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Performance Evaluation of Flat Plate Solar Collector (Model Te39) In Bauchi

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ABSTRACT: *This paper presents the thermal performance of solar flat plate water heater (Model TE 39) in Bauchi weather conditions (lat. 10.50° N, long. 10.00° E). Fluid was circulated through the imbedded copper tubes in the flat plate collector and inlet and outlet temperatures of the fluid were noted at intervals of five minutes. The experimental-time was between 11:00-13:00 hours daily for a period of 28 days. The result shows that the outlet water temperatures were dependant on the weather condition (solar radiation intensity, cloud cover) with outlet water temperature of 55°C and 70.5% optimum efficiency of the collector obtained at 12:05pm. This shows that the use of this flat plate solar collector will be viable for domestic heating application under Bauchi prevailing weather condition.*

Key words: *flat plate collector, solar intensity radiation, thermal performance.*

I. INTRODUCTION

Energy is the rate at which work is done and is an essential ingredient of socio-economic development and economic growth [1]. Energy is an essential input to all aspects of modern age and is indeed, the livewire of industrial and agricultural production, the fuel for transportation as well as for the generation of electricity in conventional thermal power plant. The nature and extent of energy demand and utilization in a national economy are, to a large extent, indicative of its level of economic development. For rapid and secured economic advancement in a productive economy, the country must pay maximum attention to the development and utilization of its energy resources and to the security of supply of its energy needs [2].

Presently, the world heavily relies on fossil fuels of oil, gas and coal to meet its energy requirements providing about 80% of the total global energy demand while renewable energies of solar, hydro, biomass and geothermal; and nuclear powers are contributing only 13.5% and 6.5% respectively [3].

The uses of renewable energy sources present an alternative use to fossil fuels. They are inexhaustible, freely available and environmentally friendly. A considerable proportion of the energy need of man could be met by the utilization of solar energy as an alternative energy source of heating water using the flat plate solar collector for domestic application.

Solar collectors capture incident solar radiation energy and convert it to heat. Solar collectors are basically classified into two general categories: Non-concentrating solar collectors and Concentrating solar collectors. In the non-concentrating solar type, the collector aperture area (i.e. the area that intercepts the solar radiation) is the same as the absorber area (i.e. the area absorbing the radiation). For temperatures below 100^{o}C, flat-plate collectors of the non-concentrating type are generally used [7]. In the concentrating collectors, the area intercepting the solar radiation is greater than the absorber area. They are basically used for temperatures greater than 100°C [7].

The flat-plate collectors are the most common used collectors for residential water and space-heating applications. A typical flat plate collector is an insulated metal box with a glass or plastic cover called the glazing and a dark-colored absorber plate. The glazing can be transparent or translucent. Translucent (transmitting light only) low-iron glass is common glazing material for flat-plate collectors because of high transmission of total available solar energy. The glazing allows the light to strike the absorber plate but reduces the amount of heat that can escape. The sides and bottom of the collector are usually insulated to minimize heat losses [9].

The flat plate water heater under investigation (i.e. Model TE 39) comprises a collecting plate which is constructed from two sheets of preformed stainless steel welded together to form integral parallel water channels. The surface of the plate in enclosed in an air tight box having a clear acrylic cover. Heat losses from the rear surface of the plate are minimized by the use of a layer insulting material. A small centrifugal pump circulates water through the absorber plate rate. The collector is supported on a base frame and is hinged so that its inclination may be adjusted [10]

The study is to evaluate the performance of the flat plate solar collector in Bauchi prevailing weather condition and assess its viability for domestic application.

II. EXPERIMENTATION

Figure 1: Experimental Set-up

The solar collector was set to angle of inclination equal to that of Bauchi and maintain throughout the experiment (i.e.10.23°). The collector was supply with water from a storage vessel connected unto it. Temperatures were measured at the water storage vessel T_1; at inlet to collector T_2; at outlet from the collector T_3 and shade temperature of the atmosphere T_4 with the aid of a mercury thermometer (0-100°C). A solarimeter was used to obtain the global solar radiation. A calibrated vessel (0-5 liters) measure the volume of water discharged (liters or centimeters) while a stop watch was used to measure the time (seconds) for volume of water discharged. The experimental time was between 11:00-13:00 p.m for period of twenty-eight days.

