# Modeling Heat Exchanger Performance with Application to Desalination Using a Vacuum Tube Solar Collector

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## Objective

One goal of this project is to develop a steady state sensible performance analysis of multi-pass cross-flow finned-tube heat exchangers. Another goal of this project to devise an inexpensive, portable means of desalinating water using vacuum tubes solar collector

## Types of cross flow heat exchangers

The investigation considers various flow circuiting, such as counter cross-flow, parallel cross-flow, and cross-flow where the tube-side flow is in parallel. A previously developed matrix approach is used to evaluate the heat exchanger performance in each case..

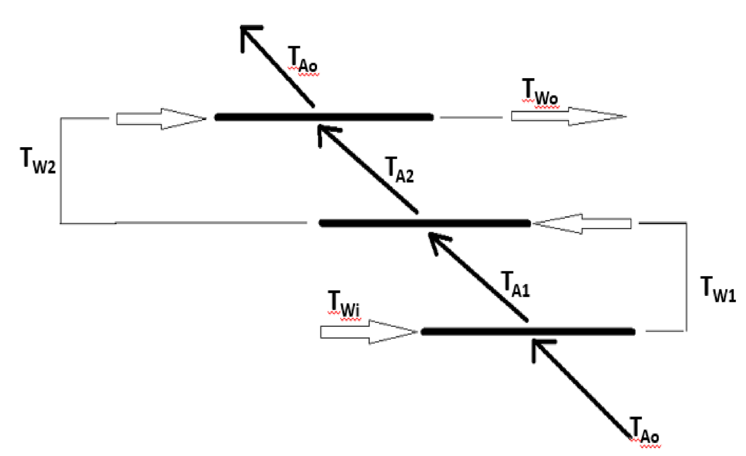

Figure 1. Flow circuiting for a three-pass parallel cross-flow heat exchanger

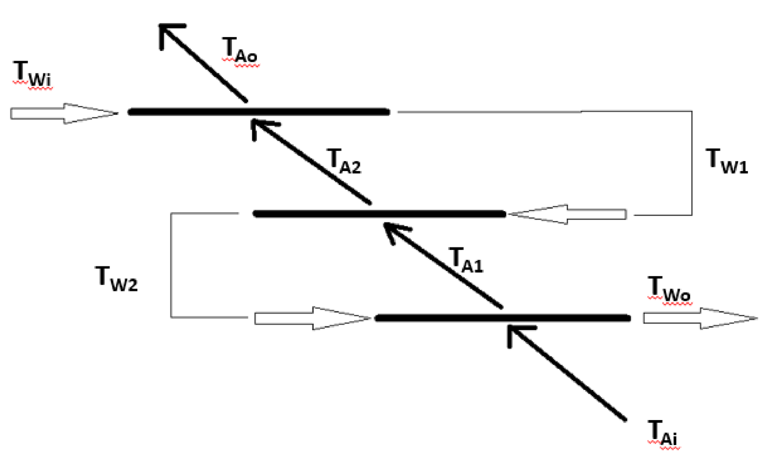

Figure 2. Flow circuiting for a three-pass counter cross-flow heat exchanger

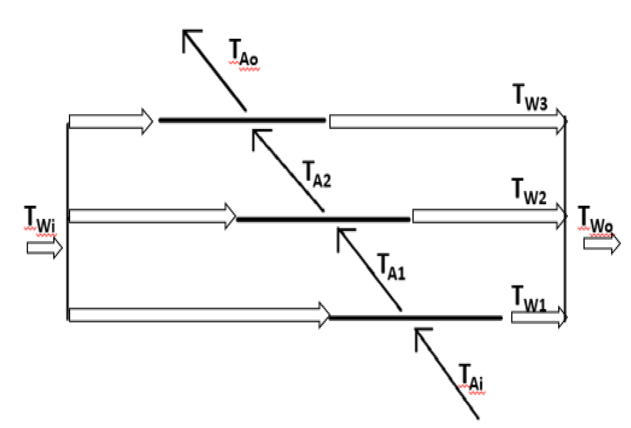

Figure 3. Flow circuiting for a three-pass pure cross-flow heat exchanger

## Performance study of cross flow heat exchangers

A parametric study was performed on cross-flow heat exchangers subject to various flow circuiting considerations, i.e., overall parallel- and counter-flow, as well as tube-side flow in parallel. If the heat capacity rates were greatly different, or if temperature variations throughout the heat exchanger between the inlet and outlet were insignificant, all multi-pass cross-flow heat exchangers exhibited similar performance characteristics. However, for all other combinations of capacity rate ratio and number of transfer units, a cross-flow heat exchanger operated in overall counter-flow yielded the best heat exchanger performance, i.e., the maximum overall effectiveness. The heat exchanger effectiveness of multi-pass cross-flow heat exchangers with the tube-side flow in parallel was intermediate between that for overall counter and parallel cross circuiting. For each flow circuiting configuration, a study was performed to assess the combination of NTU and r-values that exhibited heat exchanger effectiveness values that changed less than 1%, as the NTU values were progressively increased. That criterion was determined to be impractical when sizing multi-pass heat exchangers operated in overall counter-flow, since it yielded excessive NTU values for each capacity rate ratio. This criterion was achieved for multi-pass heat exchangers operated in overall parallel flowing many cases considered in the present study, the heat exchanger performance increased with increasing NTU (or surface area) until a certain limit was achieved. Thereafter, the increase in NTU produced perhaps only a gradual increase in the heat exchanger performance, or implied that certain locations within the exchanger would not effectively contribute to the desired heat transfer. This aspect is very important from the initial design standpoint, as increasing the NTU, i.e., the surface area (or the number of passes) means more material, more weight, and therefore more initial cost.

