COMSOL

Numerical Simulation of Pool Film Boiling Heat Transfer during Quenching of Heated Cylindrical Rods

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Global Nuclear Power Safety Center

Presentation Outline

- **Introduction and Background**
- **Experimental Facility, Test Samples, and Method**
- **Computational and Experimental Results**
- **Major Conclusions**

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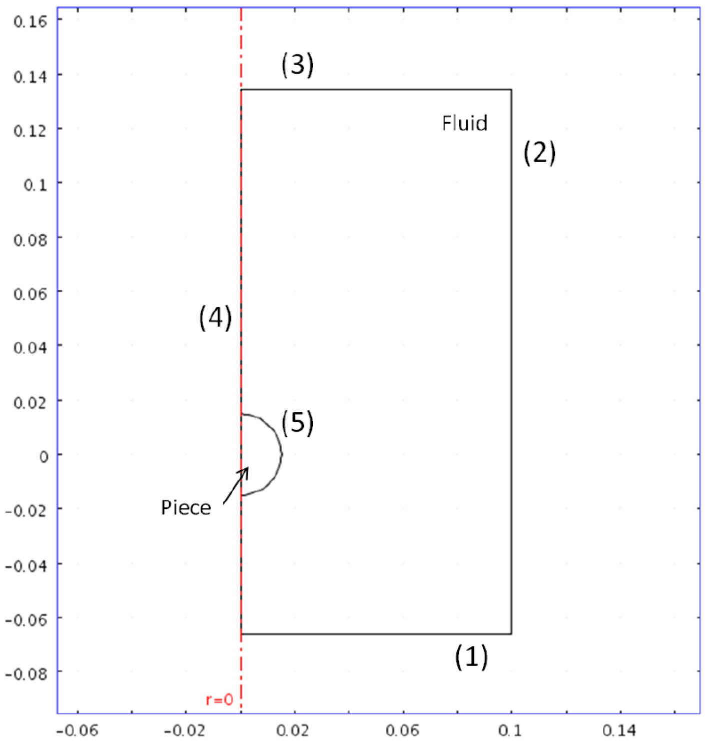
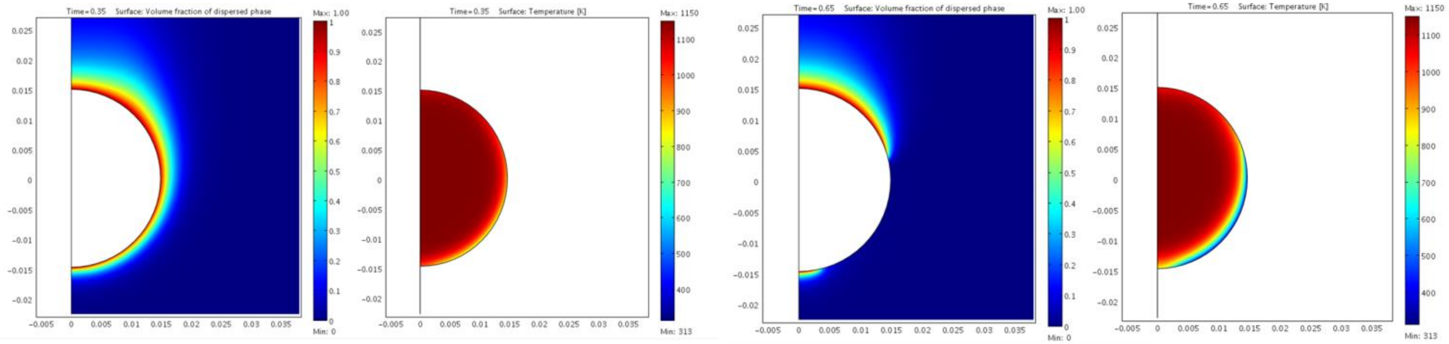
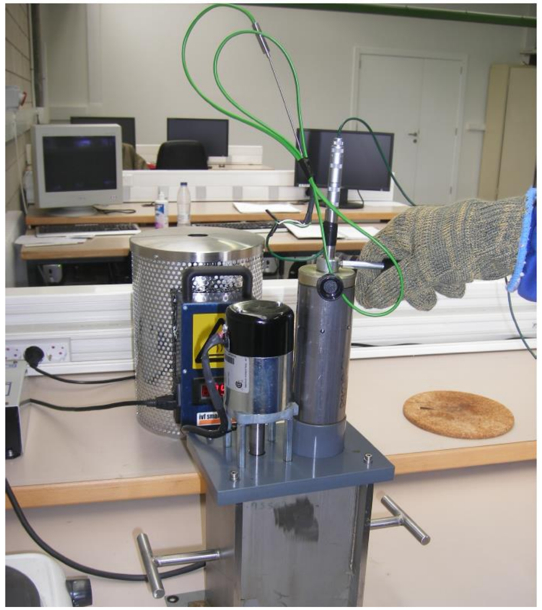
Related Previous Research