2.1 Determination of heat absorbed by the circulating water

Since the effective area of the collector is 14m^2, E_1 incident energy, is equal to the radiation intensity I.

$$\mathbf{H = \frac{v}{t}(T_3 - T_1) \times 4186.8} \qquad \ldots.(1) \qquad [10]$$

Where,

H = Heat absorbed by the circulating water(W), V = Volume of water discharge in liters

t = Measured time for volume (s), T_1 = Temperature of cold water at inlet ($^{\circ}$C)

T_3 = Temperature at outlet from the collector ($^{\circ}$C), $4186.8 = \text{constant}$

2.2 Determination of the losses and the efficiency of the flat plate solar collector

Under conditions of steady radiation, the steady flow energy flow equation for the apparatus is given by:

$$\mathbf{E_1 + E_p = H + L} \qquad \ldots..(2) \qquad [10]$$

The losses can therefore be calculated as:

$$\mathbf{L = E_1 + E_p - H} \qquad \ldots..(3) \qquad [10]$$

Where:

$E1$ = Incident energy($W/m2$), Ep = Energy input from the circulating pump(W), L = Losses (W)

And also the losses can be calculated in relationship to the shade temperature by the formula below:

$$\mathbf{L = const. \times [(T_2 + T_3)/2 - T_4]^{1.3}} \qquad \ldots..(4) \qquad [10]$$

Where: T_2 = Temperature at inlet to the collector ($^{\circ}$C), T_4 = Shade temperature of the atmosphere ($^{\circ}$C).

The losses (L) from the collector are due mainly to the process of natural convection in the surrounding air.

2.3 The overall efficiency is calculated by:

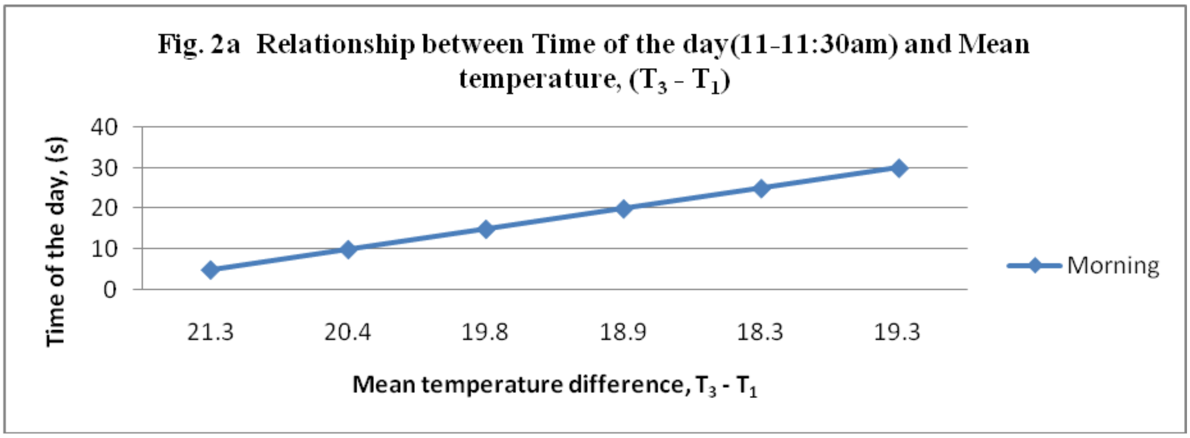
$$\eta = (H - E_p)/E_1 \qquad \dots (5) \quad [10]$$

2.4 Summary of the result obtained

The purpose of the experiment is to obtain the relationship between the rate of heat absorbed by the collector and the mean temperature of the water passing through it. The parameters considered are: mean temperature difference of water ($T_3 - T_1$), the mean shade temperature of the atmosphere, the solar radiation and corresponding heat absorbed by the collector, losses and the collector efficiency.

