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Incandescent Light Radiation On A Flat Plat Collector With Variation Inlet Water Temperature

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Abstract—Collector flat plates used to heat water. Heat captured by using radiation falling on the surface of a glass cover, some directly reflected some absorbed and continued to plate absorbent. The purpose of this research to determine the efficiency of the collector by heating inlet water temperature effect. Research conducted lights intensity 1000 W/ m^2 distance 25 cm to collector by four-warming inlet water temperature 30 ºC, 40 ºC, 50 ºC, 60 ºC, at flow rate 0.6 L/min, 0.8 L/min, and 1 L/min. These research results show warming inlet water temperature causing a rate total heat loss increased with useful energy obtained reduced, so efficiency decline, average efficiency collector acquired was, a flow rate 0.6 L/min, Tin 30.1 ºC; η 41.56 %, Tin 40.0 ºC; η 34.79 %, Tin 50.1 ºC; η 26.59 %, Tin 60.1 ºC; η 17.21 %, a flow rate 0.8 L/min, Tin 30.1 ºC; η 39.79 %, Tin 40.0 ºC; η 32.56 %, Tin 50.1 ºC; η 23.94 %, Tin 60.3 ºC; η 13.74 %, and a flow rate 1 L/min, Tin 30.1 ºC; η 36.99 %, Tin 40.0 ºC; η 29.52 %, Tin 50.2 ºC; η 20.97 %, Tin 60.1 ºC; η 11.56 %.

Index Terms—Discharge, efficiency, flat plate collector, heat transfer, inlet water temperature warming, test light, rate total heat loss, useful energy.

1 Introduction

There are many types of energy sources in the world that has obtained from various energy sources such as wind, sunlight, and fossils. Changes in various energy sources can produce electricity for lighting. In general, reaction to the lamp causes heat transfer in radiation. Heat energy can be used as one of the uses of heat energy to heat water. Utilizing the heat energy required by the device as a collector of heat energy, the heat energy is converted into useful heat energy, the device is a collector. Collector used, change heat directly to produce heat. Collector water heater, catch heat and heat water temperate regions low flows through a pipe are arranged in a collector, and be held in storage tanks isolated. Method flat-plate collectors capture heat by utilizing radiation falling on the surface of a glass cover, partly directly reflected, then partly passed on and absorbed into an absorbent plate. Radiation absorber plate to be absorbed heat to use working fluid for passing through the collector [1].

In winter or dry season, a stream has elevated temperatures used protect collector to corrosion cold temperatures and excess heat. Circulation pipe collector useful to drain fluid from bottom to the top of a collector, model circulation parallel pipe tend used for the middle of pipe having lower value fluid flow. Known a lot of heat energy collected there, large flow rate by a broad cross-section of pipe used so that the burden for ventilating the flow or do not need a pump to the circulation [2]. Research collector a small scale with the selective invalidation based on testing benchtop in a plate of collector artificial in a low-pressure room show solar input system simulated about 800 W/m², temperature plate collector 298 K in ambient temperature to 388 K in a vacuum [3]. henceforth solar collector absorption various layers tested and evaluated by studying useful heat to produce hot water, using a simulated radiation 400 W/m², 550 W/m² and 700 W/m², position angle 0º, 45º and 90º, shows solar collector on solar simulator work optimally at an angle of 45 with values of different radiation intensities [4]. Another study using a double lamp construction simulation to know performance of a solar collector. Metal halid lamps used as radiation sources, average radiation is 790 W/m² a distance of 1 m from lamp. Radiation stability and not uniform from solar simulator for testing is 0.8 % respectively and 12.34 % [5]. Further research designed for PV simulation to simulate the intensity of the Sun with the intensity and spectrum, measurements carried out to calibrate the simulator including uniformity measurement of light intensity distribution and degree of light collimation. In the beginning, measurements of one single lamp were conducted to see its light uniformity in different rotation angles of the lamp lens and next tests for 4 lamps and 20 lamps were carried out to map the illumination intensity of the simulator. It is important to mention that, understanding the performance, limitations and strengths of solar simulation equipment can lead to more effective and more reliable test results [11].

In other techniques use four-color lights, and a distance between solar cells and light sources is modified adapting to radiation values. They get high radiation applying high pulses voltage to LED. The results of the red and blue LED simulators are in good agreement using the IEC 891 Standard correction method [5, 12]. The next research method uses 1000W halogen lamps as a heat source simulates solar radiation on the Stirling engine. They have measured radiation intensity at various distances to evaluate the performance of their solar simulators [5, 13]. In one study carried out, 400W and 1000W halogen lamps as source heat have been used to assess beta type performance Stirling machines that work at relatively lower temperatures. The temperature of the cavity adjacent to the hot end of the Stirling engine cylinder displacement has been determined to be around 623 K and 873 K for each halogen lamp 400 W and 1000 W [5, 14].

From this case that to obtain direct solar radiation intensity is very difficult due to uncertain climate change. Testing collectors in a room with simulators more preferable. Generally, indoor simulations use a type of lamp that approaches the solar spectrum mounted far away from the collector, for this reason, the study uses a type of incandescent lamp that shows the light source produced through the filament heats up and then produces light other than that is relatively inexpensive and easily obtainable. The use of this lamp is a method based on radiation from a lamp that can be adjusted and which remains constant.

