> Noise <

The problem of noise has became remarkably important for all applications of the fans, so MISTRAL Aspiratori-Ventilatori S.r.l. considered necessary to indicate the noise characteristics in its catalogues along with the other fluid movement characteristics for each individual fan.

3.1 DEFINITION OF NOISE: SOUND POWER AND PRESSURE

Noise is generally defined as any sound that disturbs or damages our hearing organ and /or the human organism.
The production of sound is due to the vibrations of a body and sound spreads in anything that can vibrate.
The vibrations that generate sounds and allow their propagation are an undulatory phenomenon, the so called sound wave, governed by the laws of physics.
The emission of a sound from a machine means the expenditure of a certain amount of energy to generate the vibrations associated with it.
The energy related to the time unit, is the sound power, measured in watt (W).
The sound source, through the sound wave, causes in the air small alternated fluctuations of pressure around the barometric pressure, causing compressions and depressions. The entity of such fluctuation or more precisely its value, is called "sound pressure", measured in pascal (Pa).
Man receives the audio sensation of a sound by means of the hearing organ (the ear), that is sensitive to sound pressure.
Sound pressure, on the other hand, is also the physical quantity measured with a photometer.
To facilitate the valuation of this measurement, given the enormous extension of the range of pressures that the human ear feels, it is necessary to use a logarithmic scale.
Conventionally it has been established the concept of "sound pressure level" whose measurement unit is the decibel (dB), which, instead of representing the absolute value of the pressure, indicates the level compared with the standardized reference value:

$$Lp = 10 \log \left(\frac{p}{p_o}\right)^2 = 20 \log \frac{p}{p_o} \qquad (3.1)$$

where:
Lp = Sound pressure level in dB
p = Effective sound pressure in Pa
P_o = Reference sound pressure = $2 \bullet 10^{-5}$ Pa

Similarly the "sound power level" is defined.
The decibel is also used as measurement unit for this.

$$Lw = 10 \log \frac{Pw}{Pw_o} \qquad (3.2)$$

where:
Lw = Sound power level in dB
Pw = Effective sound power
Pw_o = Standardized reference sound power = $1 \bullet 10^{-12}$ W

The establishment of the decibel concept allows us to report the field of sound pressures variable from $2 \bullet 10^{-5}$ Pa to 200 Pa to the field of sound pressure levels variable from 0 dB to 140 dB.
The photometer used for the measurement thus changes, by means of a microphone, the sound pressure into electric signals legible on the instrument display screen directly in dB (sound pressure level). Besides this, taking into account the different behavior of the human ear in the presence of sounds of different frequency, the photometer can "weigh" by means of suitable filters, the above mentioned electric signals.

In our measurements the weight scale A has been chosen, as adopted by the international standards ISO 3744.
The same source of noise, with the same generated sound power, is more or less annoying depending on the level of the sound pressure taken at the reception point.
This test is influenced by the environment where the fan is installed and by the distance of the hearing point from the fan itself.
MISTRAL S.p.A., not knowing the conditions of the final installation of the fans, for obvious reasons, can show and guarantee only the exact measurement of the value of the "sound power level" generated by its own fans.
In fact the power sound is an absolute quantity that allows the estimate of the sound pressure level, taken around the installed fan, once the acoustic characteristics of the environment are known.
The user, on the contrary, is interested in knowing, the sound pressure level that is the one he actually perceives.
Because of this need, besides the power sound level values, also the sound pressure levels are shown in the MISTRAL catalogue,

regarding a particular environmental situation with a fan placed on a reverberating surface in a free field at a distance of 1.5 m from the fan; with the exception for roof extractors the distance for which is 5 m.
These data appear to be a piece of information easily and immediately fit for use and, in most cases, correspond to the ones measured when the fan is installed.

