COSEL

Thermal Design
Application Manual
HCA3500TF

Ver1.2　2023.11.10

Contents

Note) The contents described in this document are those available at the time of publication and are subject to change without prior notice due to product improvement and corresponding changes in the specifications. Please check the homepage of COSEL for the latest version.
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1. Thermal Design

1.1 Assembling and Installation Method

■Use with the conduction cooling e.g. water-cooled plate. The following installation is recommended.

■Recommended screw is M4. Select a screw length that allows the effective thread to be fastened to the water-cooled plate at least 4 mm.（A screw length of 60mm or more is recommended.）

■The recommended torque for the mounting screws is 0.94－1.25Nm when the male screw is iron and the water-cooled plate is aluminum or copper.

■The aluminum base plate should be cooled uniformly.

■Use TIM (Thermal interface material) such as the thermal grease between the aluminum base plate and the water-cooled plate. It is recommended to use TIM with a thermal conductivity of 1 W/mK or more.

■The unit can be mounted in any direction. When two or more power supplies are used side by side, the aluminum base plate temperature of each power supply should not exceed the temperature range shown in Item 1.2 “Derating curve depends on Output voltage”.

Fig.1.1 Assembling and Installation Method

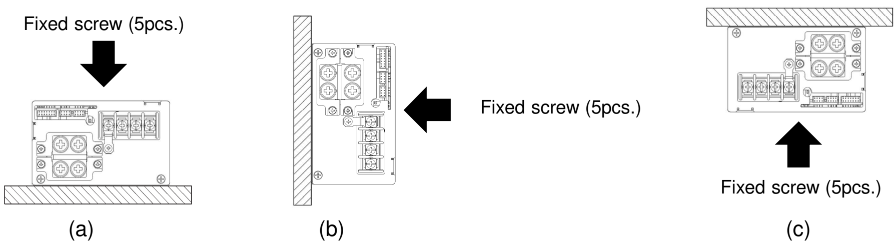
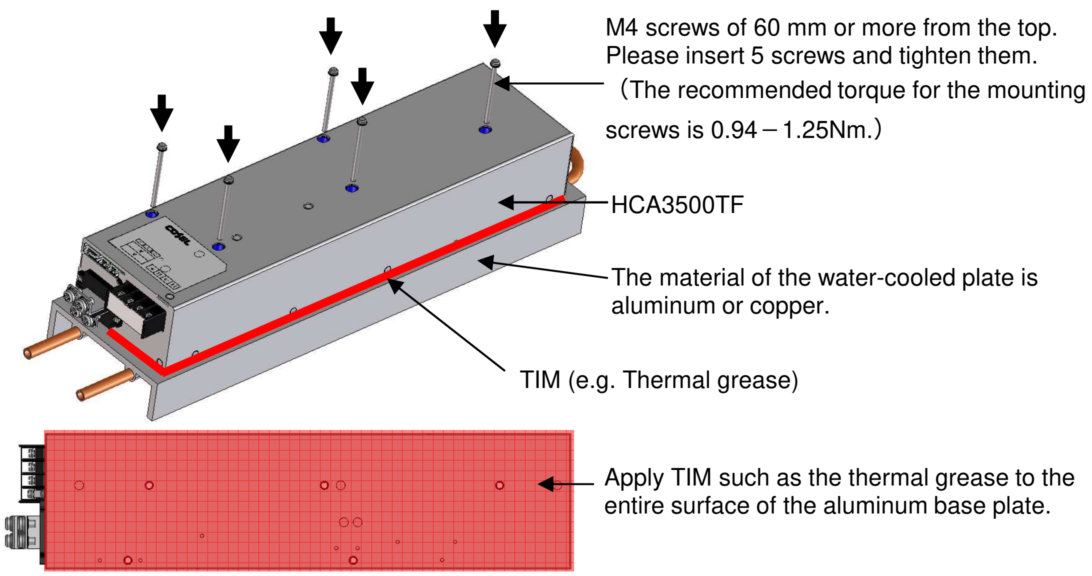


