Dividing wall columns – which wall separates Dutch industry from application?

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Dividing wall column: What’s that and how it’s working?

Thermodynamic basis: Brugma or Petlyuk Configuration
Equivalent thermodynamics, different construction
Design procedure

1) Process configuration

Superstructure

Pressure steps

- A, B, C, D
- A, B
- B, C, D
- A, B, C
- C, D
- B, C
- 1 bar
- 4 bar
- 0.1 bar
2) Process synthesis: Possibility for column integration?

Selection of the sequence: A, B, C, D; B, C, D; C, D; B, C; A, B; D.

Final design: 4 bar, 1 bar, 0.1 bar.
3) Process simulation:

programs suitable for complex simulation tasks needed:

To be specified:

11 Parameters:

- Heat duty or reflux ratio
- Number of theoretical stages in sections 1 – 6
- Liquid distribution to the sections 2 and 3
- Vapor distribution to the sections 4 and 5
- Specification for 2 product streams

Recommendation: Take equation based/simultaneous programs

Source: Asprion/Kaibel, Chemical Engineering and Processing 49(2010), 139-146
4) Experimental validation:
miniplant scale normally sufficient

Example:
Experimental set up with Petlyuk configuration
5) Control concept

• No principal differences to conventional column sequences
• Normally no control of the internal partition of gas and liquid streams (design parameter) but if necessary special parts are available

• Dynamic simulation is useful
• Model predictive control has been tested

Result of steps 1) – 5): Process flowsheet
Construction:

Internals 1:

Structured packing (usual design)

pictures from:

Montz

Sulzer
Internals 2:

- Trays
  (developing fast)

from United States Patent 6645350

Two pass sieve trays

Construction of the column

pictures from sasol
Internals 3:

- Dividing wall: may be welded in or unfixed

The unfixed dividing wall has proved to be very advantageous and versatile. The patent pending design (co-operation agreement with BASF AG) offers significant advantages over fixed, welded-in walls.

Source: Montz
internals → externals:

which column is the dividing wall column?

Source: Sasol
internals → externals:

which column is the dividing wall column?

Column shell: no differences in construction, piping, foundation etc.

Source: Sasol
Application fields and constraints

Application fields

• Total separation sequence has to be split in sequences for 3 or 4 components
• Petlyuk (heat integrated design) configuration must be possible (same pressure is a prerequisite)
• Comparable flow rates of the components to be separated are advantageous
Constraints

Wide range of boiling points among the components:
Temperature difference between condenser and reboiler may be high.

Operating pressure
No different pressure steps for the required separation possible

Column height:
A dividing wall column is always higher than either of the two alternative columns.

Hydraulic imbalances:
If the component in the side stream is too small, the hydraulics may be unequal on each side.

Rule of thumb: The bigger the side-stream part the better the dividing wall
Potential for process intensification

Petlyuk AND dividing wall columns:
• energy savings (10 – 30 %)

Dividing wall columns:
• lower investment: column, piping, heat exchangers, foundation….. (< 30 %)
• Reduced plot space (30 – 40 %)
• Reduced thermal stress for the components to be separated (lower residence time)
# Examples

## Industrial scale applications

<table>
<thead>
<tr>
<th>Sector</th>
<th>Company - Process/Product name/type</th>
<th>Short characteristic of application</th>
<th>Production capacity/Plant size</th>
<th>Year of application</th>
<th>Reported effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemical company</td>
<td>BASF</td>
<td>Wide field of applications, 50 existing columns in production scale, 10 – 15 columns under construction or planned</td>
<td>No limitations with respect to capacity</td>
<td>First start-up in 1985</td>
<td>Energy savings, investment savings, reduced plot space, better product qualities, higher yields</td>
</tr>
<tr>
<td>Chemical companies</td>
<td>Sasol, Sumitomo, Condea, Cognis, Bayer and others</td>
<td>Sasol: olefins chemicals</td>
<td>Sasol: up to 5.2 m x 107 m</td>
<td></td>
<td>Energy savings, investment savings, improved product purities</td>
</tr>
<tr>
<td>Refineries, chemical companies</td>
<td>Veba Ruhröl, Chevron, BP, CEPSA, ExxonMobil, Aral Aromatics, UOP and others</td>
<td>Pyrol. gasoline pyrol. gasoline aviation gasoline paraffins xylenes toluene hydrocarbons</td>
<td></td>
<td></td>
<td>Energy savings, investment savings, simple retrofits, extractive distillation</td>
</tr>
</tbody>
</table>