Table 1: Experimental Result

Time: 11:30am-12:30pm						
Time	$T_3 - T_1$ °C	T_4 °C	E_1	**H**	**L**	**EFFICIENCY(η)**
11:05 am	21.3	22.2	466.7	496.4	210.8	68.0
11:10 am	20.4	22.2	466.7	490.5	216.7	66.9
11:15 am	19.8	22.1	466.7	466.8	240.4	63.3
11:20 am	18.9	22.1	466.7	445.2	261.1	60.0
11:25 am	18.3	22.2	466.7	424.1	283.0	57.0
11:30 am	19.3	22.2	466.7	441.8	265.3	55.8
12:05 pm	26.5	27.9	653.2	698.0	271.4	70.5
12:10 pm	25.7	28.2	653.2	660.5	308.9	66.4
12:15 pm	24.9	28.3	653.2	613.0	355.5	61.4
12:20 pm	23.5	28.6	653.2	579.4	390.0	57.8
12:25 pm	23.4	28.6	653.2	575.9	393.5	57.1
12:30 pm	23.2	28.6	653.2	566.4	403.0	55.9



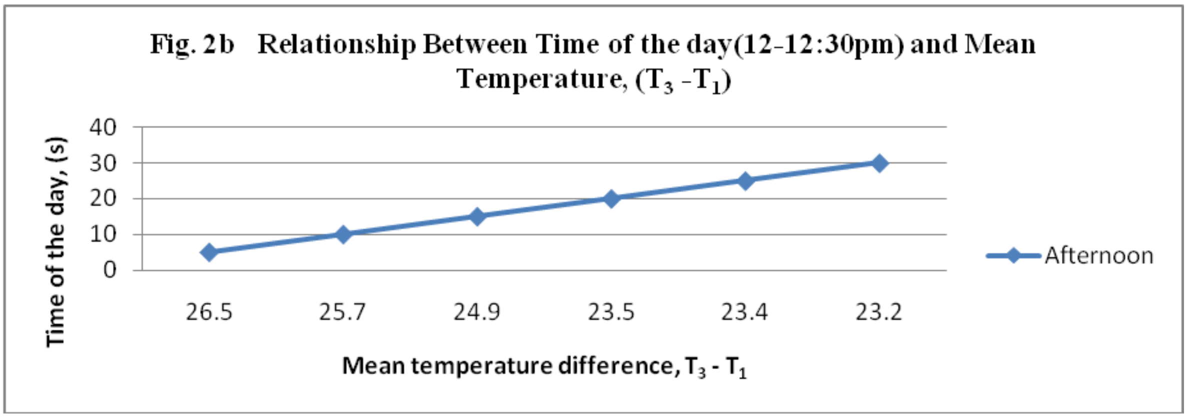


Fig. 2 Relationship of Time of the day and mean temperature difference

Fig. 2a and 2b show the relationship of time of the day with mean temperature difference by the circulating fluid, the graph follows a trend of direct proportionality. The graphs show that as the time of the day increases the mean temperature difference increases vice versa.

