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# Thermal Enhancement Using Nanofluids on High Heat Dissipation Electronic Components


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***1st ENSf, 8th 11th October 2017 Lisbon, Portugal***

# Agenda

- Importance of Electronics Cooling
- Systems With High Need of Heat Dissipation
- Active and Passive Thermal Control
- Nanofluids Concept and Applications
- Results and Discussions
- Concluding Remarks



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# Importance of Electronics Cooling

- High demand of heat dissipation:
  - Increase of processing speeds and decrease of components' sizes utilized in Satellites and Defense systems, result in higher heat densities ($W/m^2$)
  - High-Tech equipment requires reliable thermal control
  - Active and passive thermal management systems must be considered
  - Physical limits lead to the use of alternative working fluids
  - Technological issues must be addressed
- Investigate new working fluids
  - Nanofluids must operate in atmospheric environments (active liquid cooling) and saturation conditions (passive thermal control)



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# Systems with High Need of Heat Dissipation

- High heat dissipation needs:
  - High heat densities (W/m$^2$)
  - Small components generating low heat levels (i.e. 0.5 W) can result in heat densities > 50 kW/m$^2$
  - Example: square component with sides 2.5 mm X 2.5 mm
- Physical limitations of some thermal control systems cannot promote the heat dissipation
- Operation Temperature Range: -40 to 150°C



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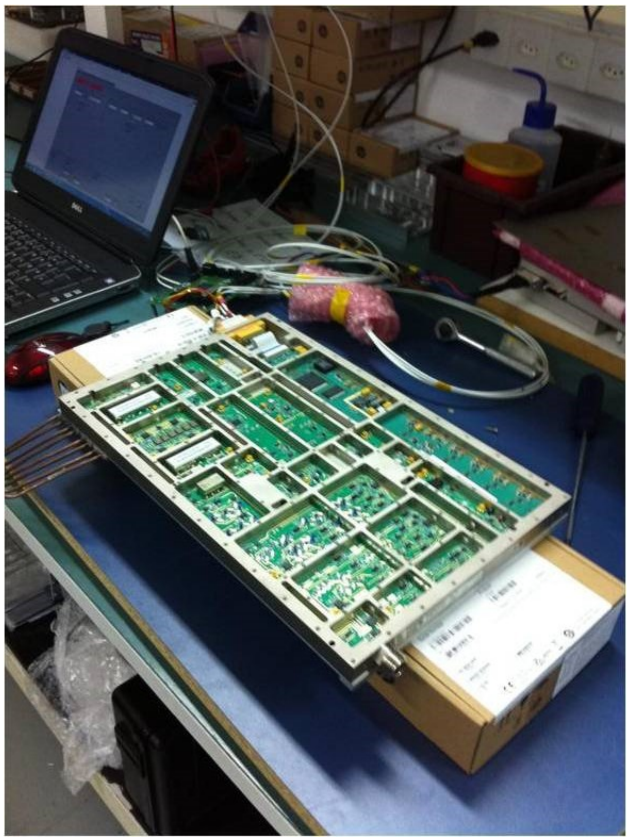
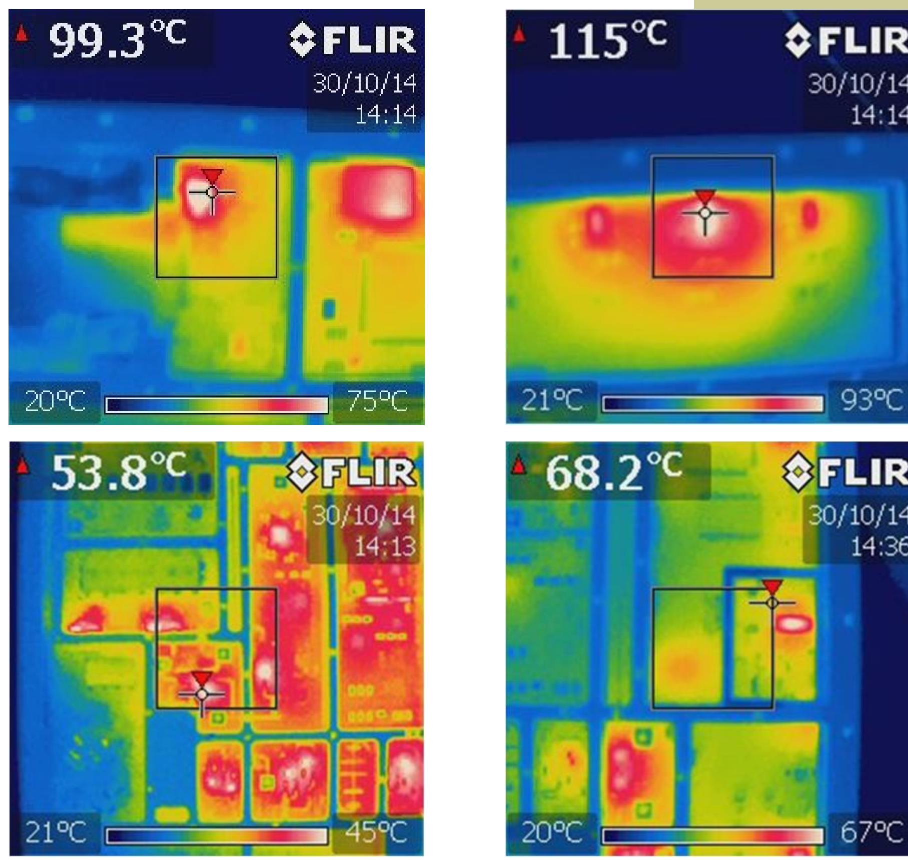
# Systems with High Need of Heat Dissipation





