290n Integration of Heat Pumps in Pervaporation Systems for Improved Energy Efficiency

Leland Vane, Franklin Alvarez, Stuart Shealy, and Donald Schupp

The removal of organic compounds from water by pervaporation is highly energy efficient when the separation factor offered by the pervaporation process is high. In cases where the separation factor is relatively small, consequential amounts of water permeate the membrane per unit mass of the organic compound. In this case, energy efficiency suffers due to the heat required to evaporate the water. When the permeate vapor is condensed, heat is released and must be removed. Heat pumps can be used to upgrade the heat released during permeate condensation to provide the heat of evaporation, thereby reducing the need for other sources of process heat.

In this study, the removal of ethanol from water was chosen as a test case. Two types of heat pumps were considered – a closed cycle heat pump and a mechanical vapor recompression heat pump (using the permeate as the compressor working fluid). Energy requirements and capital costs associated with the heat pumps systems were calculated and compared to estimates for standard electric- and steam-based heating systems. In addition, energy demands for a standard steam-based distillation system and a mechanical vapor recompression distillation system were estimated. Process variables considered included the pervaporation ethanol-water separation factor (10, 15, 20 or 40), the feed concentration of ethanol (1 or 5 wt%), and the fraction of ethanol recovered from the feed stream by the pervaporation system (90 to 99%).

Based on the analysis, it was concluded that heat pumps could significantly reduce the energy requirements for pervaporation systems removing ethanol from water. However, the additional capital costs associated with the heat pump system, particularly the compressor component, can outweigh the energy cost savings, depending on process variables. Energy requirements for a pervaporation-heat pump system were estimated to be lower than those for standard steam distillation under certain conditions, particularly at higher pervaporation separation factors. Of the systems analyzed, the least amount of energy was required for the distillation-heat pump scenario with significant energy savings achieved with relatively little additional capital cost.

*This is an abstract of a proposed poster presentation and does not necessarily reflect U.S. EPA or Shaw Environmental, Inc. policy.