Process Integration and Intensification: A Fundamental Way for Decarbonization of Chemical Processes

(Mainly for Distillation Process)

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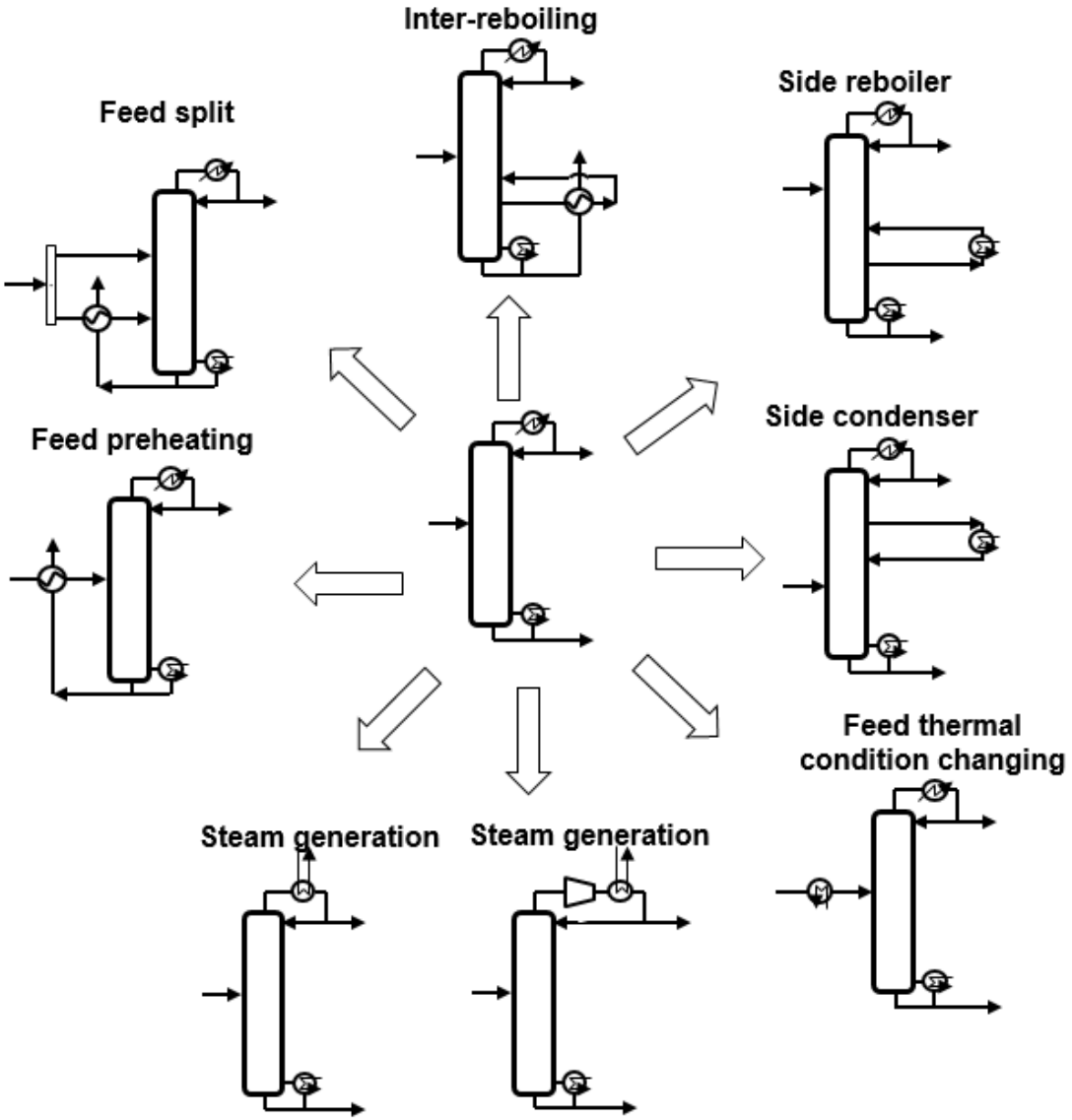
2024. 6. 19.

TNChE Asia 2024, Pataya, THAILAND

PSDC

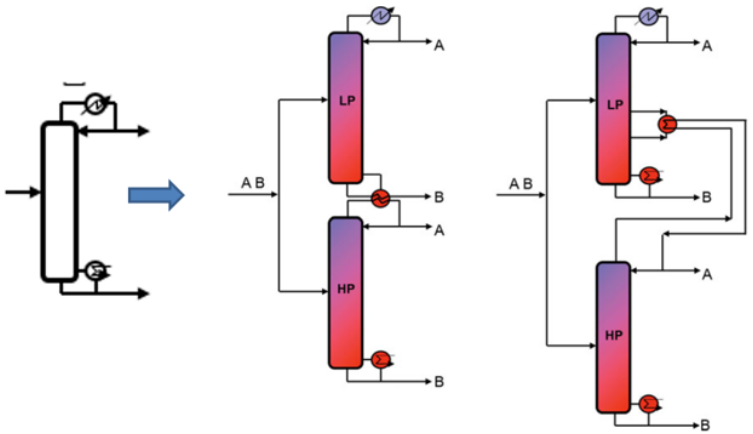
Heat Integrated Distillation

- Single Column with Two Products

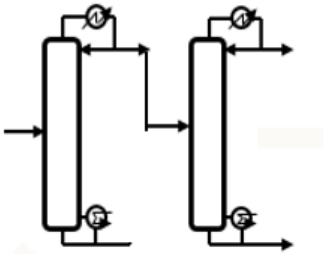


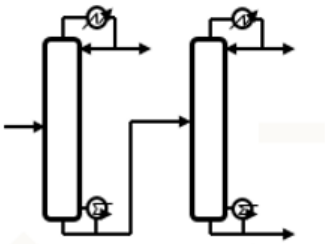
Heat Integrated Distillation

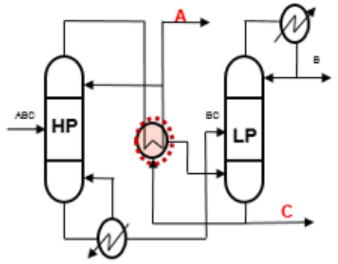
- Double-Effect Distillation (DED) for Single Column



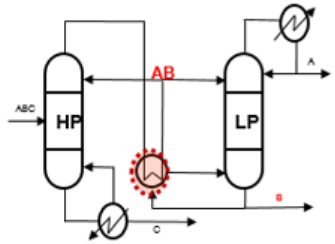
- Double-Effect Distillation (DED) for Two Columns



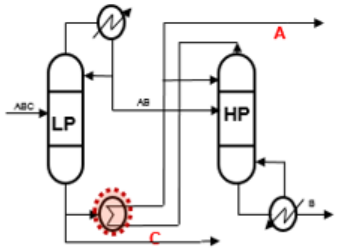




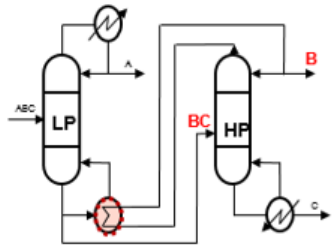
Direct forward-heat integration



Indirect forward-heat integration



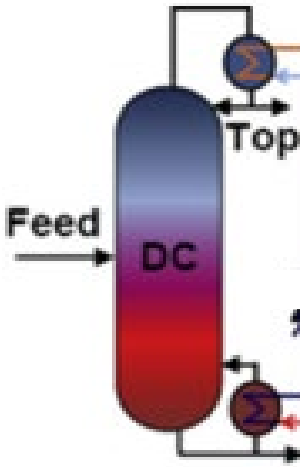
Indirect backward-heat integration

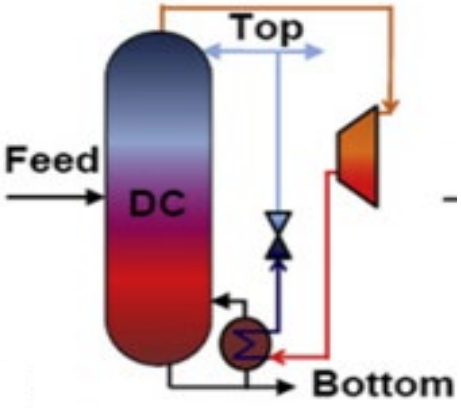


Direct backward-heat integration

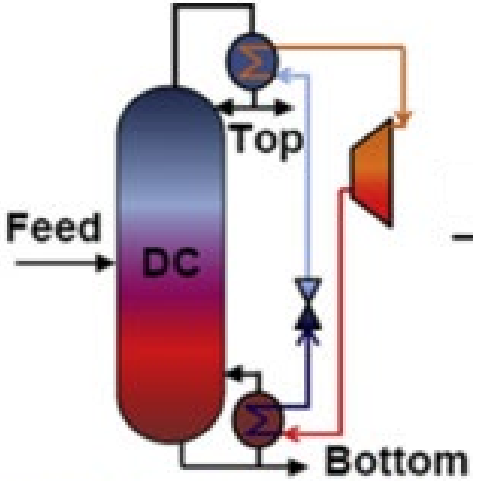
Heat Integrated Distillation

- Heat Pump Assisted Distillation: as a more aggressive way



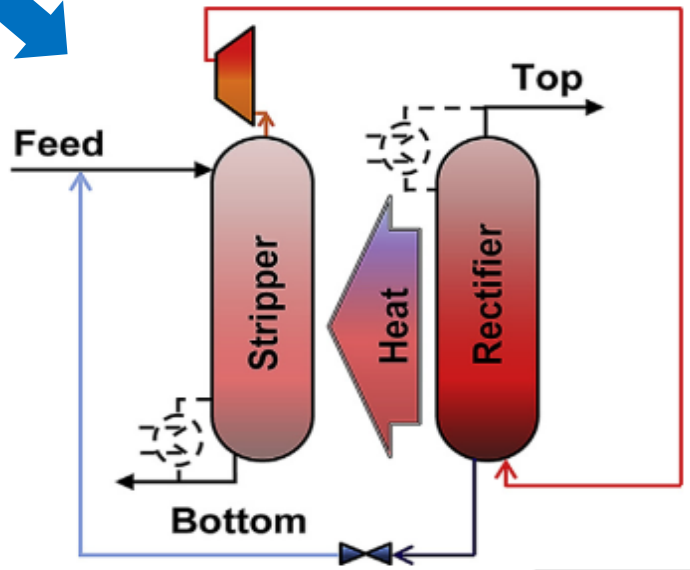


Mechanical Vapor Recompression (MVR)



Vapor Compression (VC)

coming soon?

