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Senior Design Project Report

Design of an Enhanced Solar Heat Exchanger Using Nanoparticles

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

Team Members

	Student Name	Student ID
1	Mohammed Alanazi	201202705
2	Khalid Al-Saad	201100139
3	Thamer Al-Otaibi	201002295
4	Othman Mohammad	201200426

Project Advisors:

Advisor Name: Dr. Ali Chamkha
Co-Advisor Name: Dr. Nader Nader
Course Instructor: Dr. Nader Al-sawalhi

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Abstract

Sun based water heating frameworks use heat exchangers on exchange sun oriented vitality. Consumed to sun based collectors of the fluid or air used to heat water or a space. Heat exchangers could a chance to be settled on from claiming steel, copper, bronze, stainless steel, aluminum, or cast Iron. Most solar heating systems usually use copper. Solar heating systems with air heater collectors usually do not need a heat exchanger between the solar collector and the air distribution system. Those systems with air heater collectors that heat water use air-to-liquid heat exchangers, which are like liquid-to-air heat exchangers because it is a good thermal conductor and has greater resistance to corrosion. A new area of research has emerged during the last decade or so and is related to the innovative use of metallic or metallic-oxide nanoparticles such as CuO or Al2O3 or many others to enhance heat transfer in thermal systems. This will be applied in this senior design project.

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1. Introduction

1.1 Project Definition

Renewable energy has rapidly been making inroads into the global energy market in the past few years. Last year, global investments in renewable energy were more than double the amount spent on new coal and gas-fired plants. The sector today employs 8.1 million workers globally, and 2.8 million of them are engaging in the production of solar modules. The International Energy Agency predicts that solar energy will account for over 5 percent of the global power production capacity by 2020.Vision 2030 identifies renewable energy as one of the pillars of economic diversification away from oil. It sets an “initial target” of producing 9.5 giga watts (GW) of power from renewable energy.

The projects will be pursued under the “King Salman Renewable Energy Initiative,” details of which are expected to be announced soon. The National Transformation Program 2020, which was announced in early June following the Vision 2030, set the target of 3.45GW, or 4 percent of the total power consumption, by 2020. The program also aims to employ 7,774 workers in the renewable and nuclear energy sectors combined by 2020.

Renewable energy consists of different sources of energy such as solar, wind, wave, and geothermal. Among them, solar is considered a particularly promising source of non-hydrocarbon energy in Saudi Arabia, as the Arabian Peninsula is one of the most sunshine-rich places in the world. In spite of its exceptionally long (over 3,000 hours annually) sunlight hours, solar, however, has never been harnessed as a major source of energy in Saudi Arabia or in other G.C.C. countries.10 The country’s installed solar power capacity was only 23 megawatts (MW) at the end of 2015, while that of the U.A.E., which has the largest installed solar capacity among

the G.C.C. countries, was 128MW at the same time. These numbers are strikingly small given the amount of sunshine the region receives. The installed solar capacity of Germany, a country en-dewed with only half the sunlight hours in the Gulf (slightly above 1,500 hours annually), was 40 GW – more than 300 times the U.A.E.'s and 1,700 times Saudi Arabia's.

Nevertheless, supported by the decline in the cost of solar modules, the G.C.C. countries are currently undergoing a "quiet revolution" in solar energy. The largest solar power project currently under execution in the region is the 800MW Phase III of the Mohammed bin Rashid Al Maktoum Solar Park in Dubai. The Dubai Electricity and Water Authority, which oversees the development of the park, aims to install 5GW capacity by 2030. Investors are concurrently eyeing Saudi Arabia, which they expect to be a "crown jewel" of the Gulf solar market once the industry takes off.

The Saudi government has been studying the use of solar power in the kingdom since the creation of the King Abdullah City for Atomic and Renewable Energy (K.A.C.A.R.E.) in 2010 by the royal decree of the previous king Abdullah (r. 2005–15).

The initial driver behind the Saudi government's interest in the use of solar power was its intention to preserve its capacity to export oil in light of the rising domestic consumption of oil for power. One study estimates that Saudi Arabia will be a net oil-importing country in the late 2030s if domestic oil consumption continues to increase at its current pace. K.A.C.A.R.E. previously announced its plan to produce 41GW, nearly a third of the country's projected power need, from solar energy by 2032, in addition to 17GW from nuclear energy and 9GW from wind. (However, the target year was pushed back to 2040 in January 2015, and now the plan seems to have been abandoned.

In addition to such energy-mix policy, the Vision 2030 also places an emphasis on the industrial side of renewable energy. It states:

"We will support promising sectors and foster their success so that they become new pillars of our economy. In the manufacturing sector, we will work towards localizing renewable energy and industrial equipment sectors."

"We will also seek to localize a significant portion of the renewable energy value chain in the Saudi economy, including research and development, and manufacturing, among other stages."

These statements reflect the government's awareness that acceleration of the process of economic diversification is an urgent matter. While the low price of oil has certainly been

magnifying such awareness, the essence of the problem lies in the demographic shift within the kingdom. The majority of Saudi Arabia's national population of 21.1 million is young citizens born after the first oil boom period. While the public sector, currently employing over 3.4 million citizens (out of 5.2 million employed citizens), was capable of absorbing the vast majority of Saudi workers during past periods of labor-scarcity, the sector is bloated today and has little additional capacity to employ. As a result, the number of jobless young citizens has been increasing, with the country's youth unemployment rate estimated to be over 40 percent. Currently, nearly a third of the country's national population – around 7 million – is still in schools or preschools, but they will enter the labor market over the next 15 years, needing jobs to support themselves and their families.

In this project, we are interested in increasing the heat transfer inside heat exchangers using solar energy and Nano-particles. In additional to that, we will be comparing two heat exchangers one that use nanoparticles and the one without the usage of nanoparticles. Moreover, we will be running the two heat exchangers at the same time and compare the variation in temperatures. In the end, we will be determining if the Nano-particles can indeed increase the heat transfer by the change of temperatures.

1.2 Project Objectives

Honestly, we have many objectives implementing such a project. The objectives are to reduce the consumption of fossil fuel, reducing the air pollution, and increase the efficiency of the heat transfer. When it comes to the consumption of the fossil fuel, it is important to realize that Saudi Arabia is facing high consumption of fossil fuel to generate power. Since the country is already losing in domestic use of fossil fuel, we take the reduction of consuming the fossil fuel into considerations. Moreover, our objective is to use the clean energy from the sun to reduce the air pollution. On the other hand, our project is basically a study to increase the heat transfer on the heat exchanger, therefore; we are using the nanoparticles to monitor the effect on our system or design.

1.3 Project Specifications

To be precise in terms of designing our heat exchanger we calculated certain parameters such as the flow rate of the water inside the heat exchanger, the volume, and the area of the coil to be able to determine the number of nanoparticles we need to add. Moreover, we used this formula to determine these parameters:

Pipe Diameter: D = equation 1.3

Where,

$Q = Av$ = liquid flow rate (m^3/s *or* L/s) or

V = velocity of the liquid (m/s) = $1.273\ q / d^2$

- q = *volume flow* (m^3/s)
- d = *pipe inside diameter* (m)

A = area of the pipe or channel (m^2)

Of course, the coil came with geometric specifications when purchased, therefore; the length and the diameter of the pipe or coil are given to be 6.35mm. After applying the equation, we determined that the velocity and the flow rate to be 238.5m/s and 7.553mm3/s respectively.

