Sanyo Denki

DC Fan Selection

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1. Introduction

The most important aspect of thermal management is selecting the proper fan for your application. This paper will first document how to determine how much airflow is required based on the amount of heat that needs to be removed. Once that is determined, then you must select the proper fan for your application. Sanyo Denki manufactures a variety of fans for various applications. It is important to select the proper fan for your application. In the paper, you will learn about the different types of fans and where they are typically used so you can choose the proper cooling solution.

2. Determining how much airflow is required

2.1 Definitions

V = The amount of heat to be dissipated (kW)

ΔT = Maximum allowable temperature rise (°C)

Q = Required airflow (CFM)

ρ = Air Density

Cp = Specific heat of air

2.2 Calculations

Step #1 – Determine the amount of heat that your system will need to dissipate **(V)**. Convert this number into (kW).

Step #2 – Determine what the maximum allowable temperature you require in your system **(ΔT)**. Convert this temperature into (°C).

Step #3 – Determine the transfer fluid. We are going to assume standard air

- ρ = Standard Air Density = 1.19 kg/m3
- Cp = Specific Heat = 1.007 KJ/kgK

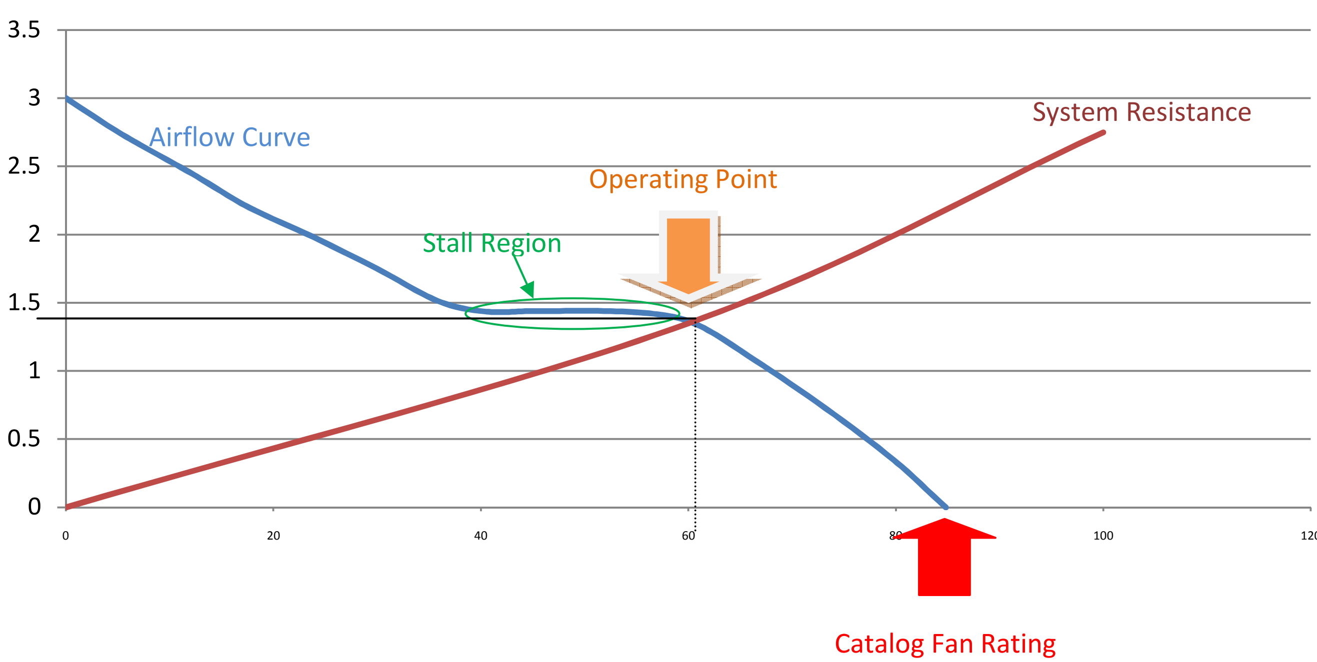
Step #4 – Calculate the amount of airflow you require.