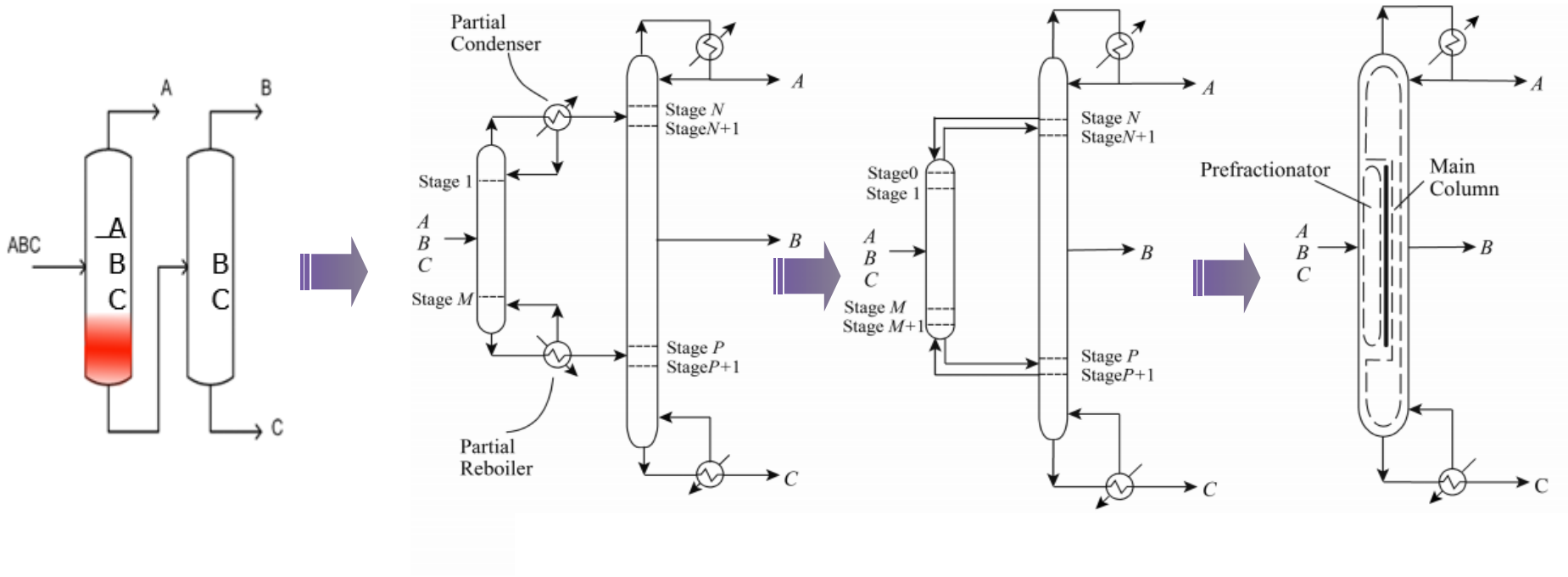


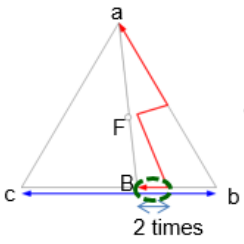
HIDiC

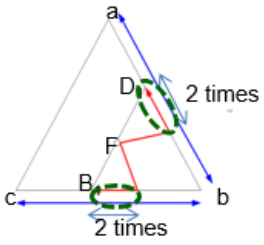
PSDC

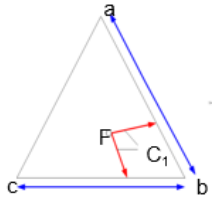
Thermally Intensified Distillation

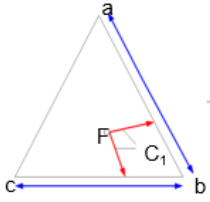
- Thermally Coupled Distillation (TCD) and Dividing Wall Column (DWC)



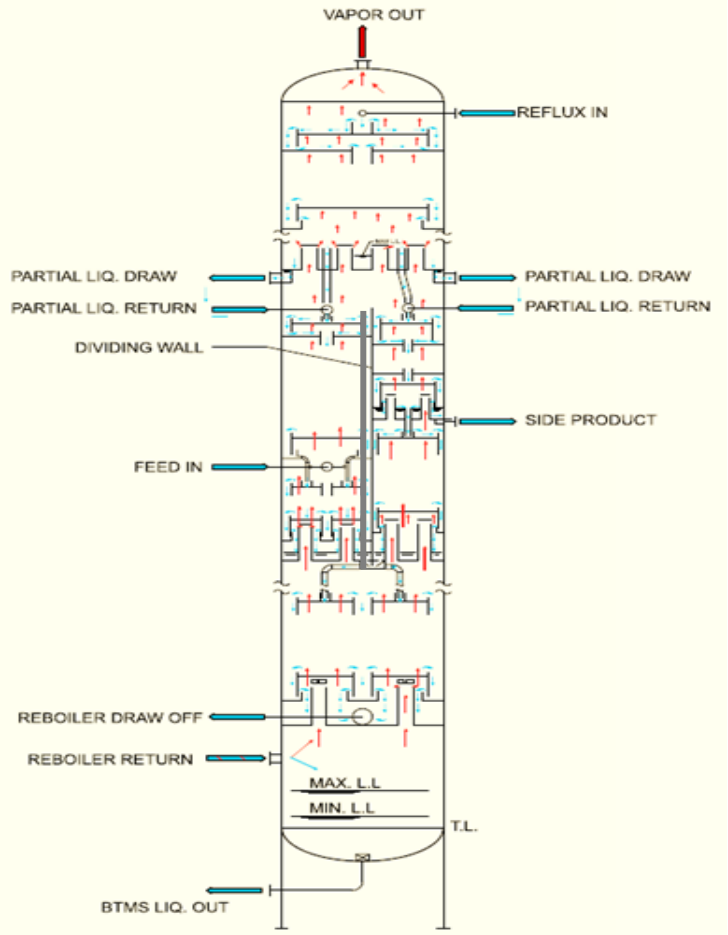


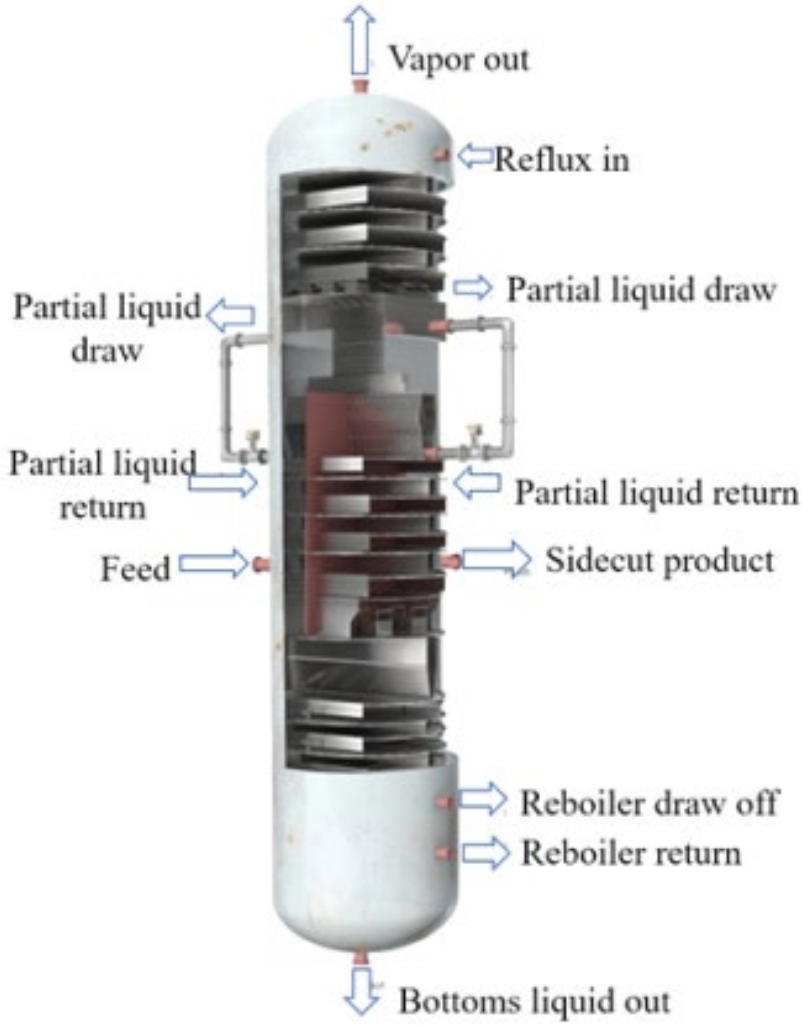






Dividing Wall Column as a fully intensified TCD



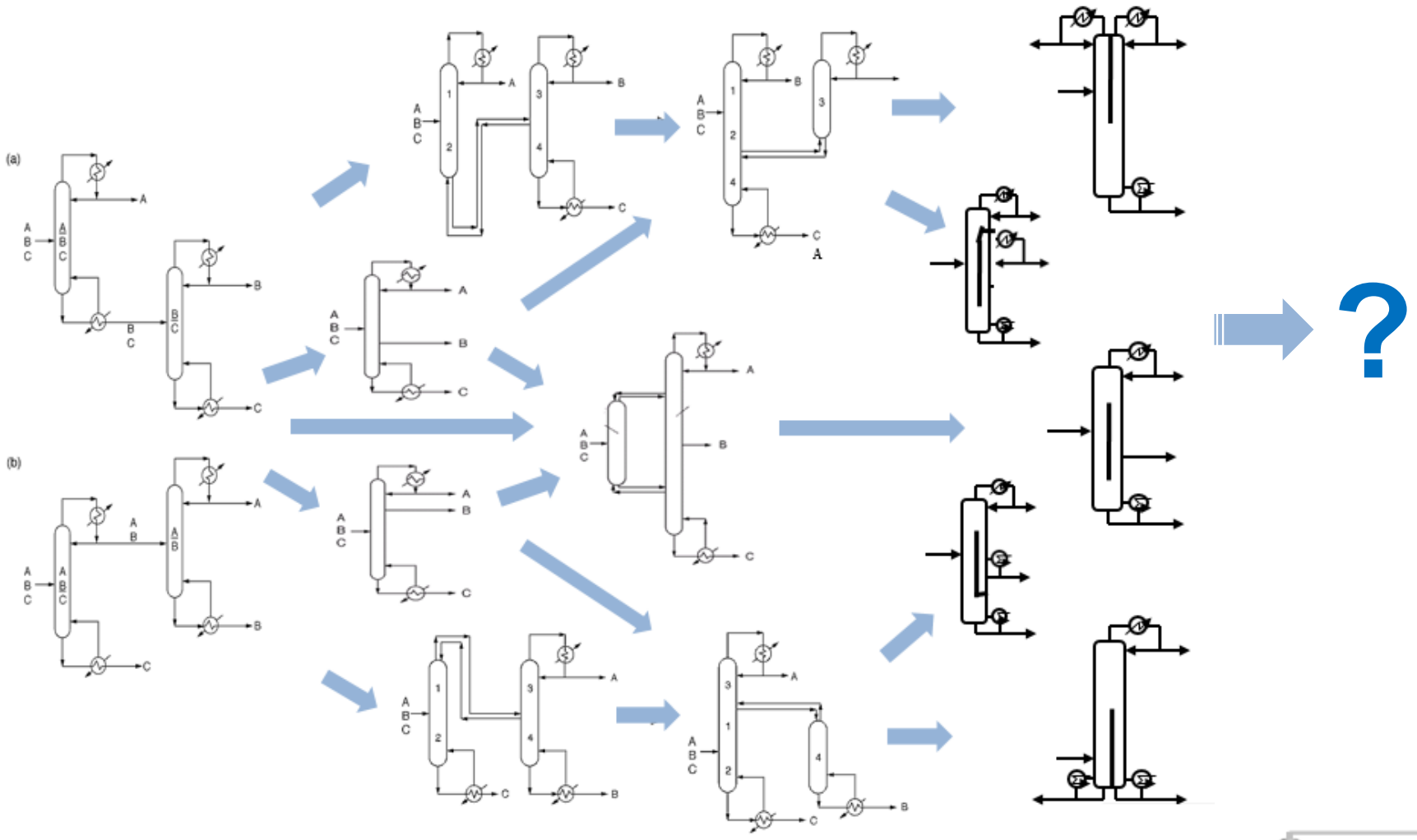


Octane, B.; Naphtha, O.F.L.; Units, I.; Wall, U.D. WHITE PAPER BOOST OCTANE AND THROUGHPUT OF LIGHT NAPHTHA USING DIVIDING WALL.

DWC Innovations Available online: https://www.dwcinnovations.com/dwc-column-inside-view/.

