Research Paper

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Effect of Condensing Cover Inclination on the Temperatures and Distillate Output of A Single Slope Solar Distillation System in An Indoor Simulation

Engineering

KEYWORDS : Condensing Cover, Convective Heat Transfer Coefficients, Distillate Output, Solar still, yield

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ABSTRACT

The objective of the present study is to find a differences in water, vapor and inner glass temperature and distillate output at different inclination angle of a single slope solar still. Three condensing covers inclined at 20°, 30° and 40° are designed and fabricated under indoor simulation for a fixed water depth of 0.17 m in room condition. The condensing cover is to be made of the flat transparent glass as found in any solar distillation system. The sides of the wall of the condensing cover are made up of GRP sheet to avoid heat losses from sides and to provide the desired inclination to the cover.
The operating temperature range for the experiment is maintained at steady state from 45oC to 90oC at an interval of 5ºC by using a constant temperature bath & yield obtained for 1 hour intervals.
It is observed that higher yield is obtained at higher temperature and at low inclination angle.

INTRODUCTION

Solar water distillation is a solar technology with a very long history, and installations were found to be built over 2000 years ago, to produce salt rather than drinking water. Solar distillation is a thermal desalination method where solar energy is used to distill fresh water from saline and brackish water. It is a great practical alternative, which offers life to those regions where the lack of fresh water hinders development.

I.I Water Distillation by Solar Still

The energy required to evaporate water is the latent heat of vaporization of water. This has a value of 2260 kJ/kg. This means that to produce 1 liter of pure water by distilling brackish water requires a heat input of 2260 kJ.

I.II Classification of Solar Distillation Systems

On the basis of various modifications and mode of operations introduced in conventional solar stills, these are classified as passive and active solar stills. In the case of active solar stills, an extra-thermal energy by external mode is fed into the basin of solar still for faster evaporation.

1.3 Principle of Solar Distillation

Working of Solar Still.

A single basin still, the main features of operation are the same for all solar stills. The incident solar radiation is transmitted through the glass cover and is absorbed as heat by a black surface in contact with the water to be distilled. The water is thus heated and gives off water vapor. The vapor condenses on the glass cover, which is at a lower temperature because it is in contact with the ambient air, and runs down into a gutter from where it is fed to a storage tank.

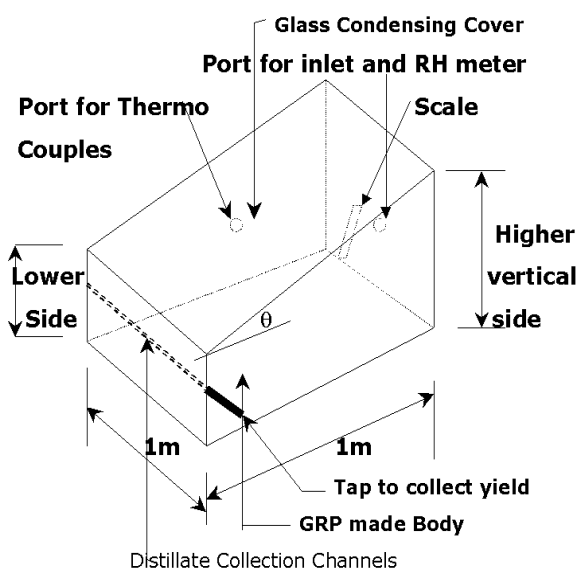
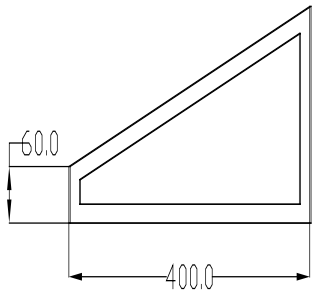


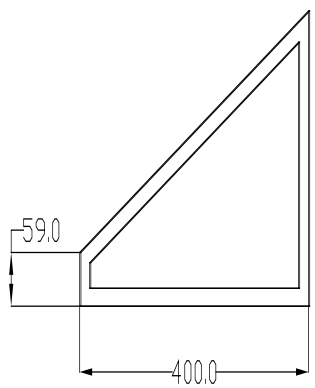
Fig 1 Condensing cover of the solar distillation system

EXPERIMENTAL SET UP

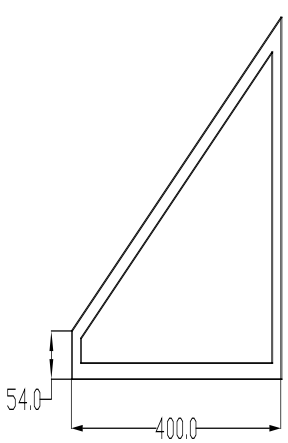
The experimental set-up includes a constant temperature bath; the condensing covers at inclination of 20°, 30° and 40°, digital temperature indicators, well calibrated thermocouples (by Zeal Thermometer), two transparent pipes of small diameter and a measuring jars. The output from the still is collected through a channel. Two plastic pipes are connected to this channel to drain the distillated water to an external measuring jar. The total capacity of the constant temperature bath is 40 L, and its effective evaporative surface area is 300 mm × 400 mm. The water is heated by bath heating coils. The line diagram of a condensing cover and a schematic diagram of a system at 20°, 30° and 40° are given in a photograph of the same.



