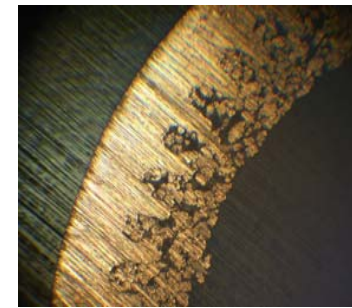
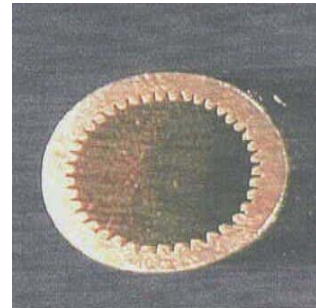
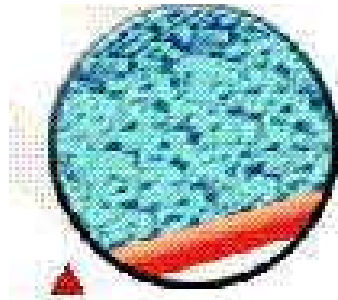


CCI HEAT PIPE DESIGN GUIDE



Rev: D01

Prepared by : CCI RD01 Heat Pipe Team

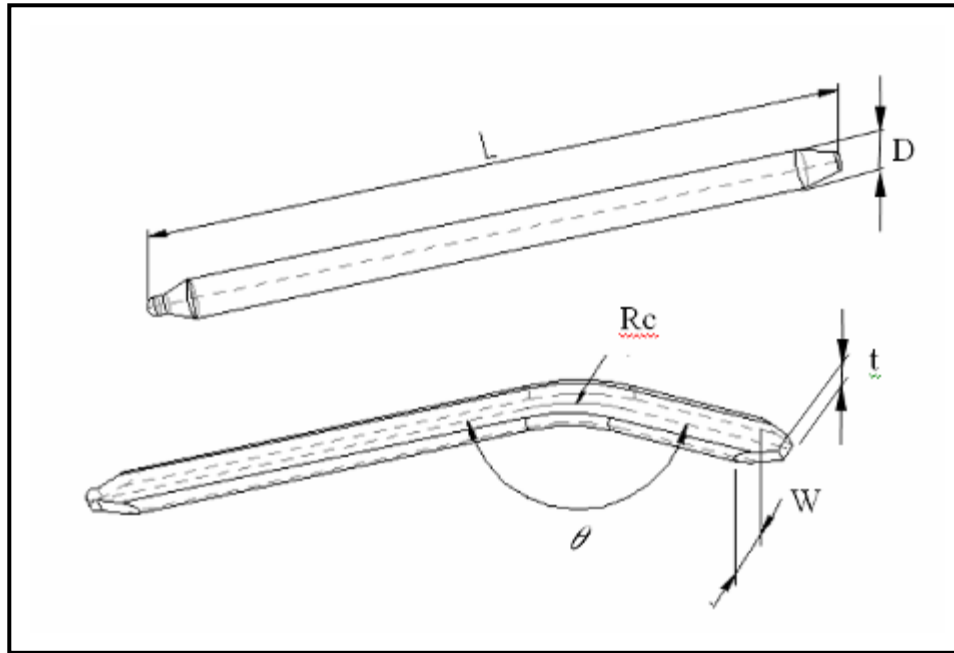
Date : 27. June. 2006

***Contents**

- **Feature descriptions & Geometry limitation**
- **Test methodology descriptions**
- **Screen Mesh**
- **Groove**
- **Sintering Powder**
- **Composite**
- **Approval sheet**

