Operation Manual

Team 7

Solar Sausage for Desalination

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April 3rd, 2015

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ABSTRACT

Much of the world lacks access to clean, drinking water. This system utilizes the Solar Sausage to desalinate saline water. The Solar Sausage concentrates light onto the trough, providing a less expensive alternative to a parabolic concentrator. This heats the trough and thus heats the water inside of it. By evaporating the saline water and then collecting and condensing the vapor, this system is able to produce clean drinking water for the consumer in need. Assembling the system should take about 40 minutes and consists of inflating the solar sausage, bolting the parts together, and then staking the stands level into the ground. Maintenance focuses on pressure, water, and sun-tracking regulation. Deconstruction is possible with foresight of inclement weather. Spare parts are listed and are sent with the total package.

ACKNOWLEDMENTS

The group would like to thank Dr. Shih and Dr. Gupta for the direction and guidance throughout the project. Thank you to Dr. Devine for the well-timed feedback following meetings and presentations as well as marketing advice for our entrepreneurial project. Also, a special thanks to Dr. Lin for his valuable input and assistance with each aspect of the project. Finally, the group would like to thank Ian Winger for assisting in the construction of the Solar Sausage as well as supplying the materials for it.

1. Functional Analysis/ Functional Diagram

This project is a low-tech and low-cost desalination system that can be easily deployed to third world regions. The system utilizes an inflatable parabolic reflector called the Solar Sausage, patent held by Florida State University, which concentrate the necessary solar radiation to desalinate the water. The system requires minimal training and has a long lifetime as a result of its simplistic design.

The system desalinates the water through a process called batch distillation. Batch distillation is the process where a still or in this case a trough is filled with a mixture and heated. The mixture evaporates turning the desired component into vapor separating it from the undesired component. The vapor is collected in a condenser on top then it is accumulated in a receiver [1].

Once assembly of the system is complete, one individual will be required to operate the system. This individual will monitor the system throughout the day and make necessary adjustments to ensure its operating in accordance with the direction. It's understood that the regions this system is being deployed in will have the required labor needed to maintain operations throughout the day on a continuous basis.

1.1 Functional Diagram

There are two subsystems within the desalination system, the solar concentration system (displayed in Orange in Figure 1), the distiller (displayed in green in Figure 1). The solar concentration system delivers heat to the distiller, supplying the necessary energy for distillation. The operator is responsible for supplying the system with air and saline water; these inputs are displayed in blue (Figure 1).

First, the operator fills the storage tank with saline water allowing it to filter out large particles and debris. The trough is the filled with the filtered water (Figure 1). Once the trough is filled, the operator uses the pressure regulation system to inflate the Solar Sausage with air. The operator will check the position and width of the focal point. These system checks are displayed in yellow (Figure 1). The operator will take the necessary action to ensure the width and position of the focal point are correct or wait a specified time before making the system checks again.

