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THERMAL PERFORMANCE EVALUATION OF THE SOLAR NANO FLUIDS HEATING SYSTEM USING NANO METAL AND NANO METAL OXIDE

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ABSTRACT

This research presents an experimental analysis Solar nanofluids heating system efficiency when copper (Cu (30nm) +Pure water), zirconium oxide (ZrO_2 (50nm) +Pure water) nanofluids are taken as operating fluid. For larger working fluid thermal conduction, the solar collector's efficiency could be better in comparison with performance of pure water. Approach used in this study to improve heat transfer and pressure fall using the helically coiled tube heat exchange in the solar energy device and the nanofluids instead of the base fluid (pure water). Two kinds of nanoparticles are used to explore at various concentration (1, 3 and 5 percent vol.), the rates of volume flow were (30, 60, 90 L/min) and the base operating fluid was pure water. Impact of various ratio of Cu and ZrO_2 nanoparticles blended with pure water as base fluid was studied for various volume flow rates (30, 60 and 90 L/min) on solar collector efficiency. The area under the curve was used as an indicator to study the impacts of volume flow rates and nanoparticles ratio on the collector's total effectiveness. The results of experiment indicate that ratio of 1% volume reveals negligible results compared to pure water. Such as nanofluids (Cu (30nm) + PW), at ratio of (1%, and 5% volume) and volume flow (30, and 90 L/ min), the thermal characteristics values of FR (τα), - FRUL were observed 0.407, 1.156 ($W/m^2.k$), 0.444 and 1.192 ($W/m^2.k$), whereas nanofluid (ZrO_2 (50nm) + PW) were 0.513, 1.233($W/m^2.k$), 0.522 and 1.275 ($W/m^2.k$) respectively. When at volume flow rates (30 L/min and 90 L/min) for pure water were 0.413, 0.973 ($W/m^2.k$), 0.442 and, 1.011 ($W/m^2.k$) respectively. In addition, using (Cu (30 nm) +PW) and (ZrO_2 (50 nm) + PW) as operating fluid can enhance thermal performance of the solar collector relative to pure water. Nanofluid types are a main factor in enhancing the transfer of heat and improving the achievement rate of the evacuated solar collector.

Keywords: nanofluids, evacuated solar collector, thermal performance.

1. INTRODUCTION

Solar power is a significant source of renewable power for use with various techniques; solar collectors capture their energy from sun. To make this development a major source for the future, research and development must address a number of issues, such as capacity, space and the environment [1]. Solar power has become more attractive because it is safe, and available without any restrictions. Solar collectors are the latest systems to capture heat from solar energy that can be used in most buildings, such as air conditioning, water heating, swimming pool heating, and so on [2]. Nevertheless, solar power as an everlasting and ubiquitous source of power is constantly changing, as main drawback between time of sunlight and use, therefore, accumulation and processing of solar power during the time of radiation is important for duration of use. Water a good source of solar power [3]. Solar collectors are a significant component of any cycle of solar power consumption There function is to capture the incoming solar radiation and convert it into heat, transition of energy to a liquid flowing through the collector (generally air, liquid or a special thermal energy fluid). [4]. Choi, S. K. and *et al* [5]; Displayed that it is possible to use nanofluids to boost thermal transfer to reservoirs from solar collectors and increase heat density. Several writers have noted that ETSC has significantly higher efficiencies than FPC, especially at low insulation temperatures. Due to its high performance tubular absorber, especially in low radiation conditions, ETSC has lower convection heat loss and lower cost throughout the year. As Kalogirou [6]; and Morrison, G., Tran and *et al.* [7]; as shown by Zambolin and Del Col [8]; and Ayompe *et al*. [9]; Otanicar and Golden. [10]; Testing of nanofluid-based solar collectors made of range of nano particles (carbon nano tubes, graphite and cupper) were published. Enhancements in the performance of solar thermal collectors were up to 5% by using nanofluids as method of absorption. The experimental and numerical results showed an efficiency increase when the volume fraction continues to increase. Taylor *et al.* [11]; Applicability to operate in solar thermal with high flow. Laboratory-scale studies on a nanofluid dish receiver suggest that an efficiency increase of up to 10 percent is feasible-relative to a regular liquid - if operating conditions have been carefully selected. Yong Yang Gan *et al* [12]; Studied the thermal efficiency evaluation and conducted an ETSC entropy measurement using nanofluids (TiO_2) as a working fluid. Titanium oxide (TiO_2 nanofluid created when scattering a small amount of TiO_2 nanoparticles into pure water. TiO_2 nanofluid's higher thermal conductivity may improve the performance of evacuated tube solar collectors (ETSC). Eventually, the rise in nanoparticles volumetric concentration significantly increases the nanofluid's thermal conductivity.

