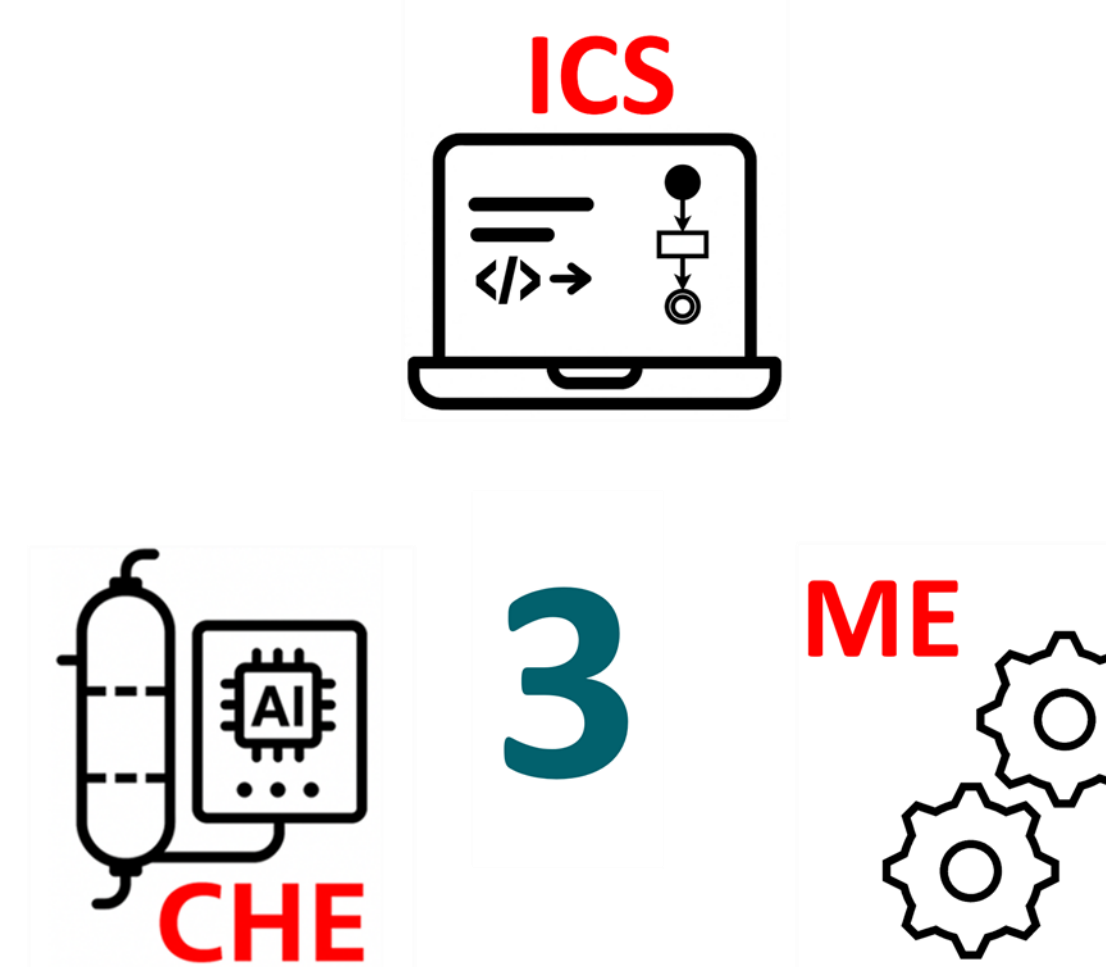


Intelligent Monitoring and Predictive System for Distillation Column Optimization

