Heat Transfer Optimization and NOx reduction by FlammaTec burners

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INTRODUCTION

Contents of Presentation

- Introduction (company overview)
- Influence on energy consumption
- Principle of NOx creation
- Advantages of FT burners
- Possible improvement
- Practical examples
- Conclusions
GS GROUP STRUCTURE

GLASS SERVICE, a.s.
Vsetin (CZ)

GS BV
Maastricht (NL)

GS USA
Stuart (USA)

F.I.C.
Penzance (UK)

FlammaTec
Vsetin (CZ)

GS CHINA
Qingdao (CN)

GS CF
Tokyo (JP)

GS ACT
Kalinovo (SK)

FlammaTec
Germany
Cottbus (DE)

AGENTS
Korea, India, Taiwan, Indonesia, Thailand, Malaysia, Philippines, Spain, Italy, Russia, ...
Total number of Flammatec BURNERS: 3014
Focused on Glass regenerative tanks

- Furnace size
- Furnace design including regenerator design
- Refractory composition
- Control system level
- Combustion system
- Fuel type
Furnace size and design

- Furnace type – cross fired, end fired, AMCO, etc.
- Length x width ratio
- Glass depth
- Crown height
- Bubbling, boosting
- Staging, oxygen application
- Barrier – air cooled, water cooled
Regenerator design

- Optimum regenerator size
- Too small = lack of combustion air
- Too big = lower combustion air temperature
- Checkers type and material
Regenerator design
Refractory composition

- Optimum refractory composition
- Expected furnace life
- Proper insulation
Control system level

- Manual control – by operator

- Control system – single loop - fuel vs. temperature

- Advance control system – ES III – multi input and multi output complex solution
Control system level

Set-Point

Temperature

Operator’s control

ES III™ control
Temp. stabilization

Energy savings

Gas

Gas Savings

Operator’s control

ES III™ control
Temp. stabilization

Energy savings

INFLUENCE ON ENERGY CONSUMPTION
Combustion system

- Proper burner size and piping dimension
- Performance flexibility
- Optimum gas velocity
- Optimum combustion air velocity
- Optimum angle of gas and air inlet
- Easy and fast adjustment
Combustion system – FT burner
Fuel type

- Petro coke
- Heavy oil
- Diesel oil
- Natural gas
- Coke oven gas
- Propane
- Biogas
- Various mixtures
Principal of NOx creation

- Oxygen content
- Nitrogen content
- Flame temperature
- Batch composition
Principal of NOx creation

- Nitrate decomposition (KNO₃ or NaNO₃): 600-900 °C
  - \(2\text{NaNO}_3 \Leftrightarrow 2\text{NO}_2 + \text{Na}_2\text{O} + 1/2\text{O}_2\)
  - 600-900 °C
  - Part of \(\text{NO}_2 \Leftrightarrow \text{NO} + 1/2\text{O}_2\)

- Fuel bound nitrogen (mainly HCN- components in oil, coal)

- Prompt NOx near flame zone (very rapid):
  - Hydrocarbon radicals reacting first with molecular \(\text{N}_2\): amines & cyano compounds

- Thermal NOx: according Zeldovich mechanism (strongly temperature dependent)
  - NOx formation takes place when at same moment and position:
    - \(\text{O}_2, \text{N}_2\) and high temperature (\(T > 1350 \degree\text{C}\))
    - Main reactions thermal NO:
      - \(\text{O} + \text{N}_2 \Leftrightarrow \text{NO} + \text{N}\)
      - \(\text{N} + \text{O}_2 \Leftrightarrow \text{NO} + \text{O}\)
      - \(\text{N} + \text{OH} \Leftrightarrow \text{NO} + \text{H}\)
Principal of NOx creation

Formation of thermal NO in combustion space:

\[ \frac{d\text{NO}}{dt} = 2[O] \cdot \left\{ k_1 \cdot k_2 [O_2] \cdot [N_2] \cdot k_{1b} \cdot k_{2b}[\text{NO}]^2 \right\} / (k_2 [O_2] + k_{1b}[\text{NO}]) \]

\( k_1, k_2, k_{1b}, k_{2b} \) are strongly temperature dependent

Or:

Formation of thermal NO in combustion space:

\[ \frac{d\text{NO}}{dt} = K_1 \cdot [N_2] \cdot [O_2]^{0.5} \cdot e^{-316000 / [R \cdot T]} \]

- \( \frac{d\text{NO}}{dt} \) = NO formation rate
- [N\textsubscript{2}] = local \( N_2 \) concentration
- [O\textsubscript{2}] = local \( O_2 \) concentration
- \( R \) = gas constant
- \( T \) = local temperature
Oxygen content

- Proper combustion ratio
- Sucking air - ingressed air
- Oxygen purity in case of oxygen combustion
- Oxygen or air staging
Nitrogen content

- Proper combustion ratio
- Sucking air - ingressed air
- Fuel quality
Flame temperature

