International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 5 May 2021, pp: 982-991 www.ijaem.net ISSN: 2395-5252

Experimental Investigation of a Single Slope Passive Solar Still Augmented With a Chimney

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Submitted: 05-05-2021 Revised: 17-05-2021 Accepted: 20-05-2021

ABSTRACT— Distilled water production using Solar Still is a process which evolved in the recent past. Several experiments have proved viability in the output but still have a long way to accelerate the rate of production. This project deals with solar desalination using solar still incident on an inclined glass plate as against the conventional horizontal plate. The rate of input has to be balanced to that of the output rate in order to avoid stagnation of heat that is lost due to the material of the wall in the still. There is also an instance that the condensed water falls back into the still which gets recycled &reduces the efficiency of the still.

The inclined surface is made conventional to overcome the shortfall in transmittance volume at the incident surface. The increased transmittance volume increases the rate of evaporation. Despite framing the underlined convention of providing inclined surface to augment transmittance volume, the process suffers balancing of heat transmission resulting in stagnation of heat. The scope of the thesis is therefore to enhance the heat transfer by providing chimney and avoid stagnation of heat by using alternate material for the wall to avoid loss of heat through transmission

I. INTRODUCTION

Water is the fundamental source of life on earth especially the drinking water is a basic necessity for human beings along with food and air. Although water is abundant on the earth but fresh water is scarce. There is acute shortage of fresh drinking water in remote and rural areas of many countries. Reports state that the amount of fresh water available per person in the world per person was 4000 m3 a year in the early 1950s. Now, the amount of fresh water available globally has reduced to 1000 m3 per person per year, which has resulted in water scarcity. The demand for fresh water is growing steadily. The presence of high amount of salts and contamination in water from sources like sea, lakes, rivers and underground water reservoir makes it unsuitable for use directly. At most places, enoughsaline water is available but it is not suitable for drinking and other domestic, agricultural and industrial applications. In addition to quantity of water, there are many places even in urban areas where water is polluted and is not completely safe for drinking. It is estimated that around 500 million people in the developing countries suffer from diseases produced by water. To solve these problems, new drinking water sources should be discovered.

II. INTRODUCTION TO DESALINATION

Desalination is the process of removal of salts (Sodium Chloride) and other minerals from the brackish water or sea water to make it suitable for human consumption and / or industrial use. It may also be defined as the process of bringing down the salinity of sea-water or brackish water from a high level of total dissolved solids of 35,000 ppm to an acceptable level of 500 ppm.

III. CONVENTIONAL METHOD OF DESALINATION

Besides the problem of water shortage, process energy constitutes another zone of problem. Desalination processes generally require a significant amount of energy. It was estimated that the production of 1 million m3 of desalinated water per day requires 10 million tons of oil annually. Besides the high expenditure of conventional energy resources, unevenexploitation of fossil fuels results in global warming, climatic changes etc. posing a serious threat to the living conditions of mankind as well as plant kingdom and animal kingdom. On the other hand, people are unable to use the existing popular desalination devices to get fresh water because of limited or even no supply of grid – connected electricity.

A. PRINCIPLE

Solar Stills operate on the same principle that produces rainfall. The sun is allowed into and trapped in the still. The sun's energy heats water to the point of evaporation. As the water evaporates, only pure water vapor rises inthe still, only to condense on the glass surface for collection. The glass (still) is sloped to the south and the condensed water runs down the glass and is collected in a trough. This process removes impurities such as salts and heavy metals as well as eliminates microbiological organisms. The end result is water is cleaner than the purest rain water. Practically, there are no moving parts in the solar still and only the sun's energy is required for operation. Hence the schematic set-up is called as Passive Solar Still.

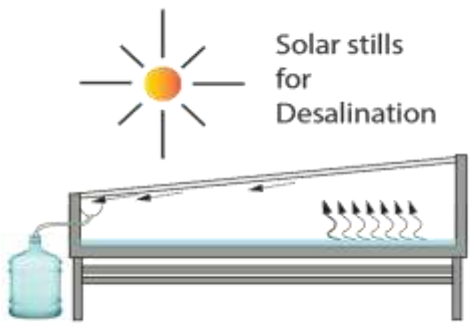

Fig. 1 Schematic Set – Up of a Solar Still

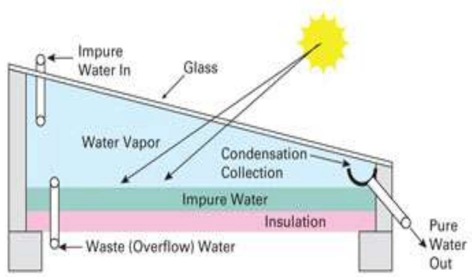

Fig.2 Solar Powered Machine for Desalination

B. PROPOSED INNOVATION

The scope of our project is to enhance the heat transfer by augmenting chimney to the solar still and avoid stagnation of heat. This eventually would pave way for a better productivity of distillate output and ultimately a significant rise in efficiency of the still is assured to a greater extent.

