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USING A SAMPLE TEMPERATURE METER WITH SOLAR IRRADIATION

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Abstract: In this article, the solar irradiance measurements collected at a point in the city of Tehuacán are reported, using a Sample Temperature Meter with Solar Irradiation (MTMCIS), which was developed at the Technological Institute of Tehuacán, with the purpose to have economically viable technology, to carry out measurements related to the project of the use of solar energy through radio-conducting tubes of solar radiation, which is registered and financed by the National Technology of Mexico. In the article, the theoretical aspects of temperature differences recorded in a portion of water placed in a cylindrical container that is subject to solar radiation are described, and the temperature differences are subsequently related to the amount of energy radiated by the sun. during the afternoon on a sunny day. The proposed methodology to take measurements and calculate irradiance in the afternoon hours is reported and compared with the values obtained and recorded in the Mexican Republic by (Salinas, et all 2020). The importance of such a study lies in the applicability in use technology for the massive implementation of solar radiation in its forms of heat and light.
Keywords: Irradiance, technology, heat, light, Tehuacán

INTRODUCTION

A proposal for the implementation of the use of radio conduction of solar radiation in its forms of heat energy or light energy requires the determination of the measurement of solar irradiation at the beginning of a tubular conduit and at its exit, when passing through a path. more or less complicated (Castillo, 2020). Said radioconductive tube is part of the project for the implementation of solar radiation for domestic use in situ, of a project financed by the National Technology of Mexico and requires a way to be evaluated as a feasible technological proposal, giving two reference measurements, the The first is irradiation at the entrance of the tube and the other is irradiation after following the desired path, to the point of use in question.

For this reason, the Electronics and Mechatronics departments, in conjunction with the Earth Sciences department of the Tehuacán Technological Institute, are given the task of implementing the measurement device that carries out, given a methodology proposed and described below, the measurement of solar irradiation (Castañeda, 2020).

DEVELOPMENT

The MTMCIS "sample temperature meter with solar irradiation" is an electronic application that consists of a program that determines the average temperature of a sample of known heat capacity. It does this by taking the average of measurements for one minute. And the next measurement is during the next minute. Between each pair of measurements, there is a time interval in which the device is hidden from radiation, thus obtaining a decrease in temperature in the sample, and then taking the next data. The system does not recover immediately, but what counts is the temperature difference, which is a function of the amount of momentary irradiation existing, so that each time another reading begins, there is a certain increase in the beginning of the reading and therefore ende at the end of this one. This for calculation purposes is considered with the difference that exists in the specific heat of the fluid considered as a function of temperature.

To determine the amount of energy that said sample receives between two consecutive measurements, it is only necessary to calculate the increase in heat ΔQ according to Eq. (1)

$$\Delta Q = mC_p\Delta T \qquad \text{Equation 1}$$

If we consider the heat capacity as the $C_p(T)$ given as a known expression for that device, and we know the mass of the sample, then we can obtain how much heat entered said sample when there was an increase in temperature ΔT in it, and since heat is a measure of energy we can also calculate the equivalent work done by solar radiation in the period of time in which the measurement was made given by the differential of Eq. (2).

$$\Delta T = T_f - T_i \quad \text{Equation 2}$$

Another known thing is that, given the geometry, it is possible to obtain the irradiation area, so we can divide the amount of heat that entered by the effective area perpendicular to the radiation. So then if we calculate using Eq. (3) the irradiance given by E.

$$E = \frac{P}{A} \quad \text{Equation 3}$$

Where P is the radiant power and A is the effective area.

And the radiant power is given by Eq. (4), where W is the work carried out in a time interval: Δt

$$P = \frac{W}{\Delta t} \quad \text{Equation 4}$$

So doing the work: W=ΔQ under the hypothesis that work has its mechanical equivalent in calories, we obtain Eq. (5) for Irradiance E.

$$E(t) = \frac{\Delta Q}{A\Delta t} = \frac{mC_p(T)\Delta T}{A\Delta t} \quad \text{Equation 5}$$

From Eq. (5) we can deduce that said expression instantly becomes the one given by Eq. (6) where the derivative of temperature with respect to time appears. Left like:

$$E(t) = \frac{m}{A} C_p(T) \frac{dT}{dt} \quad \text{Equation 6}$$

If both the measured t values and the tilt angle values are determined experimentally.

