American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN : 2320-0936
Volume-10, Issue-01, pp-197-212
www.ajer.org
Research Paper Open Access

Construction and evaluation the performance of solar collector prototypes in different month's

Eman M.Mostafa[a], Sawsan A. Mahmoud[a], Saad M. Desouky[a] , Ahmed M. Soliman[b,c] and M. S. A. Abdel-Mottaleb[d]

a) Egyptian Petroleum Research Institute, PVT center, Ahmed El-Zomr st., 11727 Nasr City, Cairo, Egypt.
b) Department of Engineering Sciences, Faculty of Petroleum and Mining Engineering, Suez University, 43721 Suez, Egypt.
c) Mechanical Engineering Department, Engineering College, Jouf University, KSA
d) Lbs of Solar, Photochemistry and Computational Chemistry, Department of Chemistry, Faculty of Science, AIN Shams University, 11566, Abbassia, Cairo, Egypt.
**Correspondence Author: Eman M.Mostafa*

ABSTRACT :
Performance and efficiency of solar collectors depends upon various factors like Design conditions (absorber material, working fluid types and collector insulations) operating conditions (working fluid flow rate and inlet temperature of working fluid) and weather conditions (Solar intensity, ambient temperature and wind speed)The use of hybrid nanofluids is attracting considerable attention in various industrial applications. Compared with conventional fluids, hybrid nanofluids improve the heat transfer rate, as well as thermal efficiency of flat plate solar collector. Two prototype flat plate solar collectors were constructed with the same, dimensions 60cm x 90 cm and were tested under the same weather and operating conditions. The obtained data were recorded during different months; November, December and March Egyptian petroleum Research Institute, Cairo, Egypt. The constructed units facilitate the comparison of different factors at the same experimental conditions. To evaluate the effect of optical absorption efficiency the black surface of one collector was coated with a liquid solution containing Zn-Fe-Ti and the solvent was evaporated. The experiments were carried out using monoethylene glycol and two heat exchangers solar collector units. The data was recorded at different time intervals along the day. The coated collector showed a higher outlet water temperature of 77oC while the temperature reaches to 71oC in the uncoated collector (in November). The efficiency of the collectors was 76% and 68.23%, respectively. The same experiment was repeated in December. To study the effect of iron vanadium oxide based on monoethylene glycol nanofluid on the solar collector efficiency, the same units were used. In March, The max outlet water temperature was 94 O C and the efficiency was increased to 80.12%.
KEYWORDS; *solar thermal; flat-plate collector; hybrid nanofluid; collector efficiency.*

Date of Submission: 04-01-2021 Date of acceptance: 19-01-2021

I. INTRODUCTION

In the last couple of decades, increasing the energy demands and using extra conventional thermal power plants increased the fossil fuel depletion and the atmospheric pollution. The most favorable solution is the utilization of renewable energies sources, particularly the solar radiation received by the Earth. The amount of solar energy that received by the earth is approximately 4 x 1015 MW which equal 200 times of human utilization [1,2]. The progress of renewable energy resources in Egypt was very low in the last couple of decades. Today with expanding environmental concern, other options to the utilization of non-sustainable and polluting fossil fuels must be investigated. One important source is solar energy, which has turned out to face the increase in popular during recent years. Two parts are required in order to have utilitarian solar energy generator. These two parts are a collector and a storage unit. The collector collects the radiation that falls on it and converts it to different types of energy (electricity, heat).Whilst the capacity unit is required as a result of the non-steady nature of solar energy, as during cloudy days the amount of energy produced by the collector will be very little. The capacity unit can keep the energy produced during the periods of maximum radiation and release it when it is required or the efficiency drops [3, 4]. In climates where there is a potential for freezing temperatures during part of the year, or in climates where liquid are exposed to high temperatures, anti-freeze/anti-boiling (coolant) is employed to protect solar systems against corrosion, solidifying temperatures, and overheating. Right now there are many different types of antifreeze like ethylene-glycol, triethylene glycol, propylene-glycol and many others. Propylene-glycol has fundamental properties like: non-toxic, low specific heat capacity, freeze safety, boil-overprotection, and anti-corrosion and rust protection. At particular focus they help for increased heat transfer applications [5,6].Working fluid is generally responsible for heat transfer; it ought to have adequate heat transfer characteristics. In this way, as normal water is an outstanding heat conductor, it is added to the solution. Heat transfer improvement is done by utilizing deferent type of fluids in solar water heating systems, in which principle working fluid mixture is propylene-glycol/water that are normally subject to deterioration at elevated temperatures. Under these conditions the heat transfer fluid may become corrosive, causing in accelerated fouling and consumption of the solar system components. They confirmed that propylene glycol has extremely low environmental, health, fire and corrosion risk: it might be a good solution if energy utilizes and life circuit costs are certainly not overriding concerns. Propylene glycol is employed in air coolers and concentrator heat exchangers and researched heat transfer characteristics. A large number of studies have been conducted on the heat transfer performance of engine coolants [7, 8]. The performance of the flat plate solar collector relies upon solar illumination, , environmental temperature, collector angles, the inlet temperature of absorbing fluid , wind speed, and material, relative humidity and thermo-physical properties of absorbing fluid, various type of insulation material, tube construction and martials coating of absorber. Heat transfer enhancement can be achieved by utilizing various type of twisted tapes, namely, helical twisted tape [9, 10], using nanomaterials thin films for coating or using nanoparticles in working fluid.

In this work, we interested in construction different designs of flat-plate collector and studying the effect of nanomaterials (Zn-Fe-Ti) thin films and iron vanadium oxide/ monoethylene glycol nanofluid on the performance of the collector.

II. THEORETICAL STUDY

This part explains the flat-plate solar collector considering the properties of its distinctive zones. In general, the analyzed control of the flat-plate solar collector contains five regions specifically glass cover, air hole, absorber, fluid and the insulation opposite to the liquid flow direction. The energy balance caused by the mass transfer during the fluid circulating within the solar collector is incorporated by the definition that the collector's temperature depends on the coordinate in the direction of the fluid flow. [11, 12] The heat absorbed by fluid in the collector, and the efficiency of the collector can be calculated from the following equations [13-15].

The heat energy is converted into thermal energy in the pipes, as:

$$Q_u = \dot{m}.C_p.(T_o - T_1) \quad (1)$$

The useful energy (Q_u) rate can be also describe as the difference between energy absorbed by absorber plate and loss energy from absorber by equation as follow:

$$Q_u = A_c F_R[\,G_T\alpha\tau - U_L(T_f - T_a)] \quad (2)$$

where Q_u is the rate of useful energy gained, $m^{\cdot}$ is the mass flow rate of fluid flow, T_O and T_i are, respectively, outlet and the inlet fluid temperature of solar collector, and also C_p is the heat capacity of fluid. The useful energy(Q_u) can also be expressed in terms of the energy absorbed by the absorber and the energy lost from the absorber.

$$\dot{m}C_p.(T_o - T_i) = A_c F_R[\,G_T\alpha\tau - U_L(T_f - T_a)] \quad (3)$$

$$(T_o - T_i) = A_c F_R/\dot{m}C_p[\,G_T\alpha\tau - U_L(T_f - T_a)] \quad (4)$$

Then the collector efficiency is obtained by using the relation,

$$\eta_i = \frac{Q_u}{(A_c G_T)} \quad (5)$$

$$\eta_i = F_R(\tau\alpha) - \left[\frac{F_R U_L(T_f - T_a)}{G_T}\right] \quad (6)$$

Eq.(6) which defines the instantaneous efficiency is known as the Hottel-Whillier equation.

Since $F_R, (\tau\alpha)$ & U_L are constant, therefore,

$$\eta_i \propto \left[\frac{(T_f - T_a)}{G_T}\right]$$

III. METHODOLOGY AND MATERIALS

This section is present in two parts. First part deals construction of flat plate collectors prototype and the second part describes the steps that has been used for experimental of flat Plate collectors prototype in different weather conditions

3.1. Thermal solar measuring devices:

The ILT1700 Research Radiomete was used to measure the solar intensity. The digital Thermometer with range 0-350°C is used to measure the inlet temperature of cold water and outlet temperature of hot water to find the temperature difference, and calculation the flow mass rate by using measuring tank the time is taken to collect 500 ml of water is noted down. This helps in calculation of flow mass rate of water flowing through the copper tubes.

