# Performance Evaluation of Low Pressure Evaporator with Low-finned Tubes for an Adsorption Cooling System


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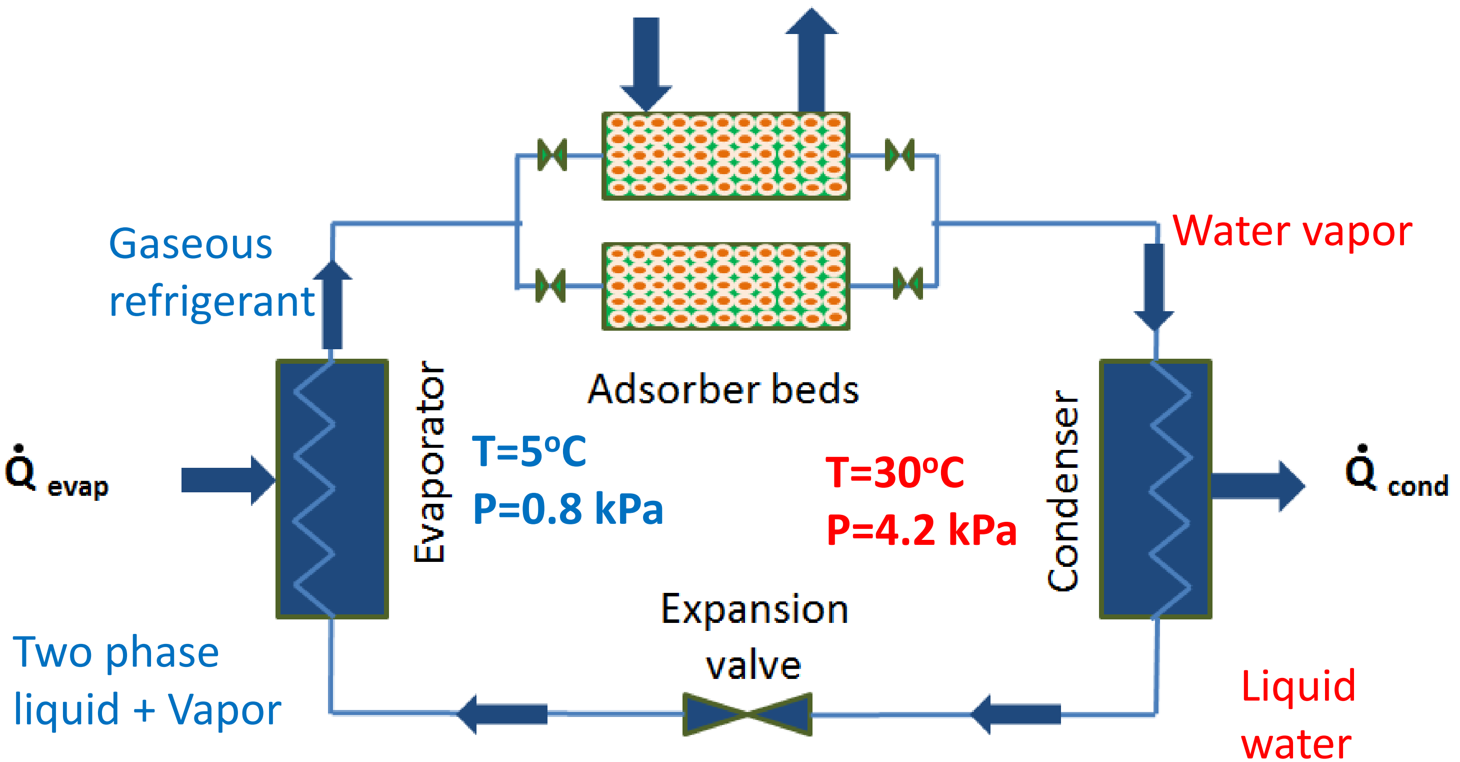
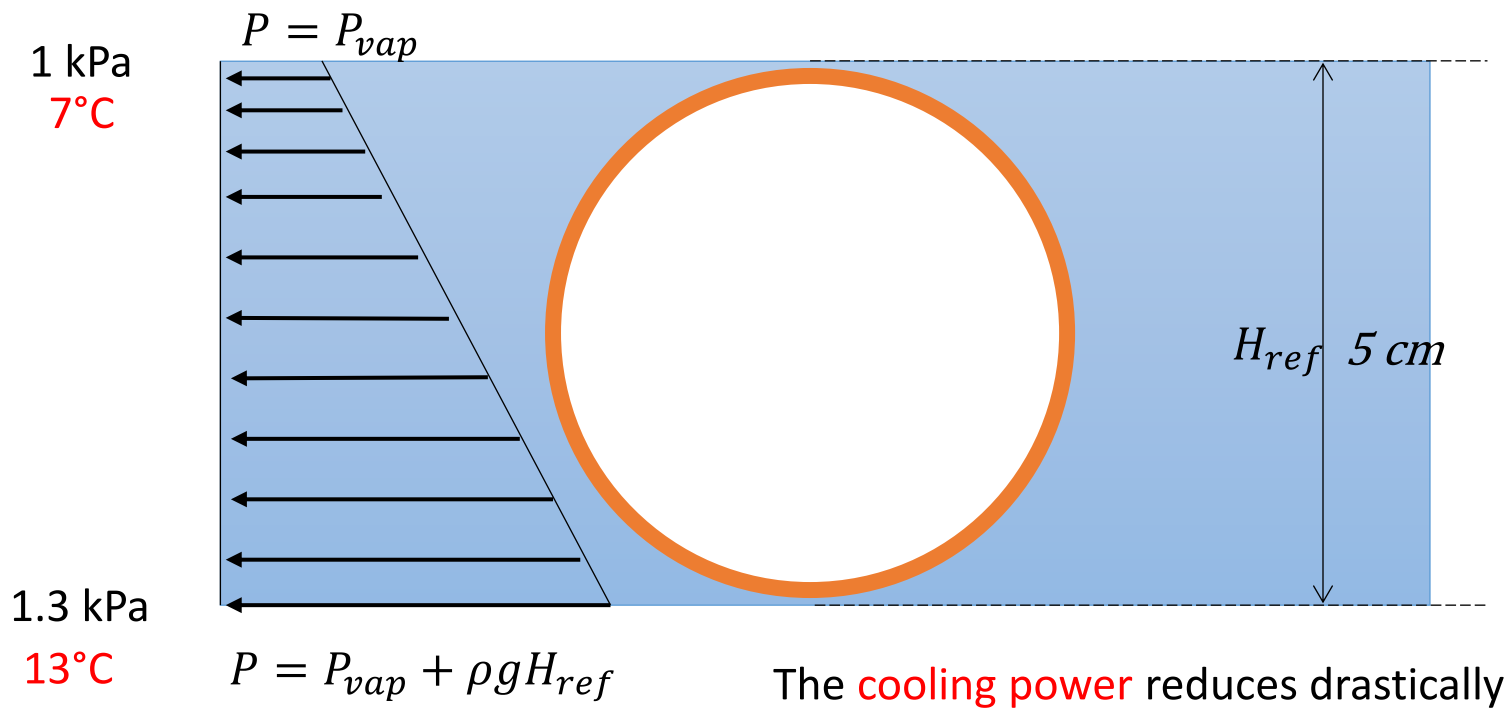
# Low pressure evaporator in adsorption cooling system




- Water as an refrigerant
  - Operating pressure is very low (close to vacuum)
  - Low Pressure (LP) evaporator

# Water height issue in the evaporator

- 5 cm of water height causes:




The cooling power reduces drastically

- [ ] The hydrostatic pressure should be minimized inside the low operating pressure evaporators

- [ ] A conventional evaporator fails to perform efficiently

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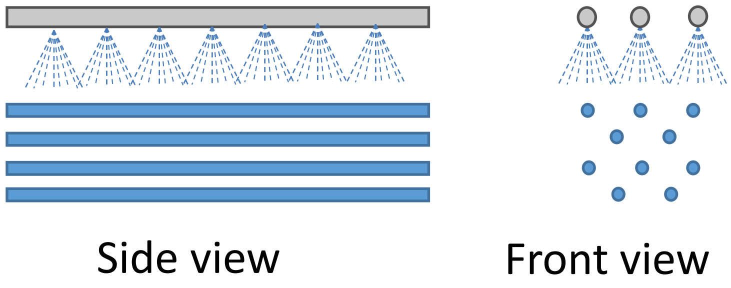
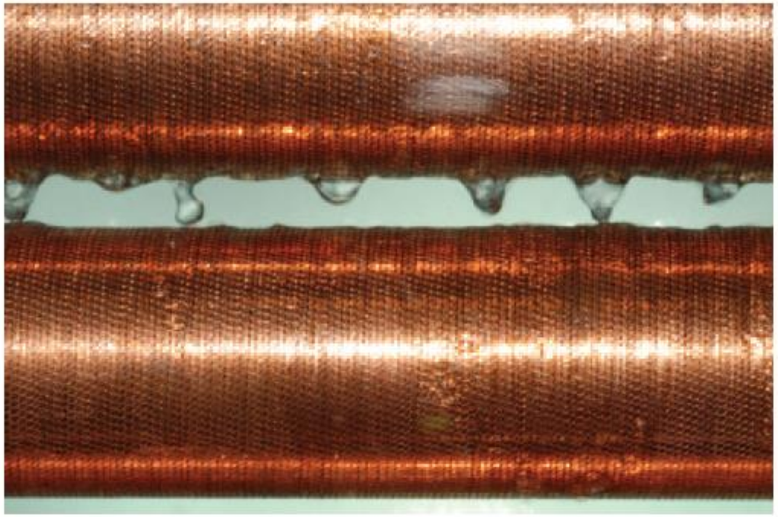
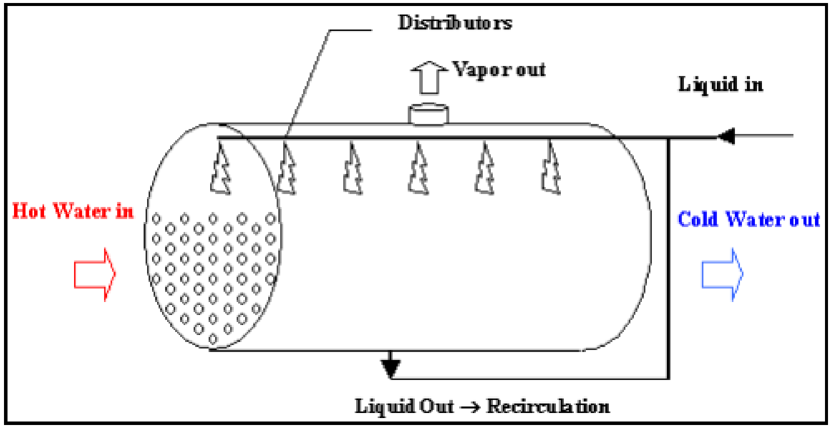
# Available solution

