Parabolic Trough-Tracking System

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Project Proposal

Document

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Introduction

A parabolic trough is a type of renewable energy used to collect solar thermal energy. Most parabolic trough are curved and lined with a polished metal mirror. In order to get the maximum energy extraction, the system requires to be portable and track the sun's movement throughout the day and with the changing seasons. Sunlight converted to heat is used to run engines such as a steam turbine. Steam engines run generators and make electricity. This is an alternative way to make energy.

The current parabolic trough-tracking system is an operable and damage has accumulated on the trough. The last time it has been operated was about 15 years ago and is currently located between the engineering building and the forestry building, in an enclosed area. The client, Dr. Kosaraju, would like to convert the absorbed solar energy into a useful form of energy.

Project Definition

In order to absorb the most solar energy from the parabolic trough, the tracking system must be repaired and damage done to the trough must also be repaired. An overall view of the system is displayed in Figure 1.

Figure 1- Overall system

The tracking system is in need of a new motor to turn the parabolic trough upon its horizontal axis and a control box is also needed to control the motor. A programmable control box is preferred in order to obtain the maximum amount on solar flux throughout the day without having to manually control it. Due to environmental constraints, the parabolic trough must also be mobile so it may not have any obstructions from sunlight. The current inoperable motor and control box is displayed in Figure 2.

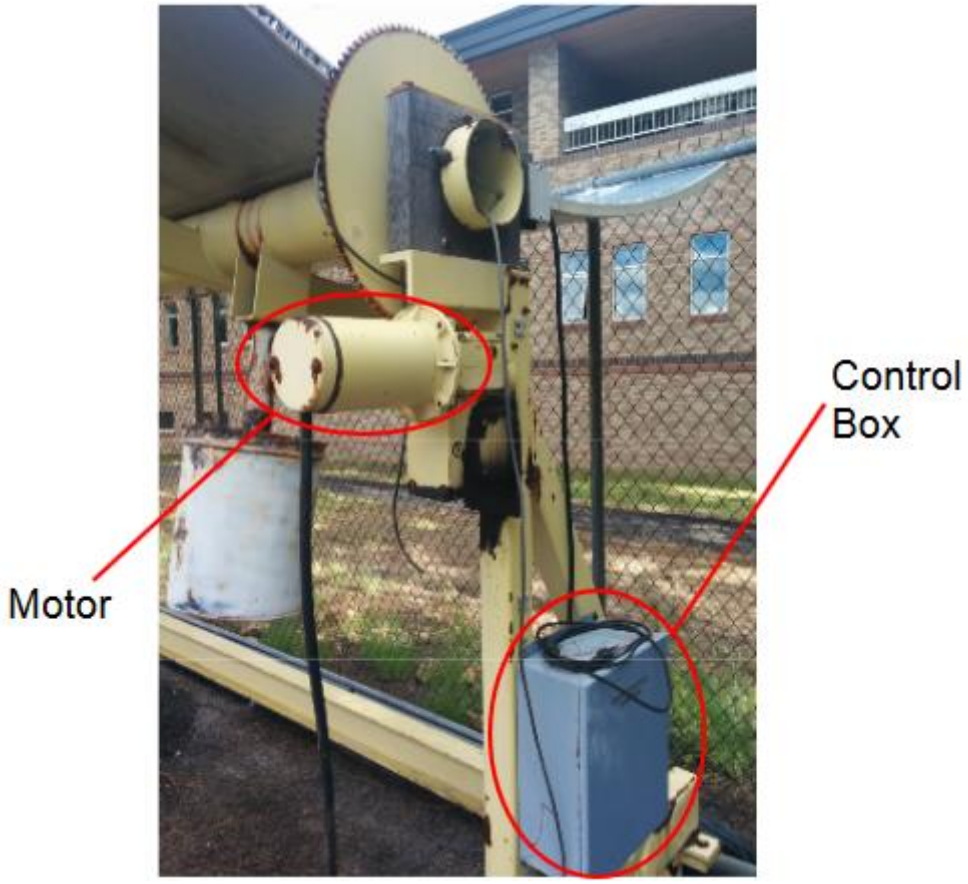

Figure 2- Motor and control box

Figure 3 shows physical damage on the parabolic trough which includes frayed edges, water damage, and holes on reflective surface. The damages on the parabolic trough must also be repaired in order to ensure all areas of the trough are effective and no further damage is accumulated.