C. MAIN COMPONENTS USED IN SCHEMATIC SET-UP

(i) Basin

It is part of the system in which the water to be distilled is kept. It is therefore essential that it must absorb solar energy. Hence it is necessary that the material has high absorptivity or very less reflectivity or very less transmissivity. These are the criteria for selecting the basin materials. For this reason, Fiber Reinforced Plastic (FRP) has been chosen. The utilization of FRP as the material for the basin eliminates the need for placing a thermocol as an insulator beneath the basin.

(ii) Walls

Except the front wall, the remaining three walls of the still are made up of asbestos. Asbestos has been chosen due to its superiority in mechanical properties than any other material. It has been noted the heat retention characteristics are marginally good than any other material. The front wall alone is made up of acrylic material in order to visualize the effects of the process of solar desalination. Also, the front wall is fabricated in a sliding up and down railing with a handle provision so that it would enable to open / close while feeding in the brackish or any salty water.

Fig.3 Components and Materials utilized in the Schematic Set - up

(iii)Black liner

The top surface of the basin is painted black in

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order to absorb maximum radiation. Black paint at the bottom of the basin acts as the black body and absorbs maximum heat.

Fig. 4 Top View depicting the Black Paint coating on the Surface of Basin

(iv) Chimney

The intention of providing a chimney is mainly to enhance the convective currents within the solar still. The chimney is made up of acrylic throughout its run. Acrylic has been chosen so that it would enable the observer to visualize and analyze the phase change from vapour to water.

Fig.5 Holes drilled in the Rear Wall of the Still &Chimney installed in it.

D. PROCESS OPERATION

The Process involves all three modes of heat transfer. The solar radiations falling on the glass cover pass through the glass cover and strike the inside surface of the basin. This leads to rise in temperature of the water and water begins to evaporate. The temperature difference between water surface and inner surface of cover glass leads to vapor condensation. The combination of gravity and surface tension causes water to flow downwards and get collected in a trough leading into a storage tank. This methodology signifies the mode of operation in a conventional solar still which has been performed here by shut – off to the chimney provision.

In the modified version, the chimney is let open in order to draw all the vapour towards it, thus motivating the vapour to travel further forward and change its phase to water at a suitable spot. By this way, a better productivity of distillate output of water is guaranteed.

Fig. 6 Process Operation after the installation of Chimney

E. PERFORMANCE ANALYSIS WITHOUT AND WITH CHIMNEY

The experimental observation was carried out for a period of 6 days continuously i.e. from Monday to Saturday in a week. In the conventional still, experimental observations were taken on alternate days i.e. on Monday, Wednesday and Friday for water depths 2 cm, 3 cm and 4 cm respectively. Likewise, in the modified still, experimentation was carried out on alternate days i.e., on Tuesday, Wednesday and Saturday for depths of water at 2 cm, 3 cm and 4 cm respectively. On all the days of experimentation, recordings were carried out for a frequency of every one hour from morning 9:00 AM till evening 5:00 PM. In the beginning at 9:00 AM, the solar intensity is low and temperature of glass cover started rising above atmospheric temperature. In the evening towards 5:00 PM, the temperature of inner surface of the glass cover will approach atmospheric temperature.

After 5:00 PM, condensation of pure water at the bottom surface of the glass cover and still hourly yield will get reduced very much. Nocturnal production of pure water takes place till saline water temperature equals to glass plate temperature. Observations were noted during the experiments in the conventional still for different depths viz. 20 mm, 30 mm and 40 mm of saline water and are given in the Tables 3, 5 and 7. Similarly recordings were performed with the modified still and are given in Tables 4, 6 and 8. All these tables comprise the observations recorded for parameters viz. solar intensity, ambient temperature, outer glass cover temperature, basin surface temperature, saline water temperature, vapour temperature, inner wall temperature, inner glass cover temperature, hourly yield of distillate etc. Though observations were taken daily in the same manner but, solar radiation depends on the cloud conditions on a particular day. Due to uneven clouds during day time, the beam (direct) radiation will be affected and causes the change of solar intensity which affects the temperatures of different still components.

