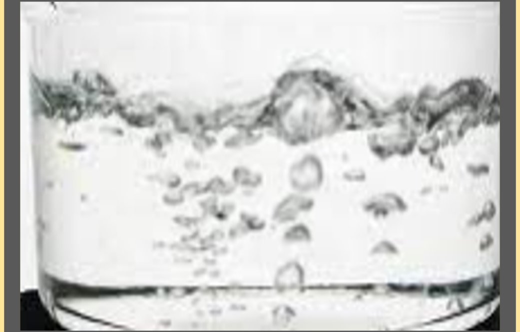
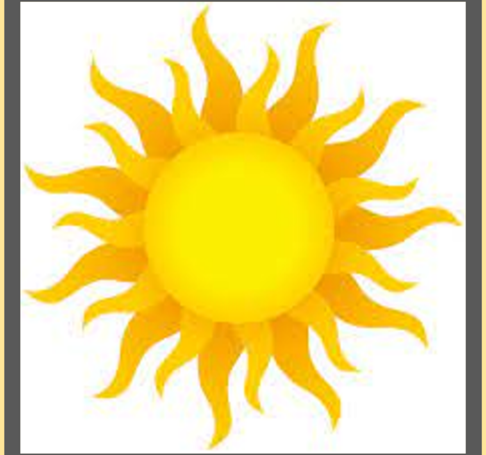
Solar Heater Design

By Athena, Justin, Julia, Sandy



Hutchinson, Sean. “Does Adding Salt to Water Make It Boil Sooner?.” Mental Floss. https://www.mentalfloss.com/article/60046/does-adding-salt-water-make-it-boil-sooner . Accessed 27 October 2021.



Clip Art Library. “Sunshine Cliparts Transparent #3089967.” Clipart Library. http://clipart-library.com/clipart/n1591757.htm . Accessed 27 October 2021.

$$\eta = \frac{P_{H_2O}}{P_{sun}} = \frac{m \cdot c \cdot \Delta T / t}{S \cdot A}$$

Introduction

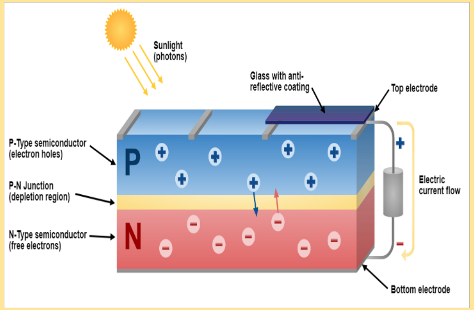
Goal: Design a solar heater that exceeds the efficiency of a 4Patriots Solar Sun Kettle.

- **What aspects of our design will make the heating process the most efficient?**
- **Variables** to consider: insulation, absorptivity, concentration of solar energy
- **Constraints** to consider: $50 budget, limitation of area size (may lower efficiency), low irradiance of Rochester
- **How do we address these variables and constraints?**

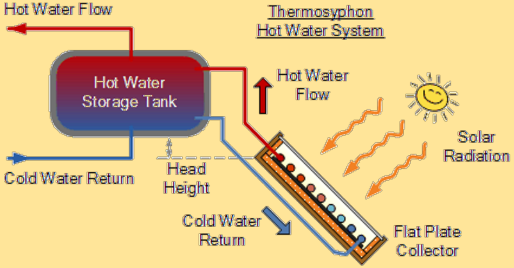
Touch of Modern. “Sunrocket Solar Kettle (Black)” Touch of Modern. https://www.touchofmodern.com/sales/sun-kettle/sunrocket-solar-kettle?email=thatkat@me.com&open=1&sale=1&utm_campaign=Daily%20Sales%202014-04-17&utm_medium=email&utm_source=Sailthru&utm_term=Subscribers-production . Accessed 27 October 2021

Background

- Instead of converting solar energy into electrical energy into thermal like a solar panel, the solar kettle will **directly convert solar energy into thermal energy** saving an energy transformation step; thus, increasing efficiency.
- **Photovoltaics** are used in a lot of solar panels, in which energy from the sunlight is absorbed by the PV cells in the panel.
- This energy creates electrical charges that move in response to an **internal electrical field** in the cell, causing electricity to flow[1].



