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PRINCE MOHAMMAD BIN FAHD UNIVERSITY

College of Engineering

Department of Mechanical Engineering

Spring 2018-2019

Senior Design Project Report

Project Title: Concentrated Solar Power Plant

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

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Abstract

This project is not only beneficial in terms of its reduced cost. Solar system energy uses an energy source (the sun) that is consistently available especially in a region like Saudi Arabia. It will be a clean source of energy and will not do damage to the environment and to the nature. Furthermore, it will not harm our earth, and since it uses renewable energy, it will last forever.

The movement for energy independence coupled with aggressive renewable energy goals and government investment incentives (2030 vision) has led the power industry to develop efficient and reliable sources of renewable power. In a power tower system, a central Solar Receiver Steam Generator is surrounded by a field of mirrors that focus and concentrate sunlight onto the receiver tubes. The energy from the sunlight is used to generate and superheat steam for electric production.

Acknowledgement

We would like to thank our advisor Dr. Aymen Jendoubi for his support and continuous help in our prototype and report, also we like to thank Dr. Bouchaib for his support and guidance that helped us achieve our senior project, also we would like to thank and express our sincere gratitude to the dean of the collage of engineering Dr. Jamal Nyfeh and the dean of the mechanical engineering department Dr. Faramarz Djavanroodi for their support and providing us with the best working and studying environment.

List of Acronyms (Symbols) used in the report

CSP	Concentrated Solar Power
CAD	Computer Aided Design
Q_{emit}	Radiation emitted the surface Surface
A_s	Surface Area
σ	The Stefan-Boltzmann Constant
Ts	Surface Temperature
η	Efficiency
w_t	Work of the turbine
w_p	Work of the pump
q_{in}	Heat entering the system
$(w_t)_s$	Work of the turbine shifted
h	Enthalpy
h_s	Enthalpy Shifted
$(w_P)_s$	Work of the pump shifted
m	Mass flow rate
A	Area of the pipe
V	Velocity
ρ	Density
F	focal length measured by hand
D_{ap}	Diameter of plate of parabolic
θ	Angle of the parabolic dish
A	Focal Point
P	Pressure
Z	Hieght
h_L	Head Loss
h_{Lt}	Head Loss of Turbine
h_{Lp}	Head Loss of Pump

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1.1. Project Definition

In 19th century, revolution of industries has started, these industries require a huge amount of energy. Based on the need of energy, there was shortage in the resources that were easily acquired such as coal. This caused many conflicts and wars which made people search for another source of energy. At that time, oil was discovered and considered one of the main sources of power. As time passes, innovation and knowledge had improved and discovered that these sources of energy had bad environment effect and they are limited energy sources.

After a period of time a new renewable clean energy sources are innovated such as dams and wind and solar energy. Solar energy uses solar panels which can't withstand high temperatures because it reduces its efficiency, so they innovate a new method that can withstand high temperatures which is concentrated solar power (CSP)

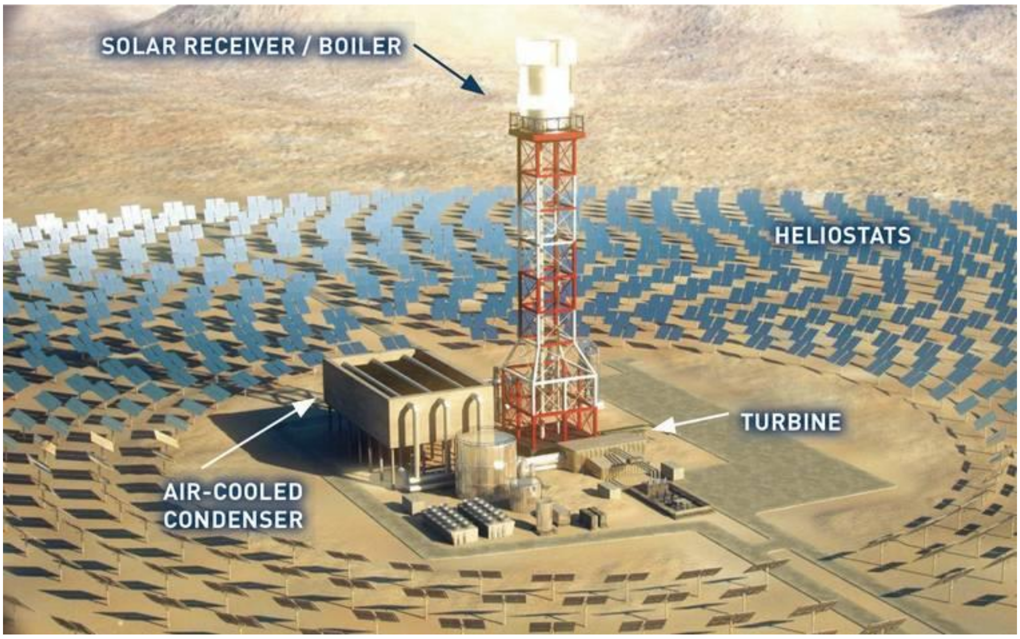

Figure 1: Example of CSP plant

CSP uses concentrated sunlight to generate energy. The CSP plant consists of 5 main parts which are, boiler, condenser, turbine, reflecting mirrors and an electric generator. The reflecting mirrors concentrate direct sunlight to the boiler where the liquid is heated and turned into steam due to high temperatures, the steam then goes to the turbine where it rotates it and the turbine rotates the electric generator shaft thus producing energy. Once the energy is produced, the steam that leaves the turbine goes to the condenser where it is turned back into liquid and the process starts again. This power plant is considered one of the cleanest and renewable power sources.

1.2. Project Objectives

CSP technology has been into many development and upgrades throughout the time. The following are the objectives of the project:

- To create an initial prototype of the CSP system with a roughly design which can be used for initial tests.
- To make the energy generated from the system renewable.
- To ensure that the system can withstand high temperatures.

1.3. Project Specification

- Prototype of CSP system will take place in 1.5m length and 1.5m width.
- CSP system contain of reflectors, boiling tower, turbine, cooling system and electrical generator.
- CSP system reflects the sun light by the reflectors to a boiler on a tower and use the heat reflected to generate electricity by turbine and electrical generator.
- Hot weather means higher temperature which make CSP system produce higher amount of energy

1.4. Application

Concentrated solar power system has one main usage, which is converting the heat gained from sunlight to electricity. Its best application is the large desert areas where the temperatures is very high. The larger the area, the and faster electricity will be produced due to the large number of mirrors.

Chapter 2: Literature Review

2.1 Project Background

2.2 Previous Work

2.3 Comparative Study

2.1. Project Background

A power station, additionally alluded to as a power plant, is an industrial facility to generate electric power. Most power stations contain one or more generators and a rotating machine that converts mechanical energy into electrical energy. The relative motion between a magnetic field and a conductor creates an electrical flow that creates current. The power source hardness to turn the generator differs widely. Most power stations on the planet use fossil fuels to burn them such as coal, oil, and natural gas to generate power. Others use nuclear energy, yet there is an expanding utilization of cleaner renewable sources such as solar, wind and hydroelectric.

