Effect of Distillation column sequence on the separation of Methanol, Ethanol and 1-propanol

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A. Background

Distillation is one of the most common and energy-intensive separation processes. These are used extensively in various chemical processes to separate components from mixtures. In these processes the feed usually contains more than two components. The distillation columns are placed in series where at each column a component is desired to be separated from the mixture based on their relative volatility. For streams containing more than 2 components, there could be more than a one way to sequence and separate the components. Therefore, the sequencing of distillation columns plays a major role in designing the separation process. In this work, two different sequences of distillation columns are simulated to separate a mixture containing aliphatic alcohols namely Methanol, Ethanol and 1-propanol and the results are compared to draw meaningful conclusion.

B. Flowsheet description

Consider a typical separation process wherein mixture of three aliphatic alcohols such as methanol, ethanol and propanol are required to be separated using a distillation column. The normal boiling points of these three components are 338 K, 352 K and 370 K respectively. A specification of 99.9 mol % pure component is set as target for the separation process.

To study the effect of sequencing of distillation column the feed is split equally using a splitter into two streams. The split streams are sent to two different sequence of distillation column, namely Sequence - 1 and Sequence - 2. In sequence - 1, 1-propanol is removed in the first distillation column (DC-1) as residual stream. The distillate from DC-1 is then sent to next distillation column (DC-2) where Methanol of required purity is obtained as distillate and Ethanol as residue. Similarly, in sequence -2, Methanol is initially removed in the first distillation column of the sequence-2 (DC-3) as distillate. The residue from DC-3 is then sent to the next distillation column (DC-4) where Ethanol and 1-propanol are separated and obtained as distillate and residue respectively. All the product streams are maintained at 99.9 mol % purity. The reflux ratio, condenser pressure and reboiler pressure are maintained at the same value for comparison purposes. For sake of brevity, it is assumed that components are ideal and follows Raoult's law.

C. Results and Discussion

The heat duty of condenser and the heat duty of reboiler are compared, and the results are tabulated as shown below. DC-1 and DC-2 are distillation columns pertaining to sequence- 1 whereas DC-3 and DC-4 are that of sequence 2.

Condenser					
Object	E_Condenser_DC-4	E_Condenser_DC-3	E_Condenser_DC-2	E_Condenser_DC-1	
Energy Flow	3360.8527	1832.3285	2088.4707	5150.8751	MW

Reboiler					
Object	E_Reboiler_DC-4	E_Reboiler_DC-3	E_Reboiler_DC-2	E_Reboiler_DC-1	
Energy Flow	-3374.1571	-2176.2093	-2093.7567	-5503.9621	MW

From the above table, it is observed that

- Sequence 1:

Total Heat required**

$$E_{total} = \left(E_{reboiler} + E_{condenser}\right)_{DC-2} + \left(E_{reboiler} + E_{condenser}\right)_{DC-1}$$

= (2088.47-2093.76) + (5150.88-5503.96)

= - 358.37 MW

- Sequence 2:

Total Heat required**

$$E_{total} = \left(E_{reboiler} + E_{condenser}\right)_{DC-4} + \left(E_{reboiler} + E_{condenser}\right)_{DC-3}$$

= (3360.85-3374.16) + (1823.33-2176.21)

= - 366.19 MW

** - It is assumed that all the heat is transferred from the condenser to the reboiler without any losses

Note: Negative sign indicates that heat is required by the system.

From the calculations above it is seen clearly that, for the given feed Sequence-2 requires comparatively low energy requirement than Sequence-1.

Thus, sequencing of distillation column or the order of separation of components from a mixture plays a critical role in the design of the separation process. The most effective arrangement depends on various chemical, economical and structural considerations. The present study can be further developed by simulating a different separating sequence where instead of a pure single component, the first distillation column results in a binary mixture. Hence, simulators help to understand how sequencing affects the process design for a given feed conditions