θ=θ(t)

We can find the angle relationship between each measurement and the change in minutes of time. To get a relationship.

$$E(\theta) = \frac{m}{A} C_p(T) \frac{dT}{dt(\theta)}$$

EXPERIMENT

The afternoon of a sunny day was chosen at the point in the Tehuacán region with coordinates Latitude 18.4791° Longitude -97.4285° Decimal degrees and the measurements were made with the MTMCIS, which are reported in Table (1). In these data appears h_i,d_i, these are taken with an extended tripod and are the measure of the height of the tripod, and the distance of the shadow. With them the angle of inclination is determined: , are the clock's time measurements on that day, in the format, hour.min.

The methodology followed in obtaining the data is the following: N_o is the number of measurements made from the data: t_i, $T1_i$, $T2_i$, $T3_i$, d_i, h_i which are the data that are showing variation, these data appear in yellow in the Tab. (1), which means that they are measured, another data measured only once is the mass attached to the sensor, which remains constant and is the one that is subject to radiation, in green the values that are derived from calculations appear. DT1,DT2 what are the differences between temperatures: T_1, T_2, T_3 while Dt is the meter's own constant that gives the difference in time between two averaged values when they are reported, and the area that is calculated uniquely using the formula for the area of a circular section. In red appears what has been taken from tables, in this case the value of the C_p of H_2O.

RESULTS

The values of t_i are recorded as hour.min, so for graphing purposes they are transformed into hour.decimal, where for example 1h:30min is 1.50 hdec.

Table 2 shows the values obtained for the inclination of solar radiation with respect to the horizontal given in radians and calculated from the measurements of the shadow projected by a point at a height h and are a shadow length d; the values also appear. times of t recorded that day in decimal format, that is, hour.fraction-of-hour. And the calculated values of E(t) and E2(t), through the formula given by Eq (5).

Figure 1 shows the spread of irradiance data calculated for the pairs of measurements: $\Delta T1=T_2-T_1$ y $\Delta T2=T_3-T_2$

T_1, T_2, T_3, They are average temperature measurements, consecutive in time with a difference of 1 minute between their reports. Because the first three measurements were only reported: T_1, T_2 the respective $\Delta T2$ is taken equal to $\Delta T1$ in those three values. While in Fig. (2) the angular coordinates of the measurements made appear instead of the temporal coordinates and on the other axis the same irradiance values declared in Fig. (1).

Note that comparing Figs (1a), (1b) the data appear inverted, this is because in the afternoon, which is when they were carried out after the maximum angle, the angle begins to decrease while time is increasing.

Table 4 shows the report of the two irradiation values obtained E(t) and E2(t) and their equivalent in w/m^2, comparing them with values approximate to the angles reported by Holman, and the quotient of E is also calculated. (t) between E_{holman} to obtain how much the value changes with respect to the data given by Holman.

In Tecno Energía they ensure an average daily irradiation value for Mexico of 5.5 Kwh/m2 (Tecno Energía, 2018), this value coincides with the maximum of the day reported on that day of 5.45 kwh/m2. And we can compare it with the one obtained for our data.

CONCLUSIONS

As the angle decreases with respect to the horizontal in the afternoon, it can be observed that the amount of solar irradiation decreases.

Making a linear fit we have that the rate of change of $\frac{\Delta E}{\Delta t}$ is: $-0.0337\, {cal}/{shcm2} = -\frac{0.337cal}{shcm2} \times \frac{\frac{4.184J}{cal}}{\frac{0.0001m2}{cm2}} = -1410\frac{J}{sm2} = -1.41kW/m2\text{h}$

what it indicates is that the irradiation in the afternoon decreases on average for a given hour by 1.41 Kw/m2

It is also observed that some atmospheric accidents, such as the presence of clouds, can cause this to be greatly reduced in short periods of time.