*Feature Descriptions

- Dimensions List



1. Mass Production Diameter : $D = \phi 4, \phi 5, \phi 6, \phi 8$ for Screen Mesh Pipe

$D = \phi 4, \phi 5, \phi 6, \phi 8$ for Grooved Pipe

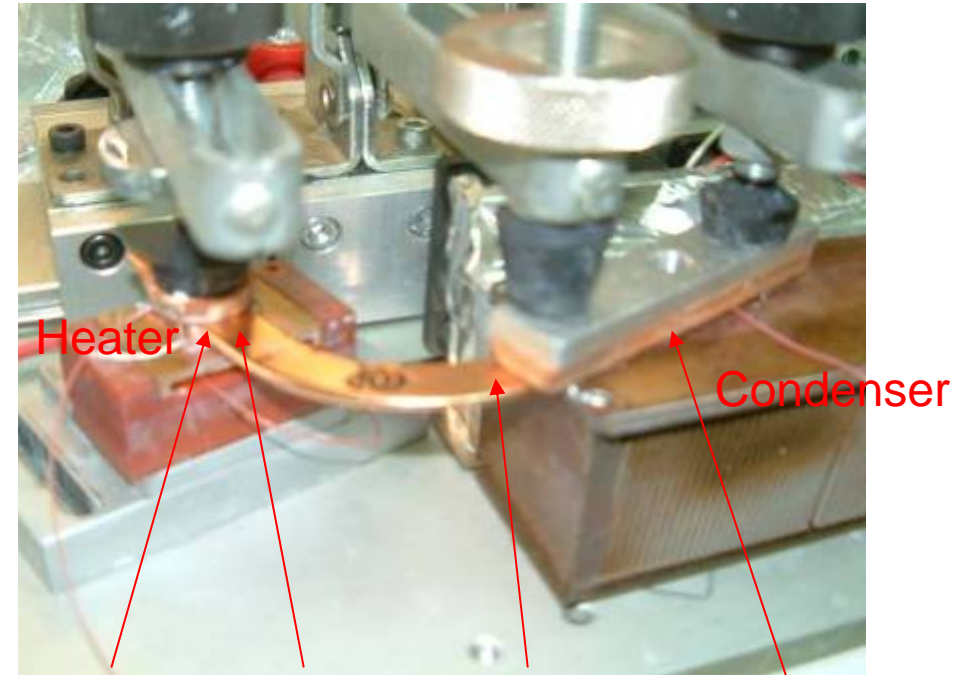
$D = \phi 6, \phi 8$ for Sintering Powder Pipe

$D = \phi 6, \phi 8$ for Composite Pipe

2. Mass Production Length : $L = 100 \sim 350$ mm

*Test Methodology

- ◆ Heater: Copper dummy heater , heat source area = 15x W mm
- ◆ Condenser: Copper fin with fan , cooling length = 60~80mm
- ◆ T_{heater} ($^{\circ}\text{C}$): Heater temperature, sensor is embedded between Heater and evaporator section of heat pipe.
- ◆ T_{hp1} ($^{\circ}\text{C}$): Evaporator temperature of heat pipe, measurement on heat pipe top side.
- ◆ T_{hp2} ($^{\circ}\text{C}$): Adiabatic temperature of heat pipe, measurement on heat pipe top side. Keep this point at 45°C by Fan speed control.
- ◆ T_{hp3} ($^{\circ}\text{C}$): Condenser temperature, sensor is embedded between HP and condenser section of heat pipe.



T_{heater}

T_{hp1}

T_{hp2}

T_{hp3}

◆ Q(watts) : Input power

$$\begin{aligned} \text{◆ } R_{\text{heat pipe}} (\text{°C/W}) &= R_{(\text{Evaporator Local contact effect})} + R_{(\text{pipe dimension effect})} + R_{(\text{Condenser Local contact effect})} \\ &= (T_{\text{herter}} - T_{\text{hp1}})/Q + (T_{\text{hp1}} - T_{\text{hp3}})/Q + (T_{\text{hp3}} - T_{\text{sink}})/Q \\ &= (T_{\text{herter}} - T_{\text{sink}})/Q \end{aligned}$$

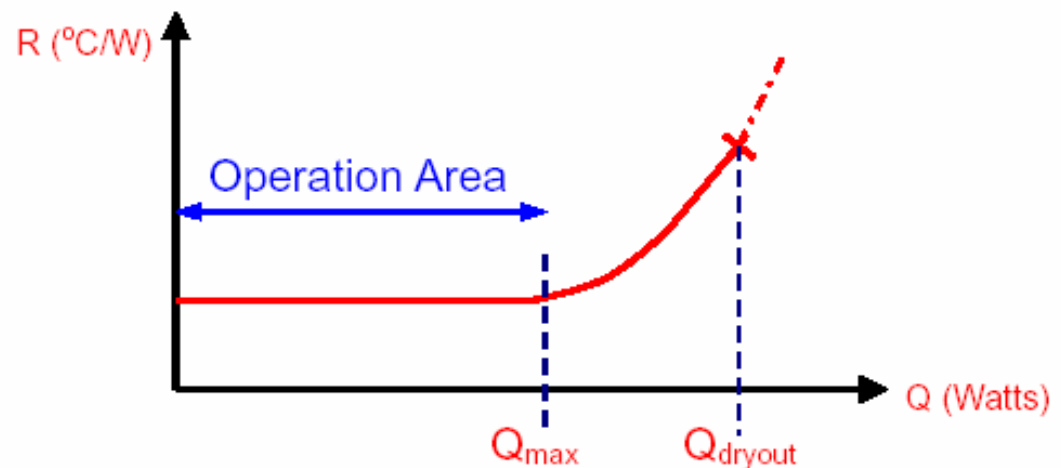
--- Term $R_{(\text{Evaporator contact effect})}$ is concerned about “Local dry out” in case of sharp heat flux loading on heat pipe.

