Invention and Development New Equation for Calculate the Intensity of Solar Radiation and Compared with the Measured Value by the Pyranometer

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***Abstract*— Identifying closely the solar energy and its uses, importance, and the positive and negative aspects as well as the study of solar radiation and its components including the effect of weather on the intensity of solar radiation. The aim of the study is to find a new equation (algorithm) to compute the irradiance and reduce the error between the computed values and the measured values by Pyranometer. Irradiance is expressed in unit as watts per square meter w/m^2 . Given ideal conditions, a solar panel should obtain an irradiance of $1000w/m^2$. Unluckily, this is depending on different geographic location and the angle of the sun .Also I will test the algorithm on different location on different countries on the world. The irradiance will be measured whole the year on different location and different weather conditions.**

***Key Words*—Solar radiation, New equation, Pyranometer.**

I. INTRODUCTION

THE sun is the source of life and the source of the energies of Earth, the solar energy is reaching the surface of the earth turn into two main forms: chemical energy and geothermal energy, each of which is reflected in several aspects lead to the emergence of a number of energies. When the sun's rays fall on the leaves of plants it reserved as a chemical energy membership form, and form the structure of plants and its source of nutrition and other organisms in general [1][2]. The emergence of an environmental problem caused by the increase in fossil energy and demand, especially by the industrialized countries, which are primarily responsible for this problem through the consumption of a large amount of carbon, oil and gas. Otherwise, the increase in the prices of these resources leads to the search by the international community for alternative sources of energy which can ensure energy saving in hand and environmental protection. This opens the mind to renewable energy and investment in such as: solar, wind and water. In this field, the world takes an important consideration for these energies and is geared towards developing and improving them, especially solar energy [3]. Renewable electricity has been projected as the most important step towards reducing emission and achieving overall sustainability in the electricity sector. Benefits of solar energy are shorted as following: Solar energy is a renewable energy source, that is, it is not depleted, renewable with the sunrise every day; Solar energy helps to generate electricity using solar panels, which encourages the elimination of electricity generation by other methods; Solar energy is an inexpensive energy source, as it does not need to be maintenance, but it needs only a little effort to maintain the continuity of the work of panels and solar pools installed; Solar energy is classified as a non-disturbing source of energy. No disturbance or noise is generated during the transformation of its rays into electrical energy; Solar energy is characterized by the possibility of monopolizing one side. Solar systems can be installed anywhere if there is not enough space to install them[4]-[7].

II. SOLAR ANGLES

Since the intensity of falling solar radiation on the earth's surface depends on the site of the surface to the sun. It is necessary to identify some of the geometric angles that describe the relationship between the surface of the earth and the sun [8][9][10]. Figure 1 shows the point on the surface of the earth facing the sun radiation.

A. Latitude (Φ):

Latitude to a point: is the angular location of the studied point studied according to the level of the equator, with the assumption that latitude is positive north of the equator, according to Figure 1, the angle between the line op and its reversal at a level the equator.

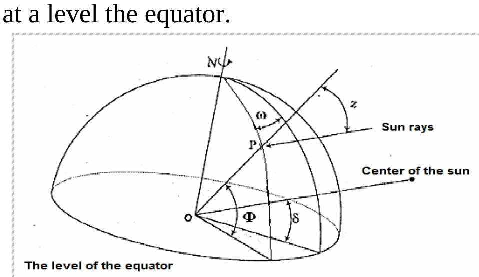

Fig. 1. Latitude Φ, deviation Courier ω, solar deviation δ [8][11]

B. Solar deviation angle (δ):

The angle distance to the sun radiation according to the level of the equator, with the assumption that north is positive. According to Figure 1, the angle between the line connecting the earth central and the sun central and the reversal of this line at the level of the equator. As a result of the nature of the

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elliptical path of the earth around the sun, the deviation angle values vary between (+23.5º) at the summer solstice and (-23.5º) at the winter solstice. As a result, the value of the deviation angle (in degrees) for any day a year can be considered fixed and is calculated from the following empirical relationship:

$$\delta = 23.45 Sin[\frac{360}{365}(284 + n)] \quad (1)$$

Where: n: is the number of the day in the year [9][11].

C. Hourly angle (ω):

Hourly angle of a point on the surface of the Earth is the angle that the Earth must rotate to put the latitude of this point directly under the sun and according to the figure it is the measured angle at the level of the equator between Longitude reversal and the reversal of the line linking central earth and the sun central.

