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# CFD Analysis of different types of single basin solar stills

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**Abstract**. The current work deals with the numerical and experimental analysis of a solar still of single basin with improved models of stepped, finned, PCM (Phase modification Materials) instrumentation in single slope. The work is additionally extended to double slope solar still of single basin and also the performances were compared with one another. The one slope basin inclinations were compared for $15^0$ and $20^0$. From the investigations it had been ascertained that single slope with $20^0$ and PCM instrumentation has given the upper productivity compared to different sorts.

## 1. Introduction

Solar stills offers a straightforward means produces clinically pure water appropriate for domestic, industrial, medical or agricultural desires. Plenty of technological analysis has been dole out for up the productivity. A simulation and experimental study was conducted to live internal heat transfer rates of the solar still [1]. A thermal analysis of a solar still was conferred with 2 compressing chambers exploitation energy balance equations for parameters like water mass, compressing covers, basin liners and reflective mirror. Numerical and experimental results were compared for the obtained results of temperatures and yield [2]. A numerical computations of yield and temperatures of water and glass cowl was dole out and ascertained that optimum annual yield was obtained once collector's inclination was $20^0$ and glass cowl inclinations was $15^0$ [3]. A comparative performance analysis was conducted between a double glass and single glass cowl and located that single glass cowl yielded higher compared to double glass cowl [4]. Experimentation was studied regarding the solar still with sponge cubes of various sizes placed within the basin and compared that liquid productivity increased from eighteen to twenty seventh. The results of various parameters like sizes of cube exploit sponge volume, depth, salinity of water and once black coal and black steel was used as cube materials were conjointly investigated [5]. The lumped constant quantity mathematical model was projected to check regarding to analyze the asymmetries that arises in temperature and yield during a solar stills with double slope. The model was compared with the experimental values [6]. The performance of a regenerative 2 basin solar still was sculpturesque, evaluated and compared with the standard still and well-tried that the productivity was increased to twenty additional. The results of insulation, wind speed, thickness of glass cowl, mass flow of water were conjointly studied [7]. The fabrication of single and double basin solar stills was tested and compared the performance throughout the amount of Feb and June month and located that the productivity was regarding 40% over that of single basin still. The very best productivity was obtained within the month of June because of highest incident radiation [8]. The assembly rate was accelerated by desegregation fins, wicks, sponged stills and well-tried that the productivity increased by 45.5% for fins, 29.6% for wick and 15.3% for sponges.

This paper deals with the theoretical, numerical and experimental study of single basin single slope solar still with steps, fins, PCM instrumentation and compared with the standard sort. This work is additionally extended with double slope and compared.

## 2. Theoretical Analysis

A MATLAB coding was generated to obtain the theoretical calculations of the following data:
Sun declination δ =23.45*sin (360*(n+284)/365) in degrees
Hour angle W =15*(12-$L_T$) in degrees
Hourly direct irradiance $I_b$ =B*sin α*exp (-C/sin α) in watt/m$^2$
Hourly diffuse irradiance $I_d$ =D*$I_{bn}$ in watt/m$^2$
Hourly global irradiance, I =$I_b$+$I_d$ in watt/m$^2$
Monthly mean hourly diffuse irradiance, $I_{bd}$ =0.15*$I_d$*(1+cos (b)) in watt/m$^2$
Monthly mean hourly direct irradiance, $I_{bb}$ = (I-$I_b$)*cosθ/sin α in watt/m$^2$
Monthly mean ground reflections, $I_{gr}$=I*ρ*0.5*(1-cos (β)) in watt/m$^2$
Global irradiance, IB=$I_{bd}$+$I_{bb}$ + $I_{gr}$ in watt/m$^2$
North cover, $Q_{tn}$=$T_n$*$A_{gn}$*$I_n$ in watt/m$^2$
South cover, $Q_{ts}$=$T_s$*$A_{gs}$*$I_s$ in watt/m$^2$
Evaporation heat transfer, $Q_{e,}$ =$H_{e,}$*$A_w$*($T_w$-$T_g$) in watt
$H_e$=0.0162*$h_{c,}$*(($P_w$-$P_g$)/ ($T_w$-$T_g$)) in watt/m$^2$
Production of still $M_{w-c}$ = $Q_{e,}$(t)/ $h_{fg}$ in lt/day

## 3. Experimental analysis

### *3.1. Solar basin still*

Figure1 shows the experimental and schematic model of solar basin still. The still instrumentation is created of steel sheets. The tank fabricated from plastic with the capability of 25 liters was accustomed avoid corrosion. The still basin was painted black and insulated with dielectric for insulation purpose. The condensed water was transferred in to the measuring jar through the versatile piping. This experimental established was designed with inner dimensions of the basin 100X100 cm$^2$.The higher glass cowl is tipped at 15$^0$ and 20$^0$ with regard to the horizontal that was put in and tested at Sri Venkateswara College Of Engineering and Technology, Chittoor, Andhra Pradesh, India. The experimental setup was placed by facing the North-South direction. The temperatures at totally different positions were measured exploitation copper-constantan thermocouples. The Condenser surface is created of 5mm normal glass plate. Rock bottom of this still is insulated with 50mm. stuffed the water up to ten cm depth. Thermocouples square measure mounted at the subsequent locations as glass plate, Water and out of doors of the glass plate.