Source: Technology Report Kaibel 2007
Example for a tray column: Sasol Prefractionator

- Biggest column with diving wall (with trays)
- Built by Linde and Sasol in South Africa with BASF acting as a consultant
- Height of 64.5 m and a diameter of between 4 and 4.5 m
Sasol Prefractionator 2: Technical Details

Two pass sieve trays

Construction of the column
Example for a Revamp: Krupp Uhde Revamp Project 1

**Specification:**

Benzene content in lights and heavies

< 1 Vol.-%  

**Diagram:**

- Pyrolysis gasoline
- Benzene cut
- Lights
- Heavies
- Feed
- Produkt
- Old core part
- New part
- Old part
- Steam

Fig. 5-02: DWC – Typical revamp option

Implementation of the Ruhr Oel (Veba) Münchsmünster Benzene Remova Project
Krupp Uhde Revamp Project 2

Implementation of the Ruhr Oel (Veba) Münchsmünster Benzene Removal Project
**Krupp Uhde Revamp Project 3**

<table>
<thead>
<tr>
<th></th>
<th>Conventional Column (before revamp)</th>
<th>Divided-Wall Column (after revamp)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Throughput</td>
<td>16.0 t/h</td>
<td>20.0 t/h</td>
</tr>
<tr>
<td>Steam consumption</td>
<td>3.9 t/h</td>
<td>4.2 t/h</td>
</tr>
<tr>
<td>Benzene content in mixed gasoline</td>
<td>5.2 wt.%</td>
<td>0.76 wt.%</td>
</tr>
<tr>
<td>Benzene yield in side draw</td>
<td>86.6 wt.%</td>
<td>99.1 wt.%</td>
</tr>
</tbody>
</table>
Example for a complex process:
BASF’s new Butadiene Extraction Process

Source: Asprion/Kaibel, Chemical Engineering and Processing 49(2010), 139-146
Actual status of industrial application of divided wall columns

- „Normal“ Dividing wall Columns (3 component separation):
  - BASF: more than 60 columns worldwide (packed columns) diameter up to 4 m, height up to 80 m
  - Sasol: 2 Tray columns, diam. up to 6 m, height up to 107 m

- Complex dividing wall Columns
  - BASF: off-center DW, additional side stream column, trays and packings mixed
  - Sasol: separation of 4 components in a tray column

- Patents:
  - actually (2009) 68 patents: 23 from BASF, 19 from other chemical companies, 19 from suppliers
New applications

1) More complex arrangements of the dividing wall

Source: Asprion/Kaibel, Chemical Engineering and Processing 49(2010), 139-146

Another good view on new developments:
Olujic, Jödecke, Shilkin, Schuch, Kaibel
„Equiment improvement trends in distillation“
Chemical Engineering and Processing 48 (2009), 1089-1104

Separation of more than 3 Components (more DW’s)

Source: Asprion/Kaibel, Chemical Engineering and Processing 49(2010), 139-146
2) Combination of reactive distillation and dividing wall

New process tested in miniplant scale:

*Transesterification of butanol with an azeotropic mixture methanol/methyl acetate to produce butyl acetate and methanol*

Source: Großmann, Kenig, CITplus 5/2007, 38-41

Source: G. Kaibel, G. Kons, H. Schoenmakers, E. Schwab, DGKM-Conference „Chances for Innovative Processes at the Interface between Refining and Petrochemistry“, October 9 – 11, 2002 Berlin, Germany
Conclusions

• Dividing wall columns are introduced in the industrial practice
• The design procedures and the construction are well established
• Experienced equipment suppliers exist
• Constraints exist in the application, thus DWC‘s are not a solution for every separation task
• There are new and extended applications, partly realised, partly under investigation
Thus the choice of a dividing wall column for a separation task is a question of readyness for decision making, it’s not really a risk, neither for construction nor for operation.