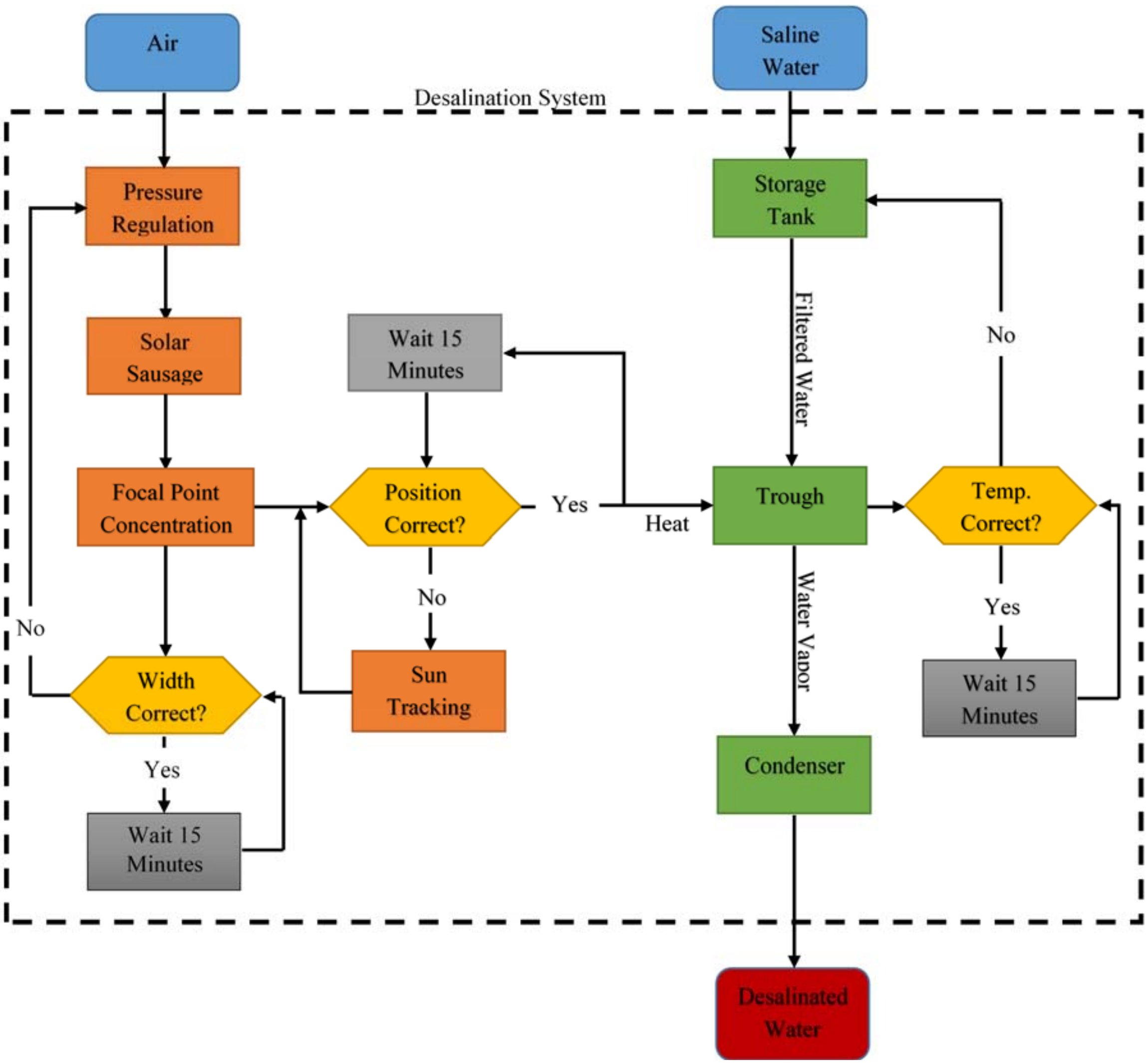

Figure 1: Functional diagram of the desalination system. The system inputs are blue and the output is red. Within the dashed box are the components, system flow and system checks of the desalination system. There are two subsystems within the system, the solar concentrator shown in orange and the distiller shown in green.

Once the focal point is the correct width and positioned on the trough, heat is then delivered to the trough. This will heat the saline water leading to evaporation, and the water vapor will rise into the condenser (Figure 1). During the evaporation process the operator will, while performing his other system checks, check that the temperature in the trough does not become too high. If the temperature is too high the operator will take corrective action or wait a given time before performing the system check again. While the operator regulates the temperature to maximize condensation, the water vapor condenses and exits the system as desalinated water, shown in red (Figure 1).

2. Project/Product Specification

The objective was to create a desalination system capable of supporting a family of four to five people at minimum cost and is easily transportable. The system was constructed of Al6061 T6, it's low cost and lightweight meeting two of our desired objectives. To support a family of four to five, the minimum production capacity of the system is 3 $gallons$. The produce this amount of water the system constructed has length of 122.5 in, height of about 67.5 in and width of 36 in (Figure 2).