(a)



(b)



(c)

Fig.2. It shows the AutoCAD designing of the condensing cover of solar still at inclination angle of 20° (a), 30° (b) and 40° (c).

Temperature and Yield Measurements

The copper-constant wire thermocouple and a digital temperature indicator were used to measure water, vapor and glass cover temperatures.

The distillate output was collected in a narrow necked bottle to minimize the evaporation losses during collection of distillate.



Fig.3 Working solar still showing the temperatures.

Experimental observation.

The temperature and yield in the natural mode for various operating temperatures were recorded as experimental data for inclinations of 20°, 30° and 40° of the condensing cover.

TABLE 1

Average values calculated for inclination of condensing cover at 20° for different bath temperatures.

S. No	Temperature (°C)				Mew (ml)
	Bath	Water	Vapor	Inner Glass	
1	45	36.7	34.1	33.3	1.23
2	50	40.7	37	36	3.73
3	55	45	40	38	6.07
4	60	49	43	40.7	10.83
5	65	54	47	44.7	13.63
6	70	58	51	48	15.59
7	75	62	55	52	24.19
8	80	67	60	57	36.29
9	85	72	64	61	60.26
10	90	75.9	68	64	88.4

TABLE 2

Average values calculated for inclination of condensing cover at 30° for different bath temparetures

S. No	Temperature (°C)				Mew (ml)
	Bath	Water	Vapor	Inner Glass	
1	45	36	34	33	0.91
2	50	39.6	36.4	35.1	2.09
3	55	45	39	37	3.13
4	60	49	42	39.3	5.53
5	65	53	46	43	8.0
6	70	57	49.4	46	9.59
7	75	61	53.3	50	12.8
8	80	66	58	55	16.19
9	85	70.6	62	59.3	23.29
10	90	74	65.6	62.6	30.69

TABLE 3

Average values calculated for inclination of condensing cover at 40° for different bath temperatures.

S. No	Temperature (°C)				Mew (ml)
	Bath	Water	Vapor	Inner Glass	
1	45	36	33.6	32.7	0.1
2	50	39.3	36	35	0.23

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3	55	45	38.3	36	0.51
4	60	49	41	38	0.76
5	65	53	45	41.1	1.7
6	70	56	48	44.9	1.93
7	75	60	52	48.1	2.06
8	80	65	56	52.6	2.41
9	85	69	60	56	2.63
10	90	72	62	58	2.83

III METHODOLOGY
THERMAL MODEL

The vapor, which consists of moisture + dry air, is freely convicted above water surface to the condensing cover by the action of pressure difference because of buoyancy force caused by density variation. This is due to the difference in temperatures between the water surface and condensing cover. This process with in the unit always happens in natural mode. However, the external heat transfer from condensing cover to the atmosphere takes place outside the still and can either be under the natural mode, depending on ambient conditions. (G.N. Tiwari, et al,)

TABLE 4
Water temperature at different inclination angles of the condensing cover.

S. No	Bath Temperature (°C)	Water Temperature (°C)		
		20°	30°	40°
1	45	36.7	36	36
2	50	40.7	39.6	39.3
3	55	45	45	45
4	60	49	49	49
5	65	54	53	53
6	70	58	57	56
7	75	62	61	60
8	80	67	66	65
9	85	72	70.6	69
10	90	75.9	74	72

TABLE 5
Vapor temperature at different inclination angles of the condensing cover.

S. No	Bath Temperature (°C)	Vapor Temperature (°C)		
		20°	30°	40°
1	45	34.1	34	33.6
2	50	37	36.4	36
3	55	40	39	38.3
4	60	43	42	41
5	65	47	46	45
6	70	51	49.4	48
7	75	55	53.3	52
8	80	60	58	56
9	85	64	62	60
10	90	68	65.6	62

TABLE 6
Inner glass cover temperature at different inclination angles of the condensing cover

S. No	Bath Temperature (°C)	Inner Glass Temperature (°C)		
		20°	30°	40°
1	45	33.3	33	32.7
2	50	36	35.1	35
3	55	38	37	36
4	60	40.7	39.3	38
5	65	44.7	43	41.1
6	70	48	46	44.9
7	75	52	50	48.1
8	80	57	55	52.6
9	85	61	59.3	56
10	90	64	62.6	58

