School of Science, Information Technology and Engineering

ENCOR 7020 Research Methodology

Progress Report

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To
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Contents

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TITTLE -

Optimization of the thermal performance of flat plate solar water heater via flow rate setting.

1. PROBLEM STATEMENT

The conservation of sun energy into usable forms through conventional and modern processes sometimes requires remodification in material and working fluid being used to produce it. To alter mechanical land chemical properties of material and working fluid there are pretty many processes are being used and developed. Methods like concentrated evacuated tube solar water heating, flat plate solar water heating, Photovoltaic, Active and passive solar water heating.

Solar hot water has come a long way in the last decade, particularly with the introduction of evacuated tube collectors that are rapidly becoming the preferred option. Evacuated tube solar water heating (as the name suggests) consist two glass tubes fused at the top and bottom. The space between the two tubes is evacuated to form a vacuum. A copper pipe (called a heat pipe) running through the centre of the tube meets a common manifold that is then connected to a slow flow circulation pump that pumps water to a storage tank below, thus heating the water during the day. The hot water can be used at night or the next day due to the insulation of the tank.

The evacuation tube systems are superior as they can extract the heat out of the air on a humid day and don't need direct sunlight. Due to the vacuum inside the glass tube, the total efficiency in all areas is higher and there's better performance when the sun is not at an optimum angle – such as when it's early in the morning or in the late afternoon. (Mobin Arab 2013)

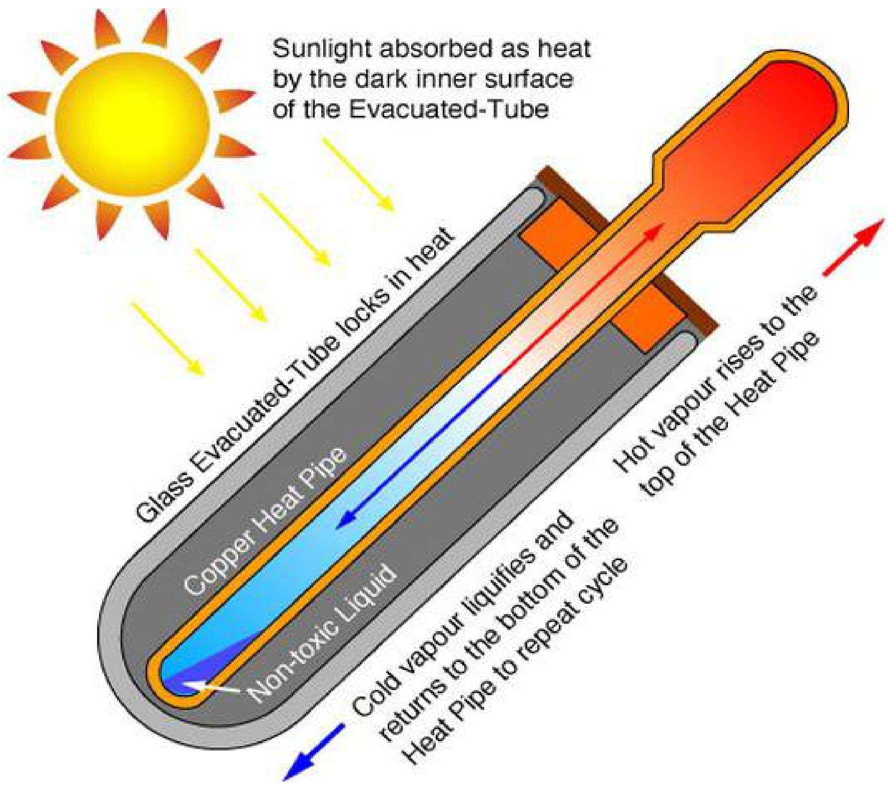
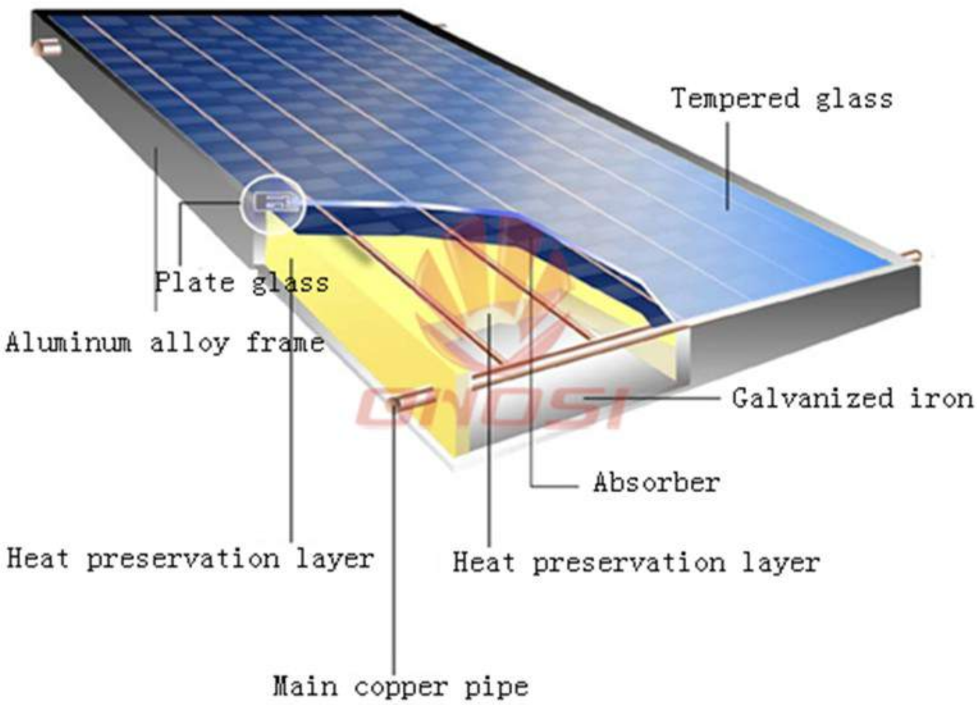


Figure 1/Evacuated tube solar water heating (manufacturar 2015)

Flat plate solar water heating collector are conventional and oldest proven technology for introducing the concept of solar water heating. A flat-plate collector consists of an absorber, a transparent cover, a frame, and insulation. Usually a low iron safety glass is used as a transparent cover as it lets trough a great amount of the radiation from the sun. Simultaneously, only very little of the heat emitted by the absorber escapes the cover (greenhouse effect). In addition, the transparent cover prevents wind from cooling the absorber. Together with the frame, the cover protects the absorber from adverse weather conditions. . (T. Rajaseenivasan a 2014)

Unlike the concentrated collectors, flat plate concentrators collate solar energy in non-concentrated manner (Davabkhaktuni et al., 2013), and are predominantly used for heating and cooling purposes. With the relatively low cost associated with the technology, its use has been on the increase in the recent years. In principle, the technique allows for heating or cooling of fluids within a highly controlled environment (Zhu 2010). As a consequence, their use in electric water heating has lately caught pace, with prospective increase in the next several years.

The functional capacity of these systems is embedded on their ability to absorb, transfer and at times store energy. Whilst the harnessed or stored power can be used in heating the water, copper tubing coated with suitable absorbent material are used in optimizing the absorption (Davabkhaktuni et al., 2013, p.558). When the water is circulated in the tubing, it is heated before being moved to the storage reservoir.



The PVT(Photovoltaic thermal system) as combination photovoltaic and thermal technology. of Regards photovoltaic thermal solar water heating is most utilisation technology for solar water heating. It working inversly affected as temperature rise. The experiments exhibits that 1^0 rise in temperature reduces photovoltaic efficiency accounts for 0.4%. However photovoltaic efficiency lies between 4% to 17% for simple solar cell (M. Boubekri a 2013). In this working fluid can be heated through heat collector which classified as concentrating and non-concentrating. A concentrating heat collector utilised for low temperature application whereas non concentrating for high temperature application. Moreover, low cost solar thermal technology has a poor photo- thermal efficiency.

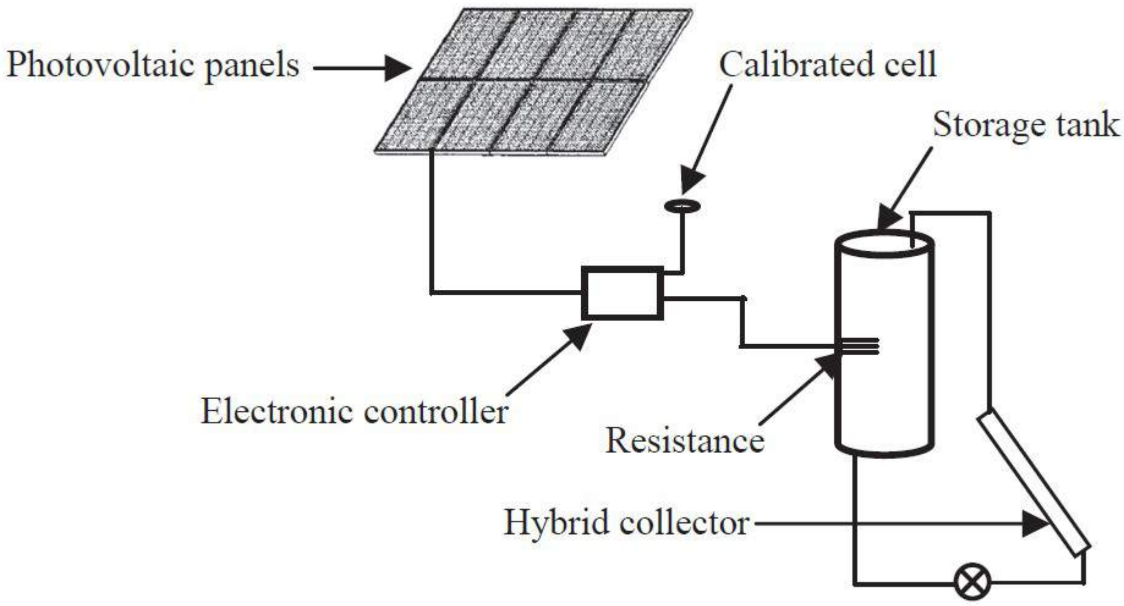


Figure 2/ Photovoltaic thermal solar water heating system

(M. Boubekri a 2013)

From the past years, many researches has been conducted on combination of both photovoltaic and solar thermal, investigation about design and working operation. The modification are made in proposed design to enhance heat abstraction process. The overall performance of combination was improved as compared to other solar systems. The basic principle of PVT System is to utilise the wastage heat from PV modules to heat water by working fluid. Fig4, represents the schematic flow of working fluid attached with PV module.

