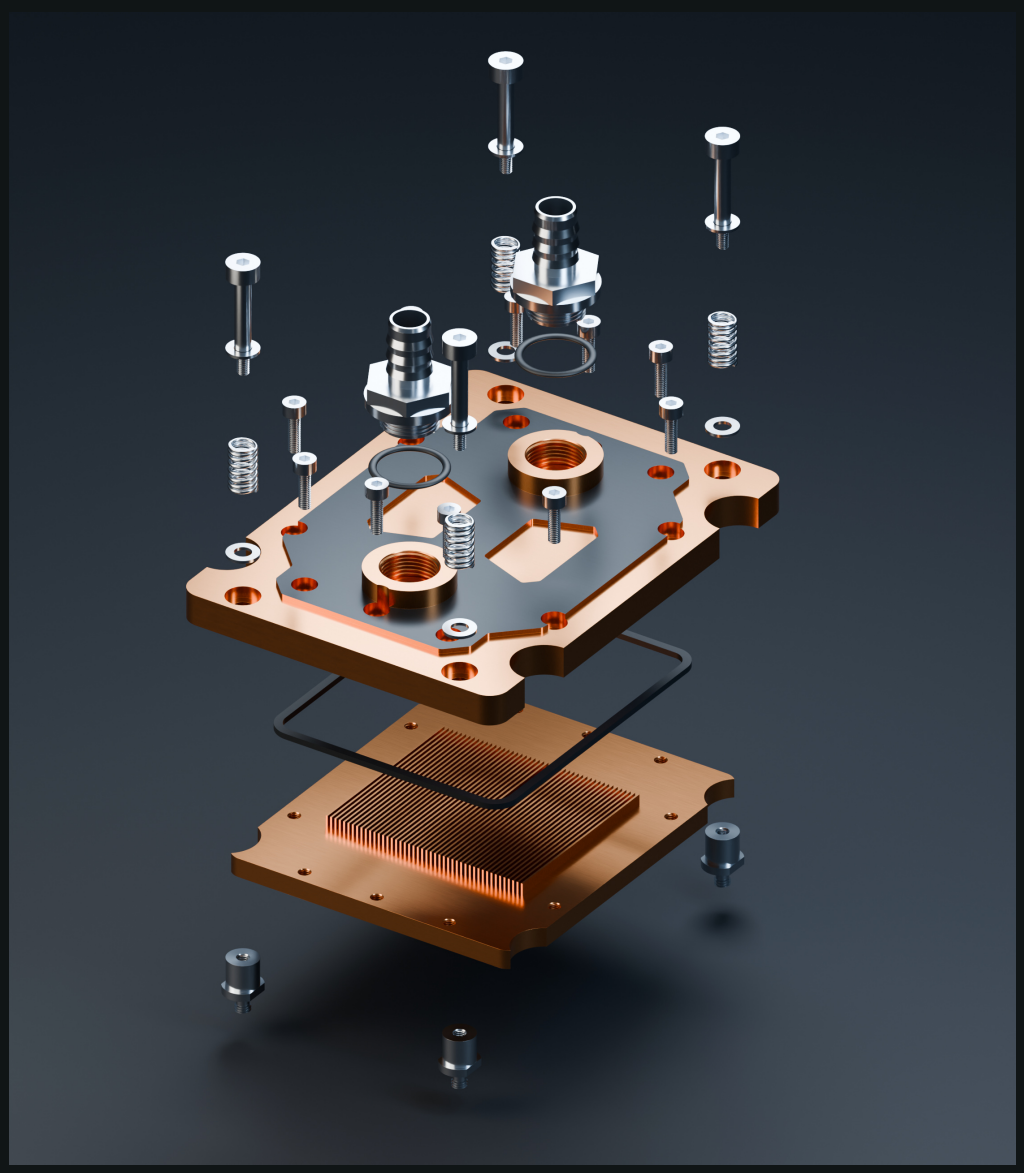
PORTFOLIO REPORT

Cold plate design: heat transfer and fluid flow

Four cooling cores. One design envelope.



