Ultra-Low NOx Lean Premix Burners
Eliminate SCRs for Process Heaters

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What we would **LIKE** to do!

What we would **NOT** like to do!
OK, fine, you may prefer to do burners, but which SCRs make the most sense?

• Really BIG ones …
• The bigger the better …
• They’re all highly effective …
• But the bigger they are the more cost-effective they become!
Build really BIG SCR's!

Firing Rate, mmBtu/hr

$mm \$ \propto (mmBtu)^{1/2}$
Be Safe or...

... I'll KILL you!
Pre-lift Safety Talk
Why we don’t like SCR's too much . . .

It’s only money!

... but when we *HAVE* to go for SCR, BIGGER is BETTER!
Developing and Retrofitting Ultra Low NOx Burners in a Refinery Furnace

The Skunk Works Approach!
Perception of Difficulty vs. Understanding

Increasingly more difficult as your understanding begins to grow ...

"Easy" because you don't know anything ...

Perceived difficulty decreases with further growth of understanding ...

"Thank God a'mighty it's 'easy' again...!"
Lots of ways to skin a cat.

Thermal NOx Concentration vs. Combustion Air Supplied

- Uncontrolled
- Air-staging
- Flue gas recirculation
- Fuel-staging
- Fuel-dilution

Peak Temperature, NOx Reaction Rate, NOx Concentration
Not really . . . it’s all about making a low-Btu fuel!
The Trick?
Deep penetration into the low-Btu regime whilst maintaining flame stability!

ULTRA LEAN PREMIX

Flammability Limit
Design burner to operate in this region

Relative NOx Emissions
Region of Stoichiometric Combustion

Diffusion Flame
Premix Flame

Fuel rich combustion → Fuel lean combustion

Flammability Limit

ULTRA LEAN PREMIX
Air as the Diluent
John Zink LPM 305F

Lean PreMix Burner in the Test Furnace

Fuel

<table>
<thead>
<tr>
<th>Btu/scf</th>
<th>(H%)</th>
<th>NOx ppm (@ 3% O2, 1700°F)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,440</td>
<td>27%</td>
<td>9</td>
</tr>
<tr>
<td>810</td>
<td>65%</td>
<td>10</td>
</tr>
</tbody>
</table>

Tulsa, Oklahoma
Chevron Richmond
#4 Crude Unit
Ultra² Low NOx Burner Retrofit
**SCR Reduction (92%) at a Burner Price!**

*For process heating you DON’T need a selective catalytic reduction flue gas treatment plant but you really DO need burners so why not super-low NOx burners?*
3 Cell Terrace Wall Furnace
22 8 Burners
250 MW total input
Test Furnace: 12 ppm
Field Application: <15 ppm
Original Burner: ~150 ppm
• Shape of curve confirmed in every capital project we have either done or studied
• Significant difference between 65% and 85%
• That kind of difference roughly DOUBLES the cost
• Paying public & stockholders like the lower cost better
OK, here’s the deal ...

On a big furnace or string of furnaces breeched together:

<table>
<thead>
<tr>
<th>Burners</th>
<th>SCR</th>
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<tbody>
<tr>
<td>CapEx</td>
<td>~$6-million</td>
</tr>
<tr>
<td>OpEx</td>
<td>0</td>
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<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Excess O₂</td>
<td>2%</td>
</tr>
<tr>
<td></td>
<td>(~$350,000/yr)</td>
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A Passion for Technology Innovation & Application

Chevron Richmond NOx Project — Huge Savings by Inspiring & Supporting the Development of Extremely Low-NOx Burners

![CapEx](No SCR at the boiler house! .................. ~$10m ~$2m/yr)

![CapEx](No SCR at crude unit F1100/F1160! ... ~$10m ~$2m/yr)

![CapEx](No SCR at hydrogen reformer F355! ... ~$10m ~$2m/yr ~$30m ~$6m/yr)

😊 Intense collaboration with burner suppliers

😊 32 vacuum cell burners installed **on-the-run**

⇒ Favorable margins — NO shutdown contributed to refinery profitability

😊 Synergy with Chevron Phillips Chemical Co’s NOx Project

😊 “EYE” thrust upgrades **Energy** (↓ fuel use), **Yield** (↑ feed rate and run length) and **Environmental** (↓ emissions) performance!