An Experimental Study of Flat Radial Fresnel Len Solar Collector for High Temperature Thermal System

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***Abstract* – The largest quantity of fossil fuel is used for power generating process nowadays, which release enormous of carbon dioxide and other defilement to the environment. More significantly, fossil fuel will disappear from our planet in the near future. In order to save our environment together with develop our civilization sustainably and less harm to living things, humans are exploring new source of substitute clean energy and solar energy is renewable which can serve as a sustainable energy source. Moreover, it will significantly become a crucial part of the future energy structure. Because of the advantages of flat radial Fresnel lens such as small volume, light-weight, mass production with low cost, it recently have been one of the best choices in the field of concentrated solar energy applications. This research aims to design and build the flat radial Fresnel lens collector with solar tracking system using in high temperature solar energy thermal system. The 9 pieces of 40×40 cm^2 with 230 mm focus length of Fresnel lens are used for the sunlight concentration to the focal point. The temperature at the focal points are measured by the data logger and Programmable Logic Controller (PLC) is used for controlling stepping motors in the sun tracking system. The working fluid used in the experiments was water has a volume of 30 liters and flow rate of 3 l/min. beside, water circulation system.**

The result of the experiments which collected between 11.00 A.M. – 02.00 P.M. Beginning, the average temperature which measured at 11.00 A.M. is 24°C and the average maximum temperature is 42°C at 2.00 P.M., which is able to generate the thermal power at 2,240 kJ. The rate of heat transposition is at 207.41 W/h and average efficiency is equal to 6.2% at average solar radiation value is 978 W/m^2 during 3 hrs. Operating time at the average atmospheric temperature of 21°C. The performance of solar concentrator which depend on many factors such as reflection of solar intensity, sun beam, mechanism and controller of the sun tracking accuracy of sun path.

Keywords - Fresnel lens, Solar Energy, Programmable logic controller, PLC, Solar tracking

I. INTRODUCTION

Solar Energy is the key to industrial development for the promotion of economic of the world population. [1, 4, 5] The rapid depletion of fossil-fuel (oil, natural gas, coal and etc.) resources on a worldwide basis has necessitated an urgent search for alternative energy sources to meet our demands for the immediate future and for generations to come. Solar energy has the greatest potential of all the sources of renewable energy [2]. This energy is the enormous power which is fallen and given the energy at 1367 W/m^2 [3] by average. Using solar energy can be inevitable when other energy sources are nearly shortage. Thus, it would be a great idea if we could produce our own energy and may not need to buy energy from the others for the better future of the word.

Francia and more, [6, 7, 8] they were designed a one and two axis microprocessor based sun tracking device for using in PV f at plate solar panels or with parabolic ref ectors. It was optimally tilted around one axis and controls the azimuth angle with another axis. This work showed that elevated temperatures could be reached using such systems. DAVID et al., [9] who evaluates Compact Linear Fresnel Ref ector (CLFR) concepts suitable for large scale solar thermal electricity generation plants. Yabe et al., [10] they had developed a solar-pumped laser system with 7%–9% slope eff ciencies. The solar-energy-pumped laser with Fresnel lenses system. A Fresnel lens (2 m ×2 m, f = 2000 mm) was mounted on a two-axis sun tracker platform and focuses solar radiation toward laser cavity. and W.T. Xie et al., [11] who study of solar energy concentration technology using Fresnel lens is an effective way to make full use of sunlight. All research and development works suggest that Fresnel lens solar concentrators will bring a breakthrough of commercial solar energy concentration application technology in the near future.

The research team by the current authors has challenged the development and design of the flat radial Fresnel lens collector with solar tracking system to concentrate solar radiation combining at absorbed radiation tube which is located at the focal point of the flat radial Fresnel lens. The novel system design essentially accomplished a goal of highly safe and eff cient solar heating and heat storage. This model can be developed for further research as the appropriateness of the model relies on the efficiency of the heat energy such the accuracy of model, the sun mission, controlling and driving mechanism and wind speed. As a result, this paper is aimed to study the design and creation of prototype of the flat radial Fresnel lens collector with solar tracking system.

