Rule 1109.1 - Refinery Equipment

Working Group Meeting #4
September 12, 2018
Agenda

1. Summary of Working Group Meeting #3
2. Progress of Rule Development
3. Rule Applicability - Boiler/Heaters and Flares
4. Control Technology Assessment - Commercially Available
5. Control Technology Assessment - Emerging Technology
6. Next Steps
Progress of Rule Development

Summary of Working Group #3 (8/1/18)

• Reviewed other Air District regulations & current SCAQMD regulations
• Discussed three of the four steps in BARCT technology assessment
• Presented revised equipment emissions data

Since last Working Group Meeting

• Analyzing submitted survey data (including ammonia slip)
• Researching NOx control technologies available and currently used in practice
• Completing Request for Proposal (RFP) for 3rd party BARCT validation
• Continuing site visits and meetings with stakeholders
Rule Applicability
Rule Applicability - **Boilers/Heaters**

- Proposed Rule (PR) 1109.1 applicable to all equipment at refineries?
  - Small heaters used to heat buildings?

- Consider excluding boilers/heaters subject to Rule 1146.2 - *Emissions of Oxides of Nitrogen from Large Water Heaters and Small Boilers and Process Heaters*
  - Rule 1146.2 applicable to:
    - Manufacturers, distributors, retailers, refurbishers, installers and operators of new units
    - Units that have a rated heat input capacity less than or equal to 2 MMBtu/hr
Rule Applicability - **Boilers/Heaters**

**Industry Specific**
- Rule 1109.1
  - Refinery equipment

**Source Specific**
- Rule 1146.2
  - NOx from small boiler and process heaters

**Boilers, Process Heaters**

- > 2 MMBtu/hr
- ≤ 2 MMBtu/hr
Staff developing Proposed Rule 1118.1 - Control Of Emissions From Non-refinery Flares

Non-refinery flares could be in operation at PR 1109.1 facilities for:
- Truck/railcar loading and unloading
- Wastewater
- Tank farm

Consider including all non-refinery flares in PR 1109.1

Refinery flares will remain subject to Rule 1118 - Control of Emissions from Refinery Flares
Rule Applicability - Flares

**Refinery Emergency Flare**

**Rule 1118 Refinery Flares**

**Non-Refinery Flares**

Loading/unloading, Tank farm, Wastewater, Asphalt blowing, Soil remediation

**Rule 1109.1 Refinery Equipment (Not Rule 1118.1)**
Pollution Control Technology Assessment
BARCT Analysis Approach Overview

1. Identify Emission Levels for Existing Units
2. Assess Rules in Other Air Districts for Same Source
3. Technology Assessment
4. Establishing the BARCT Emission Limit and Other Considerations
5. Cost Effectiveness
Technology Assessment (Steps 1 - 3 of 4)

WGM #3

- Other Regulatory Requirements
- Assessment of SCAQMD Regulatory Requirements
- Assessment of Emission Limits for Existing Units
- Assessment of Pollution Control Technologies
Technology Assessment (Step 4 of 4)

- Other Regulatory Requirements
- Assessment of SCAQMD Regulatory Requirements
- Assessment of Emission Limits for Existing Units
- Assessment of Pollution Control Technologies
Assessment of Pollution Control Technology

**Objective:** Identify and evaluate pollution control technologies, approaches, and potential emission reductions

- Pollution control technology assessment all encompassing
- Assess current status of technologies and potential emission reductions
  - Retrofit/replacement/technology transfer
- Consider environmental impacts
  - Impacts from equipment installation
  - Disposal or treatment of waste product
  - Transportation of hazardous material
Assessment of Pollution Control Technology (cont’d)

**Identified NOx controls technologies for**
- Gas turbines
- Primary internal combustion engines (ICE)
- Boiler/process heaters
- Fluidized Catalytic Cracking Unit (FCCU)
- SRU/TG incinerators & Non-SRU incinerators
- Coke calciner

**Sources of information**
- Scientific literature
- Vendor information and meetings
- Technologies currently utilized in practice
- Other regions with petroleum refineries (e.g., MARAMA, BAAQMD, NW Clean Air Agency, Texas-Houston/Galveston)
Assessment of Pollution Control Technology (cont’d)

