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Improved design of an extractive distillation system with an intermediate-boiling solvent

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ABSTRACT

Most extractive distillation systems use a solvent (entrainer) that is higher-boiling than the two key components. A two-column sequence is used in which the bottoms of the second column is the solvent stream and is recycled back to the first extractive column. There are some chemical systems in which the entrainer is an intermediate-boiling component. In this situation there are two alternative separation sequences. The direct sequence takes the light key component overhead in the first column, and the solvent recycle is the distillate from the second column. The indirect sequence takes the heavy key component out the bottom of the first column and the solvent is the bottoms from the second column.

This paper explores a design proposed in the literature for separating methanol and toluene using the intermediate-boiling solvent triethylamine. The indirect sequence is shown to be more energy efficient. More importantly the solvent flowrate given in the published paper is shown to be much larger than required. Designs with greatly reduced solvent recycle flowrates reduce energy requirements by 50%.

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1. Introduction

Separation of azeotropic mixtures is one of the most challenging and interesting areas of chemical engineering. Several alternative methods are available including pressure-swing, heterogeneous azeotropic and extractive distillation. The classical extractive distillation process uses a high-boiling solvent to separate the key components by preferentially dissolving one of the key components and taking the essentially binary mixture out the bottom of the first extractive column. The bottoms is fed to a solvent recovery column in which the other key component goes overhead and the bottoms is recycled back to the extractive column. Mass-transfer, distillation and design textbooks discuss this type of extractive distillation setup with a high-boiling solvent. Examples are Wankat [1] and Stichlmair and Fair [2]. Luyben and Chien [3] discuss both the design and control of extractive distillation for the separation of isopropanol/water using the high-boiling solvent dimethyl sulfoxide and for acetone/methanol using several solvents.

There have been many studies of distillation column sequencing. Most of the work has considered standard separation without azeotropes. Azeotropic separations require more complex configurations such as the extractive distillation system considered in this paper.

There are some extractive distillation systems in which the solvent has a boiling point that is intermediate between the two key components being separated. The example considered in this paper is the separation of methanol (boiling point 64.7 °C) and toluene (boiling point 110.6 °C) using the solvent triethylamine (boiling point 88.77 °C). Other examples with significant boiling-point difference in the key components are given by Rodriquea-Donis et al. [4] include acetone/heptane, methyl acetate/cyclohexane, dichloromethane/ethanol and ethyl acetate/heptane.

