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

Presented by

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Low pressure evaporator in adsorption cooling system

- **Gaseous refrigerant**
- **Two phase liquid + Vapor**
- **T = 5°C, P = 0.8 kPa**
- **T = 30°C, P = 4.2 kPa**
- **Water vapor**
- **Liquid water**
- **Operating pressure is very low (close to vacuum)**
- **Water as an refrigerant**
- **Low Pressure (LP) evaporator**

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**Evaporator**

**Condenser**
Water height issue in the evaporator

- 5 cm of water height causes:
  - The hydrostatic pressure should be minimized inside the low operating pressure evaporators
  - A conventional evaporator fails to perform efficiently
  - The cooling power reduces drastically

![Diagram showing pressure and height](image)

\[ P = P_{vap} + \rho g H_{ref} \]

1 kPa
7°C

1.3 kPa
13°C

The cooling power reduces drastically
Available solution

- Falling film evaporation

Limitations:
- Equal distribution of refrigerant
- Internal pump (active pumping)
- Complex
- Higher weight
Proposed solution

- **Capillary-assisted evaporation**

- Inspiration: Plants use capillary action to draw water from the ground

Advantages:
- Uniform evaporation rate along the circumference of the tube
- No parasitic energy consumption
- Lower weight
- No complexity
Previous studies on capillary-assisted evaporation

Dr. Wang
Shanghai Jiao Tong University of China

Dr. Lanzerath
RWTH Aachen University, Germany

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

Cold trap
dry ice and
IPA, -78°C

Vacuum
pump

Control
valve

P

Makeup
water

Temperature
Control
System

TCS

H

F

T

To

Ti

T1

T1

T1

T1

T1

T1

T1

Camera & LED

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.
Performance of finned tubes

Chilled water mass flow rate : 2.5 LPM
Chilled water inlet temperature: 15°C
Smaller diameter finned tube

15 mm

40 FPI, 0.6 mm fin spacing

7.9 mm

26 FPI, 1 mm fin spacing

Type – 2nd Generation (2G)

Partial capillary

Pooled water (colored)
In region I (tube is fully submerged) - overall $U$ is about 1600 W/(m$^2$·K).

In region II - the hydrostatic pressure is reduced and the overall $U$ increases by 45% from 1600 to 2320 W/(m$^2$·K)

In region III, $U$ decreases to 1720 W/(m$^2$·K) as the water level drops further as capillary force fails to cover the entire surface.

Chilled water inlet temp: 20°C
Chilled water mass flow rate: 2.5 LPM
Porous copper coated evaporator

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

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

Overall resistance (K/W)

Uncoated: 20% reduction
Coated: 30% reduction

Uncoated: 2 times higher cooling power
Coated: 2 times lower cooling power
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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Mr. Bill Korpi
Wolverine Tube, Inc.
Black bear poses next to SFU sign in best advertising photo ever

Thanks for your attention

Questions/Comments
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)
Quantifying the evaporator performance

\[ \frac{1}{UA} = \left( \frac{1}{h_o A_o} + \frac{1}{h_i A_i} + R_{o,\text{finned tube}} \right) \]

Internal Resistance

External Resistance  Material Resistance

\[ R_{o,\text{finned tube}} = R_{\text{fin}} + R_{\text{wall}} \]
Future work
CALPE- Capillary Assisted Low Pressure Evaporator

Dia of the tube

Height of the water