II. METHODES

A. Basic concept of Fresnel lens

The Flat Fresnel lens are shaped like a dart board, with concentric rings of prisms around a lens that's a magnifying glass. All of these features let them focus scattered light from the Sun into a tight beam. The flat radial Fresnel lens is a shape which can reflect sunlight or radiation where is incident parallel to the axis of the radial Fresnel lens into another (the focus). They are used in Thermal Concentrated Solar (CSP) and Low concentration PV applications, as shown in Fig. 1.

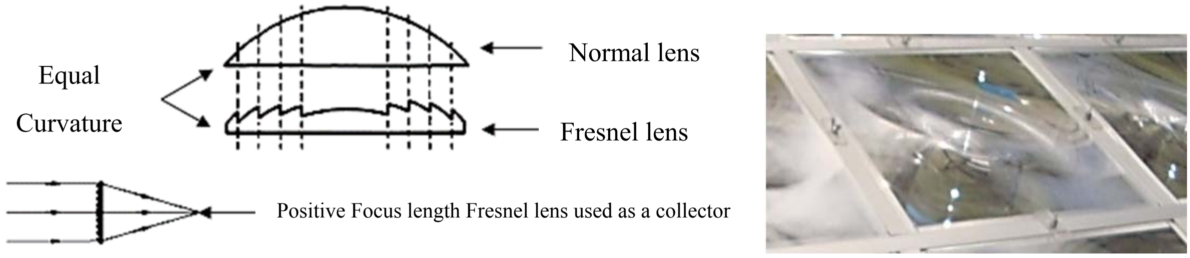

Fig. 1. Basic concept of Fresnel lens and flat radial Fresnel lens

B. Basic earth-sun angles. [12, 13]

The position of a point A on the earth's surface with respect to the sun's rays is known at any instant if the latitude (l), and hour angle (ω), for the point, and the sun's declination angle (δ) which is

The angle of each hour (ω) obtained from

$$\omega = 15(12\text{-st})$$

Declination Angle (δ) is an angle showing the angular position of the sun at solar noon. Compared with the equator, which is between $-23.45^{\circ} \leq \delta \leq 23.45^{\circ}$ by computing from the

$$\delta = 23.45\sin\left(360\times\frac{248+n}{365}\right)$$

Where st is local standard time compared with the solar noon, an area test obtained from

$$st = \text{Standard time}+E-4\left(\text{Long}_{st}-\text{Long}_{Loc}\right)$$

C. Thermal efficiency of the solar collector.

Thermal efficiency of the solar collector which influence on the adjustment in temperature of focusing collector is consists of the heat transformation rate of fluid flow within the pipe is water which is

The heat transfer (Q_u) was calculated from temperatures.

$$Q_u = \frac{mC_p(T_{out}-T_{in})}{\Delta t}$$

The heat energy (q) was calculated from temperatures.

$$q = \dot{m}C_p(T_{out}-T_{in})$$

The efficiency (η) of the solar concentrator is:

$$\eta = \frac{Q_u}{A_a I_b}$$

D. Experimental setup

The 9 pieces of 40×40 cm^2 with 230 mm focus length of flat radial Fresnel lens are used for the sunlight concentration to the focal point. The flat radial Fresnel lens is a device which used to transform the energy from the sun to heat power. The components of the collector and the flat radial Fresnel lens set as shown in Fig. 2. The positions were pointed to record the air temperature and the temperature at focus point of Fresnel lens. The testing area consists of the temperature at focus point of flat radial Fresnel lens T1 – T9, the temperature at top solar hot water storage and the ambient temperature at the testing area, as shown in Fig. 4.