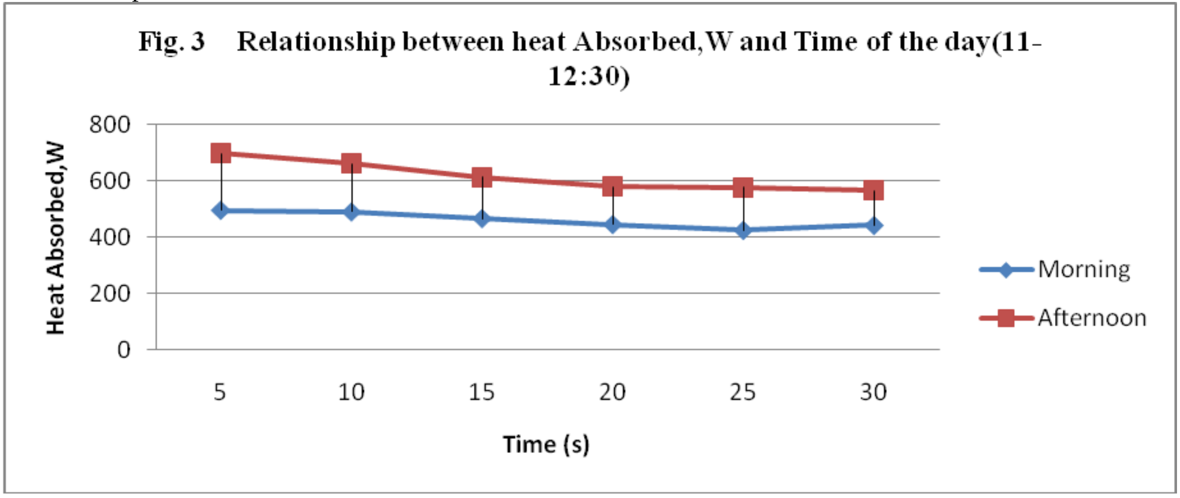
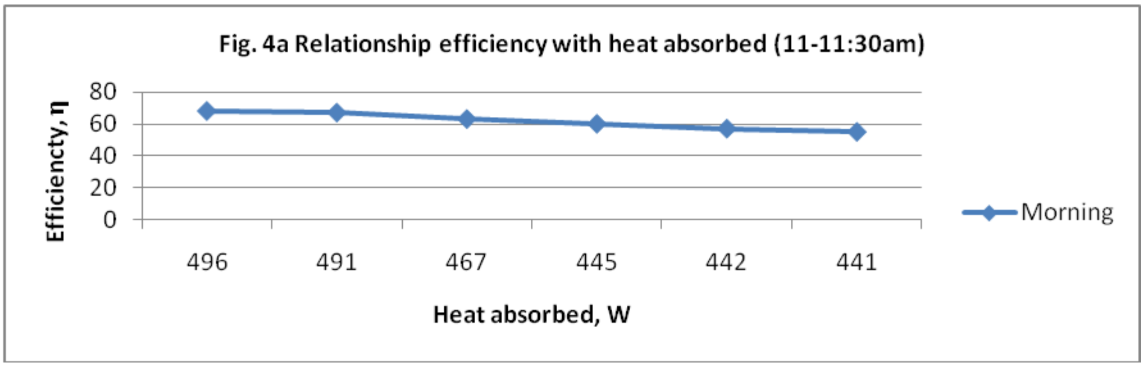


Fig. 3 Relationship of Heat absorbed and Time of the day

Fig.3 shows the relationship the relationship of Heat absorbed and time of the day. The heat absorbed by the collector was observed to be higher at the beginning of the experiment and decreases steadily as the experiment progresses with time. This is because the temperature difference between the fluids collected at the outlet of the collector and the inlet of the collector decreases. Thereby, decreasing the heat absorbed by the collector.



