Solar Still Using Active Mirrors

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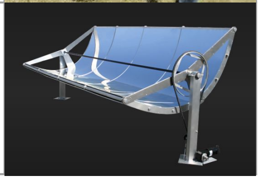
Trade Studies

Scale (1-10)

Ideas	Weight/Size	Portability	Power Collection	Cost	Total	
Solar Power Tower	3	4	8	5	20	
Disk Collection	10	10	2	9	31	
Parabolic Trough	9	9	10	8	36	

Pipes

scale(1-10)

	Thermal conductivity W/mK	Strength (GPa)	Weight (kg/m^3)	Cost $/lb	Total
copper	10 (401)	6 (120)	4 (8940)	5 (5.21)	25
stainless steel	1 (14.4)	8 (193)	5 (7780)	6 (1.6)	20
Aluminum	6 (237)	3 (70)	7 (2712)	7 (1.15)	23
Carbon steel	1 (54)	9 (200)	5 (7850)	8 (0.40)	23

Mirrors

	reflectivity	weight	Cost $/m^2	manufactuability	Total
silver coat glass	10 (0.993)	9	7 (200)	7	33
dielectric coated glass	9 (0.9)	9	5 (300)	5	28
aluminum coat glass	9 (0.9)	9	8 (150)	9	35
alum coat acrylic	5 (0.82)	10	9 (100)	10	34

Condenser

	Size (m)	Cost	Maintenance	Applications
Reflux (vent/knockback) condenser	0.5 – 2	\$500 – \$5,000	Low-cost routine checks, cleaning	Lab, pilot plants, small industries
Water cooled	1 – 3	\$1,000 – \$10,000	Low-cost routine checks, cleaning	Small HVAC systems, small refrigeration
Jet (steam)	1 – 3	\$2,000 – \$10,000	Routine cleaning, inspection	Small power plants, laboratory setups
plate heat exchanger	0.5 m² – 5 m²	\$2,000 – \$20,000	Regular cleaning and gasket checks	Small refrigeration, HVAC, lab processes

Liquid Tank

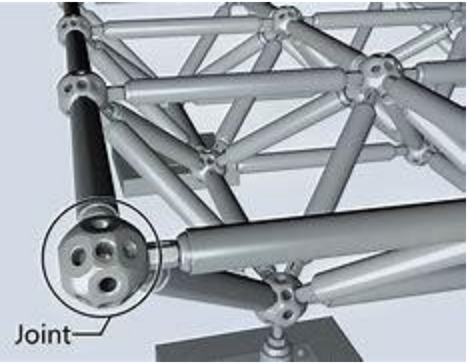
	Weight (Density g/cm3)	Cost ($ per kg)	Thermal Resistance (melting temp deg C)	UV resistance (yrs)	Bacterial growth (10^) CFU/cm3	Chemical resistance (1-5)	Total
HDPE	9 (0.95)	9 (1 to 3)	5 (120)	8 (5 to 10)	4 (4 to 5)	5	40
Stainless Steel	3 (7.5)	4 (5 to 10)	10 (870-925)	10 (indef)	8 (2 to 3)	4	39
PE	10 (0.925)	9 (1 to 3)	4 (110-135)	6 (2 to 5)	4 (4 to 5)	3	38
Silver substrate HDPE	9 (0.95)	4 (5 to 10)	5 (120)	8 (5 to 10)	10 (1 to 2)	5	41

Properties

- Hold 1-1.5 L/day
- Long term storage
- Inhibitions of biofilm formation
- Cheapen water storage, increase safety

