Fujikura Thermal Technology Overview

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Key Technology of Thermal Product

Heat Pipe

- Passive system
- Two phase heat transfer
- One directional heat flow

Vapor Chamber

- Passive system
- Two phase heat transfer
- Two directional heat flow

Micro-channel

- Active system
- Single phase heat transfer
- Multi directional heat flow
Applications Areas

- **Cooling Electronics**
- **Energy**
- **Automotive Application**
- **Global Warming & Environment**
- **Aviation**
- **Healthcare**

- Heat Pipes
- Heat Pipe Module
- Vapor Chamber
- Heat Sinks
Heat Pipe
Heat Pipe Operation Principle

- **Evaporation**
- **Heat transfer by vapour**
- **Condensation**
- **Capillary or gravity pumping**

**Equations:**

\[
\frac{2\sigma \cos \phi}{r} = \rho gh
\]

- Surface tension
- Capillary pressure
- Pore radius
- Pumping height

**Diagram:**

- Evaporator
- Wick
- Container
- Condenser
- Vapour flow
- Liquid flow
- Heat source
- Heat sink

**Cross section:**

- Sintered copper wick
- Copper tube

**Heat Pipe**

**Heat Pipe Thermal Module**
Heat Pipes have become popular and consumer products now. Approx. 13 Mil. Pcs / month heat pipes are produced in the world.
Functions of thermal control device in cooling

Heat Spreading
Heat Transfer
Heat Dissipation

Thermal circuit diagram

Air In

Air out

Heat source, $T_s$

Heat spreader

$T_e$

$T_c$

$R_{s-cp}$

$R_{c-p-hx}$

$R_{h-x-a}$

$R_t$

$T_a$

$T_s$

$T_e$

$T_c$

$T_a$

$T_s$

$T_a$
Summary of Cooling Design Trend for Desktop PCs

TYPE 1
Extrusion parallel fins

TYPE 2
High aspect extrusion parallel fins with copper embedded base

TYPE 3
High aspect extrusion radial fins with copper insertion core

TYPE 4
Fine pitch stacked fins soldered heat sink

TYPE 5
Heat pipe heat sink

PGA

Rca: 0.5 °C/W
Low Performance

LGA

Rca: 0.2 °C/W
High Performance
## Various Heat Pipe Remote Heat-Exchanger for Laptop PC

<table>
<thead>
<tr>
<th>Picture</th>
<th>Specification</th>
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</table>
| ![Image](image1.jpg) | Heat pipe dia. 6.0mm x 1pc  
*CPU 35 W (Rja < 1.25 °C/W) |
| ![Image](image2.jpg) | Heat pipe dia. 6.0mm x 3pcs  
*CPU 25W (Rja < 2.20 °C/W)  
*GPU 10W (Rja < 5.50 °C/W) |
| ![Image](image3.jpg) | Heat pipe dia. 6.0mm 1pc  
Heat pipe dia. 5.0mm 1pc  
Heat pipe dia. 4.0mm 1pc  
*CPU 27W (Rja < 1.75°C/W)  
*GPU 7 W (Rja < 5.55°C/W) |
| ![Image](image4.jpg) | Heat pipe dia. 6.0mm 1pc  
*CPU 25W (Rja < 1.70°C/W) |

*Fujikura*
Thin and Light Solution combination of 2mm thick or thinner heat pipe with Aluminum fins are applied in current Laptop PC.
Typical Consumer Products of Heat Pipes for Cooling PC

- 4 mm Heat Pipe
- 6 mm Heat Pipe
- 1 inch Heat Pipe
- Vapor Chamber
High Power Heat Pipe Heat Sink for Desktop PC

130W/CPU x 2 CPUs
Thinner Heat Pipes

◆ 1.5 mm thick : Qmax: 25 W
Rhp: 0.2-0.3 K/W

◆ 1.0 mm thick : Qmax: 10 W
Rhp: 0.3-0.5 K/W
Regardless with the total inner cross-section of the heat pipe, optimized liquid to vapor flow area ratio is with the range of 0.5~0.6