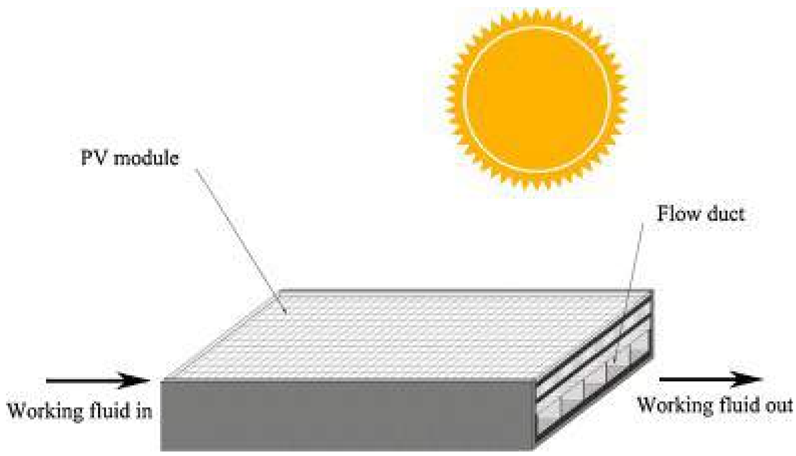


Figure 3/Photovoltaic - solar thermal water heating with PV module (Feng Shan 2013)

A literature review clearly indicates that each process is capable of heating water as per as depending on the needs. The processes used for generating energy have some shortcoming when compared within themselves and every process is not effective as other is on same type of material and working fluid using, taking advantages of this drawback it was decided to undertake the study which should identify what are the effects on solar water heater with varying flow rate. In this study it is decided to optimize thermal performance in term of effect on solar water heater so that a common understanding can be built to know that how change in flow rate of fluid effect the system taking many factor into consideration like effect of orientation, season and different weather conditions. So that more effective results can be obtained in experimental investigations.

2. LITERATURE SURVEY

To improve thermal properties of various working fluids such as water, acetone, methanol, propane, ammonia, ethylene glycol numerous research are developed in last few decades to investigate the effect of different types of solar water heaters (P.V. Durga Prasad a 2015). All of above said working fluids have advantages and disadvantages and in this study thermal performance of flat plat solar water have been studied. A working fluid "water" has been taken into consideration for testing.

Passive solar water heating system is selected to investigate the properties of different fluids as elimination of forced pump. In proposed system water tank is installed above the solar heat collector and fluid flow by natural convection. (HC 2013)

Optical and thermal performances improvement of an ICS solar water heater systems

This paper is generated as new design of integrated collector storage (ICS) solar water heater with a compound parabolic concentrator (CPC) so as to enhance the quantity and improvement in optical and thermal performance of system. This system was generated to simulate the reflection of the direct solar radiation on the CPC reflector at various angles of incidence to find out absorbed solar radiation distribution on the absorber surface. The results are compared with the old experiment to check the improvement of temperature level and in angle of incident. A ray tracing technique is used to investigate the optical performance. In this technique, combination of ICS and CPC, direct solar radiation only compared in CPC. The energy formed can be calculated by distributing direct solar rays around the absorber at different angle of incidence. A two dimensional ray tracing technique has wide applicable in calculate the energy distribution at the observer surface and line axis asymmetric compound parabolic concentrator, also find out optical efficiency as function of angle of incident for selected compound parabolic concentrator. Several assumption are made in this research which are as follows

1. Angle of incident is equal to angle of reflection.
2. All rays of interest are specular.
3. The incident direct solar flux at the aperture is considered to be a number of parallel rays, carrying equal amounts of energy.
4. Vector forms of refraction and reflection laws are applicable to ray trace in the solar system.
5. A ray entering, strikes the absorber with no previous reflections.

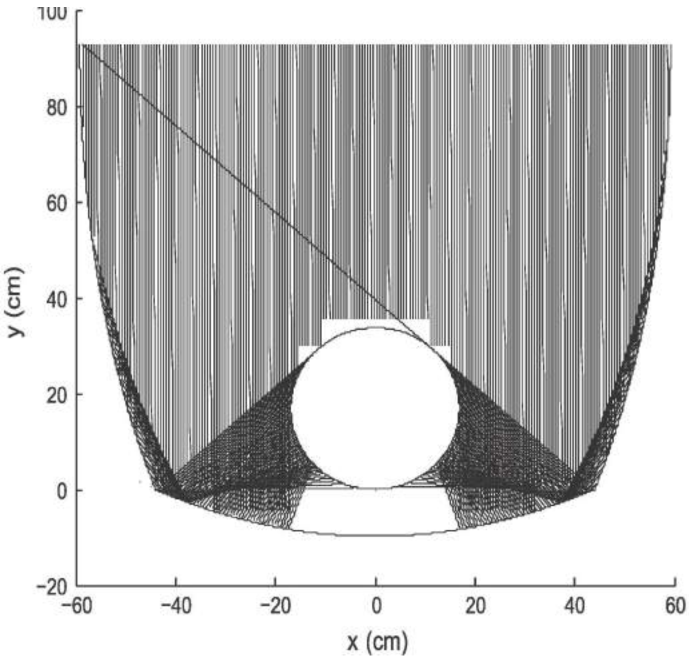


Figure 4/ Ray trace diagram for old system at angle of incidence 0 degree (Raouf Benrejeb Feb, 2015)

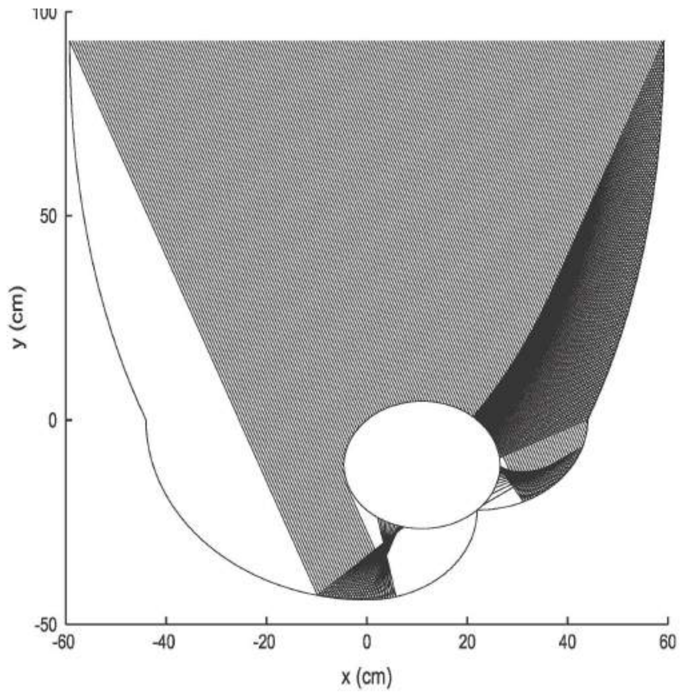


Figure 5/ Ray trace diagram for new system at an angle of incidence 20 degree (Raouf Benrejeb Feb, 2015)

The results are evaluated, making comparison with old system at different angle of incidents i.e. $0^{0,}$ 20^{0}. Increase in angle of incidence results in reduction of absorbed flux energy. In new design system, all rays are reflected towards absorbed through some reflections while in old system it went outside. For negative (-) angle, new system acts as an asymmetrical reflector. At -20 degree, all rays are concentrated only at left portion, no rays are on right portion and on upper there are only direct rays. Coming to – 40 degree, absorber receive only at lower end of left side. (Raouf Benrejeb Feb, 2015)

Model-based design and analysis of heat pipe working fluid for optical performance in a concentric evacuated tube solar water heater

This paper is talks about to develop a fully integrated model for a grooved type evacuated tube solar water heater and validated against experimental data. It depends upon the working of different fluids; here three working fluids are used to detect the effect of working fluid change in a real evacuated tube solar water heater. It was resulted that significantly that higher performance of solar water heater is achievable by improving the working fluid properties and economic performance that accounts for 84% and 50% respectively.

