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PRINCE MOHAMMAD BIN FAHD UNIVERSITY

College of Engineering

Department of Mechanical Engineering

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Senior Design Project Report

Solar Water Heater

In partial fulfillment of the requirements for the

Degree of Bachelor of Science in Mechanical Engineering

Team Members

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Abstract

Solar energy is getting popular nowadays. Most of the technologies have been developed which made solar energy a cheaper and reliable source of energy. Due to pollution and other factors, solar has become the most popular source of energy. Along with power generation, now water heaters are also developed which are working on the solar technology. It is a reliable method and can be used in areas which do not have access to wood, coal and gas.

This project is based on design and fabrication of solar water heater. In this project, active water heaters are employed which w in work indirect way. Flat plate collectors are designed according to needs and environmental constraints. A comprehensive study of solar water heaters was presented in Chapter 2. Based upon this study, a reliable and cost-effective solar water was designed. All the dimensions and design diagrams are presented in the relevant chapter. Economic evaluation of the project is also presented in the design chapter. Local materials and manufacturing methods were used to fabricate the solar water heater to limit the cost of project. At the end impact of the project was discussed on social, economic and environmental grounds.

Acknowledgments

We are thanking Dr.Fraj Alshmri For his kind guidance at every step our work. He is guiding us and from the start till to that day. We are learning good research skills from him.

Special thanks to our parents, friends, lab fellows and all other well-wishers for their consistent support during

List of Acronyms

Abbreviation	Name
A	Area of Pipe
CAD	Computer added Design
k	Thermal Conductivity
L	Length of tubes
Q	Heat Transfer Rate
r	Radius of pipe
ΔT	Temperature change
Δr	Thickness of sheet

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CHAPTER 1: INTRODUCTION

1.1 Project Definition

This project is intended to design a water heating system by using solar technology. There are various design and manufacturing constraints but here the most general and efficient way would be used. It includes thorough study of the mechanism of the solar water heater. After designing such mechanism, the heater would be manufactured, and the results would be presented.

Solar energy technology is used in various places in different ways. It is used to produce electricity and it provides energy which is used to cook food. Solar systems are designed in such a way that water can be heated to any temperature. But at domestic levels water can be heated up to 60 ºC. Evacuated types of solar heaters and glazed plate heaters are the most common types of solar powered water heaters used in the world. Some of the systems are active and others are passive. Active systems are divided into direct and indirect solar systems. In this project indirect solar system will be designed. The mechanism of our solar heater will resemble as shown in figure 1.

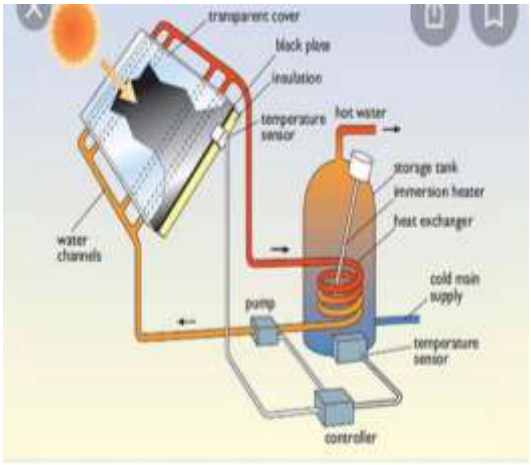

Figure 1 Solar Heater system

1.2 Objectives of the project

The main objectives of the project are as follows:

- Study, design, and analysis of the active solar water heating system according to the domestic applications.
- Modern techniques would be used to choose the economical and easily available techniques to design the solar heating system.
- Design calculations would be done where needed with the help of research and analysis.
- Fabrication of the solar heating system with the economical and easily available materials.

1.3 Project Specifications

There are many aspects which would be looked after while designing a safe and economical systems. For the solar heater following are the main sections.

- Heat Collection
- Heat transfer
- Heat storage
- Heat backup
- Extreme temperature protection.

These aspects are explained in the figure 2.

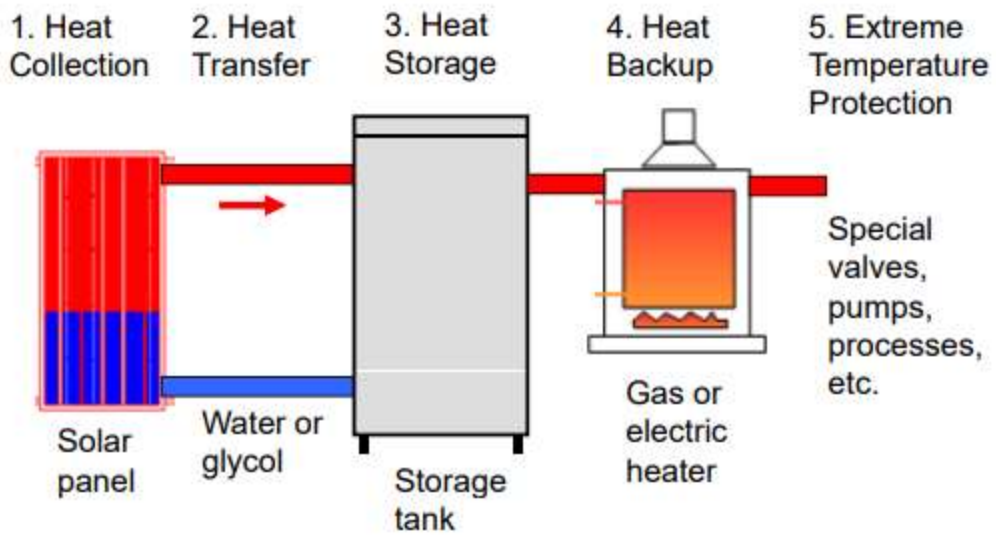

Figure 2 Main aspects of Solar Heater

Following are the main components of the solar heater.

