ETHANOL RECOVERY BY SHORTCUT DISTILLATION

Thato Baloyi

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1. Summary of study

Ethanol–water separation is a common process in biofuel production, solvent recovery, and chemical manufacturing. Due to the formation of a minimum-boiling azeotrope at 95.6% ethanol, separation beyond this point extractive distillation is used due to thermodynamic compatibility. Shortcut distillation methods evaluate feasibility and estimate column requirements for binary mixtures below this azeotropic point. In this study, a shortcut distillation simulation was conducted using DWSIM to evaluate the recovery of ethanol from a dilute fermentation stream. The goal was to assess the column performance and energy demands required to achieve ethanol purities of 91% and 95%.

2.Problem statement

Hi. We're a small lab exploring ethanol recovery from a fermentation stream. Can you run a shortcut simulation to evaluate distillation feasibility for our case? We don't need a rigorous simulation yet, just a shortcut column and recommendations.

3.Objective

To achieve an ethanol purity exceeding 90% from a ethanol-water fermentation stream.

4.Column results

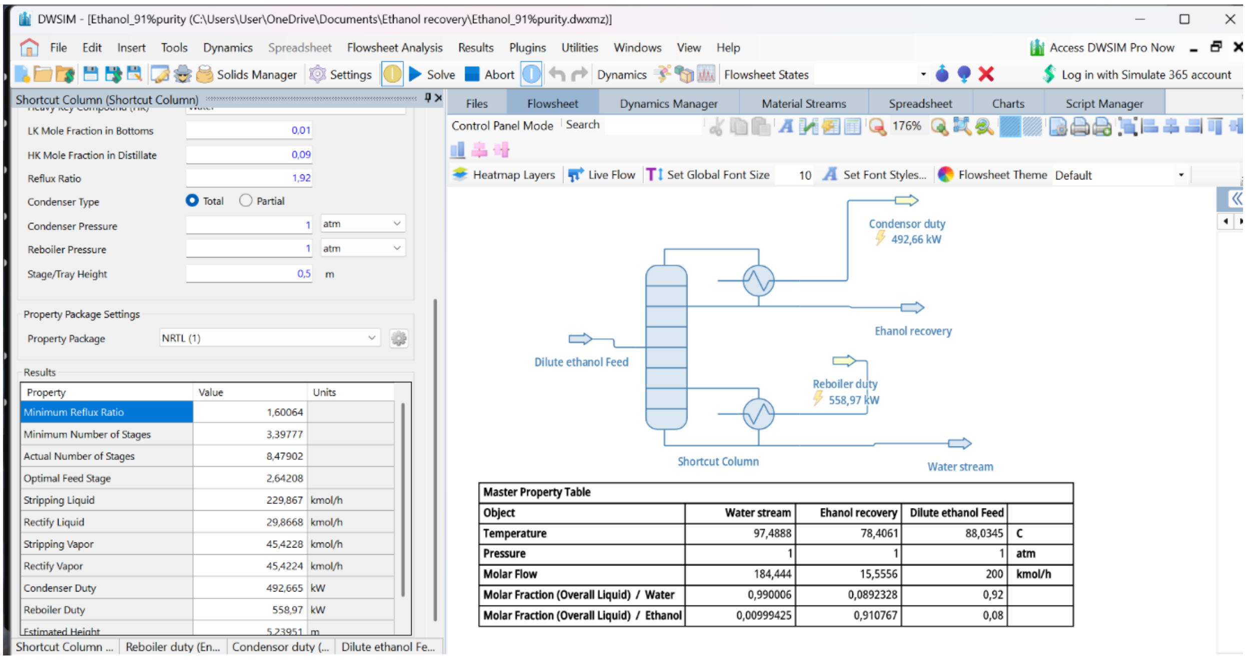

Figure 1: DWSIM flowsheet with 91% ethanol purity.

