

Performance Evaluation of Single slope and Dual Slope Solar Still

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Abstract: This article begins with an overview of solar stills. Energy from the sun can even now be used efficiently to acquire sufficient amounts of safe water from saline water in regions within which solar energy coating is higher. The main aim of this study is to evaluate how much water can be generated by a double slope solar stills basin and also to make a comparison in aspects of productivity with single slope solar still.

Keywords: Solar still, Energy storage systems (ESS), Phase Change Materials (PCM), CFD.

I. INTRODUCTION

The solar still is a simplified and long-lasting technique of water manufacturing that has been used for numerous decades. Even so, when tried to make a comparison to other desalination techniques, its main drawback is its low output. This problem has been the subject of extensive studies, with the goal of developing improved solar stills with increased productivity. Maintaining economic viability as well as easiness in building projects, maintenance, and procedure is a serious worry whereas increasing efficiency. Altered solar stills, which include completely separate condensers, thermal collectors, reflectors, sun-tracking gadgets, and other components, frequently needs more space, and thus the productivity gains may not be enough to offset the added expenses.

Rising solar still effectiveness is critical for expanding fresh water manufacturing prices, designing the best framework, and reducing financial costs. Getting an appropriate computational formula of solar stills for making an investment to improve productivity, various variables can help with this.

The use of computational fluid dynamics to design solar stills has been attempted (CFD).

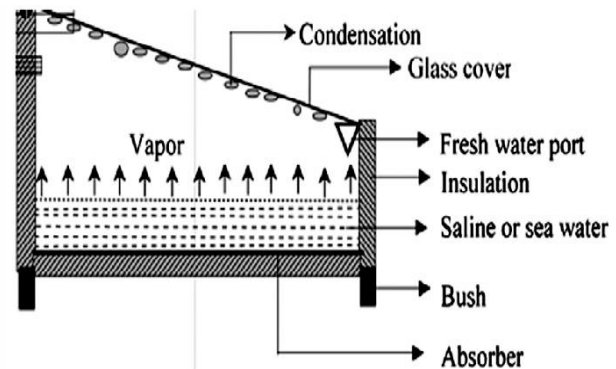


Figure 1: schematic arrangement of single slope solar still

Advantages

- The layout and implementation are simple.
- The size is small.
- Method provides pure water at quite a cheaper price in homes and small societies without the use of stationary accessories (vane, motors, etc.).

It is an environmentally friendly product because it only uses renewable energy and does not cause pollution.

The solar still was a simplified and long-lasting technique of water manufacturing that has been used for numerous decades. Not with standing, when tried to make a comparison to other desalination mechanisms, its main drawback is its reduced output. This problem has been the focus of extensive studies, with the goal of designing improved solar stills that are more productive. But even so, sustaining financial potential and easiness in layout, maintenance, and operations are major issues for higher efficiency. Customized solar stills, that may include completely separate condensers, thermal collectors, reflectors, solar tracking equipment, and other components, often demand more space and are much more complicated, so higher efficiency may not be enough to offset the higher prices.

Even now, a solar energy storing system is needed.

The heat storage framework heats or cools the disk space intermediate to store energy. The stored energy could be used for heaters, condensation, or electricity generation in the future. Heat as well as chemical energy storage devices are the two most common forms of energy storage devices used in solar stills. The comprehensive list of energy storing technologies for solar desalination applications is present already. In addition to heat and chemical grid storage, thermal mass is favoured for applications in solar extraction process because it is more cost effective. Thermal energy accumulated in the sun continues to remain in a delicate or inborn form. High temperature substances store heat as the temperature of the substantial changes.

In a solar still, investigators were using basalt rocks, black stones, and steel wool fibres as delicate heat storage devices. Heat storage components, on the other hand, absorb more heat as well as discharge that when a substance induced phase transformation. The sympathetic heat storage solution is larger and occupies more room. Heat generation storage system, i.e. PCM, stores 5 to 14 times the more heat than other thermal storage systems, making it ideal for solar stills. The temperature increases even during charging period, having broken the covalent bond inside the PCM, and the phase modifications from solid to liquid, until the superheated process is finished, the temperature and pressure remains stable. Whenever the temperature around with a liquid PCM drops, the PCM reinforces itself from liquid to solid and the energy stored is released.

