Technical Notes

Air Flow - Static Pressure Characteristics

1. Pressure Loss

When air flows along a certain path, a resistance (called "air flow resistance") is produced by anything in the path that inhibits that flow. Comparing the cases illustrated in Fig.1 and Fig.2, we see that the device shown in Fig.1 is almost empty, so there is almost no air flow resistance in the device and little decline in the air flow. By contrast, there are many obstructions of the air flow in the device shown in Fig.2, which increases air flow resistance and decreases air flow.
This situation is very similar to the role of impedance in the flow of electrical current: when impedance is low, the current flow is large, when impedance is high, the current flow is low.

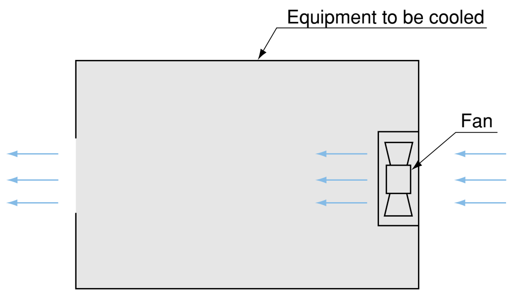


Fig. 1 Flow path with low air flow resistance

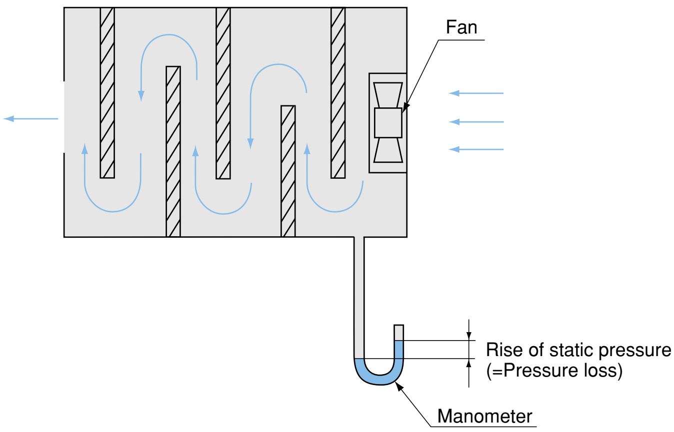


Fig. 2 Flow path with high air flow resistance

The air flow resistance becomes the pressure energy that increases the static pressure inside the device and is called pressure loss. Pressure loss is determined using by the following equation.

Pressure Loss $P = \frac{1}{2}\xi V^2 \rho$

$$= \frac{1}{2}\xi \left(\frac{Q}{A}\right)^2 \cdot \rho$$

where V : Flow speed [m/s]
ρ : Air density [kg/m^3]
ξ : Resistance factor (particular to the device)
A : Cross sectional area of the device [m^2]
Q : Air flow [m^3/s]

In terms of the fan, this equation says that to achieve a certain air flow (Q), the fan must be able to supply a static pressure sufficient to increase the pressure inside the device by

$$P = \frac{1}{2}\xi \left(\frac{Q}{A}\right)^2 \cdot \rho$$

2. Air Flow - Static Pressure Characteristics

Fan characteristics are generally expressed in terms of the relationship between air flow and the static pressure required to generate such air flow, and given as an air flow vs. static pressure characteristic curve.
As an example, say the air flow required is Q_1, and the accompanying pressure loss of the device is P1. When the fan characteristics are as shown in Fig.3, the fan is capable of a static pressure of P_2 at an air flow of Q_1. This is more than sufficient for the required air flow since it exceeds the required static pressure value of P1.