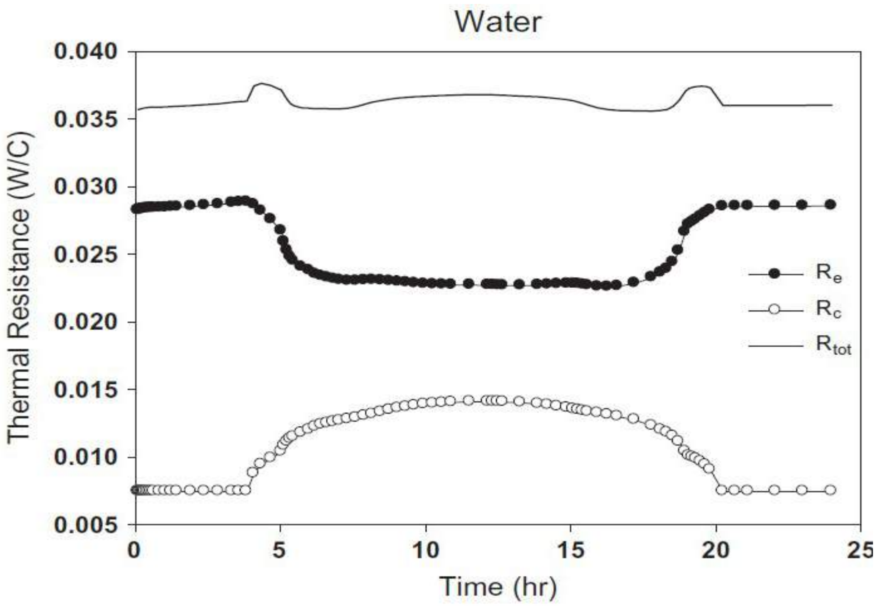


Figure 6/Variation in Thermal resistance w.r.t Time (Mobin Arab 2013)

The two main components that affect the result are thermal resistance and heat transfer capacity. In this study, total 20 pipes are taken into account in the solar water heater and water flow rate is changed with variation in time. The result is generated, effect on thermal performance with changing the fluid in solar water heater during day time. In water filled heat pipe, the thermal resistance of evacuated section declines as solar isolation resulted in hike of saturation temperature. More significantly, thermal resistance remains unchanged during the day. This reveals that rise in condenser thermal resistance results in drop of evaporator thermal resistance.

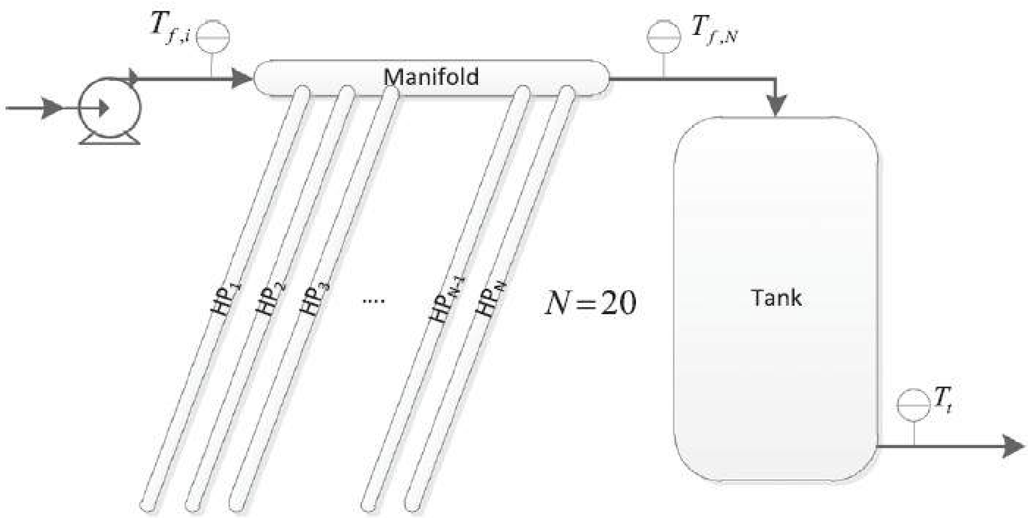


Figure 7/ Modelled System (Mobin Arab 2013)

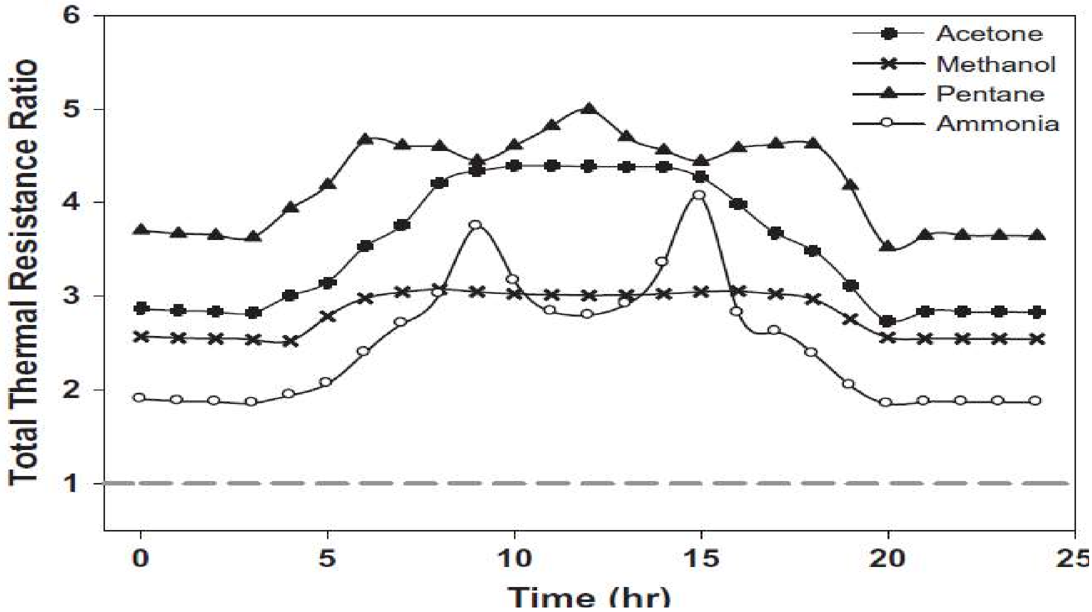


Figure 8/ comparison of different fluids on basis of thermal resistance w.r.t time (Mobin Arab 2013)

The above line chart exhibits the relation between total thermal resistance ratio and time. It describes the performance of four different fluids i.e. acetone, methanol, pentane and ammonia and comparison study with the water as fluid. The bottom straight line represents the thermal performance of water. Regards ammonia, showing vicissitudes from 9h to 15h, has best among others as thermal performance. Menthol showed stability where pentane acts as worst working fluid. The performance of all working fluids is investigated at same condition. It is crystal clear from chart that thermal performance of all four working fluids is higher than that of water. (Mobin Arab 2013)

Utilization of solar water heater in a single basin solar still -

The result of this study depends on the working of single basin solar still with flat plate collector (FPC) in natural circulation mode and in forced circulation. The objective of project is to rise the temperature of water in a basin without any extra cost. However, working of single basin solar still, escalate the productivity of system in both modes i.e. natural and in forced convection, accounting for 30% to 52% and

50% respectively with collaborated with flat plate collector. Moreover its performance varied with coupling with different equipment.

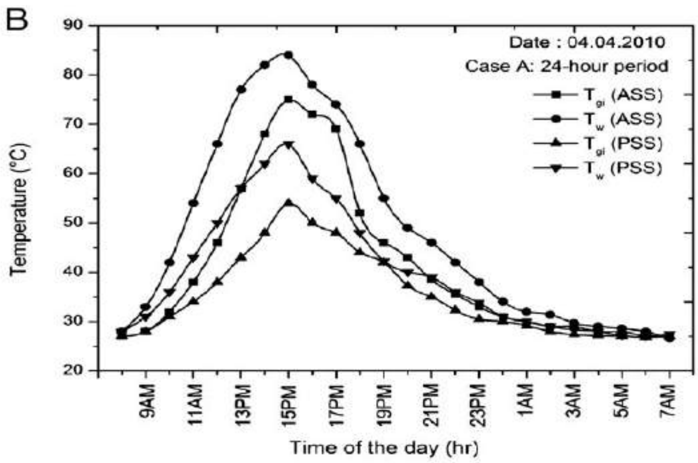


Figure 9/ Change in temperature with different intervals of time through a day (K. Sampathkumar 2012)

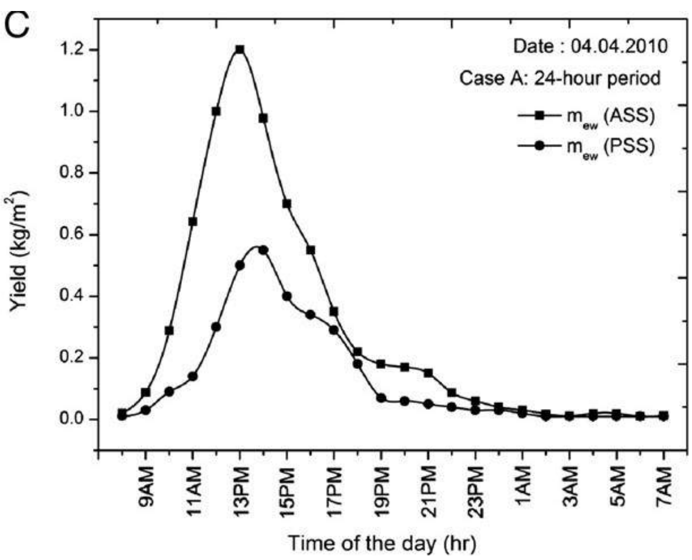


Figure 10/ variation in yield strength with day timing (K. Sampathkumar 2012)

The above results had been as we can see from the line chart, which demonstrates that inner glass temperature and water temperature, effects most the yield calculation because there are only variation in water generated, temperature, and inner glass temperature and yield strength. Yield strength showed its peak at mid-day between 11 am to 4 pm. It can be concluded that it increased as temperature rise. In fig 3(1), the variations in both temperatures vis-à-vis whole day time .The temperature rise in both are owing to extra thermal energy supplied by evacuated tube collector in basin. So it can be concluded that average performance is escalated, when single still coupled with evacuated tube collection. (K. Sampathkumar 2012)

Effect of orientation on the performance of a symmetric solar still with a Double effect solar still (comparison study)

The proposed design informed about the effect of orientation on two different slit i.e. symmetric double solar slit and asymmetric solar slit, under different climatic conditions. A computer program has been generated to express the result, which described that both the stills received a maximum solar radiation at optimum inclination angle $10^{0.}$ As seen, south –north orientation increase the performance constituting 16.75% with single still as it is most stable among other direction. Regarding double slop system, east-west orientation and south-north orientation resulted in 16.23% and 22.75% respectively.