- Solar collector panel
- Storage tank
- Heat Exchanger
- Expansion tank
- Control System

While the collector panel consists of absorber plates, tubes, glazing, thermal insulations and casing.

1.4 Applications

Solar water heater can be used in domestic, commercial, and industrial applications. They are enlisted below:

- Domestically hot water is used in bathing, washing of utensils and clothes and cleaning floors. Water requirement for a house depends on the number of family members. For a 4 members family, each consuming approximately 25 liters, on average above 100 liters are required.
- In commercial applications, a large quantity of water is required. For this purpose, large scale heating systems are used.
- In industries water is used to preheat the boiler water. Hot water is also used in food processing industries.

CHAPTER 2: LITERATURE REVIEW

2.1 Background

From the beginning of the life on earth, sun has been the most powerful force of nature. It is one of the reasons of the existence of life on earth and contributing a lot as a basic energy source. Due to its large benefits and size, it is regarded as the god in some of the religions. In the past no major benefit was taken by humanity. But as the needs of the human are increasing and other reliable sources are decreasing. Now humans are shifting towards renewable energy sources and sun is one of the biggest sources of renewable energy. In the same way solar energy is used to heat water in the industries, steam is produced by using modern techniques. In California, first solar water heater was utilized to heat the pool water in 1970 (Bennet T, 2007).

To get benefit of solar energy first started by Romans and Greeks. They built their house in such a way that solar light directly falls in and warmed their houses. But modern applications of solar energy started in 1883 as the Charles Frits developed first solar cell. In 1970s Europe and Israel invested in solar technology and reduced the cost of photovoltaic cell to compete the oil sector which was dominated by the Arab countries (Ken Butti, John Perlin, 1980). In 1983 about 60% of the households in Israel were using solar heaters to warm the water. By now around 90% of the houses in Israel are using solar water heaters. European countries are investing in solar energy and after China, Germany is producing solar energy.

In the 19th century people used wood and other exhausted sources to heat the water. In some areas it was difficult to heat water as the availability of coal, wood and gas was not enough or some areas did not have access to these sources. So, a black painted container was filled with water and

exposed to sun. But the main flaw in this system was as the sun set, the water got cooled (Charles Smith, 1995).

Solar heaters are divided into two main types. One is passive while the other is active. In passive systems, radiation or heat of the sun is directly used. This heat is either drops on the storage tanks or this heat is transferred to tank which is placed above collectors (Roger Taylor, 2006).

Active solar systems are divided into two types. One is direct and other is indirect. In direct active systems, heat is absorbed by the collectors. These collectors may be in any shape. Water is being pushed with the help of pumps to circulate in the pipes surrounding the heat collectors. After heating the water is taken back to the storage tanks. In indirect systems, water is heated with the help of some heat exchanger. In domestic indirect solar heaters, water is heated inside the heat exchanger and then transferred to the storage tank (Harrison J. Tiedman T. 1997).

Performance of the solar water heater is affected by the many factors. These includes ambient conditions, collector arrangement and fluid flow rate. It the atmosphere is clear, then sun will fall directly on the collector. Temperature determines the thermal loss from the collector. Area of solar collector and its orientation determine the absorption capacity of collector. In direct systems, if the flow rate of fluid is low then water is heated evenly while low heat transfer occurs if the flow rate is high (Kalogirou, S.A, 2004).

2.2 Previous Work

As discussed previously that there are two types of solar heaters. One is active and passive. Passive heaters circulate water by using natural means like gravity or natural circulation. These systems are less expensive. While the active solar heaters use pumps and other equipment to force the flow

rate and thus it is costly and difficult to repair. Some of the research work done on these is discussed below:

Soteris A. Kalogirou presented a paper which discussed the various types of collectors and their uses. The applications of the solar systems are dependent on the type of solar collectors used in the system. Solar collectors include flat-plate, compound parabolic, evacuated tubes, fresnel lens, parabolic trough and heliostat field collectors. These different types of collectors are used in different applications in domestic, commercial and industrial uses. Following is the comparison presented by him for different collectors (Kalogirou, S.A, 2004).

Motion	Collector type	Absorber type	Concentration ratio	Temperature range (°C)
Stationary	FPC	Flat	1	30-80
	ETC	Flat	1	50-200
	CPC	Tubular	(1-5)	60-240
Single-axis tracking	LFR	Tubular	(15-45)	60-250
	PTC	Tubular	(15-45)	60-300
	CTC	Tubular	(10-50)	60-300
Two-axis tracking	PDR	Point	(100-1000)	100-500
	HFC	Point	(100-1500)	150-2000

Figure 3 Comparison of different collectors

K. Sivakumar used elliptical flat heat collector and placed this collector at 11º to the horizontal. In this experiment condenser to evaporator length ratio, different flow rates and many inlet conditions were analyzed. Five evacuated pipes made of stainless steel were used. Tube was made of copper while the methanol was used as a working fluid for this setup. The experiment analyzed that ratio of lengths of condenser to evaporator of 0.1764 achieved greater efficiency (K. Sivakumar, 2005).

