SRP EVAP

ME 476C Spring 2025

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Jorge Cesin-Financial Manager
Brendan Steele-Test Engineer

Project Review

- Objective: Research basic parameters of water evaporation and implement an experimental apparatus to mimic SRP’s goal of installing solar panels over canals
- Sponsored by Dr. Tom Acker, Sr. Principal Engineer, Innovation and Development at Salt River Project.
- Growing interest in renewable energy sources that utilize pre-existing space and provide co-benefits
- Our data will be provided to ASU research team to assist them in their analysis

Picture Credit: Tectonicus

Design Requirements: Updated QFD

Project: Captsone SRP QFD

Date: 3/31/2025

System QFD

Correlation roof:

++

0 | -

+ | 0 | 0 | ++

- | 0 | + | + | -

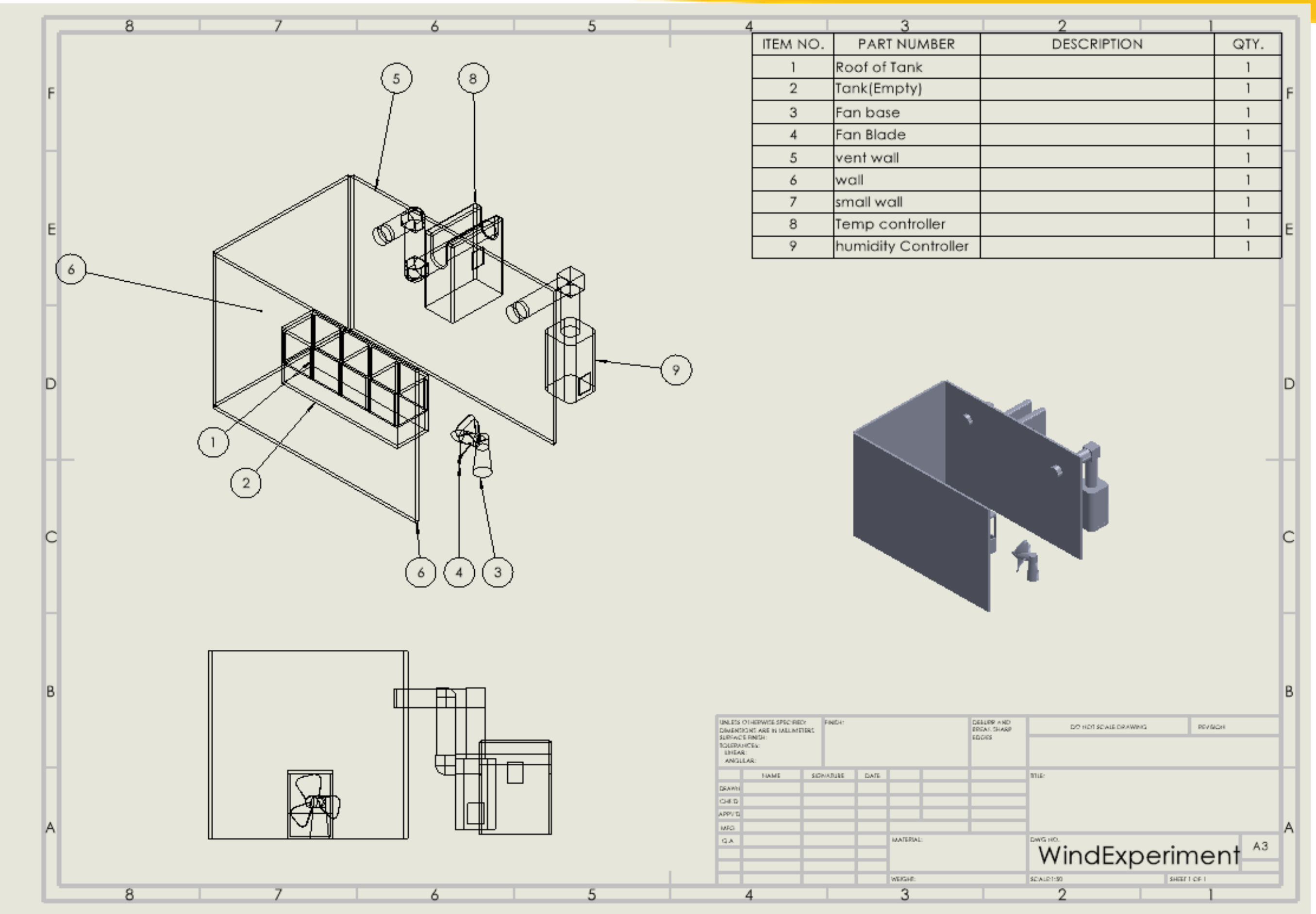
+ | - | - | - | 0 | 0

Customer Needs	Customer Weights	Evaporation Rate Measurement Precision	Enviromental Condition Monitoring & Control	Material Durability & Longevity	Geometric & Surface Area Optimization	Scalability & Adaptability to Different Environments	Economic Feasibility & Practicial Implementation	Evaporation Suppression Effectiveness	*Casa Blanca Canal Solar Project*	*Project Nexus*	*Gujarat Canal Solar Project*
		Technical Requirements (0,3,9)							**Competition (1-5)**		
Water Conservation	5	9	6	9	3	6	3	9	5	3	5
Energy Efficiency	3	3	6	3	3	6	9	3	1	4	5
Ease of Maintenance & Implementation	1	3	3	9	3	6	9	3	1	2	4
Environmental Sustainable	3	9	6	9	6	9	3	9	4	5	5
Scientific & Engineering Accuracy	5	9	9	3	3	6	3	9	2	5	3
Adaptability to Different Environments	3	6	6	3	3	9	3	6	1	5	3
Cost	3	3	3	6	6	3	9	3	2	3	3

	Evaporation Rate Measurement Precision	Enviromental Condition Monitoring & Control	Material Durability & Longevity	Geometric & Surface Area Optimization	Scalability & Adaptability to Different Environments	Economic Feasibility & Practicial Implementation	Evaporation Suppression Effectiveness
Technical Requirement Units	mm/day or L/m^2 /day	°C	Years	m^2 / m^3	Hours & m/s	$	%
