Refrigerant spray cooling of electronics

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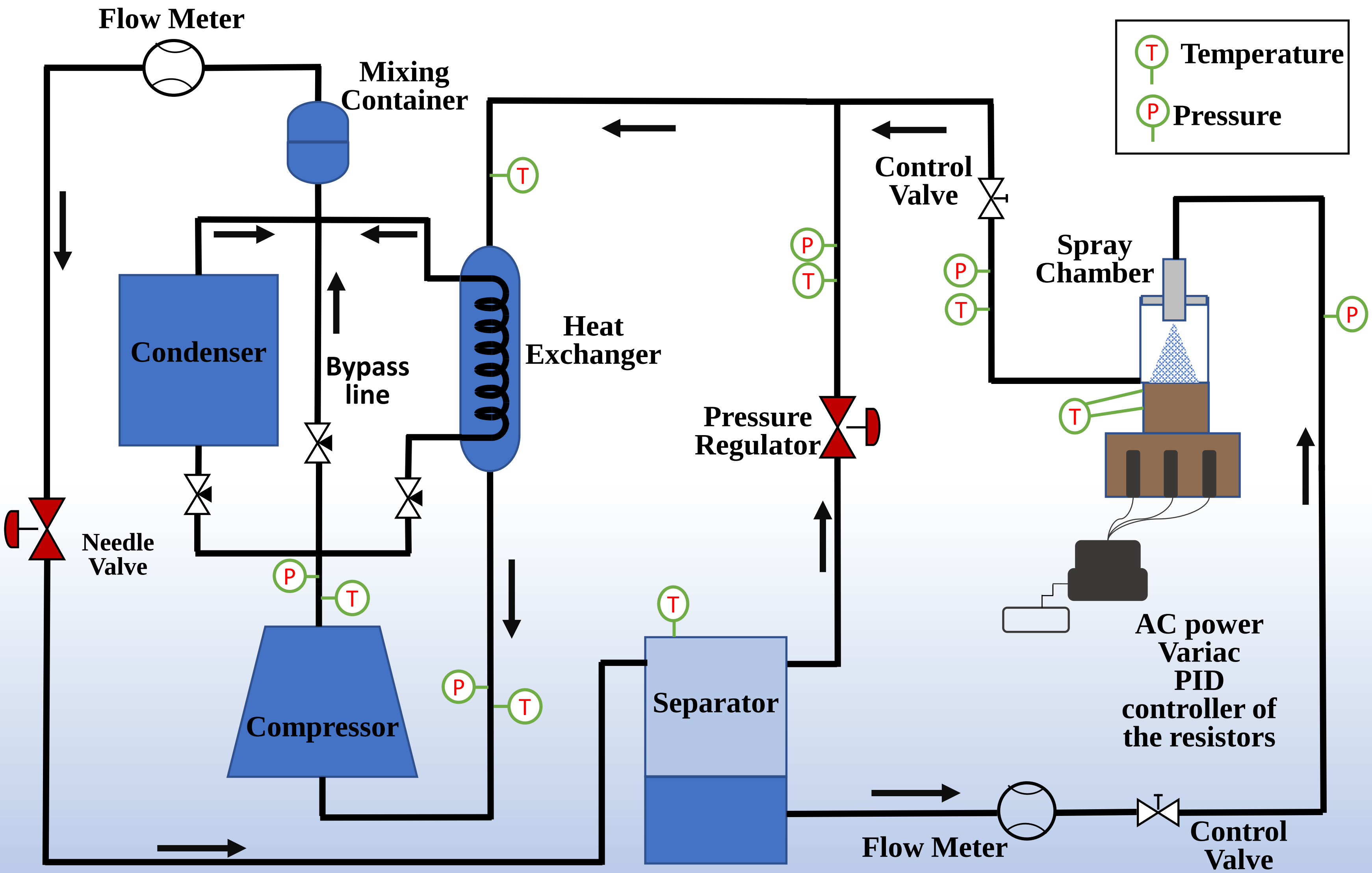
Motivation

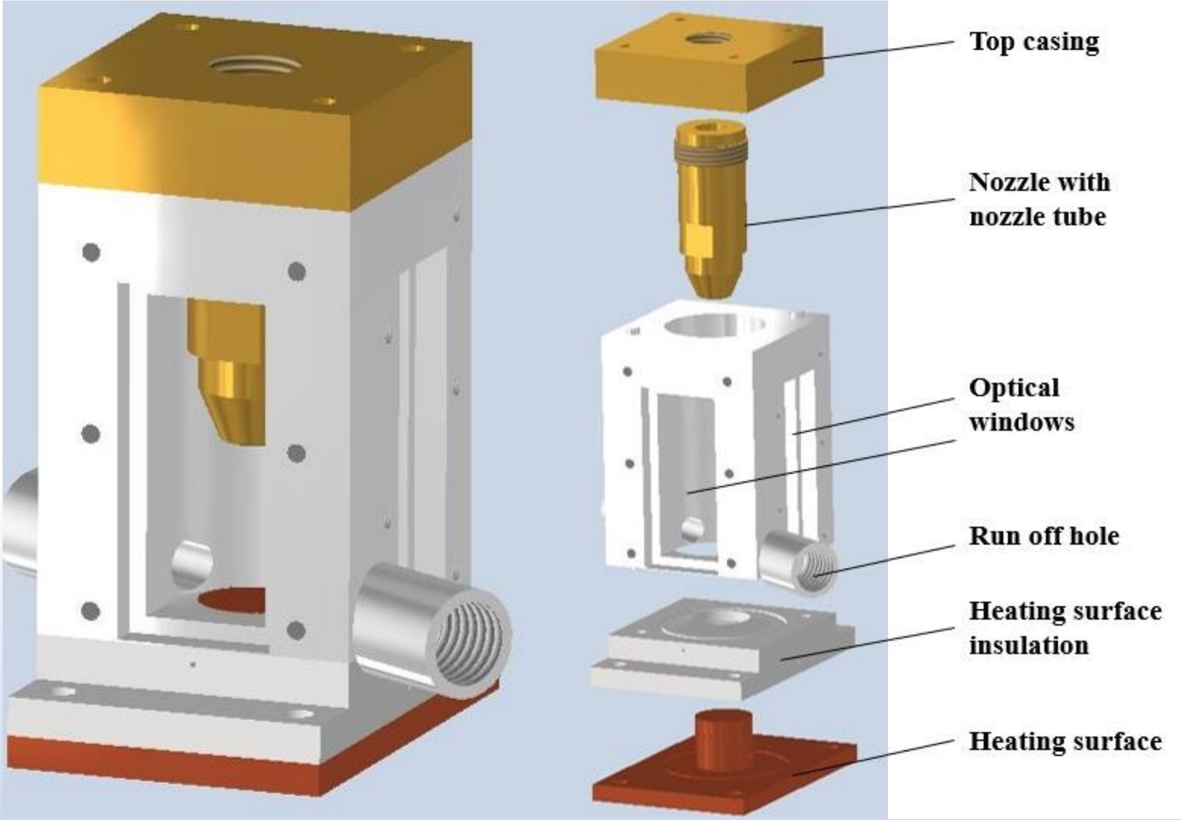
- ***Power electronics require effective cooling techniques to:***
  - Maximize power density
  - Optimize performance efficiency
  - Improve reliability and increase life expectancy
- ***Refrigerant Spray cooling as a two-phase cooling scheme can:***
  - Dissipate significant heat loads
  - Maintain the electronics temperature at the desired operating conditions
- ***Spray cooling heat transfer mechanisms involve:***
  - 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
  - Creation of secondary nucleation points due to the continuous droplets impingement