Hussain Al-Madani presented research on evacuated and cylindrical tubes. Collectors consist of copper coils and water circulates in them. Different experiments were taken, and it was concluded that maximum difference of temperature occurred has a value of 27.8 ºC. This value shows the efficiency of 42 % (Hussain, Al-Madani, 2006).

K. S. Ong worked on different solar water heaters. He and his friends used different collectors and tanks with various sizes and designs. They used short and long terms experiments and performances of different solar collectors was assessed. They concluded that in natural convection hear pipe system water was heated up to 100 ºC. They used different absorber and collector types and give the results as shown in the figure 4. (K. S. Ong W. L. Tong, 2011).

Motion	Absorber type	Collector type	Concentration ratio	Indicative temperature change
Stationary	Flat Flat Tubular	Flat Plate Collector (FPC) Evacuated tube collector (ETC) Compound parabolic collector (CPC)	1 1 1-5	30-80 50-200 60-240
Single axis tracking	Tubular Tubular Tubular	Linear Fresnel reflector (LFR) Parabolic trough collector (PTC) Cylindrical trough collector (CTC)	10-40 15-45 10-50	60-250 60-300 60-300
Two-axis tracking	Point Point	Parabolic dish reflector (PDR) Heliostat field collector (HFC)	100-1000 100-1500	100-500 150-2000

Figure 4 Collector data with different collector types

2.3 Comparative Study

As we have discussed various works of different researchers. They all used different criteria to assess the performance of solar water heater systems. They all used different criteria to assess the quality and efficiency of solar heater. In this project the aim of our project is to build a solar heater which is active in nature and the flow rate is caused by indirectly. Flat plate collectors will be used. Now we are in the study period, so further design constraints and material availability will affect the solar heater final product. When we will reach the final product, then suitable procedure and analysis will be carried out and will be compared with the work presented in the literature review.

CHAPTER 3: SYSTEM DESIGN

3.1 Design Constraints

There are different design constraints which were considered while designing solar water heater. This project is experimental based and would have following design constraints and then will be discussed one by one:

- Safety
- Cost
- Weight
- Serviceability
- Efficiency and Performance

- Solar water heater consists of many parts which will be discussed in the next section. On part which will collect the solar heat is called collector. Collector has its direction towards the sun. There is a possibility of damage to collectors as other parts will be within the housing. Collector material should have great strength which can bear the impact of possible winds and other damaging things.
- Solar water heater will be made using the locally available materials and manufacturing techniques. Those parts which are costlier to manufacture or not available locally would be purchased. The cost will be minimized by using machines which are available in the lab.
- Solar water heater will be placed on the roof or at a place where sunlight is available. So it must be placed in open. Extensive winds or wind blows can damage the solar heater. It must have sufficient weight so that it can be firmly placed on the ground.

- It is stated earlier that all the materials and parts will be purchased from the local markets. Manufacturing processes will also be carefully choosing which have low manufacturing cost. Quality was enhanced by purchasing the parts which can be manufactured locally. Materials will be chosen which have high efficiency and more capacity of absorbing heat.

3.2 Risk Factors

There are many factors which can be considered as damaging factors for the design of solar water heater. Some of which are listed below:

- Cost
- Safety
- Leakage
- Corrosion

Solar water heater would be manufactured using the local sources. Some of the parts which cannot be manufactured will be bought either from the local market or international. These parts will increase the cost of the water heater. In the lab we do not have big machines which can manufacture complex geometries. So, these parts will be manufactured by local vendors. So, cost might also be higher due to this reason.

Solar water heater will be kept outside in the sunlight. There is a chance of damage from violent winds and some other factors. Leakage is another big problem which can occur due to poor welding. Corrosion is another big problem which can damage the metal parts and also the heat exchanger.

3.3 Design Methodology

There are many components involved which make up solar water heater. But in this project collector is specifically designed to increase the efficiency of solar heater. Following are steps which will be followed to design the collector of solar water heater:

- Material Selection
- CAD Model
- Design Specifications

Design process starts with the selection of appropriate materials which give sufficient strength and have better efficiency. As stated earlier that material will be searched in the local market. Then according to our needs, dimensions will be chosen. Then CAD model will be developed and at last design specifications of other components will be enlisted. Figure 4 shows the performance of different types of collectors.

3.4 Material Selection

It is the basic step in the design process. The performance of solar water heater mainly depends on the material of collector. Collector consists of transparent cover, Heat transfer medium, absorber plate, insulation, and housing. Transparent cover traps the radiations inside the housing and increase the efficiency of heater. Following is the flat plate collector example shown in the figure 5.

