NOx emission control for Coke Oven

Application of Two-Staged combustion to the single-staged combustion chamber

Yang, Sung-Jae

Environment & Energy Department
1. POSCO at a Glance

- POSCO, the history of Korean steel industry built from literally NOTHING
- Steel, fundamental material of national economy supporting other industries

**Overview (2011)**
- **Steel Production**: Top 4th (37.3 Mt)
- **Employees**: 42 thousand including subsidiary companies
- **Sales**: 39 billion US$

**Evaluations**
- **DAVOS Global Top 100** (2010, 2012)
- **Dow Jones Sustainability Index** (8 yrs since 2005)
- **2011 CDP** Carbon Disclosure Leadership Index & Carbon Performance Leadership Index
1. POSCO at a Glance

- **Environmental Organization**

  - Environment & Energy Dept (Head office)
    - Establishes direction for environmental management policy
    - Domestic/international agreements & R&D
  
  - Environment & Energy Committee
    - Supports top management decisions on key issues
  
  - Environment & Energy Dept (Steel works)
    - Establishes action plans across all steel works
    - Oversees and supports related personnel
  
  - Research Organizations
    - APOSRI: Environmental policy
    - APOSTECH: Technical supports
    - ARIST
    - Other research institutes

Steel Solution for Green Growth
2. NOx regulation in Korea

- Air quality standards

<table>
<thead>
<tr>
<th>NOx (ppm)</th>
<th>Standards</th>
<th>USA</th>
<th>Japan</th>
<th>WHO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2001~</td>
<td>2007~</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-hour</td>
<td>0.15</td>
<td>0.10</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>24-hour</td>
<td>0.08</td>
<td>0.06</td>
<td>-</td>
<td>0.04~ 0.06</td>
</tr>
<tr>
<td>Year</td>
<td>0.05</td>
<td>0.03</td>
<td>0.053</td>
<td>-</td>
</tr>
</tbody>
</table>

- Chimney emission standards

<table>
<thead>
<tr>
<th></th>
<th>O₂ %</th>
<th>2010~2014</th>
<th>2015~</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sinter plant</td>
<td>15</td>
<td>220 ¹ /120 ²</td>
<td>200 ¹ /120²</td>
</tr>
<tr>
<td>Reheating furnace</td>
<td>11</td>
<td>200 ¹ /150 ²</td>
<td>200 ¹ /150²</td>
</tr>
<tr>
<td>Coke Oven</td>
<td>7</td>
<td>250</td>
<td>250/150³</td>
</tr>
<tr>
<td>Power Generator</td>
<td>15</td>
<td>100⁴ / 50⁵</td>
<td>80/50/20⁶</td>
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Following the adoption of PM 2.5 standard which will be effective in 2015, the government is going to regulate PM2.5 emissions from stacks

→ NOx control is essential to reduce PM2.5
3. Coke Ovens at Pohang Works

- Pohang works operates single stage combustion chamber Coke Oven

<table>
<thead>
<tr>
<th>구분</th>
<th>#1 Coke plant</th>
<th>#2 Coke plant</th>
<th>#3 Coke plant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Battery</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Combustion</td>
<td>Single staged combustion</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
4. Coke oven & NOx emission

- Schematic diagram of Coke Oven combustion chamber

- NOx emissions

![Schematic diagram of Coke Oven combustion chamber](image)

![NOx emissions graph](image)
5. NOx emission control techniques

5.3.12.2 Reduction of NO\textsubscript{X} by primary measures

\textbf{Waste gas recirculation:} The lower O\textsubscript{2} and higher CO\textsubscript{2} concentrations reduce the flame temperature.

\textbf{Staged air combustion:} by adding the combustion air in several stages, combustion conditions become more moderate, and NO\textsubscript{X} formation is reduced

\textbf{Lowering coking temperatures:} A lower coking temperature requires a lower heating chamber temperature, which results in less NO\textsubscript{X} formation.

For existing modern plants which have already incorporated low-NO\textsubscript{X} techniques, such as staged air combustion and waste gas recirculation, NO\textsubscript{X} concentrations of 322 – 414 mg/Nm\textsuperscript{3}(150~200 ppm) at 5 % O\textsubscript{2} are reported.