F. OVERALL OBSERVATION FOR 6 CONSECUTIVE DAYS

Table 1-Comparative Observation for all depths without and with Chimney

Net Output of Distillate (in liters) for 8 Hours of Experimentation	Depth of Water Surface in Basin Still		
	20 mm	30 mm	40 mm
Without Chimney	1.580	1.354	1.043
Date of Experimentation	21-3-21	23-3-21	25-3-21
With Chimney	2.636	2.160	2.158
Date of Experimentation	22-3-21	24-3-21	26-3-21
% Increase in Output of Distillate	72.53%	59.53%	53.21%

G. HEAT TRANSFER CALCULATIONS

(i) HEAT TRANSFER COEFFICIENTS BY DUNKLE'S MODEL

It is very important to know accurately the heat and mass transfer processes in basin type solar stills for improving their performance. Dunkle (1961) proposed a group of complete heat and mass transfer correlations based on a modified Grashoff number to express the operating processes of basin type solar stills. Most of the work done on solar stills has used the expressions for internal heat transfer coefficients as developed by Dunkle undersimulated condition.

$$Nu = \frac{h_{cw} d_f}{K_f} = C\left(Gr.Pr\right)^n$$

$$Nu = C\ Ra^n = 0.075 Ra^{1/3} \quad (1)$$

In the above said free convection correlation, Dunkle used coefficients as C = 0.075 and n = 0.33.

The main drawback of the analysis developed by Dunkle and used by other investigators is due to two assumptions:

1. Free convection in the still may be described by equation (1) originally developed for free convection of air without evaporation.
2. The use of the constant 0.0163 in the relationship between h_c w-gl and h_{eva} w-gl is valid only at the operating temperature of the saline in the still is less than 50° C (Tw< 50°C).
3. It is valid for the temperature difference of 2ºC between evaporative and condensing surfaces.

(ii) Internal Heat Transfer Coefficients

The convection heat transfer occurs from the air-vapour mixture to the glass. Evaporation occurs from the water to the air-vapour mixture. The condensation heat transfer occurs from the air-vapour mixture to the glass. At the steady state, the evaporation rate and the condensation rate are supposed to be equal. Thus, there are three modes by which the internal heat transfer within the still is governed. The heat exchange between evaporative

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 5 May 2021, pp: 982-991 www.ijaem.net ISSN: 2395-5252

surfaces i.e. water and inner surface of the glass cover inside the distillation unit is known as internal heat transfer.

The internal heat transfer that is heat exchange from the water surface to the glass cover is governed by three modes viz., radiation, convection and evaporation and hence the total internal heat transfer coefficient from water to glass will be the sum of all these heat transfer coefficients by each mode. These heat transfer modes are discussed separately.

Radiation heat transfer: In this case, the water surface and the glass cover are considered as infinite parallel plane under the assumption of small inclination of the glass cover. The rate of radiation heat transfer from the water surface to the glass cover is given by

$$q_{r\,w\text{-}gl} = \varepsilon_{eff}\,\sigma\left[(T_w + 273)^4 - \left(T_{gl} + 273\right)^4\right] \quad (2)$$

$$q_{r\,w\text{-}gl} = h_{r\,w\text{-}gl}\left(T_w - T_{gl}\right) \quad (3)$$

$h_{r\,w\text{-}gl}$ is the radiation heat transfer coefficient from the water surface to the glass cover and is given as

$$h_{r\,w\text{-}gl} = \varepsilon_{eff}\,\sigma\left[\left(T_w + 273\right)^2 + \left(T_{gl} + 273\right)^2\right]\left(T_w + T_{gl} + 546\right) \quad (4)$$

For Conventional Still:
Average Saline Water Temperature = 61°C
Average Basin Temperature = 63°C;
Average Ambient Temperature = 35°C and
Average Glass Cover Inner Surface Temperature = 56.8°

$$h_{r\,w\text{-}gl} = 1 \times 5.6 \times 10^{-8}\left[\left(61 + 273\right)^2 + \left(56.8 + 273\right)^2\right]\left(61 + 56.8 + 546\right) = 7.4\,\frac{W}{m^2K}$$

Convective heat transfer: Heat transfer occurs across humid air in the still from the water surface to the glass cover by free convection, which is caused by the effect of buoyancy due to density variation in the humid fluid which occurs due to the temperature gradient in the fluid. Hence the rate of heat transfer from the water surface to the glass cover by convection in the upward direction can be calculated as

$$q_{c\,w\text{-}gl} = h_{c\,w\text{-}gl}\left(T_w - T_{gl}\right) \quad (5)$$

$$Nu = \frac{h_{c\,w\text{-}gl}\,d_f}{K_f} = C\left(Gr\,Pr\right)^n \quad (6)$$

$$Gr = \frac{g\beta\rho^2 d_f^3 \Delta T'}{\mu_f^2} \quad (7)$$

$$Pr = \frac{\mu_f\, C_{Pf}}{K_f} \quad (8)$$

$$\Delta T' = \left[\left(T_w - T_{gl}\right) + \frac{\left(P_w - P_{gl}\right)\left(T_w + 273\right)}{268.9 \times 10^3 - P_w}\right] \quad (9)$$

