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Senior Design Project Report

"Design and Assembly of a CSP Photocatalytic Desalination System with Pressure Modulation"

In partial fulfillment of the requirements for the Degree of Bachelor of Science in Mechanical Engineering

Team 18

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Abstract

About 0.5% of all water on Earth is potable, half of which is naturally occurring in just six countries. Consequently, many of the remaining countries are forced to depend on desalination as a solution, to produce clean, drinking water. Desalination can be simply defined as the process of removing minerals from water to make it suitable for human consumption. Saudi Arabia, an arid country with no fresh-water resources, heavily relies on desalination to provide safe drinking water for its citizens. It is by far the largest producer of desalinated water across the entire world. Today, about half the desalination refineries in the country commonly rely on a conventional gas-powered reverse osmosis process, which utilizes high pressure to force saline water through a membrane to obtain clean water. This is an expensive, outdated, and inefficient method.

This project aims to present a more sustainable method of desalination, utilizing a concentrated solar photocatalytic system and flash vaporization. The system involves using a solar reflector to absorb photons from the sunlight in combination with a catalyst to increase the rate of production of water. The energy used for this process is mostly renewable and environmentally sustainable in comparison to the fossil fuels used in traditional methods of desalination.

Acknowledgments

The success and outcome of this prototype required guidance and support from a multitude of people within the boundaries of the university campus, as well as outside in numerous workshops. We are highly privileged and grateful to have completed our project under such professional supervision and assistance from the faculty of Prince Mohammad Bin Fahd University and its state-of-the-art facilities.

We are also unequivocally indebted to our project advisor Dr. Feroz Shaik, for taking his time out and reaching out to us with this innovative project idea and entrusting us to transform that vision into reality. His unwavering passion and commitment towards the project were instrumental in motivating us to complete this project with aplomb. Further credit also goes to our co-advisor Mr. Faizan Ahmed, for helping us come up with the component design and measurements using the lab facilities. We also owe a great deal to lab technician Mr. Stephen, without his help completing this project would be far more challenging than it was already. His assistance in addressing design constraints and any occurring problems, while also assisting in assembly and selecting the right parts, were of significance.

List of Acronyms (Symbols) used in the Report

Symbol	Definition
C_p	Heat Capacity at Constant Pressure
λ	Latent Heat of Vaporization
Q	Enthalpy
℃	Celsius
$\dot{m}$	Mass Flow Rate
P	Pressure
f	Focal Point
r	Radius
V	Velocity
W_p	Work Done by Pump
ρ	Density
$\dot{V}$	Volumetric Flow Rate

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Chapter 1: Introduction

1.1 Project Definition

This project aims to design and manufacture an efficient and renewable desalination system that utilizes concentrated solar power to raise the temperature of the water in the heat exchanger. Flash vaporization of the heated water then occurs inside a pressure modulated flash chamber before condensation of vapor to obtain desalinated water. Using a condenser, heat exchanger, vacuum pump, and photocatalytic desalination, the saline water is converted into pure, drinkable water and a leftover brine solution, which can be dried in the sun to extract salt. The overarching purpose of the project, therefore, is to create a system that can efficiently desalinate water using a robust system and produce clean, renewable energy.

1.2 Project Objectives

i. Design and assemble a CSP Photocatalytic Desalination system.
ii. Create a prototype that can be used in the future as a means in water-scarce countries to combine renewable energy and desalination systems in an efficient manner.
iii. Develop an automated reflector setup to ensure solar energy is utilized efficiently.
iv. Use renewable energy to produce clean, affordable water.

1.3 Project Specifications

The specification of the project is that we would have an initial container with water and a photocatalyst coated plate, which would use a centrifugal pump to move the water through the pipes, with a flow meter attached to measure the flow rate and a variable drive to control it.

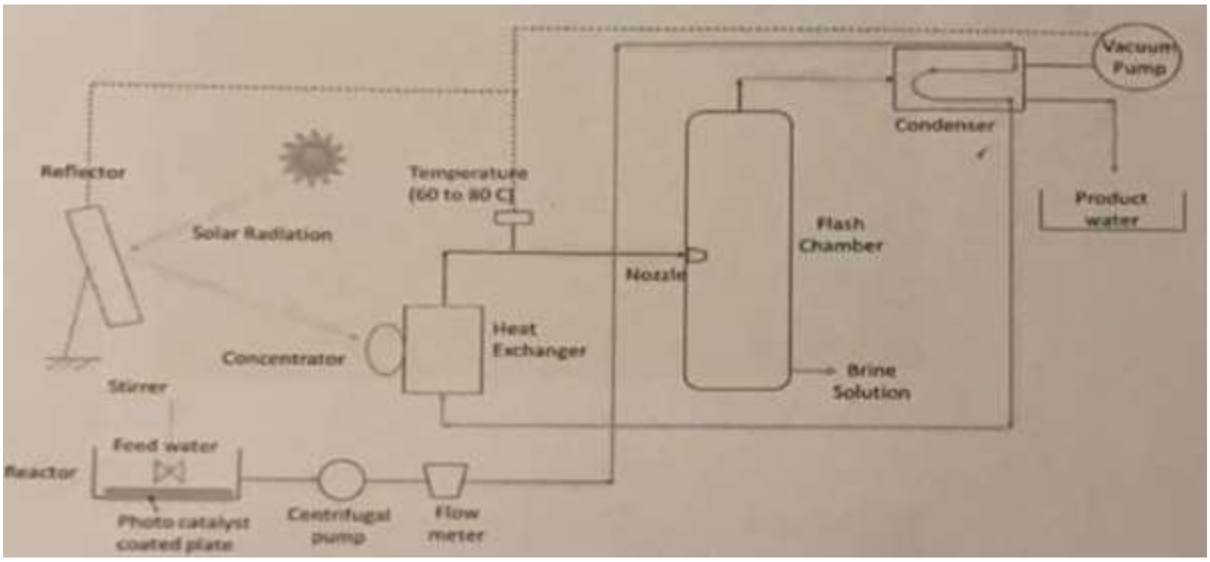


Figure 1. 1: Early schematic of the solar desalination system

It would be moved to a condenser, and the temperature would rise a small amount. Next, the water is pumped to the heat exchanger, where a copper plate is used as a concentrator to build heat through the reflected sunlight off of the mirror. The heat exchanger would raise the temperature of the water, before moving it to the flash chamber. The flash chamber, using pressure modulation, would flash vaporize the heated water, leaving behind a small amount of brine solution, while a vacuum pump would pull the water vapor to a condenser. The condenser would turn the vapor into clean water and be released into a container.

Table 1: Initial Specifications of parts for the project

Parts	Measurements
Board (Aluminum/Stainless Steel)	1.5x0.5(m)
Heat Exchanger (Stainless Steel)	5x5x10(cm)
Flash Chamber	10x10x20(cm)
Vacuum Pump	TBD
Condenser (Stainless Steel)	5x5x10(cm)
Pipes	SS 316, 0.25”
Nozzle	1mm, 1.5mm, or 2mm
2 x Glass Water Tanks	5L Capacity
Centrifugal Pump	0.5 HP

Reflector Mirrors	TBD
Valves	TBD
Temperature and Light Sensors	TBD
Microcontrollers	TBD
Copper Plate	TBD

1.4 Applications

We hope that this project can be applied in many ways. The primary application will be for the project to be used in situations that require desalination of water without using a large amount of non-renewable energy. Furthermore, for it to be used in energy-conserving ways, hopefully by groups such as companies or governments to produce multiple upscale systems inspired by the prototype for mass desalination purposes.

Chapter 2: Literature Review

2.1 Project Background

About 120 countries across the world depend on desalination for the production of water that is safe for human consumption. Most of the methods used to purify water today take advantage of fossil fuels to power water desalination plants. The carbon emitted by the combustion of fossil fuels pollutes the air and diminishes the ozone layer, accelerating the effects of global warming such as rising sea levels, increased wildfires, and rising temperatures in general. Moreover, fossil fuels are limited, which means humans must transition to renewable energy sources at some point in time. Because of this, solar desalination is seeming like more of an attractive option as time progresses [1]. The energy used in solar desalination is renewable and abundant, especially in middle eastern countries such as Saudi Arabia, the United Arab Emirates, and Kuwait.

The purpose of this project is to create a more sustainable method of desalination to lower the number of greenhouse gases circulating in the atmosphere. The system will use photons from the sun, reflected by the use of a mirror, onto a concentrator attached to a heat exchanger to heat the water, and in turn, condense it using a condenser. In addition, a catalyst, in the form of zinc oxide or titanium oxide, will be used to speed up the desalination process, hence the name, photocatalytic desalination. Moreover, a flash vaporization process is also employed to segregate the clean steam vapor from the brine solution through a different outlet.

The challenge with this project is reducing the cost of production of water by developing the technologies used for a renewable energy plant. Although the process is relatively affordable to maintain, as operational costs of the plant would be significantly low in comparison to plants that run on conventional fuels. The capital costs of a solar desalination plant remain high, as the technologies necessary for the system are expensive to acquire.

2.2 Previous Work

Among middle eastern countries, desalination was first used in Jeddah, Saudi Arabia in 1907. By 1953, several units were being built by neighboring countries- Qatar, and Kuwait. The units worked using submerged tubes, which was common during that period. By 1959, Qatar built two units at Ras Abu Aboud, based on the same mechanisms, however with different designs. GCC countries were proud to have precedence over the testing and optimizing of one of the most significant water desalination processes.

New technologies were being developed, such as Reverse Osmosis (RO) and Electrodialysis (ED). To surmount their problems, Vapor Compression (VC) and Multi-Effect Distillation (MED) were demolished and replaced. In Saudi Arabia, the first use of Reverse Osmosis was when three plants were built in 1968 [7].

State	MSF	RO	VC	MED	ED
UAE	1977	1977	-	1977	-
Kingdom of Bahrain	1975	1984	1985	2004	-
KSA	1967	1968	-	1981	-
Sultanate of Oman	1976	1982	1979	-	1983
Qatar	1962	1982	-	1996	-
Kuwait	1960	1987	-	-	-

Figure 2. 1: Types of desalination techniques used in each country with the date of use [7]

After establishing the history of water desalination in Saudi Arabia and GCC countries, a research paper on a membrane distillation process was found. The importance of this article was that it was designed for autonomous operation in Saudi Arabia. The article was utilized for consideration for the types of subsystems to be built into the desalination system [3].

The project had three major components, a solar-thermal system, solar-PV system, and membrane distillation system. A heat pump is built into the system for performance improvements. The results of the project were good, showing success in the combination of the components. This helped in understanding solar-thermal systems, adding information to the idea of a CSP system to heat the water.

A study conducted by Veera Gnaneswar Gude and Nagamany Nirmalkhandan titled *"Sustainable desalination using solar energy"* covers how desalination can be sustainable through the use of solar energy. They discuss that demand for potable water is growing and so new more efficient methods of desalination must be developed to match the demand. Solar energy is a good source of renewable sustainable energy for desalination. Their proposed system uses barometric columns, one with fresh water and one with saline water.

The temperature of the saline water column is maintained slightly higher than the freshwater column and a connection between the two columns is made at the top. The vapor from the saline water will distill into the freshwater column. The temperature in the two columns is a small enough difference that it can be achieved through solar energy. A desalination system based purely on solar energy for heating and pressure differences for vaporization and distillation is possible. The process also requires less heat as the desalination can occur at about 40-50 degrees, rather than the traditional 60-100 degrees range. They developed two possible systems, one that used direct solar energy in a solar evaporation chamber, and another that used solar power to create high-efficiency desalination [6].

The solar panels would be used to charge a battery bank throughout the day and power a DC heater to heat the evaporation chamber and maintain a set temperature throughout the day. Their experimental results showed that their proposed system could produce two times the distillate of a simple solar still configuration. The solar panels served to keep the system running during non-sunlight hours.

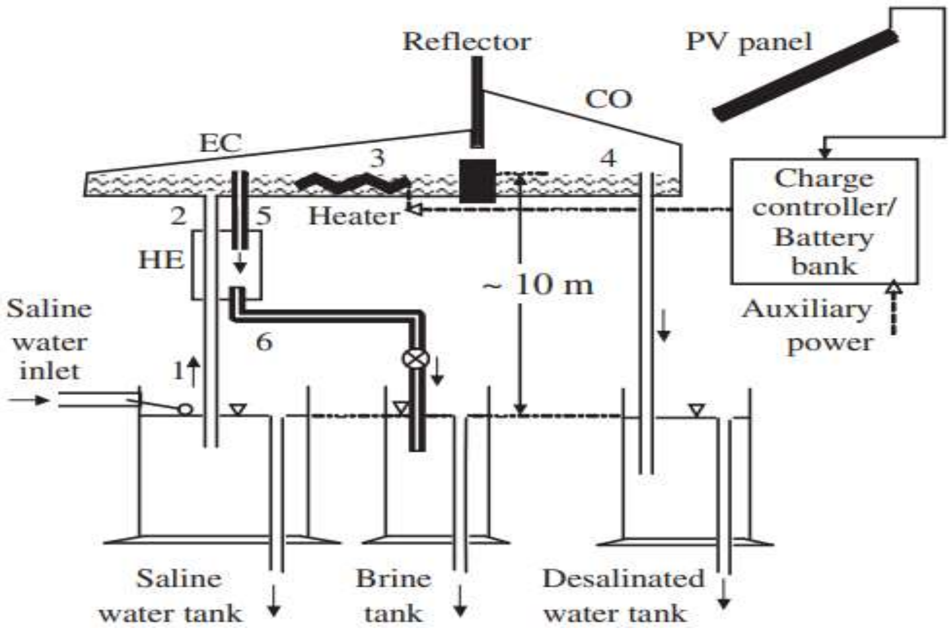
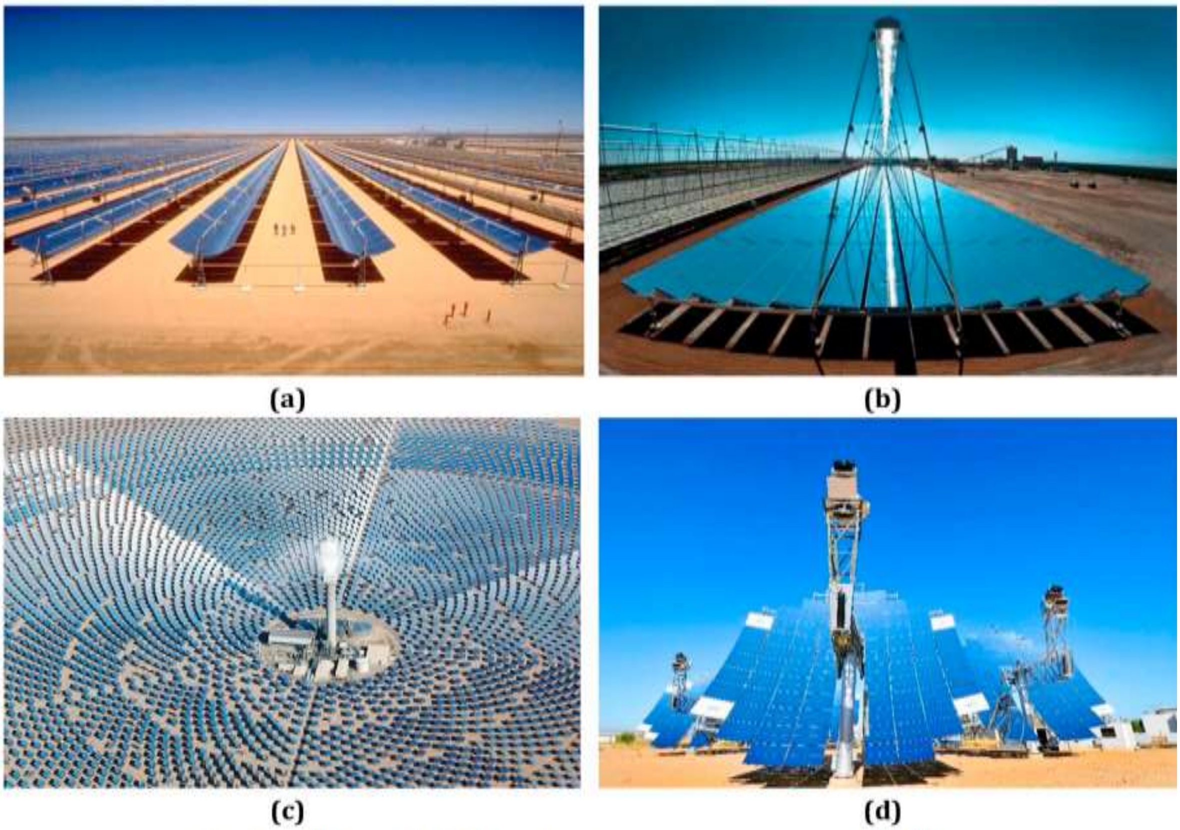


Figure 2. 2: Schematic of their proposed process [6]

Another study providing similarity to our project is *"Hybrid concentrated solar power (CSP)-desalination systems: A review"*. This previous work covers desalination technologies powered by CSP systems. CSP systems to drive desalination are a highly viable option for sustaining the required energy, making CSP appealing for large-scale desalination, especially in a country like Saudi Arabia. A solar collector uses a reflective surface to focus solar radiation on a smaller absorbing area, a medium such as a fluid or small plate. This leads to low heat losses due to the small absorbing area [4].