The innovation behind hydroelectric energy is genuinely simple, however restraining the intensity of water is a challenge. Hydro control plants are costly to fabricate, however it is not complicated to operate. The hydroelectric energy is considered one of the most useful, renewable and largest energy sources in the world with a 17.5% of the world's electricity. [1] Dams produce reservoirs that allow for a larger heights of fall and conjointly serve to manage energy withdrawal. Water is held and used once the demand for electricity is the greatest. The water is directed from the reservoir which is on a higher level to a lower level through tunnels, going through a turbine on the way. The turbine used depends on the size of the hydroelectric power plant, distance of fall and other alternatives. Francis and Kaplan turbines are the most common types being used in the hydroelectric power plants with average heights of fall. Hydro power plants with longer distances of fall, mostly use a Pelton turbine. A generator then converts the mechanical energy which is generated by rotating the turbine shaft into electrical energy, a transformer will increase the voltage and also increase the electricity that is transmitted to the grid. [2]

Figure 2: Hydroelectric Power plant

The hydroelectric power plant has advantages and disadvantages. Some of these advantages are that the hydroelectric power plant is renewable, cause no pollution, reliable, flexible and safe. On the other hand, the disadvantages of the hydroelectric power plant are that it can cause environmental issues, expensive, it wouldn't work when there is drought and it has limited reservoirs. [3]

Wind power could be a clean energy supply that may be relied on for the upcoming future. A turbine creates reliable, efficient, pollution free energy. it's cheap, clean and property. One turbine is sufficient to get energy for a house. as a result of wind could be a supply of energy that is renewable, wind turbines produce power while not exploitation fossil fuels, while not manufacturing greenhouse gases or radioactive or waste material. [4]

Figure 3: Wind Turbine

Although alternative energy plants have comparatively very little impact on the setting compared to fuel power plants, there's some concern over the noise created by the rotor blades, aesthetic impacts, and birds and buggy having been killed by flying into the rotors. Most of those issues are resolved or greatly reduced through technological development or by properly siting wind plants. [5]

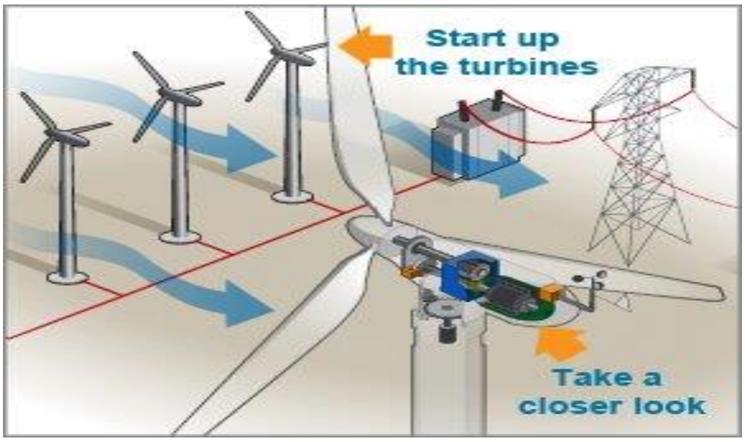

Figure 4: Wind Turbine Arial View

This aerial demonstration of a turbine plant shows how a bunch of wind turbines will build electricity for the utility grid. The electricity is distributed through transmission and distribution lines to homes, businesses, schools, and so on. read the turbine animation to determine however a turbine works or take a glance within. [6]

Coal is one of the most important sources used to generate electricity in the world. Nowadays coal it is used to generate around 40% of electricity in the world. Coal fired power plants are a kind of power plant that create use of the combustion of coal so as to produce electricity. Countries like South Africa use coal for 94% of their electricity and China and India use coal for 70-75% of their electricity desires. the utilization of coal provides access to electricity to people who antecedently did not have it, that helps to extend quality of life and scale back financial condition in those regions, but it produces giant quantities of various pollutants that reduces air quality and contributes to global climate change.

Coal laid-off power plants follow the temperature unit cycle so as to finish this method. Since they need many water to be circulated during this cycle, coal power plants must be set close to a body of water. The method of coal laid-off plants is seen below in the Figure

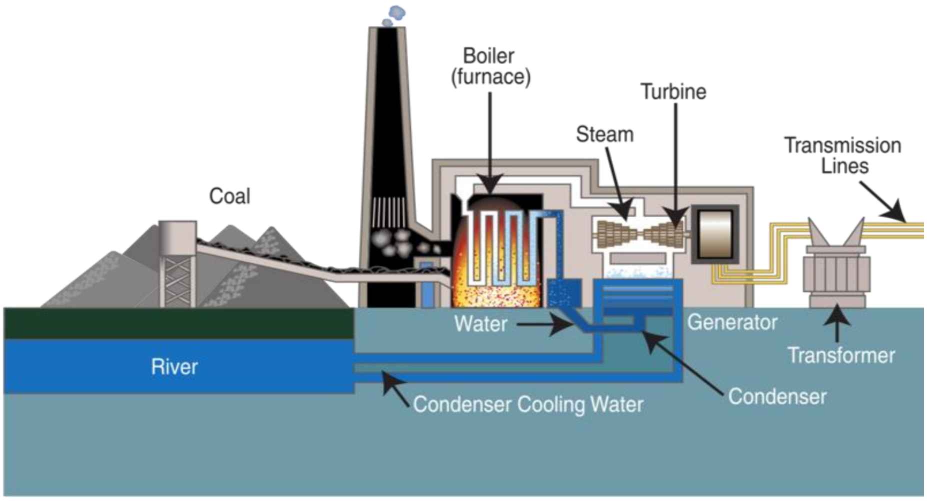

Figure 5: Coal Laid-off Plants

The disadvantages of the coal laid off plants are that it causes Environmental Impacts, Air pollution and Water Use/Pollution. [7]

Oil and gas are the world's primary sources of energy for many years. they need enabled advances all told sectors of the economy, from residential lighting and heating to transportation and industrial producing. the utilization of those fuels is additionally the most supply of greenhouse gases. In last decades the uses of the gas to provide electricity for private and business are increased to twenty-three percent worldwide. [8][9]

Natural gas power plants generate electricity by burning natural gases. There are many varieties of fossil fuel power plants that all generate electricity however serve totally different functions. All-natural gas plants use a gas turbine, together with a stream of air, that combusts and expands through this rotary engine inflicting a generator to spin a magnet, creating electricity. there's waste heat that comes from this method, thanks to the second law of physics. Some fossil fuel plants use this waste heat in addition. [10][11]

Natural gas power plants are low-cost and fast to make. They even have high thermodynamically efficiencies compared to different power plants. matter than coal and oil on the opposite hand, fossil fuel plants have considerably higher emissions than a nuclear energy plant. this suggests that air quality tends to boost. once change to fossil fuel plants from coal plants—but nuclear energy will even a lot of to boost air quality. [10][11]

As with all other sources of power it has advantages and disadvantages, the advantages are that does not pollute the bottom od the ocean and it is widely available. On the other hand, the disadvantages are that it is not renewable and it is toxic and flammable. [12]

Solar photovoltaic (PV) is a system that absorbs the heat from the sunlight and convert it to electricity. The larger the area the more electricity will be produced. What benefits from that is reducing the need for fossil fuel generation, in other words, the reliance on the renewable energy. In the past, it was not clear how PV systems combine with greenhouse gases (production wise). With the development of science, combining these two saved within 0.7 to 2 years of use of grid-connected operation, depending on the amount of sunlight. [13][14]

The Concentrated Solar Power (CSP) is a technology that uses mirrors to focus the sunlight energy and converts it into heat that creates steam to rotate a turbine that is connected to an electrical generator via a shaft therefore it starts to generate electricity. [15]

CSP technology consists of a combination of two parts, one that collects solar energy and coverts it to heat and another one is to convert the heat energy absorbed into electrical energy. This renewable source of energy is used in countries that are exposed to a large amount of sunlight. The United States it self produces from 11-21 GW of electricity using the CSP, they use it to reduce the use of fossil fuels plant since the CSP is cleaner, renewable and reduces carbon emissions. [15] [17]

Unlike PV systems that are shown in television commercials or seen on the rooftops of houses, the CSP technology needs a large area of land and uninterrupted amount of sunlight.