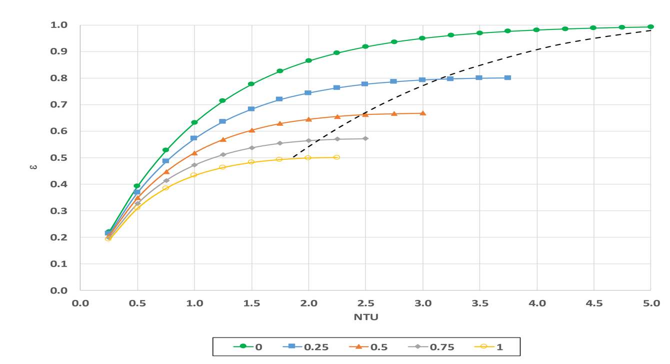

Figure 4. Thermal performance of a two-pass parallel cross-flow heat exchanger

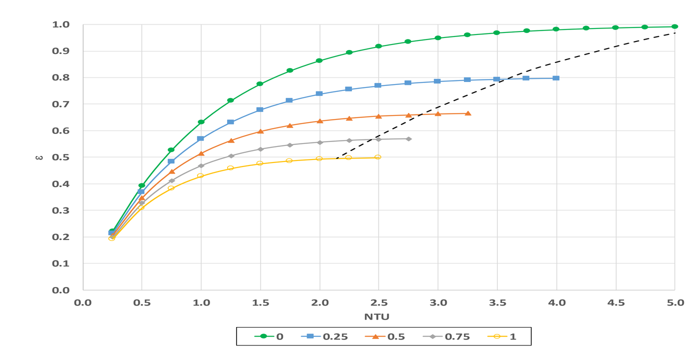

Figure 5. Thermal performance of a three-pass parallel cross-flow heat exchanger

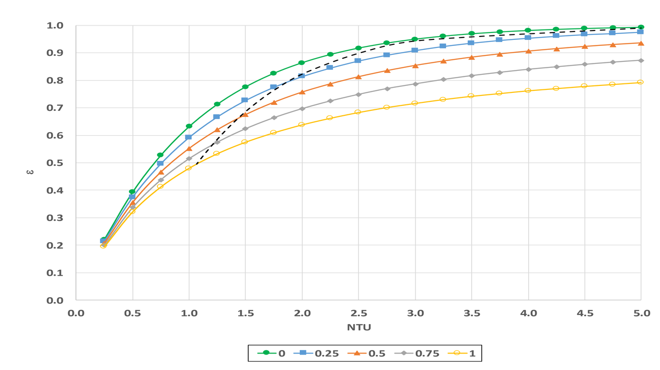

Figure 6 Thermal performance of a two-pass counter cross-flow heat exchanger.

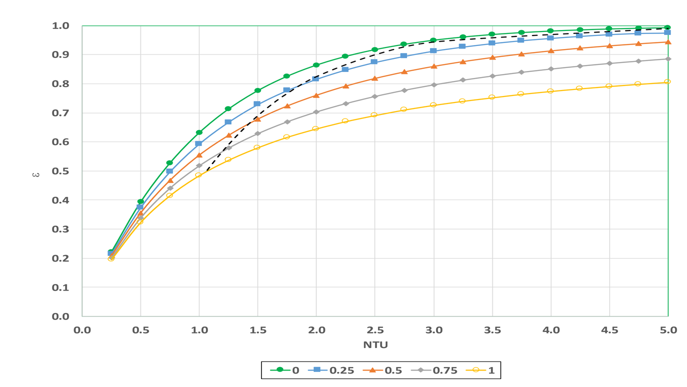

Figure 7. Thermal performance of a three-pass counter cross-flow heat exchanger

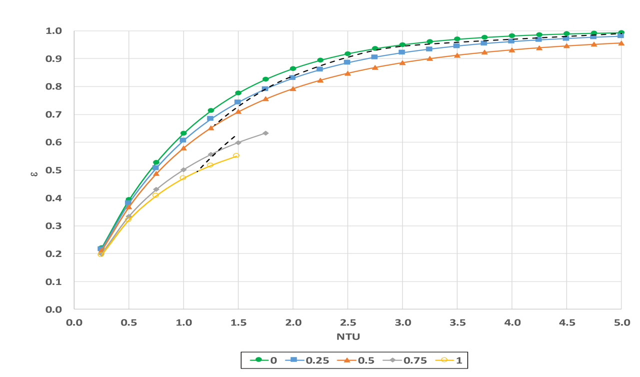

Figure 8. Thermal performance of a two-pass cross-flow heat exchanger with tube-side flow in parallel

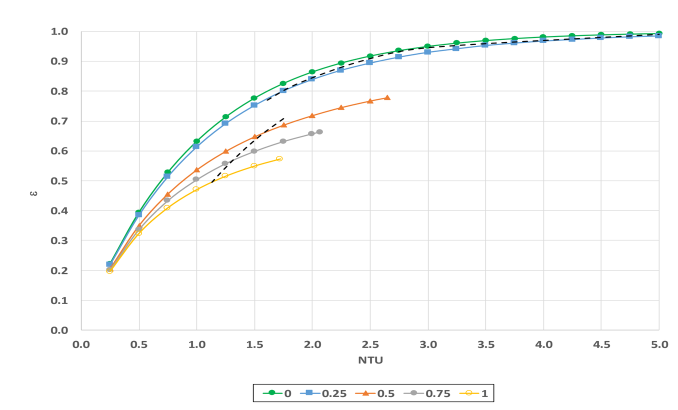

Figure 9. Thermal performance of a three-pass cross-flow heat exchanger with tube-side flow in parallel

Another goal of the project is to employ evaporation/condensation process to achieve desalination. It will incorporate an existing rooftop vacuum tube solar collector located in Lewis Hall to promote evaporation of a brine solution, and shall likewise utilize a cooling coil to condense pure water from the evaporated brine solution.

