Worldwide Pollution Control Association

WPCA/TVA

Coal & Gas Seminar

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Corrugated Catalyst for Gas Turbines

WPCA
TVA Seminar
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HALDOR TOPSOE

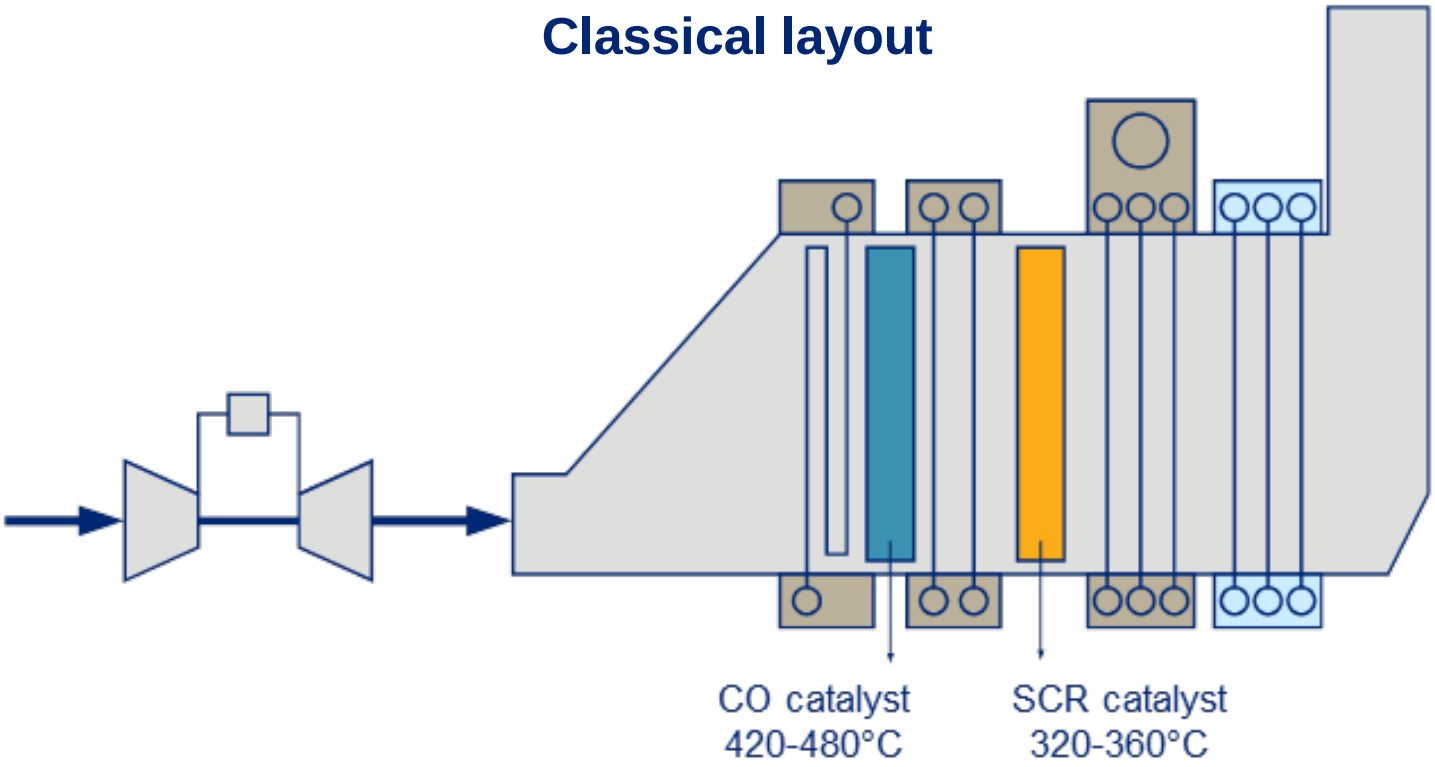
Agenda

- 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

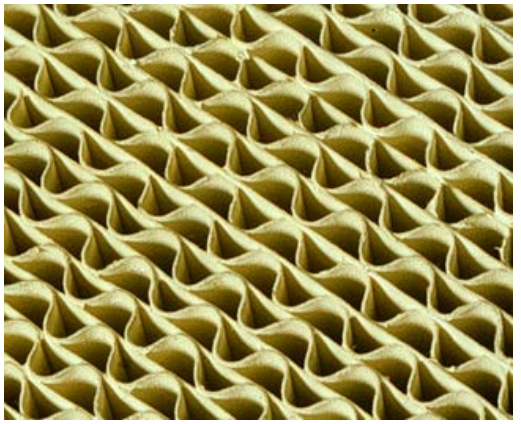
Classical layout

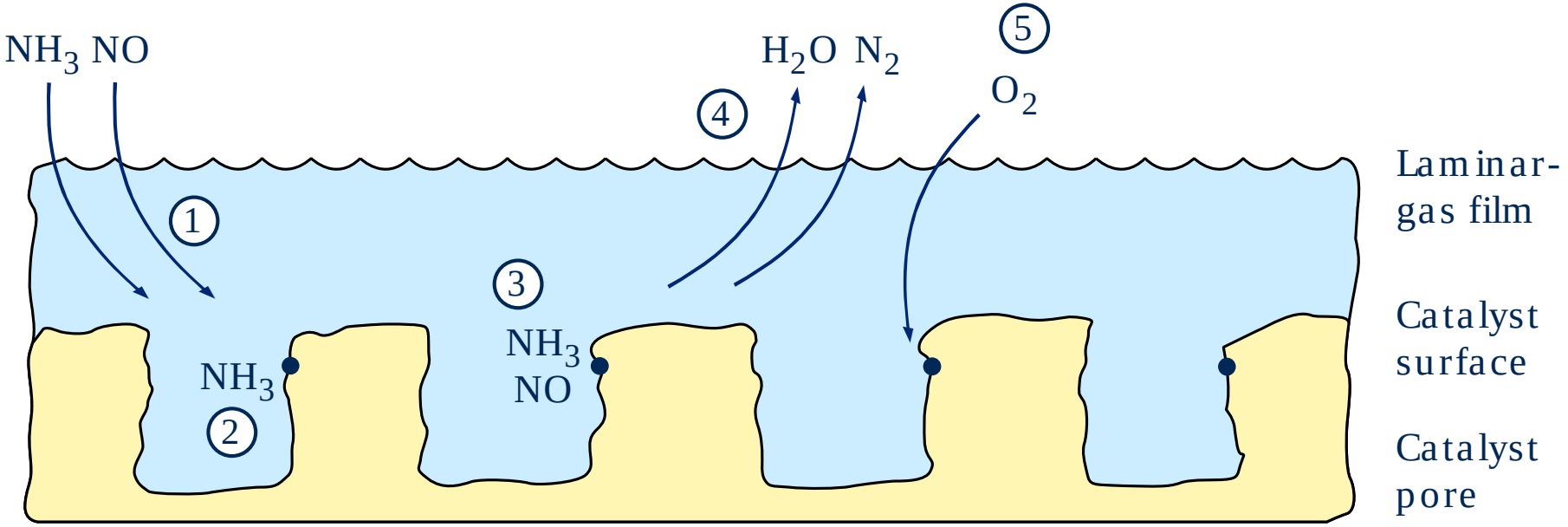



