# THEORETICAL ANALYSIS OF A BASIN TYPE SOLAR STILL WITH NATURAL CIRCULATION-TYPE PASSIVE CONDENSER AND SAND HEAT STORAGE


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## ABSTRACT


The effects of using natural circulation condenser and sand heat storage on the performance of a basin type solar still was investigated. A thermal model for predicting the temperature distribution across the proposed solar still configuration was established using Crank-Nicolson method and Thomas algorithm. Parametric analysis was performed to identify the optimal saline feedwater depth and insulation thickness to collect the highest amount of distillate in the system. The modified system is found to have higher daily distillate yield and thermal efficiency compared to the conventional system, by 24.7% and 14.23%, respectively. Economic analysis revealed that the price cost for producing water from the modified still design is 3.125 times cheaper than the local market price, with a payback period of 309 days.


## METHODOLOGY

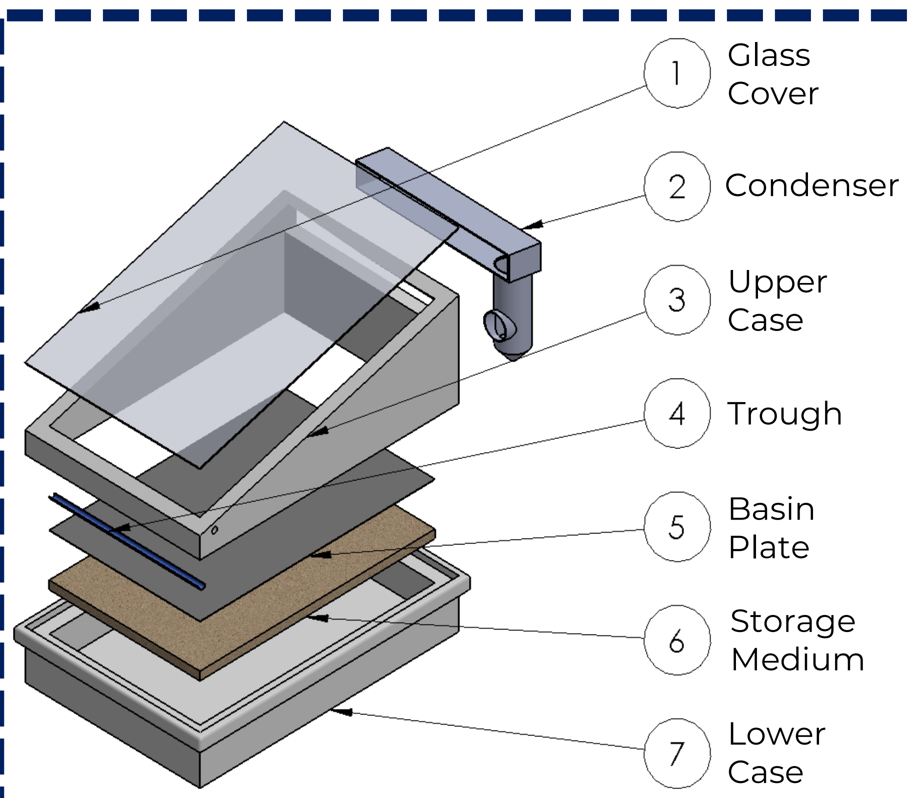



**Fig. 1:** *Exploded view of modified solar still design*

### Crank Nicholson Method

*(for 1D transient heat flow)*

$$\frac{dT_k}{dt} = \frac{1}{2}\left[\frac{dT_k{}^p}{dt} + \frac{dT_k{}^{p+1}}{dt}\right]$$

