Oxy-fuel Tableware Furnace with Novel Oxygen- and Natural Gas Preheating System

Presentation by Dr. Tunç Görüney

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Şişecam Corporate Overview

- **$2.6 BN** in Sales (50% international)
- Operations in **13 Countries**
- **21,000** Employees
- Sales to **150 Countries**
- **28%** of shares listed at BIST (SISE.IS), **72%** by İşbank
- **4 Production Groups** (11,500 TPD glass)
  - Flat / Container / Tableware / Chemicals
- Consumes **3.85%** of Turkey’s NG and **0.7%** of Turkey’s electricity
- < 1% of sales to R&D spending

<table>
<thead>
<tr>
<th>GLOBAL RANKING by Production ‘15</th>
<th>Europe</th>
<th>World</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Container</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Tableware</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Chemicals</td>
<td>4</td>
<td>10</td>
</tr>
</tbody>
</table>


*including plants outside Turkey


Şişecam Waste Heat Recovery Portfolio

- **Air-fuel**
  - Organic Rankine Cycle (9 MW\(_{e,net}\))
  - Steam Turbine (8 MW\(_{e,net}\))
  - Absorption Chillers (5 MW\(_{th,cool}\))
  - Waste Heat Boilers (18 MW\(_{th,heat}\))
    - Hot Water
    - Steam
- **Oxy-fuel**
  - Preheated Oxy-Fuel (1 MW\(_{th,preheat}\))

**Total WHR less than 4% of global Şişecam energy consumption***

<table>
<thead>
<tr>
<th></th>
<th>MW</th>
<th>kWh/ton glass*</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOTAL thermal</td>
<td>24</td>
<td>51</td>
<td>59%</td>
</tr>
<tr>
<td>TOTAL electric, net</td>
<td>17</td>
<td>36</td>
<td>41%</td>
</tr>
</tbody>
</table>

*11,500 TPD global glass production in 2015, excludes chemicals (Soda and Chromium compounds)*
The world leader in gases, technologies and services for Industry and Health

Following the acquisition of Airgas *

- More than 68,000 employees
- Present in 80 countries
- Revenue >20 € billion
- More than 3 million customers and patients
Presentation Overview

- Motivation
- Background
- Technology and Project Description
- System Layout
- Erection Phase
- Start-up and Operation Phase
  - System Performance
  - Troubleshooting
- Key Enablers and Milestones
- Performance Summary
- Conclusion
Motivation

*Increasing energy prices*

*Increasingly stringent environmental regulations*
- EU BREF BAT: 0.5-0.8 kg/ton for oxy-fuel container glass furnaces
- NOx emissions of 16 furnaces in 7 plants in Turkey continuously monitored by Ministry of Environment and Urbanization (2016)

*Probability of getting external funding for demonstration*
- **World first** at this scale and type of production (color / quality)
- Needed smaller footprint and significant CAPEX reduction for scaled down version of HeatOx technology
  - Float (AGC) → Two heat exchangers per **burner**
  - Tableware (Şişecam) → Two heat exchangers per **side**

*Industrial gas supply synergy*
- 2 Float- and 2 Tableware lines at same site in Bulgaria
- N₂ for tin bath, O₂ for melting and polishing (cryogenic)

*prior to 2012 (investment decision)*
Background

- **LIFE+ Application Submitted**
  - June 2012

- **Awarded Project Starts**
  - July 2013

- **Gas Supply Contract Signed**
  - December 2013

- **B furnace Starts up**
  - August 2014

- **Equipment Orders Placed**
  - May 2015

- **Erected in 3 mts**
  - July 2015

- **HeatOx Starts up**
  - October 2015

- **Equipment Erection Starts**
  - May 2016

- **HeatOx Restarts**
  - June 2016

- **European Commission Visit to Plant**
  - May 2016

- **Awarded Project Ends**
  - June 2016

- **TGB/PB Spin-off**
  - December 2016

- **In operation**

**Additional Note:**

- **Oxy-fuel Investment Decision Independent from LIFE+ Application**
Technology and Project Description

