ISSN: 2278-0181
CONFCALL - 2019 Conference Proceedings

Experimental Analysis of Thermal Performance of a Variable Diamter Riser Tube Solar Water Heater

S Thulasi[a] , V Thirumaran[b] , H. T. S. Mohamed Haleelulla[b]
[*a] Assistant Professor,
Department of Mechanical Engineering,
University College of Engineering, Thirukkuvalai,

***Abstract:-* Solar water heater is a device that helps to heat the water by using solar energy from the sun. Water is easily heated to a temperature of 60°- 80°C by using the flat plate collector. Solar water heaters are characterized by its thermal performance that depends on the transmittance, absorption and conduction of solar energy. The heat is transmitted from the sun to the absorber plate through radiation and from the plate the heat is conducted to the riser tubes. The flow in the riser tubes play a vital role in the enhancement of overall thermal efficiency of the SWH. But in conventional SWH poor mass flow rate is obtained due to high pressure drop raised in the riser tubes. This problem has been overcome by the new design of variable diameter riser tubes which are arranged in the diameter of 6, 8, 10, 12, 16, 12, 10, 8, 6, mm respectively. The riser tubes arrangement is being in ascending as well as in descending order. This type of riser tubes arrangement will decrease the pressure drop. The riser tubes are covered by absorber plate. Black paint is coated on the absorber plate to increase the heat absorbing capacity .The overall set up is covered with a wooden box to restrict the heat dissipation. The collector is covered with the transparent glass to transmit heat energy from to the water heating setup. The thermocouples are placed nearly 30 measurable points to measure the plate and tube temperatures. The entire set up is completely sealed to prevent the heat dissipation. The variable diameter riser tubes will increase the mass flow rate of the water. This will increase the overall thermal efficiency of the solar water heating system. The thermal efficiency of 87.75 % has been obtained in the variable diameter solar water heating system.**

1.0 INTRODUCTION

Now a days, due to the massive technological development there is a great demand for energy. We are getting energy from various sources. The most of the energy resources are Non renewable in nature. Some form of energies are simply available, renewable and Eco friendly. According to this, Solar energy is the one which is the easily available, renewable and not hazardous to nature. Here solar energy is used as a source to heat the water. In a day to day life the hot water demand is increasing vigorously. Hot water is being utilized for many purpose in many sectors. Hotels, hospitals, Industries and hostels require hot water for various purposes. These demands are resolved by water heating systems working on electricity. It consumes more electrical energy and it needs proper maintenance to be in normal operating condition. But solar water heating system operates on solar energy. It doesn`t need any maintenance and no maintenance cost. So it is a best alternative solution for electric water heating. This SWH system uses headers, riser tubes, absorber plate to absorb heat so that cold water is converted into hot water.

2.0 LITERATURE SURVEY

Vipin. B. Nanhe et al, reviewed the performance of Trapezoidal shape solar water collector with semicircular riser tubes and four sided mirror provision. In this paper, the riser tubes are in semicircular shape which are attached with absorber plate. So water in semicircular riser tubes directly contacts the absorber plate. The direct contact between water and absorber plate leads to get high efficiency. Therefore he found that Trapezoidal shape with semicircular tubes have absorbed more heat than that of circular riser tubes.

Muhammad shakaib et al, studied the performance of solar collector system on the basis of Riser tubes using CFD (Computational Fluid Dynamics) software. He analysed about the effect of heat transfer, mass flow rate with no of riser tubes. Finally he revealed that the difference in mass flow is more when diameter of riser is high. The temperature is decreased when the Reynolds no/ Inlet velocity is increased. The no of tubes should be high for better thermal performance of the system

Jayamalathi et al.(Jan 2012) Proposed the changing the design parameters of the number of riser tubes and the arrangement of riser tubes in zig-zag pattern from the existing flat plat collector system. Experiments were conducted using copper tube in header and riser with different dimensions. This presentation shows that the efficiency is 59.09% when increasing the number of riser tubes and its 62.90% in the zig-zag arrangement (Z-Configuration) of the riser tube. Now-a-days this system produces higher efficiency than the existing conventional flat plate collector.

Volker Weitbrecht et al., [4] performed the results of an experimental study conducted in a water solar flat plate collector with laminar flow conditions to analyze the flow distribution through the collector. LDA measurements were carried out to determine the discharge in each riser, as well as pressure measurements to investigate the relation between junction losses and the local Reynolds number. Analytical calculations based on the measured relations are used in a sensitivity analysis to explain the various possible flow distributions in solar collectors.

