MHeart engineering delivery — 4.7-elm

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The requested complete, manufacturable 1,000 W fuel / 200 W net electric engine has NOT been achieved. This delivery establishes the actual failures, improves one thermal component, finds a conditional dynamic candidate above 200 W, and supplies an instrumentation PCB with manufacturing files. Whole-engine simulation, full assembly acceptance and physical operation remain outstanding. The engine parts list is a development register with explicit holds, not a released machining order.

Live workbench: https://mheart-forge.artifact.oa.lessokaji.com/

Local on VH155: http://127.0.0.1:8786/

Deployed project: `D:\work\projects\mheart\ai-deck\4.0-ember\deliverables`. The directory retains its initial name; check the versions inside the files. The workbench/report version is **4.7-elm**, thermal CAD/FEA **4.2-basalt**, PCB **MH-DAQ 1.8-cedar**, and MicroPython firmware **1.1-reed**. Original files remain preserved.

1. Current status and evidence

Item	Result on VH155	Meaning
Original V1 assembly, 46 solids	24 intersecting pairs at the supplied pose	Not a released assembly
V1 motion, 12 angular poses	62 moving/fixed interference occurrences	Sampled rigid-motion check fails; not 62 unique pairs
Initial unforced candidate	Displacer reaches 4.5 mm stop at 0.14685 s	The imposed-motion power result is not self-sustained operation
Earlier bounded candidate	About 140.4 W assumed net, piston peak 4.558 mm	Below target, slightly above original 4.5 mm nominal amplitude
Larger-stroke candidate, 4.7-elm	209.49 W conditional net; bounded for the 8 s simulated interval	A useful model candidate, not hardware acceptance
New tapered neck, 3D thermal FEA	68.514 W axial heat leak	Component improvement only
Native MH-DAQ 1.8-cedar PCB	0 DRC errors, 0 warnings, 0 unconnected, 0 schematic parity issues	CAD connectivity/layout check passes
Native schematic	0 ERC errors; 17 single-pin-label warnings	Warnings identify intentionally unused Pico pins; documented, not hidden
Physical engine / populated PCB	Not available for operation in this session	No claim of measured output, powered-board validation or durability

The prior project evidence under `D:\ai-deck\reports\machine-heart` already includes a 3.1-walnut report and 3.2-hazel evidence package that do not release the whole engine. The old nominal 223 W result used prescribed frequency, amplitudes and phase, assumed conversion factors, and fuel input as a denominator without closing the complete heat path. It must not be presented as a demonstrated 20% fuel-to-electric efficiency.

The original source snapshot was preserved; its ZIP SHA-256 is `959c9d4916d149955c9111e63864e72825baca9b8e4601382cd00b1c7bac297a`.

2. What improved and what the model actually proves

The screening architecture is one beta free-piston module rather than the original two opposed modules. It uses a 42 mm piston bore, 41.76 mm displacer diameter, 8 mm rod, 4 MPa reference helium pressure, 700°C hot gas and 50°C cold gas. Candidate moving masses are 1.2 kg for the piston/translator and 0.15 kg for the displacer. These are model inputs, not masses reconciled to production drawings. Removing the opposed arrangement also leaves reaction-force isolation to be designed.

The five-space isothermal model explicitly accounts for gas work and enthalpy transport. Perfect-regenerator interface temperatures are used in that calculation, with nonideal regeneration loss added separately. The mechanical equations integrate two masses, mechanical and gas springs, friction, an RL alternator and an approximate nonlinear screen-flow pressure loss. Phase and amplitude emerge from the equations; there is no forced sinusoidal motion or clipping to manufacture a stable trace. The methods are screening approximations: finite heat transfer, leakage, the actual gas-path pressure field, flexure hysteresis and electromagnetic fields are not solved. These limitations are consistent with the distinction between preliminary and detailed Stirling analysis in the NASA Stirling Engine Design Manual and with the need to couple thermodynamics and dynamics discussed in this free-piston model paper.