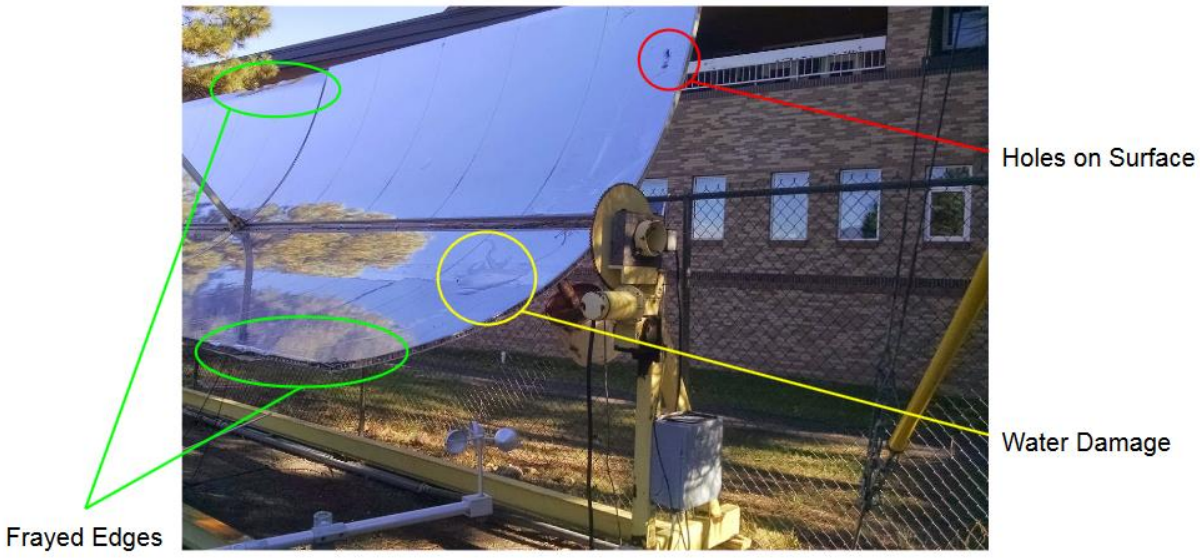

Figure 3-Parabolic Trough Damages

Objectives and Constraints

The objectives and personal goals are to restore an efficient source of solar energy. The first milestone is to repair the existing parabolic trough into operating condition. This included replacing vital parts in the operation of the trough such as a motor, tires, and chain. The reflective surface would also need repair because of cracks, water damage, and frayed edges. Once the parts are replaced and the damages are repaired then the trough can maximize efficiency in energy extraction.

Another goal is to have maximum energy extraction about it horizontal length. Many solar panels consist of three phases of rotation in order to extract energy, however, the current parabolic trough is a single phase rotation. The parabolic trough is hidden between buildings which makes sunlight minimal on the reflective surface. A relocation of the trough would help accomplish this goal.

The final goal is to expand the lifespan of the entire tracking system. Since the trough has been left inoperable for many years the harsh weather conditions have shortened the life of the trough. The lifespan can be extended using more durable and stable material to repair it and proper maintenance.

In order to accomplish the objectives, there are constraints that must be accounted for. The client would like the tracking system to be controlled by a computer or a more updated technology system of operation. The other constraints involve the potentially harsh weather

conditions of Flagstaff, Arizona. The trough needs to withstand winds up to 70 mph, temperatures between -20 and 100 degrees Fahrenheit, and various weather conditions such as rain, snow, hail, and wind. These are extreme cases, but the tracking system needs to operate regardless of weather conditions.

Motor

One of the most difficult tasks has been finding a replacement for the current motor. Figure 4 below shows some wear and tear on the motor with excessive rust. There was no tag or paperwork left behind describing what kind of motor it is, what company it is from, or any specifications. This made it difficult to find the correct motor that would match the output needed to sustain the load of the trough.