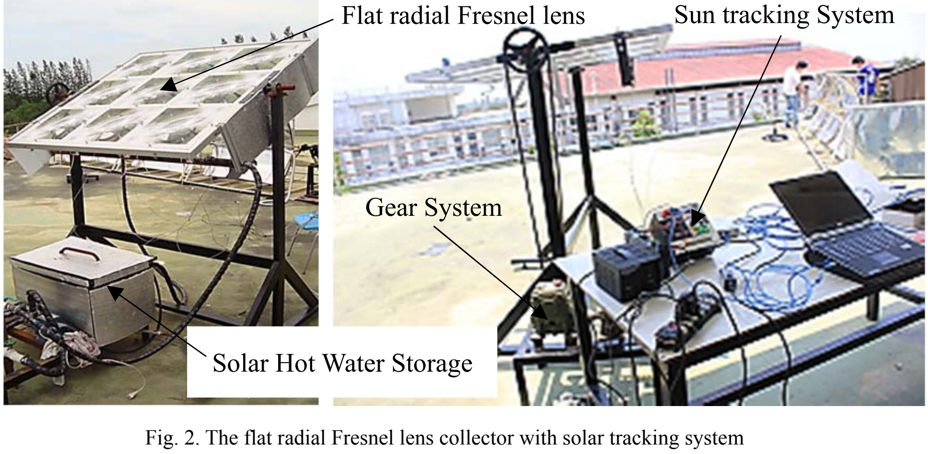

Fig. 2. The flat radial Fresnel lens collector with solar tracking system

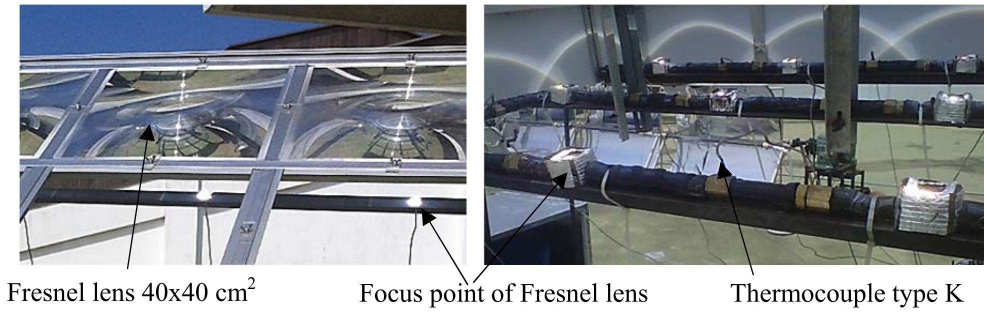

Fig. 3. The focus point of flat radial Fresnel lens and receiver

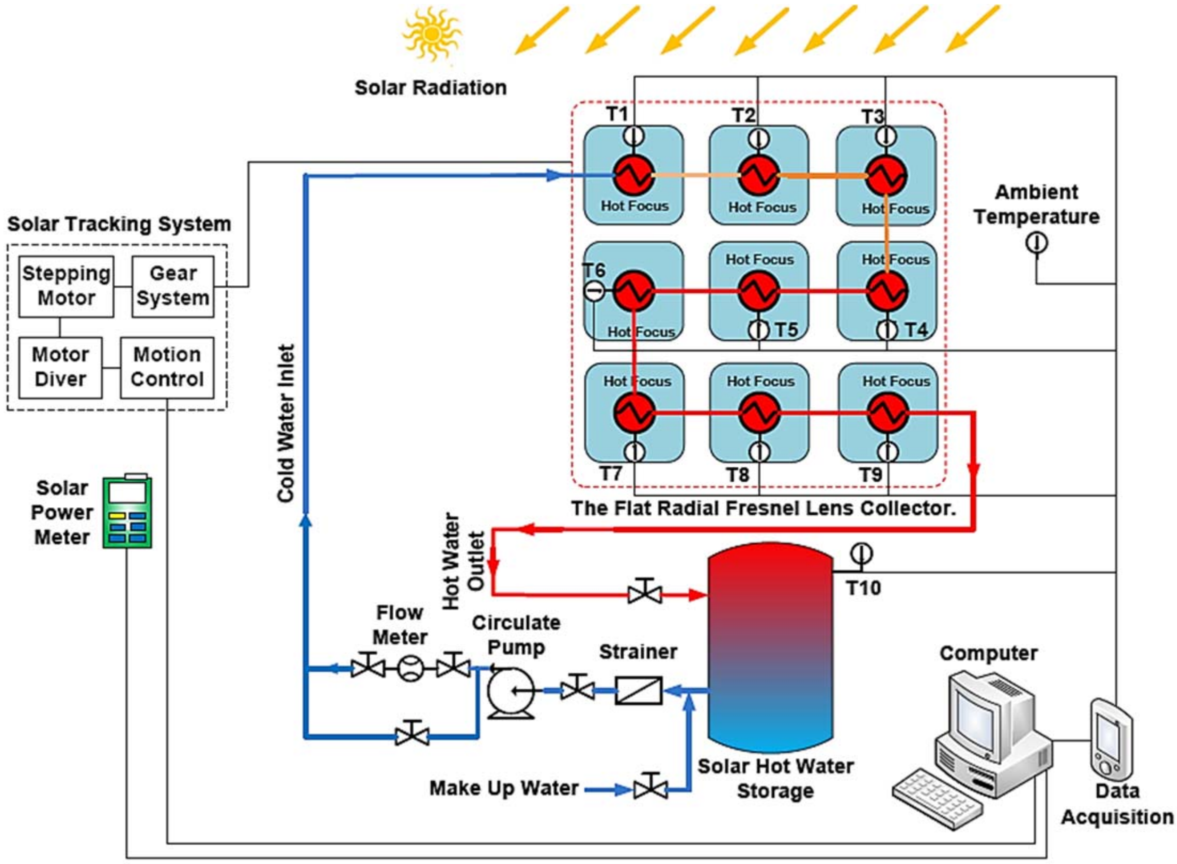

Fig. 4. Schematic diagrams of experimental apparatus

According to the experiment, it will be tested with solar by setting up the flat radial Fresnel lens on the solar tracking apparatus which moves collect the solar radiation along the east – west direction. The experiment was begun by testing a flat radial Fresnel lens collector moves to the starting position and adjust track of solar every hour of 15 degrees. The substance used in the experiments was water and flow rate of 3 liters per minute. Beside, water circulation system, which is used in Solar Hot Water Storage, has a volume of 30 liters to compare performance. Data collection will start at 11:00 A.M.-2:00 P.M. Throughout the experiment will measure and record each temperature at focus point of flat radial Fresnel lens and the ambient temperature at the trial as