Solar Still using Active Mirror

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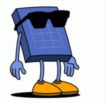
Group 4

Agenda



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- Temperature
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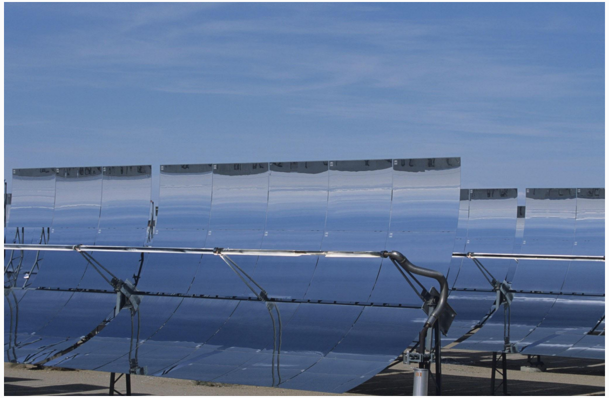
Background

Solar Distillation: Distillation takes water with increase concentration of dissolved solids (like saline solutions or contaminated with heavy metals) and utilize heat from solar radiation. Solids are separated from the vaporization process.

Active Mirrors: Redirections of sunlight to maximize heat input to distillation surface. Advantageous over static mirror use by reducing land usage for same efficiency in distillation.



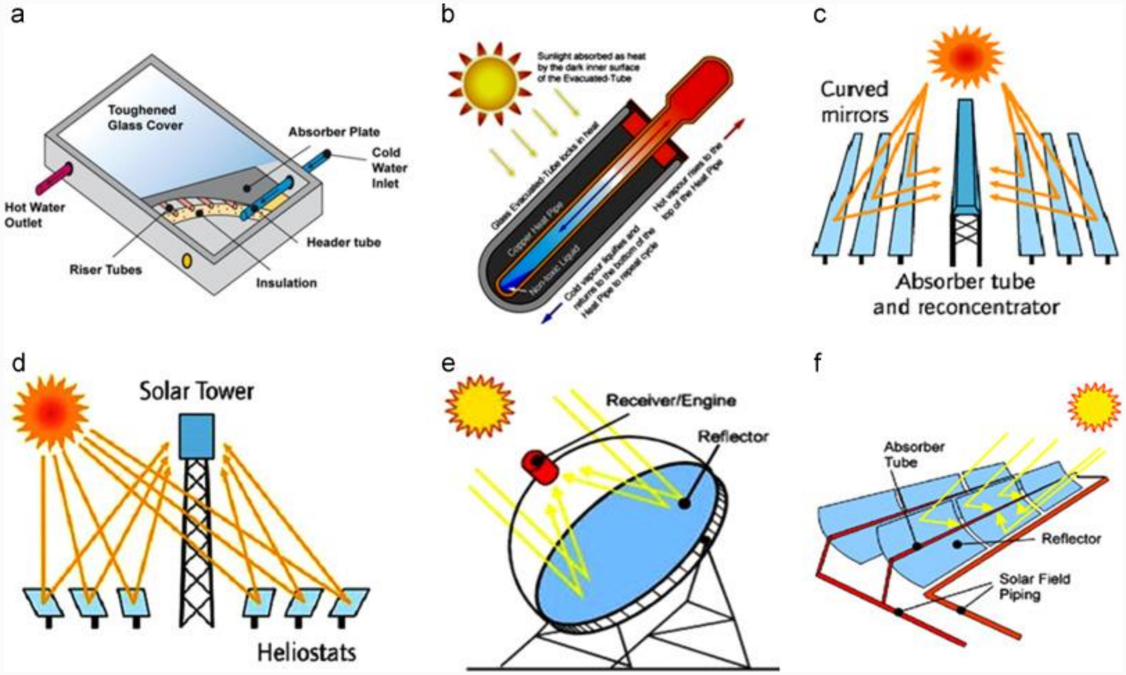
Current Technologies

Mirrors

Parabolic Reflectors
Planar mirrors
Fresnel mirrors
Compound Parabolic Concentrators

Types of Actuations

Heliostats (track sun to single point)
Single + dual axis tracking



Problem Statement

Solar distillation is way to provide clean water source for remote areas. Important for water sourcing challenged areas where solids present in the water.

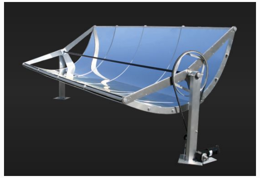
- Material choices to increase efficiency (contributing to overall efficiency) for optimizing mass flow rate.
- Increase efficiency: Constrain to focal line by more axis of rotation, changing mirror materials (optical), insulations (minimize heat loss)

Limitations

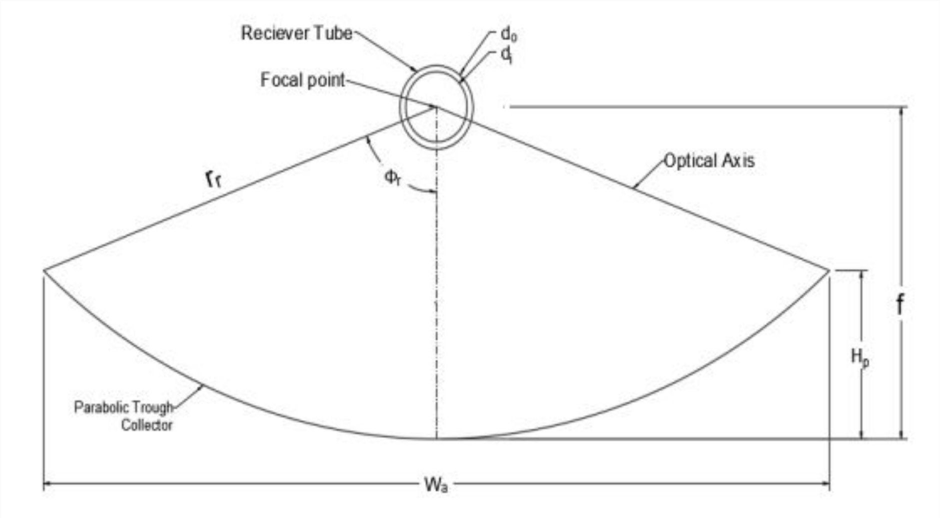
- Temperature difference of location
- Budget & sourcing may constrain to less efficient material
- Manufacturing methods limits tools
- Use of temporary fasteners for initial setup ease