THE DESIGN QUESTION

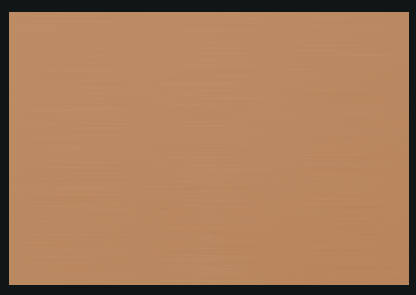
How does the internal geometry change cooling and hydraulic effort?

An independent Aster CP01 study connecting detailed CAD, structured meshes, CFX solutions and native field exports.

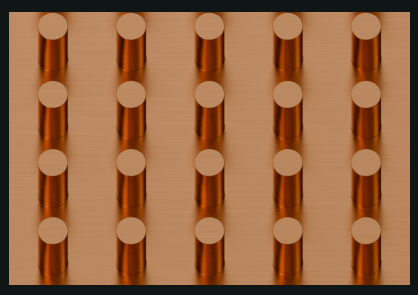
Re 1000

25 °C inlet / 1000 W heater

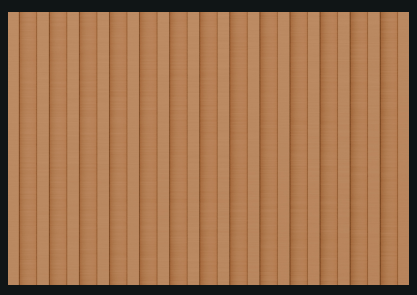
Preliminary single-phase comparison. No validated optimum is established.



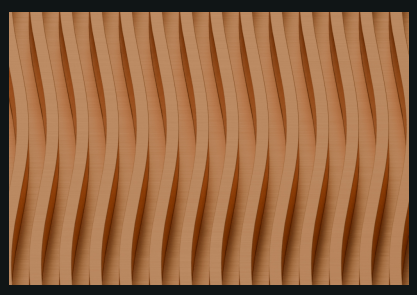
01 Plain



02 Pin fin



03 Straight

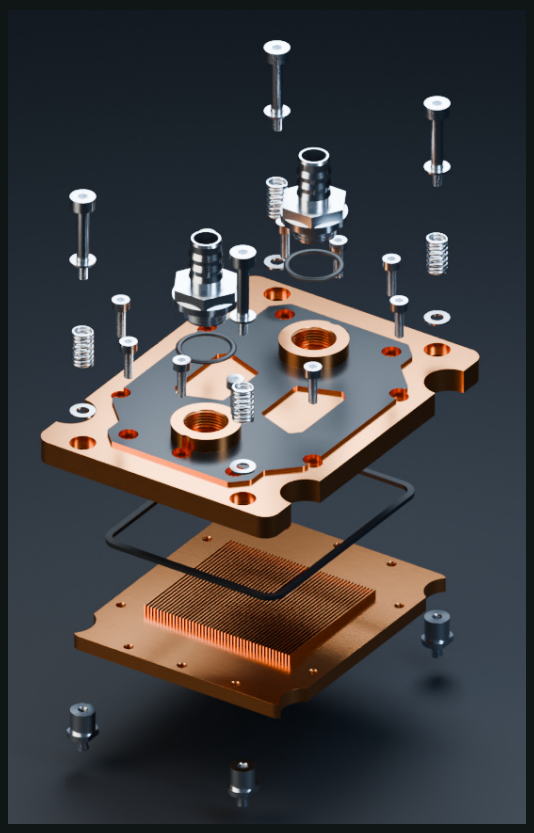


04 Wavy

01 / MODEL CONSTRUCTION

From assembly to a thermal-flow model

The straight-channel example shows the geometry reduction used to build the conjugate heat-transfer model.