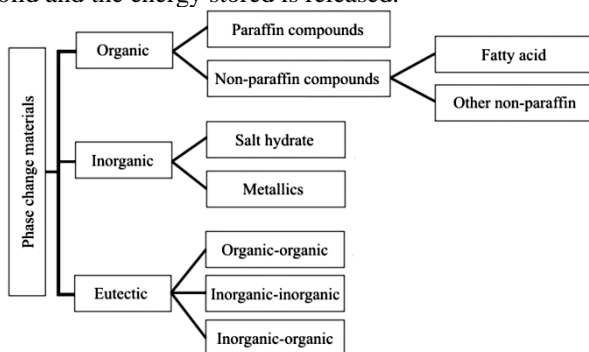


Figure 2: Classification of phase-change materials

Whenever the heater's intensity is reduced, the lesser PCM melting point is selected to help keep the thermal performance minimal. PCM with such a high melting point is recommended whenever the heaters power is extremely high to accomplish a lengthier heating period.

As a result, that each latent heat storing device must include at least three of the preceding elements:

- An appropriate PCM with a melting temperature inside the temperature range required;
- A heat transfer surface that is appropriate,
- A PCM-compatible compartment is required.

Wide categories of solid and the liquid PCM are demonstrated in the diagram 2 above, which are further divided into natural, inorganic, and eutectic components.

PCMs are classified into various groups based on the form of substance used, such as paraffin, fatty acid metabolism, hydrated solutes, and so on.

II. LITERATURE REVIEW

Siliang Chen et. al. (2021) [1] The floating solar system will be a land saving, easy-to-use, and environment friendly way to generate fresh water. As a result of its poor efficiency and low yield in genuine weather conditions, its implementation is restricted. This paper proposed a floating in the water bionic solar still depending on water absorption through root system to confront these limitations. The water supply streams were linked together in a framework, and the entire region was insulated. Because of the root modelling layout, the modern filtration system will reduce loss of heat, steady water absorption, and architectural consistency. Following preliminary research, cellulose fibre and spectacles were chosen separately as dissipating and compressing elements for the experimental systems. The external research took place in Xingtai, China, with cumulative irradiance of 21.96 MJ/m² on the days of the study. The maximal evaporating temperatures as well as everyday fresh water yield were both 59.2 degrees Celsius and 1.5 kilogrammes per square metre per day, correspondingly, the greatest values among current floating solar devices. CFD simulation was then used to investigate the influence of the continuous movement on the circulation of moist air inside the remains. The findings of this work will help to advance the invention on the floating solar stills including their application in narrow desalination..

D.E. Benhadji Serradj et al. (2021) [2] Within just a solitary slanted solar distillation configuration, the impact of vertically installed passively fins upon natural convection. A computational domain of fluid mechanics for just a baffle were still undertaken in this scenario, and the findings were verified experimentally employing particle vision velocimetry. Following this, models were run to see how the lengths and orientation of the deflectors affected still photos with radiation angles ranging from 10 to 60 degrees. The findings revealed that the grilles have a substantial effect on organic convection flow fields and can boost the thermal transmission coefficients by organic convective by approximately to 20%, which would be directly related to the productivity of a solar stills.

