Dividing Wall Column Technology
Recent Developments and Challenges

Žarko Olujić
Delft University of Technology (retired, guest associate)
Delft, the Netherlands

Thomas Rietfort
Helmut Jansen
Julius Montz GmbH
Hilden, Germany

Igor Dejanović
The University of Zagreb
Faculty of Chemical Engineering and Technology
Zagreb, Croatia

EFCE WP FLUID SEPARATIONS
Annual Meeting, 12-13 May, 2016, Copenhagen, Denmark
Towards a Sustainable Distillation Column
(Using less energy and material and doing less damage to the environment.)

Minimization of energy requirement by thermal coupling

Thermodynamic efficiency of a sequence of two or more \((n)\) conventional distillation columns as required for obtaining \((n-1)\) pure products can be maximized by utilizing full thermal coupling. Where appropriate, full thermal coupling can be implemented in single shell. Such a configuration is generally known as Dividing Wall Column (DWC).

Conventional two-column sequence $\rightarrow$ Thermally coupled column $\rightarrow$ Dividing Wall Column (DWC)

Each with a number of alternatives

Liquid and vapor split additional degrees of freedom, i.e. design variables
DWC Applications Range

**Equipment size:** Column diameters: 0.5 m – 6.5 m, Column heights: up to 100 m
Laboratory/pilot scale diameters: 0.04 – 0.2 m

**Operating pressure:** 0.002 to 10 bar

**Nature of application:** All kind of distillation applications/chemicals.

**Purity requirements:** From typical solvent recovery to ultra purity (in ppb range) specifications

Extractive distillation, Reactive distillation, ....

**Benefits:**

**Low energy requirement**
(Vapor throughput minimized, and repeated evaporation and/or condensation eliminated)

Reduced OPEX/CAPEX (~ 30 %) & footprint (plot area)

Shorter residence time

Higher yields, Less maintenance, ..... 

In revamps, energy saving enables capacity increase!
Dividing Wall Column

Number of industrial applications/Milestones

Columns in operation: > 250 (> 1/3 at BASF SE), ~ 90% are packed DWCs

Milestones:
- 1st packed DWC in operation (BASF), 1985
- 1st packed DWC with non-welded partition wall (BASF), 1996
- 1st revamp into a DWC (UHDE), 1999
- 1st tray DWC (SASOL), 2000
- 1st four-product DWC (BASF), 2002
- 1st multipurpose DWC (Lonza), 2010

Other manufacturers/licensors: (a guess)
- Sulzer: 45
- Koch-Glitsch: 30
- UOP: 10
- KBR: 5
- UHDE: 5
- Air Products: 5
- Linde: 5
- Sumitomo (Japan): 5
- S. Korean: 5
- Indian: ?
- Chinese: 10

TUD conducted large scale air (tracer)/water (dye) tests prior first industrial application at BASF

Courtesy of MONTZ
First multipurpose DWC at Lonza in Visp, Switzerland

Three periodic operations carried out in a DWC:

(i) A batch distillation column
(ii) A side product column
(iii) Conventional two-column sequence

A Novel Field of DWC Application

Cryogenic Air Distillation

Argon Rejection Using a Divided Wall Column

- Argon rejection can reduce the air compressor (MAC) power consumption by up to 4% by rejecting argon
- Traditional "sidearm" argon column is expensive
- Design is more compact and efficient if implemented using a divided wall

Source, with permission of Air Products:
M. Kalbasi, Air Products, 2015 International Forum on Mass Transfer and Separation Engineering, November 16-18, Tianjin, China
Dividing Wall Column

Constraints and concerns

One operating pressure
Higher $\Delta T$ from top to bottom
Higher pressure drop
Temperature penalty

Taller column
$\Delta T$ across the partition wall

Vapor split ratio control

Lack of detailed design know-how

Existing patents restrictions
Dividing Wall Column

Constraints, an example

NGL fractionation in (F)LNG plants

\[ \frac{C_1(A)}{C_2(B)} / C_3 + C_4(C) / C_5 + (D) \] separation sequence

As well known, benefits of thermal coupling fade away with increasing boiling point range of the feed. In given cryogenic application example, the total energy requirement was significantly reduced (17%), but at the expense of an increased amount of much costlier refrigeration (“temperature penalty”, i.e. an increased OPEX). Important consideration: energy quality - quantity.

Dividing Wall Column

Ongoing challenges

Design, construction, and operation of a fully thermally coupled 4-product DWCs

Benefits increase largely, but at the cost of increased complexities in design, construction, and operation.

To exploit full potential of a 4-p DWC, a complex, multi partition internal arrangement required (single partition designs in operation).

Details matter, and during preliminary evaluations – feasibility studies, dimensioning needs to be carried out with sufficient rigor to allow proper evaluation and choices among feasible alternative options.