Experimental Setup & Methodology



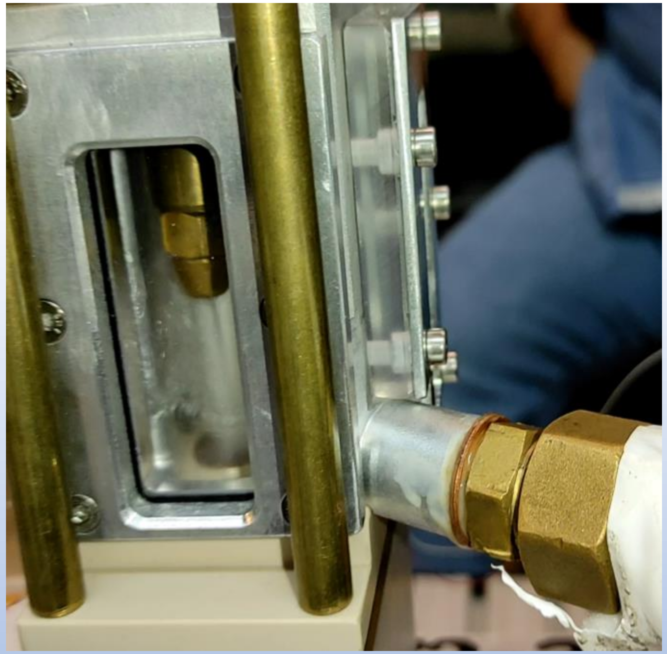
Experimental Details

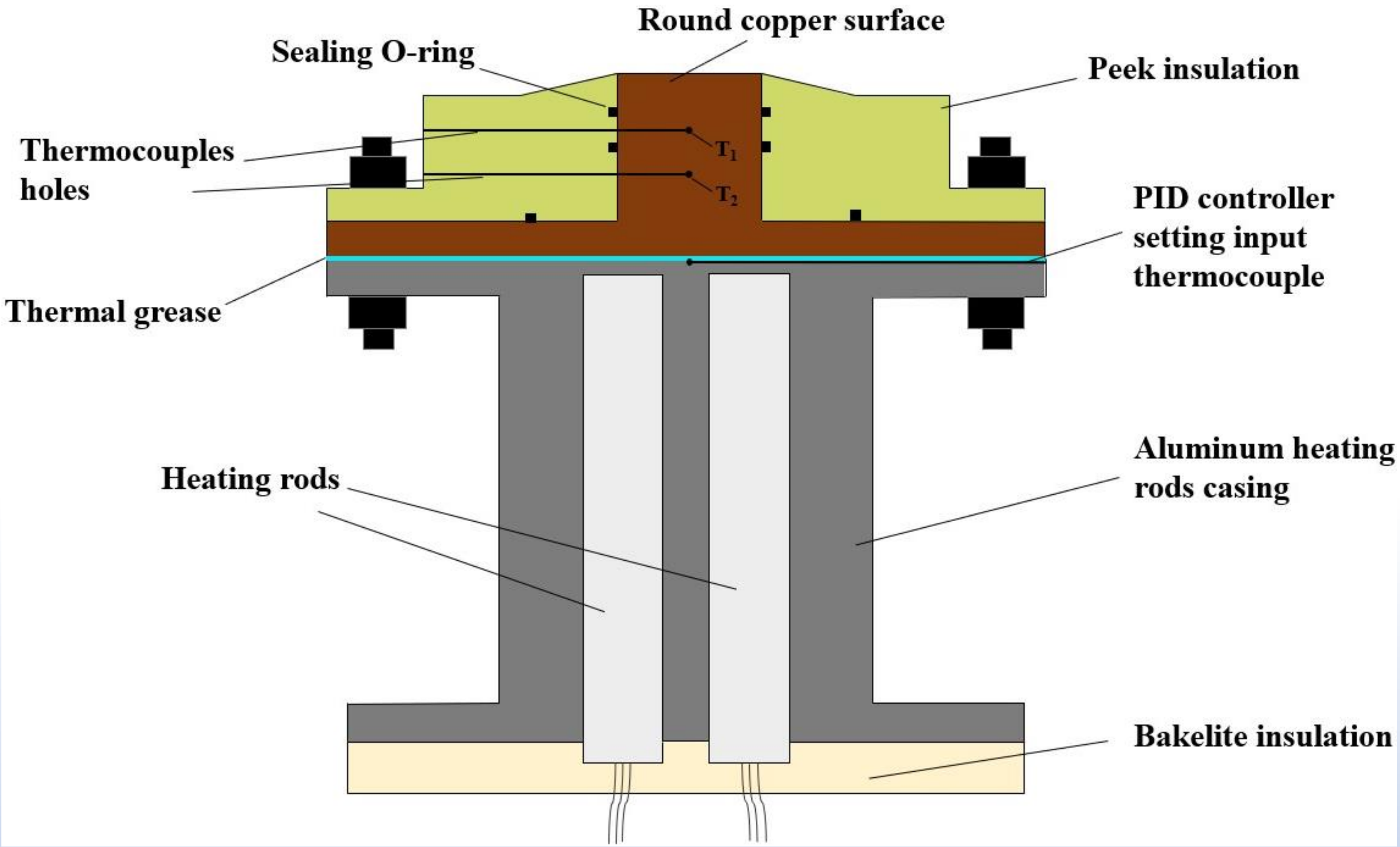
- Closed loop setup based on a modified HVAC cycle of a 12000 Btu/hr R410a system
- Valves and assisting devices are controlled by an IoT platform constructed by Meazon
- Pressure and temperature ports monitor points of interest across the system
- Heat is supplied by controlling the electric power consumption of 4 cartridge heaters through a PID controller
- Proper refrigerant flow rate adjustment allows the dissipation of different heat loads in the spray chamber