- Falling film evaporation






Limitations:

- ❑ Equal distribution of refrigerant
- ❑ Internal pump (active pumping)
- ❑ Complex
- ❑ Higher weight

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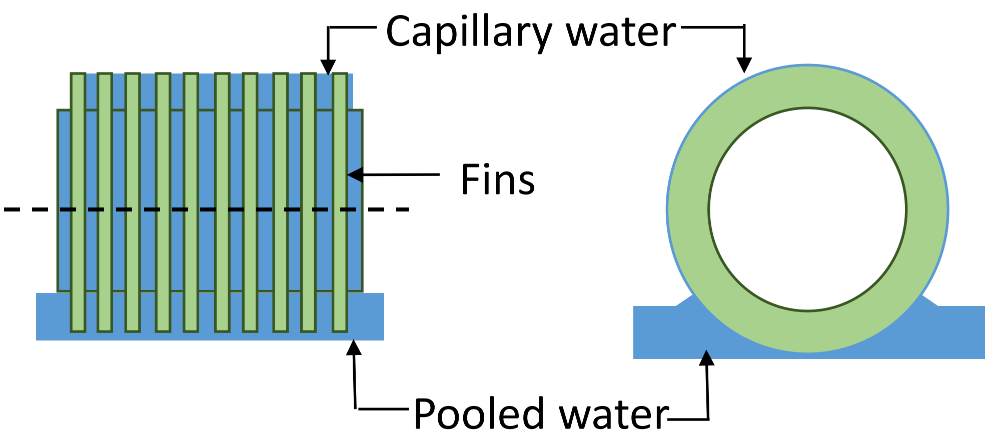
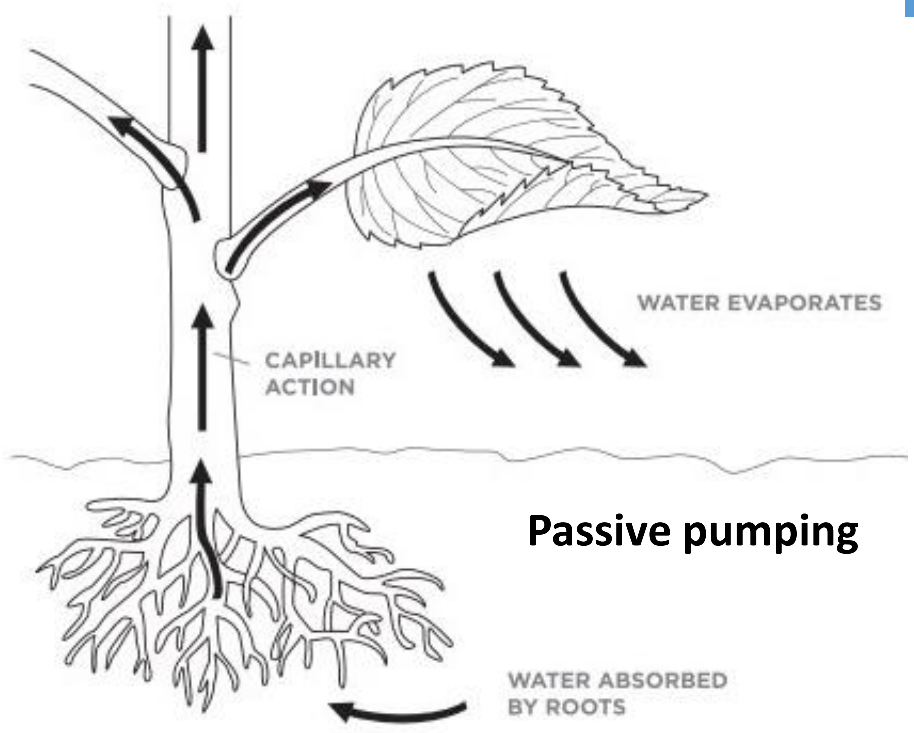
# Proposed solution

- ❑ **Capillary-assisted evaporation**
- ❑ Inspiration: Plants use capillary action to draw water from the ground




**Passive pumping**

Advantages:

- ❑ Uniform evaporation rate along the circumference of the tube
- ❑ No parasitic energy consumption
- ❑ Lower weight
- ❑ No complexity

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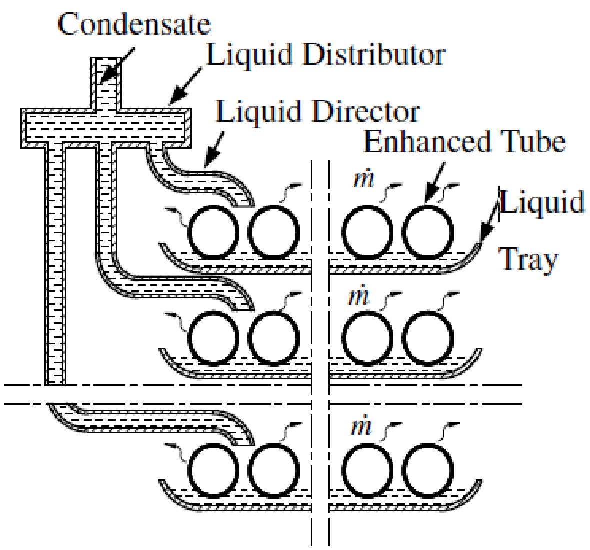
# Previous studies on capillary-assisted evaporation




Dr. Wang
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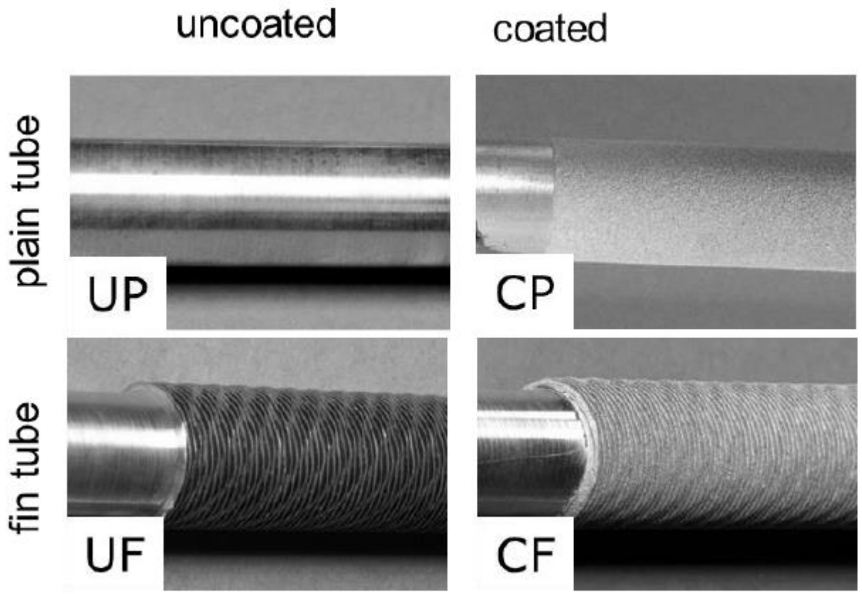


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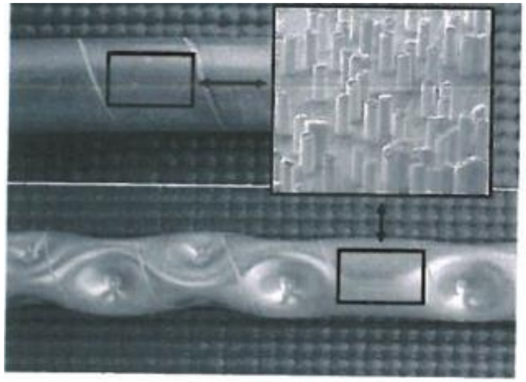
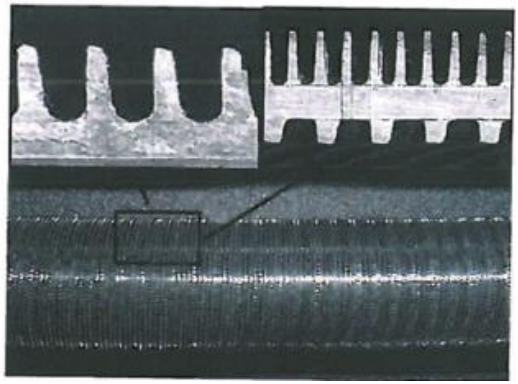




