Minimizing the energy consumption for building by using the concentrating water solar collector in hot arid region "Experimental work"

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Abstract

This work deals with the possibility of reducing energy consumption. This was accomplished by blocking or eliminating the effect of direct solar radiation in summer. Also it was achieved by using the blocked solar radiation to obtain hot water in buildings where the cooling demand is dominant and hot water is required simultaneously. The procedure was done at Baghdad (Lat. 33^o N) on 28th,29th, July and 21st, 22nd, 23rd, September 2010.In this work a room was built. Each wall is of 1m^2 area. Also, the concentrating water solar collector (CWSC) was manufactured using steel frame with mirror, glass and tubing. Water was pumped into the (CWSC) which was installed in an adjacent place to the room. This study shows encouraging results. The heat gain through the wall was reduced by 30%. In addition, the instantaneous efficiency of the solar collector was 45%. However, this value was reduced when the water inlet temperature was increased. It can be concluded from this work that using the (CWSC) helps to reduce the required energy consumption for cooling and heating simultaneously. As a result, the (CWSC) can be regarded as a good design for buildings such as small hospitals and hotels. This is especially true in hot arid region in which cooling demand is dominate and hot water is required too for special purposes such as laundry, sterilizing, …….etc. In addition to that, a beautiful view will be obtained and thus reducing the decoration cost.

الخلاصة

هذا العمل يتعامل مع أمكانية تقليل الطاقة المستهلكة. لقد تم أنجاز هذابحجز أو تحديد تأثير الأشعة الشمسية المباشرة في الصيف على البنايات. وقد تم أنجاز ذلك بأستعمال الأشعة الشمسية التي تم حجزها في تسخين المياه في البنايات التي تحتاج التبريد والماء الساخن في نفس الوقت. لقد تم أنجاز العمل في مدينة بغداد(خط عرض33شمالا") في الأيام28,29 تموز و21,22,23 أيلول 2010. في هذا العمل قد تم بناء غرفةمساحة كل جدارفيها 1م^2. كذلك قد تم تصنيع مجمع شمسي مائي مركز (CWSC) بأستعمال هيكل حديدي ,مرايا,زجاج وأنابيب ويتم تدوير الماءفي المجمع الشمسي الذي تم تثبيته

محاذياً"للغرفة التي تم بناؤها. هذه الدراسة قد أعطت نتائج مشجعةحيث أن الكسب الحراري قدتم تقليله بمقدار30%. بالأضافة الى ذلك فأن الكفاءة اللحظية للمجمع الشمسي وصلت الى 45% وكانت هذه الكفاءة تنخفض كلما أزدادت درجة حرارة الماء الداخل. يمكن الأستنتاج من هذا العمل بأن أستعمال المجمع الشمسي المائي المركز يساعد في تقليل الطاقة اللازمة للتبريد والتسخين في نفس الوقت. وأخيرا يمكن أعتبار أن المجمع الشمسي المائي المركز هو تصميم جيد للبنايات مثل المستشفيات والفنادق الصغيرة في المناطق الحارة الجافة التي تتطلب التبريد و الماء الساخنفي فصل الصيف لأغراض خاصة مثلاً"أجهزة الغسيل ,التعقيم ,.... أضافة الى ذلك فأنها ستوفر واجهة جميلة للبناية تختصر كلفة الديكورللبناية.

Introduction:

Solar energy is a very large, inexhaustible source of energy. The power from the sun intercepted by the earth is approximately $1.8*10^{11}$ MW, which is many thousands of times larger than the present consumption rate on the earth of all commercial energy sources. Thus in principle solar energy could supply all the present and future energy needs of the world on conditioning basis. This makes it one of the most promising of the unconditional energy sources [1]. On the other hand solar energy is the major one which causes the high temperature inside the buildings in summer, especially in hot arid region.

The penetration of airconditioning is increasing rapidly all around the world. This has an important energy and environmental impact. Construction is one of the most important economic sectors worldwide. Energy consumption of building sector is high. Although figures differ from country to country buildings are responsible for about 30-40% of the total energy demand [2].

With more and more energy and environmental issues, the energy saving and sustainable development of building is of utmost concern to the building industry. Passive cooling techniques can optimally utilize natural resources in order to reduce the energy consumption of buildings. At the same time it can improve the buildings thermal environment.