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Coach: Majed Al-Zayer



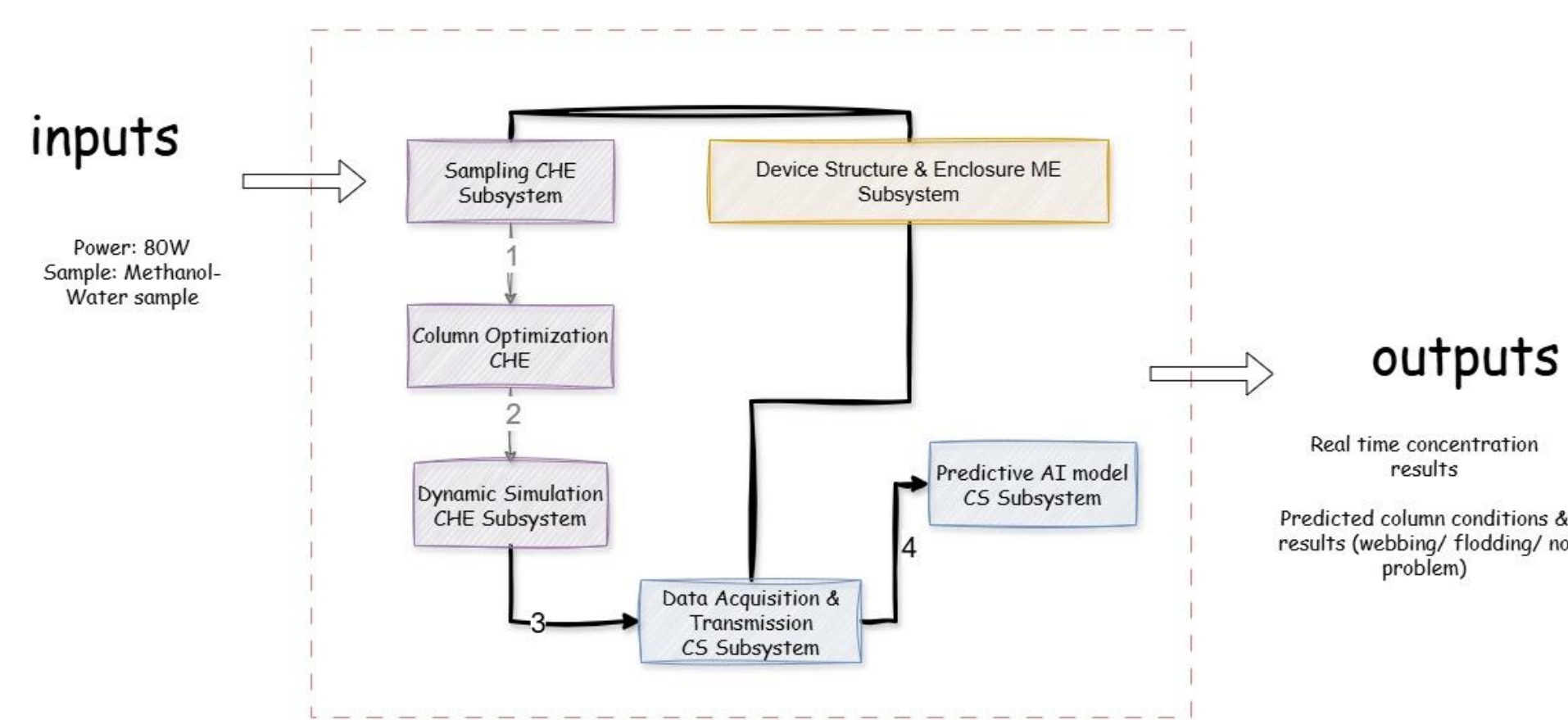
Introduction

An AI model trained on distillation simulations and validated with an ethanol-water prototype quickly identifies operating conditions and suggests heat and flow adjustments to keep the column stable and efficient.

