Proposed Rule (PR) 1147.2
NO\textsubscript{x} Reductions from Metal Processing Equipment

Working Group Meeting #3
November 6, 2019

Call-in Number / Passcode
866-705-2554 / 680785
Agenda

- Summary of Working Group Meeting #2
- Process Temperatures, Furnace Types, and NO\(_x\) Source Tests
- NO\(_x\) Formation Pathways
- Continuation of BARCT Analysis
  - Technology Assessment
  - Establishing Proposed BARCT Emission Limit
- Next Steps
Summary of Working Group Meeting #2
Summary of Working Group Meeting #2

- Rule 1147 Equipment Data Request
- BARCT Analysis
  - Assessment of Emission Limits for Existing Units
    - Metal Melting Furnaces
    - Metal Heat Treating Furnaces
  - Other Regulatory Requirements
BARCT analysis is conducted for each equipment category and fuel type.
Process Temperatures, Furnace Types, and NO$_x$ Source Tests
1. Is there a correlation between process temperatures and source test results?
2. Is there a correlation between process temperatures, furnace types, and source test results?

Stakeholders commented about effects of differing temperatures and furnace types on NO\textsubscript{x} emissions.

Staff analyzed:
- Process temperature versus source test result
- Process temperature and furnace type versus source test result

Analyses of process temperatures and furnace types seek to answer two questions:

Background & Approach
Evaluated metal melting and metal heat treating equipment categories separately for both RECLAIM and non-RECLAIM facilities.

For both equipment categories, graphed process temperatures and NO$_x$ source test results to assess any correlations.

- Process temperature obtained from permits.

For both equipment categories, grouped units into two temperature ranges.

- Focused on lowest NO$_x$ source test results in each temperature group.
Process Temperatures and Source Test Results – Assumptions

- Only furnaces that had both a process temperature and NO$_x$ source test result were included in this analysis
  - 228 of 250 units (87%) had both a source test result and listed a process temperature in its permit
  - Remaining units were not incorporated into this analysis

- Similar units processing the same materials at the same facility were given the same process temperature

- Average process temperature was used when a range of process temperatures was listed
Methodology

- Evaluated metal melting and metal heat treating equipment categories separately for both RECLAIM and non-RECLAIM facilities.
- For both equipment categories, graphed furnace type and process temperature with NOₓ source test result to assess any correlations.
  - Process temperature and furnace type obtained from permits.

Assumptions

- Furnace type as identified by permit’s equipment description may be categorized differently over time and across facilities.
- Only furnaces that had both a process temperature and a NOₓ source test result were included in this analysis.
Metal Melting Furnaces
Metal Melting – Source Test Results from Working Group #2

- 54 NO\textsubscript{x} source test results
- 50 of the 54 units with source tests also listed a process temperature
- Source test results range from 8.4 to 59.6 ppm NO\textsubscript{x} from RECLAIM and non-RECLAIM facilities
  - 10 units ≤ 30 ppm
  - 6 units ≤ 20 ppm

All Source Test Results

![Graph showing NO\textsubscript{x} source test results](image)

- Rule 1147 Limit
- 10 Units ≤ 30 ppm*
- 6 Units ≤ 20 ppm*

*At 3% O\textsubscript{2}
Metal Melting – Process Temperatures and Source Test Results

**Observations**

<table>
<thead>
<tr>
<th>Unit Count</th>
<th>≤ 1,230 °F</th>
<th>&gt; 1,230 °F</th>
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</thead>
<tbody>
<tr>
<td>≤ 50 ppm*</td>
<td>35</td>
<td>4</td>
</tr>
<tr>
<td>≤ 30 ppm*</td>
<td>9</td>
<td>No Units</td>
</tr>
<tr>
<td>≤ 20 ppm*</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>

*At 3% O_2

Group I (≤ 1,230 °F)

- Rule 1147 Limit
  - ≤ 50 ppm* ≤ 50 ppm*
  - 30 ppm* 9
  - 20 ppm* 6

Group II (> 1,230 °F)

- 50 ppm
  - 35
  - 4

**Process Temperature (°F)**

**NOx Source Test Result (ppm @ 3% O_2)**

**RECLAIM**

- ≤ 50 ppm*
- ≤ 30 ppm*
- ≤ 20 ppm*

**Non-RECLAIM**

- ≤ 50 ppm*
- ≤ 30 ppm*
- ≤ 20 ppm*
1. Is there a correlation between process temperatures and source test results*?