The main goals of this research are to consider the effects of copper (Cu) and zirconium oxide (ZrO_2) nanofluids on the performance of solar collectors, volume

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flow rate, volume concentration and size of nanoparticle more than collector efficiency.

2. NANOFLUIDS PREPARATION (Copper and Oxide Zirconium)

The nanofluids researched consists of nanoparticles of copper (cu (30 nm) and zirconium oxide (ZrO_2 (50 nm) and two-stage processes by dispersing reweighted amounts of powdered nanoparticles in the base liquid (pure water). The (pH) of each nanofluid mixture was measured in a typical process. The mixtures were ultrasonically mixed for two hours to degrade any particle clusters as shown in Figure-1.

Prepared nanofluids could remain stable for at least 4 hours. Figure-2 shows the nanofluids involving copper (Cu (30 nm)) and zirconium oxide (ZrO_2 (50 nm)).

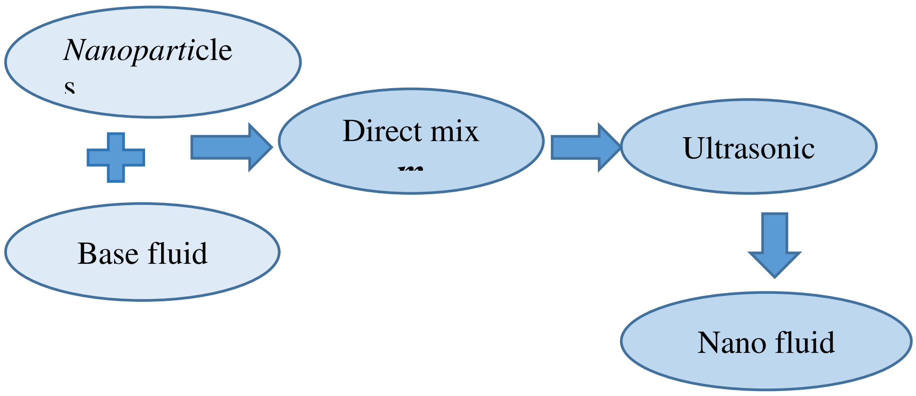

Figure-1. The preparation process of nanofluid.

Figure-2. Show the nanofluids mixtures. (ZrO_2+ PW), (Cu+PW) and pure water.

3. EXPERIMENTAL SETUP

Figures (3-6) displays the setup's schematic view. An ETSC system consisting of 10 hollow tubes was added, while a heat exchanger was added on the other hand. Circulation water pump used to transfer nanofluids at different speeds. In addition, several thermocouples were also connected to the heat exchanger on the solar collector input and output, two pressure gages with a range of (0 - 150), (0 - 400) mbar were installed, in order to measure the static pressure at the heat exchanger input and output, flow rate was accurately measured by the flow meter model Zyia. The Digital Solar Meter Make - Lutron, Made in Taiwan, measured the solar radiation. Model No.: [SPM - 1116 SD], a precision ± 10 W / m^2 solar power meter.

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Figure-3. Heat exchanger.

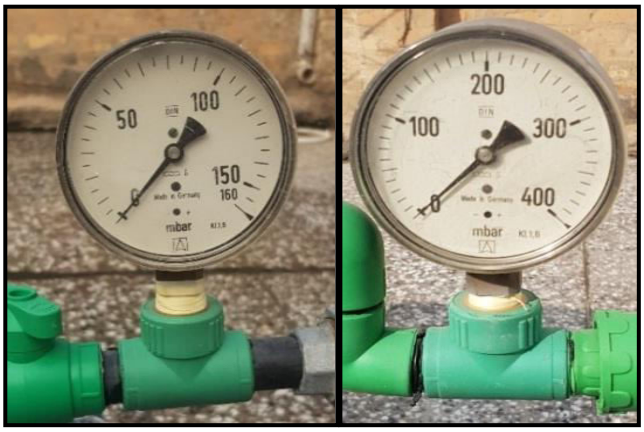

Figure-4. Pressure gauges.

Figure-5a. circulation water pump, Fig (5b) flow meter, Fig (5c) ETSC, Fig (5d) data logger.

Figure-6. The test rig.