Technical Requirement Targets	±.01 - .5 mm/day	5 °C	25yrs	150m^2	72hrs	$1.2 million	80%
Absolute Technical Importance	54	39	39	30	45	36	51
Relative Technical Importance	1st	5th	4th	7th	3rd	6th	2nd

Design Description

- A Solidworks model of the controlled climate apparatus.
- Uses two controllers (humidity and temp)
- Fan with variable speed
- 10-gallon tank with removable roof
- Completely enclosed



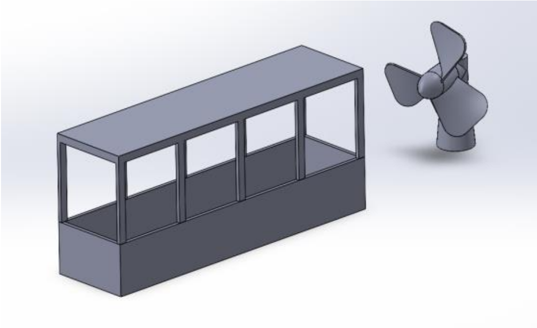
Design Description

- The 3 major sub-assemblies that are required to properly isolate out controlled environment.
  - Heat (solar infrared radiation)
    - The heat in the apparatus will be controlled with a small space heater in a sealed tent.
  - Humidity (percentage of water molecules in air)
    - The humidity will be controlled with an infinity cloud forged T3 humidity controller in a sealed tent.
  - Wind Speed
    - The Wind aspect will be tested by a 3-speed variable fan forcing wind over the surface of the water.

Figure 1: Heater

Figure 2: Humidifier

Figure 3: Fan



Previous Calculations

Equations	Purpose
$\dot{N}_A = h_m(C_{A,s} - C_{A,\infty})$	This is the convective mass flux equation, used to estimate the mass transfer rate of water vapor from the canal surface to the surrounding air.
$Sh = \frac{h_m L}{D_{AB}}$	This dimensionless equation connects the mass transfer coefficient to the geometry (L) and diffusivity (D_{AB}). It allowed us to solve for h_m and is similar to Nusselt number in heat transfer.
$sh = 0.664Re_L^{1/2}Sc^{1/3}$	Used when airflow contributes to evaporation, this correlation allowed us to determine the Sherwood number under forced convection. It uses Reynolds number which characterizes flow, and Schmidt number, which relates viscosity and diffusivity.
$Re_L = \frac{VL}{v}$	This equation determine whether the flow is laminar or turbulent. It was key in deciding whether to apply natural or forced convection relations, as different flow regimes result in different heat and mass transfer characteristics.

