Prototype Test Simulation Protocol

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1. Objective

- **Purpose of Simulation: Determine the optimal desalination operating conditions of the Cube-Pipe System within defined ranges of four different variables.**

  A. Temperature range of operation from 75F-110F.

  B. Salinity range of 3.5% to 30%.

  C. Flow rate of 0.5 gal/min to 2 gal/min.

  D. Items A, B & C with Solar Coating applied and without Solar Coating applied.

- **Key Questions:**

  A. Is there an optimal salinity concentration for evaporation?

  B. What is the optimal operating temperature range of the system?

  C. How much does the Solar coating increase the efficiency of the system?

  D. What is the optimal flow rate of the system at various temperatures?

2. Prototype Description

Overview:

A. Ocean water is brought into holding ponds, where it can warm up throughout the day and be available for the Cube System to add new water from.

B. A steel pipe irrigation system warms incoming water by transferring irradiance from the sun to the water inside the pipes.

C. The Steel pipes deliver warmed saline water to the top of the Cube system, where it is slowly fed into the Cubes.

D. The Cube is an enclosed, comprised of thermoplastic and measuring approximately W:1ft x D: 1ft x H: 16in. Inside the cube are a series of trays designed to disperse water over a maximum surface area. These conditions create a minimal depth and a maximum rate of evaporation.

E. The water can go through one cube, or multiple cubes if they are stacked on top of each other. The cubes can be stacked up to 7 high (there is a weight bearing issue past 7), with the prediction that the evaporation efficiency will increase with the number of cubes it passes through.

F. Freshwater evaporation is collected on the interior walls of the cube and ported off through a collection gutter near the bottom of the unit. Fresh water is ported off to a freshwater collection bladder, existing outside of the closed loop system. As the day progresses and more freshwater is ported off, the recirculated waste water will increase in salinity,

G. At the bottom of the cube, wastewater is either ported into the cube below it, or, if it is the bottom cube, the water exits the cube and is piped back to the steel pipe system for recirculation.

H. When we predict the optimal salinity level of the system, we will be able to calculate when to add new ocean water (3.5%) to the system and when to port hypersaline water to salt water evaporation beds. When it comes to managing salt byproduct, the system tolerating higher salinity levels directly translates to there being less salt byproduct to manage. Essentially, we would be extracting the most amount of freshwater from the least amount of ocean water.

3. Test Participants

- **Target Users:**
  Small Cities who are located within the equatorial zone, having shrimp farm beds and access to the ocean.
- Prototype Developer: Crystal Newton % US Pyramid Project
- Thurston Laboratories: Hank Thurston. Create a simulation of the Cube-Pipe System operating under four different variable conditions (Salinity, Temperature, Flow Rate, Solar Coating). Additional possible role: Interpret and format data- to be decided upon completion of simulation.
- Gavorsky Consultants: Consultation at various points.

4. Testing Environment

Digital Simulation:

A. **Irradiance range: Run simulation of a irradiance range of 5.5–8 kWh/m²/day (292–333 W/m²)**
    a. 8am-10am uniform increase from 5.5 to 8
    b. 10am-6pm run at 8
    c. 6pm-8pm uniform decrease from 8 to 5.5
B. **Temperature range: Run Simulation of a temperature range of 75F-110F.** I don't know how much more difficult it will be to incorporate the temperature variance throughout the day, but if it is possible, this is the temperature variation model I would like used:
    a. May
        i. 8am-10am: 75F-85F
        ii. 10am-6pm: 85F
        iii. 6pm-10pm: 85F-75F
    b. June
        i. 8am-10am: 78F-90F
        ii. 10am-6pm: 90F
        iii. 6pm-10pm: 90F-78F
    c. July
        i. 8am-10am: 84F-100F
        ii. 10am-6pm: 100F
        iii. 6pm-10pm: 100F-84F
    d. August
        i. 8am-10am: 86F-110F
        ii. 10am-6pm: 110F
        iii. 6pm-10pm: 110F-86F
    e. September
        i. 8am-10am: 88F-104F
        ii. 10am-6pm: 104F
        iii. 6pm-10pm: 104F-88F
    f. October
        i. 8am-10am: 75F-94F
        ii. 10am-6pm: 94F
        iii. 6pm-10pm: 94F-75F
C. **Seasonal Breakdown: Run Simulation from May 1 - October 31**
D. **Humidity: Run all tests simulating humidity variations from 0-100%.**
    a. Summer (June–September): Humidity rises slightly due to monsoon-like conditions and occasional moisture from the Gulf of California. Average relative humidity ranges from 35–50%, with higher values (up to 60–70%) during brief monsoon rains in July–August.