Passive cooling techniques is to acclimate with nature principium such as sunshine ,wind force air temperature humidity of the nature, not to resort to conventional consumption to the greatest extent. Passive design methods contain optimizing solar orientation, heat insulation best rating area of window to wall, shape, structure, shading and natural ventilating of buildings.

Shading provision should be considered as an integral part of fenestration system design for commercial and office buildings in order to balance day lighting requirements versus the need to reduce solar gains. Shading device type properties and control have significiant impact on building cooling demand.

In this work a room is built and a concentrating water solar collector (CWSC) is manufactured. The (CWSC) is installed in a place adjacent to the southern wall of the room for two purposes. It is used to block the incident solar rays off the wall and to use the blocked solar rays to obtain hot water. This design is useful for small hotels and hospitals where cooling is dominant problem as well as hot water is required for some purposes such as laundry, sterilizing equipments, etc.. In addition to that a beautiful view for the building will be obtained.

Experimental work:

The experimental work consists of two parts. The first one is:

A room is built as shown in fig (1). The area of each wall is ($1m^2$). The wall is built of brick (0.12 m)thickness. The exterior side of the wall is coated by cement layer (0.002m)thickness. The interior side of the wall is coated by gypsum layer (0.002m) thickness.

The second part of the experimental work is:

A steel frame of (1m*1m* 0.12m) is manufactured as shown in fig (2). One side of the frame is made of mirror (0.002 m) thickness and ($1m^2$) area. The other side is made of glass (0.006 m) thickness and ($1m^2$)area. The other two sides of the frame are made of mirror (0.002m) thickness and (1m*0.06m)area. A plastic tube of (0.06 m) diameter is installed on the upper side of the frame. The tube has got (20 holes) each one is (0.002 m) diameter. On the lower side, an insulated steel container (1.23m*0.12m*0.1m) volume is installed. A water pump of (0.15Kg/s) flow rate is fixed in this container. Plastic tubing of (0.12 m) is used to connect the water system as shown in fig (3). This rig is called in this work "The concentrating water solar collector" or the (CWSC).

The (CWSC) is fixed in a place adjacent to the southern wall of the room as shown in fig (4). Experiments were done at Baghdad (Lat.33^o N) on 28th, 29th July and 21st, 22nd, 23rd September 2010.

The procedure of running as follows:

The lower container is filled with water and the water pump is operated. Thermocouples are fixed at specified nodes to get the temperature readings, (T_{amb}, T_{esw}, T_{eusw}, T_{isw}, T_{iusw}, T_w).

These measurements are taken each hour from 9:00 AM to 16:00 PM to get steady state condition.

Mathematical model:

The mathematical expression for this system is:

1-For the wall

The solar radiation fig (5) is incident on the exterior surface of the wall.[1]

$$I_b = I_{bn} \cos \theta_z \qquad (1)$$

Thus, the wall surface temperature is increased.The heat transmits through the wall by conduction, Fourier's law [4]

$$q=-K*A*(dT/dX) \qquad (2)$$

2- The concentrating water solar collector (CWSC):

The solar radiation is incident on the glass cover. Assuming steady state condition, the starting point for analysis of solar collector is a simple heat balance. The heat collected is equal to the heat transmitted through the glass cover minus the heat losses.

$q = q_t - q_l$ (3)

$q_t = I_b * A_g * t_g$ (4)

$q_l = U_l * A_g * (T_g - T_a)$ (5)

The loss coefficient considers convection and radiation from the surface and conduction through the support. The conduction through the structure can be neglected.[6]

$U_l = h_w + h_r$ (6)

$h_w = 1.77 * \Delta T^{1/4}$ (7)

$h_r = 4$ £€ T^3 (8)

Useful heat energy given as

$Q_u = m * C_p * \Delta T$ (9)

Instantaneous efficiency of the system can be calculated as[1]

$\eta_i = q_u / I_b * R_b * A_g$ (10)

$R_b = \cos^{\theta} / \cos^{\theta}{}_z$

Results and discussion:

The results of this experimental work are shown in the following figures.