3.2. Thermal solar experimental procedure

All the experimental work that was done to verify the analysis took place in Egyptian Petroleum Research Institute (EPRI), Egypt using of the flat-plate solar collector a prototype in different weathering conditions. The stepwise experimental procedure was carried out as follows; all the components of the flat plate solar collector are collected and assembled together, the two units are placed at the same open place and cleaning of the absorber plate, flow tube, and glazing cover done to evacuate the dust particles and moisture content. The cold water supply is started from 9:00 Am. While the water is passing through the collector; the ambient temperature, Inlet and outlet temperature of water are recorded. Flow mass rate of water is measured by measuring the time taken for the collection of 500ml of water using measuring jar and stopwatch. Each experiment is conducted for the 1-hour duration by maintaining a constant flow mass rate of water and the readings are taken after every hour and are tabulated. In addition, the experimental procedure is repeated for the next days as previously mentioned.

3.3. Construction of Solar Flat Plate Collectors prototype.

Figures 1 and 2 show the main Components of flat plate solar collector prototypes and explained as follows: The insulation box was a wooden casing of dimensions (0.95m x .70m x 0.08m) is made for outer frame work of the collector. Wood was utilized for the manufacture of the insulation box since wood is a decent insulator, cheap, easily available, having softening point and have low weight. It surrounds and protects the components utilized in the system. Casing keeps the components free from dust and moisture. The insulation layer consists of a thin layer of thermocol of 4mm thickness and placed at the base of the casing. The insulation helps to minimize the conduction losses from bottom and sides of the casing. Absorber consists of a thin sheet of aluminum size 0.95m x .70m and covered with a highly selective coating material(Zn-Fe-Ti) that is extremely efficient in absorbing, the sunlight and converting it into usable heat. The main function of absorber plate is to absorb the solar radiation to pick up heat and transfer it to the working fluid. Flow tubes consist of 21 (0.25inches) tubes and 2 headers made of Copper with tube spacing of 4 inches and a diameter of 1.5 inches. The pipe was fixed at the top of Absorber Plate**.** Glazing was0.75 × 0.95 m and (3mm) thick glass sheet set at the highest point of the collector box to minimize the losses due to convection. The glass was utilized as glazing since it has a promising feature as easily accessible and 88% transmittance, which is higher than some other covering. It also transmits long and short wave radiations while reflecting 12% of the incident light. Hot Water collecting tank made of stainless steel and has a capacity of 50 liters. It was designed by two models. The first using heat exchanger for in direct heating and the second with outing heat exchanger for direct heating it should be insulated to store the water for a long time. Figure1 shows the construction of flat plat solar collector prototype , figure 2 show the two construction unites for collector coating by selective nanocoating material(Zn-Fe-Ti) (I) and other coating by the commercial black spray (cbs) only (II). Figure (3). Show the two constructions unite indirect heating (III) and direct heating (IV). The tubes of the two units contain the same volume of the thermal nanofluid. The two units were adjusted to be the same angle with the sun.

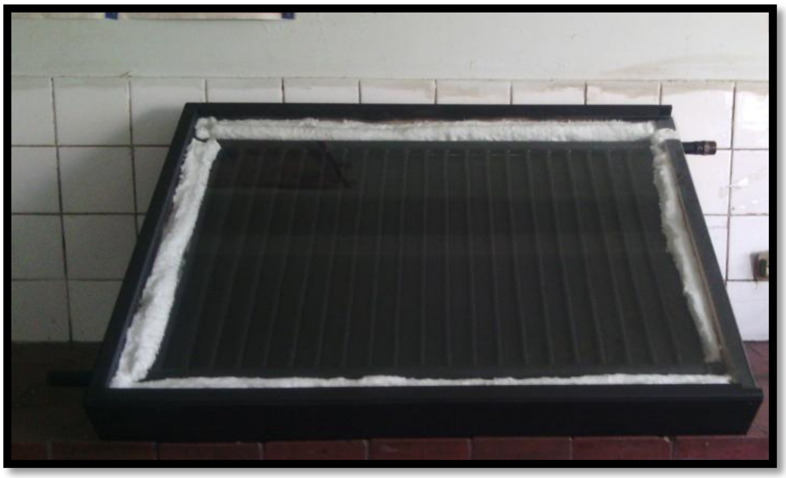

Fig. 1a: A homemade of flat-plate solar collector prtotype.

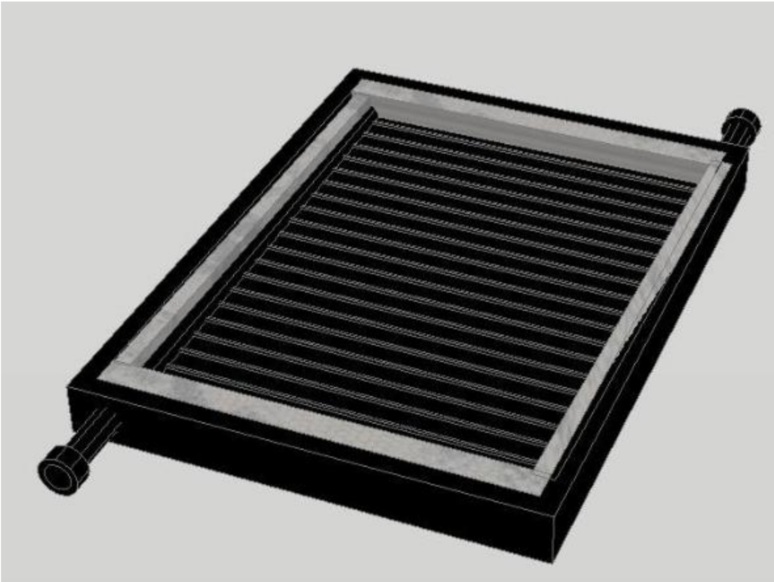

Fig. 1b: Typical of flat-plate solar collector prtotype (3D) depicted by autoCAD

Fig. 2: A homemade of flat-plate solar collectors equipped with water tank for the first experiment.

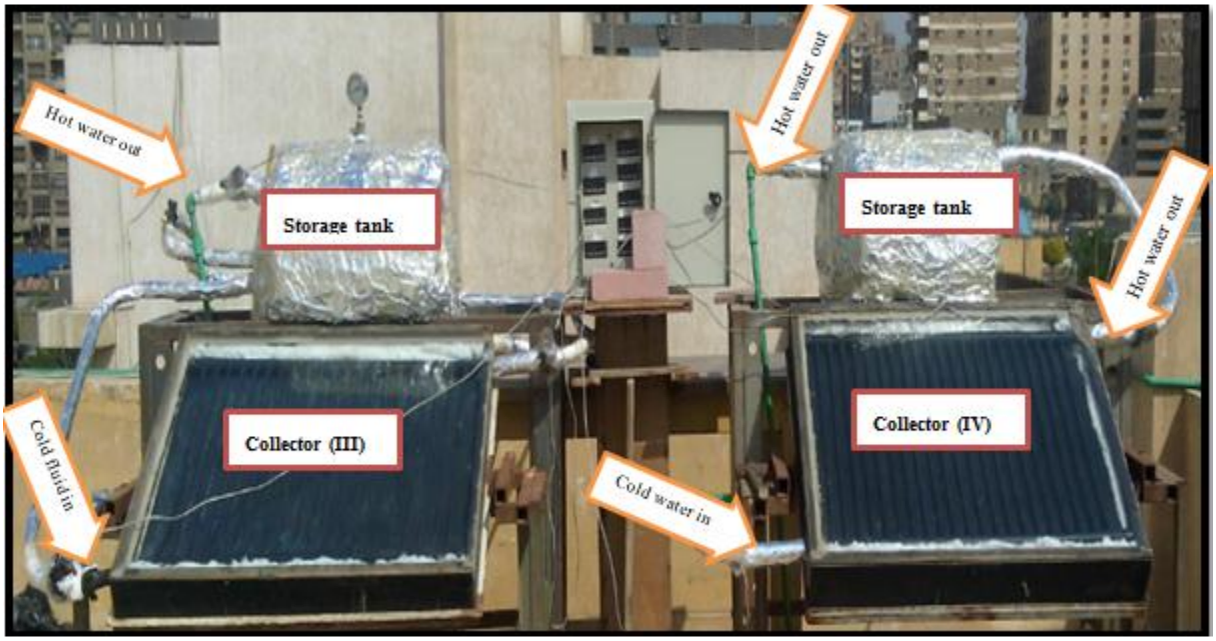

Fig. 3: A homemade of flat-plate solar collectors equipped with water tank for the second experiment.

