8. Thermal Considerations

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8.1 Overview

■To ensure operation of power module, it is necessary to keep baseplate temperature within the allowable temperature limit. The reliability of the power module depends on the temperature of the baseplate. In order to obtain maximum reliability, keep the aluminum base plate temperature low.

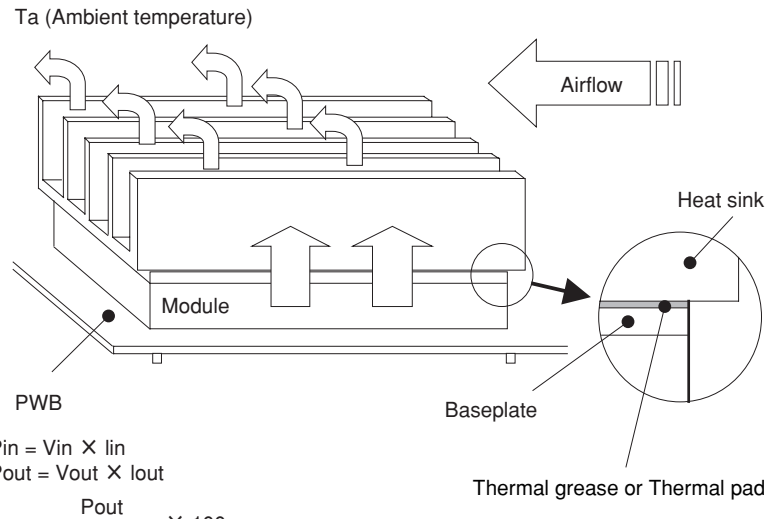
■Proper thermal design makes higher MTBF, smaller size and lower costs.

8.2 Efficiency and Dissipation power

■Not all of the input power is converted to output power, some loss is dissipated as heat power module inside. To determine the internal power dissipation, give 1 - 2 % margin of the efficiency value which is calculated by Characteristics of Efficiency vs. Output current.

■Efficiency is defined as percentage of Output power vs Input power. Efficiency (η) depends on input voltage and output current. Refer to the individual data. Here "Efficiency characteristic of CBS2004812" is shown in Fig.8.2.2 as an example.

Fig.8.2.1
Internal power dissipated



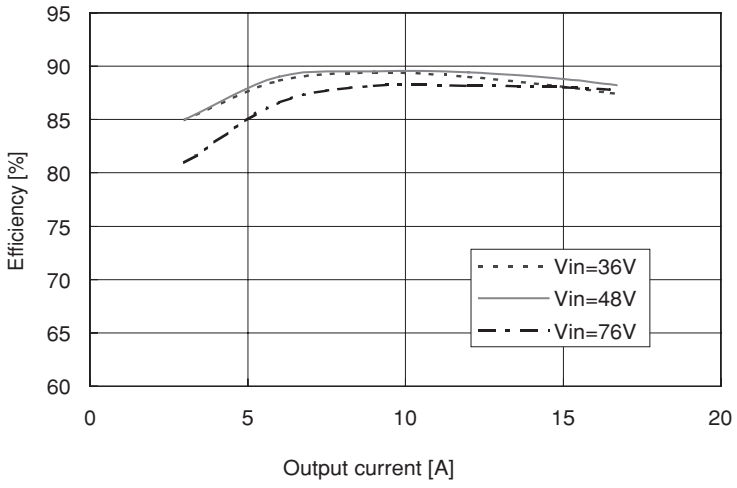
Pin = Vin × Iin
Pout = Vout × Iout

$$\eta = \frac{Pout}{Pin} \times 100$$

$$Pd = \frac{1 - \eta}{\eta} \times Pout$$

Pin : Input power(W)
Pout : Output power(W)
Pd : Internal power dissipated(W)
η : Efficiency(%)

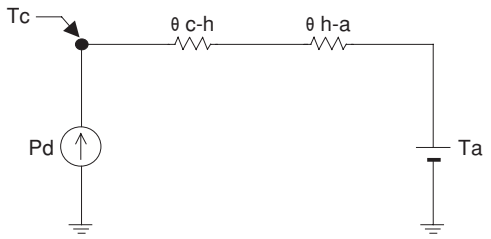
Fig.8.2.2
CBS2004812
Characteristics of
Efficiency vs.
Output current



8.3 Thermal resistance

■In most applications, heat will be conducted from the baseplate into an attached heat sink. Heat conducted across the interface between the baseplate and heat sink will result in a temperature drop which must be controlled. As shown in Fig.8.3.1, the interface can be modeled as a "thermal resistance" with the dissipated power flow.

Fig.8.3.1
Thermal resistance



The thermal resistance of heat sink is calculated by the following equation.

$$\theta \text{ h-a} = \frac{Tc - Ta}{Pd} - \theta \text{ c-h}$$

θ h-a : Thermal resistance of Heat sink (℃/W) (Heat sink - Air)
θ c-h : Contact thermal resistance (℃/W) (Baseplate - Heat sink)
Pd : Internal power dissipated (W)
Tc : Baseplate temperature (℃)
Ta : Ambient temperature (℃)

■Contact thermal resistance is between baseplate and heat sink. To decrease the contact thermal resistance, use thermal grease and thermal pad. When using thermal grease, apply in a uniform thin coat.

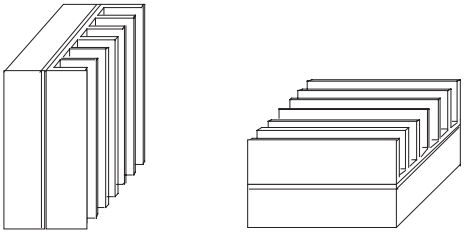
■The thermal grease and thermal pad have the following respective features.
(1) Thermal grease : low thermal resistance (0.2 - 0.3℃/W).
(2) Thermal pad : higher than thermal grease (0.3 - 0.4℃/W).

8.4 Convection cooling

■The benefits of convection cooling is low cost implementation, no need for fans, and the inherent reliability of the cooling process. Compared to forced air cooling, convection cooling needs more heat sink volume to cool down an equivalent baseplate temperature. Thermal resistance depends on heat sink shape. Therefore, refer to the detailed thermal resistance data supplied by the manufacturer prior to the selection.

■Heat sink data is almost always given for vertical fin orientation. Orienting the fins horizontally will reduce cooling effectiveness. If horizontal mounting is required, obtain relevant heat sink performance data or use forced air cooling.

Fig.8.4.1
Mounting method



(a) Vertical mounting (b) Horizontal mounting

8.5 Forced air cooling

■In forced air cooling method, heat dissipation ability of the heat sink improves much higher than convection cooling. Refer to 8.9 Heat sink size and Thermal resistance.
”Dirty” environments will require filters that must be changed regularly to maintain cooling efficiency, and neglecting to change a filter or the failure of the fan could cause the system to shut down or malfunction.

8.6 Notes on Thermal design

8.6.1 Baseplate temperature

■CBS series : Refer to Fig.8.6.1 for derating curve.
■DBS/CDS series : Refer to Fig.8.6.2 for derating curve.
■Measure the baseplate temperature at the center of the baseplate.

Fig.8.6.1
The CBS series
derating curve

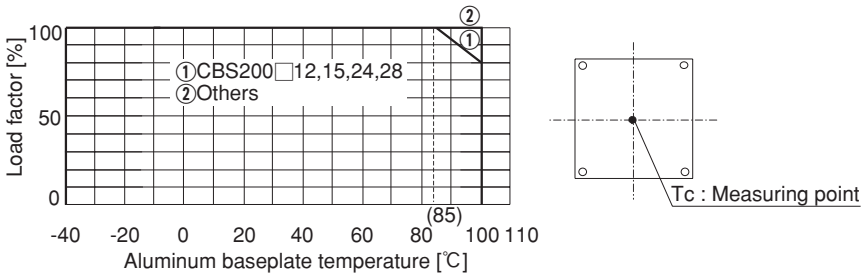
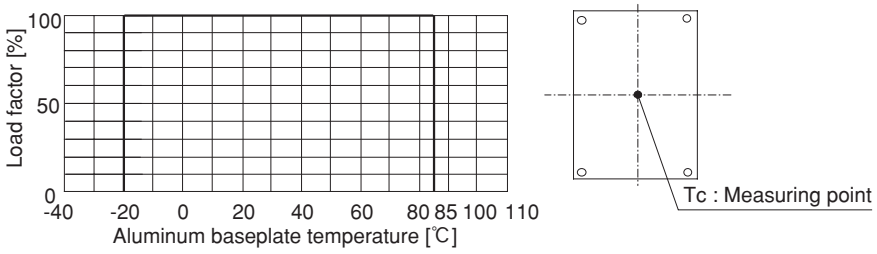


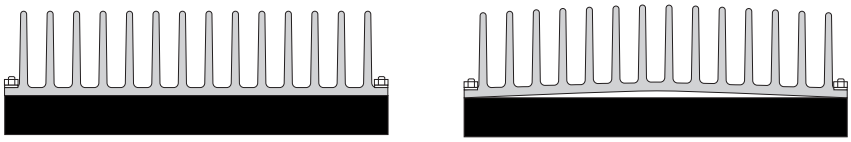
Fig.8.6.2
The DBS/CDS series
derating curve



8.6.2 Heat sink mounting

■The interface between the baseplate and heat sink is smooth, flat and free of debris.

■Unless the baseplate and the heat sink are placed in close contact with each other, contact thermal resistance will increase until heat radiation becomes insufficient. Always use either thermal grease or thermal pads.



Good Poor

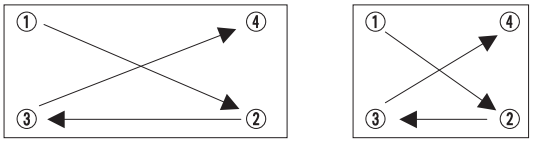
■To install the heat sink, fasten with screws through all four mounting holes.

■When mounting heat sinks to modules, use M3 screws torqued uniformly through the mounting holes provided. The following tightening sequence should be used.

(1) Lightly finger-tighten all screws.

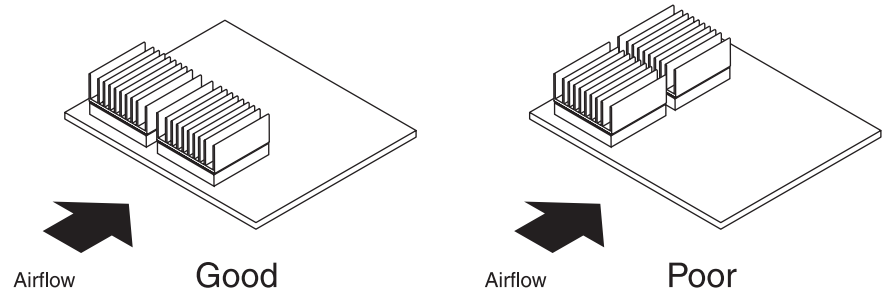
(2) Torque screws to 0.4N・m (5.0kg・cm) max as shown in Fig.8.6.3.

Fig.8.6.3
Torquing sequence

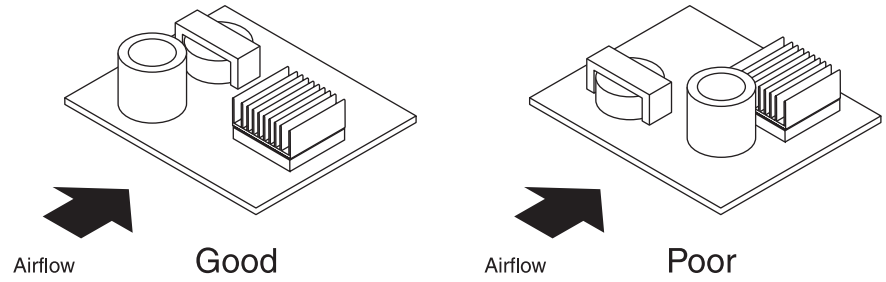


8.6.3 Installation of modules

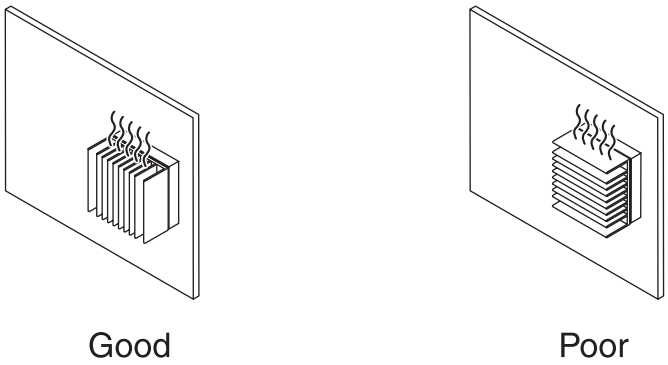
■Stagger modules to improve cooling and facilitate even heat distribution between modules.



■Avoid blocking the airflow to the modules with other components.



■Use a heat sink with fins running vertically for natural convection.



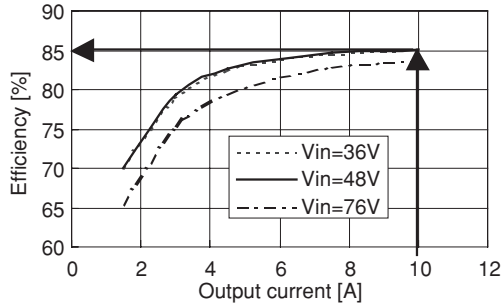
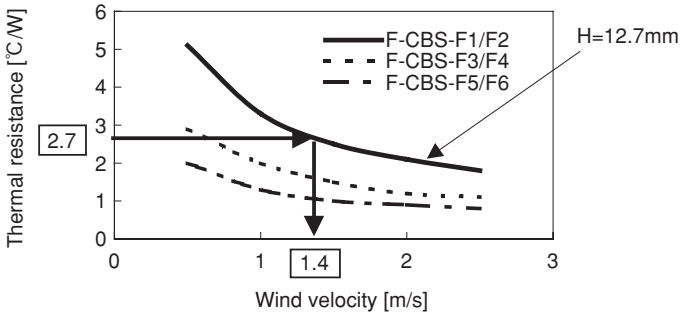
8.7 Thermal design example

■The process of thermal design is described through an example of CBS504805.

Conditions

Input voltage = 48 [V]　　Max. ambient temperature (Ta) = 50 [℃]　　Aluminum baseplate temperature (Tc) = 80 [℃]

Output voltage = 5 [V]　　Output current = 10 [A]

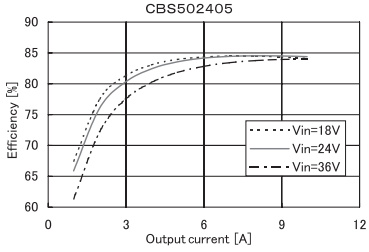
Step	Description	Design example
1	Determine the required output power (Pout) and ambient temperature (Ta) and aluminum baseplate temperature (Tc).	For higher reliability, the aluminum baseplate temperature is set up below 80℃. Ta = 50 [℃] Pout = 5 [V] × 10 [A] = 50 [W] Tc = 80 [℃]
2	Obtain the efficiency (η).	Efficiency (η) is obtained by Fig.8.7.1. Refer to 8.8 Efficiency vs. Output current. The efficiency of CBS504805 is obtained by operating at rated input (DC48V). The efficiency is 85% at DC48V input voltage and 100% output current. To give 2% efficiency will be : Efficiency (η) = 83 [%]  Fig.8.7.1 CBS504805 Characteristics of Efficiency vs. Output current
3	Calculate the internal power dissipation (Pd).	$Pd = \frac{1 - 0.83}{0.83} \times 50 = 10.2$ [W]
4	Obtain contact thermal resistance (θ c-h).	Use a thermal grease with a thermal resistance of 0.2℃/W.
5	Calculate thermal resistance of Heat sink (θ h-a).	θ h-a = $\frac{80 - 50}{10.2} - 0.2 = 2.7$ [℃/W]
6	Choose the heat sink.	Use a heat sink with H = 12.7mm. Refer to Fig.8.9.1 F-CBS-F1.
7	Obtain the required wind velocity.	Wind velocity is obtained by Fig.8.7.2. The wind velocity required to reduce the resistance to set up 2.7℃/W or below. Refer to 8.9 Heat sink size and Thermal resistance. Wind velocity required here is 1.4m/s or higher.  Fig.8.7.2 Heat sink thermal resistance curves
8	Choose the fan.	Choose the fan capable of supplying air at a velocity of 1.4m/s or higher.
9	Check the design with actual equipment.	Experience shall be conducted with CBS504805. Measure the aluminum baseplate temperature at actual conditions (Pout = 50W, Ta = 50℃). Then confirm the baseplate temperature has been kept below 80℃. The thermal design is completed.

8.8 Efficiency vs. Output current

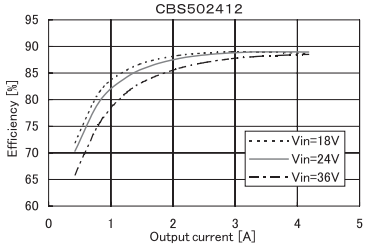
■CBS series

CBS5024

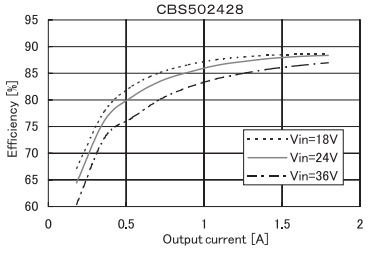
CBS502405



CBS502412

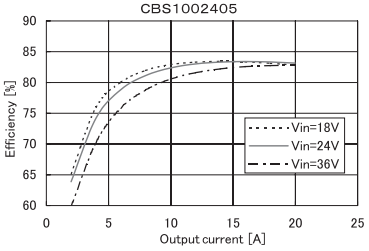


CBS502428



CBS10024

CBS1002405



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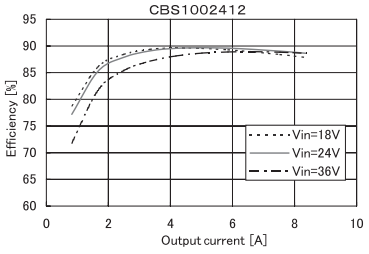

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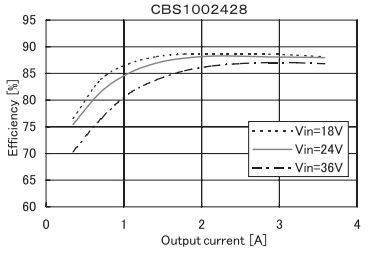
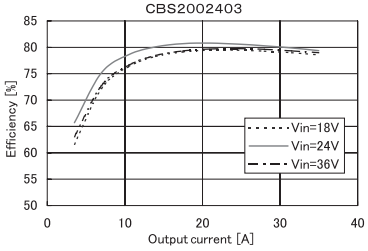


CBS20024

CBS2002403



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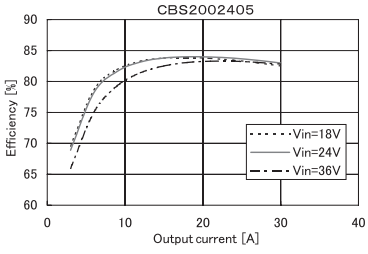

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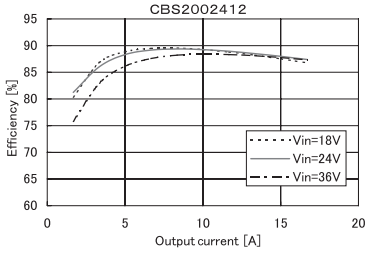

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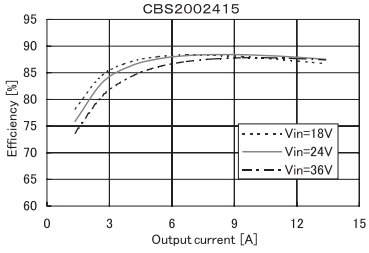

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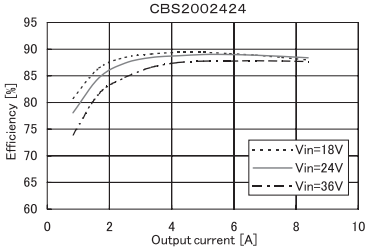

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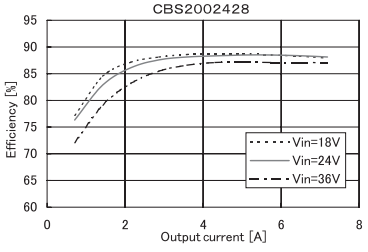
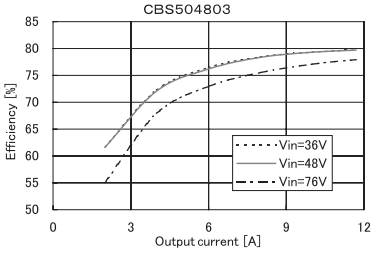
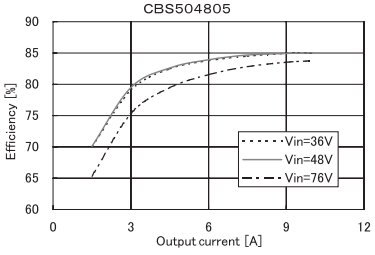


CBS5048

CBS504803



CBS504805



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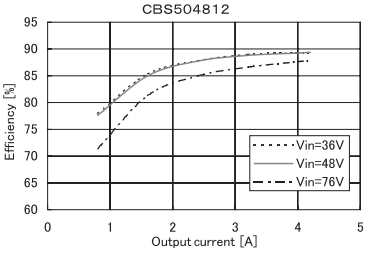

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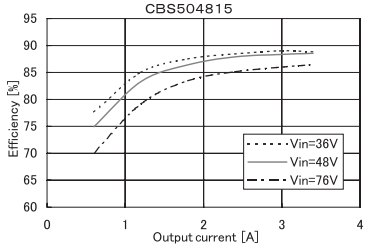