- $Q = V/(Cp*\rho*\Delta T)$
- $Q = V\ (kW)/[1.007\ KJ/(kgK) * 1.19\ kg/m^3 * \Delta T\ (K)]$

- 1 KJ = 1000 w*s
- Cp = 1.007 at 300k or 26°C
- $Q = V\cancel{(kW)} * \cancel{kg}\cancel{K}/1.007\cancel{ws} * \cancel{m}^3/1.19\cancel{kg} * 1/\cancel{K} * 60\cancel{s}/min * (3.28ft)^3/\cancel{1m}^3$
- Q = 1767 V/ΔT CFM where V is in (kW) and ΔT is in (°C)
- Example Heat Load is 500W, Max temp Rise = 15°C
- Q = 1767(.5)/15 = 58.9 CFM

Step #5- Determine the system resistance

Fans are always rated at max airflow or zero back pressure. Once a fan is put into any enclosure, it is no longer running at the max airflow. Every enclosure, no matter how dense, will provide some type of back pressure or resistance to flow. The formula above does not account for any back pressure. Therefore, if you select a fan whose catalog rating is the same as the number you calculated above, it will likely not work for your application. So, the next step is to determine the resistance of your system. The best method to accomplish this is to attach your system to an airflow chamber and measure the air resistance through the chamber.



Looking at the graph above in Figure #1, the operating point is the intersection of the system curve and the fan curve. The best place to operate a fan is just to the right of the knee of the curve. This is the point where the fan is most efficient. You want to stay away from the stall region. The stall region is where a fan can have multiple airflow outputs for the same back pressure. In this region, the fan can "hunt" or change speeds to provide a varying number of different airflows for the given pressure level. The fan will be the least efficient and loudest in this region.

Getting back to this example, you can see that it appears based on this example, the operating point is 60 CFM at just under 1.5 inH_20. Now if we look at the maximum airflow or catalog rating of this fan, you will find that it is 80 CFM. This is the fan we would need to select for this application.

Step #6 – Accounting for Backpressure

As mentioned in Step #5, the most accurate way to determine the proper fan selection would be to measure the back pressure of the system. Unfortunately, many companies do not have the luxury to be able to do that. In this case, we will provide you with a mathematical approximation for the required airflow.

In the example we were using above, the operating point was approximately ¾ of the maximum airflow. Because we are estimating the required maximum airflow, we want to err on the conservative side. We are going to assume that a typical operating point is 2/3 of the maximum flow.

$Q_{max}(2/3) = Q \rightarrow Q_{max} = 3/2Q \rightarrow 1.5Q$

So, in our example above $Q_{max} = 1.5(60) = 90$ CFM. Please note because this is only an approximation, system testing must be done to confirm.

Step #7 – Accounting for Altitude

If we go back to the original equation, $Q = V/(Cp*\rho*\Delta T)$, remember that ρ is air density. Air density is dependent on altitude. Depending where you are, altitude can really have a large impact on performance. In the previous models, we assumed sea level. At sea level, $\rho = 1.19$ kg/m^3. Let's assume we are in the Rocky Mountains where the altitude is 10,000 ft above sea level. This reduces ρ to .904 kg/m^3. Let's try and see how this affects our earlier example

$Q = V(60)(3.28)^3/(1.007*.904*\Delta T) \rightarrow 2326V/\Delta T$

$Q = 2326(.5)/15 = 77.5$ CFM

So, at sea level we only needed 58.9 CFM we now need 77.5 CFM to provide the same level of cooling.

Lastly, what is the affect that altitude will have on pressure? Above, we calculated the CFM but now we need to understand the impact on pressure otherwise our fan will not provide the level of cooling that we anticipated. Using fan laws, here is the equation

$P_{sl}/P_{alt} = (CFM_{sl}/CFM_{alt})^2$ so, $P_{alt} = Psl/(CFM_{alt}/CFM_{sl})^2$

If we continue to use the example, here is our new equation

$P = 1.45(77.5/58.9)^2 = 2.51$ inwg

We now need 77.5 CFM at 2.51 inwg to provide the same cooling at 10,000 ft above sea level. This is a large increase considering we only needed 58.9 CFM at 1.45 inwg. It is very important to account for altitude early on in the design process. The significant rise in cooling required, could mean that you need to go with a larger size fan not just a faster on the same size. This change in required flow could have an impact on the mechanical architecture of the system.