The screen-pressure model uses the Tanaka form $f = 175/Re + 1.6$, with porosity 0.70 and 50 micrometre wire. It approximates oscillatory flow by displacer volumetric flow. Its coefficient is not calibrated to a manufactured cartridge; the cited correlation is not itself a validation of this engine. See the correlation treatment in Processes 10(7), 1400.

Selected larger-stroke candidate

The selected development point is $kd = 19{,}200$ N/m, effective electrical load 6 ohm; the alternator model uses $K = 24$ N/A, $R = 0.5$ ohm, and $L = 1.8$ mH.

Quantity	Model result
Emergent frequency	66.479 Hz
Piston peak displacement	5.940 mm
Displacer peak displacement	2.726 mm
Cycle pressure range	3.451–4.698 MPa
Indicated gas work	277.561 W
Friction / screen pumping	10.548 / 13.684 W
Alternator copper loss	19.487 W
Effective AC load power	233.843 W
Net after assumed 96% rectifier and 15 W auxiliaries	209.489 W
Ideal heater demand	415.552 W
Regenerator positive heat shuttle	2,889.168 W
Assumed regeneration loss at 98% effectiveness	57.783 W
Neck / other heat-loss allowance	68.514 / 50 W
Implied fuel requirement at assumed 85% capture	696.293 W

For the final ten simulated cycles, mechanical and gas energy residuals are approximately 0.00008 W and 0.00007 W. This checks the numerical accounting within the chosen equations; it does not calibrate their physical assumptions. The last two half-second amplitude windows agree within 0.000024%. Eight simulated seconds is not a durability demonstration.

The 696 W figure is an inferred budget at fixed temperatures. The model does **not** burn a controlled 1,000 W flame and solve the resulting wall and gas temperatures. Therefore neither 209.5/696 nor 209.5/1,000 is a validated efficiency. With only about 9.5 W net margin over the target, additional real losses can erase the result. At the same load power, increasing auxiliaries from 15 to 25 W would reduce net output to about 199.5 W. At 95% rather than 98% regenerator effectiveness, the assumed fuel requirement rises to about 798 W, still subject to the missing heat-transfer calculation.

The original piston amplitude was 4.5 mm; this point needs about 11.88 mm peak-to-peak travel plus clearance. No matching full CAD assembly has been released. Sensitivity is serious: another family at 6.5 ohm was bounded with an 18,400 N/m spring, while 18,450 N/m reached the 6.5 mm analysis stop. A fixed-resistance nominal point is not a robust operating envelope. Active stroke/load control and actual spring/alternator characterization are required.

All failed trials are retained in model/results/refined.json, refined-ash.json and refined-elm.json. The initial, broad and settling results are retained separately. No result is promoted from an overstroke trial to a pass.

3. Thermal neck improvement

N01 is an open, continuously tapered HAYNES 230 tube: 56 mm bore, 120 mm length, 6 mm wall at the hot end and 2.2 mm at the cold end. Nominal outside diameters are 68 mm and 60.4 mm. The longer thermal path replaces the abrupt earlier candidate; it consumes more axial space and does not establish compliance with the original 200 mm cube envelope.

Actual CalculiX on VH155 solved a full-ring structured hexahedral thermal model with temperature-dependent conductivity, 750°C and 40°C end temperatures and insulated sides. Coarse mesh: 5,248 nodes / 3,840 elements, 68.187 W. Fine mesh: 31,104 nodes / 25,600 elements, 68.514 W. The mesh difference is 0.48%; the fine end-flow residual is 0.0082%. A companion variable-conductivity 1D result is 68.596 W.

This is about 34.4% less axial conduction than the earlier approximately 104.4 W neck candidate. It excludes radiation, contact paths, end closures, gas convection and other parallel heat bridges. It is not a whole-engine heat-loss reduction of 34.4%.

The companion Lamé screening at 6 MPa gives approximately 31.3 MPa inner hoop stress at the thick hot end and 79.5 MPa at the thin cold end. **6 MPa is an analysis input, not an approved MAWP or proof-test instruction.** No thermal-stress, joint, creep-fatigue, buckling, weld or pressure-construction release is supplied. Material conductivity and the need to distinguish temperature-dependent creep data from design allowables are based on the HAYNES 230 manufacturer data.

