NOISE LEVEL PREDICTION FOR MOORE FANS

CONTENTS

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I. HOW TO USE THE PROGRAM

GETTING STARTED . . .

This paper refers to the Noise Level Prediction option in the fan rating program furnished by Moore.

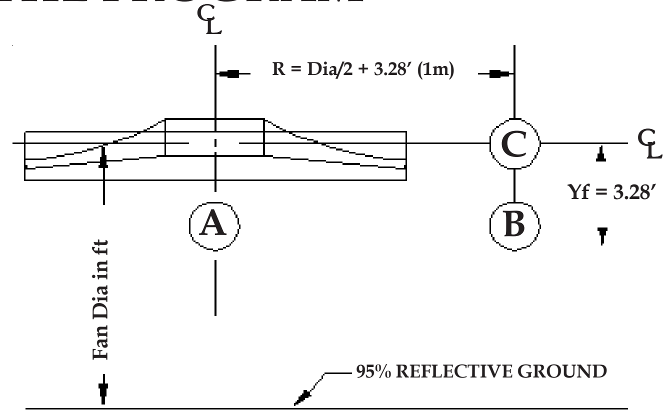


Fig. I Starulard SPL's are calculated for points ~cated at A and B

STANDARD OUTPUTS

The program will respond to your fan rating input by calculating the fan Sound Power Level (PWL) and the Sound Pressure Level (SPL) at the locations shown in Fig. 1 marked "A" and "B". These totals are given in dBA. The program also presents the corresponding noise spectrum, in dB, for centerband frequencies from 63 to 8000 Hz. Due to the masking effect of the fan ring, the SPL at point "C" is typically from 1 to2 dBA lower than at point "B". For this reason, the SPL at "B" is a more conservative prediction.

These three standard outputs are useful in comparing the noise performance of various fans. Since these are standardized values commonly used in the industry, the user is not given the option of changing the assumptions used in the calculation. You may, however, use the optional inputs for a single fan to change the assumptions used. The following sketch shows the dimensions assumed for the "Standard" SPL's: If you require these SPL's with some other ground reflectivity, the program will calculate them as discussed in the following paragraph.

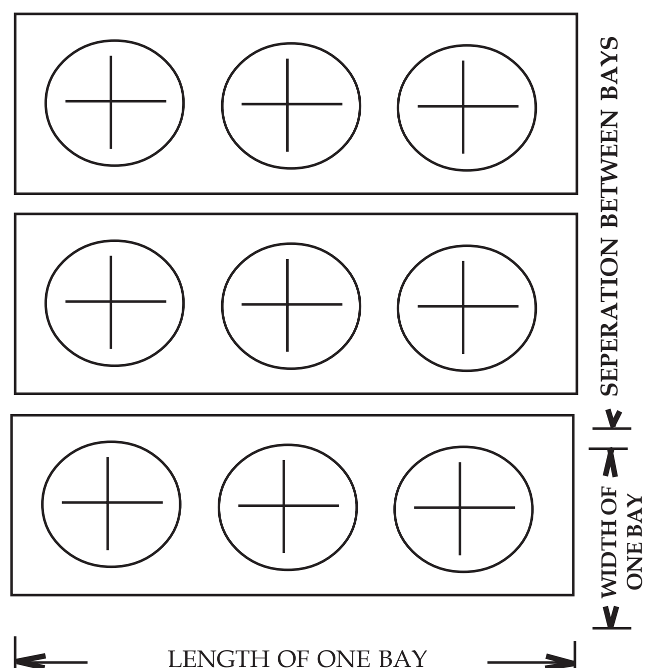
SPL FOR ONE FAN AT OTHER POINTS

After presenting the SPL's at the standard points shown above, you have an option to find the SPL at some other distance from the fan. To utilize this feature please click on the icon with a loudspeaker on it at the top of the screen. You may enter any horizontal distance (R) and any vertical distance (Y) to the desired point of measurement with one exception. Dimension Y may not be less than 3'. (See "Effect of Ring Reflection" on Page 5)

You may then enter the vertical distance from the fan centerline to the ground and your estimate of the ground reflectivity expressed as- a decimal from 0 to 1, 0 indicating a perfectly absorbing surface and 1 a perfectly reflecting surface. With this information, the program will respond with the Total SPL in dBA and the spectrum in dP, at the specified point.

