IMPROVING EFFICIENCY OF DOMESTIC GEYSER

A Final Year Project Report

Presented to

SCHOOL OF MECHANICAL & MANUFACTURING ENGINEERING

Department of Mechanical Engineering

NUST

ISLAMABAD, PAKISTAN

In Partial Fulfillment
of the Requirements for the Degree of
Bachelors of Mechanical Engineering

by

MOHSIN TANVEER
MUHAMMAD SHAHARYAR AMJAD
TALHA BIN TAHIR

June 2018

EXAMINATION COMMITTEE

We hereby recommend that the final year project report prepared under our supervision by:

MOHSIN TANWEER	NUST201432204
MUHAMMAD SHAHARYAR AMJAD	NUST201432599
TALHA BIN TAHIR	NUST201433604

Titled: "**IMPROVING EFFICIENCY OF DOMESTIC GEYSER**" be accepted in partial fulfillment of the requirements for the award of **Bachelors of Mechanical Engineering** degree with grade

Supervisor: Dr. KHALID AKHTAR, National University of Sciences and Technology.	____________________ Dated:
Committee Member: Engr.HAFIZ M.ABD-UR-REHMAN, National University of Sciences and Technology.	____________________ Dated:
Committee Member: Engr. M. NAWEED HASSAN, National University of Sciences and Technology.	____________________ Dated:

______________________ ___________

(Head of Department) (Date)

COUNTERSIGNED

Dated: ________________ ________________________

(Dr Abdul Ghafoor)

ABSTRACT

Due to the depletion of natural resources including natural gas there is a demand to develop new methods and techniques to efficiently use the existing resources. Gas geysers are being used for water heating at homes and on commercial scale. These geysers are cheap and being used most widely all over the country. These gas geysers are not efficient enough. Solar heating units are expensive as compared to traditional gas geysers, so people are forced using these currently inefficient gas geysers. We are providing a midway solution.

A way is being devised to save gas consumption by improving the efficiency of geyser while analyzing existing ways being used to do so. Minimizing the fuel consumption to reach the desirable temperature will be achieved by preheating of water. This was done using submersible helical coil (copper tube) wrapped around the exhaust. An efficiency improvement of 2.2% was observed. A payback period of 1.5 years has been worked out. The results obtained from our working prototype are used to compare the efficiency improvement from the existing gas geysers.

PREFACE

The idea of the project stems from the fact that currently, there is a shortage of natural gas being used domestically and in industries. Due to shortage, gas load-shedding is a problem being faced. Solar water heaters can be used but are not common and expensive as well. The suggested solution would not only reduce fuel consumption as well as works with low gas pressure.

ACKNOWLEDGMENTS

A lot of hard work and guidance was required for this projects completion. We are all very thankful to the people that went out of their way to help us in our project.

We are thankful to our parents for providing us with an opportunity to complete our undergraduate program.

We would also like to thank all our dear hearted teaching staff of our department. We were only able to complete this project in time just because of their patience and guidance.

ORIGINALITY REPORT

FYP

ORIGINALITY REPORT

12%	7%	7%	8%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to Federal University of Technology Student Paper	1%
2	Submitted to Kingston University Student Paper	1%
3	nptel.ac.in Internet Source	1%
4	nitayoga.com Internet Source	1%
5	www.e-ijaet.org Internet Source	<1%
6	www.comsol.pt Internet Source	<1%
7	Submitted to Institute of Technology, Nirma University Student Paper	<1%
8	www.thermal-wizard.com Internet Source	<1%
9	Submitted to Higher Education Commission	

	Pakistan Student Paper	<1%
10	www.slideshare.net Internet Source	<1%
11	"First E.C. Conference on Solar Heating", Springer Nature, 1984 Publication	<1%
12	paduaresearch.cab.unipd.it Internet Source	<1%
13	John Kanellopoulos. "A modification of the predictive analysis for the multiple site diversity performance taking into account the stratified rain", European Transactions on Telecommunications, 01/1990 Publication	<1%
14	Submitted to Modern Education Society's College of Engineering, Pune Student Paper	<1%
15	K. Vijaya Kumar Reddy, B. Sudheer Prem Kumar, Ravi Gugulothu, Kakaraparthi Anuja, P. Viajaya Rao. "CFD Analysis of a Helically Coiled Tube in Tube Heat Exchanger", Materials Today: Proceedings, 2017 Publication	<1%
16	Submitted to Coventry University Student Paper	<1%

17	worldwidescience.org Internet Source	<1%
18	Submitted to Imperial College of Science, Technology and Medicine Student Paper	<1%
19	www.mdpi.com Internet Source	<1%
20	Pin-Yang Wang, Hong-Yang Guan, Zhen-Hua Liu, Guo-San Wang, Feng Zhao, Hong-Sheng Xiao. "High temperature collecting performance of a new all-glass evacuated tubular solar air heater with U-shaped tube heat exchanger", Energy Conversion and Management, 2014 Publication	<1%
21	bccw.cityu.edu.hk Internet Source	<1%
22	"Reviewers", 2015 13th International Conference on Frontiers of Information Technology (FIT), 2015 Publication	<1%
23	researchbank.rmit.edu.au Internet Source	<1%
24	M. Smyth, P. Quinlan, J.D. Mondol, A. Zacharopoulos, D. McLarnon, A. Pugsley. "The evolutionary thermal performance and development of a novel thermal diode pre-heat	<1%

conditions", Renewable Energy, 2017
Publication

25	www.intechopen.com Internet Source	<1%
26	Submitted to University of Sheffield Student Paper	<1%
27	Submitted to University of Ulster Student Paper	<1%
28	www.engineeringtoolbox.com Internet Source	<1%
29	Mohamad Ramadan, Mahmoud Khaled, Ahmad Haddad, Bakri Abdulhay, Andy Durrant, Hicham El Hage. "An inhouse code for simulating heat recovery from boilers to heat water", Energy, 2018 Publication	<1%
30	Submitted to Cranfield University Student Paper	<1%
31	Submitted to University of Pretoria Student Paper	<1%
32	Submitted to GLA University Student Paper	<1%
33	ijaers.com Internet Source	<1%

34	Ammari, H.D.. "A mathematical model of thermal performance of a solar air heater with slats", Renewable Energy, 200308 Publication	<1%
35	Submitted to Technische Universiteit Delft Student Paper	<1%
36	Submitted to Diocesan Boys' School Student Paper	<1%
37	Alfaro-Ayala, J. Arturo, Guillermo Martínez-Rodríguez, Martín Picón-Núñez, Agustín R. Uribe-Ramírez, and Armando Gallegos-Muñoz. "Numerical study of a low temperature water-in-glass evacuated tube solar collector", Energy Conversion and Management, 2015. Publication	<1%
38	Submitted to University of Teesside Student Paper	<1%
39	www.ajas.info Internet Source	<1%
40	www.paratherm.com Internet Source	<1%
41	theses.ucalgary.ca Internet Source	<1%
42	energyeducation.ca Internet Source	<1%

43	Wu, Fuzhong. "Exergy destruction analysis of heat exchanger in waste heat recovery system in Kroll process.(Report)(Author abstract)", International Journal of Exergy Publication	<1%
44	ymcaust.ac.in Internet Source	<1%
45	www.rroij.com Internet Source	<1%
46	Submitted to Durban University of Technology Student Paper	<1%
47	doras.dcu.ie Internet Source	<1%
48	www.coursehero.com Internet Source	<1%
49	M.A. Sabiha, R. Saidur, S. Hassani, Z. Said, Saad Mekhilef. "Energy performance of an evacuated tube solar collector using single walled carbon nanotubes nanofluids", Energy Conversion and Management, 2015 Publication	<1%
50	Huang, Yu, Jian-lei Niu, and Tse-ming Chung. "Study on performance of energy-efficient retrofitting measures on commercial building external walls in cooling-dominant cities", Applied Energy, 2013.	<1%

Publication

51	Ibrahim, Oussama, Farouk Fardoun, Rafic Younes, and Hasna Louahlia-Gualous. "Reviewof Water Heating Systems:General Selection Approach based on Energy and Environmental Aspects", Building and Environment, 2013. Publication	<1%
52	www.getquick.co.uk Internet Source	<1%
53	d-scholarship.pitt.edu Internet Source	<1%
54	B. Peng, Q. W. Wang, C. Zhang, G. N. Xie, L. Q. Luo, Q. Y. Chen, M. Zeng. "An Experimental Study of Shell-and-Tube Heat Exchangers With Continuous Helical Baffles", Journal of Heat Transfer, 2007 Publication	<1%
55	Rabadi, N.J.. "Heat transfer in curved tubes with pulsating flow", International Journal of Heat and Mass Transfer, 198202 Publication	<1%

Exclude quotes	Off	Exclude matches	Off
Exclude bibliography	Off		

COPYRIGHT

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

NOMENCLATURE

v_o	Velocity of gas out from orifice in ft/s
P	Difference between absolute and outside pressure
w	Initial density of gas on the orifice inlet (lb/ft^3)
G	Acceleration of gravity (32 ft/s^2)
h	Head in feet of column of a gas
H	Gas pressure on orifice outlet
d	Specific gravity (natural gas)
A	Area of gas orifice in in^2
X	Cross section area of pipe in in^2
P	Reflectivity of CPC plate
K	Conductivity
r1	Outer radius of geyser
r2	Inner radius of cylinder
T_s	average surface temperature of geyser
D	Diameter of geyser tank
L	Length of geyser
V	Kinematic viscosity

CHAPTER 1: INTRODUCTION

Due to the Depletion of natural resources including natural gas there is a demand to develop new methods and techniques to efficiently use the existing resources. Gas geysers are being used for water heating at homes and on commercial scale. These geysers are cheap and being used most widely all over the country. These gas geysers are not efficient enough. Solar heating units are expensive as compared to traditional gas geysers, so people are forced using these currently inefficient gas geysers. We are providing a midway solution.

1.1 Problem Statement:

Fuel consumption in the domestic sector for heating water has increased a lot in the last years and continues to increase day by day this causes depletion of fossil fuels a major problem our planet is facing today.

1.2 Aims and Objectives:

The main objection of this project is to save a major fossil fuel being depleted with a large pace that is Natural Gas; to do this we intent to improve the efficiency of domestic gas geyser that are being used at homes, hospitals and in any place that requires hot water.

To improve the efficiency of geyser, first understanding the geysers functioning along with all the sub systems and components being used in it need to be analyzed and studied extensively. The components working and how are they contribute to the efficiency of geyser. All those possible ways where the components can be changed or redesigned to give the edge needed to improve the efficiency of the entire geyser are worth checking and will be analyzed.

Our motivation for this project becomes as clear as it can be, extensive wastage of gas needs to be avoided so that with less gas billing and expense we can produce more hot water. This not only produces a better economic aspect for the day to day consumer but also gives a lesser exhaust for the pollutant gases produced as a by-product for the combustion reaction that takes place in geyser. This helps to make keep the environment better and healthy rather than ruin it further by exhausting more pollutant gases into the air. All this can simply be done by improving the efficiency of the domestic gas geyser that is used daily normally in winters and cold weathers.

1.3 Major Factors:

Coming to how the efficiency of geyser will be improved by this project. The major components being discussed in this project, the ones that are identified as the main way to increase the efficiency of the geyser are the Insulation, Burner, Baffles and Solar compound parabolic collector and heat exchanger. The contribution of these major components their design and analysis will be studied as they provide the key role in heating the water in geyser and then keeping the heat stored in rather than letting it all escape. A brief introduction on how these different parts work is as follows:

Helical heat exchanger

Heat from the flue gases getting eliminated from the exhaust of the geyser, are wasted. These gases can be used to preheat cold water on the inlet of the geyser container. Hence, it reduces the time for heating water and save fuel consumption.

CHAPTER 2: LITERATURE REVIEW

Table 1 Literature review summary

Study, Year Reference	Summary
Pin-Yang Wang (2013)	Using compound parabolic collector(CPC) to heat water beyond 100 C that other collectors can't do.
CA Duff & C Bradnum (2013).	In order to investigate the ways the point of contact geyser works and fuel consumption estimate.
R.N.S.V.Ramakanth *, P.Lakshmi Reddy(2015)	Study the design and heat transfer in baffles in shell and tube heat exchanger.
A.J. Piscor (2015)	Basics of air to fuel ratio control
Walter M. Berry et al. (1921).	Investigation of burner design and having a detailed view on observations compiled from thousands of experimental analysis including effects of many variables.
A.Harris et al. (2017)	To study the shortcomings in use of geyser blankets wrapped around geysers. The study highlighted the problems including poorly secured blankets.