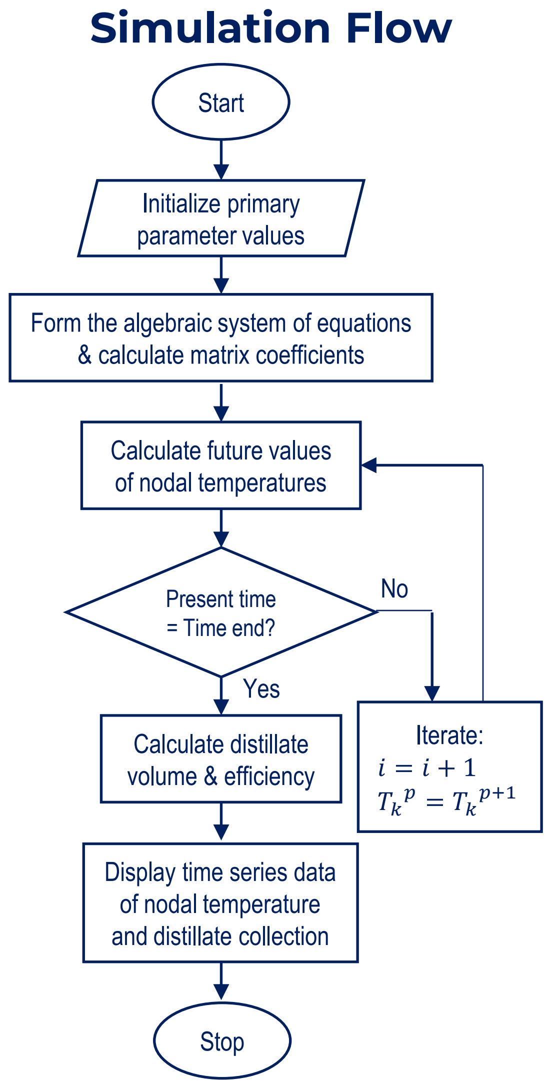
Isolating $T_k{}^{p+1}$:

$$T_k{}^{p+1} = \frac{\Delta t}{2}\left[\frac{dT_k{}^p}{dt} + \frac{dT_k{}^{p+1}}{dt}\right] + T_k{}^p$$

### Thomas Algorithm

$$\begin{bmatrix} b_1 & c_1 & 0 & 0 \\ a_2 & b_2 & c_2 & 0 \\ 0 & a_3 & b_3 & c_3 \\ 0 & 0 & a_4 & b_4 \end{bmatrix} \begin{bmatrix} T_1{}^{p+1} \\ T_2{}^{p+1} \\ T_3{}^{p+1} \\ T_4{}^{p+1} \end{bmatrix} = \begin{bmatrix} d_1 \\ d_2 \\ d_3 \\ d_4 \end{bmatrix}$$