Notified above diagrams, at east-west direction, solar radiation touched its acme for both the stills at different angles of inclination at different time. Whereas, solar radiation acceptance is highest for all different angles for both the stills. (Trad Abderachid 2012)

Performance of copper oxide/water Nano fluid in a flat plate solar water Heater under natural and forced circulations

The research based on, thermal performance of copper oxide/water Nano fluid was investigated on a 100 Littre per day (LPD) thermosiphon based indirect-type flat plat solar water heater. Thermosyphon and forced circulation are compared on the basis of different properties. For mass flow rate, forced circulation was witnessed higher frequency vis-a-vis thermosyphon circulation. Overall, thermosyphon was slight an edge over forced.

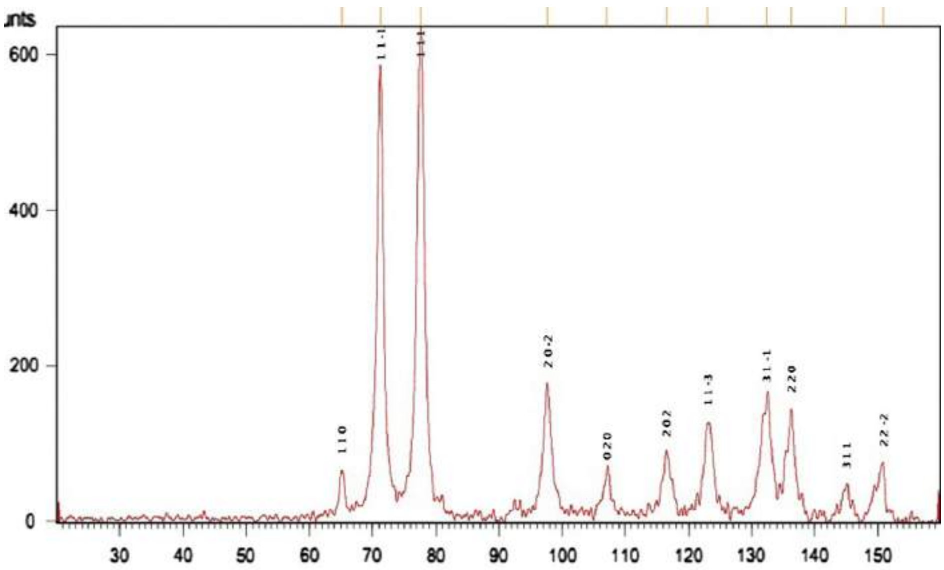


Figure 11/ XRD image of Nanoparticles (Jee Joe Michael 2015)

The performance of copper-oxide nanoparticles are compared with water in thermosiphon and two forced circulation conditions in solar water heater. The result based on comparison study of different techniques or Nano characterization tests, which is not identical for all. X-ray diffract meter (XRD) is used to developed the crystal structure and purity of the CuO particles. (Jee Joe Michael 2015)

Life cycle environmental impact assessment of a solar water heater

The proposed design reveals about the investigation of technical and environment effect with life cycle assessment (LCA) on performance of solar water heater. The main motive of study is to produce electricity for domestic and auxiliary use with lesser emission. The process centralised manufacturing stages, resource consumption and avoid wastage to the environment. The model include the assembly and manufacturing of parts of solar water heater like heat storage tank, solar collector, component box and aperture by concentrating many environment impacts like ozone depletion, acidification, greenhouse effect etc.

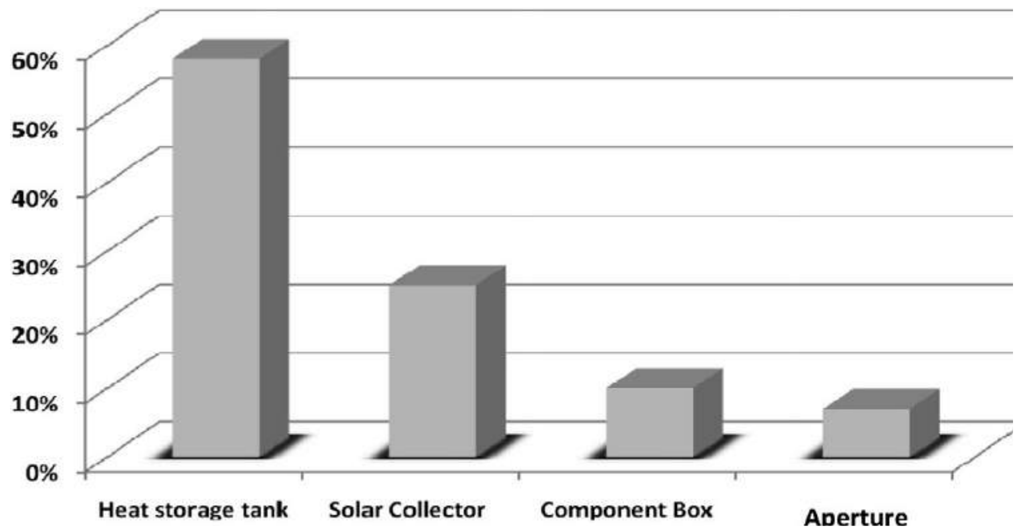


Figure 12/ Participation of the environmental impacts of each part of the understudy SWH

(Christopher J. Koroneos a 2012)

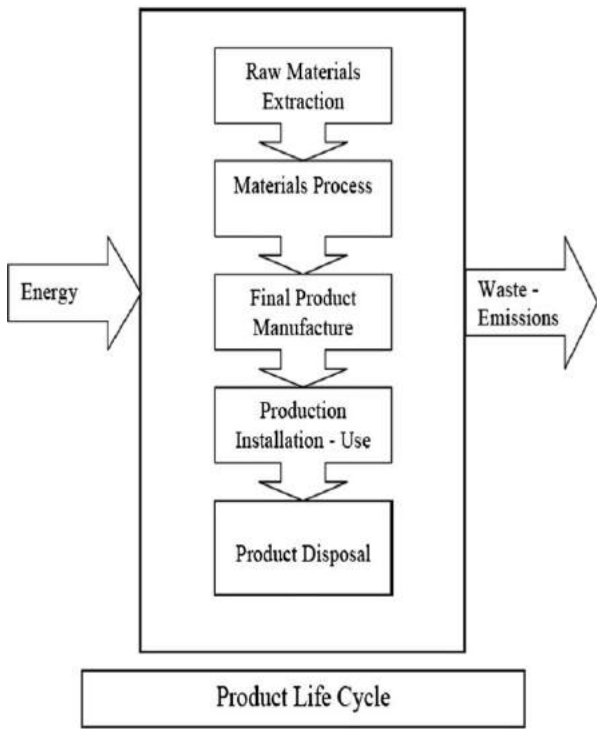
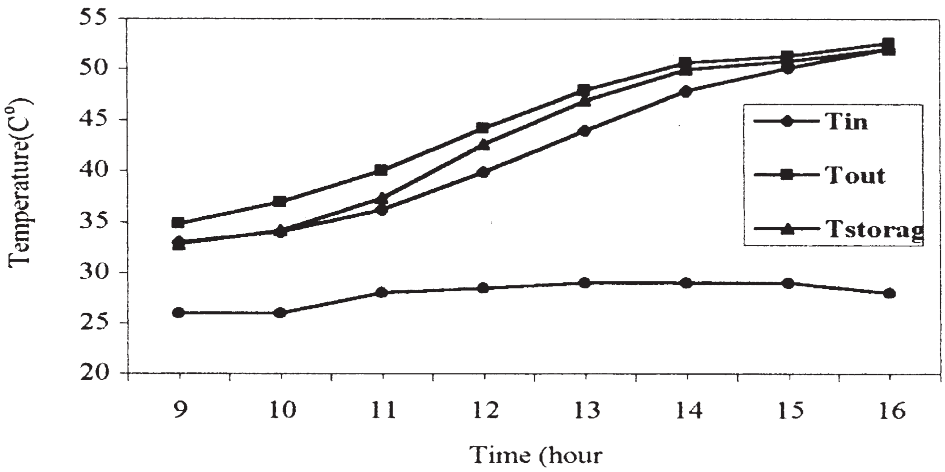


Figure 13/ Life cycle of product (Christopher J. Koroneos a 2012)

Life cycle inventory included waste material extraction from starting to end life of solar water heater. Moreover, environmental effects are considered as the installation of heat storage tank, solar collector, component box and other apparatus in manufacturing SWH *(Christopher J. Koroneos a 2012)*

Experimental study on thermosyphon solar water heater in Bahrain

In the present data, thermal properties thermosyphon water heater unit was examined, using a many sunny, cloudy and hazy days to check applicability in Bahrain in winter season. Result was collected and revealed that model is well suitable for application in Bahrain climate conditions. The results are developed, when storage water temperature is above 50^0 then the efficiency of process is 38%. The isolation rises as it reaches its peak value i.e. 695 W/m at the mid-day after it starts declined. (A.A. Karaghouli a 2001)



(A.A. Karaghouli a 2001)

The above line chart describes the variation in different temperature w.r.t time. In can be concluded that all temperatures (T_{in}, T_{out} and T_{storg}) showed escalation as from morning to afternoon and started decline after 3pm.

