Overview of Pressure-Swing Distillation Process for Separation of Azeotropic Mixture

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ABSTRACT: *Pressure-swing distillation process is widely used as an efficient method for separating pressure-sensitive azeotropic mixtures in chemical industrial processes. The pressure-swing distillation process is found significantly more economical and powerful method for separation of pressure-sensitive azeotropic mixtures than the conventional methods like homogeneous extractive distillation process. Pressure-swing distillation process provides an advantage over these techniques as it does not require any additional component. However, the effective cost to maintain high pressure in the column may be the only limitation of Pressure Swing Distillation technique. Pressure-swing distillation can be applied to both minimum-boiling and maximum-boiling homogeneous azeotropic mixtures. With minimum-boiling systems, the distillate streams are recycled. With maximum-boiling systems, the bottoms streams are recycled. This paper reviews the Pressure-swing distillation process and its applications. The Pressure-swing distillation process and its types were discussed in details.*

Key Words: *Pressure-Swing Distillation, Separation, Minimum and Maximum Boiling Azeotrope.*

I. Introduction:

Now a day's a new method known as Pressure Swing Distillation has come into picture and can be used for separation of pressure-sensitive azeotropic mixtures. This method is more economical than the conventional methods like Extractive Distillation method. Because of no extra solvent is required to achieve the separation. Therefore, day by day the use of Pressure Swing Distillation for the separation of azeotropic mixture is increased. Most researches have focused on mixtures with containing minimal boiling homo azeotropes. Pressure-swing azeotropic distillation uses two columns operating at two different pressures to separate azeotropic mixtures by taking high-purity product streams from one end of the columns and recycling the streams from the other end with compositions near the two azeotropes. This configuration mostly used due to economically. In Pressure-swing distillation process changes in pressure significantly in the distillation column shift the composition of the azeotrope. The larger the shift, the smaller the required recycle flow rates, so the smaller the energy requirements in the two reboilers. The detail Pressure-Swing Distillation process discussed below.

1.1 Pressure-Swing Distillation Process:

Pressure-swing azeotropic distillation uses two columns operating at two different pressures to separate azeotropic mixtures by taking high-purity product streams from one end of the columns and recycling the streams from the other end with compositions near the two azeotropes. Figure 1 shows the schematic representation of Pressure-swing distillation process. It is widely used to separate minimum-boiling azeotropes when the azeotropic composition has significant pressure dependence. The two columns operate at different pressures with distillate streams having compositions close to their respective azeotropes.

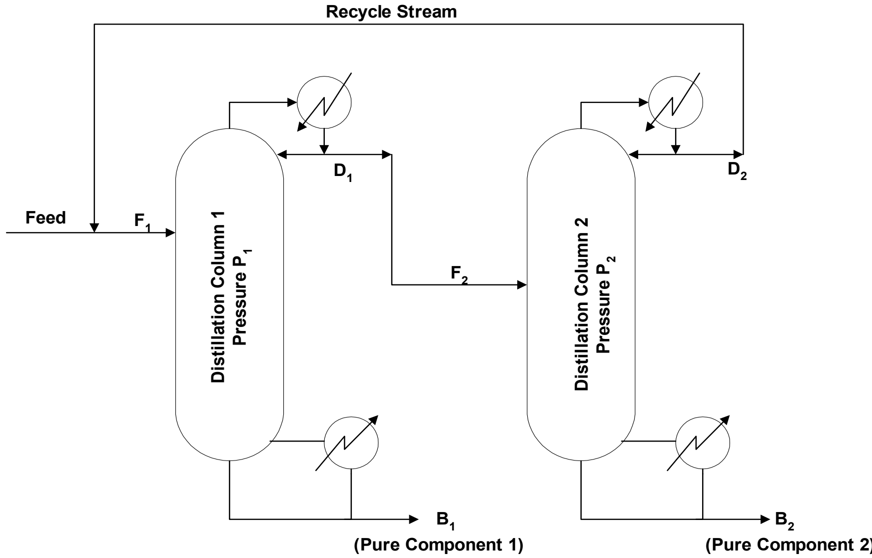

Fig. 1 Pressure-Swing Distillation Process

Pressure-swing distillation can be applied to both minimum-boiling and maximum-boiling homogeneous azeotropic mixtures. With minimum-boiling systems, the distillate streams are recycled. With maximum-boiling systems, the bottoms streams are recycled. Heat integration is typically used since column temperatures are sufficiently different to permit heat transfer.

