Rule 1109.1 – NOx Emission Reduction for Refinery Equipment

Working Group Meeting #7
April 30, 2019
Agenda

1. Summary of Working Group Meeting #6
2. Progress of Rule Development
3. Third Party BARCT Review
4. Technology Manufacturer Meetings
5. Ammonia Slip and Particulate Matter
6. Cost Effectiveness
7. Next Steps
Progress of Rule Development

Summary of Working Group #6 (1/31/19)

- Presented revised analysis of heater and boiler data from survey
- Presented meetings with technology manufacturers
- Discussed burner control technology

Since Last Working Group Meeting

- Administrative Committee approved staff recommendation for BARCT Request For Proposal on 4/12/19
- Continued meetings with technology suppliers
- Site visit to asphalt refinery using ClearSign Duplex Plug & Play technology
- Western States Petroleum Association (WSPA) Meeting
  - Staff requested more information from stakeholders
- Marathon Petroleum Corporation stakeholder meeting & site visit
- Continuing site visits
Third Party BARCT Review
Third Party BARCT Review

- Recommended two technically qualified consultants:
  - Norton Engineering
  - Fossil Energy Research Corporation (FERCo)
- Each consultant will perform separate task
- Tasks proposed by staff:
  - Norton Engineering
    - Review staff’s BARCT analysis
    - Research international low-NOx installations (achieved in practice)
    - Control technologies
    - Costs
  - FERCo
    - Difficult installations and/or retrofits
      - Space constraints
      - Burner technology installations
    - Selective catalytic reduction (SCR) and Ammonia injection grid (AIG) optimization
- Seeking approval at May Governing Board Meeting
## Third Party BARCT Review (cont’d)

<table>
<thead>
<tr>
<th>Norton Engineering</th>
<th>Fossil Energy Research Corporation (FERCo)</th>
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<tbody>
<tr>
<td>Extensive experience in refineries and petroleum process</td>
<td>Extensive background/experience in combustion and post combustion NOx control technology</td>
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<tr>
<td>Experienced in refinery NOx control projects</td>
<td>Comprehensive understanding and extensive experience with SCR systems</td>
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<td>Experienced in refinery boiler and fired heater emission controls</td>
<td>Numerous technical presentations at technical conferences pertaining to NOx controls</td>
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<tr>
<td>Process design experience with NOx controls</td>
<td>Experienced in configuring process equipment with existing equipment</td>
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<tr>
<td>Experienced in refinery heater optimization</td>
<td>Extensive experience with ammonia injection systems and optimizations</td>
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<tr>
<td>Experienced in refinery FCC NOx controls</td>
<td>Experienced in refinery NOx emission systems and optimization</td>
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<tr>
<td>Performed previous 2015 BARCT RECLAIM assessment for SCAQMD</td>
<td>Numerous NOx technology assessment studies</td>
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</table>
Tri-Mer UltraCat Technology

- Met with Tri-Mer on 2/21/19 to discuss UltraCat multi-pollutant control technology

- Catalytic ceramic filter system can remove NOx, SOx, and PM
  - Nano-form of catalyst embedded inside ceramic filter walls
  - Extended catalyst life and performance when compared to SCR
  - Ceramic filters can achieve 10+ years of service
  - New ceramic filters allow for smaller footprint of equipment
  - NOx removal not affected by particulate loading
  - Single system for multi-pollutant control

- 90% NOx removal at temperatures above 500 F (slightly lower at 400 F)
- 90% SOx removal at temperatures of 300F to 750F

- Filter removes SO₂, HCl, HF, and other gases utilizing dry sorbent injection of hydrated lime

- Modular design allows for meeting the flow volumes of different applications

- Can retrofit into existing baghouse if equipment is currently in use
ClearSign’s Plug & Play is a replacement burner technology with an integrated ceramic tile.

ClearSign achieves very low NOx emissions without the use of SCR and ammonia.

ClearSign is a possible alternative for similar small and midsized heaters due to cost-effectiveness over SCR installation:

- Presently only available in vertical fire configuration
- Design fits within existing burner opening

Due to burner design, no issues of flame impingement or coalescing.

Staff conducted site visit on 2/22/19 at an asphalt refinery in Bakersfield, CA to see a demonstration of a ClearSign Duplex Plug & Play burner in operation:

- Operating since May 2018 with no issues
- Installed in a 15 MMBtu/hr furnace with a single natural draft burner (natural gas)
- Fired duty for installed Plug & Play burner is 5.5 – 8.0 MMBtu/hr (will be replaced by a new 15 MMBtu/hr Plug & Play burner)
- NOx emission <5 ppm @3% O₂ and CO emissions <10 ppm
- Old burner that was replaced was emitting >30 ppm NOx
- Heater has permit limit of 6 ppm NOx
- Heater starts and stops daily, ClearSign burner shows no thermal stress/shock
Meeting with Umicore (Haldor Topsoe) on 3/13/19
Corrugated catalyst based on a glass finer structure
Dual function catalyst for NOx, CO, and VOC
Experienced in refinery applications
  - Unique design allows for lower SO₂ to SO₃ conversion and greater activity/unit volume
  - Lower pressure drop, potentially smaller volume
More than 1,800 installations (gas turbines, coal, cement, biomass, boilers, etc.)
395 refinery/petrochemical installations globally
For high NOx reductions, NH₃/NOx mixing is critical to meet performance targets
  - 92% removal with < 5 ppm slip, ammonia/NOx mixing critical
  - >92% removal is a challenge
Conference call with MECS & DuPont Clean Technologies on 4/2/19

