Cooling Fans

Air Flow/Static Pressure Characteristics

Pressure Loss

When air flows along a certain path, a form of 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.

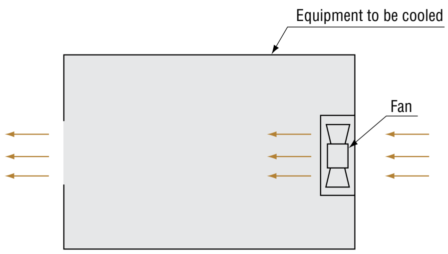


Fig. 1 Flow Path with Low Air Flow Resistance

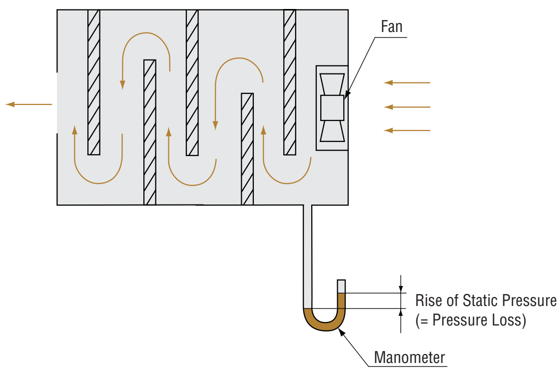


Fig. 2 Flow Path with High Air Flow Resistance

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, and when impedance is high, the current flow is low. The air flow resistance becomes the pressure energy that increases the static pressure within the device. This is called pressure loss. Pressure loss is determined using 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 coefficient specific to flow path
A = Cross-sectional area of flow path [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 static pressure sufficient to increase the pressure within the device by $P = \frac{1}{2}\xi \left(\frac{Q}{A}\right)^2 \cdot \rho$

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, given as a characteristic curve of air flow versus static pressure.
As an example, assume the air flow required is Q_1 and the accompanying pressure loss of the device is P_1. 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 P_1.

Since pressure loss is proportional to the square of the air flow, if the air flow needs to be doubled, then the fan chosen must be capable of providing not only twice the air flow but four times the static pressure, as well.

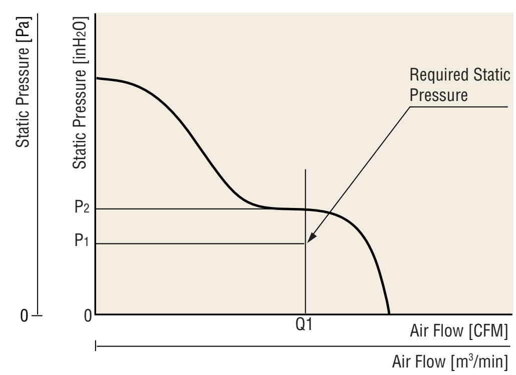


Fig. 3 Air Flow vs. Static Pressure Characteristics Curve

How to Measure the Characteristics of Air Flow/Static Pressure

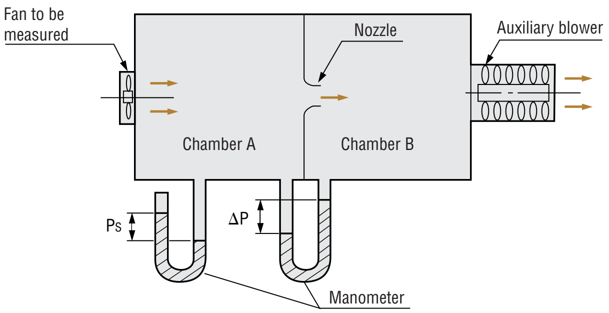


Fig. 4 Double-chamber Measuring Device

Two methods are available for measuring the air flow and static pressure: the air-duct measurement method via the pitot tube, and the double-chamber measurement method. Oriental Motor employs the double-chamber method, which offers higher accuracy than the air-duct method and is in wide use throughout the world.