A novel modification to achieve process intensification has recently been proposed that uses vapor recompression on both columns. Pressure swing distillation (PSD) is a process alternative to the broadly applied azeotropic and extractive distillations. The principle of pressure swing distillation (PSD) is based on the fact that a change in pressure can alter the relative volatility of a liquid mixture, even for liquid mixtures with a close boiling point or those that form an azeotrope. If the operating pressure is increased, the azeotropic point shifts to lower composition values of the light component. The significant positive change in the azeotrope point and enlargement of the relative volatility of azeotropic mixtures allow the separation to take place without any need for a separating agent.

Table 1: List of azeotropic mixtures separated by Pressure-Swing Distillation Process

Sr. No.	Azeotropic Mixture	Sr. No.	Azeotropic Mixture
1.	Acetone / methanol	19.	Methanol / THF
2.	Acetone / chloroform	20.	Methanol / trimethoxysilane
3.	Acetone / chloroform /toluene	21.	Methanol / benzene / acetonitrile
4.	Acetonitrile /water	22.	Methylal / methanol
5.	Acetic acid / toluene	23.	Methyl acetate / methanol
6.	Acetic acid / DMAC	24.	methyl ethyl ketone / benzene
7.	Aniline / octane	25.	Methanol / methyl ethyl ketone
8.	Benzene / isopropanol	26.	MIBK / butanol
9.	Carbon tetrachloride / ethyl acetate	27.	*N*-Heptane / isobutanol
10.	Chloroform / methanol	28.	*N*-Pentane / acetone / cyclohexane
11.	Cyclohexanone / phenol	29.	*N*-Pentane / acetone
12.	Ethanol / water	30.	Phenol / butyl acetate
13.	Ethanol / ethyl acetate	31.	Propanol / toluene
14.	Ethanol / 1-4 dioxane	32.	Propanol / cyclohexane
15.	Isobutyl alcohol / isobutyl acetate	33.	Tetrahydofuran (THF) / water
16.	Isopentane / methanol	34.	Tetrahydofuran (THF) / ethanol
17.	Methanol / dimethyl carbonate	35.	Toluene / 1-butanol
18.	Methanol / ethyl acetate	36.	Water / ethylenediamine

1.2 Classification and Operation Modes of Pressure Swing Distillation:

There are three types of operations modes in Pressure-Swing Distillation Process

1. Batch operation
2. Semicontinous operation
3. Continuous operation

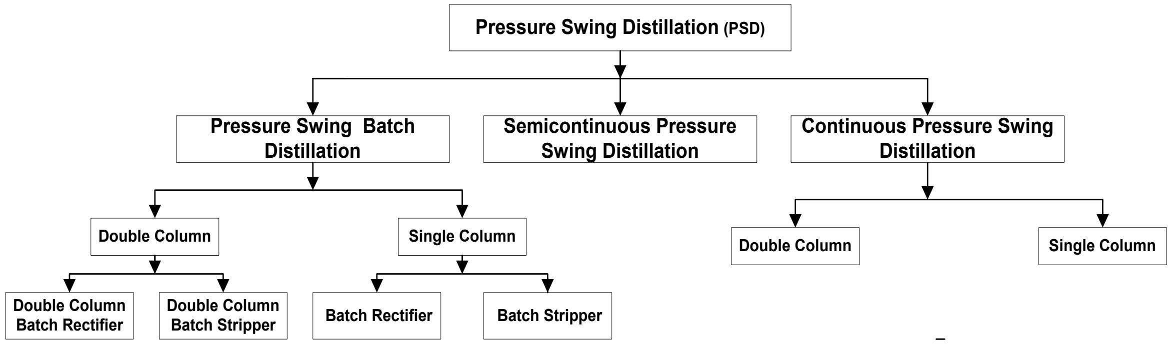

Fig. 2 Classification and Operation Modes of Pressure Swing Distillation(PSD)