"PV Panels." Apricus, *https://www.apricus.com/solar-pv-systems-pv-panels-19.html. Accessed 28 October 2021*



"Flat Plate Collector." Alternative Energy Tutorials, https://www.alternative-energy-tutorials.com/solar-hot-water/flat-plate-collector.html. Accessed 28 October 2021

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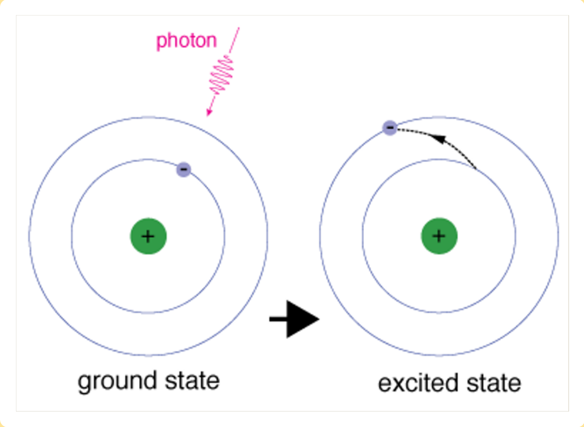
[1]*"How Does Solar Work?" Energy.Gov,* *https://www.energy.gov/eere/solar/how-does-solar-work. Accessed 28 Oct. 2021.*

Background (cont.)

- Instead, our design utilizes **reflective panels,** such as mirrors and aluminum foil, to reflect and concentrate sunlight onto the flask that collects solar energy and converts it to heat energy.
- The wavelength of light (**photons**) from the sun bounces off the mirror panels and onto the flask, ultimately **exciting the molecules of water in the flask**[2].



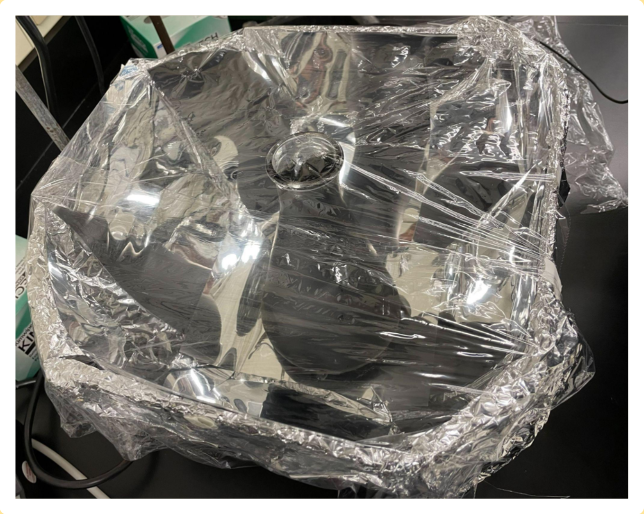
2 *"How Exactly Does Light Transform into Heat--for Instance, When Sunlight Warms up a Brick Wall? I Understand That Electrons in the Atoms in the Wall Absorb the Light, but How Does That Absorbed Sunlight Turn into Thermal Energy?" Scientific American, https://www.scientificamerican.com/article/how-exactly-does-light-tr/. Accessed 28 Oct. 2021.*

Imagine the Universe! "Understanding the Atom." NASA, https://imagine.gsfc.nasa.gov/science/toolbox/atom.html. Accessed 28 October 2021.

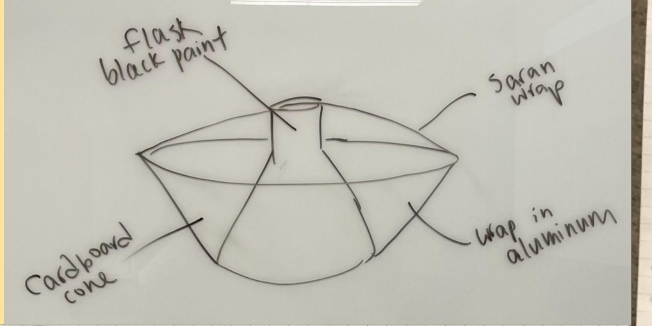
Hypothesis:

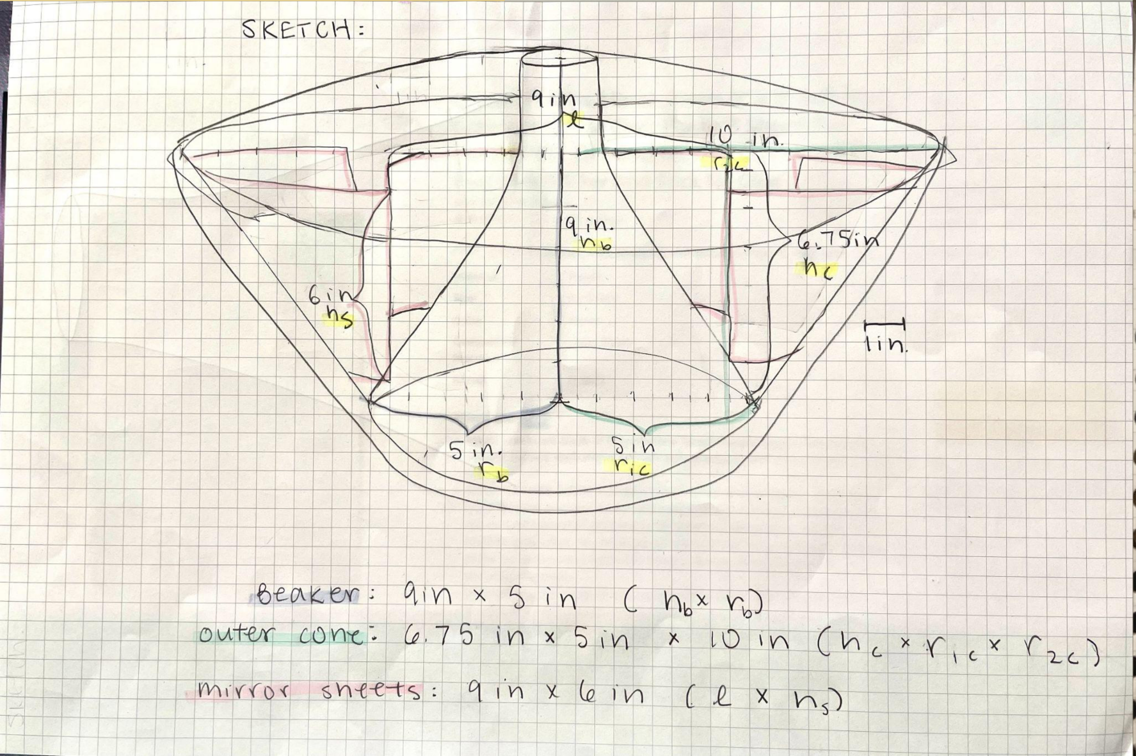
Our Solar Heater design will be more efficient than the 4Patriots Solar Sun Kettle.

