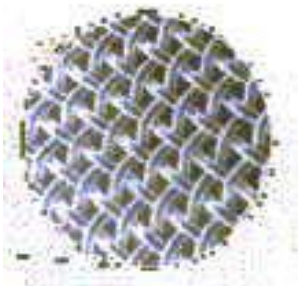
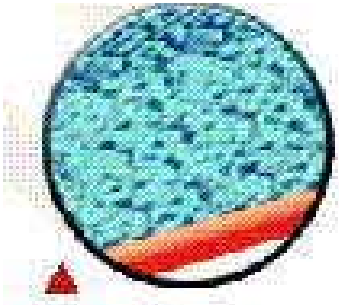
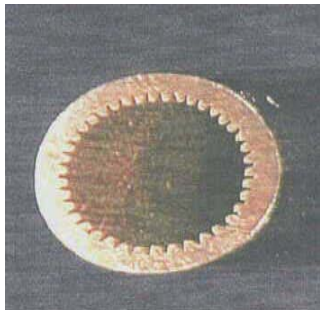
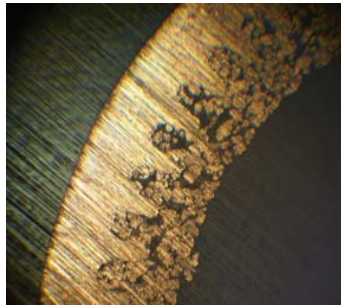
CCI HEAT PIPE DESIGN GUIDE

Rev: D01

Prepared by：CCI RD01 Heat Pipe Team

Date：27. June. 2006

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- Test methodology descriptions
- Screen Mesh
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- Sintering Powder
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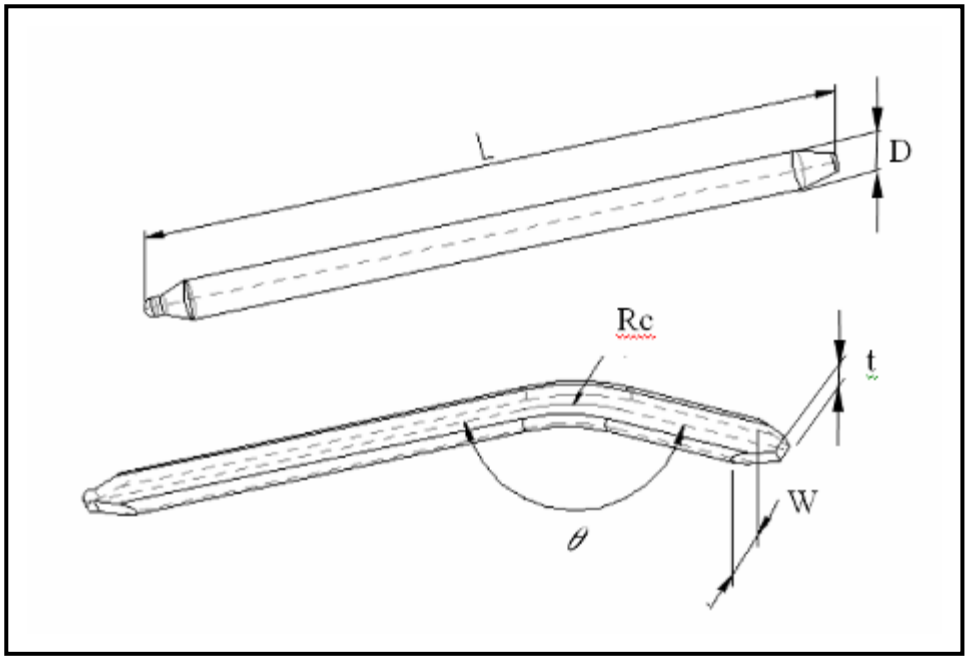
- Approval sheet