2 Analysis of Heat Transfer on a Flat Plate Collector

Radiation passes through glass cover heats the absorber plates then heat from absorber plate to heat fluid in collector pipes. This applies to one glass cover are used. In a steady state to heat loss from plate to cover glass is the same as a cover glass to the surrounding environment so that it can write in energy balance equation is established on a flat-plate collector as follows [7].

$$S \times Ap = qu + qL \quad (1)$$

The magnitude of heat which transferred to working fluid is calculated based on the following relationships [6].

$$qu = \dot{m} \times Cp \times (T_{f,o} - T_{f,i}) \quad (2)$$

Now with the approach of an equation for a flux of light and diffuse radiation is obtained by formula approach to flux incident on a surface of the top cover can be determined [7].

$$I_T = I_b R_b + I_d R_d + (I_b + I_d) I_r \quad (3)$$

The transmittance, reflectance, and absorption are functions of the incoming radiation, thickness, refractive index, and extinction coefficient of the material *K*. For our calculation, the cover material is glass, with different refractive indexes. From the solar flux available on the top surface of the transparent cover, depending upon the transmissivity of the cover, there is a reduction in the solar flux that reaches the plate surface. For transmissivity, by reflection and absorption, the transmissivity-absorptivity product for beam radiation is calculated by considering the solar incidence angle as the angle of incidence, which substituted in Snell's law [10].

$$\sin\theta_1 / \sin\theta_2 = n_2 / n_1 \quad (4)$$

Here for beam radiation $\theta_1 = \theta_2$, and n_2/n_1 represents the refractive index value, thus from the above equation, can be found. Consider

$$\rho = \sin^2(\theta_2 - \theta_1) / \sin^2(\theta_2 + \theta_1) \quad (5)$$

ρ is reflectivities of components polarisation, using which the transmissivity found.

$$\tau r = 1/2 \times (1 - \rho / 1 + (2M - 1)\rho) \quad (6)$$

Formula above continuity based on reflection and refraction, M representing the amount of cover, which is an essential parameter for continuity. Consider

$$\tau a = e^{-K\delta_c / \cos\theta_2} \quad (7)$$

Above equation is used to determine continuity based on the absorption, here *K* indicated the extinction coefficient, which is a material property, and δc represents the thickness of transparent cover. The continuity of the system cover the collector can be obtained sufficient accuracy by considering reflection-refraction and absorption of separately and given by the form of product

$$\tau = \tau_a \cdot \tau_r \quad (8)$$

The transmissivity-absorptivity product is to calculated, which defined as a ratio of flux absorbed in the absorber plate to the flux incident on the cover, and it varies, respectively, for beam and diffused radiation.

$$(\tau\alpha)_b = \tau\alpha / 1 - (1 - \alpha)\rho_b \quad (9)$$

Thus with approaches in absorbent plates on radiation equation with Diffusion and eliminate the assumption that the efficacy of radiation is the radiation directly from lights, so radiation is absorbed by absorber collector area of S is equal to a difference between incident radiation and optical loss and is given by expression.

$$S = (I_T \cdot (\tau\alpha_b)) + (I_T \cdot (R_r)) \quad (10)$$

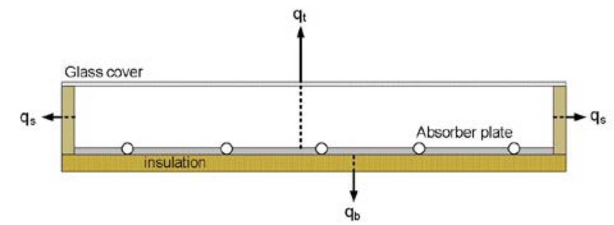

Fig. 1. Rate of total heat loss.

In the fig 1 shows, total heat loss rate that occurs, the basis for calculating the overall heat loss given from the following equation.

$$qL = qt + qb + qs \quad (11)$$

The rate of heat loss on the top of which is determined based on the rate of heat loss by convection and radiation leads to the top of the absorber plate to the cover glass and glass-front glass into the environment in the following equation with illustrations fig 2.

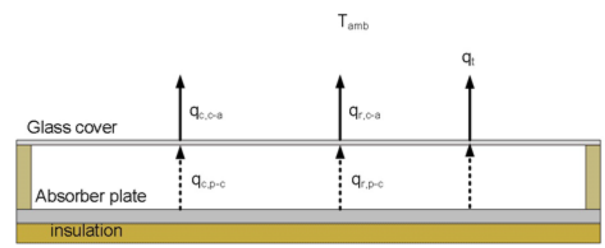

Fig. 2. Rate of heat loss at the top.

$$qt = Ap\left[h_c (T_{c(avg)} - T_{amb}) + \sigma\varepsilon_c (T^4_{c(avg)} - T^4_{amb})\right]$$
$$qt = Ap\left[h_c (T_{p(avg)} - T_{c(avg)} + \left(\sigma\left(T^4_{p(avg)} - T^4_{c(avg)} / \left(1/\varepsilon_p + 1/\varepsilon_c\right) - 1\right)\right)\right] \quad (12)$$

Now the only known is a term that means the temperature of the plates can get the formula above. After discovering temperatures mean dishes, a variety of losses, such as convection, and radiation losses come into account, and by the top, bottom, and sides of the heat loss of the overall heat transfer on initial steps can be true. After Discovering temperatures, Absorber means to calculate the rate of heat loss over the closing temperature should base on the average temperature, $T_{p(avg)}$, ie temperature plate and ambient temperature T_{amb}. On top of losing, convection and radiation losses found, between the plates and cover. Similarly, there is the loss of heat by convection and radiation between ambient and cover can be obtained with measures that have been outlined above [9].

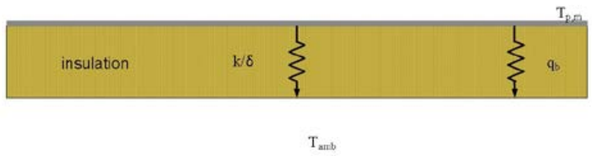

Fig. 3. Rate heat loss at the bottom.

