A Non-Equilibrium Thermodynamic Approach for the Re-Design of Membrane Systems for Separation of CO₂ from Natural Gas

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Semipermeable membranes have many applications in gas separation. One of these is separation of CO_2 from natural gas. In such systems, the permeate gas is typically recompressed (either to be re-injected into the reservoir or to undergo a further separation process). The costs for recompression power often become the largest costs in membrane separation systems. Moreover, due to the Joule-Thomson effect, the temperature of the feed gas drops as some of it expands from the high-pressure feed to the low-pressure permeate. Thus, to avoid condensation of heavier hydrocarbons as the gas cools down, some heating power is used to preheat the feed gas before treated.

In this work, we look at the entropy production of the process and find where useful work is lost. In this way, we are able to propose alternative process configurations, which reduce the heating and power requirements of the unit, without affecting separation. We re-configure the system by taking advantage of a previous work, which utilized optimal control theory to find the operating conditions that minimize the lost work. We do this by dividing the membrane unit into a series of sub-units where we control the permeate pressures at every step. Compressors at the entrance of each sub-unit were used to control the permeate pressures. We further account for non-isothermal effects due to compression and expansion of the gas. We show how the electric power consumption, as well as the heating demand of the system, can be significantly reduced in such a way.

References:

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