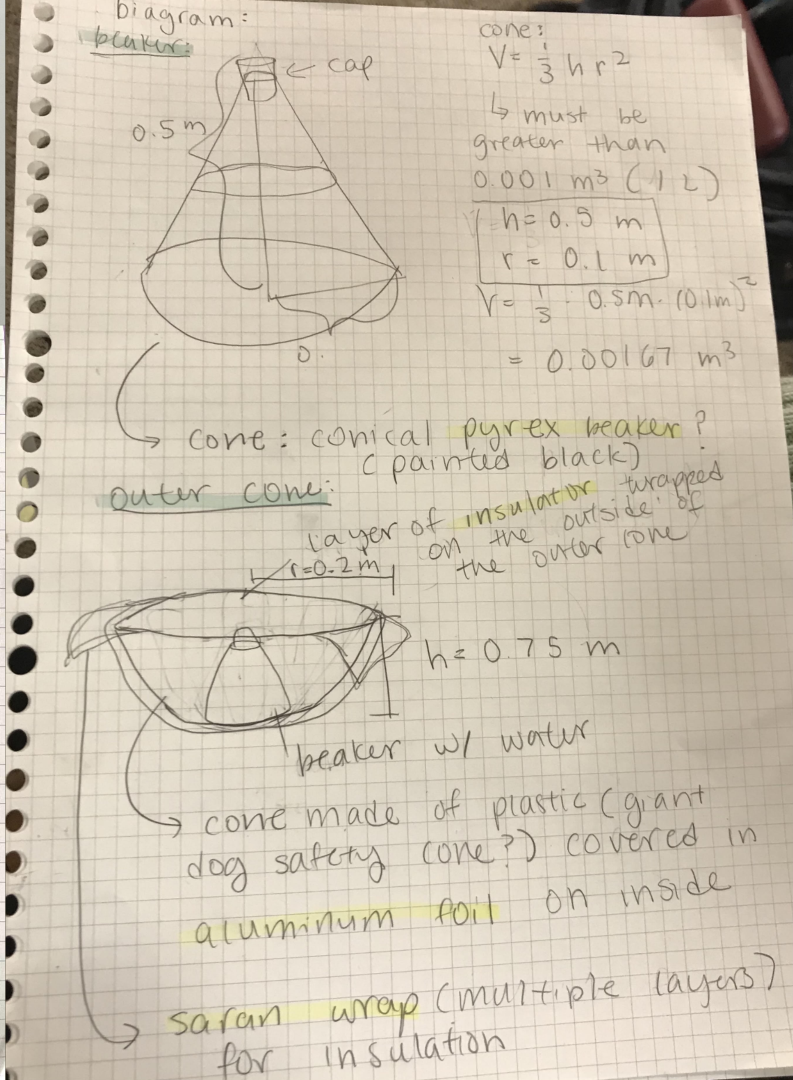
- **Glass Erlenmeyer flask, painted black**: increase absorptivity of solar energy.
- **Aluminum foil wrapped on the inside of cardboard bowl and layer of Saran wrap**: increase insulation
- **Mirror sheets lined on the insides of the bowl**: increase effective irradiance.
- These components will help our solar kettle yield increased efficiency.