Grashoff number can be calculated using equation (3). The physical properties of the humid air are calculated from the average film temperature of the air vapour mixture, T_f. $T_f = \frac{T_w + T_{gl}}{2}$ (10)

$$C_p = 999.2 + 0.1434\,T_f + 1.101 \times 10^{-4} T_f^2 - 6.7581 \times 10^{-8} T_f^3 \quad (11)$$

$$\text{Thermal conductivity} = K = 0.0244 + 0.7673 \times 10^{4} T_f \quad (12)$$

$$\text{Viscosity} = \mu = 1.718 \times 10^{-5} + 4.62 \times 10^{-8} T_f \quad (13)$$

$$\text{Density} = \rho = \frac{353.44}{T_f + 273.15} \quad (14)$$

$$\text{Expansion factor} = \beta = \frac{1}{T_f + 273.15} \quad (15)$$

Grashoff number depends on the average spacing between the water and the glass cover. In equation (6), C and n are constants depending on the Grashoff number. For the normal operating temperature range of 50ºC and d_f = 0.25 m, Dunkle had taken C = 0.075 and n = 0.33 and Dunkle derived the following expression for convection heat transfer coefficient h_c w-gl.

$$h_{c\,w\text{-}gl} = 0.884\left[T_w - T_g + \frac{\left(P_w - P_{gl}\right)\left(T_w + 273\right)}{268.9 \times 10^3 - P_w}\right]^{1/3} \quad (16)$$

$$h_{c\,w\text{-}gl} = 0.884\left[61 - 56.8 + \frac{\left(0.2086 - 0.16511\right) \times 10^5\left(61 + 273\right)}{268.9 \times 10^3 - 0.2086 \times 10^5}\right]^{1/3} = 1.957\,\frac{W}{m^2K}$$

Evaporative heat transfer: Evaporation of water from the water surface is the function of convection heat transfer. So the evaporation heat transfer coefficient (mass transfer coefficient) heva w-gl from the water surface to the glass cover is derived in terms of convection heat transfer coefficient h_c w-gl by Baum (1963).

$$\frac{h_{c\ w\text{-}gl}}{h_{eva\ w\text{-}gl}} = \frac{h_{fg} M_w 1}{C_{Pa} M_a P_T} \quad (17)$$

The rate of evaporation heat transfer per unit area from the water surface to the glass cover can be obtained by substituting the appropriate values for the parameters in equation (11) as follows:

$$q_{eva\ w\text{-}gl} = 0.0163 h_{c\ w\text{-}gl} \left(P_w - P_{gl}\right) \quad (18)$$

Equation (12) can be rearranged as

$$q_{eva\ w\text{-}gl} = h_{eva\ w\text{-}gl} \left(T_w - T_{gl}\right) \quad (19)$$

From equations (12) and (13)

$$h_{eva\ w\text{-}gl} = 0.0163 h_{c\ w\text{-}gl} \frac{\left(P_w - P_{gl}\right)}{\left(T_w - T_{gl}\right)} \quad (20)$$

$$h_{eva\ w\text{-}gl} = 0.0163 \times 1.957 \frac{\left(0.2086 - 0.16511\right) \times 10^5}{\left(61 - 56.8\right)} = 27.71 \frac{W}{m^2 K}$$

The value of h_{eva} w-gl can be more realistic for larger values of ($T_w - T_{gl}$). The values of P_w and P_{gl} can be obtained from the expression

$$P(T) = \exp\left(25.317 - \frac{5144}{T + 273}\right) \quad (21)$$

Thus total internal heat transfer coefficient obtained by combining the equations (4), (10) and (14) called overall heat transfer coefficient from the water surface and the glass cover due to the combined effect of convection, evaporation and radiation is given as

$$U_{o\ w\text{-}gl} = \left(h_{c\ w\text{-}gl} + h_{eva\ w\text{-}gl} + h_{r\ w\text{-}gl}\right) \quad (22)$$

$$U_{o\ w\text{-}gl} = \left(1.957 + 27.71 + 7.4\right) = 37.1 \frac{W}{m^2 K} \quad (23)$$

$$Nu = \frac{h_{c\ b\text{-}w} X}{K_w} = 0.54 \left(Gr\ Pr\right)^{0.25} \quad (24)$$