Mirror Support Structures

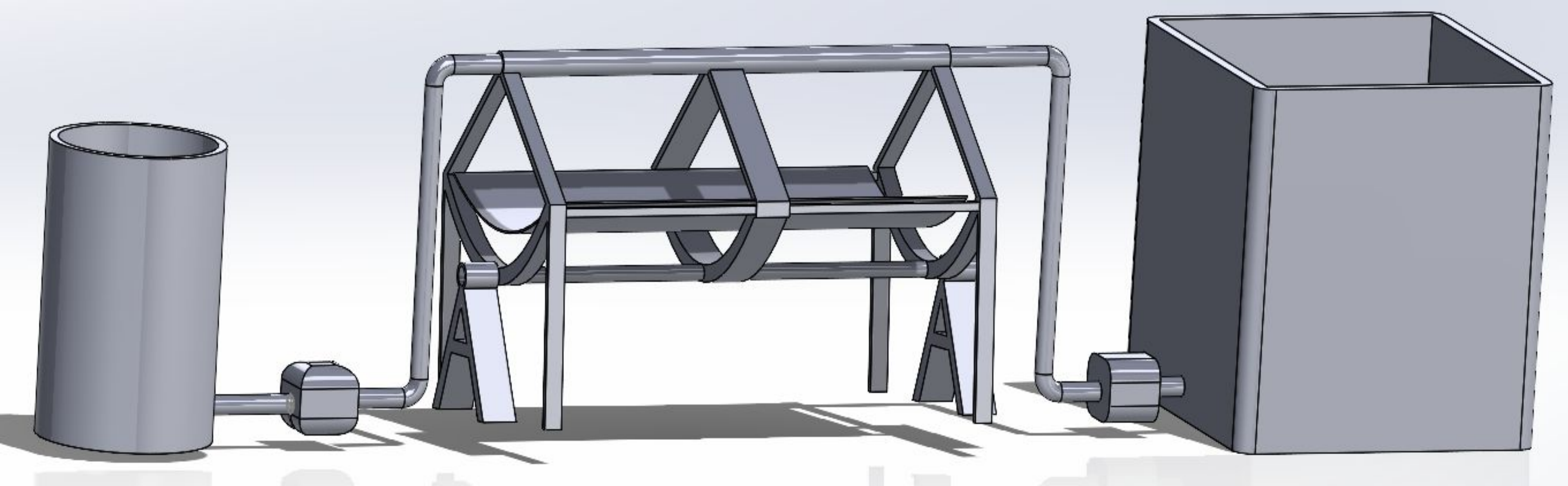
	Strength (Mpa)	Weight (Density g/cm3)	Corrosion Resistance (1-5)	Cost ($/kg)	Manufacturability	Total
Aluminum	7 (275)	8 (2.7)	4	6 (3 to 5)	CNC	26
Carbon steel	6 (250)	3 (7.9)	1	10 (.8 to 1.5)	machining + weld	20
Stainless steel	9 (505)	5 (8)	5	2 (5 to 10)	machining	26
ABS	1 (40)	10 (1)	1	8 (2 to 4)	3D	25
PLA	2 (60)	9 (1.25)	2	9 (1.5 to 3)	3D	27
PETG	2 (50)	9 (1.27)	4	6 (3 to 5)	3D	26



Properties

- Weathering Resistance needed for long term use in various climates
- Considerations of portability (movable for adjusting position)

Prototypes (CAD)



Designs Methods

Mathematical models

- Mirror focal length
- Mass flow rate, Power requirements
- Heat transfer (thermal analysis)
  - Between the pipes and fluid
  - Mirror to pipes
- Stress analysis (supports) - very simplified 2D model

FEA Representations

- Stress Analysis of supports, especially for mobility
- Thermal Analysis - heat flux heat transfer from materials

Mirror Focal Length

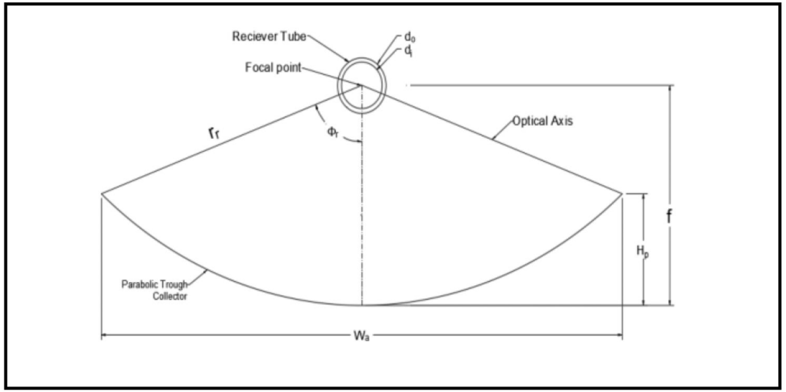
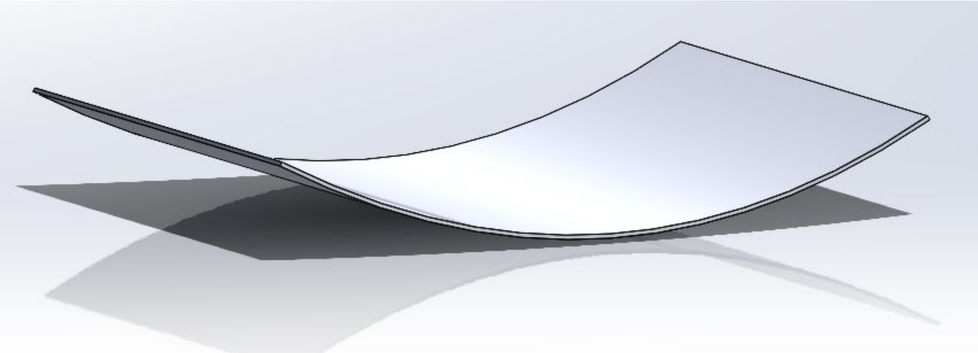


