Active Vapor Split Adjustment for Energy Optimal Control of Dividing Wall Distillation Columns: Experimental Studies

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1. Introduction
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   - Thermally coupled columns
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   - 4–product Kaibel column: Control Structure
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   - 4–Product Kaibel column
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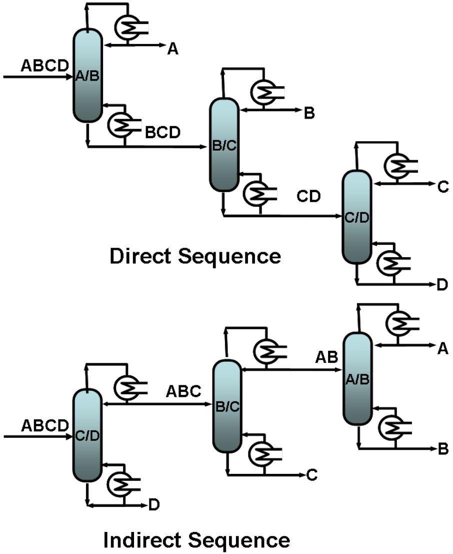
Conventional distillation

- energy intensive
  - large mixing losses
    - at interconnections
    - internal remixing
  - difficult seperation *first*
  - large ΔT at exchangers



Thermally coupled columns

- examples: prefractionator arrangements
  - Petlyuk column
    - originally proposed for 3 product
    - can be extended to more than 3 products
    - easiest separation *first*
    - low mixing losses
    - energy saving upto *50* % for 4–component
  - Kaibel Column
    - energy saving upto *30* % for 4–component

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  - Kaibel Column
    - energy saving upto *30* % for 4–component
- can be realized by divided–wall columns (DWC)

4–product Kaibel column

- A: methanol
- B: ethanol
- C: propanol
- D: butanol

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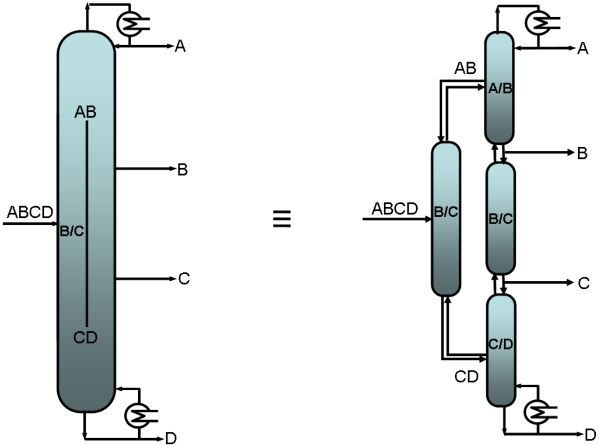
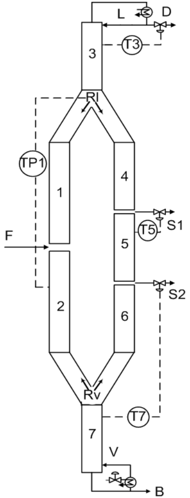


4–product Kaibel column: Control Structure

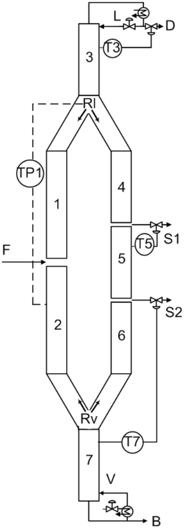
Regulatory layer when $V > V_{min}$

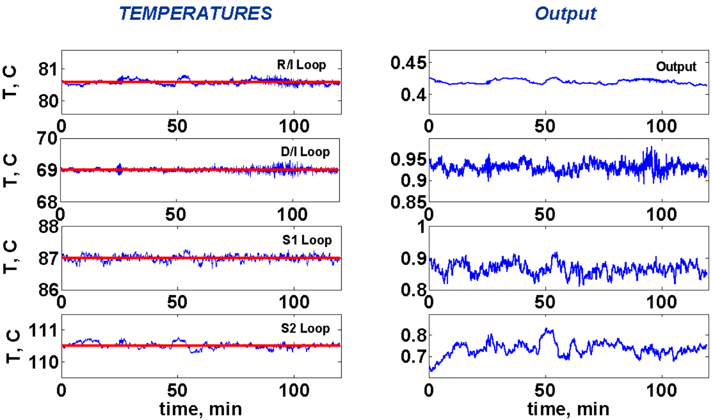
- 4 point temperature control
- inventory control
- fixed V & Rv

