

# Reducing Energy Consumption in Separations

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# Agenda

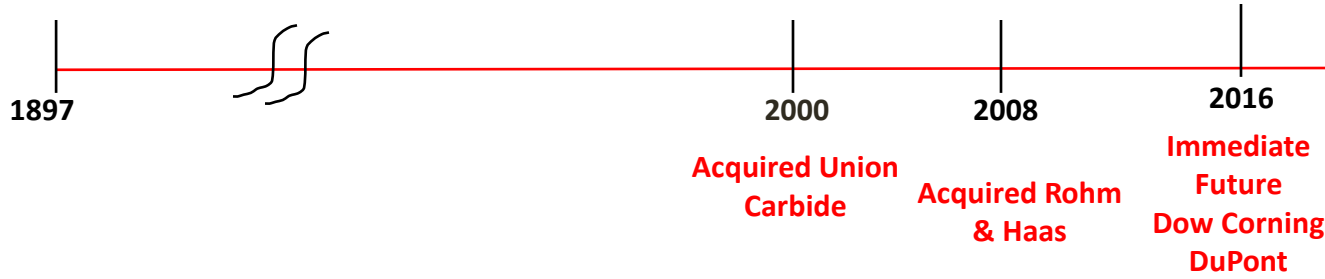
- Company Introduction
  - Limitations on Information
- Historical Perspective
- Economic Basis
- Energy Conservation Separation Methods
- Success Examples
- On the Horizon
- Questions



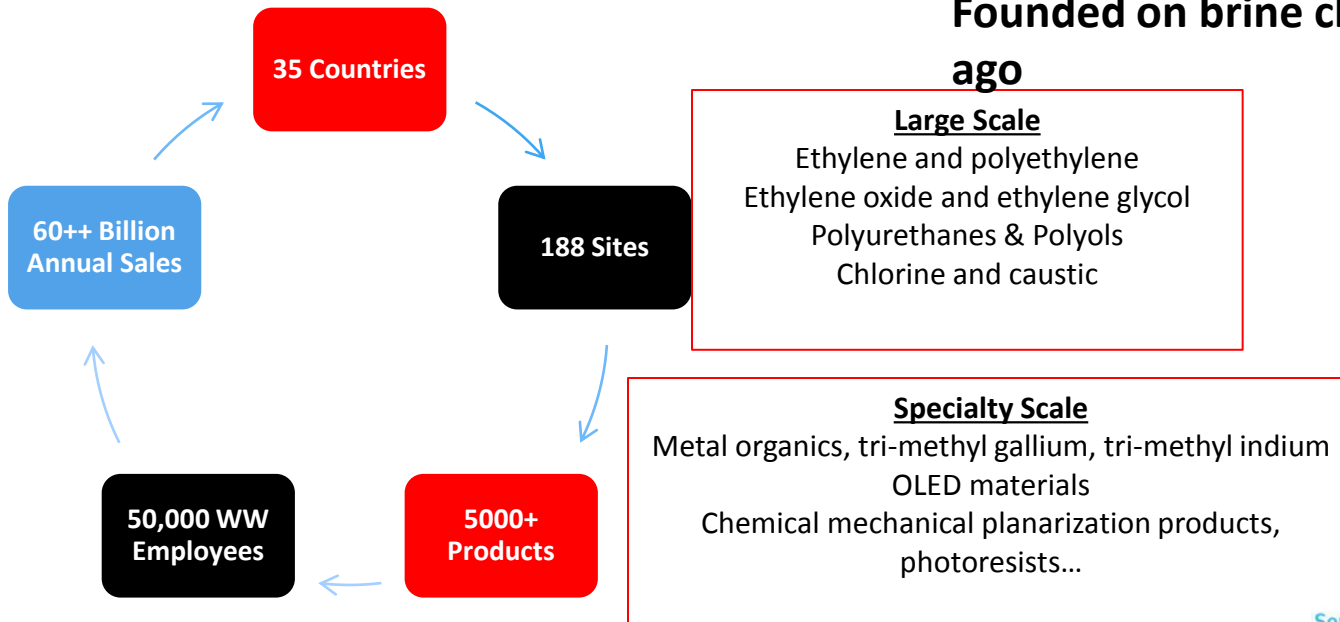
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# The Dow Chemical Company

Diversified chemical company, harnessing the power of science and technology to improve living daily



## Dow by the numbers



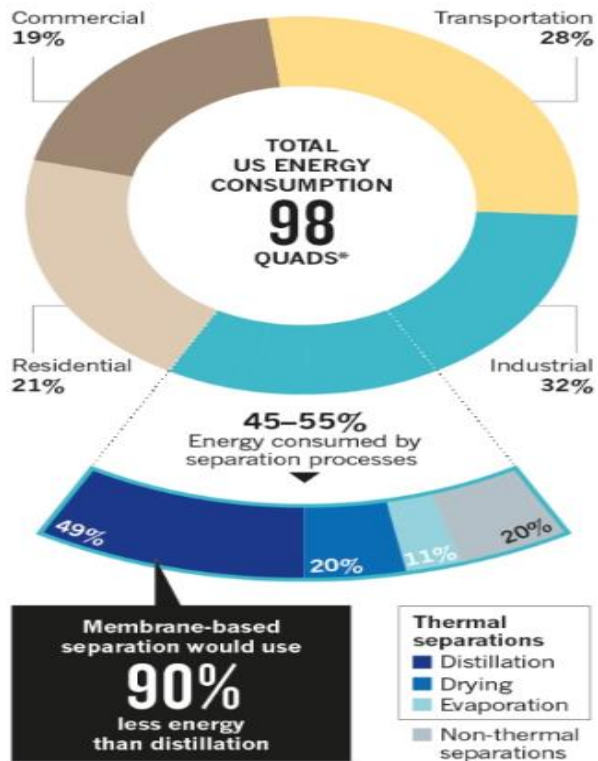
Unique perspective of commodity landscape and specialty chemicals  
Founded on brine chemistry 119 years ago



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# CUTTING COSTS

Chemical separations account for about half of US industrial energy use and 10–15% of the nation's total energy consumption. Developing alternatives that don't use heat could make 80% of these separations 10 times more energy efficient.



*Nature Magazine*, April 2016,  
D. Scholl, R. Lively

\*A quad is a unit of energy equal to  $10^{15}$  British Thermal Units (1 BTU is about 0.0003 kilowatt-hours).

