The University of Jordan

School of Engineering

Chemical Engineering Department

Chemical Engineering Laboratory (3) (0915561)

Experiment Number (2)

Distillation

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Abstract

Distillation is a widely used separation process that relies on the difference in boiling points of components in a mixture to achieve separation. The efficiency of a distillation column is crucial for optimizing the separation process and maximizing product purity. This experiment aims to investigate the relationship between reboiler power and overall column efficiency in a fractional distillation column. By varying the reboiler power and measuring the composition of the distillate and bottom streams, we can determine the overall column efficiency at different reboiler settings. The results show that the number of theoretical plates using the methods of McCabe and Thiele was 1, while the actual number of plates is 8, and the efficiency of the column is 12.5%.

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Results

➢ Part A

Table 1:Raw Data Sheet and pressure drop.

Power (kw)	Boil-up rate (ml/sec)	pressure drop (cm H_2O)	T9 (C)	T10(C)	T9(K)	T10(K)
1	1.454545455	1.368	83.4	76.4	356.4	349.4
0.75	1.5	1.3682	82.4	75.5	355.4	348.5
0.5	1.5	1.3679	82.5	75.7	355.5	348.7

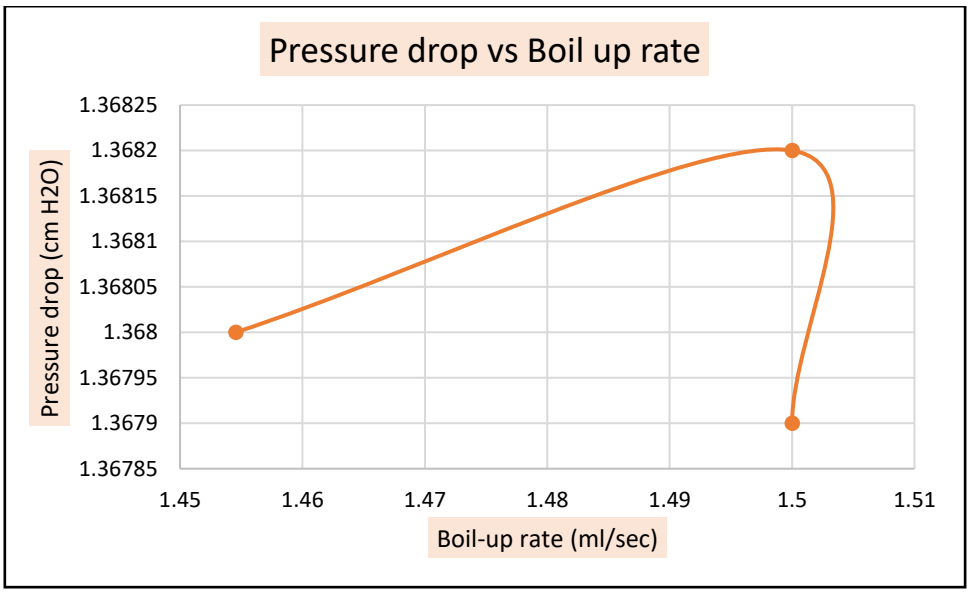

Figure 1:Pressure drop (cmH2O) vs. Boilup rate (ml/s).

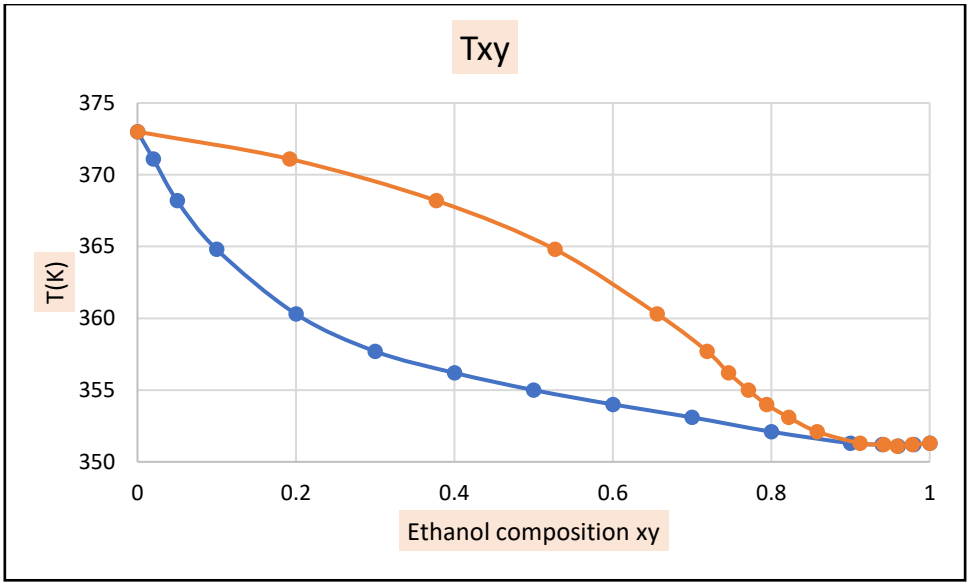

Figure 2:Txy diagram for ethanol water system.

Table 2:Compositions obtained from the Txy diagram.

X_{Bottom}	X_{Top}
0.38	0.98
0.47	0.96
0.49	0.97

➢ Part B

Table 3:Data for total reflux.