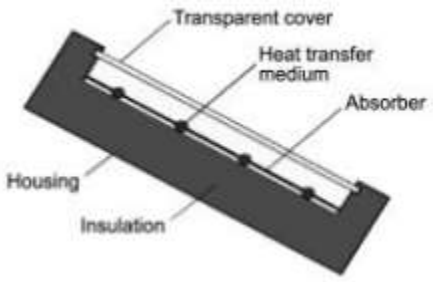

Figure 5 Flat plate collector

Following is the data of temperature change with collector efficiency:

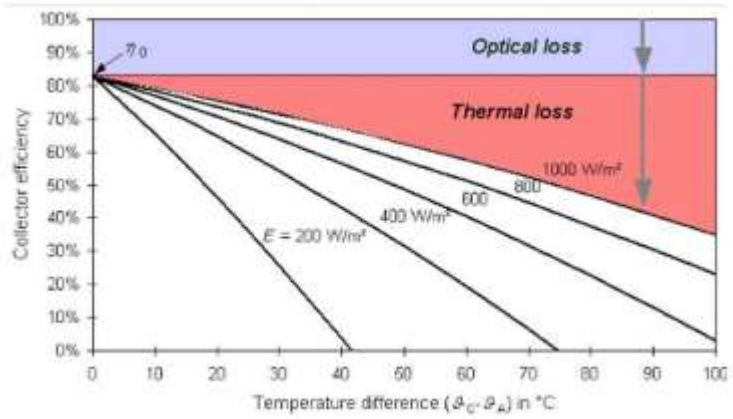

Figure 6 Collector efficiency with temperature difference

Insulation is provided to increase the heat transfer within the system. It decreases the heat loss. Selective grade of Polyurethane foam is used as insulation material. In figure 6 comparison of insulation materials is shown.

Insulating materials	Thermal conductivity	Density
Expanded polystyrene 15	0.04	15
Expanded polystyrene 30	0.037	30
Extruded polystyrene	0.27	32
Polyurethane foam	0.018	36
Phenolic foam	0.027	32
Cellular foam	0.41	125
Mineral wool	0.045	24

Figure 7 Properties of Insulation materials

3.5 Formula Used

Heat transfer can be employed using the following formula.

$$\dot{Q} = U.A.\Delta T \tag{1}$$

Where U is the heat transfer co-efficient, A is the total cross-sectional area while the ΔT is the temperature difference.

Area of the pipe is determined from the following formula:

$$A = 2\pi rL \tag{2}$$

While the heat flow can be calculated using the following formula:

$$\dot{Q} = -k.A.(\frac{\Delta T}{\Delta r}) \tag{3}$$

3.6 CAD Model

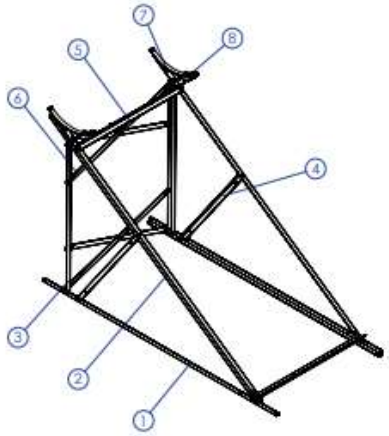

Figure 8 Frame Design

Figure 9 Solar Water Heater

Figure 10 Solar water heater design

3.7 Design Specifications

Nr.	PART NAME	DIMENSIONS	QTY.
1	Beam L (Laminate section 60 x 2.5mm)	2060 x 60mm	2
2	Beam L (Laminate section 60 x 2.5mm)	2250 x 60mm	2
4	Beam L (Laminate section 60 x 2.5mm)	925 x 60mm	2
5	Collector Support	940mm	2
6	Beam (Laminate section 33 x 2mm)	980mm	4
7	Boiler Support		2
8	Plastic Cover for Supporting Strips (Slab)		2
9	Hexagon Head Bolt M8	M8x16	28
10	Hex Nut M8		24
11	Washer	Ø8	4
12	Hexagon Head Screw with Washer		4

Figure 11 Frame Dimensions

NUMBER OF COLLECTORS	1
SYSTEM WEIGHT EMPTY / FULL (kg)	137 / 302
MAX WATER TANK OPERATING PRESSURE (bar)	8
CLOSED CIRCUIT MAX OPERATING PRESSURE (bar)	3.5

WATER STORAGE TANK	160lt
DIMENSIONS (mm)	580x1150
WEIGHT EMPTY (kg)	66
JACKET CAPACITY (lt)	13
JACKET SURFACE (m^2)	0.92
MAX TEST PRESSURE (bar)	12
MAX OPERATING PRESSURE (bar)	8

Figure 12 Total System (Ref: 10)

TOTAL AREA (m^2)	2.03
NUMBER OF MANIFOLDS	10
HEAT TRANSFER MEDIUM	PROPYLENE GLYCOL SOLUTION
CAPACITY (lt)	1.75
ABSORBER SURFACE (m^2)	1.81
TOTAL DIMENSIONS (mm)	2010x1010x110
COLLECTOR TOTAL WEIGHT (without liquid) (kg)	38
ABSORBER	SELECTIVE ALUMINIUM
ABSORBENCY / RADIATION COEFFICIENT	95% ±2% / 5% ±2%

Figure 13 Collector design (Ref: 10)

3.8 Economic Evaluation

Economic evaluation of the project is the cost analysis which describes the investment done on the project, sales generated and profit outcomes giving the payback periods.

Solar water heater is designed in such a way that it can be manufactured at a large scale. Following cashflow data is distributed over 5 years giving data about the investment and sales in the respective years. In the first year giving at 0 years, only research and development will be done, it costed around 805 SR. Then From the next year investment increases to 8050 SR and respective sales are given in the sales column. Profit margin is given in the column next to sales.