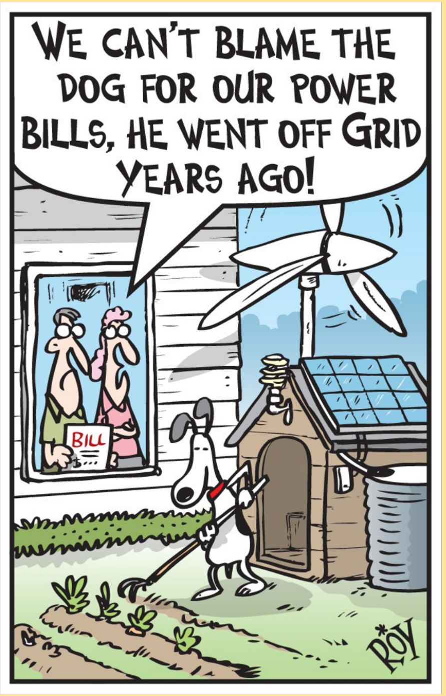
Initial Design Process



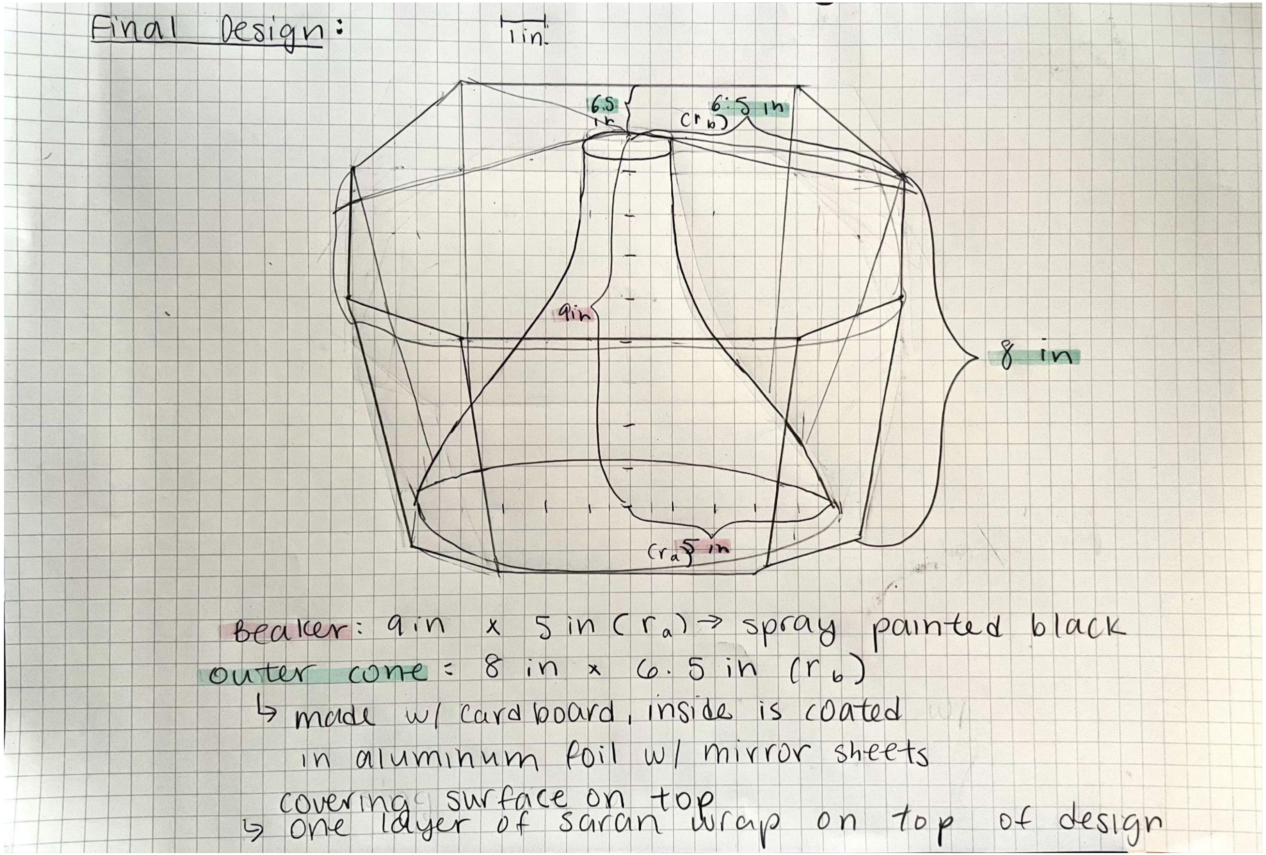




Final Design



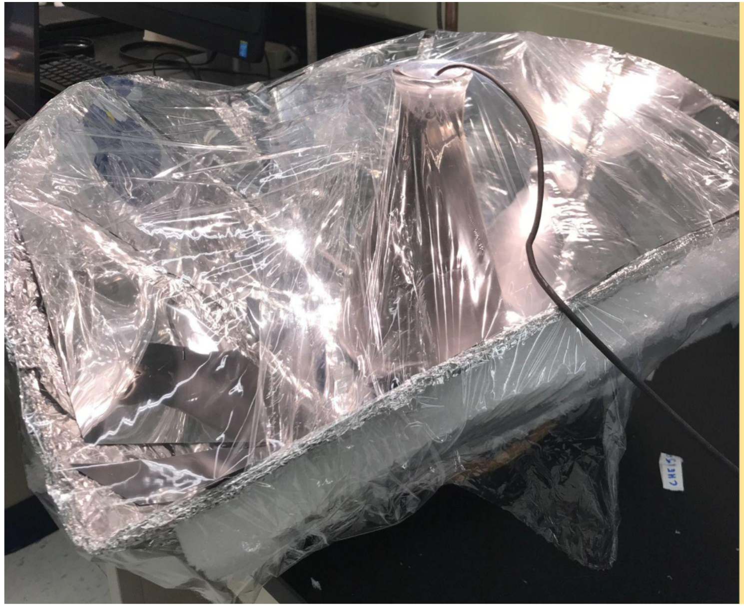
Taylor, Chris "ROY". "So, Who Should We Blame For Our High Powerbills???" . Twitter. https://twitter.com/chrisroytaylor/status/1017208519123058688. Accessed 27 October 2021