©nature

Source: Data from Ref. [1] US EIA

## Recent Perspective



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# The Nature of Distillation / Traditional Separations Research

- ❑ Most separation technology (distillation) is viewed as mature
- ❑ Many improvements will probably be incremental
  - ❑ This does not say unimportant or trivial
  - ❑ This does not say “all” will be incremental
    - ❑ Make no mistake ... breakthroughs will be difficult!
- ❑ Industrial distillation research is largely out of favor in academia
  - ❑ There are exceptions
  - ❑ Viewed as mature
  - ❑ Breakthroughs will require collaboration of diverse parties



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# Distillation Device Development

## Energy Reduction

- Device Development
  - Main stream device development by suppliers
    - Specialty devices by in-house expertise as required by business needs
  - External research must be viewed as a source of potentially attractive new devices
- Device testing and validation by
  - In-house testing as needed
  - Consortia (FRI, SRP ...)
  - Ad hoc alliances
  - External research partnerships



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# The Capital / Energy Conundrum

- ❑ Energy improvements alone will generally not support replacement investment
- ❑ Distillation improvements must support the cost of capital
  - ❑ A process may be very energy or raw material efficient, but be substantially higher in capital
  - ❑ Example: a distillation tower with a heat pump may consume less energy, but be substantially more capital intensive
- ❑ Capital is limited, and energy improvements must compete for capital
- ❑ Hierarchy of financial validity
  - ❑ Capacity
  - ❑ Quality
  - ❑ Energy



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# Subtle Aspects of the Conundrum

- ❑ Our processes (physical facilities) have long life spans
  - ❑ 30 years is not uncommon ... 50 years not unknown
    - ❑ Maintenance is performed and parts replaced
    - ❑ Instrumentation upgraded
    - ❑ Plants are by no means neglected .... but
  - ❑ Basic configuration may not have changed ... in two generations!
- ❑ How do we find and implement process alternatives to improve performance that meet our economic criterion
  - ❑ Energy cost alone will not support total replacement
    - ❑ If your organization sees this differently, great
  - ❑ Additional capacity generally will support capital expenditure
    - ❑ It must fit into the existing framework
    - ❑ We must explore “all” alternatives



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# The Nature of Separations Selection

- ❑ Sequential, single feed towers are still the first choice
- ❑ Integrated sequences (side-rectifiers, side-strippers ... etc.) make more efficient use of mass-transfer and heat integration opportunities with increased capital investment
- ❑ Numerical capabilities are now available which make rigorous sequence evaluation and selection a reality
- ❑ Risk aversion is real and entirely understandable
  - ❑ Hurdle: Seen as an increased risk by Manufacturing ... flexibility and control
  - ❑ Start-up and control can be more difficult than conventional sequences



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# Energy Saving Configurations

- Complex Distillation Column Arrangements
  - Petlyuk Column
  - Complex Column Configurations
  - Dividing Wall Columns
- Hybrid Separations
  - Distillation / PSA
  - Distillation / membranes
- Reactive Distillation
- Horizons
- Not Discussing: Improvements in Distillation Control
  - Distillation control offers major potential
  - Low to zero capital

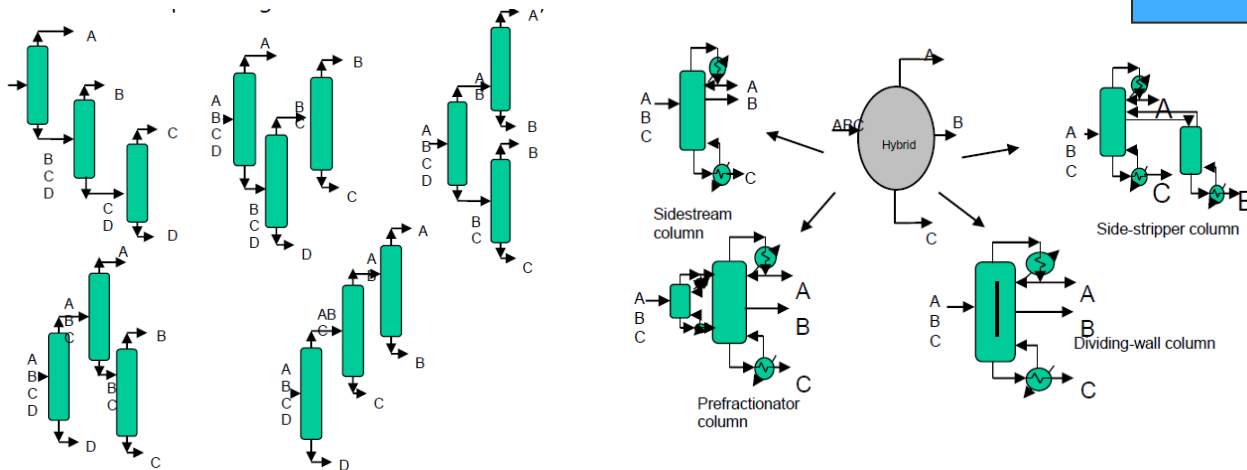


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# Separation Sequencing

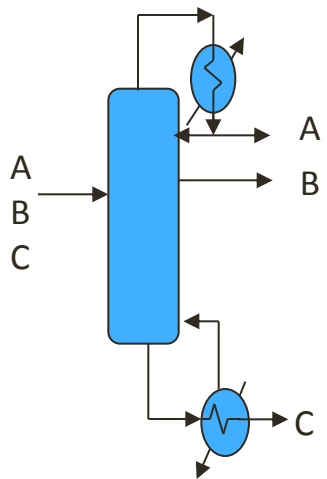
- We have the tools and the techniques to
  - Generate all sequences
  - Simple plus complex
  - Heat integrated sequences
- Use optimization tools to decide the “best” sequence
- Our challenge
  - Use these tools to build new plants
  - Even more challenging: Use these tools to find better sequences that fit our existing facilities