- *demonstrated experimentally*



4–point control: Experiments

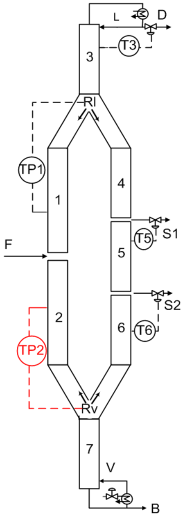




4–product Kaibel column: Control Structure

Regulatory layer when $V = V_{min}$

- *5 point* temperature control
- inventory control
- also use Rv



boilup (V_{min}) vs Vapor Split (R_v)

- $F = 1$
- $z_F = equimolar$
- purity spec: 98% for all products

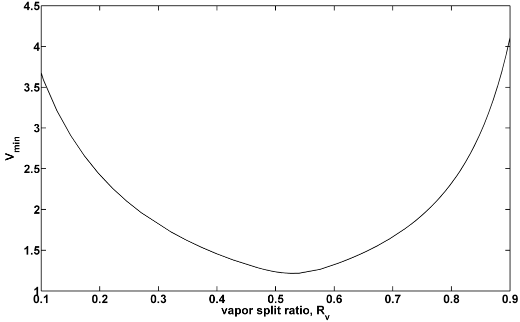


Figure: V_{min} vs R_v

boilup (V_{min}) vs Vapor Split (R_v) changes with disturbances

- V_{min} and R_v(optimal) may change with feed disturbances

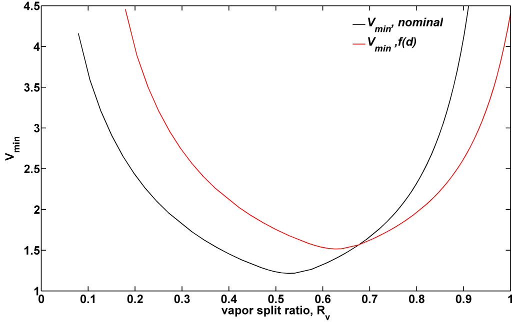


Figure: V_{min} vs R_v

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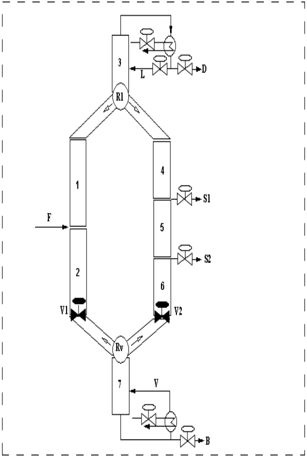
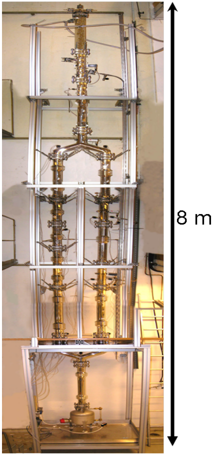
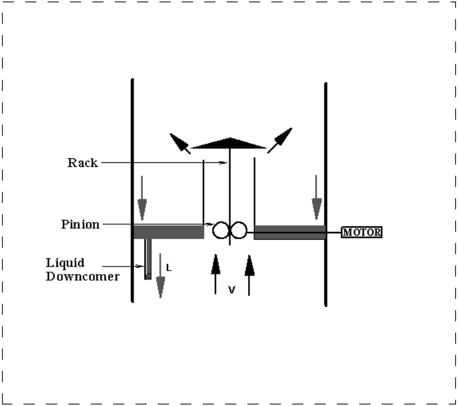
- Problem: Vapor Split may/will be uncertain
- Solution: feedback action can remove this uncertainity in input
- In four point control
  - Rl is very precise input: can be used in optimizing layer
  - Rv is uncertain input: can be used in regulatory layer with feedback