Moreover, Oriental Motor uses measuring equipment conforming to AMCA (Air Moving and Conditioning Association) standard 210, a fan measurement standard that is widely recognized around the world. In the double-chamber method the fan's air flow/static pressure characteristics are obtained by measuring the pre- and post-nozzle differential pressure (ΔP) and the pressure within the chamber (Ps), as shown in Fig. 4.
Oriental Motor's double-chamber equipment is a measuring device with the highest level of general utility that may be used regardless of whether the fan is equipped with an intake or outlet tube.

Since this method allows the speed of the fluid flowing through the nozzle to be determined from the pressure differential between chambers A and B, the air flow (Q) can be expressed as a product of the flow speed (v) through the nozzle, the nozzle area (A) and the coefficient of flow (C).
Therefore:

$$Q = 60\, CA\bar{v}$$
$$= 60\, CA\sqrt{\frac{2\,\Delta P}{\rho}} \quad [\mathrm{m^3/min}]$$

where

A: Nozzle cross-sectional area [m^2]
C: Flow coefficient
$\bar{v}$: Average flow speed at the nozzle [m/sec]
ρ: Air density [kg/m^3] (ρ =1.2kg/m^3 at 20˚C and 1atm)
ΔP=Differential pressure [Pa]

The measurement of 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. Oriental Motor's measuring equipment is connected to a computer, providing extremely precise measurements in a short period of time.

Changes in Air Flow/Static Pressure Characteristics with two fans installed

When using two fans combined it will change the characteristics depending on how the fans are installed.

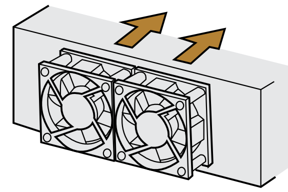
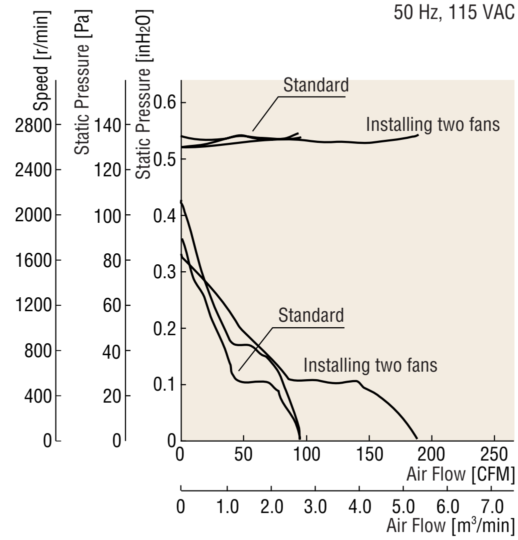


Fig. 5 Installing two fans

MU1238A-21B
50 Hz, 115 VAC



MU1238A-21B
60 Hz, 115 VAC

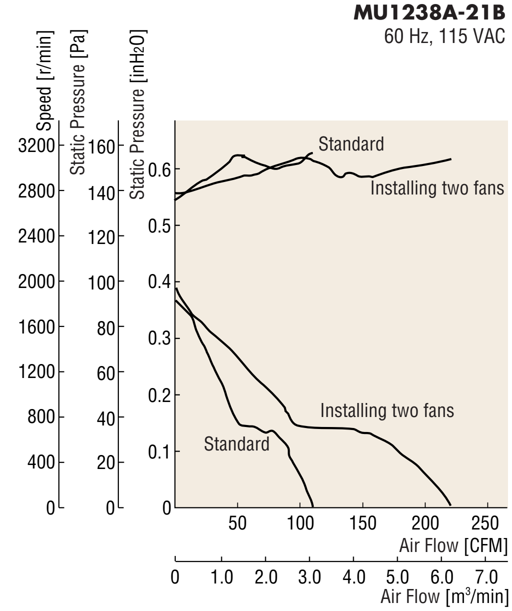


Fig. 6 Changes in fan characteristics of static pressure and amount of air flow

The graph above shows that when two fans are combined, doubles the maximum amount of air flow is achieved.

Changes in the Air Flow/Static Pressure Characteristics with Installation of Optional Parts

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

The graph in Fig. 7 shows data regarding pressure loss caused by its optional parts on a fan with the 4.69 in. sq. (119 mm sq.) frame size. The filter causes the most significant pressure loss, while the finger guard causes little loss.