Outline of Solution

- Parameter chosen for our Ideas: Weight/size, portability, Power collection, and Cost
  - Final choice: Parabolic Trough
- Parameter chosen for main pipe: Thermal Conductivity, Strength, Weight, and cost
  - Final choice: Copper Pipe
- Parameter chosen for Mirror: Reflectivity, weight, cost and manufacturability
  - Final choice: Aluminum Coat Glass (Could change depending on what's readily available)
- Parameter chosen for Tanks: Weight, Cost, Thermal resistance, UV Resistance, Bacterial Growth, and Chemical Resistance
  - Final choice: Silver Substrate HDPE
- Parameters chosen for support: Strength, Weight, Corrosion Resistance, Cost and Manufacturability
  - Final Choice: Aluminum and PLA




Outline of Solution

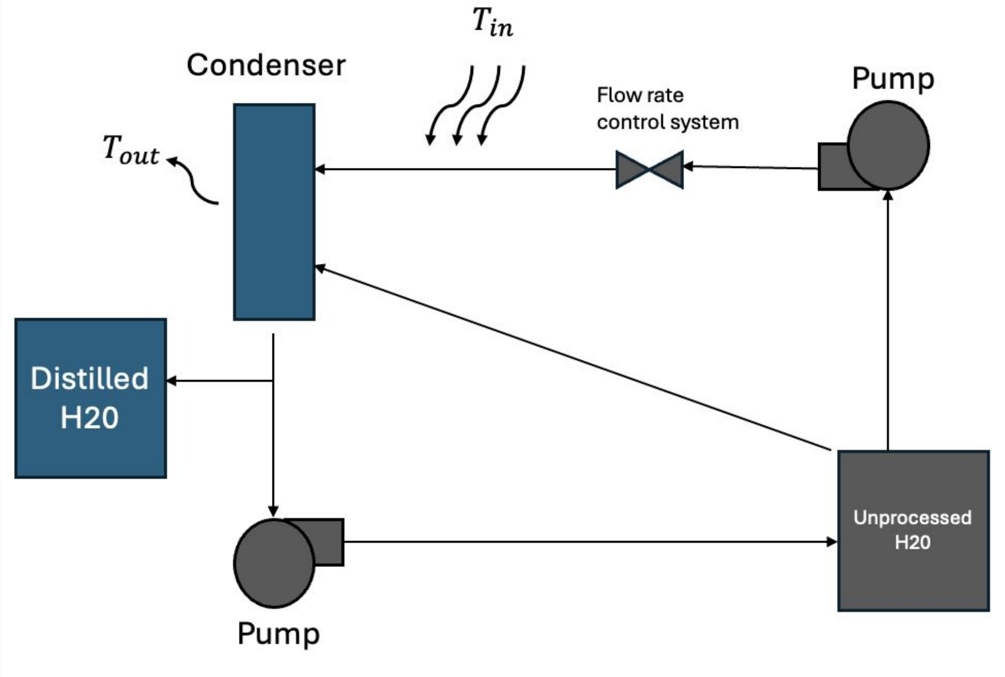


Calculating for Focal Point

Calculations:

Parameter	Symbol	Value	Units
Width of Aperture	W_a	24	inches
Focal Length	f	9	inches
Angle	ɸ	67.38	degrees
Radius of Parabola	r_r	13	inches
Vertical Length of Parabola	H_p	4	inches
Arc Length of Aperture	s	4.95	inches

Outline of Solution



Maximizing the mass flow rate

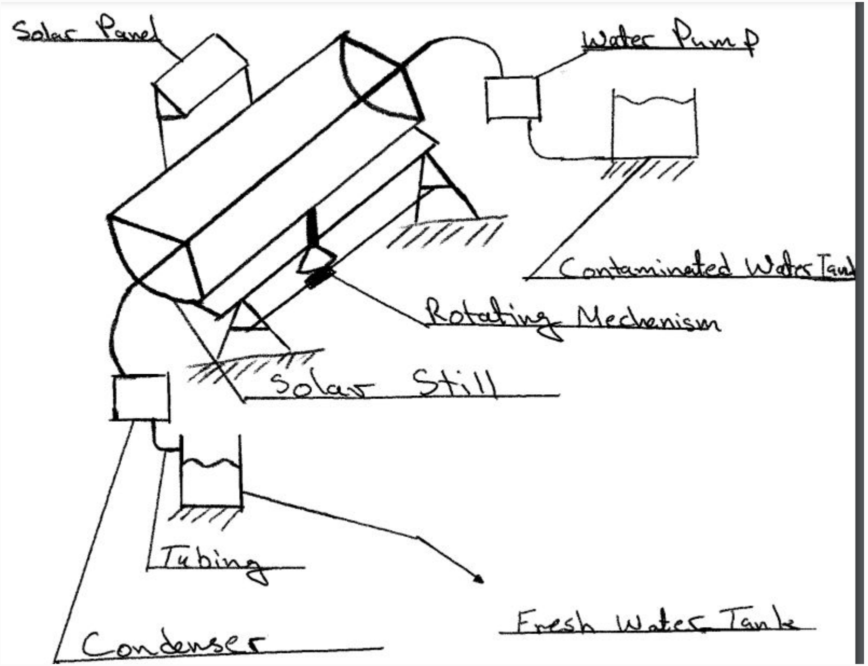
Parameters:

- Temperature input and initial temperature of water
- Condenser efficiency based on initial temperature of fluid flowing from unprocessed water outlet temperature
- Recirculation of undistilled water to reduce waste water output

Design Prototype

Design based on constraint outlined in problem statement

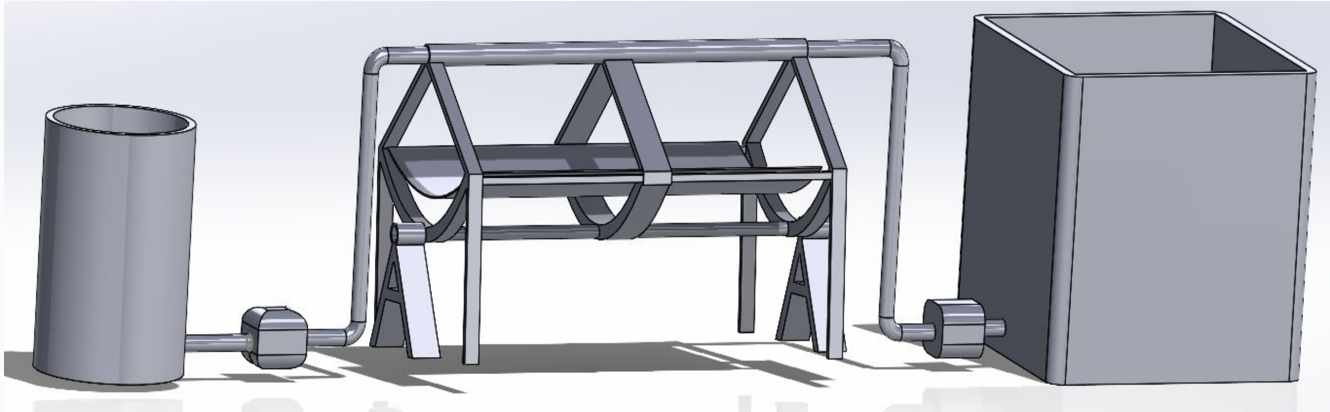
- Hand-drawn Sketch
  - Helped visualize the different parts and structure we will need
  - Provided an Idea for Placement of all components
  - Developed an understanding of what a 3D design will look like



Design Prototype

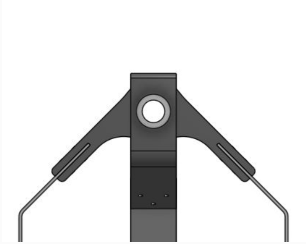
First CAD model:

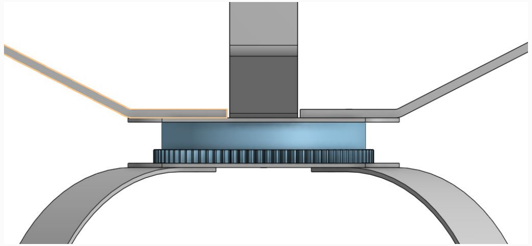
- Finalizing tentative part placement
- Idea for mirror support structure



Initial Design

- Initial Ideas
  - One axis of rotation around x-axis
  - Initial manual Alignment of direction + Seasonal Alignment
  - Simple one Rotation Support Structure using PLA
- Final Choice
  - Two axes of rotation around x and z axis
  - Automatic initial + Seasonal Alignment
  - Complicated two rotational support using Aluminum and PLA





Analysis

Pipe

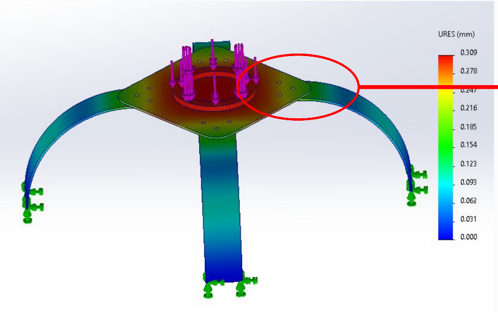
- Mass flow rate values based on extreme temperature difference in a day of November in Harlem, New York
- Mass flow rate determines the pump
- Parameters: Solar irradiation, aperture area, optical + thermal efficiency (instead of doing heat loss of each part), temperature difference

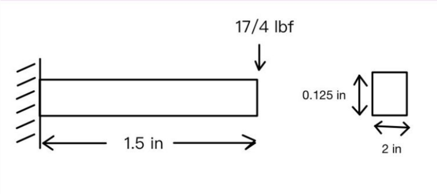
Parameter	Symbol	Value	Units
Mass flow rate	$\dot{m}$	0.926	g/s
Heat absorbed	$\dot{Q}$	5,748.29	BTU/day
Solar Irradiation	G	1,274	BTU/ft^2
Overall Efficiency	η	0.4512	

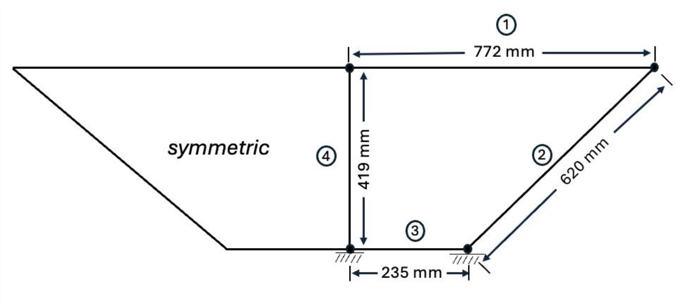
Analysis

Mirror Support Structure

- Support structure material validated by doing analysis of critical points of the structure for mas stress and displacements
- Truss structure portion of support validate through FEA (not as apparent the critical stress points)