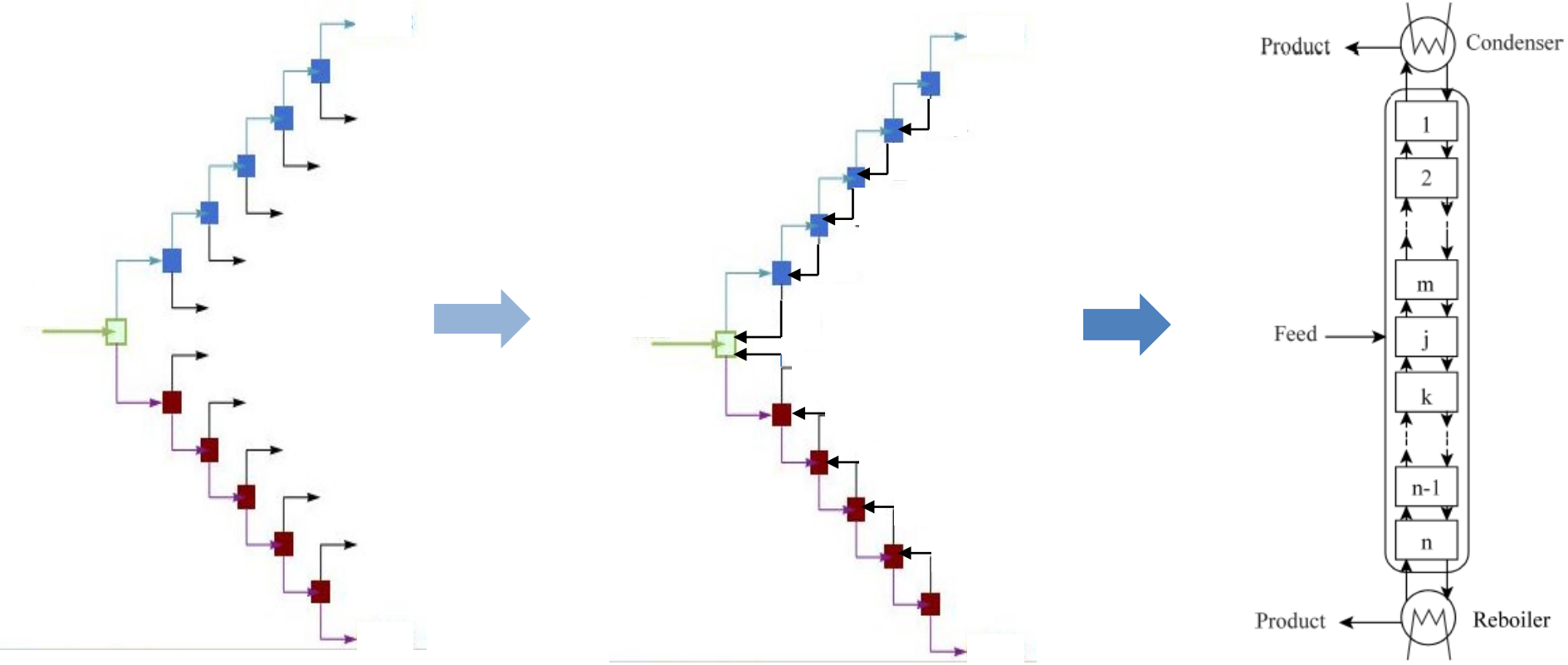
Thermally Intensified Distillation

- Evolution tracks from conventional ones to DWCs through TCDs



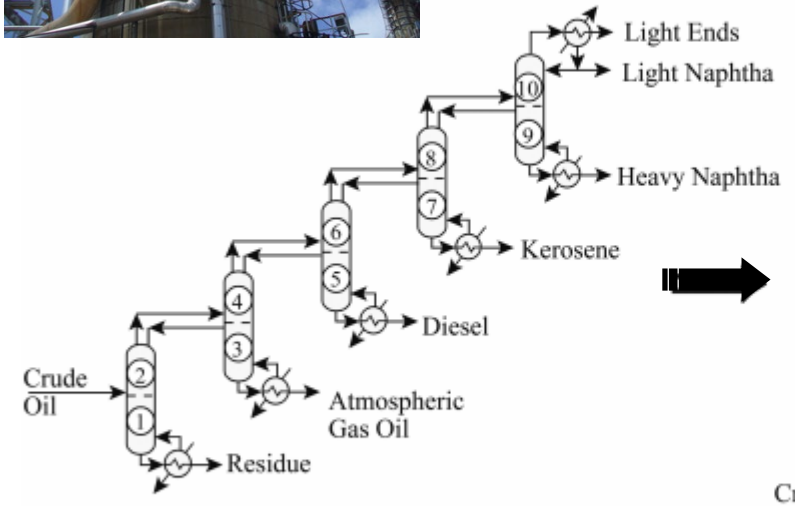
Conventional Distillation Column as a TCD

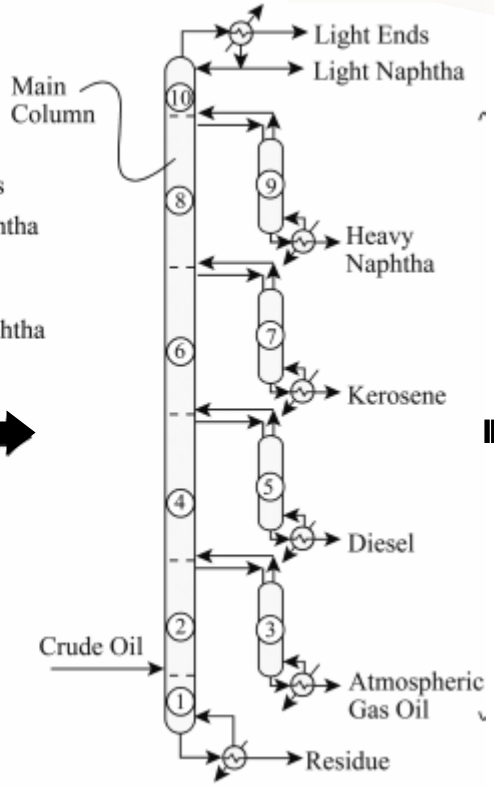
as an original TCD through vertical intensification of a multi-stage counter-flow flash drum process

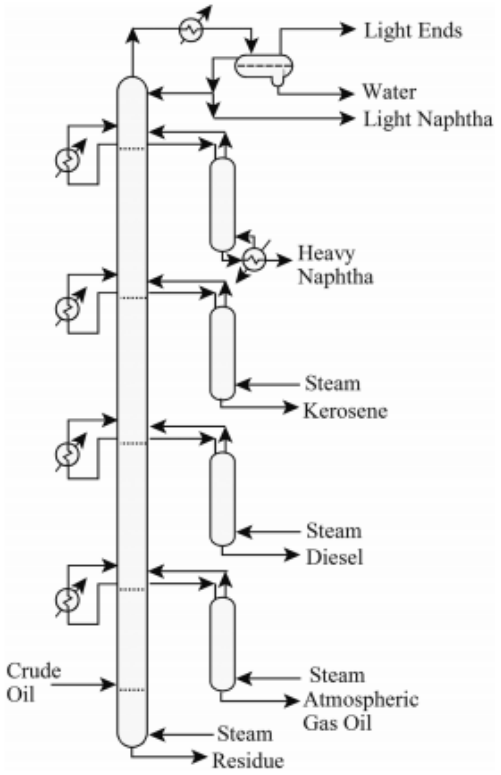


A- Tower as a more complicate TCD

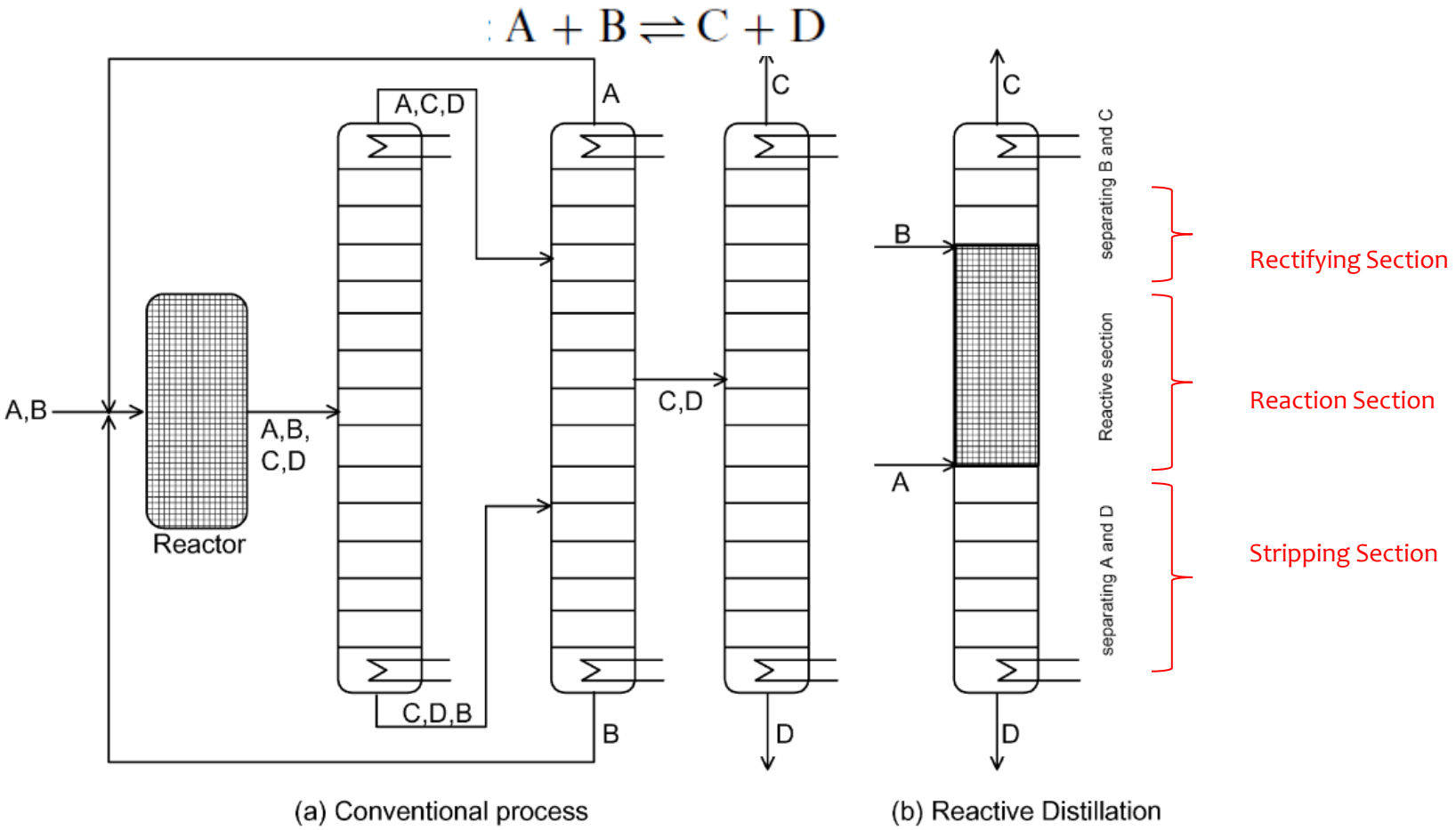
- avoid high temp reboiling & fouling
- lowers partial P of comp & more volatile
- avoid huge vapor rise up







