FAMU-FSU College of Engineering

Department of Electrical and Computer Engineering

Final Report

EEL4914/5C – ECE Senior Design Project I

SOLAR SAUSAGE PROJECT 'B'

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Sponsor: **Dr. Ian Winger**

April 16, 2015

Project Executive Summary

The Solar Sausage design project is a multi-department project completed this past year. The Solar Sausage project was initially started by a research team at The Florida State University, this team created the parabolic trough system used to create cheap electricity via solar panels. The student design team took the current system, invented by Ian Winger and Sean Barton, and found possible ways to fix inefficiencies and add applications that will help to improve the overall output of the Solar Sausage system.

The student-led design team accomplished multiple tasks throughout the year; electricity via PV panels was created and a system was designed that will be able to purify water. The design team focused on three factors to keep the system working smoothly: the sensitivity of pressure levels within the two chambers of the sausage, a type of cooling system to keep the PV panels at a safe temperature, and a process to pasteurize the water. Four pressure regulators were present in the final design in order to keep the separate chambers of the two sausages at their exact measurements. In this system, if the pressure is not exact, the output of the system alters drastically and the sausage does not perform as expected. The PV panels must be kept at such a temperature that they will not overheat, if the panels get too hot their functionality decreases. The design for the heat exchanger will pull the heat from the PV panels into the water, this is the same water that will later be pasteurized and used as drinking water. The pasteurization process will be achieved by heating the water to a certain temperature as it travels the length of the second solar sausage.

The purpose of this Solar Sausage project long term will be to provide electricity to a desired load, preferably an entire village, and to give that village clean drinking water. This specific project team used the country of Panama as their design location when thinking about design ideas. The fact that this system will end up in an underdeveloped country means that the team will need to make sure that the upkeep and replacement of the Solar Sausage is simple and the parts easily accessible to the region. The Solar Sausage system can consist of as many separate sausages that the required load needs. The prototype made by the student-led team has a simple DC 12V fan as the load connected to the system, this load can be increased to whichever the user deems necessary. The end-product of this year's design team is not advanced enough to support such large loads as a village; however the prototype created is a miniature version of a system that would be able to support an entire community.

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1. Introduction

1.1 Acknowledgements

The design team would like to thank Ian Winger for his continual commitment to the team this entire year. Dr. Winger has provided hours of support and advice in regards to his invention, giving the team opportunities to search for improvements on his original design. Dr. Winger has also provided the team with equipment to build both sausages, and parts for each subsystem if needed. Along with Dr. Winger, the design teams technical advisors, Dr. Edrington and Dr. Ordonez have helped critique and perfect ideas presented by the Solar Sausage project team. With the continued support of these individuals, the design team was able to create an efficiently working prototype for their Senior Design Project.

1.2 Problem Statement

The purpose of this project was to design a complete and working prototype of a Solar Sausage system. The end product will prove to produce a cheap and simple way to create electricity and potable drinking water; in the long run this device will be available for underdeveloped countries. There were a few main issues facing the group when it came to the analysis and design of the Sausage. The team first looked at the inefficiencies in the current model in regards to pressure regulations. Having exact pressure levels in the top and bottom chambers of the Solar Sausage is of the upmost importance to the productivity of the system. An efficient way of cooling the solar panels was designed as well. The panels can very easily overheat and without a cooling system the panels will go out of commission rather quickly

The design team was able to analyze these issues and create a solution. Since the pressure levels must be kept regulated, the design team created a purely mechanical pressure regulator system that can effectively keep the system at correct levels, ideas for future changes will be included in this analysis. The cooling process for the solar panels will include a heat exchanger. This was designed to pull the heat from the solar panels into the water. This is the water that will be used during the pasteurization process.

1.3 Operating Environment

The Solar Sausage performs at its best in hot, dry climates, making Florida a bit of a challenge to keep the system working at high efficiency. The design team will have to account for such weather conditions as humidity, pressure changes due to storms, and morning dew. Any of these changes to the environment can affect how the Sausage produces its output. The end product of this system was designed to be able to operate in a country such as Panama, as FSU has a satellite campus there and the Engineers Without Borders chapter at the FAMU-FSU College of Engineering does work in this area. This region has close to the same weather conditions that affect Florida, making it easier to work through many possible issues in Tallahassee.

1.4 Intended Use(s) and Intended User(s)

The intended use of the solar sausage is to provide electricity and potable water to impoverished countries. Water and electricity are necessities of life and the solar sausage will help in providing those necessities. Also, the solar sausage will support a 4 watt fan as the load for this project (to show electricity was produced), however, the energy storage device can support the load, the water pump, the pressure regulators, and a charge regulator via the solar panel. A scaled up version will be able to support a small village.

The intended user of the solar sausage will be people who live in villages or other impoverished countries who are not equipped with the tools or equipment needed to provide an ample amount of drinkable water or electricity.

1.5 Assumptions and Limitations

Assumptions	**Limitations**
Components for the project will be inexpensive	$5,000 budget
Provide potable water	Scarce water sources
Project will be completed in two semesters	Unforeseen circumstances
Solar Sausage and Photovoltaic panel will both have a length of 10 feet.	Storing the Solar Sausage
Power output of 900 W/m^2	Ideal Sunlight
Water will be pasteurized from 65°C – 90°C.	Continuous water flow
Upper & Lower hemispheres will maintain a constant pressure	Morning dew
One axial rotation	Few moving parts to track the sun
Reflective material is convenient	The tension on both ends of the sausage

1.6 Expected End Product and Other Deliverables

The design team produced an end product consisting of a two-sausage Solar Sausage system to their client, in this case their advisors. This prototype was designed, built, and delivered, and this year's team will not be supplying any other deliverables after the completion of the project. The system being provided will consist of two solar sausages working together, creating electricity and cooling the PV panels in the first sausage and finishing the pasteurization process of the water in the second sausage. This end system was built with a load of 35W total needed to be supported. A scaled up version of the design teams project should in theory be able to support a larger load, for example a small village. The end product was delivered April 14, 2015.

