

NanoArc Hydrogel Electrolyte-Carrier Screen

Calcium Alginate and Agar Coupon Programme

Programme	HYDROGEL-CARRIER-001
Status	Approved plan; materials not procured or tested
Revision	Rev0
Date	2026-08-13
Budget	CA\$60 before shipping, excluding owned reusable tools
Authority	Tristan retains experiment, safety, and disposition authority
RevA impact	None

Purpose. Compare calcium alginate and ordinary agar as passive carriers for a benign conductive liquid. The programme measures repeatability, impedance, leakage, drying, compression recovery, and handling before any plating chemistry or pen hardware is introduced.

Boundary. This is a low-energy material screen, not electroplating. No DC source, metal-bearing electrolyte, plating coupon, ACE connection, or NanoArc hardware is permitted. Food-grade sourcing does not make laboratory specimens edible.

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Objective and decision

The screen answers one question: which gel can repeatedly hold and conduct a standard saline solution while remaining mechanically usable as a future wet contact? It does not attempt to optimize a pen tip or predict performance with metal ions.

The two routes share specimen geometry, saline concentration, equilibration, electrodes, compression, measurement settings, and acceptance gates. Recipe changes during the campaign are prohibited. If both routes fail, the result is a valid baseline for a later concentration screen.

Decision rule

A route must pass every hard gate before electrical ranking. Among passing routes, the lower stable median 1 kHz impedance wins. Lower drying drift breaks a tie. A visually attractive gel cannot win by bypassing repeatability, containment, or handling requirements.

Programme boundaries

- Coupon materials only; no mock pen or reservoir.
- No copper, nickel, zinc, citrate, sulfate, plating salt, or unknown additive.
- No DC resistance measurement, bench supply, electrolysis, or current forcing.
- No claim of plating compatibility or service life.
- No ACE, Dreadnaught, Service Key, firmware, connector, or shared-interface change.
- All containers, tools, and specimens become laboratory-only.

Procurement and identification

Material baseline

Code	Material	Required identity	Initial amount
ALG	Sodium alginate	Single ingredient, food or reagent grade; supplier and lot recorded	100 g or smallest economical pack
CA	Calcium chloride dihydrate	CAS 10035-04-8; documented hydrate and grade	100 g or smallest economical pack
AGR	Agar powder	Single ingredient, food grade; not a prepared dessert mix	100 g
NACL	Sodium chloride	Pure non-iodized reagent or pickling salt; no anti-caking additive if practical	100 g minimum
WATER	Distilled water	Sealed retail or laboratory container; lot/source recorded	2 L

The basket must remain at or below CA\$60 before shipping. Do not substitute agarose, premium bacteriological agar, calcium lactate, table salt with unknown additives, or an undocumented calcium-chloride hydrate merely to complete the order. If compliant materials exceed the cap, stop and return the basket to Tristan for sourcing review.

Incoming record

For each material, record the supplier, product name, package size, price, shipping allocation, ingredient statement, CAS number where provided, grade, hydrate state, lot, received date, storage condition, SDS location, and package photograph. Reject damaged, wet, unlabelled, or compositionally ambiguous stock.

Reusable apparatus

- 0.01 g scale;
- distilled-water-compatible glassware and dedicated utensils;
- hotplate and temperature probe for agar preparation;
- PETG coupon mould, nominal 20 mm diameter by 3 mm deep;
- vernier caliper or equivalent dimensional tool;
- fixed-stop impedance/compression fixture;
- two identical flat stainless-steel electrodes with 20 mm active diameter;
- FNIRSI LC1020E and its Kelvin leads;
- documented 100 g test mass;
- absorbent test papers and sealable labelled containers;
- camera or webcam, timer, gloves, and splash eye protection.

Above-bath printed parts are PETG. PLA or PLA+ may serve as dry templates only. Measure and record the actual mould and fixture dimensions before use.