1-Concentrating water solar collector (CWSC)

Fig (6) shows the effect of using the concentrating water solar collector (CWSC) on water temperature. From fig (6) we can notice that the water temperature is increasing with time. The water temperature is (36) at 9:00 AM, still increasing until it reaches to (51.2C^o) at 16:00 PM. From fig (7) we can notice that the water temperature is (34) at 9:00 AM and it is (48C^o) at 16:00 PM.

Fig (8) shows that the instantaneous efficiency of the (CWSC) is 45% at 10:00AM and it reduces as the water inlet temperature increases.

Using equations (6, 7, 8) the overall heat transfer coefficient U_l is equal to (30W/m^2.c^o) on 28th July 2010.

2-The heat gain through the wall

With using the concentrating water solar collector (CWSC) on the southern wall, a shade is found on this wall. That happens because the (CWSC) is installed in a place adjacent to the room so that the back side of the mirror faces the exterior wall surface.

From fig (9) we can notice that the temperature of the exterior surface of the shaded wall is (34.8C^o) at 9:00 AM and it is (44C^o) at 16:00 PM. These results are compared with another southern wall but it is not shaded. This unshaded wall is built with the same specification of the shaded wall under interest. Then, from fig (9) we can notice that the temperature of exterior surface of the unshaded wall is (39.4C^o) at 9:00 AM and it is (48.1C^o) at 16:00PM.

Reffering to fig(10) and using the exterior shaded wall surface temperature (T_{esw}), the interior shaded wall surface temperature (T_{isw}), the exterior unshaded wall surface temperature (T_{eusw}), and the interior unshaded wall surface temperature (T_{iusw}) in equation (1) we can get the heat gain through the two walls. The heat gain through the shaded wall is (72W) at 14:00 PM on 22nd September and the heat gain through the unshaded wall is (101W) at the same time. This means that the heat gain is reduced by (30%).

Comparision between the shaded wall surface temperature of the day 28th July 2010 and the day 22nd September 2010, we can notice that the shaded wall surface temperature is reduced on 22nd September more than 28th July. This refers to the long period of using the CWSC shade on the same wall on 22nd September than 28th July.

Conclusion:

From this experimental work it can be concluded that

1-Using the concentrating water solar collector (CWSC) leads to reduce the heat gain through the wall by 30% during summer time.

2-Using the (CWSC) is a good method for heating water.

3-The instantaneous efficiency of the (CWSC) is 45%.

4-The heat gain is minimized and the energy required to obtain hot water is minimized too, hence a valuable amount of energy is saved.

5-Using the (CWSC) is an effective method to use in buildings in hot arid region.

Nomenclature:

A_g- glass area (m^2)

A_m- mirror area (m^2)

Cp- specific heat (J/Kg.c^o)

h_r- the heat transfer coefficient due to radiation (W/m^2.c^o)

h_w- the heat transfer coefficient due to convection (W/m^2.c^o)

I_b- hourly beam radiation (W/m^2)

I_{bn}- beam radiation in the direction of the rays (W/m^2)

m- mass (Kg)

T_{amb}- the ambient temperature (C^o)

T_{esw}- the temperature at the exterior side of the shaded wall (C^o)

T_{eusw}- the temperature at the exterior side of the unshaded wall (C°)
T_{isw}- the temperature at the interior side of the shaded wall (C°)
T_{iusw}- the temperature at the interior side of the unshaded wall (C°)
T_g- glass temperature (C°)
U_l- the overall heat transfer coefficient (W/m^2.c°)

θz- the zenith angle
t_g- glass transmissivity
£- Stefan Boltzmann constant
€- glass emissivity

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[6]مقدمة في الطاقة الشمسية / سول وايدر/مديرية دار الكتب للطباعة و النشر_الموصل/1989

[7]Iraq meteorological organization "Climatic ATLAS of Iraq", 2010

Fig (1) The room is built of brick (0.12m) thickness and coated by cement layer (0.002m) thickness