Therefore, the mostly common users of the CSP systems are industries or governments with access to large areas of desert land. [16]

Figure 6: Ivanpah CSP Plant

The CSP systems has three main types of systems which are, trough systems, power tower systems and dish/engine systems. [15]

Trough systems are large parabolic (U-Shaped) reflectors that have oil filled pipes called receivers that are located at the center of the reflector. As shown in figure (7). The reflectors are located toward the sun and the focused sunlight hits the receivers therefore heating the oil inside up to 400 degrees Celsius. The heated oil then is used to heat up the water which generate steam that drives the turbine that is connected to the electrical generator therefore generating electricity. [15]

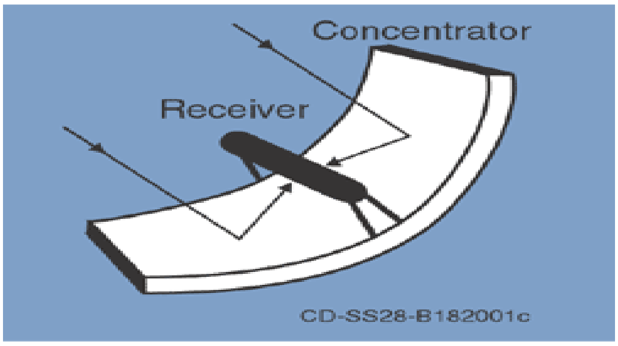

Figure 7: Trough System

Power Tower Systems (PTS), also known is central receivers uses a large amount of flat heliostats (mirrors) reflectors to focus the sunlight onto the receiver. As shown in figure

(8). The receiver is located on top of a tall tower in order to heat up the fluid inside, where temperatures can reach up to 565 degrees Celsius. The hot fluid inside the receiver can be used immediately to generate electricity by driving the turbine to drive the electric generator or it can be stores for later use. [15]

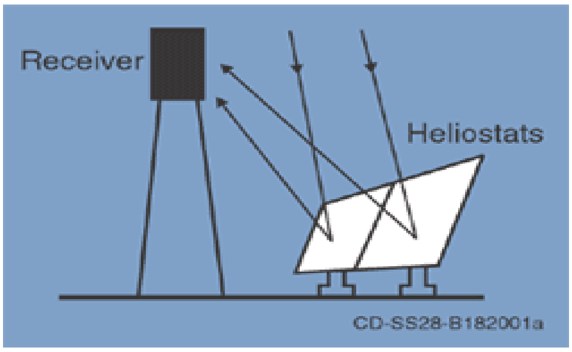

Figure 8: Power Tower System

Dish systems use mirror dishes that are large in size to concentrate the sunlight onto a receiver. As shown in figure (9). The receiver is located at the focus point of the dish. To get the maximum benefit from the sun, the dish has a controller that controls it motion depending on where the most amount of sunlight is. The engine which is the receiver contains gas which runs through the tubes that run along the engine's piston cylinders. As the sunlight hits the receiver, the gas inside the tubes heats up and expands in which it moves the pistons which are connected to the electric generator though a crankshaft, therefore generating electricity. [15]

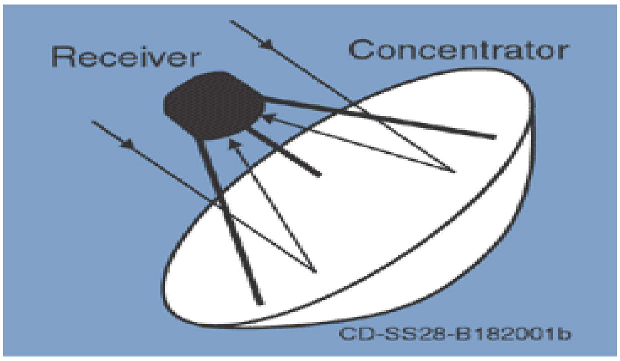

Figure 9: Dish System

The CSP systems has pros and cons, some of the pros are that it is easy to focus the sunlight in a specific point and generate heat, large areas of desert or land are all over the world, mirrors are cheap and it decreases the mechanical failure since it doesn't need a mechanism to run it through the day. On the other hand, there are some cons about the CSP which are it is costly to start a CSP plant, the plant requires a large areas of land, CSP plants runs on water and they are mostly located in the deserts where water supply is limited and it needs uninterrupted amount of sunlight. [16]

2.2. Previous Work

The concentrated solar power was first mentioned in Greece 214-212 BC by Archimedes, but it was for a very different purpose. He used it as a defensive tactic, from a bronze shield to concentrate the sunlight onto invaders ships. Even though it was a myth, the Greek Scientist Dr. Loannis Sakkas proved the myth by lining up 60 Greek sailors, holding oblong bronzed coated mirrors tipped to reflect the sunlight and directing them at a ship approximately 200 feet away, which within minutes caught fire. [18]

he first documented use of concentrated solar power technology was in 1866 where Auguste Mouchout used parabolic troughs to heat water and produce steam to run the first solar steam engine. Later on, solar power plant was first established in 1913 at Al Meadi which lies south of Cairo on the Nile River and figure () shows the plant. This plant was used to operate a 100 HP solar engine; it was initially intended for producing electric power but instead it was used for pumping water from the river. [18]

The first operation was in Italy 1968, by professor Giovanni Francia when he built the concentrated solar power plant with its central receiver surrounded by a field of solar collectors. In 1982 the U.S. Department of energy, along with several industries began operating Solar One, a 10MW central receiver demonstration project, which lead to the establishment of the feasibility of power tower systems. Few years later, the world's largest solar thermal facility, located in Kramer Junction, California, was commissioned. The solar field contained rows of mirrors that reflected the sunlight onto a system of pipes that surrounds the heat transfer fluid. This fluid is used to produce high pressure vapor, which powered a conventional turbine to produce electricity. In 1996 the U.S. Department of energy, alongside a group of industries began operating Solar Two (an upgrade of its Solar One tower). Until 1999, Solar Two demonstrated how solar energy can be stored efficiency and economically so that power can be produced even when there is no sunlight. Which later on, the interest of power towers has been increased. [18]

Figure 10: 1968, by professor Giovanni Francia the concentrated solar power plant.

2.3. Comparative Study

SunBorne Energy company has collaborated with three universities which are university of south Florida, iMdea and ETH led by Dr. Nitin Goel in order to build a solar power tower. In 2012, the team's objective was to make a 1 MW watt central receiver prototype plant. With encouragement and support of the Indian Government, the team has planned and designed to build the central power plant. After doing various researches, they got to choose which materials are suitable for their project. The plant consists of four main parts which are suitable for their project. The plant consists of four main parts which are receiver, heliostat, thermal storage and solar field control. [19]

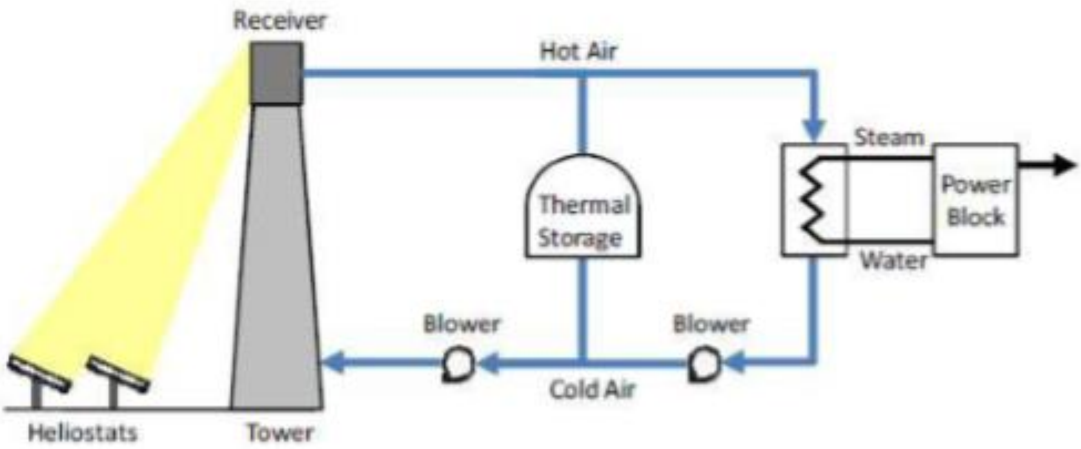

Figure 11: Schematic of the 1 MW the solar power tower system

Receiver:

The team made an open volumetric receiver utilizing ambient air as the heat transfer fluid is presently under development. The concentrated solar radiation from the heliostats was made incident on a volumetric receiver where it is absorbed inside the porous structure volume of the receiver. The team has worked to transfer the thermal energy to the heat transfer fluid flowing through the porous structure. Also, the team have incorporated a novel design feature for reducing the energy spillage across the absorber. [19]

Heliostat:

The team has adapted PV dualaxis tracking technology to develop a non-pedestal heliostat system having a size of 150m2. The team's current cost projections show that the 1MWth solar field can be manufactured at less than 150 USD/m2 as compared to SANDIA's reference of 200 USD/m2 for a 50MWe plant. [19]

Solar Field Controls:

The team has proposed a control architecture where the heliostat aiming strategy is driven by a central control system. In such control methodology, the local heliostat control is required to achieve the desired azimuth and elevation positions as directed by the central control system.