**Metal Melting Furnace**

**Temperature Groups**
- **Group I** ($\leq 1,230 ^\circ F$)
  - $\leq 30$ ppm: 9 Units
  - $\leq 20$ ppm: 6 Units
- **Group II** ($> 1,230 ^\circ F$)
  - $\leq 50$ ppm: 4 Units
  - $\leq 40$ ppm: 1 Unit

*At 3% $O_2$
Metal Melting – Process Temperatures and Furnace Types

<table>
<thead>
<tr>
<th>Unit Count</th>
<th>Crucible &amp; Pit</th>
<th>Other*</th>
<th>Pot &amp; Kettle</th>
<th>Reverberatory</th>
<th>Total</th>
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</thead>
<tbody>
<tr>
<td>≤ 50 ppm†</td>
<td>5</td>
<td>7</td>
<td>5</td>
<td>22</td>
<td>39</td>
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<tr>
<td>≤ 30 ppm†</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>6</td>
<td>9</td>
</tr>
<tr>
<td>≤ 20 ppm†</td>
<td>2</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>

* Other: Box, Furnace, Rotary (Non-Sweating), and Stack

†At 3% O₂
2. Is there a correlation between process temperatures, furnace types, and source test results*?

*At 3% O₂

All furnace types except Other exhibit a wide range of NOx source test results
Metal Heat Treating Furnaces
Metal Heat Treating – Source Test Results from Working Group #2

Summary

- 196 NOx source tests
- Results range from 4.6 to 115 ppm NOx from RECLAIM and non-RECLAIM facilities
  - 64 units ≤ 30 ppm
  - 32 units ≤ 20 ppm
- 178 of the 196 units with source tests also listed a process temperature

All Source Test Results

- 64 Units ≤ 30 ppm*
- 32 Units ≤ 20 ppm*

*At 3% O₂
Metal Heat Treating – Process Temperatures and Source Test Results

**Observations**

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<thead>
<tr>
<th>Unit Count</th>
<th>≤ 1,500 °F</th>
<th>&gt; 1,500 °F</th>
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</thead>
<tbody>
<tr>
<td>≤ 30 ppm*</td>
<td>36</td>
<td>23</td>
</tr>
<tr>
<td>≤ 20 ppm*</td>
<td>20</td>
<td>11</td>
</tr>
</tbody>
</table>

*At 3% O₂

**Rule 1147 Limit**

- 30 ppm
- 20 ppm

**Group I**

**Group II**

NOₓ Source Test Result (ppm @ 3% O₂)

**Process Temperature** (°F)
Metal Heat Treating – Process Temperatures and Source Test Results

1. Is there a correlation between process temperatures and source test results*?

<table>
<thead>
<tr>
<th>Equipment Category</th>
<th>Temperature Groups</th>
<th>Source Test Results</th>
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<tbody>
<tr>
<td>Metal Heat Treating Furnace</td>
<td>Group I ≤ 1,500 °F</td>
<td>≤ 30 ppm: 36 units</td>
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<tr>
<td></td>
<td>Group II &gt; 1,500 °F</td>
<td>≤ 20 ppm: 20 units</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≤ 30 ppm: 23 units</td>
</tr>
<tr>
<td></td>
<td></td>
<td>≤ 20 ppm: 11 units</td>
</tr>
</tbody>
</table>

- No correlation observed across temperatures
- \( \text{NO}_x \) concentrations ≤ 20 ppm exist across temperatures

*At 3% \( \text{O}_2 \)
Metal Heat Treating – Process Temperatures and Source Test Results

