Evaporation of Water using Steam – Unitary Model Analysis

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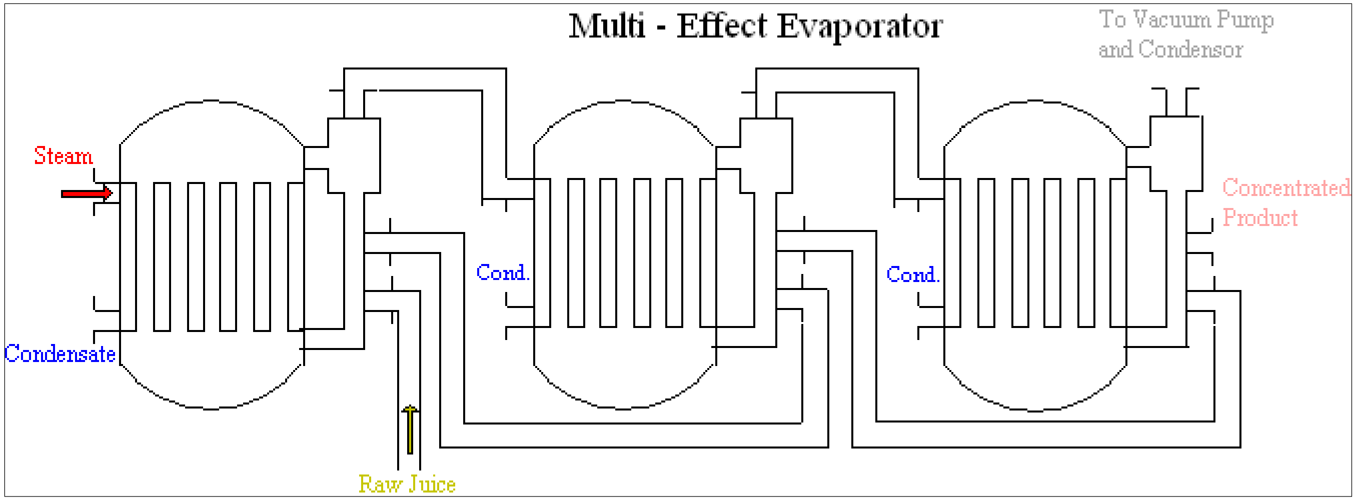
Multiple effect evaporators