Topsoe DNX Catalyst – Design

Basic SCR Reactions

- $4\ NO + 4\ NH_3 + O_2 \rightarrow 4\ N_2 + 6\ H_2O$
- $NO + NO_2 + 2\ NH_3 \rightarrow 2\ N_2 + 3\ H_2O$
- $2\ NO_2 + 4\ NH_3 + O_2 \rightarrow 3\ N_2 + 6\ H_2O$





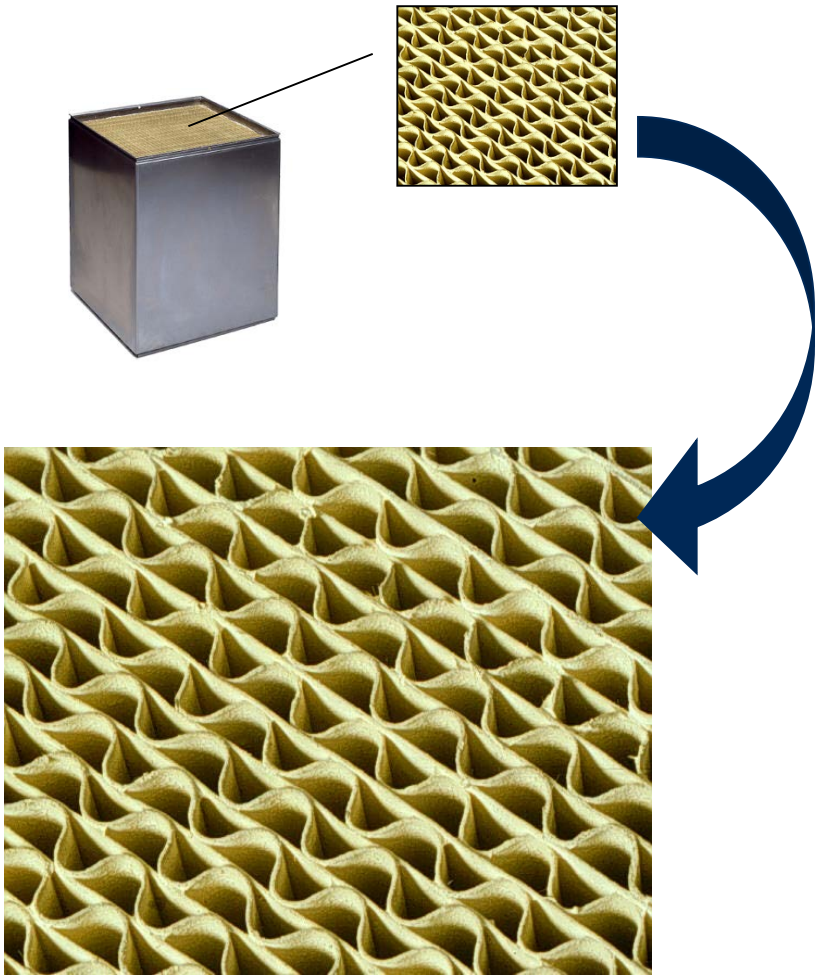
Benefits of Corrugated Catalyst

Topsoe Corrugated (DNX® GT-Series) Catalyst

- Plate carrier is corrugated to provide plate separation. It is fused with TiO_2 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

