Application Note

Thermal Design for the P-Series

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Rev. A 3/94
ANPH-2

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1.0 Introduction

Thermal management and reliability are important and interrelated considerations in the application of power converters. Excessive heat is the primary cause of failure in DC-DC converters. Because all converters dissipate power internally, heat must be effectively removed or the internal temperature of the power converter will rise excessively, shortening its operating life. The following flow chart describes the thermal design process for P-Series modules.

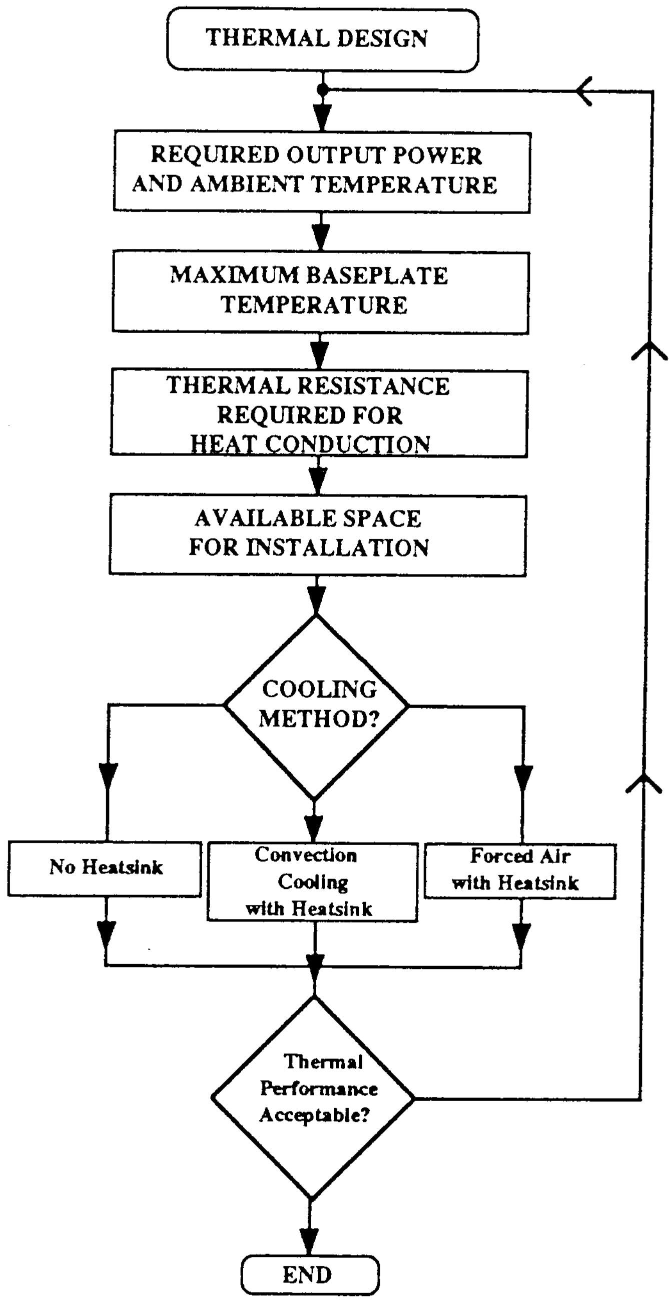


Figure 1-1 P-Series Flow Chart

2.0 Maximum Operating Baseplate Temperature

The maximum operating temperature of a power converter is determined by the internal rise of its components. Internal to the power module are several significant power dissipaters that conduct heat to the baseplate. Some of these key heat sources include the following:

- Switching transistor junctions
- Cores of filter capacitors with high ripple current
- Transformer Cores and Windings
- Rectifier Junctions

A conservative design ensures that the temperature generated from these and other heat sources meet the design and reliability guidelines for the power module. The P-Series modules have a maximum baseplate temperature limit of 85°C.

The PH, PF, PR and PT modules have a thermal shutdown circuit that senses the baseplate temperature between the range of 85 - 115°C for an overtemperature condition. Once an overtemperature condition occurs, the power modules must have their input voltage recycled to resume operation.

$$P_{DISS} = P_{IN} - P_{OUT}$$

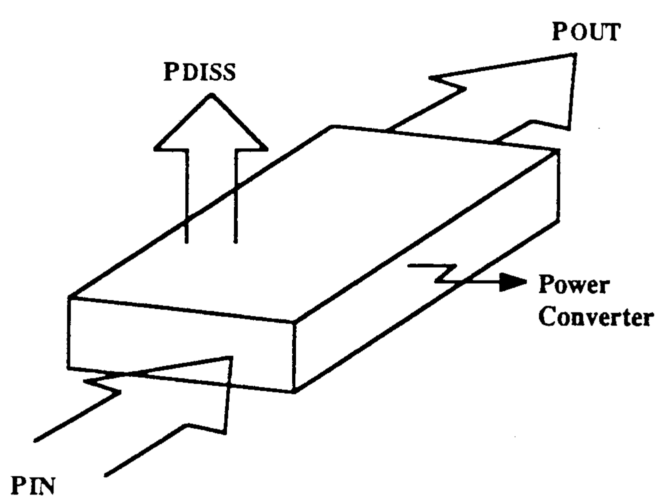


Figure 2-1 Power Flow Diagram

Equation 1 - The amount of input power converted to heat is a function of the efficiency as given by the equation below:

$$\text{Efficiency} = \eta = \frac{P_{OUT}}{P_{IN}}$$

Equation 2- The internal power dissipated is given by the following equation:

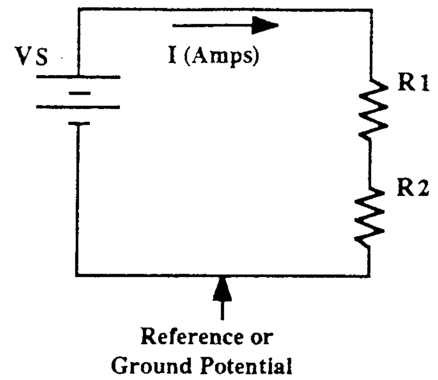
$$P_{DISS} = P_{OUT}\left[\frac{1-\eta}{\eta}\right]$$

2.1 Thermal Flow Diagram

The use of a power flow diagram (Figure 2-1) allows the user to predict the internal power dissipation or heat dissipated from a power converter. The amount of input power that is converted to heat is a function of the power module's efficiency, which can be expressed as shown in Equation 2. Once the internal power dissipation is known, the thermal impedance can be computed from measuring the baseplate and ambient temperatures.

Thermal circuits are useful tools for predicting the heat transfer characteristics of the baseplate of a power module to a heatsink mounted on its baseplate. Thermal circuits which are analogous to electrical circuits are used to analyze thermal performance as shown on the following page. Using this concept, the path of heat flow is similar to the current flowing in an electrical circuit.