3.2 UTILIZATION OF THE SOUND POWER LEVEL VALUES

When one wants to know the noise of a fan at a distance, and in an environment differing from the ones specified in the catalogue curves, it is necessary to proceed as follows from the known sound power level values (Lw).
The sound pressure (Lp) close to a source of noise depends on the effect imposed by two types of sound waves:

***a) Direct waves:** coming directly from the fan*
***b) Reflected waves:** coming from the walls surrounding the environment where the fan is installed.*

3.2.1. SOUND PRESSURE LEVEL DUE TO DIRECT WAVES

The part of the total sound pressure to the direct waves is given by the following formula:

$$Lp_d = Lw - d_1 + d_2 \qquad (3.3)$$

where:
Lp_d = Direct wave pressure level in dB
Lw = Sound power level in dB
d_1 = Factor function of the distance (in meters) between the source and the hearing point:

$$d_1 = 10 \bullet \log (4\pi \bullet r^2) \qquad (3.4)$$

d_2 = Factor function of the directivity coefficient Q:

$$d_2 = 10 \bullet \log Q \qquad (3.5)$$

The d_1 factor can be calculated by the formula in (3.4) or got from Table II.
The coefficient Q takes different values depending on the position of the fan with regard to reflective surfaces as shown in figure 4 and exactly:
1) The fan is distant from any wall.
In this case: Q = 1 and thus $d_2 = 0$ for the formula (3.5)
2) The fan is places on a flat surface distant from any vertical wall (hemispheric field of sound irradiation).
In this case : Q = 2 and so $d_2 \cong 3$.
3) The fan is places inside a solid angle formed by two walls: dihedral (e.g. placed on a floor and near a vertical wall).
In this case : Q = 4 and $d_2 \cong 6$.
4) The fan is placed inside a solid angle formed by 3 walls: trihedron (e.g. placed on the floor and near two vertical walls)
In this case: Q = 8 and so $d_2 \cong 9$

table II

distance (m)	d_1(dB)
0,50	5
0,70	8
1	11
1,25	13
1,50	14,5
1,75	16
2	17
2,50	19
3	20,5
4	23
5	25
6	26,5
8	29
10	31
15	34,5
20	37
25	39
30	40,5
40	43
50	45

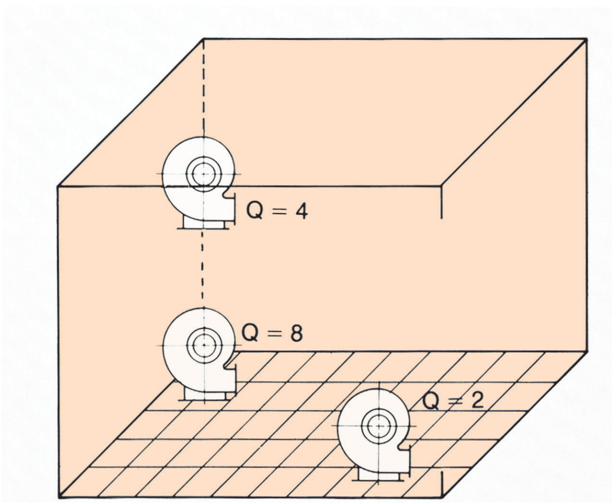

Fig. 4
Directivity coefficient depending on the position of the fan

3.2.2 SOUND PRESSURE LEVEL DUE TO REFLECTED WAVES

The part of the total sound pressure due to the reflected waves is given by the following formula:

$$Lp_r = Lw + d_3 \qquad (3.6)$$

where:
Lp_r = Sound pressure level of the reflected waves in dB
Lw = Sound power level in dB
d_3 = Factor function of the α coefficient of acoustic absorption of the walls in dB

d_3 can be obtained from the graph in Fig. 5 or it can be calculated by using the following formula:

$$d_3 = 10 \log \left[\frac{4 \bullet (1 - \alpha)}{S \bullet \alpha} \right] \qquad (3.7)$$

where:
S = Total area of reverberating surfaces in m^2
α = Average coefficient of the acoustic absorption of the surfaces