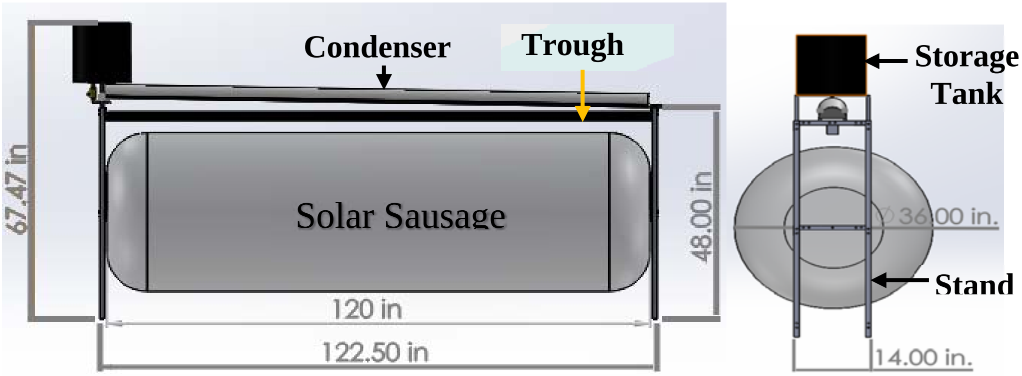

Figure 2: Master Assembly of the Desalination System showing crucial components and dimensions. Left, side view of the system. Right, cross-sectional view of the system.

2.1 Solar Sausage

The Solar Sausage concentrates incoming solar radiation and focuses it into a single point 3/8th inch wide called the focal point. In laboratory settings, the focal point has reached a temperature of 752°F [2]. The Solar Sausage has a length of 120 in and diameter of 36 in giving a total reflective surface area of 4080 in^2 (Figure 2).

2.2 Storage Tank

The storage tank has a capacity of 5 $gallons$ and is black to maximize heat absorption from the sun (Figure 2). The upper section of the storage tank has a felt filter that removes particles larger than 100 $microns$. A manual .5 in ball valve controls the flow of saline water into the trough.

2.3 Trough and Condenser

Like the solar sausage, the trough and condenser have a length of 120 in. The condenser sets directly above the trough to easily collect the water vapor.

2.3.1 Trough

The trough is constructed of a $2\ in\ by\ 2\ in$ aluminum channel and has a wall thickness of $.125\ in$. Accounting for wall thickness the trough is capable of holding 1.5 $gallons$ of water.

2.3.2 Condenser

The condenser has a width of $5\ inches$ and a radius of 2.5 $inches$. The condensing dome has a length of $120\ inches$ giving a total surface area of $960\ in^2$. The end of the channels that extend $4\ inches$ past the collection dome will have $1/4\ in$ diameter holes bored in them where the desalinated water will be collected. The end of the condenser by the storage tank is raised two inches to create a sufficient gradient to drive the water to the holes for collection (Figure 2).

3. Project Assembly

The solar sausage, trough, and condenser will arrive constructed. The stand must first be constructed followed by the storage tank. The components are constructed and secured together with $^{3}/_{8}$ $inch$ hex bolts and nuts.

3.1 Stand

The stand, comprised of two legs and two crossbars, is 4 feet (48 inches) tall and 14 inches wide. The legs and crossbars are constructed of 1 inch square aluminum tubing. The legs and cross bars are aligned to with L-plates and bolts. Two stands will have to be constructed.

3.1.1 Stand Construction

First, align the upper and lower cross bars between the two legs (Figure 3). The lower cross bar has one hole in the center. The holes must be parallel to the legs in order to connect.

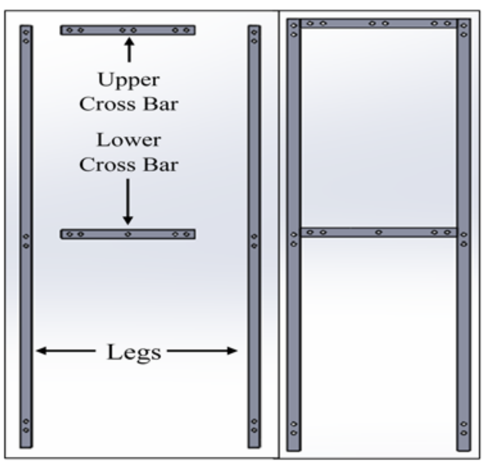

Figure 3: Leg and Cross bar alignment. Right, the four components and their placement. Left, the components alignment.

