Design Of A Modern Hydrogen Production and Recovery Facility

IPRO Team Members

- Ankit I. Mehta- Team Leader
- Bello Ayobamidele
- Predrag “Pecci” Barac
- Alex Bartman
- Odemena Ekelemu
- Richard Gaicki
- Celeste Gaydos
- Kendra Hardin
- Mariam Kittaneh
- Bernadette Lawardi
- Michelle McKinney
- Maheen Malik
- Tony Thomas
- April Trauscht

Overview

- Objectives
- H_2 derivatives and uses: Fuel Cell
- Survey of other processes
- Process design
- Economics
- Safety and environmental concerns
- Conclusion and discussion

Objectives

- Apply engineering principles of separation processes to recover hydrogen from mixed gases
- Analyze the feasibility and economics of commercial and innovative processes for the recovery operation
- To study hydrogen itself and its global importance

H_2 Derivatives and Uses: Fuel Cells

- ENERGY CRISIS: One of biggest issues in world today

- Main sources of energy now are fossil fuels, oil, coal

- Problem? Limited resources, unlimited demand
  Pollution and global warming

- Solution? Hydrogen-powered fuel cells may be the answer

Benefits of Fuel Cells

- Environmental
  - Decrease CO_2 emissions
  - Reduce global warming effect
- Economic
  - US imports 55% of oil and projected to reach 68% by 2025
  - Fuel cells would greatly reduce foreign import dependence
- Industrial Applications
  - Residential Energy Generators
  - Transportation
  - Telecommunication

Several H_2 Recovery Processes

- Electrolysis
- Material Recycling
- Membrane Separation
- Steam Reformation
- Biological Resources
- Off-Gas Cleanup
- Photo Processes
- Hydrolysis
- Thermal Dehydrogenation (scope of project)

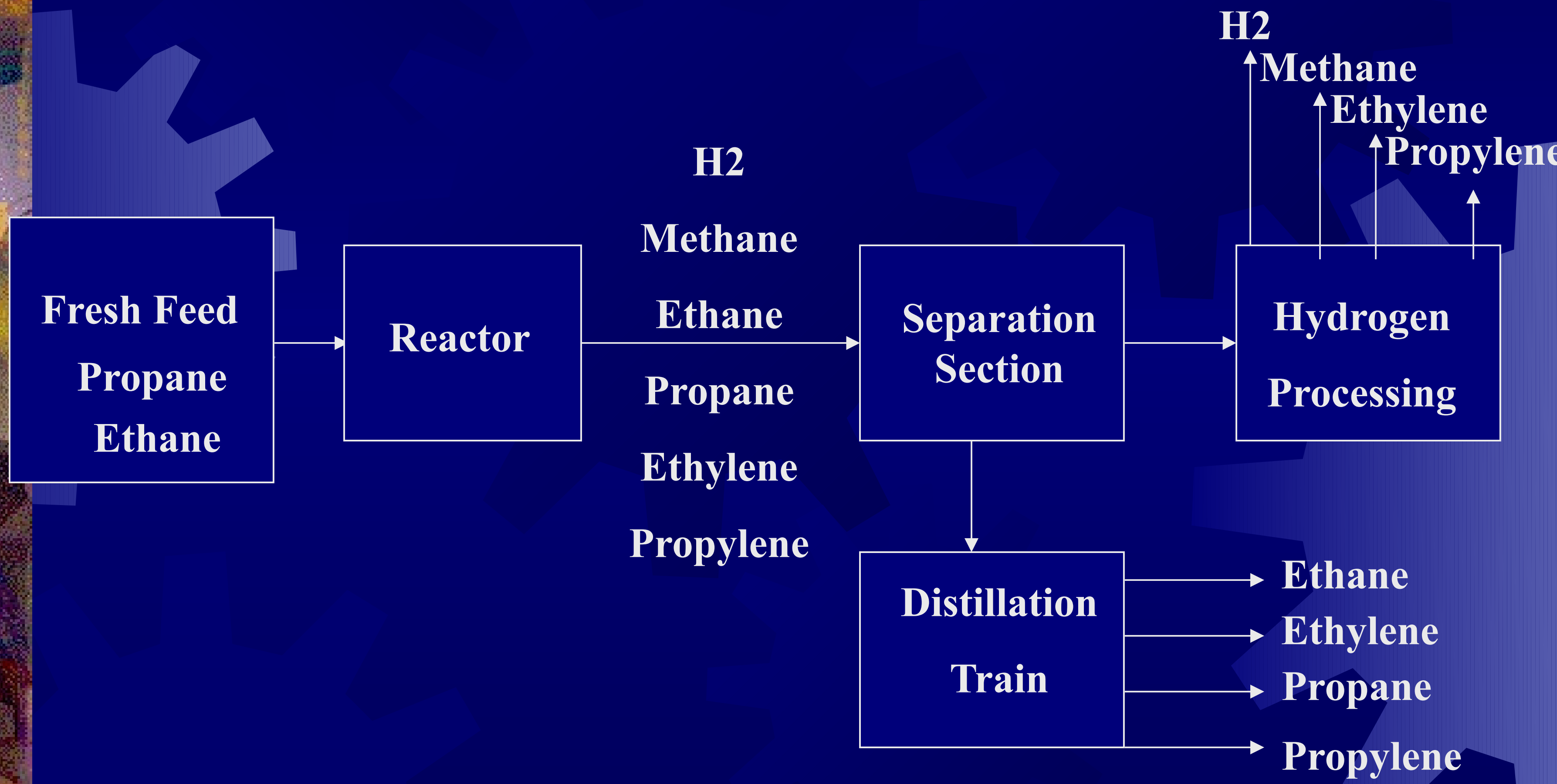
Why Thermal Dehydrogenation?

