

Demonstration cases and result figures

MAT4EU | Illustrated Word companion | 28 September 2026

What this document shows

Confirmed: the six original result figures are embedded on pages 2-7, with a case description, reading guide and limits beside each. These are saved numerical results from 15 September 2026; no new simulation was run for this companion.

Status: numerically verified screening [checked calculations under stated assumptions]. Experimental validation [comparison with real measurements] for the sample material is not established. The sample uses AlSi12 [an aluminium-silicon alloy] with published material assumptions.

The main assumed sample

Size: 40 x 30 x 10 mm [millimetres]; mass: 31.704 g [grams]; starting temperature: 500 degC [degrees Celsius]. One controlled wall heats it at 620 degC for 40 seconds, then cools it at 500 degC for 20 seconds. Other walls are insulated. Melting occurs at the assumed 576 degC. The working grid [small blocks used in calculation] is 5 x 3 x 33 cells.

Heat moves by conduction [heat spreading through material]. Density stays fixed. Liquid movement, a container, imperfect contact, radiation, expansion and cycling damage are outside this model. The calculated heat recovery is not a device-efficiency claim.

Find the demonstrations

Page	Case	What is on the page
2	Case A	Heating, melting and freezing: the complete cycle
3	Case A	Temperature and melting through the thickness
4	Case B	Seven material-property scenarios
5	Case C	Grid and time-step checks; rejected coarse grid retained
6	Case D	Three faces at different temperatures: a three-dimensional example
7	Case E	Melting and freezing against exact mathematics

Keep the evidence boundary clear

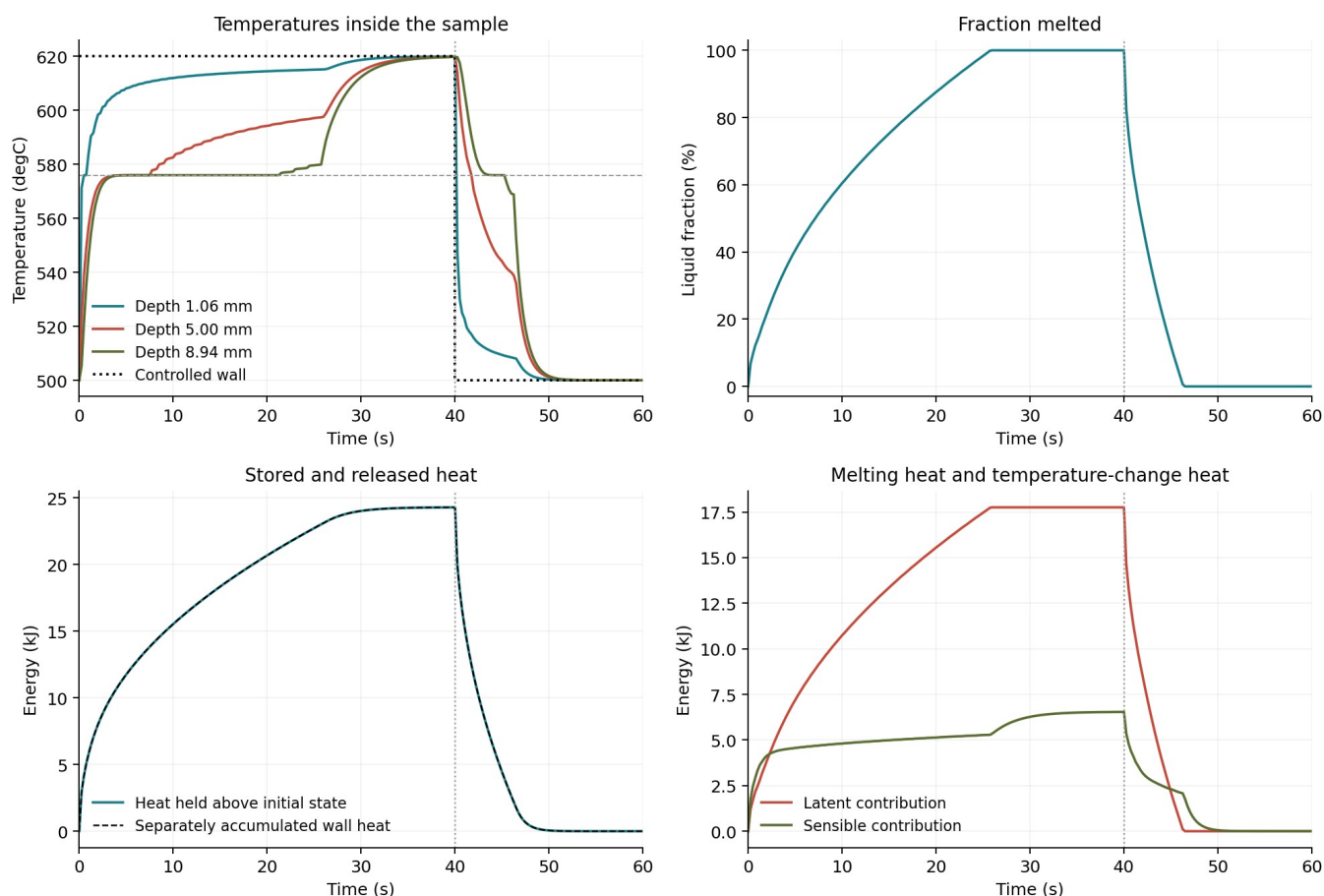
The raw screening campaign remains FAIL: 219 of 220 checks passed. The 17-cell coarse grid failed its centre-temperature target and is rejected. The originally selected 33-cell working grid passes its finer-grid and time-step comparisons. A separate earlier mathematical test set passed 434 checks across 31 cases.