Hourly angle at noon equal to zero with the assumption it is positive in the afternoon as the earth move on Longitude takes one hour so hourly angle can be written by degrees as follows:

$$\omega = \pm \frac{1}{4} \text{ (number of minutes from local solar noon)} \quad (2)$$

Where Positive signal indicating the afternoon hours and negative signal indicating the hours of the morning. In addition to the three geometric angles shown in Figure 1, it is appropriate to calculate solar radiation by determine the position of the sun for the sky through the angles shown in Figure 2 [8][10][12].

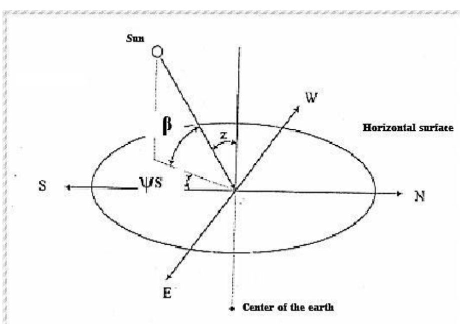

Fig.2. Vertical azimuth angle Z, β elevation angle, and the angle of the horizontal azimuth Ψs [8][12]

D. The vertical solar azimuth angle (z):

The vertical solar azimuth angle is the angle between the sun's rays and plumb.

E. Solar elevation angle (β)

Solar elevation angle (β) is the angle between the sun and the horizontal level.

$$Z + \beta = \frac{\pi}{2} = 90 \quad (3)$$

Thus, we find that the relationship between these angles is given as follows:

$$\text{Cos } Z = \text{Sin}\beta = \text{Sin } \Phi . \text{ Sin } \delta + \text{Cos } \Phi . \text{ Cos } \delta . \text{ Cos} \quad (4)$$

F. Horizontal solar azimuth angle (Ψs):

It is the angle measured in the horizontal level between the South and the reversal of sunlight, and the trend towards the West is positive, this angle is calculated according to the following relationship:

$$\text{Cos } \psi s = \frac{\sin \beta \sin \Phi - \sin \delta}{\cos \beta \cos \Phi} \quad (5)$$

To calculate the solar radiation falling on the oblique surface is necessary to calculate the three other angles related to the direction of the surface as shown in Figure 3.

G. Inclination of the surface angle (γ):

Inclination of the surface angle is the angle between the surface and the horizontal level.

H. Azimuth surface angle (Ψk):

Azimuth surface angle is the angle measured at the horizontal level between the reversals of straight line which is perpendicular with surface and south. Direction towards the west is positive.

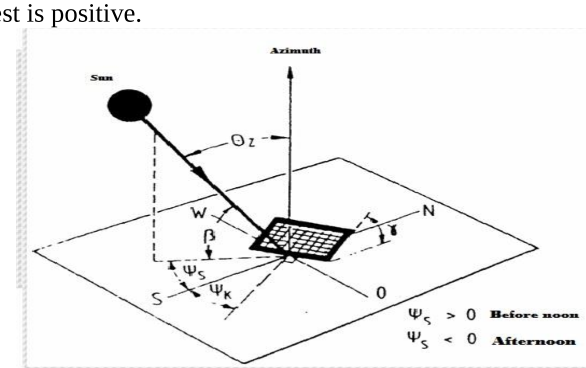

Fig. 3. Inclination of the surface angle γ, azimuth surface angle Ψk, the fall of the radiation angle θk [8][10]

I. Solar of incidence angle (θk):

Solar of incidence angle is the angle between the sun's rays and the vertical line on the surface. For Horizontal surface is (z = θk) [8][9][12]. The following equation shows the relationship between these angles and prior angles to any given surface:

$$\text{Cos}\theta k = \text{Sin}\beta \cos\gamma + \text{Cos}\beta \text{ Sin}\gamma \text{ Cos}(\psi s - \psi k) \quad (6)$$