**Porosity,** $\varepsilon$ : 0.7 (Experimental Value)
0.6 for similar shape powder wick

**Contact Angle,** $\theta$ : 18 deg (Experimental Value)

**Permeability,** $K$ : $8.0 \times 10^{-10}$ (Calculated Value)
$7.5 \times 10^{-11}$ for similar shape powder wick
Wick Structure of Thin & Flat Heat Pipe

Features:
- Sufficient Capillary Force
- Sufficient Vapor Space
- Liquid Flow Through Fiber and Groove under Fiber

Cross-Section of Center Fiber Wick For 0.8mm to 2mm Thick Heat Pipe

Spiraled Type
- Cu Wire

Twisted Type

Center Fiber Wick

Wick

Vapor Space

X-Ray Picture of Straight Thin Heat Pipe
For a 2.0mm flattened thickness with the effective length 110mm, Qmax can be up to 48W.
Ultra-Thin Heat Pipe Performance

1) D1.0mm Heat Pipe Thermal Performance

Heat Pipe Specification

Length = 75mm

Wick: Center Fiber Wick

Vapor Flow Area

Wick

Liquid Flow Area

50C hot water

Thermal Tape Become Red at 45C
EXPERIMENTAL STUDY: Fabricated Module #1

**Specification**

- **Heat Pipe**: L 300.0mm T 1.3mm
- **Module Weight**: 27gm and 20gm
- **Maximum Height**: 5.0mm
- **Heat Source**: In Center

Using D8.0mm Qmax : 68W
Using D6.0mm Qmax : 64W
EXPERIMENTAL STUDY : Fabricated Module # 2

**Specification**

Heat Pipe: L 140.0mm W 9.0mm T 1.0mm  
Module Weight: 19gm (Including Fan)  
Maximum Height: 4.0mm

Current module Qmax About 20W if Air Flow Available
**EXPERIMENTAL STUDY : Fabricated Module # 3**

**Specification**
- Heat Pipe: L 100.0mm W 9.4mm T 0.8mm
- Module Weight: 14gm (Including Fan)
- Maximum Height: 3.8mm

**Total Resistance**
- Horizontal Qmax 5W
- Top Qmax 5W
- Bottom Qmax 7W

**Temperature Profile**
- Heater Temp Below 60C At All Heat Mode

**Current module Qmax is 5~7W**
EXPERIMENTAL STUDY: Fabricated Module # 4

Specification

Heat Pipe: L 140.0mm T 0.8mm
Module Weight: 12gm
Maximum Height: 3.8mm
Fin Assy: W 40mm L 10mm H 3.0mm

Estimated highest Qmax is 12.0W.
**EXPERIMENTAL STUDY : Fabricated Module # 5**

### Specification

- **Heat Pipe**: L 100.0mm, W 4.5mm, T 0.6mm
- **Module Weight**: 8gm
- **Heat Source**: Three Heat Sources
  - H1: 3W, H2: 1.5W, H3: 1.5W
- **Maximum Height**: 0.7mm

### Comparison

Current Module vs 0.7mm Thick Graphite Sheet

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<th>Th1[C]</th>
<th>Th2[C]</th>
<th>Th3[C]</th>
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<tbody>
<tr>
<td>Current Module</td>
<td>75.0</td>
<td>67.5</td>
<td>69.0</td>
</tr>
<tr>
<td>0.7mm Graphite Sheet</td>
<td>85.0</td>
<td>77.8</td>
<td>81.2</td>
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For current module Th is 5~10°C lower than graphite sheet.
Concept – Heat pipe + Spreader plate

Heat pipes and spreader plate
- Heat pipes 0.7-1mm thick.
- Metal (Al or Cu) spreader plate 0.2mm thick.
- Heat pipe is a super heat conducting device, better than any known metal due to its 2-phase internal heat transfer. Therefore, heat pipe is used to spread the heat more efficiently on the heat spreader plate for better cooling.
Heat Pipe Applications for Vehicles

- Head Lamp Cooling
- Display LED Back-Light Cooling, Car Navigation CPU Cooling
- Rear Lamp Cooling
- Preheated Intake Air (Fuel System, Energy Conservation)
- Power Drive unit (PDU) Cooling
- Battery Cooling (Hybrid)