Worldwide Pollution Control Association

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Corrugated Catalyst for Gas Turbines

WPCA
TVA Seminar
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Agenda

• Introduction of Haldor Topsoe
• SCR catalyst basics
• Corrugated catalyst vs. extruded catalyst
• Considerations for switching to corrugated catalyst
• Catalyst replacement experience
• Catalyst regeneration
• Dual function catalyst for gas turbines
• Review of talking points
SCR BASICS
Catalyst 101 – DNX® GT
Basic SCR Layout

Classical layout

CO catalyst 420-480°C
SCR catalyst 320-360°C
Basic SCR Reactions

- $4\text{NO} + 4\text{NH}_3 + \text{O}_2 \rightarrow 4\text{N}_2 + 6\text{H}_2\text{O}$
- $\text{NO} + \text{NO}_2 + 2\text{NH}_3 \rightarrow 2\text{N}_2 + 3\text{H}_2\text{O}$
- $2\text{NO}_2 + 4\text{NH}_3 + \text{O}_2 \rightarrow 3\text{N}_2 + 6\text{H}_2\text{O}$

NH$_3$ NO

1

NH$_3$

2

NH$_3$ NO

3

H$_2$O N$_2$

4

O$_2$

5

Laminar-gas film
Catalyst surface
Catalyst pore
Benefits of Corrugated Catalyst
Topsoe Corrugated (DNX® GT-Series) Catalyst

• Plate carrier is corrugated to provide plate separation. It is fused with TiO₂ and fibers.
• A controlled pore volume is generated.
• V-oxide/W-oxide as the active catalytic material are impregnated generating a homogeneous ceramic.
• A front edge hardening promoter is added.
• Monolith inserted in element boxes.
• Variable plate height: 250 to 540 mm
DNX® GT-Series
Tailor-Made for Gas Turbines

• Maximised activity
  • Resulting from low density and high porosity
• Lowest available pressure drop
• Customizable module design
• Lighter catalyst and module frame
• Sturdy and robust module sealing
• Rapid low-temperature response
Advantages of DNX Catalyst – Surface Area

DeNOx reaction is “Diffusion Limited”
more highways = higher diffusion rate = higher activity
Tri-modal pore structure
Advantages of DNX Catalyst – Ultra High Porosity – ABS Tolerant
Advantages of DNX Catalyst – Pore Volume

- Topsoe tri-modal pore volume compared to plate and extruded catalyst
Advantages of DNX Catalyst – Pore Volume

- Topsoe’s pore volume is twice that of plate and extruded catalyst
Other Advantages of DNX Catalyst

- High mechanical and thermal resistance
- High poison resistance
- Very low $\text{SO}_2$ oxidation
- Very low draft loss
- Low weight - Rapid heat absorption
- No seals or gaskets between blocks to blow out
Considerations for Corrugated Catalyst - Structural

- No additional support steel required
  - Corrugated catalyst ~40% lighter

- Little to no modifications to existing structural steel
  - Module sizes are customized to align with supports and/or match previous module design

- Module to support frame attachment system design is simple and effective, requiring no welding or special tools.
Considerations for Corrugated Catalyst – Balance-of-Plant

- The reduction in pressure drop is an improvement in efficiency for gas turbines
- The physical structure of the catalyst is different, but the overall process is the same
Considerations for Corrugated Catalyst –
Reagent Usage

- Less ammonia is used during start-ups due to the increased response time of the catalyst.
- Ammonia can be turned on sooner for improved NOx reduction due to the low-temperature performance of the catalyst.
Considerations for Corrugated Catalyst – Other Gas Constituent Impacts

- Lower sulfur oxidation reduces the formation of undesirable ammonium bisulfate salts
- $< 0.5 \text{ SO}_2$ oxidation at normal operating temperatures
Previous Experience –
Switching to Corrugated Catalyst

• Topsoe has extensive experience with replacements of other manufacturers’ catalyst
  • > 50 replacements of extruded catalyst alone
  • Experience includes replacements for every major competitor and all catalyst types – extruded, corrugated, and plate