III. INTENSITY OF SOLAR RADIATION ON HORIZONTAL AND SLANTED SURFACES

The intensity of the radiation falling on the earth's surface for a specific site at a specific time depends on the surface orientation and inclination. Note that the surface perpendicular to the sun's rays will receive the largest amount of solar radiation. However, the process of tracking the sun is often expensive and impractical in many cases. Turned out to be the most appropriate solution is using oblique complexes in the construction process. Consequently, it is necessary to calculate the falling solar radiation on the slanted surfaces. Shown in Figure 4 direct radiation falling on the horizontal and slanted surfaces, and so we can write the following relations: Severity of the incident solar radiation on the earth's surface on a clear day can be expressed in the following relationship:

$$E_{dirs} = A.e^{\frac{B}{\beta}} = A.e^{-Bm} \quad (7)$$

E_{dirs} (W / m²): direct solar radiation at free fall; A (W / m²): solar radiation at the theoretical air density equal to zero; B: attenuation coefficient of the atmosphere; β: angle of the sun rise; m: air density.

$$E_{dir.h} = E_{dir.s} \sin\beta \quad (8)$$

The change of values A, B depends on the annual change of the distance between Earth and the sun and the quarterly change in atmospheric content such as moisture and other components. Table I gives the values of A, B, C for the twenty-first day of each month. In places dominated by clear, dry air (high places), or places where cloudy and wet weather is prevailing, the resulting values from the relationship (10) must be multiplied by the factor of serenity [8][9].

ASHRAE book for applications (American Society of Heating, Refrigeration and Air Conditioning) gives a simplified relationship to calculate wasteful radiation from the sky and falling on optional surface on the earth as a percentage of direct solar radiation falling freely as follows:

$$E_{dfu} = C \bullet E_{dir.s} \cdot f_{ss} \quad (9)$$

E_{dfu} (W / m²): wasteful solar radiation from the sky; C: solar radiation scattering coefficient is given in the table (2-1); Fss: laboratory angular between the surface and the sky, where: Fss = 0.5 (1-cosγ) inclined surface at an angle γ
The vertical surface Fss = 0.5 horizontal surface Fss = 1.0
Finally, the total solar radiation incident on a horizontal surface is the sum of the direct and dissipative rays:

$$H = E_{dir.h} + E_{dfu} \quad (10)$$

$$\text{Cos } \theta_k = \frac{H_{Bt}}{H_{Bn}} \quad (11)$$

$$\text{Cos } Z = \frac{H_B}{H_{Bn}} \quad (12)$$

Where: H_{Bt} direct radiation on the surface oblique [W / m²].
ASHRAE relations Constants for the 21th day of each month as shown in Table I.

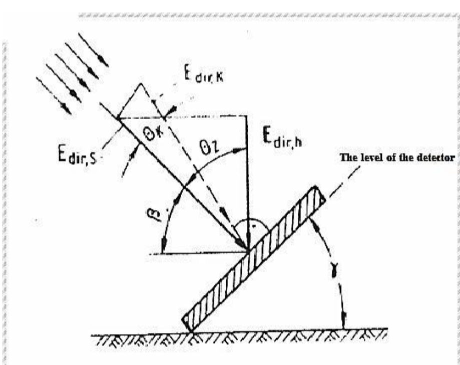

Fig .4 direct radiation falling on horizontal and oblique surfaces[8][10]

Table I: ASHRAE relations Constants (ASHRAE, 1995-1996)[8].

Month	AW/M²	B	C
Jan.	1230	0.142	0.058
Feb.	1215	0.144	0.060
Mar.	1185	0.156	0.071
April	1136	0.180	0.097
May	1104	0.196	0.121
June	1088	0.205	0.134
July	1085	0.207	0.136
Aug.	1107	0.201	0.122
Sept.	1152	0.177	0.092
Oct.	1193	0.160	0.073
Nov.	1221	0.149	0.063
Dec.	1234	0.142	0.057

The severity of total solar radiation falling on the oblique surfaces given optionally through the following relationship:

$$H_t = E_{dir.h} R_B + E_{dfu}\left(\frac{1+COS\gamma}{2}\right) + H\rho_g\left(\frac{1-COS\gamma}{2}\right) \quad (13)$$

Where: ρ_g :earth reflection coefficient of the direct and dissipative rays. In current calculations they are taken as constant. R_B : Inclination direct radiation coefficient.

IV. The Generation of Electric Power Using Solar Energy

Solar energy can be converted into electrical energy in two basic ways: the thermal conversion, and the direct conversion using PV cells (that is the aim of this research).

A. Direct Conversion of Solar Power to Electric Energy

PV cells is one of the most known and favourable method to convert solar energy into an electrical one in the near future, this method is characterized by a number of advantages, compared to the thermodynamic method, including: It does not require regulating the necessary heat stages and processes. The structure of power plants operating in this way is much simpler, as they contain fixed panels which give the possibility to sometimes reducing the maintenance, or entirely dispensing of, these stations, and therefore: such investment will be easy in remote areas where technical staff and specialist are not available, and therefore: the expenses of service and maintenance will be low.