Fig.1 Parameters of the parabolic trough collector



Focal length is given as:

$$f = \frac{W_a}{4\tan\left(\frac{\phi_r}{2}\right)}$$

Radius of parabola calculated by:

$$r_r = \frac{2f}{1+\cos\phi_r}$$

The vertical height of parabola is given by:

$$H_p = \frac{{W_a}^2}{16f}$$

Arc length of parabola:

$$S = \frac{H_p}{2}\left\{\sec\left(\frac{\phi_r}{2}\right)\tan\left(\frac{\phi_r}{2}\right) + \ln\left[\sec\left(\frac{\phi_r}{2}\right) + \tan\left(\frac{\phi_r}{2}\right)\right]\right\}$$

Aperture area is calculated by:

$$A_p = W_a \times L$$

Effective aperture area is calculated by:

$$A_p = (W_a - d_o) \times L$$

Mass Flow Rate Power Requirements

Useful heat $$Q_u = \Delta T\, \dot{m} C_p$$

Incident heat $$Q_i = A I_s$$

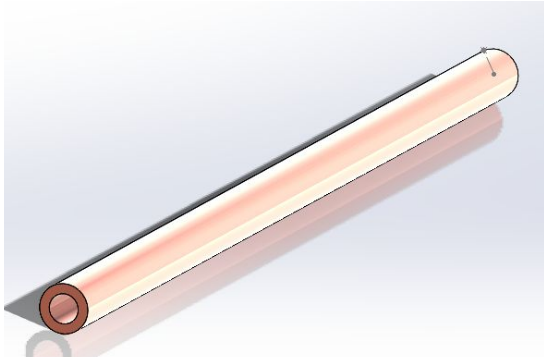
Efficiency based on incidental heat $$\eta_{col} = \frac{Q_u}{Q_i}$$

Efficiency of Mirror reflectance $$\eta_{Thermal,g} = \frac{q_{SolAbs-a} - q_{ThermalLoss,g}}{AG_s}$$

$$Q_{loss} = U_L \cdot A_{ro} \cdot (T_r - T_{am}),$$

$$Q_{loss} = \frac{\sigma \cdot A_{ro} \cdot \left(T_r^4 - T_c^4\right)}{\frac{1}{\varepsilon_r} + \frac{1-\varepsilon_c}{\varepsilon_c} \cdot \frac{A_{ro}}{A_{ci}}},$$

$$Q_{loss} = A_{co} \cdot h_{ca} \cdot (T_c - T_{am}) + \varepsilon_c \cdot A_{co} \cdot \sigma \cdot \left(T_c^4 - T_{am}^4\right),$$



Heat Transfer

Thermal Analysis

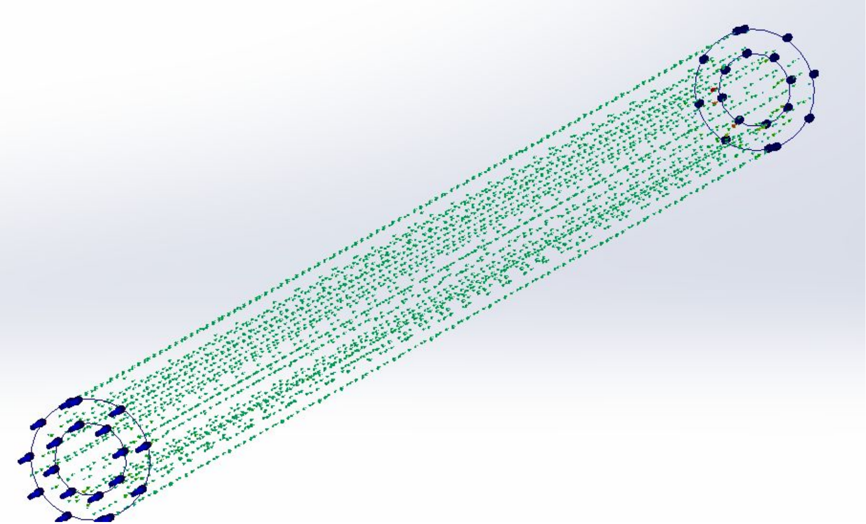
Through pipes $$Q = -kA\frac{dT}{dx}$$

Internal flow $$q_s = \dot{m}c_p[T_{mo} - T_{mi}]$$

$$\bar{T}_m = (T_{mi} + T_{mo})/2$$

$$Re_D = \frac{\bar{u}D}{\nu} \qquad \dot{m} = \rho\bar{u}\frac{\pi D^2}{4}$$

$$q_s'' = h(x)[T_s - T_m(x)]$$



Solar Panel

- Pump Power Requirements

$$Re = \frac{VD}{\nu} \qquad Q = VA$$

$$h_L = \frac{LV^2}{2Dg} \qquad P = \rho g Q h_L$$

- Selecting the Rotation motor and condenser

  will allow us to determine the total power needed
- Total Power will allow for the selection of the solar panel needed