Investment, sales and profits for all years are given in the table 1. Profits are analyzed and payback periods are calculated. In the first column payback period is given in years while in the next column it is given in months.

Table 1 Cashflow data

YEAR	INVESTMENT	REVENUE FROM SALES	Profit	Payback period	Months
0	-805				
1	-8050	1500	9550	0.186335404	2.236024845
2	-16100	30000	46100	1.863354037	22.36024845
3	-24150	45000	69150	1.863354037	22.36024845
4	-32200	60000	92200	1.863354037	22.36024845
5	-40250	75000	115250	1.863354037	22.36024845

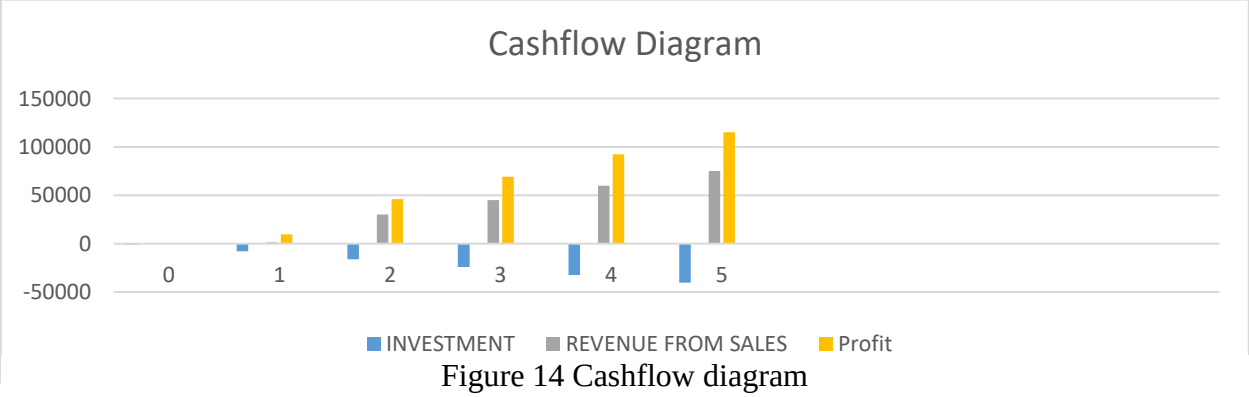

Figure 14 Cashflow diagram

Figure 14 shows the cashflow diagram which based on the table 1. Figure clearly shows that in the year 0 no profit is generated while in the next year's profit increases as the investment increases with sales.

Payback period was also calculated by using the data of investment with sales and profit. This analysis is given in the figure 15 and figure 16.

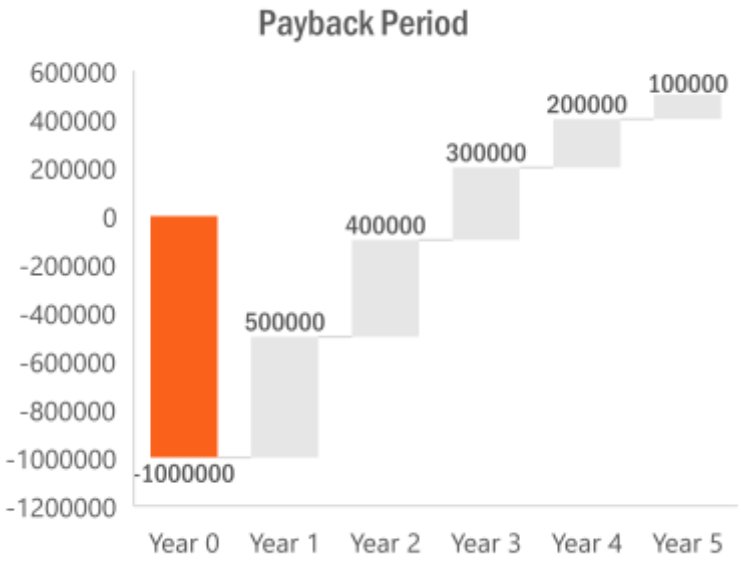

Figure 15 Payback period

Figure 16 Payback Period Chart

3.9 Assembled Model

Each component was fitted within the frame of solar water heater. Collector was placed at an angle to catch the heat from the sun. Storage tank and piping system are also attached. Fully assembled model is given in the figure 17.

