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# Note on Design Parameters and Performance of a Gravitation Water Vortex Turbine (GWVT) with Zotloeterer Turbine

**[1]Florentin Smarandache*, [2]Victor Christianto, and [3]Yunita Umniyati**

**Author's Affiliations:**
[1]Dept. Mathematics and Sciences, University of New Mexico, Gallup, NM.
[2]Malang Institute of Agriculture, East Java, Indonesia
[3]Dept. Mechatronics, Swiss-German University, Tangerang, Indonesia.

***Corresponding author:**
Florentin Smarandache
Dept. Mathematics and Sciences, University of New Mexico, Gallup, NM.
E-mail: smarand@unm.edu

**ABSTRACT**

Micro-hydro power is a critical component of decentralized renewable energy systems, particularly in remote regions with low-head, low-flow water resources. Traditional large-scale turbine designs (e.g., Francis, Kaplan) are often inefficient, costly, or environmentally inappropriate for these conditions. The **Gravitation Water Vortex Turbine (GWVT)**, exemplified by the Zotloeterer design, emerged as a promising alternative [1-2]. It harnesses energy from a gravity-driven, free-surface vortex within a cylindrical tank, offering a simple, robust, and environmentally friendly—often "fish-friendly"—solution. In the present article, we discuss among other things, aspects of design parameters and performance of GWVT and CVT (a new design) along with Zotloeterer Turbine.

**KEYWORDS**

Decentralized Renewable Energy Systems, Micro-Hydro Power, Gravitation Vortex Water Turbine, Zotloeterer Design, Confined Vortex Turbine

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## INTRODUCTION

Hydropower is one of the most sustainable and desirable renewable energy sources. Micro-hydro power is a critical component of decentralized renewable energy systems, particularly in remote regions with low-head, low-flow water resources. Traditional large-scale turbine designs (e.g., Francis, Kaplan) are often inefficient, costly, or environmentally inappropriate for these conditions. The **Gravitation Water Vortex Turbine (GWVT)**, exemplified by the Zotloeterer's design, emerged as a promising alternative.[1] It harnesses energy from a gravity-

[1] Added note: from Schauberger's viewpoint, such a vortex water power plant can be expected to exhibit what he calls as "implosion" of water which in turn is likely to improve water-healthiness (see for instance, Schauberger, *Nature as Teacher*).

driven, free-surface vortex within a cylindrical tank, offering a simple, robust, and environmentally friendly—often "fish-friendly"—solution. However, the GWVT's operational principle involves a highly complex, turbulent, and two-phase (air-water) flow field [1,2,3]. This complexity hinders precise analytical modelling and performance optimization. This article analyses the key design parameters and performance limitations of the Zotloeterer GWVT and proposes a simplified, more stable alternative: the **Confined Vortex Turbine (CVT)**.

## DESIGN PHILOSOPHY OF WATER VORTEX POWER PLANT: HARMONY WITH NATURE

The Gravitation Water Vortex Power Plant (GWVPP/GWVT), featuring the Zotlöeterer turbine, represents a profound departure from conventional hydropower. Its design philosophy is rooted in the unconventional and deeply ecological theories of Schauberger (1885–1958), an Austrian forester and natural scientist. While traditional hydropower relies on high-pressure, straight-line flow (explosion principle) to drive turbines, often with severe ecological consequences, the GWVT power plant embraces Schauberger's principle of implosion—the centripetal, and vortical movement of water—to generate power while simultaneously revitalizing the waterway.

## THE POWER OF IMPLOSION AND LIVING WATER

Schauberger viewed water not merely as a chemical compound ($H_2O$) but as a **living substance** with a vital energy, or "*lifeblood of the Earth.*" His observations of natural river flows, fish movements, and vortex phenomena led him to a radical conclusion: nature operates on the principle of implosion, a dynamic, inward-spiralling movement that concentrates and vitalizes energy. This is fundamentally opposed to the destructive, centrifugal force of explosion that characterizes most industrial processes, including conventional turbines and straightening rivers.

Schauberger posited that when water is forced into straight channels or subject to the outward-pushing forces of conventional turbines, it loses its natural vitality and becomes "sick" or aggressive, leading to erosion and degradation of the surrounding environment. Conversely, a **centripetal, inwardly spiralling vortex**—the implosion principle—causes water to cool, densify, and become energized. This centripetal motion is critical for:

- **Rejuvenation and Self-Purification:** The vortex's natural, swirling motion facilitates self-purification and aeration. As a vortex forms, the densest water is drawn to the centre, while the spiralling action homogenously disseminates contaminants, increasing the contact surface for purifying microorganisms and aquatic plants.
- **Creating "Healthy" Water:** Schauberger argued that this implosive, vortical movement is essential for water to carry its full electrical life force. Water that has experienced this motion is said to introduce **more healthy characteristics** to the river, benefiting the fishes and the plant life surrounding the river, as described in his work, such as *Nature as Teacher*.

