DESIGN, IMPLEMENTATION AND PERFORMANCE TESTING OF A NOVEL SOLAR COLLECTOR

A Thesis

Submitted to the College of Engineering of

Al-Nahrain University in Partial Fulfillment of the

Requirements for the Degree of Master of Science in

Mechanical Engineering

By

Ahmed Khalid Habeeb Al-Salihi

(B.Sc. 2001)

Rajab	**1425**
September	**2004**

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Abstract

The aim of this work is to design, construct and evaluate the performance of a solar water heater system called a novel solar collector system [2] with an experimental and mathematical calculation, where the behavior of the collector is mathematically presented. The new type of the solar water heating system differs from the other conventional systems by integrating the collector and the storage tank into one piece of equipment, which can be considered as self-contained unit, acting as a solar collector and a storage tank at the same time.

The experimental part of this work included the measuring of the pipes surface temperature, inlet water temperature, outlet water temperature, glass temperature and ambient temperature under given flow rates.

In the theoretical part, outlet wa[illegible] temperature, useful energy and the amount [illegible] calculated by applying the governing equation and were compared with measured data.

It has been found from the assumption of one dimensional heat flow that some deviation occurs between the experimental investigation and numerical results of collector mean plate temperature due to the systematic and instrumentations errors in temperature measurements and the assumption of no temperature gradient around the tubes.

It was found for the constructed system that the value of the overall heat loss coefficient was about 7.5 $W/m^2.\ ^\circ C$ (average value) and it is accepted when compared with the literature, also the values of heat removal factor are found in the range 0.86-0.88 and the collector efficiency factor

value about 0.98 as a mean value. The instantaneous collector efficiency was found to be about 0.8-0.86, which is larger than that for the conventional system.

The comparison of the predicted temperature difference across the collector and the efficiency of the system showed a good agreement with the experimental results.

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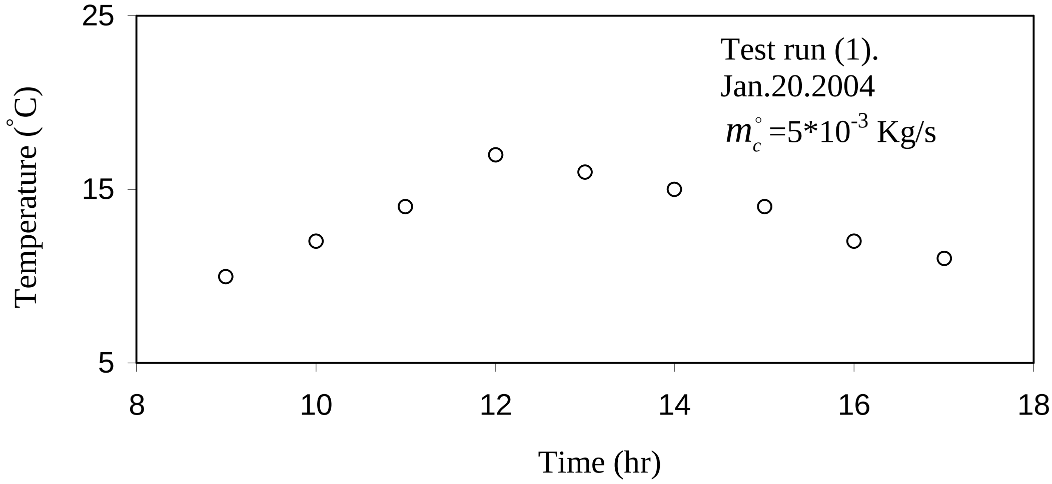


Figure (5-1a) Ambient temperature variation with time

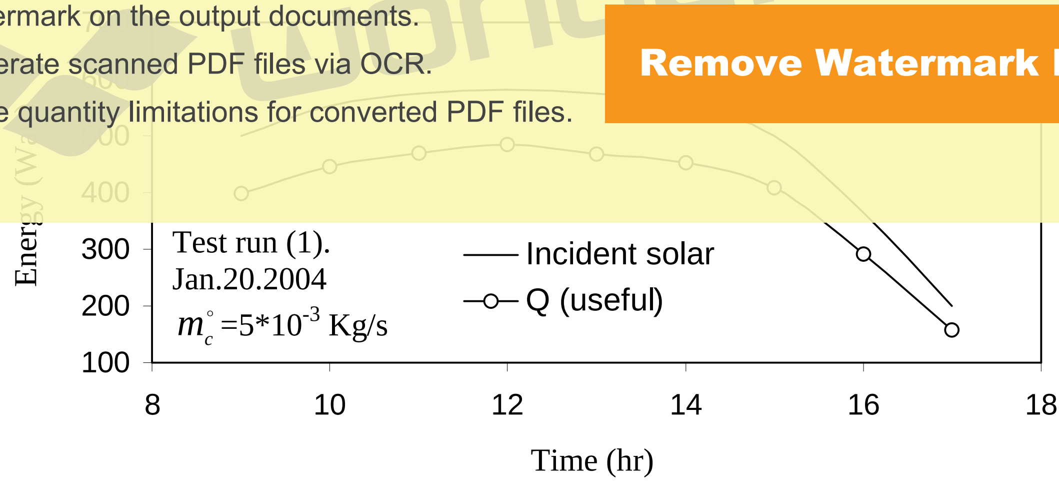


Figure (5-1b) Variation of total radiation on the collector surface and useful energy gain with time

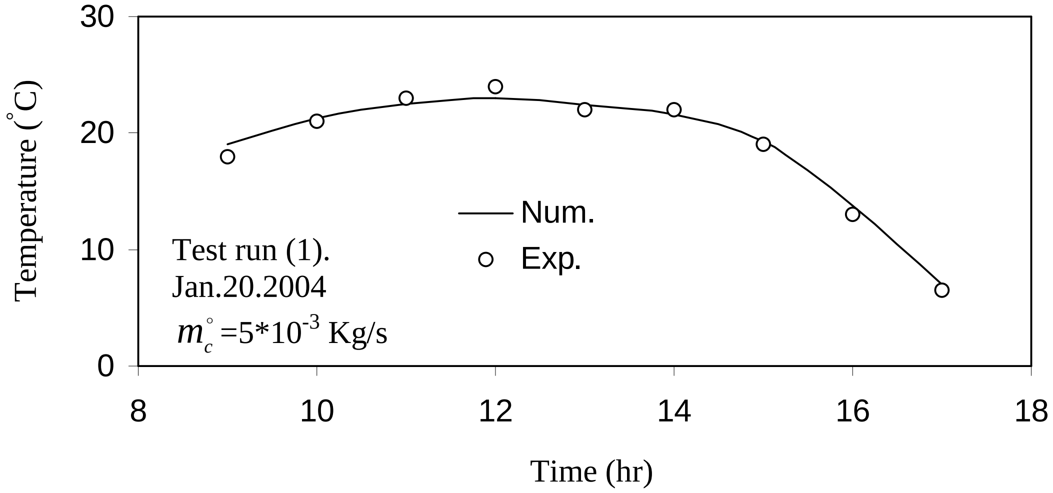


Figure (5-1c) Variation of temperature difference across the collector with time

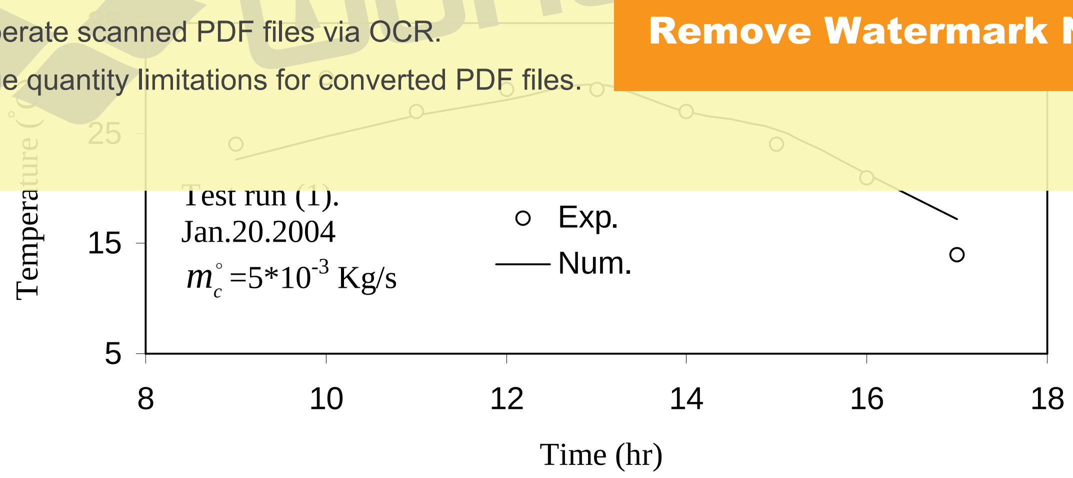
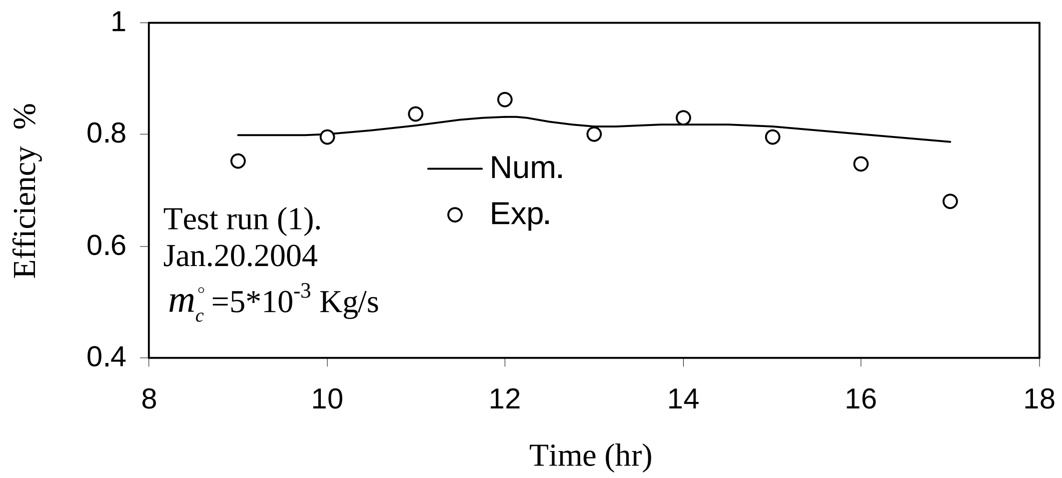


Figure (5-1d) Mean plate temperature variation with time



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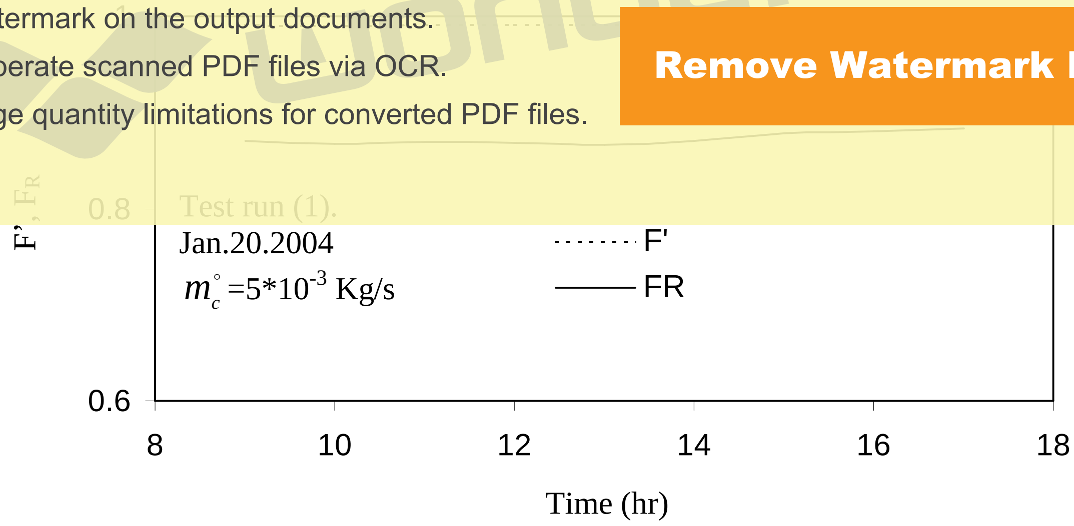

Figure (5-1f) Variation of Collector Heat Removal Factor
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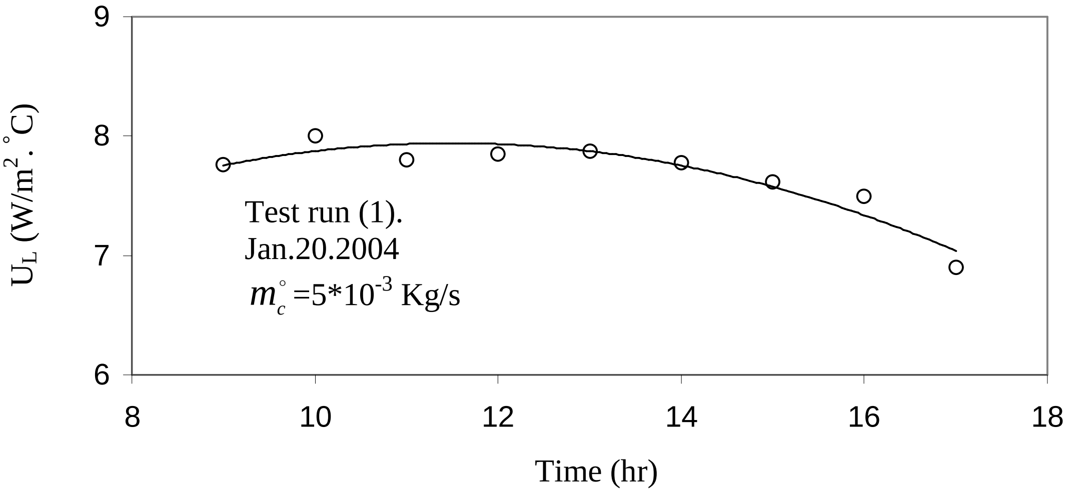


Figure (5-1g) Variation of Overall heat loss coefficient with time

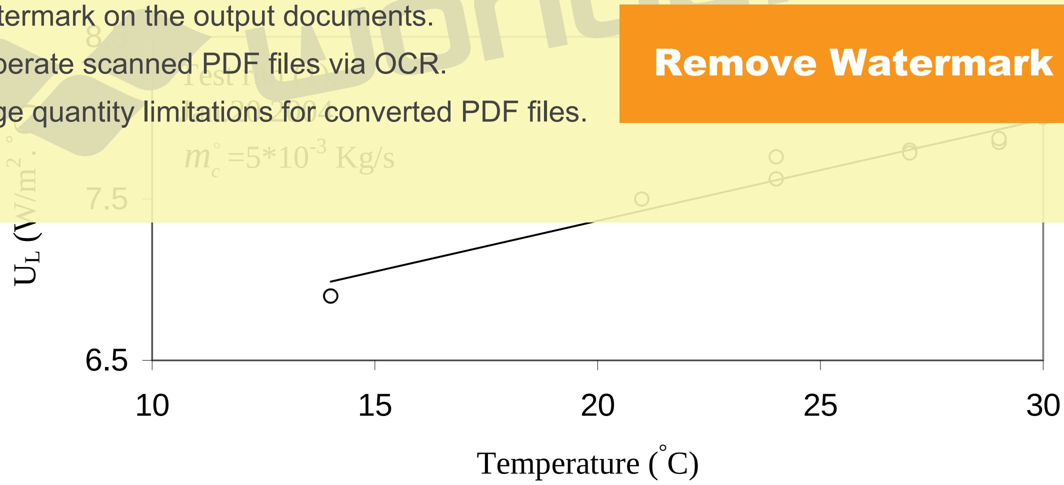
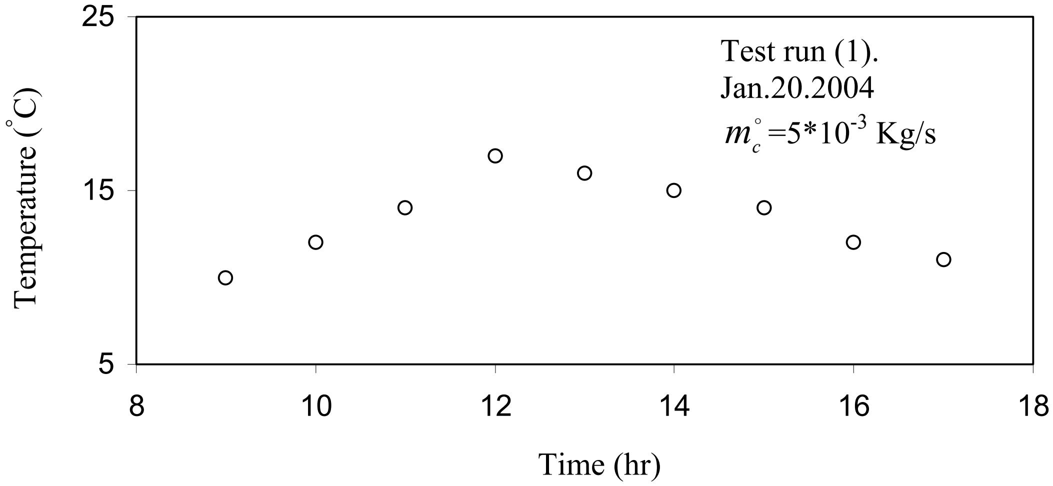


Figure (5-1h) Variation of Overall heat loss coefficient with mean plate temperature



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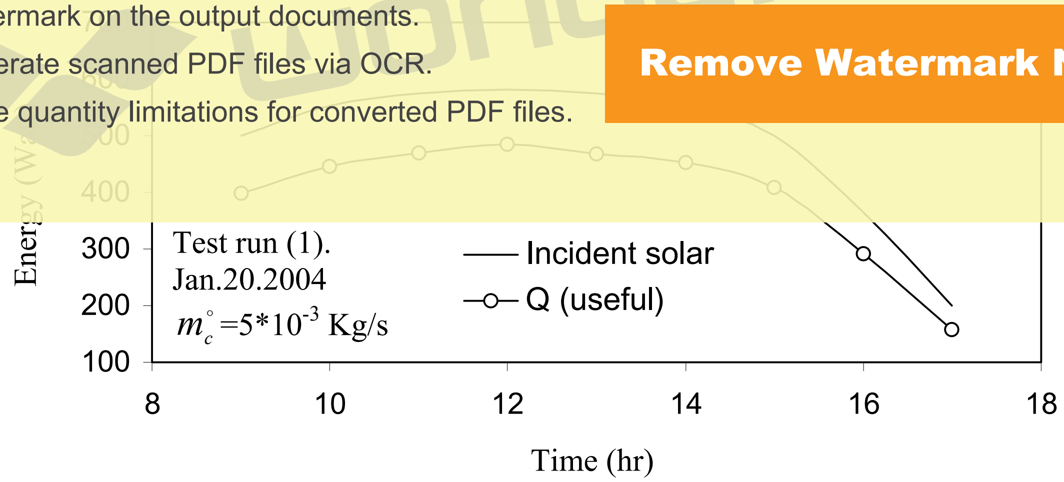


Figure (5-1b) Variation of total radiation on the collector surface and useful energy gain with time

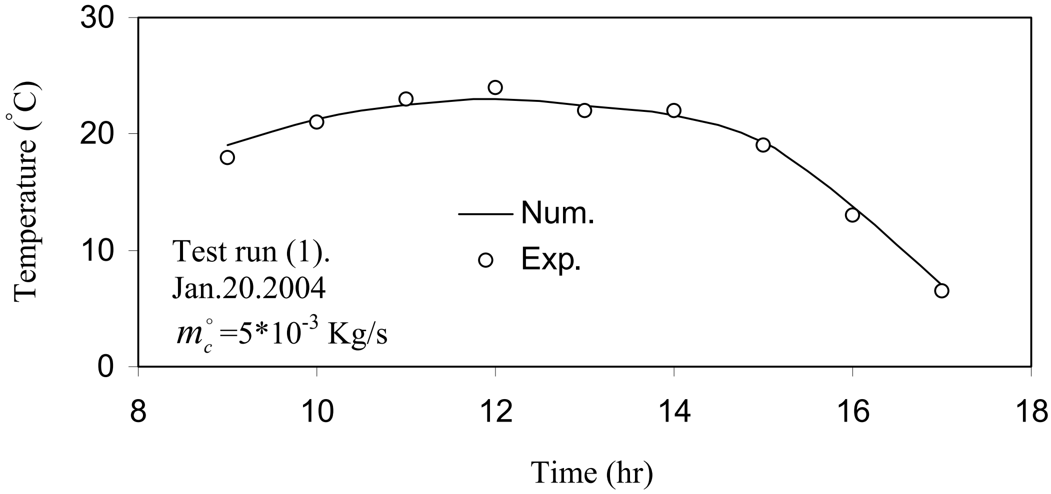


Figure (5-1c) Variation of temperature difference across the collector with time

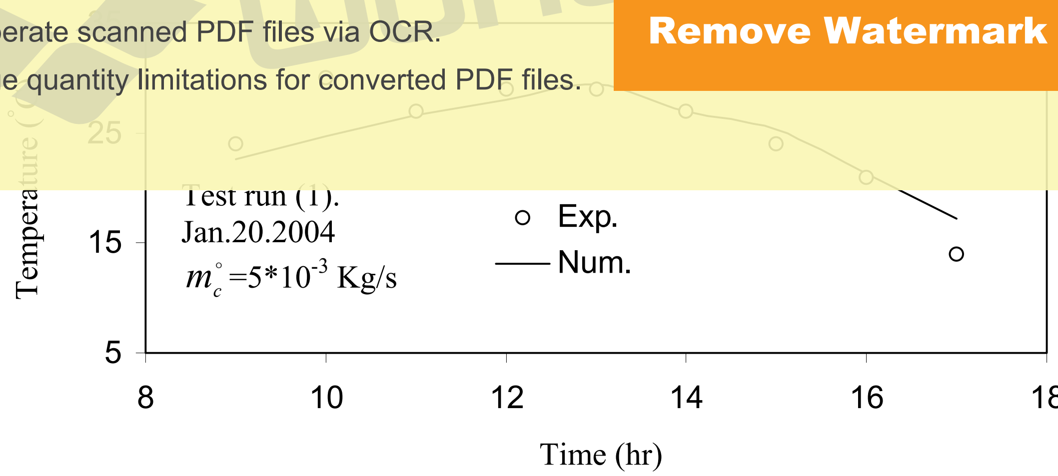
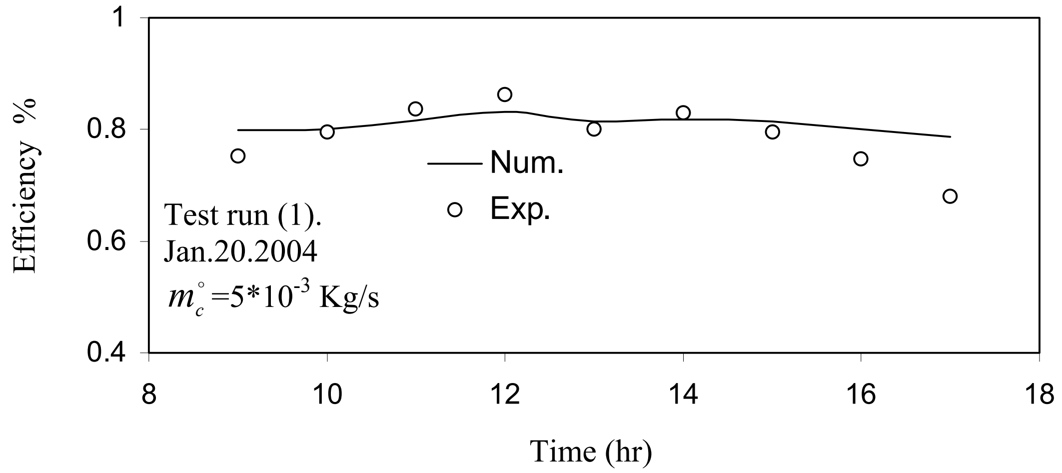


Figure (5-1d) Mean plate temperature variation with time



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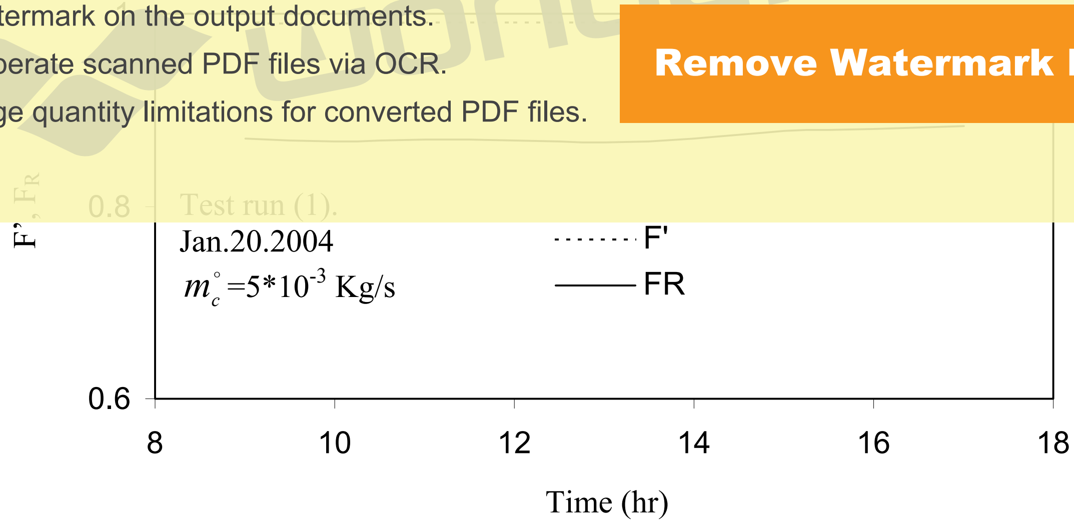

Figure (5-1f) Variation of Collector Heat Removal Factor
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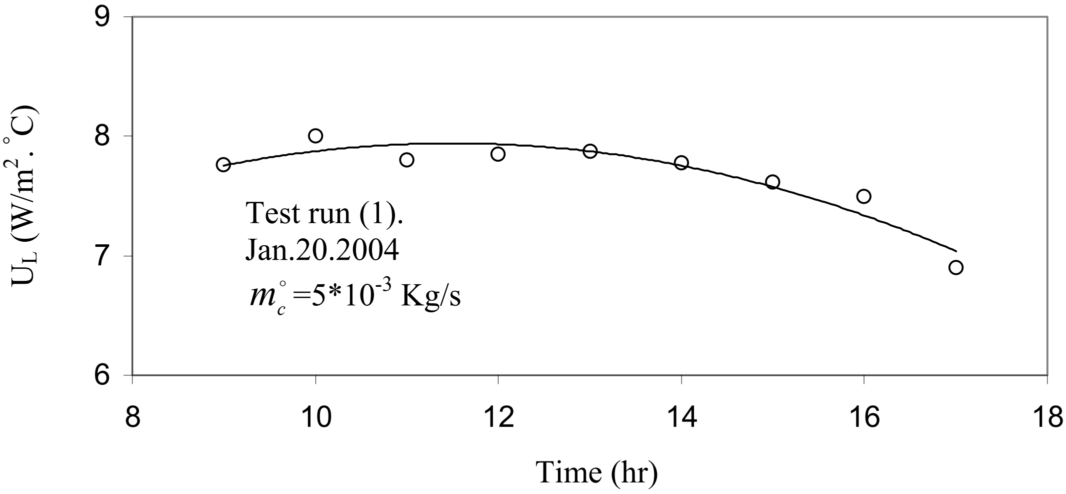