The following is the rate of heat loss in the bottom of the collector who expressed show on fig 3 acquired from the following equation [7].

$$qb = K_{insulation} \cdot (Ap(T_{p(avg)} - T_{amb}) / \delta_{insulation} \tag{13}$$

Formula $h_{c,p-c}$ is calculated using Nusselts number, where the value for air properties taken from heat transfer book, for mean temperature $(T_{p(avg)}+T_{c(avg)})/2$ [8]

Here,

$$Gr_L = g \cdot \beta(T_{p(avg)} - T_{c(avg)} \cdot L^3 / v^2 \tag{14}$$

Based on the above equation, the equation for Rayleigh number taken, on the state of free convection.

$$Ra_L = Gr_L \times \Pr \tag{15}$$

Empirical Nusselt numbers approach happens free-convection between the plates with glass cover.

$$Nu = 0{,}54 \cdot Ra_L^{1/4} \tag{16}$$

Now with a useful heat value of thermal efficiency of a flat-plate collector is calculated with the following equation.

$$qu = Ap \cdot S - qL \tag{17}$$

Next collector Efficiency is obtained based on the equation below

$$\eta = qu / Ap \times I_T = Ap \cdot S - qL / Ap \times I_T \tag{18}$$

A procedure above is used to calculate the efficiency of a col-lector on research.

3 Experiment Method

The design equipment and test points used presented in the fig 4. Some water heater collector materials with the following sizes are length (L) = 1000 mm, width (W) = 640 mm, and height (H) = 80 mm. Flat plate, absorber length of aluminum (L) 980 mm, width (W) 640 mm and thickness of plate 1.2 mm, pipe designed parallel to the length of copper material (L) = 1200 mm pipe, 0.8 mm thick, and diameter 0.5 inches. The test lamp is placed parallel to the collector, a distance of 25 cm.

This testing a done that a lamp operates stably after 30 min, following the steps in the tests carried out between them, adjusting the flow rate of the incoming water tested. Furthermore, it regulates the temperature of the incoming water in four inlet liquid temperatures (Tf, i), each (30 °C, 40 °C, 50 °C, 60 °C) with a controlled thermostat which maintained at a fixed condition. This test is carried out after the output temperature (Tf,o) is stable by setting the light intensity using the SCR dimmer regulator at the beginning and end of the test, the small scale value of tool used is 1 W/m².

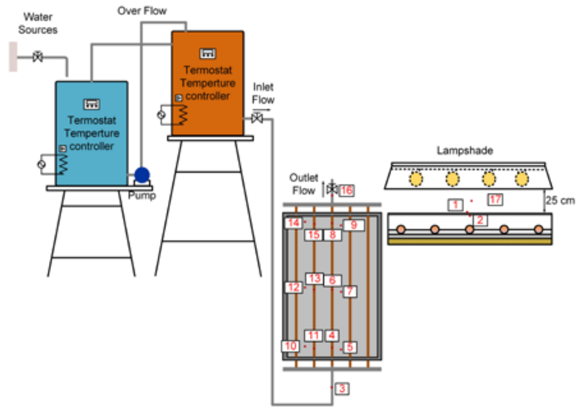

Fig. 4. Design tools and measurement point.

Description:

1. Outside glass temperature (T1)
2. Inner glass temperature (T2)
3. Inlet water temperature (T3)
4. Temperature plates and pipes (T5-T14)
5. Outlet water temperature (T16)
6. Temperature between collector-lamps (T17)
7. Fluid temperature shelter (T18)

4 Result and Discussion

This flat plate collector made of aluminum which is bent by a plate using a wooden block made of grooves, the outer casing is made of slippery zinc formed using a bending machine on the sides. The collector cover uses frosted glass with a thickness of 5 mm glass cover. After that, the insulator used made of polyurethane foam with a thickness of 2 cm side section and 3 cm bottom. The next is making five heating pipes made of copper with the parallel flow and the distance between the heating pipes is 10 cm. when flat plate collector has completed a section flow test is carried out to determine whether there is a leak in the heating pipe. Based on research conducted by (Gallardo et.al., 2013) efficiency factors for parallel flow flat plate collectors. One of the results of his study is that the efficiency of the centered in the plate type collector is better than the tubes on top of a plate and tubes under a flat plate. Other research conducted by (Zulfa, 2017) parallel flow collector with vertical pipe arrangement has the best performance in terms of heat loss coefficient and efficiency but has a higher pressure drop value compared to horizontal arrangement collector. Collectors that use glass covers and collectors with smaller mass flow rates have the best performance in terms of heat loss coefficients and efficiency. Performance of parallel flow solar water heater with natural circulation in Nigeria. The research results show that the thermal efficiency of the collector influenced by the mass flow rate and the intensity of solar radiation where the highest efficiency obtained during the day with an optimum flow rate of 0.1 kg/s (Bolaji, 2006).

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Examined the thermal performance of flat plate solar collectors with bent plates according to the shape / roll-bond size of the pipe used compared to flat plates that are not bent. The results showed that the efficiency of flat plates bent according to the shape of the pipe was better than the flat plates that were not bent (Davide Del Col et.al., 2013).

The performance of the collector depends on the heat absorbed, the higher the heat absorbed, the better the performance of the collector is that the collector performance has a linear relationship with the intensity received, heat absorbed and heat loss released in this case all loss occur. To optimize and test the performance of the collector working fluid is needed at a constant temperature. But need to know in advance the collector working temperature used. Flat plate solar collectors have an output temperature below 95 °C. In its application, a flat plate collector is used to heat air and water (Gosmawi, 1999). Heating the inlet water temperature is done to test the performance of a collector that been made. The test carried out was using experimental incandescent lamps, at flow rates of 0.6 L/min, 0.8 L/min, and 1 L/min, the intensity of incandescent lamps measured at 1000 W/m², arranged at an angle of 0° parallel to a collector, test do out until outlet water temperature is less than 0.5 °C, which is at 135 min in each test.