1.4 Product Architecture and Components

In this project the components that we have used are:

Two heat-exchangers

Four water tanks

Six valves

Four thermocouples

Large table stand

Copper Nano-particles

Digital weighing scale

Figure 1.1 shows two heat exchangers which are designed with the same specifications.

Figure 1.1 - Heat Exchangers

Figure 1.2 shows the water tank used in this project which is made of plastic materials.

Figure 1.2 - Water Tank

Figure 1.3 shows the valve which is made of copper materials.

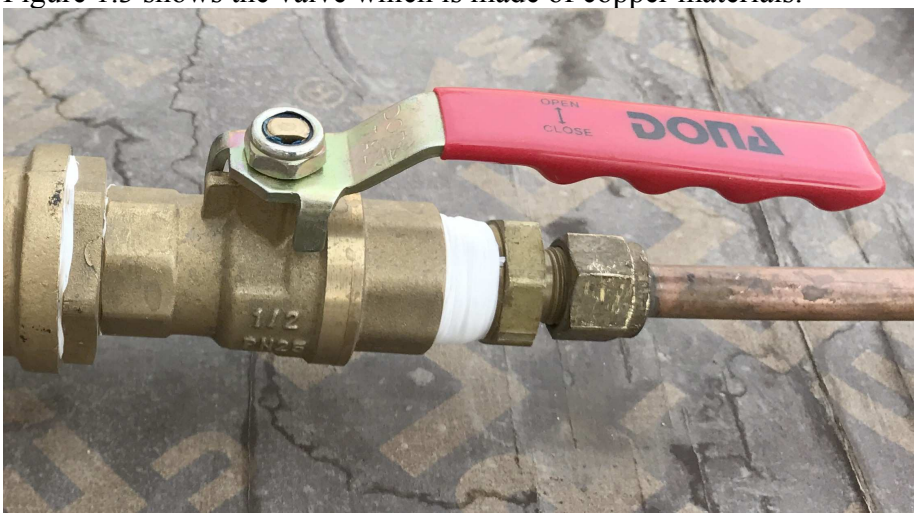

Figure 1.3 - Valve

Figure 1.4 shows the nanoparticles we purchased that made of copper materials.

Figure 1.4 - Copper Nano-particles

Figure 1.5 and 1.6 they show the thermocouple and the digital weighing scale that used for collecting data.

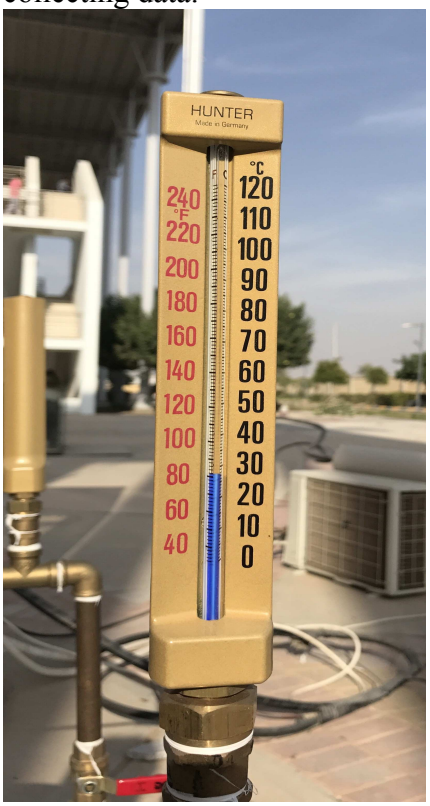

Figure 1.5 - Thermocouple

Figure 1.6 - Digital weighing scale

1.5 Applications

Solar heat exchanger using nanoparticles can be used in many applications in the smaller scale, such as operating as bathroom water heater, swimming pool water heater and so on.

2. Literature Review

2.1 Project background

Heat exchangers are broadly utilized as a part of industry both for cooling and warming expansive scale modern procedures. The sort and size of heat exchanger utilized can be custom fitted to suit a procedure relying upon the kind of liquid, its stage, temperature, thickness, consistency, weights, substance organization and different other thermodynamic properties. In numerous modern procedures, there is misuse of vitality or a heat stream that is being depleted, Heat exchangers can be utilized to recoup this warmth and put it to use by warming an alternate stream all the while.

This practice spares a great deal of cash in industry, as the warmth provided to different streams from the warmth exchangers would some way or another originate from an outside source that is costlier and more destructive to the earth. Energy sources have huge impacts on our environment. Fossil fuels do significantly more harm than renewable energy including water contamination, public health damages, global warming emissions and much more. The correct sort and force of natural effects differs relying upon the innovation utilized, the geographic area, and various elements. Solar power helps in slowing/stopping global warming, saving society billions or even trillions of dollars, providing energy reliability and independence, and in creating new job opportunities.

By comprehension the present and potential natural issues connected with each renewable vitality source, we can make changes to successfully keep away from or minimize these effects. The sun provides a marvelous supply for generating clean and environmental heat and electricity and solar power in Saudi Arabia has gotten to be important to the nation, as oil costs have raised. In 2011, over 50% of electricity was produced by burning oil. The Saudi agency in charge of developing the nation's renewable energy sector, Ka-care, announced in May 2012 that the nation would install 41 gig watts (GW) of solar capacity by 2032[1]. One of the soonest employments of copper nanoparticles was to shading glass and earthenware production amid the ninth century in Mesopotamia [2]. At the point when the stoneware was prepared at high temperatures in lessening conditions, the metal particles moved to the external part of the coating and were diminished to metals [2].

The final product was a twofold layer of metal nanoparticles with a little measure of coating in the middle of them. At the point when the completed ceramics was presented to light, the light would enter and reflect off the primary layer. The light entering the main layer would reflect off the second layer of nanoparticles and cause impedance impacts with light reflecting off the primary layer, making a radiance impact that outcomes from both productive and dangerous interference [3].

Our project (enhanced solar heat exchanger using Nano-particles/fluids) fits in the usage of solar energy to be used for various systems. In numerous designing applications, having warming process, solar energy is widely used. For the greater part of the household water warming purposes, sun powered flat plate collectors are utilized. The warmth trade between the liquid and convective heat transfer administers encompassing high temperature source. In the present time, superior warmth exchange hardware with negligible surface range is the modern

necessity. Likewise, to infer ideal energy conversion, the plan of the framework must give high productivity requiring low cost. More often in all sun based vitality applications; the authority territory represents the efficiency and measure of occurrence sun oriented radiation.

The improvement of heat dissipation to the working liquid and utilizing a working liquid of high warmth exchange execution will build the proficiency of gatherers. For over 10 years, analysts had performed numerous studies in the past to demonstrate improved properties of Nano fluids and will come about a specific increment in the heat transfer attributes in tube stream. But, heat convection attributes in useful warmth trade instruments should likewise be concentrated on. Numerous specialists have centered test and numerical examinations for constrained convection heat transfer studies in a pipe with various material and convergence of nanoparticles, additions and limit conditions in turbulent and laminar stream administration in plain tubes.

2.2 Previous Work

The idea of building a heat exchanger using solar energy has been there for a long time. However, the design of the heat exchanger is the main difference. There are many designs and ideas out there but we chose the most effective design for testing our experiment. We have been searching to find the latest techniques to design our heat exchanger and we found a very efficient design that looks better than the typical heat exchanger. We found similar work and we quote from the article “Solar water heating is a renewable energy technology.” Solar water heating collectors capture and retain heat from the sun and transfer this heat to the fluid. Solar thermal heat is trapped using the “greenhouse effect” in this case; it is the ability of a reflective surface (a transparent glass sheet) to capture the heat in the solar collector.

