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EXPERIMENTAL ANALYSIS OF PERFORMANCE OF SOLAR WATER HEATER FOR VARIATION IN SOLAR RADIATION LEVEL

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ABSTRACT

Solar radiation falling on the surface of the Earth may be proven to be a major source of energy, which can be used to utilize various fields to maximize their efficiency and Output at optimum levels. Paper is also based on the Solar Radiation falling on the flat plate collector that is absorbed by the water flowing in the Copper tube Inside the collector. We try to optimize the uses of Solar Radiation for household purposes by perfect solar radiation intensity, which varies from a high radiation level at 597 W/m² to a medium radiation level at 300 W/m². In this range, we get maximum efficiency concerning solar radiation, on the other side at low radiation levels results are different. So the main aim of the experiments is to optimize the best utilization the solar radiation.

KEYWORDS: *Solar Radiation Level, Solar Efficiency, Heat Loss Coefficient, Forced Flow.*

INTRODUCTION

Solar water heating system is an important part of human life, not only in India, where it is used extensively in the world. It helps to save a huge amount of energy and serves in continuously to maintain human comfort, basically in India presence of solar radiation varies in nature day by day, which is why we have done experiments on the scenario of this concept, generally in this paper tried to improve utilization of variated solar radiation in our experimental setup. Solar water heater system works on the principle "Green House Effect" in which heat is trapped inside the flat plate collector and transferred to the tube in which flowing water absorbs heat and got heated and the temperature of the water increases. Solar energy is the perfect energy source, but there are so many difficulties, like weather conditions, losses of heat, and instrument efficiency. The solar heater is a device that is used for heating water, for producing steam for household and industrial purposes by utilizing solar energy.

Our experiment analysis works on the radiation of solar energy which is not in a proper and continuous manner but still, it is a most useful and powerful source of energy, that is why in the current scenario solar energy is most considered to use at a large scale. We work on the principle In which is how solar radiation differs when solar radiation varies from a high radiation level to a low radiation level, we also use a forced flow water system and make other parameters constant like wind flow, tilt angle, and inlet water temperature. we collect data from the experiments which are performed in the laboratory, and output and results show in form of graphs and tables.

In this area, some other works also motivate us to enhance the proper utilization of solar energy for solar water heater systems. Other works performed in a multidirectional way to enhance solar energy like heat storage as a phase change material, variation tilt angle, variation in wind speed in India, etc.

Solar radiation is a very wide area to learn about to abstract maximum energy from the sun and it can be proven to use as a main source of energy if perfect analysis will be performed in suitable directions.

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Experimental Apparatus

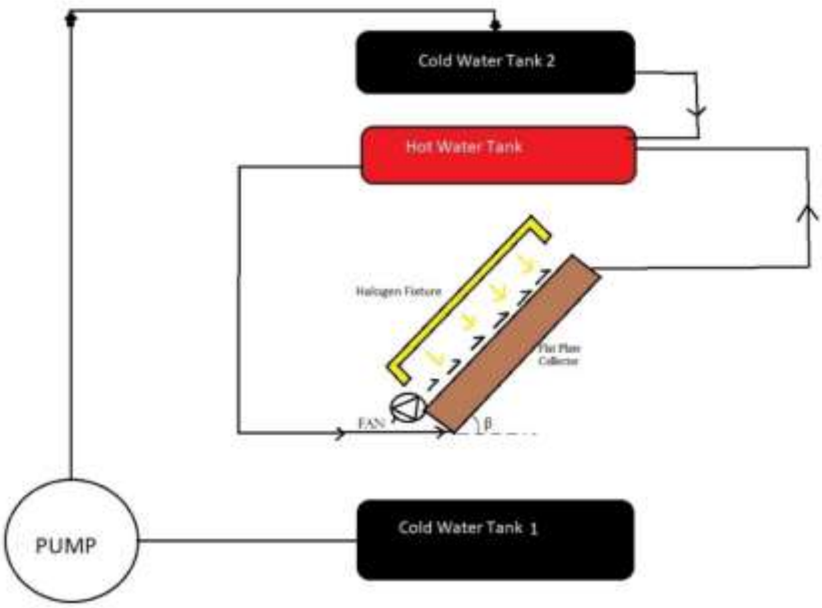

Fig.1. Schematic diagram of solar water heater .

