Regenerator Repair without production loss, possible?

Benjamin Köster
- Environmental friendly
- Full recycling of glass cullet
- Full recycling of water
- Highest safety standards / procedures
- High safety due to use of cooled water
- Fully closed circuit, no overflow
- Plug and play installation
- All equipment tested and certified
Furnace Heat Up

-The “Hotwork” method is worldwide standard
-Over 1,000 successful Furnace Heat Ups and Draining's
-Engineers with over 15 years of experience
-Senior Engineers with over 25 years of experience
-Experienced with all types of furnaces:
  - Float/Container/Fiber/LCD/Electric/Oxy-fuel/Special Glass
-International Crews
-Over 16 spoken languages
Being an International company, we reach out to any location worldwide... doesn’t matter if it’s in the Jungle, Desert or the cold north of Siberia.
Innovative Combustion Systems

Control Skids

Furnace Controls / DCS

Gas/Oil/Oxygen Burner
Correct regenerator function is vital for efficient furnace operation

Regenerator checker blockage and collapses result in:

- Increased gas consumption
- Increased furnace pressure
- Increased refractory corrosion and potential for defects
- Reduced furnace pull and thermal efficiency
- Increased costs
Regenerators – main issues

Crown: ~ 1350 – 1550°C
Port neck: ~ 1400 – 1600°C
Top Checkers: ~ 1350 – 1550°C
Rider arch ~ 500 – 800°C

Target wall and Port sill: Carryover erosion and corrosion
Target wall – movement inwards due to creep & forsterite growth

Crows/Dividing walls: Thermal Creep; alkali corrosion; shelling

Port necks – refractory shelling/blockage

Particulate carryover (batch/cullet)
Alkali gases (e.g. NaOH), CO

Top checkers:
- Carryover blockage; forsterite bursting, refractory shelling, V₂O₅ corrosion

Middle checkers: blockage (from above), sulphate attack, collapse due to overheating

Middle/Lower checkers – reducing conditions promoting Na₂CO₃ attack

Lower checkers/Rider arches: sodium sulphate blockage (oxidising conditions)/Spalling, Thermal cycling
Regenerators - useful process variables to monitor

- Regenerator crown temperatures (daily – linked to SCADA)
- Rider arch/lower chamber temperatures (daily – linked to SCADA)
- Chimney damper position/OP% (daily) – is OP% increasing (suddenly/gradually)?
- Reversal damper operation – reversing and sealing correctly (weekly)
  - Procedure to follow in the event of prolonged reversal failure?
- External structure – visual/thermographic inspection for hotspots, cracks, sting-out
- Upper and lower chamber pressure; firing and non-firing side (every 2 months)
- Waste gas combustion (manual) analysis – O₂, CO, NOx (weekly/pull change/colour change)
- Smoke/flames at the rider arches?
- Visual inspection of port necks, upper chamber and top checkers (weekly)
- Radiation pattern in regenerator bases (monthly – visual mirror inspection/mapping)
  - Any evidence of broken checker bricks?
- Endoscope inspection of upper chamber structure and checkers (6-12 months)
- Establish baseline trends and monitor regenerator health!
Regenerator problems

So, what are the options when you face major regenerator problems?
Regenerator problems

Option 1: Do nothing.....

Probable results:
• Further deterioration of the checker pack leading to premature furnace shutdown.
• Increasing difficulty in controlling furnace pressure and combustion.
• Pull reductions required.
• $NO_x$, $SO_x$, CO emissions increase.
• Glass quality reduction.
• Difficulty in meeting production orders.
• Unhappy management and customers....
Regenerator problems

Option 2: checker removal

- Hot removal of collapsed checker layers/channel creation
- Only helpful if the first 2-3 course are blocked and access available

- **Advantages:**
  - Low cost option
  - Fast implementation.

- **Disadvantages:**
  - Reduced regenerator efficiency and increased energy cost.
  - Short term solution (middle pack exposed to higher temperature, carry over attacks etc.)
  - Increased emissions
  - Increased waste gas temperatures
Regenerator problems

Option 3: Furnace hot-hold and regenerator repair (e.g. checkers, crown)

- Furnace temperatures are held in the range 1200-1300°C for the duration of the repair using high velocity burners
- Typical repair duration for an end-fired furnace is 17 to 24 days depending on size, access and scope of repair
- Regenerators are isolated from the furnace, cooled down and repaired accordingly

Advantages:
- Re-establish regenerator integrity and restores design thermal efficiency

Disadvantages:
- Increased capital expenditure
- No production during the regenerator repair period
- Difficulty in meeting production orders
Regenerator problems