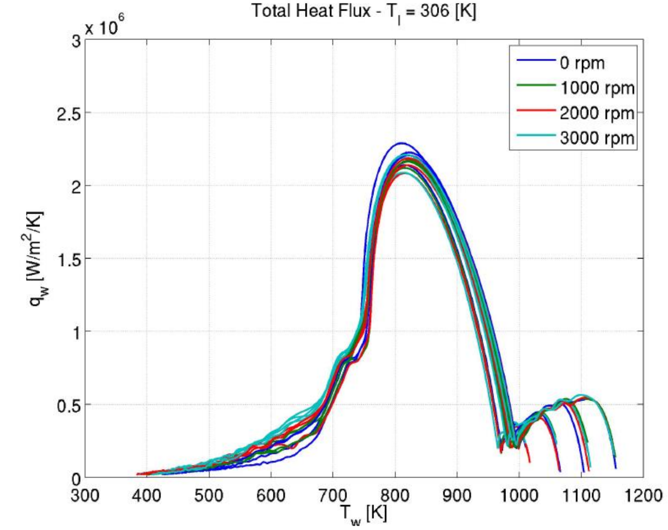




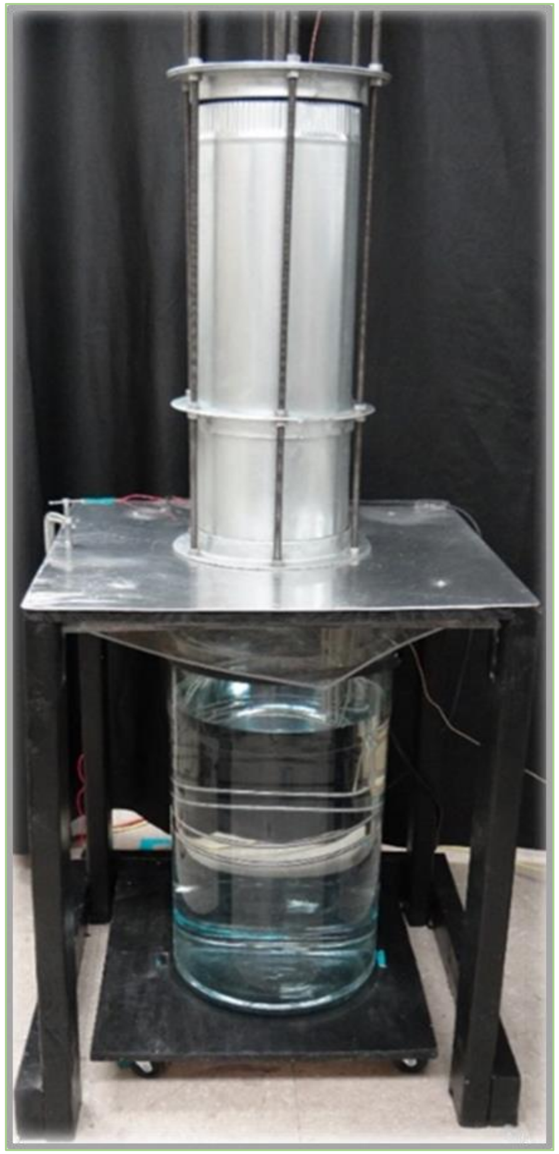
[D N Passarella, 2011]

[D N Passarella, 2014]





The Objectives of the Current Research



Study the Effect of Various Parameters on Pool Film Boiling

- **Effect of Liquid Subcooling**

  (2 – 10 degrees of liquid subcooling)

- **Effect of Surface Material**

  (Stainless steel and Zirconium rods)

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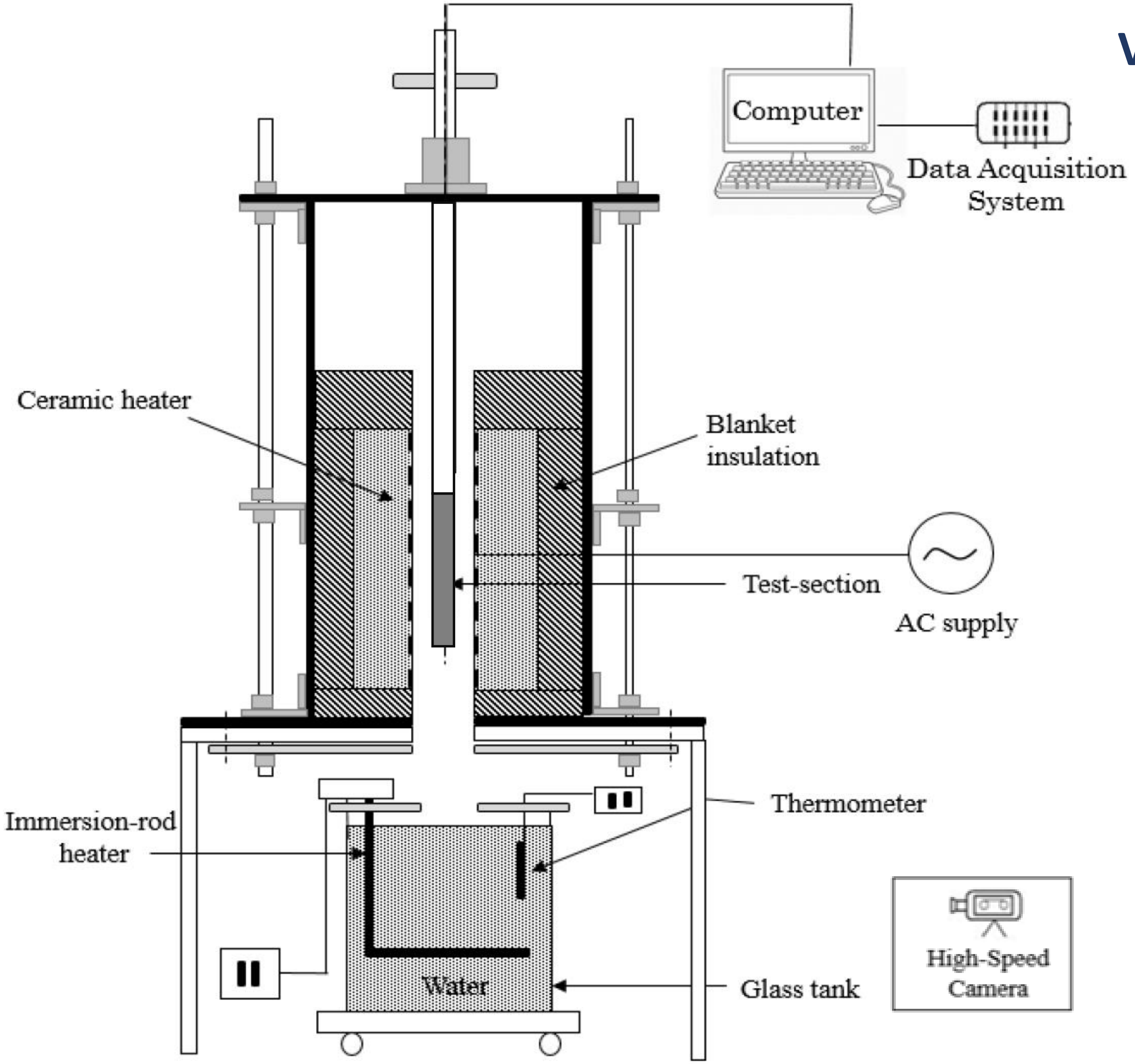
Experimental Test Facility