Oxy-fuel waste heat recovery by preheating reactants (HeatOx)
- 12 MW O₂ and NG heat exchangers, 8 preheated- 2 nonpreheated burners
- Preheating gaseous O₂ (up to 550°C) and NG (up to 450°C) - design condition

Safety features
- Intermediate heat exchange fluid (air) used
- Exhaust (ColdOx) mode → Emergency hot air discharge outside building

EU LIFE+ Environment Policy and Governance project application
- Coordinating Beneficiary (Project Coordinator) → Paşabahçe Bulgaria EAD
- Associated Beneficiary (Project Partner) → Air Liquide
- Total project budget: 4.3 MM EUR
- Industrial prototype: < 50% of total budget
- 1.7 MM EUR funding

Project goal to demonstrate;
- Compared to oxy-fuel combustion
  - 9% fuel savings
- Compared to air-fuel combustion
  - 15% CO₂ reduction (fuel and batch)
  - 90% NOx reduction
System Layout

- 4 HeatOx burners on each side
  - Separate O₂ (top) and NG bodies
  - Work with hot- and cold reactants
- Dual stage recuperators per side due to architectural limitations
  - Roof → Dual stage recuperators
  - Beam → Uneven duct path

Source: Kang et. al., *Environmental assessment of reactant preheating technology*, DGG/HVG Goslar, Germany, June 6-8, 2016
Erection Phase

- Building originally designed for endport regenerative furnace
- Modification of existing flue gas channels on-the-fly
- Relocation of interfering pipework
- Completed in 3 months
- Very tight space
- Compliance with architectural / structural limitations
Start-up and Operation Phase

System Performance (compared to oxy-fuel)

- Practically no impact on furnace pressure management
- No effect on glass quality and color
- Furnace aging → OK but need to finish campaign for final assessment
- Very flexible and adaptable to variations in process (pull, cullet, O₂/NG ratio, etc.)
- Monitoring energy and emissions performance via measurements (composition and flow)

![Graph showing system performance](image)

<table>
<thead>
<tr>
<th>Date</th>
<th>Mode</th>
<th>NOx (ppm)</th>
<th>O₂ (%)</th>
<th>NOx expressed as NO₂ (mg/Nm³)</th>
<th>Pull rate (tpd)</th>
<th>Fumes (Nm³/h)</th>
<th>NOx as NO₂ (kg/T)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oct-15</td>
<td>HeatOx-B</td>
<td>752.5</td>
<td>2.1</td>
<td>1059</td>
<td>200</td>
<td>2113</td>
<td>0.268</td>
</tr>
<tr>
<td>Nov-15</td>
<td>HeatOx-B</td>
<td>760.5</td>
<td>0.65</td>
<td>993</td>
<td>200</td>
<td>2113</td>
<td>0.252</td>
</tr>
<tr>
<td>Mai-16</td>
<td>HeatOx-B</td>
<td>767.1</td>
<td>1.70</td>
<td>1057</td>
<td>198</td>
<td>2133</td>
<td>0.273</td>
</tr>
</tbody>
</table>

* NOx expressed as NO₂ corrected @ O₂ 8%
Start-up and Operation Phase

Troubleshooting

**Clogging**
- ID fan early warning
- Analyses point to $\text{Na}_2\text{SO}_4$ deposition
- Estimated cause
  - Architectural limitations (retrofit)
  - Transitional regimes (debugging phase)
- Implemented design changes to enable declogging w/o interruption to HeatOx

**Dampers**
- Design revisited on-the-go to better adapt to current process conditions based on learnings during operation phase

Source: Beerkens, *Deposits and condensation from flue gases in glass furnaces*, Thesis

*Clogging: $\text{Na}_2\text{SO}_4$ deposition (endoscopy image)*
Start-up and Operation Phase

Troubleshooting

**Flue Gas Channel**
- On-the-go improvements to minimize ambient air leaks into flue gas channels and reduce heat losses

**Air Side**
- On-the-go improvements to minimize process (hot) air leaks

**Carbon Build-up**
- Intensifies prior to Cold/Hot transition
- Most of the time only one burner
- Ongoing investigation, nozzle change under evaluation