There is a possibility of designing PV cells with different sizes and multi-functions which can consist of separate sections, which have the same effects as the entire cell. There is a big possibility of enhancing and producing PV cells (the main element in PV stations) and that in order to reduce its size and cost as well as increasing its ability. The PV cells are of a high reliability function. In addition, the PV cells are able to function efficiently and in high quality for a long and an unlimited time. The main reason for the non-proliferation of PV cells manufactured of semiconductors in the scientific life is the rise in costs, where the cost of one watt for the production of possible vehicle equal to ($ 50) in 1970. In 1988, thanks to technological progress of PV cells production and working condition's improvement, such cost has decreased to ($ 5), and it is yet constantly decreasing. Silicone material is one of the most important semiconductors used in PV cells, which are simple to install and has been well-studied. In 1954, the first silicon PV cell was produced in the Institute Bell labs in the United States with a rate of (6%). It is worth mentioning that the silicon as a pure substance is not found in nature on the individual level, but united with other substances. It is one of the most common elements on Earth after oxygen, it is located in the outer layers of the earth and it is found in nature in the form of silica dioxide [13].

B. Definition of PV Cells

The PV cells' adapters take energy from the sun and convert it into another type of energy, where solar cells convert sunlight into electricity and expel a large amount of heat without any effective action (or noise pollution or radiation or maintenance).

PV cells' panels are adjusted into a suitable tendency's angle to face the sun, so the sun's rays fall vertically to them. Solar cells convert energy directly into electrical power without any mediating operations, they absorb most of the solar spectrum and convert part of this radiation into electrical energy that can immediately be used or stored.

Such systems of this type are mainly designed for facilities in remote locations and for long periods as they are known for their very severe weather; therefore, such facilities should be of strong resistance to winds, humidity, cold and sand storms, and have a design against the attacks of birds, animals and corrosion; that's why the basic materials to which the cells are attached must resist these things, so the cells' metal cannot be exposed to erosion. This is a very important point where most PV cells are made of silicon which is half the metal that can be a dielectric or a conductor. In the case of being a conductor, its electrons atoms are not tightly linked which lead to an easy flow when voltage is applied. In the other case, its electrons atoms are tightly linked which lead to no electronic flow when voltage is applied. The silicon was chosen because it has: High thermal conductivity, Good consistency with the surrounding weather, Excellent dielectric of electricity, High capacity.

V. MODELS OF EQUATIONS FOR CALCULATE THE SOLAR RADIATION

Intensity at the beginning of this study, the objective of the study was to study some models of equations. Calculate the solar radiation intensity of one of the Libyan cities. The choice was made for the city of Hun. The three most used equations were used to calculate the intensity of the solar radiation falling per square meter in cooperation with the Hoon meteorological station. The equations are:

- Equation proposed by the American Association of Heating, Cooling and Air Conditioning Engineers (ASHRAE).
- Equation called desert to calculate the intensity of solar radiation.
- Equation to calculate the intensity of solar radiation in terms of the proportion of solar brightness.

1) Calculation of solar radiation outside the atmosphere:

$$HO = (R1 * R2) * (R3 + (R4 * R5)) \quad \text{------} \quad (1\text{-}1)$$
$$R1 = ((24*3600 * ISC) / 3.141592654) \quad \text{------} \quad (1\text{-}2)$$
$$R2 = (1 + (.033 * ((360 * n) / 365))) \quad \text{------} \quad (1\text{-}3)$$
$$R3 = COS\ ø * COS\ \delta * SIN\ \omega s \quad \text{------} \quad (1\text{-}4)$$
$$R4 = ((3.141592654 * \omega s) / 180) \quad \text{------} \quad (1\text{-}5)$$
$$R5 = SIN\ ø * SIN\ \delta \quad \text{------} \quad (1\text{-}6)$$

2) Equation proposed by the American Association of Heating, Cooling and Air Conditioning Engineers (ASHRAE).

$$Iit = (IDN * COS\ \Theta + Ids + Ir) \quad \text{------} \quad (2\text{-}1)$$
$$IDN = (A / EXP\ (B / SIN\ \alpha s) \quad \text{------} \quad (2\text{-}2)$$

A and B where that are constants based on the order of the month in the year as reported in Source 6 Constant spread C also shows this Table II:

Table II: Constants used in the equation of the American Association of Heating, Cooling and Air Conditioning Engineers (ASHRAE).