Series of evaporators

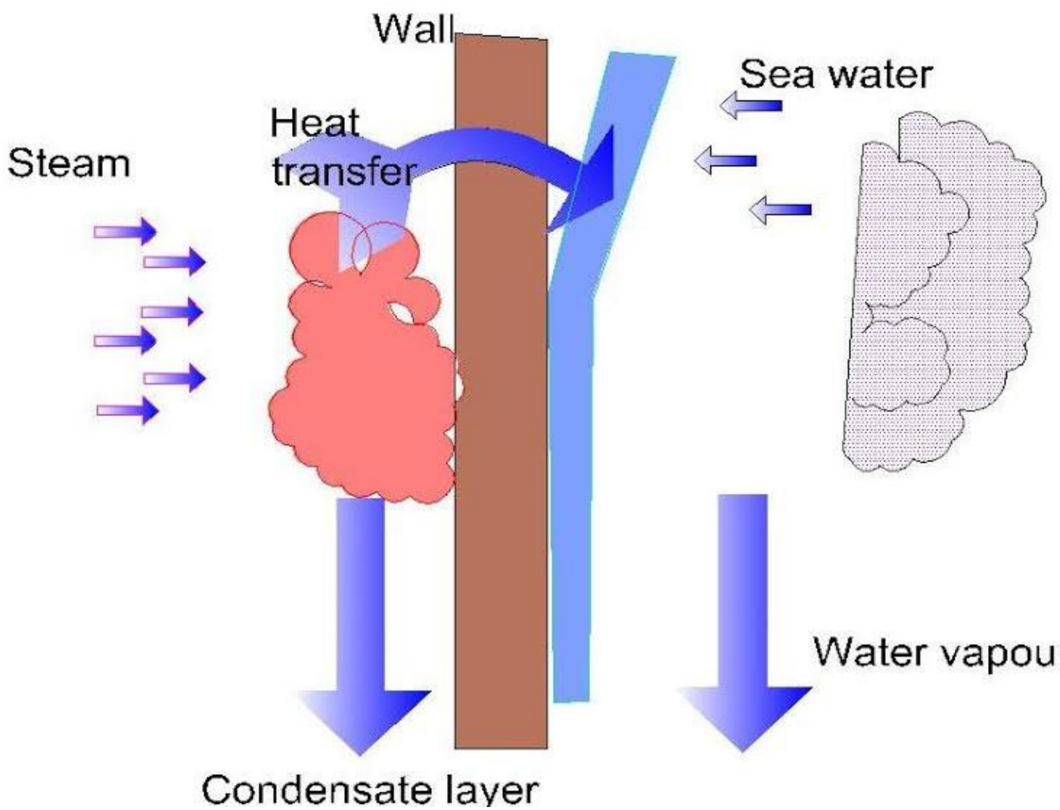


Source: Genemco, Inc. 2006

- Maintained at decreasing levels of pressure and temperature.
- Use steam as source of heat for evaporation


Collection
Collection tank
Primary Clarifier
Homogenization
Aeration Tank
Secondary Clarifier
Filtration
Filtration Rejects
MEE
Centrifuge
WHIRLER CENTRIFUGAL PVT. LTD.
25 PDM Exported To Spain - SS 316L

Heat transfer



Purpose

- The study is a proof of concept of the phase change phenomenon due to transfer of heat from steam to water with insulated system walls separating it from the surroundings.

COMSOL model has been developed to predict the time for evaporation.

Experiment

- Two sets of analysis varying
  - temperature of the steam
  - altering water properties
    - Altering water properties was done by introducing salt concentration. Differing salt concentration influences several properties of the water including density, viscosity, specific heat, thermal conductivity, etc

Steady flow heat transfer has been modeled.

System geometry

- Two rectangular spaces representing water and steam domains were modeled

It had 7 boundaries – six boundaries interacting with the surroundings and one an interaction between the domains.

Mesh Settings

- Mesh sizing criteria: Grid independence
  - Trial and error of mesh sizes were carried to obtain the point where results remains constant on increasing the size of the grid.

Name	Value
Maximum element size	0.0265
Minimum element size	1.5E-4
Resolution of curvature	0.3
Maximum element growth rate	1.3
Predefined size	Fine

144 degrees of freedom or nodes in the mesh were solved for present analysis.

Parameters defined

Name	Expression	Description
T_trans	100[degC]	Phase change transient temperature
dT	1[K]	Step function
l_v	2257[kJ/kg]	Latent heat of vaporization
To	25[degC]	Temperature of water
Thot	110[degC]	Temperature of steam
Rho_water	997[kg/m^3]	Density of water
Cp_water	4179[J/kg/K]	Specific heat of water
k_water	0.613[W/m/K]	Thermal conductivity of water
Rho_steam	0.863[kg/m^3]	Density of steam
cp_steam	1.7512[kJ/kg/K]	Specific heat of steam
k_steam	0.03159[W/m/K]	Thermal conductivity of steam

The model was run to capture the effects of changing steam temperature from 150°C to 200°C and variation in salt concentrations in water from 1 to 50 g/kg.

Governing Equation

- Assuming there is no mixing in the liquid phase, the conduction equation in the material co-ordinates has been used as the governing equation.

