Multi-Pollutant Catalyst for Combustion Turbine Power Plants

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Presentation Overview

- Multi-Pollutant Catalyst (METEOR™ MPC)
  - Background
  - Full-Scale Installation

METEOR™ MPC in ELITE™ Configuration

Ennis Power Company, LLC
Multi-Pollutant Catalyst (METEOR™ MPC)

→ BACKGROUND
BACKGROUND

Traditional HRSG Layout
→ CO Oxidation Catalyst → AIG → SCR Catalyst
**BACKGROUND**

**Catalyst Overview**

**METEOR™ MPC**

- Homogeneously extruded honeycomb catalyst (1 layer)
- **SCR** functionality $\rightarrow$ $V_2O_5$-WO$_3$/TiO$_2$
- **Oxidation** functionality $\rightarrow$ PGM (Pd and/or Pt)
- Initially developed and patented by **Siemens Energy** (US 7,390,471)
- Optimized and fully developed into commercial production by **Cormetech**

**Compounds Removed**

- $4NO + 4NH_3 + O_2 \rightarrow 4N_2 + 6H_2O$
- $2NO + 2NO_2 + 4NH_3 \rightarrow 4N_2 + 6H_2O$
- $6NO_2 + 8NH_3 \rightarrow 7N_2 + 12H_2O$
- CO oxidation to CO$_2$
- VOC oxidation to CO$_2$ and H$_2$O

*Installed in the place of traditional SCR*
BACKGROUND
Single Layer HRSG Layout
→ AIG → METEOR™ MPC

Oxidizing Function:
CO oxidation to CO₂
VOC oxidation to CO₂ and H₂O

Reduction Function:
4NO + 4NH₃ + O₂ → 4N₂ + 6H₂O
2NO + 2NO₂ + 4NH₃ → 4N₂ + 6H₂O
6NO₂ + 8NH₃ → 7N₂ + 12H₂O
**BACKGROUND**

**Example Lab-Reactor Data**

**METEOR™ MPC**

- **DeNOx and CO oxidation** → high conversion rates over wide temperature range.
- **Active for VOC oxidation** → rate depends on hydrocarbon speciation.
- **PGM loading** can be adjusted to optimize performance at low/high temperature.
- **Applications**: CCGT, SCGT, diesel/gas RE, refinery process units

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**Test Conditions**

**DeNOx and CO Oxidation**

- Test Conditions
  - NOx = 25 ppm
  - CO = 25 ppm
  - O₂ = 15%
  - H₂O = 7%
  - NH₃ slip 3 - 7 ppm
  - Constant SV

**VOC Oxidation**

- Test Conditions
  - NOx = 25 ppm
  - O₂ = 15%
  - H₂O = 7%
  - [C₃H₈ = 20 ppm, or C₃H₆ = 20 ppm]
  - NH₃ slip 3 - 7 ppm
  - Constant SV

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![Graphs showing DeNOx and CO Oxidation vs. Temperature](image-url)
**BACKGROUND**

**Example Lab-Reactor Data**

**METEOR™ MPC**

- **Similar** $\text{SO}_2$ oxidation rate as traditional SCR catalyst.
- Short-term exposure to **50 ppm $\text{SO}_2$** has **no significant impact** on CO oxidation.

**SO$_2$ Oxidation**

<table>
<thead>
<tr>
<th>Test Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx = 25 ppm</td>
</tr>
<tr>
<td>Inlet MR = 1.1</td>
</tr>
<tr>
<td>$\text{O}_2$ = 15%</td>
</tr>
<tr>
<td>$\text{H}_2\text{O}$ = 8%</td>
</tr>
<tr>
<td>CO = 100 ppm</td>
</tr>
<tr>
<td>$\text{SO}_2$ = 500 ppm</td>
</tr>
<tr>
<td>Constant SV</td>
</tr>
</tbody>
</table>

**Sulfur Durability**

<table>
<thead>
<tr>
<th>Test Conditions</th>
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<tbody>
<tr>
<td>NOx = 25 ppm</td>
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<tr>
<td>Inlet MR = 1.1</td>
</tr>
<tr>
<td>$\text{O}_2$ = 15%</td>
</tr>
<tr>
<td>$\text{H}_2\text{O}$ = 5%</td>
</tr>
<tr>
<td>CO = 100 ppm</td>
</tr>
<tr>
<td>Constant SV</td>
</tr>
</tbody>
</table>
**BACKGROUND**

**Summary of Benefits**

**METEOR™ MPC**

- **Simplicity:** *one catalyst layer vs. two.*
  - Smaller footprint in HRSG.
  - Lower pressure drop.
  - Lower capital and O&M costs.

- **Flexibility:** applicable to new units, retrofits, and replacements.

- **Lower SO$_2$ oxidation rate,** relative to the traditional two catalyst layout.
  - Potential for reduced backend fouling.

- **Highly resistant to sulfur** compounds in the flue gas.
  - Broader load flexibility from reduced sensitivity to sulfur fouling agents when operating at low temperature.
BACKGROUND
Financial Benefit of Reduced Pressure Drop
METEOR™ MPC

Example:
- Reduced DP by 2” H₂O

Full load:
- Increased power sold.

Intermediate load:
- Lowered gas consumption.