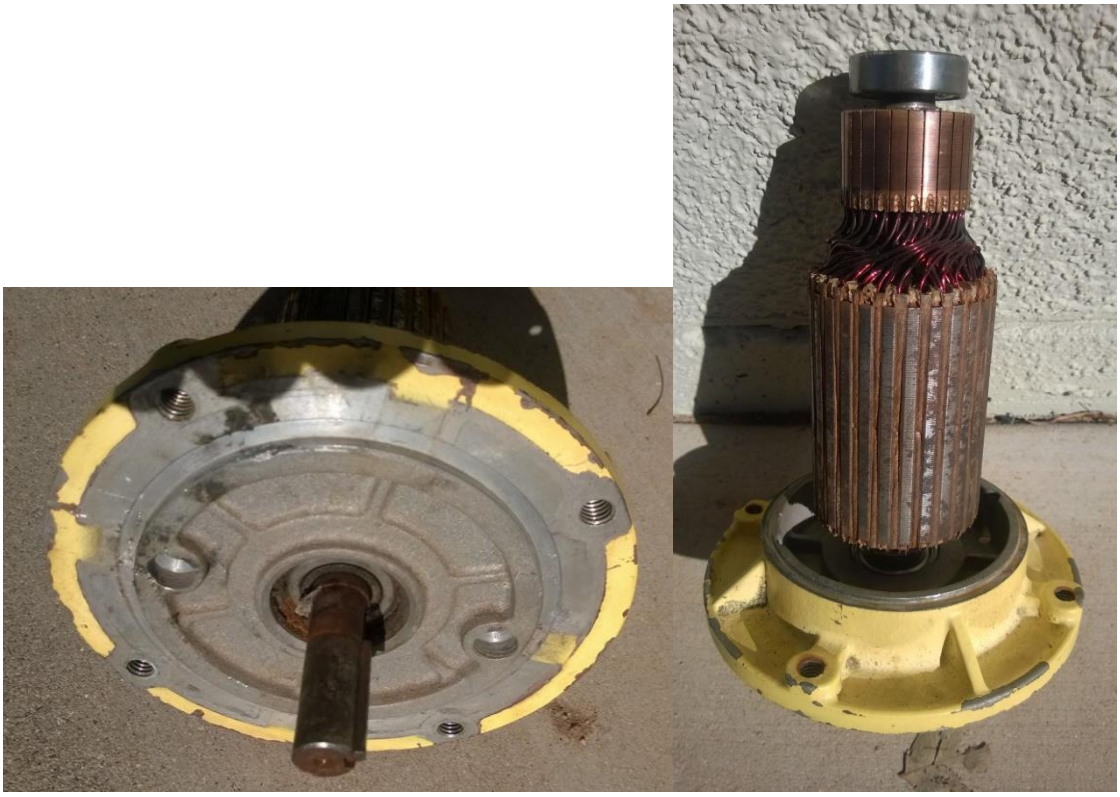

Figure 4 - Motor shaft and face (left) and side view of entire motor (right)

Since the motor seemed to match the gear box, we searched the gear box and found the company Boston Gear labeled on it. Thus, we contacted Boston Gear and spoke to a specialist on their gears and motors. Based on the description, the specialist said it sounded like a ⅙ hp motor with a 56C face. He recommended a particular model, but we were not sure that amount

of power would sustain the trough load. Also, since this motor was at least 15 years old there was not an exact motor match, in particular the dimensions. The client recommended that we find a 1 hp motor that would match the current gear box. General specifications of most motors include 90 volts and 170-1800 rpm. The motor found, displayed in Figure 5, has all the correct specifications of what the trough needs. These specifications are a power of 1 hp, output of 90 volts, 1750 rpm, shaft size of ⅝ inch diameter, and a 56C face. The motor found is from Baldor company, model CDP3445, at $743.30. This would be a suitable motor for what the trough needs.

Figure 5 - Baldor motor, supplied by Applied Industrial Technology

Control Box

Another difficult task was finding a control box that would be compatible with the motor. The given control box is worn, rusted, and inoperable due to lack of maintenance and weather getting inside the box.

Most supplied motors are simple control boxes that are on and off switches or just regulate the motor speed. Originally we found a Boston Gear motor that worked, we contacted Boston Gear to try to match the gearbox, motor, and control box from the same supplier. When Boson Gear was contacted to find a control box that met the trough's needs, the company said that the control box we wanted was obsolete. We needed a control box that could operate the

trough based on a programming the control box or setting a timer. The goal is to program the trough to angle towards the sun without constant manual control. We came to the conclusion that we were very likely to find a motor and control box from different companies. The control box found is from Dart Controls, a company that specializes in control boxes. It is model MD30E-7 and is the largest control box in Figure 6.