4. ANALYSIS OF DATA AND VALIDATION

Useful thermal energy, temperature distribution, and efficiency of the collector was determined using equations (1-7) which were derived from [13-15]. In order to acquire a relationship between the temperature and the flow rate of the volume, the equation for useful thermal energy (Qu), as:

$$Q_U = A_C F_R\left[I\,\alpha\,\tau - \left(T_{nf,in} - T_a\right)\right] \tag{1}$$

The thermal energy is converted into thermal energy of water in the pipes as:

$$Q = \dot{m}C_p(T_{nf,o} - T_{nf,i}) \tag{2}$$

Then

$$\dot{m}C_p(T_{nf,o} - T_{nf,i}) = A_C F_R[I\,\alpha\,\tau - (T_{nf,in} - T_a)] \tag{3}$$

Therefore,

$$(T_{nf,o} - T_{nf,i}) = \left\{\frac{A_C F_R}{\dot{m}C_p}\right\}[I\,\alpha\,\tau - U_L(T_{nf,in} - T_a)] \tag{4}$$

F_R may be obtained from

$$F_R = \frac{\dot{m}C_p}{A_C\,U_L}\left[1 - \exp\left(\frac{A_C\,U_L\hat{F}}{\dot{m}C_p}\right)\right] \tag{5}$$

Then the collector effectiveness was got by utilize the relation,

$$\eta_{s,c} = \frac{Q_U}{A_C I} \tag{6}$$

Substitute Eqs. (2) and (3) of the Eq. (5) stays,

$$\eta_{s,c} = F_R\left[\alpha\,\tau - \frac{U_L(T_{nf,in} - T_a)}{I}\right] \tag{7}$$

Since F_R, $\alpha\,\tau$ & U_L are constant,

$$\eta_{s,c}\ \alpha\ \left[\frac{(T_{nf,in} - T_a)}{I}\right] \tag{8}$$

5. NANOFLUID THERMAL MEASUREMENT - PHYSICAL PROPERTIES

Empirical relationship used in research to compare nanofluid properties with practical readings. The previous equations were used to calculate thermal transfer-physical properties at average nanofluid temperatures. Volume fraction (Φ) of the nanoparticles specified by equation [16].

$$\Phi = \frac{V_p}{V_p + v_f} = m\frac{\pi}{6}d_p^{-3} \tag{9}$$

Density [18]

$$\rho_{nf} = \rho_{nf}\,\Phi + (1-\Phi)\rho_{Dw} \tag{10}$$

Viscosity [17]

$$\mu_{nf} = (1-\Phi)\mu_{DW} + \Phi\mu_{DW} \tag{11}$$

Specific heat [18]

$$cp_{nf}\rho_{nf} = \Phi(\rho_s cp_s) + (1-\Phi)(\rho_{DW}cp_{DW}) \tag{12}$$

Suresh S. *et al.* [18] previously, addressed an efficient model for conductivity (Eq.12)

$$\frac{K_{nf}}{K_{DW}} = \left[\frac{cp_{nf}}{cp_{DW}}\right]^{-0.023}\left[\frac{\rho_{nf}}{\rho_{DW}}\right]^{1.358}\left[\frac{\mu_{nf}}{\mu_{DW}}\right]^{0.126} \tag{13}$$

Table-1. Thermo - physical properties of the nanofluids employed [19].

Particles of nano scale	density (Kg/m^3)	Specific heat (J/kg k)	thermal transmittance ($W/m^2 k$)	$\beta *10^5$ (k^{-1})	$\alpha *10^5$ (m^2/s)
Copper (Cu)	8933	385	401	1.67	11.7
Zirconium oxide (ZrO_2)	5890	278	22.7		12.4

6. RESULTS AND DISCUSSIONS

The primary purpose of the project is to increase the solar collector's thermal efficiency. The performance of the evacuated solar tube was discussed in details when the nanoparticles were applied to the collector. Comparisons are made with copper Cu and zirconium oxide (ZrO_2) nano fluids at ratios (1, 3, 5%vol) and rates of volume (30, 60, 90 L/min). Useful heat gain is related to how collectors can accumulate a quantity of energy it can be calculated by equations (1) and (2) respectively. The useful heat is gained by solar collectors at different inlet temperatures, volume flow rate (30, 60 and 90 L/min) and volume fraction (1, 3 and 5%vol) are shown in Figures (7-8), the heat gained when using pure water is (40.058W, 42.6261W, 47.308W,58.805W, 68.2726W, 73.3055W, 74.6337W, 81.4343W),for the volume flow rate (30 L/min). Nanofluids (Cu + PW, ZrO_2 + PW) at 5 %vol. has shown better results relative to pure water about same flow rate, this means that, by increasing the concentration rate, the amount of heat gain is increased. The efficiency, improvement values have been increased gradually as show in Figures (9-10) and Table-2, Notice that the efficiency enhancement increases as volumetric flow rate and volume concentration values increased.