To operate these collectors, a solar tracking mechanism is necessary, for efficiency. Otherwise, the manual movement would be needed to work it throughout the day. Understanding this important note from previous works led to the decision of a CSP system with a smart subsystem to automatically track sunlight and follow the sun. The study reports that there are two types of tracking systems, a line-focusing system, and a point-focusing system. The line focusing system only requires a single-axis tracking system to follow the sun and concentrate the solar radiation linearly, reflecting the sunlight in a line. The point-focusing system uses two-axis tracking to focus the solar radiation onto a single point, such as a small metal plate.

There are four types of CSP technologies, Parabolic Troughs, Linear Fresnel, Solar Tower, and Parabolic Dish, illustrated in Figure 2.3. A parabolic trough is a bent sheet of reflective materials that reflect solar rays onto a solar collector. These are usually mass-produced and built-in very long lines that follow the sun to reflect onto tube-shaped solar collectors. A linear Fresnel reflector is similar to a parabolic trough but rather than having solar collectors that are tubes attached along the length of the mirrors, these are flatter mirrors that all direct their light onto one large tower that the light is concentrated on.



Main CSP technologies: (a) Parabolic troughs, (b) Linear Fresnel, (c) Solar tower, and (d) Parabolic dish.

Figure 2. 3: Four examples of the main four CSP technologies [4]

While cheaper and require less structural support, they suffer from shading and blocking from adjacent mirrors. Solar tower systems are too large to even consider for the current project, so that will be skipped over, but the name is very self-explanatory; a very large solar tower is built to collect all the solar rays and it is circled by a field of mirrors to reflect light onto the central point at the top of the tower. Finally, the parabolic dish is the best option in shape for the mirror, as it is a parabolic dish that can reflect light onto a point.

The final study utilizes a solar parabolic dish to direct solar rays to a receiver for a Stirling engine. The solar dish consists of a parabolic reflector, with a Stirling engine mounted on the focus (focal point) to receive solar rays. The dish automatically tracks the sun to ensure the sunrays reflects properly onto the Stirling engine [5].

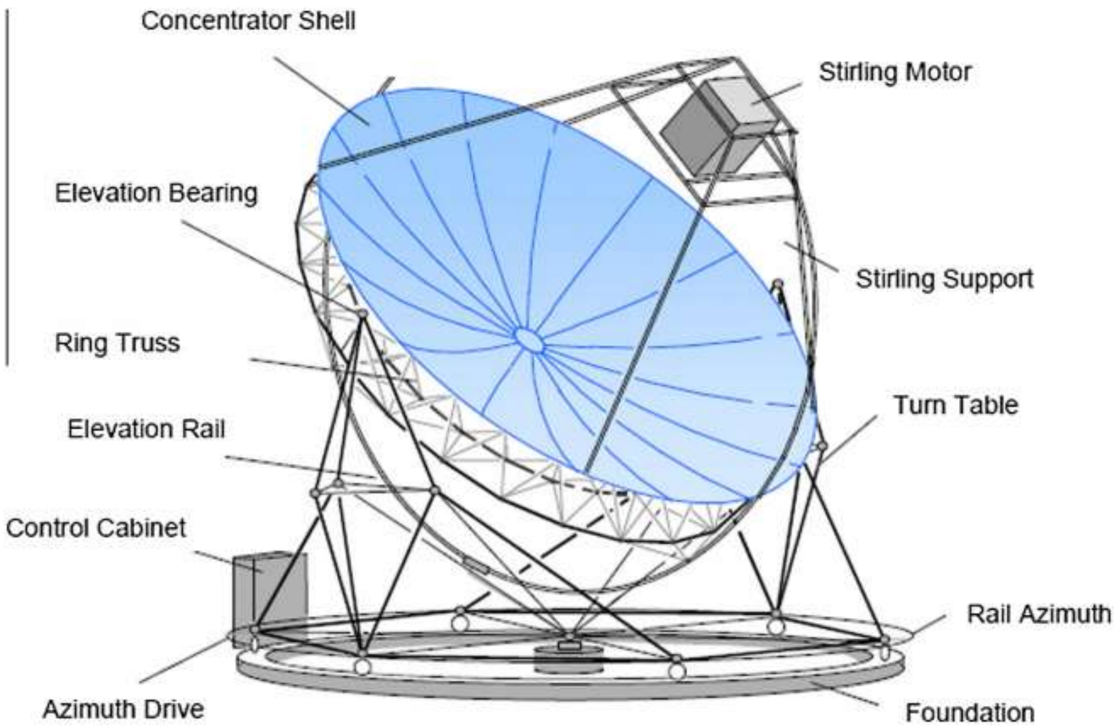


Figure 2. 4: Diagram of Solar Parabolic dish with Stirling engine [5]

The article specifies that the solar dish reflectors must have the following properties: reasonable weight, durability against moisture and temperature changes, hardness against deflection and wind load, flexible, low cost, and effective reflecting materials. The Stirling engine is a kinematic Stirling engine that uses hydrogen as a working fluid. There is a chart that is used for following the steps to design the parabolic dish before it can finally be chosen.

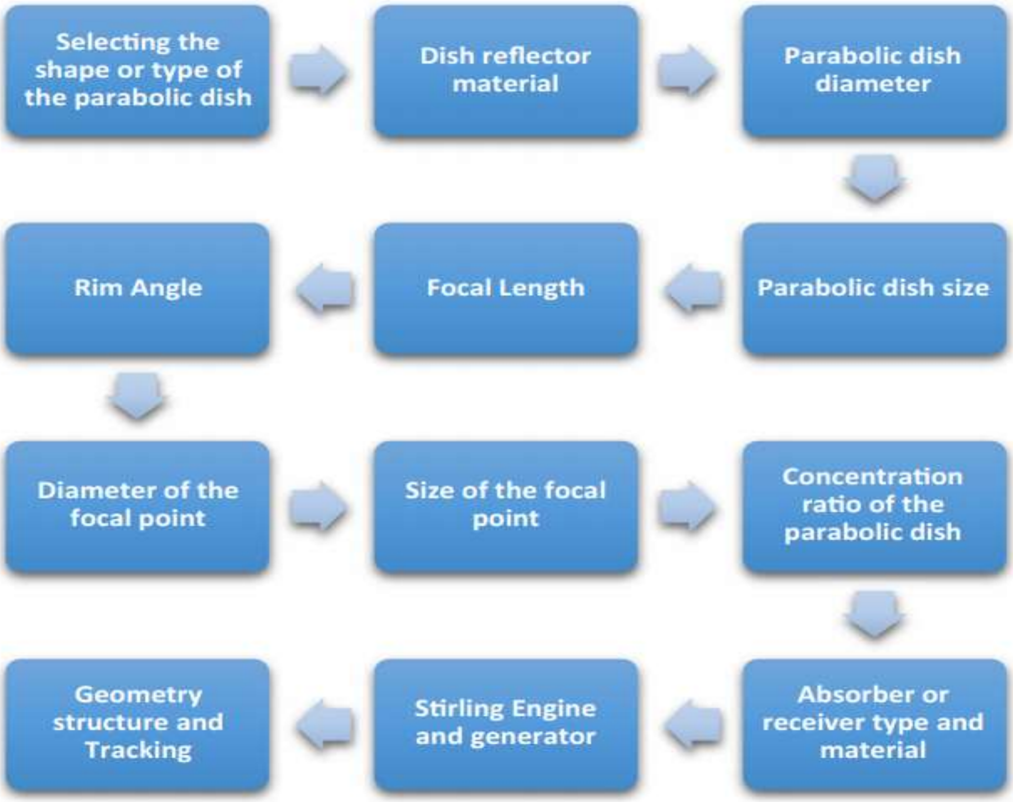


Figure 2. 5: Chart of Steps for Parabolic Dish Design [5]

They tested many different materials for the reflector to compare which is the best for a solar parabolic dish. They found that polymeric film that is non-metal had the best efficiency in conversion power, totaling more than 97.07%. They also considered the best diameter for each material, with Polymeric Film being most efficient at a diameter of 8.48m.

2.3 Comparative Study

In a study done by Manisha Sindal, Narendra Singh, and Ajay Sharma, published in the Journal of Chemical, Biological, and Physical Science, the three of them work on testing Zinc Oxide as a photocatalyst for Desalination. We can compare our project to this concerning the photocatalysts because we are planning to use Zinc Oxide or Titanium Dioxide. Going through projects similar to our own will help enhance ideas and plans for what materials to use. The study becomes very useful because they have the same end goal as us, clean water, and clean energy. [1]

The experimental portion may be of help in the installation of a photocatalyst, but the results are more important to us. The study involves building a solar still with a glass cover for transparency. The class was fixed at a 60-degree angle and a PVC pipe was installed to collect condensed water, all sealed off with an adhesive to ensure minimal loss of vapors. [1] They also used a thick waterproof board as the body of the solar still to provide minimum heat loss. The system was set up to have an inlet for raw water and an outlet for desalinated water, with two galvanized trays inside the solar still with a galvanized plate in the tray. Understanding how they set up their experiment is important to us in understanding methods of installing the photocatalyst in our project.

The most important part of this study is the results and discussion, to help us understand if Zinc Oxide is a photocatalyst a good option and the type of results it would give us. It was found that the ZnO helped increase the amount of desalinated water, but also achieved a better quality of water. Their best results were found at midday, which makes sense in a logical sense, as we also planned to do our tests for best results at midday when the sun is at its most intense. From their figures and tables, we know that Zinc Oxide is extremely useful as a photocatalyst and a very good candidate for us. The figures below show results of Zinc Oxide as a photocatalyst compared to desalination without Zinc Oxide.

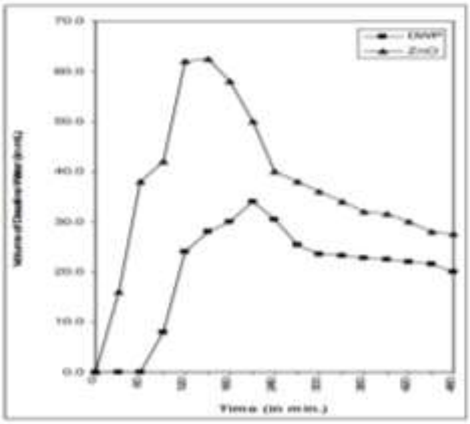


Figure 2. 6: Rate of production of desalinated water in presence of oxides [1]

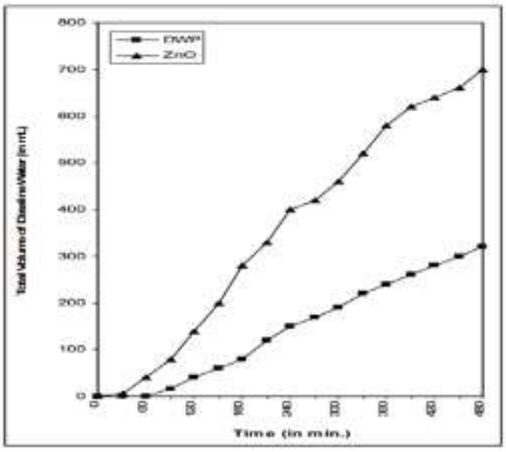


Figure 2. 7: Total volume of desalinated water in presence of oxides [1]

The table below is a comparative study in the quality of water without photocatalyst and with Zinc Oxide as a photocatalyst.

Table 2. 1: Effect of photocatalyst on desalinated water [1]

Parameter	Raw Water	Desalinated water without use of photocatalyst	Desalinated water with use of photocatalyst (ZnO)
pH	8.2	7.2	7.1
Conductivity	0.954	0.739	0.062
TDS	1500.0	850.0	60.0
Free CO_2	18.0	10.0	2.0
Total Alkalinity	160.0	32.0	10.0
Chloride	1050.0	85.0	34.0
Total Hardness as $CaCO_3$	350.0	68.0	28.0
Calcium	63.0	8.4	4.2
Magnesium	70.0	14.5	5.8
Fluoride	5.00	2.0	0.8
Ammonium	0.048	0.060	0.098
Nitrate	48.0	12.0	5.0
Cadmium	0.010	0.006	0.004
Iron	1.2	0.8	0.5
Sulphate	62.4	60.6	50.7

In another similar study done by the faculty at Department of Chemistry in M. L. Sukhadia University, the use of photocatalysts in solar desalination was studied. While much work has been done and many technical advancements have been made in the field of desalination, little has been done to improve the water quality and increase the desalination rate using photocatalysts.

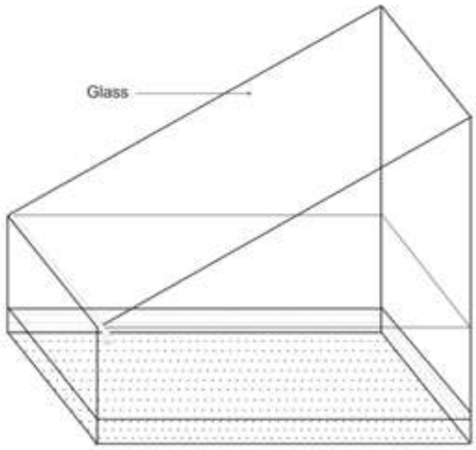


Figure 2. 8: Schematic diagram of a solar still desalination plant [2]

The study also involves building a solar still with a glass cover for transparency in Figure 2.8. The class was fixed at a 60-degree angle and a PVC pipe was installed to collect condensed water, all sealed off with an adhesive to ensure minimal loss of vapors. Two galvanized trays (563×263×50 mm) are placed inside of the solar still and a galvanized plate (560×260 mm) containing a coat of photocatalyst was placed inside the tray. An inlet for fresh water was made at the bottom of the vertical wall of the basin, and an outlet for desalinated water was made at the top. [2]

The results show that this method will solve the problem of how solar desalination increases water quality, the volume of water obtained after desalination is comparatively small, and it may not be enough to meet the demand. Second, certain chemical impurities are transferred to desalinated water. To address these issues, the tray's base is coated with semiconducting oxides, resulting in improved water quality as well as a higher rate of desalination efficiency. Since semiconducting oxides act as photocatalyst and therefore, it can be useful from both these viewpoints.

Figures 2.9 and 2.10 show the results of as the sun rises, the rate of development of desalinated water rises, hits an optimum after 2–3 hours, and then falls as sunset approaches. As seen in Fig. 2.9, both of the metal oxides used increase the rate of desalinated water production as opposed to desalinated water production without a photocatalyst. It has also been noted that as the phase of exposure increases, the volume of desalinated water produced also increases. When photocatalysts (CuO, PbO2, and MnO2) are present, the total amount of water released is higher than when they are absent.

