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Spray cooling of electronic devices with R410A refrigerant

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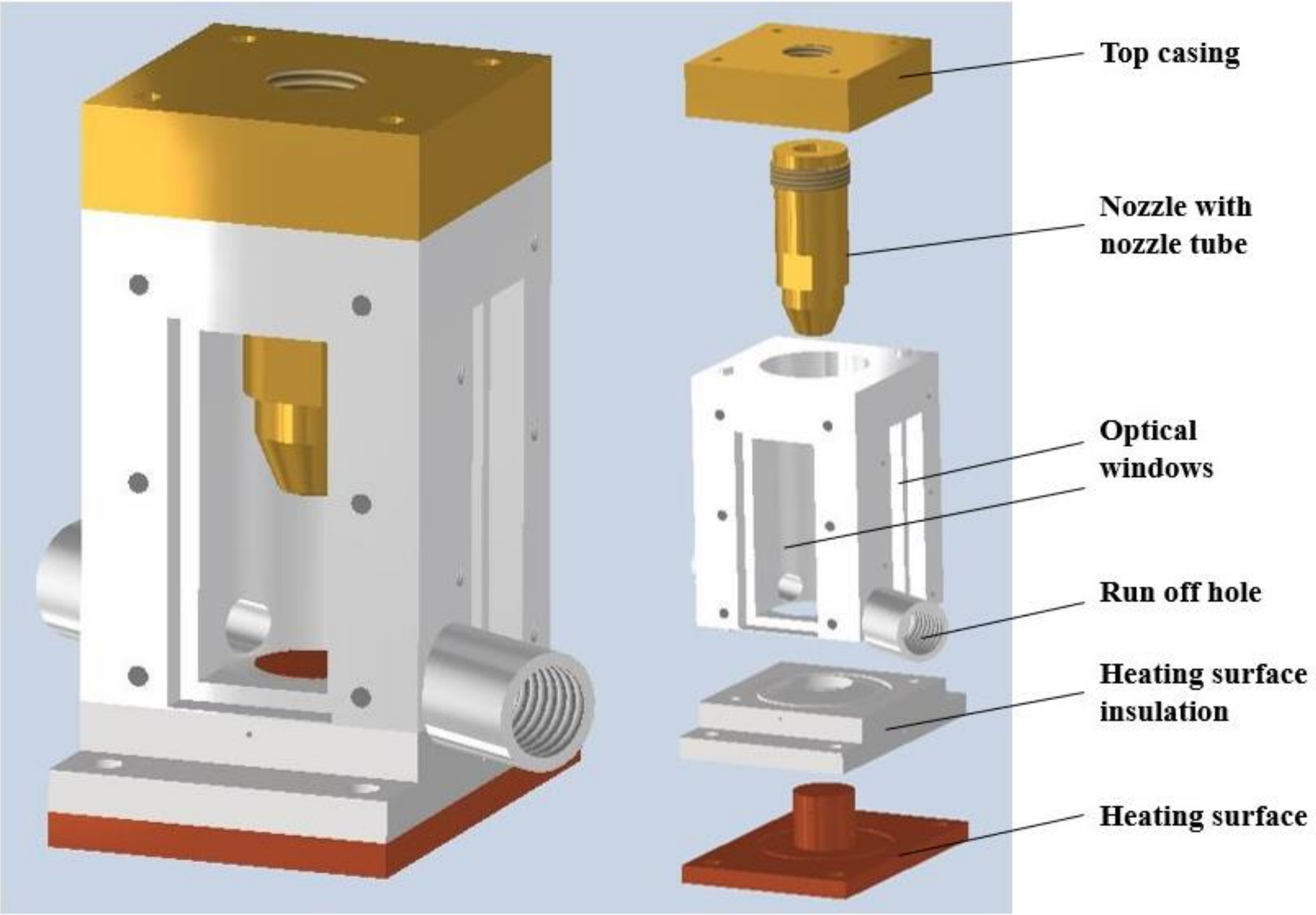
Motivation

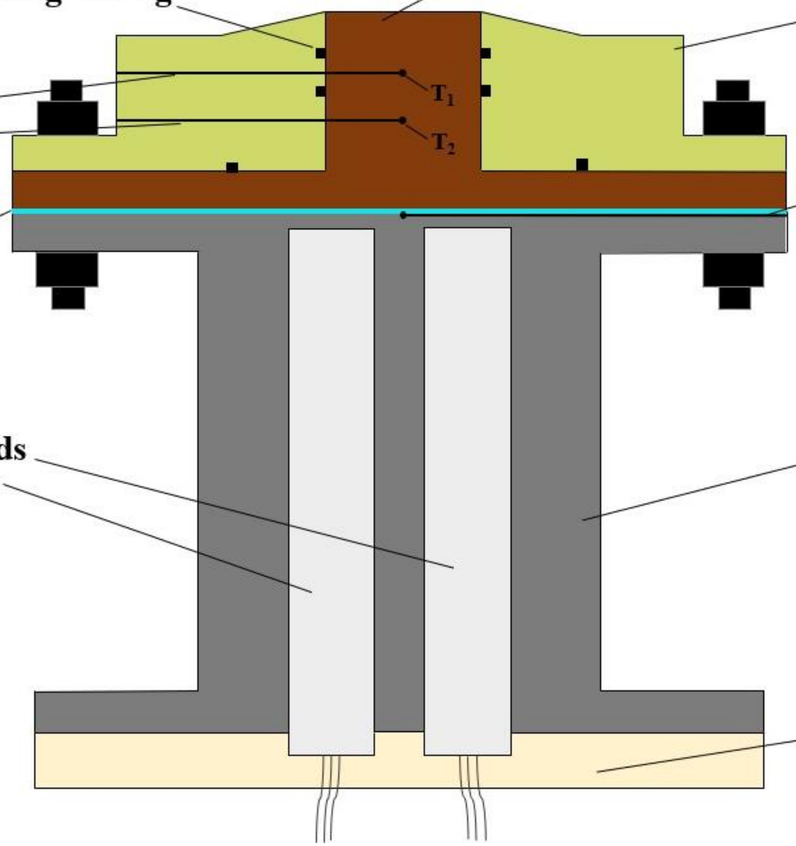
- **Thermal management of electronics requires innovative cooling techniques to:**
  - ✓ Effectively dissipate the thermal energy amounts produced
  - ✓ Increase the power density,
  - ✓ Optimize performance and
  - ✓ Improve the reliability of the electronic components
- **To this end spray cooling with refrigerants has emerged as a promising option, able to**
  - ✓ Achieve large heat fluxes by sensible and latent heat removal
  - ✓ Operate in an appropriate temperature range, by careful selection of refrigerant
- **Dominating heat transfer mechanisms in spray cooling**
  - ✓ Evaporation of the liquid film over the surface,
  - ✓ Turbulent forced convection heat transfer due to the impact of the sprayed droplets,
  - ✓ Formation of active nucleation sites resulting in the appearance of bubbles and
  - ✓ Creation of secondary nucleation points due to the continuous droplets impingement