Fig.1.2 Recommended mounting example

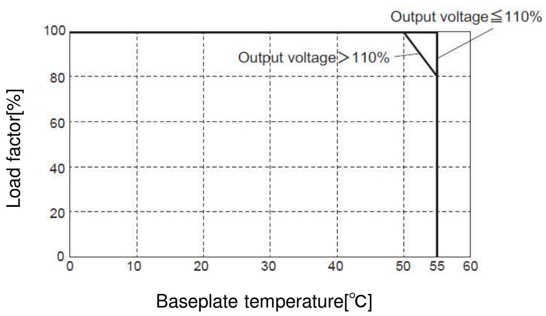


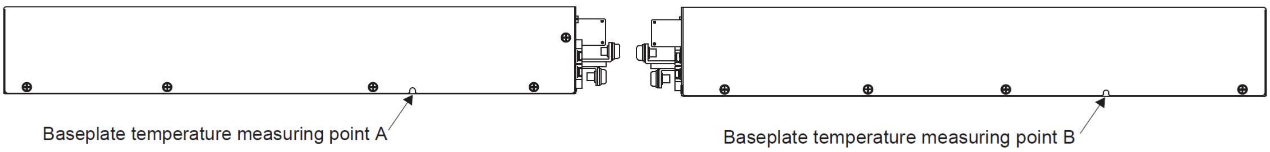
Aluminum base plate side of HCA3500TF

1.2 Derating curve depends on Output voltage

■The unit should be used by the conduction cooling such as the water-cooled plate.
■The temperature of both points A and B has to be within the derating curve.
■Ambient temperature must keep between -10℃ and 70℃.

Fig.1.3
Derating curve



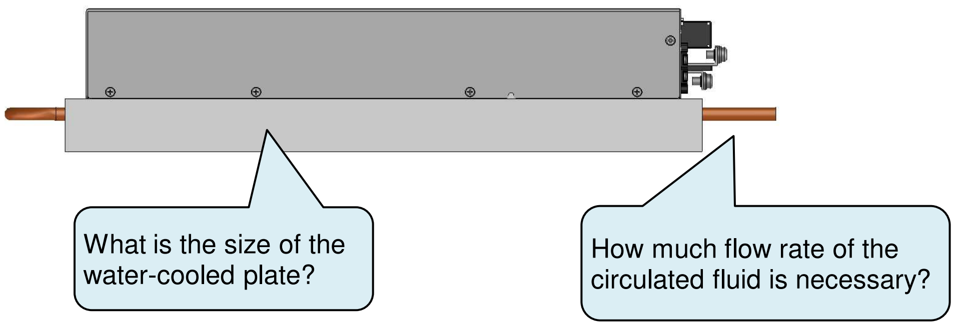


1.3 Thermal Design

1)Overview

To ensure operation of HCA3500TF, it is necessary to keep base plate temperature within the allowable temperature limit. The temperature should be measured in the actual condition. Before that, it is advised to conduct the thermal design since it may be related to the final product.

Fig.1.4
Overview of Thermal Design



2) Thermal design calculations

①Power dissipation

Not all of the input power is converted to the output power since some loss is dissipated as heat. The Power dissipation of the power supply can be calculated as below.

$Pin = Vin \times Iin \cdots (1)$

$Pout = Vout \times Iout \cdots (2)$

$\eta = \frac{Pin}{Pout} \times 100 \cdots (3)$

$Pd = Pin - Pout \cdots (4)$

OR

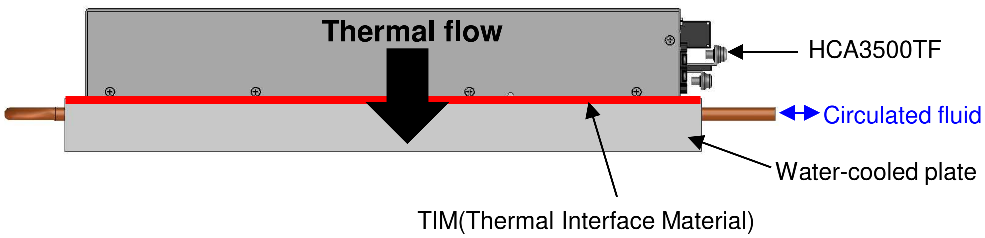
$Pd = \frac{1-\eta}{\eta} \times Pout \cdots (5)$