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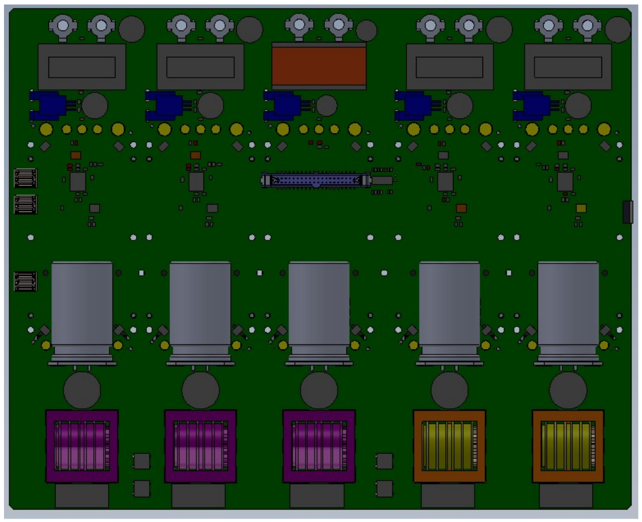
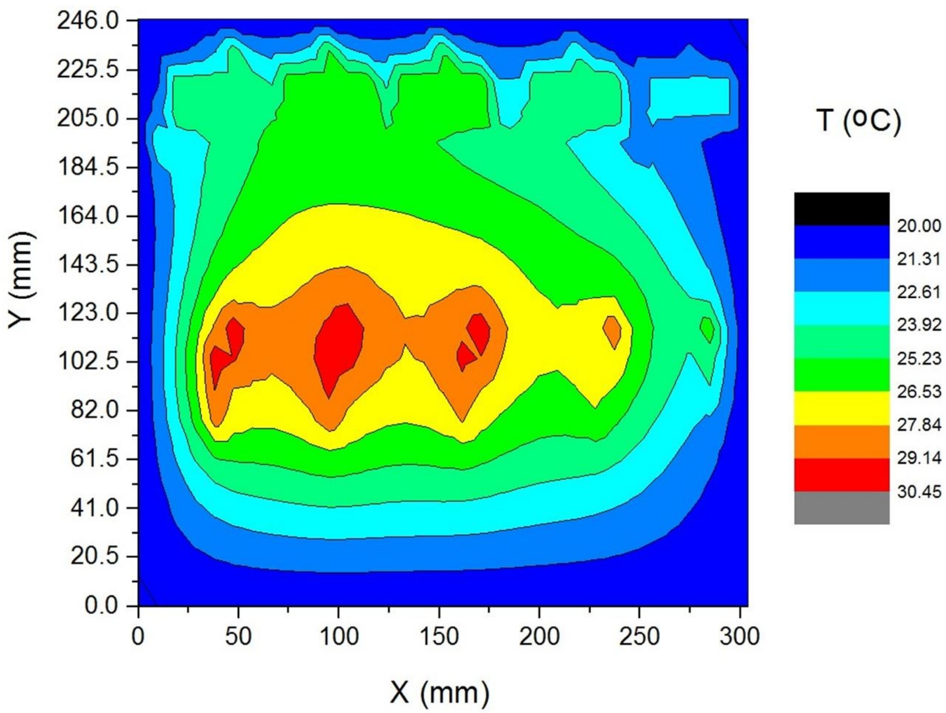


| Component | Q (W) | Dimension (mm) | | Heat Flux (W/m2) |
|---|---|---|---|---|
| | | X | Y | |
| R15 | 0.10 | 1.65 | 3.25 | 19,393.94 |
| R16 | 0.10 | 1.65 | 3.25 | 19,393.94 |
| R17 | 0.14 | 1.35 | 2.20 | 47,138.05 |
| R32 | 0.14 | 1.35 | 2.20 | 47,138.05 |
| L1 | 1.15 | 1.40 | 2.20 | 374,025.97 |
| L5 | 1.15 | 1.40 | 2.20 | 374,025.97 |
| L12 | 1.15 | 1.40 | 2.20 | 374,025.97 |
| L9 | 2.20 | 1.40 | 2.20 | 715,259.74 |