Option 4: Temporary oxygen-firing conversion and regenerator repair

Furnace is converted to oxygen-firing for the duration of the checker repair

- Typical repair duration for an end-fired furnace is 17 to 24 days depending on size, access and scope of repair
- Furnace temperatures are maintained at normal production settings to allow continued production during the regenerator repair
- Regenerators are isolated from the furnace, cooled down and repaired accordingly

Advantages:
- Re-establish regenerator integrity and restore design thermal efficiency
- Maintain production output and glass quality at normal levels
- Allows a fast response to emergency situations
- Can be used on a longer term basis if refractory materials are not immediately available

Disadvantages:
- May not be justifiable financially, depending on post-repair campaign life expectations
Why Oxygen firing is suitable to regenerator repairs

Increased Flame Temperature vs. normal air-fuel combustion

- Flame temperature is determined by calorific value of the fuel and the mass of waste gases generated from the combustion processes
- Compared to air-fuel combustion, oxy-fuel combustion generates a much lower mass of waste gases (and can also be exhausted via temporary flues used in the repairs)
- This means that flame temperatures are higher with oxy-fuel firing compared to air-fuel firing

Flame temperature comparisons (stoichiometric combustion)

- Natural gas and ambient (20°C) air: ~1950°C
- Natural gas and preheated (1300°C) air: ~2400°C
- Natural gas and ambient (20°C) oxygen: ~2800°C
- So, with oxy-fuel firing we don’t need preheat as we do with the combustion air
- Perfect when we don’t have the regenerators available for preheating!
Oxy-fuel burner system – underport firing

Regulating Oxygen Burners compatible with ~95% of existing underport firing configurations

Regulating Oxygen Burners
Good flame coverage, Low Nox
Adjustable flame pattern
Oxy-fuel burner system – underport firing

- Oxygen Burners normally utilise existing plant natural gas line to connect to burners.
- Alternatively a dedicated Gas/LPG station can be supplied
- Oxygen Burners also compatible with fuel oil
- In an emergency situation, maintain the furnace with heat up burner and hot-hold at short notice, whilst Oxygen equipment and supply are organised
  - Our group have hot hold burner equipment available at 10 Global locations, also in Mexico
### OXYGEN SOLUTION RUNNING COST VS SALES

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QUANTITY</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAS</td>
<td>710</td>
<td>NM3/HR</td>
</tr>
<tr>
<td>OXYGEN</td>
<td>1600</td>
<td>NM3/HR</td>
</tr>
<tr>
<td>GAS COST</td>
<td>€0.22</td>
<td>EUROS/NM3</td>
</tr>
<tr>
<td>GLASS PULL</td>
<td>180</td>
<td>TONS/DAY</td>
</tr>
<tr>
<td>GLASS SALE</td>
<td>408</td>
<td>EUROS/TON</td>
</tr>
<tr>
<td>OXYGEN COST</td>
<td>€0.16</td>
<td>EUROS/NM3</td>
</tr>
<tr>
<td>REPAIR COST (EQUIPMENT + LABOUR)</td>
<td>€480,000</td>
<td>EURO - 24 DAY REPAIR DURATION</td>
</tr>
<tr>
<td>REFRACTORY COST</td>
<td>€250,000</td>
<td>EUROS</td>
</tr>
<tr>
<td>DAILY OXY + GAS</td>
<td>€9,739</td>
<td>DAILY GAS + OXY COST</td>
</tr>
<tr>
<td>TOTAL OXY + GAS</td>
<td>€233,741</td>
<td>24 DAY REPAIR PERIOD</td>
</tr>
<tr>
<td>GLASS SALES VALUE PER DAY</td>
<td>€73,440</td>
<td>EURO</td>
</tr>
<tr>
<td>GLASS SALES VALUE - 24 DAY REPAIR</td>
<td>€1,762,560</td>
<td>EURO</td>
</tr>
<tr>
<td>GLASS SALES MINUS REPAIR COSTS</td>
<td>€798,819</td>
<td>EURO</td>
</tr>
</tbody>
</table>