For mean film temperature of water and basin liner Tf w is calculated to find the physical properties of water

$$T_{f\ w} = \frac{T_b + T_w}{2} = \frac{63 + 61}{2} = 62^\circ C$$

Physical properties of water at 62°C are:
ρ = 983.9 kg/m^3; ν = 0.466 ×10-6 m^2/sec; K_w = 6.53 × 10^{-3} W/m K; Pr = 2.94; C_P w = 4184.2 J/kg K; β = 1/T_{fw} = 1/ 335 = 2.985 × 10^{-3} X = 1m; ΔT = 2°C
With Gr. Pr = 7.9 × 1011

$$h_{c\ b\text{-}w} = 0.54 \left(7.9 \times 10^{11}\right)^{0.25} 0.653 = 332 \frac{W}{m^2 K}$$

Similar to the above said procedure, internal heat transfer coefficients for the modified regenerative still with gravel are also calculated and given below as

Convection heat transfer coefficient of water with glass cover $h_{cw\text{-}gl}$ = 1.79 W/m^2 K
Evaporation coefficient of water with glass cover h_{eva} w-gl = 23.85 W/m^2K
Radiation heat transfer coefficient of water with glass cover h_r w-gl = 6.6 W/m^2 K
Overall heat transfer coefficient of water with the glass cover U_o w-gl is given as

$$U_{o\ w\text{-}gl} = \left(1.79 + 23.85 + 6.6\right) = 32.24 \frac{W}{m^2 K}$$

Similarly, convection coefficient of gravel to water $h_{cg\text{-}w}$ is calculated for the average temperatures of gravel and water. For mean film temperature of water and gravel $T_{fg\text{-}w}$ is calculated to find the physical properties of water

$$T_{fwg} = \frac{T_g + T_w}{2} = \frac{61 + 59}{2} = 60^\circ C$$

Physical properties of water at 60°C are:
ρ = 985 kg/m3; ν = 0.478 ×10-6 m2/sec; Kw = 651 × 10-3 W/m K; Pr = 3.02; $C_{P\ w}$ = 4183.2 J/kg K; β = 1/T_{fwg} = 1/ 333 = 3 × 10^{-3} X = 1m; ΔT = 2°C
From equation (12.24), Gr Pr = 7.7 × 1011

$$h_{c\ g\ w} = 0.54 \left(7.7 \times 10^{11}\right)^{0.25} 0.651 = 300 \frac{W}{m^2 K}$$

External Heat Transfer Coefficients

External heat transfer occurs outside of the solar still from the glass cover, bottom and side surfaces of the still through insulation. From the glass cover heat loss occurs by convection and radiation independently to the ambient air. Latent heat of condensation released due to condensation of water vapour tends to heat the glass cover. As heat capacity of the glass cover is less than the air ($C_{P\ gl}$ = 800 J/kg K), the glass cover is heated reducing the condensation. Therefore to improve the efficiency of the still that latent heat of condensation has to be reused for additional evaporation of saline water.
Overall heat transfer coefficient from basin to ambient air through bottom and sides of the basin due to combined effect of conduction and convection can written as

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$$U_{o\,b\,a} = \left[\frac{1}{h_{c\,b\,w}} + \frac{L_{ins}}{K_{ins}} + \frac{L_w}{K_w} + \frac{1}{h_{c\,b\,a}}\right]^{-1} \quad (25)$$

$$U_{o\,b\,a} = \left[\frac{1}{332} + \frac{0.0125}{0.052} + \frac{0.04}{0.037} + \frac{1}{1.5}\right]^{-1} = 0.504\frac{W}{m^2K}$$

Top Loss Coefficient: Due to small thickness of the glass cover, the temperature in the glass may be assumed to be uniform. The external heat transfer by radiation and convection losses from the glass cover to outside ambient air can be expressed as

$$q_{gl\ a} = q_{r\,gl\,a} + q_{c\ gl\ a} \quad (26)$$

$$q_{r\,gl\text{-}a} = \varepsilon_{eff}\sigma\left[(T_{gl}+273)^4 - (T_a+273)^4\right] \quad (27)$$

$$q_{r\,gl\,a} = h_{r\,gl\text{-}a}\left(T_{gl} - T_a\right) \quad (28)$$

$h_{r\ gl\text{-}a}$ is the radiation heat transfer coefficient from the glass cover and ambient air given as

$$h_{r\,gl\text{-}a} = \varepsilon_{eff}\sigma\left[\left(T_{gl}+273\right)^2 + \left(T_a+273\right)^2\right]\left(T_{gl}+T_a+546\right) \quad (29)$$