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

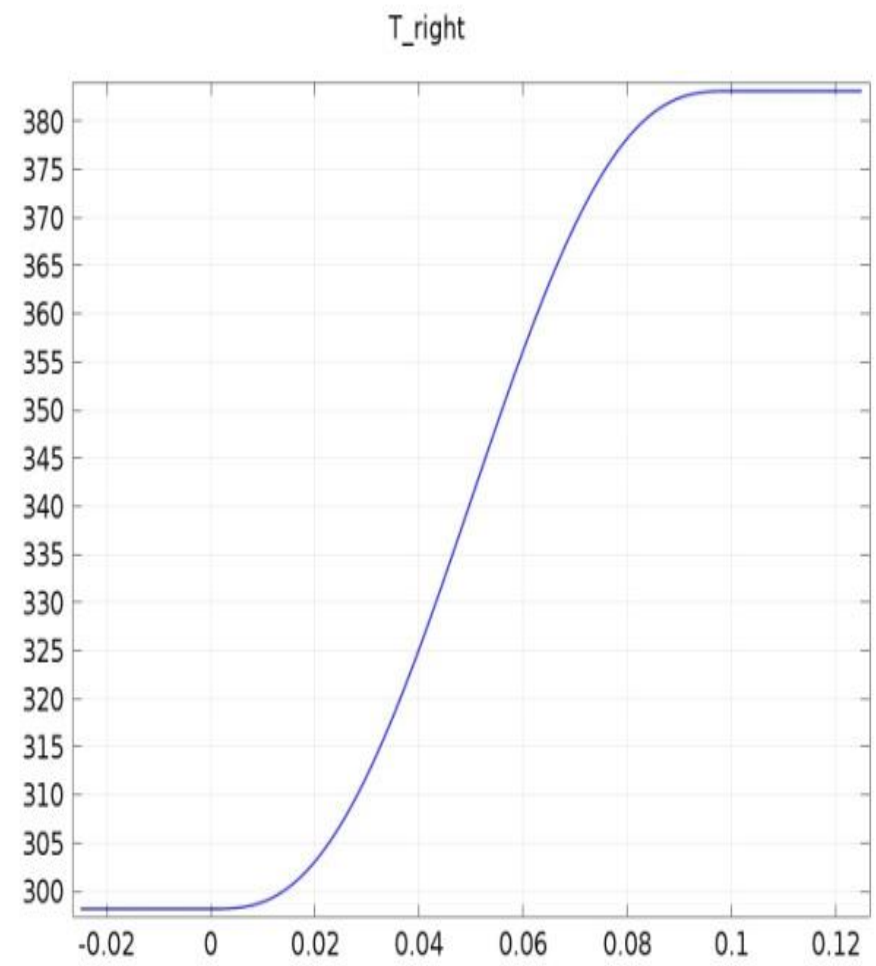
where ρ (kg/m^3) is the density, C_{eq} (J/kg·K) is the effective heat capacity at constant pressure, k_{eq} is the effective thermal conductivity (W/m·K), T is temperature (K), and Q is a heat source (W/m^3).

During the phase change, the density is modified, resulting in volume compression.

Boundary Condition

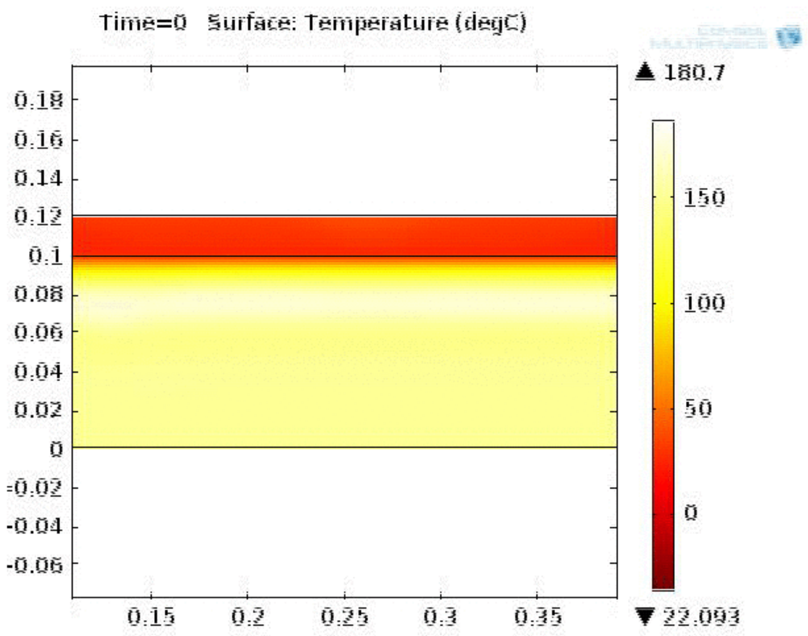
- The boundary conditions for this model are
  - adiabatic at x = 0;
  - isothermal at x = 0.01;