Previous Calculations

Equations	Purpose
$Sc = \frac{v}{D_{AB}}$	This dimensionless number compares momentum diffusivity and mass diffusivity and was used in Sherwood number correlations.
$u^* \frac{\partial T^*}{\partial x^*} + v^* \frac{\partial T^*}{\partial y^*} = \frac{1}{Re_L Pr} \frac{\partial^2 T^*}{\partial y^{*2}}$	This energy equation represents energy conservation in boundary layer flow, accounting for convective and conductive heat transfer.
$Pr = \frac{v}{\alpha}$	The Prandtl number characterizes the relative thickness of the velocity and thermal boundary layers and is necessary to apply the thermal boundary layer equations. However, we can get this value from Table A-15.
$\overline{Nu} = \frac{\bar{h}L}{k} = 0.664 Re^{1/2} Pr^{1/3}$	This equation is used in heat transfer to relate the average convective heat transfer coefficient to the system's thermal and flow characteristics.

Previous Calculations

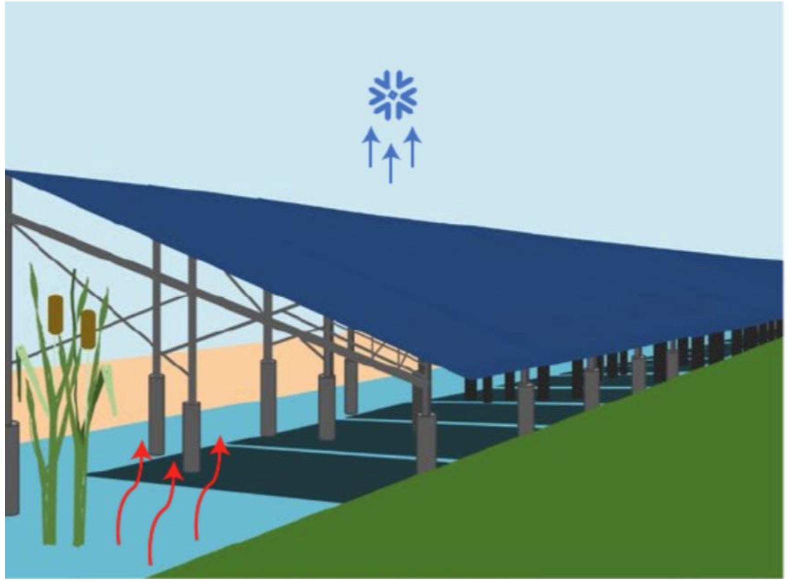
Equations	Purpose
$\bar{h} = \frac{\overline{Nu}k}{L}$	This equations calculates the average convective heat transfer coefficient over a surface, using the average Nusselt number, the thermal conductivity of the fluid, and a characteristic length.
$Le = \frac{\alpha}{D_{AB}}$	This is the Lewis number, a dimensionless number that characterizes the relationship between thermal diffusivity and mass diffusivity.
$\frac{h}{\overline{\overline{h_m}}} = \frac{k}{D_{AB}Le^n} \rightarrow \overline{h_m} = \frac{\bar{h}D_{AB}Le^{1/3}}{k}$	This equations allows conversion between heat and mass transfer coefficients using the Lewis number Le and is essential for connecting theoretical models across different physical mechanisms. This equation enables the calculation of the mass transfer coefficient h_m using the average heat transfer coefficient $\bar{h}$, the Lewis number, and know fluid properties.