Spray Chamber



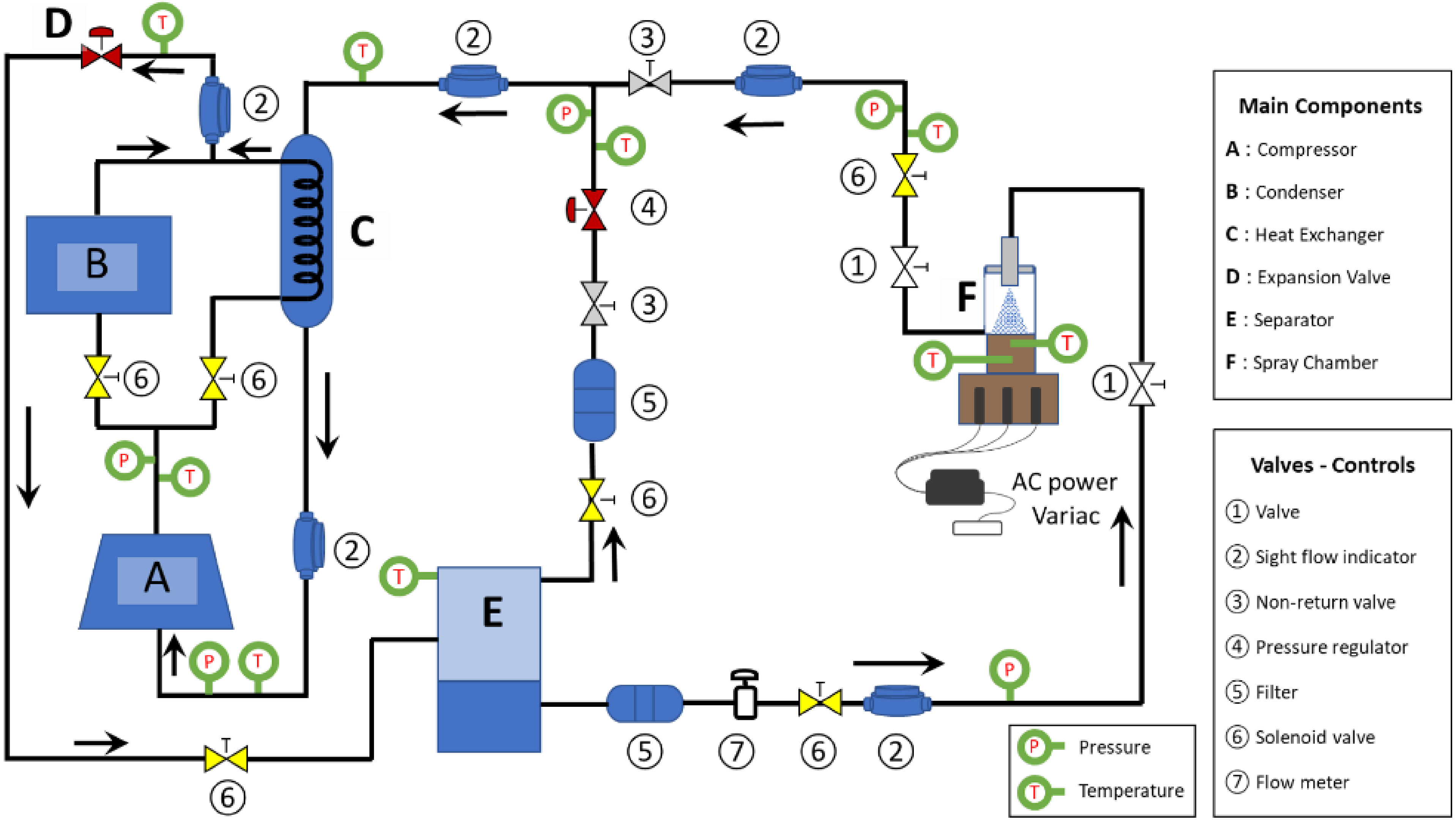
Spray chamber	50 ml internal volume
Heating surface	Ø 16 mm pure copper plain surface
Spray Height	4 nozzle tubes for 4 spray heights (15, 20, 25 ,30 mm)
Nozzle	Danfoss OD full cone (60°)
Run off	2 x Ø8 mm holes
Optical Windows	Transparent windows for visualization

Heating System



1 D Heat conduction along copper neck	
Peek insulation	
Heat flux evaluation	2 x K type thermocouples
Heat source	4 x 400-Watt heating rods
Heat flux control	PID controller

Experimental Setup - Closed Refrigeration Loop



Experiment details

- Pressure and temperature monitored at points of interest along the closed-loop system
- Spray mass flow rate measured using liquid flow-meter with 5% uncertainty
- Heat flux measured using temperature difference between 2 points across copper module
- Electrical consumption of the heaters measured
- Copper base temperature regulated using PID controller
- All valves and assisting devices are monitored and controlled by an IoT platform constructed by Meazon
- Modified HVAC cycle based on a 12000 Btu/hr R410a system

Investigation domain

Test conditions

Spray heights (mm)

15

20

25

30

×

Mass flow rates (gr/s)