IV. RESULT & DISCUSSION

This work was carried out to increase the efficiency of the constructed solar collector. For this purpose, two identical units of solar collector were used. The black surface of one collector was sprayed with a thin film of Ti-Fe-Zn (TFZ) in the ratios 70 %: 20%: 10 %, respectively. The surface of other unit was covered with the commercial black spray (cbs) only. The tubes of the two units contain the same volume of the thermal nanofluid. The two units were adjusted to be the same angle with the sun.

$\dot{M}_w = 0.002\ kg/sec$, C_P = 4.187kJ/kg.K and Collector area (A) = 0.54 m^2.

4.1. Experimental readings taken during 30th of November 2015 using Iron vanadate oxide/EG as thermal nanofluid. .

Figure (4) shows the relation between the variation of outlet temperature with local time for flat collector coating with Ti-Fe-Zn and blank unit using iron vanadate oxide/EG as thermal nanofluid in November 2015. It is clear that the T_{out} changed from 48 $°C$ to 77 $°C$ for collector coating by nanomaterial although the T_{out} changed from 40 $°C$ to 71 °C for blank collector as a solar radiation changed from 750 W/m^2 to 1000 W/m^2 throughout the experiment time. Also figure (5) shows relation between the variation of collector efficiency with local time and figure (6) shows variation of solar radiation(I) and useful energy gain (Q_u) with local time in the same experimental condition.

Table (1) shows the calculated parameters of the coated and blank collectors using iron vanadium oxide thermal nanofluid by indirect heating. It is obvious that at 12:00 pm the high thermal efficiency (η, 76%) at heat gain (Q_u)(410.33 w) this could be attributed to high solar intensity. On the other hand, the blank flat collector (I) the thermal efficiency (η, 68.23%) and heat gain (Q_u) (368.46 w) at the same conation and solar intensity. By these results the a solar flat plate collector coating by nanomaterial gains using Iron vanadate oxide/EG as thermal nanofluid more heat effectively and produce high performance.

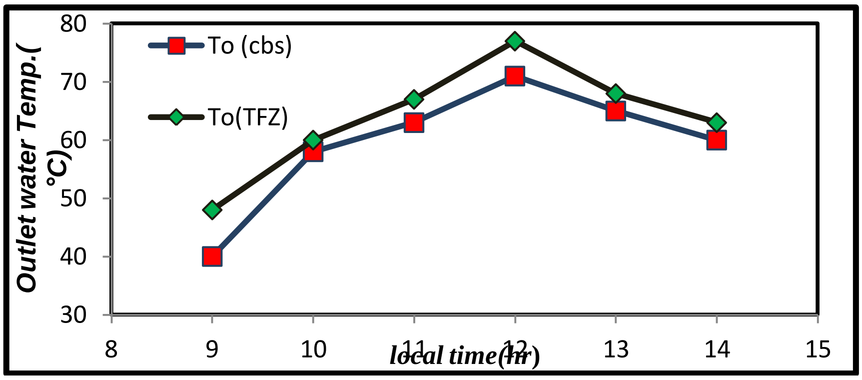

Fig.4:.Variation of outlet temperature with local time for iron vanadate oxide/EG fluid

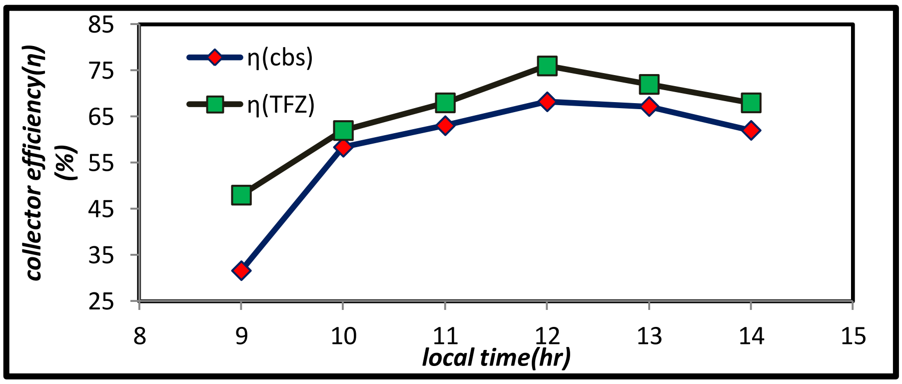

Fig.5:.Variation of collector efficiency with local time for iron vanadate oxide/EG fluid

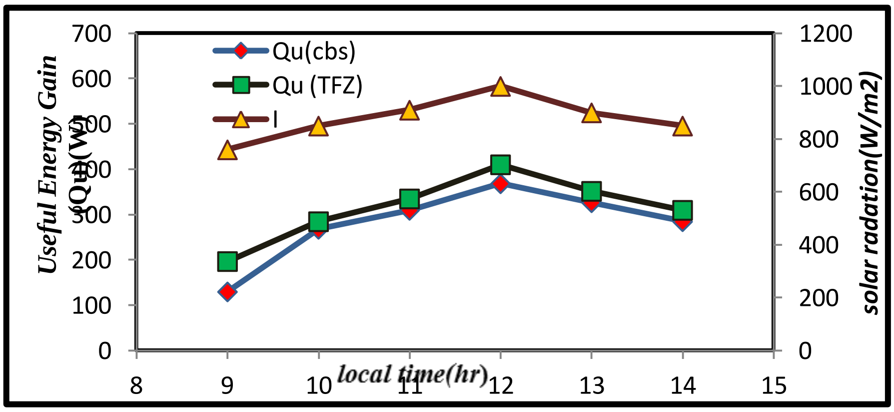

Fig.6: Variation of solar radiation (I)and useful energy gain (Q_u) with local time for iron vanadate oxide/EG fluid

Table 1: Experimental readings taken during 30th November 2015 for flat collector coating by nanomaterials coated and blank unit using iron vanadate oxide/EG as thermal naniofluid.

Time (hrs)	Solar intensity I W/m^2	Ambient temp. (T_{amb}°C)	I (blank unit)(cbs) Inlet water Temp. (T_{in} °C)	Outlet water Temp. (T_{out} °C)	Heat gain Q_u (w)	Thermal efficiency η(%)	II(nanomaterial coating unit)(TFZ) Inlet water Temp. (T_{in} °C)	Outlet water Temp. (T_{out} °C)	Heat gain Q_u (w)	Thermal efficiency η(%)
09:00AM	760	23	24.5	40	129.8	31.63	24.5	48	196.79	48
10:00AM	850	23.5	26	58	267.97	58.38	26	60	284.72	62
11:00PM	910	24	26	63	309.84	63.05	27	67	334.96	68
12:00PM	1000	24	27	71	368.46	68.23	28	77	410.33	76
1:00 PM	900	23	26	65	326.59	67.20	26	68	351.71	72
2:00PM	850	23	26	60	284.72	62.03	26	63	309.84	68

4.2. Experimental readings taken during 3rd of December2015 using monoethylene glycol as thermal fluid.

Figure (7) shows the relation between the variation of outlet temperature with local time for flat collector coating by Nano(Ti-Fe-Zn) and bank (cbs) unit using monoethylene glycol as fluid at 03.December 2015 .It is clear that the T_{out} changed from 57.6 $°C$ to 73.5 $°C$ for collector coating by nanomaterial(Ti-Fe-Zn) although the T_{out} changed from 48.5 $°C$ to 60.5 $°C$ for blank collector when the solar radiation varied from 745 W/m^2 to 990 W/m^2.

