Published by :
http://www.ijert.org

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 05, May-2023

Experimental Analysis of Flat Plate Solar Collector Water Heater Placed in Benghazi City

[1] Salah M. E-Badri; [2] Naser S. Sanoussi
[1,2]College of Mechanical Engineering Technology-Benghazi

Abstract

Flat plate collector (FPC) is a special kind of heat exchanger that transforms solar radiation energy to internal energy which is transferred through a working fluid. FPC is a well-known solar collector in the market for water heating application. Simple design, easy to operate and require low maintenance make the FPC commonly found in domestic home. The principles involve in FPC is to gain as much as possible the radiation energy from the sun by heat absorption. The energy which has been collected is transferred through conduit tubes by working fluids (usually water) which are integrated with heat absorber plate. Then, the warm water carries the heat to the hot water system or to storage subsystem which can be used during low sun radiation. This project is focusing on the analysis of flat plate solar collector using water as a working fluid and covered the calculation of the efficiency, useful heat gain of the collector. The results shown that, the useful heat gain and outlet temperature increase when the solar radiation increases. The outlet temperature depends on several factors such as solar radiation, ambient temperature, velocity. Also, the efficiency increases when the absorber and an ambient temperature increase.

Keywords: flat plate solar collector, working fluid, useful heat gain

1. Introduction

The use and cost of energy affects each of us every day of our lives. Many issues arise from the use of energy: greenhouse gas emissions, acid rain, climate change, and dependency on depleting supplies of fossil fuels— especially from politically unstable regions of the world. Today, 80% of the world's electrical production comes from fossil and nuclear fuels, and virtually all transportation is fueled by liquid petroleum (gasoline). The World Energy Council projects primary energy demand will triple by 2050, as population grows to 8-9 billion and developing nations elevate living standards. The fossil fuels by definition are nonrenewable and are destined to run out — so economies will be forced to change as these fuels are depleted. Rich nations will be insulated a bit longer, yet scarcity will surely create geopolitical tensions. The emissions from the burning of fossil and nuclear fuels creates atmospheric, water, and land pollution and toxic waste. The United Nations Intergovernmental Panel on Climate Change (IPCC) says this combustion is causing a discernible change of the global weather and climate patterns that will affect all humanity in decades to come. There is an increasing demand for the solar collectors, especially the flat-plate liquid solar collector. Therefore, extensive research has been done to model the flat plate solar collector's operation and to predict the performance of different types solar collector.

Hasson S. H, etc , their study was a mathematical model and simulation of flat plate solar collector are developed, in their work, different fluids and different absorbing materials were used to indicate their effect on the performance of flat plate solar collector. Operating parameters, which considered as variables, are the mass flow rate, the inlet and the outlet temperature difference and the total solar radiation flux. The simulation program had written by using EES (Engineering Equation Solver) software program. The results of their analysis show that the copper and aluminum give a good efficiency up to (0.6) with value (0.02) of collector performance coefficient when water as a working fluid, it has been also showing that the solar collector efficiency is higher in case of using water as working fluid than that of propylene glycol solution.[11]

Stephan Fischer and Erich Hahne, explained and characterized the efficiency of solar collectors. Authors have also summarized the importance of collector cover in improving the thermal efficiency of solar collectors. The thermal efficiency of a solar collector is basically characterized by two physical phenomena:

1. The ability to convert as much of the solar radiation into useful heat as possible.
2. The ability to lose as little as possible of the converted energy to the environment.

The ability to convert the solar radiation into heat is influenced by the solar transmittance τ of the collector cover, the solar absorptance α of the absorber coating and the collector efficiency factor F‟. The heat losses of the collector mainly are influenced by the quality and thickness of the insulation material and the emittance ε of the used absorber coating.

The thermal efficiency of a solar collector is crucially influenced by the collector cover and its solar transmittance, because only the transmitted solar radiation is at disposal to the absorber for the photo thermal conversion of the solar radiation into heat. Thus, it is very important in design of solar collector that a proper and most efficient cover and black absorber plate are selected among choice available. The properties of these materials can be modified by various techniques, which also must be taken into consideration. [12]