The essence of the GWVT's philosophy is to utilize the natural gravitational drop to initiate this beneficial, centripetal vortex, rather than disrupt the natural flow.

## THE ZOTLÖTERER TURBINE AND GWVT CONFIGURATION: DESIGN FOR ECOLOGICAL HARMONY

The Gravitation Water Vortex Power Plant, pioneered by Austrian inventor **Franz Zotlöeterer**, is the practical realization of Schauberger's hydro-ecological principles. It is specifically designed as an ultra-low head hydropower system, typically operating with a vertical drop of 0.7 to 3 meters, which is unsuitable for conventional turbines [4].

The physical configuration of the GWVT is its primary philosophical statement, centered on minimal environmental impact and bi-directional ecology:

- **The Rotation Tank (Vortex Chamber):** Water is diverted from a river via a coarse screen and an open inlet gate into a circular or conical basin. The tangential entry and the basin's geometry induce a large, stable, free-surface **Gravitation Water Vortex**. This large, slow-rotating vortex is the heart of the system, transforming the water's potential energy into rotational kinetic energy.

- **The Zotlöterer Turbine:** Placed coaxially within the vortex, the turbine is the energy converter. The design is a crucial innovation: it is a slow-rotating, wide-bladed turbine (often with few blades) that harnesses the rotational energy of the vortex. Crucially, the slow speed (below 2 m/s at the blade tips) and geometry are specifically engineered to prevent physical harm to fish, which can pass through the turbine unharmed in both upstream and downstream directions. This contrasts sharply with the high-speed, high-pressure operation of conventional turbines, which often cause high fish mortality.
- **No Guide Vanes or Nozzles:** Unlike reaction turbines that use complex guide vanes and nozzles to convert pressure into velocity, the Zotlöeterer turbine operates **without** those components. This simplifies the design, reduces complexity, and further ensures that the natural, gentle turbulence of the water flow is maintained, allowing fish to pass without losing orientation.

## THE GWVT AS A BIOREACTOR

The GWVT extends beyond mere power generation; it functions as a **novel bioreactor**. The rotation tank is designed to foster a healthy, diverse aquatic environment:

- Water Aeration and Cooling: The large, open vortex significantly increases the water surface area, promoting natural aeration. In the summer, this increased surface area also enhances evaporation, helping to reduce the water's temperature, a key tenet of Schauberger's philosophy to maintain water vitality.
- Habitat and Food Generation: The walls and floor of the rotation tank become a high-bioactive area, fostering the growth of aquatic plants and microbes. These microbes serve as a direct food source for fish, effectively drawing them into the GWVT and aiding their upstream passage.
- Fish Passage and Migration: The GWVT acts as an integrated, low-velocity fish pass. Fish are attracted by the water flow and the microbial food, easily finding the entrance. The low water speed and the gentle, slow rotation of the Zotlöterer turbine allow fish to ascend and descend with minimal exertion and no risk of injury, *addressing one of the most significant ecological failings of conventional hydroelectric dams.*

In essence, the design philosophy of the GWVT is a holistic one: it seeks to generate green electricity not *despite* ecological harmony, but as a consequence of it, by embracing the self-organizing, life-enhancing, and implosive force of the water vortex as first championed by Schauberger.

## OPERATING PRINCIPLE AND STRUCTURE OF THE ZOTLOTERER’S GWVT

The Zotloeterer’s design of GWVT structure typically comprises a vertical, often slightly conical, cylindrical tank.[2] Water is introduced tangentially via one or more inlets, establishing a rotational flow. Due to the centrifugal force and the central outlet at the tank bottom, a characteristic air-core vortex forms. The potential energy of the water column is converted into rotational kinetic energy, which is captured by a specialized, low-speed runner (impeller) suspended within the vortex chamber.
Key Components:

- Vortex Chamber: The main tank body (Diameter, $D_{tank}$).
- Tangential Inlet(s): Determines the initial angular momentum.
- Zotloeterer Runner: A multi-bladed, usually vertical-axis, impulse-type runner (Diameter, $D_{runner}$).
- Central Drain/Outlet**:** Defines the air-core size and flow rate ($D_{out}$).

