• SCR = Selective Catalytic Reduction
• Purpose is to reduce NO\(_x\) (NO & NO\(_2\)) from combustion exhaust
• Ammonia (NH\(_3\)) is injected into flue gas as reducing agent. Flue gas passes through catalyst layers installed in a reactor
• NH\(_3\) reacts with NO\(_x\) on the catalyst surface to form nitrogen and water vapor

\[
\begin{align*}
4\text{NO} + 4\text{NH}_3 + \text{O}_2 & \xrightarrow{\text{Catalyst}} 4\text{N}_2 + 6\text{H}_2\text{O} \\
2\text{NO}_2 + 4\text{NH}_3 + \text{O}_2 & \xrightarrow{\text{Catalyst}} 3\text{N}_2 + 6\text{H}_2\text{O}
\end{align*}
\]
**SCR Catalyst Types**

**Plate-Type**
- Ceramic material on SS substrate
- Individual flexible plates
- Rectangular flow channels
- Ideal for particulate-laden flue gas

**Honeycomb**
- Homogenously extruded ceramic
- Rigid structure, square channels
- High cell density, high surface area
- Ideal for particulate-free flue gas
SCR Presence in the US

- Appeared in late 1980s / early 1990s
- Proven technology for achieving low NO\textsubscript{x} emission rates
- ~260 Utility coal-fired units with SCR (135,000 MW)
- 100s of combustion turbines (SC/CC)
- 1000s of stationary diesel engines
- Marine applications
- Off-road mobile applications
- On-road mobile applications
Traditional Approach for Coal-fired Applications

- High-dust SCR configuration (directly downstream of boiler outlet)
- Reactors with 2 or 3 initial catalyst layers, 1 or 2 empty spare layers
- 80-90% deNOx, emission rates < 0.05 lb/MBTU
- ≤2 ppm NH₃ slip at end of catalyst lifetime
- Catalyst management a major concern due to fly ash plugging and deactivation
  - Frequent catalyst change-out, 2-3 years between additions/replacement
  - Replacements with new, used, regenerated catalyst
New Approaches and Developments for SCR

• >90% deNOx with low NH\textsubscript{3} slip
• New applications
• Catalyst product improvement
• Hg oxidation, co-benefit
High deNOx, 90-95%+

- Traditional approach for high deNOx
  - over-injecting ammonia
  - excess catalyst volume
  - Trade-offs include higher cost and high ammonia slip
- Improve NH$_3$-NO$_x$ mixing for low ammonia slip (< 2 ppm)
  - NH$_3$:NO$_x$ distribution $\leq$ 5% RMS typical for up to 90% deNOx
  - For higher deNOx, NH$_3$:NO$_x$ distribution $\leq$ 2.5% RMS
  - Sophisticated flow modeling tools (CFD, physical) used for design
- Development of advanced NH$_3$ slip control catalysts
  - High deNOx, low NH$_3$ slip
  - Extend catalyst operating life
New SCR Applications

- SCR for US lignite-fired units
  - High ash concentration, high alkali concentrations (K, Na) – risk for fast catalyst deactivation, fouling
  - First TX lignite-fired unit with SCR started in 2009
  - 3 units now operating
  - Investigating SCR for ND lignite firing
- Investigating use with cement kilns
  - Produce high NO\textsubscript{x}
  - High ash exhaust gas – high risk for catalyst
  - SCR would likely be in “low-dust” configuration, downstream of ESP or baghouse
Other “Challenging” SCR Applications

- Flue gas with particulate deactivates catalyst – poisoning, fouling, erosion
- Biomass combustion – high risk of poisoning by alkalis and phosphorus
- Waste (trash) combustion – high risk of poisoning by heavy metals and acid gases
- Tail-end SCR configuration – downstream of particulate collection
  - Prevents fast catalyst deactivation
  - High cell density/surface area catalyst, lower volume requirement
  - Allows long catalyst lifetime, avoid frequent catalyst maintenance
- Trade-offs with Tail-end SCR
  - Position where flue gas temperature is low
  - Operating target of 400 – 540 °F may require flue gas reheating
  - Cost to install and operating flue gas reheating equipment
Tail-End SCR

- Typical configuration for European WTE plant SCR installations
- SCR after scrubber/particulate collection equipment
- Long catalyst life expected
- Special catalyst formulations for low temperature, 400 – 540 °F
- Low concentrations of SO₂, SO₃ required
Continuous Catalyst Product Improvement

- High deNOx activity, low SO₂ oxidation activity – reduce volume, cost
- Poison resistance – extend catalyst life
- Special formulations for high temperature operation
- Low temperature operation
- Ammonia slip control – extend catalyst life, achieve high deNOx rates
- Enhance Hg oxidation
Hg Oxidation, Hg$^0 \rightarrow$ Hg$^{2+}$

- Mercury emission control from Coal combustion
  - Activated Carbon injection or other Novel sorbents
  - Capture in wet FGD
  - These methods work better on Hg$^{2+}$
- Hg oxidation is a co-benefit of SCR catalyst
- Hg oxidation rate strongly dependent on
  - Presence of halogens in flue gas – Cl, Br
  - Temperature, < 700 °F
  - Catalyst formulation and volume
- Catalysts being developed with enhanced Hg oxidation capability while preserving performance on deNOx and SO$_2$ oxidation
Thank You!

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