SPL FOR MULTIPLE FANS

A second option for measuring SPL for multiple fans is found at the icon with a loudspeaker with a "+" sign. You will be asked a series of questions describing a typical heat exchanger unit. The terminology used is consistent with that used in API Recommended Practice 631M, "Measurement of Noise from Air Cooled Heat Exchangers". The sketch below illustrates how the program would assume bays were arranged in a 3-bay unit with three fans in each bay.



Fig,. 2 Arngement of Bays Assumed by

The program makes the following assumptions:

The bays are arranged with their longest sides adjacent, separated by a constant distance (which may be zero.) All fans in the unit are identical. The fans are arranged symmetrically in the bay(s). For example, if you indicate that there are two 10' diameter fans in a 30' long bay, the center to-center distance between the fans will be 15'.

The distance Y from the fan centerline, the height of the fans from the ground and the ground reflection are assumed to be the same as those entered for the SPL for one fan (as discussed under the preceding heading) assuming this information has already been entered. If not, you will be asked to supply this information at this point.

The program assumes the maximum SPL is required for a point at the specified distance from the periphery of the unit. The program first calculates the SPL at the specified distance perpendicular to the length of one bay. If the number of bays per unit is greater than the number of fans per bay, the program also will calculate the SPL at the specified distance perpendicular to the bay-end side of the unit. The SPL reported will be the greater of these values.

CHANGING YOUR ENTRIES

Caution - the program is not sophisticated in detecting inputs that may be (mechanically) impossible. For example, if you were to increase the number of fans per bay at the change data screen without increasing the length of one bay, the program will accept the entry even though the new number of fans might not fit in the bay.

SOUND POWER LEVEL (PWL)

The total power level in dBA for the fan is:

Eq.1

$$PWL = 55.2 + 30 \text{ Log } V_T + 10 \text{ Log } HP$$

Where: V_T = Fan tip speed in ft/min x 10^{-3}

$= \pi$ X Dia. X RPM / 1000

HP = Input Fan Horsepower

(Not motor horsepower)

SOUND PRESSURE LEVEL (SPL)

SPL due to the fan (SPL_F)

In deriving the formula used for calculating the sound pressure levels, the fan is treated as a ring source of sound with a " center of sound " (analagous to the center of gravity) at 6/7 of the fan radius. Integration over the fan area yields the following formula:

For the sake of simplifying this discussion, we will assign a variable to the denominator in Eq. 2. We can then rewrite Eq. 2 in decibel form simply as:

From Eq. 3, it is apparent that the SPL always equals the PWL reduced by some value that depends entirely on the two coordinates of the point of interest (R and Y) and the fan diameter (D).

Eq. 2

In Sl Units:

$$\text{SOUND POWER PER SQUARE METER} = \frac{\text{TOTAL SOUND POWER}}{4 \pi (0.0929)\sqrt{\left(\left(R+\frac{6}{7}\frac{D}{2}\right)^2 + Y^2\right) \left(\left(R-\frac{6}{7}\frac{D}{2}\right)^2 + Y^2\right)}}$$

Where:

R = Horizontal distance from center of fan to the point of measurement, in ft

Y = Vertical distance from the fan centerline to the point of measurement, in ft

D = Fan diameter, in ft

(0.0929) converts square feet to square meters

Total Sound Power is in watts

Eq. 3

$$SPL_F = PWL - 10 \text{ Log } K$$

Where:

PWL = The Sound Power Level in dBA as calculated in Eq. 1

K = The denominator in Eq. 2

Logs are to the base 10

SPL_F = the SPL due to the fan only. The equation does not include the effect of ground or ring reflec-

The diameter becomes insignificant as the distance from the fan increases.