4.5

5.5

6.5

7.5

⇨

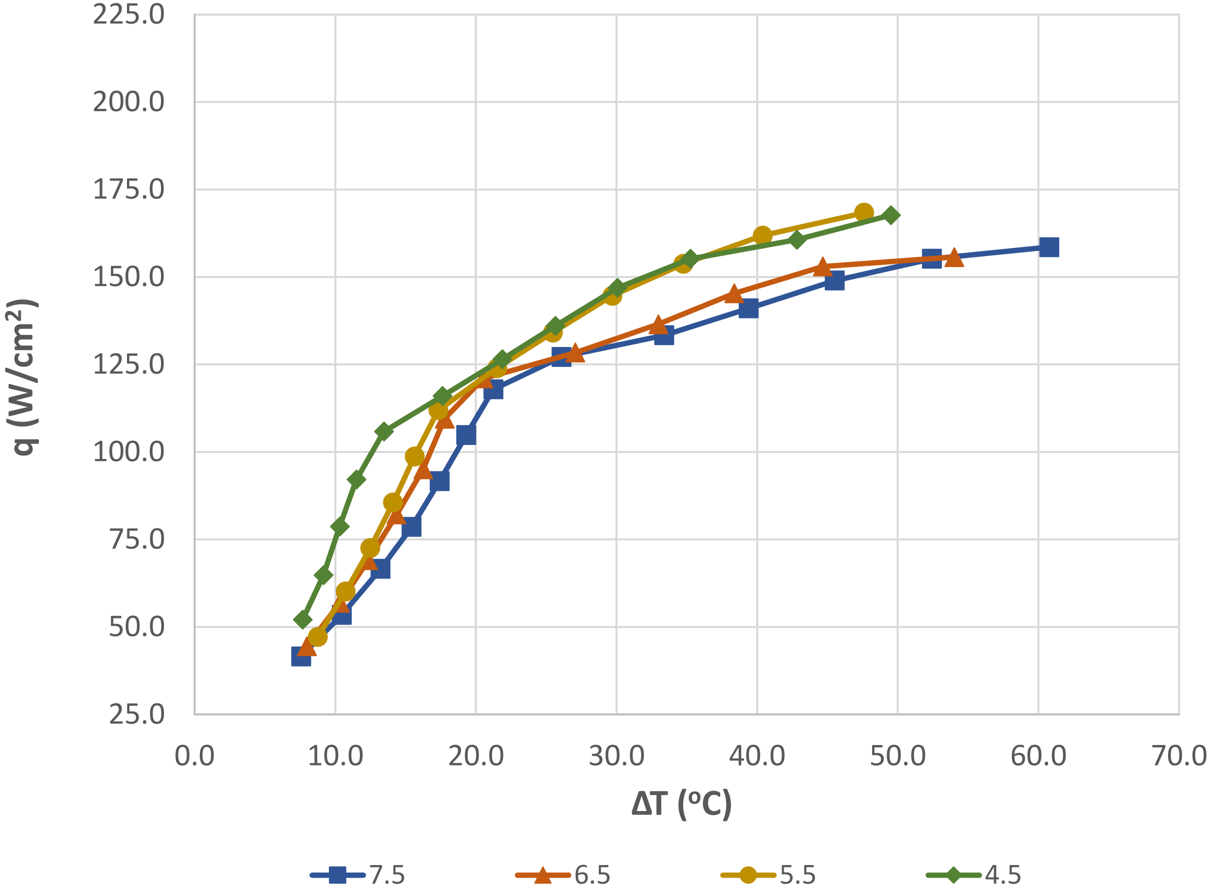
Results

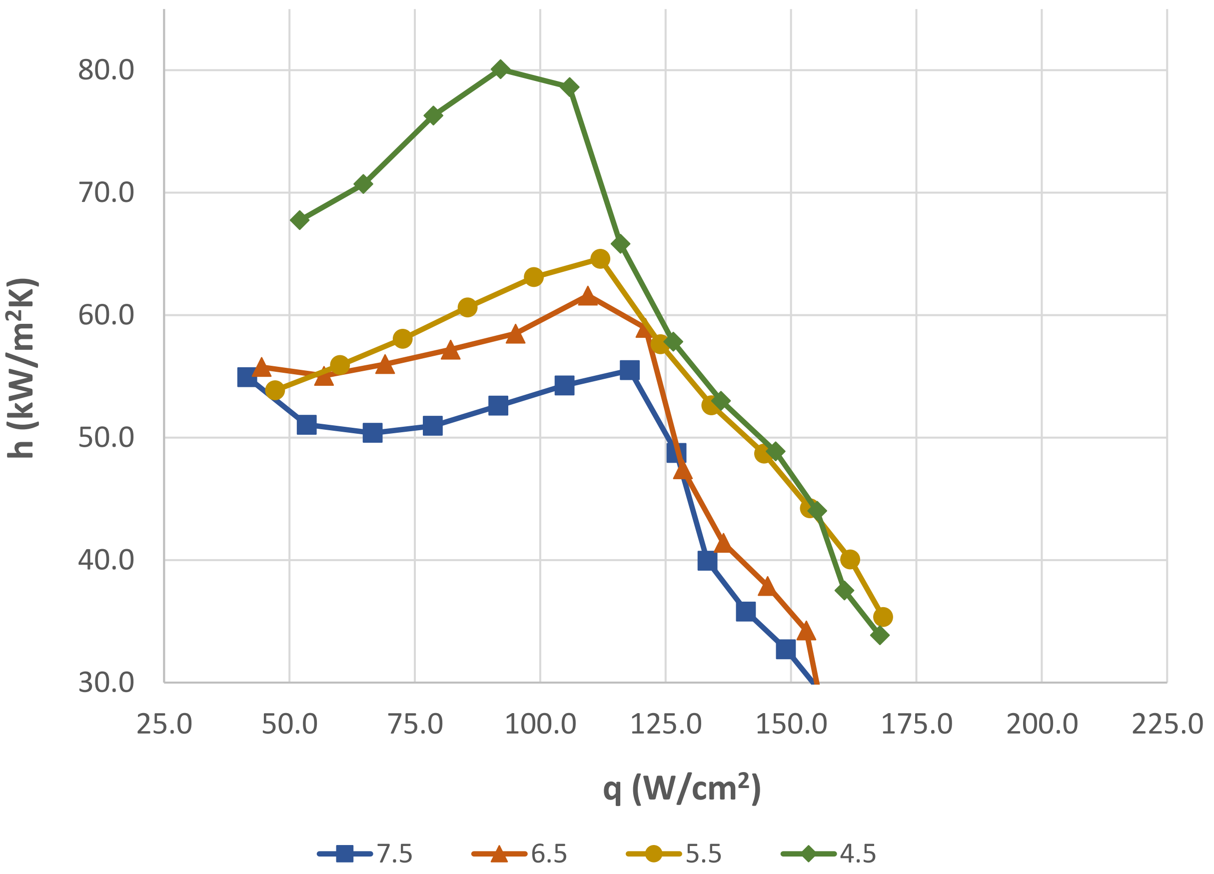
Heat flux

Heat Transfer Coefficient