Mustafa B. Al-Hadithi and Obaid T. Fadhil, explained an experimental and numerical study to investigate the heat transfer enhancement of flat plat collector (FPC) using three types of twisted tapes (single twisted tape (ST), double twisted tape (DT) and mixed twisted tape (SDT)) which are compared with plain tube with twist ratios (TR=2). The study are considered under fully developed turbulent flow with solar radiation heat gain are changing with time. The designed FPC consists of four pipes with 1.25cm in diameter and 1mm thick are placed above the plate to act as a heat removal fluid passage ways. The system consists of two collectors, each one has (40cm x 160cm x 15cm) and connected to two tanks, each one is 20 liters. The amount of heat gain from solar radiation depends on many effective parameters are used; type of twisted tape are using, type of collectors plate metal (aluminum or copper), value of Reynolds number, amount of sun rays available at the site, number of glass covers and orientation of the collectors with respect to the south direction. From the experimental results was obtained which are demonstrate that the DT are more efficient than ST and SDT, since the heat transfer enhancement which increases the output temperature of the working fluid. The experimental study also show that the temperature of outlet water from mixed twisted tape collector is higher than the other type of plain tube collector by 10°C. The outlet water temperature of collector made from cupper is more than the collector made of aluminum about 6°C. The outlet water temperature from collector which has Reynolds number of 5000 less than 5°C for copper collector and less than 4°C for aluminum collector from the other with Re number is 10000. Increasing of the temperature of the outlet water in the collector which has two glass cover is about 4°C from one glass cover. The numerical analysis was based on finite volume numerical techniques to solve the governing partial differential equations in three dimensions, using ANSYS FLUENT commercial CFD software, to study the effect of Reynolds number and twisted tape types on the heat transfer enhancement and friction factor. The comparison between the experimental and numerical results shows a high agreement, and the maximum error was 8.3% occurred with mixed twisted tape [13]

The Libyan energy market has been growing and prosperity, and in the third chapter it will discuss the method of designing and reconstructing of Flat Plate Solar Collector Water Heater and the important equations to improve the efficiency of the solar collector to heat water and obtain water of an appropriate temperature.

2. Physical processes inside a flat-plate solar collector

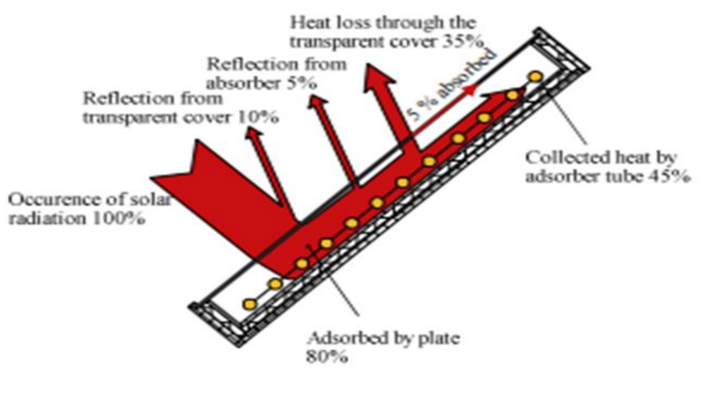


Figure (1) Heat flow through a flat-plate solar collector [10]

The main use of this technique is in residential buildings where demand for hot water has a significant impact on energy bills, or where the demand for hot water is excessive and can also be used for heating purposes if the building is outside the electric grid or if the use capacity was subject to frequent interruptions.

The hot water used in homes with a high bill materially and the environmental pollution resulting from traditional sources of energy requires the search for alternative technologies that use energy renewable, clean and physically comfortable as solar collectors.

This project is focusing on the analysis of flat plate solar collector using water as a working fluid. The experimental analysis covered the efficiency, the outlet temperature and the useful heat gain of the collector.

3. Mathematical model of solar collector

In a stable state, the performance of the solar collector can be calculated by the useful gain energy of the Qu collector, which is defined as the difference between absorbed solar radiation and thermal loss or useful energy outputs of the collector:

$$Qu = A_c F_R \left[I(\tau\alpha) - U_l \left(T_{fi} - T_a \right) \right] \quad (1)$$

The collector heat removal factor, F_R, is the ratio of the actual useful energy gain of a collector to the maximum possible useful gain if the whole collector surface were at the fluid inlet temperature. It is defined as

$$F_R = \frac{GC_p}{A_c U_L} [1 - exp^{-\left(A_c U_L F' / GC_p \right)}] \quad (2)$$

The mass flow rate per square meter:

$$G = {m^{\cdot}}/{A_c} \quad (3)$$

The overall heat losses U_l:

$$U_l = U_b + U_e + U_t \quad (4)$$

the edges of the collector

$$U_e = \frac{k}{x} \quad (5)$$

Coefficient of heat loss from the bottom:

$$Ub = \frac{k}{x} \quad (6)$$

Where the heat losses from the top of collectors U_t can calculate by:

$$U_t = \left\{ \frac{N}{\frac{C}{Tpm}\left[\frac{Tpm - Ta}{N+f}\right]^e} + \frac{1}{h_w} \right\}^{-1} + \frac{\sigma(Tpm + Ta)\left(Tpm^2 + Ta^2\right)}{\left(\epsilon_p + 0.0059hw\right)^{-1} + \frac{2N + f - 1 + 0.133\epsilon_p}{\epsilon_g} - N} \quad (7)$$

$$f = (1 + 0.08hw - 0.1166hw * \varepsilon_p)(1 + 0.07866N) \quad (8)$$

$$\left\{ \begin{matrix} 70 > \beta > Zero \quad C = constant = 520(1 - 0.000051\beta^2) \\ 90 > \beta > 70\ use\beta\ = 70 \end{matrix} \right\} \quad (9)$$