![Carbon build-up on nozzle tip](image-url)
Key Enablers and Milestones

50% co-funding (LIFE+ 2012)
- Total budget: 4.3 MM EUR
- Total eligible budget: 3.4 MM EUR
- EU funding: 1.7 MM EUR

Outsourced industrial gas supply synergy
- $O_2 \rightarrow$ Tableware (melting & polishing)
- $N_2 \rightarrow$ Float (tin bath)

Debottlenecking flue gas side issues
- Fixing ambient air leaks and insulation
- More robust by-pass dampers
- De-clogging $\rightarrow$ Cleaning ports

Debottlenecking air side issues
- Fixing process air leaks
- Fixing thermal expansion issues

Strong commitment and teamwork
- Group Management - Plant - R&D - Corporate Engineering - Technology Provider - Suppliers - Consultants

EC visit to Paşabahçe Bulgaria

Right after Start-up

Air Liquide $O_2$ & $N_2$ plant
# Performance Summary

<table>
<thead>
<tr>
<th>Aspect</th>
<th>Experience from Project</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Safety</strong></td>
<td>No issue reported</td>
</tr>
<tr>
<td><strong>Glass Color &amp; Quality</strong></td>
<td>No issue reported</td>
</tr>
<tr>
<td><strong>Furnace Aging</strong></td>
<td>No issue reported so far, need to revisit at end of campaign</td>
</tr>
<tr>
<td><strong>Energy (NG and O₂)</strong></td>
<td>- Preheating: ~8%* fuel savings demonstrated on average</td>
</tr>
<tr>
<td></td>
<td>- Foam: initial results favorable compared to oxy-fuel, further investigation needed for validation</td>
</tr>
<tr>
<td><strong>Emissions</strong></td>
<td>Similar to oxy-fuel (&gt;90% NOx reduction wrt air-fuel)</td>
</tr>
<tr>
<td><strong>Maintenance / Reliability</strong></td>
<td>- Retrofit (architectural constraints, no-WHR mindset)</td>
</tr>
<tr>
<td></td>
<td>- Learnings (flue gas- and air) → leaks, clogging, dampers</td>
</tr>
<tr>
<td></td>
<td>- Carbon build-up believed to intensify prior to Cold/Hot transition → ongoing investigation</td>
</tr>
<tr>
<td><strong>Ease of Use</strong></td>
<td>Start-up and shut-down with the push of a button</td>
</tr>
<tr>
<td></td>
<td>Highly flexible and adaptable to variations in process</td>
</tr>
<tr>
<td><strong>Project Management</strong></td>
<td>On budget / On time</td>
</tr>
</tbody>
</table>

*1.0-1.5% more savings expected at design condition with improvements in progress*
Conclusion

**World’s first tableware scale preheated oxy-fuel waste heat recovery demonstration**

- ~8% *fuel savings* demonstrated, 1.0-1.5% more savings expected at design condition with improvements in progress (~$250-480K/yr depending on NG price)
- More than *90% NOx reduction* demonstrated compared to air-fuel: ~0.3 kg/ton
  [BAT: 0.5-0.8 kg/ton for oxy-fuel container glass furnaces]
- Added value of technology provider and glassmaker working together

**Şişecam positioning in advance of increasingly stringent environmental regulations**

- Potential NOx regulation change in Turkey in 2017 (operational domain COP21)
- Positive outlook for Oxy-fuel combustion or DeNOx equipment
- Şişecam’s unique multi-segment production structure at same site

**Şişecam continuing to invest in innovative technologies that bring value and reduce environmental footprint of glass manufacturing**

- Partial/full oxy-fuel combustion- and WHR for new investments and retrofits
- Leveraging external partnerships and in-house R&D capabilities
LEVENT KAYA

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Thank you for your attention

Paşabahçe Bulgaria and Air Liquide thank EC LIFE+ program for funding this project.

For any questions, please contact tgoruney@sisecam.com

Visit us @ www.ecoheatox.com
www.pasabahce.com
www.sisecam.com

…and don’t forget to