Figures (11-12) showed the difference in temperature and higher temperature of inlet, the difference in temperature was more deviant than pure water. This implied that the two sources of nanofluids could get more heat, so the heat loss of the collector was lower than of pure water. It was unquestionable that temperature difference decreased when the inlet temperature and the rates of volume raised.

7. CONCLUSIONS

Thermal improvement of the performance of the solar collector was investigated as working fluid with nanofluids (Cu (30nm) +PW) and (ZrO_2 (50nm) +PW). The two forms of nanoparticles can be used to analyze the

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concentration ratios of particles (i.e., 1, 3 and 5% vol) and pure water was the working liquid. The results are summarized as follows:

a) Type and size of nanoparticles play a major role in optimizing the heat transfer rate and improving the efficiency of the solar collector evacuated.
b) Nanofluid (Cu (30 nm) solar performance was better than nanofluid (ZrO_2 (50 nm)) and high copper thermal conductivity due to the small copper particulate matter relative to oxide zirconium.
c) Using nanofluids (Cu (30 nm) and ZrO_2 (50 nm) as operating fluid can boost thermal production of the evacuated solar collector relative to pure water, particularly at the higher inlet temperatures.
d) By using Nano fluids, the thermal transfer characteristic of the coil is better than pure water.
e) The increase in the rate of concentration leads to an increase in the amount of heat gain.

Table-2. The efficiency, improvement values.

	Concentration (% Vol)	Q (Lpm)	Model	Area under curve X100 (A)	R^2
Nano fluid (Cu (30nm) - Dw)	1	30	$\eta = -1.156\,X + 0.407$	1.35	0.975
	3	30	$\eta = -1.163\,X + 0.421$	1.36	0.970
	5	30	$\eta = -1.192\,X + 0.444$	1.38	0.982
	1	60	$\eta = -1.201\,X + 0.465$	1.39	0.984
	3	60	$\eta = -1.215\,X + 0.484$	1.41	0.971
	5	60	$\eta = -1.225\,X + 0.506$	1.43	0.986
	1	90	$\eta = -1.233\,X + 0.513$	1.44	0.978
	3	90	$\eta = -1.245\,X + 0.534$	1.45	0.982
	5	90	$\eta = -1.257\,X + 0.552$	1.52	0.995
Nano fluid (ZrO_2 (50nm)-Dw)	1	30	$\eta = -1.014X + 0.295$	1.21	0.997
	3	30	$\eta = -1.033\,X + 0.312$	1.22	0.987
	5	30	$\eta = -1.052\,X + 0.328$	1.23	0.983
	1	60	$\eta = -1.061\,X + 0.335$	1.24	0.973
	3	60	$\eta = -1.072\,X + 0.342$	1.26	0.984
	5	60	$\eta = -1.087\,X + 0.357$	1.30	0.978
	1	90	$\eta = -1.090\,X + 0.363$	1.31	0.987
	3	90	$\eta = -1.110\,X + 0.366$	1.32	0.978
	5	90	$\eta = -1.129\,X + 0.367$	1.34	0.984
Distilled water (Dw)	0	30	$\eta = -0.945\,X + 0.252$	1.19	0.985
	0	60	$\eta = -0.974\,X + 0.274$	1.24	0.984
	0	90	$\eta = -1.050\,X + 0.312$	1.27	0.978