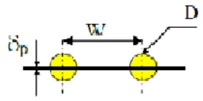
$$e = 0.43 \left(1 - {100}/{Tpm} \right) \quad (10)$$

$$\sigma = 5.6667 * 10^{-8} \left({W}/{m^2 . k^4} \right) \quad (11)$$

$$hw = 5.7 + 3.8V \quad (12)$$

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 05, May-2023

The Collector efficiency factor *F'* given by:



$$F' = \frac{1}{\frac{w u_l}{\pi D_i h f i} + \frac{w}{D+(w-D)F}} \quad (13)$$

Where *F* is the fin efficiency for straight fins with rectangular cross section and defined as:

$$F = \frac{[\tanh m(w-D)/2]}{m(w-D)/2} \quad (14)$$

Where *m* is a parameter of the fin-air arrangement defined as:

$$m = \sqrt{\frac{u_t}{k_p \delta_p}} \quad (15)$$

The heat transfer coefficient of the fluid:

$$h_{fi} = \frac{k}{Di} N_u \quad (16)$$

The Nestle number:

$$N_u = \left\{4.36 + \frac{0.067\left[\left({}^{D_i}/_{L}\right) Re\, Pr\right]}{1+0.04\left[\left({}^{D_i}/_{L}\right) Re\, Pr\right]}\right\} \quad (17)$$

The Reynolds number:

$$R_e = \frac{4m}{vp} Di \quad (18)$$

The prandtl number:

$$Pr = cp.v\,({}^{p}/_{k}) \quad (19)$$

The rate of absorbent plate temperature T_{pm}

$$T_{pm} = T_{fi} + \frac{Q_u}{h\, \pi\, D_i{}^{n\, l}} \quad (20)$$

$$T_{fm} = T_{fi} + \frac{Q_u/A_C}{U_l F_R}\left[1 - \frac{F_R}{F'}\right] \quad (21)$$

Angle of solar deviation δ

$\delta = 23.45 \sin \frac{360}{365}\,(284 + N)$. Where N is the number day in the year.

The solar collector efficiency is defined as:

$$\eta = \frac{Q_u}{A_c I} \quad (22)$$

4. Rebuilding and assembling of solar water heater

After going through all of the types of solar water heaters, we selected the flat plat solar collector that was damaging at wilding workshop to rebuild and replace all parts were corroded and damaged, For the design or rebuild our solar water heater system, All materials were purchased from market such as (Copper Tubes 3/4 inch , Copper Tubes 3/8 inch, Thermal Insulation, Black Paint, Copper Elbow 3/4 inch, Connection Joint 3/4 inch, and preparing collector stand, Valves 3/4 inch, Plastic Tube 3/4).

Table 1: Parts that used to build the flat plat collector

Component Name	Component Size
Copper Tubes	Length:5m / Diameter:3/4 inch
Copper Tubes	Length:15m / Diameter:3/8 inch - Soft Annealed
Insulation	Length:150x120cm / Width: 4mm
Glass	Lenght:150x120cm / Width: 4 mm
Valves	Size: 3/4 inch
Connection Joint 3/4	Size: 3/4 inch
Collector Stand	Angle: 32°
Easylog Thermocouple	Measure: Inlet, Outlet & Absorber Temperature
Collector Housing	Length: 150cm / Height: 120cm / Width: 10cm
Absorber plats	Height: 149cm / Length: 11cm
Flat Plate	Length: 150cm / Height: 120cm /Width: 4mm

5. Test of solar collector

The work became interesting when we decided to move the complete unit outside to the sun after chosen the right position of reading sensors, Which were installed in (inlet - outlet) lines and in Absorber plate by used electrical drill machine with 8 mm drill bit and fixed by silicone to prevented and water leakage. The solar collector implemented in this project was carried out several tests in order to measure its efficiency and to know the highest temperature reached by the water at the exit of the solar water heater unit.

- Testing the solar collector in case of natural water flow.
- Testing the solar collector in case of holding water inside and forcibly moving.

The first experiment was done when water flows through the solar water heater collector naturally. The object was to reach the highest temperature of the water when it flows naturally. On Sunday (22-09-2019) The solar collector is connected as shown below and the water flows are forced under pressure of collage tank, Temperature sensors were set after about half an hour by use Easylog Thermocouple devices and we start to take solar radiation readings as well as ambient temperature and wind speed reading were recorded. This experiment retuned more than one day.