NOV	OCT	SEP	AUG	JUL	JUN	MAY	APR	MAR	FEB	JAN	M
1199	1172	1131	1088	1066	1096	1084	1115	1164	1193	1209	A
0.149	0.166	0.177	0.201	0.207	0.205	0.196	0.180	0.156	0.144	0.142	B
0.063	0.073	0.092	0.122	0.136	0.134	0.121	0.097	0.071	0.060	0.058	C

$$Ids = (C * IDN * Fss) \quad \text{------} \quad (2\text{-}3)$$
$$Fss = ((1 + COS\beta / 2) \quad \text{------} \quad (2\text{-}4)$$
$$IR = (Itr * Sg * FSg) \quad \text{------} \quad (2\text{-}5)$$
$$Itr = (IDN * (C + SIN\ \alpha s)) \quad \text{------} \quad (2\text{-}6)$$
$$Fsg = ((1\text{-}COS\beta / 2) \quad \text{------} \quad (2\text{-}7)$$

Where: Sg = 0.2 it's Constant

3) Equation called desert to calculate the intensity of solar radiation

$$HT1 = 1.53 * c1 * EXP\ (f1) \quad \text{------} \quad (3\text{-}1)$$
$$c1 = 4.186 * (c2 + c3) \quad \text{------} \quad (3\text{-}2)$$
$$c2 = ((ssh / 12) * (0.2)) / (1 + 0.1 * ø) \quad \text{------} \quad (3\text{-}3)$$
$$c3 = C4 * COS\ ø \quad \text{------} \quad (3\text{-}4)$$
$$f1 = C5 * (C6 - C7) \quad \text{------} \quad (3\text{-}5)$$
$$C5 = (ø * \pi) / 180 \quad \text{------} \quad (3\text{-}6)$$
$$C6 = ((ssh) / 12) * (rh \wedge (1 / 3)) / 100 \quad \text{------} \quad (3\text{-}7)$$
$$C7 = 1 / \alpha s \quad \text{------} \quad (3\text{-}8)$$

4) Equation calculation of the intensity of solar radiation in terms of proportion of solar brightness. The model for the calculation of solar radiation intensity in terms of the ratio of solar brightness to 1924 was used when the world produced an equation between the average daily and monthly solar radiation and the solar radiation for a sunny day with the ratio of the hours of brightness to the hours of the day [14].

H = a + (b * n / N) * Hc ------ ANGSTROM Q ----- (4-1)

Solar radiation for a sunny day is recorded for a very sunny day and this is one of the difficulties that led Hc researchers and ask for this equation.

To find an alternative equation and the result of continuing studies was reached in 1964 to a general equation as follows[15]:

H = a + (b * n / N) * Ho --------------------------------- (4.2)

*Hc where solar radiation has been replaced for sunny day recorded for sunny day.

*Which is calculated from equation (1-1) Ho value of the solar beam outside the atmosphere.

However, when calculating the three equations and extracting the results and comparing them with the values measured by the Pyrameter and these values taken from the center of research and studies of solar energy in the city of Tripoli, it was found that there is a significant difference between the measured values and the values calculated in the three equations. The following table shows the a comparison of three different algorithms to calculate the irradiance.

Fig.5. The Pyrameter.

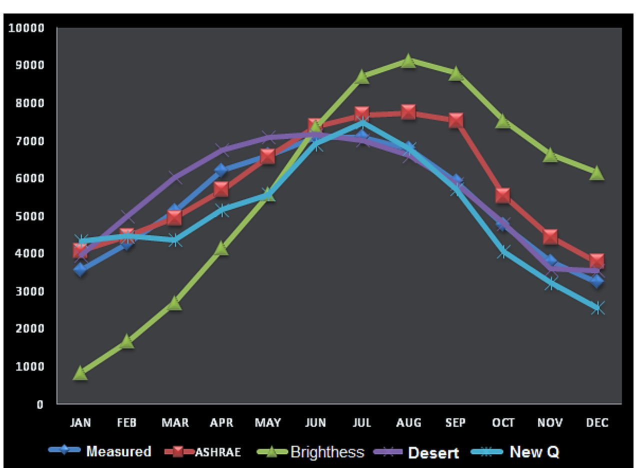

Fig.6. Comparison of all equations used to calculate solar radiation intensity and measured value