A. Kim (1985)	To study the air to air heat exchanger and see if the flu gases can be used to heat the room.
Majid Azimi (2015)	Study solar heating phenomenon using evacuated glass tubes collector for the purpose.
Energy observer (December 2008)	Explained some method to reduce energy lose with the help of better insulation.
Ahmed Aboulmagd et Al. (2014)	Study the performance of evacuated glass tube collector for heating for solar heating.
D. M. S. Al-Homoud (2004)	Shows extensive comparison between the materials how materials may provide a better advantage over others. Some even tough seem quite feasible but still cannot be used in thermal insulation.
B. P. Jelle (2011)	A huge research mainly upon all the new and major materials that provide ground breaking insulations.
Prof.N.B.Totala (2013)	Showed in his paper is the critical radius of all the given material can be calculated and it is quite important.

Typical water heating involves transferring heat from heat source whether it be energy from burning of fossil fuels or heat from natural source like sun to water for using domestically or industrially. In homes heated water is used when temperature is low and cold water can't be used for bathing, drinking, etc. Industrially hot water or steam is used for many purposes.

2.1 Types of water heaters

There are mainly two types of water heating system

1. Storage type water heating
2. Tankless instantaneous water heater

2.1.1 Storage type water heater

Storage type water heaters are the traditional water heaters being used all over the world from old times. They have an oval shaped cylinder made of metal and can run on multiple energy sources. In case of gas geyser, it has burner inside its body on bottom which burns fuel as an energy source. Gas geysers are common in countries where gas is available in cheap price and is supplied to houses by pipes in low price. In most of countries including Pakistan vertical tanks are being used while in Spain and some other countries horizontal tank is used. Besides gas, there are other type of geysers which use electric resistance element. The heat from resisting electric current is used to heat water. Energy wasted when water is not use is called standby losses which will be studies later on. Different capacity storage tanks are used according to need from 20 to 80 gallons. Fan assisted gas water heater is being used to reduce energy losses.

The image [1] shows the normal working of storage type water heating system.

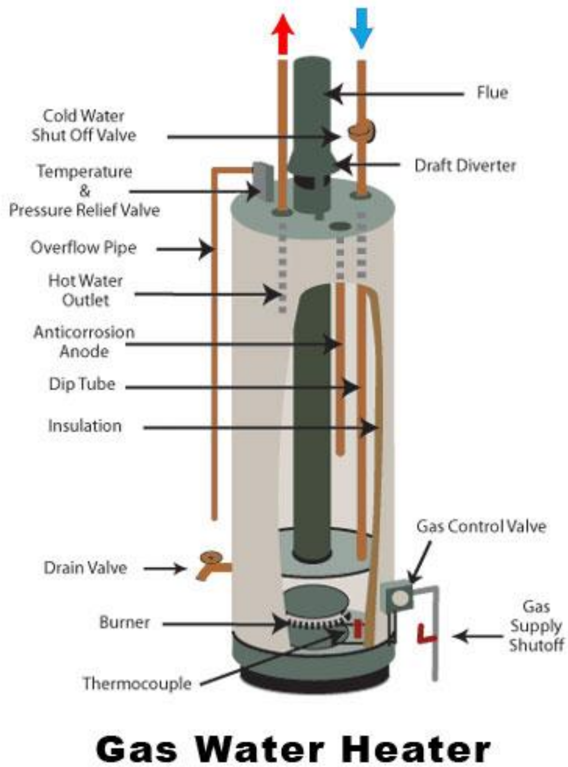

Figure 1 Storage type geyser

Also there is another type of storage water heater system called point of use electric heater which is used to heat water at specific spots for instance kitchen or specific washroom, etc. If we compare normal and point of use water geyser, for normal domestic use normal storage type heating system is good enough but for large buildings and plazas, point of use heating system is better to use to avoid long wait for hot water.

2.1.2 Tankless instantaneous water heater system

Tankless instantaneous water heating system is a new trend which has no tank and only water being stored is in coil of heat exchanger. Point of use tankless water heating system is more common than centrally installed water heating system.

Following [2] is the figure showing instantaneous water heating system

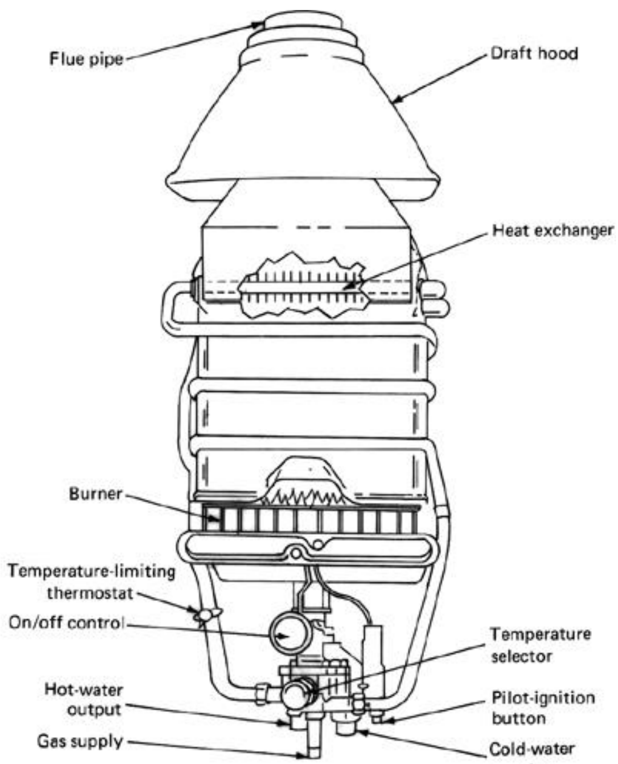

Figure 2 Instantaneous heating geyser

It has flow sensors which turn on when water is flowing giving signal that hot water is now required as water is being used. Also there are many hybrid gas geysers also available which combine tankless heaters with central heating systems or point of contact heating system.

2.2 Comparison of both types

If we do a comparison on storage water heater vs tankless water heater we see both have their merits and demerits.

The merit of using tankless water heater is that it doesn't need delay to heat water. It heats and supplies water instantaneously without any wait. Unlike water storage tank, it doesn't lose energy with the passage of time. A lot of water is saved as we don't have to waste water to get hot water. When there is minimum use of water, it actually spends lesser energy.

Its demerits are a few. Firstly, it consumes energy at a faster rate than storage tank heaters if it is run for longer durations. In Pakistan or other underdeveloped countries, it is a major concern for people. Secondly, when water is required at multiple points, it can supply water at fix spots.

2.3 Aspects to look into for improving a domestic gas geyser

We had to study all the aspects of a domestic gas geyser.

- Combustion
- Solar heating
- Insulation/Geyser blankets
- Baffles
- Timing of use/ flow meter
- Heat Exchanger

2.3.1 Combustion:

Combustion is the process in which fossil fuels reacts with oxygen to produce heat and water in an exothermic reaction. The measure of success of combustion process is dependent upon combustion efficiency. For hundred percent combustion efficiency, fuel should be completely burnt and no carbon and hydrogen remain unburnt. It is dependent upon air to fuel ratio. We can calculate the theoretical air to fuel ratio but can’t be achieved due to unreliable factors. When the combustion process is complete, the process becomes cheap and fuel is saved. More air also ensures that maximum of carbon monoxide reacts with oxygen.

In order to improve the combustion process, the burner design was to be considered. Dr. Gunther Bethold in Worgas Company gave the basics of stoichiometric reactions for the air to fuel reaction. Burner can be fan-powered which premix the air or atmospheric type which basically involves partial premixing of the air. John. H Eisman [3] wrote about the maximum limits which burner could be designed without blow off or flashback. Walter M. Berry [4] worked to provide a burner design, how the increasing or decreasing the quality of gas requires the injector tube and orifice to be set as optimal parameters. Most of the domestic and industrial water heating systems use burners with channel type orifice hence reducing the maximum velocity due to gas constriction. C.A Duff [5] presented the solution of waste of energy by suggesting point of contact geyser. Several papers regarding industrial burner design for educational purposes have been published by the American Gas Association. They don’t illustrate much detail about the gas properties with numerical evidences that how these effects the flow change.

2.3.2 Solar heating

There are two types of solar thermal heating system

1. Passive heating system
2. Active type solar heating system

Passive solar heating system

It is also called direct gain type heating system is the one in which water is sent directly to collector to be heated. It has also two types.

Integrator collector storage(ICS) has water tank incorporated into collector. It is cheap to use but it has disadvantage that significant amount of heat is lost in the night due to non-insulation of side of collector facing the sun.

Convection heat storage unit(CHU) is different from the ICS for the fact that it has separate water tank and collector. The heat transfer takes place by convection.

Active solar heating system

In indirect type solar heating system, the fluid mostly antifreeze is pumped into collector to heat and then transfer heat to water via a heat exchanger. The heat transfer fluid can be water but mostly it is antifreeze with corrosion inhibitor. Copper is very important element in the solar water heating system due to its high corrosion resistance and high conductivity.

Components of solar heating

1. **Collector**

   Two types of collectors

   - Flat plate collector

     The glass of flat plate is the reason it is considered the most long-standing type of collector. The glass of flat plate collector is tampered, low iron which is very hard to break. Unglazed collector also being used which have no thermal insulation, hence they are less efficient than flat plate type. The fluid travels from lower pipe pumped and after being heated it absorbs heat in the absorber plate then travels from upper pipe back.

Following [6] is the image of a flat plate collector.

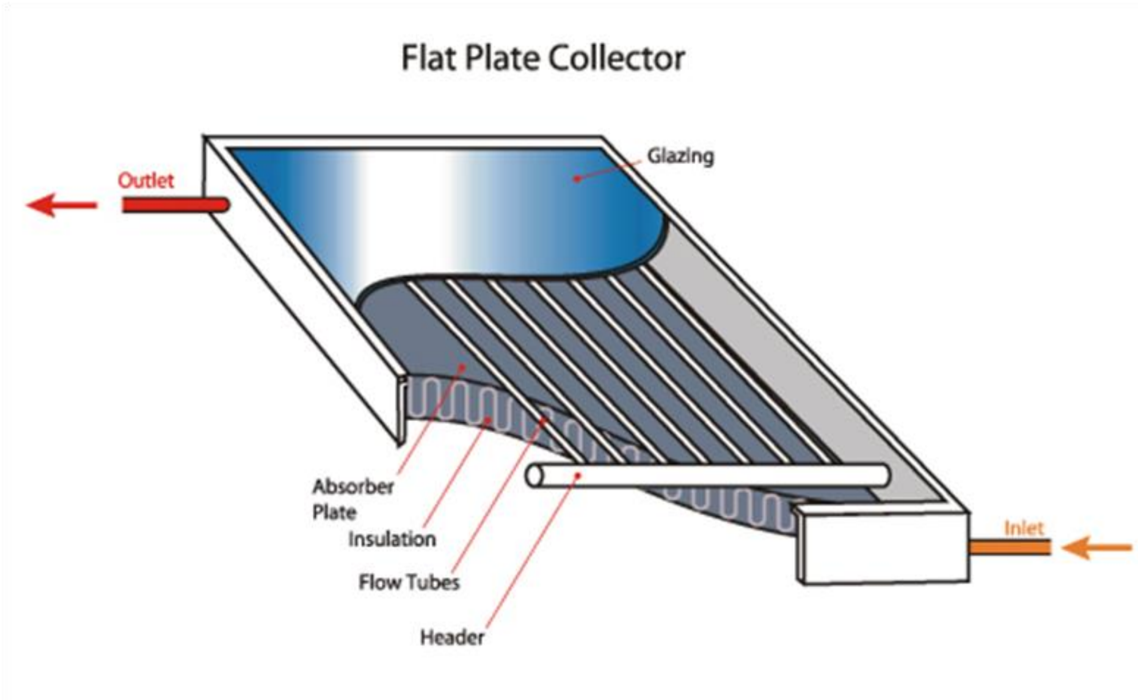

Figure 3 Flat plate collector

2. **Evacuated tube collector**

It is basically an improved version of flat plate collector. A lot of energy is lost from the flat plate collector is lost due to no insulation. As heat transfer due to convection can't happen due to vacuum, so once heat entered can't escape from tube. Heat transfer mechanism and procedure is basically same for flat plate collectors. There is another type of evacuated tube collector known as CPC (concentrated parabolic collector). CPC can not only accept and absorb radiations from wide angles as compared to other collectors. Most of the flat plate collectors also use CPC and less attention has been focused on evacuated type solar collectors

Following diagram [7] shows the working of evacuated glass heater.