Heat and infrared radiation (IR, invisible radiant energy that is emitted particularly by heated objects) are produced when sunrays hit a collector's absorber. The "working" fluid for the heat transfer is usually pure water because water has high heat capacity. Water in contact with the absorber collects the trapped heat to transfer it to the storage [3]. As shown on figure 2.1 the principle is the same, our design main function is to collect the heat from the sun and transfer it to the fluid inside the copper tube. However, the only difference is we are using Nano-particles to achieve the maximum efficiency. Moreover, we are designing not only one heat exchanger but also two, one for the performing the test without the Nano- particles and the other with the nanoparticles.

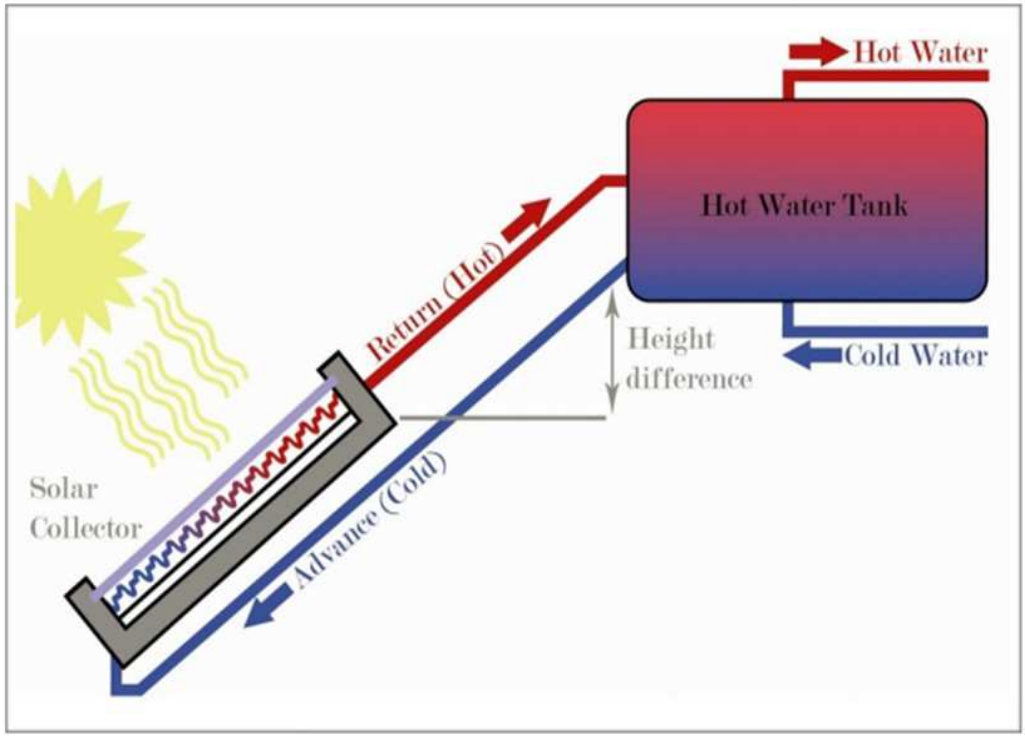

Figure 2.1 – Advanced Solar Heat Exchanger

2.3 Comparative Study

Looking at table 2.3 a previous study done by the Department of Mechanical Engineering, Indian Institute Of Technology (Banaras Hindu University) shows that very limited information is available on flat-plate solar collectors using Nano fluids which motivated there investigation, and the major goal of their theoretical study [4].

Their study investigates the effect of using Al2O3 Nano fluid with different particle volume concentrations (0.5-2%). Their conclusion was that the 1.5% (optimum) particle volume fraction of Al2O3 Nano fluid increases the thermal efficiency as well as kgCO2/kWh saving in hybrid mode of solar collector in comparison with water as working fluid by 31.64%.

Table 2.3 - Efficiency parameter of the Flat-plate solar collector for Al2O3 Nano fluid mass flow rates

Mass flow rates (Liter/min)	**FRUL**	**η**
0.5	42.6	0.643
1.0	34.52	0.702
1.5	24.56	0.712
2.0	26.52	0.616

3. System Design

3.1 Design Constraints

3.1.1 Design Requirements

The enhanced solar heat exchanger using nanoparticles is highly dependent upon the weather temperature. This means the system should be operated in a summer conditions. This requirement has limited the scope and freedom of the design of our heat exchanger. Unlike other groups we have assembled our prototype earlier to avoid any limitations to perform our tests. Moreover, as we read in an article there are similar limitations regarding summer conditions that talk about seasonal heat storage. Moreover, we wanted to implement this method but since, we have limited time to test our experiment we instead finished our prototype earlier.

As we read about the issue of using the solar energy on winter "Thermal energy storage systems (TES) can help us avoid the sporadic characteristics of renewable energy resources, like solar energy. Such systems can store solar heat in summer to be used in winter, or during sunny days to be used for cool nights. TES can also help us in utilizing our natural energy resources, i.e. summer heat, winter cold. These are renewable resources, which have not been fully exploited before. Summer heat is a result of solar radiation heating the earth`s air, soil and surface water. Storage in summer for winter and/or in winter for summer is the so-called seasonal storage system. These systems contribute significantly to improved energy efficiency of energy use". [1]

3.1.2 Constraints

There have been several constraints considered while developing the design of the system. First, we wanted to cover up the copper coils with a tube that has wider diameter to create vacuum. In this manner, we will be able to reduce the losses of heat. However, since the copper coil is concentric and 15ft long it became nearly impossible to do so. Therefore, we decided to insulate the system strictly.in addition to that, one of the constraints is choosing the proper nanoparticle fluid. After searching properly on the Nano particle types, we reached a decision that copper Nano particles are the best to perform our tests.

3.1.3 Sustainability

If we started to reduce the power consumption by using solar energy, then we can sustain our resources for the next generations. In our design, we are seriously focused on power optimization; therefore we are using glass and mirror reflectors to use the sun energy.
As shown in figure 3.1

Figure 3.1 - Mirror reflectors

3.1.4 Environmental

If we want to relate our project to solar water heater which is used widely in Europe and North America to produce boiling hot water for your home. They can be utilized as a part of any atmosphere, and the fuel they utilize - sunlight - is free. On the other hand, we must remember that our project is based upon heating water and only water. Therefore, unlike typical heat exchangers that use gases and water where the fouling occurs, we are not impacting the environment. In fiure 3.2 and 3.3 the proccess of the solar water heater is domenstrated.

Figure 3.2 - solar panel installed on the roof of a house

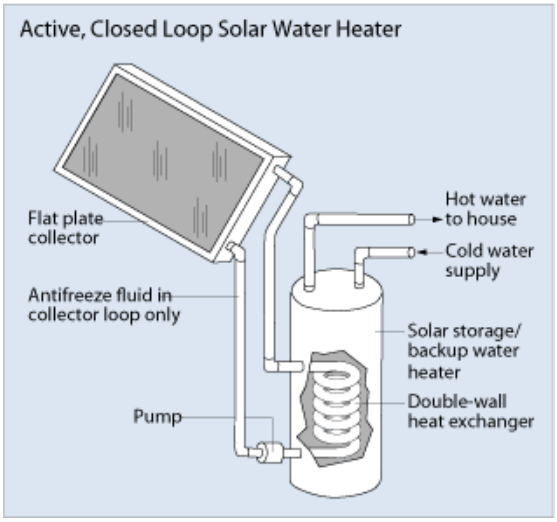

Figure 3.3 - Active, closed loop solar water heater

3.1.5 Economically

As known for company's money is everything. Therefore, the solar heat exchanger using Nano particles is an experiment to increase the efficiency of the heat transfer and not impacting the environment. However, if we succeeded to prove that a Nano particle is going to improve the heat transfer substantially, we can make a break in the industry.

