# Infinity Turbine LLC
# 2012 Inflow Radial Turbine Rotor with $CO_2$

Geometry measured from the 2012 3D model (R245-Inflow_Radial_Turbine_20121107) and the 2013 ITmicro Radial Impeller drawing. Potential output with $CO_2$ on the lab cart (100 °C heat source, 10 °C condenser cooling), compared with the wheel's original R245fa duty.

Prepared for Gregory Giese | Rev A, 15 November 2026

## Summary

**Bottom line.** This is a conventional, well-proportioned 2-inch radial inflow turbine wheel. With $CO_2$ it is a **50–70 kW-class machine**: at its natural operating point it would pass about 2.8 kg/s of $CO_2$ at about 68,000 rpm. That is roughly 16 times what the Cat 310 can pump. On the lab cart it can only run in deep partial admission at reduced speed. Expect about **2.4 kW at 4 gpm** (at about 32k rpm, 43 % efficiency) and about **153 W at 20,000 BTU/hr**. Running it at its $CO_2$ design speed on the cart would cost more power in churning the idle blade passages than it produces.

• **Geometry:** Ø2.000 in (50.8 mm) wheel, 0.750 in long, 10 full blades plus 10 splitters, radial-element blades at the inlet, about 61° exducer exit angle. Rotor inlet radius 24.8 mm with a 3.0 mm (0.12 in) blade height; exducer from 8.4 to 15.0 mm radius (exit area 4.85 cm²). About 121 g in 304 stainless.

• **Original R245fa duty:** at the same 100 °C / 10 °C conditions, the wheel makes about 3.9 kW shaft at 0.13 kg/s and about 75,000 rpm.

• **With $CO_2$ at full flow:** about 48 kW at 100 bar or 70 kW at 120 bar, about 18× the R245fa output from the same wheel. $CO_2$ leaves the turbine about 24× denser, so much more mass passes through the same passages. But this needs 0.55–0.62 MW of 100 °C heat and a 2.3–2.8 kg/s pump using 15–26 kW.

• **On the lab cart** the nozzle would cover only 1–4 % of the rotor circumference. The rest of the passages churn dense $CO_2$ (about 150 kg/m³). Best speeds are 15–32k rpm, giving 23–43 % efficiency.

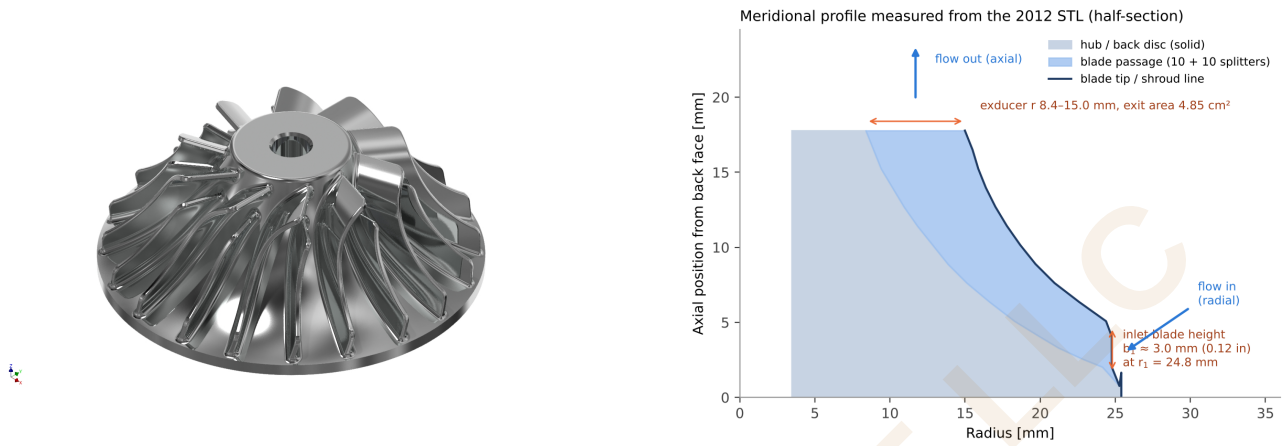
• **Compared with the other options on the cart:** at 4 gpm this wheel (about 2.4 kW) is below the bucket turbine estimate (3.65 kW at 65 %). At 20,000 BTU/hr it is below even the Tesla stack (about 0.15 kW vs 0.29 kW model ceiling).