General Project Assumptions

These are the base parameters that we will be designing our experiment around:

(In Summer) (U.S. Customary Units)

- ❑ Temperature of Air: 85°F, 100°F, 115°F
- ❑ Temperature of Water(Body): 60°F, 75°F, 90°F
- ❑ Temperature of water(surface):63°F, 78°F, 93°F
- ❑ Relative Humidity: 10%, 20%, 30%
- ❑ Wind Speeds: 5.8mph, 14mph, 22.4mph
- ❑ Top Width: 80ft, Bottom Width: 24ft
- ❑ Water Level: 16.5ft, Height of canal: 20ft
- ❑ Height of Roof from Top of canal: 3ft, 10ft, 15ft
- ❑ Still Water, No Clouds
- ❑ Solar noon
- ❑ Tolerance for maintaining parameters during experimentation: ±5°F, ±5%, ±2mph



Picture credit: [5]

Samantha Synk, 3/31/2025, SRP EVAP

Calculations

Diffusive molar flux of water vapor:

$$J_A^* = -D_{AB}\frac{dC_A}{dx} = \frac{-D_{AB}(C_{A,\infty} - C_{A,s})}{L} = \frac{kmol}{s * m^2}$$

$T_s = 26°C = 75°F$

$T_\infty = 38°C = 100°F$

$T = 32°C$

$\emptyset = 20\%$

$L_1 = 3ft = 0.914m$

$L_2 = 10ft = 3.048m$

$L_3 = 15ft = 4.572m$

$$D_{AB} = 2.62 * 10^{-5}\frac{m^2}{s}\ (interpolated\ from\ Table\ 14-4)$$

$$C_{A,\infty} = \frac{\rho_{air} * \omega_\infty}{\mathcal{M}_{water}} = \frac{1.1342 * 0.008}{18.02} = 0.000504\frac{kmol}{m^3}$$

$\rho_{air@T_\infty} = 1.1342\frac{kg}{m^3}$ (from Table A − 15)

$\omega_\infty = 0.008$ (from Psychrometric chart)

$\mathcal{M}_{H_2O} = 18.02\frac{kg}{kmol}$ (from Table A.4)

$$C_{A,s} = \frac{\rho_{air} * \omega_s}{\mathcal{M}_{water}} = \frac{1.180 * 0.004}{18.02} = 0.000262\frac{Kmol}{m^3}$$

$\rho_{air@T_s} = 1.180\frac{kg}{m^3}$ (from Table A − 15)

$\omega_s = 0.004$ (from Psychrometric chart)

$\mathcal{M}_{H_2O} = 18.02\frac{kg}{Kmol}$ (from Table A.4)

Calculations

When Cover is 3ft High:

$$J_{A1}^{*} = -\left(2.62 * 10^{-5}\frac{m^2}{s}\right)\left(\frac{0.000504\frac{kmol}{m^3} - 0.000262\frac{kmol}{m^3}}{0.914m}\right) = -6.95287 * 10^{-9}\frac{kmol}{m^2 * s}$$

When Cover is 10ft High:

$$J_{A2}^{*} = -\left(2.62 * 10^{-5}\frac{m^2}{s}\right)\left(\frac{0.000504\frac{kmol}{m^3} - 0.000262\frac{kmol}{m^3}}{3.048m}\right) = -2.08495 * 10^{-9}\frac{kmol}{m^2 * s}$$

When Cover is 15ft High:

$$J_{A3}^{*} = -\left(2.62 * 10^{-5}\frac{m^2}{s}\right)\left(\frac{0.000504\frac{kmol}{m^3} - 0.000262\frac{kmol}{m^3}}{4.5728m}\right) = -1.38997 * 10^{-9}\frac{kmol}{m^2 * s}$$