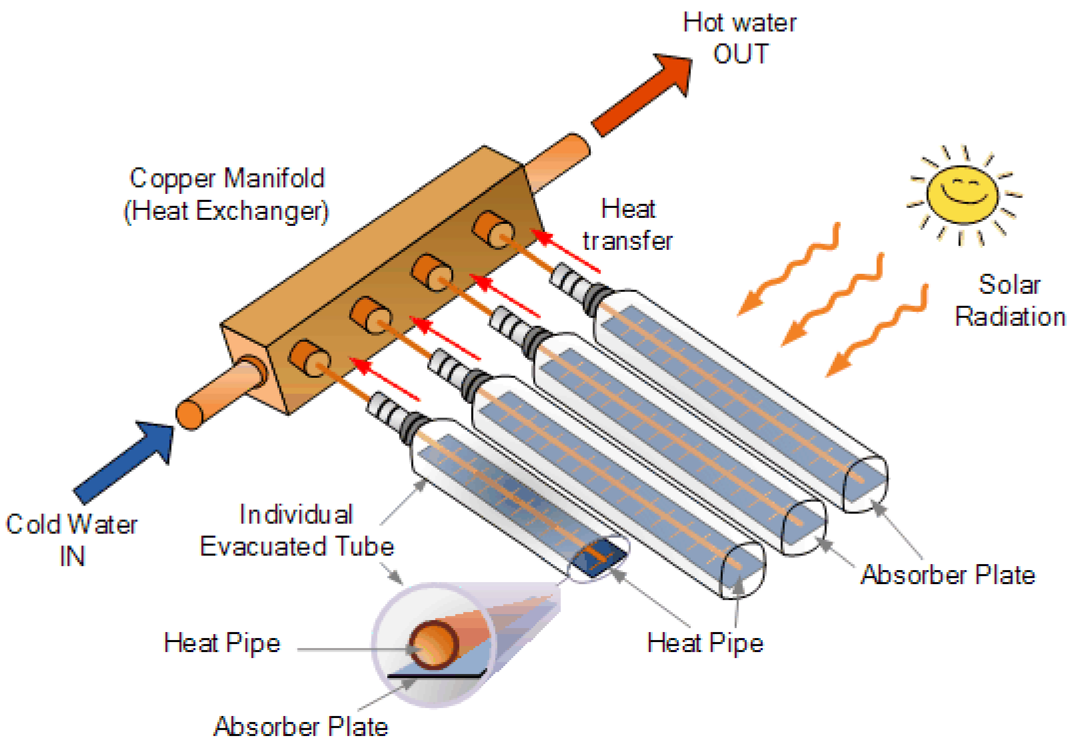

Figure 4 Evacuated type collector

Flat plate collectors are more efficient than evacuated type collectors under normal weather and conditions but under cloudy weather, it efficiency is greatly reduced due to energy loss.

3. Controller

   The controller works on the principle of temperature difference between water in the collector and the water in the tank. When the temperature difference is significant, it starts the pump and it turns off the pump when the temperature difference is not no large. That makes sure pump doesn't turn on and off for excessive times.

4. Pump

   Used to power an active system via photovoltaic panel.

Ong [8] analyzed and modeled that how the performance of a solar flat-plate air heater can be measured. Garg and Adhikari [9] did a performance evaluation of a single solar air heater with n number of sub collectors. Tchinda [10] showed a mathematical mode for CPC solar energy collectors, essentially how the air collectors thermal performance gets effected by quantification of heat transfer. Majid Azimi [11] gave the mathematical model as well as simulated the vacuum tube solar collector as a solution to Iran's energy problems. Bainbridge [12] gave a complete overview of solar collectors. As we know solar heating system are divided into active and passive type solar heating systems. Passive systems need no external power to support while active systems need external power or fan to operate. Passive solar heating system are further subdivided into two classes. Pin-Yang Wang [13] worked on a different type of gas tube that can be used within a compound parabolic concentrator (CPC). CPC can not only accept and absorb radiations from wide angles as compared to other collectors. Most of the flat plate collectors also use CPC and less attention has been focused on evacuated type solar collectors. CPC requires an expensive initial investment but is rather quite effective in its working and has a good payback time period, the processing of CPC is complex so the additional charges are quite reasonable. Hottel and Whillier, [14] developed the flat plate collectors that are divided into three common types.

The types are

(1) A flat plate absorber with darkened surface,
(2) for reducing heat loss introducing covers that are transparent,
(3) a fluid for transfer of heat (air, antifreeze or water; heat is removed from absorber)

(4) Insulated back for reducing heat escape.

A polycarbonate cover or casing is used in the absorber to provide insulation to avoid heat loss. A thin absorber sheet is preferred that is often backed with a coil or grid of a fluid tubing, for the heating of water, the fluid is normally circulated in the tubes that gains heat through solar radiations, then from the fluid the heat in then transferred directly into water; a heat exchanger can also be used to avoid mixing of water and the heating fluid.

Another way is by using the multiple evacuated glass tubes that work as absorber plates, the heat pipe is fused with these glass tubes. Such a system is called Evacuated heat pipe tubes (EHPTs). The heat is transferred to fluid or a heat exchanger called ‘’manifold’ ’insulation in majorly done by a plastic case and protection coating is done by sheet metal. The evacuated glass tubes types varies as well depending on glass-metal or glass-glass layer. In glass-metal the heat pipe in enclosed by a vacuum inside glass absorber; while in the glass-glass type there is glass on the both ends of the vacuum. The absorber and heat pipe themselves are kept at normal atmospheric pressures.

2.3.3 Heat exchanger for preheating water

Heat exchanger is used to transfer heat between two fluids. The figure shows a simple heat exchanger.

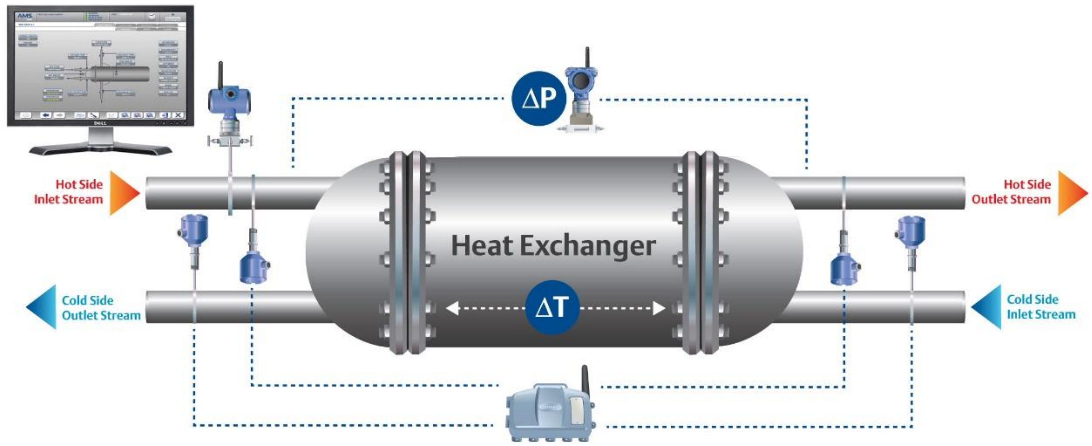

Figure 5 Simple heat exchanger

What are heat exchangers?

Heat exchangers are devices used to transfer heat energy from one fluid to another. Typical heat exchangers experienced by us in our daily lives include condensers and evaporators used in air conditioning units and refrigerators. Boilers and condensers in thermal power plants are examples of large industrial heat exchangers. There are heat exchangers in our automobiles in the form of radiators and oil coolers. Heat exchangers are also abundant in chemical and process industries.

Straight Tube Heat Exchangers

There has been a number of research studies conducted on heat exchangers in the past century to quantify the parameters affecting their heat transfer characteristics. A heat exchanger uses two fluids with a temperature difference to transfer heat from one to another, most commonly through a solid interface. Heat exchangers come in a variety of shapes and sizes and are used in almost every industry imaginable including automotive, oil, semiconductor, HVAC, and alternative energy. One of the most common heat exchangers in use is the concentric tube counter flow heat exchanger involving a straight pipe and a straight pipe shell with the inner and outer fluids flowing in the opposite direction

Helical Type Heat Exchangers

In an effort to provide the same amount of heat transfer as a straight tube heat exchanger in a smaller space, engineers replace the straight inner pipe with a helical coil. This allows for more heat transfer surface area in a smaller length shell, but increases the pressure drop across the heat exchanger. Helical coil heat exchangers have a more complex flow pattern due to the geometrical configuration of helical coils, which also impart additional centrifugal force on the inner coil flow and increasing the pressure drop on the shell side.

In 1997, Yildiz et al. [10] conducted an experimental study on a helical tube in a shell heat exchanger containing inside springs. The springs were placed inside the helical tube as a way to passively increase the heat transfer inside the loop. The experimental setup consisted of 5 mm helical pipes with a curvature diameter of 75 mm. The shell was well insulated and air and water were used as the working fluids in the coil and shell sides, respectively. It was not stated whether the air was undergoing heating or cooling, we can assume it was undergoing heating. The information we are interested in for this present research is the results of the experiments without springs. As for the results with the introduction of the spring in the coil, an increase in heat transfer effectiveness of up to 30% is seen in the heat exchanger while the pressure drop also increases up to 10 times that of the empty tube flow.

In 1998, Guo et al. [11] experimentally studied the effects of pulsatile flow on heat transfer in helically coiled tubes. The experiment was conducted using two-phase steam water as the working fluid. The experiment had a total of 102 thermocouples on the outside of the tube, varied axially as well as peripherally. This provided a very detailed description of the temperature field. Part of the experiment was conducted under steady single-phase flow.

.

Shell and tube heat exchanger can be used to preheat water in the geyser by using flue gases

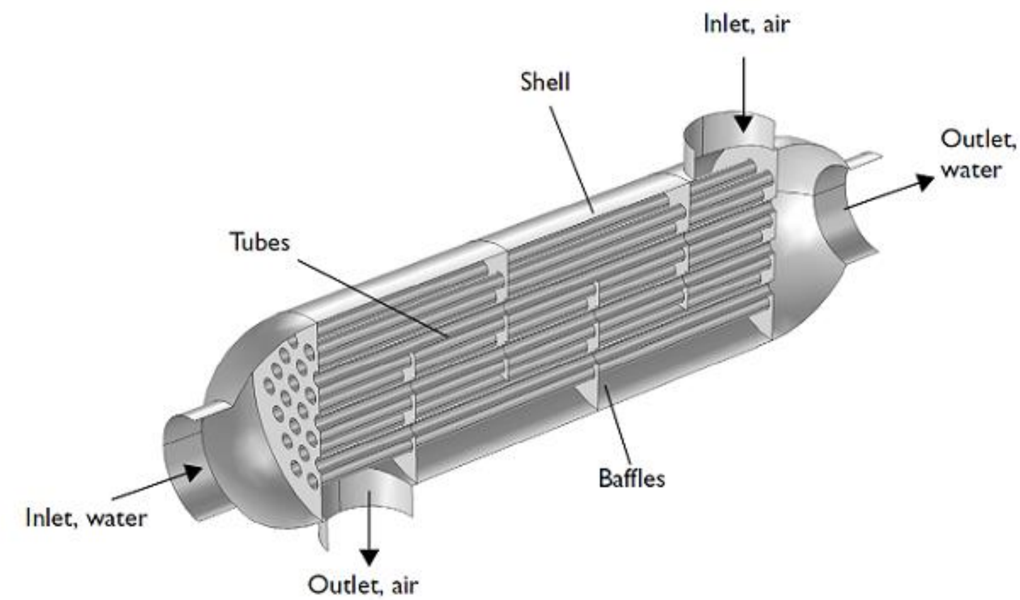

Figure 6 shell and tube heat exchanger

2.3.4 Insulation/ Geyser blanket

With the extension of knowledge, a large amount of materials has been identified that can be used as insulators so there comes a need for a standard comparison among them which are better and can be considered as best candidates for the insulation to be done. Geyser blanket is an external layer of insulation that can be used to reduce standby losses by wrapping around geyser. Although geyser blanket's typically is 50 to 75mm of thickness but it has also 100 to 150mm thickness for larger cylinders.