Figure (5-1g) Variation of Overall heat loss coefficient with time

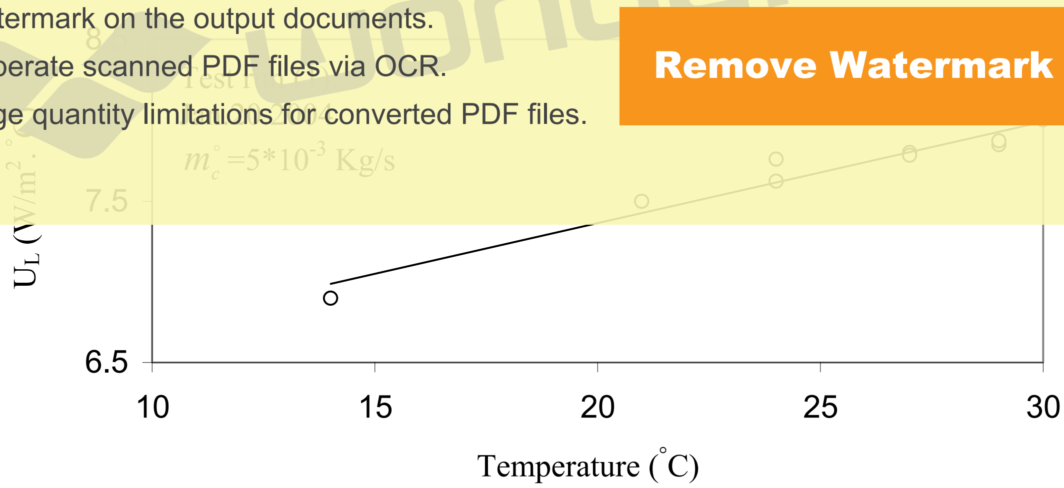


Figure (5-1h) Variation of Overall heat loss coefficient with mean plate temperature

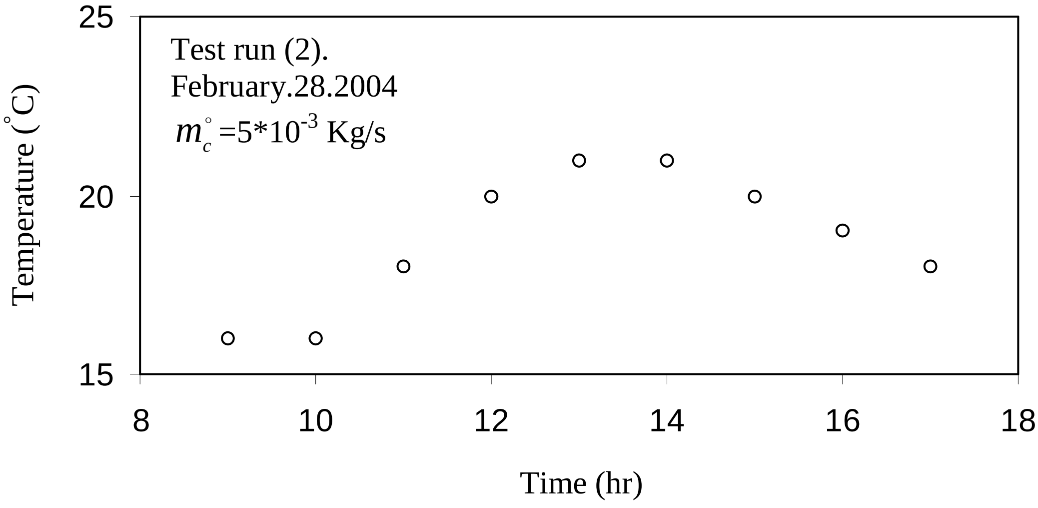


Figure (5-2a) Ambient temperature variation with time

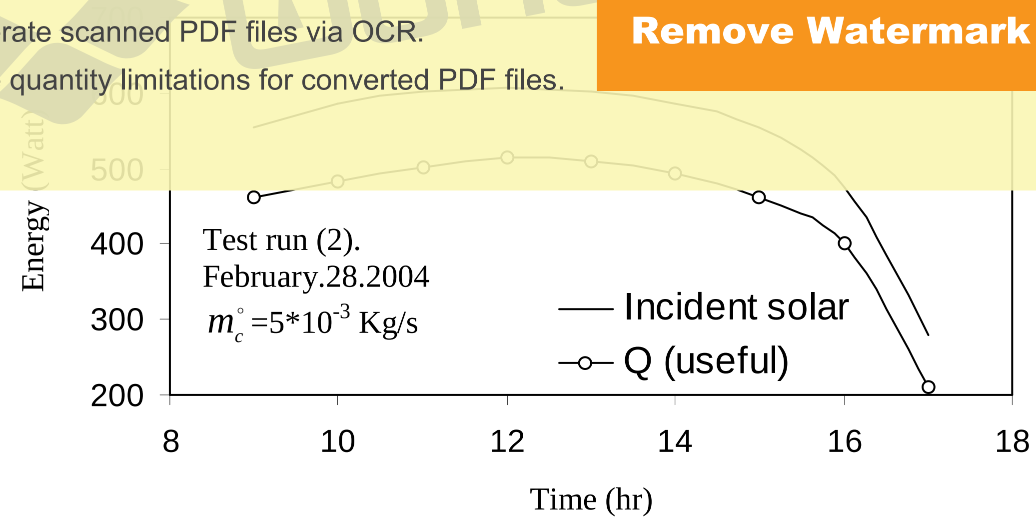


Figure (5-2b) Variation of total radiation on the collector surface and useful energy gain with time

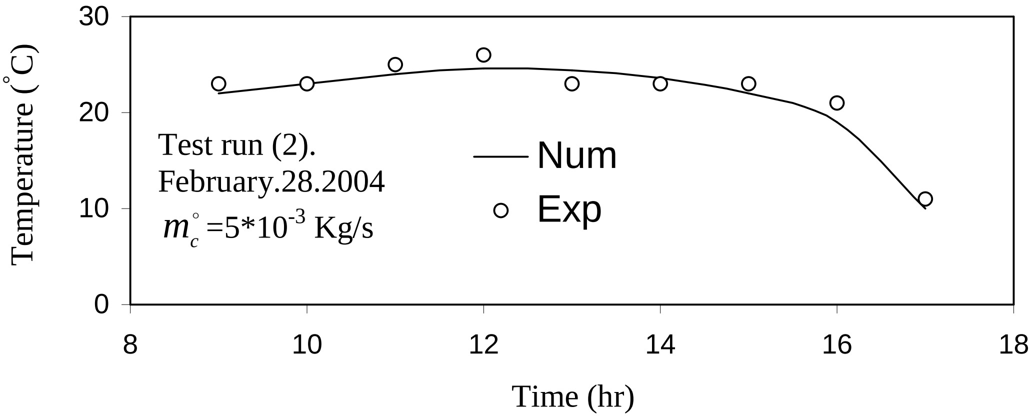


Figure (5-2c) Variation of temperature difference across the collector with time

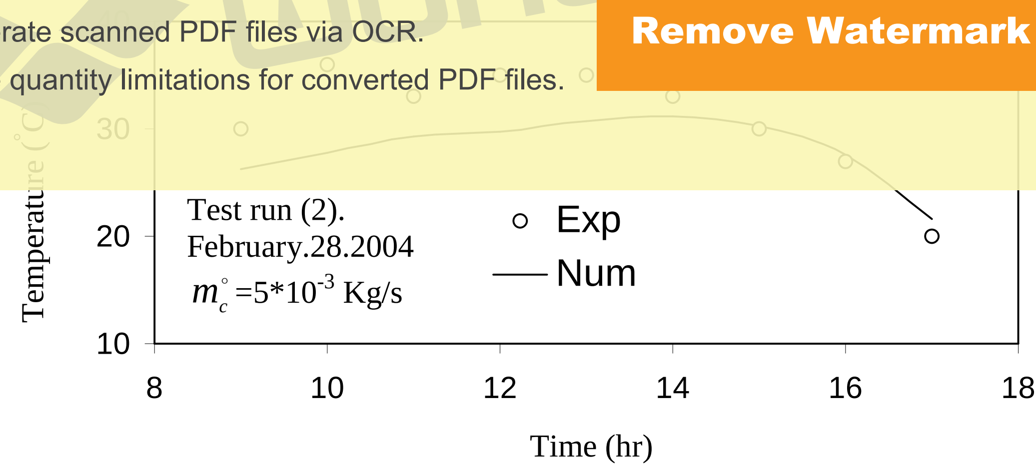


Figure (5-2d) Mean plate temperature variation with time

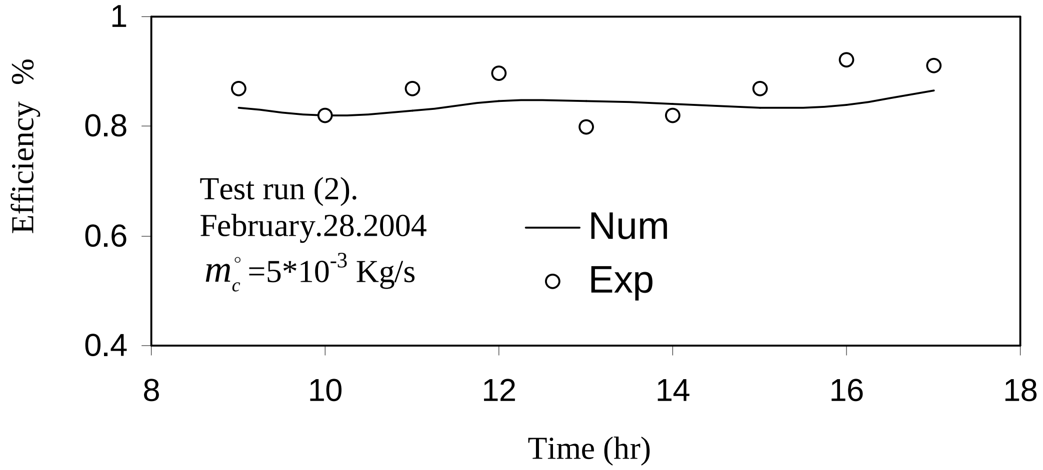


Figure (5-2e) Instantaneous efficiency variation with

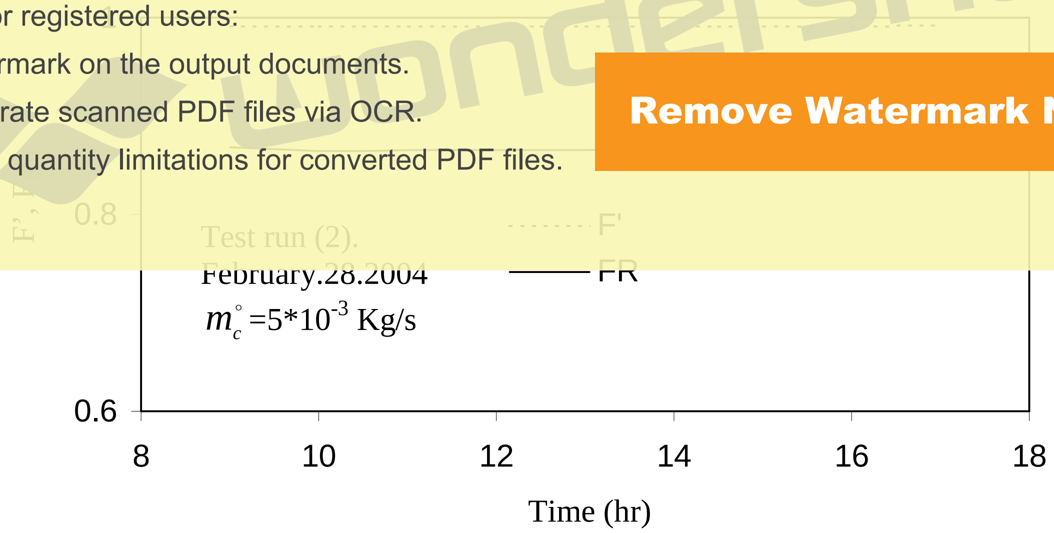


Figure (5-2f) Variation of Collector Heat Removal Factor and Collector Efficiency Factor with time

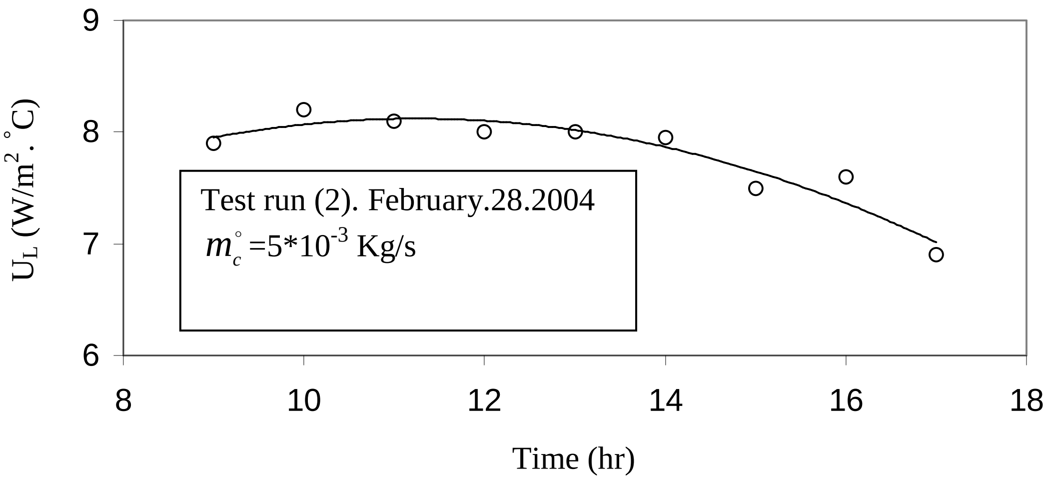


Figure (5-2g) Variation of Overall heat loss coefficient with

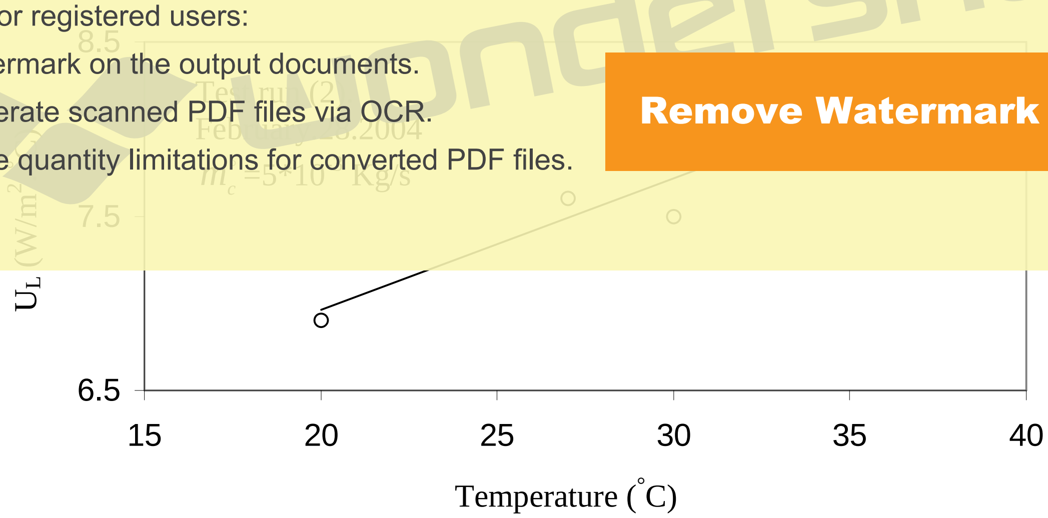


Figure (5-2h) Variation of Overall heat loss coefficient with mean plate temperature

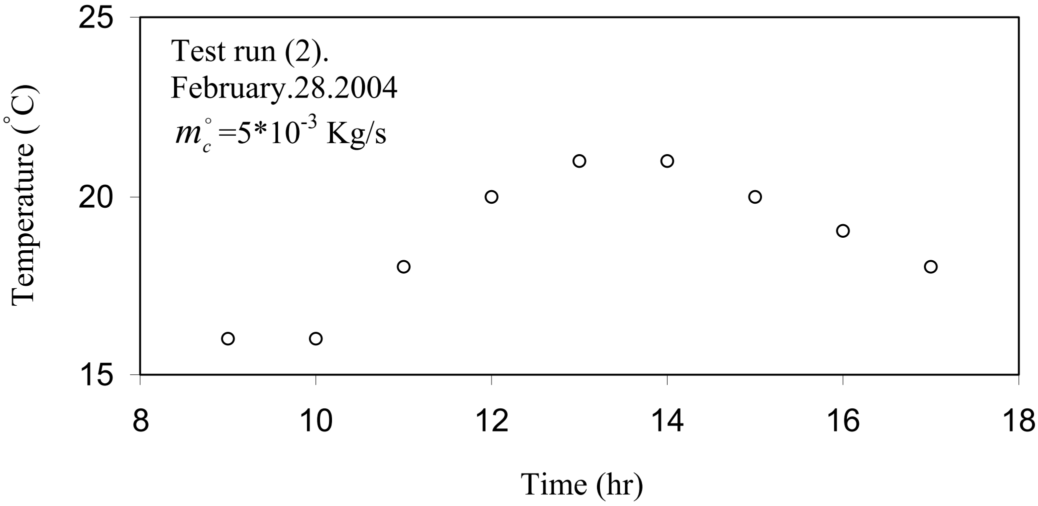


Figure (5-2a) Ambient temperature variation with time

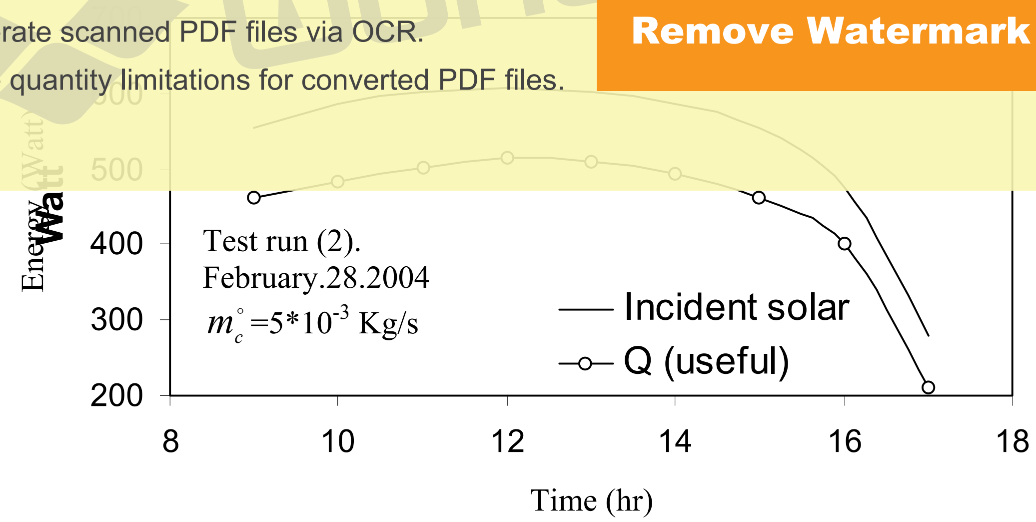
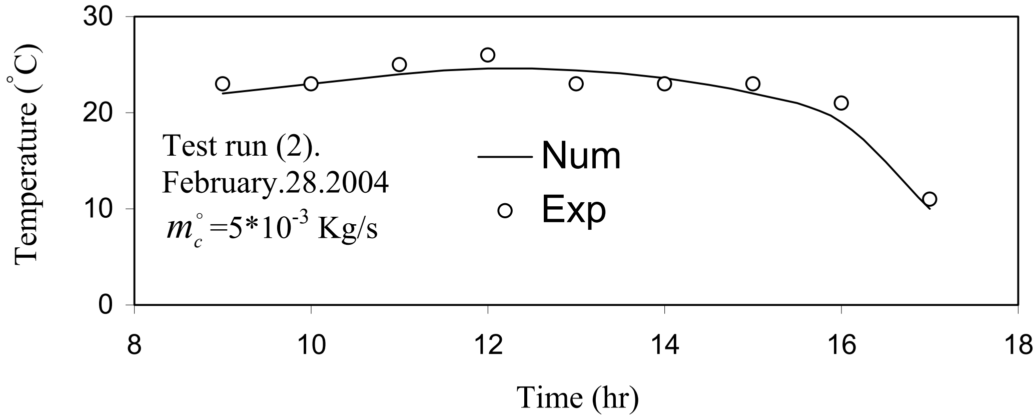


Figure (5-2b) Variation of total radiation on the collector surface and useful energy gain with time



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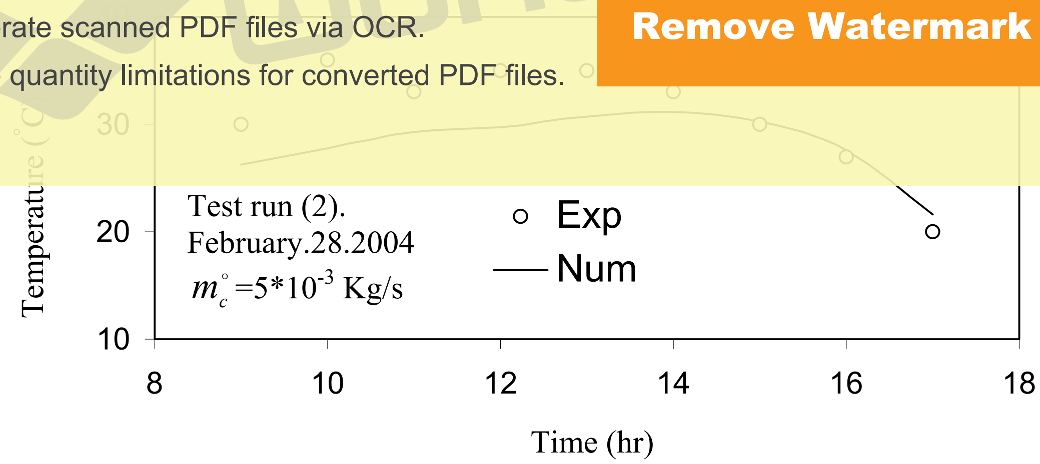

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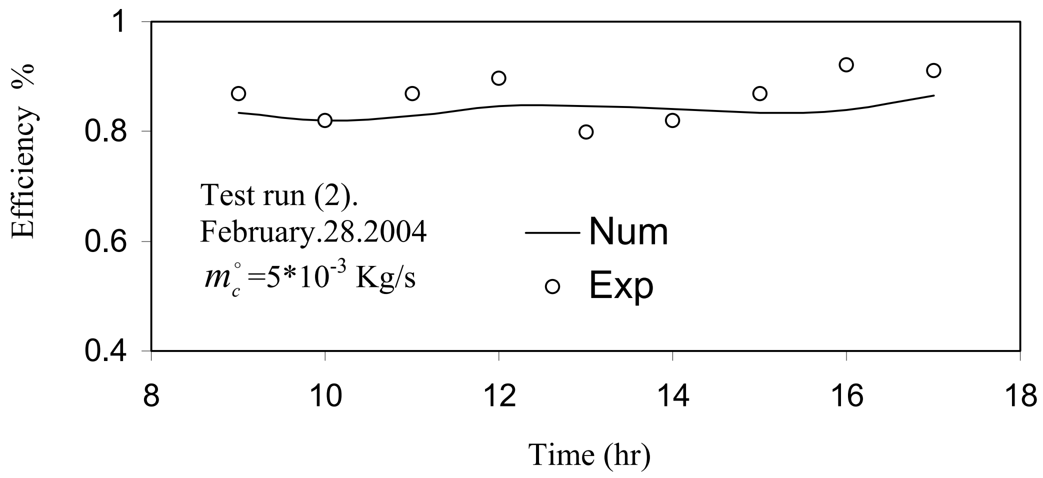

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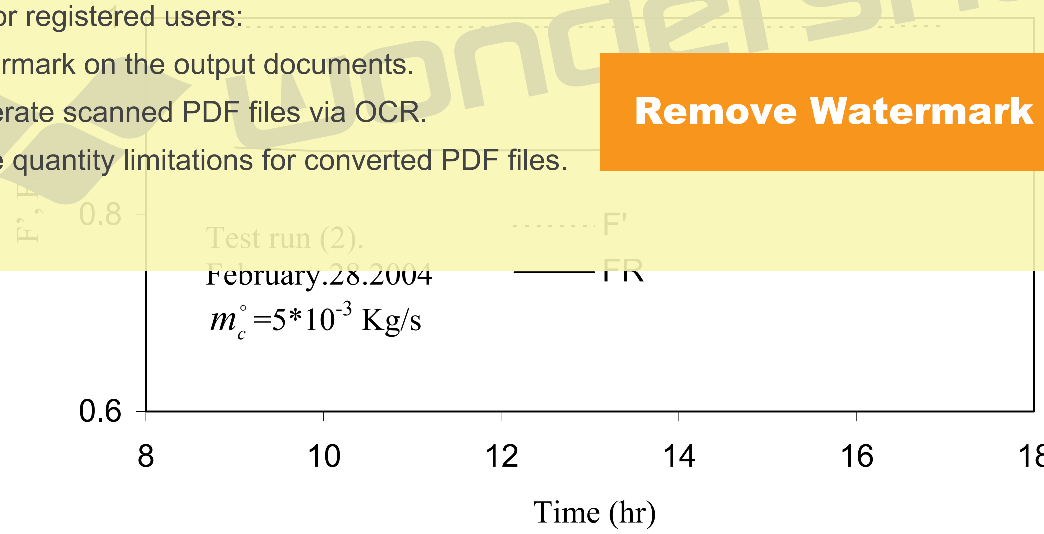

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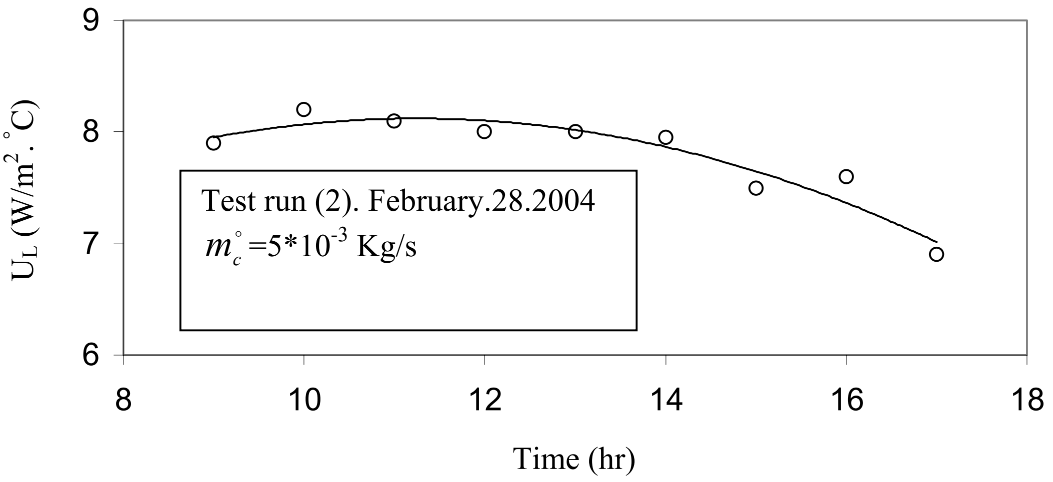