Reactive Distillation – Intensification of Reaction and Distillation



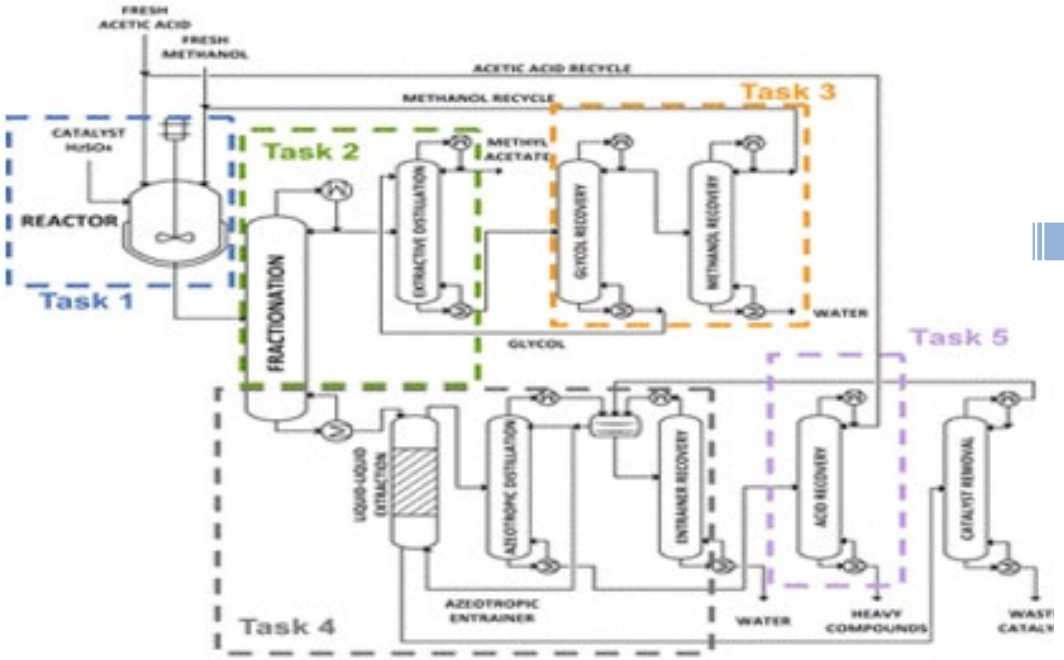
(a) Conventional process (b) Reactive Distillation

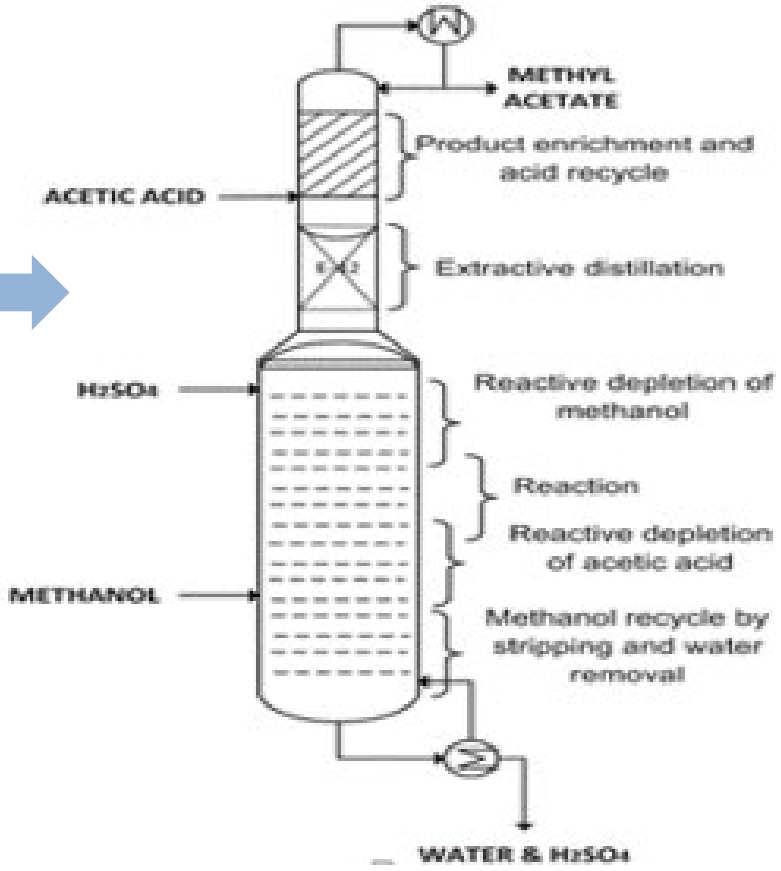
* Modelling reactive distillation R. Taylor!,", R. Krishna#

- Combining Reaction and Separation in a single vessel is termed as Reactive Separation Process.
- Significant Importance over Conventional Reactor-Separation Unit.
- Reduction in both energy and equipment costs.
- A single reactive column could be replaced a conventional multi-unit process that consumed 5 times m ore energy and capital investment

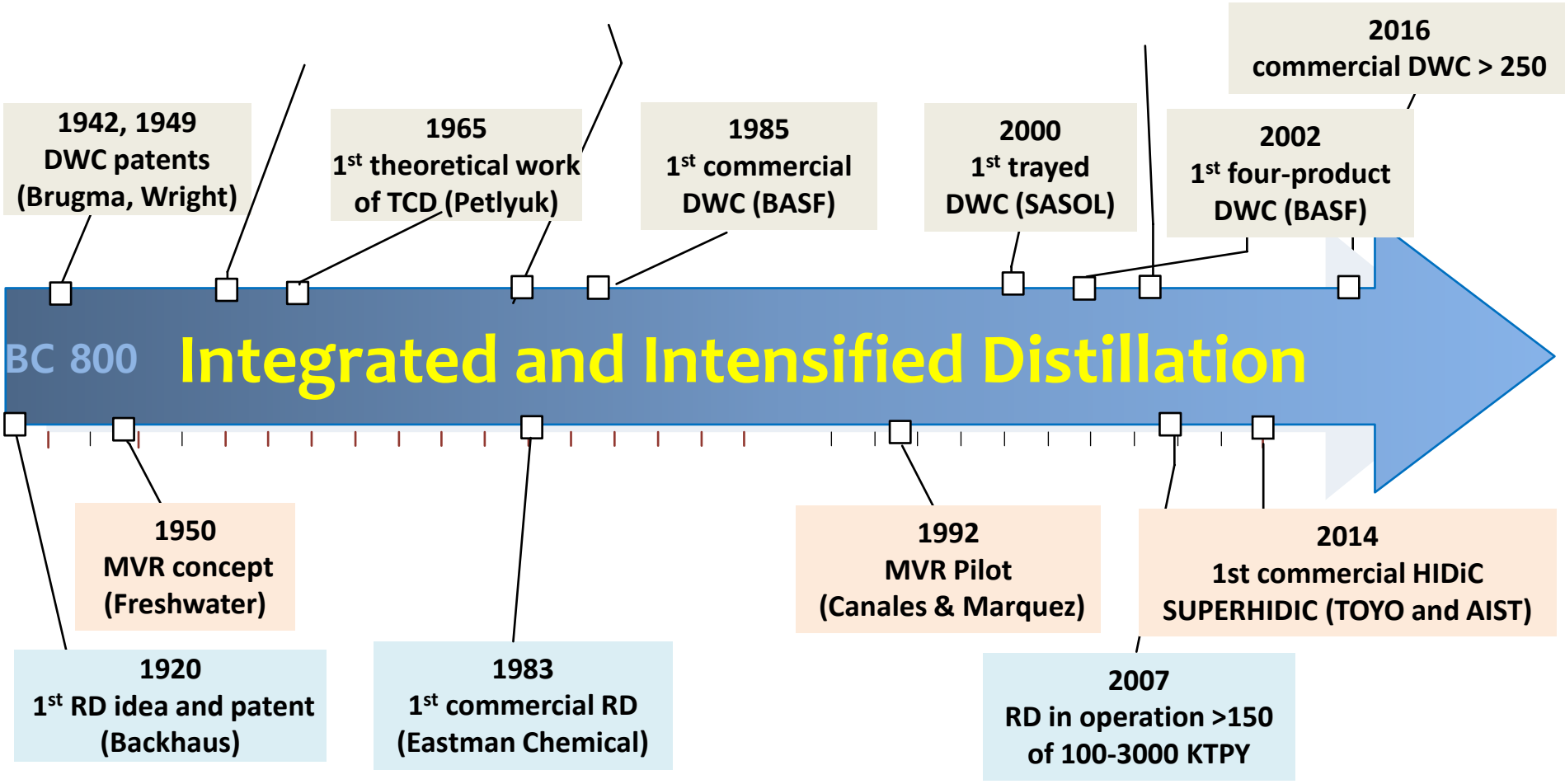
Reactive Distillation – Intensification of Reaction and Distillation

- Eastman Chemical Plant with 23 ton/hr commercial RD unit for esterification for methyl acetate production in 1983.





Integrated and Intensified Distillation – Yesterday and Today



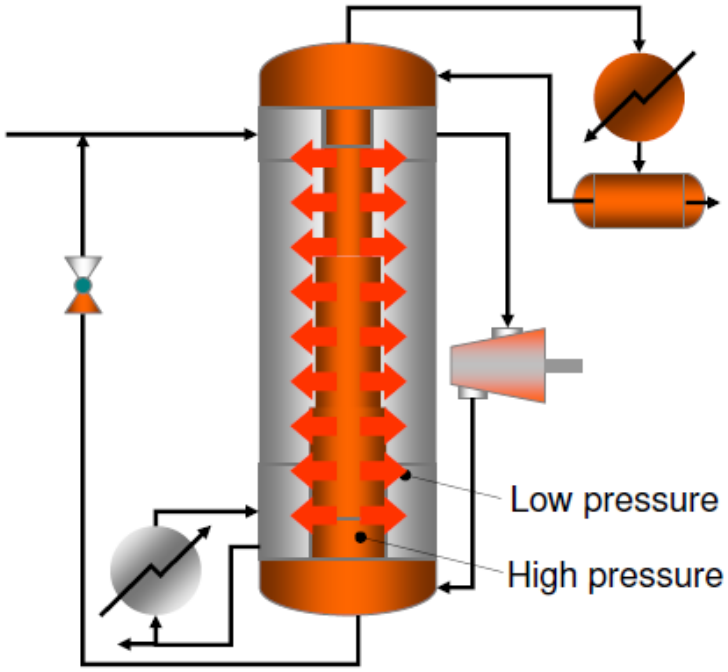
Integrated and Intensified Distillation – Tomorrow

What it will look like?

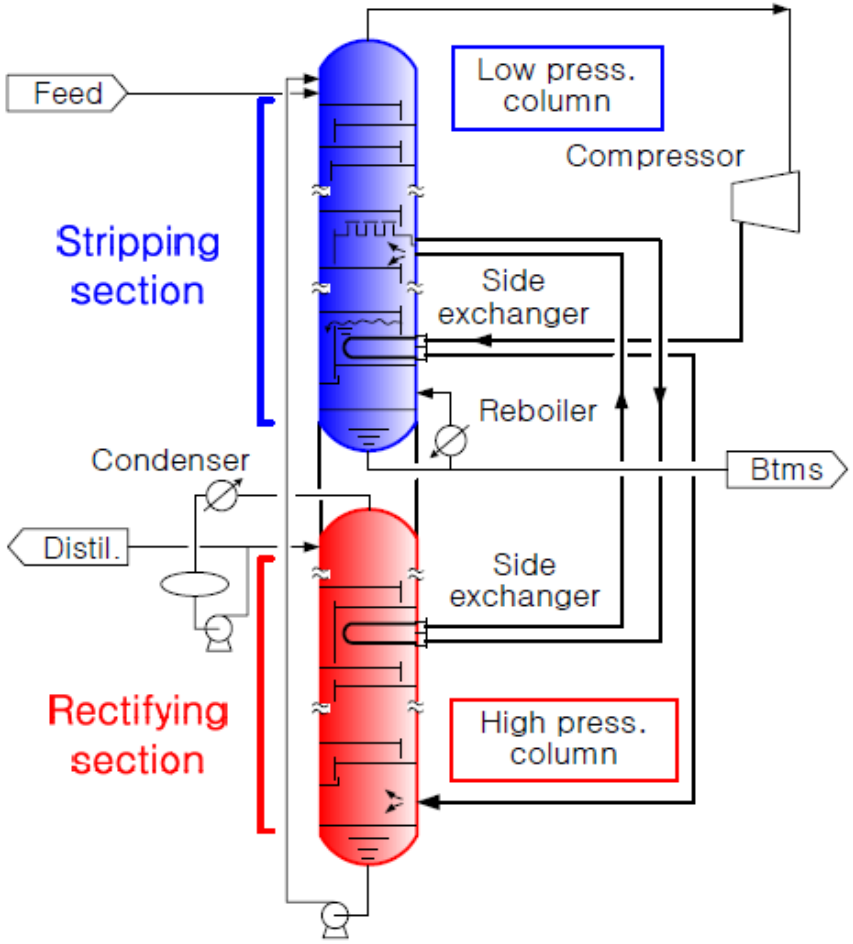
- It will come true in a practical alternative form.
- It will be more popular by overcoming main huddles and concerns.
- It will become more integrated, intensified, and combined.