Analysis

Power Requirements

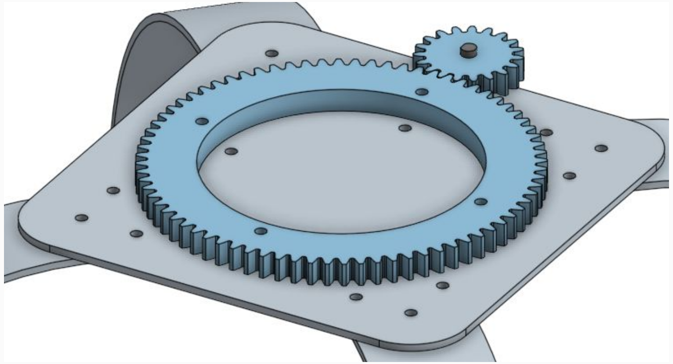
- For pump, based on flow conditions (flow rate, water property, determine flow type, head loss). 0.000065 W/pump and another 0.0836 Watts for height difference for a total of 0.083665
- Motor Requirements based mostly on frictional torque, low RPM of 0.000694, 0.013 Nm torque and power of 0.0000378 Watts
- Actual Power required for motor and and pump is too small, so a 7.5 watts motor and 15 watts pump were chosen for a total power required of 45 Watts for the solar panel

Parameter	Symbol	Value	Units	Converted Imperial Value	Imperial Units
Velocity	V	0.02933	m/s	0.0962	ft/s
Pipe inner Diameter	D_i	0.00635	m	0.25	in
Water density	ρ	997	kg/m^3	62.2407	lb/m^3
kinematic viscosity	υ	$1.004 \cdot 10^{-6}$	m^2/s	$1.0807 \cdot 10^{-5}$	ft^2/s
Reynolds Number	Re	185.50			
Flow Rate	$\dot{\upsilon}$	$0.9288 \cdot 10^{-6}$	m^3/s	$3.28 \cdot 10^{-5}$	ft^3/s
Head Loss	h_f	0.00726	m	0.0238	ft
Pump Power	P	0.00006595	W		

Analysis

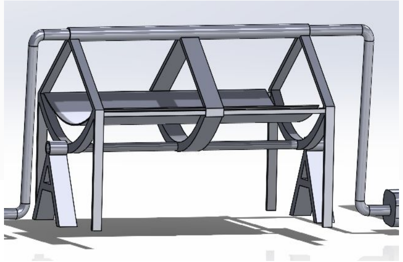
Base Gear

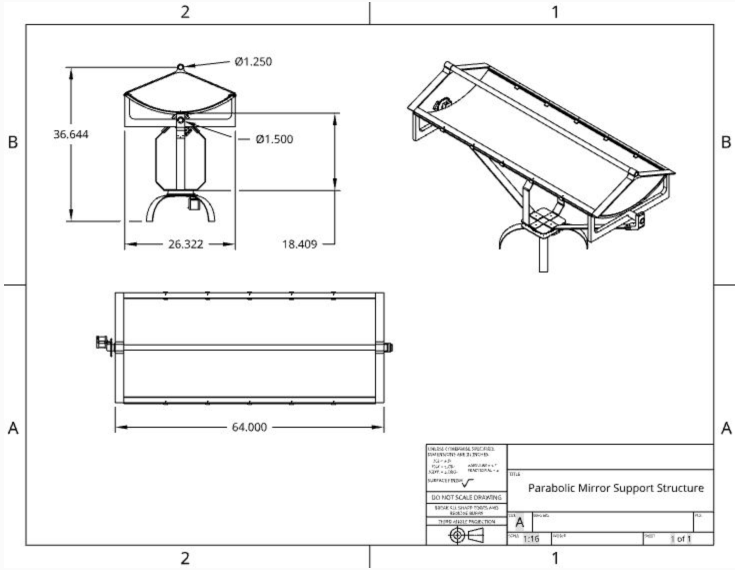
- Calculated based on part availability of bearing platform.
- Gear ratio of 4:1 for torque heavy cases



Gear	Diametrial Pitch (teeth/in)	Pitch Diameter in	Number of teeth
Base Gear	12	6.327	76
Motor Gear	12	1.583	19