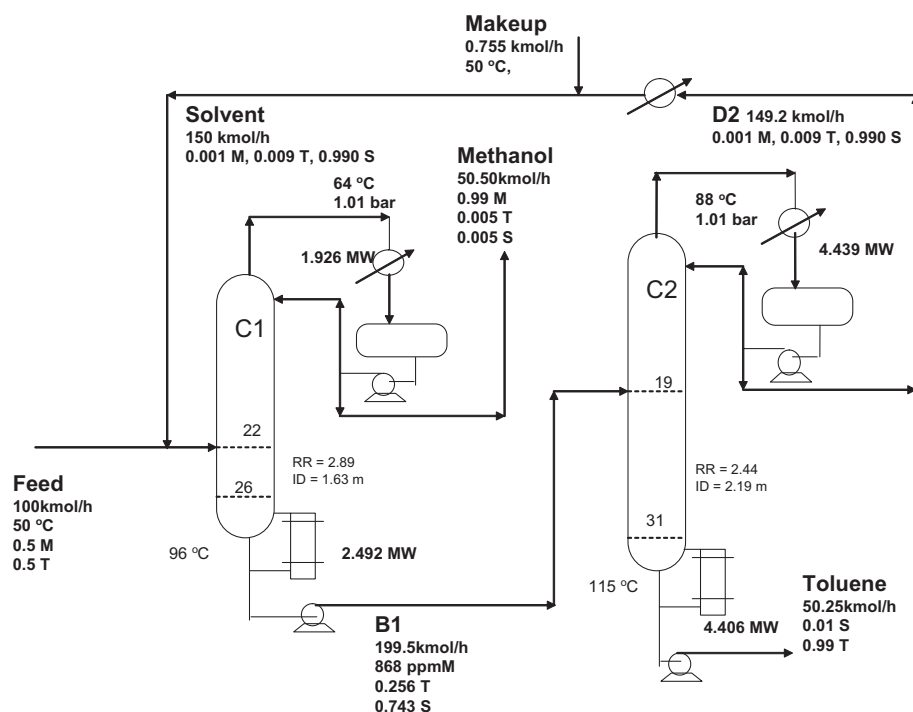
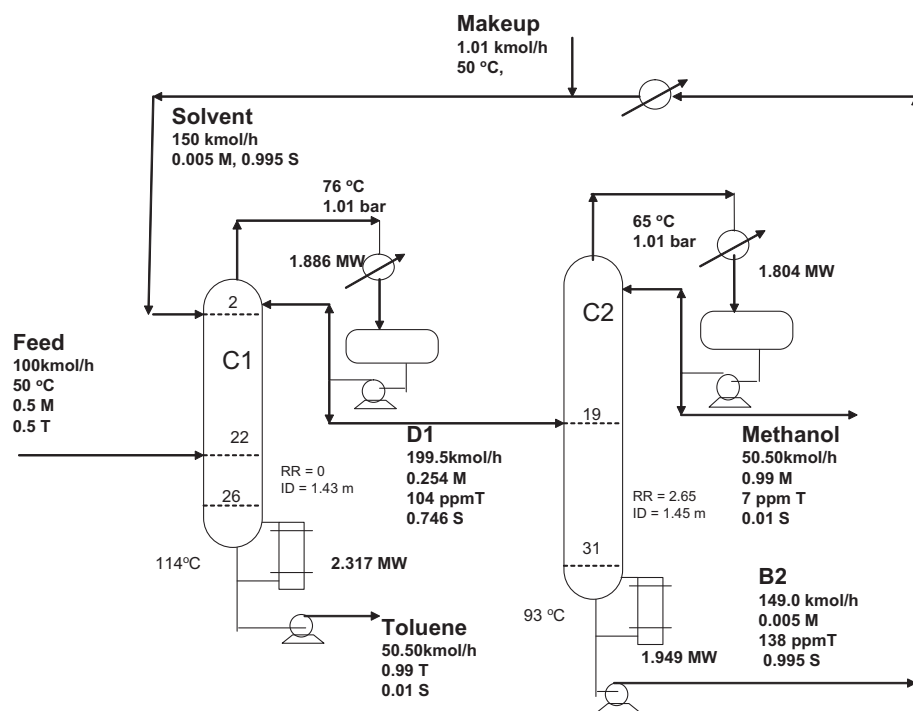
Doherty and Malone [5] discuss in detail the conceptual design of extractive distillation columns. Both high-boiling solvents and intermediate-boiling solvents are illustrated. The methanol/toluene system using the intermediate-boiling solvent methyl butyrate is presented.

Since the solvent boils between the two key components, it can be recovered in two alternative separation sequences of two conventional columns, as illustrated in Figs. 1 and 2. In the direct separation sequence, the light key component is removed as the distillate in the first extractive column. The solvent and the heavy key component go out the bottom and are fed to a second column in which the heavy key component goes out in the bottoms and the distillate is the solvent, which is recycled back to the first column.

In the indirect separation sequence, the heavy key component is removed as the bottoms in the first extractive column. The solvent and the light key component go overhead as the distillate and are fed to a second column in which the light key component goes out

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Fig. 1. Direct separation; $S = 150$.Fig. 2. Indirect separation; $S = 150$.

in the distillate and the bottoms is the solvent, which is recycled back to the first column.

The decision as to which of the two alternative separation sequences is “best” depends on the economics (capital investment and energy costs) and dynamic controllability. In this paper we consider a recently published paper [6] that presents only the direct separation sequence and compares its economics with two other process configurations. The first process increases

the pressure in the solvent recovery column so that the two columns can be heat integrated (overhead vapor from the high-pressure recovery column is used to provide heat to the lower temperature reboiler in the extractive column). The second process explores the use of a divided-wall column and substantial reductions in energy requirements and total annual costs are claimed. No consideration of dynamic controllability is mentioned.

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