Recommendation: use these figures as numerically verified screening evidence, and make independent sample measurements the next milestone.

1. Heating, melting and freezing

Case A: one complete heat-storage cycle. A 40 x 30 x 10 mm sample starts at 500 degC. One wall is held at 620 degC for 40 seconds, then at 500 degC for 20 seconds. The other walls are insulated.

MAT4EU | AlSi12 screening: heating and freezing
Assumed 40 x 30 x 10 mm guarded sample; literature inputs; NOT experimental validation



How to read it: Read left to right. The dotted line at 40 seconds marks the start of cooling. Top left: temperatures at three depths. Top right: liquid fraction [share that has melted]. Bottom left: stored heat. Bottom right: latent heat [heat used for melting] and sensible heat [heat that raises temperature].

Confirmed saved prediction: 24.293 kJ [kilojoules, a heat-energy unit] stored at 40 seconds and 24.293 kJ released during cooling. The sample reaches 99% melted in 25.25-25.50 seconds and 99% frozen 6.00-6.25 seconds after cooling starts.

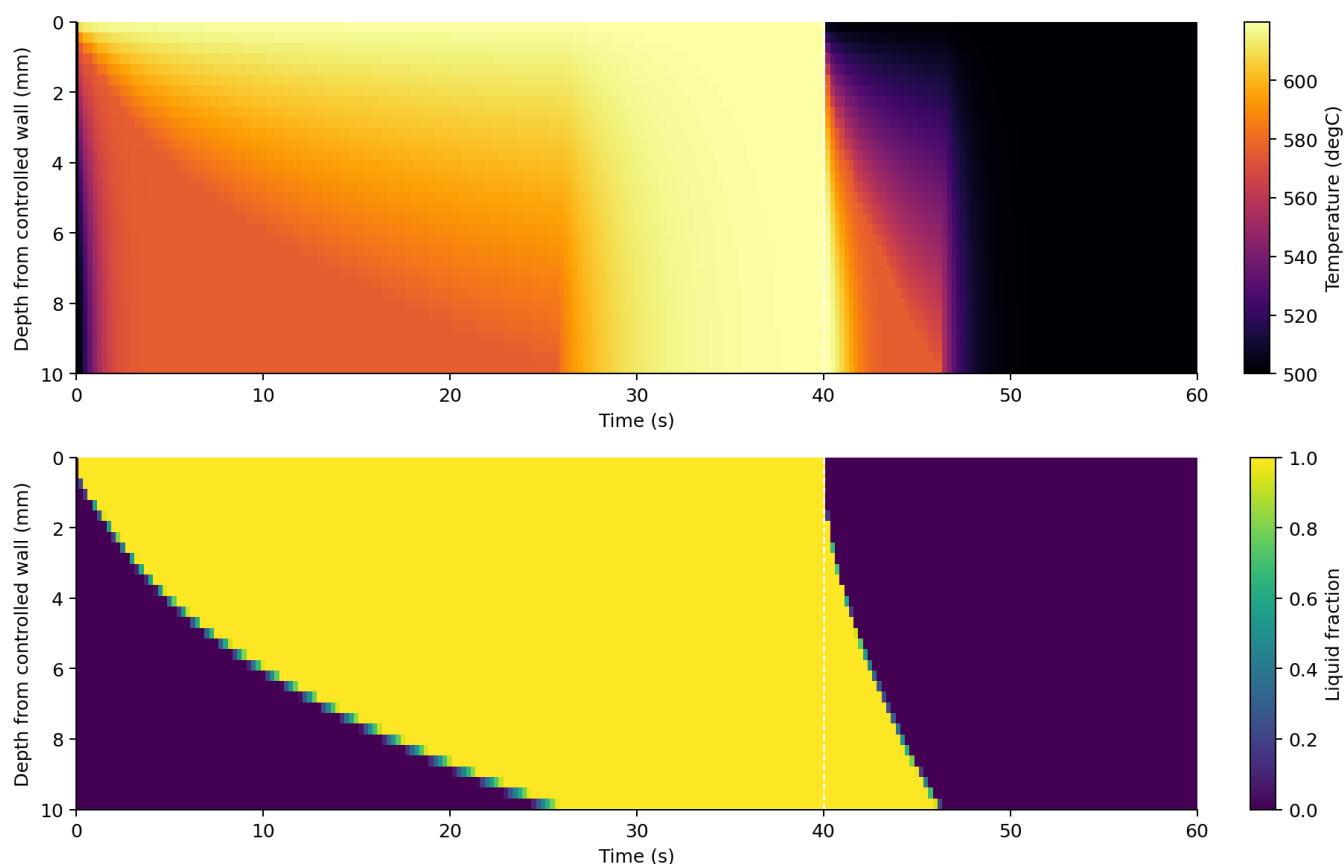
Limit: near-complete recovery follows from the ideal insulated setup. It is not an efficiency claim. The time ranges come from saving results every 0.25 seconds; they are not measured uncertainty.

Saved case: nominal_n33_r4; screening_claim.json; REPORT.md.

2. What happens inside the sample

Case A, viewed through the 10 mm thickness. These maps use the same heating and cooling cycle as page 2. The controlled wall is at depth zero, at the top of each map.

MAT4EU | Temperature and phase through the thickness
Screening prediction, not measured data; cell samples without spatial interpolation



How to read it: Move right to follow time; move down to look deeper into the sample. The upper map shows temperature. The lower map shows liquid fraction [share that has melted]: 0 means solid and 1 means liquid. Each colour scale is printed beside its map.