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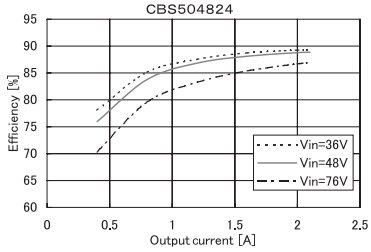

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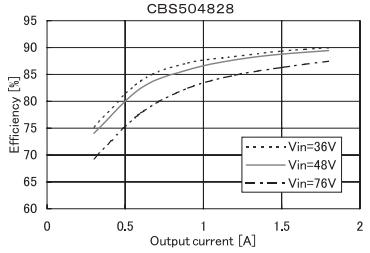
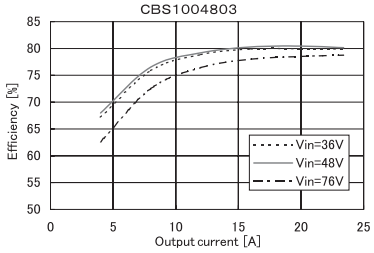


CBS10048

CBS1004803



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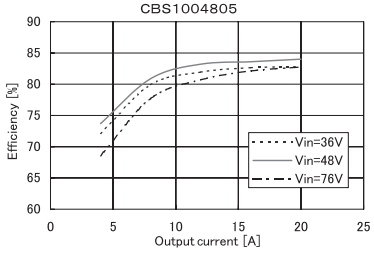

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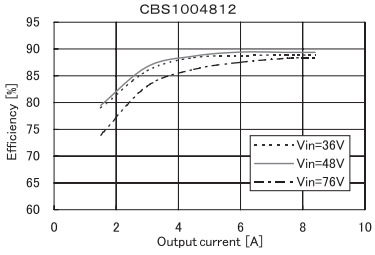

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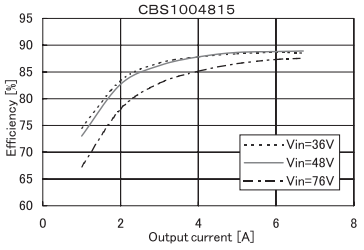

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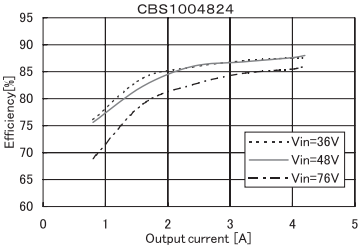

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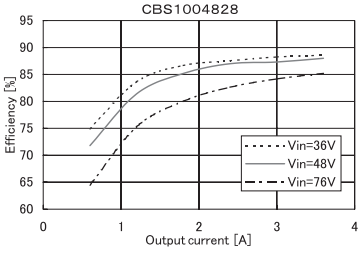
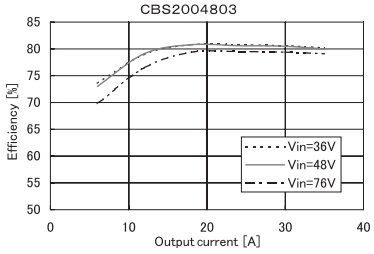


CBS20048

CBS2004803



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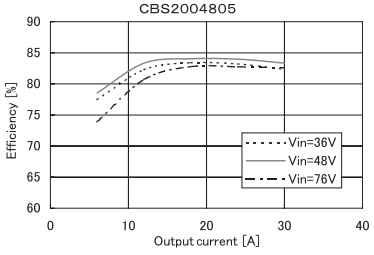

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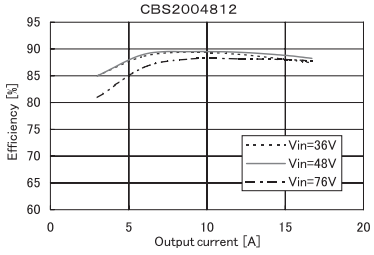

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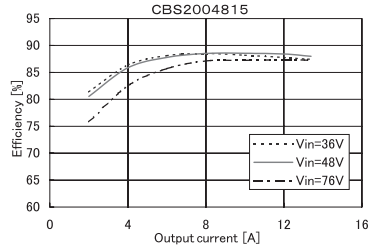

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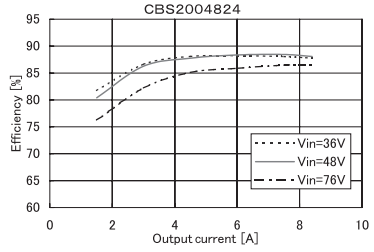

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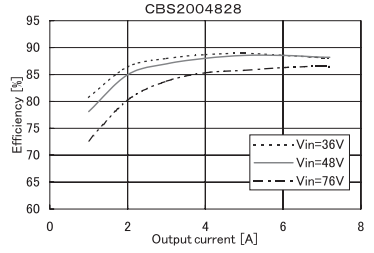
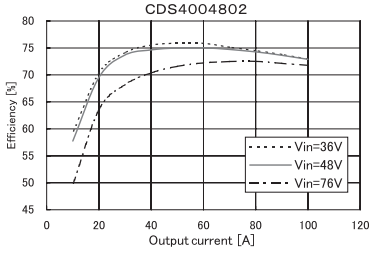


Thermal Considerations

■CDS series

CDS400

CDS4004802



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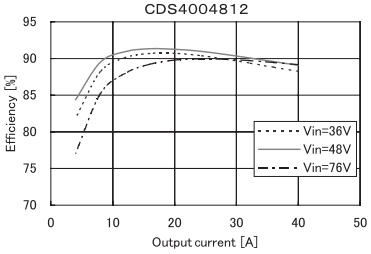
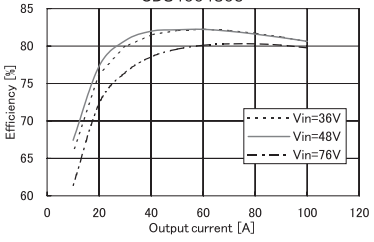


CDS4004803



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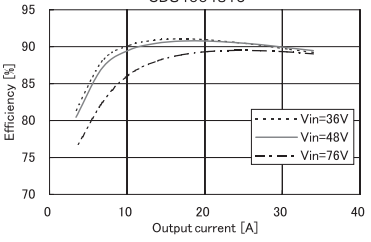

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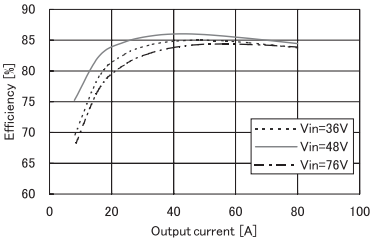

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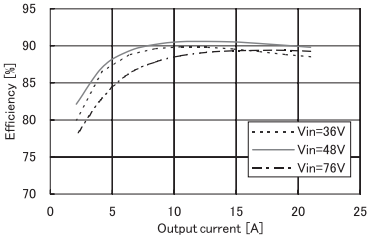

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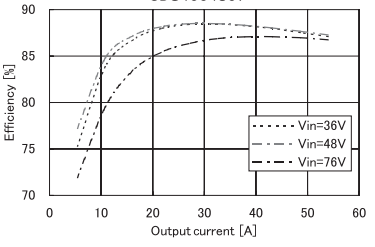

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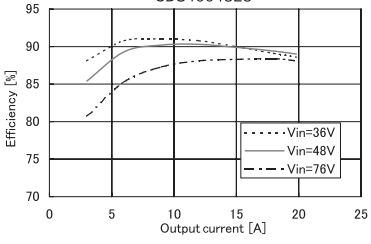
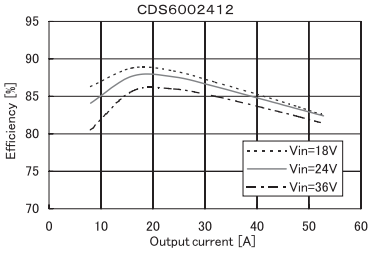


CDS600

CDS6002412



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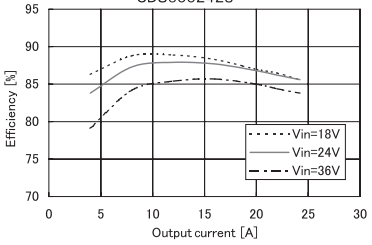

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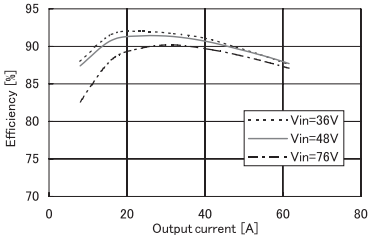

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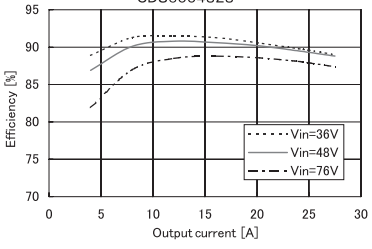
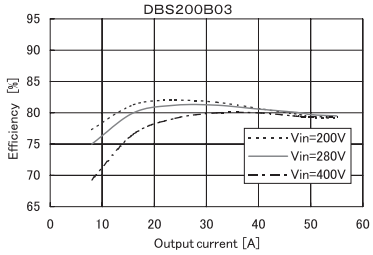


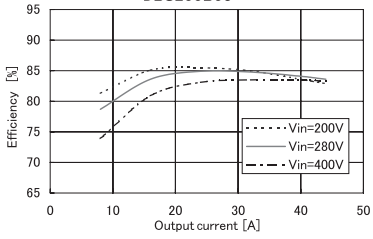
■DBS series

DBS200B

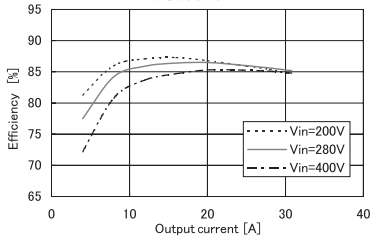
DBS200B03



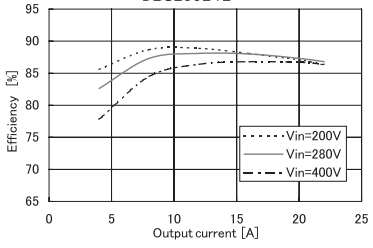
DBS200B05



DBS200B07

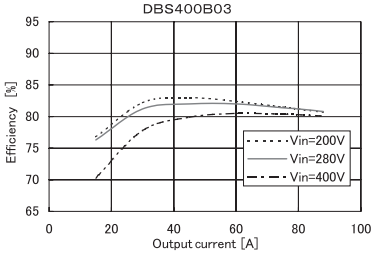


DBS200B12



DBS400B

DBS400B03



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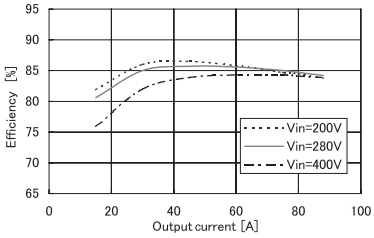

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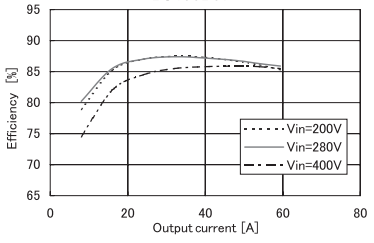

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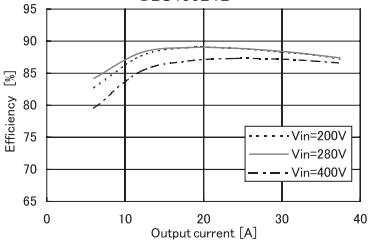
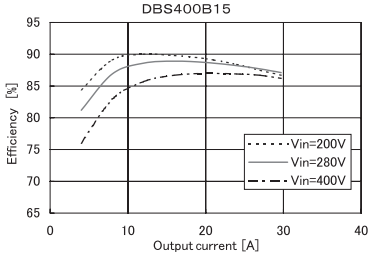
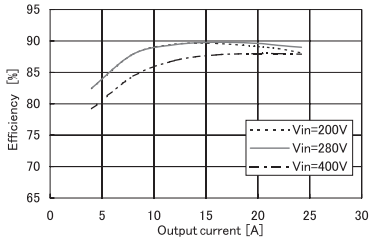


DBS400B15



DBS400B18



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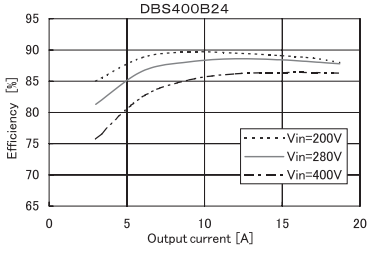
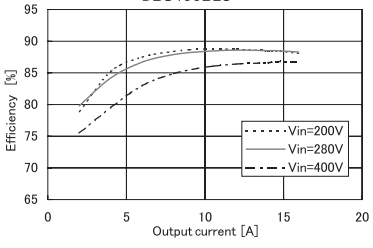


DBS400B28



8.9 Heat sink size and Thermal resistance

■Half Brick size

Heat sink is prepared in CBS series Optional Parts.

Chart : List of Heat sink for CBS series

No.	Model	Size [mm]			Thermal resistance [℃/W]		Style
		H	W	D	Convection (0.1m/s)	Forced Air	
1	F-CBS-F1	12.7	57.9	61.5	7.5	Refer Fig.8.9.7	Vertical
2	F-CBS-F2	12.7	58.4	61.0			Horizontal
3	F-CBS-F3	25.4	57.9	61.5	4.6		Vertical
4	F-CBS-F4	25.4	58.4	61.0			Horizontal
5	F-CBS-F5	38.1	57.9	61.5	3.0		Vertical
6	F-CBS-F6	38.1	58.4	61.0			Horizontal

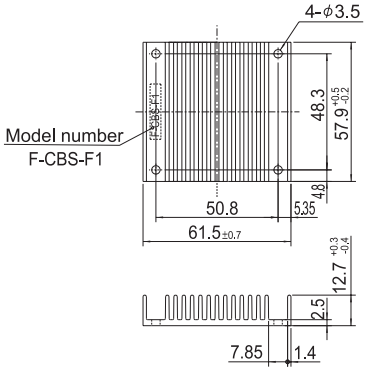


Fig.8.9.1 F-CBS-F1 (external view)

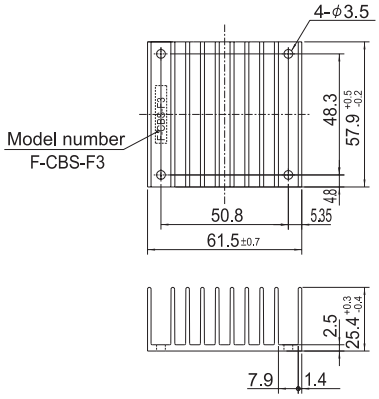


Fig.8.9.2 F-CBS-F3 (external view)

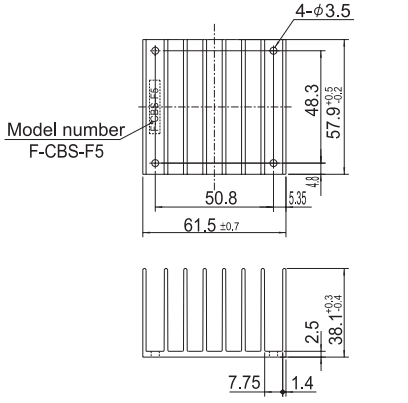


Fig.8.9.3 F-CBS-F5 (external view)

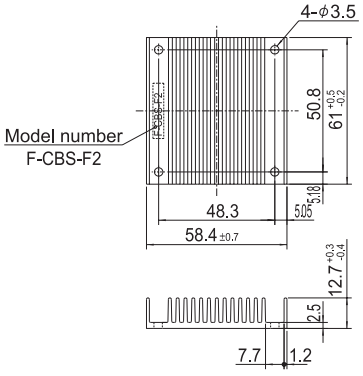


Fig.8.9.4 F-CBS-F2 (external view)

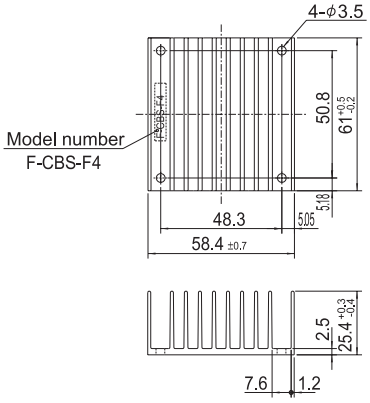


Fig.8.9.5 F-CBS-F4 (external view)

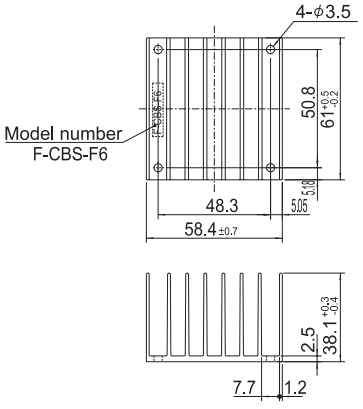
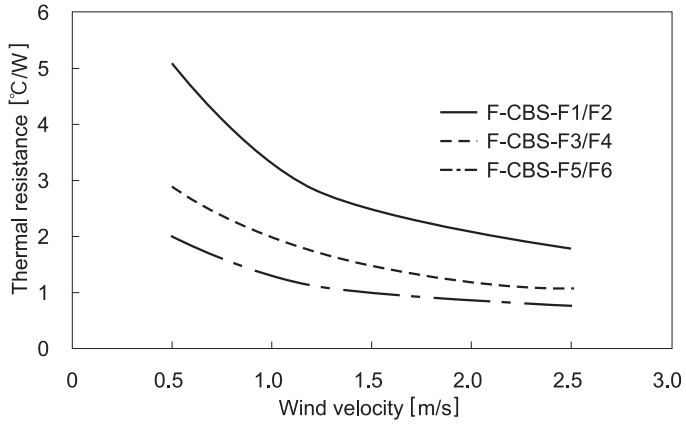


Fig.8.9.6 F-CBS-F6 (external view)

Fig.8.9.7
Heat sink thermal resistance curves



■Full Brick size

Chart: List of Heat sink for DBS/CDS series

No.	Model	Size [mm]			Thermal resistance [℃/W]		Style
		H	W	D	Convection (0.1m/s)	Forced Air	
1	Heat sink A	20.0	60.5	116.0	3.0	Refer Fig.8.9.10	Vertical
2	Heat sink B	20.0	60.5	116.0	2.7		Horizontal

✻ Heat sink A and B are not sold in our company.

Fig.8.9.8
Heat sink A
(external view)

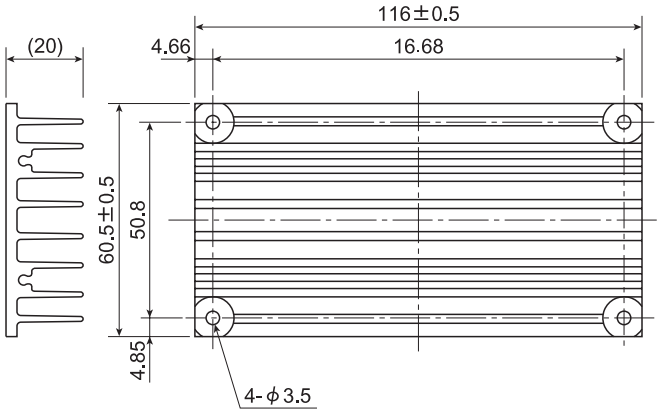


Fig.8.9.9
Heat sink B
(external view)

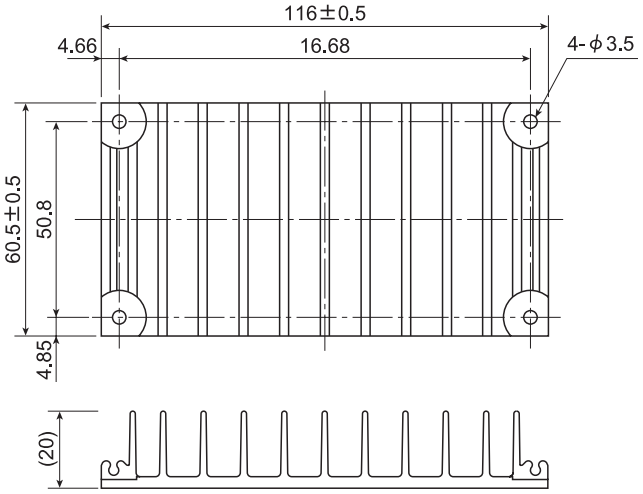
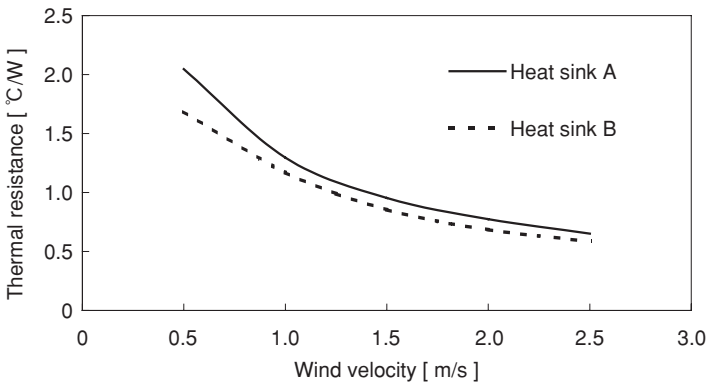


Fig.8.9.10
Heat sink thermal
resistance curves



8.10 Thermal curves

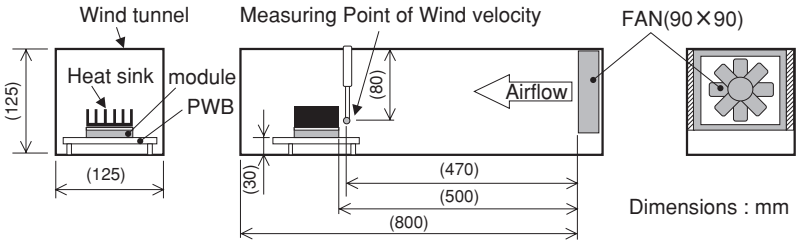
Shown the Thermal curve with measuring environment as shown below.