defined by the thermocouple type K (Fig. 3) as well as measuring the solar radiation (I) in units of W/m^2 with solar power meter models tes-1333R every 1 minute, then measuring the average value in one hour until 3 hours. Finally these results will be plotted to find the relationships.

III. RESULTS AND DISCUSSION

A. Result of solar radiation with time

This experiment was conducted in April-May by collecting data every 1 minute for an average time of one hour from 11:00 A.M. to 2:00 P.M. for three hours. The latter is choosing the results in any day with a clear sky and sunny throughout the day. The solar radiation is shown in Fig. 5.

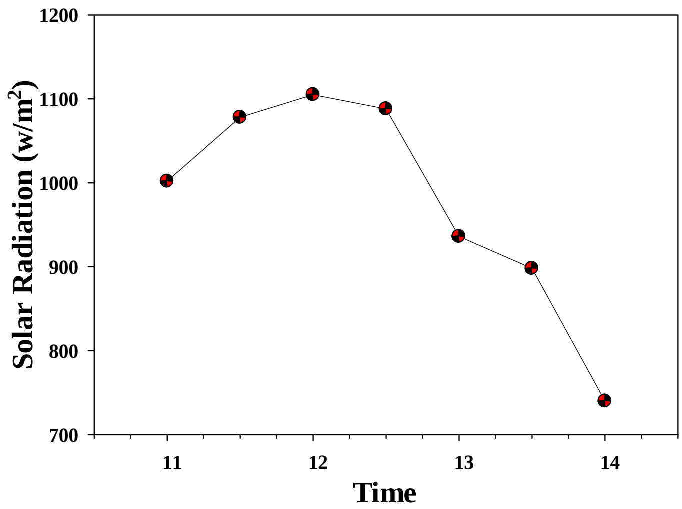

Fig. 5. Variation of solar radiation with time

According to Fig. 5, it illustrates the comparison between solar radiations with time. The intensity of radiation will be raised from 11:00 A.M. to 12:00 A.M. and the solar radiation will reach a peak between 11:30 A.M. to 12:30 P.M. solar radiation levels are dwindling during the period from 12:30 P.M. - 2:00 P.M. and the average solar radiation value is 978 W/m^2.