- Commercially feasible
- Tractable feed selection
- Minimal CO_2 release
- By-products (ethylene and propylene) are used in industry
- Economically efficient

Design of a Hydrogen Production & Recovery Facility

- Scope of Design
  - recovery operations from a hydrocarbon stream
- Process Design Using HYSYS and ChemCad
  - Usage of various design programs to better illustrate design concepts

Process Design Schematics



Initial Design Section

- Fresh feed of precursors of H_2
  - ethane, ethylene, propane, propylene
- First sent to reactor
  - for thermal dehydrogenation
  - for production of “easily-separated” components

Direct Fire Furnace

- Serves as reactor for this design
  - basic process:
    - thermal decomposition of ethane and propane prevents total decomposition of carbon and hydrogen
    - operates at low pressure, high temperature and low residence time
    - heat transfer by convection and radiation
    - use of steam diluent to reduce hydrocarbons' partial pressure

Reaction Information

- Reactions included:
  - direct and free radical
- Component Conversions:
  - ethane: 56.6%
  - propane: 73.6%
  - hydrogen yield: 80.9%
  - ethylene yield: 79.1%
  - propylene yield: 15.5%

Continuation of First Design Section

- Cooling
  - accomplished via heat exchangers
  - utility fluid used is refrigerant
- Removal of water from condensed hydrocarbons
  - 3 phase separator
  - absorber (silica gel utilized)
- Compression and cooling prior to flash drum (for vapor-liquid separation)
- Separated liquid sent to demethanizer; vapor to hydrogen recovery “section”

Separation Train

- Series of distillation towers
  - first, methane (99.3%) and hydrogen (100%) separation; then, sent to hydrogen recovery "section"
  - next, ethylene separation (99.9%)
  - followed by ethane (99.9%),
  - propylene (97.9%),
  - propane (99.8%),
  - 1,3-butadiene and i-butene

Hydrogen Recovery Section

- Vapor stream from demethanizer & overhead product from first distillation tower sent by countercurrent flow through series of “cold boxes” and separators
  - hydrogen recovery completion
  - trace amounts of ethylene and propylene recovered

Overall Recovery Statistics

Fresh Feed

- Ethane
  - 183,562 lbs/hr
- Propane
  - 121,555 lbs/hr

Product

- Hydrogen
  - 12,531 lbs/hr
- Ethylene
  - 197,229 lbs/hr
- Propylene
  - 59,809 lbs/hr
- Methane
  - 28,403 lbs/hr

Process Optimization

- Reactor: simulation ran at various reactor temperatures to maximize component conversion
- Heat exchangers and compressors: simulated using various temperatures and pressures to maximize efficiency
- Distillation columns: simulated using various combinations of temperatures, pressures and numbers of trays

HYSYS Simulation

- Reactor
  - HYSYS does not handle free-radical reactions
  - Excel was used to extrapolate overall reactions and conversions from previous industrial modules

Economics

Bare Module Costs

ChemCad Used For Costing

- Total Furnace Cost
  $3,868,383.00
- Total Heat Exchanger Cost
  $231,069.00
- Total Cooler Cost
  $266,388.00
- Quench Tower Cost
  $852,922.00
- Absorber Cost
  $2,410,000.00
- Flash Drum Cost
  $386,219.00
- Compressors Cost
  $8,093,450.00
- Total Distillation Columns
  $6,266,530.00

Economics

Total Costs

- Total Fixed Capital Cost (TFC)
  - $167.33M
- Total Working Capital
  - $91M
- Total Operating Cost (TOC)
  - $469M
- Net Present Worth at Start-up (NPW)
  - $37.8M

Economics

Production Schedule

- Hydrogen
  - 12,531 lbs./hr at 70 cents/lb.
- Ethylene
  - 197,229 lbs./hr at 30 cents/lb.
- Propylene
  - 59,809 lbs./hr at 27 cents/lb.
- Fuel
  - 222MBtu/hr at $2.50/MBtu
- Total Revenue = $704M/yr

Hydrogen Safety Issues

- Hydrogen Concerns - Explosions
- Hydrogen Properties
- Safety Issues
  - Hydrogen Use
  - Transportation
  - Storage

Conclusion

Thermal dehydrogenation process is:

- feasible for industry production and recovery of hydrogen
- economically efficient (at start up, is approx. 37.8 million USD profitable)
- environment-friendly: can be a “clean” energy

Conclusion (continued)

- H_2 is a vital element for current times; can be a beneficial "fuel" when handled and stored properly
- There are several methods of producing hydrogen, but our process, thermal dehydrogenation, is more economically viable

Teamwork

- Importance of Communication
  - Accomplished through weekly meetings, email, and personal conversations
- Organization and planning
  - Division of tasks
  - Scheduled deadlines
  - Weekly follow-ups

Group Dynamics

- Sophomores
  - Tasks were divided among members according to interest levels
  - Promoted initiative and exposure to design
- Seniors
  - Tasks were divided among members according to skills and interest levels
  - Promoted leadership and reinforcement of design principles

The End

Questions? Comments?