Files: editable spreadsheet-driven N01_neck_4.2-basalt.FCStd, STEP, STL, dimension sketch, raw CalculiX INP/DAT/FRD, summary JSON and source script. The STL is only for a cold fit/display model. The open tube cannot be pressurized as an engine.

4. Assembly findings and manufacturing release

FreeCAD 1.1.3 ran on VH155 against the actual original STEP. The native audited document colors intersecting parts red. Representative clashes include stator/cold-flange overlap, translator/flexure-blank overlap and liner/backiron overlap. Some fixed-pose overlaps may represent intended joints or unfinished effective solids; that does not make them completed manufacturing detail. In particular, a flexure blank is not a deformable, fatigue-qualified flexure.

The motion check samples 12 poses at 30-degree increments and treats flexure blanks as rigid fixed solids. It neither proves an insertion sequence nor models compliant motion, hot clearance, tolerance stacks or continuous swept volumes. There is **no passing whole-engine assembly simulation** in this delivery. The new neck is a valid single solid; that is a component geometry result only.

The accompanying 37-line parts.csv/parts.json register identifies quantity, proposed specification, make/buy status and readiness. Entries marked HOLD must not be used as released machining instructions. Missing dimensions have been left explicit rather than invented.

5. PCBs and immediate bench build

The supplied PCB set comprises the custom **MH-DAQ 1.8-cedar** carrier, one Raspberry Pi Pico, two MAX31856 thermocouple boards and one INA228 power-monitor board. These form a measurement platform. The active rectifier/startup inverter, DC regulator, dump protection and fuel safeguard remain unselected or undesigned; the DAQ is not a substitute for those power/control boards.

Bench item	Quantity	Specification
MH-DAQ bare PCB	1	101.6 × 88.9 mm, two-layer FR-4, 1.6 mm, 1 oz copper, plated through holes
Pico RP2040, non-wireless	1	Headers fitted; USB end toward board title
1 × 20 female sockets	2	2.54 mm pitch; 17.78 mm row spacing
1 × 8 male headers	2	MAX31856 labeled harnesses
1 × 4 male header	1	INA228 logic
1 × 2 male headers	3	0–5 V position/pressure inputs
15 kΩ, 0.1%, axial resistor	3	10.16 mm lead spacing footprint
20 kΩ, 0.1%, axial resistor	3	10.16 mm lead spacing footprint
4.7 nF C0G capacitor	3	5.0 mm lead spacing, 50 V
100 nF capacitor	1	5.0 mm lead spacing, 50 V
MAX31856 Adafruit #3263	2	Type-K thermocouple measurement
INA228 Adafruit #5832	1	Onboard 15 milliohm shunt; high-current path stays off DAQ
Mounting hardware	4 sets	M3, 3.2 mm board holes

The board has 22 placed items including four mounting holes. KiCad 10.0.6 on VH155 filled the copper zones, ran DRC and schematic parity, and exported Gerbers, Excellon drill, schematic PDF and PCB PDF. All 86 schematic electrical pins also matched the expected pin-to-net map. Seven exact footprint definitions are included in a project library to avoid substitution by a different KiCad library version; their license is included.

ERC retains 17 warnings for unused Pico connector pins with labels but no second connection. There are no ERC errors. This passive carrier schematic does not model internal Pico or breakout circuitry, so ERC is not proof of sensor logic compatibility or hardware operation.

Follow pcb/WIRING.md and MH-DAQ_BOM.csv. J3/J4 require a labeled harness; their pin order is not the physical pin order of the Adafruit breakout. The 0–5 V inputs use 15 kΩ/20 kΩ dividers, giving 2.857 V at the ADC for a 5 V input. The 4.7 nF capacitors provide a nominal 3.95 kHz pole; this is insufficient as a precision anti-alias filter for a 4 ksample/s capture. Use raw samples, actual timestamps and calibrated channel timing. The board has no industrial input overvoltage protection.