## GOVERNING FLUID DYNAMICS AND DESIGN PARAMETERS

The flow field is dominated by the complex interaction of gravity, rotation, and viscous dissipation at the tank walls and the free air-water surface [5].

[2] For illustration, see: ZOTLÖTERER-TURBINE

The velocity field within the tank approximates an irrotational, **free vortex** (outside the boundary layer), where the tangential velocity is inversely proportional to the radius. In real-world GWVTs, viscous effects are significant, and the exponent n deviates from the ideal value of -1, empirically ranging from -0.7 to -0.9.

**Table 1: Zotloeterer's GWVT Design Parameters and Impact, cf. [4,5,7,8].**

| **Design Parameter** | **Rationale/Function** | **Impact on Performance** |
|---|---|---|
| Flow Rate (Q) & Head (H) | Primary energy source. | $P \propto Q \cdot H$. Sets the maximum achievable power. |
| Inlet Angle (α) | Angle relative to the tangent of the tank wall. | Controls angular momentum transfer. Optimal $\alpha \approx 10^\circ - 20^\circ$. |
| Tank-to-Runner Ratio (Dtank/Drunner) | Controls the leverage of the vortex on the runner. | Critically affects torque. Typical optimal range is 2.5 to 3.5. |
| Outlet Diameter (Dout) | Defines the size and stability of the air core. | Smaller $D_{out}$, increases water volume/head, but can choke the flow. |

## COMPUTATIONAL MODELING AND SIMULATION

A precise prediction of GWVT performance requires complex Computational Fluid Dynamics (CFD), specifically using multiphase models (e.g., Volume of Fluid, VOF) to track the free surface. However, a simplified analytical model based on the Euler Turbine equation and an empirical velocity profile provides an essential starting point for design parameter exploration [4,7].

*Mathematica Code for Governing Equations*

The following Mathematica code block calculates the theoretical maximum torque (tau) and output power based on key design parameters, assuming a non-ideal free vortex profile and specified runner geometry.

Mathematica (outline only)

```
(*Mathematica Code for Zotloeterer GWVT Theoretical Performance Analysis *) (* --- Define Physical and Design Constants --- *) rho = 1000; (*Density of Water in kg/m^3 *) g = 9.81; (* Acceleration due to Gravity in m/s^2 *) H = 1.2; (*Effective Head in meters *) Q = 0.15; (* Volumetric Flow Rate in m^3/s *) omega = 6.28; (*Runner Angular Velocity in rad/s (e.g., 60 RPM) *) (* --- Define Zotloeterer Design Parameters --- *) r1 = 0.4; (* Runner Outer Radius in meters *) r2 = 0.1; (* Runner Inner Radius (near air core) in meters *) r_ref = r1; (* Reference Radius for velocity profile (often runner outer radius) *) v_ref = 1.5; (* Reference Tangential Velocity at r_ref in m/s *) n = -0.8; (* Empirical Vortex Exponent (Non-ideal free vortex) *) (* --- 1. Hydraulic Input Power --- *) Pin = rho * g * Q * H; Print ["1. Hydraulic Input Power (W): ", Pin]; (* --- 2. Vortex Velocity Function --- *) Vtheta [r_] := v_ref * (r/r_ref)^n; Print["2. V_theta at r1 (m/s): ", Vtheta[r1] // N]; Print[" V_theta at r2 (m/s): ", Vtheta[r2] // N]; (* --- 3. Euler's Turbine Equation (Torque) --- *) (* Tau = rho * Q * (r1*Vtheta[r1] - r2*Vtheta[r2]) *) Tau = rho * Q * (r1 * Vtheta[r1] - r2 * Vtheta[r2]); Print["3. Theoretical Torque (N*m): ", Tau // N]; (* --- 4. Theoretical Output Power --- *) Pout = Tau * omega; Print ["4. Theoretical Output Power (W): ", Pout // N]; (* --- 5. Theoretical Hydraulic Efficiency --- *) Eta_h = Pout / Pin; Print ["5. Theoretical Hydraulic Efficiency (%): ", Eta_h * 100 // N]; (* --- Sensitivity Analysis Example: Effect of Flow Rate Q --- *) Plot[rho * g * Q_var * H, {Q_var, 0.05, 0.3}, PlotLabel -> "Input Power vs. Flow Rate", AxesLabel -> {"Flow Rate Q (m^3/s)", "Power P_in (W)"}]
```

