ON THE ESTIMATION OF THE PRODUCTIVITY OF THE ROOF TYPE SOLAR STILLS AT DIFFERENT LOCALITIES IN THE U.A.R.

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1) Considerable attention has been paid in Egypt to solve the problem of water supplies in the arid and semi-arid zones. In addition to the many other methods, the method of utilizing solar energy to distill water has been considered.

2) Numerous experiments on solar distillation, has been carried on since 1955 by the University College for Girls and the National Research Centre. Numerous stills including several variations have been constructed and tested, and a great deal of information has been accumulated on their maintenance, production and efficiency. From the practical point of view, solar stills of the greenhouse type with symmetrical glass cover has been found superior to the inclined tray units.

3) As far as the roof type is concerned, two important experiments have been undertaken :

a) the construction of a permanent base still (1) of an area of 40 m^2 : the results obtained, for a period of nearly a whole year, are presented in figure 1. It gives the relation between the daily productivity and the amount of incident solar radiation received on a horizontal surface per day.

b) the construction of a metallic foldable still (2) of an area of 1.2 m^2 : the results obtained for 3 summer months are shown in figure 2. It gives the relation between the hourly production for clear sky conditions and the corresponding amount of the incident solar radiation.

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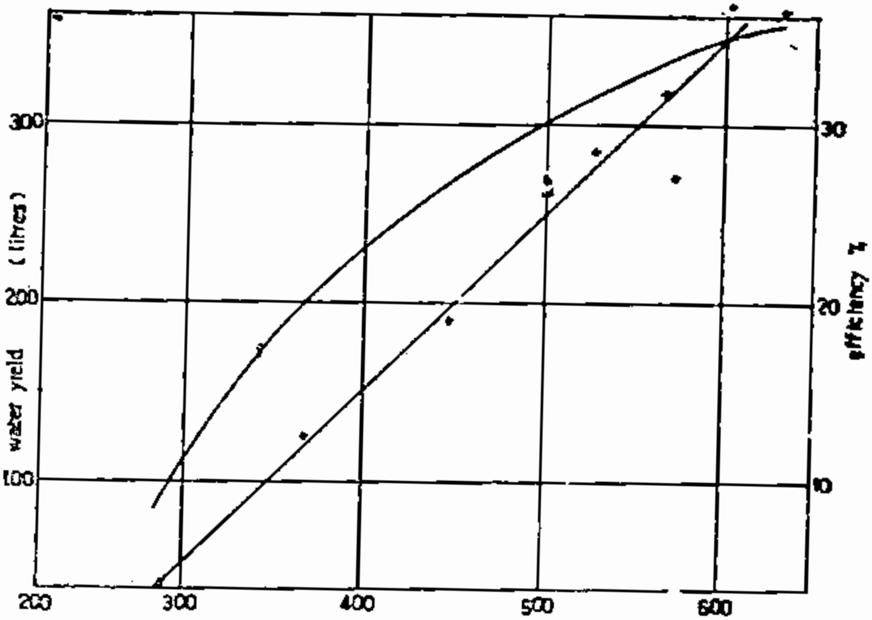
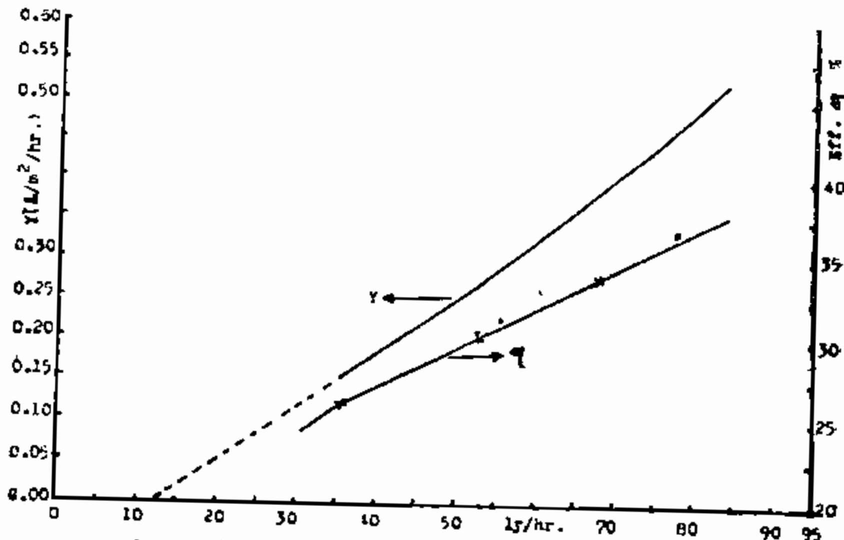


FIGURE ( ) Intensity of total solar radiation (ly/day)

4) To make use of the results obtained in estimating the productivity of any still of the roof type, constructed at any locality in the U.A.R., it is required to know, for the different months of the year, either the mean values of the total daily radiation falling on a horizontal surface, or its hourly distribution.



Figure(II).Variation of yield and efficiency with incident solar energy on the roof type still.

5) Regression equations of the Angstrom type have been used for many years for estimating mean values of the total daily radiation falling on horizontal surfaces from sunshine records.

The original Angstrom formula has been modified by Black, Bonython and Prescott (3) and is written in the following form :

$$Q = Q_0 \left(0.23 + 0.84 \frac{n}{N}\right) \qquad (1)$$

where Q = mean global daily radiation on the horizontal plane for the period under consideration (for clear sky conditions).

Q_0 = total radiation per unit area falling on a horizontal plane outside the atmosphere.

n = mean daily amount of bright sunshine hours.

N = maximum possible amount of sunshine hours.