Dr. Mohammad S. Al-Homoud [15] has published a paper showing extensive comparison between the materials that how materials may provide a better advantage over others. Some even tough seem quite feasible but still cannot be used in thermal insulation for the cylindrical wall of geyser such an example is Polyurethane/Polyisocyanurate-Foam whose R-value is very good but its disadvantage is that it shrinks down exposing the surface, in regard it is incapable to be used in some cases such as geyser insulation.

The comparison among the insulating material is done by the units of U-Values, R-Values and Thermal conductivity. A basic idea or a tip comparing these is that the material with higher R-value is good and U-values need to be lower. R-value is measured by dividing the length of the material with its thermal conductivity. U-values are calculated by the addition of convection and radiation heat losses with the reciprocal of R-value. So it can be concluded that U- values are the best since they give most accurate results by accounting the different ways heat loss can occur through the material. Omer Kaynakli [16] in his paper has provided the U-values of all the major materials being used along with how with thickness the heat transfer varies. This research gives us the major optimal thickness of all the insulation material that need to be used in walls of a building and how that gives reduction to the heat transfer. Azra Korjenic [17] has calculated U-values of materials composed of renewable resources. These materials are very vital since most of the insulators that are being used are mainly non-renewable and provide a great disadvantage. Bjørn Petter Jelle [18] has presented a huge research mainly upon all the new and major materials that provide ground breaking insulation among one of them is Aerogels produced by NASA used in their space shuttles .A.Harris [19] writes about how the standing losses and how they can be reduced in geyser by introduction of geyser blankets. Prof.N.B.Totala [20] shows in his paper the critical radius of all the given material can be calculated and it is quite important. As if the outer radius of a material falls short than the critical radius then material instead of working as an insulator, it works as a conductor. This aspect always needs to be the basis of analysis when installing a material that need to work as an insulator.

2.3.5 Baffles

Baffles [21] are extensively used in the industry among heat exchangers, mixing chambers, chemical plants, they provide an obstruction in the flow direction of fluid. They are in the shape of vanes and panels and are places inside the vessel tanks. The implantation of baffles requires an expert analysis on the cost, size, and major effectiveness with or without the introduction inside the vessel. As geyser are actually heat exchangers they are used to increase heat transfer. They provide support to the tubes by directing the flow. General classification of the baffles is as follows:

- Longitudinal Flow type baffle
- Orifice Baffle type
- Single segmental baffle type
- Double segmental baffle type

Baffles are an integral part of the shell and tube heat exchanger design. A baffle is designed to support tube bundles and direct the flow of fluids for maximum efficiency. Baffles are generally used in heat exchangers. Heat exchangers being one of the most important heat & mass transfer apparatus in industries like oil refining, chemical engineering, electric power generation etc. are designed with preciseness for optimum performance and long service life. R.N.S.V.Ramakanth [22] did experimental investigation of helical baffle heat exchanger using the Kern method with varied shell side flow rates. This is a proven method used in counter flow design of Heat Exchangers The paper also consists of the thermal analysis of a helixchanger.

2.4 Conclusion after literature review:

1. The process of combustion is needed to be overviewed as no improvement in gas burner design of gas geysers is observed from past several years. But changing the burner design brings about difficulties in maintenance.
2. The concept of baffles has been explored considerable time in the past and is being used in geysers in market, so no need to explore it.
3. Flow meters can be used to make efficient use of geyser but require expensive sensors, which increase considerable price.
4. Solar heating is the way of future so probably a hybrid of solar and gas that doesn’t increase the price significantly.
5. Best insulations are already being used.
6. Heat Exchangers can be installed inside the geyser to preheat the water, as heat from the flue gases are being wasted.

CHAPTER 3: METHODOLOGY

This study has been confined to the development of an efficient heat exchanger that can be manufactured and installed by the geyser fabricators. Natural gas burner is used to heat water in a geyser. The burner runs on oil or gas. The flue gas on burning of gases get wasted in normal geyser. Heat recovery needs to be done which basically use the flue gases and it can be used to preheat water in the cylinder. Baffles are already there in most of geysers now days, which increase the contact area for heat. For preheating water, we can use thermal heat exchanger so it takes heat from flue gases and heat water before it enters into the cylinder. Our suggested heat exchanger type is coil type. A copper tube of 0.5 inch diameter is being used for the geyser.

Copper tubing is helically wound around the exhaust which gets heated by the exhaust gases and transfers the heat to water in the copper tube.

3.1 Experimental setup

Copper tube has been used with a diameter of 0.5 inch. It has been wrapped around central vertical pipe of length 25 inch and diameter of 2.5 inch. It has 34 turns.

Approximate length of copper tube is 27 feet.

Figure 7 image of heat exchanger

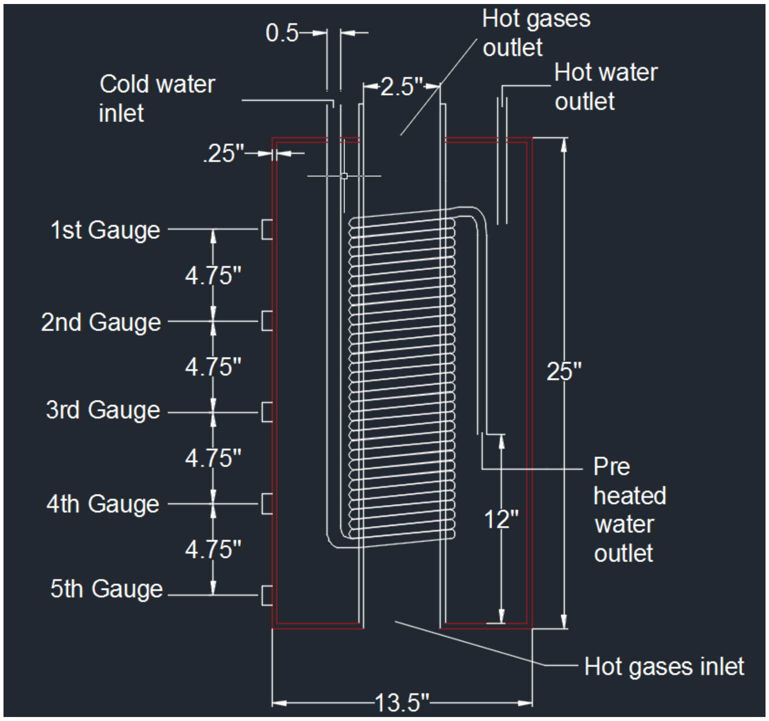

Figure 8 schematic diagram of the modified geyser model

3.2 Theoretical/software calculations

3.2.1 Inner flow

We can find the Nusselt number of the flow in our heat exchanger by [23]

$$Nu_i = \frac{\left(f/_8\right)(R_{ei} - 1000)Pr_i}{1 + 12.7\left(f/_8\right)^{1/2}(P_r^{\,2/3} - 1)}$$

Where *fi is* the frictional constant of the inner surface of the inner tube calculated from the following formula

For 0.5 ≤ Pr ≤ 2000   3000 ≤ Re ≤ 5*10^6

$$fi = (0.79 \ln Re_i - 1.64)^{-2}$$

For 3000 ≤ Re ≤ 5*10^6

3.2.2 Outer flow

We can calculate the Nusselt number for outer flow in our heat exchanger by [23]

If the flow is laminar:

$$Nu_o = \frac{h_o(D_o - D_i)}{k_o}$$

If the flow is turbulent:

$$Nu_o = \frac{\left({}^{f}/_{8}\right)(Re_o - 1000)Pr_i}{1 + 12.7\left({}^{f}/_{8}\right)^{1/2}\left({Pr_o}^{2/3} - 1\right)}$$

For 0.7≤Pr≤16700   Re≥10000

Where *Pr* is the Prandtl number of the outer fluid,

Reynolds number for outer flow can be calculated as

$$\text{Re} = \frac{4m}{\pi(D_o - D_i)u_o}$$

Where *fo is* the frictional constant of the inner surface of the inner tube calculated from the following formula

$$fo = (0.79 \ln Re_o - 1.64)^{-2}$$

For 3000≤Re≤5*10^6

$\boldsymbol{\nabla T_{ln}}$ is the logarithmic mean temperature difference (LMTD) calculated by [23]

$$\boldsymbol{\nabla T_{ln} = \frac{(T_{a,out} - T_{w,in}) - (T_{a,in} - T_{w,out})}{ln\frac{(T_{a,out} - T_{w,in})}{(T_{a,in} - T_{w,out})}}}$$

Overall heat transfer constant can be found as, estimating for both water and air

$$U = \frac{1}{\frac{1}{h_w} + \frac{1}{h_a}}$$

$\boldsymbol{T_{w,in}}$and $\boldsymbol{T_{a,in}}$ are the water and air inlet temperatures.

$\boldsymbol{T_{w,out}}$and $\boldsymbol{T_{a,out}}$ are the water and air outlet temperatures.

U is the overall heat transfer coefficient between the two fluid streams.

A is the area of heat transfer between the two fluids.

$\boldsymbol{\nabla T_{ln}}$ is the Logarithmic mean temperature difference between the two fluids.

The equation used to theoretically calculate the outlet temperature of the water after getting heated by the heat exchanger is given by the following equation:

$$T_e = T_s - (T_s - T_i)e^{-hA/mC_p}$$

Where T_e is the exit temperature of water from heat exchanger.

T_s is the surface temperature of the inner pipe.

T_i is the inlet water temperature of the heat exchanger.

m is the mass flow rate of the water.

ASSUMPTIONS:

1- The copper helix is so tightly packed that it can be considered as a vertical cylinder
2- Average wall temperature is used to calculate the final temperature

3.3 Experiments conducted

Cold water enters the heat exchanger i.e. copper tubes which are being heated by the continuous flow of flue gases out of the central pipe. The central pipe is made of steel and first it gets heated up and then heats the copper tube wrapped around it. This heated water is then dropped inside the water cylinder body of the gas geyser having diameter 13 inch. This water is then heated by the heat from the burner to a specified temperature. The temperature gauges are used to read the varying temperatures as the water further gets heated up and graphs are plotted for temperature vs time.

Experiment 1:

Thermostat is set at the hot setting to calculate the time required to reach maximum temperature by both simplified and modified geyser has been observed.

Experiment 2:

The temperature drop is noted for continuous withdrawal of water for 15 minutes for both simplified and modified models.

Experiment 3:

Temperatures from different gauges were noted to reach the maximum value for modified model.

Experiment 4:

Thermostat was set at warm setting and time was recorded to reach the maximum value.

Temperature gauges:

Five temperature gauges were installed along the length of the geyser at a distance of 4.75 inch from one another. Another gauge is installed at the outlet of the heat exchanger which shows the temperature of the water coming out of the heat exchanger after getting pre-heated.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1 Calculations

The theoretical results were obtained for the water flowing in the outer pipe at a mass flowrate of 0.14 Kg/s which has been worked out by observing the time required for filling a 500ml bottle. Five reading were taken and the average value has been used

Outer pipe calculations:

Ti=20˚C

Re=4137

f=0.039

Nu=13.45

h=184.85 W/m^2-k

A=0.1266 m^2

Te=36˚C

Simulation of transient heat analysis in Ansys at the outlet of the heat exchanger showed the temperature contours as well as outlet temperature at the heat exchanger.