Vapor Film Covers the Rod

Film Boiling

Vapor Film Starts to Break

Transition Boiling

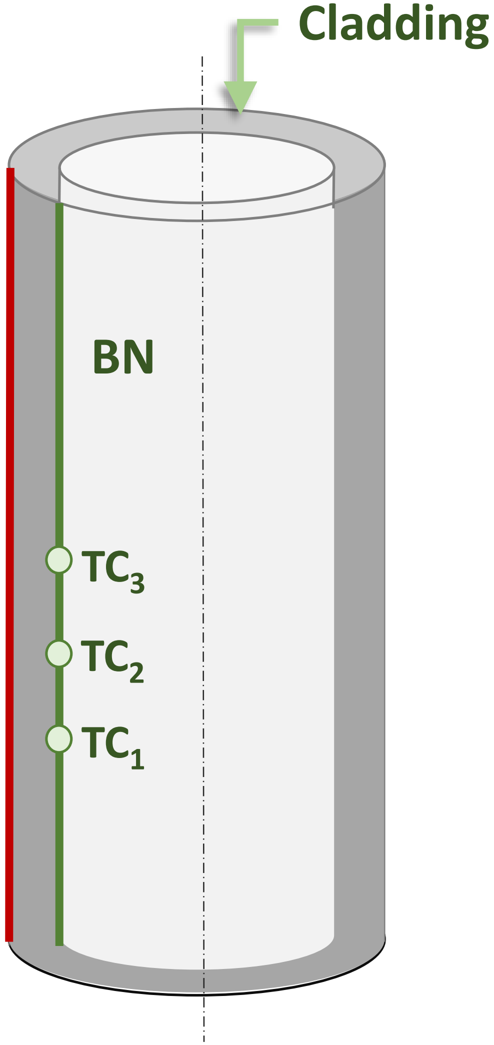
Bigger Bubble

Nucleate Boiling

Fabrication of the Test Samples

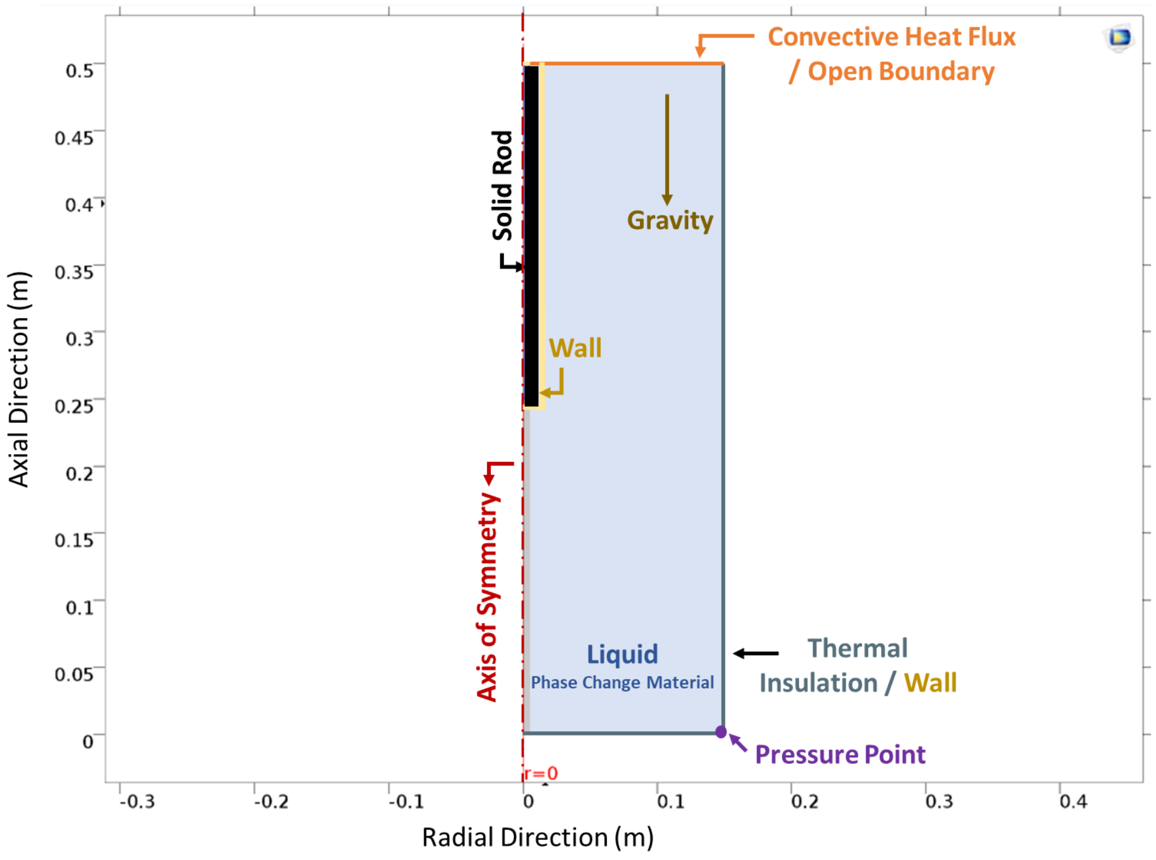
Stainless Steel Zirconium

- D_{rod} = 9.5 mm and L_{rod} = 25 cm
- $t_{cladding}$ = 0.95 mm
- Three K-type thermocouples
- $L_{TC,2}$ = 5 cm
- Inverse Heat Conduction Method