The system of Wang X.A., Wu. L.G. [6] performed several collectors with parallel connection and which can be interpreted as a single collector where the number of risers must be multiplied by the number of collectors and were analyzed.

Fanney and Kleinet al.,[3] evaluated the side by side the experimental investigation to analyze the thermal performance of 9 riser tube arrangement in solar domestic hot water system. The arrangement system was a direct solar hot water system utilizing a usual circulation return tube to the storage space tank. The system shows improvements in the overall system performance as a result of lowering the flat plate collector fluid flow rate.

Kim and Seo et al**.,** [10] investigated the theoretical and experimental performance of four different shapes of absorber tubes, ranging from the single tube to U-tubes with different cross-sectional shapes of the absorber plates that are welded onto the copper U-tubes.

Sathish. D *et al*., performed the result and experiment, the efficiency of water heating system mainly depends on the arrangement of riser tubes and the number of riser tubes.

3.0 EXPERIMENTAL SETUP:

This system is consisted with nine riser tubes of different diameters, absorber plate, uniform header, storage tank, wooden frame and transparent glass. The wooden frame of 1m*1m is used to carry the riser tubes and absorber plate. The riser tubes are made from copper tube having different diameter as said earlier. The absorber plate also made from copper metal having thickness of 0.3mm and the transparent glass have 4mm thick.

In this system the modification is fully based on the diameters of riser tubes. The diameter of riser tubes are 6mm, 8mm, 10mm, 12mm, 16mm. The riser tube arrangement is 6mm, 8mm, 10mm, 12mm, 16mm, 12mm, 10mm, 8mm, 6mm. Riser tubes are enclosed by absorber plate. Both ends of riser tubes are connected with uniform header at two sides. Black paint is coated over the absorber plate and riser tubes. Finally the arrangement is covered by placing transparent glass on top side of the frame. The whole assembly is kept at 12^0 latitude with the earth which is most suitable value for our living region. The existing SWH system has nine riser tubes of same diameter. Due to same size riser tubes, the overall mass flow rate attains minimum value so it leads to low efficiency. By using the different diameter riser tubes, we can get more mass flow rate as well as high efficiency.

Now let`s see the working procedure. When the solar radiation falls on glass, it is directed towards the absorber plate and riser tubes. The riser tubes of variable diameter will give better mass flow rate. So the conduction of heat takes place between absorber plate and riser tubes. Then heat is convicted to water passing through the tubes from the lower header. After the water absorbing heat from the riser tubes where the density variation occurs. Because the hot water is less denser than cold water. So the hot water floats up to the cold water and it flows to the upper header through the riser tubes.

And moreover the black paint is also helping to improve heat transfer. Because the black body has the ability to absorb more heat energy until it can and it doesn`t return the energy to the outside whereas no colors has this property. Finally the hot water goes to the storage tank of 100 liters capacity which is made up of stainless steel. Then the hot water is used for further application. And the temperature variation or heat absorption is noted by thermocouples. Nearly 30 thermocouples are fixed at 30 measurable point to note the temperature which is placed over the riser tubes of different diameter, absorber plate, inlet and outlet pipes. The fig(1) shows the experimental set up of variable diameter riser tube solar water heater.

Fig (1) Parallel variable diameter riser tubes solar water heater

4.0 DATA REDUCTION:

This chapter illustrates the utilization of various equations to find out the Nusselt number (Nu) and thermal performance factor (η) at different mass flow rates of the variable diameter rises tubes.

4.1 HEAT TRANSFER CALCULATION:

The riser tubes are brazed to the bottom of a black absorber plate and the captivated solar energy is carried out to the riser tubes. The heat is transferred by convection from the tube wall to the fluid.

The total heat gain Q, is shared to overall heat transfer coefficient by the following equations from which the internal convective heat transfer coefficient (h_i) has been calculated (2000).

The subsequent equations for the evaluation of Heat Transfer rate in the single riser tube is given in Equations 1 and 2(Liao Q, Xin MD,2000).

$$Q = mc_p(T_{out} - T_{in}) = U_0 A_0 (T_{w0} - T_m) \quad (1)$$

$$\frac{1}{(U_0 A_0)} = \frac{1}{(h_i A_i)} + \frac{\ln(D_0/D_i)}{(2\pi k_w L)} \quad (2)$$

The Equations 1 and 2 have been used to determine the internal convective heat transfer co-efficient(h_i).The Equation.3 has been used to find the experimental Nusselt number.

$$Nu = h_i D_i / k. \quad (3)$$

All the fluid thermo physical properties are determined at the bulk mean temperature, T_m.

