An Experimental Study on Applying Miniature Loop Heat Pipes for Laptop PC Cooling

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Outline

1. Introduction
2. Experimental setup and parameters.
3. Application in PC cooling.
5. Additional heat pipe applications.
Introduction - Thermosyphon

Winter Operation

- Very Cold Air
- Fins

Vapor Condenses & Liquid Falls Back

Rising Vapor

- 2"

Summer - Nothing Happens!

- Relatively Warm Air
- NH₃ sits at bottom (Not to scale)

- Hope ground doesn’t thaw by September!
- Relatively Cold Ground

Remove as much heat as you possibly can from footing area.

- Relatively Warm Ground
- Liquid Evaporates & Vapor Rises

- Falling Condensate
Introduction - Heat Pipe

Passive Device that Moves Heat with low temperature difference

1. Heat Enters
2. Evaporation
3. Vapor Flows
4. Vapor Condenses Releasing Latent Heat
5. Working Fluid Is ‘Pulled’ Back To The Evaporator

- ΔT not affected by length of pipe
- Heat pipe shell material and working fluid dependent on operating temperature range of application
- Heat pipe is a vacuum vessel

Courtesy to Thermacore
Introduction - Loop Heat Pipe

• Loop Heat Pipes for Electronics Cooling:
  ➢ Passive
  ➢ Orientation insensitive
  ➢ Flexible lines
  ➢ Potential alternative solution to remote cooling
Flat LHP vs Conventional LHP

Conventional loop heat pipe with cylinder shape evaporator, the compensation chamber is separate from evaporator.

Advantages of Flat LHP: Evaporator in flat plate design reduces the contact resistance by applying directly to the chip surface; Evaporator combined with the compensation chamber simplifies the manufacturing process.

Loop heat pipe with flat evaporator, its evaporator combined with the compensation chamber.
Research Objectives

Apply MFLHP to PC Cooling:
(1) Operation of MFLHP: Analyzing the effect of diameter and length of connecting pipe to optimize the MFLHP heat sink design
(2) Performance of MFLHP heat sink at different heat loads
MFLHP Heat Sink inside a Laptop
MFLHP for Laptop PC Cooling

(a) Original conventional heat pipe solution

(b) MFLHP solution

Thp6
Thp3
FIN
Thp5
Thp4
Thp1
Tblock2
Tblock1
Experimental Parameters
Experimental Parameters

The length of water cooling module is 100mm, circulating water temperature is 30°C

The thermocouple distribution schematic of the experiment setup for MFLHP
The thermal performance improved with the increase of the length of the evaporator. In particular, when the length of the evaporator increased from 40mm to 50mm, the thermal resistance significantly declined. It revealed that there was a critical length of the evaporator for MFLHP to start up.
2、EFFECT OF THE LENGTH OF CONNECTING PIPELINE

The lowest thermal resistance belonged to the MFLHP of 300mm length of connecting pipeline. The second one was the case of 400mm length with a little thermal resistance increase, while the worst one appeared in the case of 200mm length. It indicated there was an optimal length of the connecting pipeline for the MFLHP operation. It could be interpreted by the pressure drop due to friction losses in liquid and vapor flow through the pipeline, which calculated by Darcy–Weisbach equation.

\[
\Delta P = f \frac{l \rho u^2}{d} \\
\Delta P = \frac{128}{\pi} \frac{l}{d^4} \frac{\mu m}{\rho}
\]

\[ f = \frac{64}{Re} \quad Re = \frac{\rho u d}{\mu} \quad u = \frac{m}{\rho A} = \frac{4m}{\rho \pi d^2} \]
Conclusion

(1) By analyzing the temperature record of MFLHPs in different heat loads, it was concluded that the MFLHP can cope with the higher power dissipation rate and main stable heater temperature stable with the increase of heat loads, which met the laptop cooling requirements.

(2) The effect of lengths of the evaporator and the connecting pipe was investigated. The results showed that the lengths of the connecting pipe and the evaporator were the main factors affecting the MFLHP start-up. The thermal performance of MFLHP increased with the increase of the length of the evaporator. There is an optimal length of the connecting pipe for the MFLHP.

(3) A novel heat sink attached to a MFLHP was developed for cooling a CPU of laptop, the thermal design power (TDP) of which was 45W. The results showed the CPU heat sink with MFLHP maintained the average temperature of cooper block (dummy heater of CPU) at about 63.1°C in 45W. Compared to the conventional heat pipe solutions, MFLHP had better performance and offered the potential to make a lighter heat sink.
Loop Heat Pipe GPU Heat Sink Design

- fan
- fin group 3
- fin group 5
- fin group 4
- fin group 2
- fin group 1
- aluminum plate with a semicircular channel
- graphics card
- graphics processing unit (GPU)
- an aluminum plate for mounting clips
- MFLHP

Design details:

1. Aluminum plate for mounting clips
2. Fan
3. Fin group 3
4. Fin group 5
5. Fin group 4
6. Fin group 2
7. Fin group 1
8. Graphics card
9. Graphics processing unit (GPU)
10. MFLHP
Loop Heat Pipe GPU Heat Sink Design
Test Results in Actual System

TDP = 185 w
Fan = 100%
Room temp = 27.4°C
ASIC Temp = 59 °C
Ultra-Thin Heat Pipe Technology
Interior Structure of Ultra-thin Heat Pipe

- Sinter
- Fiber
一种热管的制作方法及其热管

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一种热管的制作方法及其热管

（57）摘要
本发明提供一种热管的制作方法及其热管。一种热管的制作方法，包括如下步骤：将热管插入热管体内，然后压入管体，再在管体内填入不能延缓的热管体，然后取出热管体，以及，再次填入热管体，进一步填入热管体。
## Mass Production Cases Of Ultra-Thin HP-1

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<thead>
<tr>
<th>Spec.</th>
<th>Structure</th>
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Photos Of Mass Production Ultra-thin HP-1
Photos Of Mass Production Ultra-thin HP-2
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<thead>
<tr>
<th>Type</th>
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