Modeling Domain and Boundary Conditions

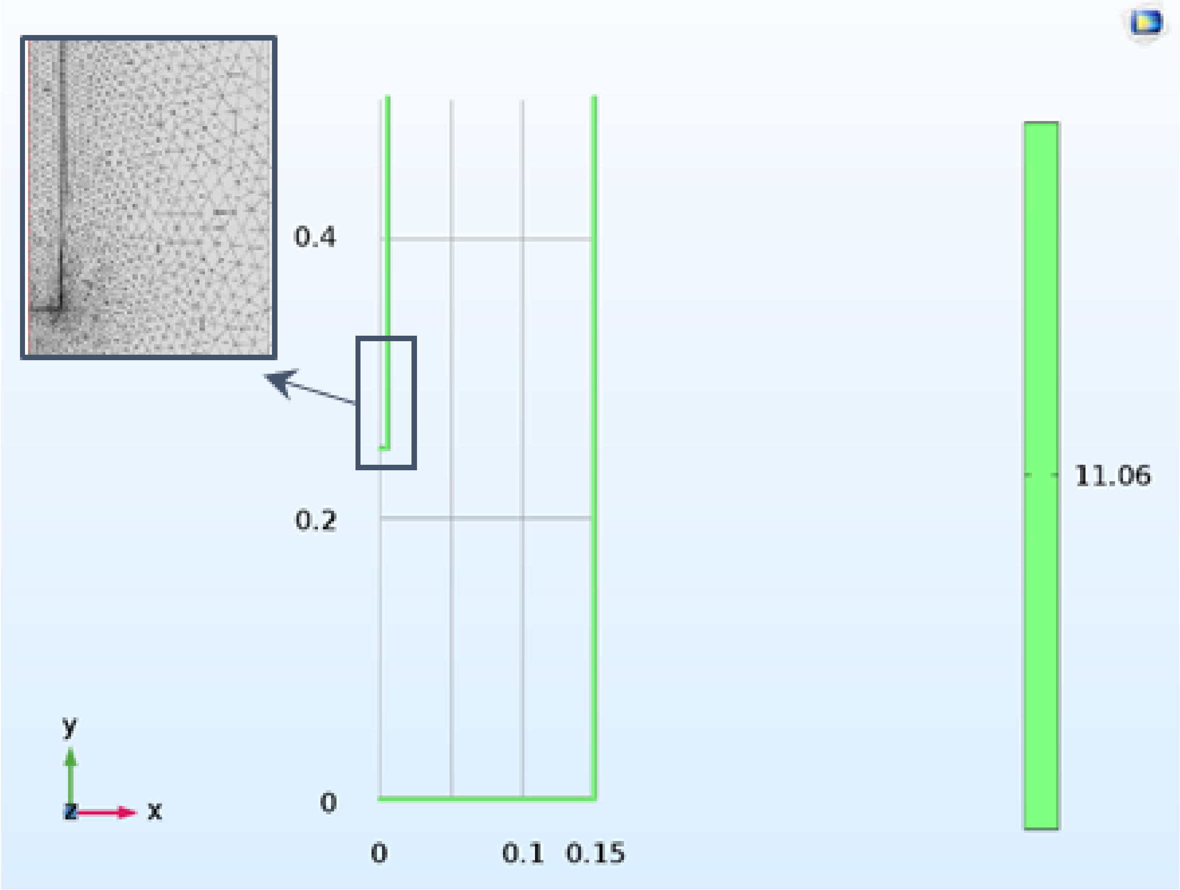
- **A 2D axisymmetric domain with heat transfer in fluid, phase change, and turbulent flow physical models were selected**
- **Gravity force was added to the water to involve the buoyancy force**
- **The water domain was selected as a phase change material under the heat transfer in the fluid model. The latent heat of vaporization is given (2264.76 kJ/kg)**



Material	Density (m^3/s)	Thermal Conductivity (W/m.K)	Heat Capacity (J/kg.K)
SS-316	8238	13.4	468
Zr-702	6570	22.7	278

Meshing Analysis

- **The mesh study was performed for 4600, 8083, 16039, 42243, and 78669 elements**
- **The last two provide the closest results to the experimental data**
- **In order to save memory and computational time, the grid 42243 are considered in this study**
- **The recommended wall-lifts-off on most of the walls is 11.06**