Experiments using test lamps show the intensity of the lamp paralell on the absorber plate. Thus the heat collected will be high, and it can conclude that there is a linear relationship between the absorbent plate area and the useful heat (qu) [4], so higher the heat released by absorber plate causes totalheat loss increase. This section explains the tests carried out to see the effect of incoming water temperature with a flow rate of 0.6 L/min, 0.8 L/min and 1 L/min, at 30 °C, 40 °C, 50 °C, 60 °C. Results of data test, on the slope of the parallel angle, causes a higher intensity to be reflected. The next effect of inlet temperature, total heat, increases significantly at the collector, the heat release by working fluid through the collector increase then the absorption will decrease with the thermal efficiency of the collector. The values can discuss in the table.

TABLE 1

THE RESULT OF TEST INLET WATER TEMPERATURE AT FLOW RATE 0.6 L/MIN

Temperature 30 °C at mass flow rate 0.6 L/minute

Time Min	Temp In [°C]	Temp Out [°C]	Tamb [°C]	Temp Plate [°C]	Temp Cover [°C]	qL Watt	qu Thermal Watt	Thermal Performance %
15	30.2	35.4	39.5	47.2	42.0	65.997	216.564	38.67
30	30.2	35.4	39.8	47.3	42.0	64.045	218.516	39.02
45	30.2	35.6	40.4	47.4	42.0	56.208	226.353	40.42
60	30.1	35.6	41.6	47.5	44.0	52.968	229.593	41.00
75	30.1	35.8	42.1	47.5	44.0	46.510	236.051	42.15
90	30.1	35.8	42.4	47.8	44.0	45.131	237.429	42.40
105	30.1	35.8	43.5	47.9	46.0	43.591	238.969	42.67
120	30.1	36.0	44.1	48.1	46.0	36.956	245.605	43.86
135	30.1	36.0	44.2	48.3	46.0	36.834	245.726	43.88
Ave	30.1	35.7	42.0	47.7	44.0	49.804	232.756	41.56

Temperature 40 °C at mass flow rate 0.6 L/minute

Time Min	Temp In [°C]	Temp Out [°C]	Tamb [°C]	Temp Plate [°C]	Temp Cover [°C]	qL Watt	qu Thermal Watt	Thermal Performance %
15	40.0	44.4	43.9	53.8	49.0	101.382	181.178	32.35
30	40.0	44.4	44.0	53.9	49.0	100.163	182.398	32.57
45	40.1	44.6	44.4	53.9	49.0	94.643	187.918	33.56
60	40.0	44.6	45.8	54.3	51.0	91.725	190.835	34.08
75	40.1	44.8	46.4	54.6	51.0	85.905	196.655	35.12
90	40.0	44.8	46.5	54.6	51.0	84.522	198.038	35.36
105	40.0	44.9	47.9	54.8	53.0	80.468	202.092	36.09
120	40.0	45.0	48.3	54.9	53.0	76.039	206.521	36.88
135	40.0	45.0	48.5	55.2	53.0	74.833	207.728	37.09
Ave	40.0	44.7	46.2	54.4	51.0	87.742	194.818	34.79

Temperature 50 °C at mass flow rate 0.6 L/minute

Time Min	Temp In [°C]	Temp Out [°C]	Tamb [°C]	Temp Plate [°C]	Temp Cover [°C]	qL Watt	qu Thermal Watt	Thermal Performance %
15	50.1	53.4	49.0	61.8	57.0	147.371	135.190	24.14
30	50.1	53.4	49.3	62.1	57.0	145.685	136.875	24.44
45	50.2	53.6	49.7	62.2	57.0	140.333	142.227	25.40
60	50.1	53.6	50.9	62.3	59.0	138.807	143.754	25.67
75	50.2	53.8	51.4	62.3	59.0	132.201	150.359	26.85
90	50.1	53.8	51.6	62.4	59.0	129.390	153.171	27.35
105	50.1	53.8	52.8	62.7	61.0	128.209	154.352	27.56
120	50.1	54.0	53.3	62.7	61.0	121.208	161.352	28.81
135	50.1	54.0	53.4	62.7	61.0	119.728	162.832	29.08
Ave	50.1	53.7	51.3	62.3	59.0	133.659	148.901	26.59

Temperature 60 °C at mass flow rate 0.6 L/minute

Time Min	Temp In [°C]	Temp Out [°C]	Tamb [°C]	Temp Plate [°C]	Temp Cover [°C]	qL Watt	qu Thermal Watt	Thermal Performance %
15	60.2	62.1	52.9	70.3	63.0	203.662	78.899	14.09
30	60.2	62.2	53.3	70.6	63.0	199.568	82.992	14.82
45	60.1	62.2	53.7	70.6	63.0	194.318	88.242	15.76
60	60.1	62.4	55.1	70.7	65.0	188.772	93.788	16.75
75	60.0	62.4	55.4	70.7	65.0	184.989	97.571	17.42
90	60.1	62.6	55.8	71.0	65.0	180.525	102.036	18.22
105	60.1	62.6	57.0	71.1	67.0	178.190	104.371	18.64
120	60.2	62.8	57.3	71.1	67.0	173.612	108.949	19.46
135	60.1	62.8	57.4	71.1	67.0	172.086	110.474	19.73
Ave	60.1	62.5	55.3	70.8	65.0	186.19	96.369	17.21

4.1 The flow rate at 0.6 L/min

The flow rate at 0.6 L/min, in each inlet water temperature has increased at the temperature of the collector plate, when the warming effect of the inlet water temperature has increased, the heat release by free convection and radiation occurs on the working fluid flowing on the heating pipes of the heating pipe towards the absorbent plate then the cover glass goes to the surrounding environment, this event causes a loss of the collector's upper part to increase so that it causes an increase in the ambient temperature around the collector.