The data obtained by our test method are above those reported by Holman, by a ratio of 6 for near the largest top angle and 1.2 for small horizontal angles.

If the irradiance value is integrated during the 3.7 recorded hours of the afternoon where the measurements were made, a total value of radiated energy is obtained in that period of 3.7 hours.

$$E_T = 11124.32\ wh/m2 = 11.124\ kwh/m2$$

Dividing this value by time we obtain the average radiation in that period of time

$$\bar{E} = 3.006 \text{ kW/h}$$

IMPORTANT OBSERVATIONS

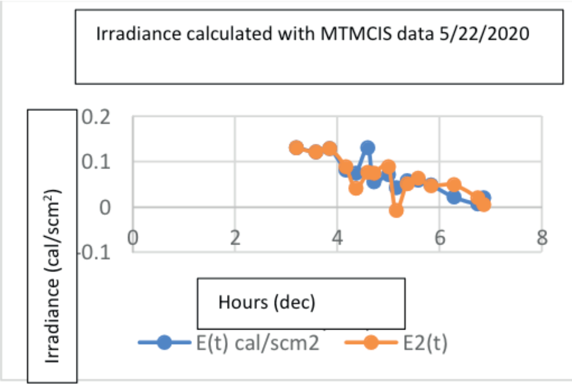
Regarding the data that Holman published in his Heat Transfer book, on data from the Proc. ASCE Power Division in July 1962. Used for the prediction of Temperature in rivers and lakes, the data reported here are superior to what if applied to said predictions would raise the temperature obtained by that study.

Number	t(hr. min)	T1(°C)	T2(°C)	T3(°C)	d(cm)	h(cm)	DT1 (°C)	DT2 (°C)	m (g)	Dt1 (s)	Dt2 (s)	CpH2O (cal/gs) T2	Dt (s)	A cm2
1		29.7	31.82		6	10.3	2.12		10	60	60	4.182	60	11.341
2	3.35	32.19	34.16		6.5	10.3	1.97		10	60	60	4.178	60	11.341
3	3.51	33.94	36.04		7.4	10.3	2.1		10	60	60	4.178	60	11.341
4	4.1	33.82	35.14	36.58	8.5	10.3	1.32	1.44	10	60	60	4.178	60	11.341
5	4.22	34.14	35.34	36	9.5	10.3	1.2	0.66	10	60	60	4.178	60	11.341
6	4.36	33	35.12	36.36	10.5	10.3	2.12	1.24	10	60	60	4.178	60	11.341
7	4.43	33.41	34.31	35.51	11.4	10.3	0.9	1.2	10	60	60	4.178	60	11.341
8	5	33.75	34.9	36.34	12.7	10.3	1.15	1.44	10	60	60	4.178	60	11.341
9	5.09	34.14	34.82	34.68	13.7	10.3	0.68	-0.14	10	60	60	4.178	60	11.341
10	5.22	33.41	34.34	35.17	15.2	10.3	0.93	0.83	10	60	60	4.178	60	11.341
11	5.35	33.29	34.24	35.26	16.9	10.3	0.95	1.02	10	60	60	4.178	60	11.341
12	5.5	31.72	32.5	33.26	19.3	10.3	0.78	0.76	10	60	60	4.178	60	11.341
13	6.17	30.28	30.62	31.41	24.3	10.3	0.34	0.79	10	60	60	4.178	60	11.341
14	6.45	27.3	27.4	27.72	35.4	10.3	0.1	0.32	10	60	60	4.179	60	11.341
15	6.52	26.91	27.23	27.3	48	10.3	0.32	0.07	10	60	60	4.179	60	11.341

Table 1: The experimental values recorded on 05/22/2020 in Tehuacán, at the coordinates parallel 18°37' north latitude meridian 97°38'. (measured in yellow, calculated in green and tables in red)