3.1.6 Manufacturability:

Our project can be manufactured with a small budget and can be used in different fields. As An experiment, it took us only one month to build the prototype and order the nanoparticles.

3.2 Design Methodology

In the solar heat exchanger using nanoparticles project our methodology is to start researching on the subject and ways of constructing the heat exchanger. First, we will start researching the ways of assembling the heat exchanger that made of wood and glass. Second, come the part collecting where we have to go to work shops, stores that sell wood, and stores that sell coils. Also, since we have a low budget we must pick the best quality places with the minimum prices. Third, the difficult part where we must assemble the heat exchange as our advisor instructed us. Fourth, we must make sure that there is no leakage or issue while operating the heat exchanger; therefore, we must test it before the experiment. Before getting the results and comparing data using the nanoparticles we will do several experiments. Finally, we will publish the results.

3.2.1 Alternatives Considered:

Use Nano-particles made of copper to enhance the heat transfer:

This alternative includes the use of copper Nano-particles instead of copper oxide nanoparticles. Therefore, we will be ordering form trusted website to perform the test. Taking into consideration that we are using copper coils therefore; we cannot use the copper oxide nanoparticles. The copper oxide can damage our coils because it acts like a ceramic.

Use two prototypes instead of one to compare results:

This alternative includes the usage of two prototypes to compare the efficiency increase using the nanoparticles or without using it.

SoildWorks:

We have used solid works in order to design the shape of the base and the glass used in the heat exchanger as shown in figure 3.4 the main design is explained.

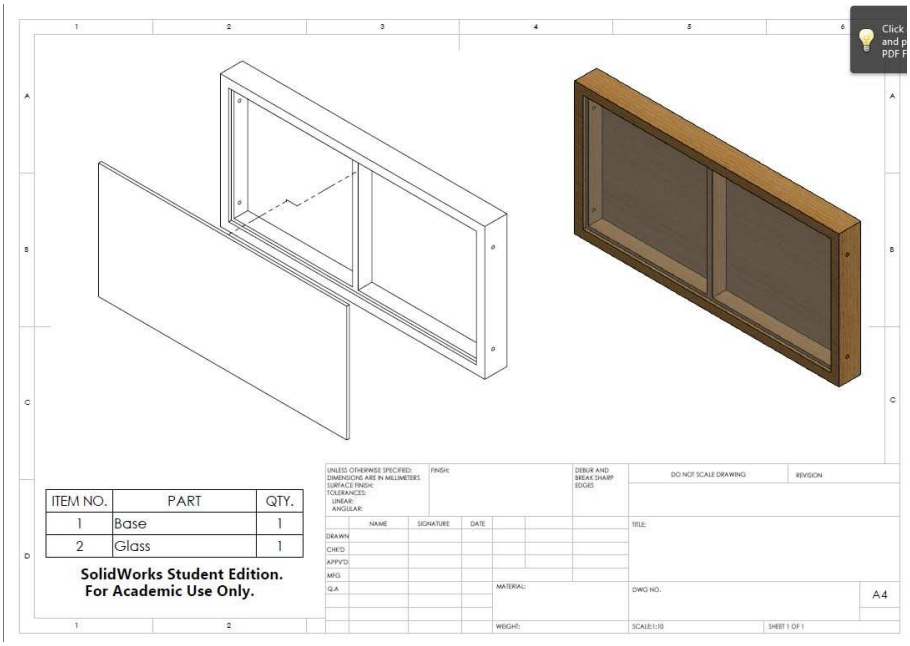

Figure 3.4 - Wood base and glass to hold the coils

3.3 Product Subsystems and Components

Base and frame:

Wood: we used wood for our project structure because it is a natural insulator due to its air pockets within its cellular structure. It is also light in weight, easy to install, easy to shape, and cheap in price.

Figure 3.5 - Base and frame

Tubing:

Copper Tubes: the properties of copper for thermal efficiency are desirable for our project. Copper has high thermal conductivity, which allows heat to pass through it quickly. In heat exchangers, copper has many desirable properties including corrosion resistance, fatigue strength, hardness, high melting point, allowable internal pressure, and ease of fabrication & joining.

Figure 3.6 concentric copper coils

Cover:

Glass: an observable choice for solar energy applications, glass is a highly transparent and durable material. It is stable under solar radiation and it can survive harsh environmental conditions. It can also protect sensitive components from water and humidity entrance.

Figure 3.7 - Glass cover

Fluid:

Water & Copper (Cu): copper based particles 1 to 100 nm in size, are added to water to increase the efficiency of the heat transfer.

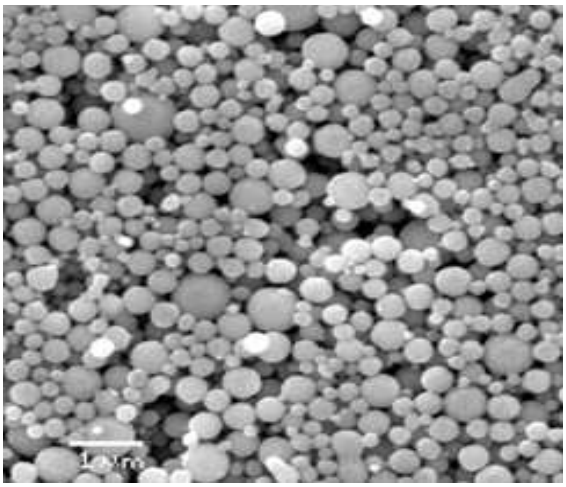

Figure 3.8- nanoparticles

3.4 Implementation

It is very important to know the main task of the project to move on smoothly such as knowing the project design and sketch, market and cost survey, purchasing the parts, virtual design stage, assembly stage, and ordering the nanoparticles. As shown in table 3.4.1 the main tasks of the project and its description are explained.

Table 3.4 the project main tasks and its description

Main tasks	**description**
Project design and sketch	Draw several designs in solid works and select the most proper design.
Market and cost survey	Before buying the tools and parts we went to stores and searched on the internet to have an idea of the costing price.
Purchasing the parts	After the cost survey, we have found the best quality and less expansive parts to purchase.
Virtual design stage	After buying the parts we had to change the sketch of the design and designed the apparatus using solidworks
Assembly stage	In week three we have finally gathered all needed parts, and then we assembled it.
Ordering the Nano-particles	Ordering the Nano-particles form an authentic website.

4. System Testing and Analysis

4.1 System testing

Objectives

After assembling all the parts of our project, we looked forward to testing it. Our main goal is to prove that the heat exchanger's efficiency increased with the use of the copper nano-particles. We also have to choose the perfect timing to test our system because the weather has a huge impact and effect on the heat exchangers.