The performance of a cylindrical solar water heater

This study gave knowledge about how to calculate the performance of cylindrical solar water heater was experimentally performed, having a different dimensions Results came to for that it is capable of producing heat energy from sun energy but expensive than flat plate collector. It consists of spiral copper tube having inner and outer diameter 0.14 and 6mm respectively. The efficiency of was detected, that value during the change of temperature at inlet and outlet temperature is 41.8% and mass flow rate calculated is 9 kg/h. This study also lay emphasis on the comparison between cylindrical and flat plate collector. (Al-Madani 2006)

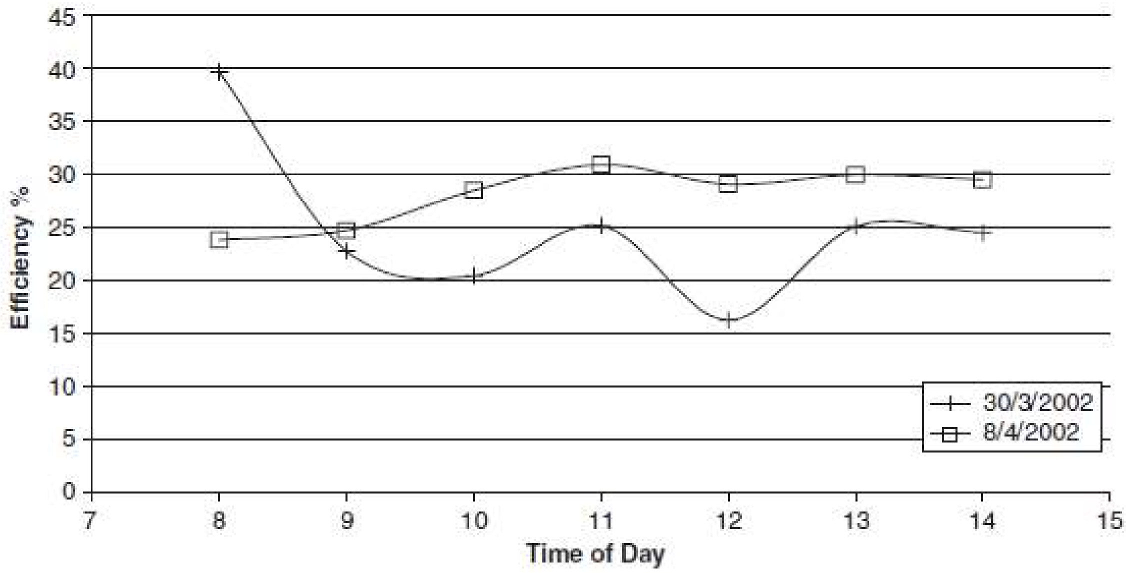


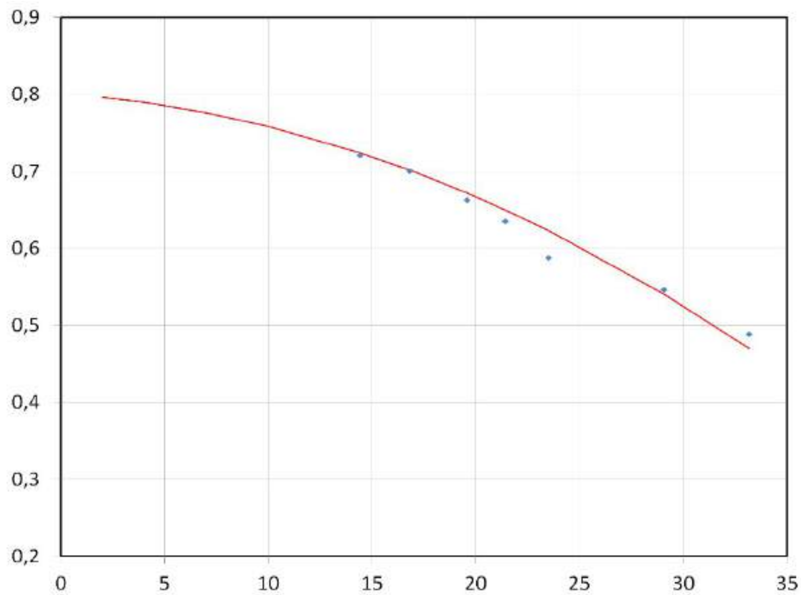
Figure 14/Efficiency versus time of day

In this paper, to check performance of the cylindrical solar water heater different parameters were calculated. As follows,

1. Instantaneous Efficiency
2. Useful energy gained(Q_u)
3. Overall coefficient of heat losses(U)
4. Collector heat removal factor (F_R)
5. Absorbed solar Radiation (S)

Domestic Water heating with flat Plat collector-

The objective of paper is to examine experimentally temperature curves at different measuring point and thermal power of solar collector. This research reveals that output power of collector and input power as artificial are detected at different temperatures and flow rate, which varied with variation in temperature. The maximum efficiency is detected at the steady state condition. To maintain a constant temperature, storage tank is filled with continuously cold water. Owing to hydrostatic pressure head, more effective cooling is achieved which leads to enhancement of efficiency. (G.U.N.T, Domestic water heating with flat plat collector May, 2013)



(G.U.N.T, Domestic water heating with flat plat collector May, 2013)

The above diagram describes the relation between temperature differences And efficiency of process. Though which x-axis indicates temperature and y- axis demonstrates efficiency. As temperature difference is increased, it resulted into drop into efficiency. The pre- selected temperature of difference was higher than necessary one. The temperature difference is higher to fill the gap during lack at collector to the storage tank.

3. SCOPE OF PROPOSED WORK

Although lot of research work has been done to study the effect of the different parameters on solar water heater like working fluid, orientation, weather, season etc. Moreover study has been done to investigate the thermal performance of flat plate solar water heater using gaseous as working fluid in federation university .But to know how flow rate can be effective on flat plate type of solar heating system in comparison to BALLARAT Weather, nothing has been done. In this work main emphasis will be given to thermal investigation of system under flat plate collector. System performance of solar water heaters depend upon collector and storage tank design and sizing and weather conditions (solar radiation intensity and ambient temperature). Nocturnal reverse flow and tank insulation dictate the degree of overnight water temperature drop in the storage tank. A tropical country like Australia has widely fluctuating and intermittent solar radiation. It is neither practical nor feasible to conduct outdoor tests such as that proposed by International Standards. Indoor collector tests are expensive to conduct and would not provide meaningful information to the domestic or commercial end user. Outdoor system tests would be more informative to consumers who would like to compare the water temperatures that could be achieved in order to choose from the wide range of commercial products available. This paper reports the results of outdoor tests conducted on flat plate solar water collector under natural and forced convection.

Although tested at different times, the long and short term test procedures have been employed allowed us to compare the performances of the system as if they will be tested under different climatic conditions

Although there are number of working fluid accessible for solar water heater but in this exploration it was decided to limit only to Water. So that a basic analysis of the work done can be made instead of running into random situation without any concrete solution. To study how this working fluids effects the efficiency of system, thermal conductivity, freezing and boiling point of fluids on performance of passive solar heating will be undertaken to clearly know how effective these processes are under different operating conditions.

To establish the similarity between the different materials, only material with similar kind of thermal properties or which are similar chemical composition will be taken into consideration so that the validity of the obtained result can be maintained.

Solar energy can reduce the national demand.

4. PROPOSED APPROACH

The literature review shows that to know the effect the change in weather condition, variation in day temperature, different orientation i.e. north-south and east-west, under different circulations i.e. forced or natural circulation, technical and environmental was taken into account. Some of these are numerical values so in my practical study the change in these value will be studied in accordance with the different processes so that a result can be obtained.

Following systematic approach will be applied for undertaking this study:-

- Study of different research papers, books or any other available resource to understand the effect of different parameters.
- Abstracting and collecting data of effected properties in concerned study
- Experimental task – The performance of solar water will be tested using different flow rate of fluid in flat plate solar water heater. The storage tank will be filled up with water and all reading will be recorded from sunrise to sun set.
- Calculations have been made for Thermal efficiency and Maximum use energy by different equations for instance Hottlier-Whilier- bliss equation. For this following measurement are carried out.
    - i. Average temperature of water in storage tank
    - ii. Environmental factors like solar radiation intensity, ambient temperature and wind conditions.
    - iii. Tilt Angle of the system
    - iv. Design factor and ratio of collector plate area to area of volume of the storage tank.
    - v. Other measurements are enlisted for final calculation like incidence angle modified, optical efficiency and constant parameter like Retrieval factor, Heat loss coefficient, mass and heat capacity of water.

