PerNOxide \( NO_x \) Control Technology

URS and FMC Corporation
McIlvaine Hot Topic
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Introduction

- Current and future regulations will require further NOx reductions from coal fleet
- SCR widely implemented on larger, higher-emitting plants where capital investment justified
- Low Nat Gas prices have reduced dispatch of smaller, higher cost plants
- Technology void exists for plants needing moderate (40-60%) NOx reductions with minimal capital investment
- FMC/URS are developing technology to meet need
# NOx Technology Comparison

<table>
<thead>
<tr>
<th></th>
<th>SNCR</th>
<th>PerNOxide</th>
<th>SCR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Reagent</strong></td>
<td>Urea</td>
<td>Peroxide</td>
<td>Ammonia</td>
</tr>
<tr>
<td><strong>Nox Removal</strong></td>
<td>15-40%</td>
<td>30-70%</td>
<td>75-90%</td>
</tr>
<tr>
<td><strong>Capital Cost</strong></td>
<td>Low</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td><strong>Operating Cost</strong></td>
<td>Low</td>
<td>Mid-High</td>
<td>Mid</td>
</tr>
</tbody>
</table>

PerNOxide offers moderate NOx reductions with low upfront capital investment.
PerNOxide Injection Process

1) Peroxide Injection @ 600-1100°F

2) NO oxidation to NO₂, N₂O₅

3) NO₂ Capture in WFGD

Note: Other possible capture options include SDA, CDS, CFB
PerNOxide Process Overview

- **Two-Step Process**
  - NO oxidation using hydrogen peroxide
  - Capture of the oxidized nitrogen species

- **NO Oxidation**
  - Hydrogen peroxide injected via dual-fluid nozzles
  - Injection between economizer & air preheater
  - Products include NO₂ & higher-order oxides

- **Capture via Wet or Dry Scrubbing**
  - NO₂ removal is critical for good performance
NO\textsubscript{x} Capture Options

- NO\textsubscript{x} Capture Enhancement
  - Wet lime / limestone / sodium scrubbers
  - Spray Dryer Absorbers (SDA) - lime
  - Circulated Dry Scrubbers (CDS) – lime

- NO\textsubscript{x} Removal in Wet Scrubbers
  - Higher-order nitrogen oxides are very soluble with removal efficiencies > 95%
  - NO\textsubscript{2} is less soluble, but removal is enhanced by dissolved sulfite
  - Reaction products include nitrate, S-N species, and nitrogen gas
Technology Development

- **Early Development (1996-2003)**
  - Univ. Central Florida, EPA, NASA KSC, others
  - Treatment of NO$_x$ from KSC boilers
  - Patent #6,676,912 – NASA

- **Later Development (2006-2010)**
  - FMC Corporation – exclusive licensee of IP
  - Pilot Low-Temp Testing (SDA)
  - Full-scale High-Temp Trials (proof of concept)

- **Current Development (2011-2012)**
  - URS/FMC – Joint Commercialization Agreement
  - Laboratory R&D programs to optimize process
    - WFGD NOx Capture (URS)
    - NO Oxidation and Dry NOx Capture (EERC)
  - FMC – additional patents pending – peroxide activation
Technology Demonstration

• Full-Scale Demonstrations (FMC-2010)
  • 120 MW, E. Bit, No FGD
  • 440 MW, H-S Lignite, Limestone Inhibited-Ox FGD
  • 800 MW, PRB, Limestone Gypsum FGD
    – High NO oxidation achieved (50-80%)
    – Relatively poor NOx capture in WFGD

• Wet FGD Chemistry Lab Study (URS-2011)
  – NO\textsubscript{2} capture of >70% achieved
  – Key chemistry variables liq-sulfite, pH, buffer

• Dry FGD Pilot Study (EERC-2011)
  – Tested various fuels (NG, PRB, E. Bit, Lignite)
  – Up to 50% NOx capture achieved in SDA

• Pilot WFGD and Full-Scale Demo (URS/FMC-2012)
# Technology Cost Comparison

<table>
<thead>
<tr>
<th>Basis</th>
<th>Units</th>
<th>SNCR</th>
<th>PerNOxide</th>
<th>SCR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Capacity Treated</td>
<td>MW</td>
<td>400</td>
<td>400</td>
<td>400</td>
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<tr>
<td>Inlet NOx</td>
<td>lb/MMBtu</td>
<td>0.20</td>
<td>0.20</td>
<td>0.20</td>
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<tr>
<td>NOx Removal</td>
<td>%</td>
<td>20</td>
<td>50</td>
<td>80</td>
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<tr>
<td>NOx Emissions</td>
<td>lb/MMBtu</td>
<td>0.16</td>
<td>0.10</td>
<td>0.04</td>
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<tr>
<td>NOx Removed</td>
<td>TPY</td>
<td>526</td>
<td>1,316</td>
<td>2,102</td>
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<tr>
<td>Capacity Factor</td>
<td>%</td>
<td>75</td>
<td>75</td>
<td>75</td>
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<tr>
<td>Reagent</td>
<td>Urea</td>
<td></td>
<td>Peroxide</td>
<td></td>
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<tr>
<td>Reagent Molar Ratio</td>
<td>mol:mol NOx</td>
<td>0.20</td>
<td>1.50</td>
<td>0.80</td>
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<tr>
<td>Reagent Cost</td>
<td>$/ton</td>
<td>$500</td>
<td>$1,000</td>
<td>$600</td>
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<tr>
<td>Soda Ash Cost</td>
<td>$/ton</td>
<td>$0</td>
<td>$300</td>
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<td>Catalyst Cost</td>
<td>$/c.f.</td>
<td></td>
<td></td>
<td>$150</td>
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<tr>
<td>SCR Catalyst Life</td>
<td>Yrs</td>
<td></td>
<td></td>
<td>3</td>
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<tr>
<td>Power Cost</td>
<td>$/MW-hr</td>
<td>$30</td>
<td>$30</td>
<td>$30</td>
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<tr>
<td>Annual Maint. Cost</td>
<td>% of Capital</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
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<tr>
<td>Capital Cost</td>
<td>$/kW</td>
<td>$15</td>
<td>$25</td>
<td>$250</td>
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<tr>
<td>Capital Recovery Period</td>
<td>Yrs</td>
<td>20</td>
<td>20</td>
<td>20</td>
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<tr>
<td>Capital Discount Rate</td>
<td>%</td>
<td>8</td>
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<tr>
<td>Capital Recovery Factor</td>
<td>%</td>
<td>10</td>
<td>10</td>
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</tbody>
</table>
Annualized Costs

![Annualized Costs Graph]

- **Capital**
- **Maintenance**
- **Power**
- **Catalyst**
- **Chemicals**

**Annualized Costs ($/Yr)**

- **SNCR**
- **PerNOxide**
- **SCR**
SNCR + PerNOxide offers 60-70% removal at <$3000/ton NOx
Summary

• **PerNOxide Technology is a 2-Step Process**
  – Oxidation of NO – Capture in Wet/Dry FGD

• **Capture of NO\textsubscript{2} is Critical**
  – WFGD: mass-transfer, sulfite, pH - important
  – Scrubber chemistry modification may be required

• **PerNOxide is Low-Cost Alternative to SCR**
  – Capital costs $1/10^\text{th}$ that of SCR
  – Annualized costs $1/3^\text{rd}$ that of SCR
  – Cost effectiveness ($/\text{ton}$) 1/2 that of SCR
  – Incremental SCR costs > $10,000/\text{ton NOx}$
  – Economics improved when combined with SNCR
Questions?

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