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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

GLOBAL RANKING by Production '15		
	Europe	World
Flat	2	5
Container	4	4
Tableware	2	3
Chemicals	4	10

Former HQ | New HQ | R&D Center

*including plants outside Turkey

http://www.sisecam.com.tr/en/investor-relations/presentations-and-bulletins/annual-reports

http://www.sisecam.com.tr/tr/Documents/Sustainability/Sustainability%20Reports/Sisecam_surdurulebilirlik-raporu_2014.pdf

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*

	MW	kWh/ton glass*	% of Total
TOTAL thermal	24	51	59%
TOTAL electric, net	17	36	41%

*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 *

AIR LIQUIDE
Creative Oxygen

More than
68,000
employees

Present in
80
countries

Revenue
>20
€ billion

More than
3 million
customers and patients

* on May 23, 2016

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
- COP21 – United Nations Climate Change Conference (2015)
- 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

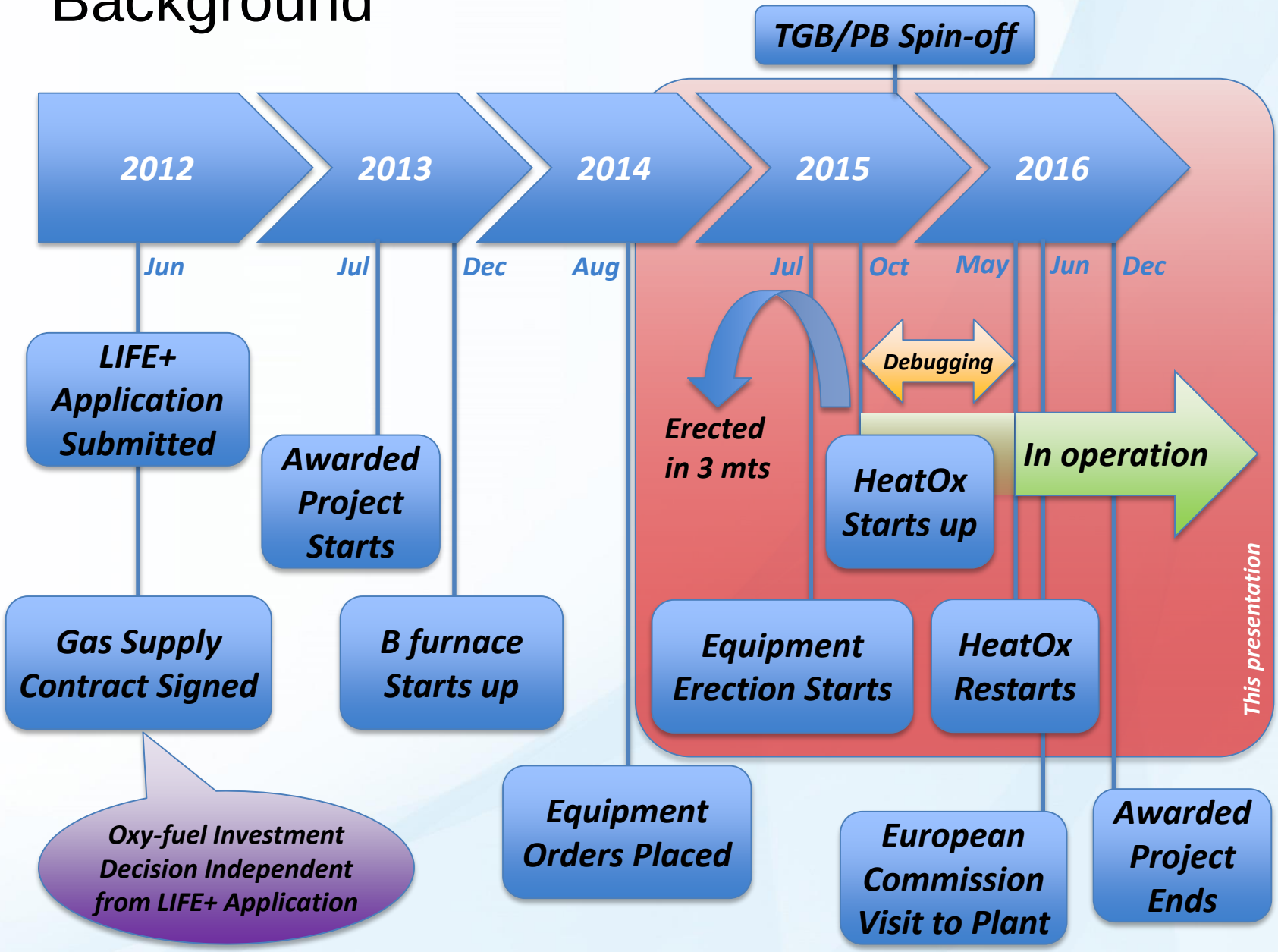
- **World first** at this scale and type of production (color / quality)
- Needed smaller footprint and significant CAPEX reduction for scaled down version of HeatOx technology
  - Float (AGC) → Two heat exchangers per **burner**
  - Tableware (Şişecam) → Two heat exchangers per **side**