*Feature Descriptions

- Dimensions List

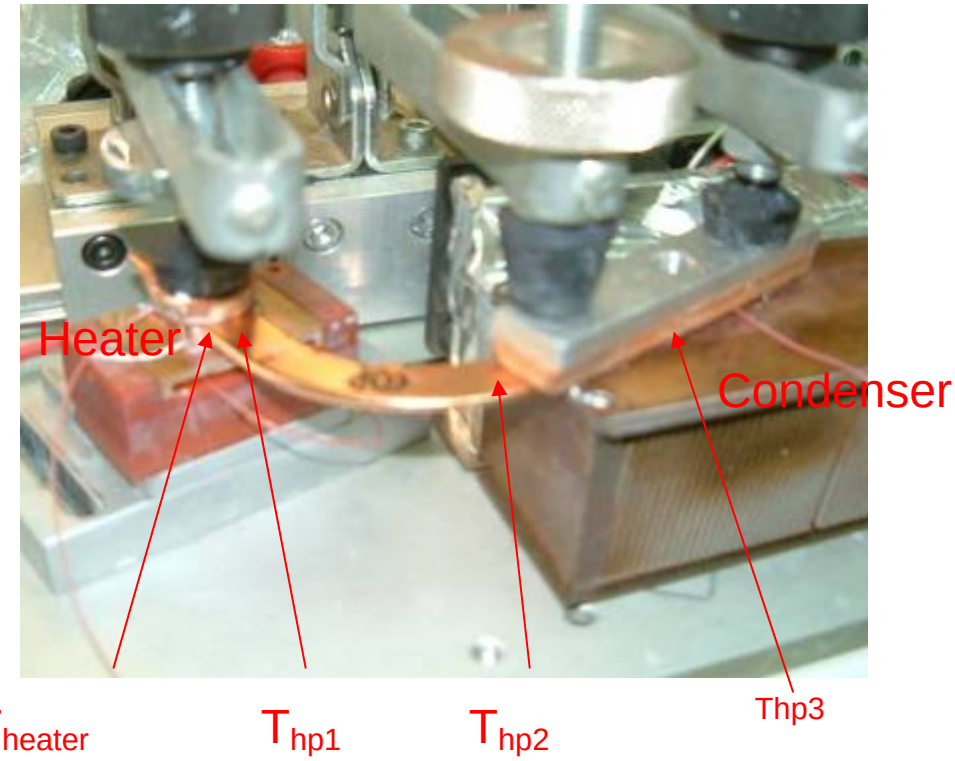


1.Mass Production Diameter : D= ϕ4, ϕ5, ϕ6, ϕ8 for Screen Mesh Pipe
D= ϕ4, ϕ5, ϕ6, ϕ8 for Grooved Pipe
D= ϕ6, ϕ8 for Sintering Powder Pipe
D= ϕ6, ϕ8 for Composite Pipe

2.Mass Production Length : L= 100 ~ 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} (℃): Heater temperature, sensor is embedded between Heater and evaporator section of heat pipe.
- T_{hp1} (℃): Evaporator temperature of heat pipe, measurement on heat pipe top side.
- T_{hp2} (℃): Adiabatic temperature of heat pipe, measurement on heat pipe top side. Keep this point at 45°C by Fan speed control.
- Thp3 (℃): Condenser temperature, sensor is embedded between HP and condenser section of heat pipe.



- Q(watts) : Input power
- $R_{heat\ pipe}$ ($^oC/W$)= $R_{(Evaporator\ Local\ contact\ effect)}$ + $R_{(pipe\ dimension\ effect)}$ + $R_{(Condenser\ Local\ contact\ effect)}$