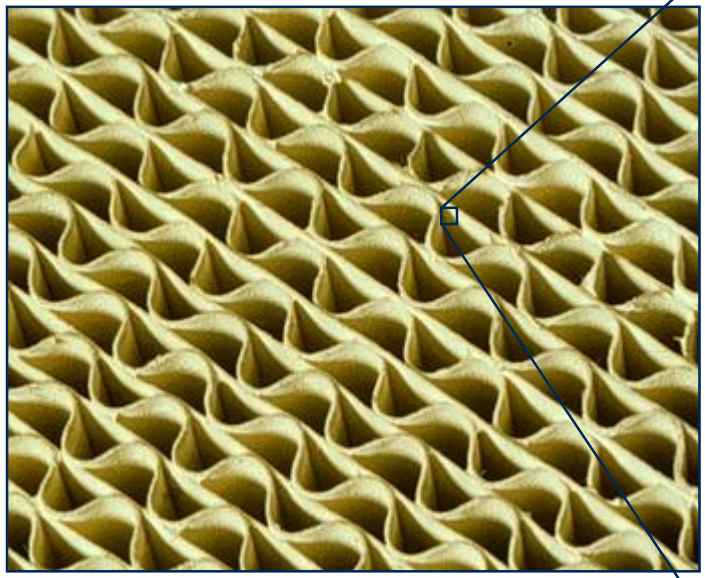
DNX® GT-Series
Tailor-Made for Gas Turbines

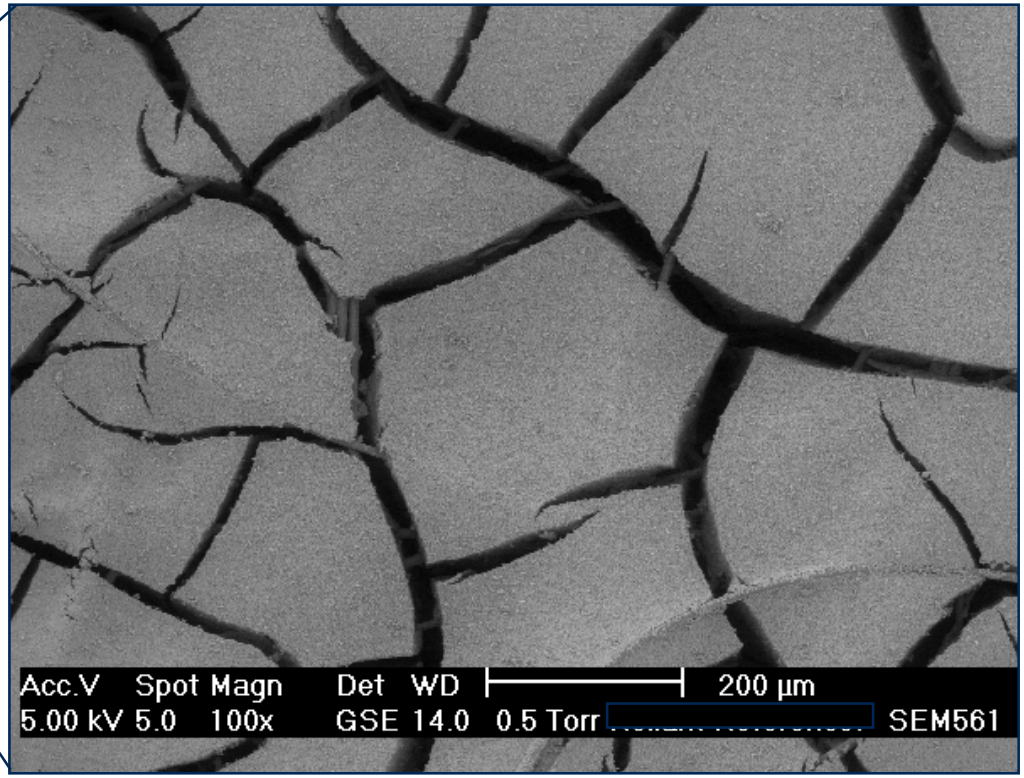
- Maximized activity
  - Resulting from low density and high porosity
- Lowest available pressure drop
- Customizable module design
- Lighter catalyst and module frame
- Sturdy and robust module sealing
- Rapid low-temperature response