- 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}

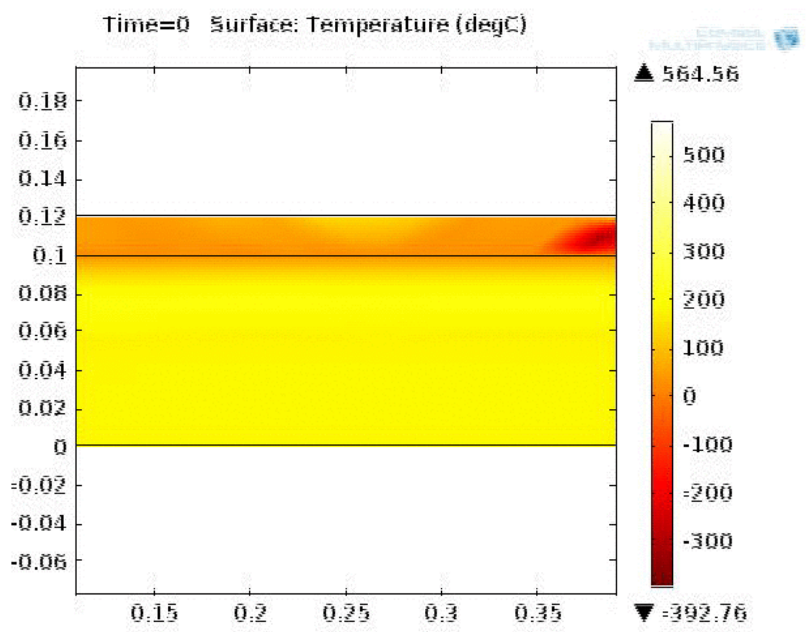


Contours

150 degree Celsius steam

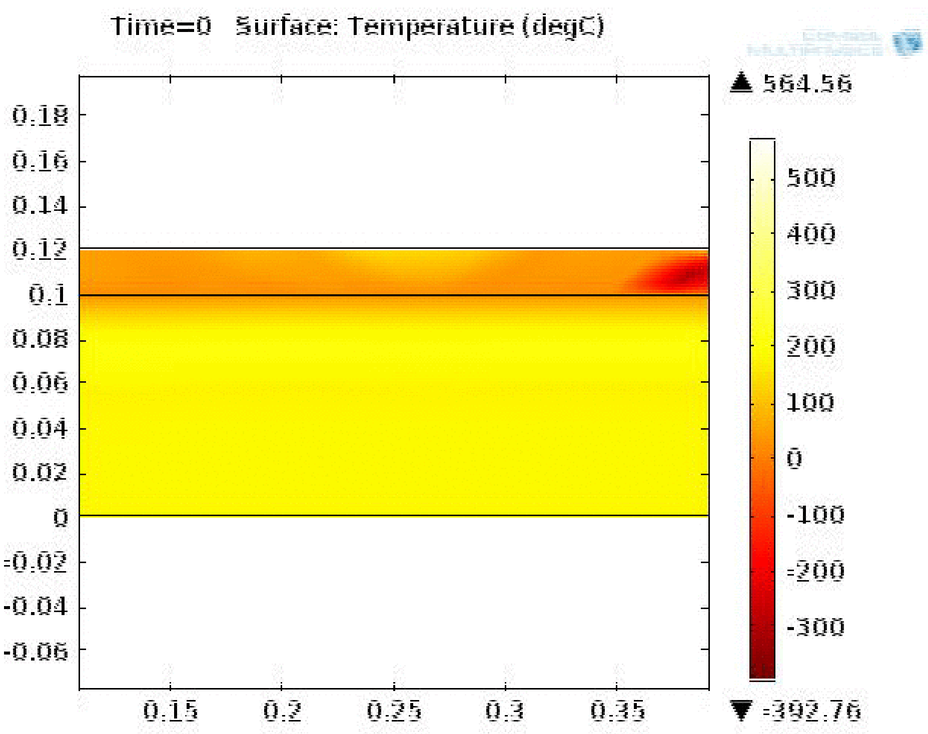


180 degree Celsius steam