Evolution of Design

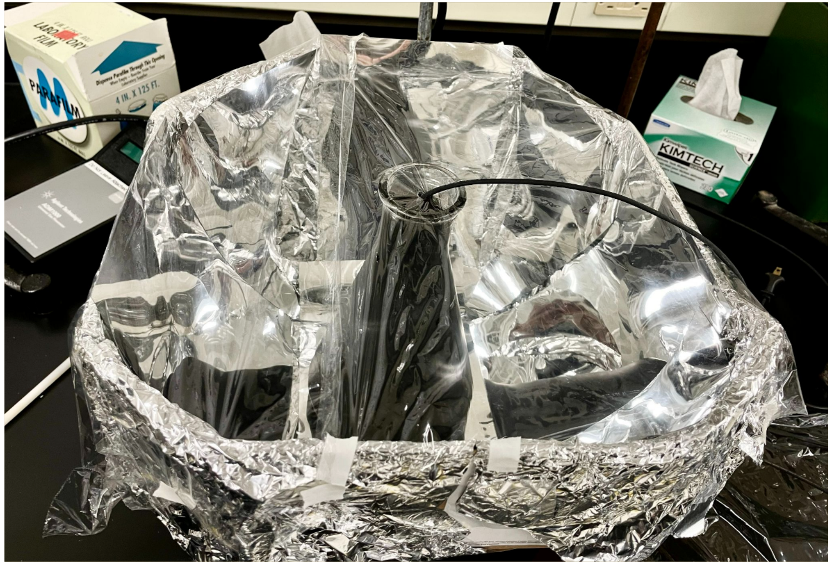
Initial

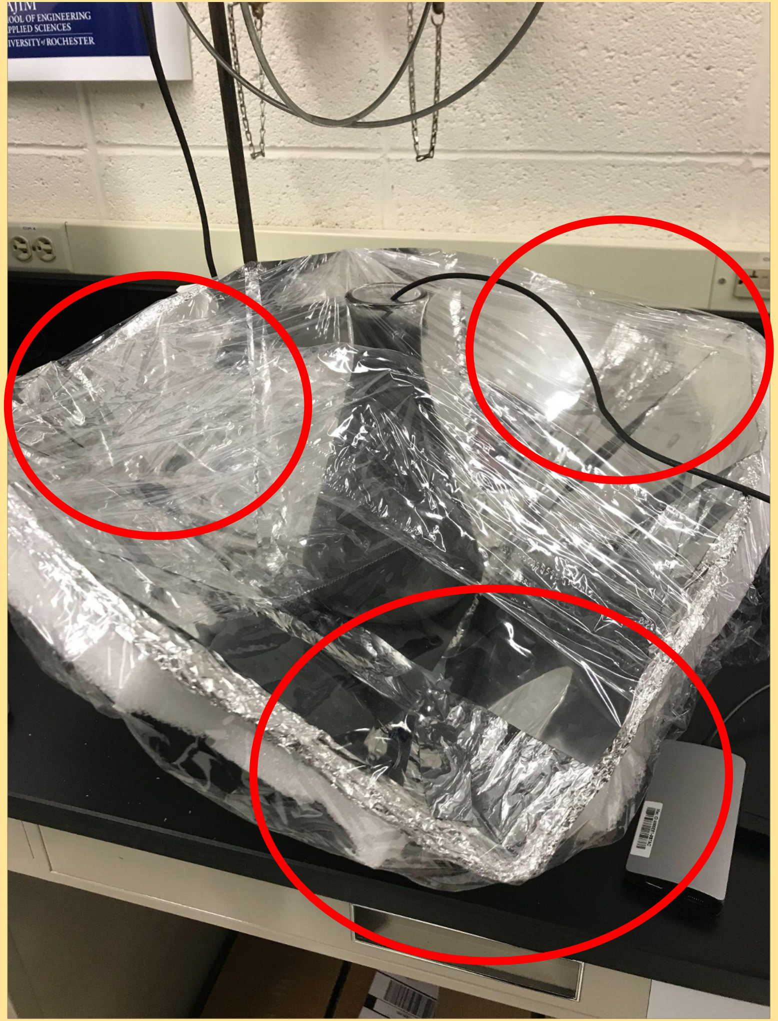
- Triangular-shaped.
- Larger collector surface area.
- Large angles.

