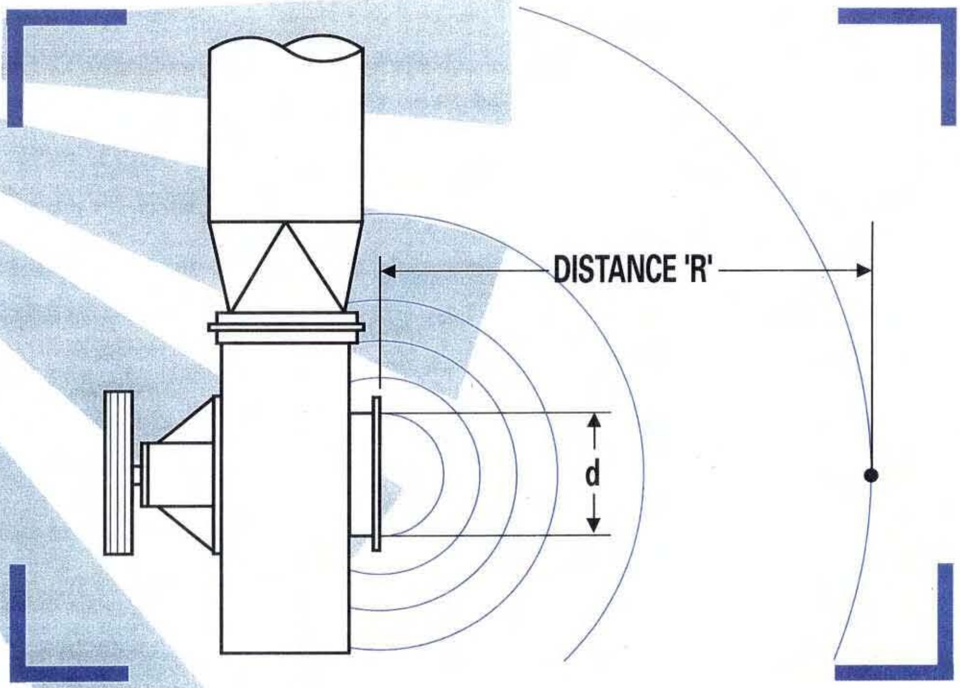
PROCEDURE FOR EVALUATION OF FAN NOISE LEVELS

by D.A. Scott ©



HALIFAX FAN

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INTRODUCTION

To some people, noise may be described as the pejorative synonym of sound. Sound is what we elect to listen to, noise is something imposed upon us. It can create resentment, frustration, in certain cases, ill health. Little wonder then that it is now a focus of organised protest, along with environmental pollution, and a source of interest to those who guard our health and safety in government and all the strata of local authority.

And the noise which causes most offence is that created by others, particularly that created by industry. Not only must industry present opportunities for gainful employment, in areas convenient to those who work within it , these objectives must be achieved with minimum adverse impact upon the environment in which it is located. Hence to the growing need for dust control, pollution control and odour control, is added noise control.

These requirements have specific reference to any system involving air movement, be it in dust and fume control, heating or ventilating, pneumatic conveying, drying or cooling. Halifax Fan are very mindful that in such systems it is now as important to examine the level of noise created, and if necessary, make provision for an appropriate reduction level, as it is to ensure that the fan selected will give the required performance in terms of volume handled against the resulting pressure differential absorbing the calculated horsepower. The required noise level is that deemed within statutory and local legislation and acceptable to adjoining residential sensitivities.

Now while it is possible to predict the noise levels which will emanate from a fan in a proven fan range of sound intrinsic design, it is rather more complicated to anticipate the effect of those noise levels from a fan in a particular location, mounted and installed in a certain way, upon the immediate surroundings. All those external factors must be considered in the light of the distortion they may impose upon the dissemination of the calculated noise level generated by the fan. These notes now presented form a simple instruction on predicting noise levels generated by Halifax Fans in a variety of locations.

The data used for these calculations is based upon laboratory tests, installation tests in situ, and on a few simple physical laws relating to the transmission of power and sound.

DEFINITION OF NOISE

Noise results from the generation and propagation of wave movements in numerous media. In the case of fans, noise is the generation of airborne pressure waves which affect the human ear. If these waves are transmitting pressure, they are transmitting force, which means that noise waves transmit energy, or power. Hence noise can be related to both pressure and power.