• **Mechanical:** at the 68,000 rpm design speed the bore stress in 304 stainless reaches about 200 MPa, at its yield. Use 17-4PH H1025 or Ti-6Al-4V for full-speed $CO_2$ work. At the cart's 25–35k rpm, 304 is fine.



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# 1. The rotor: what the files show



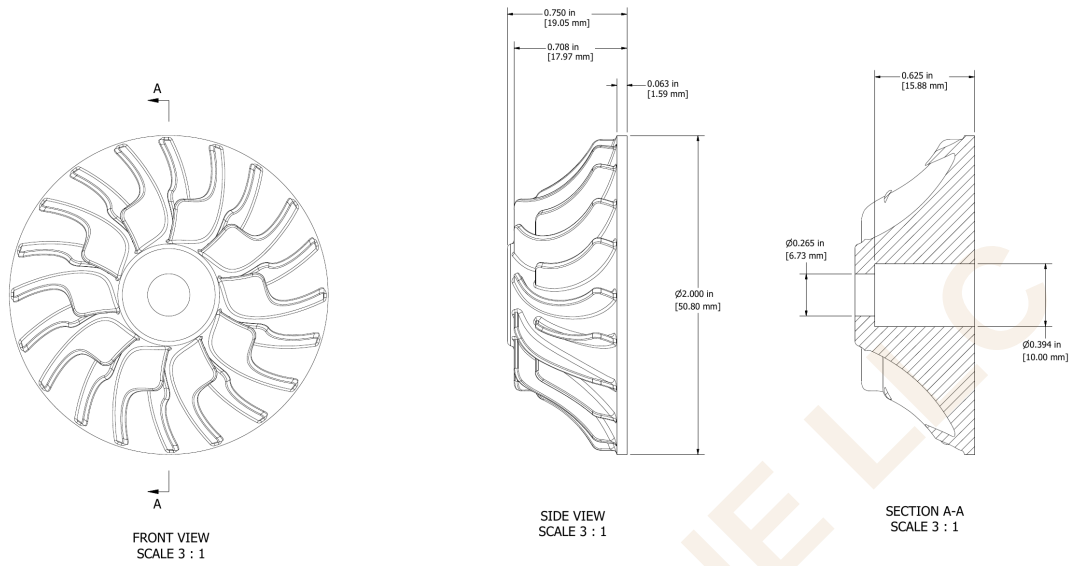

Left: 2012 render (R245-Inflow_Radial_Turbine_20121108-ortho.jpg). Right: half-section measured by slicing the STL every 0.02 in.

| Dimension | Imperial | Metric | Source / note |
|---|---|---|---|
| Wheel / back-disc diameter | 2.000 in | 50.8 mm | STL and 2013 drawing |
| Rotor inlet (blade tip) radius $r_1$ | 0.975 in | 24.8 mm | STL slices |
| Inlet blade height $b_1$ | 0.12 in | 3.0 mm | STL, back face to shroud break |
| Back-disc thickness | 0.063 in | 1.6 mm | drawing |
| Exducer hub / tip radius | 0.33 / 0.59 in | 8.4 / 15.0 mm | STL at z = 0.70 in; $r_{3s}/r_1 = 0.61$ |
| Exit annulus area (gross) | 0.751 in² | 4.85 cm² | about 12 % blade blockage assumed |
| Inlet passage area (gross) | 0.735 in² | 4.74 cm² | $2\pi\, r_1\, b_1$ |
| Overall axial length | 0.750 in | 19.05 mm | STL and drawing |
| Blades | 10 full + 10 splitters | — | splitters end about 0.57 in from the back face |
| Inlet blade angle | about 0° (radial element) | — | planar wrap under about 10° |
| Exducer exit blade angle | about 60–62° from axial | — | blade wrap 4–5° per 0.02 in near the exit |
| Blade thickness (exducer) | about 0.03 in | about 0.8 mm | STL sections |
| Bore / counterbore | Ø0.265 thru / Ø0.394 × 0.625 deep | Ø6.7 / Ø10.0 mm | drawing |
| Volume / mass (304 SS) | 0.934 in³ | 121 g | STL volume |

The STEP file path ("CO2T_LCO2 turbine with pump") and its name ("R245 Inflow Radial Turbine") suggest the wheel was drawn for R245fa and considered for $CO_2$. The 2013 ITmicro drawing has the same envelope (Ø2.000 × 0.750 in, 304 SS).