Daytime humidity can drop to 20–30% under intense heat (38–42°C or 100–108°F).

b. Coastal Influence: Areas closer to the Gulf (e.g., El Golfo de Santa Clara, ~20–50 km from the coast) may see slightly higher humidity (5–10% more than inland areas like Mexicali) due to sea breezes. However, the delta's core, being 50–100 km inland, experiences more desert-like conditions.

c. Daily Fluctuations: Humidity varies diurnally, dropping during hot days (as low as 10–20% in summer afternoons) and rising at night (up to 50–60% in cooler conditions)

E. **Steel Pipes: Stainless Steel Grade 316:** 1" OD, 0.75" ID, 0.125" thick wall. Standard 316 grade steel pipes have a moderate absorptivity (α ≈ 0.4–0.6, depending on surface finish). We will assume 0.6 for the simulation due to the brushing of the steel pipe surface (reduction in reflectivity).
   a. Thermal Conductivity: ~15–17 W/m·K (for 304/316 stainless steel), lower than carbon steel but sufficient for efficient heat transfer to fluids like water or thermal oil. Conductivity ensures rapid transfer from the pipe's surface to the internal fluid.
   b. Thermal Stability: Stable up to 800°C (1472°F) in air, far exceeding the delta's 47°C ambient or solar collector temperatures (typically 100–400°C for parabolic troughs).
   c. Environmental Durability of Grade 316: Enhanced resistance to chloride corrosion (e.g., from brackish water), ideal for delta applications involving saline fluids. Molybdenum content improves pitting resistance.

F. **ThermoPlastic: Polyetherimide (PEI), 0.25" thick wall:**
   a. Thermal Conductivity: ~0.22 W/m·K (low, excellent for heat retention). PEI is an amorphous thermoplastic with good insulating properties, ideal for minimizing heat loss.
   b. Thermal Stability: Melting point of ~219°C (426°F), with a continuous service temperature of ~170°C (338°F). It easily handles the delta's maximum temperatures (47°C/117°F) without degradation.
   c. Environmental Suitability: PEI is resistant to UV light, chemicals (though susceptible to polar chlorinated solvents), and low humidity, making it suitable for the delta's arid, sunny conditions. Its high dielectric strength also supports applications in electrical insulation.
   d. Applications: Used in aerospace (e.g., aircraft parts), medical devices, and circuit boards, PEI could be applied in the delta for insulated enclosures or thermal storage systems.

G. **Plastic Tubing: Polytetrafluoroethylene (PTFE, e.g., Teflon®):**
   a. Thermal Conductivity: ~0.25 W/m·K. Widely used in heat exchanger tubing.

b. Thermal Stability: Continuous service temperature of -270°C to 260°C (-454°F to 500°F), well beyond delta requirements. Highly stable in hot, dry conditions.
c. Distance: Each tube will carry water for no more than 100 ft; the distance covered when the brackish water leaves the Cube system and is returned to the steel pipe solar collector. If a tube diameter measurement is needed, assume a 1" diameter.

H. **Steel Pipe Solar Coating Paint (TiNOX)**: Applying a selective solar coating to the steel pipes increases absorptivity to α > 0.9 (typically 0.92–0.96) while maintaining low emissivity (ε ≈ 0.05–0.15) to minimize heat loss via infrared radiation.
   a. Performance: α ≈ 0.95, ε ≈ 0.05–0.10. Highly selective, maximizing solar absorption while minimizing heat loss. Optimized for solar thermal collectors.
   b. Thermal Stability: Stable up to 400°C (752°F)
   c. Durability: Excellent resistance to UV, humidity, and corrosion, ideal for the delta's arid, saline environment. Withstands thermal cycling without degradation.

I. **Cube Solar Coating Paint (SOLKOTE HI/SORB-II):** Applying the solar coating to the cube system will decrease the heat loss of the thermoplastic cube.
   a. **Solar Absorptivity (α)**: ~0.90–0.95 (on metals like stainless steel 316; similar on PEI with proper priming). Captures 90–95% of solar radiation (0.3–2.5 μm), leveraging the delta's high irradiance (5.5–6.5 kWh/m²/day).
   b. **Thermal Emissivity (ε)**: 0.2–0.4 on low-emissivity substrates (e.g., stainless steel, aluminum); ~0.4–0.8 on high-emissivity substrates like PEI. Thinner coats (0.5 mil dry) reduce ε, improving selectivity.