After the legs and cross bar are aligned, use the L-plates to square them. Once they are square bolt them together (Figure 4). This needs to be done at all four places the legs and cross bars meet, this completes construction of the stand. Before bolting together the stands with the pressure gauges, storage tank platform needs to be bolted into top of legs (Figure 5). This is further discussed in Section 3.2.

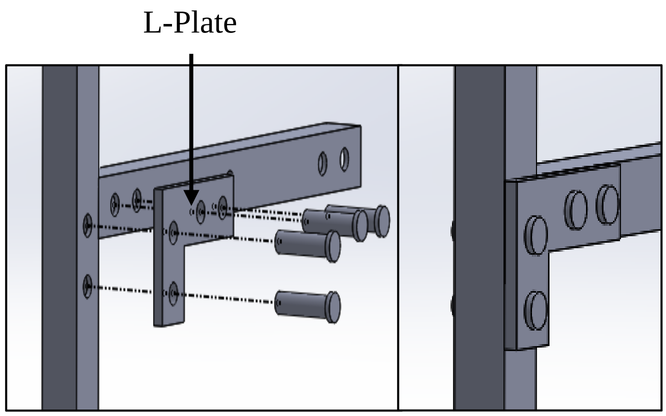

Figure 4: The L-plate is used to square the legs and cross bars, then bolted together. Left, shows the alignment of the L-plate and bolts. Right, shows the legs and cross bars bolted together.

3.2 Storage Tank

The storage tank has three components: the bucket, the storage tank platform and the ball valve (Figure 5). First, the storage tank platform legs must be inserted into the top of the legs while maintaining the holes' alignment (Figure 5). Use the L-plates to bolt the platform in place followed by the upper cross bar, completing construction of the stand.

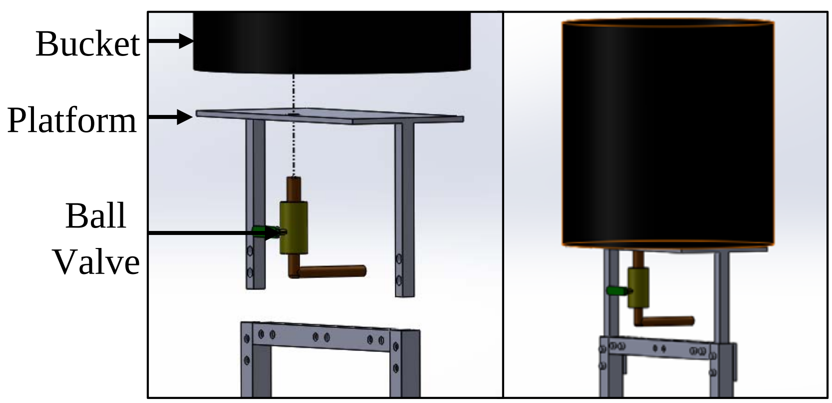

Figure 5: Assembly of the storage tank. Left, shows the alignment of the components. Right, shows the assembly of the storage tank

With the platform in place, set the bucket on the storage tank being sure to align the hole in the bucket and platform. Once aligned fit the male piece of the ball valve with an O-ring, and insert through the bottom of the platform and the storage tank. On the inside of the bucket, fit the male piece with another O-ring and secure with a compression. This secures the bucket to the platform completing construction of the storage tank.

3.3 Trough and Condenser

The trough and condenser come assembled and constructed. The trough only needs to be bolted to the stands, and the condenser should be set on top of the stand.

3.3.1 Trough

The trough will be installed after the stands and storage tank have been constructed. The trough attaches at each end to the upper cross bar of the stand (Figure 6). Each end of the through has two holes so that it can be bolted to the upper cross bar. Be sure the circle hook of the lower cross bar is on the same side the through is connected to.