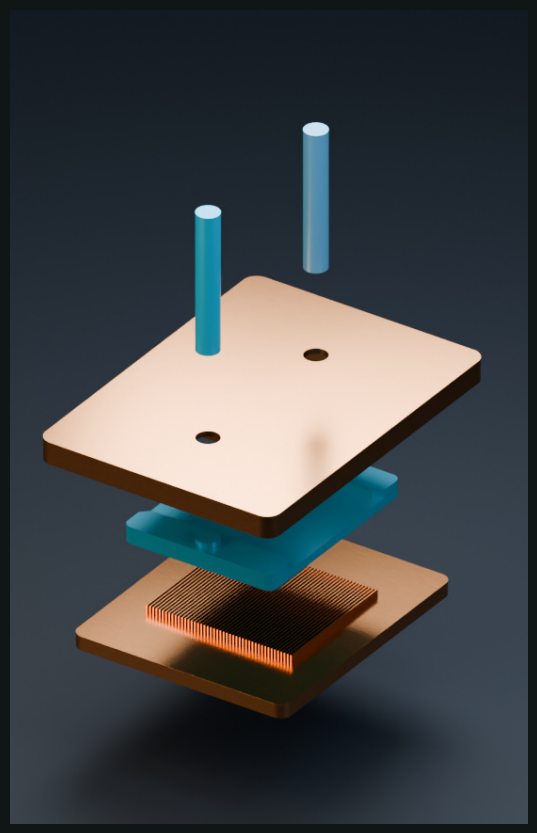
01 Detailed assembly

Mechanical hardware and sealing details



02 Simplified copper

Retained thermal-flow geometry



03 Solid and fluid domains

Copper solids, coolant and port extensions

COMMON CONDITIONS

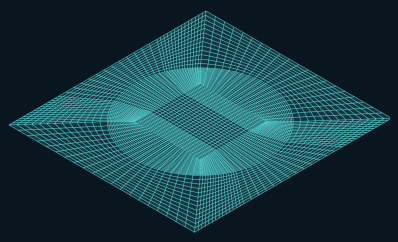
Inlet	Re = 1000; D = 8 mm; U = 0.11157 m/s
Coolant	Water at 25 °C; steady laminar flow
Heat input	1000 W; nominal centered 50 × 50 mm footprint
Outlet	0 Pa average static gauge pressure; 1 atm reference

Model assumptions: constant properties, perfect solid contact, adiabatic exterior and single-phase coolant. Heat input was normalized to the sampled heater mask. Flow was solved first; energy was then solved with the flow field frozen.

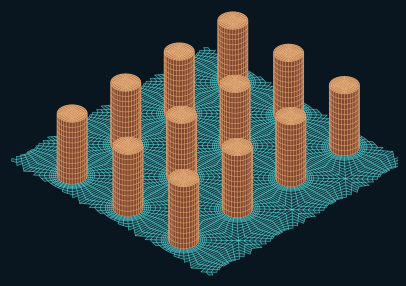
02 / STRUCTURED MESHING

Native topology, traceable mesh versions

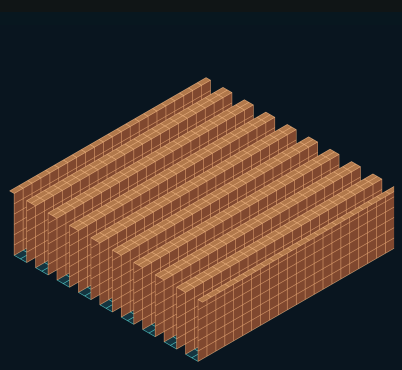
Fully structured hexahedral meshes. The images below show actual native topology from saved illustration meshes.