# Tested tubes and fin structures

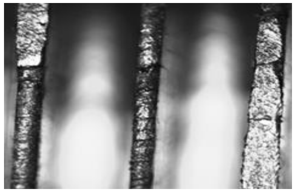
Industrial partners

Wieland Thermal Solutions., Germany

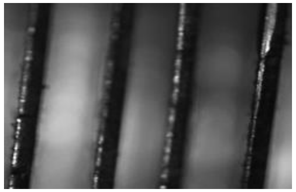
Wolverine Tube Inc., USA

Plain tube

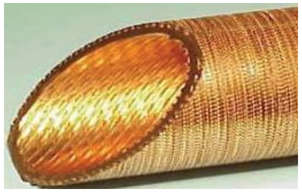
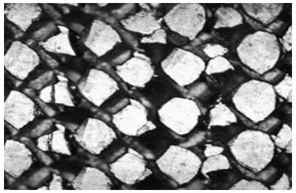
Turbo Chil-26 FPI (Wolverine Tube Inc.)

Turbo Chil-40 FPI (Wolverine Tube Inc.)

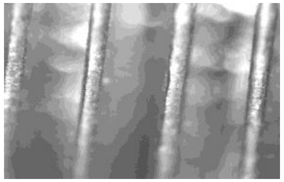
Turbo ELP (Wolverine Tube Inc.)

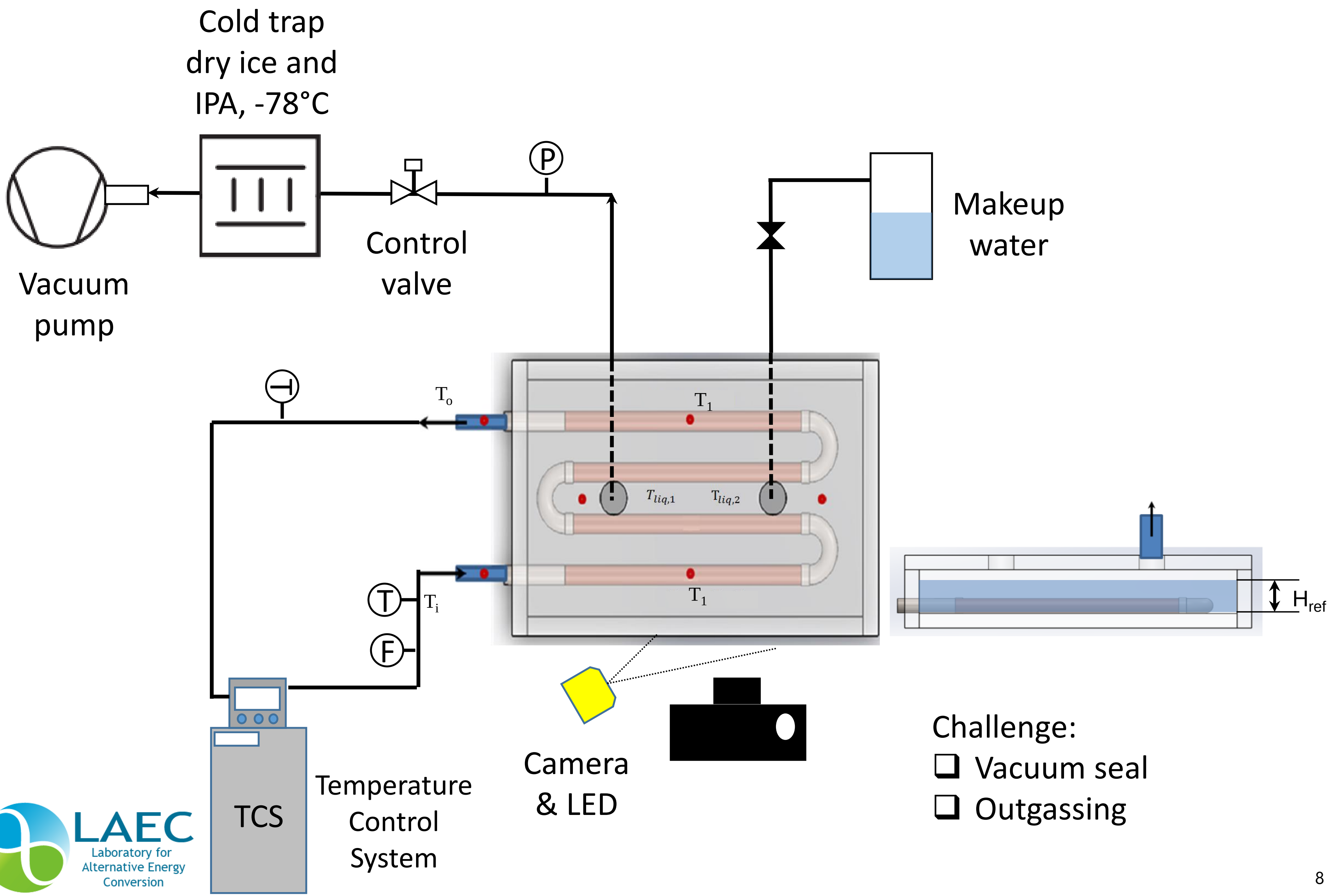
Turbo CLF-40 FPI (Wolverine Tube Inc.)


Confidential-NDA (Wieland Thermal Solutions)

GEWA-KS-40 FPI (Wieland Thermal Solutions)