Md Hemmat Esfe et al. (2021) [3] The analytical simulation and the wet air approach are used to evaluate the influence of the dimensions of a solar gradients still containing TEC on the water production capacity in this work. The simulations are laminar, steady, and incompressible. The effect of desalination size was evaluated using modifications in chilling systems lengths, low elevation, and heat surface length. The findings reveal that now the TEC device has a greater throughput over traditional desalination. The pattern of changes in water production process with rising length, low flying, and distance of the chilling system's heat surface is downwards, upwards, and upward, correspondingly. Dimensional alterations are among the main causes of these variation in the amount of rotating flows.. Conversely, due to

increased free convection, its pace of water generation improves as that of the circulation rate rises. The fresh water generation ratio reduced by around 10% with a 50% rise in L , as per the data. In furthermore, the thermoelectric device resulted in a 6.8% increase in the efficiency of fresh water generation. The major goal of this research is to improve the effectiveness of fresh water generation in an one rooftop solar still by adding a thermoelectric chillers and modifying the solar still's design.

Md Hemmat Esfe et al. (2021) [4] The effect of solar irradiance on the efficiency of a solitary tilting solar still is investigated in this paper. The solar radiation flux is affected by geographical location, seasons, and duration. The length and temperatures of the basins are kept consistent in this research, and the influence of irradiance on solar distilleries' water efficiency is investigated as a consequence of the duration, month (April), the position (Semnan province). For such average sea surface Nusselt quantity as well as water generation rates, the mathematical technique's correctness was tested using several simulations and empirical studies. The findings also demonstrate that irradiation fluctuation trends are identical to rate of production designs.

Shahin Shoeibi et al. (2021) [5] This study was carried out to verify the various strategies for optimising these systems, taking into consideration productivity, economics, and environmental factors. Additionally, a thorough comparison of manufacturing costs, exergoeconomic evaluation, Reduction of carbon, and environmental economic assessment of various geometry and layouts of these devices was undertaken. Furthermore, an overview of past studies comparisons was provided and examined in depth to provide academics with a better understanding of cost-effective and ecologically friendly photovoltaic still design. The overall cost of generating water using solar stills ranged between 0.0014\$ to 0.29\$ per litre, while the largest lifecycle CO_2 mitigating in a solar power plant with such a photovoltaic framework and a solar module was predicted to be around \$ 1129, 53 tonnes.

Shahin Shoeibi et al. (2021) [6] With the dual solar distillation, the impact of employing air and water-cooled glassware has been realised mathematically and practically. The cooling of the thermoelectric panels cools a jet of water which passes through into water-cooled solar remains through the glass lid. Inside the air cooling solar remains, however, air velocity was employed to chill the transparent cover. The turbulent heat transmission value is used as a glasses surface boundaries conditions. The results reveal that the mathematical model as well as the empirical studies are in excellent accordance.. Water production was 81.1 percentage greater in a water-cooled solar still than in an air cooling solar stills. The impact of the depth of the transparent cover, the velocity, and the temperatures of the water cooling glass on the efficiency of a solar water cooling still are also investigated. Initial studies revealed that this alteration of water cooling solar energy still enhances water efficiency by 21.53 percentage when comparing to water cooling solar energy. Furthermore, the cost of water generated for such water and air-cooled solar images was

roughly \$ 0.243 / L and \$ 0.277 / L, correspondingly, according to the price assessment.. The Carbon dioxide absorption of the air and water-cooled, and enhanced water cooling solar stills were 7.75, 13.09, and 16.27 tonnes, correspondingly, pertaining to the findings. When comparison to water-cooling solar systems, the upgraded water chilling solar plants enhanced their environmental-economic as well as disruption to normal variables by 24.3 percentage and 63.21 percentage respectively.

M. Keshtkar, M. Eslami & K. Jafarpur (2020) [7] A novel transitory mathematical modelling technique for photovoltaic stops is suggested in this work. Present climatic and irradiance information are the only inputs again for existing CFD model, which eliminates the need to define glass and water levels as initial variables. By computing the irradiation transmission equations DO, the absorbing of solar irradiance and also the transmission of heat by radiated in the different elements of the renewable are still taken account. The water vapour speciation problem is resolved by linking it to the power formula through consumer functions, rather than utilising expensive multiphase approaches. In this approach, the variable sink / origin in the conservation equations is the heat capacity of vaporisation / condensing.. Combining Fick's theory on water with glass surfaces yields the appropriate evaporator and condenser ratios. By incorporating a variable with an acceptable value of 0.5, it is believed that now the heat source of the phases shift is shared between the two adjoining entities. As a result, the transitory dispersion of temperatures and concentrations, as well as production, in passively solar images over the course of a day, may be computed with a minimal amount of computer work. It has been demonstrated that expanding the quantity of steps exceeding six is not useful using the existing technique on multilevel active solar photovoltaic cells.