The know-how available in public domain is sufficient in this respect, for packed DWCs.
Starting Point: 4-p Kaibel DWC ("2-4" configuration)

Proven in practice

- Proposed by G. Kaibel 1987
- Single partition wall
- Theoretical savings: larger than experienced with 3-p DWCs (> 30%)
- Not a full Petlyuk arrangement, i.e. less efficient, but practical
- First application: 2002 at BASF
A Full Scale 4-p DWC ("2-3-4" configuration)

A 4-p Petlyuk arrangement accommodated within one shell

"2 - 3 - 4"

A DWC with three partition walls, i.e., three vapor and three liquid splits (Not attempted yet in practice!)
4-p DWC Design Method Development

The collaborating institutions/people (2009 on)

I. Halvorsen, SINTEF (Norway)
S. Skogestad, NTNU (Norway)

Identification and evaluation of feasible configurations (V-min diagram method)

Process control considerations*

I. Dejanović, Univ. of Zagreb (Croatia)

Detailed simulation and estimation of stage and reflux requirements

Ž. Olujić, TU Delft (Netherlands)

Choice of equipment and dimensioning of packed DWCs

H. Jansen, J. Montz (Germany)
B. Kaibel (Presently with BASF SE)
T. Rietfort

* SINTEF and NTNU process dynamics and control studies concerning four-product DWCs:
DESIGN CASE: 15 component feed → 4 products

Based on actual aromatics plant data

Identification and evaluation of feasible configurations (V-min diagram method)
(A stand-alone Matlab program or implemented in a commercial software package)

Detailed estimation of stage and reflux requirements
(Utilizing tools available in commercial simulation packages, initial guesses output of Vmin diagram method)

4-p packed DWC dimensioning
(An Excel subroutine)

Total annualized cost estimation
(An Excel subroutine)

Base case configuration

- Feed 31.7 t/h
- C1:
  - S1 (BRC) 3.9 t/h
- C2:
  - D (C5-C6) 7.4 t/h
  - S2 (toluene) 8.0 t/h
- C3:
  - S1 (BRC) 3.9 t/h
  - S2 (toluene) 8.0 t/h
  - B (heavies) 12.4 t/h

Product specs:
- C5-C6 fraction < 1.3 mass % benzene
- BRC > 67 mass % benzene
- Toluene purity > 97 mass %
Details on preliminary rigorous simulation, dimensioning and cost estimation of these configurations can be found in:


$V_{\text{min}}$ diagram method

Differences in peak heights give operational/design flexibility

\begin{align*}
V_{\text{con}} & >> V > V_{\text{min}} \\
V & = V_{\text{min}}
\end{align*}

<table>
<thead>
<tr>
<th>Configuration</th>
<th>C1-C2-C3</th>
<th>“2-4” DWC</th>
<th>“2-3-4” DWC</th>
<th>“2-2-4” DWC</th>
<th>“2-3-3” DWC</th>
</tr>
</thead>
<tbody>
<tr>
<td>V/F (-)</td>
<td>2.21</td>
<td>1.34</td>
<td>1.11</td>
<td>1.11</td>
<td>1.11</td>
</tr>
<tr>
<td>Saving (%)</td>
<td>-</td>
<td>40</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>


4-p (“2-3-3”) DWC

Pressure drop balancing in partitioned part

For $p_5 = p_6$:

\[ \Delta p_I + \Delta p_H = \Delta p_Y \]
\[ \Delta p_H + \Delta p_G = \Delta p_A \]
\[ \Delta p_G + \Delta p_F = \Delta p_X \]

Fine-tuning by adjusting free area of collectors

Range: 5 – 30%

If insufficient: additional flow resistance needs to be introduced, where appropriate to generate missing $\Delta p$!
Hydraulic Design in EXCEL Solver

Interactively, by adjusting free area of liquid collectors

Pressure drop estimation:

Packed column internals


Structured packings: Delft Model

(all working equations can be found in:)


Relevant numbers for four alternative arrangements:


Similar computational Excel tables for all packed beds and liquid distributors.
Increasing, when a 4-p DWC is considered!

- **One operating pressure**
- Larger $\Delta p$ and $\Delta T$ over the column,
  -> expensive cooling and/or heating!?
- Larger **column height**, -> large h/d ratio!?
- Fraction of **wall zone** area much larger
  -> a serious concern for packed columns!
- Non-circular cross section areas in partitioned sections
  -> internal liquid (mal)distribution patterns may be different!
- Large $\Delta T$ across the partition wall
  -> thermal insulation (packed columns-high purities!)
- Very high purities (ppm & ppb):
  -> leak-free non-welded wall!? 
- **Revamp (retrofit)**
  -> time available for this may become a limiting factor!

- **Control of vapor split** by design -> **control devices**!
Dividing Wall Column

Vapor split control concerns and challenges

A vapor split is arranged by design, and can to a lesser extent be controlled by manipulation of liquid split (limited range!)

Active control of vapor split needed to enable full operational flexibility of a DWC.

Availability of such devices would stimulate design and building multipartition DWCs for four and more products (OPEX and CAPEX savings in range of 50% and more!).

Two designs of a vapor-splitter described in Chinese patents. Prototypes tested extensively in air/water and cold mass transfer tests.

Not yet fully developed to be implemented in industrial practice.
4-p DWC: 2-2-4 as retrofit option

Circumventing multiple vapor split problem!

Jansen, Dejanović, Kaibel, Olujić
Concluding Remarks

A DWC is a genuinely sustainable distillation column (minimum energy, capital and plot-area)!

Four-product DWCs -> higher gains (± 50 %)!

Single-partition DWC proven; multi-partition maximizes energy efficiency/savings

New designs or retrofit (single shell revamps not an option, two shells in series yes!)

Two-partition, two vapor splits (“2-2-4”) DWC, a feasible configuration to start with, either as new design, or a retrofit!

Arranging and control of multiple vapor splits, a serious concern/challenge!

Status of DWC technology in general.

Manufacturers know how to make it, and some daring on industrial side is required!

H. Schoenmakers (former BASF) :

“The choice of a dividing wall column for a separation task is a question of readiness for decision making, it is not really a risk, neither for construction nor for operation”

GO FOR IT, where appropriate!!!
THANK YOU
for your interest and kind attention!

Courtesy of J. Montz