جامعة الأمير محمد بن فهد
PRINCE MOHAMMAD BIN FAHD UNIVERSITY

College of Engineering

Department of Mechanical Engineering

Fall 2016-17

Senior Design Project Report

Project Title

Design of a Vacuum Tube Solar Cooker

Team Members

	Student Name	Student ID
1	Abdullatif Alabdulqader	201202484
2	Abdulrahman Alamoudi	201002591
3	Feras Alabdulwahed	201101505
4	Hassan Alqatari	201102989

Project Advisors:

Advisor Name: Dr. Ali Chamkha
Co-Advisor Name: Dr. Nader Nader

Abstract

Cooking is the major necessity for people all over the world. It accounts for a major share of energy consumption in developing countries. Therefore, solar cookers are recommended to be used in the domestic sector in these countries. The advantages of the use of solar cookers would result in the reduction of the release of CO_2 in the environment.

This paper reviews the gradual progress made in our vacuum tube solar cooker. The energy and heat transfer analysis of a vacuum tube solar cooker based prototype has been carried out experimentally. The cooker was tested during several clear days in Khobar city (25˚). Detailed temperature distributions and their time dependences were measured. The working temperature obtained was between 93˚C to 232˚C. Our Vacuum Tube Solar Cooker can achieve a maximum temperature of 288˚C in ideal situation and power output of 200 Watts in full sunlight. These results make this compact solar cooker competitive in performance to many other solar cooker types.

Keywords: Evacuated Borosilicate Tubes, Solar Cooking, Durability

Acknowledgement

We have taken efforts in this project. However, it would not have been possible without the kind support and help of many individuals and organizations. We would like to extend Our sincere thanks to all of them.

First of all, we are thankful our Adviser Dr. Ali Chamkah and Co- Adviser Dr. Nader Nader for their guidance and constant supervision as well as for providing necessary information regarding the project & also for their support in completing the project.

We would like to express our gratitude towards our Families for their kind co-operation and encouragement which help us in completion of this project.

We would like to thanks AlBatboot Workshop and Manufacturing Co, for their help on designing and manufacturing the parts.

Our thanks and appreciations also go to our colleagues in developing the project and people who have willingly helped us out with their abilities.

Contents

Chapter 1

Introduction

1.1 Project Definition

A vacuum tube solar cooker is essentially a vacuum sealed between two layers of glass. Compound parabolic reflectors and tubular design converts nearly 80% of all sunlight entering its reflectors into useable heat. The evacuated glass tube Cooking Technology is a near-perfect insulator, allowing one to solar cook in even the most challenging conditions. By effectively capturing light from a broad range of angles, the vacuum tube does not require frequent readjustment to the Sun, making for easy stress-free meals.

1.2 Project Objectives

We are offering this product to reduce air pollutants, use clean renewable energy and increase awareness about other alternatives. Also, understanding the concept of environment and the need for rational use of natural resources, as well as, understanding how they can help with the management and conservation of resources. This project will be very helpful for people in perverted countries due to the free energy resources.

1.3 Project Specifications

For the project specifications, we have the temperature range, capacity, vacuum/pressure range, type/configuration, heating and control.

Dry Weight: 7 lbs (3.18kg)

Oven Volume: 40oz (1.2L) fluid or up to 3 lbs (1.4kg) of food

Oven Dimensions: 2.7” (70mm) outside diameter, 2.1” (54mm) inside diameter , 24” (610mm) length

Unit Open Size: 24” (610mm) long x 16” (410mm) tall x 12” (300mm) wide

Unit Closed Size: 24” (610mm) long x 8” (200mm) tall x 5” (130mm) wide

Estimated Power Output: 200 Watts in full sunlight

Maximum Temperature: 550°F (288°C)

Working Temperature: 200°F (93°C) – 450°F (232°C)

1.4 Product Architecture and Components

Draw functional diagram.

Shop drawing by the solidworks.

Photo of real system.

Brief description.

Table for the relation between the heat and time.

1.5 Applications

Preheating: Heating to an appropriate temperature immediately prior to austenitizing when hardening heavy sections or high hardenability constructional steels.

Quenching: Quenching units are used for rapid cooling of heated media. Quenching furnaces are typically identified by the more specific technology utilized: direct quenching, fog quenching, hot quenching, interrupted quenching and internal quenching.

Sterilizing: Sterilizing ovens heat objects to temperatures high enough to kill bacteria and germs.

Drying: drying uses temperature to remove moisture from an object within an oven/furnace.

Laboratory: Laboratory ovens are used in a variety of thermal processing applications, including general lab work, component and stability testing, core hardening, drying glassware, and sterilizing.

Chapter 2

Literature Review: Design of a Vacuum Tube Solar Cooker

2.1 Project Background

Other than its general meaning, energy is vital for human activities within the environment. Studies that focus on solving energy-related problems are quite significant since most human activities are energy-driven. Fossil fuels still constitute the largest share of global energy consumption. However, calls for renewed focus on clean energy continue to grow due to increasing environmental concerns. Vacuum Tube Solar Cooker is a machine that can absorb the sunlight and convert it to heat in order to cook food , solar cookers are relatively new on the market , and there are different kinds of it , expensive and low price one , small and big , all depends on the needs of it , Vacuum Tube Solar Cooker can be absolutely useful tool to cook in countries where the Sun light is available most of time , in addition because this device uses no fuel to function, that can save and minimal the fuel consumption when other devices are used.

2.2 Previous Works

James Dewar invented the double walled vacuum insulation vessel in 1892 [1]. Since then, his design has been widely adopted for keeping food or drink hotter or colder than its surroundings. Since the 1980s, designs based on the same principles have been applied to the manufacture of solar water heating tubes, constructed from borosilicate glass. The growth of the renewable energy industry has led to the refinement of this design and mass production has driven down the price of glass-in-glass tubes. In 2009, 8.5 million meters' square of solar hot water tubes were manufactured in China alone [2]. At a meeting of Solar Cookers International in Granada, 2006, Alex Kee Koo Yak suggested using these ubiquitous tubes for pasteurizing water [3]. Since then, interest in this application has grown, and extended to food cooking. At the time of writing, there are at least three different evacuated tube cookers on the market. Some of these designs have convenient stands, and reflectors which increase the cooking power available within the tube [4]. Such stoves are very efficient at converting sunlight into sensible heat that can be used for cooking. In addition, because of excellent thermal insulation, they can maintain cooked food at serving temperature for several hours. One obstacle to wider adoption of this efficient technology is the perception that these evacuated glass tubes are fragile and of uncertain durability. The solar cooker is turned towards the sun and left until the food is cooked. Unlike cooking on a stove or over a fire, which may require more than an hour of constant supervision, food in a solar cooker is generally not stirred or turned over, both because it is unnecessary and because opening the solar cooker allows the trapped heat to escape and thereby slows the cooking process. If wanted, the solar cooker may be checked every one to two hours, to turn the cooker to face the sun more precisely and to ensure that shadows from nearby buildings or plants have not blocked the sunlight. If the food will be left untended for many hours during the day, then the solar cooker is often adjusted to face the point where the sun will be at its peak, instead of towards its current position. The evacuated tube is a product which has been optimized in terms of geometry and performance. Evacuated tubes consist of two concentric glass tubes which are sealed in a semi-circular shape on one side and are joined to one another on the other side. The space between the tubes is evacuated and then hermetically sealed (evacuated insulation). To use solar energy, the internal glass tube is coated with an environmentally friendly, highly selective layer on the outside, thus turning it into an absorber.

From literature, a variety of materials have been used in the past to improve the glazing properties of solar cookers, especially the box-type cookers Some of these materials include fiberglass. Studies [7] have also focused on transmission capabilities of solar structures where single-pane and double-pane glasses were preferred to other materials for this purpose. With time, focus shifted to optimizing the gap between the glass panes. This change was necessitated by heat losses through convective heat transfer. In other words, large air gaps were observed to aggravate heat losses. With time, developers in this field adopted the use of vacuum tubes to ensure maximum heat retention. Over time, long wave radiations were reported increase the temperature of the surrounding glass panes leading to excessive heat losses. In a research that compared the performance of two different types of collectors for solar cookers, i.e. a plate collector and a vacuum tube collector, Zhou and Zhang [9] found that the vacuum tube collector was more suitable and reliable under varied climatic conditions.

The efficiency of a solar cooking system depends on the type of collector used. Concentrated research efforts have recognized flat plate collectors (FPC) as the most suitable and productive solar collectors used in solar cookers [8]. However, these collectors have low temperatures and exhibit a relatively low efficiency. FPCs have remained popular for decades due to their simple design and low-cost maintenance. However, these collectors have two main limitations. First, they lack a sun-tracking device, making it difficult to maximize heat energy absorbed under varying intensities of sun rays. Second, they suffer from convective heat losses via the glass cover mounted on top of the collector. While several technologies exist to tap solar radiation for solar cookers, evacuated (vacuum) tube technology or vacuum tube solar converters are of particular interest to this study.

Several authors including Ayompe [5], argue that vacuum tube solar collectors for solar cookers exhibit remarkable efficiencies at low temperatures compared to flat plate solar collectors. In the same study, investigated the performance of a vacuum tube and flat plate solar cookers for domestic water-heating purposes. Their efficiencies were compared under similar environmental conditions, and were found to be 60.7 and 46.1 percent respectively. On the other hand, the efficiencies were 50.3 and 37.9 percent respectively for the vacuum tube and FPC respectively.

2.3 Comparative Study

The proposed design can be compared to the previous works of other researchers such as Kumar et al. (215) who demonstrated the performance of a solar cooking system mounted with double-walled vacuum tube solar collectors, an integrated heat pipe, and a working fluid or refrigerant (Freon 407C). From the comparative model, the system can heat-up within a short period of time and the cooking times ranged from 27 up to 70 minutes. While the robustness of impressive model depends on the workability of the refrigerant used, its efficiency is limited to the thermo physical properties of the working fluid injected within the integrated heat pipes, as well as the prevailing meteorological conditions [6].

The proposed vacuum tube solar cooker is fabricated at a considerably low cost compared to conventional, double-walled vacuum tube since a working fluid is not required. In addition, the vacuum tube minimizes heat losses between glass tubes. Unlike the case of the comparative model, the proposed design is tubular, with compound parabolic reflectors, and supports sun-tracking effects. Moreover, the performance of the proposed vacuum tube solar cooker is not entirely influenced by the prevailing weather conditions. In essence, the internal components of the system are not susceptible to erosion since no working fluid is required. Thus, the possibilities of condensation that could cause the system to malfunction are reduced.

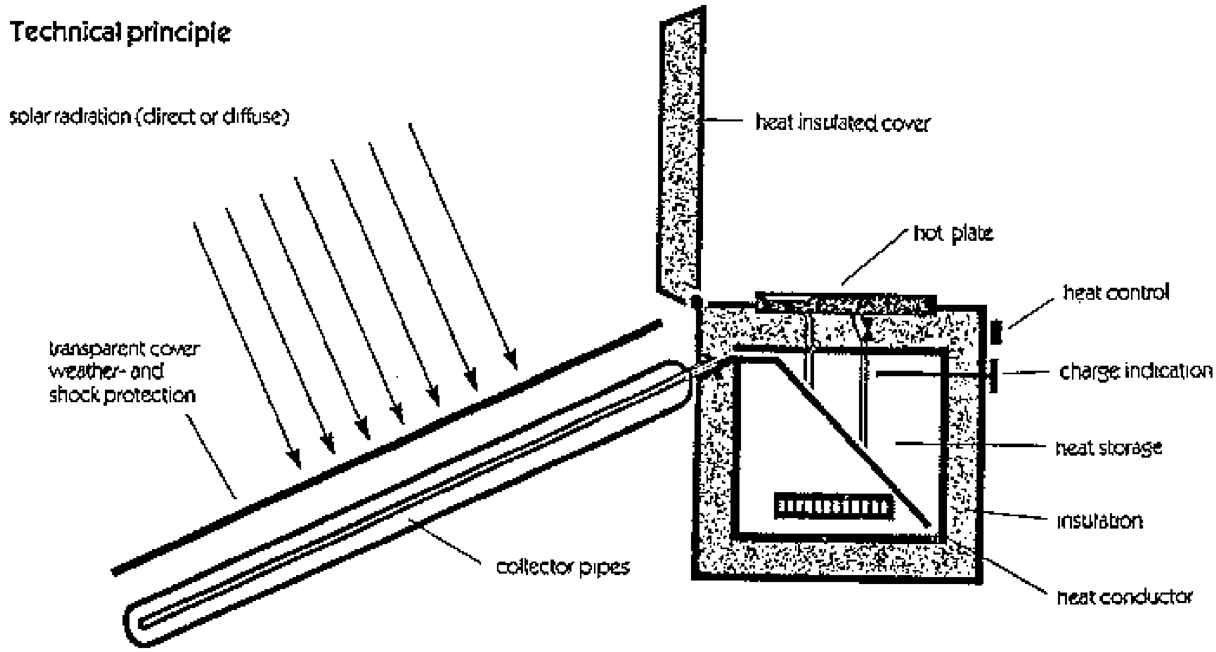


Figure 2.1: Comparative Model of a Double-walled Vacuum Tube Solar Cooker [6]

Generally, the thermal performance of the proposed system is outstanding since it provides an acceptable heat efficiency, expedient installation and ease of transportation. The comparative model is rectangular-shaped, implying that the peak energy output would only be achieved during midday when the sun's rays are perpendicular to the surface of the double-walled solar collectors [6] as shown in **Figure 2.1**. In contrast, the vacuum tubes used to tap energy in the proposed solar cooker are cylindrical in shape. Thus, these tubes can track energy from the sun passively throughout the day. The vacuum tubes are mounted at 90 degrees from the surface of the collector. Worth noting, the vacuum tube in both cases evacuates the air in the interior tube, thus minimizing conductive and convective heat losses.

In addition, the proposed system is cheap fabricated and maintain. In case a tube breaks, the solar collector will still operate at a low efficiency, and the system will continue working unlike in the comparative scenario, where the working fluid would leak from the system. With the proposed model, it would be relatively easy to replace a damaged tube but in the latter case, the whole system must be shut down prior to making any replacements. In addition, some internal components of the comparative model (for example, the heat pipes) are non-removable, making it quite difficult to clean the system.

In a nutshell, this study has presented a literature review on the design of a vacuum tube solar cooker. First, this review has examined the background of solar energy usage, and Vacuum Tube Solar Cooker. Second, this review has examined some previous projects and studies on the vacuum tube solar cookers. Finally, this review has compared the proposed design to previous projects on vacuum tube solar cookers. Overall, the proposed design has excellent absorption properties and highly impressive cooking performance.