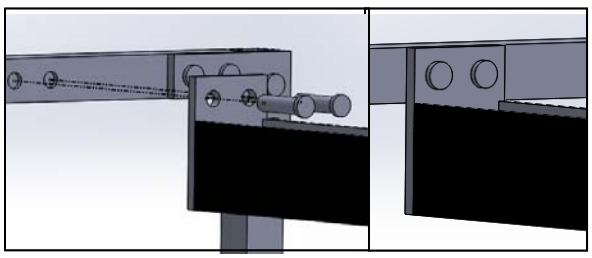

Figure 6: Trough is bolted to the upper cross bar and the end of each stand. Left, shows the alignment. Right, shows the assembled view

3.3.2 Condenser

Once the through is attached, the condenser can now be placed on the stand. The condenser sets on top of the stand (Figure 7). The end with the risers sits on the side with the storage tank.

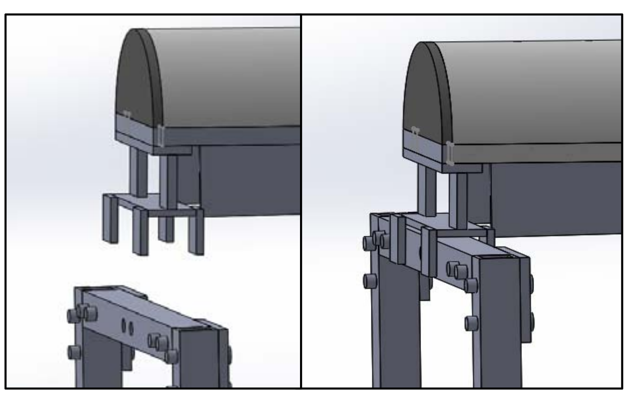

Figure 7: Condenser set on the stand. Left, show the components. Right, shows how the condenser sets on the stand

3.4 Solar Sausage

The Solar Sausage attaches to the lower cross bar between the two stands. Each lower cross bar has a circle hook facing the inside. The ends of the Solar Sausage have loops made of $1/8\ in$ wire rope that simply slip over the circle hook to attach the Solar Sausage.

3.4.1 Sun Tracking

The sun tracking system is easy to attach to the Solar Sausage. The sun tracking bar will be placed underneath the Solar Sausage with the closed eye bolts shut. The operator will the attach one of the slide-bolts to the closed eye bolt. Once attached the operator will run the wire underneath and across the Solar Sausage and clip the slide-bolt to the tie down on the Solar Sausage. This step will be repeated for the second wire but on the other side of the sun tracking bar (Figure 8).

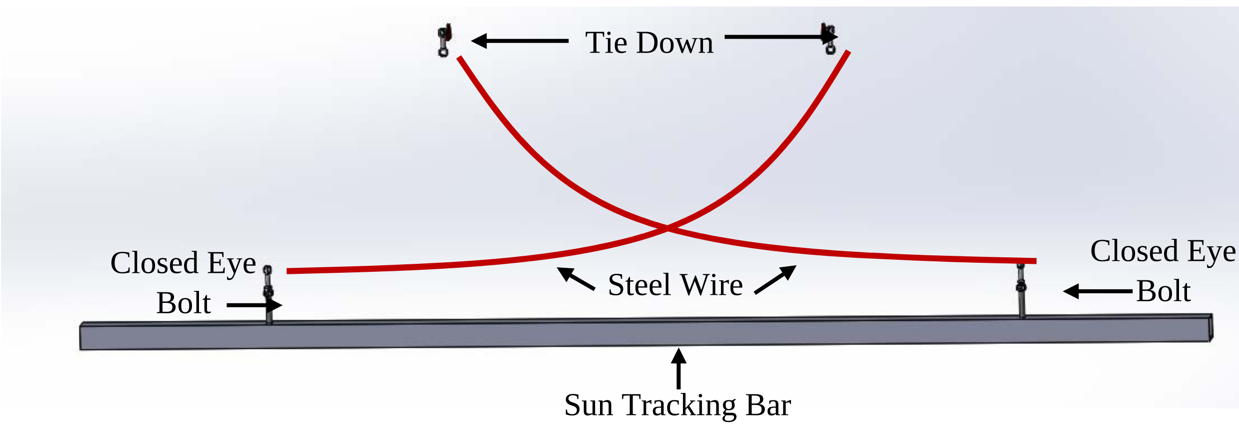

Figure 8: Sun Tracking System. The steel wires have slide-bolts at each end. One end attaches to the closed eye bolt. The wire is then run underneath and across the Solar Sausage. The the slide-bolt on the other end is attached to the tie down glued to the Solar Sausage.