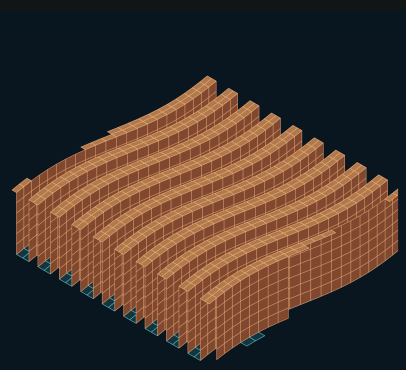
Plain



Pin fin



Straight



Wavy

MESH DENSITIES ARE DIFFERENT

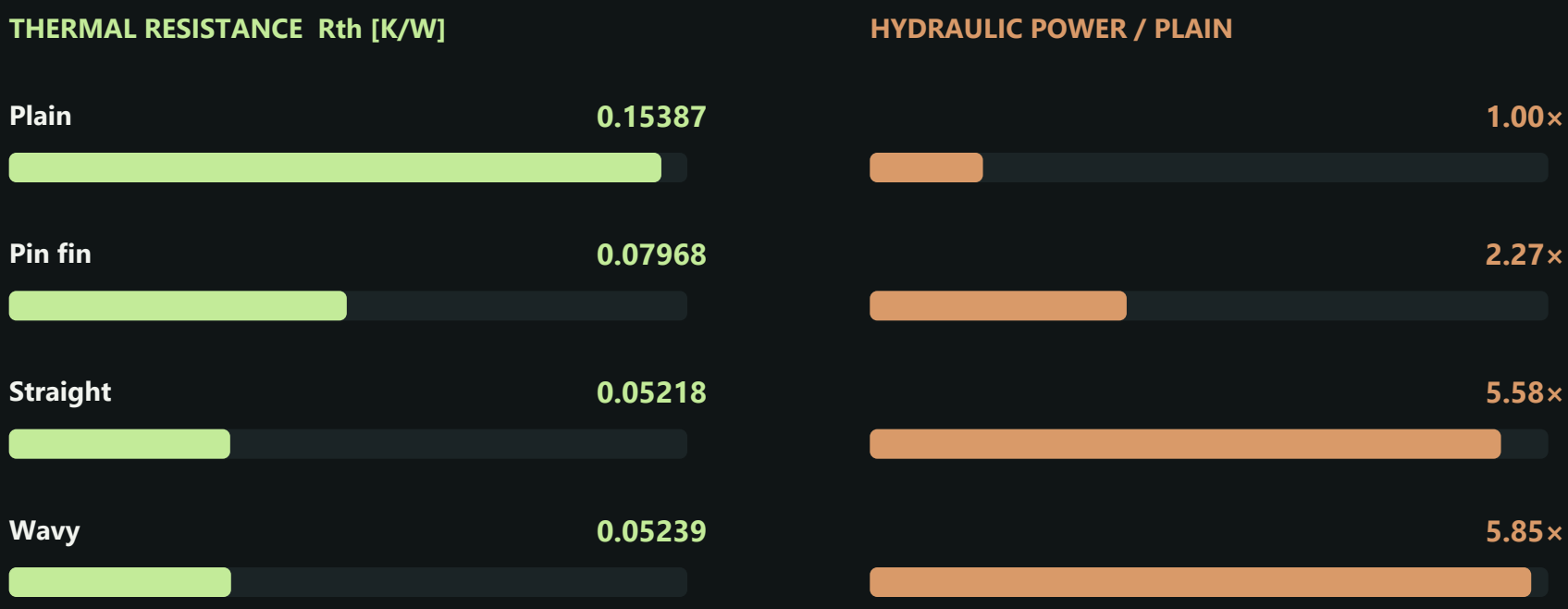
Case	Illustration cells	Solved comparison cells
Plain	5,043,560	**4,044,160**
Pin fin	8,065,920	**5,724,696**
Straight	1,523,868	**5,252,212**
Wavy	1,523,868	**5,252,212**

1000 native stations were exported per case. Comparisons of local core metrics use 732 common valid stations and 731 adjacent intervals. Sampling density does not establish mesh independence.