Chapter 3

System Design

3.1 Design Requirements, Constraints and Specifications

The Vacuum Tube Solar cooker as shown in **Figure 3.1** is divided into three major components: (1) the parabolic reflection surface and mounting; (2) the evacuate glass tube; and (3) the slider or tray assembly. The parabolic surface comprised of two surfaces hinged to close and open into a functioning reflection surface when the cooker is set up to cook. The mounting sets up to enable placement of the cooker on a surface to maintain its stability. It also has another mounting on the inside area for the tube and slider when cooking. The evacuated glass tube comprised of a tube with and internal diameter according to specification painted with absorbent black paint and a clear exterior surface. The two surfaces are separated by a vacuum area which optimizes heat transmission. The slider assembly is containing tray, a sealer (steam vent) for the open end and a handle for the users. **Figure 3.2** shows an exploded view of our prototype and the bill of materials.

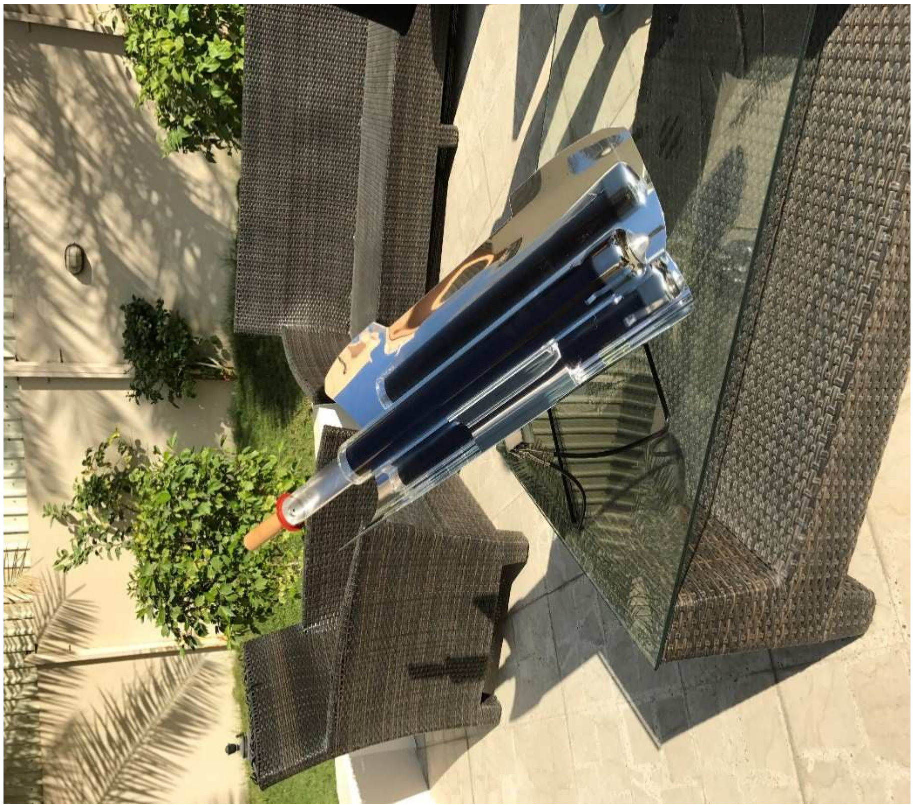


Figure 3.1: Vacuum Tube Solar Cooker

3.1.1 Requirements for the vacuum tube solar cooker

Flexibility to allow cooking in varying sun intensity.

Portable and compact.

Food grade parts.

Outdoor functionality (tough, durable and easy to clean).

3.1.2 Constraints

Light weight.

Easy to use and set up.

Can be carried on a normal camping gear set.

Relatively cheap.

Tough (outdoor use).

Safe: (1) exterior temperature not hot to touch; and (2) superior finishing standards to avoid dangerous edges.

3.1.3 Technical specifications

Stainless steel polished parabolic reflector with scratch proof coating.

Mounting system.

Approximately 3.2kg when empty.

Capacity: About 1-1.2L (40oz) for fluid or 1.2-1.5kg solid food.

Oven parameters:

-Borosilicate evacuated glass tube with black internal absorbent surface.

-620mm long with 70mm external diameter and 55mm internal diameter.

-Slider with stainless steel tray (food cooking area).

-Food grade rubber sealer.

-Wooden handle.

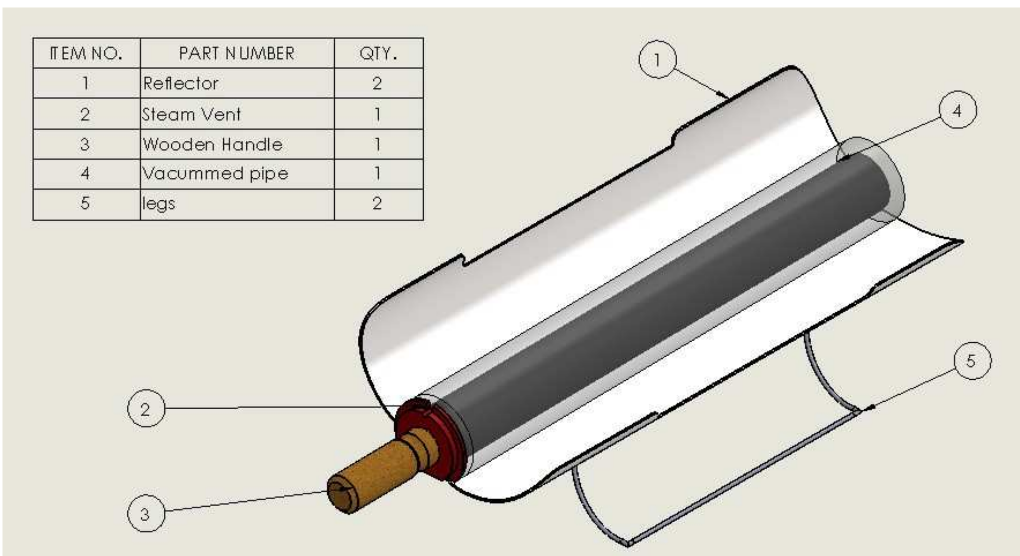
Operational parameters

-Dimensions 620mm long*300mm wide * 410mm (height).

-Working temperature of 93ºC- 232ºC.

-Maximum temperature 288ºC.

-Power output: 200 watts in full sunlight.



ITEM NO.	PART NUMBER	QTY.
1	Reflector	2
2	Steam Vent	1
3	Wooden Handle	1
4	Vacummed pipe	1
5	legs	2

Figure 3.2: Project Assembly + BOM

3.2 Design Methodology and considerations

As the constraints, which were considered showed, clients would like a compact, light, cheap, easy to use cooker that they can carry to their picnic or camping escapades with no fear of the safety in operation and use. This forms the core of the design of the cooker and the constraints and justifications below will prove.

As discussed in chapter two, there have been other methods used in cooking using solar energy. As research showed, the methods have low efficiencies, are bulky and have relatively high costs in terms of purchase and maintenance. The above proposed designed improves on all the aspects and fault of the other cookers. First, there are no fluids that are relied upon in transmission of solar energy. The system uses an evacuated glass (vacuum) which research has shown to improve the efficiency of the heating. the internal absorbent surface means that the outer are which will be clear, will not be hot when there is food heating up inside the tube. The slider is made from durable food grade components that keep the food fresh without loss in energy to get clean food ready very fast.

The strategies used in the design were hinged on the constraints and the required standards that are required for food handling. For instance, the parabolic reflection surface is hinged and made from polished stainless steel. The reason for this is that the metal in its nature is shiny which is essential, Additional polishing will create a mirror finish. To keep the surfaces of that mirror finish, a coating of protective layer will be considered along with alternatives of including regular polishing to remove any scratches that may compromise the reflection of sun rays. The choice of stainless steel is also due to its durability and outdoor capability given that it is not susceptible to rust and has high strength.

Hinging the parabolic surface was another design consideration that was desired to create a compact cooker that can fit on camping gear. The ideology is that, the rays of the sun as shown in the preliminary design in chapter two indicated that the rays will not hit the area beneath the tube and can still be optimized when there was a hinge below. Considering that the cooker has a span of 300mm when open and the other dimensions desired, it would need an entire bag just to carry it. As the design above shows, this is a component that can be fitted inside a standard camping bag with aesthetics that appeal to the users as well.

3.3 Product Subsystems and Components

As highlighted in the requirements, the cooker has three major parts with different functions:

3.3.1 The parabolic reflection surface and mounting

A reflection surface comprises of a shiny surface from where incident sun rays can be directed or concentrated on a particular surface. The options for this was either to use two halves of parabolic mirrors as per dimensions with wooden exterior, use exterior aluminum plus parabolic mirrors or use polished stainless steel.

Polished stainless steel was selected. The use of mirrors is a disadvantage considering that the cooker will be used in outdoor environments, mostly carried and can be subject to crash. Stainless steel offers the reflection surface with an added advantage of durability, aesthetics and possible little maintenance when polished by the user regularly to maintain the mirror finish.. Overall it adds to the durability and appeal of the product. **Figure 3.3** shows the design of the reflector by solidwork.

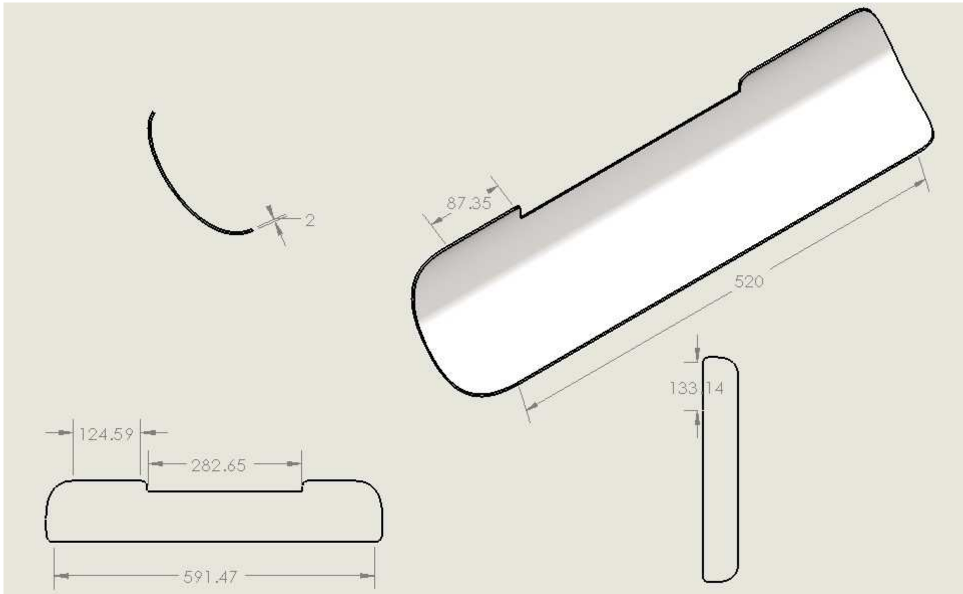


Figure 3.3: Design of Reflector

Moreover, we have used these equations to finalize our parabola design. A parabola is the locus of a point that moves so that its distances from a fixed line and a fixed point are equal. This is shown on **Figure 3.4**, where the fixed line is called the directrix and the fixed-point *F,* the focus. Note that the length *FR* equals the length *RD.* The line perpendicular to the directrix and passing through the focus *F* is called the axis of the parabola. The parabola intersects its axis at a point *V* called the *vertex,* which is exactly midway between the focus and the directrix.

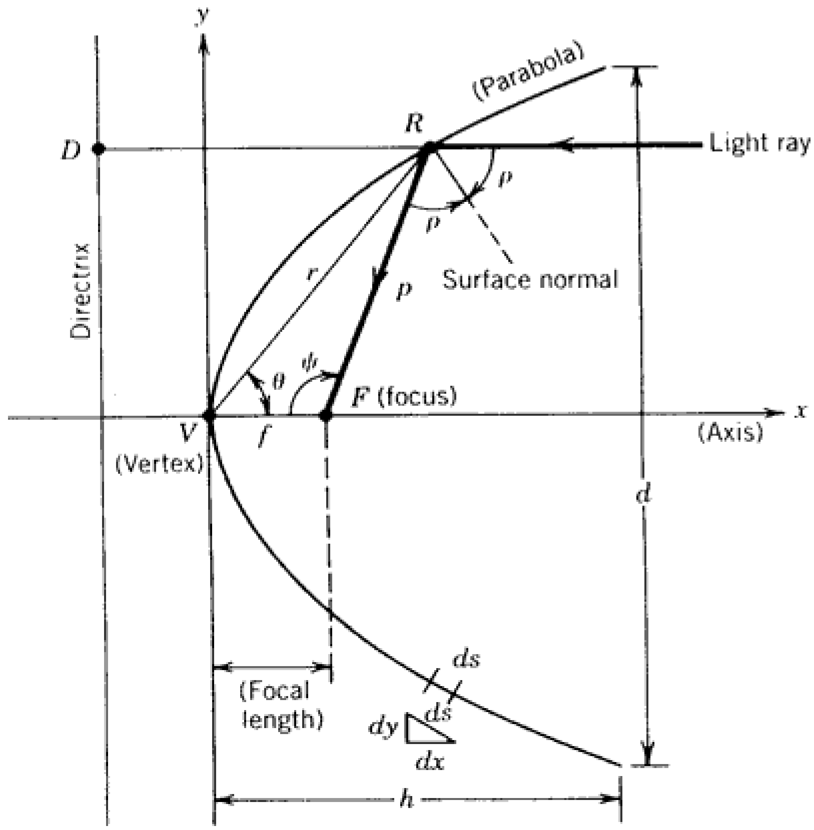


Figure 3.4 The parabola

If the origin is taken at the vertex V and the x-axis along the axis of the parabola, the equation of the parabola is

$$y^2 = 4fx \quad (m^2)$$ Equation (3.1)

where f, the focal length, is the distance VF from the vertex to the focus. When the origin is shifted to the focus F as is often done in optical studies, with the vertex to the left of the origin, the equation of a parabola becomes

$$y^2 = 4f(x + f) \quad (m^2)$$ Equation (3.2)

In polar coordinates, using the usual definition of r as the distance from the origin and θ the angle from the x-axis to r, we have for a parabola with its vertex at the origin and symmetrical about the x-axis

$$\frac{\sin^2 \theta}{\cos \theta} = \frac{4f}{r}$$

Equation (3.3)

Often in solar studies, it is more useful to define the parabolic curve with the origin at F and in terms of the angle ψ in polar coordinates with the origin at F. The angle ψ is measured from the line VF and the parabolic radius p, is the distance from the focus F to the curve. Shifting the origin to the focus F, we have

$$p = \frac{2f}{1 + \cos \psi} \quad (m)$$

Equation (3.4)

The parabolic shape is widely used as the reflecting surface for concentrating solar collectors because it has the property that, for any line parallel to the axis of the parabola, the angle p between it and the surface normal is equal to the angle between the normal and a line to the focal point. Since solar radiation arrives at the earth in essentially parallel rays and by Snell's law the angle of reflection equals the angle of incidence, all radiation parallel to the axis of the parabola will be reflected to a single point F, which is the focus. Careful inspection of the geometry described in **Figure 3.4** will show that the following is true:

$$\psi = 2\rho$$

Equation (3.5)

The general expressions given so far for the parabola define a curve infinite in extent. Solar concentrators use a truncated portion of this curve. The extent of this truncation is usually defined in terms of the rim angle ψ_{rim} or the ratio of the focal length to aperture diameter *f/d.* The scale (size) of the curve is then specified in terms of a linear dimension such as the aperture diameter *d* or the focal length *f*. This is readily apparent in **Figure 3.4**, which shows various finite parabola having a common focus and the same aperture diameter.