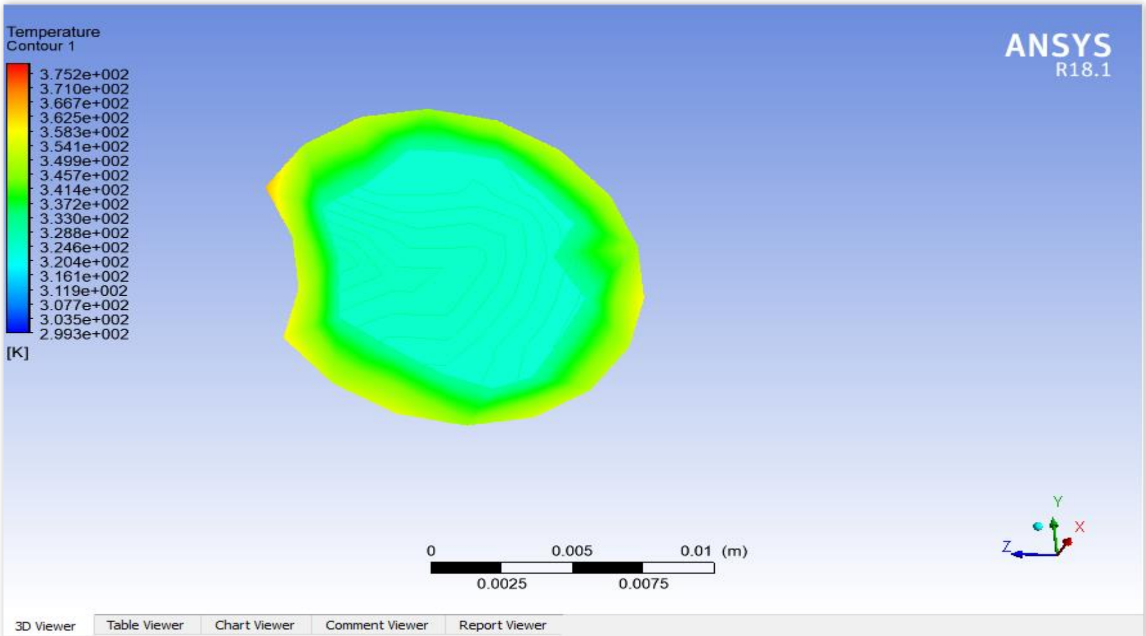

Figure 9 Contour of heat exchanger outlet

The Temperature obtained is about 320 K, which means that the rise of the water temperature is about 20 degrees while there is a difference of temperature that was calculated theoretically and that is due to fact that the whole helical coil was considered to be cylinder as the rings of copper tubes are tightly packed and the temperature used for the calculation was used at an average temperature.

The experiments were conducted with copper tube having 0.5 inch diameter, hence for a better understanding of the phenomenon analysis using the tube with 0.375inch and 0.75 inch has been done.

The following result was obtained when the diameter of the Copper tube was 0.375 inch.

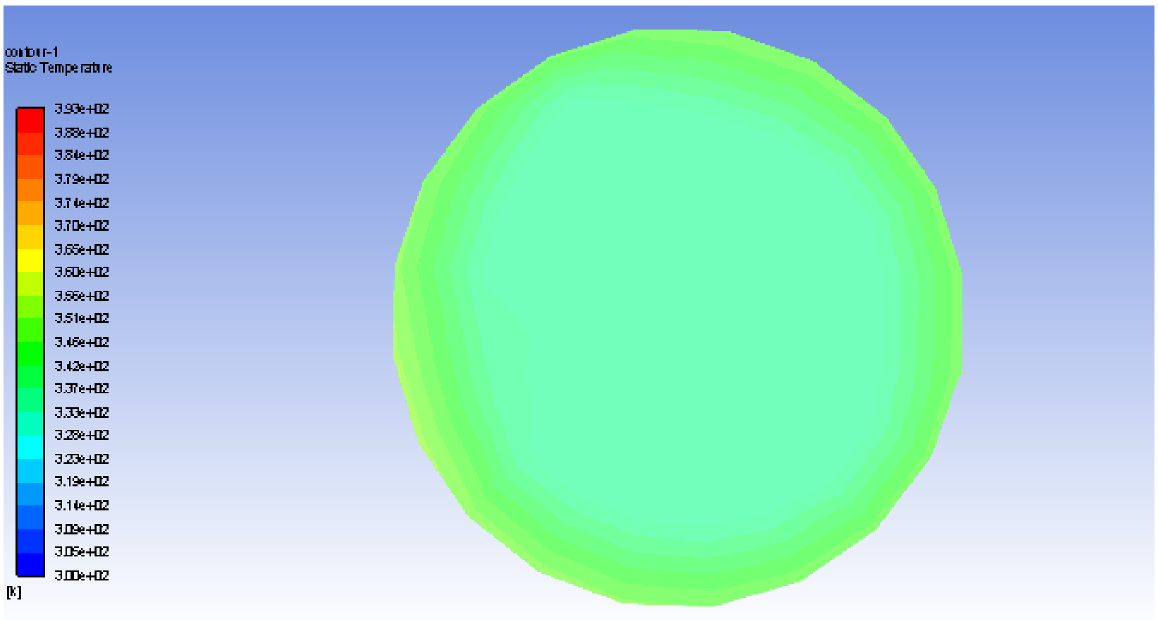

Figure 10 Temperature Contour of heat exchanger outlet

This analysis is performed for a diameter of 0.375inch which is smaller than our coil diameter (0.5 inch). The temperature at the outlet of this coil is slightly higher than the one that we calculated for our heat exchanger coil of diameter 0.5 in. This is due to the fact that since the mass flow rate of the water remains the same and reducing the area of the coil increases its Reynolds number which ultimately increases the heat transfer coefficient and hence the temperature is greater than the temperature achieved by our heat exchanger (0.5 inch)

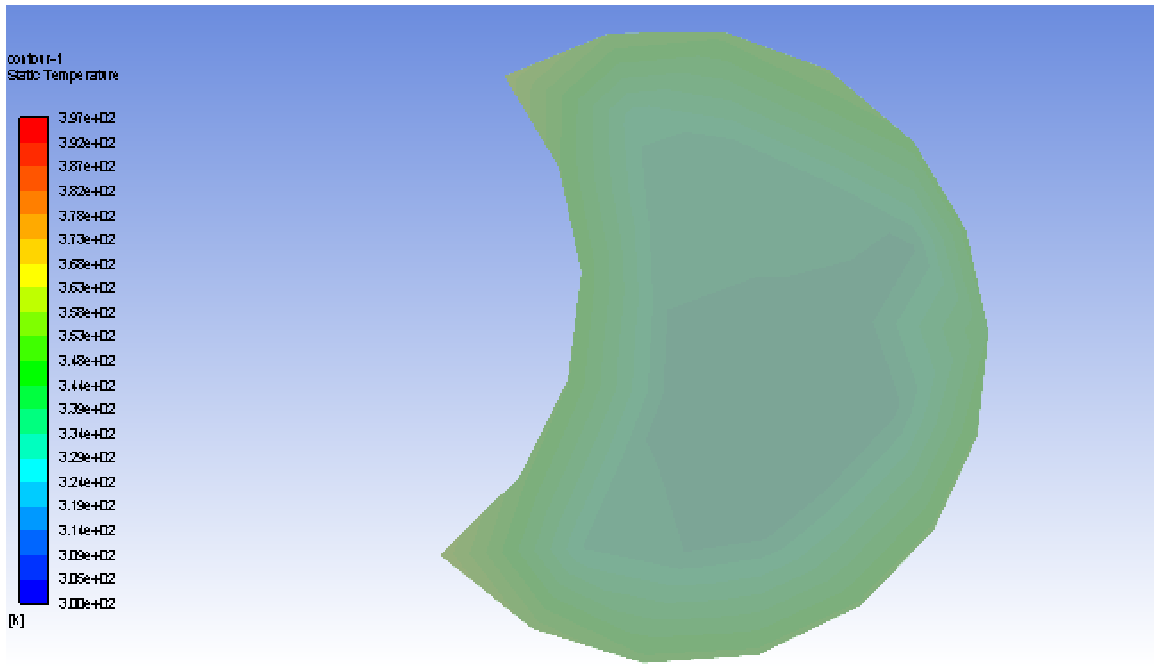

Figure 11 Temperature contour at heat exchanger outlet

This result is obtained when the diameter of the coil is increased from 0.5 inch to 0.75 inch. The results obtained show that the temperature at the outlet of the heat exchanger in this case is lower than the temperature achieved by our heat exchanger which is due to the fact that as the area increases Reynolds number decreases which ultimately reduces the heat transfer coefficient and the temperature reduces.

The temperature rise for both simple and modified geysers with time being taken by it to reach our desired set temperature by means of the thermostat has been obesrved. Domestic geysers are generally set at 50 C. Results are shown below. It is seen that although initially our modified geyser temperature curve was lower than the normal geyser, with the passage of time when flue gases amount increased so it heated the water in heat exchanger get heated and finally it takes less time to heat the same quantity of water. Curve fitting has been done.

Table 2 Time to heat water upto maximum temperatures

Time (mins)	simple model	modified model
0	24	23
1	25.3	26
2	25.6	26
3	28.6	26.7
4	28.9	27
5	30.4	27
6	30.9	27.7
7	32.2	30
8	33.5	30.9
9	34.1	32
10	34.4	32
11	35.2	32
12	36.3	34
13	37.3	34
14	38.2	34.7
15	37.5	36
16	38	37
17	38.5	38
18	38.9	38
19	40.3	38.2
20	40.9	39
21	42.1	40

22	42.5	40.7
23	42.9	42
24	43.7	42
25	43.6	43
26	45	44
27	45.2	45.2
28	46.3	46.7
29	48	48
30	48.5	49.1
31	49.3	50
32	50	50

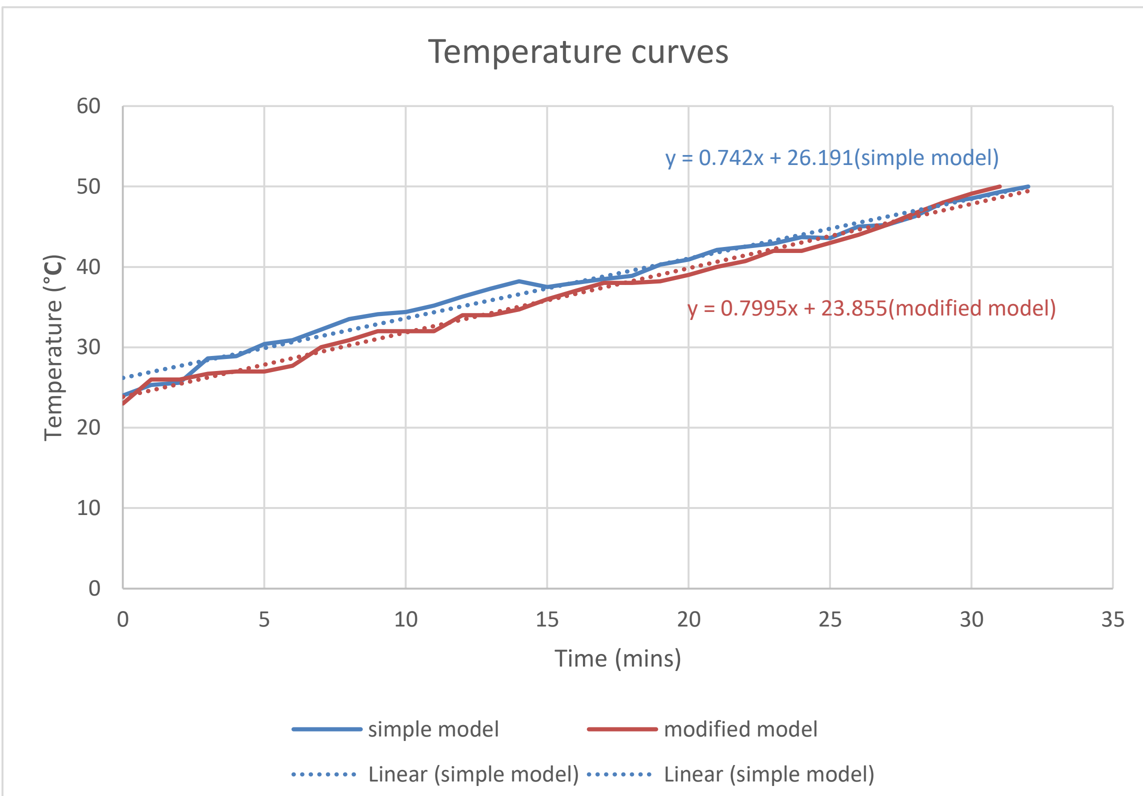

Figure 12 Time to heat water upto maximum temperatures

The discharge temperature at the outlet is measured. The mass flow rate has been worked out to be 0.14 kg/s. For normal geyser we can observe temperature drop.