Experience in optimizing emission performance of sulfur recovery plant and sulfuric acid plant operation
  - Tail end treatment
  - Combustion optimization

Tail end treatment control options
  - Dynawave® Reverse Jet Scrubber – Quenching, SOx absorption and particulate removal all in one vessel

NOx abatement can be realized by an ozone generation process

Combustion optimization (sulfuric acid plant furnace)
  - Sulfuric acid plant furnace optimization – VectorWall™ Ceramic Tile
    - Creates optimized flow pattern to create optimal combustion environment in furnace
    - Works with industry experts like John Zink Hamworthy Combustion and Blasch Precision Ceramics to optimize furnace emission performance
    - Reduces NOx emissions
Ammonia Slip and Particulate Matter
Stakeholders expressed concern with retrofit co-pollutant emissions
  - Equipment replacement or retrofit with SCR may result in higher PM emissions due to ammonia slip
  - If PM emission increases more than one pound a day, BACT will be required
  - If replaced with new equipment, subject to NSR/BACT but would provide efficiency gains and co-pollutant reductions
  - Feasible technical options to comply, but could be costly:
    - Pre- or Post-treatment
    - Fuel treatment to remove sulfur

Staff is aware of the concern and more information will be forthcoming
Ammonia/PM Analysis

- Analysis of ammonia slip and PM$_{10}$ in December 2015 Final Program Environmental Assessment for NOx RECLAIM
  - Projected increase use of ammonia by 39.5 tons per day (tpd) does not mean increased emissions of ammonia by 39.5 tpd
  - 39.5 tpd represents the amount injected by all flue gas streams by all potential SCRs needed to reduce NOx
  - Majority of the ammonia will react with NOx in flue gas with a small amount of unreacted ammonia
  - Regional simulation analyses were conducted to determine impacts of increased ammonia
    - NOx reduced by 14 tpd, resulting in an annual PM$_{2.5}$ decrease of approximately 0.7 μg/m$^3$
    - Increased use of ammonia results in an annual increase of PM$_{2.5}$ by 0.6 μg/m$^3$
    - Increased ammonia from the NOx shave would result in net annual PM$_{2.5}$ decrease of 0.1 μg/m$^3$
    - Overall decrease in annual PM$_{2.5}$ would occur provided that all 14 tpd of NOx emissions are reduced
  - Concluded the impacts to regional PM$_{2.5}$ and ozone due to ammonia slip in simulations would not create a significant impact
Cost Effectiveness
Cost-Effectiveness

- Cost-effectiveness is a measure comparing costs of pollution reduction to amount of pollutant reduced
  - Measured in cost per ton of pollutant reduced
- South Coast AQMD typically uses the Discounted Cash Flow Method to calculate cost effectiveness
  - Cost-Effectiveness = Present Value/Emissions Reduced Over Equipment Life
  - Present Value = Capital Cost + (Annual Operating Costs x Present Value Formula)
  - Present Value Formula = \( (1-1/(1+r)^n)/r \)
    - \( r = (i-f)/(1+f) \)
    - \( i \) = nominal interest rate
    - \( f \) = inflation rate
    - \( n \) = number of cycles
- South Coast AQMD Governing Board established $50,000/tons of NOx removed with approval of 2016 Air Quality Management Plan
EPA SCR Cost Model

- Staff will evaluate cost-effectiveness of installing SCRs based on EPA cost model
- U.S. EPA’s Air Pollution Control Cost Estimates Spreadsheet for Selective Catalytic Reduction* used to determine retrofit cost
  - Methodology based on U.S. EPA Clean Air Markets Division Integrated Planning Model
  - Costs of SCR depends on size of unit, emission rate, fuel type burned, NOx removal efficiency, reagent consumption rate, and catalyst costs
  - Capital cost annualized over 25 years at 4% interest rate
  - Inflation accounted for in Chemical Engineering Plant Cost Index (CEPCI)
    - Dec 2018 CEPCI equals 616
  - Values reported in 2018 dollars
  - Conservative cost model number and assumes cost for SCR retrofit
  - Staff using degree of difficulty (retrofit factor) to address challenging installations (e.g., space constraints)
    - Retrofit difficulty level: 0.8 to 1.5
    - Retrofit factor provided in survey by stakeholders
    - Retrofit factor of 1.2 is used if not provided
  - Running SCR model at various concentration levels to determine cost effectiveness

