LoTOx™ flue gas cleanup technology

- Works on any “dirty” exhaust gas streams to oxidize and then capture NOx, Hg and other pollutants
- Needs oxygen supply for ozone generation
- Suitable when
  - NOx removal required is greater than 80% OR
  - Stack emissions must be below 20 ppmv
- Co-benefit Hg oxidation in 30-80 %
- Integrated easily with wet or dry (spray dryer) scrubber
- Commercial installation on 25 MW Coal fired
- Presently 25 FCC regenerator Off Gas is retrofitted with LoTOx for NOx control
Typical stationary NOx source

Combustion or other NOx Gas Emissions Source

NOx, SOx, HCl, Particulates, Heavy Metals

Raw NOx, NO and NO2

New or Existing Scrubber
LoTOx process integrated

Combustion or other NOx
Gas Emissions Source

NOx, SOx, HCl,
Particulates, Heavy Metals

Raw NOx,
NO and NO2

New or Existing
Scrubber

Ozone

Oxygen/Ozone Supply

Analyzers & Controls

Linde Confidential
LoTOx system process reactions

Oxidation with O₃

Converts insoluble NOx to highly soluble form

\[ \text{NO} + \text{O}_3 \rightarrow \text{NO}_2 + \text{O}_2 \]

\[ 2 \text{NO}_2 + \text{O}_3 \rightarrow \text{N}_2\text{O}_5 + \text{O}_2 \]

Oxidizes Hg

\[ \text{Hg}^0 + \text{O}_3 \rightarrow \text{Hg}^{+2} + \text{O}_2 \]

Very slow to oxidize CO and SO₂

\[ \text{CO} + \text{O}_3 \rightarrow \text{CO}_2 + \text{O}_2 \quad \text{(Slow)} \]

\[ \text{SO}_2 + \text{O}_3 \rightarrow \text{SO}_3 + \text{O}_2(\text{Slow}) \]

Oxidized NOx is very soluble in aqueous media

\[ \text{N}_2\text{O}_5 + 2 \text{H}_2\text{O} \rightarrow 2 \text{HNO}_3 \]
LoTOx™ - Medical College of Ohio

25 MW Coal-fired power plant - LoTOx™ reactor duct and scrubber
LoTOx System results on 25 MW coal fired boiler

Performance of LoTOx System at MCO
December 6, 2001
Outlet NOx Setpoint = 5 PPM Changed to 10 PPM

Flue Gas Temp = 179 - 234 F
Scrubber Temp = 75 - 100 F
Inlet SOx = 74 - 178 ppm
Inlet CO = 150 - 300 ppm
# Commercial LoTOx installations

<table>
<thead>
<tr>
<th>#</th>
<th>Application</th>
<th>Exhaust gas flow (Nm(^3)hr(^{-1}))</th>
<th>NOx Inlet (mg/m(^3))</th>
<th>NOx Outlet (mg/m(^3))</th>
<th>Startup Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>400 HP NG fired boiler</td>
<td>6 300</td>
<td>55-130</td>
<td>4</td>
<td>1997-8</td>
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<tr>
<td>2</td>
<td>Stainless steel pickling</td>
<td>6 300</td>
<td>6 400</td>
<td>188</td>
<td>2000</td>
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<tr>
<td>3</td>
<td>25 MW coal fired boiler</td>
<td>142 000</td>
<td>375</td>
<td>19 – 38</td>
<td>2001</td>
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<tr>
<td>4</td>
<td>Lead recovery furnace</td>
<td>41 000</td>
<td>95-280</td>
<td>19</td>
<td>2002</td>
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<td>5</td>
<td>1000 HP NG fired boiler</td>
<td>16 000</td>
<td>37.5-75</td>
<td>8</td>
<td>2001</td>
</tr>
</tbody>
</table>

**2003-2012**

| 6-10 | Five FCCs in US                                   | 60 000-410 000                         | 130-225                 | 15-38                    | 2007         |
| 11-12| Sulfuric acid dual plants                         | 2 x 26 500                             | 170                     | 19                       | 2008         |
| 13-21| Six additional FCC + Three LoTOx ready installations in USA | 20 000 – 485 000                       | 130 – 470               | 19-35                    | 2008-13      |
| 22-29| Seven FCC + 1st Refinery Boiler + One LoTOx ready installation in China | 306 000-620 000                       | 185 - 320               | 37 - 137                 | 2012-15      |
| 30   | 1st FCC in Thailand                               | 210 000                                 | 480                     | 38                       | 2014         |
| 31-42| 12 Demos and feasibility studies                 | >315                                    | vary                    | 9                        | 1999-2011    |