Verify final design by actual temperature measurement.

8.10.1 Measuring environment

■CBS series (Half Brick size)

Fig.8.10.1
Measuring environment
(CBS series)



■DBS/CDS series (Full Brick size)

Fig.8.10.2
Measuring environment
(DBS/CDS series)

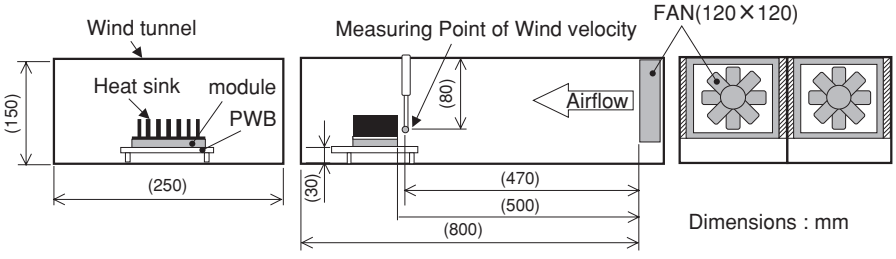
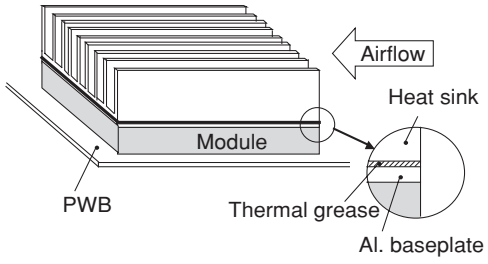


Fig.8.10.3
Measuring method



■Example of CBS504812

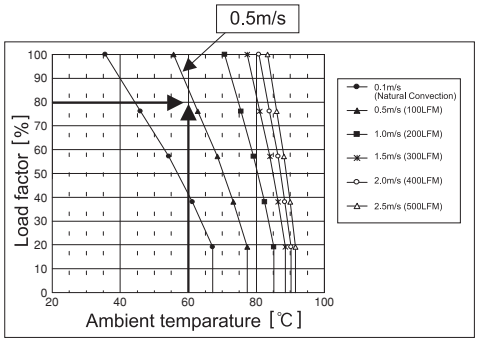
Conditions Load factor : 80 [%]

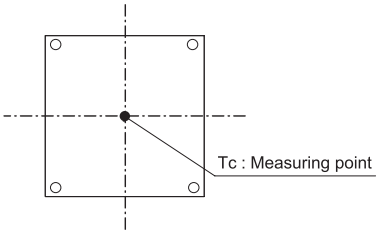
Ambient temperature : 60 [℃]

Shown in Fig.8.10.4, it is necessary to keep the wind velocity more than 0.5m/s. Refer to 8.10.2 Thermal Curves. Keep the baseplate temperature is lower than its derating curve temperature. Refer to 8.6.1 Baseplate temperature.

Measure the baseplate temperature at the center of the baseplate.

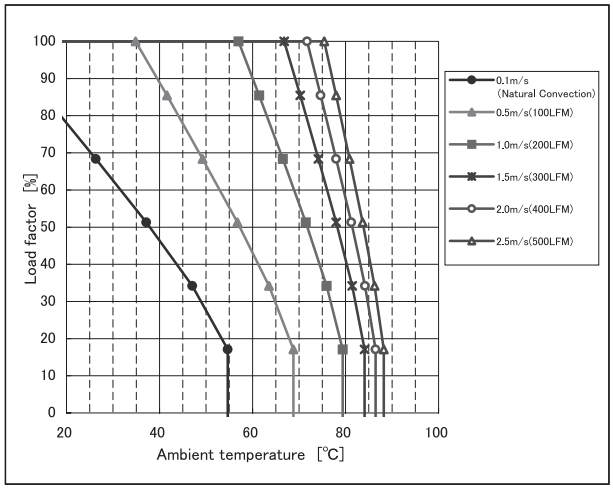
Fig.8.10.4
Example of Thermal curves



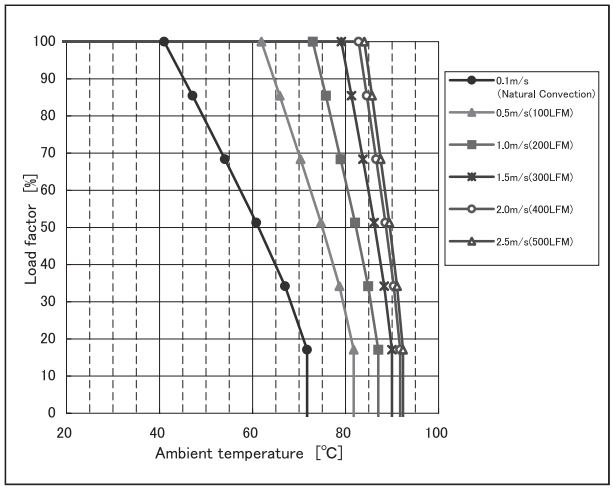


8.10.2 Thermal curves

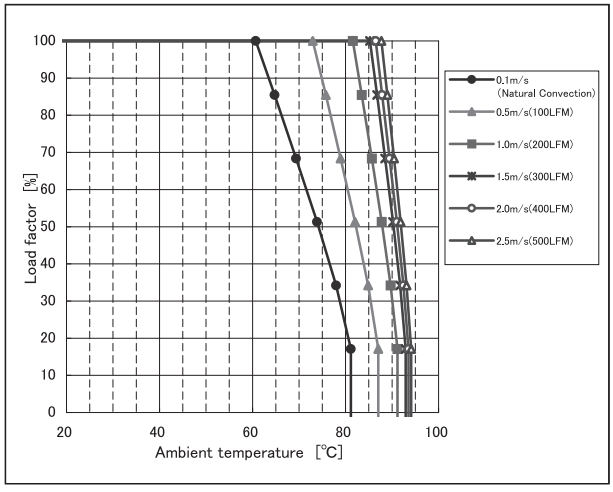
CBS50□03



F-CBS-F1/F2 (H = 12.7mm)

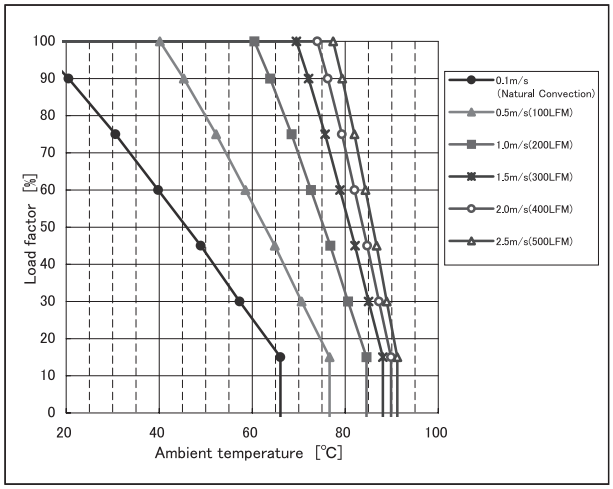


F-CBS-F3/F4 (H = 25.4mm)

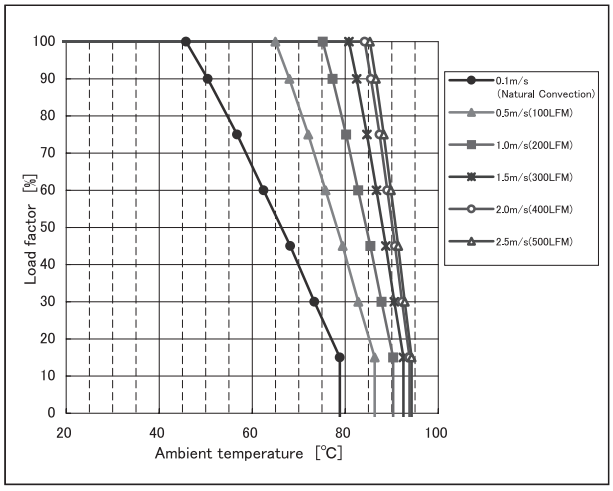


F-CBS-F5/F6 (H = 38.1mm)

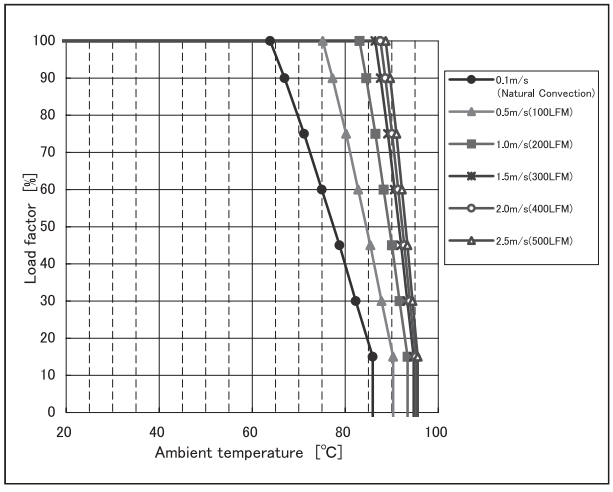
CBS50□05



F-CBS-F1/F2 (H = 12.7mm)



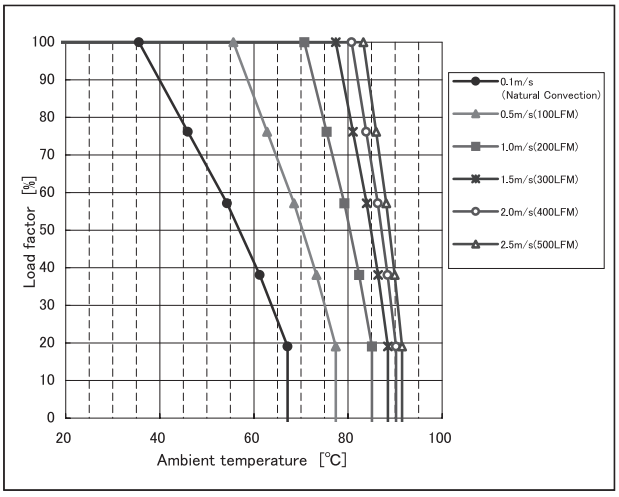
F-CBS-F3/F4 (H = 25.4mm)



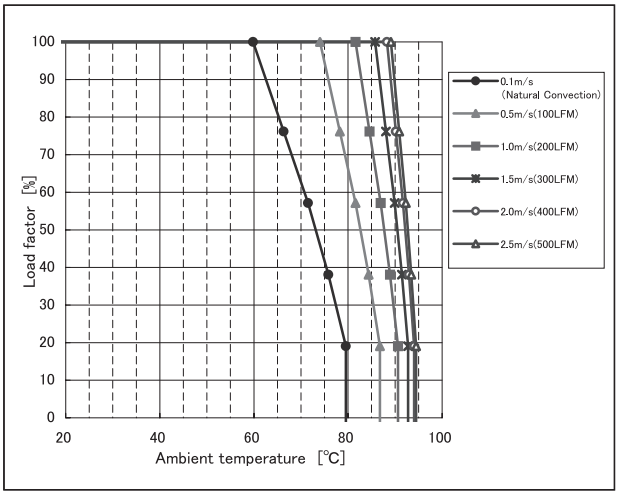
F-CBS-F5/F6 (H = 38.1mm)

Thermal Considerations

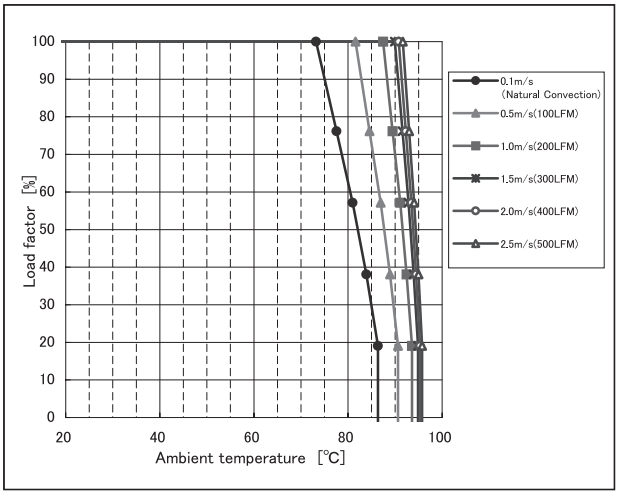
CBS50□12



F-CBS-F1/F2 (H = 12.7mm)

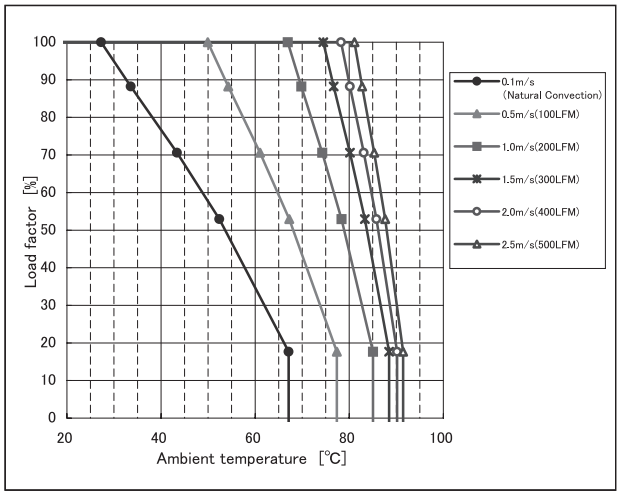


F-CBS-F3/F4 (H = 25.4mm)

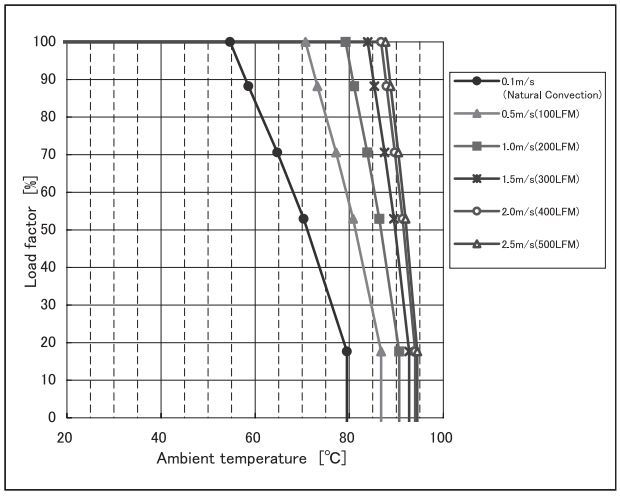


F-CBS-F5/F6 (H = 38.1mm)

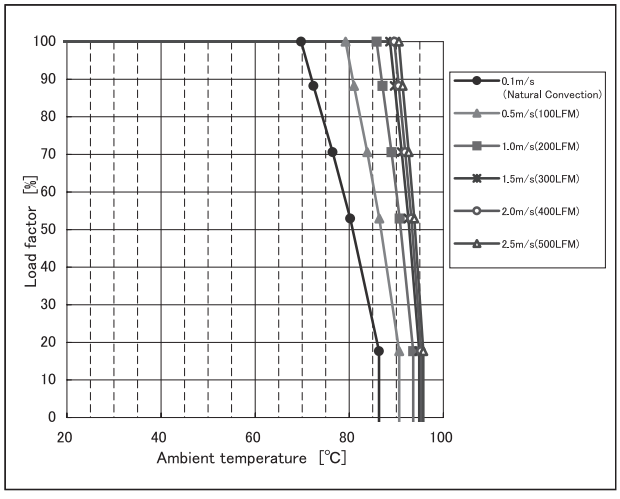
CBS50□15



F-CBS-F1/F2 (H = 12.7mm)

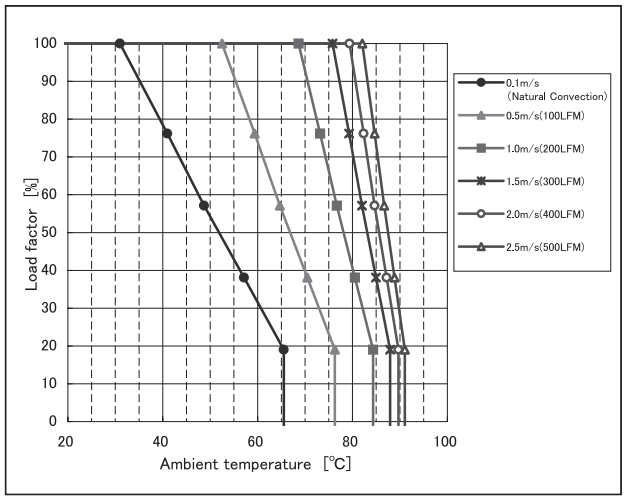


F-CBS-F3/F4 (H = 25.4mm)



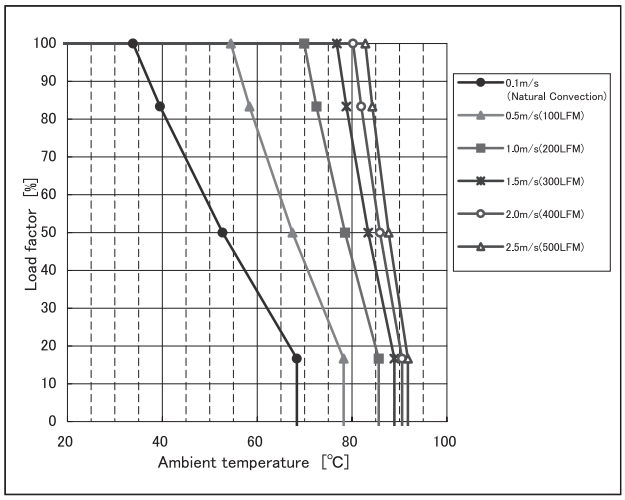
F-CBS-F5/F6 (H = 38.1mm)

CBS50□24

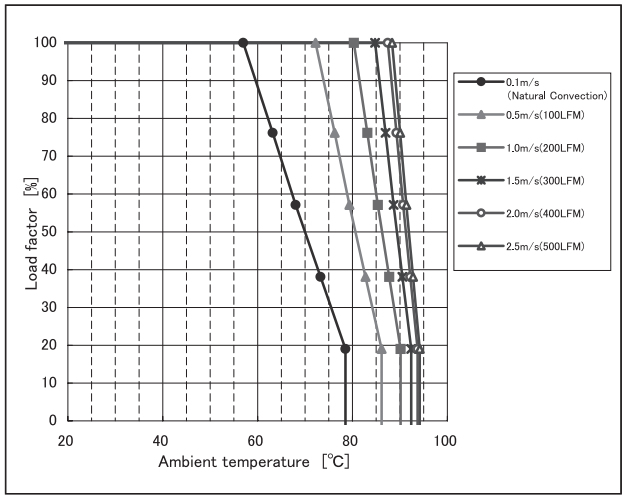


F-CBS-F1/F2 (H = 12.7mm)

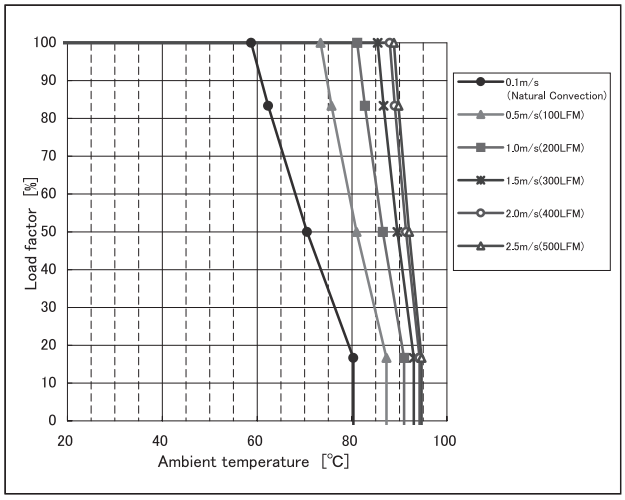
CBS50□28



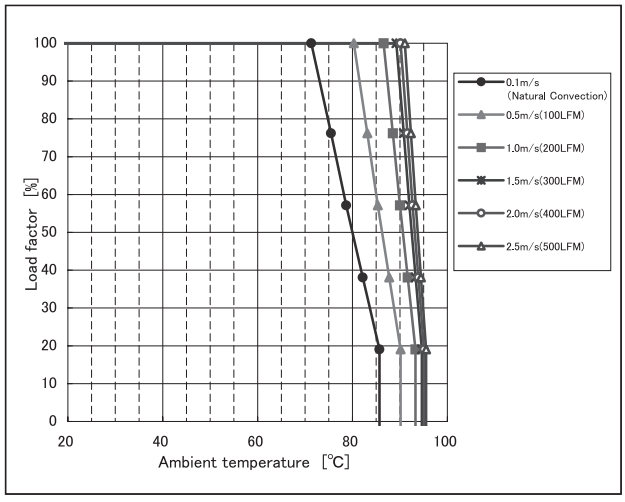
F-CBS-F1/F2 (H = 12.7mm)



