SELAS-LINDE GmbH
Petrochemical Furnaces

Volkmar Lemme
Munich, Sep 14, 2011
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2. EDC FURNACES
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SELAS has experience in designing and building diverse Specialty Furnaces which are not very common and require specific know how in design.

**EDC Heater**  
Cracking Furnace for production of VCM (Vinylchloromonomer) as basis for PVC-production

**KETEN Heater**  
Cracking Furnace for production of Acetic Anhydride as basis for cellulose acetate (synthetic fibre)

**TiCl4 and O2**  
Gas heater for highly corrosive and reactive gases for production of TiO2 (white pigment)

**CS2**  
Production of CS2 from CH4 and Sulphur

**MTP**  
Gas heater for Coal to Gas, Coal to Liquid processes (MTP = Methanol to Propylene)

**Ethylene**  
Cracking Furnace for production of Ethylene, Propylene and Butadiene as basis for various plastics
EDC FURNACES – EXPERIENCE

SELAS has experience in designing and building EDC Cracking Furnaces since 1960

Built Crackers    132 altogether
thereof       31 since 1987

SELAS has done EDC Furnace Design for all major Process Licensors:

• B.F. Goodrich   >> GEON       >> Oxy-Vinyls
• Hoechst          >> Vinnolit (Contractor: Uhde)
• Solvay
• Stauffer         >> EVC
• Monsanto
• ICI
• DOW
• Mitsui Toatsu
• PPG Industries
EDC FURNACES – CRACKER FOR VESTOLIT, MARL

EDC flow rate 64,6 t/h
Conversion ration EDC to VC 60,0 %
Product temperature 500 °C
Outlet pressure 12,5 bar, a
Absorbed heat 18,25 MW
Preheated liquid hot oil 220,8 t/h
Preheated liquid EDC 66,5 t/h
NOx - emission 100 mg/Nm³
Efficiency (LHV basis) 92,0 %
<table>
<thead>
<tr>
<th>Program</th>
<th>Description</th>
</tr>
</thead>
</table>
| VCM      | Process Design EDC Cracking Furnaces  
Step by step calculation of the reaction kinetics under consideration of process parameters (like: pressure, temperature, residence time) across the radiant coil length.  
Calculation of the main- and side reactions dependent from the process parameters, EDC consistency and heat flux distribution |
| CAPFA    | Furnace heat balance  
Fire box design  
Combustion calculation |
| CONVX    | Design of convection section  
EDC superheat  
EDC preheat (if applicable)  
Steam generation / -superheat  
BFW preheat  
Air preheat |
| WDURCH   | Furnace lining calculation |
| DRAFT    | Stack design |
EDC FURNACES – DUAL FUEL SUPPLY SYSTEM (i.e. VESTOLIT / QVC)
EDC FURNACES – TYPICAL FORCED DRAFT NOZZLE MIX BURNER BY HCEL
EDC FURNACES – MECHANICAL SIDE – UPRIGHT
EDC FURNACES – MECHANICAL SIDE – OFFSET (QVC)
Highlights of Linde's Cracking Furnace Technology.
Proven Performance and Reliability...

April 2013
Content – Overview

1. Introduction
2. Radiant Coil
3. Firing System
4. Quench Exchanger
5. Process Control
6. Decoking
7. Summary
Selas Linde Plants in India: Opal Dahej

- 110 kta ethylene furnace capacity
- 7+1 Twin-cell furnaces
- Mixed firing
- Ultra LowNOx-burners
- Cyclone decoking
- Conforms with EN 746-2
Linde's recent cracking furnace reference

- 250 kta ethylene furnace capacity
- 6+1 Twin-cell furnaces
- 2 x 20 passes PyroCrack 2-2
- 62% conversion
- 45 days run length
- Three stage quench exchanger system (LQE as primary)
- 100% floor firing (2 x 30 burners)
- 162 MW fired duty
- Ultra LowNOx-burners with 100 mg/Nm³ NOx (rep. as NO2, dry)
- Firebox decoking
- Conforms with EN 746-2
Furnace Capacity and Layout

- Ethylene Capacity per Furnace [kta]
- Year

Linde furnace references

Graph showing the increase in ethylene capacity per furnace over the years from 1980 to 2015.
Reliability of Furnaces

Most important causes for furnace outage:

Source:
Ethylene Producer’s Committee (EPC) survey in 2009
Reliability and maintenance of ethylene furnaces
Participation of 67 plants worldwide
PYROCRACK Coil Design - Increase of Selectivity

- Small diameters at inlet
  - Rapid temperature rise
- Large diameters at outlet
  - Small pressure drop
- Short coil length
  - Short residence time

PYROCRACK - Coil
**PyroCrack™ Radiant Coils for Gas Cracking**

<table>
<thead>
<tr>
<th>PyroCrack Coil Type</th>
<th>Schematic arrangement</th>
<th>Residence Time [sec]</th>
<th>Tube I.D [mm]</th>
<th>Equivalent number of coils</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 - 2</td>
<td></td>
<td>0.40 - 0.60</td>
<td>80-110 / 110-150</td>
<td>4</td>
</tr>
<tr>
<td>2 - 2</td>
<td></td>
<td>0.25 - 0.40</td>
<td>65-90 / 90-125</td>
<td>8</td>
</tr>
<tr>
<td>1-1</td>
<td></td>
<td>0.15 - 0.25</td>
<td>35-60 / 50-80</td>
<td>16-24</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>0.45 - 0.65</td>
<td>90 - 125</td>
<td>6</td>
</tr>
</tbody>
</table>
Radiant Coil Failures

- Mechanisms of radiant coil failure:

  - Carburization
  - Stress Rupture
  - Bowing/Twisting
  - Brittle Fracture
  - Plugging
  - Welding defects
  - Metal Dusting
  - Erosion
  - Oxidation/Scaling
  - Fuel Ash Corrosion
  - Sulfidation

Linde furnace design has focus on preventing tube failures.
Return Bend Design - PyroCrack Coils

PREVIOUS SOLUTION

A) Short return bends
   stiff system
   low stresses

or

B) Long return bends
   flexible system
   high stresses

IMPROVED SOLUTION

C) S-shaped return bends
   flexible system
   low stresses
   no guide-pins required
   extended coil life
Radiant Coil Failure Prevention

- S-Bends
- No guide pins and bumpers
- Inline coil arrangement

- no coil bending
- no hot spots
- reduced stress
- increased coil life and run length
Radiant Coil Installation

- special device for easy exchange (patented by SL)
- allows maximum degree of prefabrication also for replacement coils
- reduces downtime during major overhaul period
Introduction
Radiant Coil
Firing System
Quench Exchanger
Process Control
Decoking
Summary
Firing and Burners & Burner Types

Sidewall Burner
- Typical Firing Capacity: 0.3 - 0.45 MW per Burner
- Typical design: partial premix (but also nozzle mix)
- Typical: staged fuel for NOx reduction

Floor Burner
- Typical Firing Capacity: 1.0 - 3.3 MW per Burner
- Typical design: nozzle mix
- NOx reduction by staged fuel or staged air and flue gas recirculation

Increasing requirements over last years
- Emission (NOx)
- Fuel Flexibility
- Operation / Safety
Typical modern Radiant Wall Burner –
Example Callidus LE-CARW Burner (Staged Fuel)
Typical modern Floor Burner – Example Callidus Flat Flame LE-CFSG
Linde has decent insight into the design of firing system

Floor Firing
- Few burners / less maintenance
- High automation (duty & comb. air)
- Avoids back-firing
- Flexible for fuel gas quality
- High turn-down ratio

Mix Firing
- Combines advantages

Sidewall Firing
- Optimal heat flux
- Longer run length
- Longer coil life
- Allows high fireboxes and compact furnace design

Firing concept selected on a case by case decision
Safety and Automation

Depending on customer requirements we can provide highly automated systems also allowing remote ignition using retractable HV Igniter lances.

For compliance with requirements along EN746-2 we provide flame scanners for every second burner for surveillance at firebox temperatures below 760 °C.
Reliability of Furnaces

- Most important causes for furnace outage:

  - Radiant Coil (recoil, repair, plugging)
  - Quench Exchanger Cleaning
  - Instrumentation
  - Quench Exchanger Repair
  - Refractory
  - Decoking Piping
  - Other Steam System Components
  - Other Piping
  - Other
  - Fans
  - Burners

Source: Ethylene Producer’s Committee (EPC) survey in 2009
Reliability and maintenance of ethylene furnaces
Participation of 67 plants worldwide
Quench Exchanger Failures

- Ranking of quench exchanger (TLE) failures:

<table>
<thead>
<tr>
<th>Failure Type</th>
<th>TLE type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tube Blockage</td>
<td>conventional</td>
</tr>
<tr>
<td>Waterside Corrosion</td>
<td>both</td>
</tr>
<tr>
<td>Inlet Tube Sheet Erosion</td>
<td>conventional</td>
</tr>
<tr>
<td>Failure of Tube to Tube Sheet Weld</td>
<td>both</td>
</tr>
<tr>
<td>Refractory Failures</td>
<td>conventional</td>
</tr>
<tr>
<td>Gasket or Seal Failures</td>
<td>both</td>
</tr>
<tr>
<td>Distortion of the Coke Deflector</td>
<td>both</td>
</tr>
<tr>
<td>Outlet Fitting Erosion</td>
<td>both</td>
</tr>
<tr>
<td>Gas inlet Reducer Failure (LQE)</td>
<td>LQE</td>
</tr>
<tr>
<td>Tube Erosion</td>
<td>both</td>
</tr>
<tr>
<td>Other Weld Failures</td>
<td>both</td>
</tr>
<tr>
<td>Waterside Fouling</td>
<td>conventional</td>
</tr>
<tr>
<td>Failure of the Outer Tube or Shell</td>
<td>conventional</td>
</tr>
<tr>
<td>Bowing of Tube Sheet</td>
<td>conventional</td>
</tr>
</tbody>
</table>

0 10 20 30 40 50
Erosion and Tube Blockage

Example: Ethane cracking high severity
**Quench Concepts**

<table>
<thead>
<tr>
<th>Stages</th>
<th>Single</th>
<th>Two/Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>TLE Type</td>
<td>Conventional</td>
<td>Linear (LQE)</td>
</tr>
<tr>
<td>Application</td>
<td>Liquid Cracking</td>
<td>Gas Cracking</td>
</tr>
</tbody>
</table>

- Stages: Single vs. Two/Three
- TLE Type: Conventional vs. Linear (LQE)
- Application: Liquid Cracking vs. Gas Cracking

Diagrams showing temperature ranges:

- 330 - 380°C
- 330 - 390°C
- Ca. 500°C
- 200°C
- 350°C
Coil / TLE Connection

Conventional TLE

Linear TLE (LQE)

Arch Lining

Fire-box

Coil Outlet Tubes

Source: Alstom

Source: Borsig
Linear quench exchangers (LQE) are providing reduced maintenance and maximum availability

**LQE arrangement**
- One exchanger tube per each coil outlet tube

**Mechanical**
- No cast collector fittings
- No refractory lined inlet cone
- No tube sheets, no erosion

**Availability**
- No plugging
- No mechanical cleaning

- Reduced maintenance
- Maximum availability

Linde strongly recommends LQE's for ethane application
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Linde Fuel Balancing – Focus on process optimization

Firing adjusted individually per zone (here: 2 x 3 zones)

Equal cracking conditions in all coils:
- XOT
- severity
- selectivity
- coking

Hydrocarbons
Dilution Steam

Convection Preheat and superheat
Cross-over-Headers
Venturi nozzles
Radiant Section

Fuel
TLEs
Cracked Gas
Staged shut-down concept leads to improved availability

- **Total Shut-Down**
- **Partial Shut-Down ("HSSB")**

- **Flue gas**
- **BFW**
- **HPS**
- **Cracked gas**
- **HC**
- **DS**
- **Fuel**

- "Pilot Standby (not shown)"

- ▶ = Partial Shut-down ("HSSB")
- ◆ = Total Shut-Down
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Design aspects for efficient decoking

- **Identical conditions for all coils**
  - Equal coil inlet conditions (XOT) due to collecting header at convection outlet
  - Venturi nozzles at coil inlet ensure same throughput of steam and air for each coil
  - Individual control of coil outlet temperature for each radiant coil group

- **No undefined distribution**
  - Each radiant coil outlet tube is directly linked with one individual quench exchanger tube
  - All quench exchanger tubes have the same throughput of steam and air too

- **ID of quench exchanger higher than ID of radiant coil outlet tubes**
  - No erosion at the inlet of the quench exchangers
  - No blockage of exchanger tubes

All radiant coils and quench exchanger tubes are evenly and reliably decoked
Cell decoking enhances flexibility for high capacity furnaces

One furnace cell in decoking mode
One furnace cell in normal operation

- Double set of cracked gas/decoking gas valves
- Flue gas monitoring in the individual fireboxes (O2, CO)
- Material upgrades in convection section/crossover

- Production remains at 50% during decoking
- Increased operational flexibility
- Long-term experience available
Recent furnace section reference with cell decoking feature

- **BP "GOFER" Project**
- Cologne, Germany, 2008
- 5 new furnaces replace 18 (!) old ones
- 100 kta Ethylene Capacity per furnace
- Naphtha, LPG, UCO
- Cell Decoking Feature (4.5 + 0.5 concept)
Thank you for your attention.