<table>
<thead>
<tr>
<th>Unit Count</th>
<th>Aging</th>
<th>Annealing</th>
<th>Billet</th>
<th>Forging</th>
<th>Furnace</th>
<th>Homogenizing</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 30 ppm</td>
<td>9</td>
<td>1</td>
<td>7</td>
<td>23</td>
<td>12</td>
<td>7</td>
<td>59</td>
</tr>
<tr>
<td>≤ 20 ppm</td>
<td>7</td>
<td>0</td>
<td>6</td>
<td>13</td>
<td>2</td>
<td>3</td>
<td>31</td>
</tr>
</tbody>
</table>

*Source Test Result* (ppm @ 3% O₂)

*At 3% O₂
Metal Heat Treating – Process Temperatures and Furnace Types

2. Is there a correlation between process temperatures, furnace types, and source test results*?

- Forging-related units majority of applications > 1,500 °F
- NO\textsubscript{x} concentrations ≤ 20 ppm exist for all types across all temperatures

*At 3% O\textsubscript{2}
NO\textsubscript{x} Formation Pathways
Thermal & Process NO$_x$

- Thermal NO$_x$ is formed from dissociation of N$_2$ from elevated temperatures, namely flame temperature
- Other sources of NO$_x$, although minor for natural gas, are captured in source test results
- Electric furnaces not required to source test for NO$_x$
  - EPA AP-42* provides a 0.22 lb NO$_x$/ton material processed emission factor for use in electric arc furnaces processing steel
  - 682 tons/month processed = 5 lb NO$_x$/day

**Electric Furnaces & Process NO\(_x\)**

- Approximately 150 electric furnaces identified
- Largest electric furnaces have low NO\(_x\) emissions relative to natural gas-fired furnaces
  - Majority of electric furnaces emit < 1 lb/day NO\(_x\)
- Staff will continue to investigate cost-effectiveness of SCR control for process NOx

<table>
<thead>
<tr>
<th>Electric Rating (KW)</th>
<th>Material Process Rate (ton/day equivalent)</th>
<th>NO(_x) Emissions (lbs/day)</th>
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<tbody>
<tr>
<td>2,500</td>
<td>83.2</td>
<td>18.3</td>
</tr>
<tr>
<td>1,250</td>
<td>39.9</td>
<td>8.8</td>
</tr>
<tr>
<td>1,250</td>
<td>39.9</td>
<td>8.8</td>
</tr>
<tr>
<td>1,250</td>
<td>39.9</td>
<td>8.8</td>
</tr>
<tr>
<td>1,500</td>
<td>31.7</td>
<td>7.0</td>
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</table>
Continuation of BARCT Analysis
Working Group Meeting #3: Current Progress

*BARCT analysis is conducted for each equipment category and fuel type
Previous Work Group Meetings established initial categories, analyzed permit limits and source test results, and reviewed existing regulations of other agencies.

Average NO\textsubscript{x} concentration in proposed universe
- Metal Melting: 44 ppm
- Metal Heat Treating: 42 ppm

Other California air district BARCT limit
- Metal Melting: 60 ppm
- Metal Heat Treating: 60 ppm

U.S. EPA BACT limit
- Metal Melting: 33 ppm
- Metal Heat Treating: 39 ppm
Assessment of Pollution Control Technologies – Methodology & Approach

Researched multiple sources for available NO\textsubscript{x} control technologies

- Scientific Literature
- Vendor meetings
- Consultant meetings
- Facility site visits

Analyzed Sources to:

- Identify relevant burner technologies
- Identify post-combustion control technologies
- Understand capability and limitations of each technology
Purpose of technology assessment is to assess current NO$_x$ control technologies for metal melting and metal heat treating furnaces.

Two strategies utilized to reduce NO$_x$ emissions for metal melting and metal heat treating furnaces:

- Combustion Control
  - Low NO$_x$ Burners
  - Flue Gas Recirculation

- Post-Combustion Control
  - Selective Catalytic Reduction

- Recuperative & Regenerative Burners
- Selective Non-catalytic Reduction
Low NO$_x$ Burners

- Low NO$_x$ burners implement a variety of combustion optimization techniques to lower NO$_x$ emissions:
  - **Combustion Staging**: Performing partial combustion
  - **Low Excess Air**: Lowers excess air to < 2% and is obtained through feedback control systems to minimize flame temperature
  - **Flame Enlargement**: Lowers peak flame temperature but may overlap with adjacent burner flames or impinge parts
  - **Radiant Burning**: Firing mechanism to produce lower NO$_x$ emissions with higher excess air; more suited for new installations than retrofits
Emissions Performance & Applicability