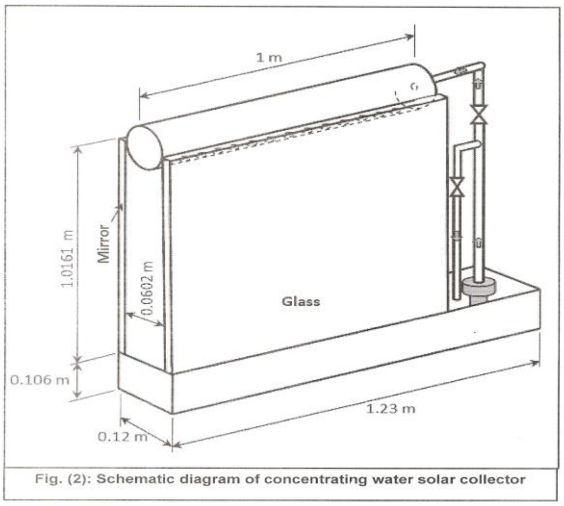

Fig. (2): Schematic diagram of concentrating water solar collector

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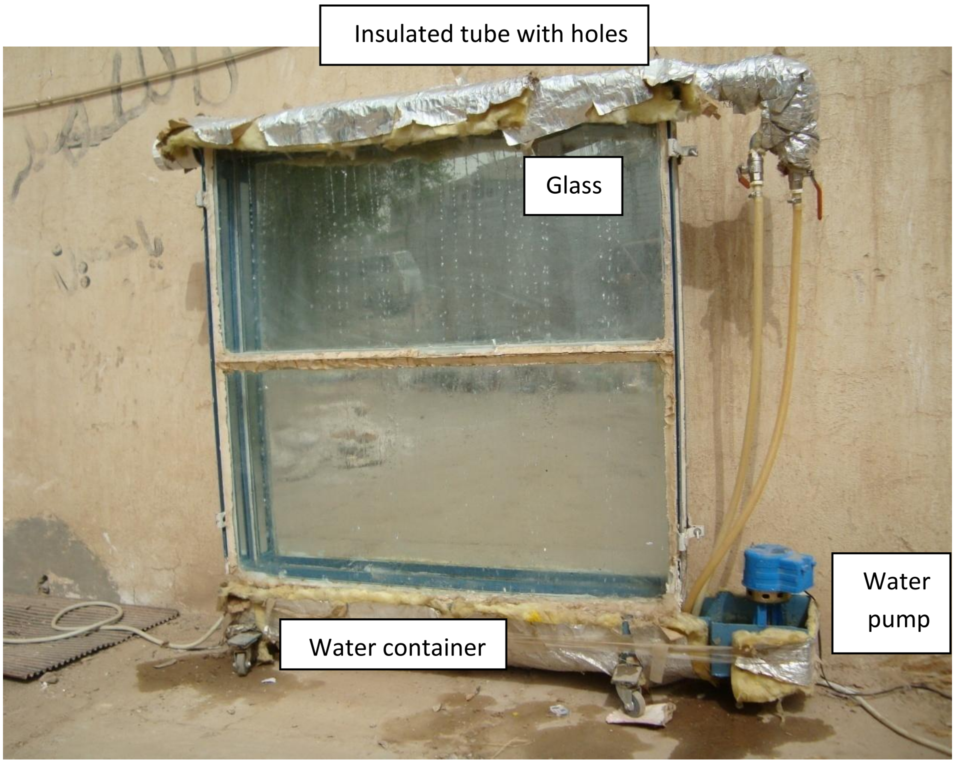