Solar Constant = 1366 W/m$^2$

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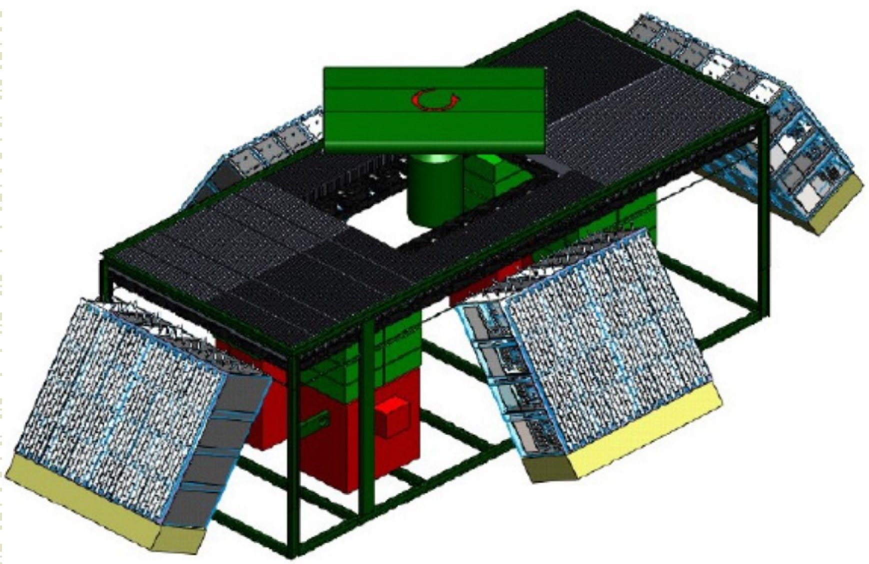
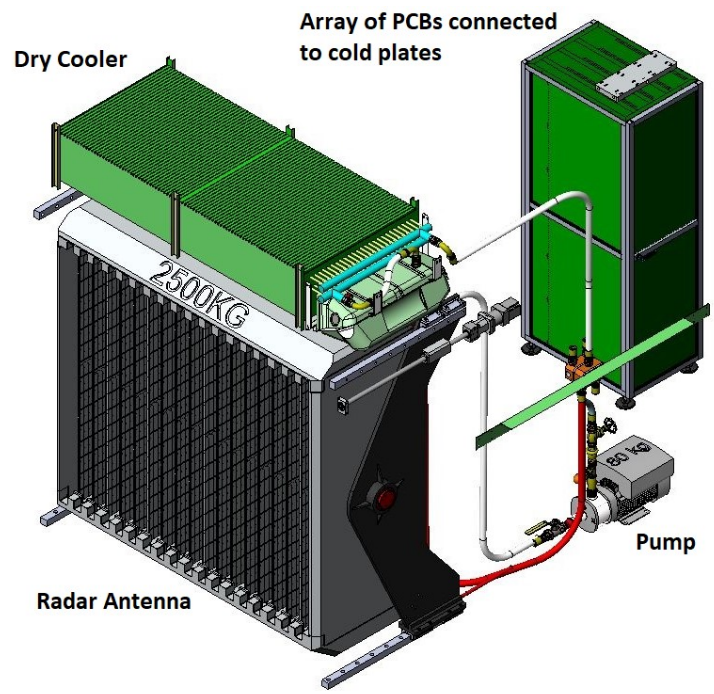
# Active and Passive Thermal Control

- Active System: liquid cooling





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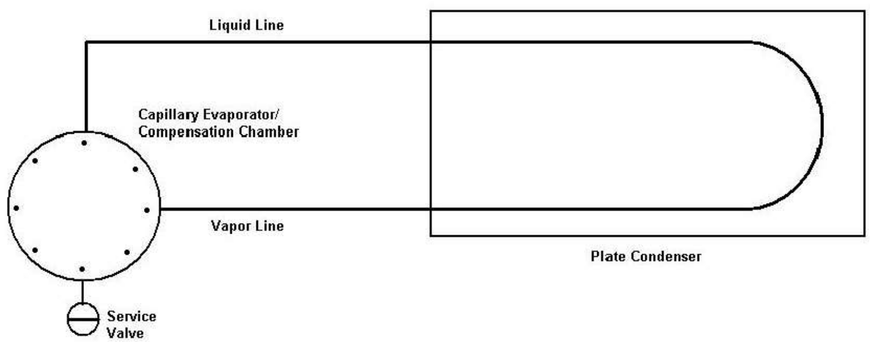
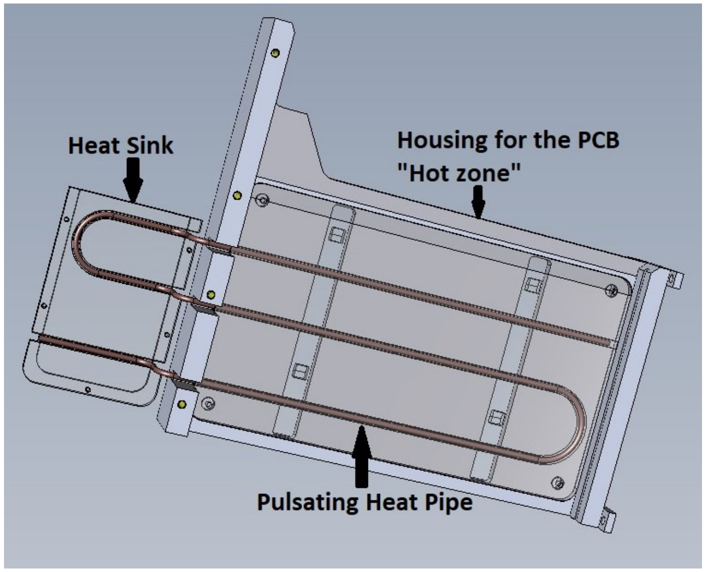
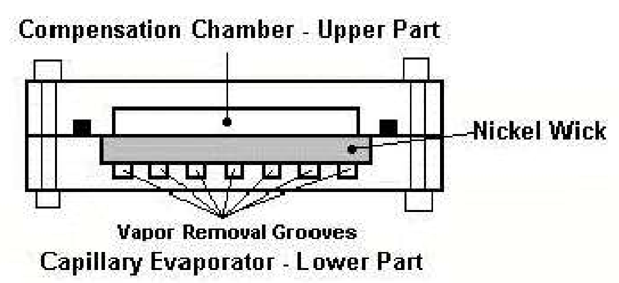
# Active and Passive Thermal Control