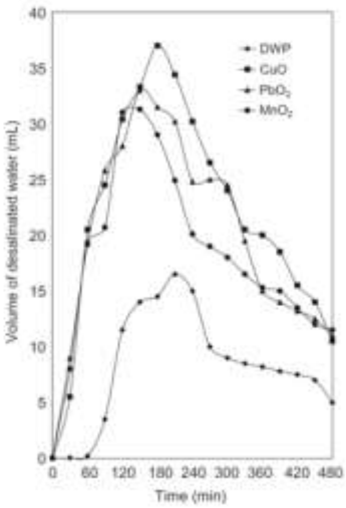


Figure 2. 9: Rate of production of desalinated water in presence of oxides [2]

Parameter	Raw water	Desalinated water without use of photocatalyst	Desalinated water with use of photocatalyst		
			MnO_2	PbO_2	CuO
pH	8.0	7.1	7.2	7.0	7.1
Conductivity	0.629	0.084	0.038	0.025	0.050
TDS	700.0	368.0	48.0	52.0	48.0
Free CO_2	8.0	14.0	6.0	6.0	7.0
Total alkalinity	157.0	28.0	20.0	12.0	18.0
Chloride	42.6	14.2	14.2	14.2	14.2
Sulphate	49.4	20.6	28.8	41.2	32.9
Total hardness as $CaCO_3$	170.0	16.0	8.0	8.0	6.0
Calcium	59.7	5.5	2.5	2.5	1.7
Magnesium	5.1	0.5	0.4	0.4	0.4
Fluoride	0.5	0.2	0.3	0.3	0.1
Iron	0.6	0.3	0.3	0.5	0.4
Nitrate	4.5	1.6	2.1	1.2	1.1

All value except pH, conductivity are in ppm. Conductivity is in mmhos cm^{-1}.

Figure 2. 10: Comparative study of water with and without photocatalyst [2]

To conclude, to a nearly similar degree, all three oxides are effective in lowering TDS in raw water. All three metal oxides decrease overall alkalinity, with PbO2 being the most powerful of the three. Metal oxides are used to minimize the conductivity of raw water, with PbO2 being the most effective of the three oxides used.

Chapter 3: System Design

3.1 Design Methodology and Constraints

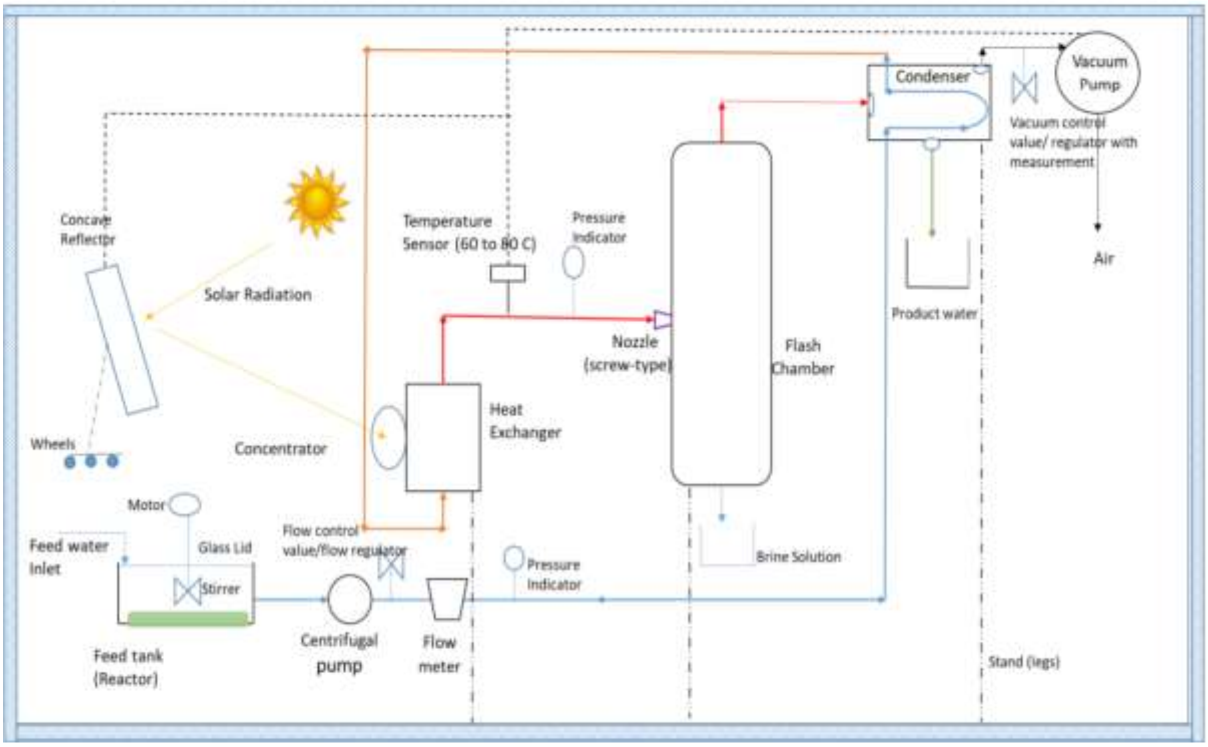


Figure 3. 1: Working system diagram

3.1.1 Methodology

The project had primary goals that needed to be met:

- Design the experimental set up to perform study
- Create a system that is portable and not extremely large
- Desalinate water using clean, renewable energy
- Make a mirror system to project sunlight, and modulate pressure based on the temperature at the same time
- Optimize the system through comparison of the experimental results versus the theoretical results
- Attempt to innovate on CSP Desalination with a Photocatalyst and Pressure Modulation

The approach taken with the design was starting at the basics, understanding that the project had to fit on a board/table that was 2x1m maximum. This was because it needed to be moved around and portable, especially for testing and presenting. The project needed to prove that efficient desalination could be made through a CSP system. At first, the approach of setting everything on the board was considered, but it was discovered that there would not be enough space and the machine would be too large for the goals. This led to deciding to build a vertical setup that would allow water to move efficiently through all the subsystems.

Flowmeters, pressure sensors, and temperature sensors were chosen to keep proper track of what was going on in the internal of the system, so that efficiency can be optimized, bringing the experimental results as close to theoretical results as possible. The technique for desalination was decided after consideration of what would be required; the focus was CSP to power the desalination but there would be more than just heating that mattered, so using a photocatalyst to react with the saline water at first was decided.

Another important consideration would be how to cool the steam after desalination in the condenser once it needs to be condensed. This led to the decision of passing the saline water through the coils in the condenser before it reaches the heat exchanger to help in cooling the steam that is in the condenser. Finally, there was the consideration of how the water would be heated through CSP and what would be used. A solar concentrator that would heat up due to solar radiation would be attached to a heat exchanger through which water would pass through. Finally, the reflector dish would need to follow the sun, as well as the pressure in the flash chamber modulated.

The first step in the system is to add feed water into a feed tank where water would react with a photocatalyst by being stirred in the feed tank. A centrifugal pump would now pull the water through the pipes, passing it through the condenser to act as cooling for the steam that will be pulled through the condenser later. At the same time, the concentrator on the heat exchanger will be heated up through solar radiation that is reflected onto it by the reflector dish. The water then moves into the heat exchanger from the condenser and gets heated up.

A temperature and pressure sensor are attached between the heat exchanger and the next part, the flash chamber, to modulate the pressure inside the flash chamber. The now heated water moves from the heat exchanger into the flash chamber. Flash vaporization occurs in the flash chamber. A vacuum pump then pulls the vapor out of the flash chamber, and any excess water(now a brine solution) is released into another container. The vacuum pump pulls the vapor into the condenser mentioned previously. Returning the vapor into liquid water which is now desalinated and collected in a container. This ends the process of desalination.

3.1.2 Design Constraints

Geometrical

As mentioned earlier, geometrical constraints were based on the fact that the project needed to be moved around and portable. So, the geometrical constraints were built off the fact that the board could be 2x1m maximum. This meant that the parts be arranged in a compact manner and not be spread out. Also, since the project had to be carried and moved, minimizing weight for transport is a notable geometrical constraint. This led to the decision of creating a vertical setup, rather than everything being on the same vertical level and horizontal to each other, the parts would now be varying in heights. The parts would be chosen based on weight and there would be control if any of the parts were manufactured to our design, such as the flash chamber.

Sustainability

For the project to be sustainable, there were two main factors to consider. The first was sustainable energy, and the second was physical wear on the parts, such as wear and tear as well as corrosion. The parts had the potential to wear down due to all the saline water passing through, as well as all the varying temperatures, and constant exposure to the sun. This led to some important choices such as stainless steel being needed. As for sustainable energy, the system mainly focused on CSP and external power sources (for the sensors and pumps), which could potentially be switched out with solar panels to power itself completely through the sun.

Environmental

The impact of the project on the environment would be a positive one. This is because the project uses solar power to desalinate water, a clean and renewable source of energy. Furthermore, desalination would help create more clean drinkable water, rather than having to constantly use freshwater sources or import from elsewhere, creating more energy usage from transportation.

Social

The social impact this project yields is indefinitely beneficial. The desalination system creates a convenient source of clean water that can be spread throughout the country. It can be given to the government as an idea to be mass-produced and have a better source of clean water. The benefits for our social environment can be seen, as those forced to rely on salty water for daily consumption can now opt for a cleaner source.

Economic

The final costs have not been tallied up yet, so at the moment not much can be said on the economic factor. The goal is to reduce any extreme prices to a minimum while keeping safety and efficiency as the most important factor. Few of the components, including the vacuum pump, variable frequency drive, and stirrer were borrowed from the labs in the university to cut costs.

Manufacturability

The hope for manufacturability is that using stainless steel, copper, and glass as the main materials would mean that it is easy to manufacture and hopefully even mass produce for future use. The materials are not extremely expensive either and most parts are readily available on the market, except for the flash chamber, which is designed on computer software (SolidWorks), then manufactured to specification.

Safety

As the system deals with many varying temperatures, pressures, and water flow, the first thing taken into consideration is for the system to stay functional without any dangers. Meaning leakage, vibrations, thermal expansion, and pressure resistance are of paramount importance. The setup is highly safe due to the presence of a variable frequency drive controlling the flow of the pump, making sure it stays under control.

Risk Factors

Several risks were taken into consideration when designing the system. The biggest one was corrosion. Corrosion is a major risk, especially when dealing with saltwater, as salt can accelerate the corrosion process. To combat the risk of corrosion, stainless steel (grade 316) was picked as the material to use for almost every component of the system, like the pipes, flash chamber, heat exchanger, and condenser.

Another risk that affected the design of our system was the possibility of the vacuum pump taking in too many water molecules, this could cause the vacuum pump to fail. To combat this risk, a semi-permeable stainless-steel sheet was placed near the vapor outlet of the flash chamber to minimize the risk of water entering the vacuum pump. Valves were also placed between the condenser and the product water tank, as well as between the flash chamber and the brine solution tank.

Moreover, there was also the issue of water traveling in the opposite direction back into the feedwater tank when the pump was not functioning. To resolve this, a check valve was placed before the feed water tank and the centrifugal pump, keeping the flow unidirectional and steady.

3.2 Engineering Design Standards

3.2.1 Introduction and Parts:

The standards will be primarily based on ASTM labels, especially with the stainless-steel, as all the stainless-steel grade utilized throughout the project is SS-316. A general list of parts along with their standards as well as specifications will be shown below.

3.2.2 Stainless Steel Ball Valves ¼":

Table 3. 1: Valve dimensions [10]

Parameter	Value
Model no.	VBS02-025
Max. Working pressure	1,000 PSI
Temperature Range	-40C to 204C
Diameter	0.43mm
Length	2.02mm
Height	2.17mm
Width	4.08mm

Table 3. 2: Ball valve standards [10]

Designation	Material
Body	SS 316 (CF8M)
Ball	SS 316 (CF8M)
Cap	SS 316 (CF8M)
Seat	RPTFE
Thrust washer	304
Stem packing	PTFE
Stem	SS 316
Body seal	PTFE
Gland nut	SS 304
Stem nut	SS 304
Stem seal	PTFE
Handle	SS 304
Handle cover	Plastic

3.2.3 ¼' Pipe Union:

Table 3. 3: Pipe Union Specification [8]

Parameter	Specification
Engineering Standard	ACI Grade CF8M (316)
Material	SS 316 Stainless Steel Casting
Pressure Rating	1 MPa
Weight	0.086kg
Dimensions	D = 1.26, E = 1.14

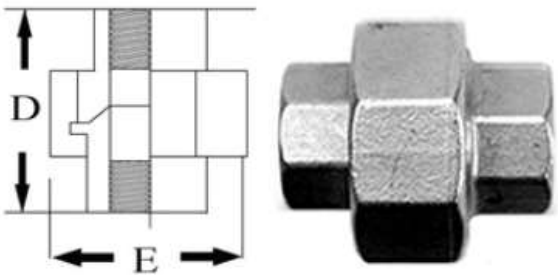


Figure 3. 2: Dimensions of Union [8]

3.2.4 Vacuum Pump:

Table 3. 4: Vacuum Pump Specs

Parameter	Value
Model	VE 235D
Ultimate Vacuum	3 x 10^{-1} Pa
Voltage	110 – 220 V/ 50 – 60 Hz
Power	0.3 HP
Oil Capacity	350 ml

3.2.5 Pipes:

Table 3. 5: Pipe Specification

Material	Stainless Steel
Grade	316
Standard	UNS S31600/A312-TP316
Nominal Size	¼’
Schedule	40
Wall Thickness	0.088 in
Manufacturing	ISO 9001:2008
Working Pressure	2100 psi

3.2.6 Centrifugal Water Pump:

Table 3. 6: Pump Specifications

Parameter	Value
Model	QB60
Flow Rate Max	40 L/min
Voltage	110 – 220 V/ 50 – 60 Hz
Power	0.5 HP
Max. Head	40m
Min. Head	5m

3.2.7 Variable Frequency Drive:

This device is used to control the speed and flow rate of the centrifugal pump. The specifications are given below.

Figure 3. 3: VFD Ratings [9]

Model : SV xxx iC5 – 2x			004
Max motor capacity[1]		[HP]	0.5
		[kW]	0.4
Output ratings	Capacity [kVA][2]		0.95
	FLA [A]		2.5
	Frequency		0 ~ 400 [Hz][3]
	Voltage		Three Phase 200 ~ 230V[4]
Input ratings	Voltage		Single Phase 200 ~ 230V (±10%)
	Frequency		50 ~ 60 [Hz] (±5%)
	Current		5.5

3.3 Theory and Theoretical Calculations

3.3.1 Focal Point of the Parabolic Dish

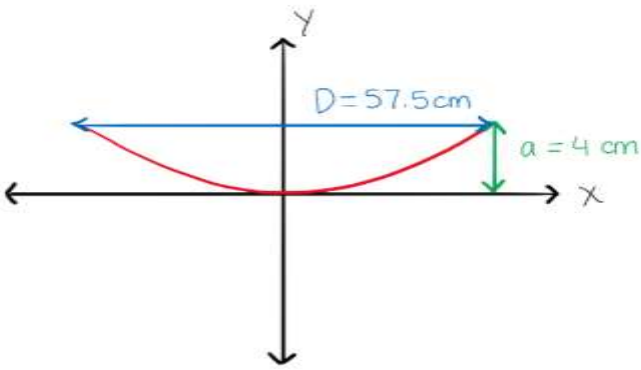


Figure 3. 4: Parabolic Dish Diagram

The focal point is an important part of the reflector mirror to calculate as it is the point on the axis of a mirror where parallel rays of light converge. In terms of our mirror, it is the point where solar radiation converges and where the sunlight is most intense.

