Evaporation of Water using Steam – Unitary Model Analysis

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Introduction: Multiple effect evaporators use steam of temperature 120-200° C as a source of heat to evaporate water from solutions. Multiple effect evaporators are widely used by the Food, Desalination and Waste water treatment industry to concentrate solutions which otherwise cannot be concentrated by heating due to scaling and other issues like sugarcane juice whose nature can be altered by the application of heat directly. Altering water properties density, viscosity, specific heat, thermal conductivity can be done by introducing salt concentration. [1]

Results: It was observed that in 3 hours and 20 minutes, steam of 150° C enclosed in dimension 0.5 m × 0.1m with insulated walls evaporated water this time reduced to1 hour 40 minutes and 1 hour 6 minutes, respectively with increase in temperature to 180° C and 200° C. Linear decrease in time was observed with increase in steam temperature. Salt concentration did not change time of evaporation.

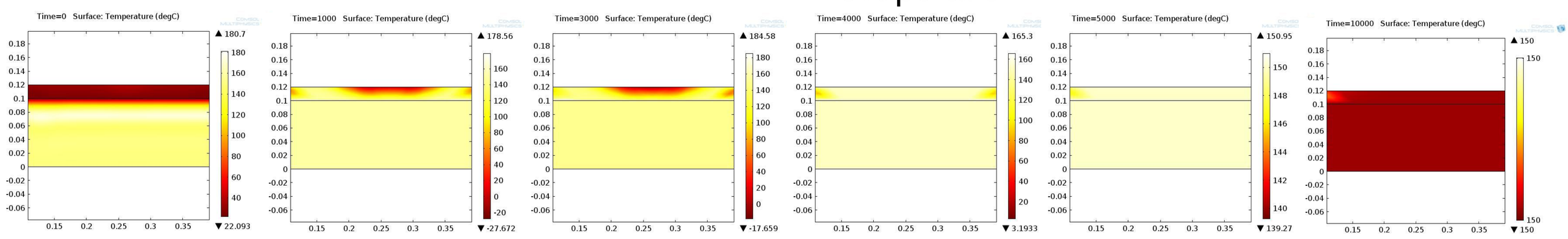

Figure 3. Phase Change

In the present study as a proof of concept, multi-physics modeling has been done to demonstrate the phenomenon of evaporation of water with steam.

Computational Methods: Assuming there is no mixing in the liquid phase, the conduction equation in the material co-ordinates was used as physics in the model [2].

$$\rho C_{eq} \frac{\partial T}{\partial t} + \nabla.\left(-k_{eq} \nabla T\right) = Q$$

The boundary conditions for this model are

- thermal insulation at x = 0;
- fixed temperature at x = 0.01;

In order to avoid temperature discontinuity at the starting time, a smoothened step function T_{right} that increases the temperature from T_0 to T_{hot} in 0.1 s was created for T_{hot}.