- Passive System: Heat Pipes and Loop Heat Pipes



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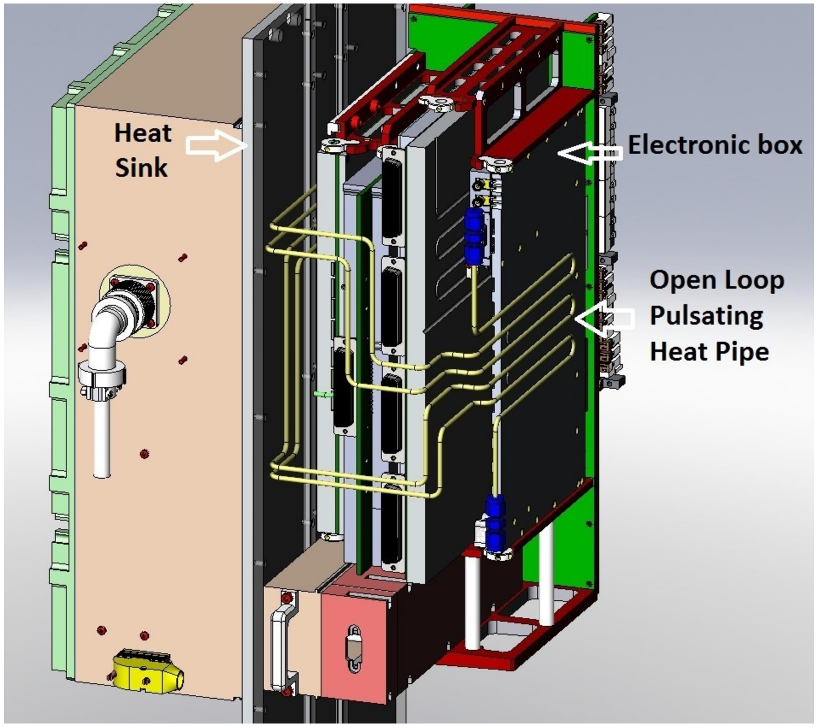