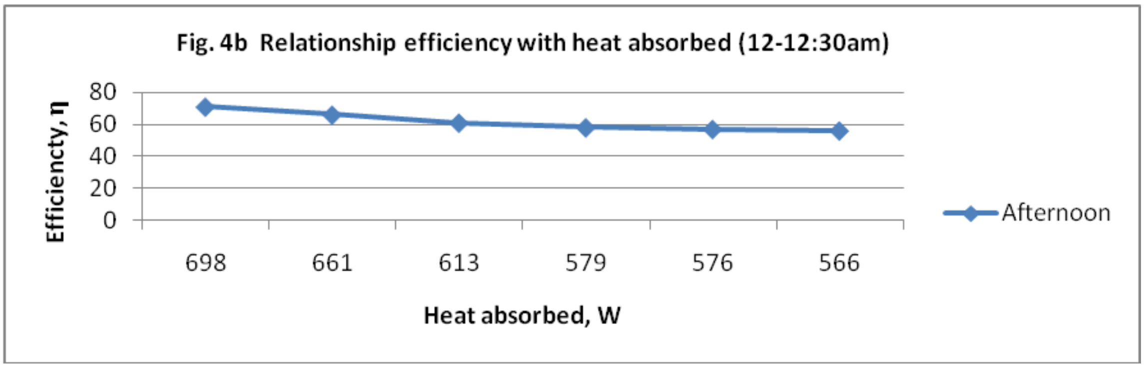
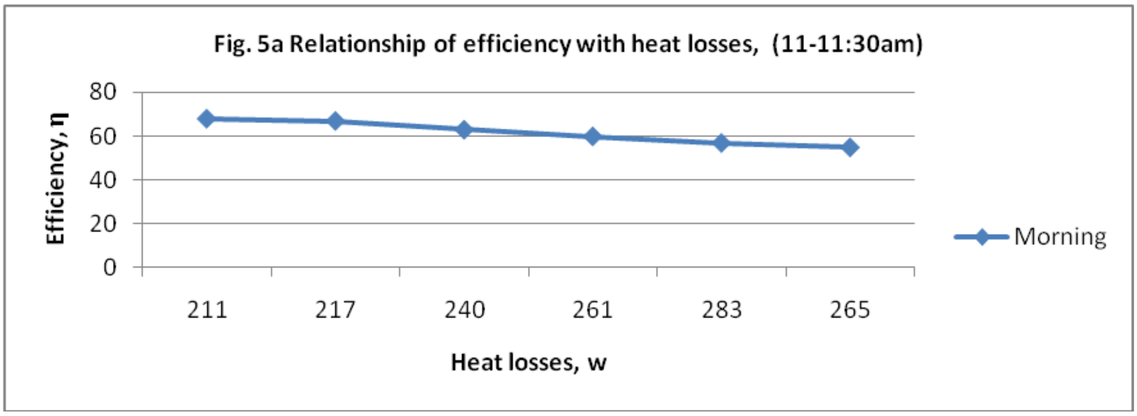


Fig.4 Relationship of efficiency with heat absorbed by circulating fluid

Fig. 4a and Fig. 4b show the relationship of efficiency with heat absorbed by the circulating fluid, the graph follows a trend of direct proportionality. For constant incident energy, the efficiency of the flat plate collector depends on the heat absorbed by the circulating water. This gives a linear graphs for both experiment (conducted in the morning and afternoon). Since the efficiency is the ratio of power output and power input. The incident energy being the power input to the collector, the heat absorbed by the circulating water is the power output from the collector. The heat absorbed by the collector depends on so many factors such as air mass factor.