Result of simulation:

$$\text{"1. Hydraulic Input Power (W): "1765.81."}$$

$$\text{"3. Theoretical Torque (N * m): "150. }\left(-\frac{0.6309573444801932\text{v\_ref}}{\left(\frac{1}{\text{Pattern[0.1, \_ref]}}\right)^{0.8}}+\frac{0.8325532074018732\text{v\_ref}}{\left(\frac{1}{\text{Pattern[0.4, \_ref]}}\right)^{0.8}}\right)$$

$$\text{"4. Theoretical Output Power (W): "942. }\left(-\frac{0.6309573444801932\text{v\_ref}}{\left(\frac{1}{\text{Pattern[0.1, \_ref]}}\right)^{0.8}}+\frac{0.8325532074018732\text{v\_ref}}{\left(\frac{1}{\text{Pattern[0.4, \_ref]}}\right)^{0.8}}\right)$$

$$\text{"5. Theoretical Hydraulic Efficiency (\%): "100. Eta\_h"}$$

*Note:* This code provides a first-order estimate. A complete analysis would require integrating the velocity profile across the blade surfaces and accounting for hydraulic losses (shock, friction, and leakage).

**Performance Characteristics and Efficiency**

Typical overall efficiency for the Zotloeterer GWVT ranges from **30% to 50%**. This is low compared to commercial reaction turbines but acceptable for the ultra-low head, low-power niche.

Performance Limiting Factors

1. Free Surface Instability: The air-core radius and position are highly sensitive to Q and H variations, causing vortex wobble and unsteady torque generation.
2. This significantly reduces overall reliability and efficiency.
3. Viscous Losses: Friction with the large tank walls and the highly turbulent nature of the flow dissipate considerable energy.
4. Runner Design: The runner must operate in a non-uniform velocity field and is prone to shock losses at the blade inlet due to varying flow angles.
5. No Pressure Recovery**:** The open-bottom design, while simple, prevents the use of an efficient draft tube to recover kinetic energy at the outlet.

**Further Alternatives to Zotloeterer's Gravitational Water Vortex Turbine**

While the Zotloeterer's Gravitational Vortex Water Turbine Power Plant (GWVT) is celebrated for its environmental benefits, particularly water re-oxygenation and fish safety, its low efficiency (30–50%) and high sensitivity to flow variations limit its commercial viability. This necessitates the exploration of alternatives that retain the low-head applicability but improve hydraulic efficiency and stability. The primary goal is to transition from an open, gravity-driven system to a controlled, pressure-managed system.

**a. Alternative Arrangement: The Series GWVT for River Flow Capture**

For long, low-slope river stretches, the traditional approach of building a single high-head structure is environmentally disruptive. An alternative is the Series Arrangement of GWVTs, designed to capture cumulative head drop while maintaining a low-impact, cascading flow.

Principle of Series Arrangement

This system places multiple, small-head GWVT units sequentially. Crucially, the design incorporates the vertical turbine and conical vortex in a series flow path within each stage to optimize energy transfer and minimize wake effects.

1. Water Intake: Water is diverted from the river into the first stage basin.
2. Turbine Stage: The flow passes through the vertical-axis turbine runner (e.g., a simplified propeller or cross-flow turbine) which extracts kinetic and potential energy.
3. Vortex Stage: The outflow from the turbine is immediately directed into a conical vortex chamber (like the Zotloeterer's design) to manage energy dissipation, re-oxygenate the water, and ensure a smooth, stable discharge into the next stage or the tailrace.

4. Cascading: The flow then continues to the next station, capturing the next segment of head drop.
   This arrangement maximizes the utilization of the available river slope while maintaining the GWVT's ecological benefits.

*Where the design of series arrangement of GWVT can be found useful:*
The series arrangement of Gravitational Water Vortex Power Plants (GWVTs) becomes particularly useful and effective in long, low-gradient river stretches or irrigation canals. This is where the total available head is significant (e.g., 5 meters over 500 meters of distance), but the head available at any single, practical location is very small (e.g., 1 meter). Building a single, large structure is often environmentally or geographically unfeasible. The series arrangement allows for "better harvesting" by installing multiple small, low-impact GWVT stations sequentially. By extracting the head drop in cascading stages, this configuration maximizes the utilization of the total river slope while minimizing flow disruption at any one point. It is an optimal strategy for decentralized power generation and for maintaining the environmental benefits (aeration and fish passage) across the entire length of the watercourse.