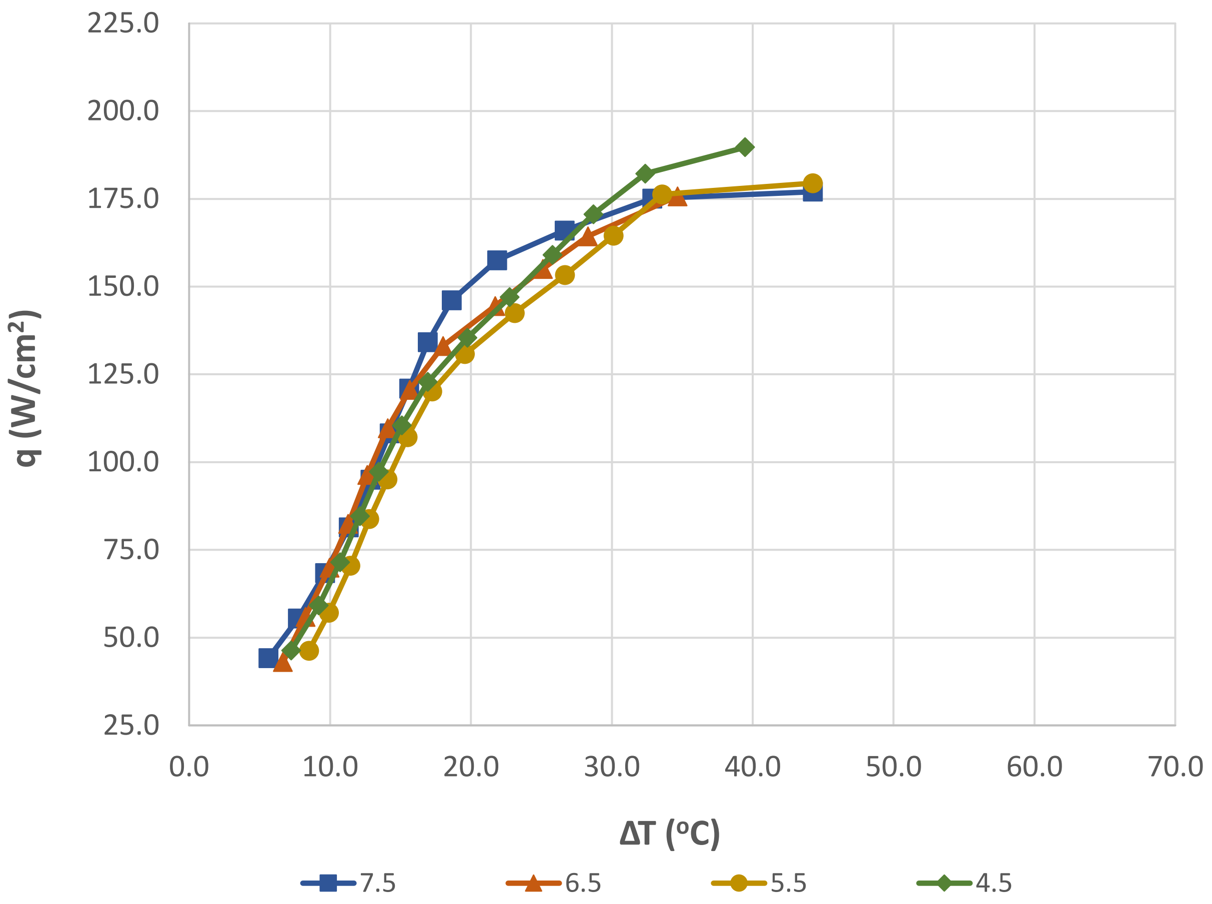
Surface Superheat

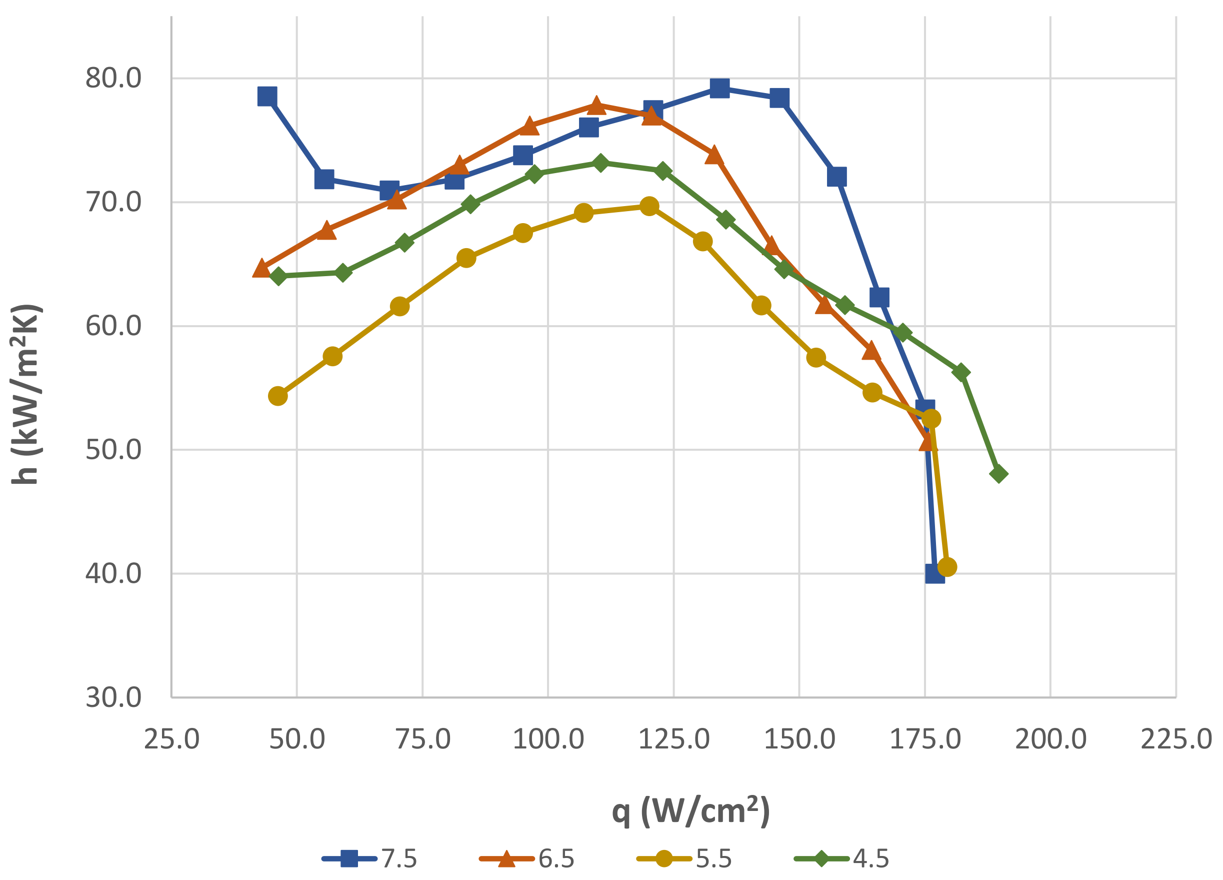
Results - Mass flow rate effect for 15 mm Spray height