Design Validation: FMEA

Product Name: EvapBox 1.0		Development Team: SRP-EVAP25				Page No 1 of 1			
System Name: Evaporation Apparatus SRP						FMEA Number: 1			
Subsystem Name: EVP						Date: 3/31/2025			
Component Name : Scale Canal									
Part # and Functions	Potential Failure Mode	Potential Effect(s) of Failure	Severity (S)	Potential Causes and Mechanisms of Failure	Occurance (O)	Current Design Controls Test	Detection (D)	RPN	Recommended Action
1.Scaled Roof Covering of Canal Vessel	Error in Scalability or ratio	Distorts radiation input; affects evaporation simulation	7	Incorrect geometric scaling or not matching thermal properties	5	Visual Inspection; energy input simulation	4	140	Use IR lamps or heaters to replicate solar; perform thermal matching test, heat flux sensor
Scaled Canal Vessel	Error in Scalability or ratio	Misrepresentation of measurements	5	Incorrect fluid depth, surface area ratio, or boundary conditions	5	Dimensional verification through are calculations	3	75	Apply scaling analysis (Re, Sh, Sc) to ensure dynamic similarity, CFD simulation
3. Fan Base	Mechanical instability	Misalignment o vibration affects airflow	5	Vibration damping inadequate or weak base	3	Vibration Test	2	30	Reinforce mounting; add vibration isolators
4. Fan Blades	Blade imblance or deformation	Unsteady airflow affects evaporation	6	Blade warping from heat, humidity, or imbalance	3	Spin test: air flow measurement	2	36	Thermally stable blades; balance before install
5. Vented Wall (Sealed Container)	Imporoper Sealing or leaking	Alters pressure and humidity balance; hinders boundary layer	8	Clogged vents or improper sealing method	6	Leak test; humidity stability test	5	240	Hydropobic filters, check valves, multi-layer seals, RT humidity sensor
6. Standard Wall (Sealed Container)	Air Laeakage or wall condensation	Alters internal properties; skews evaporation rate	7	Seal failure or thermal gradient across walls	4	Seal integrity test; IR camera for condensation	5	140	Thernal insulation, Transparent materials with low thermal cond.
7. Temperautre Controller	Drift or response lag	Inaccurate water/air temp; invalid evap rate	8	Faulty sensor, lag, or calibration error	4	Thermocouple cross-check	6	192	Digital feedback, software-based calibration checks
8. Humidity Controller	Poor regulation or sensor inaccuracy	Relative humidity error; mass fluz error	9	Senor degradation; delay in humidity response	4	RH logging and error analysis	5	180	High resolution and fast RH sensor, calibration checks

Project Budget

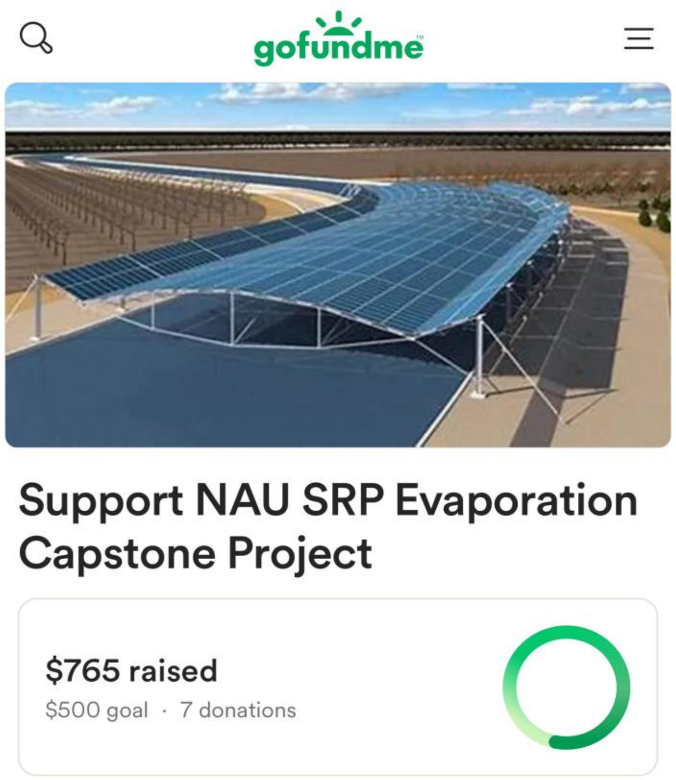
Overall Budget:

Our overall budget is $5,000, with the majority of the budget going to testing and experimentation. A portion of the budget will go towards traveling to the ASU campus to see the prototype

Item	Category	Description	Total
SRP Comp. Funding	Funds	$5,000 to use on evaporation research	$5,000
Fundrasing	Funds	A minimum of 10% of the total fund needs to be fundraised by the group	$765
Fee	Fees	Fee from gofundme	($25)
		Estimated Total:	$5,740

Trip to ASU Campus in Tempe	
Gas	~$60 (Round Trip)
Hotel	N/A / Undecided
Food	~ $150 ($25 Each)
	Total: ~$210