In this study a practical analysis will be done and relevant calculations to know the variation in the output obtained from the different processes for different material to locate the root cause and for suggesting the a common approach.

5. TEST PROCEDURE AND SYSTEM DESCRIPTION –

As my research project is based on optimization the thermal performance of flat plate solar water heater via flow rate setting. The experiment will be performed at mount Helen campus, federation university Australia. Now looking at weather in these days is not favourable to perform practical task as most of the days are cloudy and rainy. Also, for the best result I need variant temperature throughout the days to make my work good in graphical way. But, ambient temperature is too low to get desired result. So, I decide to perform experiment in next few week as weather forecasting, it is expected to have get better results in coming days. The Experiment will be as follows.

Objective –

Optimization of the thermal performance of flat plate solar water heater via flow rate setting.

Table of Contents

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Apparatus –

1. Flat plate collector
2. Centrifugal pump
3. Radiation Pyrometer
4. Thermocouple Wires
5. Connection Pipes.
6. Storage Tank
7. Flow meter
8. Non Return valve
9. Pressure Relief valve
10. Air Bleed valve
11. Power supply (230v, 50 Hz)

Mobile Support: - Square tube, welded, black powder coated

Width	2000	mm
Depth	850	mm
Height	2145	mm
Weight	240	kg

Power Supply: 230 V, 50 Hz

Solar Collectors (Absorber)-

Max. Power	1430	W
Absorber Surface Area	1.77	
m2		
Transfer Fluid	Water	
Nominal Throughput	100 - 200	l / h

Storage Tank:

Dimensions	850 x 750 x 600 mm	
Weight	85	kg
Capacity	140	l

Circulating Pump (hot water circuit):

Rating	85	W
Max. Flow Rate	3	m^3/h
Max. Head	4	m

Solar Unit:

Circulating Pump	85	W
Thermometer	0 - 120	°C, NG 63
Pressure Expansion Vessel	8 l, 5 bar	
Filler Device, Safety Valve		

Flowmeter:

Type	Variable-area	
Measuring Range	40 - 440	l/h
Connection	1”	

Thermometer:

Type	Bi-metallic, Threaded Sensor	
Diameter	NG 63	
Measuring Range	0 - 120	°C

Regulator:

Type	Differential Temperature Regulator
Inputs	2 (Pt 1000)
Output	1 (Relay)

(G.U.N.T, HL 313 Single Solar(Instructional Manual) 2013)

Solar water heater set is consists with flat plate collector orientated to different directions tilted at different angle, a well-insulated water storage tank consists of connection pipes.

Nomenclature-

C_P- Specific heat of working fluid (KJ/Kg ^oc)

I_C - Global isolation on absorber

A_C–Area of absorber (m^2)

Q_U – Rate of useful energy gain (W)

F’ – Collector efficiency factor

α – Absorbance of collector plate (0.9 - 0.95)

U_C – overall heat loss coefficient (W/m^2 ^oc)

Calculation Procedure –

The following measurements will be taken

1. **Inlet temperature of water (T_i)**
2. **Outlet water temperature (T_O)s**
3. **Mass flow rate of water (m)**
4. **Radiation Intensity (H)**

In relation to above measurements as variation in mass flow rate, number of graph can be generated like

1. Instantaneous efficiency of solar collector.
2. Hourly variation temperature for selected day

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3. Hourly variation of isolation and useful energy for selected day
4. Variation of efficiency with time of day.

The collected data will examine to ensure that it presents quasi steady state conditions according to the recommendations. Then, the concluded data are divided into test periods, each of which is 15 minutes. The data for each test period are averaged and used in the analysis as a single point, while other data are rejected. Knowing inlet (Ti) and outlet (To) fluid temperatures and the mass flow rate of water (m), the useful energy (Qu) is given by

$$Q_u = m\ C_p\ (Ti - T_O)$$

Where C_p is the specific heat of water. The instantaneous collector efficiency (h) which is defined as the ratio between the useful energy and the total radiation (G) incident on the collector surface area (Ac) can be expressed in the form:

$$Efficiency = Q_U / A_c.G$$

It is basic equation to find out an efficiency of system. There are pretty many complicated derivation to check out efficiency, which can be used further in theoretical criteria.

The efficiency of the solar water heater is directly proportional to the mass flow rate & specific heat of the heat transfer fluid, temperature difference between the outlet and inlet fluid to the solar collector and inversely proportional to the area of the solar collector and incident solar radiation falling on the solar collector. Assuming negligible uncertainty in the specific heat and area of the solar collector.

Inspite of the fact that Mount Helen is suitable for such an application, it is applied here due to two main reasons; the first being the availability and low cost of the conventional energy sources and the second reason being awareness among the public and households about the application of solar energy and its technology.

The results of the experimental test of such a system will be carried out in Mount Helen, in order to demonstrate the utilization of solar energy and to encourage its wide use in the country.

The thermal performance of a flat plate solar collector may be expressed in the Form of a linear performance characteristic, relating the rate of useful heat output Per unit aperture area (*q*u) and the solar radiation input (*I*c) and the heat losses (*U*c).

$$Q_U = \_Ic\ Ac\ (\tau\alpha) - Uc\ Ac\ (Tc\text{-}Ta).$$

The instantaneous efficiency of the collector is defined as the ratio of useful heat gain (*Q*u) desciapiated per unit area to the solar radiation intensity (*I*c).

$$\eta = Q_u / A_C\, I_C$$

The collector’s instantaneous efficiency is influenced by several factors such as;

The materials used, the design of the absorber, the properties of glass and weather and operation conditions. It could be expressed in the form of the following Efficiency equation

$$\eta = F'(\tau\alpha) - F'U_L (Tm - Ta)$$

Where *F*' (tα) is the maximum efficiency collector at no heat loss from the collector, when

$$Tm=Ta$$

The above equation has the convenient form of a straight line when plotted with as the
Dependent variable and [(*T*m- *T*a)/*I*] as the independent variable. Thus *F*' (tα) would be the *y*-axis intercept and *F*'*UL* would be the slope of the line. The efficiency Curve slopes downward with an increase in [(*T*m- *T*a)/*I* at the rate of *F*'*U*L until it Intersects the horizontal axis.

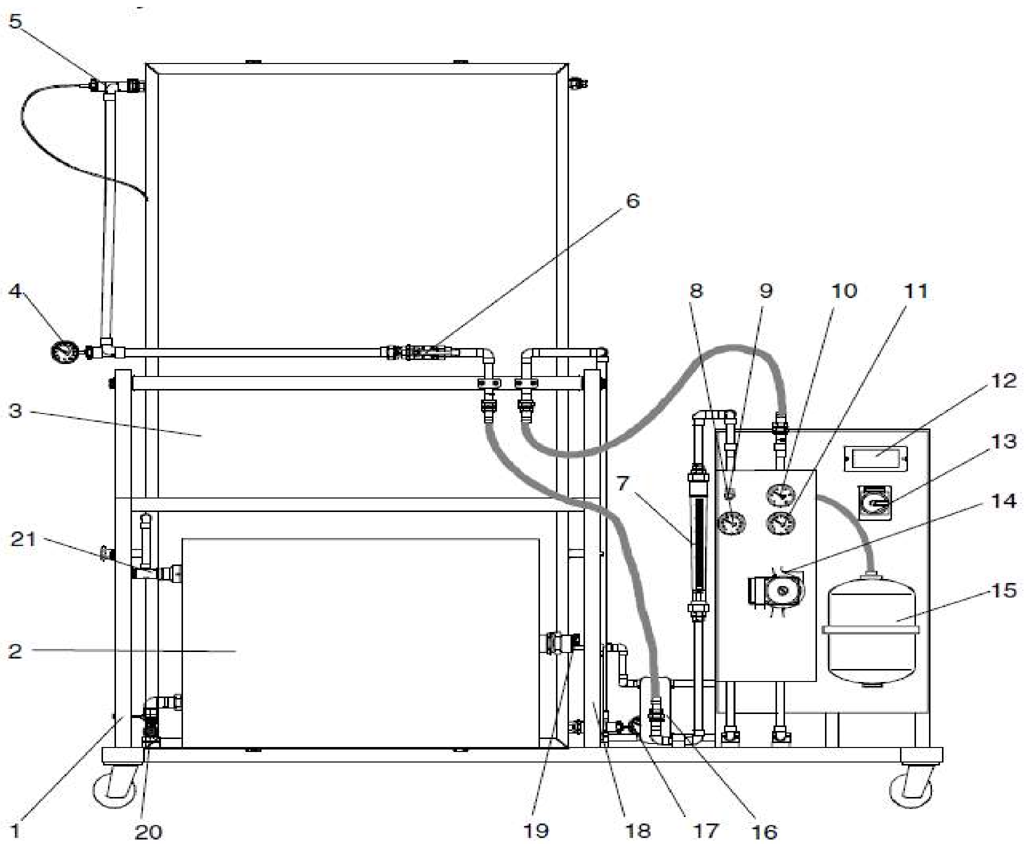
This point on the axis represents stagnation Conditions, when no useful heat is being removed from the collector. The useful heat gained in the collector can be obtained by measuring the fluid flow rate (*m˙)* through the collector and the inlet T_f,i and outlet T_f,o fluid temperatures as