Problem Statement

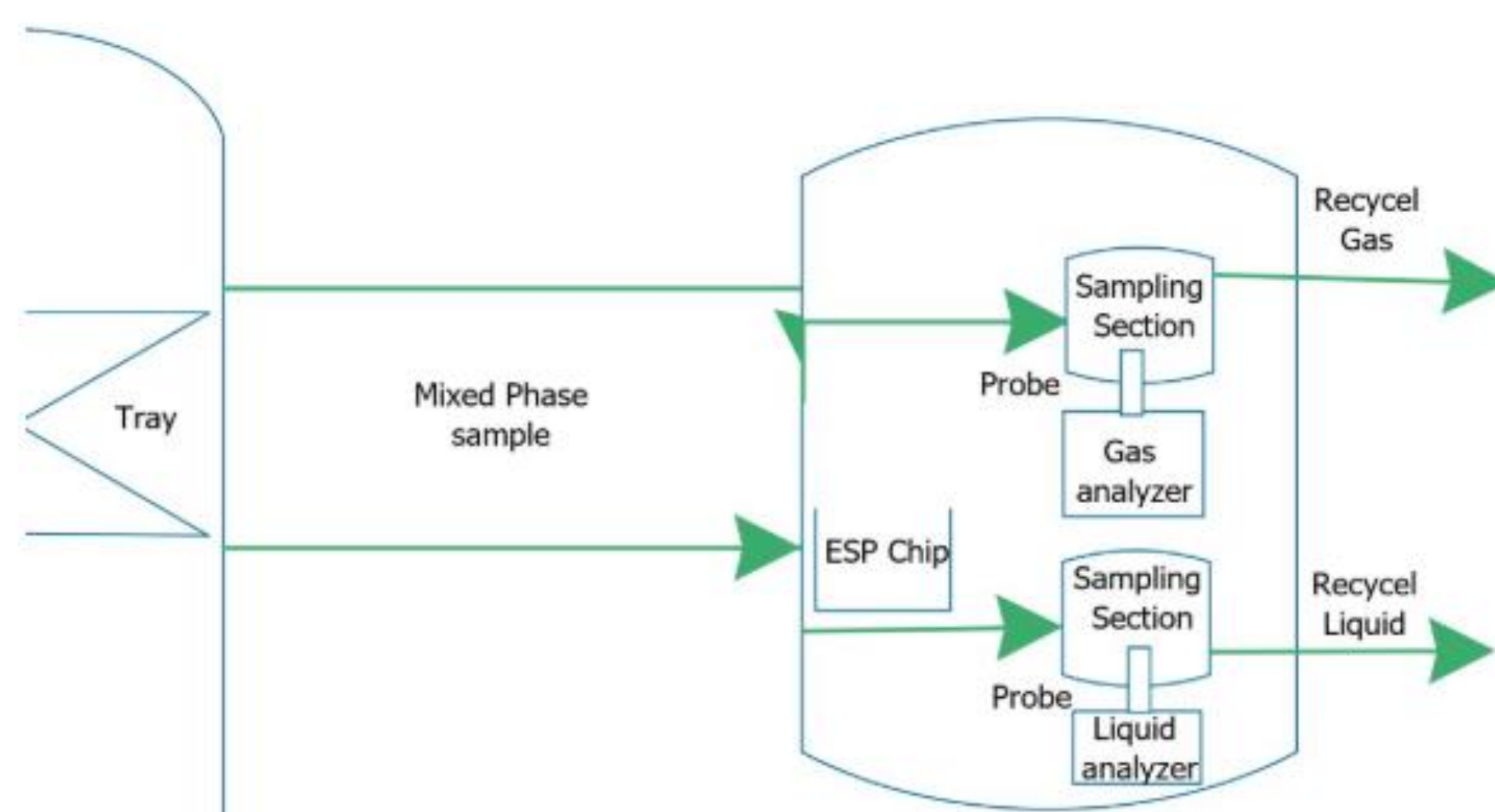
Distillation columns often fail to maintain product specifications due to undetected weeping and flooding issues. Our optimized online sampling and AI-based monitoring system provides prediction of these issues and recommends corrective actions before their occurrence, maintaining product quality.