Implementing Dreams via. Practical Alternatives

- **It will come true in a practical alternative form !**



HIDiC

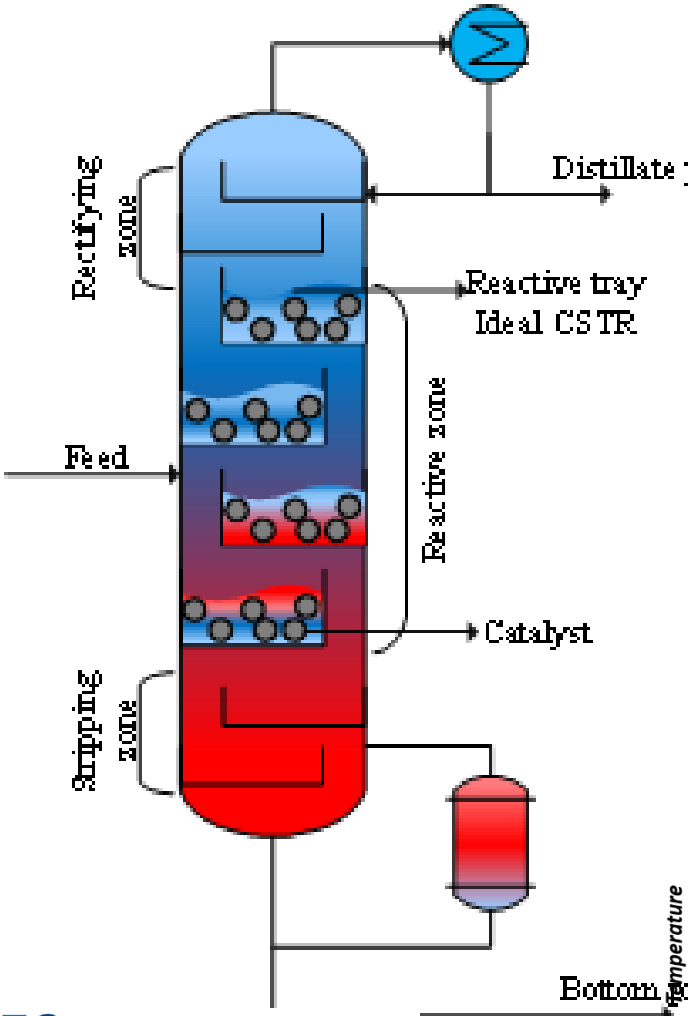


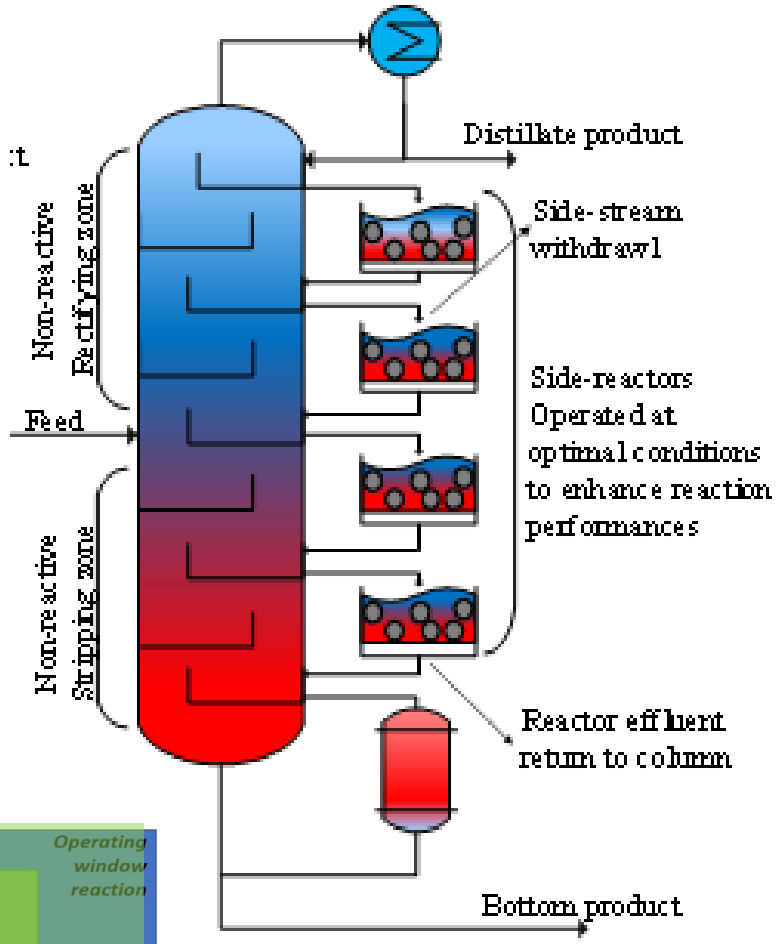
SuperHIDiC (TOYO and AIST)

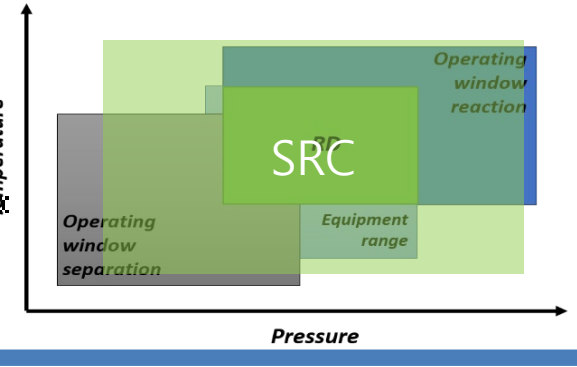
PSDC

Implementing Dreams via. Practical Alternatives

- It will come true in a practical alternative form !





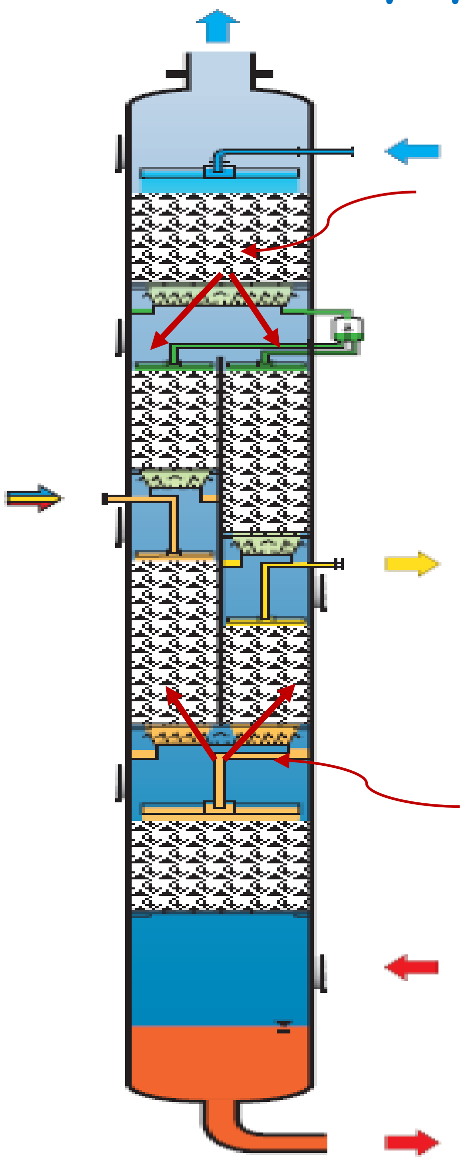


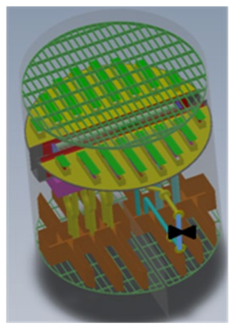
I&EC research
Process Design Alternatives for Producing Ultra-high-purity Electronic-Grade Propylene Glycol Monomethyl Ether Acetate
Arif Hussain, Yus Donald Chaniago, Amjad Riaz, and Moonyong Lee

Chemical Engineering & Processing: Process Intensification
journal homepage: www.elsevier.com/locate/cep
Design method for the feasibility and technical evaluation of side-reactor column configurations
Arif Hussain, Yus Donald Chaniago, Amjad Riaz, Moonyong Lee

Going over hurdles with innovative key unit technology

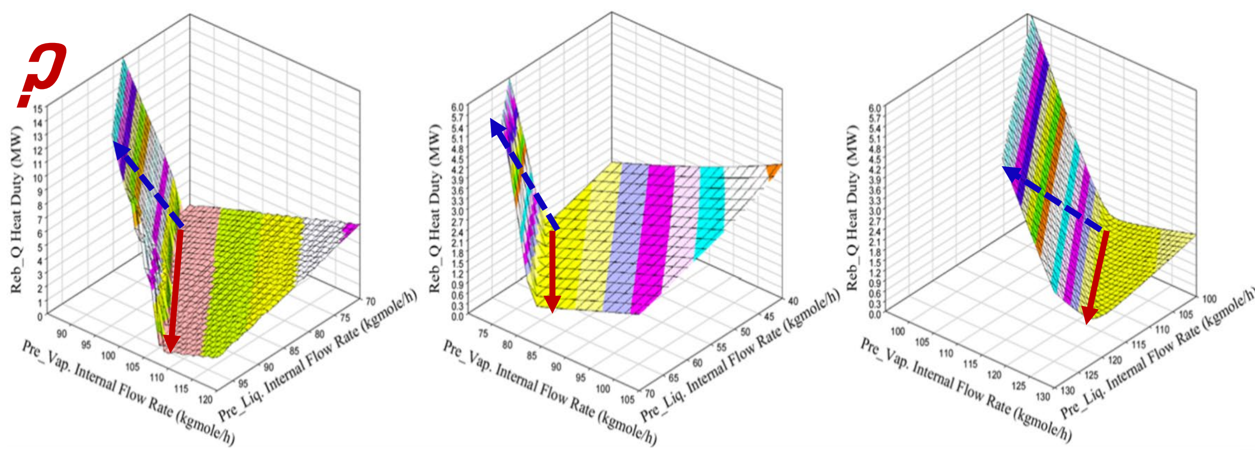
- more popular by overcoming main huddles and concerns !