Md M. Khairat Dawood et al. (2020) [8] A noble transitory mathematical modelling technique for photovoltaic disruptions is suggested in this paper. The sole inputs for the present CFD model are present solar irradiation and weather data, which eliminates the need to define the temperatures of the glass as well as water as initial conditions. Calculating the radiation transmission equation DO takes into account solar radiation absorbing and heat transmission by radiation in the various elements of the photovoltaic distillation. The water vapour species equation is resolved by linking it to the energy formula utilizing user-defined procedures, rather than utilising expensive multiphase approaches. This research proposes a new transitory mathematics modelling approach for photovoltaic disturbances. The current CFD model's only inputs are current solar irradiance and meteorological data, eliminating the requirement to establish the glass and water degrees as initial state. In order to calculate the radiation transfer equation DO, solar radiation absorption and thermal conveyance by radiated in the different components of the photovoltaic distillation must be taken account. Rather of using expensive multiphase techniques, the water vapour speciation solution is calculated by tying it to the power equation using consumer techniques. When the existing technology is used to multi -phase active solar photoelectric

cells, it is discovered that having more than six steps is not useful..

III. METHODOLOGY

Mathematical analysis of solar still:

Assumptions to write the energy and mass balances for solar still

- ❖ The solar still unit is vapour leakage proof, and well insulated.
- ❖ The temperature gradient through the PCM is negligible, thus
- ❖ The temperature gradient in the basin water is negligible.
- ❖ The heat conduction flow from basin liner to PCM is in one direction.
- ❖ Condensate and falling glass water is not thermal resistance to heat flows through the glass cover.
- ❖ The absorptivity of basin water and cooling water between glasses are negligible.

The heat capacity of cooling water is negligible and the temperature of cooling water is assumed to vary in stream direction

B CAD modelling of single slope solar still:

For the creation of three dimensional CAD model of single slope solar still created using ANSYS design modular having the dimensions of base 1.1 m x 1.1 m, front wall dimensions of 0.25 m in height and back wall of 0.9 m. The three dimensional CAD model of solar still is shown in figure 4.

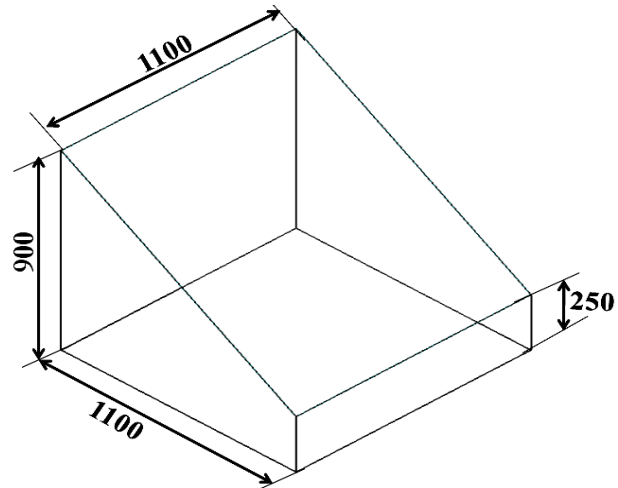


Figure 4: CAD mode of single slope solar still

C. **Meshing:** Since accomplishing the CAD geometric features of a solitary slope solar panel, it was still imported into ANSYS workstation for further assessment, and the meshing process began. In finite element model, meshing is a crucial step in which the CAD configuration is broken down into a series of smaller pieces. Mesh refers to the small parts. Figure no. 5 shows the mesh generated for single slope solar still throughout this task. The overall amount of nodes is 137082, and the overall number of components with hexahedral type significant element is 128832.

