
Impact of Porous Copper Coating on Capillary-Assisted Low Pressure Evaporator for an Adsorption Chiller

Presented by

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Co-authors

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International Sorption Heat Pump Conference

ISHPC2017

Tokyo, Japan

August 08th, 2017

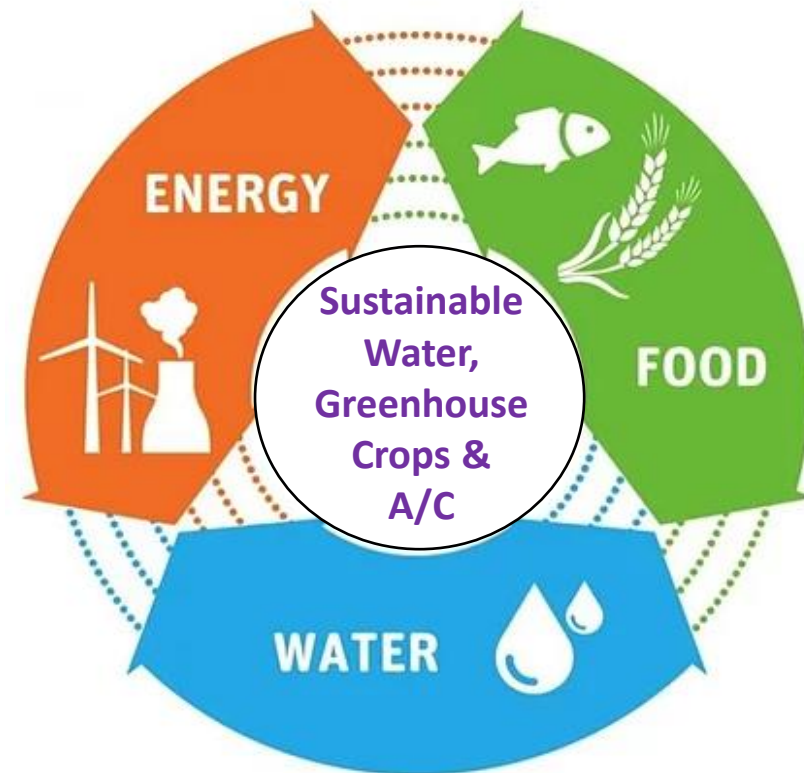
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Laboratory of Alternative Energy
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Projects at LAEC



Natural Sciences and Engineering Research
Council of Canada (NSERC)

The Canadian Queen Elizabeth Advanced
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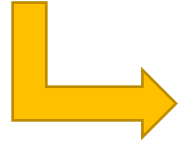


Reducing Greenhouse Gases



Paris Agreement, 2016
 2°C above pre-industrial levels

CFC



HCFC

- Montreal Protocol, 1989



HFC

- Still specified as GHG under Kyoto protocol



Water

Use water
 as
 refrigerant

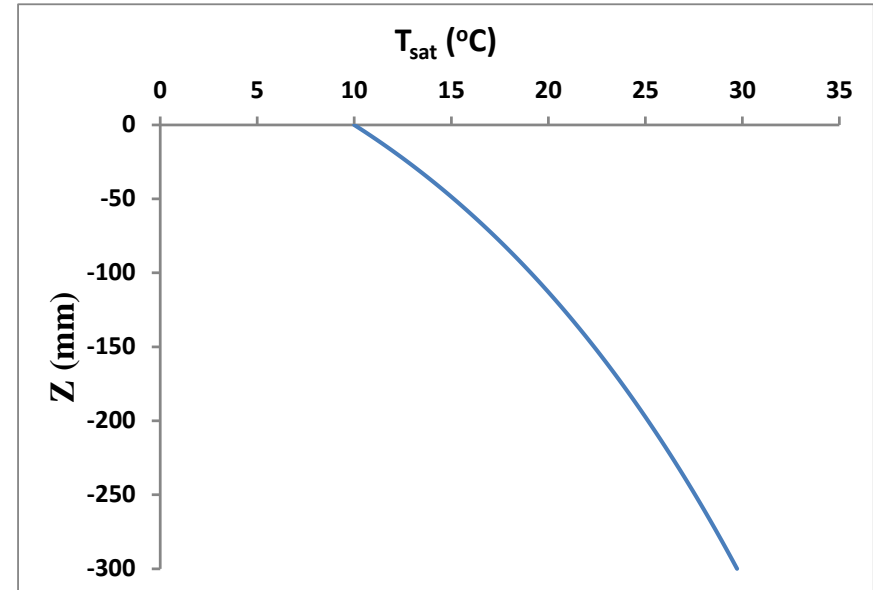
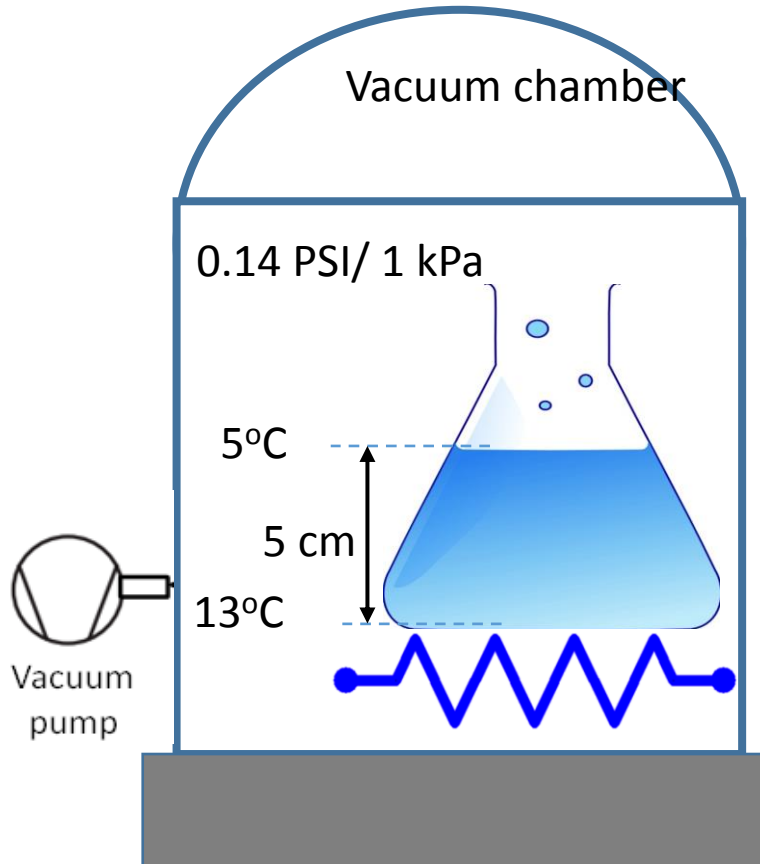


Utilize low grade
 waste heat



Evaporation at
 sub-atmospheric
 low-pressures

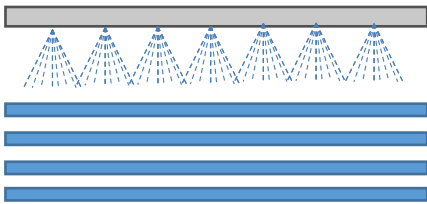
- Effective low pressure evaporation is a challenge



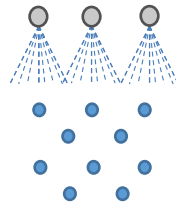
The **cooling power** reduces drastically

Thus, **water static pressure** should be minimized inside the **low operating pressure** evaporators

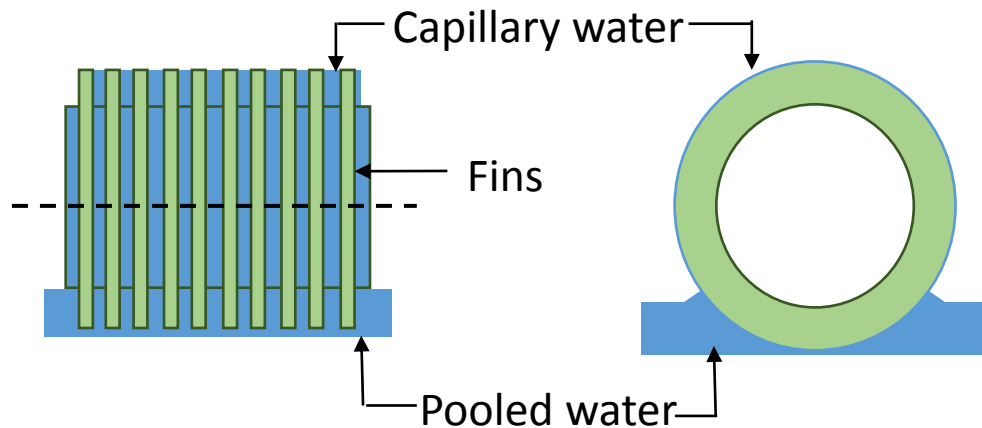
- Falling film evaporation



Side view



Front view



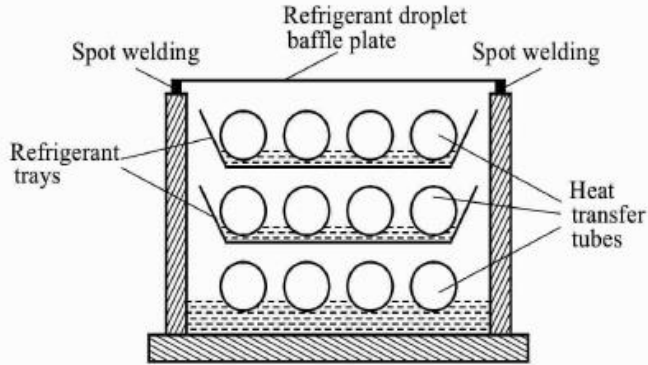
Limitations:

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

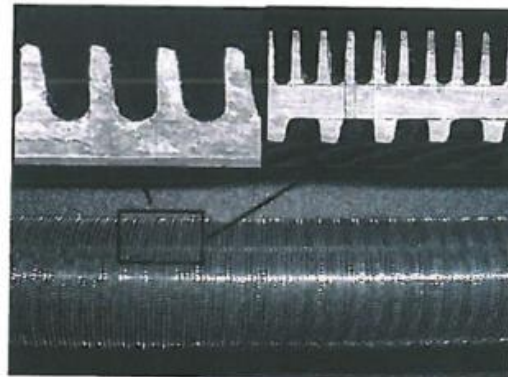
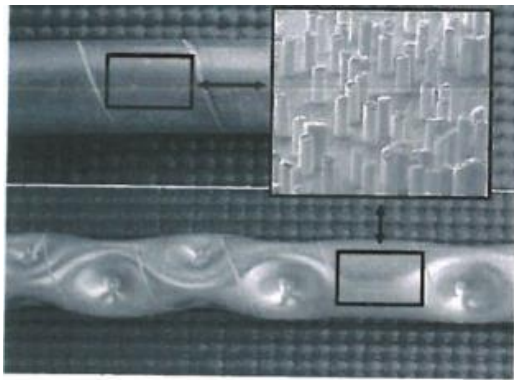
Advantages:

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

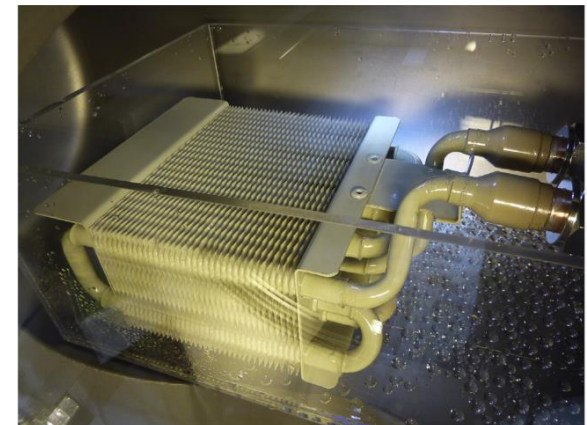
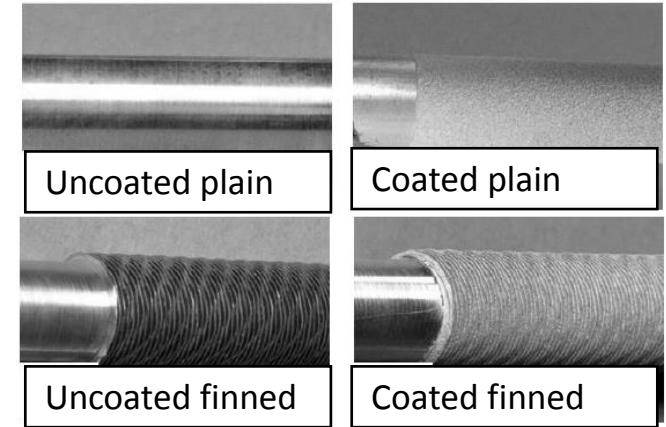
Dr. Wang
Shanghai Jiao Tong University of China



Dr. Schnabel
Fraunhofer Institute for Solar Energy Systems ISE ,
Germany



Dr. André Bardow
RWTH Aachen University, Germany



Industrial partners



Wieland Thermal Solutions., Germany



Wolverine Tube Inc., USA

OD: 3/4" (19 mm)

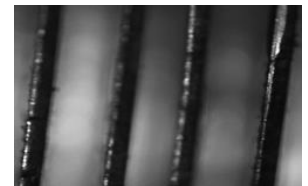


Plain tube

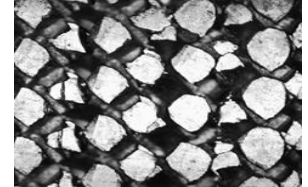
Turbo Chil **26 FPI**
(Wolverine Tube Inc.)



Turbo Chil- **40 FPI**
(Wolverine Tube Inc.)



Turbo **ELP**
(Wolverine Tube Inc.)



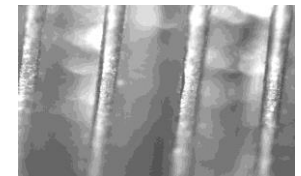
Turbo CLF **40 FPI**
(Wolverine Tube Inc.)

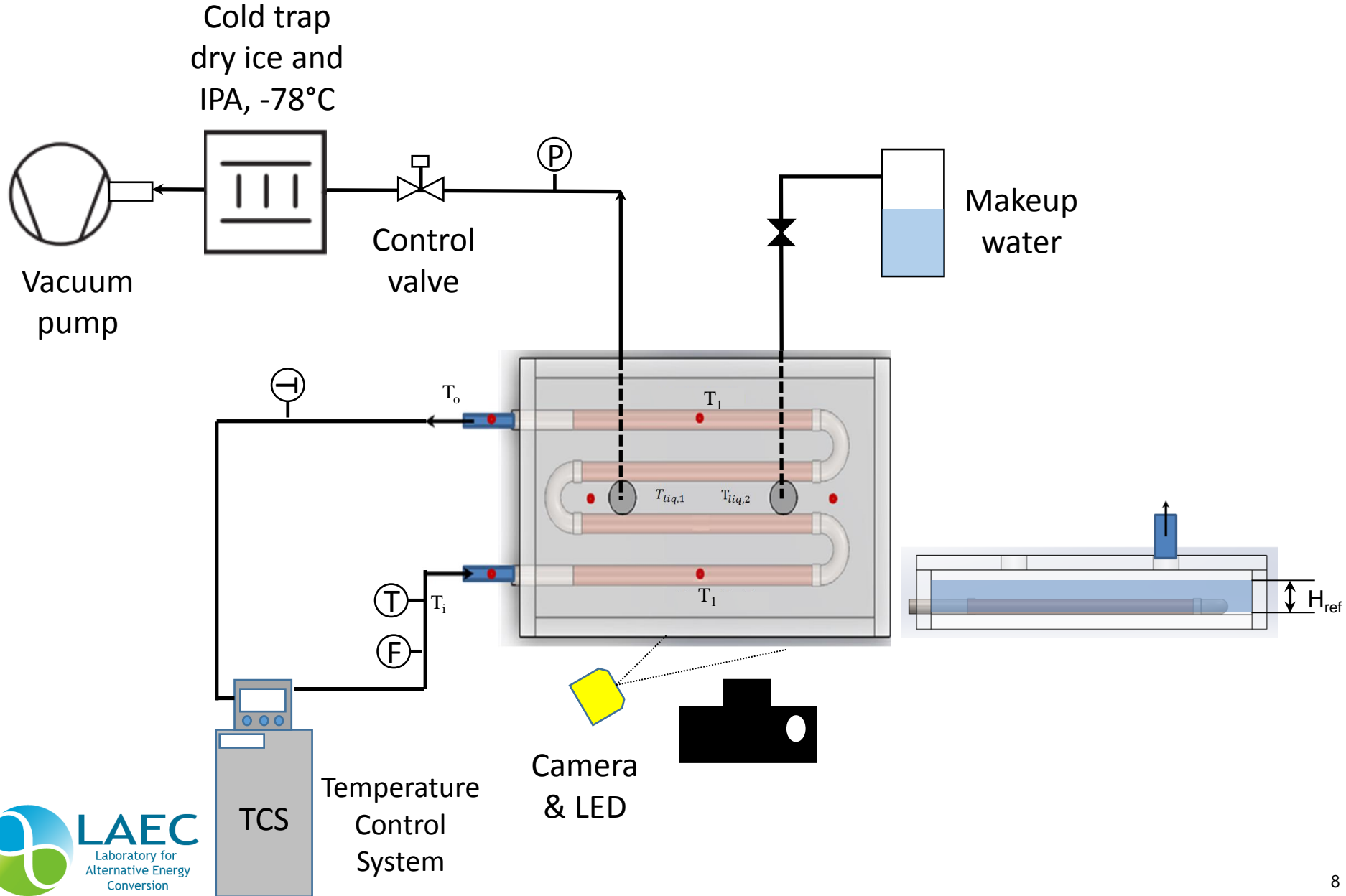


Confidential-NDA
(Wieland Thermal Solutions)

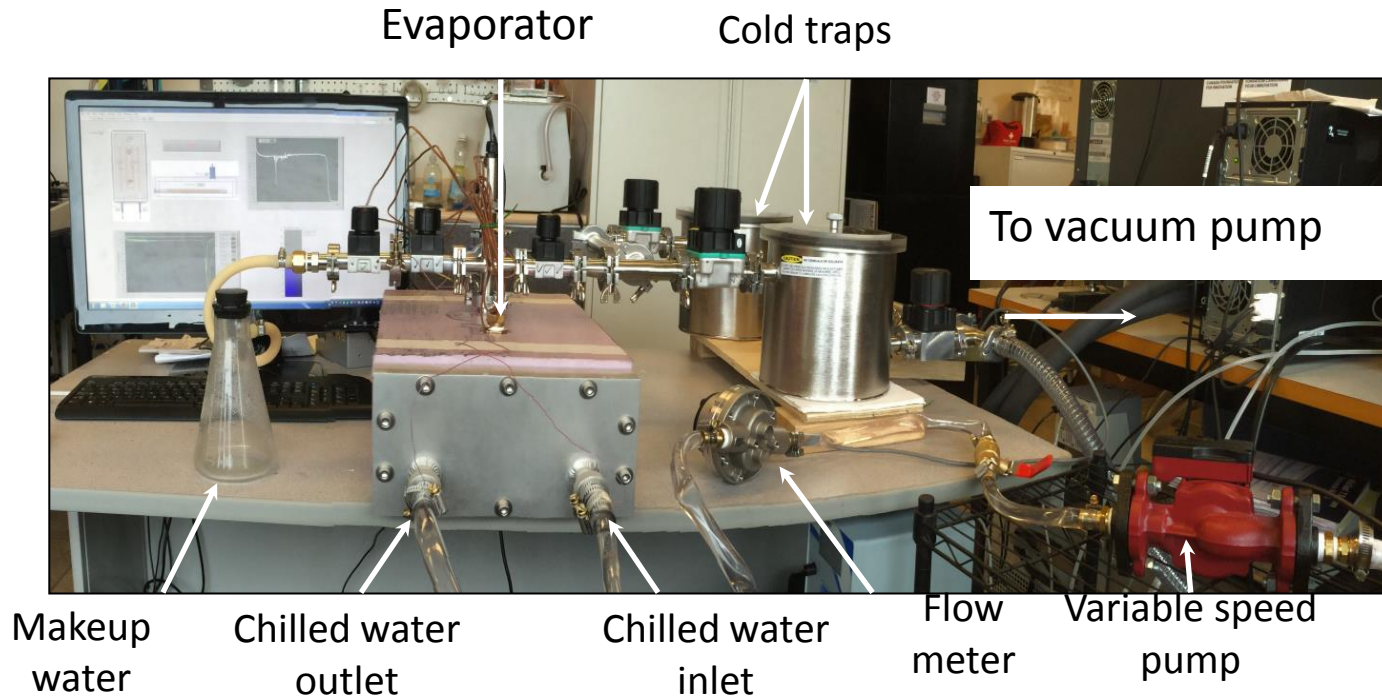


GEWA-KS **40 FPI**
(Wieland Thermal Solutions)