• Topsoe is the leading market provider for low dust and no dust catalyst units
  • Maintains ~95% loyalty for replacements of Topsoe catalyst
Previous Experience – Switching to Corrugated Catalyst

• Exelon – Wolf Hollow
  • (2) 501G Engines
  • Deltak HRSG’s
  • Replaced extruded catalyst

• Packing for existing catalyst had blown out with catalyst elements beginning to fall out

• Little to no deactivation after 2 years of operation
Previous Experience – Switching to Corrugated Catalyst

- NAES – New Harquahala
  - (3) 501G Engines
  - NEM HRSG’s
- Replaced 2 layers of competitor catalyst with 1 layer of Topsoe catalyst
- Catalyst replacement resulted in significant operational cost saving
Previous Experience – Switching to Corrugated Catalyst

- City of Redding
  - (2) GE Frame 5 Gas Turbine
  - High temperature peaking units – 832 °F average temperature
  - Replaced extruded catalyst
- Normal installation of catalyst layer
  - Only difficulty was removing existing modules
Catalyst Regeneration

• SCR catalyst for gas turbines can potentially be regenerated, but is seen as an unproven and impractical solution

• Unlike coal applications, gas turbines usually utilize a single layer of catalyst, making reliability and stable performance more critical

• The catalyst deactivation observed for gas turbine units is most often due to a general wearing out of the catalyst over time (e.g. dusting, thermal fatigue)

• Regeneration of thin-walled, small pitch catalyst can weaken the overall structural integrity
What if both SCR catalyst and CO catalyst could be combined in one layer?
Dual Function Catalyst for Gas Turbines

Comparison – About the Position of the CO Catalyst

<table>
<thead>
<tr>
<th>Classical Layout</th>
<th>Dual Function Layout</th>
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</thead>
<tbody>
<tr>
<td>Lower CO-catalyst volumes</td>
<td>Lower specific pressure drop</td>
</tr>
<tr>
<td>Higher HC oxidation</td>
<td>Lower SO$_2$ oxidation</td>
</tr>
<tr>
<td>Not exposed to NH$_3$</td>
<td>Not impacted by SO$_2$</td>
</tr>
<tr>
<td></td>
<td>Easier installation</td>
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<tr>
<td></td>
<td>Liquid ammonia injection</td>
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</tbody>
</table>
The Dual Function Position – Reactions

4 NO + 4 NH₃ + O₂ → 4 N₂ + 6 H₂O

CO + ½ O₂ → CO₂

SCR-Cat

OXI-Cat

CO = 100 ppm
NOx = 50 ppm
NH₃ = 50 ppm

CO = 100 ppm
NOx < 5 ppm
NH₃ < 5 ppm

CO < 5 ppm
NOx < 5 ppm
NH₃ < 5 ppm
The Dual Function Catalyst – Basic Principle

- Noble metal based
  - Pd
- Supported on a DeNOx catalyst
  - V,W on Titania

CO = 100 ppm
NOx = 50 ppm
NH₃ = 50 ppm

CO = 100 ppm

CO < 5 ppm
NOx < 5 ppm
NH₃ < 5 ppm
Summary

• Primary advantages of corrugated catalyst include:

• Maximized catalyst activity
• Enhanced poison resistance
• Lowest pressure drop
• Lighter catalyst
• Efficient usage of ammonia
• Lowest sulfur oxidation
Summary

- Haldor Topsoe has extensive experience replacing competitors’ catalyst in gas turbines and other applications.
- Replacement with corrugated catalyst requires no major structural alterations and Topsoe’s highly customizable modules will fit any reactor space.
- Switching to corrugated catalyst results in savings from reduced ammonia usage and pressure drop.
- Catalyst regeneration is considered generally unsuitable for small-pitch gas turbine applications.
- Dual function catalyst can be an attractive option for the lowest possible pressure drop and sulfur oxidation.