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2013 ITmicro Radial Impeller drawing (front, side and section views).

## 2. Method

This is a one-dimensional meanline assessment, with real-fluid properties from CoolProp 8.0:

• **Cycle** is the lab-cart basis: 100 °C source and turbine inlet at 90 °C; 10 °C cooling water, so $CO_2$ condenses at 18 °C (54.7 bar). R245fa: saturated at 85 °C (8.9 bar), 5 K superheat, condensing at 18 °C (1.14 bar).

• **Design speed** is set by the classic radial-turbine optimum: blade-tip speed $U_1 = 0.70 \times$ the spouting velocity $c_0$.

• **Flow capacity** is set by the exducer: exit axial velocity $C_3 = 0.25\ U_1$ through the net exit area. This gives a specific speed $N_s = 0.41$ for every fluid, close to the efficient range. Peak efficiency comes from a radial-turbine $N_s$ correlation (about 78 % here).

• **Lab-cart flows** (Cat 310 at 1–4 gpm, and the 20,000 BTU/hr case) are far below capacity, so the wheel is modeled in partial admission. The nozzle arc follows from nozzle exit density, velocity, blade height and a 75° nozzle angle. Losses: a stage-efficiency curve peaking at 70 %; ventilation of idle passages $\zeta_v = 0.13\ (1-\varepsilon)/\varepsilon\ (U/c_0)^3$ (Suter–Traupel type); back-face disc friction (Daily–Nece).

Uncertainty: about ±10 efficiency points on the meanline results, and about ±50 % on ventilation loss, which matters most at high speed. The trends and the factor-of-16 flow mismatch are robust.

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## 3. Wheel capacity: $CO_2$ versus R245fa

| At the wheel's natural operating point | R245fa (design fluid) | $CO_2$, 100 bar | $CO_2$, 120 bar |
|---|---|---|---|
| Turbine inlet | 8.9 bar / 90 °C (129 psia / 194 °F) | 100 bar / 90 °C (1,450 psia) | 120 bar / 90 °C (1,740 psia) |
| Pressure ratio | 7.8 | 1.81 | 2.17 |
| Isentropic enthalpy drop | 38.6 kJ/kg | 27.2 kJ/kg | 31.5 kJ/kg |
| Spouting velocity $c_0$ / nozzle Mach | 278 m/s / 1.9 | 233 m/s / 0.95 | 251 m/s / 1.10 |
| Design speed ($U_1/c_0$ = 0.70) | 75,008 rpm (195 m/s) | 62,940 rpm (163 m/s) | 67,766 rpm (176 m/s) |
| Exhaust density | 6.3 kg/m³ | 130 kg/m³ | 150 kg/m³ |
| Mass flow capacity | 0.13 kg/s (17 lb/min) | 2.26 kg/s (298 lb/min) | 2.82 kg/s (373 lb/min) |
| Specific speed $N_s$ / estimated efficiency | 0.41 / 78 % | 0.41 / 78 % | 0.41 / 78 % |
| **Shaft power** | **3.9 kW (5.3 hp)** | **48.0 kW (64 hp)** | **69.6 kW (93 hp)** |
| Heat input required | 33 kW (111,524 BTU/hr) | 548 kW (1.87 M BTU/hr) | 623 kW (2.13 M BTU/hr) |
| Pump work (fluid) | 0.09 kW | 14.6 kW | 26.1 kW |
| Net electric (95 % generator, 85 % pump drive) | 3.6 kW | 28.4 kW | 35.4 kW |

