Archimedes / Fluid devices

A one-way valve with no moving parts, 2.5x better.

A Tesla valve lets fluid flow easily one way and resists it the other way, with nothing moving. Archimedes had to do it with a single element, and beat a published design of the same size by 2.5x. The evidence is 2D simulation only.

ARCHIMEDES TECHNICAL CASE STUDY

How to interpret this report

Results apply only to the stated geometry, operating conditions, numerical models, and verification record.
They are not product certification, safety approval, or a general claim outside the documented scope.
Limitations and adverse findings are retained because they are part of the engineering result.

REPORT ID
`tesla-valve`

CANONICAL SOURCE
`standardphysics.com/archimedes/tesla-valve`

2.5x
better at blocking backflow than a published design of the same size

34
different design programs written by the agents

1,463
designs tried on 32 cloud machines in 3 hours

The ask

Block backflow as strongly as possible with exactly one valve element.

Water, a 24 by 20 mm footprint, and no repeated stages.

What it did

Bent the channel around an island and added a hooked trap for backflow.

Reverse flow gets caught and turned back on itself, while forward flow takes the smooth branch.

What it found

A straight main channel caps how well one element can work.

Backflow has to be forced into a collision. A straight path lets it slip through.

Fine print

Simulation only, in 2D.

A finer simulation kept the 2.5x result. There is no 3D, manufacturing or physical test yet.

For engineers

The full record, unedited.

Interactive comparison`explore the measured results`

MEASURED COMPARISON

One element, measured against the literature geometry

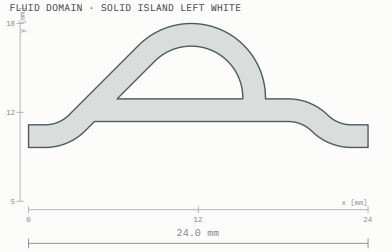
Select a topology to compare measured diodicity at Re 300. The plate shows the exact recorded baseline and winner fluid domains; no return-jet path is inferred. The T45 comparator uses shortened 2W legs to fit the common footprint.

RECORDED GEOMETRY COMPARISON

FIXED PROJECTION · COMMON SCALE

A · BASELINE / Adapted T45 comparator

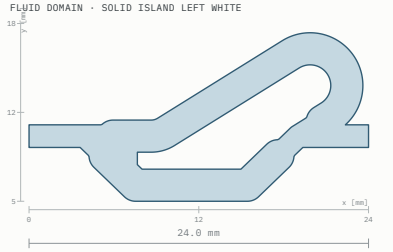
FLUID DOMAIN · SOLID ISLAND LEFT WHITE



SOURCE ID ea1cc48531c3ecd4

B · RESULT / Archimedes S16c

FLUID DOMAIN · SOLID ISLAND LEFT WHITE



SOURCE ID 364d35e20d11d413

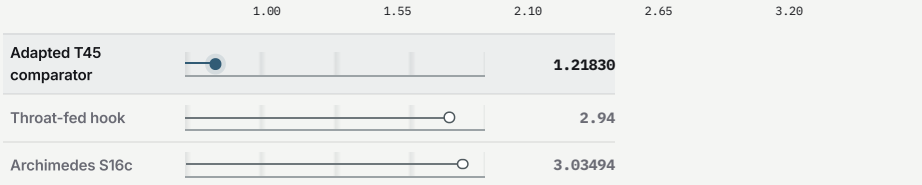
Recorded 2D fluid passage. 24.0 mm common envelope. Geometry is reconstructed from the recorded campaign artifacts.

Geometry only. No inferred streamlines, pressure field, or unrecorded physical detail is shown.

A source: results/evolve/robustness/tesla/designs/ea1cc48531c3ecd4.py · ea1cc48531c3ecd4 · Recorded CAD boundary tessellation of the exact 2D passage with constant-depth display extrusion.
B source: results/evolve/robustness/tesla/designs/364d35e20d11d413.py · 364d35e20d11d413 · Recorded CAD boundary tessellation of the exact 2D passage with constant-depth display extrusion.

DIODICITY AT RE 300

HIGHER IS BETTER →



Diodicity is reverse pressure drop divided by forward pressure drop at equal flow. The refined-mesh values are stated in each selected design's record.