Figure 6 - The control box selected is from Dart Controls (top right)

The specifications are 7.4 by 5.53 inches in dimensions, 1 hp of power output, and 120 volts listed at about $200. According to Applied Industrial Technology, the control box is compatible with the selected motor.

Tire Information and solution

At the beginning of the semester, the parabolic trough's four tires, one of four in Figure 7 were all damaged and needed to be replaced.

Figure 7- Damaged tires

The tires were replaced with Marathon 4.10/3.50-4 tires, which cost $14.50 per tire plus shipping. After the tire was purchased, the team started the process of installing the new tires on the trough.

During installation of the new tires, one of the four casters broke, which then generated three solutions to this problem. The first option was to replace all the casters with new casters that are only sold with tires and not separately. The total cost was $65.99 for each combination of caster and tire with a subtotal of $263.96 if the Marathon tires were returned. The second option was to weld the broken caster using the NAU machine shop. Although this option would have no cost, if the caster was welded, the durability of the caster would be unknown and may fail again with the load of the parabolic trough. The third option was to replace only one caster that would come in combination with a new tire and keep one of the purchased Marathon tires as a spare at a cost of $65.99 . One caster and tire combination was purchased as it was the best solution at a reasonable cost. The purchased caster and tire combination is displayed in Figure 8.

Figure 8- Replaced Caster with the tire

Chain information

When researching chains, the specifications needed were the length, pitch, and roller width. We measured the length using a tape measure around the large sprocket, seen in Figure 9, and small sprocket (not pictured). The measured distance found was 75 inches or 6.25 ft. From McMaster-Carr, the chain lengths are rounded up to the nearest foot. Therefore, the chain length we need was 7 feet. Also measured was the pitch and roller width needed with a tape measure. The values measured are ⅝ in pitch and ⅜ in roller width. With these values, an ideal chain was found on McMaster-Carr's website. The chain purchased is a standard steel ANSI 50 roller chain and links, with a pitch of ⅝ in and roller width of ⅜ in. This chain has a working load limit at 561 lbs and costs $5.98 per foot that had a total of $41.86 before shipping.

Figure 9- Big Sprocket with missing chain

Gear Box

At the beginning of the semester, one of the tasks to complete was to check the interior of the gearbox and determine the condition of the parts by removing the rust and oil from assembly. The process was started by disassembling the gearbox part, which contains an upper level gearbox and lower level gearbox.

The upper level gearbox is connected to the motor which can be seen in Figure 10. The motor shaft and the worm gear are secured together by a rectangular key. After disassembling the cover plate lubricating oil was found that turned from a golden color to black. Since the system has not been operated or maintenance over 15 years, there was minimal amount of oil left in the upper level gearbox, . Most of the lubricating oil drained down to the lower level of the gearbox. The interior surface and the worm gear holding the horizontal shaft showed some rust.

Figure 10- Motor connected to the upper level gearbox

Figure 11 shows the helical gear secured by a bolt and a washer has some rust and will be replaced. The helical gear has minimal rust but can be cleaned by a wire brush. However, the shaft was able to rotate, but we still to decide if it can work efficiently in the near future.

Figure 11- Upper gearbox with the cover off

The rubber gasket has stretched and deteriorated from the weather of Flagstaff. The gasket will need to be replaced before the system is put back online. The defective gasket was the cause of the rusted parts in the upper level gearbox which are pictured in Figure 12. Moisture and condensation found its way through the gasket and the addition of minimal lubrication oil, the results was rust. There is a possibility that the cover plate will need to be replaced, but until it has been cleaned and tested, it will be unknown. The six bolts securing the cover plate will be replaced. The pink, once red in color, filler cap is made of plastic and will be decided at a later time if it needs to be replaced. The drain plug located on the upper level gearbox is in good working condition.

