83a A Continuous-Jet Hydrate Reactor for the Formation of Co_2 Hydrate Particles: Hydrate Formation and Dissolution in a High-Pressure Water Tunnel Facility

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At relatively high-pressure and low-temperature conditions, some gases form solid clathrate structures with water known as gas hydrates. These structures are supported by the gas molecules which are trapped in cages formed by hydrogen-bonded water molecules. In this work, a three-phase Continuous-Jet Hydrate Reactor (CJHR) has been developed to produce dense CO_2 hydrate particles for the purpose of ocean carbon dioxide sequestration. The CJHR injector/reactor will be described and experimental results using a High-pressure Water Tunnel Facility (HWTF) at the National Energy Technology Laboratory (NETL) will be presented and discussed. The inputs to the reactor are liquid CO_2 and seawater and the output is composite particles containing CO_2 hydrate, unreacted liquid CO_2, and seawater. Injections of composite particles were performed at pressures equivalent to 1200-1800 m depth and temperatures of 3-5 °C. Immediately after injection, the cylindrical particles were observed to break off of the injector tip and aggregate into sinking clumps. The water in the tunnel was then counter flowed to suspend the particles, and images of the particles were continuously recorded for later analysis. After several minutes, the clumps were observed to break up into discrete particles. Selected particles were then studied until they became too unstable to follow. The particles initially sank at rates of 10-50 mm/s and then sank more slowly as they shrank in size. Particles were observed to dissolve at $5\text{-}10\times10^{-6}$m/s. CO_2 hydrate dissolution at intermediate ocean depths was modeled using pseudo-homogeneous and heterogeneous mass-transfer models to predict dissolution rates under different operating conditions. The pseudo-homogeneous model predicts a linear decrease of the particle diameter with time, and mass transfer inside the hydrate layer controls the global dissolution process, while the two-step heterogeneous model predicts a more complex behavior.