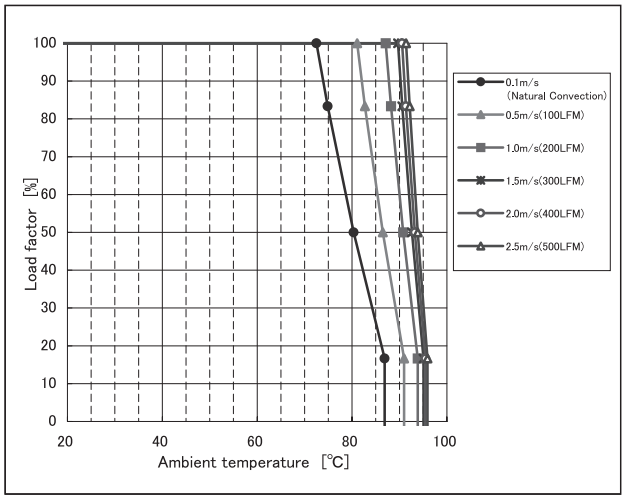
F-CBS-F3/F4 (H = 25.4mm)



F-CBS-F3/F4 (H = 25.4mm)



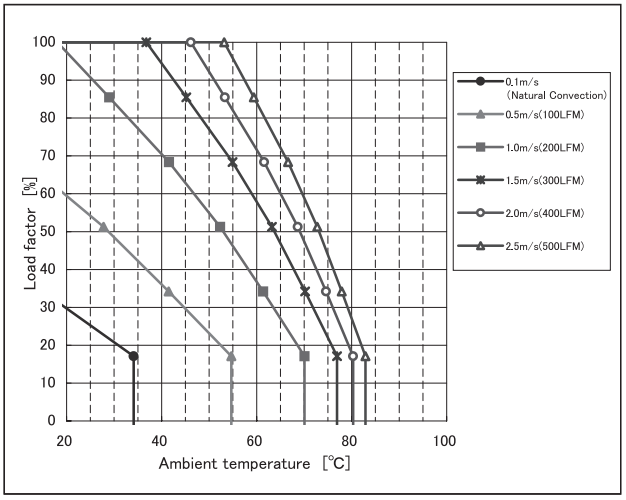
F-CBS-F5/F6 (H = 38.1mm)



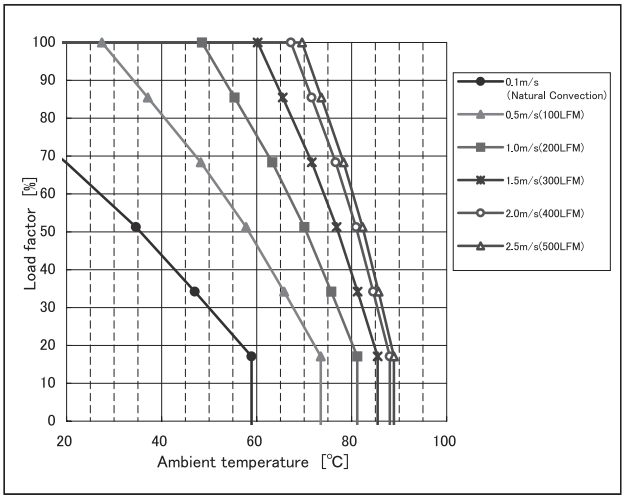
F-CBS-F5/F6 (H = 38.1mm)

Thermal Considerations

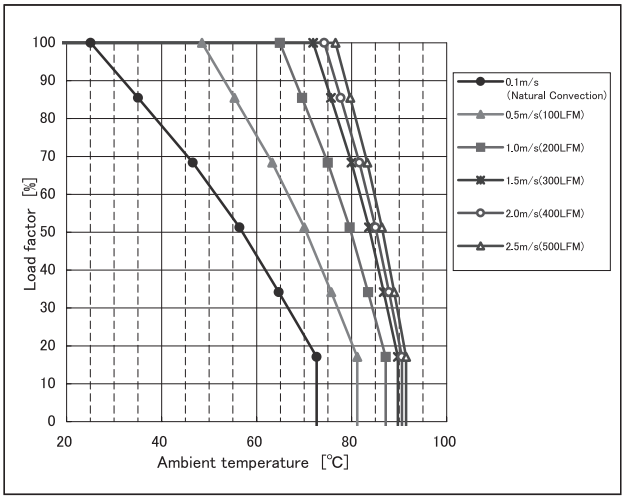
CBS100□03



F-CBS-F1/F2 (H = 12.7mm)

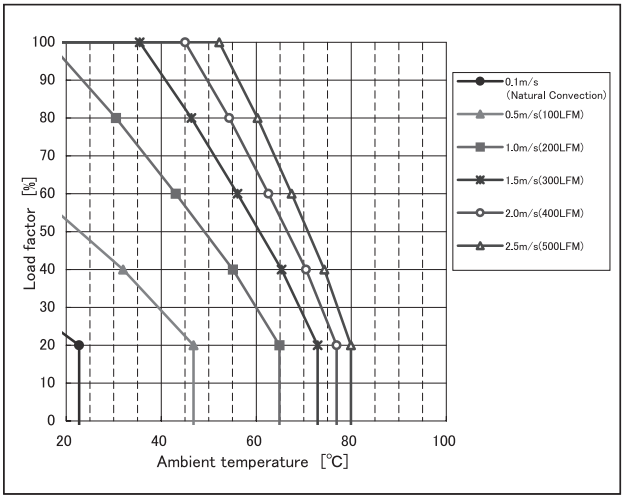


F-CBS-F3/F4 (H = 25.4mm)

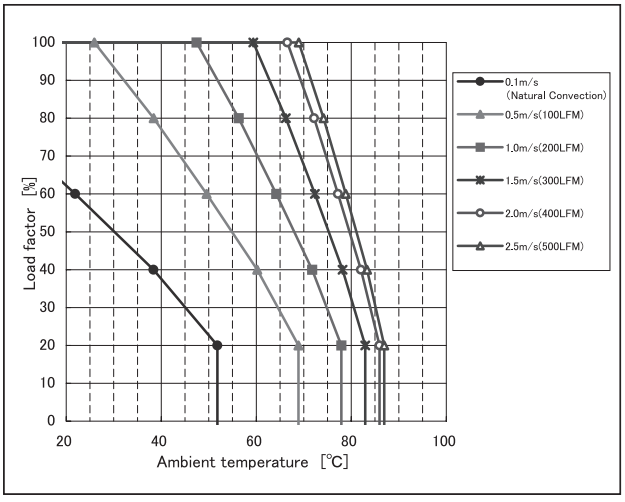


F-CBS-F5/F6 (H = 38.1mm)

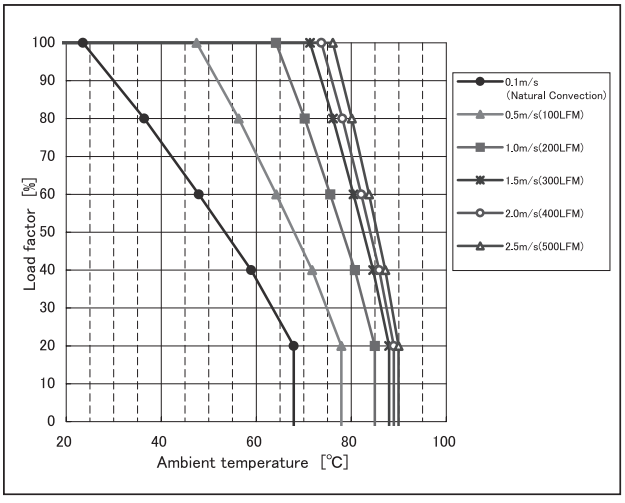
CBS100□05



F-CBS-F1/F2 (H = 12.7mm)

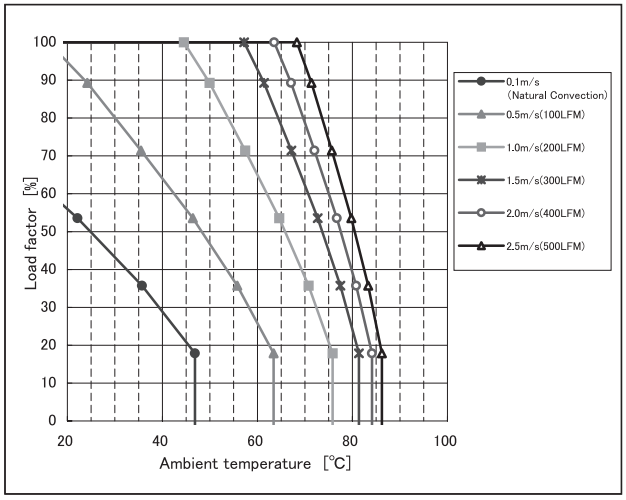


F-CBS-F3/F4 (H = 25.4mm)

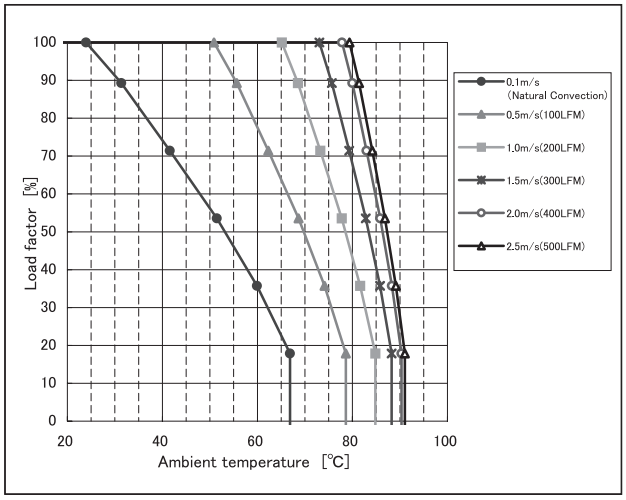


F-CBS-F5/F6 (H = 38.1mm)

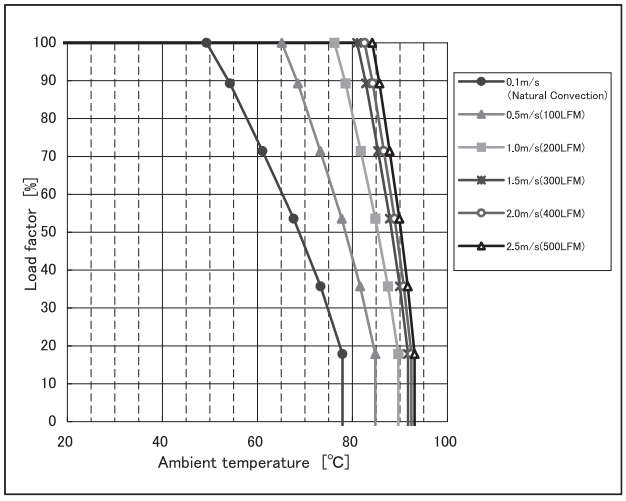
CBS100□12



F-CBS-F1/F2 (H = 12.7mm)

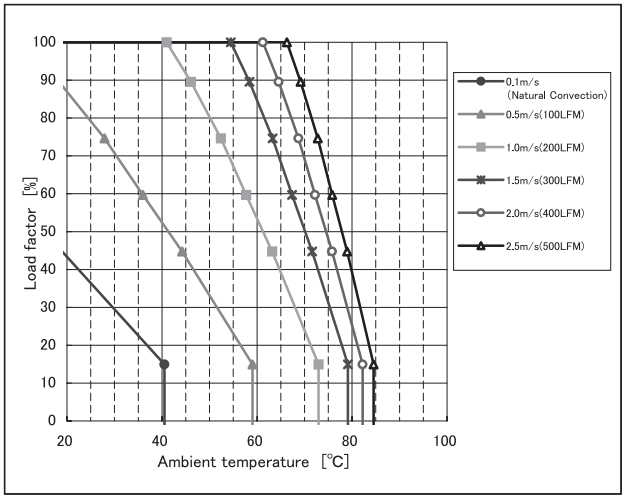


F-CBS-F3/F4 (H = 25.4mm)

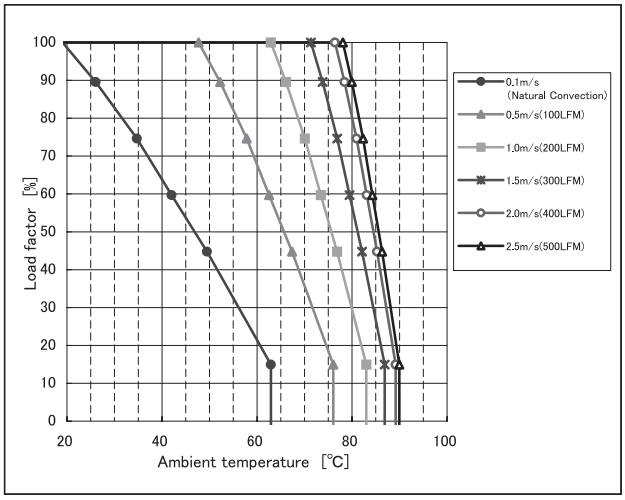


F-CBS-F5/F6 (H = 38.1mm)

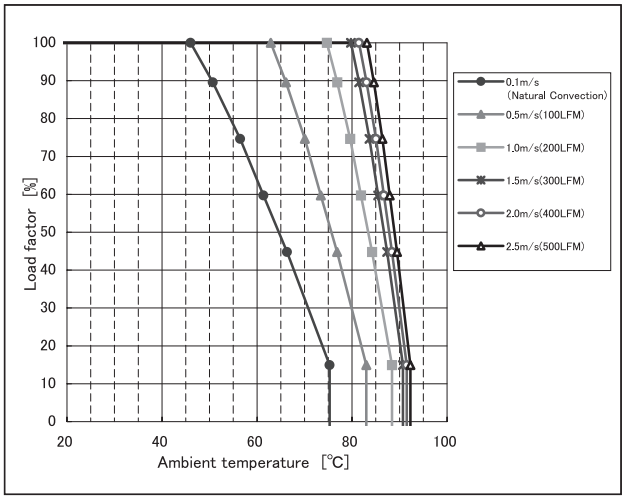
CBS100□15



F-CBS-F1/F2 (H = 12.7mm)



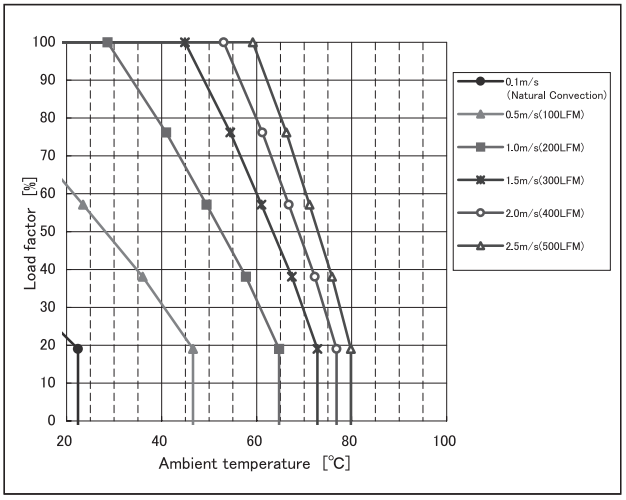
F-CBS-F3/F4 (H = 25.4mm)



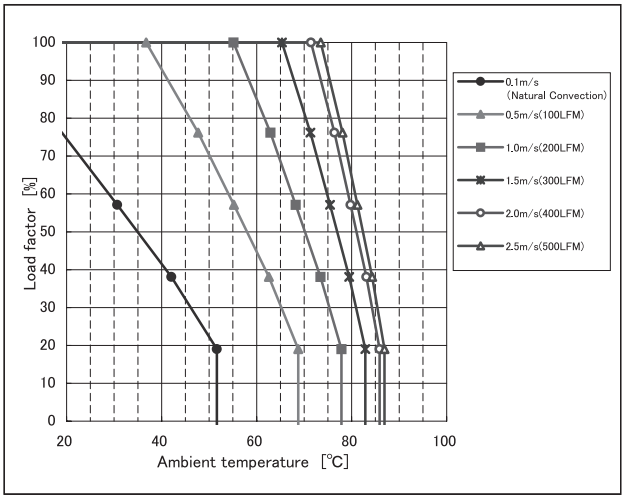
F-CBS-F5/F6 (H = 38.1mm)

Thermal Considerations

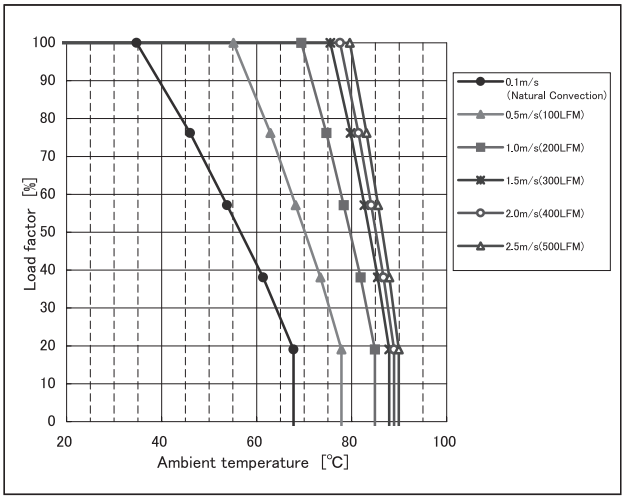
CBS100□24



F-CBS-F1/F2 (H = 12.7mm)

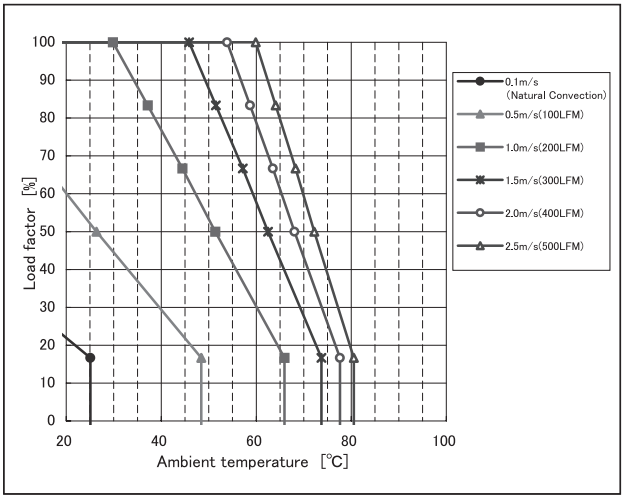


F-CBS-F3/F4 (H = 25.4mm)

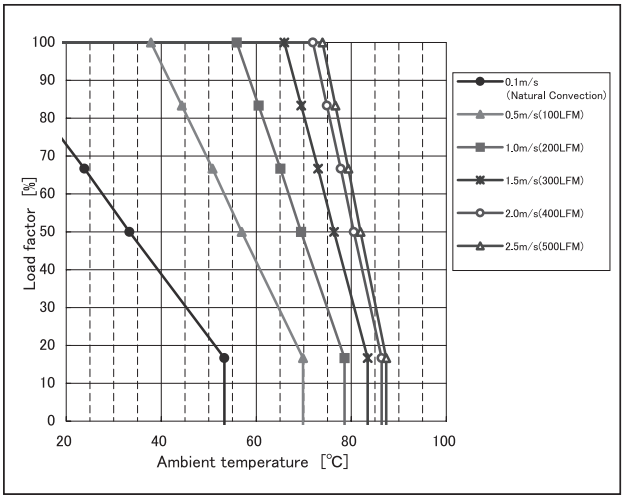


F-CBS-F5/F6 (H = 38.1mm)

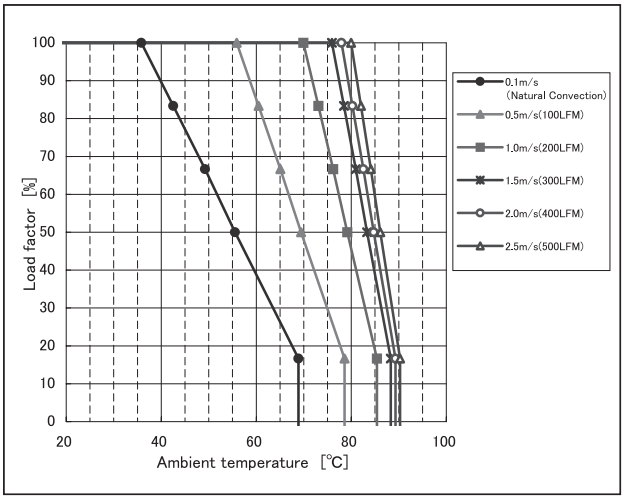
CBS100□28



F-CBS-F1/F2 (H = 12.7mm)

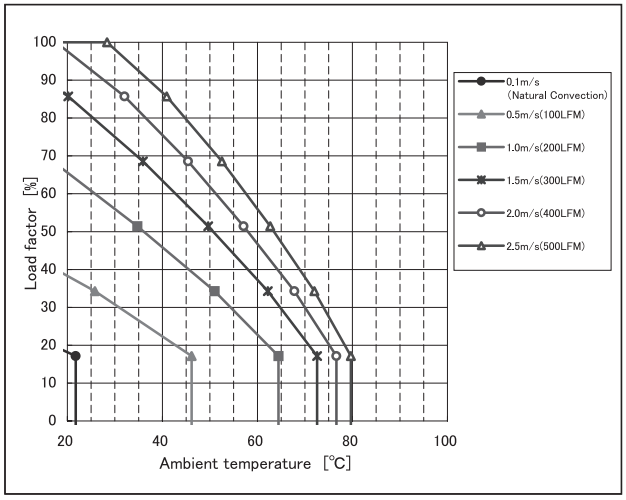


F-CBS-F3/F4 (H = 25.4mm)