**b. Confined Vortex Turbine (CVT), a new design**

To address the complexity and instability of the free-surface Zotloeterer design, the **Confined Vortex Turbine (CVT)** can be proposed as an alternative to GWVT. The CVT maintains the vortex energy extraction principle but operates within a fully sealed, pressurized environment, eliminating the problematic air-core and free surface.
CVT Design and Principle

- Enclosure: The large, open tank is replaced by a compact, volute-like pressure casing typical of Francis turbines.
- Flow Field: The flow is pressure-driven, maintaining a single-phase (water only) flow field, which is stable and predictable.
- Guide Vanes: Crucially, the CVT incorporates adjustable guide vanes upstream of the runner. These vanes precisely control the magnitude and angle of the tangential velocity entering the runner, ensuring optimal performance across a wide range of flow rates.
- Runner: A simplified, high-efficiency vertical or horizontal axis propeller runner can be employed, designed for a more uniform flow field.

**Table 2. Comparative Performance and Advantages between Zotloeterer's GWVT and CVT; cf. [4,5,7,8].**

| Feature | Zotloterer GWVT | Confined Vortex Turbine (CVT) |
|---|---|---|
| Flow Stability | Low (Vortex Wobble, Air Entrainment) | High (Single-phase, Pressurized Flow) |
| Modeling Complexity | Very High (Multiphase CFD, VOF) | Low (Standard Single-Phase CFD) |
| Pressure Recovery | None (Open Drain) | Yes (Sealed Draft Tube) |
| Ideal Head Range | 0.7 m−3 m | 2 m−10 m |

**Table 3. Design Comparison between Zotloeterer's GWVT and CVT**

| Feature | Zotloeterer's Open GWVT | Confined Vortex Turbine (CVT) |
|---|---|---|
| Flow Regime | Free Surface, Two-Phase (Water/Air), Unstable. | Fully Pressurized, Single-Phase (Water Only), Stable. |
| Flow Control | Passive (Basin Geometry). | Active (Adjustable Guide Vanes) for precise tangential velocity. |
| Head Utilization | Primarily Potential Energy (gravity). | Potential Energy + Kinetic Energy Recovery (Draft Tube). |

| | | |
|---|---|---|
| Efficiency Goal | 30%–50% (Eco-centric). | ≥ 80% (Power-centric). (Due to guide vanes and draft tube) |

The CVT shifts the focus from structural simplicity (of Zotloeterer design) to **hydraulic simplicity and control**, allowing for higher efficiency and robust operation in slightly higher but still "*low-to-medium head*" applications.
The CVT's sealed volute casing replaces the open conical basin, allowing the use of highly optimized runners and draft tubes similar to those in Francis or Kaplan designs. This control over flow dynamics is the foundation of its better performance.

## DISCUSSION

### Technical analysis of CVT design and Trade-offs in Micro-Hydro Design

The enhanced efficiency of the CVT requires a robust engineering approach, particularly in estimating energy production and modelling the highly constrained fluid dynamics. The energy estimation relies on the standard hydraulic power equation, and for the high-efficiency CVT, we assume a practical efficiency (eta) of 82%.

<u>**Mathematica code to estimate energy output:**</u>

Mathematica (outline only)

```
(* Mathematica Code: Confined Vortex Turbine Energy Production Estimate *) ClearAll["Global`*"]; (* 1. Define Parameters for a typical low-head CVT installation *) rho = 1000; (* Density of water in kg/m^3 *) g = 9.81; (* Acceleration due to gravity in m/s^2 *) H = 4.0; (* Effective Head in meters (low to moderate head for a CVT) *) Q = 12.0; (* Design Flow Rate in m^3/s *) eta = 0.82; (* Estimated Efficiency of the Confined Vortex Turbine (82%) *) (* 2. Power Output Calculation (P = eta * rho * g * Q * H) *) Pwatts = eta * rho * g * Q * H; (* 3. Display Results *) Print["--- Confined Vortex Turbine (CVT) Energy Estimation ---"]; Print["Design Head (H): ", H, " meters"]; Print["Design Flow Rate (Q): ", Q, " m^3/s"]; Print["Assumed Efficiency (η): ", eta * 100, "%"]; Print["Estimated Mechanical Power Output: ", NumberForm[Pwatts, {5, 0}], " Watts"]; Print["Estimated Mechanical Power Output: ", NumberForm[Pwatts / 1000, {5, 2}], " kW"];
```

<u>**Result of simulation:**</u>

```
"Design Head (H): "4. "meters"
"Design Flow Rate (Q): "12. "m^3/s"
"Assumed Efficiency (η): "82. "%"
"Estimated Mechanical Power Output: ""386120. ""Watts"
"Estimated Mechanical Power Output: ""386.12""kW"
```

### Mathematica Code for Approximate 3D Navier-Stokes Solution (Vortex Flow)

The confinement in a CVT requires solving the 3D Navier-Stokes (N-S) equations to accurately model the boundary layer effects near the enclosure walls. For an *approximate* solution, we utilize the **Rankine Vortex Model** for the core flow (tangential velocity) combined with the assumption of axisymmetry and steady flow. This simplifies the N-S equations into a coupled system for the radial, axial, and tangential velocities, cf. [1,4].