Thermal Storage:

The team has been evaluating few indigenous rocks as thermal storage media readily available in India. The cost of such material is about 3-4 INR/kg. The team made a thermal storage system packed with rocks as the sensible storage medium. They evaluated various rocks locally available in India. The selected thermal storage media properties are compared with different thermal storage materials in Table 1. It shows that the new material has much higher energy density in comparison to molten salt. In addition, the packed bed configuration will eliminate the cost associated with molten salt. systems due toits corrosive and molten state requirements. [19]

Material	Density, kg/m^3	Specific Heat, J/kg-K	Energy Density, kJ/m^3-K
Aluminum	2700	920	2484
Cast Iron	7200	540	3889
Fireclay	2100 – 2600	1000	2100 – 2600
Al_2O_3	3900	900 – 930	3150 – 3255
SiO_2	2320	800 – 840	1856 – 1950
Fe_2O_3	5206	650 – 700	3384 – 3645
Iron	7800	460	3588
Molten Salt	1680	1560	2620
Selected Thermal Storage Media	**3200**	**851 (@ 200C) 1158 (@ 400C)**	**2723 (@ 200 C) 3703 (@400 C)**

Figure 12:Comparison of thermal energy density in different media

Team project objectives:

- The system must have Higher temperature (higher efficiency)
- The system must be suitable for air cooled systems (conserve water)
- The system must be flexibility in the use of heat transfer fluid (Oil, Water, Air, Molten Salt)
- The system must be flexibility in the solar field expansion
- The system must be suitable for high temperature process heat application
- Flat mirrors are required (lower cost)
- Dual axis solar tracking is required (higher efficiency)
- The system must have Lower receiver losses (higher efficiency)

Chapter 3: System Design

3.1 Design Constraints and Methodology

3.2 Engineering design standard

3.3 Theoretical Calculations

3.4 Product Subsystems and selection of Components

3.1. Design Constraints and Methodology

The concentrated solar system that can be used in desert area. In order to achieve successful result of the concentrated solar system, you will need a good quality design. Using a CAD such as SOLIDWORKS will definitely assist in achieving the target. Therefore, there are multiple constraints need to be overcome during designing:

- Unclear weather.
- Air flow reduces the heat transferred to the boiler.
- Reflecting material.
- Concavity of the reflector.
- Impurities on the reflector's surface.
- Boiler's material.
- Leakage between boiler and turbine.

In order to get the most efficient results out of this system, these major constraints should be avoided. First of all, the weather must be clear enough to proceed in this system. in addition, the air flow work as a cooler on the boiler, so this system will not provide enough efficiency in some areas where the speed of air is high. For example, on mountains and high hills. After that, the material chosen to be used should be well-reflective to sunlight, well-concaved as well, which will produce more accurate focus point. Moving forward, the reflector have to be polished very well to get the efficiency needed. Based on the research done, the most absorbed material found was stainless steel. The pipe used to connect the main system parts must be designed for complete connection, so that leaks will be avoided by fitting the inlets with outlets.

3.2. Engineering design standard

Chemical Composition of Stainless Steel 304

Typical chemical composition for 304 stainless steel alloys

%	304	304L	304H
C	0-0.07	0-0.03	0.04-1
Mn	0-2	0-2	0-2
Si	0-1	0-1	0-1
P	0-0.05	0-0.05	0-0.05
S	0-0.02	0-0.02	0-0.02
Cr	17.5-19.5	17.5-19.5	17.5-19.5
Ni	8-10.5	8-10.5	8-10.5
Fe	Balance	Balance	Balance

Mechanical Properties of Stainless Steel 304

Grade	304	304L	304H
Tensile Strength(mpa)	520-720	500-6070	520-720
Compression Strength(mpa)	210	-	-
Proof Stress 0.2%(mpa)	210	200	210
Elongation A5(%)	45 MIN	45 MIN	40 MIN
Hardness Rockwell B	92	-	-

Typical physical properties for 304 stainless steel alloys

Property	Value
Density	7.93 g/cm3
Melting Point	1450 degree centigrade
Modulus of Elasticity	193 GPa
Electrical Resistivity	0.072*10-6 U.m
Thermal Cnductivity	16.2 W/m.K
Thermal Expansion	17.2*10-6/k

Table 1: ASTM Standards

Material	Thermal Conductivity (W/K m)
Copper	399
Gold	317
Aluminum	237
Iron	80.2
Carbon Steel	43
Stainless Steel	15.1
Glass	0.81

Table 2: Thermal Conductivity

Material	Thermal Diffusivity (m^2/s)
Silver	149×10^{-6}
Gold	127×10^{-6}
Copper	113×10^{-6}
Aluminum	97.5×10^{-6}
Iron	22.8×10^{-6}
Mercury	4.7×10^{-6}
Stainless Steel	4.2×10^{-6}

Table 3: Thermal Diffusivity

3.3. Theoretical Calculation

- Radiation Heat Transfer:

- $Q_{emit} = \varepsilon\sigma A_s T s^4$ Radiation emitted by real Surface (Equation 3.1)

q = heat transfer per unit time (W)

σ = 5.6703 *10^8 (W/m2K4) - The Stefan-Boltzmann Constant

T = absolute temperature in kelvins (K)

A = area of the emitting body (m2)

- Thermal Efficiency:

$$\eta = \frac{w_t - w_p}{q_{in}}$$

Wt = work of turbine

Wp = work of pump

Qin = heat entering the system

- Turbine Efficiency:

$$\eta_t = \frac{(w_t)}{(w_t)_s} = \frac{h_1 - h_2}{h_1 - h_{2s}}$$

Wt = work turbine

(Wt)s = work turbine shifted

- Pump Efficiency:

$$\eta_p = \frac{(w_p)_s}{(w_p)} = \frac{h_{4s} - h_3}{h_4 - h_3}$$

Wp = work pump

(Wp)s = work pump shifted

- Mass flow rate:

$$m = \rho V A$$

V = velocity

A = area

ρ = Density

- Angle of Parabolic: (Equation 3.4)

$$\phi_{rim} = \tan^{-1}\left(\frac{8f/D_{ap}}{16\left(f/D_{ap}\right)^2 - 1}\right)$$

$= \tan^{-1}\left(\frac{3.2}{1.56}\right) = 64°$

F = focal length measured by hand

D_{ap} = Diameter of plate of parabolic

- Bernoulli Equation:

$$\frac{P_1}{\rho g} + \frac{V^2}{2} + Z_1 + h_{Lp} = \frac{P_2}{\rho g} + \frac{V^2}{2} + Z_2 + h_{Lt} + h_L$$

- Head Loss:

$$h_L = [\{\frac{fL}{D} + \{K_L]\frac{V^2}{2g}$$

- Focal Point:

$X^2 = 4 * a * y$

X^2 = is width squared (150)

A = focal point

Y = height (28cm)

Focal Point A = $\frac{150}{112} = 1.339cm$

3.4. Product Subsystems and selection of Components

System Design Drawing:

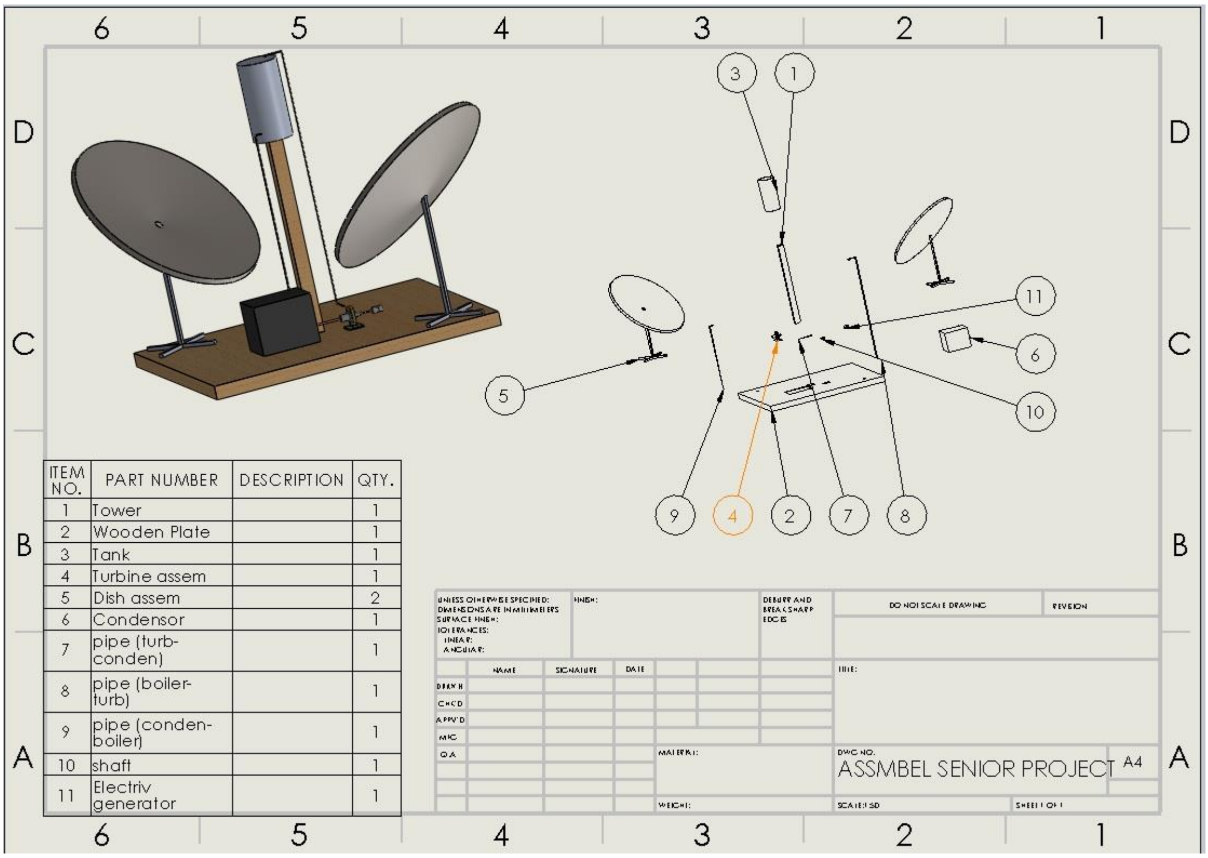

Figure 13: CAD Drawings

Solar Reflectors:

Solar reflector is one of the main parts in the system. Without the solar reflector, there is no way one can re-orient the sunlight to transfer its solar energy. Unlike other parts, solar reflector requires a bit more cautions when choosing the right material for it. The reason behind that is the fact that every material has its own reflection ratio. For this system, satellite dishes were used and wrapped it with a reflective film.

Figure 14: Dish

Figure 15: Wrapping the Dish

The satellite dishes were chosen because it has a concave shape that has a significant role in in concentrating the sunlight. As a team, the biggest challenge was to choose the right material and reflector film for this system. Another challenge was the machining work to remove the impurities from the dish before wrapping it to get the maximum light needed for the process.

Figure 16: Trying the dish reflection

Boiler:

This part considered one of the main parts in this system. As it gains the heat reflected from the sunlight through the reflector. It is important to choose the proper material to get the maximum efficiency of the system, which is in this case the material chosen is stainless steel. When the heat is transferred to the boiler, the water gets boiled and produces steam. After it turns into steam, it gets out through the pressure valve to the steam turbine. Which is the goal of this part.

Figure 17: Boiler

Turbine:

A Steam Turbine is a mechanical device that produce thermal energy from pressurized steam and convert it into work. Since the turbine produces rotary motion, it is especially fit to driving electrical generators – about 90% of all electricity generation in the United States (1996) is by use of steam turbines. As the name infers, a steam turbine is fueled by steam. As hot, vaporous steam flows past the turbine' spinning blades, steam extends and cools, emitting most of the energy it contains. This steam turns the blades constantly. The blades in this manner convert most of the steam's potential energy into kinetic energy. The turbine is then used to run a generator, producing electricity.

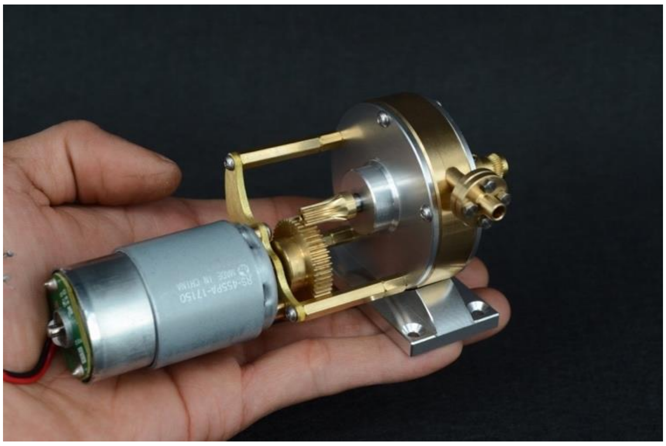

Figure 18: Steam Turbine

Condenser:

The condenser is a device used in many systems especially in the refrigeration systems. Condensers play a large role in many closed systems due to their importance. The main use a condenser is to convert the gas coming into the condenser into liquid form. This process happens when the gas enters the condenser which is a cold reservoir at a high temperature and the meets the cold surroundings of the condenser, at this point the gas releases energy which is heat and condensation happens where the gas is turned into liquid.

Figure 19: Condenser

Pump:

A pump it’s a device that moves fluid (liquid, gasses), by mechanical action. Pumps divided into three different methods to move fluid: direct lift, displacement, and gravity pumps. Every type of a pump consume energy to preform mechanical work to move fluid into any system. Mechanical pumps serve in wide range of application like: car industry, home use, energy industry, cooling towers. Pumps uses impeller or double impeller to move the fluid in the system in high pressure. in this system the pump has important role which is circulating water in the system from the conducer to the boiler to complete the cycle.

Figure 23: Water pump impeller

Figure 24: Water pump

Chapter 4: System Testing and Analysis

4.1 Experimental Setup, Sensors and data acquisition system

4.2 Results, Analysis and Discussion

4.1 Experimental Setup, Sensors and data acquisition system

4.1.1: Infrared gun

At this part, we need to use a type of thermometer to measure the temperature of the boiler. Since that the boiler surface will be hot, we had to use such a tool to measure the temperature from a distance. We used an Infrared gun to measure the surface temperature of the boiler.

Specifications:

- Infrared IR thermometer with red laser pointer
- Temperature Range: -25 to 716 °F (-32 to 380 °C)
- Large LCD display: 4 digits & multiple functions, white backlight
- Quick response time: 0.5 seconds
- Data Hold and auto shut-off Battery: 9V
- Brand: Nicety(R)
- Model: FBA_ST380+
- Item Weight: 0.198 kg
- Product Dimensions: 15 x 10 x 2.5 cm
- Item model number: ST380A
- Manufacturer Part Number: FBA_ST380+
- Voltage: 9 volts

Figure 20: Infrared Gun

4.1.2: Pressure Gauge

A pressure gauge is used to measure the pressure of the steam inside the boiler when the valve is closed, also to measure the steam pressure when we open the valve. The gage will give an indication of the best pressure value that is needed to rotate the turbine.