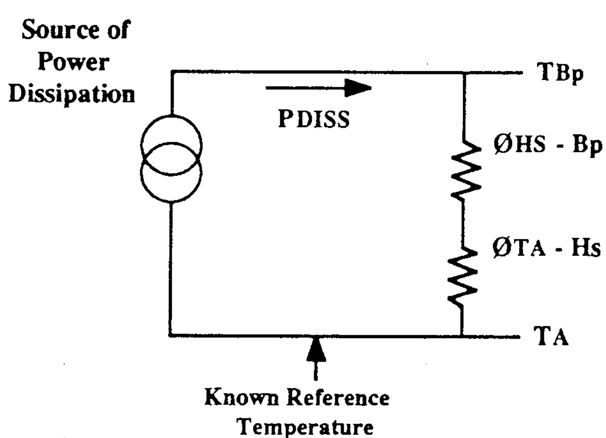
Electrical Circuit



$$(R1 + R2) = \frac{Vs}{I}$$

V(Volts) = [I(Amps) x R(Ohms)]

Thermal Circuit



$$(ØHS - Bp + ØTA - Hs) = \frac{(TBp - TA)}{PDISS}$$

ΔT(°C) = [P(Watts) x Ø(°C/Watts)]

Figure 2-2 Electrical and Thermal Circuits

3.0 Selection of Cooling Method

3.1 Conduction Cooling

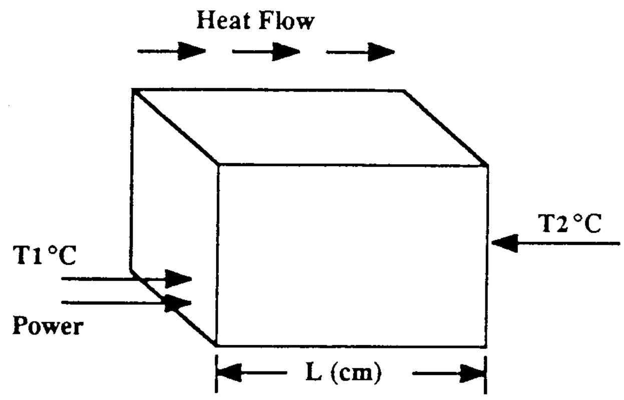


Figure 3-1 Basic Relationship for an Element with Two Surfaces (A)

The following relationship describes the concept of conduction cooling between two surfaces separated by a distance 'L', measured in centimeters. Thermal resistance of heat flow is given by the following equation:

Thermal Resistance : $\Delta T/P = L/KA$

$P = (KA/L)(T2 - T1)$
$[T2 - T1 = \Delta T = PL/KA]$

K = Proportionality constant thermal conductivity
P = Watts
A = Square centimeters (cross sectional area)
K Aluminum = 2.25 Watts / Sw. cm / cm°C

Heatsinks conduct heat from their fin surfaces to the layer of air immediately surrounding the fins. As the air warms up it expands and rises, resulting in a boundary layer of air moving upward past the surface of the fins. The more fins present (surface area), the greater number of heat or calories removed. The thermal efficiency of the heat sink increases at higher levels when the operating temperature is higher.

Heat transfer depends upon the following:

- Thickness and thermal conductivity of the boundary layer
- Velocity of air particles
- Fin height and height to spacing ratio of the fins
- Total fin area

3.2 Forced Air Cooling

In an effort to achieve higher power density and overall better cooling, the forced air cooling approach can be used. Calculating thermal impedance is more difficult than calculating with conduction. It is dependent upon the mechanical configuration of the enclosure, which can cause changes in air turbulence along with variances in back pressure. When characterizing heatsinks such as the PH heatsink accessories, a wind tunnel was constructed to obtain a controlled environment. The wind tunnel ducts the fan air, producing a uniform air flow through the fins of the heatsink. The airflow is measured with an aerometer at the inflow and outflow point, thus producing an average wind velocity. Refer to Figure 3-2 *Measuring Point'* below.

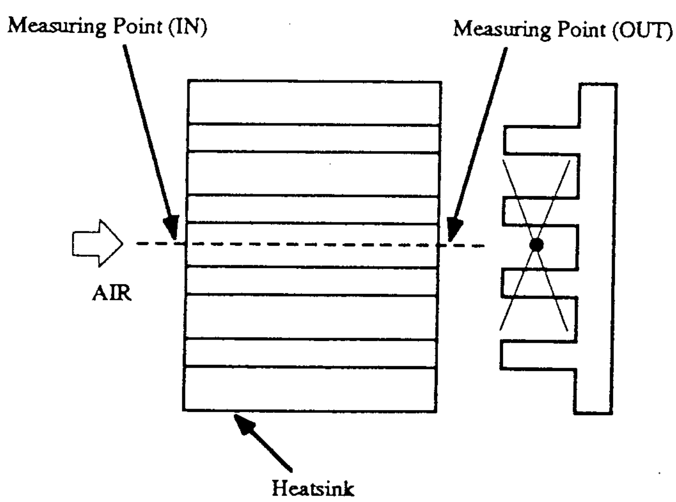


Figure 3-2 Measuring Point

In practice, airflow typically ranges anywhere from 150LFM to 800LFM in systems with various mechanical configurations. This makes it extremely difficult to predict thermal performance by measuring only the average airflow over the heatsink with a fan rated at "X"LFM. Therefore, practical testing must be performed in each application to confirm the 'true' thermal performance.

Included are thermal performance data for heatsink kits that support the P-Series. Note that heatsink kits are available in both 12mm and 23mm fin heights.

4.0 Heatsink Selection Example

Given:

Heatsink = PAH146L23 with Q-Pad Thermal Insulator
PH300F-280-5
Vin = 280V
Iout = 60A
Vout = 5.0V
Forced Air @ 600LFM
Ambient Temperature = 40°C
Maximum Allowable Baseplate Temp. = 85°C

- Determine if the above heatsink is adequate for this application.

- Determine the power dissipated for the above conditions.

Step #1 - Obtain the efficiency from Figure 4-1 *'Efficiency and Input Current vs. Output Current'* on the following page for the above conditions.

i.e. : $\eta = 83\%$

Step #2 - Calculate the internal power dissipation (PDISS).

$$P_{DISS} = \left(\frac{1-\eta}{\eta}\right) P_{OUT}$$

$$P_{DISS} = \left(\frac{1-0.83}{0.83}\right)(300) = 61.45W$$

- Determine the maximum allowable baseplate temperature at an ambient temperature of 40°C.

TBP (Max Rise) = 85°C - 40°C = 45°C

- Verify that the baseplate temperature rise is within the TBP (Max) operating limit from Figure 4-2 *PAH146L23 Thermal Performance'* on the following page.

i.e. : TBR (RISE) = 18°C (from the graph) @ 600LFM

This application would require at least 200LFM airflow using the PAH146L23 heatsink.