3.3.2 The evacuated glass tube

The evacuate glass tube receives the concentrated solar rays that go through the clear surface, the vacuum and finally to the absorbent black inner lining. The function of this component is to convert the reflected UV rays into heat that will be transmitted to the food inside. **Figure 3.5** shows the design of our vacuum tube by solidwork.

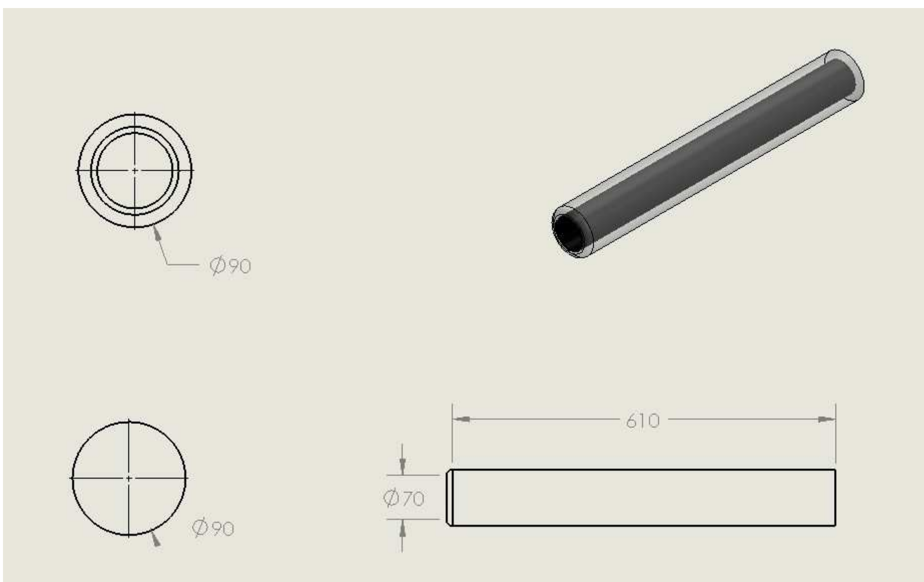


Figure 3.5: Design of Vacuum Tube

3.3.3 The slider or tray assembly

It will be holding the food that the user wants to cook. The tray is made of a half-cylinder which will have clearance from the internal diameter of the tube. One end has a rubber steam vent as shown in **Figure 3.8** that will have an interference fit (tight-fit) to the internal diameter of the tube. The purpose of the sealer is to avoid loss of heat during the cooking process as well as keeping the food clean from external dust and contamination. Also, there will be a wooden handle included as shown in **Figure 3.7** where the user will hold to push or to extract the tray from the tube. The tray will definitely be hot and the wooden handle is insulated from the heat. **Figure 3.6** shows the design of our tray assembly.

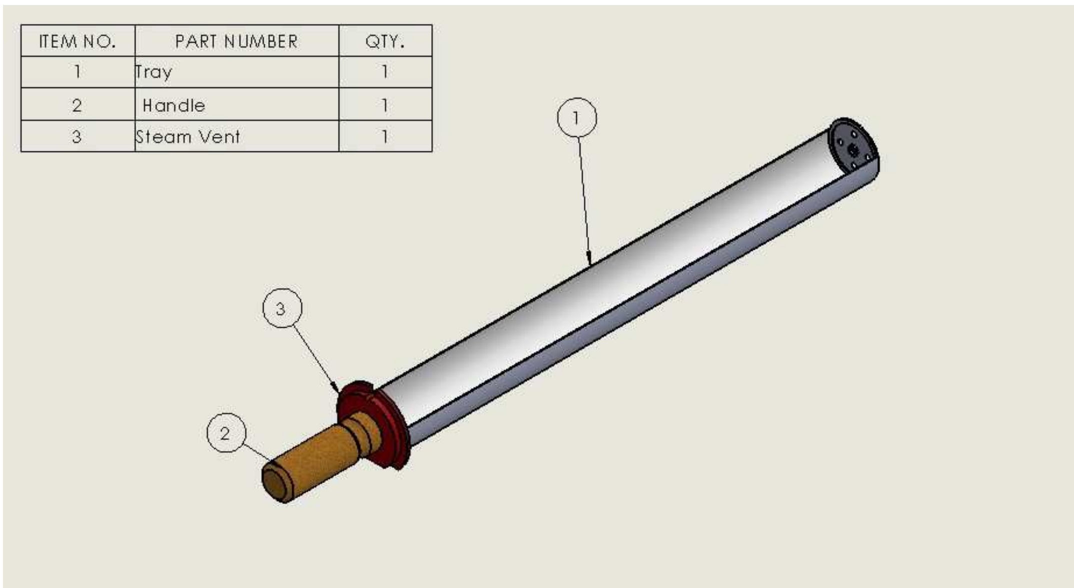


Figure 3.6: The Tray Assembly

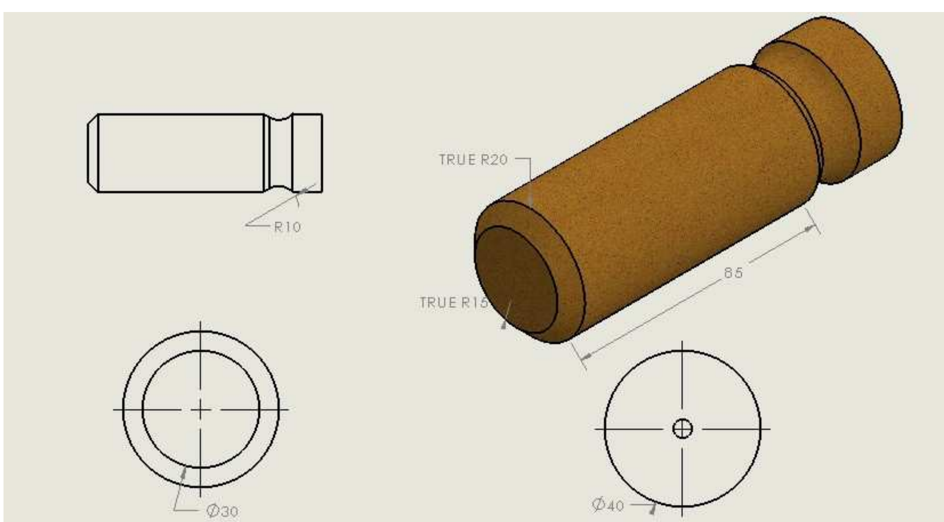


Figure 3.7: Design of The Wooden Hanlde

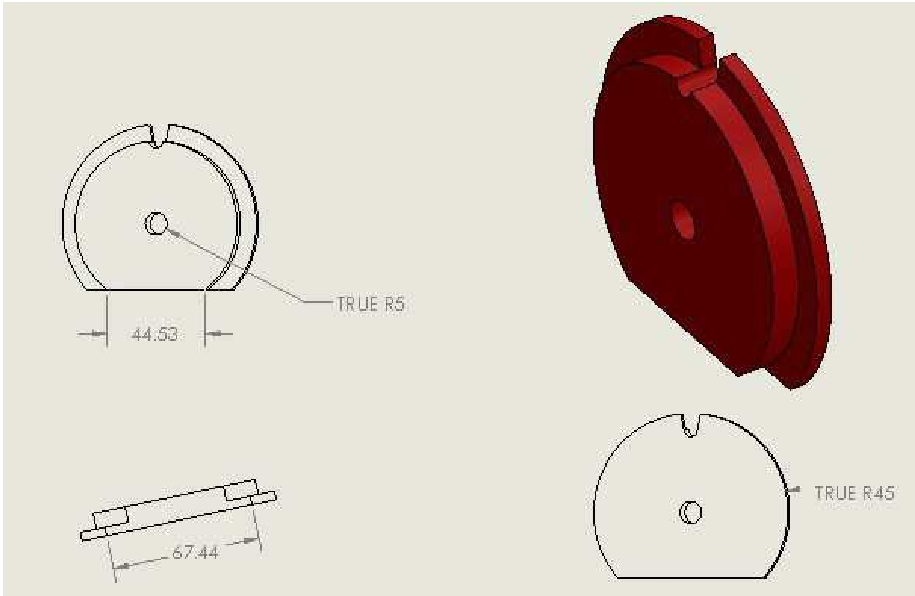


Figure 3.8: Design of The Steam Vent

3.4 Implementation

The system is created in three phases. First, the stainless-steel parts will be cut and fabricated. It will involve creating the parabolic surfaces from cut steel plate bent to meet the specifications of the design. Next, the mounting system will be fabricated and attached to the parabolic surfaces and then hinged. The internal rest for the tube will also be fabricated and fixed onto the surface. The tray is also made of stainless steel will be made at this stage. A plain stainless sheet will be cut and bent to the needed diameter and one end welded onto a semi-circle steel plate. This is the part that goes into the tube. On the other side the semi-circular plate will be welded onto a rod that will be the handle for the tray. A rubber sealer will be cut and machined to specifications and dimensions to get a tight fit. After this, the wooden handle will be fixed on the rod to complete the slider assembly. The vacuum tube will follow the specifications and get a black paint on the inner lining. Testing will be the last step in the process with needed adjustments done to ensure the rays all converge onto the surface. At this point the system will be complete and ready for use.

Chapter 4

System testing and Analysis

4.1 Experimental set up

The objective of this experiment is to study the thermal performance of the evacuated tube solar.

The photograph of the experimental setup is shown in **Figure 4.1**.

The experimental set up in this project consist of:

- glass vacuum tube
- Reflector
- Tray and steam vent
- infrared thermometer

Figure 4.1: The Project Setup

4.1.1 Glass evacuated tube

The evacuated tube used in this system is shown in **Figure 4.2**. The evacuated tube consists of two concentric glass tubes which are made from borosilicate glass and between two tubes there is a vacuum. The outer tube is transparent and the inner tube is coated with a coating (Al-N/Al) for better absorption of solar radiation.

Figure 4.2: The Evacuated Tube

4.1.2 Reflector

Reflector is used under the evacuated tube to reflect the sunlight onto the evacuated tube. It is made of stainless steel and coated with zinc to bring good reflectivity. It can easily reflect the incident solar radiation to the tube due to which the outlet temperature is increased. **Figure 4.3** shows the reflector setup.

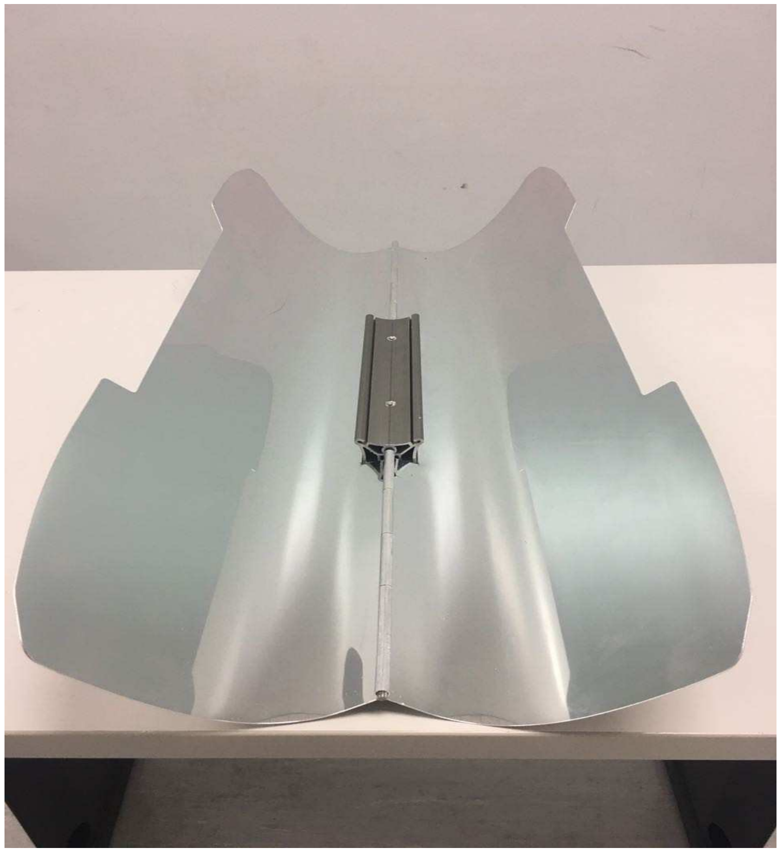


Figure 4.3: The Reflectors

4.1.3 Tray and steam vent

It is a tray made of stainless steel for better heat absorbing as in **Figure 4.4**. A steam vent added to control the pressure inside the tube because during the experiment the pressure should be controlled as in **Figure 4.5**.

Figure 4.4: The tray **Figure 4.5: Steam Vent**

4.1.4 Infrared thermometer gun

Is a thermometer which infers temperature from a portion of the thermal radiation, the device's ability to measure temperature from distance. **Figure 4.6** shows the infrared thermometer gun that we have used.

Figure 4.6: The Infrared Thermometer Gun

4.2 Thermal analysis

The system analysis is based on the following simplify assumptions:

the whole system is at mean temperature

the various thermo-physical properties remain constant with temperature

solar irradiant and ambient temperature are constant

solar collector is placed facing the sun and exposed to solar radiation and kept of the dust

We have used **Equation 4.1** to find (Qconv):

$Qconv = h_c A (T_a - T_b)$ (Equation 4.1)

Where:

Qconv = heat transferred per unit time (*W, Btu/hr*)

A = heat transfer area of the surface (m^2, ft^2)

h_c = convective heat transfer coefficient of the process ($W/(m^2 K)$ or $W/(m^2\ ^\circ C)$, $Btu/(ft^2\ h\ F)$)

$(T_a - T_b)$ = temperature difference between the surface and the bulk fluid *(K or ˚C, F)*

If a hot object is radiating energy to its cooler surroundings, the net radiation heat loss rate can be expressed as in **Equation 4.2:**

$q = \varepsilon \sigma (T_h^4 - T_c^4) A_c$ (Equation 4.2)

Where:
T_h = hot body absolute temperature *(K)*
T_c = cold surroundings absolute temperature *(K)*
A_c = area of the object *(m^2)*
ε = emissivity coefficient of the object (one - 1 - for a black body)

***σ = 5.6703 10^{-8} (W/m^2K^4) -** The Stefan-Boltzmann Constant*

4.3 system operation

The experiment was conducted in a semi-sunny day, temperature was around 23˚C to 25˚C and the device was set with an angle facing the sun for better performance. In experiment 1, the tray was filled with 10 hotdogs. **Figure 4.7** shows the experimental setup. The system was exposed to direct sun radiation for time period of 90 minutes. Infrared thermometer gun was used to measure the temperature inside.