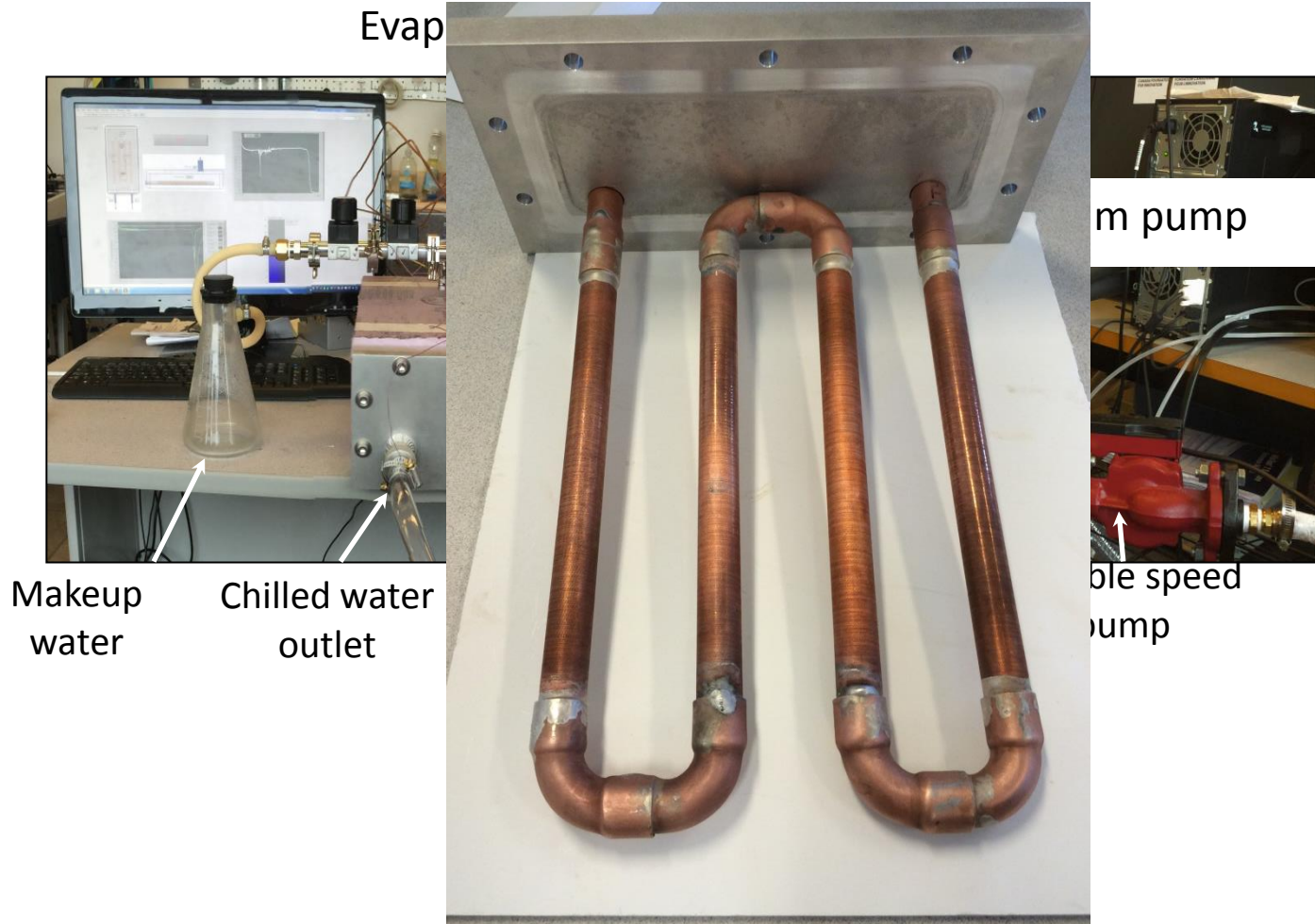


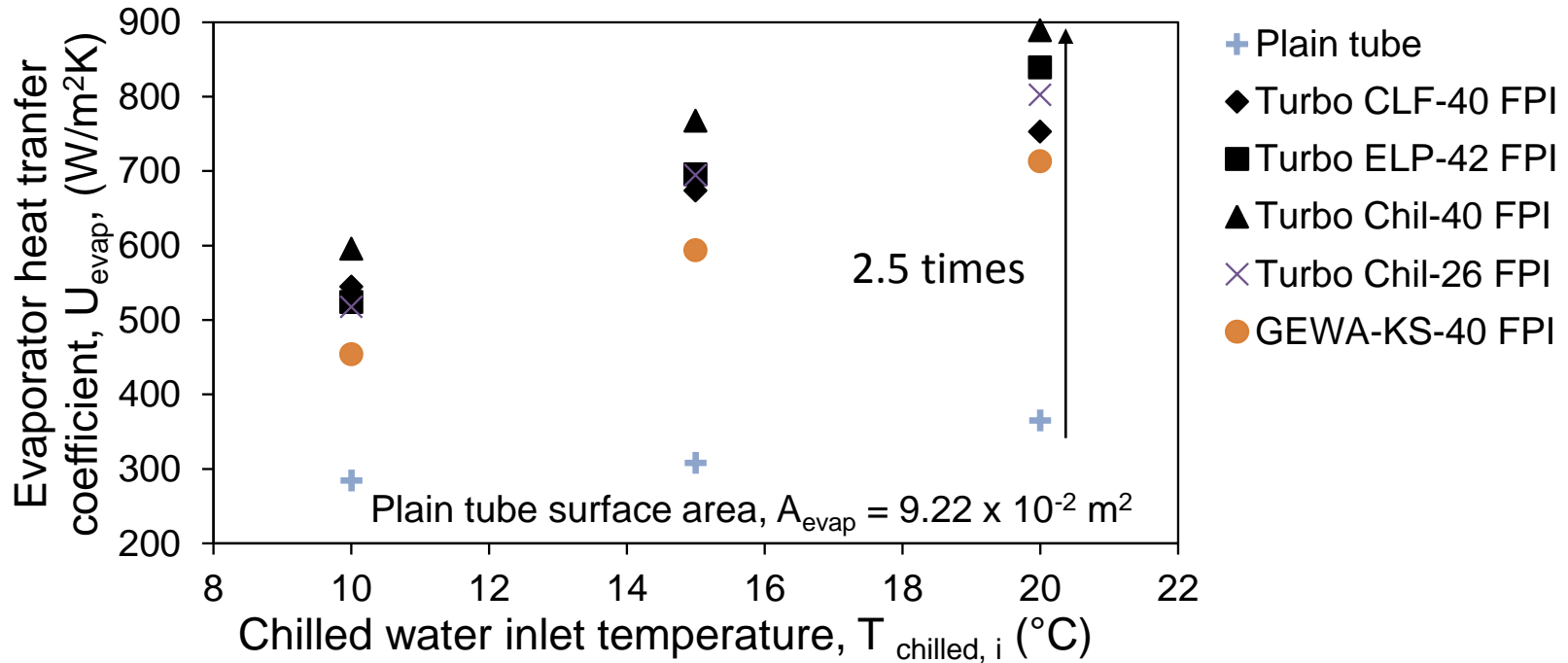


Low pressure evaporator experimental setup



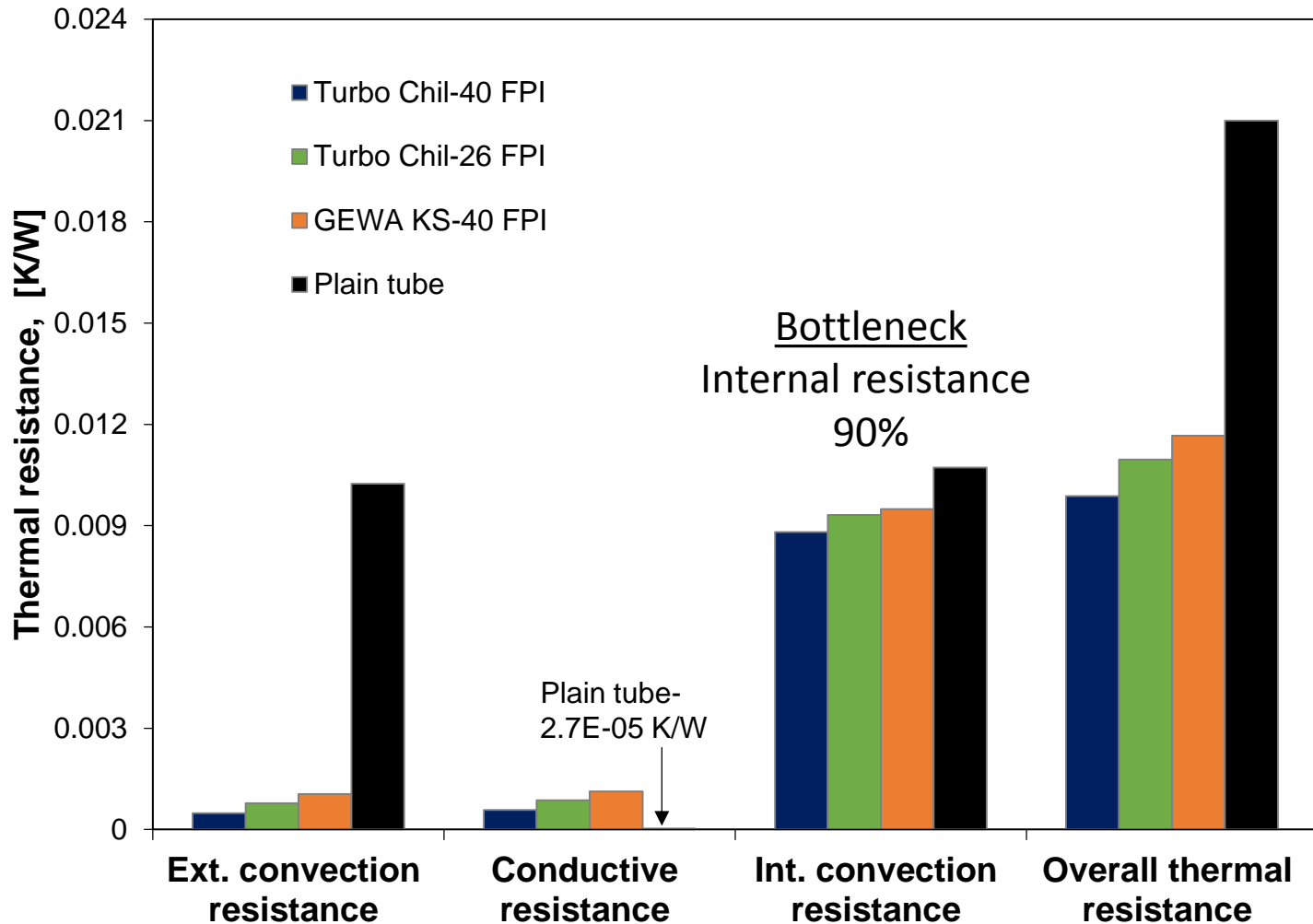
Low pressure evaporator experimental setup