It is noted that as the glass cover radiates heat to the atmosphere, the effective shape factor from a small object to a large enclosure is 1

$$h_{r\,gl\text{-}a} = 1\times5.67\times10^{-8}\left[\left(56.8+273\right)^2+\left(35+273\right)^2\right]\left(56.8+35+546\right) = 0.736\frac{W}{m^2K}$$

Convective heat transfer coefficient: Heat transfer from the glass cover to ambient air by convection is considered as forced convection if air is blown over the glass cover with velocity of V m/sec. Then the empirical relation is

$$h_{c\,gl\text{-}a} = 2.8 + 3.0V \quad (30)$$

Hence the rate of heat transfer from the water surface to the glass cover by convection in the upward direction can be calculated as

$$q_{c\ gl\text{-}a} = h_{c\ gl\text{-}a}\left(T_{gl} - T_a\right) \quad (31)$$

The convection coefficient can be obtained from the convection correlation

$$Nu = \frac{h_{c\,gl\text{-}a}X}{K_a} = C\left(Gr\,Pr\right)^n \quad (32)$$

$$Gr = \frac{g\beta\rho^2X^3\Delta T}{\mu^2} \quad (33)$$

$$Pr = \frac{\mu\,C_{Pa}}{K_a} \quad (34)$$

Convection correlation for the upward direction from a horizontal surface to air is given a

$$Nu = 0.15\left(Gr\,Pr\right)^{0.33}\ \text{for}\ 8\times10^6 < Gr\,Pr > 10^{11} \quad (35)$$

Grashoff number can be calculated using equation (33). The physical properties of the ambient air are calculated from the average film temperature between the glass cover temperature and ambient temperature $T_{famb.}$

$$T_{f\,a} = \frac{T_{gl} + T_{ave\,a}}{2} = \frac{56+35}{2} = 45.5^\circ C \quad (36)$$

Mean film air temperature between glass cover and ambient air $T_{f\ a}$ can becalculated from the glass cover temperature T_{gl} and average ambient temperature $T_{ave\ a}$ Physical properties of air are taken from Tables for the mean film temperature as

ρ = 1.107 kg/m^3; υ = 17.56 $\times10^{-6}$ m^2/sec; Pr = 0.698; K_a = 27.58 $\times10^{-3}$ W/m K;
$\beta = 1/T_{f\,a}$ = 1/319 = 3.13 $\times10^{-3}$ 1/K; X= 1 m; ΔT = 20°C

From equations (12.33) and (12.34), Gr. Pr = 1.39 $\times$ 10^9

$$h_{c\,gl\text{-}a} = 0.15\left(1.39\times10^9\right)^{0.333}27.58\times10^{-3} = 4.58\frac{W}{m^2K}$$

Total top loss coefficient or Overall heat transfer coefficient of glass cover to ambient air is the combination of convection and radiation heat transfer coefficients.

$$U_{o\,gl\text{-}a} = h_{c\,gl\text{-}a} + h_{r\,gl\text{-}a} = 4.58 + 0.736 = 5.316\frac{W}{m^2K}$$

H. PERFORMANCE ANALYSIS

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In this section, performance of the conventional still and modified still i.e. the still augmented with chimney are discussed separately and compared. From the experimental observations, temperature variations of saline water, glass cover and air-vapour mixture with the time for different quantity (depth) of saline water in a conventional still are analyzed. Interpretation of temperature variations for different still components gives the effect of depth of saline water on the performance of the conventional still. Similarly relation between the quantity (depth) of saline water and hourly yield is discussed. In the modified still, owing to the presence of a chimney, temperature variations of different components like saline water and glass cover are discussed.

I.PERFORMANCE ANALYSIS OF THE CONVENTIONAL STILL

Fig. 7 shows the variation of still hourly yield with the time. It is found that for a certain lower depth (20 mm) of saline water, the hourly yield is low and increases with the depth and again starts decreasing beyond certain depth of saline water. It is predicted that for particular depth of water (30 mm), hourly

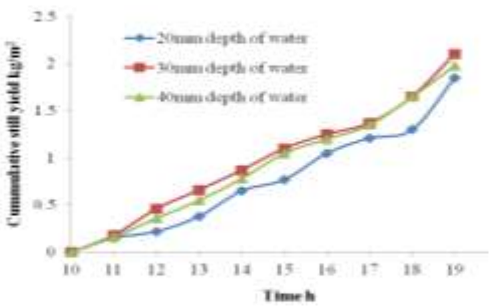

Fig. 7 Cumulative yield for different depths of saline water in the Conventional Still

