Novel Contact Liquid for Energy-Efficient, Cost-Effective, and Scalable Cryogenic Carbon Capture

Alqarni, Areej (School: Al-Batool International School)

With rising carbon dioxide (CO_2) emissions accelerating climate change, carbon capture technologies have become essential. Cryogenic carbon capture (CCC) leverages low temperatures to separate CO_2 from gas streams containing SO_x, NO_x, nitrogen, and other components. However, CCC's scalability is hindered by the volatility of isopentane, the conventional contact liquid, compromising stability. This study aims to enhance CCC efficiency, stability, and environmental impact by developing novel contact liquid blends. Blends of ethanol, ethyl acetate, and isopentane were formulated at 4:1 and 4:2 ratios and characterized using Fourier-transform infrared spectroscopy, gas chromatography, and differential scanning calorimetry to assess volatility, thermal stability, and phase-change properties. CO_2 capture efficiency was tested using a 10:90 CO_2-to-nitrogen gas stream, measured with a Testo gas analyzer. Optimal performance conditions were determined by varying temperature and CO_2 concentration. Pilot-scale testing was conducted using a CCC trailer to evaluate energy consumption, refrigerant loss, and pressure stability. FTIR, GC, and DSC analyses confirmed reduced volatility and enhanced thermal stability of the novel blends, making them suitable for cryogenic conditions. A 4:1 ethyl acetate–isopentane blend achieved 100% CO_2 capture efficiency, surpassing isopentane's 85%. Stability was maintained at -95°C across varying CO_2 concentrations. Pilot-scale testing showed improvements over isopentane, with energy consumption decreasing by 13.84%, refrigerant loss by 35.76%, and pressure fluctuations by 52%. These findings demonstrate CCC's capacity to eliminate point-source CO_2, highlighting its potential for negative carbon emissions and global industrial applications.

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