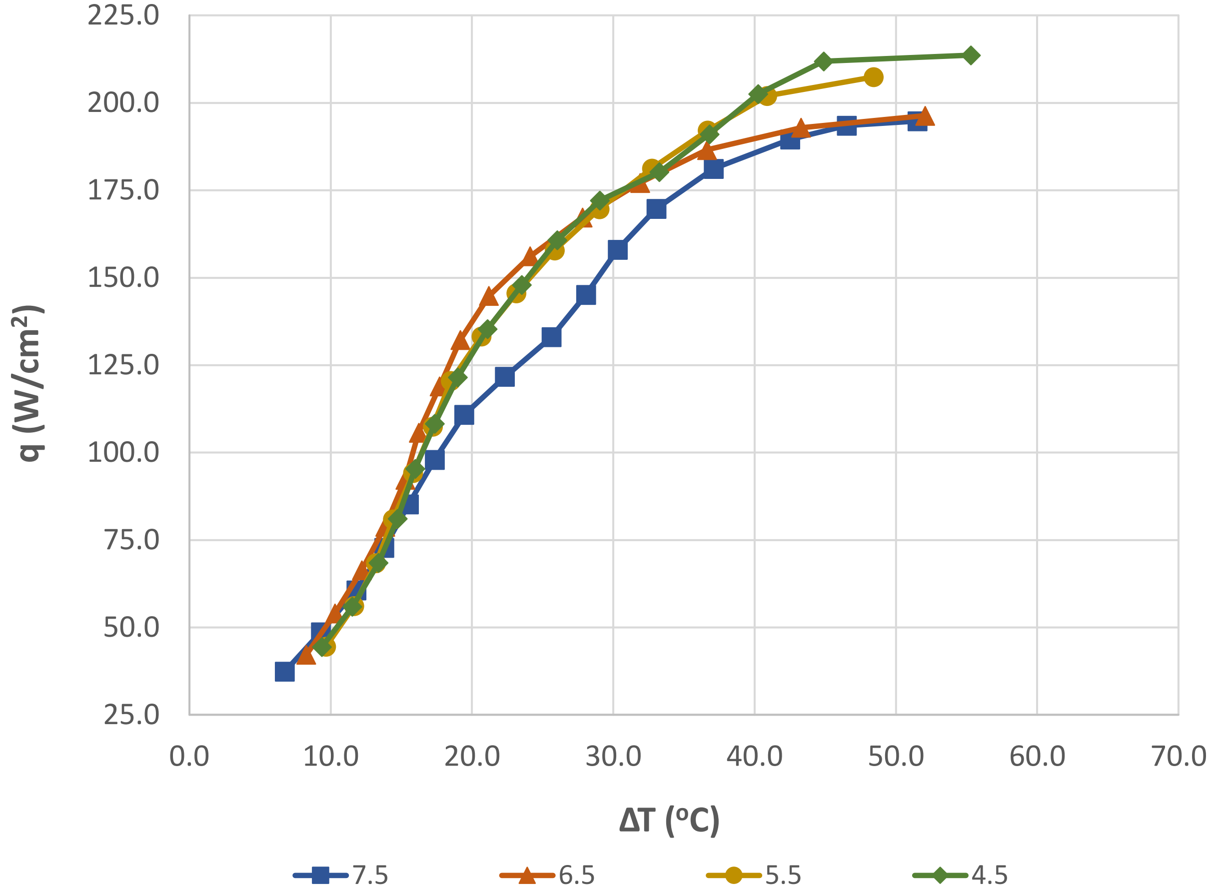


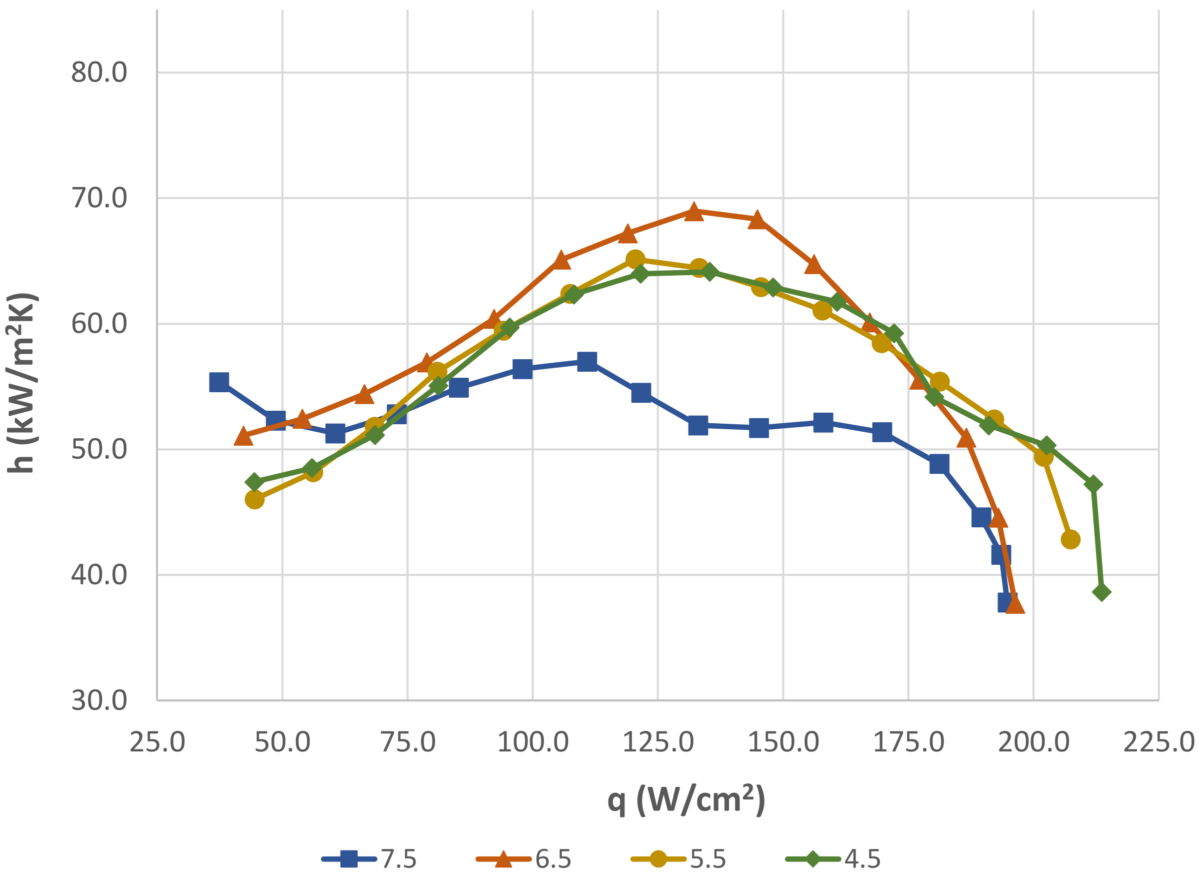
Results - Mass flow rate effect for 20 mm Spray height