3. Fan Selection

Just because you now know the airflow and pressure that is required, you're still not done. Selecting the right fan/s can be the next challenging step. There are many types of cooling fans: tube-axial, guide vane or vaneaxial, counter rotating, and blowers. This section will document the different types of fans, their differences, and when to use each type. Sometimes, airflow and pressure will dictate which one to chose.

3.1 Tube-axial Fans

Tube-axial fans are the standard cooling fans that have been around the longest. Typically, they have an outside mounting frame that is square. They have 3 or four struts that hold the motor in the middle of the frame. Figure #2 below shows a picture of a typical tube-axial fan.

Figure #2

They are used in applications that require low back pressure, low noise, and low power. They also require the system to have a plenum to allow the airflow to develop. If you look at Figure #3 below, you can see the exit airflow velocities are pretty low and the airflow spreads out as the flow gets further from the fan.

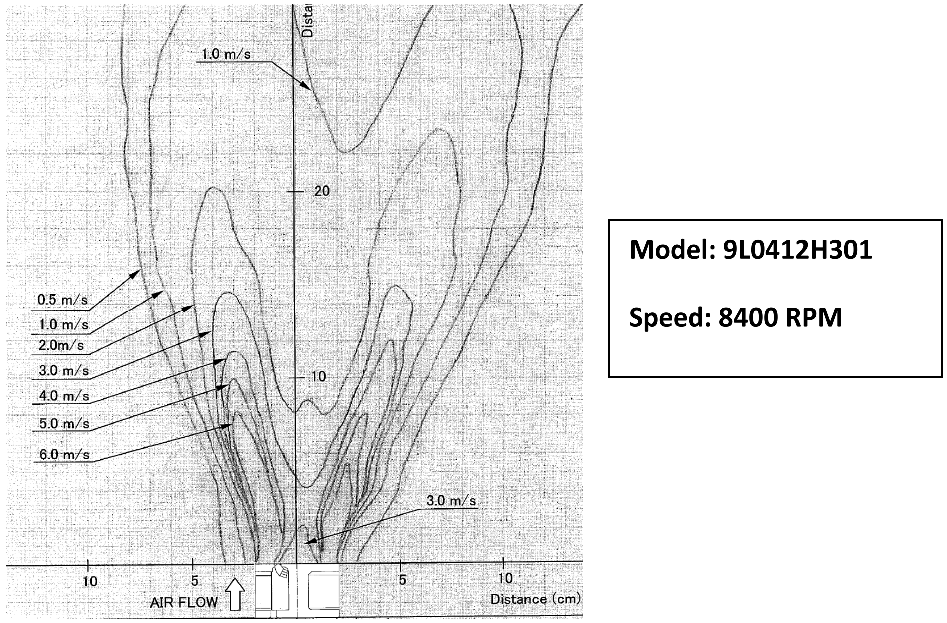


Figure #3

<u>3.2 Guide Vane Fans</u>

While tube-axial fans are great for lower pressure applications, many customers are trying to keep their latest designs the same size while fitting more technology into that system. For these higher pressure applications, Sanyo Denki has guide vane fans. These are our 9GV series of products. Guide vane fans are very similar to tube-axial fans except they don't have struts connecting the motor to the frame, they have guide vanes. The guide vanes are actually fixed impeller blades that are shaped counter clockwise from the shape of the impeller blades. The picture in Figure #4 will show a typical fan with guide vanes.