Industrial gas supply synergy

- 2 Float- and 2 Tableware lines at same site in Bulgaria
- N_2 for tin bath, O_2 for melting and polishing (cryogenic)

*prior to 2012 (investment decision)

Background


TGB/PB Spin-off
2012
2013
2014
2015
2016
Jun
Jul
Dec
Aug
Jul
Oct
May
Jun
Dec
LIFE+ Application Submitted
Awarded Project Starts
Gas Supply Contract Signed
B furnace Starts up
Oxy-fuel Investment Decision Independent from LIFE+ Application
Equipment Orders Placed
Erected in 3 mts
Debugging
HeatOx Starts up
In operation
Equipment Erection Starts
HeatOx Restarts
European Commission Visit to Plant
Awarded Project Ends
This presentation

Technology and Project Description

Oxy-fuel waste heat recovery by preheating reactants (HeatOx)

- 12 MW O_2 and NG heat exchangers, 8 preheated- 2 nonpreheated burners
- Preheating gaseous **O_2 (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

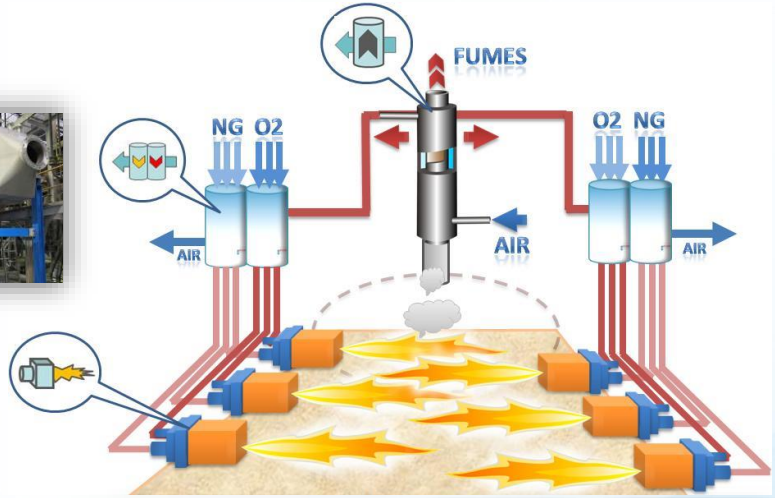
Project goal to demonstrate;

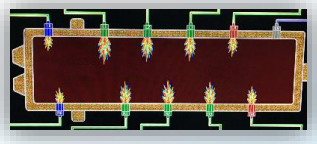
- Compared to oxy-fuel combustion
  - **9% fuel** savings
- Compared to air-fuel combustion
  - **15% CO_2** reduction (fuel and batch)
  - **90% NOx** reduction