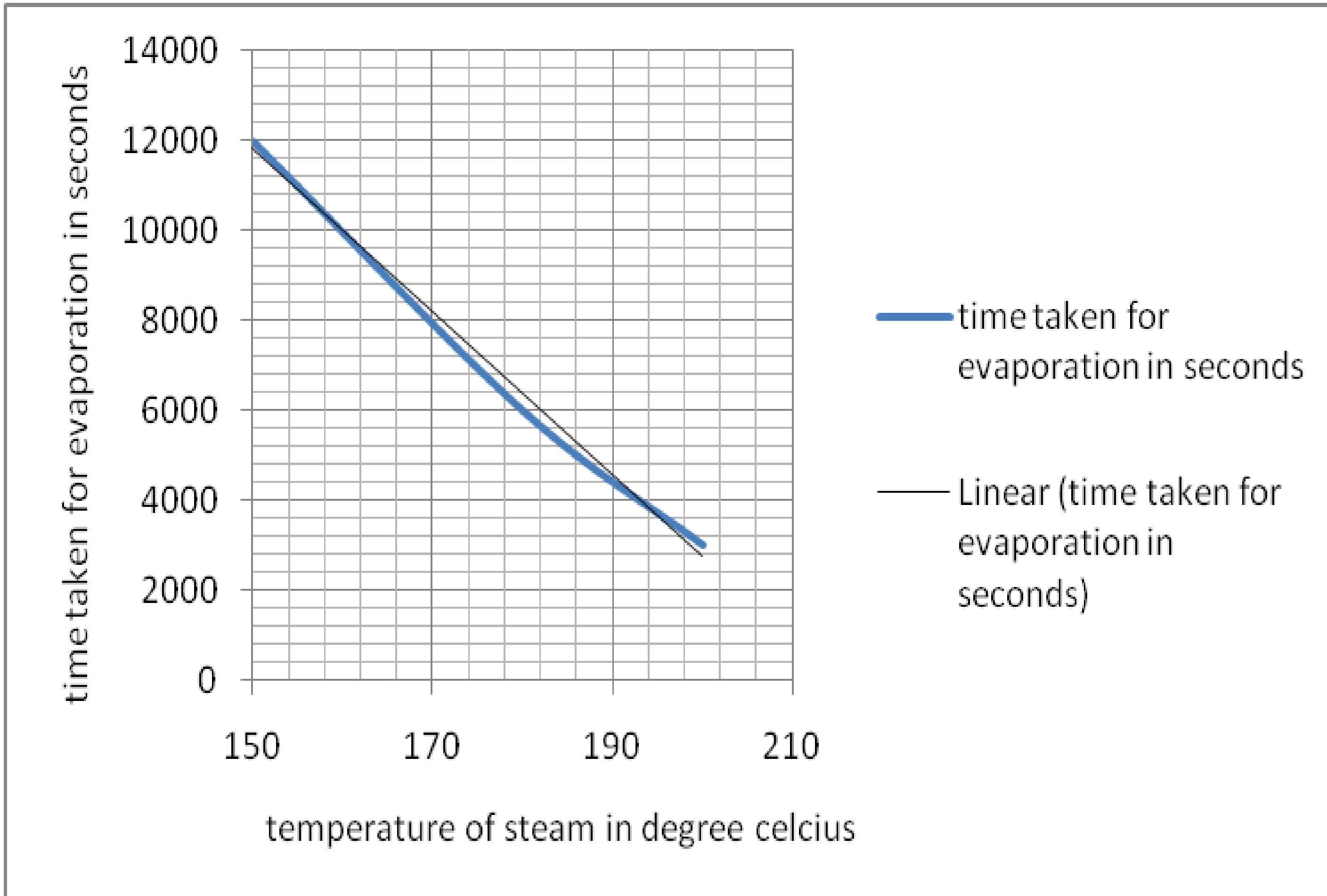
Contours

200 degree Celsius steam



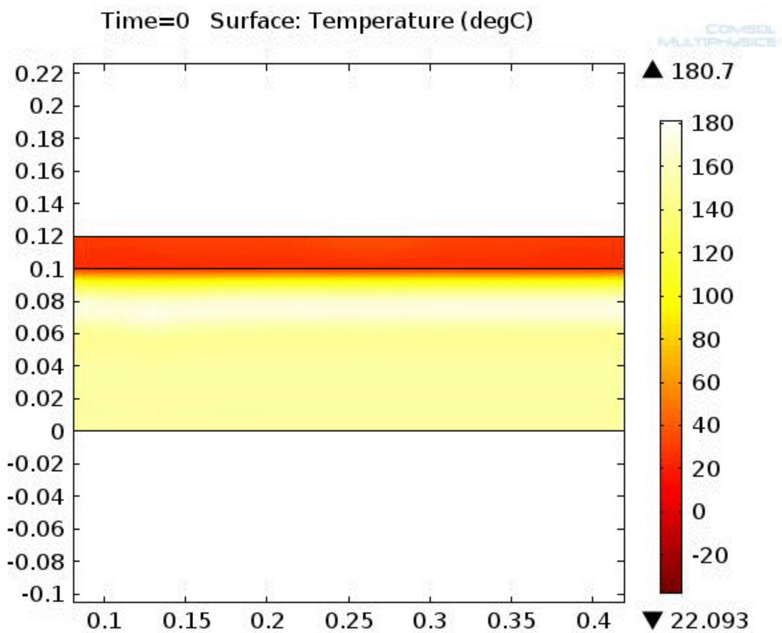
Linear decrease in time was observed with increase in steam temperature.

Temperature of steam Vs time taken for evaporation