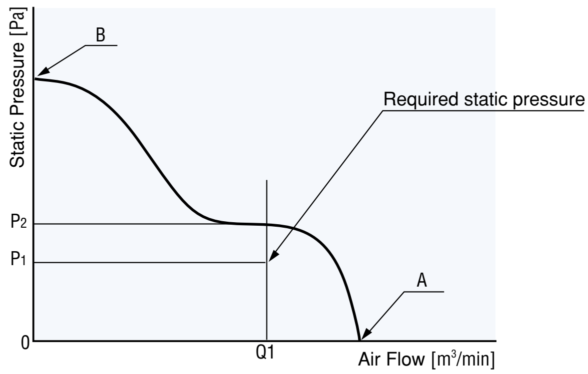


Fig. 3 Air flow -static pressure characteristics

At point A in Fig. 3, the static pressure is 0, meaning there is absolutely no pressure loss and the air flow the fan can deliver is at its maximum. The air flow at this point is called the maximum air flow.
At point B, on the other hand, the pressure loss is so large that air flow is 0. This point is called the maximum static pressure. In actual applications, however, the fan will not be used with maximum static pressure or maximum air flow. Although maximum static pressure and maximum air flow are used as fan specifications, they are in fact only important for the comparison of characteristic values.
Since pressure loss is proportional to the square of the air flow, if air flow is needs to be doubled, the fan chosen must be capable not only of twice the air flow but of four times the static pressure as well.

3. Measuring Air Flow - Static Pressure Characteristics

There are two methods for measurement of the air flow vs. static pressure characteristics: one using a wind tunnel and pitot tubes, and the other using a double chamber. Oriental Motor uses the double-chamber method because its higher accuracy has greater international acceptance. Oriental Motor's measuring is based upon the authoritative standard 210 of the AMCA(Air Movement and Control Association). It measures the air flow and air pressure generated by a given fan (see Fig. 4) by measuring the pressure difference above and below the nozzle (P_n) and that within the chamber (P_s).

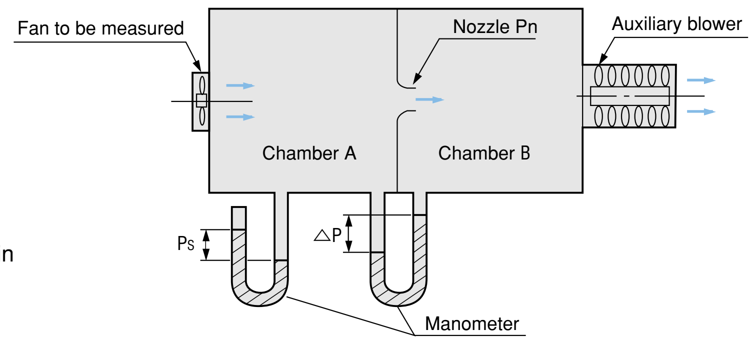


Fig. 4 Double chamber measuring set-up

Since this method allows the speed of the fluid flowing through the nozzle to be determined from the pressure differential between chamber A and chamber B, the air flow Q can be expressed as a product of the flow speed $\bar{v}$ through the nozzle, the nozzle area *A* and the flow coefficient *C*.
Thus,

$$Q = 60CA\bar{v}$$

$$= 60CA\sqrt{\frac{2\Delta p}{\rho}} \quad [\mathrm{m^3/min}]$$

where
A : Nozzle sectional area [m^2]
C : Fluid coefficient
$\bar{v}$: Average flow speed at the nozzle [m/s]
ρ : Air density [kg/m^3]
(at 20˚C and one atmosphere γ=1.2kg/m^3)
Δp : Pressure differential [Pa]

Measurement of the air flow vs. static pressure characteristics uses an auxiliary blower to control the pressure in chamber B, altering the pressure in chamber A. Thus, each point on the characteristics curve can be measured. The Oriental Motor measuring equipment is connected to a computer, enabling highly precise measurements in a short period of time.

4. Change in Characteristics when Installing Two Fans

Air flow and static pressure of two fans with identical characteristics will vary greatly depending on whether the fans are installed in series or in parallel.

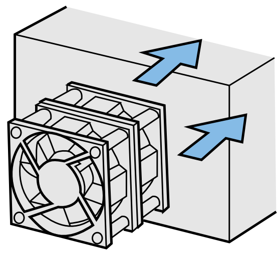


Fig.5 Installing two fans in series

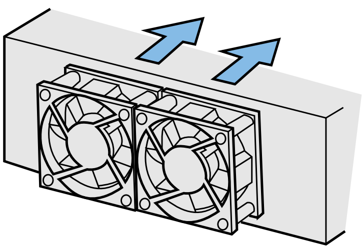
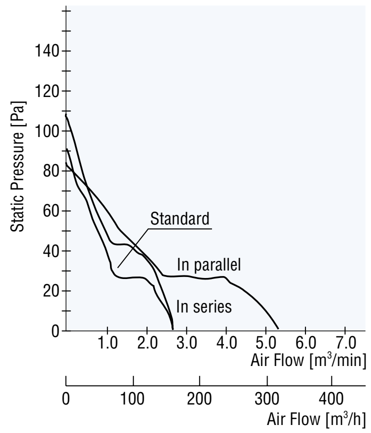