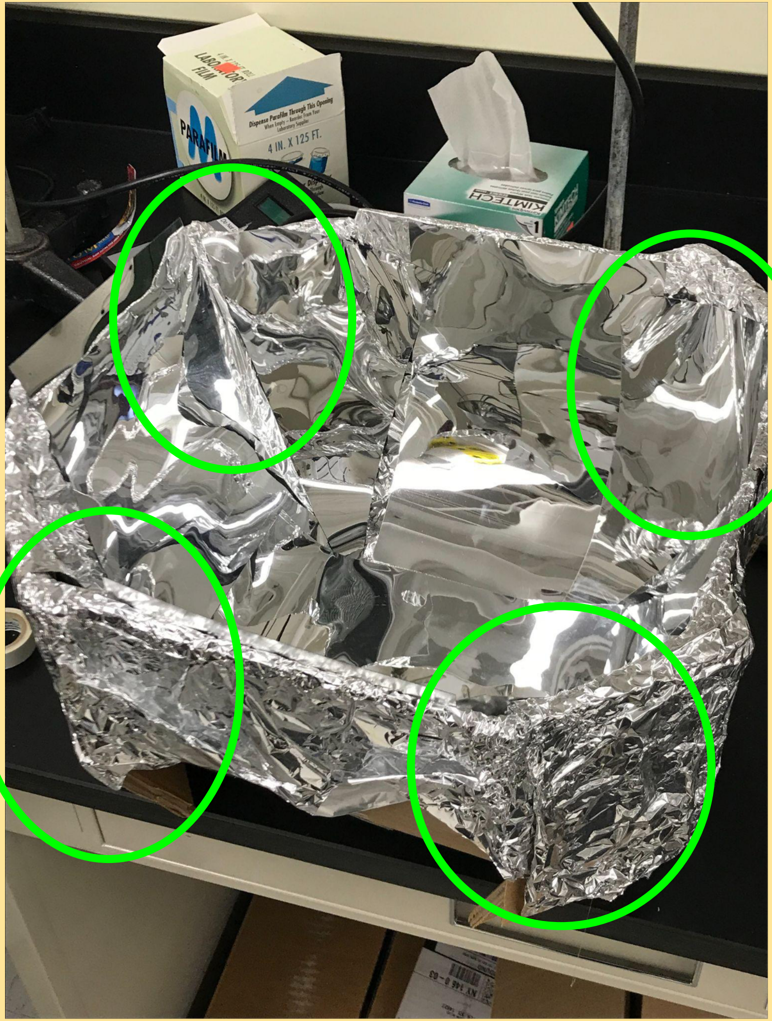


Final

- More circular.
- Smaller collector surface area.
- Effectively enclosed.






PARAFILM
4 IN. X 125 FT.
KIMTECH

Experimental Trials (Controlled)

a. T(°C)=0.254°C/mV*mV-1.398°C
b. T(°C)=0.253°C/mV*mV-0.886°C

Trial #	Initial Voltage (mV)	Final Voltage (mV)	Initial Temperature (°C)	Final Temperature (°C)	Change in Temperature (°C)	Boiling Time (min/s)
1 (9/24) Partly sunny.	91 mV	101 mV	a. 21.716 °C	a. 24.256 °C	**a. 2.54 °C**	**31 mins (1800 sec)**
2 (10/11) Mostly sunny.	92 mV	154 mV	a. 21.97 °C	a. 37.718 °C	**a. 15.748 °C**	**56 mins (2880 sec)**
3 (10/12) Mostly sunny.	94 mV	203 mV	a. 22.478 °C	a. 50.164 °C	**a. 27.686 °C**	**82 mins (4920 sec)**

Efficiency (Controlled)

$$\eta = \frac{P_{H_2O}}{P_{sun}} = \frac{m \cdot c \cdot \Delta T / t}{S \cdot A}$$