03 / THERMAL AND HYDRAULIC COMPARISON

A close thermal result, a clear flow penalty

Saved results at the same nominal inlet Reynolds number. Straight and Wavy are too close thermally to rank reliably.



Straight 0.05218 K/W / Wavy 0.05239 K/W

A 0.40% difference in thermal resistance. Their hydraulic power is 5.58× and 5.85× Plain, respectively. Incomplete energy convergence prevents a validated thermal ranking.

Case	Total-pressure loss [Pa]	Hydraulic power [mW]	Energy termination
Plain	10.02	0.0561	Target met
Pin fin	22.75	0.1275	Stopped early
Straight	55.88	0.3133	Stopped early
Wavy	58.55	0.3283	Stopped early

Definitions. Rth = (heat-flux-weighted heater temperature - inlet bulk temperature) / heater heat input. Hydraulic power = original-port total-pressure loss × volume flow. The loss excludes the computational extensions; hydraulic power excludes pump inefficiency.

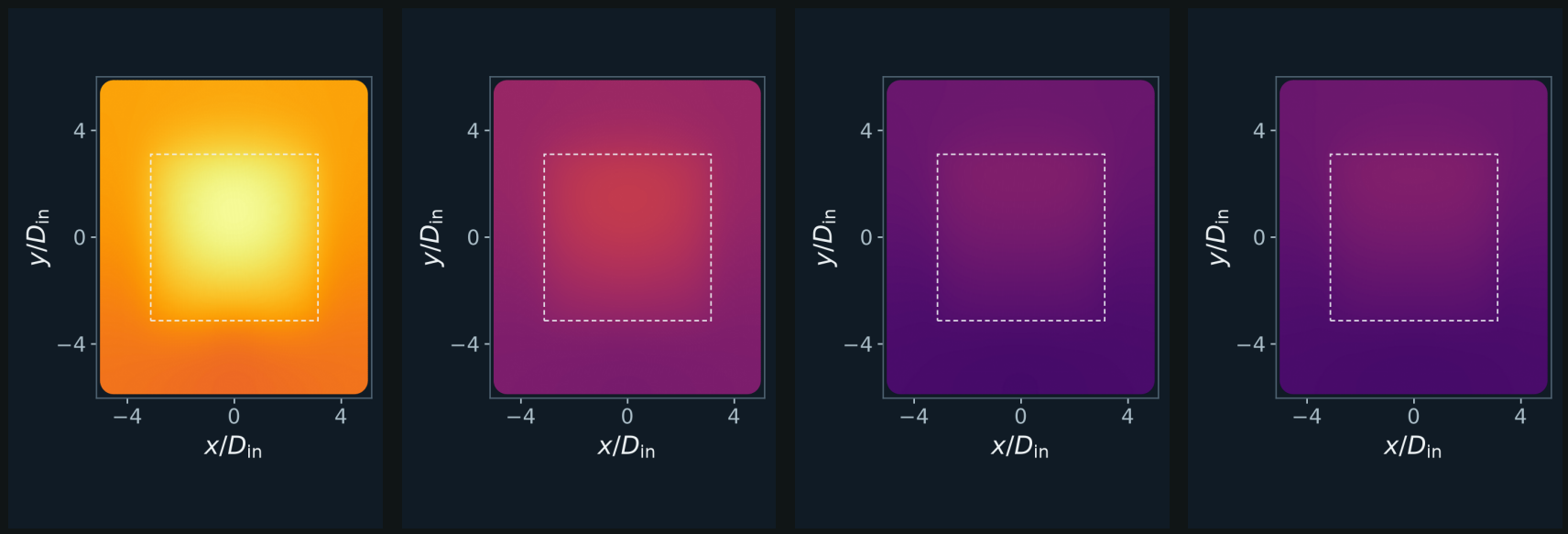
04 / TEMPERATURE FIELDS

Compare the fields on one temperature scale

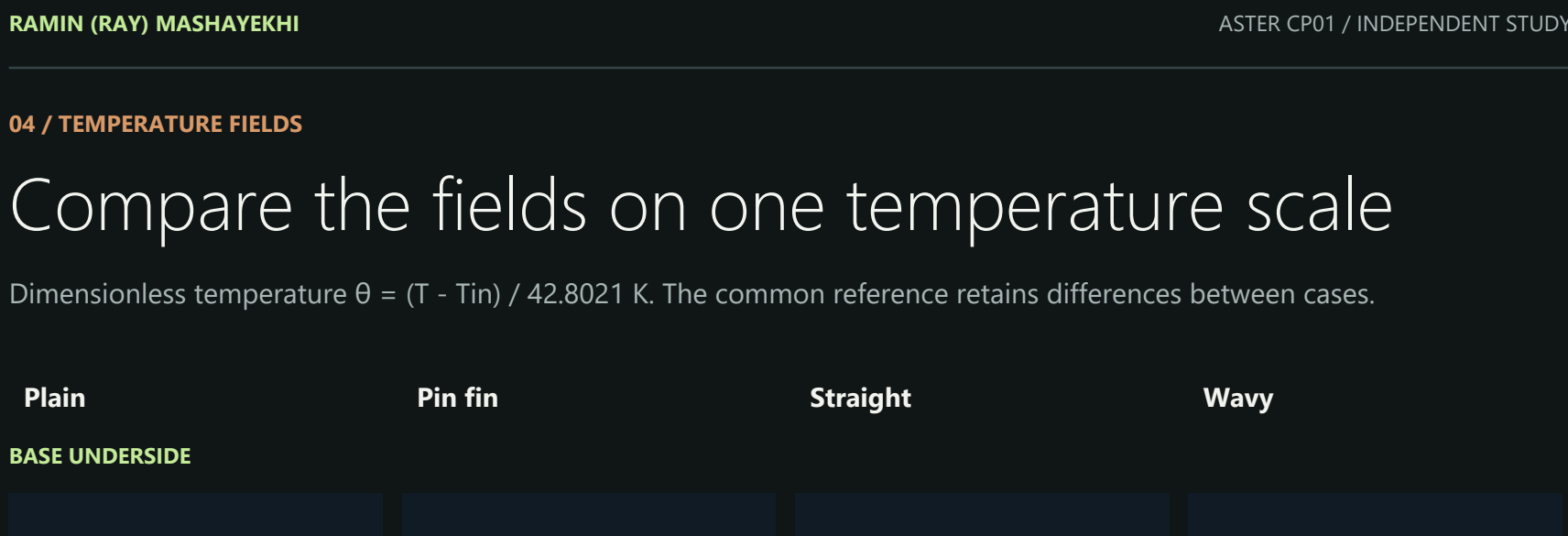
Dimensionless temperature θ = (T - Tin) / 42.8021 K. The common reference retains differences between cases.

Plain **Pin fin** **Straight** **Wavy**

BASE UNDERSIDE



FLUID MIDPLANE





All eight panels share the same color range. Dashed underside outlines mark the nominal heater footprint. The coolant slice is at z/Din = 0.8125; coordinates use the common 8 mm inlet diameter.

The elevated Plain temperatures require an operating-pressure and boiling assessment. These single-phase model temperatures do not demonstrate a feasible physical operating point.