Fig(3) Components of the (CWSC

Fig(4)shows the location of the (CWSC) and the room

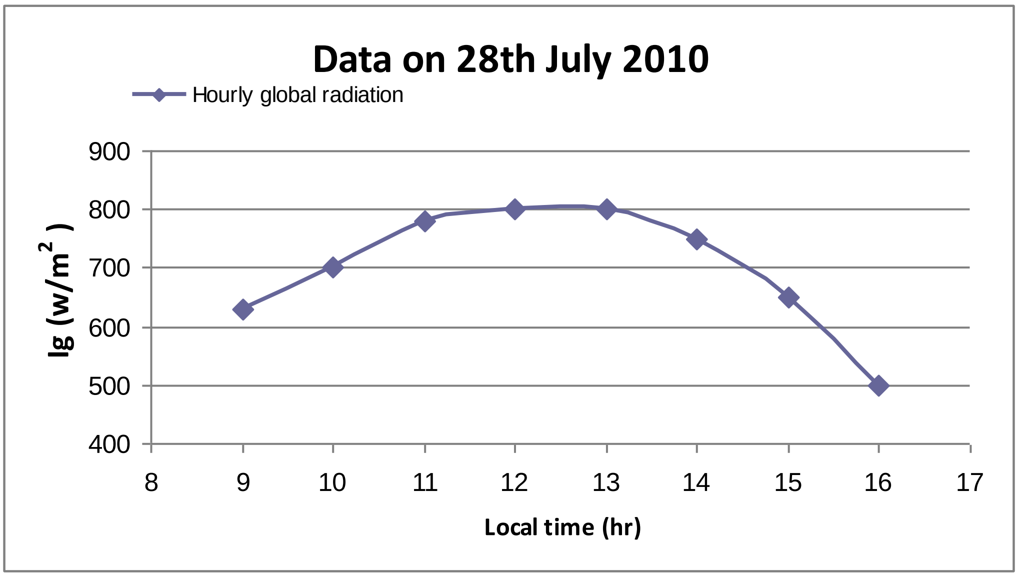


Fig (5) Incidient solar radiation at Baghdad (Lat.33N) ref[7]