--- Term $R_{(\text{Pipe structure effect})}$ is concerned about the capability of dimension and wick structure of heat pipe itself.

--- Term $R_{(\text{Condenser contact effect})}$ is concerned about “Flooding” in case of over cooling on heat pipe.

◆ Q_{max} (watts) : Thermal resistance $R_{\text{heat pipe}}$ is significant increase when Power input is larger than a certain Power.

◆ Q_{dryout} (watts) : Thermal resistance $R_{\text{heat pipe}}$ is ramp up and almost unsteady when Power input is larger than a certain Power.



*Screen Mesh type

D	t	t :Tolerance	W	W:Tolerance	Rc	Shrinking length
φ4	3.0	±0.05	4.72	±0.1	Rc ≥ 20	Head end: 7.0 Tail end: 3.5
	2.5		5.02			
	2.0		5.33			
	1.8		5.43			
	1.6		5.54			
	1.5		5.59			
φ5	3.0	±0.05	6.40	±0.1	Rc ≥ 25	Head end: 7.5 Tail end: 4.0
	2.5		6.64			
	2.0		6.86			
	1.8		6.95			
	1.6		7.04			
	1.5		7.09			
φ6	4.0	±0.05	7.41	±0.1	Rc ≥ 30	Head end: 11.0 Tail end: 5.0
	3.5		7.66			
	3.0		7.95			
	2.5		8.23			
	2.0		8.48			
	1.5		8.73			
φ8	5.0	±0.05	10.03	±0.1	Rc ≥ 40	Head end: 14.5 Tail end: 8.0
	4.0		10.59			
	3.5		10.91			
	3.0		11.13			
	2.8		11.23			
	2.5		11.38			
	2.0		11.63			
	1.5		11.88			

*Grooved type

D	t	t :Tolerance	W	W:Tolerance	Rc	Shrinking length
φ5	3.0	±0.05	6.37	±0.1	$Rc \geq 20$	Head end: 10.0 Tail end: 3.0
	2.8		6.49			
	2.5		6.64			
	2.0		6.91			
	1.8		7.02			
φ6	4.0	±0.05	7.40	±0.1	$Rc \geq 24$	Head end: 11.5 Tail end: 3.0
	3.5		7.68			
	3.0		8.01			
	2.8		8.08			
	2.5		8.25			
	2.0		8.51			
	1.8		8.61			
φ8	5.0	±0.05	10.07	±0.1	$Rc \geq 32$	Head end: 15.0 Tail end: 3.0
	4.5		10.36			
	4.0		10.65			
	3.5		10.93			
	3.0		11.21			
	2.8		11.32			
	2.5		11.49			
	2.0		11.77			
	1.5		12.05			

Remark: All definition of dimension and tolerance is excluded from the Dent of pipe, especially on both end and bend location of a pipe.

*Sintering Powder type

D	t	t :Tolerance	W	W:Tolerance	Rc	Shrinking length
φ4	3.0	±0.05	4.70	±0.1	Rc ≥ 12	Head end: 7.0 Tail end: 3.0
	2.8		4.83			
	2.5		4.96			
	2.0		5.25			
	1.8		5.35			
	1.6		5.44			
φ5	3.0	±0.05	6.34	±0.1	Rc ≥ 15	Head end: 10.0 Tail end: 3.0
	2.8		6.45			
	2.6		6.53			
	2.5		6.6			
	2.4		6.66			
	2.0		6.86			
φ6	4.5	±0.05	7.09	±0.1	Rc ≥ 18	Head end: 11.5 Tail end:3.0
	4.0		7.39			
	3.5		7.66			
	3.2		7.79			
	3.0		7.9			
	2.8		8.02			
	2.5		8.15			
φ8	6.0	±0.05	9.54	±0.1	Rc ≥ 24	Head end: 15 Tail end: 3.0
	5.5		9.84			
	5.0		10.11			
	4.5		10.37			
	4.0		10.62			
	3.5		10.89			
	3.2		11.02			
	3.0		11.12			