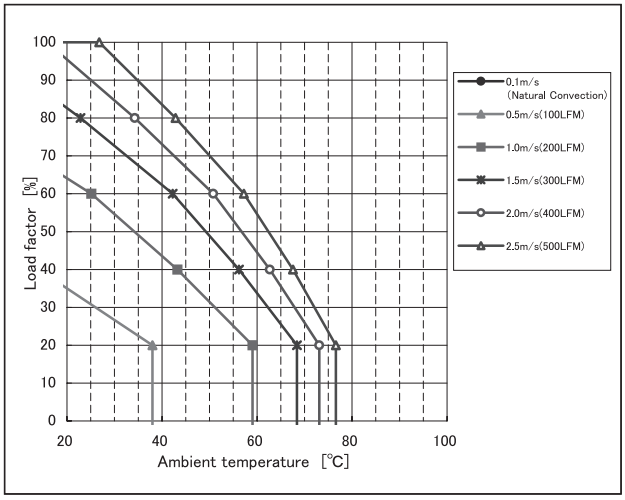
F-CBS-F5/F6 (H = 38.1mm)

CBS200□03

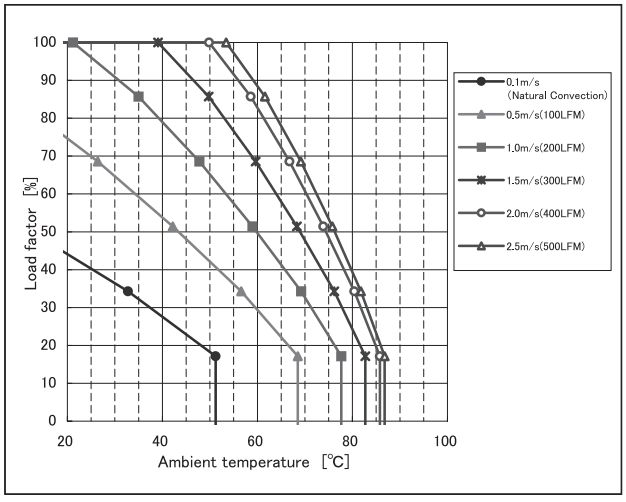


F-CBS-F1/F2 (H = 12.7mm)

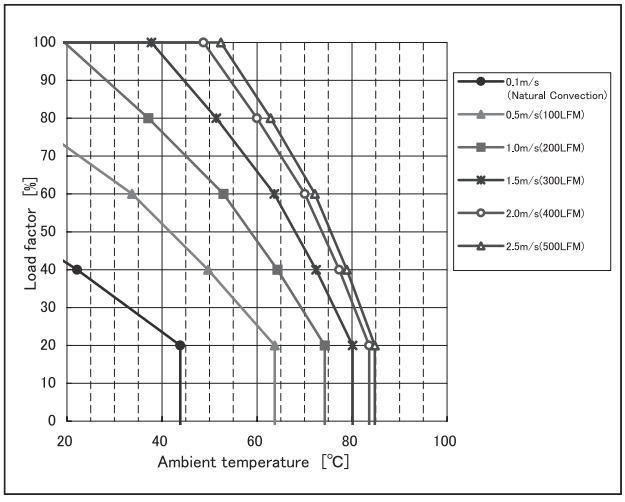
CBS200□05



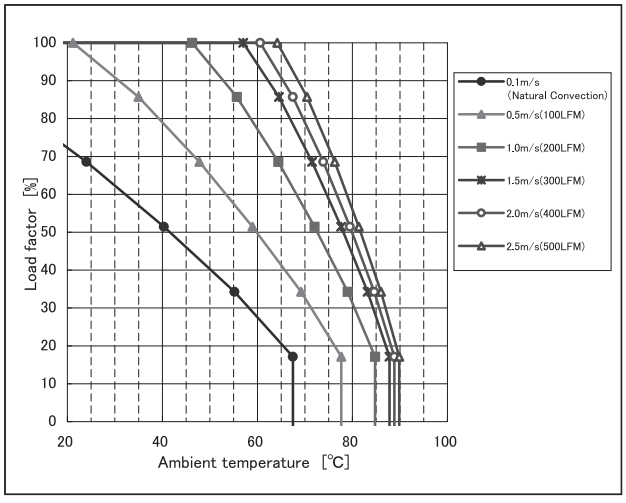
F-CBS-F1/F2 (H = 12.7mm)



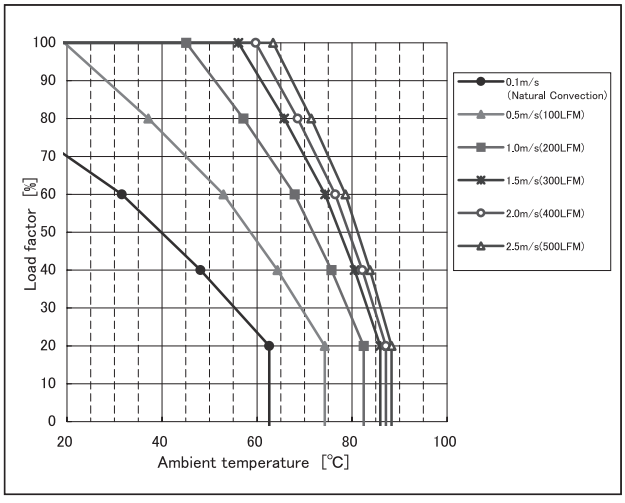
F-CBS-F3/F4 (H = 25.4mm)



F-CBS-F3/F4 (H = 25.4mm)



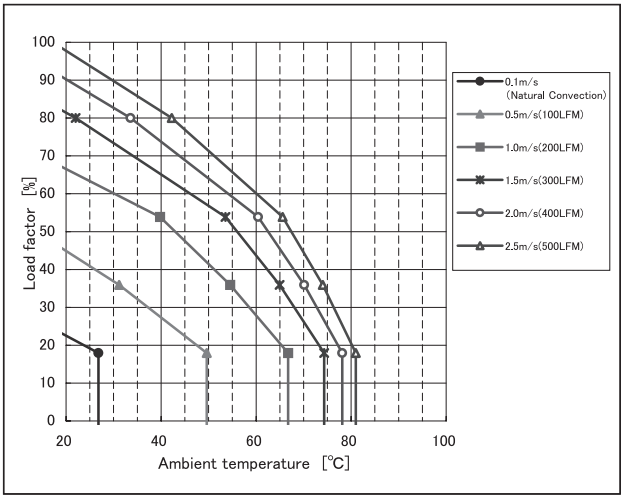
F-CBS-F5/F6 (H = 38.1mm)



F-CBS-F5/F6 (H = 38.1mm)

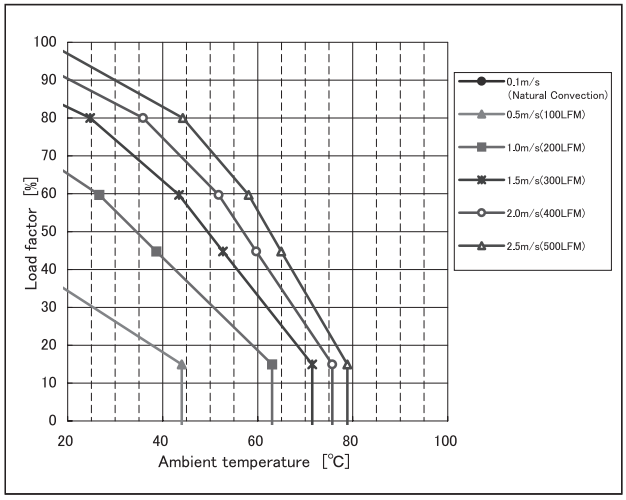
Thermal Considerations

CBS200□12

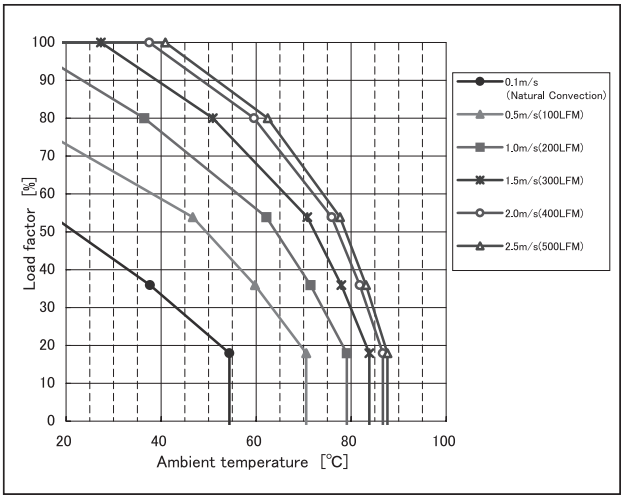


F-CBS-F1/F2 (H = 12.7mm)

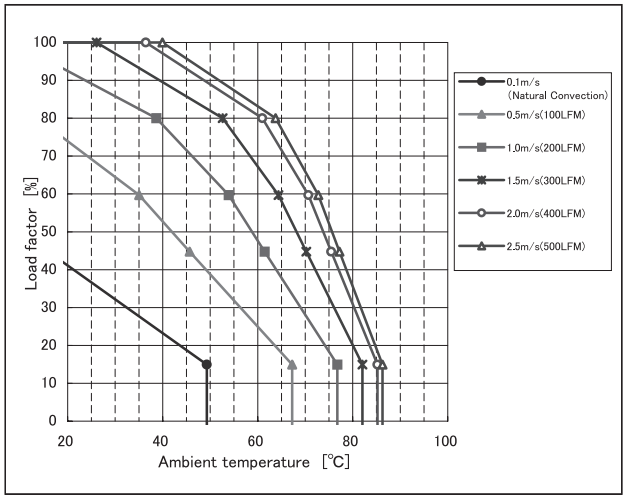
CBS200□15



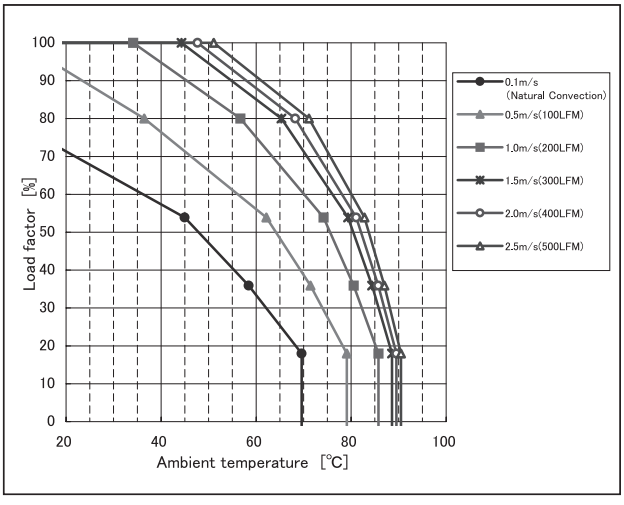
F-CBS-F1/F2 (H = 12.7mm)



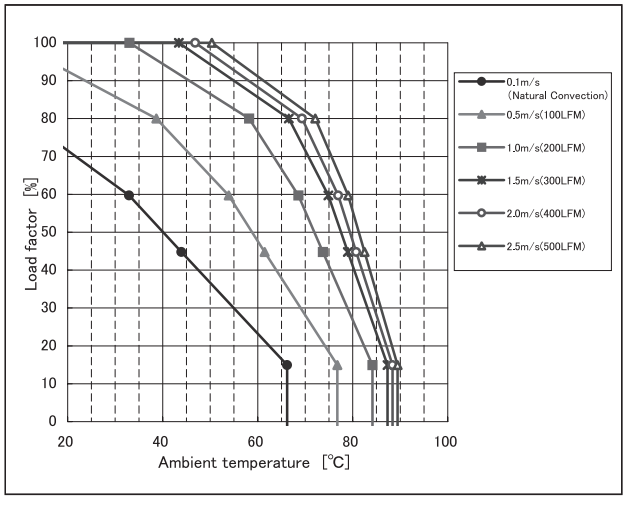
F-CBS-F3/F4 (H = 25.4mm)



F-CBS-F3/F4 (H = 25.4mm)

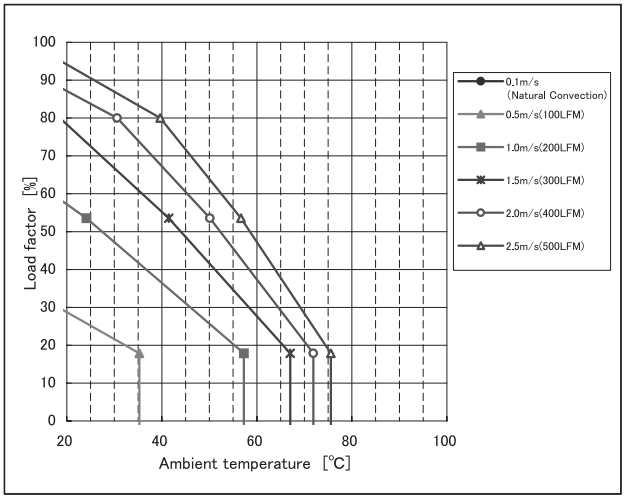


F-CBS-F5/F6 (H = 38.1mm)



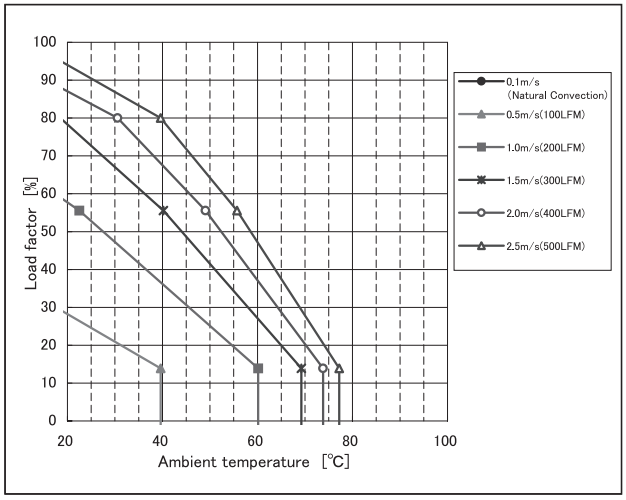
F-CBS-F5/F6 (H = 38.1mm)

CBS200□24

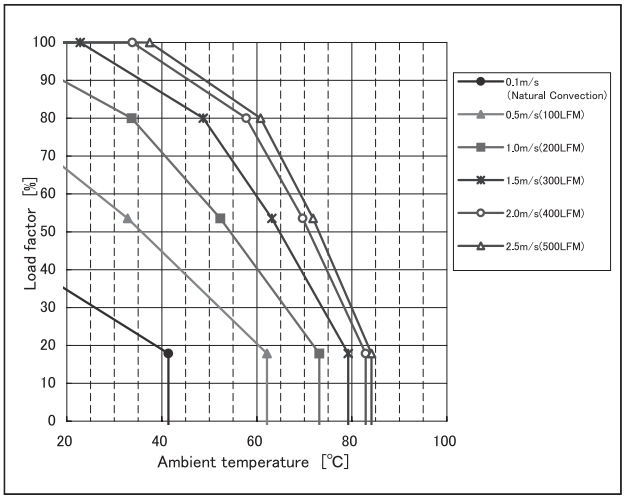


F-CBS-F1/F2 (H = 12.7mm)

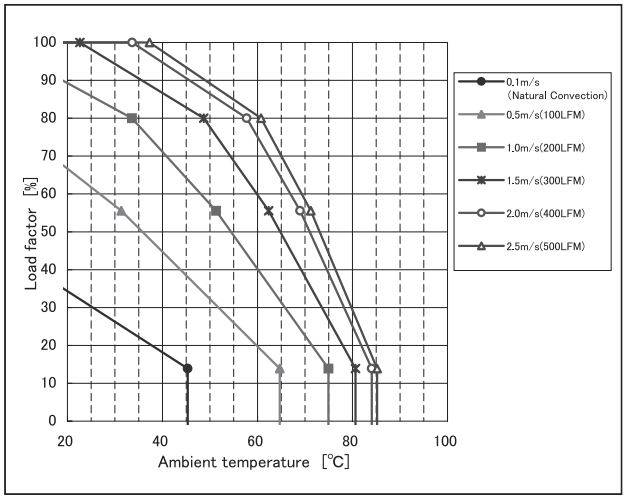
CBS200□28



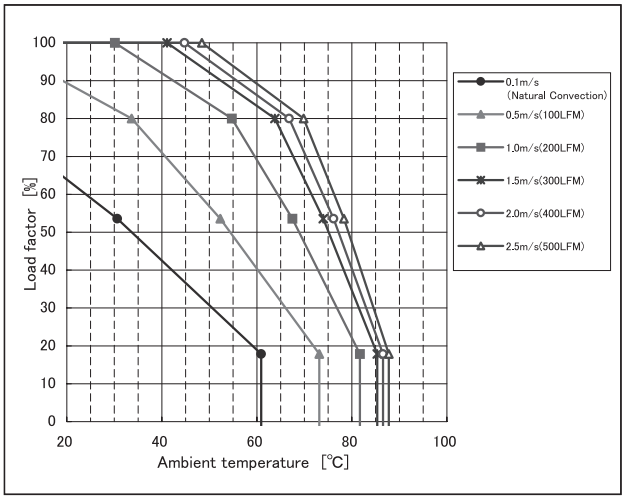
F-CBS-F1/F2 (H = 12.7mm)



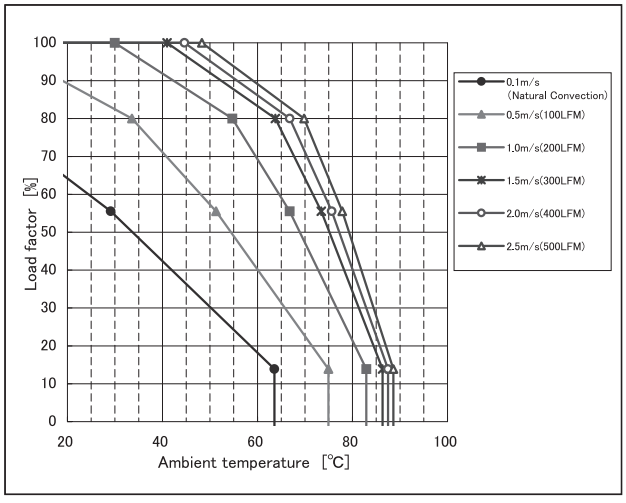
F-CBS-F3/F4 (H = 25.4mm)



F-CBS-F3/F4 (H = 25.4mm)



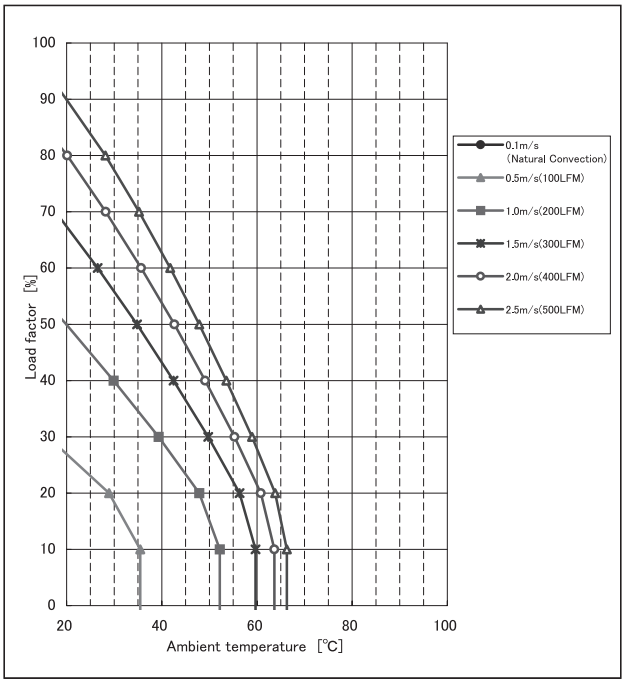
F-CBS-F5/F6 (H = 38.1mm)



F-CBS-F5/F6 (H = 38.1mm)