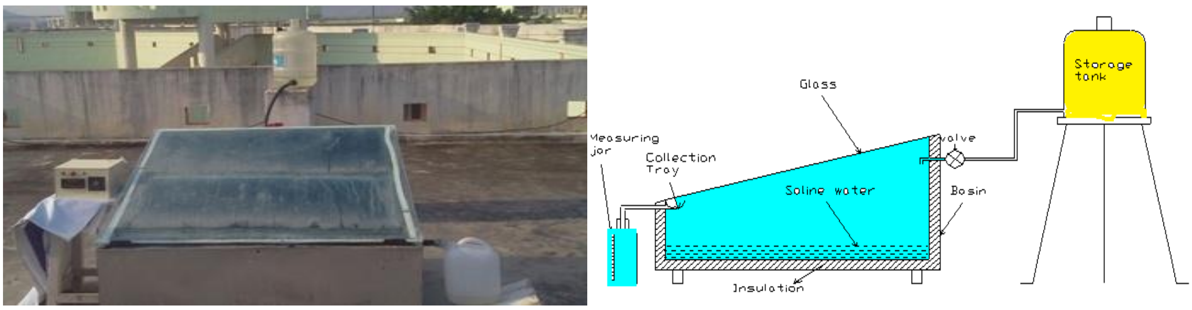


**Figure 1**. Experimental established of solar basin still

### *3.2. Stepped basin*

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Figure 2 two shows the experimental and schematic model of stepped basin. This is often as almost like the basin sort solar still, however steps square measure organized within the basin as a result of to scale back the convention, convection and radiation losses. The Steps square measure unreal with equal distance every of seven cm height and water is stuffed up to 5cms.

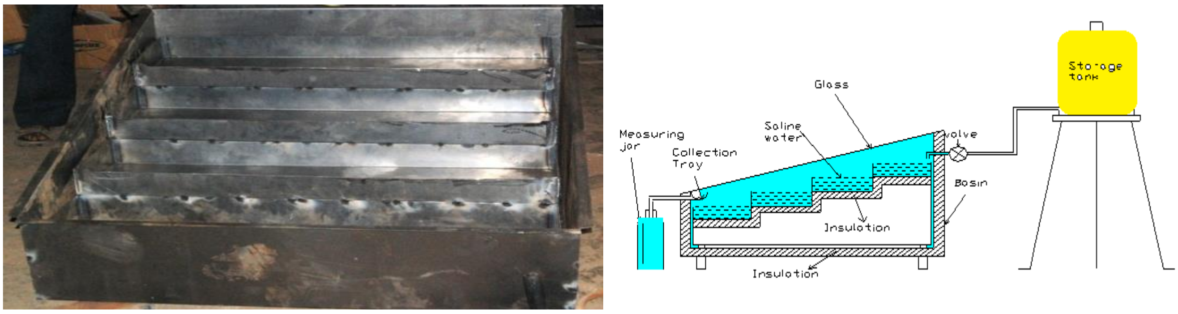

**Figure 2**. Solar still with stepped basin

*3.3. Solar basin with PCM*

Figure3 shows the experimental and schematic model of the basin still full of Stearic acid at rock bottom of the basin and placed a receptacle to store water. The peak of the PCM instrumentation is of 8cm and also the water is poured to a height of 5cm. Here PCM is employed to store heat within the day time and unharnessed the warmth throughout night which provides continuous production of water.

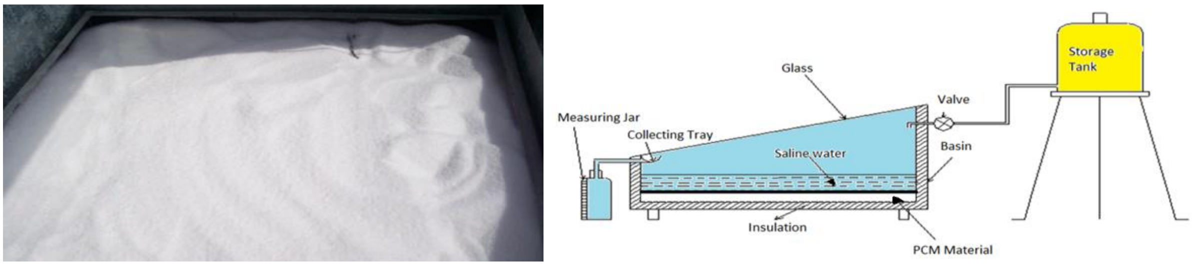


**Figure 3**. Solar still with PCM material

*3.4. Solar basin with Fins*

Figure 4 (a) shows the schematic model of fin sort basin. This is often as almost like the basin sort solar still, however fins square measure organized within the basin as a result of to scale back the convention, convection and radiation losses. The fins are of 10 cm height.

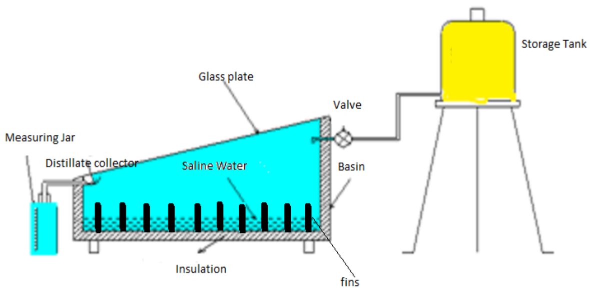


**Figure 4**. (a) Solar still with Fins

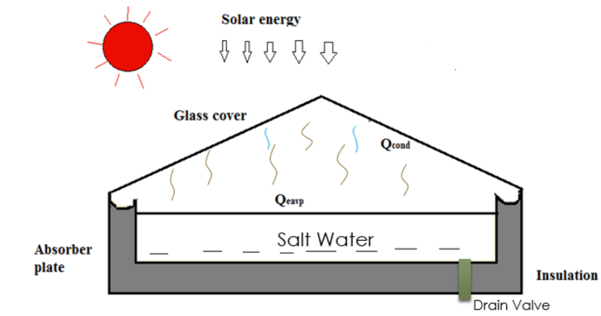


**Figure 4**. (b) Double slope

*3.5. Solar still with double slope*

Figure 4 (b) represents the solar still with single basin double slope. The solar still was unreal with steel of 5mm thickness. The highest of the still is roofed with 5mm glass plates and inclined at $30^0$.