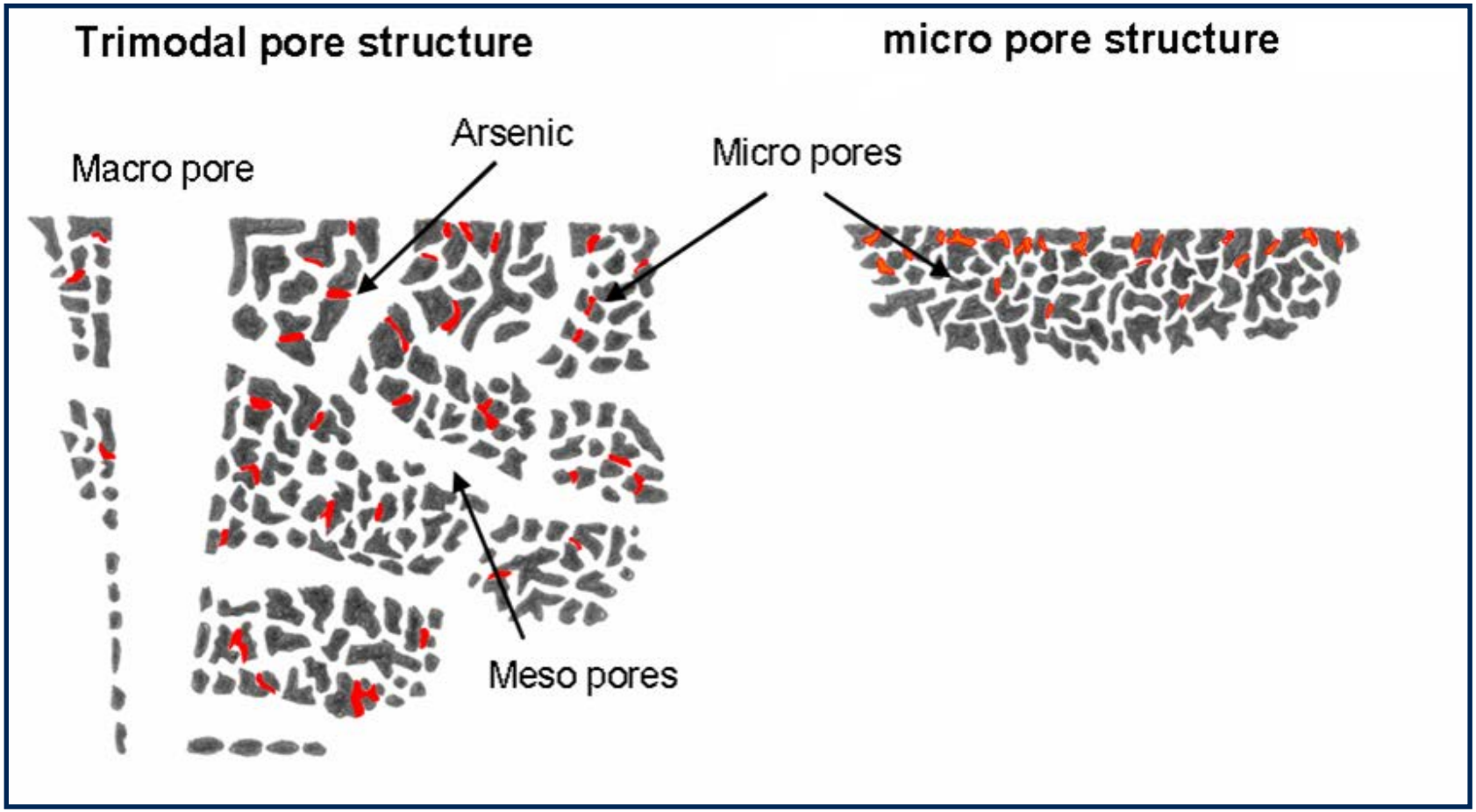
Advantages of DNX Catalyst – Surface Area

DeNOx reaction is "Diffusion Limited"
more highways = higher diffusion rate = higher activity
Tri-modal pore structure