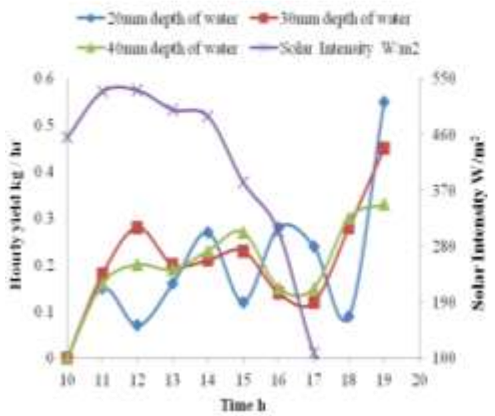

Fig. 8 Hourly yield for different depths of saline water in the Conventional Still

In Fig 9, hourly yield for different depths of saline water is compared under the same climatic condition. For 30 mm depth of saline water, the hourly yield is around 0.44 kg for the period of three hours from 13.00 hours to 15.00 hours. Maximum solar intensity of 1071 W/m^2 is being received at 13.00 PM. The time delay is due to the high heat capacity of the saline water and heat losses in the still.

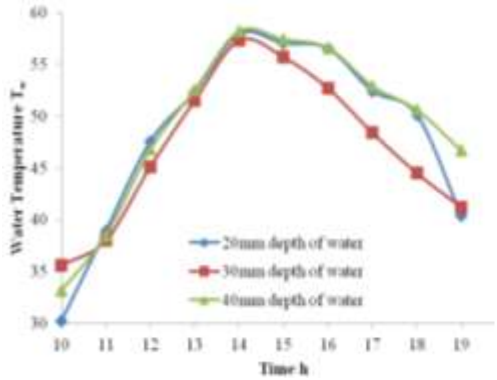

Fig. 9 Water temperature for different depths of saline water in the Conventional Still

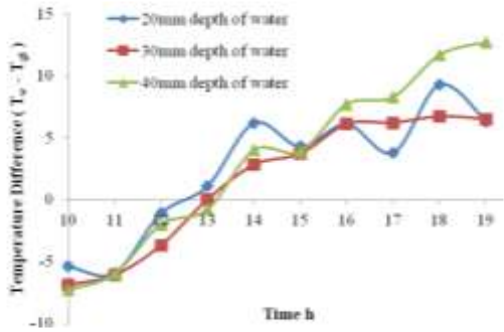

Fig. 10 Temperature difference between the water and the glass cover for different depths of saline water in the conventional still

From Fig. 9, it could be understood that for 30 mm depth of saline water, temperature of the saline water attained higher value and remained higher for longer period whereas for 40 mm depth the temperature of saline water did not attain so high as that of 30 mm depth of saline water. For 20 mm depth of saline water as thermal capacity is low, temperature of the saline water is high and equal to that of 40 mm depth, But in the afternoon hours when solar intensity start decreases temperature also decreases rapidly.

From Fig. 10, it is understood that the temperature difference between the saline water surface and bottom of the glass cover is high for 20 mm depth of saline water than that of 30 mm depth. It is noted that still experienced higher temperature difference between the water and the glass cover for 20 mm depth of saline water, it led to higher heat loss from the still not utilized for the evaporation.

In evening hours temperature difference is high for the 30 mm depth of saline water than other two depths. Hence hourly yield during evening hours are high for 30 mm depth.

J. PERFORMANCE ANALYSIS OF THE MODIFIED STILL – STILL AUGMENTED WITH CHIMNEY

To evaluate the performance of the modified still which uses earth heat as storage medium, experiments were conducted in the same solar still under the same climatic conditions for different thickness (10, 20and 30 mm) of layer of saline water. Experiments were conducted and wide range of parameters such as temperature of water, temperature of glass cover and temperature of ground heat were observed.

From the Experimental results given in the Tables 4, 6 and 8, it is understood that the saline water temperature gets increased considerably. Similarly temperature of the glass cover also considerably gets reduced for the increasing the thickness of saline water. This reduces the heat loss from the water surface and from the glass cover.

