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Synthesis and computational methods for the design of efficient distillation systems

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Abstract

The work in this thesis has been developed to facilitate understanding of limitations in distillation, as well as to aid the design of efficient distillation systems, by introducing useful methods, techniques, tools, and novel process configurations.

It is well-established that distillation is a very inefficient process (Mix et al., 1978; Humphrey, 1995; Ognisty, 1995), yet it is by far the most industrially widespread separation technique, accounting for some 90–95% of product recovery worldwide (Humphrey and Siebert, 1992; Humphrey, 1995).

There are substantial environmental and financial incentives to reduce the energy requirements of distillation systems. To this end, several different approaches have been proposed over the last few decades, including diabatic columns, complex columns, heat-pump assisted distillation, and heat-integrated distillation columns.

These solutions have not yet been widely implemented, partly owing to some practical hurdles, but also largely due to the difficulty of their design. The work in this thesis addresses several of these problems.

The major approach used in this work is to consider the process limitations in distillation systems imposed by entropy generation, pinch points, and the relationships of these phenomena to minimum reflux.

Two methods are presented for locating pinch points in non-ideal distillation systems, with one focusing on finding all pinch points in a given search space, and the other on efficiently constructing pinch point curves. The concept of finite-reflux distillation boundaries is also introduced. This, together with pinch points and pinch point curves, can be used for effective design of distillation systems using the column profile map method (Holland et al., 2004a; Tapp et al., 2004).

Heat-pump-assisted distillation is also considered, with particular emphasis on vapour recompression. A tool is derived for the rapid determination of whether or not vapour recompression is favourable to conventional dis-

tillation, and whether or not it can be implemented practically. The tool is consolidated as a single chart, and requires only the product temperatures.

Novel vapour recompression configurations are also devised, circumventing some of the major limitations of standard vapour recompression. These new configurations are applicable to light liquid feeds and heavy vapour feeds, and typically result in energy savings in the region of 50–80% compared to conventional distillation.