Also figure (8) shows relation between the variation of collector efficiency with local time and figure (9) shows variation of solar radiation (I) and useful energy gain (Q_u) with local time. Table (2) shows that flat collector coating by nanomaterial using monoethylene glycol as thermal fluid for indirect heating (II) at 12:00 pm the higher thermal efficiency is 72.84 % and heat gain (Q_u) (389.391 w) This could be attributed to high solar intensity, Although the blank flat collector (I) the thermal efficiency (η) (65.01%) and heat gain (Q_u) (347.52 w) at the same temperature and solar intensity. by these results the a solar flat plate collector coating by nanomaterial gains more heat effectively and produce high performance

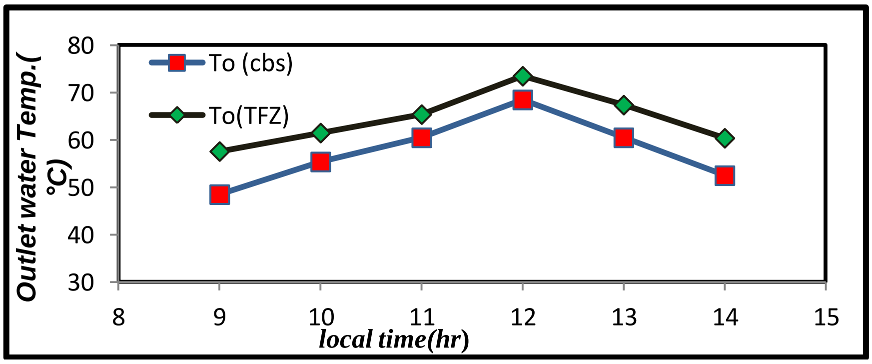

Fig.7: Variation of outlet temperature with local time for Monoethylene glycol fluid

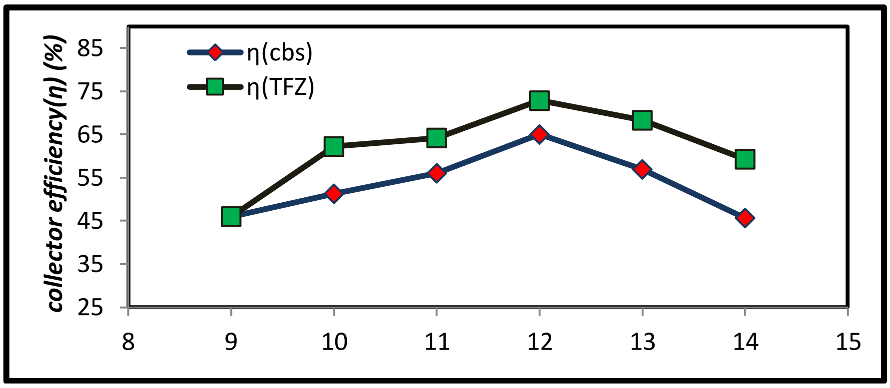

Fig.8: Variation of collector efficiency with local time for monoethylene glycol fluid

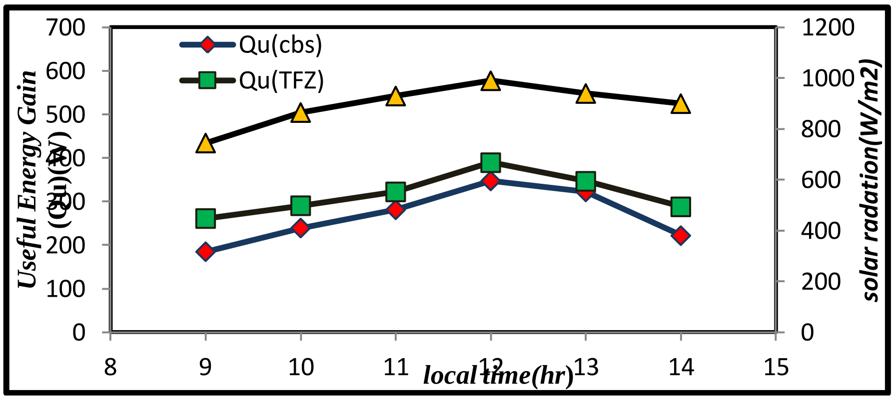

Fig.9: Variation of solar radiation (I) and useful energy gain (Q_u) with local time for monoethylene glycol fluid

Table 2: Experimental readings taken during December 3, 2015 for flat collector coating by nanomaterial coated and blank unit using monoethylene glycol as thermal fluid .

Time (hrs)	Solar intensity I W/m^2	Ambient temperature T_{amb}	I (blank unit)(cbs)				II(nanomaterial coating unit)(TFZ)			
			Inlet water Temp. (T_{in} °C)	Outlet water Temp. (T_{out} °C)	Heat gain Q_u (w)	Thermal efficiency η(%)	Inlet water Temp. (T_{in} °C)	Outlet water Temp. (T_{out} °C)	Heat gain Q_u (w)	Thermal efficiency η(%)
2009:00AM	745	22	26.4	48.5	185.0654	46.00	26.4	57.6	261.2688	64.94
10:00AM	865	24	26.8	55.4	239.4964	51.27	26.8	61.5	290.5778	62.21
11:00PM	930	24	26.9	60.5	281.3664	56.03	26.9	65.4	322.399	64.20
12:00PM	990	25	27	68.5	347.521	65.01	27	73.5	389.391	72.84
1:00 PM	940	23	26	60.5	288.903	56.92	26	67.4	346.6836	68.30
2:00PM	900	23	26	52.5	221.911	45.66	26	60.4	288.0656	59.27

4.3. Experimental readings taken during 22th of December 2015 using Iron vanadate oxide/EG fluid

Figure (10) show the relation between the variation of outlet temperature with local time for flat collector coating by nanomaterial (Ti-Fe-Zn) and blank (cbs) unit using Iron vanadate oxide/EG as fluid at 22th of December 2015 .It is clear that the T_{out} changed from 36.5. ℃ To 73.5 $℃$ for collector coating by nanomaterial but the T_{out} changed from 33 ℃ to 62 ℃ for blank collector when the solar radiation varied from 750 W/m^2 to 1000 W/m^2.

Also figure (11) shows relation between the variation of collector efficiency with local time and figure (12) shows variation of solar radiation (I) and useful energy gain (Q_u) with local time. Table (3): shows that the flat collector coating by nonmaterial and using iron vanadate oxide/EG as thermal nanofluid for indirect heating (II) at 12:00pm the high thermal efficiency at 75.99% heat gain (Q_u) (410.33 w) This could be attributed to high solar intensity although the blank flat collector(I) the thermal efficiency (η) (53.50 %) and heat gain (Q_u)

(288.90 w) at the same temperature and solar intensity . by these results the solar flat plate collector coating by nanomaterial gains more heat effectively and produce high performance.

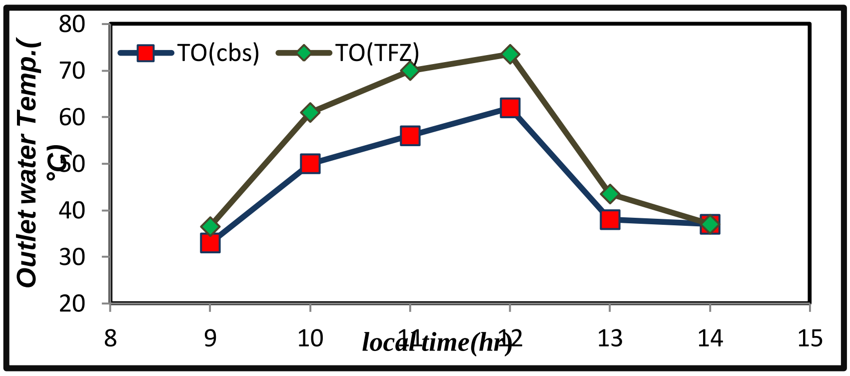

Fig.10: Variation of outlet temperature with local time for iron vanadate oxide/EG nonofluid