Trial	Efficiency
1 (Partly Sunny)	0.0622
2 (Mostly Sunny)	0.241
3 (Mostly Sunny)	0.248
Average of Trial 2 and 3	**0.245**

m= 1 L = 1000 g

c= 4.18 J/gxC

A= SA of kettle = 508.781 in^2 = 0.328 m^2

S= October in Rochester = 1.04 MJ/m^2/hr = 288.889 W/m^2

Experimental Trials (Designed)

a. T(°C)=0.254°C/mV*mV-1.398°C
b. T(°C)=0.253°C/mV*mV-0.886°C

Average: T(°C)=0.250°C/mV*mV-0.724

Trial #	Initial Voltage (mV)	Final Voltage (mV)	Initial Temperature (°C)	Final Temperature (°C)	Change in Temperature (°C)	Boiling Time (min/s)
1 (10/25) Old Design Halogen Lamp.	92 mV	102 mV	22.478 °C	24.51 °C	**2.032 °C**	**15 minutes (900 sec)**
2 Final Design Sunny	84 mV	90mV	20.276°C	21.776°C	**1.5 °C**	**15 minutes (900 sec)**
3 Final Design Sunny	88 mV	94 mV	21.276°C	22.776°C	**1.5 °C**	**15 minutes (900 sec)**
4 Final Design Sunny, with mixing	89 mV	98 mV	21.526°C	23.776°C	**2.25 °C**	**15 minutes (900 sec)**

Efficiency (Designed)

$$\eta = \frac{P_{H_2O}}{P_{sun}} = \frac{m \cdot c \cdot \Delta T / t}{S \cdot A}$$

Trial	Efficiency
1 (Old Design, Used Lamp)	0.0256
2 (Sunny)	0.0639
3 (Sunny)	0.0639
4 (Sunny, with occasional mixing)	0.0959
Average of 2 and 3	**0.0639**

m= 1 L = 1000 g

c= 4.18 J/gxC

A= SA of design = 585 in^2 = 0.377 m^2

S (T 2-4) = October in Rochester = 1.04 MJ/m^2/hr = 288.889 W/m^2

S (T 1) = Lamp = 1061.033 W/m^2

Conclusions and Results

- The efficiency of the 4Patriots Solar Sun Kettle was **0.245 (24.5%).**
- The efficiency of our designed solar heater was **0.0639 (6.39%).**
- While not even close to the commercial kettle, we estimate that our kettle is efficient given all of the constraints
- We estimate that our hypothesis (black paint for absorptivity, mirrors as concentrator and aluminum as insulator) is correct **except** for using saran wrap as an insulator

Deering, John. "Strange Brew." The Comic Strips. https://www.thecomicstrips.com/comic-strip/Strange+Brew/2017-12-19/166302 Accessed 27 October 2021

Sources of Errors and Possible Improvements

- During our trials, **the water near the top of the flask was very warm while the water near the bottom of the flask was still cold.** This could be due to:
  - shape of the flask (uneven heating)
  - Intensity difference of irradiance due to the uneven slants of bowl-shaped structure
- To ensure that the **water heats more evenly throughout**, we can:
  - Use a wider or flatter and more symmetrical container to hold water (increase SA)
  - Use a stir bar to ensure the water is heated more evenly

Meerman, Ruben. “Hot and Cold Water.” ABC Scientist. https://www.abc.net.au/science/surfingscientist/pdf/teachdemo10.pdf Accessed 27 October 2021

Sources of Errors and Possible Improvements (cont.)

- Hypothesis is incorrect that Saran wrap increases efficiency.
- There may have been **heat loss due to Saran wrap** (difficult to tape down).
- The reflectiveness of the Saran wrap may have also decreased efficiency.
    - This can be solved by using a thin layer of plastic sheet to act as a cover instead of Saran wrap.

“Transparent plastic wrap texture.” dreamstime, https://www.dreamstime.com/abstract-transparent-plastic-wrap-texture-background-used-transparent-plastic-wrap-texture-image117277651. Accessed 28 October 2021.

THANK YOU!