" Comparison between using of artificial devices and caloric apparatus to measure the solar radiations"[1]

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Abstract

Electrical radiometers have the disadvantage of measuring only a limited part of the wavelengths of the solar radiation. Most of the radiometers have their maximum sensitivity in the range of visible light and in the nearby of shortwave infrared range.

This paper presents an effective method to measure the light density independently of the spectral distribution of the radiation using a nonselective sensor. It is an horizontal absorption surface (brass- copper) along with the prevailing meteorological conditions encountered during the measurement period and with a well known mass, absorption area and specific heat capacity. In addition to the solar radiation measurements by using the proposed method, **the solar radiation by a radiometer at the same time and ambient temperature were performed.**

Finally, a comparison between both measurements of the solar radiation was demonstrated in diagrams and finding a correction factor to correct the errors by using the artificial devices to measure the solar radiation in any time of the year long. It was found that the correction factor is reasonably considered for any solar energy project to determine the amount of solar radiation accurately.

Keywords: Test body, Solar radiation, Radiometer, Corrected factor

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1. Introduction

The only available data issued by most of the meteorological stations is the total solar radiation (direct and diffuse radiations) received on the surface of an object placed horizontally artificially (M.A.M. Shaltout et all, 2001), (D.W. Meek, 1997) and (Foken Th, Oncley, SP., 1995). Very few stations provide data for the total radiation striking objects placed in a vertical position.

Every location on Earth receives sunlight at least part of the year. The amount of solar radiation that reaches any one "spot" on the Earth's surface varies according to the following factors (J. De Soza et all, 2005):

- Geographic location
- Time of day
- Season
- Local landscape
- Local weather.

(B. Goldberg, W.H. Klein, 1971) has found that the diffuse radiation is increased by reflection from clouds and cannot be separated out of the global measurements.

Because the Earth is round, the sun strikes the surface at different angles ranging from 0º (just above the horizon) to 90º (directly overhead). When the sun's rays are vertical, the Earth's surface gets all the energy possible. The more slanted the sun's rays are, the longer they travel through the atmosphere, becoming more scattered and diffuse.

Country like the Saudi Arabia , which lie close to the meridian, receive more solar energy in the summer not only because days are longer, but also because the sun is nearly overhead. The sun's rays are far more slanted during the shorter days of the winter months.

The rotation of the Earth is responsible for hourly variations in sunlight. In the early morning and late afternoon, the sun is low in the sky. Its rays travel further through the atmosphere than at noon when the sun is at its highest point. On a clear day, the greatest amount of solar energy reaches a solar collector around solar noon.

Scientists measure the amount of sunlight falling on specific locations at different times of the year. They estimate the amount of sunlight falling on regions at the same latitude with similar climates. Measurements of solar energy are typically expressed as total radiation on a horizontal surface, or as total radiation on a surface tracking the sun (A. Lester, D.R. Myers, 2006).

The solar-radiation variation over horizontal surfaces was calculated for Riyadh by (Al-Sanea Sami A. at all, 2004). The solar radiation measurements, temperatures, pressure, wind speed, precipitation and relative humidity were observed by (Ahmet Aksakal and Shafiqur Rehman, 1999) in the Arabian Gulf Coast near the city of Dhahran.

(S. Sh. Soulayman and N. Daudé, 1995) has developed An effective method to reduce considerably the high errors normal in solar radiation data obtained by actinographs or by non-calibrated Eppley-type pyranometers.

2. Design of the experiment unit

A rectangular(15x15x5 cm^3) plate from brass-copper with surface area of 0.0225 m^2 is used as absorption body. The test body is carefully insulated by polyurethane foam. The inside test body temperature is measured by a digital thermometer using its external k-type thermocouple as temperature sensor. Same types of thermometers are used to record the ambient temperature and surface temperature of test body. A radiometer(formerly Et 200.02) is used to measure the radiation density falls on the flat test body. The experiment was designed and manufactured at King Khaled university , thermodynamic lab in Kingdom of Saudi Arabia. The set up of the experiment is demonstrated in Fig. 1. The experiment was achieved in September 1, 2006, which was a clear sky day at 11:00 a.m.