- Product literature for two manufacturers\(^1,2,3\) claim that both low and high temperature burners can meet 30 ppm @ 3% O\(_2\)
- Excess air and combustion air temperature identified as key metrics in burner applicability

Other Findings

- Of the units with control technology, 86% of the technologies are listed as Low NO\(_x\) or Ultra-low NO\(_x\) Burners on the unit permit
  - Use of Low and Ultra-low NO\(_x\) language may not necessarily correlate to NO\(_x\) concentration
  - 64% of units with Low and Ultra-low NO\(_x\) Burners are > 30 ppm

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\(^1\) [http://digital.bnpmedia.com/publication/?i=169784&article_id=1471463&view=articleBrowser&ver=html5](http://digital.bnpmedia.com/publication/?i=169784&article_id=1471463&view=articleBrowser&ver=html5)

\(^2\) [https://www.eclipsenet.com/products/furnnox/](https://www.eclipsenet.com/products/furnnox/)

\(^3\) [https://www.asminternational.org/c/portal/pdf/download?articleId=HTP00801P033&groupId=10192](https://www.asminternational.org/c/portal/pdf/download?articleId=HTP00801P033&groupId=10192)
Flue Gas Recirculation (FGR)

- Recirculation of exhaust gas via dampers, fans, and educators to the burners to dilute the combustion air.

- Emissions Performance & Applicability
  - In the steel mill industry, FGR alone has shown to reduce NO\(_x\) by an additional 10%.
  - Can be retrofitted onto furnaces but may require ductwork and additional fan capacity.
  - Is often combined with Low NO\(_x\) Burners.

- Mechanism
  - Flue gas contains combustion products that dilute oxygen content and lower the peak flame temperature.
  - Typically 10 – 15%* of combustion air is replaced with recirculated flue gas.

* In the boiler industry
Recuperative & Regenerative Burners

- Specific burner types utilizing heat exchange methods between exhaust gas and combustion air
- Due to elevated pre-heat temperatures, unit efficiency increases but NO\(_x\) concentrations may increase
- Emissions Performance & Applicability
  - NO\(_x\) concentration may not decrease due to elevated air pre-heat temperatures
  - Primary mechanism of NO\(_x\) mass emission reductions is by reducing fuel use by 30 – 50%
  - Regenerative burners are better suited for new installs rather than retrofits
  - Recuperative burner units demonstrated to have ≤ 30 ppm NO\(_x\) concentration
Injection of ammonia or urea into flue gas stream to reduce NO\textsubscript{x} to N\textsubscript{2} and H\textsubscript{2}O with the use of catalysts

**Optimal Settings**
- Optimal temperature: 500 – 1,000 °F
- Requires a 0.9:1 – 1:1 molar ratio of NH\textsubscript{3}:NO\textsubscript{x}

**Emissions Performance & Applicability**
- NO\textsubscript{x} Reduction Efficiency: 80 – 85%+
- One active furnace installation utilizes SCR to achieve an 80% NO\textsubscript{x} reduction
- Additional operating costs will be incurred over combustion control technologies (e.g. approximately $26,000/yr for a 44 MMBtu/hr furnace)
- Regeneration of catalyst 40% less expensive than catalyst replacement
Selective Non-catalytic Reduction (SNCR)

- Injection of ammonia or urea into flue gas stream to reduce NO\textsubscript{x} to N\textsubscript{2} and H\textsubscript{2}O without the use of catalysts

- Optimal Settings
  - Optimal temperature: 1,500 – 2,200 °F
  - Requires a > 1 s residence time and a 2:1 – 4:1 molar ratio of NH\textsubscript{3}:NO\textsubscript{x}, leading to higher ammonia slip than SCR

- Emissions Performance & Applicability
  - NO\textsubscript{x} Reduction Efficiency: 60%*
  - When combined with Low NO\textsubscript{x} Burners, can achieve greater NO\textsubscript{x} reductions than SCR alone (95%+ reductions)
  - Approximately 20% lower operating costs than SCR due to lack of catalyst
  - Optimal temperature difficult to maintain
    - No active installations in the proposed universe

*60% is typical in the boiler industry
Working Group Meeting #3: Current Progress

*BARCT analysis is conducted for each equipment category and fuel type*
BARCT Limit Guidelines

- California Health and Safety Code Section 40406 defines BARCT as
  "...an emission limitation that is based on the maximum degree of reduction achievable, taking into account environmental, energy, and economic impacts by each class or category of source."