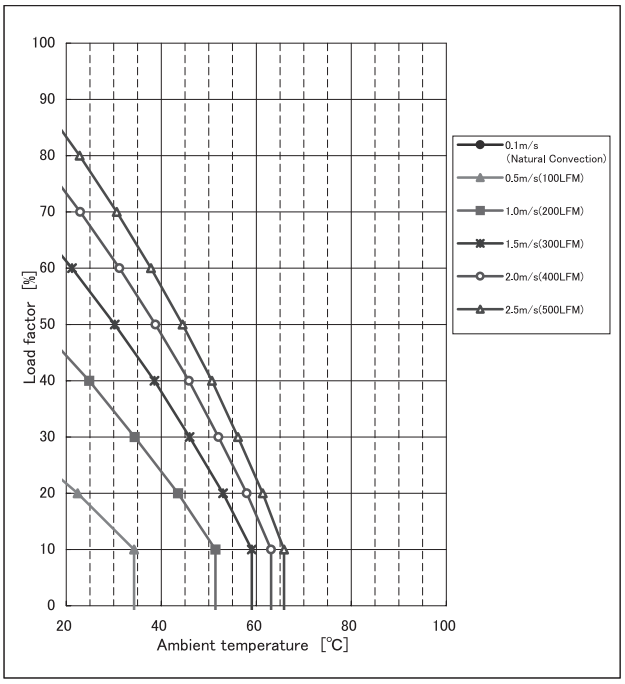
Thermal Considerations

CDS4004802

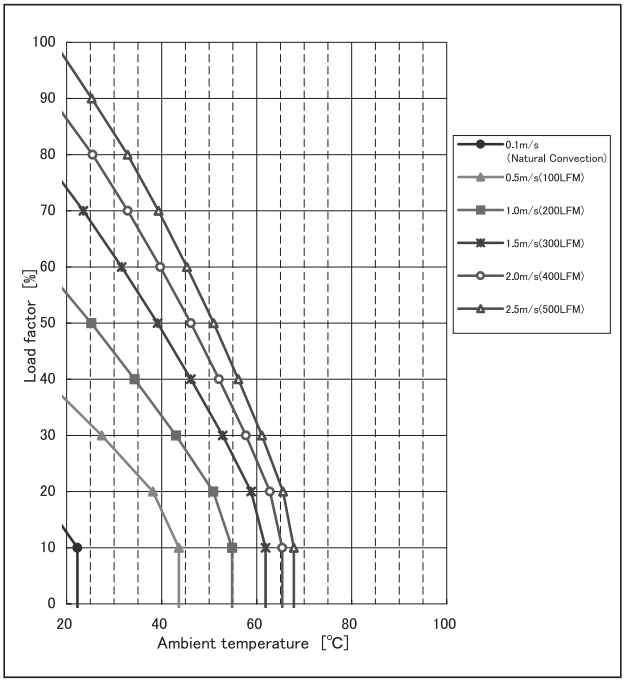


Heat sink A

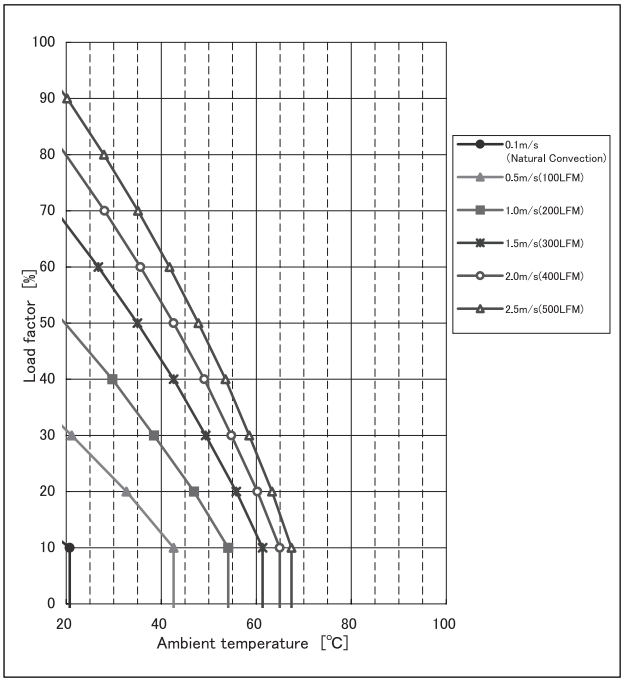
CDS4004803



Heat sink A

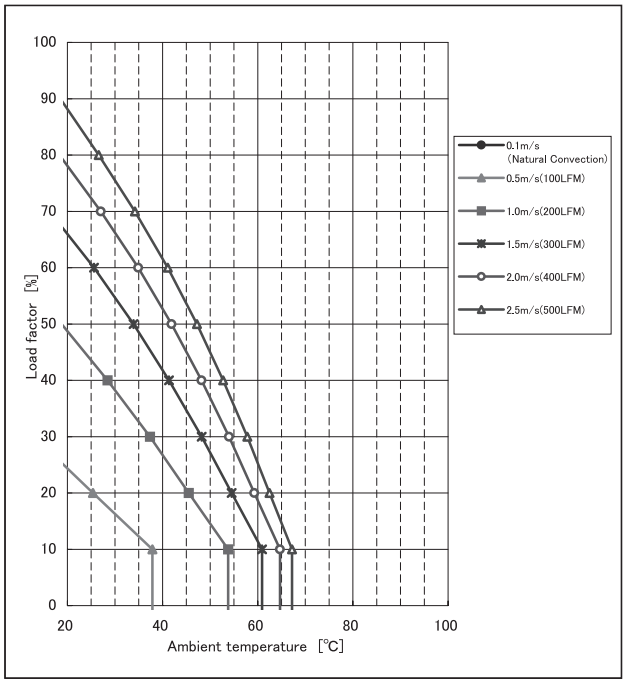


Heat sink B



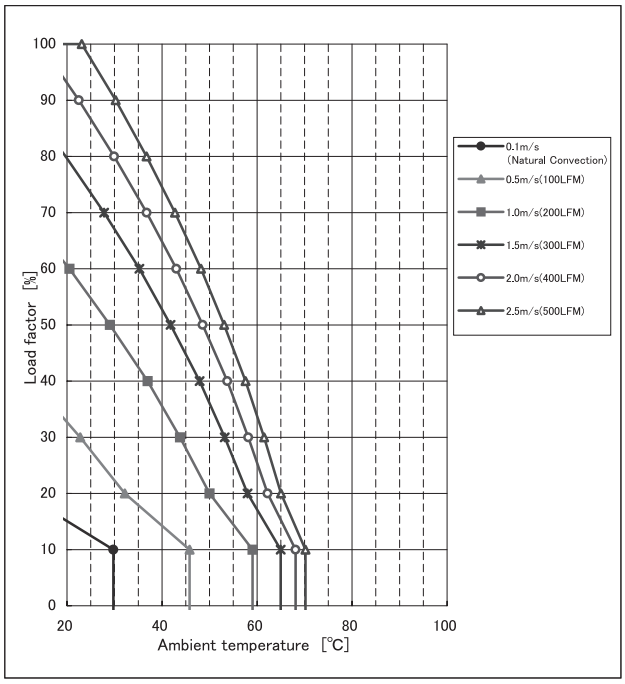
Heat sink B

CDS4004805

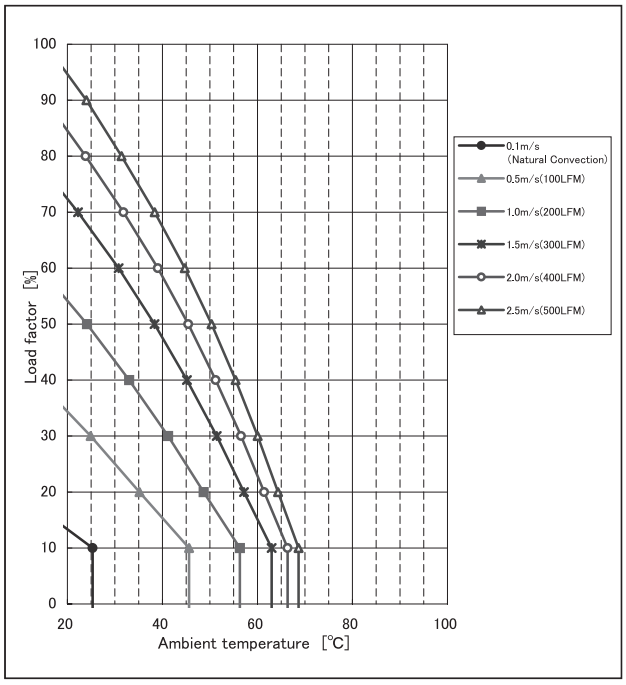


Heat sink A

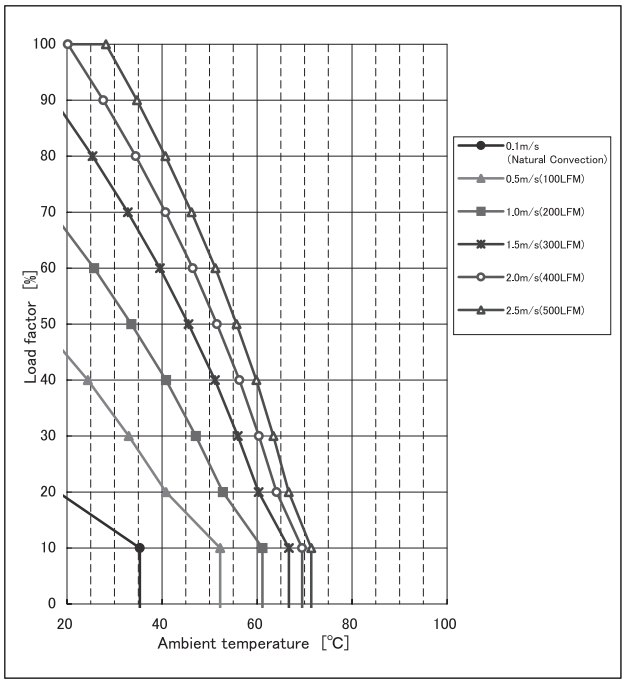
CDS4004807



Heat sink A

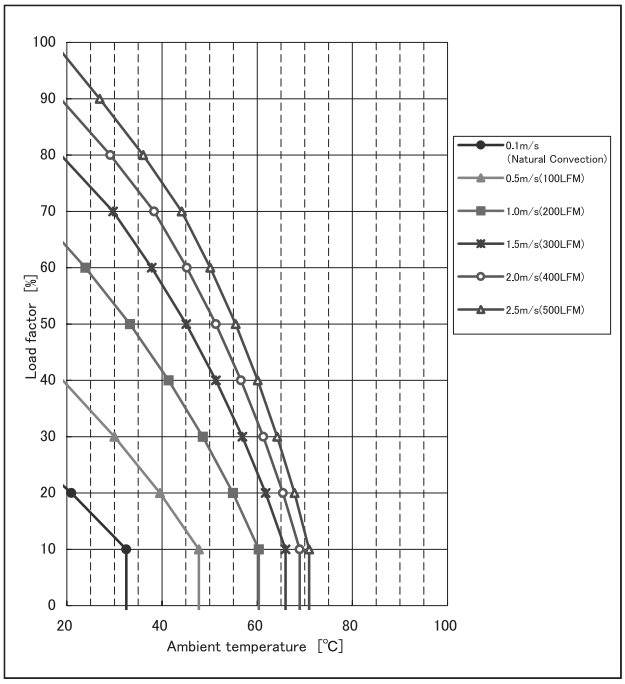


Heat sink B



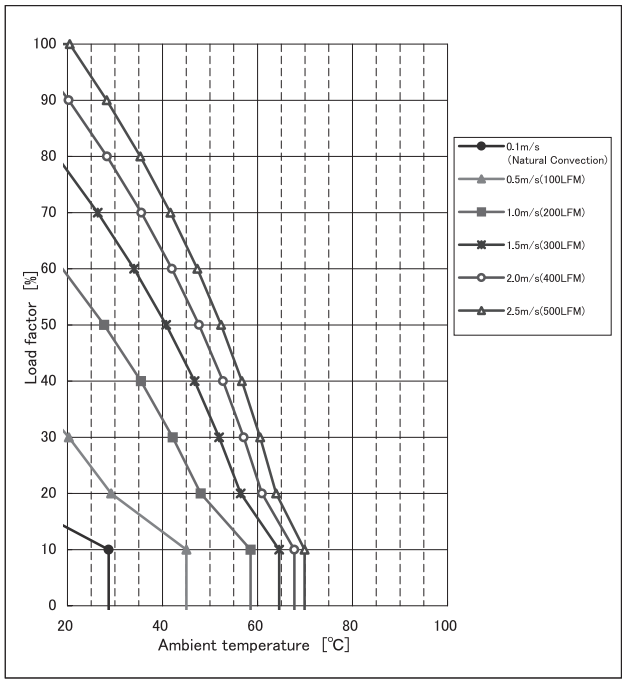
Heat sink B

CDS4004812

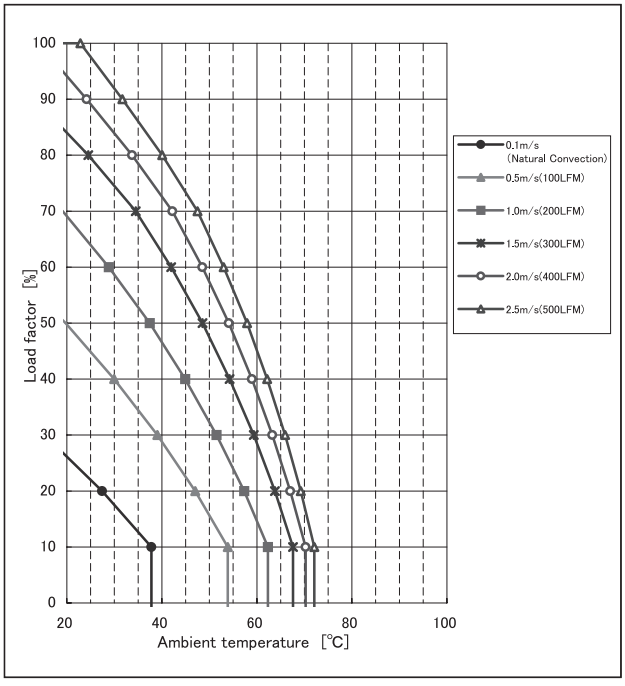


Heat sink A

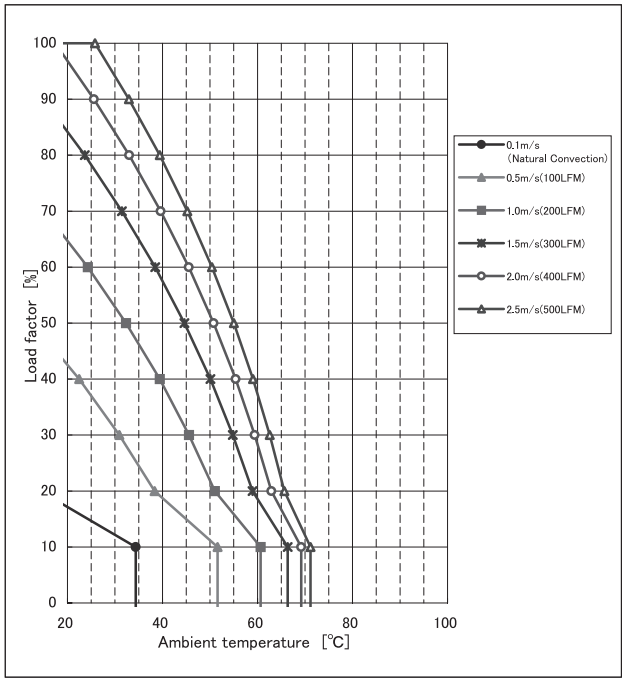
CDS4004815



Heat sink A

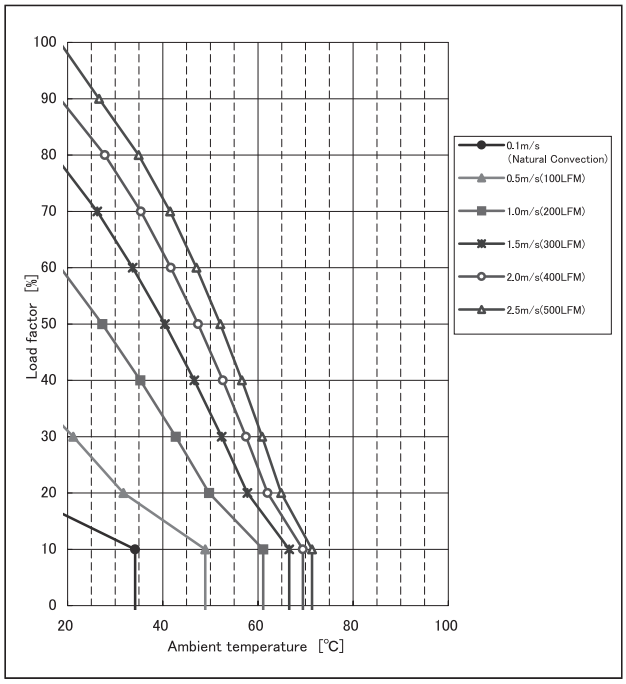


Heat sink B



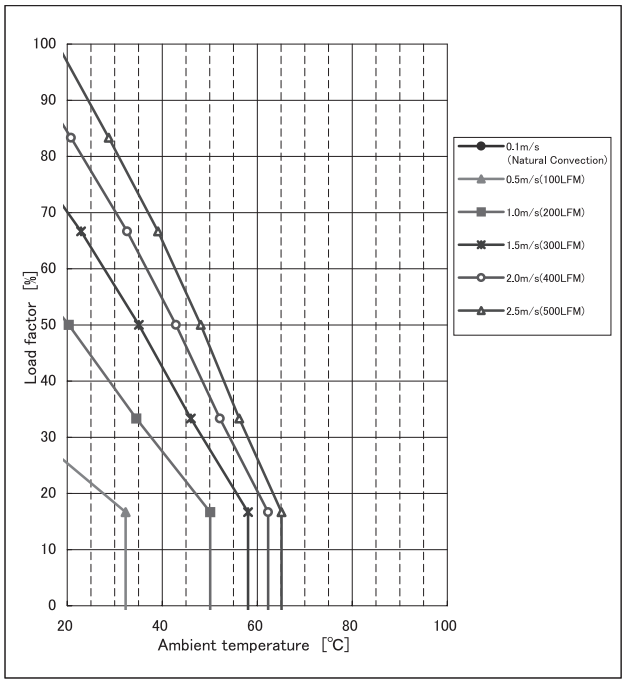
Heat sink B

CDS4004824

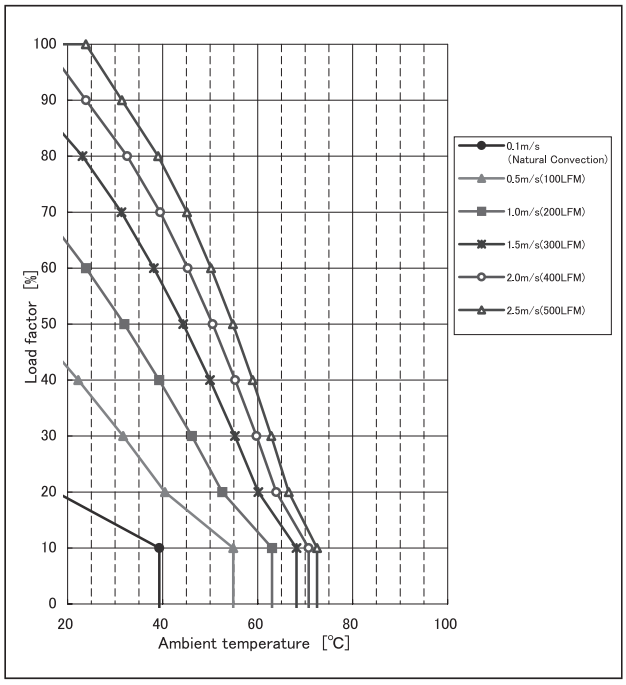


Heat sink A

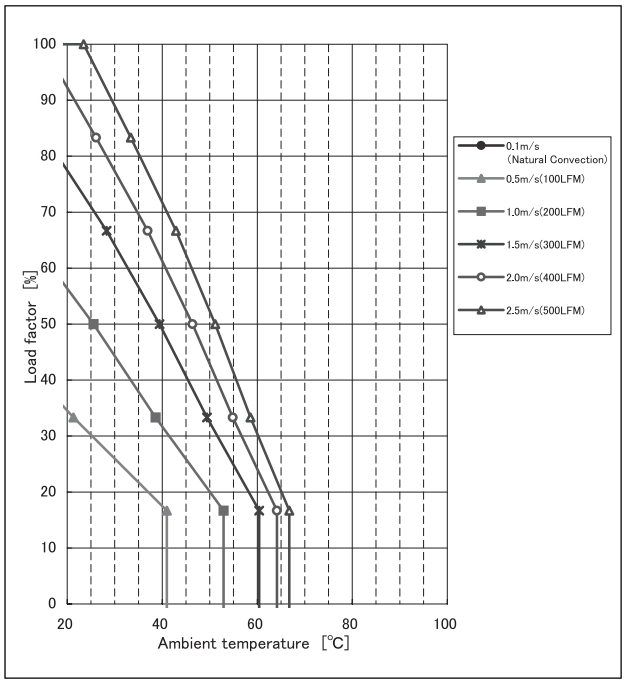
CDS4004828



Heat sink A

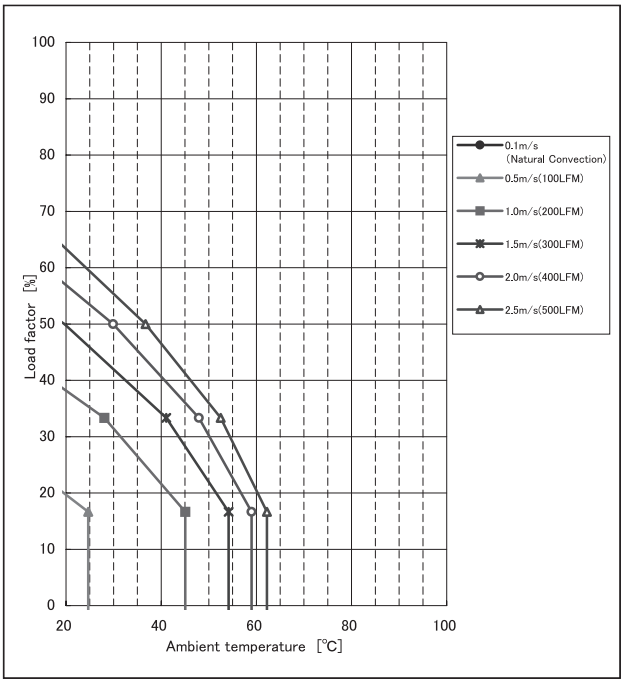


