Innovative Application of Low GWP Refrigerants in Hydrate-Based Water Desalination

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Hydrate-based desalination (HBD) operates at lower temperatures and pressures than conventional methods, reducing energy consumption. HBD efficiency depends on refrigerant selection, influencing hydrate formation kinetics and system feasibility. While propane is commonly used, its high flammability presents safety risks. The purpose of this study is to determine the hydrate formation efficiency of R-1234yf and R-1234ze through testing the temperatures and pressures at which the hydrates form. Experiments used high-pressure stirred automated lag time apparatus (HPS-ALTA) to investigate hydrate formation conditions in different solution combinations. These included deionized water, 1 wt.% NaCl solution with seawater, and the hydrate promoter sodium dodecyl sulfate (SDS). Conventional refrigerants R-134a and R-410A were tested under similar conditions to allow direct comparison. The pressure-time and temperature-time graphs for each refrigerant were analyzed over 24 cycles, where pressure drops determined hydrate formation. Results showed that R-1234ze exhibited a hydrate formation temperature of 11.5°C and pressure of 4.51 Pa, outperforming all tested refrigerants. R-1234yf formed hydrates at 8.69°C and 4.56 Pa, showing lower efficiency. R-134a and R-410A required higher pressures (4.5–11.28 Pa), making them less energy-efficient. The presence of SDS significantly enhanced hydrate formation, lowering pressure by over 50% across all refrigerants, while CTAB exhibited a moderate effect on improving formation condition. This suggests R-1234ze as a viable replacement for conventional refrigerants. The study provides important benchmarks for optimizing HBD systems, advancing sustainable desalination technology and improving energy efficiency, safety, and environmental impact.

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