ON THE DETERMINATION OF THE TOTAL AMOUNT OF SOLAR RADIATION RECEIVED BY A FLAT PLATE COLLECTOR

By

M. K. Elnesr* and A. M. Khalil**

---

1 — One of the most important applications of solar energy is the production of hot water for domestic use. The flat plate solar heat collector is commonly used. It consists of :

a) an insulated heat absorbing surface painted black to increase heat absorption. This surface may be a metallic sheet fastened to its side, facing the sun rays, some form of piping through which water may be circulated.

b) insulating material below and adjacent to the lower surface of the absorber, protected in a wooden box.

c) one or more sheets of glass (or any other transparent material) above the absorbing surface covering the collector edge to edge and sealed by good mastic sealing compound to prevent dust or rain entering the collector.

The collector should be inclined towards the equator at a certain angle of tilt governed by the locality. The angle of optimum tilt (i.e. when the collector receives maximum energy) is that angle which a south facing tilted surface can make with the horizontal, such that the solar beam will fall normally on it at noon time.

For our latitude 30°N, the optimum tilt angle for the different months of the year, as we have calculated (1) are :

J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
51	43	32	20	11	7	9	16	27	39	49	53

---

* University College for Women Ain Shams University.
** National Research Centre.

2 — For any study on the performance of a heat collector, it is required to know the amount of incident radiation falling on it at any time. This can be done by using a solarimeter or a pyrheliometer tilted to the horizontal at the same angle as the collector. In most solar energy laboratories, pyrheliometers are very delicate and require continuous calibration and are used only for recording the solar radiation on the horizontal. The other alternative which is commonly used is the evaluation of incident energy on the collector from that measured on the horizontal. The procedure used (2) is as follows :

— estimate (3) from the total solar radiation intensity on the horizontal, its direct and diffuse parts.

— calculate by simple trigonometry (1), the component of the direct part on the collector.

— add to this direct component the amount of diffuse radiation (3) expected to be received by the collector at the optimum tilt angle.

Evidently such method is laborious especially it should be repeated several times during the operation of the collector. To simplify the problem, we have adopted the above procedure, to the pyrheliometric measurements at Helwan Observatory (4) and calculated for clear sky conditions and for the different months of the year, the energy falling on the collector when tilted at the optimum tilt angle. The ratio between the hourly amounts of this energy and that received on a horizonatl surface are shown in Table 1.

Table 1. Ratio hetween the hourly rates of total solar radiation on a surface at the optimum tilt angle and that on a horizontal surface ($\phi = 30°N$)

Solar Time AM	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.	Solar Time PM
6	—	—	—	—	.92	.94	1.00	1.00	—	—	—	—	18
7	—	1.90	1.14	.94	.98	1.00	.98	.95	.96	1.42	—	—	17
8	2.00	1.46	1.13	.98	.99	.98	.99	.97	1.05	1.31	2.07	2.17	16
9	1.65	1.37	1.14	1.02	.99	.99	.98	1.00	1.07	1.25	1.57	1.76	15
10	1.54	1.32	1.14	1.04	1.00	.99	1.00	1.03	1.09	1.23	1.45	1.59	14
11	1.48	1.29	1.14	1.05	1.02	1.00	1.01	1.03	1.11	1.24	1.42	1.53	13
12	1.46	1.30	1.14	1.06	1.02	1.01	1.01	1.04	1.09	1.23	1.41	1.52	14

To calculate the amount of solar energy incident on the collector at the optimum tilt angle, at any time of the day for the same latitude, the corresponding intensity on the horizontal as measured by a solarimeter is multiplied by the suitable ratio from Table1.

3 — Before applying such simple method, it has been found necessary to check its validity. To this end, a Kipp solarimeter has been fixed on a movable wooden board such that it can be oriented at any direction. During a period of two months, May and June 1962, and on every clear day, the optimum tilt angle was calculated in advance and the solarimeter was adjusted accordingly. The ratio between the readings of the solarimeter at this position and when it is horizontal was calculated hourly and the results obtained, as shown in Table 2, are compared with the corresponding estimated values given in Table 1.

Table 2. Comparison of measured and estimated values of the ratio, R, between the intensity of radiation on optimum tilt and horizontal surfaces :

Month	No. of runs	Ratio R											
		S.T.	9	10	11	12	13	14	15	16	17	18	Mean
May	7	Rexp.	—	.97	1.01	1.02	1.01	1.01	1.00	.98	.96	—	.95
		Rcal.	.99	1.00	1.02	1.02	1.02	1.00	.99	.99	.98	.92	1.00
June	7	Rexp.	1.00	1.00	1.01	1.02	1.01	1.00	1.00	.99	.97	.93	.99
		Rcal.	.99	.99	1.00	1.01	1.00	.99	.99	.98	1.00	.94	.96

The excellent agreement between the experimental and calculated ratios confirms the validity of this method in converting solarimetric readings on the horizontal to the corresponding heat values on a flat plate solar collector mounted at the same locality and tilted at the optimum tilt angle.

References

(1) Brown, A.I.x Marco, S.M. Introduction to Heat transfer, N.Y. McGraw Hill 69 (1951).
(2) Anderson, L.B. Symposium on Space Heating with Solar energy, M.J.T. p. 17 (1950).
(3) Heat. Vent. Air Condition. Guide, 30, 266-271 (1952).
(4) Elnesr, M.K. & Khalil, A.M. U.N. Conference on new sources of energy. Rome 35/S/12 (1961).