2. System Design

2.1 Overview of the System

The block diagram below illustrates the design team's final design for the Solar Sausage System. The end product of this system provided sufficient power to support a load of about 35 watts **(location 7),** the power produced by the solar panel was 40W giving the system a net energy of 5W. This load was connected to **position (3)** of the flow chart, in the form of a 12V battery for energy storage. When the load received enough power from the system, the design team was able to conclude that the system worked in regards to the power output. The second function that this system needed to achieve was the production of potable drinking water. This process occurred throughout the entire system. The water was heated to 150 degrees during testing via the heat exchanger, this was about 50 degrees less than the desired temperature of 210 degrees, **(position 2)** the process would be completed in the second solar sausage **(position 5)**. The team believes that this temperature can easily be reached with further testing of the focal point accuracy. An additional process was added to cool the water once it has been pasteurized to make it safe to drink. The design team implemented a natural refrigeration cycle to cool down the potable water produced. This process is highlighted in red in the following diagram. Using this method, the water that is made potable will return to the heat exchanger portion of the system **(position 2)** using an exact replication of that system. With the hot water running next to the incoming cool water, the potable water will be cooled fast enough to avoid bacteria build up and allow drinkability. A bonus to this method is the fact that when the hot water passes the cool water, it also heats up the cool water, this will allow that incoming water to be at a hotter temperature when the pasteurization process begins, allowing the water to be made potable more quickly.

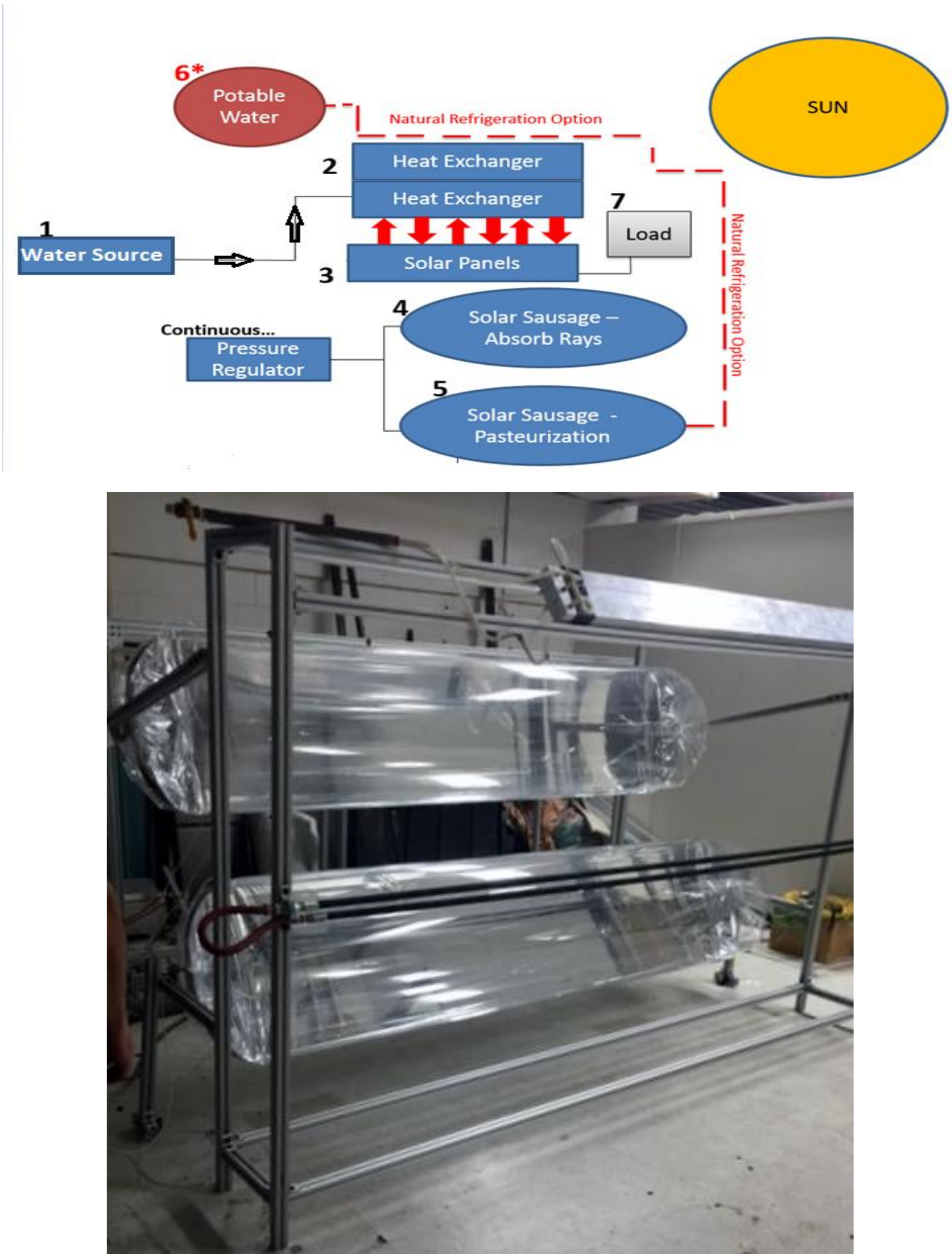

Figure 1: Solar Sausage Complete System

2.2 Major Components of the System

2.2.1 Water Source

The water source for this project came from a bucket at the beginning of the system. A water pump was used to pump the dirty water through the system, at the end of the pasteurization process the water will be dumped into a separate clean bucket. However, when the Solar Sausage is being used by villages the first dirty bucket will be replaced with a tank that has collected water from a nearby source, and the end “clean” bucket will be a different tank in which the users can take potable water directly from.

Figure 2: Water Pump

2.2.2 Heat Exchanger

This component serves two purposes: the heat exchanger is used to cool the PV panels in order to keep them in working condition, and simultaneously the water running through the heat exchanger will be heated by the panels beginning the pasteurization process.

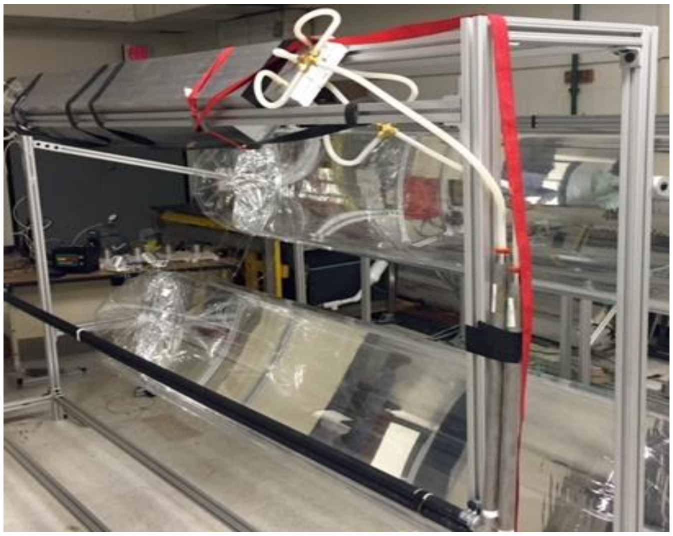

Figure 3: Heat Exchanger System

2.2.3 Solar Power System

There are four major components in the final solar power system design; these components include the load, the solar panel, a charge regulator, and an energy storage device (12V battery). The purpose of the solar panel is to absorb the concentrated sunlight (via solar simulator) which will be used to make the cheap electricity. The solar panel used in for this design project was made given specific dimensions; it is very hard to find solar panels in this long rectangular shape. Using this solar panel design, the team was able to create a heat exchanger that could fit directly behind the panel comfortably. The solar panel in use for this project puts out 40W according to testing. The design team is using a 10" portable fan, a 12V Flojet Water Pump, and four regulator pumps which draws 35W from the system. The power generation being produced from the PV panel can be increased by using multiple solar panels and sausages; if the load desired is for a small village our design can be scaled.