Specifications:

- Basic Gauge Case Material Plastic
- Basic Gauge Wetted Parts Brass / Bronze
- Gauge Connection Size1/4"
- Gauge Connection Location Center Back
- Gauge Primary Range Units psi
- Gauge Primary Range Values 0 to 160
- Gauge Secondary Range Units kPa
- Gauge Secondary Range Values 0 to 1100

- Gauge Accuracy+/-3-2-3%

Figure 21: Pressure Gauge

Testing Parameters	Objective
Infrared Gun	To measure the temperature of the boiler
Pressure Gauge	To measure the pressure of the steam

Table 4: Parts

4.2 Results, Analysis and Discussion

Ambient temperature (C)	Pressure kpa	Boiler temperature (C)
27	53	119
29	76	148
30	98	181

Table 5: Data of the results

In this section, there are relation between the temperature and the pressure in c, kpa. as noticed the increasing of temperature the pressure increase.

Chapter 5: Project Management

5.1 Project Plan

5.2 Contribution of team members

5.3 Project Execution Monitoring

5.4 Challenges and Decision Making

5.5 Project Bill of Materials and Budget

In this project, there are many tasks included. Each task is assigned to one or more members. Here is the all information about the tasks, team members, and the duration of each task to be completed. See table 5.1 for project plan and table 5.2 for the assigned members and their contribution.

5.1 Project Plan

	Start Date	Days to complete	Members
Task 1 Plan			
Identifying Project	1/6/2019	3	Mohammed Y
Determine objectives	1/9/2019	5	Nasser
Subdividing small tasks to collect information	1/17/2019	7	All
Search and write small report about useful instruments	1/23/2019	6	All
Task 2 Report			
Workout a software shows collected data	1/24/2019	1	Abdulrhman
Analyze data collected	1/24/2019	1	All
Writing chapter 1 Introduction	1/25/2019	3	Mohammed M, Nasser
Writing chapter 2 Literature Review	1/31/2019	6	Mohammed Y, Abdulrhman, Abdullah
Mention same projects	2/4/2019	2	Mohammed Y
Prepare for midterm	2/8/2019	20	All
Task 3 SOLIDWORKS			
Parts	2/12/2019	2	Mohammed M, Abdullah
Assembly	2/14/2019	2	Mohammed M, Abdullah
Task 4 System Design			
Design the prototype	2/7/2019	5	All
calculations	2/7/2019	10	Mohammed Y
Type of material	2/7/2019	3	Nasser
Taking calculation of turbine	2/7/2019	10	Nasser
Length of the tower and the degree of the reflector	2/7/2019	5	Abdullah
Prototype assembly	2/18/2019	15	All
Task 5 Testing			
Testing the prototype	3/5/2019	5	All
Testing the efficiency of the turbine	3/5/2019	2	Nasser
Testing required sunlight and temperature	3/5/2019	2	Abdulrhman
Task 6 Finalizing Project			
Conclude the report	3/10/2019	10	Mohammed M, Abdullah

Presentation	3/17/2019	7	All
Prepare for Final	3/25/2019	20	All

Table 6: Project Plan

5.2 Contribution of Team Members

#	Tasks		Assigned	Cont. %
1	Chapter 1: Introduction		All	100%
2	Chapter 2: Literature Review	Project Background	Abdulla	33%
			Abdulrhman	33%
			Mohammed M	34%
		Previous Work	Mohammed Y	34%
			Nasser	33%
			Mohammed M	33%
		Comparative Study	Mohammed Y	33%
			Nasser	34%
			Abdulrhman	33%
3	Chapter 3: System Design	Design Constraints and Design Methodology	Mohammed Y	30%
			Abdulla	30%
			Nasser	30%
			Abdulrhman	10%
		Engineering Design standards	Mohammed M	50%
			Abdulrhman	50%
		Theory and Theoretical Calculations	Nasser	50%
			Abdulla	30%
			Mohammed M	20%
		Product Subsystems and selection of Components	Mohammed M	30%
			Mohammed Y	40%
			Abdulrhman	30%
		Manufacturing and assembly	Abdulla	50%
			Mohammed M	50%

4	Chapter 4: System Testing &Analysis	Experimental Setup, Sensors and data	All	100%
		Results, Analysis and Discussion		
5	Chapter 5: Project Management	Project Plan	All	100%
		Contribution of Team members		
		Project Execution Monitoring		
		Challenges & Decision Making		
		Project Bill of Material & Budget		
6	Chapter 6: Project Analysis	Life Long Learning	All	100%
		Impact of Engineering Solution		
		Contemporary Issues Addressed		
7	Chapter 7: Conclusion & Recommendation	Conclusion	All	100%
		Future Recommendation		
8	Design of Prototype	Boiler and tubes	Abdulrhman Mohammad Y Mohammad M	100%
		Reflectors and bases	Abdulrhman Mohammad Y Mohammad M	
		Tower and base	Mohammad M	100%
		Pressure gauge and extension valve	Mohammad M	100%
		Pressure gauge	Abdullah Nasser	

9	Parts Purchase	Steam turbine	All	100%
10	Manufacturing	Boiler and tower	All	100%
		Dish reflctore		
		Bases and the conctione between the parts		
11	Testing	All the parts	All	100%

Table 7: Tasks Assigned to team members

5.3 Project Execution Monitoring

Time/Date	Activities/Events
Once a week	Assessment class
Weekly	Meeting with group members
Biweekly	Meeting with the advisor
19 March, 2019	Finishing first prototype
21, March 2019	Midterm presentation
9, April 2019	First test of the system
13, April 2019	Finishing final prototype
14, April 2019	Test the system
2, May 2019	Final Submission of the report
2, May, 2019	Final presentation

Table 8: Dates and Activates of Events

5.4 Challenges and Decision Making

During the project phases, we faced some challenges that effect the progress of the project. Following challenges are the main challenges we have faced:

- Selection of materials
- Weather constraints
- Pipes

First, we selected stainless steel to be the boiler's material and found that the thermal conductivity was poor comparing to copper and aluminum. The boiler has been changed to aluminum since copper is too expensive to manufacture.

The major constraint was the weather, because we cannot control it. Unfortunately, the last couple of weeks the weather was cloudy and rainy, so we struggled with the testing.

The connection between the boiler and turbine was challenging a bit. Since the inlet of the turbine was too small to fit the pipe, which caused losses of steam.

5.5 Project Bill of Materials and Budget

Materials	Cost (SR)
Two Reflectors	180
Tower	150
Boiler	280
Bases of Reflectors	80
Steam Turbine	510
Foils	100
Pipes	50
Pressure Gauge	60
Valves	50
Total	**1460**

Table 9: Bill of Materials

Chapter 6: Project Analysis

6.1 Life-long Learning

6.2 Impact of Engineering Solutions

6.3 Contemporary Issues Addressed

6.1 Life-long Learning

Working on this project have improved us and broaden our knowledge in various aspects. As a group, we have started with an idea that can be improved and be applied in real world applications, through brainstorming, develop and discussing the alternatives. Through our meetings, we have divided the tasks among us in equal manner and succeed within the pre-scheduled time. During assembling the project, we used some new hardware devices and software tools, that helped us to complete the project build up.

- Hardware devices

  For the hardware devices, we used an infrared gun to measure the temperature of the boiler when it is reflected from the dishes. In addition to that, pressure gauge was used to measure the steam pressure needed to rotate the turbine and generates electricity.

- Software tools

  For this part, the main program that we used is SOLIDWORKS to design our system. Part drawing and proper dimensions, manufacturing, and finding the factor of safety. In addition, Microsoft word and excel are used to make the project report and to manage the tasks in Gannt chart form.

- Time management skills

  Having several meetings have developed our time management skills. Moreover, following the deadlines given by the department lead us to manage our time. Dividing the tasks and subtasks on the group members to deliver the goal.

