Results of a technology recovering waste heat to preheat oxygen and natural gas for oxy-fuel furnaces

(* AL) (**AGC Glass Europe)

Outlines

- Introduction
- Development of heat recovery technology for oxy-Float furnace
- Industrial results
- Economic approach
Introduction
Introduction

Example of Sankey Diagram for a typical SLS air-fired furnace:

- Preheated air: 6.2 MW (34%)
- Fuel: 12.1 MW (66%)
- Glass melt: 6 MW (32.3%)
- Structural losses: 2.1 MW (11.4%)
- Flue gas: 10.3 MW (56.3%)
- Flue gas: 4.1 MW (22.4%)

<table>
<thead>
<tr>
<th></th>
<th>Air-fired</th>
<th>Oxy-fired</th>
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<tbody>
<tr>
<td>Flue gas Lost Enthalpy</td>
<td>4.1 MW</td>
<td>4 MW</td>
</tr>
<tr>
<td>Flue gas ratio</td>
<td>22.4%</td>
<td>45%</td>
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Fig. 1. Typical Sankey Diagram for container glass furnace

Difference between Oxy-furnace fumes / Air-furnace fumes

- Higher enthalpy (1400°C vs 500°C after regenerators)
- Higher content of thermally efficient species
  - CO2, H20 radiative molecules (About 75% in Oxy-fired)
  - Less thermally inefficient N2 (Air-fired)
Potential solutions to increase furnace efficiency is to recover flue gases energy:

Examples of recovering energy system:
- Before APC: Batch/cullet preheater (up to 300°C for 240 tpd), Flue gases recirculation (mostly for CCS process), regenerative burners
- After APC: Boiler for steam production, Power generator

Technical constraints:
- Flue gases contamination (dusts, sulfates, carry-over, aggressive molecules) → clogging, materials attack (reduce equipment lifetime)
- Temperature & species: materials that can bear up to 50% H2O vapor content, up to 1400°C

Fig. 2. Concept of heat recovery in oxy-fired furnaces
**Air Liquide / AGC Glass Europe Solution:** Extract a part of the flue gases energy to preheat oxygen and natural gas in full-oxy fired furnaces by indirect exchange and use of staged combustion to get Low-NOx and homogeneous furnace temperature ensuring glass quality.

**Introduction**

![Graph showing energy savings with reactants preheating](image1)

![Graph showing heat balance evolution with reactants preheating](image2)
Development of heat recovery technology
Development of the heat recovery technology
Presentation of the Concept **ALGLASS™ HeatOx**

- A technology made in four steps

Fig. 5. Heat recovery concept

Fig. 6. Air/O2 Industrial Exchanger
Development of the heat recovery technology

ALGLASS SUN Burner

Choice of the burner technology: separated jet is the safest for avoiding flame ignition in the burner.

Fig. 7. ALGLASS SUN Burner concept

Fig. 8. ALGLASS SUN Flame in AL R&D Laboratories

Fig. 9. NOx Performances of a full-oxy Borosilicate glass furnace

<table>
<thead>
<tr>
<th>Burner Type</th>
<th>Fumes Composition per Stack</th>
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<tbody>
<tr>
<td></td>
<td>% CO₂</td>
</tr>
<tr>
<td>ALGLASS SUN</td>
<td></td>
</tr>
<tr>
<td>Tertiary oxygen ratio = 75 %</td>
<td>65</td>
</tr>
<tr>
<td>ALGLASS SUN</td>
<td></td>
</tr>
<tr>
<td>Tertiary oxygen ratio = 50 %</td>
<td>65</td>
</tr>
</tbody>
</table>
Development of the heat recovery technology

CFD Modeling

Fig. 10. CFD Modeling of furnace slice for understanding flame/furnace interaction (a) 3D View (b) Side View

High coverage

No overheating along the crown wall despite temperature of reactants
Industrial results
One challenge of heat recovery project at the beginning was related to the evaluation of the preheated oxygen/natural gas hazards.

The main risks were anticipated and studied:

**No Nodules**

**No corrosion**

Fig. 11. Macroscopic views of materials samples (Left) MEB Picture (Right) Atomic migration pretreatment

Today thanks to procedures on the plant, the use of preheated O2 and preheated natural gas does not present a higher risk than in cold reactants configuration.
Successful start-up

The following operations tracked: Heating-up curve, Safety equipments validation, Efficiency of the exchangers

Fig. 12. Air fumes recuperators (Left) Picture (Right) Schematic view with piping and connection with secondary exchangers
Results:

- **Burner flexibility**: possibility to switch the fuel as a function of fuel costs (on a day to day basis)

- **Large burner power range**: from -40% to +70% of nominal

- **Flame lengths**:
  - 4 to 7 meters in natural gas as a function of power
  - 3 to 6 meters in fuel-oil configurations

- **Fuel consumption gain**: target -25% (vs air)

- **SOx and CO2 emissions reduced**

- **NOx emission**: down to 80% NOx reduction (vs air)
Industrial results
Effect of reactants preheating on production

No modification of furnace operation control vs cold reactants regarding:

- Batch and foam behavior
- Crown temperatures
- Glass quality
- Furnace refractories
- Flue gases
Economic aspects
Economic approach
Baseline data & Financial tool

Baseline case: standard data of Float Furnace
- Pull rate: 550 tpd
- Lifetime: 15 years

Assumptions (mostly based on BREF 2009)
- Maintenance costs of 3%/y
- CO2 credit = 20 €/ton (today)
- Standard OPEX costs for DeSOx and DeDust (air fuel case modified)
- No DeNOx costs
- Fuel cost = 40 €/Mwh

Discounted cash flow approach (Net Present Value)

Time evolution of discounted cumulated cash flow difference between two O2 investment projects: (#1) oxy-Float with heat recovery (#2) oxy-Float without.
Time evolution of discounted cumulated cash flow difference between two O2 investment projects: (#1) oxy-Float with heat recovery (#2) oxy-Float without.

Fig. 13. Time evolution of discounted cumulated cash flow difference between two O2 investment projects (#1) oxy-Float with HeatOx (#2) oxy-Float without.
Summary

Results

Challenge #1
Higher efficiency

Challenge #2
Low NOx

Heat Recovery Technology & ALGLASS SUN technology

Perspectives:

- Long-term follow-up (refractories, materials...)
- Improve furnace operations
  - Burner’s settings
  - Global efficiency
Thank you very much for your attention

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For any question, please contact

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