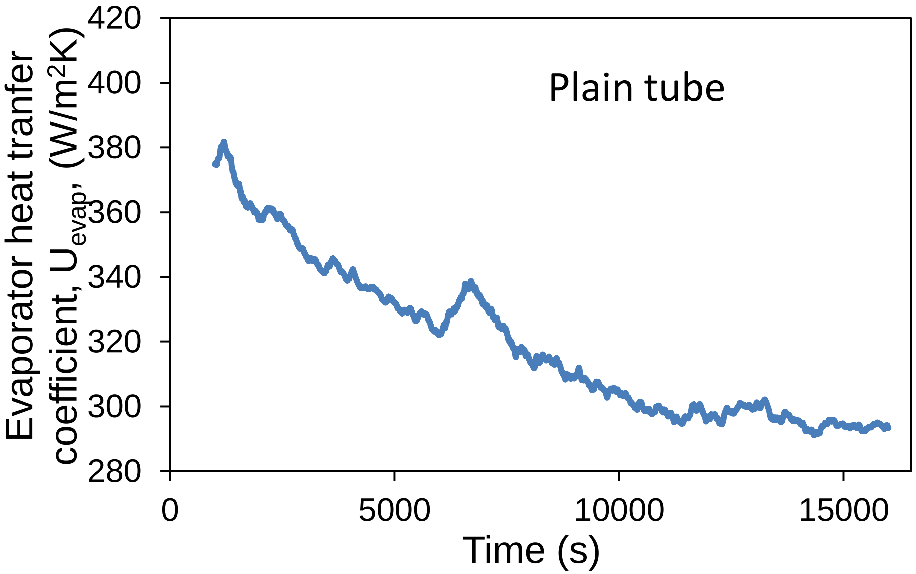



# Low pressure evaporator experimental setup

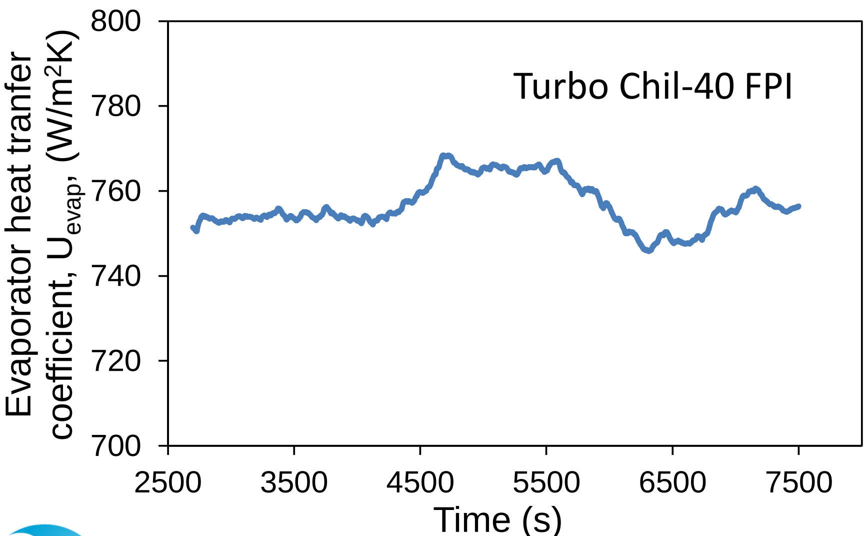


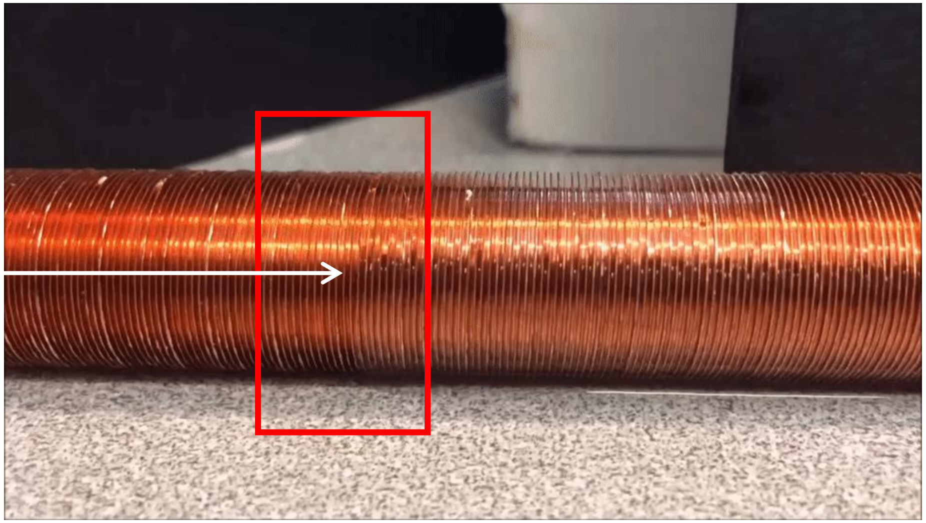

Challenge:
- ❑ Vacuum seal
- ❑ Outgassing

# Plain Tube Vs. Finned tube




- ❑ The plain tube fails to maintain the evaporator heat transfer coefficient



- ❑ Maintains constant evaporator heat transfer coefficient

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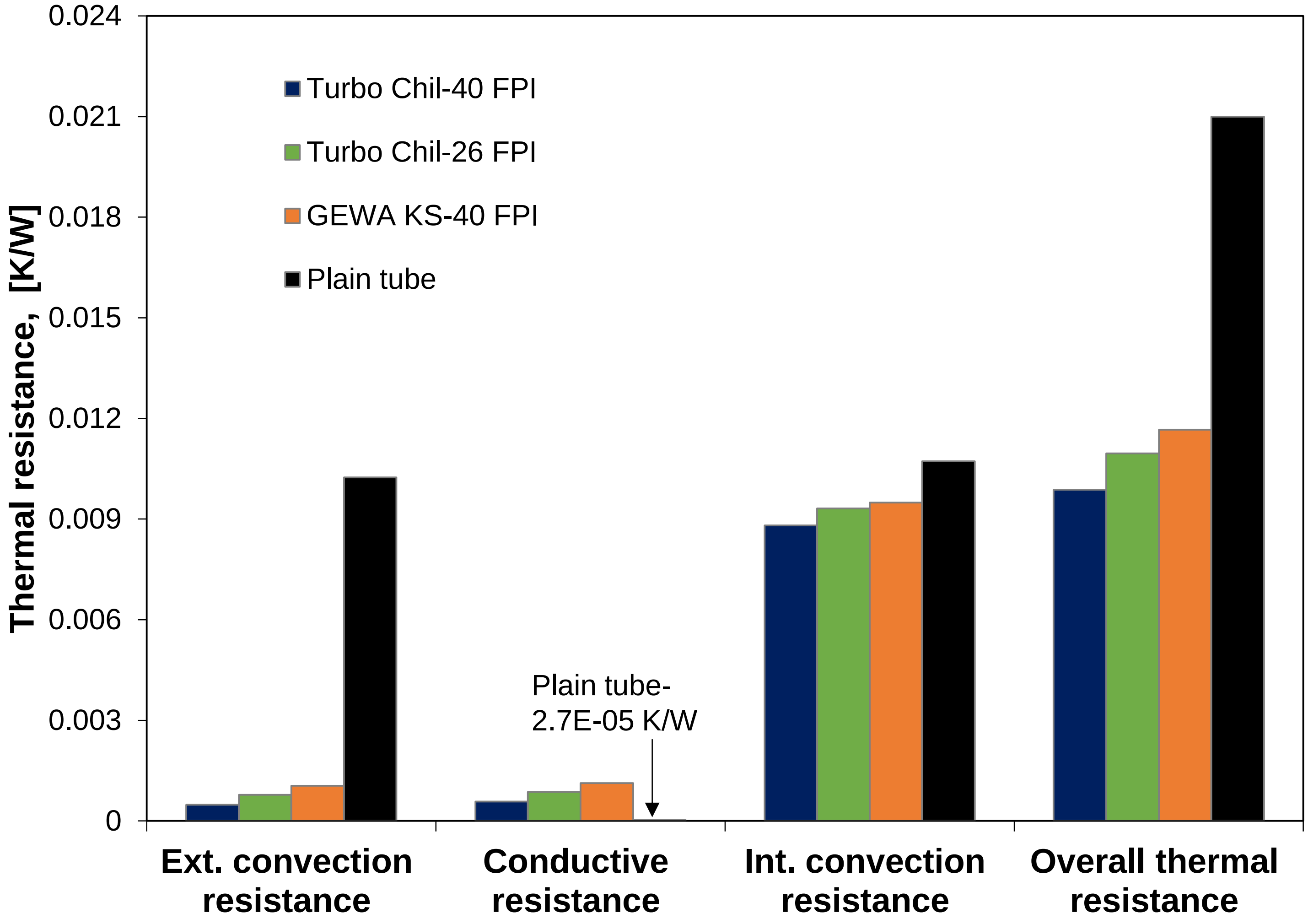
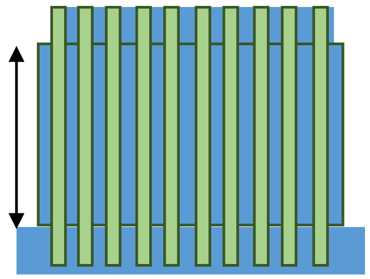
# Performance of finned tubes



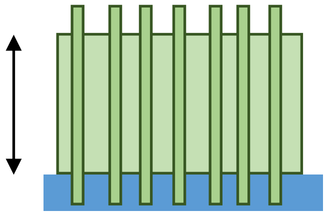

Chilled water mass flow rate : 2.5 LPM

Chilled water inlet temperature: 15°C

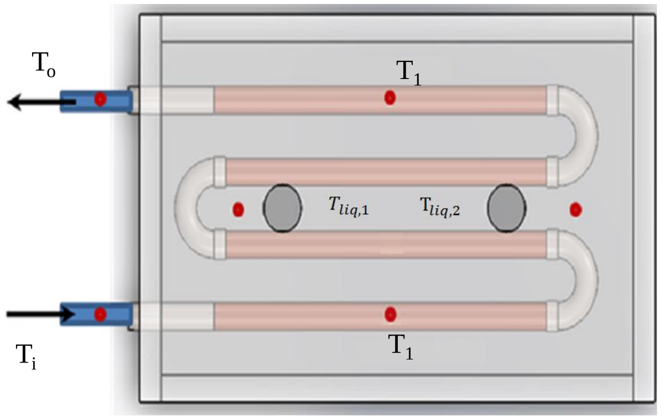
# Smaller diameter finned tube

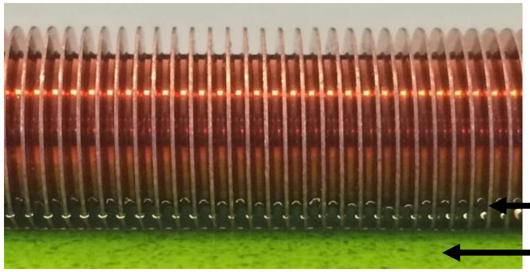



40 FPI, 0.6 mm fin spacing



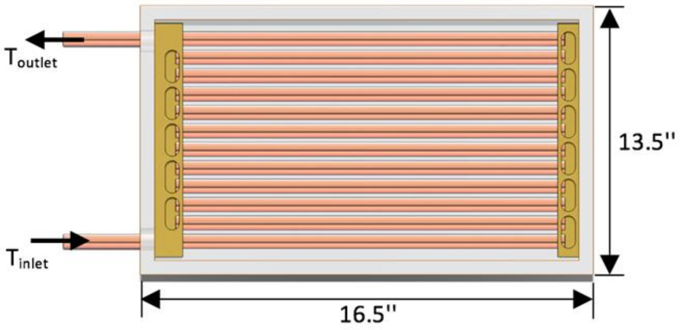

26 FPI, 1 mm fin spacing



Partial capillary

Pooled water (colored)




Type – 2nd Generation (2G)