LIFE+ information board

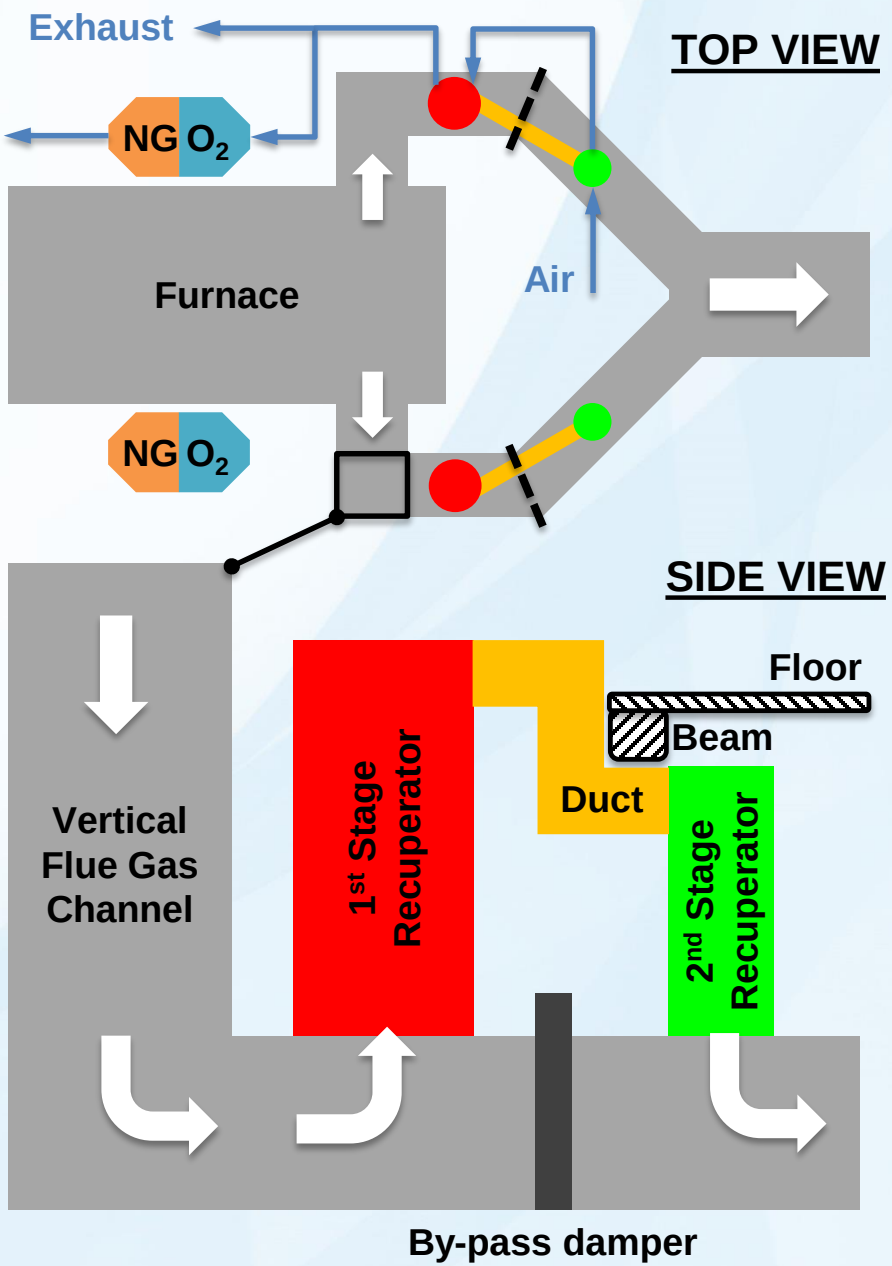
System Layout

- 4 HeatOx burners on each side
  - Separate O_2 (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





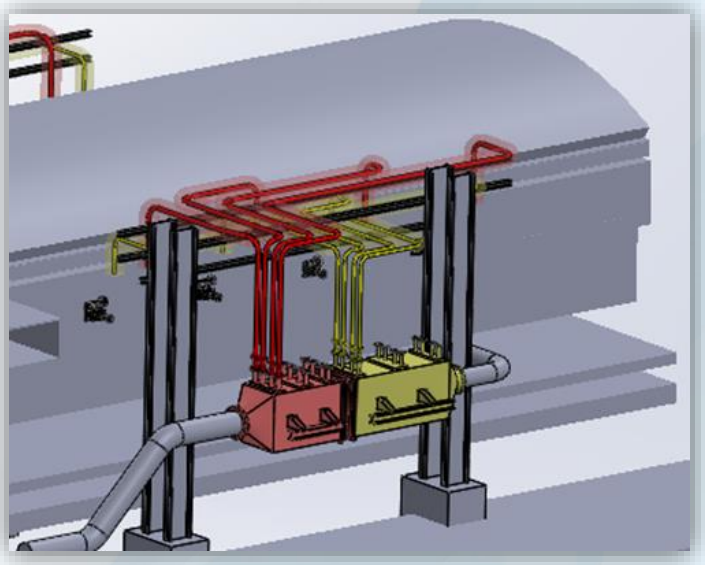
Source: Kang et. al., *Environmental assessment of reactant preheating technology*, DGG/HVG Goslar, Germany, June 6-8, 2016