4.2 THERMAL PERFORMANCES:

The thermal performance of a solar water heater is calculated using the Hottel and Whillier equation [14] as follows

$$\eta = F_R(\tau\alpha) - F_R U_l \frac{T_{in} - T_a}{H_t} \quad (4)$$

The overall heat loss coefficient (U_l) is calculated using the following equations from Duffie and Beckman [130]

$$Q = H_t(\tau\alpha) - U_l(T_p - T_a) \quad (5)$$

$$U_l = \frac{Q - H_t(\tau\alpha)}{T_a - T_p} \quad (6)$$

The collector heat removal factor (F_R) is calculated as follows

$$Q = F_R(H_t(\tau\alpha) - U_l(T_{in} - T_a)) \quad (7)$$

5.0 RESULTS AND DICUSSION:

From the experimental setup the heat transfer and thermal performance characteristics are analysed. The readings are tabulated and compared by graphs.

5.1 HEAT TRANSFER CHARACTERISTICS:

The experiment is done. As a sunny day, the readings are taken from 9.00 am to 1.00 pm is considered as phase 1 and from 1.00 to 4.00 pm is considered as phase 2. In phase 1 the plate temperature increases with the increase in solar radiation but in phase 2 the plate temperature is gradually decreases due to decrease in solar radiation. This shown in graph are shown in Fig5.1 (a) and 5.1 (b)

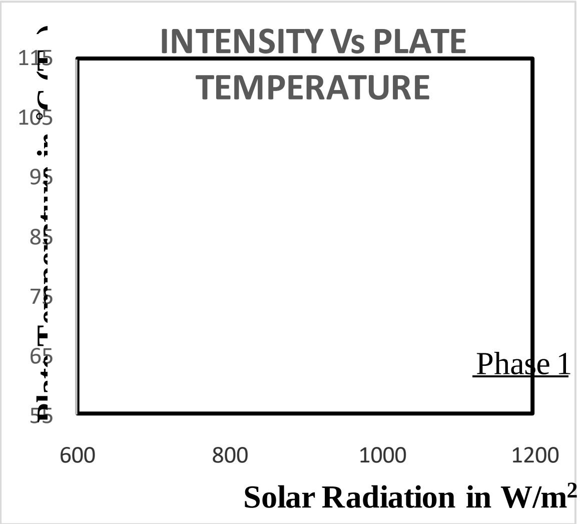

Fig 5.1 (a) Solar intensity Vs Plate temperature (phase-1)

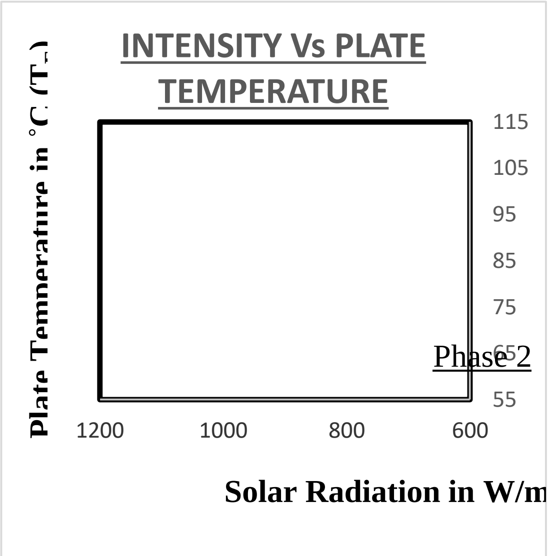

Fig 5.1 (b) Solar intensity Vs Plate temperature (phase-2)

The fig 5.2 (a & b) shows that the range between intensity and convective heat transfer in SWH. It has a gradually increases at phase 1 and vice versa at phase 2. The convective heat transfer coefficient has enhancing as per the radiation on time. The raise in intensity has provides the effective convective heat transfer.