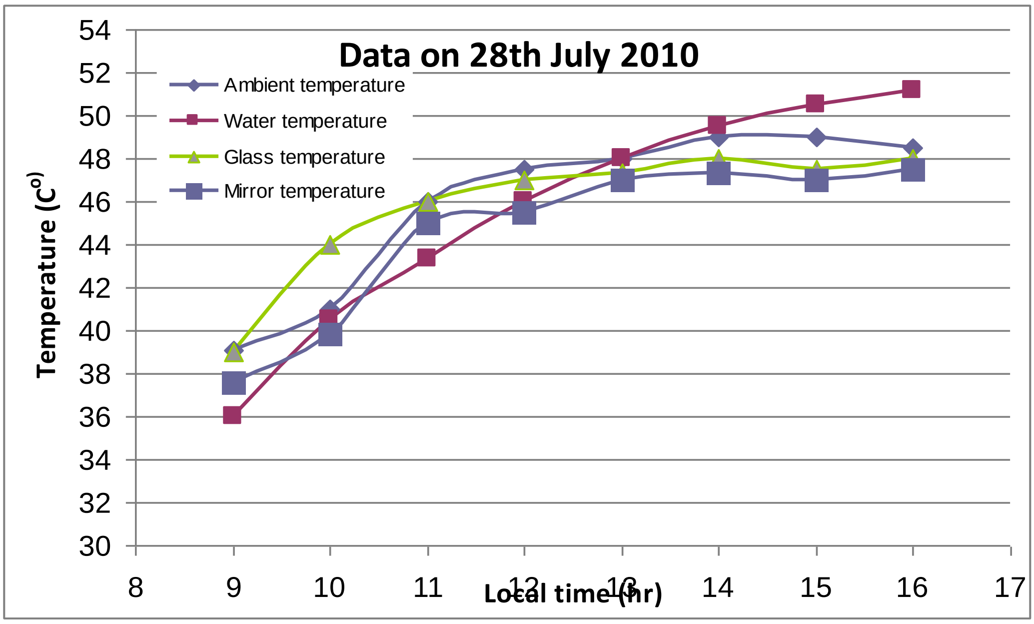
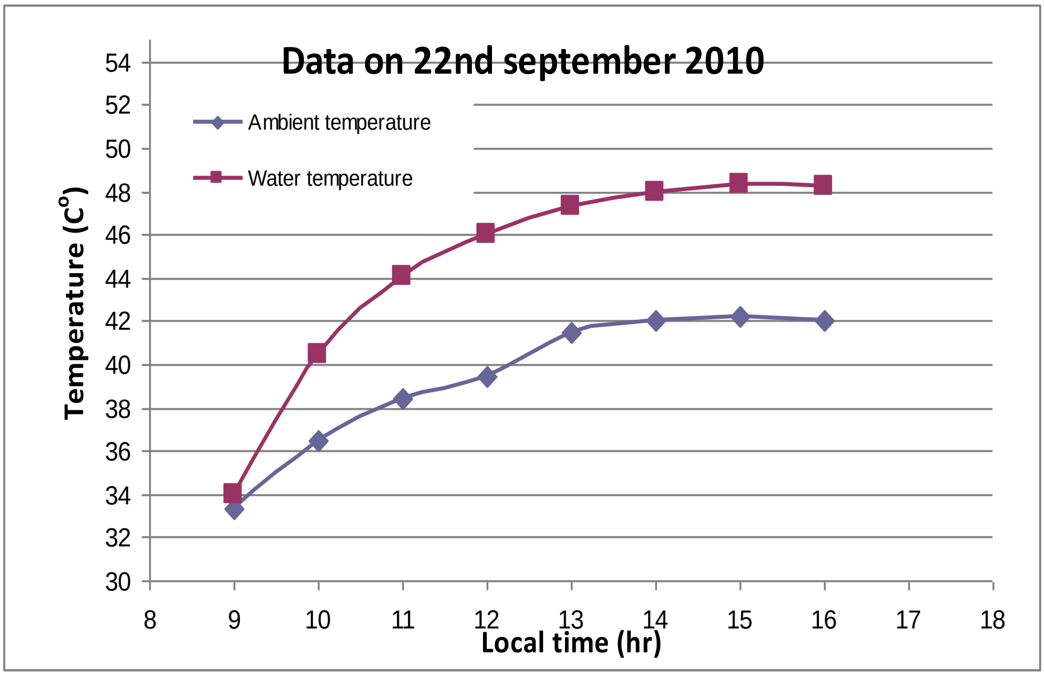
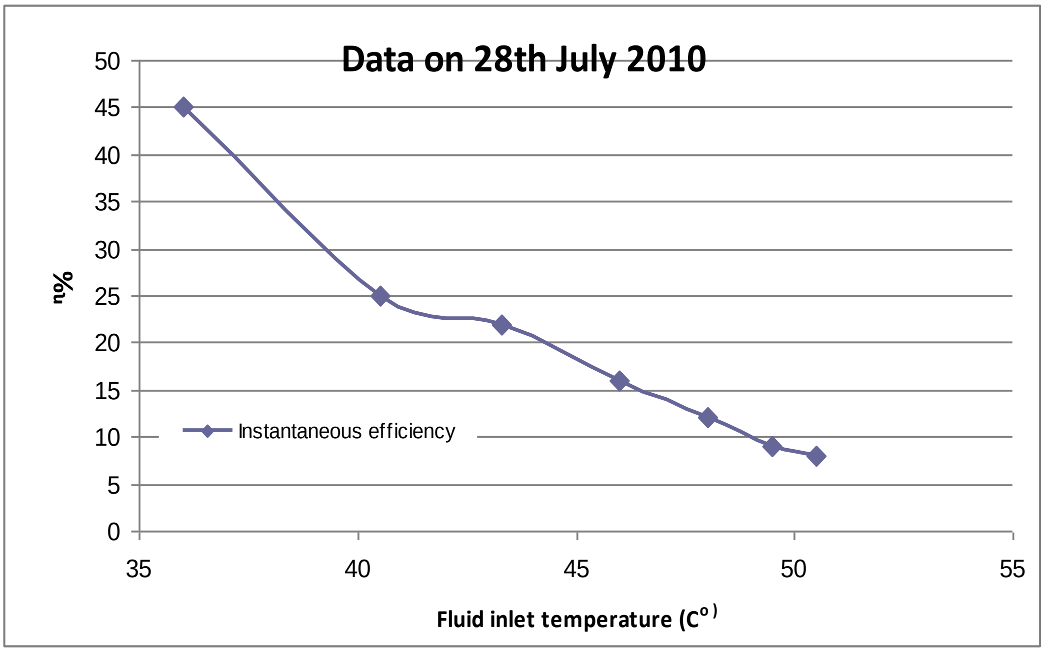