Figure (5-2g) Variation of Overall heat loss coefficient with

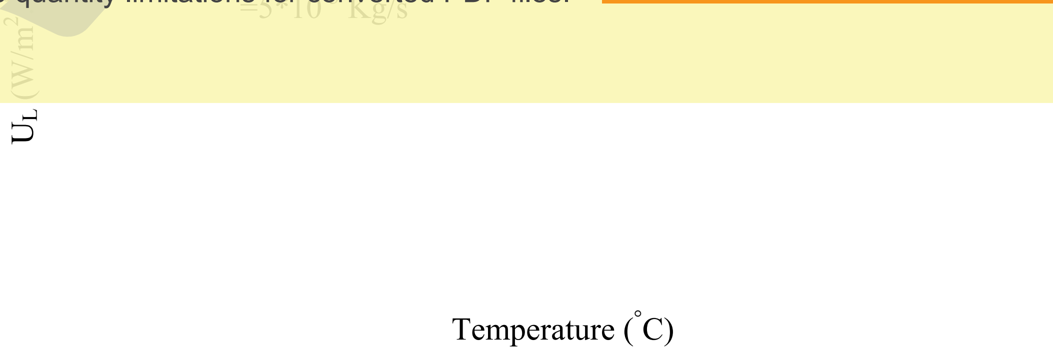


Figure (5-2h) Variation of Overall heat loss coefficient with mean plate temperature

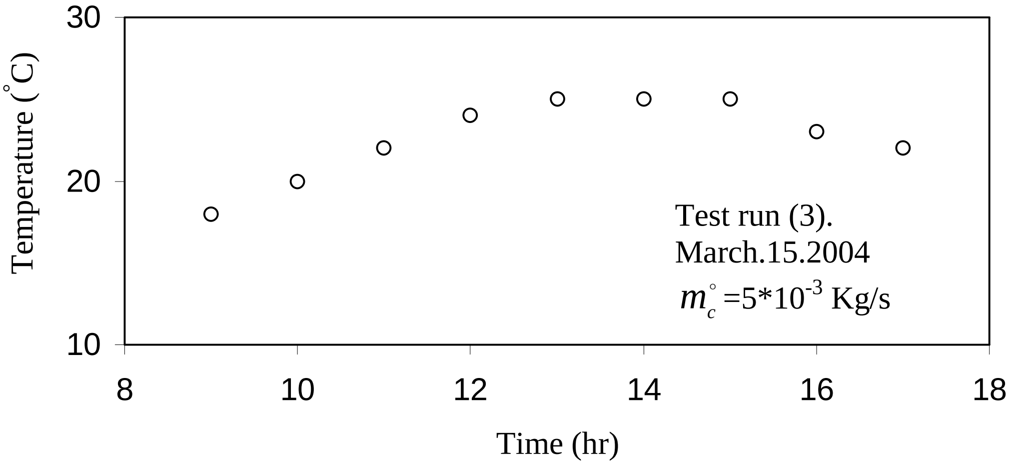


Figure (5-3a) Ambient temperature variation with time

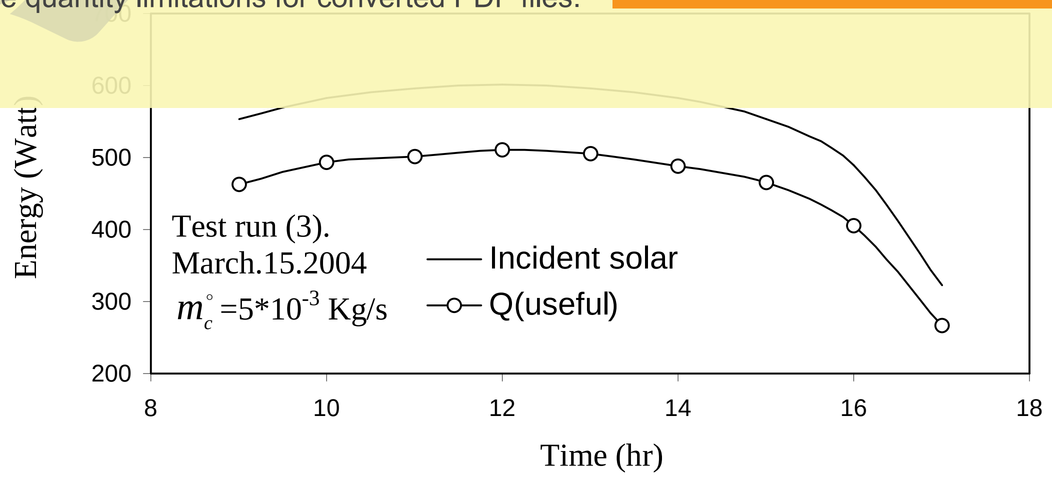
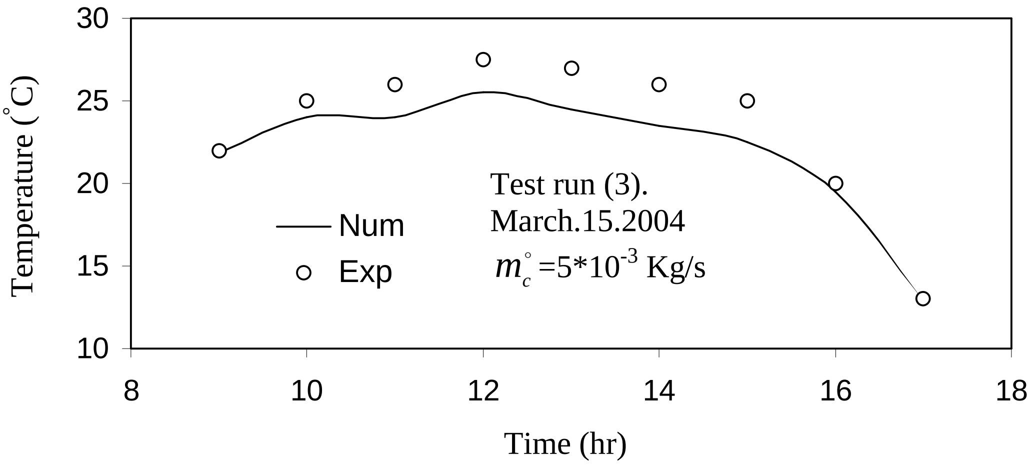


Figure (5-3b) Variation of total radiation on the collector surface and useful energy gain with time



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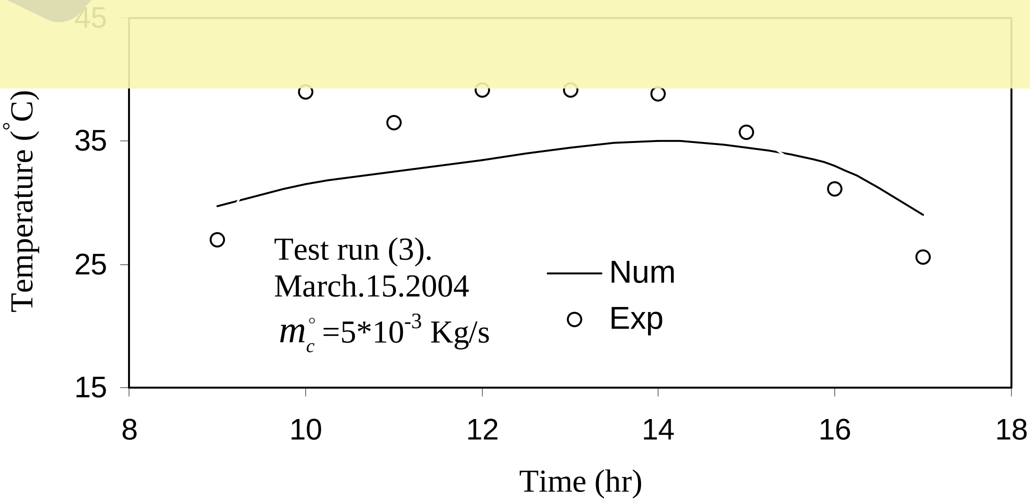


Figure (5-3d) Mean plate temperature variation with time

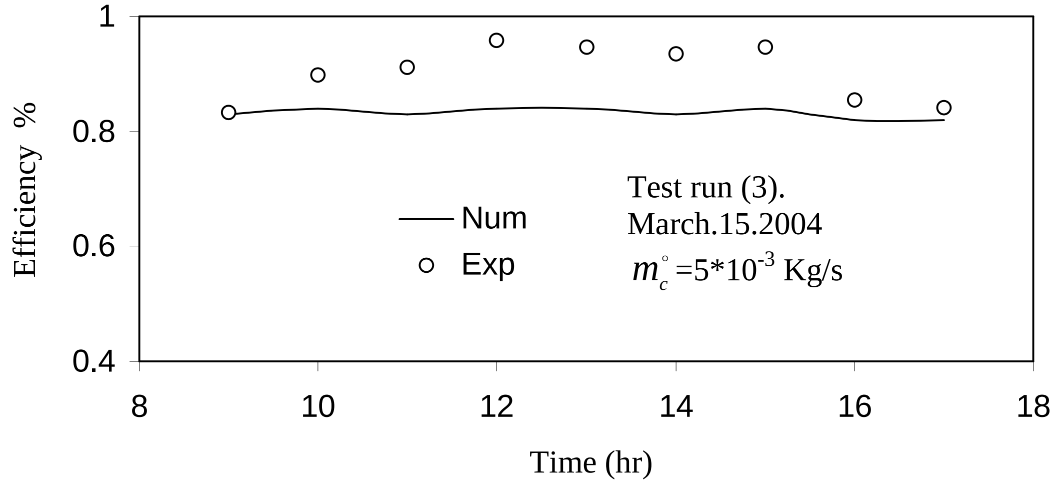


Figure (5-3e) Instantaneous efficiency variation with time

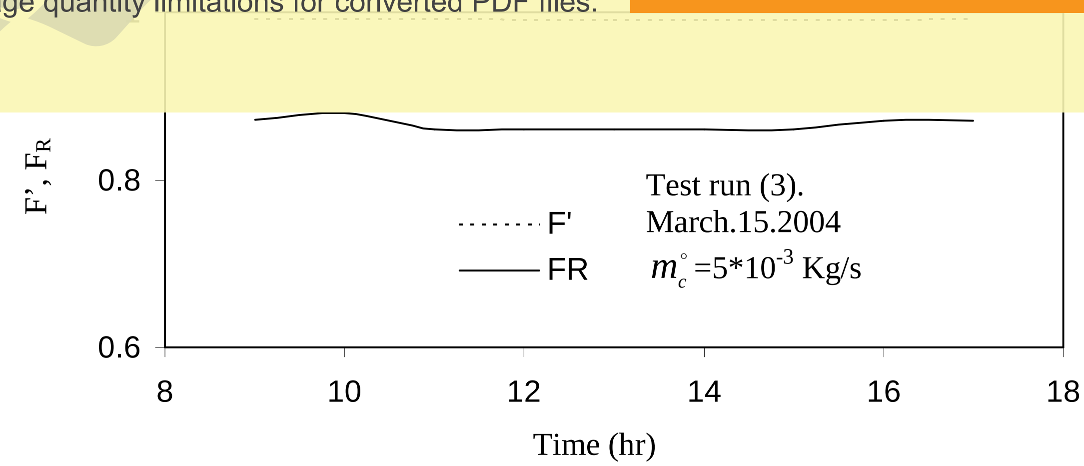


Figure (5-3f) Variation of Collector Heat Removal Factor and Collector Efficiency Factor with time

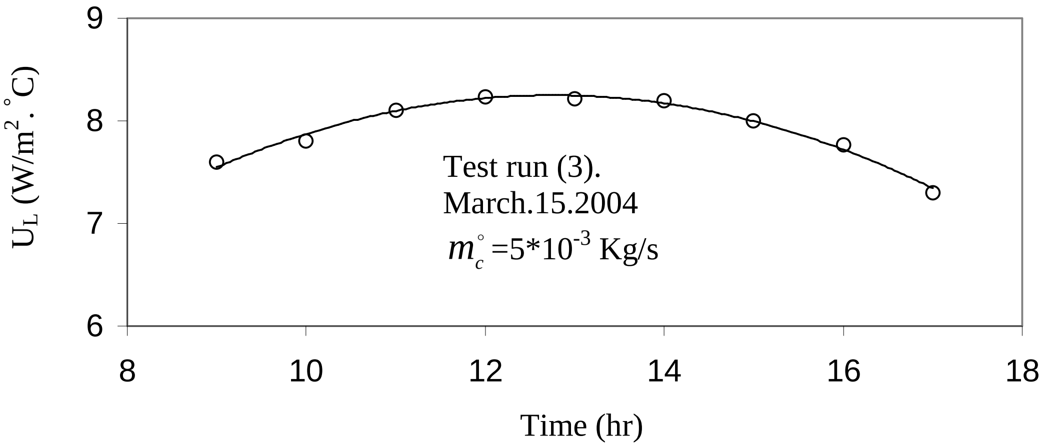


Figure (5-3g) Variation of Overall heat loss coefficient with time

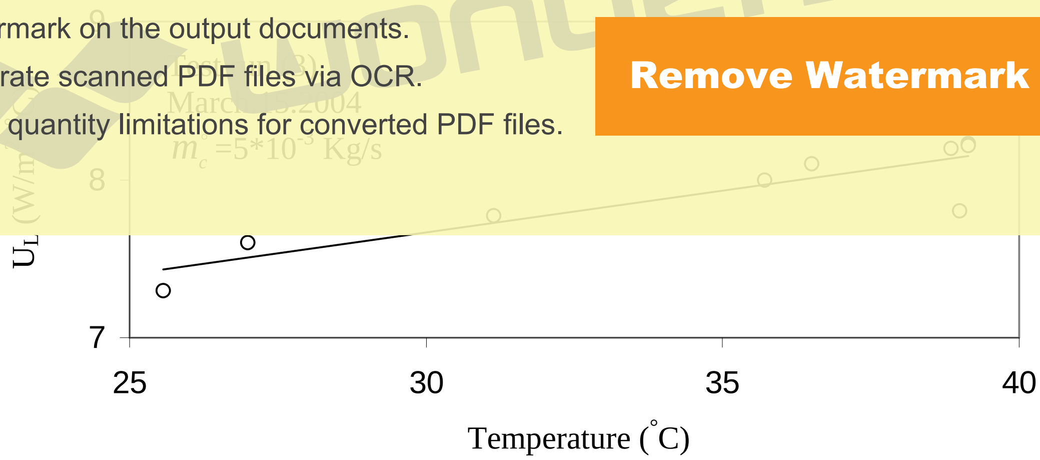


Figure (5-3h) Variation of Overall heat loss coefficient with mean plate temperature

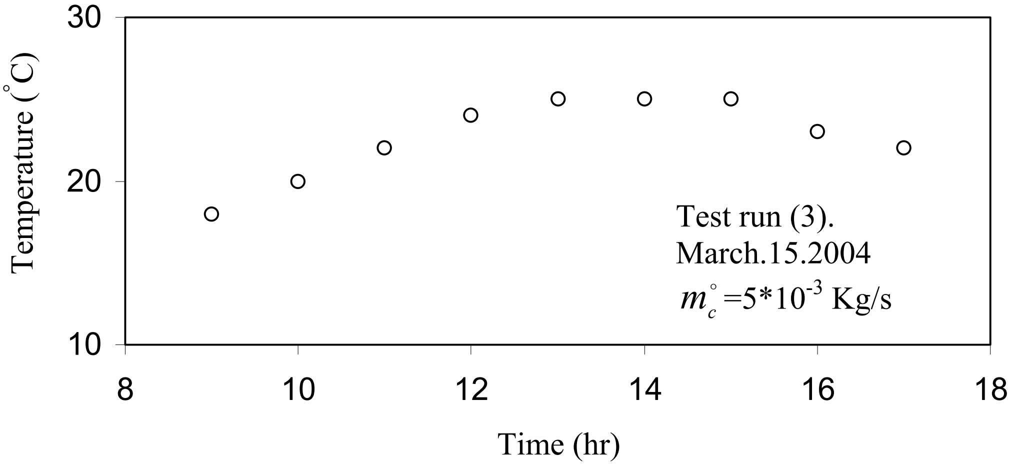


Figure (5-3a) Ambient temperature variation with time

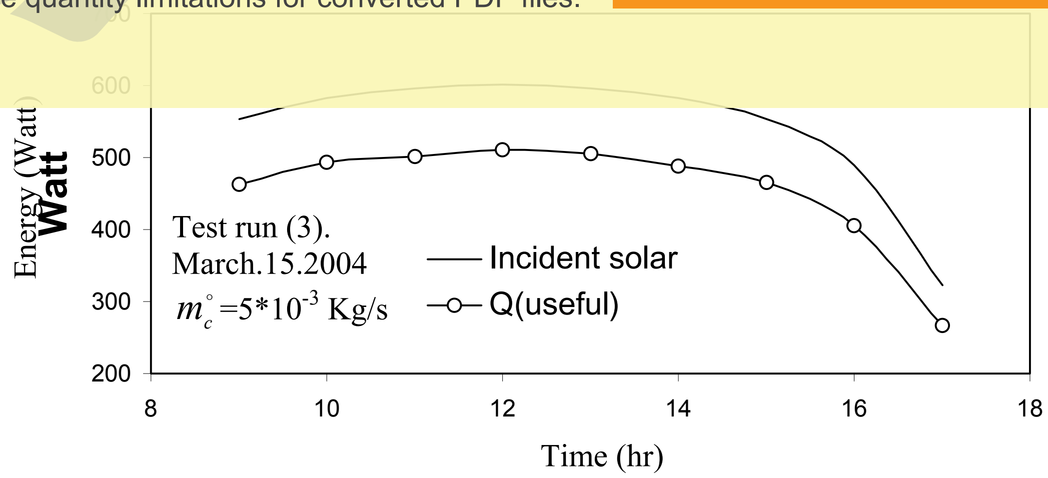
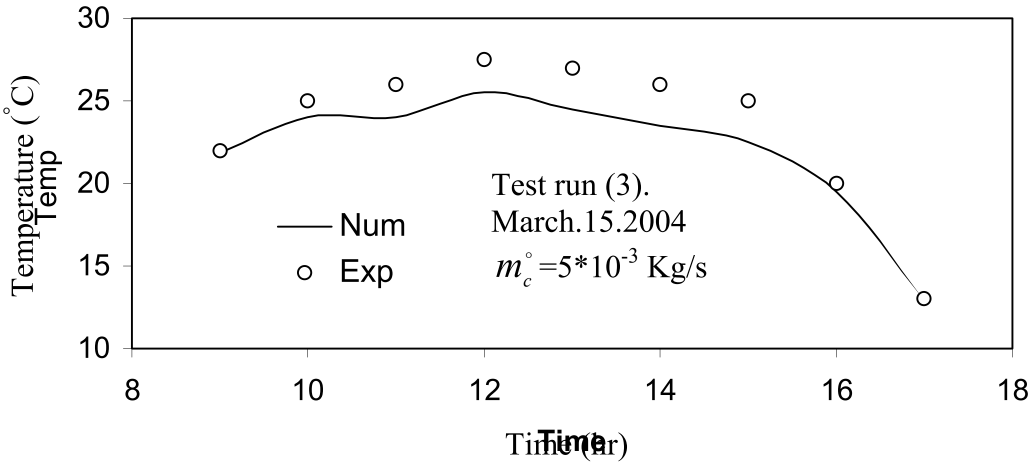
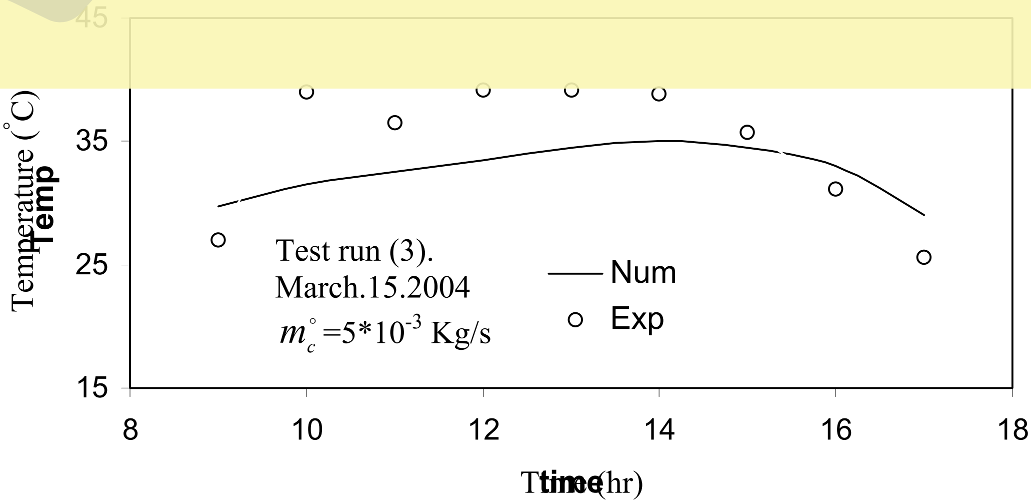


Figure (5-3b) Variation of total radiation on the collector surface and useful energy gain with time



collector with time



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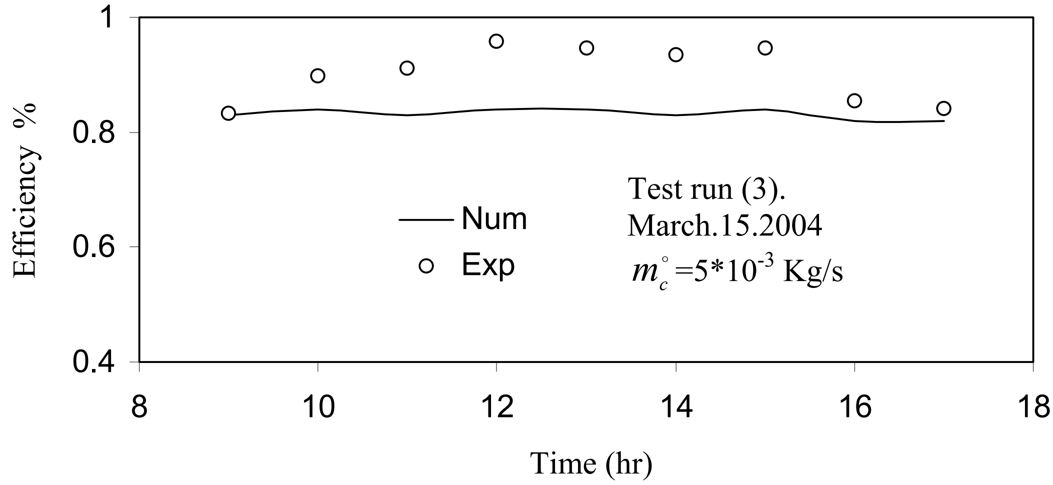

Figure (5-3e) Instantaneous efficiency variation with time

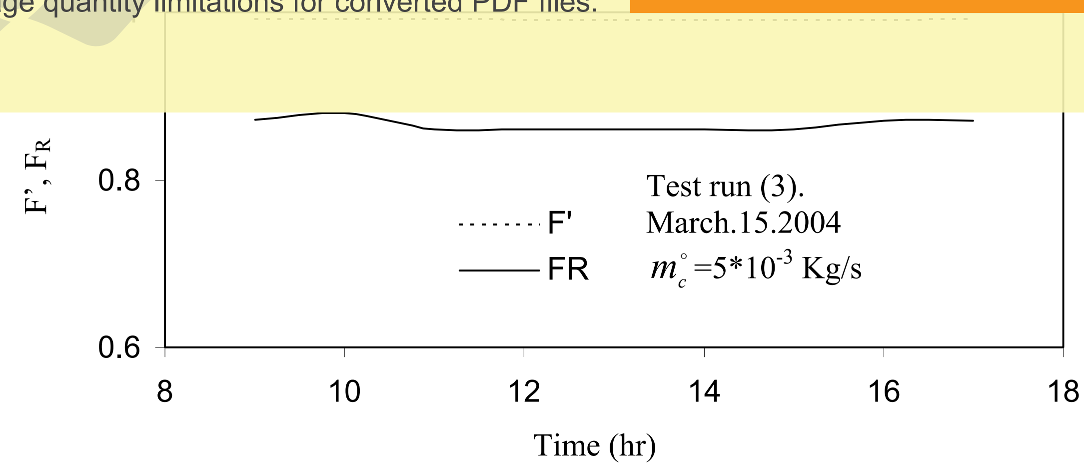

Figure (5-3f) Variation of Collector Heat Removal Factor
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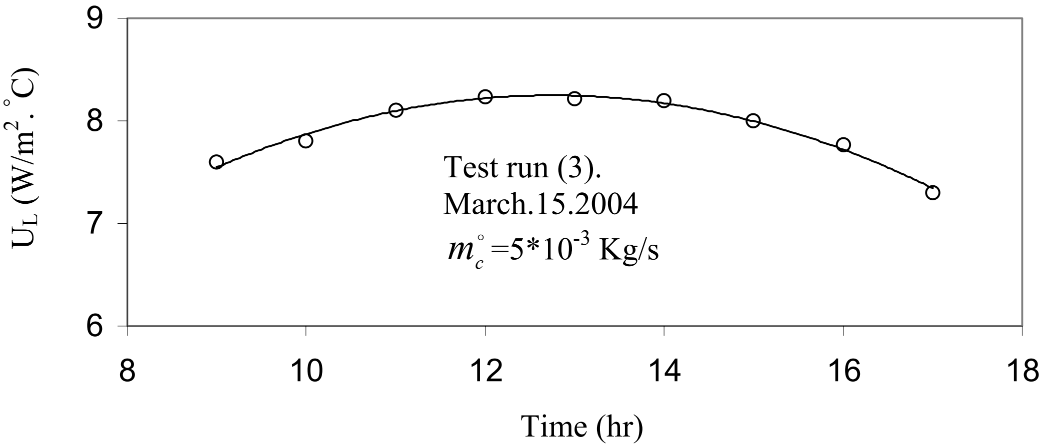