- BARCT limit will adhere to Health and Safety Code Section 40920.6, which establishes requirements prior to adopting rules or regulations regarding retrofit control technologies

- In addition to the overall cost-effectiveness, additional considerations for:
  - Outliers
  - Stranded assets
  - Incremental cost-effectiveness
  - Accounting for recent installations – implementation of previous requirements (BARCT or BACT)
### Metal Melting – Initial BARCT Emission Limit

<table>
<thead>
<tr>
<th>Step</th>
<th>Requirements</th>
<th>Units</th>
<th>Air Districts</th>
<th>Assessment</th>
<th>Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>South Coast AQMD Regulatory Requirements</td>
<td>60 ppm</td>
<td>9 – 59 ppm 13 (26%) ≤ 30 ppm 7 (14%) ≤ 20 ppm</td>
<td>SCR Installation: 11 ppm</td>
<td>Burner Replacement: 20 – 30 ppm</td>
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<tr>
<td>2</td>
<td>Existing Units (Source Testing)</td>
<td>60 ppm</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Other California Air Districts</td>
<td></td>
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<td></td>
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<tr>
<td>4</td>
<td>Technology Assessment</td>
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</tr>
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<td>5</td>
<td>Initial BARCT Emission Limit</td>
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Slide Updated
Heat Treating – Initial BARCT Emission Limit

<table>
<thead>
<tr>
<th>Step</th>
<th>South Coast AQMD Regulatory Requirements</th>
<th>Existing Units (Source Testing)</th>
<th>Other California Air Districts</th>
<th>Technology Assessment</th>
<th>Initial BARCT Emission Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>ppm</td>
<td>60 ppm</td>
<td>5 – 115 ppm 59 (33%) ≤ 30 ppm 31 (17%) ≤ 20 ppm</td>
<td>60 ppm</td>
<td>SCR Installation: 11 ppm</td>
<td>11 ppm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Burner Replacement: 20 – 30 ppm</td>
<td>20 – 30 ppm</td>
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Next Steps

- Continue site visits
- Conduct Cost-effectiveness Analysis
- Continue meetings with burner manufacturers
- Draft Proposed Rule Language initial concepts

<table>
<thead>
<tr>
<th>Rule Development Activity</th>
<th>Tentative Schedule</th>
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<tbody>
<tr>
<td>Next Working Group Meeting</td>
<td>December 2019</td>
</tr>
<tr>
<td>Public Workshop</td>
<td>January 2020</td>
</tr>
<tr>
<td>Set Hearing</td>
<td>February 2020</td>
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<tr>
<td>Public Hearing</td>
<td>March 2020</td>
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# Contacts

<table>
<thead>
<tr>
<th>PR 1147.2</th>
<th>PAR 1147</th>
<th>RECLAIM Questions</th>
<th>General Questions</th>
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<tbody>
<tr>
<td>James McCreary</td>
<td>Shawn Wang</td>
<td>Kevin Orellana</td>
<td>Susan Nakamura</td>
</tr>
<tr>
<td>Assistant Air Quality Specialist</td>
<td>Air Quality Specialist</td>
<td>Program Supervisor</td>
<td>Assistant</td>
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<td>Uyen-Uyen Vo</td>
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<tr>
<td>Program Supervisor</td>
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</tr>
<tr>
<td>Mike Morris</td>
<td>Michael Krause</td>
<td>Michael Krause</td>
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<td>Planning and Rules Manager</td>
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<td>909-396-2706</td>
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<tr>
<td>Kevin Orellana</td>
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<tr>
<td>909-396-3121</td>
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**RECLAIM Questions**

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