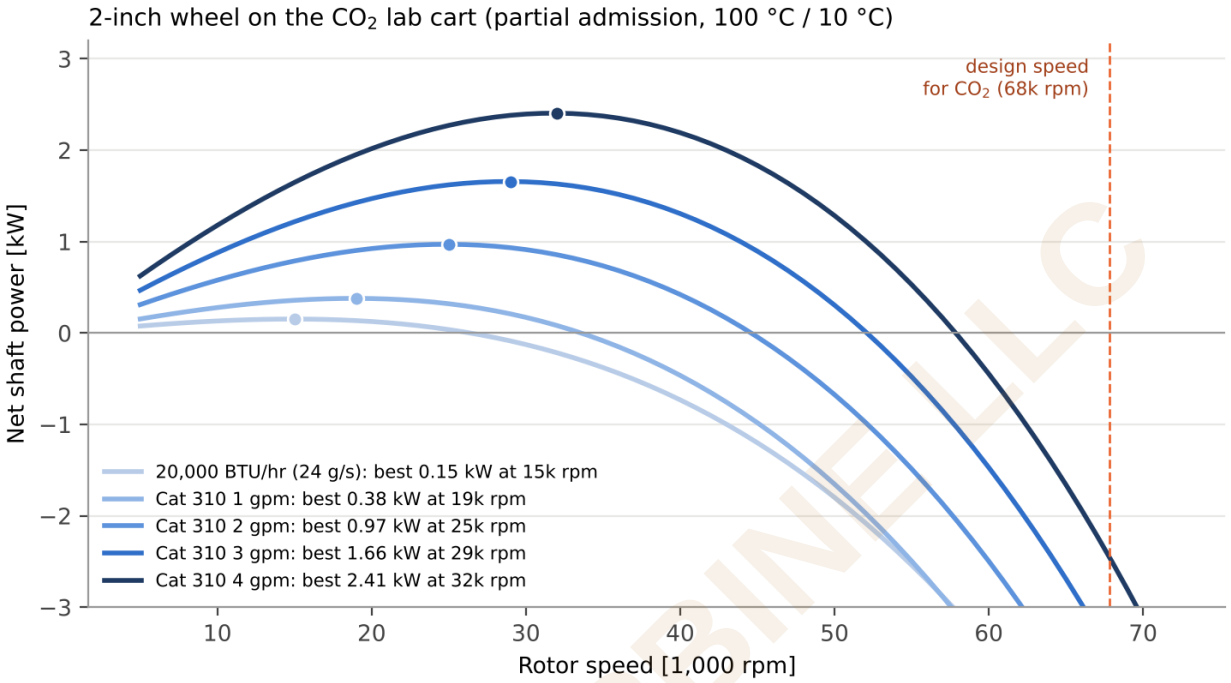
With $CO_2$, the same 2-inch wheel produces 12–18× the shaft power it makes on R245fa. The cost is a much larger pump: the back-work is 30–37 % for $CO_2$ versus 2 % for R245fa. The R245fa nozzle is supersonic (Mach 1.9); the $CO_2$ nozzle is near sonic.

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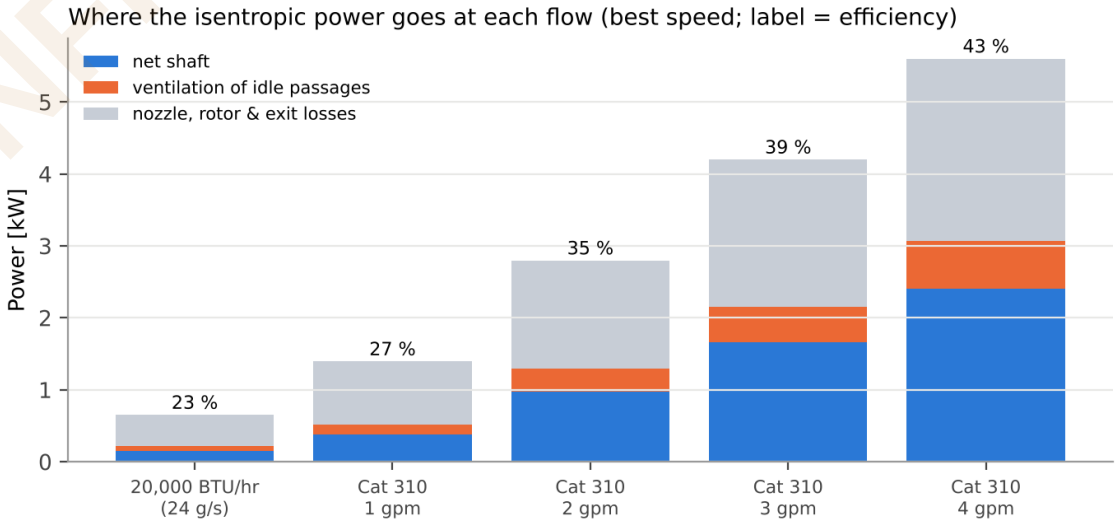
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## 4. On the $CO_2$ lab cart