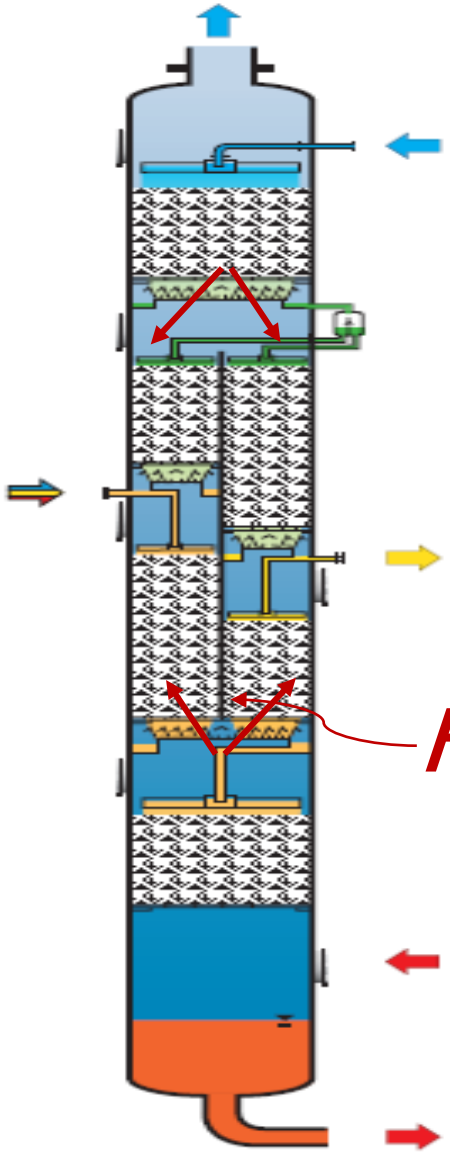
- control of (multiple) vapor splits is a serious concern/ challenge to enable full operational flexibility of a DWC !

How ?

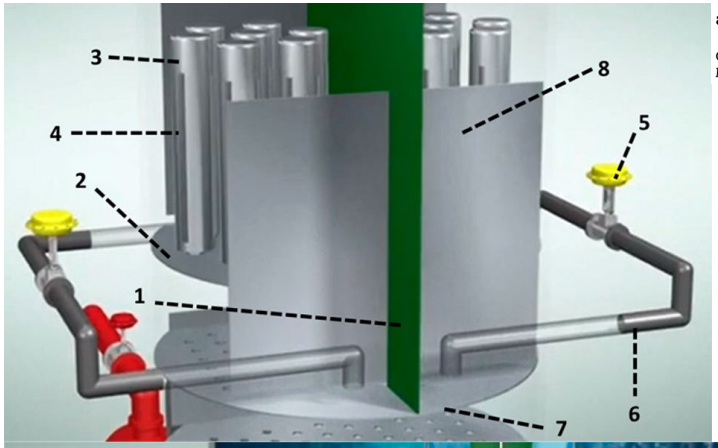


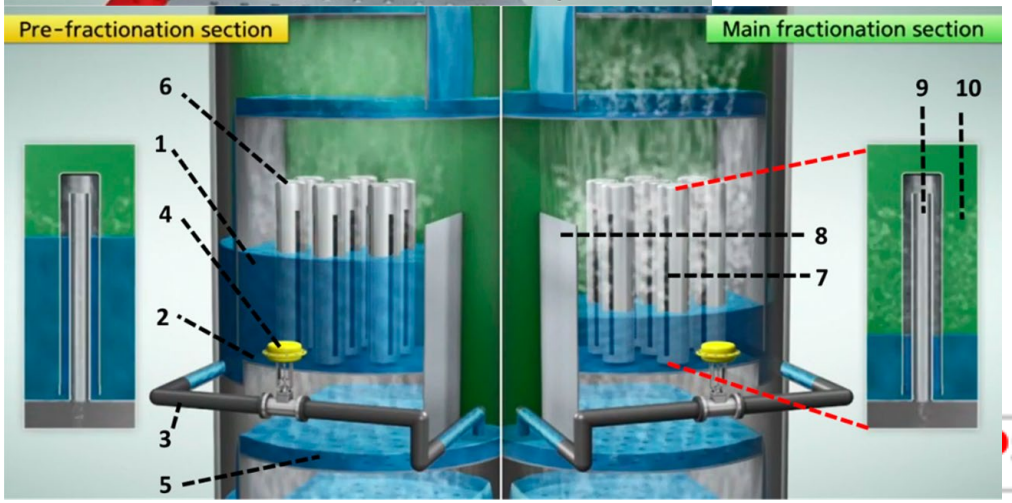
Going over hurdles with innovative key unit technology

- more popular by overcoming main huddles and concerns !



How ?





I&EC research

Article

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Hydraulic Driven Active Vapor Distributor for Enhancing Operability of a Dividing Wall Column

Ki Joon Kang,† Gregorius Rionugroho Harvianto,‡ and Moonyong Lee*,‡

Contents lists available at ScienceDirect

Chemical Engineering Research and Design

journal homepage: www.elsevier.com/locate/cherd

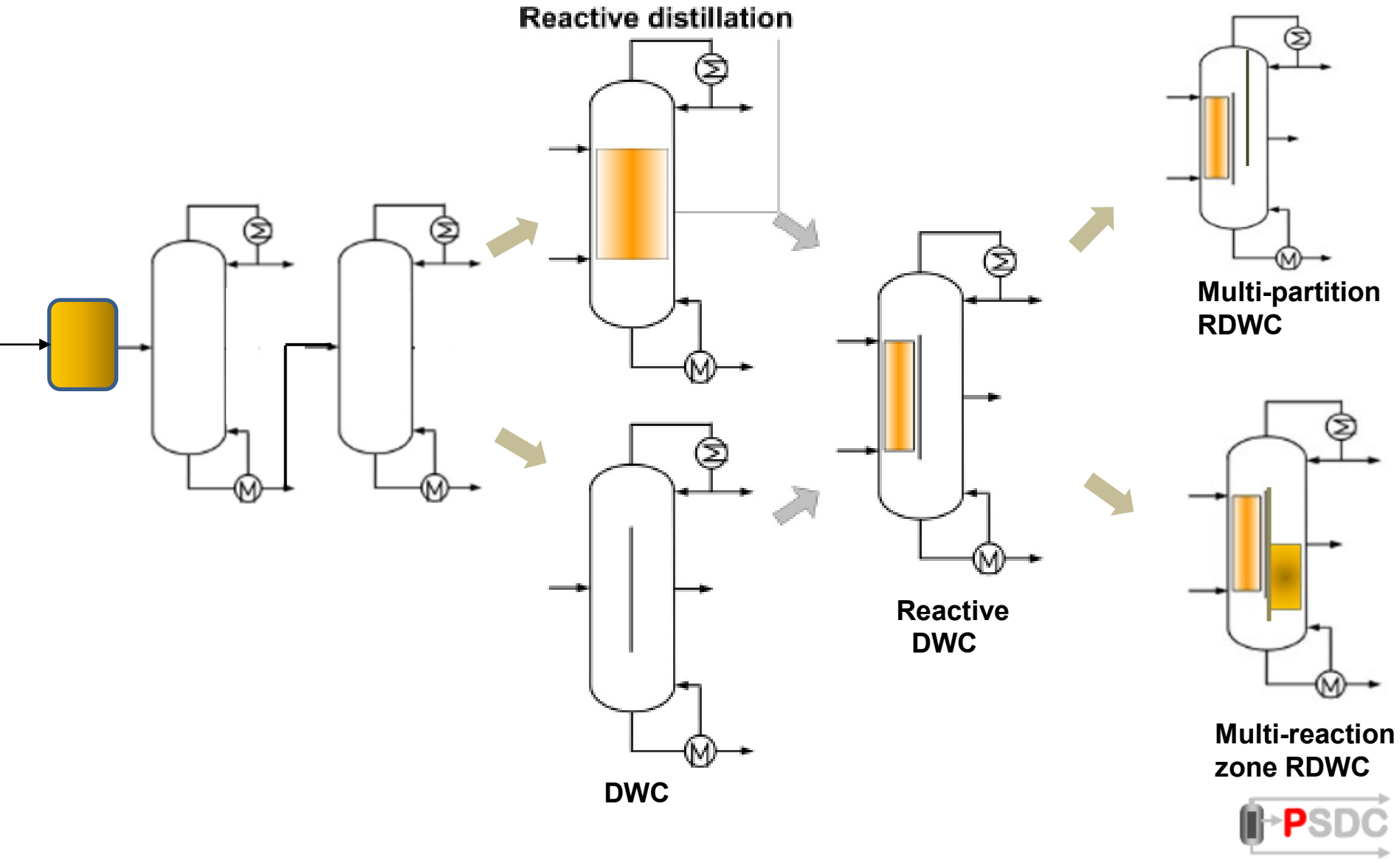
ELSEVIER

Optimal operation of a dividing wall column using an enhanced active vapor distributor

Gregorius Rionugroho Harvianto[a], Kwang Hyun Kim[a], Ki Joon Kang[a,**], Moonyong Lee[b,*]

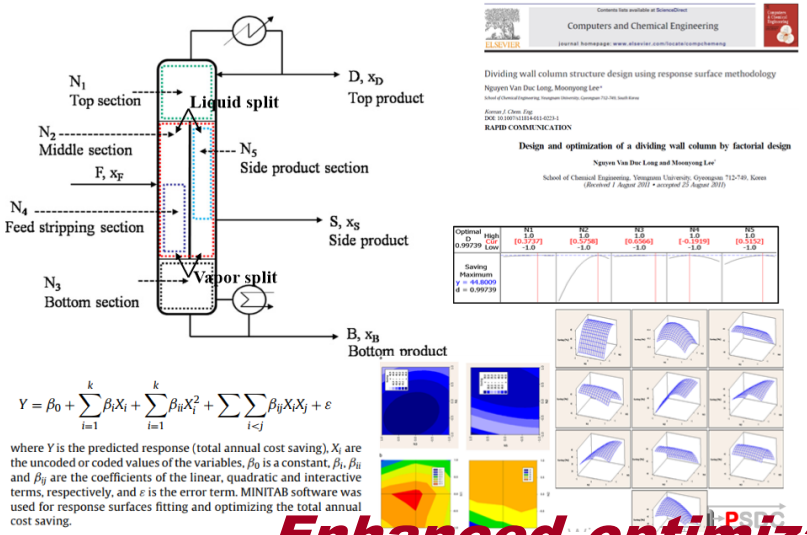
More Integrated, Intensified, and Combined

- more integrated, intensified, and combined



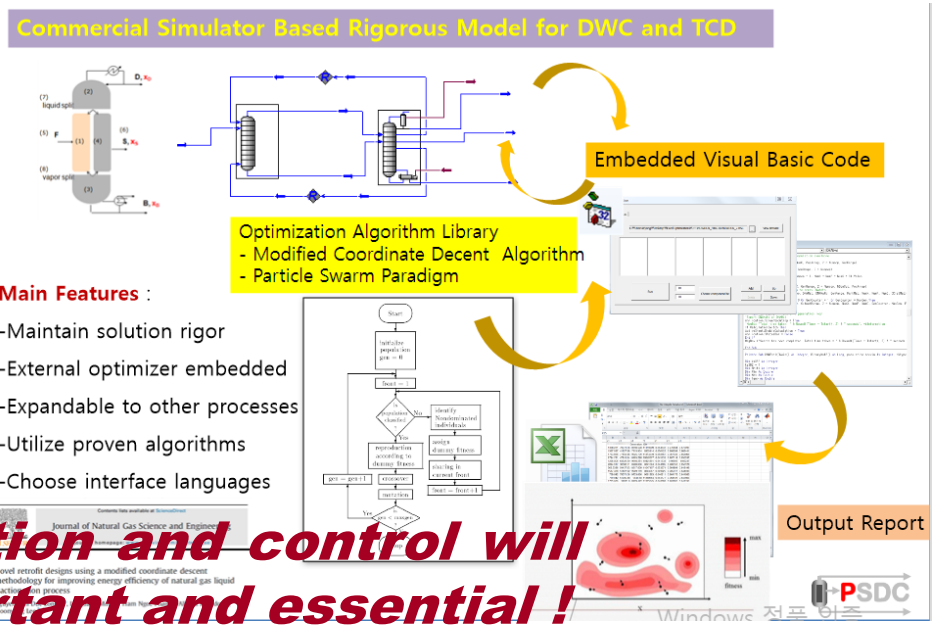
More Integrated, Intensified, and Combined