Fig.6 Installing two fans in parallel

MU1238A-51B
50Hz,230V



MU1238A-51B
60Hz,230V

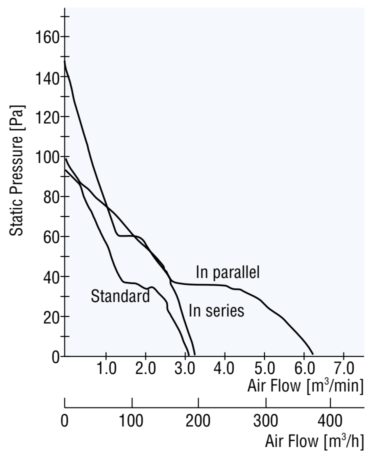


Fig.7 Characteristics for different installation methods

As shown in the graphs, fans installed in series generate greater static pressure, while fans mounted in parrallel provide double the air flow.

5. Change in Characteristics By Installing Optional Parts

When installing the fan in equipment, the safety and reliability of the overall apparatus can be improved considerably by attaching optional parts such as finger guards or filters. However, these optional parts produce air flow resistance, affecting fan characteristics and fan noise. This factor should therefore be taken into account when selecting fans and optional parts.

There is shows pressure loss when optional parts are attached to a fan. Loss is greatest with a filter, and practically negligible with the finger guard. For an example of pressure loss, see Fig.8.

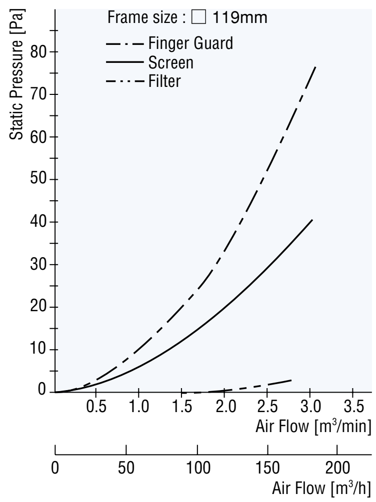


Fig.8 Pressure loss due to optional parts

Fig.9 shows how characteristics may change with the installation of optional parts, using the **MU1225S-51** as an example.

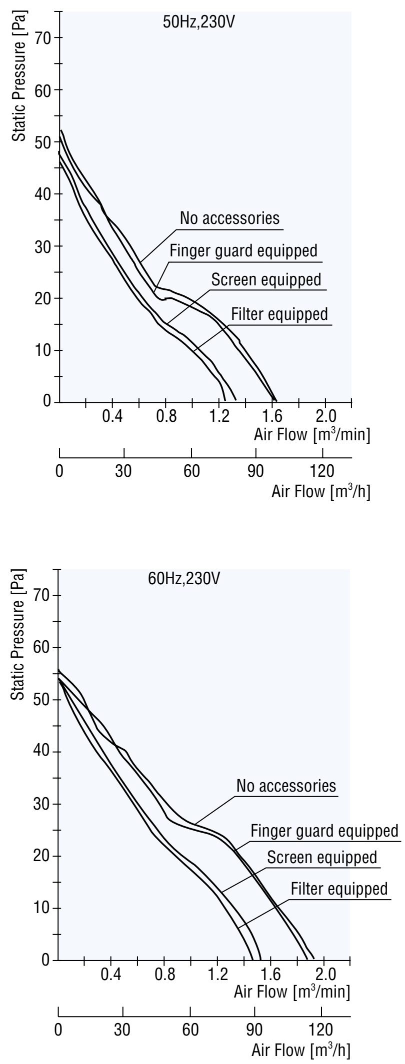


Fig.9 Changes in characteristics with optional parts attached to the **MU1225S-51**

As the graphs show, the larger the pressure loss caused by optional parts, the greater the reduction in air flow and static pressure characteristics.