Final Design





Final Design

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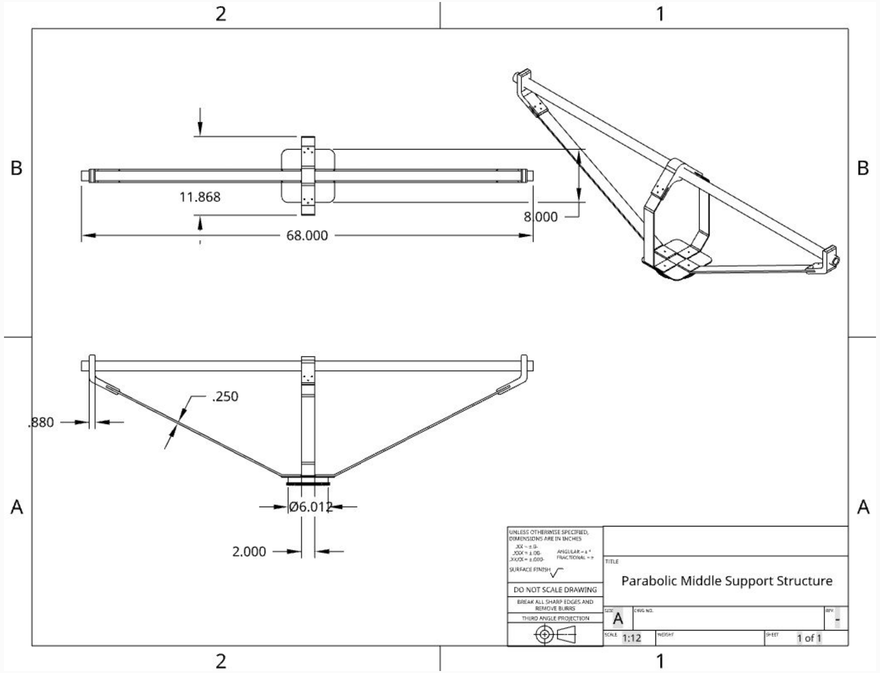
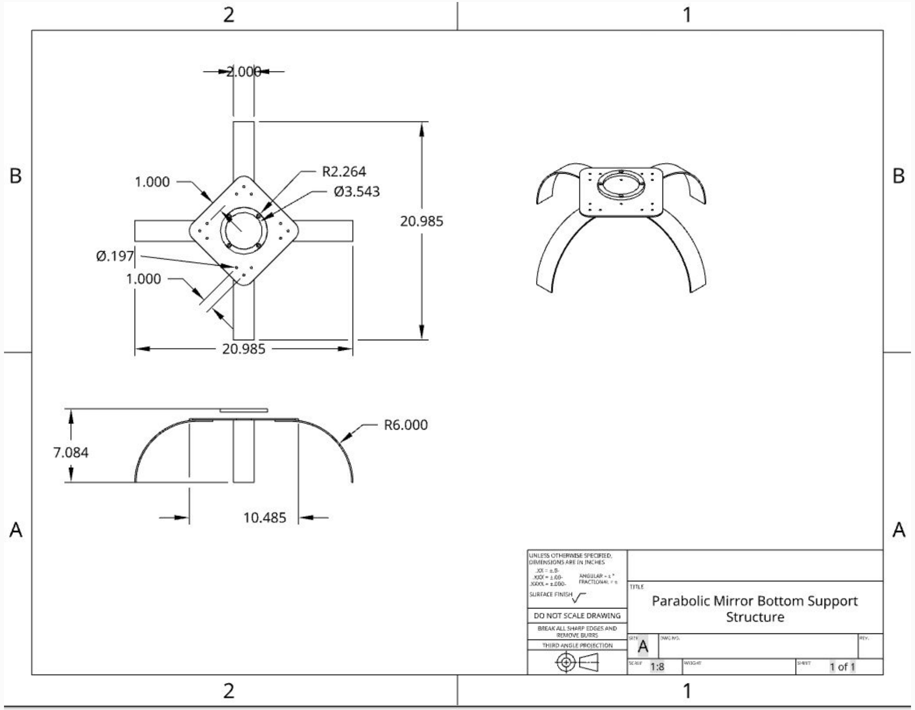
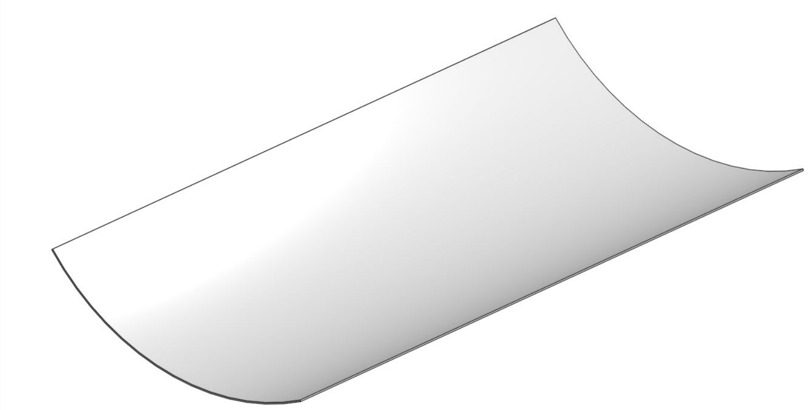
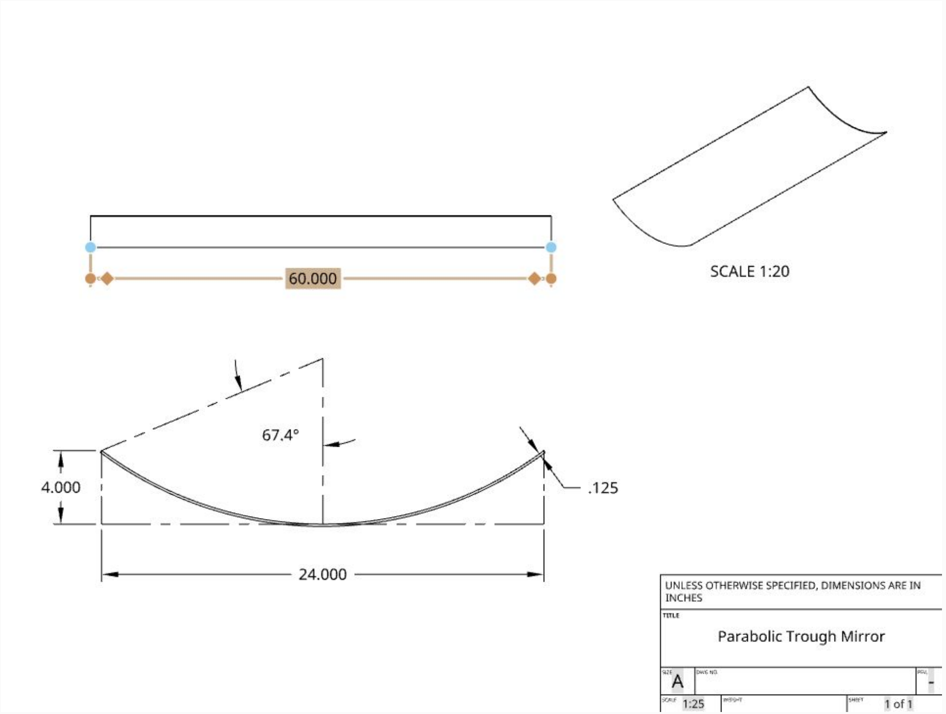