Table 3 Readings of water discharge of simple geyser at 0.14kg/s

Time (mins)	Temperature(C)
1	49
2	49.5
3	47.8
4	46.3
5	45.4
6	44.2
7	43.6
8	42.3
9	40.5
10	38.9
11	38.6
12	36.8
13	35.6
14	35.8
15	36.4

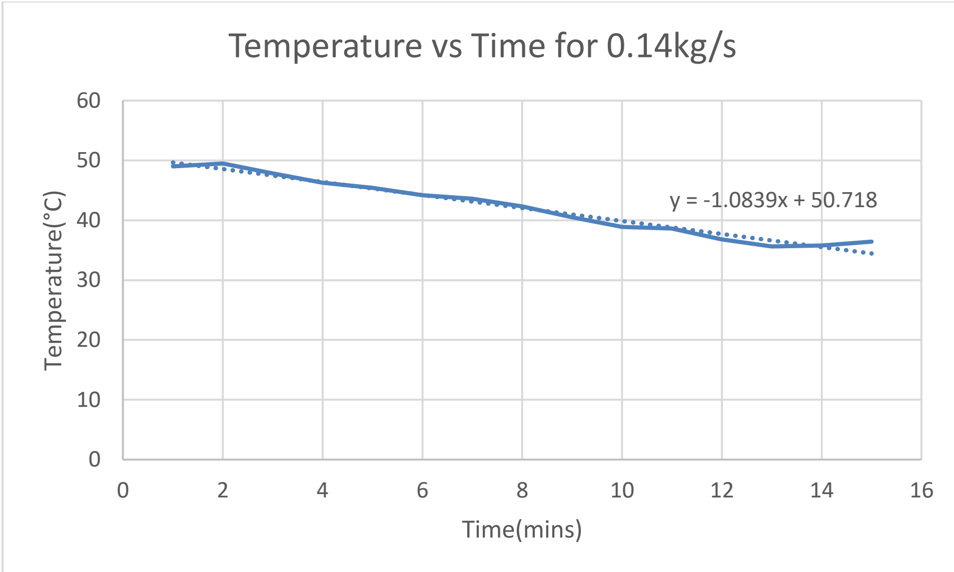

Figure 13 Temperature drop of simple geyser

The temperature drop in the modified geyser doesn't follow the trend of simpe geyser. Due to water in the heat exchanger it warms water even with the discharge taking place. The heat exchanger not only helps heating water more quickly, and saving in fuel consumption but also retains heat within confines of cylinder.

Table 4 Temperature drop from the modified geyser

Time(mins)	Temperature(C)
1	51
2	49.7
3	47
4	45.4
5	43
6	42.7
7	42.4
8	42
9	41.2
10	40

11	39.9
12	39.7
13	39.4
14	39.2
15	39

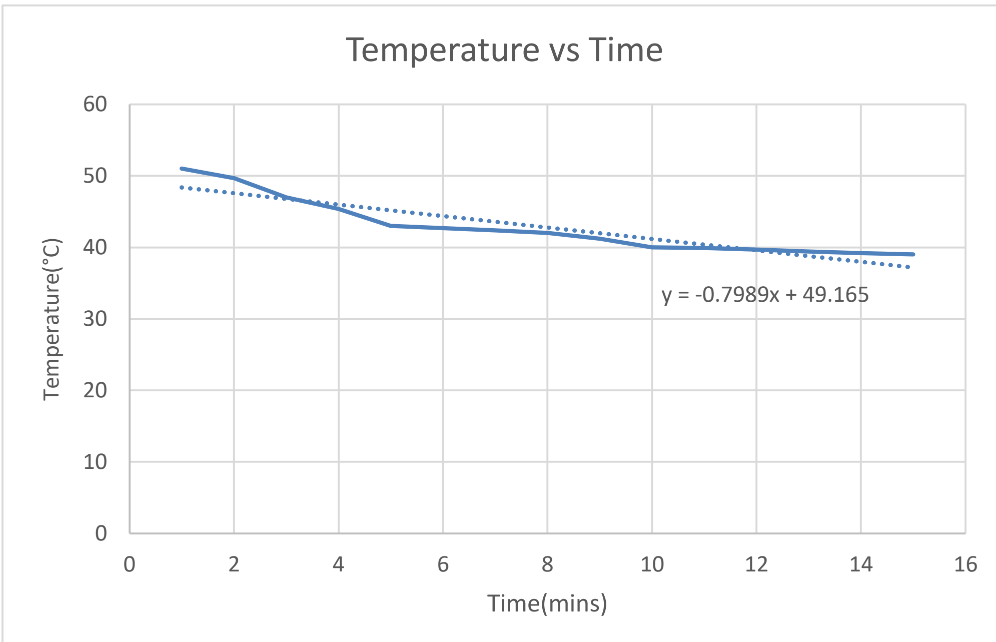

Figure 14 Temperature drop from the modified geyser

The experiment is performed by recording the different temperatures and then plotting them against the time taken to reach the max temperature at hot setting.

Equation used to calculate the theoretical outlet temperature is given below [24]

$$T = T_i + \frac{\dot{Q}}{\dot{m}c_p}\left[1 - e^{\left(\frac{-\dot{m}}{m}t\right)}\right]$$

T is the outlet temperature of water.

T_i is the initial temperature of water

$\dot{Q}$ is the heat input

$\dot{m}$ is the mass flow rate of water

c_p is the specific heat capacity of water

m is the mass contained in the cylinder

t is the time taken to heat the water to a specific temperature

Assumptions

1- No heat is dissipated from the water cylinder

2- No work is done by or on the control volume

3- Specific heat capacity of water remains the same

Table 5 Comparison of theoretical results with readings from temperature guages for the modified geyser

Time(sec)	Guage 1	Guage 2	Theoretical
0	32	31	31.5
30	32.5	31.5	33.34
60	32.7	31.7	35.06
90	33	32	36.65
120	34	32	38.13
150	34	32	39.51
180	34	32	40.79
210	34	32	41.97
240	34.7	32.5	43.07
270	35	33	44.10
300	35.5	33.5	45.05

330	37	35	45.93
360	38	36	46.75
390	38	36.5	47.51
420	38.5	37	48.22
450	38.5	37	48.87
480	39	38	49.48
510	39.5	38.5	50.05
540	40	39	50.57
570	40	39	51.06
600	40	39	51.52
630	40.5	39.5	51.94
660	40.7	39.5	52.33
690	41	39.7	52.69
720	42	40	53.03
750	42	40	53.34
780	42	40	53.63
810	42	40	53.90
840	42.5	40.5	54.15
870	43	41	54.39
900	44	41	54.60
930	44	41	54.81
960	44	42	54.99
990	44	42	55.17
1020	44.5	42.5	55.33
1050	45	42.5	55.48
1080	45	43	55.62
1110	46	43.7	55.74
1140	46	44	55.86
1170	46	44	55.98
1200	46.5	44.5	56.08
1230	46.7	44.7	56.17
1260	47	45	56.26
1290	47.5	45.5	56.35
1320	48	46	56.42
1350	48	46	56.49
1380	48	46	56.56
1410	48.5	46.5	56.62
1440	48.7	46.7	56.68

1470	49	47	56.73
1500	49.7	47.7	56.78
1530	50	48	56.83
1560	50	48	56.87
1590	50	48	56.91
1620	50	48	56.95

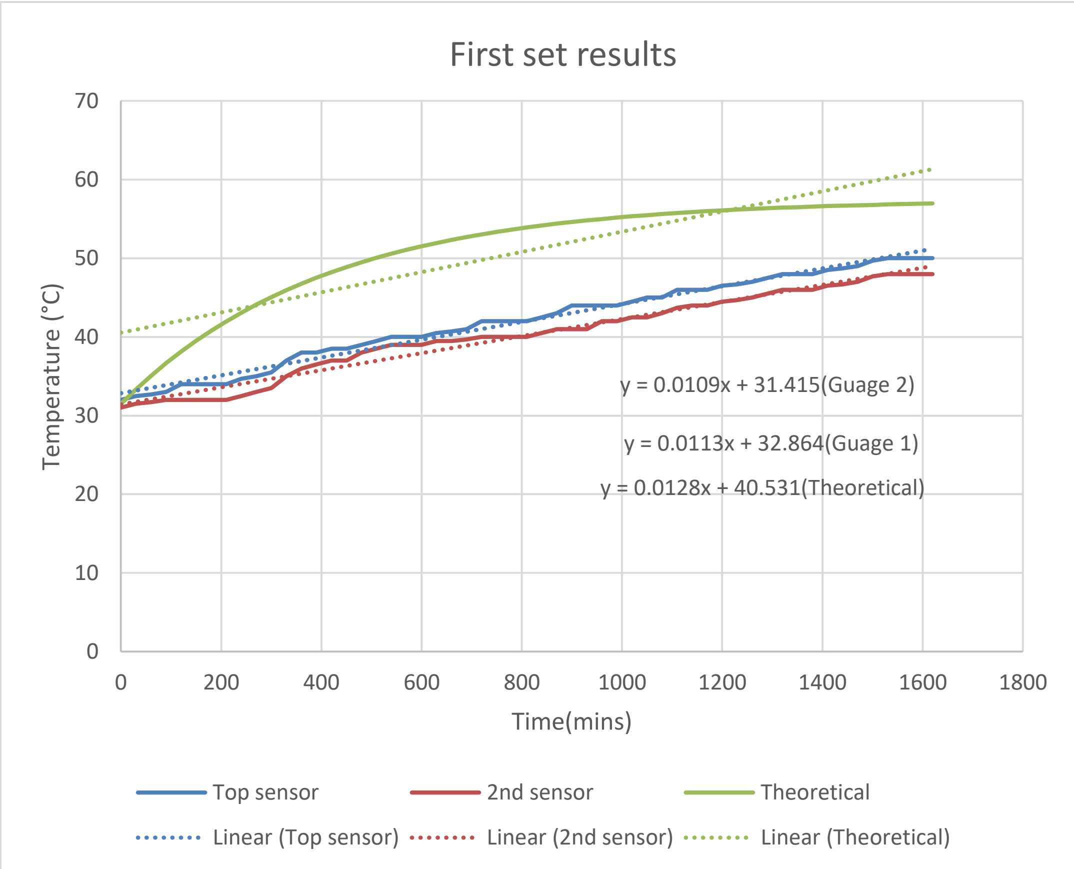

Figure 15 Comparison of theoretical results for the modified geyser to reach 50(C)

The difference between the experimental and the theoretical results is due to the fact that equation used for the theoretical calculations doesn't incorporate any heat losses from the vertical cylinder.

All the temperature readings were taken using the temperature gauges

Second set of readings has been observed using the gauges.

Table 6 Comparison of theoretical results using temperature gauges for the modified geyser

Time (sec)	Temp (°c)	Gauge 1	Gauge 2	Gauge 3
0	26.5	30	23	30
30	28.34	30	24	30
60	30.06	30	26	30
90	31.65	30.2	26	31
120	33.13	31	26	31
150	34.51	31.5	26.2	32
180	35.79	32	26.7	33
210	36.97	32	27	33
240	38.07	32	27	33
270	39.10	32	27	34
300	40.05	32	27	35
330	40.93	32	27	35
360	41.75	32.7	27.7	36
390	42.51	33	28	36
420	43.22	34	30	36
450	43.87	34	30	36
480	44.48	34	30.9	36
510	45.05	34.8	31	36
540	45.57	35	32	36
570	46.06	35.7	32	37
600	46.52	36	32	38
630	46.94	36	32	38
660	47.33	36	32	38
690	47.69	36.7	32.7	38
720	48.03	37	34	39

750	48.34	37	34	39
780	48.63	38	34	39
810	48.90	38	34.7	39
840	49.15	38	34.7	40
870	49.39	38	35	40
900	49.60	38.7	36	40
930	49.81	39	36	40
960	49.99	40	37	41
990	50.17	40	37	41
1020	50.33	40	38	42
1050	50.48	40	38	42
1080	50.62	40.7	38	42
1110	50.74	41	38.2	43
1140	50.86	41	38.2	43
1170	50.98	42	39	43
1200	51.08	42	39	44
1230	51.17	42	39.7	44
1260	51.26	42	40	45
1290	51.35	42.7	40.7	45
1320	51.42	43	40.7	45
1350	51.49	43	41	45
1380	51.56	44	42	45
1410	51.62	44	42	46
1440	51.68	44.5	42	46
1470	51.73	45	42	46
1500	51.78	45	43	47
1530	51.83	46	44	47
1560	51.87	46	44	47
1590	51.91	46	44	47
1620	51.95	46	44	48
1650	51.98	47	45	48
1680	52.01	47	46	48
1710	52.04	48	46	48
1740	52.07	48	46	49
1770	52.09	48	46	49
1800	52.12	48.5	46.5	49
1830	52.14	48.7	46.7	49
1860	52.16	49	47	50