The main features to be considered are

- i) continuous parallel fins
- ii) high fin density

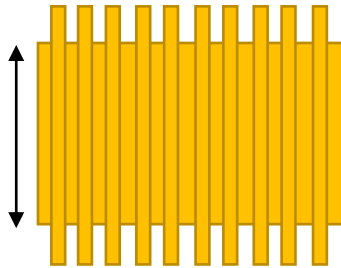


Chilled water mass flow rate : 2.5 LPM
 Chilled water inlet temperature: 15°C

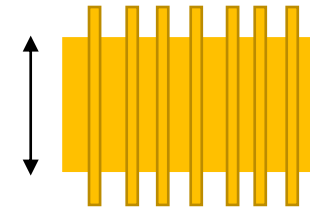
Low pressure evaporator experimental setup

40 FPI, 0.6 mm
fin spacing

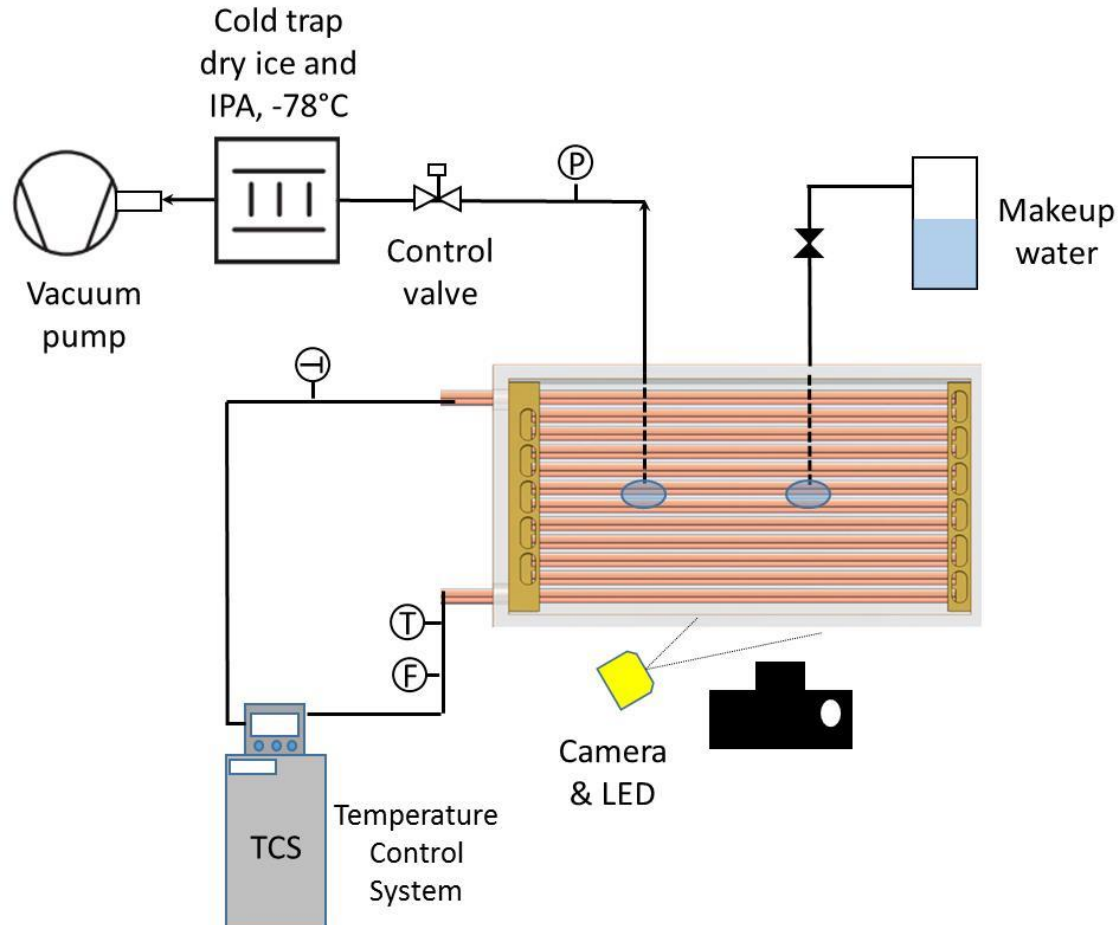
15 mm

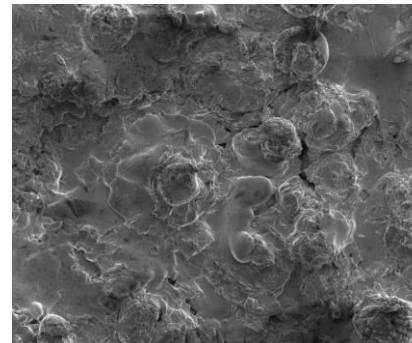
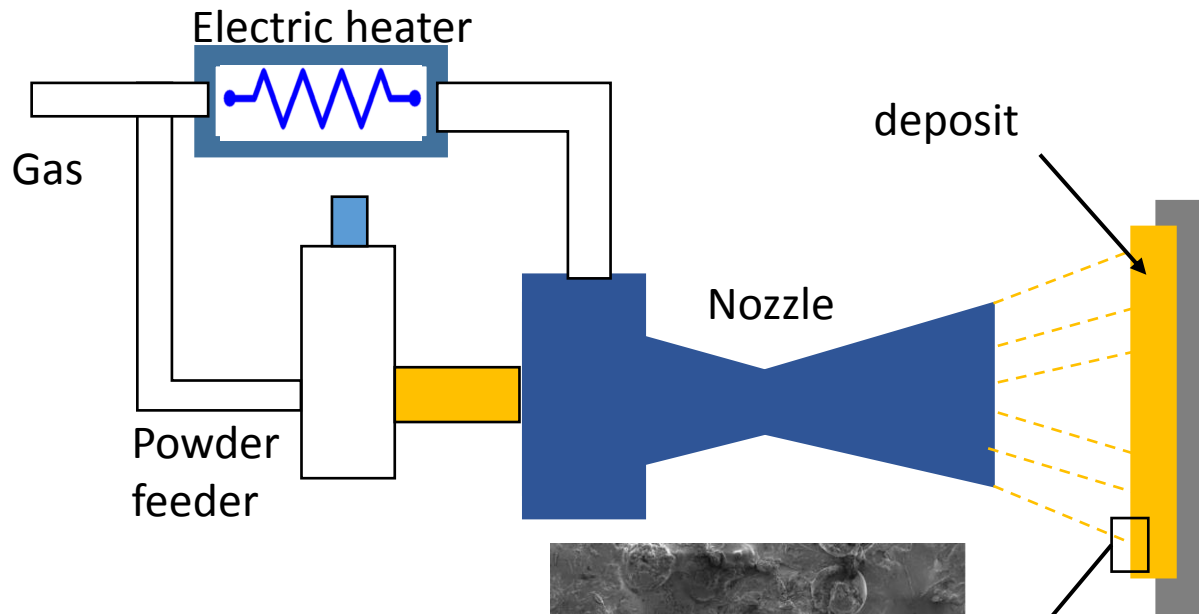
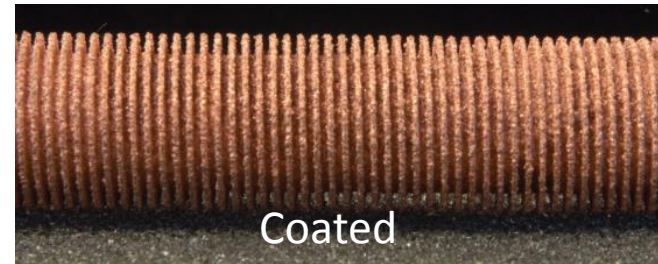
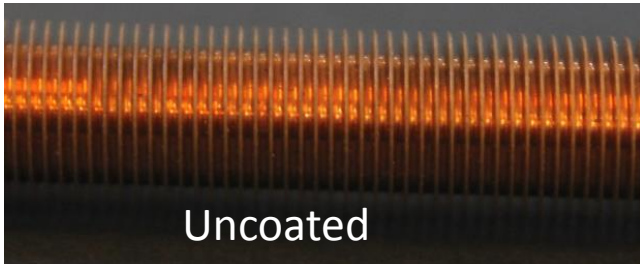


7.9 mm

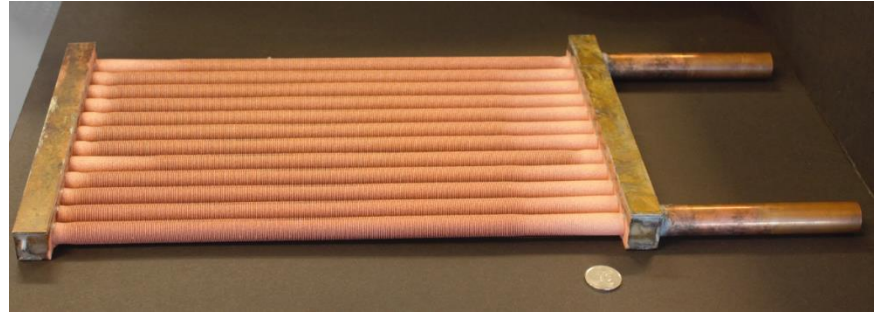
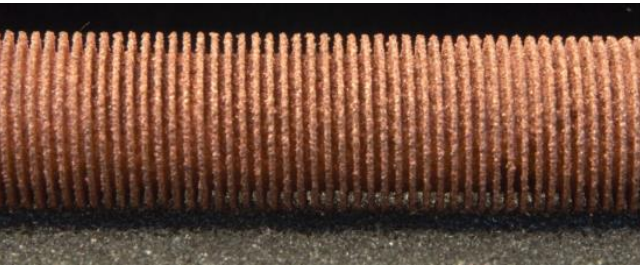
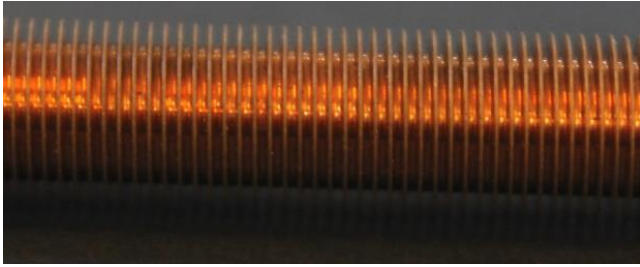