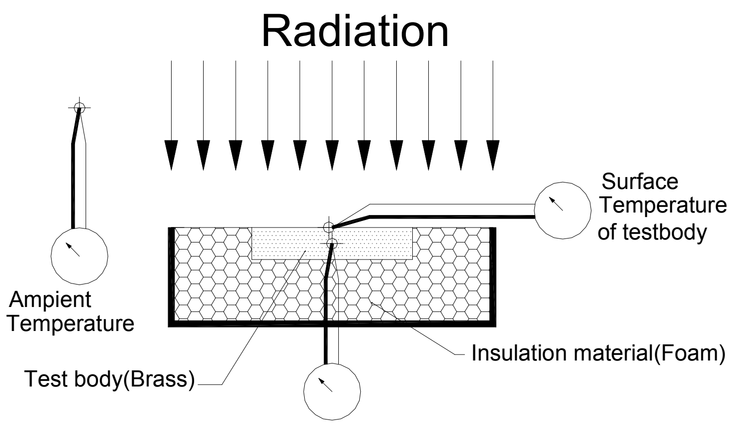


Fig. 1. The set-up of the experiment

To minimize the reflection of the test body surface the absorption surface is covered with soot. The absorption body is set under the solar radiation and starts warming up.

3. Thermal handling by the test body

The absorbed energy by the test body from the solar radiation Q_{in} is increasing the internal energy of the body ΔU. At the same time part of the energy Q_{out} is dissipated to the ambient. So, based on the first law of thermodynamics (R. Sonntag et all, 2003).

$$dU = dQ$$
$$\Delta U = Q_{in} - Q_{out} \qquad (1)$$

It is to be considered that main variables are only changing slowly. In a time intervals Δt the mean temperature can be taken in account and the derivative equations can transformed into differential equations. The change in internal energy of the body can be determined from following equation

$$\Delta U = m_b . C_{pb} . \Delta T_b \qquad (2)$$
$$\Delta T_b = \frac{T_{bc2} + T_{bs2}}{2} - \frac{T_{bc1} + T_{bs1}}{2}$$

$T_{bc}\ ^{o}C$ and $T_{bs}\ ^{o}C$ are the test body corn and surface consequently.
While the gain energy from radiation is

$$Q_{in} = \int \alpha.A\ .e.dt = \alpha.A\ .e.\Delta t \qquad (3)$$

Where (α) is the absorption coefficient and (e) is the density of the light. Whereas A is the absorption area (J.A. Duffie, W.A. Beckman, 1991) and (M. Iqbal, 1983)

The dissipated heat energy can be given in the following simple form :

$$Q_{out} = \int Ak(T_{bs} - T_{am})dt = k.A(T_{bs} - T_{am})\Delta t \qquad (4)$$

Where (k) is the coefficient of heat transfer from the test body to the ambient. T_{bs} and T_{am} are the temperatures of the test body surface and ambient in a time interval of Δt .
Substitute equations (2),(3)and(4) in equation (1), then the result will be the light density.

$$e = \frac{m_b.C_{pb}.\Delta T_b}{\alpha.A.\Delta t} + \frac{k(T_{bs} - T_{am})}{\alpha} \qquad (5)$$

The absorption coefficient can be set near to 1. With the temperature of the test body at the beginning of the time interval $T_{b_1} = \frac{T_{bc1} + T_{bs1}}{2}$ and at the end of interval $T_{b2} = \frac{T_{bc2} + T_{bs2}}{2}$, thus equation (5) can be written in this form .

$$e = \frac{m_b.C_{pb}(T_{b2} - T_{b1})}{A.\Delta t} + k(\frac{T_{bs1} + T_{bs2}}{2} - T_{am}) \qquad (6)$$

The ambient temperature T_{am} considered constant during a time interval.
The coefficient of heat transfer k is determined experimentally through a cooling down process implemented inside the lab directly after heating the test body by the solar radiation.
It is

$$k = \frac{m_b.C_{pb}(\frac{T_{bc2}+T_{bs2}}{2} - \frac{T_{bc1}+T_{bs1}}{2})}{[(\frac{T_{bs2}+T_{bs1}}{2}) - T_{am}]A.\Delta t} \qquad (7)$$

4. Determination of some parameters for the test body

1) The specific heat coefficient C_{pb}

With the help of the lab equipment, the specific heat coefficient of a sample from the test body materials was determined experimentally, It was found $C_{pb} = 0.203$ j/(g.K).