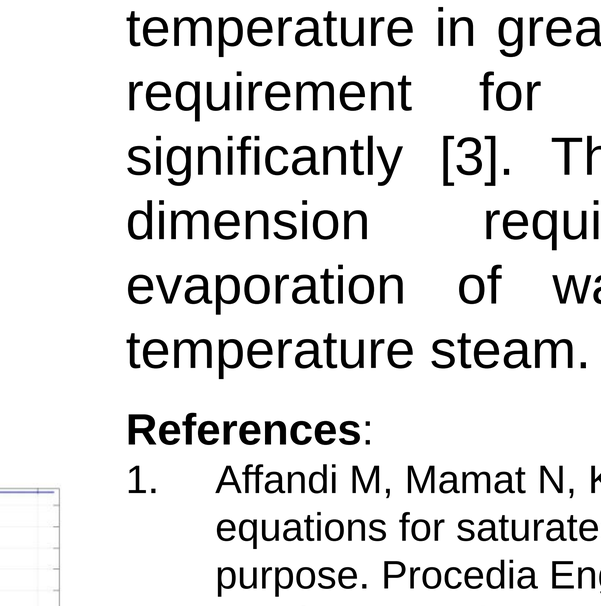

Figure 4. Temperature of steam Vs time taken for evaporation

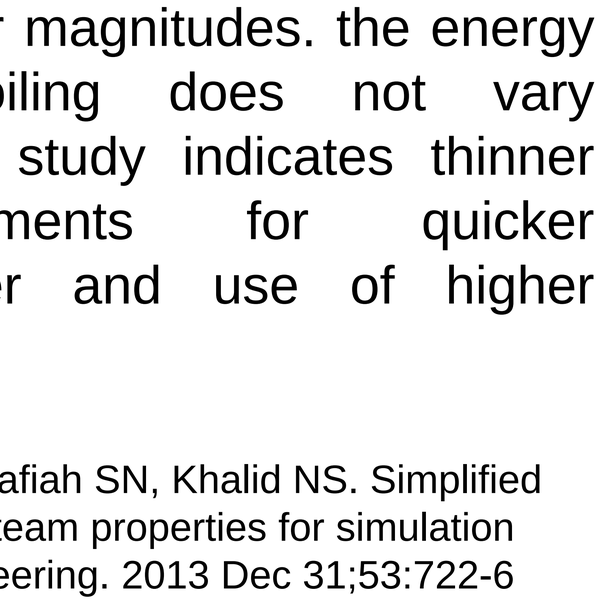

Figure 5. Correlation between Temperature and Pressure of salt water for different salt concentrations

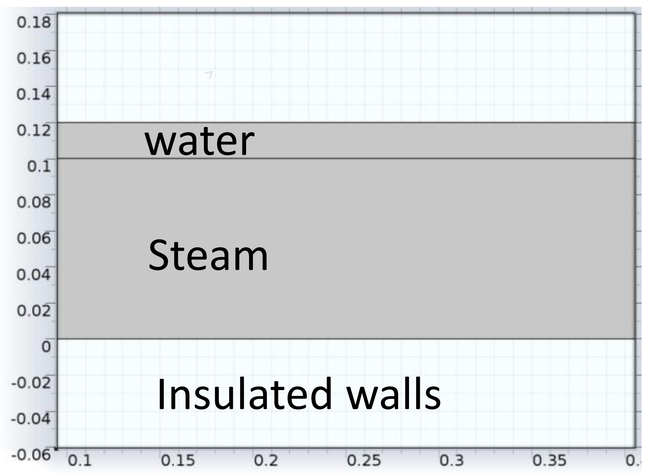

Figure 1. System geometry

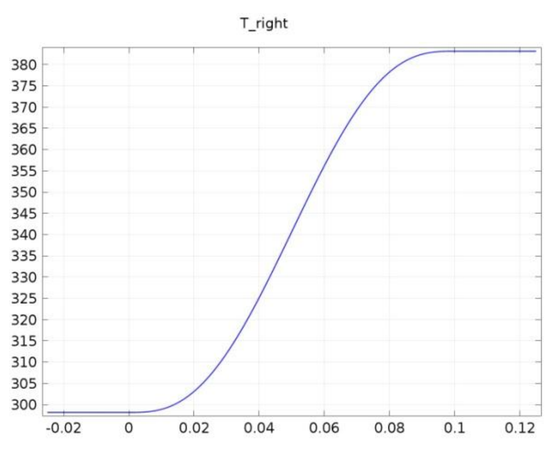

Figure 2. Step function graph

Conclusions: change in salt concentration in water does not significantly change the boiling temperature in greater magnitudes. the energy requirement for boiling does not vary significantly [3]. The study indicates thinner dimension requirements for quicker evaporation of water and use of higher temperature steam.

References:

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3. Sharqawy MH, Lienhard JH, Zubair SM. Thermophysical properties of seawater: a review of existing correlations and data. Desalination and Water Treatment. 2010 Apr 1;16(1-3):354-80.8.