stack cannot exceed +/- 10%
- Back pressure at the turbine not to increase more than 1.0 IWC above current levels
- CO reduction of 90% must be guaranteed for 3 years at 6,000 hrs/yr
- Pressure drop across the catalyst must be less than 1.75 IWC
- Turbine must be able to operate from 5 to 50 megawatts
On February 18, 2004 Turner EnviroLogic received a letter of intent from Burbank Water and Power to proceed with the retrofit work. The decision was based 30% on the experience and qualifications of the company and its personnel, 40% on the technical proposal offered, 20% on price and 10% on schedule. A rather tight time schedule was requested as the project was to be completed in 2-1/2 months, beginning March 1, 2004 with completion May 17, 2004.

**CO Catalyst Replacement Major Tasks**

Turner EnviroLogic’s proposed solution involved several key tasks. First, the airflow distribution had to be corrected in order to achieve optimum performance, and to prevent premature failure of the replacement catalyst. Second, the catalyst blocks were to be replaced by those of a different manufacturer. Third, the transition directly after the turbine exhaust had to be redesigned to allow for thermal expansion.

**Airflow Distribution**

In order to correct the airflow problems, the existing perforated plates were removed. Perforated plates were originally employed as a means of distributing the airflow, a very common method used in many SCR designs. These plates were shown to be ineffective, especially under the wide range of airflow rates the turbine was to operate under. Perforated plates work on the principle of distribution via backpressure. When the air volume is reduced significantly under partial loading of the turbine, the backpressure is reduced to even a greater degree. Consequently, the airflow distribution capability of the perforated baffles is greatly degraded.

Turner EnviroLogic decided to tear out the existing perforated baffles and replace them with distribution vanes. A system of vanes and baffles was conceived to counter the rotational motion of the turbine exhaust, slow the velocity, and provide uniform flow over the entire operating range of the turbine. The existing housing was modified to accept these components, while allowing for thermal expansion and maintenance access. Distribution vanes are much more effective at equalizing airflows over a wide range of airflow rates. Vanes are also much more effective at preventing the swirling action produced by the turbine exhaust.

The plant had long experienced problems in performing compliance tests and RATA certifications, due to the location of the test ports, and flow stratification in the stack. A system of vanes and flow redistributors was designed for the entry to the exhaust stack. The vanes at the stack designed to even the airflow to improve emission testing and reduce RATA testing requirements.

**Catalyst Replacement**

The existing CO catalyst was removed and returned for recycling. The existing CO catalyst frame was disconnected and relocated further downstream, to a point immediately preceding the ammonia injection grid. This provided the extra space necessary for the flow redistribution devices. It also placed the CO catalyst in a horizontal flow section, as opposed to the previous location in a transition section. This helped provide laminar horizontal flow at the catalyst face, improving activity levels within the catalyst cells, as well as overall flow distribution.
The larger cross section allowed for a lower face velocity, as well as a lower space velocity, and a reduction in pressure drop. The CO catalyst was replaced by a metal monolith design with a platinum/palladium oxidation catalyst, supplied by Johnson Matthey.

After Turner EnviroLogic designed modifications to the SCR, Computational Fluid Dynamic (CFD) modeling was used to verify the effectiveness of the solutions conceived. This modeling was performed using the Fluent modeling software. A very comprehensive mathematical model was constructed, using an extremely tight matrix to achieve a fine resolution. The model was run to full convergence. Due to the size and configuration of the model, it required four processors running in parallel for twelve hours to complete each model run. The graphics presented below show the before and after conditions as determined by CFD modeling.
SCR Geometry & CFD Modeling Before Retrofit

SCR Geometry & CFD Modeling After Retrofit

Figure 6: New Geometry With Final Recommended Flow Guidance Devices Installed
Transition Piece Modifications

In order to maintain SCR integrity, the turbine exhaust transition piece needed to be redesigned and repaired. It had shown extensive cracking due to thermal expansion and contraction. The transition piece was originally designed as a solid housing directly contacting the hot exhaust gases. This housing was rigidly attached to the base structure and was externally insulated. As such, there was insufficient allowance for thermal expansion and the housing showed signs of cracking at the welded seams. The insulation was also being damaged as the transition piece expanded vertically.