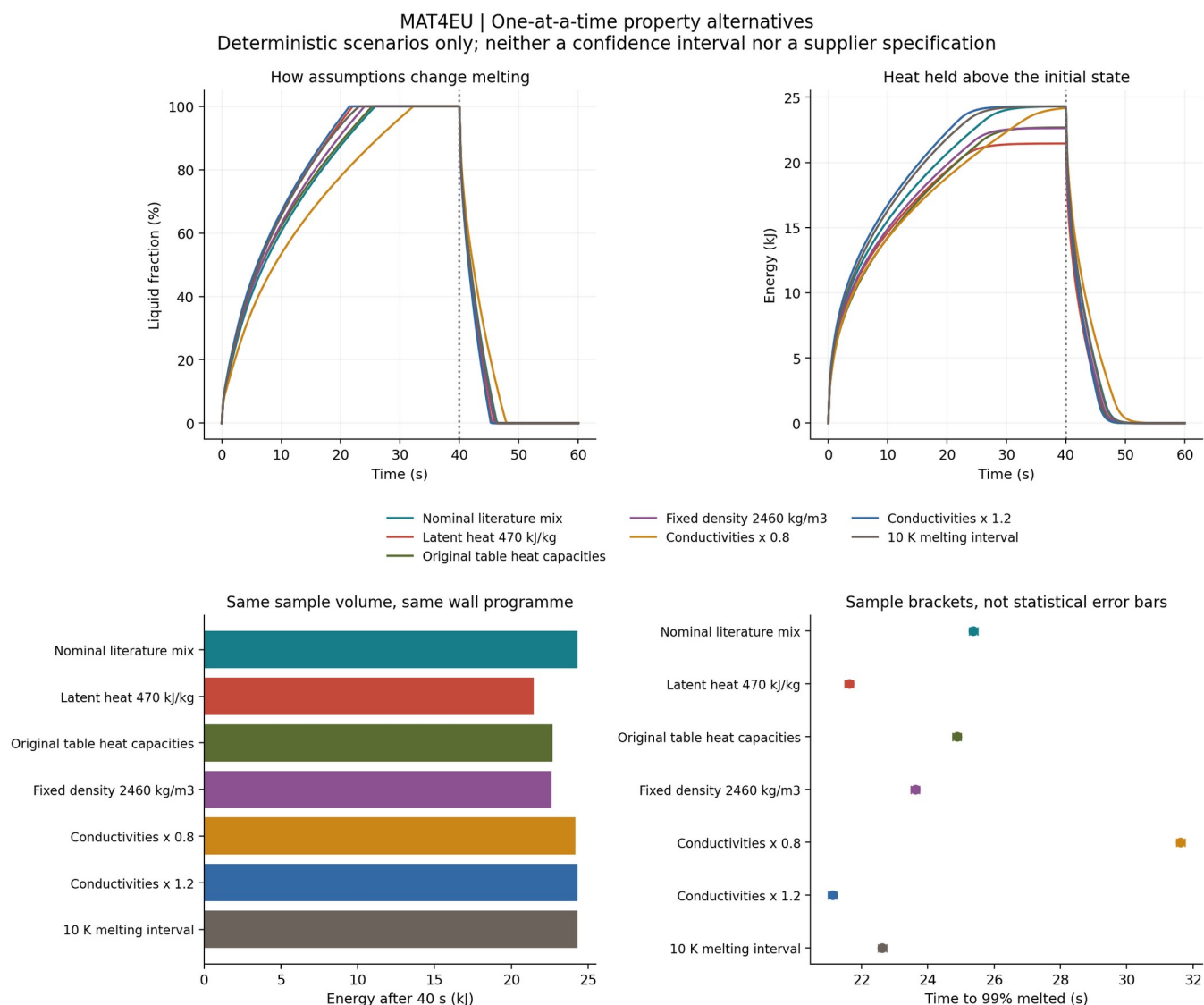
Confirmed saved prediction: heating and melting move from the controlled wall into the sample. Cooling starts at 40 seconds, marked by the white dashed line. Freezing then progresses inward from that same wall.

Limit: these are calculated cell values, not camera images or measurements. A cell is one small block of the calculation. The model has no liquid movement, container or imperfect thermal contact. Depth is measured inward from the heated face.

Saved case: nominal_n33_r4; nominal_depth_history.csv.

3. Why measured material inputs matter

Case B: repeat the same sample and wall programme, changing one material assumption at a time. Seven scenarios compare melting heat, heat capacity [heat needed per degree], density, heat conduction and a wider melting interval.