## 4. Numerical Analysis

### *4.1. Modeling*

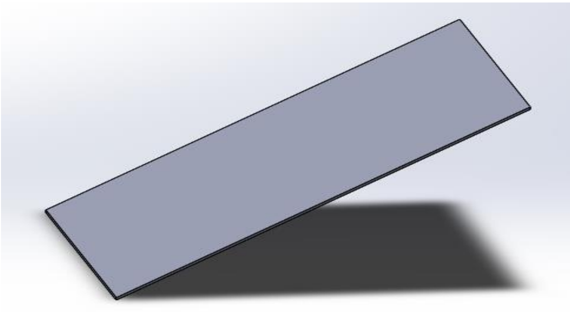

**Figure 5**. Glass plate model

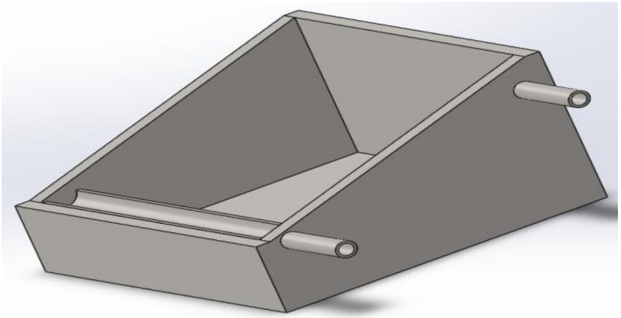

**Figure 6**. Tray model with $20^0$ inclination

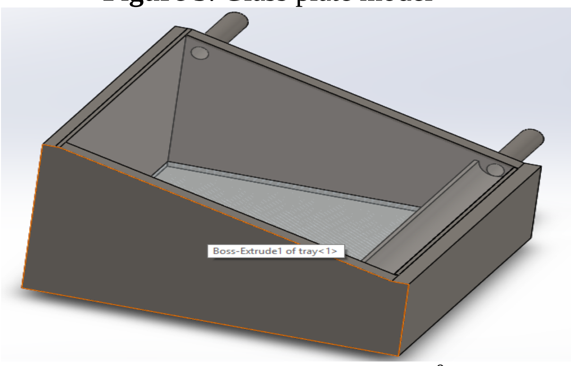


**Figure 7**. Tray model with $15^0$ inclination

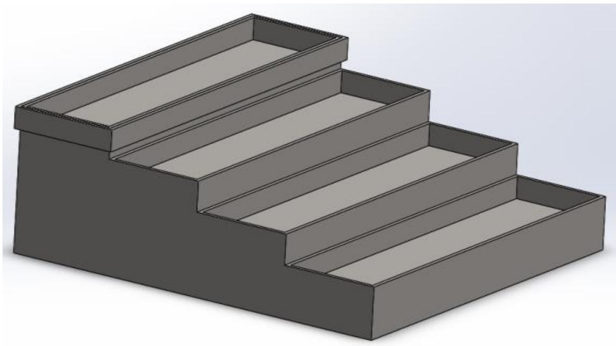

**Figure 8**. Stepped model

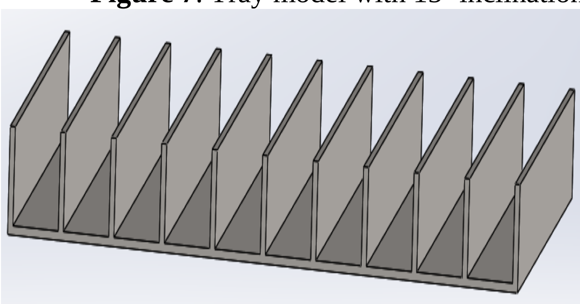

**Figure 9**. Finned Model

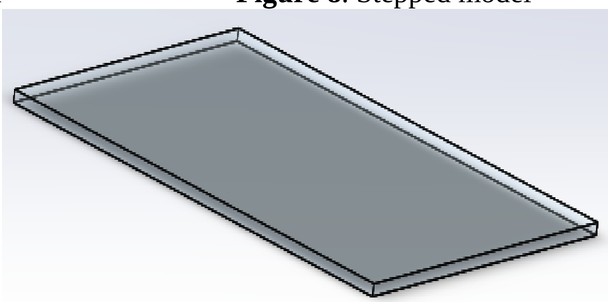

**Figure 10**. PCM container model

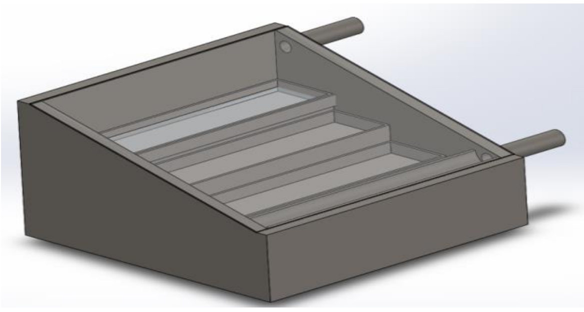

**Figure 11**. Assembled stepped model

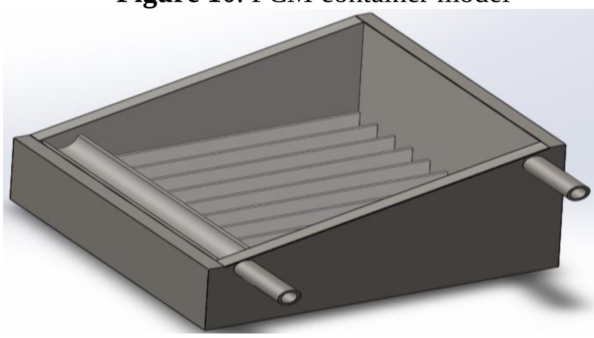

**Figure 12**. Assembled fin model

The geometric model of solar basin still has been created in Solid Works. Figures 5 to 9 shows the part model of solar basin tray, stepped, fin and PCM container and Figures 10 & 11 shows the assembled model of stepped and fin type models.

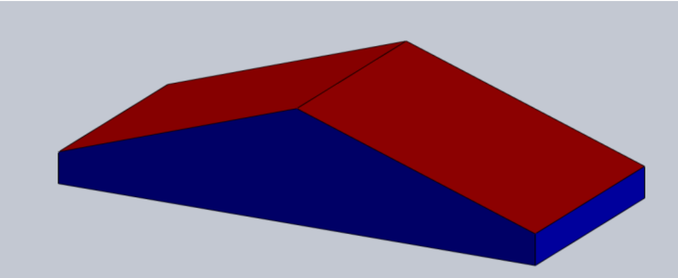

**Figure 13**. Assembled model of solar still with Double slope

The above Figure 13 shows the model of double slope solar still. The still consists of the elements like instrumentation, basin, left glass plate, right glass plate and collectors on each the edges of the still.