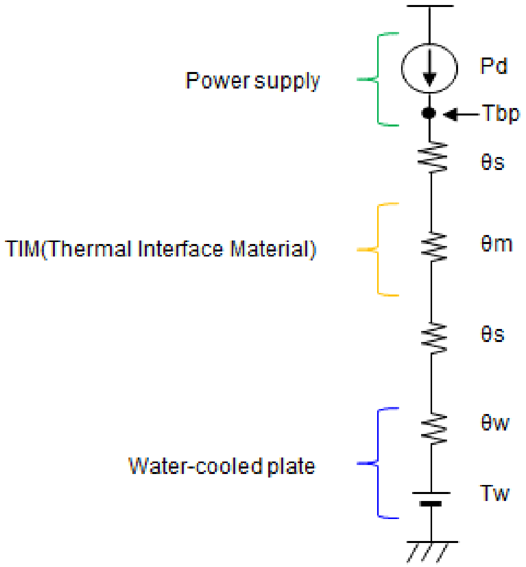
Pin : Input power[W]
Pout : Output power[W]
Pd : Power dissipation [W]
η : Efficiency [%]

②Thermal resistance

In the case of the HCA series, heat will be conducted from the base plate into an attached water-cooled plate through the thermal interface material. Fig. 1.5 is the equivalent thermal circuit. The base plate temperature in arbitrary conditions can be calculated with thermal resistance of the water-cooled plate and the thermal interface material by the equivalent thermal circuit.

Fig.1.5
Equivalent
thermal circuit





Pd : Power dissipation [W]
Tbp : Upper limit temperature of base plate [℃]
θs : Thermal contact resistance [℃/W]
θm : Thermal resistance of TIM [℃/W]
θw : Thermal resistance of water-cooled plate [℃/W]
Tw : Circulated fluid temperature [℃]

Base plate temperature is calculated by following equation.

$Tbp = Pd \times (\theta s + \theta m + \theta s + \theta w) + Tw \cdots (6)$

③Thermal design example

The process of thermal design is described through an example of HCA3500TF-65. The required thermal resistance of water-cooled plate at use conditions is calculated.

Use conditions
・Output voltage：65V
・Output current：50A

Step1 Calculate power dissipation

Download HCA3500TF-65 characteristic of from the "Performance Data" on COSEL website. The efficiency data in the Performance Data can be used to calculate the dissipation power.

$$Pout = Vout \times Iout \cdots (7)$$
$$= 65 \times 50$$
$$= 3250\ [W]$$

Pin：Input power [W]
Pout：Output power [W]
Pd：Power dissipation [W]
η：Efficiency [%]

$$Pd = \frac{1-\eta}{\eta} \times Pout \cdots (8)$$
$$= \frac{1-0.947}{0.947} \times 3250$$
$$= 181.89\ [W]$$

Table.1.1
Performance Data

Load Current [A]	Efficiency [%] Input Voltage 200[V]	Input Voltage 400[V]	Input Voltage 480[V]
0.0	-	-	-
5.0	85.6	86.1	86.2
10.0	89.6	90.7	90.8
20.0	92.7	94.1	94.4
25.0	93.0	94.6	94.7
30.0	93.0	94.6	94.8
40.0	92.9	94.7	94.9
50.0	92.7	94.7	95.0
54.0	92.5	94.6	94.9
59.4	92.3	94.5	94.8
-	-	-	-

Efficiency at
Vin = 400VAC
Iout = 50A

※For reference

Step2 Calculate thermal resistance of Thermal interface material

The thermal interface material (TIM) shall be placed in contact surfaces to reduce thermal resistance and increase heat dissipation efficiency. The base plate of the power supply and the water-cooled plate as contact surfaces have surface asperities since they are made by metal. When these surfaces are contacted, the thermal resistance will be unstable and increased by the air gap.

The soft material such as the grease or the silicone should be attached between the base plate of the power supply and the water-cooled plate so that the thermal contact resistance can be reduced since it can fill up the air gap. It is so difficult to obtain the actual value of the thermal contact resistance since it depends on many conditions like a contact pressure and the hardness of the surface material. On this calculation example, the thermal pad and "3" of the thermal contact resistance as the worst case will be used.