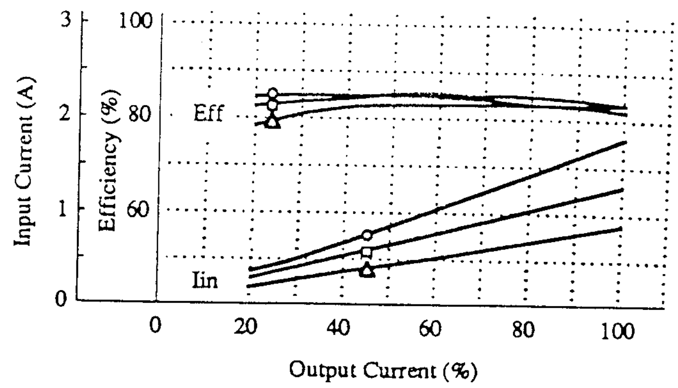


Figure 4-1 PH300F-280-5 Efficiency and Input Current vs. Output Current Graph

The thermal resistance of the PAH146L23 heatsink using a SIL PAD thermal pad insulator can be computed as follows:

$$\O_{Bpa} = \left(\frac{T_{BP} - T_a}{P_{DISS}}\right)$$

ØBp-a = Thermal Resistance (Baseplate - Ambient) (°C/W)
PDISS = Internal Power Dissipation (W)
Ta = Ambient Temperature (°C)
TBP = Baseplate Temperature (°C)

$$\O_{bp\text{-}a} = \frac{58 - 40}{61.4W} = 0.293\ ^\circ C/W$$

Conclusion :

Expected Baseplate Temp. = (TBP) = 18 + 40 = 58°C @ Full Load, 40°C, which is well within the maximum baseplate temperature

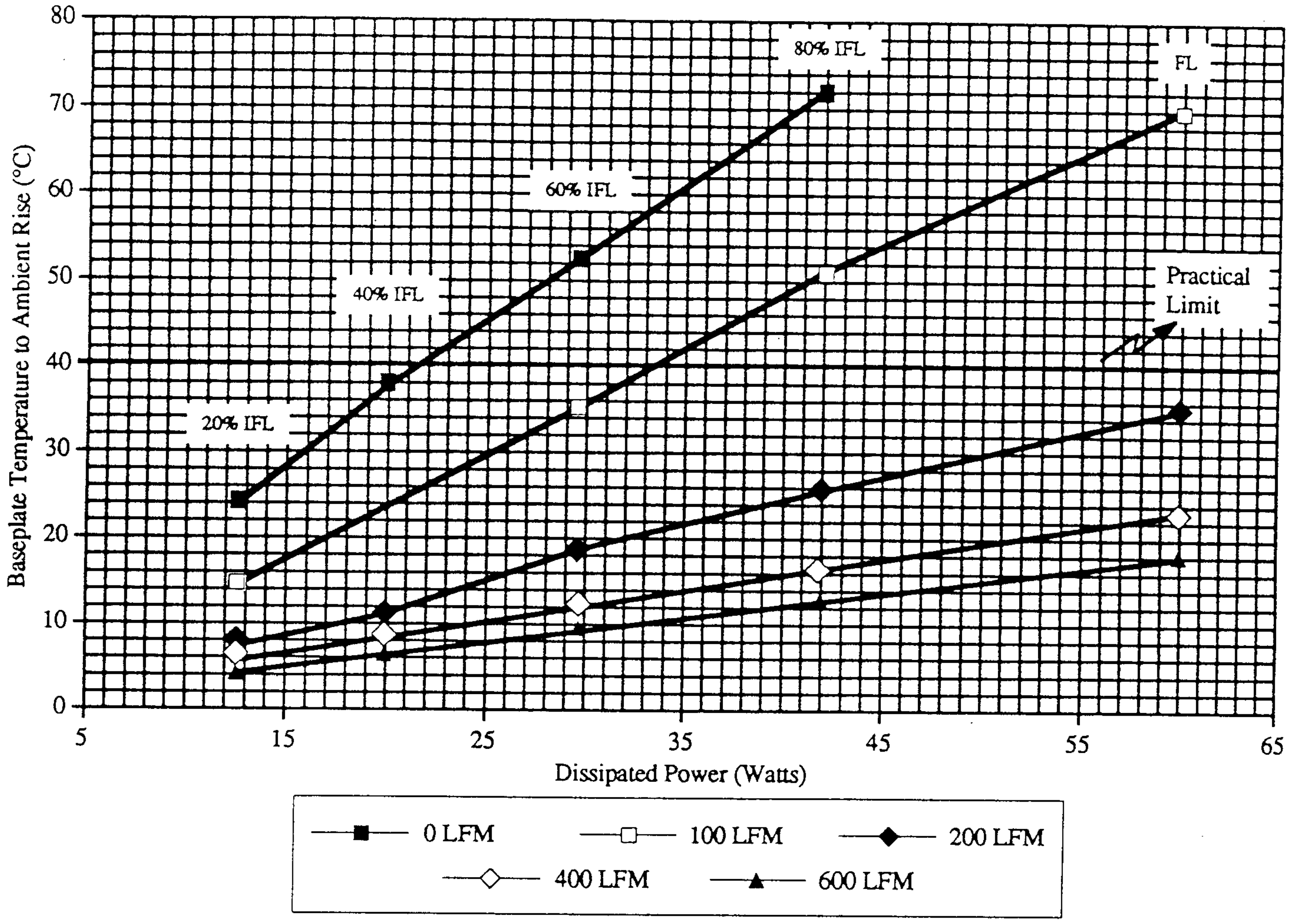


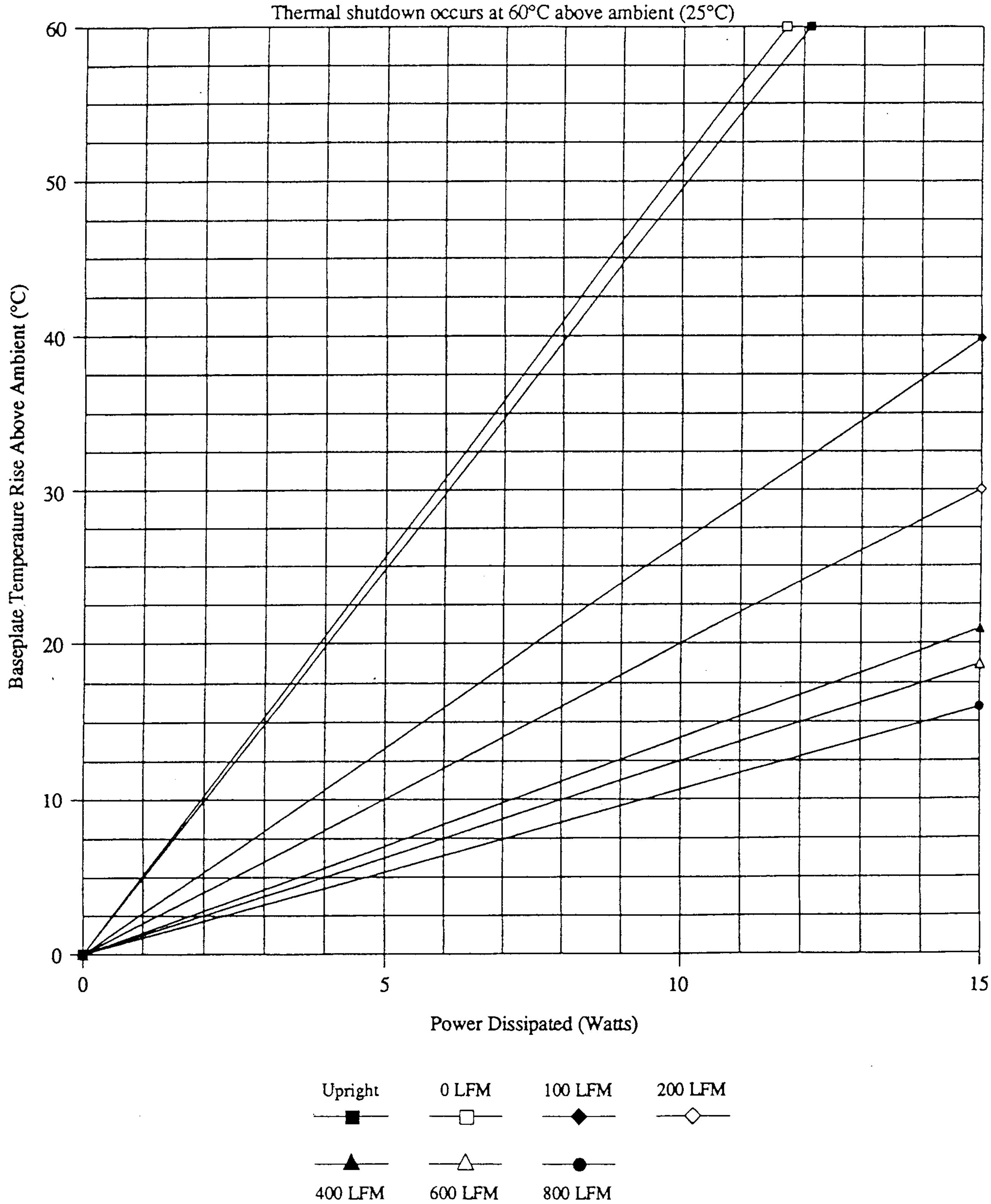
Figure 4-2 PAH146L23 Thermal Performance Chart
(23mm with Q-Pad Thermal Insulator)