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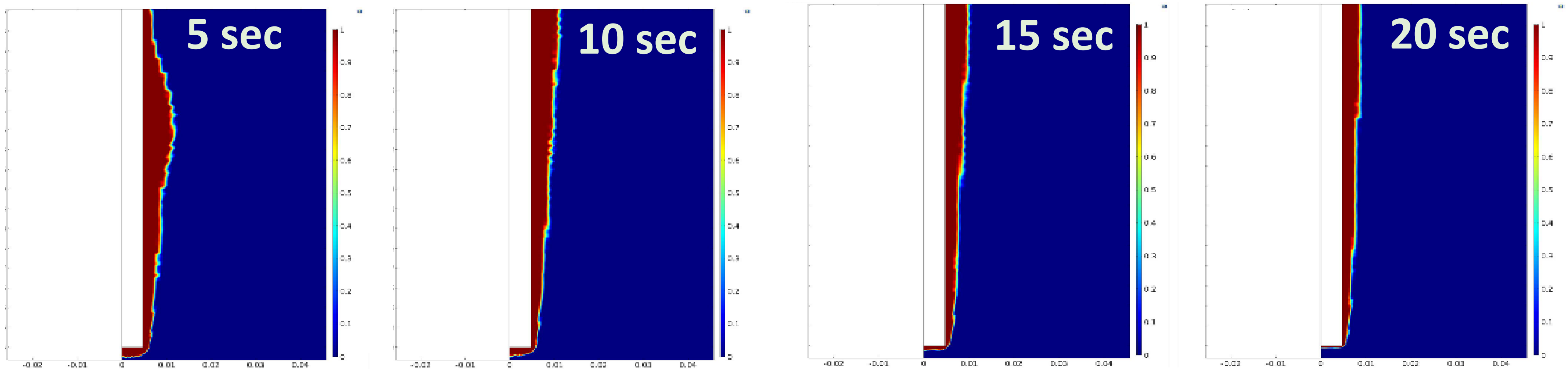
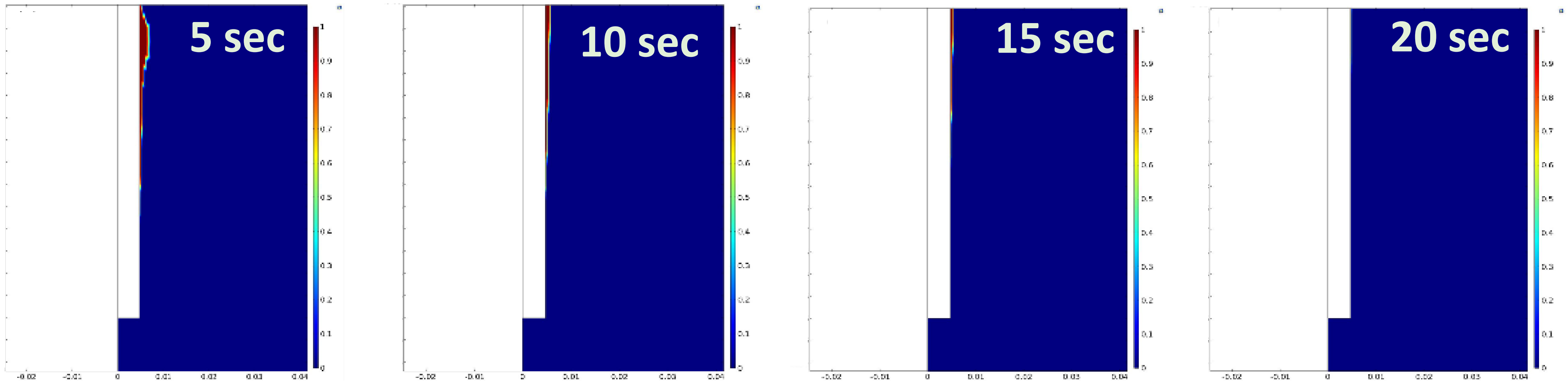
Vapor Film Thickness in Film Boiling Regime