Pilot Plant



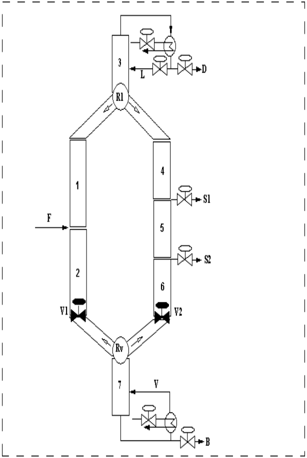


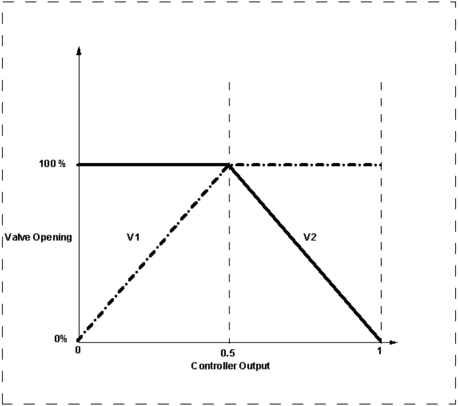
Vapor Split Valves



stepper motor

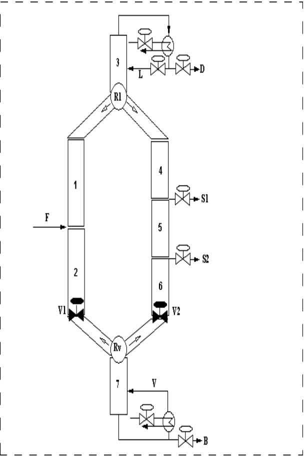
Split range logic





Pulse width modulation

Vapor valve characterstics- Manual mode



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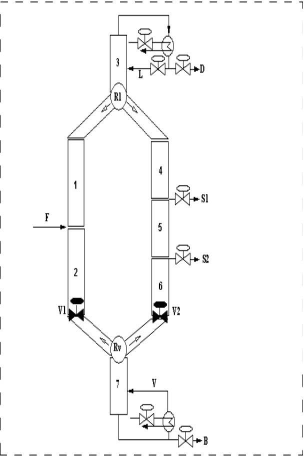

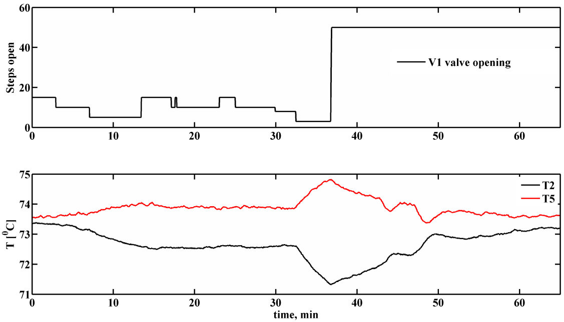

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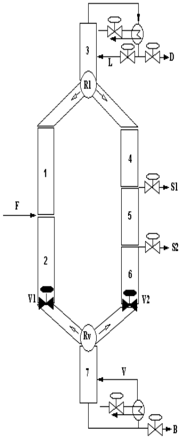
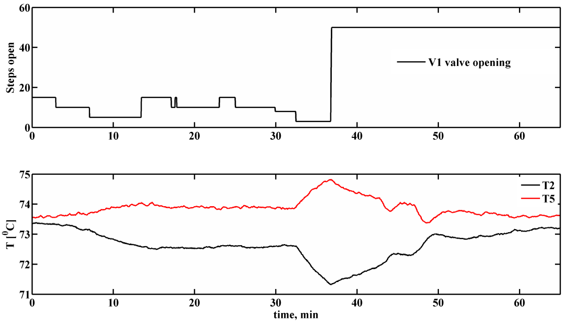
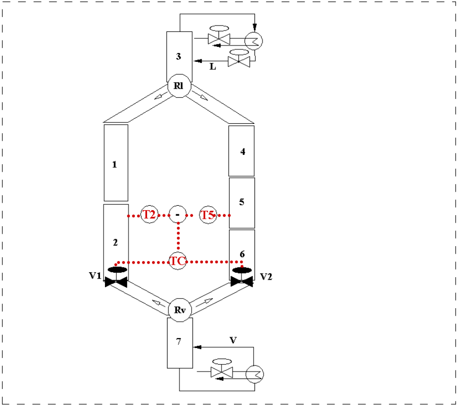