Audible Noise

1. Audible Noise

We generally call sounds that are unpleasant to us "noise". In the case of fans, noise is generated as the rotation of the fan blades causes a change in air pressure. The greater the change in air pressure, the louder is the noise produced.

2. Measuring Audible Noise

The noise of Oriental Motor fans is measured in the A range at a distance of 1m from the intake (at a point above the center line of the intake).

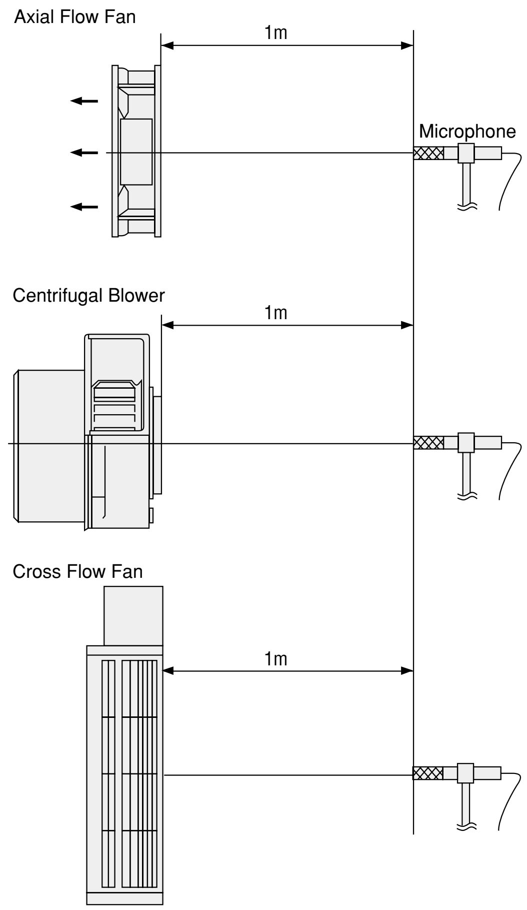


Fig.10 Measurement of fan noise.

3. Combined Audible Noise

This section will describe the method used to calculate combined noise, using as an example two 40dB fans operated simultaneously.
Noise, or relative loudness, is expressed in decibel units, and combined noise cannot be determined simply by adding individual noise levels. The value that expresses this combined noise is found by determining the energy of the noise, and then using it to calculate the increase in sound pressure. If *J* denotes acoustic energy and *P* sound pressure, the relationship between the two values is given by the following equation:

$$J = \frac{P^2}{\rho c},$$

where ρ is equal to the air density and c is equal to the speed of sound propagation. This expression can be used to find the loudness in decibels as follows:

Sound pressure level $= 20 \log P/P_o$
$= 10 \log J/J_o$
P: Actual sound pressure
J: Measured acoustic energy
P_o, J_o: Minimum acoustic energy audible by the human ear

Thus, this expression gives the noise level in decibels based on the audible acoustic energy J_o. This expression can be used to calculate the sound pressure for two or more fans operated simultaneously. If n is the number of fans, then n times the amount of acoustic energy is produced, as follows.

Noise level $= 10 \log n \cdot J/J_o$
$= 10 \log J/J_o + 10 \log n$

In other words, when n fans are operated simultaneously, the increase in noise is equal to $10 \log n$ (dB).
In this example, if two 40dB fans (n=2) are operated simultaneously, the increase in noise level is equal to 10 log 2 or 3dB, and the combined noise level is 43dB.
What would be the combined noise level be if a 40dB fan and a 50dB fan were operated together? Again, the combined noise level is not given by the simple arithmetic sum, but obtained as follows (also refer to Fig. 11):

Take the difference between the two noise levels: 50dB − 40dB = 10dB

↓

At the 10dB point on the x-axis of the graph find the corresponding point on the curve and read the y-axis value: 0.4dB.

↓

Add 0.4 to the larger of the two noise levels, 50dB.

↓

The combined noise level when operating the two fans simultaneously is 50.4dB.