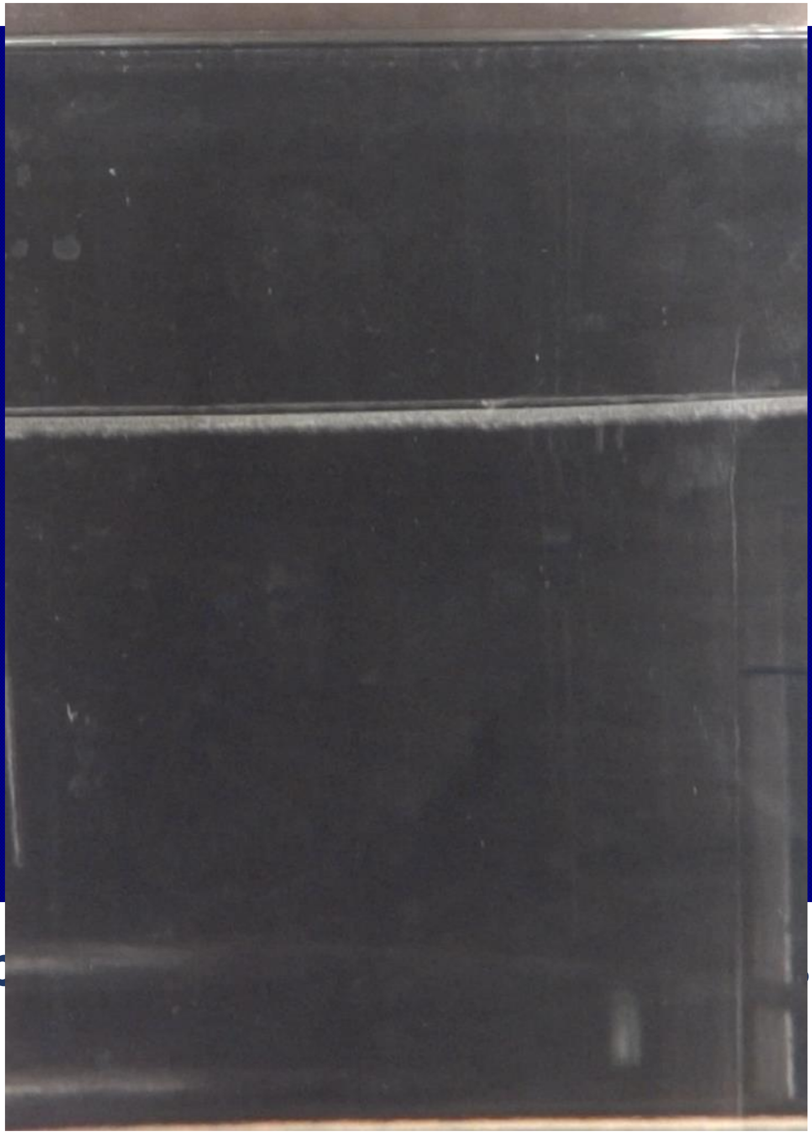


Two degrees of liquid subcooling pool



Ten degrees of liquid subcooling pool

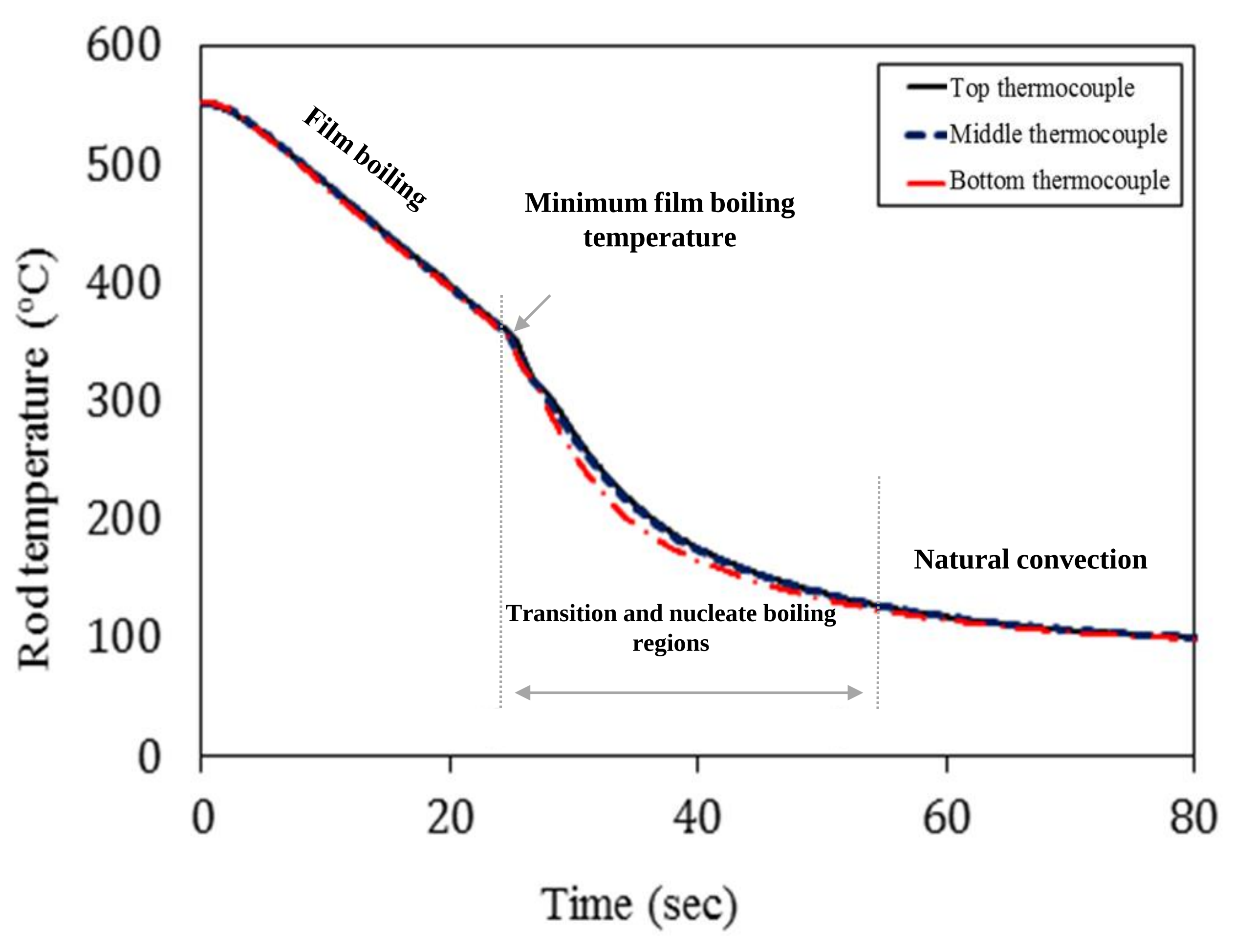
Vapor Film Thickness in Film Boiling Regime