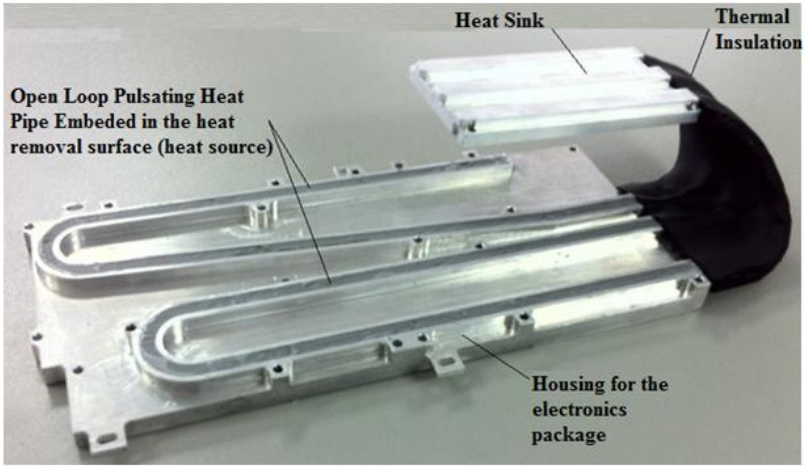




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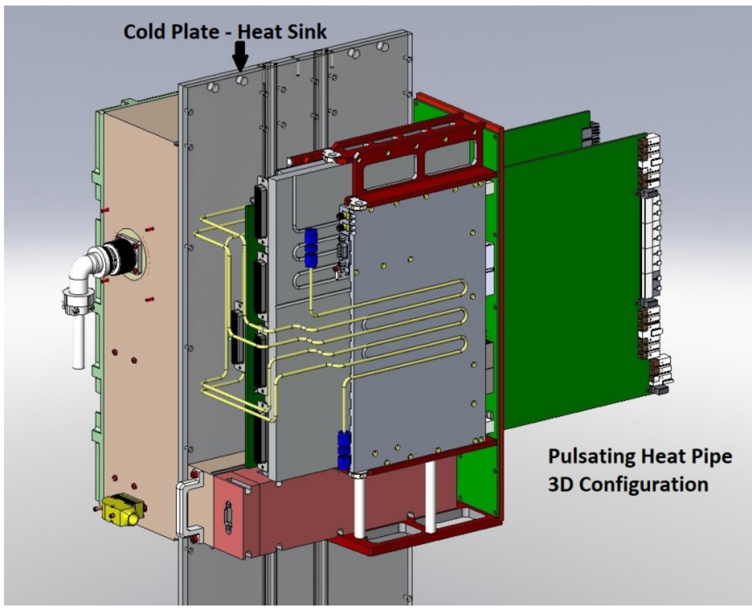
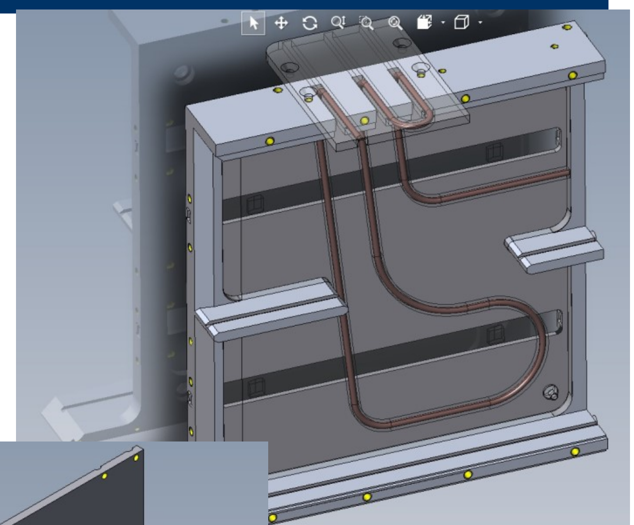
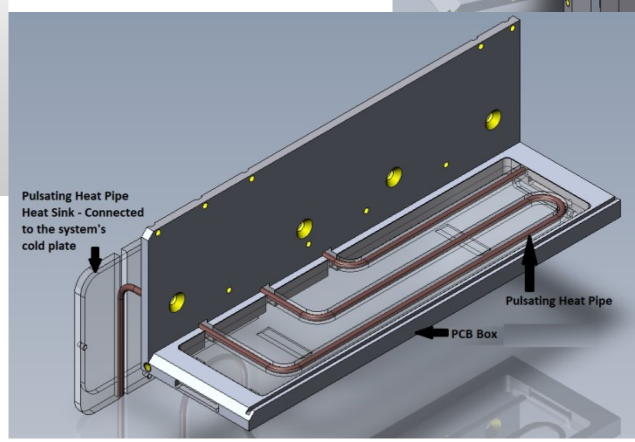



Unit under analysis - 1






Unit under analysis - 2



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# Nanofluids Concept and Application

- Composed by a pure substance (base fluid) and solid nanoparticles:
  - Usually mixed with mass fractions up to 5%
  - Sizes below 100 nm
  - High purity (CuO): 98% / 29 nm
  - Ultra Pure (Cu): > 99.98% / 2 nm


- Influence on the properties:
  - May increase the liquid thermal conductivity by 20%
  - Improve heat transfer capability (proven on single-phase heat transfer devices)



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# Nanofluids Concept and Application

- Nanofluid must be a homogeneous solution
- Solid nanoparticles cannot present sedimentation
- Nanofluid must be chemically compatible
- Wetting characteristics on wick materials must be observed
- Surfactants use must be avoided

| Wick | Water | | | Acetone | | | Methanol | | |
|---|---|---|---|---|---|---|---|---|---|
| Material | Ni | Cu | Al | Ni | Cu | Al | Ni | Cu | Al ** |
| Copper | Poor | Good | * | Poor | Good | Poor | Poor | Good | Poor |
| Nickel | Good | Poor | * | Good | Poor | Poor | Good | Poor | Poor |
| Polyethylene | Poor | Poor | * | Poor | Poor | Poor | Poor | Poor | Poor |

* Water – Aluminum are incompatible substances – non-condensable gases are generated.
** Methanol – Aluminum have presented chemical incompatibility and unstable solubility.



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# Results and Discussion

- Liquid cooling system: $T_{op}$ = 55 $^oC$ maximum
  - Operating with de-ionized water and CuO selected as the nanofluid combination at atmospheric condition
    - Over 400 m of lines with 11 mm diameter
    - No use of surfactants due to chemical issues
- Passive system: $T_{op}$ = 90 $^oC$ maximum – due to cold junction
  - Connects the PCBs that are far from the cold plates
  - Operating with de-ionized water and CuO selected as the nanofluid combination at saturation condition
    - Total of 240 pulsating heat pipes divided in 4 arrays



