Rule 1109.1 - NOx Emission Reduction for Refinery Equipment

Working Group Meeting #6
January 31, 2019
Progress of Rule Development

Summary of Working Group #5 (11/28/18)

- Presented survey data analysis
- Stakeholders requested more clarity on boiler heater data
  - How are low emissions being achieved? BACT or BARCT?
  - BACT installations or new installs are optimized for control technology performance
  - Manufacturer guarantees should
    - Achieve limits all the time not just some of the time
    - Consider what context (ideal conditions vs. real-world conditions)
    - Be representative of each equipment, since each case is different

Since Last Working Group Meeting

- Revised and updated survey data
- Coke calciner stakeholder meeting #2 (December 14th)
- Met with control system suppliers (catalyst, burners, and SCR system)
- Continuing site visits and meetings with stakeholders
- RFP closed
Request For Proposal Updates
Request for Proposal Update

- Seeking Consultant with:
  - Engineering background
  - Refinery experience
  - Knowledge of NOx control technologies

- Bid Submissions
  - Three bids submitted
    - Fossil Energy Research Corporation
    - Norton Engineering
    - MD Environmental

- Tentative review panel selection
  - Planning
  - Engineering
  - BACT Team
  - Engineer from other air agency
Comments regarding cost effectiveness calculations
- SCAQMD uses the more general Marshall & Swift (M&S) Index covering all industry sectors
- Recommends alternative cost indices more representative
  - IHS Market Downstream Capital Costs Index (DCCI)
  - Nelson Farrar (N-F) Cost Index
- Staff preparing formal response
Control Manufacturer Meetings

- Met with four control technology manufacturers with experience in refinery applications (all with 30+ years experience)
  - Cormetech - Catalyst manufacturer (11/28/18)
  - Peerless - SCR system manufacturer (11/29/18)
  - Zeeco - Burner manufacturer (11/29/18)
  - Babcock Power/Struthers Wells - Process heater/boiler manufacturer, heat transfer equipment, burner manufacturer & SCR systems manufacturer (1/15/19)

- Key topics discussed
  - Refinery applications
  - Impacts of refinery fuel gas on NOx emissions
  - Capabilities in achieving NOx reduction with refinery equipment
  - Emission guarantees and performance (conditions)
  - Generalized cost estimates for equipment retrofits
  - Space limitations around equipment will affect costs
Specializes in catalyst design and SCR Systems

Experience with SCR reactor design, ammonia injection grid design, ammonia systems

The size, cost, and capability of an SCR system are case specific

Key variables are inter-related and have a cascading affect on performance and cost

- **Key Design Inputs:** flue gas flow rate, NOx inlet, flue gas constituents, fuel type, particulate loading, reactor size, geometry, unit type
- **Performance requirements:** NOx removal efficiency, ammonia slip, pressure drop, SO₂ oxidation limit
- **Scale up factors:** Maldistribution (Ammonia, temperature, velocity)
- **Catalyst deactivation and catalyst pitch selection:** Fuel type, unit type, ash characteristics, pressure drop
- **Catalyst formulation:** Unit type, SO₂ oxidation limit, temperature range, NO/NO₂ ratio, required potential (function of DENOX %, inlet NOx, and slip)
- **Output:** NOx emission target, end of life slip
Peerless - SCR System Manufacturer

- Specializes in retrofit applications - more than 1,000 SCR installations
- Full service: System design, performance analysis, engineering, fabrication, project and construction management
- SCR systems can achieve 90%+ NOx reduction & <7 ppm ammonia slip
- In-house Computational Fluid Dynamics and cold flow physical model used to optimize duct arrangement and flow devices for:
  - Pressure drop
  - Temperature gradient
  - Velocity distribution
  - Ammonia injection system
  - Mixing uniformity
- Experienced in engineering and building structural steel support
- Provide expert advice on workable design and duct arrangement for tight spaces
Refinery Experience
- Riley Power manufactures boilers and low NOx gas & oil burners
- Vogt Power International heat recovery steam generators w/ and w/o SCRs
- Struther Wells heat transfer solutions including fired process heaters and once through steam generators
- Thermal Engineering International (TEI) feedwater heaters, condensers, and heat exchangers
- Boiler Tube Company of America (BTA) loose tubes and tube coil modules

In-line SCRs
- Supplier of high performance SCRs through the use of patented mixing technology
- Experience to optimize the system design
  - Life-cycle cost
  - Operational & emissions performance
  - System reliability
  - Construction efficiency
- Single OEM supplier provides the entire SCR system design under one contract wrapping all guarantees & providing a single point of responsibility reducing overall project risk and cost
Zeeco - Burner Manufacturer

