NOx CONTROL WITH SNCR TECHNOLOGY
CEMENT PLANTS

Industrial Accessories Company
4800 Lamar Ave
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IAC is a Innovative Technology & Solution Provider

**OEM PRODUCTS:** Baghouses & Bulk Material Handling
Pneumatic Conveying

**SYSTEMS:** DSI & Hg Mitigation for MATS Compliance
Recirculation Scrubber & Semi-Dry FGD
NOx Control; SNCR Technology
Frac Sand Terminals and Distribution
Bolted Tanks with Installation

**SERVICES:** Demonstration Testing for Hg & MATS Compliance
ESP & Baghouse Conversions
Baghouse Maintenance & Bag Change-out
Parts and Component Sales
Mechanical Installation

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WHAT IS NOx

NOx is defined as Mono-nitrogen oxides (NO & NO$_2$)

- Produced during combustion at high temperatures.
- NOx formation is promoted by rapid fuel-air mixing, which produces high peak flame temperatures and with excess oxygen, forms NOx emissions.

The high temperatures and oxidizing atmosphere required for cement manufacturing are also favorable for NOx formation. In cement kilns, NOx emissions are formed during fuel combustion by two primary mechanisms:
1. Oxidation of molecular nitrogen present in combustion air (thermal NOx)
2. Oxidation of nitrogen compounds in fuel (fuel NOx).
THERMAL NOx

Thermal NOx results from the homogeneous reaction of oxygen and nitrogen in the gas phase at high temperatures.

\[ 2 \text{N}_2 + \text{O}_2 = 2 \text{NO} + 2 \text{N} \]

\[ \text{N} + \text{O}_2 = \text{NO} + \text{O} \]

NO vs. temperature at various O2 levels
NOx COMPLIANCE – CEMENT PLANTS

The NO\textsubscript{x} emission specifications apply to units placed into service before December 31, 1999:

- long wet kilns
- long dry kilns
- preheater kilns
- preheater-precalciner kilns
- precalciner kilns
CEMENT KILNS

Long Wet and Dry Cement Kiln Process

KILN FEED
GASES TO PRECIPITATOR

KILN DRIVE
CALCINING ZONE
DRYING ZONE

COOLER
COOLER FANS
CLINKER TO STORAGE

BURNER FAN
COAL WATER FUEL
GAS
COKE

CLINKERING ZONE
CEMENT KILNS

Preheater and Precalculator Kiln Process

KILN FEED
GASES TO PRECIPITATOR

PREHEATER TOWER

DRYING ZONE
TIRE FEED

GAS COKE
COAL WATER FUEL

BURNER FAN

COOLER
COOLER FANS

CLINKER TO STORAGE

CLINKERING ZONE
CALCINING ZONE

KILN DRIVE

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NOx COMPLIANCE – CEMENT PLANTS

EPA amended the new source performance standards to reduce NOx; SO2 & PM for new Kilns. NOx & SO2 controls are required per the NSPS standards & SIP establishes the plant specific compliance requirements.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Emission Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx</td>
<td>1.5 lb/ton clinker, averaged over 30 days</td>
</tr>
<tr>
<td>SO2</td>
<td>0.4 lb/ton clinker, averaged over 30 days</td>
</tr>
</tbody>
</table>
NOx CONTROL FOR CEMENT KILNS

The NO\textsubscript{x} emission specifications apply to units placed into service before December 31, 1999:

- Combustion Modifications
- Low NO\textsubscript{x} Burners
- Staged Air Combustion
- SNCR
- SCR

<table>
<thead>
<tr>
<th>FUEL</th>
<th>KILN TYPE</th>
<th>WET</th>
<th>LONG (DRY)</th>
<th>PREHEATER</th>
<th>PRECALCINER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural Gas</td>
<td></td>
<td>9</td>
<td>7 - 9.5</td>
<td>5.65</td>
<td>1.7 - 3</td>
</tr>
<tr>
<td>Coal</td>
<td></td>
<td>1.45 - 4.33</td>
<td>2.4 - 4.6</td>
<td>1.5 - 2.85</td>
<td>1.35 - 1.95</td>
</tr>
</tbody>
</table>

Kg of NO\textsubscript{2}/Ton of Clinker

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SNCR-NOx REDUCTION

An SNCR system’s performance depends on temperature, residence time, turbulence, oxygen content, and a number of factors specific to the given gas stream.

SNCR removes NOx (90–95% of NOx in flue gas is NO) by a two-step process, as follows:

Ammonia reacts with available hydroxyl radicals to form amine radicals and water:
NH3 + OH = NH2 + H2O (1)

Amine radicals combine with nitrogen oxides to form nitrogen and water:
NH2 + NO = N2 + H2O (2)

These 2 steps are typically expressed as follows:
4 NO + 4 NH3 + O2 = 4 N2 + 6 H2O (3)
4 NH3 + 2 NO2 + O2 = 3 N2 + 6 H2O (4)

Equation 3 is the predominant reaction because 90–95% of NOx in flue gas is NO.
SNCR FOR CEMENT KILNS

SNCR systems are applied where favorable reduction conditions in the cement burning process are found, at a temperature window of 1550 – 2000°F with sufficient retention time. An injection of ammonia water as the carrier of the reduction agent ammonia is the most applied technique. A good ammonia distribution is required to optimize utilization and to reduce the ammonia slip.