Setup

We set our system in a safe area with the help of technicians and in a spot where the sunlight strikes directly. Our setup for this project was to fill the water tanks with somewhat cold water, and then open the inlet valve to flow the water through the heat exchangers with holding the exit valves closed. In this manner, we trapped the water inside the heat exchangers to allow them to absorb as much heat as possible. We kept the exit valves closed for an hour in each stage of our experiment. An hour later, we opened the exit valve for the water to flow through the exit pipes and for the water to be measured by the thermocouples.

We applied the same procedure throughout our experiment's three stages for both heat exchangers.

4.2 Overall Results, Analysis, and Discussion

Equations for determining the volume fraction or mass of nanoparticles

% volume concentration, % of Nano-particles = equation 4.2

Or in other ways, =

Where:

Wcu: is the weight of the copper nanoparticles

P_{Cu}: is the density of the copper nanoparticles

W_{Water}: is the weight of the water

P_{Water}: is the density of the water

Knowing that

We get the volume fraction or the percentage of the nanoparticles in water to be:

= equation 4.3

The results from our experiment

Diagram 4.2 shows the comparison between exit temperatures with or without using nanoparticles. We have started the experiment earlier in the day at 10 am then we continued until 12pm to collect data for this study case. Initially, we reduced the amount of water from the tanks because we have ordered a small quantity of copper nanoparticles and so there will be no benefit if we are going to spill this small amount of nanoparticles into a large amount of water. Moreover, we brought a blending machine to blend the nanoparticles inside the water. After emptying the tanks from water, we used filled the blending machine with 266.7g or 0.2667l of water. Then using the equation of the volume fraction we calculated the percentage of nanoparticles needed. Then, we spilled the blended fluid to the tank again. In conclusion, the diagram exhibits how much the temperature if we about to add different nanoparticles percentages. The highest temperature we reached was 50 Celsius by adding 0.5 % of nanoparticles. The second highest temperature we reached was 35 Celsius by adding 0.2 % of nanoparticles.

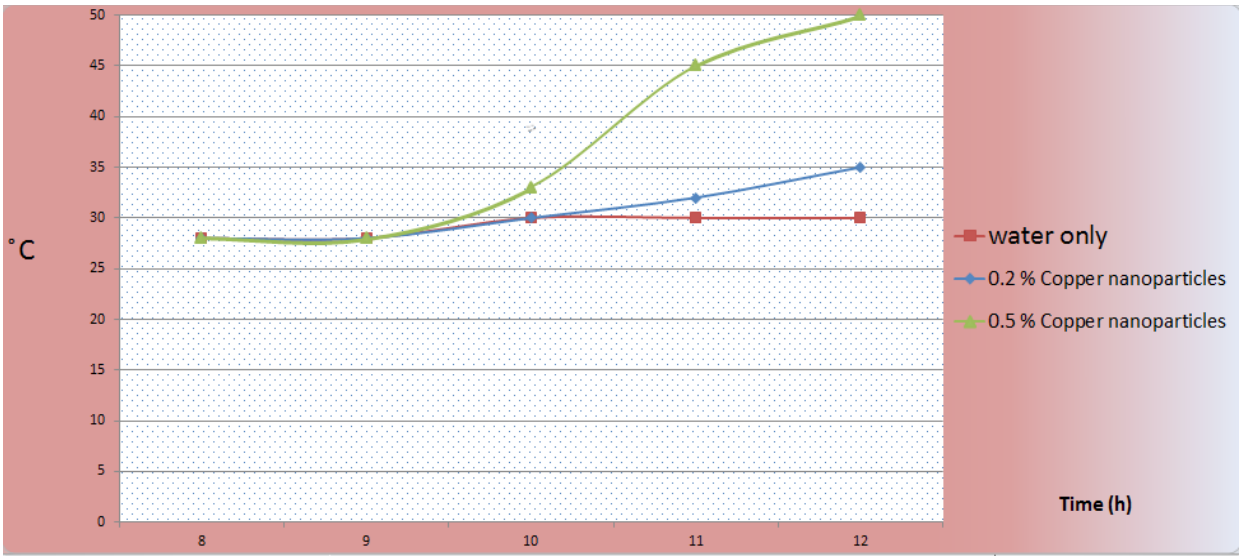

Diagram 4.2 the variation in temperatures for different nanoparticles percentages

5. Project Management

5.1 Project Plan

As soon as the semester began specifically on October the first, we started to set a map to manage the project effectively. At the beginning, we had some doubts how can we elaborate with the project since it is a new subject for us and we have not estimated the cost of such a project. Therefore, all team members sat together and started the estimation based on their familiarity with the basic tools such as the wood, cover glass, coils, and Nano-particles. Then, after all the calculations for the cost estimate, we settled and agreed that the cost should be between 2000-3500 Saudi Riyals. After conducting the initial estimation in paper, we decided to go and visit the shops for verification on the prices. Therefore, Khaled and Mohammed were sent out to check the prices for the final estimation on the duration of 23rd of October to the 24th of October. After getting done with the final cost estimation, Khalid went to a store that is well known for him to purchase the needed tools to assemble the heat exchanger. The main tools we needed are the wood, cover glass, black paint, copper coils, valves, water tanks, thermocouples, and the nanoparticles. To clarify, the wood was needed to design the base and the frame of the heat exchanger. On the other hand, the cover glass was needed to cover the copper coils and to absorb the sun heat. Additionally, the reason of using the black paint all around the heat exchanger is to make the absorption of the sun more intensive. On the other hand, the reason of selecting the copper coils is to have high thermal conductivity during the heat exchanging operation. The valves were selected for controlling the flow rate of the water entering and exiting the heat exchanger. In additional to that the water tanks were chosen to store the water for both sides, the inlet and the exit. Finally, the nanoparticles were selected to conduct our study on increasing the heat transfer efficiency. After getting done with the tool purchasing on November the second, we started the assembling on 23rd of November. In additional to that, after finishing the assembly on the 25th of December, we started testing the prototype and started to record the results and

publish it on the 30th of December. Mainly, in table 5.1 you can find the summary of the tasks, assigned members, and the duration of the accomplishment.

Table 5.1-Main tasks for implementing the project

Task	Team Members	Duration
Initial cost estimation	All team members	October the first-October the tenth (2016)
Final cost estimation	Khalid and Mohammed	23rd of October-24th of October (2016)
Tool purchasing	Khalid	November the second (2016)
Assembling	Khalid and Mohammed	23rd of November- 25th of December
Testing	All team members	30th of December 2016
Result recording	All team members	30th of December 2016
Result publishing	All team members	30th of December 2016

5.2 Contribution of Team Members

Working in groups is crucial in the engineering environment and almost all companies require teamwork skills. Therefore, the contribution of the team members is very important. In our project, we have been collaborative in terms of completing the work assigned. Team member Mohammed's main contributions were dealing with the paper works, assembling the prototype, and leading the team. When it comes to the paper work, member Mohammed was responsible for

writing the weekly reports and the final report with the help of his team members. Assembling the prototype and installing the project parts were also some of the contribution that Mohammed had been doing. Team member Khalid's contributions were mainly estimating the cost, purchasing the tools, and assembling the prototype. When it comes to estimating the cost of the project, Khalid did a great job going to all the shops that sell the needed parts as well as purchasing it. Team members Thamer and Othman contributed in doing the midterm presentation and helped Khaled to purchase the tools. On the other hand, Team member Othman contributed in doing the presentation, writing the final report, and tested the prototype. In table 5.2 you can see the summery of all members Tasks and contribution throughout the semester.

