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Determination of Total Internal Heat Transfer Coefficient of Single Slope Solar Still with Different Depth of Water

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Abstract

Two domestic type single slope solar stills to inclinations 23^0 and 30^0 in accordance to the latitude of Indore (M.P) for summer conditions . Analysis of convective heat transfer coefficient was done based on the normal atmospheric conditions. The yield with both 23^0 and 30^0 of inclinations and in considerations with different parameters such as depth of water , latitude of Indore and inclinations of upper surface was evaluated. After the evaluations and calculations it was found thatthe yield in case of 30^0 inclinations. Solar still was more and increase with the increase in the angle of inclinations.

Keywords: Heat transfer coefficient, solar distillation.

1. Introduction

The basic process for solar distillation is converting is converting salt water / saline water from sea into potable water by using solar energy. Due to the increase in demand of distill water in the feild of biomedical industries,batteries, automobiles and other industries. It has become the need of the day to avail such huge quantity of water every day. A study on the present conditions of research work was carried out to achieve the distill water at more efficient and faster rate. Only two domestic type single slope solar stills with different angles of inclinations were designed. According to the latitude of Indore monthly performance of both the still were studied for the installations at Indore.

METHODOLOGY

Experimental procedure: Two domestic type single slope solar stills of 23^0 and 30^0 inclinations are designed according to the latitude of Indore. The base of both solar stills is of dimensions 50X50 cm. The entire still is covered by a FRP (fibre rainforced plastic) sheet while the upper surface of the still is covered by a toughened glass. It consist of one inlet and one outlet. Both the solar still consists of water at different depths. The evaporative pan was covered bysheet of clear glass which is tilted at different angle to let fresh water that conenses on its underside move down to a collecting trough. For different modes of experimentation and different depth . some parameters were measured every hour for a period of 24 hour.

1.Total radiation on the glass cover.

2. Diffuse radiation on the glass cover .

3. Global radiation on the glass.

4.Inner glass temperature.

5.Temperature of fresh water in the still.

6. Temperature of vapour on the glss cover .

7.Ambient temperature.

8. Output from the still.

The temperature of outer glass, inner glass, vapour were observed and noted with the help of temperature indicators. The hourly difference between solar radiation, glass cover ambient temperature and hourly yield was recorded. The hourly output with different depth of water were used to calculate the values of different heat transfer coefficients. The values of the observations are shown in the table. The present result s of these value will be used in calculating and comparing the heat transfer coefficients. The photograph of the active solar still used for experimentation are shown in the fig.

The methodology used by Tiwari & Shruti (1998), and Kumar and Tiwari 1996 evaluating c & n. We know the relation between Nusselt no. , Grashoff no., Prendtl no.

$Nu=f(Gr.Pr)$

For heat flow from the horizontal water surface in the upward direction, i.e. against the forces of gravity, Jakob (1994, 1957) has suggested the following relationship by correlating the experimental data of Mull and Reiher:

$Nu= C\,(Gr.Pr)^n$

$Nu = (h_{cw}.d/k) = C(Gr.Pr)^n$

$h_{cw} = (k/d)\,C(Gr.Pr)^n$

The relation between evaporative heat transfer coefficient and convective heat transfer coefficient.

$$h_{ew} = 0.016273*h_{cw}*(P_w-P_{ci} / T_w-T_{ci})$$

$$h_{ew} = 0.016273*[(k/a)c(Gr.Pr)^n*(P_w-P_{ci}/ T_w-T_{ci})]$$

Thus the heat transfer per unit area per unit time evaporation from the water surface to glass cover