SNCR functions best in an oxidizing atmosphere.

\[4\text{NO} + 4\text{NH}_3 + \text{O}_2 = 4\text{N}_2 + 6 \text{H}_2\text{O}\]

In a reducing atmosphere, CO competes with ammonia for available OH radicals, thus inhibiting reaction of Ammonia with the OH radical.

\[\text{CO} + \text{OH} = \text{CO}_2 + \text{H}\]
EQUIPMENT NEEDED FOR SNCR

1. STORAGE & TRUCK UNLOADING.
2. INJECTION PROCESS:
   A. PUMP.
   B. PUMP SKID.
   C. AMMONIA FLOW CONTROL UNIT.
   D. CONVEY PIPING & LANCES
   E. MEASUREMENT OF AMMONIA FEED.
   F. TEMPERATURE MONITORS.
   G. NOx MEASUREMENT IN FLUE GAS EXIT.
SNCR-NOx REDUCTION WITH AMMONIA & UREA AT VARIOUS TEMPERATURE RANGE

![Graph showing NOx reduction efficiency vs temperature for Ammonia and Urea]
SNCR-NOx REDUCTION & RESIDENCE TIME

![Graph showing NOx Reduction Efficiency vs Temperature](image-url)
NO\textsubscript{x} reduction depending on NH\textsubscript{3}/NO molar ratio for precalciner kilns

source: Krupp Polysius AG(ZKG 7/2001)
# TEMPERATURE AT INJECTION LOCATION

<table>
<thead>
<tr>
<th>Reference</th>
<th>Ammonia/Urea</th>
<th>Gas Temp (°C)</th>
<th>Gas Temp (°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EC/R Report</td>
<td>Urea</td>
<td>870–1,090</td>
<td>1,600–2,000</td>
</tr>
<tr>
<td>Mussati</td>
<td>Urea</td>
<td>900–1,150</td>
<td>1,650–2,100</td>
</tr>
<tr>
<td>Florida Rock test report</td>
<td>Urea</td>
<td>1,000</td>
<td>1,830</td>
</tr>
<tr>
<td>EC/R Report</td>
<td>Ammonia</td>
<td>920–980</td>
<td>1,660–1,840</td>
</tr>
<tr>
<td>Mussati</td>
<td>Ammonia</td>
<td>870–1,100</td>
<td>1,600–2,000</td>
</tr>
<tr>
<td>Florida Rock test report</td>
<td>Ammonia</td>
<td>950</td>
<td>1,750</td>
</tr>
<tr>
<td>Technical evaluation – Suwanee</td>
<td>Both</td>
<td>850–1,050</td>
<td>1,560–1,920</td>
</tr>
<tr>
<td>NESCAUM</td>
<td>Both</td>
<td>870–1,100</td>
<td>1,600–2,000</td>
</tr>
<tr>
<td>Draft 1 fond report</td>
<td>Both</td>
<td>800–1,100</td>
<td>1,470–2,000</td>
</tr>
<tr>
<td>Penta report</td>
<td>Both</td>
<td>900–1,000</td>
<td>1,650–1,830</td>
</tr>
</tbody>
</table>
## REPRESENTATIVE SNCR PERFORMANCE

<table>
<thead>
<tr>
<th>Plant/Source</th>
<th>Control Level (lb/t)</th>
<th>Efficiency (%)</th>
<th>NSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 European kilns⁹</td>
<td>NA</td>
<td>25–50; 35–60; 42–72</td>
<td>0.6; 0.8; 1.0</td>
</tr>
<tr>
<td>Ash Grove, Seattle¹³</td>
<td>2.2; 1.3</td>
<td>25; 55</td>
<td>0.5; 1.0</td>
</tr>
<tr>
<td>Hercules; PA¹⁹</td>
<td>300 ppm ~3.0</td>
<td>12–25</td>
<td>NA</td>
</tr>
<tr>
<td>Suwannee American³⁸</td>
<td>2.0</td>
<td>33–50</td>
<td>NA</td>
</tr>
<tr>
<td>Florida Rock⁷ without tires</td>
<td>1.9; 2.6</td>
<td>47; 29</td>
<td>0.47; 0.35</td>
</tr>
<tr>
<td>Florida Rock⁷ with tires</td>
<td>2.1</td>
<td>34</td>
<td>0.12–0.25</td>
</tr>
<tr>
<td>Holcim – Texas⁵⁴ (2 kilns)</td>
<td>NA</td>
<td>47, 32</td>
<td>0.7</td>
</tr>
<tr>
<td>Skovde, Sweden³, ⁵¹</td>
<td>0.5–1.0</td>
<td>80–85</td>
<td>1.0–1.1</td>
</tr>
<tr>
<td>Slite, Sweden³, ⁵¹</td>
<td>1.1</td>
<td>80</td>
<td>1.0</td>
</tr>
<tr>
<td>Taiwan-2 kilns¹</td>
<td>194 ppm; 284 ppm ~2.0; 2.9</td>
<td>50; 46</td>
<td>NA</td>
</tr>
<tr>
<td>Cemex; FL-preheater kiln²⁴</td>
<td>2.0</td>
<td>50</td>
<td>0.6–0.7</td>
</tr>
<tr>
<td>European Report⁵² - achievable</td>
<td>1.0</td>
<td>80–85</td>
<td>NA</td>
</tr>
<tr>
<td>European Report⁵² - actual operation</td>
<td>2.5–4.0</td>
<td>10–50</td>
<td>0.5–0.9</td>
</tr>
</tbody>
</table>
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