Extremely challenging but very important

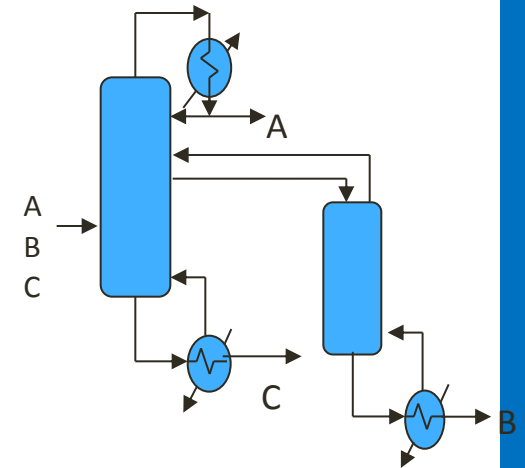
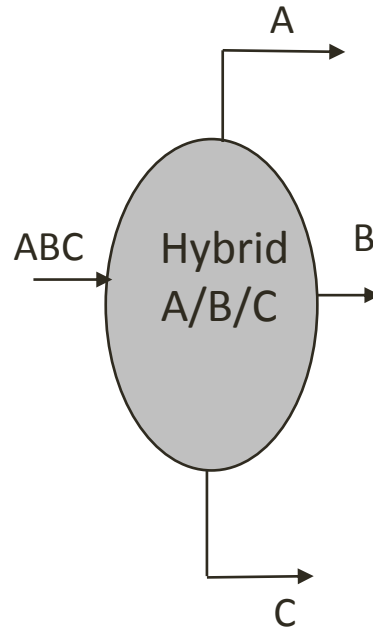


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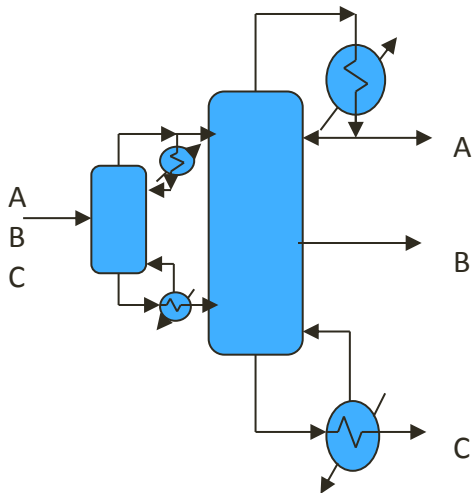
# Transformation of Hybrid



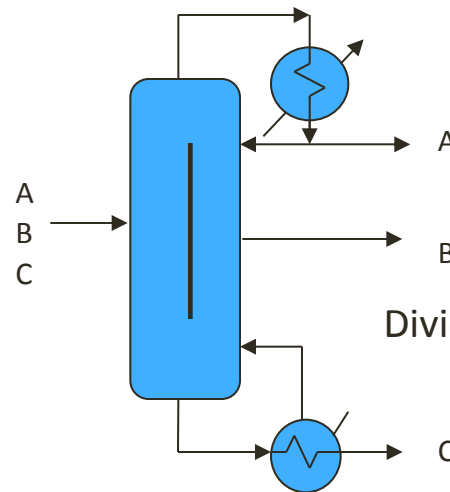
Sidestream column



Side-stripper column



Prefractionator column



Dividing-wall column

# Energy Savings in Separations

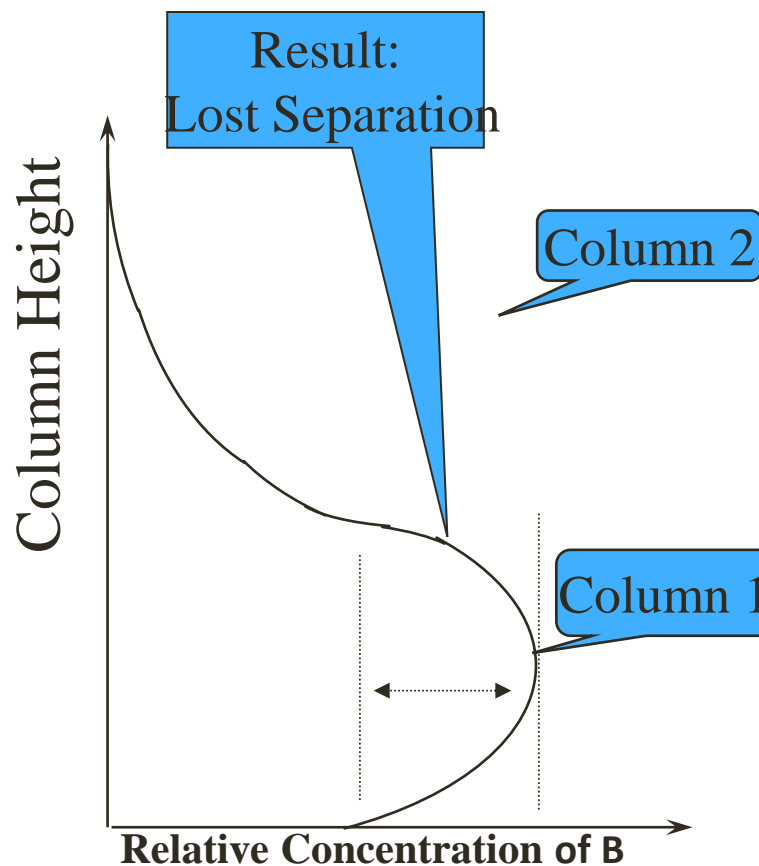
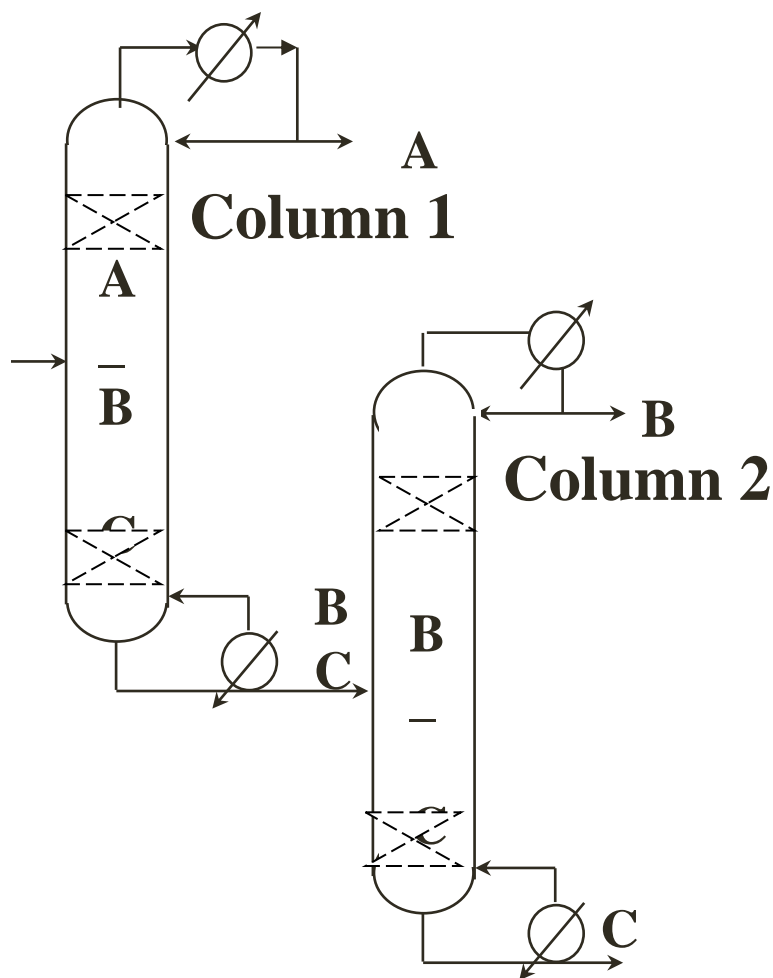
## □ Dividing Wall Columns

- Value: 30% less capital and energy where properly employed
- Potential Impact: Distillation accounts for 70% of the capital and energy of our traditional processes
- Status: Full numerical and experimental validation available
- Hurdle: Seen as an increased risk by Manufacturing ... reduced flexibility and control
  - Reality: BASF has installed ~80 of these units!
  - Exxon has operational units
  - Dow has a number of operation units
- Key Energy Note
  - DWC will be better from a First Law perspective
  - Not necessarily better from a Second Law perspective



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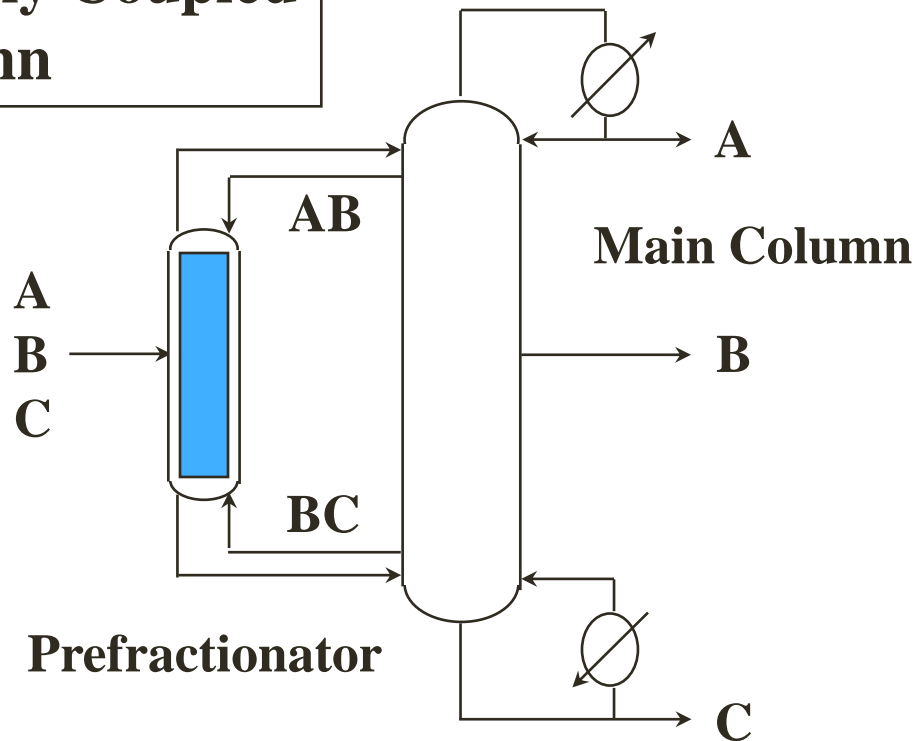
# Dividing Wall Column Basics



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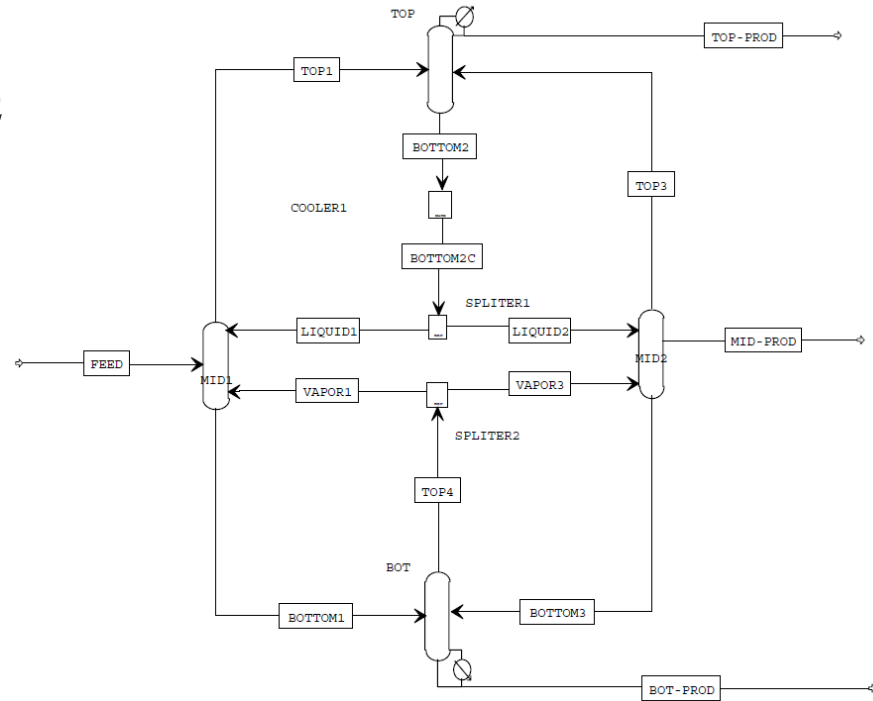
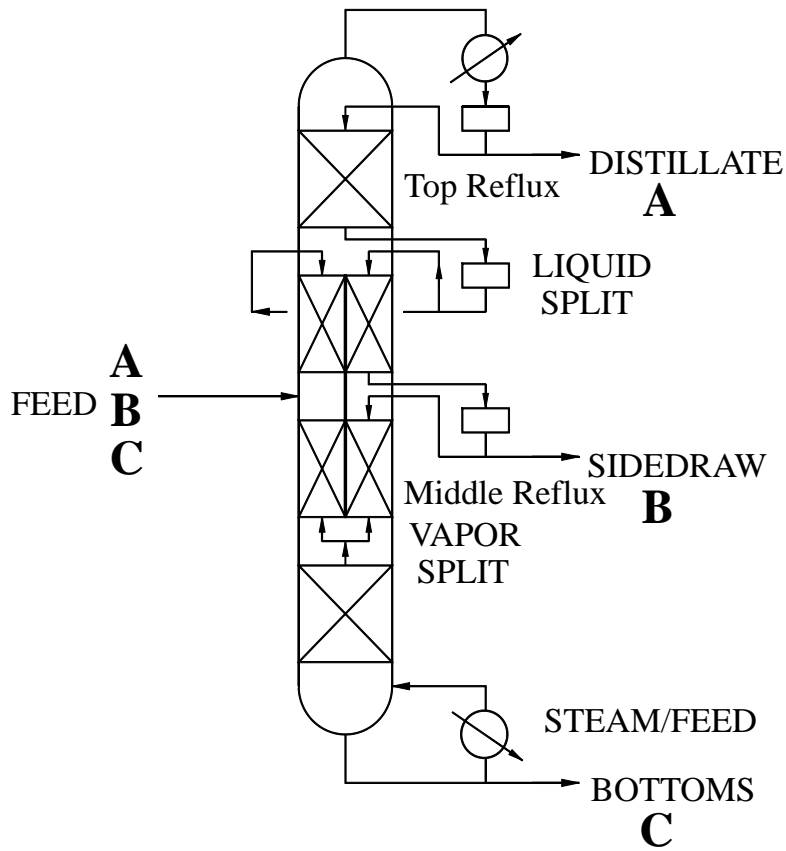
# Dividing Wall Column: First Step

**Fully Thermally Coupled  
Petlyuk Column**



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# Simplified Schematic of DWC and Rigorous Simulation

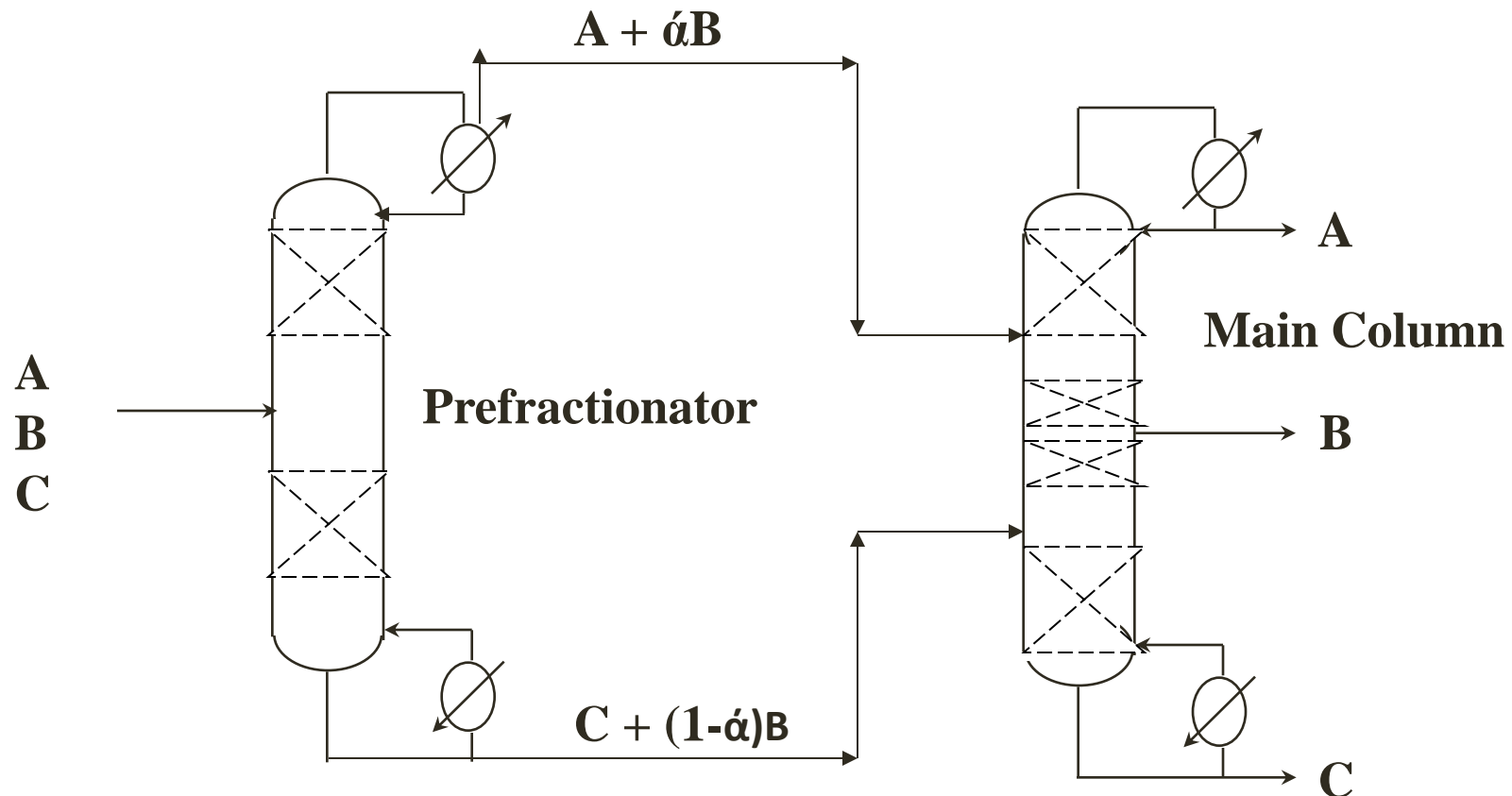


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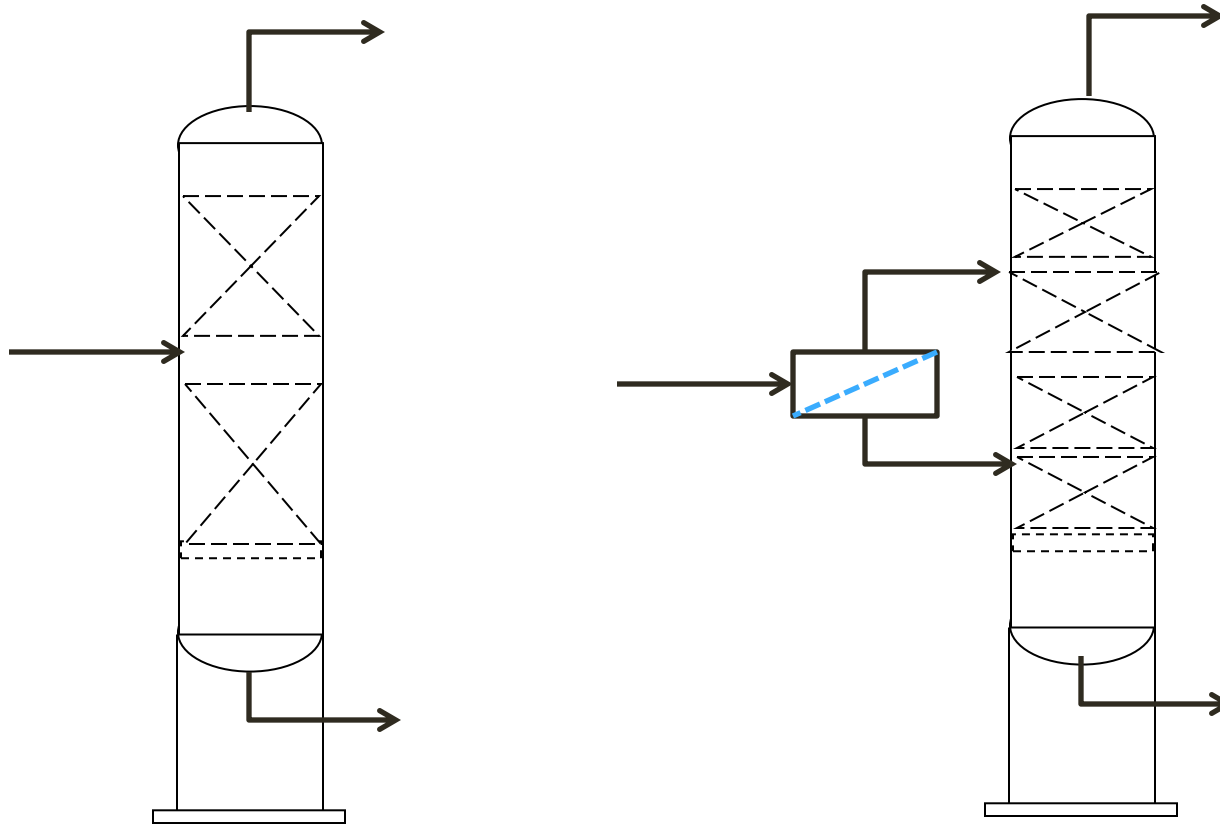