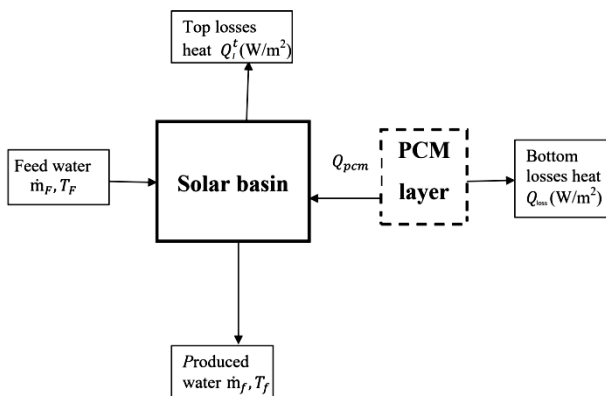


Figure 3: Schematic block diagram of the solar still in discharging mode

A Computational Fluid Dynamics Analysis of Solar Still

Computational fluid dynamics seems to be the use of desktop simulation to analyse systems encompassing fluid flow and heat transfer. The method is extremely versatile and can be used in both industrial as well as non-industrial settings. The step evolving substance is used in the current work to perform computational fluid dynamics assessment utilising ANSYS fluent for solar stills. This computational study is conducted using the necessary equations such as the continuity equations, conservation of momentum, as well as governing equations.

Mathematical algorithms for dealing with fluid flows challenges are at the heart of computational fluid dynamics. Those Computational Fluid Dynamics parcels involve advanced user interfaces for entering the boundary variables and examining the outcomes in sequence providing immediate access to one's solving power. As a result, there are three basic aspects.

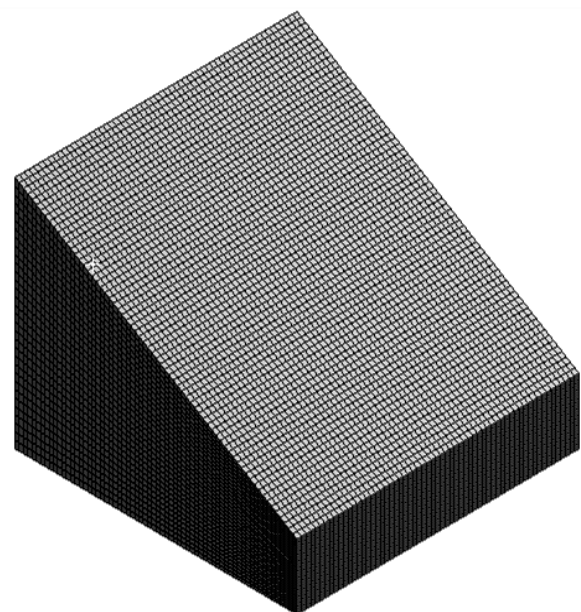


Figure 5: Meshing of single slope solar still

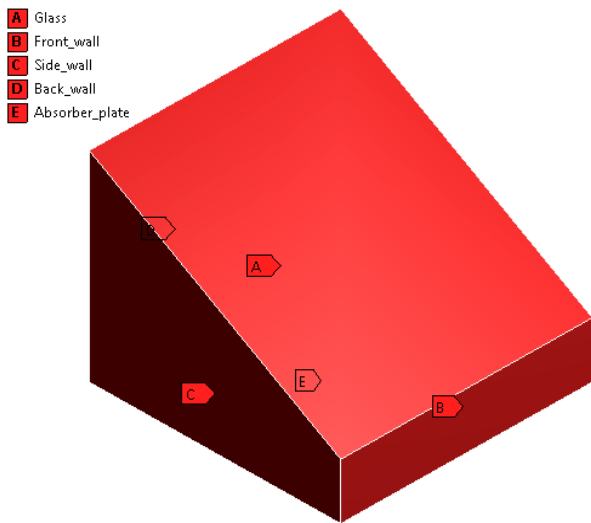


Figure 6: Different boundaries of single slope solar still

D. CAD modelling of double slope solar still:

For the creation of three dimensional CAD model of double slope solar still created using ANSYS design modular having the dimensions of base 2.2 m x 1.1 m, front wall dimensions of 0.25 m in height and back wall of 0.9 m. The three dimensional CAD model of solar still is shown in figure 7.