For each source category, staff evaluated:

- Available technology
- NOx control principles, key features, and considerations
- Emission reduction potential
- Technology transfer

NOx control technologies include:

- Combustion control technologies
- Post-combustion control (add-on)
- Trim technologies (low cost with limited reduction potential)
- Replacement with new cleaner equipment
Assessment of Pollution Control Technology (cont’d)

NOx emission limit achievable for each control technology still being evaluated

- Evaluation will continue through RFP
- Staff will continue to meet with vendors
- NOx emission limit achievable for each technology will be presented in future working group meeting
### NOx Control Principles

<table>
<thead>
<tr>
<th>Principles</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduce peak flame temperature</td>
<td>Excess of fuel, air, steam, or flue gas to reduce thermal NOx</td>
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<tr>
<td>Reduce residence time</td>
<td>Prevents formation of thermal NOx</td>
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<tr>
<td>Chemical reduction of NOx</td>
<td>Chemically reducing/removing oxygen from NOx to form $N_2$</td>
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<tr>
<td>Oxidation of NOx with absorption</td>
<td>Convert NOx to $N_2O_5$ using catalyst, ozone, or $H_2O_2$ with subsequent scrubber</td>
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<tr>
<td>Sorbent</td>
<td>Injected into flue, baghouse, and combustion chamber followed by filtration and/or ESP</td>
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<tr>
<td>Removal of $N_2$ (O$_2$ Enhanced)</td>
<td>Remove $N_2$ as a reactant in the combustion process</td>
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<tr>
<td>Combination of these methods</td>
<td>Methods can be combined to achieve lower NOx</td>
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Assessment of Pollution Control Technology

Technology Assessment evaluated

Commercially available control technologies
- Available and applicable
- Commercially demonstrated/licensed
- Source-specific application with considerations for technology transfer

Emerging control technologies
- Not commonly used in industry/not reached commercial demonstration/licensing
- Novel technologies not yet demonstrated in the field applications
- Limited data available for source specific applicability
Commercially Available Control Technology
<table>
<thead>
<tr>
<th>Combustion Source</th>
<th>Water/Steam Injection</th>
<th>FGR</th>
<th>NOx Additive</th>
<th>Dry Low-NOx Combustor</th>
<th>Ultra Low-NOx Burners</th>
<th>Low-NOx Burners</th>
<th>LoTOx™ w/ WGS</th>
<th>WGS+™</th>
<th>SNCR</th>
<th>NSCR</th>
<th>SCR</th>
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<tr>
<td>Boilers/Steam Generators</td>
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<tr>
<td>Heaters/Furnaces</td>
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<td>Gas Turbines</td>
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<td>Control Type</td>
<td>Description</td>
<td>Principle</td>
<td>Key Features</td>
<td>Considerations</td>
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<tr>
<td>Selective Catalytic Reduction (SCR)</td>
<td>Promotes reaction between NH₃ and NOₓ</td>
<td>Chemical reduction of NOₓ</td>
<td>High NOₓ removal</td>
<td>Increased pressure drop&lt;br&gt; • NH₃ and secondary pollutant&lt;br&gt; • Space requirements&lt;br&gt; • Hazardous storage&lt;br&gt; • Waste disposal</td>
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<tr>
<td>Ultra-Low NOₓ Burner (ULNB)/Low-NOₓ Burner (LNB)</td>
<td>FGR pre-mix upstream and rapid mixing of air/fuel near ignition point</td>
<td>Reduce peak flame temperature/residence time</td>
<td>Low operating cost&lt;br&gt; • Stable short flame</td>
<td>Complex design&lt;br&gt; • Requires FGR&lt;br&gt; • Long flame length&lt;br&gt; • Fan capacity&lt;br&gt; • Coalescing/Impingement</td>
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<tr>
<td>Selective Non-Catalytic Reduction (SNCR)</td>
<td>Inject reducing reagent to react with NOₓ</td>
<td>Chemical reduction of NOₓ</td>
<td>Low operating cost&lt;br&gt; • Moderate NOₓ removal</td>
<td>Temperature dependent&lt;br&gt; • NOₓ reduction less at lower loads&lt;br&gt; • NH₃ handling/slip&lt;br&gt; • Furnace geometry temperature profile</td>
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<tr>
<td>Flue Gas Recirculation (FGR)</td>
<td>&lt;30% flue gas (inert) recirculated with air</td>
<td>Reduce peak flame temperature</td>
<td>High NOₓ reduction potential</td>
<td>Affects heat transfer/system pressures&lt;br&gt; • Fan capacity&lt;br&gt; • Furnace pressure&lt;br&gt; • Burner pressure drop&lt;br&gt; • Turndown stability</td>
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Boiler/Heaters