J. **CAD Design of System: (see separate Attachment)**

5. Test Scenarios

- **Scenario Set Up:**
  - **One Row:** 2 cubes wide, 10 cubes long, 3 cubes high. Stacked Cubes port into each other: the top cube process water and dumps waste water into the Cube below and onto the cube below. Once the bottom cube is reached, the waste water is piped back to the steel pipe collector system for reprocessing.
  - **Set up Two Rows with a 1 ft separation between the rows.** This creates a wind tunnel that is a functional part of the design of the system. The wind passes in between the cube rows, cooling one side wall of a cube at any given point in the system; creating greater condensation development within the cube.
- **Scenario List:**
  - **Scenario A1:**Evaporation efficiency from 78F-110F using 3.5% Salinity.
  - **Scenario A2:**Evaporation efficiency from 78F-110F using 4.0% Salinity.
  - **Scenario A3:**Evaporation efficiency from 78F-110F using 4.5% Salinity.
  - **Scenario A4:**Evaporation efficiency from 78F-110F using 5.0% Salinity.
  - **Scenario A5:**Evaporation efficiency from 78F-110F using 5.5% Salinity.
  - **Scenario A6:**Evaporation efficiency from 78F-110F using 6.0% Salinity.
  - **Scenario A7:**Evaporation efficiency from 78F-110F using 6.5% Salinity.
  - **Scenario A8:**Evaporation efficiency from 78F-110F using 7.0% Salinity.
  - **Scenario A9:**Evaporation efficiency from 78F-110F using 7.5% Salinity.
  - **Scenario A10:**Evaporation efficiency from 78F-110F using 8.0% Salinity.
  - ……………………………………………………………..….**to 30% Salinity**
  - **Scenario B:** Scenario A replicated with Solar Coating
  - **Scenario C (Flowrate):** Scenario A replicated with variable flow rates tested at 0.5 gpm, 1.0 gpm, 1.5 gpm and 2.0 gpm (Without Solar Coating).
  - **Scenario D:** Scenario C with Solar Coating.

6. Data Collection Methods

Methods:
1. Use the chemical and physical properties of the system constituents (provided in this document) to predict the freshwater production of the system along variable operating conditions; an operating temperature range of 75F-110F, 0-100% Humidity, 5.5-8 Irradiance, 3.5% to 30% salinity, with and without solar coating.

2. Assume irradiance metrics and environmental variables consistent with the Colorado Delta Region (provided in this document).

3. Use CAD drawings to simulate system (provided in a separate document)

Success Metrics:
A. Establishing the distillation efficiency of the Cube-Pipe System along various salinity concentrations along the defined salinity range of 3.5%-12%.

B. Establishing the distillation efficiency of the Cube-Pipe System along various points of the defined temperature range of 78F-110F.

C. Establishing the efficiency difference of the Cube-Pipe System with and without thermal coating.

7. Testing Procedure

- Crystal will provide simulation metrics to Thurston Labs: that is this document.
- Thurston Labs will clarify items in this document.
- Thurston Labs will build a digital model of the system and perform tests according to the instructions provided in this document.
- Thurston Labs will contact Crystal when simulation is complete, in order to review the data.
- Thurston Labs and Crystal will consider how to process the data at this point. The data may be organized, analyzed and interpreted by Thurston Labs, or be sent to an additional 3rd Party.

8. Analysis and Reporting

- **Data Analysis:**
  Data will be collected by Thurston Labs and reviewed by both Thurston labs and Crystal. A decision will be made at this time as to what party will take control of analyzing and interpreting the data.
- **Reporting:**
  A final report establishing the conclusion of the simulation will be developed by either Thurston Labs, Gaavorksy Consultants or a Third Party; to be determined once the data is reviewed.

9. Iteration Plan

- **Feedback Incorporation:**
  Thurston Labs will review this document and obtain clarification with Crystal on any unclear or missing items. Once clarification is reached, Thurston labs will begin building the model to simulate the test.
- **Timeline:**
  Clarification on this document will likely take place until June 1, 2025. Simulation building is likely to take up to four weeks. Thurston Labs and Crystal have a goal of concluding the simulation and producing raw data by the end of July, 2025.