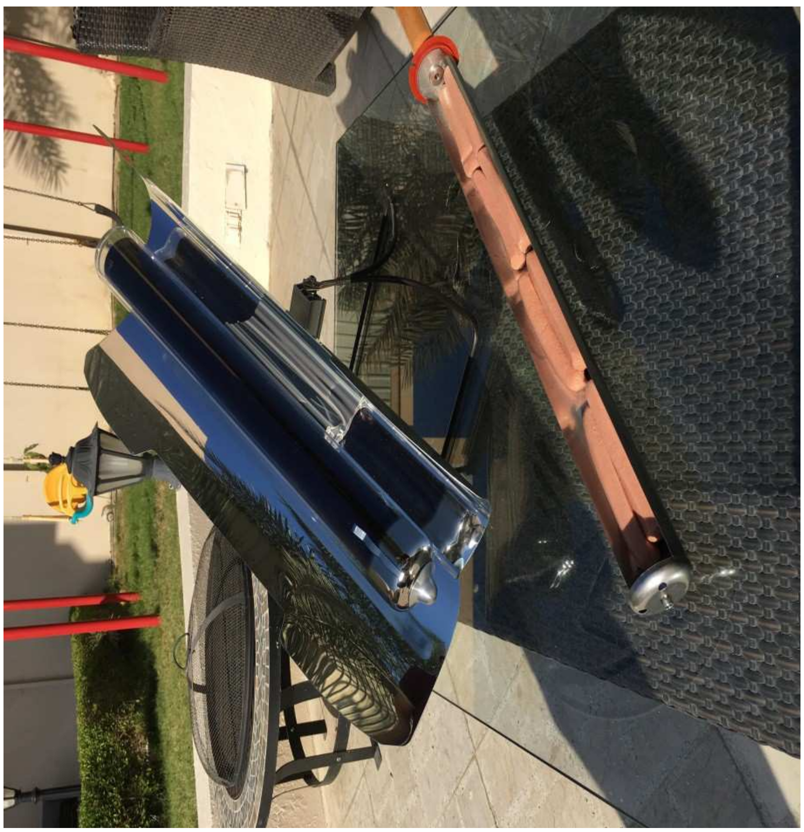


Figure 4.7: The first experiment

Later on, the same experiment was conduct with different kind food, frozen vegetables, with time period of 30 minutes as shown in **Figure 4.8**. The two experiments were conducted at time interval of one and a half hour from 11:00 to 12:30 in the afternoon.

Figure 4.8: Shows the second experiment

4.4 Result & Discussion

The experiment was conducted for a number of days and also corresponding to the different values of load. You can cook in winter and summer. As long as the sun is up, the stove would work. Cooking times vary greatly depending on food type and sun strength. We heated cold hotdogs one day in about 90 minutes with a surrounding temperature of 25˚C**. Tables 4.1 and 4.2** shows the results conducted for our project and previous results**. Figure 4.9** shows the comparison between the two devices. The vegetable dish was done in less than 30 minutes. the glass tube traps moister from the cooking and it is sealed tightly that almost no steam escape.

Table 4.1: double-walled vacuum tube solar cooker

Time in minutes	Degree in Celsius
11:00	25 ˚C
11:15	27 ˚C
11:30	32 ˚C
11:45	49 ˚C
12:00	52 ˚C
12:15	66 ˚C
12:30	80 ˚C

Table 4.2: Evacuated tube solar cooker

Time in minutes	Degree in Celsius
11:00	25 ˚C
11:15	40 ˚C
11:30	63 ˚C
11:45	77 ˚C
12:00	92 ˚C
12:15	105 ˚C
12:30	110 ˚C

Figure 4.9: comparison between the two types

Figure 4.10: Cooking Time (In Minutes)

We have conducted an experiment to find the time elapsed for each kind of food we cooked and we gathered the results and plot it into an analytical graph to get, **Figure 4.10** where it shows what time of the day is best for cooking.

Chapter 5

Project Management

5.1 Project Plan

Table 5.1: Team member contribution throughout the project duration

Duration	Tasks	Team members
2 days	Brainstorming	All members
1 day	Abstract	AAA
7 days	Literature review	HQ
2 days	First presentation	AKA
10 days	Design and shop drawings	AAA/FW
4 days	Searching for materials	AKA/HQ
25 days	Ordering the parts	AKA/FW
10 days	Manufacturing	All team members
3 days	assembly	AAA/HQ
7 days	Testing	All team members
2 days	Mid-term presentation	AKA/FW
5 days	Results and discussion	HQ/FW
1 day	Project management	AAA
1 day	Conclusion	HQ
7 days	Finalizing the final paper	All team members
3 days	Final presentation	All team members

Table 5.1 shows the project planning process and consist the sequence of tasks to be performed. This table defines the approach to be taken, and the commitment been assumed. It contains the details required to successfully execute the project.

5.2 Contribution of Team Members

Table 5.2: Team contribution percentages

Team member	**Contribution percentage**
Abdullatif K. Alabdulqader	25%
Abdulrahman A Alamoudi	25%

Feras F. Alabdulwahed	25%
Hassan H. Alqatari	25%

Abdullatif AL Abdulqader is the group leader. He was responsible of arranging all meeting. He has the ability to communicate with the others easily. Moreover, Abdullatif has a very good time management skills.

Abdulrahman AL Amoudi is a very good editor. He is the one responsible of editing and correcting the grammar and spelling mistakes. He has different skills in typing, as a wide background of Microsoft office program.

Hassan AL Qatari has different skills in solidwork program. He is a hard worker and really enjoying what is he doing. He has different backgrounds of heat transfer and thermodynamics laws.

Feras AL Abdulwahed has different skills in interacting with other people. He was responsible of ordering parts, visiting workshops and solidwork solutions. He has a very enthusiastic personality which helped us a lot during the project period. **Table 5.2** shows the team members contribution percentages.

5.3 Project Execution Monitoring

Academic advisors support and partner with us as students so that we can make informed decisions, develop goals to succeed academically, and plan for the future works. The decisions we made regarding the selection of the materials and equations we are going to use for our project were made collaboratively with our department academic advisor to ensure that we are completing the correct requirements.

Meeting with the advisor also helped us to clarify our goals, track our progress, and make decisions supportive of completion on time.

Group projects. By now, you realize that they can be a blessing and a curse because you have to deal with the people you are given. The truth is these group exercises are also exercises in life because, in the workplace, you are going to experience the same exact types of people. However, meetings with our group members were conducted twice a week to share the work requirements. In the last month, we finally reached the final stage of our project which is testing. We have performed two major tests. In the first test, we have used our vacuum tube solar cooker to cook sausages, the test was successfully conducted and the results were perfect. In the second test, we tried to cook some frozen vegetables. The results were not as good as the first experiment where the efficiency was far less than the first experiment due lack of sun light. In the second experiment, it took us a longer time to reach our target but finally we reached it.

5.4 Challenges and Decision Making

Differences are inevitable when passionate people work together. Eventually, after a team gets through an initial orientation with a new task, members usually come to the realization that working together to accomplish a common goal is tough work.

This occurs in the “dissatisfaction” stage of team development when the team recognizes the discrepancy between what is expected of them and the reality of getting it done. As a leader it is important to differentiate between the different types of conflict teams experience and to have a plan for helping the team move forward. It happened once, when two of our group members were arguing about the project and it was going now where. The group leader stopped the group and asked each member to take a turn talking with no interruption or debate. The rest are just to listen and try to understand where they are coming from and why they are posing the solution that they are.

Another challenge we have faced happened when ordering the parts. A delay on receiving the parts happened because of the charismas holiday. This delay affected our progress with the assembly part of our project. However, after we receive the delay parts, one of the parts accidentally felt down and broken. We had to make another order and assemble the parts together in a short time period.

5.5 Project Bill of Materials and Budget

Table 5.3: bill of materials and costs

Part Number	Part Name	Quantity	cost
1	Solar Evacuated Tube	1	1500 SR
2	Reflector	2	1000 SR
3	Cooking Tray	1	50 SR
4	Cooking Handle	1	50 SR
5	Steam Vent	1	25 SR
6	Cleaning Attachment	1	10 SR
7	Top Bracket	1	50 SR
8	Bottom Bracket	1	50 SR
9	Tensioning Bolt	1	10 SR
10	Reflector Securing Nuts	4	25 SR
11	Legs	2	100 SR
12	Leg Tensioning Nuts	2	25 SR
13	Tube slider	1	50 SR
14	Reflector Pin	2	50 SR
Total Cost			2995 SR

Budgeting finances for our project begins with the creation of a detailed and accurate forecast of our total anticipated costs which will be around 3500 SR. We have taken every aspect of our project into consideration, consult with others who will be involved, and calculate our figures down to the last Hlala.

Along with our budget, we have created a contingency fund around 500 SR, to be used in emergency situations such as work delays due to bad weather, underestimated resource costs and issues with suppliers.

Table 5.3 shows the parts we have used and its production costs. Our project's cost was a little bit below our estimated number by 1000 SR. However, this accomplishment meets our budgetary goal which is to complete the project at or below our estimate, without accessing contingency funds.

Chapter 6

Project Analysis

6.1 Life-long Learning

During this project we have come across several of new information and technicality which we had to do research to find out what is it and how to deal with it, as well as some forgotten information. We as a group have divided some of the work between us and the other was a group work. We have successfully finished our work project to meet the expectations we are acquired to do. During the semester we have worked with different hardware’s, software’s, and gained different kind of skills that helped us a lot to reach our goal.

6.1.1 Software and hardware

During the semester we have worked with different software’s that helped us to achieve the criteria to get the best model to show at the end of the semester. We have worked with Solidwork, Microsoft Excel, Gantt Chart.

6.1.2 Project Management and Time management

With any project people will face some problems, but good project management will have a second plan and third plan just in case anything happens. In the Beginning of the semester, we had an inside problems between the group members, but we overcame these obstacles. We started making schedule that everybody had to give their highest commitment to the program and deliver the best we can.

6.2 Impact of Engineering Solutions

Our project have many impact on society due to using a clean renewable energy, solar energy, to cook food or boil water, etc. there are many other advantages the society can benefit from our design:

- To cook food in the process of using solar energy instead of electricity or fuel.
- To reduce air pollutants that causes “Global Warming”.
- To use less electricity.
- Can be used to cook food or pasteurize water during emergencies.

6.3 Contemporary Issues Addressed

Here in Saudi Arabia, when it comes to energy we are concentrating more on crude oil for power generation and many other energy that causes damage to the environment than benefit it, where our design as mentioned before is environment friendly.

Chapter 7

Conclusions and Future Recommendations

7.1 Conclusions

Our project (Vacuumed tube solar cooker) has shown a great potential to lead the solar energy industries , VTSC has been compared with different type of solar cookers (box solar cooker) , and it presents outstanding performance due to the unique design and the used materials for construction :

Vacuumed tube has shown great incensement in the efficiency by 24% and more sun rays are absorbed due to the coated parabolic reflectors. The ability to reflect 80% of Sun rays which is considered high percentage. More heat is kept inside the pipe for longer period of time caused by Vacuumed tube which results to extend cooking time despite the preset of the Sun. The desired maximum temperature 288 C was achieved in shorter time period, the ability to gain higher temperature faster. Due to the parabolic reflectors and folding mechanism, we achieved totally Portable and compatible device.

Mounting system is added to collect sun rays from multiple angles. Rotation for 360 degree and vertical rise up to 60 degree when the box cooker should get rotated fully to track sun rays.

7.1.1 Challenges

When there’s too much food inside the tray or not enough space, a noticeable increase in cooking time in order to get done. Insufficient space inside to the pipe due to the steam produced during cooking process may lead to overpressure and break the tube. Therefore, it's advised to not overfill the tray. Due to the complexity of designing Vacuumed tube and unique used material, the manufacturing process was considered costly.

The vacuity of the double pipe makes it totally sensitive to crashes and may break easily. During testing period, a vacuumed pipe was broken by small accident and another pipe was re-designed and manufactured again. The tray should not be preheated and then enter the food, it's recommend to fill the tray from the beginning, when the cooking process starts any try to open the tray may lead to lose amount of heat. Maintenance of the tube itself is relatively hard, because it is a vacuumed tube, any crack in the outer pipe will shut down the whole system. A new pipe should be replaced.

The weather conditions may affect the efficiency of the system greatly, in order to operate the cooker for maximum efficiency, full sun should be presented, in rainy weather conditions the system will find difficulties to work properly.

Its relatively new technology especially the Vacuumed tube and it is not available in many countries yet, thus to replace and find spare parts for maintenance might be difficult, in some cases, parts need to be ordered from overseas countries.

7.2 Future Recommendations

Vacuumed tube solar cooker and solar cookers particularly new technology in the markets, we believe in couple of years from now the efficiency and designs will improve dramatically.

Firstly, the next generation of VTSC could have larger diameter of the pipe in order to cook more food at once which is more convenient way for those with special needs.

Secondly, the Vacuumed tubes are very fragile and sensitive to crashes; therefore, more research should be carried out on this particular issue in order to improve the durability and strength of these tubes.

Thirdly, adding a Thermometer outside the cooker should make the device more functional, some certain kind of food needs specific temperature to be cooked properly.

Lastly, placing two separate Vacuumed tubes instead of one might be better feature for those who desire to cook various kind of food simultaneously yet without mixing them in the same tray.

References

[1] https://en.wikipedia.org/wiki/Vacuum_flask - accessed 20th January, 2016

[2] http://www.folkecenter.net/mediafiles/folkecenter/pdf/Solar-Tubes.pdf - accessed 20th January, 2016.

[3] http://solarcooking.org/Granada06/12_alex_kee.pdf - accessed 20th January, 2016.

[4] http://www.slicksolarstove.com/wp-content/uploads/2015/08/150829-SM70-instructions.pdf - accessed 20th January, 2016.

[5] Ayompe, L., Duffy A., Mc Cheever, M., Conlon, M., McCormack, S. Comparative field performance study of flat plate and heat pipe evacuated tube collectors (ETCs)for domestic water heating systems in a temperate climate. Energy 2011; 36:3370–8.

[6] Kumar, R., Adhikari, R.S., Carg, H.P., & Kumar, A. "Thermal performance of a solar pressure cooker based on evacuated tube solar collector" Applied Thermal Engineering, Vol. 21, pp. 1699-1705, 2001.

[7] Riffat, S., & Cuce, E. A review on hybrid photovoltaic/thermal collectors and systems. Int J Low – Carbon Technol 2011;6 (3):212–241.

[8] Sahin A.D., Dincer, I., & Rose, M.A. Thermodynamic analysis of solar photovoltaic cell systems. Solar Energy Mater Solar Cells 2007; 91:153–159.

[9] Zhou, S.J., Zhang, X.S. Comparison of two kinds of solar collector/energy storage. In: First international conference on building energy and environment, Dalian, China; 13–16 July 2008.