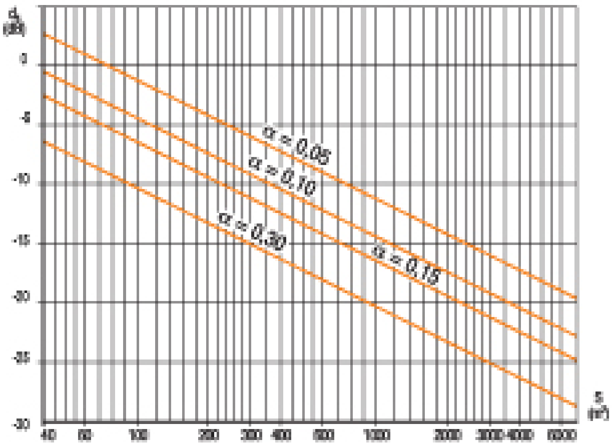

Fig. 5
Empty room with smooth walls of hard material (very reverberant room): $\alpha \sim 0.05$.
Room full of machinery with smooth walls of hard material (average reverberant room): $\alpha \sim 0.10$.
Room with at least one wall of deadening material (not very reverberant room): $\alpha \sim 0.15$
Room with all walls of deadening material (non-echoing room): a$\alpha \sim 0.30$.

3.2.3 THE TOTAL EFFECTIVE SOUND PRESSURE LEVEL

The noise effectively perceived at the established point, near the fan, is the sum of two sound pressure levels: pressure due to direct waves and pressure due to reflected waves.

The relative formula is:

$$Lp = 10 \log \left(\text{anti log} \frac{Lp_d}{10} + \text{anti log} \frac{Lp_r}{10} \right) \qquad (3.8)$$

As the sound power levels are measured in dB(A), the calculated sound pressure level will correspond to the effective acoustic sensation of noise.

3.3 SIMILARITY LAWS FOR NOISE

Similar to what happens for the flow rate and the pressure, also in the case of noise a law of similarity exists that allows us to obtain the noise levels for different diameters and for different revolution numbers of the impeller.
According to what has been established by the American standards AMCA 300/67 and by the French standards S31/021, the law of similarity is expressed by the following relation:

$$Lw_1 = Lw_o + 70 \log \frac{D_1}{D_o} + 50 \bullet \text{Log} \frac{n_1}{n_0} \qquad (3.9)$$

where:
Lw_0 = Sound power of the reference fan in dB
Lw_1 = Sound power of he new fan in dB
D_0 = Impeller diameter of the reference fan
D_1 = Impeller diameter of the new fan
n_0 = Number of revolutions of the reference fan
n_1 = Number of revolutions of the new fan

Naturally if the diameter or the revolutions do not vary the relative term is nullified.

3.4 CALCULATION EXAMPLE

We want to calculate the noise perceived at 3 m distance from the fan model AR57 working under the following conditions:
a) It is connected to the outlet of a specific machine: the fan inlet is open and is operating in the maximum efficiency zone
b) It is placed on the floor and it near to one wall of the room
c) The room has the following size: width 15 m., length 20 m., height 4 m.
d) The walls are of plastered concrete and the room is full of other machines

From the sound power table shown in the AR series catalogue, a sound power level for the AR57 model, in the specified working conditions is given Lw = 94.8dB(A).

As the fan is situated inside a dihedral the result is:

$Q = 4$ and so $d_2 \cong 6$

For the 3 m. distance, from the formula (3.4), we get:

$d_1 = 10 \bullet \log(4\pi \bullet 3^2) = 20{,}5$ dB

For the direct wave we thus obtain:

$Lp_d = 94{,}8 - 20{,}5 + 6 = 80{,}3$ dB(A)

The total surface of the room results as:

$S = (15 \bullet 4 \bullet 2) + (20 \bullet 4 \bullet 2) + (20 \bullet 15 \bullet 2) = 880\ m^2$

As the room has smooth walls but it is full of machinery we may consider an average coefficient of acoustic absorption:

$\alpha = 0{,}10.$

From formula (3.7) we get:

$$d_3 = 10 \log \left[\frac{4 \bullet (1 - 0{,}1)}{0{,}1 \bullet 880}\right] = 13{,}9 \text{ dB}$$

For the reflected wave we have:

$Lp_r = 94{,}8 - 13{,}9 = 80{,}9$ dB(A)

So the effective sound pressure level for formula (3.8) is:

$$Lp = 10 \log \left(\text{antilog} \frac{80{,}3}{10} + \text{antilog} \frac{80{,}9}{10}\right) = 83{,}6 \text{ dB(A)}$$