## Water desalination process

With growing energy demands, intense search is being made to find energy efficient and environment-friendly water desalination methods. In many of these methods, harnessing available solar energy has been the central idea. My work deals with evaporation of sea water utilizing both electrical energy and solar energy and finally condensing the evaporated hot vapor thereby producing distilled water. In my work Utilization of heat energy (both electrical & solar energy) is augmented by the inclusion of phase change material (Magnesium chloride hexahydrate) in the boiler tank wherein the sea water evaporation process takes place. The choice of magnesium chloride hexahydrate as the phase change material (PCM) is based on its melting point ( approximately 118$^0$C) being closer to the evaporation temperature of salt water. Ethylene glycol which extract radiation heat energy from the sun rejects the energy to the sea water in the boiler as shown in figure 11. Apart from glycol there are two heating elements which act as heating sources in the boiler tank to evaporate the sea water. As shown in figure 10, the hot sea water vapor coming out of the boiler tank gets condensed in the condenser leading to the formation of distillate. The cold sea water which acts as cooling medium in the condensing vessel is pumped to the boiler tank for evaporation. Heat energy released from the heating sources in the boiler tank gets absorbed by the PCM which stores the heat and this heat is released during certain periods of heating demand.

## Conclusion

Research needs to be done as to analyze the efficiency of PCM in the test setup and this includes complicated heat transfer analysis needs to be done in condensing vessel and the boiler tank.

