

NanoArc 5 g PCM Test-Cell Family

Design, Procurement, and Fixture Specification

Status	Approved plan; hardware not procured, built, or qualified
Revision	Rev0
Date	2026-08-13
Authority	Tristan retains design, safety, approval, and disposition authority
Programme	RevB characterization with possible later Rumi/RevC application
RevA impact	None

Definition. A PCM test cell is a discrete thermal-energy-storage specimen container used for preparation, cycling, observation, and comparison. It is not an electrochemical cell.

Boundary. The cell and fixture are non-pressure-rated laboratory apparatus. They do not establish a cartridge design, safety claim, firmware policy, or Rumi duty-cycle credit.

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Design intent

The family standardizes the external envelope, 5.000 g specimen mass, closure, fixture datums, identification, sensing location, and test environment across pure SAT controls and nucleator screens. Route mechanisms remain attributable.

The initial fixture operates one cell sequentially in a stirred water bath. Three independently prepared cells are required for every formal condition; repeated cycles in one cell are not independent specimens.

Cell family

Variant	Purpose	Rev0 implementation
STD	Pure SAT, seeded control, chemical nucleator	Common vial and closure
COLD	External cold-spot trigger	STD cell with unobstructed marked contact area; trigger tool deferred
RSEED	Retained SAT seed	Interface reserved; insert geometry deferred pending measured gradients

All experimental cells use a 5.000 g total specimen. The RSEED main charge remains 5.000 g; its later seed-pocket mass is recorded separately.

Glass envelope

Pilot baseline:

- clear 10 mL Type-I borosilicate serum vial;
- nominal 24 mm outside diameter by 50 mm height;
- nominal 20 mm crimp finish;
- flat or manufacturer-standard serum-vial bottom;
- matching clean 20 mm butyl stopper;
- pilot quantity: 25 vials plus at least 25 stoppers.

The current small-quantity candidate is the BuyNeedles 10 mL clear serum vial, listed at CA\$1.25 each, with a matching 20 mm stopper listed separately. Confirm current dimensions, stock, price, shipping, glass declaration, stopper identity, and lot information before purchase.

Closure

Seat the butyl stopper consistently. PTFE tape around the exterior stopper/neck seam is secondary vapour control; it is not structural retention and does not make the vial pressure-rated.

A reusable rigid screw retainer advances only to a measured fixed stop. It holds the seated stopper against displacement but cannot apply arbitrary additional compression. Establish its stop position using water blanks. Do not substitute “tighten until secure.”

The fixture must include transparent fragment/splash guarding and secondary containment. Never open a hot cell or force a stuck closure.

Identification and records

Mark the vial above the bath line using heat-resistant paint or marker. Duplicate the unique ID on an engraved metal fixture tag and the run sheet. Never engrave, scratch, or mechanically score the

glass.

Each cell record includes:

- cell ID, variant, formulation, specimen batch, and replicate;
- vial and stopper supplier, part number, lot, and incoming inspection;
- measured vial dimensions and empty mass;
- component masses, filled mass, closure method, and calculated headspace;
- sensor placement photograph, cycle history, video reference, faults, and disposition.

Reusable fixture

Mechanical arrangement

- One vial runs at a time in a stirred 500 mL water bath on the SH-2.
- A metal cradle locates the vial without glass-to-glass or glass-to-heater contact.
- A top frame carries the fixed-stop closure retainer and prevents cell movement.
- Hot, structural, and wetted components are metal and made with hand tools.
- PETG may align or guard components only above the bath and away from hot glass.
- PLA or PLA+ may serve as room-temperature templates, never hot structural parts.
- Every printed part has a functionally equivalent hand-built metal fallback.

The holder must expose the marked COLD wall area and must reserve overhead space for a later RSEED closure insert without defining either mechanism.

External temperature sensing

Tape the DMM thermocouple bead to a dry, marked upper-wall datum aligned as closely as practical with the measured specimen fill region. Keep the bead and Kapton tape above the bath water. Standardize:

- tape manufacturer and lot;
- bead orientation and marked height;
- number and width of tape wraps;
- lead strain relief;
- placement photograph before every run.

The cell-wall channel is paired with a household thermometer in the stirred bath. Calibrate both together in an ice-water slurry and one stirred hot-water point before every campaign. A webcam records both displays and a visible clock.

This arrangement measures a repeatable wall proxy, not the bulk specimen directly. Determine wall-to-bath offset and lag during qualification.

Operating envelope

- Begin closure qualification at 25-65 C, then qualify separately at 25-80 C.
- Characterize actual heating and cooling curves before claiming 0.5 C/min ramps.
- Keep stopper, PTFE seam, identifier, and cell thermocouple dry.
- Do not permit vigorous bath boiling, bath boil-dry, unattended operation, or firmware-only over-temperature protection.
- Stop on leakage, stopper movement, glass damage, sensor disagreement, abnormal pressure indication, uncontrolled heating, or guard failure.

A future ACE-derived controller may automate profile generation and logging, but may not redefine cell geometry, safety stops, or evidence already collected.

Route interfaces and deferred work

Chemical nucleators

STD directly supports SAT-0, SAT-SEED+, SAT-SS5, SAT-CA05, and other approved 5.000 g formulations. Formulation arithmetic remains based on total specimen mass.

Cold-spot triggering

COLD is physically identical to STD. Reserve a visible, obstruction-free wall patch and repeatable fixture datum. Design the copper cold finger only after standard cells establish thermal lag, contact accessibility, and condensation behaviour.

Retained seed

Do not fabricate an RSEED insert at Rev0. First map temperatures near the main charge, neck, stopper, and fixture during empty and standard-cell 65 C and 80 C holds. The later insert must provide a communicating seed pocket, prevent seed fall-through and bulk convection, avoid pressure trapping, and demonstrate a seed temperature below 55 C with at least 3 C steady-state margin.

Procurement baseline

Item	Initial quantity	Acceptance evidence
10 mL Type-I clear borosilicate serum vial, 20 mm finish	25	Product declaration, dimensions, lot
Matching 20 mm butyl stopper	At least 25	Material, size, lot, temperature suitability
PTFE tape	1 documented roll	Manufacturer/lot, clean condition
Kapton tape	1 documented roll	Manufacturer/lot, width, temperature rating
Metal cradle/retainer stock and fasteners	1 fixture set	Dimensions and material recorded
Transparent guard and secondary tray	1 each	Fit and hot-water compatibility
Cell ID paint/marker and engraved metal tags	25 IDs	Legibility after bath cycling

Do not purchase from a listing that cannot establish glass type, closure fit, or dimensions. Procurement approval remains Tristan's decision.

Acceptance and disposition

The design advances only after the companion qualification protocol passes its incoming inspection, fit, water-blank, sensing, logging, and staged thermal tests. The current 0.01 g scale supports pilot leakage screening only. A 0.001 g scale is required before claiming the formal 0.2% mass-retention gate for a 5.000 g cell.

Archive representative successful cells intact when storage permits. Record any opening, recovery, breakage, disposal, or inability to archive. A shared note or single successful cycle is not qualification evidence.

References

1. J. Li, M. A. Parkes, and C. G. Salzmann, *Crystal Growth & Design* 24 (2024), 8292-8300, DOI 10.1021/acs.cgd.4c00691.
2. Chemistry/SAT/NanoArc_SAT_Crystallization_Route_Plan_Rev0.md.
3. Chemistry/Proposals/NanoArc_PCM_Cartridge_PCM_Reconciliation.md.