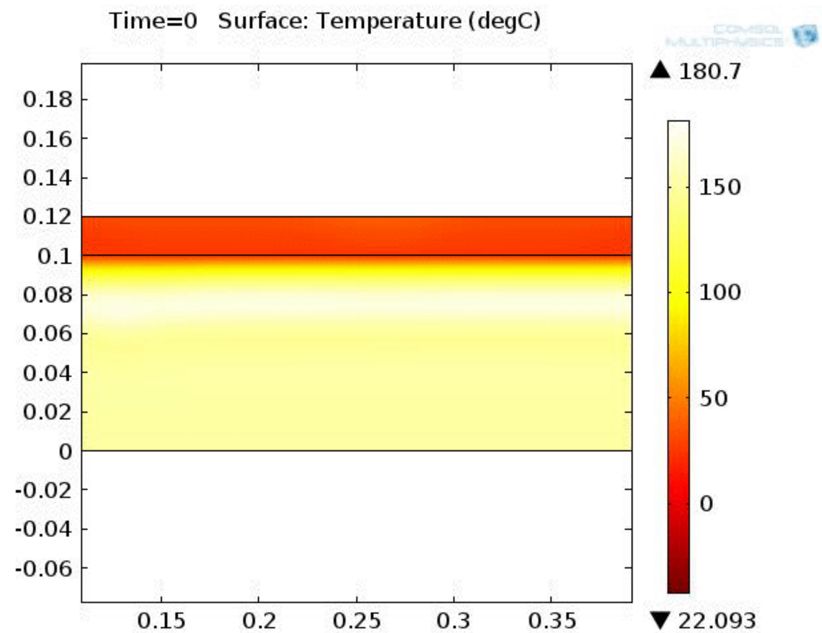


Contours

20 g/kg salt concentration



50 g/kg salt concentration



However the evaporation took similar time range 11,000 seconds to 12,000 seconds.