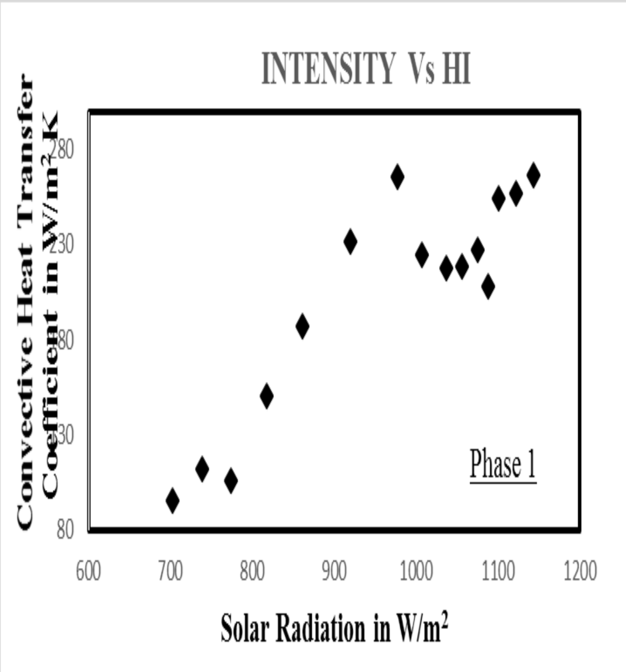

Fig 5.2 (a) solar intensity Vs H_i (phase-1)

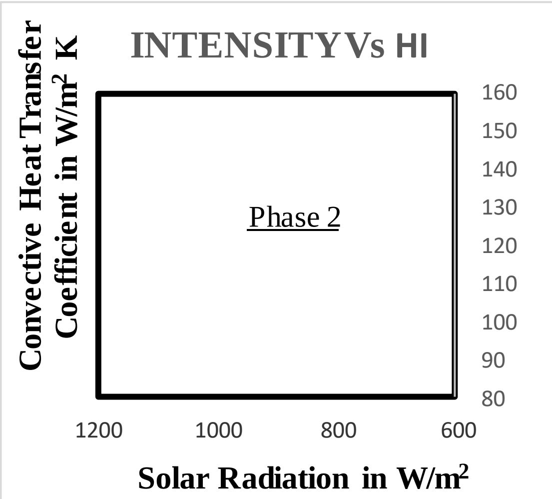

Fig 5.2 (b) Solar intensity Vs H_i (phase-2)

From the Fig 5.3 (a & b) Reynolds number is compared with the nusselt number which we has discussed the surface heat transfer rate and the flow of the fluid. In the graphical representation it has a gradual convective heat transfer is takes place in which the flow mixture is determined as per the nusselt number. The flow of the fluid in solar water heater is directly propotional to the convective heat transfer. Graph has two phases the phase one provides the gradual increase due to increase in intensity as vice versa at phase 2.

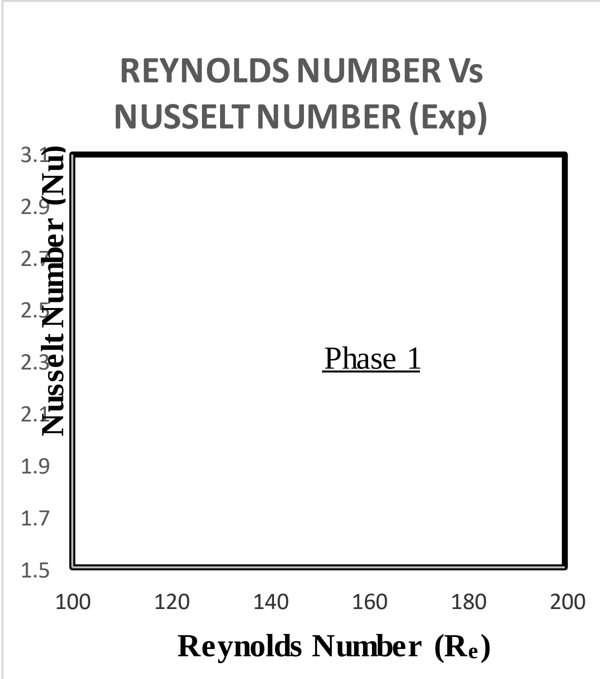

Fig 5.3 (a) Reynolds number Vs nusselt number (phase-1)