Standard solutions and specimens

Common 0.100 M NaCl solution

1. Tare a clean container and weigh 2.922 g sodium chloride.
2. Dissolve in approximately 400 mL distilled water.
3. Transfer quantitatively to a graduated vessel and bring the final volume to 500.0 mL with distilled water.
4. Mix until clear, label NACL-0.100M, and record preparation time, temperature, material lot, actual mass, and final volume.

The 0.01 g scale supports this screening solution. Do not energize the solution with DC. Sodium chloride is selected only to avoid calcium-sulfate precipitation and citrate-driven calcium removal during this benign carrier comparison.

Calcium-alginate route

1. Weigh 2.00 g sodium alginate and prepare 100.0 mL total mixture with distilled water for a nominal 2.00% w/v alginate solution.
2. Add powder gradually with mixing. Cover and allow bubbles and dry agglomerates to clear; record the actual rest time.
3. Weigh 2.00 g calcium chloride dihydrate and prepare 100.0 mL total cross-link bath with distilled water for nominal 2.00% w/v.
4. Fill four measured mould cavities without entrained dry pockets.
5. Cross-link each specimen completely in the calcium bath for 60 minutes, turning once at 30 minutes without squeezing it.
6. Rinse each specimen twice for 30 seconds in separate distilled-water portions.
7. Assign ALG-2-R1, ALG-2-R2, ALG-2-R3, and destructive witness ALG-2-W.

Cut ALG-2-W through its centre after cross-linking. A liquid or paste-like core fails the batch. Do not extend only the measured specimens' treatment after seeing the witness; repeat the complete batch under a new campaign suffix.

Agar route

1. Weigh 2.00 g agar and prepare 100.0 mL total mixture with distilled water for nominal 2.00% w/v.
2. Heat with stirring until the agar is fully dispersed and the mixture is uniformly clear or consistently translucent. Record peak temperature and time; do not permit boil-dry.
3. Cool while covered to 55-60 °C, then fill four measured mould cavities.
4. Allow to gel undisturbed for 60 minutes at recorded room temperature.
5. Assign AGR-2-R1, AGR-2-R2, AGR-2-R3, and destructive witness AGR-2-W.

Cut AGR-2-W through its centre. A liquid core, dry powder pocket, or grossly nonuniform structure fails the batch.

Saline equilibration

Place the three intact specimens from each route in separate labelled covered baths of NACL-0.100M for 24.0 hours at room temperature. Use at least 10 mL solution per specimen. Never share equilibration liquid between routes. Record pre-soak and post-soak mass and dimensions.

Fixture and instrument controls

Fixed geometry

The fixture presents two clean, parallel stainless-steel electrodes to the flat faces of a 20 mm coupon. A mechanical stop fixes the electrode separation at the recorded specimen thickness; it must not depend

on operator grip. The fixture shall also provide a second stop at 80% of the specimen's initial thickness for compression cycling.

Before wet work, photograph the fixture and record electrode material, active diameter, separation, surface condition, cleaning method, lead attachment, and stop dimensions. Inspect for sharp edges that could cut a gel.

LC1020E configuration

1. Warm the instrument for 30 minutes.
2. Fit the same leads and fixture used for all specimens.
3. Perform open and short calibration at each selected frequency.
4. Select Z as the primary parameter, 0.1 V RMS, and 0.0 V internal bias.
5. Measure at 100 Hz, 1 kHz, and 10 kHz.
6. Record impedance magnitude and phase angle. The primary endpoint is 1 kHz.
7. Take five readings after the display stabilizes; do not cherry-pick readings.

Validate the assembled fixture using one documented resistor within the LC1020E's range before and after the wet session. A reference drift greater than 2% invalidates the session pending fixture inspection and recalibration.

Do not use the DMM resistance mode on the gel. DC polarization and electrode reactions would make the comparison time-dependent and would violate the non-electrolysis boundary.

Test sequence

Run all three alginate and all three agar replicates through the same sequence. Alternate route order between specimens so elapsed time does not systematically favour one material.

Stage A - incoming condition

- Blot each specimen with one identical, documented contact procedure; do not squeeze it.
- Record mass, diameter at two axes, thickness at three positions, appearance, surface liquid, tears, bubbles, and photographs.
- Record room temperature and relative humidity if available.