1.2.1 Batch Operation

The batch process is one of the best known distillation processes. It is mostly used in fine chemistry, for seasonal products, in the pharmaceutical, and in food industry, despite the competition of the continuous process. Mainly the energy demand is much higher than for the continuous processes. But if the whole producing costs are considered there could be an advantage of the discontinuous process compared to the continuous process. But one main advantage is that the process structure (one column) is much simpler than for a continuous operation and or flexible in the scope of product changes and also product amount changes.

1.2.2 Semicontinuous operation

Semicontinuous operation involves only a single distillation column, which has lower investment costs and, when the mixture to be separated is changed, shorter downtimes. Liquid level are maintained, where reboiler and condenser is in charged condition. An optimal-control algorithm is employed to determine desirable campaigns, and to schedule pressure switch-over policies.

1.2.3 Continuous Operation

Two columns are in operation for the continuous pressure swing distillation system at two different pressures. Feed streams with different concentrations have to be put into the suitable column, depending on the concentration under or above the azeotropic point. For concentrations under the azeotropic point, the feed is put into the low pressure column. For concentrations above the azeotropic point the feed has to be put into the high pressure column. In both columns pure product is withdrawn from the bottom. At the top of the columns there are azeotropic mixtures with concentrations depending on the pressure in the column. The distillate stream is recycled into the other column, so there is a mass integration between the columns.

II. Pressure Swing Distillation (PSD) for separation of Maximum Boiling Point Azeotrope and Minimum Boiling Point Azeotrope

The two columns are working at different pressures. The A-B binary mixture forming minimum azeotrope is fed into the first column shown in Figure 3, where first distillation column is working at lower pressure. Pure component A is removed as bottom product and a mixture of nearly azeotropic composition at this pressure is the distillate. This stream is fed into the second distillation column. Since the pressure has changed the composition of the feed is not the azeotropic one at this higher pressure. Hence pure component B can be produced as bottoms and a nearly azeotropic mixture as distillate, which is recycled to the first distillation column. A similar system shown in Figure 4 is used for maximum azeotropes. In this case the pure components are obtained as distillate and the bottoms of the second column is recycled.