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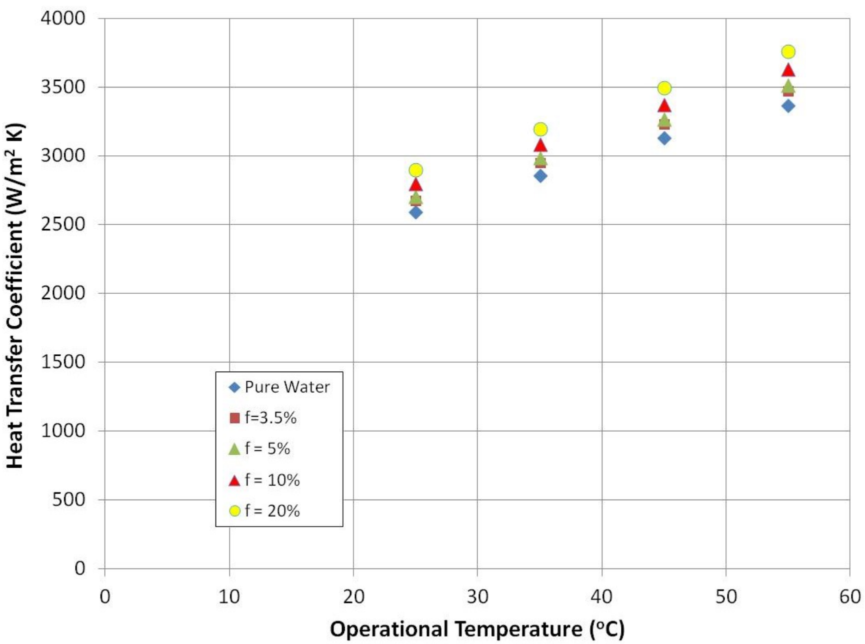
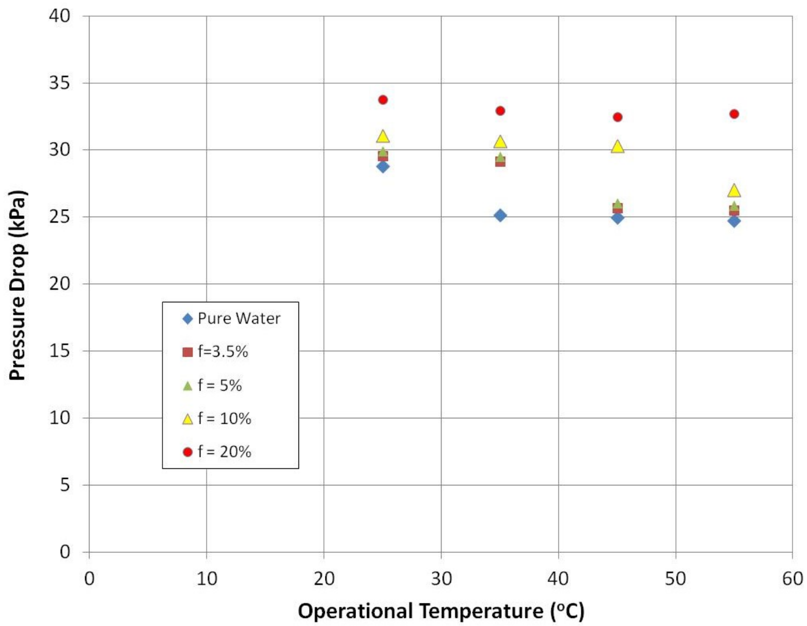
# Results and Discussion

- Liquid cooling system:




Increase of 12% on the heat transfer coefficient and 32% on the pressure drop for *f*=20%



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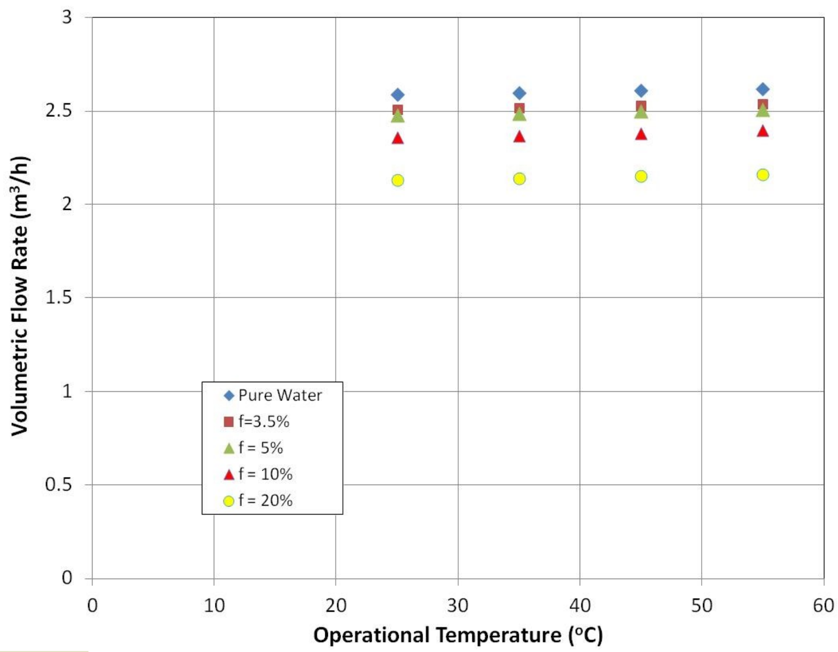
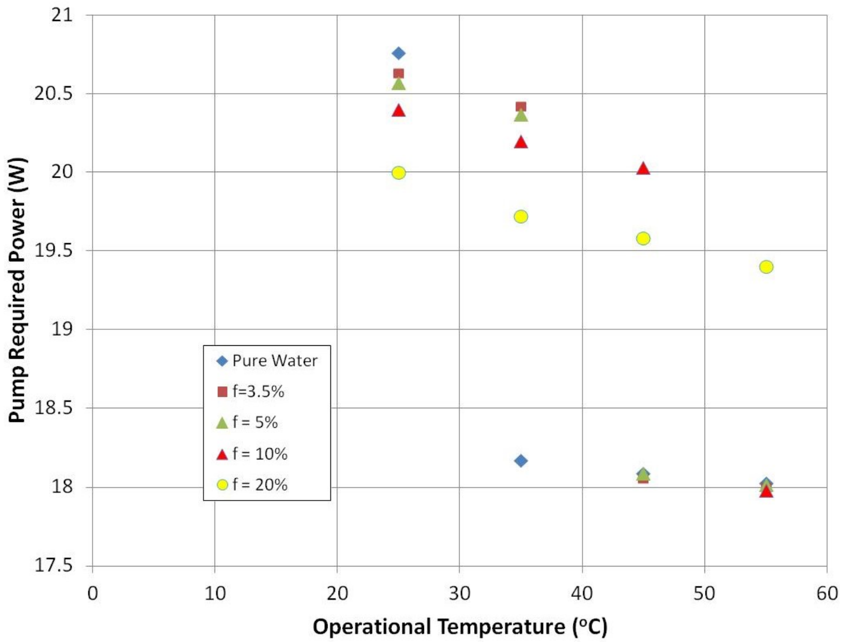
# Results and Discussion