Figure (5-3g) Variation of Overall heat loss coefficient with time

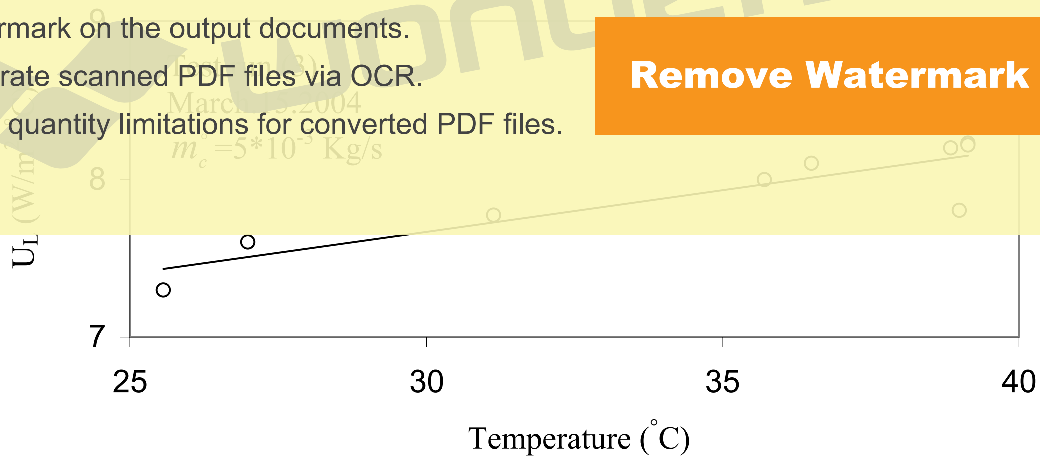


Figure (5-3h) Variation of Overall heat loss coefficient with mean plate temperature

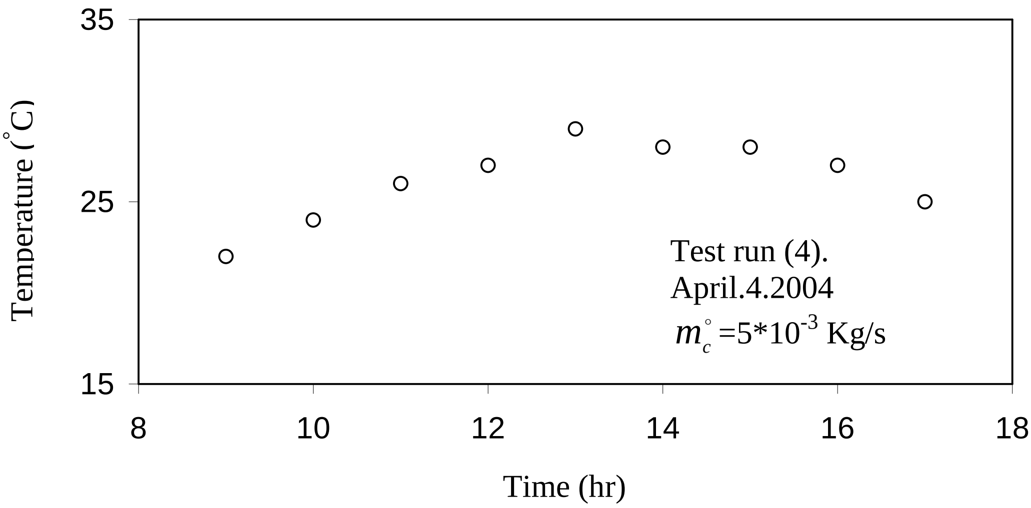


Figure (5-4a) Ambient temperature variation with time

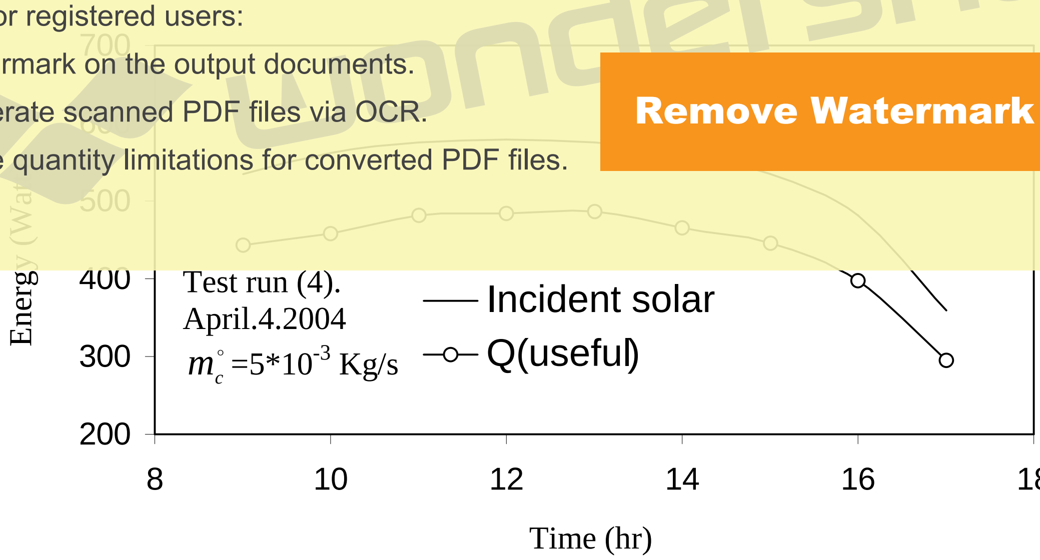


Figure (5-4b) Variation of total radiation on the collector surface and useful energy gain with time

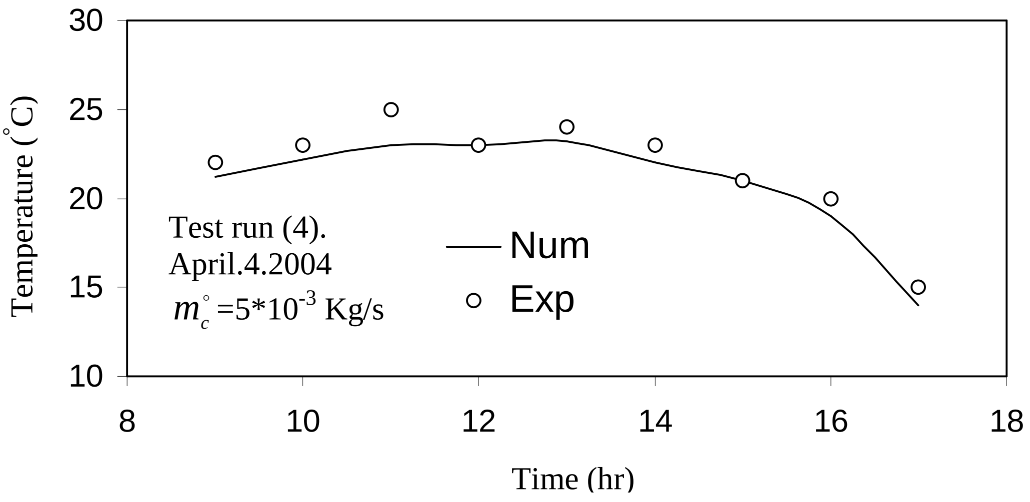
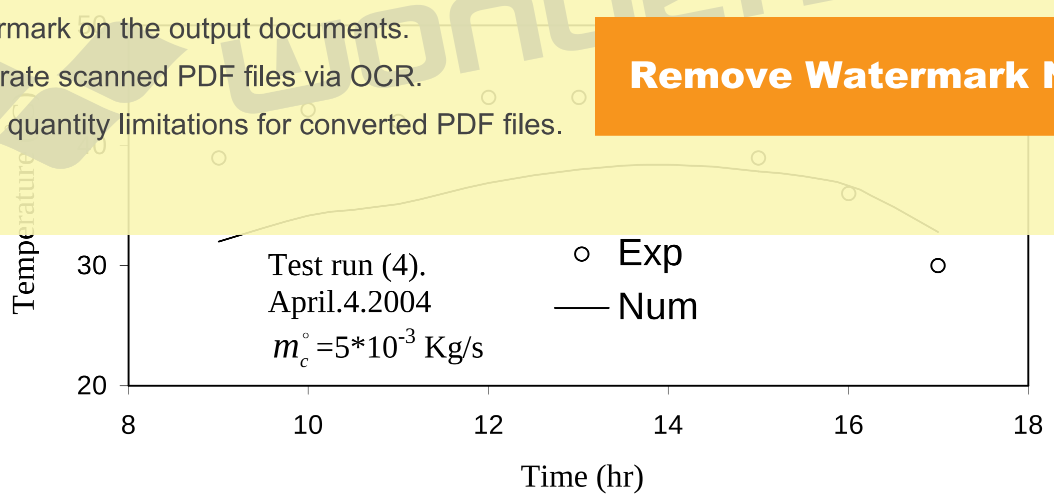


Figure (5-4c) Variation of temperature difference across the collector with time



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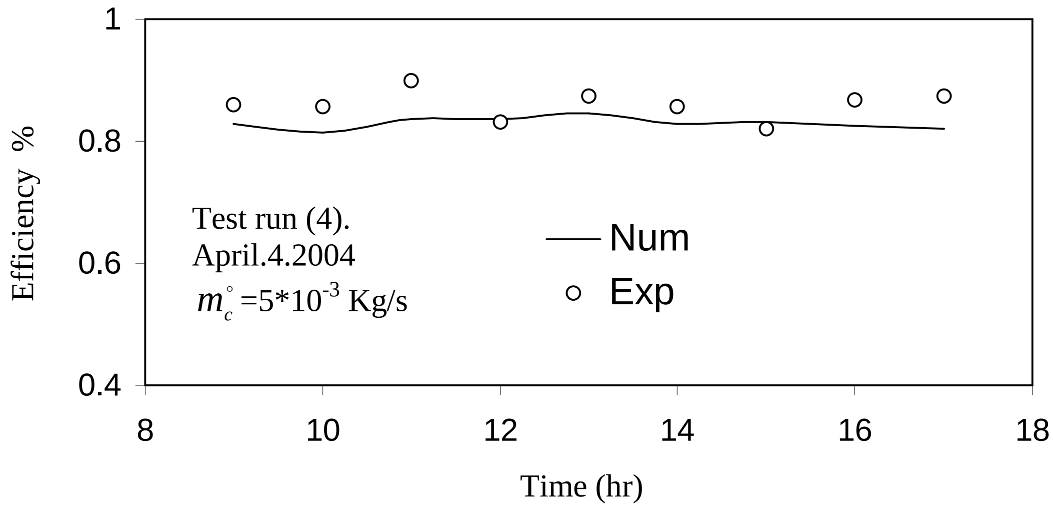

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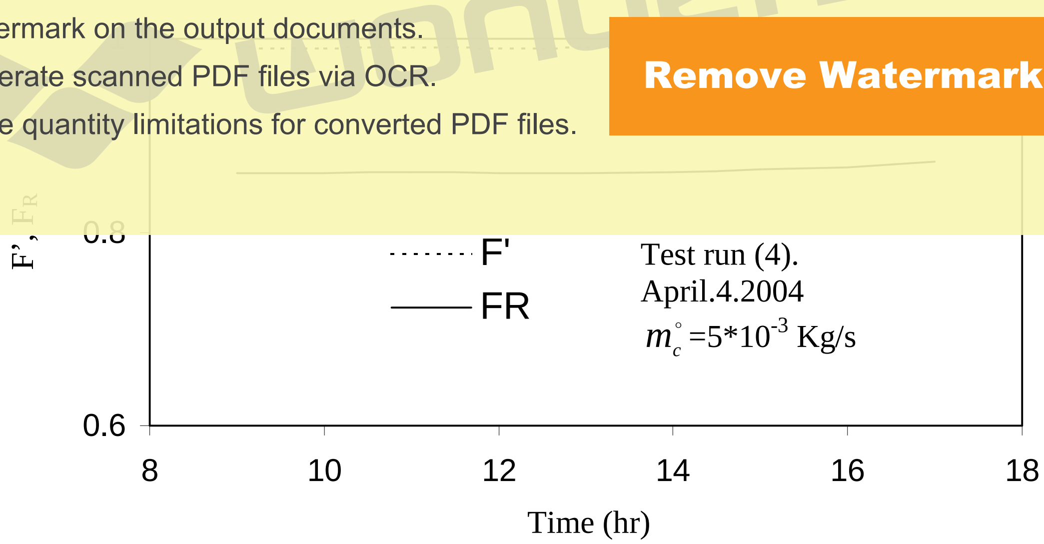

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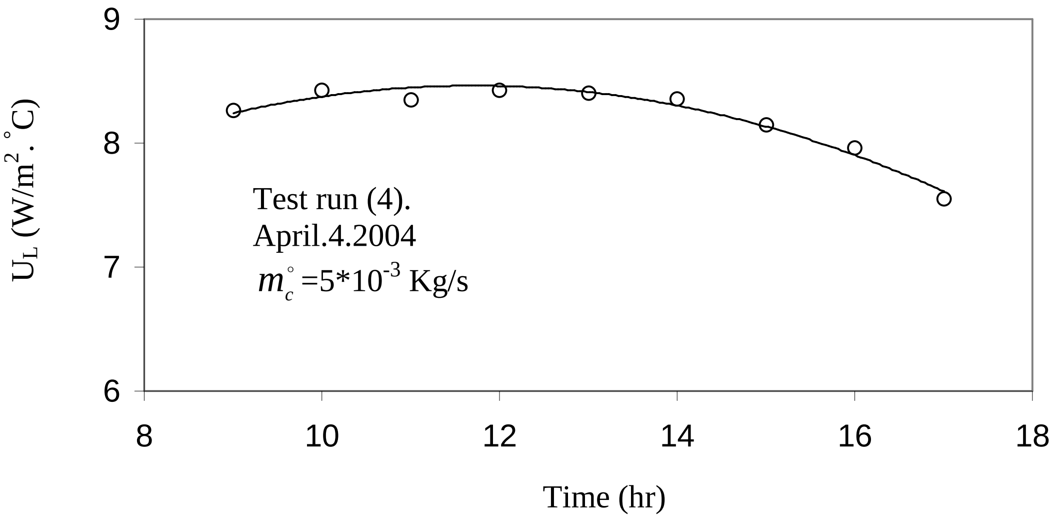

Figure (5-4g) Variation of Overall heat loss coefficient with time

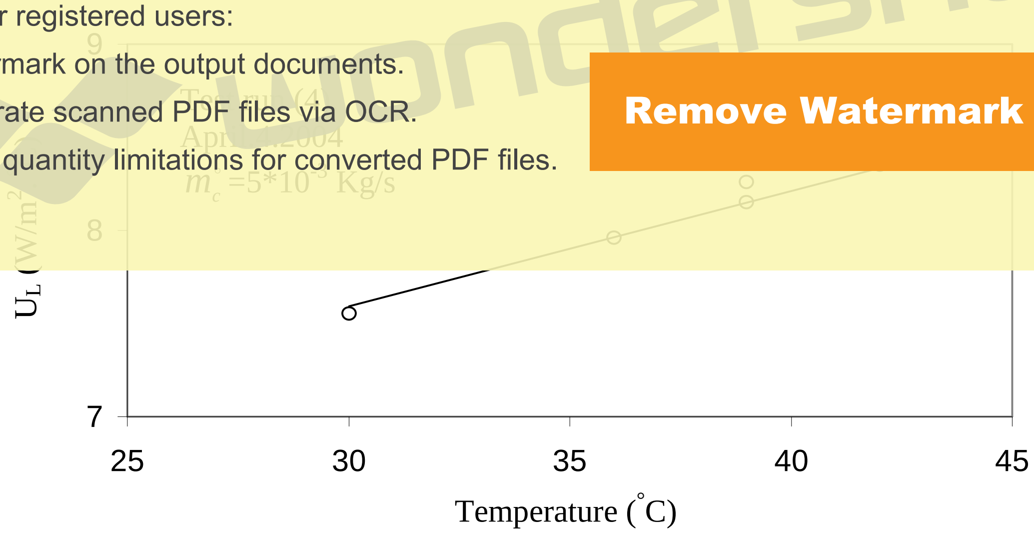

Figure (5-4h) Variation of Overall heat loss coefficient with mean plate temperature.

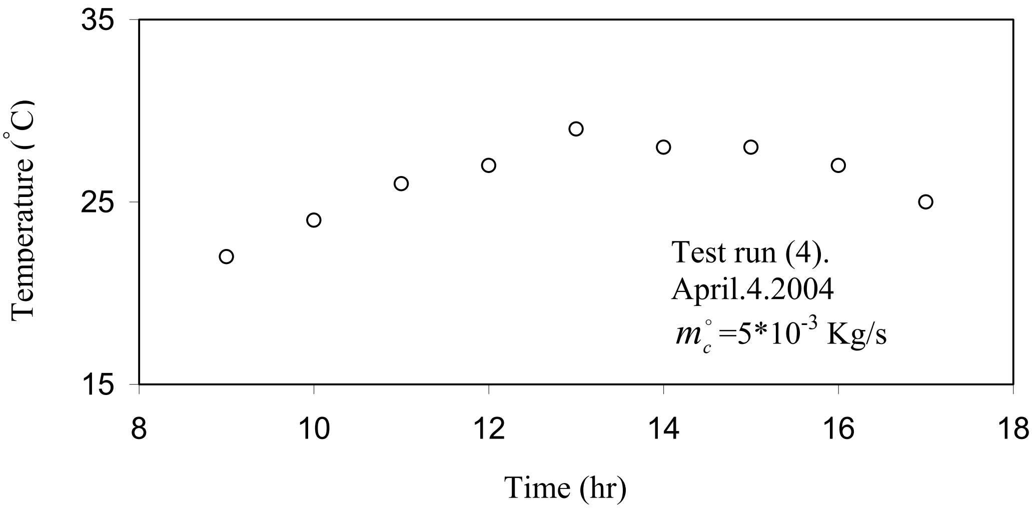

Figure (5-4a) Ambient temperature variation with time

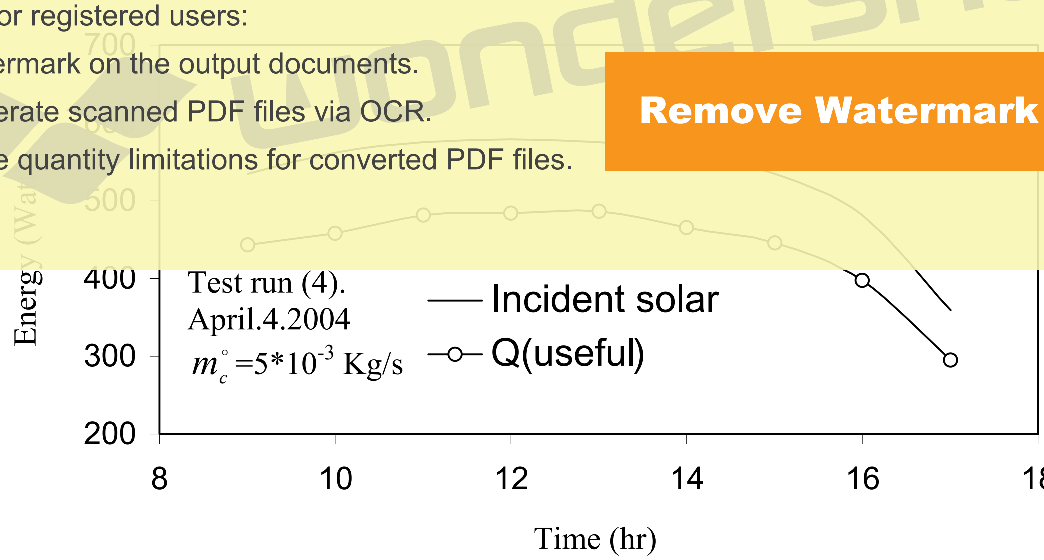

Figure (5-4b) Variation of total radiation on the collector surface and useful energy gain with time

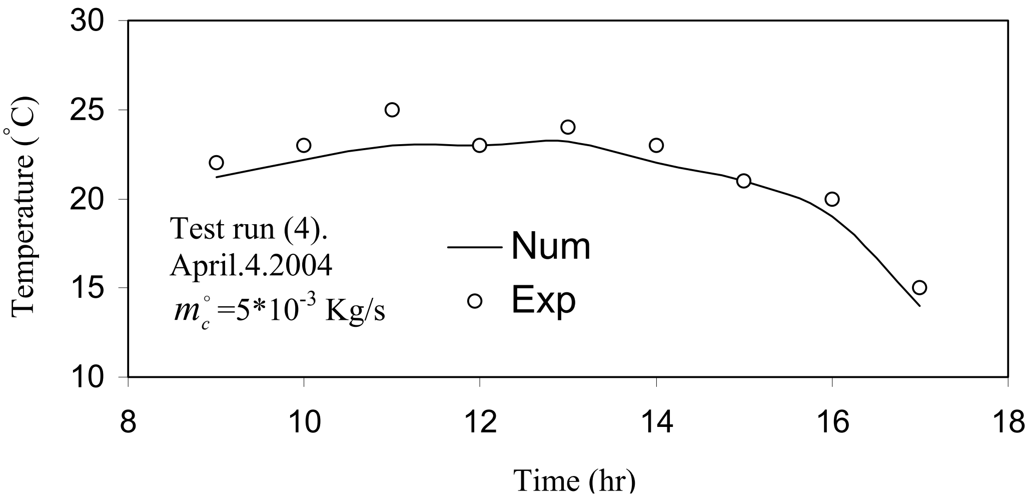

Figure (5-4c) Variation of temperature difference across the collector with time

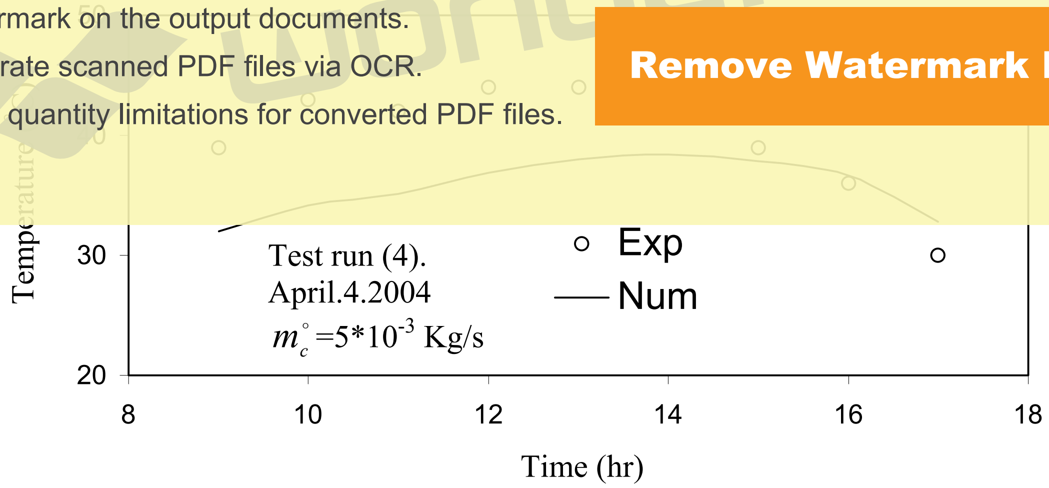

Figure (5-4d) Mean plate temperature variation with time

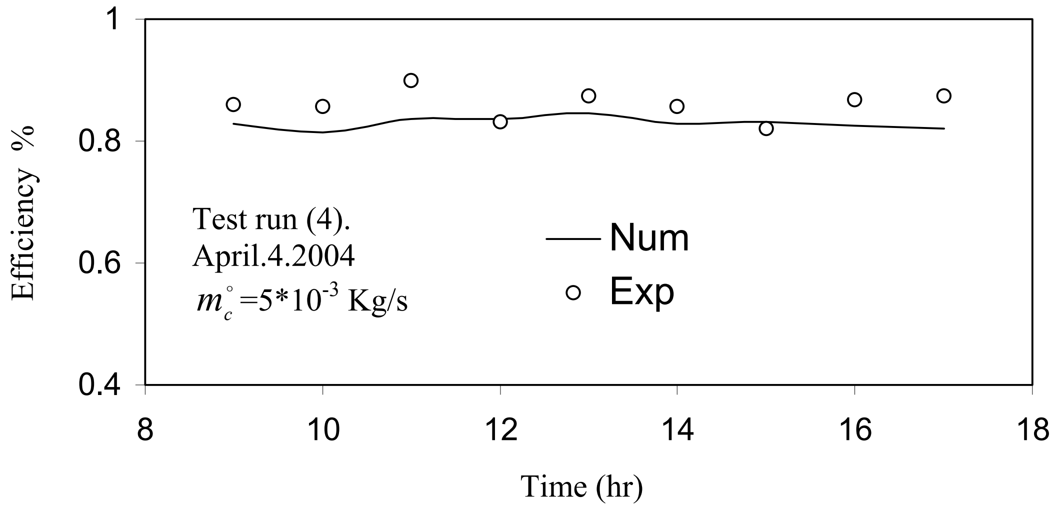

Figure (5-4e) Instantaneous efficiency variation with time

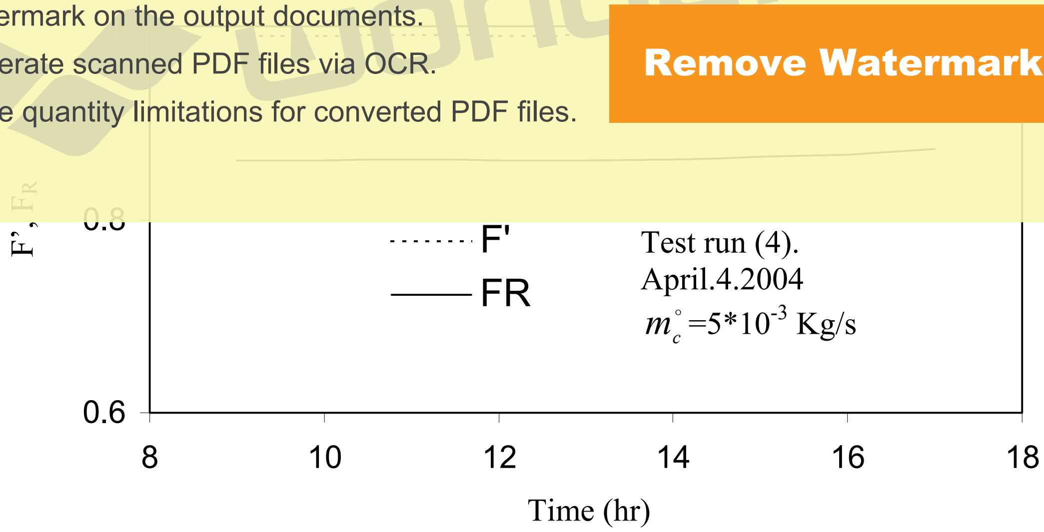

Figure (5-4f) Variation of Collector Heat Removal Factor and Collector Efficiency Factor with time

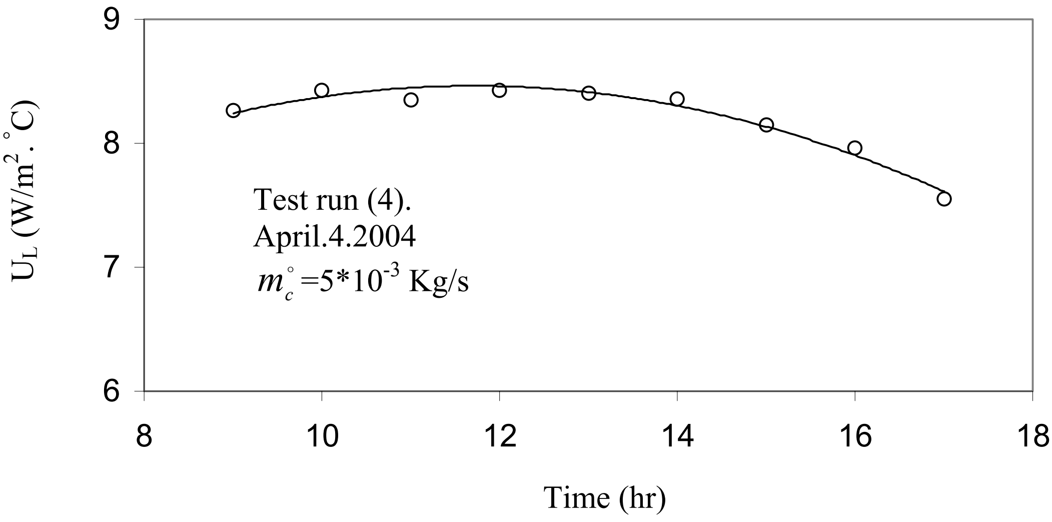

Figure (5-4g) Variation of Overall heat loss coefficient with time

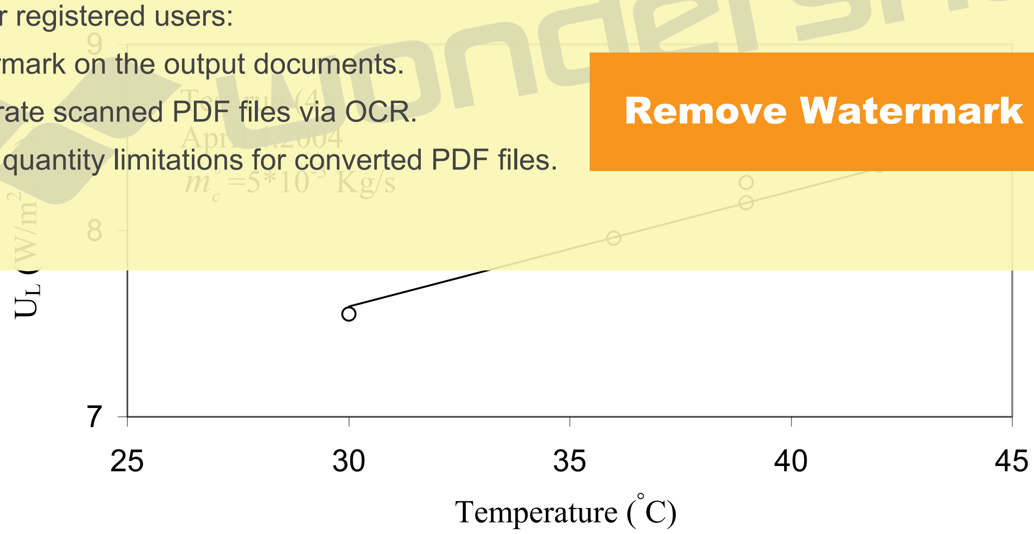

Figure (5-4h) Variation of Overall heat loss coefficient with mean plate temperature.