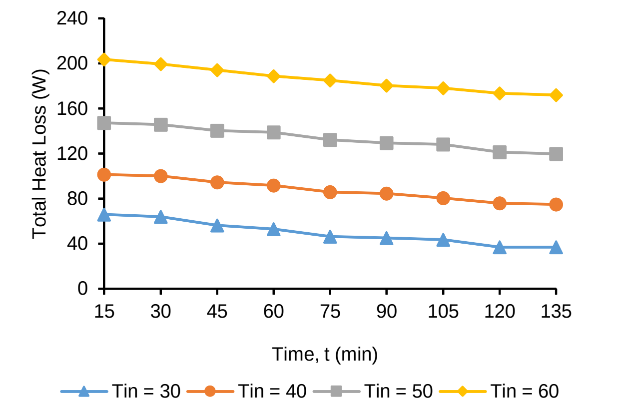

Fig. 5. Total heat loss (qL), at flow rate (Q) = 0.6 L/min.

Fig. 5. Performances, the total heat loss of 0.6 L/min, occurs at the top, side, and bottom of the collector. Losses tend to decrease because heat absorption occurs in the working fluid through the collector, while the inlet warming temperature causes total heat loss to increase, equal to 36.834 W reaching 172.086 W. The higher the absorption rate, the lower the total heat loss that occurs this can see inlet water temperature at 30oC with which decreases from 65.997 W to 36.834 W compared to the inlet water temperature at 60 ºC which reduces by 203.662 W to 172.086 W. Inlet water temperatures 40 ºC and 50 ºC experience the same thing with different values.

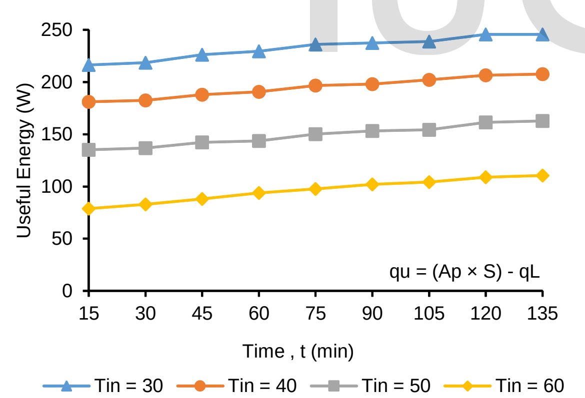

Fig. 6. Useful energy (qu), at flow rate (Q) = 0.6 L/min.

Fig. 6. The show, when the effect of inlet water temperature at 30 ºC, useful energy obtained increases from 216.564 W, the useful energy increases in 135 minutes by 245.726 W, while at 40ºC it decreases by 207.728 W. Absorption starts it looks downward, at the inlet water temperature of 50 ºC, useful energy absorbed by working fluid is getting a reduction of 135.190 W to 162.832 W, then at inlet water temperature of 60 ºC, it can be seen that the useful energy decreases significantly compared to the inlet temperature of 30 ºC to 50 ºC, this is because the effect of the temperature of inlet water has increased so that the absorption that occurs in working fluid through the collector decreases.

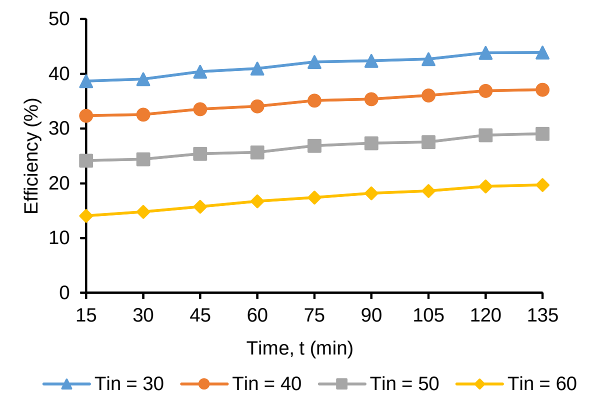

Fig. 7. Thermal efficiency (%), at flow rate (Q) = 0.6 L/min.

Fig. 7. Efficiency shows obtained from a flow rate of 0.6 L/min have increased at inlet water temperature 30 ºC of 43.88%, however, has decreased at an inlet water temperature of 40 ºC of 37.09%. Furthermore, a fairly sharp decrease was experienced at the inlet water temperature of 50 ºC and 60 ºC, a considerable reduced in collector performance at a water temperature of 60 ºC of 19.73%.

TABLE 2

THE RESULT OF TEST INLET WATER TEMPERATURE AT FLOW RATE 0.8 L/MIN

Temperature 30 ºC at mass flow rate 0.8 L/minute								
Time	Temp		Tamb	Temp	Temp	qL	qu	Thermal
	In	Out		Plate	Cover		Thermal	Performance
Min	[ºC]	[ºC]	[ºC]	[ºC]	[ºC]	Watt	Watt	%
15	30.1	33.8	38.9	47.8	42.0	78.456	204.104	36.45
30	30.0	33.8	39.3	47.8	42.0	73.249	209.312	37.38
45	30.1	34.0	39.9	47.9	42.0	67.446	215.114	38.41
60	30.1	34.0	41.1	48.1	44.0	63.550	219.010	39.11
75	30.1	34.2	41.7	48.2	44.0	56.539	226.021	40.36
90	30.1	34.2	41.9	48.2	44.0	54.598	227.963	40.71
105	30.2	34.4	43.3	48.2	46.0	48.893	233.668	41.73
120	30.2	34.4	43.4	48.3	46.0	47.302	235.259	42.01
135	30.2	34.4	43.5	48.5	46.0	47.485	235.075	41.98
Ave	30.1	34.1	41.4	48.1	44.0	59.724	222.836	39.79