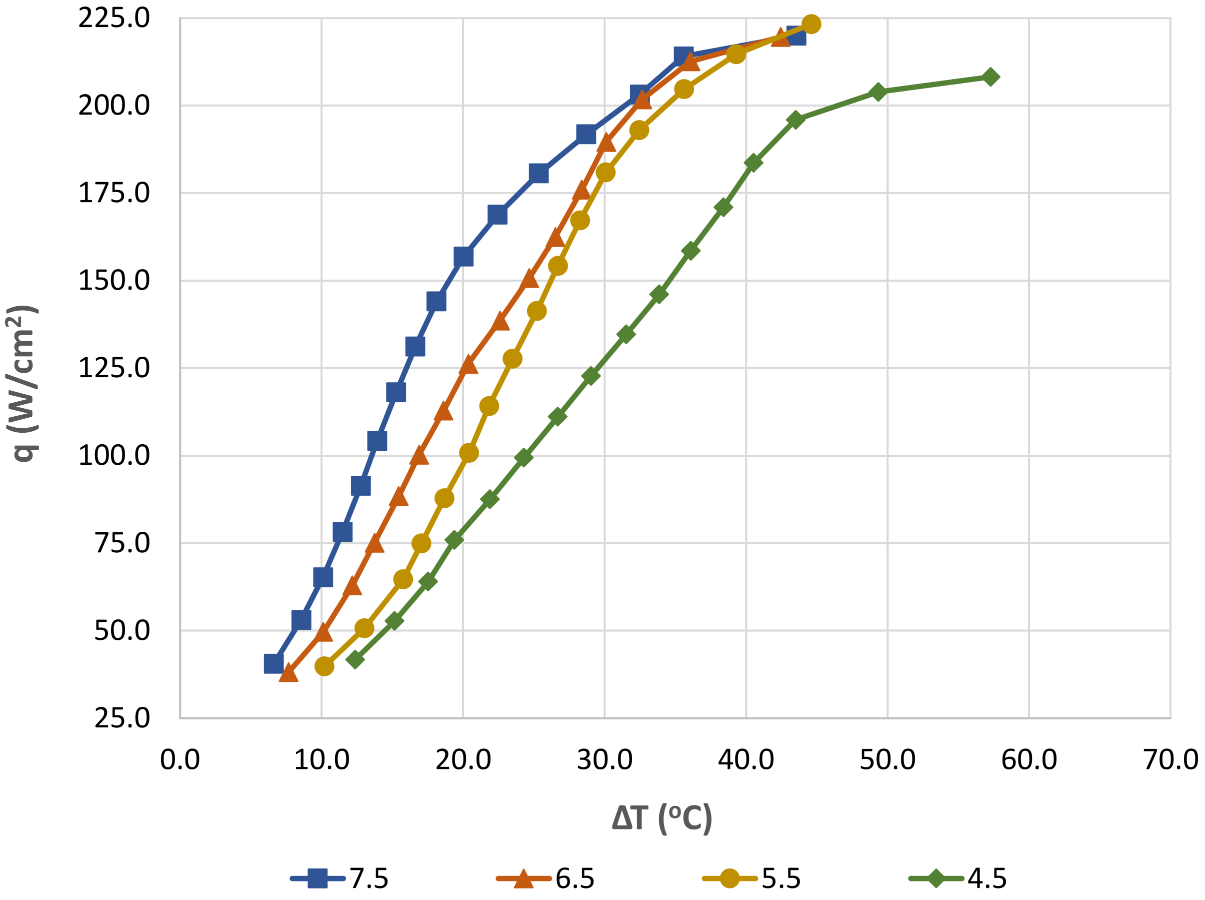


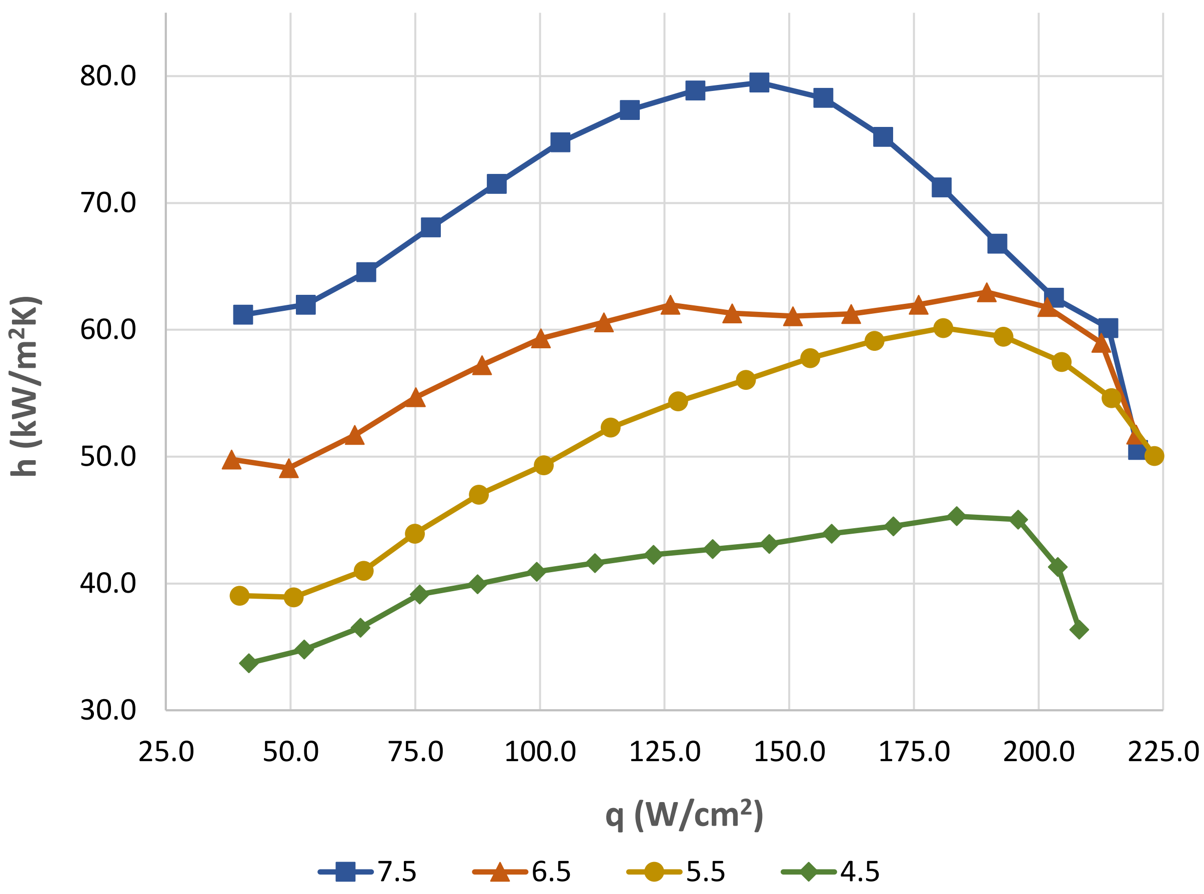
Results - Mass flow rate effect for 25 mm Spray height