The focal point was calculated below using the following equation: $f = \frac{r^2}{4a}$

Where,

$$f = focal\ point;$$

$$r = radius\ of\ the\ dish;$$

$$a = depth\ of\ parabola;$$

Given that,

$$r = 28.75cm\ ; a = 4.0cm$$

Substituting them in the equation, we get

$$f = \frac{28.75^2}{4(4)}$$

$$f = \frac{826.5625}{16}$$

$$\boldsymbol{f = 51.66\ cm}$$

The theoretical focal point is determined to be approximately 51.66 cm away from the vertex (center) of the parabola along the y-axis.

3.3.2 Mass Balance and Entropy Equations

Assumptions:

- Mass in = mass out
- The temperature of seawater is 25^{o}C (reference temperature)
- Salinity of seawater = 36 ppt
- Density of seawater = 1025 $\frac{\text{kg}}{\text{m}^3}$
- Seawater flow rate = 1 $\frac{\text{L}}{\text{min}} = 1.67 \times 10^{-5} \frac{m^3}{s}$

To get the mass flow rate:

$$\dot{\text{m}} = \rho\dot{V}$$

$$\dot{\text{m}} = 1025 \frac{\text{kg}}{\text{m}^3} * 1.67 \times 10^{-5} \frac{\text{m}^3}{\text{s}}$$

$$\dot{\text{m}} = \mathbf{0.0171}\ \frac{\mathbf{kg}}{\mathbf{s}}$$

1. **Heat Exchanger**

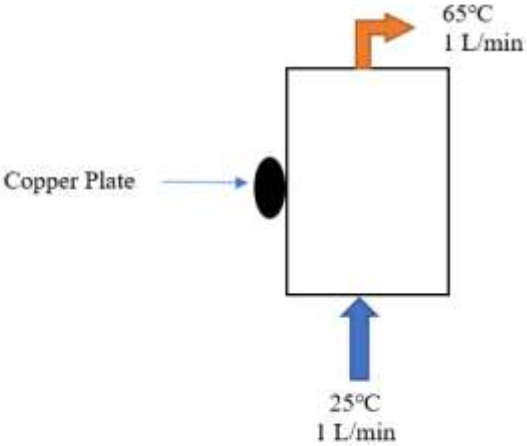


Figure 3. 5: Heat Exchanger Flow Diagram

From Enthalpy Equation,

$$Q = \dot{m}C_p\Delta T$$

$$(\dot{m}C_p\Delta T)_{in} = \dot{m}C_p\Delta T_{out} + Q$$

Temperature,

$$T_1 = \frac{inlet\ water\ temp + ref.\ temp}{2}$$

$$T_1 = \frac{30 + 25}{2} = \mathbf{27.5\ C}$$

$$T_2 = \frac{outlet\ water\ temp + ref.\ temp}{2}$$

$$T_2 = \frac{65 + 25}{2} = \mathbf{45\ C}$$

Enthalpy Change,

$$Q = (\dot{m}C_p\Delta T)_{in} - \dot{m}C_p\Delta T_{out}$$

$$Q = (0.0171\frac{kg}{s})(3.997\frac{kJ}{kg * C})(30C - 25C) - (0.0171\frac{kg}{s})(4.004\frac{kJ}{kg * C})(65C - 25C)$$

$$\mathbf{Q = -2.39\ kJ}$$

2. Flash Chamber

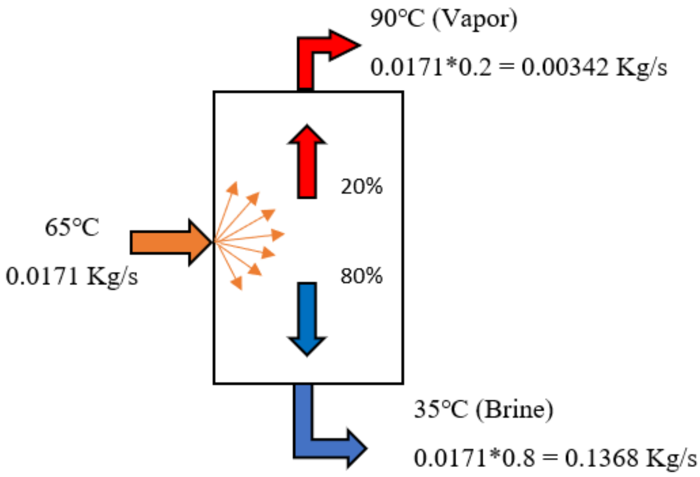


Figure 3. 6: Flash Chamber Flow Diagram

Enthalpy Balance Equation,

$$(\dot{m}C_p\Delta T)_{in} = (\dot{m}C_p\Delta T)_{out}$$

Case I: Heat Inlet

$$\mathrm{Q_{in}} = \dot{\mathrm{m}}\mathrm{C_p}\Delta\mathrm{T}$$

$$\mathrm{Q_{in}} = \left(0.0171\frac{\mathrm{kg}}{\mathrm{s}}\right)\left(4.004\frac{\mathrm{kJ}}{\mathrm{kg} * \mathrm{C}}\right)(65\mathrm{C} - 25\mathrm{C})$$

$$\mathbf{Q_{in} = 2.738\ kJ}$$

Case II: Vapor Exit

Since 20% of mass exits as vapor, mass flow rate is given as:

$$\dot{\mathrm{m}}_{\mathrm{vapor}} = 20\% \text{ of } (0.0171\tfrac{\mathrm{kg}}{\mathrm{s}}) = 0.00342\ \mathrm{kg/s}$$

Enthalpy,

$$Q_{out\ vapor} = \dot{\mathrm{m}}_1 C_p\Delta T + \lambda$$

where λ is latent heat of vaporization

$$\mathrm{T_{avg}} = \frac{90 + 25}{2} = 57.5\ \mathrm{C}$$

From Table,

$$C_p = 4.182\,\frac{kJ}{kg{*}C},$$

$$\lambda = 2.364\ kJ/kg$$

$$Q_{out\ vapor} = \left(0.00342\,\frac{kg}{s}\right)\left[\left(4.182\,\frac{kJ}{kg * C}\right)(90C - 25C) + 2.364\,\frac{kJ}{kg}\right]$$

$$\mathbf{Q_{out\ vapor} = 0.937kJ}$$

Case III: Brine water exit

As 80% of remaining flow rate comes out as brine water,

$$\dot{m}_{brine} = 80\%\ of\ (0.0171\frac{kg}{s}) = 0.1368\ kg/s$$

Temperature,

$$T_{avg} = \frac{35 + 25}{2} = 30\ C$$

From Table,

$$C_p = 3.998\,\frac{kJ}{kg{*}C}$$

$$\lambda = 2.342\ kJ/kg$$

Enthalpy,

$$Q_{out\ brine} = \dot{m}_2 C_p \Delta T + \lambda$$

$$Q_{out\ brine} = (0.1368\ kg/s)[\left(3.998\,\frac{kJ}{kg * C}\right)(35C - 25C) + 2.342\,\frac{kJ}{kg}]$$

$$\boldsymbol{Q(out\ brine) = 5.79kJ}$$

3. Condenser

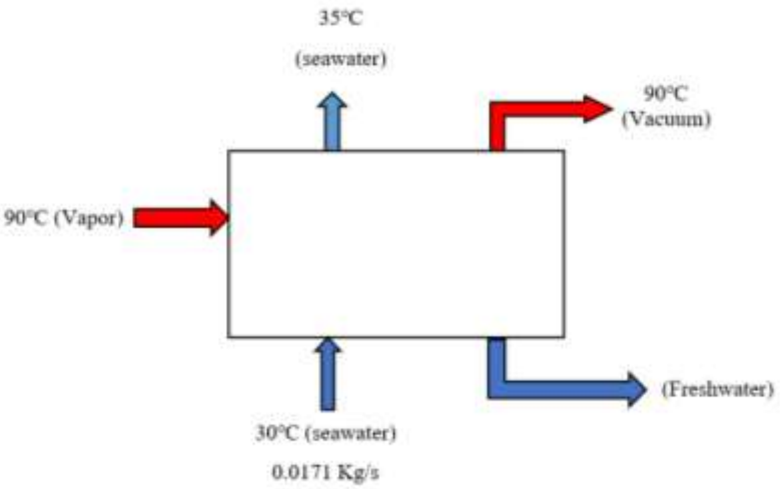


Figure 3. 7: Condenser Flow Diagram

Enthalpy Balance Equation,

$$(\dot{m}C_p\Delta T)_{in} = (\dot{m}C_p\Delta T)_{out}$$

Case I: Seawater Inlet

Temperature,

$$T_{avg} = \frac{30 + 25}{2} = 27.5\ C$$

From Table,

$$\mathrm{C_p} = 3.997\,\frac{\mathrm{kJ}}{\mathrm{kg*C}}$$

$$\lambda = 2.348\ \mathrm{kJ/kg}$$

Enthalpy Change,

$$Q_{in\ seawater} = mC_p\Delta T + \lambda$$

$$\mathrm{Q_{In\ seawater}} = \left(0.0171\,\frac{\mathrm{kg}}{\mathrm{s}}\right)[\left(3.997\,\frac{\mathrm{kJ}}{\mathrm{kg*C}}\right)(30\mathrm{C} - 25\mathrm{C}) + 2.348\,\frac{\mathrm{kJ}}{\mathrm{kg}}]$$

$$\mathbf{Q_{In\ seawater} = 0.8\ kJ}$$

Case II: Seawater Exit

Temperature,

$$T_{avg} = \frac{35 + 25}{2} = 30\ C$$

From Table,

$$C_p = 3.998 \frac{kJ}{kg * C}$$

Enthalpy,

$$Q_{out\ seawater} = mC_p\Delta T$$

$$\mathrm{Q}_{\mathrm{out\ seawater}} = \left(0.0171 \frac{\mathrm{kg}}{\mathrm{s}}\right)\left(3.998 \frac{\mathrm{kJ}}{\mathrm{kg} * \mathrm{C}}\right)(35\mathrm{C} - 25\mathrm{C})$$

$$\mathbf{Q}_{\mathbf{out\ seawater}} = \mathbf{0.683\ kJ}$$

Case III: Vapor Input

$$Q_{in\ vapor} = m_1 C_p \Delta T$$

Temperature,

$$T_{avg} = \frac{90 + 25}{2} = 57.5\ C$$

From Table,

$$C_p = 4.182 \frac{kJ}{kg * C}$$

Enthalpy Change,

$$Q_{In\ vapor} = \left(0.0171 \frac{kg}{s} * 0.2\right)\left(4.182 \frac{kJ}{kg * C}\right)(90C - 25C)$$

$$\mathbf{Q}_{\mathbf{In\ vapor}} = \mathbf{0.93\ kJ}$$

Case IV: 1% Vapor in Vacuum

Temperature,

$$T_{avg} = \frac{90 + 25}{2} = 57.5\ C$$

From Table,

$$C_p = 4.182 \frac{kJ}{kg*C}$$

$$\lambda = 2.364\ kJ/kg$$

Enthalpy Change,

$$Q_{out\ 1\%\ vapor\ in\ vacuum} = m_3 C_p \Delta T + \lambda$$

$$\mathrm{Q_{out\ 1\%\ vapor\ in\ vacuum}} = \left(0.0171\frac{\mathrm{kg}}{\mathrm{s}} * 0.2 * 0.01\right)\left(4.182\frac{\mathrm{kJ}}{\mathrm{kg} * \mathrm{C}}\right)(90\mathrm{C} - 25\mathrm{C}) + 2.364\ \mathrm{kJ/kg}$$

$$\mathbf{Q_{out\ 1\%\ vapor\ in\ vacuum} = 9.37\ J}$$

Case V: Fresh Water Exit

Temperature,

$$T_{avg} = \frac{28 + 25}{2} = 26.5\ C$$

From Table,

$$C_p = 4.185\frac{kJ}{kg * C}$$

Enthalpy Change,

$$Q_{out\ 99\%\ fresh\ water} = m_4 C_p \Delta T$$

$$\mathrm{Q_{out\ 99\%\ fresh\ water}} = \left(0.0171\frac{\mathrm{kg}}{\mathrm{s}} * 0.2 * 0.99\right)\left(4.185\frac{\mathrm{kJ}}{\mathrm{kg} * \mathrm{C}}\right)(28\mathrm{C} - 25\mathrm{C})$$

$$\mathbf{Q_{out\ 99\%\ fresh\ water} = 42.5\ J}$$

3.4 Product Subsystems and selection of Components

Since the prototype setup is going to be primarily utilizing saltwater as its medium, it becomes imperative to adopt components made of materials that can work well under those conditions without yielding. This is why stainless steel, specifically SS-316 parts, and components, were given priority. All measurements for pipes diameters and the board were approximately based on existing laboratory-sized setups at the University.

The heat exchanger, flash chamber, and condenser were given arbitrary dimensions and to be manufactured with SS-316 material. The other components were to be selected based on market availability and time conveniences, as well as subject to trial and error associated with testing the compatibility of the individual parts with one another.

The list of components used in designing the prototype with (projected) initial and final specifications are illustrated in Table 3. 7 below.

Table 3. 7: Initial and Final Specifications List

S No.	Primary Parts	Projected Specifications	Final Specifications
1.	Board Aluminium	1.5 m x 0.8 m	Marine Board (2x1)m
2.	Insulated Heat Exchanger Stainless Steel ss316	L = 5 cm, W = 5 cm, H = 10 cm	L = 5 cm, W = 5 cm, H = 10 cm
3.	Concentrator plate (*for heat exchanger*) Copper	D = 5 cm, t = 1 cm	D = 5 cm, t = 1 cm
4.	Insulated Flash Chamber Stainless Steel ss316	L = 10 cm, W = 10 cm, H = 20 cm	L = 10 cm, W = 10 cm, H = 20 cm
5.	Vacuum Pump	-	1/3 HP
6.	Insulated Condenser Stainless Steel ss316	L = 5 cm, W = 5 cm, H = 10 cm	L = 5 cm, W = 5 cm, H = 10 cm
7.	Stainless Steel ss316 Pipes	SS 316, 0.25 in	SS 316, 0.25 in
8.	Flow Meter/Rotameter	0 – 5 L/min	1 – 11 L/min
9.	Nozzle screw Stainless Steel ss316	1 mm	1.5 mm
10.	Feed Water Tank w/ Lid Glass	5L max. L = 21 cm, W = 16 cm, H = 23 cm	15.625 L L = W = H = 25 cm
11.	Product Water Tank Glass	half of feed tank size	L = W = H = 15 cm
12.	Brine solution Tank Glass	half of feed tank size	L = W = H = 15 cm
13.	Centrifugal/Peristaltic Pump	P = 0.5 HP, Q = 40 L/min, low H	P = 0.5 HP, Q = 40 L/min, H = 40 m
14.	Solar Parabolic Dish	D = 50 cm	D = 57.5 cm, 3.3 kg
15.	Flow Control Valve	1 pc x SS ¼”	3pcs x SS ¼”
16.	Temperature Sensor	-	0 – 1024^{o}C
17.	Pressure Sensor	-	P = 16 bars
18.	Stirrer Stainless Steel	Small Coffee stirrer	Magnetic stirrer
19.	**4 x** Stands (heat exchanger, condenser, mirror, flash chamber)	H = 0.5 m	N/A
20.	Pump Automatic Regulator	Automatic Regulator	Variable Frequency Drive
21.	Connectors	N/A	Brass
22.	Reducers	N/A	SS 316
23.	Union	N/A	SS 316

Parts such as connectors, reducers, and unions were not originally under consideration due to limited knowledge concerning the practicality of plumbing in our system but were understood to be of utility once consulted with by technicians specializing in the field.

3.5 Manufacturing and assembly (Implementation)

The manufacturing process started with sketching the system on an A4-sized paper. This allowed for visualization of the entire system put together. This step was crucial in determining and confirming measurements, such as pipe lengths and other components' dimensions. Subsequently, SolidWorks was used to design the major components of the system, such as the flash chamber, heat exchanger, and condenser. The SolidWorks models were then handed over to a specialist to manufacture the required parts at a metal workshop.