Temperature 40 ºC at mass flow rate 0.8 L/minute								
Time	Temp		Tamb	Temp	Temp	qL	qu	Thermal
	In	Out		Plate	Cover		Thermal	Performance
Min	[ºC]	[ºC]	[ºC]	[ºC]	[ºC]	Watt	Watt	%
15	40.1	43.0	43.0	54.8	49.0	120.977	161.584	28.85
30	40.0	43.0	43.4	55.0	49.0	117.162	165.399	29.54
45	40.1	43.2	43.9	55.1	49.0	110.667	171.894	30.70
60	40.0	43.2	45.3	55.1	51.0	104.958	177.603	31.71
75	40.1	43.4	45.8	55.1	51.0	98.010	184.551	32.96
90	40.0	43.4	46.2	55.3	51.0	93.737	188.823	33.72
105	40.0	43.5	47.6	55.3	53.0	88.272	194.288	34.69
120	40.0	43.6	47.9	55.4	53.0	84.861	197.700	35.30
135	40.0	43.6	48.0	55.4	53.0	83.456	199.105	35.55
Ave	40.0	43.3	45.7	55.2	51.0	100.233	182.327	32.56

Temperature 50 °C at mass flow rate 0.8 L/minute								
Time	Temp		Tamb	Temp Plate	Temp Cover	qL	qu Thermal	Thermal Performance
Min	In	Out						
	[°C]	[°C]	[°C]	[°C]	[°C]	Watt	Watt	%
15	50.1	52.2	48.3	63.0	57.0	168.099	114.461	20.44
30	50.1	52.2	48.5	63.0	57.0	164.477	118.084	21.09
45	50.1	52.4	49.0	63.1	57.0	157.685	124.876	22.30
60	50.1	52.4	50.3	63.1	59.0	154.118	128.443	22.94
75	50.1	52.6	50.9	63.2	59.0	146.486	136.075	24.30
90	50.1	52.6	51.1	63.2	59.0	142.816	139.744	24.95
105	50.1	52.8	52.6	63.3	61.0	135.710	146.850	26.22
120	50.1	52.8	52.8	63.3	61.0	133.903	148.657	26.55
135	50.1	52.8	52.9	63.4	61.0	133.260	149.301	26.66
Ave	50.1	52.5	50.7	63.2	59.0	148.506	134.055	23.94

Temperature 60 °C at mass flow rate 0.8 L/minute								
Time	Temp		Tamb	Temp Plate	Temp Cover	qL	qu Thermal	Thermal Performance
Min	In	Out						
	[°C]	[°C]	[°C]	[°C]	[°C]	Watt	Watt	%
15	60.4	61.4	52.4	71.8	63.0	224.957	57.604	10.29
30	60.3	61.4	52.5	71.9	63.0	223.192	59.369	10.60
45	60.4	61.6	53.0	71.9	63.0	216.171	66.390	11.86
60	60.3	61.6	54.4	72.0	65.0	210.999	71.561	12.78
75	60.2	61.6	54.8	72.0	65.0	204.941	77.620	13.86
90	60.2	61.8	55.4	72.1	65.0	196.338	86.223	15.40
105	60.2	61.8	56.6	72.1	67.0	192.562	89.999	16.07
120	60.1	61.8	56.8	72.2	67.0	190.904	91.657	16.37
135	60.1	61.8	57.0	72.6	67.0	190.657	91.903	16.41
Ave	60.3	61.6	54.7	72.1	65.0	205.64	76.925	13.74

4.2 The flow rate at 0.8 L/min

Collectors with a flow rate of 0.8 L/min, tend to experience the same thing in each inlet temperature, namely the top loss rate which increases from a flow rate of 0.6 L/min, but the increase tends to be higher due to changes in flow rate, causing collector absorption diminishes.

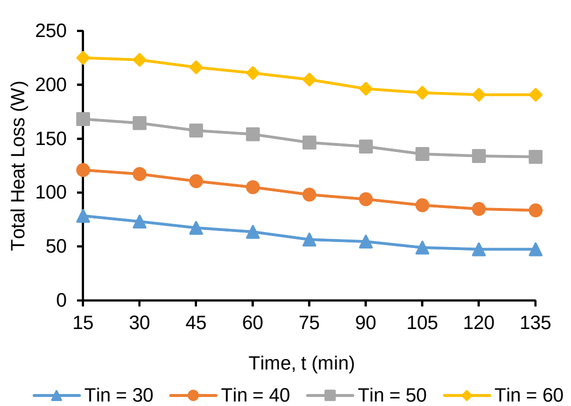

Fig. 8. Total heat loss (qL), at flow rate (Q) = 0.8 L/min.

Fig.8. Total heat loss at a flow rate of 0.8 L/min, compared with a flow rate of 0.6 L/min, increased by 190.657 W at an inlet water temperature of 60 °C, the greater flow rate flowing through the collector with the heat from the fluid passing through it. The higher level of temperature released from a fluid by causing an increase in temperature of the collector to cause a loss at top, bottom and side parts with a greater total loss.

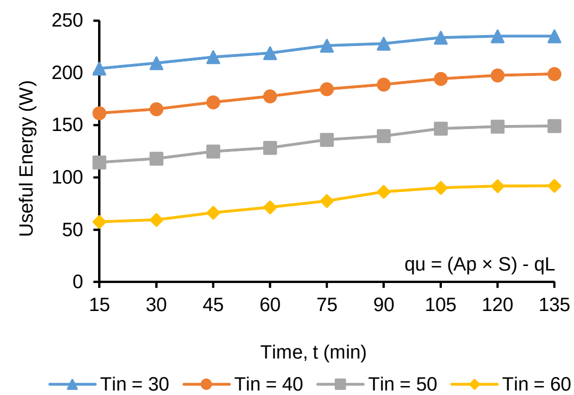

Fig. 9. Useful energy (qu), at flow rate (Q) = 0.8 L/min.