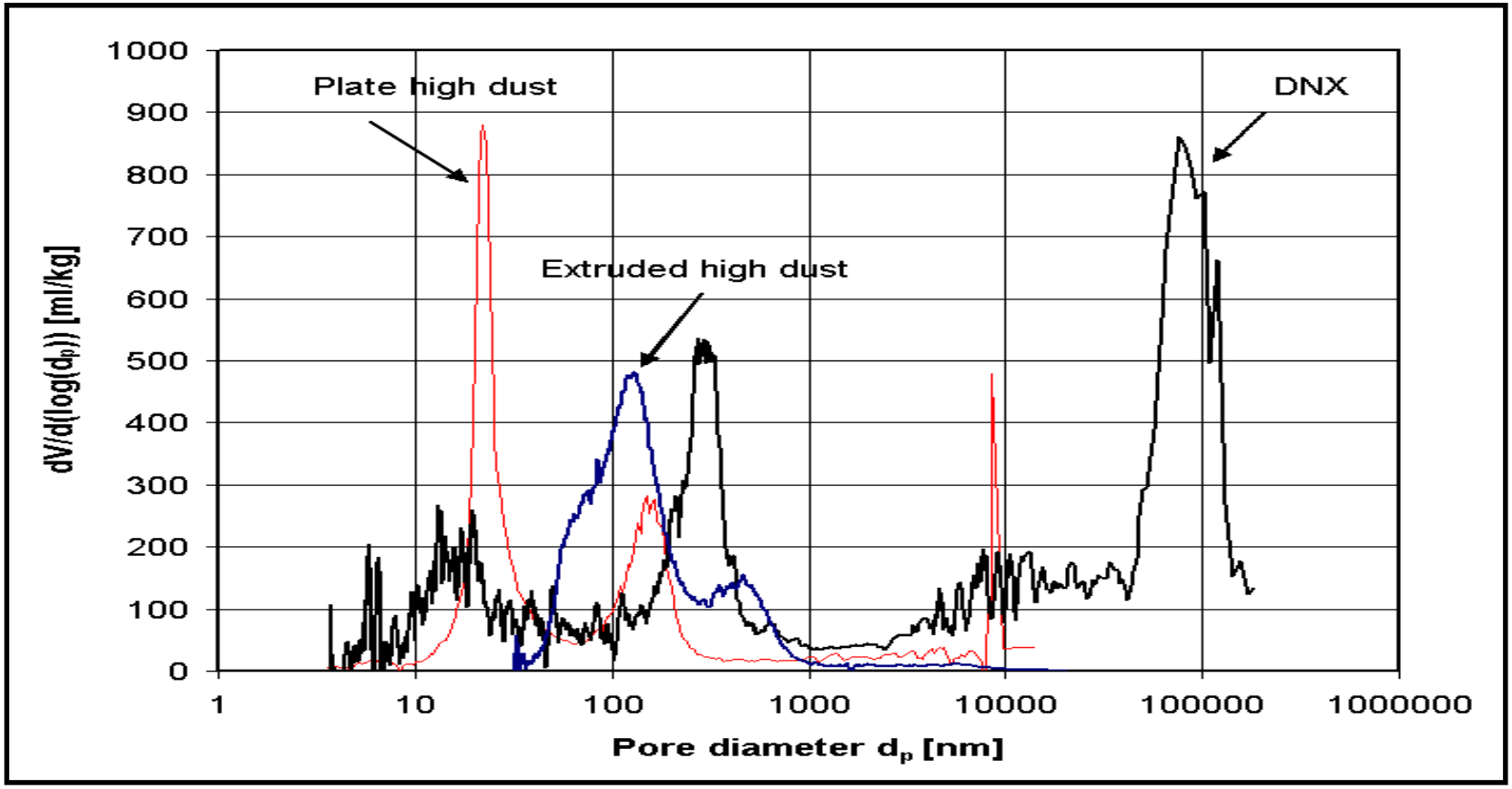


Advantages of DNX Catalyst – Ultra High Porosity – ABS Tolerant



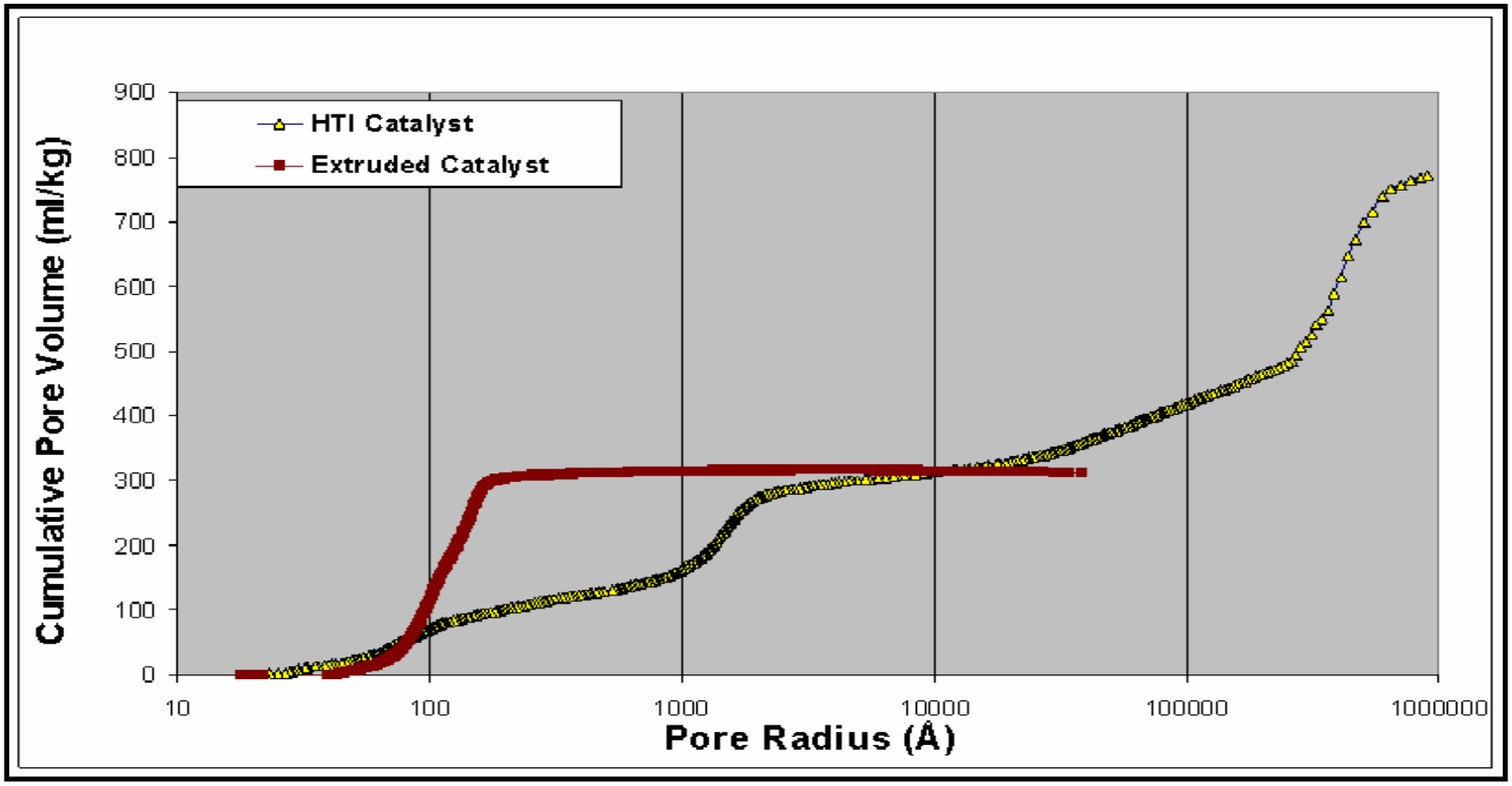
Advantages of DNX Catalyst – Pore Volume

- Topsoe tri-modal pore volume compared