Hydraulics of Kettle-Reboiler Circuit on Distillation Columns

Tony Cai, Mike Resetarits, and Ahmad Shariat
Fractionation Research, Inc.

Distillation Honors Session: Professor Michael Schultes
2010 AIChE Annual Meeting, Salt Lake City, UT

November 9, 2010
Dr. Schultes at FRI Experimental Unit in 1998
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Captain Dr. Schultes
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Introduction

- Reboilers are commonly used heat exchangers on distillation columns, supplying most of the energy required for the column.
- It is very important to properly design and operate the overall reboiler circuit.
  - If too much heat is supplied, the tower will flood; too little heat is available, separation performance decreases.
- Significant number of fractionator problems can be attributed to either improper bottom circuit design or poor reboiler circuit layout.
- Reboiler problems are thought to be the second-most common cause of tower problems.
Typical Kettle Reboiler Circuit
Problems & Objectives

- Tower bottom hydraulics is not generally investigated as much as mass transfer is.
- This paper focuses on the hydraulics of kettle reboiler circuits.
- Experimental results are compared to analytical predictions.
Approaches

- Pressure drops of vapor phase between the reboiler and the column were measured using differential pressure transmitter.
- The liquid level at the bottom of the column was measured using a bubbler.
- Pressure drops of liquid and vapor phases across the reboiler circuit were calculated/estimated using basic fundamental fluid dynamics.
FRI Experimental Unit
Kettle Reboiler Circuit

Return Line

Reboiler
Locations of Pressure Drop Measurements

Reboiler Circuit
Location of Bubbler
Pressure Transmitter
Standard Kettle Reboiler Circuit
Reboiler Pressure Drop (Vapor Phase)
iC₄/nC₄  165 psia (11.4 bar)

Capacity Factor Cₛ, m/s

Measured Reboiler DP
Reboiler Pressure Drop (Vapor Phase)

$\text{iC}_4/\text{nC}_4$ 165 psia (11.4 bar)

![Graph showing the relationship between Return Line Velocity and Reboiler Pressure Drop.](image)

- **X-axis:** Return Line Velocity, ft/s
- **Y-axis:** inch H$_2$O

**Legend:**
- ○ Measured Reboiler DP
Reboiler Pressure Drop (Vapor Phase)
iC₄/nC₄ 165 psia (11.4 bar)

![Graph showing the relationship between capacity factor (Cₘ) and pressure drop (H₂O). The graph includes data points for measured and calculated reboiler pressure drop.]
Reboiler Pressure Drop (Vapor Phase)

iC\textsubscript{4}/nC\textsubscript{4} 165 psia (11.4 bar)

![Graph showing reboiler pressure drop vs. return line velocity]

- Measured Reboiler DP
- Calculated Reboiler DP
Column Bottom Liquid Levels
iC$_4$/nC$_4$ 165 psia (11.4 bar)

![Graph showing measured column bottom level](image)

- **Capacity Factor C$_S$, ft/s**
- **Measured Column Bottom Level**
Column Bottom Liquid Levels
iC₄/nC₄ 165 psia (11.4 bar)

Return Line Velocity, ft/s

Measured Column Bottom Level
Rise of Column Bottom Liquid Level

$iC_4/nC_4$ 165 psia (11.4 bar)

Capacity Factor $C_S$, ft/s

Rise of Column Bottom Level

Reboiler Circuit

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Rise of Column Bottom Liquid Level

$iC_4/nC_4$ 165 psia (11.4 bar)
Rise of Liquid Level and Reboiler Pressure Drop
iC₄/nC₄ 165 psia (11.4 bar)

capacity factor Cₛ, ft/s

Reboiler Circuit
Rise of Liquid Level and Reboiler Pressure Drop

$iC_4/nC_4$ 165 psia (11.4 bar)

Capacity Factor $C_S$, ft/s

- Measured Reboiler DP
- Rise of Column Bottom Level
- Calculated Total Pressure Drops
Reboiler Pressure Drop (Vapor Phase)

C₆/C₇ 5 psia (1.65 bar)

Pressure Drop, in H₂O

Capacity Factor Cs, ft/s

▲ Calculated △ Measured
Reboiler Pressure Drops (Vapor Phase)
$C_6/C_7$ 5 psia (1.65 bar)

- Pressure Drop, in H$_2$O
  - 25.0
  - 20.0
  - 15.0
  - 10.0
  - 5.0
  - 0.0

- Capacity Factor Cs, ft/s
  - 0.00
  - 0.10
  - 0.20
  - 0.30
  - 0.40
  - 0.50
  - 0.60

- Data points:
  - ▲ Calculated
  - △ Measured
  - ▲ Calculated (with estimated entrainment)
Conclusions

• Pressure drops across the reboiler circuit and liquid levels can be measured and monitored using differential pressure transmitters

• Measured pressure drops and liquid levels agree reasonably well with the calculated/estimated values

• Pressure drop of liquid phase can be significant portion of total pressure drops, which needs to be considered and included in the reboiler circuit designs
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