$q_{ew} = h_{ew}\,(T_w-T_{ci})$

$q_{ew}= 0.016273*[(k/d)c(Gr.Pr)^n*(P_w-P_{ci} / T_w-T_{ci})*(T_w-T_{ci})]$

$= 0.016273[(k/d)c(Gr.Pr)^n(P_w-P_{ci})]$

It can also be written as $q_{ew} = h_{ew}\,(T_w-T_{ci})$

The rate of mass transfer m_{ew} is given by

$m_e = q_{ew}/L$

$m_w = 0.016273(P_w-P_{ci})(k/d)c(Gr.Pr)^n*(3600/L)*A_w$

let, $R=0.016273(P_w-P_{ci})(k/d)(3600/L)*(0.5*0.5)$

$m_w=RC(R_a)^n$

therefore, $R_a= (Gr.Pr)$

$m_w/R =C(R_a)^n$ ……….(1)

equation (1) can be written as,

$y = a\,x^b$ ………(2)

where, $y= m_w/R$; $a=c$; $x=R_a$; $b=n$

equation (2) can be reduced in an equation of straight line by taking log on both sides

Thermal equations for analysis

EVALUATION OF CONVECTIVE HEAT TRANSFER COEFFICIENT

Convective heat transfer coefficient can be defined as the amount of heat transmitted for a unit temperature difference between the fluid and unit area of the surface in unit time. The value of h_c depends on the following factors:

1. Thermodynamic and transport property (viscosity, density, specific heat etc.)
2. Nature of fluid flow
3. Geometry of the surface

Some dimensionless number:

1. Nusselt's no.(Nu) = $h_{cw}/(k/d)$ = convective heat transfer coefficient/ conductive heat transfer coefficient
2. Grashoff's no.(Gr) = $g\beta d^3\rho^2\Delta t/\mu^2$ = Buoyancy force/ Viscous force

3. ~~.~~ Prendtl no.(Pr) =$\mu C_p/k$ =momentum diffusivity/ thermal diffusivity
4. Rayleigh no.(Ra) = (Gr.Pr)

In actual convection, transition in a boundary layer depends on the relative magnitude of the buoyancy and viscous force in the fluid. It is correlated in terms of a Ra number, which is the product of Gr and Pr numbers, where Gr looks after the type of flow and Pr the type of fluid. The temperature dependent physical properties of vapour (humid air) used.

Temperature dependent physical properties of vapour

Quantity	Symbol	Expression
Specific heat	C_p	999.2+0.1434 x T_v + 1.101 x 10^{-4}x T_v^2-6.7581x 10^{-8}x T_v^3
Density	ρ	353.44/(T_v x 273.15)
Thermal conductivity	k	0.0244 x 0.7673 x 10^{-4} x T_v
Viscosity	μ	10718 x 10^{-5} + 4.620 x 10^{-8}xT_v
Latent heat of Vaporization of water	L	3.1615x10^6x[1-(7.616x10^{-4}xT_v)];
for $T_v > 70^0$C		2.4935x10^6x[1-9.4779x$10^{-4}$$T_v$ + 1.3132x10^{-7}xT_v^2-
Partial saturated Vapor pressure at condensing cover temperature	P_{ci}	exp[25.317 – 5144/(T_{ci} + 273)]
Partial saturated vapor pressure at water temperature	P_w	exp[25.317 – 5144/(T_w + 273)]
Expansion factor	β	1/(T_v + 273.15)

DETERMINATION OF RADIATIVE HEAT TRANSFER COEFFICIENT

H_{rw}=€effσ[$(T_w+273)^2+(T_g+273)^2$][T_w+T_g+546]
Where H_{rw} is the radiative heat transfer coefficient from the water surface to the glass cover

DETERMINATION OF EVAPORATIVE HEAT TRANSFER COEFFICIENT

$H_{ew} = 16.273*10^{-3}H_{cw}(P_w- P_g)/(T_w-T_g)$

Observations:

Dimension of single slope solar still with 23° inclination

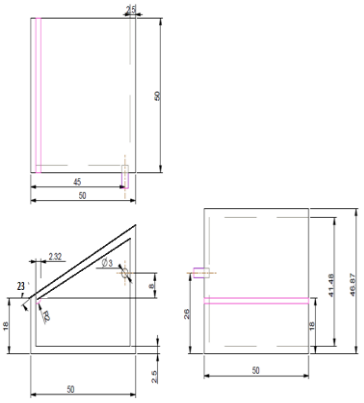


Fig : layout of single slope solar still with 23° inclination

Dimensions of single slope solar still with 30° inclination

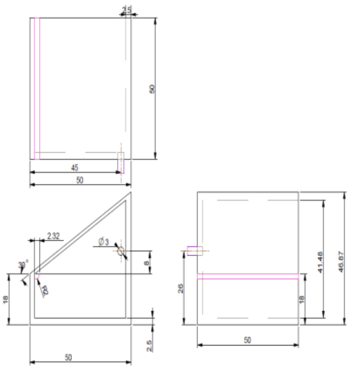


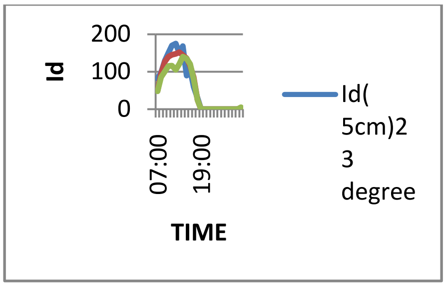
Fig : layout of single slope solar still with 30° inclination

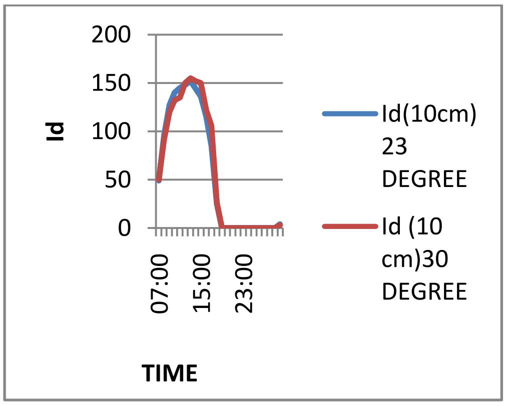
S No.	Time	I_g (W/m^2)	I_d (W/m^2)	T_w (°C)	T_{gi} (°C)	T_{go} (°C)	T_a (°C)	Y_a (%)	Yield (ml)
1	7:00	83.33	55.9	24	26	25	25	30.7	0
2	8:00	270	86.8	26	32	30	27	40	1
3	9:00	570	100	29	39	36	21	31	1
4	10:00	805	110	34	41	38	31	25	1
5	11:00	929	101	39	43	41	32	17	2.3
6	12:00	1005	120	46	47	45	33	19	32.3
7	13:00	950	122	50	46	42	33	12	58.1
8	14:00	863	113	50	47	44	34	10	62.2
9	15:00	611	83	49	45	40	33	13	76.8
10	16:00	320	65	47	43	39	34	10	66
11	17:00	77	44	43	38	34	33	10	40.5
12	18:00	29	25	39	34	31	31	10	47.2
13	19:00	0	0	36	31	29	30	10	25.4
14	20:00	0	0	33	29	27	28	10	23.2
15	21:00	0	0	31	27	26	27	10	15.4
16	22:00	0	0	29	26	25	26	11	12.3
17	23:00	0	0	28	25	24	26	12	8.3
18	0:00	0	0	27	24	24	26	11	8.3
19	1:00	0	0	26	24	24	25	18	6.2
20	2:00	0	0	26	24	23	25	20	5
21	3:00	0	0	25	24	23	26	25	4
22	4:00	0	0	25	23	22	24	24	5
23	5:00	0	0	25	23	22	22	27	4
24	6:00	5	3	24	22	21	22	31	4

