Optimal Model-Based Production Planning for Refinery Operation

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Outline

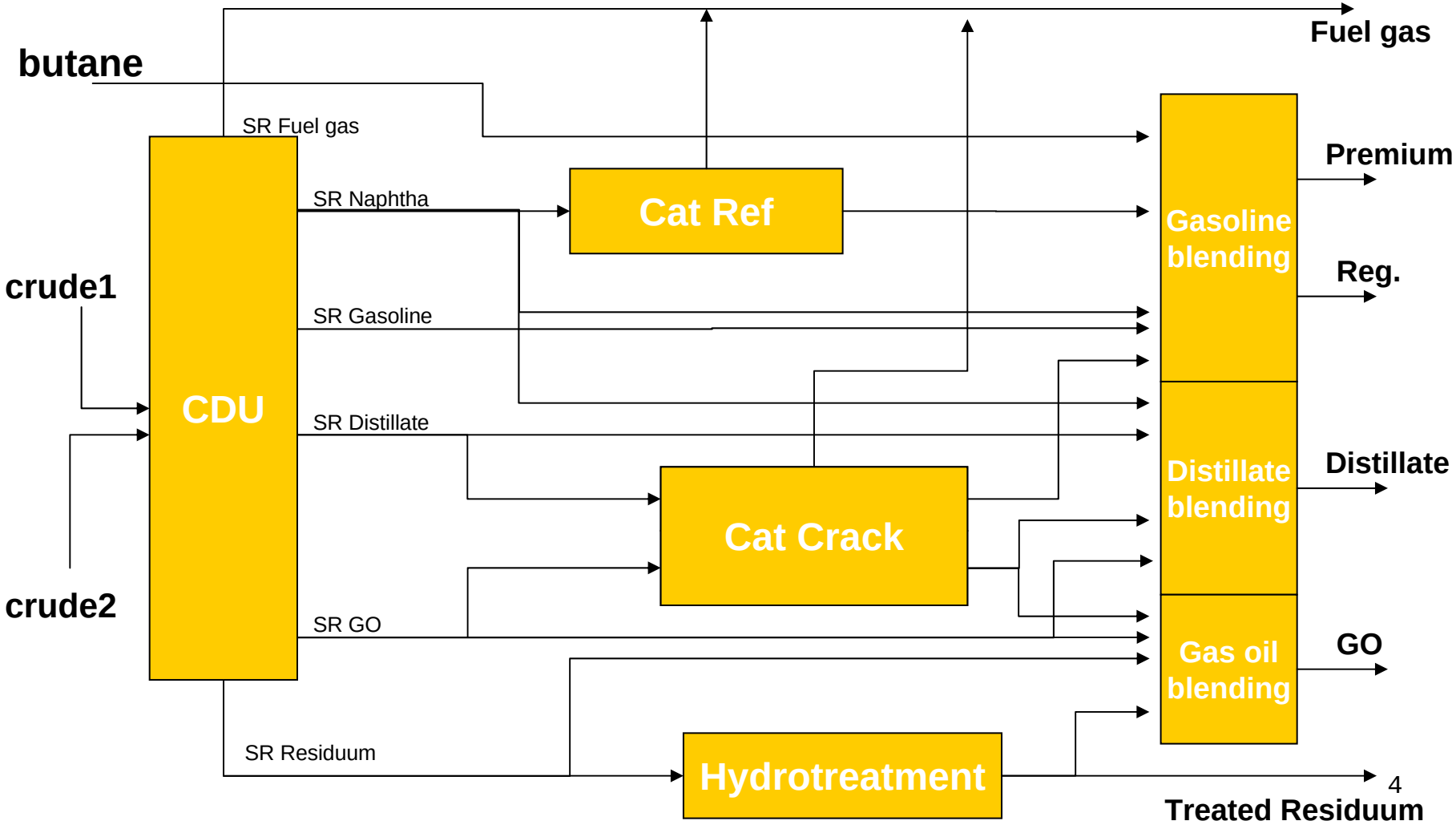
- Introduction
- Problem Statement
- CDU Aggregate Model
  - Conventional distillation column
  - Steam distillation column
- Conclusion