The following code defines and plots the simplified tangential velocity field using the Rankine model, which is a key characteristic of the flow derived from the tangential momentum equation under the inviscid assumption.

<u>**Mathematica**</u> **(outline only)**

```
(* Mathematica Code: Approximate 3D Navier-Stokes Solution (Rankine Vortex Tangential Velocity) *) ClearAll["Global`*"]; (* Define Parameters for Confinement *) r_c = 0.4; (* Core radius (Approximation of the forced vortex boundary layer) in meters *) r_max = 3.0; (* Confinement/Volute Outer Radius in meters *) Gamma_0 = 40; (* Circulation constant (a measure of vortex strength) in m^2/s *) (* 1. Calculate the Angular Velocity (Omega) for continuity at r_c *) (* u_theta_forced(r_c) = u_theta_free(r_c) => r_c * Omega = Gamma_0 / (2 * Pi * r_c) *) Omega = Gamma_0 / (2 * Pi * r_c^2); (* 2. Define the Approximate Tangential Velocity Profile (u_theta) *) u_theta[r_] := Piecewise[{ {r * Omega, r <= r_c}, (* Forced Vortex (Solid Body Rotation) in the boundary layer/core *) {Gamma_0 / (2 * Pi * r), r > r_c} (* Free Vortex (Potential Flow) in the main flow path *) }]; (* 3. Plot the Approximate Velocity Profile *)
```

```
Plot[u_theta[r], {r, 0.01, r_max}, PlotLabel -> Style["Approximate Tangential Velocity Profile (Rankine Vortex Model)", Bold], AxesLabel -> {"Radial Distance r (m)", "Tangential Velocity u_θ (m/s)"}, PlotStyle -> {Thick, Darker[Blue]}, PlotRange -> All, Epilog -> {Dashed, Red, Line[{{r_c, 0}, {r_c, u_theta[r_c]}}], Text[Style["Forced/Free Transition", Small], {r_c + 0.7, 30}]}} ]
```

Summarizing, the choice between the Zotloeterer GWVT and the CVT hinges on the application's constraints. The Zotloeterer design (GWVT) is arguably the ultimate choice for ultra-low head (<1) and maximum structural simplicity (e.g., for non-invasive installations where no pressure pipe is feasible). However, its low efficiency and high sensitivity limit its power generation potential.

The CVT, while requiring a slightly higher head and a pressure casing, offers a compelling trade-off: **significantly higher efficiency and operational stability** due to the removal of the free surface. This improved hydraulic performance makes it the better choice for maximizing power output and ensuring long-term reliability in low-head sites.

## CONCLUDING REMARK

The Zotloeterer's Gravitational Water Vortex Power Plant (GWVT), while a powerful concept for ultra-low-head sites (sub-2 meters), is quite limited by the instability of its free-surface flow, leading to low efficiencies (30-50%). Optimization requires a delicate balance of the runner-to-tank diameter ratio and inlet design.

The Confined Vortex Turbine (CVT) provides a better hydraulic alternative, eliminating the air core and incorporating precise guide vanes to achieve flow stability and high efficiencies (~ 80%) in low-head applications. Crucially, the comparison shifts dramatically at **medium heads (e.g., 5 to 10 meters)**. At these elevated heads, the Zotloeterer design is entirely unsuitable due to the massive flow rates required to sustain the vortex and the catastrophic instability of a high-energy free surface.

In contrast, the **CVT excels at medium heads**. Its pressurized, volute-cased design allows it to harness the increased pressure and kinetic energy efficiently, competing directly with established Francis or Kaplan turbines, making the CVT the universally better and often the only viable vortex-based choice for medium-head sites seeking high power output and reliability.

This improved hydraulic performance makes it the better choice for maximizing power output and ensuring long-term reliability in low-head sites.

Last but not least, further research is recommended in the direction outlined above.

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Version 1.1: 9th Nov. 2025
FS, VC

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