SCR and Zero-Slip™ Technology

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Presentation Outline

- Mitsubishi/Cormetech Background
- SCR Experience
- Zero-Slip™ Technology
- Zero-Slip™ Commercial Status
Mitsubishi Experience

- Leading SCR System Supplier in the World
  - Pioneered SCR Systems in Japan in 1970’s
  - Delivered/Installed > 500 units
  - Various Applications:
    - Boiler, GT, Diesel Engine, FCC, Process Heater
  - Various Fuels:
    - Coal, Oil, Natural Gas, Orimulsion, BFG, COG and etc.

- Examples
  - Highest NOx Removal (>95%) at T-Point 330MW GTCC, which is Mitsubishi's 501G verification power plant since 1997 at Takasago Machinery Works in Japan
  - Lowest Emissions (< 2 ppm NOx and NH3) at ANP/Blackstone GTCC
  - High Temperature Applications
    - 1000 °F class GT simple cycle (2 units in Kanagawa, Japan)
Cormetech Experience – SCR Catalysts

- #1 SCR catalyst supplier: > 700 Units
  - Gas Turbines: 437 units
  - Gas Boilers: 56 units
  - Utility Coal Boilers: 67 units
  - Refining & Industrial: 126 units
  - Stationary Diesel Engines: 17 units
- 100% Performance Warranty Compliance
- 100% On-Time Deliveries
- Highest NOx Removal Efficiencies
  - > 95% at SCE Mandalay (Gas-Fired Boiler)
  - > 93% at AECI New Madrid 2 (PRB Coal-Fired Boiler)
- Lowest NOx emissions
  - Ten units with less than 2 ppm NOx and 2 ppm NH3 Slip
Innovation in SCR Systems & Catalysts

- High Performance SCR for Gas Turbines and Coal-Fired Boilers
- High Temperature (1,000°F Class) SCR for Simple Cycle Gas-Fired Plants
- Ultra-Low Emission SCR for Combined Cycle Plants
- Zero-Slip™ Technology for GT’s
Zero-Slip™ Technology - Purpose

- Tighter Regulations (e.g. Southern CA, Mass.)
  - NOx < 2 - 5 ppm
  - NH3 Slip < 2 - 3.5 ppm
- Upcoming Particulate Matter (PM) Regulations
  - NH3 is Constituent of PM
- Mitsubishi/Cormetech Technology Development
  - “Zero” Ammonia Slip Technology
- Applicability of Zero-Slip™ Technology
  - Gas-Fired Combined Cycle De-NOx – New or Retrofit
- Future: < 1 ppm NOx Versions
Chemical Composition of PM2.5 in 2000
(EPA preliminary analysis)

Red implies counties with 1999/2000 FRM PM2.5 levels exceeding standard; note need 3 yrs of data

Source: EPA
Zero-Slip™ Technology - Purpose

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Zero-Slip™ Technology

- Enhanced SCR Technology for Gas Turbines to Achieve “Zero” Ammonia Slip
- Zero-Slip™ System Consists of Typical SCR System, Plus the Zero-Slip™ Catalyst:
  - SCR and Zero-Slip™ Catalysts
  - Reactor Housing
  - Ammonia Injection Grid (AIG) & NH3 Skid
  - Static Mixer (if needed)
Zero-Slip™ System Configuration

Mixer

Al G

SCR Catalyst

Zero-Slip™ Catalyst

GT

HRSG

ZERO SLIP SCR SYSTEM

HRSG

STACK
Reactions

DeNOx Reactions Over SCR Catalyst

\[
\begin{align*}
\text{NO} + \text{NH}_3 + \frac{1}{4} \text{O}_2 & \rightarrow \text{N}_2 + \frac{3}{2} \text{H}_2\text{O} \\
\text{NO} + \text{NO}_2 + 2 \text{NH}_3 & \rightarrow 2 \text{N}_2 + 3 \text{H}_2\text{O}
\end{align*}
\]

Zero-Slip Reactions Over Zero-Slip™ Catalyst

\[
\begin{align*}
\text{NO} + \text{NH}_3 + \frac{1}{4} \text{O}_2 & \rightarrow \text{N}_2 + \frac{3}{2} \text{H}_2\text{O} \\
4 \text{NH}_3 + 3 \text{O}_2 & \rightarrow 2 \text{N}_2 + 6 \text{H}_2\text{O}
\end{align*}
\]

“Zero” NH3 and < 2 ppm NOx
Durability Tests

❖ Lab-Scale Test
  ➢ 1,800 Hrs in the Presence of 100 ppm SO$_x$
  ➢ Result: Negligible Change in Catalyst Activity

❖ Samples in Full-Scale Commercial Unit
  ➢ Operating Time > 3,000 Hours
  ➢ Results:
    ❖ Meets Expected Outlet NOx and NH3 Slip
    ❖ Small Activity Decline per Expectation
Full-Scale Commercial Demonstration

- Host: Paramount Petroleum Corp.
- Location: Los Angeles Basin
- Unit: 7 MW Cogeneration
- Startup: January 2003
Full-Scale Commercial Demonstration

- Startup: January 2003
- Operating Time: 3,000 Hours
- Result: Meeting Performance Targets
  - < 0.1 ppm NH3 Slip
  - < 2 ppm NOx
Conclusions – Zero-Slip™ Technology

- Zero-Slip™ Technology has been Demonstrated Commercially
  - Guaranteed Performance: < 0.1 ppm NH3 and < 2.0 ppm NOx
  - Actual Performance: Much Lower NH3 and NOx
- Zero-Slip™ Systems are being Offered for CC Units
- System Design is Flexible to Meet Customer Needs
  - Extremely Low NOx Levels, and/or
  - Extremely Low Ammonia Slip
- Handles Backup Oil Firing with Low Sulfur Oil