How to read it: Top: melting and stored heat over time. Bottom left: heat stored after 40 seconds. Bottom right: time to 99% melted. Colours identify the scenarios. The short horizontal time bars reflect the 0.25-second saving interval.

Confirmed saved predictions: using 470 instead of 560 kJ/kg [kilojoules per kilogram] for melting heat changes stored heat from 24.293 to 21.445 kJ. Lowering heat conduction by 20% moves 99% melting to 31.50-31.75 seconds; raising it by 20% gives 21.00-21.25 seconds.

Limit: these are selected alternatives, not statistical error bars or measured supplier limits. The volume stays the same; changing density also changes sample mass. Measuring the actual material remains necessary.

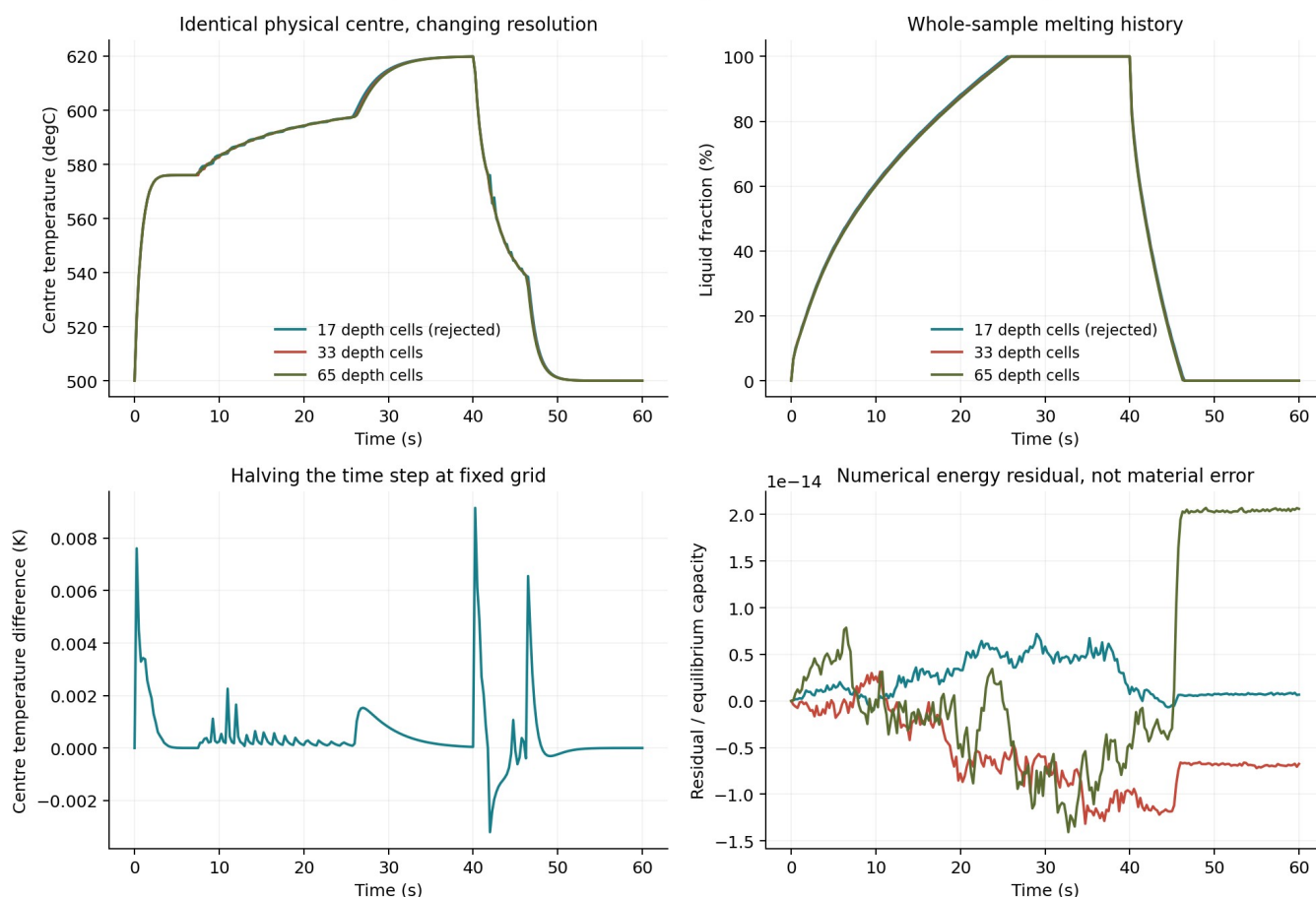
Saved table: `scenario_summary.csv`; property sources and limits: `PROPERTY_AUDIT.md`.