to plate and extruded catalyst



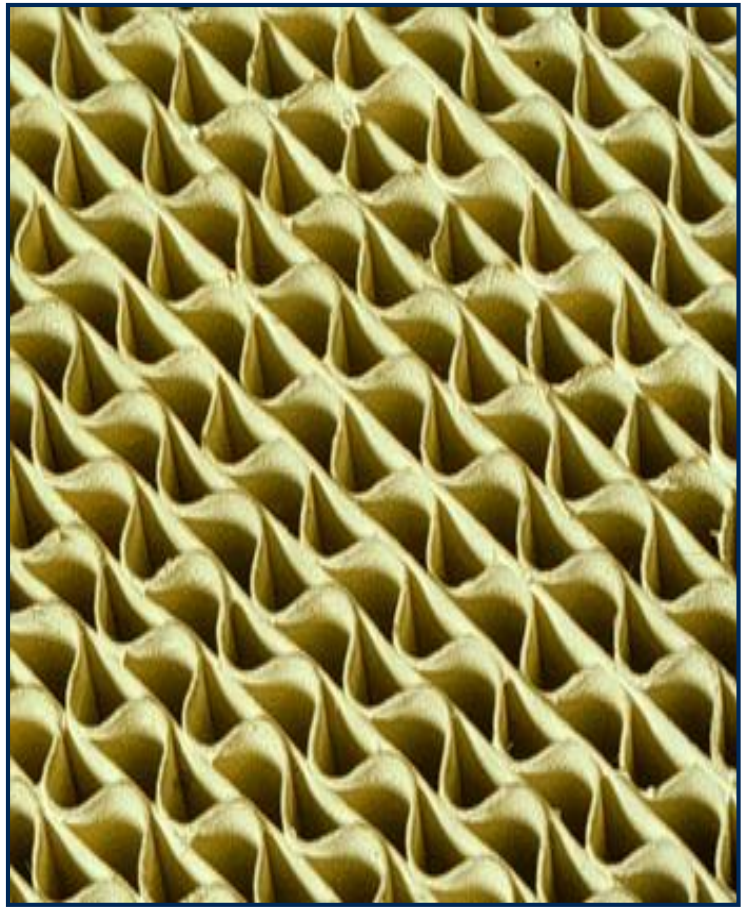
Advantages of DNX Catalyst – Pore Volume

- 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 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