S No.	Time	I_g (W/m^2)	I_d (W/m^2)	T_w (°C)	T_{gi} (°C)	T_{go} (°C)	T_a (°C)	Y_a (%)	Yield (ml)
1	7:00	100	32	25	27	25	25	31	0
2	8:00	300	75	25	32	31	27	37	6.9
3	9:00	590	86	27	37	36	30	38	6
4	10:00	831	96	30	41	41	31	18	0.5
5	11:00	941	108	34	44	42	32	16	1
6	12:00	982	110	40	45	45	33	12	8
7	13:00	918	130	44	47	44	33	23	16.3
8	14:00	781	95	47	47	45	34	17	33.2
9	15:00	540	78	47	46	43	33	10	45.2
10	16:00	310	65	46	42	38	34	10	43
11	17:00	80	50	44	39	36	33	10	46.2
12	18:00	26	25	42	36	32	32	15	53
13	19:00	0	0	40	33	30	30	13	25.1
14	20:00	0	0	37	31	28	29	11	33.2
15	21:00	0	0	35	29	27	28	10	27.3
16	22:00	0	0	33	29	27	28	10	23
17	23:00	0	0	32	27	26	27	11	20
18	0:00	0	0	31	27	26	27	15	15.2
19	1:00	0	0	30	26	25	26	16	13.1
20	2:00	0	0	29	26	25	27	15	8.8
21	3:00	0	0	28	26	24	26	17	6.2
22	4:00	0	0	28	25	23	25	19	8.1
23	5:00	0	0	27	24	23	25	18	4.2
24	6:00	5	4	26	23	22	24	18	8.1

COMPARISION OF I_D FOR BOTH STILL

The diffused radiation for both still at different water level as illustrated below and it is found that the higher value is found in case of 15cm depth of water for both still at different angle of inclination.





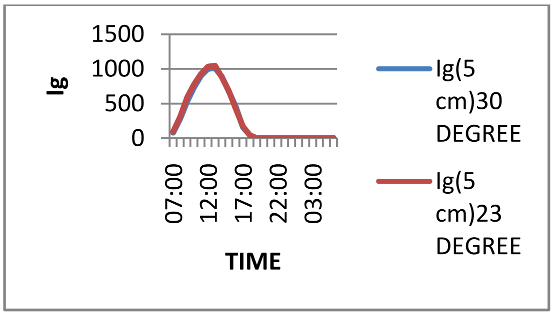
Gr	Pr	C	N	hc, TI	hc, DUNK	Overall η
8583629	0.69831	1.176666	0.175336	1.747766	2.99388	20.80294
14788817	0.697564			1.914303	2.743343	
13279513	0.696889			1.901196	2.546813	
7249922	0.696354			1.727299	2.163041	
2479885	0.695692			1.450156	2.093199	
5121964	0.695198			1.661585	3.165901	
12046952	0.69506			1.934306	3.299629	
12012294	0.695129			1.930727	3.527615	
13613146	0.695373			1.964028	3.377735	
15133019	0.695837			1.983015	2.759136	
16688706	0.696467			1.993725	2.947699	
16694917	0.697006			1.974546	2.197827	
15089053	0.697443			1.925094	2.087932	
13495551	0.697809			1.87600	1.551013	
11884593	0.698099			1.825742	0.96726	
10241822	0.69831			1.772618	1.36539	
10293312	0.69848			1.769103	1.228968	
8610613	0.698609			1.711153	2.010291	
6896720	0.698652			1.644952	2.177648	
5178926	0.698696			1.56361	2.435995	
5194216	0.698782			1.562166	2.356106	
6937436	0.698826			1.641913	2.510954	
6958963	0.698913			1.640436	2.648726	