4. Operation Instruction

Once the system is assembled using the project assembly above, the operation may begin. Attach the Solar Sausage to the lower crossbar hooks. The first step of the operation is pressure regulation. This will be done by filling the top chamber to 1.0 psi using the foot pump and reading the corresponding pressure gauge. The bottom chamber will be filled to 0.5 psi as well, making sure the focal point width that is less than the width of the trough. The finer the focal point, the quicker the evaporation will occur. Adjust the pressure in the two chambers to adjust the focal point to the desired setting. The more pressure existing in the top, the more concave the reflective membrane and thus the lower the focal point will be.

The sun-tracking system ensures the alignment of the focal point with the bottom of the trough. During routine check-ups, the bar should be moved in the opposite of the focal point direction.

The saline water regulation is the final operational aspect of the system. The storage tank should be filled with 3 gallons of saline water. Then, open the valve to release water into the trough. The valve should be closed once the trough is filled with about one inch of water. More detailed operation instructions are available in Appendix B.

5. Trouble Shooting

Troubleshooting is vital to the progress of the design. The group has made theoretical calculations in order to get an idea of how the system will perform. It can be expected that many of these values will vary slightly when the actual testing occurs due to human error, variations in nature, and other factors. Troubleshooting will allow the group to make changes based on how the actual Solar Sausage performs to maximize the end result.

Maintaining the focal point is critical in starting the process of the system. Pressure regulation between the upper and lower chambers will determine the width of the focal point, which should remain as fine as possible and less than the width of the bottom of the trough. This is done using the foot pumps and pressure gauges. Constant maintenance will be required in order to achieve this.

The most significant factor to the system is the condensation rate. This can be improved by using the reflective material to prevent the sun from heating the upper side of the condenser. Pouring cold saline water over the condenser's top side will also assist in this process. If the evaporation rate far exceeds the condensation rate, the focal point can be widened in order to reduce heat input.

These are the most significant concerns in the process, but all others can be found in the Failure Modes Effects Analysis (FMEA) in Appendix A.

6. Regular Maintenance

The system requires maintenance in order to stay safe, efficient and to avoid future discrepancies. Local residents will be in charge of maintenance on daily and weekly bases. Instructions for how to maintain the system will be provided in the instruction manual.

6.1 Daily Maintenance

Daily maintenance routines will be necessary to ensure cleanliness and functionality of the system. The trough will collect saline and must be cleaned daily in addition to the condenser to avoid any type of buildup. The Solar Sausage should also be checked thoroughly for any tearing or potential future issues. Any minor implications on the system should be noted and taken into consideration to avoid future complication. Maintenance is required throughout the day in order to maximize heat input and optimize the desalinated water collection. The solar sausage will need to be turned throughout the day to line up the reflective membrane with the sun as the sun moves, maximizing the amount of solar insulation captured by the system.

6.2 Weekly Maintenance

There will be weekly maintenance requirements for the Solar Sausage system. There is a filter located on the system that will collect all of the dirt and debris in order to provide complete decontamination. This filter will need to be rinsed at least once a week in order to properly filter the water. The storage tank that collects the desalinated water will also need to be cleaned on weekly basis to ensure sanitation. It is important that all the connections on the pressure regulation system are tightened to minimize heat loss. The desalinated water piping system should also be cleaned of all build up to avoid further contamination.

The residents should be properly instructed on how to maintain this solar desalination system before they begin the process. Sufficient maintenance will improve cleanliness and efficiency of the system and will help to avoid many of the complications that could occur.

7. Spare Parts

Each Solar Sausage for Desalination system is comprised of many individual components. Each component requires specific materials in order to be assembled and function properly. The items included in each package will contain one solar sausage in addition to items for the trough, condenser, storage tank, saline piping system, spikes, pressure regulation, construction, and maintenance. A detailed list of what is included in one package can be seen below in Table 1.