Numerical basis: 2D steady laminar Navier-Stokes (OpenFOAM simpleFoam, body-fitted mesh); Re 25-2000 sweep, with values above Re 500 treated as steady-solver results only

LITERATURE-DERIVED GEOMETRY

Adapted T45 comparator

The literature-derived T45 uses shortened 2W legs in the same 24 by 20 mm footprint.

Diodicity 1.21830

- Same 24 by 20 mm footprint
- Shortened 2W legs
- Same frozen 2D evaluator

NEAR WINNER

Throat-fed hook

A hooked capture mouth increases the reverse-flow share entering the loop before the collision.

Diodicity 2.94

- Bent lower passage
- Captured reverse jet
- Forward loss kept low

REFINED-MESH WINNER

Archimedes S16c

The tear-drop island, 2.269 mm loop legs, and 44.125° re-entry angle create the strongest recorded collision.

Diodicity 3.03494, 2.5x the comparator

- 168° jet collision angle
- 2.97311 on the 1.5x mesh
- Comparator 1.20157 on the same refined mesh

Diodicity at Reynolds number 300

Diodicity is reverse pressure drop divided by forward pressure drop at equal flow. The comparator is shortened to the campaign footprint.

Passage	Search mesh	1.5x mesh	Mechanism
Adapted T45	1.21830	1.20157	Literature-derived, shortened 2W legs
Throat-fed hook	2.94	Not separately refined	Captured reverse jet
Archimedes S16c	3.03494	2.97311	Single island and 168 deg collision

Operating window

The steady laminar solver remains the only evidence above the onset of unsteadiness.

Reynolds number	Record	Interpretation
200 to 500	Advantage retained	Steady 2D laminar range
500 to 2,000	Steady-solver advantage retained	Not unsteady-validated
Refinement	One 1.5x level	Not a formal convergence study
Geometry rule	One non-repeating element	24 by 20 mm footprint

Applicability

The 2.5x statement is a 2D steady laminar comparison against an adapted T45. It is not a 3D, unsteady, tolerance, or physical-prototype result.

References and source records

Truong and Nguyen (2003), construction of the T45 valve used for the comparator.
Forster et al., literature T45 geometry adapted to the 24 by 20 mm harness.

Campaign lock: 1.6 mm ports, 0.1875 m/s, laminar simpleFoam, both flow directions.

The exact brief as given to the agents

Maximize fluidic diodicity D = dp_reverse / dp_forward for water at Re = 300 (1.6 mm ports, 24 x 20 mm footprint, minimum wall clearance >= 0.8 mm). STRICT RULE: Exactly ONE diode element - no repeated loops, cells, baffle chains, or periodic stages.

ARCHIMEDES
3.0 h autonomous swarm search

COMPUTE RECORD
1,463 bidirectional CFD solves across 32 cloud workspaces

Decision log how the agents reasoned, step by step

REASONING TRACE

What changed, and why

The critical insight was to stop preserving a straight main passage. Once the entire element wrapped around one island, the geometry could favor forward flow while forcing reverse flow into a momentum-cancelling collision.

SWARM EXPLORATION · 34 PARAMETRIC PROGRAMS

Discovering why a straight main channel limits single-stage diodicity

OBSERVED	INFERRED	CHANGED AND MEASURED
Round 0 produced D = 1.64764.	By deflecting the main channel	The winner reached D =

The search then tested channel curvature, capture-mouth position, loop width, and collision angle as coupled variables.	around a central island and placing a hooked capture lip directly on the reverse inlet centerline, reverse flow is rammed into the upper loop while forward flow glides past the hook.	3.03494. Relative to the same-footprint T45 comparator, reverse pressure drop rose by about 71% while forward pressure drop fell by about 31% in the recorded Re 300 solve.

Engineering finding

headline numbers and the mechanism

A passive valve that earns its footprint

The result offers a compact route to directional flow control where reliability, contamination, or scale makes moving parts undesirable.