Stage B - initial impedance

- Install the specimen at the uncompressed fixed stop.
- Record five stable readings at 100 Hz, 1 kHz, and 10 kHz.
- Remove it and inspect the electrodes and specimen for residue or damage.
- Rinse and dry electrode surfaces identically before the next specimen.

Stage C - handling

Perform ten complete installation/removal cycles. A cycle includes alignment, closure to the uncompressed stop, reopening, and removal by hand without tools. Record fracture, permanent deformation, sticking, residue, or loss of a usable flat contact surface.

Stage D - compression

Perform ten cycles from the uncompressed stop to 80% initial thickness, hold for five seconds, and release. Do not exceed the stop. After five minutes of recovery, measure thickness at the same three positions and repeat the 1 kHz impedance measurement.

Stage E - controlled leakage

1. Weigh a clean absorbent test paper to 0.01 g.
2. Place the specimen on the paper beneath the documented 100 g test mass for five minutes using a flat load spreader.
3. Remove the specimen without wiping the paper and reweigh the paper.
4. Record transferred mass, wet-halo dimensions, free droplets, and photographs.

Transferred mass is a screening metric, not a vapour-loss measurement. Use a new paper for every replicate.

Stage F - open-air drying

Place each specimen on its own nonabsorbent labelled support. Record mass, diameter, thickness, appearance, and 1 kHz impedance at 0, 2, 8, and 24 hours. Record temperature and relative humidity whenever available. Do not rehydrate specimens during this stage.

Stage G - final inspection

Photograph both faces and the edge. Record cracks, curling, shrinkage, residue, electrode staining, biological growth, odour, tack, and handling condition. Retain representative specimens sealed and labelled until Tristan reviews the campaign disposition.

Analysis and acceptance

Calculations

For each route calculate:

- mean, median, range, and coefficient of variation for initial 1 kHz impedance;
- median post-compression impedance drift;
- individual thickness recovery after five minutes;
- transferred mass in the leakage test;
- mass, diameter, thickness, and impedance change through 24 hours.

Coefficient of variation is $100 \times \text{standard deviation} / \text{mean}$. Do not calculate it from fewer than three valid replicates.

Hard gates

Gate	Requirement
Internal cure	Witness has no liquid core, dry pocket, or gross nonuniformity
Handling	No fracture, free-running liquid, or loss of usable contact surface in ten cycles
Electrical contact	All replicates produce stable in-range readings at all three frequencies
Repeatability	Initial 1 kHz impedance coefficient of variation is at most 20%
Electrical durability	Route median 1 kHz drift after compression is at most 25%
Recovery	Every replicate returns to at least 90% of initial thickness after five minutes
Leakage	Every replicate transfers no more than 0.10 g in five minutes
Fixture integrity	Reference resistor drift is at most 2%; no electrode corrosion or fixture failure

Any single hard-gate failure prevents that route from winning. Report all data; do not discard an inconvenient replicate unless a separately documented fixture or operator fault invalidated it before the result was known.

Disposition

- **SELECTED:** passes every hard gate and wins the decision rule.
- **PASS / NOT SELECTED:** passes every hard gate but ranks second.
- **RETEST REQUIRED:** campaign invalidated by a documented fixture, instrument, or preparation-control failure.
- **FAILED:** one or more valid specimens fail a hard gate.

If both routes fail, do not improvise a new concentration. Close HYDROGEL-CARRIER-001 and propose a separately identified formulation campaign. Passing this screen authorizes only a later passive mock-tip plan. It does not authorize plating chemistry.