  = $(T_{herter} - T_{hp1})/Q + (T_{hp1}-T_{hp3})/Q + (T_{hp3}-T_{sink})/Q$

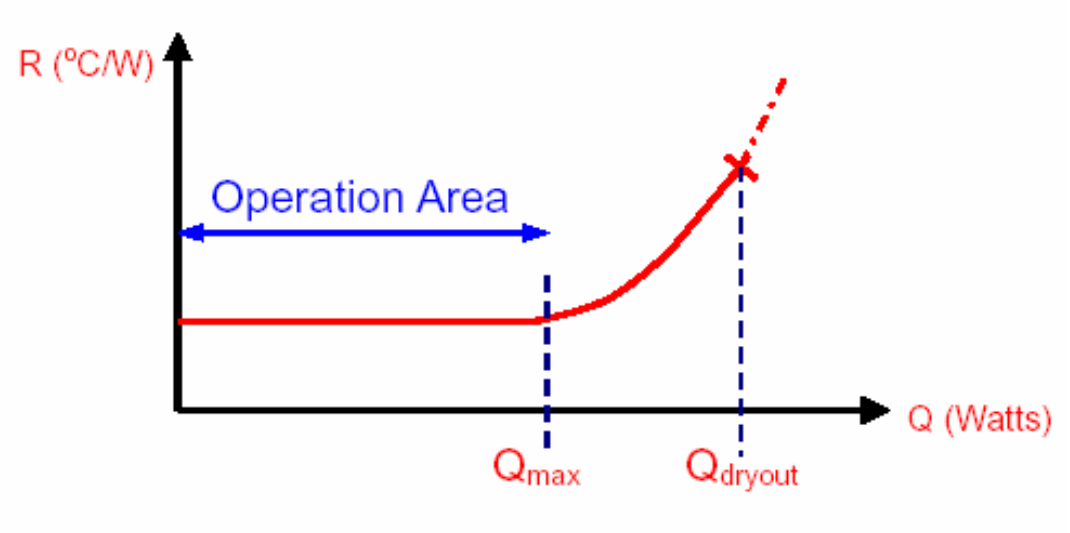
  = $(T_{herter}-T_{sink})/Q$

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

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

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

- Q_{max}(watts) : Thermal resistance $R_{heat\ pipe}$ is significant increase when Power input is larger than a certain Power.
- Q_{dryout}(watts) : Thermal resistance $R_{heatpipe}$ 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≧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≧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≧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≧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≧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 ^{o}C

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

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

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

Diameter D: (mm)	Flat t: (mm)	Pipe Thermal Resistance R_{pipe} (℃/W)	Operating Max. Power Q (W)
ϕ6 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

Diameter D: (mm)	Flat t: (mm)	Pipe Thermal Resistance R_{pipe} (℃/W)	Operating Max. Power Q (W)
ϕ8 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

Diameter D: (mm)	Flat t: (mm)	Pipe Thermal Resistance R_{pipe} (℃/W)	Operating Max. Power Q (W)
ϕ8 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

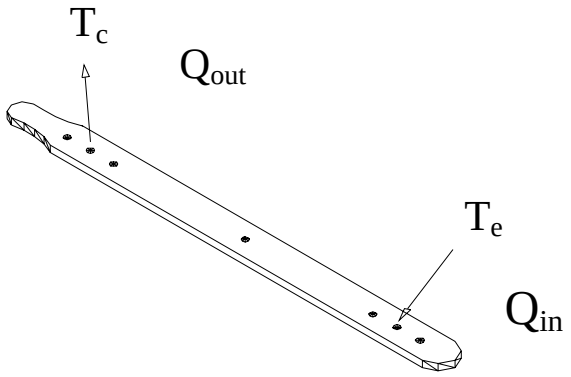
Note: Increase ~ 50mm of pipe length, Operating max. will drop ≈ 12%

* Performance Reference 2: Grooved type

Conditions •Heating / Cooling: Evaporator section Le＝15 ㎜ electric resistance heater,
Condenser section Lc＝60 ㎜ with fin air cooling

•Orient : Horizontal

•Working Temperature (Adiabatic) : 70 °C



$$R_{pipe} = (Te - Tc) / Q_{in}$$

Diameter D: (mm)	*Flat t: (mm)*	*Pipe Thermal Resistance R_{pipe} (℃/W)*	*Operating Max. Power Q (W)*
ϕ5 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} (℃/W)	Operating Max. Power Q (W)
ϕ5 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} (℃/W)	Operating Max. Power Q (W)
ϕ6 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} (℃/W)	Operating Max. Power Q (W)
ϕ6 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

Diameter D: (mm)	Flat t: (mm)	Pipe Thermal Resistance R_{pipe} (℃/W)	Operating Max. Power Q (W)
ϕ6 Length:200mm Straight Pipe	Round	0.02 ~ 0.03	45
	3.0	0.03 ~ 0.08	40
	2.5	0.03 ~ 0.10	35
	2.0	0.03 ~ 0.70	5