2) Coefficient of heat transfer

To determine the accurate value of the coefficient of heat transfer by convection from the test body to the ambient a cooling down process of the test body was done. So after heating the test body by the solar radiation it was cooled directly inside the lab under steady state conditions. The cooling process last half hour. Going back to equation (7) thus the value for heat transfer coefficient under considered conditions is $k = 16.5$ kw/(m².k)

5. Results and discussion

1) In Case of heating by solar radiation

The changes of the inside and surface of the test body and the ambient temperatures are shown in Fig. 2. It is obvious that the ambient temperature was relatively constant during recording of measured data while the inside and the surface temperatures of test body increased. The time interval was set to 1 minute for heating up for total period of 30 minutes. It can be seen that the linear approach for the time interval is permissible.

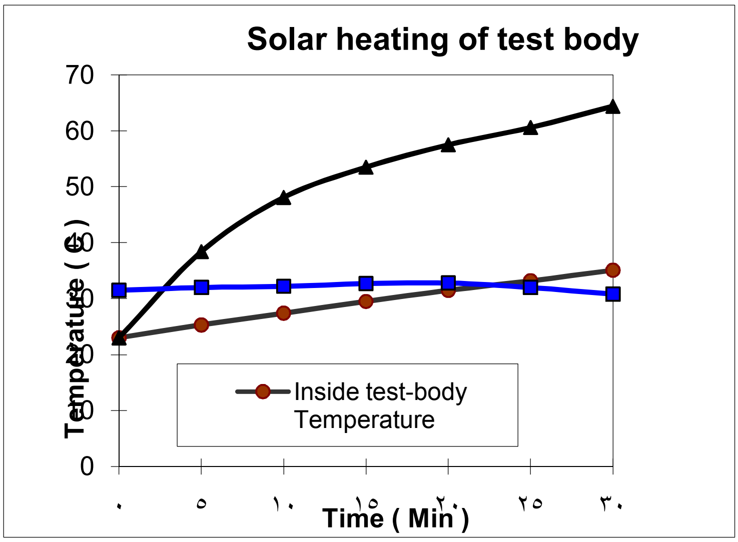


Fig. 2. **Changes of inside and surface temperature of the test body and ambient temperature during a heat up process**

Fig. 3. shows the density of light measured by Radiometer. As mentioned above the time interval was also set to 1 minute for heating process by the sun during time period of half hour (time of experiment implementation). As can be shown in fig. 3 the reason of getting variables measured values of the solar radiation during the experiment period is disappearing of the sun some times because of the events of clouds in the lab region.

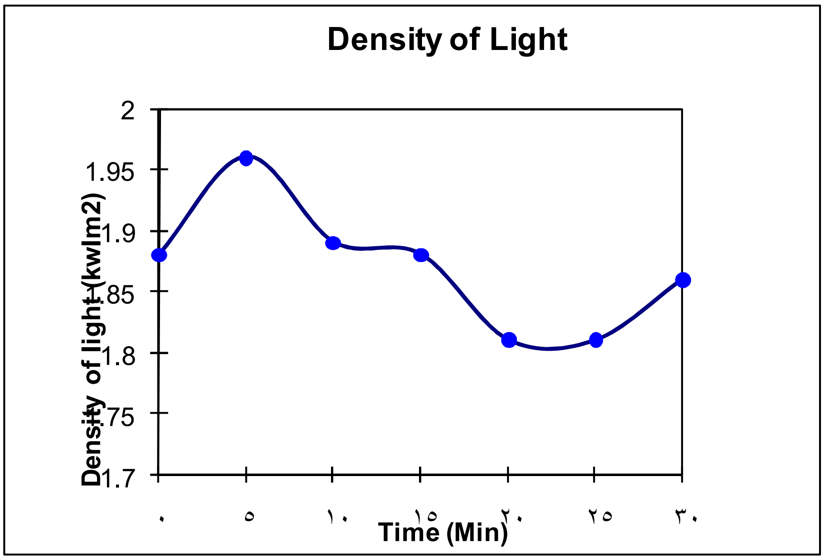


Fig. 3. Density of light as measured with Radiometer

2) In Case of cooling

To determine the heat transfer coefficient during the cooling process. The test body was heated by the solar energy than placed directly inside the lab of the thermodynamics. Fig. 4. shows that the surrounding temperature of the lab was constant (steady state cooling process). During the short time of cooling process the inside test body temperature changed slightly, while the temperature of the surface of the test body changed in evident way.