Final Design

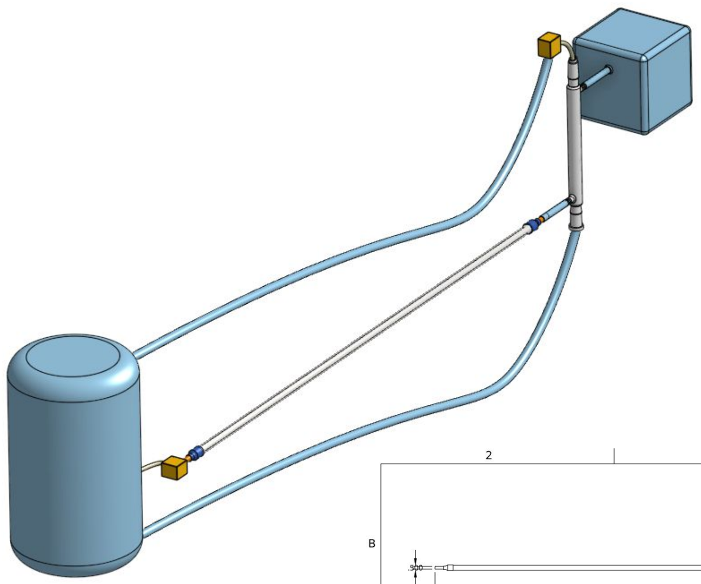


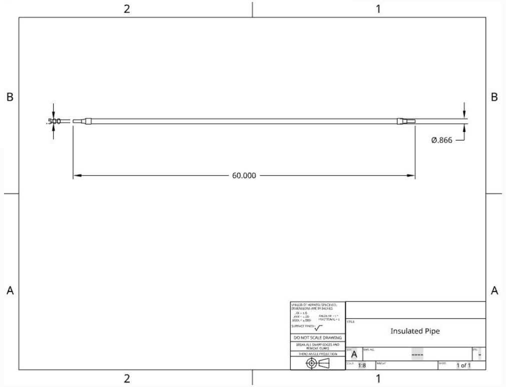


Final Design

Pipe

- Undistilled water tank
- Distilled water tank
- Top and bottom pipelines function to move undistilled water through the condenser
- The straight pipe is a main component of the system where the distillation will take place

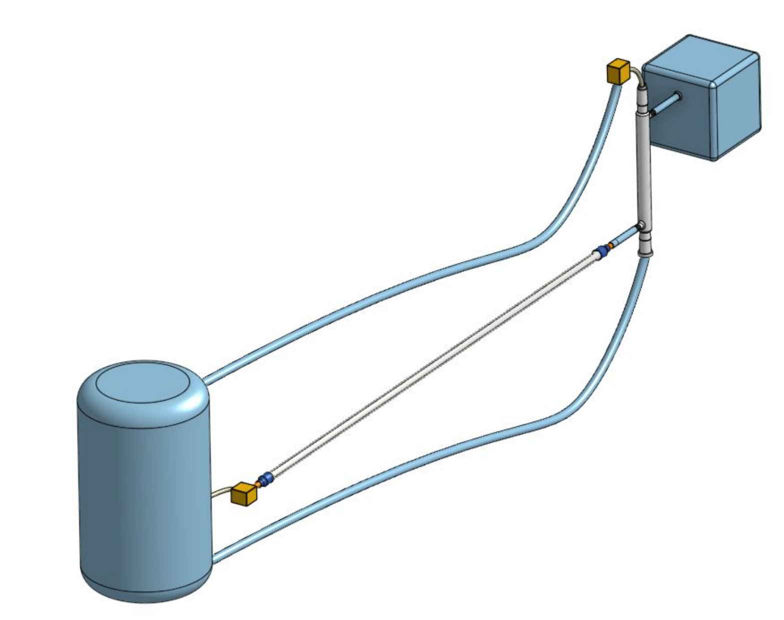




Build: Materials

Materials:

- Copper
- Polycarbonate tubing
- Flexible tubing
- Stepper motor pump



Build: Materials

Materials

- Copper
- Acrylic and Mylar
- Aluminum
- 3D prints

Costs

Item		Amount	Vendor	Cost	Link
Acrylic		1	Grainger	$177.28	acrylic sheet
Reflective Mylar Film		1	Amazon	$24.99	Mylar film
Adhesive		1	Grainger	$7.89	construction adhesive
Copper Tube		1	Grainger	$39.84	copper pipe
Graham Condenser		1	Grainger	$54.48	condenser
Tank		2	Target	$11.98	tank selection
Stepper Motor pump		2	Amazon	$33.98	pump
Solar Cell		1	Amazon	$15.99	solar cell
Nema 17 Stepper Motor		2	Amazon	$28.76	motor
Step Down Module		1	Amazon	$4.99	step down module
Solar Charge Controller		1	Amazon	$10.78	solar charge controller
TDS Sensor		1	Amazon	$11.99	TDS
PH sensor		1	Amazon	$10.99	PH