Appendix (A)

Month	r	c
January	2.150	0.142
February	2.050	0.144
March	1.925	0.156
April	1.75	0.18
May	1.6	0.196
June	1.512	0.205
July	1.462	0.207
August	1.487	0.201
September	1.587	0.177
October	1.736	0.160
November	1.975	0.149
December	2.050	0.142

Table (A-1) values of r a

Appendix (A)

Month	r	c
January	2.150	0.142
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Table (A-1) values of r an[illegible]

Appendix (B)

Sample of calculation:

Date of experiment 20/10/2004 at local time 12:00 A.M

1-Calculation of solar radiation amount:

Given data: n=20, M=12, I_{cs}=1353 W/m^2, Ø=33.3^o and from appendix r=2.150, c=0.142

From eq. (4.27), eq. (4.24) and eq. (4.25) we obtained that

E=1.033 [illegible] and ω=0

By substation the value of Ø, γ and ω in eq. (4.23) lead to sin λ=0.[illegible]

From G=1+r sin λ

G=2.27[illegible]

[illegible] incident solar radiation on the tilted collector surface H_T from eq. (4.26) is equal to 809.67 W/m^2

2- Calculation of the collector parameters:

Given data:T_p=302 K, T_A=290 K, T_{in}=15C^o, N=1 and $\overset{\circ}{m}_c$=5*10^{-3} Kg/s

With V=3.5 m/s as average of wind speed, h_w =8.7+3.8 V =22 W/m^2. $^\circ$C

And $f=\left(1.0-0.04h_w{}^2+\left(5*10^{-4}h_w{}^2\right)\right)*\left(1+0.058N\right)$=-19.1682

Substation the above values in eq. (4.3) lead to U_t=5.622 W/m^2. $^\circ$C

By using eq. (4.4) and eq. (4.5) obtained that U_e=1.093 W/m^2. $^\circ$C and U_b=1.125 W/m^2. $^\circ$C

Then from eq. (4.2) U_L=7.84 W/m^2. $^\circ$C

With D=8cm and D_i=7.8cm, $F^{'}$=0.991 {eq. (4.9)}

S=HR ($\overline{\tau\alpha}$) = 1.01H_T $\tau\alpha$ =737.23 W/m^2

The result of eq. (4.14) is T_o=38 C^o

From eq. (4.16), eq. (4.17) we obtained F_R=0.868, U_{useful}= 4.84.4 W/m^2

And T_{pm} from eq. (4.19) equal to 28 C^o

Finally the instantaneous efficiency of the collector from eq. (4.21) is

η_c=0.832

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E=1.032[illegible]20.28[illegible]

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[illegible]2.27[illegible]

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Certificate

We certify that we have read this dissertation entitled “Design, implementation and performance testing of a novel solar collector”, and as an examining committee, examined the student in its contents and that in our opinion it meets the standard of a dissertation for the degree of Master of Science in Mechanical Engineering.

Signature:
Name: Dr. A. N. Khalifa
(Supervisor)
Date: / / 2004

Signature:
Name: Asst. Prof.
Dr. Khalil E. J. Al-Jumaily
(Supervisor)
Date: / / 2004

Signature:
Name: Asst. Prof.Asad Tuma
(Member)
Date: / / 2004

Signature:
Name: Dr. Adnan A. Al-Qalamchi
(Member)
Date: / / 2004

Signature:
Name: Asst. Prof. Adnan M. Rashid
(Chairman)
Date: / / 2004

Approved by the Dean of the College of Engineering:

Signature:
Name: Prof. Dr. Fawzi M. Al-Naima
(Dean of Engineering College)
Date: / / 2004

Certification

We certify that the preparation of this thesis entitled "Design, implementation and performance testing of a novel solar collector", was prepared under our direct supervision by Engineer Ahmed Khalid Habeeb at the college of engineering of Al-Nahrain University in partial fulfillment of the requirements for the degree of Master of science in Mechanical Engineering.

Signature:

Name: Dr. A. N. Khalifa

Date: / / 2004

Signature:

Name: Asst. Prof. Dr. Khalil E. J. Al-Jumaily

Date: / / 2004

Signature:

Name: Prof. Dr. Husham T. Rashid

(Head of Department)

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Chapter Five

Results and Discussion

5.1 Results:

The novel solar water heating system has been evaluated under actual weather condition in Al-Nahrain University in Baghdad. The results of this work can be divided in to two main parts, the first part deal with the result of mathematical model, which included the investigation of parameters governing the performance of the system with experimental results. The second part includes the calculation of the percentage error of efficiency determination.

Percentage error of daily efficiency determination:

The numerical and experimental v [illegible] system for the first four tests presented in table (5.1) below.

Test No.	Predicted efficiency	Experimental efficiency	Percentage error %	Flow rate (Kg/s)
1	81.2	80.1	1.47	$5*10^{-3}$
2	83.7	86	2.32	$5*10^{-3}$
3	84	81.3	3.21	$5*10^{-3}$
4	83	86	3.48	$5*10^{-3}$

Table (5.1) Experimental and numerical efficiency and percentage deviation between them for the different test runs.

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Chapter four

Mathematical Calculation

4.1 Introduction:

In this chapter mathematical modeling and theoretical analysis of the novel solar collector will be described by considering the thermal factors affecting the system and the governing equations for the mechanics of the system considering the boundary conditions for the particular system and calculation the amount of solar radiation on the collector.

4.2 System Modeling:

A model for the solar collector will be presented; the model utilizes the experimental data specified for [illegible] product and th[illegible]

4.2.1 Assumptions:

To model the situation, a number of simplifying assumptions can be made to lay the foundations without obscuring the basic physical situation.
These assumptions are:

1- There is no absorption of solar energy by the cover.

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5- Temperature gradients around tubes can be neglected.

6- Loss through front and back of the collector is to be at the same ambient temperature.

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4.2.2 The collector:

The novel solar collector is considered as a flat plate collector. The heat transfer behavior of the collector is of transient type due to the variation of weather conditions and load distribution. With previous simplifying assumptions and steady approximation, the Hottel-Bliss-Whillier [1] theory can be applied to calculate the fluid out let temperature from the collector in which overall loss coefficient is dependent on water inlet temperature. Thus the following simple relation results:

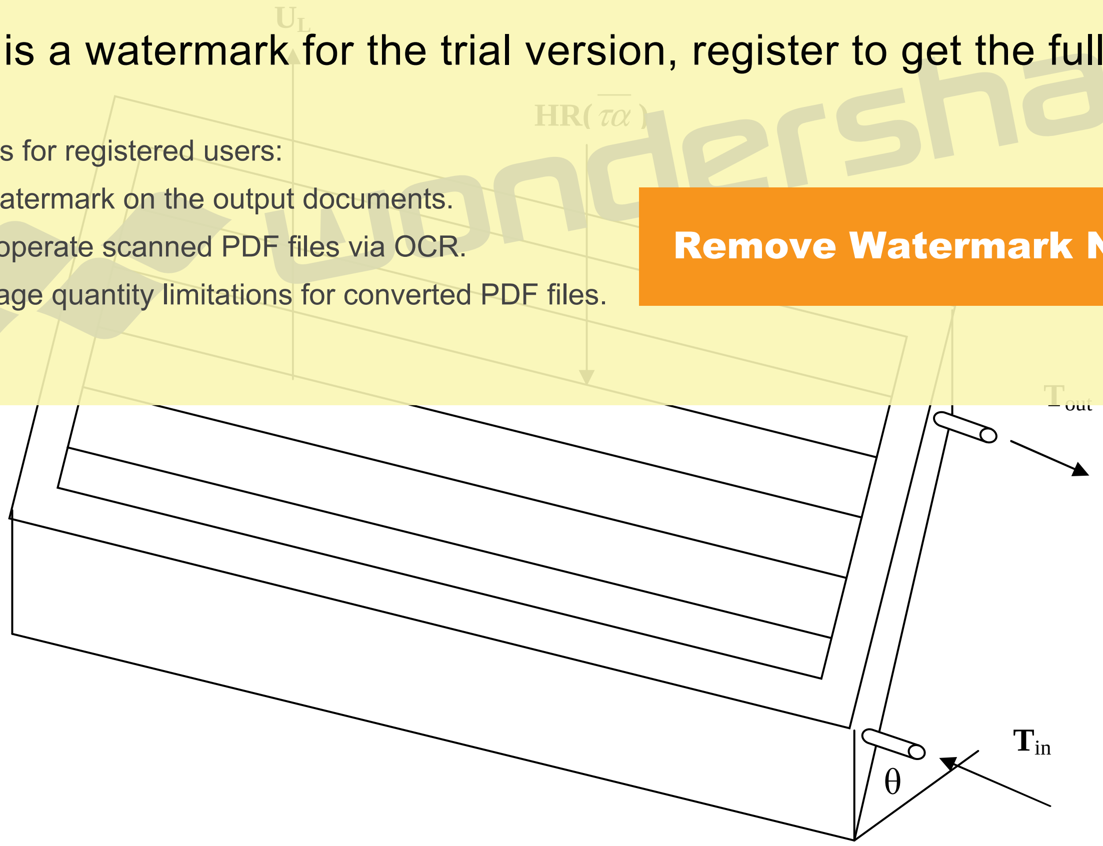

Figure (4.1) Schematic diagram of the collector.

The useful heat gain by the collector per unit length is given by:

$$q_u = D\left[S - U_L\left(T_p - T_A\right)\right] \tag{4.1}$$

The net solar energy absorbed is calculated by the formula:

$$S = HR\left(\overline{\tau\alpha}\right)$$

Where:

$$\left(\overline{\tau\alpha}\right) = 1.01\tau\alpha$$

And

$$R = U_T / U$$

The overall loss coefficient of the collector is given as:

$$U_L = U_t + U_b + U_e \tag{4.2}$$

The top loss coefficient is calculated by the formula Ref. [1]:

$$U_t = \left[\frac{N}{\left(344/T_p\right)\left[\left(T_p - T_A\right)/\left(N + F\right)\right]^{0.31}} + \frac{1}{h_w}\right]^{-1} + \left[\frac{\sigma\left(T_p + T_A\right)\left(T_p^{\,2} + T_A^{\,2}\right)}{\left[\varepsilon_p + 0.0425N\left(1 - \varepsilon_p\right)\right]^{-1} + \left[\left(2N + f - 1\right)/\varepsilon_g\right] - N}\right] \tag{4.3}$$

Where:

$$h_w = 8.7 + 3.8V$$

$$f = \left(1.0 - 0.04h_w{}^2 + \left(5 * 10^{-4} h_w{}^2\right)\right) * \left(1 + 0.058N\right)$$

$$U_e = \frac{K * 2(l + W_e)\delta}{X_e A_c} \quad \textbf{(Edge loss coefficient)} \qquad (4.4)$$

$$U_b = \frac{K}{X_b} \quad \textbf{(Back loss coefficient)} \qquad (4.5)$$

Also the useful heat gain from eq. (4.1) must be transferred to the fluid. The resistance to heat flow to the fluid result from bond

expressed in term of the two resistance as:

$h_{fi} = 300W/\ m^2.C^\circ$ For laminar flow. Ref. [1]

$$C_b = \frac{k_b b}{\gamma_b}$$

Since there is no sheet associated with the tube, the term $1/C_b$ can be taken as zero. Sub. In eq. (4.6)

$$\textit{So that eq.}(4.2)\textit{ becomes} \quad T_p = T_f + \frac{q_u}{h_{f,i}\pi D_i} \qquad (4.7)$$

By substitution eq. (4.7) in eq. (4.1)

$$q_u = D\left[S - U_L\left(T_f + \frac{q_u}{h_{f,i}\pi D_i} - T_A\right)\right] \tag{4.8}$$

$$q_u = \frac{1/U_L}{D\left(\frac{1}{DU_L} + \frac{1}{h_{f,i}\pi D_i}\right)} * D\left[S - U_L\left(T_f - T_A\right)\right]$$

Let the term $\frac{1/U_L}{D\left(\frac{1}{DU_L} + \frac{1}{h_{f,i}\pi D_i}\right)} = F'$ (4.9)

Where F' is the collector efficiency factor

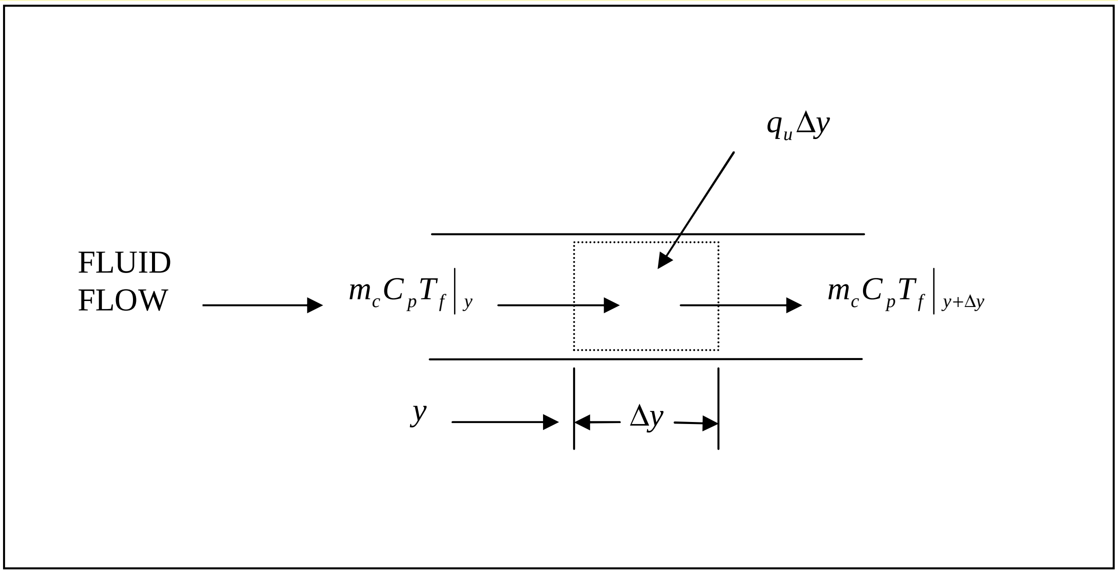

Figure (4.2) Section of one tube

By energy balance on the fluid flowing through a section of one pipe as shown in Fig. 4.2.

$$\mathring{m}_c C_p T_f \big|_y - \mathring{m}_c C_p T_f \big|_{y+\Delta y} + \Delta y q_u = 0 \qquad (4.11)$$

Sub.eq. (4.10) in eq. (4.11)

$$\mathring{m}_c C_p \frac{dT_f}{dy} - F' D\left[S - U_L\left(T_f - T_A\right)\right] = 0$$

$$\frac{dT_f}{\left(T_f - T_A - \frac{S}{U_L}\right)} = -\frac{DF'U_L}{\mathring{m}_c C_p} dy \qquad (4.12)$$

[illegible]

$$\frac{\left(T_0 - T_A - \frac{S}{U_L}\right)}{\left(T_i - T_A - \frac{S}{U_L}\right)} = \exp\left[-\frac{DF'U_L y}{\mathring{m}_c C_p}\right] \qquad (4.13)$$

$$T_o = T_A + \frac{S}{U_L} + \left[\left(T_{in} - T_A - \frac{S}{U_L}\right) * \exp\left[-\frac{DF'U_L y}{\mathring{m}_c C_p}\right]\right] \qquad (4.14)$$

$$F_R = \frac{\mathring{m}_c C_p \left(T_o - T_{in}\right)}{A_c\left[S - U_L\left(T_{in} - T_A\right)\right]} \qquad (4.15)$$

Where F_R is the collector heat removal factor which is defined as the ratio of actual useful energy gain of the collector to the useful energy gain if the whole collector surface at the fluid inlet temperature.

$$F_R = \frac{\overset{\circ}{m}_c C_p}{A_c U_L}\left[1 - \exp\left[-\frac{DF' U_L y}{\overset{\circ}{m}_c C_p}\right]\right] \qquad \text{Ref. [1]} \qquad (4.16)$$

From eq. (4.15)

$$Q_{useful} = A_c F_R \left[S - U_L \left(T_{in} - T_A\right)\right] \qquad (4.17)$$

$$T_{f,m} = T_{in} + \frac{Q_{useful}}{A_c U_L F_R}\left[1 - \frac{F_R}{F'}\right] \qquad (4.18)$$

Where:

$T_{f,m}$ is the mean fluid temperature

$$T_{p,m} = T_{f,m} + Q_{useful} R_{p-f} \qquad (4.19)$$

$$R_{p-f} = \frac{1}{h_{f,i} \pi D_i n L} \qquad (4.20)$$

Where:

R_{p-f} is heat transfer resistance between the plate and the fluid

The Instantaneous Collector Efficiency:

It is defined as the rate at which incident solar energy is being converted into thermal energy by the absorber unit and is given by:

$$\eta_c = \frac{Q_{useful}}{H_T A_c} = \frac{\overset{\circ}{m}_c\, Cp\left(T_{out} - T_{in}\right)}{H_T A_c} \qquad (4.21)$$

The daily collector efficiency:

It is the total useful energy gain to the total incident solar radiation for one day.

$$\eta_{day} = \frac{\sum Q_{useful}}{A_c \sum H_T} \qquad (4.22)$$

4.3 Solar radiation amount calculation:

This part includes the calculation of the theoretical amount of the solar radiation in Baghdad for the selected clear test day.

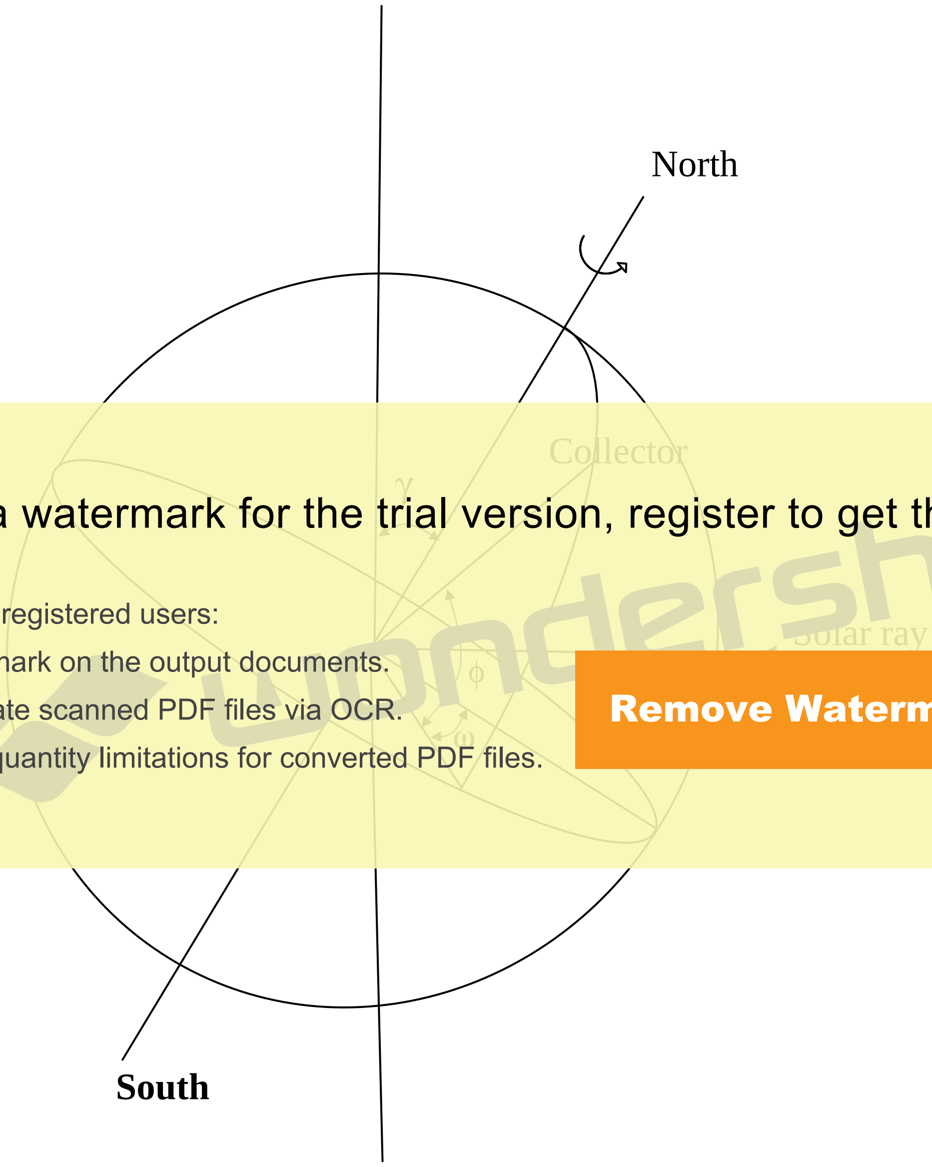

Figure (4.3) Schematic diagram of the earth

The total incident solar radiation on the tilted surface is given by [12]:

$$H_T = I_{cs} * E * \exp\left(\frac{-cG}{\sin\lambda}\right) \qquad (4.26)$$

Where:

I_{cs} = Solar constant =1353 $W/\ m^2$ [1]

And the earth decentralization coefficient E is given by

$$E = \left[1 - 0.01673\cos\left(\frac{360n}{365.2563}\right)\right]^2 \qquad (4.27)$$

Where:

n = Day number from the first day of January

As example: n=59 for 28/2/2003

$$G = 1 + r\sin\lambda$$

Where the values of (c) and (r) are given in appendix (B).

The altitude angle of the sun can be found from the relation [12]:

$$\sin\lambda = \sin\gamma\sin\phi + \cos\gamma\cos\phi\cos\omega \qquad (4.23)$$

ϕ =33.3° For Baghdad city.

