DISTILLATION PROCESS USING MICROCHANNEL TECHNOLOGY

TECHNICAL FIELD

[0001] This invention relates to a distillation process for separating two or more components having different volatilities from a liquid mixture containing the components. The process employs microchannel technology for effecting the distillation and is particularly suitable for conducting difficult separations, such as the separation of ethane from ethylene, wherein the individual components are characterized by having volatilities that are very close to one another.

BACKGROUND

[0002] Distillation is a method of separation that is based on the difference in composition between a liquid mixture and the vapor formed from it. This composition difference arises from the dissimilar effective vapor pressures, or volatilities, of the components of the liquid mixture. Distillation as normally practiced involves condensation of the vaporized material, usually in multiple vaporization/condensation sections.

[0003] Distillation is a widely used industrial method for separating liquid mixtures and is at the heart of the separation processes in many chemical and petroleum plants. The most elementary form of the method is simple distillation in which the liquid is brought to boiling and the vapor formed is separated and condensed to form a product. If the process is continuous it is called flash distillation. If the feed mixture is available as an isolated batch of material the process is a form of batch distillation and the compositions of the collected vapor and residual liquid are thus time dependent. The term fractional distillation, which may be contracted to fractionation, was originally applied to the collection of separate fractions of condensed vapor, each fraction being segregated. In modern practice the term is applied to distillation processes in general, where an effort is made to separate an original mixture into two or more streams, at least one of which is enriched in at least one component. When the vapors are enriched by contact with counter-flowing liquid reflux, the process is often called rectification. When fractional distillation is accomplished with a continuous feed of material and continuous removal of product fractions, the process is called continuous distillation. When steam is added to the vapors to reduce the partial pressures of the components to be separated, the term steam distillation is used.

[0004] Most distillations conducted commercially operate continuously, with a more volatile fraction recovered as distillate and a less volatile fraction recovered as bottoms or residue. If a portion of the distillate is condensed and returned to the process to enrich the vapors, the liquid is called reflux. The apparatus in which the enrichment occurs is usually a vertical, cylindrical vessel called a still or distillation column. This apparatus normally contains internal devices for effecting vapor-liquid contact; the devices may be categorized as plates or packings.

[0005] A problem with many distillation processes is that they employ relatively large pieces of equipment that are highly inefficient with respect to energy consumption. Distillation accounts for about a quadrillion BTUs of energy consumption per year in the United States. Conventional distillation systems could reduce lost work and increase plant energy efficiency by incorporating capital-intensive reboilers at multiple sections. However, the capital cost of adding multiple reboilers to conventional distillation columns is typically prohibitive. The trade-off between energy and capital often results in favoring the lower cost solution. The efficiency of mass transfer sections in distillation columns is set by the effectiveness of trays or packing, which has not changed significantly in many years. For separation of components with similar boiling points, such as separating ethane from ethylene, commercial distillation columns are typically hundreds of feet high, due to the need to use many mass transfer sections.

[0006] Another problem relates to the fact that the equipment (e.g., distillation columns, reboilers, condensers, etc.) used in many of these distillation processes require relatively large internal volumes for processing the materials being treated. These large internal volumes render the equipment slow to respond to changes in operating conditions (e.g., temperature, etc.). This makes the distillation processes using this equipment slow to start up and subject to imprecise control.

SUMMARY

[0007] The present invention provides a solution to these problems by employing a distillation process using microchannel technology. With the present invention, in one embodiment, process intensification is achieved through the use of stacked layers of thin sheets of material with stamped or etched channels, that is, microchannels, providing narrow flow paths with short diffusion distances for mass transfer. The use of these microchannels can provide for dramatic reductions in the required flow length of the section dominated by mass transfer, resulting in relatively short distillation units. Heat inputs and outputs can be closely integrated with microchannel vapor-liquid equilibrium stages resulting in processes that can approach reversible distillation.

[0008] This invention relates to a process for distilling a fluid mixture in a microchannel distillation unit, the microchannel distillation unit comprising a plurality of microchannel distillation sections, the fluid mixture comprising a more volatile component and a less volatile component, the process comprising: flowing a vapor phase of the fluid mixture in a first microchannel distillation section in contact with a liquid phase of the fluid mixture, part of the more volatile component transferring from the liquid phase to the vapor phase to form a more volatile component rich vapor phase, part of the less volatile component transferring from the vapor phase to the liquid phase to form a less volatile component rich liquid phase; separating the more volatile component rich vapor phase from the less volatile component rich liquid phase; flowing the less volatile component rich liquid phase to another microchannel distillation section upstream from the first microchannel distillation section; and flowing the more volatile rich vapor phase to another microchannel distillation section downstream from the first microchannel distillation section.

[0009] In one embodiment, each microchannel distillation section comprises at least one process microchannel and at least one adjacent liquid channel, the liquid channel comprising a wicking region.

[0010] In one embodiment, the microchannel distillation unit further comprises a heat exchanger.