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Parabolic Solar Trough

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Parabolic Solar Trough

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What is a Parabolic Solar Trough?

- A type of concentrating solar technology
- Heats fluid by concentrating solar energy at a focal line
- Working fluid in this design is water

Credit: Mark Fedkin [1]
Why are we building one at UP?

- Heated water will be used in an Organic Rankine Cycle (ORC), designed in 2017/18

- Advantages:
  - Easily integrated into the existing ORC system
  - Cost effective for comparable energy gains

Credit: P. Kiameh [2]
Problem Statement

Who
• Shiley mechanical engineering students and professors

What
• Parabolic solar trough module that is segmented for future lab use

Why
• Aid in heating water for the hot side of the Organic Rankine Cycle
## Design Criteria

<table>
<thead>
<tr>
<th>Constraint</th>
<th>Weight</th>
<th>Functional Requirement</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost (&lt;$2040)</td>
<td>5</td>
<td>Safety for students and faculty</td>
<td>5</td>
</tr>
<tr>
<td>Dimensions (8'X16')</td>
<td>3</td>
<td>Increase water temperature 20°C from inlet to outlet</td>
<td>5</td>
</tr>
<tr>
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<td>3</td>
<td>Straightforward installation and plumbing</td>
<td>4</td>
</tr>
<tr>
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<td>Stationary water line</td>
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</table>
Development: Overall Design

- 30-inch x 7.5-inch parabola
- 0.02-inch Aluminum sheet metal
- 0.25-inch Aluminum ribs
- 1-inch diameter copper pipe, painted black
- Aluminum support frame
Development: Overall Design

- Parabola shape is a function of the trough's depth \( (h) \), width \( (a) \), focal length \( (f) \), and rim angle \( (\emptyset) \). The most efficient rim angle is 90 degrees.

\[
h = \frac{a^2}{16f}
\]

\[
f = \frac{a \sin(0.267)}{\sin(\emptyset)}
\]

All dimensions are in inches
Development: Overall Design

- Solar Tracker System: photo resistors change resistance based off light present
- Trough rotates until sensors have same resistance
  - Parabolic Trough
  - Photo Resistors
  - Sun Blocker
  - Linear Actuator
Modeling and Analyses

Thermodynamic Modeling

- $E = mc\Delta T$
- Trough surface area is the ratio of energy needed to heat the water to the incoming solar energy ($A_{\text{surface}} = \frac{E_{\text{need}}}{E_{\text{solar}}}$)

Heat Transfer Analysis

- Compare circular vs square cylinder to determine shape with least resistance to heat transfer
Modeling: Expected Data

Expected Temperature Change
Surface Area CR = 9.75

- 10 gpm
- 5 gpm
- 1 gpm
- Single Trough

Change in Temperature (°C)

x Distance (ft)
Prototyping: Tracking System

• Uses photo resistors to track the position of the sun
• Rotates the system until both resistors measure same amount of light
Testing: Infrared Imagery
## Conclusions: Assessment of Design Criteria

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Conclusions

Future Design Improvement

• Polish Aluminum, overall improvement of reflectiveness
• Improved tracking system for greater range of motion
• Increase number of troughs

Future Work

• More data collection over the summer
What We Learned

• Deeper understanding of realistic thermal systems and their constraints
• Teamwork, task delegation
• Communication
• Design process
Acknowledgements

• Dr. Dillon: Advising Professor, energy research extraordinaire, #1 Fan
• Jacob Amos: Shop Technician
• Jared Rees: Circuits/Electronics Shop Technician
• Allen Hansen: Safety Advisor
• Shiley School of Engineering, Galarneau Fund
• Becca Baldwin: Industry Advisor
Questions

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References


NREL Solar Data

- Average solar energy data from National Renewable Energy Lab (NREL) website for Portland, OR in July over one day
- What we can expect energy input to system will look like.
Analysis: Expected Temperature Change for Unconcentrated Pipe

![Graphs showing expected temperature change for unconcentrated pipe with varying flow rates and distance.](image-url)