*4.2. Meshing*

The Steam and collector geometry of different model created are imported to ANSYS ICEMCFD and tetrahedral meshing is generated. **Table 1**. shows the number of nodes and elements for different domains created for CFD analysis.

**Table 1.** Nodes and Elements of different types of domains

| Domain | Nodes | Elements |
|---|---|---|
| 15 angle | 18969 | 104253 |
| 20 angle | 18984 | 110816 |
| Steps | 11475 | 57729 |
| Fins | 21006 | 109982 |
| With PCM materials ( Stearic Acid) | 20055 | 109737 |
| Double Slope | 35362 | 170791 |

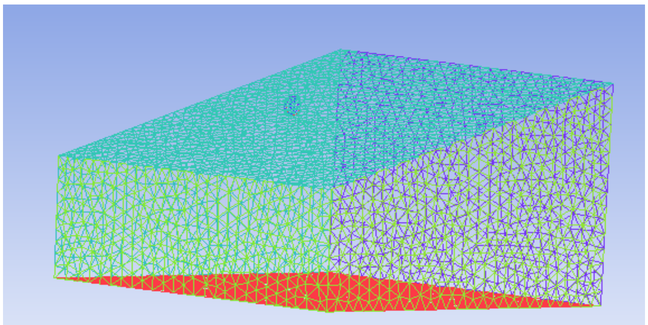

**Figure 14** (a). Meshed model of $15^0$ solar still

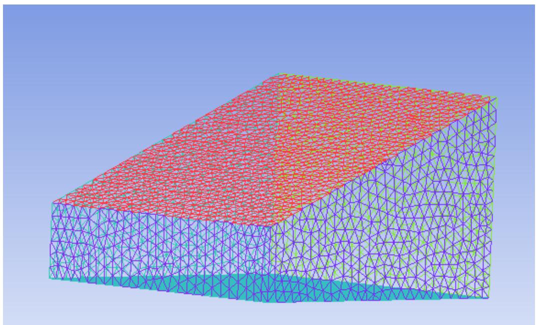

**Figure 14(b)**. Meshed model of $20^0$ solar still

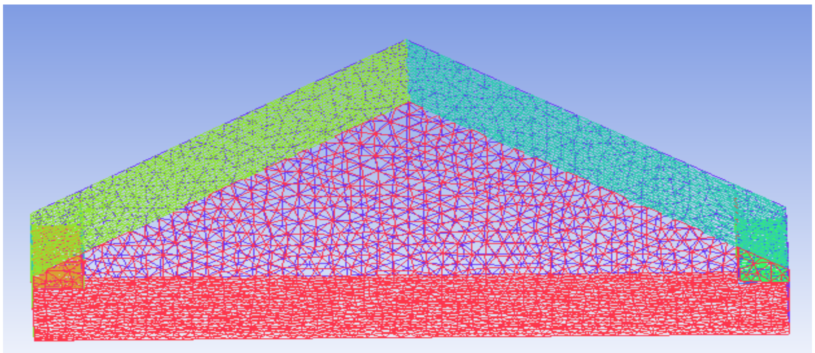

**Figure 14(c).** Meshed model of double slope solar still

Figure 14 (a, b, c) shows the meshed models of the solar still with $15^0$, $20^0$ and double slope. Two phase domain is created in Ansys CFX for liquid water and water vapour. The boundary conditions applied are heat flux is applied on the glass cover with free slip boundary; the bottom plate is given with initial temperature of water. The fluid domain created was given with free slip boundary to vapour and no slip boundary to liquid water. Transient Analysis was carried for 8 hours with 1 hour time step.

## 5. Results and discussions

### *5.1. Post-process results of $15^0$ inclinations solar still*

Figure 15 shows the vapour velocity inside the steam which moves in the circular path due to convection of heat and Figure 16 shows the velocity of water which is shown upwards towards the glass plate.