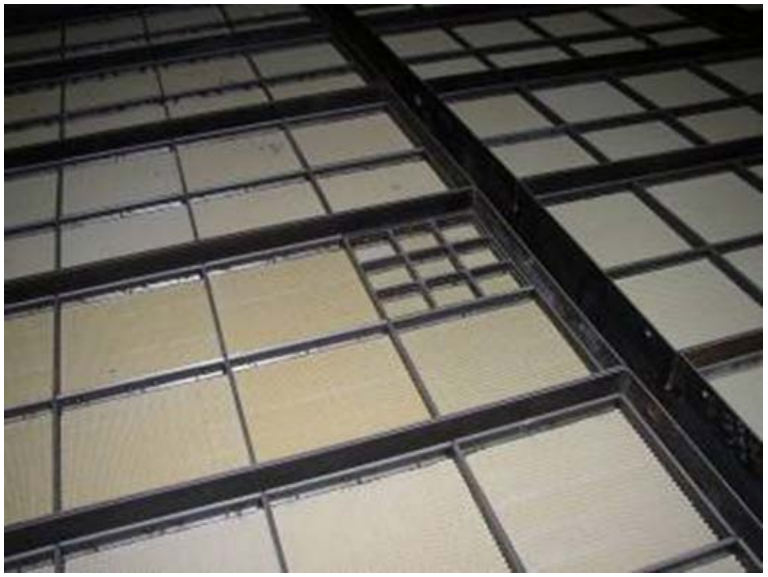
- No additional support steel required
  - Corrugated catalyst ~40% lighter
- Little to no modifications to existing structural steel
  - Module sizes are customized to align with supports and/or match previous module design
- Module to support frame attachment system design is simple and effective, 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 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

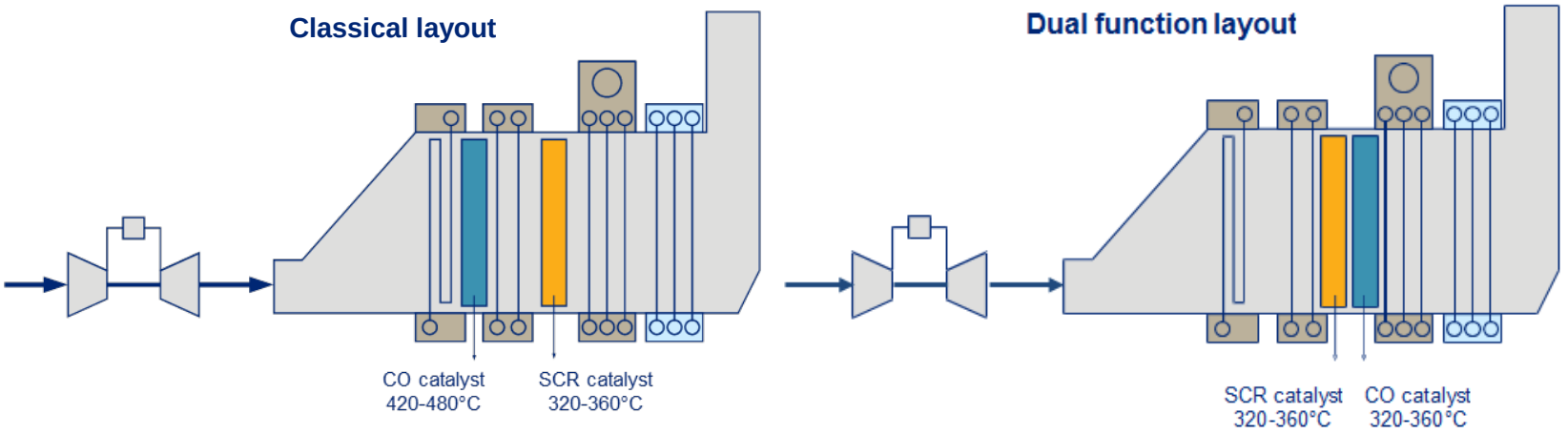
Previous Experience – Switching to Corrugated Catalyst