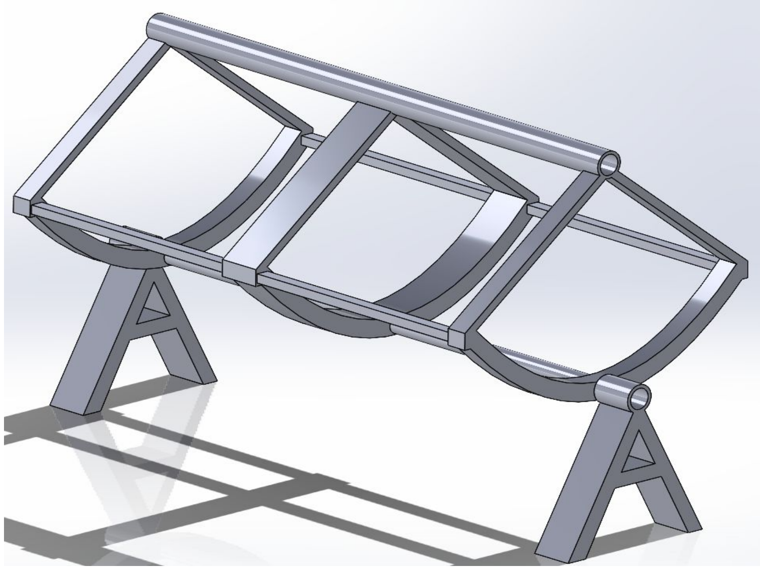
Stress Analysis

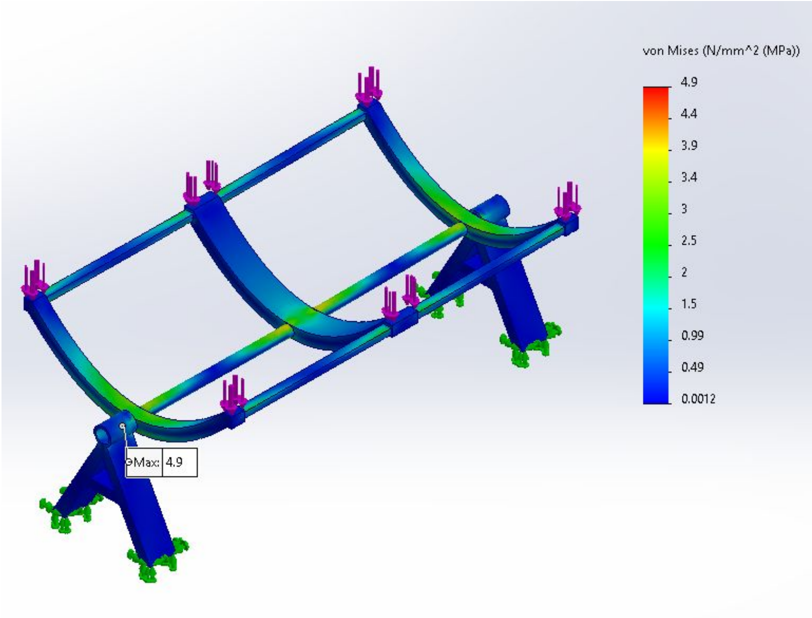
$$\begin{Bmatrix} u_1' \\ u_2' \end{Bmatrix} = \begin{bmatrix} C_x & C_y & C_z & 0 & 0 & 0 \\ 0 & 0 & 0 & C_x & C_y & C_z \end{bmatrix} \begin{Bmatrix} u_1 \\ v_1 \\ w_1 \\ u_2 \\ v_2 \\ w_2 \end{Bmatrix}$$

FEA Simplified geometry for matrix representations. Based on PLA

$$\begin{Bmatrix} f'_{1x} \\ f'_{2x} \end{Bmatrix} = \frac{AE}{L} \begin{bmatrix} 1 & -1 \\ -1 & 1 \end{bmatrix} \begin{Bmatrix} u_1' \\ u_2' \end{Bmatrix}$$

$$\{\sigma\} = \frac{E}{L}[-1 \quad 1][T^*]\{d\}$$





Next Steps

Sensors: Digital Level (Electronic Level), Optical Level (Spirit Level), Water Level Sensor

Cost analysis: more pinpointed budgeting

Reiterate design based on stress and thermal analysis

Thank You!