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Comparative study on the methods of calculating theoretical minimum energy requirement for desalination

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ABSTRACT

Theoretical calculations to estimate the minimum required energy for desalination are compared. In order to calculate the reversible energy to produce purified water from saline water, three different theoretical methods are applied, which are the second law of thermodynamics, the osmotic pressure theory and the vapor compression theory. For each method, the derivation of the equations to calculate the theoretical minimum energy is reviewed in detail from the background and assumptions, and the equations are summarized for an infinitesimal and a finite recovery cases. Various temperatures, recoveries and the salinities of feed and product water are considered for case studies to analyze the quantitative difference between the methods. For 25°C and 35,000 ppm feed saline water, the minimum required energy to produce a unit product water of 0 ppm is calculated as 0.762, 0.742 and 0.761 kWh/ton for an infinitesimal recovery and 1.068, 1.071 and 1.098 kWh/ton for a 50% recovery from the second law of thermodynamics, the osmotic pressure theory with the van't Hoff equation and the vapor compression theory with the boiling point elevation Eq. (33), respectively. In general, it is supposed that the calculation of theoretical minimum energy could include 5%–10% uncertainty, depending on the conditions of the concerned case and the applied equation. It is believed that for the same conditions the theoretical minimum energy for desalination should be identical in nature, regardless of the type of desalination, for example, membrane, thermal or any other way of desalination.

Keywords: Desalination; Theoretical minimum energy; Minimum separation work; Second law of thermodynamics; Osmotic pressure theory; Vapor compression theory

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