Results and Conclusion

- 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 of 25°C in dimension 0.5 m × 0.02 m.

- Time required for evaporation reduced to 1 hour 40 minutes and 1 hour 6 minutes for steam of temperature 180°C and 200°C respectively.

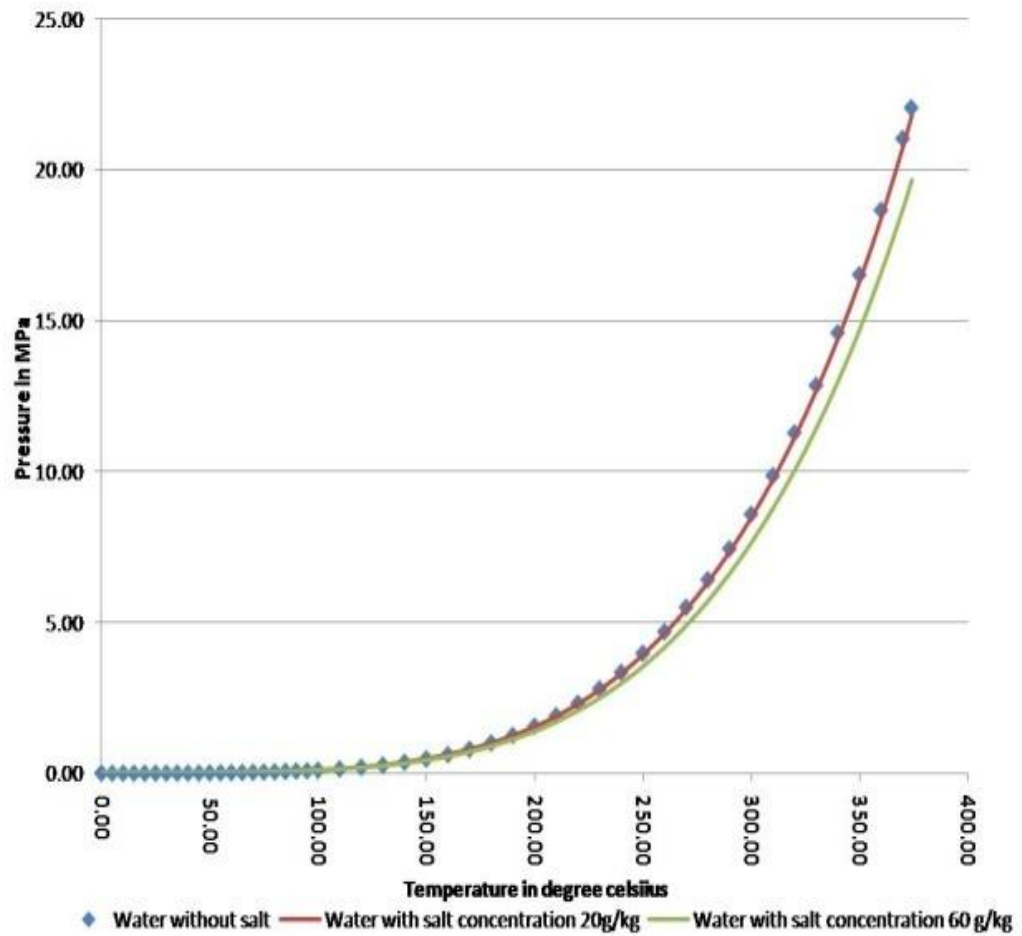
Results and Conclusion

- The modeling was also extended increasing the salt concentration of the water to 20 g/kg and 50 g/kg.

- The properties of the water specially density, specific heat, thermal conductivity, boiling temperature and latent heat were altered in the model to reflect change in properties on increasing salinity.

Results and Conclusion

- It can be concluded that change in salt concentration in water does not significantly change the boiling temperatures hence the energy requirement for boiling does not vary significantly. The study indicates thinner dimension requirements for quicker evaporation of water and use of higher temperature steam.



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