Fig.1 shows the schematic diagram of experimental setup of flat plate collector. The flow of from the bottom of collector plate inclined at an angle β which is taken by us is 60 degree, with the horizontal. The irradiation from 597 Watt/m^2 is artificially generated by halogen fixture. In the setups forced flow of air over the collector surface flowing through the fan. The warmed water flow out from the collector tubes through an outlet placed at the top of collector plate by thermo siphon effect and goes into the mixing chamber of hot water tank. The setup is equipped with multiple electronic and mechanical monitoring and control equipment included with the sensors. Halogen Fixture is a part of the setup and artificial radiation source which is inclined at 60 degree from latitude, with fixed orientation, we can change orientation of Flate Plate Collector from 40 degree to 60 degree.

Methodology

Experiments were performed as per the manual in which Instruction is given for Analysis. And calculation and analysis are also done with help of basic formula and methods:

Total Heat Loss Coefficient (U_{total})

Total heat loss is important parameter in the field of Thermal energy, Heat loss can May be direct many form like Conduction, Convection And Radiation also, it may be occur from the source of the generation to the absorption of heat at the surface of the flat plate collector. In every system, no one can be perfectly ideal but in the case of the thermal system Insulation can be play a important role to avoiding the losses. In our System try to minimize losses of heat in two ways, where is one in the collector and another one in the pipes. In which they provide the better Insulation up to minimize most of the heat loss to the environment. In our setup there are three point where as heat loss may occur, from the top, from the bottom and the edge of the flat plate collector. If the losses increases then usefull heat decreases, in the experiment we try to generate more usefull heat and try to save heat heat without the losses. Therefore, we need to calculate Total heat loss coefficient. So there is a specific formula to calculate total heat loss coefficient formula.

$U_{total} = U_t + U_b + U_e$

From the Klein (1975), the top heat loss using the flowing formula for the calculations,[2]

$$U_t = \left\{\frac{\frac{1}{N}}{\frac{C}{T_P}\left[\frac{T_P - T_a}{N+f}\right]^{0.33} + \frac{1}{h_a}}\right\} + \left\{\frac{\sigma(T_P+T_a)(T_P^2+T_a^2)}{\left(\varepsilon_p + 0.05N(1-\varepsilon_p)\right)^{-1} + \frac{2N+f-1}{\varepsilon_g} - N}\right\}$$

Where,[1], $C = 365.9*(1-0.00883\beta+0.0001298\beta)$,

$F = (1+0.04h_a - 0.0005h_a^2)*(1 + 0.091N)$,

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$h_a = 5.7 + 3.8v$

U_t is the heat loss coefficient in the form of losses by top of the surface of the solar collector to the environment.
heat loss coefficient by the bottom, $U_b = \frac{k_b}{x_b}$

heat loss coefficient by the edge, $U_e = U_b\left(\frac{A_e}{Ac}\right)$

U_b and U_e are the heat loss coefficient from the bottom and edge respectively.

Heat Removal Factor (F_R)

Heat removal factor plays an important role in the system where heat transformation occurs, the importance of the heat removal factors remains with the efficiency of the system. It is the combination of the factors like inlet water temperature, outlet water, ambient temperature, and area of the collector etc. Heat removal factor is the ratio of the actual useful energy gain to the useful energy gain if the entire collector were at the fluid inlet temperature.

$$F_R = \frac{\text{Actual useful energy gain}}{\text{Useful energy gain if the entire collector were at the fluid inlet temperature}}$$

Mathematically,

$$F_R = \frac{\dot{m}C_p\left[T_{fo} - T_{fi}\right]}{A_c\left[I_t\tau_o\alpha_o - U_L\left(T_{fi} - T_a\right)\right]}$$

Thermal Efficiency

Efficiency deals with the output directly, Efficiency is the most important part of the system's output. The efficiency of the system depends upon some parameters like the product of the glazing's transmittance and absorbing plate's absorption, intensity of radiation falling on the collector, water inlet temperature and ambient air temperature. In our experimental setup for flat plate collector based solar water heater system the efficiency is define as the ratio of the useful energy delivered to the energy incident on the collector aperture.

Thermal Efficiency is the Ratio of the usefull heat gain to the total input energy.