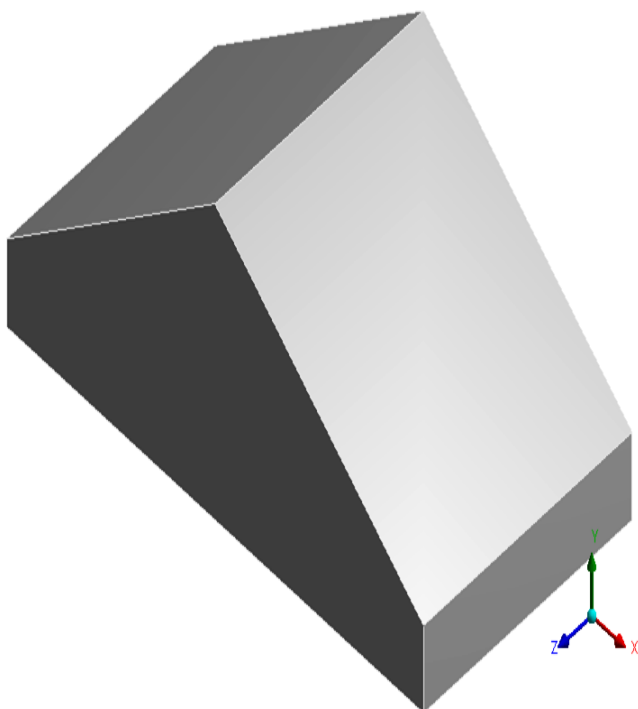


Figure 7: CAD mode of double slope solar still

E. Material properties

Table 1: Thermo physical property of paraffin C18 material

Property	Values
Melting temperature (T_m) [$^{\circ}C$]	53.7
Specific heat (C_{p_s}) [kJ/kg.K]	2.0
Specific heat (C_{p_l}) [kJ/kg.K]	2.15
Thermal conductivity (k_s) [W/m.K]	0.24
Thermal conductivity (k_l) [W/m.K]	0.22
Density (ρ_s) [kg/m ³]	910
Density (ρ_l) [kg/m ³]	790
Latent heat of fusion [kJ/kg]	190

Table 2: Different parameter compared with C. Gnanavel et al 2020 & present work

S. No	Parameters	C. Gnanavel et al 2020	Present work	% Difference
1	Volume fraction of water	0.1056	0.1095	3.69%
2	Temperature	305.1	311.2	1.99%
3	Vapour density	0.8104	0.8585	5.94 %

IV. RESULT AND DISCUSSION

The fundamental purpose of this research is to determine how much moisture is created by double stepping solar still basins and to compare the performance of the same with single slope solar still. The ANSYS model has been used to produce three-dimensional CAD designs of single and the double slanted stills featuring base proportions of 1.1 m x 1.1 m, front wall proportions of 0.25 m tall, and rear wall dimensions of 0.9 m, and dual slope base features of 2.2 m x 1.1 m. Multiphase simulations are expressed as VOF explicit compositions with the number of iteration stages for air, moisture, including moisture, and also multiphase connections. Phase change transmission processes include vapours to gaseous form as well as gaseous to water evaporation chilling. Utilizing Pick Square Root Windward for such Energy and Momentum formulations, using paraffin C18 as that of the nano-fluid, energy from the sun was used on the translucent covering of the sun even with a geographical positioning of longitude 77.4 $^{\circ}$ E, latitude 23.2599 $^{\circ}$ N, as well as standard time GMT+5:30 hour, for the clean sky scenario. After completing comprehensive studies on the both single and dual gradation sun still layouts, the section examines certain sketches and visual findings.

