

2) SRS — System Requirements Specification

2.1 Definitions

- **θ-axis:** rotational axis of baking plate.
- **Trim valve:** per-branch flow adjuster downstream of the manifold.
- **CIP:** cleaning-in-place routine for wetted parts.

2.2 Functional Requirements (Fxx)

- F-01** The system shall rotate the plate at **1.0 rev/s** ($\pm 1\%$) during dispense.
- F-02** The system shall deposit batter via **7 nozzles** forming concentric rings.
- F-03** The system shall control the pump to deliver **28.3 mL/s** ($\pm 5\%$) total during the 5s dispense.
- F-04** The system shall provide per-nozzle **trim adjustment** to achieve target **mL/s** proportional to ring radius.
- F-05** The system shall regulate plate temperature to **210–230 °C** with **$\pm 3 °C$** steady-state error.
- F-06** The system shall home the θ-axis using a hub sensor and prevent motion if homing fails.
- F-07** The system shall provide an HMI to set temperature, start/stop cycle, and display alarms/status.
- F-08** The system shall log temperature, cycle count, and alarms once per second (min.).
- F-09** The system shall support **CIP mode** (pump rinse sequence without heat).
- F-10** The system shall expose a serial/USB debug interface for service.

2.3 Safety Requirements (Sxx)

- S-01** The system shall implement an **E-stop** with **two NC channels** that **hard-disable** θ-enable and SSR control.
- S-02** The system shall implement a **cover interlock** (NC) in series with the safety chain.
- S-03** The system shall include a **thermal cutoff** device in series with the heater.
- S-04** The MCU shall mirror safety states but shall **not** be required to remove power.

2.4 Performance Requirements (Pxx)

- P-01** Cycle time per injera: **$\leq 5.0 \text{ s}$** ; jitter **$\leq 0.2 \text{ s}$** after warm-up.
- P-02** Plate temperature stability: **$\pm 3 °C$** at load steps of $\pm 25\%$ flow.
- P-03** Flow accuracy: total **$\pm 5\%$** ; per-ring **$\pm 10\%$** after trim.
- P-04** Repeatability: diameter **$\pm 2 \text{ mm}$** , thickness **$\pm 0.3 \text{ mm}$** .
- P-05** Noise: < **75 dBA** at 1m during steady operation (goal).

2.5 Environmental & Regulatory (Exx)

- E-01** Operating: **15–35 °C**, 20–80% RH non-condensing.
- E-02** Materials: food-contact **SS304/316**, food-grade tubing.
- E-03** Electrical: earthing per applicable standards; segregated AC/24V wiring.
- E-04** EMC/LVD readiness for CE marking (documentation in technical file).

2.6 Interfaces (Ixx)

I-01 Mechanical: Plate Ø450 mm, nozzle arm with **7 outlets**, manifold with **7 equal-length branches**.

I-02 Electrical: 230 VAC mains; 24 VDC bus for controls; terminal blocks on NS35 rail.

I-03 Sensors/Actuators: PT100 (3-wire) to MAX31865 (SPI), SSR output, TB6600 STEP/DIR/EN, θ home switch, LEDs, buzzer, E-stop, cover switch.

I-04 HMI: 24 V panel or UART3 (115200 8N1); minimal Modbus/serial protocol optional.

2.7 Data & Logging (Dxx)

D-01 Log at 1 Hz: plate temp, pump duty, θ RPM, E-stop/cover states, cycle count, faults.

D-02 Store last **1,000 cycles** in non-volatile memory or export via UART.

2.8 Reliability & Maintainability (Rxx)

R-01 MTBF target for electronics: **>20,000 h** (bench-top estimate).

R-02 Replaceable parts: SSR, RTD probe, nozzles, tubing, stepper driver, NEMA23 motor, E-stop head.

R-03 CIP time: **≤30 min**; tool-less nozzle removal preferred.

2.9 Verification (Vxx) — Testable Criteria

- **V-01:** Demonstrate 10 consecutive cycles at **≤5.0 s** with thickness in spec.
- **V-02:** Step change ±25% load; hold **±3 °C** at plate.
- **V-03:** Measure per-nozzle flow vs. targets; each within **±10%** after trimming.
- **V-04:** E-stop opens both NC channels; θ-EN and SSR_CTRL low within **<50 ms**.
- **V-05:** Cover interlock halts motion/heat; alarm on HMI.
- **V-06:** Thermal cutoff opens at rated temperature.
- **V-07:** EMC pre-scan passes (no functional upset); L/N leakage within limits.

2.10 Dependencies & Risks

- Batter viscosity variability → mitigated by trim valves and recipe calibration.
- Thermal gradients across plate → mitigated by sensor placement and insulation.
- Pump wear/tubing set → mitigated with PM schedule and spare kits.

2.11 Acceptance

This SRS is accepted when the verification items **V-01..V-07** are met on a pilot machine, and KPIs in the PRD section **1.4** reach targets during a full 8-hour run.

End of PRD v1.0 Draft