- Liquid cooling system:




Increase of 8% on the required pumping power for *f*=20% and 55 °C operation temperature



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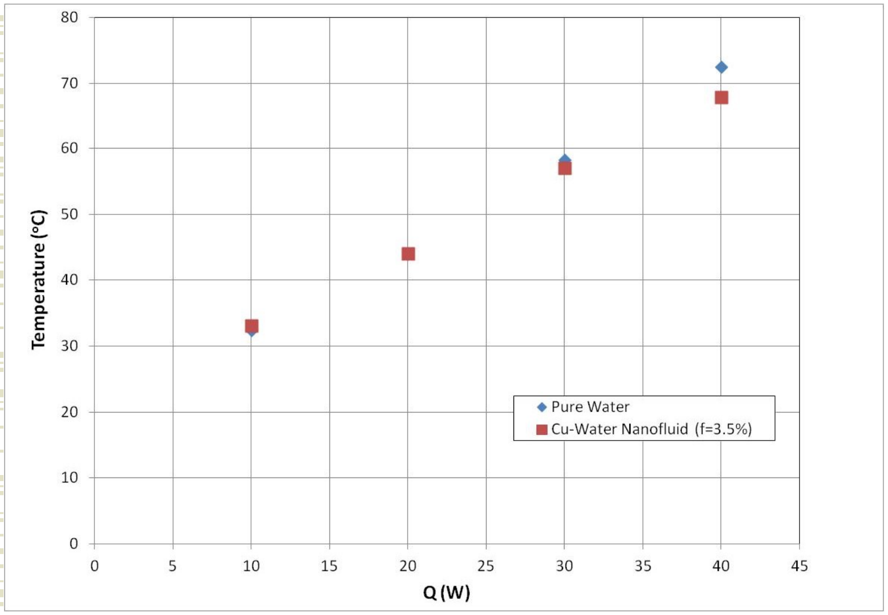
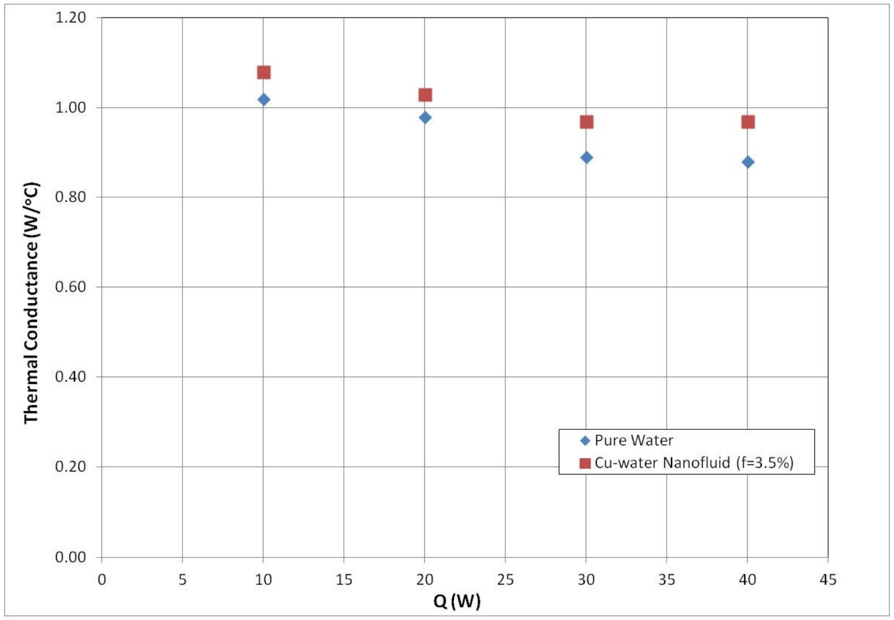
# Results and Discussion