Heat sink B



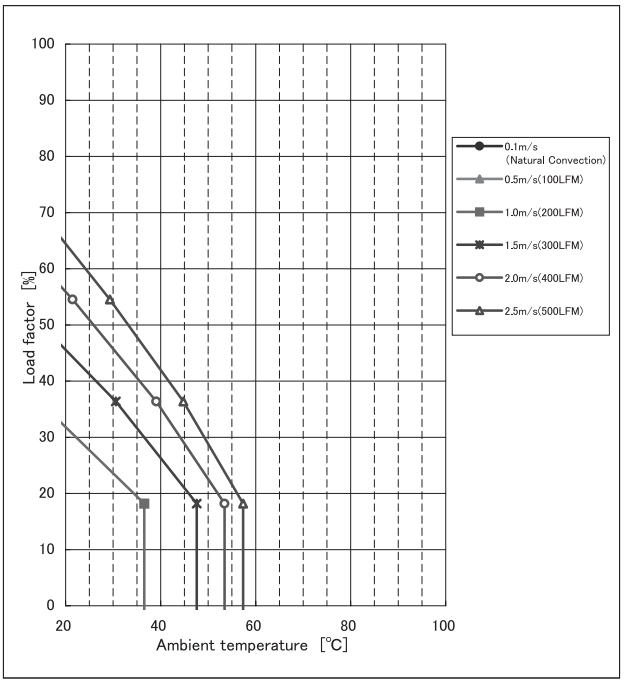
Heat sink B

CDS6002412

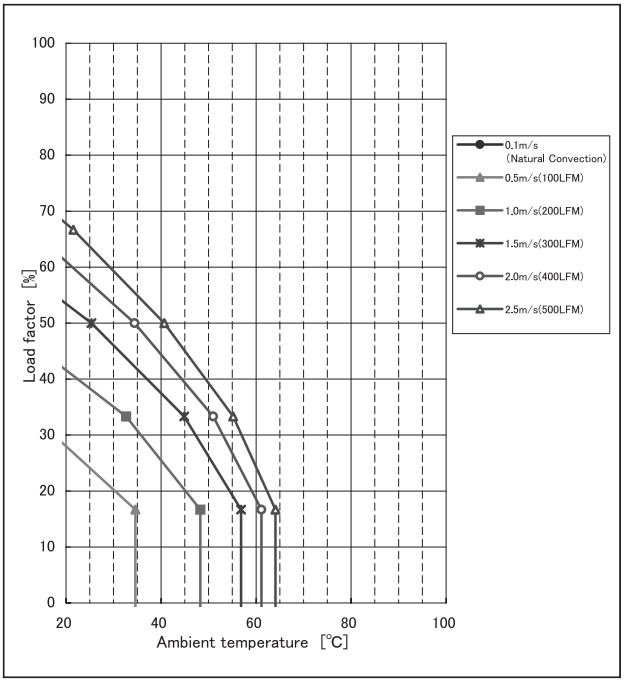


Heat sink A

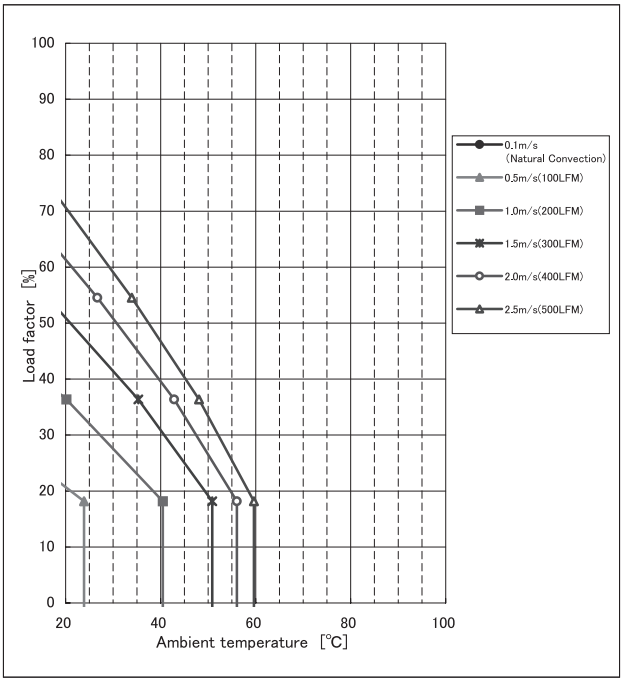
CDS6002428



Heat sink A

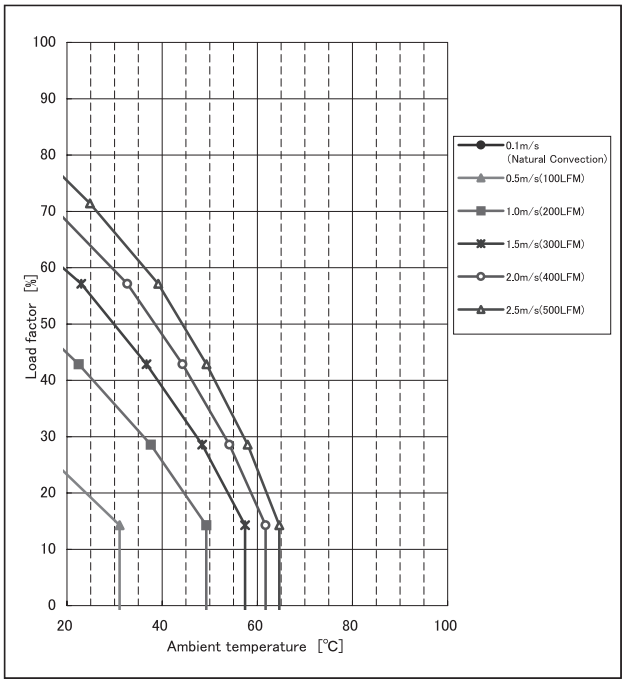


Heat sink B



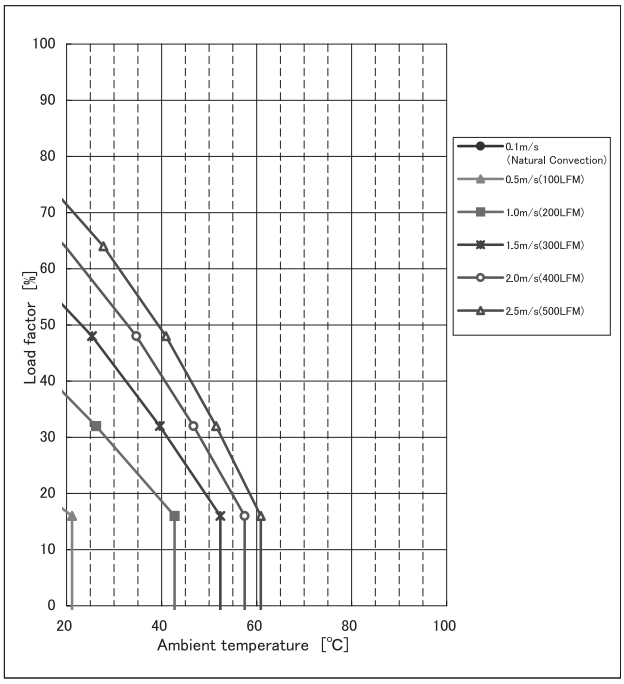
Heat sink B

CDS6004812

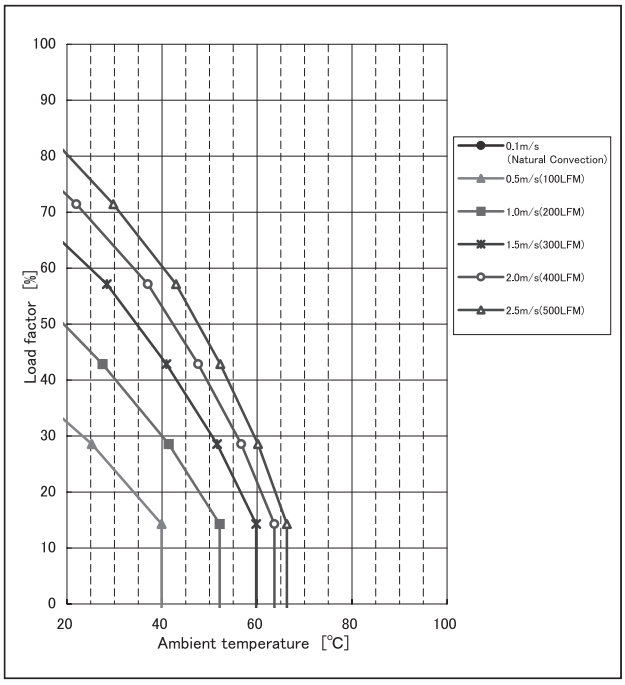


Heat sink A

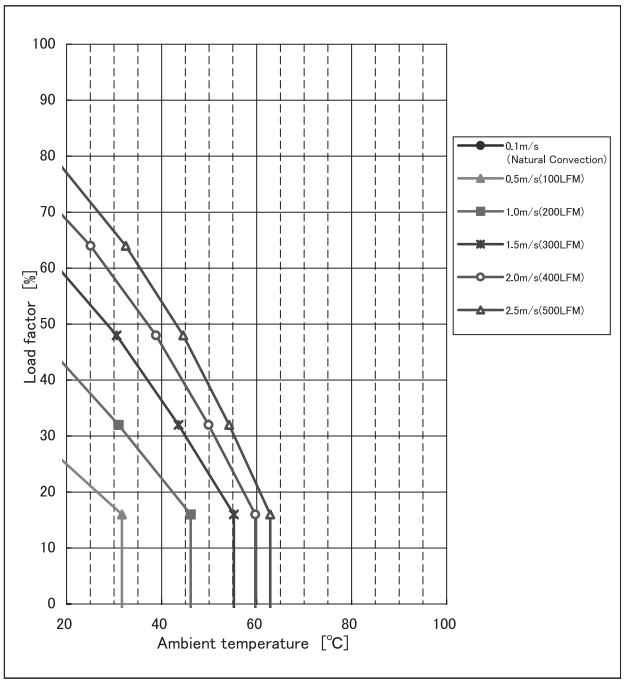
CDS6004828



Heat sink A

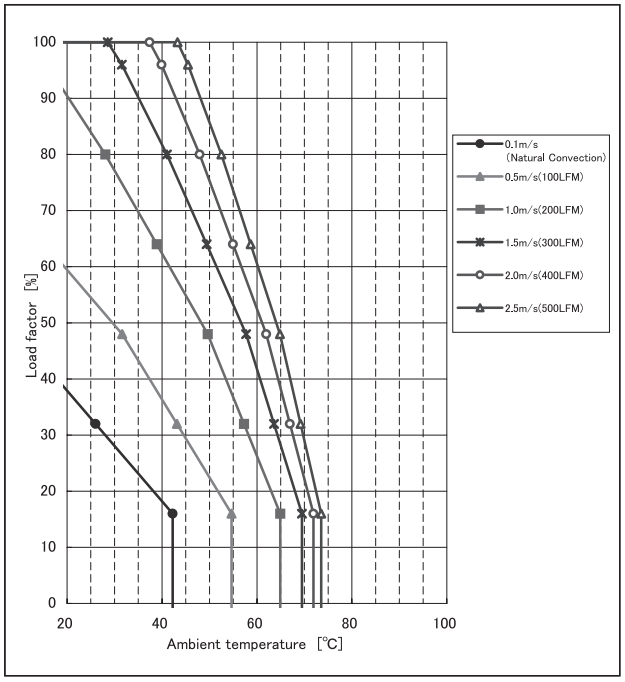


Heat sink B



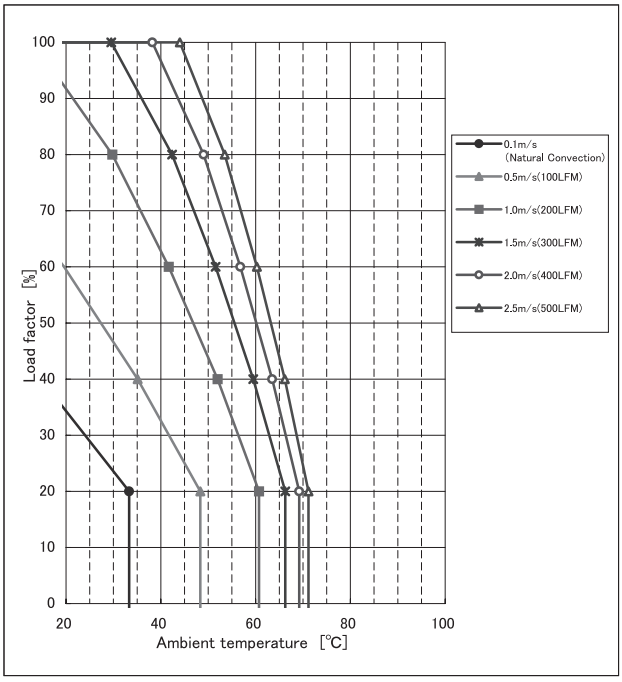
Heat sink B

DBS200B03

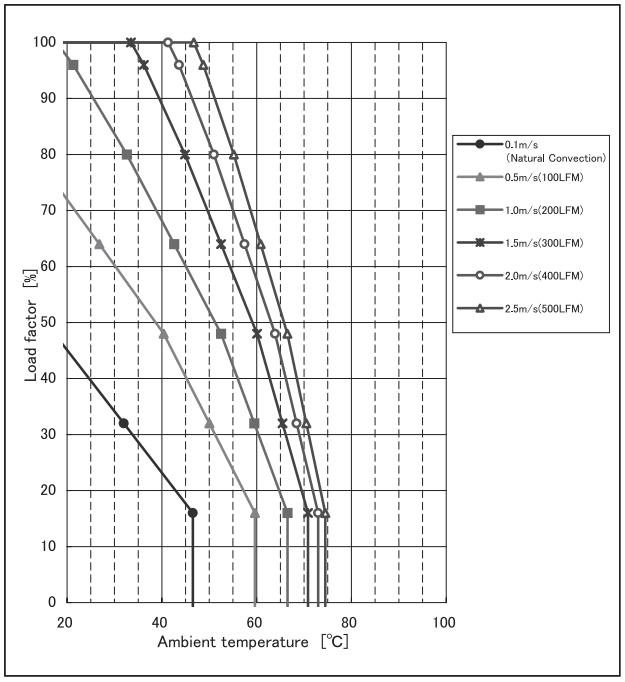


Heat sink A

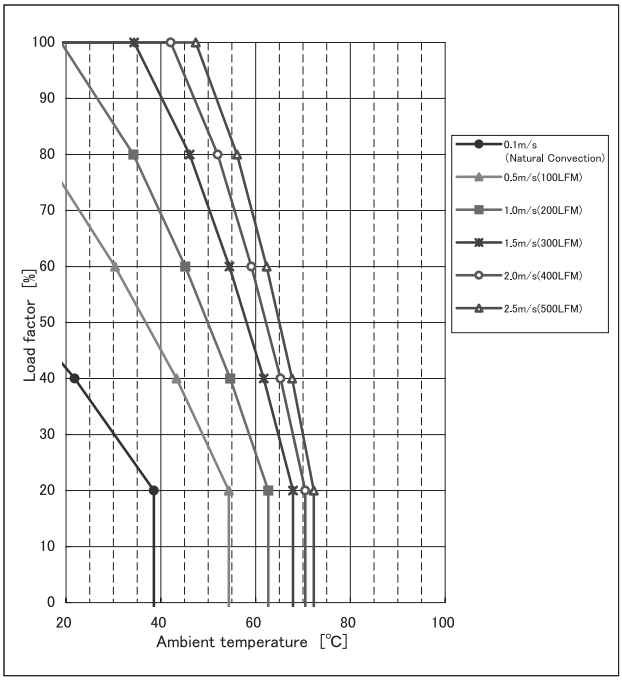
DBS200B05



Heat sink A

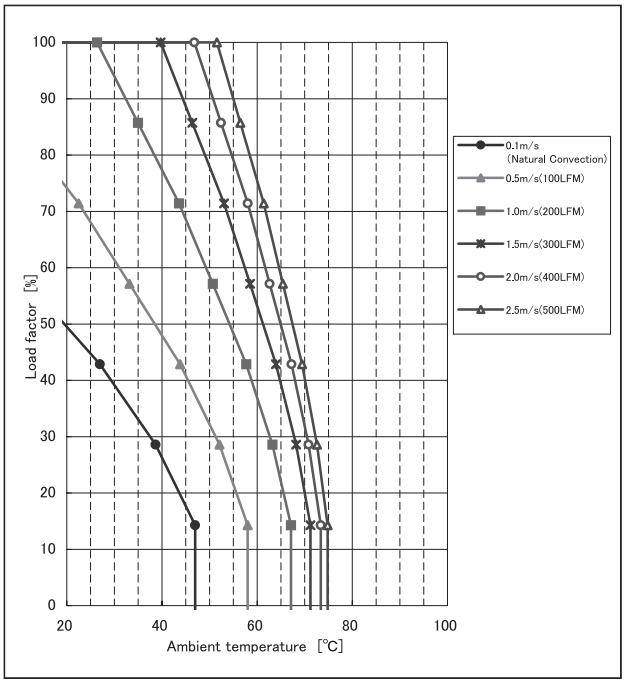


Heat sink B



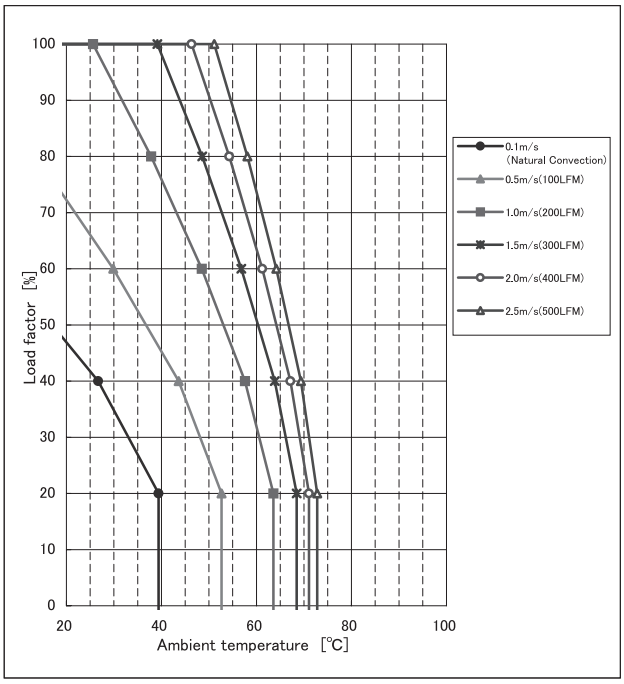
Heat sink B

DBS200B07

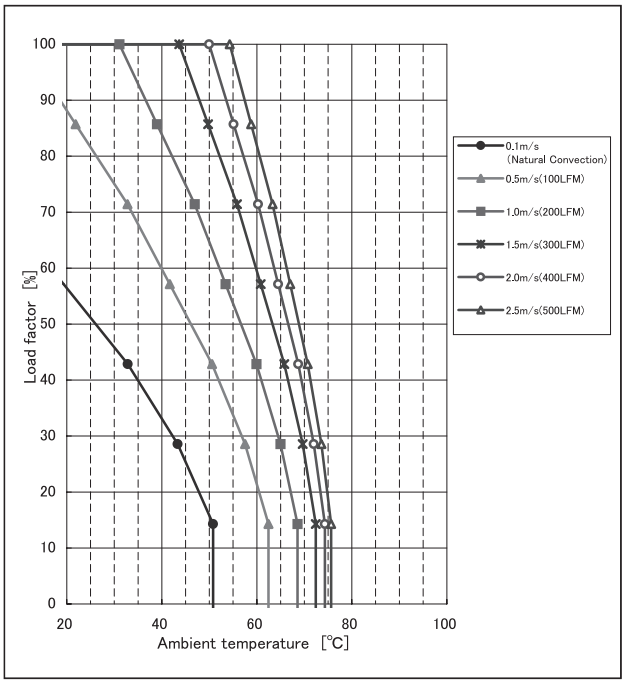


Heat sink A

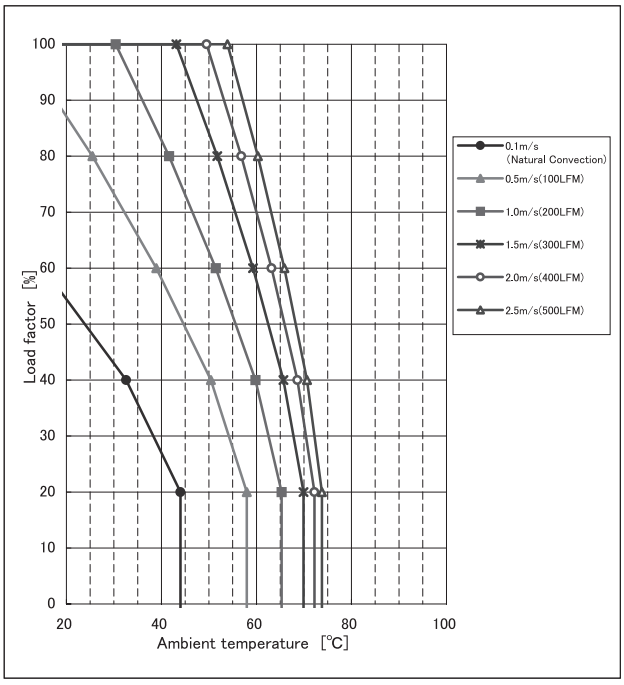
DBS200B12



Heat sink A

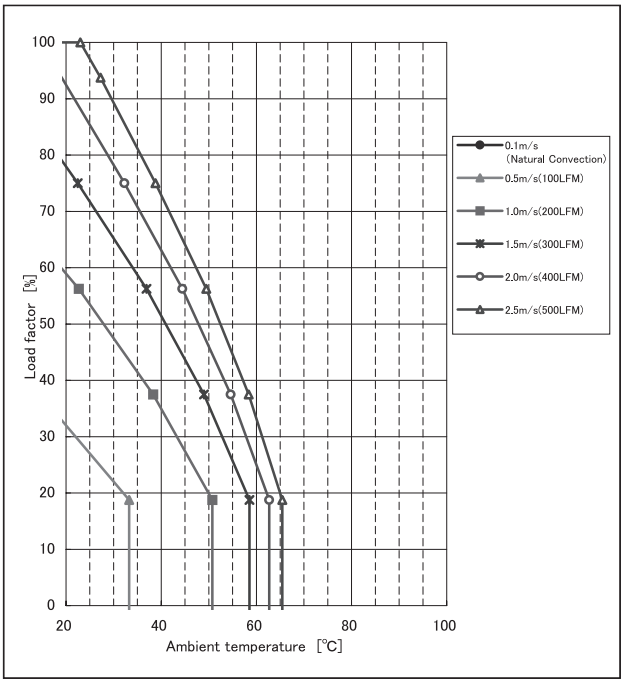