Fig. 9. Show, when there is useful energy absorption at the collector. Then heating the working fluid to the collector heating pipes. But effect of heating the water flowing on the collector heating pipes, causes the useful energy absorbed to decrease due to the working fluid on the pipe heating pipes participate in heating the absorbent plate so that the level of temperature of the collector is high with the acquisition of useful energy which reduced 91.903 W at the inlet water temperature of 60 °C.

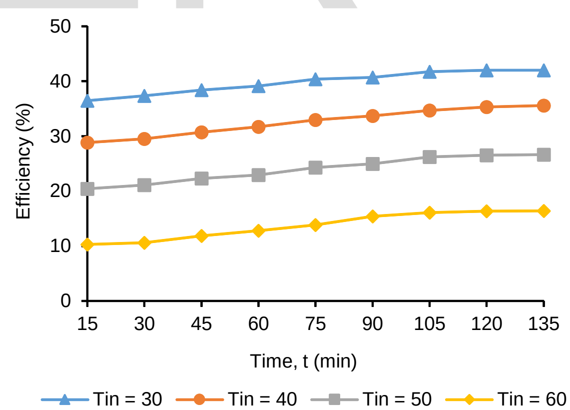

Fig. 10. Thermal efficiency (%), at flow rate (Q) = 0.8 L/min.

Fig. 10. shows the efficiency obtained a flow rate at 0.8 L/min. Efficiency that increases the inlet water temperature 30 °C after the lamp operates, at 36.45% to 41.98%. The efficiency increase is quite significant compared to the inlet water temperature at 40 °C, which only reaches 35.55% while at the inlet water temperature 50 °C looks lower at 26.66%. Furthermore, the inlet water temperature at 60 °C efficiency obtained, there was a sharp decline reaching 16.41%. This decrease is influenced by increased flow rate so that the useful energy reduced. Effect of the inlet water temperature on fig. causes a total heat loss from

working fluid to the environment around the collector.

4.3 The flow rate at 1 L/min

In the variation mass flow rate of 1 L/min, there is a considerable decrease from before, when a flow rate increases, the addition of heat from the fluid through the collector, due to the heat of the fluid, collector temperature increases with decrease useful energy and the total heat loss rate is increasing. more significant the collector flow rate, useful energy absorbed decreases, and inlet water temperature causes total heat loss to increase.

TABLE 3
THE RESULT OF TEST INLET WATER TEMPERATURE AT FLOW RATE 1 L/MIN

Temperature 30 °C at mass flow rate 1 L/minute								
Time	Temp		Tamb	Temp Plate	Temp Cover	qL	qu Thermal	Thermal Performance
Min	In	Out						
	[°C]	[°C]	[°C]	[°C]	[°C]	Watt	Watt	%
15	30.1	32.8	38.1	48.2	42.0	92.417	190.143	33.95
30	30.0	32.8	38.4	48.4	42.0	90.411	192.150	34.31
45	30.1	33.0	38.9	48.4	42.0	83.188	199.373	35.60
60	30.1	33.0	40.3	48.6	44.0	78.528	204.033	36.43
75	30.2	33.2	40.6	48.6	44.0	74.292	208.269	37.19
90	30.1	33.2	41.0	48.7	44.0	69.842	212.719	37.99
105	30.1	33.2	42.4	48.8	46.0	64.557	218.003	38.93
120	30.2	33.4	42.6	48.9	46.0	62.677	219.884	39.26
135	30.2	33.4	42.6	48.9	46.0	62.677	219.884	39.26
Ave	30.1	33.1	40.5	48.6	44.0	75.399	207.162	36.99

Temperature 40 °C at mass flow rate 1 L/minute								
Time	Temp		Tamb	Temp Plate	Temp Cover	qL	qu Thermal	Thermal Performance
Min	In	Out						
	[°C]	[°C]	[°C]	[°C]	[°C]	Watt	Watt	%
15	40.1	42.2	42.5	55.7	49.0	135.017	147.543	26.35
30	40.0	42.2	42.9	56.0	49.0	132.108	150.452	26.87
45	40.0	42.3	43.4	56.0	49.0	125.146	157.415	28.11
60	40.0	42.4	44.8	56.0	51.0	118.778	163.783	29.25
75	40.0	42.4	45.0	56.0	51.0	115.992	166.568	29.74
90	40.0	42.5	45.3	56.0	51.0	111.817	170.743	30.49
105	40.1	42.6	46.8	56.6	53.0	109.028	173.533	30.99
120	40.0	42.6	47.2	56.7	53.0	104.653	177.907	31.77
135	40.0	42.6	47.4	56.7	53.0	102.540	180.021	32.15
Ave	40.0	42.4	45.0	56.2	51.0	117.23	165.33	29.52

Temperature 50 °C at mass flow rate 1 L/minute								
Time	Temp		Tamb	Temp Plate	Temp Cover	qL	qu Thermal	Thermal Performance
Min	In	Out						
	[°C]	[°C]	[°C]	[°C]	[°C]	Watt	Watt	%
15	50.2	51.6	47.6	63.7	57.0	183.454	99.107	17.70
30	50.1	51.6	47.9	63.7	57.0	179.111	103.450	18.47
45	50.2	51.8	48.7	64.2	57.3	174.094	108.466	19.37
60	50.2	51.8	49.9	64.3	59.0	169.780	112.780	20.14
75	50.3	52.0	50.4	64.4	59.0	162.898	119.663	21.37
90	50.2	52.0	50.7	64.5	59.0	160.134	122.426	21.86
105	50.2	52.0	51.9	64.6	61.0	155.932	126.628	22.61
120	50.3	52.2	52.2	64.6	61.0	151.475	131.086	23.41
135	50.3	52.2	52.4	64.6	61.0	149.247	133.313	23.81
Ave	50.2	51.9	50.2	64.3	59.0	165.125	117.436	20.97