B. Result of temperature with time.

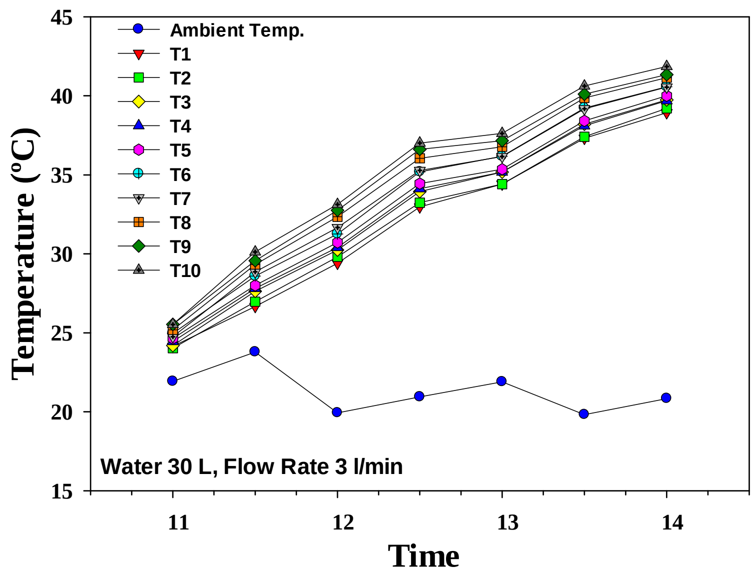

Fig. 6. Variation of temperature with time

According to Fig. 6, it illustrates the comparison between temperatures with time at different positions. The graph show that temperatures each day are similar at the same time and the temperatures will reach a peak at 2:00 P.M. The beginning average temperature which measured at 11.00 A.M. is 24°C and the average maximum temperature is 42°C at 2.00 P.M. as shown in Fig. 7 at volume of water 30 liters and flow rate of 3 l/min. While the average temperature of the ambient temperature is 21 °C.

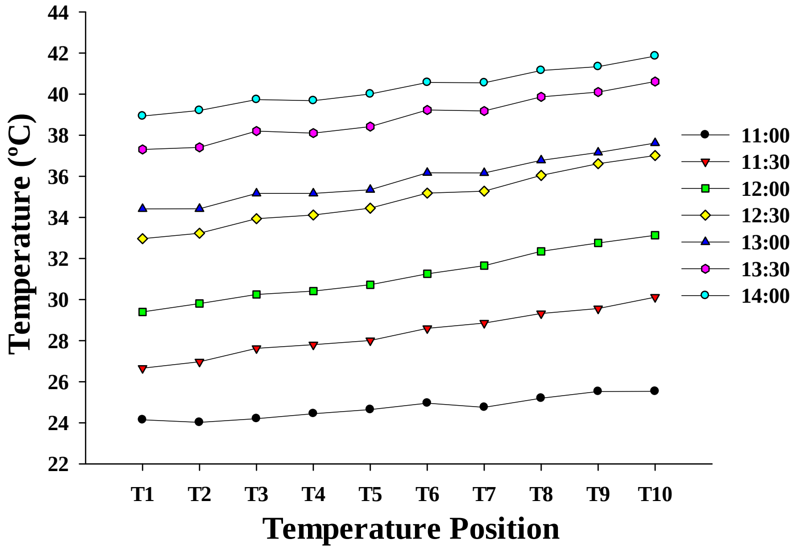

Fig. 7. Variation of temperature with temperature measure position

The result as shown in Fig. 7, the temperatures each day are similar at the same time and the maximum temperature approximately occurs at 2 P.M.