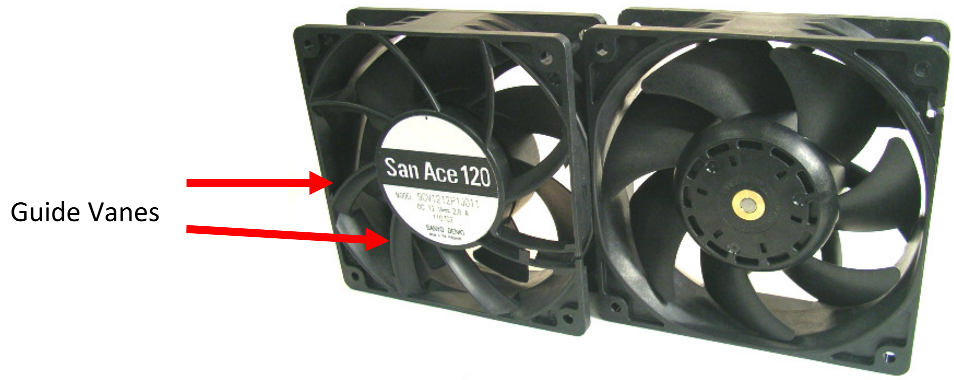
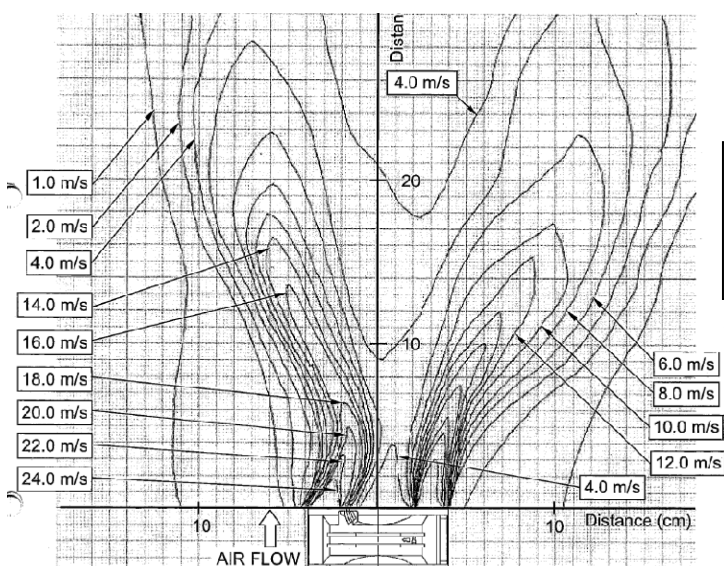


Figure #4

The blades will centralize the airflow and increase the exit air velocities. This makes the guide vane fans great for high pressure applications or for spot cooling. Because of the centralized flow, these fans do not need a plenum. They can be placed directly against an object such as a heatsink. If you look at the picture below, you can see the airflow pattern along with the much higher exit air velocities compared to the standard tube-axial fan. There are a few negatives with guide vanes. They will typically require more power and will increase the noise level.



Model: 9GV0812P1G03

Speed: 10,200 RPM

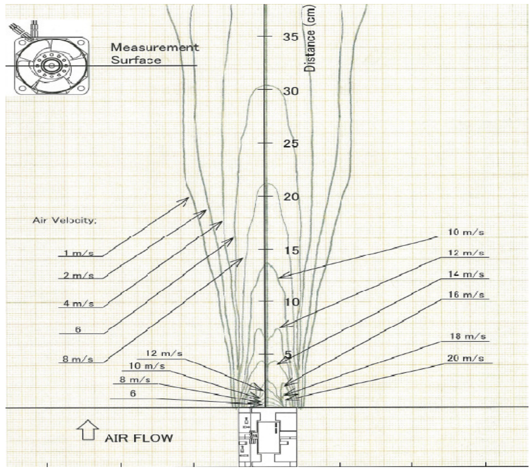
Figure #5

3.3 Counter Rotating Fans

Counter Rotating fans (called CR fans going forward) were developed for very high back pressure applications. If you stack to tube-axial fans in series, theory will tell you that the airflow will remain unchanged but the back pressure doubles. Unfortunately, this does not hold true in the actual system. The reason is there is impedance from the impeller of the second fan so that it impedes flow. This seriously reduces the maximum increase in back pressure. When fans are mounted back to back, the airflow has 2 sets of struts to pass through. This also reduces flow and adds noise. Sanyo Denki's CR fans are mounted nameplate to nameplate to optimize flow and sound. Figure #6 below shows a typical Sanyo Denki CR fan.