- NOx control may vary depending on
  - Unit size
  - Burner configuration
  - Fuel combusted
- Primary control technologies used are SCR, ULNB/LNB, SNCR, and FGR
- Control technologies can be combined to increase overall NOx reductions
- Other technologies considered, but NOx reduction is limited

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<thead>
<tr>
<th>Control Type</th>
<th>Reduction Achievable</th>
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<tbody>
<tr>
<td>SCR</td>
<td>90% to 95%</td>
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<tr>
<td>ULNB/LNB</td>
<td>60% to 85%</td>
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<tr>
<td>SNCR</td>
<td>40% to 50%</td>
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<tr>
<td>FGR</td>
<td>30% to 50%</td>
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<tr>
<td><strong>LoTOx™ w/Wet Gas Scrubber</strong></td>
<td>Inject ozone to flue gas (NOx to N₂O₅) followed by wet scrubbing</td>
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<tr>
<td><strong>ExxonMobil WGS+ (Wet Gas Scrubber Plus)™</strong></td>
<td>New 20' to 30' section added to existing scrubber/inject additive to remove NOx</td>
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<tr>
<td><strong>DENOX® or ELIMINOx™ NOx Reduction Additive</strong></td>
<td>Low NOx promoter catalyst added 1% to 3% of fresh catalyst feed</td>
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<tr>
<td><strong>Selective Non-Catalytic Reduction (SNCR)</strong></td>
<td>Inject reducing reagent (urea) to react with NOx</td>
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NOx control retrofits for FCCU vary according to:
- Size
- Type of unit
- Primary control used is SCR
- LoTox™ with WGS
  - Achieve same reductions as SCR (multi-pollutant)
  - Successfully installed and operated in FCCU Marathon Texas City refinery
  - Achieving NOx levels <10 ppm
  - Outlet NOx can be varied by controlling ozone

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<th>Control Type</th>
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<tbody>
<tr>
<td>SCR</td>
<td>90% to 95%</td>
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<tr>
<td>LoTox™ w/Wet Gas Scrubber</td>
<td>80% to 95%</td>
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<tr>
<td>ExxonMobil WGS+ (Wet Gas Scrubber Plus)™</td>
<td>50% to 90%</td>
</tr>
<tr>
<td>DENOX® or ELIMINOx™ NOx Reduction Additive</td>
<td>50% to 75%</td>
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<tr>
<td>SNCR</td>
<td>40% to 50%</td>
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<td>Control Type</td>
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</tbody>
</table>
| Selective Catalytic Reduction (SCR)  | Promotes reaction between NH₃ and NOx            | Chemical reduction of NOx                     | • High NOx removal                          | • Increased pressure drop  
• NH₃ and secondary pollutant  
• Space requirements  
• Hazardous storage  
• Waste disposal |
| Ultra-Low NOx Burner (ULNB)/         | FGR pre-mix upstream and rapid mixing of air/fuel| Reduce peak flame temperature/residence time | • Low operating cost  
• Stable short flame                        | • Complex design  
• Requires FGR  
• Long flame length  
• Fan capacity  
• Coalescing/Impingement |
| Low-NOx Burner (LNB)                 | near ignition point                              |                                               |                                             |                                                                                  |
| Flue Gas Recirculation (FGR)         | <30% flue gas (inert) recirculated with air      | Reduce peak flame temperature                | • High NOx reduction potential              | • Affects heat transfer/system pressures  
• Fan capacity  
• Furnace pressure  
• Burner pressure drop  
• Turndown stability |
| Water/Steam Injection                | Inject water or steam to mix with air flow       | Reduce peak flame temperature                | • Moderate capital cost  
• NOx reduction similar to FGR  
• Increased system efficiency         | • Higher power for fan  
• Increases CO  
• Reduces steam available for process |