C. Result of temperature, solar radiation with time

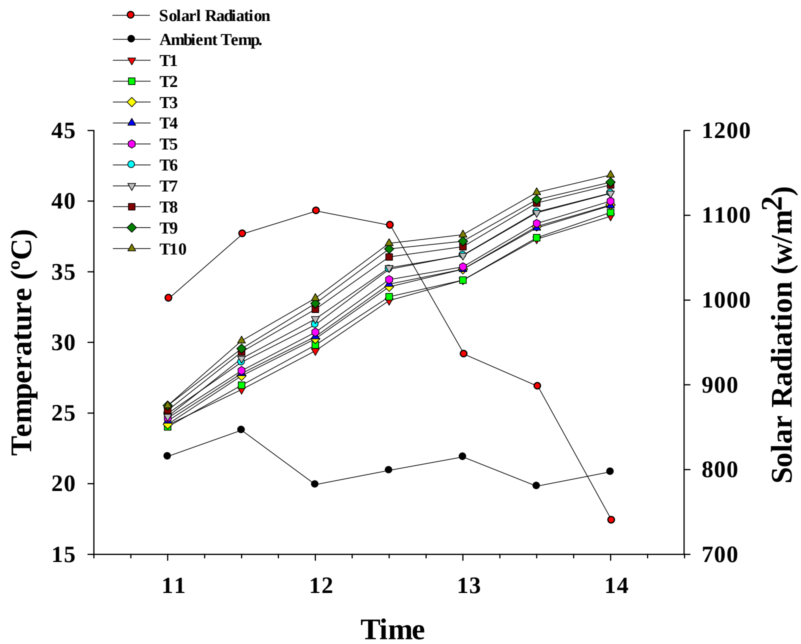

Fig. 8. Variation of temperature, solar radiation with time

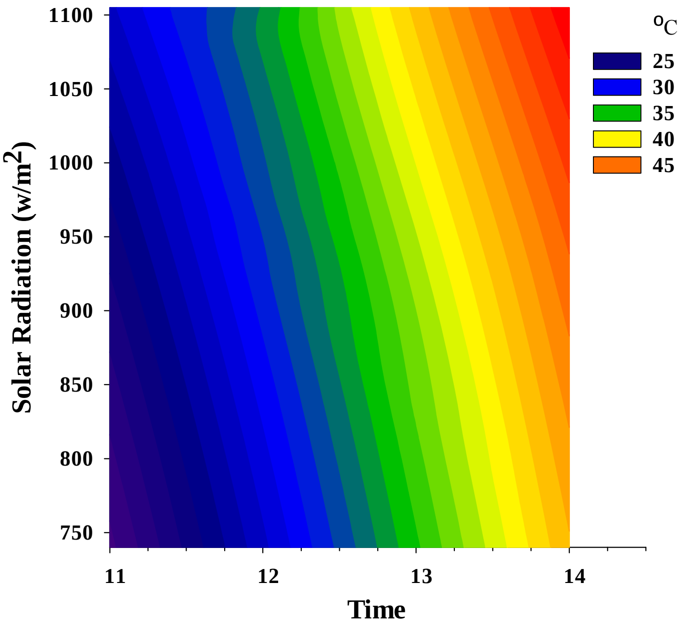

Fig. 9. Contour of solar radiation, temperature with time

The experiment data as shown by the line graph in Fig. 8 and the contour chart in Fig. 9, the solar radiation intensity during the day are expressed the temperatures at focal of Fresnel lens in Fig. 8 and the values of the color contour in Fig. 9 are similar to the values of the solar intensity and temperatures in Fig. 6. As a result, The combined heat power at flow rate 3 l/min and volume of water 30 liters will obtain the higher heat power and given power of heat by average 2,240 kJ at flow rate of 3 liters per minute and the rate of heat transposition is at 207.41 W/h.

III. CONCLUSIONS

The 9 flat radial Fresnel lens with a focal length of 230 mm and area of 40×40 cm^2 have been designed and built to test their ability to generate heat by using thermocouple type K which was placed at the focal point of the flat radial Fresnel lens collector. The working fluid used in the experiments was water has a volume of 30 liters and flow rate of 3 l/min. beside, water circulation system. The result of the experiments which collected between 11.00 A.M.–02.00 P.M., operating time at the average atmospheric temperature of 21°C. The beginning average temperature which measured at 11.00 A.M. is 24°C and the average maximum temperature is 42°C at 2.00 P.M., which is able to generate the thermal power at 2,240 kJ. The rate of heat transposition is at 207.41 W/h and average efficiency is equal to 6.2 % at average solar radiation value is 978 W/m^2 during 3 hrs. The performance of solar concentrator which depend on many factors such as reflection of sun beam, solar intensity, controller and mechanism especially the tracking accuracy of sun moving paths. In another term, using this solar parabolic troughs system of direct solar energy and convert it into thermal energy that can be used directly for several applications such us water heating, electricity generation using stirling engine, vapor production, etc.

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NOMENCLATURE

A	component area, m^2	q	The heat energy, J
C_p	specific heat capacity of air, kJ/kgK	T	temperature, K
E	equation of time, hrs.	*Greek letters*	
f	focus length, m	δ	Declination Angle
I	solar irradiance, W/m^2	η	Efficiency
L	collector length, m	ω	The angle of each hour
Long	Longitude drag	*Subscripts*	
m	water mass, kg	in	inlet
$m^{\bullet}$	water mass flow rate, kg/s	Loc	local time.
n	the day of the year, day	out	outlet
Q	heat transfer rate, watt	u	useful energy

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