Fig. 3 below illustrates the results of this equation. For this illustration, we have assumed that Y = 3' and plotted the SPL relative to the PWL: That is, the vertical scale represents the difference in dBA between SPL and PWL.

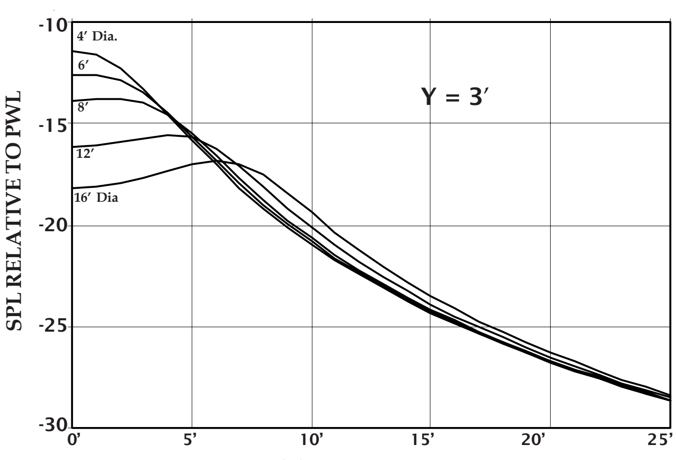


Fig.3 SPL Relative to PWL for various fan diameters

The illustration above shows, for example, that a 12' Dia. fan with a PWL of (say) 90.0 dBA will have a SPL (neglecting ground reflection) of about 70.0 dBA at a point 10' from the fan center. We can also see that at a distance of 25' from the fan center, a fan of any diameter will have a SPL about 28 dBA less than the PWL under these conditions. The program, of course, calculates the exact SPL by formula. Fig. 3 is for illustration only.

SPL due to ground reflection (SPL_G)

Te SPL due to ground reflection is calculated as if a second identical fan were located at a distance below the ground plane equal to the distance the real fan is located above the ground. As an illustration, we have revised Fig. 1 to include the virtual image of the fan. See Fig. 4.

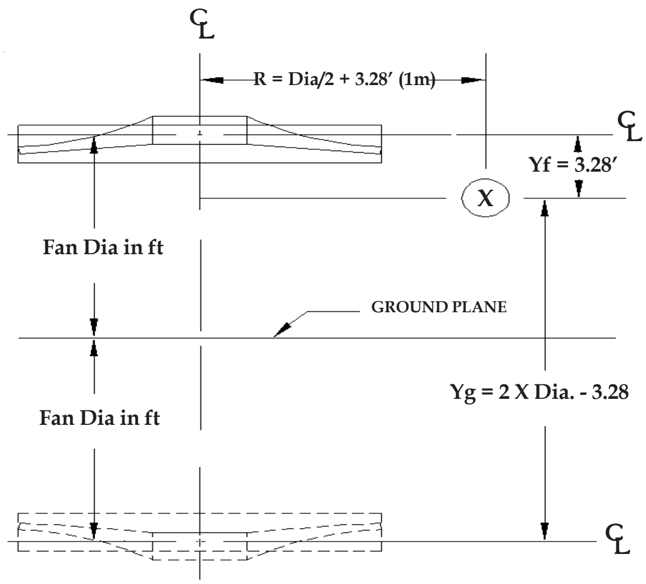


Fig.4 Dimensions for SPL_G at Point X

The dimensions shown in Fig. 4 are for the standard point "B" in Fig. 1. The user may input dimensions for the other outputs. The calculation for SPL_G is identical to that for SPLF except for the reduction of the PWL if reflection is less than 100%.

Total SPL when R>D/2

If the point of measurement is not under the fan, the SPL is the logarithmic sum of SPL_F and SPL_G.

For multiple fans, it is necessary to calculate the SPL for each fan using the distance R for that fan. The total SPL's are then added logarithmically.