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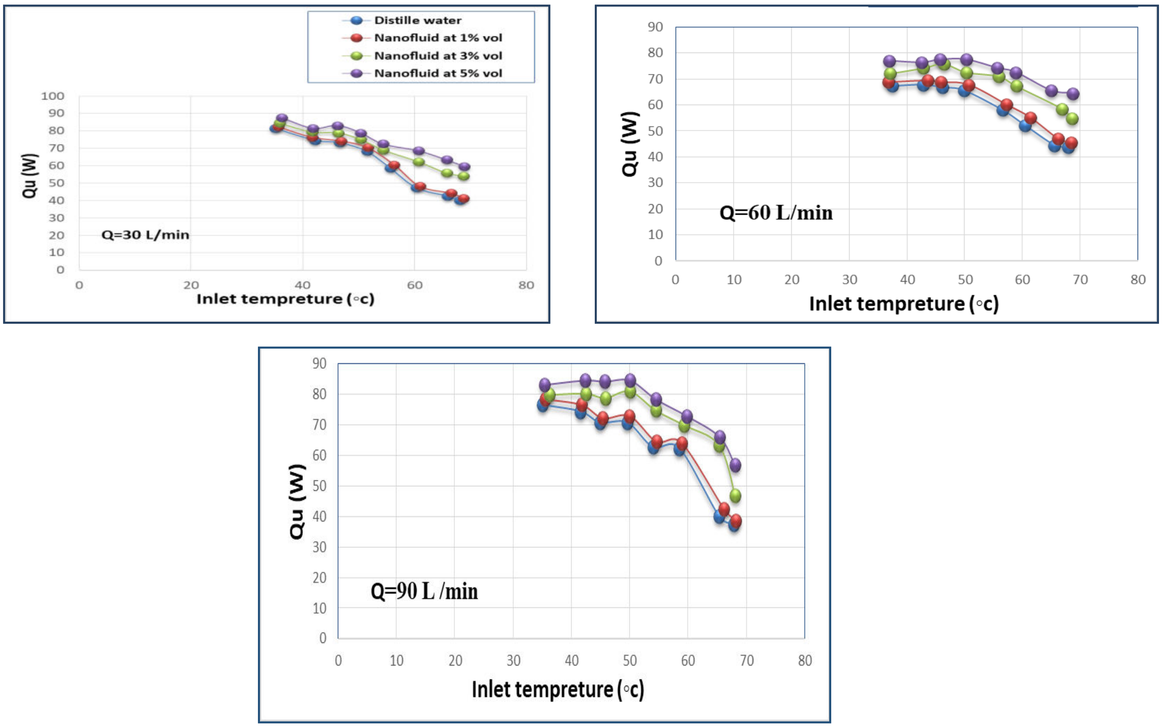

Figure-7. Gain beneficial heat of solar Collector at several Φ for Nano particles (Cu) with Dw at different flow rate.

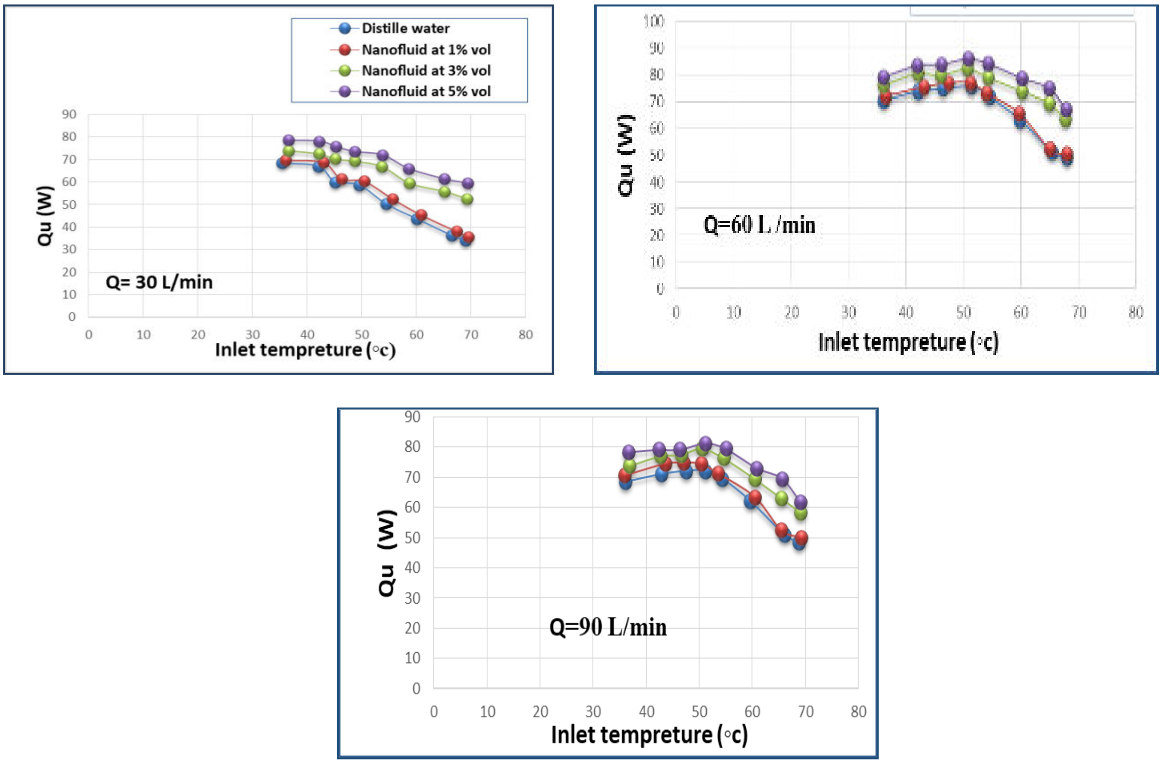

Figure-8. Gain beneficial heat of solar Collector at several Φ for Nano particles (ZrO_2) with Dw at different flow rate.