26 FPI, 1 mm
fin spacing

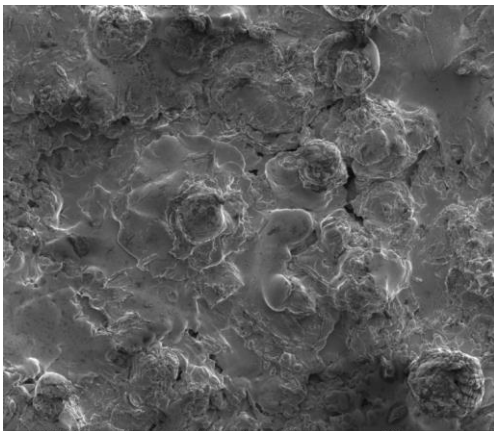




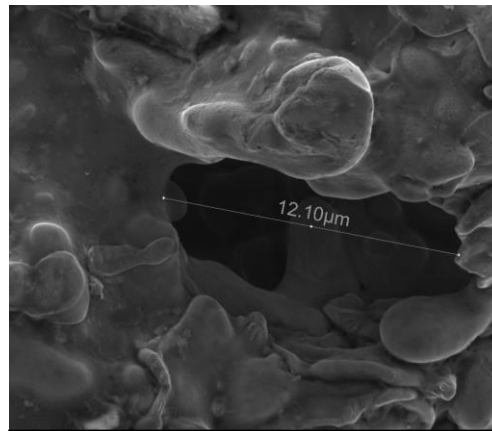
Porous copper coated evaporator



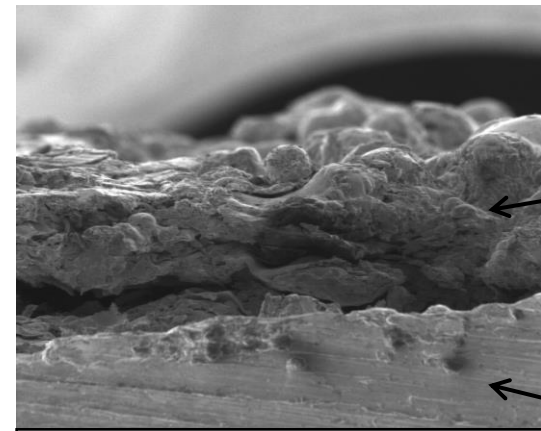
- ❑ The porous copper coating from thermal spray deposition technology
- ❑ Deposition is compatible with the material of evaporator



Scale: 200 μm



Scale: 5 μm



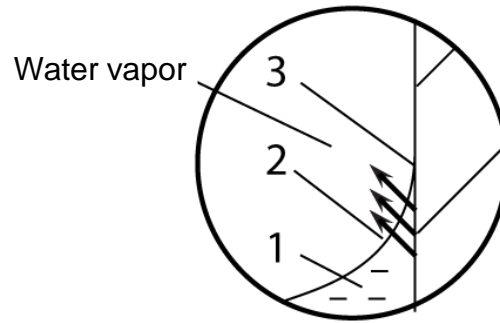
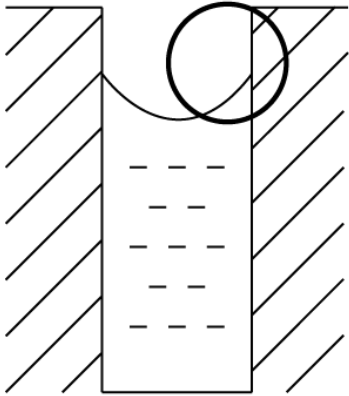
Scale: 200 μm

coatings

Substrate
(copper fin)

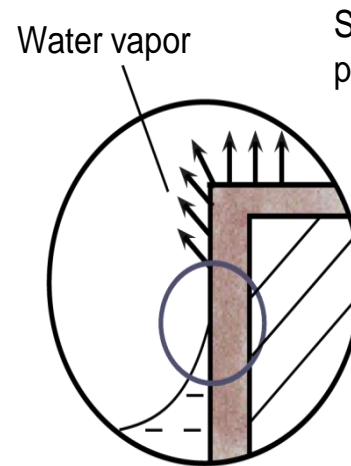
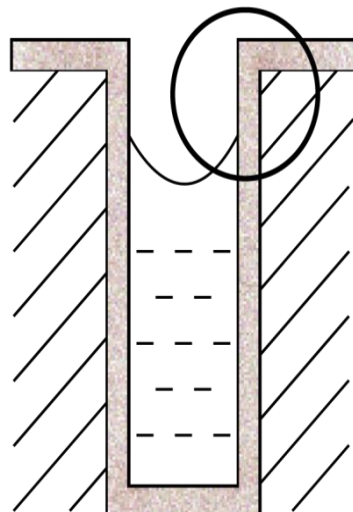
SEM images of the porous coatings

How porous coatings help?

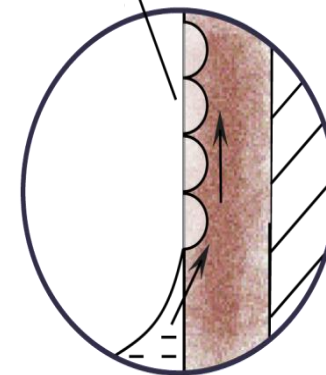


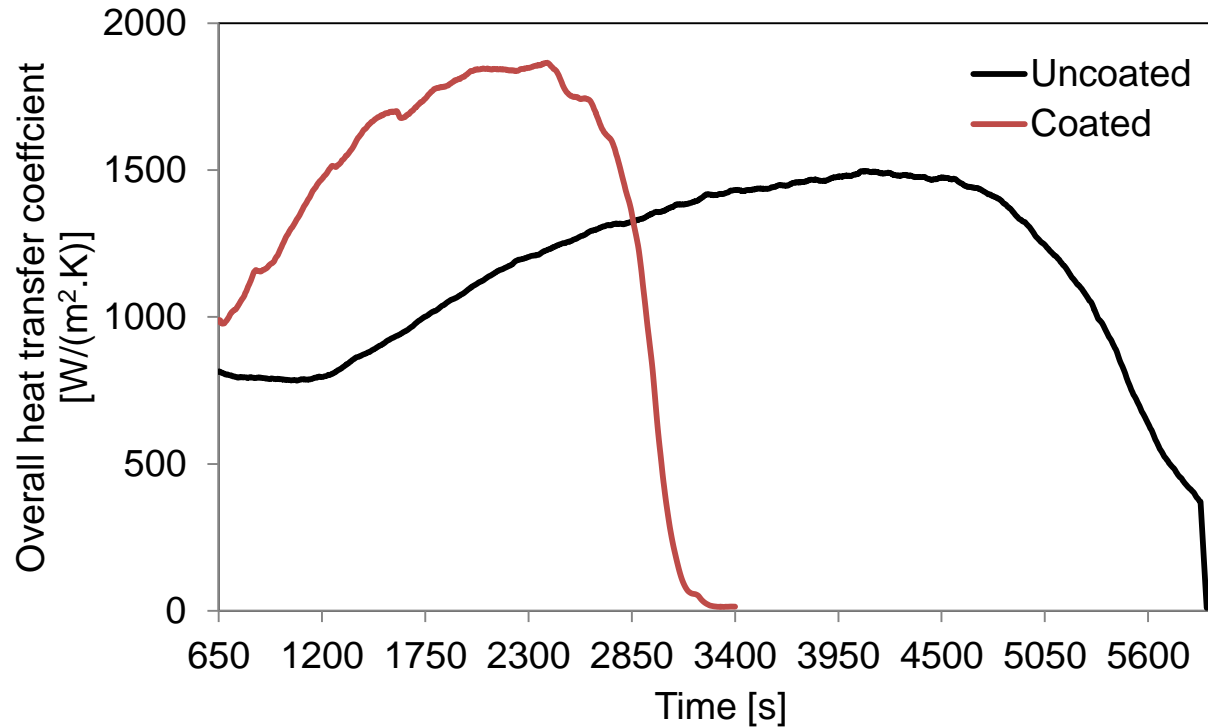
In region 2, the highest heat transfer and evaporation rate occur.