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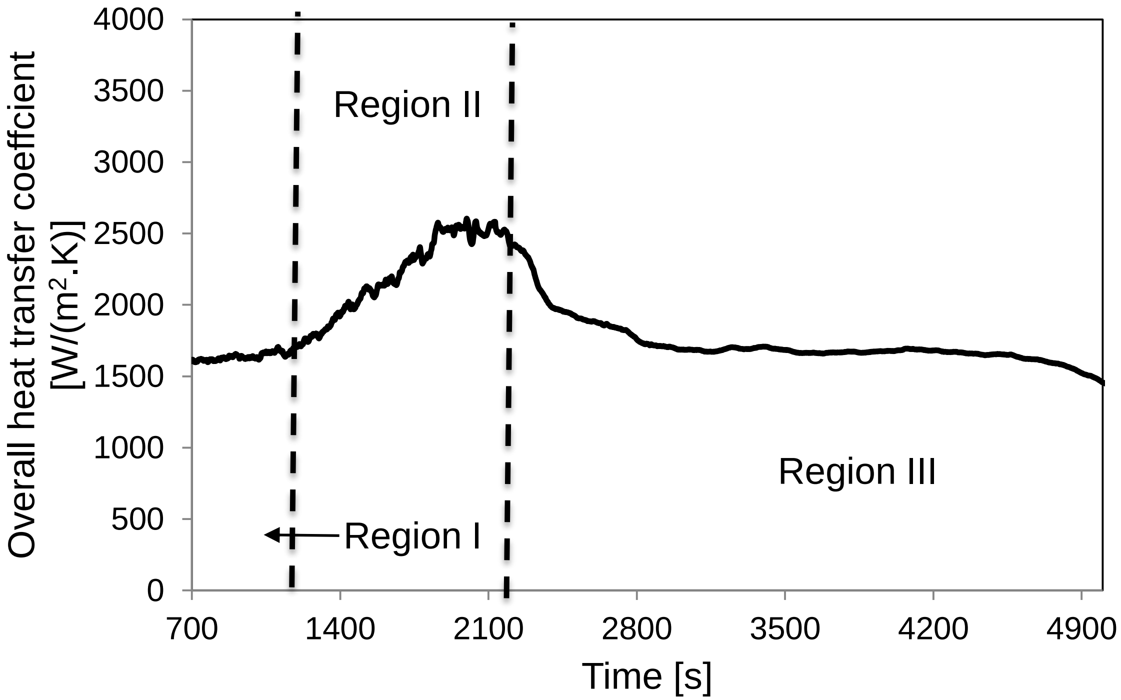
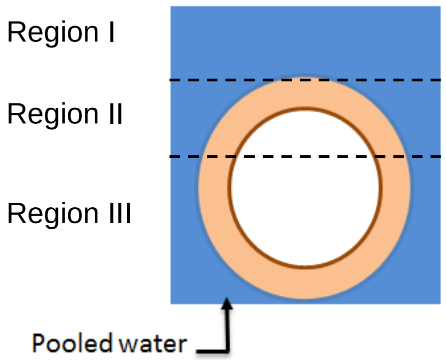
# Behaviour of overall heat transfer coefficient




Chilled water inlet temp : 20°C
Chilled water mass flow rate: 2.5 LPM

- In region I (tube is fully submerged)- overall U is about 1600 W/(m²·K).
- In region II- the hydrostatic pressure is reduced and the overall U increases by 45% from 1600 to 2320 W/(m²·K)
- In region III, U decreases to 1720 W/(m²·K) as the water level drops further as capillary force fails to cover the entire surface.

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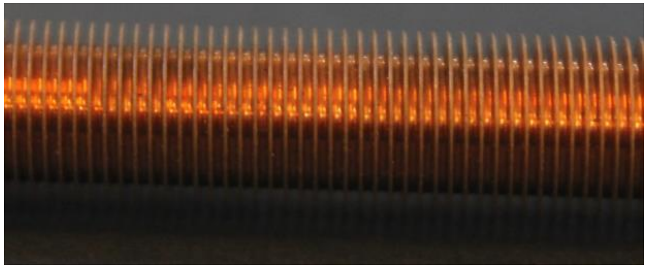
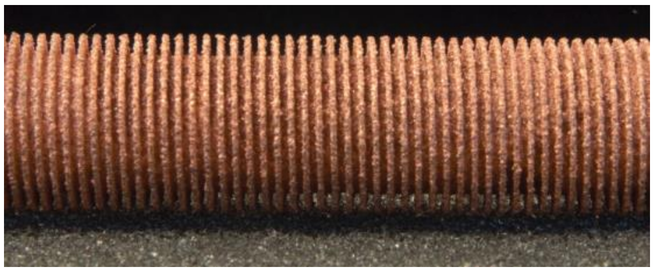
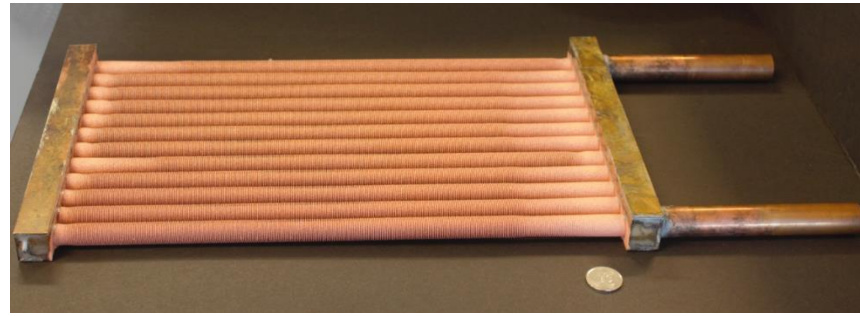
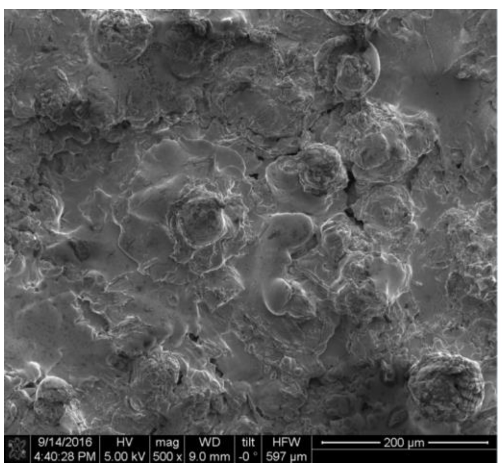
# Porous copper coated evaporator

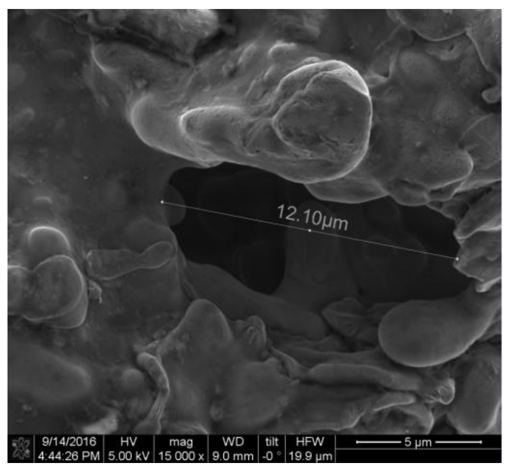


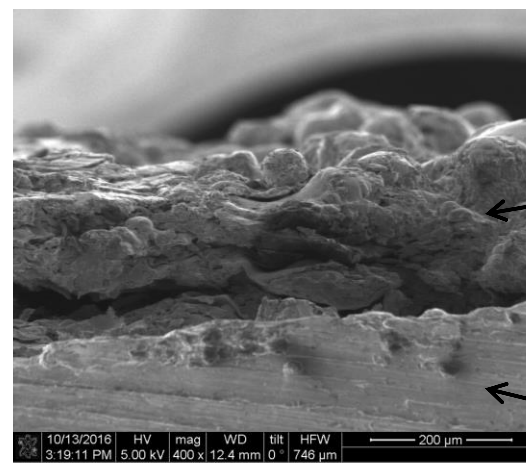




- The porous copper coating from thermal spray deposition technology
- Deposition is compatible with the material of evaporator