Spray chamber characteristics

- 50 ml internal volume
- 5 x nozzle tubes corresponds for 5 spray heights (15, 20, 25, 30, 35 mm)
- 2 x Danfoss OD full cone nozzles (45^o & 60^o)
- 2 x Ø8 mm run off holes
- Ø17 mm plain pure copper surface as the heating medium
- Transparent visualization windows





Heating System

- 1D Heat conduction along copper component
- Peek Insulation
- 4 x 400-Watt heating rods serving as heat source
- Heat flux control via the temperature setting of the copper base using the PID controller
- 2 x K-type thermocouples for the evaluation of the heat flux along the copper surface

Experimental conditions

Spray nozzle angles
45º
60º

×

Spray Heights (mm)
15
20
25
30
35

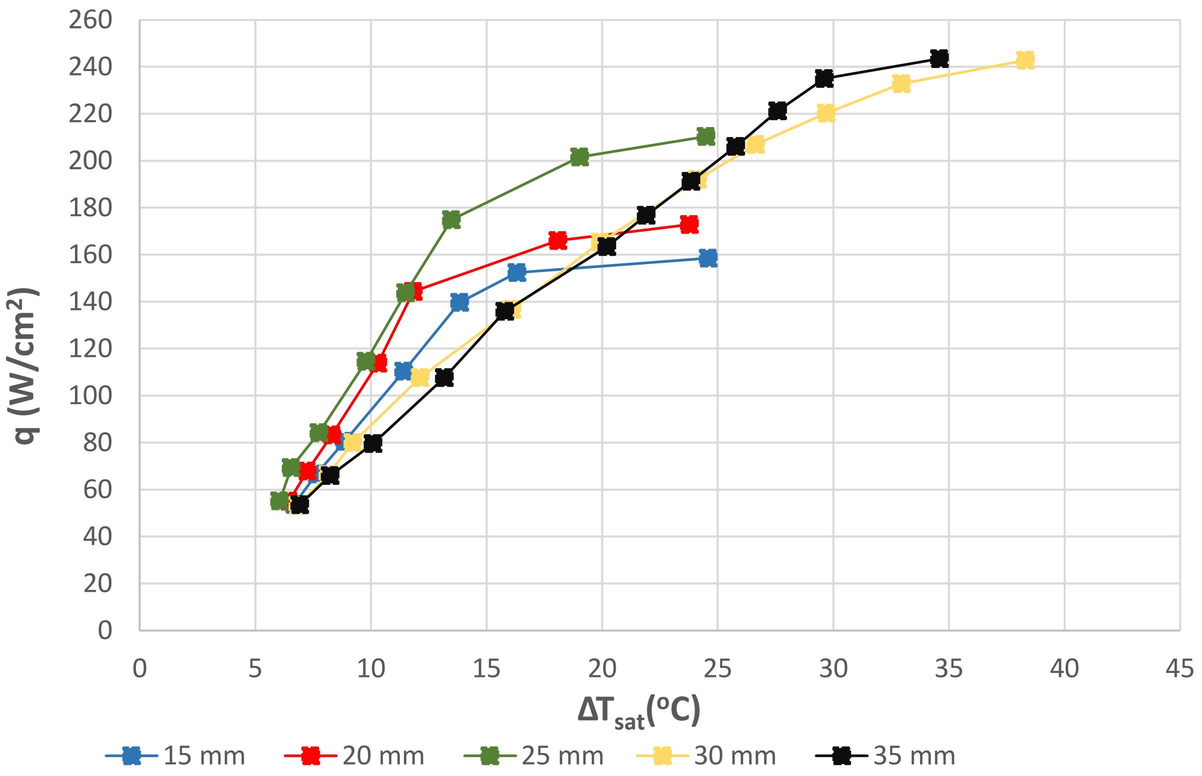
×

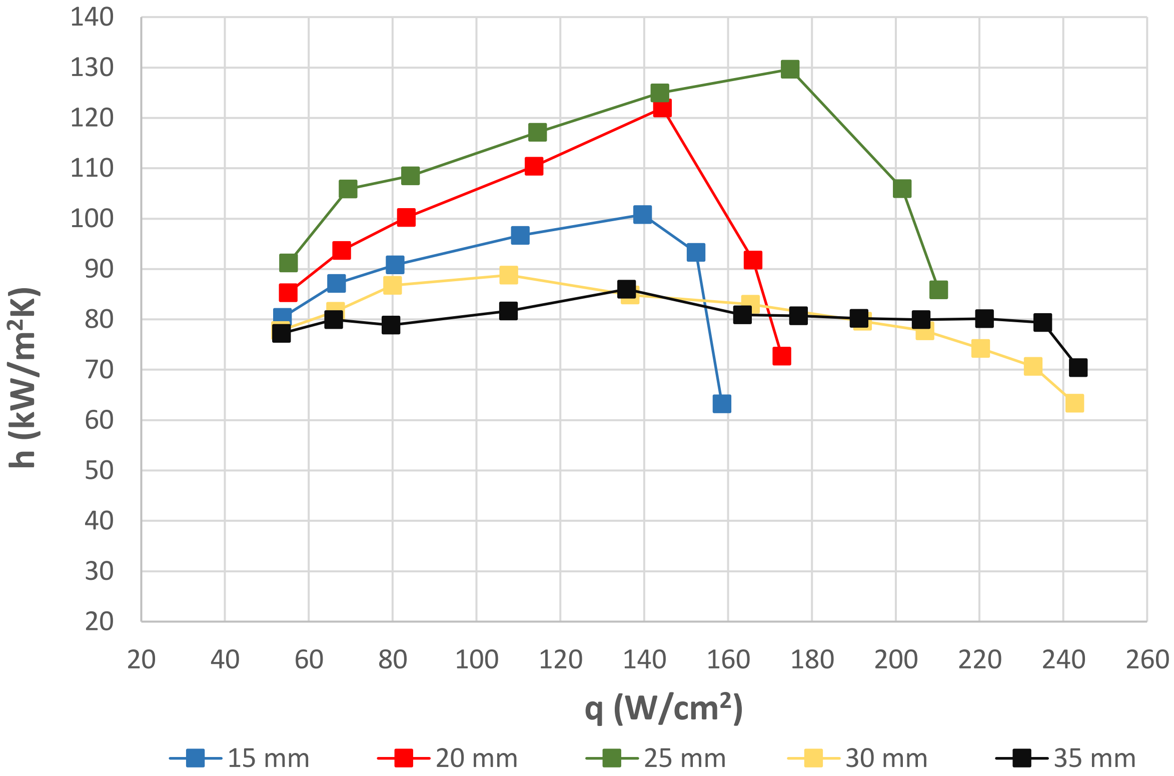
Mass flow rates (gr/s)
4.5
5.5
6.5
7.5

Variables of Interest

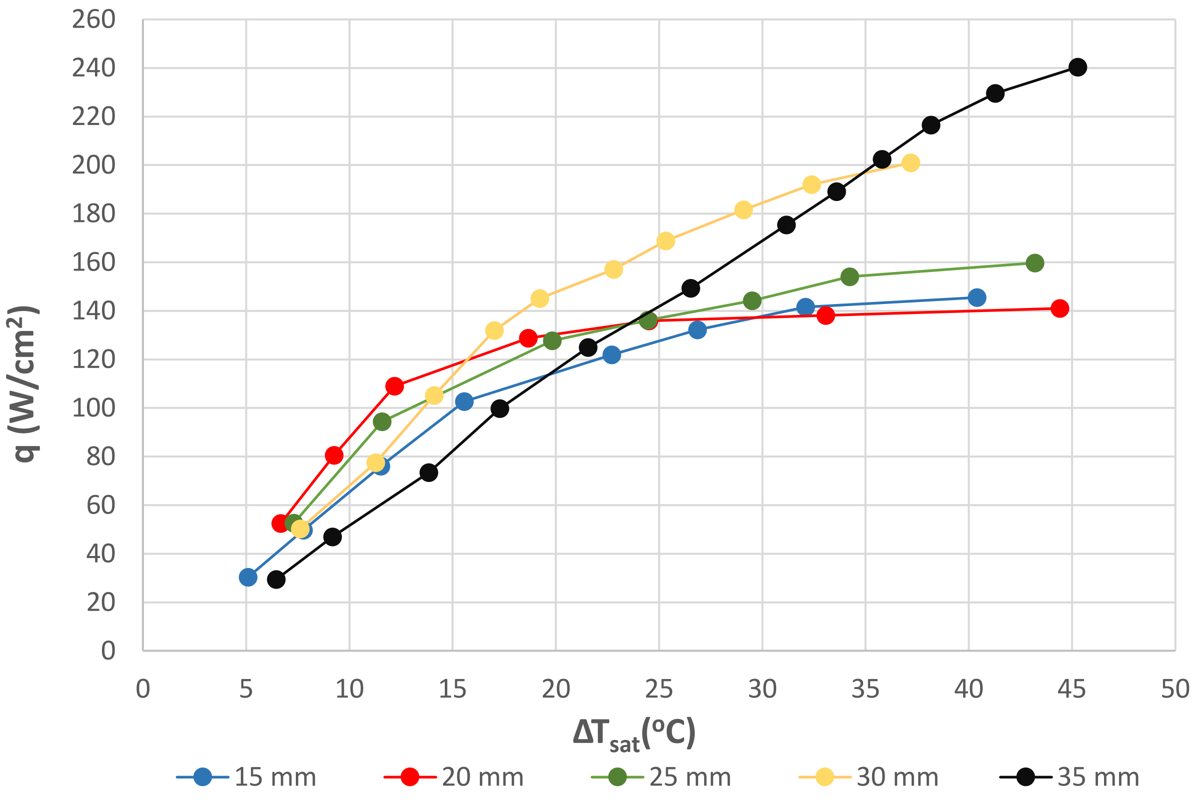
Variables of Interest
Heat flux
Heat Transfer Coefficient
Surface Superheat