Figure 4: 12V DC O2 Cool Fan- Load

2.2.4 Pressure Regulator

The pressure regulator is used to make sure that the two chambers of the Solar Sausage are maintained at the required levels. This is a very vital part of the system, if the pressure is off in either chamber it greatly effects the efficiency of the solar sausage design. The pressure regulators made for this project can detect if the pressure is too low and will inflate the sausages, however they are not capable of reading if the pressure is too high and reducing the pressure back to a safe value. This characteristic will need to be added to the pressure regulators in the future in order for the solar sausages to be kept at their precise pressure measurements most efficiently.

Figure 5: Pressure Regulators

2.2.5 Pasteurization Process

This sub-system produces the potable water for the consumer. The pasteurization section of the Solar Sausage uses the water that is run through the heat exchanger to cool the PV panel; once this water is heated to the required temperature the water is considered potable. This water will be extremely hot when exiting the system, and will need to be cooled fast enough as to not let bacteria form.

2.2.6 Natural Refrigeration Cycle

This process will cool the potable water produced during the pasteurization process. The water will be pumped back to the heat exchanger where the water is cooling the PV panels and beginning its heating for pasteurization; here the already potable water, which is extremely hot, will be pumped through an exact duplicate of the heat exchanger directly on top of the PV panels, the water will be running beside the incoming cool water and a natural refrigeration will occur. The hot water will cool to a temperature that is safe to drink, and the cool water on its way to be pasteurized will receive a bump in temperature allowing for pasteurization to be reached more quickly.

2.3 Design of Major Components

2.3.1 Load

The load that was used in the demonstration for this project was a 12V, 10-inch O2Cool fan. This fan operates on 12V and 0.35A. From the equation:

$$P = VI \qquad \textit{Equation 1}$$

The power absorbed by this fan will be 4.08W.

Figure 6: 12V DC O2 Cool Fan- Load

2.3.2 Solar Panels

The solar panel is the main component of this whole project; it provides the power for the entire system. In this project the team used a monocrystalline solar panel; this type of solar panel usually has higher efficiency in comparison to a polycrystalline panel.

Figure 7: PV Panel Testing

The solar panel used in this demonstration was, as previously mentioned, made in specific dimensions. The rectangular shape of this solar panel will allow for the concentrated sunlight to occupy much of the area available. The concentrated light will appear as a straight line across the majority of the panel's length. It is very difficult to find a solar panel with our required dimensions, due to this limitation the design team was provided a single PV Panel by Ian Winger with a heat sink attached to the back. The heat sink is meant to keep the panels cool; in a perfect demonstration the team would use an exact replica of this solar panel minus the heat sink. With no heat sink the panel could rest directly on the bottom of the heat exchanger allowing for the water to be heated more efficiently than the team was able to show. The single PV panel was able to support our 35W load on its own with 5W to spare.

The graph below represents the model inside the solar panel. The dotted line indicates the non-ideal model; this includes the shunt resistance and series resistance. Many things can influence the I-V curve, such as insolation, temperature, and shade.

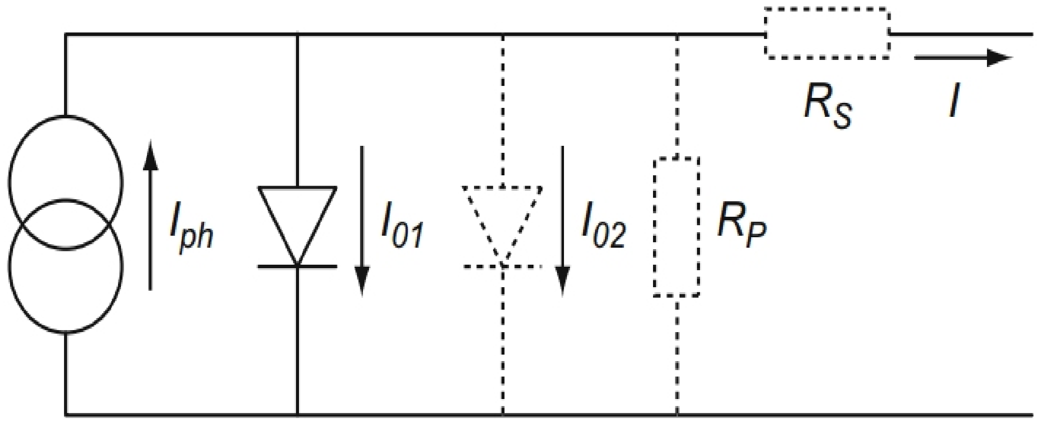

Fig 8 The model of the circuitry inside solar panels

2.3.3 Charge Regulator

In the solar energy system, the charge regulator is very important. The importance of the charge regulator is apparent in the following aspect; firstly, it can limit the rate at which electric current is added to or drawn from the battery, in addition, it helps prevent the battery from being overcharged. If the battery is overcharged, it will cause the battery's life to decrease very quickly; in this way, it will damage the battery.

Fig 9 Sun force 7A battery charge regulator

This charge regulator has the peak efficiency reaching around 98.3%. Inside the regulator, there are advanced electronic protections, without significant incurring losses. The Solar Charge Controller was connected as follows: positive (+) wire to the positive (+) battery terminal, then connect the Solar Charge Controller negative (-) wire to the negative (-) battery terminal. The charge controller will then be connected directly to the solar panel. The light indicator on the charge controller will appear green when the battery is fully charged and the charging light indicates when the battery is being charged.

2.3.4 Energy Storage Device (Battery)

The design team executed the need for energy storage by connecting the charge regulator to a battery. Using a battery for energy storage is a traditional method used to store a systems power generation, especially in a solar power system. The purpose for an energy storage device is to make sure that, even during non-ideal weather conditions; the energy that has been created can still be easily used. The Republic of Panama frequently has inclement weather, and if it is overcast, the sun will no longer be able to excite the solar panels to generate electricity; moreover, the output power of the solar panel is not a constant value (it changes throughout the day).