Table III: Comparison between the values calculated by the three equations and the measured value by the Pyranometer

month	Measured Value by Pyranometer	ASHRAE Equation	Desert Equation	Brightness Equation
JAN	**3560**	4070	3949	**831**
FEB	**4271**	4460	4998	**1668**
MAR	**5125**	4940	6029	**2692**
APR	**6200**	5680	6747	**4144**
MAY	**6609**	6570	7094	**5568**
JUN	**7076**	7370	7156	**7345**
JUL	**7093**	7680	7005	**8701**
AUG	**6780**	7740	6598	**9127**
SEP	**5913**	7530	5852	**8787**
OCT	**4751**	5530	4805	**7520**
NOV	**3793**	4440	3587	**6621**
DEC	**3238**	3770	3544	**6151**

Table IV. Comparison between the values calculated by the New equations and the measured value by the Pyranometer

M	n No. of day	hta Measured	ht1 New equation	Percentage of error %
JAN	17	3560	4330	0.17
FEB	47	4271	4460	0.04
MAR	75	5125	4360	-0.17
APR	105	6200	5170	-0.19
MAY	135	6609	5570	-0.18
JUN	162	7076	6910	-0.02
JUL	198	7093	7480	-0.05
AUG	228	6780	6780	0
SEP	258	5913	5710	-0.03
OCT	288	4751	4050	-0.17
NOV	318	3793	3230	-0.17
DEC	344	3238	2560	-0.26

VI. CONCLUSION

The first irradiance algorithm was proposed by Angstrom in 1924.This method can calculate the irradiance only on clear day, but it cannot compute the irradiance on cloudy or dusty day. Angstrom's algorithm has been improved in 1964, but the error between the computed values and the measured values by Pyranometer still large. Nowadays, the researcher are trying to investigate a method to reduce the error between the computed values and the measured values by Pyranometer.

Thus, the equation of Bin Achibin was invented, which gives closer values when comparing the measured values and the values calculated in this equation, which are equal to some of the points as in the months of summer, the percentage of error is equal to zero, As shown in Figure 6 and Table IV.

New equation(Bin Achibin Equation):

H = {a + (b * (n / N)) * Ho * 0.0036 * (n / N) * 5 / J

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APPENDIX (1)

```
CLS
X = 3.141592654# / 180
PRINT TAB(5); "TABLE(1): SOLAR RADIATION CALCULATED USING
ASHRAE EQN. AND THE TROPICAL EQN.";
PRINT TAB(15); "WITH THE RECORDED VALUES PROGRAM(2)."
PRINT"*************************************************************"
PRINT TAB(3); "m"; TAB(10); "n"; TAB(16); "rh"; TAB(22); "ssh"; TAB(29);
"sal"; TAB(40); "how"; TAB(52); "ht1"; TAB(62); "hta"; TAB(74); "IT"
PRINT"*************************************************************"
PRINT TAB(15); "(%)"; TAB(22); "(hr)"; TAB(28); "(deg)"; TAB(38); "(w/m^2)";
TAB(50); "(w/m^2)"; TAB(59); "(w/m^2)"; TAB(73); "(w/m^2)"
PRINT"====================================================="
FOR i = 1 TO 12
READ m$
READ C4
REM C4 = 1.28
L = 29.13
c3 = (C4 * COS(L * X))
READ ssh
REM SSH = 6.7
c2 = (ssh / 12) * (.2 / (1 + (.1 * L)))
c1 = 4.186 * (c2 + c3)
c5 = (L * 3.141592654#) / 180
READ rh
REM rh = 62
c6 = ((ssh) / 12) * (rh ^ (1 / 3)) / 100
READ N
REM N = 17
D = 23.45 * SIN((360 * (284 + N) / 365) * X)
st = 12
h = (15 * (st - 12))
REM K=SIN (SAL)
K = (COS(L * X) * COS(D * X) * COS(h * X)) + (SIN(L * X) * SIN(D * X))
REM UU=TAN(SAL)
UU = K / SQR(1 - K ^ 2)
sal = ATN(UU)
sal = sal * (180 / 3.141592654#)
REM PRINT "sal="; sal
c7 = 1 / sal
f1 = c5 * (c6 - c7)
HT1 = 1.53 * c1 * EXP(f1)
HT1 = HT1 / 3.6
HT1 = HT1 * 200
HT1 = INT(HT1)
READ HTA
HTA = HTA * 100
sd = ((HT1 - HTA) / HTA) * 100
SL1 = 0
READ N1
Z = (((360 * (284 + N1) / 365) * X))
```