← Enhanced Optimization and UQ/UA by AI and Digitalization Technologies

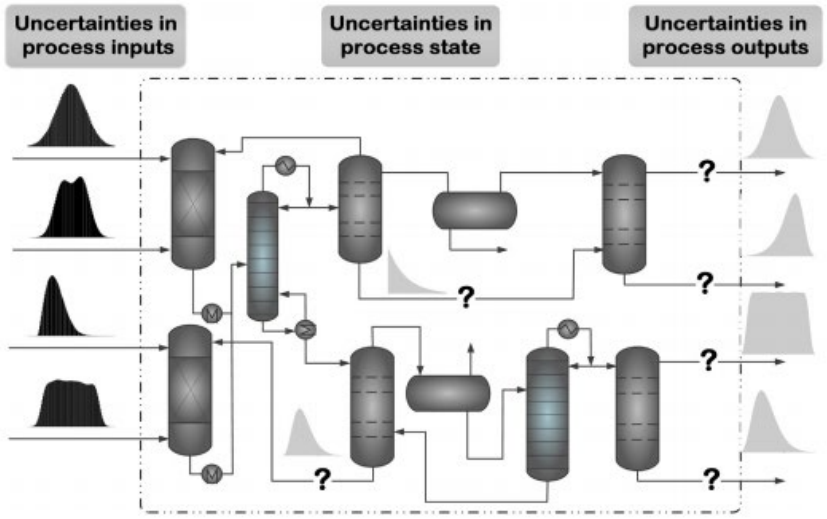


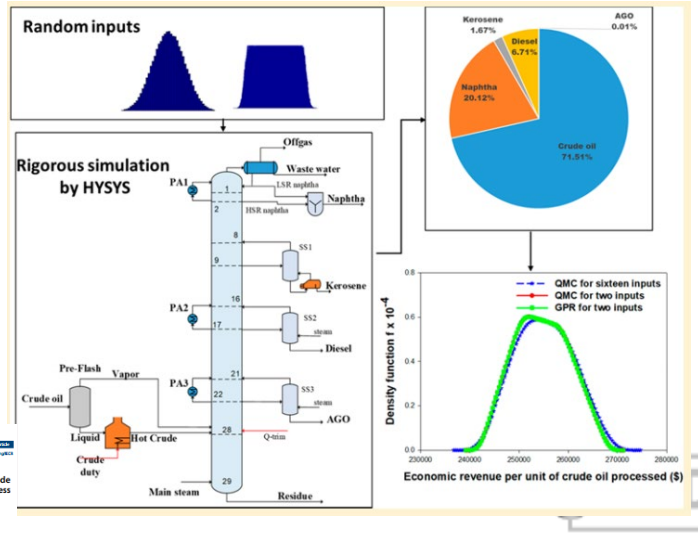
$$Y = \beta_0 + \sum_{i=1}^{k}\beta_i X_i + \sum_{i=1}^{k}\beta_{ii}X_i^2 + \sum\sum_{i<j}\beta_{ij}X_iX_j + \varepsilon$$

where Y is the predicted response (total annual cost saving), X_i are the uncoded or coded values of the variables, β_0 is a constant, β_i, β_{ii} and β_{ij} are the coefficients of the linear, quadratic and interactive terms, respectively, and ε is the error term. MINITAB software was used for response surfaces fitting and optimizing the total annual cost saving.



Enhanced optimization and control will become more important and essential !





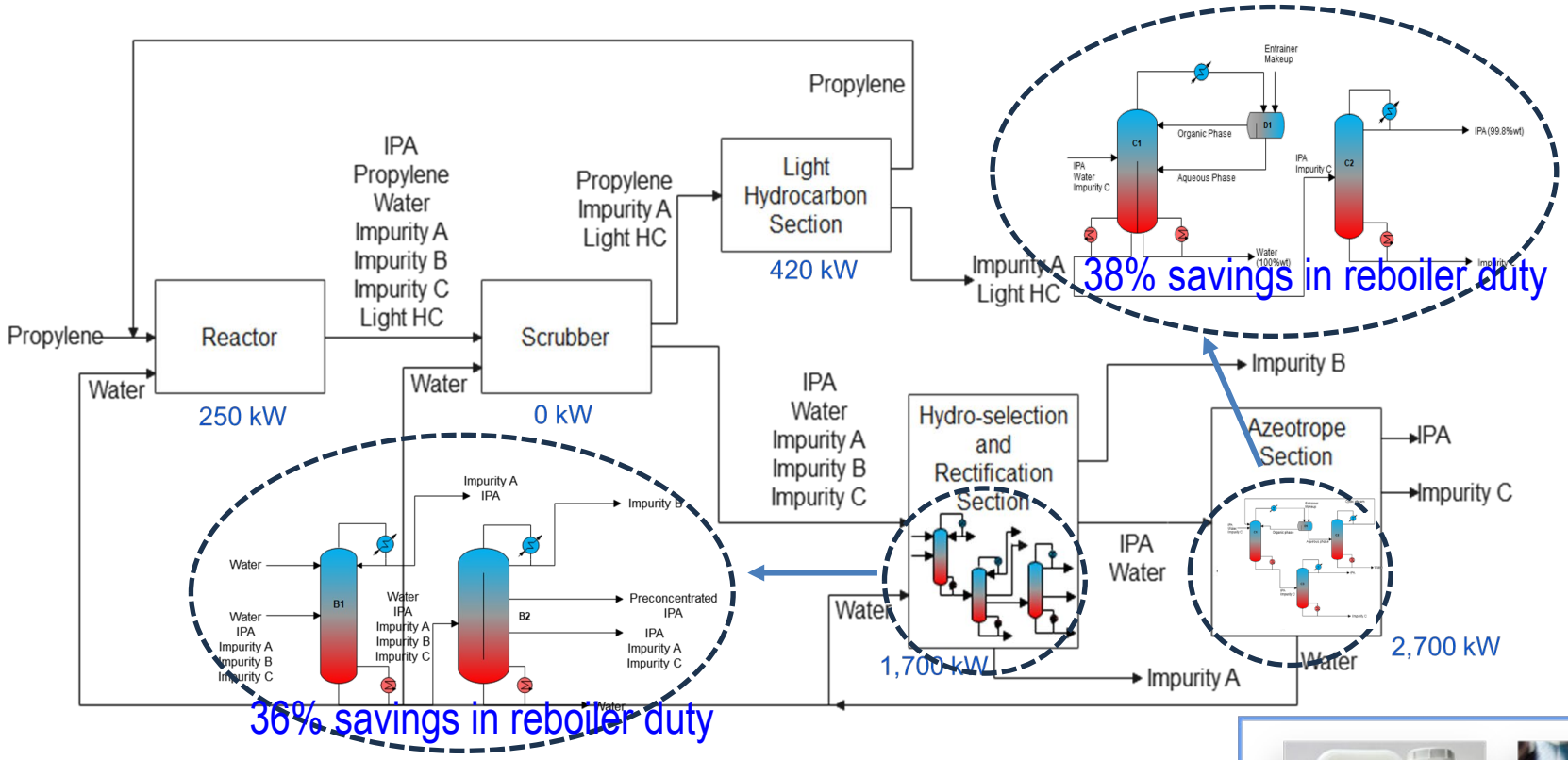
I&EC research

Global Sensitivity Analysis and Uncertainty Quantification of Crude Distillation Unit Using Surrogate Model Based on Gaussian Process Regression

Le Quang Minh,* Pham Luu Trung Duong,* and Moonyong Lee*

IPA Production Process

- Heat Integration via. Process Intensification

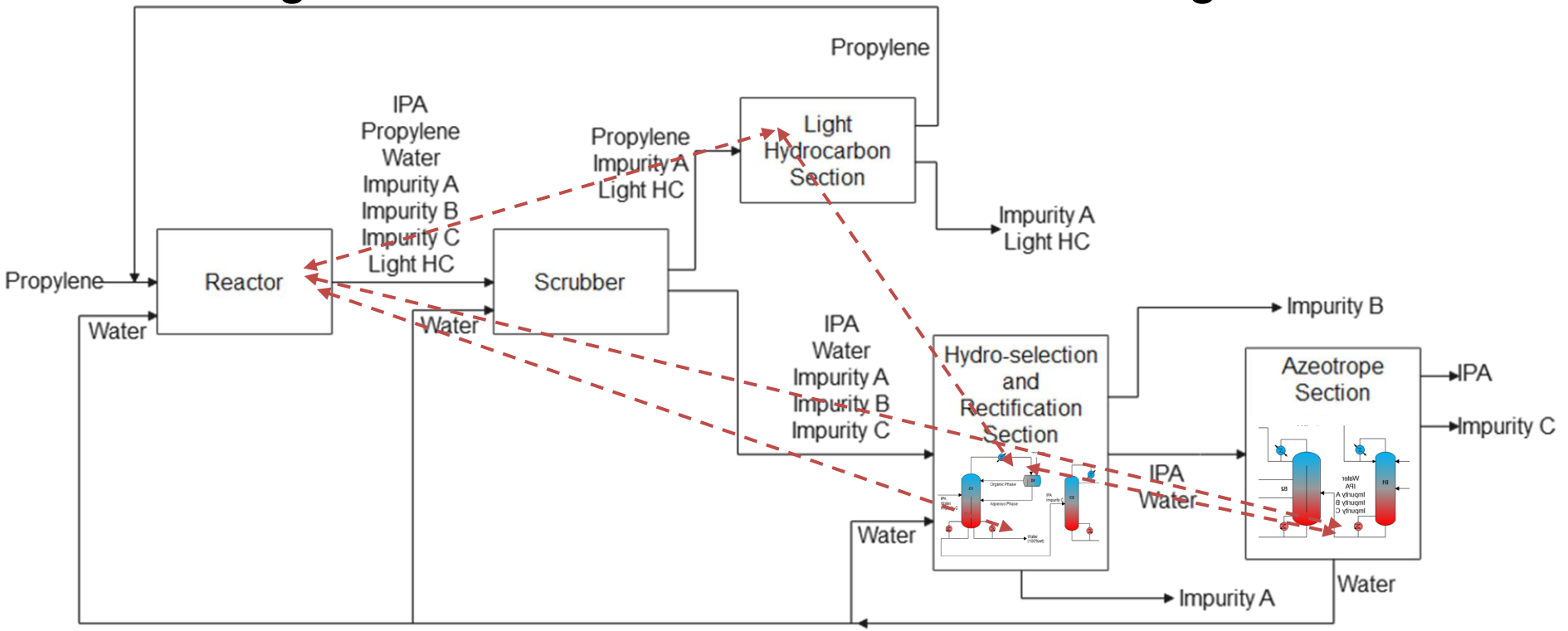


Total reboiler duty 4980 (kW) → 2980 (2087) (kW)

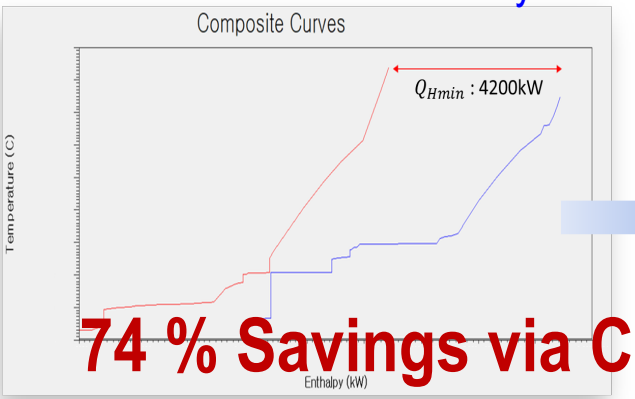
38 (57) % Savings via Distillation Intensification (with simple HI)!