The declination angle given by:

$$\gamma = 23.45 \sin\left(\frac{360(284+n)}{365.2563}\right) \tag{4.24}$$

And the hour angle is given by:

$$\omega = |12 - M| * 15 \tag{4.25}$$

Where:

M = Time

As example: 9 A.M. → M = 9

2 P.M. → M = 14

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Where:

$$h_w = 8.7 + 3.8V$$

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$$q_u = \frac{1/U_L}{D\left(\frac{1}{DU_L} + \frac{1}{h_{f,i}\pi D_i}\right)} * D\left[S - U_L\left(T_f - T_A\right)\right]$$

Let the term $\frac{1/U_L}{D\left(\frac{1}{DU_L} + \frac{1}{h_{f,i}\pi D_i}\right)} = F'$ (4.9)

Where F' is the collector efficiency factor

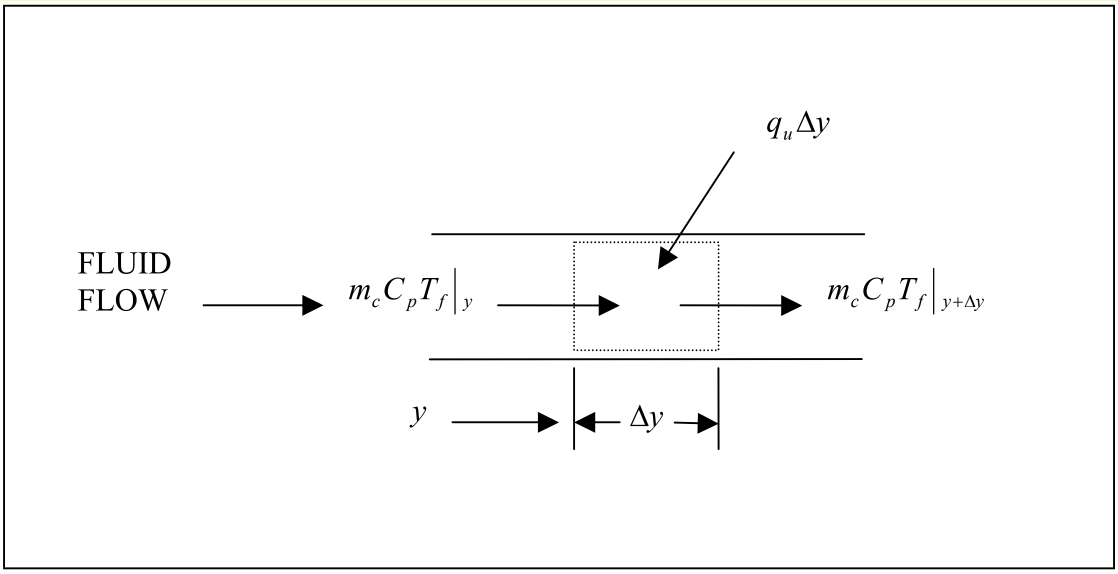

Figure (4.2) Section of one tube

By energy balance on the fluid flowing through a section of one pipe as shown in Fig. 4.2.

$$\overset{\circ}{m}_c C_p T_f \big|_y - \overset{\circ}{m}_c C_p T_f \big|_{y+\Delta y} + \Delta y q_u = 0 \tag{4.11}$$

Sub.eq. (4.10) in eq. (4.11)

$$\overset{\circ}{m}_c C_p \frac{dT_f}{dy} - F' D\left[S - U_L\left(T_f - T_A\right)\right] = 0$$

$$\frac{dT_f}{\left(T_f - T_A - \frac{S}{U_L}\right)} = -\frac{DF'U_L}{\overset{\circ}{m}_c C_p} dy \tag{4.12}$$

By integration of eq. (4.12)

$$\frac{\left(T_0 - T_A - \frac{S}{U_L}\right)}{\left(T_i - T_A - \frac{S}{U_L}\right)} = \exp\left[-\frac{DF'U_L y}{\overset{\circ}{m}_c C_p}\right] \tag{4.13}$$

$$T_o = T_A + \frac{S}{U_L} + \left[\left(T_{in} - T_A - \frac{S}{U_L}\right) * \exp\left[-\frac{DF'U_L y}{\overset{\circ}{m}_c C_p}\right]\right] \tag{4.14}$$

$$F_R = \frac{\overset{\circ}{m}_c C_p\left(T_o - T_{in}\right)}{A_c\left[S - U_L\left(T_{in} - T_A\right)\right]} \tag{4.15}$$

Where F_R is the collector heat removal factor which is defined as the ratio of actual useful energy gain of the collector to the useful energy gain if the whole collector surface at the fluid inlet temperature.

$$F_R = \frac{\overset{\circ}{m}_c C_p}{A_c U_L}\left[1 - \exp\left[-\frac{DF' U_L y}{\overset{\circ}{m}_c C_p}\right]\right] \qquad \text{Ref. [1]} \qquad (4.16)$$

From eq. (4.15)

$$Q_{useful} = A_c F_R\left[S - U_L\left(T_{in} - T_A\right)\right] \qquad (4.17)$$

$$T_{f,m} = T_{in} + \frac{Q_{useful}}{A_c U_L F_R}\left[1 - \frac{F_R}{F'}\right] \qquad (4.18)$$

Where:

$T_{f,m}$ is the mean fluid temperature

$$T_{p,m} = T_{f,m} + Q_{useful} R_{p-f} \qquad (4.19)$$

$$R_{p-f} = \frac{1}{h_{f,i}\pi D_i n L} \qquad (4.20)$$

Where:

R_{p-f} is heat transfer resistance between the plate and the fluid

The Instantaneous Collector Efficiency:

It is defined as the rate at which incident solar energy is being converted into thermal energy by the absorber unit and is given by:

$$\eta_c = \frac{Q_{useful}}{H_T A_c} = \frac{\overset{\circ}{m}_c Cp(T_{out} - T_{in})}{H_T A_c} \qquad (4.21)$$

The daily collector efficiency:

It is the total useful energy gain to the total incident solar radiation for one day.

$$\eta_d = \frac{\sum Q_{useful}}{A_c \sum H_T} \qquad (4.22)$$

4.3 Solar radiation amount calculation:

This part includes the calculation of the theoretical amount of the solar radiation in Baghdad for the selected clear test day.

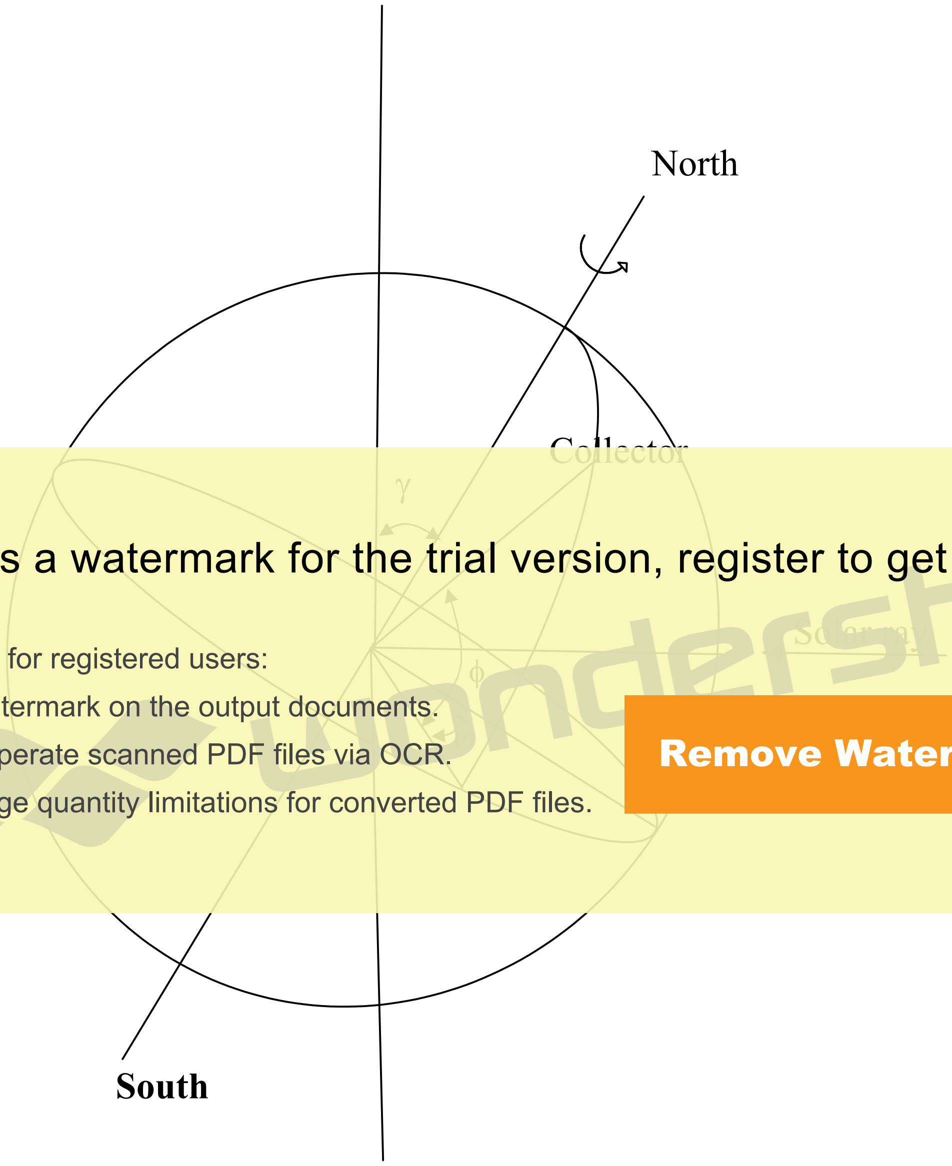

Figure (4.3) Schematic diagram of the earth

The total incident solar radiation on the tilted surface is given by [12]:

$$H_T = I_{cs} * E * \exp\left(\frac{-cG}{\sin\lambda}\right) \qquad (4.26)$$

Where:

I_{cs} = Solar constant =1353 $W/\ m^2$ [1]

And the earth decentralization coefficient E is given by

$$E = \left[1 - 0.01673\cos\left(\frac{360\,n}{365.25}\right)\right]^{-2} \qquad (4.27)$$

Where:

n = Day number from the first day of Ja

As example: n=59 for 28/2/2003

$$G = 1 + r\sin\lambda$$

Where the values of (c) and (r) are given in appendix (B).

The altitude angle of the sun can be found from the relation [12]:

$$\sin\lambda = \sin\gamma\,\sin\phi + \cos\gamma\,\cos\phi\,\cos\omega \qquad (4.23)$$

ϕ =33.3° For Baghdad city.

The declination angle given by:

$$\gamma = 23.45 \sin\left(\frac{360(284 + n)}{365.2563}\right) \qquad (4.24)$$

And the hour angle is given by:

$$\omega = |12 - M| * 15 \qquad (4.25)$$

Where:

M = Time

As example: 9 A.M $M = 9$

2 P.M $M = 14$

Chapter six

Conclusions and Recommendations

5.1 Conclusions:

The general mathematical analysis verified the temperature histories and the performance of the novel solar water heating system with good accuracy. Radiation /weather data, experimental results and hot water withdrawn patterns as well as system configurations were used as inputs to the governing equations to describe the behavior of the system.

The following conclusions were obtained:

1. The results obtained from the theoretical part namely the mean plate temperature, outlet temperature, useful energy gain and the efficiency of the collector were in good agreement with the experimental values. This is true for all results except for the mean plate temperature were some devia[illegible] an[illegible] the numer[illegible] were found.

2. The increase of water temperature across the collector was in the range of 6.5-27 $^{\circ}$C compared with 5-12°C for the conventional system Ref. [8].

3. The instantaneous efficiency of the system improves with operation under actual condition and it was found to be greater than that of the conventional flat plate collectors. The instantaneous efficiency of the novel solar collector was found to be in the range 0.8-0.85 compared with 0.21-0.35 for the conventional one (Ref.[8]).

4. The heat removal factor for the novel collector was in the range 0.86-0.88 compared with 0.52-0.58 for the conventional collector. This may be one of the reasons for the higher instantaneous efficiency.

5. The study confirmed that the collector efficiency factor and the collector heat removal factor could be taken as constants for a given collector design.

5.2 Recommendation for Future Work:

1. In order to get more accuracy of the mean plate temperature between the experimental and the numerical especially, a two-dimensional assumption is suitable.
2. To increase the information about the temperatures of plate, more thermocouple wire be inserted around and along the tubes.
3. For low losses and decreasing of the overall heat loss coefficient, double-glazing system is present instead of single glazing system.
4. Measuring the temperature gradient along the flow path

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CHAPTER FIVE

CHAPTER SIX

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5.2 Discussion:

Several performance tests were carried out and for the present discussion; the first four test runs will be discussed here.

Figure (5-1a) to Figure (5-4a) show the variation of the ambient temperature with time, which is measured experimentally.

Figure (5-1b) to Figure (5-4b) show the solar radiation pattern and the useful energy absorbed by the system, which is calculated by eq. (4.17). The behavior of the useful energy curves found is to follow closely the variation of the solar radiation intensity during the operation period.

The experimental and numerical time variations of the temperature difference across the collector are shown [illegible] [illegible] agreement between the experi[illegible] obtained data are found. The variation of temperatures with time may be due to the variation of solar intensity and the thermal capacity. The increase of water temperature across the collector was in the range of 6.5-27 °C.

Mean plate temperature variation with time is given in Figure (5-1d) to Figure (5-4d) and it was found to have a large deviation between the measured and the numerical temperatures, which is found from eq. (4.19). This deviation is clearly noticed in Figure (5-3d) and Figure (5-4d) due to least number of fixed thermocouples and this lead to weak of temperatures history for different location of tubes and the error of the thermocouple fixing and the error of temperatures measuring and the condition of the tests.

The measured and predicted instantaneous efficiency of about 80% as can be seen in Figure (5-1e) to Figure (5-4e) is found to be greater than that for other conventional systems of about 35% Ref. [6]. The increase of temperature difference across the collector and the increase of its heat removal factor lead to higher daily efficiency. Table (5.1) gives the values of the experimental and predicted daily efficiencies and the percentage error between them.

Figure (5-1f) to Figure (5-4f) shows the weak variation of both the collector efficiency factor, predicted from eq. (4.9), and the heat removal factor, calculated from the eq. (4.15) and eq. (4.16). These factors can be considered constant for a given design Ref. [6]. Eq. (4.9), derived in chapter four, gives higher values of colle[illegible] [illegible] flat plate collector given i[illegible] [6] affects the results of eq. (4.16) and lead to greater values of this factor. For eq. (4.15) the increase in temperature difference across the collector gives higher values for the heat removal factor. The higher values for heat removal factor from the two equations can be taken as the reason for the increase in both the daily and the instantaneous efficiency.

Equation (4.2) gives the values of the overall heat loss coefficient of the collector and Figure (5-1g) to Figure (5-4g) give the variation of the overall heat loss coefficient with time and Figure (5-1h) to Figure (5-4h) gives the variation of the overall heat loss coefficient with the mean plate temperature. It was found that the overall heat loss coefficient is increased with the increase in the mean plate temperatures as can be seen from eq. (4.3).

Mean plate temperature for intermittent hot water withdrawal in evaluated in test runs 5 and 6, Figures 5 and Figures 6, using the withdrawal pattern shown in Figure (5-5d) and Figure (5-6d) to represent amore realistic case than continuous withdrawal. It can be seen that the mean plate temperature and hence water temperature inside tubes, could reach up to about 60 $^{\circ}$C at noon compared to 40 $^{\circ}$C for continuous withdrawal.

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Chapter three

Construction and Experimental work of the novel solar collector

In this chapter the properties of the novel solar collector components will be described with apparatus used in this investigation.

3.1 The constructed novel solar collector system:

The novel solar collector differs from the traditional water heating system by integrating the absorber (tubes) and the storage tank into one piece [illegible], will [illegible] as a solar collector [illegible] time with total capacity of 46 liters. The small capacity of the system is due to the unavailability of tubes and cost.

The components of the system are given below and are shown in Figure (3-1).

3.1.1. Absorber/storage tank:

It is constructed entirely from six copper tubes with 8 cm outside diameter, 7.8 cm inside diameter, 150 cm long each and 12cm center-to-center distance. The copper tubes are welded to inter-connection pipes to form a series flow pattern. The tube is coated with ordinary black paint with absorbability of 0.98 Ref. [4] to increase the solar energy absorption rate.

3.1.2. Connecting pipes:

Inlet, outlet tubes and connections between tubes are made of copper pipes with 15 mm outside diameter and 13 mm inside diameter. This allows for fast, leak free sweat filling plumbing connections.

3.1.3. Insulation:

Rigid closed cell isofoam board is used to maximize heat retention. All the sides, ends, bottom and between the tubes have 4 cm thickness insulation.

3.1.4. C

The sides of the collector case is made of a frame wall and glazing caps all made from aluminum sections with inside dimensions of 80 × 170 cm . The bottom of the frame supported by aluminum plate 2 mm thicknesses.

3.1.5. Glazing:

The collector is single glazed with (4 mm) glass thickness. The space between glazing and tubes is 3 cm.

3.1.6. Glazing gaskets:

Adhesive silicon rubber compressed by the glazing caps and case is used to seal out the weather from the absorber tubes.

Figure (3-1) Cross section of the constructed novel solar collector

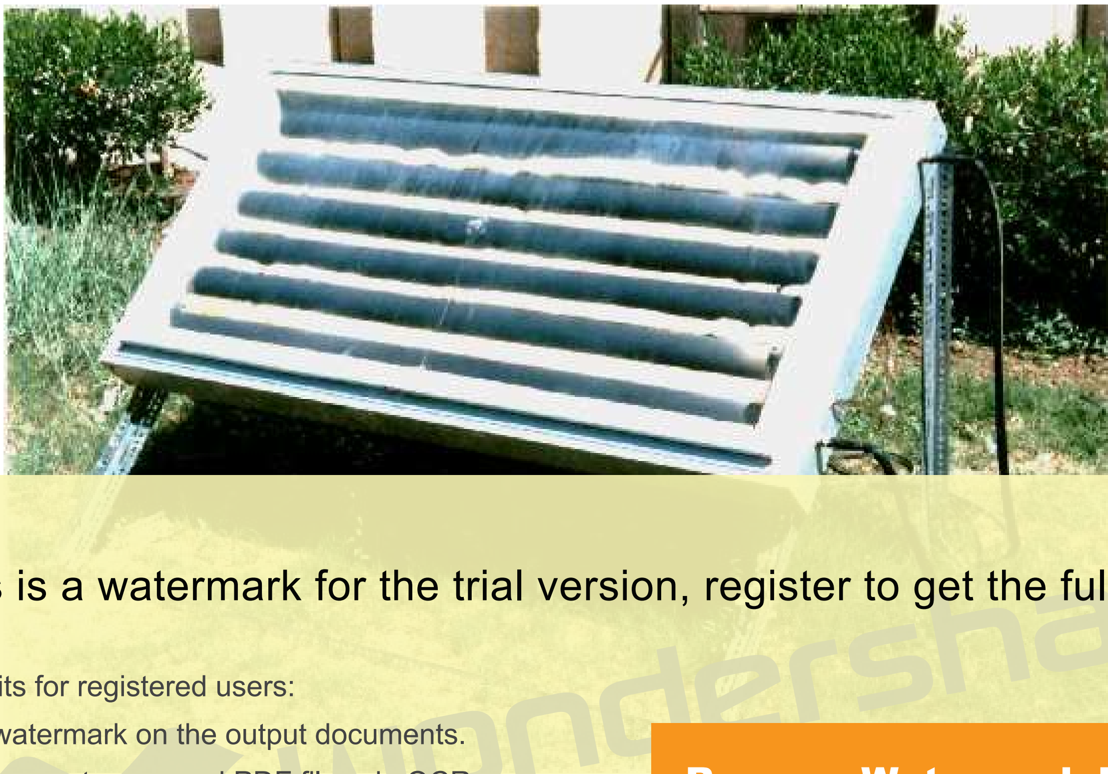

Figure (3-2) The novel collector system photograph.

3.2 Instrumentation:

The following instrumentation have been used in this system

3.2.1. Temperature measurements:

Copper-constantan thermocouple T-type were used for the temperature measurements of system [5] which is distributed at the connecting pipes between the main tubes, glass cover, inlet water and outlet water to the collector according to a certain configuration as shown in figure 3.3.

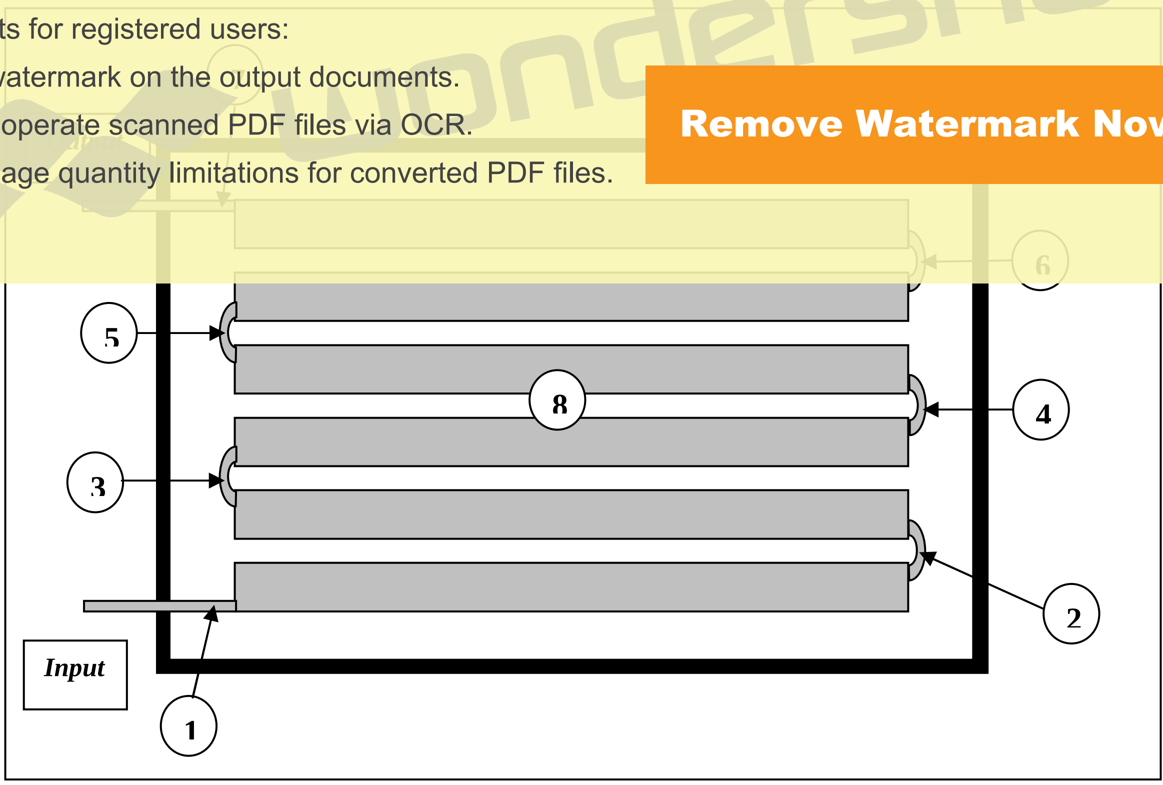

Figure (3-3) thermocouple locations

The thermocouples, which are numbered from 1 to 7, located on the top the surface of the connection pipes between the absorber tubes by sticking and tightening them to the surface, assuming that the measured outlet temperature form one tube is the inlet temperature to the following one.

Thermocouple location **(8)** represents the thermocouple used for measuring the temperature of the outer surface of glass cover and thermocouples locations (1) and (7) used for measuring the inlet and outlet water temperature for the system.

All the above thermocouples were connected to the digital thermometer through multi channels selector switch.

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For more accuracy of temperature measurement, calibration of thermocouple wires was made with mercury thermometer of accuracy (1%) as reference reading and plotted against thermocouple wire reading as shown in figure (3-4) below. The equation shown in figure (3-2) gives the correction of the measured value by the thermometer.

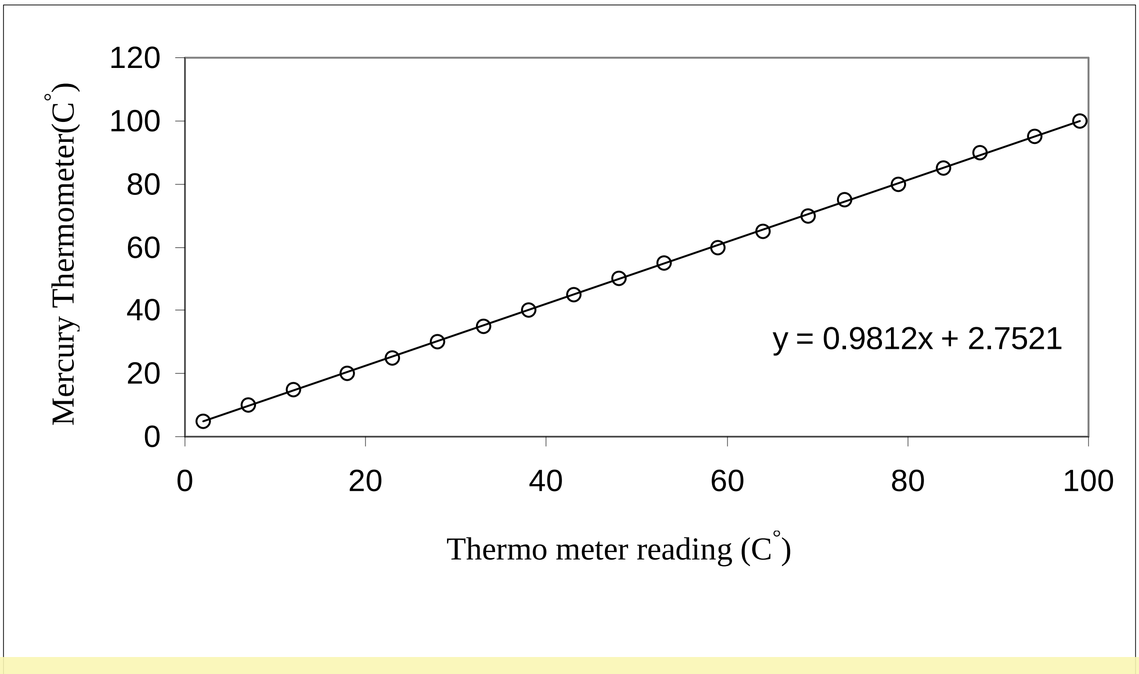

Figure (3-4) Calibration of thermocouple wire

3.5. The Experimental work:

The test carried out in selected clear days in January, February, March and April 2004.

The procedure includes the measurement of temperature of the tubes, glass cover and the collector inlet and outlet as well as the flow rate of the with drawn hot water during the test run for a certain load pattern after cleaning the glass cover and checking the thermocouple where the system face is placed to ward the south and tilted from the horizontal plane at angle of 45°. The test run repeated for each pattern of load, and then the performance and the efficiency of the system can be determined.