Inlet Fan **Figure #6** Exhaust Fan

From the pictures in Figure #6, you can see the inlet impeller has much more surface area than the exhaust fan. This is done intentionally. The inlet impeller will carry the majority of the airflow while the exhaust fan impeller is meant to add the pressure capability. The small amount of surface area allows for the air to pass through with little impedance. The exhaust fan impeller also rotates in an opposite direction from the inlet impeller. This is the same concept as the guide vanes except instead of having fixed vanes, we have a 2nd moving impeller. For this type of fan, the flow patterns are similar to the GV fan. Figure #7 below illustrates the high exit air velocities and more centralized flow from the CR fans.



Model: 9CR0412H501

Inlet Speed: 13,300 RPM

Outlet Speed: 9,300 RPM

Figure #7

Customers will use the CR fans in very high pressure applications. The airflow curve is very steep and does not have that stall region in the middle of the airflow curve like tube-axial fans. The curve looks much more like a blower than a fan. Figure #8 below shows a typical CR airflow curve.

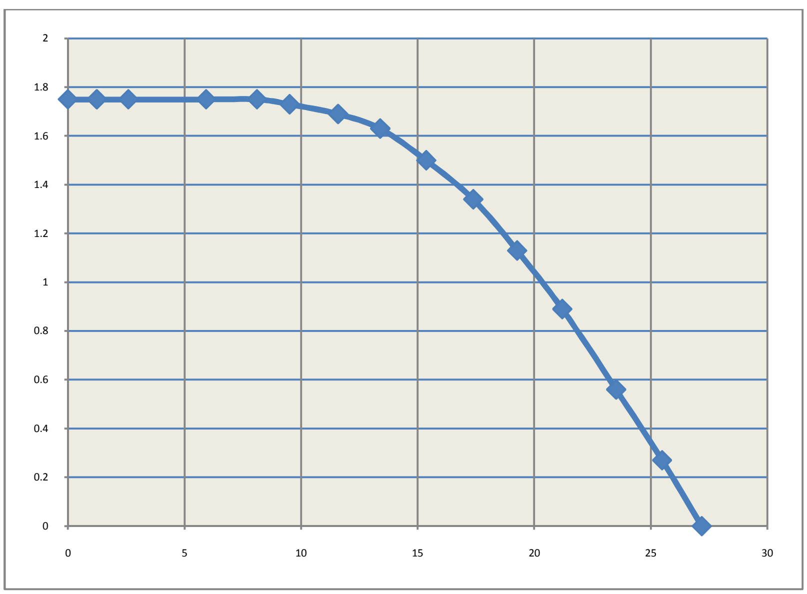


Figure #8

3.4 Blowers

A blower is another option a customer can choose. With all of the fans mentioned above, the airflow exits 180° from where it enters and exits over the entire surface. With a blower, the air exits 90° from where it enters and it usually exits through a reduced discharge area. Figure #9 below shows a picture of a typical blower.

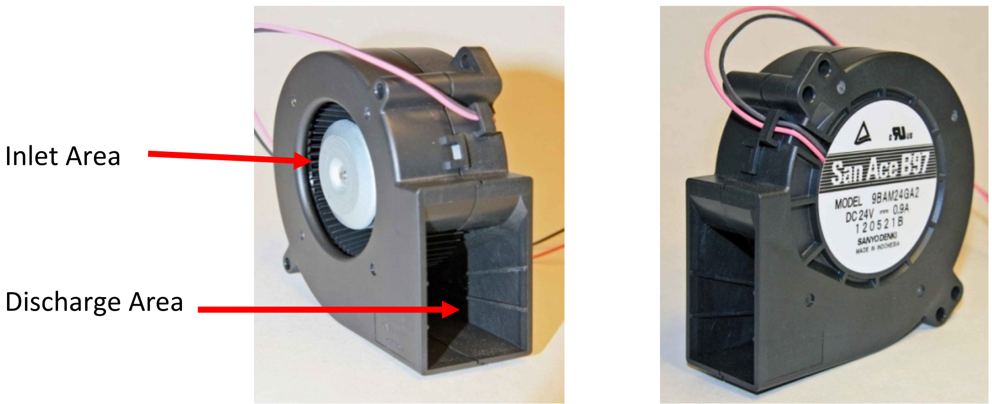
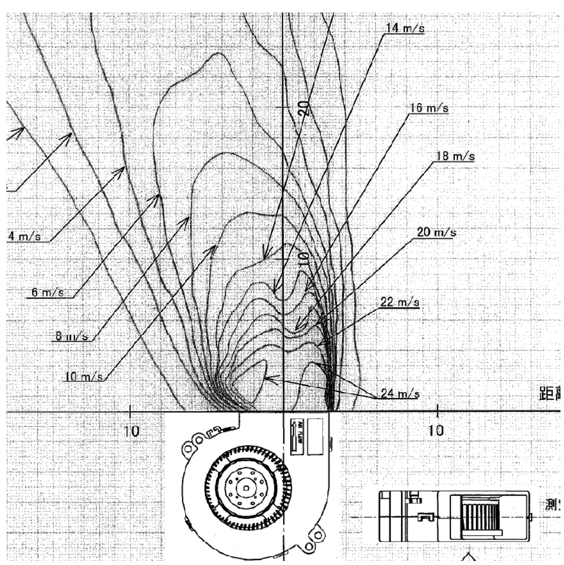