4. Checking the size of calculation steps

Case C: compare grids [small blocks used in calculation] with 17, 33 and 65 cells through the thickness. Also halve the time step [time advanced per calculation] on the 33-cell working grid.

MAT4EU | Resolution and conservation checks

Matched times and centre position; no interpolation, experimental tolerance or convergence-order claim



How to read it: Top: compare centre temperature and the share melted at matching times. Bottom left: the effect of halving the time step. Bottom right: numerical energy residual [unbalanced heat in calculation], divided by the heat the sample would hold at 620 degC above its initial state. Here K means kelvin: a 1 K difference equals a 1 degC difference.

Confirmed: the 17-cell grid is rejected. Its maximum centre-temperature difference is 5.7487 K, above the 3 K limit. The 33-versus-65-cell comparison gives 1.4207 K; halving the time step gives 0.0092 K. The originally selected 33-cell grid is accepted for these screening targets.

Raw campaign status remains FAIL: 219 of 220 checks passed. The separate working-grid decision does not erase that failure or change any limit. These checks concern the calculation, not agreement with a real sample. No measured convergence order is claimed.

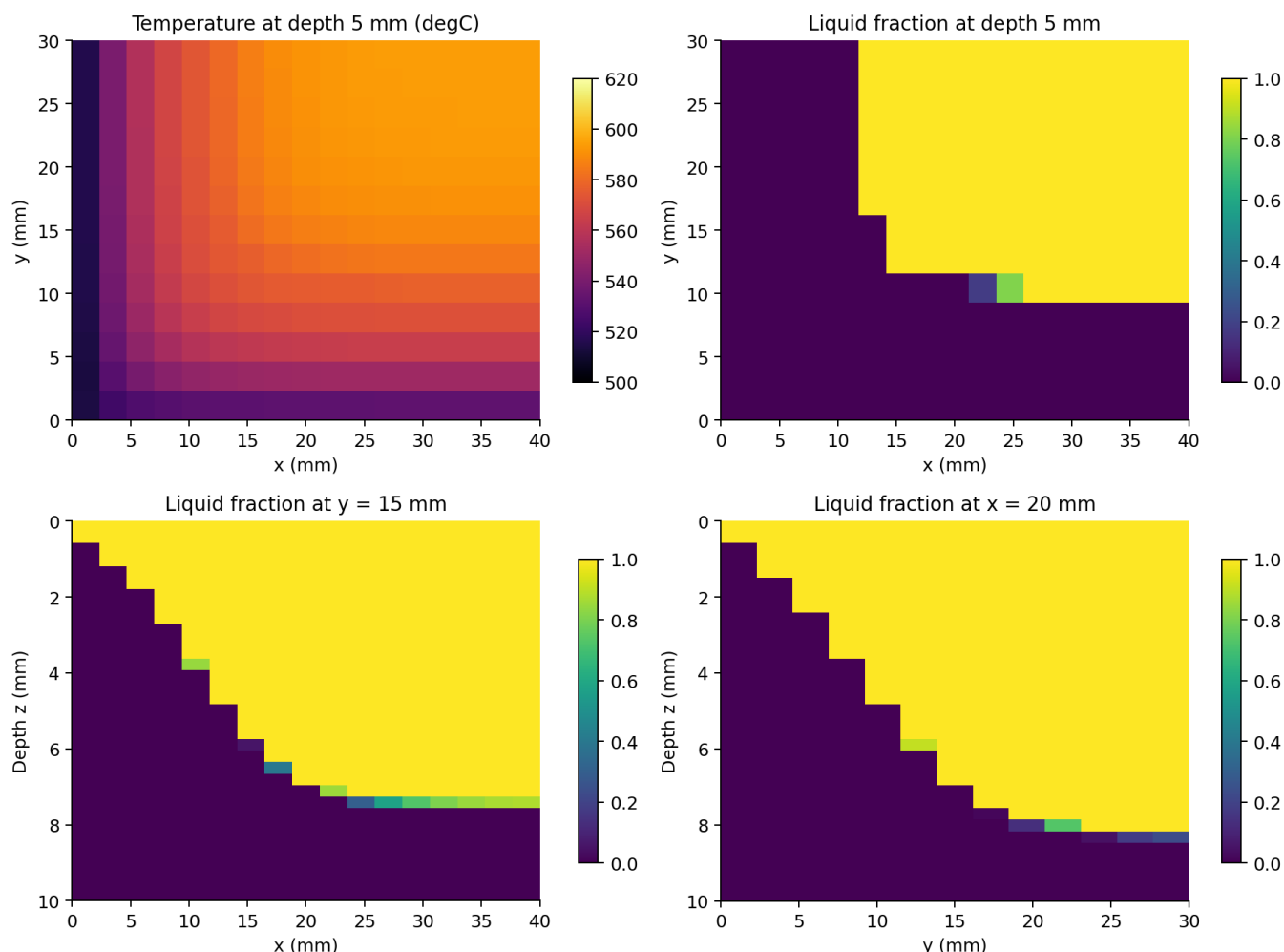
Saved decisions: `screening_claim.json`; `baseline_qualification.json`.