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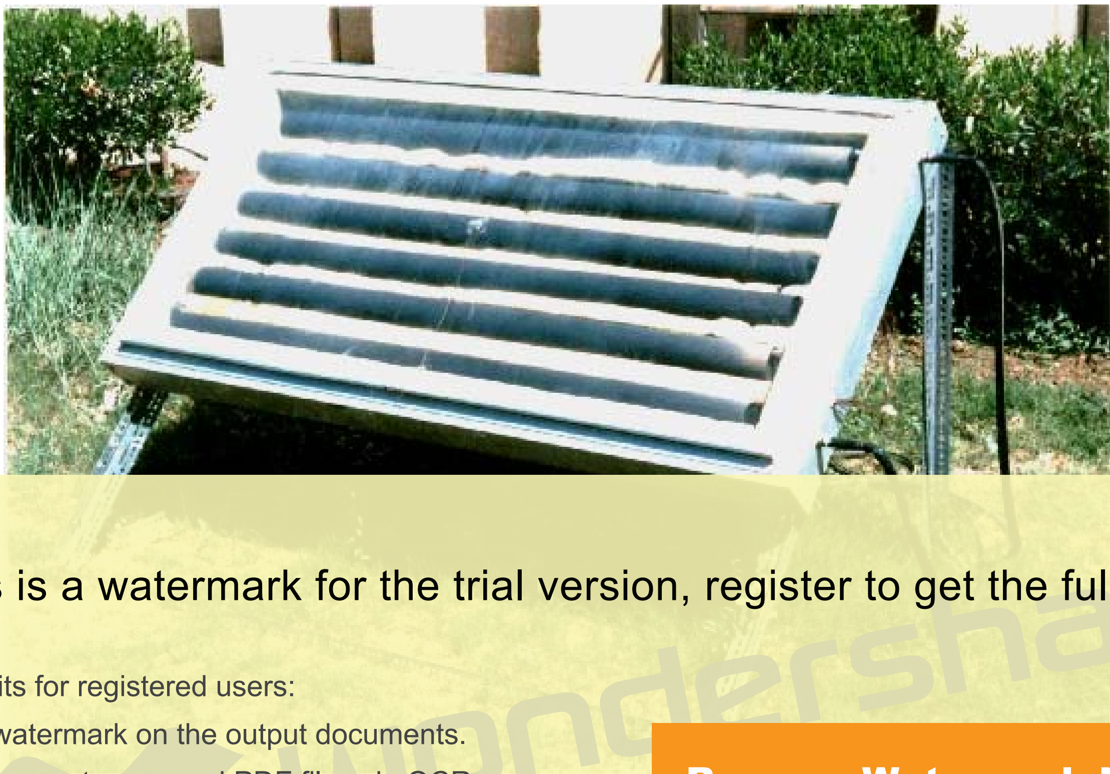

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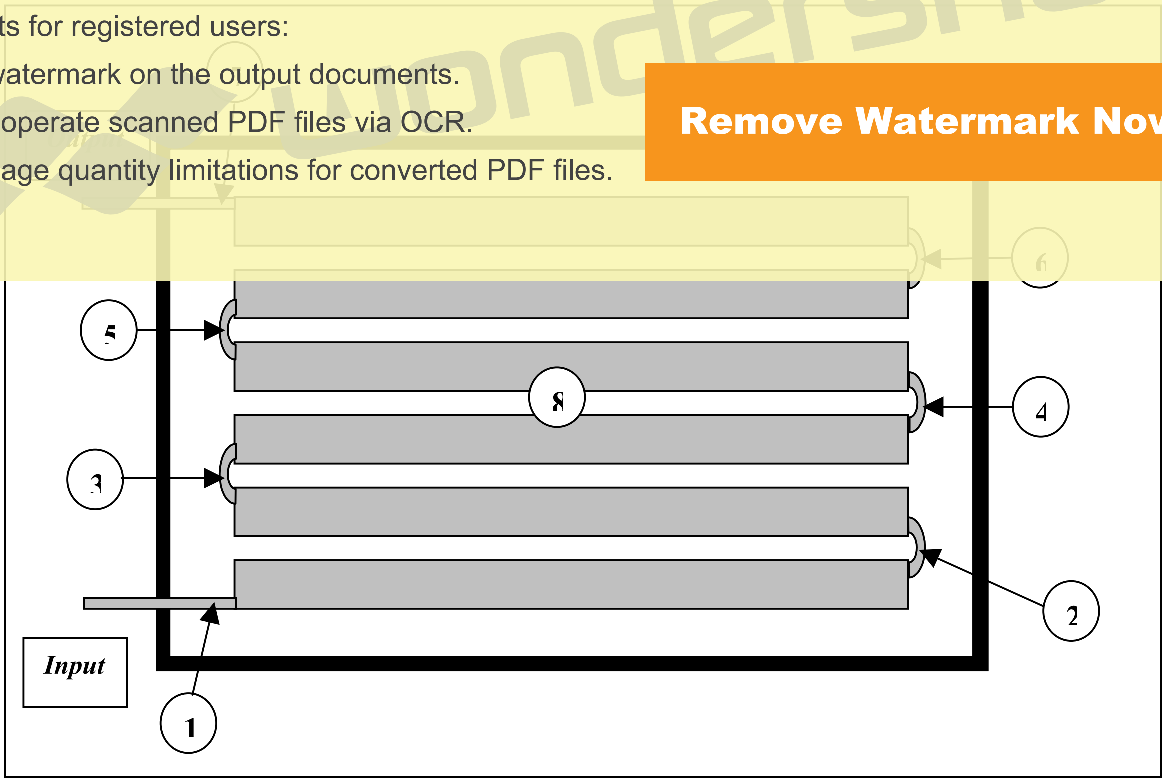

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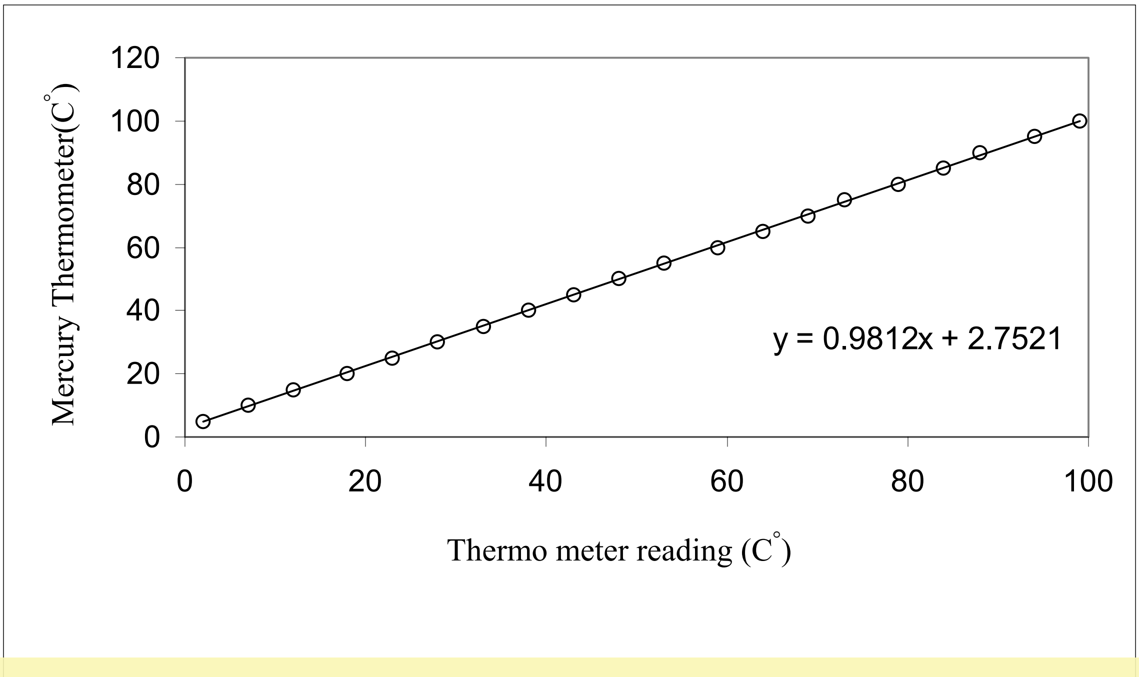

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Chapter one

INTRODUCTION

1.1 General:

The sun provides an everlasting source of solar energy. Without optical concentration the amount of solar radiation reaching the top of the earth's atmosphere per square meter normal to the solar beam is known as the solar constant, which varies between 1393.6 (W/m^2) around January 3 to 1312 (W/m^2) around July 4 Ref. [1] with wavelength range from 0.3 to 3.0 μm which considerably shorter than the emitted radiation form most energy – absorbing surface. Solar energy is by far the most attractive alternative energy source for the future.

Solar energy is considered as a new [illegible] has been utilized as a result of increasing cost of energy from conventional resources and the problems of importing and extracting fuel. The engineering design and analysis of solar processes present a unique problem, due to the intermitted and diffuse nature of the resources and the high inlet cost of the process.

This type of energy considers the thermal processes in which solar radiation is absorbed by a surface (normally black surface) and converted into a heat, then this heat is stored and/or used directly in wide applications range from small single collector system to quite sophisticated solar farms for power generation.

The solar collector is the essential item of equipment that transforms solar radiant energy from a distance source of radiant energy (the sun) to some other useful energy form. One of the solar energy applications is water heating by using of a classic solar collector which differs in several respects from more conventional heat exchangers because of the heat exchanger usually accomplished a fluid -to-fluid exchange with high heat transfer rate.

The conventional solar water heating system consists of mainly three parts, which are, one or two flat plate collectors delivers the heat derived from solar radiation to the water which stored in the storage tank where the connection pipes provide water flow between the storage tank and the collector.

In most applications solar water heating systems used as a pre-heater to a terminal, instantaneous or conventional water heater when the hot water is used in the household, reducing or eliminating electricity or gas usage for heating water [illegible] is being an a[illegible] the solar energy for domestic uses and the [illegible] at moderate temperatures which results in an economic collection of incident solar radiation.

However as with all solar water heaters, the total amount of solar contribution to the system depends upon the hot water consumption pattern of the household, daily weather conditions, and variable amounts of sun light throughout the year.

In this work heating water is by using a novel solar collector system or the “progressive passive solar water heater”. It is a self-contained unit that acts as a solar collector and storage tank, integrated into one piece of equipment as shown in figure 3.1 therefore the difference between the later and the conventional system is simplicity of structure because of no split collector, storage tank, connections pipes and small area need for installation.

The system is considered a passive system because it has no moving parts and operates on local water pressure and solar radiation. There are no pumps, controls and no electrical energy is required to make it function. Once installed, the system will operate automatically.

Objectives of the work:

The objective of this work is to construction a novel solar water heating system, evaluation the system performance under variable load conditions and makes a comparison between the performance of the new system and the conventional solar water heating system.

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This type of energy considers the thermal processes in which solar radiation is absorbed by a surface (normally black surface) and converted into a heat, then this heat is stored and/or used directly in wide applications range from small single collector system to quite sophisticated solar farms for power generation.

The solar collector is the essential item of equipment that transforms solar radiant energy from a distance source of radiant energy (the sun) to some other useful energy form. One of the solar energy applications is water heating by using of a classic solar collector which differs in several respects from more conventional heat exchangers because of the heat exchanger usually accomplished a fluid -to-fluid exchange with high heat transfer rate.

The conventional solar water heating system consists of mainly three parts, which are, one or two flat plate collectors delivers the heat derived from solar radiation to the water which stored in the storage tank where the connection pipes provide water flow between the storage tank and the collector.

In most applications solar water heating systems used as a pre-heater to a terminal, instantaneous or conventional water heater when input hot water is used in the household, reducing or eliminating electricity or gas usage for heating water [illegible] being an [illegible] the solar energy for domestic uses and the [illegible] at moderate temperatures which results in an economic collection of incident solar radiation.

However as with all solar water heaters, the total amount of solar contribution to the system depends upon the hot water consumption pattern of the household, daily weather conditions, and variable amounts of sun light throughout the year.

In this work heating water is by using a novel solar collector system or the "progressive passive solar water heater". It is a self-contained unit that acts as a solar collector and storage tank, integrated into one piece of equipment as shown in figure 3.1 therefore the difference between the later and the conventional system is simplicity of structure because of no split collector, storage tank, connections pipes and small area need for installation.

The system is considered a passive system because it has no moving parts and operates on local water pressure and solar radiation. There are no pumps, controls and no electrical energy is required to make it function. Once installed, the system will operate automatically.

1.2 Objectives of the work:

The objective of this work is to construction a novel solar water heating system, evaluation the system performance under variable load conditions and makes a comparison between the performance of the new system and the conventional solar water heating system.

Chapter two

LITERATURE SURVEY

No publications were found which deals with this system, as it is a novel solar collector, also there are no reference dealing with the system as a self-storage collector with natural circulated water through the system. Some papers, which deal with studies concerning the flat plate collector, which is the closest to the type of the tested system, will be presented.

ROPERT AND FERGUSON [6] developed a digital simulation model that act as an analysis tool in design and optimization studies of solar collector subsystems by considering the [illegible] performance which are directly affected [illegible] orientation, equal emphasis is placed on the definition of the energy processes within the collector and environmental forcing functions, also the collector performance parameter are based on a day of operation rather than the often misleading “high noon” instantaneous performance.

LIN [7] proved that the using of the extended surface for increasing the over all heat transfer coefficient is not applicable to the sheet and tube type of the solar absorber because of the available heat transfer surface of a sheet and tube solar absorber is not effectively used so for utilization of the total available heat transfer surface, three recommended geometric configuration examples Ref. [4] of the flat solar absorber are proposed. Also in order to minimize the heat loss, the top surface of a flat solar absorber should be flat.

COOPER AND LACCY [8] described a method of performance testing and rating of solar water heating systems. This method considered the completed system rather than the individual components with the dimensions and rating factors .The comparison of the experimental performance of a reference system and a test system show a linear relationship between the auxiliary electricity used by each system .To minimize the uncertainties resulting from experimental errors and thermostat it would necessary to continuo testing over an extended period of time, thus he concluded that the proposed method is unsatisfactory as a short term [illegible]

ABDUL AL-ZAHRA GOUDI [9] carried out an experimental study with a thermosyphon solar water heater fo[illegible] [illegible] and summer. The fina[illegible] was measured daily which enable the calculation of the possible contribution of solar energy for domestic hot water supply in Basra/Iraq, for cases of load and no load conditions and for intermittent and continuous load. It was found that the temperature distribution for water in the tank and collector can be assumed linear, the radiation of the thermosphone system and the temperature difference across the collector follow the variation of solar radiation intensity and last of the overall bulk efficiency of the system improved when the system was operated under a load condition with the improvement being better with increased loading.

MORRISON AND BRAUN [10] developed a numerical simulation model to study the characteristics of vertical and horizontal storage tanks of thermosyphon systems .The results indicated that the thermosyphon system have an optimum performance when daily collector volume flow is approximately equal to the daily load volume.

FANNY AND KLEIN [11] conducted an analytical and experimental investigation to show how the yearly performance of forced circulation in SDHW (solar domestic hot water) systems can be obtained with a minimum of two indoor tests in accordance with ASHRAE slandered 95-1981 also the research described in this investigation extends the ability to predict long-term performance based on short term test results to integral collector storage system which requires two system parameters $(\tau\alpha)_n$ and U_L which are readily computed from the solar rating and certification slandered 200-82[2] test result. The predicted performance [illegible] [illegible] with carefully monito[illegible] [illegible] Bureau of Standards.

MULLICK AND SAMDARSH [12] presented good approach to evaluate the top heat loss factor of a flat plate collector with a single glass cover by applying the heat loss factor equation in the analytical form instead of the semi-empirical form. The glass cover temperature is, however, estimated by an empirical relation. The values of the top heat loss factor calculated by this simple technique are within 3 percent (maximum error) of those obtained by iterative solution of the heat balance equations and found an improved of accuracy by factor greater than five over the semi empirical equations when the range of variables is 50 $^{\circ}$C to 150 $^{\circ}$C in absorber plate temperature, 0.1 to0.95 in absorber coating emitance and 5 $W/m^2.^{\circ}C$ to 45 $W/m^2.^{\circ}C$ in wind heat transfer coefficient. The effect of variation in air properties with temperature has been taken in to account.

RICHARD AND BANNEROT [13] examined the issue of the evaluation of the average storage temperature. This issue was not completely resolved and was shown to be strongly dependent on the location of the measurements. Two examples are presented that demonstrate the usefulness of knowing the average storage temperature .The examples also give a quantitative demonstration of the effect of withdrawal flow rate on the amount of thermal energy that can be withdrawal from a given system. As a result the reduction in flow rate by a factor of four increased the delivered energy by 70 percent.

KHALIFA [14] showed the imp [illegible] they are related by making several measurements which included the temperature distribution along the fin between the absorber tubes and in the flow direction and the thermosphonic mass flow rate by using this data the main parameters of the solar collector were obtained. Compression between the experimental and theoretical temperature distribution in the flow direction of the absorber is presented. The instantaneous collector efficiency is found to be 0.21-0.35, mass flow rate agreed with that given in the literature for natural circulation and average top heat loss about of 7.2 $W/m^2.^{\circ}C$ It was confirmed that the collector efficiency factor and the collector heat removal factor could be taken constant for a given design.

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NOMENCLATURE

1-Simple Variables:

Symbol	Definition	Units
A_c	Collector Surface Area	m^2
Cp	Specific Heat	J/kg. °C
C_b	Bond conductance	W/m. °C
c	Atmospheric extinction coefficient	-
D	Diameter of tube	m
E	Earth decentralization coefficient	-
F'	Collector efficiency Factor	[illegible]
F_R	Collector Heat Removal Factor	[illegible]
G	Weather correction coefficient	-
H	Total solar Radiation on Horizontal Surface	W/m^2
H_T	Total solar Radiation on Tilted Surface	W/m^2
h_{fi}	Inside Heat Transfer Coefficient in tube	W/m^2. °C
h_w	Wind Heat Transfer Coefficient	W/m^2. °C
k	Thermal Conductivity	W/m. °C
L	Total length of tubes	m
l	Length of the side insulation	m
$\overset{\circ}{m}_c$	Collector Mass flow rate	kg/s

N	Number of Collector Covers	-
n	Number of tubes	-
q_u	Useful heat gain of the collector	W/m
Q_{useful}	Total useful energy gain of the collector	W
R	Ratio of Total Radiation on Tilted plan to that on horizontal plan of measurement	-
$R_{p\text{-}f}$	Heat transfer resistance between plate and fluid	$^{\circ}C/W$
S	Net solar energy absorbed	W/m^2
T	Temperature	$^{\circ}C$
U_L	Overall heat loss coefficient	$W/m^2.^{\circ}C$
U_t	Top loss coefficient	$W/m^2.^{\circ}C$
U_e	Edge loss coefficient	$W/m^2.^{\circ}C$
U_b	Back loss coefficient	$W/m^2.^{\circ}C$
[illegible]	Wind Speed	[illegible]
W	Center to center distance between tubes	m
W_e	Width of the side insulation	m
X	Thickness of insulation	m

2-Greek Symbols:

Symbol	Definition	Units
θ	Slop of Collector	Degree
ϕ	Latitude angle	Degree
γ	Declination angle	Degree
ω	Hour angle	Degree
λ	Sun solar altitude angle	Degree
δ	Thickness of the pipe	m
ε	Emissivity	-
η	Efficiency	
σ	Stefan-Boltzmann constant	$W/m^2.K^4$
τ	Transmissivity	
α	Absorptivity	
$\overline{(\tau\alpha)}$	Effective Transmittance-absorptance product	-

3-Subscripts:

Symbol	Definition
A	Ambient
av	Average
b	Back
c	Collector
e	Edge
Exp	Experimental
f	Fluid
g	Glass
in	Inlet to the collector
m	Mean
N[illegible]	Numerical
Out	Outlet from the collector
p	Plate

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Exp	Experimental
f	Fluid
g	Glass
in	Inlet to the collector
m	Mean
N	Normal
Out	Outlet from the collector
p	Plate

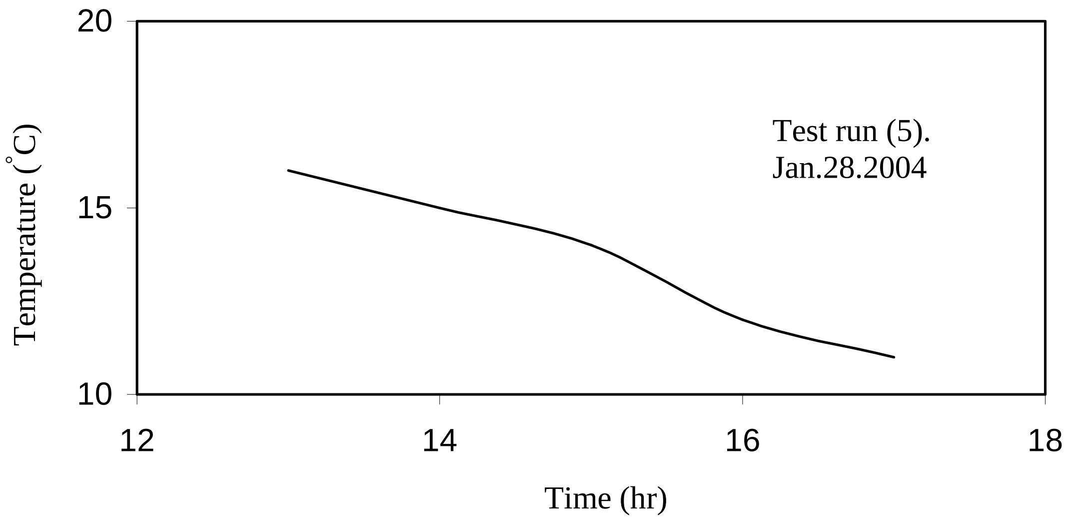


Figure (5-5a) Ambient temperature variation with time

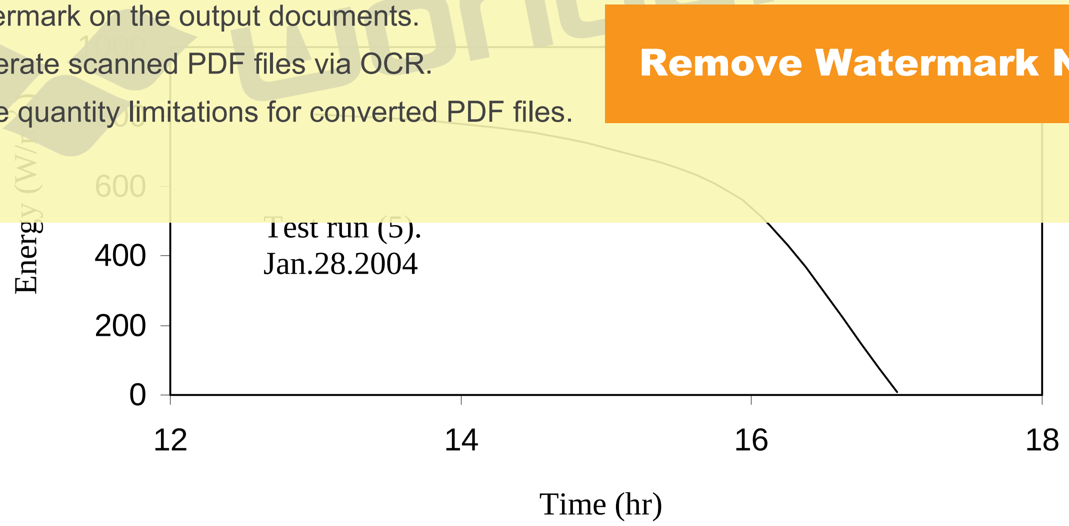


Figure (5-5b) Variation of total radiation on the collector surface with time

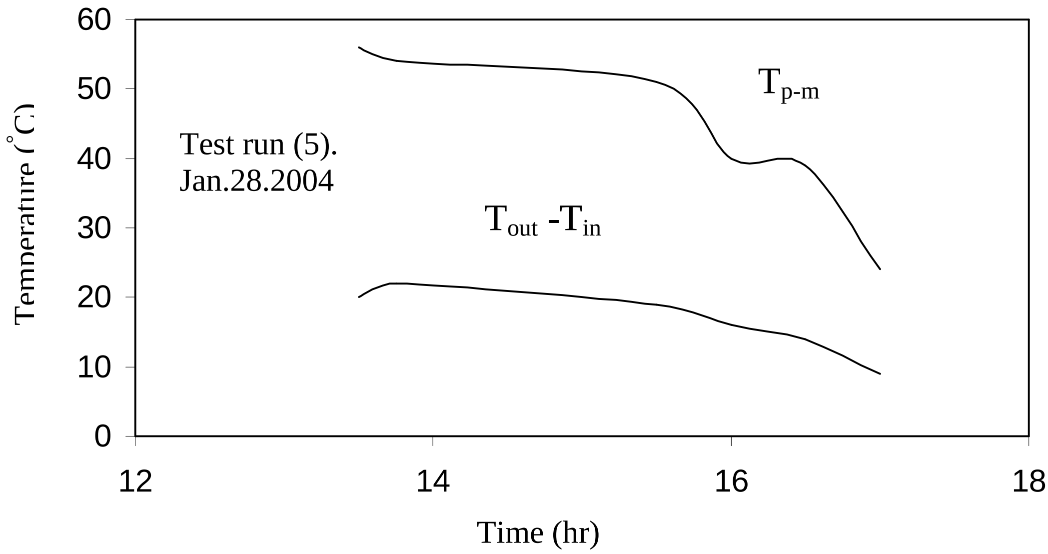


Figure (5-5c) Variation of mean plate temperature and temperature difference across the collector with time

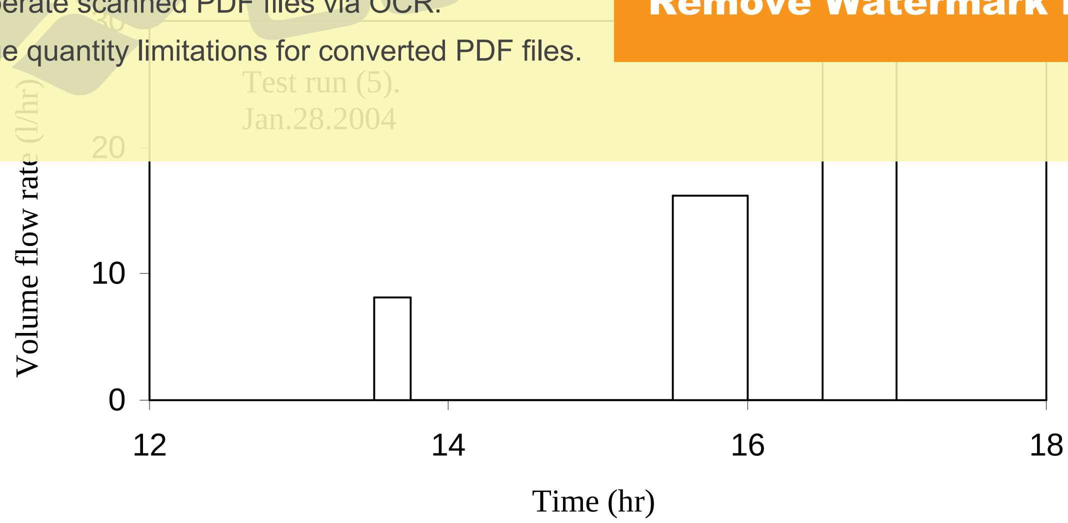
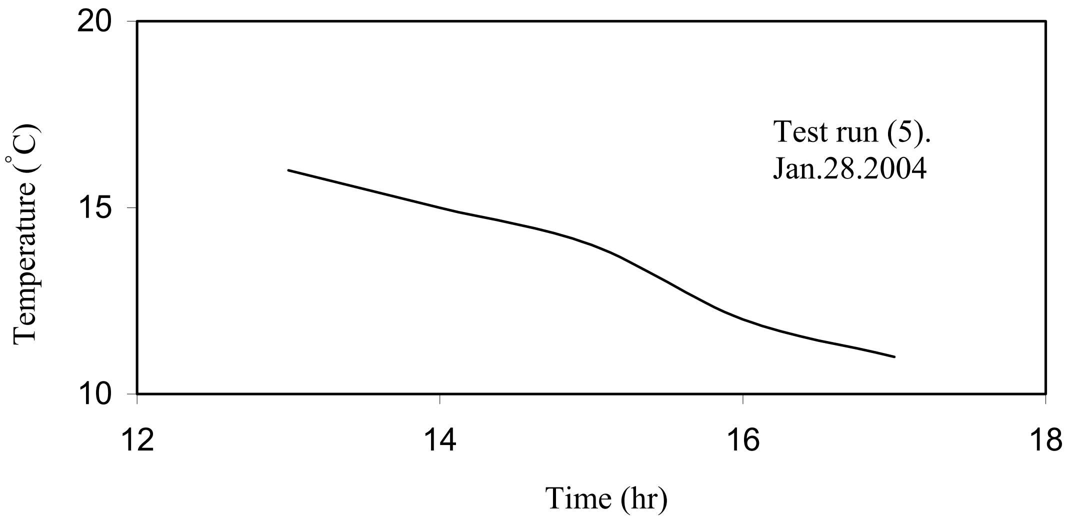


Figure (5-5d) Volume flow rate variation with time



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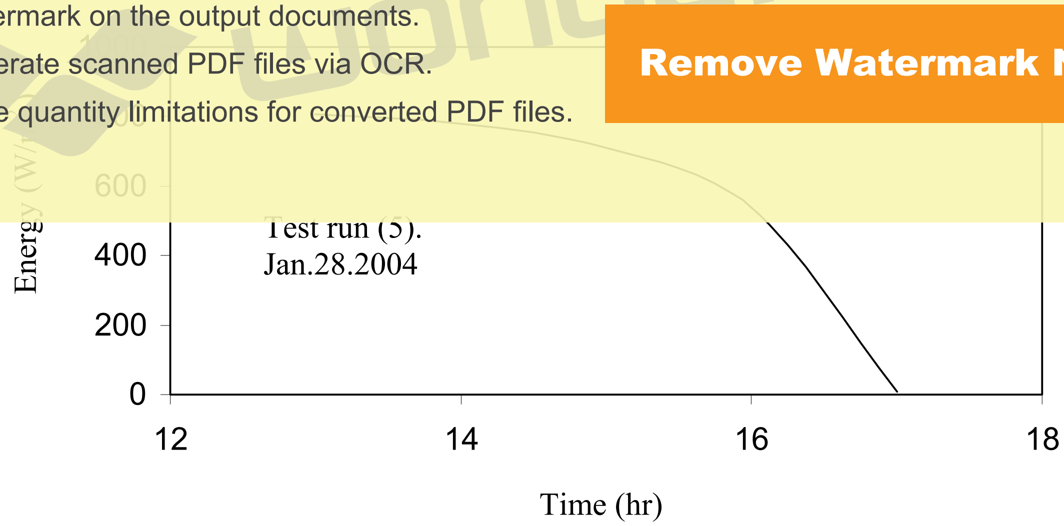