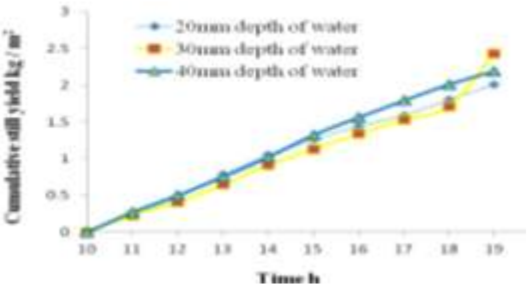

Fig. 11 Cumulative still yield for different thickness of saline water in the still augmented with Chimney

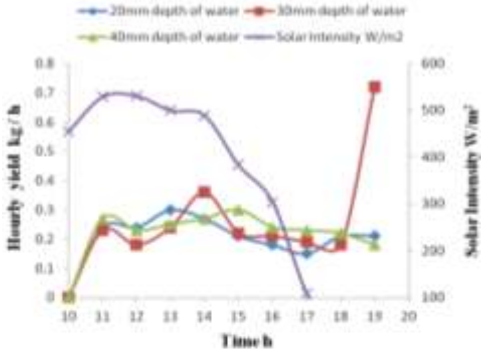

Fig. 12 Hourly Yield with time for different thickness of saline water in the still augmented with Chimney

In Fig. 12, variation of hourly yield with the time for different thickness of saline water is given. It is predicted that for 30 mm depth of saline water, hourly yield is very high as 0.36 kg at 13:00 PM and it is around 0.5 kg during the period of 11.30 hours to 12:30 hours. Again during the evening, 13:00 hours to 15:30 hours the hourly yield attain the value of 0.6 kg. Compared with this, for other thickness of saline water, hourly yield is quietly low. Again it is noted that after 17:00 hours there is a steep increase in still yield till 19:00 hours.

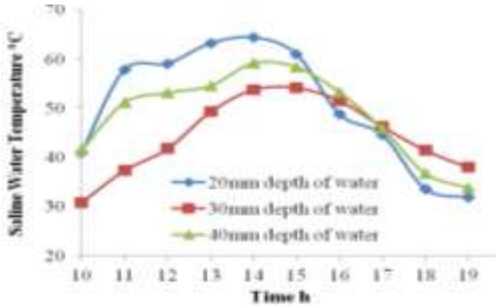

Fig. 13 Comparison of saline water temperature for different thickness of saline water in the still augmented with Chimney

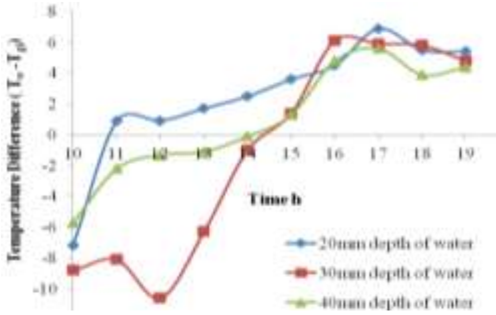

Fig. 14 Temperature difference for different thickness of saline water in the still augmented with Chimney

Fig. 13 compares the saline water temperature for different thickness of saline water in the modified still. For 20 mm thick of saline water attains very high temperature of about 64.4° C at 13:00 hours. Hence for 40 mm thick layer of saline water temperature is about 59.2°C. From Fig. 8, for 20 mm depth of saline water temperature difference is high from 11:30 to 13:00 hours but hourly still hourly yield is not so high. The high temperature difference leads to increase of radiation loss. Whereas for 40 mm depth of saline water even though temperature difference is not so high during the peak hours hourly still hourly yield is high.

K. CONCLUSION

Thus, it is seen by comparing the quantity of output water that there is a significant increase in the evaporation rate which has augmented the yield of distillate output by 72.53%, 59.53% and 53.21% for water depths of 20mm, 30mm and 40mm respectively in the basin still. This experimentation has revealed that a ventilated basin had a positive effect on the efficiency of the evaporator of a solar still. A solar chimney that was used to increase the air circulation increased the convective heat transfer. This increased the evaporation rate and hence lowered the temperature of water to be evaporated. This in turn increased the temperature difference between the basin surface and the water stored in it. As a result, the solar irradiance absorbed by the basin surface was used more efficiently by supplying more energy to be used as latent heat of evaporationThus Solar Energy has proved a promising source to achieve Desalination. The Solar Desalination involves zero maintenance cost and no energy costs as it involves only solar energy which is free of cost. Thus, scavenging the vapour generated within the still by provision of chimney at a suitable height has made way for the vapour to be driven away and directed in aunique path wherein the phase change to water is felt at a desired spot. Such an arrangement has ultimately yielded a significant rise in the output quantity of the distillate water. Thus the provision of chimney has proved worthy by minimizing the heat loss and thereby enhancing the rate of condensation. Also the passive approach of solar desalination is the most environment friendly method with better solution to the problem of energy security with almost negligible running cost.

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