Appendix A

Progress reports

SDP – WEEKLY MEETING REPORT

Department of Mechanical Engineering
Prince Mohammad bin Fahd University

SEMESTER: ACADEMIC YEAR:	FALL 2016-2017	Date:	20-10-2016
PROJECT TITLE	Design of a Vacuum Tube Solar Cooker		
SUPERVISORS	Dr. Ali chamkha , Dr. Nader Nader		

Member Name	Present/Absent	Arriving on time
Abdulrahman Alamoudi	✓	✓
Abdullatif Alabdulqader	✓	✓
Hassan Alqatari	✓	✓
Feras Alabdulwahed	✓	✓

Task progress report for the last week effort:

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	**Group meeting and brainstorming**	ALL	100%	Done
2	**Finish the first presentation**	FA-AAA	100%	Presented
3	**Collecting Data about the project**	HQ-AKA	90%	The reports
4	**Prepare the Gantt Chart**	HQ- AKA	50%	presented

Task allocation for the next week:

#	Task description	Team member assigned
1	**Meeting with the manufacturer**	AAA-AKA
2	**Sketch the final design**	HQ-FA
3	**Literature review first draft**	AKA- HQ

Outcome f:
An understanding of professional and ethical responsibility.

Criteria	None (1)	Low (2)	Moderate (3)	High (4)
f.1 Demonstrate professionally responsibility at all times.	Fails to demonstrate responsibility for his actions and does not deal with others professionally	Shows some sense of responsibility for his actions but needs improvement in dealing with others professionally	Takes full responsibility for his actions and deals with others professinally	Demonstrates high moral and professional ethics, takes complete responsibility for his actions and is excellent in interacting and dealing with others

Outcome d: An ability to function on multidisciplinary teams.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
d.1 Develop a work plan and distribute tasks	Fails to develop a work plan and tasks are assigned ad hoc	Develops a work plan without much thought and tasks distribution is not balanced	Develops a good work plan and distributes tasks in a balanced way	Develops a realistic and well thought out work plan and distributes tasks in a balanced way and according to the skills and expertise of the team members
d.2 Take responsibility in team efforts to complete the assigned tasks.	Does not perform assigned tasks; often misses meetings and, when present, does not have anything constructive to say; relies on others to do the work;	Performs assigned tasks but needs many reminders; attends meetings regularly but generally does not say anything constructive; sometimes expects others to do his/her work;	Performs all assigned tasks; attends meetings regularly and usually participates effectively; generally reliable;	Performs all tasks very effectively; attends all meetings and participates enthusiastically; very reliable.
d.3 Show respect to other team members.	Often argues with team mates; doesn't let anyone else talk; occasional personal attacks and "put-downs"; wants to have things done his way and does not listen to alternate approaches;	Usually does much of the talking; does not pay much attention when others talk, and often assumes their ideas will not work; no personal attacks and put-downs but sometimes patronizing; when others get through to him, works reasonably well with them;	Generally listens to others' points of view; always uses appropriate and respectful language; tries to make a definite effort to understand others' ideas;	Always listens to others and their ideas; helps them develop their ideas while giving them full credit; always helps the team reach a fair decision.

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	**Abdullatif Alabdulqader**	3	3	3	3
2	**Abdulrahman Alamoudi**	3	2	2	3
3	**Hassan Alqatari**	2	3	3	2
4	**Feras Alabdulwahed**	3	3	3	3

Comments on individual members

Name	Comments
AKA	
AAA	
HQ	
FA	

SDP – WEEKLY MEETING REPORT

Department of Mechanical Engineering
Prince Mohammad bin Fahd University

SEMESTER: ACADEMIC YEAR:	FALL 2016-2017	Date:	3-11-2016
PROJECT TITLE	Design of a Vacuum Tube Solar Cooker		
SUPERVISORS	Dr. Ali chamkha , Dr. Nader Nader		

Member Name	Present/Absent	Arriving on time
Abdulrahman Alamoudi	✓	✓
Abdullatif Alabdulqader	✓	✓
Hassan Alqatari	✓	✓
Feras Alabdulwahed	✓	✓

Task progress report for the last week effort:

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	Meeting with the manufacturer	AAA-AkA	70%	The reports
2	Sketch the final design	HQ- FA	50%	in progress
3	Literature review second draft	HQ-AKA	100%	2ND Draft
4	Prepare the e-portfolio	AAA-FA	100%	The File

Task allocation for the next week:

#	Task description	Team member assigned
1	Finalize the Final sketch by solid works	HQ-FA
2	Start manufacturing the final product	AAA-AKA
3	Prepare the 2nd presentation	AAA- HQ

Outcome f:
An understanding of professional and ethical responsibility.

Criteria	None (1)	Low (2)	Moderate (3)	High (4)
f.1 Demonstrate professionally responsibility at all times.	Fails to demonstrate responsibility for his actions and does not deal with others professionally	Shows some sense of responsibility for his actions but needs improvement in dealing with others professionally	Takes full responsibility for his actions and deals with others professionally	Demonstrates high moral and professional ethics, takes complete responsibility for his actions and is excellent in interacting and dealing with others

Outcome d: An ability to function on multidisciplinary teams.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
d.1 Develop a work plan and distribute tasks	Fails to develop a work plan and tasks are assigned ad hoc	Develops a work plan without much thought and tasks distribution is not balanced	Develops a good work plan and distributes tasks in a balanced way	Develops a realistic and well thought out work plan and distributes tasks in a balanced way and according to the skills and expertise of the team members
d.2 Take responsibility in team efforts to complete the assigned tasks.	Does not perform assigned tasks; often misses meetings and, when present, does not have anything constructive to say; relies on others to do the work;	Performs assigned tasks but needs many reminders; attends meetings regularly but generally does not say anything constructive; sometimes expects others to do his/her work;	Performs all assigned tasks; attends meetings regularly and usually participates effectively; generally reliable;	Performs all tasks very effectively; attends all meetings and participates enthusiastically; very reliable.
d.3 Show respect to other team members.	Often argues with team mates; doesn't let anyone else talk; occasional personal attacks and "put-downs"; wants to have things done his way and does not listen to alternate approaches;	Usually does much of the talking; does not pay much attention when others talk, and often assumes their ideas will not work; no personal attacks and put-downs but sometimes patronizing; when others get through to him, works reasonably well with them;	Generally listens to others' points of view; always uses appropriate and respectful language; tries to make a definite effort to understand others' ideas;	Always listens to others and their ideas; helps them develop their ideas while giving them full credit; always helps the team reach a fair decision.

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	**Abdullatif Alabdulqader**	3	3	3	3
2	**Abdulrahman Alamoudi**	3	3	3	2
3	**Hassan Alqatari**	3	3	3	2
4	**Feras Alabdulwahed**	3	3	3	3

Comments on individual members

Name	Comments
AKA	
AAA	
HQ	
FA	

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

SEMESTER: ACADEMIC YEAR:	FALL 2016-2017	Date:	24 - 11 - 2016
PROJECT TITLE	design of a vacuum tube Solar cooker		
SUPERVISORS	Dr. Ali Chamkha - Dr. Nader Nader		

Member Name	Present/Absent	Arriving on time
Abdullatif Alabdulqader	✓	✓
Abdulrahman Alamoudi	✓	✓
Hassan Alqatari	✓	✓
Feras Alabdulwahed	✓	✓

Task progress report for the last week effort:

#	Task description	Team member assigned	Progress 0%-100%	Delivery proof
1	**Meeting with the manufacturer**	AKA AAA HQ	100	
2	**Sketch the final design**	HQ	80	
3	**Chapter 3 first draft**	HQ- FA	100	
4	**Parts ordering**	AKA-AAA-FA	100	

Task allocation for the next week:

#	Task description	Team member assigned
1	**Solidworks final sketch**	AAA-FA-HQ
2	**Assembly**	AKA-HQ
3	**Testing and Analysis**	AAA-FA-AKA-HQ
4		
5		

Outcome f: An understanding of professional and ethical responsibility.				
Criteria	None (1)	Low (2)	Moderate (3)	High (4)
f.1 Demonstrate professionally responsibility at all times.	Fails to demonstrate responsibility for his actions and does not deal with others professionally	Shows some sense of responsibility for his actions but needs improvement in dealing with others professionally	Takes full responsibility for his actions and deals with others professinally	Demonstrates high moral and professional ethics, takes complete responsibility for his actions and is excellent in interacting and dealing with others

Outcome d: An ability to function on multidisciplinary teams.				
Criteria	**None (1)**	**Low (2)**	**Moderate (3)**	**High (4)**
d.1 Develop a work plan and distribute tasks	Fails to develop a work plan and tasks are assigned ad hoc	Develops a work plan without much thought and tasks distribution is not balanced	Develops a good work plan and distributes tasks in a balanced way	Develops a realistic and well thought out work plan and distributes tasks in a balanced way and according to the skills and expertise of the team members
d.2 Take responsibility in team efforts to complete the assigned tasks.	Does not perform assigned tasks; often misses meetings and, when present, does not have anything constructive to say; relies on others to do the work;	Performs assigned tasks but needs many reminders; attends meetings regularly but generally does not say anything constructive; sometimes expects others to do his/her work;	Performs all assigned tasks; attends meetings regularly and usually participates effectively; generally reliable;	Performs all tasks very effectively; attends all meetings and participates enthusiastically; very reliable.
d.3 Show respect to other team members.	Often argues with team mates; doesn't let anyone else talk; occasional personal attacks and "put-downs"; wants to have things done his way and does not listen to alternate approaches;	Usually does much of the talking; does not pay much attention when others talk, and often assumes their ideas will not work; no personal attacks and put-downs but sometimes patronizing; when others get through to him, works reasonably well with them;	Generally listens to others' points of view; always uses appropriate and respectful language; tries to make a definite effort to understand others' ideas;	Always listens to others and their ideas; helps them develop their ideas while giving them full credit; always helps the team reach a fair decision.

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	**Abdullatif Alabdulqader**	3	3	4	3
2	**Abdulrahman Alamoudi**	3	3	4	3
3	**Hassan Alqatari**	3	3	4	3
4	**Feras Alabdulwahed**	3	3	4	3

Comments on individual members

Name	Comments
Abdullatif Alabdulqader	
Abdulrahman Alamoudi	
Hassan Alqatari	
Feras Alabdulwahed	