- Specializes in low-NOx burners (LNB) and ultra low-NOx burners (ULNB)
  - Currently have new burners scheduled to be retrofit in two hydrotreater heaters (both 102 MMBtu/hr)
  - 15 ppm guarantee on refinery fuel gas (dependent on heater duty and operating conditions)
- Manufacturer has test facility for burners that uses natural gas and/or hydrogen
  - NOx emissions are typically 10% to 15% higher when using refinery fuel gas (refinery fuel gas contains hydrogen)
  - Burner arrangement and spacing in firebox matters due to flame characteristics of LNB/ULNB and can affect performance
  - Manufacturer issues guarantees and performs an analysis of each heater
    - Case by case basis, some retrofits may require more modifications than others
    - Many variables to consider for low-NOx burner or ultra low NOx burner performance
- Burner emission guarantees are over a specified operating heater parameter (excess air, volumetric heat release, burner adjustment)
  - Typically encompasses the design case for the heater
  - Designed in accordance with API 535 and API 560 standards
Burner Technology Revised

- No clear definition of what constitutes a LNB and ULNB, so will classify as burner control technology
- Burner performance is dependent upon multiple variables, some include:
  - Burner orientation & arrangement
  - Firebox size & heater type (force or natural draft)
  - Fuel type
- Burner classification does not assure burners will be effective in achieving NOx levels guaranteed
- Burner NOx emissions will vary in real world applications
- Burner control technology can be applied to a majority equipment, but may not apply to some heater or boiler applications
- Newer burner control technology performs better than conventional burners

### Burner projects currently in the permitting process

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Guaranteed NOx (ppm)*</th>
<th>Expected NOx (ppm)</th>
<th>(Number of burners) @ rating of each</th>
<th>Total Heater Rating</th>
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<tbody>
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<td>ZEESCO GLSF</td>
<td>15</td>
<td>9</td>
<td>(72) @ 1.42 MMBTUH</td>
<td>102 MMBtu/hr</td>
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<td>Callidus/Honeywell</td>
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<td>(64) @ 1.44 MMBTUH</td>
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<td>(16) @ 4.81 MMBTUH</td>
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<td>Callidus/Honeywell</td>
<td>15</td>
<td>13</td>
<td>(16) @ 4.38 MMBTUH</td>
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*Over specific operating conditions
Survey Data Update
Survey Data Revised
Process Heaters & Boilers
Adequate control information from survey already made available for most categories, but more clarity requested for heaters/boilers.
Heaters & Boilers by Category Updated

- Process Heaters & Boilers (235)
  - Process Heaters
    - Primary Heaters (196)
    - Start-up/Shutdown Heaters (0)
  - Boilers (27)
  - Hydrogen Reformer Heaters (7)
  - Sulfuric Acid Plant Heaters
    - Furnace (2)
    - Start-up/shutdown Heaters (3)
Process Heaters & Boilers Categories

**Process Heaters**
- **Primary Heaters**: All direct-fired heaters used in a majority of refinery processing units fueled by RFG or NG
- **Start-up/Shutdown Heaters**: Heaters used for start-up and shutdown only (excludes FCCU start-up heaters)
- **Hydrogen reformer heaters that use refinery gas as a primary fuel (6 heaters)**

**Boilers (steam generation)**
- Fuel-fired boilers that produce plant steam from boiling water
- Excludes heat recovery steam boilers and CO boilers (heat input is from heat recovery)

**Hydrogen Reformer Heaters**
- Primary fuel is PSA off gas
- Trim fuel can either be refinery gas or natural gas

**Sulfuric Acid Plant Heaters**
- **Furnaces**: Spent acid and/or hydrogen sulfide is decomposed by combusting with air and fuel gas
- **Start-up/Shutdown Heaters**: Used as preheat during start-up, shutdown, maintenance activities and heater exhaust gases are aggregated with furnace
## Heaters & Boilers Categories Revised

<table>
<thead>
<tr>
<th>Size/Capacity (MMBtu/Hr)</th>
<th>Heaters</th>
<th>Boilers</th>
<th>Hydrogen Reformer Heaters (PSA off-gas)</th>
<th>Sulfuric Acid Plant Heaters</th>
<th>Total</th>
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<td></td>
<td>Primary Heaters</td>
<td>Start-up &amp; Shutdown Heaters</td>
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</table>
Process Heaters & Boilers Considerations