Two very important factors must now be taken into account.

(a) The effect of noise on an individual can only be measured in terms of the pressure generated on the individual's ear. However, the origin of noise is the power generated, and any calculation to establish the effect of noise must be related to the noise power generated.

A simple analogy can be drawn by considering an electric heater. The output of the heater is measured by the power consumed, i.e. watts, but its effect upon an individual is related to the temperature obtained at the location of the individual. This can be calculated from the power dispersed by the heater, the location of the individual relative to the heater, and the relevant environmental conditions applying at the time. If two heaters are applied, the effect is not measured by adding two temperatures together. Similarly the effect of two sources of sound on one location is not obtained by adding two sound pressure levels together.

(b) We are not interested so much in the quantitative measurement of noise, but the qualitative measurement of noise in so far as the human ear reacts to it.

This latter point leads to the need to relate sound pressure to some reference level reflecting the hearing ability of the human ear, and to select a scale of measurement which will be in harmony with the method of response of the ear to changes of pressure and the frequency of those changes of pressure. Because the ear responds to pressure intensity, it responds to $(\text{pressure})^2$ rather than pressure.

And the lowest noise intensity detectable by the normal healthy human ear is 10^{-12} watts/m^2, while the highest intensity withstood within the threshold of pain is 10 watts/m^2. This presents an enormous linear scale of 10^{13} unit divisions.

However, the reaction of the human ear to changes in intensity is logarithmic rather than linear, so that it is more realistic and happily more convenient to consider noise levels in terms of $\log_{10}$ (pressure)^2. The relevance of a numerical noise level to the human ear is further enhanced if it is also related to some constant value of (pressure)^2. The constant value selected is that relating to the lowest level the human ear can detect, which in terms of pressure is 20μPa, or 2×10^{-5}N/m^2.

Hence our selected unit of noise becomes :-

$$\log_{10} \frac{(\text{pressure})^2}{(2 \times 10^{-5})^2}$$

This unit is defined as a Bel, which gives the number of tenfold changes between two quantities. There are, on this basis, thirteen divisions between the lower limit of human hearing and the threshold of pain. Now thirteen divisions is considered too restrictive for this range, and the unit finally selected is $^1/_{10}$ of a Bel, that is a decibel. The noise pressure level=

$$10 \log_{10} \frac{(\text{sound pressure})^2}{(\text{reference pressure})^2} \text{ dB.}$$

This is usually known as the Sound Pressure Level, SPL.

Similarly, the sound Power Level becomes :-

$$10 \log_{10} \frac{(\text{sound power})}{(\text{reference power})} \text{ dB.}$$

where reference power = 10^{-12} watts. Sound Power Level is abbreviated SWL.

Now, as has been explained previously, while sound pressure levels can be measured, they must be converted to sound power levels before noise calculations are carried out for any particular system. Equations relating sound pressure levels, SPL, to sound power levels, SWL, for particular specified conditions are given later in the text. Whilst they vary with temperature and pressure at the time of measurement, for normal industrial fan calculations, these variations can be ignored.

There is now the aspect of the frequency of noise in its effect upon the human ear to be considered. The ear is more sensitive to mid frequency bands than to low or high frequency bands, so if a noise level is measured at selected frequencies, a differential weighting is required to reflect the ear's reaction to it. The frequency bands used for noise analysis are octave bands, that is bands where the upper frequency is twice the lower frequency. These weighting scales have been internationally agreed and are designated A, B and C. (Fig. 1).