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

O_2 and NG exchangers and hot piping



Recuperator delivery

Recuperator installation

Recuperators in place

O_2 and NG exchangers

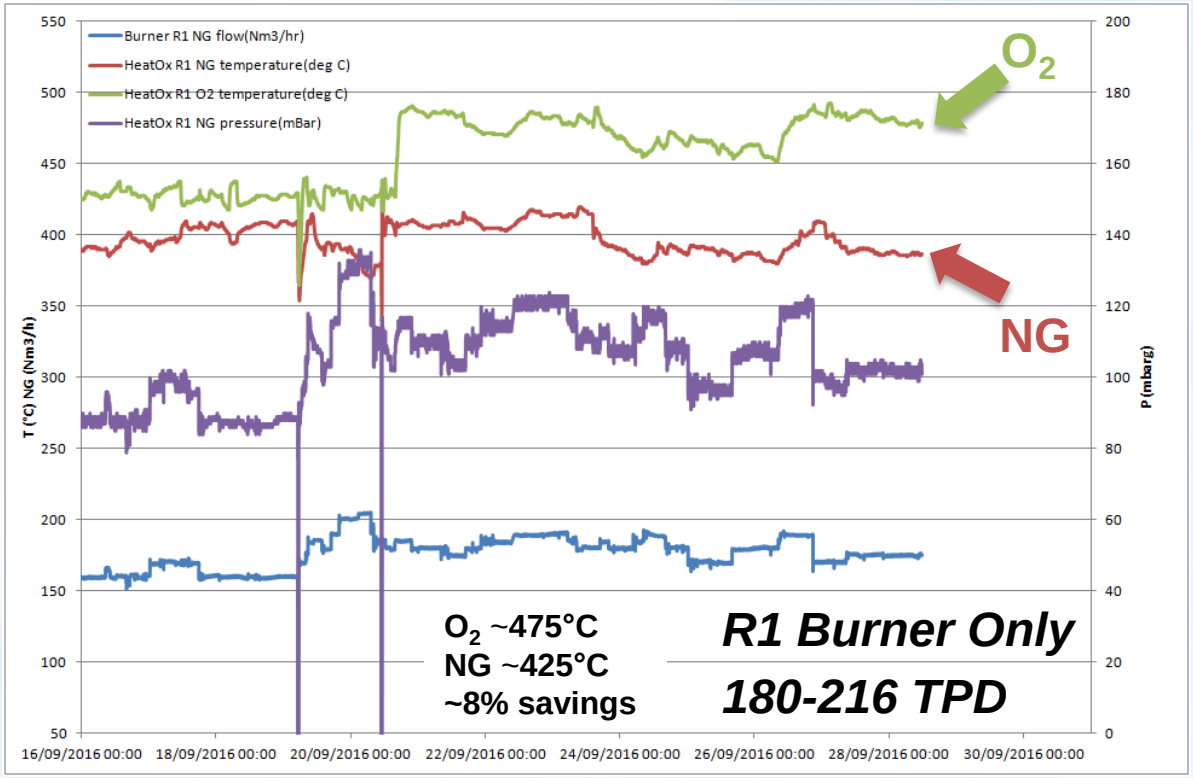
Start-up and Operation Phase

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, O_2/NG ratio, etc.)
- Monitoring energy and emissions performance via measurements (composition and flow)

Date	oct-15	nov-15	mai-16
Mode	**HeatOx-B**	**HeatOx-B**	**HeatOx-B**
NOx (ppm)	752.5	760.5	767.1
O2 (%)	2.1	0.65	1.70
NOx expressed as NO2 (mg/Nm3)	1059	993	1057
Pull rate (tpd)	200	200	198
Fumes (Nm3/h)	2113	2113	2133
NOx as NO2 (kg/T)	0.268	0.252	0.273

** NOx expressed as NO_2 corrected @ O_2 8%*

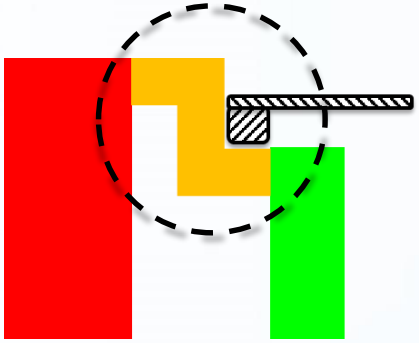


Start-up and Operation Phase

Troubleshooting

Clogging

- ID fan early warning
- Analyses point to Na_2SO_4 deposition
- Estimated cause
  - Architectural limitations (retrofit)
  - Transitional regimes (debugging phase)
- Implemented design changes to enable declogging w/o interruption to HeatOx