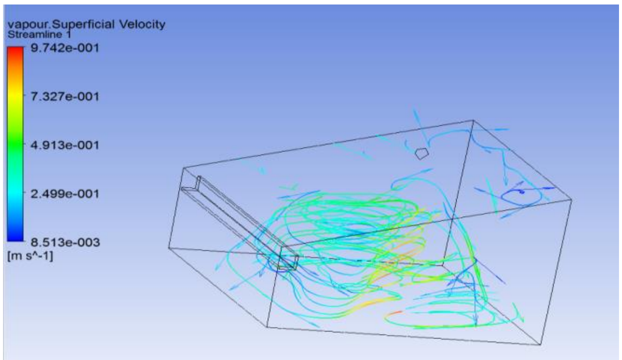


**Figure 15**. Vapour streamlines velocity

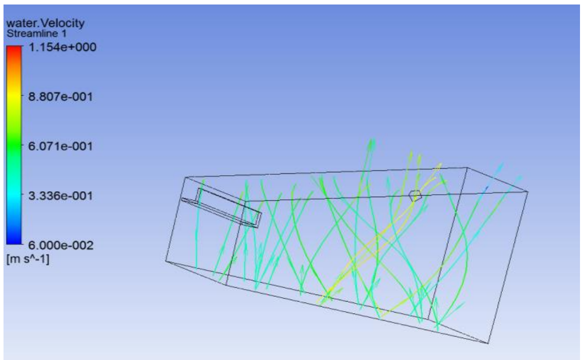


**Figure 16**. Water streamlines velocity

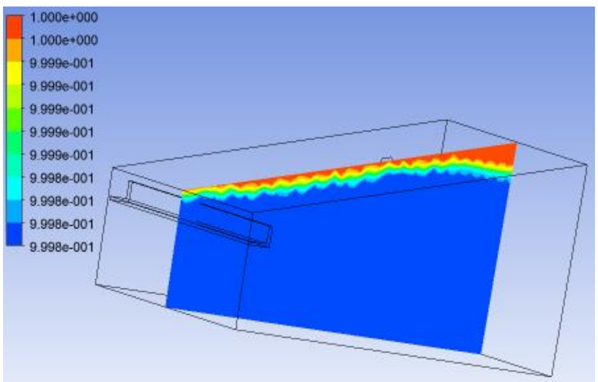


**Figure 17**. Water mass fraction

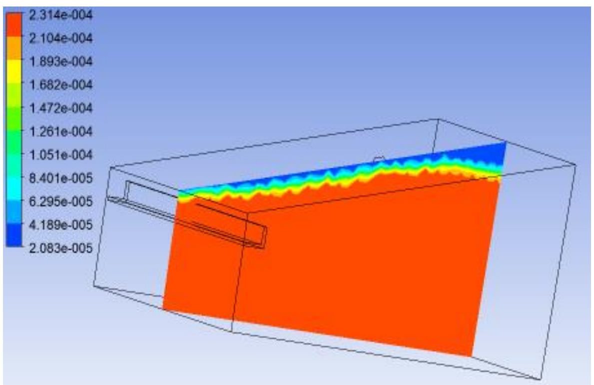


**Figure 18**. Vapour mass fraction

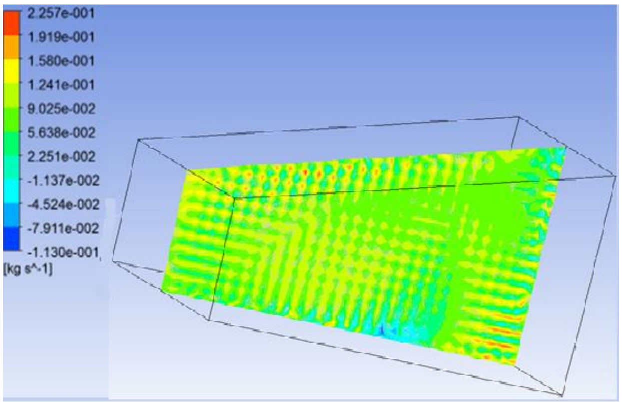


**Figure 19.** Water mass flow

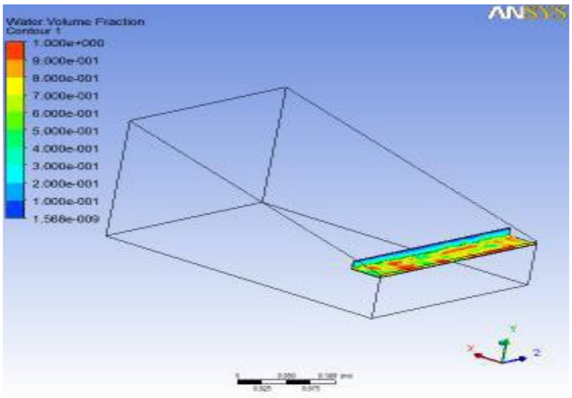


**Figure 20**. Water volume fraction of tray

Figures 17 and 18 shows the fraction of water and vapour within the domain and it's found that water is offered additional below the glass plate which might be condensed into water droplets and picked up within the collector plate. Figure 19 shows the water mass flow within the domain and also the volume fraction of water in Figure 20 shows the amount of water collected in it.

### *5.2. Post-process of $20^0$ inclination solar still*

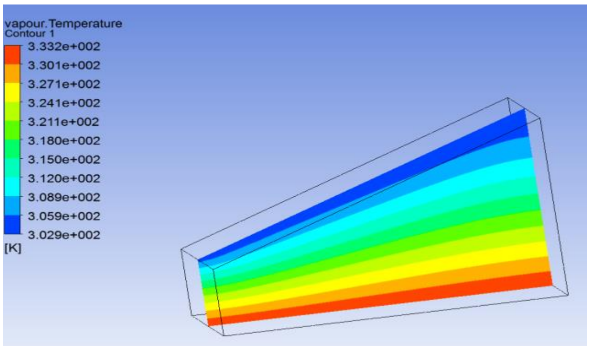


**Figure 21**. Vapour Temperature

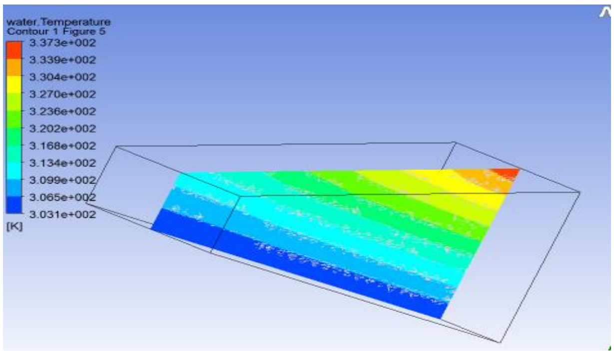


**Figure 22**. Water Temperature

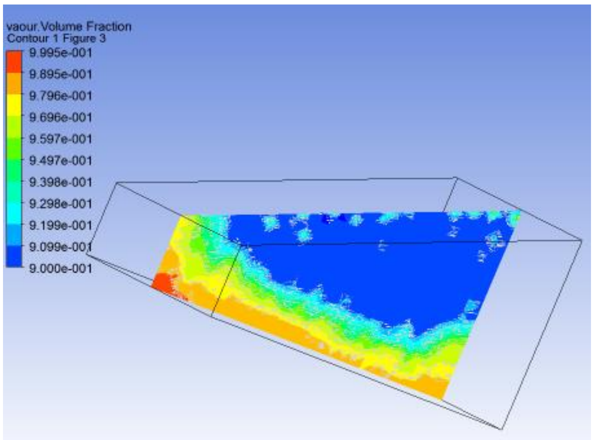


**Figure 23.** Vapour Volume Fraction

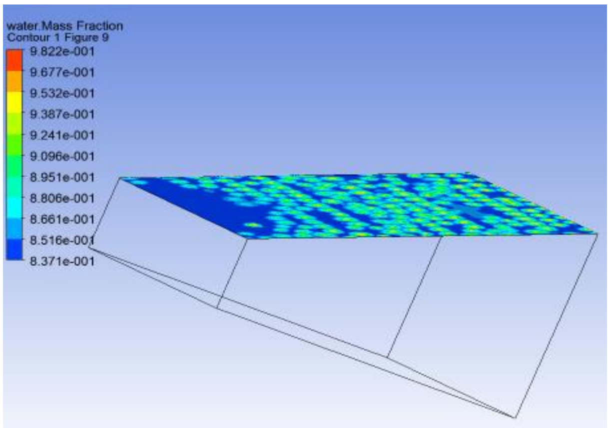


**Figure 24**. Water Volume Fraction

Figures 21 to 32 shows the water temperature and volume fraction of different types of models simulated in single basin solar still.