For single and dual slope solar stills, an overview with computational fluid dynamics assessment is provided

Table 3: CFD analysis of single slope solar still

water volume fraction	vapor volume fraction	Vapour Density [Kg/m ³]	Mass flow rate [kg/s m ²]	Temperature [K]
0.0278	0.0987	0.8585	1.23E-03	311.2

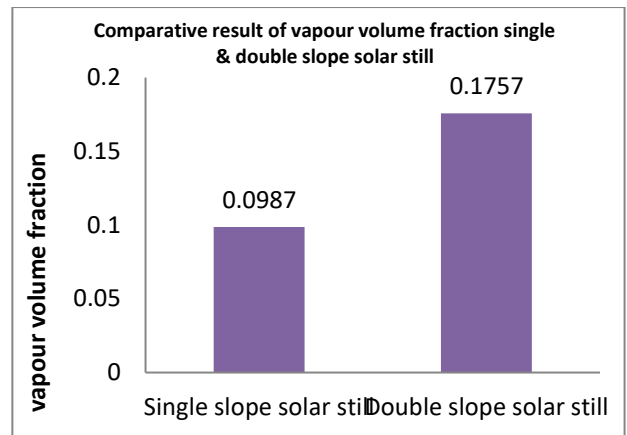


Figure 9: Comparison of single and dual slope solar stills for vapour volume fraction

Table 4: CFD analysis of Double slope solar still

water volume fraction	vapor volume fraction	Vapour Density [Kg/m ³]	Mass flow rate [kg/s m ²]	Temperature [K]
0.1262	0.1757	0.8585	2.20E-03	316.7

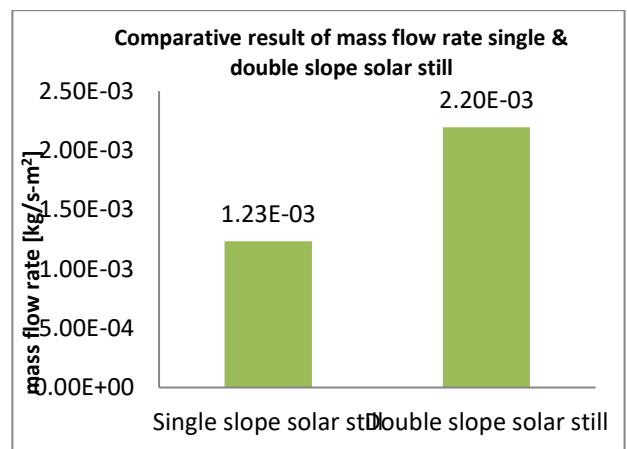


Figure 10: The mass flow velocity of single and dual slope solar stills were compared

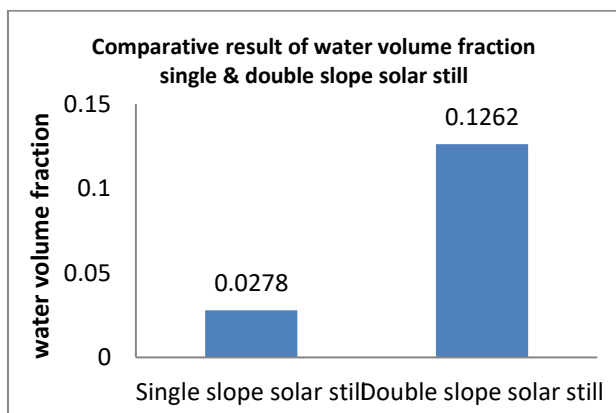


Figure 8: Comparison of single and dual slope solar stills for water volume percentage