If 40dB of noise is combined with 50dB, the resulting increase in noise is only 0.4dB. Thus, when fans of different noise levels are operated simultaneously, it is more important to reduce noise from the fan with the higher noise level.

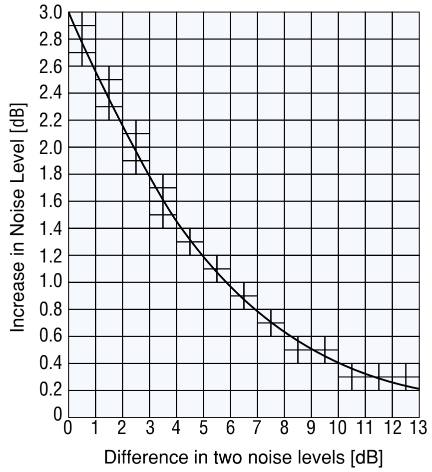


Fig. 11 Combined Audible Noise

4. Relationship Between Audible Noise and Distance

The noise level decreases as the distance from the source of the noise increases. The decrease in noise due to distance is given by the following expression:

$SPL_2 = SPL_1 - 20\log r_2/r_1$

where,
SPL_2: noise level at distance r_2
SPL_1: noise level at distance r_1

In the following example, the noise level at a point 2m from a fan whose noise level is 40dB at a point 1m from the intake side will be calculated.

Since r_2 = 2m, r_1 = 1m, and SPL_1 =40dB, substituting in the expression gives

$SPL_2 = 40 - 20 \log 2/1$
$= 34$dB.

Thus, at a distance of 2m, the noise level decreases by 6dB.
The value $20 \log r_2/r_1$ in above expression represents the ratio between two distances. Thus, if the values used above were 3m and 6m, the result would have been the same. Therefore, if the noise level at a certain distance is known, the noise level at another distance can be estimated.

Fan Life

1. Fan Life

Fan life refers to the period that a fan can be operated continuously without losing ventilating capacity or emitting so much noise that it cannot be used. Therefore, there are two components of fan life:

Fan Life
- ① Rotation life: Defined as the period the fan can be operated before rotation decreases by a certain value.
- ② Acoustic life: Defined as the period the fan can be operated before noise increases by a certain value.

Rotation life can be easily measured so long as the factors involved can be clearly specified numerically; this is usually what is meant when referring to fan life. Acoustic life, however, is defined by the increase in decibel level, and determining exactly what amount of increase marks the end of acoustic life depends on the judgment of the user. Moreover, fans can still meet operating requirements even after reaching the pre-determined increase in noise. In general, then, standards relating to noise and the length of acoustic life have not been established.

Oriental Motor defines fan life by rotation life; a fan is judged to have reached the end of its service life when rotational speed declines to 70% of the rated speed.

2. Product Life

The following is a description of the fan parts that are most important in determining fan life, beginning with the relationship between time and failure rate.

Generally, when parts have been used for a long time, their failure rate relative to the duration of use fits the pattern of the bathtub shaped curve shown in Fig. 12 below.

The first period is the initial failure period in which sub-standard parts tend to break down. The second period is called the accidental failure period, characterized by a highly stable, low failure ratio. If this period were to continue forever, the parts life would not be a concern. However, depending on the part, the failure rate increases again, and enters a third period called the friction fault period.

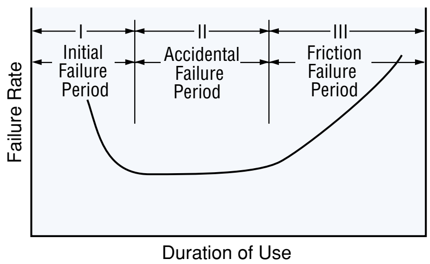


Fig. 12 Relationship between the duration of use and failure rate

Bearings are the parts within a fan whose life is most affected by this friction failure period. Therefore, fan life could be said to be determined by the life of the bearings used.

3. Fan Bearing Life

The following is an explanation of the factors involved in the life of ball bearings, which are the type of bearings used in most fans.