- Passive system: Unit 1 – shorter PHP ($L_{eff}$=190 mm)

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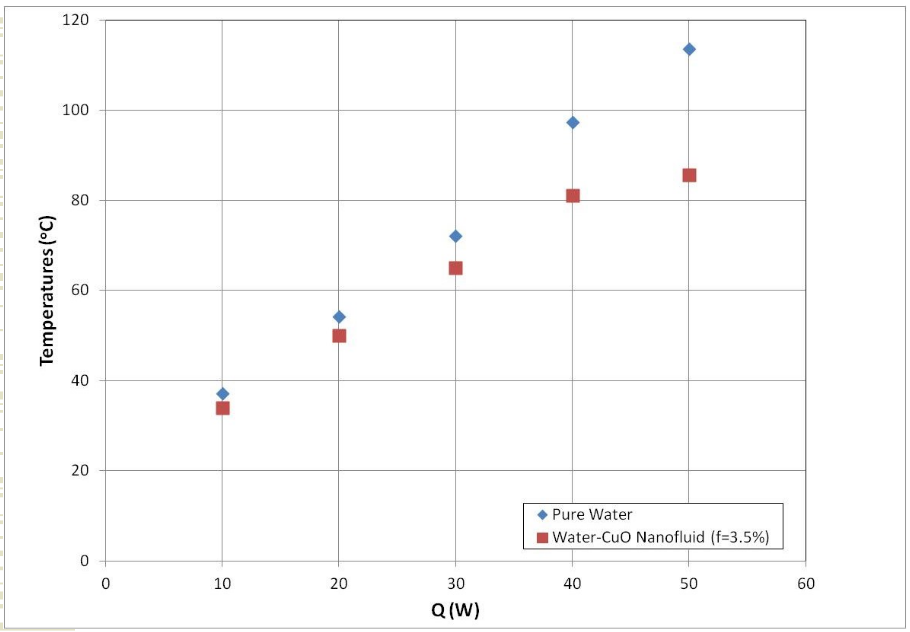
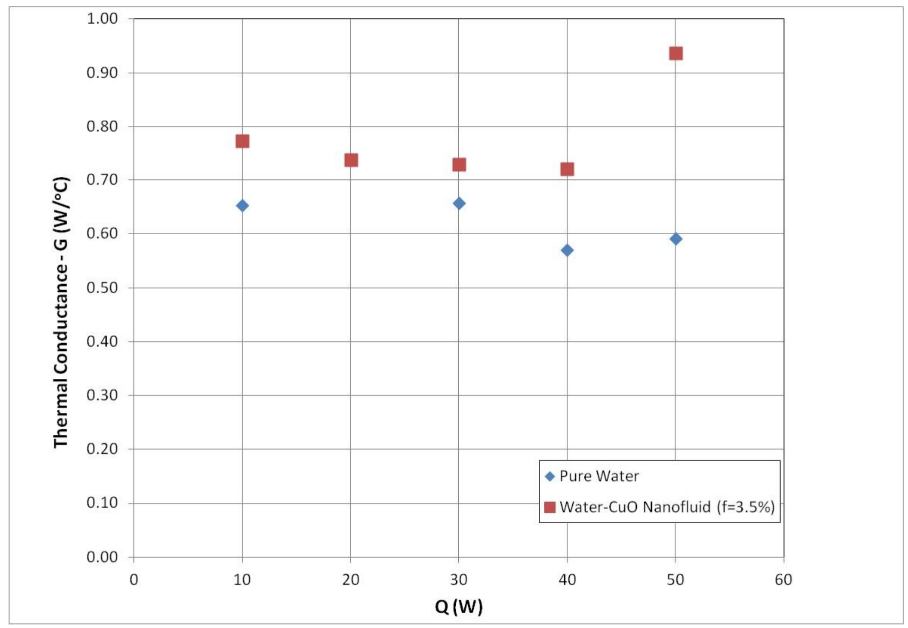
# Results and Discussion

- Passive system: Unit 2 – longer PHP ($L_{eff}$=225 mm)




Significant decrease on the operation temperature at higher power and gains on *G*



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# Concluding Remarks

- Higher heat transfer coefficients can be reached with the increase of the solid nanoparticles concentration, representing an enhancement of up to 12% for *f*=20% at 55 °C when comparing with water;
- The pressure drop also increases as the concentration of nanoparticles increases, which could compromise the pump operation;
- Even with the use of solid nanoparticles, the required pumping power does not represent to be the major issue on this specific project, as this requirement can be easily addressed as the calculated values are rather low;
- Pulsating heat pipes can keep the heat source temperature below 90 $^{o}$C.



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# Heat Powered Cycles Conference 2018
# 16.-19.09.2018

Heat Powered Cycles Conference
Center of Energy Technology, University of Bayreuth, Germany

Extended Abstracts Deadline: 18 Nov 2017

https://heatpoweredcycles.org/

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# Thank You !

# Questions ?

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