The design team chose the battery below to use in the final demonstration:

Fig 10 Battery: Everstart U1R-7 Lawn & Garden Battery -12V

This battery has proven to support the system. The system includes the load (fan) which drew 4 W, a 12V water pump which drew 25W, and four pressure regulator pumps which drew 6W. The solar panel itself can support the load, and in inclement weather the battery will be able to take over and power the system. Overall the system supported a load of about 35W.

Everstart U1R-7 Lawn & Garden Battery -12V	
Voltage	12 V
Chemistry	Lead Acid
Length	8.25 inches
Width	5.19 inches
Height	7.19 inches

Table 1 Specs of the Everstart Battery

2.3.5 Pasteurization

The pasteurization process is the process in which all bacteria is killed. The temperature for this to occur is 210^0 F. Upon exiting the pasteurization pipes in the system the water got up to a temperature of approximately 150^0 F. This failure can be fixed using a couple of different techniques.

Firstly, the pasteurization pipes can be placed closer to the sausage. By placing the tubes closer to the sausage the focal point of the parabola will become more precise. The pipes selected for this are only ½ inch pipes; therefore, the focal line should not be thicker than the pipes. Another possible solution would be to actually have the pipes placed along the inside of the pasteurization sausage. This possible solution would cause for extreme calculation, because more holes would have to be placed on the sausage.

Secondly, having solar panels sit directly on the heat exchanger. Due to a number of hiccups the design team was unable to get the correct solar cells. Custom solar cells and panels were used in the design; however, there was a heat sink attached to the back of the solar cells. The sink displaced heat and the exchanger (where the water was pumped through) displaced the remaining heat. By removing the sink the exchanger will be the only source for displacing the heat from the PV panels by direct conduction.

With the application of both of these corrections the temperature needed in the pasteurization process will be reached and possibly exceeded. Exceeding the desired temperature can be easily solved by increasing the mass flow rate of the system.

2.3.6 Heat Exchanger

The photovoltaic panel utilized our heat exchanger system that cooled down the surface temperature of the photovoltaic panel in order to increase the efficiency of the photovoltaic cells. The heat exchanger design uses the principal theories behind internal forced convection, where fluid in such applications is forced to flow by a fan or pump through a tube that is sufficiently long to accomplish the desired heat transfer.

The water will enter the system via a tank, the pump that was chosen will pull the water into the pipes. As the water flowed through the heat exchanger that was located on top of the photovoltaic panel, the fluid will collect some heat from the photovoltaic cells. This process keeps the panels operating at their desired temperatures which range from 25°C to 50°C. The convective heat transfer rate of the heater exchanger system is going to be highest at the entrance region. As the fluid flowed throughout the pipeline system the convective heat transfer rate went down. The water flowing out from the heat exchanger comes out at a temperature of 50°C. This prepared the water for pasteurization which occurred after the water flowed out of the heat exchanger. The design of the heat exchanger was chosen to be 6 identical 2x1 inch tubes of 1/8th inch thickness. The three tubes on the bottom heated up the water and the three on the bottom are for cooling the water down when the pasteurization process was complete. An example drawing for the heat exchanger can be seen in the figure below.

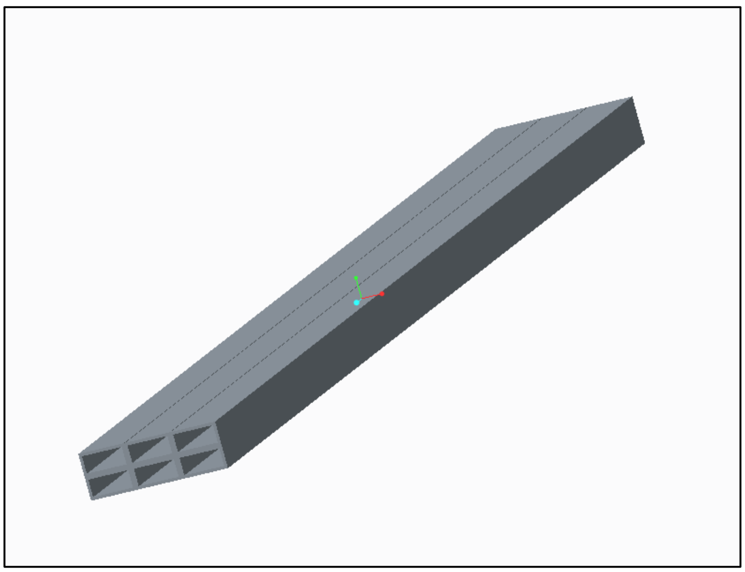

Figure 11: Heat Exchanger in Creo Parametric

The test plan portion of the heat exchanger describes in further detail why this design had some issues completing its tasks with the amount of pressure using in the experiment. Using a low pressure, under 10psi for pumping would be an ideal pressure range for this heat exchanger design.

2.3.8 Pressure Regulator

The pressure regulator was used to maintain the pressures inside the Solar Sausage. The Solar Sausage has a reflective film that separates the device into two pressure chambers, a high pressure chamber and a low pressure chamber. The chambers must always have a differential pressure of 0.005 psi. This differential pressure controlled the focal length of the solar sausage. The higher the differential pressure, the closer the focal length was to the solar sausage and the lower the differential pressure was the further away the focal length became. The pressure regulator made it possible to maintain the pressures near the desired pressures. The team slightly modified the current design of pressure regulators to regulate the pressure inside the solar sausage. The new pressure regulators were made from a polycarbonate material instead of wood. Polycarbonate has more strength compared to wood.

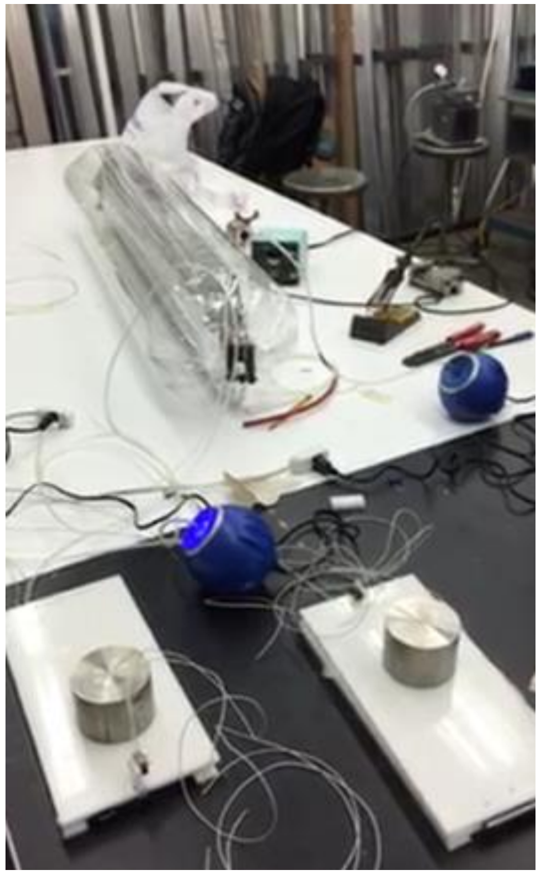

Figure 12 – Shows the pressure regulators connected to a solar sausage

This system of pressure regulators came with two micro-switches that controlled the pressure inside each half of the solar sausage. If the solar sausage had a deficiency in pressure, the micro-switch turned on allowing more air to be pumped into the solar sausage. The reverse occurred when the solar sausage was over pressurized. The regulators also come with an air bag that also helps track the levels of pressure inside the solar sausage. The air bag deflated when the pressure of the solar sausage was low and inflated when the pressures were high inside the solar sausage. The weights seen in figure 12 were used to monitor the differential pressure inside the solar sausage. Each weight weighed 0.5 lbs and by adjusting the position of the second weight we were able to achieve the desired pressures of the solar sausage.