APPENDIX (2)

```
CLS
REM " THIS PROGRAM CALCULATES THE SOLAR VALUES USING
ASHRAE AND THE TROPICAL"
REM " EQUATIONS AVERAGED OVER 11 HOURS DAILY FOR HUN  29.13
DEG.TABLE (7-4)"
X = 3.141592654# / 180
LPRINT"*************************************************************"
LPRINT TAB(3); "m"; TAB(10); "n"; TAB(16); "rh"; TAB(22); "ssh"; TAB(29);
"sal"; TAB(40); "how"; TAB(52); "ht1"; TAB(62); "hta"; TAB(74); "MIT"
LPRINT"*************************************************************"
LPRINT TAB(15); "(%)"; TAB(22); "(hr)"; TAB(28); "(deg)"; TAB(38);
"(w/m^2)"; TAB(50); "(w/m^2)"; TAB(59); "(w/m^2)"; TAB(73); "(w/m^2)"
LPRINT"====================================================="
FOR i = 1 TO 12
READ m$
READ C4
REM C4 = 1.28
L = 29.13
c3 = (C4 * COS(L * X))
READ ssh
REM SSH = 6.7
c2 = (ssh / 12) * (.2 / (1 + (.1 * L)))
c1 = 4.186 * (c2 + c3)
c5 = (L * 3.141592654#) / 180
READ rh
REM rh = 62
c6 = ((ssh) / 12) * (rh ^ (1 / 3)) / 100
D = 23.45 * SIN((360 * (284 + N) / 365) * X)
st = 12
h = (15 * (st - 12))
REM K=SIN (SAL)
K = (COS(L * X) * COS(D * X) * COS(h * X)) + (SIN(L * X) * SIN(D * X))
REM UU=TAN(SAL)
UU = K / SQR(1 - K ^ 2)
HTA = HTA * 100
sd = ((HT1 - HTA) / HTA) * 100
LPRINT TAB(0); m$; TAB(8); N; TAB(15); rh; TAB(21); ssh; : LPRINT USING
"##.##"; TAB(28); sal; : LPRINT TAB(39); HOW; : LPRINT TAB(51); HT1;
TAB(61); HTA; : LPRINT USING "####.###"; TAB(72); mit
IF i = 12 THEN GOTO 10
LPRINT "------------------------------------------------------------------------------------"
10 FOR T = 1 TO 3000: NEXT T
NEXT i
LPRINT"*************************************************************"
END
```

APPENDIX (3)

```
CLS
 x = 3.141592654# / 180
 L = 29.13
 A = .3
 b = .43
```

```
j = 0
nn = 0
10 j = j + 1
IF j = 13 THEN END
READ A$
PRINT TAB(40); A$
PRINT"***************************************************"************"
PRINT TAB(3); "DAY"; TAB(10); "a"; TAB(16); " b"; TAB(22); "nt"; TAB
(28); "Ho"; TAB(35); "n"; TAB(50); "Hta"; TAB(62); "Ht2"; TAB(71);
"SD"
PRINT"**************************************************************"
PRINT TAB(20); "h"; TAB(26); "(w/m^2)"; TAB(42); "(kw.h/m^2.day)";
TAB(57); "(kw.h/m^2.day)"; TAB(71); "(%)";
PRINT"==========================================================="
mn = 0
mnn = 0
ss = 0
sss = 0
s = 0
SNT = 0
SHTA = 0
ON j GOTO 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210
, 220
100 W = 1: ND = 31: GOTO 220
110 W = 32: ND = 59: GOTO 220
120 W = 60: ND = 90: GOTO 220
130 W = 91: ND = 120: GOTO 220
140 W = 121: ND = 151: GOTO 220
150 W = 152: ND = 181: GOTO 220
160 W = 182: ND = 212: GOTO 220
170 W = 213: ND = 243: GOTO 220
180 W = 244: ND = 273: GOTO 220
190 W = 274: ND = 304: GOTO 220
200 W = 305: ND = 334: GOTO 220
210 W = 335: ND = 365: GOTO 220
220 noO = 0
FOR no = W TO ND
noO = noO + 1
READ nt
READ Hta
Z = (((360 * (284 + no) / 365) * x))
d = 23.45 * SIN(Z)
GSC = 1353
PRINT : PRINT
GOTO 10
END
```