Appendix B

Solidwork Shop Drawing

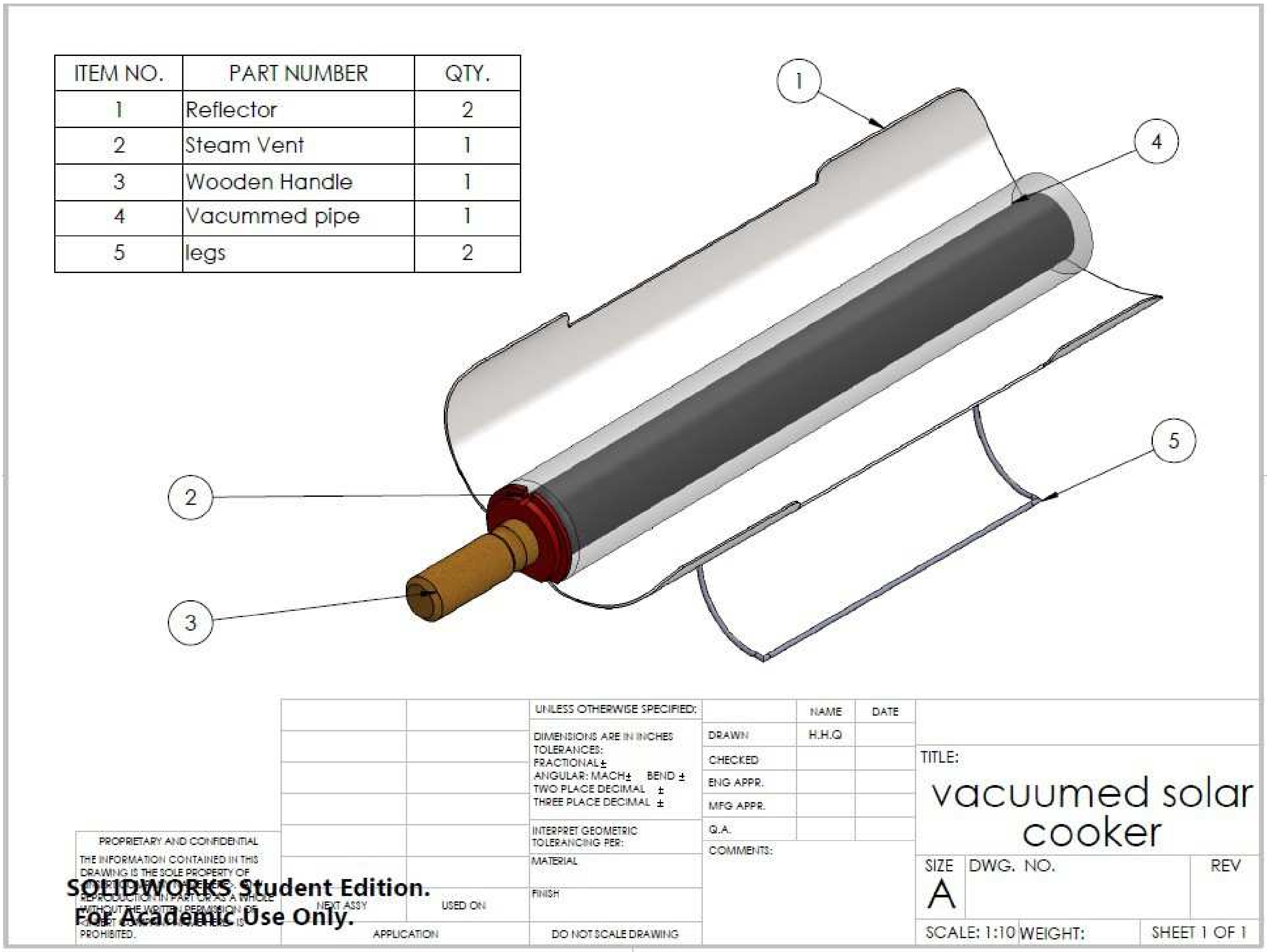


Figure 1: Vacuum Solar Cooker

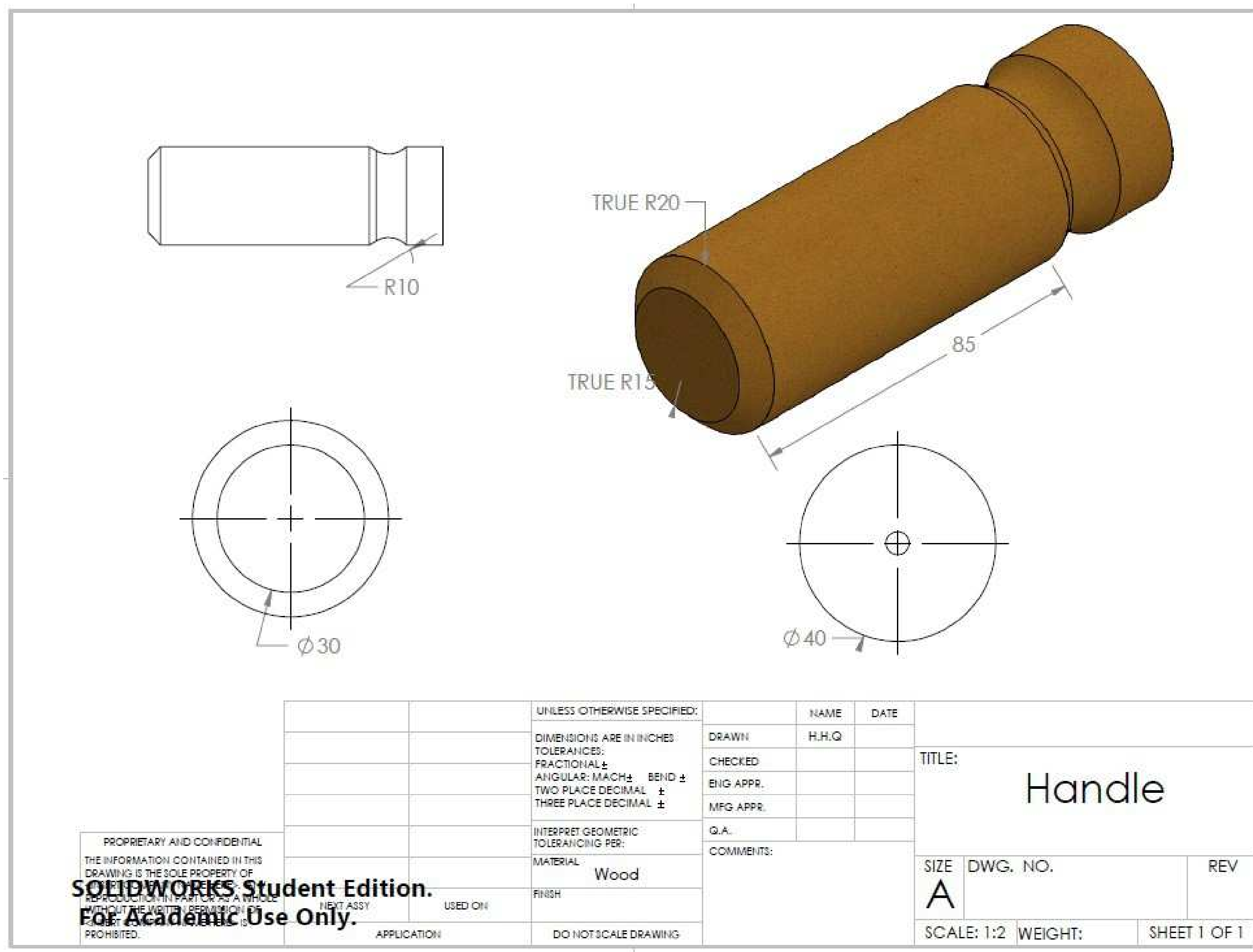


Figure 2: Handle

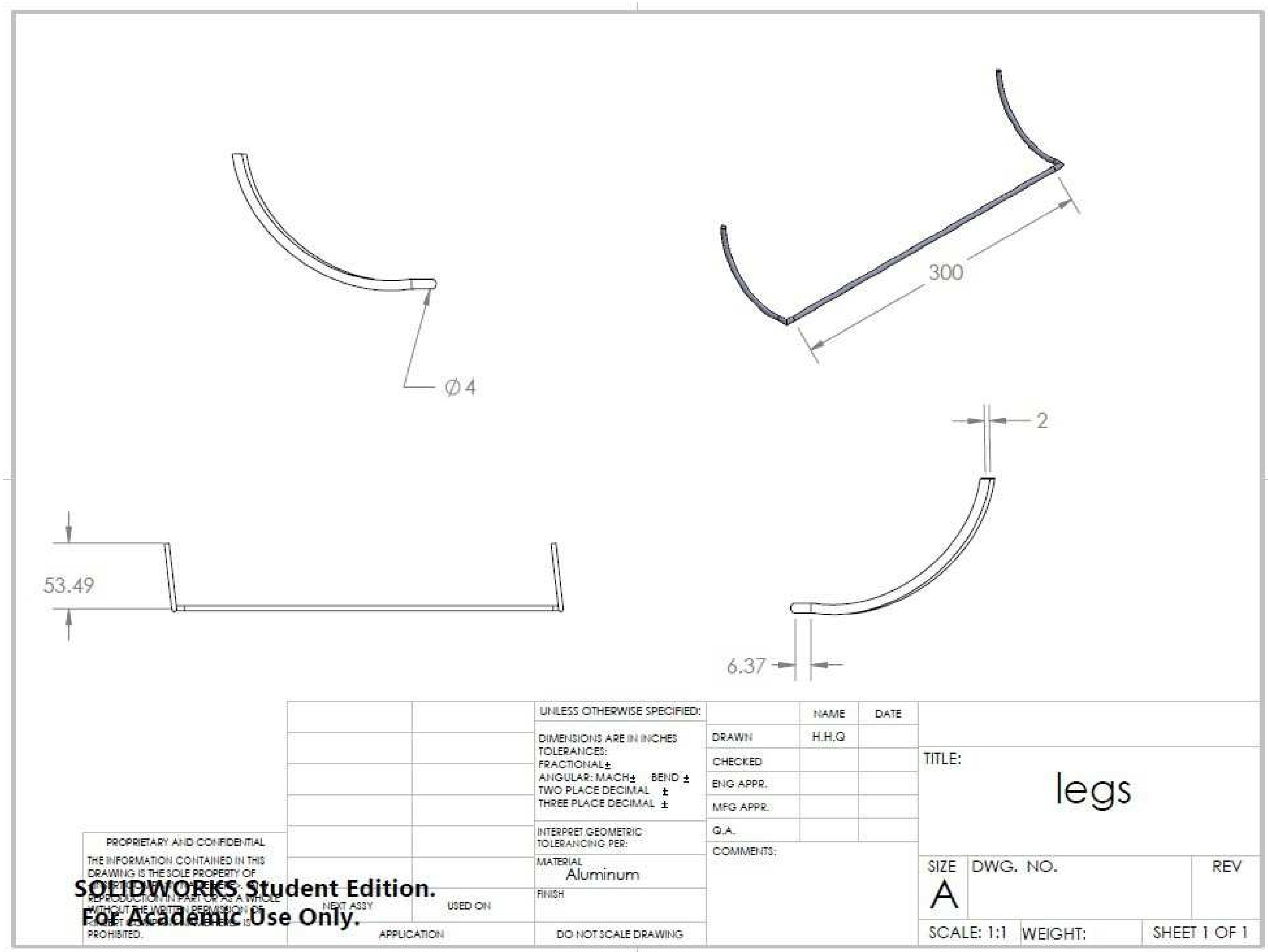


Figure 3: Legs

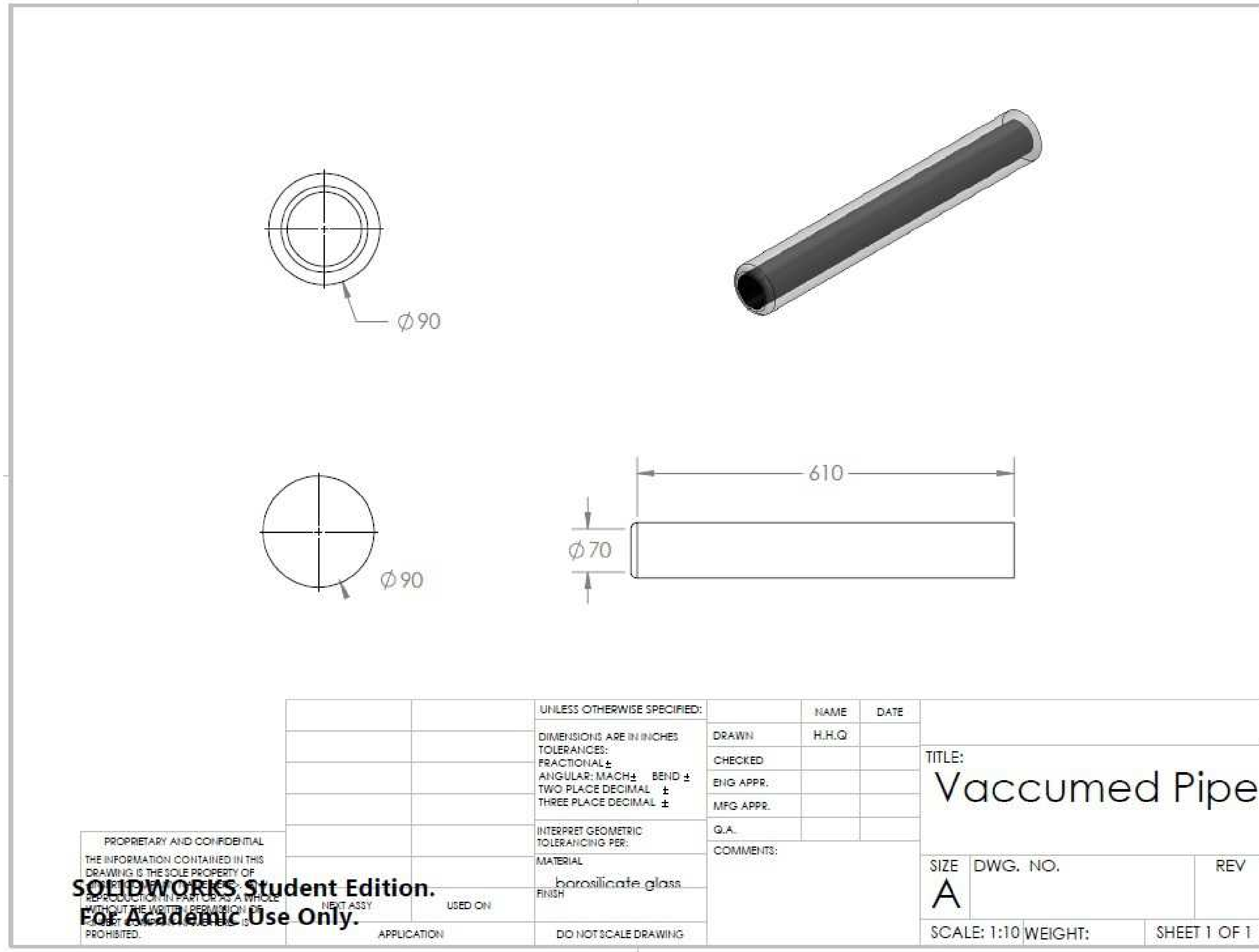


Figure 4: Vacuumed Pipe

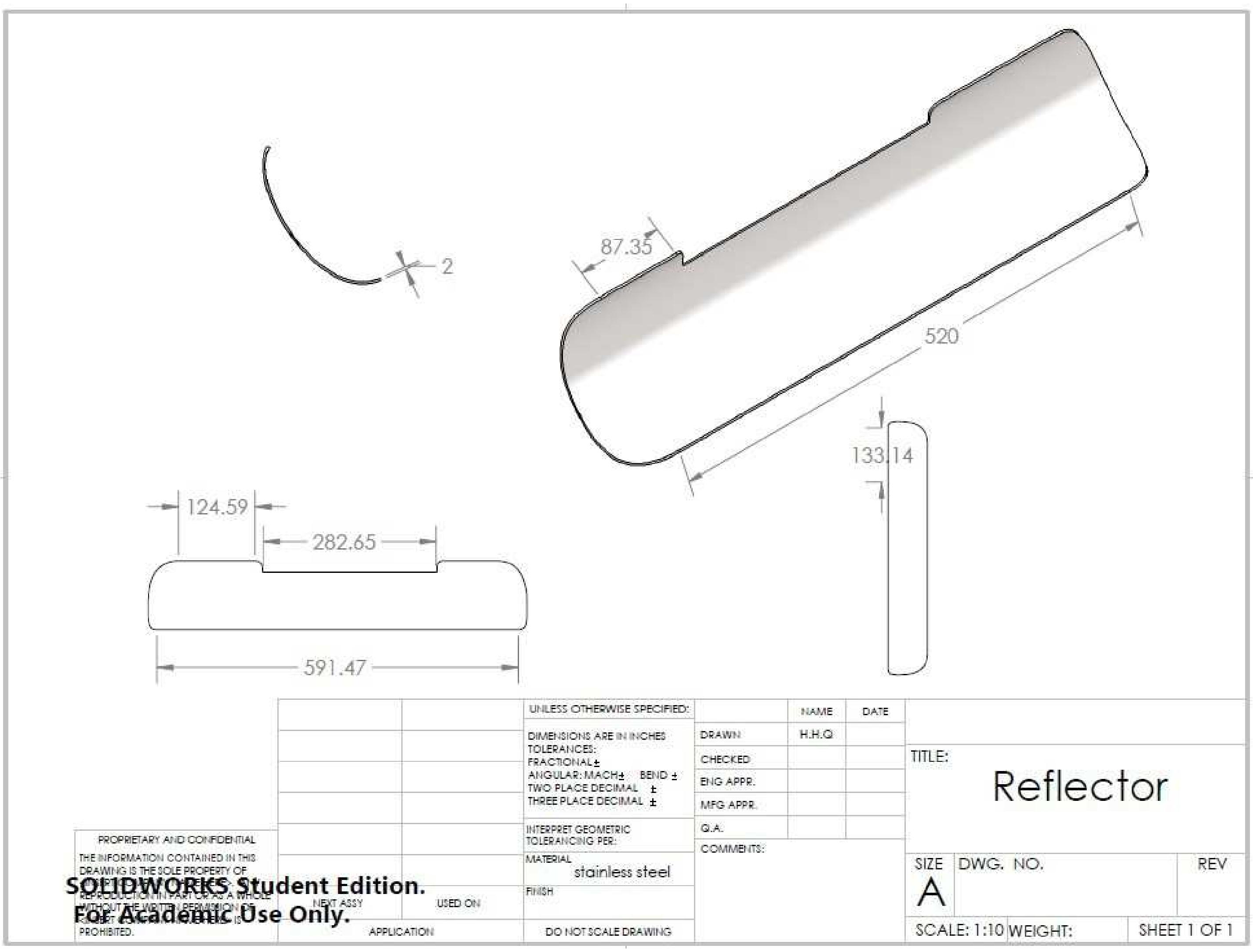


Figure 5: Reflector

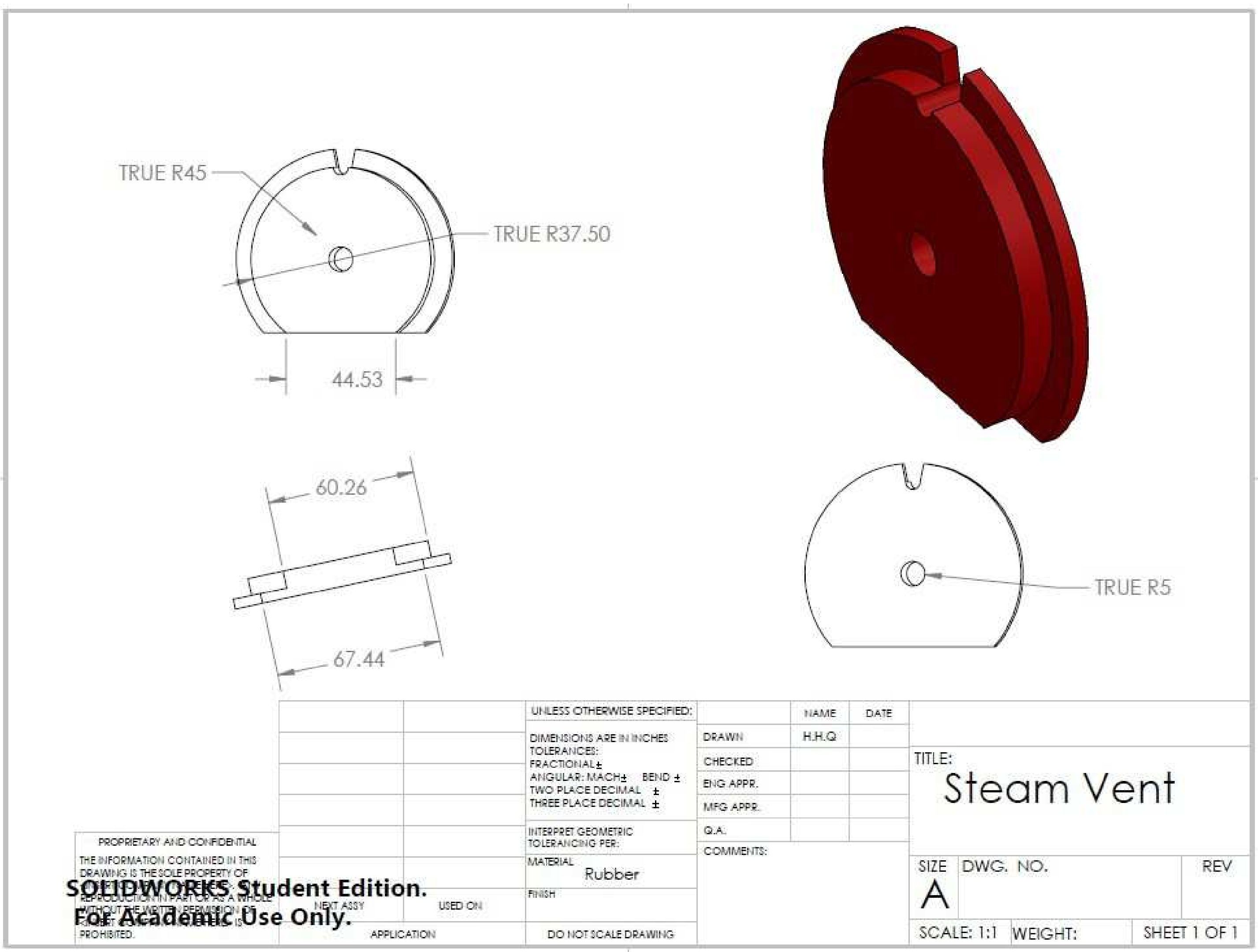


Figure 6: Steam Vent

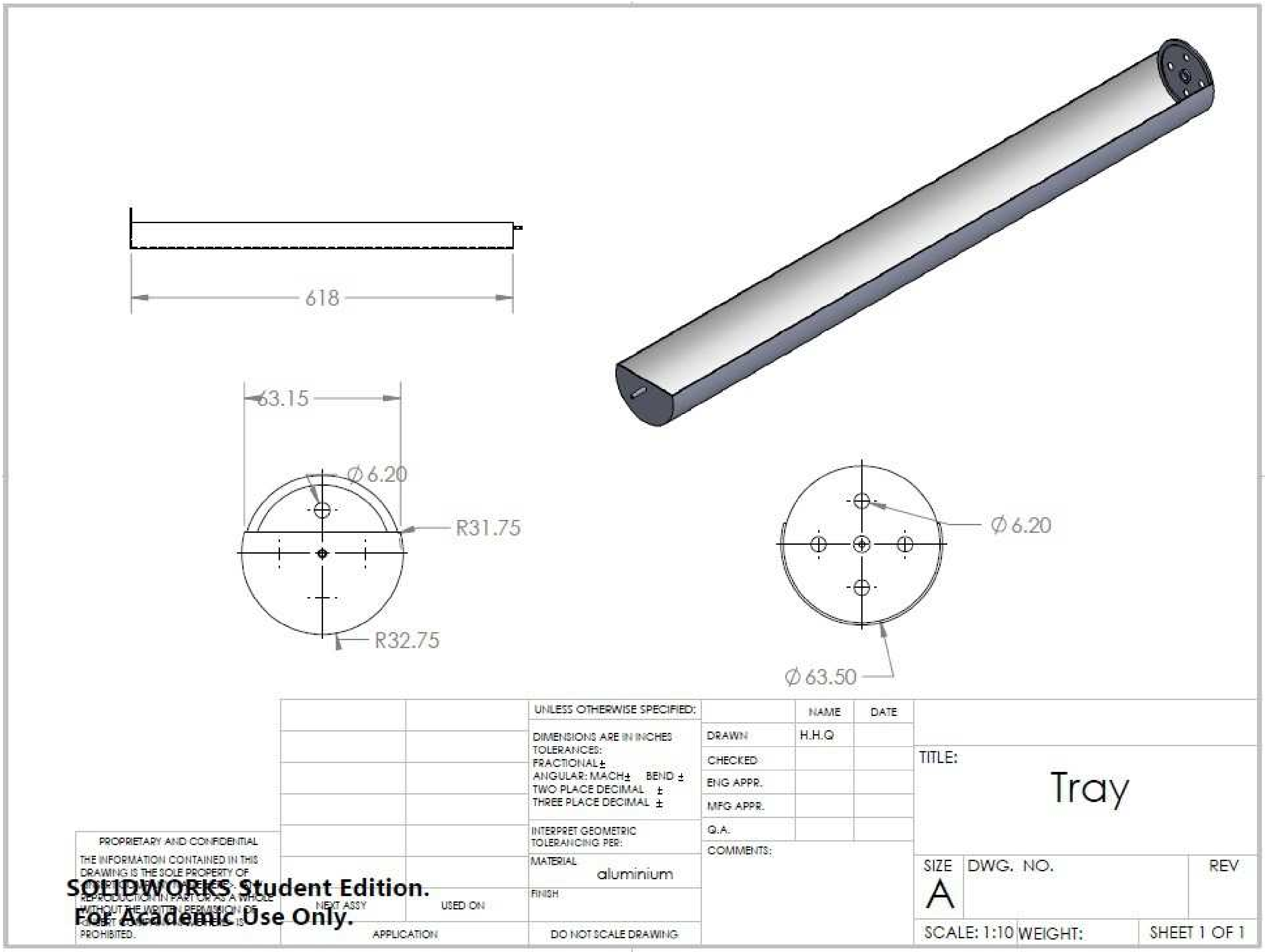


Figure 7: Tray

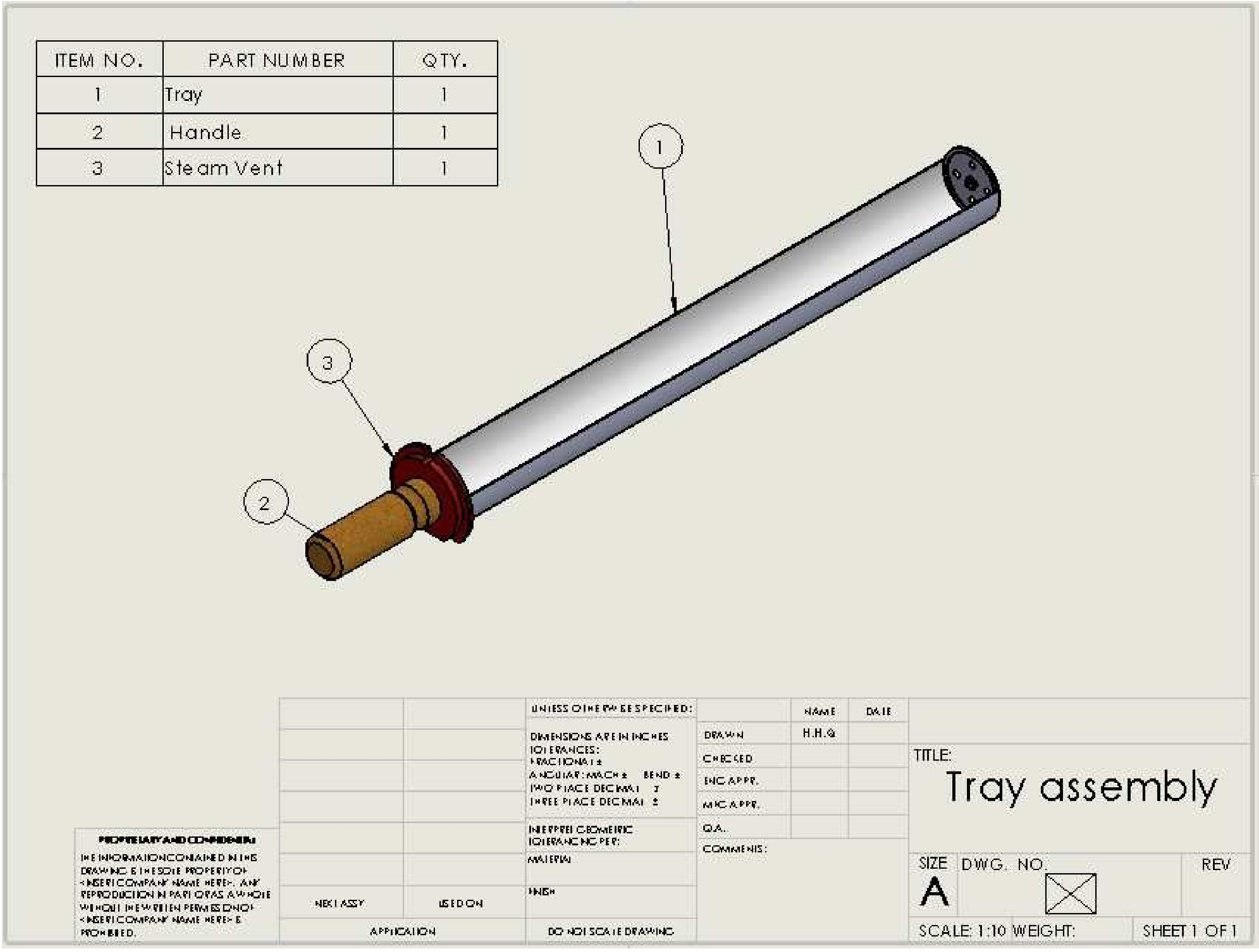


Figure 8: Tray Assembly

Appendix C

Tables and Charts

Tables 1 and 2 shows the results conducted for our project and previous results**.**

Table 1: double-walled vacuum tube solar cooker

Time in minutes	Degree in Celsius
11:00	25 ˚C
11:15	27 ˚C
11:30	32 ˚C
11:45	49 ˚C
12:00	52 ˚C
12:15	66 ˚C
12:30	80 ˚C

Table 2: Evacuated tube solar cooker

Time in minutes	Degree in Celsius
11:00	25 ˚C
11:15	40 ˚C
11:30	63 ˚C
11:45	77 ˚C
12:00	92 ˚C
12:15	105 ˚C
12:30	110 ˚C

Figure 1: comparison between the two types

Figure 2: Cooking Time (In Minutes)

Table 3: Team member contribution throughout the project duration

Duration	Tasks	Team members
2 days	Brainstorming	All members
1 day	Abstract	AAA
7 days	Literature review	HQ
2 days	First presentation	AKA
10 days	Design and shop drawings	AAA/FW
4 days	Searching for materials	AKA/HQ

25 days	Ordering the parts	AKA/FW
10 days	Manufacturing	All team members
3 days	assembly	AAA/HQ
7 days	Testing	All team members