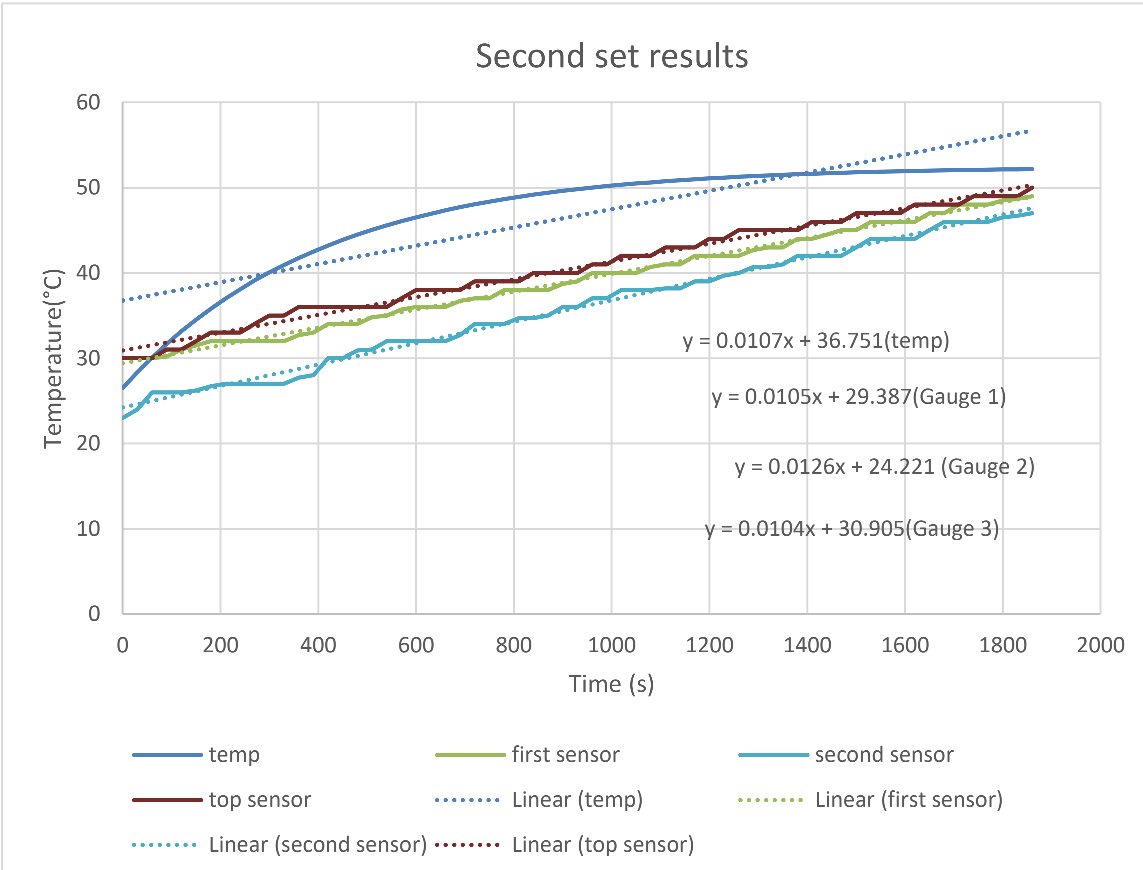

Figure 16 Comparison of theoretical results using temperature gauges for the modified geyser

The rise and fall in the values of the temperature for each gauge is due to the fact that when water gets heated up there is decrease in its density and then this less dense hot water is replaced by the incoming denser cold water and this phenomenon continues until a steady state is achieved and at the end the variations start reducing and the temperature doesn't vary a lot for all the gauges since all the water inside the geyser is in the vicinity of the final temp.

Table 7 Temperature values at warm setting

Time(sec)	Gauge 1	Gauge 2
0	32	31
30	32.5	31.5
60	32.7	31.7
90	33	32
120	34	32
150	34	32
180	34	32
210	34	32
240	34.7	32.5
270	35	33
300	35.5	33.5
330	37	35
360	38	36
390	38	36.5
420	38.5	37
450	38.5	37
480	39	38
510	39.5	38.5
540	40	39
570	40	39
600	40	39
630	40.5	39.5
660	40.7	39.5
690	41	39.7
720	42	40
750	42	40
780	42	40
810	42	40
840	42.5	40.5
870	43	41

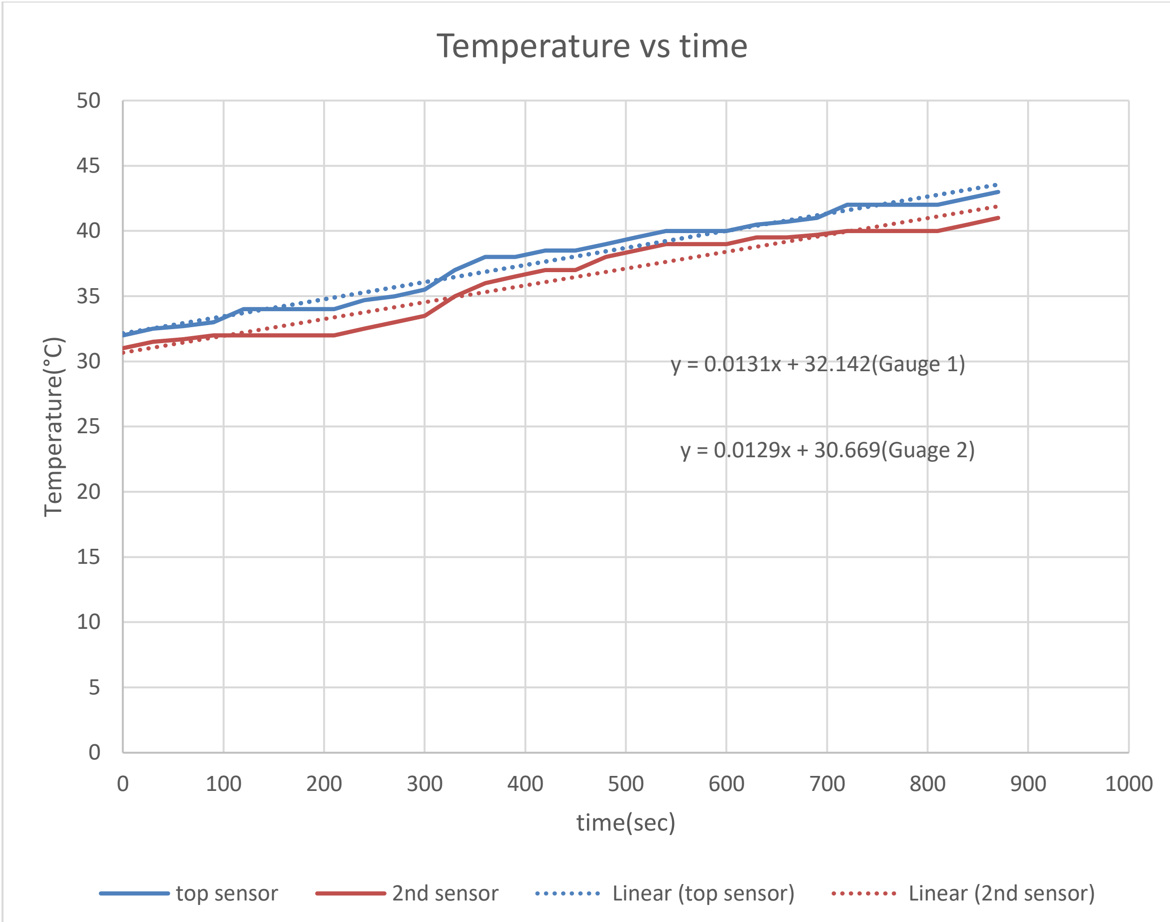

Figure 17 Temperature vs time graph for keeping the thermostat at 43(°C) mode

4.2 Cost analysis

Here is the graph showing gas consumption of a family in Pakistan within a year

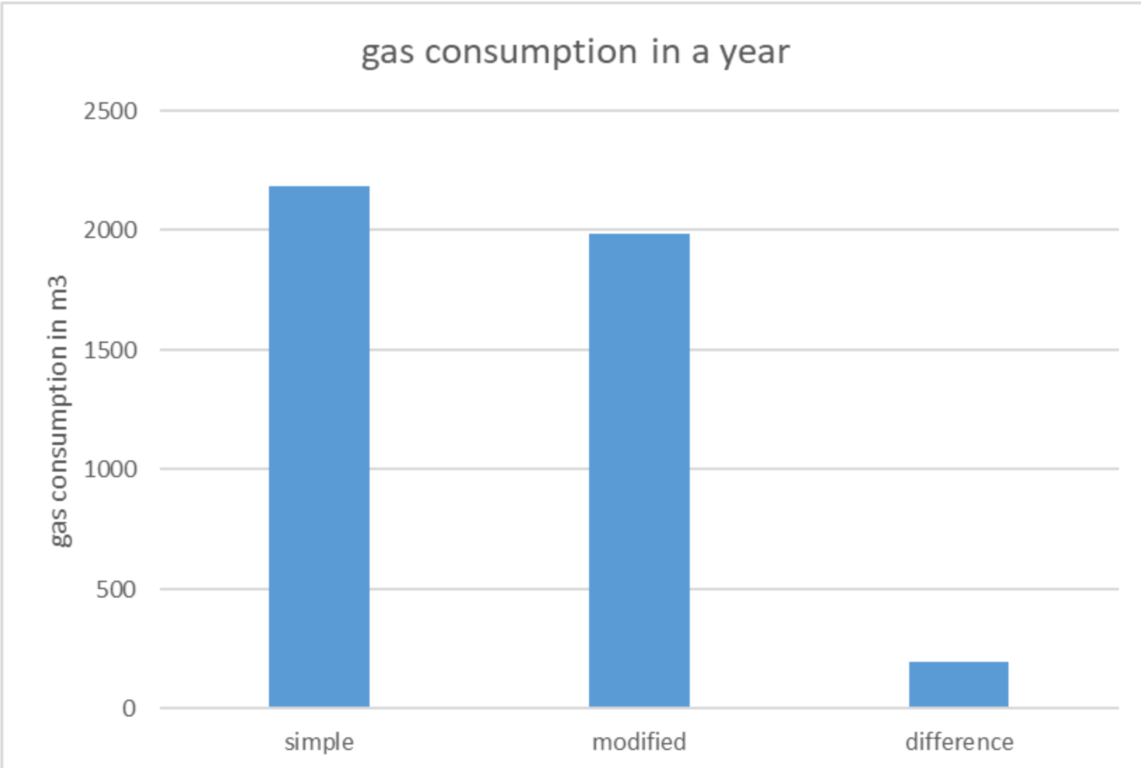

Figure 18 gas consumption of a family of 4 across the year

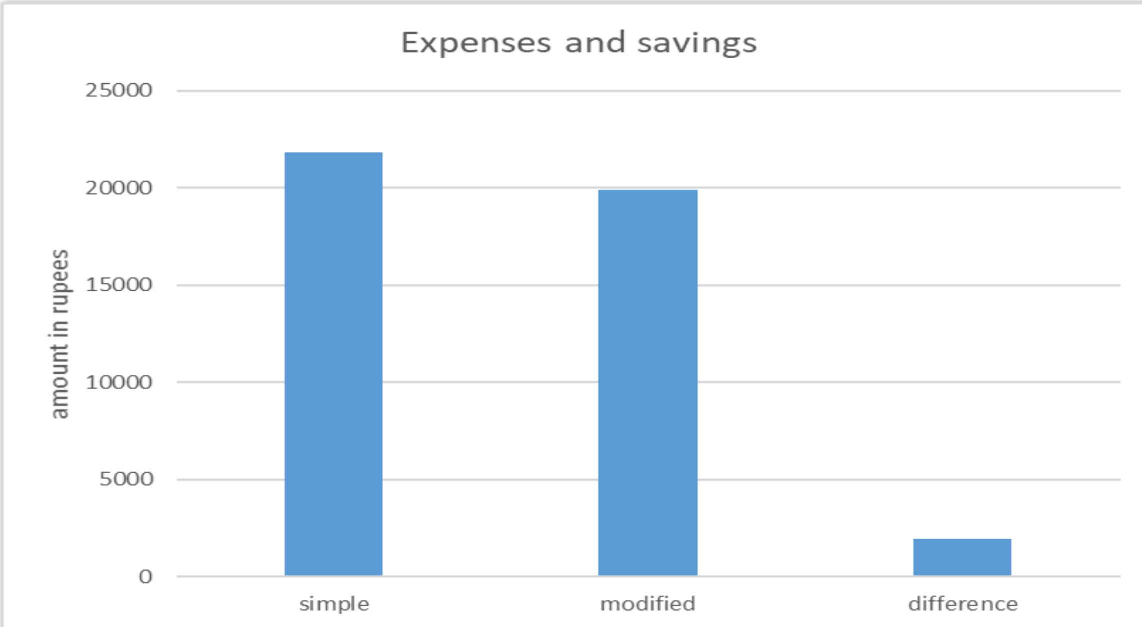

Figure 19 Comparison of saving of simple and modified geysers

For Simple Model

Gas consumed for one month = 185.83 m^3.