Campaign worksheet

Approval and materials

Field	Record
Campaign suffix	
Operator	
Date range	
Tristan approval to begin	
Evidence directory	Chemistry/Images/HYDROGEL - CARRIER-001/
Total procurement before shipping	CA\$
Budget pass	Pass / Fail

Code	Supplier / product	Grade / identity	Lot	Received	Price	Accepted
ALG						Pass / Fail
CA						Pass / Fail
AGR						Pass / Fail
NACL						Pass / Fail
WATER						Pass / Fail

Solution and batch record

Field	NaCl	Alginate	Calcium bath	Agar
Target mass g	2.922	2.00	2.00	2.00
Actual mass g				
Final volume mL	500.0	100.0	100.0	100.0
Water lot				
Start time				
Peak temperature C	N/A	Ambient	Ambient	
Rest / treatment time	N/A		60 min	60 min
Appearance				
Deviations				

Witness	Internal condition	Photograph	Batch disposition
ALG-2-W			Pass / Fail
AGR-2-W			Pass / Fail

Fixture and calibration

Field	Record
Electrode material / active diameter	
Fixture revision / photograph	
Uncompressed stop mm	
80% compression stop mm	
Electrode cleaning method	
Reference resistor ID / value	
Initial measured value	
Final measured value	
Reference drift %	
Open/short calibration complete	100 Hz / 1 kHz / 10 kHz
Test level / bias	0.1 V RMS / 0.0 V

Specimen worksheets

Incoming and initial impedance

ID	Mass g	Diameter A/B mm	Thickness 1/2/3 mm	100 Hz Z / phase	1 kHz Z / phase	10 kHz Z / phase
ALG-2-R1						
ALG-2-R2						
ALG-2-R3						
AGR-2-R1						
AGR-2-R2						
AGR-2-R3						

Attach the five individual readings for every frequency as a continuation sheet or machine-readable log. The table above records the median and phase summary.

Handling, compression, and leakage

ID	10 handling cycles	10 com- pression cycles	Recovered thickness %	Post-cycle 1 kHz Z	Drift %	Transfer g	Pass
ALG-2-R1							
ALG-2-R2							
ALG-2-R3							
AGR-2-R1							
AGR-2-R2							

ID	10 handling cycles	10 compression cycles	Recovered thickness %	Post-cycle 1 kHz Z	Drift %	Transfer g	Pass
AGR-2-R3							

Drying series

Use one row per specimen at each time point.

ID	Hour	Mass g	Diameter mm	Thickness mm	1 kHz Z	Phase	Appearance / failure
	0						
	2						
	8						
	24						
	0						
	2						
	8						
	24						

Continue until all six specimens are recorded.

Route summary and approval

Result	Alginate	Agar
Witness cure	Pass / Fail	Pass / Fail
Initial 1 kHz median		
Initial 1 kHz CV %		
Median post-cycle drift %		
Minimum recovery %		
Maximum transferred mass g		
All hard gates	Pass / Fail	Pass / Fail
Final disposition		

Selected route: _____

Reason: _____

Open limitations: _____

Tristan approval / date: _____

Safety, storage, and waste

- Wear splash eye protection and gloves during solution preparation and gel handling.
- Add calcium chloride to water gradually; dissolution may warm the solution.
- Guard against hot agar, hot glassware, steam, splashes, and boil-dry.
- Keep the LC1020E and its connectors dry. Only the removable electrode faces contact specimens.
- Never apply DC to chloride-bearing specimens. Stop on unexpected gas, discolouration, odour, corrosion, or heating.

- Keep this programme separate from copper compounds, plating residues, SAT, food preparation, and NanoArc hardware.
- Label retained specimens and liquids LAB - NOT FOOD.
- Do not assume drain or household disposal. Hold all specimens and liquids until Tristan reviews the recorded ingredients and local disposal route.

References

1. FNIRSI, [LC1020E product specifications and measurement modes](#), accessed 2026-08-13.
2. K. Ino et al., "Hydrogel electrodeposition based on bipolar electrochemistry," *Lab on a Chip* 18 (2018), 2425. DOI [10.1039/C8LC00465J](#).
3. J. B. Meloni et al., "Design of gel electrolytes for electrochemical studies on metal surfaces with complex geometry," *Electrochimica Acta* 197 (2016), 228-236. [Open manuscript](#).
4. NanoArc, Chemistry/Proposals/Chemistry_Applications_Idea_Register.md, current revision.
5. NanoArc, /home/tristan/Documents/tech_docs/ACE_RevB_RevC_Modular_Applications_Proposal.md, current revision.