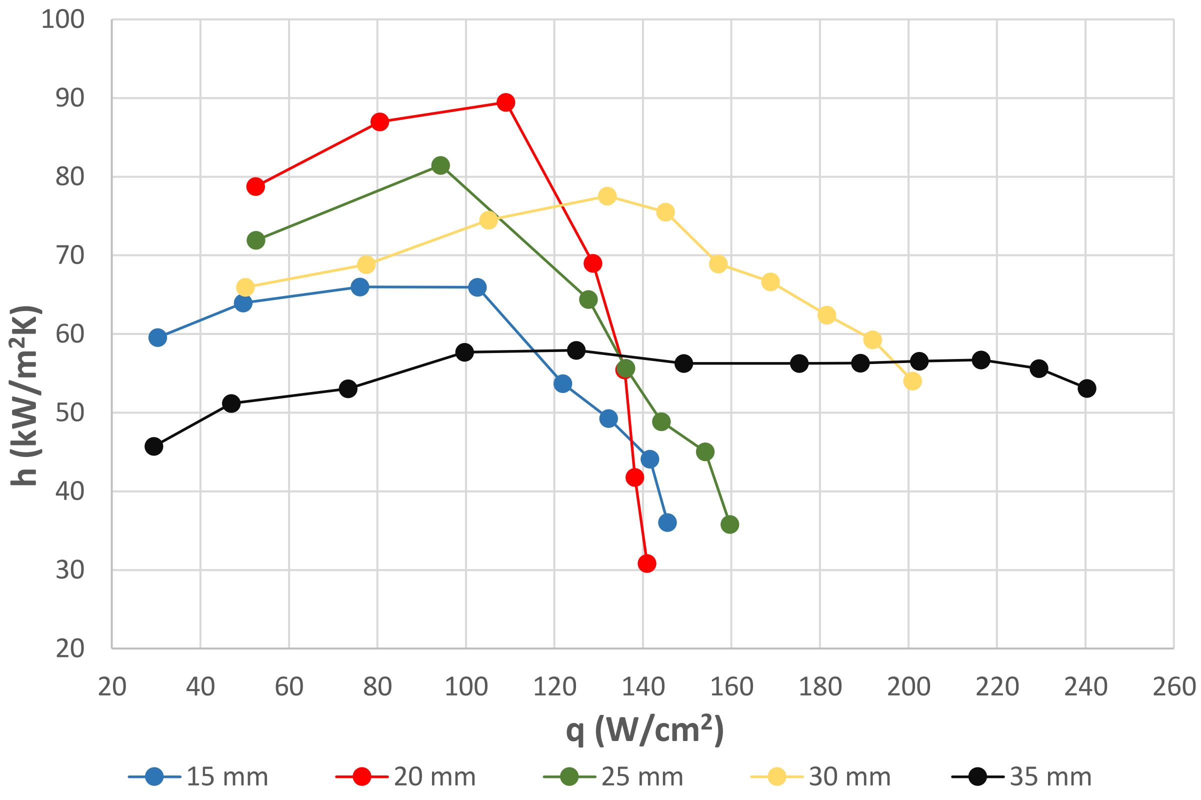
Spray height effect for 60º spray nozzle @ 4.5 gr/s mass flow rate