*Composite type

D	t	t :Tolerance	W	W:Tolerance	Rc	Shrinking length
φ6	4.0	±0.05	7.40	±0.1	$Rc \geq 27$	Head end: 11.5 Tail end: 3.0
	3.5		7.68			
	3.0		8.01			
	2.8		8.08			
	2.5		8.25			
	2.0		8.51			
	1.8		8.61			
φ8	5.0	±0.05	10.07	±0.1	$Rc \geq 36$	Head end: 15.0 Tail end: 3.0
	4.5		10.36			
	4.0		10.65			
	3.5		10.93			
	3.0		11.21			
	2.8		11.32			
	2.5		11.49			
	2.0		11.77			
	1.5		12.05			

* Performance Reference 1: Screen Mesh type

- Orient : Horizontal
- Working Temperature (Adiabatic) : 70 °C

<i>Diameter D: (mm)</i>	<i>Flat t: (mm)</i>	<i>Pipe Thermal Resistance R_{pipe} (°C/W)</i>	<i>Operating Max. Power Q (W)</i>
φ4 Length:150mm Straight Pipe	<i>Round</i>	<i>0.50 ~ 0.70</i>	<i>20</i>
	<i>3.0</i>	<i>0.50 ~ 0.70</i>	<i>20</i>
	<i>2.5</i>	<i>0.55 ~ 0.80</i>	<i>18</i>
	<i>2.0</i>	<i>0.65 ~ 0.90</i>	<i>15</i>

<i>Diameter D: (mm)</i>	<i>Flat t: (mm)</i>	<i>Pipe Thermal Resistance R_{pipe} (°C/W)</i>	<i>Operating Max. Power Q (W)</i>
φ5 Length:150mm Straight Pipe	<i>Round</i>	<i>0.40 ~ 0.55</i>	<i>25</i>
	<i>3.0</i>	<i>0.45 ~ 0.60</i>	<i>25</i>
	<i>2.5</i>	<i>0.45 ~ 0.65</i>	<i>22</i>
	<i>2.0</i>	<i>0.50 ~ 0.80</i>	<i>18</i>

<i>Diameter D: (mm)</i>	<i>Flat t: (mm)</i>	<i>Pipe Thermal Resistance R_{pipe} (°C/W)</i>	<i>Operating Max. Power Q (W)</i>
φ6 Length:100mm Straight Pipe	<i>Round</i>	<i>0.20 ~0.35</i>	<i>50</i>
	<i>3.0</i>	<i>0.25 ~0.35</i>	<i>50</i>
	<i>2.5</i>	<i>0.25 ~0.40</i>	<i>45</i>
	<i>2.0</i>	<i>0.35 ~0.60</i>	<i>35</i>

<i>Diameter D: (mm)</i>	<i>Flat t: (mm)</i>	<i>Pipe Thermal Resistance $R_{pipe} (°C/W)$</i>	<i>Operating Max. Power Q (W)</i>
$\phi 6$ Length:150mm Straight Pipe	Round	0.20 ~ 0.35	45
	3.0	0.25 ~ 0.35	45
	2.5	0.25 ~ 0.40	40
	2.0	0.35 ~ 0.60	35

<i>Diameter D: (mm)</i>	<i>Flat t: (mm)</i>	<i>Pipe Thermal Resistance $R_{pipe} (°C/W)$</i>	<i>Operating Max. Power Q (W)</i>
$\phi 8$ Length:100mm Straight Pipe	Round	0.15 ~0.30	60
	3.0	0.20 ~0.30	60
	2.5	0.20 ~0.35	55
	2.0	0.30 ~0.55	50