Deliverables

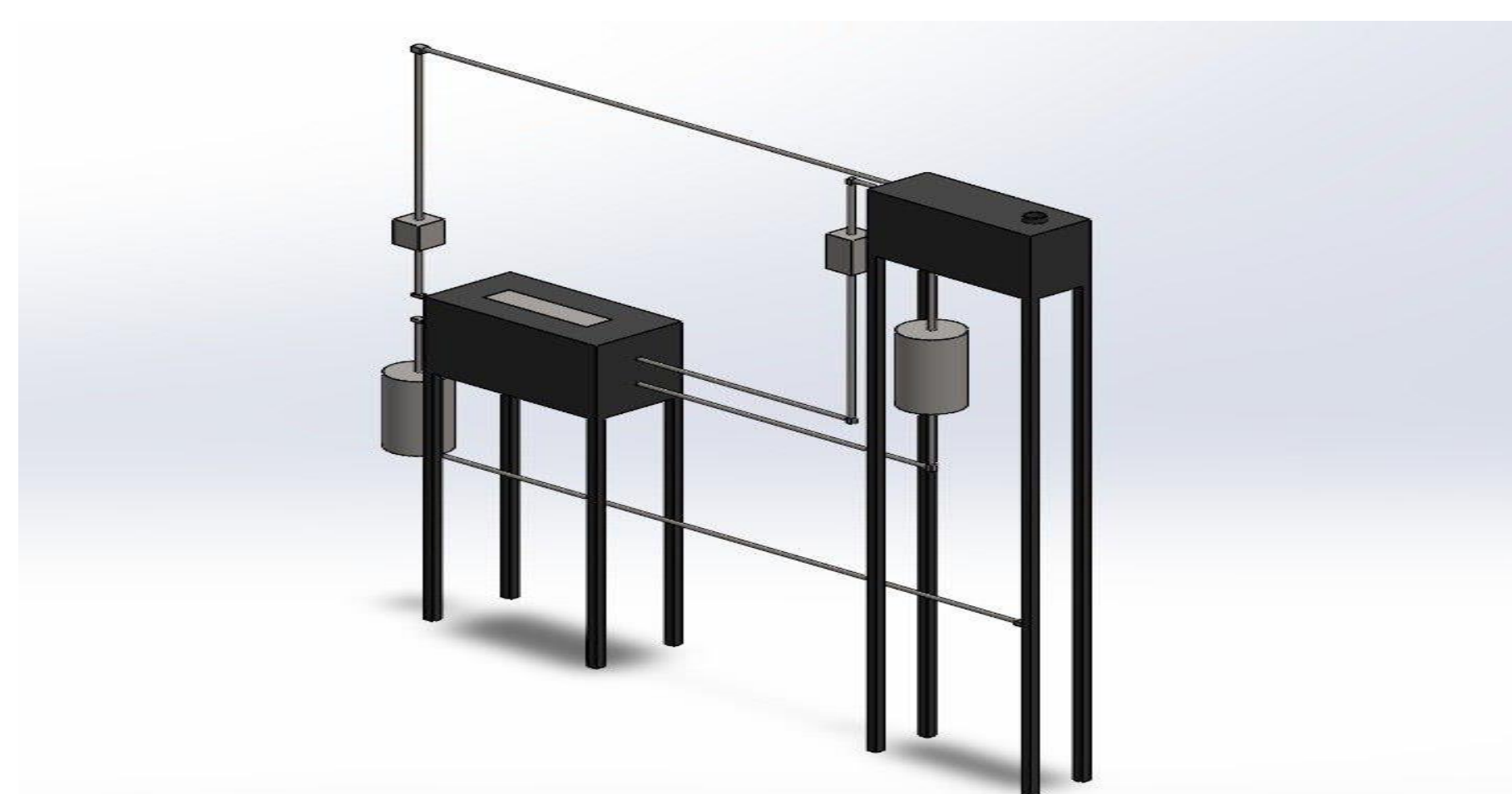


Multidisciplinary Roles

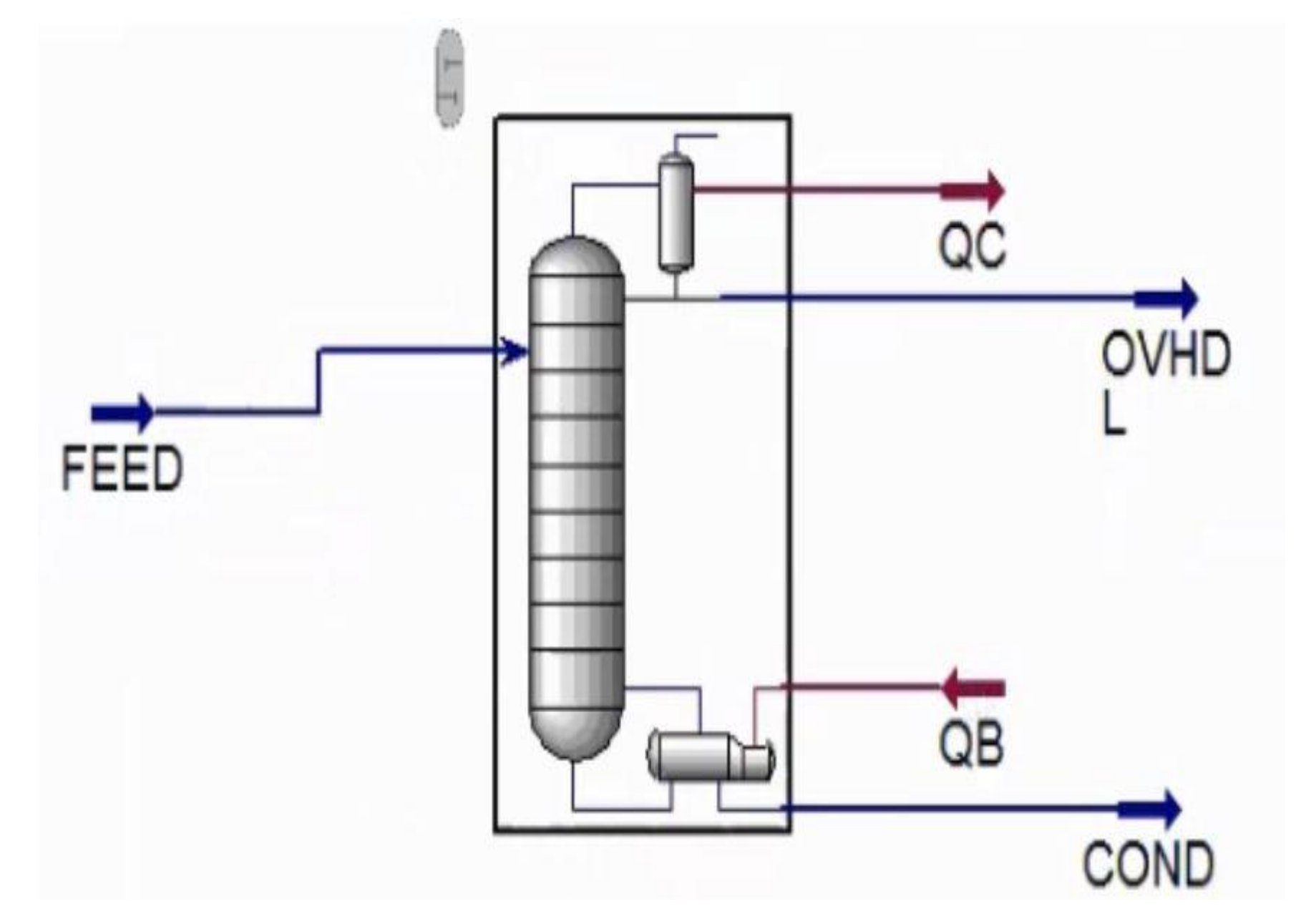
Prototype



Prototype Industrial Use

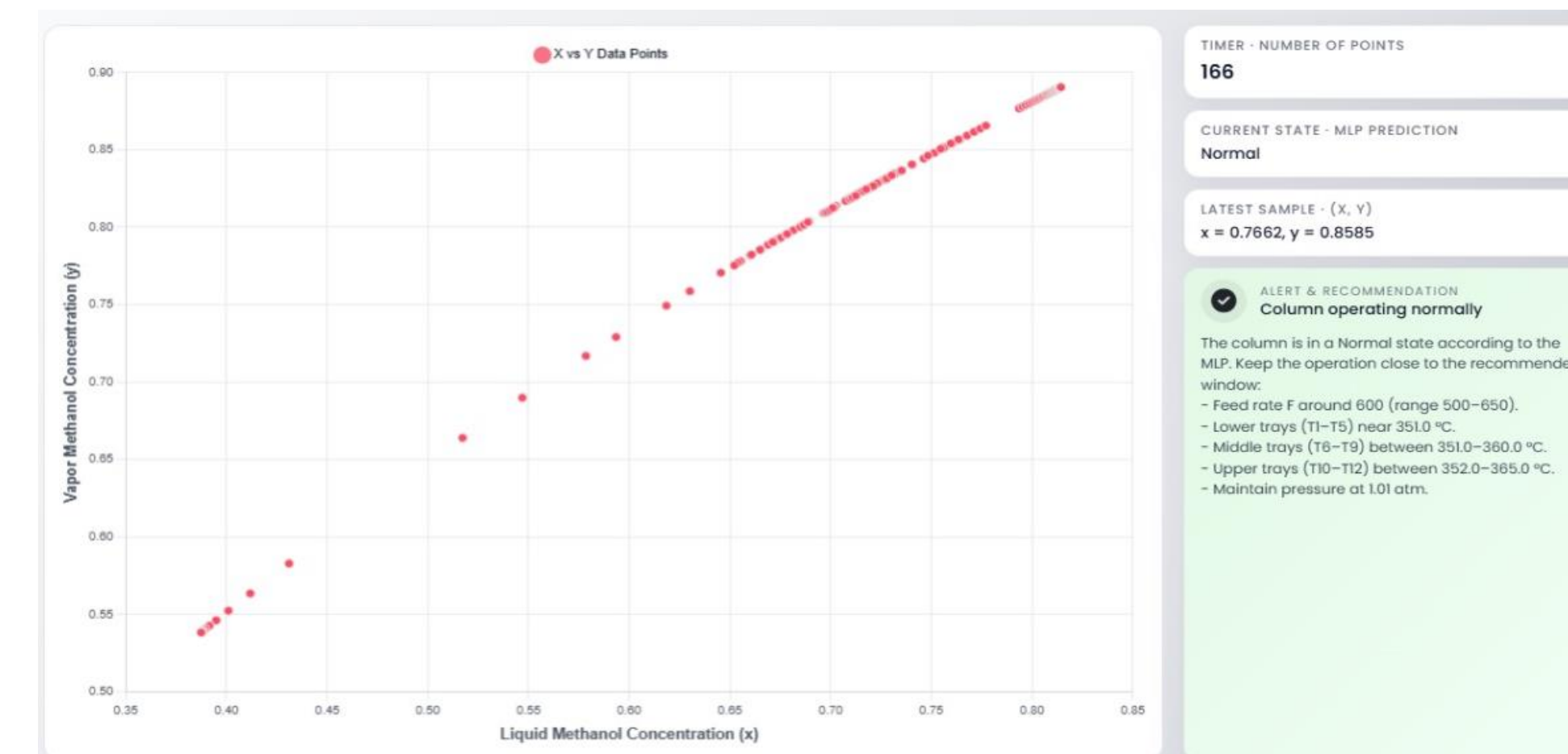


Designed Prototype Scheme

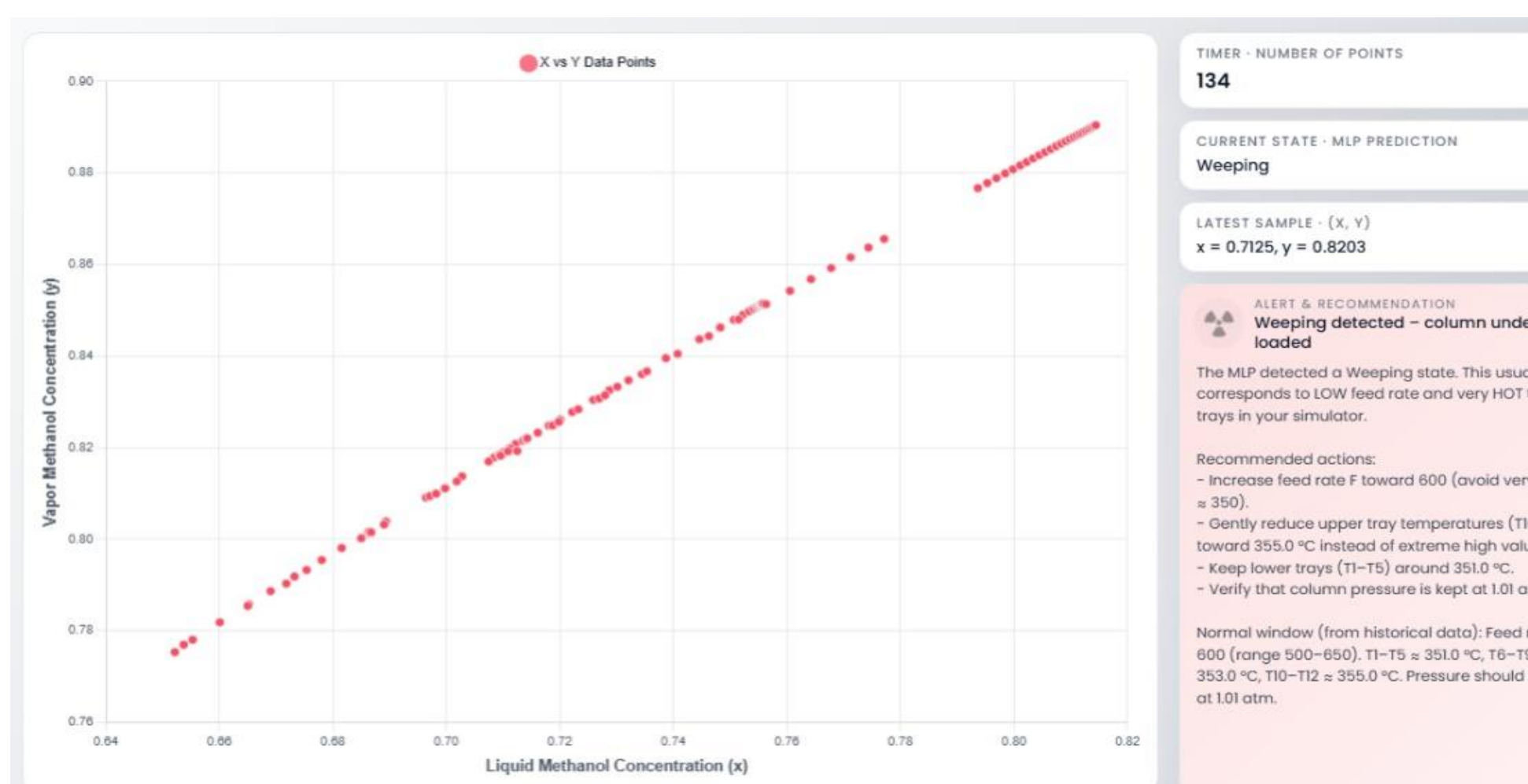


Dynamic Simulation

Achievements



Predicted Column Conditions



Recommendation of Predicted Weeping

Test and Validation

$$\begin{aligned} \text{Volume of Tray} &= 13 \times 19 \times 7 = 10 \times 16 \times 7 = 609 \text{ cm}^3 \\ \text{Volume of Analyzer Box} &= 15 \times 10 \times 20 = 12 \times 10 \times 17 = 960 \text{ cm}^3 \\ \text{Total Volume} &= V_1 + V_2 = 1569 \text{ cm}^3 \quad \angle \quad