$$Qu = m\ Cp(T_f, o - T_{f,i})$$
$$\eta = m\ Cp\ (T_f, o - T_{f,i})$$

System description –

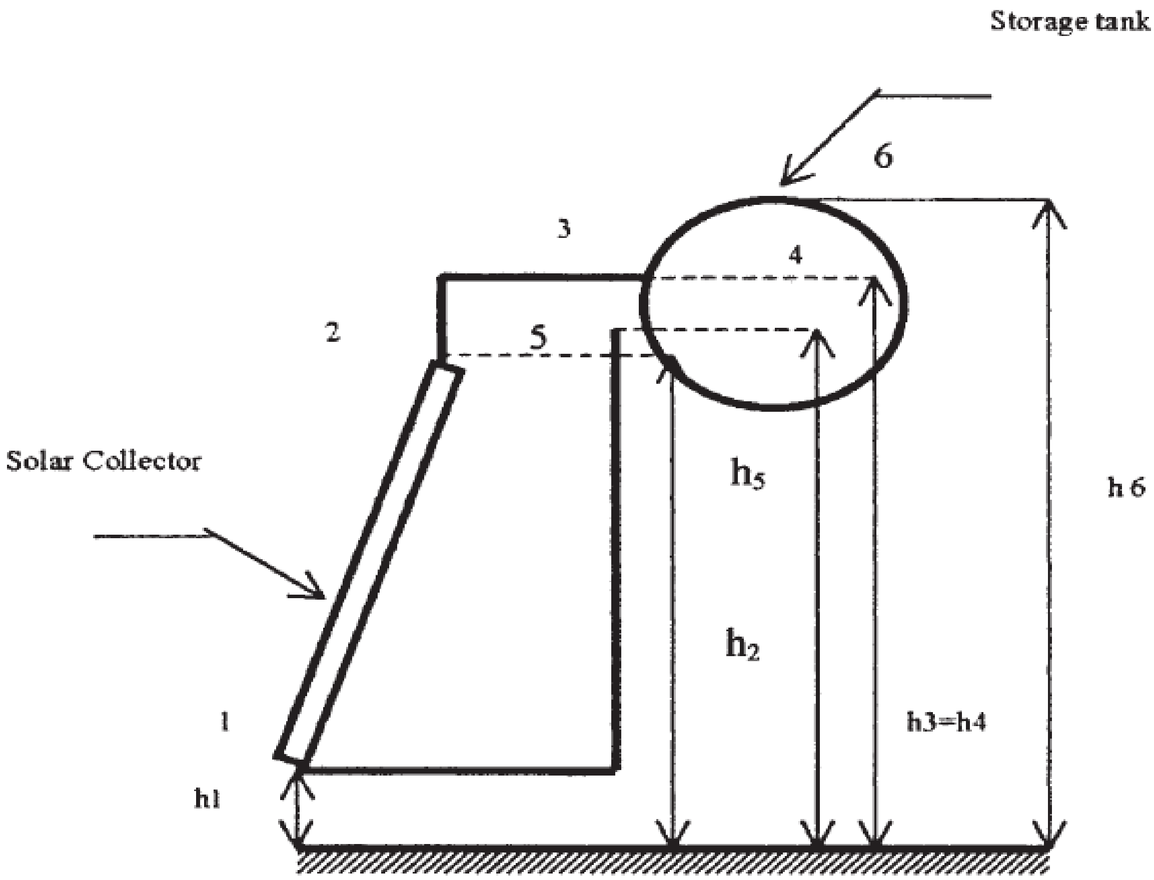
The following is the unit layout of apparatus, which will be used to perform experiment task.

Jagmeet Singh Dhillon
30129527



1. Mobile, Swivelling Support
2. Storage Tank
3. Collector Surface
4. Thermometer T_2 Collector Outlet
5. Temperature Sensor TC Collector Outlet
6. Ball-Cock for Flow Adjustment
7. Flowmeter F for Solar Circuit
8. Thermometer T_3 Return Flow
9. Filler Valve Solar Circuit
10. Pressure gauge P Solar Circuit
11. Thermometer T_4 Flow Pipe
12. Differential Temperature Regulator
13. Main Switch
14. Circulating Pump (Solar Circuit)
15. Pressure Expansion Vessel
16. Plate Heat Exchanger
17. Thermometer T_1 for Collector Inlet
18. Circulating Pump (Hot Water Circuit)
19. Temperature Sensor T_T Storage Tank
20. Cold Water Inlet
21. Hot Water Outlet

(G.U.N.T, HL 313 Single Solar(Instructional Manual) 2013)



Schematic Diagram of Flat plate solar water heater (M.S. Hossainb 2011)

Thermocouple wires are inserted at water collector inlet, water collector outlet, two positions in the storage tank, in addition to two other wires measuring ambient and collector back temperatures. A pyrometer is also installed to measure the total radiation at different tilt angles. For this analysis several sunny and cloudy days in winter were chosen. On each day, the total storage tank water was drained in the morning and refilled with clean tap water.
Thermal collector, Direct and diffuse sunlight from the surrounding environment strikes an absorber and is converted into heat by the transfer of energy to, e.g., water molecules. To be able to reach temperatures and efficiencies that are as high as possible, the absorber is thermally insulated to the surrounding environment. To be able to absorb a large amount of sunlight, the thermal insulation at least on the front must be of transparent design. The heat generated is fed to a load using a liquid or gaseous transfer system.

Although, most of the days in winter are cloudy in Ballarat. So some sunny days will be chosen to study the performance of system.

The flat plate collector will be tilted at some angle corresponding to the latitude of the location at Mount Helen campus (Federation University Australia). The temperature of the different locations can be measured, using PT-100 RTD sensors. The solar radiation was measured on the plane of the solar collector using a pyrometer

(Available in campus laboratory); the ambient temperature and the wind speed were measured using prescribed laboratory equipment's. All the sensors will be connected to a data acquisition system, will record every 5 min continuously and plotted in graphs. A booster pump can be used during forced circulation testing.

HIRAC Report-

The following HIRAC report has been prepared as safety measure to perform experiment.

HIRAC Report

Risk, Health and Safety

Federation UNIVERSITY•AUSTRALIA

This form relates to OHS Procedure – *Hazard Identification, Risk Assessment and Control (HIRAC)*

Date: 26/04/2016

Plant, Building, Task, Activity, Item Description: Solar hot water system

Campus: Mount Helen School/ Section: SEIT

HIRAC conducted by Jagmeet Singh Dhillon Email: dhillonjagmeet99@gmail.com

HAZARD DESCRIPTION	RISK ASSESSED	CONTROL MEASURE(S)	WHO / WHEN	DATE COMPLETED
Biomechanical and Postural	Very low	I will not have to lift any heavy objects when I am conducting my experiments. The rig I am using is on wheels.	Jagmeet	
Physical Environment	Very low	Drain tank in case of risk of frost. Secure system and solar collectors in case of storm (tie down).	Jagmeet	
Mechanical	No assessable risk	The apparatus has no exposed moving parts or mechanical hazards. However, appropriate footwear will be worn whilst I am conducting my experiments and whenever I am in the lab.	Jagmeet	
Electrical **Electric shock**	Low	Prior to working on the electrical system, switch off main switch and unplug apparatus from the mains.	Jagmeet	

		If need be, work on the electrical system is only to be performed by suitably qualified personnel ONLY. Protect the electrical system from moisture and splashes.		
Chemicals and Toxicity	Low	Heat transfer fluid contains glycol sealed in heat pipes and solar collector. Occasional skin contact with this liquid is not hazardous Will certainly avoid contact with the eyes in case of leakage.	Jagmeet	
Biological and Human risk	No assessable risk	The apparatus has no biological or human hazards		
Risk of Burns	Low	Heat transfer fluid and pipes can in good solar conditions reach 100°C. Heat pipes are mostly insulated but I will avoid contact with heat pipes and any other hot surfaces.	Jagmeet	
Public Place	Low	As this experiment will be done in public walkway outside Y-building and electric cables will be used. As precaution measures, signage or cones are required to alert the public that experiment is in progress.	Jagmeet	

Design of Experiment –

The experiment for data collection will be done with Muzamal, because he is also working on same apparatus, but our focus be different as Muzamal is investigating on the effect of air velocity and my exploration relates to effect of flow rate.

It would be better to work as a team to collect data.

Description of the Projects:

Muzamal's project: The effect of air velocity on the performance of the Solar Thermal Collector at different operating conditions.

Independent factors are:

I. Velocity of air flowing past (3 levels).
II. Tilt angle (3 levels)
III. Atmospheric conditions (noise – just recorded)

IV. Illuminance (3 levels)

Dependent variables:

I. Heat acquired from light source to the hot fluid
II. Heat transferred to the cold fluid
III. Efficiency

Experimental strategy if adequate time is available: 3x3x3

NOTE*: IF WORKING INDOORS FIX DISTANCE TO LIGHT SOURCE AND FIX THE HORIZONTAL ORIENTATION. RECORD THESE VALUES AND USE THEM TO PISTION THE COLLECTOR AT EVERY EXPERIMENT*

Jagmeet's project: The effect of flow rates on the performance of solar collectors at different operating conditions.