Relation of Adiabatic Flame Temperature with NO$_x$ Emissions
Flame temperature

PRINCIPAL OF NOX CREATION
Flame temperature

**PRINCIPAL OF NOX CREATION**

**Short Flame & Low emissivity**
- Low Energy Transfer
- Flame - Glass
- High Flame Temperature
- High Flue Gas Temperature
- High Crown Temperature
- High Energy Consumption
- High NOX Emission

**Maximum Flame coverage & High emissivity**
- High Energy Transfer
- Flame - Glass
- Low Flame Temperature
- Low Flue Gas Temperature
- Low Crown Temperature
- 5...15% Energy saving
- Increased Glass pull
- NOX: 300...600mg/Nm² (8% O₂)
- 100...150 ppm (13% O₂)

![Diagram showing temperature and combustion rate comparisons between short flame and maximum flame coverage.](image)
Long time practical experience

- Each project is tailor made
- Possible hot conversion
- Optimization by GFM software
- Long service life
- Better heat transfer
- Excellent service by educated and experienced staff
Each project is tailor made

- On-site measurement
- DWG drawing creation
- Adaptation on existing situation
- Burner block design and position optimization
- Possible port design optimization
- Possible remote control of flame length and shape
Possible hot conversion

- Adaptation to existing burner bracket and socket plate design
- No influence on production quality
- Wide experience with any type of burner replacement
- Energy savings
- NOx level decreasing
Possible hot conversion – original burner
Possible hot conversion – FT burner
Optimization by GFM software

- Mathematical simulation of combustion process
- Deep analysis of existing situation
- Consulting with the customer
- Optimum burner design calculation
- Optimum gas distribution
Optimization by GFM software
ADVANTAGES OF FLAMMATEC BURNERS

Optimization by GFM software
Long service life and better heat transfer

- Crown temperature decreasing
- Regenerator temperature decreasing
- Bottom temperature raising
- Energy savings or higher pull
- Optimum gas distribution
Long service life and better heat transfer

![Graph showing the comparison of Previous Inj., FlammaTec, and Poly. (Previous Inj.) and Poly. (FlammaTec) with Y axis graduated in 0.5 mm btu/ton increments.]
Long service life and better heat transfer

Float Furnace Pull Rate vs. Energy Consumption

Benchmark data presented by TNO at ESG  FT Burner
Excellent service

- Flexible reaction on customer’s request
- Practical experience with glass production
- Support by GS laboratory
- Many offices and agencies worldwide
Excellent service

Glass Service Company Structure Worldwide

Glass Service, a.s. (Vsetin headquarters)
Czech Republic

Glass Service USA, Inc.
USA

Glass Service, B.V.
The Netherlands

Glass Service Russia
Russia

Glass Service China Co., Ltd.
China

CERAMIC FORUM
Japan

GS ACT
Slovakia

Divisions of Glass Service:
- R&D
- GFM Furnace & Forehearth Simulation
- Glass Forming Simulation (GS ACT)
- Physical Modelling
- Advanced Furnace Control ESIII
- Glass Defects Analysis
- Engineering (small furnaces)
- Raw Materials Deliveries
- Burners (FlammaTec)
- Electric Heating Systems (F.I.C., UK)

THERMOJET
Brasil

HEM Engineering
Turkey

CQ MASSO
France

KUK DONG INT. CO.
L. LTD.
Korea

CHIEF UP INT. CORP.
Taiwan

Ms. Ann Hsing LEW
Malaysia

MULTIUSINESS
ALLIANCE CO., LTD.
Thailand

CERACON ENG. PVT.
LTD.
India
Possible improvement

- Optimize furnace design with using of GFM
- Installation of proper combustion system – FT
- Installation of O2 and NOx sensors
- Installation of ES III
- Electric boosting
- Air staging
- Oxygen staging
Optimize furnace design

Optimize furnace design by utilizing furnace modelling [adjustment to combustion size, air flow (oxidizer) speed and angle, fuel (gas) injection speed, and angle will provide the most optimal scenario]
Installation of FT burners

Install flexible adjustable fuel (gas) injector to vary speed, momentum and angle independent of total gas input (eg FlammaTec Flex or Freejet)
Installation of O2 and NOx sensors

Install O$_2$ (and NO$_x$) sensors to check and control the optimum actual stoichiometry
Installation of ES III

Install reliable high-level, closed-loop control of stoichiometry and furnace temperatures (e.g. model-based control such as ES III™)

**Possible Improvement**

![Graph showing standard deviation]

- Standard Deviation (Right Side Fire)
- **ESIII** and **Operator**
Electric boosting

- Decreasing of crown temperature
- Less fuel
- Less oxygen from combustion air
- Still question about Nox level, created in power station
Air staging
Air staging

- Optimum location for staging air
- Proper amount of staging air
- Higher energy consumption
- Additional costs for vent
Oxygen staging
Oxygen staging

- Optimum location for staging oxygen
- Proper amount of staging oxygen
- Lower energy consumption – energy savings
- Additional costs for oxygen
Practical examples