In an uncoated evaporator, the area of zone 2 is limited



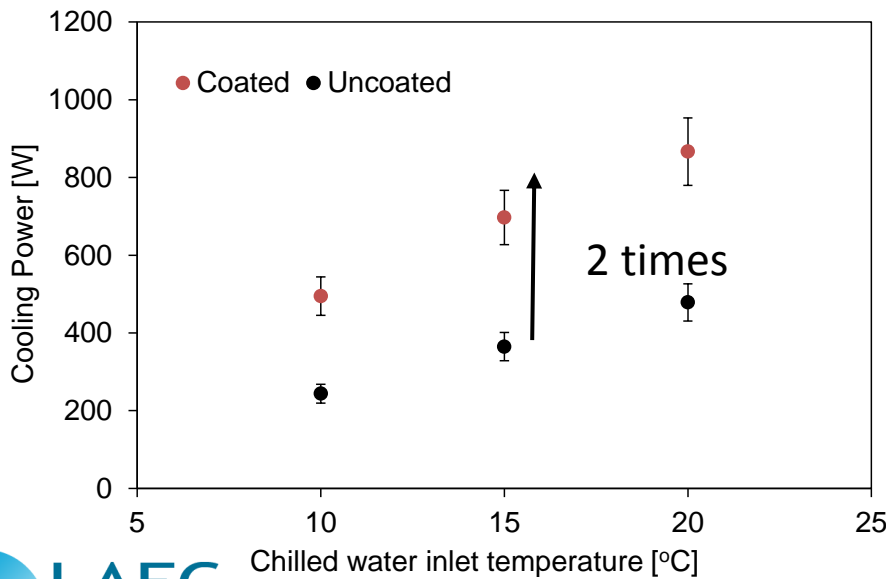
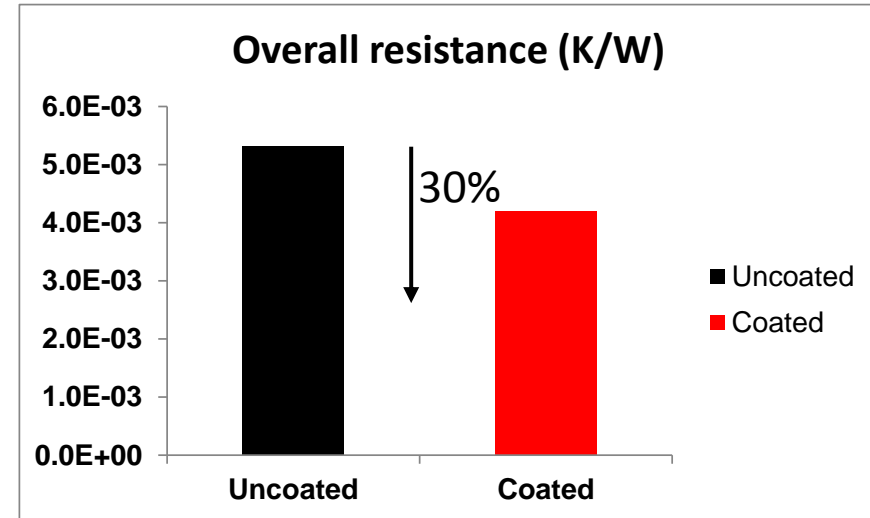
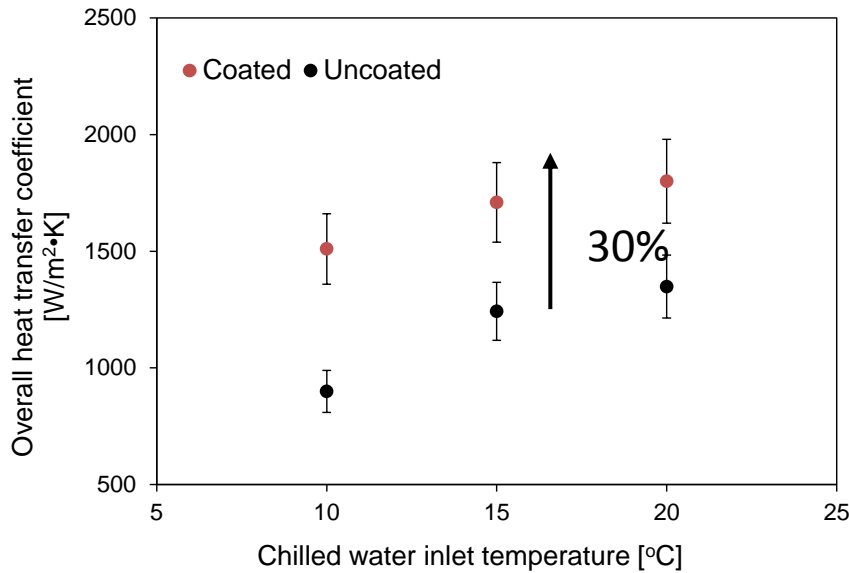
Small liquid menisci in pores of coating



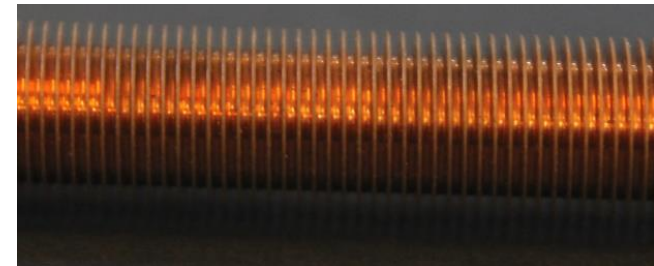


The evaporation of the same volume of water is nearly twice as fast as compared to its uncoated counterpart.

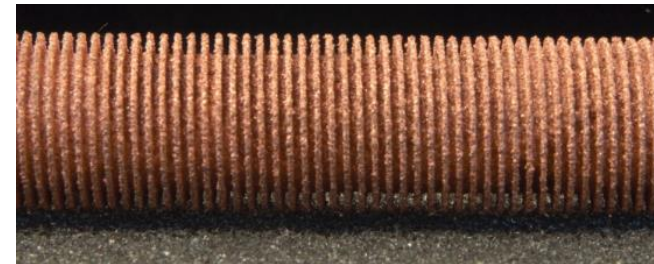
SFU Comparison between uncoated and coated evaporator



Uncoated



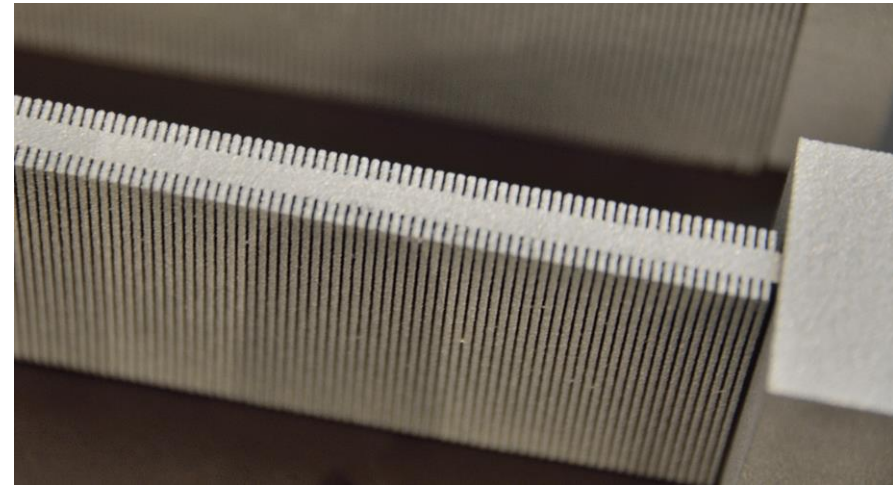
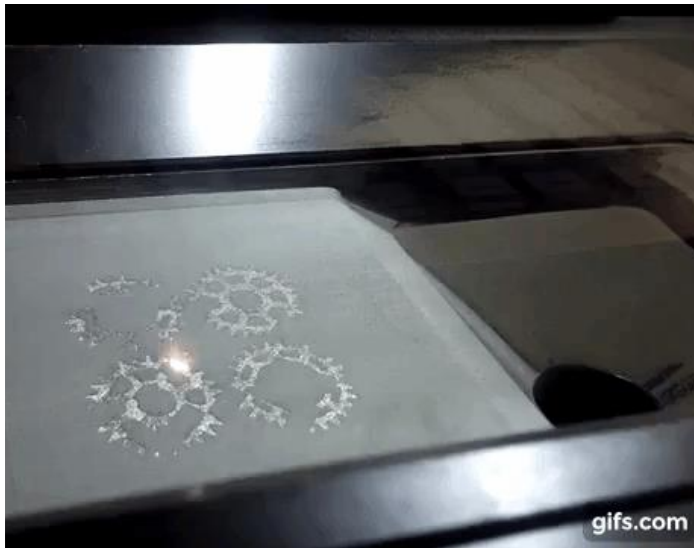
Coated



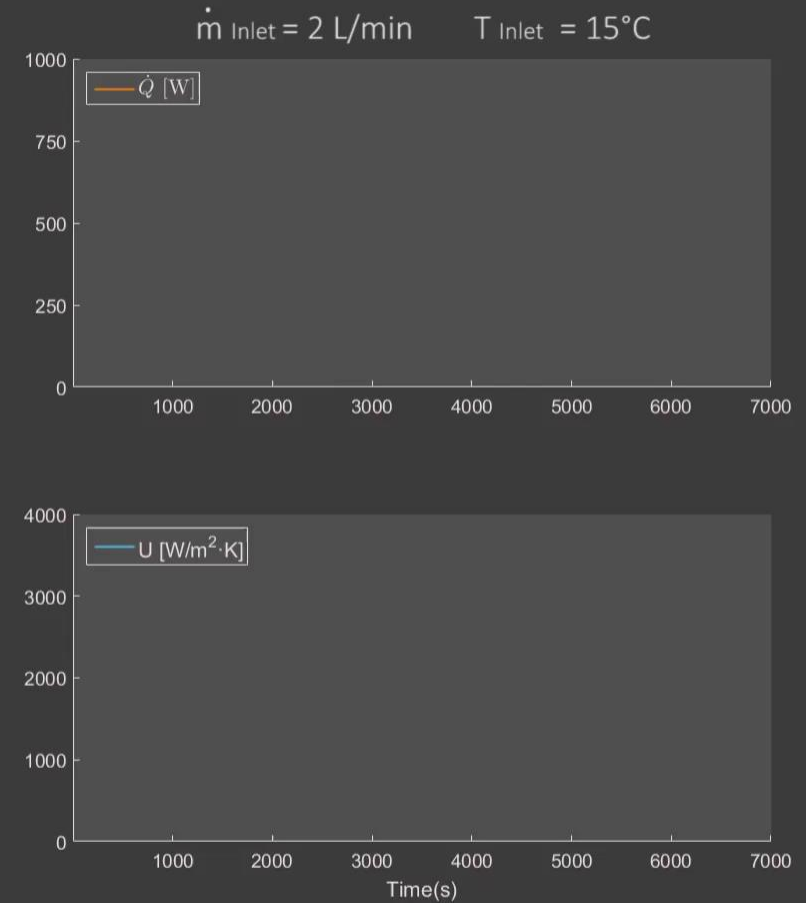
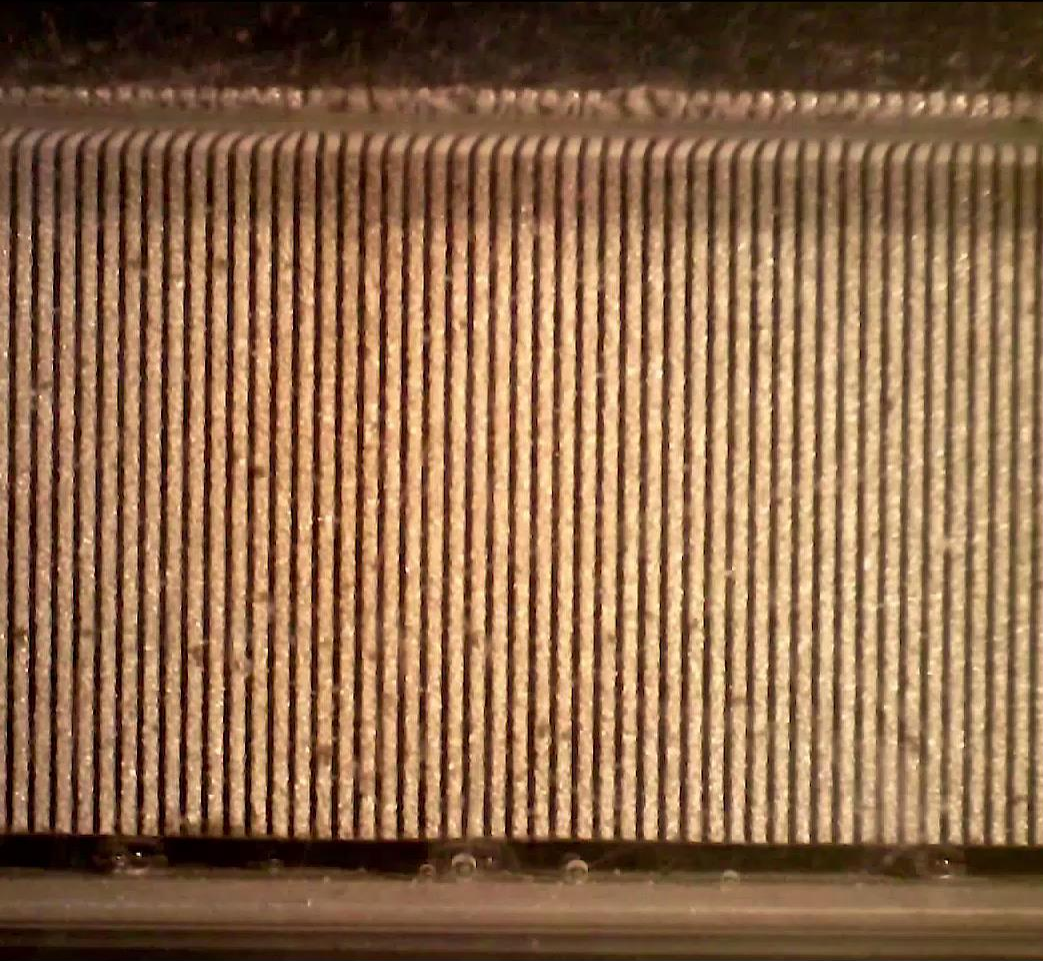
Following the detailed evaluation of low pressure evaporators,

