# Modeling and Validation of a Pilot-Scale Falling-Film Evaporator

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**Abstract**: Falling-film evaporators are widely used for handling heat-sensitive products, but their non-linear dynamics and fluid retention can make them difficult to control. Because standard physical equations do not account for variations in real-world equipment, they may be supplemented with empirical relations derived from plant data. However, using purely data-driven black-box models may lead to physical inconsistency and may require large data sets.

This work presents a hybrid modeling approach implemented on a pilot-scale falling-film evaporator. To ensure physical validity and data efficiency, a mechanistic model is employed to describe the core fundamental mass and energy balances. This baseline is supplemented with data-driven modules to capture equipment-specific effects such as variations in heat transfer coefficients and liquid residence times. To calibrate the model, the pilot-scale falling-film evaporator was operated across multiple setpoints, systematically varying feed flow rates, sugar concentrations, and product discharge rates to capture both transient and steady-state behavior.

The hybrid model is evaluated by direct comparison against the standalone first-principles baseline. Performance is quantified by the prediction accuracy of individual trajectories during both transient and steady-state periods. Ultimately, this integration of data-driven elements provides a method for utilizing experimental plant data to support the development of process monitoring and control.

*Keywords*: Hybrid modeling, pilot-scale, falling-film evaporation, parameter estimation