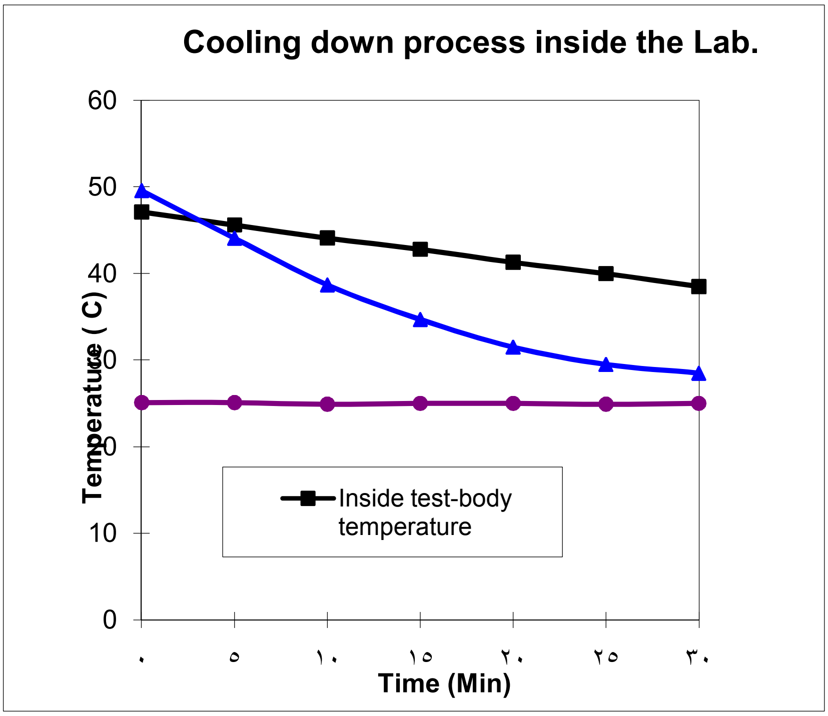


Fig. 4. Changes of inside and surface temperature of the test body and ambient temperature during a cool down process

6. Correction Coefficient

The correction coefficient is calculated by following equation

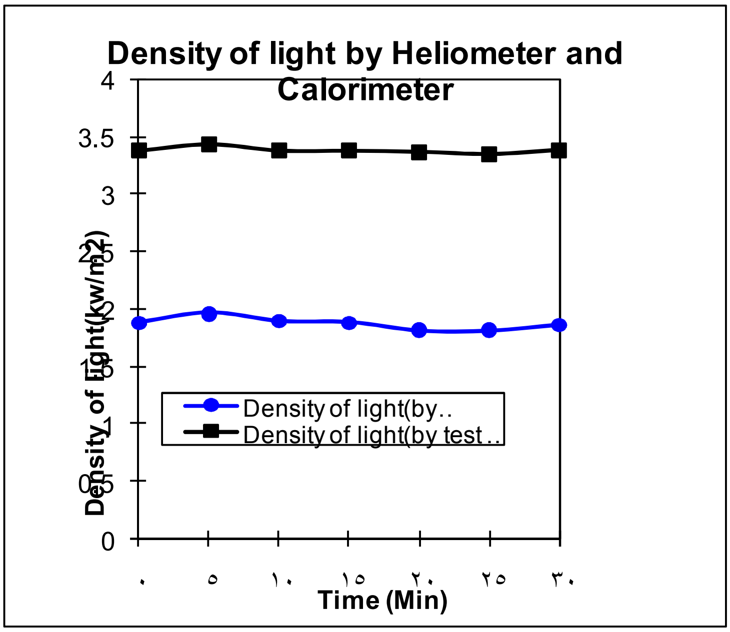
$$C = \frac{e_{cal}}{e_{Rad}} \qquad (8)$$

Whereas : e_{cal} is the measured light density determined by the caloric experiment eq. (6).

e_{Rad} is the density of light measured by the radiometer.

Fig. 5. shows that there is considerable difference between both values of density e_{cal} and e_{Rad} . The average value of the correction coefficient is :

$$C_{ave.} = 1.8$$



Figure(4): compares the radiometer readings with the measured light density determined by the caloric experiment

7. Conclusion

It was found that there is a notable difference between the measured values of solar radiation taken by electrical radiometers and the real solar radiation determined by the presented effective method demonstrated in this paper. Therefore, the calculated correction coefficient is reasonably to consider for using the solar energy as a renewable energy resource. Finally, this will increase the efficiency of any solar energy project evaluation.

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