**Lower DP achieves tangible financial benefits.**

<table>
<thead>
<tr>
<th>Saving due to new pressure loss @ Full Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>GT gross MW generated</td>
</tr>
<tr>
<td>Pressure drop reduction (inch H₂O)</td>
</tr>
<tr>
<td>Natural Gas price $/MMBtu</td>
</tr>
<tr>
<td>Catalyst guarantee (year)</td>
</tr>
<tr>
<td>Operating hours per year</td>
</tr>
<tr>
<td>Annual gross power output MW</td>
</tr>
<tr>
<td>Price of electricity sold $/MWh</td>
</tr>
<tr>
<td>Power output correction with correction curves for pressure drop</td>
</tr>
<tr>
<td>Total revenue for electricity sold</td>
</tr>
<tr>
<td>Total revenue for electricity sold with new pressure drop</td>
</tr>
<tr>
<td>Increase revenue from power sold over 5 years</td>
</tr>
<tr>
<td>Annual revenue increase from power sold/unit/year</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Saving due to new pressure loss @ Intermediate Load</th>
</tr>
</thead>
<tbody>
<tr>
<td>GT gross MW generated</td>
</tr>
<tr>
<td>GT Gross Heat Rate Btu/kWh (HHV)</td>
</tr>
<tr>
<td>Pressure drop reduction (inch H₂O)</td>
</tr>
<tr>
<td>Natural Gas price $/MMbtu</td>
</tr>
<tr>
<td>Catalyst guarantee (year)</td>
</tr>
<tr>
<td>Operating hours per year</td>
</tr>
<tr>
<td>Heat rate correction with correction curves for pressure drop</td>
</tr>
<tr>
<td>Total gas consumption</td>
</tr>
<tr>
<td>Total gas consumption corrected with new pressure drop</td>
</tr>
<tr>
<td>Gas consumption saving from improved heat rate over 5 years</td>
</tr>
<tr>
<td>Annual gas consumption saving/ unit/ year</td>
</tr>
<tr>
<td>Total net benefit over 5 years</td>
</tr>
<tr>
<td>Annual net benefit/unit/year</td>
</tr>
</tbody>
</table>
BACKGROUND
Module Options
METEOR™ MPC

1. Traditional Horizontal Flow “Standard Module”

2. Patented “Advanced Module” for Gas-Fired SCR Units

3. Canister: ULFA:


METEOR™ MPC + ELITE™ Module = Optimal Low DP
Multi-Pollutant Catalyst (METEOR™ MPC)

→ Full-Scale Installation
Ennis Power Company, LLC (Ennis, Texas).

Siemens 501G unit combustion turbine (340MW combined cycle mode).

**METEOR™ MPC / ELITE™** replaced existing SCR catalyst in November 2015.

**Guaranteed emission reductions** of NOx, NH₃ slip, CO and VOC.

Successfully operating. Currently at >5,000 hours run time.
FULL-SCALE INSTALLATION
Ennis Power Company, LLC
Motivation

Replacement of existing SCR layer with a METEOR™ MPC catalyst layer enabled:
(1) Capability to operate at lower loads while maintaining CO emission compliance.
(2) Faster compliance of CO emissions during unit startup.

Data slide courtesy of Siemens.
FULL-SCALE INSTALLATION
Ennis Power Company, LLC
Field Test Data (April 2016)

- Field testing validation: measured SCR inlet and outlet gas composition
  - SCR inlet = GT exhaust gas.
  - Fresh catalyst achieved ~99% CO oxidation at 36% GT load point.
  - DeNOx achieving target value. NH₃ slip is very low due to the fresh catalyst state.

<table>
<thead>
<tr>
<th>GT Load</th>
<th>SCR Temperature (°C)</th>
<th>GT Exhaust Gas Composition</th>
<th>SCR Outlet Gas Composition</th>
<th>Meteor SCR Catalyst Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>GT Exhaust CO (ppm)</td>
<td>GT Exhaust NOₓ (ppm)</td>
<td>SCR Outlet CO (ppm)</td>
</tr>
<tr>
<td>98%</td>
<td>342</td>
<td>0.5</td>
<td>29.4</td>
<td>0.0</td>
</tr>
<tr>
<td>76%</td>
<td>334</td>
<td>0.6</td>
<td>32.8</td>
<td>0.0</td>
</tr>
<tr>
<td>36%</td>
<td>322</td>
<td>172</td>
<td>44.0</td>
<td>2.2</td>
</tr>
</tbody>
</table>
- CO emissions reduced after METEOR™ MPC installed.
- CO emissions vs. GT load: impact of METEOR™ MPC installation.
- **METEOR™ MPC installation increased the unit’s turndown capability.**

![Diagram](image-url)

**Normalized GT Load**

- Turndown limited to ~50% normalized GT load
- Multi-Pollutant Catalyst Installed
- Achieving 35% normalized GT load
FULL-SCALE INSTALLATION
Ennis Power Company, LLC
Plant Operating Data

- Same NOx emissions (per design).
- Lower NH$_3$ slip emissions (fresh catalyst).
No change in NH$_3$ usage rate after METEOR™ MPC installation.
~2 inch H$_2$O reduction in system backpressure (compared at constant flow)
Inspected catalyst on October 25, 2016:

The catalyst was in excellent condition, and the cells were clean and open. These observations are consistent with the measured back pressure trends.
Simultaneously reduces NOx, CO, VOCs and NH3 slip to compliance levels in one catalyst layer located at the traditional SCR catalyst location.

- Lower system pressure drop.

Provides benefits:

- Total emissions regulation compliance.
- Extended operating flexibility by extending the unit load operating range.
- Reduction of corrosion of the HRSG section downstream of the SCR.
- Lower O&M costs.

Applicable to new units, retrofits, and replacements.

Successfully operating at Ennis Power Company, LLC.
Thank you for your attention!

See us at our PowerGen booth, send us an e-mail, or give us a call!

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