Figure (5-5b) Variation of total radiation on the collector surface with time

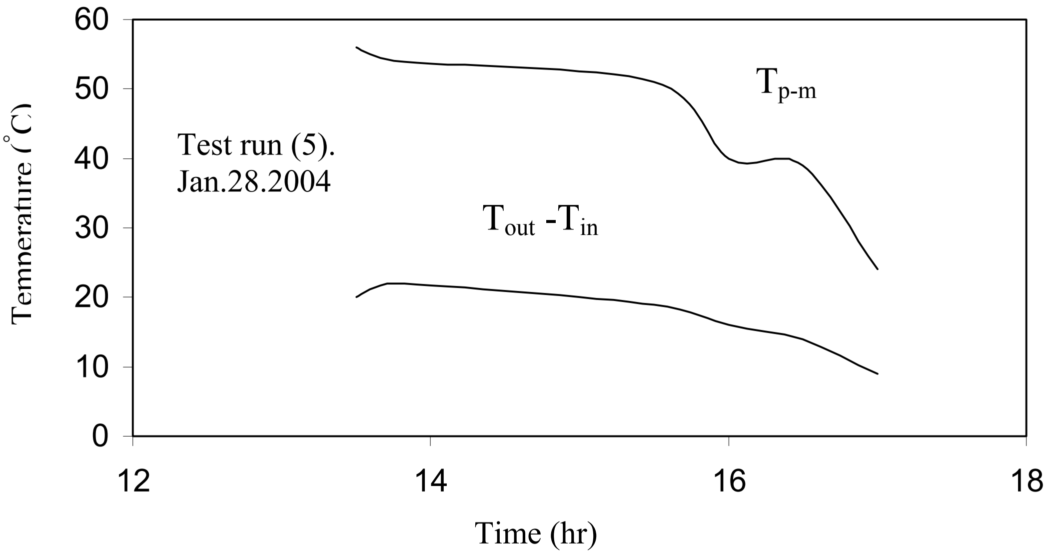


Figure (5-5c) Variation of mean plate temperature and temperature difference across the collector with time

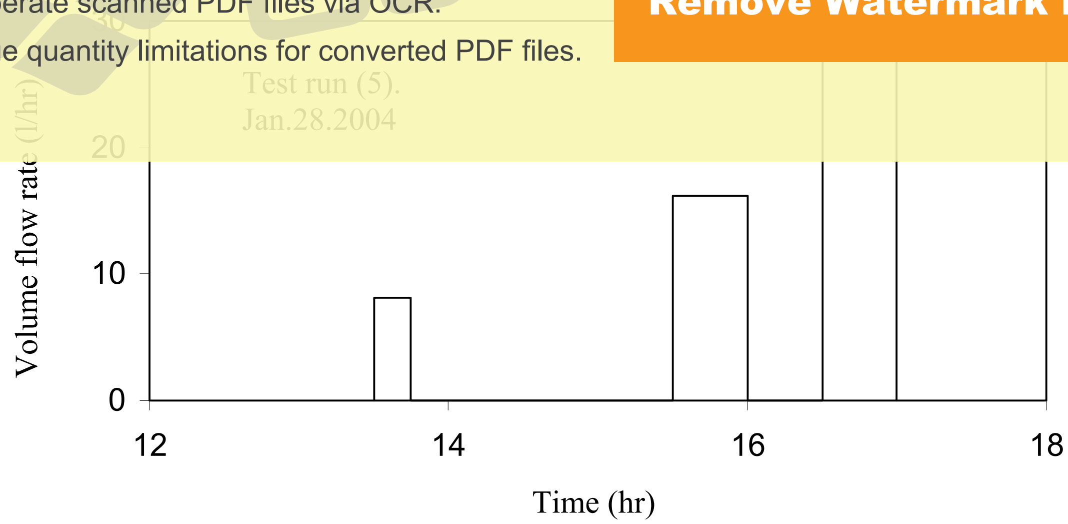


Figure (5-5d) Volume flow rate variation with time

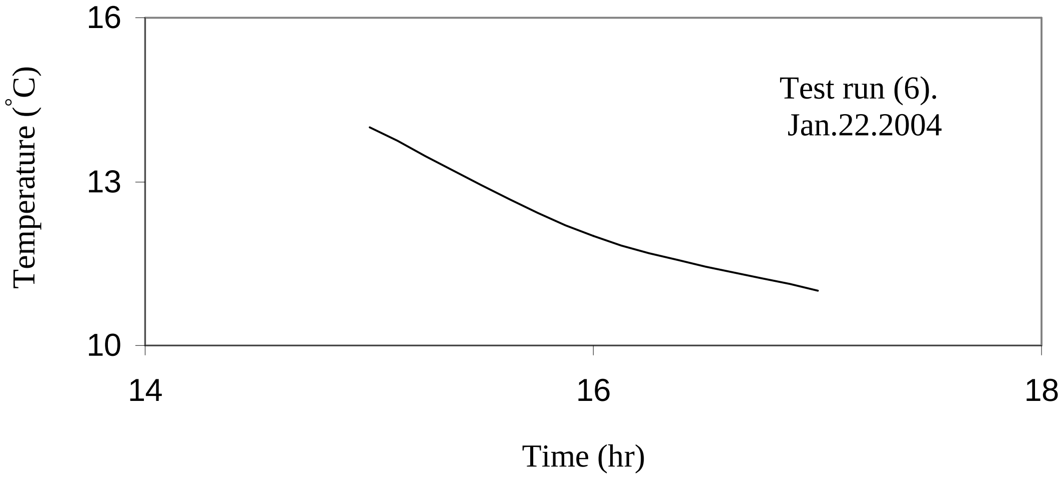


Figure (5-6a) Ambient temperature variation with time

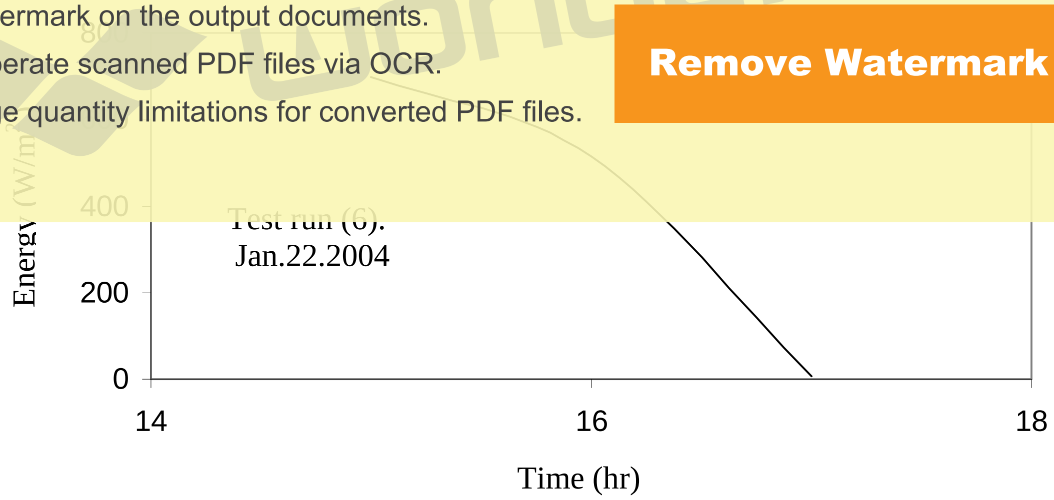


Figure (5-6b) Variation of total radiation on the collector surface with time

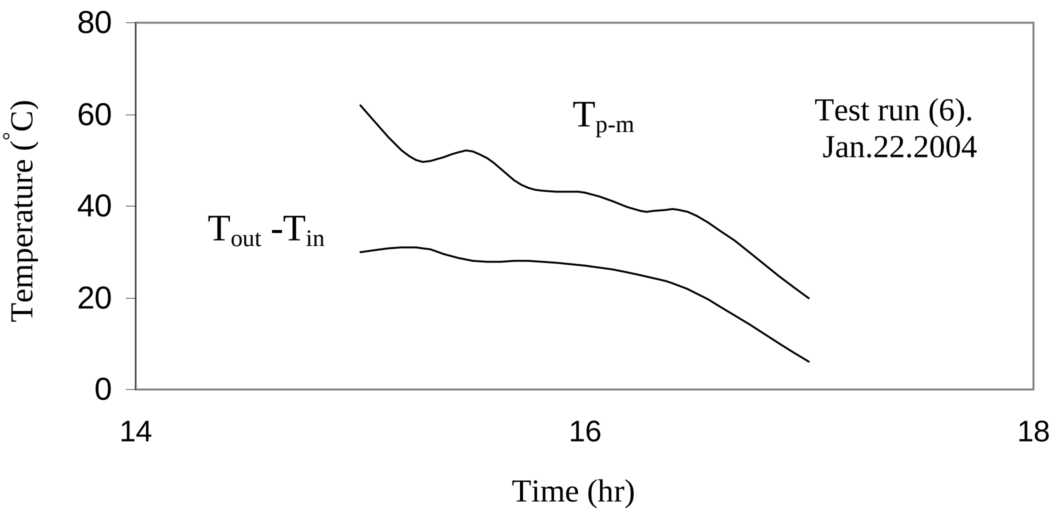


Figure (5-6c) Variation of Mean plate temperature and temperature difference across the collector with time

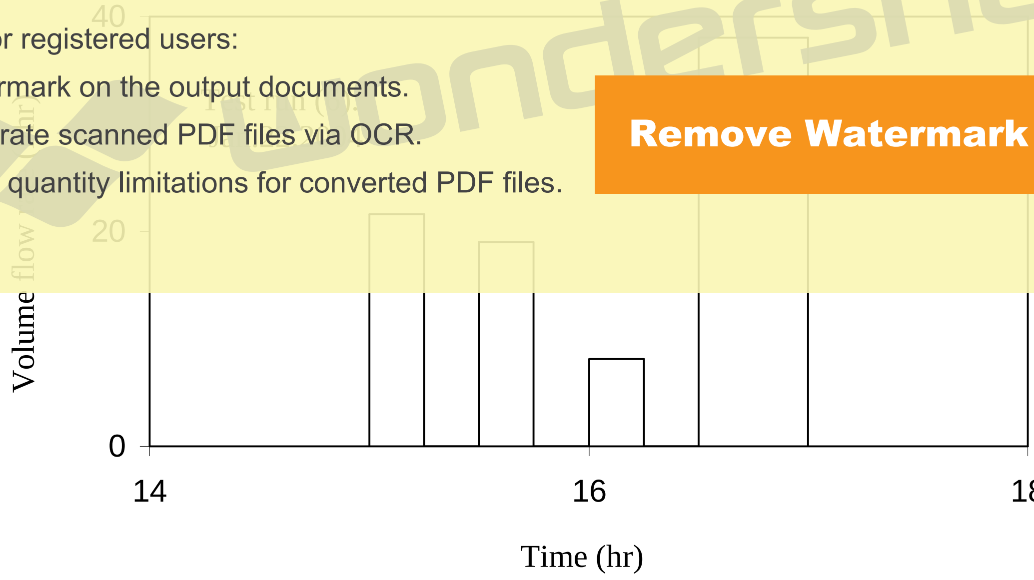


Figure (5-6d) Volume flow rate variation with time

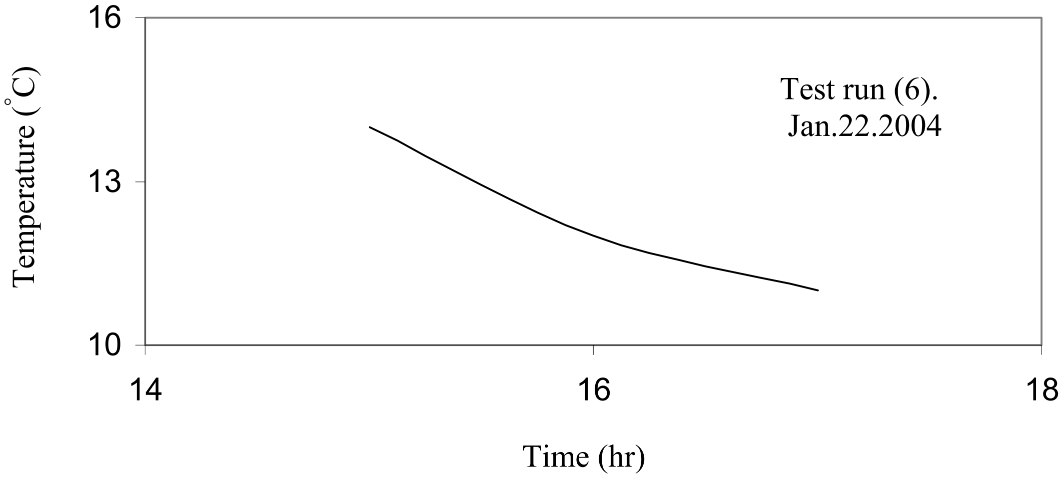


Figure (5-6a) Ambient temperature variation with time

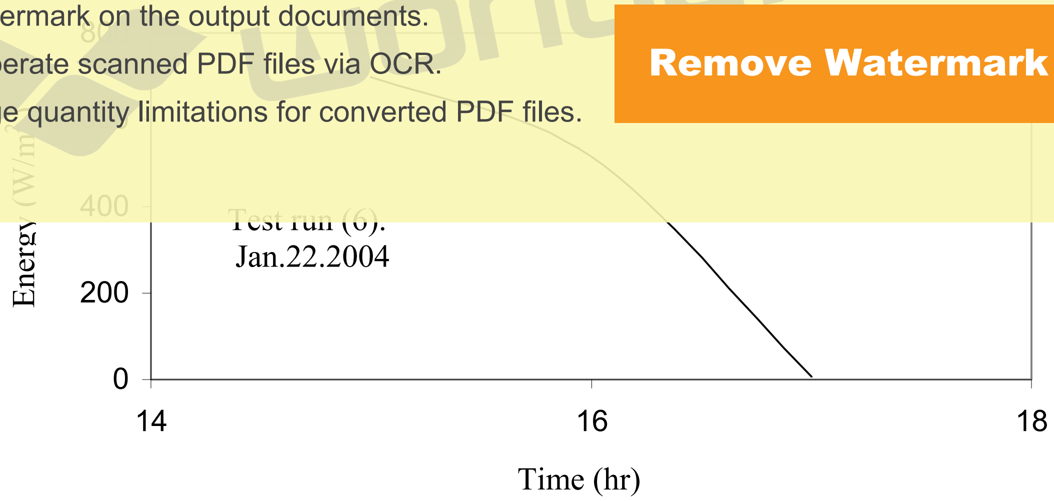
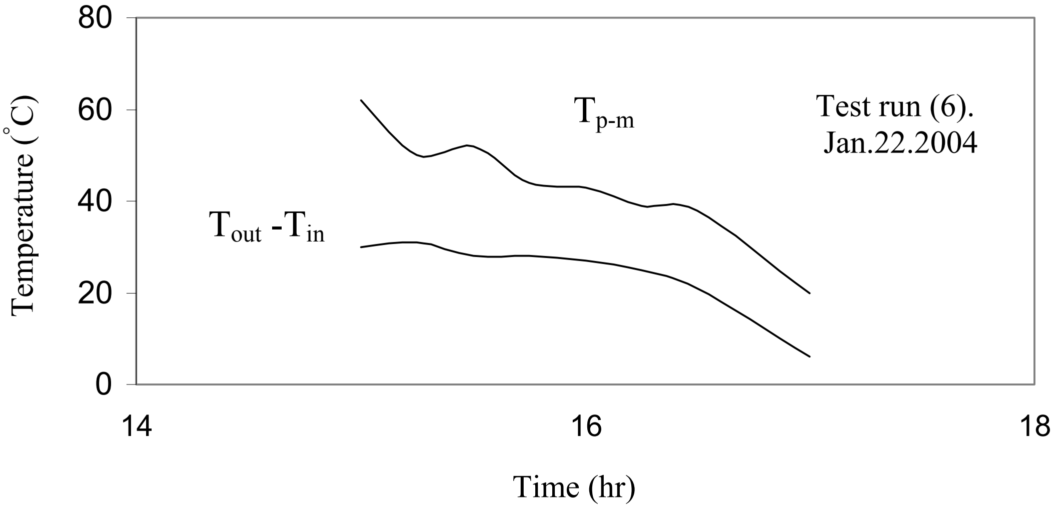


Figure (5-6b) Variation of total radiation on the collector surface with time



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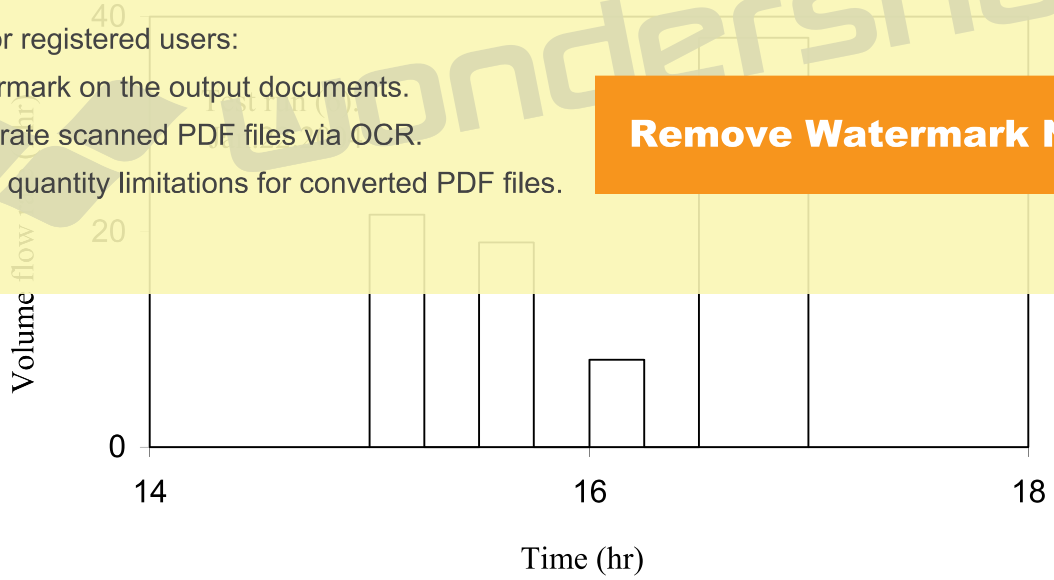

Figure (5-6d) Volume flow rate variation with time

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16. American Society, International Solar Energy Society and Solar Energy Society of Canada Inc., "Solar collector", VoL.2, (1976).

ألخلاصة

ألهدف من هذا ألبحث هو تصميم و تنفيذ سخان شمسي جديد و إختبار أدائه ألحراري من خلال ألتنبؤ ألعملي و ألنظري لاداءه الحراري و تمثيل سلوك ألمنظومة رياضيا حيث إن هذا النوع الجديد من ألسخانات ألشمسية تختلف عن ألسخانات ألتقليدية من حيث دمج المجمع الشمسي و خزان ألماء في جزء واحد و إعتبار هذه ألمنظومة ذاتية ألخزن للماء وبدون خزان تعمل كمجمع شمسي للإشعاع ألساقط و خزان للماء في نفس ألوقت.

في الجزء ألعملي من هذا ألمشروع تم قياس درجة حرارة ألماء ألداخل من و إلى ألمنظومة كذلك درجة حرارة سطح ألأنابيب و درجة حرارة ألمحيط وألزجاج خلال فترة عمل ألمنظومة.

[illegible] فقد تم حساب درجة حرارة ألماء ألخارج من ألمنظومة و درجة حرارة سطح ألأنابيب ومقارنتها مع ألنتائج [illegible] حساب كمية ألإشعاع ألشمسي [illegible]

من خلال وضع نظرية ألإنسياب ألحراري بإتجاه واحد وجد إن هناك بعض ألفروق بين ألقياس ألعملي والحساب ألنظري لدرجات حرارة سطح الأنابيب وإن هذه ألفروق ناتجة أيضا عن الأخطاء ألعملية في ألقياس و ظروف ألتجربة و كذلك فرضية عدم وجود تدرج او تغير في درجة ألحرارة على محيط ألأنابيب .

من خلال الجزء العملي والنظري وجد ان متوسط قيم معامل خسارة الحرارة العام للمجمع (U_L) حوالي $7.5\ W/m^2.\,^{\circ}C$ وهي مقبولة مقارنة مع المصادر كذالك وجد ان قيم معامل نقل الحرارة (F_R) تتراوح بين 0.86 و0.88 ومتوسط قيمة لمعامل كفاءة المجمع (F') تساوي 0.98.

كما وجد ان الكفاءة الحظية للمجمع (η_c) تتراوح بين 0.8 الى 0.86 وهذه قيم عالية مقارنتاً مع قيم المجمعات الشمسية التقليدية.

اوخيراً وجد في هذا ألبحث إن ألمقارنة بين الحساب ألعملي و ألنظري لكل من منحنيات ألفرق في درجات ألحرارة عبر المنظومة وكفائة ألمنظومة تقع في ألمدى ألمقبول.

ألخلاصة

ألهدف من هذا ألبحث هو تصميم و تنفيذ سخان شمسي جديد و إختبار أدائه ألحراري من خلال ألتنبؤ ألعملي و ألنظري لاداءه الحراري و تمثيل سلوك ألمنظومة رياضيا حيث إن هذا النوع الجديد من ألسخانات ألشمسية تختلف عن ألسخانات ألتقليدية من حيث دمج المجمع الشمسي و خزان ألماء في جزء واحد و إعتبار هذه ألمنظومة ذاتية ألخزن للماء وبدون خزان تعمل كمجمع شمسي للإشعاع ألساقط و خزان للماء في نفس ألوقت.

في الجزء ألعملي من هذا ألمشروع تم قياس درجة حرارة ألماء ألداخل من و إلى ألمنظومة كذلك درجة حرارة سطح ألأنابيب و درجة حرارة ألمحيط وألزجاج خلال فترة عمل ألمنظومة.

أما في الجزء ألنظري فقد تم حساب درجة حرارة ألماء ألخارج من ألمنظومة و درجة حرارة سطح ألأنابيب ومقارنتها مع ألنتائج ألعملية كذلك حساب كمية ألإشعاع ألشمسي [illegible]

من خلال وضع نظرية ألإنسياب ألحراري بإتجاه واحد وجد إن هناك بعض ألفروق بين ألقياس ألعملي والحساب ألنظري لدرجات حرارة سطح ألأنابيب وإن هذه ألفروق ناتجة أيضا عن ألأخطاء ألعملية في ألقياس و ظروف ألتجربة و كذلك فرضية عدم وجود تدرج او تغير في درجة ألحرارة على محيط ألأنابيب .

من خلال الجزء العملي والنظري وجد ان متوسط قيم معامل خسارة الحرارة العام للمجمع (U_L) حوالي $7.5\ W/m^2.\ ^{\circ}C$ وهي مقبولة مقارنة مع المصادر كذالك وجد ان قيم معامل نقل الحرارة (F_R) تتراوح بين 0.86 و 0.88 ومتوسط قيمة لمعامل كفاءة المجمع (F') تساوي 0.98.

كما وجد ان الكفاءة الحظية للمجمع (η_c) تتراوح بين 0.8 الى 0.86 وهذه قيم عالية مقارنتاً مع قيم المجمعات الشمسية التقليدية.

اوخيراً وجد في هذا ألبحث إن ألمقارنة بين الحساب ألعملي و ألنظري لكل من منحنيات ألفرق في درجات ألحرارة عبر المنظومة وكفائة ألمنظومة تقع في ألمدى ألمقبول.

تصميم وتنفيذ سخان شمسي جديد واختبار اداءه الحراري

رسالة

مقدمةالى كلية الهندسة في جامعة النهرين وهي جزء من متطلبات نيل

درجة ماجستير علوم في الهندسة الميكانيكية

المهندس

احمد خالد حبيب الصالحي

بكالوريوس هندسة ميكانيكية (٢٠٠١)

وذلك في

رجب ١٤٢٥

ايلول ٢٠٠٤

شكر وتقدير

الحمـد   على ما انعم وله الشكر علىما الهم والثناء بما قدم والصلاة والسلام
على احسن الخلق نبينا محمد (صلى ا   عليه وسلم) ..... وبعد

يـود الباحث ان يعبر عن شكره وامتنانه الى كل من مشرفيه الدكتور عبد الجـبار نعمـة خلـيفة و الدكتور خليل انجاد جندل وذلك لما ابدياه من نصح سديد وتوصيات حكيمة لاجل اعداد هذا البحث.......

كمـا يـتقدم بالشكر الى رئيس قسم الهندسة الميكانيكية المحترم والكادر [illegible] لما قدموه من تسهيلات لانجاز هذا البحث......

ويـود ايضا شكر المهندسة [illegible] حسن وعائلتها الكريمة لما قدموه

ولاينسى الباحث اصدقائه الاعزاء الذين قدموا مابوسعهم خلال عمله هذا.......

واخيرا يقدم عظيم شكره وامتنانه الى عائلته التي ساندته ودعمته طيلة فترة البحث......

احمد خالد الصالحي

تصميم وتنفيذ سخان شمسي جديد واختبار اداءه الحراري

رسالة

مقدمةالى كلية الهندسة في جامعة النهرين وهي جزء من متطلبات نيل

درجة ماجستير علوم في الهندسة الميكانيكية

من قبل

المهندس

احمد خالد حبيب الصالحي

بكالوريوس هندسة ميكانيكية (٢٠٠١)

وذلك في

رجب ١٤٢٥

ايلول ٢٠٠٤

شكر وتقدير

الحمد لله على ما انعم وله الشكر علىما الهم والثناء بما قدم والصلاة والسلام على احسن الخلق نبينا محمد (صلى الله عليه وسلم) ..... وبعد

يود الباحث ان يعبر عن شكره وامتنانه الى كل من مشرفيه الدكتور عبد الجبار نعمة خليفة و الدكتور خليل انجاد جندل وذلك لما ابدياه من نصح سديد وتوصيات حكيمة لاجل اعداد هذا البحث.......

كما يتقدم بالشكر الى رئيس قسم الهندسة الميكانيكية المحترم والكادر [illegible] لما قدموه من تسهيلات لانجاز هذا البحث......

ويود ايضا شكر المهندسة الفاضلة [illegible] حسن وعائلتها الكريمة لما قدموه من [illegible]

ولاينسى الباحث اصدقائه الاعزاء الذين قدموا مابوسعهم خلال عمله هذا.......

واخيرا يقدم عظيم شكره وامتنانه الى عائلته التي ساندته ودعمته طيلة فترة البحث......

احمد خالد الصالحي