<i>Diameter D: (mm)</i>	<i>Flat t: (mm)</i>	<i>Pipe Thermal Resistance $R_{pipe} (°C/W)$</i>	<i>Operating Max. Power Q (W)</i>
$\phi 8$ Length:150mm Straight Pipe	Round	0.15 ~0.30	60
	3.0	0.20 ~0.30	65
	2.5	0.20 ~0.35	50
	2.0	0.30 ~0.55	45

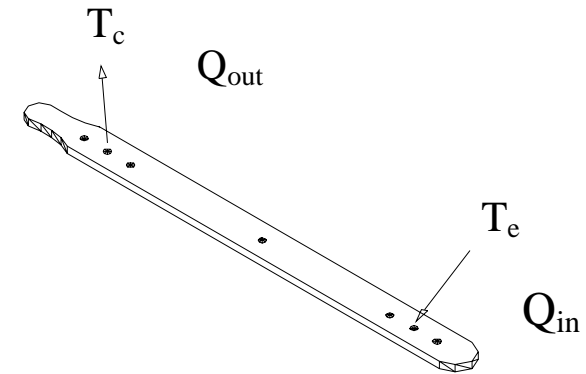
Note: Increase ~ 50mm of pipe length, Operating max. will drop \approx 12%

* Performance Reference 2: Grooved type

Conditions •Heating / Cooling: Evaporator section $L_e = 15 \text{ mm}$ electric resistance heater,
 Condenser section $L_c = 60 \text{ mm}$ with fin air cooling

- Orient : Horizontal
- Working Temperature (Adiabatic) : $70 \text{ }^\circ\text{C}$

$$R_{\text{pipe}} = (T_e - T_c) / Q_{\text{in}}$$



<i>Diameter D: (mm)</i>	<i>Flat t: (mm)</i>	<i>Pipe Thermal Resistance R_{pipe} ($^\circ\text{C}/\text{W}$)</i>	<i>Operating Max. Power Q (W)</i>
$\phi 5$ Length: 100mm Straight Pipe	Round	0.02 ~ 0.04	40
	3.0	0.03 ~ 0.05	40
	2.5	0.03 ~ 0.06	30
	2.0	0.20 ~ 0.45	5

Diameter D: (mm)	Flat t: (mm)	Pipe Thermal Resistance R_{pipe} ($^{\circ}C/W$)	Operating Max. Power Q (W)
$\phi 5$ Length:150mm Straight Pipe	Round	0.03 ~ 0.05	35
	3.0	0.03 ~ 0.05	30
	2.5	0.04 ~ 0.06	25
	2.0	0.40 ~ 0.70	5
Diameter D: (mm)	Flat t: (mm)	Pipe Thermal Resistance R_{pipe} ($^{\circ}C/W$)	Operating Max. Power Q (W)
$\phi 6$ Length:100mm Straight Pipe	Round	0.02 ~ 0.03	75
	3.0	0.02 ~ 0.05	70
	2.8	0.02 ~ 0.05	60
	2.6	0.03 ~ 0.05	50
	2.5	0.03 ~ 0.05	45
	2.4	0.03 ~ 0.05	45
	2.2	0.05 ~ 0.10	25
	2.0	0.10 ~ 0.32	5

Diameter D: (mm)	Flat t: (mm)	Pipe Thermal Resistance R_{pipe} ($^{\circ}C/W$)	Operating Max. Power Q (W)
$\phi 6$ Length:150mm Straight Pipe	Round	0.02 ~ 0.03	65
	3.0	0.03 ~ 0.04	60
	2.8	0.03 ~ 0.05	50
	2.6	0.03 ~ 0.05	45
	2.5	0.03 ~ 0.05	40
	2.4	0.04 ~ 0.06	35
	2.2	0.10 ~ 0.20	20
	2.0	0.40 ~ 0.60	5

<i>Diameter D: (mm)</i>	<i>Flat t: (mm)</i>	<i>Pipe Thermal Resistance R_{pipe} ($^{\circ}C/W$)</i>	<i>Operating Max. Power Q (W)</i>
$\phi 6$ Length:200mm Straight Pipe	<i>Round</i>	<i>0.02 ~ 0.03</i>	<i>45</i>
	<i>3.0</i>	<i>0.03 ~ 0.08</i>	<i>40</i>
	<i>2.5</i>	<i>0.03 ~ 0.10</i>	<i>35</i>
	<i>2.0</i>	<i>0.03 ~ 0.70</i>	<i>5</i>