### HOT HOLD RUNNING COST VS SALES

<table>
<thead>
<tr>
<th>ITEM</th>
<th>QUANTITY</th>
<th>UNIT</th>
</tr>
</thead>
<tbody>
<tr>
<td>GAS</td>
<td>600</td>
<td>NM3/HR</td>
</tr>
<tr>
<td>COMBUSTION AIR</td>
<td>0</td>
<td>AIR FROM HV BURNERS</td>
</tr>
<tr>
<td>GAS COST</td>
<td>€0.22</td>
<td>EUROS/NM3</td>
</tr>
<tr>
<td>GLASS PULL</td>
<td>180</td>
<td>TONS/DAY</td>
</tr>
<tr>
<td>GLASS SALE</td>
<td>-408</td>
<td>EUROS/TON (NEGATIVE, NO PRODUCTION)</td>
</tr>
<tr>
<td>REPAIR COST (EQUIPMENT + LABOUR)</td>
<td>€262,000.00</td>
<td>EURO - 24 DAY REPAIR DURATION</td>
</tr>
<tr>
<td>REFRACTORY COST</td>
<td>€250,000</td>
<td>EUROS</td>
</tr>
<tr>
<td>DAILY GAS COST</td>
<td>€3,168.00</td>
<td>DAILY GAS COST</td>
</tr>
<tr>
<td>TOTAL GAS COST</td>
<td>€76,032.00</td>
<td>GAS COST 24 DAY REPAIR PERIOD</td>
</tr>
<tr>
<td>LOST GLASS SALES VALUE PER DAY</td>
<td>-€73,440.00</td>
<td>EURO</td>
</tr>
<tr>
<td>LOST GLASS SALES VALUE - 24 DAY REPAIR</td>
<td>-€1,762,560.00</td>
<td>EURO</td>
</tr>
<tr>
<td>LOST GLASS SALES PLUS REPAIR COSTS</td>
<td>-€2,350,592.00</td>
<td>EURO</td>
</tr>
</tbody>
</table>

**Simple comparison – Oxygen solution vs Hot hold**
Stage 1: **Scope definition** Engineering, method statements and risk assessments
**Stage 2:** Oxygen storage and station commissioning, production and safety training.
Stage 3: Temporary exhaust flue installation

Stage 4A: Port neck isolation with dampers
Stage 4B: Regenerator chamber cooldown;
Stage 4C: Port neck insulation
Stage 4D: Transition to oxygen firing – production support and burner optimisation
Stage 5: Demolition during production
**Stage 6:** Rebuilding checker/Regenerator

**Stage 7:** Heat up of regenerator chamber

**Stage 8:** Port neck damper removal and transition from Oxygen to main fuel firing

**Stage 9:** Resealing of regenerator expansions and joints
## Oxygen firing regenerator repair examples

<table>
<thead>
<tr>
<th></th>
<th>Furnace A</th>
<th>Furnace B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Furnace Type</strong></td>
<td>Container</td>
<td>Container</td>
</tr>
<tr>
<td><strong>Regenerator type</strong></td>
<td>End fired/double pass</td>
<td>End fired/single pass</td>
</tr>
<tr>
<td><strong>Repair Type</strong></td>
<td>Emergency: Oxy-conversion</td>
<td>Planned: Oxy-conversion</td>
</tr>
<tr>
<td><strong>Pre-repair pull (design)</strong></td>
<td>340 tpd</td>
<td>440 tpd</td>
</tr>
<tr>
<td><strong>Pull during repair</strong></td>
<td>260 tpd*</td>
<td>440 tpd</td>
</tr>
<tr>
<td><strong>Chambers repaired</strong></td>
<td>2 (Left and right)</td>
<td>2 (left and right)</td>
</tr>
<tr>
<td><strong>Scope of repairs</strong></td>
<td>Crowns/target walls/dividing wall/rider arches/checkers</td>
<td>Crowns/endwalls/innerwalls and checkers</td>
</tr>
<tr>
<td><strong>Repair duration</strong></td>
<td>14 days*</td>
<td>21 days</td>
</tr>
</tbody>
</table>

* Furnace A ran for 6 months on oxygen prior to regenerator repair. LPG supply restrictions at site meant that furnace had to run at reduced load during repair period. Alternative to repair was a furnace cold repair.
Turn Key Solution

- Unique collaboration between Lizmontagens Melting and Services, Hotwork International and The Linde Group allows us to provide a turn-key solution for oxygen conversion and regenerator repair, leveraging the core-competencies of each company:
  - **Lizmontagens Melting and Services** – Project management, engineering, materials refractory demolition and installation services.
  - **Hotwork International** – Oxygen combustion system, combustion engineering, hold hot, cooldown and heat-up management, production support.
  - **Linde Group** – Oxygen supply including temporary cryogenic storage facilities, vaporiser, piping, distribution and oxygen delivery.
Regenerator Repair without production loss, possible?

Yes!

Thanks for Listening

Special Thanks to:
Mike Rose, Gianni Carbone, Matthias Görisch