Moreover, the system required the manufacturing of glass tanks for the feed water, brine solution, and product water. These were manufactured at a glass workshop with careful consideration of the dimensions, including volume and thickness to ensure the system is optimized.

In addition to the glass tanks, a concave mirror, the centerpiece of the system, was required. Manufacturing the mirror required improvisation since no concave mirrors are found in the market. The mirror was constructed by purchasing a satellite dish and attaching small rectangular pieces of mirror to it.

For the board, waterproof marine wood was eventually utilized rather than its aluminum counterpart owing to costs as well as ease of workability with wood. A two planar structure was devised to house the prototype. The tubing was hammered onto the board with clamps to fix them in position and control the vibration occurring from the pump and water flow.

3.6 Economic Evaluation

3.6.1 Capital Expenses

After purchasing the entire equipment, a table was formulated to record the total costs. Table 3.11 below illustrates the final, as well as the approximated costs expected for various parts associated with this project's completion.

Table 3. 8: Equipment Cost Estimate

Component	Cost (SAR)
Centrifugal Pump	212.75
2 Pressure Gauge with Oil	287
3 Ball Valves ¼”	40.25
Tank Connector	25
Temperature Sensor	40
ESP32 Microcontroller Unit	46
Mirrors	250
Glass Tanks	330
25 Adapter Fittings	290
Concentrator Plate	32
Condenser, Heat Exchanger, and Flash Chamber	200
SS316 pipes (with threading)	340
Marine boards	185
Mirror stand	45
Total	**2323**

3.6.2 Operating Costs

Components such as vacuum pump, centrifugal pump, and VFD (variable frequency drive) will require external power to run and as such add to the operational costs.

<u>Energy Consumption Calculation</u>

$$P_{Consumed} = 1kW$$

Where P is the sum of all the power consumed by the parts in the system

Assuming the plant runs for 5 hours a day,

$$t = time\left({}^{h}/_{day}\right) = 5\,{}^{h}/_{day}$$

$$Energy\ ({}^{kWh}/_{day}) = E = P_{Consumed} * t$$

$$E = 1\,kW * 5\,{}^{h}/_{day} = 5\,{}^{kWh}/_{day}$$

<u>Energy Cost Calculation</u>

The electrical cost/kWh taken as per SEC guidelines for industrial use,

$$Cost\ per\ kWh = 0.18\,{}^{SAR}/_{kWh}$$

Cost per day,

$$Total\ Cost\ per\ Day = E * Cost/kWh$$

$$= 5\,{}^{kWh}/_{day} * 0.18\,{}^{SAR}/_{kWh}$$

$$\boldsymbol{= 0.9\,{}^{SAR}/_{day}}$$

Cost per year,

$$Total\ Cost\ per\ Year = (Total\ cost\ per\ day) * (365\,{}^{day}/_{year})$$

$$= 0.9\,{}^{SAR}/_{day} * 365\,{}^{day}/_{year}$$

$$\boldsymbol{= 328.5\,{}^{SAR}/_{year}}$$

The total operational costs amount to about 328.5 SAR yearly.

3.6.3 Cash Flow

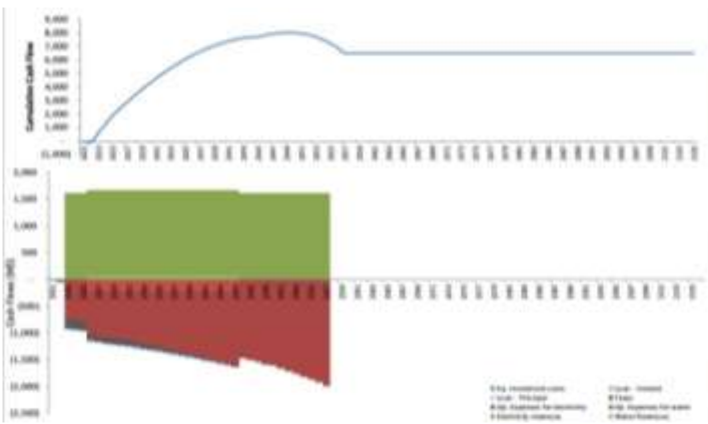


Figure 3. 8: Cash flow diagram

A simulation using the DEEP desalination software was run to generate the cash flow diagram for the prototype since all of the parts were not fully gathered yet. Figure 3.8 above represents a large-scale setup of our prototype that can be represented as a single unit desalination facility to provide for an entire city utilizing cleaner sources of energy.

3.6.4 Payback Period

The project was not intended to generate profit as its primary purpose was to research and develop a prototype that can be set as a benchmark for other larger-scale commercial desalination setups to follow suit, as a result of which the payback period cannot be computed.

3.6.5 Simple Cost

Table 3. 9: Simple Cost Analysis

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Capital Costs											
Equipment	10,000	0	0	0	0	0	0	0	0	0	0
Construction	45,000	0	0	0	0	0	0	0	0	0	0
Total	55,000	0	0	0	0	0	0	0	0	0	0
Operating Cost											

Energy	5,000	5000	5,000	5000	5,000	5000	5,000	5000	5,000	5000	5000
Electricity	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
Labour	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000	12,000
Insurance	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Taxes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Total	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000	27,000
Revenues											
Product 1	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000
Total	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000	45,000
Profits		18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000

Chapter 4: System Testing and Analysis

4.1 Experimental Setup, Sensors, and data acquisition system

In order to test the prototype out, measurement of the following parameters was imperative: temperature and pressure of the heated water flowing from the heat exchanger to the flash chamber and flow rate of the pumped water from the tank. To achieve this purpose, three sensors were utilized: a thermocouple sensor, 2 pressure gauges, and a rotameter.

4.1.1: Thermocouple Sensor

The thermocouple sensor was acquired to check and regulate the heat flowing through the feedwater in the setup. It is based on the principle of Seebeck effect, where voltage generated between the wires is then converted to temperature difference. The sensor module, programmed through a code, is connected to the computer through a wire which displays the variation in temperature of water over time. The temperature sensor is connected to the piping via a T-connector.

Table 4.1: Thermocouple Temperature Sensor Specs

Specs	Data
Standard	ANSI/ASTM E230
Interface	SPI
Test Temperature Range	0 ^{O}C – 1024 ^{O}C
Converter Temperature Resolution	0.25 ^{O}C
Operating Voltage Range	5.5V
Operating Current	50mA
Operating Temperature Range:	20 ^{O}C – 85 ^{O}C
Module Size	15mm * 28mm, with a 3mm dia screw hole

Figure 4.1: Thermocouple Sensor Setup

4.1.2: Pressure Gauge

Two glycerin pressure gauges were utilized throughout the setup to measure and compare the feedwater pressure drop at different points. One sensor was established between the flash chamber and heat exchanger, whereas the other gauge was connected at the pump output to study the pressure changes caused by the pump on the working fluid.

The pressure gauges were attached to the piping system via a T-connector made from the same material as the pipes.

Table 4. 2: Pressure Gauge Specs

Specifications	Data
Dial Size	2.5 in
Connection	SS ¼' NPT Bottom
Reading Range	0-15 psi
Engineering Standard	ASME B40.100

Figure 4.2: Pressure Gauge

4.1.3: Rotameter

This mechanical sensor, comprising of a regulating valve, is utilized in the system as a water flow meter with a measuring capacity of 0.3-3GPM or 1-11LPM. The rotameter is placed just beside the pressure gauge at the outlet of the feedwater pump.

Figure 4.3: Rotameter

Table 4.3: Testing Parameters

S. No.	Testing Parameters	Function
1.	Thermocouple Sensor	Measure temperature of water flowing through pipes
2.	Pressure Gauge	Measure the pressure drop inside pipes throughout the process
3.	Rotameter	Measure flowrate of pumped water

4.2 Results, Analysis and Discussion

Another important aspect of the project was to study the solar heat transferred from the parabolic mirror to the copper plate on the heat exchanger. In this experiment, the focal point of the mirror was directed to the heat exchanger for a period of time in broad daylight and temperatures were recorded. As Table 4.4 below indicates, the experiment was recorded for 2 hours from 7:45 am – 9:45 am, with the max temperature reaching 38.4 ^{O}C. The table was plotted into a graph where the temperatures were taken as a function of time. As can be seen from Figure 4.4 below, the result is an upward sloping curve as the temperature rises over time.

Table 4.4: Time Vs. Temperature Observation

Time (AM)	Temperature (^{O}C)
7:45	27.4
7:55	28.2
8:05	28.8
8:15	29.6
8:25	30.8
8:35	32.5
8:45	33.5
8:55	34.1
9:05	35.3
9:15	36
9:25	36.8
9:35	37.5
9:45	38.4

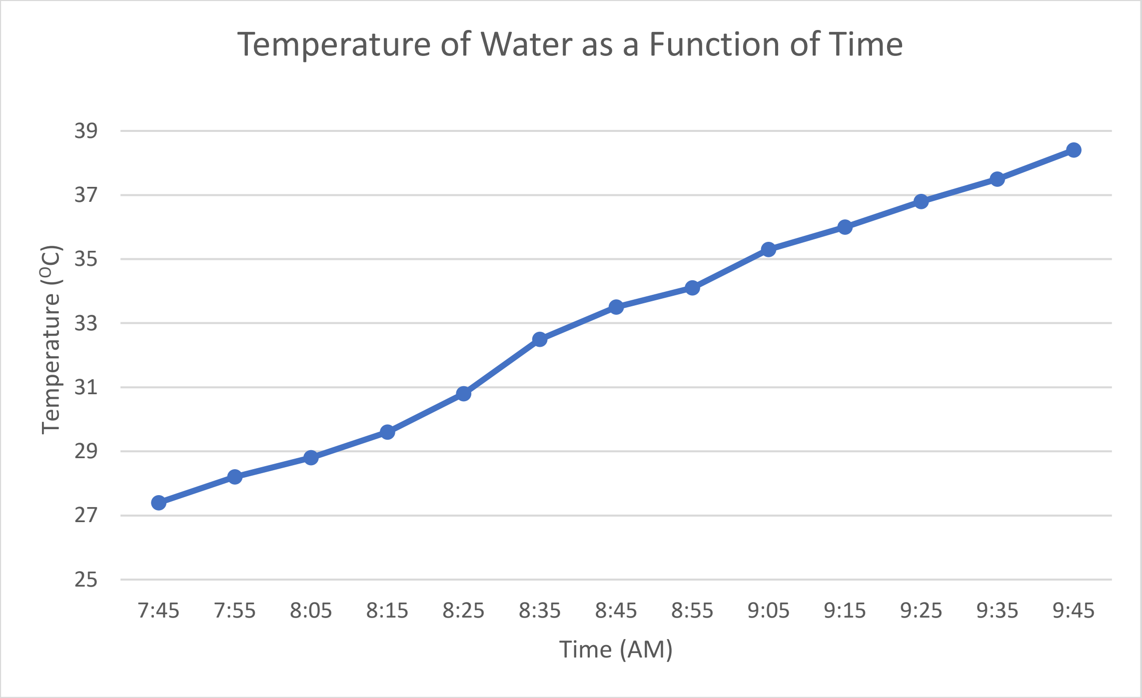


Figure 4.4: Plot of Water Temperature as Function of Time

Chapter 5: Project Management

5.1 Project Plan

Our project plan was split into two sections for clarity in objectives. We split it into a plan for the report, and a more specific plan for designing and building the prototype. This section will include a table for each, and which members were assigned as well, so there will be a total of four tables. Each person was assigned tasks based on their strengths so we can give our best work.

Table 5. 1: Tasks and their Durations

Tasks		Start	End	Duration
Chapter 1: Introduction		15-02-21	19-02-21	4 days
Chapter 2: Literature Review	Project Background	10-02-21	20-02-21	10 days
	Previous Work			
	Comparative Study			
Chapter 3: System Design	Design Constraints & Methodology	21-02-21	25-03-21	1 month
	Engineering Design Standards			
	Theory and Theoretical Calculations			
	Project Subsystems & Component Selection			
	Manufacturing & Assembly			
	Economic Evaluation			
Chapter 4: System Testing & Analysis	Experimental Setup, Sensors & Data	01-04-21	10-05-21	40 days
	Results, Analysis, & Discussion			
	Project Plan	14-05-21	15-05-21	1 day
	Contribution of Team Members			
	Project Execution Monitoring			

Chapter 5: Project Management	Challenges & Decision Making			
Chapter 6: Project Analysis	Lifelong Learning	06-05-21	10-05-21	4 days
	Impact of Engineering Solution			
	Contemporary Issues Addressed			
Chapter 7: Conclusion & Recommendation	Conclusion	13-05-21	15-05-21	2 days
	Future Recommendation			

Table 5. 2: Days taken to complete project deliverables

Project Deliverables	**Start Date**	**Days to Complete**
Group Formation	24-01-21	3
Initial Advisor Meeting	24-01-21	6
Design Conceptualization and Specification	24-01-21	3
Objectives	26-01-21	2
System Design, Diagram & Planning	07-02-21	`14
SolidWorks Sketches	14-02-21	5
Purchase Pipes, Pressure Gauges, Flow Meters	21-02-21	10
Manufacture Major Components	28-02-21	10
Theoretical Calculations	07-03-21	5
Prepare for Mid Presentation	21-03-21	5
Purchase Boards	28-03-21	1
Prototype Assembly	25-04-21	9
System Experimentation and Data Collection	09-05-21	2
Finalize Report	12-05-21	15
Brochure and Banner Design & Printing	12-05-21	5
Prepare for Final Presentation	16-05-21	4
Cost Analysis of Components	18-03-21	5

Table 5. 3: Members assigned to tasks

Tasks		Assigned Members
Chapter 1: Introduction		Ibrahim Alkhadra
Chapter 2: Literature Review	Project Background	Hashim Almomen
	Previous Work	Danyal Alawami
	Comparative Study	Ammar Hassan & Abdulrahman Rasheeduddin
Chapter 3: System Design	Design Constraints & Methodology	Ibrahim Alkhadra
	Engineering Design Standards	Ibrahim Alkhadra & Abdulrahman Rasheeduddin
	Theory and Theoretical Calculations	Danyal Alawami & Ibrahim Alkhadra
	Project Subsystems & Component Selection	Ibrahim Alkhadra & Abdulrahman Rasheeduddin
	Manufacturing & Assembly	Hashim Almomen
	Economic Evaluation	Ammar Hassan
Chapter 4: System Testing & Analysis	Experimental Setup, Sensors & Data	All
	Results, Analysis, & Discussion	
Chapter 5: Project Management	Project Plan	Ibrahim Alkhadra & Hashim Almomen
	Contribution of Team Members	Ibrahim Alkhadra
	Project Execution Monitoring	Ibrahim Alkhadra
	Challenges & Decision Making	Ibrahim Alkhadra
	Project Bill of Material & Budget	Ammar Hassan
Chapter 6: Project Analysis	Lifelong Learning	Ibrahim Alkhadra
	Impact of Engineering Solution	
	Contemporary Issues Addressed	
	Conclusion	

Chapter 7: Conclusion & Recommendation	Future Recommendation	Abdulrahman Rasheeduddin

Table 5. 4: Members assinged to project deliverables

Project Deliverables	Assigned Members
Group Formation	All
Initial Advisor Meeting	All
Design Conceptualization and Specification	All
Objectives	All
System Design, Diagram & Planning	All
SolidWorks Sketches	Hashim Almomen
Purchase Pipes, Pressure Gauges, Flow Meters	Ammar Hassan
Manufacture Major Components	Ammar Hassan & Hashim Almomen
Theoretical Calculations	Danyal Alawami
Prepare for Mid Presentation	All
Purchase Boards	Ammar Hassan
Prototype Assembly	Ammar Hassan & Hashim Almomen
System Experimentation and Data Collection	All
Finalize Report	Ibrahim Alkhadra, Hashim Almomen, & Abdulrahman Rasheeduddin
Brochure and Banner Design & Printing	Ibrahim Alkhadra & Abdulrahman Rasheeduddin
Prepare for Final Presentation	All
Cost Analysis of Components	Ammar Hassan

5.2 Contribution of Team Members

In this section we will list the percentages of contribution from each team member in their assigned tasks above.