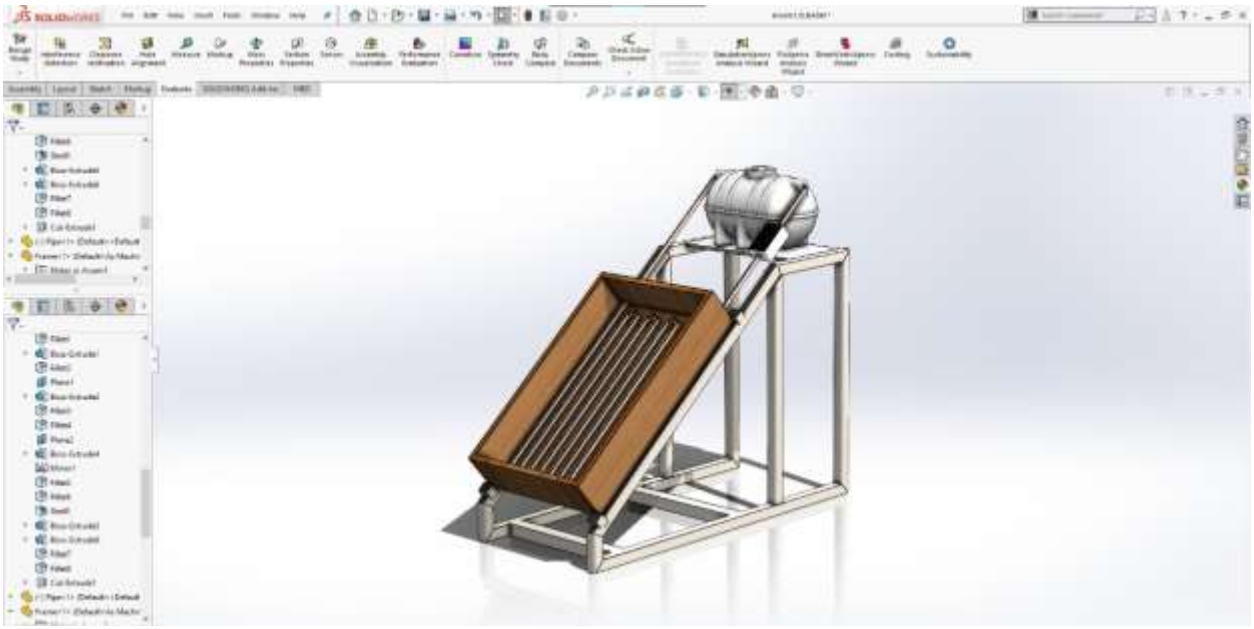

Figure 17 Assembled model of Solar Water Heater

CHAPTER 4: PROJECT MANAGEMENT

This chapter deals with the different tasks related to the project. These include project plan, tasks completed by individuals and budgeting.

4.1 Project Plan

This section deals with the different tasks related to the project from the start to the end. It shows the planning and management associated with the task from preparing proposal to the final presentation and report submission. It is a senior design project, and it took around 13 weeks for completion. Following figure shows the project plan.

Task	Description Months	Start Date	End Date
1	**Development of Methodology**	**JAN.25**	**FEB.23**
1.1	developing the project management	JAN.27	FEB.04
1.2	prototyping the design and the mechanis	JAN.25	FEB.10
1.3	selecting the material	FEB.11	FEB.23
2	**Specification of Integrated System**	**FEB.25**	**MAR.15**
2.1	buying supplies for prototype	FEB.25	FEB.30
2.2	assemblying water heater	FEB.30	MAR.05
2.3	installing electronic components to water	MAR.06	MAR.10
2.4	programming controllers & temp. sensors	MAR.06	MAR.10
2.5	~~installing solar panel to prototype~~	MAR.01	MAR.15
3	**Feasibility Studies for each region**	**MAR.16**	**APRL.30**
3.1	progress report 1	MAR.16	APRL.30
3.2	progress report 2	MAR.16	APRL.30
3.3	final progress report	TBA	TBA
4	**Project Management and Coordination**		
4.1	prototype testing	TBA	APRL.30
	Milestones and Deliverables		
	report part 1		APRL.30
	report part 2		APRL.30
	final report and prototype presentation		TBA

Figure 18 Project Plan

4.2 Contributions of the team members

It is a senior design project, so four members are doing this project. In the table given below, students name and there IDs are listed below.

Table 2 Name and IDs of Team members

ID Number	Member Name
201701489	Faisal Alzahrani
201502828	Faisal Alyami
201600448	Waleed Alsubaie
201600922	Ahmed Barbea

Project was carried in such a way that it was divided into different tasks. These tasks were completed one by one. Each member contributed in different tasks. Some of them were completed individually while mostly tasks included collective contribution of team members. Following table shows the tasks and members.

Table 3 Tasks and final execution of the project

Tasks	Team members Assigned
Designing	Faisal Alzahrani, Ahmed Barbea
Manufacturing	Faisal Alyami, Waleed Alsubaie
Economic Evaluation of project	Waleed Alsubaie, Ahmed Barbea
Report writing	Faisal Alyami, Waleed Alsubaie, Ahmed Barbea
Final Presentation	Faisal Alzahrani, Ahmed Barbea

4.3 Project Budgeting

This part covers the budget of the project related only to the components. It also includes all the manufacturing and assembling of the different parts. As mentioned earlier that some components needed to be purchased and others were machined in local markets. At the end of the project, is costed about 5000 SAR in total. Details are given in the following table 4.