6.2 Impact of Engineering Solutions

In brief words, our project is inspired by the Kingdom's vision 2030 where there establishing new renewable energy systems. Part of these projects will be solar concentrated power plants.

6.2.1: society

The impact of this project on society is creating job opportunities, enhancing the behavior of life in the Kingdom to a better future. Achieving the 2030 vision of reduce the needs of finite sources with renewable energy sources. Moreover, building this project in remote areas will freshen these particular areas.

6.2.2: Economy

The main purpose of this project is to improve our country's economy, by reducing the use of the other gas power plants. Increase job opportunity, take advantage of un used land.

6.2.3: Environment

This project will decrease the use of fossil fuels which have bad effects on the environment. The renewable energy is to use the steam generated by solar, which is considered clean and continues source.

6.3 Contemporary Issues Addressed

As discussed earlier, the goal of the Kingdom's vision 2030 is to minimize the use of fossil fuels as much as possible. In last decades, the high depends on fossil fuels caused environmental issues, such as air pollution that are produced from emissions of refineries which may come as an acidic rain. The workers in these refineries are more susceptible to diseases such as cancer and skin diseases. The fossil fuel is a "finite" source which means that it may drain one day. That is an eternal issue presented since the discovery of these sources.

Chapter 7: Conclusions and Future Recommendations

7.1 Conclusion

7.2 Recommendations

7.1. Conclusion

All in all, as a team we started designing and manufacturing a Concentrated Solar Power Plant System. It is a system which can convert the solar energy to electrical energy by using the concepts of mechanical engineering. It starts by locating the focal point of the moving dish that is covered by aluminum foil to reflect the sunrays into the boiler. Then the boiler starts to heat the liquid stored inside it which is water in our case, and begin to generate the steam. The steam is pressurized to a certain value that gives us the pressure needed to rotate the turbine. Finally, the turbine starts to generate electricity.

Throughout building this system, we got to develop our own skills such as time management, divide the tasks equally and accomplish them in a timely manner. A better understanding for choosing the proper material for different cases, for instance based on their conductivity and diffusivity. In welding process, there was a misunderstanding of welding two dissimilar materials, after taking it into consideration a few changes were taken to fit the system

7.2. Future Recommendation

- Installing a sun tracking system
- Installing a condenser
- Installing a pump
- Changing reflecting material
- Using bigger Dish
- Using a bigger Turbine
- Using a bigger eclectic generator

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Appendix

Appendix A: Monthly Progress Reports

Appendix B: Engineering Standards

Appendix C: CAD Drawing and Bill of Materials

Appendix D: Prototype Pictures

Appendix E: Operation Manual

Appendix A: Monthly Progress Reports

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

SEMESTER:	Spring	ACADEMIC YEAR:	Senior
PROJECT TITLE	Concentrated Solar Power Plant		
SUPERVISORS	Dr. Aymen Jendoubi		

Month:

ID Number	Member Name
201500818	Mohammed Alarfaj
201500011	Abdullah Almubayedh
201202089	Abdulrhman Thuwaqib
201501066	Nasser Alsubaibani
201403938	Mohammed Alafaliq

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	Abstract	Nasser Alsubaibani	100%	SPD02
2	Introduction	Abdullah Almubayedh	100%	Milestone 2
3	Literature Review	All Members	100%	Milestone 2
4	Buying Reflectors	Mohammed Alafaliq Abdulrhman Thuwaqib	60%	Working on it

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	CAD Design	Mohammed Alarfaj
2	Design and Calculation	Abdullah Almubayedh Mohammed Alafaliq
3	Buying Equipment's	All Members
4	Assembly of the prototype	All Members
5	Testing the prototype	All Members
6	Preparing for the Midterm	All Members

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

Outcome f: An understanding of professional and ethical responsibility.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
f1. Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Fails to Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Shows limited and less than adequate understanding of engineering professional and ethical standards in dealing with public safety and interest	Demonstrates satisfactory an understanding of engineering professional and ethical standards in dealing with public safety and interest	Understands appropriately and accurately the engineering professional and ethical standards in dealing with public safety and interest

Outcome d: An ability to function on multidisciplinary teams.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
d1. 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	Understands and applies proper and accurate team work plans and allocate resources and tasks
d2. Ability to participate and function effectively in team work projects	Fails to participate and function effectively in team work projects	Shows limited and less than adequate ability to participate and function effectively in team work projects	Demonstrates satisfactory ability to participate and function effectively in team work projects	Understands and participates properly and function effectively in team work projects
d3. 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	3. Understands and 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 (d1)	Criteria (d2)	Criteria (d3)	Criteria (f1)
1	Mohammed Alarfaj	3	4	4	3
2	Abdullah Almubayedh	4	3	4	3
3	Abdulrhman Thuwaqib	4	4	4	3
4	Nasser Alsuhaibani	3	3	4	3
5	Mohammed Alafaliq	4	4	4	3

Comments on individual members

Name	Comments
Mohammed Alarfaj	Very Good
Abdullah Almubayedh	Very Good
Abdulrhman Thuwaqib	Very Good
Nasser Alsuhaibani	Very Good
Mohammed Alafaliq	Very Good

SDP – WEEKLY MEETING REPORT

Department of Mechanical Engineering
Prince Mohammad bin Fahd University

SEMESTER:	Spring	ACADEMIC YEAR:	2018/2019
PROJECT TITLE	Concentrated solar power plant		
SUPERVISORS	Dr. Aymen Jendoubi		

Month:

ID Number	Member Name
201202089	Abdulrhman Thawaiqib
201501066	Nasser Abdulrahman Alsuhaibani
201500818	Mohammed Alarfaj
201500011	Abdullah Almubayedh
201403938	Mohammed Alafaleq

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	**Design and manufacturing of the boiler**	Thawaiqib-Alafaleq	100%	
2	**Design and manufacturing of the Tower**	Almubayedh-Alsuhaibani	100%	
3	**Purchasing the turbine**	Alarfaj	100%	
4	**Testing**	All Members	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	**Turbine Installation**	All Members
2	**Tubes Installation**	All Members
3	**Condenser Installation**	All Members
4	**Assembly of the system**	All Members
5	**Final Testing**	All Members

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

Outcome f: An understanding of professional and ethical responsibility.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
f1. Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Fails to Demonstrate an understanding of engineering professional and ethical standards in dealing with public safety and interest	Shows limited and less than adequate understanding of engineering professional and ethical standards in dealing with public safety and interest	Demonstrates satisfactory an understanding of engineering professional and ethical standards in dealing with public safety and interest	Understands appropriately and accurately the engineering professional and ethical standards in dealing with public safety and interest

Outcome d: An ability to function on multidisciplinary teams.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
d1. 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	Understands and applies proper and accurate team work plans and allocate resources and tasks
d2. Ability to participate and function effectively in team work projects	Fails to participate and function effectively in team work projects	Shows limited and less than adequate ability to participate and function effectively in team work projects	Demonstrates satisfactory ability to participate and function effectively in team work projects	Understands and participates properly and function effectively in team work projects
d3. 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	3. Understands and 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 (d1)	Criteria (d2)	Criteria (d3)	Criteria (f1)
1	Abdulrhman Thawaiqib	4	4	4	3
2	Nasser Abdulrahman Alsuhaibani	3	4	4	4
3	Mohammed Alarfaj	4	3	4	4
4	Abdullah Almubayedh	4	4	3	4
5	Mohammed Alafaleq	4	4	4	3

Comments on individual members

Name	Comments
Abdulrhman Thawaiqib	
Nasser Abdulrahman Alsuhaibani	
Mohammed Alarfaj	
Abdullah Almubayedh	
Mohammed Alafaleq	

Excellent Job! all the team! Successful work!