AB 617 requires the “highest priority to those permitted units that have not modified emissions-related permit conditions for the greatest period of time.”
<table>
<thead>
<tr>
<th>Low NOx emitting units and fuel type</th>
<th>Emissions achieved and number of units</th>
<th>Age of Equipment</th>
<th>Control Technology (new, retrofit or replacement)</th>
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<tbody>
<tr>
<td>• Primary heaters</td>
<td>• &lt;5 ppm (9 units)</td>
<td>• &lt;15 years old</td>
<td>New/retrofit burners &amp; SCR</td>
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<tr>
<td>• Achieving ≤10 ppm</td>
<td>• 5 to 10 ppm (6 units)</td>
<td>• &lt;35 years old</td>
<td>New/retrofit burners &amp; SCR</td>
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<td>• RFG, NG</td>
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<td>New/retrofit burners &amp; SCR</td>
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<tr>
<td>• Hydrogen reformer heaters</td>
<td>• &lt;5 ppm (4 units)</td>
<td>• &lt;25 years old</td>
<td>New/retrofit burners &amp; SCR</td>
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<td>• Achieving ≤10 ppm</td>
<td>• 5 to 10 ppm (2 units)</td>
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<td>New/retrofit burners &amp; SCR</td>
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<tr>
<td>• PSA-off gas</td>
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<td>New/retrofit burners &amp; SCR</td>
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<td>• Boilers</td>
<td>• &lt;5 ppm (1 unit)</td>
<td>• &lt;36 years old</td>
<td>Retrofit/replacement burners</td>
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<td>• Achieving ≤10 ppm</td>
<td>• 5 to 10 ppm (7 units)</td>
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<tr>
<td>• RFG, NG</td>
<td>• 14.4 ppm (1 unit)</td>
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<tr>
<td>• Sulfuric acid heaters</td>
<td>• 20 ppm (1 unit)</td>
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<td></td>
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<tr>
<td>• Achieving ≤20 ppm</td>
<td>• 14.4 ppm (1 unit)</td>
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<td>• RFG, NG</td>
<td>• 58 years old</td>
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<td>• 28 years old</td>
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</table>
High emissions in each category

NOx emissions and number of units

- Primary heaters:
  - >100 ppm (2 Units)
  - 50 to 100 ppm (8 Units)

- Hydrogen reformer heater:
  - 13 ppm (2 Unit)

- Boilers:
  - >100 ppm (4 Units)
  - 50 to 100 ppm (2 Units)

- Sulfuric Acid Plant Heaters:
  - >25 ppm (2 Units)

Age of equipment

- >30 years old
- 30 years old
- >30 years old
- 28 years old

Control technologies installed

- Retrofit burners & no post combustion control
- New burners & new SCR
- No control
- New burners & no post combustion control
Data Assumptions

- Determining new, replacement, or retrofit requires an installation date
- Not all installation dates provided in survey, either missing or not available
- Engineering and permitting division looking to verify installation dates
- If no dates available, assumptions were made based on other data provided
- Assumed data highlighted in dark red

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<th>Permit Limit</th>
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<th>&gt;15 ppm</th>
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<td>Age Assumptions</td>
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<td>Control Assumptions</td>
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### Primary Heaters (<20 to 40 MMBtu/hr)

<table>
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<tr>
<th>Size/Capacity Range (MMBtu/hr)</th>
<th>NOx Emissions @3% O2 (ppm)</th>
<th>% Capacity Utilized</th>
<th>Fuel Type</th>
<th>NOx Permit Limit (ppm)</th>
<th>Ammonia Limit (ppm)</th>
<th>Original Installation Date</th>
<th>Age (years)</th>
<th>New, Retrofit, or Replacement</th>
<th>Combustion Control</th>
<th>Post-Combustion Control</th>
<th>Representative Year NOx Emissions (tons/yr)</th>
<th>Control</th>
<th>Number of Burners</th>
<th>Installation Date</th>
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*Share a common SCR
## Primary Heaters (40 to >110 MMBtu/hr)

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<tr>
<th>Size/Capacity Range (MMBtu/hr)</th>
<th>NOx Emissions @3% O2 (ppm)</th>
<th>% Capacity Utilized</th>
<th>Fuel Type</th>
<th>NOx Permit Limit (ppm)</th>
<th>Ammonia Limit (ppm)</th>
<th>Original Installation Date</th>
<th>Age (years)</th>
<th>New, Retrofit, or Replacement</th>
<th>Combustion Control</th>
<th>Number of Burners</th>
<th>Installation Date</th>
<th>Post-Combustion Control</th>
<th>Installation Date</th>
<th>Representative Year NOx Emissions (tons/yr)</th>
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<td>1.5</td>
<td>78</td>
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</table>