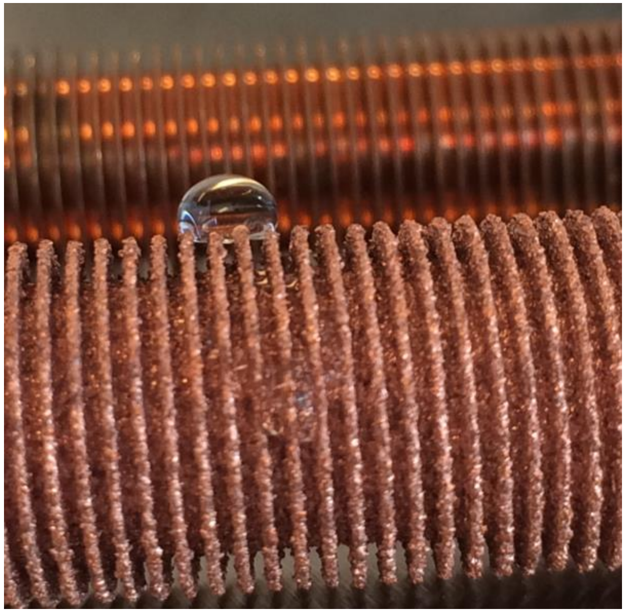




coatings

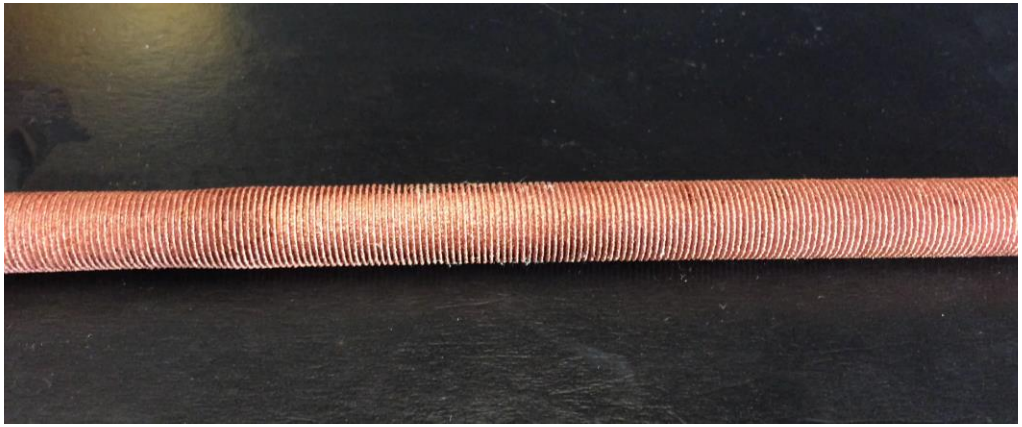
Substrate
(copper fin

SEM images of the porous coatings

# Behaviour of the porous coated surface

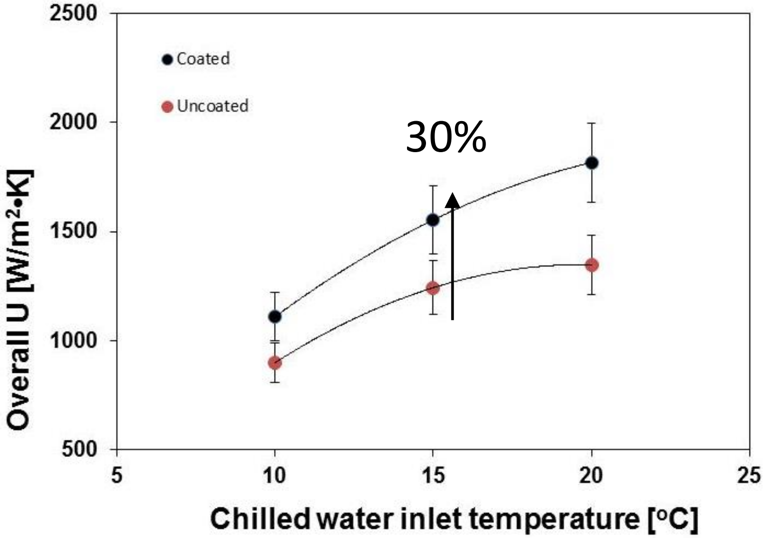


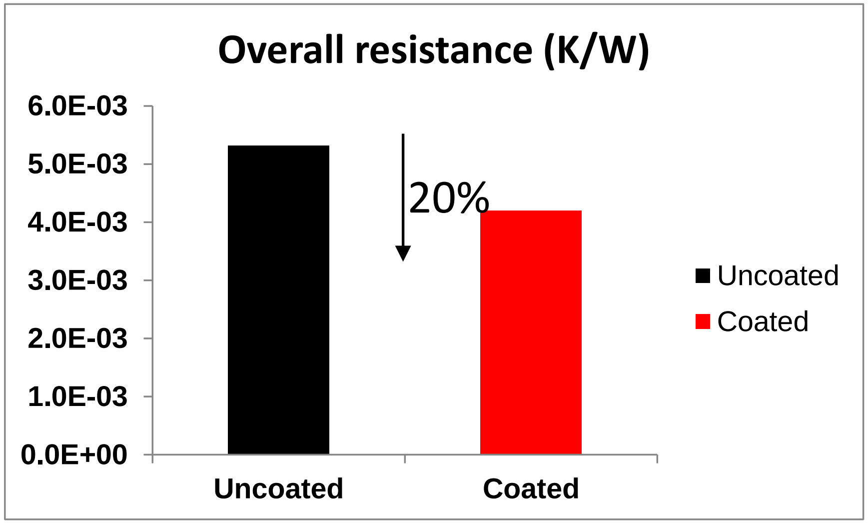
Dry surface- Hydrophobic

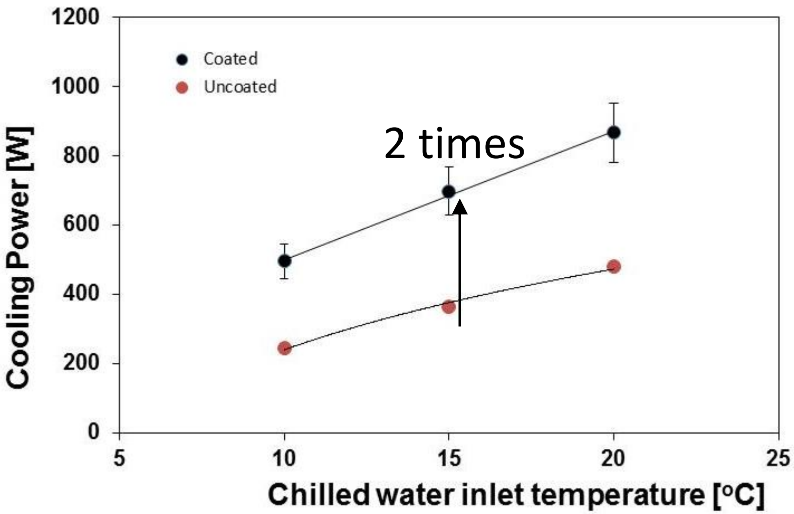


Wetted surface- Enhances wicking

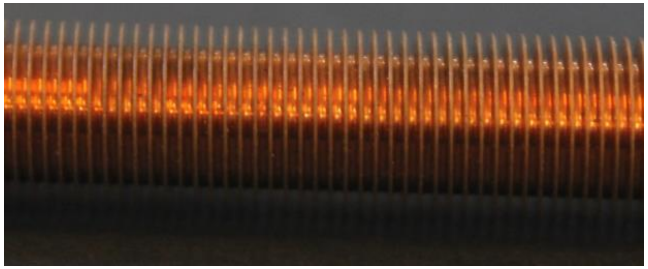
# Comparison between uncoated and coated evaporator



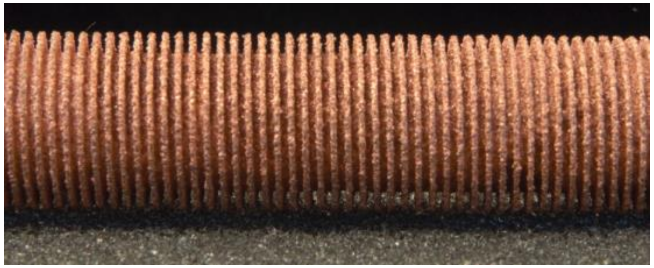




Uncoated



Coated



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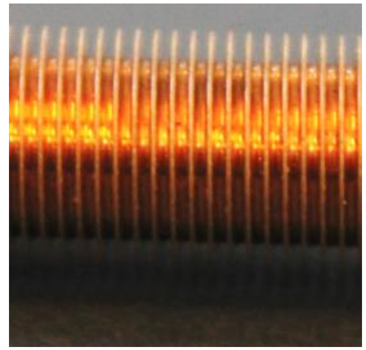
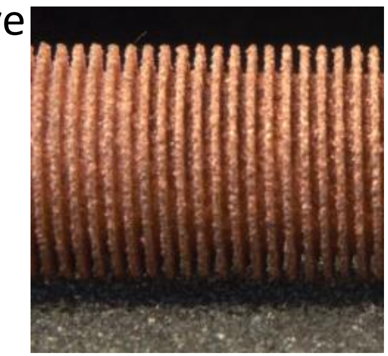
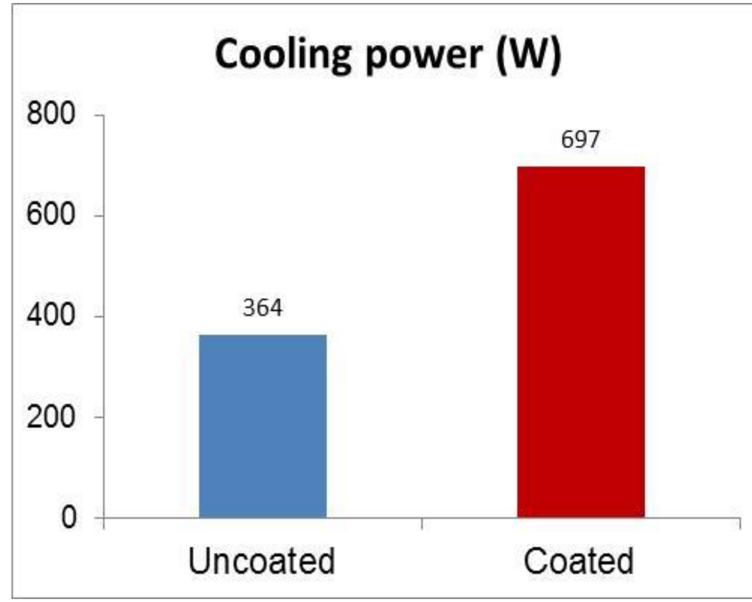
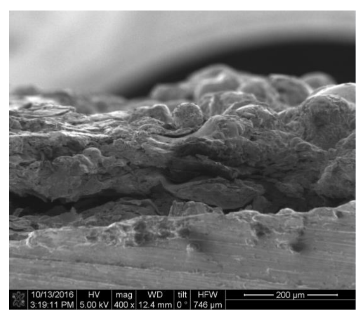
# Conclusions

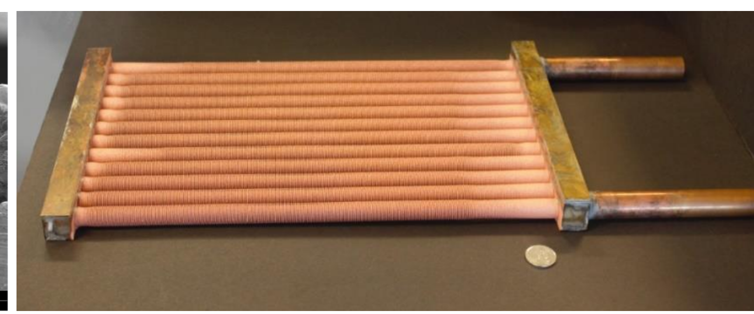
- The tube internal dia was reduced to increase the $h_i$ ($\alpha_i$)
- Porous copper coatings to improve the capillary evaporation.
- The overall U of the coated evaporator increased by 30%
- The cooling power of the coated evaporator improved by 2 times.