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*5.3. Analysis of Stepped Model*

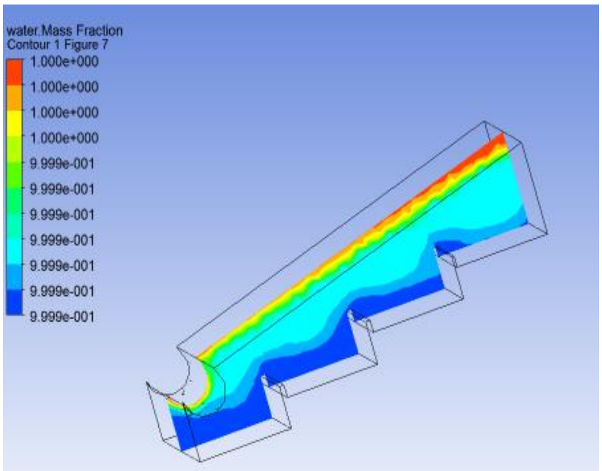


**Figure 25.** Water Mass Fraction

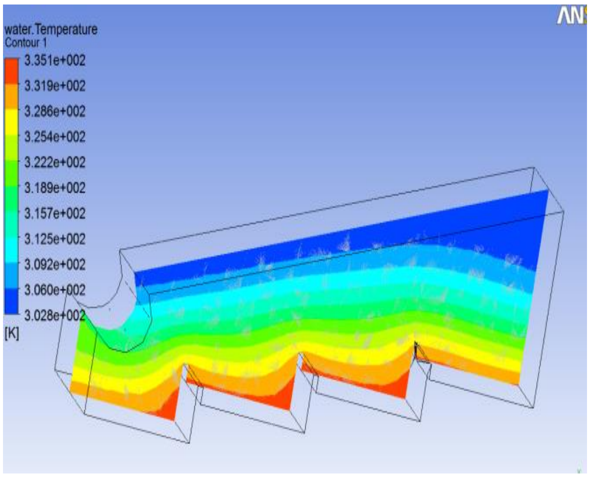


**Figure 26.** Water Temperature

*5.4. Analysis of Finned model*

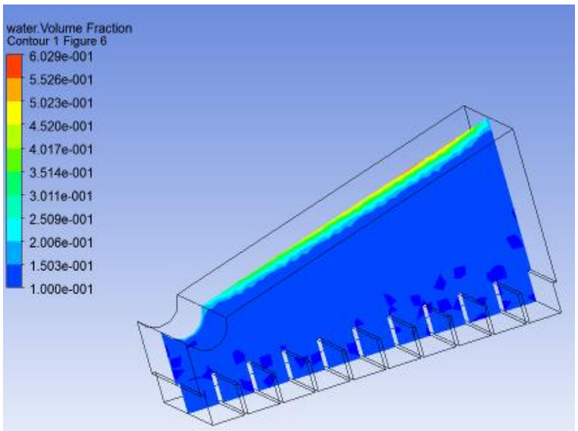


**Figure 27**. Water Volume Fraction

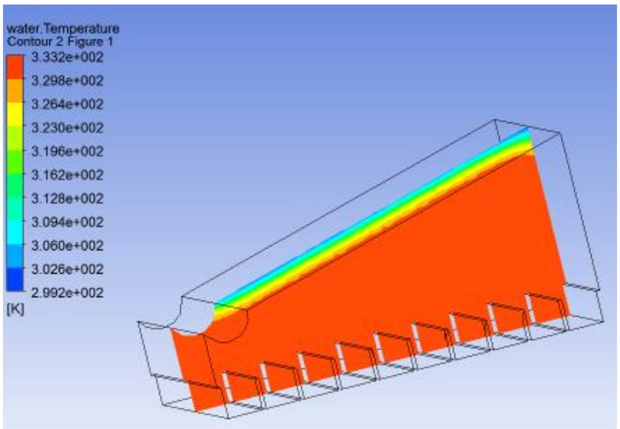


**Figure 28**. Water Temperature

*5.5. Analysis of PCM model*

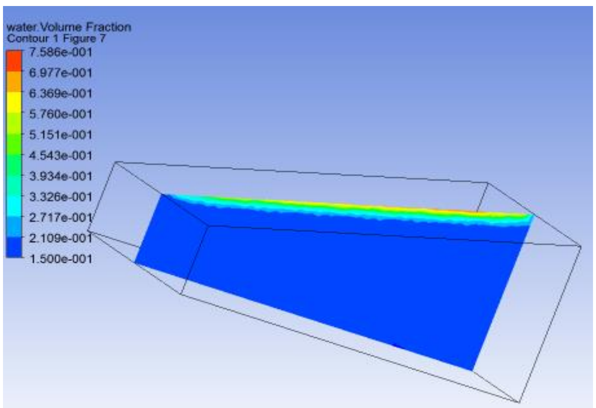


**Figure 29**. Water Volume Fraction

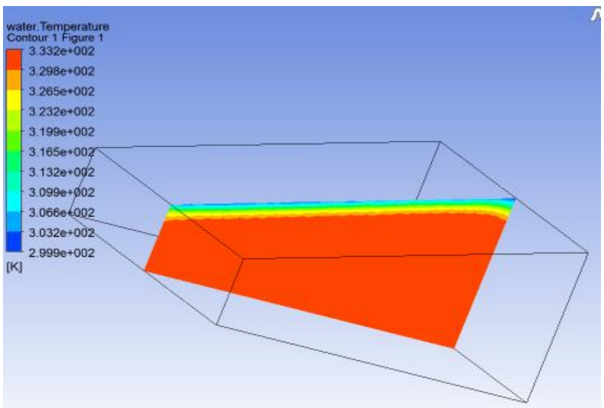


**Figure 30**. Water Temperature

*5.6. Analysis of Double slope model*

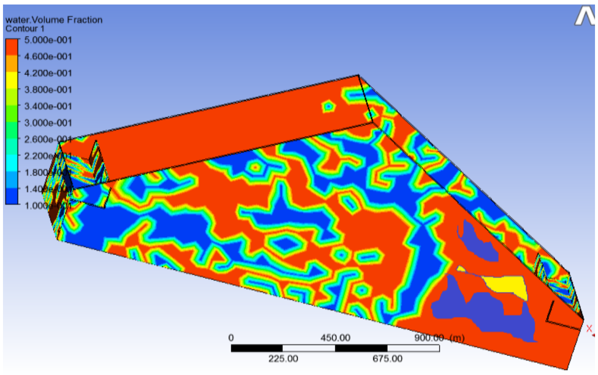


**Figure 31**. Water Volume Fraction

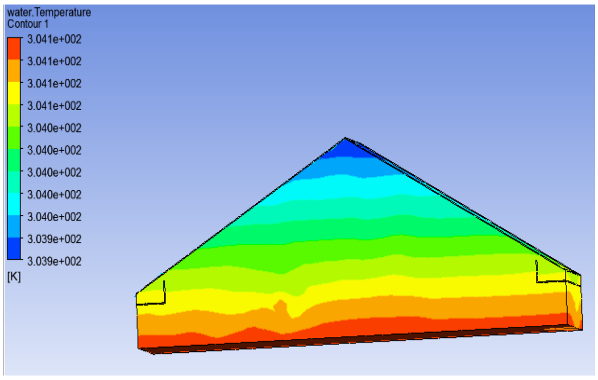


**Figure 32**. Water Temperature

*5.7. Water Temperature*

The theoretical values and also the numerical values obtained were same. From the higher than results water temperature foretold by CFD simulation are compared with obtainable experimental knowledge for $15^0$ and $20^0$ inclinations shown in Figures 33 to 35. This graph has been drawn with Water temperature as ordinate and time in hours as Cartesian coordinate. Water temperature is in smart agreement with experimental knowledge.

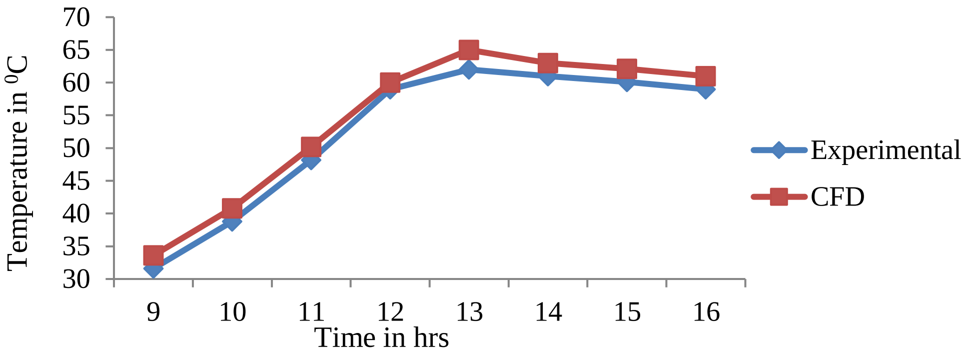


**Figure 33.** Foretold water temperature for $15^0$

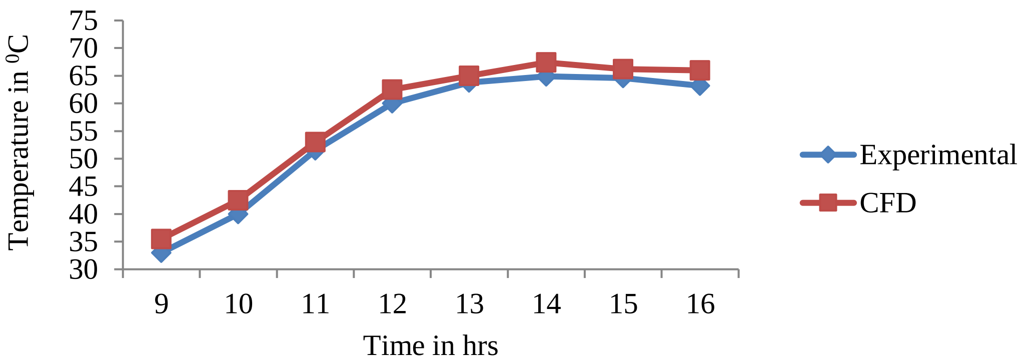


**Figure 34.** Foretold Water temperature for $20^0$

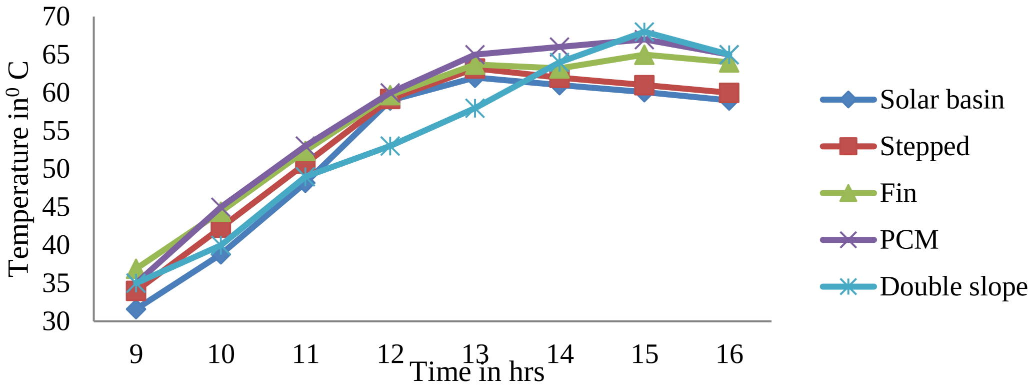


**Figure 35.** Water temperature obtained by experimental knowledge for various forms of solar still

*5.8. Productivity*

From the higher than observations it had been found that solar still with $20^0$ angles provides additional output compared to $15^0$ angles. And solar still with PCM material provides additional output than all sorts as well as night times once the sunshine isn't obtainable thence it's the simplest potency compared to other sorts. Figures 36 and 37 presents the productivity of distillate in different models of stills.

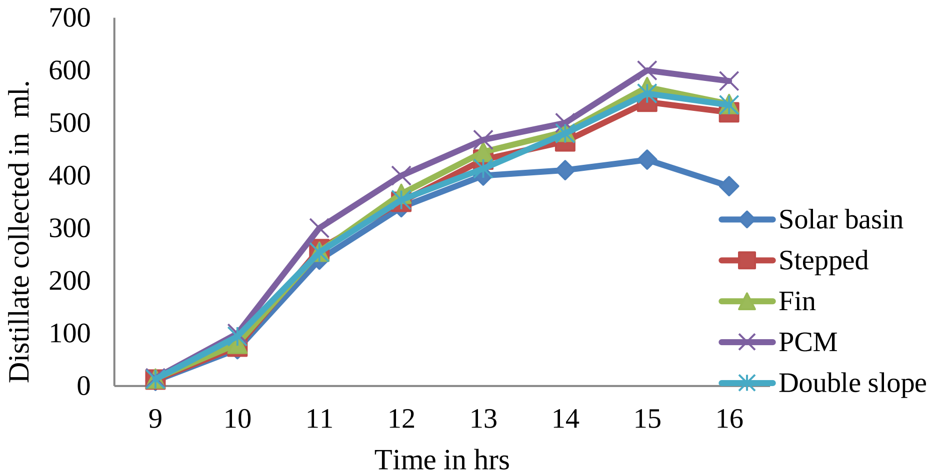


**Figure 36**. Distillate liquid collected by experimental knowledge for various forms of solar still

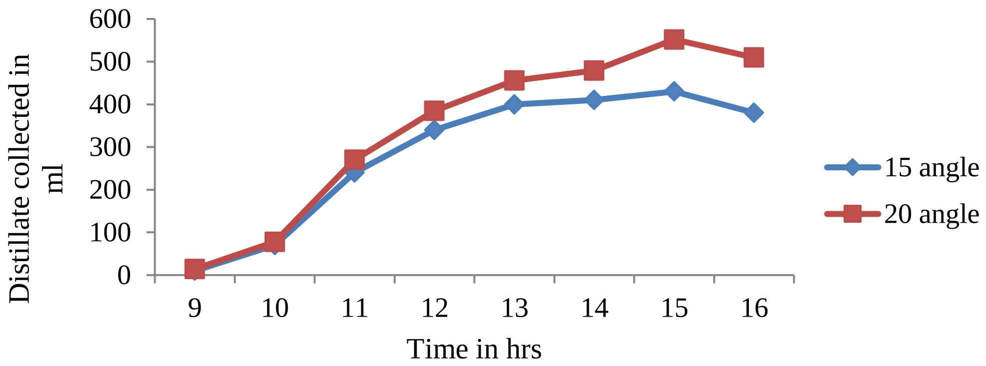


**Figure 37.** Distillate liquid collected by experimental knowledge for $15^0$ and $20^0$ angle solar still

## 6. Conclusions

The temperature distribution of the water and vapour within the totally different form of single slope and double slope is set by exploitation CFD tool and also the results square measure conferred. It's found that $20^0$ inclined solar still provide higher results than $15^0$ inclined solar still. From the experimental and CFD results, the distillated water production rate is foretold and located that PCM still is best suited that provides additional output compared to different sorts and it will be utilized in the getting dark conjointly Paraffin has higher performance although it's instructed to use Stearic acid in PCM still because it is definitely obtainable and economical.

**Acknowledgement**

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## Appendix

B, C, D = ASHRAE value
L= latitude angle
$L_s$= the quality meridian
$L_l$= the great circle of location
$L_T$= the local standard time
b= the inclined plane angle
a= the albedo
$T_n$= transmittance of north glass cover
$T_s$= transmittance of south glass cover
$A_{gn}$=cover area on north side
$A_{gs}$=cover area on south side
$I_n$=incidence irradiance on north cover
$I_s$=incidence irradiance on south cover
$T_w$=the water temperature
$T_g$=the glass plate temperature
$P_w$= the partial pressure of water
$P_g$= the partial pressure of glass
$A_w$=the area of water basin
S=23.45*sin (360*(n+284)/265);
P= (360*(n-81))/365;
$E_T$=9.87*sin (2*P)-7.53*cos (P)-1.50*sin (P);
$S_T$=$L_T$+ ($E_T$/60)-(4/60)*( $L_s$-$L_l$);
W=15*(12.0-$S_T$);
Elevation angle Y=cos (L)*cos (S)*cos (W) + (sin (L)*sin(S));
Hourly diffuse irradiance =$I_b$=B*Y*exp (-C/Y);
Hourly direct irradiance=$I_d$=D*$I_b$;
Azimuth angle =X=sin(S)*sin (L-b) + cos(S)*cos (L-b)*cos (W);
Mean hourly direct irradiance =$I_{bb}$= (I-$I_d$)*X;
Mean hourly ground reflection =$I_{gr}$=I*a*0.5*(1-cos (b));
Total irradiance transmittance= $Q_t$=$Q_{tn}$+$Q_{ts}$
$h_c$=0.884*(($T_w$-$T_g$) + ($P_w$-$P_g$))*( $T_w$+273.15)/269800-$P_w$) ^1/3;
t= time
$h_{fg}$=latent heat of condensed water

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