Improving the Operational Performance of Existing Heat Exchangers used in the Hydrocarbon Processing Industries
(UKHTC 2017)

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Heat Exchanger Considerations

Not all designs take into account the following…

• Fouling (type)
• Maldistribution
• Phase stratification
• Thermal stratification
• Mechanical problems (e.g. vibration)
• Corrosion/Erosion
• And more…
Examples of Heat Exchanger Revamp Goals

1. Increased exchanger duty in laminar flow, mitigating thermal stratification
   • Product heater case study

2. Improved fluid distribution
   • Condensing case study

3. More stable operation by suppressing film boiling and mist flow
   • Vapouriser case study
hiTRAN® Thermal Systems

Working Principle
How hiTRAN Works?

- Removes the laminar boundary layer
- Mixes fluid with bulk flow
- Reduces residence time at the tube wall
hiTRAN® Range in Comparison to Empty Tube Data
1. Product Heater Case Study

Improved Duty
Viscous Product Heater
Revamp Goal: Increased outlet temperature

TEMA Type: AEL
372 Tubes

4 Pass
25.4mm x 1.65mm x 4000mm
Viscous Product Heater Revamp

<table>
<thead>
<tr>
<th></th>
<th>Empty 9.2 bar</th>
<th>hiTRAN 2.7 bar</th>
<th>hiTRAN 6.3 bar</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of passes</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Steam Pressure (bar)</td>
<td>9.2</td>
<td>2.7</td>
<td>6.3</td>
</tr>
<tr>
<td>Steam temp. (°C)</td>
<td>176</td>
<td>128</td>
<td>160</td>
</tr>
<tr>
<td>Tube side HTC (W/m²K)</td>
<td>100</td>
<td>207</td>
<td>206</td>
</tr>
<tr>
<td>Tube side outlet temp (°C)</td>
<td>101</td>
<td>101</td>
<td>124</td>
</tr>
<tr>
<td>Tube side dP (bar)</td>
<td>2.7</td>
<td>3.3</td>
<td>2.9</td>
</tr>
</tbody>
</table>

Steam temperature (176°C)

Inlet temperature (38°C)
2. Condensing Case Study

Improved Fluid Distribution
Introduction – Revamps to Improve Fluid Distribution

Heat exchanger design programs assume equal distribution for...

- Bundles
- Inside Tubes

Differences in distributions can have considerable implications on exchanger performance

**hiTRAN effect on distribution**

- Improved mixing affects the tube side distribution
- Can be used as a tool, if necessary, to increase the bundle pressure drop, affecting bundle distribution
Case Study – Feed/Effluent Exchanger Retrofit

User: LUKOIL Refinery
Location: Volgograd, Russia
Service: Feed/Effluent exchanger upstream of a hydrotreater reactor

Condition:
• Boiling feed on the shell side
• Condensing effluent on the tube side

Problem description:
• Calculated performance should be 60% higher
• No spare capacity of fired heater to increase throughput
Exchanger Configuration

Shells: 3 in series, 2 in parallel
Bundle: 2521 tubes, 1 pass
20mm x 1.8mm x 9000mm

Calculated Exchanger Performance
Tube side dP calc./allowed: 2.5kPa / 45kPa
Shell side HTC: 900 W/m²K
Tube side HTC: 285 W/m²K
Duty: Measured 20MW / real +60%

Application is heavily tube side controlled, therefore targeting tube side performance
Problem Identification!
Bundle Maldistribution

Expected severe fluid maldistribution in the bundle on the tube side

• Tube side pressure drop of 25mbar very low with 85% of dP within the nozzles
  (allowable tube side dP 450mbar!)

• Axial Tube side nozzles contribute to maldistribution

Higher tube side pressure drop would be beneficial!
Bundle CFD Simulation of first shell De-superheating; \( x = 1 \)
CFD simulation continued…

Empty Tube, Tube side dP: 25mbar (>85% nozzles)

hiTRAN Tube, Tube side dP: 200mbar (~10% nozzles)
Tube Side Maldistribution

Calculation show that tube side flow regimes for Shell 2 and Shell 3 are *wavy stratified*.

Liquid Re ~ 1500

Vapour Re ~ 11000

Poor cooling heat transfer to liquid

Poor cooling heat transfer to vapour

**Snapshot 2nd shell**

\[ m \text{ Flux} = 25\text{kg/m}^2\text{s} \]

\[ x = 0.54 \]

Accumulation of non-condensables
hiTRAN enhancement

Much improved vapour cooling

Improved mass transfer: vapour - liquid

Much improved liquid cooling
## hiTRAN Installation & Benefits

<table>
<thead>
<tr>
<th></th>
<th>Before (Empty)</th>
<th>After (hiTRAN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tube side pressure drop</td>
<td>25mbar (&gt;85% nozzles)</td>
<td>200mbar (~10% nozzles)</td>
</tr>
<tr>
<td>Tube side heat transfer</td>
<td>&lt;285 W/m2K</td>
<td>~980 W/m2K</td>
</tr>
<tr>
<td>Shell side feed outlet temperature</td>
<td>240°C</td>
<td>314°C</td>
</tr>
<tr>
<td>Tube side effluent outlet temperature</td>
<td>115°C</td>
<td>82°C</td>
</tr>
<tr>
<td>Mass Flow</td>
<td>27 kg/sec</td>
<td>42 kg/sec</td>
</tr>
<tr>
<td>Load on Fired Heater</td>
<td>4.2 MW</td>
<td>2 MW</td>
</tr>
</tbody>
</table>

Annual Energy Savings of $233000
3. Vapouriser Case Study

Supressed film boiling / mist flow
Ethylene Evaporator

After commissioning the exchanger did not perform

<table>
<thead>
<tr>
<th>TEMA Type</th>
<th>BEU</th>
</tr>
</thead>
<tbody>
<tr>
<td>No. of passes</td>
<td>2</td>
</tr>
<tr>
<td>Tube length (mm)</td>
<td>4000</td>
</tr>
<tr>
<td>Tube OD (mm)</td>
<td>25.4</td>
</tr>
<tr>
<td>Tube count</td>
<td>702</td>
</tr>
</tbody>
</table>
Detailed Investigation Along the Tubes

- Inlet leg
- Outlet leg

Graphs showing tube side HTC (W/m²K) as a function of length from entry (mm). The graphs illustrate different boiling mechanisms and temperature conditions, including Enhanced Convective Boiling and Enhanced Superheating.
## Summary Before / After

<table>
<thead>
<tr>
<th></th>
<th>Empty Tube</th>
<th>hiTRAN installed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Tube Side</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flow Rate (t/hr)</td>
<td>52</td>
<td>76</td>
</tr>
<tr>
<td>Temperature In/Out (°C)</td>
<td>-100 / -1 (sat)</td>
<td>-100 / 30 (superheated)</td>
</tr>
<tr>
<td>Pressure In/Out (bar)</td>
<td>40 / 39.93</td>
<td>40 / 39.74</td>
</tr>
<tr>
<td>Heat Transfer Coefficient (W/m²K)</td>
<td>613</td>
<td>2390</td>
</tr>
<tr>
<td>Pressure Drop ( kPa)</td>
<td>8</td>
<td>25</td>
</tr>
<tr>
<td><strong>Shell Side</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pressure In/Out (bar)</td>
<td>10.1 / 10.1</td>
<td>2.2 / 2.19</td>
</tr>
<tr>
<td>Temperature In/Out (°C)</td>
<td>138 / 137</td>
<td>86 / 85</td>
</tr>
<tr>
<td><strong>General</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Heat Duty (kW)</td>
<td>261</td>
<td>618</td>
</tr>
<tr>
<td>EMTD (°C)</td>
<td>164</td>
<td>100</td>
</tr>
</tbody>
</table>
Any questions?

• Working in Industry for over 35 years
• More than 20,000 exchangers enhanced worldwide
• Business ~90% export
• Engineering Services include…
  • Analytical Engineering
  • Design Services
  • CFD Services
  • ACHE Troubleshooting

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