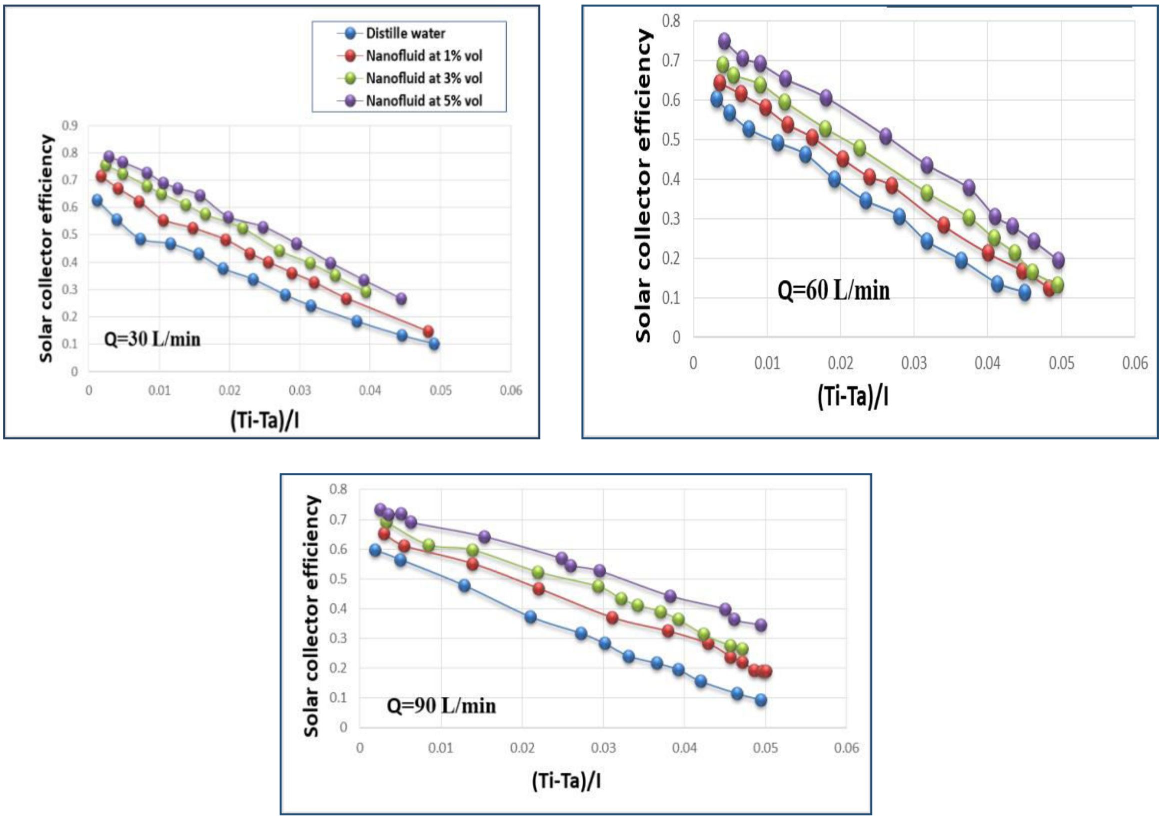

Figure-9. Efficiency Collector of Nano particles (Cu) with Dw at various Φ.