Table 2: Constant parameters of the collector [16]

Constant	
ε_p	0.92
α	0.95
τ	0.92
σ	5.6669×10^{-8}
E_g	0.88

Figure (2) shown the first experiment of flow water inside the collector

6. Results and Discussion

Using equations from (1) to (22), the result was as following:

Table (3) shown the reading of the first experiment on Sunday 22-09-2019

Reading date & Time	Inlet Temp (C°)	Absorber Temp (C°)	Outlet Temp (C°)	Wind velocity (m/s)	Ambient Temp (C°)	Solar Radiation (w/m²)	Q_u (W)	η
22/09/2019 09:45	36.5	88.8	70.3	0.3	29	1000	1307.344	0.7263
22/09/2019 10:15	36.7	60	50	0.3	30.1	1047	1384.758	0.7347
22/09/2019 10:45	37	62.9	50.6	0.3	31.5	1050	1403.022	0.7423
22/09/2019 11:15	38	65.7	53.4	0.8	32	1180	1550.372	0.7299
22/09/2019 11:45	38	66.1	53.8	0.3	34	1190	1618.698	0.7556
22/09/2019 12:15	38	66.9	55.2	0.3	34	1210	1646.724	0.7560
22/09/2019 12:45	37	62.7	54.1	0.9	37	1208	1668.137	0.7671
22/09/2019 13:15	37	65.3	50.3	0.8	37.6	1199	1667.872	0.7728
22/09/2019 13:45	37	63.9	49.4	0.9	37.3	1155	1599.174	0.7692
22/09/2019 14:15	37	62	48.4	0.9	38.2	1095	1528.94	0.7757
22/09/2019 14:45	35	59.9	47.5	0.8	30	1095	1444.491	0.7328
22/09/2019 15:15	35.6	56.4	45.1	0.8	31	870	1139.735	0.7278
22/09/2019 15:45	33	51.7	42.2	0.3	29	770	1027.886	0.7416

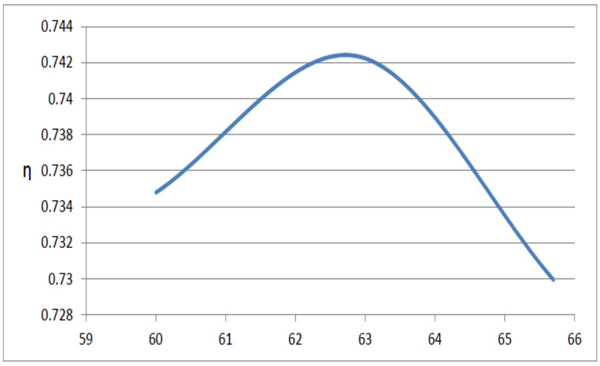


Figure (3) shows the effect of Absorber plate on the efficiency

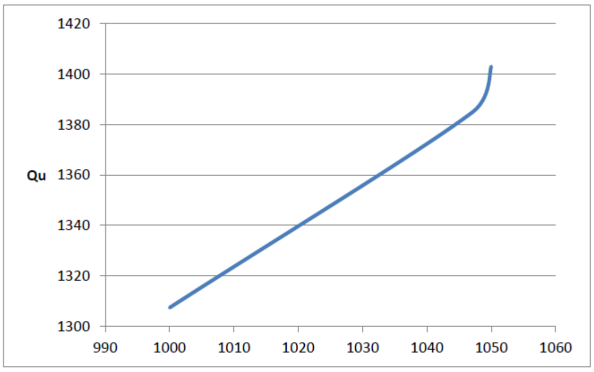


Figure (4) shows the effect of solar radiation on the Q_u

The result shows that the absorber Temperature increase, the efficiency increase as well. The solar radiation increase, the Q_u increase too.

Table (4) shown the reading of the first experiment on Tuesday 24-09-2019

Reading date & Time	Inlet Temp (C°)	Absorber Temp (C°)	Outlet Temp (C°)	Wind velocity (m/s)	Ambient Temp (C°)	Solar Radiation (w/m²)	Q_u (W)	η
24/09/2019 12:00	39.5	66	53.1	0.9	32.6	1160	1547.121	0.7409
24/09/2019 12:20	39.1	65.2	52.3	0.3	32.9	1174	1613.243	0.7634
24/09/2019 12:40	38.7	64.3	49.2	1.4	30.9	1181	1535.481	0.7223
24/09/2019 13:00	38.5	64.1	51.4	1.5	30	1171	1506.084	0.7145
24/09/2019 13:20	38.4	63.8	51.3	0.6	30.9	1144	1534.889	0.7453
24/09/2019 13:40	38.5	62.9	50.5	2.9	30.6	1126	1392.296	0.6869
24/09/2019 14:00	38	62.1	50.2	1.6	30.9	1179	1531.56	0.7216
24/09/2019 14:20	38.3	61	49.7	0.9	30.9	1120	1483.448	0.7358
24/09/2019 14:40	38.2	59.4	48.7	1.3	31.2	990	1285.845	0.7215
24/09/2019 15:00	37.7	56.6	46.6	0.3	30.6	918	1236.933	0.7485
24/09/2019 15:20	38.1	53.4	44.1	1.3	30	811	1021.916	0.7000
24/09/2019 15:40	38	69.3	39	0.3	31.4	730	974.018	0.7412
24/09/2019 16:00	38.3	54.3	35	4.4	30	613	660.3461	0.5985