3. Test Plans

3.1 Solar Panel Test

The following test will be carried out on the solar panel to ensure the load has a sufficient amount of power to operate correctly. Over or under powering can be detrimental to this load, and will only be magnified once this project is scaled up to full size.

Test Item: Solar Panel Power Output

Tester Name: Jonathan Melton, XiaoXiang Gao

Tester ID No: 0001

Test Date: 10/16/2014

Test No: 1

Test Time: 3:30 PM

Test Type: Test

Test Location: College of Engineering Parking Lot A

Test Result: Pass

Test Objective:

The objective of this test is to verify the power output of the solar panels will be sufficient to support the load.

Test Description/Requirements:

The equipment required for this test is the solar panel, a potentiometer, and a multi-meter. When measuring the solar panels voltage we will need to connect the solar panel to the potentiometer, and the multi-meter will be connected in parallel with the pot. Once the proper connection is in place then there will be a series of different resistances that will be used by the potentiometer in order to see the voltage across the pot at a desired resistance. The different voltages with corresponding resistances will be documented. Next we will connect the multi-meter in series with the pot; thus, gaining a reading of the current flowing through the pot using the same resistances that were used during the voltage tests. This will develop a nice I-V characteristic curve. The load that the solar panels will be powering will only use 12 volts and around 1 amp of current when running on high, and about ¾ of that when running on low. The max power output to run the fan will only need to be 12 Watts.

Anticipated Results:

The output of the solar panels be 20 Watts of power. The excess can be used for energy storage or powering a water pump if a different geographical location were to be selected.

Requirement for Success:

A power output of at least 14 Watts

Actual Results:

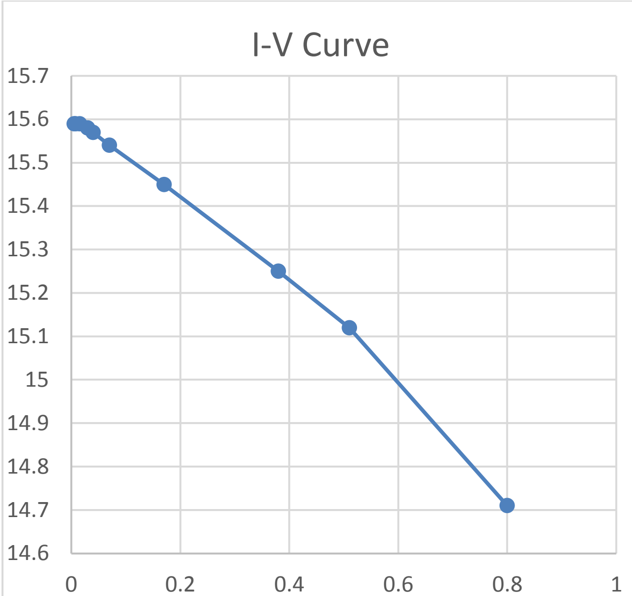

Fig 1 i-v charerstic curve from Preliminary Solar panel testing

Some pins have dedicated features assigned to them and cannot easily be configured as either input or output.

The solar panel had an output of well over the power needed to operate the load efficiently.
Reason for Failure:
N/A

Recommended Fix:
N/A

Other Comments:
These calculations were made relatively quickly and are not as accurate as the group would desire; however, a second round of testing will take place in the future.

3.1.1 Solar Panel Test 2

The following test was carried out on the solar panel to ensure the load had a sufficient amount of power to operate correctly during our final demonstration conditions.

Test Item: Solar Panel Power Output

Tester Name: Jonathan Melton

Tester ID No: 0001

Test Date: 4/14/2015

Test No: 2

Test Time: 10:30 AM

Test Type: Test

Test Location: ESC Lab FSU Main Campus

Test Result: Pass

Test Objective:
The objective of this test is to verify that the power output of the solar panels will be sufficient to support the load.

Test Description/Requirements:
The equipment required for this test is the solar panel, two multi-meters, and the load. When measuring the solar panels voltage we connected the solar panel to the multimeter, and the multi-meter will be connected in series with the second multimeter to find current. The readings will be seen in the viewing room of the Solar Simulator lab as the demonstration is taking place.

Anticipated Results:
The output of the solar panel is expected to provide about 20 Watts of power, and near 3A.

Requirement for Success:
A power output of at least 4 watts to power the load (12V DC fan)

Actual Results:
The solar panel read a voltage of about 13V and 0.83A. The current reading was much lower than expected.
.
Reason for Failure:
The failings in the current readings could have been in response to a bad multimeter, these low readings could have also occurred due to an error in breaking the circuit for the measurement.

Recommended Fix:
Re-wire the circuit to only include one multimeter which would read current, simplifying the devices in the circuit. Make sure the multi-meter is in series with the circuit and not in parallel.

Other Comments:

Elongating the demonstration time and increasing the heat will allow for higher readings.

3.2 Potable Water Test

The following test will be executed to ensure that the water coming out of the system is safe for human consumption. This is one of the major parts of this project; therefore, selecting the components to carry out this test will be selected very carefully.

Test Item: Water Sterilization

Tester Name: Jonathan Melton, XiaoXiang Gao — Tester ID No: 0002

Test Date: TBD — Test No: 1

Test Time: TBD — Test Type: Test

Test Location: TBD Test Result: N/A

Test Objective:
The objective of this test is to verify that the water is properly sterilized.

Test Description/Requirements:
The equipment required for this test is a water testing kit and the water being tested. The team will use pH strips to show that the water exiting the system is completely potable.

Anticipated Results:
Assuming that the heat exchanger brings the water to the correct high temperature, this test will be successful. In order for water to be sterilized it must reach a temperature point where all of the bacteria die, as long as our system reaches this temperature the water will be sterile.