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**Note:**
- SCR: Selective Catalytic Reduction
- FGR: Flue Gas Recirculation
- ULNB: Ultra-Low NOx Burner
- LNB: Low-NOx Burner
- NOx: Nitrogen Oxides
Gas Turbines (Combined Cycle)

- SCR is primary post combustion control
- Burners are intrinsic to the turbine - not usually available as retrofit
- Combination control technology can further increase NOx reduction
  - ULNB, SCR, CO
  - ULNB, WI, SCR w/CO catalyst
  - 95% or more achievable

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<tbody>
<tr>
<td>SCR</td>
<td>90% to 95%</td>
</tr>
<tr>
<td>ULNB</td>
<td>50% to 85%</td>
</tr>
<tr>
<td>FGR</td>
<td>30% to 50%</td>
</tr>
<tr>
<td>Water/Steam Injection</td>
<td>25% to 60%</td>
</tr>
<tr>
<td>LNB</td>
<td>25% to 35%</td>
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<tr>
<td>Control Type</td>
<td>Description</td>
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</tbody>
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| Selective Catalytic Reduction (SCR)  | Promotes reaction between NH₃ and NOₓ | Chemical reduction of NOₓ          | • High NOₓ removal                                | • Increased pressure drop  
• NH₃ and secondary pollutant  
• Space requirements  
• Hazardous storage  
• Waste disposal                                      |
| Non-Selective Catalytic Reduction (NSCR) | Unburned hydrocarbon fuel as reducing agent | Chemical reduction of NOₓ          | • Low operating cost  
• No reducing agent                                | • Runs rich (catalyst requires <0.5% O₂ in exhaust) |
| Air/Fuel Ratio                       | Air/fuel ratio mixture non-stoichiometric | Reduce peak temperature           | • Low cost                                       | • Combustion instability  
• Engine performance                                    |
| Exhaust Gas Recirculation (EGR)      | Adding combustion products to fresh air/fuel during intake | Reduce peak temperature and combustion pressure | • Low cost  
• Increase knocking tolerances                      | • Loss in engine performance  
• Engine efficiency                                    |
Primary ICE

- Primary control for stationary ICE is SCR and/or EGR
- Combining both SCR and EGR can achieve up 95% or more achievable
- NSCR can achieve up to 90% reduction, but increases fuel consumption
- EGR and/or air/fuel alone
  - Low cost
  - Achieve up to 54% reduction
  - Adversely affects engine performance

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<tr>
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<tbody>
<tr>
<td>SCR</td>
<td>90% to 95%</td>
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<tr>
<td>NSCR</td>
<td>70% to 90%</td>
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<tr>
<td>Air/Fuel Ratio</td>
<td>35% to 50%</td>
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<tr>
<td>EGR</td>
<td>22% to 54%</td>
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<td>Control Type</td>
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</table>
| **LoTOx™ w/Wet Gas Scrubber**    | Inject ozone to flue gas (NOx to N₂O₅) followed by wet scrubbing            | Oxidation of NOx with subsequent absorption                               | • Low operating temp  
• Multi-pollutant control  
• Not affected by load swings                        | • Waste treatment  
• Recovery of Nitric Acid generated                                                                 |
| **UltraCat**                     | Ceramic filters with embedded catalyst and particulate capture               | Chemical Reduction of NOx                                                  | • Multi-pollutant control  
• Low operating temperature                                    | • Operating cost  
• Large plot space requirement                                                                 |
| **Selective Catalytic Reduction (SCR)** | Promotes reaction between NH₃ and NOx                                      | Chemical reduction of NOx                                                   | • High NOx removal                                                                                     | • Increased pressure drop  
• NH₃ and secondary pollutant  
• Space requirements  
• Hazardous storage  
• Waste disposal                                                                 |
Coke Calciner

- Control technology is currently being evaluated
- Assessed other coke calciners
  - Calciners are either equipped with
    - Wet gas scrubber or gas-fired pyroscrubber with dry scrubbing system for SOx control
    - Flue gas waste heat recovery boilers with steam turbine (electricity generation)
    - Multiclone Dust Collection System (particulate and flue gas SO₂ neutralization byproduct control)
- Added complexity of controlling SOx
  - Multi-pollutant control technology is most feasible approach