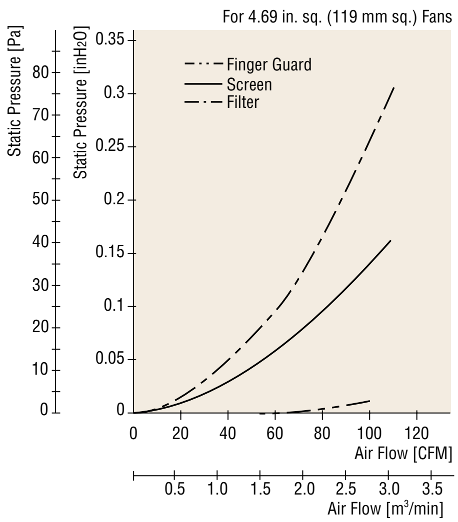


Fig. 7 Changes in Characteristics with Optional Parts

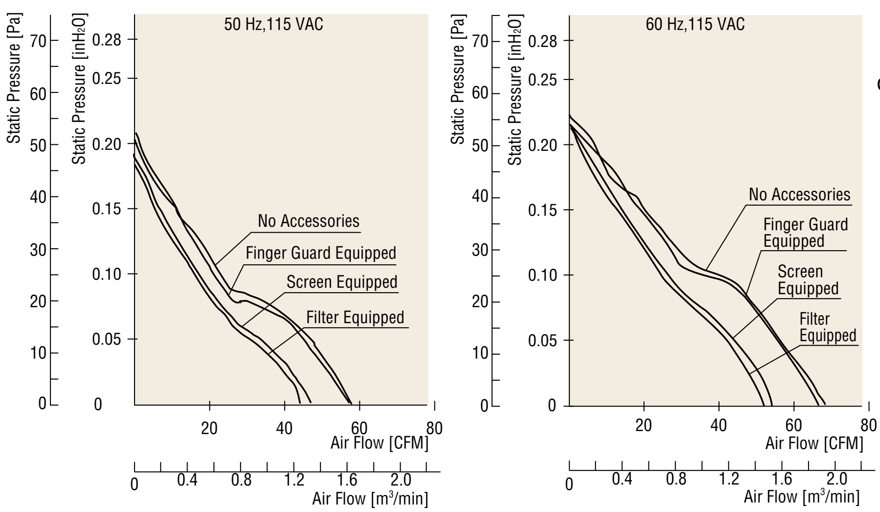


Fig. 8 Changes in Characteristics with Optional Parts Attached to the **MU1225S-21**

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

Noise

What is Noise?

We generally refer to sounds that are unpleasant to us as "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 the resulting noise will be.

Measuring Noise

The noise of Oriental Motor fans is measured in the A range at a distance of 3.3 feet (1m) from the intake (at a point above the center line of the intake).