θ= tan-1 (h/d)	t (hrdec)	E(t) cal/scm2	E2(t)
1.04332574	3.2	0.13029186	0.13029186
1.00784543	3.58	0.12095729	0.12095729
0.94779708	3.85	0.12893925	0.12893925
0.88085188	4.17	0.08104753	0.08841548
0.82578024	4.37	0.07367957	0.04052376
0.77578308	4.60	0.13016724	0.07613556
0.73475027	4.72	0.05525968	0.07367957
0.68142661	5.00	0.07060959	0.08841548
0.64466797	5.15	0.04175176	0.00859595
0.59555533	5.37	0.05710167	0.0509617
0.5473518	5.58	0.05832966	0.06262763
0.49022622	5.83	0.04789172	0.04666373
0.40091171	6.28	0.02087588	0.04850572
0.28314314	6.75	0.00614143	0.01965259
0.21137787	6.87	0.01965259	0.004299

Table 2: Los valores temporales, de inclinación de la radiación solar y de irradiación obtenida



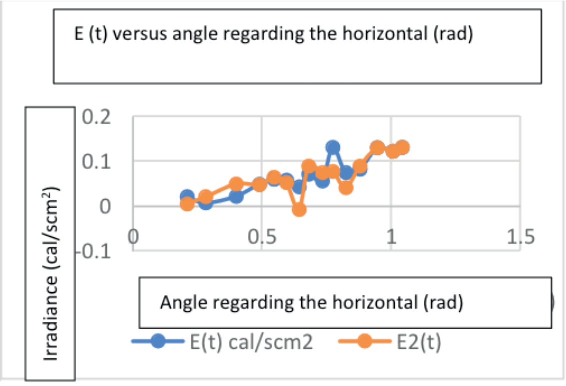


Figure 1 a.b. a) The irradiance values obtained as a function of time. b) The two Irradiance values as a function of the angle obtained by using the MTMCIS

t (hrdec)	E(t) cal/scm2	E2(t) cal/scm2	E(t) w/m2	E2(t) w/m2	Theta tan-1(h/d)	theta °	Holman w/m2	E(t)/EHolman
3.2	0.130291861	0.13029186	5451.41148	5451.41148	1.04332574	59.7781617	901.1	6.04972975
3.583	0.120957294	0.12095729	5060.85316	5060.85316	1.00784543	57.7452895		
3.85	0.128939247	0.12893925	5394.81809	5394.81809	0.94779708	54.3047723		
4.167	0.081047527	0.08841548	3391.02852	3699.30384	0.88085188	50.469095	871.4	3.89147179
4.367	0.07367957	0.04052376	3082.7532	1695.51426	0.82578024	47.3137225		
4.6	0.13016724	0.07613556	5446.19731	3185.51164	0.77578308	44.449096	710.4	7.66638135
4.717	0.055259677	0.07367957	2312.0649	3082.7532	0.73475027	42.0980895	636	3.63532217
5	0.070609588	0.08841548	2954.30515	3699.30384	0.68142661	39.0428689	636	4.64513388
5.15	0.041751756	-0.00859595	1746.89348	-359.65454	0.64466797	36.9367538	554.6	3.14982596
5.367	0.057101667	0.0509617	2389.13373	2132.23763	0.59555533	34.1228069	554.6	4.30785021
5.583	0.058329659	0.06262763	2440.51295	2620.34022	0.5473518	31.3609479	472.1	5.16948305
5.833	0.04789172	0.04666373	2003.78958	1952.41036	0.49022622	28.0878932	381.4	5.25377446
6.283	0.020875878	0.04850572	873.446739	2029.47919	0.40091171	22.9705488	290.7	3.00463274
6.75	0.006141434	0.01965259	256.957588	822.26428	0.28314314	16.2229068	200	1.28478794
6.867	0.019652588	0.004299	822.26428	179.870311	0.21137787	12.1110598		

Table 4: Report of the irradiations obtained under the methodology and the approximate comparison with the average data reported by Holman

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