Heat sink B



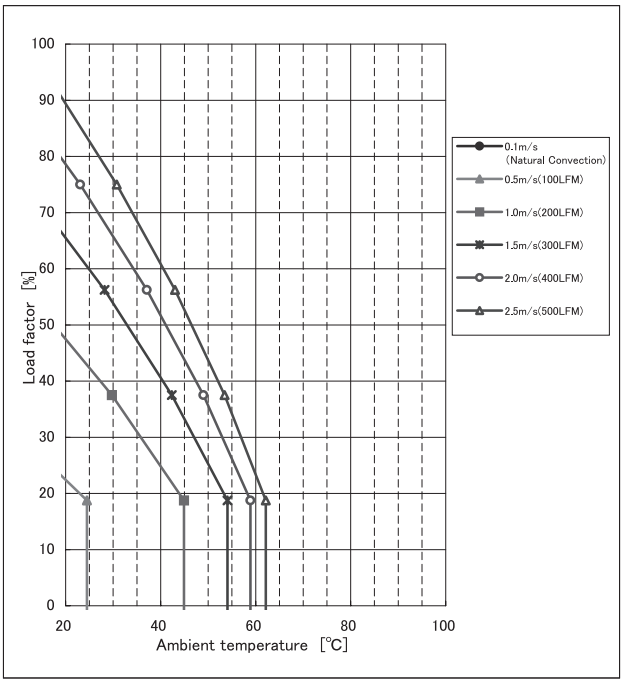
Heat sink B

DBS400B03

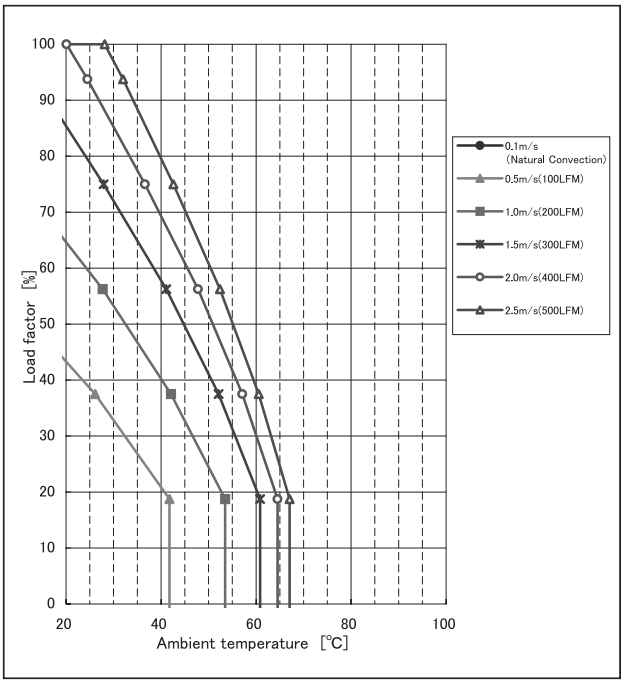


Heat sink A

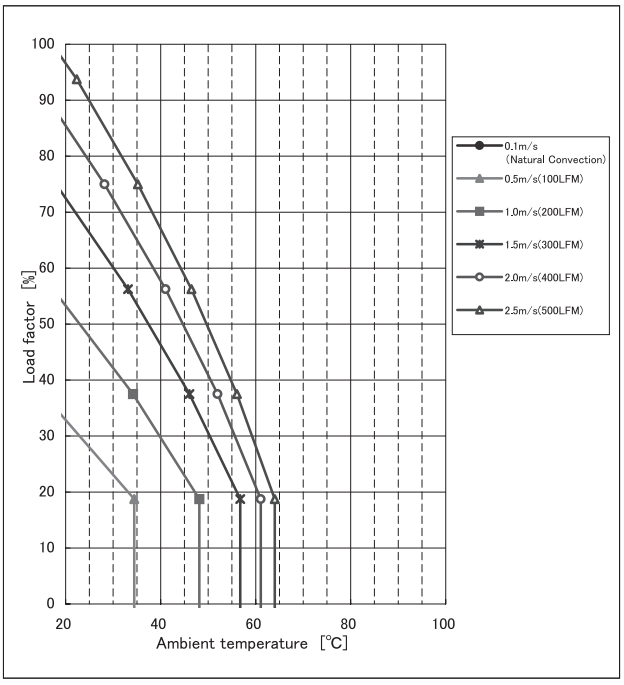
DBS400B05



Heat sink A

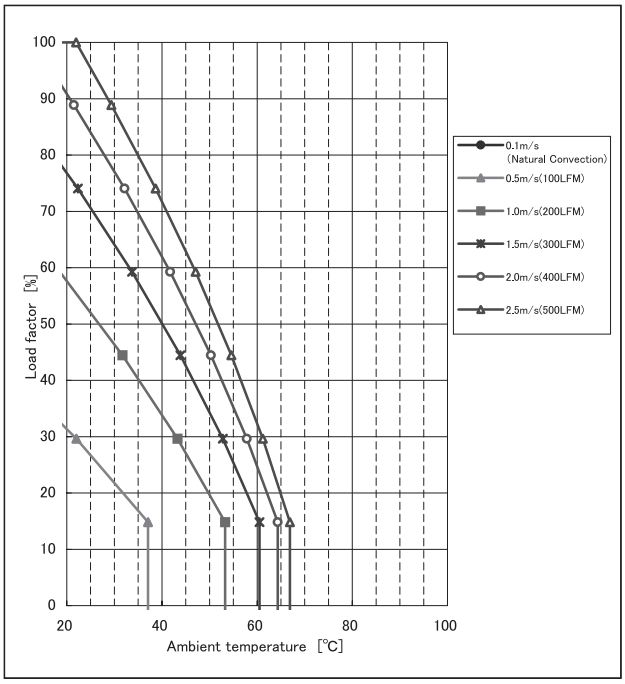


Heat sink B



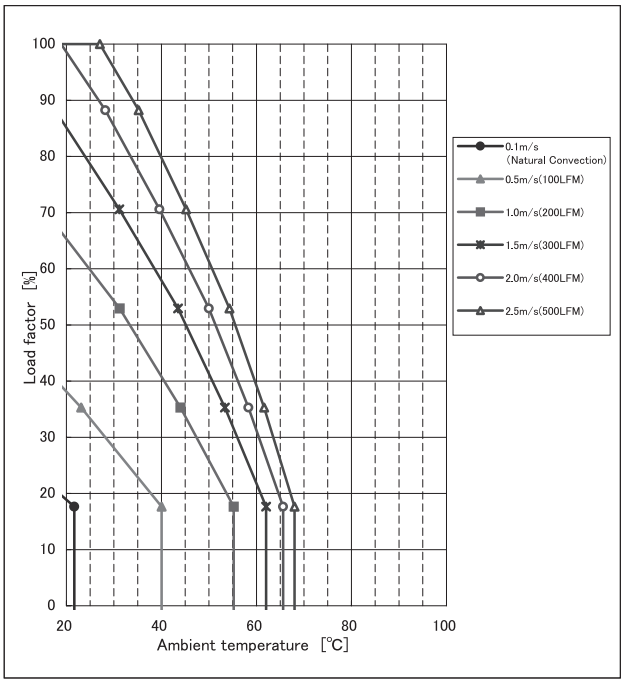
Heat sink B

DBS400B07

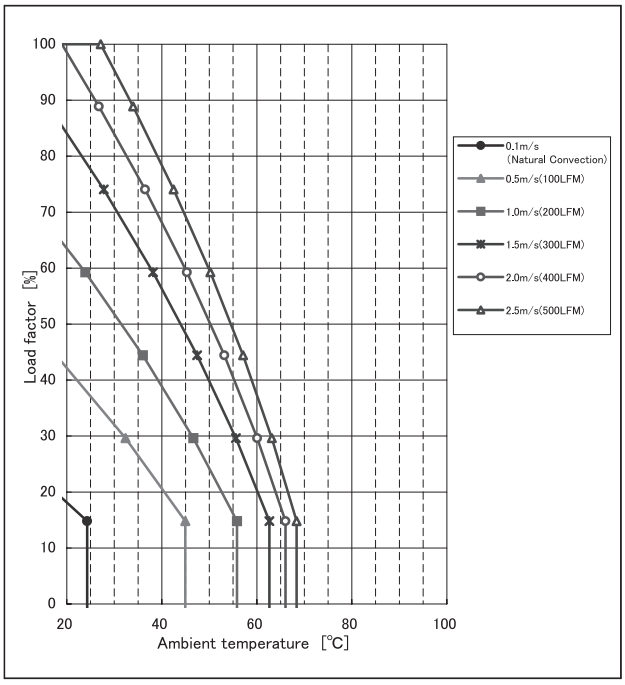


Heat sink A

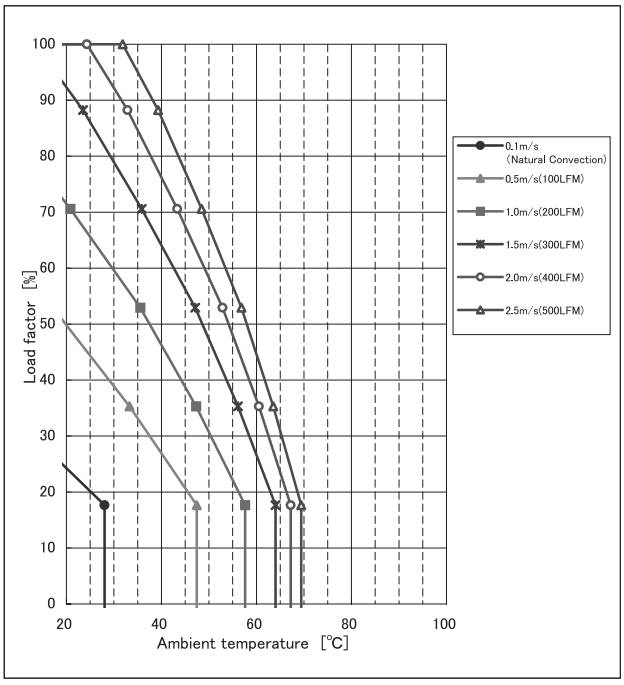
DBS400B12



Heat sink A



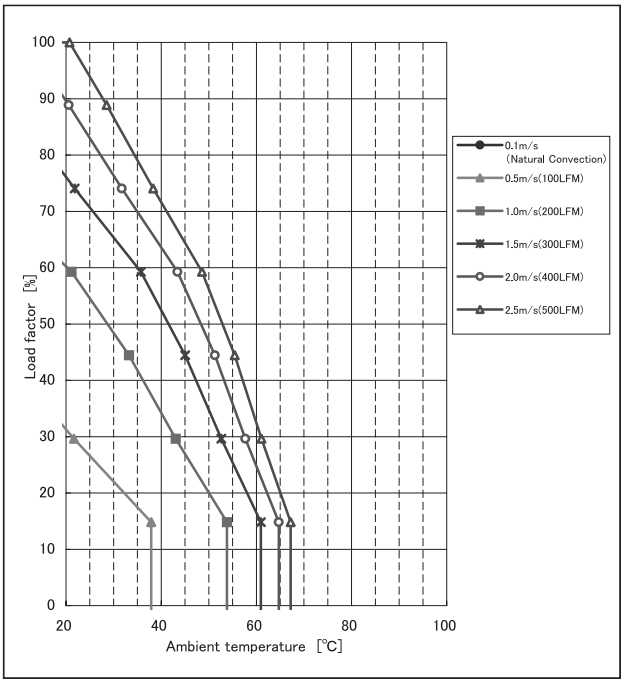
Heat sink B



Heat sink B

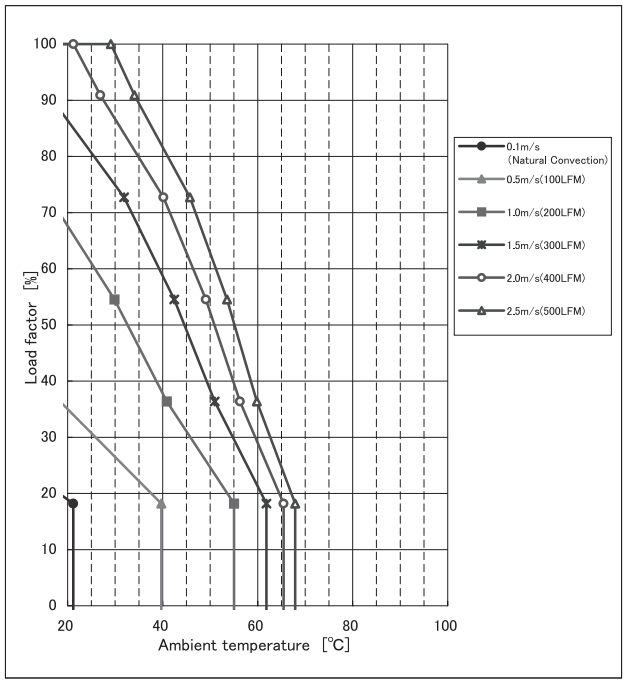
Thermal Considerations

DBS400B15

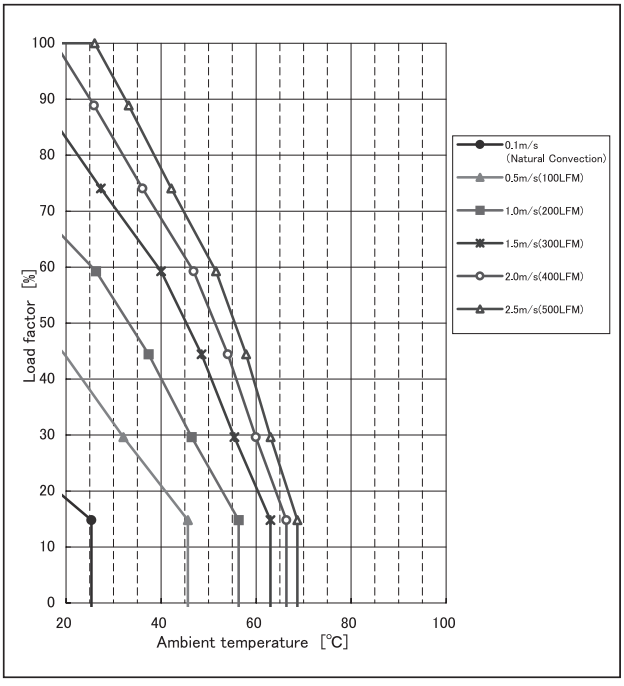


Heat sink A

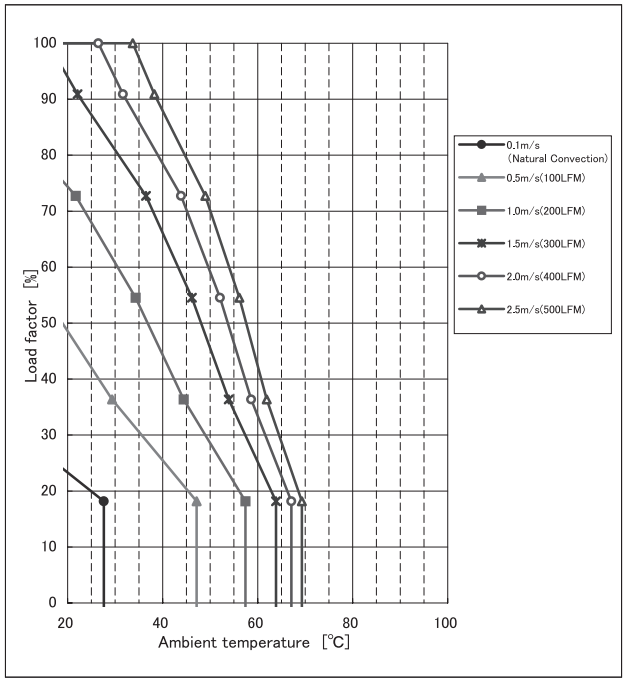
DBS400B18



Heat sink A

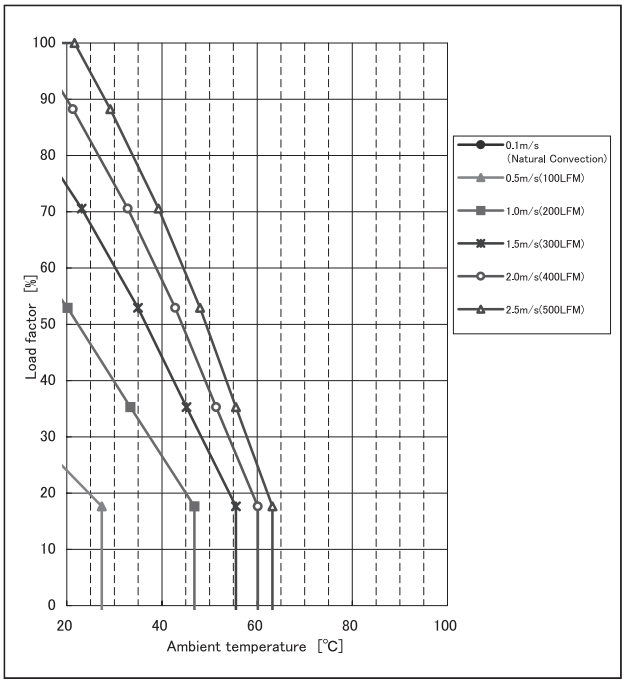


Heat sink B



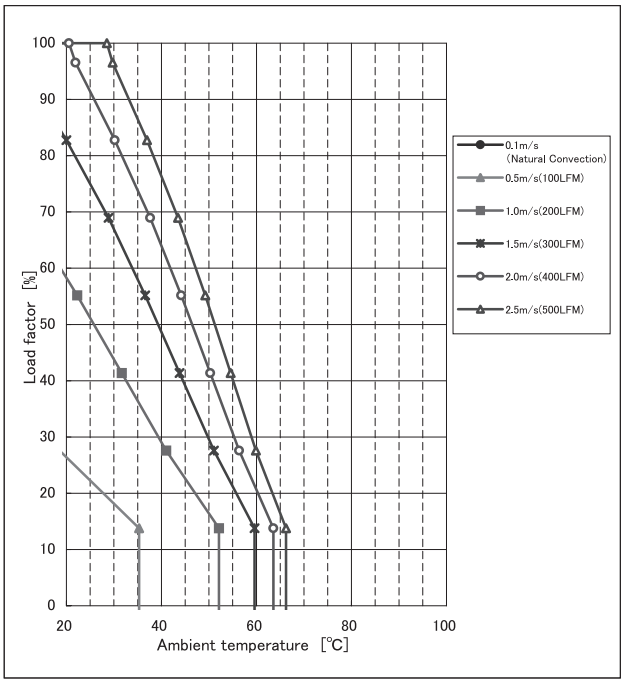
Heat sink B

DBS400B24

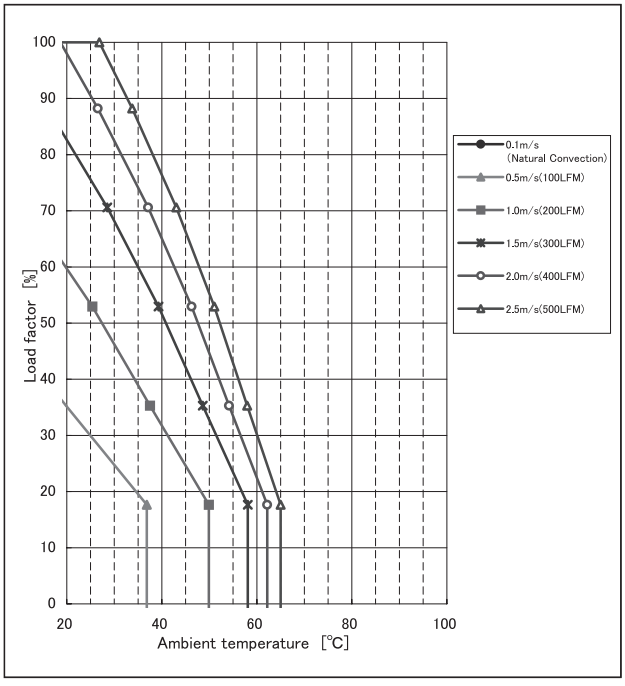


Heat sink A

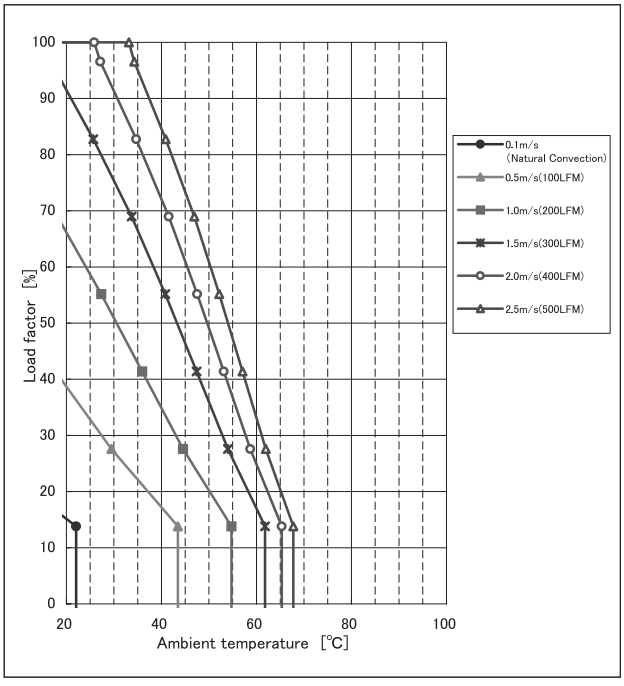
DBS400B28



Heat sink A



Heat sink B



Heat sink B