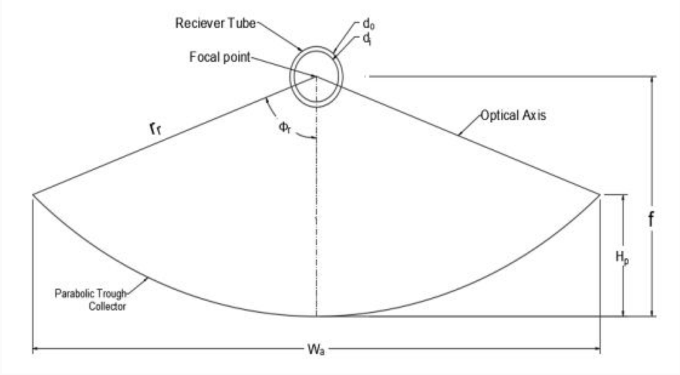
Costs

Temperature Sensor		1	Amazon	$10.99	temperature sensor
GPS Module		1	Amazon	$12.99	GPS
Silicon Sealant		1	Grainger	$12.42	silicon sealant
Black Coating		1	Amazon	$16.99	heat absorbent coating
Glass tube		1	Grainger	$39.96	polycarbonate tube
Ball Bearings		2	Grainger	$4.93	ball bearing
Battery		1	Grainger	$27.02	lead-acid battery
ALUMINUM					
	main 4 support	4	Grainger	$30.16	support bars
	supporting rod	1	Grainger	$20.52	support rod
	sheet	1	Grainger	$11.34	sheet
Flexible tubing		1	Grainger	$14.82	flexible tubing
			Total:	636.08	

Manufacturing

Assembling the mirror

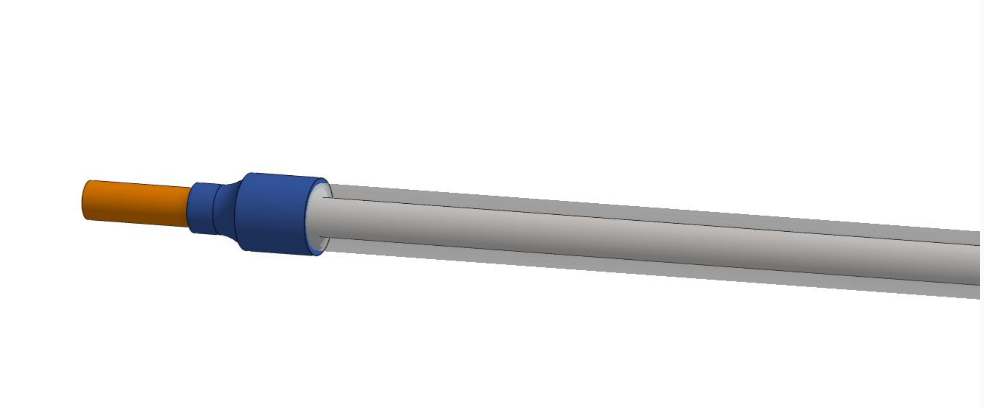
- Using concrete molding
- 3d print shape of tool for molding
- Heat gun to make sheet malleable
- Adhesive to hold metal sheet to the trough designed



Manufacturing

Piping system

- Insulation tubing supported with printed end caps & silicon sealant
- Flexible tubing to join parts of varying heights
- Piping joints with sealant for tight seal



Manufacturing

Support:

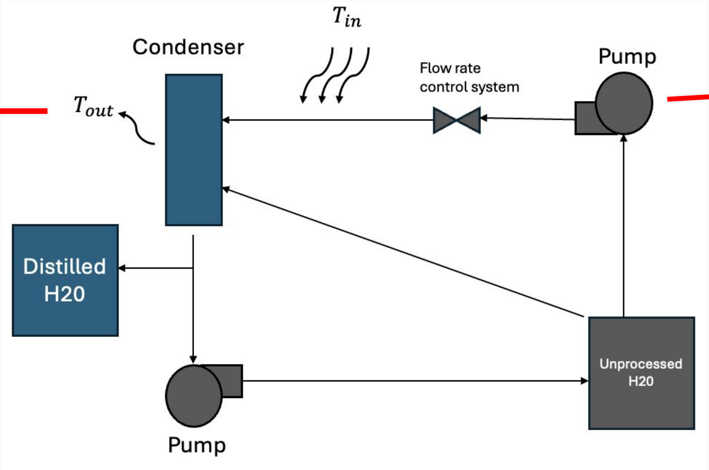
- The bottom support will be made using Aluminum
- The middle is the lazy-susan bearing
- The rod is also Aluminum
- The claps/clips are PLA

Manufacturing

Solar Panel:

- Will be using solar cells
- Solar charge controller to connect to battery

How We Will Make it Work



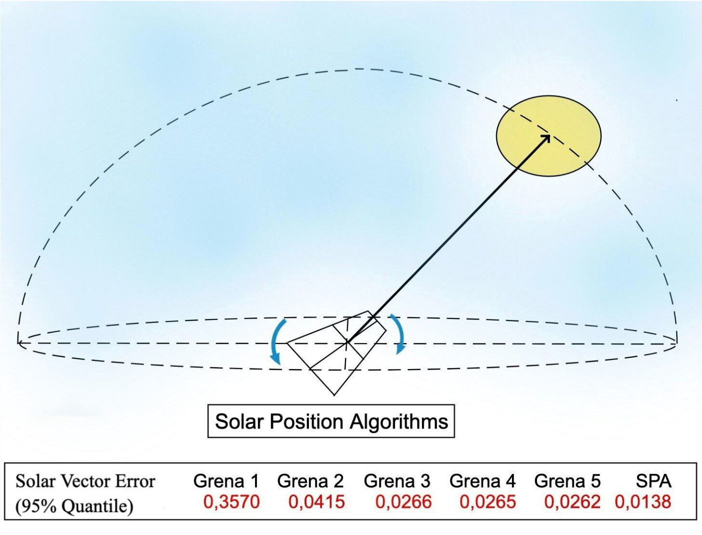
Condenser
- Graham Condenser made of borosilicate Glass to handle thermal shock
- Coilings to increase surface area of cooling