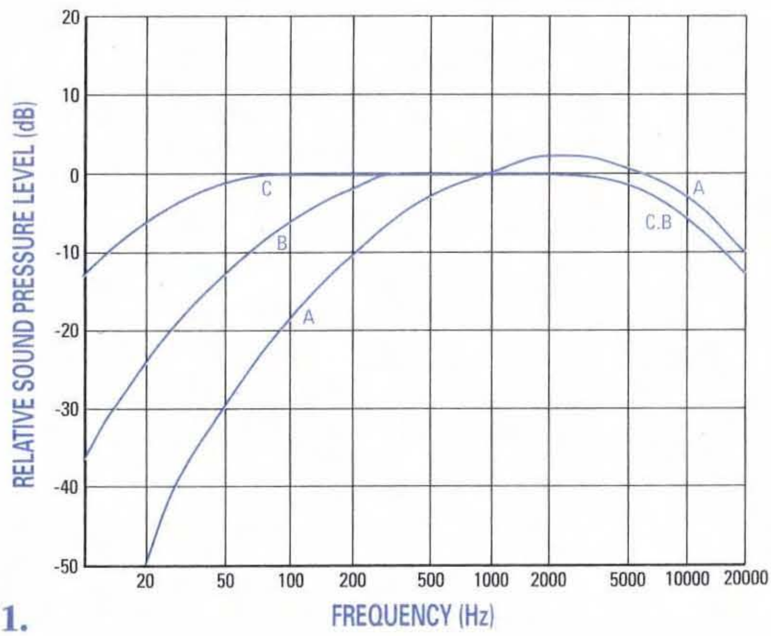


Fig. 1.
Graph Showing
A,B & C Scale Ratings

The A weighted scale is generally used and involves the following corrections.

Octave Mid Band Frequency	Hz	63	125	250	500	1000	2000	4000	8000
Weighting Correction	dB	-26	-16	-8.5	-3.2	0	+1.2	+1.0	-1.1

Finally it is convenient to combine the weighted noise levels for various octave mid band frequencies to give a figure reflecting the overall weighted noise pressure level. This is derived from the formula

$$\text{Overall SPLdBA} = 10\log_{10} \left(\frac{\text{antilog}_{10}\ \text{SPL}_{63}}{10} + \frac{\text{antilog}_{10}\ \text{SPL}_{125}}{10} + \ldots \frac{\text{antilog}_{10}\ \text{SPL}_{8000}}{10} \right)$$

NOISE CALCULATIONS

APPLIED TO HALIFAX FANS

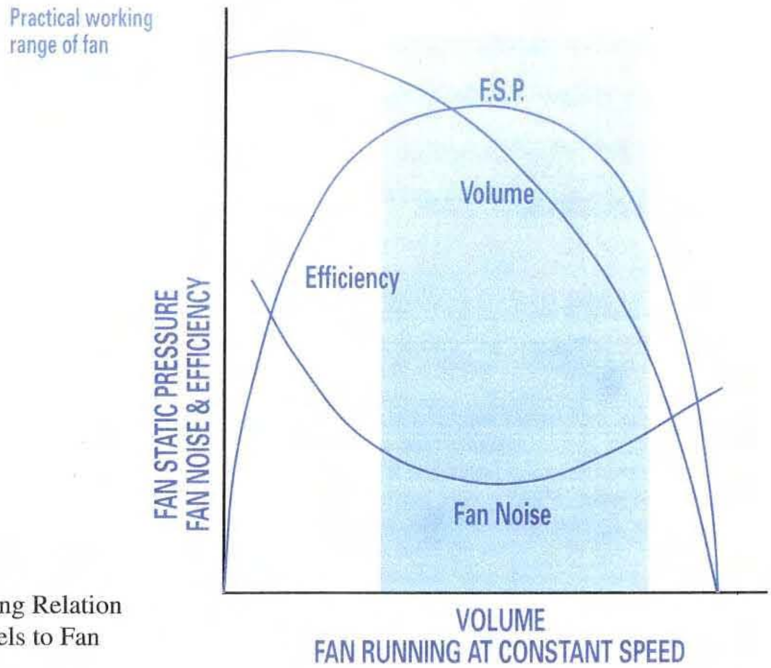


Fig. 2.
Graph Showing Relation of Noise Levels to Fan Efficiency

A well designed fan produces the minimum level of noise when operating at maximum efficiency, Fig.2. To simplify what could otherwise be an exceptionally tedious calculation, Halifax take the noise level at the end of the working range to apply over the whole of the working range. This approach also has the advantage of introducing a beneficial safety factor in many fan noise calculations.

The sound power level generated by a fan is given by the equation

$SWL = 25 + 10\log_{10}V + 20\log_{10} FSP$ dB where V = volume Flow m^3/hr

FSP = Fan Static Pressure mm Water Gauge

SWL = Overall Sound Power Level in octave frequency bands 31.5 to 8000Hz.

From the overall sound power level, the relative frequency noise spectrum can be produced by subtracting the values in Table 1 given below for each octave mid band frequency.