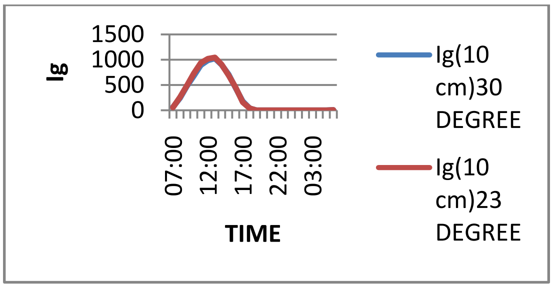
TABLE FOR CONVECTIVE HEAT TRANSFER COEFFICIENT					
30 DEGREE INCLINATION			TIME	23 DEGREE INCLINATION	
DEPTH OF WATER				DEPTH OF WATER	
S.NO	5CM	5CM		5CM	10CM
1	1.537856	1.318744	7.00	1.92654	1.726989
2	1.749102	1.59596	8.00	2.099574	1.945465
3	1.786233	1.727546	9.00	2.065263	2.001262
4	1.739187	1.75516	10.00	1.869692	1.994681
5	1.571702	1.691017	11.00	1.326273	1.906658
6	1.2374	1.536142	12.00	2.06658	1.610058
7	1.545311	1.373269	13.00	1.988567	1.944754
8	1.870337	1.389794	14.00	2.205859	2.058639
9	1.956737	1.76753	15.00	2.356148	2.117417
10	1.963574	1.854881	16.00	2.293174	2.101508
11	1.992532	1.879231	17.00	2.31198	2.086163
12	1.971891	1.881194	18.00	2.253482	1.627253
13	1.93289	1.867868	19.00	2.236043	1.632359
14	1.89838	1.860228	21.00	2.185946	2.046008
15	1.862505	1.836977	22.00	2.085021	2.020404
16	1.826971	1.812842	23.00	2.02306	2.015128
17	1.713019	1.787634	00.00	1.950567	2.009923
18	1.605438	1.761111	01.00	1.86192	2.004788
19	1.658996	1.756892	02.00	1.85993	1.99972
20	1.657215	1.752769	03.00	1.745035	1.994718
21	1.655459	1.748739	04.00	1.743212	1.970188
22	1.700077	1.746757	05.00	1.854142	1.967761
23	1.652027	1.744799	06.00	1.852271	1.96535

COMPARISION OF I_g FOR BOTH STILL

The global radiation for both the still varies with almost same characteristics and it is found higher during time interval 11am to 2 pm in this interval the global radiation is almost 1000 to 1050W/m^2.

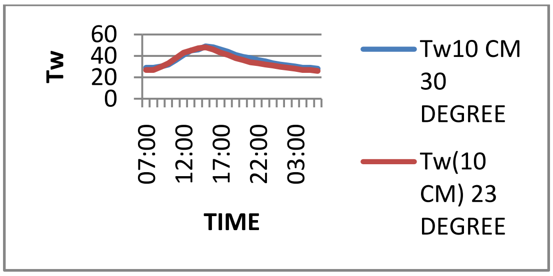
And the comparison of the I_g for same depth of water separately for both still is also illustrated in fig as this varies almost similar way there is no more deviation found.





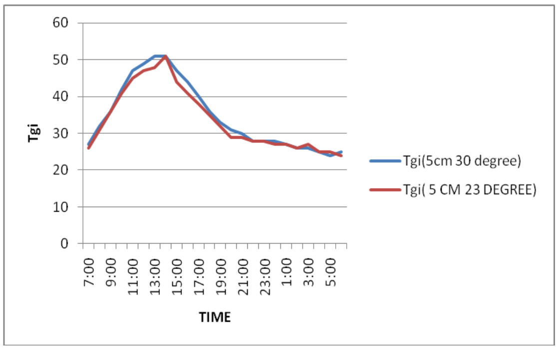
COMPARISION OF T_W FOR BOTH STILL

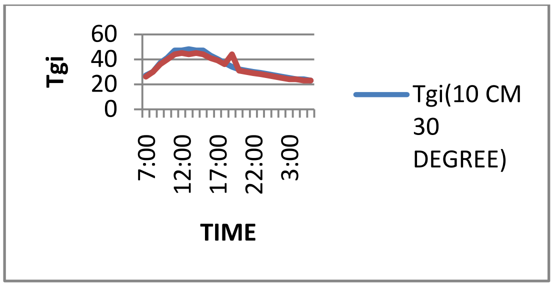
The variation of temprature of water for both still at different water level is illustrated and is found its value higher when the depth of water is minimum and its value is approximately 54 degree in all cases either seperately at different level or combined for both the still. And its value is higher during time 1to 2 pm and water temprature varies similarly for different depth at difffrent angle of onclination.



COMPARISION OF T_{GI} FOR BOTH STILL

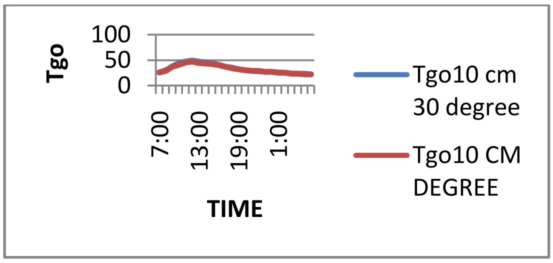
The variation of temprature of inner glass surface with different glass cover inclination at difrent depth of water is illustrated its variation is similar for both still and higher value is also same for all depth of watereither seperately or combined and its value is approximately equal to52 degree centigrate and it is found during 1pm to 2pm.

