First Experience with SNCR DeNox System in QAFCO Reformer Furnace

In 2009, Qatar Fertilizer Company (QAFCO) commissioned their first SNCR DeNox System in a Primary Reformer in their Ammonia 3 Plant. This paper explains how the system was designed and describes the initial operating experience.

The installation has successfully reduced NOx emissions from the reformer by more than 50%

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Introduction

The regulatory authorities in the State of Qatar previously imposed limits on NOx emissions from combustion sources in the country and the primary reformer furnace in the Ammonia-3 plant at Qatar Fertilizer Company did not meet the limits. A study was initiated to investigate the NOx reduction options and concluded that a secondary abatement system was the most economical alternative. The DeNox system design used was a Selective Non Catalytic Reduction (SNCR) type and is capable of using either Urea or Aqueous Ammonia solution as a reductant. An experienced engineering company was contracted to design and construct the system using a concept initiated by Qafco engineers.

This paper explains how the system was designed and describes the initial operating experience.

QAFCO Site

The QAFCO site in Mesaieed, Qatar includes 4 ammonia-urea trains with 2 more and a Melamine plant under construction at the time of writing. The Qafco Ammonia 3 Plant was designed by Uhde with a nominal capacity of 1500tpd and was commissioned in 1997.

NOx Reduction Program

The new statutory limits imposed by the authorities resulted in a review of all combustion equipment in Qafco and due to the maintenance turnaround schedule, the Ammonia 3 Plant and associated utilities was selected as the test case
for applying NOx reduction technology. Accordingly, after a feasibility study, three technologies were chosen for the targeted equipment as shown in Table 1.

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Technology</th>
<th>Design NOx Before*</th>
<th>Design NOx After*</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>mg/Nm³ (ppm)</td>
<td>mg/Nm³ (ppm)</td>
</tr>
<tr>
<td>Primary Reformer Furnace</td>
<td>SNCR secondary abatement</td>
<td>220(120)</td>
<td>110(60)</td>
</tr>
<tr>
<td>HRSG Boiler</td>
<td>SCR secondary abatement</td>
<td>270(145)</td>
<td>&lt;50(25)</td>
</tr>
<tr>
<td>Auxiliary Fired Boiler</td>
<td>Low NOx burners with FGR</td>
<td>400(210)</td>
<td>55(30)</td>
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</tbody>
</table>

* Dry at 3% O2

Reformer Furnace NOx Reduction Alternatives

The Ammonia 3 primary reformer is a natural gas downfired Foster Wheeler furnace with a heat release of 180 MW (614 mmBtu/h) supplied by 108 preheated air staged burners using natural gas and process offgas as fuel. The flue gas generated contains a NOx concentration of 220 mg/Nm³ (120 ppm).

In investigating NOx Reduction alternatives for the primary reformer furnace, five options were considered;

1) Reducing the NOx load on the reformer
2) Selective Catalytic Reduction (SCR) using aqueous ammonia or Urea solution as the reduction media
3) Low NOx burners
4) Selective Non-catalytic Reduction (SNCR) using aqueous ammonia or Urea solution as the reduction media
5) A combination of 2 of the above

Offloading the reformer furnace, by installing a pre-reformer for example, was eliminated for economic reasons.

SCR DeNox technology was eliminated due to the following reasons;
- Space constraint in the convection section flue gas duct
- Adverse impact on duct pressure drop and effect on ID fan capacity.
- The need to stop every 2 years to change SCR catalyst
- Economics

The cost of a retrofit using Low NOx burners to guarantee the targeted reduction, without affecting the process performance of the reformer, was prohibitive.

The SNCR option incurred the lowest life cycle cost to meet the NOx reduction requirement. No additional investment to revamp equipment such as ID fans or ducting was required. However, there was limited experience in the ammonia industry for this type of technology.

A significant factor in justifying the SNCR option was the fact that the company had already committed to developing the infrastructure to supply aqueous ammonia and urea solution on site.

The option of combining technologies was deferred depending on the outcome of the SNCR system performance

Non-Catalytic NOx Reduction Process

In a selective non-catalytic reduction process, reductants in an aqueous solution or gaseous form are injected into hot flue gases to convert nitrogen oxides into molecular nitrogen and wa-
The reaction is selective in that the ammonia or urea reagents react primarily with NOx in the flue gas. SNCR systems can typically achieve a 50-70% reduction in NOx emissions. The reactions for urea are:

\[
\text{NH}_2\text{CONH}_2 + 2\text{NO} + \frac{1}{2}\text{O}_2 \rightarrow 2\text{N}_2 + \text{CO}_2 + 2\text{H}_2\text{O}
\]

Or for ammonia:

\[
4\text{NH}_3 + 4\text{NO} + \text{O}_2 = 4\text{N}_2 + 6\text{H}_2\text{O}
\]

As shown in Figure 1 below, the optimum temperature range for NOx reduction is between 900 and 1100°C (1,652-2012°F) depending on the composition of the flue gas. Above this range, ammonia is oxidized to form more nitrogen oxides and at lower temperatures the reaction rate slows causing ammonia slip which can result in the formation of potentially corrosive ammonia salts further downstream.