Dr Ayman

Appendix B: Engineering Standards

Chemical Composition of Stainless Steel 304

Typical chemical composition for 304 stainless steel alloys

%	304	304L	304H
C	0-0.07	0-0.03	0.04-1
Mn	0-2	0-2	0-2
Si	0-1	0-1	0-1
P	0-0.05	0-0.05	0-0.05
S	0-0.02	0-0.02	0-0.02
Cr	17.5-19.5	17.5-19.5	17.5-19.5
Ni	8-10.5	8-10.5	8-10.5
Fe	Balance	Balance	Balance

Mechanical Properties of Stainless Steel 304

Grade	304	304L	304H
Tensile Strength(mpa)	520-720	500-6070	520-720
Compression Strength(mpa)	210	-	-
Proof Stress 0.2%(mpa)	210	200	210
Elongation A5(%)	45 MIN	45 MIN	40 MIN
Hardness Rockwell B	92	-	-

Typical physical properties for 304 stainless steel alloys

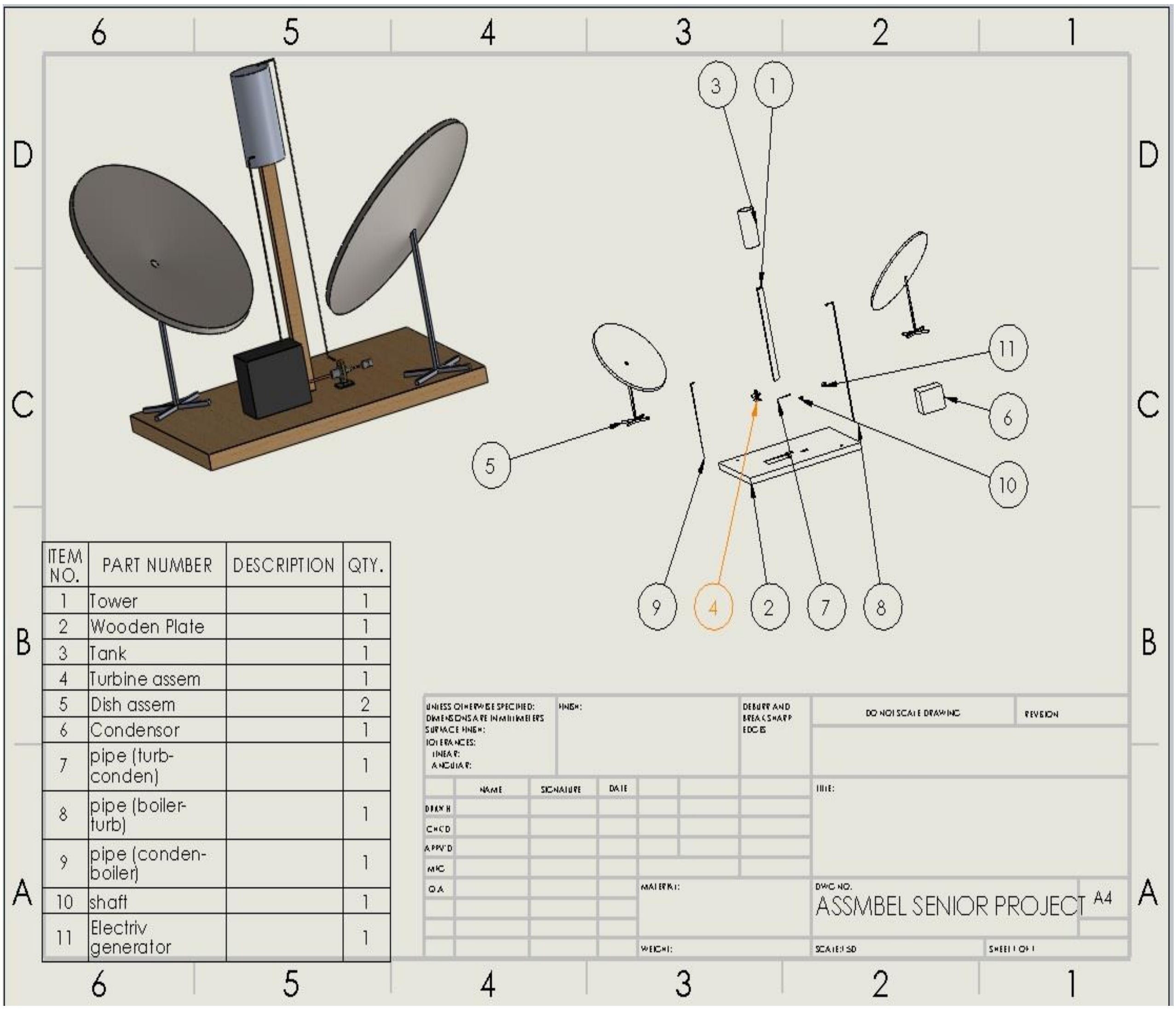
Property	Value
Density	7.93 g/cm3
Melting Point	1450 degree centigrade
Modulus of Elasticity	193 GPa
Electrical Resistivity	0.072*10-6 U.m
Thermal Cnductivity	16.2 W/m.K
Thermal Expansion	17.2*10-6/k

Table 10: ASTM Standards

Material	Thermal Conductivity (W/K m)
Copper	399
Gold	317
Aluminum	237
Iron	80.2
Carbon Steel	43
Stainless Steel	15.1
Glass	0.81

Material	Thermal Diffusivity (m^2/s)
Silver	149×10^{-6}
Gold	127×10^{-6}
Copper	113×10^{-6}
Aluminum	97.5×10^{-6}
Iron	22.8×10^{-6}
Mercury	4.7×10^{-6}
Stainless Steel	4.2×10^{-6}

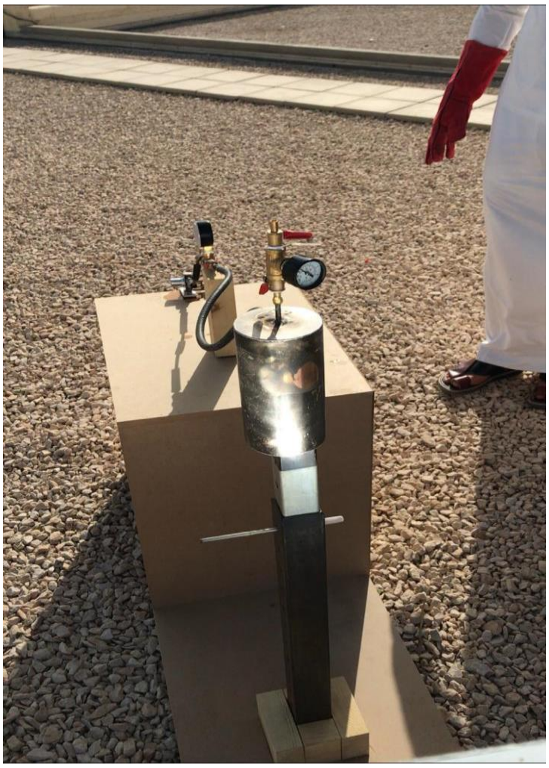
Appendix C: CAD Drawing and Bill of Materials



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Tower		1
2	Wooden Plate		1
3	Tank		1
4	Turbine assem		1
5	Dish assem		2
6	Condensor		1
7	pipe (turb-conden)		1
8	pipe (boiler-turb)		1
9	pipe (conden-boiler)		1
10	shaft		1
11	Electriv generator		1

Materials	Cost (SR)
Two Reflectors	180
Tower	150
Boiler	280
Bases of Reflectors	80
Steam Turbine	510
Foils	100
Pipes	50
Pressure Gauge	60
Valves	50
Total	**1460**

Appendix D: Prototype Pictures



Appendix E: Operation Manual

Starting the Experiment:

Step 1:
Locate the focal point by adjusting the reflecting dish.

Step 2:
Add water inside the boiler.

Step 3:
Place the boiler on top of the tower where the focal point hits.

Step 4:
Wait until the water inside the the boiler is boiled and the steam is generated.

Step 5:
Open the valve holding the steam from reaching the turbine.

Step 6:
The turbine is now turning causing the generator to turn and power is generated.

Safety Notes:

- Use safety gloves
- Use safety goggles
- Keep yourself about 2 meters away from the system
- Have a fire distinguisher