For existing plants without process-integrated deNO\textsubscript{X} measures, achievable levels for NOX are in the higher range up to 1783 g/t coke, with concentrations up to 1700 mg/Nm\textsuperscript{3}(830 ppm) at 5 % O\textsubscript{2}.

5.3.12.3 Reduction of NO\textsubscript{X} by secondary measures Description

- NOX emissions from coke oven firing are preferably minimized by process-integrated measures, but end-of-pipe techniques may also be applied. (applicable only to new plant)

Reference: EU Best Available Techniques (BAT) Reference Document for Iron and Steel Production
2012 March
5. NOx emission control techniques

- How to reduce NOx for the conventional Coke Oven
  - Application of SCR?
    - Only applicable to New Plant
  - Lowering Coking temperature?
    - Decrease the Coke productivity
  - Installation of Staged air combustion?
    - Need to restructure of Coke Oven (refractory)

☞ Supplying air through the emergency burner pipe can be used as two-staged combustion
5. NOx emission control techniques

- Concept diagram of two staged combustion using conventional Coke Oven

- TRIZ tool was introduced to find out the solution
  - Technical contradiction (temperature ↓ ⇒ quality ↓, temperature ↑ ⇒ quality ↑)
  - Forty principles: Segmentation, Asymmetry, ...
6. Pilot test at the #1 Coke Oven (19 combustion chambers)

- **Conditions for stable operation**

  1. **Determination of secondary combustion air flow rate**
     - Total air flow rate: 12,800 Nm³/hr (3% O₂, mixed gas calorific value 1000 Kcal/Nm³)
     - Secondary air flow rate: 30% of total flow rate (benchmarked at the #10 Coke Oven) ⇒ 3,840 Nm³/hr

     | #10 Coke Oven operation conditions |
     |-----------------------------------|
     | ![Diagram](image)                 |

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<thead>
<tr>
<th></th>
<th>1st</th>
<th>2nd</th>
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<tbody>
<tr>
<td>Damper open ratio</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Air flow rate</td>
<td>69%</td>
<td>31%</td>
</tr>
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</table>

  2. **Measuring Scarping Blower flow rate**

     [Scarping Blower Air flow rates]
     S/B: 5100 Nm³/hr (Static pressure 260 mmH₂O)
     - Not appropriate since it had low static pressure (requires > 1,000 mmH₂O)
6. Pilot test at the #1 Coke Oven

3. Maintaining optimal Coke Oven Pressure

- Target: O2 contents 2-4%, Pressure: 1.5-3.5 mmH2O

- Waste gas pressure was measured to adjust top pressure by adjusting damper

4. NOx Emission measurement

- CMS was installed on the chimney
7. Results of the test

- **Operation conditions were identified**
  - Secondary air flow rate : 4,100Nm³/hr (32% of total air flow rate)
  - Coke rate : 115%, Temperature : 1088℃
  - O₂ contents : 2-4%, Top pressure : 1.5 – 3.5 mmH₂O

- **Dramatic reduction of NOx**
  - 45% reduction (220ppm → 120ppm)

![Graph showing NOx concentrations before and after single staged combustion](image)
8. Replication at the #8 Coke Oven (76 combustion chambers)

- Replicated at the larger scale Coke Oven
  - New air blower for supplying secondary combustion air

Cost analysis

<table>
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<tr>
<th>Index</th>
<th>POSCO Technology</th>
<th>SCR</th>
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<tbody>
<tr>
<td>Investment cost</td>
<td>Billion Won</td>
<td>1.7</td>
</tr>
<tr>
<td>Operation cost</td>
<td>(approx. 0.9 M$)</td>
<td>0.4</td>
</tr>
</tbody>
</table>

☞ Much more economical than end-of-pipe technology
9. Conclusions

- POSCO successfully reduced 45% of NOx emission at the conventional Coke Oven by applying secondary combustion air through COG scarping pipe.

- NOx emission control technology was successfully replicated at the #8 coke oven plant and it is under installation in other Ovens at the Pohang works.

- POSCO continues its efforts on developing new environmental technology.