- 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

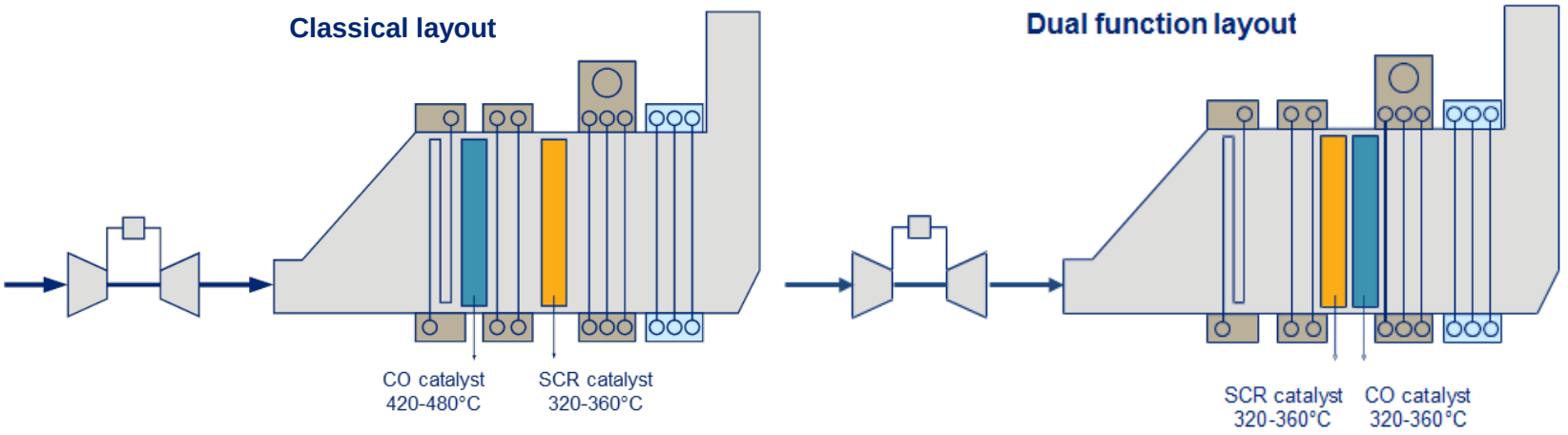
Dual Function Catalyst for Gas Turbines



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

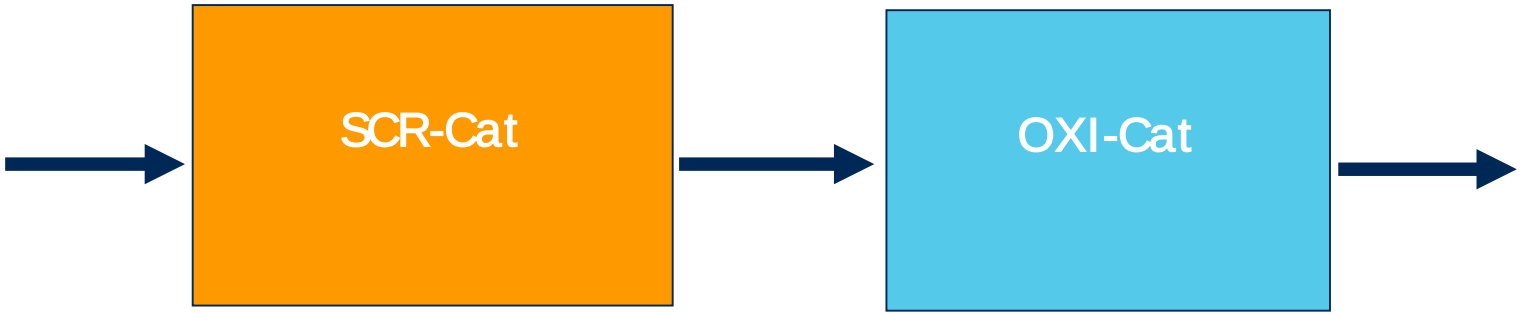


Classical Layout	Dual Function Layout
Lower CO-catalyst volumes	Lower specific pressure drop
Higher HC oxidation	Lower SO_2 oxidation
Not exposed to NH_3	Not impacted by SO_2
	Easier installation
	Liquid ammonia injection

The Dual Function Position – Reactions

$$4\ NO + 4\ NH_3 + O_2 \rightarrow 4\ N_2 + 6\ H_2O$$

$$CO + \tfrac{1}{2}\ O_2 \rightarrow CO_2$$



CO = 100 ppm

NOx = 50 ppm

NH_3 = 50 ppm

CO = 100 ppm

NOx < 5 ppm

NH_3 < 5 ppm

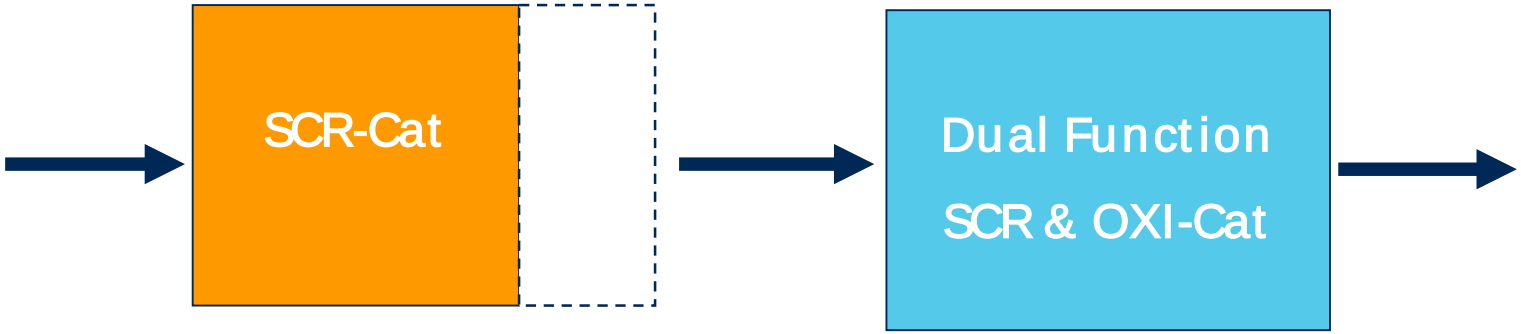
CO < 5 ppm

NOx < 5 ppm

NH_3 < 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

NH_3 = 50 ppm

CO = 100 ppm

CO < 5 ppm

NOx < 5 ppm

NH_3 < 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