Table 1	Octave Mid Band Frequency							
Hz	63	125	250	500	1000	2000	4000	8000
Forward Curved (Multivane)	2	6	13	18	19	22	25	30
Backward Curved (Beaufort)	4	6	9	11	13	16	19	22
Backward Inclined (Mistral)	9	4	5	10	13	19	24	29
Paddle Blade	3	5	11	12	15	20	23	26

FREE FIELD CONDITIONS

In the case of fan installations, we must consider the noise propagated from the fan freely in all directions or from the fan mounted on a flat surface in otherwise free field conditions. The first case involves noise radiating from the fan casing equally in all directions, i.e. through a sphere, and in the second case noise radiating through a hemisphere. The following relationships between sound power level and measured sound pressure level then apply.

For spherical sound radiation:

$SWL = SPL + 20\log_{10}R + 11dB$

and for hemispherical sound radiation:

$SWL = SPL + 20\log_{10}R + 8dB$

where R is the radial distance in metres measured from the sound source, and SWL is the sound power level at source.

Noise pressure levels at a distance from the fan, when there is little or no reflection, that is in free field conditions, are proportional to the square of the distance from the source. This means that the noise pressure falls 6dB for each doubling of distance.

For in-duct fan testing:

$SWL = 10\log_{10}A$ dB + SPL

where A is the cross section of the Duct in square metres.

FAN BREAK-OUT NOISE LEVEL

A fan is normally connected to a ducting system, either at the fan outlet, inlet, or both. In this latter situation, the noise level created at the outer surface of the fan casing is termed the fan break-out noise level, and will occur whether a silencer is fitted to either the fan inlet, fan outlet, or both.

The level of break-out noise is best determined empirically for a selected range of fans running over a pre-determined range of operating performances, and the results thereby obtained extrapolated to cover the full working range of the fans concerned.

These results from Halifax Mistral Fans, for example, are obtained using Table 2. The break-out noise level is reached by subtracting the appropriate value from Table 2, relevant to the specified operational condition, from the sound power level given by the formula:-

$$SWL = 25 + 10\log_{10}V + 20\log_{10}FSP \text{ dB}$$

The Sound Pressure Level at 1 metre distance from the fan casing will be approximately 85% of the break-out sound level.

For other distances, the sound pressure levels can be derived by again considering how the sound pressure waves radiate from the fan. The surface area of a sphere is $4\pi R^2$ and as sound is considered relative to a specified point, it is necessary to consider the sound being dissipated over a hemisphere of surface area $2\pi R^2$, Fig. 3.

FSP	Table 2										m³ / hr x 1000										
mm	1	2	3	4	5	6	7	8	9	10	15	20	30	40	50	60	70	80	100	150	RPM
0/50	24	24	21	20	19	19	18	18	17	17	15	14	13	12	11	10	-	-	-	-	0 to 3000
51/100	26	25	24	22	21	20	19	-	-	-	-	-	-	-	-	-	-	-	-	-	2000 to 3000
51/100	21	21	20	20	19	19	19	18	18	18	16	15	14	13	-	-	-	-	-	-	0 to 2000
101/200	23	23	22	22	21	21	20	20	20	19	-	-	-	-	-	-	-	-	-	-	2000 to 3000
101/200	19	19	19	19	18	18	18	18	18	17	16	16	15	14	13	13	13	13	11	-	0 to 2000
201/300	23	23	23	22	21	21	20	20	20	20	18	17	-	-	-	-	-	-	-	-	2000 to 3000
201/300	18	18	18	18	18	17	17	17	17	17	17	16	16	15	14	14	14	-	-	-	1000 to 2000
201/300	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11	11	11	11	11	0 to 1000
301/400	22	22	22	22	21	21	20	20	20	20	18	17	-	-	-	-	-	-	-	-	2000 to 3000
301/400	18	18	18	18	18	18	17	17	17	17	17	16	15	14	14	14	13	12	11	10	0 to 2000
401/500	22	22	22	22	21	21	20	20	20	20	18	17	-	-	-	-	-	-	-	-	2000 to 3000
401/500	18	18	17	17	17	17	17	17	17	17	17	16	15	14	14	13	13	12	11	10	0 to 2000