S_{\text{Spec}} V = 150 \times \pi \times 50^2 = 1177500 \text{ cm}^3 \\ \text{Volume of Analyzer Box} &= 15 \times 10 \times 20 = 12 \times 10 \times 17 = 960 \text{ cm}^3 \\ \text{Total Volume} &= V_1 + V_2 = 1569 \text{ cm}^3 \quad \angle \quad S_{\text{Spec}} V = 150 \times \pi \times 50^2 = 1177500 \text{ cm}^3 \\ \text{Density of Cast Iron} &= 7.1 \text{ g/cm}^3 \rightarrow m = V \rho = 6.11 \text{ kg} \quad \angle \quad 7 \text{ kg} \\ \text{Max Power} &= 12 + 12 + 5 + 5 + 10 + 10 = 54 \text{ W} \quad \angle \quad 80 \text{ W} \\ \text{Liquid Flowrate} &= 24 \text{ L/H} = 0.4 \text{ L/min}, \text{ Vapor Flowrate} = 0.2 \text{ L/min}, \Delta P = 160 \left(1 - \frac{0}{1.8}\right) \\ \Delta P_L &= 124.4 \text{ Psi}, \Delta P_V = 142.22 \text{ Psi} \end{aligned}$$



Gas and Liquid Flowrates

Constraints and Specifications

- CH CHE CHEMICAL ENGINEERING**
 - C1 Continuous run ≤ 2 hours before recalibration/shutdown
 - C2 Operate in non-corrosive service at ≤ 1 atm
 - \$1 Sample volume per cycle: 5-10 mL
 - IS1 Product purity $\geq 98\%$ (Aspen verified; steady + dynamic)
 - IS2 Energy use reduction $\geq 50\%$ vs manual baseline
- CC ICS COMPUTER SCIENCE / CONTROL**
 - C1 AI inference runs on server only (not on ESP32)
 - C2 Valid only for single-phase liquid; vapor fraction > 0.2 (no slurries/multiphase)
 - \$4 Data transmission ≥ 1 Hz
 - \$5 Processing-to-dashboard latency ≤ 3 s
 - \$6 Flooding/weeping alert: ≥ 5 min horizon; $\geq 80\%$ threshold
 - IS3 Dashboard latency < 1 s; polling ≤ 2 s
- ME ME MECHANICAL ENGINEERING**
 - C1 Housing mass ≤ 5 kg
 - \$7 Envelope ≤ 150 cm (H) $\times 100$ cm (D)
 - \$9 Total system mass ≤ 7 kg
 - \$11 Tool-free mounting
- SHARED**
 - C6 Vapor fraction $0.2 \leq Z \leq 0.8$ is difficult to maintain
 - \$10 Peak power ≤ 80 W

Conclusion

The prototype demonstrates that distillation column performance issues can be predicted before they occur. The model identifies early indicators of instability and recommends corrective actions to prevent these conditions, ensuring stable operation and consistent product quality.