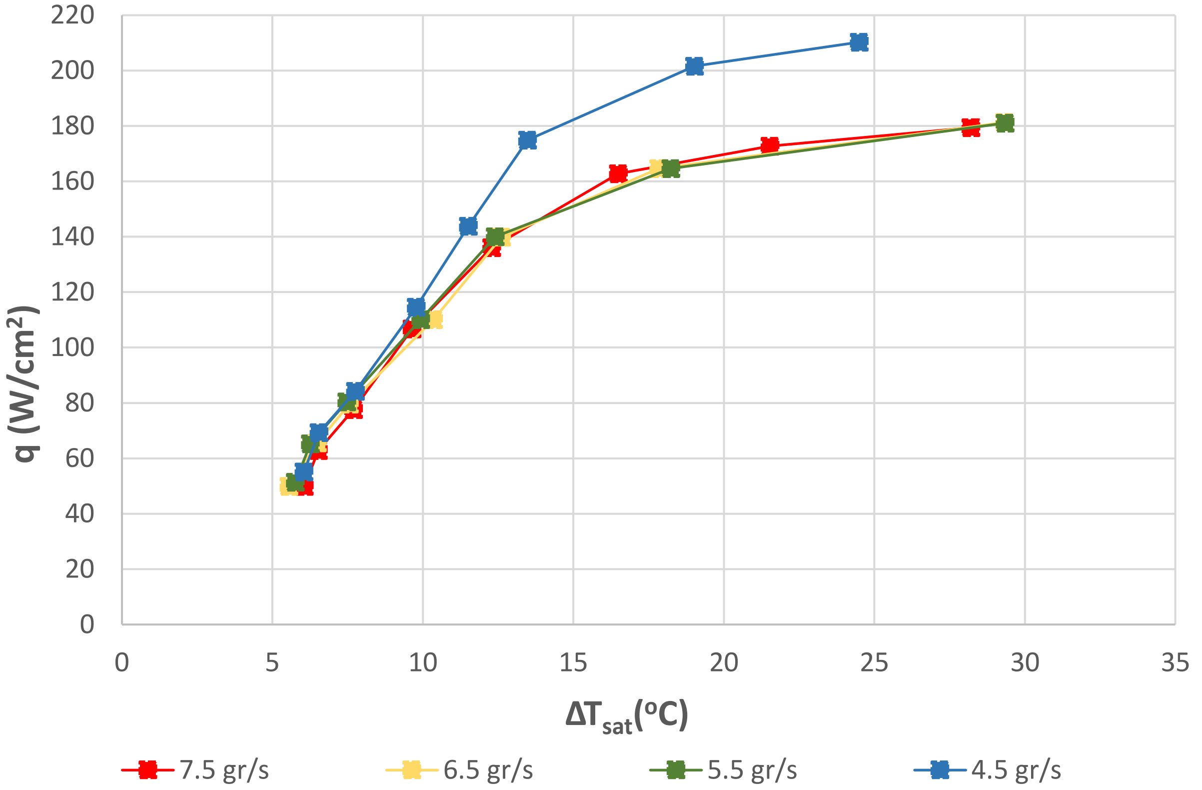


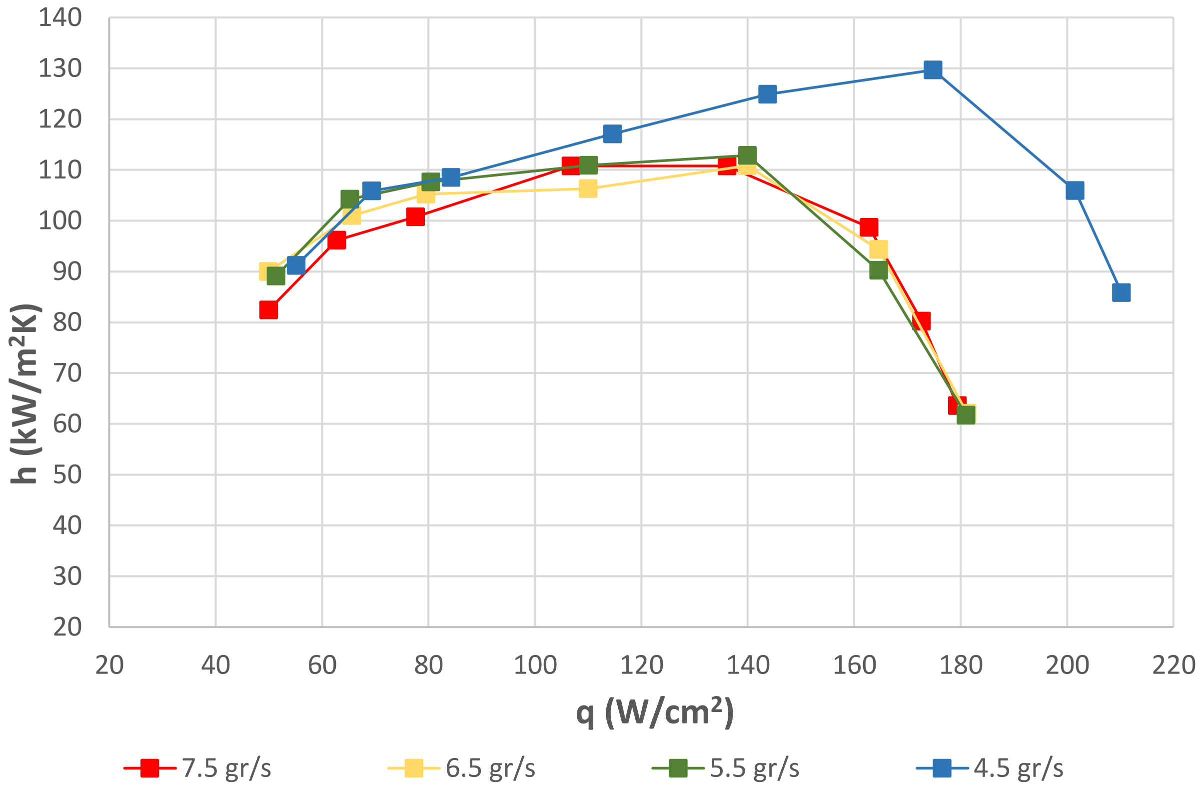
Spray height effect for 45º spray nozzle @ 4.5 gr/s mass flow rate