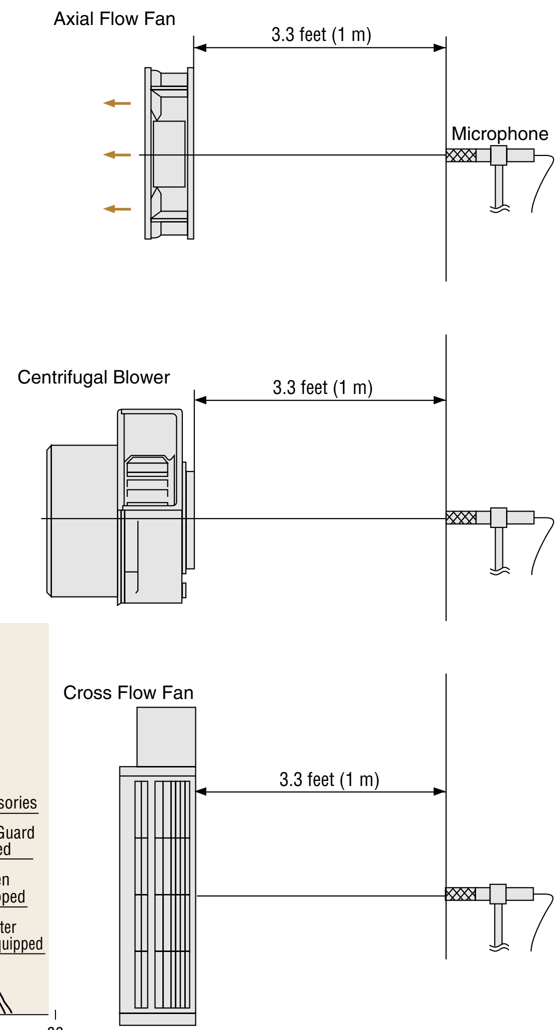


Fig. 9 Measurement of Fan Noise

Composition of Noise

This section discusses the noise value when using two fans, each of which produces 40 dB of noise.

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.

The relationship between sound energy (J) and sound pressure (P) is expressed in the following equation:

$J = \frac{P^2}{\rho c}$ where, (ρ = Air density, c = Speed of sound propagation)

Using the above equation, the noise value can be expressed in decibel units as follows:

Noise value $= 20 \log P/P_0$
$= 10 \log J/J_0$

P: Actual sound pressure
J: Measured noise energy
P_0, J_0: Minimum noise energy audible to the human ear

In this equation the noise value is expressed in decibels based on the reference energy of J_0. As the noise energy for n fans is n times that of a single fan, the sound pressure obtained by this equation will be:

Noise value $= 10 \log n \cdot J/J_0$
$= 10 \log J/J_0 + 10 \log n$

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 40 dB fans ($n=2$) are operated simultaneously, the increase in noise level is equal to 10 log 2 or 3 dB, and the combined noise level is 43 dB.

What would the combined noise level be if a 40 dB fan and a 50 dB fan were operated simultaneously? Again, the combined noise level is not given by a simple arithmetic sum but is obtained as follows:

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

↓

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

↓

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

↓

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

If 40 dB of noise is combined with 50 dB, the resulting increase in noise is only 0.4 dB. In other words, the noise level is always controlled by the larger of noise values, so it is important to suppress the noise of the fan producing greater noise.

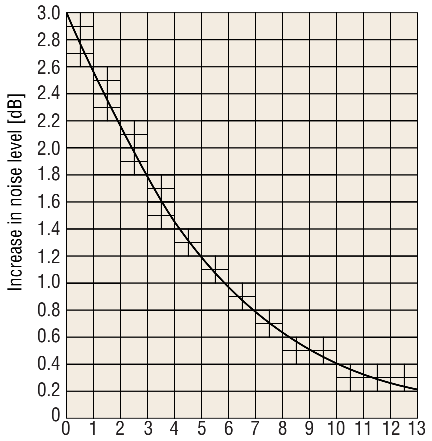


Fig. 10 Difference in Two Noise Levels

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:

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

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 6.6 feet (2m) from a fan, whose noise level is 40 dB at a point 3.3 feet (1m) from the intake side, is calculated.

Since r_2 = 6.6 feet (2m), r_1 = 3.3 feet (1m), and $SPL_1 = 40$ dB, substituting in the expression gives

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

Thus, at a distance of 6.6 feet (2m), the noise level decreases by 6 dB. The value 20log r_2/r_1 in the above expression represents the ratio between two distances. Thus, if the values used above were 9.9 feet (3m) and 19.7 feet (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

The term "fan life" refers to the condition in which the fan's blowing ability has deteriorated due to continuous fan operation for a certain period of time, or the fan can no longer be used due to significant noise.

① Rotation life: Fan life as defined by certain deterioration in fan rotation
② Acoustic life: Fan life as defined by certain increase in noise

Rotation life can be easily measured as 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 an increase in decibel level, while determining exactly what amount of increase marks the end of acoustic life depends on the user's judgment. Moreover, fans can still meet operating requirements even after reaching the predetermined increase level in noise. In general, 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 drops to 70 percent of the rated speed.