A new micro evaporator is designed and built in the lab

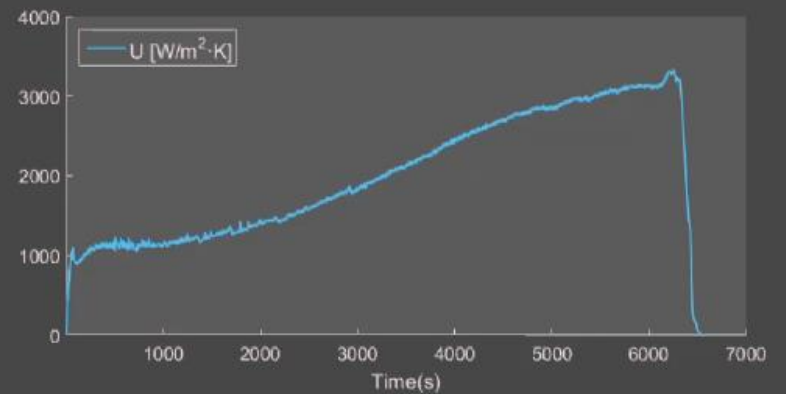
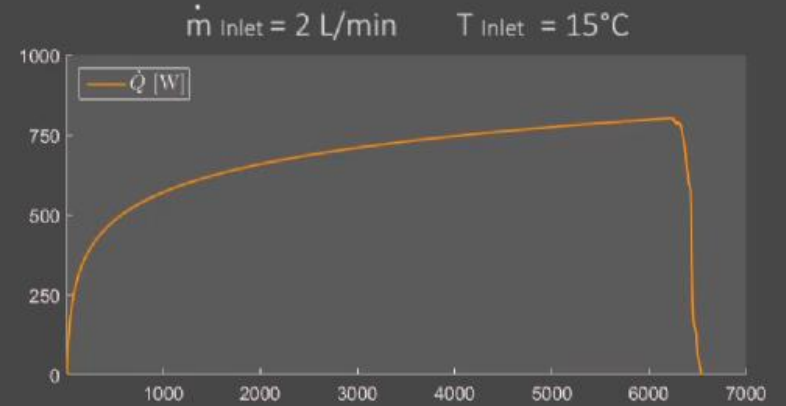
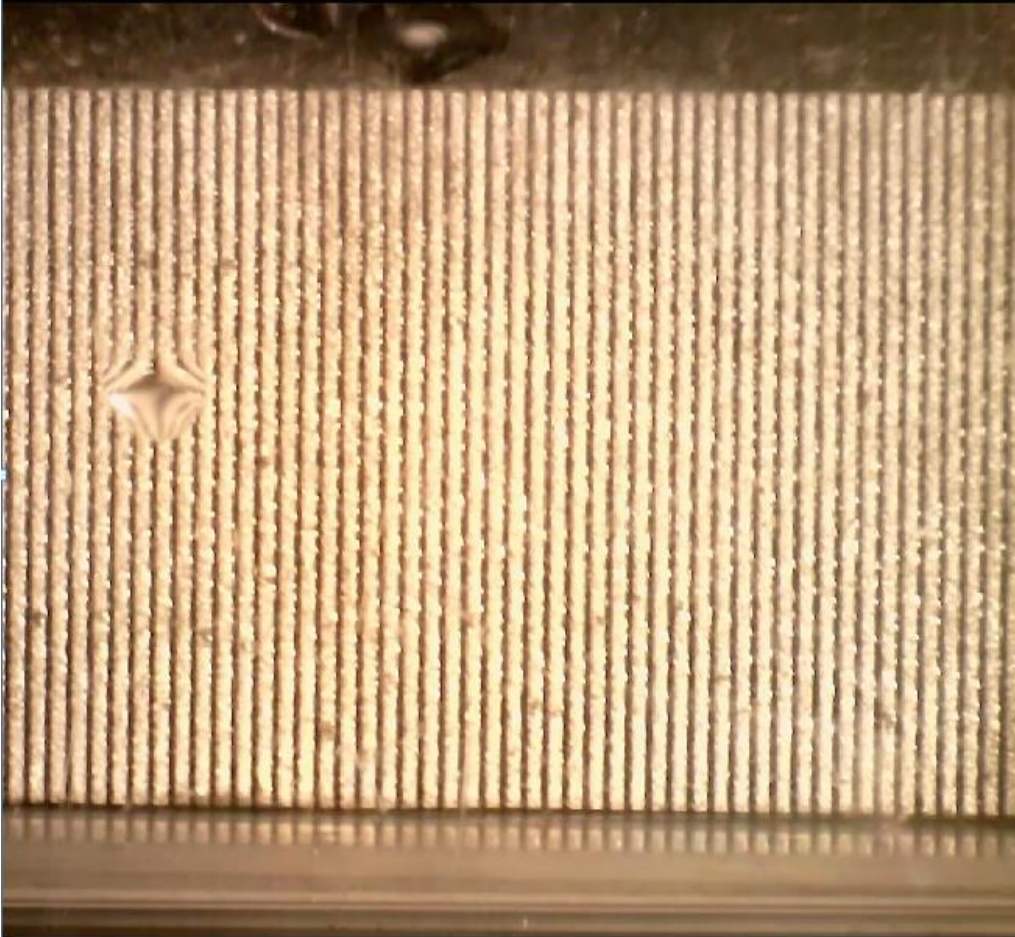
Direct
Metal Laser
Sintering
(DMLS)
And
3D Printing

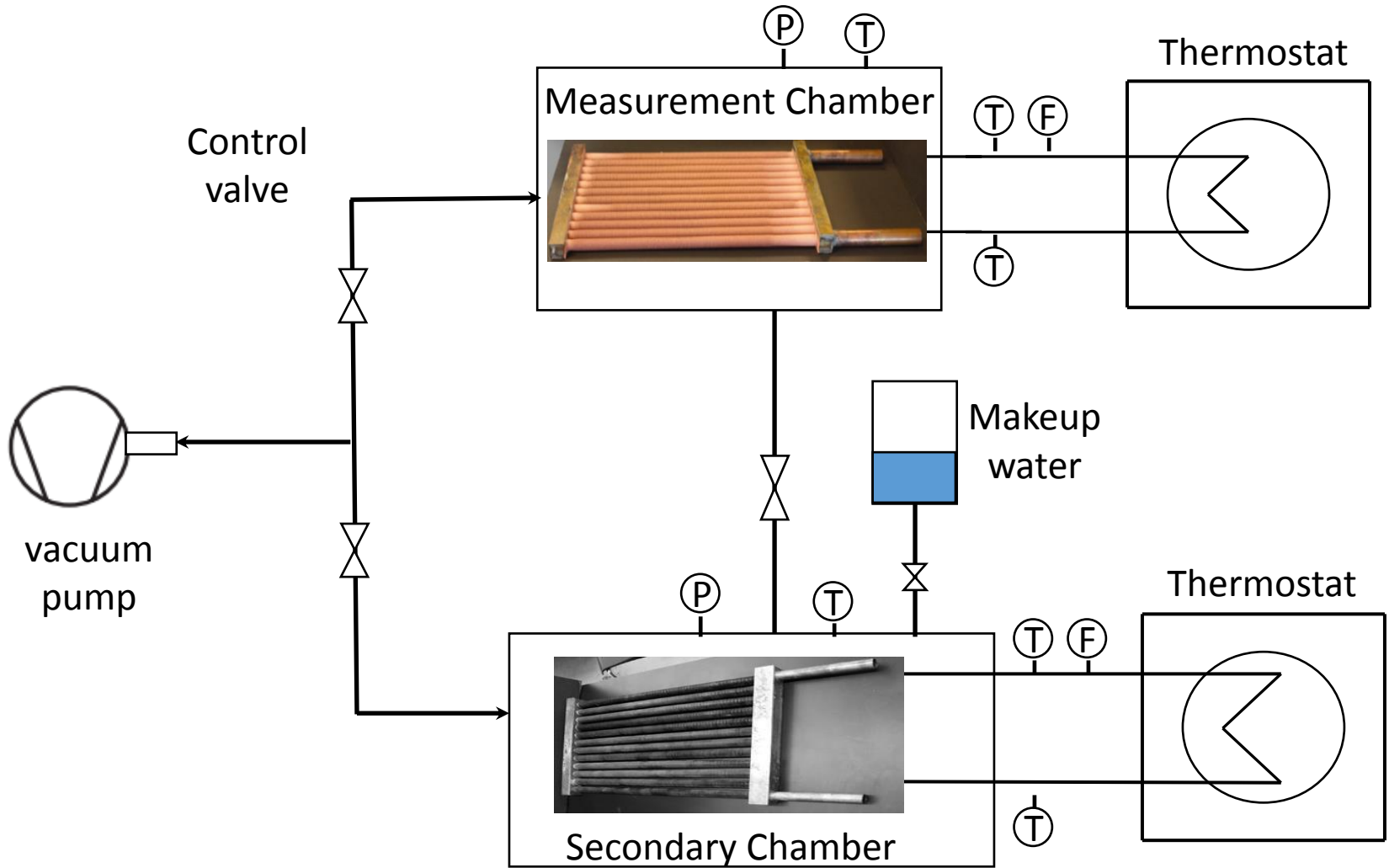


Variation of U with water height



Variation of U with water height







Natural Sciences and Engineering Research Council of Canada (NSERC)
The Canadian Queen Elizabeth Advanced Scholarship (QES-AS) Program