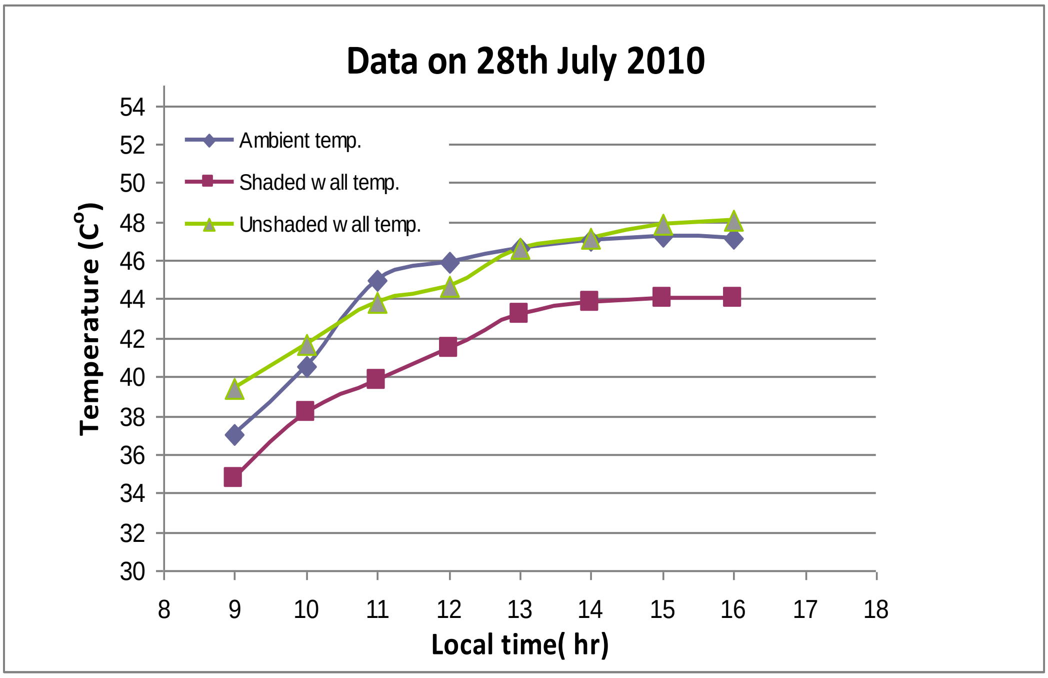
Fig (6) Effect of using the (CWSC)on water temperature as afunction of local time



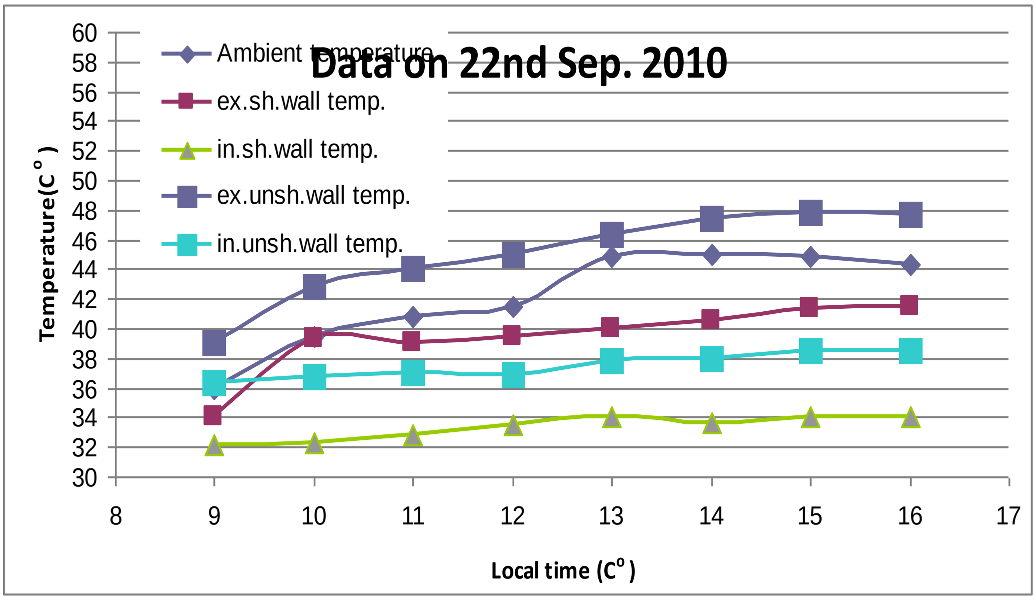
Fig(7) Effect of using the (CWSC) on water temperature as afunction of local time



Fig(8) Variation of efficiency of (CWSC) with fluid inlet temperature



Fig(9) Effect of using the (CWSC) shade on wall surface temperature as afunction of local time



Fig(10) Effect of using the(CWSC) shade on wall surface temperature as afunction of local time

ex.sh.wall temp._exterior shaded wall surface temperature
in.sh.wall temp._interior shaded wallsurface temperature
ex.unsh.wall temp._exterior unshaded wall surface temperature
in.unsh.wall temp._interior unshaded wall surface temperature