Abstract

Accurate temperature regulation in liquid mixing systems is essential in many domestic and industrial applications. However, achieving precise and stable outlet temperature is challenged by disturbances such as variations in inlet flow rates, inlet temperatures, and nonlinear valve behavior. Conventional mechanical mixing systems lack sufficient accuracy and require continuous manual adjustment, while existing automated designs rely on a single feedback loop monitoring only the final mixed outlet temperature, leaving them unable to detect or respond to hydraulic disturbances until after the outlet temperature has already deviated from the desired setpoint.

This project presents the design, physical implementation, and experimental evaluation of a temperature controlled liquid mixing system that overcomes these limitations, in which two liquid streams at different temperatures are automatically blended to achieve a desired outlet temperature based on a user defined setpoint value.

This project deals with the development of an energy balance based mathematical method for calculating initial valve opening positions based upon the measured inlet temperatures, inlet flow rates, and the user defined setpoint temperature, the selection and characterization of system components, the mechanical and electrical assembly of the complete prototype, and the experimental evaluation of the proposed temperature controlled liquid mixing system. A systematic step by step development methodology is adopted, ensuring that each subsystem is individually validated before full system integration.

The open loop behavior of the physical system was first analyzed, revealing steady state errors primarily attributed to valve nonlinearity within certain operating regions and interpolation inaccuracies in the lookup tables, which highlighted the need for feedback control to achieve precise temperature regulation. To address this, a discrete nudging based closed loop control strategy was developed and experimentally validated, successfully reducing the maximum steady state error to within ± 0.5 °C of the desired setpoint across all tested setpoint temperatures. A disturbance handling strategy was further implemented to detect and correct changes in inlet flow rates and inlet temperatures, employing dual threshold detection and multi stage settling verification to correctly identify real disturbances while avoiding false triggering, restoring the mixed outlet temperature to within ± 0.5 °C of the desired setpoint following all tested disturbances.