Parts Determining Fan Life

Certain fan parts are most critical 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 wide, U-shaped curve shown in Fig. 11.

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

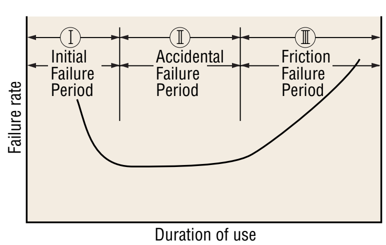


Fig. 11 Relationship between the Duration of Use and Failure Rate

Fan Bearing Life

Unlike the bearings of motors and gearheads, the load applied to fan bearings is negligible. Fan life is therefore determined by the deterioration of the grease in the bearings. Since the fan's operating and starting torques are significantly smaller than those of a motor, lack of lubrication due to grease deterioration will result in an extremely high voltage, which may prevent the fan from starting.
Deterioration of grease also increases the noise generated by the bearings, further affecting fan life.

Grease life is given by the following expression:

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

where,

t: Average grease life
K_1, K_2, K_3, K_4: Constants determined by grease
Nmax: Maximum rotation allowed by grease lubrication
n: Rotational speed of bearings
T: Operating temperature of bearings

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

Estimated Product Life Curve

Figure 12 gives the estimated average life of the bearings of the **MU1238A** type fan. This is 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.

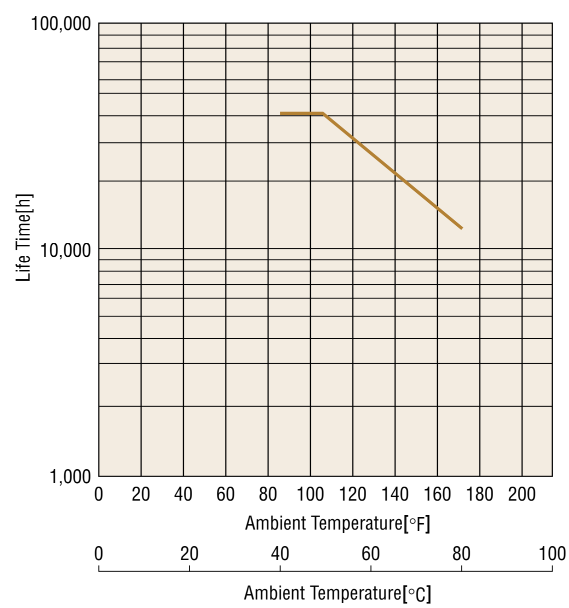


Fig. 12 Estimated Life Characteristics of the **MU1238A** Fan

Note:
The data shown in the above estimated life curve does not represent guaranteed values.

Capacitor

Capacitor-run motors contain an auxiliary winding offset by 90 electric degrees from the main winding. The capacitor is connected in series with the auxiliary winding, causing the current in the auxiliary winding to lag the current in the main winding.
The motor employs metallized electrode capacitor. This type of capacitor, which uses a metallized paper or plastic film as an element, is also known as a “self-healing (SH) capacitor” because of the self-healing property of the capacitor element. Although most of the previous capacitors used paper elements, the plastic film capacitor has become a mainstream model in recent years due to the growing demand for compact design.

Capacitance

The use of a capacitor with a different capacitance may cause excessive motor vibration and heat generation or may result in torque drops and unstable operation. Be sure to use the capacitor supplied with the fan. The capacitor‘s capacitance is expressed in microfarads (μF).

Rated Voltage

Using the capacitor at a voltage level exceeding the rated voltage may significantly reduce the capacitor’s service life. Be sure to use the capacitor supplied with the fan. The rated voltage of the capacitor is expressed in volts (V). The capacitor’s rated voltage is indicated on the surface of the capacitor casing. Take proper precautions, since the capacitor’s rated voltage is different from that of the fan.

Rated Conduction Time

The rated conduction time is the minimum design life of the capacitor when operated at the rated load, voltage, temperature and frequency. The standard life expectancy is 25,000 hours. We recommend that the capacitor be replaced after the rated conduction time.

Overheat Protection Device

If a fan in run-mode locks due to overload or 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.

