Achieve Challenging Targets in Propylene Yield using Ultra System Fractionation Trays

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Presentation overview

• Options for revamping distillation trays:
  - Conventional trays
  - High capacity trays

• What is a ConSep tray?

• Flooding limits for ConSep trays.

• Recent revamps using ConSep trays.
  - FCC Depropanizer
  - FCC Debutanizer

• Development goals for the future.

• Potential new applications for ConSep trays

• Conclusions
Revamp options for conventional trays

High capacity trays

Many examples available showing up-to + 30% capacity increase

Capacity enhancement is achieved by:

- Truncated downcomers
- Special Fixed valves
- Etc..
Revamp of Shell C2 Splitter in Europe

- 1-for-1 retray of 4-pass conventional trays by 130 HiFi sieve trays at 450mm tray spacing.
- High pressure C2 Splitter operating at 20 barg with a diameter of 4.4m

Results
- Capacity increase ~ 45%
- Required reflux : feed ratio unchanged
- Pressure drop reduced by 30%
Revamp of Shell C3 Splitter in Europe

- Replaced 150 conventional 4-pass trays at 450mm tray spacing with 211 HiFi sieve trays at 300mm tray spacing
- High pressure C3 Splitter operating between 11-18 barg with a diameter of 5.9m

Results
- Capacity increase ~ 30%
- Required R:F reduced by 25%
- Pressure drop reduced by 30%
Revamp options for high capacity trays

“Ultra High” capacity trays

Limited cases reported in open literature although technology has been available for at least a decade (ConSep since 1995) and tested at FRI in 2004.
ConSep comparison with high capacity tray

Efficiency Comparison with high capacity trays at FRI

(iC4/nC4 at 11.4 bar)

1-path layout

2-path layout

Significant capacity gain for ‘ultra-high’ capacity ConSep tray, at expense of some efficiency loss
What is a ConSep tray?

- **Contacting tray**

Combined with:

- ‘high g’ Separation device

**Diagram:**
- Blue arrows represent *Liquid flow*.
- Red arrows represent *Vapour flow*.
ConSep tray

- Tray arrangement can be a conventional single pass, multiple pass tray or a high capacity Shell HiFi tray.
- Any perforation possible (sieve, floating valve etc.).
- Separation is performed using high capacity swirl tube separators.
ConSep ‘G/L separator fundamentals’

- Maximum liquid load: $L_{\text{max}} \approx 1100 \text{ m}^3/\text{m}^2/\text{Hr}^{(1)}$

- Maximum vapour load: $C_{\text{factor}}_{\text{max}} \approx 1 \text{ m/s}^{(1)}$

- ConSep performance depends on % swirl tube area installed! Typically 15-30% swirl-tube area installed.

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(1) Values based on swirler cross sectional area
ConSep measurements:

- Max. C-factor = \(C_{\text{max}_{\text{swirler}}} \times 0.18 = 0.18 \text{ m/s}\)
- Max. liquid load = \(L_{\text{max}_{\text{swirler}}} \times 0.18 = 200 \text{ m}^3/\text{m}^2/\text{hr}\)

Swirltube area layout: 18%
ConSep air/water data

Max. C-factor = $C_{\text{max}}_{\text{swirler}}^{*0.18} = 0.18 \text{ m/s}$

Max. liquid load = $L_{\text{max}}_{\text{swirler}}^{*0.18} = 200 \text{ m}^3/\text{m}^2/\text{hr}$

18% swirltube area layout
## ConSep flooding limitations

<table>
<thead>
<tr>
<th>Conventional &amp; high capacity trays</th>
<th>ConSep trays</th>
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<tr>
<td>Jet flooding (entrainment)</td>
<td>Separator ‘prevents’ jet-flood limitation</td>
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<tr>
<td>Downcomer choking</td>
<td>Downcomer capacity enhanced due to ‘clear’ liquid</td>
</tr>
<tr>
<td>Downcomer back-up</td>
<td>Downcomer back-up</td>
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</table>
Gamma-scan ConSep iC4/nC4 11 bar

Flooding mechanism: downcomer back-up

Tray spacing 450mm,

$C_f = 0.11 \text{ m/s}$
Factors influencing ConSep capacity

Back-up constraints can be reduced by:

• Extending downcomers to the maximum.
• Increase number of ConSep swirl tubes
• Increase open area (at expense of turndown).
## ConSep applications