Published by :
http://www.ijert.org
International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 05, May-2023

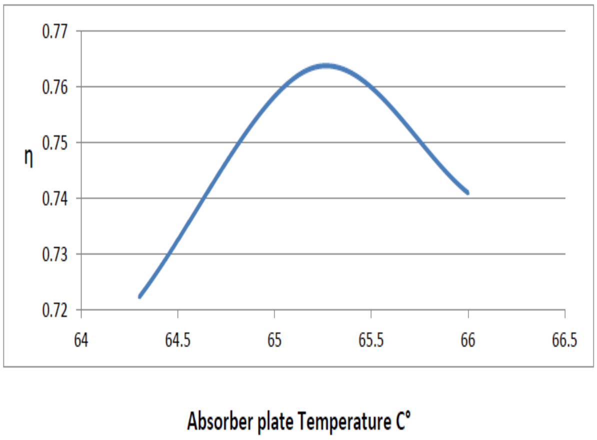


Figure (5) shows the effect of Absorber efficiency

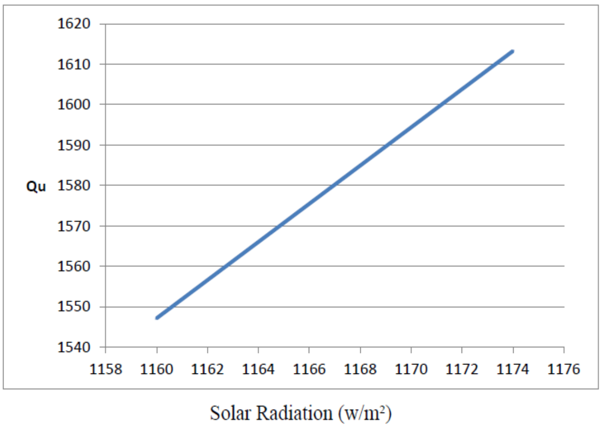


Figure (6) shows the effect of solar plate on the radiation on the Q_u

The result show that the Absorber Temperature increase , the efficiency increase too. the result show that the solar radiation increase , the Qu increase too.The second experience of the solar collector in case of holding water inside the collector and not forcibly moving. The time required for water to reach the highest possible temperature when locked inside the solar collector. So, the flat solar collector was connected to the water tank as shown below, We opened the suction valve and drained the air from system then we closed the outlet of collector, the water was locked up for a certain period of time and the temperature of the outgoing water was measured and recoded.

Figure (7) shown the second experiment of holding water inside the collector

Table (5) shown the reading of the Second experiment on Monday 23-09-2019

Reading date & Time	Inlet Temp (C°)	Absorber Temp (C°)	Outlet Temp (C°)	Wind velocity (m/s)	Ambient Temp (C°)	Solar Radiation (w/m²)
23/09/2019 9:45	38	83.9	48.6	0	32	766
23/09/2019 10:15	38	68	66	0.6	33	1005
23/09/2019 10:45	39	97.8	79	0.3	35	1085
23/09/2019 11:15	39	103.1	71	0.3	35	1155
23/09/2019 11:45	39	90	70	0.3	35	1205
23/09/2019 12:15	40	108	97.3	0.3	35.5	1225
23/09/2019 12:45	40	93.6	96.3	0.1	33.5	1218
23/09/2019 13:15	41	82.2	70	0.5	33.5	1192
23/09/2019 13:45	41	89.3	86	0.6	33	1150
23/09/2019 14:15	40	96.7	94.9	0.3	33	1092
23/09/2019 14:45	39	76.7	74.5	0.3	32	990
23/09/2019 15:15	39	71.2	70	0.3	31	875
23/09/2019 15:45	38	66.6	67.2	0.9	28	725