**Furnace type:** tableware  
**Glass type:** SODA – LIME Glass  
**Pull:** 100 MTPD  
**Cullet:** 23%  
**Total gas consumption:** 648 Nm3/h  
**Heat value of gas:** 10390 kcal/kg  
**Combustion heat:** 6029 KW  
**Melter area:** 34.2 m2  
**Glass depth melter:** 1245 mm  
**Spec. pull:** 2.92 MTPD/m2  
**Spec. energy consumption:** 5.209 MJ/kg  
**NOx level:** 2 250 mg/Nm3
**Practical examples**

**Furnace type**: tableware  
**Glass type**: SODA – LIME Glass  
**Pull**: 100 MTPD  
**Cullet**: 23%  
**Total gas consumption**: 612 Nm3/h  
**Heat value of gas**: 10390 kcal/kg  
**Combustion heat**: 5697 KW  
**Melter area**: 34.2 m2  
**Glass depth melter**: 1245 mm  
**Spec. pull**: 2.92 MTPD/m2  
**Spec. energy consumption**: 4.922 MJ/kg  
**NOx level**: 1430 mg/Nm3

FT burners
Practical examples

- **Furnace type**: container
- **Glass type**: Green
- **Pull**: 251 MTPD
- **Cullet**: 53%
- **Total gas consumption**: 1 005 Nm³/h
- **Heat value of gas**: 11 192 kcal/kg
- **Combustion heat**: 9550 KW
- **Melter area**: 82.8 m²
- **Glass depth melter**: 1150 mm
- **Spec. pull**: 3.03 MTPD/m²
- **Spec. energy consumption**: 3.66 MJ/kg
- **NOx level**: 920 mg/Nm³
- **El. Boosting**: 1082 KW

Old burners
**Furnace type**: container  
**Glass type**: Green  
**Pull**: 251 MTPD  
**Cullet**: 53%  
**Total gas consumption**: 963 Nm³/h  
**Heat value of gas**: 11,192 kcal/kg  
**Combustion heat**: 9550 KW  
**Melter area**: 82.8 m²  
**Glass depth melter**: 1150 mm  
**Spec. pull**: 3.03 MTPD/m²  
**Spec. energy consumption**: 3.54 MJ/kg  
**NOx level**: 650 mg/Nm³  
**El. Boosting**: 1082 KW  

**Practical examples**

FT burners
### Practical examples

<table>
<thead>
<tr>
<th>End fired furnace - tableware</th>
<th>PREVIOUS BURNERS</th>
<th>FT BURNERS</th>
<th>DIFFERENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total energy consumption Nm³/h</td>
<td>648</td>
<td>612,3</td>
<td>5,51</td>
</tr>
<tr>
<td>Specific energy consumption MJ/T</td>
<td>5 209</td>
<td>4 922</td>
<td>5,51</td>
</tr>
<tr>
<td>NOx level</td>
<td>2 250</td>
<td>1 430</td>
<td>36,65</td>
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</tbody>
</table>

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</tr>
</thead>
<tbody>
<tr>
<td>Total energy consumption Nm³/h</td>
<td>1005</td>
<td>963</td>
<td>4,18</td>
</tr>
<tr>
<td>Specific energy consumption MJ/T</td>
<td>3,66</td>
<td>3,54</td>
<td>3,28</td>
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<tr>
<td>NOx level</td>
<td>920</td>
<td>650</td>
<td>29,35</td>
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</tbody>
</table>

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</tr>
</thead>
<tbody>
<tr>
<td>Total energy consumption Nm³/h</td>
<td>543</td>
<td>514</td>
<td>5,34</td>
</tr>
<tr>
<td>Specific energy consumption MJ/T</td>
<td>5 135</td>
<td>4 861</td>
<td>5,34</td>
</tr>
<tr>
<td>NOx level</td>
<td>2375</td>
<td>1625</td>
<td>31,58</td>
</tr>
</tbody>
</table>
### Practical examples

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<th>PREVIOUS BURNERS</th>
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<th>DIFFERENCE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cross fired furnace - float</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total energy consumption Nm3/h</td>
<td>4 820</td>
<td>4 615</td>
<td>4,25</td>
</tr>
<tr>
<td>Specific energy consumption MJ/T</td>
<td>6 200</td>
<td>5 937</td>
<td>4,25</td>
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<tr>
<td>NOx level</td>
<td>2 420</td>
<td>1 870</td>
<td>22,67</td>
</tr>
<tr>
<td><strong>End fired furnace - container</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total energy consumption Nm3/h</td>
<td>1050</td>
<td>960</td>
<td>8,58</td>
</tr>
<tr>
<td>NOx level</td>
<td>3 300 – 3 800</td>
<td>1 200 – 1 400</td>
<td>63,4</td>
</tr>
</tbody>
</table>
Conclusion

The practical results fully confirmed the expected benefits

- flame is easy to tune from short turbulent shape up to a long low turbulent shape and highly luminous flame
- highly luminous stable flame is achieved
- batch melting was enhanced after a change to FLAMMATEC burner creating shorter batch piles
- bottom temperatures were visibly increased, allowing glass quality improvements and a fuel reduction
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