### Chemical Engineering Plant Cost Index (CEPCI)

<table>
<thead>
<tr>
<th>Components of Index</th>
<th>Weight of Components</th>
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<tbody>
<tr>
<td><strong>Equipment Index:</strong></td>
<td></td>
</tr>
<tr>
<td>Heat exchangers and tanks</td>
<td>34</td>
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<tr>
<td>Process machinery</td>
<td>13</td>
</tr>
<tr>
<td>Pipe, valves, and fittings</td>
<td>19</td>
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<tr>
<td>Process instruments</td>
<td>10</td>
</tr>
<tr>
<td>Pumps &amp; compressors</td>
<td>6</td>
</tr>
<tr>
<td>Electrical equipment</td>
<td>7</td>
</tr>
<tr>
<td>Structural supports &amp; miscellaneous</td>
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</tr>
<tr>
<td><strong>% of total</strong></td>
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<tr>
<td><strong>Construction Labor Index</strong></td>
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<tr>
<td><strong>Buildings Index</strong></td>
<td>5</td>
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<tr>
<td><strong>Engineering and Supervision</strong></td>
<td>15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>100</td>
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Cost Estimates

- EPA SCR cost model only applicable to SCR installations (e.g., not burner retrofits, other control technologies)
- Stakeholders provided cost estimates for currently installed and planned SCR when available
- Technology control suppliers provided additional cost estimates (site specific considerations not included)
- For those units requiring >92% removal efficiency from SCR to achieve BARCT, the cost of burners will be added to the overall cost effectiveness from the EPA SCR cost model
  - Burner costs and operating cost provided in survey from stakeholders
  - Discounted Cash Flow will be used to calculate cost effectiveness for burner control in units that require burner control
Enter the following data for your combustion unit:

Is the combustion unit a utility or industrial boiler?  Industrial

Is the SCR for a new boiler or retrofit of an existing boiler?  Retrofit

Please enter a retrofit factor between 0.8 and 1.5 based on the level of difficulty. Enter 1 for projects of average retrofit difficulty. Retrof

Retrofit factor provided by stakeholder in survey and default of 1.2 used if not provided

Complete all of the highlighted data fields:

What is the maximum heat input rate (QB)?  28.5 MMBtu/hour

What is the higher heating value (HHV) of the fuel?  1,400 Btu/scf

What is the estimated actual annual fuel consumption?  99,760,143 scf/year

Enter the net plant heat input rate (NPHR)  8.2 MMBtu/MW

Default value - used to estimate the amount of electricity needed for daily operation of SCR (e.g. ammonia vaporization, ID fan, etc.)
Based on operating hours reported in survey

Typical catalyst life 3 to 5 years (3 years used)

NOx permit limit (CEMS Data if no permit limit)

Reduction required to achieve proposed BARCT limit

Typical catalyst life 3 to 5 years (3 years used)

Aqueous ammonia

To validate the data inputs, staff set reduction to 99.9% to verify NOx removed is within 2 tons/year of reported annual emissions (actual reported NOx emissions used and adjusted accordingly)

Default values in SCR cost model - Quote from manufacturer for typical install is 2 chambers (1 empty) with 1 layer of catalyst
Enter the cost data for the proposed SCR:

- Desired dollar-year
- CEPCI for 2018
- Annual Interest Rate (i)
- Reagent (Cost_{\text{reag}})
- Electricity (Cost_{\text{elect}})
- Catalyst cost (CC_{\text{replace}})
- Operator Labor Rate
- Operator Hours/Day

Note: The use of CEPCI in this spreadsheet is not an endorsement of the index, but is there merely to allow for availability of a well-known cost index to spreadsheet users. Use of other well-known cost indexes (e.g., M&S) is acceptable.

- Adjusted to 24 hours for refinery operations (default: 4 hours)
- Confirmed price of reagent grade aqueous ammonia from local supplier (factored freight cost into price)

Quote from several catalyst manufacturers and averaged catalyst cost* (default: $160)

*Catalyst volume proprietary and based on catalyst technology selection

CEPCI
December 2018

Confirmed price of reagent grade aqueous ammonia from local supplier (factored freight cost into price)
Installation cost varies, but using 40% of Total Capital Investment. Staff proposing to increase installation cost by 20% to account for Senate Bill (SB) 54 labor (construction) rates in CA
Considerations for Initial Rule Concept

- Difficult installations
  - Firebox floor spacing constraints for burner retrofit
  - Space constraints around specific equipment
  - Establish physical criteria and/or definition that constitutes space constraint or firebox constraint
  - Potential options for new more efficient equipment with similar footprint

- Phased in implementation schedule to allow additional time for difficult installations and turnaround schedule
  - Phase one – X% of equipment, focusing on the oldest units with no control and highest emissions
  - Phase two – Y% of additional equipment
  - Phase three – 100% of equipment, difficult installations and/or equipment replacements

- Low-usage exemptions
  - Capacity threshold
  - Hours operated per year or over multiple years

- Allow keeping higher NOx limits for units close to BARCT limit
- Maintain existing ammonia permit limit, only if:
  - Meeting the NOx BARCT limit and not upgrading equipment
Next Steps

1. Consultant Recommendation to May Governing Board
2. Continue BARCT Assessment and CEMS data analysis
3. Continuing Site Visits
4. Propose BARCT Limits
5. Consultant Final Assessment Report
6. Finalize BARCT Limits
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