Mathematically,

$$\eta = F_R\left[\left(\tau_o\alpha_o\right) - \frac{U_L\left(T_i - T_a\right)}{I_t}\right]$$

Observation

The Experiments was performed to optimize results and calculations with the help of Solar Water Heater System in the Laboratory under the supervision of professional expertise. Aim of the experiments is defined the solar energy to use heat up the water for household purpose at various ambient conditions in which solar radiation also varying in nature, which is maximum to minimum by every day and also different in monthly wise and year wise also. Based on calculations and output we optimize the results and used above methodology and formulas to get all parameters and factors affecting variables concluded.

Wind speed (v): 3.4 m/s
Ambient Temperature (T_a): 30^0C
Radiation level (I): 597 W/m^2
Water mass flow rate (m.): 0.06800 kg/sec

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S. no.	U_t	Ue	U_b	U_l	F_R	Effi.
1.	3.2670	0.354	0.8	4.421024	0.694186	0.58572
2.	3.2586	0.354	0.8	4.412624	0.58137	0.497545
3.	3.2530	0.354	0.8	4.407017	0.48299	0.423347
4.	3.2684	0.354	0.8	4.422484	0.40643	0.373956
5.	3.2849	0.354	0.8	4.438938	0.323326	0.306063

Table 1. Observation for Efficiency and all Heat Loss Coefficient at varying varying Other Parameter.

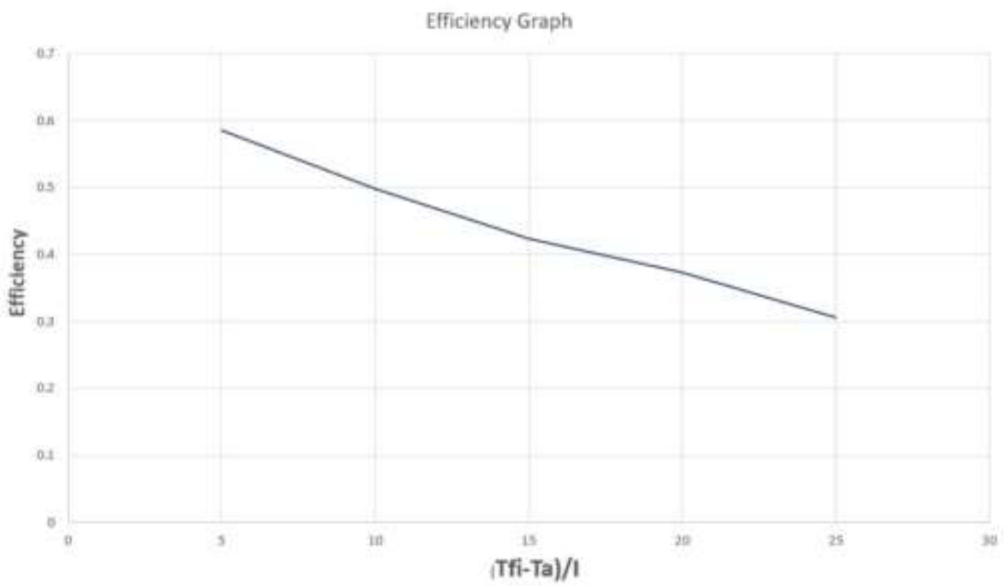

Fig.2. Efficiency Graph for different Radiation levels.

Fig.2. shows the relation between Efficiency and variations in solar radiation falls on the flat plate collector at various ambient conditions. Graph plot on the basis of the result from the experimental calculation, in which maximum efficiency start from 68% which is decreased up to 30%. These experiments performed at high radiation level at 597 W/m^2 which is set according to the experimental setup and get efficiency up to maximize level.

Wind speed (v): 3.4 m/s
Ambient Temperature (T_a): 30^0C
Radiation level (I): 300 W/m^2
Water mass flow rate (m.): 0.06800 kg/sec

S. no.	U_t	Ue	U_b	U_l	F_R	Effi.
1.	3.2670	0.354	0.8	4.421024	0.694186	0.545438
2.	3.2586	0.354	0.8	4.412624	0.58137	0.467953
3.	3.2530	0.354	0.8	4.407017	0.48299	0.382277
4.	3.2684	0.354	0.8	4.422484	0.40643	0.285358
5.	3.2849	0.354	0.8	4.438938	0.323326	0.17959

Table 2. Observation for Efficiency and total Heat Loss Coefficient at radiation level of 300 W/m^2

