Gas Hydrate Wall Film Growth as a Precursor to Pipeline Blockage

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In subsea oil and gas pipelines, high-pressure reservoir fluids will cool upon exposure to the cool subsea environment. At low temperature, small hydrocarbon molecules (e.g. methane) and liquid water will react to form gas hydrate particles, which may fully occlude and block the pipeline. Conventional management strategies focus on complete avoidance of hydrate by removing the pipeline's conditions out of the hydrate stability zone. In deep-water systems, this avoidance strategy may be economically unviable. In order to move toward a hydrate management strategy, the mechanism of hydrate blockage formation must be well characterised. Limited studies have suggested a hydrate film may form on the pipeline wall early in hydrate blockage formation, but this phenomenon has not been directly observed to date. This study introduces a new suite of high-pressure sapphire autoclave experiments, where gas hydrate plugs were formed over a range of watercut (10-100 vol% of the liquid phase) and hydrate inhibitor (0-30 wt% monoethylene glycol) conditions. Visual observation of the sapphire cell informs a new conceptual picture for hydrate blockage formation, where initial hydrate nucleation is consistently proceeded by the formation of a hydrate film at the wall. The growth and annealing rate of this film was found to depend on both hydrate guest availability and the driving force for growth. The film plays a critical role in enabling the formation of a moving hydrate bed at the gas-water or oil-water interface, and the deposition of solid hydrate particles or aggregates in the latter stages of hydrate plug formation. This data informs a new approach to hydrate management strategies, where the prevention of hydrate film formation, as opposed to complete prevention, may enable a transportable slurry with a controlled hydrate volume fraction.