2.5x

diodicity of the same-footprint literature-derived T45 comparator (3.03494 vs 1.21830 at Re 300)

2D steady laminar CFD · Re 300

2.2 - 2.5x

steady-solver lead over the T45 comparator from Re 200 to 2000, peaking at D = 3.78844 versus 1.60091 at Re 750

7-point Reynolds-number sweep · high-Re values not unsteady-validated

2.973

diodicity on the 1.5x refined mesh against 1.202 for the literature T45 (2.5x ratio held)

1.5x refined mesh verification

Why the mechanism works

The search bent the main passage around one tear-drop island, added a hooked reverse-flow capture mouth, widened the loop legs to 2.269 mm, and tuned a 44.125 deg re-entry angle with a 168 deg collision angle. In the computed reverse direction, this geometry raises dissipation while the forward direction follows the smoother branch.

What the baseline got wrong

In the same-footprint T45 comparator, the reverse-flow loop and main conduit recombine too gently to create the same dissipation as the winning single-element geometry.

Full technical record

appendices, families and limits

CAMPAIGN RECORD AND LIMITATIONS

Appendix

The detailed brief, decision record, search families, solver basis, and verification checks are exposed below without tabs or collapsed panels.

Appendix A: Frozen brief and campaign scale

Maximize fluidic diodicity D = dp_reverse / dp_forward for water at Re = 300 (1.6 mm ports, 24 x 20 mm footprint, minimum wall clearance >= 0.8 mm). STRICT RULE: Exactly ONE diode element - no repeated loops, cells, baffle chains, or periodic stages.

Search duration 3.0 h	**Evaluations** 1,463
Compute fleet 32 cloud workspaces	**Solver basis** 2D steady laminar Navier-Stokes (OpenFOAM simpleFoam, body-fitted mesh); Re 25-2000 sweep, with values above Re 500 treated as steady-solver results only

Appendix B: Full decision log

01 Hour 00:00 - 01:15 · Swarm Exploration · 34 Parametric Programs

Discovering why a straight main channel limits single-stage diodicity

OBSERVATION

Round 0 produced D = 1.64764. The search then tested channel curvature, capture-mouth position, loop width, and collision angle as coupled variables.

REASONING

By deflecting the main channel around a central island and placing a hooked capture lip directly on the reverse inlet centerline, reverse flow is rammed into the upper loop while forward flow glides past the hook.

ACTION AND RESULT

The winner reached D = 3.03494. Relative to the same-footprint T45 comparator, reverse pressure drop rose by about 71% while forward pressure drop fell by about 31% in the recorded Re 300 solve.

Appendix C: Search families

34 parametric programs. These are distinct programs or engineering configurations, not cosmetic renders.

- Single-island hooked capture loop with widened 2.2 mm legs (Winner S16c, D = 3.035)
- Throat-fed capture hook with bent lower passage (D = 2.94)
- Floor-step pinch variant with a lower outlet restriction
- Literature-derived T45 comparator with shortened 2W legs in the same 24 x 20 mm footprint (D = 1.218)

Appendix D: Numerical basis and verification

2D steady laminar Navier-Stokes (OpenFOAM simpleFoam, body-fitted mesh); Re 25-2000 sweep, with values above Re 500 treated as steady-solver results only

- The 1.5x refined mesh preserves the result: D = 2.97311 for the winner and 1.20157 for the comparator.
- No 3D, unsteady, fabrication-tolerance, or physical validation is recorded. The Re > 500 sweep remains a steady-solver comparison.

Appendix E: Reported outcomes and limits

2.5x diodicity of the same-footprint literature-derived T45 comparator (3.03494 vs 1.21830 at Re 300) Basis: 2D steady laminar CFD · Re 300.	**2.2-2.5x** steady-solver lead over the T45 comparator from Re 200 to 2000, peaking at D = 3.78844 versus 1.60091 at Re 750 Basis: 7-point Reynolds-number sweep · high-Re values not unsteady-validated.
2.973 diodicity on the 1.5x refined mesh against 1.202 for the literature T45 (2.5x ratio held) Basis: 1.5x refined mesh verification.	

Explicit limitations

- No 3D, unsteady, manufacturing-tolerance, or physical validation is recorded.
- The T45 comparator is literature-derived and adapted to the common footprint, not an exact full-length literature specimen.
- Reynolds-number results above 500 are steady-solver values only.

Recorded Archimedes run: 3.0 h autonomous swarm search. Compute record: 1,463 bidirectional CFD solves across 32 cloud workspaces.