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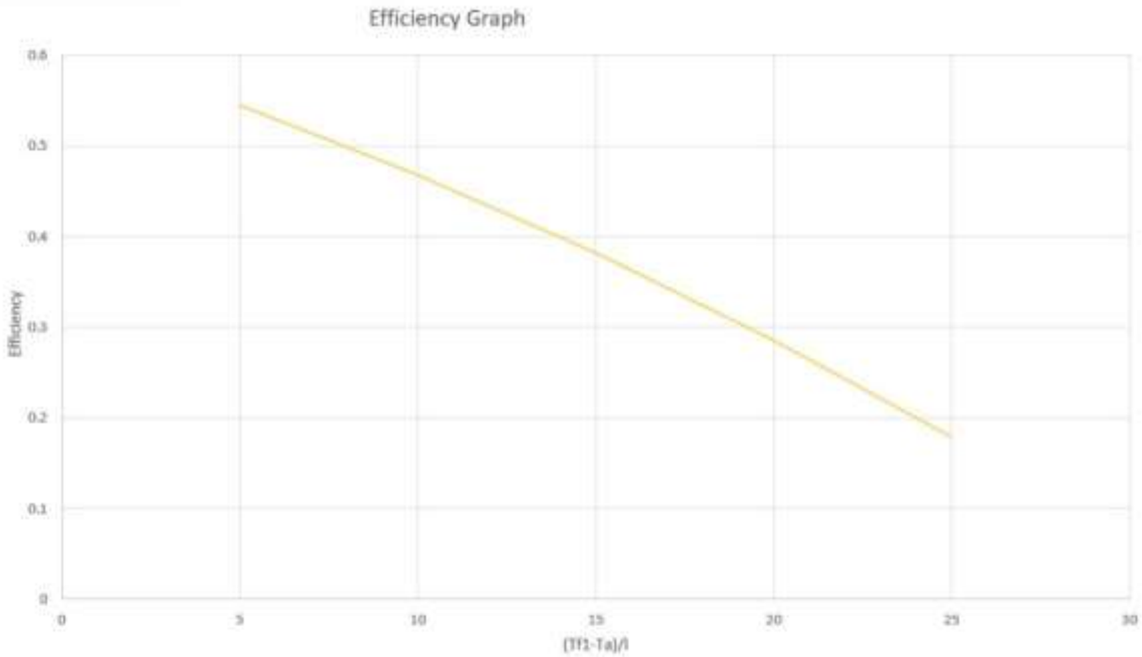

Fig.3. Efficiency Graph at Radiation level of 300 W/m^2.

Fig.3. shows the relation between Efficiency and variations in solar radiation falls on the flat plate collector at various ambient conditions. Graph plot on the basis of the result from the experimental calculation, in which maximum efficiency start from 55% which is decreased up to 19%. These experiments performed at high radiation level at 300 W/m^2 which is set according to the experimental setup and get efficiency up to maximize level.

Wind speed (v): 3.4 m/s
Ambient Temperature (T_a): 30^{0}C
Radiation level (I): 160 W/m^2
Water mass flow rate (m.): 0.06800 kg/sec

S. no.	U_t	Ue	U_b	U_l	F_R	Effi.
1.	3.2670	0.354	0.8	4.421024	0.6935	0.5863
2.	3.2586	0.354	0.8	4.412624	0.4850	0.4328
3.	3.2530	0.354	0.8	4.407017	0.3421	0.3093
4.	3.2684	0.354	0.8	4.422484	0.1703	0.1942
5.	3.2849	0.354	0.8	4.438938	0.0599	0.0790

Table 3. Observation for Efficiency and all Heat Loss Coefficient at varying varying Other Parameter.