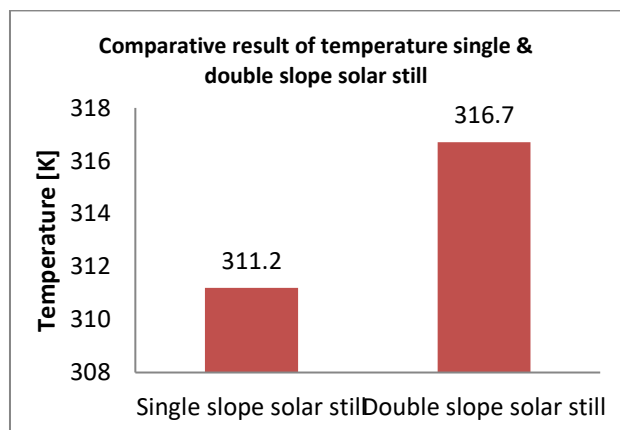


Figure 11: Temperature results from single and dual slope solar stills are compared.

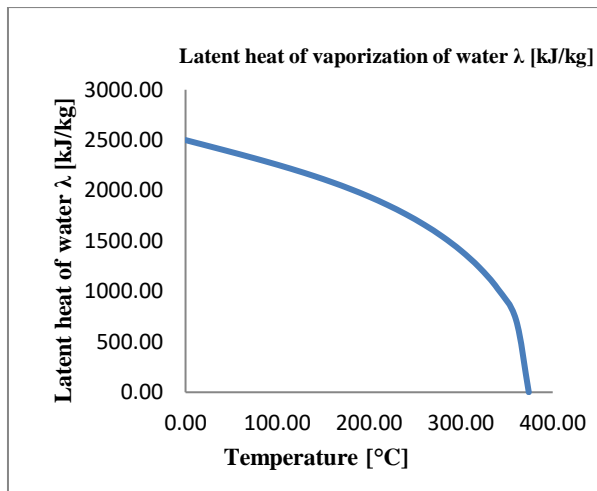


Figure 12: [kJ/kg] Latent heat during vaporisation of water

V. CONCLUSION

Computational fluid dynamics analysis have been performed by creating three dimensional CAD mode of single and double slope solar still using ANSYS design modular having the dimensions of base 1.1 m x 1.1 m, front wall dimensions of 0.25 m in height and back wall of 0.9 m. the dimensions of base for double slop 2.2 m x 1.1 m. Multiphase model as VOF implicit formulation by using number of Eulerian phase 03 for air, water-liquid & water-vapour with multiphase interaction evaporation-condensation for mass transfer mechanism vapour to vapour and vapour to water, paraffin C18 used as Nano-fluid. For the fair meteorological conditions, sun rays have been used on transparent cover of the solar still with a global position of longitude 77.4, latitude 23.2599, and time zone +5.5 hour. According to the above assessment, the conclusions were drawn.

For the fair weather condition, solar radiations were used on the transparent cover of the solar still with a global standing of longitude 77.4°E, latitude 23.2599°N, and standard time GMT+5:30 hour. According to the above assessment, the following conclusions have been drawn.

- The maximum moisture volume fraction is 0.1095, the highest vapour volume fraction is 0.0987, the mass circulation rate is $1.233e-3 \text{ kg/s m}^2$, and the highest temperature is 311.2 K. At this temperature, the hourly productivity is 335.93 ml/hr and the daily productivity is 8398.25 ml/day.
- After conducting computational fluid dynamics analysis on a dual slope solar still, the higher water volume fraction was 0.1262, the highest vapour volume fraction was 0.1757, the mass circulation rate was $2.20E-03 \text{ kg/s m}^2$, the highest temperature was 316.7 K, and the hourly efficiency was 805.58 ml/hr and the daily productivity was 20139.5 ml/day. It has been observed that when the temperature of fluid increased by 5.5 degree Kelvin, the daily productivity

increased by 1.398 times as compared with single slope solar still.

From the above concluding, the water volume percentage of a dual slope solar still enhanced by 0.0978, the vapour volume percentage enhanced by 0.077, the mass flow rate enhanced by 0.00097, and the temperature rises by 5.5 degrees, which is 1.77 percentage more than a single slope solar still, whereas the hourly and daily productivity of a dual slope solar still is 1.398 times that of a single slope solar still, so it is recommended that double slope solar stills be used.

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