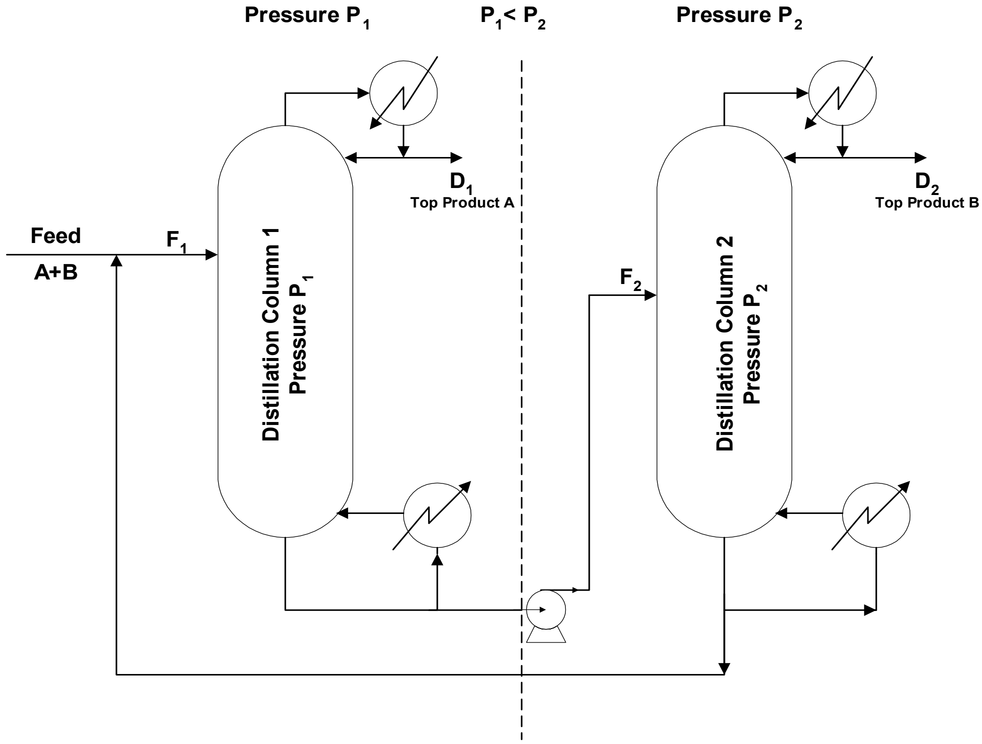

Fig. 3 Separation of Maximum Boiling Point Azeotrope

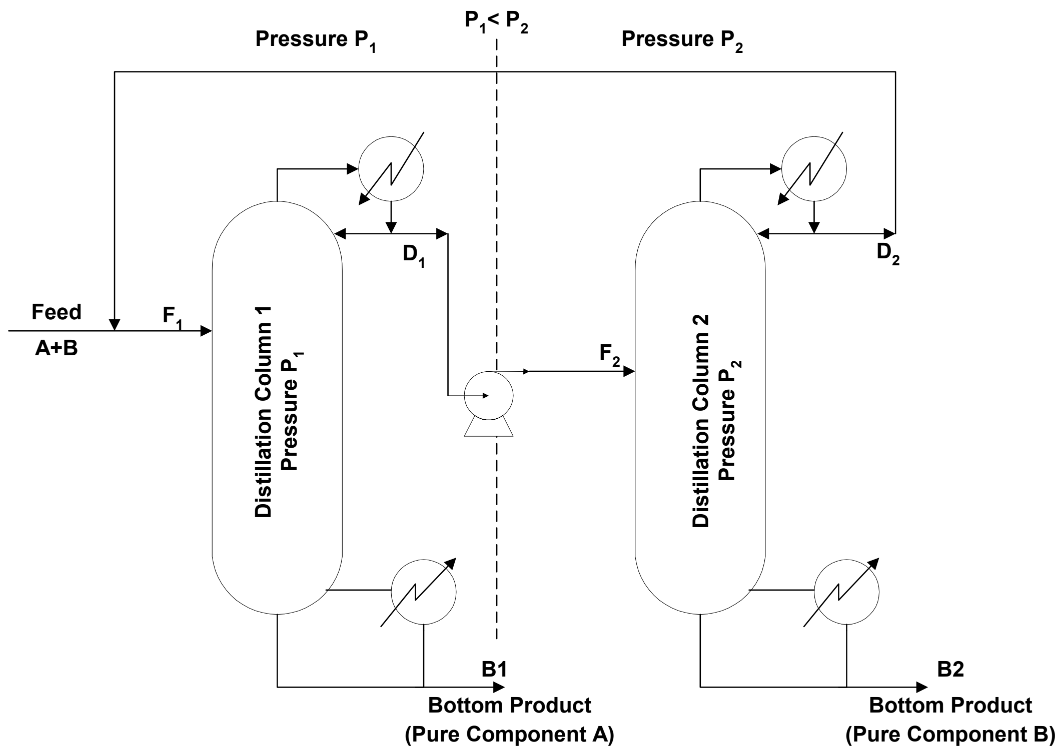

Fig.4 Separation of Minimum Boiling Point Azeotrope

III. *Advantages and disadvantages of Pressure-Swing Distillation (PSD)*

Pressure-Swing Distillation **(**PSD) process itself has same main advantages compared to other unit operations for the separation of homogenous azeotropic mixtures. Some advantages and disadvantages are mentioned below.