Introduction

- Refinery production planning models
  - Optimizing refinery operation
    - Crude selection
  - Maximizing profit; minimizing cost
  - LP-based, linear process unit equations
- Current Project
  - Collaboration with BP Refining Technology
  - Goal: develop a refinery planning model with nonlinear process unit equations, and integrated scheduling elements

Problem Statement

Typical Refinery Configuration *(Adapted from Aronofsky, 1978)*



Problem Statement

- Information Given
  - Refinery configuration: Process units
  - Feedstock & Final Product
- Objective
  - Select crude oils and quantities to process
    - Maximizing profit
    - single period time horizon

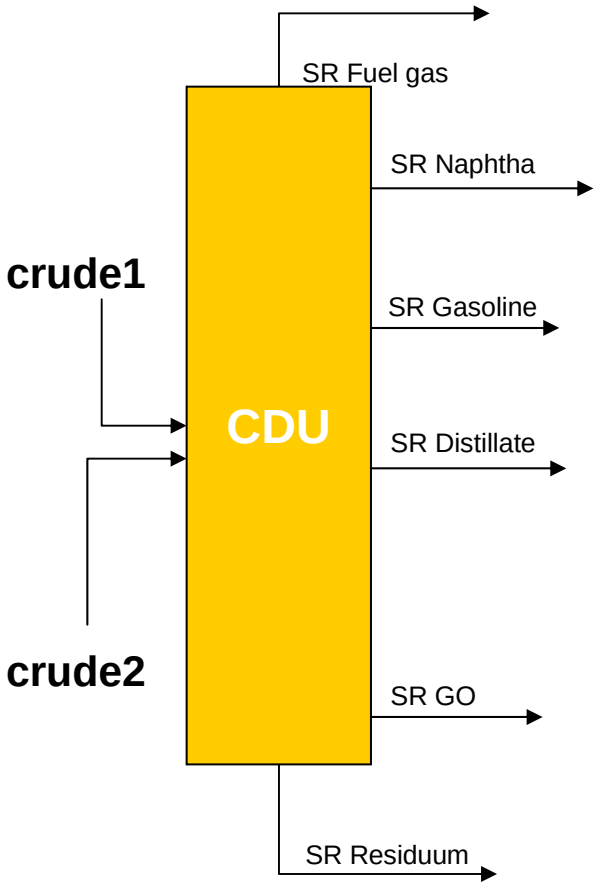
CDU Models

- Process Models in Refinery Planning Model
  - Linear yield calculation assumption: LP requirement
  - Tradeoff: accuracy vs. robustness & simplicity
- Initial Focus on CDU
  - Front end of the every refinery
  - LP models
    - Fixed-yield equation:

$$F_{outlet} = a_{unit,feed,outlet} * F_{feed}$$

    - Swing cut equation:

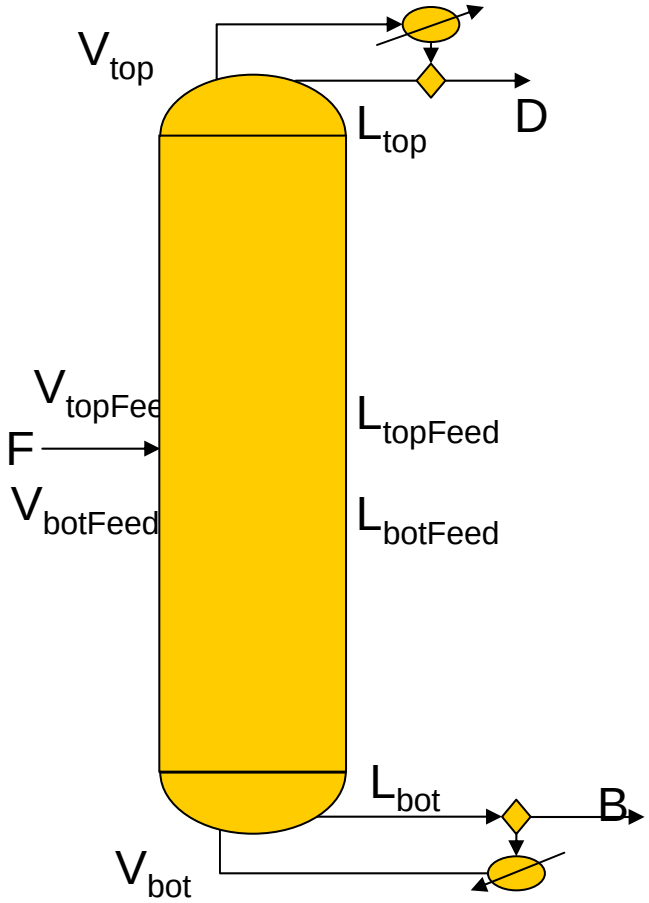
$$F_{outlet} = a_{CDU,feed} * F_{feed} + b_{CDU,outlet,front} + b_{CDU,outlet,back}$$



Typical Crude Distillation Unit (CDU)

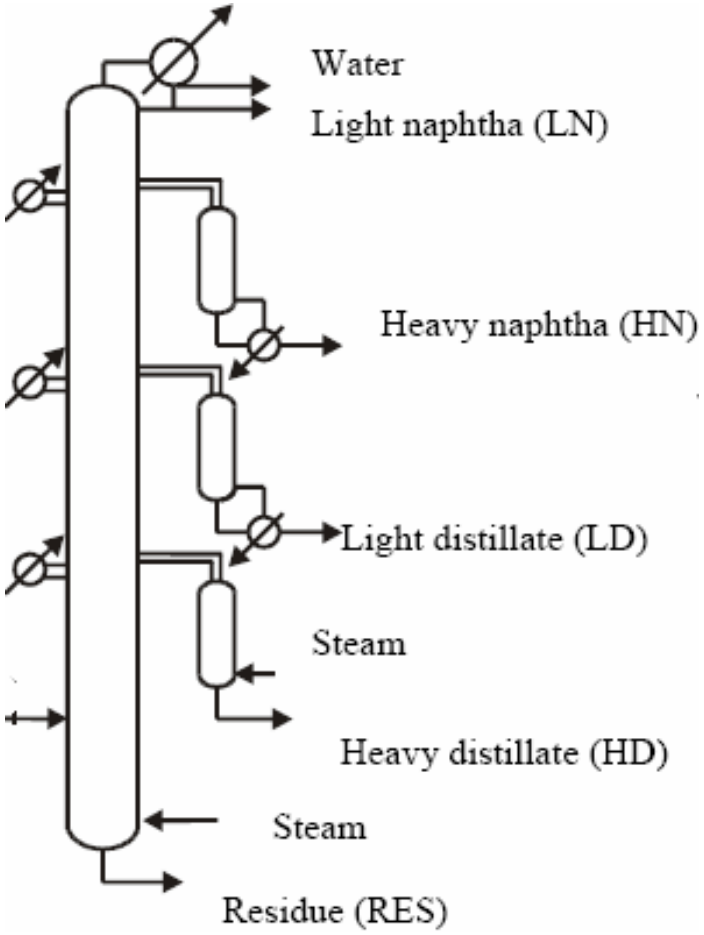
CDU Aggregate Model

- Aggregate Distillation Column Model
  - Proposed nonlinear implementation
  - Adds simplest process modeling to planning
  - Based on work of Caballero & Grossmann, 1999
  - Principle
    - Top and bottom integrated heat and mass exchangers around the feed location
    - Constant flow in each section
    - Pinch location is at the feed section