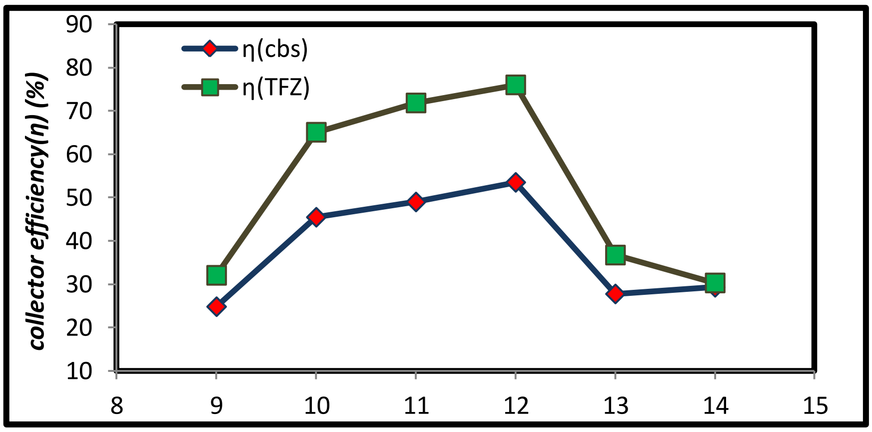

fig.11: Variation of collector efficiency with local time for iron vanadate oxide/EG nonofluid

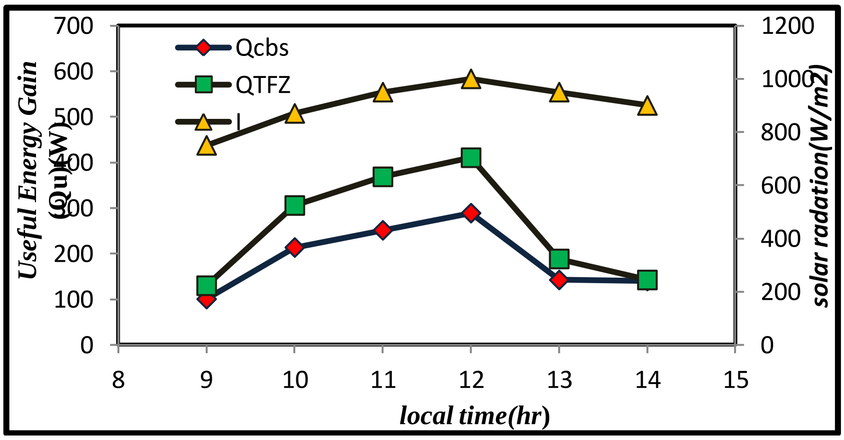

Fig.12: Variation of solar radiation (I) and useful energy gain (Q_u) with local time for iron vanadate oxide/EG fluid

Table 3: Experimental readings taken during the 22 th of December 2015 for flat collector coating by nanomaterial and blank unit using iron vanadate oxide/EG fluid.

Time (hrs)	Solar intensity I W/m^2	Ambient Temp. (T_{amb}°C)	I (blank unit)(cbs)				II(nanomaterial coating unit)(TFZ)			
			Inlet water Temp. (T_{in} °C)	Outlet water Temp. (T_{out} °C)	Heat gain Q_u	Thermal efficiency η(%)	Inlet water Temp. (T_{in} °C)	Outlet water Temp. (T_{out} °C)	Heat gain Q_u	Thermal efficiency η(%)

			(w)					(w)		
09:00AM	750	19	21	33	100.49	24.81	21	36.5	129.80	32.05
10:00AM	870	22	24.5	50	213.54	45.45	24.5	61	305.65	65.06
11:00PM	950	23	26	56	251.22	48.97	26	70	368.46	71.82
12:00PM	1000	24	27.5	62	288.90	53.50	27.5	76.5	410.33	75.99
1:00 PM	950	20	21	38	142.36	27.75	21	43.5	188.42	36.73
2:00PM	900	19	20	37	142.36	29.29	20	37	142.36	29.29

- **4.4. Experimental readings taken during 27th of December 2015 using iron vanadate oxide/EG as thermal fluid.**

Figure (13) shows the relation between the variation of outlet temperature with local time for flat collector coating by nanomaterial and blank unit using Iron vanadate oxide/EG as thermal nanofluid at 27.December 2015 .It is clear that the T_{out}changed from 60. ℃ to 79 ℃ for collector coating by nanomaterial although the T_{out} changed from 50 ℃ to 68.5 ℃ for blank collector when the solar radiation varied from 750W/m^2 to 1000 W/m^2.

Also figure (14) shows relation between the variation of collector efficiency with local time and figure (15) shows variation of solar radiation (I) and useful energy gain (Q_u) with local time. Table (4): shows that flat collector coating by nanomaterial and using iron vanadate oxide /EG as thermal nanofluid for indirect heating (II) at 12:00pm and high thermal efficiency at 82% heat gain (Q_u)(417.80 w) This could be attributed to high solar intensity, although blank flat collector (I) the thermal efficiency (η) (65.02 %) and heat gain (Q_u)(330.062 w) at the same temperature and solar intensity by these results the a solar flat plate collector coating by nanomaterial using iron vanadate oxide /EG as thermal nanofluid gains more heat effectively and produce high performance.

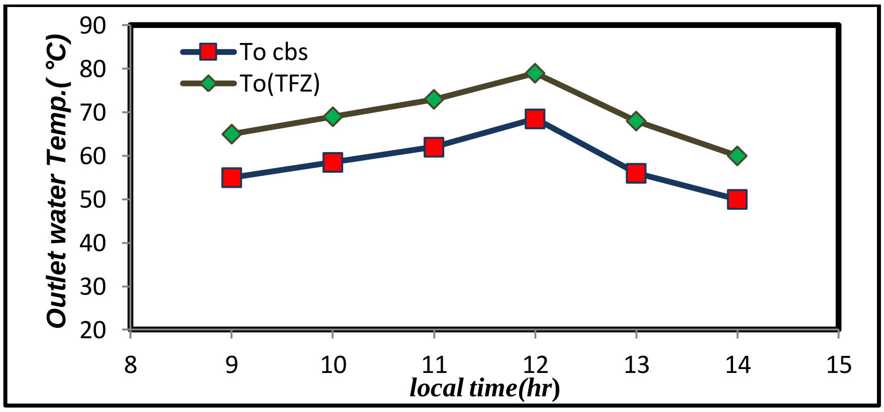

Fig. 13: Variation of outlet temperature with local time for Iron vanadate oxide/EG fluid.

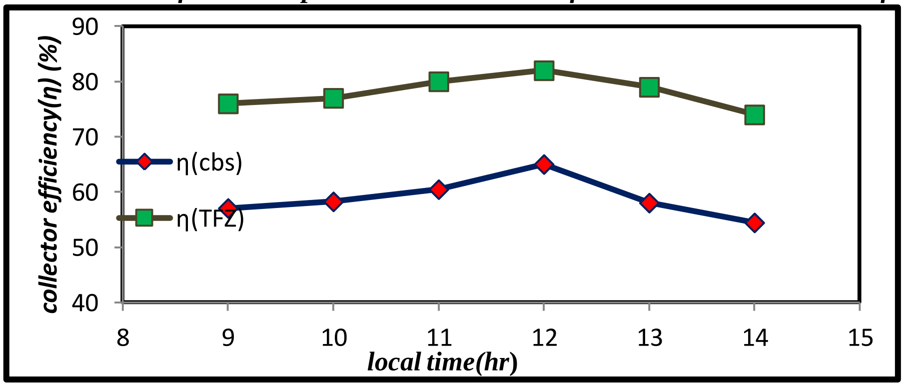

fig. 14: Variation of collector efficiency with local time for iron vanadate oxide/EG fluid.

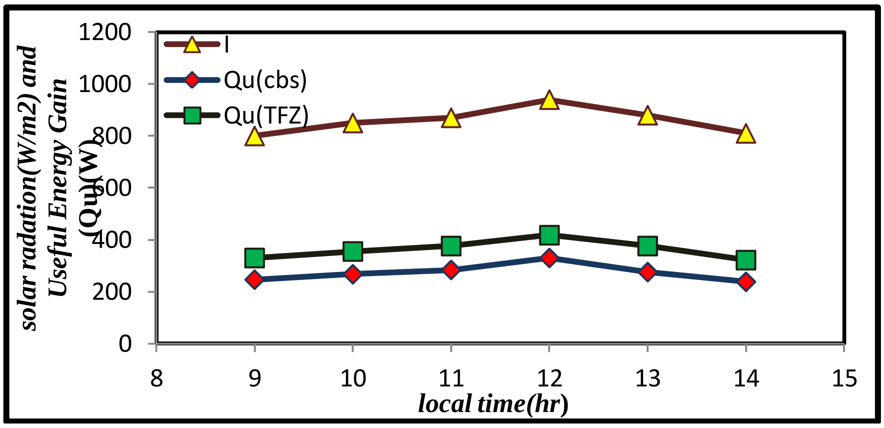

Fig.15: Variation of solar radiation (I) and useful energy gain (Q_u) with local time for iron vanadate oxide/EG fluid

Table 4: Experimental readings taken during the 27th of December 2015 for flat collector coating by nanomaterial and blank unit using iron vanadate oxide/EG thermal nanofluid .