| Flow case | $CO_2$ flow | Admitted arc | Nozzle area | Best speed | Isentropic power | Net shaft | Efficiency |
|---|---|---|---|---|---|---|---|
| 20,000 BTU/hr (24 g/s) | 0.024 kg/s (3.2 lb/min) | 0.7 % (1.0 mm) | 0.8 mm² | 15,000 rpm | 0.66 kW | **0.15 kW** | 23 % |
| Cat 310 1 gpm | 0.044 kg/s (5.9 lb/min) | 1.0 % (1.5 mm) | 1.2 mm² | 19,000 rpm | 1.40 kW | **0.38 kW** | 27 % |
| Cat 310 2 gpm | 0.089 kg/s (11.8 lb/min) | 1.9 % (3.0 mm) | 2.4 mm² | 25,000 rpm | 2.80 kW | **0.97 kW** | 35 % |
| Cat 310 3 gpm | 0.133 kg/s (17.6 lb/min) | 2.9 % (4.5 mm) | 3.5 mm² | 29,000 rpm | 4.20 kW | **1.66 kW** | 39 % |
| Cat 310 4 gpm | 0.178 kg/s (23.5 lb/min) | 3.8 % (6.0 mm) | 4.7 mm² | 32,000 rpm | 5.61 kW | **2.41 kW** | 43 % |

Cat 310 cases at 120 bar; the 20,000 BTU/hr case at 100 bar. Blade pitch at the inlet is 7.8 mm, so even at 4 gpm the nozzle arc (about 6 mm) is less than one passage wide.

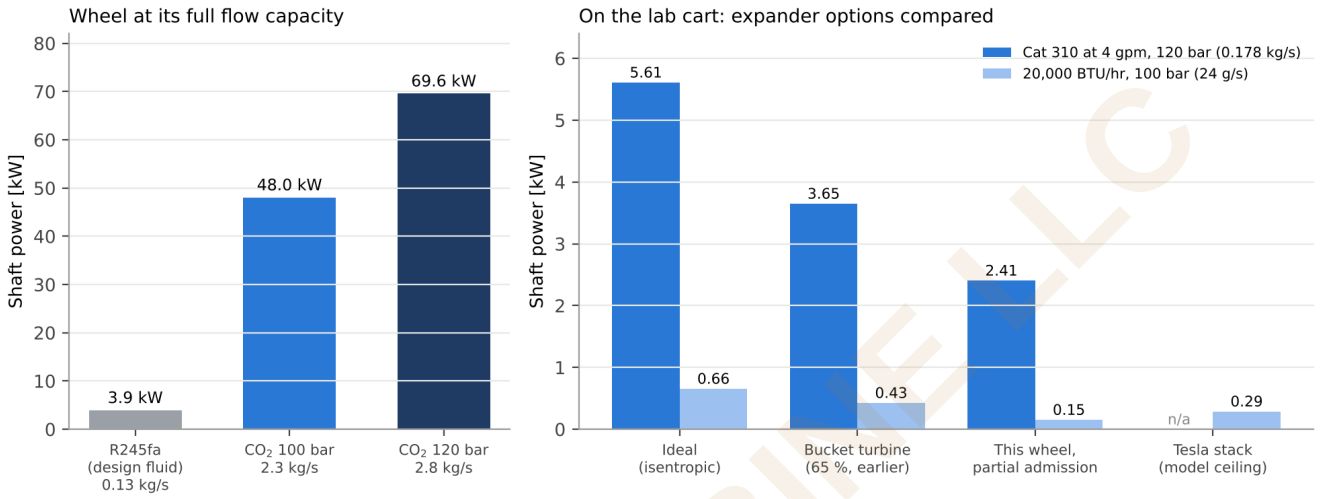





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At low admission the best speed falls to $U/c_0$ of 0.2–0.33, far below the 0.7 the wheel was designed for. Ventilation rises with the cube of speed: at 68,000 rpm the idle passages would absorb about 6 kW, more than any cart flow can supply.