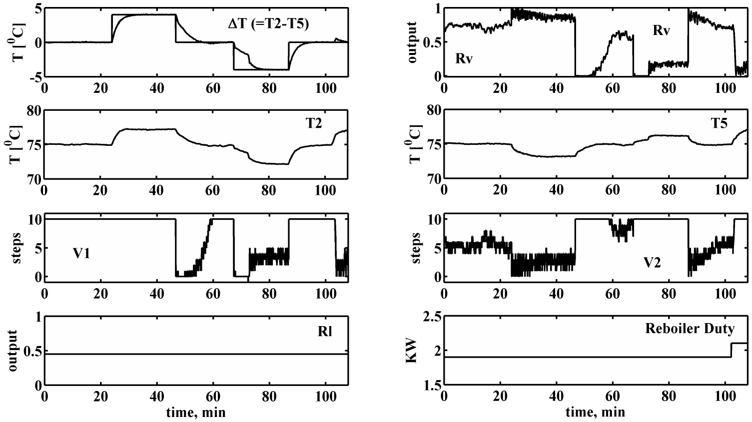
Conclusion: Really bad valve!

Experiments: total reflux

- total reflux conditions
- valve control: split range logic
- control variable:
  $\Delta T = T2 - T5$

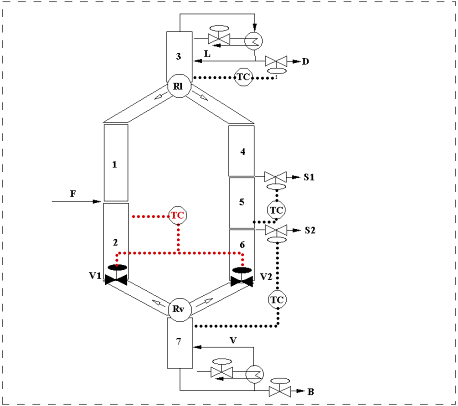


Run


ΔT (=T2-T5)
T [0C]
Rv
output
T2
T5
V1
V2
steps
Rl
Reboiler Duty
KW
time, min
time, min

Experiments: 4–Product Kaibel column

- 4–point temperature control
- 1 temperature in prefractionator controlled with Rv *in place of Rl*
    - control variable: $T2$
- 3 temperature controlled with L, S1 & S2
    - control variable: $T3$, $T5$ & $T6$
- Rl is very precise input
    - can be used as optimizing input



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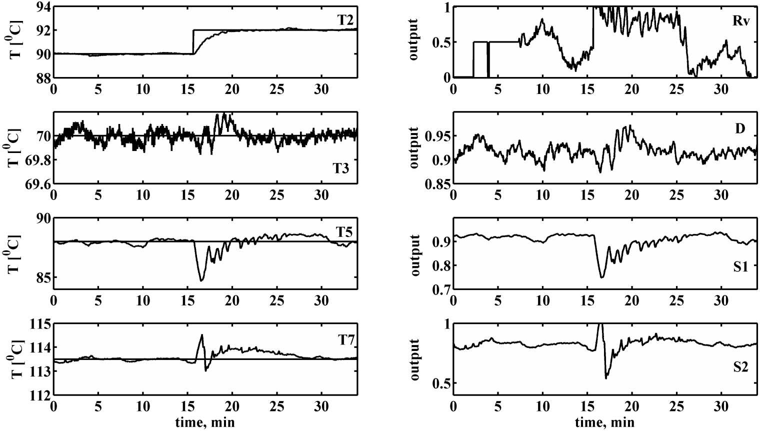

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- Further works needed
    - Superior valve design to operate in low pressure drop applications