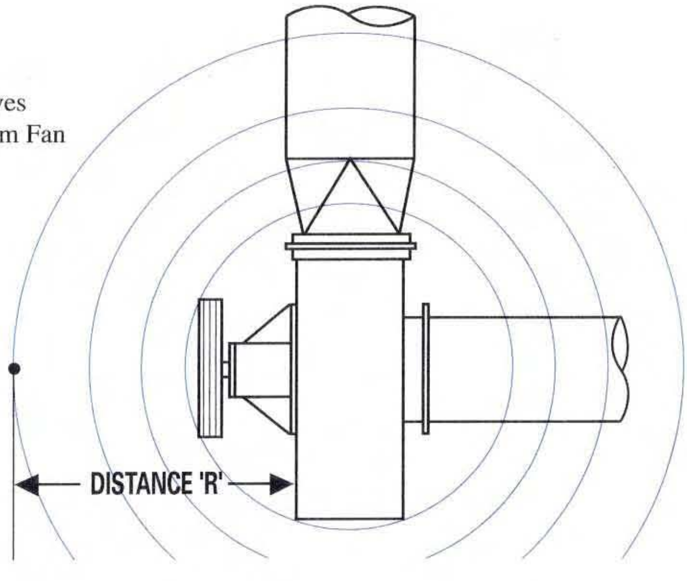
The difference in sound pressure levels will then be given by:-

$$SPL_{R_1} - SPL_{R_2} = 20\log_{10}\frac{R_2}{R_1} \text{ dB}$$

If R_1 = 1 metre

$$SPL_{R_1} - SPL_{R_2} = 20\log_{10} R_2 \text{ dB}$$

Fig. 3.
Pressure Waves Radiating from Fan



SOUND LEVELS FROM FAN

WITH OPEN INLET OR OUTLET

The relevant surface area for sound dissipation is given by the hemi-sphere, diameter d, Fig. 4 refers. If it is a rectangular cross section the equivalent diameter (d) to be considered is $1.2\sqrt{A}$ where A is the cross sectional area in square millimetres. The sound radiating from the fan to the surrounding area will be reduced when passing through the fan inlet or outlet. Fig. 5. shows the reduction in sound power levels, SWL

Fig. 4.

Sound Loss from
Inlet or Exit of Fan

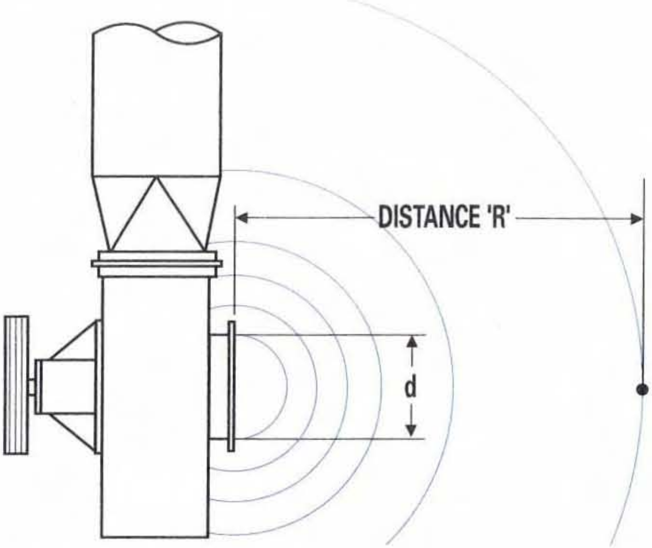
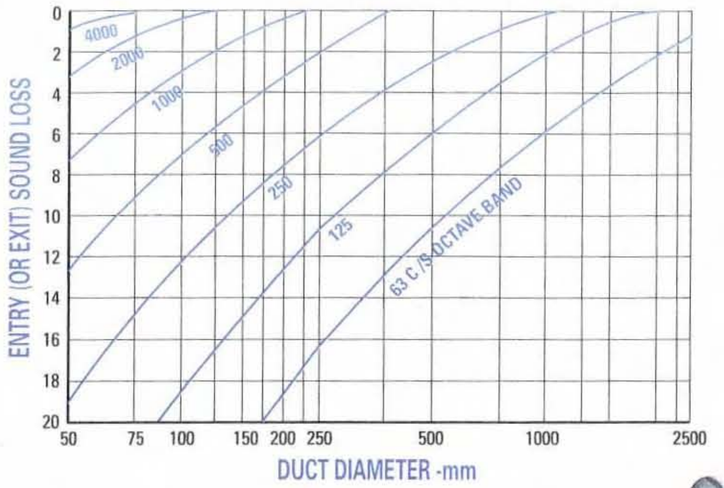


Fig. 5.