Second experiment was on Tuesday 24-09-2019

Table (6) shown the reading of holding water for 20 minutes inside the collector

Reading date & Time	Inlet Temp (C°)	Absorber Temp (C°)	Outlet Temp (C°)	Wind velocity (m/s)	Ambient Temp (C°)	Solar Radiation (w/m²)
24/09/2019 10:00	32.4	72.6	53.8	2.2	29	918
24/09/2019 10:20	33	72.8	82.2	0.9	30	1000
24/09/2019 10:40	39	76	82.1	1.3	30	1000
24/09/2019 11:00	39.9	85.5	74.2	0.7	31.2	1079
24/09/2019 11:20	40.5	87.9	74.8	3	31.7	1121
24/09/2019 11:40	39.7	90.4	75.4	1.6	32	1151

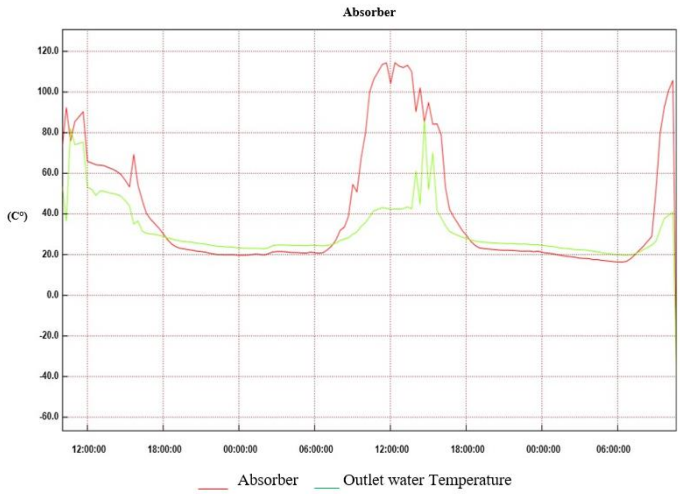


Figure (8) shown the reading of holding water inside collector for 20 minutes

The tables below show the second experiment that was on several days.

Table (7) shown the reading of holding water for 1hour inside the collector on Wednesday 25-09-2019

Reading date & Time	Inlet Temp (C°)	Absorber Temp (C°)	Outlet Temp (C°)	Wind velocity (m/s)	Ambient Temp (C°)	Solar Radiation (w/m²)
25/09/2019 13:30	53	110.2	75.4	0.4	32.7	1138
25/09/2019 14:30	56	102.1	88.3	0.3	33	1051
25/09/2019 15:30	55.3	95.4	82.1	0.3	33	915

Table (8) shown the reading of holding water for 30 minutes in side collector on Thursday 26-09-2019

Reading date & Time	Inlet Temp (C°)	Absorber Temp (C°)	Outlet Temp (C°)	Wind velocity (m/s)	Ambient Temp (C°)	Solar Radiation (w/m²)
26/09/2019 11:29	38.8	105.3	69.6	0.3	36.2	1169
26/09/2019 11:59	40.2	103.3	79.5	0.3	34.8	1202
26/09/2019 12:29	41.7	104.3	83.5	0.5	36.5	1210
26/09/2019 12:59	43	104.4	97.1	0.3	42.2	1198
26/09/2019 13:29	45	104.1	87.6	0.9	35.5	1153
26/09/2019 13:59	45	100.7	99.3	0.4	36.7	1104
26/09/2019 14:29	47	93	97.2	0.9	39.5	1030

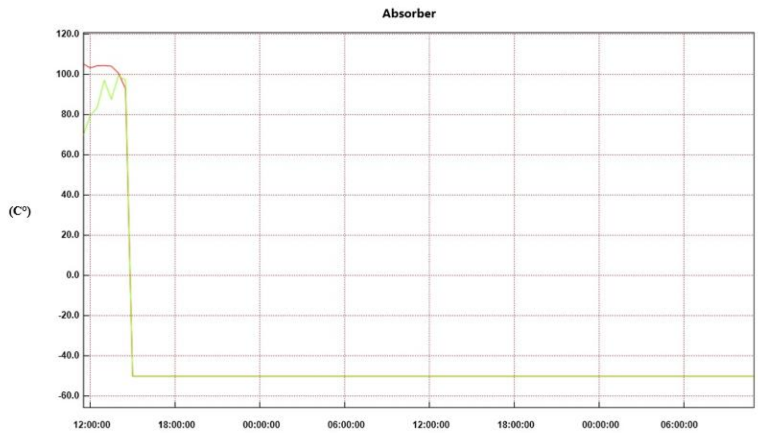


Figure (9) shown the reading of holding water inside collector for 30 minutes

Table (9) the reading of holding water for 20 minutes in side collector on Saturday 28-09-2019