TABLE 7
Temperature Difference (ΔT) at 20°

S. No	Temperatures (°C)			$T_w - T_g$
	Bath	Water	Inner Glass	
1	45	36.7	33.3	3.4
2	50	40.7	36	4.7
3	55	45	38	7.0
4	60	49	40.7	8.3
5	65	54	44.7	9.3
6	70	58	48	10.0
7	75	62	52	10.0
8	80	67	57	10.0
9	85	72	61	11.0
10	90	75.9	64	11.9

TABLE 8
Temperature Difference (ΔT) at 30°

S. No	Temperature (°C)			$T_w - T_g$
	Bath	Water	Inner Glass	
1	45	36	33	3.0
2	50	39.6	35.1	4.5
3	55	45	37	8.0
4	60	49	39.3	9.7
5	65	53	43	10.0
6	70	57	46	11.0
7	75	61	50	11.0
8	80	66	55	11.0
9	85	70.6	59.3	11.3
10	90	74	62.6	11.4

TABLE 9
Temperature Difference (ΔT) at 40°

S. No	Temperature (°C)			$T_w - T_g$
	Bath	Water	Inner Glass	
1	45	36	32.7	3.3
2	50	39.3	35	4.3
3	55	45	36	9.0
4	60	49	38	11.0
5	65	53	41.1	11.9
6	70	56	44.9	11.1
7	75	60	48.1	11.9
8	80	65	52.6	12.4
9	85	69	56	13
10	90	72	58	14

TABLE 10
Comparison of distillate output for different inclination angles of the condensing cover.

S. No	Bath Temperature (°C)	m_{ew} (ml)		
		20°	30°	40°
1	45	1.23	0.91	0.1
2	50	3.73	2.09	0.23
3	55	6.07	3.13	0.51

4	60	10.83	5.53	0.76
5	65	13.63	8.0	1.7
6	70	15.59	9.59	1.93
7	75	24.19	12.8	2.06
8	80	36.29	16.19	2.41
9	85	60.26	23.59	2.63
10	90	88.4	30.69	2.83

This experiment was conducted daily for 10 readings at different bath temperature ranging from 45°C to 90°C for three different inclination angles of the condensing cover i.e., 20°, 30° and 40° respectively. The readings of water temperature, vapor temperature and inner glass temperature for one hour interval were recorded and distillate output is also measured at regular one hour intervals.

It is clearly seen (Fig.1, Fig.2 and Fig.3) that the water temperature, vapor temperature and inner glass temperature of the condensing cover increases with the decrease of inclination angle of the condensing cover and decreases with the increase in the inclination angle of the condensing cover. So here we are observing that the water temperature, vapor temperature and inner glass temperature of the condensing cover for 20° inclination angle of the condensing cover is maximum than the 30° & 40° inclination angle of the condensing cover and the water temperature, vapor temperature and inner glass temperature of the condensing cover for 30° inclination angle of the condensing cover is greater than the 40° inclination angle of the condensing cover.

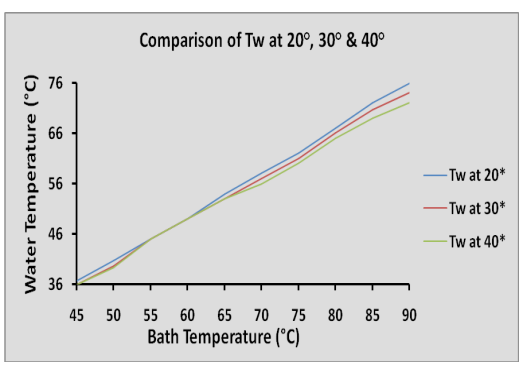

Fig. 1. Variation of water temperature at different inclination angles of condensing covers.

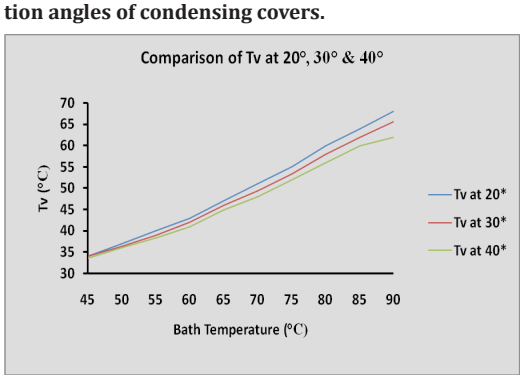

Fig. 2. Variation of vapor temperature at different inclination angles of condensing cover.

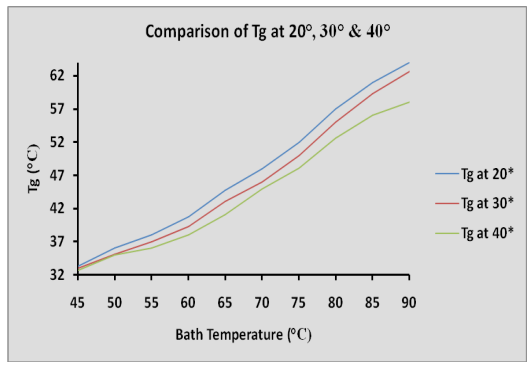

Fig. 3. Variation of inner glass cover temperature of condensing cover at different inclination angles of condensing cover.