Time (hrs)	Solar intensity (I W/m^2)	Ambient Temp. (T_{amb}°C)	I (blank unit)(cbs)				II(Nanomaterial coating unit) (TFZ)			
			Inlet water Temp. (T_{in} °C)	Outlet water Temp. (T_{out} °C)	Heat gain(Q_u) (w)	Thermal efficiency η(%)	Inlet water Temp. (T_{in} °C)	Outlet water Temp. (T_{out} °C)	Heat gain Q_u (w)	Thermal efficiency η(%)
09:00AM	800	20	25.5	55	246.50	57.06	25.5	65	330.06	76
10:00AM	850	22	26.5	58.5	267.39	58.26	26.5	69	355.13	77
11:00PM	870	23	28	62	284.10	60.47	28	73	376.02	80
12:00PM	940	24	29	68.5	330.06	65.02	29	79	417.80	82
1:00 PM	880	20	23	56	275.75	58.03	23	68	376.02	79
2:00PM	810	18	21.5	50	238.15	54.45	21.5	60	321.71	74

44.5. Experimental for direct and Indirect heating :

This part was carried out to study of direct and indirect heating using iron vanadate/EG nanofluid and monoethylene glycol as thermal fluids .For this purpose, two identical units of solar collector were used; on of collector connected direct and the other connected indirect using heat exchanger .The two units were adjusted to be the same angle with the sun.

4.5.1. Experimental readings during the 16 th of March using iron vanadate oxide/EG nanofluid.

Figure (16) shows the relation between the variation of outlet temperature with local time for flat collector direct and indirect using Iron vanadate oxide/EG as fluid for indirect at16 March 2015 .It is clear that the T_{out} changed from 48. °C To 91.5 °C for direct although the T_{out} changed from 49 °C to 94 °C for indirect collector using Iron Vanadate oxide/EG thermal nanofluid when the solar radiation changed from 890 W/m^2 to 1200 W/m^2.

Also figure (17) shows relation between the variation of collector efficiency with local time and figure (18) shows variation of solar radiation (I) and useful energy gain (Q_u) with local time. Table (5): shows that the flat collector (II) using (iron vanadate oxide/EG) thermal nonfluid for indirect heating the high temperature at 12:00pm and high thermal efficiency at 80.12% heat gain (Q_u)(519.19 w) This could be attributed to high solar intensity although a direct flat collector(I) using water as thermal fluid(I) the thermal efficiency (η)(77.54 %) and heat gain(Q_u)(502.44 w) at the same temperature and solar intensity . By these results the a solar flat plate collector using iron vanadate oxide /EG as thermal nanofluid gains more heat effectively and produce high performance

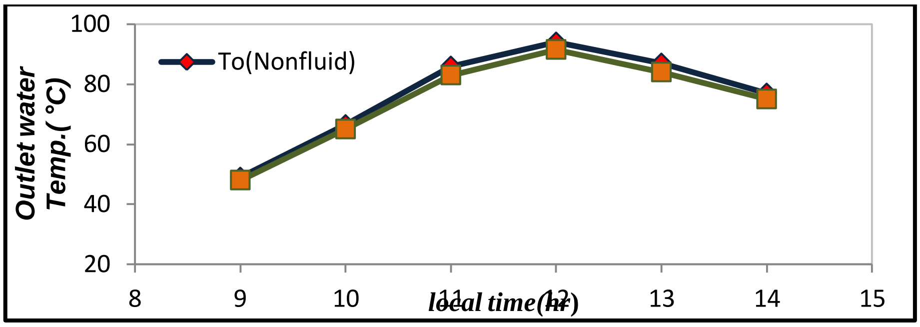

Fig.16: Variation of outlet temperature with local time for indirect using (iron vanadate oxide/EG) nanofluid and direct heating.

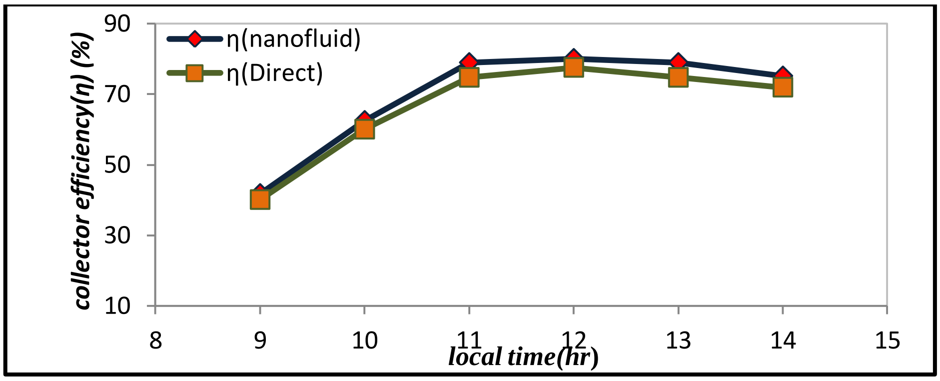

fig.17: Variation of collector efficiency with local time for indirect using iron vanadate oxide/EG) nanofluid and direct heating.

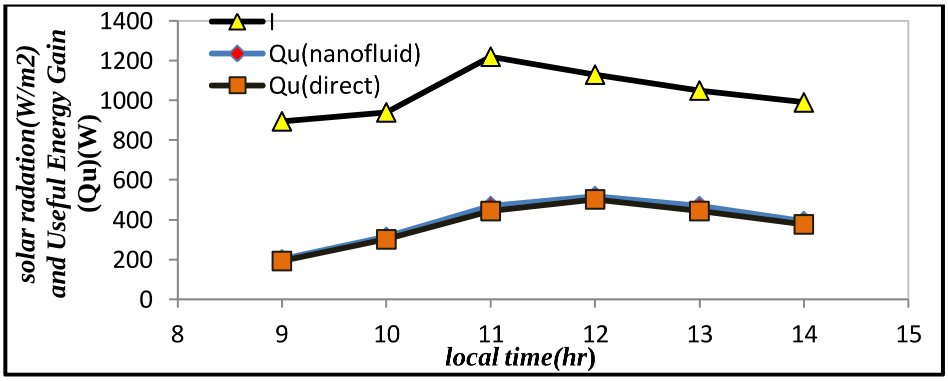

Fig. 18: Variation of solar radiation (I) and useful energy gain (Q_u) with local time for indirect using (iron vanadate oxide/EG) nanofluid and direct heating.

Table (5): Experimental readings during the 16th of March 2015 for indirect heating and direct using iron vanadate oxide/EG nanofluid for indirect heating.

Time (hrs)	Solar intensity I W/m^2	Ambient Temp. (T_{amb}°C)	III (indirect heating) Iron Vanadate oxide/EG nanofluid	IV(direct heating)

			Inlet water Temp. (T_{in} °C)	Outlet water Temp. (T_{out} °C)	Heat gain Qu (w)	Thermal efficiency η(%)	Inlet water Temp. (T_{in} °C)	Outlet water Temp. (T_{out} °C)	Heat gain Qu (w)	Thermal efficiency η(%)
09:00AM	890	22	25	49	200.98	41.82	26	48	192.60	40.08
10:00AM	930	23	29	66.5	314.03	62.53	28	65	301.46	60.03
11:00PM	1100	24	30	86	468.94	78.95	30	83	443.82	74.72
12:00PM	1200	26	32	94	519.19	80.12	33	91.5	502.44	77.54
1:00 PM	1100	24	31	87	468.94	78.95	31	84	443.82	74.72
2:00PM	970	24	30	77	393.58	75.14	30	75	376.83	71.94

4.5.2. Experimental readings during the 20th of March using monoethylene glycol fluid.

Figure (19) shows the relation between the variation of outlet temperature with local time for flat collector direct and indirect using monoethylene glycol (EG) as thermal fluid for indirect at 20thMarch 2015 .It is clear that the T_{out}changed from 46.5 ℃ to79 ℃ for direct although the T_{out} changed from 40 ℃ to 72 ℃ for indirect collector using monoethylene glycol fluid when the solar radiation varied from 890 W/m^2 to 1200 W/m^2.