Table 1: Parts list and the additional parts

Item	Component	Quantity	Additional
Solar Sausage	Solar Sausage	1	
Mallet	Construction	1	
Socket Head Cap Screws	Construction	36	5
Allen Key	Construction	1	1
Zinc Aluminum Coated Steel Hex Nut	Construction	36	5
High-Temperature Paint, Aerosol	Trough	1	
Stainless Steel Coating	Trough/Condenser	2	
Aluminum Channel	Condenser	3	
UN-Compliant Plastic Shipping Pail (5 Gallons)	Storage Tank	1	
NSF-Certified Brass Ball Valve	Saline Piping System	1	
Copper Pipe (1/2”)	Saline Piping System	1	
Copper Male Adapter (1/2”)	Saline Piping System	1	
Brass Pipe Nipple (1/2”)	Saline Piping System	1	
O-Ring	Saline Piping System	2	2
90 Degree Elbow (1/2”)	Saline Piping System	1	
Flare Nut (5/8”)	Saline Piping System	1	
Aluminum Square Bar 6061	Storage Tank Platform	2	
Aluminum Plate 6061	Spike (4) & Storage Tank Platform (1)	5	
Aluminum Round bar 6061	Spike	4	
Needle Valve	Pressure Regulation	2	
Wilmar Foot Pump	Pressure Regulation	2	

References

[1] Engel, Yunus A. *Fundamentals of Thermal-fluid Sciences*. 4th ed. Singapore: McGrawHill, 2012. Print.

[2] Group Seven, Ian . Personal interview. 8 Sept. 2014. FAMU-FSU College Of Engineering Building A Atrium.

Appendix A Failure Modes Effects Analysis

Team #:	TEAM 07
Project Title	Solar Sausage for Water Desalination

Key Process Step or Input	Potential Failure Mode	Potential Failure Effects	SEV	Potential Causes	OCC	Current Controls	DET	RPN	Actions Recommended	Resp.	Actions Taken	SEV	OCC	DET	RPN
What is the Process Step or Input?	In what ways can the Process Step or Input fail?	What is the impact on the Key Output Variables once it fails (customer or internal requirements)?	How **Severe** is the effect to the customer?	What causes the Key Input to go wrong?	How **often** does cause or FM **occur**?	What are the existing **controls** and procedures that prevent either the Cause or the Failure Mode?	How well can you **detect** the Cause or the Failure Mode?		What are the actions for reducing the occurrence of the cause, or improving detection?	Who is Responsible for the recommended action?	Note the actions taken. Include dates of completion.				
Storage Tank holds, partially filters, and preheats saline water	Leak causes saline water to leak out of storage tank	Water doesn't reach trough and entire process is stopped	6	Poor valve sealing	1	Good valve seal	2	**12**	O-rings inserted for proper seal between valve and bucket	Operator	O-rings inserted	6	1	2	**12**
	Filter doesn't take out large salt particles	Large salt particles remain in water	2	Poor filter manufacturing, bad placement of filter	2	Proper manufacturing and placement	8	**32**	Replace filter	Operator	Filter replaced	2	2	8	**32**
	Saline water doesn't heat enough	Evaporation rate is reduced	7	Not enough heat transfer to storage tank	4	Placed in direct sunlight	2	**56**	Longer pre-heating time	Operator	Not Necessary	7	2	2	**28**
	Saline water evaporates prematurely	Some saline water doesn't reach trough	5	Too much preheating of the saline water	4	None	2	**40**	Shorter pre-heating time	Operator	Current condition	5	4	2	**40**
Trough evaporates saline water	Temperature isn't high enough to evaporate	Evaporation rate is stopped	10	Poor focal point from Solar Sausage	2	Better pressurization and alignemnt of Solar Sausage	3	**60**	Two pressure guages for initial pressure and visual alignment	Operator	Pressure guages replaced and working	10	2	3	**60**
	Trough's too hard to level and keep water from bunching	Evaporation and condensation rate reduced	8	Trough isn't leveled	4	Proper height adjustment through stake depth in ground	2	**64**	Visually level water in trough by adjusting stake height	Operator	Done with assembling	8	4	2	**64**
Solar Sausage concentrates sun onto trough	Pressure difference isn't maintained	Temperature from focal point is improper	5	Wind or shading decreasing pressure, sun increasing pressure	5	Constant pressure regulation from workers	5	**125**	Regular check ups and adjustments for optimal focal point	Operator	Done with routine maintenance	5	5	5	**125**
	Focal point is too hard to keep and maintain	Sun doesn't focus onto trough	9	Sun's movement without proper alignment	4	Constant worker supervision	2	**72**	Regular check ups and adjustments for optimal focal point	Operator	Done with routine maintenance	9	4	2	**72**
Condenser condenses water	Evaporation rate too high for condensation	Water is unable to condense quickly	5	Trough is reaching too high of a temperature	5	Solar Sausage pressure regulated	4	**100**	Widen the focal point to lower temperature	Operator	Done with routine maintenance	5	5	4	**100**
	Evaporated water doesn't reach condenser	Condensing process can't begin	9	Water vapor escapes through ends	1	Guard rails on sides, wider condenser than trough, accept minimal losses	7	**63**	Redesigning the entire condenser	Team 7	Fixed during testing accepting minimal losses	9	1	7	**63**
	Condesing dome slope causes loss of clean water	Clean water is lost	7	Dome's angle of declination isn't optimal	2	Circular dome design of 2 inches	3	**42**	Adjusting the condenser slope	Team 7	Fixed during testing	7	2	3	**42**
	Sun heats condenser and impeads process	Condeser rate is diminished or depleted	9	Heat reaches condenser from top surface	3	Reflective prevention	4	**108**	Pour saline water to cool material	Operator	Done when deemed necessary	9	3	4	**108**
Channels run water from condenser to clean water storage	slope doesn't allow for proper water runoff	Clean water stays in channels and doesn't reach storage	8	Improper slope design of the condenser	1	Proper calculated slope design	2	**16**	Design better slope runoff angle of declination	Team 7	Fixed during testing	8	1	2	**16**