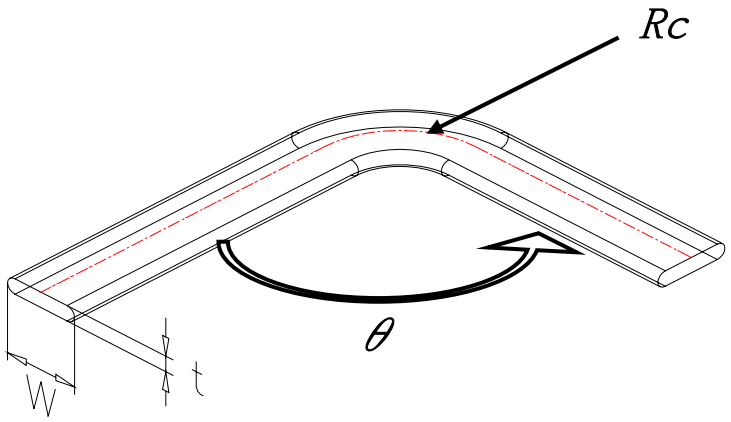
Diameter D: (mm)	Flat t: (mm)	Pipe Thermal Resistance R_{pipe} (℃/W)	Operating Max. Power Q (W)
ϕ8 Length:150mm Straight Pipe	Round	0.002 ~ 0.007	80
	4.5	0.003 ~ 0.015	70

Diameter D: (mm)	Flat t: (mm)	Pipe Thermal Resistance R_{pipe} (℃/W)	Operating Max. Power Q (W)
ϕ8 Length:200mm Straight Pipe	Round	0.002 ~ 0.007	75
	4.5	0.003 ~ 0.015	65

Note: ϕ6 heat pipe Increase ~50mm of pipe length, Operating max. power will drop ≈ 15%

ϕ8 heat pipe Increase ~50mm of pipe length, Operating max. power will drop ≈ 7%

Diameter D: (mm)	θ: (°)	Pipe Thermal Resistance R_{pipe} (℃/W)	Operating Max. Power Q (W)
ϕ6 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



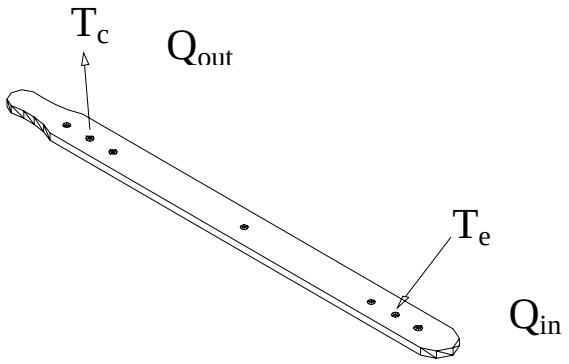
Note: Through one 90° bend, Operating max. power will drop ≈ 25%.

* Performance Reference 3: Sintering Powder type

Conditions •Heating / Cooling: Evaporator section Le＝15 ㎜ electric resistance heater,
Condenser section Lc＝60 ㎜ wi

•Orient : Horizontal

•Working Temperature (Adiabatic) : 70 °C



R_{pipe}＝（Te－Tc）/ Q_{in}

Diameter D: (mm)	*Flat t: (mm)*	*Pipe Thermal Resistance R_{pipe} (℃/W)*	*Operating Max. Power Q (W)*
ϕ5 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} (℃/W)*	*Operating Max. Power Q (W)*
ϕ5 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*

Diameter D: (mm)	Flat t: (mm)	Pipe Thermal Resistance R_{pipe} (℃/W)	Operating Max. Power Q (W)
ϕ6 Length:100mm Straight Pipe	Round	0.02 ~ 0.03	75
	3.0	0.02 ~ 0.04	70
	2.5	0.03 ~ 0.05	45

Diameter D: (mm)	Flat t: (mm)	Pipe Thermal Resistance R_{pipe} (℃/W)	Operating Max. Power Q (W)
ϕ6 Length:150mm Straight Pipe	Round	0.02 ~ 0.03	65
	3.0	0.03 ~ 0.04	60
	2.5	0.03 ~ 0.05	40

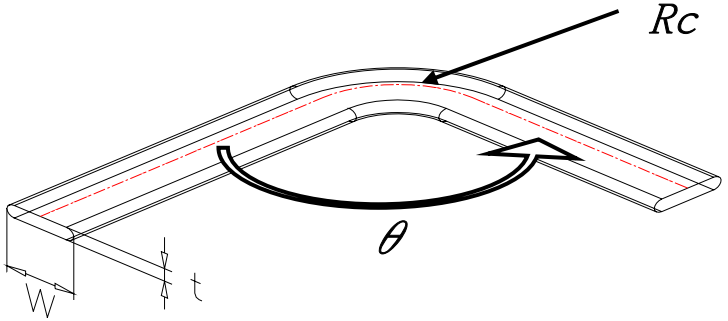
Diameter D: (mm)	Flat t: (mm)	Pipe Thermal Resistance R_{pipe} (℃/W)	Operating Max. Power Q (W)
ϕ6 Length:200mm Straight Pipe	Round	0.02 ~ 0.03	50
	3.0	0.03 ~ 0.06	45
	2.5	0.03 ~ 0.08	35