# Energy Saving Arrangements

## Retrofit Opportunities



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# Energy Saving Arrangements

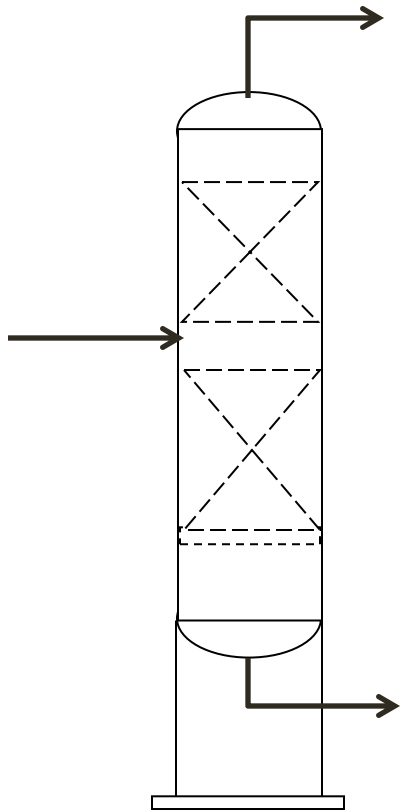


Distillation & Pre-fractionation Membrane

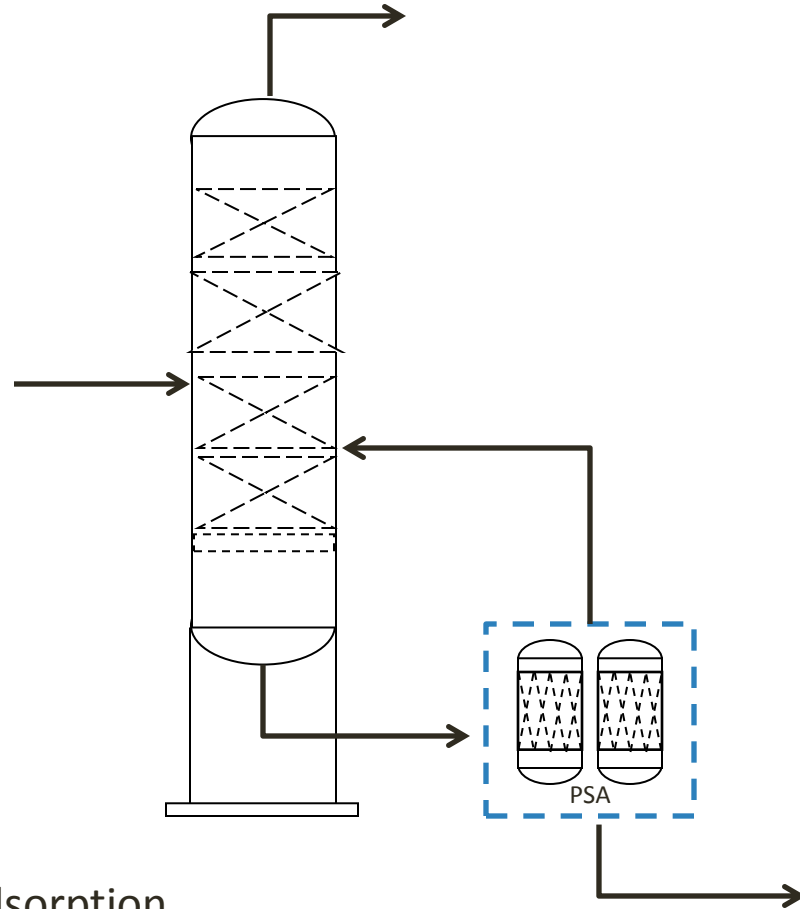


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# Energy Saving Arrangements