Pumps
- Stepper Pump control mass flow rate
- Connected to microcontroller, adjusting flow rate

How We Will Make it Work

Softwares

- **Solar position tracker:** Algorithm used to track azimuth and elevation angles. Accounts for atmospheric conditions and location
- **Mass flow rate:** stepper motor pump control
- **Sensor data:** to monitor water quality



Hardware Information input

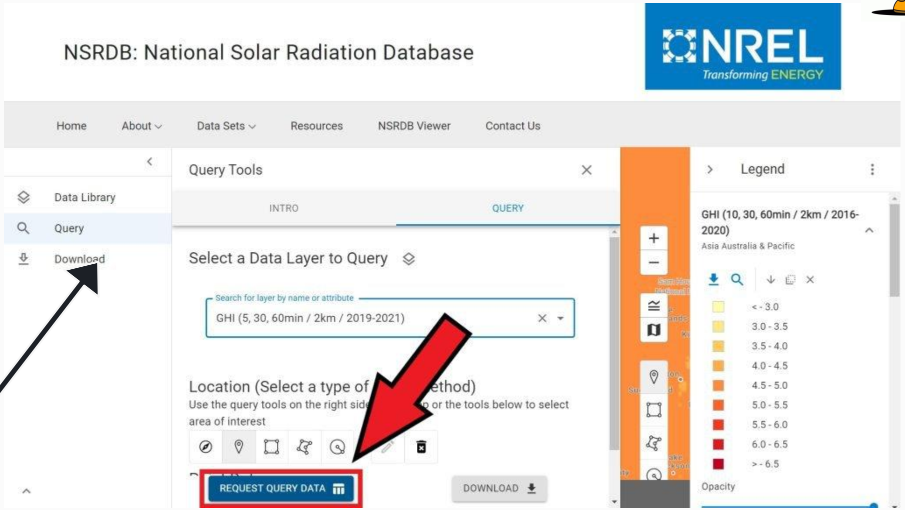
- UTC data
- Location data

Testing

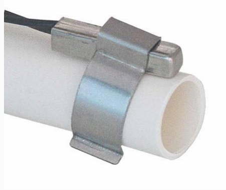
Adjusting Flow rate

Radiation - using pyrometer to see how much radiation actually going into system. If expensive track based on sourced data

Temperature input output water temp through copper pipes.



$$\dot{m} = \frac{G \cdot A \cdot \eta}{c_p(T_{\text{out}} - T_{\text{in}})}$$

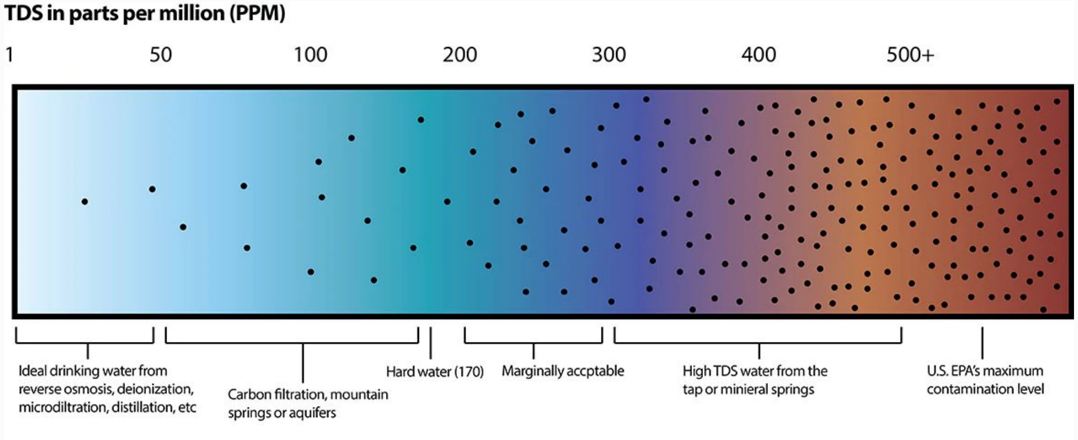


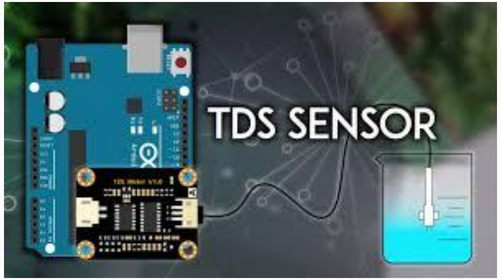
Testing

Water Quality

Total Dissolved solids - (should measure between 300 -500 ppm)

PH levels - Measure before and after purification to ensure water quality has improved





Testing Validations

Problems

- Flow rate lower/higher than necessary, reducing the efficiency
- Solid concentration higher than safe amount
- Alignment of mirror focal line with the Sun, cause low initial temperature.

Actions

- Adjust flow rate, directly incoded to stepper motor. May need to account for other loses based on adjustments made in build
- Check TDS at various parts of the system - checking distillation effectiveness
- Adjusting positioning (code)

Thank You!