APPENDIX (4)

```
CLS
REM                    " PROGRAM (5)"
REM "THIS PROGRAM CALCULATES THE CONSTANTS A AND B FOR
SUN-SHINE HOURS
REM  EQUATION GIVEN BY DUFFIE TABLE (3-4). "
x = 3.141592654# / 180
L = 29.13
j = 0
nn = 0
sam = 0
sbm = 0
PRINT "*********************************************************"
PRINT TAB(11); "m"; TAB(23); "a"; TAB(33); "b"
PRINT "================================================="
10 j = j + 1
IF j = 13 THEN GOTO 111
SHTA = 0
ON j GOTO 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200,
210, 220
100 W = 1: ND = 31: GOTO 220
110 W = 32: ND = 59: GOTO 220
120 W = 60: ND = 90: GOTO 220
130 W = 91: ND = 120: GOTO 220
140 W = 121: ND = 151: GOTO 220
150 W = 152: ND = 181: GOTO 220
160 W = 182: ND = 212: GOTO 220
170 W = 213: ND = 243: GOTO 220
180 W = 244: ND = 273: GOTO 220
190 W = 274: ND = 304: GOTO 220
200 W = 305: ND = 334: GOTO 220
210 W = 335: ND = 365: GOTO 220
220 noo = 0
ws = ws * (180 / 3.141592654#)
PRINT"**********************************************************"
 PRINT "ay="; msam
 PRINT "by="; msbm
 END
A = .53
b = .44
10 J = J + 1
IF J = 13 THEN
END"***********************************************************"
PRINT TAB(3); "DAY"; TAB(10); "a"; TAB(16); " b"; TAB(22); "nt"; TAB(30);
"n"; TAB(37); "Hta"; TAB(51); "Htt"; TAB(69); "SD"
PRINT"**********************************************************"
PRINT TAB(22); "h"; TAB(33); "(kW.h/m^2.day)"; TAB(50); "(kW.h/m^2.day)";
TAB(69); "(%)";
PRINT"=================================================="
GOTO 10
END
```

APPENDIX (5)

```
CLS
x = 3.141592654# / 180
L = 29.13
A = .53
b = .44
IF J = 13 THEN END
READ A$
PRINT TAB(40); A$
PRINT"**********************************************************"
PRINT TAB(3); "DAY"; TAB(10); "a"; TAB(16); " b"; TAB(22); "nt"; TAB(30);
"n"; TAB(37); "Hta"; TAB(51); "Htt"; TAB(69); "SD"
PRINT"**********************************************************"
PRINT TAB(22); "h"; TAB(33); "(kW.h/m^2.day)"; TAB(50); "(kW.h/m^2.day)";
TAB(69); "(%)";
PRINT"=================================================="
ON J GOTO 100, 110, 120, 130, 140, 150, 160, 170, 180, 190, 200, 210, 220
100 W = 1: ND = 31: GOTO 220
110 W = 32: ND = 59: GOTO 220
120 W = 60: ND = 90: GOTO 220
130 W = 91: ND = 120: GOTO 220
140 W = 121: ND = 151: GOTO 220
150 W = 152: ND = 181: GOTO 220
160 W = 182: ND = 212: GOTO 220
170 W = 213: ND = 243: GOTO 220
180 W = 244: ND = 273: GOTO 220
190 W = 274: ND = 304: GOTO 220
200 W = 305: ND = 334: GOTO 220
210 W = 335: ND = 365: GOTO 220
220 noO = 0
noO = noO + 1
READ hta
Z = (((360 * (284 + no) / 365) * x))
d = 23.45 * SIN(Z)
GSC = 1353
REM R1 = (86400 * GSC) / 3.141592654#
REM R2 = (1 + (.033 * ((360 * N) / 365)))
REM R3 = (COS(L * X) * COS(D * X) * SIN(Ws * X))
REM R4 = ((3.141592654# * Ws) / 180)
REM R5 = (SIN(L * X) * SIN(D * X))
REM HOJ = (R1 * R2) * (R3 + (R4 * R5))
s = s + HOW
htt = (A + (b * (nt / n))) * HOW * 0.0036 * ((nt / n) * 5 / J)
MHOKW = (MHOW / 1000) * 3.6
PRINT "MHtt="; MHtt
GOTO 10
END
```