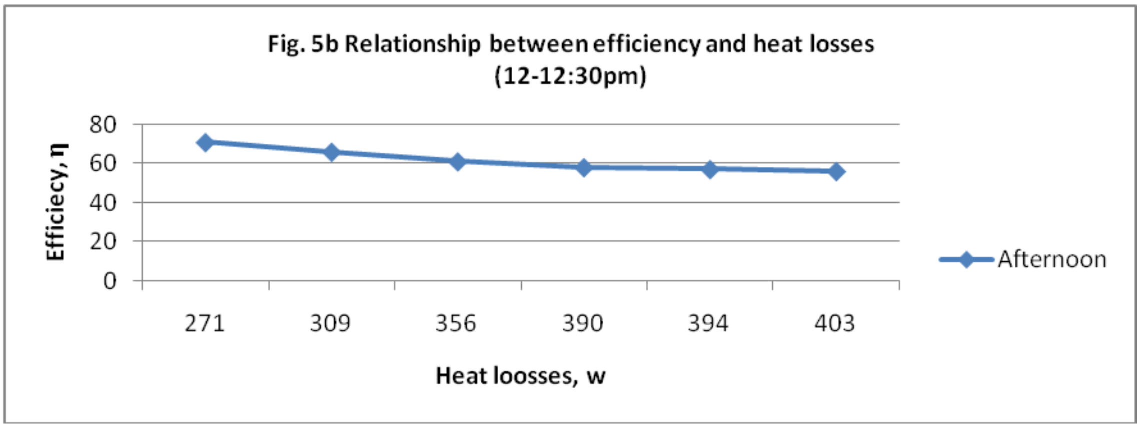
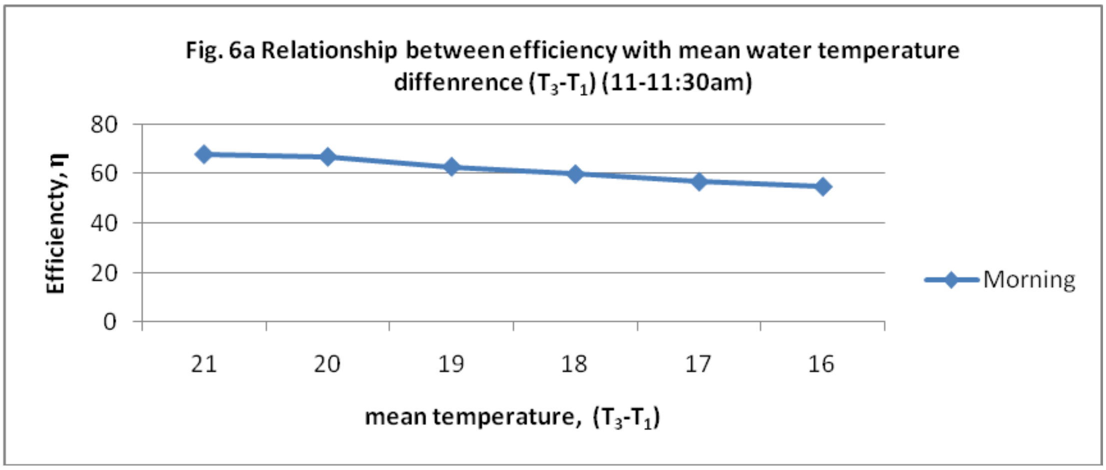


Fig.5 Relationship of efficiency with losses from the collector

Fig. 5a and Fig. 5b shows the relationship of efficiency with losses, the losses are the unused energy input from the collector, which is the long wave reflected radiation from the collector surface. The graphs show that, at higher heat loss from the collector, the efficiency is low and at lower heat loss from the collector, the efficiency of the flat plate collector is higher.