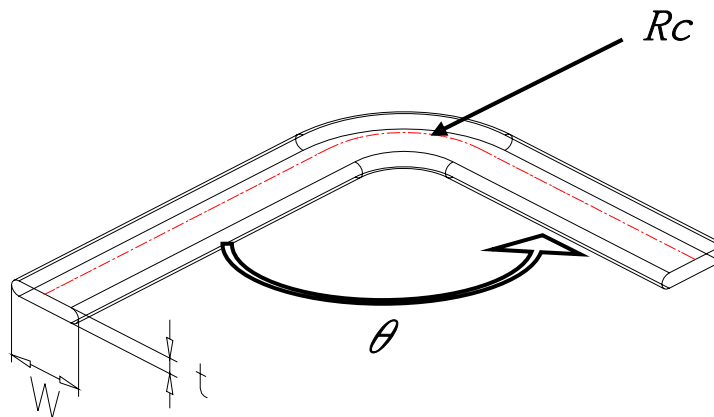
<i>Diameter D: (mm)</i>	<i>Flat t: (mm)</i>	<i>Pipe Thermal Resistance R_{pipe} ($^{\circ}C/W$)</i>	<i>Operating Max. Power Q (W)</i>
$\phi 8$ Length:150mm Straight Pipe	<i>Round</i>	<i>0.002 ~ 0.007</i>	<i>80</i>
	<i>4.5</i>	<i>0.003 ~ 0.015</i>	<i>70</i>

<i>Diameter D: (mm)</i>	<i>Flat t: (mm)</i>	<i>Pipe Thermal Resistance R_{pipe} ($^{\circ}C/W$)</i>	<i>Operating Max. Power Q (W)</i>
$\phi 8$ Length:200mm Straight Pipe	<i>Round</i>	<i>0.002 ~ 0.007</i>	<i>75</i>
	<i>4.5</i>	<i>0.003 ~ 0.015</i>	<i>65</i>

Note: $\phi 6$ heat pipe Increase ~50mm of pipe length, Operating max. power will drop $\approx 15\%$

$\phi 8$ heat pipe Increase ~50mm of pipe length, Operating max. power will drop $\approx 7\%$

Diameter D: (mm)	θ: (°)	Pipe Thermal Resistance R_{pipe} (°C/W)	Operating Max. Power Q (W)
$\phi 6$ Length:150mm Rc:18mm Flat:2.5mm	180	0.03 ~ 0.05	40
	150	0.03 ~ 0.08	35
	120	0.03 ~ 0.10	35
	90	0.03 ~ 0.12	30



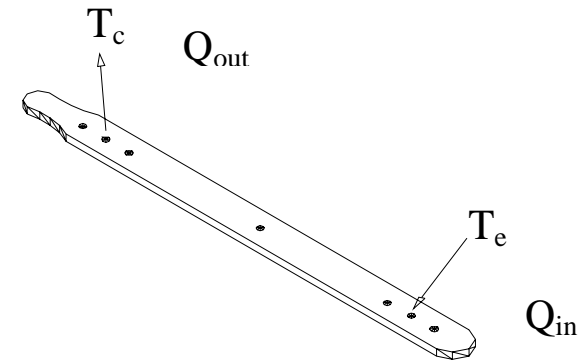
Note: Through one 90° bend, Operating max. power will drop \approx 25%.

* Performance Reference 3: Sintering Powder type

Conditions •Heating / Cooling: Evaporator section $L_e = 15 \text{ mm}$ electric resistance heater,
 Condenser section $L_c = 60 \text{ mm}$ wi

- Orient : Horizontal
- Working Temperature (Adiabatic) : $70 \text{ }^\circ\text{C}$

$$R_{\text{pipe}} = (T_e - T_c) / Q_{\text{in}}$$



Diameter D : (mm)	Flat t : (mm)	Pipe Thermal Resistance R_{pipe} ($^\circ\text{C}/\text{W}$)	Operating Max. Power Q (W)
$\phi 5$ Length: 100mm Straight Pipe	Round	0.02 ~ 0.04	40
	3.0	0.03 ~ 0.05	40
	2.5	0.03 ~ 0.06	30
	2.0	0.15 ~ 0.40	5