Thermal Protector

The **MRS** Series, **MB** Series [certified products with runner diameters of 3.15 inch (80 mm) or more] and **MF** Series fans include a built-in, automatic-return type thermal protector. The structure of the thermal protector is shown in Figure 13. The thermal protectors employ bimetal contacts, with solid silver used in the contacts. Solid silver has the lowest electrical resistance of all materials, along with a thermal conductivity second only to copper.

- Operating Temperature of Thermal Protector
  open 248˚F±9˚F (120˚C±5˚C)
  close 170.6˚F±27˚F (77˚C±15˚C)

(The fan motor’s allowable winding temperature, where the thermal protector is working, is slightly higher than the operating temperature listed above.)

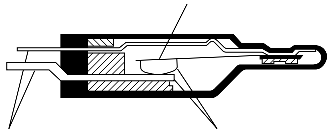


Fig. 13 Structure of Thermal Protector

Impedance Protection

The **MU** and **MB** Series (**MB520**, **MB630**) fans are equipped with impedance protection. Impedance-protected fans are designed with higher impedance in the fan windings so that even if the fan locks, the increase in input current will be minimized and the temperature will not rise beyond a certain level.

Glossary

Air Flow—Static Pressure Characteristics

With the air flow on the X-axis and static pressure on the Y-axis, the graph of air flow/static pressure characteristics shows how much static pressure is produced when the fan is generating a certain amount of air flow.

Point A in Figure 14 indicates the maximum amount of air flow that can be generated by a fan with a static pressure of zero, at which there is no loss of pressure. Point B indicates the maximum level of static pressure that can be produced by the fan, known as "maximum static pressure." However, in actual application a fan is rarely used at the maximum air flow or maximum static pressure. The maximum air flow or static pressure value is generally used for reference purposes to compare fan characteristics.

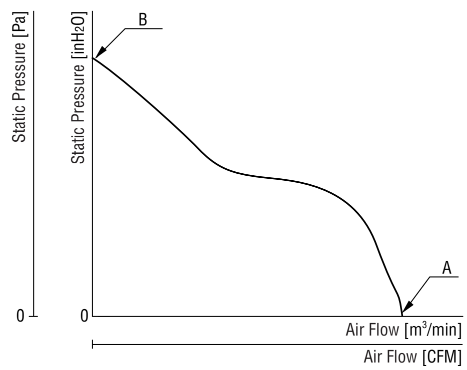


Fig. 14 Air Flow/Static Pressure Characteristics Curve

Noise Frequency Analysis

Oriental Motor adopts the "1/3-octave noise frequency analysis," in which the noise frequency components are expressed in the sound pressure level (average value) for each 1/3 octave band.

If the frequency is slightly off, the average human ear cannot detect it; Only when the frequency is off by about 1/3 of an octave can the difference be heard. The 1/3-octave noise frequency analysis therefore indicates the noise analysis data according to human audibility.

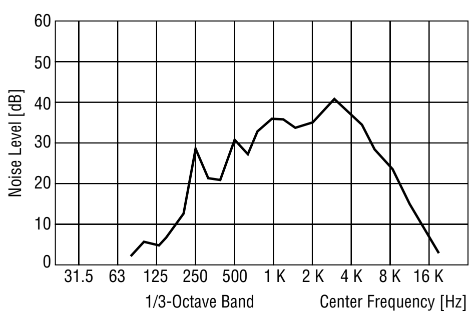


Fig. 15 Noise Frequency Analysis

Decibels (dB)

Noise level is expressed in decibel units (dB). When the noise level is expressed based on the linear scale, with the minimum level of noise audible to the human ear being 1, the maximum level of noise the human ear can withstand is expressed in such a substantial figure as 5,000,000. In contrast, if noise (level of acoustic pressure) is expressed in decibels, then

Sound pressure level $= 20\log P/P_0$

P = Actual sound pressure
P_0 = Minimum sound pressure perceptible by the human ear

Therefore, the range of sound pressure audible to the human ear can be conveniently expressed as 0 to 130 dB.