Requirement for Success:
Potable drinking water.

Actual Results: TBD

Reason for Failure:
N/A

Recommended Fix:
N/A

Other Comments:
TBD

3.2.1 Potable Water Test 2

The following test was executed to ensure that the water coming out of the system is safe for human consumption. This was one of the major parts of this project; therefore, selecting the components to carry out this test was selected very carefully.
Test Item: Water Sterilization
Tester Name: Morgan Bublitz, Madanha Chibudu, James Harrell
Tester ID No: 0002
Test Date: 04/14/2015 Test No: 2
Test Time: 5:00 PM Test Type: Test
Test Location: ESC Solar Simulator Lab Test Result: Fail

Test Objective:
The objective of this test was to verify that the water is properly sterilized.

Test Description/Requirements:
The equipment used during this test was a setup of thermocouples and infrared heat gun. The team will run the experiment and record temperature data at select points along the water line.

Anticipated Results:
It was expected that with the proper focal length and precise differential pressure the receiver tube was going to reach a high enough temperature to bring the contained water up to boiling.

Requirement for Success:
Potable drinking water.

Actual Results:
Water was brought up to a temperature of 45 deg C for a brief amount of time before dropping.

Reason for Failure:
Focal length was not correct.

Recommended Fix:
Bring Solar Sausage closer to the receiver tube to maintain a sharper more precise focus.

Other Comments:
Consider filling water in system then turning off pump to bring water to temperature.

3.3 Heat Exchanger Test

Test Item: Heat Exchanger

Tester Name: Morgan Bublitz, James Harrell, Brian Chibudu

Tester ID No: 0003

Test Date: 2/23/15

Test No: 1

Test Time: 3:00 PM

Test Type: Calibration Test

Test Location: CAPS

Test Result: N/A

Test Objective:

The objective of this test is to verify the performance of the heat exchanger at varying heat loads and water flow rates.

Test Description/Requirements:

In order to administer such a test it would be necessary to have the PV panel and heat exchanger properly assembled. It would then be necessary to create a test environment where there are several high intensity lights that could be moved at fixed distances from the heat exchanger system. It would be beneficial to know the direct radiation being emitted on the heat exchanger so it would be convenient to measure this using a Pyrheliometer. From there the heat exchanger would have water flowing through it for 10-15 minutes or until a steady state has been reached. The inlet and outlet temperatures would be measured using thermistors located directly inside the flow. The flow rate would be measured using an inline flow meter. This procedure would be repeated for different light intensities along with different flow rates at each intensity.

Anticipated Results:

A calibration curve could be produced with the most heat transfer at different flow rates and intensities.

Requirement for Success:

Create a calibration curve showing the ideal flow rate versus light intensity.

Actual Results: N/A Reason for Failure: N/A Recommended Fix: N/A

Other Comments:

Test has yet to be done.

3.3.1 Heat Exchanger Test 2

Test Item: Heat Exchanger
Tester Name: Morgan Bublitz, James Harrell, Brian Chibudu
Tester ID No: 0003
Test Date: 2/23/15
Test No: 2
Test Time: 3:00 PM
Test Type: Calibration Test
Test Location: CAPS
Test Result: Pass

Test Objective:
The objective of this test is to verify the performance of the heat exchanger at varying heat loads and water flow rates.

Test Description/Requirements:
In order to administer such a test we had the PV panel and heat exchanger properly assembled. It was necessary to create a test environment where there were several high intensity lights that could be moved at fixed distances from the heat exchanger system. It would be beneficial to know the direct radiation being emitted on the heat exchanger so it would be convenient to measure this using a Pyrheliometer. From there the heat exchanger would have water flowing through it for 10-15 minutes or until a steady state has been reached. The inlet and outlet temperatures would be measured using thermistors located directly inside the flow. The flow rate would be measured

using an inline flow meter. This procedure would be repeated for different light intensities along with different flow rates at each intensity.

Anticipated Results:

A calibration curve could be produced with the most heat transfer at different flow rates and intensities.

Requirement for Success:

Create a calibration curve showing the ideal flow rate versus light intensity.

Actual Results:

The water that was used to during the test, successfully flowed throughout the heat exchanger. The heat exchanger was able to reach a flow rate of 0.08 gallons per min. This flow rate was enough to cool the water to its required temperature.

Reason for Failure:

During the course of testing the heating exchanger, a couple of problems came along such as linkage in the piping system and failure of the heat exchanger caps.

Recommended Fix:

The failure of the piping system resulted from lose hose clamps. This problem was solved by tightening the hose clamps. The failure problem of the caps was resolved by closing all the channels that experienced this problem.

3.4 Pressure Regulator Test

Test Item: Pressure Regulator

Tester Name: Morgan Bublitz, James Harrell, Brian Chibudu

Tester ID No: 0004

Test Date: 2/27/15

Test No: 1

Test Time: 2:00 PM

Test Type: Performance Test

Test Location: Keen Lab

Test Result: N/A

Test Objective:

The objective of this test is to verify the performance of the pressure regulator in regards to its capability of inflating, deflating, and maintaining proper pressure levels.

Test Description/Requirements:

1. Microcontroller Switch
2. No air leakages should be present when performing the test.

Process:

The first step of the testing is to check if the pressure regulator can maintain pressure at the desired output. The solar sausage is going to be heated to a point where the pressure is over the desired pressure. The top microcontroller switch should sense the increase in pressure and begin the process of deflating the solar sausage to the desired pressure. The solar sausage is also going to be cooled down to pressures below the desired pressure. When this occurs the bottom microcontroller switch should sense the decrease in pressure and begin the process of inflating the solar sausage to the desired pressure.

Anticipated Results:

The pressure regulator should be able to maintain a pressure of 0.500 psi for the top hemisphere of the solar sausage and 0.495 psi for the bottom hemisphere of the solar sausage. Both microcontroller switches should be able to sense any changes in pressure.

Requirement for Success:

Solar sausage should be able to maintain the desired pressure at all times.

Actual Results: N/A Reason for Failure: N/A Recommended Fix: N/A

Other Comments:

Test has yet to be done.

3.4.1 Pressure Regulator Test 2

Test Item: Pressure Regulator

Tester Name: Morgan Bublitz, James Harrell, Brian Chibudu

Tester ID No: 0004

Test Date: 4/14/2015 Test No: 2

Test Time: 2:00 PM Test Type: Performance Test

Test Location: ESC Solar Simulator Lab Test Result: Pass

Test Objective:

The objective of this test was to verify the performance of the pressure regulator in regards to its capability of inflating and maintaining proper pressure levels.