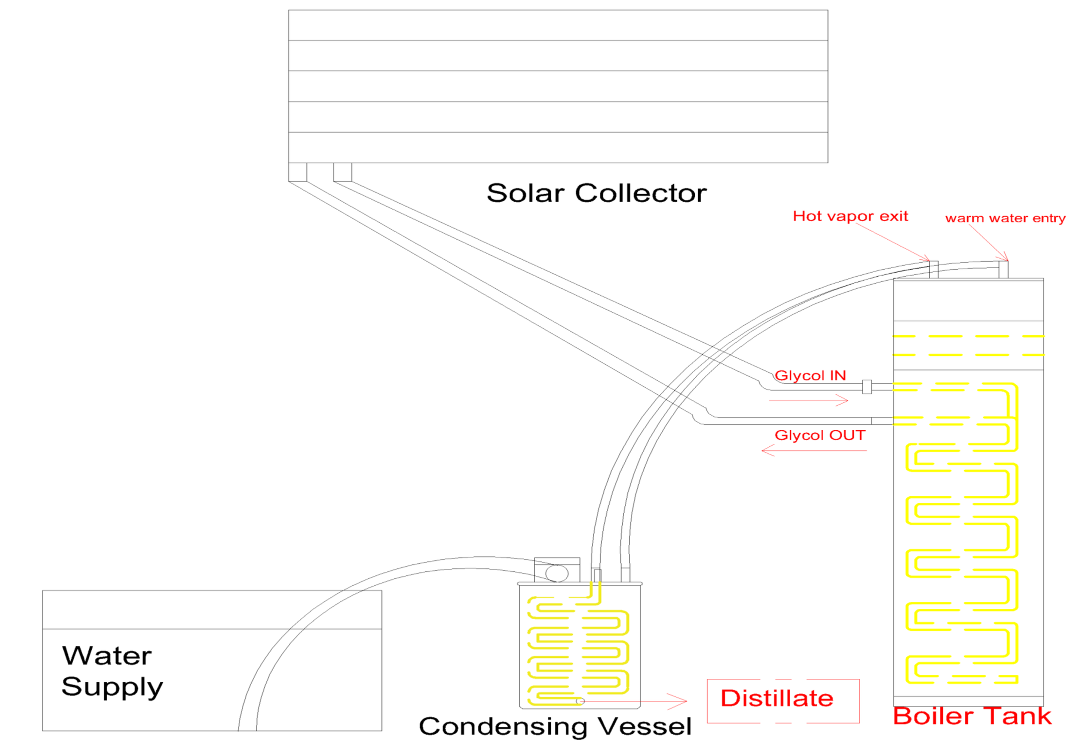


Figure 10: Schematic of solar assisted water desalination test setup

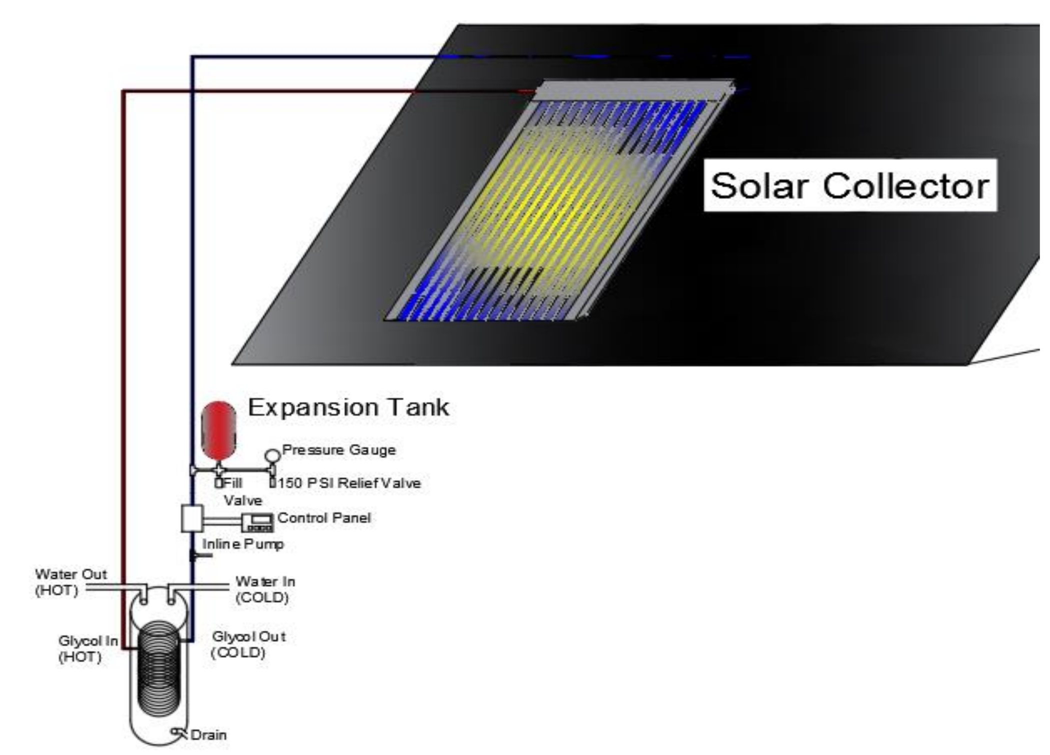


Figure 11: Schematic showing the connection between the boiler tank and solar collector

Figure 12: solar collector

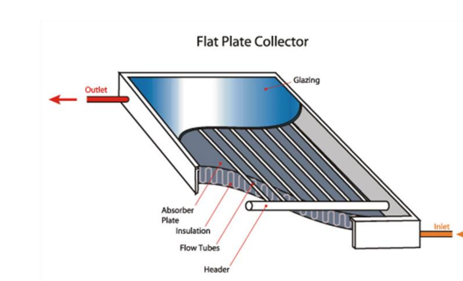

Figure 13: Cut section of solar collector

## References

1. Silaipillayarputhur, K. and Idem, S., 2013, “A General Matrix Approach to Model Steady State Performance of Cross-Flow Heat Exchangers”, Heat Transfer Engineering, Volume 34, Issue 4, pp. 338-348
2. http://stars.library.ucf.edu/cgi/viewcontent.cgi?article=3051&context=etd