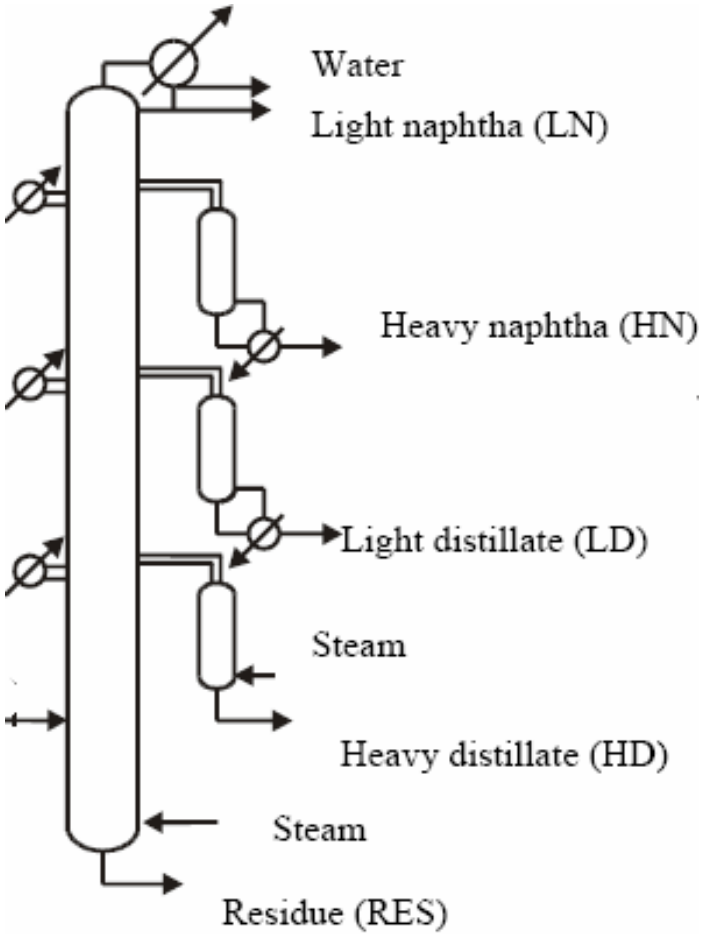
Complexity of CDU

- CDU depends on steam stripping for fractionation, not reboilers
  - Crude stability
- Multiple side streams
  - Single column configuration
- Side strippers with steam stripping and reboilers
- Side condensers



Typical Crude Distillation Column
(Gadalla et al, 2003)

CDU & Cascaded Columns



Typical Crude Distillation Column
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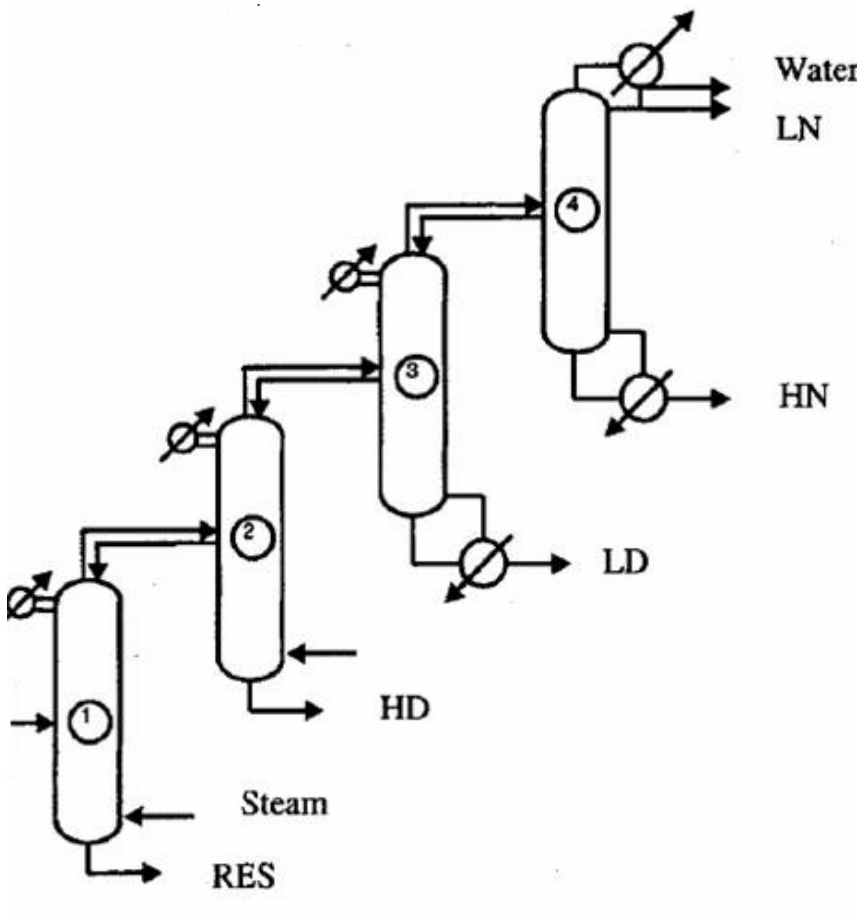
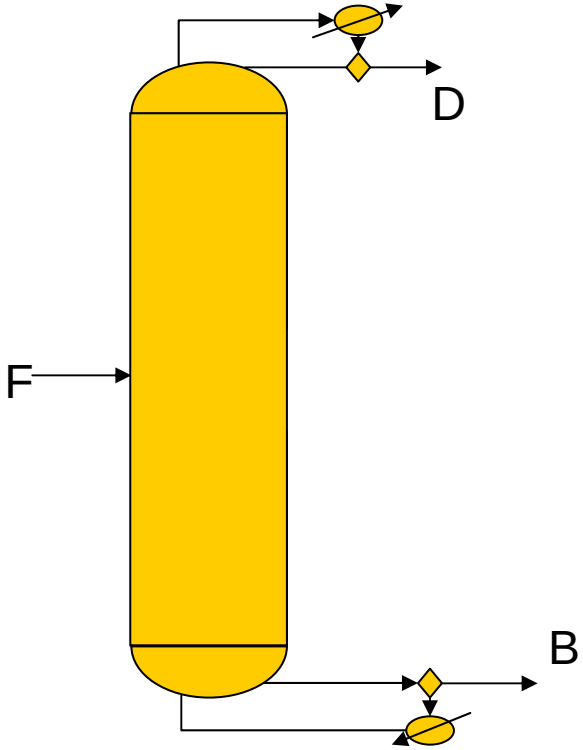
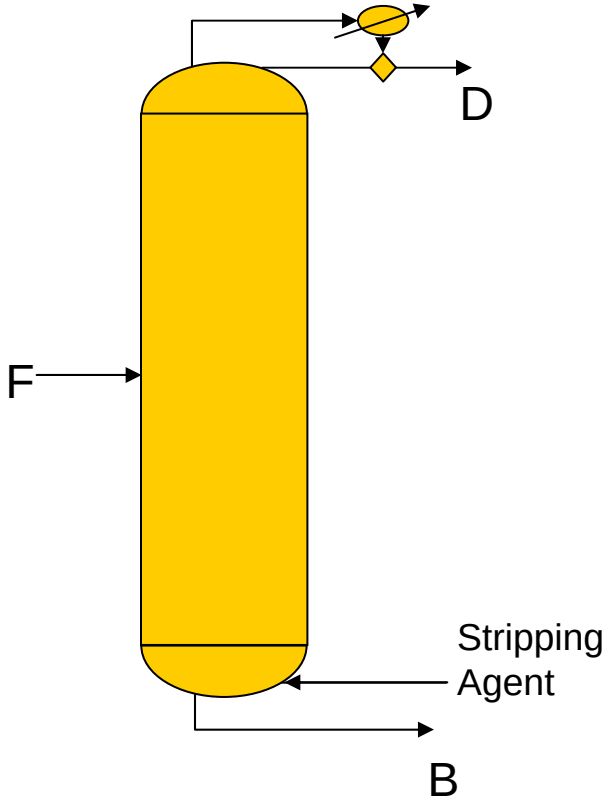