Table 4 Project Budgeting (Bill of materials)

Design and Engineering	Cost (SR)
Frame	1200
Collector	400
Pump	350
Heat Exchanger	650
Control Systems	200
Tank	600
Labor Cost	400
Assembling Cost	500
Miscellaneous Cost	700
Total Cost	= 5000 SR

CHAPTER 5: PROJECT ANALYSIS

5.1 Lifelong Learning

- This project gave us good experience in terms of technical and engineering knowledge. Overall, it was good while working on a project like this. We got to know new things and learnt unseen things. We improved our research skills like management and software knowledge base. Following are experiences which we came across in our journey of this project.
- In the initial phase of the project, design section of the project was most challenging one. First of all, we studied literature review. We got many designs and, in these designs, to find the best suited one for our conditions and required results was difficult part. Design process became complicated as we were using materials and manufacturing methods from the local markets. At last, we choose a feasible and reliable design for our solar water heater. The project was chosen such that it can be completed within 4 months. We modified some of the components according to availability and requirements and applied reverse engineering.
- Purchasing materials and manufacturing required parts from local venders and machinist was terrible experience. In the era of COVID19, it became difficult to meet the deadlines. Somehow, we managed it also. In designing, it was ensured that materials were selected which were easily available and can give same performance if original or standard material was not available at that time.
- As the project started, we asked our professor and seniors about the software which can help us in designing process. Then we learnt these softwares and used them in designing and planning our project. These includes AutoCAD, Creo and MS Project.

5.2 Impact of our Project

It has been discussed in the literature review that renewable technologies are increasing day by day. These technologies provide safe, reliable, and cheap sources of energy. Solar technologies are improving and became famous in every field. Solar water heaters are becoming famous in Saudi Arabia also. Impact of solar water heater is discussed on social, economic, and environmental grounds.

- **Social:** Hot water is the need of almost every person. It is used in bathing, cleaning, and cooking. Solar technology is ever growing field which have great opportunities. So, solar water heaters provide social benefits like health, and advancement of technologies. It improves the social standards of people, education and provides opportunities to communicate.
- **Economic:** It is one of the forms of renewable energy consumption. It also uses its own source which is the Sun and does not depend on energy sources of the state. It is cheaper and utilize local sources which increases the productivity of the local markets. It reduces the risks of energy shortages. It also lowers the burden on fossil fuels like gas and oil. Renewable energy technologies like this one can have great impact on economy of regions. It can increase regional development and create jobs for the locals. Only drawback is the high initial investment in these projects. One it is installed; it can serve for 10 to 20 years without much maintenance.
- **Environmental:** Solar water heaters have a great impact on improving the environment. It reduces the carbon emissions by using the clean energy. It creates awareness about climate change by using renewable technology and discouraging oil and gas. Solar water heater can limit green house gases and reduces the water and air pollution.

CHAPTER 6: CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

It was a senior design project and intended to design and fabricate a solar water heater. This project was completed by following the research and theoretical knowledge. A reliable and low-cost solar water heater according to the local needs was developed as stated in the objectives. It involved a great research knowledge while designing the components and management skills. A critical study was made, and survey of local markets was done to ensure the availability of materials and manufacturing methods. All the parts were manufactured and assembled to achieve the desired results by using the local materials and technologies.

As stated earlier that project was designed and completed with local needs, it helps a lot to reduce the cost of project. It reduces the time and cost of the materials and manufacturing. It was a good project which involved four people.

It was a great privilege for us to work in this project and complete it within time. We leant many research skills from our Professor which were used in achieving goals of the project. Cost effectiveness was the main objective which was fulfilled throughout the project. We learnt to work more in less time. New softwares were learnt and new experiences were faced.

6.2 Recommendations

There are many design improvement ideas which can be implemented. Some of it are given below:

- Collector material and design should be improved which can provide better efficiency in low sunny areas.
- Heat exchanger can be designed with regional needs and according to the type of applications.

- Such materials should be developed which do not overheat. Overheating effects the performance of solar water heater.

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APPENDIX A: PROGRESS REPORT

SEMESTER:		**ACADEMIC YEAR:**	
PROJECT TITLE	**Solar Water Heater**		
SUPERVISORS			