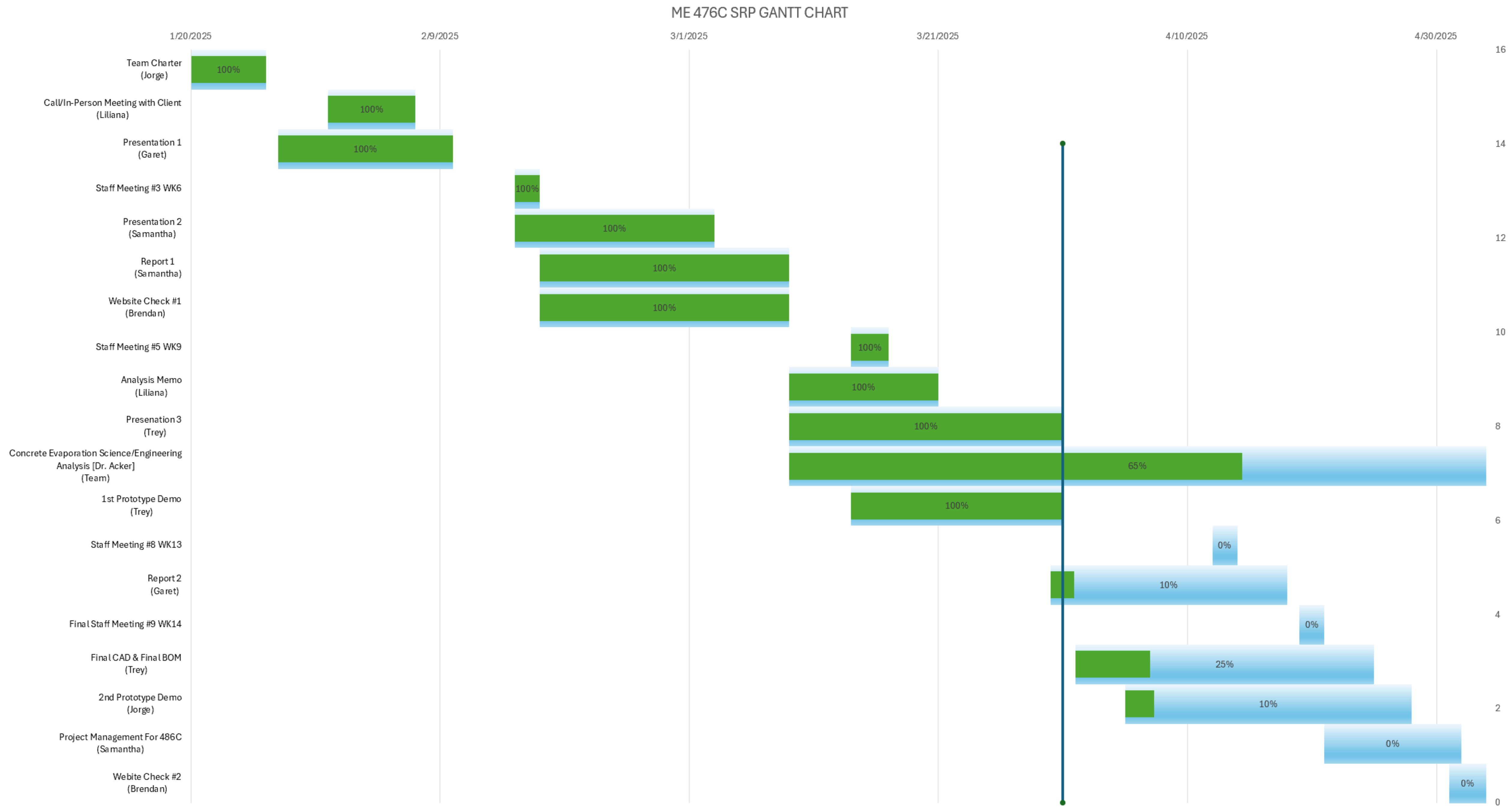
Item	Category	Description	Unit Cost	Quantity	Costs
Climate Box	Tests/Experiments	Box in order to control variables like humidity and evaporation	$200 - $700	1	$200 - $700
UV Lamp	Tests/Experiments	UV lamp to simulate evaporation from the sun	$10 - $40	6	$60 - $240
Humidity Controller	Tests/Experiments	Humididty Controller to accuratly read and adjust the humidity in the box. This will be used to create a constant humidity before each test.	$100	1	$100
Temperature Sensor	Tests/Experiments	Temperature Sensor to read temperature at the top of the tent and right above the water.	$20 - $150	2	$40 - $300
Water Tank	Tests/Experiments	Water tank to hold water. 2 units just incase the primary one breaks.	$10 - $100	2	$20 - $200
Temperature Controller	Tests/Experiments	Heater to properly set the temperature inside the box	$150	1	$150
Fan	Tests/Experiments	Fan to simulate wind	$20 - $200	2	$40 - $400
Wind Sensor	Tests/Experiments	Wind Sensor to test for wind variables.	$25 - $300	2	$50 - $600
				~Total Cost:	$660 - $2690