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Dr. Achim Gotterbarm, Director Global R&D

Dr. Evraam Gorgy, Director of R&D
Mr. Bill Korpi
Wolverine Tube, Inc.


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Black bear poses next to SFU sign in best advertising photo ever


# Thanks for your attention

Questions/Comments

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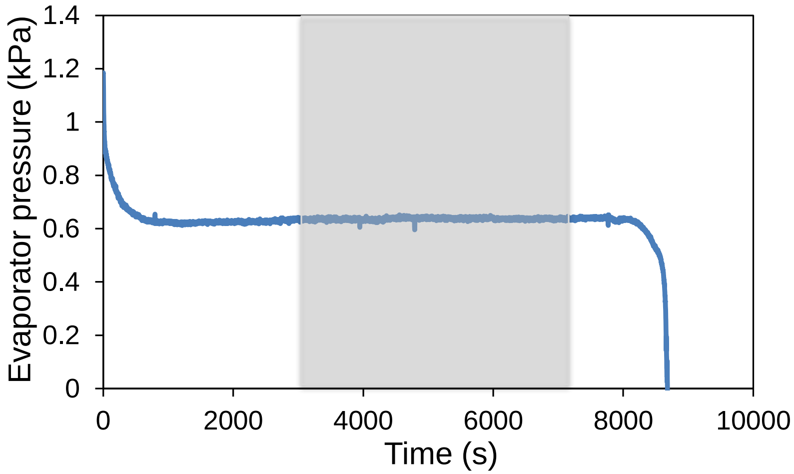
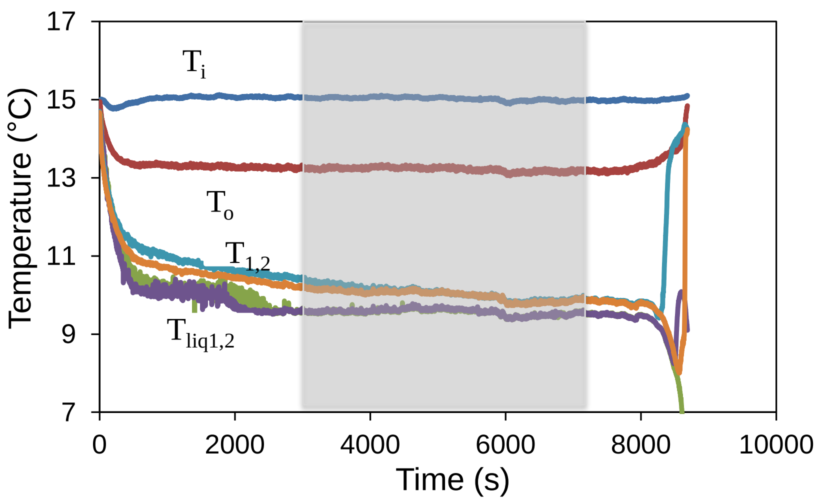
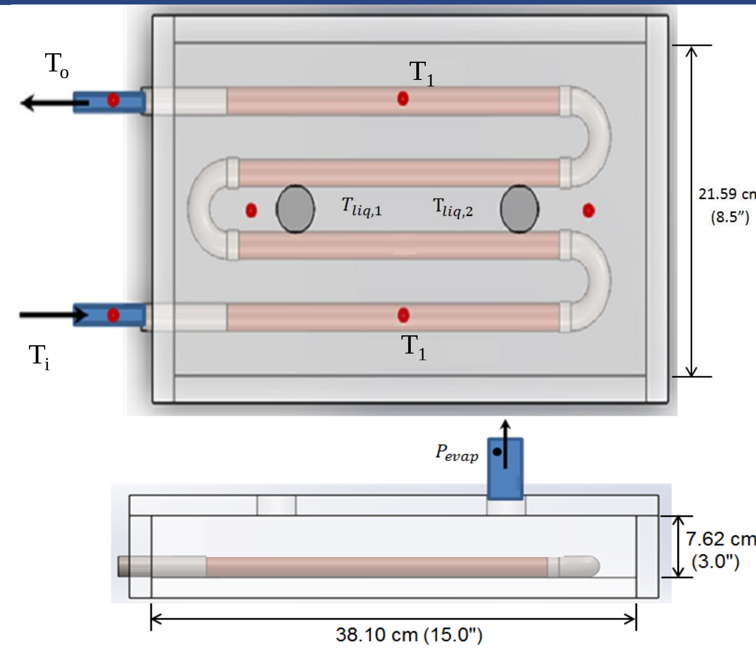
# Why Design of Evaporator of an ACS is Different? Contd.




- All thermocouples have same reading at the beginning (Equilibrium State)
- Evaporator pressure reduces when the control value is opened and remains constant until evaporator runs out of water
- For all calculations, data were extracted from demarcated region (Steady state)

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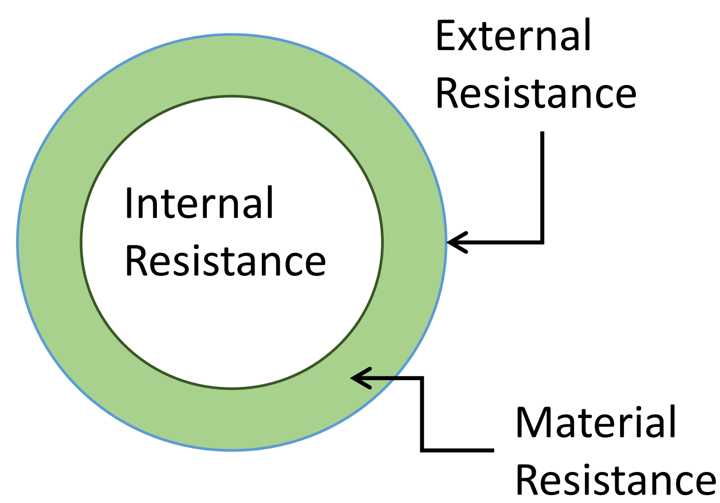
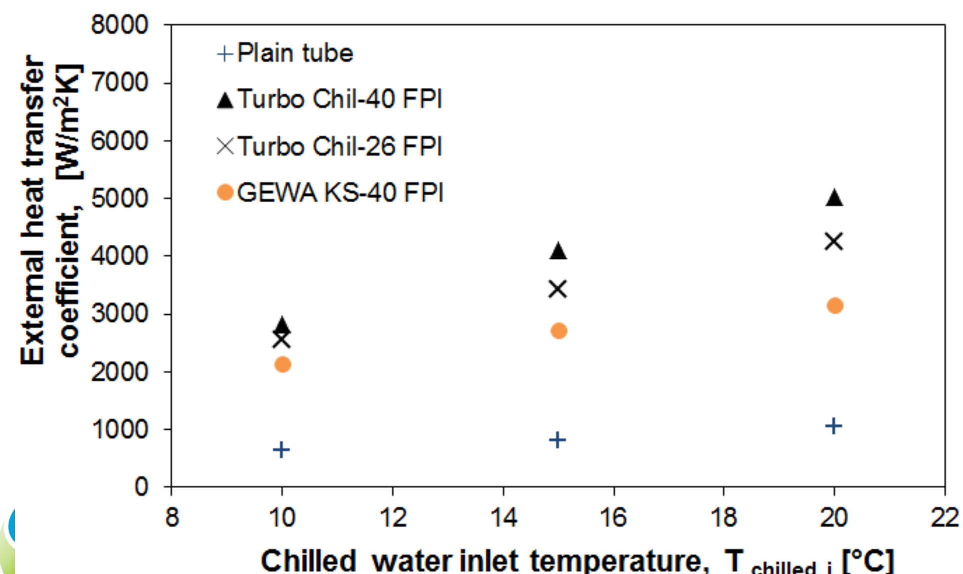
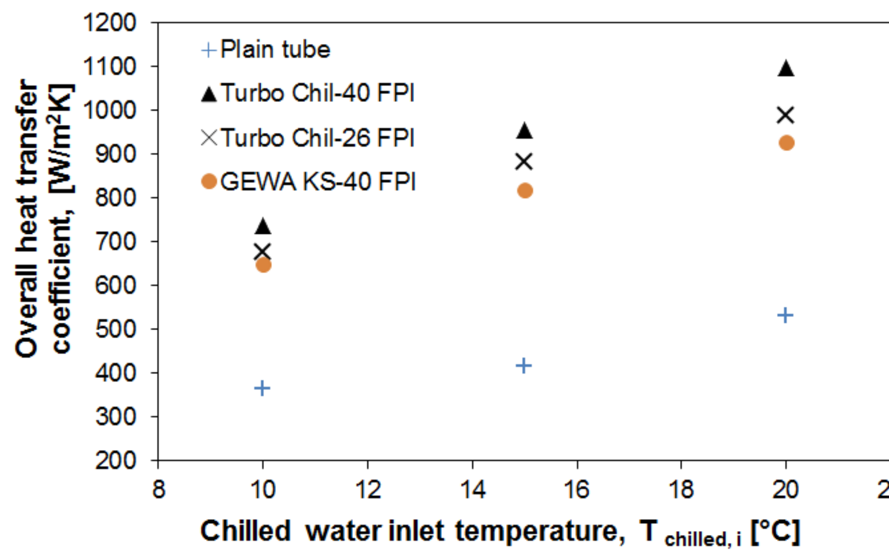
# Quantifying the evaporator performance