Diameter D : (mm)	Flat t : (mm)	Pipe Thermal Resistance R_{pipe} ($^\circ\text{C}/\text{W}$)	Operating Max. Power Q (W)
$\phi 5$ Length: 150mm Straight Pipe	Round	0.03 ~ 0.05	35
	3.0	0.03 ~ 0.05	30
	2.5	0.04 ~ 0.06	25
	2.0	0.35 ~ 0.60	5

<i>Diameter D: (mm)</i>	<i>Flat t: (mm)</i>	<i>Pipe Thermal Resistance R_{pipe} ($^{\circ}C/W$)</i>	<i>Operating Max. Power Q (W)</i>
$\phi 6$ Length:100mm Straight Pipe	<i>Round</i>	<i>0.02 ~ 0.03</i>	<i>75</i>
	<i>3.0</i>	<i>0.02 ~ 0.04</i>	<i>70</i>
	<i>2.5</i>	<i>0.03 ~ 0.05</i>	<i>45</i>

<i>Diameter D: (mm)</i>	<i>Flat t: (mm)</i>	<i>Pipe Thermal Resistance R_{pipe} ($^{\circ}C/W$)</i>	<i>Operating Max. Power Q (W)</i>
$\phi 6$ Length:150mm Straight Pipe	<i>Round</i>	<i>0.02 ~ 0.03</i>	<i>65</i>
	<i>3.0</i>	<i>0.03 ~ 0.04</i>	<i>60</i>
	<i>2.5</i>	<i>0.03 ~ 0.05</i>	<i>40</i>

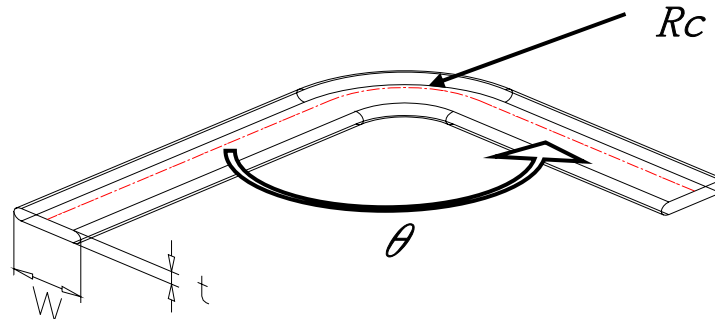
<i>Diameter D: (mm)</i>	<i>Flat t: (mm)</i>	<i>Pipe Thermal Resistance R_{pipe} ($^{\circ}C/W$)</i>	<i>Operating Max. Power Q (W)</i>
$\phi 6$ Length:200mm Straight Pipe	<i>Round</i>	<i>0.02 ~ 0.03</i>	<i>50</i>
	<i>3.0</i>	<i>0.03 ~ 0.06</i>	<i>45</i>
	<i>2.5</i>	<i>0.03 ~ 0.08</i>	<i>35</i>

Note: Increase ~50mm of pipe length, Operating max. power will drop \approx 12%

<i>Diameter D: (mm)</i>	<i>Flat t: (mm)</i>	<i>Pipe Thermal Resistance R_{pipe} ($^{\circ}C/W$)</i>	<i>Operating Max. Power Q (W)</i>
$\phi 8$ Length:150mm Straight Pipe	<i>Round</i>	<i>0.002 ~ 0.004</i>	<i>80</i>
	<i>4.5</i>	<i>0.003 ~ 0.011</i>	<i>70</i>

Diameter D: (mm)	Flat t: (mm)	Pipe Thermal Resistance R_{pipe} ($^{\circ}C/W$)	Operating Max. Power Q (W)
$\phi 8$ Length:275mm Straight Pipe	Round	0.002 ~ 0.004	80
	4.5	0.003 ~ 0.012	70

Diameter D: (mm)	θ : ($^{\circ}$)	Pipe Thermal Resistance R_{pipe} ($^{\circ}C/W$)	Operating Max. Power Q (W)
$\phi 6$ Length:150mm Rc:18mm Flat:2.5mm	180	0.02 ~ 0.04	40
	150	0.02 ~ 0.07	35
	120	0.03 ~ 0.08	35
	90	0.03 ~ 0.10	30



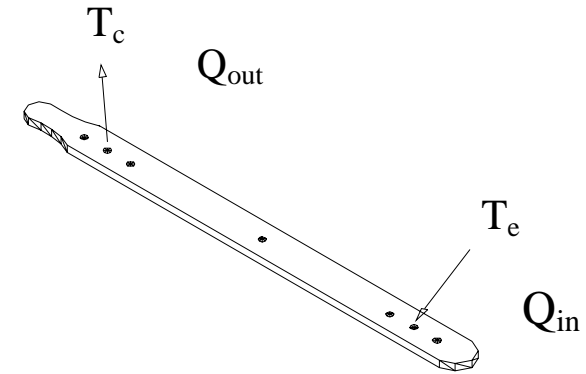
Note: Through one 90° bend, Operating max. power will drop \approx 25%.

