Simulation Analysis of the CO_2/Ethane Extractive Distillation Column

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Background & Description:

Despite following the well-established two-column extractive distillation process proposed by Luyben (2013) for separating CO_2 and ethane using a C3+ solvent, the current simulation results suggest a partial failure in meeting one of the key separation objectives.

The extractive column was configured according to the original process design: CO_2 as the light key (targeted in the distillate), ethane as the heavy key (to be retained in the bottoms), and a solvent composed of natural gas liquids (C3+ hydrocarbons) introduced near the top of the column. The simulation operated at 24 bar with 51 theoretical stages and a reflux ratio near the design value of 6.035.

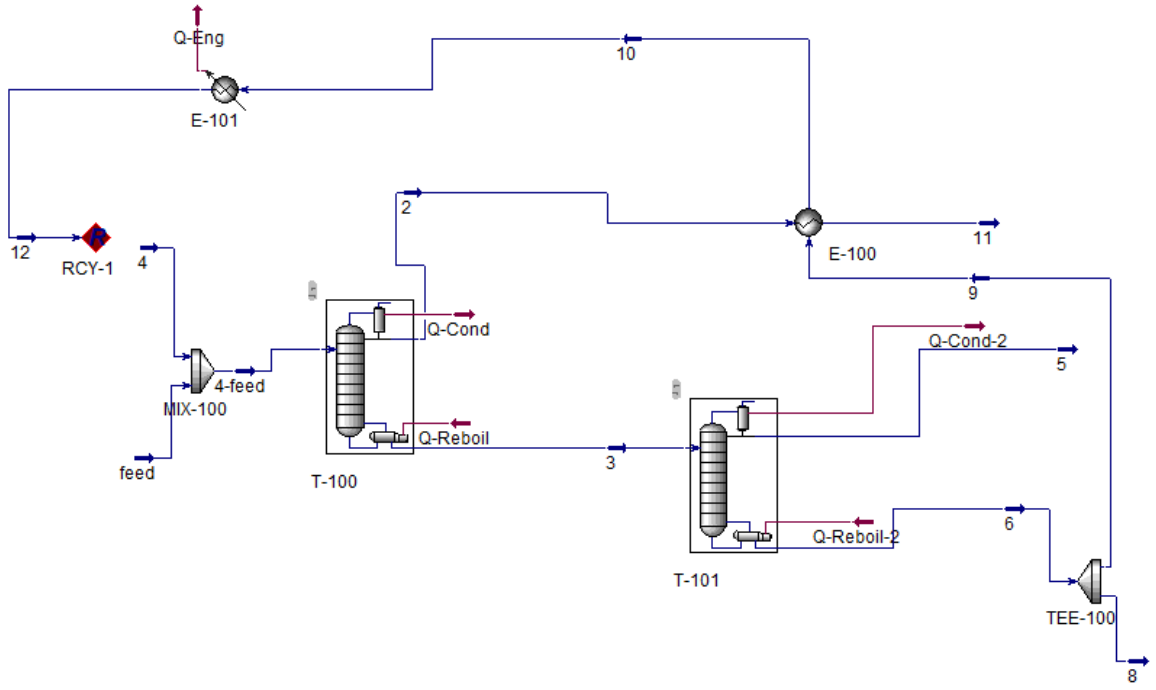
While the CO_2 recovery in the distillate stream was close to the expected purity target (above 95%), the ethane content in the distillate remained significantly higher than anticipated. Instead of achieving the target impurity level of 3.17 mol% C_2 in the distillate, the simulation plateaued with much higher ethane concentrations, indicating that the separation was incomplete.

Several parameter variations were tested, including increasing the reboiler duty, adjusting reflux ratio, and modifying feed locations. None of these led to successful suppression of ethane in the distillate. As a result, the simulation did not achieve the intended component split, and no clear reason could be identified for the persistent presence of ethane in the top product.

Therefore, it is concluded that this simulation — while operationally converged — does not meet the performance criteria of the original process. The extraction of ethane was insufficient, and without an identifiable cause, the simulation is considered unsuccessful in its primary separation objective.

Thermodynamic package: The Peng–Robinson (PR) equation of state was selected for this simulation due to its suitability for vapor–liquid equilibrium modeling in hydrocarbon systems. It is particularly appropriate for gas-phase separations involving light hydrocarbons and CO_2, such as in this extractive distillation process.

Flowsheet



Results:

Master Property Tableau								
Object	**4**	**feed**	**2**	**3**	**5**	**6**		
T (°C)	**60.67**	**46.85**	**-18.77**	**61.52**	**0.66**	**101.7**		
P (kPa)	**24**	**25.33**	**24**	**24**	**24**	**24**		
Molar Flow	**9077**	**1.44e4**	**6930**	**1.65e4**	**4442**	**1.21e4**		
Molar Flow (C20)	**0**	**4644**	**4643**	**0**	**0**	**0**		
Molar Flow (Ethane)	**0.0034**	**6657**	**2283 (2XX expecte d)**	**4374 (6xxx expected)**	**4373 (6xxx expected)**	**0**		

Nb : Insignificant quantities (<0) of components in the product streams can be considered negligible, effectively approximating them to zero without impacting the overall process results or conclusions (see flowsheet).

References: Luyben, W. L. (2013). Control of an extractive distillation system for the separation of CO2 and ethane in enhanced oil recovery processes. Industrial & Engineering Chemistry Research, 52(31), 10780-10787.