$$\frac{1}{UA} = \left( \underbrace{\frac{1}{h_o A_o}}_{\text{External Resistance}} + \overbrace{\frac{1}{h_i A_i}}^{\text{Internal Resistance}} + \underbrace{R_{o,\, finned\ tube}}_{\text{Material Resistance}} \right)$$

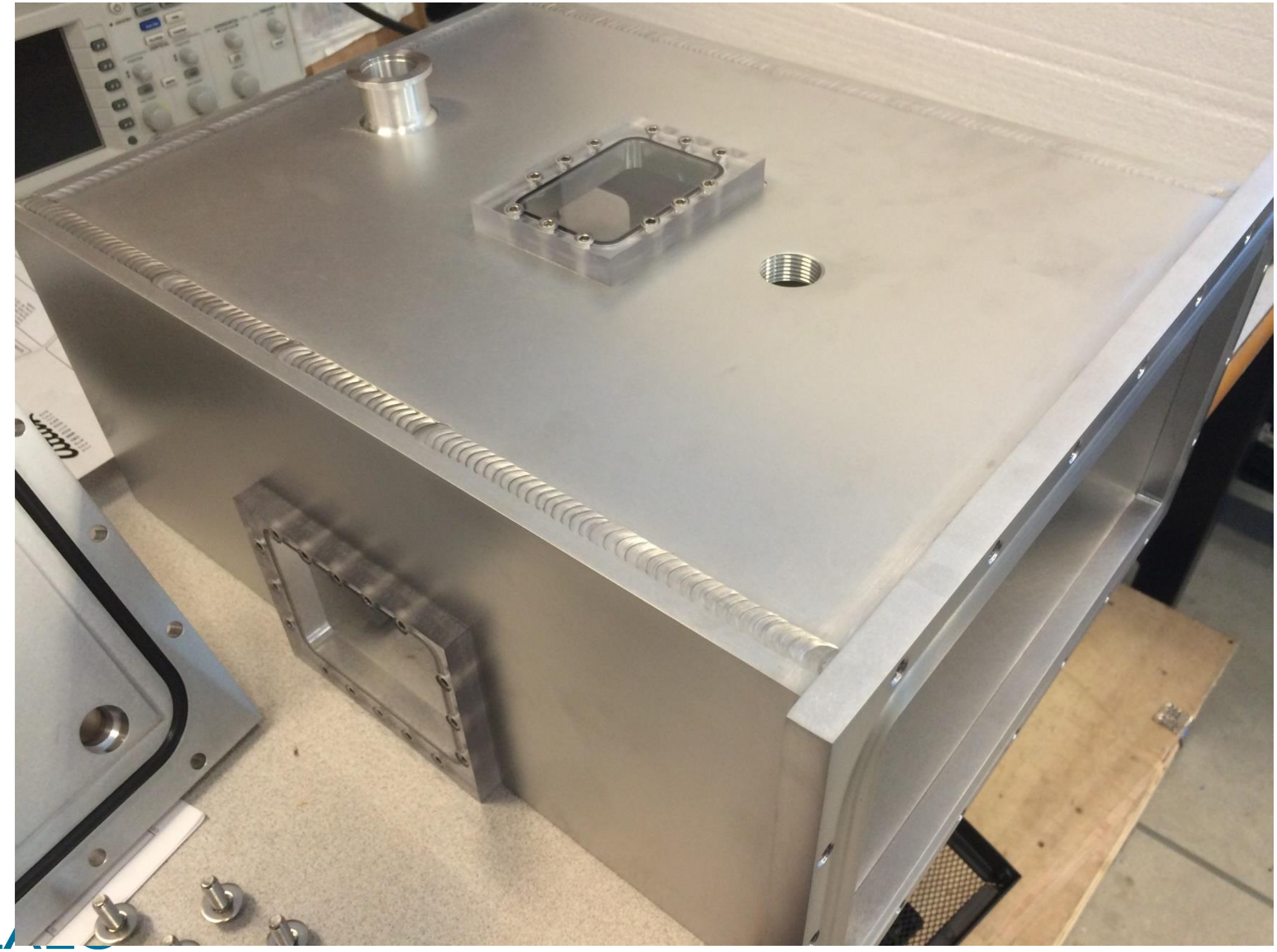



$$R_{o,\, finned\ tube} = R_{fin} + R_{wall}$$



# Future work



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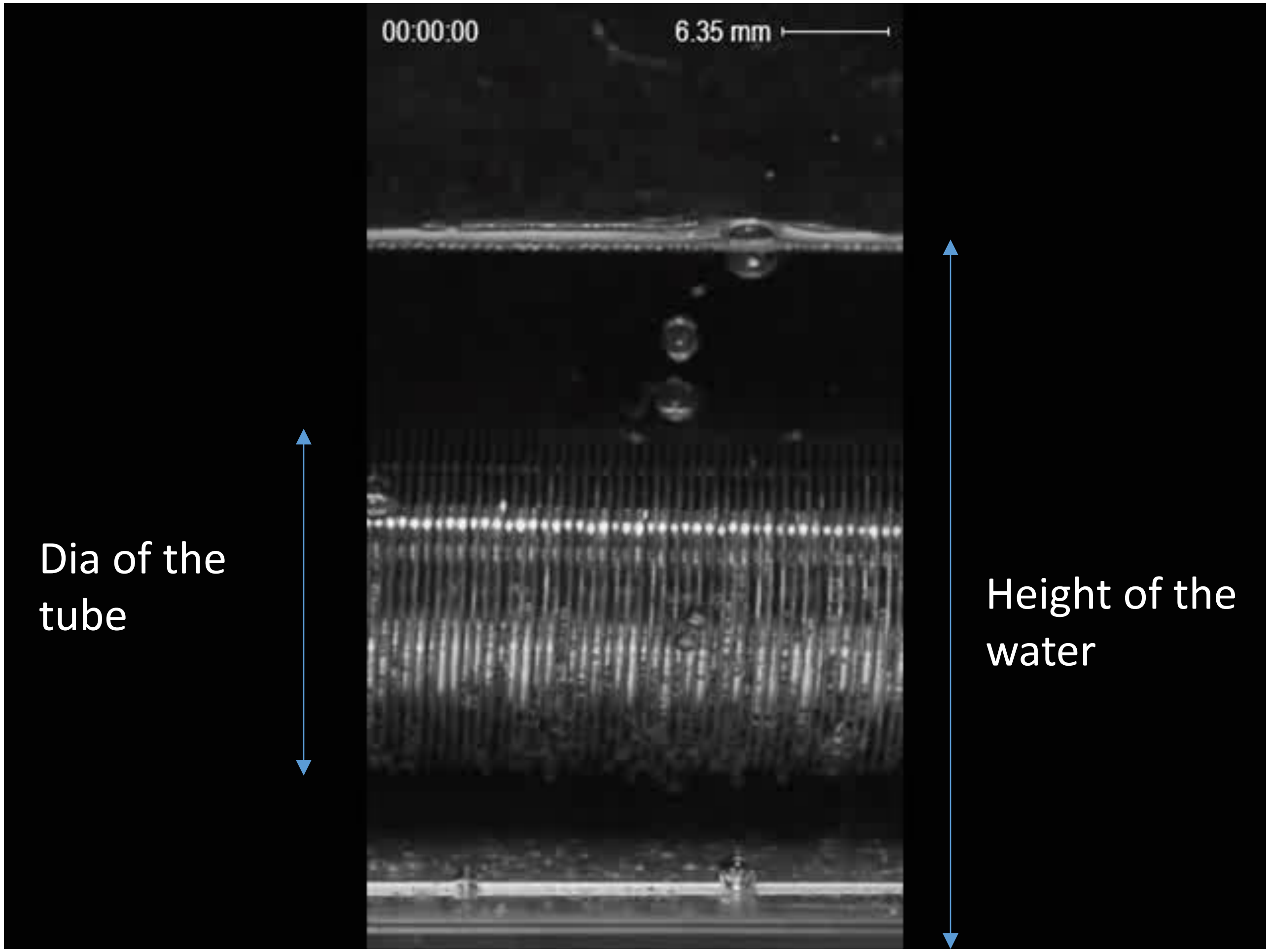
# CALPE- Capillary Assisted Low Pressure Evaporator

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