Figure #9

Because a blower turns the flow 90° and does not use the entire surface to discharge, the airflow is very low; however, the back pressure is very high. Blowers are usually noisier and draw more power than standard tube-axial fans. They are used only in limited applications where pressure is the #1 design criteria or in applications where spot cooling is used. The blower makes a great spot cooler because almost all of the flow can be positioned to blow over a particular heat source. In figure #10 below, you can see the very high exit air velocities from a typical blower.



Model: 9BM24P2K01

Speed: 6850 RPM

Figure #10

3.5 Centrifugal Fans

In all the above products, we discussed applications where high pressure or high airflow was needed. What if you have an application that needs both high pressure and high airflow? The answer is centrifugal fanss. These products are also referred to as motorized wheels or backward curve impellers. Figure #11 below shows a typical centrifugal fans.

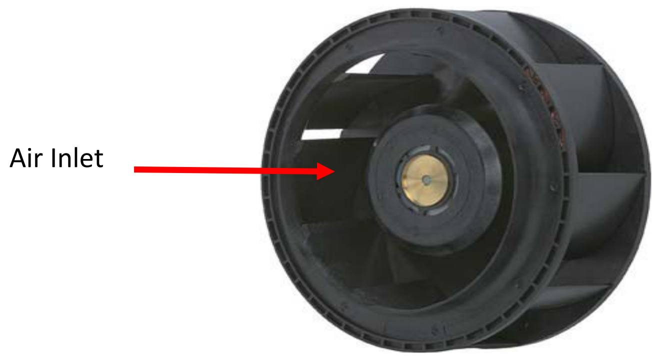


Figure #11

With a centrifugal fan, the air enters through the entire front surface of the wheel. The inlet is very similar to a tube-axial fan. The output; however, is much different. The air exhausts out of this fan at 90° from the entry point like that of a standard blower. In the case of the centrifugal, the air then exhausts out at 360° around the circumference. Because of this configuration, the centrifugal fan can achieve airflows like that of a tube-axial fan and deliver pressure levels of a standard blower. The drawbacks with this type of fan are that they are relatively loud and can consume more power. These fans are great for telecomm applications, where they can be put at the top of a rack system or cabinet, and draw air up through the chassis. The air would then discharge the air out of the sides and/or the rear of the panel. This way, if there is another system mounted above, the hot air does not enter that other system.

4. Conclusion

Fan selection is a critical for thermal management. The first thing you need to do is calculate the amount of airflow and pressure you will have for your system based on the conditions of where it will be used. Once you know the flow and pressure, then you can select the right type of fan to cool your system. If you are working on a low pressure system, a tube axial fan will probably work for you. If you need much higher airflow, a guide vane type fan will probably be the best fit. If you need high pressure applications, then select a CR fan or blower. The scope of this paper does not cover all fan specifications that would be needed to make the final selection. For detailed specs such as voltage range, noise level, temperature range, life, etc, please visit the Sanyo Denki website at www.sanyo.denki.com.