Test Description/Requirements:

3. Microcontroller Switch
4. No air leakages should be present when performing the test.

Process:

The first step of the test was to calibrate the pressure sensor to the correct pressure level. Once the pressure was found, the proper pressure differential had to be attained. Once at this state, the system was left alone and monitored. Once the pressure drops to the specified level the micro switch is to turn on the pump. Once the pump brings the sausage up to the desired pressure it should turn off the pump. This test was repeated several times to ensure success.

Anticipated Results:

The pressure regulator should be able to maintain a pressure of 0.250 psi for the top hemisphere of the solar sausage and 0.245 psi for the bottom hemisphere of the solar sausage. Both microcontroller switches should be able to sense any changes in pressure.

Requirement for Success:

Solar sausage should be able to maintain the desired pressure at all times.

Actual Results:

The pressure regulator did turn on at around 0.225 psi and turned off at 0.250 psi for the top and a 0.005 psi decrease for both values on the bottom.

Reason for Failure: N/A

Recommended Fix: N/A

Other Comments: N/A

3.5 System Integration Test

This test will check to ensure that the full system is integrated and all components are functioning properly. Refer to the test plans above to see what each component needs to ensure proper functionality. This test will be carried out only once each component has passed its individual test.

Test Item: Complete System
Tester Name: Jonathan Melton, XiaoXiang Gao, James Harrell
Tester ID No: 0010
Test Date: TBD
Test Time: TBD
Test Location: TBD
Test No: 1
Test Type: Test
Test Result: TBD

Test Objective:
The objective of this test is to verify the system is operating properly with all working components connected.

Test Description/Requirements:
The equipment required for this test will just be the water testing kit and a thermometer. The load will test the power output, and the water testing kit will test the water at the end. The thermometer will be there to ensure that the water at the end of the system has cooled down to room temperature.

Anticipated Results:
Perfectly harmonized system!

Requirement for Success:
Operational load and drinkable water.

Actual Results:
TBD
Reason for Failure:
N/A

Recommended Fix:
N/A

Other Comments:
TBD

3.5.1 System Integration Test 2

This test checked to ensure that the full system was integrated and all components were functioning properly. Refer to the test plans above to see what each component needed to ensure proper functionality. This test was only carried out only once each component passed its individual test.

Test Item: Complete System
Tester Name: Jonathan Melton, XiaoXiang Gao, James Harrell
Tester ID No: 0010
Test Date: 4/14/2015 Test No: 2
Test Time: 10:30am Test Type: Test
Test Location: ESC Building Main Campus Test Result: Failed on certain parts

Test Objective:
The objective of this test is to verify the system is operating properly with all working components connected.

Test Description/Requirements:
The load tested the power output, and the water testing kit will test the water at the end. The thermometer will be there to ensure that the water at the end of the system has cooled down to room temperature.

Anticipated Results:
Perfectly harmonized system!

Requirement for Success:
Operational load and drinkable water.

Actual Results:
The system was able to generate an operational load of 40 Watts. This was sufficient for us to operate the pump, fan, and pressure pumps. The water was able to reach temperatures around

150 degrees Fahrenheit but unfortunately it did not reach high enough temperatures to be pasteurized.

Reason for Failure:
The focus was not fine enough and the focal length was not of the correct length.

Recommended Fix:
Moving the sausage closer would help create more heat per unit area.

4. Recommendations for the Future

The design team hopes that this project continues after this year, if so, there are certain aspects of the project that could be made more efficient to yield a better result. Some of the changes that should be made are listed below:

- Buy or build custom PV panels that will fit directly on the heat exchanger
- Depending on final load, use at least two PV panels to achieve power output
- Modify Heat Exchanger
  - Weld better manifold caps
- Modify Pressure Regulator to be more precise
  - Use micro-switches with better tolerance
  - Possibly include microcontroller and digital pressure gauges
- Implement automatic tracking system
- Implement smart flow system for optimal heating

5. Risk Assessment

The overall risk assessment analyzes the overall functionality of the system design. Pertaining to the sola sausage we have to factor in the electrical components and water which an important factor in the risk of electrocution. It would be unrealistic to think that the design team's project proposal can be completed without any possibility of risk. Many factors can risk the quality of the system's output. Risks can include the following:

- Technical Risks
  - Electrocution – exposure of the wires to nearby water
    - Probability:
      - Medium
    - Consequences: Severe or Catastrophic
      - Injury or death
    - Strategy:
      - To make sure there are no exposed wires throughout the system and that every component meets IEEE standards
  - Battery Life
    - Probability:
      - Low

        - Consequences
            - Moderate
        - Strategy:
            - To refine the use of our energy storage techniques.

- Schedule Risks
    - Optimistic Scheduling
        - Probability: Moderate
            - At the beginning of the project the design team was carefully warned by Dr. Frank that the projects will have hiccups and bumps along the way. The anticipation of something failing or going wrong was taken into consideration; however, with that being said, no one can predict the future and there is always the probability of some unforeseen extenuating circumstance that could arise.
        - Consequences: Severe
            - The consequences of optimistic scheduling have the potential to be catastrophic. This could cause a huge amount of time to be consumed on the realistic circumstance. This would delay the entire project and could cause an extreme delay in progress. If delayed long enough it could cause the design team to not be able to graduate.
        - Strategy
            - The group has designed a flexible schedule that has lighter workloads in some weeks than others. If there is an obstacle that presents itself to be great, then the group can simply push other dates back to fill the easier weeks with tasks.
    - Change of Delivery Date
        - Probability: Low
            - The delivery date is set in stone. The conclusion of the semester is already known; therefore, the final product has to be submitted before that date. Moving it up may be proposed; however, the schedule has been set to have the project completed a couple of weeks prior to the conclusion of the semester anyway. This can be compensated by the risk listed above.
        - Consequences: High
            - If the delivery date is changed then the consequences then the consequences could play out to be relatively high. This would cause a rift in the entire schedule if the date is moved too far back.
        - Strategy
            - The delivery date has been set according the conclusion of the spring 2015 academic semester. This date has been set by Florida A&M University and Florida State University. These dates will not change.
    - Excessive Scheduling of events
        - Probability: High