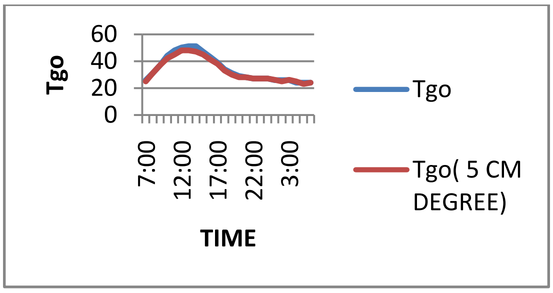




COMPARISION OF T_{go} FOR BOTH STILL

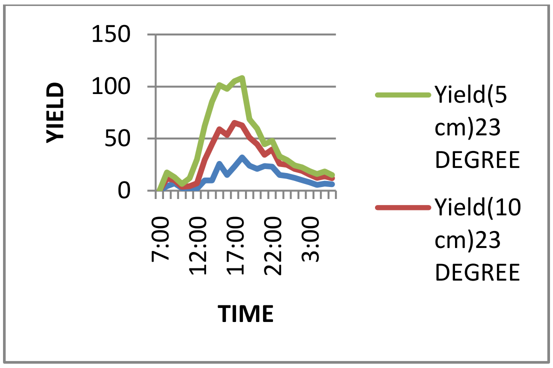
The variation of temprature of outer glass surface with different glass cover inclination at difrent depth of water is illustrated its variation is similar for both still and higher value is also same for all depth of watereither seperately or combined and its value is approximately equal to51 degree centigrate and it is found during 1pm to 2pm





COMPARISION OF YEILD FOR BOTH STILL

The variation of yield with different angle of inclination of different depth of water is illustrated bellow . the value of yeild is found higher at 5cm depth of water for both the still during 3pm to 4pm but when the grapf is ploted seperately at same depth of water and different angle of inlination is also shown.the higher value is found in 30 degree angle of inclination for all the depth of water seperately and it is found during same time intervalas above for combined graph.



Result and Discussion

The fig indicates that the internal heat transfer coefficient decreases with the increase of water pepth in the basin due to decrease in the temperature difference between glass and water temperature . Further it is impotannt to note that the fluctuations in internal convective heat transfer coefficient decrease with the increase of water depth due to storage effect presents the theoretical and experimental results of the hourly yield for the studied water depths in the basin. From table it is observed that there is a fair agreement between the

fluctuations in internal convective heat transfer coefficient decrease with the increase of water depth due to storage effect presents the theoretical and experimental results of the hourly yield for the studied water depths in the basin. From table it is observed that there is a fair agreement between the experimental and theoretical results. For 0.05 meter depth in the basin. However for higher depths (0.10m and 0.15m), the fluctuations between the experimental and theoretical results is large. Convective heat transfer coefficients is found higher for 10cm depth of water except 12 :00 noon to 3:00 pm during this period convective heat transfer is higher for 0.5 cm depth of water. This is due to higher solar energy available for less quantity of water . Hence it is depicted that 10 cm depth of water is favourable to achieve higher convective heat transfer coefficient.

After experiment and calculation we conclude that 30 degree inclination of still is more efficient and effective for all point of view as heat transfer coefficient, yield, global radiation, defused radiation etc because in this case its value is found higher than 23 degree inclination of angle.

We all conclude that at the angle of inclination is found optimum hence it is equal to the altitude of the place where it is setup and experimentation is done.After experiment and calculation we conclude that 30 degree inclination of still is more efficient and effective for all point of view as heat transfer coefficient, yield, global radiation, defused radiation etc because in this case its value is found higher than 23 degree inclination of angle.We all conclude that at the angle of inclination is found optimum hence it is equal to the altitude of the place where it is setup and experime

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