Appendix B Detailed Operation Instructions

Operation Instruction

1. Assemble system using Project Assembly.
2. Put filter in storage tank (bucket).
3. Fill up the storage tank (bucket) with collected salt water to allow for pre-heating.
4. Attach the ends of the Solar Sausage to the crossbar hooks.
5. Attach each of the two small tubing to either side of the T-valve. Connect one of the small tubes to the Solar Sausage and the other to the foot pump. Connect the long tubing to the top of the T-valve and the bottom of the pressure gauge. Attach a tubing from the pressure valve to the side of the pressure gauge to allow for release of air as needed. (Make sure valve is closed.)
6. Repeat Step 5 for other Solar Sausage chamber.
7. Begin pumping air into the top half of the Solar Sausage using the foot pumps provided. Be sure to fill the top chamber to 1.0 psi using the corresponding pressure gauge.
8. Next, pump air into the bottom section of the Solar Sausage using the foot pump. Monitor the pressure gauge so that the bottom section is filled to 0.5 psi as well.
9. Look underneath the trough and move the Solar Sausage to identify the focal point. This focal point should entirely fit along the bottom of the trough. If it is wider than the trough, see Step 10; otherwise, move to Step 11.
10. Using the foot pump, pump more air into the upper section of the Solar Sausage. Monitor the focal point. For ideal conditions, the focal point should be as thin and focused as possible.
11. Using the Aluminum bar below the Solar Sausage, adjust the Solar Sausage's angle so that the focal point rests in the center of the trough. Move the bar in the opposite direction of the desired direction of the focal point.
12. Using the valve on the storage tank, release approximately one inch of water from the storage tank into the trough.
13. Check the system every fifteen minutes.
    a. Maintain the focal point. This can be done by adjusting the aluminum bar below the Solar Sausage. Also, be sure the Solar Sausage's inflation is still consistent.

b. If required, pump more air into the upper section of the Solar Sausage.
c. If temperature exceeds 220F, release more water from the storage tank into the trough to help cool the system.

14. Replace bladder when necessary.
15. Repeat steps 9 - 14
16. Using heat-resistant gloves provided, remove the condenser from above the trough. Clean out any saline build up within the trough.
17. Deconstruct the Solar Sausage, trough and condenser from stand.
18. Store overnight to prevent damage.