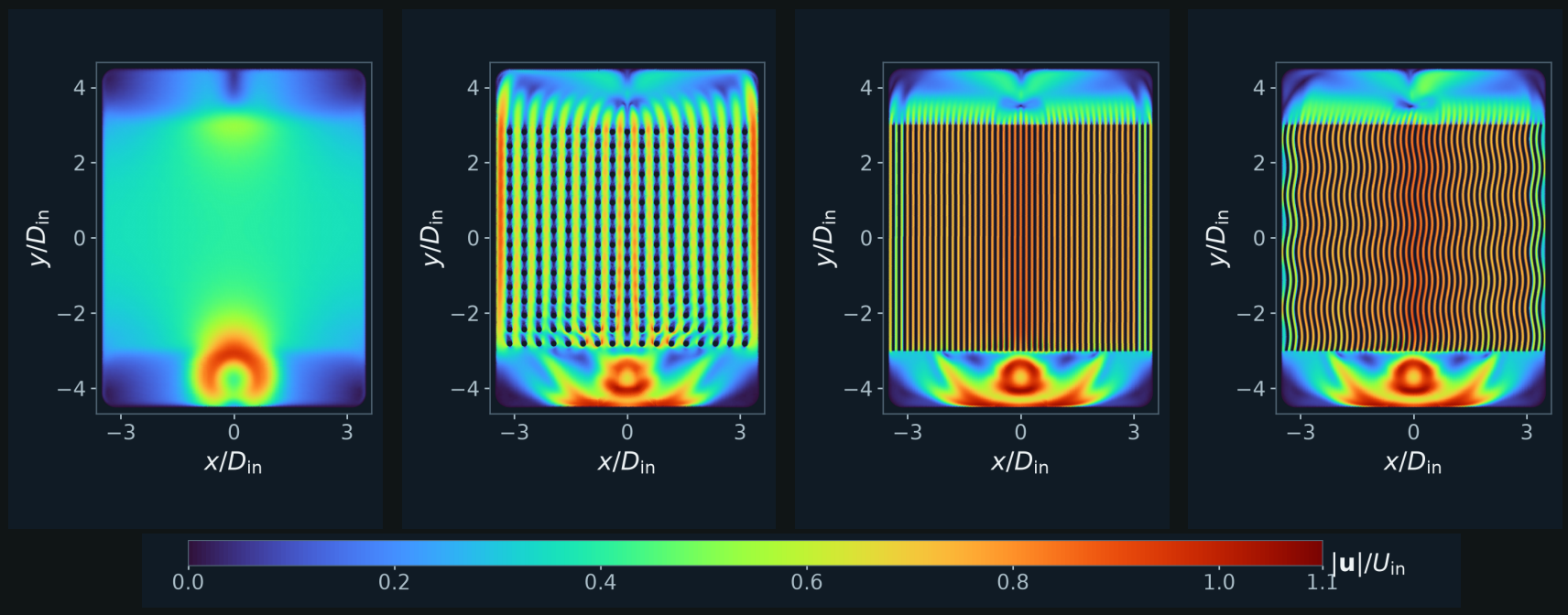
05 / FLOW AND PRESSURE FIELDS

Geometry changes where flow accelerates

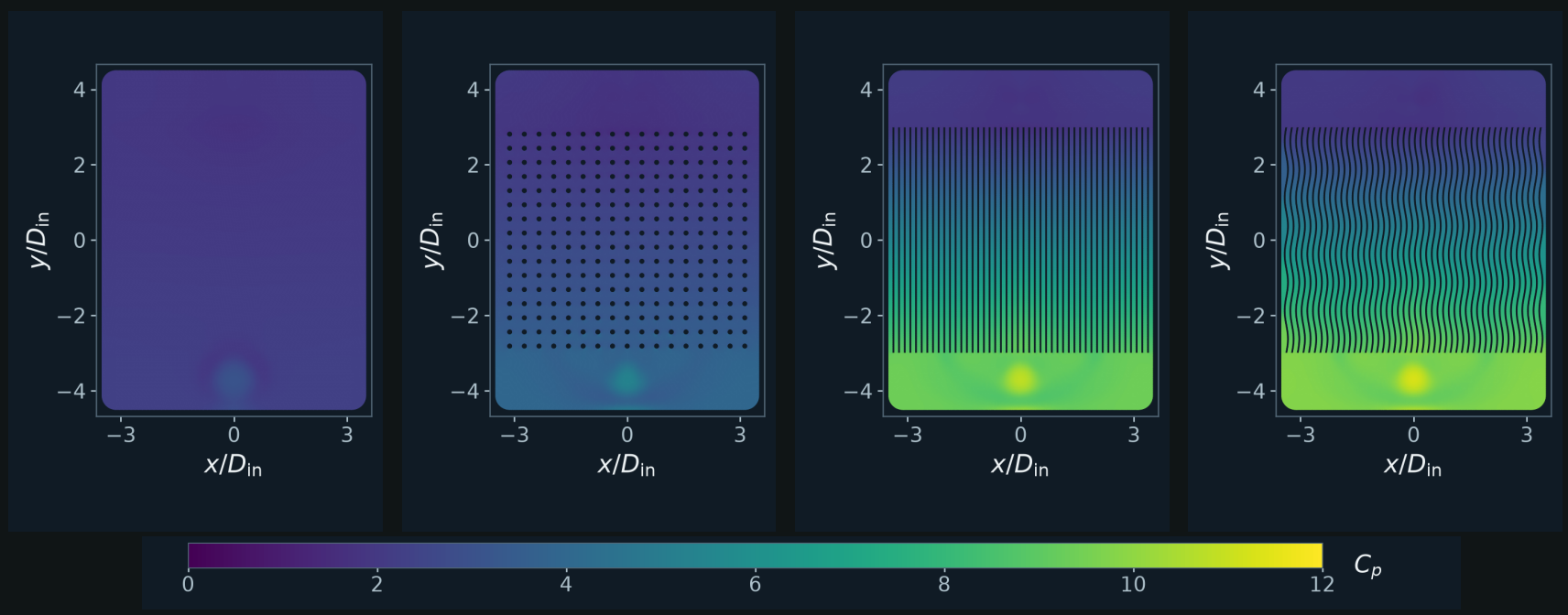
The same saved field exports support both the spatial maps and the thermal-hydraulic comparison.

Plain **Pin fin** **Straight** **Wavy**

NORMALIZED SPEED |u| / Uin



STATIC-PRESSURE COEFFICIENT Cp



Cp = (static pressure - mass-flow-averaged static pressure at the original outlet) / inlet dynamic pressure. Cp is distinct from the original-port total-pressure loss used for hydraulic power. Each row uses a common color range across the four cases.

06 / INTERPRETATION AND SOURCE TRAIL

What this study supports

A documented comparison of internal geometry under one modeled condition, with the remaining validation work made explicit.

READ THE RESULTS AS PRELIMINARY

The saved channel cases show lower thermal resistance than Plain and higher hydraulic effort. Straight and Wavy remain a near tie in Rth. These data do not establish a validated optimum or performance at equal pumping power.

Convergence

Only Plain reached the requested energy RMS target of 1e-11. Pin fin, Straight and Wavy ended on a stop instruction before that target.

Model validity

Constant-property, steady laminar, single-phase CHT was assumed. Hot-wall and phase-change feasibility remain unverified.

Comparison scope

One nominal inlet Re and one 1000 W load were studied. The local sampling density does not establish mesh independence or experimental agreement.

Next verification

Complete the energy solutions, test mesh sensitivity for each core, assess pressure and boiling feasibility, then compare across flow conditions and a pump model.

ORIGINAL SOURCES AND REPRODUCTION

Native geometry: **Cold_Plate_Native_Studio_RevD_30fps.blend** and CAD-to-CFD render assets. Native topology: saved **Portfolio_RevB_MeshViews** images. Fields: original **midplane_fields.csv** and **heater_fields.csv** exports.

Charts and tables were rebuilt from **global_dimensionless_metrics.csv**, checked against **global_metrics.tsv**. Definitions are preserved in **definitions.json**; termination was verified in each **EnergyConfig_001.out**. The accompanying generator and source manifest preserve the asset trail.