Firmware 1.1-reed provides JSON telemetry, a timestamped ADC capture, thermocouple configuration readback, periodic open-wire detection, and INA228 voltage/current conversion. Only syntax was checked; no Pico was connected. Temperature open-wire detection is periodic and must not be treated as a fuel shutdown function. See Pico documentation, MAX31856 pinouts, MAX31856 datasheet, INA228 board and TI INA228 documentation.

6. What is required before an engine build can be released

1. Freeze fuel and output interface: fuel type/composition and LHV basis, regulated DC voltage, standalone/battery operation, duty life, fabrication capabilities and permitted envelope. The preliminary analysis uses a fuel-neutral LHV budget; it does not qualify a propane or methane burner.

2. Close the actual thermal/fluid path: heater/cooler channels and conductance, regenerator geometry with measured oscillatory pressure loss and effectiveness, seals/leakage, combustion/recuperator and coolant auxiliaries. About 416 W ideal heater demand across the assumed 50 K wall/gas difference suggests a minimum lumped conductance near 8.3 W/K, but oscillatory finite-transfer design and peak flux still require solution.

3. Reconcile the whole assembly with the model: 11.88 mm piston travel, displacer motion, real moving masses, flexure spring geometry and fatigue life, both bounce chambers, cold liner, gas passages and alternator air gaps. Resolve every unintended interference and demonstrate assembly/removal access and tolerance/hot-clearance margins.

4. Release the hot pressure boundary with qualified materials, joints, closures and life calculations. Complete controlled proof/leak qualification using approved procedures and setpoints.

5. Design and characterize the alternator and power electronics together. Demonstrate startup, stroke regulation, normal load, load rejection, dump operation, overtemperature and loss-of-sensor response. The present effective resistor is a model parameter, not a completed rectifier circuit.

6. Build and calibrate the DAQ, then qualify the regenerator, heater, alternator and moving mechanism before a fuelled system trial. Measure fuel energy, gross DC, every auxiliary load and coolant heat. Demonstrate at least 200 W net at no more than 1,000 W LHV input with uncertainty stated, stable temperatures/stroke, and a defined endurance duration. A preliminary one-hour run is a development gate, not a lifetime claim.

These requirements are unresolved engineering and physical work. No claim of final achievement is made merely because the software workbench is alive.

7. Software, deployed scene and reproducibility

VH155 uses existing FreeCAD 1.1.3 with its bundled Python/CalculiX and newly installed official signed KiCad 10.0.6. Local support tools include FreeCAD, KiCad libraries, CalculiX and ngspice. KiCad was installed and exercised through the actual Windows UI. Long computations, exports and servers ran in TerminalMan sessions.

The live scene is the Chrome MHeart workbench, FreeCAD's audited V1 and N01 component documents, and KiCad's MH-DAQ 1.8-cedar PCB/3D viewer on **VH155, artheru-rog6900hx**. TerminalMan session 26177a74c7 (mheart-workbench-live) serves port 8786; session faedd7f1d9 (mheart-oa-broker) carries the OA tunnel. The isolated TerminalMan service is on that machine's loopback port 8776. Keep these terminals and applications open for inspection.

The OA pool was full. A dedicated loopback relay route on hub port 61267 was added for this artifact through the live route API, with existing eight assignments preserved and no relay restart. Rollback material is kept privately under /root/ai-deck/mheart/4.4-forge/rollback on lessokaji-hub. Credentials and broker scripts are excluded from the public deliverables.

Model commands, from the deployed project directory using the bundled FreeCAD Python, are deliverables\model\analyze.py, neck_fea.py, dynamic_screen.py, settle.py, refine.py, refine_ash.py and refine_elm.py. Use a TerminalMan terminal. neck_fea.py expects the local bundled ccx.exe; review.FCMacro runs in the actual FreeCAD GUI and points at the preserved V1 source. The checked native KiCad files are authoritative; generator scripts are provenance and may recreate earlier intermediate revisions.

Open Status, Models & evidence, Parts & PCBs, and Download in the live workbench. Select the larger-stroke trace, inspect the changing budget assumptions, filter parts, open CAD/PCB PDFs and download the fabrication and evidence archives. This is a checkable software engineering scene. It is not a running physical Stirling engine.