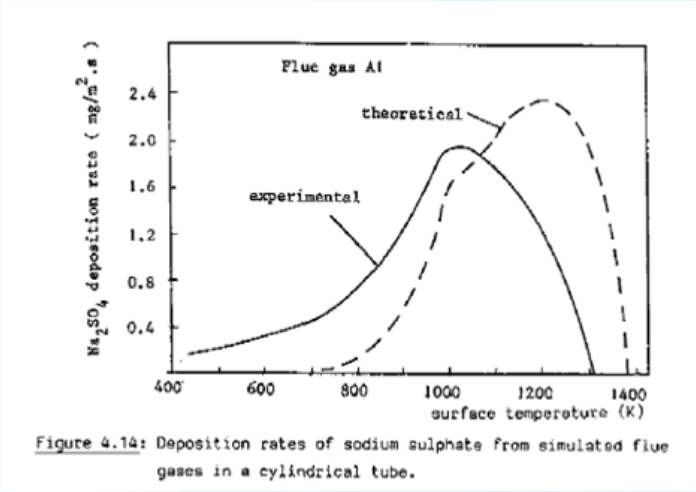
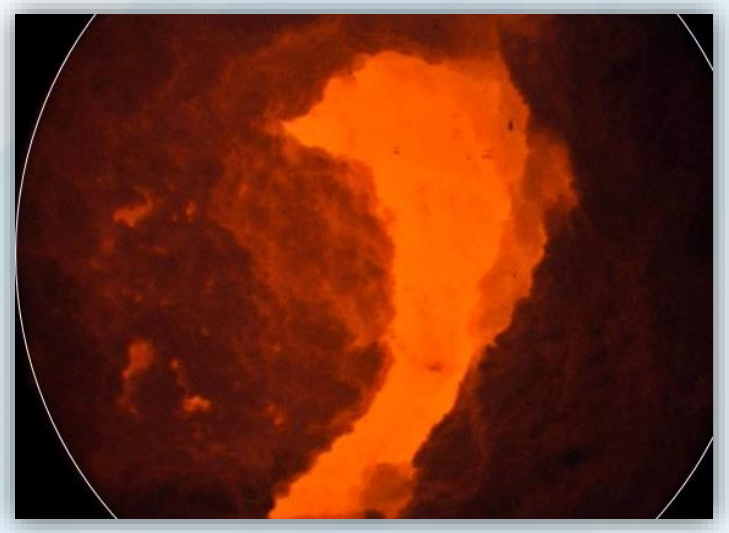


Figure 4.14: Deposition rates of sodium sulphate from simulated flue gases in a cylindrical tube.

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

Dampers

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



Clogging: Na_2SO_4 deposition (endoscopy image)

Start-up and Operation Phase

Troubleshooting

Flue Gas Channel

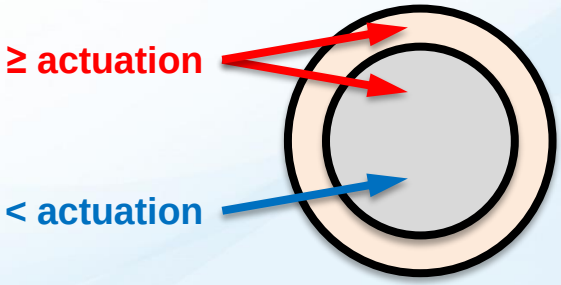
- On-the-go improvements to minimize ambient air leaks into flue gas channels and reduce heat losses

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

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 → Tableware (melting & polishing)
- N_2 → Float (tin bath)

Debottlenecking flue gas side issues

- Fixing ambient air leaks and insulation
- More robust by-pass dampers
- De-clogging → Cleaning ports

Debottlenecking air side issues

- Fixing process air leaks
- Fixing thermal expansion issues

Strong committment 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

Aspect		*Experience from Project*
Safety	↑	No issue reported
Glass Color & Quality	↑	No issue reported
Furnace Aging	↑	No issue reported so far, need to revisit at end of campaign
Energy (NG and O_2)	↑	- Preheating: ~8%* fuel savings demonstrated on average - Foam: initial results favorable compared to oxy-fuel, further investigation needed for validation
Emissions	↑	Similar to oxy-fuel (>90% NOx reduction wrt air-fuel)
Maintenance / Reliability	●	- Retrofit (architectural constraints, no-WHR mindset) - Learnings (flue gas- and air) → leaks, clogging, dampers - Carbon build-up believed to intensify prior to Cold/Hot transition → ongoing investigation
Ease of Use	↑	Start-up and shut-down with the push of a button Highly flexible and adaptable to variations in process
Project Management	↑	On budget / On time

*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

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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
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…and don't forget to