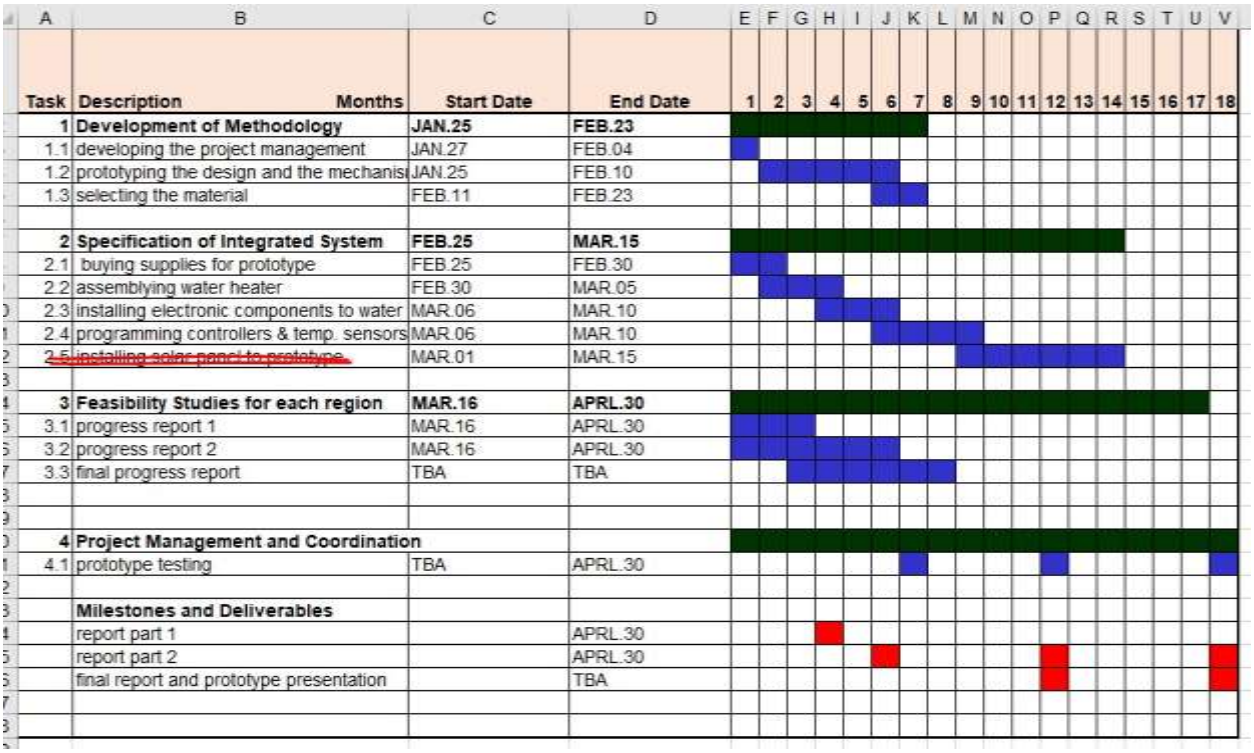
Student Group

ID Number	Member Name
201701489	Faisal Alzahrani
201502828	Faisal Alyami
201600448	Waleed Alsubaie
201600922	Ahmed Barbea

Task Distribution

Tasks	Team members Assigned
Designing	Faisal Alzahrani, Ahmed Barbea
Manufacturing	Faisal Alyami, Waleed Alsubaie
Economic Evaluation of project	Waleed Alsubaie, Ahmed Barbea
Report writing	Faisal Alyami, Waleed Alsubaie, Ahmed Barbea
Final Presentation	Faisal Alzahrani, Ahmed Barbea

Project Plan



Task	Description	Months	Start Date	End Date
1	**Development of Methodology**		**JAN.25**	**FEB.23**
1.1	developing the project management		JAN.27	FEB.04
1.2	prototyping the design and the mechanis		JAN.25	FEB.10
1.3	selecting the material		FEB.11	FEB.23
2	**Specification of Integrated System**		**FEB.25**	**MAR.15**
2.1	buying supplies for prototype		FEB.25	FEB.30
2.2	assemblying water heater		FEB.30	MAR.05
2.3	installing electronic components to water		MAR.06	MAR.10
2.4	programming controllers & temp. sensors		MAR.06	MAR.10
2.5	~~installing solar panel to prototype~~		MAR.01	MAR.15
3	**Feasibility Studies for each region**		**MAR.16**	**APRL.30**
3.1	progress report 1		MAR.16	APRL.30
3.2	progress report 2		MAR.16	APRL.30
3.3	final progress report		TBA	TBA
4	**Project Management and Coordination**			
4.1	prototype testing		TBA	APRL.30
	Milestones and Deliverables			
	report part 1			APRL.30
	report part 2			APRL.30
	final report and prototype presentation			TBA

APPENDIX B: PROJECT BUDGETING

Design and Engineering	Cost (SR)
Frame	1200
Collector	400
Pump	350
Heat Exchanger	650
Control Systems	200
Tank	600
Labor Cost	400
Assembling Cost	500
Miscellaneous Cost	700
Total Cost	= 5000 SR

APPENDIX C: DESIGN SHEET

Frame Dimensions

Nr.	PART NAME	DIMENSIONS	QTY.
1	Beam L (Laminate section 60 x 2.5mm)	2060 x 60mm	2
2	Beam L (Laminate section 60 x 2.5mm)	2250 x 60mm	2
4	Beam L (Laminate section 60 x 2.5mm)	925 x 60mm	2
5	Collector Support	940mm	2
6	Beam (Laminate section 33 x 2mm)	980mm	4
7	Boiler Support		2
8	Plastic Cover for Supporting Strips (Slab)		2
9	Hexagon Head Bolt M8	M8x16	28
10	Hex Nut M8		24
11	Washer	Ø8	4
12	Hexagon Head Screw with Washer		4

System Design

NUMBER OF COLLECTORS	1
SYSTEM WEIGHT EMPTY / FULL (kg)	137 / 302
MAX WATER TANK OPERATING PRESSURE (bar)	8
CLOSED CIRCUIT MAX OPERATING PRESSURE (bar)	3.5

WATER STORAGE TANK	160lt
DIMENSIONS (mm)	580x1150
WEIGHT EMPTY (kg)	66
JACKET CAPACITY (lt)	13
JACKET SURFACE (m^2)	0.92
MAX TEST PRESSURE (bar)	12
MAX OPERATING PRESSURE (bar)	8

Collector Design

TOTAL AREA (m^2)	2.03
NUMBER OF MANIFOLDS	10
HEAT TRANSFER MEDIUM	PROPYLENE GLYCOL SOLUTION
CAPACITY (lt)	1.75
ABSORBER SURFACE (m^2)	1.81
TOTAL DIMENSIONS (mm)	2010x1010x110
COLLECTOR TOTAL WEIGHT (without liquid) (kg)	38
ABSORBER	SELECTIVE ALUMINIUM
ABSORBENCY / RADIATION COEFFICIENT	95% ±2% / 5% ±2%