Cascaded Columns Representation
of a Crude Distillation Column
(Gadalla et al, 2003)

Distillation Columns



Conventional Distillation Column
(Energy separating agent)



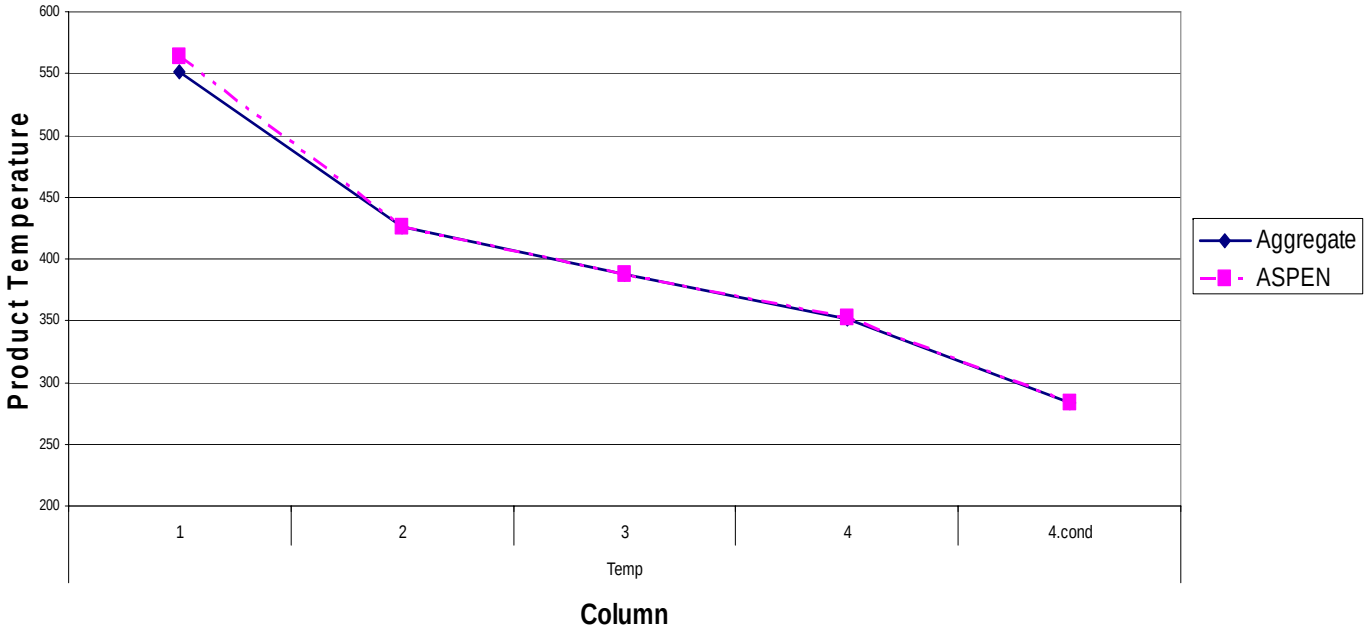
Stripping Distillation Column
(Mass separating agent)

