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Investigation of Mass Transfer for RPB Distillation at High Pressure

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Abstract : In recent decades, there has been a significant emphasis on the pivotal role of Rotating Packed Beds (RPBs) in absorption processes, encompassing the removal of Volatile Organic Compounds (VOCs) from groundwater, deaeration, CO2 absorption, desulfurization, and similar critical applications. The primary focus is elevating mass transfer rates, enhancing separation efficiency, curbing power consumption, and mitigating pressure drops. Additionally, substantial efforts have been invested in exploring the adaptation of RPB technology for offshore deployment. This comprehensive study delves into the intricacies of nitrogen removal under low temperature and high-pressure conditions, employing the high gravity principle via innovative RPB distillation concept with a specific emphasis on optimizing mass transfer. Based on the author's knowledge and comprehensive research, no cryogenic experimental testing was conducted to remove nitrogen via RPB. The research identifies pivotal process control factors through meticulous experimental testing, with pressure, reflux ratio, and reboil ratio emerging as critical determinants in achieving the desired separation performance. The results are remarkable, with nitrogen removal reaching less than one mole% in the Liquefied Natural Gas (LNG) product and less than three moles% methane in the nitrogen-rich gas stream. The study further unveils the mass transfer coefficient, revealing a noteworthy trend of decreasing Number of Transfer Units (NTU) and Area of Transfer Units (ATU) as the rotational speed escalates. Notably, the condenser and reboiler impose varying demands based on the operating pressure, with lower pressures at 12 bar requiring a more substantial duty than the 15-bar operation of the RPB. In pursuit of optimal energy efficiency, a meticulous sensitivity analysis is conducted, pinpointing the ideal combination of pressure and rotating speed that minimizes overall energy consumption. These findings underscore the efficiency of the RPB distillation approach in effecting efficient separation, even when operating under the challenging conditions of low temperature and high pressure. This achievement is attributed to a rigorous process control framework that diligently manages the operational pressure and temperature profile of the RPB. Nonetheless, the study's conclusions point towards the need for further research to address potential scaling challenges and associated risks, paving the way for the industrial implementation of this transformative technology.

Keywords : mass transfer coefficient, nitrogen removal, liquefaction, rotating packed bed
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