5. Three-dimensional demonstration

Case D: the same 40 x 30 x 10 mm sample starts at 500 degC. For 20 seconds, three faces are held at different temperatures: $z=0$ at 620 degC, $x=0$ at 500 degC and $y=0$ at 520 degC. The other faces are insulated. The grid is 17 x 13 x 33 cells.

MAT4EU | Three controlled faces, at 20 s

Walls: $z=0$ at 620 degC, $x=0$ at 500 degC, $y=0$ at 520 degC; illustrative, not device validation



How to read it: These are four slices through the sample at 20 seconds. Top left: temperature halfway through its depth. The other panels show liquid fraction [share that has melted] in three perpendicular slices. A value of 0 means solid; 1 means liquid. The x, y and z labels identify the three directions.

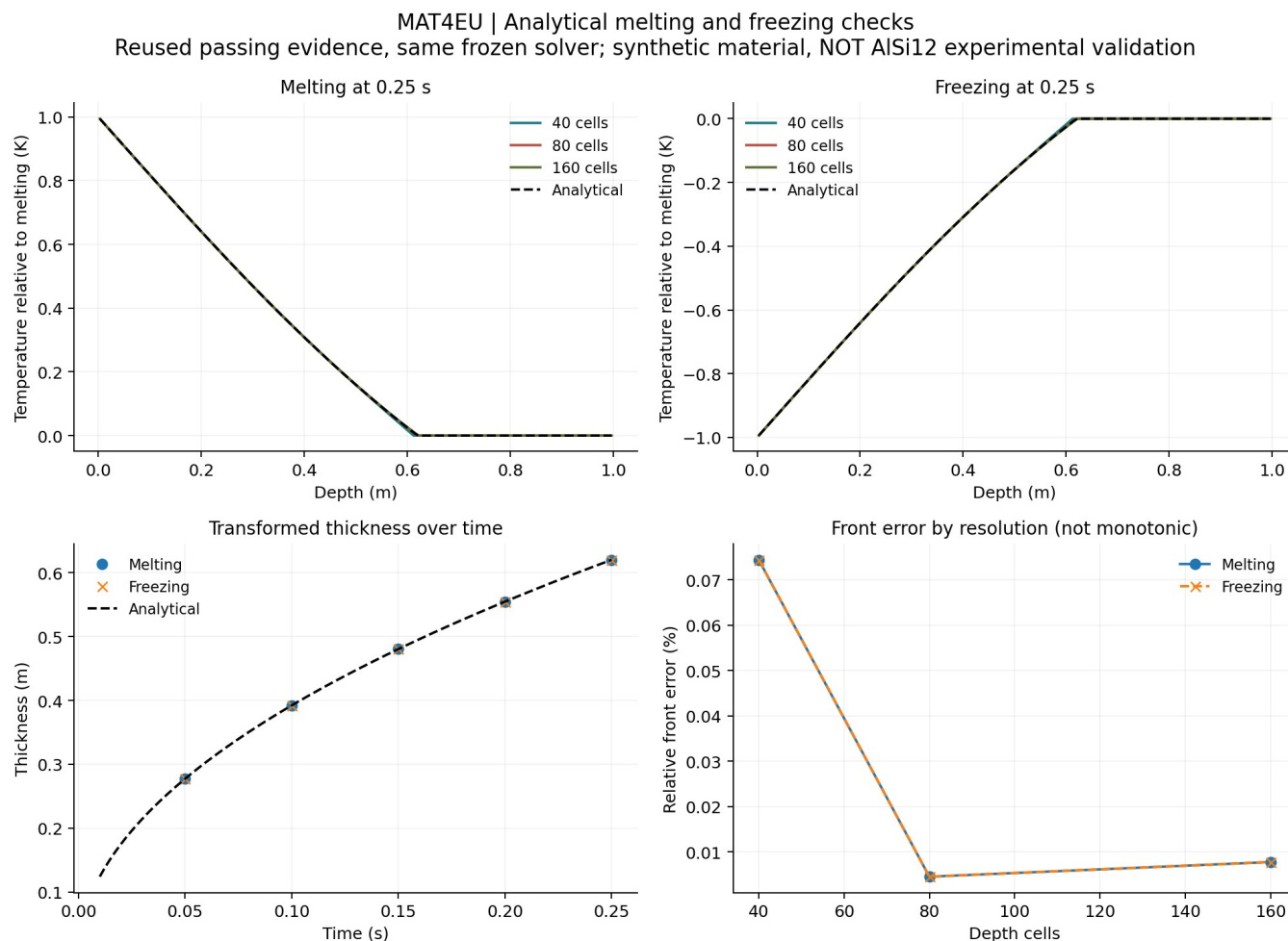
Confirmed: the saved fields vary in all three directions. Heating one face while holding two adjacent faces cooler creates a different melting pattern near their meeting corner. Four graphics processors shared the calculation.

Limit: this demonstrates a three-dimensional calculation under assumed wall temperatures. It has no separate grid-accuracy claim and does not establish the behaviour, charging time or efficiency of a storage device.

Saved case: three_face_3d_r4; original result.json and embedded configuration; screening_claim.json.

6. Checking against exact mathematics

Case E: simplified melting and freezing problems with an analytical solution [an exact mathematical answer]. These checks use a synthetic material [an invented test material] and 40, 80 and 160 depth cells. They are separate from the aluminium-silicon sample example.



How to read it: Top: calculated temperature profiles at 0.25 seconds against the dashed exact answer. Bottom left: how far melting or freezing has progressed over time. Bottom right: the relative front error [difference in boundary position] for each grid.

Confirmed saved evidence: the prior mathematical test set passed 434 checks across 31 cases using the same recorded source and program. At 160 depth cells, the largest melting/freezing front error is 0.00773%. The figure displays six selected cases from that set.

Limit: grid error does not decrease steadily in these results, so no measured convergence order is claimed. Numerical verification does not establish material accuracy. Independent sample measurements are still needed.

Saved evidence: `benchmark_evidence/index.json`, `claim.json` and six selected case folders.