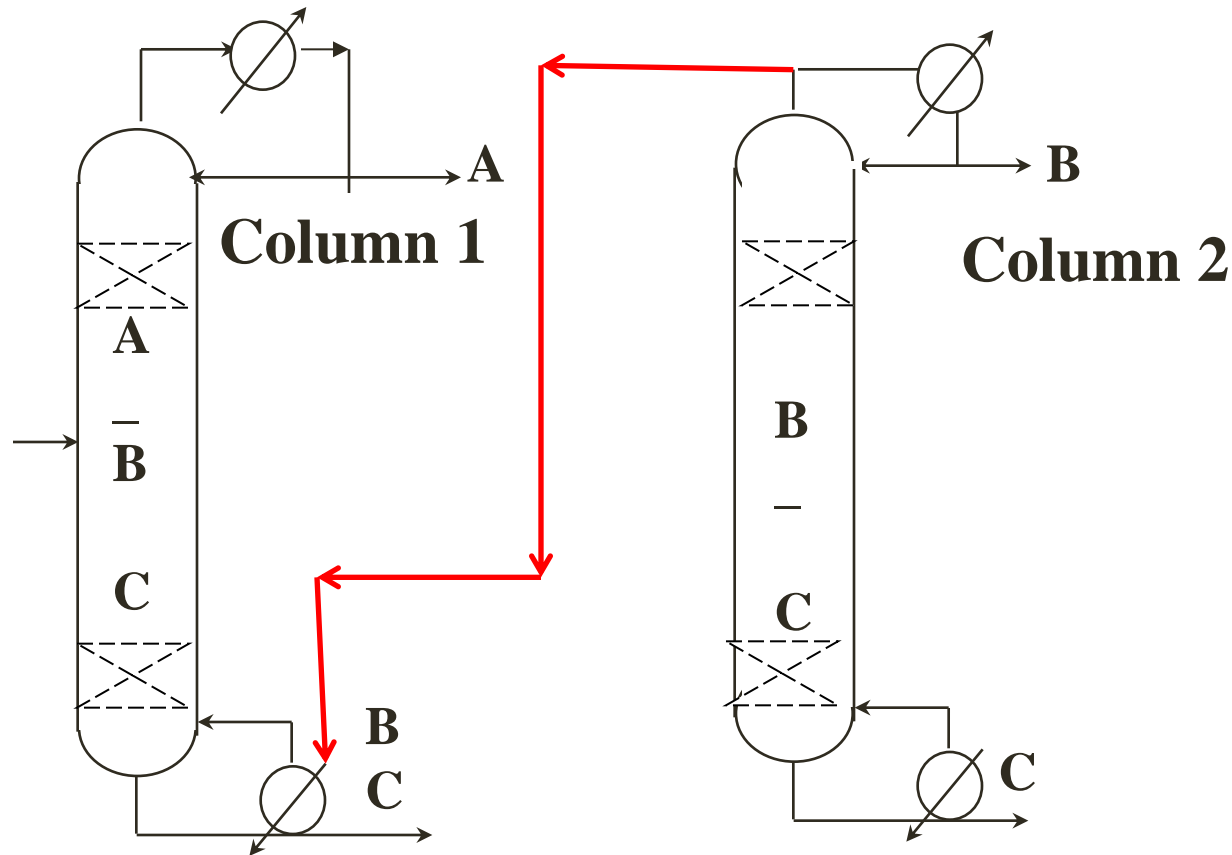


Distillation Plus Pressure Swing Adsorption



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# Energy Saving Arrangements