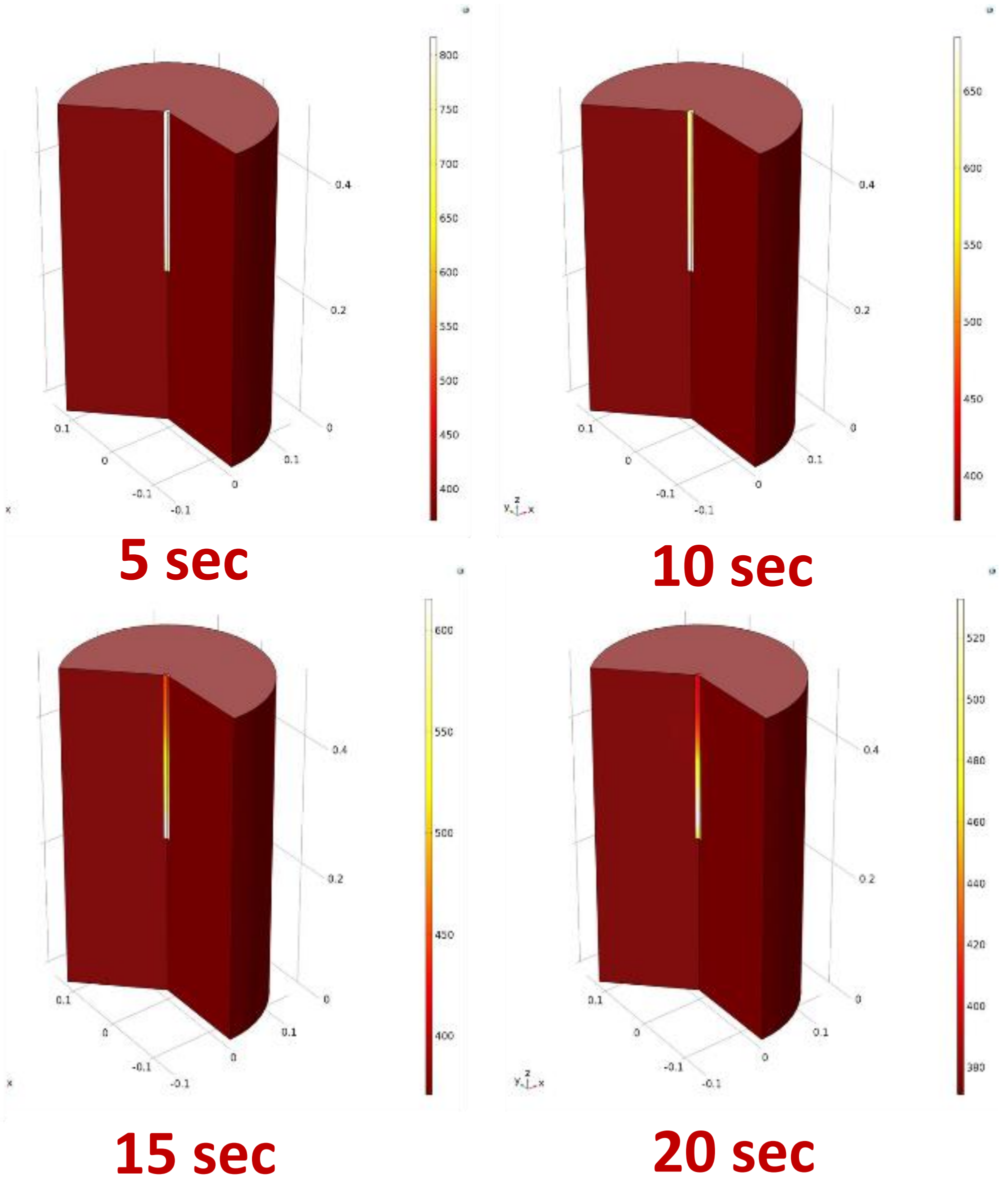


Two degrees of liquid sub

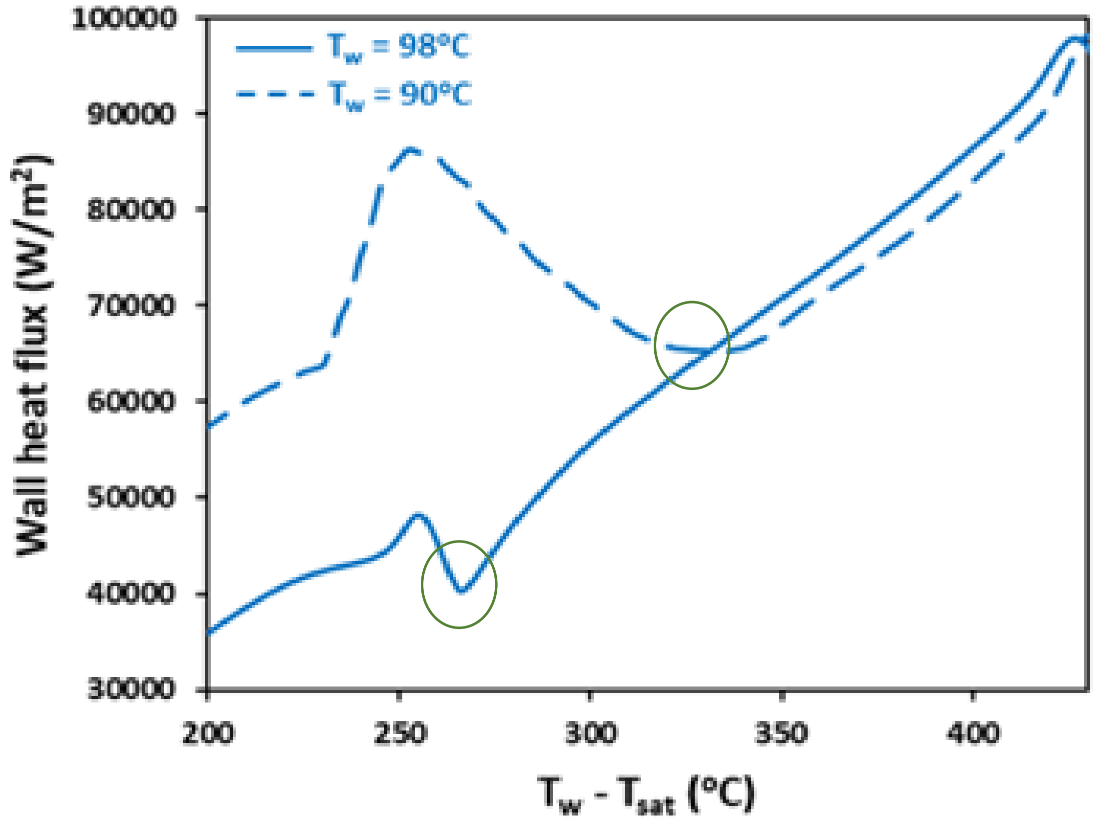
of liq id subcooling pool

Quenching Curve

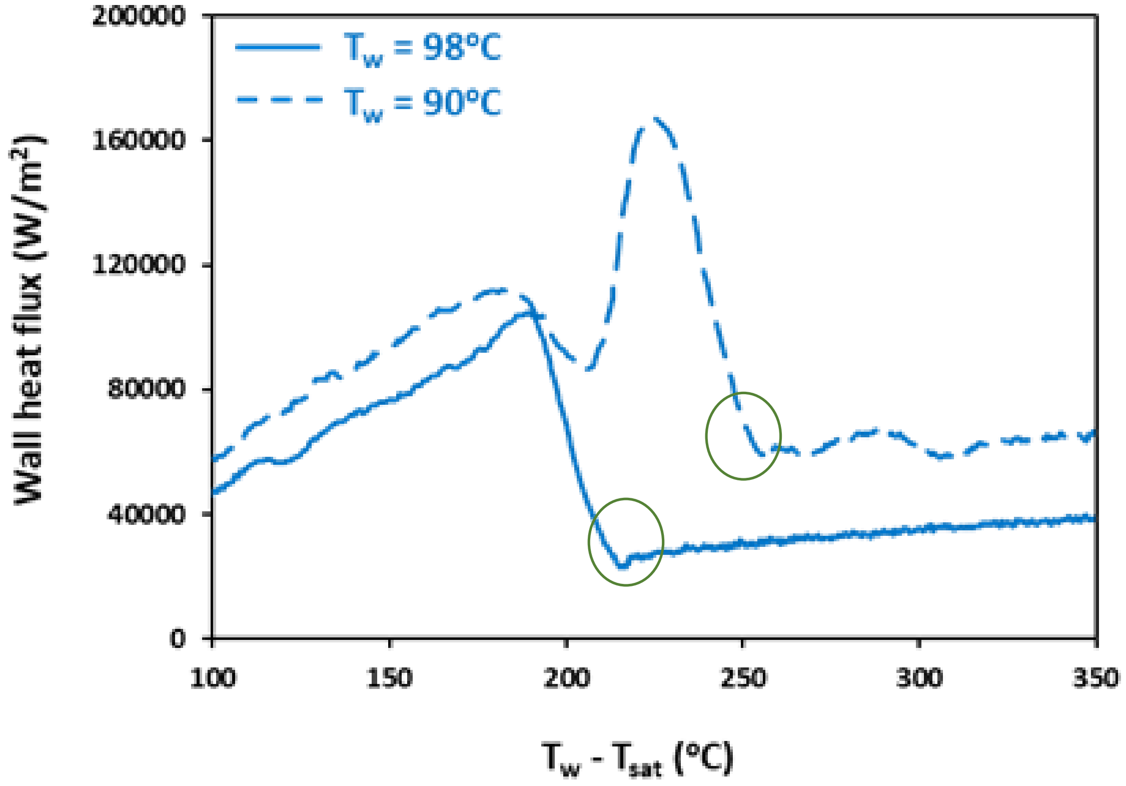




T_{min} for various Liquid Subcooling

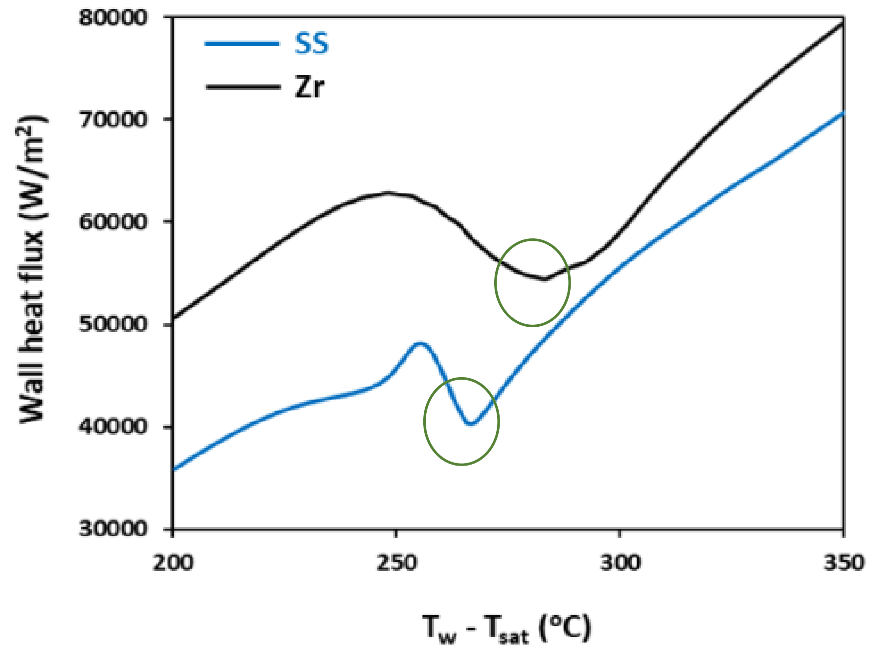


Simulated Boiling Curve

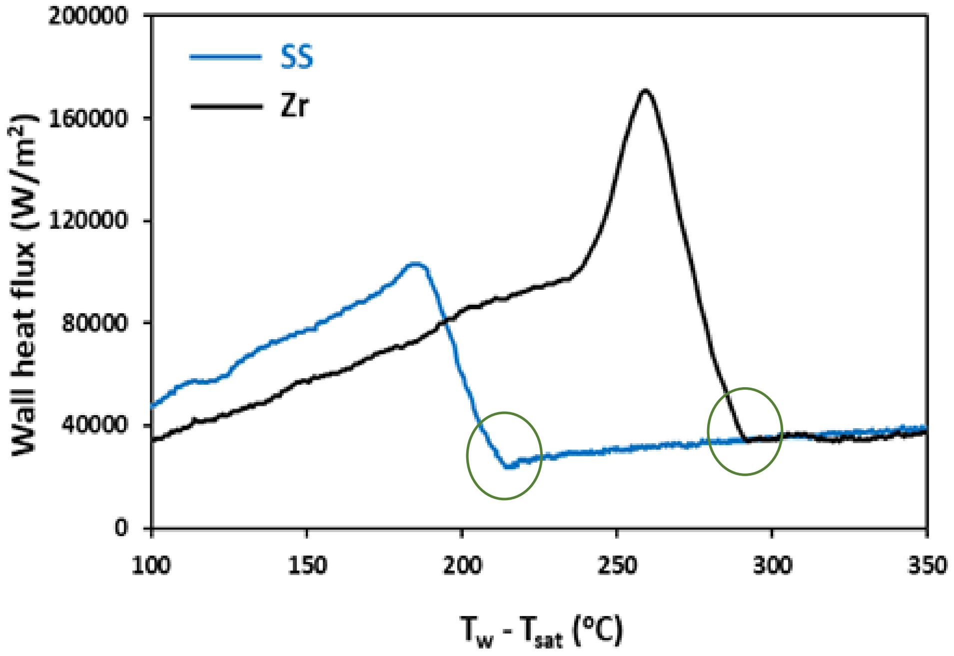


Experimental Boiling Curve

T_{min} for SS and Zr Samples



Simulated Boiling Curve



Experimental Boiling Curve

Substrate	Experimental (°C)	Simulated (°C)	Error (%)
Stainless Steel $\Delta T_{sub} = 10^oC$	355	420	18.3
Stainless Steel $\Delta T_{sub} = 2^oC$	320	367	14.6
Zirconium $\Delta T_{sub} = 2^oC$	389	393	1.0

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Major Conclusions

- **As liquid subcooling increases, Tmin increases**
- **Higher $\rho k c_p$ value of the substrate material contributes to a lower Tmin**
- **As the subcooling increases, the vapor film thickness decreases**
- **As the subcooling increases, the vapor film quenches faster indicating an enhancement in heat transfer**

Questions?

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