### Simulation Flow



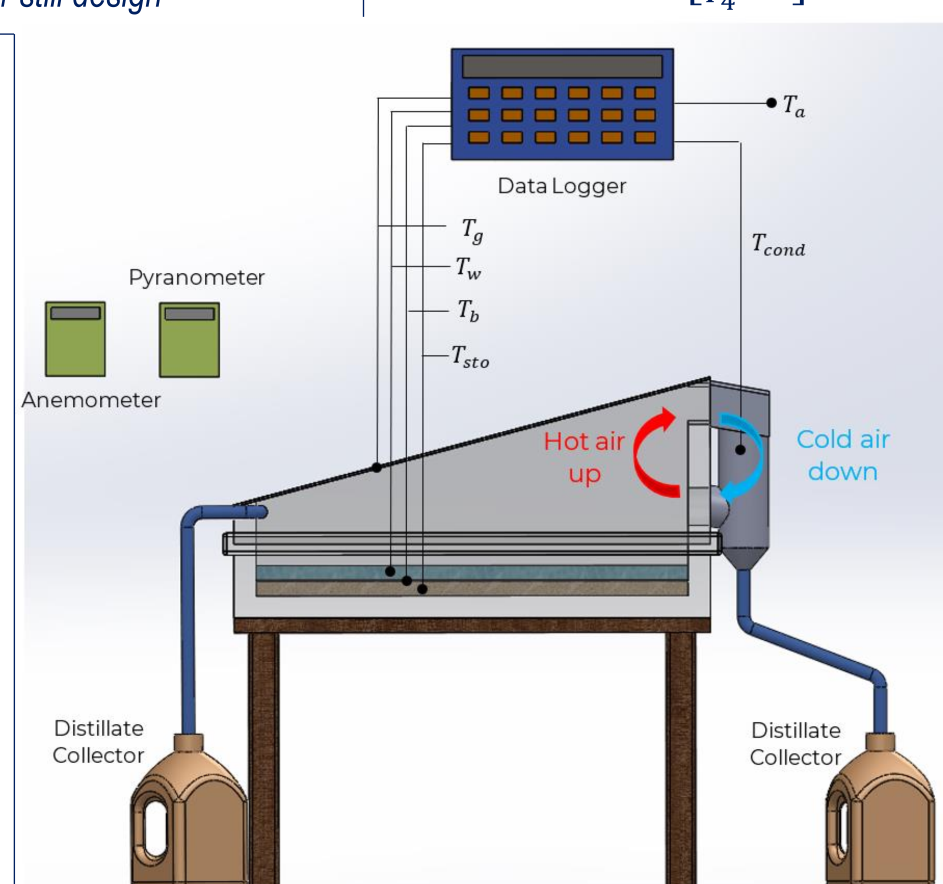




**Fig. 2:** *Test setup for thermal performance analysis*

## CONCLUSIONS

1. Adding a natural circulation passive condenser and sand HSM improves solar still thermal efficiency by 14.23% and distillate yield by 24.7%
2. For optimized distillate collection, the solar still must have a shallow saline feedwater depth (1cm), thicker insulation wall (4cm), and thinner sand heat storage layer (1cm)
3. Rate of distillate yield for stills with sand HSM are higher from 15:00 onward, implying better performance during the lack of sunshine
4. Distillate produced by the proposed system is 3.125 times cheaper than the market, with a payback period of 309 days
5. The thermal model can be improved by considering heat losses at the walls of the solar still
6. Latent heat storage mediums can have promising effect to improve the performance of stills with passive condenser

## INTRODUCTION

One of the pressing issues of the passive solar still is its thermal efficiency. The common workaround for this is to keep the water-glass temperature gap to be wider enough. However, this is challenged by the heat build up on the glass cover, due to the heat generated as water vapor is condensed. To address this, a study by Arunkumar et al. (2012) tried to flow cooling water over the glass plate, however, increase in yield is not large due to some of the incident solar radiation being reflected by the ripple formed in the flowing water film. Nijegorodov et al. (1994), on the other hand, removed part of the hot humid air in a solar still by using an exhaust fan, and passed it through a condenser where the latent heat of water vapor is used to preheat the cold saline water for the basin. With the design's technical complexity, this leaves its feasibility to remote areas in question.

Debates about forced vs free air circulation have emerged. In a study by Fath et al. (2003), it was found out that decreasing the circulating air flow rate shows an insignificant effect on still productivity and efficiency. However, a decreased air flow rate of up to 0.001 kg/s partially increases the productivity. This directs to the possibility of using natural circulation to drive the air flow since it has a very important implication on the still economy and water production. Also, with the still's dependence to solar energy, heat storage medium are used to perform better during cloudy days and to facilitate nocturnal distillation. Hence, this study will focus on applying the two concepts to a basin type solar still design.

## RESULTS AND DISCUSSIONS

### Parametric Analysis: water depth and insulation thickness

Table 1a:

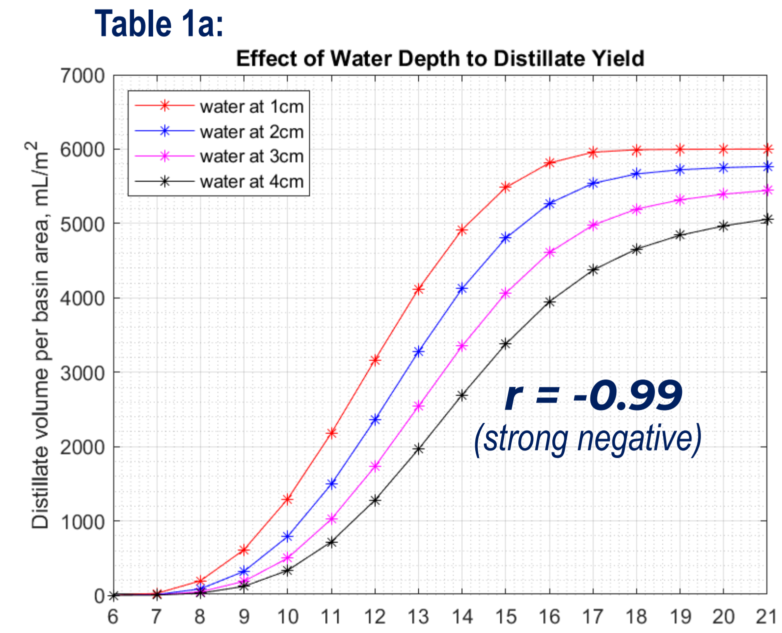
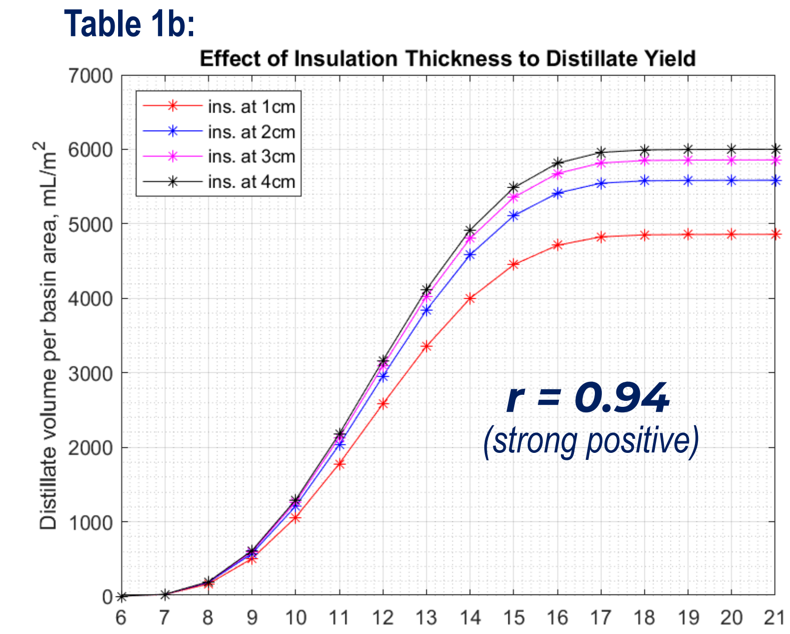
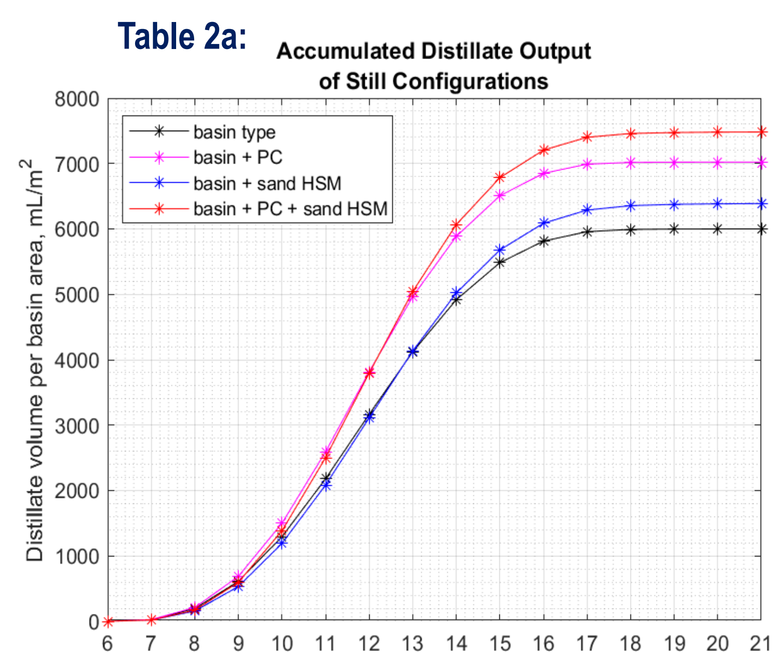