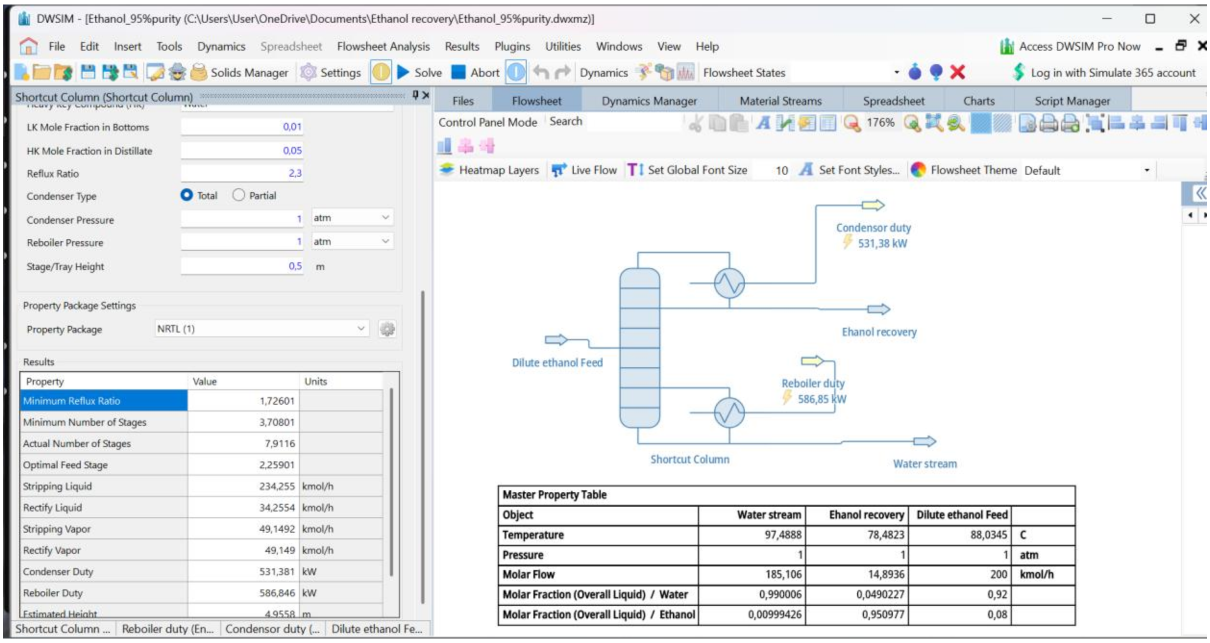

Figure 2: DWSIM flowsheet with 95% ethanol purity.

Table 1: Shortcut distillation results for ethanol-water separation at 91% and 95% purity.

Parameter	**91% Ethanol purity**	**95% Ethanol purity**
Reflux Ratio	1.92	2.30
Minimum Reflux Ratio	1.60	1.73
Actual Number of Stages	8.48	7.91
Minimum Number of Stages	3.40	3.71
Optimal Feed Stage	2.64	2.26
Reboiler Duty kW	-558.97	-586.85
Condenser Duty kW	492.67	531.38
Estimated Height m	5.24	4.96
Estimated Diameter m	0.64	0.67

Table 2: Feed specs

Feed	200 kmol/h
Composition	8 mol% ethanol, 92% water
Pressure	1 atm
Target	> 90% ethanol in distillate

5. Discussion of results

5.1. Reflux Ratio and Separation Efficiency

The reflux ratio was increased with the purity to allow a sharper separation. The number of minimum stages is low which indicates an easy separation.

5.2. Number of Stages

There is an insignificant increase in the number of stages due to an increase in the reflux ratio. Higher reflux means higher separation which negates the need to add stages.

5.3. Energy Consumption

Higher reflux ratio led to greater energy requirements in the reboiler and higher recovery in the condenser.

5.4. Column Sizing

The column sizing increased insignificantly due to an increased reflux ratio. The sizing is within reasonable limits for small -scale distillation systems.

5.5. Feasibility

The minimum reflux ratios and stages for both simulations were relatively low. This indicates that the ethanol–water system is easy to separate under these conditions.

6. Conclusion

The shortcut distillation simulations demonstrate that separating an ethanol–water mixture with low ethanol concentration to achieve 91%–95% purity is feasible using a low number of stages and reasonable energy input. The required reflux ratios were above the minimum and the actual stage counts stayed below 9, indicating that the system is not difficult to separate under these conditions. Energy duties increased with higher purity, but remained within practical limits for small to medium-scale applications.

7. Recommendations

Maintain reflux ratios between (1.2-1.5) × Rmin, as they provide good separation with manageable energy costs. Use azeotropic distillation for purity exceeding 95.6%. Explore heat integration opportunities like using condenser energy to heat feed to reduce energy consumption in full-scale designs. Use rigorous distillation to model the column stage-by-stage with real thermodynamics for accurate sizing, energy use, and composition profiles.