Temperature 60 °C at mass flow rate 1 L/minute								
Time	Temp		Tamb	Temp Plate	Temp Cover	qL	qu Thermal	Thermal Performance
Min	In	Out						
	[°C]	[°C]	[°C]	[°C]	[°C]	Watt	Watt	%
15	60.1	60.8	51.9	72.4	63.0	236.625	45.936	8.20
30	60.1	60.8	52.3	72.4	63.0	231.856	50.705	9.05
45	60.0	60.9	52.8	72.5	63.0	224.837	57.724	10.31
60	60.1	61.0	54.0	72.5	65.0	220.624	61.937	11.06
75	60.0	61.0	54.4	72.6	65.0	215.803	66.757	11.92
90	60.0	61.1	54.7	72.6	65.0	211.259	71.302	12.73
105	60.1	61.2	55.9	72.7	67.0	208.867	73.694	13.16
120	60.1	61.2	56.3	72.9	67.0	205.407	77.153	13.78
135	60.1	61.2	56.3	73.0	67.0	205.117	77.444	13.83
Ave	60.1	61.0	54.3	72.6	65.0	217.82	64.739	11.56

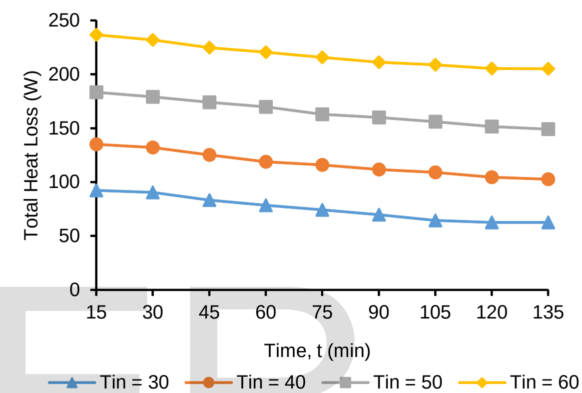

Fig. 11. Total heat loss (qL), at flow rate Q = 1 L/min.

Fig.11. Is a loss that occurs at the top, side, and bottom of the collector. This loss influenced by the heat factor of the working fluid which is involved in heating the collector pipes. This because the effect of inlet water temperature has increased so that the absorption that occurs in the working fluid through the collector reduced.

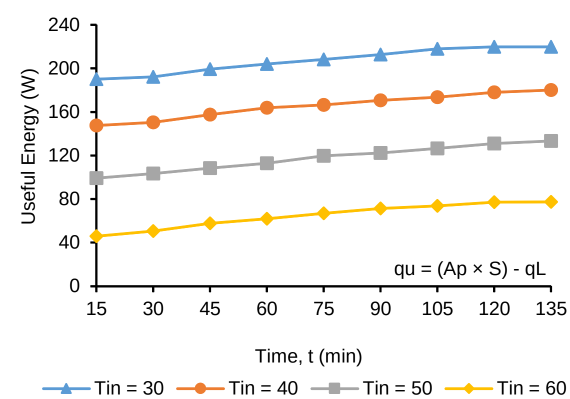

Fig. 12. Total heat loss (qL), at flow rate Q = 1 L/min.

Fig.12. Show, the same event at a flow rate of 1 L/min, with total losses likely to be higher. The higher flow rate passing through the collector, the greater total heat loss obtained from

the effect of inlet temperature, it shows that, the greater flow rate, absorption in the collector tends to decrease, while effect of inlet water temperature decreases the acquisition of useful energy, from 219.884 W to 77.444 W.

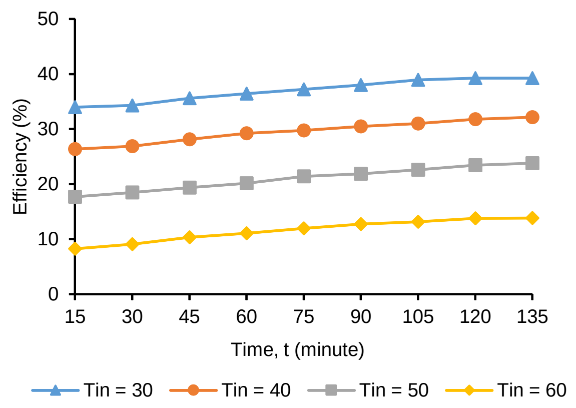

Fig. 13. Total heat loss (qL), at flow rate Q = 1 L/min.

Fig.13. Show, is efficiency of the flat plate collector obtained, efficiency value decreases from 39.26 % to 13.83 %, inlet water temperature increases from 30 ºC to 60 ºC. This decrease is caused by a high collector temperature level when the fluid inlet water temperature increases, from rate total heat loss that is happening at top, bottom and sides of collector increases. These values are related to rate of loss and useful energy absorbed. The higher useful energy obtained, greater efficiency of the collector. But greater rate of loss, more efficiency will be reduced.

5 Conclusion

Based on the experimental results and the data that have obtained, it can show that the effect of warming inlet water temperature, causes of total heat loss to increase and useful energy produced decreases with decreased efficiency. This is because of the effect of temperature from water passing through the collector, so that there is an increase in temperature in the collector which causes increased heat losses to the collector. The higher the fluid heat passing through the collector, the higher the heat release that occurs with the absorption of heat decreases. Besides that the mass flow rate causes increased heat release from the heating temperature of the inlet, increased mass flow rate of 0.6 L/min, 0.8 L/min, 1 L/min causes heat release to rising due to the heat absorption rate of the collector which decreases, resulting from changes in the mass flow rate. Furthermore, changes that occur at the inlet temperature caused by several factors, namely the pressure from the source of the flow, the return flow in the collector, the circulation of overflow in the reservoir. The intensity of the incandescent lamp greatly affects the collector's outgoing water temperature. The greater the intensity, the higher absorption rate of heat that occurs but there are a maximum absorption of work heat in flat plate type collectors.

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