Figure 12: Upper gearbox cover

After disassembling the side cover mounted to the gearbox to observe the interior of it. It was found that it contains a vertical worm gear connected to the vertical shaft that rotates a helical gear in the same shaft located at the upper gearbox. The worm gear is connected perpendicularly to another helical gear located in the horizontal shaft that rotates the outer small sprocket. The vertical gear coming down has a roller ball bearing attached to it. As seen in Figure 13 the bearing sits between the upper level gearbox and the lower level gearbox to reduce friction and secure the vertical shaft. The roller ball bearing and the vertical shaft are in good condition. This is due to the lubricating oil protecting the parts from condensation and moisture.

Figure 13- Vertical worm gear connecting the upper level to the lower level gearbox.

The gearbox was taken to Coconino Auto Suppliers to get it professionally cleaned. The total cost for the cleaning was $35, and the material for a new gasket is also sold there for $8 a sheet. The upper and lower gearbox cleaned up well with the exception of a small bit of rust on the worm gear located in the upper gearbox. Figures 14-17 show the gearbox after it was professionally cleaned. The gearbox will be used for the tracking system of the parabolic trough.

Figure 14- Sprocket and shaft assembly

Figure 15-Post-cleaning upper gearbox

Figure 16-Post-cleaning lower gearbox

Edge Trimming

Due to the trough sitting outside in the environment for so long, the trim around the edges has almost completely broken off. Plastic trim was previously used when the parabolic trough was built, but after over 15 years it has become brittle and aesthetically displeasing. Most of the trim had already broken off, so new trim would be needed in order to seal the edges and also help make the trough look better. Figure 16 shows the previous conditions of the edges when the trough began to be worked on . After measuring the perimeter of the trough, it was decided that 74 feet of trim with a 1 inch channel gap would be needed to enclose all edges.

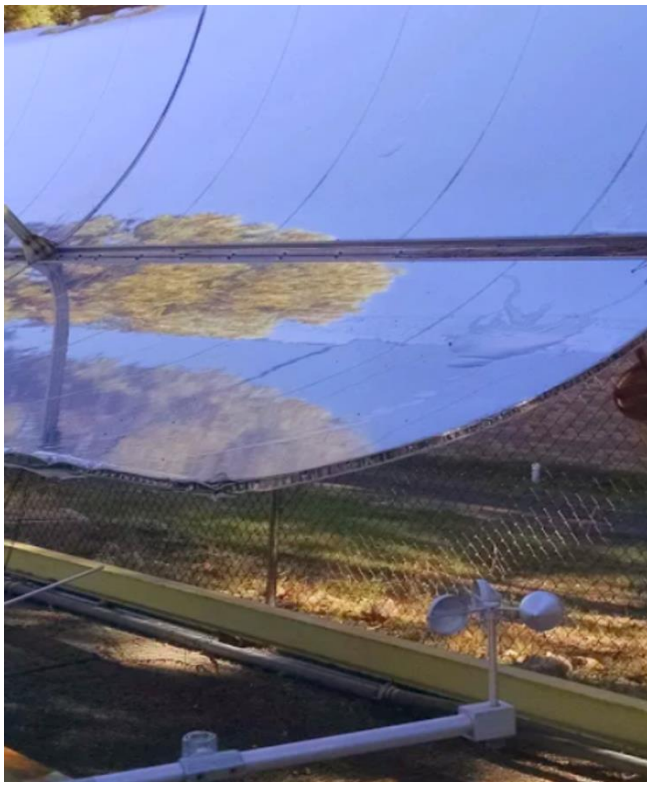

Figure 16 - Initial condition of edges

In order to determine what kind of trim to use, a material that has a long lifespan was desired. Although plastic was previously used, metal became the new material of choice because of the longer lifespan it has over plastic, it was found to be less expensive, and it could also hold down the areas of the edge that were bent, shown in Figure 17. Aluminum specifically was chosen because it is cheap and easy to work with. From Metals Depot, 8ft sections of 1 ¼" length legs, 1 ¼" base width, and ⅛" thickness, giving us the 1" gap needed, were found and were ready to be shipped. Once the material was chosen, ten 8ft sections were ordered to ensure that we would have enough material in case anything during installation went wrong. The total cost of the aluminum trim was $220.38. Installation is currently in progress, but has been delayed due to weather conditions.