## 5. Comparison with the other lab-cart expanders




The bucket turbine and Tesla figures are from the earlier lab-cart and Tesla reports in this series (65 % assumed for the bucket turbine; Tesla model ceiling). On the cart, this wheel is a reasonable demonstrator at 3–4 gpm but not the best performer. Its strength is at much higher flow.

## 6. Mechanical notes

| Speed | Tip speed | Nominal centre stress | At bore (×2) | 304 SS (yield about 205 MPa annealed) |
|---|---|---|---|---|
| 32,000 rpm (cart, 4 gpm) | 83 m/s | 22 MPa | 45 MPa | Fine |
| 50,000 rpm | 130 m/s | 55 MPa | 110 MPa | Acceptable |
| 68,000 rpm ($CO_2$ design) | 176 m/s | 101 MPa | 203 MPa | **At yield**: use 17-4PH H1025 or Ti-6Al-4V |
| 75,000 rpm (R245fa design) | 195 m/s | 125 MPa | 250 MPa | **Over yield** |

Stresses use the rotating-disc approximation $(3+\nu)/8 \cdot \rho U^2$, doubled at the bore. Blade root and splitter stresses need a proper FEA before any high-speed run. With $CO_2$, the back face sees roughly nozzle-exit pressure and the exducer sees exhaust pressure. Size the axial thrust bearing for the full-admission case even if the cart runs in partial admission.

## 7. Recommendations

• **For the lab cart (Cat 310, 1–4 gpm):** run this wheel with one converging nozzle of about 4.7 mm² (4 gpm) to 1.2 mm² (1 gpm), set at about 75° from radial, at 25–35k rpm. Fit a shroud over the non-admitted arc to cut ventilation: shrouding idle passages is the standard fix and could add several hundred watts. Expect about 1.5–2.5 kW at 3–4 gpm.

• **Do not plan on it for the 20,000 BTU/hr case** (about 0.15 kW). At that flow a positive-displacement or hydraulic expander, such as the ROT 06 concept, or a much smaller impulse wheel is more suitable.

• **As a production machine, this wheel suits $CO_2$ at about 2.3–2.8 kg/s**: 48–70 kW shaft from 0.55–0.62 MW of 100 °C heat. That is a natural single-module size for the Cluster Mesh / data-center waste-heat concept, with a pump in the 15–26 kW class instead of the Cat 310.



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• **Baseline test with R245fa:** running the wheel on the IT10 at its design fluid (about 3.9 kW at 0.13 kg/s) gives a measured efficiency to calibrate the $CO_2$ predictions.

• **Before any $CO_2$ run above about 50k rpm:** re-make the wheel in 17-4PH or titanium, check blades by FEA, balance to G2.5 or better, and design the thrust bearing for $CO_2$ pressures.

• **To use this wheel family at cart flows,** scaling is the problem. Holding the same specific speed at 0.18 kg/s would need a 12 mm wheel at about 270,000 rpm. This is why small $CO_2$ test loops favor partial-admission impulse or positive-displacement expanders.

## Sources and notes

• Gregory Giese files: R245-Inflow_Radial_Turbine_20121107.stl / .stp (Autodesk Inventor 2013, 13 Nov 2012), R245-Inflow_Radial_Turbine_20121108-ortho.jpg, 2013 ITmicro Radial Impeller noHex.pdf (17 Jan 2013).

• Geometry measured here by slicing the STL (trimesh/shapely) at 0.02 in steps; blade count and angles from polar sampling of each section.

• Fluid properties: CoolProp 8.0 (Span–Wagner for $CO_2$; Lemmon for R245fa).

• Meanline relations: $U/c_0$ optimum about 0.7 and the $N_s$–efficiency trend for radial inflow turbines (Rohlik / Balje); partial-admission ventilation of Suter–Traupel form; disc friction from Daily & Nece.

• Bucket-turbine and Tesla comparison values come from the earlier Infinity Turbine lab-cart and Tesla reports in this series (15 Nov 2026).

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