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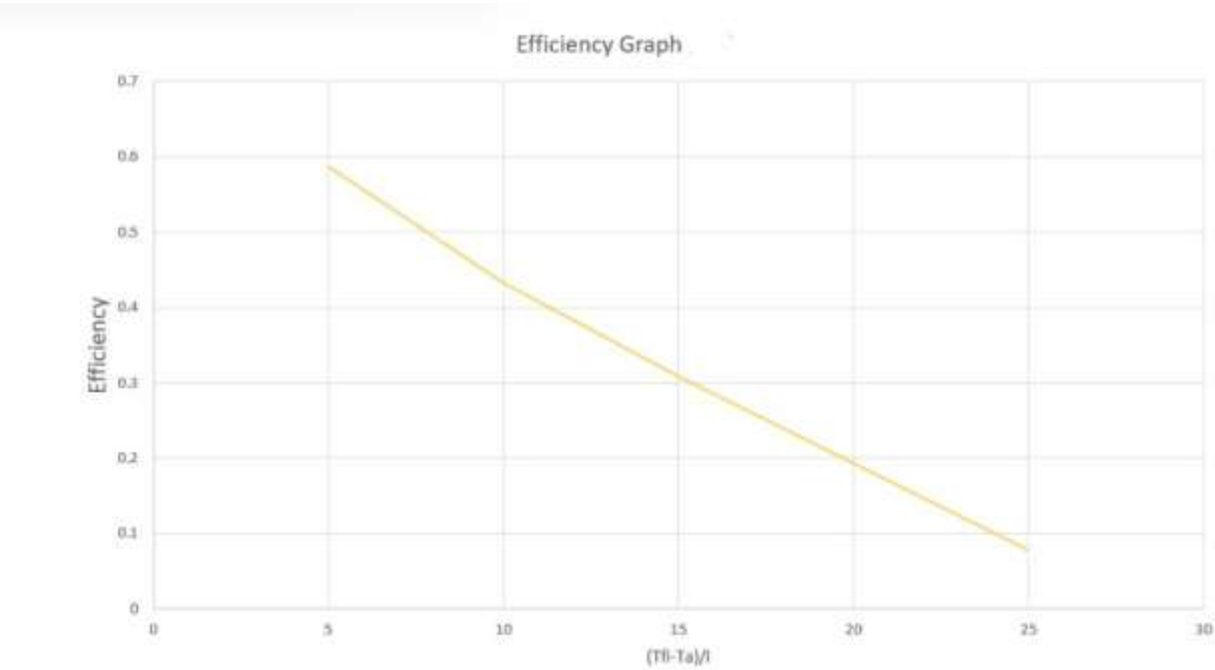

Fig.4. Efficiency Graph for different Radiation levels.

Fig.4. shows the relation between Efficiency and variations in solar radiation falls on the flat plate collector at various ambient conditions. Graph plot on the basis of the result from the experimental calculation, in which maximum efficiency start from 58% which is decreased up to 8%. These experiments performed at high radiation level at 160 W/m^2 which is set according to the experimental setup and get efficiency up to maximize level.

