J. App. Em. Sc: 1(1) 195-208, June 2004

THE THEORETICAL ANALYSIS FOR A FLAT PLATE COLLECTOR

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Abstract:

Theoretical calculations are performed on various flat plate collectors, i.e., dull nicked plated steel, tin plated, nickel, copper and aluminum sheets, at various tilt angles for Quetta (Pakistan) and were found in good agreement with experimental results. We used isotropic model to calculate total solar radiations, optimization of thermal performance of flat plate collectors both at chiect and tilt angles and indeed the statistical analysis. Absorbed energies for them flat plate collectors were determined we found that the maximum solar energy in the form of absorbed heat is intercepted at s=o/s= &-150, where S I the tilt angle and d is the latitude of Quetta (o/=18030, altitude 1799m. Aluminum sheet is found as the best receptor of solar energy as compared to other flat plate collectors. The thicknesses of all the collectors used are same.

Introduction.

We estimated the global solar radiation on an inclined surface [table No.1], by using the isotropic model of Hay[J.H.Hay, (1979)], for a period of 1985-1994, at Quetta, Pakistan by considering yearly average values over the months of the year.

In this study we considered thermal systems of solar energy. Different methods have been devised to harness energy from the sun in the form of heat [Howard.J.Moor (1993)], to reasonable temperature up to 300^0C. This includes the concentrating surface tracking devices, etc. However, in its simplest arrangement flat plate collectors normally raise the temperature in the range of 60^0-100^0C, depending on the specific treatment and design of the surface employed.

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TABLE.1.

TOTAL SOLAR RADIATION (Ht) RECEIVED ON INCLINED SURFACE AT QUETTA ($MJ\ m^{-2}\ d^{-1}$).

The calculation for solar radiations were done using isotropic model [1] at various tilt angles where ϕ=18.30° is the latitude of Quetta.)

Month	S=0°	S=Φ+15°	S=Φ+30°	S=Φ+45°	S=Φ°	S=Φ-15°	S=Φ-30°	S=Φ-45°	S=60°
JAN	12.62	20.69	12.80	6.48	28.91	34.27	6.58	32.96	3.71
FEB	16.69	23.96	9.88	10.05	29.59	32.48	10.05	26.84	5.53
MAR	17.84	21.48	18.08	13.25	23.21	44.71	19.86	15.52	9.20
APR	23.37	24.40	23.71	20.14	23.03	19.83	15.17	10.78	12.28
MAY	25.36	23.91	25.0	24.26	20.21	15.12	11.07	7.86	21.17
JUNE	25.44	22.96	25.06	25.8	17.25	13.72	9.62	7334	23.30
JULY	22.16	20.43	21.06	21.86	17.09	13.26	9.77	7.75	28.63
AUG	22.05	21.73	22.35	20.27	19.71	16.0	12.13	8.82	16.82
SEP	21.56	24.30	21.56	17.16	22.87	22.52	18.54	13.70	12.21
OCT	18.24	23.94	18.50	12.17	26.12	28.91	26.85	22.20	7.45
NOV	14.15	22.32	14.15	7.56	29.25	34.27	34.98	31.50	4.10
DEC	11.98	20.65	12.14	5.75	29.60	35.90	33.94	30.49	6.93

One third of energy consumption in domestic and commercial appliances where about 80% of energy which is used for water and space heating for ranging between 60^0-80^0C. For this purpose low grade fuel is required or alternatively the application of simple collector could meet this requirement, thus providing a substantial share of global energy demand which could, in principle, be supplied by the simple solar energy collection devices. A number of medium temperature collectors of various designs and using different materials as a source of heat transfer have been developed for commercial applications [Close, D.J, 1962, - Gupta C.L and Gary H.P. 1986,- Nahar N.M, (1988),- Nahar N.M and Gupta J.P.1987.- Yellol S.L and Sobotka. R.1964] . N.M.Nahar[Nahar.N.M. 1992] compared pay back periods for various water heating systems using fire wood, coal and other fuels with that for a flat plate collector. He showed that solar collector is economically viable in terms of pay back period. Extensive research and development efforts are being carried out in suitable designing commensurate with effective heat transfer for material selection to achieve high performance efficiency and to make it cost effective. J.E. Minardi and H.N Chung[J.E Minardi and H.N Chuang, 1975.] , D.K. Land Storm, et.al.[D.K. Land Storm, et.al 1978] studied the performance of a collector using the black liquid concept. G.Camera Roada and M.Bertla [D.K.Land Strom, G.H.Stick Ford, Jr.S.G. Talbert and R.E.Hers. 1978] analysed black liquid solar collector and presented a model that could be used to determine design criterion for such type of collector. Nevertheless the design of collector followed the use of selective coatings to achieve maximum thermal energy absorption.

OPTIMIZATION OF SPECTRAL EMISSIVE POWER FOR SOLAR RADIATIONS.

The efficiency of collector to convert solar energy into thermal energy depends upon several parameters such as diffusivity (α) of the collector surface for incident solar radiation, emissivity (ε) of collector surface for longer wave lengths and heat losses due to conduction, convection and radiation.

The methods of optimization for these parameters are briefly reviewed [Twidell and Tony1986]. When a metal surface receives radiation from sun it gets heated and then radiated in the longer wavelength region [Siegel Howell, (1972)] . An equilibrium is reached when the energy absorbed by the surface equals to the energy radiated or lost by the surface. A solar collector absorbs radiation at wave length around 0.5μm (from a source at 6000K) and emits radiation at wave lengths around 10μm (from a source at >>350K).

Therefore an ideal surface for a collector would maximize its energy gain and minimize its energy loss by having a high diffusivity α and low emmitance ε[Siegel Howell, (1972)]. Thus the thermal performance of a flat plate collector can be improved by increasing the transmission of energy through the collector to the working fluid by reducing thermal losses. The thermal properties of five different materials used in flat plate collector are given in table [2].

The theoretical analysis for a flat plate collector is well established and can be summarized as

$$Q_0=Q_a-Q_l$$

Where Q_0 is the power output,Q_a is the power absorbed by the collector and Q_l is the power lost to the surroundings.