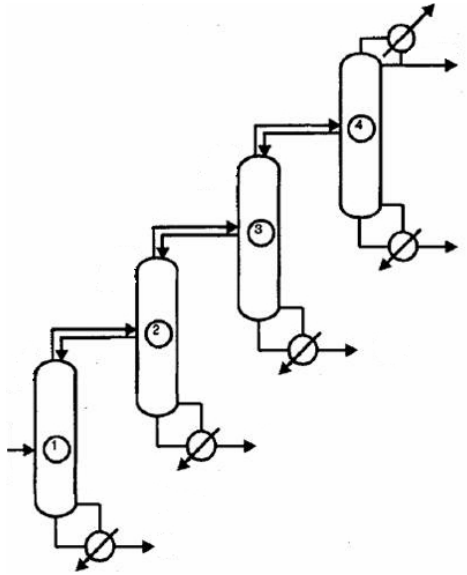
Aggregate Model – Conventional Distillation Column

- Base model for the more complicated CDU model
- Successful initialization
  - Initial values are generated using series of optimized column material balances
- Additional constraints are identified to ensure convergence of the model
  - $R_j \geq R_{j-1}+B_j$ (R_i reflux of column j)
  - $F_1=D_j+\Sigma B_k$
- Successful model
  - Example: 4 cascaded conventional columns, with 18-component feed (C3-C20)

$$\sum_{k=1}^{j}$$

Aggregate Model Results





Cascaded Conventional Columns (based on Gadalla et al, 2003)

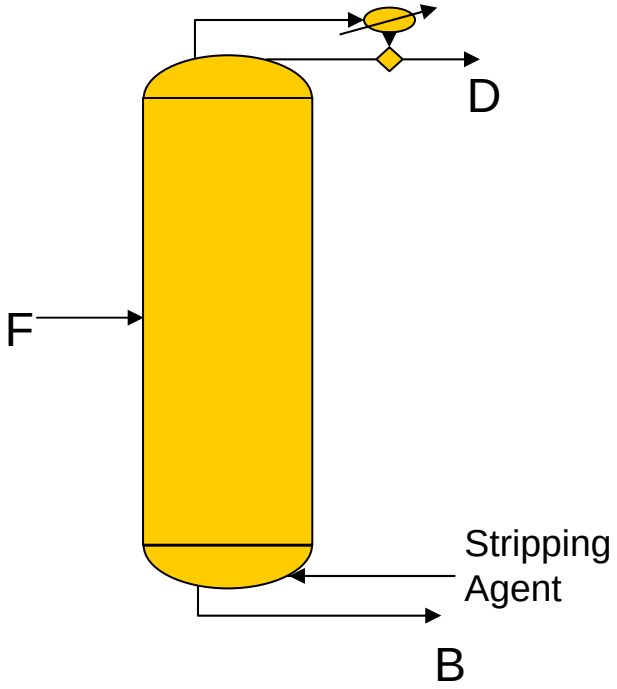
Aggregate Model Results

- Example run using GAMS
- Solver: CONOPT
- Model is robust
  - Different feed and column arrangements

	18 component, 4 columns	8 components, 3 columns
SINGLE EQUATIONS	1696	935
SINGLE VARIABLES	1666	779
Time, sec	1.484	1.28

Aggregate Model – Steam Stripping Distillation Column

- Building on the successful conventional distillation column
- Lack of reboiler and addition of live steam
  - Requires modified constraints in the model
  - Consideration for the column reflux should be accounted for in the feed
  - Different temperature profile and pressure calculation



Summary

- Preliminary research to build a nonlinear refinery planning & scheduling model
  - Current focus on CDU
- CDU Aggregate Model
  - NLP model
  - Used cascaded column approach to address complexity of the CDU
  - Built base model for conventional distillation column
    - Model proved robust
  - Upgraded the base model for steam distillation column
    - Modified original aggregate model
    - Identified additional constraints

Future work

- Integrating the CDU aggregate model into the production planning model
- Explore other nonlinear models
  - Rigorous simulation models and packages
  - Assessing the benefit in terms of accuracy, robustness & simplicity
- Upgrade process model for other important units
  - Cat. Cracking unit
  - Cat. Reforming Unit
- Extend the model to multi-period
- Add scheduling elements