Also figure (20) shows relation between the variation of collector efficiency with local time and figure (21) shows variation of solar radiation (I) and useful energy gain (Q_u) with local time. Table (6): shows that the flat collector (III) using monoethylene glycol as thermal fluid for indirect heating the high temperature at 12:00 pm and high thermal efficiency at 56.27 % heat gain (Q_u) (519.19 w) This could be attributed to high solar intensity although a direct flat collector (IV) using water the thermal (I) efficiency (η)(72.58 %) and heat gain (Q_u) (502.44 w) at the same temperature and solar intensity by these results the a solar flat plate collector using monoethylene glycol as thermal fluid gains more heat effectively and produce high performance.

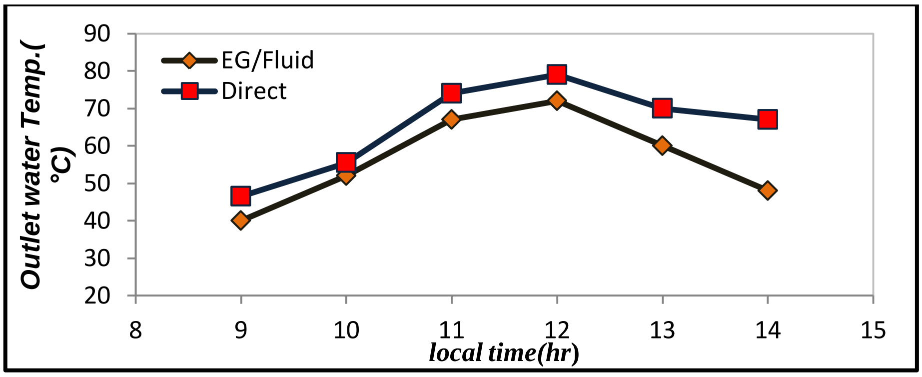

Fig.19: Variation of outlet temperature with time with local time for indirect using (monoethylene glycol fluid and direct heating

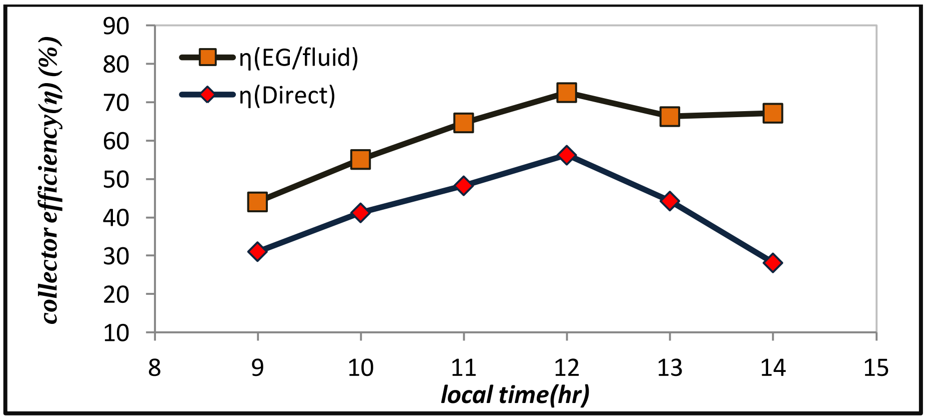

fig.20: Variation of collector efficiency with local time for indirect using (monoethylene glycol fluid and direct heating

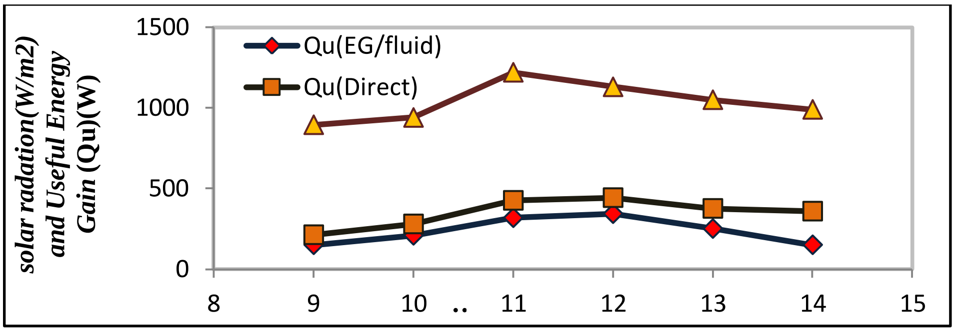

Fig.21: Variation of solar radiation (I) and useful energy gain (Q_u) with local time for indirect using (monoethylene glycol fluid) and direct heating

Table 6: Experimental readings during the 20 th of March 2015 for indirect heating and direct using monoethylene glycol fluid for indirect heating.

Time (hrs)	Solar intensity I W/m^2	Ambient Temp. (T_{amb}°C)	III (indirect heating) (Blank)monoethylene glycol				IV direct heating			
			Inlet water Temp. (T_{in} °C)	Outlet water Temp. (T_{out} °C)	Heat gain Qu (w)	Thermal efficiency η(%)	Inlet water Temp. (T_{in} °C)	Outlet water Temp. (T_{out} °C)	Heat gain Qu (w)	Thermal efficiency η(%)
09:00AM	890	20	22	40	150.732	31.19	21	46.5	213.078	44.09
10:00AM	930	21	27	52	209.35	41.24	22	55.5	279.926	55.15
11:00PM	1100	22	29	67	318.212	48.30	23	74	426.156	64.69
12:00PM	1200	24	31	72	343.334	56.27	26	79	442.868	72.58
1:00 PM	1100	23	30	60	251.22	44.31	25	70	376.02	66.32
2:00PM	970	22	30	48	150.732	28.20	24	67	359.308	67.21

- **4.6. Comparative study of iron vanadate/EG nanofluid and monoethylene glycol as thermal fluids.**

The experiments have been carried out using two identical solar collectors at the same conditions. The heat absorbed by fluid in the collector, and the efficiency and the temperature circulation, useful heat energy and the collector efficiency were calculated.

4.6.1. Useful heat gain (Q_u) and thermal efficiency.

The figure (22 &23) show that the collector efficiency and the useful heat gain Q_u. the useful heat gain Q_u changed from(200.98 W to 519.19 W)for flat collector contains iron vanadium oxide/EG as thermal nanofluid on the other hand , the useful heat gain Q_u changed from (150.732 W to 343.334 kW)for flat collector contains (EG) as fluid the useful heat gain first increases, reach a peak value around noon and then decreases. The useful heat gain Q_u for collector contains iron vanadium oxide/EG nanofluid is higher than collector using EG fluid.

The figure (23) shows the change in the efficiency of the flat collector with time. The same behavior was observed the collector efficiency increases to reach a maximum value and then decreases. The thermal efficiency of collector using iron vanadate oxide /EG as thermal fluid is higher than using monoethylene glycol .The maximum recorded thermal efficiency was 80 %.

4.6.2. Outlet temperature

The figure (24) shows the variation of outlet temperature with time. the outlet temperature T_o changed from (49 **°C** to 94 **°C**) for flat collector using iron vanadium oxide/EG as thermal nanofluid and the outlet temperature T_o changed from (40 **°C** to 72 **°C**) for flat collector using (EG) thermal fluid . The outlet temperature T_o first increases, reach a peak value around noon and then decreases. The outlet temperature T_o for collector contains iron vanadium oxide/EG as thermal nanofluid is higher than collector contains EG thermal fluid.