3.1 Advantages

- Low investment cost because of a smaller number of distillation columns (compared to concepts with entrainer).
- Energy savings is high in the case of the continuous PSD operation.
- No additional substances (entrainer) are needed for the separation in PSD

3.4 Disadvantages

- Available and reliable azeotropic data.
- More complex control structure and automation concept.
- Pressure sensitive azeotropic mixture.
- In the case of a low temperature azeotrope, the products are in the column bottom, which could be mean that there are also all contaminations (high boiling by-products).

3.4 Comparison of Pressure-Swing Distillation Process (PSD) with Extractive Distillation

- Energy Demand of Extractive distillation is lower than Pressure-Swing Distillation.
- Higher recovery is achieved by Extractive distillation than the process by the PSD
- Extractive distillation needs much more operation steps than the PSD
- The control of PSD is easier than that of the Extractive distillation since the columns are operating practically in steady state
- The capital cost of the Pressure-Swing Distillation (PSD) are higher than that of the Extractive distillation

IV. *Conclusion:*

This article provides an overview of the Pressure-Swing Distillation process. Pressure-swing distillation (PSD) is the process to be utilized to separate the pressure-sensitive mixture with close boiling point or forming azeotrope. The separation of a binary homogeneous azeotropic mixture by pressure swing distillation (PSD) is discussed. Pressure Swing Distillation (PSD) provides an advantage over other conventional methods like extractive distillation. PSD is a special distillation process in which no additional component (entrainer) is needed. The main advantages and disadvantages are explained in this overview. However, the effective cost to maintain high pressure in the column may be the only limitation of Pressure Swing Distillation technique.

References

1. Hosgor, Eda, et al. "Design and control of distillation processes for methanol/chloroform separation." *Computers & Chemical Engineering* 67 (2014): 166-177.
2. Luyben, William L. "Comparison of extractive distillation and pressure-swing distillation for acetone-methanol separation." Industrial & Engineering Chemistry Research 47.8 (2008): 2696-2707.
3. Kanse, Nitin G., S. D. Dawande, and Prashant B. Dhanke. "Effect of Feed Temperature and Solution Concentration on Pervaporation for separation of Azeotropic Mixtures." Materials Today: Proceedings 5.2 (2018): 3541-3550.
4. Knapp, Jeffrey P., and Michael F. Doherty. "A new pressure-swing-distillation process for separating homogeneous azeotropic mixtures." Industrial & engineering chemistry research 31.1 (1992): 346-357.
5. Kanse, Nitin G., and S. D. Dawande. "Separation of Ethanol/Water (Azeotropic mixture) by Pervaporation using PVA Membrane." Materials Today: Proceedings 4.9 (2017): 10520-10523.
6. Wei, Hong-Mei, et al. "Design and control of dimethyl carbonate–methanol separation via pressure-swing distillation." Industrial & engineering chemistry research 52.33 (2013): 11463-11478.
7. Luyben, William L. "Comparison of pressure-swing and extractive-distillation methods for methanol-recovery systems in the TAME reactive-distillation process." Industrial & engineering chemistry research 44.15 (2005): 5715-5725.
8. Luyben, William L. "Pressure-swing distillation for minimum-and maximum-boiling homogeneous azeotropes." Industrial & Engineering Chemistry Research 51.33 (2012): 10881-10886.
9. Zhang, Zhishan, et al. "Design and control of methyl acetate-methanol separation via heat-integrated pressure-swing distillation." Chinese journal of chemical engineering 24.11 (2016): 1584-1599.
10. Li, Weisong, et al. "New pressure-swing distillation for separating pressure-insensitive maximum boiling azeotrope via introducing a heavy entrainer: design and control." Industrial & Engineering Chemistry Research 52.23 (2013): 7836- 7853.