*Share a common SCR
Observations/characteristics
- Equipment can emit lower than what is permitted
- Higher NOx emissions
  - Have no control
  - Older units
  - Highest NOx (154 ppm) is from oldest equipment with no control
- New installation vs. retrofit
  - New install units (<25 years old) with burner control technology and SCR combination achieve the lowest NOx emissions (<5 ppm and 5 ppm ammonia slip)
  - Retrofit units can also achieve low NOx emissions with burner control technology and SCR combination (<5 ppm and 5 ppm ammonia slip)
  - Units with SCR control only are also capable of achieving low NOx emissions (<5 ppm and 5 ppm ammonia slip)
- Multiple heaters with burner control can share a common SCR system
### Hydrogen Reformer Heaters

All hydrogen reformer heaters fueled by PSA off-gas in category

<table>
<thead>
<tr>
<th>Size/Capacity Range (MMBtu/hr)</th>
<th>NOx Emissions @3% O2 (ppm)</th>
<th>% Capacity Utilized</th>
<th>Fuel Type</th>
<th>NOx Permit Limit (ppm)</th>
<th>Ammonia Permit Limit (ppm)</th>
<th>Original Installation Date</th>
<th>Age (years)</th>
<th>New, Retrofit, or Replacement</th>
<th>Combustion Control</th>
<th>Number of Burners</th>
<th>Installation Date</th>
<th>Control Type</th>
<th>Installation Date</th>
<th>Post-Combustion Control</th>
<th>Representative Year NOx Emissions (tons/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;110</td>
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<td>68</td>
<td>PSA off-gas</td>
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</table>

All hydrogen reformer heaters fueled by PSA off-gas in category.
Hydrogen Reformer Heaters Summary

- **Observations/characteristics**
  - Large units (>110 MMBtu/hr)
  - All, except one, are equipped with burner control technology
  - All equipped with SCR
    - 5 new installation
    - 2 retrofit
  - Newest units achieve low emissions (<5ppm and <20 ppm ammonia slip)
  - Combination control can achieve 5 ppm or less
  - Retrofit units achieve 9 ppm or less
  - New burner control technology and SCR combination achieve the lowest NOx emissions
## Boilers (Steam Generation)

<table>
<thead>
<tr>
<th>Size/Capacity Range (MMBtu/hr)</th>
<th>NOx Emissions @3% O2 (ppm)</th>
<th>% Capacity Utilized</th>
<th>Fuel Type</th>
<th>NOx Permit Limit (ppm)</th>
<th>Ammonia Permit Limit (ppm)</th>
<th>Original Installation Date</th>
<th>Age (years)</th>
<th>New, Retrofit, or Replacement</th>
<th>Combustion Control</th>
<th>Post-Combustion Control</th>
<th>Representative Year NOx Emissions (tons/yr)</th>
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</thead>
<tbody>
<tr>
<td>&lt;20</td>
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<td>53</td>
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</table>
Boilers Summary

- **Observations/characteristics**
  - <20 MMBtu/hr: High ppm due to no SCR and high permit limit
  - 20 - 40 MMBtu/hr: Low NOx ppm likely due to NG and permit limit (no controls)
  - 40 - 110 MMBtu/hr: High NOx due to no control and no limit
  - >110 MMBtu/hr:
    - Low NOx due to burner control (new/retrofit)
    - Higher NOx due to no control and age
  - Highest NOx emissions
    - Older boilers
    - Larger boilers (>110 MMBtu/hr)
  - New boilers with burner control technology and/or SCR achieve the low NOx emissions
  - Can retrofit older boilers with control technology to achieve low NOx emissions
### Sulfuric Acid Plant Heaters

All sulfuric acid heaters/furnaces in category

<table>
<thead>
<tr>
<th>Sulfuric Acid Furnaces &amp; Heaters</th>
<th>NOx Emissions @3% O2 (ppm)</th>
<th>% Capacity Utilized</th>
<th>Fuel Type</th>
<th>NOx Permit Limit (ppm)</th>
<th>Original Installation Date</th>
<th>Age (years)</th>
<th>New, Retrofit, or Replacement</th>
<th>Combustion Control</th>
<th>Post-Combustion Control</th>
<th>Representative Year NOx Emissions (tons/yr)</th>
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<tr>
<td>Size/Capacity Range (MMBtu/hr)</td>
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<td></td>
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<td>Control</td>
<td>Number of Burners</td>
<td>Installation Date</td>
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<td>1990</td>
<td>No Control</td>
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</tbody>
</table>
Observations/characteristics
- Older units (>30 years old)
- Equipped with burner control only
- No post combustion control (e.g., SCR)
- Start-up and shutdown heaters
  - High NOx
  - No control
  - Low use/low emitting
- Low NOx achieved with burner control and no SCR
Next Steps

Continuing Data Analysis
Propose BARCT Limits
Cost Effectiveness
Develop Rule Concepts

Review Bids and Select Consultant
Consultant Recommendation to Board
Contract Execution
Commence BARCT Review Assessment
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