Turner EnviroLogic modified the transition piece by greatly reinforcing the base and reconfiguring the lagging on the insulation so that the insulation did not get damaged when the transition piece expanded from the heat.

A local contractor from Long Beach, CA was chosen by Turner EnviroLogic to do the on-site construction work. This contractor was familiar with Turner EnviroLogic having installed other SCR’s for Turner on past projects. All of the components for the retrofit were manufactured at Turner EnviroLogic’s facility in Deerfield Beach, FL. Equipment was completely pre-engineered, pre-fabricated and pre-staged to facilitate quick installation.

Careful planning and experienced project management allowed the retrofit installation to be accelerated by approximately three weeks from the original schedule. The accelerated schedule was requested by Burbank Water and Power to take advantage of a time window to do other unplanned work at the power plant. Turner EnviroLogic was able to accommodate the tighter schedule.
Performance Results After Retrofit

The chart below summarizes the results of air flow distribution improvements.

<table>
<thead>
<tr>
<th>Location</th>
<th>CFD Model before Modifications</th>
<th>CFD Model after Modifications</th>
<th>Measurements after Modifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO Catalyst Face</td>
<td>38.2 %</td>
<td>7.7 %</td>
<td>7.6 %</td>
</tr>
<tr>
<td>NOx Catalyst Face</td>
<td>28.6 %</td>
<td>15.6 %</td>
<td>13.3 %</td>
</tr>
<tr>
<td>Exhaust Stack</td>
<td>33.7 %</td>
<td>9.2 %</td>
<td>8.9 %</td>
</tr>
</tbody>
</table>

As these results show, not only was the air flow distribution greatly improved but the actual tested results proved the CFD modeling to be very accurate. Removal of the original perforated baffles also reduced the system overall pressure drop significantly. Pressure drop across the CO catalyst was only 0.07 IWC and the overall system pressure drop actually decreased as a result of the modifications.
Overall performance of the Lake One facility after retrofit modifications is summarized in the chart below.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Performance Guarantee</th>
<th>Actual Tested Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO Catalyst Velocity Distribution</td>
<td>+/- 10 %</td>
<td>+/- 7.6 %</td>
</tr>
<tr>
<td>CO Reduction</td>
<td>90 % (5 ppm)</td>
<td>94 % (3 ppm)</td>
</tr>
<tr>
<td>Pressure Drop of CO Catalyst</td>
<td>&lt; 1.75 IWC</td>
<td>0.07 IWC</td>
</tr>
<tr>
<td>Turbine Backpressure Increase</td>
<td>&lt; 1.0 IWC</td>
<td>Backpressure Decreased</td>
</tr>
</tbody>
</table>

**Phase II – NOx Catalyst Replacement**

Even with the improvements in air flow distribution done in Phase I, further improvement was needed to the NOx catalyst portion of the SCR. The newly installed CO catalyst exceeded performance requirements, allowing the plant to increase NOx water injection to the turbine to maintain compliance with permitted NOx levels. Additionally, the distribution of ammonia vapor across the NOx catalyst face was very uneven due to the ammonia header design, complicated by the complex system of valves used to balance the ammonia grid. This resulted in ammonia slip levels approaching permit maximums, and excessive ammonia usage.

Once again Burbank Water and Power sought competitive bids from several qualified companies. Burbank Water and Power’s proposal request only asked for NOx catalyst replacement though the responsibility for overall performance of the catalyst and responsibility for compliance with permit limits for NOx and ammonia slip was assigned to the successful bidder. Once again Turner EnviroLogic was chosen to undertake the project.

**NOx Catalyst Replacement Project Guarantees**

Guaranteed performance requirements requested by Burbank Water and Power for Phase II are shown below.

- NOx reduction of 90% for 5 years or 18,000 hrs of operation
- Pressure drop across the NOx catalyst not to exceed 3.0 IWC
- Ammonia slip to be less than 3.5 ppm

As before, the project schedule was tight and the project was to be completed on a turnkey basis just like Phase I. There also was a lot more equipment to fabricate and install. The contract was awarded to Turner EnviroLogic on February 1, 2005 and the project work was completed on June 6, 2005. The team of Turner EnviroLogic and the local contractor, who were both now very familiar with the SCR at Burbank Water and Power, completed the project as planned.
SCR Retrofit
CASE STUDY: IMPROVING PERFORMANCE

SCR Catalyst Replacement Major Tasks

Field data was collected to evaluate the distribution of ammonia at the face of the catalyst, since this is critical to catalyst performance. This data, confirmed by calculations and CFD analysis, revealed that the existing ammonia distribution system was not capable of providing the distribution required for long term compliance.