### Control Type Reduction Achievable

<table>
<thead>
<tr>
<th>Control Type</th>
<th>Reduction Achievable</th>
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<tbody>
<tr>
<td>LoTOx w/WGS</td>
<td>85% to 92%</td>
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<tr>
<td>UltraCat</td>
<td>85% to 95%</td>
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<tr>
<td>SCR</td>
<td>90% to 95%</td>
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| LoTOx™ w/Wet Gas Scrubber                        | Inject ozone to flue gas (NOx to N₂O₅) followed by wet scrubbing            | Oxidation of NOx with subsequent absorption                               | • Low operating temp  
• Multi-pollutant control  
• Not affected by load swings | • Waste treatment  
• Recovery of Nitric Acid generated |
| Selective Catalytic Reduction (SCR)              | Promotes reaction between NH₃ and NOx                                        | Chemical reduction of NOx                                                 | • High NOx removal                                                        | • Increased pressure drop  
• NH₃ and secondary pollutant  
• Space requirements  
• Hazardous storage  
• Waste disposal |
| Ultra-Low NOx Burner (ULNB)/Low-NOx Burner (LNB) | FGR pre-mix upstream and rapid mixing of air/fuel near ignition point       | Reduce peak flame temperature/residence time                             | • Low operating cost  
• Stable short flame                                                         | • Complex design  
• Requires FGR  
• Long flame length  
• Fan capacity  
• Coalescing/ Impingement |
SRU/TG Incinerators

- Primary control technology used for SRU/TG incinerators is SCR and ULNB/LNB
- LoTOx™ with WGS has good reduction potential and multi-pollutant control

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<tr>
<td>LoTOx™ with Wet Gas Scrubber (WGS)</td>
<td>85% to 95%</td>
</tr>
<tr>
<td>Selective Catalytic Reduction (SCR)</td>
<td>90% to 95%</td>
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<tr>
<td>Ultra-Low NOx Burner (ULNB)</td>
<td>50% to 80%</td>
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<tr>
<td>Low-NOx Burner (LNB)</td>
<td>25% to 35%</td>
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</tbody>
</table>
Non-SRU

- Incinerators or thermal oxidizers not used in SRU
  - 12 total units
- Actual emissions are uncertain due to inadequate monitoring
- Variable fuel characteristics (composition, heating value, contaminants)
- Used in other refining related processes
  - Loading racks
  - Wastewater
  - Air pollution control
  - Soil remediation
- Control technologies used
  - LNB or ULNB
## Commercially Available Technology Summary

<table>
<thead>
<tr>
<th>NOx Control Technologies</th>
<th>Application</th>
<th>Reduction Achievable (%)</th>
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<tbody>
<tr>
<td>LoTOx™ with WGS</td>
<td>Calciner, FCCU</td>
<td>92</td>
</tr>
<tr>
<td>Water/Steam Injection, ULNB, SCR</td>
<td>Gas Turbines</td>
<td>95 or more</td>
</tr>
<tr>
<td>ULNB and SCR</td>
<td>Boilers/Heaters</td>
<td>95</td>
</tr>
<tr>
<td>LNB</td>
<td>SRU Incinerators</td>
<td>80</td>
</tr>
<tr>
<td>SCR</td>
<td>ICE (Diesel)</td>
<td>95</td>
</tr>
<tr>
<td>ULNB and SCR</td>
<td>Gas Turbines</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>Boilers/Heaters</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>SRU/TG Incinerators</td>
<td>95</td>
</tr>
<tr>
<td></td>
<td>FCCU</td>
<td>95</td>
</tr>
</tbody>
</table>
Emerging Control Technologies
Emerging Control Technology

• Not commonly used in industry or not reached commercial demonstration/licensing
• Limited data available for source specific applicability
• Multi-pollutant control
  • EMx Catalyst
• Technology examples:
  • Great Southern Flameless Heater
  • ClearSign Duplex burner technology
• SCAQMD continually reviews emerging technologies
EMx Catalyst