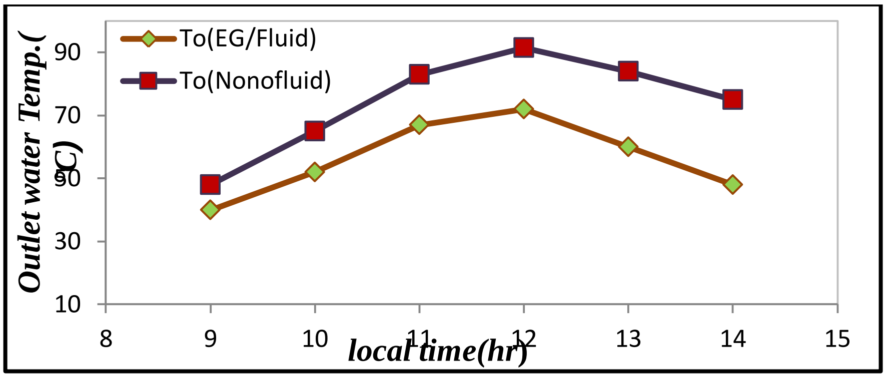

Fig.22: Variation of outlet temperature with time for using (iron vanadate oxide/EG) nanofluid and EG/fluid.

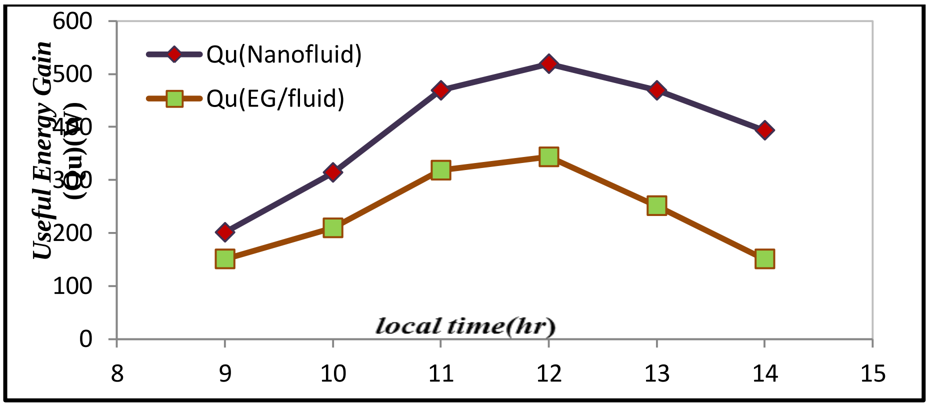

fig.23: Variation of collector efficiency for using (iron vanadate oxide/EG) nanofluid and EG./fluid .

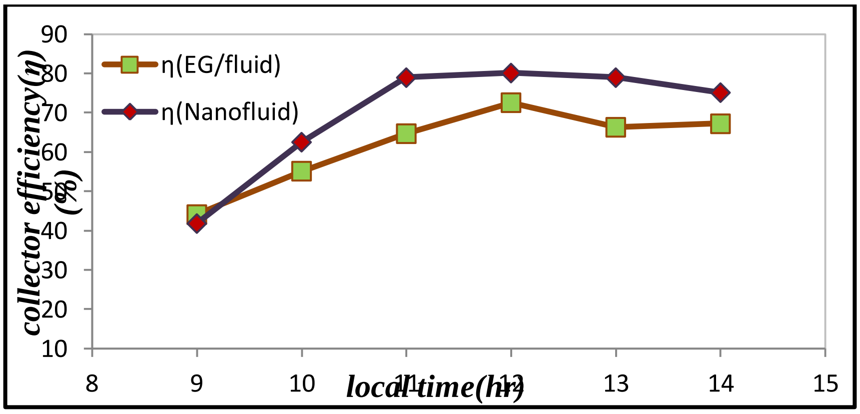

Fig.24: Variation of solar radiation (I) and useful energy gain (Q_u) with local time for using (iron vanadate oxide/EG) nanofluid and EG./fluid .

V. CONCLUSION

- The useful energy gain (Q_u) of flat plate collector coating by nanomaterial's (Ti-Fe-Zn) is higher than the useful energy gain (Q_u) of collector coating with blank(csb) also the thermal efficiency of coating nanomaterial's is higher than other .
- The useful energy gain (Q_u) by thermal nanofluid (iron vanadate oxide/EG) is higher than the useful energy gain (Q_u) by direct heating for flat plate collector.
- The useful energy gain (Q_u) by thermal nanofluid (iron vanadate oxide/EG) is higher than the useful energy gain (Q_u)by monoethylene glycol as thermal fluid for flat plate collector and observed that the thermal efficiency is variation in the same trend.

REFERENCES

[1]. A.A. Hawwash, Ali K. Abdel Rahman , S.A. Nada , S. Ookawara, Applied Thermal Engineering 130 (2018) 363–374

[2]. P.K. Nagarajan, J. Subramani, S. Suyambazhahan, R. Sathyamurthy, Nanofluids for solar collector applications: a review, Energy Procedia 61 (2014) 2416– 2434.

[3]. J. Ramesh, J. Kanna Kumar, Dr. E.V. Subbareddy " Design, Fabrication and Performance analysis of a Parabolic trough solar collector waterheater," International Journal of Innovative Research in Science Engineering and Technology, Vol. 4, Issue. 7, July 2015, PP. 6038-43.

[4]. P. Rhushi Prasad, H.V. Byregowda, P.B. Gangavati, "Experiment Analysis of Flat Plate Collector and Comparison of Performance with Tracking Collector", European Journal of Scientific Research ISSN 1450-216X Vol.40 No.1(2010), pp.144 155.

[5]. J.A. Duffie, W.A. Beckman, Solar Engineering of Thermal Processes, second ed., Wiley, 2006.

[6]. Kalogirou S., Solar energy collectors and applications. Prog Energy Combust Sci, 30(3), (2004)pp. 231- 95.

[7]. Y. Ding, H. Alias, D. Wen, R.A. Williams, Heat transfer of aqueous suspensions of carbon nanotubes (CNT Nanofluids), Int. J. Heat Mass Transfer 49 (2006) 240–250performance of building integrated solar collectors, Solar Energy Materials &solar cells, 94, 350-354.

[8]. U. K. Nayak, Dr. S. C. Roy, Dr. M K Paswan and Dr. A. K. Gupta, Heat Transfer And Flow Friction Characteristics Of Solar Water HeaterWith Inserted Baffel Inside Tube. International Journal of Mechanical Engineering & Technology (IJMET), 5 (4) (2014), pp. 16–22.

[9]. P. Sivashanmugam, S. Suresh, Experimental studies on heat transfer and friction factor characteristics of laminar flow through a circular tube fitted with helical screw-tape inserts, Appl. Therm. Eng. 26 (2006) 1990–1997.

[10]. S. Jaisankar, T.K. Radhakrishnan, K.N. Sheeba, Experimental studies on heat transfer and friction factor characteristics of forced circulation solar waterheater system fitted with helical twisted tapes, Sol. Energy 83 (2009) 1943–1952.

[11]. Augustus M. and Kumar S., 2007, Mathematical modeling and thermal performance analysis of unglazed transpired solar collectors, Solar Energy, 81,62-75.

[12]. S. Irfan Sadaq, S. Nawazish Mehdi, Ishrath M.M, Afroz Mehar, NBV. Lakshmi Kumari, "Performance Analysis of Solar Flat Plate Collector," Proceedings of Third IRF International Conference, 07th March-2015, Mysore, India, ISBN: 978-93-82702-74-0, pp 51-56.

[13]. Rai, G.D., 2005. Solar Energy Utilization. Khanna Publishers, pp. 102–104 and 135-145.

[14]. Sivakumar, P., Christraj, W., Sridharan, M., Jayamalathi, N., 2012. Performance improvements study of solar water heating system. ARPN J. Eng. Appl. Sci. 7 (1), 45–49.

[15]. Sukhatme, S.P., Nayak, J.K., 2008. Solar Energy, Principles of Thermal Collection and Storage. Tata McGraw Hill Education Private Limited, pp. 109–158.

Eman M.Mostafa, et. al. "Construction and evaluation the performance of solar collector prototypes in different month's."*American Journal of Engineering Research (AJER)*, vol. 10(1), 2021, pp. 197-212.