Table 5.2-Contribution of team members

Team Member	Tasks	Contribution %
Mohammed Alanazi	Paper-works, assembling the project, and team leading.	88%
Khalid Al-Saad	Cost estimation, purchasing tools, and funding the project. Initially Khalid paid for the tools then we paid him back.	85%
Thamer Al-Otaibi	Associating Khalid and Mohammed	83%
Othman Mohammad	Presentation work and testing	83%

5.3 Project Execution Monitoring

To enhance our project, we set a weekly meeting the first month of the semester as team members. The main goal for this meeting is to monitor the updates for our project. At first, the meeting did not help much due to our lack of experience on this specific topic but as soon as we did our research in this topic it improved. The first three meetings mainly were about estimating the project cost and purchasing the parts. Then, forth meeting was about selecting the proper location for assembling the prototype and set the assembly process. In addition, the fifth meeting was about how to test the project and record the needed data. Finally, the last meeting was to complete the final presentation.

On the other hand, we also had meetings with our advisor and co-advisor to guide us when we are lost. We had many meetings to discuss important aspects of the project such as the geometry of the prototype, the material of the nanoparticles, and the material of the heat exchanger. When it comes to the geometry of the prototype our advisor and co-advisor recommended us to work in a small scale and not to go large. In other words, they asked us to design the heat exchanger in smaller scale. On the other hand, they also recommended us to buy copper nanoparticles, due to its high thermal conductivity. Lastly, they recommended us to use wood, glass, and copper piping to design our heat exchanger.

5.4 Challenges and Decision Making

5.4.1 Challenges Faced:

We have been faced with different kind of challenges. However, these challenges contributed in developing our engineering skills. The main challenges that we have been through are ordering Nanoparticles from a trusted website and assembling the heat exchangers. The nanoparticles can vary in terms of type, therefore; we had to order whatever our instructor has recommended us with. Our professor asked us to look for copper nanoparticles. Moreover, the challenge we encountered is from where to get the nanoparticles. Fortunately, we had a friend who knew a trusted website and we ordered it. On the other hand, assembling a heat exchanger was a new experience for us, therefore; we had to do extra work and ask experienced people to advise us. Also, we had some challenges in terms of meeting the deadlines especially writing the final paper because we wanted to achieve the best quality we can offer. Eventually, we can say that we have gained a lot of skills such as teamwork skill and communication skill.

5.5 Project Bill of Materials and Budget

The project bill of materials and budget have been divided into ten parts copper coils, wooded base, wooded frame, glass frame, valves, thermocouples, tanks, digital weighting scale, copper nanoparticles, and wave maker. The copper coils have a quantity of two concentric pieces and it cost 200 SR. The wooded base has a quantity of two pieces and it cost 80 SR. The wooded base has a quantity of 2 pieces and it cost 33 SR. The Glass frame has a quantity of 2 pieces and it cost only 25 SR. The valves were the most expansive parts we purchased, it cost 800 SR and it has a quantity of 6 pieces. The thermocouples cost us 750 SR and it has a quantity of 4 pieces.

The water tanks cost us 350 SR and the copper nanoparticles cost us 500 SR. In table 5.3 we can see the Item description, the quantity, and the cost.

Table 5.5 Bill of materials

Item#	**Description**	**Quantity**	**cost**
1	copper coil	2	200SR
2	Wooded base	2	80SR
3	Wooded frame	2	33SR
4	Glass frame	2	25SR
5	Valves	6	800SR
6	Thermocouples	4	750SR
7	Tanks	4	350SR
8	Digital weighting scale	1	50SR
9	Copper Nanoparticles	1	500SR
10	Wave maker	1	220SR
			TOTAL= 3008SR

6. Project Analysis

6.1 Life-long Learning

Mainly in this senior design project we have learned two skills teamwork skills and decision-making. We have used many resources throughout the semester such as Google scholar, the university library, and engineering books. As repeated previously teamwork skill is what an employer needs the most. Normally, collaboration is characterized as: Co-operation between the individuals who are taking a shot at an assignment. Collaboration is for the most part comprehended as the readiness of a gathering of individuals to cooperate to accomplish a typical point. For instance, we regularly utilize the expression:" he or she is a decent cooperative person". Therefore, I emphasize on developing the teamwork skill continuously.

When it comes to decision-making, we all know it is the action or process of making important decisions. We had equal opportunity to make important decisions such as dividing the tasks and who takes the initiative to complete the tasks. On the other hand, of course to write this paper with the best quality possible we used many sources to support us. These sources were helpful such as Google scholar, the university library, and engineering papers. Google scholar was very helpful for us because of its ability to give a basic approach to comprehensively look for academic writing. From one place, you can look crosswise over many teaches and sources: articles, proposals, books, modified works and court assessments, from scholarly distributers, proficient social orders, online stores, colleges and other sites.

Google helps you find applicable work over the universe of insightful research. The second source we have used is the university library; unfortunately our topic is a new area of study. Therefore, the only book we used is Mass and heat transfer written by Pan, X. The third source we used in this paper is trusted universities websites. Overall, we must say after completing this project the main skills gained are working in groups and making the right decision in the right time. Therefore, we hope to develop these skills further.

6.2 Impact of Engineering Solutions

Although our project is for small-scale usage, it is very inexpensive and easy to install project. Moreover, it uses the clean energy from the sun and it has no impact on the environment. Moreover, people in Europe and north America have already used the solar heaters for many purposes. Therefore, as a developing country we should start thinking of the clean energy to live a clean and healthy life. Today's reality is subordinate upon non-renewable and naturally harming wellsprings of vitality. Driving our future will require supplanting numerous present innovations, changing the biggest ventures on the planet, tapping an unlimited exhibit of renewable sources, and evolving conduct. Meeting this vitality challenge and securing the earth requires arrangements that traverse approach, science and innovation. Examples of renewable energy sources are sun oriented energy, wind energy, hydro control, geothermal vitality, and biomass vitality. These sorts of energy sources are not quite the same as fossil powers, for example, coal, oil, and common gas. In our project, we depend on solar energy using glass and black paint. This method helped us to gain the most of the solar energy to heat up the water trapped in the copper coils inside the heat exchanger. This project, can offer engineering solutions in terms of pricing, air pollution reduction, and its simplicity of installation.

6.3 Contemporary Issues Addressed

Since our county is in ongoing hardship from the economic crisis due to the drop of the oil prices, we are looking for alternative solutions to stop depending fully on oil. Therefore, our design of an enhanced solar heat exchanger using nanoparticles comes as a small contribution to reduce the usage of fossil fuel and use the clean energy. Moreover, using the clean energy comes due to the fact of high pollution generated by the usage of fossil fuel burning. We've all paid a service charge or obtained fuel. Those speak to the immediate expenses of fossil powers; cash paid out of pocket for energy from coal, normal gas, and oil.

In any case, those costs don't reflect the aggregate cost of fossil fuel to each of us independently or to society all in all. In other words, there is a direct cost and indirect cost of the usage of the fossil fuel. Air pollution for instance can cause cancer and other disease that cost a lot of money to survive from. Moreover, indirect cost that can result from using the fossil fuel are the process of extracting fossil fuel, coal mining, underground mining, surface mining, and much more than we imagine. Also, one of the most important costs we must consider is the process of transporting the fossil fuel. Depending on the location that that the fossil fuels has been extracted from, it may require traveling across long distances. However, transporting fuel can increase the potential for catastrophic Failures. Therefore, in our project we are concentrated on clean energies more specifically the sun energy. This is of course to promote the usage of renewable energy in the country of Saudi Arabia.