Fundraising:

As a team, we set up a go fund me that has so far raised $765, with a goal of $500.

Jorge Cesin, 3/31/2025, SRP EVAP

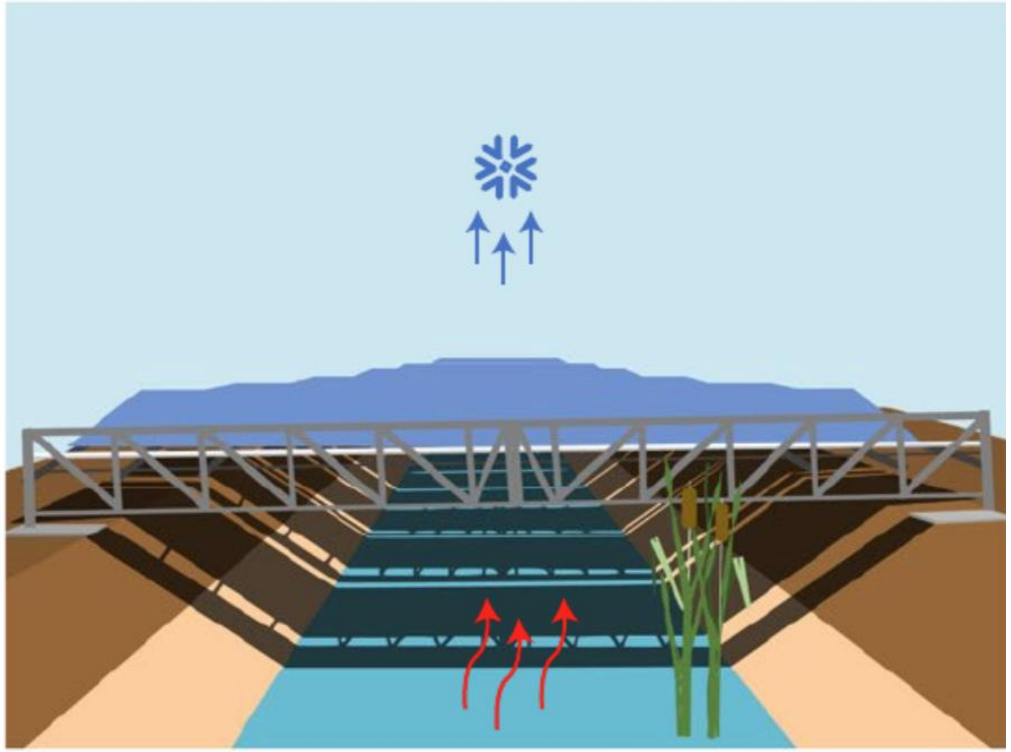


Garet Bowles, 3/31/2025, SRP EVAP

Conclusion

Future Work

- ❑ Finalize CAD with all major part drawings and assembly
- ❑ Meet with ASU again to share research findings
- ❑ Start purchasing materials for prototype
- ❑ Start constructing sub-system prototypes for heat, humidity, and wind.
- ❑ Continue Convective Mass Transfer research



Picture credit: [5]