Entry or Exit Sound
Loss Correction, ESL



Hence the sound level at point

$$X = SWL - ESL - 10\log_{10} 4\left(\frac{R}{d}\right)^2$$

where R = distance between measuring point and fan inlet or outlet in metres. ESL is the entry or exit sound loss derived from Fig. 5. and is the reduction in sound power radiating into open space which occurs due to sound reflection effected by the fan inlet or outlet.

SOUND REFLECTION

As has been mentioned earlier, fan sound ratings refer to free field conditions, which assume that the fan is located in a completely open area without any adjacent surfaces from which radiated sound can be reflected. This condition is rarely encountered in practice, and it is necessary to take radiated sound effects into account when predicting noise levels for any proposed fan installation, Fig. 6 refers.

Obviously any detailed analysis would call for some very complex calculations. However, a good approximation of the effect of reflected sound can be obtained by adding 3dB to the free field condition level if the fan is located near to the side of a building with a surface finish conducive to sound reflections. If the floor is also sound reflective, a further 3dB should be added. The equivalent of an enclosed reflective area may lead to an increase of 10dB.

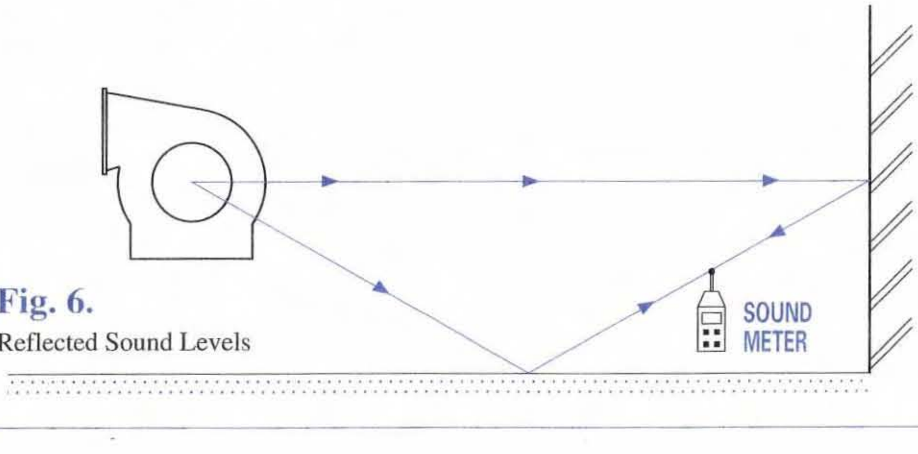


Fig. 6.

Reflected Sound Levels

EFFECT OF FAN BEARINGS,

MOTOR & DRIVE ON NOISE LEVEL ACHIEVED

Electric motors can produce a surprisingly high noise level which must be taken into account when considering the combined noise levels obtained. Values as high as over 80dB are not uncommon and precise data on this aspect would be obtained from the motor manufacturers.

Noise generated by fan bearings and V rope drives, where used, can generally be ignored in contrast to either fan or motor, because they make little significant contribution to the combined noise levels when properly maintained and adjusted.

Where the bearing noise level is required, it can be derived from the formula:

Bearing Noise dB = 21 $\log_{10}$ RPM

OVERALL SOUND PRESSURE LEVEL, dBA

This is only relevant if it is within 9dB of the overall sound level. Otherwise it can be ignored.

WORKED EXAMPLE:

A Halifax Mistral Backward Inclined Fan No. 33 is to handle 20,388M³/hr against 279 mm water gauge static pressure when running at 1370 RPM. It is to be considered with ducted inlet and outlet.

$$SWL = 25 + 10\log_{10}V + 20\log_{10}FSP$$
$$= 25 + 10\log_{10}20388 + 20\log_{10}279$$
$$= 25 + 43 + 49$$
$$+ 117$$

FAN BREAK - OUT SOUND

From Table 2 for FSP 201-300 mm at 0-2000 RPM and 20,000M^3/hr,

Table 2 gives a value of 16dB.