        - This project has already been declared as extremely difficult, and major aspects of the project have been cut out due to the difficulty. All of the foreseen aspects of this project have already been proven difficult; therefore, excessively scheduling events is easy to do. All the members of the project have ideas that go into the scheduling, and certain people get weighed down with extreme amounts of work that is not possible to complete.
    - Consequences: Moderate
        - The consequence of this would be a loss of time that could be spent on doing more relevant and attainable things. This could be compensated by the lack of optimism in the schedule already; however, some things could take too much time.
    - Strategy
        - The group has designed a flexible schedule that has lighter workloads in some weeks than others. If there is an obstacle that presents itself to be great, then the group can simply push other dates back to fill the easier weeks with tasks.
- Omissions
    - Probability: Low
        - This risk has a very low probability of coming true. Dr. Frank ensured that each team went through and made sure their schedule would compensate for things like the risks mentioned above. The plan was carefully thought out and discussed amongst the entire group.
    - Consequences: Low
        - This risk would have low impact on the overall schedule, because like mentioned above we have scheduled time for any setbacks.
    - Strategy
        - Conversing with Dr. Ian Winger helped clear up any omissions. Winger helped clarify what he expects, and what he wants improved. He informed the group of things that would be a waste of time, and things that the group was forgetting and should consider.
- Delay in tasks
    - Probability: Moderate
        - Majority of the components used on the Solar Sausage are custom made; therefore, the group will have to go through him to recreate the things needed to complete the project. There is very little room for error with some of these things, so some tasks can be delayed.
    - Consequences: Low
        - Consequences could prolong the completion but not by much if any at all. For example, the solar panels are custom designed solar panels in which need to be recreated. If some unforeseen complication happens then it would cause an extra day or two to be needed to complete the task.
    - Strategy

      - Dr. Winger will be assisting the team in building all of the necessary components. This will help keep the team on track and ensure that everything is being built the correct way.
  - Project is more complex than anticipated
    - Probability: High
      - Complications has already been made aware to the group. Quite a bit of the complications have been cut from the project; however, some complications have not been, and the schedule may need to be altered a little to compensate for these complications.
    - Consequences: Moderate
      - Since some of these complications have been cut and others have been revealed to the group the extra time gained from cutting certain parts out of the project can be used to work harder on the more complex parts.
    - Strategy
      - Working closely with Dr. Edrington and Dr. Ordonez will help discover any major complications that would extend outside the scope of the project, or anything that may require more time.

- Budget Risks
  - Insufficient Funding
    - Probability: Low
      - The probability is low because most of our materials are being donated directly from Dr. Winger. He informed the group that they will have more than enough materials to run all types of testing, and prototyping.
    - Consequences: High
      - Although the probability of insufficient funding is low the consequences are high. If the sponsor decides not to come out of pocket with any more money, then the project will die. Thus causing all other risks to come true and the project will not be completed and the team will not graduate.
    - Strategy
      - To assist in overspending all purchases will be discussed by the entire team; once an agreement is reached, the team will take the purchase to Dr. Winger and ensure that it is necessary for the project. Also a business student will be added to the team in the spring semester to Summary of Risk Status

6. Schedule – Gantt Chart

	Milestone #1	7 days	Wed 9/10/14	Thu 9/18/14
	Milestone #2	13 days	Wed 10/1/14	Fri 10/17/14
	Milestone #3	11 days	Thu 10/30/14	Thu 11/13/14
	Build First Sausage	4 days	Tue 9/9/14	Fri 9/12/14
	Research and Design for System	148 days	Wed 10/1/14	Fri 4/24/15
	Heat Exchange Testing	**63 days**	**Mon 11/17/14**	**Wed 2/11/15**
	Design model			
	Calc. temp. to cool PV panels			
	Testing: Make sure system cools effectively			
	Power Analysis	**36 days**	**Wed 11/26/14**	**Wed 1/14/15**
	Total output measurement	5 days	Wed 11/26/14	Tue 12/2/14
	Energy Storage	11 days	Tue 12/2/14	Tue 12/16/14
	Design DC-AC conversion	20 days	Thu 12/18/14	Wed 1/14/15
	Pressure Regulator Implementation	**40 days**	**Fri 11/28/14**	**Thu 1/22/15**
	Calculate psi for each chamber	3 days	Fri 11/28/14	Tue 12/2/14
	Design a device to read pressure	32 days	Tue 12/2/14	Wed 1/14/15
	Test system at calculated pressures	5 days	Wed 1/14/15	Tue 1/20/15
	Filter/ Pasteurization	**27 days**	**Mon 3/16/15**	**Tue 4/21/15**
	Design process for pasteurization			
	Test temperatures the process takes place			
	Determine duration of pasteurization			
	Water Pump	**18 days**	**Tue 3/10/15**	**Thu 4/2/15**
	Decide on location of water (well, surface, etc.)	2 days	Tue 3/10/15	Wed 3/11/15
	Design pump to effectively bring water to system	16 days	Thu 3/12/15	Thu 4/2/15

7. Budget

Expenses			
Item	**Quantity**	**Cost**	**Total**
Water Pump	1	$102.00	$102.00
Aerator Pump	4	$8.00	$32.00
7A Charge Regulator	1	$35.00	$35.00
12V Battery	1	$38.00	$38.00
DC Fan	1	$15.00	$15.00
ME- Materials	1	$982.00	$982.00
ME- Materials	1	$1,300.00	$1,300.00
	Expense Total		**$2,504.00**

8. Conclusion

The boundary conditions chosen for this project was a typical four person home in Uganda. This home on average would consume 576 Whr of energy per day. This home would also typically use 47 gallons of water per day. The system used for this Ugandan family would contain two solar sausages, one for electricity generation and one for potable water production. With this setup there would be a gross energy production of 960 Whr. The Energy used by the air and water pumps throughout the day to run the air constantly and to run the water pump to generate 50 gallons of water would consume 268 Whr. This would leave a net energy of 692 Whr which would be sufficient for a typical family of four in Uganda to power their home appliances for the day. This shows that the design team's project, as is, could support a family in Uganda. Given this information, if this system was scaled up this design could support a much larger load.

This document shows the final updates that the design team chose to perfect the Solar Sausage system infrastructure. The team put into action many of the thoughts shared to them via the faculty advisors. The system produced proved to be a more reasonable and efficient design than that which the team members created at the beginning of the project. This report will verify that the Solar Sausage team has successfully designed a working prototype of a solar sausage system. The failures that occurred throughout the testing process are easy to overcome, recommendations for these changes should help the team that follows perfect this system. This project is great for society as a whole, producing cheap electricity and potable water; the design team is looking forward to what will come of their results. Many aspects of engineering were instrumental in the completion of this project, from thermodynamics to building mechanical structures and setting up an electrically sound power system. A well rounded experience was definitely met while completing this Solar Sausage design process. The team believes that this project should be continued, the concept is very inspirational and has the ability to be the next big thing in solar energy if the system is perfected to optimal efficiency.

9. References

1. “Everstart U1R-7 Lawn and Gardeb Battery.” *Web. 16 Apr, 2015.* < http://www.walmart.com/ip/EverStart-U1R-7-Lawn-Garden-Battery/16795214>
2. “7 Amp Solar Charge Controller User’s Manual.” Web. 12 Apr, 2015. < http://lib.store.yahoo.net/lib/theshorelinemarket/60012-Manual.pdf>