Unlike the bearings of motors and gearheads, the load applied to fan bearings is negligible. Therefore, fan life is determined by deterioration of the grease in the bearings. Since fans have low running and starting torque compared with motors used to drive machinery, they cannot rotate at the proper speed if the grease deteriorates and loses its effectiveness as a lubricant. With severe deterioration, starting voltage increases significantly, and the fan may not start. Deterioration of grease also increases the noise generated by the bearings, further affecting fan life.

Grease life is given by the following expression:

$$\log t = K_1 - K_2 \frac{n}{N\,\mathrm{max}} - \left(K_3 - K_4 \frac{n}{N\,\mathrm{max}}\right) T$$

where,

t : Average grease life (h)
K_1, K_2, K_3, K_4 : Constants determined by the grease
N max : Permissible speed of grease lubrication
n : Rotational speed of the bearings
T : Operating temperature of the bearings

As indicated by the above expression, N max is pre-determined by the ball bearings, so grease life depends on temperature and the rotational speed of the bearings. However, Oriental Motor's products are designed such that the life of the bearings is only minimally affected by their rotational speed. Thus, the average grease life is determined by the temperature since $\frac{n}{N\,\mathrm{max}}$ is a constant value.

4. Characteristic Curve for Estimating Product Life

Figure 13 shows the estimated average life characteristics of the **MU1238A** type fan.

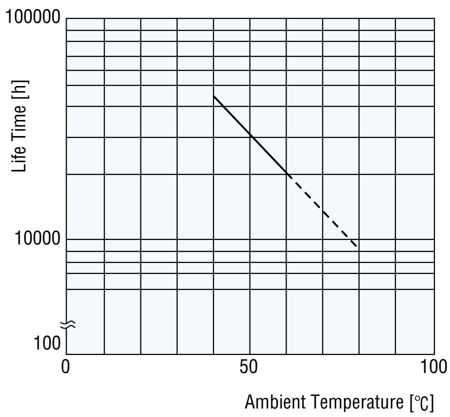


Fig.13 Characteristic curve for estimating life

Note: The values given in this estimated life characteristic curve cannot be guaranteed.

Fig. 13 gives the estimated life of the bearings of the **MU1238A** type fan, obtained by measuring the temperature rise of the ball bearings at the rated voltage and calculating life using the expression for ball bearing grease life.

Overview and Characteristics of Fans
Types of Fans
Selecting a Fan
Q & A
Glossary
Use of Fans
Technical Notes

Overheat protection device

If a fan in run-mode locks due to overload, the ambient temperature rises suddenly, the input increases for some reason, the fan temperature rises suddenly. If the fan is left in this state, the performance of the insulation within the fan may deteriorate, shortening service life and, in extreme cases, scorching the winding and causing a fire. In order to protect the fan from such thermal abnormalities, UL, CSA, EN and IEC standard fans from Oriental Motor are equipped with the following overheating protection devices.

1. Thermal protector

MRS, **MB(MB1665**, **MB1255, MB1040, MB840) MF** series contain a built-in automatic return type thermal protector. The construction of thermal protector is shown in following fig.1
The **MB840** is protected with impedance protection that prevents the temperature from rising to the temperature at which the thermal protector is triggered, even if the fan is locked due to the usage voltage or ambient temperature.

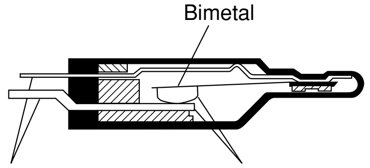


Fig.1 Construction of thermal protector

The thermal protectors employ a bimetal contact, with solid silver used in the contacts. Solid silver has the lowest electrical resistance of all materials and has a thermal conductivity second only to copper.

Operating temperature of thermal protector

open ··········· 120°C±5°C
close ··········· 77°C±15°C

The fan motor winding temperature, where the thermal protector is working, is slightly higher than the operating temperature listed above.

2. Impedance protection

MU, **MB** series(**MB520**,**MB630**) are equipped with impedance protection. Impedance protected motors are designed with higher impedance in the motor windings so that even if the motor locks, the increase in input current is kept down and the temperature does not rise beyond a certain constant level.

3. DC Fan

The DC fan are equipped with overheat protection circuits. When the circuits detect a restraining load, the power switches on and off automatically to control the power flowing through the coil. Consequently, overheating will not occur when restraining load is applied to the fan blades.