Reading date & Time	**Inlet Temp (C°)**	**Absorber Temp (C°)**	**Outlet Temp (C°)**	**Wind velocity (m/s)**	**Ambient Temp (C°)**	**Solar Radiation (w/m²)**
28/09/2019 11:30	38	103.8	58.8	0.3	34	1060
28/09/2019 11:50	40	95.7	62.3	0.9	34.3	1255
28/09/2019 12:10	40	99.3	84.9	0.4	35.4	1225
28/09/2019 12:30	42	98.1	83.5	0.3	32.8	1208
28/09/2019 12:50	43.2	99.5	100.4	0.3	32.6	1175
28/09/2019 13:10	41	95	81.3	0.7	35.5	1160
28/09/2019 13:30	41	95.6	65.7	0.4	31	1120
28/09/2019 13:50	42	93.9	88.7	0.9	32.3	1102
28/09/2019 14:10	43.5	95.6	100.8	0.3	30	1080
28/09/2019 14:30	41	78.4	73.5	0.3	34.8	1050

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 05, May-2023

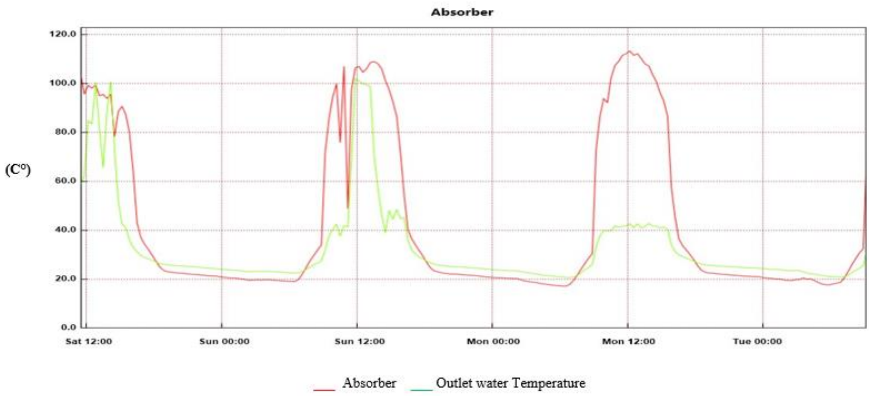


Figure (10) shown the reading of holding water inside collector for 20 minutes.

Table (10) shown the reading of holding water for 30 minutes in side collector on Tuesday 1-10-2019

Reading date & Time	Inlet Temp (C°)	Absorber Temp (C°)	Outlet Temp (C°)	Wind velocity (m/s)	Ambient Temp (C°)	Solar Radiation (w/m²)
01/10/2019 10:30	39.2	61.2	47.7	0	32.6	1063
01/10/2019 11:00	39.6	86.9	65.8	0.3	32	1137
01/10/2019 11:30	43	103.1	93	2	32	1178
01/10/2019 12:00	43	103.1	93	1.6	30	1120
01/10/2019 12:30	44	103.3	89.1	0.9	31.2	1193

7. Cost of building the flat plate collector

Using the measurements adopted and the local prices of each component, the following table summarizes the cost for building the collector.

Table (11) shown the cost of material of building flat plate solar collector

Component	Size	Price
Copper Tubes 3/4"	5 meters	175 LYD
Copper Tubes 3/8"	15 meters	200 LYD
Insulation	150x120cm	50 LYD
Valves	3/4"- 3pieces	35 LYD
Valves	1/2"	10 LYD
Connection Joint	3/4" - 3pieces	75 LYD
Connection Joint	1/2"	2.5 LYD
Elbow	1/2"	2.5 LYD
Copper Elbow	3/4"	10 LYD

Absorber black paint	5kg	35 LYD
Copper plugs	3/4" -2pieces	10 LYD
Storage tank	80 liters	195 LYD
Spray paint	4	29 LYD
Silicone	1	10 LYD
Plastic Tube	3/4" -25meters	45 LYD
Tube clamp	2	4 LYD

The total price of collector building is around 890 LYD

8. Conclusion

The flat-plate solar collectors are probably the most fundamental and most studied technology for solar-powered domestic hot water systems. The overall idea behind this technology is simple. The Sun heats a dark flat surface, which collect as much energy as possible, and then the energy is transferred to water, air, or other fluid for further use. In this experimental work of flat plate solar collector has been forced for different parameters. More attention was paid on the outlet temperature, useful heat gain and efficiency of the collector using water as a working fluid. The results show that, the useful heat gain increases when the solar radiation increases, Also the efficiency increase when the ambient and absorber temperature increases, while the outlet temperature depends on several factors such as solar radiation, ambient temperature and velocity. Through the first experiment, which is the water passage into the flat plate solar water heater collector, the highest temperature obtained from this process are:

- On Sunday 22-09-2019 the highest outlet water temperature is 55.2 C°
- On Tuesday 24-09-2019 the highest outlet water temperature is 53.1 C°
- On Tuesday 01-10-2019 the highest outlet water temperature is 52.4 C°