It is well known fact in the field of distillation that the amount of distillate output received will be higher for the higher temperature of evaporative surface and also for lower temperature of condensing surface. In other words, the higher value of evaporative surface temperature and lower value of condensing surface temperature, both leads to the rise in distillate output. A little consideration reveals that both of this increase the temperature difference ΔT between evaporative and condensing surfaces. The hourly difference in water and inner glass temperatures for different operating temperatures of the water bath, i.e., ΔT.

It is explicit that the fluctuation in water temperatures decreases with the increase in the inclination angle of the condensing cover (Fig. 1) due to large evaporative surface.

Fig. 4 It is clearly seen that from 45° C to 70° C the ΔT rises very fast and after that it slow down.

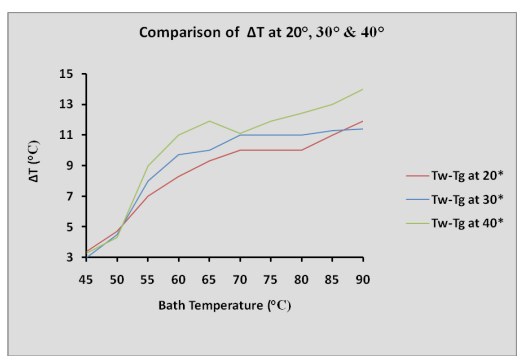

Fig. 4. Variation of ΔT at different inclination angles of the condensing cover.

It shows that the distillate output increases as the operating temperature or the constant water bath temperature increases. The distillate output rise at a much faster rate after 80° C constant water bath temperature or 67° C water temperature.

It shows the yield increases continuously as the operating temperature or water temperature of the system increases.

Due to the increase in the inclination angle of the condensing cover the water, vapor and inner glass temperature decreases which results in the decrease of ΔT temperature. Therefore fewer yields are measured when the inclination angle of the condensing cover is increased.

As we all know that the yield increases as the operating temperature of the constant water bath or water temperature increases.

It shows that practical yield used to decrease as the inclination angle of the condensing cover increases.

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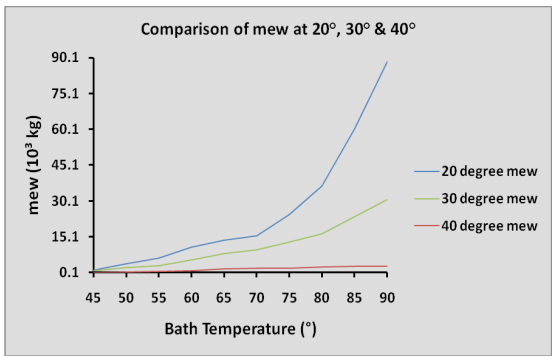

Fig.5 Comparison of distillate output at 20°, 30° & 40° inclination of the condensing cover.

Fig 5 clearly explain the difference in water temperature and inner glass temperature as the yield decreasing as the inclination angle of the condensing cover increases or the water , vapor and inner glass temperature decreases.

It is because of the fact that yield is the product of evaporative heat transfer coefficient and ΔT and if either of these two is lower the yield will be lower. In case of higher water depth the water and inner glass temperature both remains on the higher side and ultimately ΔT falls, which reduces the yield obtained.

For 20° inclination angle of the condensing cover the yield obtained is very steep after 70° C and it used to increase as the water temperature increases and in the case of 30° inclination angle of the condensing cover the yield obtained is very less as compared to 20° because of decrease in water temperature due to increase in inclination angle.

SUMMARY AND CONCLUSIONS

On the basis of this study the following conclusion are drawn:

- It obtains high distillate output at higher operating temperatures and at lower inclination of the condensing cover.
- A distillation unit with a condensing cover at a 20° inclination in indoor simulation can obtain the highest yield.
- Among the non conventional methods to disinfect the polluted and saline water, the most prominent method is the solar distillation. The solar distillation engineering system is meant to get distilled water for various purposes. The production rate is proportional to the area of the solar still. The basic heat and mass transfer relation responsible for developing, and testing of various design of solar stills. The work on solar distillation includes water sources water demand availability of potable water and purification methods.

The present study leads to the conclusion that water temperature, vapor temperature and inner glass temperature are important for varying inclination angle of the condensing cover to optimize the same for the highest yield in summer climatic condition for a single slope passive solar distillation unit. This will also be useful for designing efficient solar distillation systems. It has also been seen that the highest output and efficiency are at lower inclination angle of the condensing cover.

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