2 days	Mid-term presentation	AKA/FW
5 days	Results and discussion	HQ/FW
1 day	Project management	AAA
1 day	Conclusion	HQ
7 days	Finalizing the final paper	All team members
3 days	Final presentation	All team members

Table 4: Team contribution percentages

Team member	Contribution percentage
Abdullatif K. Alabdulqader	25%
Abdulrahman A Alamoudi	25%
Feras F. Alabdulwahed	25%
Hassan H. Alqatari	25%

Table 5: bill of materials and costs

Part Number	Part Name	Quantity	cost
1	Solar Evacuated Tube	1	1500 SR
2	Reflector	2	1000 SR
3	Cooking Tray	1	50 SR
4	Cooking Handle	1	50 SR

5	Steam Vent	1	25 SR
6	Cleaning Attachment	1	10 SR
7	Top Bracket	1	50 SR
8	Bottom Bracket	1	50 SR
9	Tensioning Bolt	1	10 SR
10	Reflector Securing Nuts	4	25 SR
11	Legs	2	100 SR
12	Leg Tensioning Nuts	2	25 SR
13	Tube slider	1	50 SR
14	Reflector Pin	2	50 SR
Total Cost			2995 SR

DESIGN OF A VACUUM TUBE SOLAR COOKER

SUPERVISED BY:

DR.ALI CHAMKHA
ADVISOR

DR. NADER NADER
CO ADVISOR

PROJECT DONE BY:

ABDULLATIF K. ALABDULQADER 201202484
ABDULRAHMAN A. ALAMOUDI 201002591
FERAS F. ALABDULWAHED 201101505
HASSAN H. ALQATARI 201102989

OUTLINE

- Objectives
- Background
- System Design
- Tasks
- Testing and Analysis
- Future Recommendations
- Conclusion

OBJECTIVES

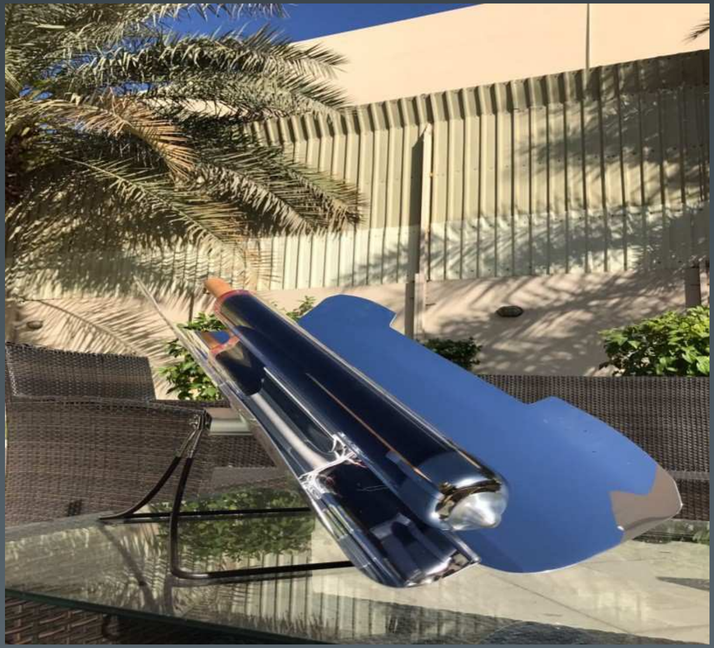
- To cook food in the process of using solar energy
- To reduce air pollutants that cause “Global Warming”
- To use less electricity
- Can be used to cook food during emergencies
- Easy to install
- Low maintenance