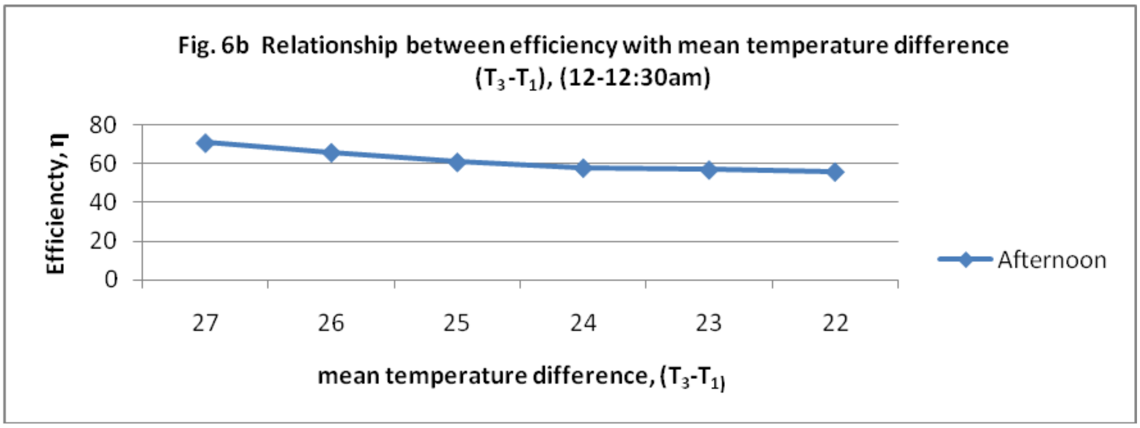


Fig. 6 Relationship of efficiency with mean water temperature difference

Fig. 6a and Fig. 6b show the relationship of efficiency with mean water temperature difference, this will take an order of direct proportionality as thus; the efficiency of the flat plate collector is directly proportional to the heat absorbed by the circulating fluid and the heat absorbed by the circulating fluid is dependent on the temperature difference of the fluid passing through the collector mean. The practical conclusion to be drawn from this is that, the higher the difference between the fluid at the outlet and the inlet the higher the efficiency of the collector.

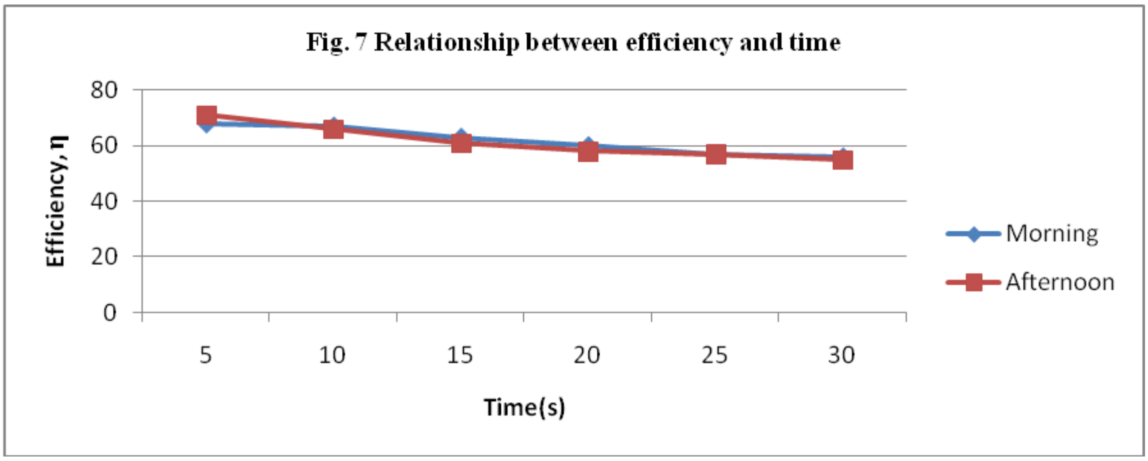


Fig. 7 Relationships between efficiency with time of the day

Fig. 7 shows the efficiency of the flat plate collector for the values obtained for the experiment conducted in the morning (11-11:30am) and afternoon (12-12:30pm). The maximum efficiency of the flat plate collector was gotten as 12:05 as 70.5% while the lowest is obtained at 55.9%. The efficiency of thecollector was observed to be higher at the beginning of the experiment and decreases steadily as the experiment progresses with time. This is because the temperature difference between the fluids collected at the outlet of the collector and the inlet of the collector decreases, thereby decreasing the heat absorbed by the collector and invariably causing a decrease in the efficiency of the flat plate collector. A comparative efficiency of the flat plate collector obtained in the morning and that of the afternoon shows that efficiency of the flat plate collector is comparatively higher in the morning compare to that obtainable in the afternoon.

III. CONCLUSION

The efficiency of the collector was observed to be higher at the beginning of the experiment and decreases steadily as the experiment progresses with time, though some variations that can be ascribed to the effect of wind speed were observed. The comparison between the efficiencies shows that efficiency of the flat plate collector is comparatively higher in the morning period as experimentally determined against that obtained in the afternoon due to the moderately higher incident energy observed in the afternoon. In conclusion, at a steady radiation, the higher the heat absorbed, the higher the efficiency of the collector. The use of the flat plate solar collector (Model TE 39) for domestic and commercial heating purposes in Bauchi is viable since reasonable temperatures (outlet from the collector, T_3) were realized.

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