Table.1.2
Thermal contact resistance

Thermal Interface Materials	Thermal contact resistance [℃・cm^2/W]※1
Thermal grease	0.2～1
Thermal pad	1～3

※1 Thermal contact resistance per unit area.
It is inversely proportional to contact pressure and proportional to hardness of surface material.

※For reference only.

Fig.1.6
Necessity of TIM

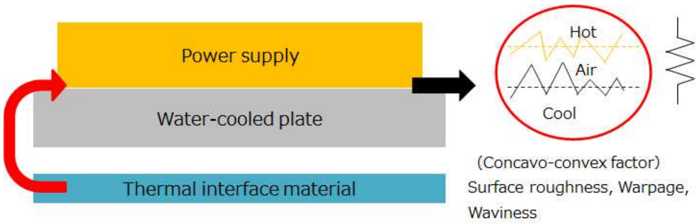


Fig.1.7
Thermal resistance of TIM

$$\theta s = \frac{\theta s(\text{per unit area})}{Sp} \cdots (9)$$

$$= \frac{3 \times 10^2}{110 \times 420}$$

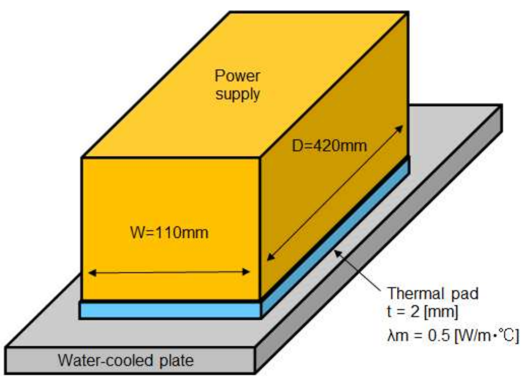
$$= 0.0065\ [℃/W]$$

$$\theta m = \frac{t}{\lambda m \times Sp} \cdots (10)$$

$$= \frac{2 \times 10^3}{0.5 \times 110 \times 420}$$

$$= 0.0866\ [℃/W]$$

θs：Thermal contact resistance [℃/W]
θs(per unit area)：Thermal contact resistance per unit area [℃・cm^2/W]
Sp：Area of Power supply base plate [mm^2]
θm：Thermal resistance of TIM [℃/W]
t：Thickness of TIM [mm]
λm：Thermal conductivity of TIM [W/m・℃]



Step3 Calculate thermal resistance of water-cooled plate

From the power dissipation calculated in Step 1, calculate the thermal resistance required for the entire heat dissipation path.

$$\theta t = \frac{Tbp - Tw}{Pd} \cdots (11)$$

$$= \frac{55-28}{181.89}$$

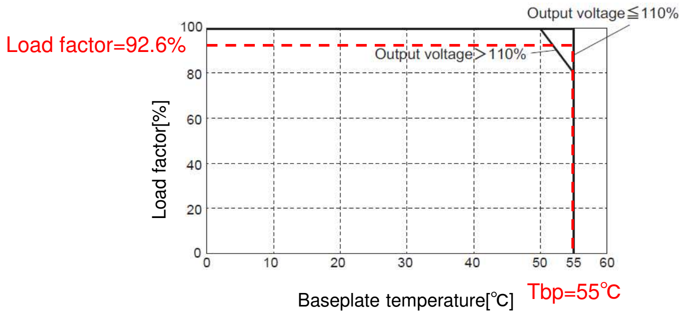
$$= 0.148 \ [℃/W]$$

θt : Thermal resistance of entire heat dissipation path [℃/W]

Tbp : Upper limit temperature of base plate [℃]
55℃ at Iout=50A (Load factor=92.6%)
from item 1.2 "Derating curve depends on Output voltage"

Tw : Temperature of circulated fluid [℃]
It is assumed to 28 at this calculation.

