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
The Dow Chemical Company
Diversified chemical company, harnessing the power of science and technology to improve living daily

Dow by the numbers

- **35 Countries**
- **188 Sites**
- **60++ Billion Annual Sales**
- **50,000 WW Employees**
- **5000+ Products**

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

**Large Scale**
- Ethylene and polyethylene
- Ethylene oxide and ethylene glycol
- Polyurethanes & Polyols
- Chlorine and caustic

**Specialty Scale**
- Metal organics, tri-methyl gallium, tri-methyl indium
- OLED materials
- Chemical mechanical planarization products, photoresists...

Acquired Union Carbide
Acquired Rohm & Haas
Immediate Future Dow Corning DuPont

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Recent Perspective

*Nature Magazine*, April 2016, D. Scholl, R. Lively
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
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
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
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
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
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
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
Transformation of Hybrid

Sidestream column

Prefractionator column

Hybrid A/B/C

Side-stripper 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
Dividing Wall Column Basics

Result: Lost Separation
Dividing Wall Column: First Step

Fully Thermally Coupled Petlyuk Column

Prefractionator

Main Column

A

B

C
Simplified Schematic of DWC and Rigorous Simulation

1. FEED (A, B, C)
2. Top Reflux to DISTILLATE A
3. Middle Reflux to SPLIT B
4. VAPOR SPLIT
5. STEAM/FEED
6. BOTTOMS C
7. LIQUID SPLIT

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Energy Saving Arrangements
Retrofit Opportunities

A + αB

Prefractionator

Main Column

C + (1-α)B

A

Main Column

B

C

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Energy Saving Arrangements

Distillation & Pre-fractionation Membrane
Energy Saving Arrangements

Distillation Plus Pressure Swing Adsorption

PSA
Energy Saving Arrangements

Heat Integration via Cross Exchange
Example: Large Scale Prefractionator

Patent US8129436 B2

Diagram showing a process flow with labels T-3830, T-3840, T-3850, T-3870, T-3860, and T-3880. The process includes a pre-fractionator and lights, product, and heavy product stages.
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

Phase segregation section

25% reduction in capital
40% reduction in energy

28% reduction in capital
30% reduction in energy

Finishing train

* 70-80% recycle
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
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
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