APPENDIX A

Heatsink PAH41L12

The following modules use heatsink PAH41L12:

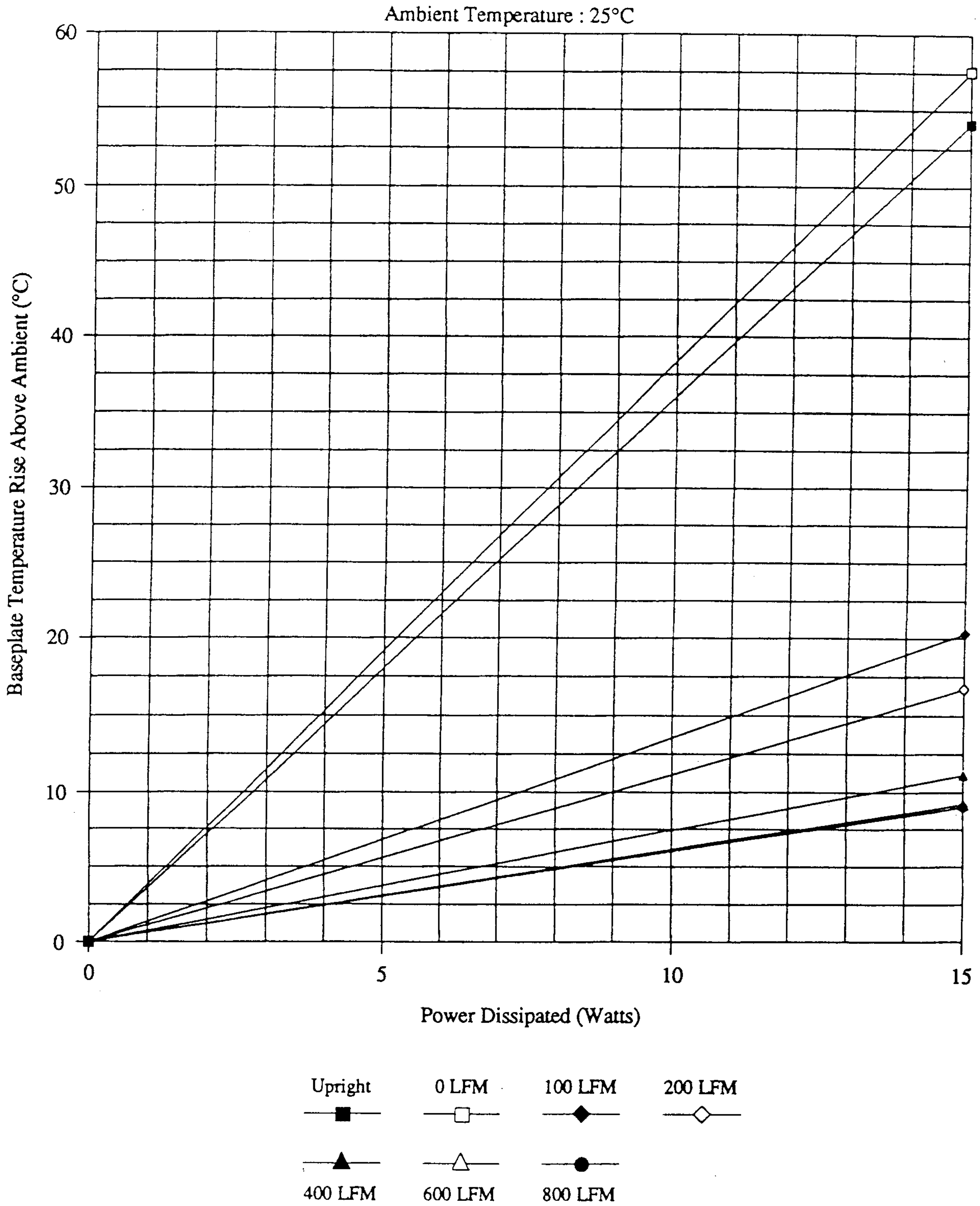
- PH50S
- PH75S



Heatsink PAH41L23

The following modules use heatsink PAH41L23:

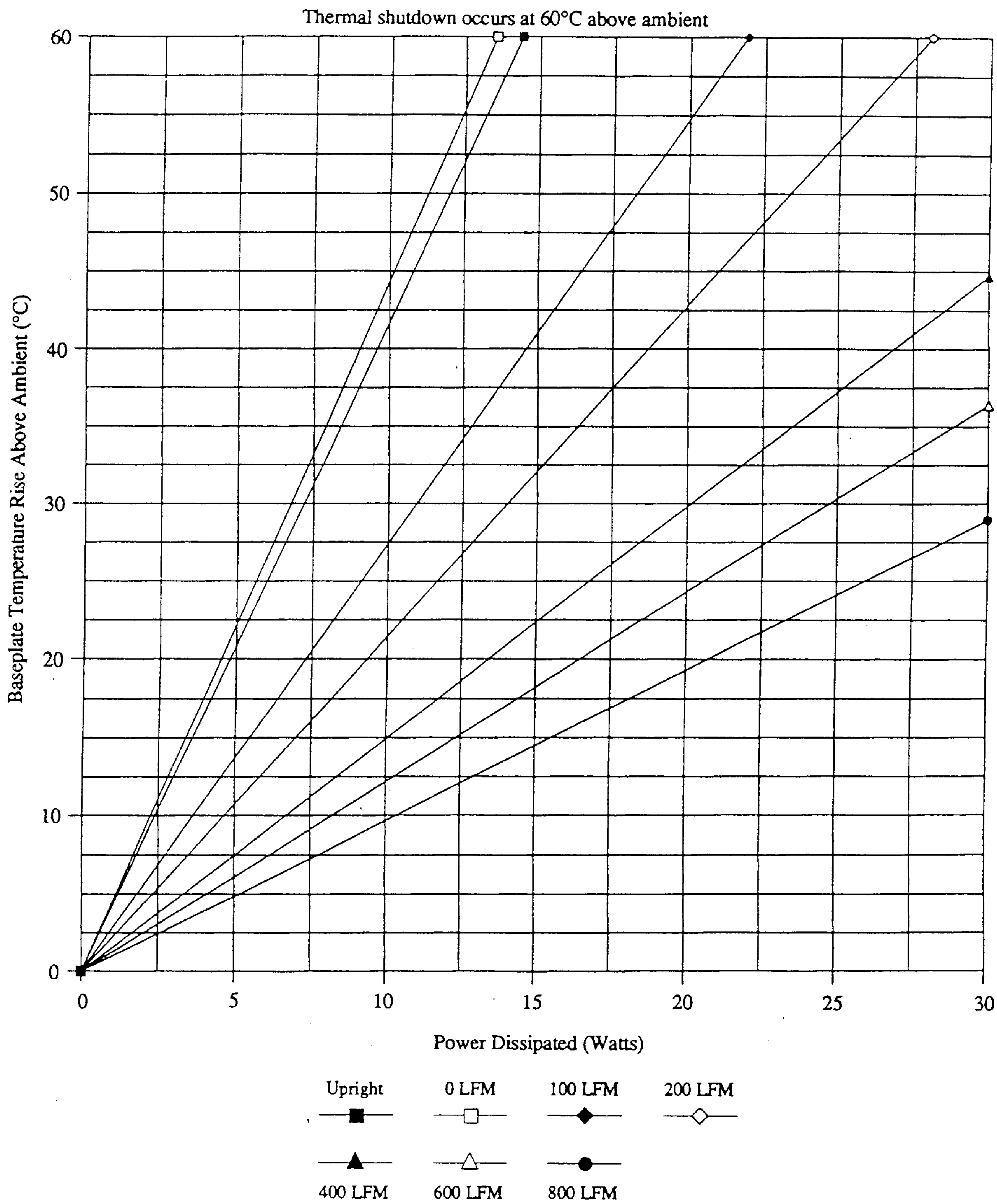
- PH50S
- PH75S



Heatsink PAH62L12

The following modules use heatsink PAH62L12:

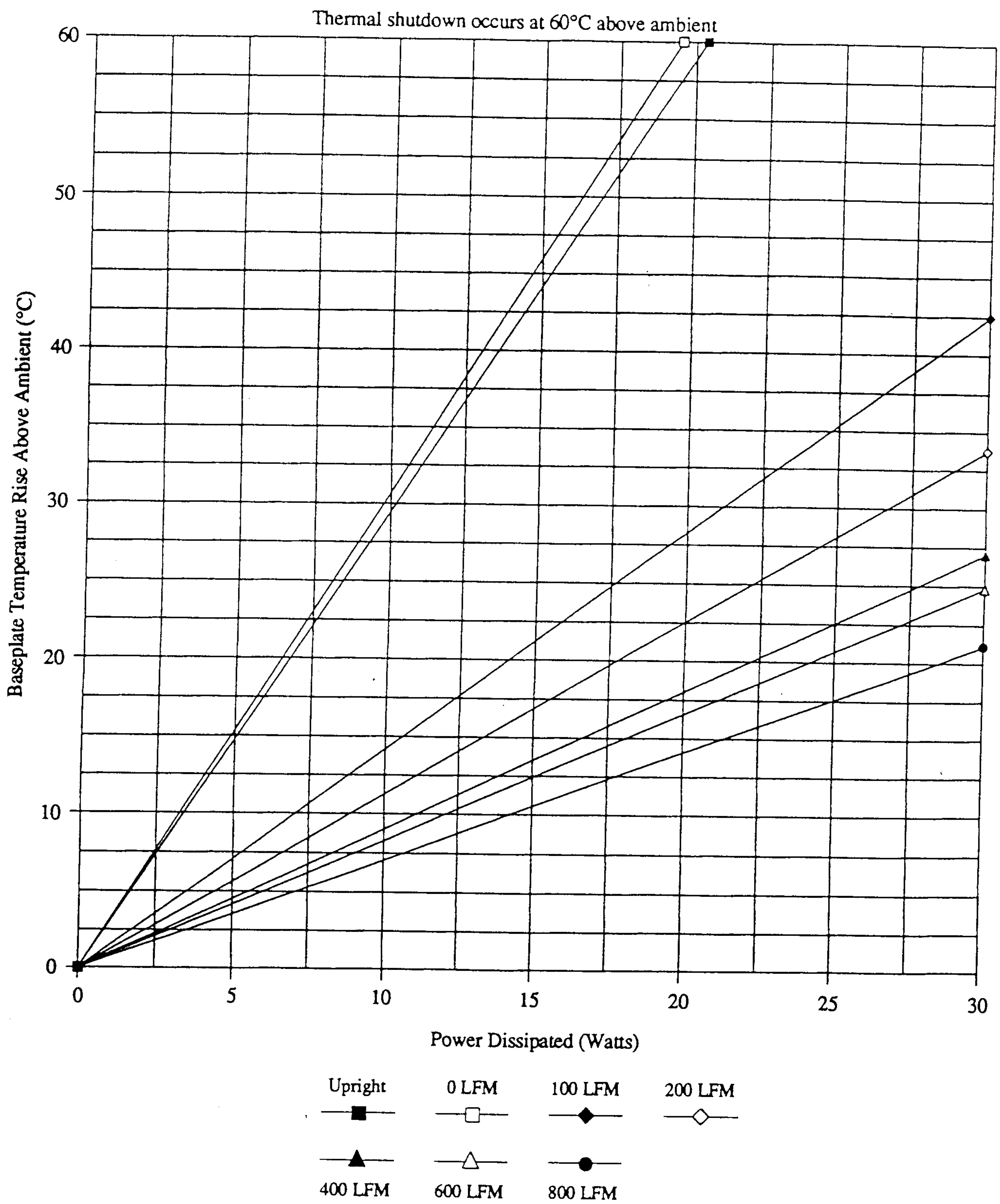
- PH75F
- PH100S
- PN3207



Heatsink PAH62L23

The following modules use heatsink PAH62L23:

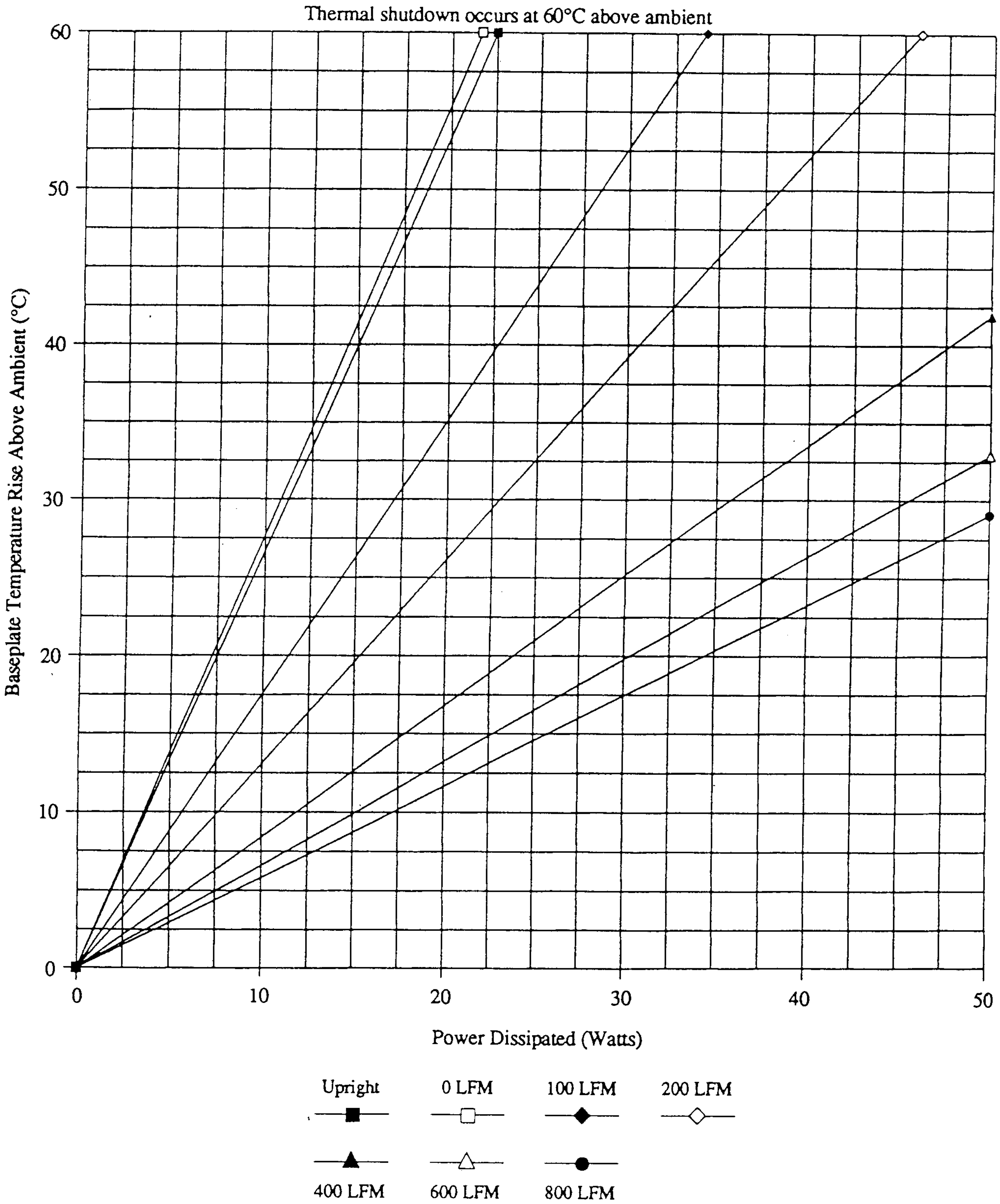
- PH75F
- PN3207
- PH100S



Heatsink PAH72L12

The following modules use heatsink PAH72L12:

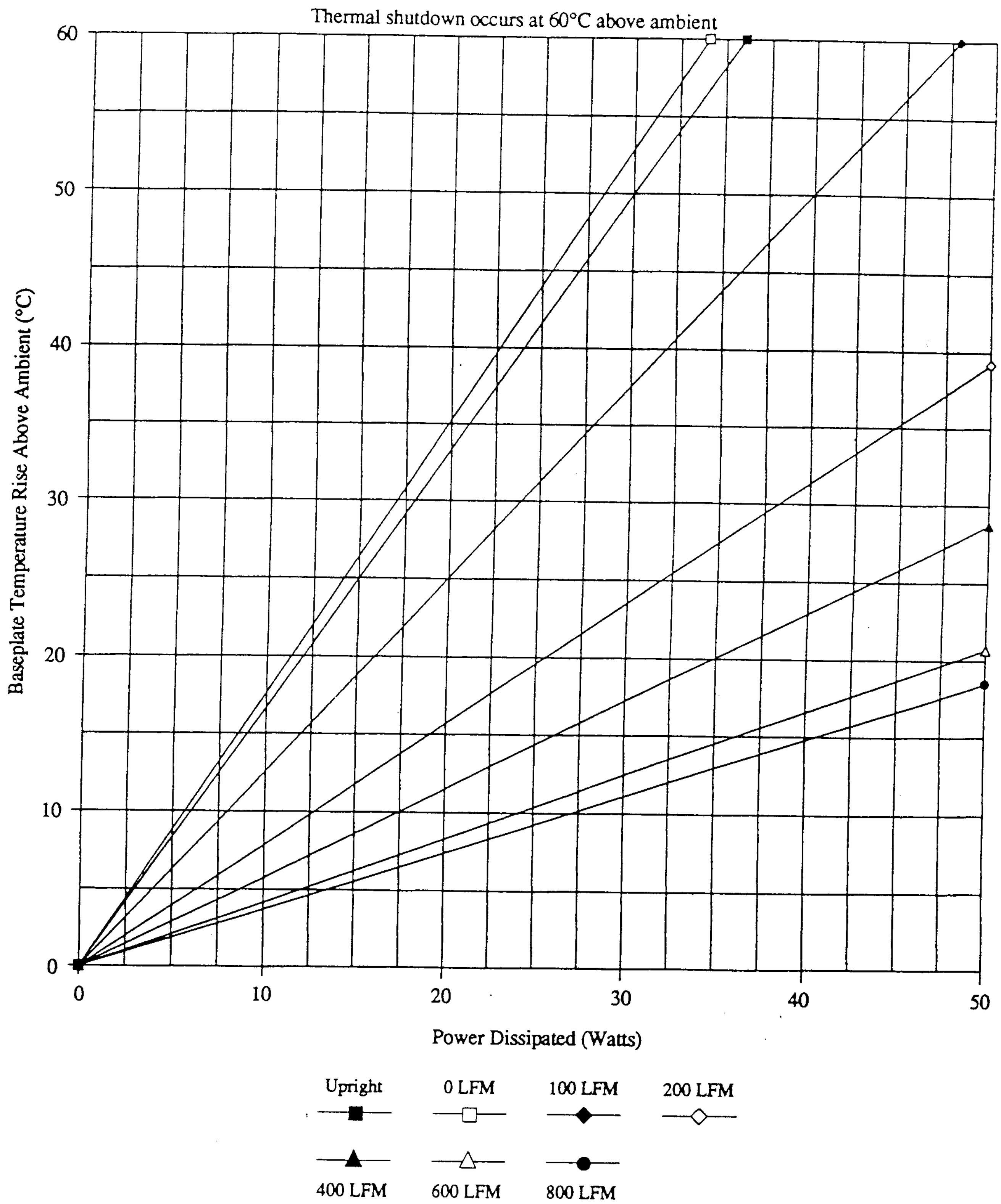
- PH150S



Heatsink PAH72L23

The following modules use heatsink PAH72L23:

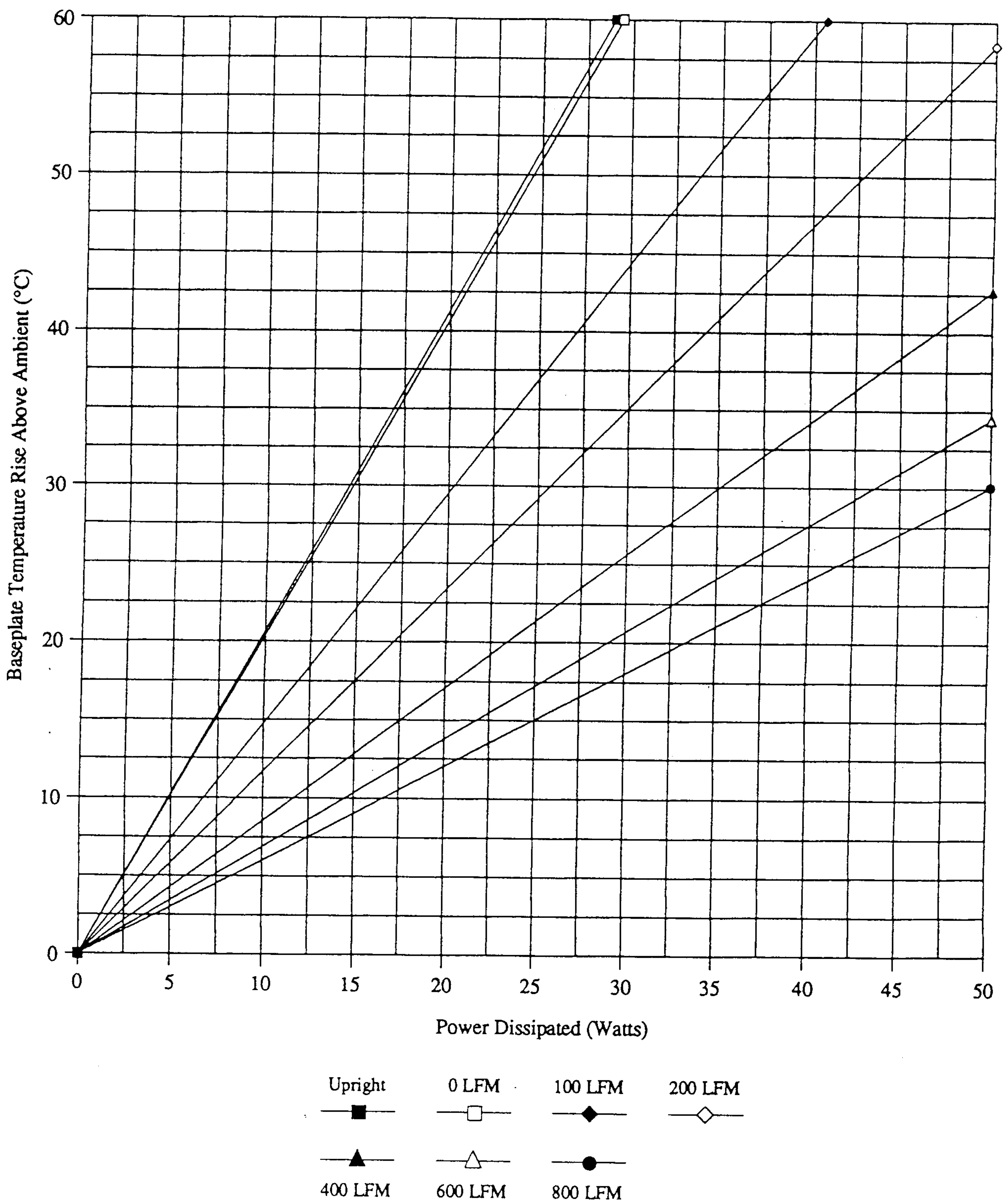
- PH150S



Heatsink PAH83L12

The following modules use heatsink PAH83L12:

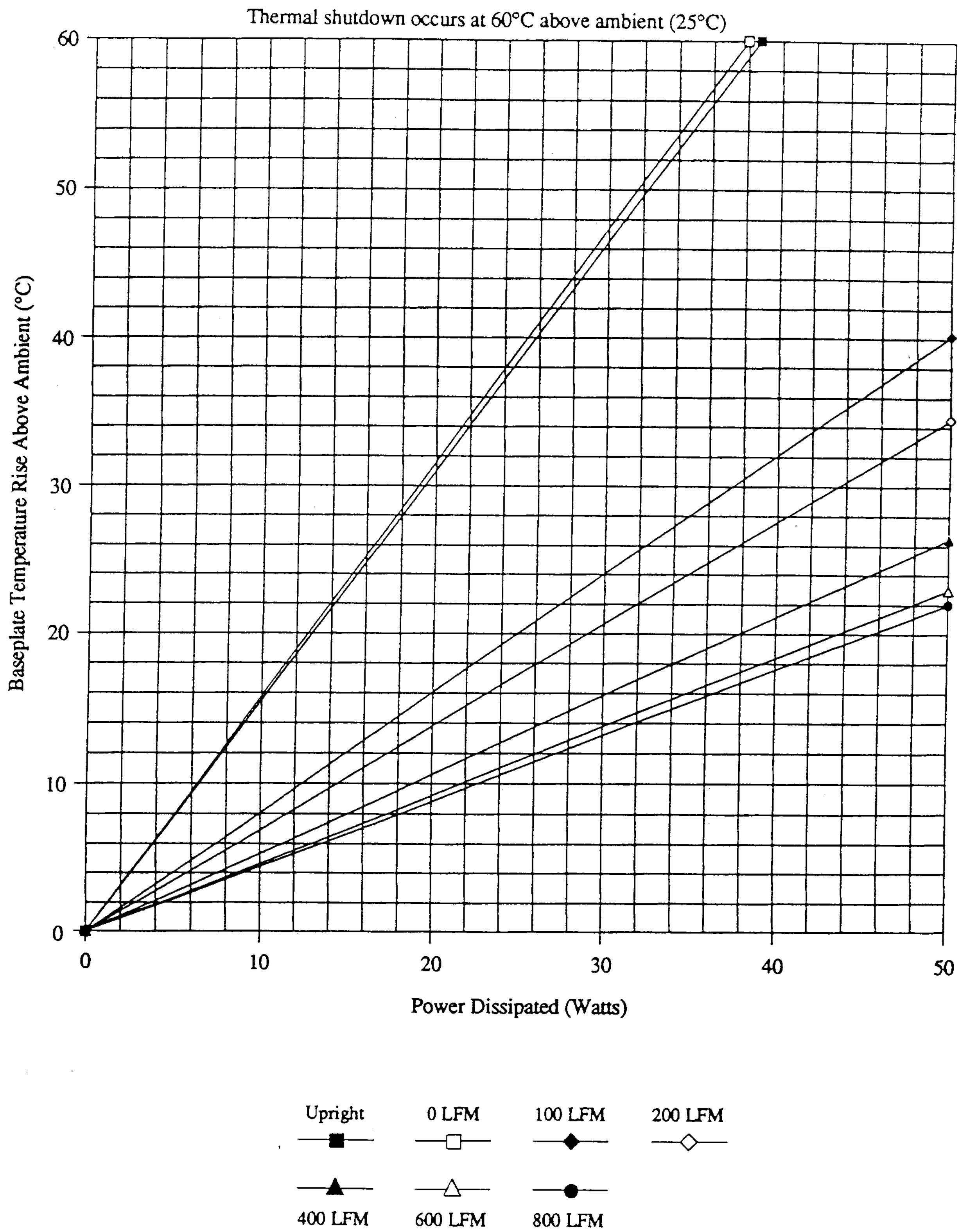
- PH150F
- PF500
- PN3215
- PR500



Heatsink PAH83L23

The following modules use heatsink PAH83L23:

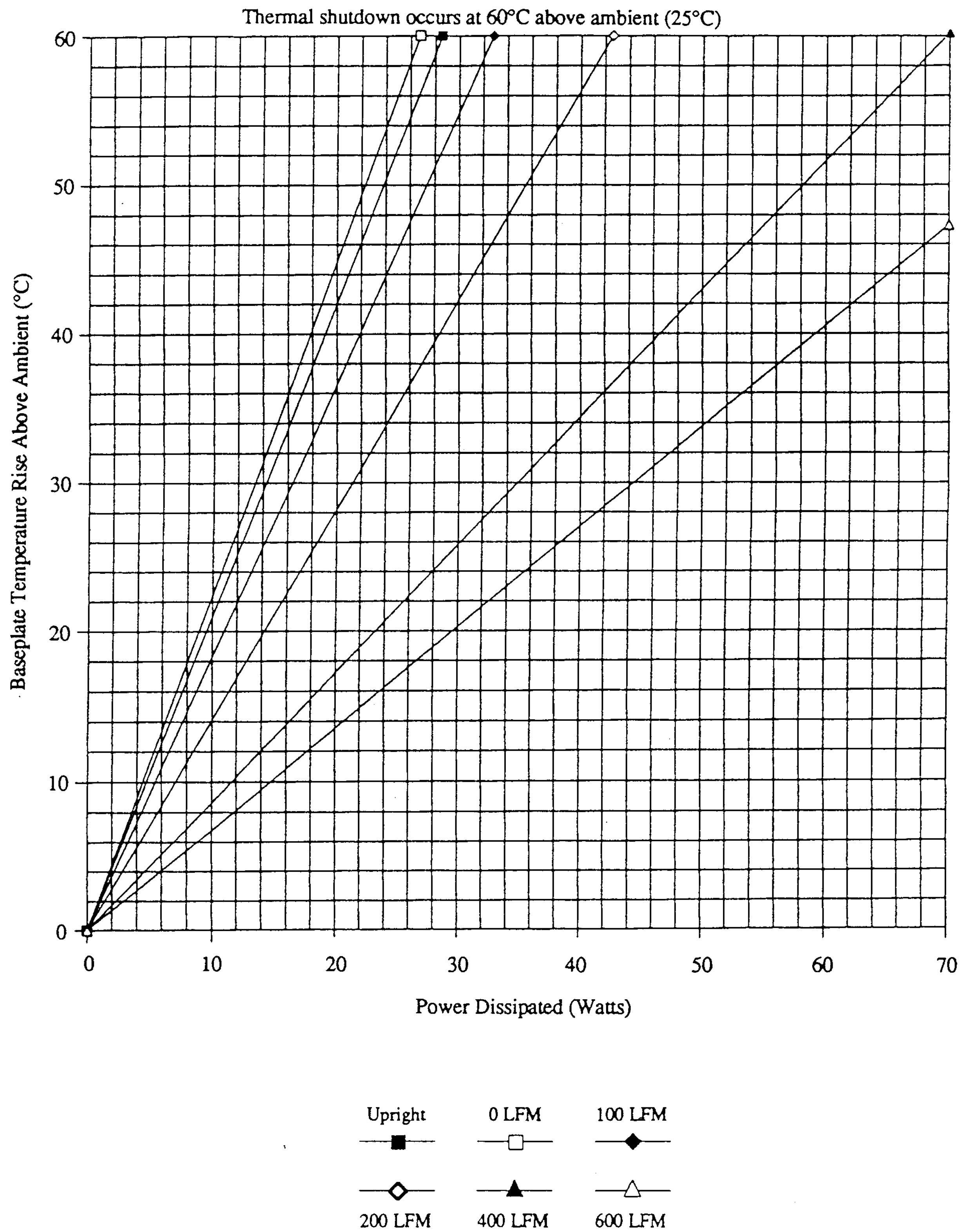
- PH150F
- PF500
- PN3215
- PR500



Heatsink PAH146L12

The following modules use heatsink PAH146L12:

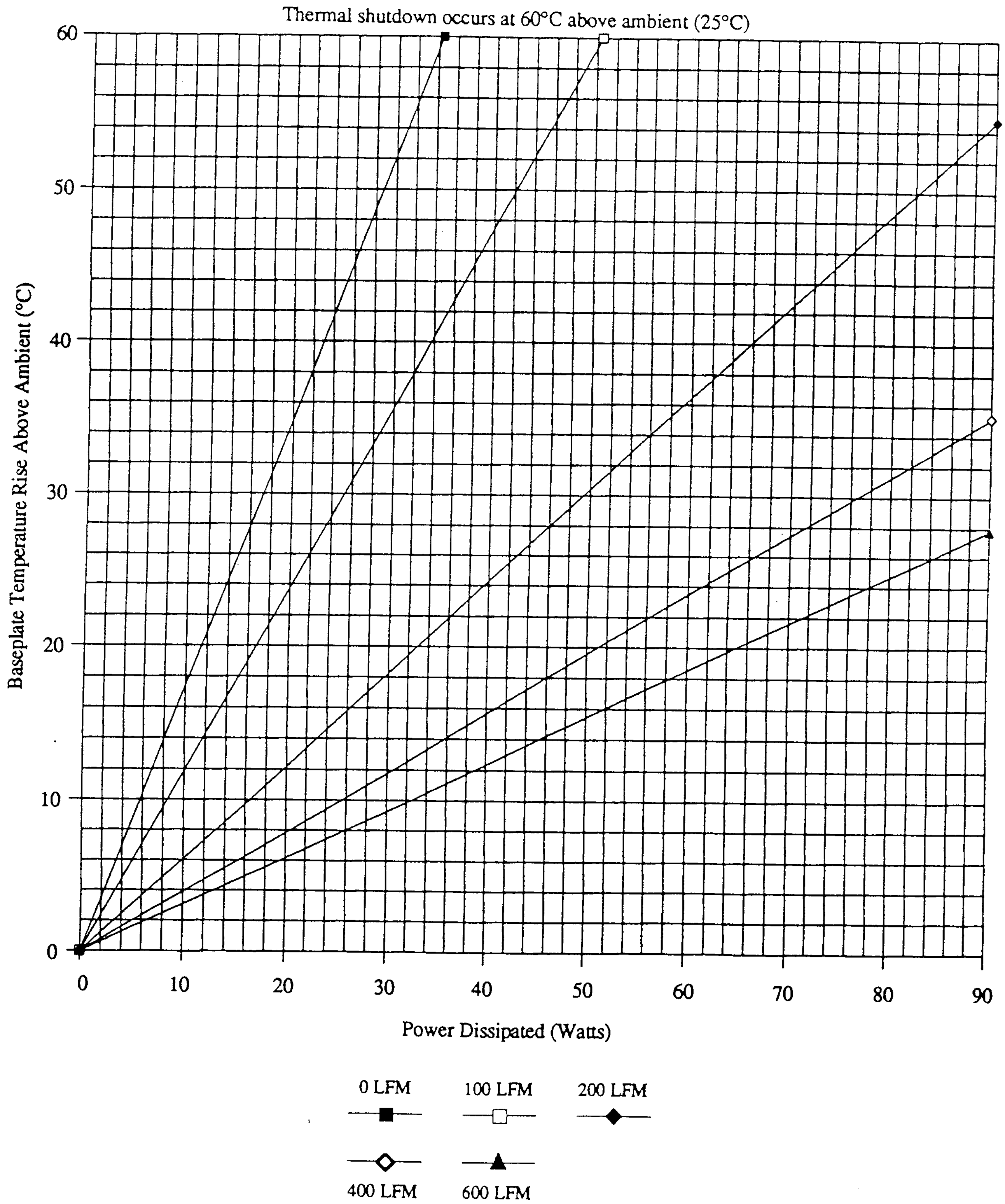
- PH300F • PF1000
- PT500



Heatsink PAH146L23

The following modules use heatsink PAH146L23:

- PH300F
- PF1000
- PT500



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