Table 5. 5: Contribution of members on specific tasks

Tasks		Assigned Members	Cont. %
Chapter 1: Introduction		Ibrahim Alkhadra	100%
	Project Background	Hashim Almomen	100%
	Previous Work	Danyal Alawami	100%

Chapter 2: Literature Review	Comparative Study	Ammar Hassan & Abdulrahman Rasheeduddin	100%
Chapter 3: System Design	Design Constraints & Methodology	Ibrahim Alkhadra	100%
	Engineering Design Standards	Ibrahim Alkhadra	50%
		Abdulrahman Rasheeduddin	50%
	Theory and Theoretical Calculations	Danyal Alawami	80%
		Ibrahim Alkhadra	20%
	Project Subsystems & Component Selection	Ibrahim Alkhadra	50%
		Abdulrahman Rasheeduddin	50%
	Manufacturing & Assembly	Hashim Almomen	100%
	Economic Evaluation	Ammar Hassan	100%
Chapter 4: System Testing & Analysis	Experimental Setup, Sensors & Data	All	100%
	Results, Analysis, & Discussion		100%
Chapter 5: Project Management	Project Plan	Ibrahim Alkhadra	50%
		Hashim Almomen	50%
	Contribution of Team Members	Ibrahim Alkhadra	100%
	Project Execution Monitoring	Ibrahim Alkhadra	100%
	Challenges & Decision Making	Ibrahim Alkhadra	100%
	Project Bill of Material & Budget	Ammar Hassan	100%
Chapter 6: Project Analysis	Lifelong Learning	Ibrahim Alkhadra	100%
	Impact of Engineering Solution		100%
	Contemporary Issues Addressed		100%
Chapter 7: Conclusion & Recommendation	Conclusion	Abdulrahman Rasheeduddin	100%
	Future Recommendation		100%

Table 5. 6: Contribution of members on project deliverables

Project Deliverables	Assigned Members	Cont. %
Group Formation	All	100%
Initial Advisor Meeting	All	100%
Design Conceptualization and Specification	All	100%
Objectives	All	100%
System Design, Diagram & Planning	All	100%
SolidWorks Sketches	Hashim Almomen	100%
Purchase Pipes, Pressure Gauges, Flow Meters	Ammar Hassan	100%
Manufacture Major Components	Ammar Hassan	50%
	Hashim Almomen	50%
Theoretical Calculations	Danyal Alawami	100%
Prepare for Mid Presentation	All	100%
Purchase Boards	Ammar Hassan	100%
Prototype Assembly	Ammar Hassan	50%
	Hashim Almomen	50%
System Experimentation and Data Collection	All	100%
Finalize Report	Ibrahim Alkhadra	30%
	Hashim Almomen	20%
	Abdulrahman Rasheeduddin	50%
Brochure and Banner Design & Printing	Ibrahim Alkhadra	60%
	Abdulrahman Rasheeduddin	30%
	Hashim Almomen	10%
Prepare for Final Presentation	All	100%
Cost Analysis of Components	Ammar Hassan	100%

5.3 Project Execution Monitoring

Due to the COVID-19 Pandemic, a lot of our meetings in the first 2 months of the project were held online, especially because one of our members fell ill from the virus. When we were all sure we were healthy and not infected, we began to meet more often at the

University or at a group members house. Our meetings were weekly or bi-weekly depending on importance, held online or in person. Meeting with advisors were numerous in the first month but then shifted to once per month as we could communicate with them at any time on WhatsApp which made asking for advice and questions very easy. The Assessment class only met for the first two weeks of the semester.

Table 5. 7: Important dates of tasks and events

Activity/Event	**Time/Date**
Assessment Class	First Two Weeks of Semester
Meeting with group members	Weekly to Bi-Weekly
Meeting with advisor and co-advisor	Monthly
Report Writing	Daily
Finishing Design of prototype	10th April 2021
Midterm Presentation	8th April 2021
Building Prototype	12th April 2021
Test the System	12th May 2021
Finalizing Prototype	10th May 2021
Final Submission of Report	15th May 2021
Final Presentation	20th May 2021

5.4 Challenges and Decision Making

This section will serve to discuss some problems faced during the course of the project. We had to make some decisions to cut out initial ideas from the project and switch things around. The project was also stunted in terms of being able to meet consistently due to many different circumstances.

5.4.1 Problems with Meeting

Problems with group meetings arose due to a lot of factors. The first and largest factor was the current COVID-19 pandemic going on, which affected our ability to meet in person, especially when one of the group members fell ill from the virus. All of us being seniors also contributed to time constraints as we all had heavy class schedules with differing timings, so we would have to squeeze into any free time to meet up.

Another large factor in problems with group meetings was the semester being cut short due to Ramadan, so our classes and assignments became even more cramped, and we had to cancel some meetings or have much shorter meetings online to discuss the project. In the end, we chose to dedicate any free time possible to meeting up so we can get work done on the project.

5.4.2 Design Problems

Some design problems were faced in terms of the shape of the prototype. Initially, we thought the prototype would be built on an aluminum board, everything laid out horizontally with a bit of verticality. Once parts were acquired and we began to visualize assembly once more to acquire our board, we realized that most of the set up would not work horizontally and switched over to a vertical wood board which also changed design of the piping.

This design problem that arose also affected a side part of the project that was being researched and developed. This was the solar tracker. Ultimately, the solar tracker had to be scrapped as the vertical set up proved far too challenging to implement a proper solar tracker and the increased complexity left us with no time to actually implement it into the prototype. The difficulty was to the extent that this solar tracker can be considered a project on its own.

5.4.3 Testing and Device Issues

Although not many issues arose in testing and devices of the prototype, there was one issue that arose. Our pipes and water tanks experienced some leaking and were not sealed well enough, which required us to revisit the parts and ensure they were sealed properly.

5.5 Project Bill of Materials and Budget

Table 5. 8: Total Final Cost Table

Item	Cost (SAR)
Centrifugal Pump	212.75
2 Pressure Gauge with Oil	287
3 Ball Valves ¼”	40.25
Tank Connector	25
Temperature Sensor	40
ESP32 Microcontroller Unit	46
Research & Development for Solar Tracker(Programmer costs, parts for experimenting and testing)	494.75
Mirrors	250
Glass Tanks	330
25 Adapter Fittings	290
Concentrator Plate	32
Condenser, Heat Exchanger, and Flash Chamber	200
SS316 pipes (with threading)	340
Marine boards	185
Mirror stand	45
Labor Costs	700
Total	**3517.75**

Chapter 6: Project Analysis

This section will serve to discuss and analyze three important subjects for the project. These three analyses are Life-long Learning, Impact of Engineering Solutions, and the Contemporary Issues Addressed. The importance of these three are to understand the benefits achieved from such a project and how we have improved.

6.1 Life-long Learning

Working on this project really put our capabilities for research and learning to the test. From understanding how to apply CAD designs to real world situations, to working on software and experiencing the limitations of oneself, with the importance of having a group of members with a variety of knowledge. The tools we used in acquiring the following knowledge were Google, variety of forums and journals for programming, hardware, software, mechanical engineering, CAD, etc. We also enlisted the assistance of our advisor and lab technicians at PMU to help visualize what we have learned.

6.1.1 Hardware and Software Skills

To start with, we gained an immense amount of knowledge on hardware devices and software tools in our research and development for project goals. Initially, the project was to have an automated solar tracker so the mirror arrangement could move on its own, but this was ultimately scrapped after months of research, development, and testing due to time constraints, complexity, and the abilities of mechanical engineers with no experience in hardware and software development. Although the idea was scrapped, the information gained from it was extremely valuable as we can use it moving forward, in other work, where we must find group members who specialize in such skills or committing a lot more time due to inexperience. We also have a temperature sensor that is installed in the prototype and that itself required understanding of hardware and software.

The knowledge gained in hardware was about Microcontroller Units of many varieties and how to pick them. Arduino MCUs, ESP32s and all their variants, and much more Microcontrollers were considered in R&D. Learning that we should read the documentation on these microcontrollers and dig until we find the right one for our task is very important, because we want something tailored for efficient success in our idea.

Software tools could then be decided and learned about based on the MCU we chose. We had to begin to understand more C than we learned in our Introductory class on C, and also understand python. Beyond that, we learned the complexity of a Development Environment and how hard it is to set up a full environment on our own. The solution to this difficulty was given to us when researching and googling when we learned of IDE's (Integrated Development Environment).

With the use of an IDE known as Arduino IDE we could begin to develop and test our solar tracker. Using the help of a fellow programmer we created a rudimentary light tracker to attempt to create a proof of concept of our idea. Ultimately after more research, the idea was scrapped due to complexity of implementation into our project prototype, but the knowledge gained is extremely valuable and can be used in our futures.

6.1.2 Application of University Studies

Applying our knowledge from CAD classes, heat transfer(and prerequisite) classes, and design classes took some research as a lot of what we learned was theoretical or general knowledge, and now we had to apply it to practical solutions and specific knowledge. Designing parts in CAD took research and meeting with instructors at the university, creating our overall design was made easier through design software as we could visualize the 3D spaces used. Applying heat transfer formulae to create an ideal design and choose our parts instilled in us an ability to create practical solutions out of theoretical knowledge.

6.1.3 Project Management Skills

We also learned a great deal on management skills. Both time and project management skills. While project management skills were learnt differently by each member, as the team leader learned the most in that regard, time management was learned in equal amounts by all the group members. Project management skills such as delegating tasks, acknowledging people's specialties and skillsets, applying the knowledge in what to assign each member, and decision making (inclusive of making the best decision while also minimizing sacrifices but accepting those sacrifices) were all gained by the group as a whole. While the team leader had to learn all these, the group members had to learn how to communicate their thoughts and abilities to the team leader for an efficient group to be made.

An example would be our team writer communicating to the group and leader at the start of the project that his best skills are in writing and organizing and that he could take on any leftover work where others might need help, therefore he was assigned to put the most work in reports and presentations, and he was also assigned to be the main one to work on the solar tracker. Using this same example for decision making, with the decision of scrapping the solar tracker, it came down to a discussion and vote on what to do and understanding that we had to sacrifice the solar tracker so that the rest of our time and effort could be spent perfecting the project.

6.1.4 Time Management Skills

Time management is one we had a lot of experience with throughout our time at university, but we never truly understood its weight until we had to apply it to a semester long complex project such as this project. Mistakes were made along the way but ultimately we now know that time management is actually not meant to be extremely strict, and part of that management is creating leeway and flexibility in our schedules.

For example, we could dedicate one week to the design and fabrication of a heat exchanger, but leeway and flexibility comes in the possibility of assigning a 2nd task for the end of that week as design and fabrication might be much quicker or easier as initially thought; leeway and flexibility can also come in assigning more than a week due to possible failures or mistakes at the end of the 1st week, if the heat exchanger is not right for the job or breaks, we need more time to make adjustments. These small examples eventually expand into a much larger picture of considering multiple factors and creating a strong schedule of management to get the various jobs done.

6.2 Impact of Engineering Solutions

The impact of the project is hopefully meant to be a great impact. We hope to be able to help the economy and environment mainly, and with both being helped, the society will improve as a side effect.

6.2.1 Economic Impact

In terms of economic impact, currently efficient desalination can be very pricey and constant attempts are being made at creating cost effective desalination methods, so the impact of our project would be to create a desalination method that’s most expensive part will be to build our desalination system, which in itself is not very expensive, and running it is very cost effective. Most continuous costs will be maintenance and upkeep. As this is meant to be a very economical project, we can hope to benefit our government and country to boost the economy with home sourced fresh water that is cheap to make.

6.2.2 Environmental Impact

In terms of environmental impact, a lot of current desalination systems are based on fossil fuels, which are not good for the earth's climate and environment surrounding the systems. Our project is designed to use completely clean energy, where any powered systems, such as our sensors or vacuum pump, will be using clean energy. Thus our project can help shift the use of fossil fuels as energy for desalination systems to a cleaner source of energy, eventually creating a good impact for the environment and help in that regard.

6.2.3 Society Impact

The impact on society may not be a large impact, but with an impact on the economy of a country comes the benefit of the society of a country. We can hope that with an improvement in economy and environment can lead to an improvement of society, where people can experience a better economy, cleaner environment, easier access to water, and much more; easier access to water benefits all.

6.3 Contemporary Issues Addressed

Of many topics of interest and focuses on Saudi Arabia and the GCC, fresh water and shifting to clean renewable energy are two very important topics. Saudi Arabia can only rely on groundwater and desalinated water for self-sourced fresh and clean water. There is a need to shift fresh water sources to desalination methods to help with water usage and conservation in our groundwater supply. The problem is that desalination is a very expensive method for acquiring fresh water and is also bad for the environment due to the heavy reliance on fossil fuels.

Our project addresses both issues as it is meant to be a cheap method of desalination that can be automated with regular maintenance and upkeep that uses clean energy. Since Saudi Arabia wants to shift to clean renewable energy, our project's reliance on clean energy addresses that want and concern. At the same time, our project's ability to desalinate water for much cheaper than current methods helps the issue of requiring fresh water and improves on our current systems.

Chapter 7: Conclusions and Future Recommendations

7.1 Conclusions

The results indicate that a process as strenuous and cost prohibitive as desalination can indeed be tackled with an innovative approach, helping eventually phase out pollutive traditional gas-powered plants with renewables such as solar and wind. Of course, every technology comes with its own certain limitations. For our project purposes, it can include challenges like requiring clear skies and the presence of sun for the prototype to function, as well as being time intensive in waiting for the water to reach boiling temperatures.

Having considered all of that, CSP being an emerging eco-friendly technology means that further research & development will only accelerate its growth to a point where, in the near future, it can eventually replace fossil fuel plants and become a sustainable source for water-scarce countries, by combining renewable energy and desalination systems efficiently.

7.2 Future Recommendations

Throughout the process of building the prototype, many design specifications were compromised to make the system. The system that was designed is far from perfect, and in fact, has several flaws. Therefore, several things can be changed in order to enhance our system and improve it.

One important component of the system that could have been changed to make the system more optimal is the copper concentrator attached to the heat exchanger. The purpose of the concentrator is to attract the sun's heat and transfer it to the steel wall of the heat exchanger, which in turn will transfer the heat to the water. For more effective heat transfer, a thinner copper plate could have been used as the concentrator instead of the 1 cm thickness that was used in the prototype. This will reduce the amount of heat losses and ensure that more heat will reach the water in the heat exchanger.

Another component that was compromised in the prototype was the condenser. The condenser is supposed to convert the vapor leaving the heat exchanger into water by means of heat transfer from the vapor to the water running through it via a steel pipe. The condenser can be improved by adding coils to allow for more surface area to be in contact with the vapor. This will allow for more condensation, and therefore more product water.

Moreover, a solar tracker can make the system better by allowing the mirror to track the sun as it moves throughout the day. This solar tracker will act as the brain of the mirror, programmed to alter the angle of the mirror with time so it reflects more light onto the copper plate. This was in the initial plan until it was realized that it would make this prototype significantly more expensive and time consuming.

Lastly, although this does not improve the project, acrylic tanks could have been used instead of the glass tanks for the brine solution, product water, and feedwater. Acrylic tanks would have made the project less costly and would have also reduced the weight of the prototype.

To conclude, many things can be done to enhance the system and make it better as many shortcuts were taken during the process of this project to ensure the budget was not exceeded. Moreover, it is important to note that this project was intended to be lab-scale, to allow for ease of mobility and demonstration.