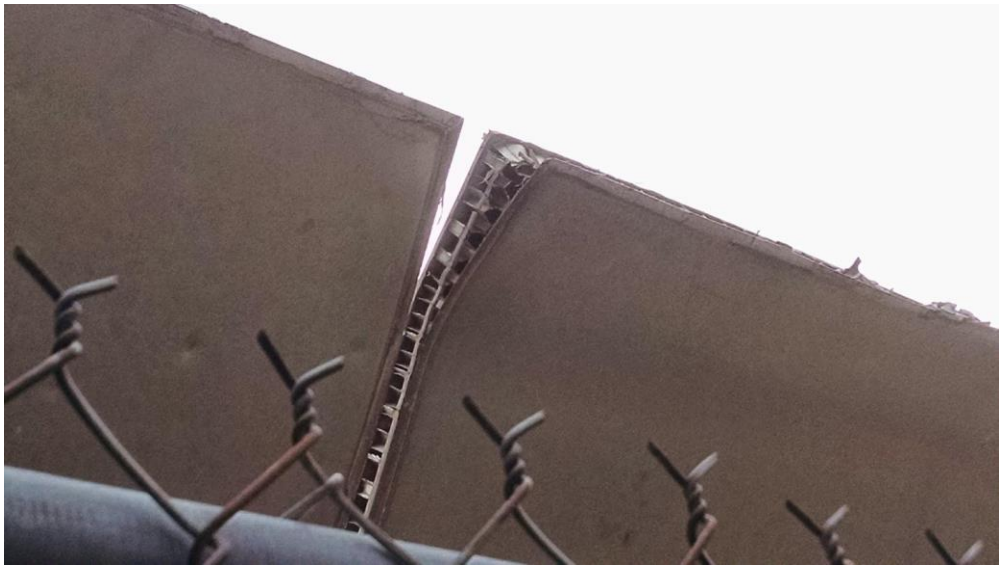

Figure 17 - Bent corner of trough

For the curved edges, a way to install the trim had to be decided since bending the 8ft lengths of aluminum was not possible given the resources available. In order to overcome this, 2 inch sections were cut and installed individually in order to ensure that there would be no gaps in the trim due to the curve. Figure 18 shows how these small segments look on the trough, showing that there are no gaps.

Figure 18 - Installed trim on flat and curved edges

Another concern about the installation of the aluminum trim is that there is a small gap in the center of the trough perpendicular to its axis of rotation, (0.5” on one side, 2” on the other) which does not allow room for sliding the trim on. To overcome this, there are several options to choose from. One way to apply the trim would be to cut the aluminum in half along its length, then applying each half to each side of the trough, and sealing the cut with the adhesive. Another option would be to just lay a material across the gap, such as Mylar, and leave the edge open, but it will still be protected from rain and snow since the trough will always be in its upright position. The only problem with this is that because Mylar is so thin, a puncture in the material would be easy due to the size of the gap. Placing a stronger material underneath for support would solve this problem, but application may be inefficient and alter the reflective surface towards the parabola’s focal point. The third option is to remove one or two of the supports in order to slightly bend the trough and slide the aluminum onto the edge. Because the materials of the trough are already flexible, this option could be simple if the supports are easy to remove, but could be very difficult due to the condition of the corrosion wearing down the supports and possibly losing the supports entirely. These options will be visited and analyzed in the near future once weather conditions improve and availability of group members is decided.

While installing, adhesive has also been used to help seal the edges. A construction grade, weather resistant multi-surface adhesive was chosen due to the harsh conditions the trough may experience. This was found at Home Depot for only $2.40 a bottle, with a total cost of $7.20 for three bottles needed.

Material to Cover Damaged Surface

Due to the holes and water damage in the parabolic surface, shown in Figure 19, the reflectivity is hindered and will not be at peak efficiency in this current condition. In order to retain an entire reflective surface, something that could be applied to the surface and still be as reflective as what is on there currently is needed.

Figure 19 - Holes and water damage in surface

For this application, Mylar was chosen due to its low cost, flexibility, and most importantly is reflectivity. Another benefit of this material is that it can be used to cover the trim that will be hanging over the reflective surface. This will help maximize the solar energy that will be absorbed. Using Amazon.com, a 100 ft^2 (4 feet wide, 25 feet long) roll was found for $20.00.

Installation of the Mylar has not yet begun due to the trim not being completed yet. Once all of the trim is installed, the Mylar will be applied to the surface and edges, and the trough will once again be able to rest in its upright position, rather than be tied upside down.