- EMx is the 2nd generation of SCONOx technology
  - SCONOX was determined BACT for combine-cycle and cogeneration gas turbines (natural gas) by SCAQMD 2.5 ppmvd NOx at 15% O₂ (1-hr avg)
- Applicability
  - Coke calciners
  - Gas turbines
  - Reciprocating IC engines
  - Industrial/utility boilers
- Proven on gas turbines, but not refinery applications
  - Transferable technology

<table>
<thead>
<tr>
<th>Key Features</th>
<th>Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single system multi-pollutant control technology, 90 to 95% for NOx</td>
<td>High upfront cost due to precious metals</td>
</tr>
<tr>
<td>Single catalyst for NOx, CO, PM and VOC</td>
<td>No current refinery application</td>
</tr>
<tr>
<td>No Hazardous byproducts</td>
<td>Requires hydrogen to regenerate catalyst</td>
</tr>
<tr>
<td>Wide operating temperature (400°F to 1100°F)</td>
<td>Proven in cogeneration gas turbines only</td>
</tr>
</tbody>
</table>
Great Southern Flameless Heater

- Flameless crude heater has been operating continuously since March 15, 2013 (5+ years) at Coffeyville, KS Refinery (3,442 BPD) using refinery fuel gas
- Can be scaled up to any required process heater size
- GSF has recently developed a retrofit option for existing heaters rather than replacing entire heater

<table>
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<tr>
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<th>Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx emissions equal to or lower than traditional combustion with SCR (2-4 ppm)</td>
<td>No current data for large refinery applications (&gt;90,000 BPD)</td>
</tr>
<tr>
<td>Elimination of any possibility for hot flue gas or flame impingement (no coil fouling)</td>
<td></td>
</tr>
<tr>
<td>No handling of hazardous chemical</td>
<td></td>
</tr>
<tr>
<td>Improved reliability compared to traditional combustion with varying refinery fuel gas composition</td>
<td></td>
</tr>
<tr>
<td>No ammonia slip</td>
<td></td>
</tr>
</tbody>
</table>
Great Southern Flameless Heater (cont’d)

• Cost is equivalent to a conventional double fired heater with conventional balanced draft air preheat system (actual cost is dependent on system)
• Replacement technology
• Retrofit/revamp option currently being developed
  • Vertical cylindrical heaters
  • Horizontal cabin heaters
### Key Features

<table>
<thead>
<tr>
<th>Feature</th>
<th>Considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 ppm or less without FGR and SCR systems</td>
<td>Refinery application data limited</td>
</tr>
<tr>
<td>Flame length reduced 80%</td>
<td>&gt; 40 MMBtu application not proven in refineries</td>
</tr>
<tr>
<td>Stable flame (wide operating range)</td>
<td>Limited data for refinery fuel gas</td>
</tr>
<tr>
<td>Improved fuel efficiency and throughput</td>
<td></td>
</tr>
<tr>
<td>No ammonia slip</td>
<td></td>
</tr>
</tbody>
</table>

- Duplex system consists of upper and lower tile system
- Duplex burner keeps oxygen at normal operating levels (1 to 3%), unlike low NOx burner systems
- Duplex burner delays combustion until sufficient entrainment of air and fuel gas which ensures low flame temperatures
- Does not pose safety risk
ClearSign Duplex™ Burner (cont’d)

- Does not require FGR system
- Radiates heat to process and away from combustion products, lowering temperature and NOx emissions
- Retrofit technology
- Has been retrofitted into a multiple-burner, vertical-cylinder (VC) reformer process heater
- Does not require ammonia
- Lower cost than SCR systems
Emerging Control Technology Summary

• Both ClearSign Duplex and GSF process heaters:
  • Produce NOx levels which have previously only been achievable with SCR (<5 ppm)
  • Eliminate the operational cost and chemical exposure hazards associated with SCR operation
  • Enhance heat transfer characteristics
  • Eliminate flame impingement issues associated with ULN burners on furnace process tubes
  • Potential for improved operational performance and longer run lengths
Next Steps

1. Compile and Evaluate Survey Data
2. BARCT Limits
3. Cost Effectiveness Analysis
4. Issue RFP for 3rd Party Validation
5. Develop Rule Concepts
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