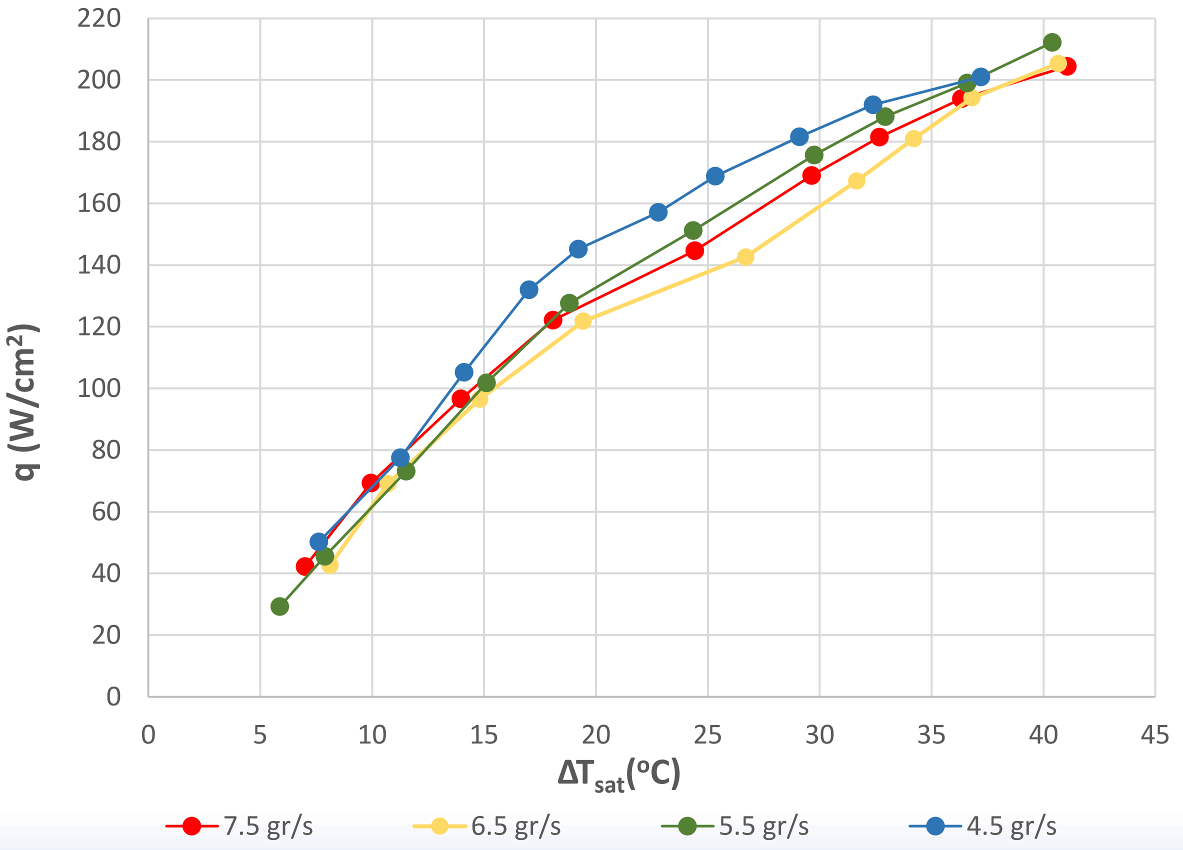


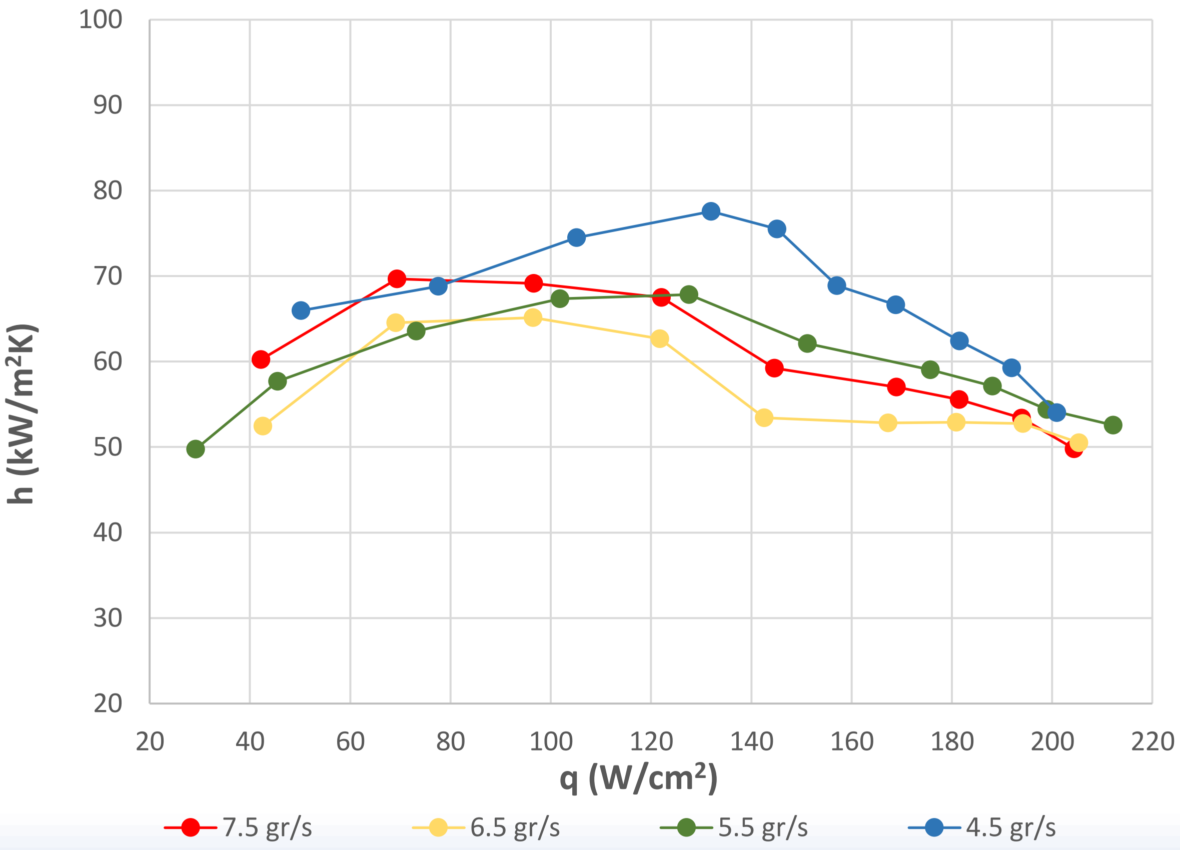
Mass rate effect for 60° spray nozzle @ 25 mm spray height



