OXYGEN SOLUTIONS FOR NOX REDUCTION AND ENERGY SAVINGS IN GLASS PRODUCTION

Pedel Julien, Tasca Abilio
Linde Gas

May 14-15, 2019
Linde continues to deliver Best of Oxy-Fuel Combustion to Glass Industry

- Recent commercial deployment of two innovative, low-cost oxygen technologies:
  - **Oxygen Enhanced NOx Reduction (OENR) technology:**
    - Reduce furnace NOx emissions below 800 mg/Nm³
    - Installed at two large-size end-port container furnaces in Italy
    - Small amount of oxygen to lower NOx emissions by 18% up to 27%
  - **Oxy-fuel technology for glass forehearths:**
    - Adoption of oxy-fuel combustion for forehearth limited due to over-heating and capital cost
    - Linde new oxy-fuel solution addresses both issues while maintaining the fuel savings benefits
    - Oxy-fuel technology implemented on a 35 TPD boro-silicate forehearth with 60% fuel savings
OENR implementation in large-scale regenerative container glass furnaces

- OENR first implemented in a 600 tpd cross-fired float glass furnace in 1998 and later in an 80 tpd end-port white soda-lime glass furnaces.
- In 2018, Praxair and Rivoira implemented OENR in two large-scale (400 tpd) container end-port furnaces in Italy. Customer interested in meeting NOx EU limit of 800 mg/Nm$^3$.
- One-month trial period on each furnace to demonstrate OENR performance:
  - Achieve 15 – 30% NOx reduction with a small amount of oxygen (80-150 Nm$^3$/hr)
  - No increase in CO concentration in the flue gas at the top of the regenerators and at the stack
  - Maintain glass production and glass quality
Oxygen Enhanced NOx Reduction (OENR) technology principle

- OENR provides an alternative to conventional staging techniques for NOx reduction, such as cold air staging, that may result in increased fuel consumption in the melter.

- Excess air and stoichiometric ratio (SR) reduction of primary air flame is the key factor in NOx reduction.

- About 30% NOx reduction is achieved by 9% reduction in primary SR.

- As the primary SR is reduced, CO emission or reducing atmosphere over glass surface becomes the limiting factor for NOx reduction.

- Secondary oxidant injection is needed to burn out residual CO/H₂ without increasing NOx.
Furnace 1: OENR trial results

- 410-435 tpd of flint glass with a high specific pull rate of 4 tpd/m²
- Operating with only 0.2% excess oxygen in the flue gas
- Oxygen flow rates varied from 50 to 140 Nm³/hr to determine the optimal amount
- Natural gas input maintained constant while the air flow is reduced

- Best results were achieved with O₂ flow rates of 80-120 Nm³/hr:
  - NOx in flue gas reduced from 1080 to ~800 mg/Nm³
  - CO level maintained around 200 ppm
  - No increase on SO₂ levels and crown temperature

- Overall, NOx reduction of 24-27% compared to the baseline

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>OENR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pull rate (ton/day)</td>
<td>435</td>
<td>435</td>
</tr>
<tr>
<td>Fuel (Nm³/h)</td>
<td>1745</td>
<td>1745</td>
</tr>
<tr>
<td>Electric Boost (kWh)</td>
<td>1000</td>
<td>1000</td>
</tr>
<tr>
<td>Air flow (Nm³/hr)</td>
<td>17800</td>
<td>17275-17450</td>
</tr>
<tr>
<td>Air/fuel ratio</td>
<td>10.2</td>
<td>9.9-10</td>
</tr>
<tr>
<td>Oxygen (Nm³/h)</td>
<td>0</td>
<td>80 - 120</td>
</tr>
<tr>
<td>Overall excess O₂ (%)</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>CO in flue gas stack (ppm dry)</td>
<td>200</td>
<td>210</td>
</tr>
<tr>
<td>NOx (mg/Nm³ at 8% O₂ dry)</td>
<td>1080</td>
<td>790-820</td>
</tr>
<tr>
<td>NOx reduction (%)</td>
<td>0%</td>
<td>24% - 27%</td>
</tr>
</tbody>
</table>
Furnace 2: OENR trial results

- Furnace 2: end-port air-regenerative furnace producing 380 tpd of flint glass
- Customer collected statistical data before and after OENR implementation
- NOx emissions reduced by 18% from 960 mg/Nm3 to 790 mg/Nm3 with 80 Nm3/hr of oxygen
- Statistically significant reduction of NOx standard deviation observed, indicating a more stable process
- CO emissions remained the same at about 200 ppm at the stack. No change in glass quality and regenerator crown temperature observed.
- Customer was satisfied with the OENR system performance on both furnaces and decided to adopt the technology on a long-term basis.
Linde has developed a novel solution for forehearth:

- Energy savings of 55-70% compared to air-fuel
- Low cost and simple retrofit to existing premixed air-fuel forehearth system
- Avoids over-heating issue commonly associated with oxy-fuel solutions
- Low operating cost
- Solution has been successfully demonstrated for forehearth with cover plate
Pilot test at customer site (2017-2018)

- Small specialty container glass furnace (30 tpd)
  - Premixed air/fuel burners with LPG fuel
  - Indirect heating (cover plate separates combustion space from glass)
  - Customer motivated to reduce fuel consumption

- Phase 1 (2017): Drain section conversion
  - no glass flow (section not in use)
  - 50-70% fuel savings achieved while maintaining zone temperature

- Phase 2 (2018): Distributor section conversion
  - Installed in May 2018 for 3 months (until rebuild)
  - Amber glass flow, no impact on glass quality
  - 63% fuel savings achieved

- Customer satisfied and decided to convert new forehearth to oxy-fuel (2019)
Conclusion

**Oxygen Enhanced NOx Reduction (OENR) technology:**
- Can reduce NOx emissions by 15% up to 30% in air-fired furnaces
- Commercial demonstration at two large-size end-port container furnaces
- Low installation and operation cost with less than 120 Nm3/hr of oxygen flow needed
- No adverse impact on crown and regenerator temperature, CO and SO2 levels, and glass color

**Oxy-fuel technology for glass forehearths:**
- Can lower fuel consumption by 50-65% in forehearth
- Low retrofitting cost to existing premixed air-fuel systems
- Limited risks of over-heating refractories
- Implemented in two zones on a 35 TPD boro-silicate forehearth and demonstrated 60% fuel savings
- Customer satisfied and decided to convert new forehearth to oxy-fuel (2019)
Thanks for your attention.