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Appendix A: Progress Reports

	SDP – WEEKLY MEETING REPORT
	Department of Mechanical Engineering **Prince Mohammad bin Fahd University**

SEMESTER:	**Spring**	**ACADEMIC YEAR:**	**2021**
PROJECT TITLE	**Design and Assembly of a Smart CSP Photocatalytic Desalination System with Pressure Modulation**		
SUPERVISORS	**Advisor:** Dr. Feroz Shaik, **Co-advisor:** Mr. Faizan Ahmed		

Month 1: February

ID Number	Member Name
201701335	Abdulrahman Rasheeduddin*
201800665	Ibrahim Alkhadra
201701619	Ammar Hassan
201401264	Hashim Almomen
201700096	Danyal Alawami

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	Purchasing of pump, tanks, connections, and sensors	Ammar	100%	
2	CAD model of flash chamber, fabricating concave mirror	Hashim	100%	
3	Literature Review and meet with the manufacturer to discuss system components.	Danyal	100%	
4	Introduction and Literature Review; Researching tracking system and compiling a list of parts	Ibrahim	100%	

List the tasks planned for the month of March and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
1	Overlook manufacturing of Condenser, Heat Exchanger and Flash Chamber	Ammar

2	Theoretical Calculations, manufacturing of nozzle and heat exchanger, economic evaluation of the project	Danyal
3	Editing of reports and preparing presentations, managing other tasks, and assisting in report writing and calculations	Abdulrahman
4	Tracking system integration in the mirror arrangement, working with a programmer for tracking system; main report writer	Ibrahim
5	CAD model of heat exchanger, mirror experiments and calculations	Hashim

- **To be Filled by Project Supervisor and team leader:**
- **Please have your supervisor fill according to the criteria shown below**

<u>Outcome MEEN4:</u>
an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts

Criteria	None (1)	Low (2)	Moderate (3)	High (4)
MEEN4A. Demonstrate an understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental and societal context	Fails to demonstrate an understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Shows limited and less than adequate understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Demonstrates satisfactory understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Understands appropriately and accurately the engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts

<u>Outcome MEEN5:</u>
an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives

Criteria	None (1)	Low (2)	Moderate (3)	High (4)
MEEN5A: Ability to develop team work plans and allocate resources and tasks	Fails to develop team work plans and allocate resources and tasks	Shows limited and less than adequate ability to develop team work plans and allocate resources and tasks	Demonstrates satisfactory ability to develop team work plans and allocate resources and tasks	Properly and efficiently makes team work plans and allocate resources and tasks

MEEN5B: Ability to participate and function effectively in team work projects to meet objectives	Fails to participate and function effectively in team work projects to meet objectives	Shows limited and less than adequate ability to participate and function effectively in team work projects to meet objectives	Demonstrates satisfactory ability to participate and function effectively in team work projects to meet objectives	Function effectively in team work projects to meet objectives
MEEN5C: Ability to communicate effectively with team members	Fails to communicate effectively with team members	Shows limited and less than adequate ability to communicate effectively with team members	Demonstrates satisfactory ability to communicate effectively with team members	Communicates properly and effectively with team members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)

#	Name	Criteria (MEEN4A)	Criteria (MEEN5A)	Criteria (MEEN5B)	Criteria (MEEN5C)
1	Ammar Hassan	4	4	4	4
2	Danyal Alawami	4	4	4	4
3	Hashim Almomen	4	4	4	4
4	Ibrahim Alkhadra	4	4	4	4

Comments on individual members

Name	Comments
Ammar Hassan	Working hard in getting the equipment for fabrication of the prototype model
Danyal Alawami	Working hard on theoretical calculations
Hashim Almomen	Working hard on design and fabrication of the prototype model
Ibrahim Alkhadra	Working hard on process control

	SDP – WEEKLY MEETING REPORT
	Department of Electrical Engineering **Prince Mohammad bin Fahd University**

SEMESTER:	**Spring**	**ACADEMIC YEAR:**	**2021**
PROJECT TITLE	**Design and Assembly of a CSP Photocatalytic Desalination System with Pressure Modulation**		
SUPERVISORS	**Advisor:** Dr. Feroz Shaik, **Co-advisor:** Mr. Faizan Ahmed		

Month : March

ID Number	Member Name
201701335	Abdulrahman Rasheeduddin*
201800665	Ibrahim Alkhadra
201701619	Ammar Hassan
201401264	Hashim Almomen
201700096	Danyal Alawami

List the tasks conducted this month and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	Overlook manufacturing of Condenser, Heat Exchanger and Flash Chamber	Ammar	100%	
2	Theoretical Calculations, manufacturing of nozzle and heat exchanger, economic evaluation	Danyal	100%	
3	Final editing of reports and preparing presentations	Abdulrahman	100%	
4	Solar Tracking system design, preparing presentation and scripts, fixing/cleaning calculations	Ibrahim	100%	
5	CAD model of heat exchanger, mirror experiments and calculations	Hashim	100%	

List the tasks planned for the month of April and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
1	Taking actual measurements between the parts in order to purchase the SS pipes and working on preparing the boards needed.	Ammar

2	Responsible for creating stands for components, contributing in assembly.	Hashim
3	Responsible for building and testing of solar tracker for mirror arrangement to integrate into the final prototype.	Ibrahim
4	Reworking literature review and working on feedback regarding energy calculations	Danyal
5	Overlooking report corrections, assigning tasks to members, as well as supervising piping setup for the prototype.	Abdulrahman

- **To be Filled by Project Supervisor and team leader:**
- **Please have your supervisor fill according to the criteria shown below**

Outcome MEEN4: an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
MEEN4A. Demonstrate an understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental and societal context	Fails to demonstrate an understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Shows limited and less than adequate understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Demonstrates satisfactory understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Understands appropriately and accurately the engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts

Outcome MEEN5: an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
MEEN5A: Ability to develop team work plans and allocate resources and tasks	Fails to develop team work plans and allocate resources and tasks	Shows limited and less than adequate ability to develop team work plans and allocate resources and tasks	Demonstrates satisfactory ability to develop team work plans and allocate resources and tasks	Properly and efficently makes team work plans and allocate resources and tasks

MEEN5B: Ability to participate and function effectively in team work projects to meet objectives	Fails to participate and function effectively in team work projects to meet objectives	Shows limited and less than adequate ability to participate and function effectively in team work projects to meet objectives	Demonstrates satisfactory ability to participate and function effectively in team work projects to meet objectives	Function effectively in team work projects to meet objectives
MEEN5C: Ability to communicate effectively with team members	Fails to communicate effectively with team members	Shows limited and less than adequate ability to communicate effectively with team members	Demonstrates satisfactory ability to communicate effectively with team members	Communicates properly and effectively with team members

Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)

#	Name	Criteria (MEEN4A)	Criteria (MEEN5A)	Criteria (MEEN5B)	Criteria (MEEN5C)
1	Abdulrahman	4	4	4	4
2	Danyal	4	4	4	4
3	Ibrahim	4	4	4	4
4	Ammar	4	4	4	4
5	Hashim	4	4	4	4

Comments on individual members

Name	Comments
Ammar	Working hard on obtaining pipes
Hashim	Working hard on project plan and assembly
Danyal	Working hard on reworking literature review
Abdulrahman	Working hard on report corrections and piping setup
Ibrahim	Working hard on building and testing the solar tracker

	SDP – WEEKLY MEETING REPORT
	Department of Electrical Engineering **Prince Mohammad bin Fahd University**

SEMESTER:	**Spring**	**ACADEMIC YEAR:**	**2021**
PROJECT TITLE	**Design and Assembly of a CSP Photocatalytic Desalination System with Pressure Modulation**		
SUPERVISORS	**Advisor:** Dr. Feroz Shaik, **Co-advisor:** Mr. Faizan Ahmed		

Month : April

ID Number	Member Name
201701335	Abdulrahman Rasheeduddin*
201800665	Ibrahim Alkhadra
201701619	Ammar Hassan
201401264	Hashim Almomen
201700096	Danyal Alawami

List the tasks conducted in April and the team member assigned to conduct these tasks

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	Taking actual measurements between the parts in order to purchase the SS pipes and working on preparing the boards needed.	Ammar	**100%**	
2	Responsible for creating stands for components, contributing in assembly.	Hashim	**100%**	
3	Responsible for building and testing of solar tracker for mirror arrangement to integrate into the final prototype.	Ibrahim	**100%**	
4	Reworking literature review and working on feedback regarding energy calculations	Danyal	**100%**	

List the tasks planned for the month of May and the team member/s assigned to conduct these tasks

#	Task description	Team member/s assigned
1	Compiling and editing final report and ensuring smooth task management.	2
2	Final Presentation Submission	All

3	Banner and Brochure	All
4	Final Report Submission	All

- **To be Filled by Project Supervisor and team leader:**
- **Please have your supervisor fill according to the criteria shown below**

Outcome MEEN4: an ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
MEEN4A. Demonstrate an understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental and societal context	Fails to demonstrate an understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Shows limited and less than adequate understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Demonstrates satisfactory understanding of engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts	Understands appropriately and accurately the engineering professional and ethical standards and their impact on engineering solutions in global, economic, environmental, and societal contexts

Outcome MEEN5: an ability to function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
MEEN5A: Ability to develop team work plans and allocate resources and tasks	Fails to develop team work plans and allocate resources and tasks	Shows limited and less than adequate ability to develop team work plans and allocate resources and tasks	Demonstrates satisfactory ability to develop team work plans and allocate resources and tasks	Properly and efficently makes team work plans and allocate resources and tasks
MEEN5B: Ability to participate and function effectively in team work projects to meet objectives	Fails to participate and function effectively in team work projects to meet objectives	Shows limited and less than adequate ability to participate and function effectively in team	Demonstrates satisfactory ability to participate and function effectively in team work	Function effectively in team work projects to meet objectives

		work projects to meet objectives	projects to meet objectives	
MEEN5C: Ability to communicate effectively with team members	Fails to communicate effectively with team members	Shows limited and less than adequate ability to communicate effectively with team members	Demonstrates satisfactory ability to communicate effectively with team members	Communicates properly and effectively with team members

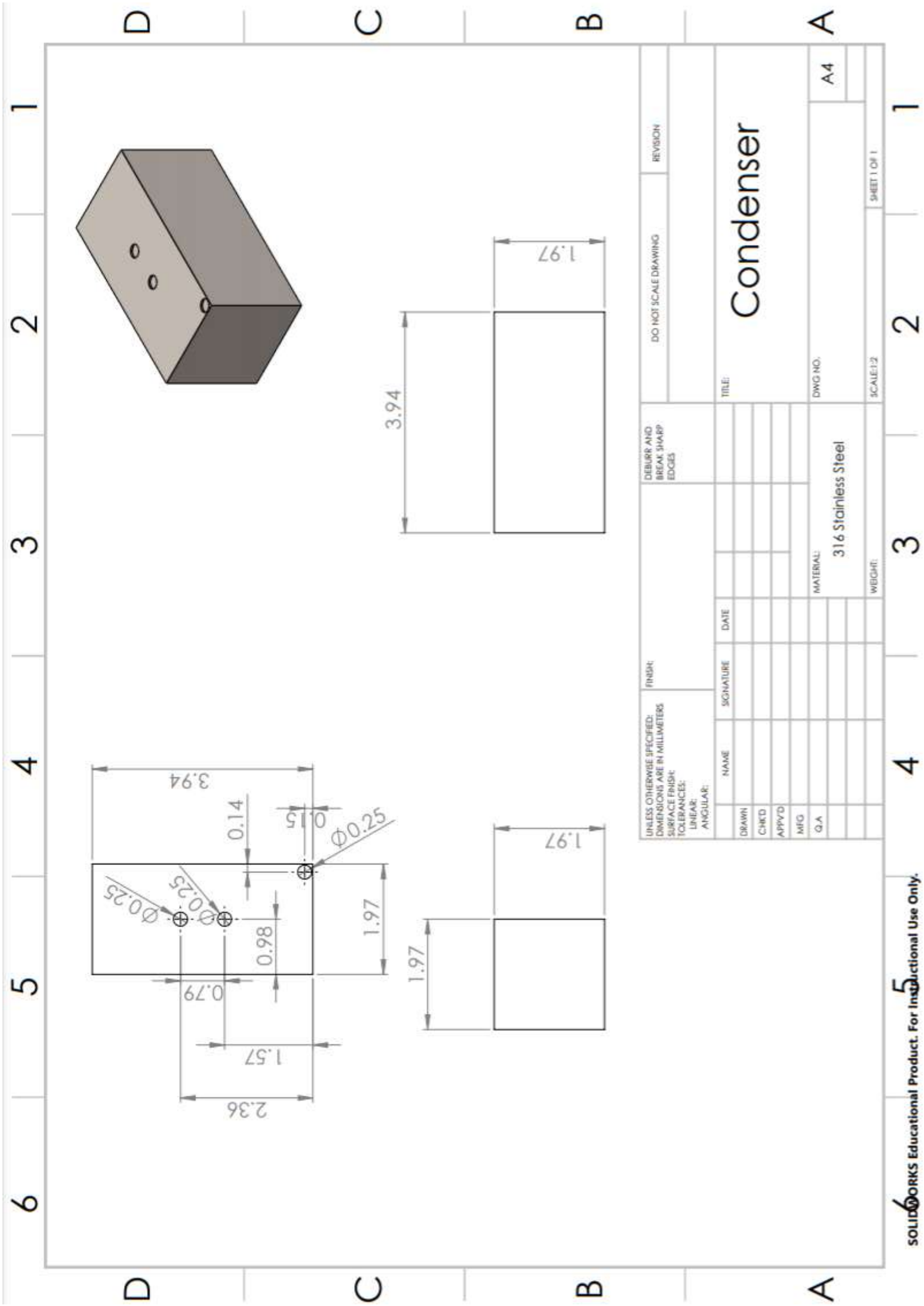
Indicate the extent to which you agree with the above statement, using a scale of 1-4 (1=None; 2=Low; 3=Moderate; 4=High)

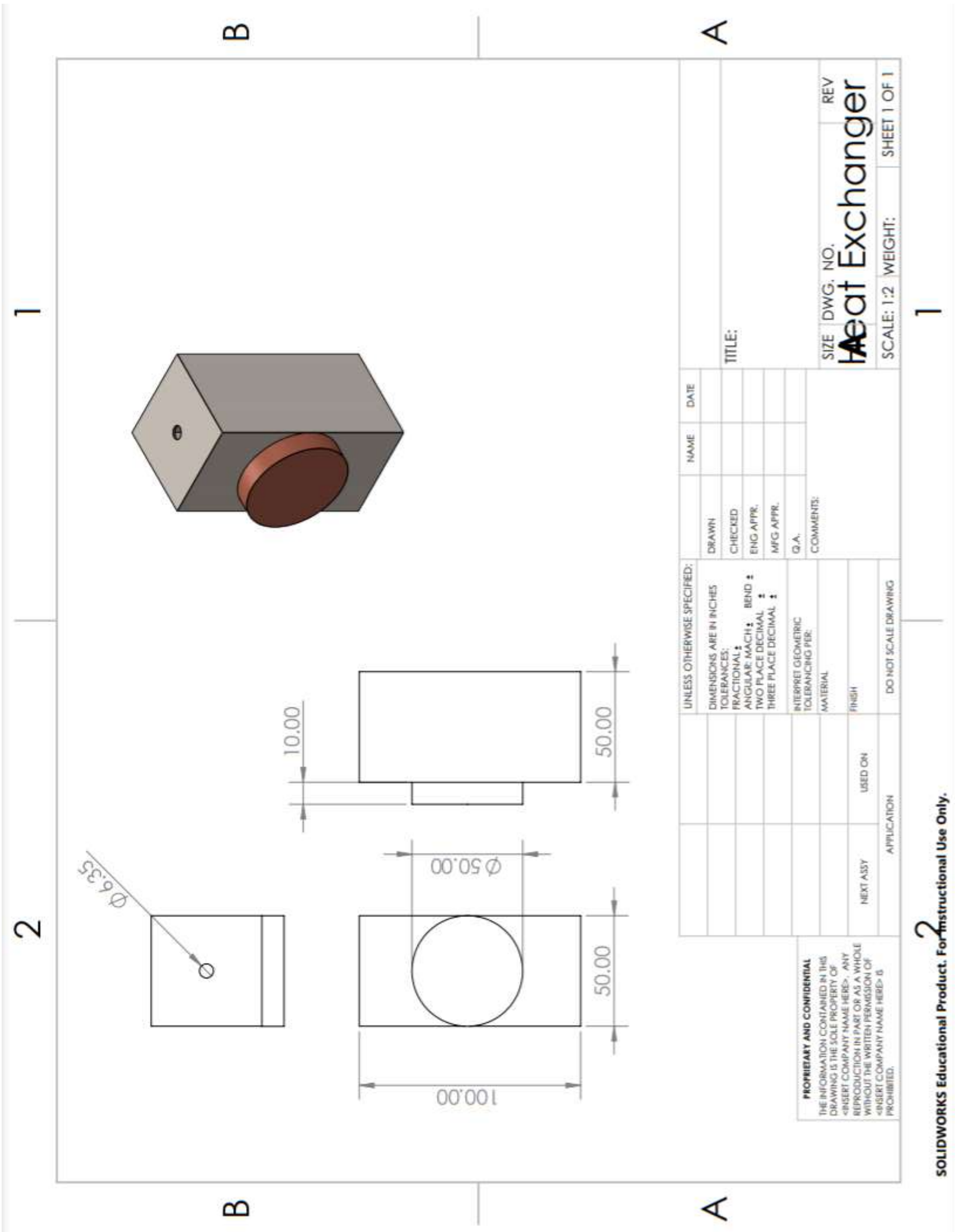
#	Name	Criteria (MEEN4A)	Criteria (MEEN5A)	Criteria (MEEN5B)	Criteria (MEEN5C)
1	Abdulrahman	4	4	4	4
2	Danyal	4	4	4	4
3	Ibrahim	4	4	4	4
4	Ammar	4	4	4	4
	Hashim	4	4	4	4