Power (kw)	Boil-up rate (ml/sec)	RI (Top)	Top Composition (mol/mol)	RI (Bottom)	Bottom Composition (mol/mol)	Efficiency
1	1.454545455	1.3671	0.41	1.3565	0.16	12.5
0.75	1.5	1.3659	0.34	1.357	0.165	12.5
0.5	1.5	1.3653	0.31	1.357	0.165	12.5

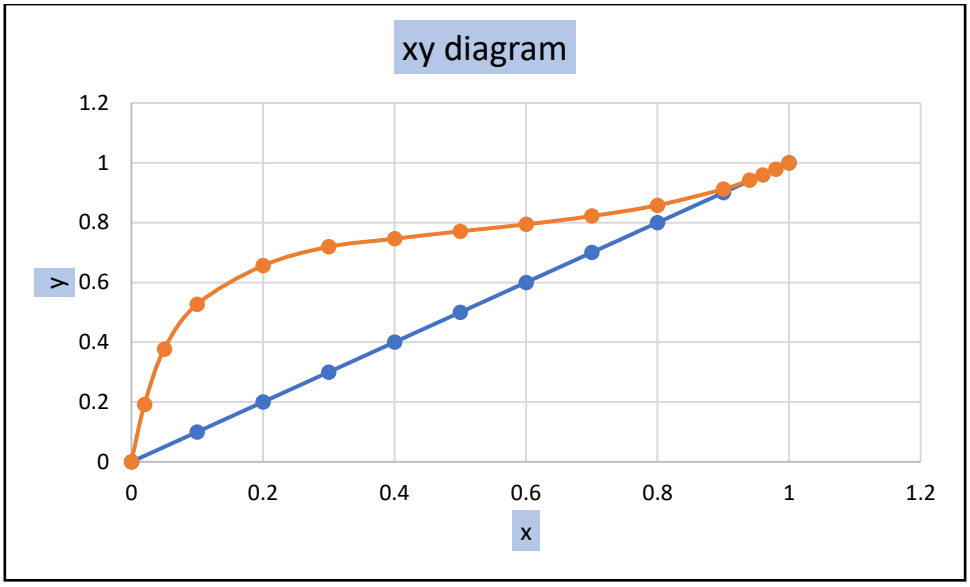

Figure 3:xy diagram for ethanol water system.

Table 4:Efficiency according to Macabe thiele method.

For 1kw	
yn	**xn**
0.41	0.05
For 0.75 kw	
yn	**xn**
0.34	0.02
For 0.5kw	
yn	**xn**
0.31	0.01
So, we have single stage for each power	
Number of theoritical stages	1
Number of actual stages	8
Efficiency	12.5

Discussion

Batch distillation was employed to separate ethanol and water. By adjusting the reboiler power, we anticipated an increase in the boil rate, consistent with the logical outcome of higher power input leading to a greater volumetric boil-up rate. As expected, increased power correlated with higher temperatures and vaporization.

Figure 1 show that the pressure drop increase then decrease with boil- up rate because initially, increasing the boil-up rate requires more heat input to vaporize the liquid. As the heat input reaches its maximum capacity, further increases in the boil-up rate may be limited by the available heat source. In such cases, additional vaporization may become less efficient, leading to a decrease in pressure.

Figure 2 depicts the Txy diagram for the ethanol-water system, revealing an azeotrope around 95.6°C where vapor and liquid phases have equal composition. Although partial separation is possible at the azeotropic point, it is energy-intensive and demands numerous trays. Due to operational power constraints, achieving a 99% purity was unattainable. Moreover, increased power led to reduced composition at the top, indicating an insufficient condenser duty for pure component separation. This highlights the necessity for a distillation column with more trays to enhance the efficiency of ethanol-water separation.

As shown in table 4 the theoretical number of stages equal 1 because the process approached purification, given the close boiling point of water to methanol.

Additionally, the observation that an increase in power results in a decrease in the composition at the top indicates that the condenser is not operating at the required duty for achieving separation with a pure component ،this underscores the necessity for a distillation column with more trays to achieve a more efficient separation of the ethanol-water system.

Conclusion

- Pressure drop increase then decrease with boil- up rate.
- It is not suggested to separate the mixture by distillation due to Azeotropic points which complicate distillation by causing similar vapor pressures, hindering effective separation in distillation columns.
- To separate the mixture that has azeotropic points, it is recommended to use azeotropic distillation which break the azeotropic, or by using extraction columns.
- The top composition gradually changes while the bottom composition remains constant due to the same feed flow rate.
- The temperature remains almost constant at all sites inside the distillation column.

Reference

1) Chemical engineering laboratory "3" (0915561); University of Jordan; faculty of engineering and Technology; Department of Chemical engineering.

Appendix

➢ Sample of calculation

❖ **Part A:** Variation of Column Pressure Drop

➔ At power = 1 kW

- Boil up rate = $\frac{V}{B} = \frac{30\ L}{20.625\ L} = 1.45$
- Where: V = amount of liquid boiled back into the column.

  B = amount of liquid leaving the column = $\frac{F\ X_F}{X_B} = \frac{10\ L \times 0.33}{0.16} = 20.625\ L$
- Pressure drops (From manometer in cmH_2O) = 1.3653
- From TXY diagram (Figure 2), at T_9 → X_{Bottom} = 0.38, at T_{10} → X_{Top} = 0.98

❖ **Part B:** Overall Column Efficiency

➔ At power = 1 kW

- Boil up rate = $\frac{V}{B} = \frac{30\ L}{20.625\ L} = 1.45$
- RI in the top = 1.3671 → From Calibration curve, X_{Top} = 0.41
- RI in the bottom = 1.3565 → From Calibration curve, X_{Bottom} = 0.16
- Start from X_{Top} and use calibration curve until reach a value less than feed
- So, from the McCabe–Thiele method and XY diagram, the number of theoretical stages = 1 and the number of the actual stages = 8.
- The Efficiency of the distillation (%) is:

$$\frac{\text{No. of theoretical stage}}{\text{No. of actual stage}} \times 100\% = \frac{1}{8} \times 100\% = 12.5\ \%$$