Independent factors:

1. Flow rate of cold fluid (3 levels)
2. Flow rate of hot fluid (3 levels)
3. Cold water temperature(Inlet and outlet)
4. Hot water temperature (Inlet and outlet)
5. Atmospheric conditions (noise – just recorded)
6. Illuminance (3 levels)

Dependent variables:

I. Heat acquired from light source to the hot fluid
II. Heat transferred to the cold fluid
III. Efficiency

Experimental strategy if adequate time is available: 3x3x3

NOTE: *TAKE THE MEASUREMENTS WHICH CORRESPOND TO ONE AIR VELOCITY SITTINGS DONE BY MUZAMAL*

Combined Data Collection Plan

Task #	Details	Days	Comments
1	Familiarization	2	Data collection runs with the purpose of getting used to the correct procedure of setting the parameters in order to ensure safety and accuracy of operation.
2	About 243 data points will be collected at steady state conditions.	15days	To allocate for about 15 minutes per data point to reach steady state and record data
3	About 10 random data points to test produced hypothesis	2	To conduct test review whether it is matched with project specifications.

Number of days needed for experiments: **19days** as per the above table. These days do not have to be sequential but rather as the weather and lab conditions permit. Which includes two days for familiarization of experiment, 15 days for collect data at steady state condition and rest of two days for testing of hypothesis.

Equipment needed:

Eqp#	Details	Availability	Purpose
1	Solar thermal collector	Available but access has been denied so far.	Main subject of project
Light source	Can be either the natural sun or a proposed substitute.	Sun can be used on sunny clear days.	To operate the collector.
3	Variable speed fan	Not sure. However, this is very affordable	Even a domestic fan can be used to create the needed effect.
3	Air speed meter	Available	

This brief document presents a data collection plan for the Master by course work projects of Muzamal and me. An estimate has been made as to the number of days needed to run the experiments and as to the equipment required for the projects.

Me and my mate Muzamal (Mentioned above) doing our Research project on same topic and we will use same apparatus but our concern is different. As mentioned above, Muzamal is pursuing his research on effect of air velocity on the performance of the Solar Thermal Collector at different operating conditions. Whereas, my exploration is based on the effect of flow rates on the performance of solar collectors at different operating conditions.

6. TIMELINE FOR PROPOSED WORK

As this project is required to be completed by the November 2016 but due to hinders in experiment, now it is need to complete by January 2017. So accordingly I have planned to undertake this study and break this study into number of tasks so that every tasks can be completed within time. As this does not require any experimental investigations but still I have to undertake lot reading of collect the data for effected properties and to know reasons for their change. In the end I need to develop a common strategy for effect of flow rate setting on desired solar heating system so that more effective results can be obtained.
The following GANT chart was generated with the help of Minitab.

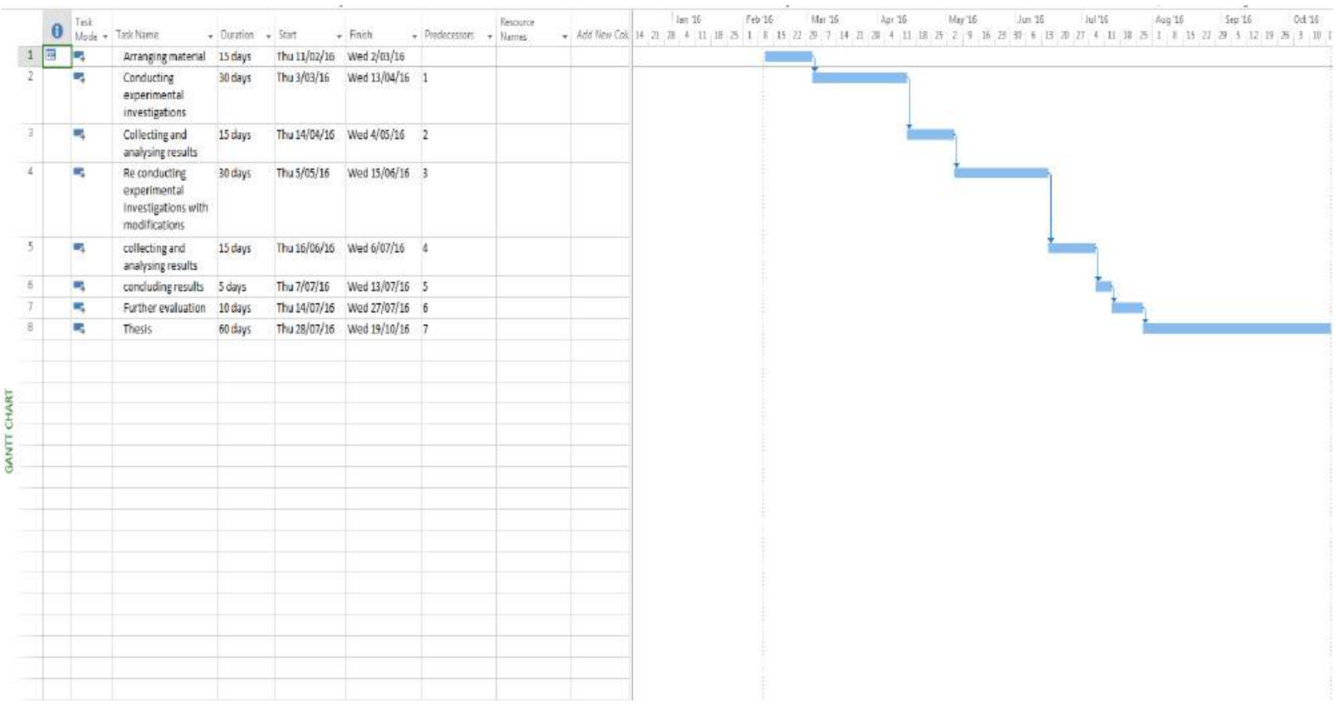


Figure 15/ GANT chart representing the time schedule for different tasks

7. TABLE OF CONTENTS FOR THESIS WRITING -

8. REFERENCES

A.A. Karaghouli a, *, W.E. Alnaser b. 2001. "Experimental study on thermosyphon solar." *Renewable Energy* 389-396.

Al-Madani, Hussain. 2006. "The performance of a cylindrical solar water heater." *Renewable energy* 1751-1763.

canada, Health. 2013. *Statement of the Science Report for Ethylene Glycol.* Accessed June 24, 2013. http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/psl2-lsp2/ethylene_glycol/index-eng.php#a2436.

Christopher J. Koroneos a, *, Evanthia A. Nanaki b. 2012. "Life cycle environmental impact assessment of a solar water heater." *Production of cleaner energy* 154-161.

Davabkhaktuni, V., Alam, M., Depuru, S.S. S. R., Green, R. C., Nims. 2013. " Solar energy: Trends and enabling technologies." *Renewable and sustainable Energy review* 555-564.

Feng Shan, Lei Cao, Guiyin Fang,. 2013. "Dynamic performances modeling of a photovoltaic–thermal collector with water heating in buildings." *Energy and buildings* 485-494.

G.U.N.T. May, 2013. "Domestic water heating with flat plat collector." *Energy and Enviornment.*

G.U.N.T. 2013. "HL 313 Single Solar(Instructional Manual)." Instruction Manual, Barsbuttel, Germany.

HC. 2013. *Statement of the Science Report for Ethylene Glycol.* 24 June. http://www.hc-sc.gc.ca/ewh-semt/pubs/contaminants/psl2-lsp2/ethylene_glycol/index-eng.php#a2436.

Jee Joe Michael, S. Iniyan. 2015. "Performance of copper oxide/water nanofluid in a flat plate solar water." *Energy conversion and Management* 160-169.

K. Sampathkumar, P. Senthilkumar. 2012. "Utilization of solar water heater in a single basin solar still—An experimental study." *Desalination* 8-19.

M. Boubekri a, A. Chaker a, A. Cheknane b,∗. 2013. "Modeling and simulation of the continuous production of an improved." *Desalination* 6-15.

M.S. Hossainb, ∗, R. Saidura,b, H. Fayazb, N.A. Rahimb, M.R. Islama, J.U.

Ahameda, M.M. Rahmanb. 2011. "Review on solar water heater collector and thermal energy performance of circuylating pipe." *Renewable and Sustainable Energy Reviews* 3801-3811.

manufacturar, solar hot water and heating. 2015. *Sun max solar.* http://www.sunmaxxsolar.com/evacuated tube solar water heating.

Mobin Arab, Ali Abbas. 2013. "Model-based design and analysis of heat pipe working fluid for." *Solar energy* 162-176. Accessed 2013.

P.V. Durga Prasad a, ⇑, A.V.S.S.K.S. Gupta b, M. Sreeramulu b, L. Syam Sundar c,

M.K. Singh c,. 2015. "Experimental study of heat transfer and friction factor of Al2O3 nanofluid." *Experimental Thermal and Fluid Science 62* 141-150.

parts, Machine. 2013. *Mechanism for solar collector for flat plate.* sunday june. Accessed 2013. http://newmachineparts.blogspot.com.au/2013/06/mechanism-of-solar-collector-for-flat.html.

Raouf Benrejeb, Olfa Helal, Bechir Chaouachi. Feb, 2015. "Optical and thermal performances improvement of an ICS solar water heater system." *solar energy* 108-119.

T. Rajaseenivasan a, P. Nelson Raja a, K. Srithar b. 2014. "An experimental investigation on a solar still with an integrated flat." *Desalination* 131-137.

Trad Abderachid, Kaabi Abdenacer. 2012. "Effect of orientation on the performance of a symmetric solar still with a." *Elsevier* 68-77.

Zhu, J., & Cui, Y. 2010. " Photovoltaic: More solar cells for less." *Natural material* 183-184.