A Range

It is generally said that the audible range of the human ear is between 20 Hz and 20 kHz. Moreover, low frequency and extremely high frequency sounds are not disturbingly loud to the human ear. For this reason an accurate indication of loudness as perceived by the human ear cannot be achieved simply by measuring sound pressure without taking frequency into account. Therefore, measurements of the level of acoustic pressure must be corrected according to frequency in order to accurately reflect the human perception of loudness. This corrected range of measured acoustic pressure values is called the A range.

Figure 16 compares the frequency-corrected measured values (A range) with the uncorrected measured values (C range).

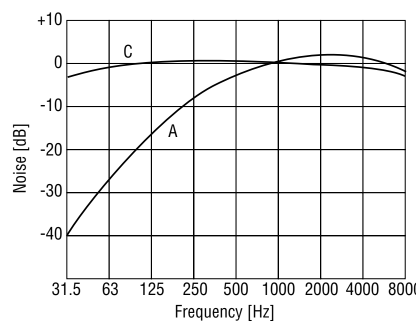


Fig. 16 Comparison of Sound-Pressure Level

Fire-Resistant Grade

The fire-resistant grade represents the degree of fire retardancy for plastic materials used in equipment parts. The generally accepted standards for fire-resistant grade are the UL-approved standards (UL94, standard for tests for flammability of plastic materials for parts in devices and appliances). The UL standards rate the fire-resistant grades of plastic materials based on the burning rate, duration of burning from the onset of fire, fire ignited by a dripping substance and other items. Fire resistance is rated in four different grades, as shown in the table below. ORIX FAN uses blades and frames with materials that receive the highest grade in this classification, V-0.

Grade	Fire Resistance
V-0	High
V-1	↑
V-2	
HB	Low

Q&A

Q1

Can fans be used above the range of operating voltage?

A1

The AC and DC fans are designed to operate properly within the range of operating voltage. Use these fans within the specified operating voltage range.

Q2

Are fans, like motors, equipped with overheat-protection devices?

A2

All AC fans in the ORIX FAN line that meet the UL, CSA and EN standards either have motors with impedance protection or are equipped with thermal protectors to prevent them from burning out. The DC fans include a current-detection function in their drive circuits. In the case of abnormalities, the fan's input current is controlled to prevent an increase in temperature and thus protect the fan motor from burning out. For details regarding impedance and thermal protection, see the section on overheating protection devices on page F-57.

Q3

Is there a simple, way to reduce the noise of a propeller fan?

A3

Noise usually decreases as fan speed drops. The **MU** Series fans are available in two fan speeds: standard-speed and middle-speed. Fan noise can be reduced by using the middle-speed of fan, operating at lower rate of rotation. For example, if you wish to reduce fan noise while maintaining the air flow of a standard-speed fan, you should simply choose a middle-speed fan in a larger size.
And, if you use thermostat (**AM1-WA1**, **AM1-XA1**) you can run the cooling fan when temperature inside the cabinet rise to pre-set temperature. Using this system it is possible to reduce total amount of noise.

Q4

Where should a fan be mounted to achieve the most effective ventilation and cooling?

A4

Three points should be kept in mind when using a fan for ventilation and cooling:

- ●Do not allow interference to air flow (Fig. 1).
- ●Do not let the air remain stagnant (Fig. 1).
- ●Do not allow short air flow paths (Fig. 2).

Based on the above, the ideal fan position is where air flows in one direction without interference, as shown in Fig. 3.
As long as the fan is mounted in an ideal position, there should basically be no significant difference as to whether an intake or exhaust fan is used. However, the exhaust fan will be more effective at maintaining uniform internal temperature.

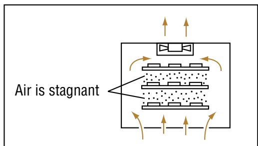


Fig. 1 Greater air flow interference, stagnant air

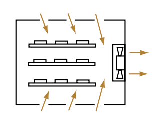


Fig. 2 Short airflow path

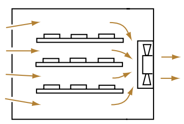


Fig. 3 Example of effective circulation and cooling