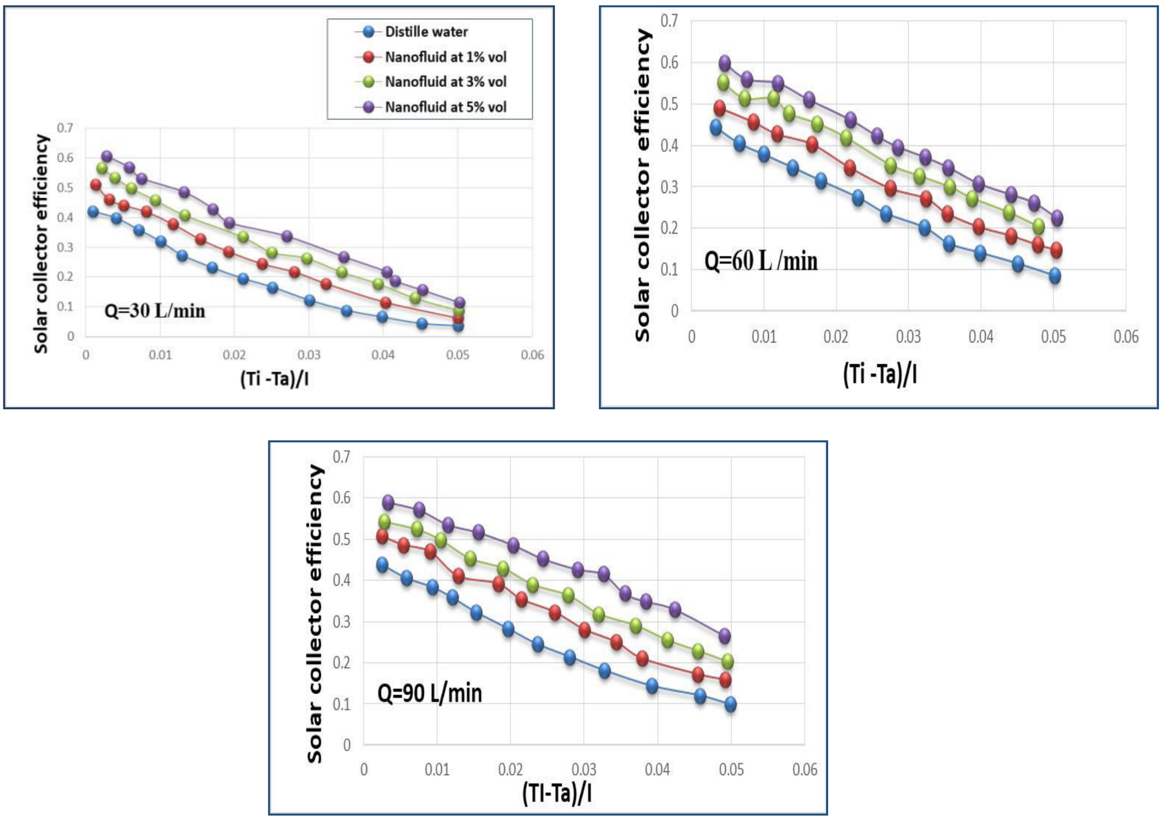

Figure-10. Efficiency Collector of Nano particles (ZrO_2) with Dw at various Φ.

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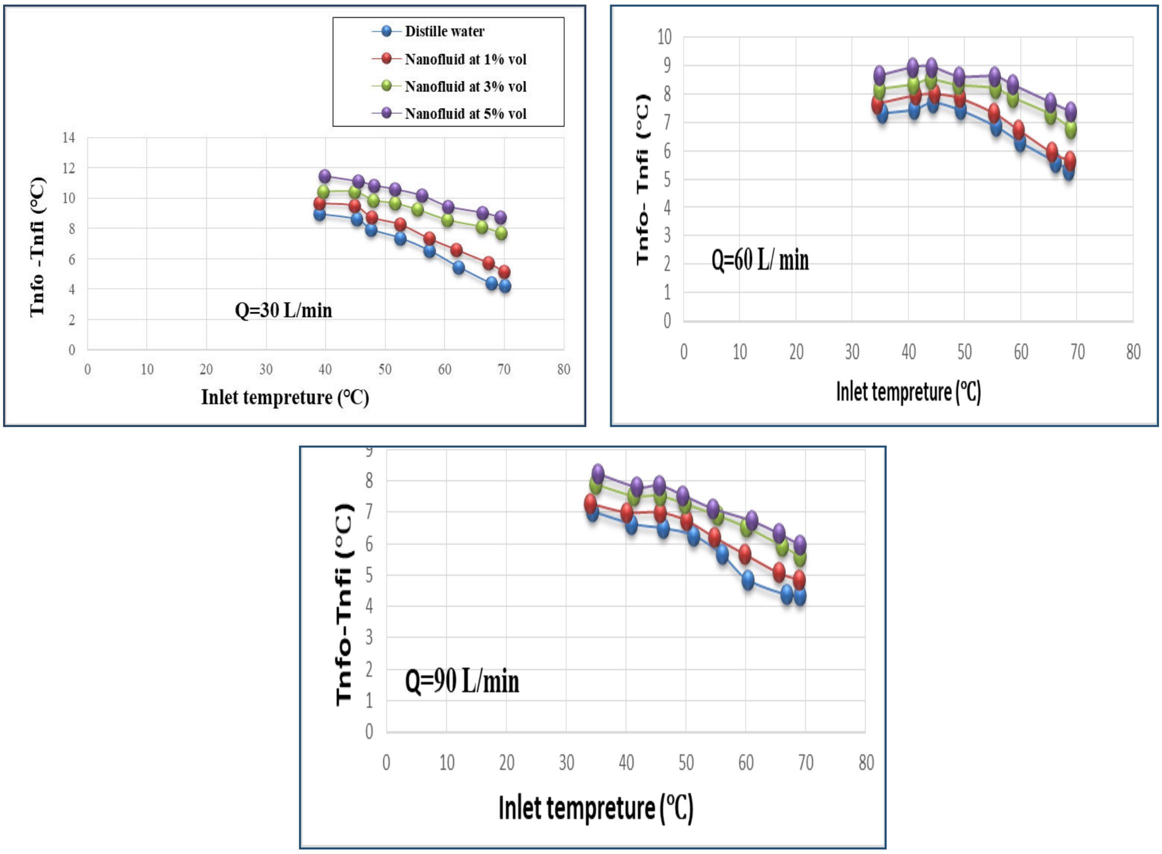