Table 1b:




### Thermal Performance of Solar Still Configurations

Table 2a:

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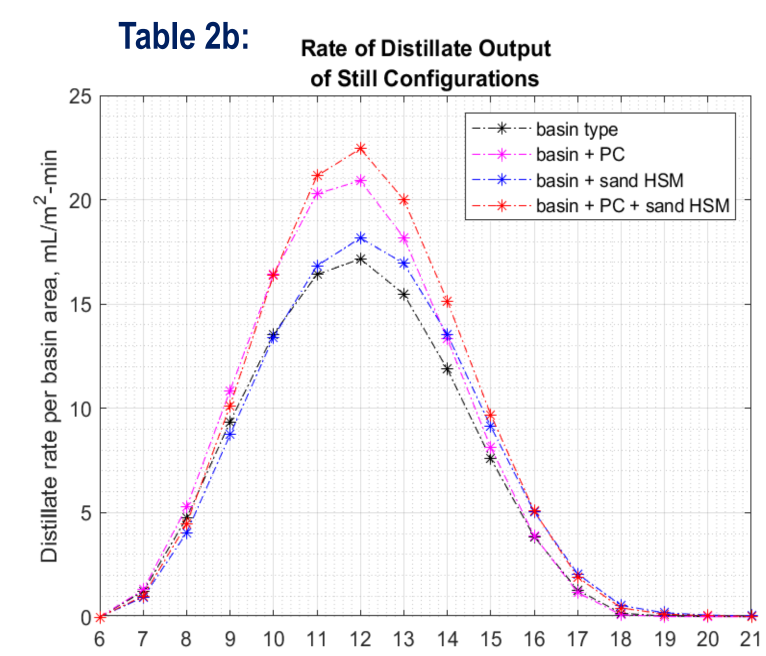


Table 2c:

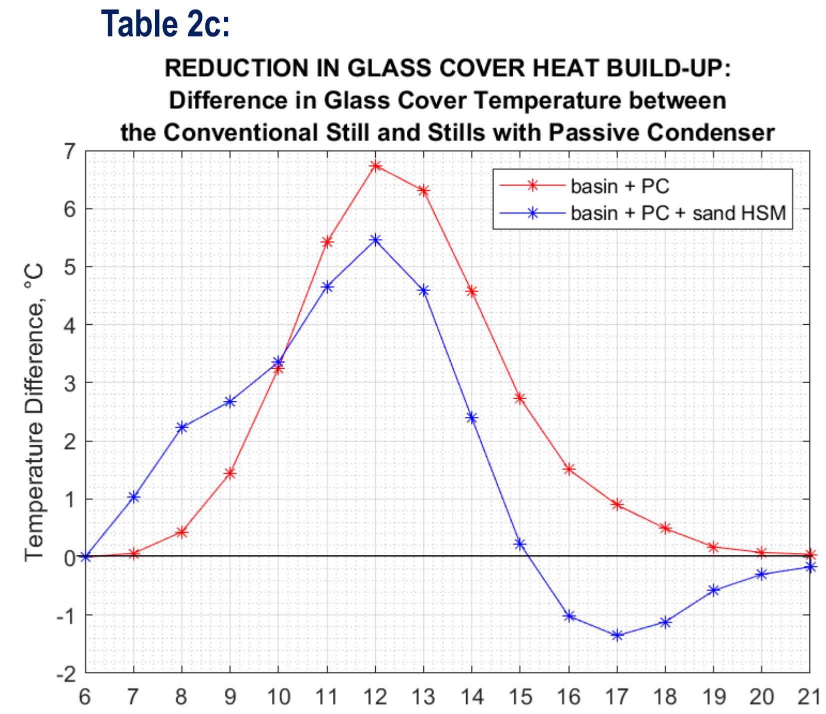


Table 2d: