

## 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 5 s 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:  **$\leq 5.0$  s**; jitter  **$\leq 0.2$  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  **$\pm 2$  mm**, thickness  **$\pm 0.3$  mm**.
- P-05** Noise:  **$< 75$  dBA** at 1 m 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,  $\theta$  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,  $\theta$  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:  **$\leq 30$  min**; tool-less nozzle removal preferred.

## 2.9 Verification (Vxx) — Testable Criteria

- **V-01:** Demonstrate 10 consecutive cycles at  **$\leq 5.0$  s** with thickness in spec.
- **V-02:** Step change  $\pm 25\%$  load; hold  **$\pm 3$  °C** at plate.
- **V-03:** Measure per-nozzle flow vs. targets; each within  **$\pm 10\%$**  after trimming.
- **V-04:** E-stop opens both NC channels;  $\theta$ -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.

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**End of PRD v1.0 Draft**