Fig.1.8 Upper limit temperature of base plate



From the thermal resistances θs, θm, and θt obtained in Step 2, calculate the thermal resistance θw required for the water-cooled plate.

$$\theta w = \theta t - \theta s \times 2 - \theta m \cdots (12)$$

$$= 0.137 - 0.0065 \times 2 - 0.0866$$

$$= 0.049 \ [℃/W]$$

θw : Thermal resistance of water-cooled plate [℃/W]

θt : Thermal resistance of the entire heat dissipation path [℃/W]

θs : Thermal contact resistance [℃/W]

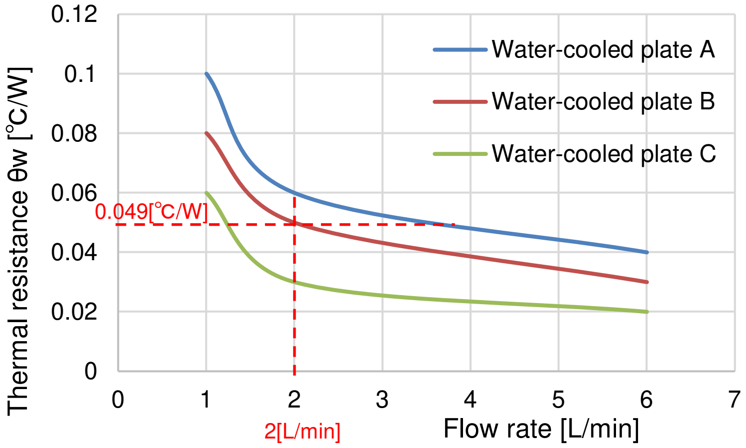
θm : Thermal resistance of TIM [℃/W]

Step4 Selection of water-cooled plate

Based on the obtained θw, select a required water-cooled plate. Make the assumption that water-cooled plates A, B and C which have the characteristic as shown in Fig.1.9 are candidates. The thermal resistance of the water-cooled plate depends on the flow rate of the circulated fluid. When the assumed flow rate is 2L/min, it can be considered as follows.

Water-cooled plate A is inappropriate.
Water-cooled plate B is borderline.
Water-cooled plate C is appropriate with enough margin.

Fig.1.9
Selection example of water-cooled plate



Step5 Check the design with actual equipment

Measure the aluminum base plate temperature under actual conditions and confirm whether it is below 55°C.

3) Note for thermal design

①Thermal design example

Although the design procedure is shown above, please use the thermal design example only for a reference. The design example is not including the thermal radiation. Design values and measured values do not necessarily match due to factors in the surrounding environment.

If the base plate temperature is higher than the design calculation value, reduce the thermal resistance of the water-cooled plate in the following ways.

◎Change to a water-cooled plate with low thermal resistance.

◎Increase the flow rate of the circulated fluid.

②Water-cooled plate characteristics

In general, the thermal resistance of the water-cooled plate on the manufacturer's catalog do not include the thermal contact resistance. Since the thermal contact resistance of the water-cooled plate changes greatly depending on the installation condition, be sure to measure the base plate temperature on the actual condition.

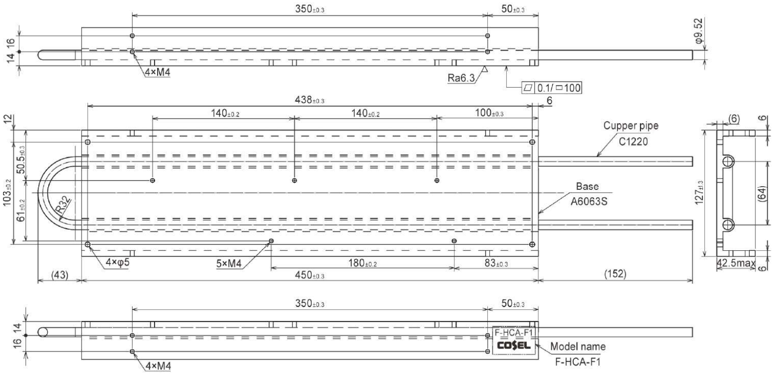
1.4 Examples of conduction cooling

■Here is an example of conduction cooling with water-cooled plate.

■Since the available output power depends on the heat dissipation condition and so on, this is just a design reference. Measure the base plate temperature under the actual conditions.