* Performance Reference 2: Composite type (Groove Powder)

Conditions •Heating / Cooling: Evaporator section $L_e = 15 \text{ mm}$ electric resistance heater,
 Condenser section $L_c = 60 \text{ mm}$ with fin air cooling

- Orient : Horizontal
- Working Temperature (Adiabatic) : $70 \text{ }^\circ\text{C}$

$$R_{\text{pipe}} = (T_e - T_c) / Q_{\text{in}}$$



<i>Diameter D: (mm)</i>	<i>Flat t: (mm)</i>	<i>Pipe Thermal Resistance R_{pipe} ($^\circ\text{C}/\text{W}$)</i>	<i>Operating Max. Power Q (W)</i>
$\phi 6$ Length: 150mm Straight Pipe	Round	0.002 ~ 0.003	65
	3.0	0.003 ~ 0.004	60
	2.8	0.003 ~ 0.005	50
	2.6	0.003 ~ 0.005	45
	2.5	0.003 ~ 0.005	40
	2.4	0.004 ~ 0.006	35
	2.2	0.010 ~ 0.020	20

<i>Diameter D: (mm)</i>	<i>Flat t: (mm)</i>	<i>Pipe Thermal Resistance R_{pipe} ($^{\circ}C/W$)</i>	<i>Operating Max. Power Q (W)</i>
$\phi 6$ Length:200mm Straight Pipe	Round	0.002 ~ 0.003	45
	3.0	0.003 ~ 0.008	40
	2.5	0.003 ~ 0.010	35
	2.0	0.03 ~ 0.070	5

<i>Diameter D: (mm)</i>	<i>Flat t: (mm)</i>	<i>Pipe Thermal Resistance R_{pipe} ($^{\circ}C/W$)</i>	<i>Operating Max. Power Q (W)</i>
$\phi 8$ Length:150mm Straight Pipe	Round	0.002 ~ 0.007	80
	4.5	0.003 ~ 0.015	70

<i>Diameter D: (mm)</i>	<i>Flat t: (mm)</i>	<i>Pipe Thermal Resistance R_{pipe} ($^{\circ}C/W$)</i>	<i>Operating Max. Power Q (W)</i>
$\phi 8$ Length:200mm Straight Pipe	Round	0.002 ~ 0.007	75
	4.5	0.003 ~ 0.015	65

Note: $\phi 6$ heat pipe Increase ~50mm of pipe length, Operating max. power will drop \approx 15%

$\phi 8$ heat pipe Increase ~50mm of pipe length, Operating max. power will drop \approx 7%

*Approval List:

ITEM		SPECIFICATION
SHAPE	ROUND	$\phi 4 \sim \phi 8$
	FLAT	T = 1.6~3.5 mm
BENDING / SHAPE		Drawing
MATERIAL OF CONTAINER		C1020
WORKING FLUID		DI Water
WICK STRUCTURE		Grooved / Screen Mesh / Powder / Composite
FAIL TEMP (No cooling)	ROUND	300 °C Leakage
	FLAT	110~140 °C Inflation
MAX. HEAT TRANSFER RATE		0~80 W
APPLICATION INCLINATION		Horizontal
GUARANTY		3 Years

*Quality Control:

Heat Pipes after bending
and flatten

120°C, 48hrs Thermal Oven
Accelerated Life
(100%)

Qmxa Go/NG Test
(100%)

Burst Temp. Test
(Sampling)

1. Sintered Powder and Grooved are good in case of block high $\geq 4.0\text{mm}$
2. Mesh is good in case of all pipe need to flat to $\geq 1.6\text{ mm}$
3. Grooved is good in case of all pipe need to flat to $\geq 2.5\text{ mm}$
4. Bending $R_c \geq 4.5$ times of D is good
5. Bending $\theta \geq 90^\circ$ is good



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