Fencing

The parabolic trough, at its current location, doesn't get the most sunlight within a day. In order to increase the efficiency of the parabolic trough it needs to be moved to a different location. The current area where the parabolic trough is, it's being obstructed by trees and the forestry building. Another drawback for the parabolic trough at its current location is movement. To track the sun's motion throughout the day, from east to west, the parabolic trough doesn't have the space to do so. The shack, fence line and other renewable energy projects creates a tight space so the trough can extract energy. A new location is required for repairing, testing and operation. To prevent damage to the parabolic trough and other existing structures the fenced area will need to be extended.

The original fencing perimeters were going to be 30 feet to the east, and 40 feet

north/south, connecting back to a pole that is already in place next to the shack. After inspection and professional opinion, however, the ground conditions would make this perimeter impractical due to holes in the ground and a tree directly in the way. Because of this, a new fencing perimeter was made, using less material and still ensuring that the trough will fit in the enclosed area.

The new area will be extended from the southeast corner by 30 feet to the east direction, 33 feet in the northeast direction and 37 feet west, connecting back to the solar shack, a schematic shown in Figure 20.

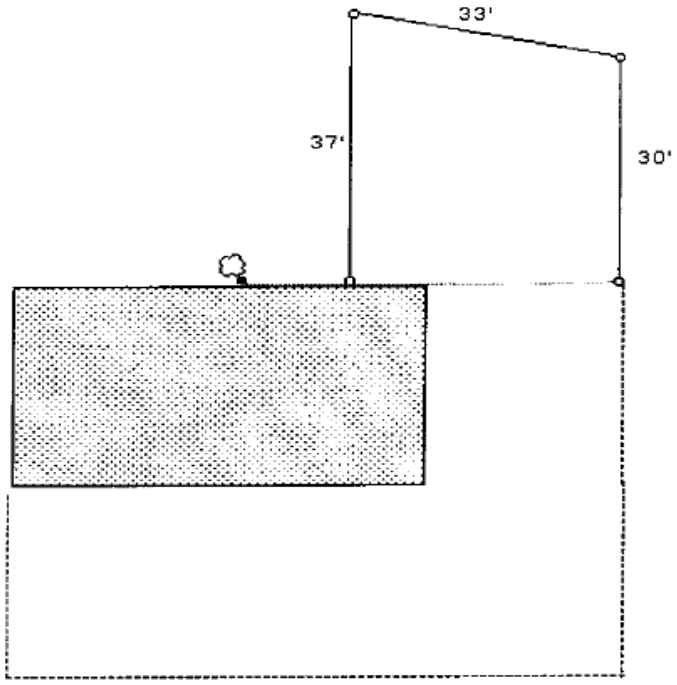

Figure 20- Fence

The team called around in the local area for fencing supplies and materials. Hardware and farm stores didn't carry the 8 feet fence needed to lengthen the existing fence. The next step was to call the local fence companies. The team worked with three local companies; Alamo Fence Company Inc., Buffalo Fence and Barn Company, and Coconino Fence Company.

Coconino Fence Company said they did not do business with Northern Arizona University due to insurance reasons. The person also said that they have done previous business with NAU and did not feel the paperwork was worth the hassle.

Buffalo Fence and Barn Company was the most helpful and expensive. Buffalo Fence

estimated it will cost $1121.27 to lengthen the fence to the existing fence. The team was given a quote without the labor cost so we asked for another quote. The total cost with labor for the fence installation through Buffalo Fence and Barn Company is $2,800. Buffalo Fence said the earliest they can install the fence is toward the end of December. The quote is shown in Figure 21 below.