<table>
<thead>
<tr>
<th>Plant</th>
<th>Operating Pressure (Bara)</th>
<th>Year</th>
<th>Max capacity increase achieved&lt;sup&gt;(1)&lt;/sup&gt;</th>
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<tbody>
<tr>
<td>NGL Debutanizer</td>
<td>3-5</td>
<td>1995</td>
<td>22%&lt;sup&gt;(2)&lt;/sup&gt;</td>
</tr>
<tr>
<td>FCC Debutanizer</td>
<td>8-12</td>
<td>1996</td>
<td>30%&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>HCU Main Fractionator</td>
<td>3-4</td>
<td>1999</td>
<td>50%&lt;sup&gt;(3)&lt;/sup&gt;</td>
</tr>
<tr>
<td>NGL Debutanizer</td>
<td>3-5</td>
<td>1999 &amp; 2000</td>
<td>15%&lt;sup&gt;(2)&lt;/sup&gt;</td>
</tr>
<tr>
<td>FCC Debutanizer</td>
<td>8-12</td>
<td>2000</td>
<td>20%&lt;sup&gt;(2)&lt;/sup&gt;</td>
</tr>
<tr>
<td>FCC Debutanizer</td>
<td>8-12</td>
<td>2006</td>
<td>10%&lt;sup&gt;(4)&lt;/sup&gt;</td>
</tr>
<tr>
<td>FCC Depropanizer</td>
<td>18-20</td>
<td>2006</td>
<td></td>
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1. Capacity achieved in excess of the existing high capacity trays.
2. Limited by reboiler capacity.
3. Limited by feed to the column.
4. Has only just started up, no constraints observed yet.

Not limited by ConSep
FCC Depropanizer ConSep application 2006

- 18-20 bar operating pressure
- 25 ConSep trays replacing non-Shell high capacity trays in rectification section
- Revamp target + 15% capacity

Picture taken during ConSep tray installation
Internals installed over 5 day period by contractor with no prior ConSep tray experience

Including setup, PWHT & QA, everything was completed within a 2 week period.
FCC Depropanizer performance to date.

- Column started up without any problems.
- Throughput limited by available feed @ 80% of design conditions.
- Transition to ‘high conversion’ conditions at FCCU not complete yet.
- Tray efficiency at current maximum operating conditions above 85% for stripping and rectification section.

Highest pressure application of ConSep to date (18-20 bara). Vapour density ≈ 45 kg/m³, Liquid density ≈ 460 kg/m³.

Early 2007 FRI tests for ConSep are carried out: Vapour density > 80 kg/m³, Liquid density < 410 kg/m³.
FCC Debutanizer ConSep application 2006

FCC was debottlenecked in 2002 aiming at 30% capacity increase relative to original design. Gasoline RVP specs were also more severe relative to original design. → Debutanizer main constraint. After implementation of project Debutanizer was a constraint (as expected).

- 8-12 bar operating pressure
- 2006 revamp target + 10% capacity
FCC Debutanizer ConSep application 2006

Alternatives considered for Debutanizer:

1. Large Debutanizer feed-preheat (to shift duty to rectification section). This would require new preheater and possibly an increase of the condensing capacity.

2. ConSep trays in stripping section with no modifications to condenser and preheater.

➔ 20 ConSep trays replacing Shell HiFi+ trays in stripping section proved to be most cost effective.
FCC Debutanizer performance to date.

- Column started up without any problems.
- Throughput of FCC unit could be increased by 10% without any constraints seen on Debutanizer.
- All product specs attained.
- Reflux ratio for Debutanizer has remained the same as before the revamp. Efficiency is comparable to high capacity trays installed previously.

Is third FCC Debutanizer in Shell revamped with ConSep. A fourth ConSep FCC Debutanizer revamp is planned for (outside Shell).
Current ConSep development targets

Typically only part of potential ConSep capacity gain is required for revamps (note that not of the ConSep application in Shell are limited by the trays).

» Current R&D focus is not on further capacity enhancement but on:

• Determining constraints at very high pressure
• Focus on tray efficiency (and low tray spacing)
Some potential new ConSep applications

<table>
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<tr>
<th>Units</th>
<th>Comments</th>
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</thead>
<tbody>
<tr>
<td>CDU</td>
<td>Revamp with ConSep expected in 2007</td>
</tr>
<tr>
<td>C2-splitter</td>
<td>Case study presented at AIChE Spring meeting 2005</td>
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<tr>
<td>Deethanizer</td>
<td>Feasible</td>
</tr>
<tr>
<td>Demethanizer</td>
<td>Feasibility pending outcome of very high pressure tests</td>
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- In general ConSep can be applied to most distillation columns, and will be most ideal for revamping columns already equipped with high capacity trays.
- ConSep is not applicable for (mild) vacuum columns or fouling service.
Conclusions

• ConSep trays are a proven solution for revamping high capacity trays.
• Wide range of applications possible.
• Tray efficiencies can be as high as 85-90%.
• Number of applications is steadily growing, and probably it is only a matter of time that even large Superfractionators will be revamped with ConSep trays.