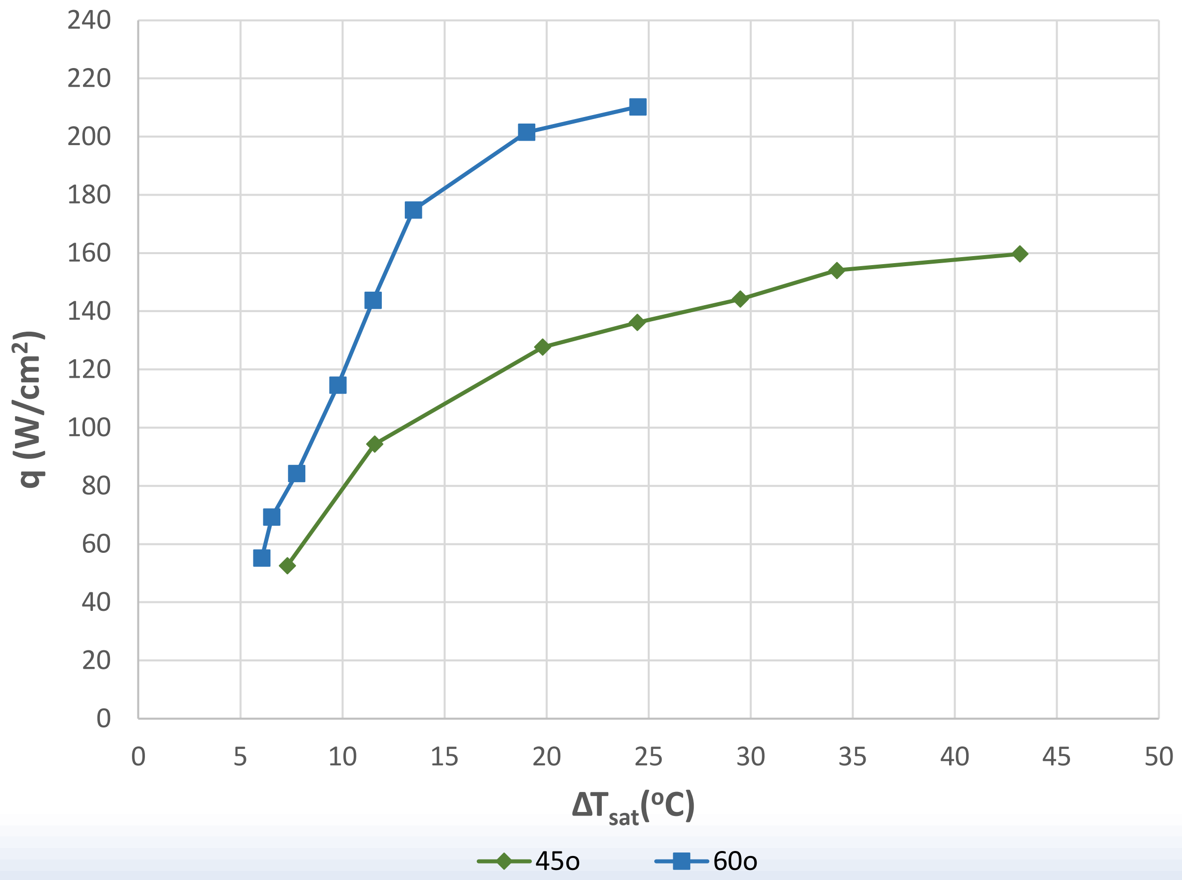


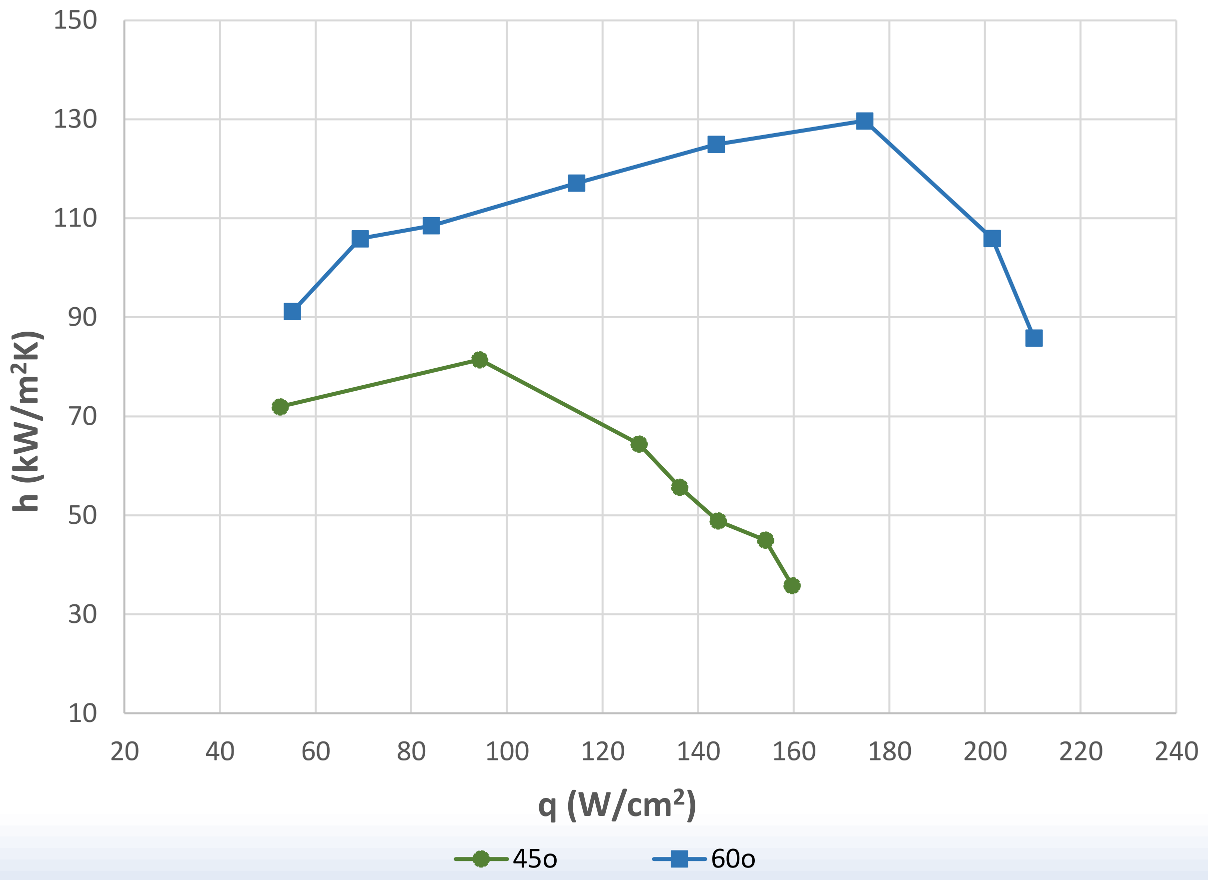
Mass rate effect for 45º spray nozzle @ 30 mm spray height





Spray cone angle effect @ 25 mm spray height & 4.5 gr/s mass flow rate



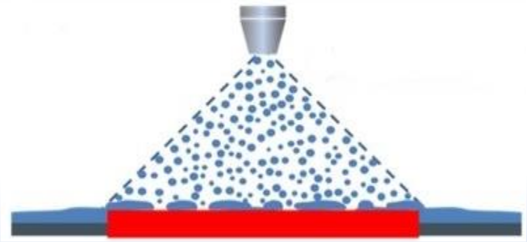


Summary & Conclusions

- Formation of active nucleation sites and secondary nucleation points due to droplets impingement is the main heat transfer mechanism
- **243.52 W/cm^2** maximum heat flux is achieved for 4.5 gr/s mass flow rate at 35 mm spray height and 60^o spray nozzle
- **129.68 kW/m^{2}K** maximum heat transfer coefficient is achieved for 4.5 gr/s mass flow rate at 25 mm spray height and 60^o spray nozzle
- The increment of spray height results in the optimal performance in terms of HTC at 25 mm for 60^o spray nozzle and at 20 mm for 45^o spray nozzle respectively
- Increasing spray height leads to larger heat fluxes both in 45^o & 60^o spray nozzles
- For 25 mm spray height, 4.5 gr/s mass flow rate exhibits the best cooling ability in terms of HTC and heat flux while the rest of the mass flow rates tested show the same behavior
- For 30 mm spray height 4.5 gr/s mass flow rate displays a slightly better cooling performance than the other mass flow rate examined
- The 60^o spray nozzle has a better cooling ability compared to the 45^o spray nozzle both in HTC and heat flux

THANK YOU FOR YOUR ATTENTION

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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