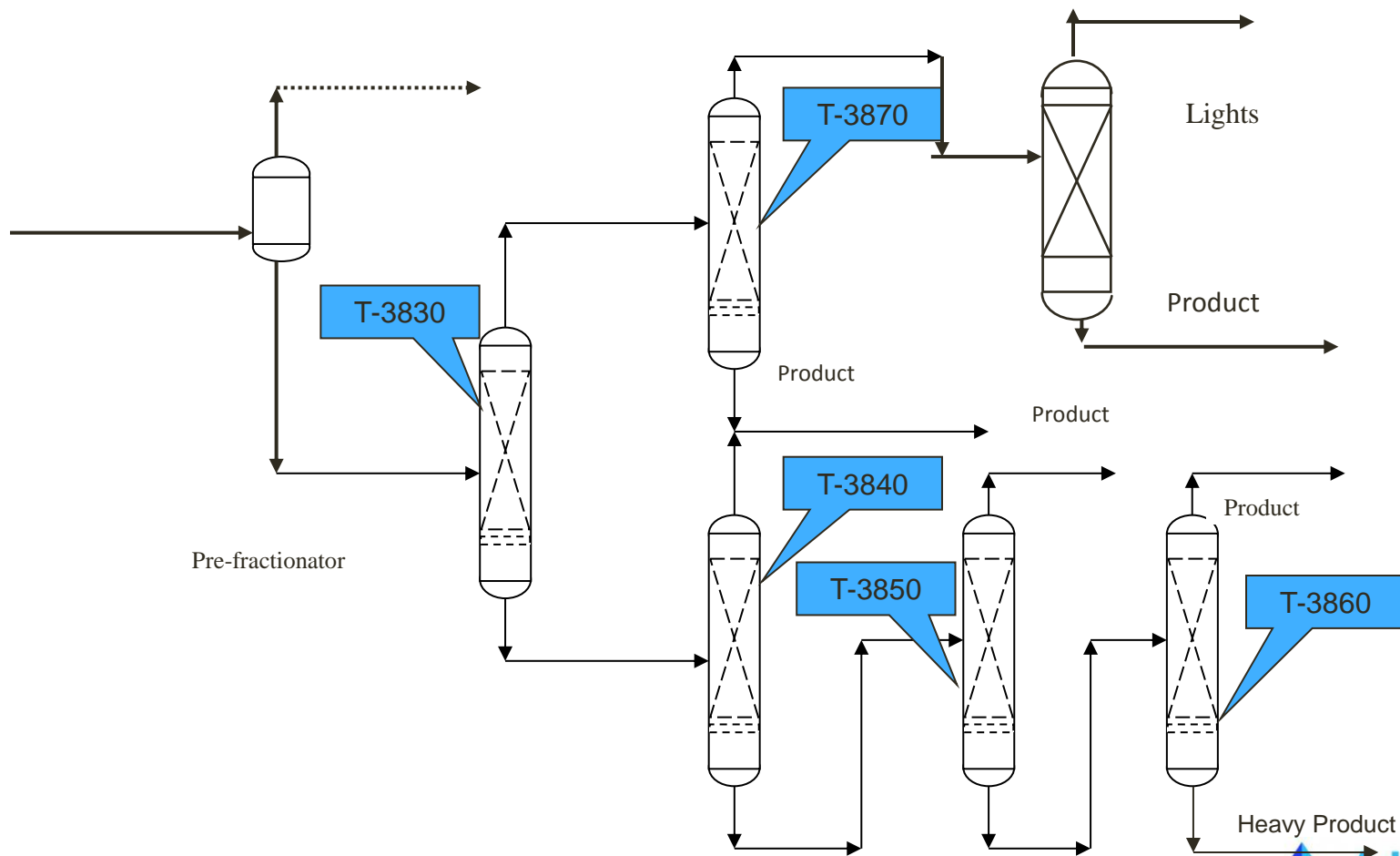
Heat Integration via Cross Exchange



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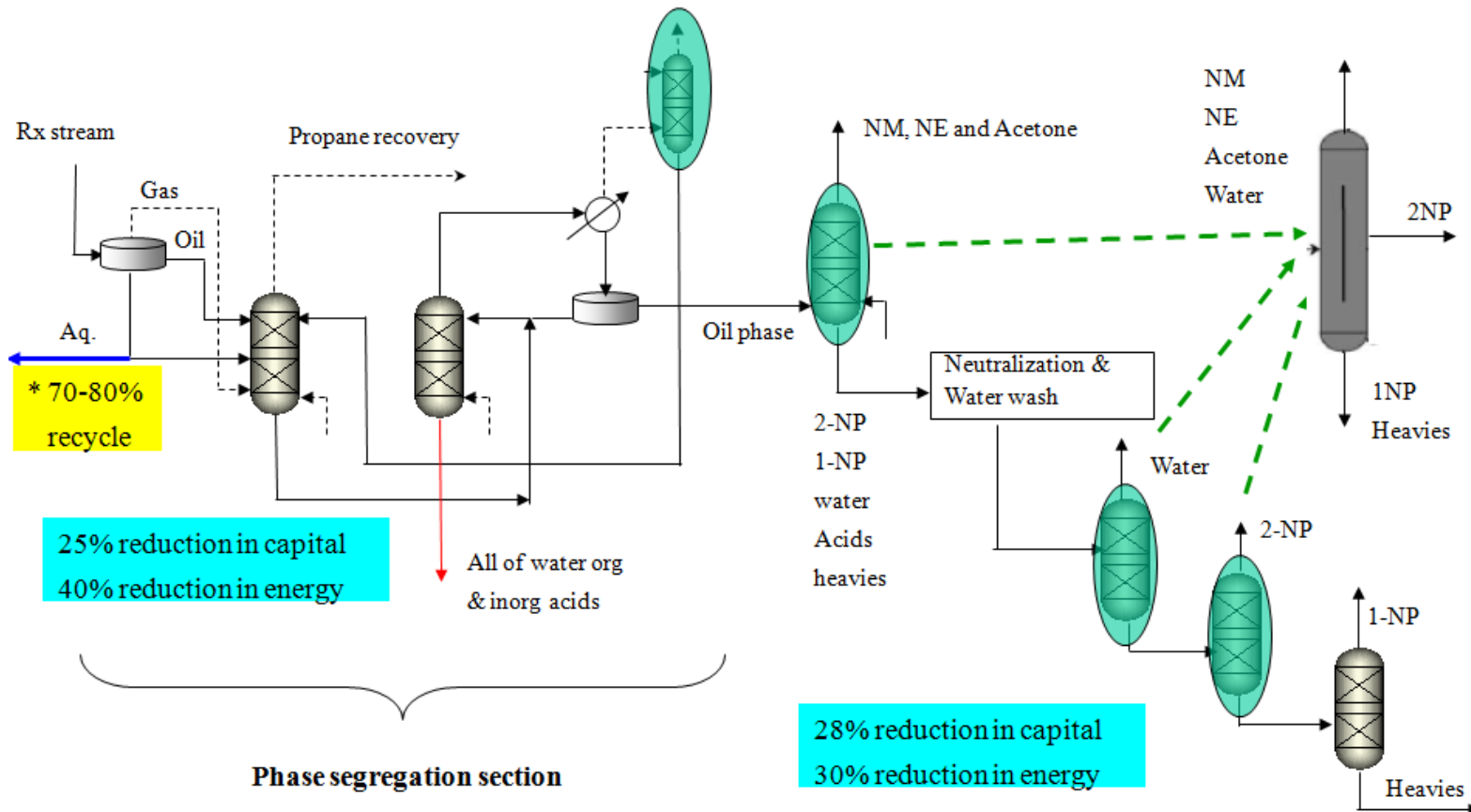
# Example: Large Scale Prefractionator

Patent US8129436 B2



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# Example: Consolidation and DWC



US 8,410,323

Process for Downstream Recovery of Nitroalkane using Dividing Wall Column

US 8,431,754: Process for nitroalkane recovery by aqueous phase recycle to nitration reactor



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# What is on the Horizon?

- Elements on the horizon that may alter the distillation research perspective
  - Legislation to lower greenhouse gases
  - Carbon taxes
  - Substantially higher energy costs
  - Mandates to lower potentially harmful inventories
    - Legislation
    - Community mandate



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# Potential Game Changers

## Ionic liquids

- Drawback: expensive, some have toxicity issues
- Opportunities: can be highly selective, phase change

## MOF's

- Drawback: expensive, not available in commercial quantities
- Opportunity: can be highly selective

## Membrane reactors

- Opportunity: Remove products, drive conversion
- Drawback: temperature limitations and cost

## Reactive absorption

## Reactive PSA



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# Thank You

- Dans ses écrits, un sage Italien, Dit que le mieux est l'ennemi du bien
- In his writings, an Italian wise (man) said that the perfect is the enemy of the good
- *Voltaire*
  
- Questions



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