7. Conclusions and Future Recommendations

7.1 Conclusions

After conducting our experiment on the topic of enhanced solar heat exchanger using nanoparticles, although we have encountered many challenges, the results we achieved were valuable. After running the experiment and comparing data between the heat exchanger that uses Nano particles and the one without the usage of nanoparticles we concluded that indeed the nanoparticles did increase the efficiency of the heat exchanger. However, there are some limitations because our project was done in a short duration. Nonetheless, we could see the effectiveness of the nanoparticles in terms of heat conductivity, temperature increase, and heat transfer. In this project, we have learned many great aspects of engineering execution, teamwork skill, decision-making, and team managing skill. Moreover, we have learned how to work under pressure especially in this semester the duration was short and it is winter time. When it comes to the duration, the time given to finish the prototype, testing, and final paper was short. However, this experience has taught us to take the pressure and work with extra energy. On the other hand, when it comes to the season that we conducted out study on, we had some issues that it is not sunny day everyday but we overcame it thankfully. In this project, we have learned many great skills that will help us in our future careers.

7.2 Future Recommendations

Initially when we took the idea from our advisor, we had some difficulties designing our system. It is important to choose the write design for the project from day one. Moreover, since we live in a country with sun available intensively in the summer, we recommend executing this project during summer times. Lastly, we used nanoparticles to conduct our experiment. Therefore, we recommend ordering the nanoparticles early on.

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3	Wooded frame	2	33SR
4	Glass frame	2	25SR
5	Valves	6	800SR
6	thermocouples	4	750SR
7	Tanks	4	350SR
8	Digital weighting scale	1	50SR
9	Copper Nanoparticles	1	500SR
			TOTAL= 2788SR

Appendix A: Bill of Materials

Table A.1 the bill of materials of the project

Appendix B: Operation Manual

B.1 image of the system after assembly

B.2 the inlet tank and the thermocouple that connected to the copper pipe

B.3 this image illustrates the addition of nanoparticles

B.4-the heat exchanger, where the water will be trapped in to be heated.

B.5 the outlet tanks and the outlet thermocouples

Figures used in report:

Figure 1.1 - Heat Exchangers

Figure 1.2 - Water Tank

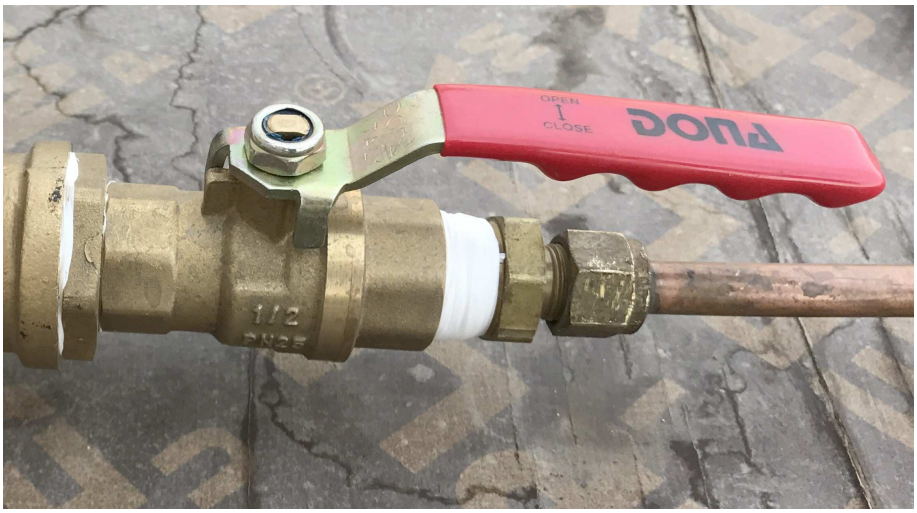


Figure 1.3 - Valve


Figure 1.4 - Copper Nano-particles

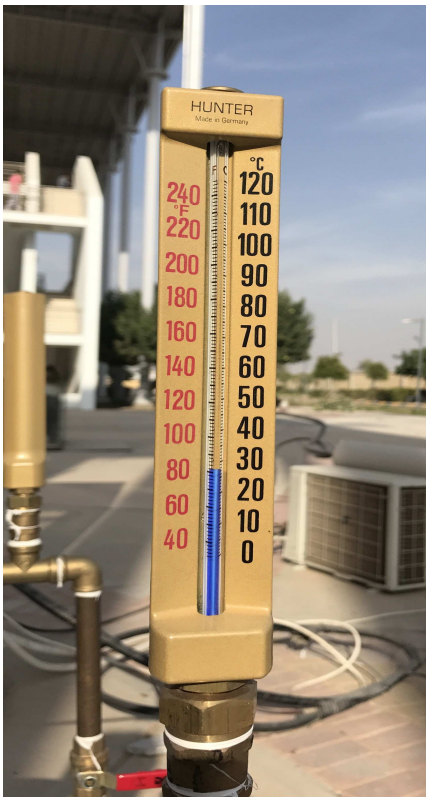


Figure 1.5 - Thermocouple

Figure 1.6 - Digital weighing scale

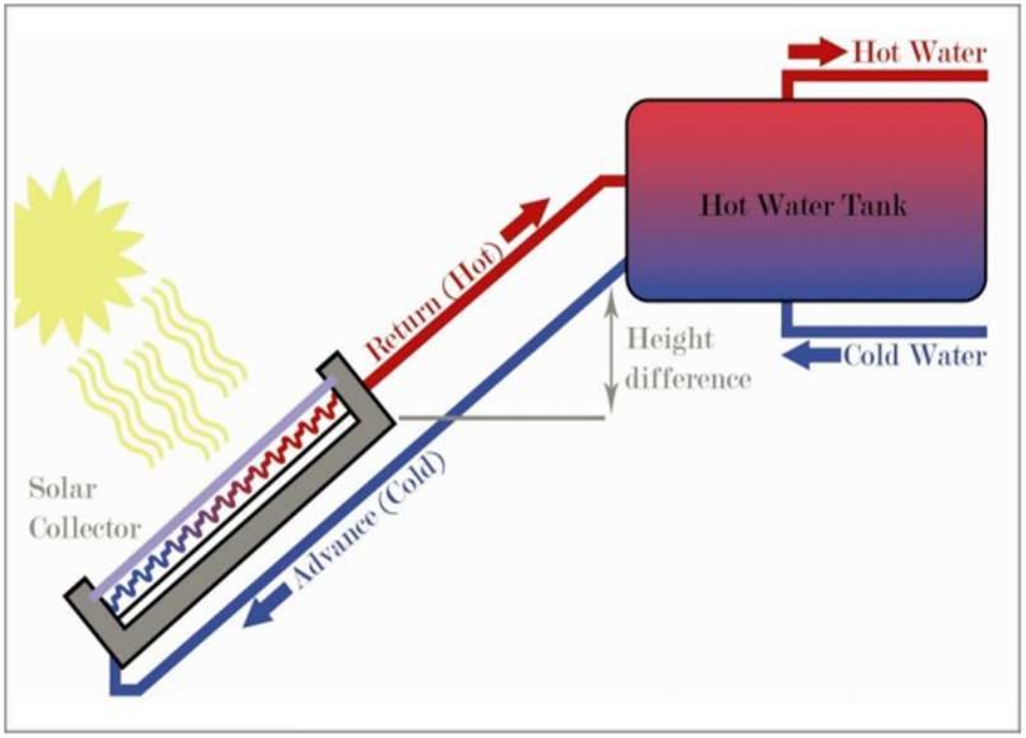


Figure 2.1 – Advanced Solar Heat Exchanger

Figure 3.1 - Mirror reflectors

Figure 3.2 - solar panel installed on rooftops

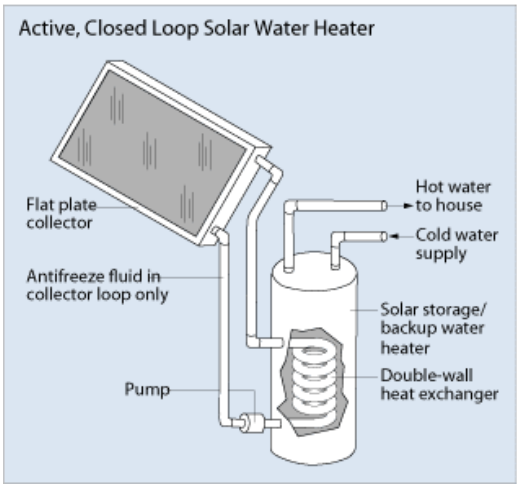


Figure 3.3 - Active, closed loop solar water heater

Figure 3.5 concentric copper coils

Figure 3.6 - Base and frame

Figure 3.7 - Glass cover

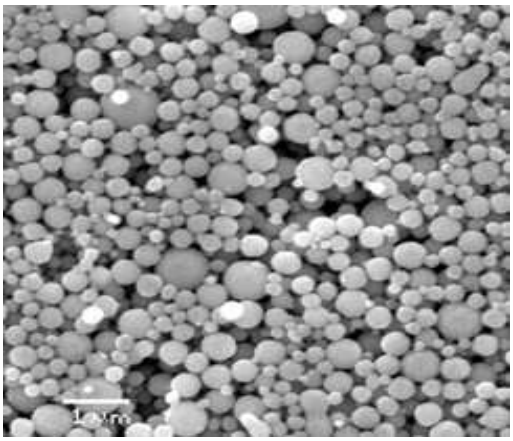


Figure 3.8 - nanoparticles

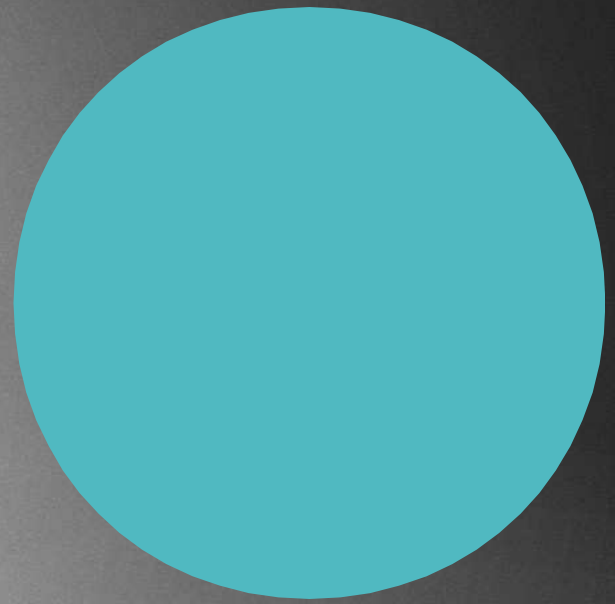
Learning Outcome Assessment III - 107
Department of Mechanical Engineering

# of an Enhanced Solar Heat Exchanger Using Nanoparticles

1. Thamer Otibi 201002295
2. Mohammed alanazi 201202705

Agenda

- Background & Motivation
- Design and Specification
- ..
- ..



Background

- Solar systems play an important role in the production of energy from renewable sources.
- Heat transfer enhancement in solar devices is one of the significant issues in energy saving and compact designs.
- collectors, water heaters, solar cooling systems, solar cells, solar stills, solar absorption refrigeration systems

Background

- Particle shape, size, mixture combinations and slip mechanisms, surfactant
- 170 kg less CO_2 emissions

Background

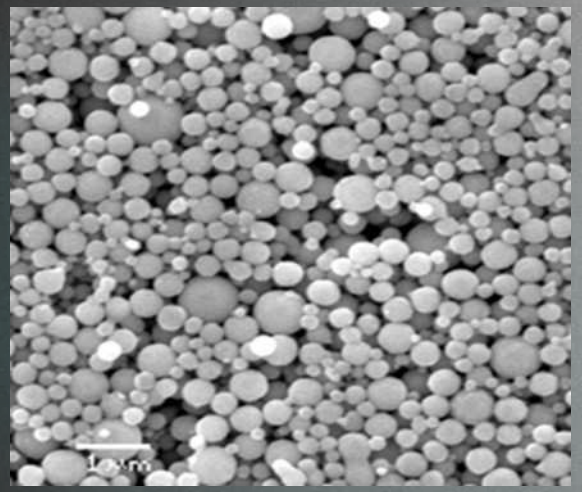
- Features:
  - High specific surface area
  - Reduced pumping power
  - Reduced particle clogging as compared to conventional
  - Adjustable properties, including thermal conductivity and surface wettability

Design and Specification

base and frame

Copper coils

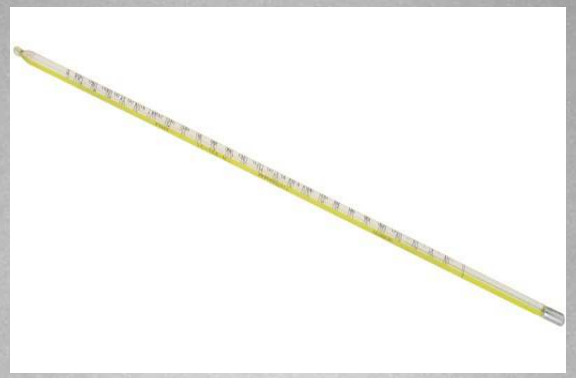
Glass cover



Copper and water Nano particles

Mirror refractors

Small tank to store the water



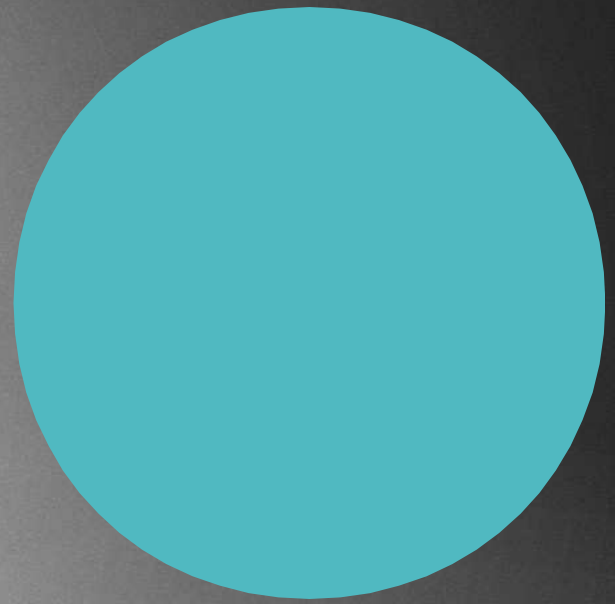
Measurements for the two prototypes

Base 69cmx69cm

Frame 64cmx64cm

Copper coils 4.6 m

Glass thickness 0.4 mm



How to determine the Nano-particles %

Calculate the weight of the heat exchanger before pumping water and after

Up to date progress