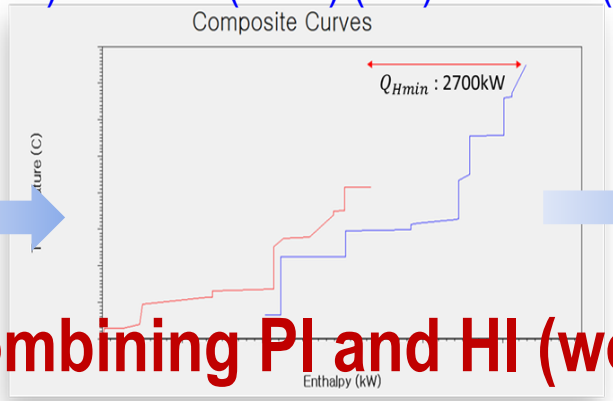
IPA Production Process

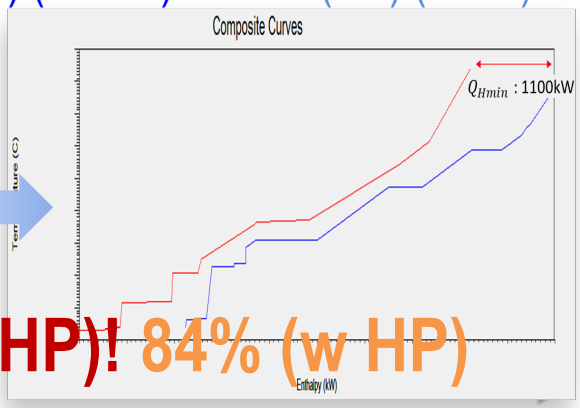
- Combining Process Intensification and Heat Integration



Total reboiler duty 4980 (kW) → 2980 (2087) (kW) → 1194 (kW) (wo HP) → 787 (kW) (w HP)



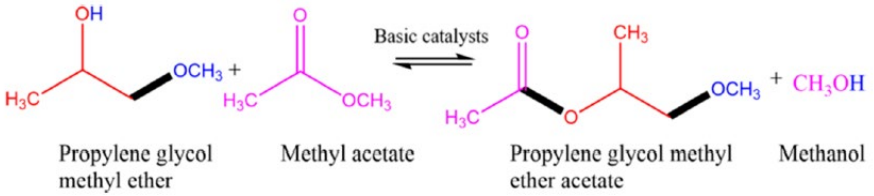




74 % Savings via Combining PI and HI (wo HP)! 84% (w HP)

PGMEA Production Process

Reactive Pressure Swing DWC Process for PGMEA Production



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Reactive Pressure-Swing Distillation toward Sustainable Process of Novel Continuous Ultra-High-Purity Electronic-Grade Propylene Glycol Monomethyl Ether Acetate Manufacture

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Article

Pressure Swing-Based Reactive Distillation and Dividing Wall Column for Improving Manufacture of Propylene Glycol Monomethyl Ether Acetate

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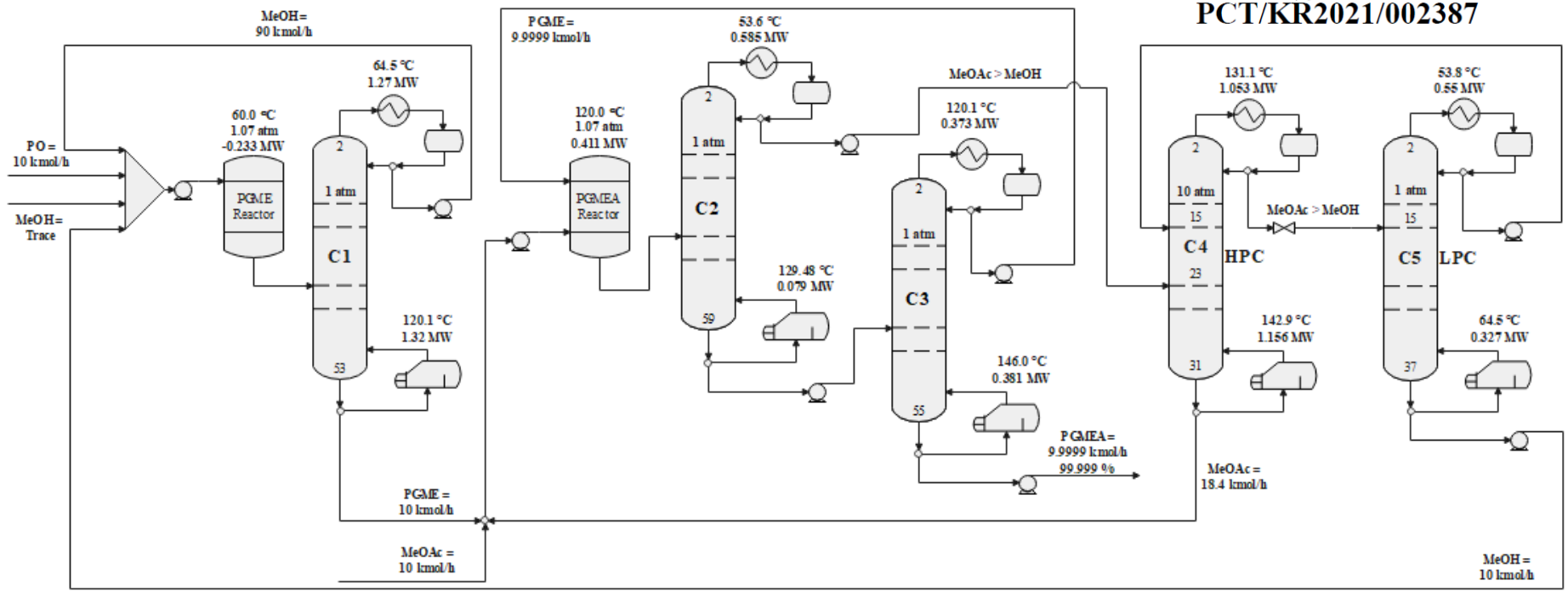
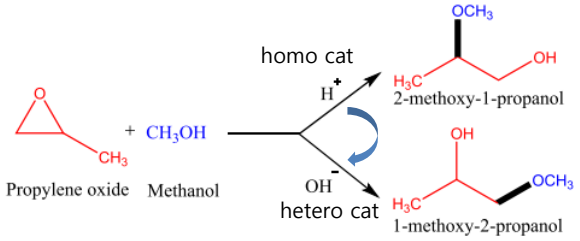
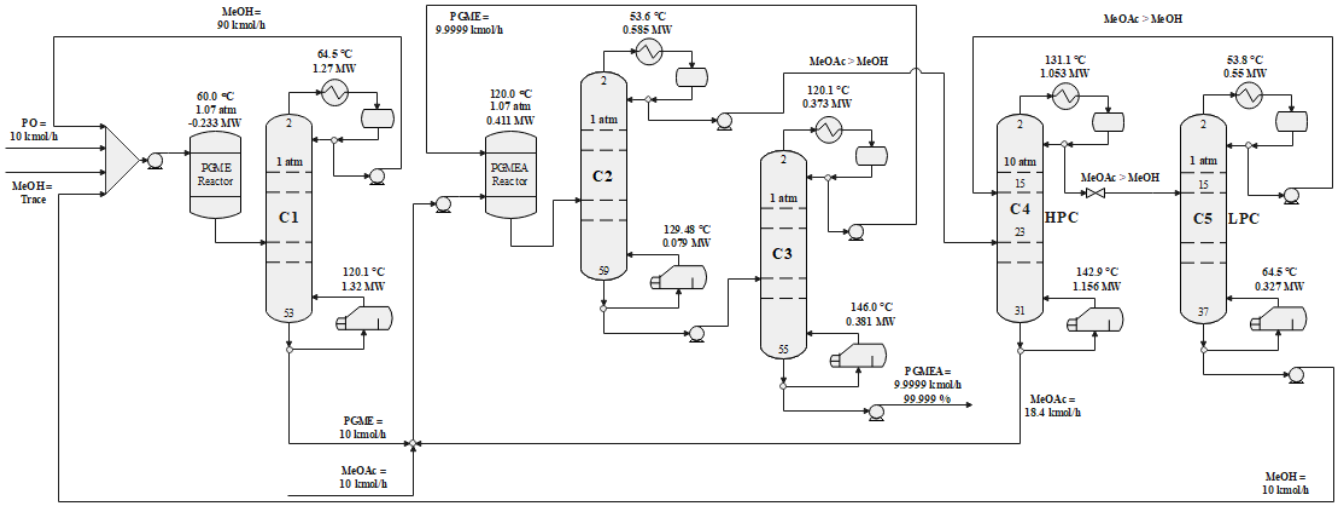


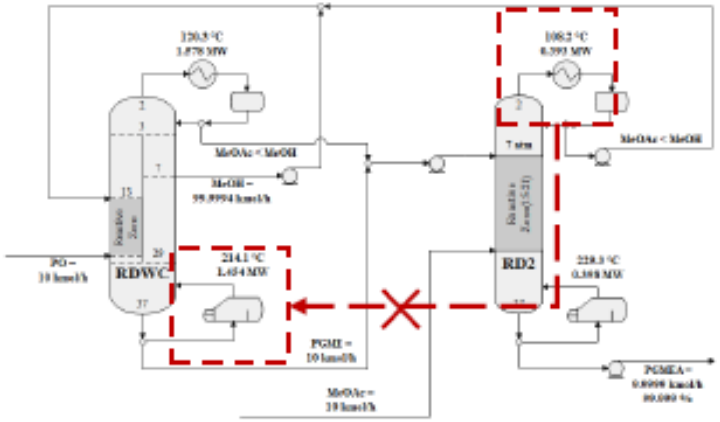


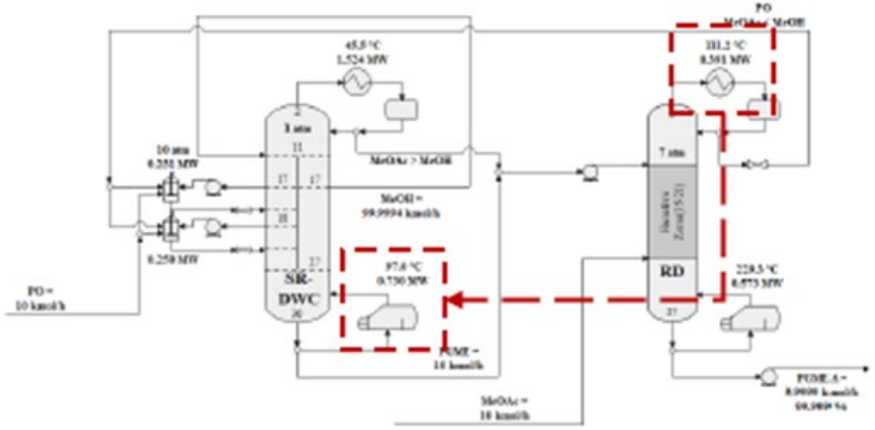
PSDC

PGMEA Production Process

Reactive Pressure Swing DWC Process for PGMEA Production







Conclusions

- PI^2 will be much more popular by extending its application to a real industry and by coming to us as it will :

  - come true in a practical alternative form.
  - overcome main huddles and concerns.
  - become more integrated, intensified, and combined.

- PI^2 will thus be one of effective and powerful ways and workhorses for sustainable process industry.