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Operation data from OPTIMELT™ Heat Recovery System
on a Tableware Glass Furnace
at Libbey Leerdam

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Outline

- OPTIMELT Technology. Short explanation

- OPTIMELT Project at Libbey Leerdam. Furnace Discussion
  - Project Introduction
  - Project description

- OPTIMELT Project at Libbey Leerdam. Furnace Data
  - Preliminary Results

- OPTIMELT Project at Libbey Leerdam. Furnace Experience
OPTIMELT™ Technology I

- High efficiency **non-catalytic** reforming process

- Reforming of natural gas in regenerators recovers twice as much heat from the flue gas of oxy-fuel furnaces as just preheating oxygen/fuel
  - Regenerative system takes advantage of high operations temperatures
  - Recycled flue gas contains CO2 and H2O needed for endothermic CH4 reforming
    \[
    2\text{CH}_4 + \text{H}_2\text{O} + \text{CO}_2 \rightarrow 3\text{CO} + 5\text{H}_2
    \]

- Hot syngas is burned with oxygen in the furnace

\[
\begin{align*}
\text{CH}_4 + \text{H}_2\text{O} & \rightarrow \text{CO} + 3\text{H}_2 \quad 2060 \text{ kcal/Nm}^3 \\
\text{CH}_4 + \text{CO}_2 & \rightarrow 2\text{CO} + 2\text{H}_2 \quad 2630 \text{ kcal/Nm}^3
\end{align*}
\]
OPTIMELT™ Technology II

- Injection of Natural Gas into Flue Gas Recirculation
- Preheating of Mixture
- Endothermic Reaction to Syngas (CO and H₂)
- Hot Syngas to Furnace
OPTIMELT™ Technology III

Heating Regenerator

Reforming Regenerator

Combustion of Syngas with Oxygen jets
OPTIMELT Project at Libbey Leerdam
Furnace Discussion
OPTIMELT Project at Libbey Leerdam

- Libbey’s Goals
  - Best-in-class furnace technology to reduce energy consumption and lower emissions
  - Support of Libbey’s sustainability strategy and alignment with European carbon reduction roadmap
  - Positioning Leerdam location for the sustainable production of premium tableware products

- Changes at Libbey Leerdam plant
  - From recuperative to oxy-fuel combustion
  - OPTIMELT technology as highest potential in energy saving compared to other existing waste heat recovery options
LIFE OPTIMELT Project Timeline

- Oxy-fuel furnace in operation since May 2017
- OPTIMELT continuous operation January 2018
- Frequent project updates at http://www.lifeoptimelt.com
OPTIMELT Project - System Description I

- Side-fired oxy-fuel furnace with two end-port TCR
- Cycle time typically 20 min. Possible 30 min.
- Oxy-fuel system always on stand-by
OPTIMEHLT Project – System Description II

- Oxy-Fuel Port Neck
- OPTIMEHLT Port Necks
- OPTIMEHLT Flue Gas Skid
- 3 OPTIFIRE JL Oxy-fuel Burners
- Right/Left Regenerator
- Downcomer for Flue Gas

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OPTIMELT Project - System Description III

Oxy-Fuel Mode Flames

Oxy-fuel Burners

OPTIMELT Ports

Oxy-fuel Burners

Oxy-fuel flames nearly invisible at IR camera image

High luminosity flame / More effective heat transfer
Foam disappears under OPTIMELT flame

LIFE15 CCM/NL/000121 - LIFE OPTIMELT
OPTIMELT Project – Final Installation

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OPTIMELT Project at Libbey Leerdam
Furnace Data
Best-in-class furnace. Reduce Energy & emissions

Overall Fuel Consumption with Pull

Fuel Consumption [GJ/ton] vs. Pull [tpd]
Key Parameters Affecting Fuel Savings

- Basic input parameters
  - Fuel & Oxygen quality variation and flow measurement
  - Charge rate and quality variation
    - Batch composition and moisture
    - Cullet ratio and moisture

- Operating parameters and condition
  - Throat temperature (linked to Furnace temperature)
  - Flame profile (Oxy-fuel firing profile or OPTIMELT flame shape)
  - Excess O2
  - Ambient temperature
  - Cycle time affects oxy-fuel firing
  - Furnace pressure affects air infiltration
Normalization Parameters

- Throat Temperature
  - Fuel consumption in the distributor depends on throat temperature, the same throat temperature should be used for comparison
  - If different throat temperatures are used, then fuel consumption in distributor should be included for comparison

- Batch/Cullet Moisture
  - Batch & Cullet moisture could be influenced by weather. Is controlled?. Which % to be used?
  - +1% moisture increase in cullet ==> increases fuel consumption by 0.8% for oxy-fuel and 0.6% for OPTIMELT

- VPSA O2 purity
  - Normalization at 91% O2 is recommended

- Ambient temperature effect:
  - NG & O2 temperature drops by 10 C (less heat available)
  - Batch/cullet temperature drops by 10C (more heat required)
  - Furnace wall cold face temperature drops by 10C (more heat loss)
Key Parameters Affecting Fuel Savings I

Averaged daily O2 Concentration at the fan inlet

Averaged daily Glass Bottom Temperature TDL0101R

Throat temperature is a result of the target glass quality = < 0.03 seeds/gr
Key Parameters Affecting Fuel Savings II

Averaged daily gas inlet temperature of NG and O₂

Averaged daily crown temperature profile

Legend: blue=OPTIMELT Feb-Apr, magenta=Oxy Apr-Jun, red=OPTIMELT Jun-Aug, black=Today
OPTIMEHLT – Positive Experience – Energy

- Good energy results
- Goal, recuperative / OPTIMEHLT energy reduction of 54 %
- We are at 53% reduction on energy consumption
- Goal, Oxyfuel / OPTIMEHLT 15 % reduction (80 TPD production)
- We are at 13,5 % reduction on energy consumption. Can be reached by further tuning of the process
OPTIMELT – Positive Experience - Quality

- Glass quality can be met
  - Identified lowest possible furnace temperature for good quality
  - Slight differences in operation to achieve glass quality with OPTIMELT
  - No production losses during all project!
OPTIMELT – Positive Experience – Emissions

- Excellent emission results
  - 50-90% reduction vs. L7/L9 achieved in all emissions
  - OPTIMELT emissions lower than Oxy-fuel
OPTIMELT Project at Libbey Leerdam

Furnace experience
L1 OPTIMELT – Lessons Learned

- Condensation in cold parts of ducts
  - Lower OPTIMELT exhaust temperature makes condensation more challenging – redesign of air dilution system
- Regenerator design/construction and seal at port neck
  - Seal of regenerators against air inleakage at the bottom and syngas leak at the top not easy – solved with additional effort
- Energy recovery a little less than expected and requires further optimization
  - Air inleakage must be minimized
  - Heat loss in regenerators limits recoverable energy – add better insulation for skew lines and doors
  - Traditional regenerator design not a good choice
    - Difficult to seal
    - High heat loss from supporting structure and skew lines

Integrated outside support & seal structure is better

No fundamental issues encountered – system operates well
**Inspection September 2018**

- Port Necks, Regenerator and RFG Ducts inspected after 10 months
- Very little deposits on walls and checkers
- Checker passages completely free
- Clean checkers suggest possible self-cleaning process?? ➔ Thermodynamic analysis with Celsian to confirm
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