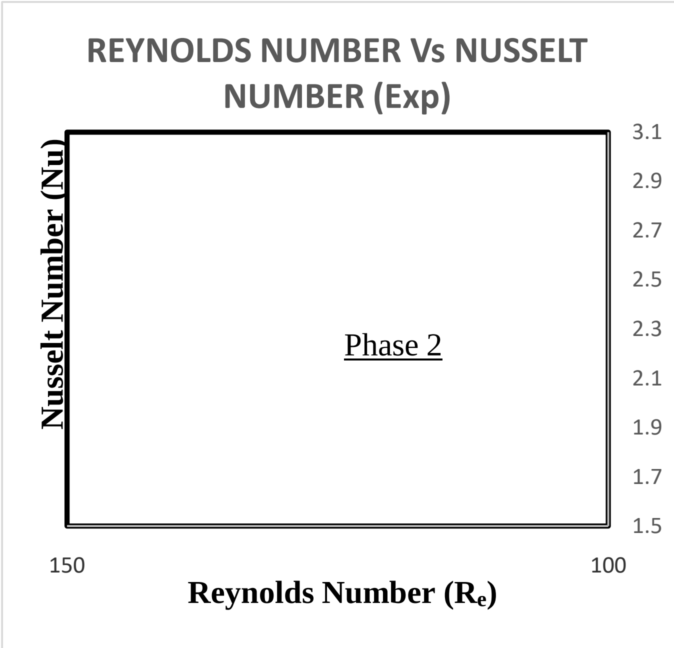

Fig 5.3 (a) Reynolds number Vs nusselt number (phase-2)

The Fig 5.4 represent the thermal performance of the solar water heating system. In which the system has a gradual increase in efficiency as per the intensity, H_i and convective heat transfer coefficient. The increase in the intensity and convective heat transfer proves the maximum thermal conductivity as per the graph. The graph shows at the peak time of 1.00 it has the maximum thermal efficiency of 87.75 % in the designed solar water heating system. The thermal performance is based on solar radiation.

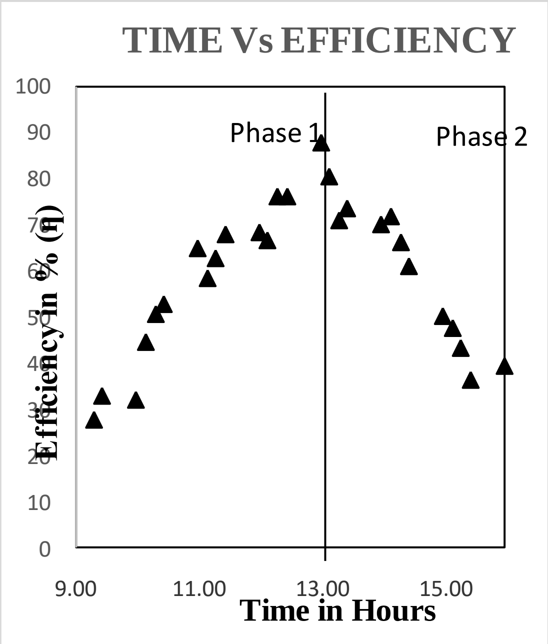

Fig 5.4 (a) time Vs efficiency

6.0 CONCLUSION

As expected from the literature analysis the combination of idea obtained a design modification in conventional solar water heater has improve the thermal efficiency and mass flow rate. In the solar water heating system the variable diameter riser tube provides the pressure drop in the system and also it helps to equal flow in every riser tubes it acquires through the arrangement of riser tubes has in ascending and descending order. Experimentally arises the maximum thermal efficiency at the peak time. The analyzed system provides 87% of thermal efficiency has improved thermal efficiency. The average nusselt number has in the range of 3.33581. The average friction factor is 0.042. The Reynolds number is in the range of 121 to 413. Through analysis the mass flow rate is increased by variable diameter riser tube solar water heating system.

REFERENCES

[1] Vipin.B nahe (june 2016), performance analysics of flat plate solar collector using trapezoidal shape semicircular tubes: a review, international research journal of engineering and technology: volume zero; 03, issue 03
[2] Muhammad shakib, (july 2016) analysis of fluid flow and temperature profiles in flat plate solar collector using CFD ; proceeding at ISER international conference (139th)
[3] N.jayamalathi (jan-2012) performance improvement study of solar water heating system, ARPN journal of engineering and applied sciences, vol-07, no-01
[4] Volker waitbrecht (dec-2002) flow distribution in solar collectors with laminar flow conditions; vol-73, no-06, PP433-441
[5] Fanney and Kleinet (NOV 2004) the experimental investigation to analyze the thermal performance of 9 riser tube arrangementin solar domestic hot water system; vol-43, no-08
[6] Kim and seo, (jun 2003) the theoretical and experimental of four different shape of solar absorber in U tube; vol-23
[7] Wang. X.A. and Wu .L.G. 1990. Analysis and performance of flat-plate solar collector arrays. Solar Energy. 45(2): 71-78.