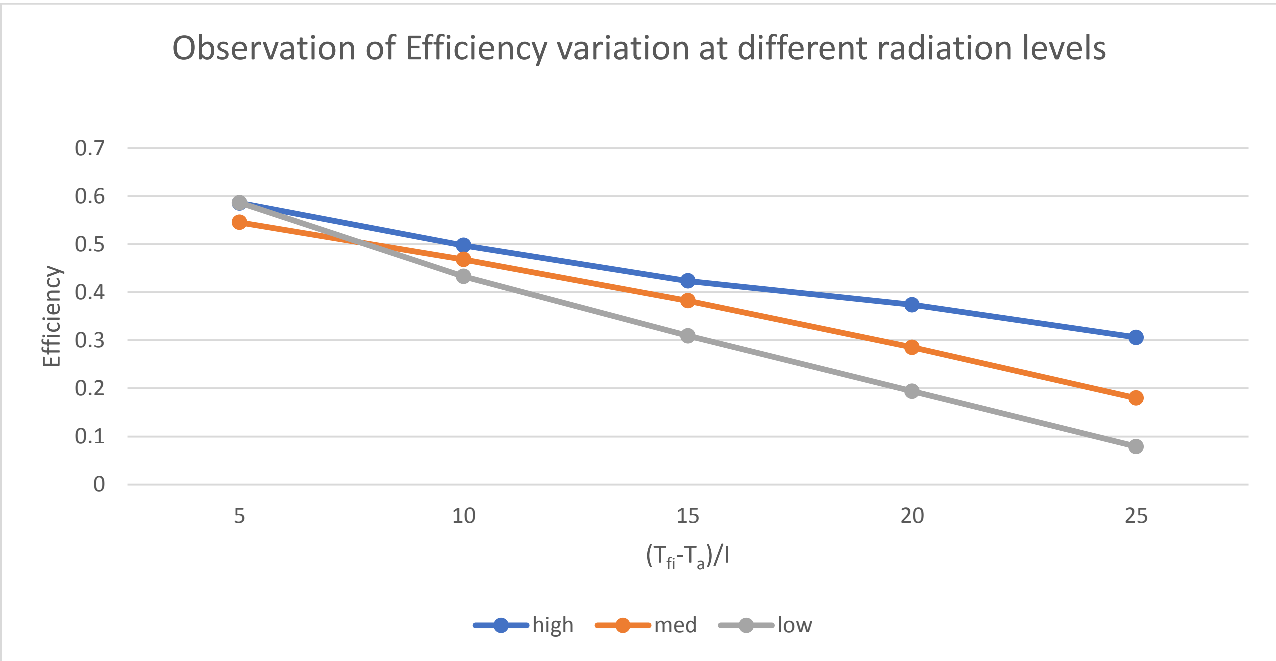

Fig 5. Comparative efficiency graph at various radiation levels.

In the graph value of **high** is 597 W/m^2, **med** is 300 W/m^2 and **low** is 160 W/m^2.

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RESULT AND DISCUSSION

The experimental Setup has given optimized results to understand the effect of heat transfer variables for the study of solar heat collectors. As in Fig.1. we can conclude that when the solar collector plate is parallel to the source of radiation, almost all the radiation falls perfectly which results is least loss of heat between the collector fluid its convective environment and the loss through conduction in raising the plate temperature which do not take part in increasing the temperature of fluid flowing through the collector.

The variation in the solar radiation shows as shown in Fig.4. and the data is collected in Tablas that up to a particular radiation Level can be differentiated and conclude Efficiency is maximum at high radiation Level from 68% to 30%, that means variation in Efficiency is Minimum at high radiation Level, but if we talk about other radiation Level like medium radiation is 300 W/m^2, variation in Efficiency from 55% to 18% which just similer to high radiation Level but in the case of low radiation level Efficiency from 58% to 8%, which is huge difference, that can be conclude low radiation level is not desirable for proper human comfort at any level, variation in Efficiency with the solar radiation may effect the entire system of the solar water heater system, and uneven Outputs makes the system less usefull of Solar energy.

Nomenclature

Ac	:	collector's area = 0.74115m^2
Ae	:	edge's area = 0.32775 m^2
C_P	:	Sp. Heat of water = 4180 Joule/kg-^oK
I_t	:	Radiation received on the collector (W/m^2)
k_b	:	back insulation conductivity = 0.04 W/m-K
k_e	:	edge insulation conductivity (W/m-K)
m	:	mass flow rate of water (kg/sec)
N	:	Number of glass cover = 1
T_a	:	atmospheric temperature (^{0}C)
T_p	:	temperature of plate (^{0}C)
U_t	:	heat loss coefficient from top (W/m^{2}K)
U_b	:	heat loss coefficient from bottom (W/m^{2}K)
U_e	:	heat loss coefficient from edge (W/m^{2}K)
U_b	:	constant for experiment
U_e	:	constant for experiment
V	:	velocity of wind (m/sec)
x_b	:	thickness of back insulation = 0.05 mm
x_e	:	thickness of edge insulation = 25 mm
τ_0	:	glass cover Transmissivity = 0.85
α_0	:	absorbing plate Absorptivity = 0.96
ε_p	:	absorbing plate Emissivity = 0.12
ε_g	:	glass cover Emissivity = 0.88
σ	:	constant of Stephen Boltzmann = 5.67 x 10-8 W/m^2 $^-$K^4
β	:	collector's tilt angle (degree)

In the experiments following parameters are taken for the analysis to get optimized results and minimize heat losses with the help of experimental setup in the Laboratory.

- Wind Flow speed in m/sec
- Solar Radiation Intensity (I_t) in W/m^2
- Ambient Temperature of Collector surface in ^{0}C
- Temperature of Inlet Water at Collector (T_{fi}) in ^{0}C
- Temperature of Outlet Water at Collector (T_{fo}) in ^{0}C
- Tank Storage Temperature (T_s) in ^{0}C
- Heat loss factor, (U_{Loss}) in watt/meter^2.

CONCLUSION

Based on the results and outputs of our experiments, the plotted graphs are able to describe, when the solar irradiance is high, which is taken by us is 597 W/m2 and moderate whose value is 300 W/m2, flowing Sufficiently to transfer heat to water and at the same time, it gives better efficiency at minimum variation level except for low radiation level. The difference in efficiency is greater in low radiation levels but both high and medium radiation levels are desirable for the system to work.

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