Appendix B: Engineering standards (Local and International)

Part	**Engineering Standard**	**Details**
Pipe	UNS S31600	¼", Sch 40
Ball Valves	UNS S31600	D=0.43mm, L=2.02mm
Pipe Union	ACI Grade CF8M (316)	Wt.=0.086kg
Condenser	UNS S31600	L = 5 cm, W = 5 cm, H = 10 cm
Heat Exchanger	UNS S31600	L=5 cm, W=5 cm, H=10 cm
Flash Chamber	UNS S31600	L = 10 cm, W = 10 cm, H = 20 cm
Connector	FMSI Universal	Brass, 1" dia
Thermocouple Sensor	ASTM E230	0 ^{O}C – 1024 ^{O}C, 5.5V, 50mA
Pressure Gauge	ASME B40.100	1 bar

Appendix C: CAD drawings

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REV
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SCALE: 1:2
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SHEET 1 OF 1
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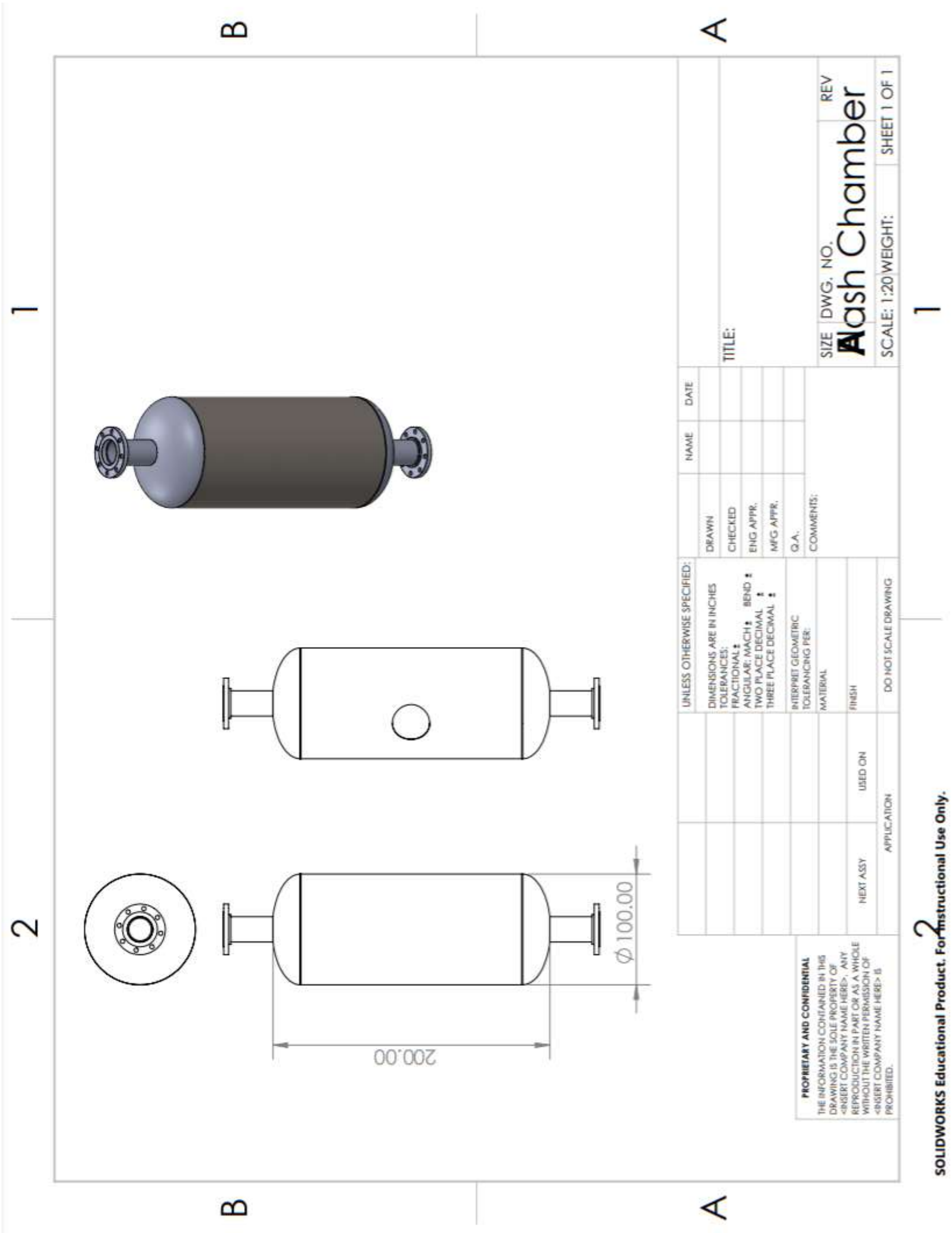

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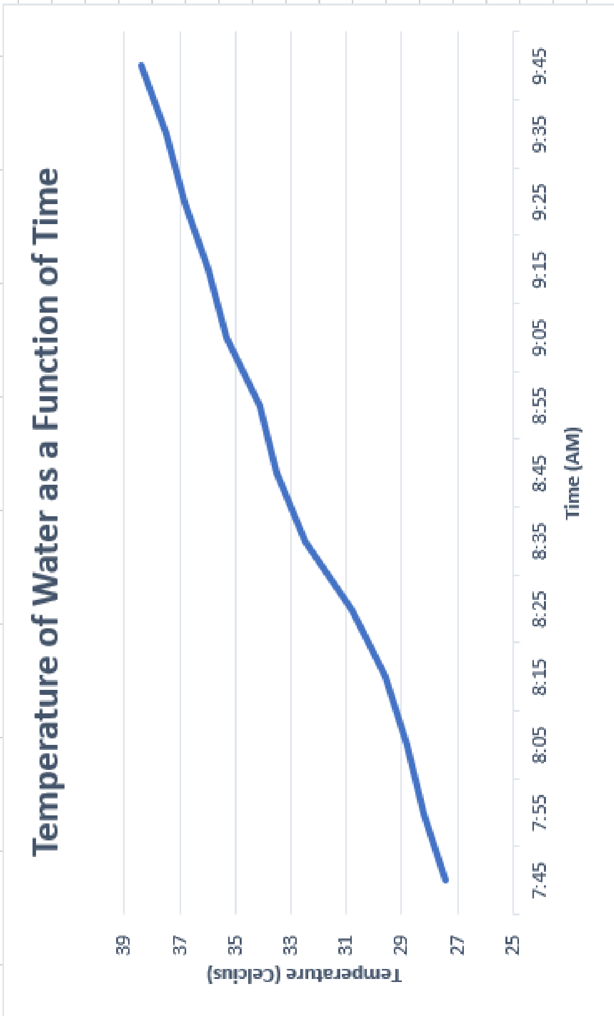
Appendix D: Datasheets



Time (AM)	Temperature (Celcius)
7:45	27.4
7:55	28.2
8:05	28.8
8:15	29.6
8:25	30.8
8:35	32.5
8:45	33.5
8:55	34.1
9:05	35.3
9:15	36
9:25	36.8
9:35	37.5
9:45	38.4

Appendix E: Program Codes

Thermocouple Sensor code for Arduino:

```
#include "max6675.h"

#include <SPI.h>

int thermoDO = 4;

int thermoCS = 5;

int thermoCLK = 6;

MAX6675 thermocouple(thermoCLK, thermoCS, thermoDO);

void setup() {

  Serial.begin(9600);

  Serial.println("Solar Desalination");

  delay(500);

}

void loop() {

  // basic readout test, just print the current temp

   Serial.print("C = ");

   Serial.println(thermocouple.readCelsius());

   Serial.print("F = ");

   Serial.println(thermocouple.readFahrenheit());

   // For the MAX6675 to update, you must delay AT LEAST 250ms between
reads!

   delay(2000);

}
```

Appendix F: Operation Manual

In order to run the prototype, following procedures should be undertaken:

- Place the mirror such that it angles the sunlight onto the copper plate attached to the heat exchanger.
- Connect the pump, VFD, and the vacuum pump to a 220V external power supply and switch them on.
- Start the VFD by setting a frequency value of 30 Hz, which sets off the centrifugal pump and water starts flowing through the pipes.
- Wait for salt water to get heated in the heat exchanger as the CSP process takes effect.
- Once steam starts collecting in the flash chamber, open the discharge valves to collect the fresh water and brine solution from the condenser and heat exchanger outlets, respectively.

Running the code:

- Connect the laptop to the temperature sensor via a USB cable and upload the code.

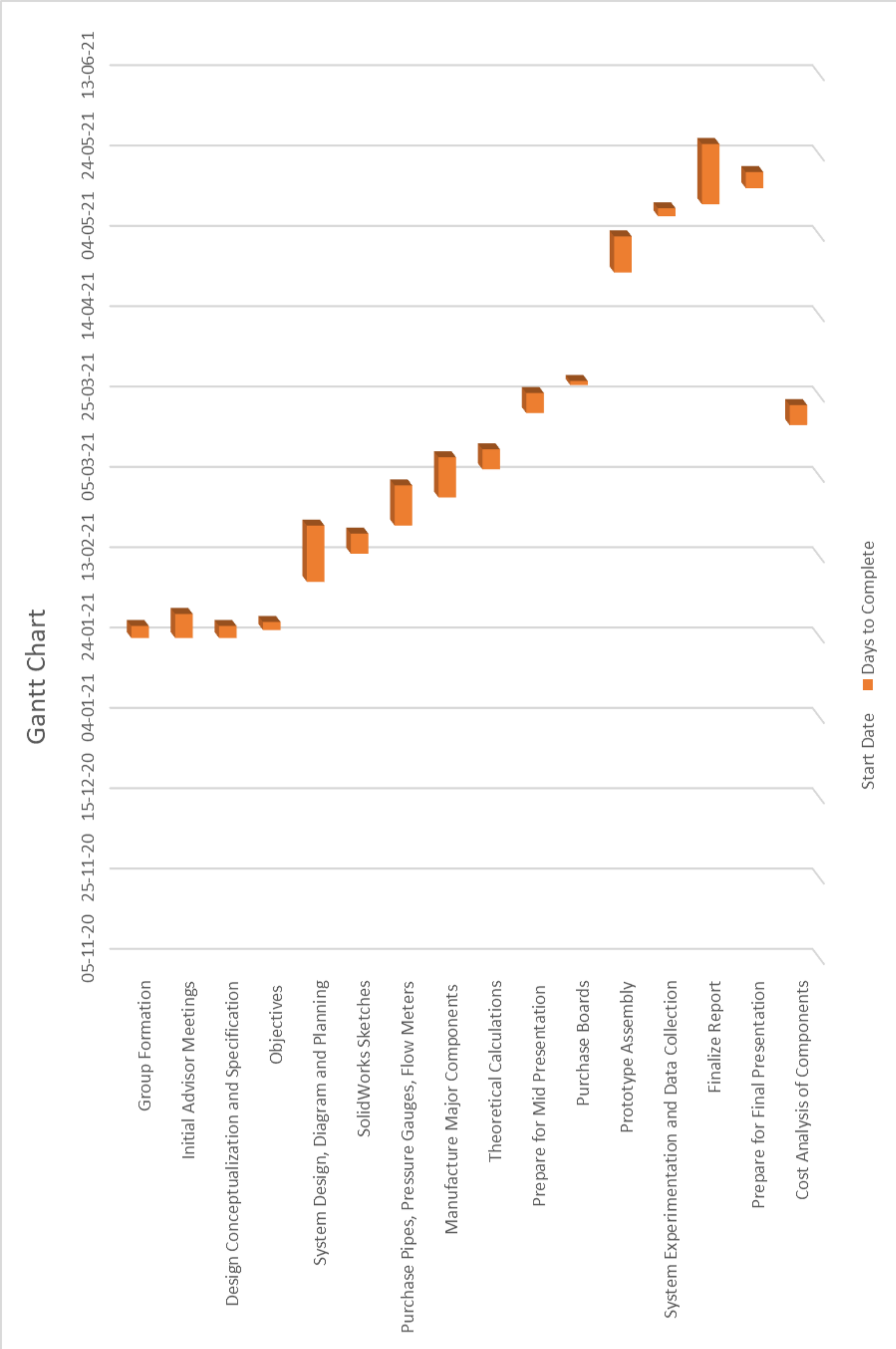
Following outcomes are to be expected:

- Pressure drop across the centrifugal pump and heat exchanger is observed on the pressure gauges.
- Temperature gradually touches above 60^{o}C and pressure from the pump reduces water to saturated steam.
- Steam gets flashed in the vaporizing chamber and gets condensed to clean water through the condenser.

Appendix G: Gantt Chart

PRINCE MOHAMMAD BIN FAHD UNIVERSITY
College of Engineering
Department of Mechanical Engineering

Project Deliverables	**Start Date**	**Days to Complete**
Group Formation	24-01-21	3
Initial Advisor Meetings	24-01-21	6
Design Conceptualization and Specification	24-01-21	3
Objectives	26-01-21	2
System Design, Diagram and Planning	07-02-21	14
SolidWorks Sketches	14-02-21	5
Purchase Pipes, Pressure Gauges, Flow Meters	21-02-21	10
Manufacture Major Components	28-02-21	10
Theoretical Calculations	07-03-21	5
Prepare for Mid Presentation	21-03-21	5
Purchase Boards	28-03-21	1
Prototype Assembly	25-04-21	9
System Experimentation and Data Collection	09-05-21	2
Finalize Report	12-05-21	15
Prepare for Final Presentation	16-05-21	4
Cost Analysis of Components	18-03-21	5


Gantt Chart
05-11-20
25-11-20
15-12-20
04-01-21
24-01-21
13-02-21
05-03-21
25-03-21
14-04-21
04-05-21
24-05-21
13-06-21
Group Formation
Initial Advisor Meetings
Design Conceptualization and Specification
Objectives
System Design, Diagram and Planning
SolidWorks Sketches
Purchase Pipes, Pressure Gauges, Flow Meters
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Theoretical Calculations
Prepare for Mid Presentation
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Finalize Report
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Start Date
Days to Complete