BACKGROUND

- Energy is vital for human activities within the environment
- Fossil fuels still constitute the largest share of global energy consumption
- Vacuum Tube Solar Cooker
  - Is a machine that can absorb the sunlight and convert it to heat in order to cook food
  - It can be absolutely useful tool to cook in countries where the Sun

SYSTEM DESIGN

- The vacuum tube solar cooker is divided into three major components:
  - Parabolic reflection surface and mounting
  - Evacuate double-glass tube



SOLAR EVACUATED TUBE

- Borosilicate evacuated glass tube with black internal absorbent surface
- 610 mm long with 70 mm external diameter and 55 mm internal diameter
- Approximately 3.2kg when empty
- Capacity: About 1-1.2 L for fluid or 1.2-1.5 kg solid food

REFLECTORS

- Stainless steel and coated with zinc (for good reflectivity)
- Parabolic Shape

SOLAR COOKING TRAY

- Stainless steel tray (for better heat absorbing)

WOODEN HANDLE AND STEAM VENT

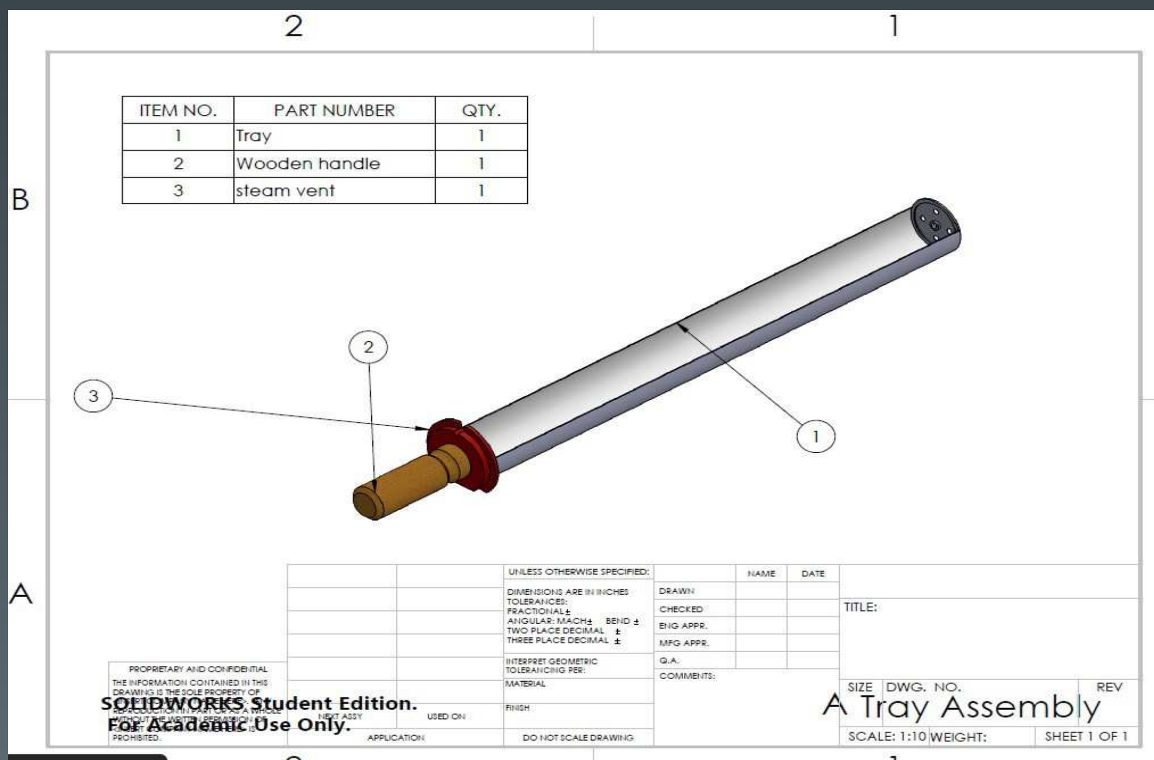
- Wooden handle

No Heat Conductivity

- Steam vent (Rubber sealer)

For Pressure control

COOKING TRAY ASSEMBLY

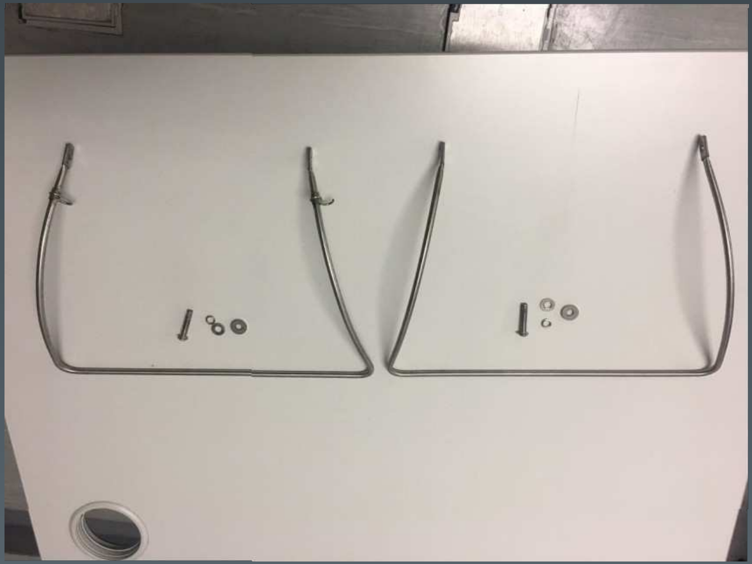


TOP AND BOTTOM BRACKET

- BOTTOM

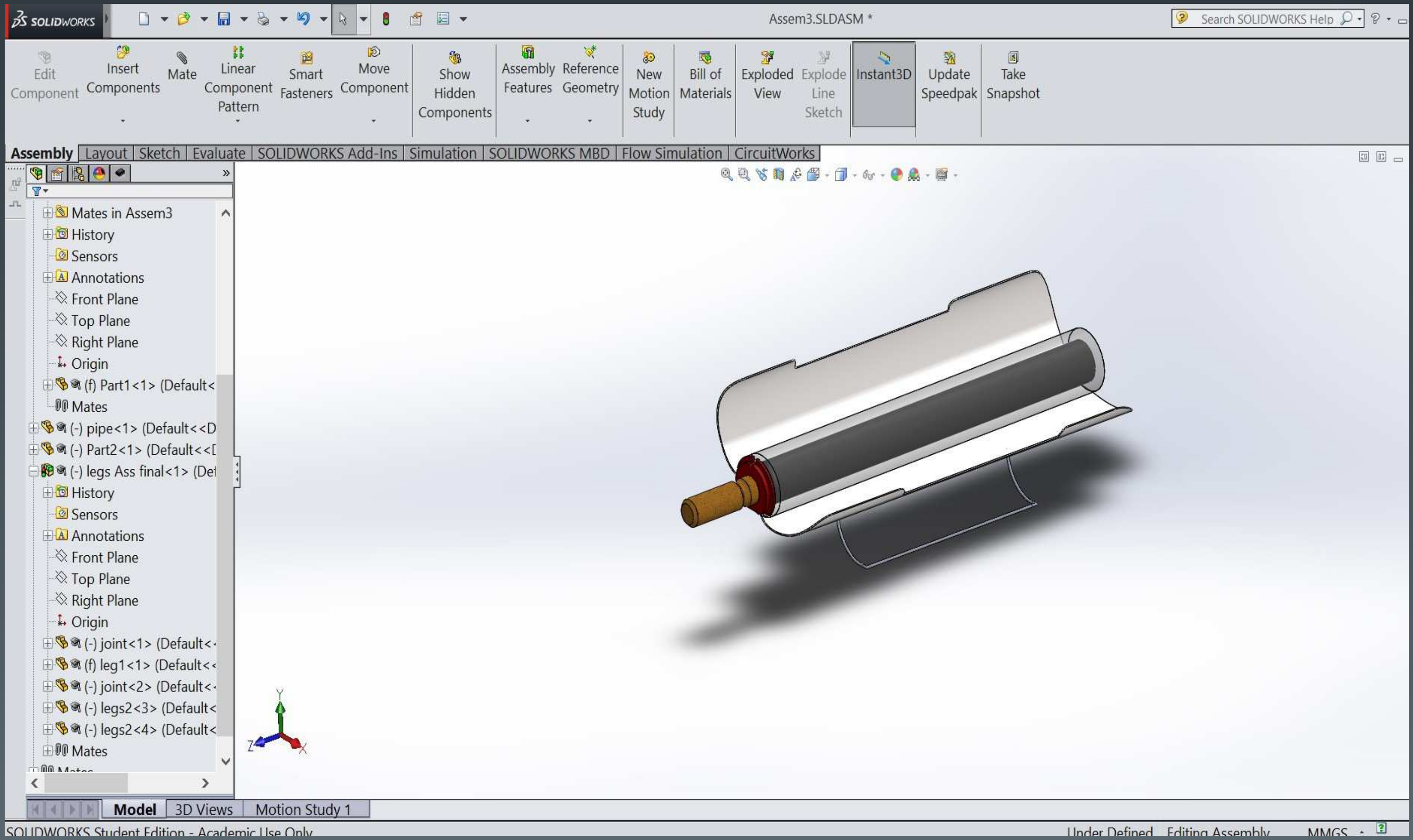
- TOP

LEGS



TASKS

- Brainstorming and Research
- Solidwork and Design
- Material Searching
- Material Ordering
- Manufacturing and workshop Details
- Testing and Collecting Data


SOLIDWORKS
Assem3.SLDASM *
Search SOLIDWORKS Help
Edit Component
Insert Components
Mate
Linear Component Pattern
Smart Fasteners
Move Component
Show Hidden Components
Assembly Features
Reference Geometry
New Motion Study
Bill of Materials
Exploded View
Explode Line Sketch
Instant3D
Update Speedpak
Take Snapshot
Assembly
Layout
Sketch
Evaluate
SOLIDWORKS Add-Ins
Simulation
SOLIDWORKS MBD
Flow Simulation
CircuitWorks
Mates in Assem3
History
Sensors
Annotations
Front Plane
Top Plane
Right Plane
Origin
(f) Part1<1> (Default<
Mates
(-) pipe<1> (Default<<D
(-) Part2<1> (Default<<[
(-) legs Ass final<1> (Def
History
Sensors
Annotations
Front Plane
Top Plane
Right Plane
Origin
(-) joint<1> (Default<
(f) leg1<1> (Default<<
(-) joint<2> (Default<
(-) legs2<3> (Default<
(-) legs2<4> (Default<
Mates
Model
3D Views
Motion Study 1
SOLIDWORKS Student Edition - Academic Use Only
Under Defined
Editing Assembly
MMGS

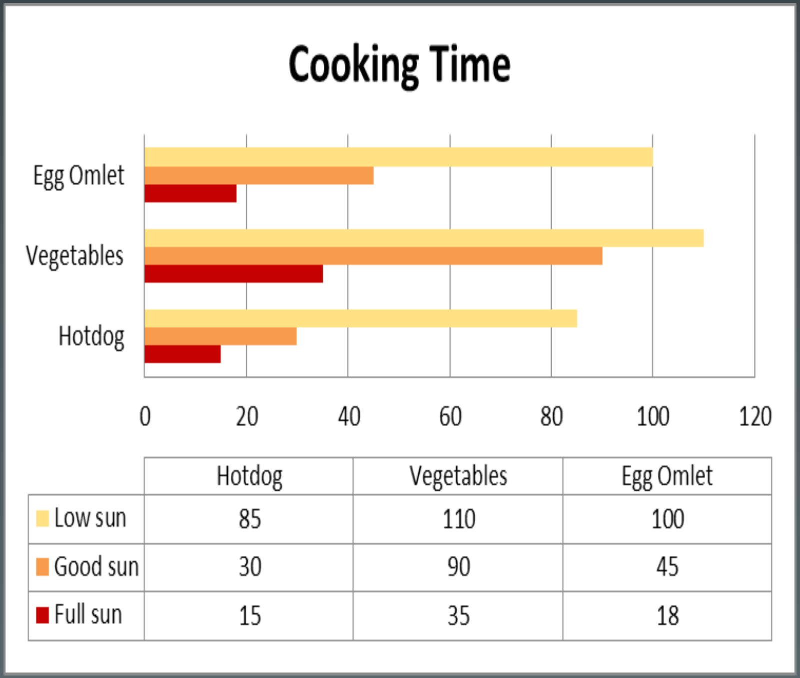
MEASUREMENT EQUIPMENT

- Infrared Thermometer Gun

TESTING AND ANALYSIS

COOKING TIME

- Full sun: 11:00 – 12:30
- Good sun:
- Low sun:



	Hotdog	Vegetables	Egg Omlet
Low sun	85	110	100
Good sun	30	90	45
Full sun	15	35	18

ADVANTAGES

- Higher temperatures overall due to the vacuum glass tube's ability to insulate
- This type of cooker could be called the "microwave" of the solar cooker (world due to its faster overall cooking times)
- Can attain and hold effective cooking temperatures (a little better than many solar cookers on less than ideal sunny days)
- High quality, durable materials

DISADVANTAGES

- Not quite as much volume (space) for food as some box style solar cookers
- Glass is durable, but it is not completely break proof, one has to take care to not abuse the cooker
- A little more costly than some solar cookers

BUDGET

- The table shows the parts we have used and its production costs

- Along with our budget, we have created a contingency fund around 800 SR, to be used in emergency situations

Part Number	Part Name	Quantity	cost
1	Solar Evacuated Tube	1	1500 SR
2	Reflector	2	1000 SR
3	Cooking Tray	1	50 SR
4	Cooking Handle	1	50 SR
5	Steam Vent	1	25 SR
6	Cleaning Attachment	1	10 SR
7	Top Bracket	1	50 SR
8	Bottom Bracket	1	50 SR
9	Tensioning Bolt	1	10 SR
10	Reflector Securing Nuts	4	25 SR
11	Legs	2	100 SR
12	Leg Tensioning Nuts	2	25 SR
13	Tube slider	1	50 SR
14	Reflector Pin	2	50 SR

CHALLANEGES

- Time management
- Conflict resolution

FUTURE RECOMMENDAIONS

- Add a digital thermometer (for easier measurement and tracking of temperature)

- VTSC could have larger diameter of the pipe in order to cook more food at once

CONCULOSION

- Why this Project
- We thought it is a unique project never been done in PMU
- Good idea to be used in KSA due to our hot climate
- Environment friendly

Thank You

Q & A