Hence Break-Out Sound =

117 - 16 = 101dB

Sound Level at one metre distance from the fan =

101 x 0.85 = 86dB

Now consider the Relative Frequency Spectrum using values for the Mistral Fan in Table 1.

OCTAVE MID BAND FREQUENCY

Hz	63	125	250	500	1000	2000	4000	8000
	86	86	86	86	86	86	86	86
	-9	-4	-5	-10	-13	-19	-24	-29
	77	82	81	76	73	67	62	57

To convert sound levels from linear scale to an A weighted scale dBA the following corrections now apply.

Hz	63	125	250	500	1000	2000	4000	8000
	77	82	81	76	73	67	62	57
	-26	-16	-8.5	-3.2	-0	+1.2	+1	-1.1
	51	66	72.5	72.8	73	68.2	63	55.9

The example worked above has given the A weighted Sound Levels, dBA, for a range of mid band frequencies from 63Hz to 8000Hz. It is convenient to arrive at a sound level figure which represents the effect of the combination of all the sound levels worked out above. This figure is known as the Overall Sound Level, dBA, and is derived as follows, using the graph in Fig. 7.

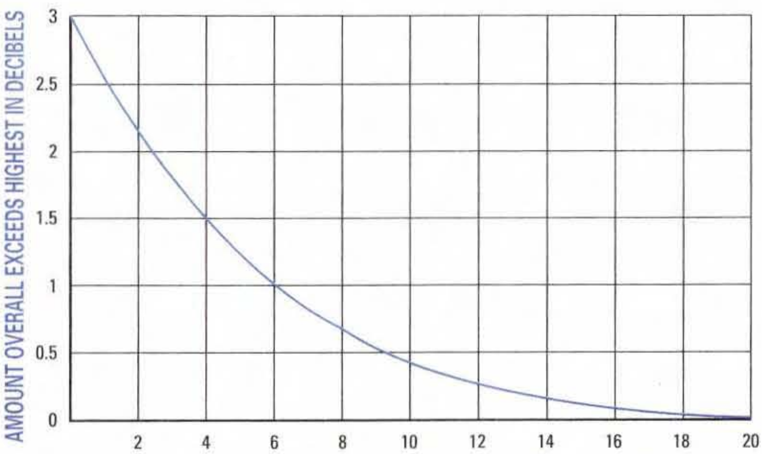
First rearrange the calculated sound levels in order of descending values. The first two values are 73 and 72.8. The difference is 0.2. From graph a difference of 0.2 gives a value of 2.7 on the y axis (Amount overall exceeds highest in Decibels.) Add 2.7 to 73 to give 75.7. Now take the difference between 75.7 and the next highest value, which is 72.5. The difference between these two figures is 3.2 which, when read off the x axis gives a value of 1.75 on the y axis. This is added to 75.7 giving 77.45. The process is repeated for all the sound levels of the mid band frequencies as follows:-

73 - 72.8 = 0.2; 73 + 2.7 = 75.7
75.7 - 72.5 = 3.2; 75.7 + 1.75 = 77.45
77.45 - 68.20 = 9.25; 77.45 + 0.45 = 77.90
77.90 - 66.00 = 11.90; 77.90 + 0.25 = 78.15
78.15 - 63.00 = 15.15; 78.15 + 0.09 = 78.24
78.24 - 55.90 = 22.34; 78.24 + 0.00 = 78.24

Result: Overall Sound Pressure Level = 78dBA

Fig. 7.

Difference between Overall Level & Background Level alone (dB)



DIFFERENCE BETWEEN TWO INDIVIDUAL LEVELS - IN DECIBELS
CORRECTIONS FOR COMBINED LEVELS

BEARING NOISE

$$dB = 21\log_{10}RPM \quad dB = 21 \times 3.137 = 66$$

As this is not within 9dB of the Overall Sound Level (78dBA) it can be ignored.

NOTE: Whist the data given on fan prediction and the worked example are based on the best practical data available, it must be stated that the normal tolerances allowed in conventional engineering manufacturing practices could affect the predicted overall sound pressure and power levels by ± 2dB.

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ACKNOWLEDGMENTS

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