In order to ensure equalized ammonia distribution across the NOx Catalyst face, Turner EnviroLogic recommended complete replacement of the ammonia injection grid (AIG) with a self-balancing H-header design. The effectiveness of this design had been proven by CFD analysis as well as field performance.

H-Header Ammonia Injection Grid Modules

The ammonia vaporization system was also inadequate for use with the replacement distribution headers. The original SCR design used 65 KW electric heaters to vaporize the ammonia. These heaters had failed several times in the past, and were not considered to be reliable. Because the heaters could not heat up quick enough to support the plant’s required 10-minute start, the plant had been forced to operate them continuously. In addition to shortening heater life, this resulted in higher operating costs for electrical consumption.
Recommended Changes

After careful analysis, the following recommendations were made by Turner EnviroLogic. Each of these recommendations were based on the success Turner EnviroLogic has had on past SCR designs.

- Install new NOx Catalyst supplied by Haldor-Topsoe.
- Add two (2) cooling fans to lower the exhaust temperature to 800 F. Install VFD’s on the fans to prevent over cooling.
- Install a new ammonia vaporization system that uses a slip stream of turbine exhaust to heat and vaporize the ammonia.
- Install a new ammonia vaporization grid (AIG) designed by Turner EnviroLogic. The new AIG is self-balancing eliminating the need for balancing valves.
- Provide a supplemental PLC to control the system interfaced with the plant’s DCS system.

Ammonia Distribution

Turner EnviroLogic also decided to scrap the existing ammonia vaporization system and replace it with one that uses a slipstream of hot turbine exhaust gas to vaporize the ammonia. With the new ammonia vaporization system the SCR can come online more quickly since no time is required to have electric heaters heat up. Significant electrical power savings are also realized by eliminating the electric heaters.

The ammonia vaporizer was replaced with a waste heat system, designed to use turbine exhaust gas for ammonia evaporation. This system allows ammonia to be vaporized as soon as exhaust temperatures reach 300 F, which normally occurs within a minute of turbine light off. With no heaters and simplified controls, the system has proven itself to be more reliable.

Performance Results After Retrofit

The chart below shows the performance results after all retrofit work was completed.

<table>
<thead>
<tr>
<th>Load</th>
<th>25 %</th>
<th>50 %</th>
<th>75 %</th>
<th>100 %</th>
<th>Emission Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow Rate (dscfm)</td>
<td>150,482</td>
<td>171,085</td>
<td>174,663</td>
<td>184,981</td>
<td></td>
</tr>
<tr>
<td>NOx (ppm @ 15% O2)</td>
<td>4.19</td>
<td>4.42</td>
<td>4.38</td>
<td>4.32</td>
<td>5.0</td>
</tr>
<tr>
<td>Ammonia Slip (ppm)</td>
<td>1.4</td>
<td>1.2</td>
<td>1.0</td>
<td>1.0</td>
<td>3.5</td>
</tr>
<tr>
<td>Output (MW)</td>
<td>15</td>
<td>25</td>
<td>37</td>
<td>44</td>
<td></td>
</tr>
</tbody>
</table>

By all accounts both retrofit phases were deemed complete successes. Every performance requirement was exceeded and both phases were completed on or ahead of schedule.
Conclusions

Many SCR's that were installed in the early 2000's may be experiencing premature catalyst deactivation. While this may appear to be a catalyst issue, it often is caused by less than optimum system design, which may be compensated for by an actual over performance of the catalyst, which occurs normally with new catalysts, before effectiveness declines to a slightly lower, long term performance level. Careful analysis of the SCR design should be done when catalyst replacement is anticipated, to determine if system modifications should also be undertaken to maximize performance, save energy and improve system longevity, as well as extending catalyst life to meet or exceed original design parameters.