Second experiment, which is holding water inside the collector and not forcibly moving, the highest temperature obtained from this process are:

- On Monday 23-09-2019 It is noted from the reading taken at 12:15 that it held water for 30 minutes that the water turned into a semi-vapor 97.3 C°.
- 2- On Tuesday 24-09-2019 which held the water inside the collector for 20 minutes the highest reading was 82.2 C°
- On Wednesday 25-09-2019 the highest temperature was 88.3 C°.
- On Thursday 26-09-2019 held water inside for 30 minutes the water turned into Vapor.
- On Saturday 28-09-2019 held water inside the flat plate solar collector for 20 minutes the water turned into Vapor.
- On Tuesday 1-10-2019 held water inside the collector for 30 minutes the highest temperature was 93 C°.

References

[1] International Journal of Advance Research and Innovation Issue 1 (2015) 138-141A Review of Solar Flat Plate Liquid Collector's Components.
[2] www.studentenergy.org/topics/renewable-energy#reference-1.
[3] News.energysage.com/advantages-and-disadvantages-of-renewable-energy/.
[4] Sciencedirect.com/topics/engineering/solar-thermal-energy.
[5] Solar Heating and Cooling Technologies | Renewable Heating and Cooling: The Thermal Energy Advantage | US EPA.
[6] AU Solar Decathlon – Flat Plate Collectors Diagram.
[7] Solar Water Heater Training Course – Installer and User Manual.
[8] www.engineeringtoolbox.com.
[9] Struckmann F. 2008. Analysis of a flat-plate solar collector. Project Report, MVK160 Heat and Mass Transport, Lund, Sweden.
[10] Experimental Investigation on Solar Power System used for street lights in the College of Mechanical Engineering Technology in Benghazi City [2017].
[11] Hasson S. Hamood, Badran M. Salim, Nabeel M. Abdulrazzaq | Theoretical Analysis of Flat Plate Solar Collector Placed in Mosul City by using different Absorbing Materials and Fluids.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 12 Issue 05, May-2023

[12] S. Fischer, E. Hahne, the effect of Different Glass Covers on the Yearly Energy Gain of a Solar Collector, University of Stuttgart, Pfaffenwaldring 6, D-70550 Stuttgart,
[13] Mustafa B. Al-Hadithi, Obaid T. Fadhil, Braa Khalid Ameen | Heat Transfer Enhancement of Flat Plate Solar Collectors for Water Heating in Iraq Climatic Conditions.
[14] Himangshu Bhowmik | Efficiency improvement of flat plate solar collector using reflector.
[15] J.Fan. Z.chen, S. Furbo, B. Perers, B. Karlsson "Efficiency and Lifetime of Solar collectors heating plants "2009.

List of symbols

A_c	Solar collector area (m^2)
D	Outer diameter of tube (m)
D_i	Inner diameter (m)
W	Distance between the tubes (m)
x	Insulation thickness (m)
δ_p	Absorber thickness (m)
$\dot{m}$	Total collector mass flow rate (kg/s)
m	Parameter of the fin-air arrangement
T_a	Ambient temperature (ºC)
T_i	Fluid temperature at collector inlet (ºC)
T_o	Fluid temperature at collector exit (ºC)
T_{pm}	Mean plate temperature (ºC)
Q_u	Useful gain from collector (Watt)
I	Intensity of incident radiation (W/m^2)
C_p	Specific heat (kJ/kg.K)
U_L	Overall loss coefficient of the collector ($W/m^2.K$)
U_e	Side Heat Loss ($W/m^2.K$)
U_t	Heat loss factor from the top ($W/m^2.K$)
U_b	Heat loss factor from the bottom ($W/m^2.K$)
F_R	Collector heat removal factor
F	Fins efficiency coefficient
F'	Collector efficiency factor
G	Heat flow rate of the liquid for the square meter (kg/m^2)
h_{fi}	Forced convection heat transfer coefficient inside of tubes ($W/m^2.K$)
h_w	Air Heat Transfer Factor.V3.8+5.7
K	Thermal conductivity (W/m.K)
K_{fi}	Conductivity factor for liquid (W/m.K)
v	Liquid viscosity (m^2/s)
V	Wind speed (m/s)
N	Transparent Covers number of glass
Re	Reynolds number
Pr	Prandtl number
E_g	The softest of the transparent plank
ε_p	Emissivity of the absorbant board
α	Absorptance
β	Collector slope (degree)
ρ	Fluid density (kg/m^3)
τ	Transmission coefficient of glazing.
η	Instantaneous efficiency of solar collector
Kp	Average thermal conductivity of the board.
δp	Thickness of absorbent board.