Dr. Karine Brand,
Dr. Achim Gotterbarm, Director Global R&D

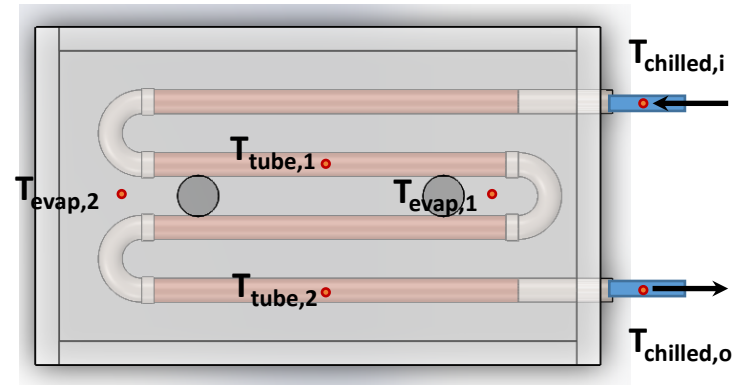
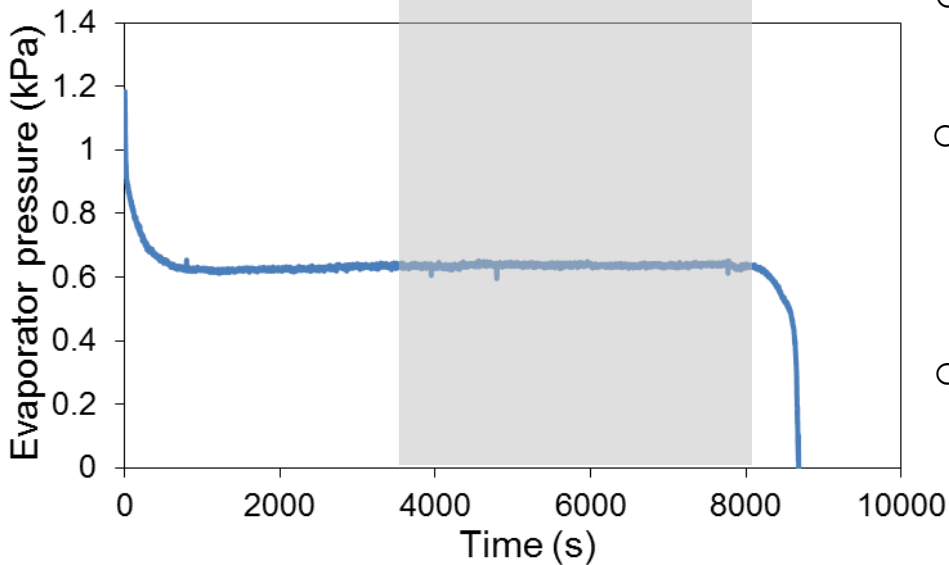
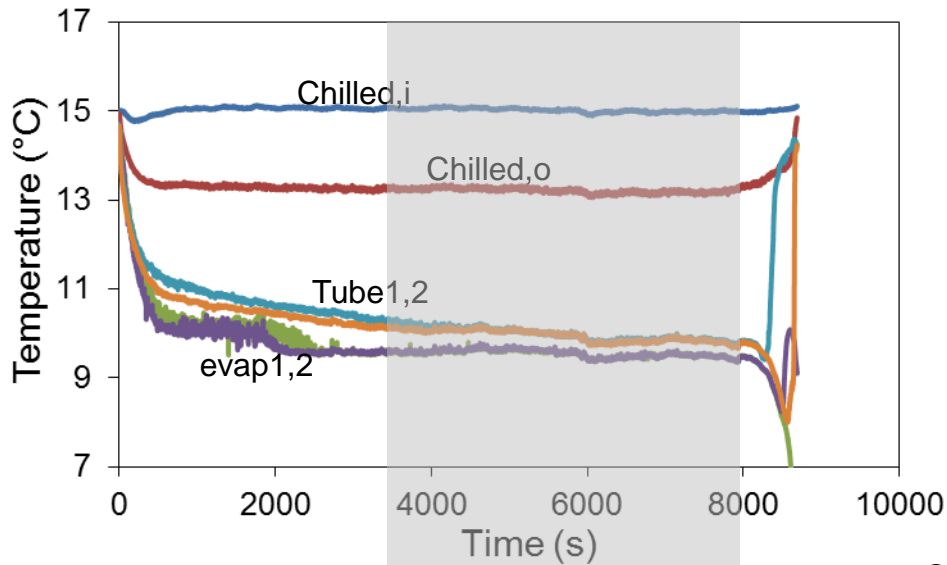


Dr. Evraam Gorgy, Director of R&D
Mr. Bill Korpi
Wolverine Tube, Inc.

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



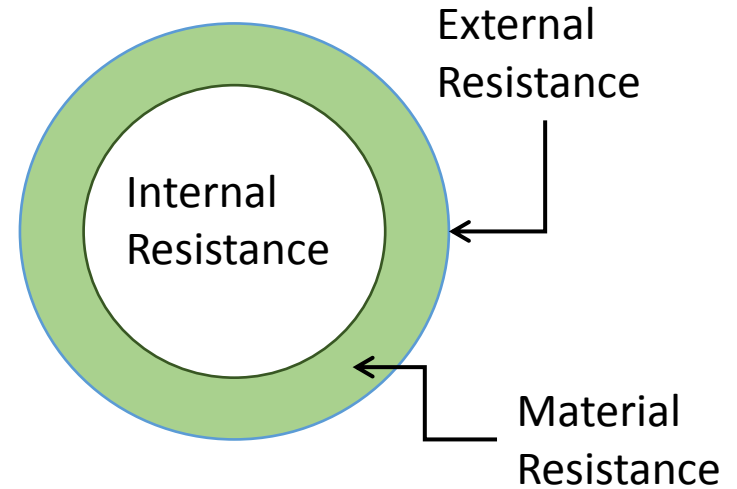
Thanks for your attention
Questions/Comments



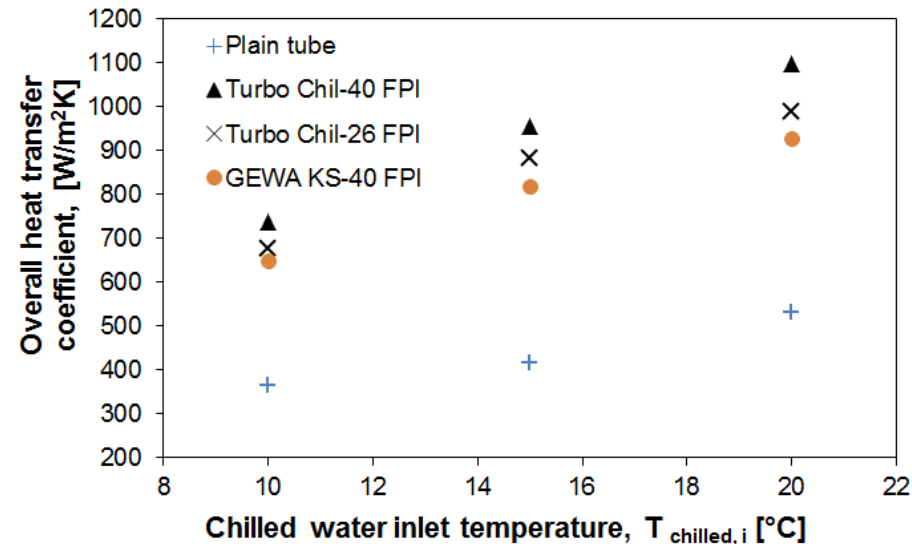
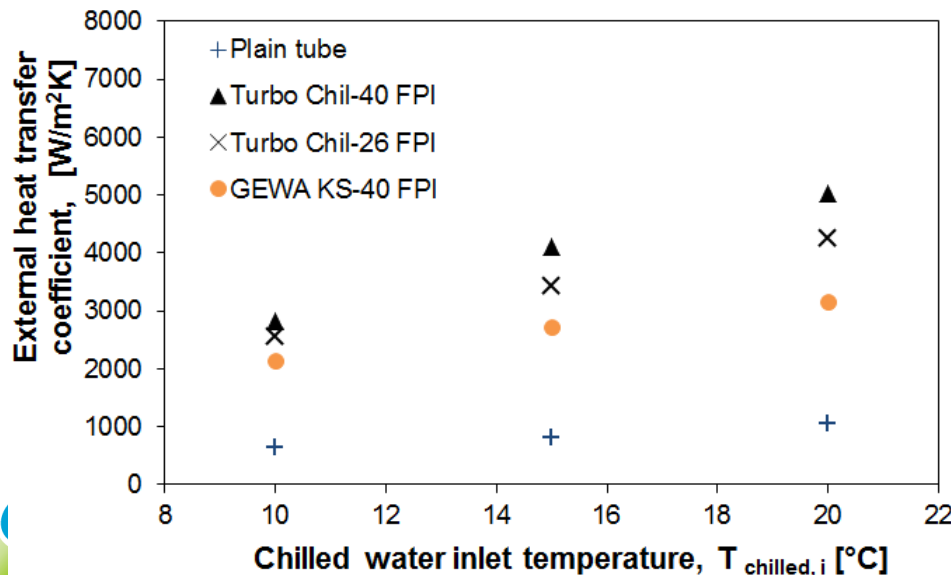
- All thermocouples have same reading at the beginning (Equilibrium State)
- Evaporator pressure reduces when the control valve is opened and remains constant until evaporator runs out of water
- For all calculations, data were extracted from demarcated region (Steady state)

Quantifying the evaporator performance

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



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



Future work