Non-Catalytic NOx Reduction in Reformer Furnace

Since Qafco had previously decided to build the infrastructure on site to produce 19% aqueous ammonia and 32% urea solution as a separate project, the reformer DeNox system was designed to accommodate and test both reductants. An experienced engineering company in the field was contracted to design and construct the system.

The basic components of the DeNox system included the following (See Figure 2);

i) A solution storage tank capable of accommodating aqueous ammonia or urea solution

ii) A dilution water tank
iii) A solution pump capable of supplying urea or ammonia solution  
iv) An inline dilution mixer  
v) Dosing pumps which supply diluted solution to injection lances located in the transition section of the reformer convection section  
vi) Injection lances as mentioned above  

**Design**

There were several engineering challenges to overcome during the project.

**Flow Distribution**

Uniform flow distribution and fully atomized solution were key design objectives. Inadequate distribution (or low temperature) can lead to salt formation and corrosion problems in downstream convection coils.

The atomizing injection lances were required to fit into a space upstream of the feed/steam superheater coil in a flue gas stream of 230,000 m³/h (8mmscf/h) at 1000°C (1,832°F). A maximum slip of 30 mg/Nm³ (40ppm) of ammonia in the flue gas exhaust was also a design requirement.

A CFD study was done to determine the number, size and location of injection lances required to guarantee uniform flow distribution of reductants and complete atomization of liquid droplets within the flue gas duct.

Also, to ensure balanced solution flow to each injection lance, separate metering pumps were incorporated in the design. Each pump was designed with an automatic standby unit for reliability.

Material chosen for injection lances was A312.Gr 310 due to the process environment.

Also the selected lance supplier had extensive experience with SNCR systems in similar conditions in other industries.

Due to the harsh conditions in the transition section, the lance design also included replacement tips and protection pipes flushed with barrier air to prevent solution vaporization or decomposition within the lances.

A provision to replace the injection lance tips online was also a requirement.

**Solution Supply**

The supply of 32% urea and 19% aqueous ammonia solution is provided from a nearby plant at Qafco.

The Ammonia 3 Reformer DeNox Skid includes one solution day tank with a maximum capacity of 2 days consumption. It is filled on a batch basis.

**Area Classification**

All equipment was required to meet the plant’s area classification of IEC Zone 2, Gas Class IIC, and Temp Class T4.

**Instrumentation and Controls**

The system was required to be operated in automatic mode from an existing DCS to maintain the targeted NOx level in the flue gas exhaust as the setpoint. To accomplish this, an integral online NOx and O2 analyzer was included in the scope of work and the solution pumps were driven by actuated variable speed motors.

Protective systems included a 2 out of 3 high and low flue gas temperature trip as well as an interlock which stopped the system in the event of a reformer shutdown.
Other

A water scrubber was installed on the vent of the solution tank to prevent ammonia emissions when aqueous ammonia is being used as the reductant.

Operating Experience

Project mechanical completion was achieved in November 2009 after the plant maintenance turnaround. After a short commissioning process, the system was placed on line on 25 November 2009.

The initial performance was positive with the following results;

Table 2: SNCR Performance Results

<table>
<thead>
<tr>
<th></th>
<th>Inlet NOx*</th>
<th>Outlet NOx*</th>
<th>Outlet NH3</th>
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<tbody>
<tr>
<td></td>
<td>mg/Nm³ (ppm)</td>
<td>mg/Nm³ (ppm)</td>
<td>mg/Nm³ (ppm)</td>
</tr>
<tr>
<td>Design</td>
<td>220(120)</td>
<td>110(60)</td>
<td>&lt;30(40)</td>
</tr>
<tr>
<td>Actual</td>
<td>290(155)</td>
<td>140(75)</td>
<td>&lt;5(7)</td>
</tr>
</tbody>
</table>

* Dry at 3% O2

In spite of a higher than design NOx content in the incoming flue gas at 290mg/Nm³(155ppm), the SNCR urea solution injection was able to reduce the emission to 140mg/Nm³(75ppm), with an ammonia slippage of <5 mg/Nm³(7ppm) although the consumption of urea was higher than initially expected.

The reliability of the system was affected by several teething problems.

Initially, delivered flow from the dosing pumps was erratic and unpredictable. This caused lifting of relief valves and hydraulic oil loss from the units. This was rectified by the adjustment of discharge pulsation dampeners.

Incorrect flue gas temperature readings caused several spurious trips of the system. This was later rectified by replacing the respective thermowells.

Initial readings from the NOx analyzer were incorrect due to errors in the calibration gas used.

The injection lances were removed and tested after 4 months of operation and found to be in good condition.

At the time of writing, the aqueous ammonia injection system was being prepared for commissioning

Conclusion

The installed DeNOx system on the Ammonia 3 Primary Reformer at Qafco met the performance criteria of reducing NOx emissions by 50% but the initial reliability of some components was affected by teething problems.

References

Figure: 2
SNCR-DeNOx UNIT
FOR PRIMARY REFORMER IN AMMONIA-3

COMPRESSED AIR

DEMIN WATER

DILUTION WATER TANK

Air

SCOURBER

AQUEOUS AMMONIA

UREA SOLUTION

SOLUTION STORAGE TANK

From reformer

MIXER

SOLUTION PUMP

DOSING PUMP