Prototype 1 Shade Experiment

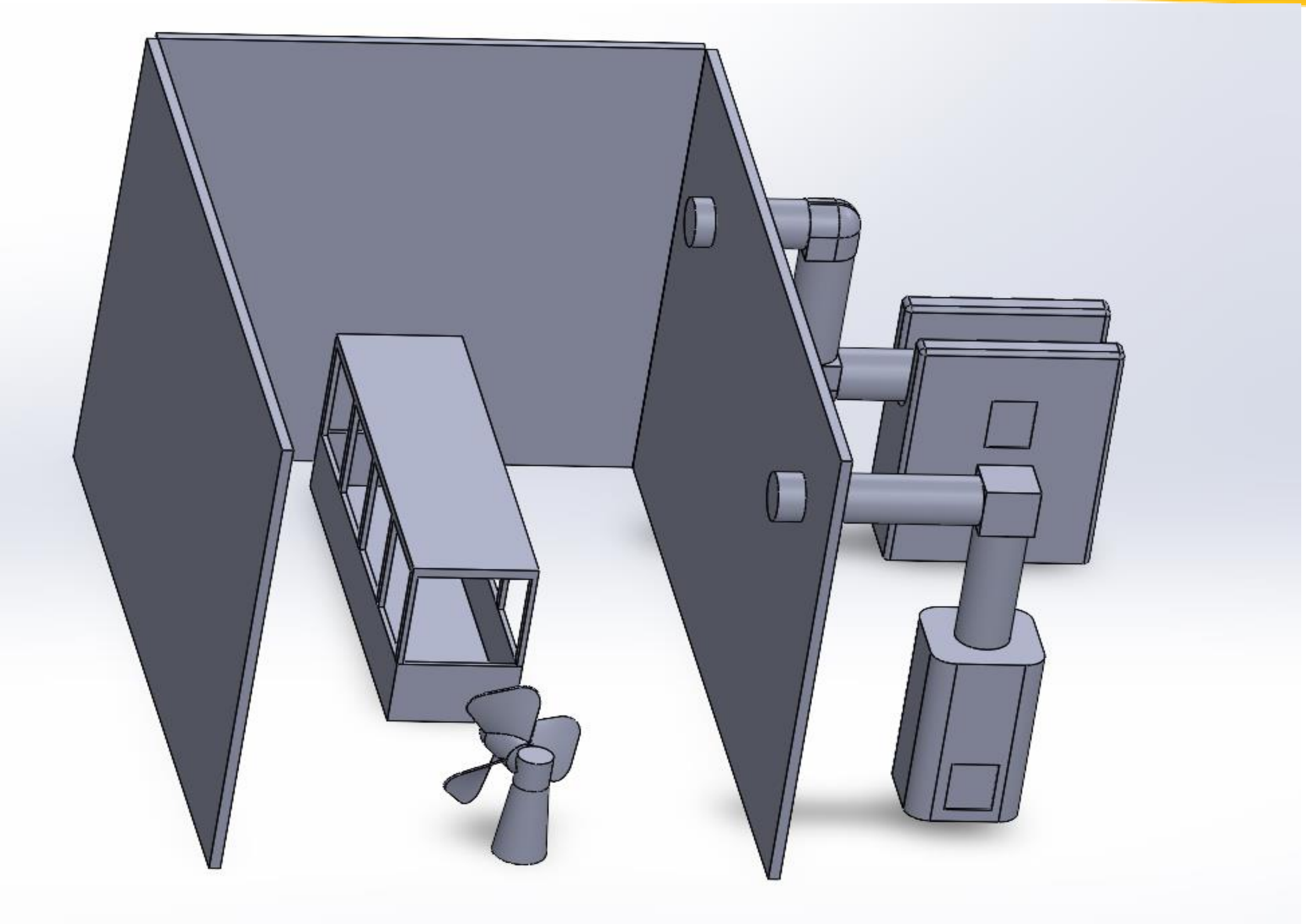
Time: 12:00 PM
Temperature: 52 F
Wind Speed: 16 MPH

Time: 1:20 PM
Temperature: 54 F
Wind Speed: 18 MPH

Time: 2:40 PM
Temperature: 55 F
Wind Speed: 19 MPH

Time: 4:00 PM
Temperature: 54 F
Wind Speed: 20 MPH

Prototype 2



Thank You!

Refrences

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