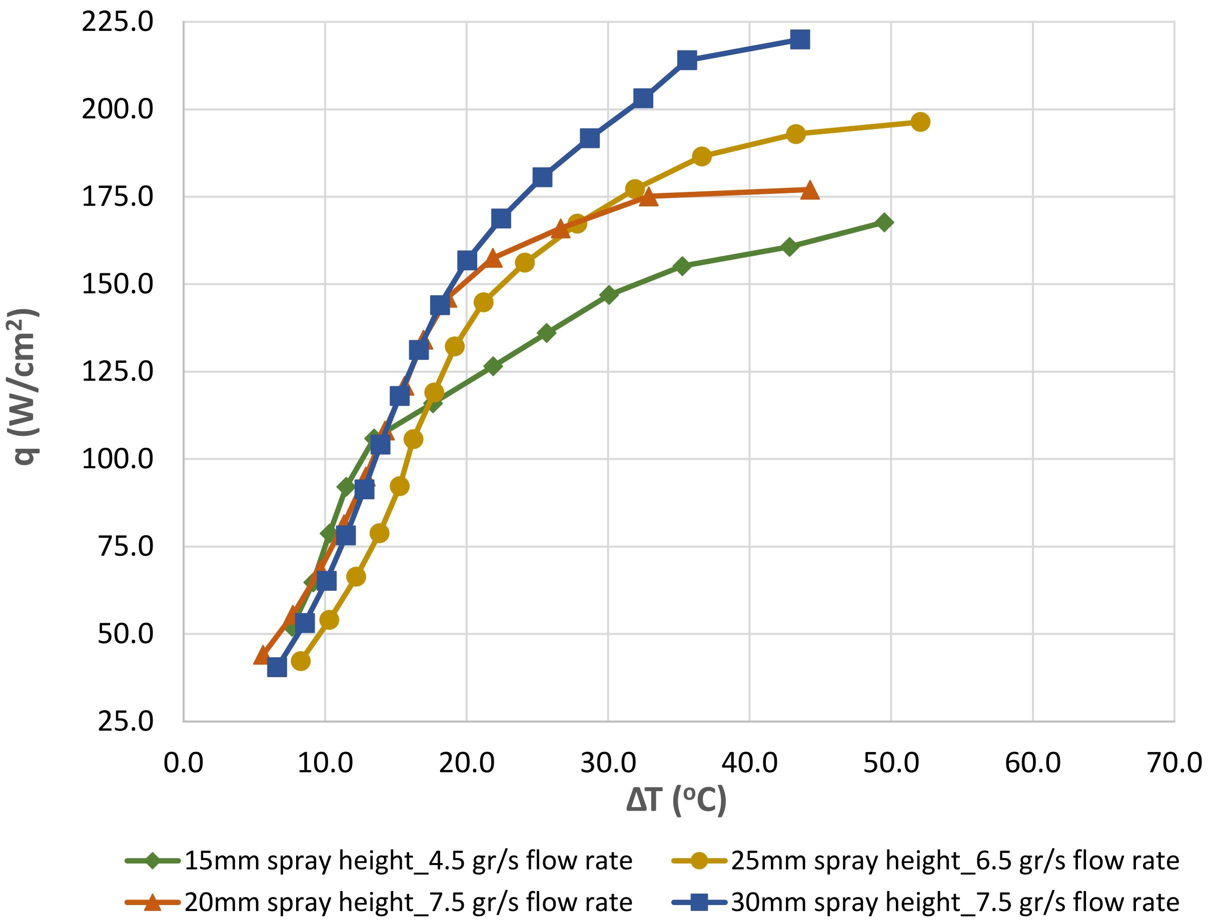


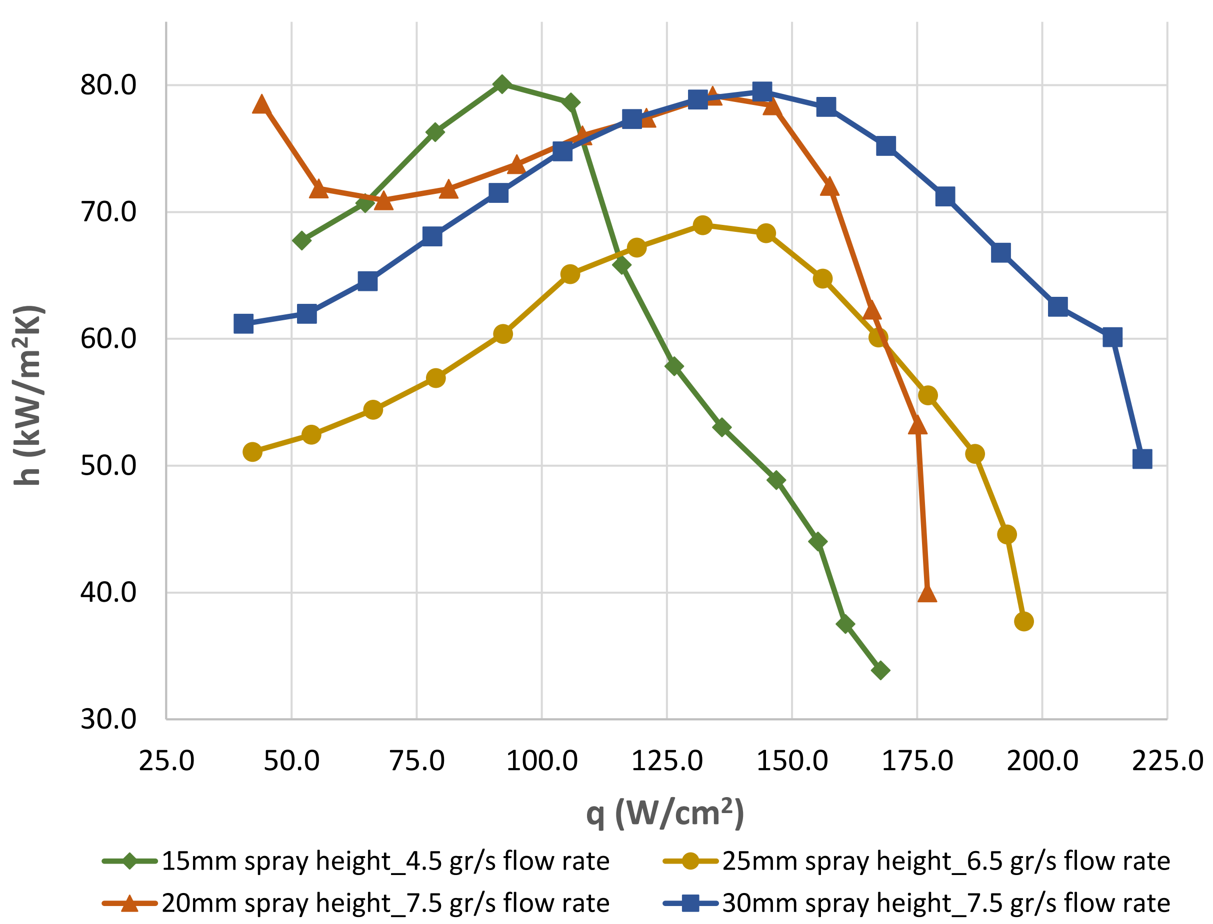
Results - Mass flow rate effect for 30 mm Spray height





Results - Optimal mass flow rate performance per spray height





Conclusions

- The order of magnitude of heat flux and heat transfer coefficient in all experiments, indicates that the flashing spray technique is the main heat transfer mechanism
- 223.25 W/cm^2 maximum heat flux achieved for 5.5 gr/s mass flow rate at 30 mm spray height
- 80.09 kW/m^2 K maximum heat transfer coefficient achieved for 4.5 gr/s mass flow rate at 15 mm spray height
- Increasing spray height results in larger heat fluxes
- For 30 mm and 20 mm spray height 7.5 gr/s mass flow rate shows the best cooling ability, while for 25 mm and 15 spray height the optimal flow rates are 6.5 gr/s and 4.5 gr/s respectively
- Increasing spray height shifts the heat transfer coefficient vs heat flux curve to the right, meaning that, larger spray heights shows better cooling ability for larger heat fluxes

THANK YOU FOR YOUR ATTENTION

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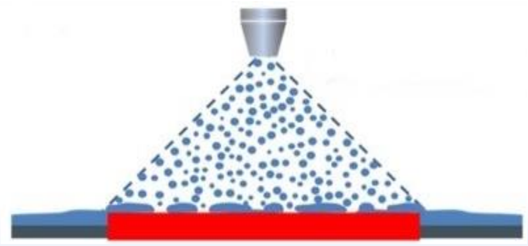
LABORATORY OF APPLIED THERMODYNAMICS



SprayElectroCooling project

High Efficiency Heat Dissipation and Energy Conservation for Ultra-High Power Electronic Devices Based on Flashing Spray

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meazon

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Ευρωπαϊκή Ένωση
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