Design Description Document

Large Portable Imaging Solar Concentrator

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Product Description
The Large Portable Imaging Solar Concentrator (LPISC) is a device with the main body consisting of a wooden frame, a vacuum pump and a reflective film. By pumping vacuum in the cavity, the reflective film will be shaped into catenary, which is used to concentrate sunlight to a small spot of a given diameter with high intensity at about 10 feet away from the device.

**Product Requirement Document**

(See digital document 001)

**System Block Diagram**

**Design 1:**

Overview:
The mirror will consist of a reflective mylar film with a wooden frame. The frame will have a hole on the side for a vacuum pump, which will shape the mylar film. The mirror will be exposed to sunlight and concentrate the solar radiation onto a spot <2 inches in diameter at a distance of 10 feet from the base of the concentrator.
Design 2:

Overview:
The design will consist of a reflective mylar film and a transparent mylar film with a ring frame. The frame will have a hole for an air pump, which will shape the mylar films. The mirror will be exposed to sunlight, transmit through the transparent mylar, and concentrate the solar radiation onto a spot <2 inches in diameter at a distance of 10 feet from the base of the concentrator.

Figure 1: CAD model of the frame for design 1.

Figure 2: The computer simulation of the vacuum model was created in LightTools by using a freeform surface defined by a matrix of sag values generated using a sampling of our shape curve.
Figure 3: CAD model of the frame for design 2.

Figure 4: The computer simulation of the balloon model was created in LightTools and was analyzed using a blackbody spectrum. The reflective surface is the same used in the vacuum model but with a freeform sheet with the properties of clear mylar in front of it.
First Order Analysis/Measurement:

To measure the shape, we attached a string on the mirror across the center. The string was marked every inch. After pumped the vacuum, we measured the distance from the string to the mirror surface for every inch. The unit in the plot below has been converted into cm. The dash curve stands for the simulated function of our data and the solid one is the linear combination of a standard catenary and a standard parabola, with a ratio of 0.85 to 0.15.

![Graph showing measurement data](image)

Figure 5: Measurement of the sag across the LPISC prototype built by Dr. Knox. In the figure the best fit curve was overlapped onto the measurement.

It is a possibility that the two sides of the mylar have different reflectivity from each other. In order to find out if one side would reflect better, the reflectivity of the two sides of the mylar film was tested using the AudioDev and 623.8 nm HeNe Laser. A Max Mirror was used as a reference surface for the AudioDev. A power meter was used to measured the power of a HeNe Laser and was compared to the power after reflections from the Max Mirror and both sides of the mylar.
Figure 6: Reflectivity of side A (left) and side B (right) of the mylar film over some wavelength.

![Graph 1](image1.png)

Figure 7: Power of HeNe Laser measured with a power meter without any reflection, reflection off of Max Mirror, and reflection of both sides of the mylar film.

![Graph 2](image2.png)

Based on the results from the AudioDev and the HeNe laser test, side B of the mylar film was found to be more reflective than side A. It was concluded that the two sides of the mylar film have different reflectivities.
Young's modulus is the stiffness of an elastic material. The young's modulus of the mylar film was measured by the tensile test machine at mechanical engineering department at the University of Rochester. With the measurement of young's modulus, the shape of the mirror was modelled.

The results validated our earlier findings of the shape of the mylar film.
Software:

Creo Parametric was used to model the wood frames for both designs for the LPISC ETA-ARC-AT and ETA-STC softwares were used with the AudioDev to measure the reflectivity of the mylar film
Lighttools is used to measure the performance of the LPISC
Patran FEA software used to model the shape of the mirror using the Young’s Modulus data

Performance Testing

Figure 10: Optical computer modelling was done in LightTools v8.1.0. The source used in the simulation was a circular source that approximated the angular size of the sun. The reflective surface was an aluminum freeform surface and the transmissive surface for the balloon design was given the transmission spectrum of mylar given by subtracting the differences in our earlier reflectance tests of the two sides. Picture shows source at 20 feet but a distance of 80 feet with current size was used in actual simulation.
Clearly the vacuum model was the most efficient in setting the cardboard on fire. There were significant difference in time between the vacuum model and the other two models (balloon and prototype), while the other two models were not significantly different from each other.

The output power could not be directly measured since it would exceed the maximum optical power and thermal capacity of any detector available to our group. To establish a metric of power we used two alternative methods to establish a baseline. The first approach was to measure the time that is needed for three models to ignite a cardboard square located at the best focus for each mirror. The result was shown in figure 11. The other approach was to use a FLIR thermal camera to measure the highest temperature of an aluminium plate located a set distance from the mirror, this
distance was determined by the prototype mirror and the time under exposure was constant. The result was shown in figure 12

**Risk Analysis**

The biggest risk comes from testing and using the model. When taking measurements on the mylar film and when the prototype and the final models are tested, it will involve using light sources such as LED lights, HeNe laser, laser pointer, and sunlight. It is important to be aware of the surroundings to make sure that the light source does not cause damages to the eye. In an outdoor setting, it is extremely important that the sunlight never focus on people. Users should be aware of others walking across the focused sunlight when the concentrator is in use as it can cause burns. The reflective face of the concentrator should not be pointed towards anything highly flammable.

**Follow Up**

Both designs meet requirement overall and are more efficient than the prototype, hopefully they will provide inspiration for further innovation. The customer may desire a continuation of this project and have another team work on it so that more innovative designs can be created and improvement can be made. The applications of the concentrator were not specified by the customer but our recommendation is that a thermal exchange system could be paired with this system to harness the concentrated energy. Our team enjoyed working on this project and are thankful to our customer and professor Dr. Knox for giving us this opportunity.