

## **Abstract**

An adaptive control system for plasma protein fractionation dynamically regulates precipitant addition using real-time feedback. A sidestream from the precipitation vessel is analyzed by integrated sensors (e.g. turbidity, ultrasonic, and optional UV absorbance after micro-filtration) to assess precipitation progress. A controller computes the protein precipitation level and modulates a reagent pump accordingly, minimizing overshoot and optimizing yield. The dosing hardware comprises a multi-axis micro-dosing manifold of gear pumps feeding a ring injector, capable of precise microliter additions under closed-loop control. The system supports various sensor modalities (optical, acoustic, dielectric, particle analysis) and advanced algorithms (model-predictive, rule-based, machine-learning anomaly detection) to adapt dosing in real time. Self-calibrating features (auto-zero test loops) and cloud connectivity (remote machine-learning model updates) further enhance performance. The entire apparatus is CIP/SIP or single-use compliant and maintains aseptic conditions, providing improved efficiency and consistency in protein precipitation processes.