100' - 96" high 9 GA. GALVANIZED (2" Mesh) CHAIN LINK FABRIC Fencing

QTY.	PART #	ITEM	AMOUNT
100	CL969	96" 9 GA. GALVANIZED (2" Mesh) CHAIN LINK FABRIC @ 4.79 /Ft. =	479.00
5	PP158DQ40252	1 5/8" X 21' DQ-40 PIPE TOP RAIL @ 42.42 /Ea. =	212.10
4	PP278DQ40126	2 7/8" X 10'6" DQ-40 PIPE POST @ 55.18 /Ea. =	220.72
8	PP238DQ40126	2 3/8" X 10'6" DQ-40 PIPE POST @ 40.28 /Ea. =	322.24
7	BB278	2 7/8" REGULAR BRACE BAND @ .77 /Ea. =	5.39
49	TB278	2 7/8" REGULAR TENSION BAND @ .67 /Ea. =	32.83
7	PSRE158	1 5/8" PRESSED STEEL RAIL-END @ 1.49 /Ea. =	10.43
8	PSET238158	2 3/8" X 1 5/8" PRESSED STEEL EYE-TOP @ 3.21 /Ea. =	25.68
4	PSDC278	2 7/8" PRESSED STEEL CAP @ 1.55 /Ea. =	6.20
3	TRS158	1 5/8" SLEEVE @ 1.42 /Ea. =	4.26
100	STW99	8 1/2" 9 GA. STEEL TIE WIRE @ .13 /EA =	13.00
100	STW79	7 1/2" 9 GA. STEEL TIE WIRE @ .13 /EA =	13.00
48	CB516114	5/16" X 1 1/4" CARRIAGE BOLT @ .34 /Ea. =	16.32
1	TW9GA	9 GA. 10# (170') SMOOTH TENSION WIRE @ 15.04 /ROLL =	15.04
50	HRS9GA	9 GA. STEEL HOG RING @ .028 /Ea. =	1.40
40	PREMIX	60LB BAG SACK PREMIX @ 3.76 /Ea. =	150.40
		MATERIALS TOTAL:	$ 1528.01
		10.00% DISCOUNT:	- 152.80
		8.446% STANDARD TAX:	116.15
		LABOR TOTAL:	1308.64
		TOTAL:	$ 2800.00

Figure 21-Buffalo Fence Quote

Alamo Fence Company Inc. was the last fence company we dealt with. There was some misunderstanding between the team and Alamo Fence. Once it was clarified and the company stopped by the area, we were given a quote with labor included. The price for installation through Alamo Fence Company is $2,750. The company will be available to start installing the fence by December 15 if we decide to go with them.

Total Cost

The total cost is the amount that has been spent so far since the team has started the parabolic trough project and is listed in Table 1. Three products that have not been bought but the team are still looking and are making a final decision are the motor, control box and fence. The prices shown for the three products are the ideal products for the project. We are currently looking for alternative, up to date and competitive prices. Final decision will be made by the

availability of the product and the client.

Table 1- Total Cost of project thus far

	Quantity	Cost (dollars)	Total Cost (dollars)
Tires	4	14.50	58.00
Caster	1	71.48	71.48
Chain (ft)	7	5.98	41.86
Motor	1	743.30	743.30
Control Box	1	200.00	200.00
Trim (8ft)	10	22.04	220.40
Adhesive	3	2.40	7.20
Gearbox Cleaning	1	35.00	35.00
Gasket	1	8.00	8.00
Gear Oil (75W90)	1	8.50	8.50
Fencing (ft)	100	28.00	2800.00
Mylar ($100ft^2$)	1	20.02	20.02
Rope	1	6.27	6.27
Subtotal			**4220.03**

Conclusion

Task that are completed up to this point, starting with the parabolic trough surface. Most of the trim has been installed. The only section left are the problematic areas that need extra attention. When the decision is made on how to go about installation we will continue applying the trim. When all the trim is installed the next application is the Mylar. Mylar will cover the damaged reflective surface. It will also cover the edges where the trim has been installed. All tires have been ordered and installed. While one tire was being installed the caster broke so a new assembly including the tire was purchased. The parabolic trough is now portable and can be moved to any location. The gearbox has been professionally cleaned by Coconino Auto Supply and is ready for oil gear oil to be added. The chain required to turn the sprockets has been

ordered but the team is waiting on the motor. To install the chain the motor position needs to be determine so we can measure the exact length of the chain. The new location of the parabolic trough has been decided. Quotes for the new fence dimensions are from two local fencing companies. The client will have the final decision to move forward with this.

Unfinished duties that will be resolved during the break or near future are the ordering of the motor and control box. Price, availability, and compatibility are beginning to be problematic in deciding with these two components. Once the new location has been fenced off the parabolic will be moved and the Mylar will be applied to the damaged surface.

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