Figure-11. Temperature changing between input and output solar collector at several Φ for nanoparticles (Cu) and distilled water.

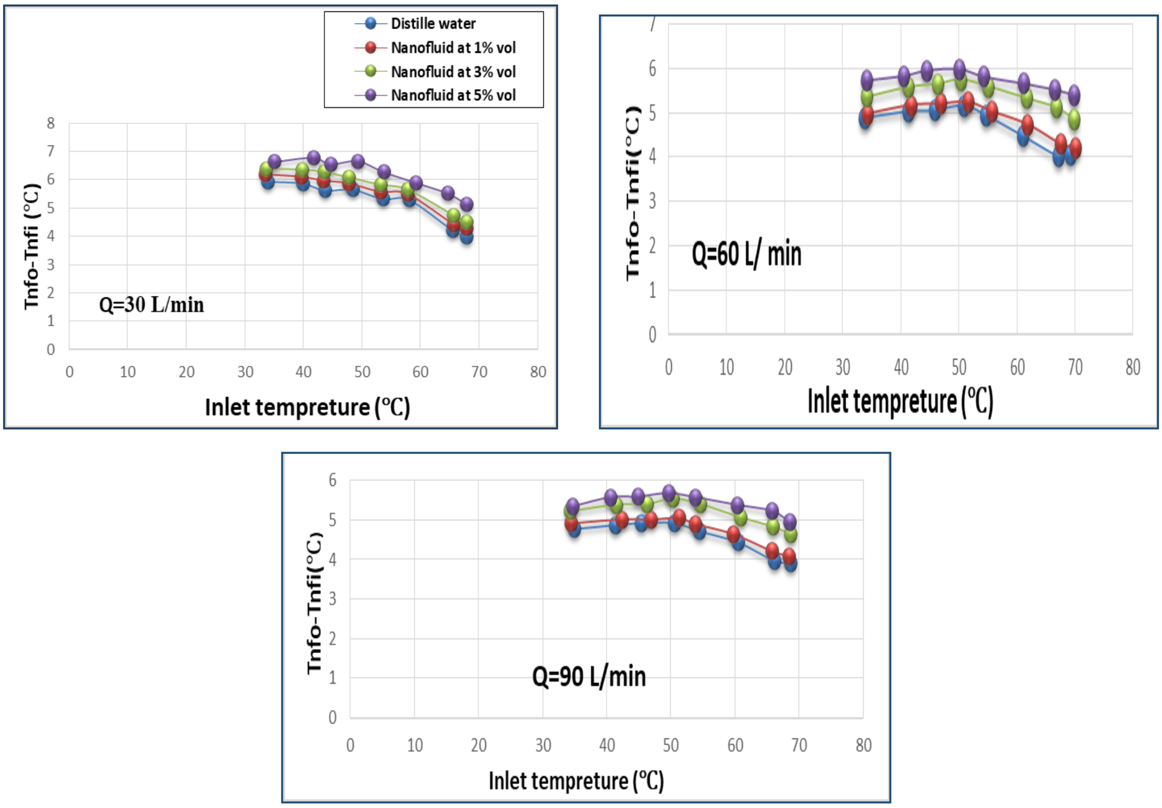

Figure-12. Temperature changing between input and output collector solar at various Φ for nanoparticles (ZrO_2) and distilled water.

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