Fig.1.10 Water-cooled plate example

F-HCA-F1 Optional Parts
Thermal resistance : 0.035°C/W (at 2L/min)



Circulated fluid : Water
Circulated fluid temperature : 20°C

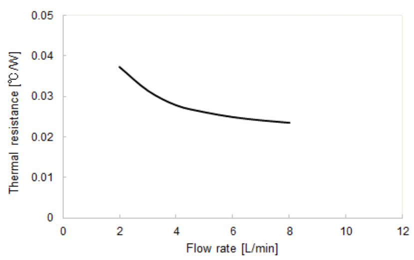
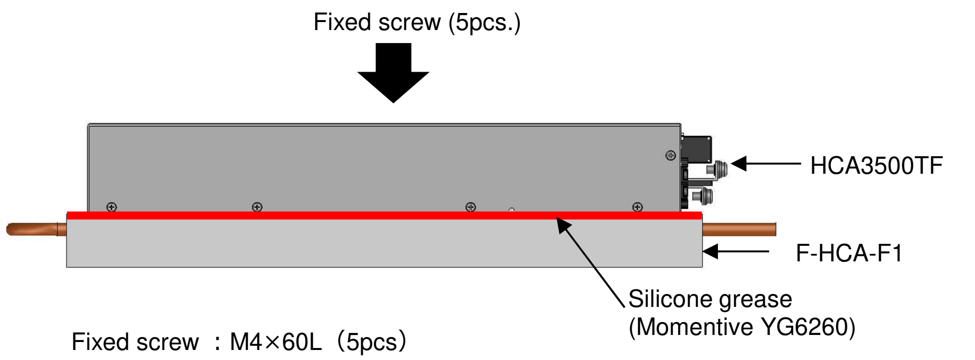


Fig.1.11 Environment



Fixed screw : M4×60L (5pcs)

Material : iron

Torque for the mounting screws is 0.94－1.25Nm

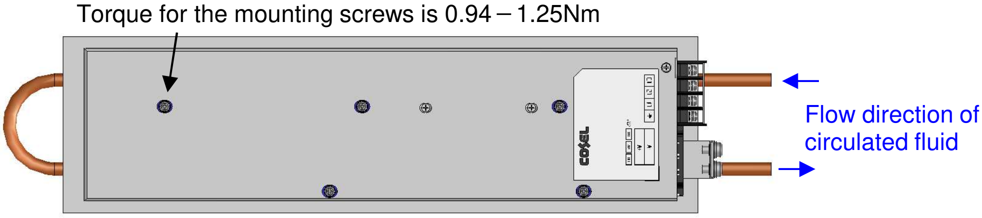
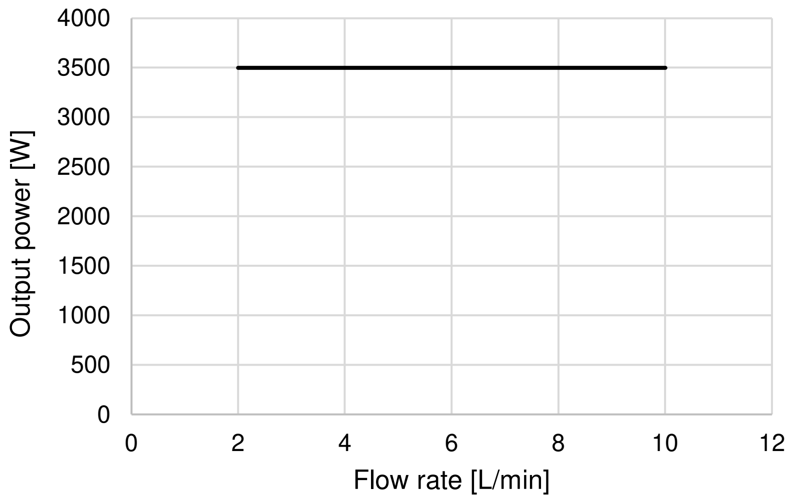


Fig1.12
Measurement result



Measurement conditions
■Power supply:HCA3500TF-48
■Ambient temperature:70°C
■Circulated fluid temperature:40°C

A. Revision history

No.	Date	Rev.	Page	Content
1	2023.5.23	1.0	-	First edition.
2	2023.8.1	1.1	5	Fixed typos in formulas (9) and (10).
3			6	Change the wording in Step4.
4	2023.11.10	1.2	7	Fig1.10 Change the Water-cooled plate part number.
5				Fig1.11 Add the Water-cooled plate part number.
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