Thermal Analysis

Pressure Drop Calculations in a Chassis

Before performing thermal analysis on a chassis, it is necessary to calculate total pressure drop within the system. This consists of the pressure drops of all system subcomponents. The total pressure drop (system curve), which also depends on the volumetric flow rate in the system, can be shown as:

$$H_{system} = R_{total} \times G^2 \text{ , where , } R_{total} = \sum R_i$$

are the system component resistances, and R_i is the volumetric flow rate.

Generally, one or two fan trays can be used to deliver air through a chassis. The operating point of a fan tray is where the system curve intersects the fan tray curve.

Figure 1 shows the operating point. It is recommended to operate the fans below the stall range.

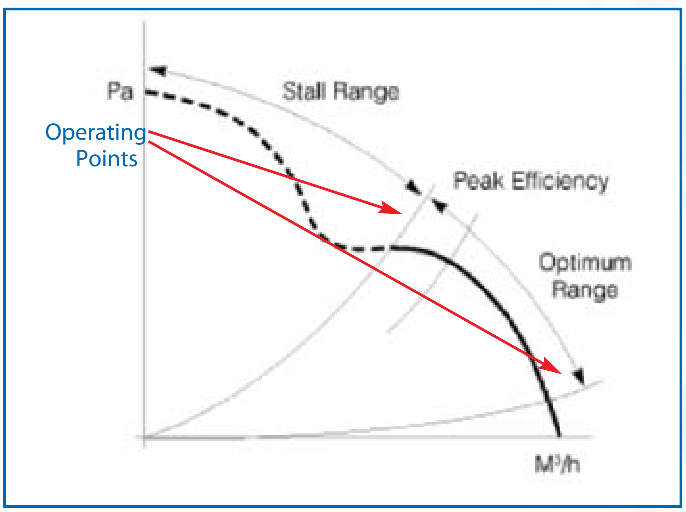

Figure 1. Graph showing the intersection of system and fan curve.

This intersection equals the system pressure, and thus provides the flow rate through the system. Total pressure drop is generally affected by the following subcomponents if they are part of that specific chassis:

1. Air filter
2. Honeycomb
3. Fan tray due to sudden expansion and contraction of flow through blades
4. Flow bending from inlet to plenum
5. Contraction to the inlet plenum
6. Expansion from inlet to plenum
7. Circuit cards component blockade
8. Circuit card friction (generally small)
9. Flow bending to exit plenum
10. Contraction to exit of plenum
11. Expansion from exit of the plenum

The following shows the calculation of several of the above resistances. The units are square meter for the area, cubic meter per second for volumetric flow rate and Pascal for pressure.

A. Perforated plate:

$$R = \frac{0.828}{A^2}(Pa/(m^3/\sec)^2)$$

Where A is the area of open holes exposed to air flow

B. Filter:

$$R = \frac{L \times 510.79}{A^2}$$

Where A is the filter exposed area and L is the filter loss coefficient provided by manufacturer.

C. Boards:

$$R = \frac{4.2 \times L}{A^2}$$

Where L is the board length and A is the effective free area of the channel. If there are N similar boards mounted in a chassis in parallel, their equivilent resistence is calculated as:

$$\frac{1}{\sqrt{R_{combined}}} = \frac{N}{\sqrt{R_{board}}}$$

D. Fan trays contraction and expansion:

The flow going into and out of the fan trays exhibits contraction and expansion with their associated losses.

Sudden Expansion:

$$R = 0.46 \times \left[\frac{1}{A1} \times \left(1 - \frac{A1}{A2}\right)\right]^2$$

Where A1 is the small area and A2 is the larger.

Contraction:

$$R = \frac{0.321}{A^2}$$ Where A is the small area.

E. Fan tray

When fans are mounted in a fan tray, the combined fan curve is calculated based on the fan laws. For M fans in parallel assembled in one fan tray, the fan volumetric flow rate increases by a factor of M for the same pressure drop. For two fan trays in series such as a push-pull system, pressure doubles for the same volumetric flow rate. So if the characteristic curve of one fan is:

$$\Delta P = f(G)$$

The characteristic curve of the combined fans can be represented as:

$$\Delta P = 2f(MG)$$

The factor 2 is for two fan trays and M is the number of fans in one tray.

The total head generated by a push-pull system is:

$$\Delta P = 2f(MG) + 0.658 \times \left(\frac{G}{Af}\right)^2$$ Where Af is the fan duct size.

Inlet Cross section (m^2)	0.03
Single perforated plate resistance	2933
Combined perforated plate resistance	14668
Filter resistance	4540
Total system resistance	19208
Fan curve	225-1665XG
Push pull Fan tray curve	2(225-1665/2*G)

Table 1. Flow resistances for different system components.

The second term is the velocity pressure head associated with the entrance fan that contributes to the total pressure. Solving the following equation, it would yield the system pressure drop and volumetric flow rate:

$$\Delta P = H_{system}$$

The above relations can be used for a quick analysis of a system to find the volumetric flow rate, which can then yield the system temperature rise if the total heat dissipation is known. As a simple example, consider a system that has two fan trays. Each fan tray has two fans. This system has five perforated plates with a 56% opening. Let's assume the area open to air flow is about 0.03 m^2 and that the system also has a filter at the inlet with a loss coefficient of 0.008. The fan curve indicates that maximum pressure is 225 Pa at zero flow and 0.13 m^3/sec at zero pressure. Assuming a linear relationship between the pressure and the volumetric flow rate would give the single fan curve as:

$$\Delta P = 225 - 1666G$$

Assuming negligible resistance from boards and fan hubs, Table 1 shows the resistances due to all the parameters and their calculated values.

Solve the following equation:

$$19208 \times G^2 = 2(225 - 1665/2 \times G)$$

Which yields a value for G equal to 0.12 m^3/sec for the system volumetric flow rate.

References:

1. Ellison G., Thermal Computations for Electronic Equipment, Krieger Publishing Company, 1984.