6) To calculate Q_0, the values determined by Milanovitch given in the Smithsonian Meteorological Tables (4) were increased by the ratio 2.00/1.94 to allow for the changed value of the solar constant as a result of Johnson's recommendations. The values for an individual day were plotted on an extended scale. A smooth curve was drawn and Q_0 was obtained by planimetry. The results obtained (mean monthly values) for latitudes 20°N & 30°N are given in Table 1.

Table 1 : Mean values for calendar months of total daily radiation on a horizontal plane outside the atmosphere of the earth. Latitude 20°N & 30°N (Solar constant 2.00 cal. cm^{-2} min^{-1}) :

	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
Lat. 20°N	659	747	848	924	959	965	959	934	877	784	687	631
Lat. 30°N	521	632	772	899	1073	1063	987	927	822	683	558	487

7) The number of hours of sunshine, n, are evaluated by means of a sunshine recorder. In remote areas, where solar distillation is needed no records are obtained and it has been found necessary to account for observations of cloudiness, taken at the widespread network of meteorological stations. Table 2 gives the values, we have obtained for such localities.

Table 2: Monthly variation of the degree of cloudiness (0-8)

Zone	Cloudiness J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
Mediterranean	3.5	3.1	2.9	2.4	2.1	1.2	1.3	1.5	1.6	2.1	3.0	3.4
Arabic Desert	1.9	1.6	1.4	1.2	0.2	0.2	0.3	0.5	0.9	1.2	1.9	0.9
Lybian Desert	1.4	1.2	0.8	0.9	0.2	0.1	0.1	0.1	0.5	0.9	1.5	0.9

The sunshine duration, or the cloudiness is now known, the amount of solar radiation incident daily on a horizontal surface can be calculated. With the help of figure 1, an approximate evaluation of the daily water yield can be obtained.

8) On the other hand, in case it is required to give a more precise evaluation of the productivity of the still, it is recommended to make use of the experimental results obtained and presented in figure 2. To this end, the hourly distribution of the total solar radiation q_0 should be calculated (7) from the relation:

$$\frac{q_\theta}{Q} = \frac{\pi}{4} \times \frac{\frac{24}{\pi}\sin\frac{\pi}{24}\ \text{ces}\ \omega - \cos\omega_s}{\sin\omega_s - \omega_s \sin\omega_s} \qquad (2)$$

where :

Q = solar radiation received during the day.
q_θ = solar radiation received during the hour from $\theta - 1/2$ to $\theta + 1/2$

ω = hour angle from noon = $\frac{\pi}{12}\theta$ ($\theta = 15^\circ$ per hour).
ω_s = hour angle at sunset [$\cos\omega_s = -\tan\phi\ \tan\delta$]
ϕ = latitude of the place.
δ = solar declination.

The most important conclusion to be drawn from this equation is that the ratio of hourly to daily radiation for a given hour is a function of the sunset hour angle ω, or in other words of the theoretical maximum possible duration of sunshine for the particular latitude and time of the year.

9) As an application of this study, the daily productivity of

Table 3 :- Estimated hourly values of total radiation q(ly/hr) and water yield y $cm^3/m^2/hr$ for the different months

w(hour)	±1		±2		±3		±4		±5		±6		Q	Y
Month	q	y	q	y	q	y	q	y	q	y	q	y	(ly/day)	(L/m^2/ day)
Jan.	42	300	39	180	31	125	21	60	9	-	-	-	284	1.63
Feb.	54	280	50	250	42	200	30	120	16	25	-	-	384	2.25
March	67	380	62	335	53	270	41	19[illegible]	25	85	8	-	512	3.02
April	71	410	67	380	58	305	46	225	31	125	15	20	576	3.44
May	73	425	69	390	61	330	50	250	36	160	20	55	618	3.72
June	75	440	71	410	62	335	52	265	38	180	23	70	642	3.94
July	74	340	70	400	62	335	51	255	37	165	22	70	632	3.81
Aug.	72	420	68	385	59	315	48	235	33	135	1[illegible]	35	594	3.55
Sep.	68	385	63	350	55	285	42	200	27	100	11	—	532	3.14
Oct.	57	300	52	265	44	210	33	140	19	45	3	—	416	2.42
Nov.	44	210	40	185	33	140	23	125	10	—	-	—	300	1.82
Dec.	39	180	36	155	29	115	19	45	7	—	-	—	260	1.49

solar stills at Giza has been estimated. We have proceeded as follows :

a. calculate the hourly values of the total radiation for the different months of the year using equation 2. (The values of Q used are those of the actual measurements at Giza (8).
b. evaluate for every hour, the corresponding expected yeild from figure 2.
c. add 0.5 L/m^2 to the sum of the hourly amounts per day, to represent the production by night.

The results obtained are presented in Table 3, showing a good agreement with the results obtained experimentally (1).

References

(1) Elnesr, M.K. Proceeding of the Math. and Phys. Soc. of the U.A.R. 24, p. 25 (1960).
(2) Soliman, S.H. M. Sc. Thesis Cairo University (1963).
(3) Black, J.N. Q.J. Roy. Met. Soc., 84, p. 231 (1954).
(4) Smithsonian. Meteorological Tables 6th Ed. Washington (1951).
(5) Johnson, F.S. J. Met. 2(6) p. 131 (1954).
(6) Climatological Normals. Meteorological Dept. Cairo (1952).
(7) Whillier, A. Arch. fur Meteo. Geophysik und Bioklimatologie Serie B, 7 p. 197 (1956).
(8) Elnesr, M.K. & El-Sabban. J. of Solar Energy Science & Engineering, 4, 1, p. 48 (1960).