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

Diameter D: (mm)	Flat t: (mm)	Pipe Thermal Resistance R_{pipe} (℃/W)	Operating Max. Power Q (W)
ϕ8 Length:150mm Straight Pipe	Round	0.002 ~ 0.004	80
	4.5	0.003 ~ 0.011	70

Diameter D: (mm)	Flat t: (mm)	Pipe Thermal Resistance R_{pipe} (℃/W)	Operating Max. Power Q (W)
ϕ8 Length:275mm Straight Pipe	Round	0.002 ~ 0.004	80
	4.5	0.003 ~ 0.012	70

Diameter D: (mm)	θ: (°)	Pipe Thermal Resistance R_{pipe} (℃/W)	Operating Max. Power Q (W)
ϕ6 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



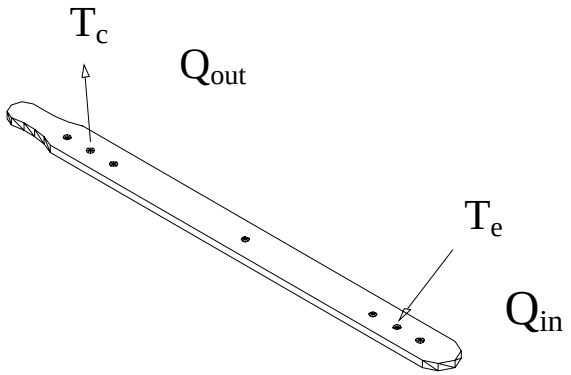
Note: Through one 90° bend, Operating max. power will drop ≈ 25%.

* Performance Reference 2: Composive type (Groove Powder)

Conditions •Heating / Cooling: Evaporator section Le＝15 ㎜ electric resistance heater,
Condenser section Lc＝60 ㎜ with fin air cooling

•Orient : Horizontal

•Working Temperature (Adiabatic) : 70 ^{o}C



R_{pipe}＝（Te－Tc）/ Q_{in}

Diameter D: (mm)	*Flat t: (mm)*	*Pipe Thermal Resistance R_{pipe} (℃/W)*	*Operating Max. Power Q (W)*
ϕ6 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*

Diameter D: (mm)	Flat t: (mm)	Pipe Thermal Resistance R_{pipe} (℃/W)	Operating Max. Power Q (W)
ϕ6 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

Diameter D: (mm)	Flat t: (mm)	Pipe Thermal Resistance R_{pipe} (℃/W)	Operating Max. Power Q (W)
ϕ8 Length:150mm Straight Pipe	Round	0.002 ~ 0.007	80
	4.5	0.003 ~ 0.015	70

Diameter D: (mm)	Flat t: (mm)	Pipe Thermal Resistance R_{pipe} (℃/W)	Operating Max. Power Q (W)
ϕ8 Length:200mm Straight Pipe	Round	0.002 ~ 0.007	75
	4.5	0.003 ~ 0.015	65

Note: ϕ6 heat pipe Increase ~50mm of pipe length, Operating max. power will drop ≈ 15%

ϕ8 heat pipe Increase ~50mm of pipe length, Operating max. power will drop ≈ 7%

*Approval List:

ITEM		SPECIFICATION
SHAPE	ROUND	ϕ4～ϕ8
	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 ℃ Leakage
	FLAT	110~140 ℃ Inflation
MAX. HEAT TRANSFER RATE		0～80 W
APPLICATION INCLINATION		Horizontal
GUARANTY		3 Years

*Quality Control:

1. Sintered Powder and Grooved are good in case of block high >= 4.0mm
2. Mesh is good in case of all pipe need to flat to >= 1.6 mm
3. Grooved is good in case of all pipe need to flat to >= 2.5 mm
4. Bending R_c>= 4.5 times of D is good
5. Bending θ >= 90^o is good

Heat Pipes after bending

and flatten

120℃,48hrs Thermal Oven Accelerated Life

(100%)

Qmxa Go/NG Test

(100%)

Burst Temp. Test

(Sampling)