Gas consumed for whole year = 185.83 * 12 m^3

= 2230 m^3

Cost of gas consumed per year:

1 Hm^3 = 1000 rupees

2230 m^3 = 22300 rupees

For Modified Model

Gas consumed for one month = 169.43 m^3.

Gas consumed for whole year = 169.43 * 12 m^3

= 2033.2 m^3

Cost of gas consumed per year:

1 Hm^3 = 1000 rupees

2033.2 m^3 = 20332 rupees

Difference between the gas bill for a year = 1968 rupees

Price of simple geyser = 15000 rupees

Price of modified geyser = 18000 rupees

Payback period for difference in price = 1.52 years

The current value of gas is 10 Rs per cubic meter. If the price per cubic meter starts increasing the savings increases linearly

If the price of the gas increases the savings per year is given as

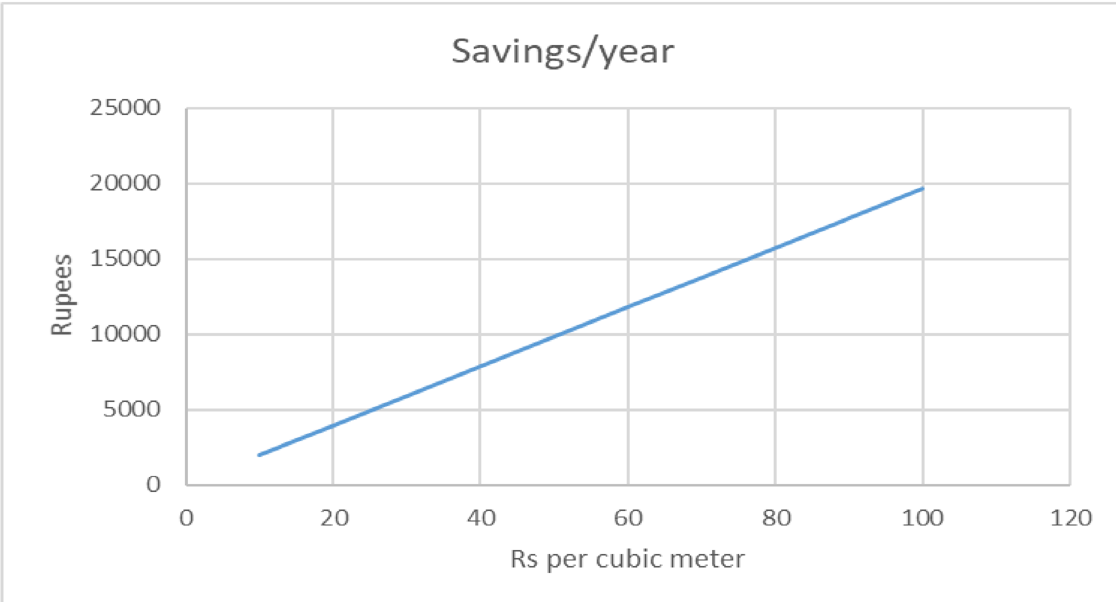

Figure 20 Price of gas vs saving

The payback period reduces as the savings increases

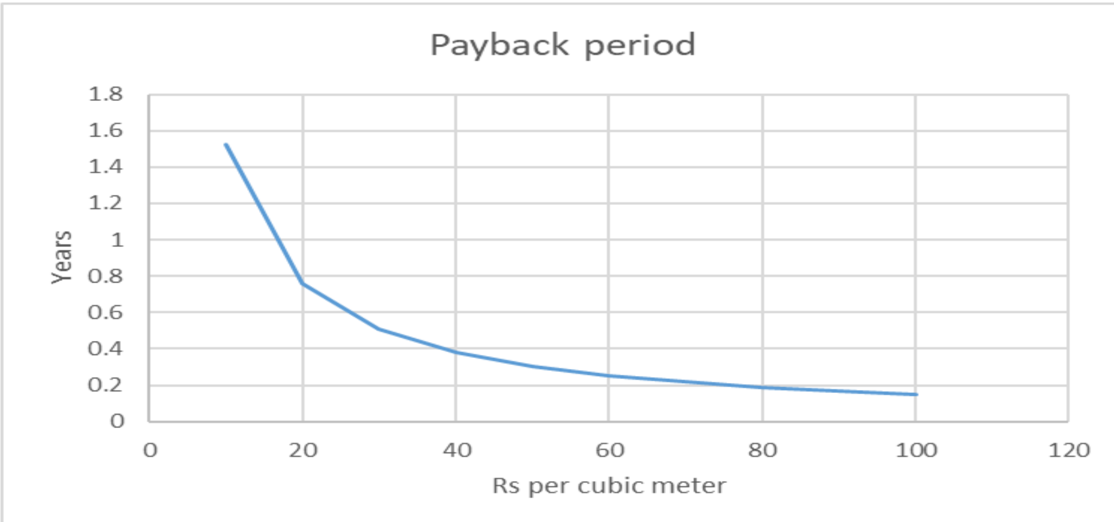

Figure 21 Payback period

Gas Consumption for the country

The number of households in Pakistan are 32.21 million bringing the average size of household to 6.45 people. If 50% of these household use our modified model instead of the simple models available in the market, the amount of gas that can be saved per year comes out to be **3160.608 million cubic meter**

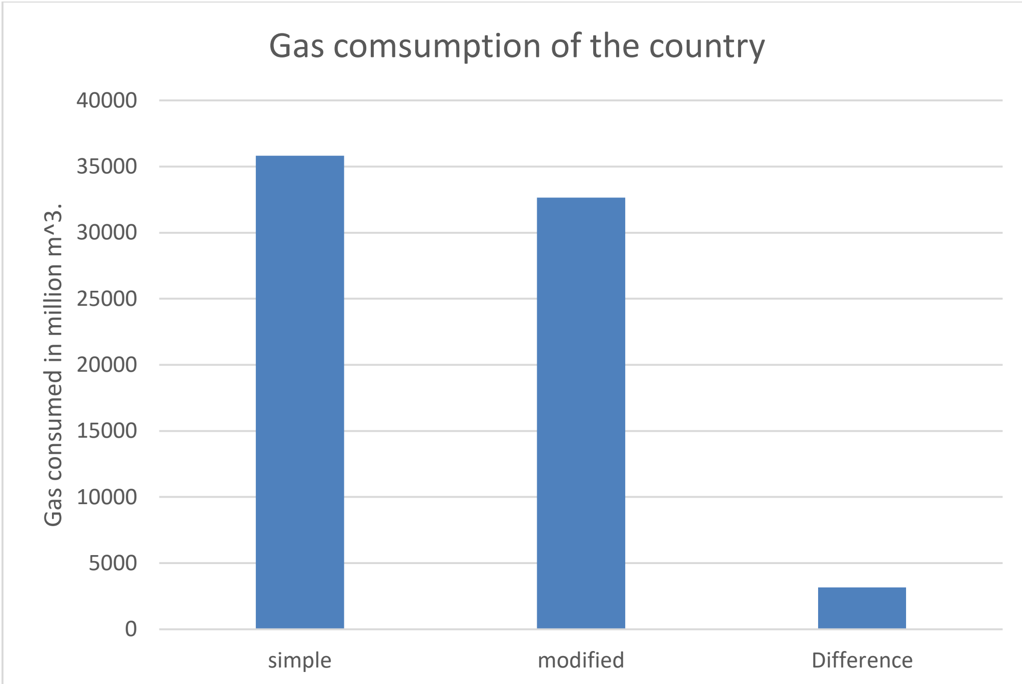

Figure 22 Comparison of gas consumption for Pakistan between simple and modified geyser

4.3 Efficiency

The efficiency of the geyser [24] can be found as

$$\boldsymbol{\epsilon = \frac{mC_p\Delta T}{Vth}}$$

m is the mass of water in the cylinder equal to 50 kg.

$C_p$is the specific heat capacity in J/kg.K equal to 4184 J/Kg.K

V is the volume flowrate of the gas equal to 1.3 cubic meter per hour.

h is the enthalpy of combustion of fuel.

t is the time taken.

ΔT is the rise in temperature 30C.

Efficiency of simple geyser = 19.3%

Efficiency of improved geyser = 21.5%

2.2% increase in efficiency of geyser.

4.4 Conclusions

1. It has been observed that placement of submersible helical coil results in saving of gas
2. There is and improvement of 2.2% due to the use of heat exchanger
3. On an average for small household saving is Rs 2000 per annum at present gas price
4. Payback period is calculated to be 1.52 years

REFERENCES

[1] "Wikipedia," [Online]. Available: https://en.wikipedia.org/wiki/Storage_water_heater.

[2] "Wikipedia," [Online]. Available: https://encyclopedia2.thefreedictionary.com/instantaneous-type+water+heater.

[3] E. R. W. F. A. S. John H. Eiseman, "A method for determining the most favorable design of gas burner," in *Bureau of Standards Journal of Research*, pp. 673-679.

[4] V. B. F. M. B. S. Walter M. Berry, "Design of atmospheric gas burners," in *Technologic papers bureau of standards*, 1921.

[5] C. B. CA Duff, "Design of domestic water heating system to save water and electricity," 2013.

[6] "Go green heat solution," [Online]. Available: http://www.gogreenheatsolutions.co.za/sites/default/files/flat20plate20collector1.png.

[7] "Alternate energy tutorials," [Online]. Available: http://www.alternative-energy-tutorials.com/images/stories/heating/alt36.gif.

[8] O. KS, "Thermal performance of solar air heaters: mathematical model and," *Energy,* 1995.

[9] A. R. Garg HP, "Performance evaluation of a single solar air heater with n-subcollectors.," *Energy,* pp. 403-14, 1999.

[10] T. R., "Thermal behavior of solar air heater with compound parabolic concentrator," *Energy conversion and managment,* pp. 529-40, 2008.

[11] S. S. M. A. M. Majid Azimi, "Simulation and Optimization of Vacuum Tube Solar Collector Water Heating System in Iran," *Journal of Science and Engineering,* vol. 07, no. 01, 2015.

[12] D. A. Bainbridge, The Integral Passive Solar Water Heater Book, 1981.

[13] H.-Y. G. Z.-H. L. G.-S. W. ,. F. Z. H.-S. X. Pin-Yang Wang, "High temperature collecting performance of a new all-glass evacuated tube tubular solar air heater with U-shaped tube heat exchanger," *Energy Conversion and Management,* 2013.

[14] "Wikipedia," 2018. [Online]. Available: https://en.wikipedia.org/wiki/Solar_thermal_collector.

[15] D. M. S. Al-Homoud, "Performance characteristics and practical applications of common building thermal insulation materials," *Building and Environment,* 2004.

[16] O. Kaynakli, "A review of the economical and optimum thermal insulation thickness for building applications," *Renewable and Sustainable Energy Reviews,* 2011.

[17] V. P. J. Z. J. H. Azra Korjenic, "Development and performance evaluation of natural thermal-insulation materials composed of renewable resources," *Energy and Buildings*, 2011.

[18] B. P. Jelle, "Traditional, state-of-the-art and future thermal building insulation materials and solutions – Properties, requirements and possibilities," *Energy and Buildings,* 2011.

[19] M. a. E.-A. A.Harris, "Domestic energy savings with geyser blankets," 2017.

[20] A. A. R. K. R. S. R. Prof.N.B.Totala, "Analysis for critical radius of insulation for a cylinder," *Journal of Engineering,* vol. 3, no. 09, 2013.

[21] "Wikipedia," [Online]. Available: https://en.wikipedia.org/wiki/Baffle_(heat_transfer).

[22] P. R. R.N.S.V.Ramakanth, "Design of helical baffle in shell and tube heat exchanger with using copper oxide Nano particle.," *International Journal of Engineering Sciences and Research Technology*, 2015.

[23] M. G. E. R. K. Mohamad Ramadan, "Parametric analysis of air–water heat recovery concept," *Elsevier,* 2015.

[24] D. P. D. ,. L. S. L. Frank P. Incropera, Fundamentals of Heat and Mass Trasnfer, John Wiley & Sons.