Fig. 5 shows the effect of ground reflection on a

$$SPL_G = (PWL) - 10 \text{Log } K + 10 \text{ Log Refl} \qquad \text{Eq. 4}$$

Where:

Refl = The reflectivity of the ground, expressed as a decimal (O to 1)

PWL = The Sound Power Level in dBA calculated in Eq. 1

K = The denominator in Eq. 2

Logs are to base 10

SPL_G = SPL due to ground reflection only.

6' and a 16' diameter fan. The abrupt "jog" in each case is the effect of the ring reflection explained in the following paragraph.

Effect or Ring Reflection

If the point of measurement is outside of the fan ring near the fan centerline, the ring will mask the sound by an amount that cannot be accurately calculated but is estimated to reduce the SPL by 1 to 2 decibels at a point 3' from the ring. This is why, in order to be con-

$$SPL = 10\text{Log}\left(1O^{(SPL_F/10)} + 10^{(SPL_G/10)}\right) \qquad \text{Eq. 5}$$

servative, the program will not accept a "Y" dimension less than 3'.

If the point of measurement is under the fan, however, the opposite is true: In order to be conservative, we must add the effect of the inner-reflected sound from the ring. For this reason, if R<= D/2, the program adds 2.0 dBA to SPL.

Fig. 5, which follows, illustrates the effect of ground and ring reflections when added to the SPL of the fan. Notice the 2-dBA changes in the SPL where R equals the radius of the fan. The vertical scale gives the difference between SPL and PWL as it did in Fig. 3. Fans are forced draft units.

Effect of the bundle on induced draft units:

The effect of the bundle cannot be calculated but test have shown that the SPL is typically about 3 dBA lower than predicted, indicating that the bundle reflects about half of the sound upward. For this reason, the program subtracts 3 dBA from the SPL

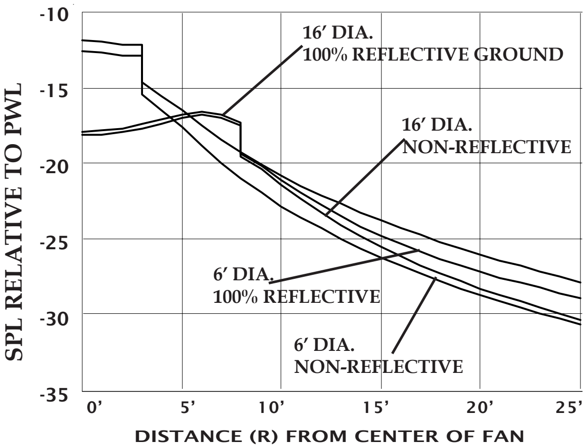


Fig.5 The effect of ground and ring reflecttions

when R<D/2 for induced draft fans. If the point of measurement is not under the fan, SPL is calculated as for forced draft units

NOISE LEVEL SPECTRUM

For the Total Power Level (PWL) and for each of the Sound Pressure Levels (SPL) reported by the program, the spectral analysis is shown for centerband frequencies from 63 to 8000 Hz. There are two factors involved:

1. The frequency distribution shown in the table at right distributes the total PWL or SPL by frequency according to the nature of the sound source (the fan). These values are added.

2. The A-scale weighting for each of the centerband frequencies must be subtracted from the PWL or SPL to convert from dBA to dB.

The total correction is the factor applied to the appropriate PWL or SPL by the program.

Since these values are logs (i.e. exponential values) they are added or subtracted rather than multiplied or divided. The Total Correction is added to the PWL or SPL.

SPECTRUM CORRECTION VALUES

CENTER-BAND FREQUENCY	A-WEIGHTED FREQUENCY DISTRIBUTION	A-SCALE WEIGHTING	TOTAL CORRECTION
63	-20.2	-26.2	+ 6
125	-11.1	-16.1	+5
250	-6.6	-8.6	+ 2
500	-6.2	-3.2	-3
1000	-6.0	0	-6
2000	-11.8	+ 1.2	-13
4000	-16.0	+ 1.0	-17
8000	-24.1	- 1.1	-23

III. PROGRAM LIMITATIONS

THEORETICAL LIMITATIONS

Cooler design and surrounding objects:

The calculations used by the program have been derived with a "generic" aerial cooler in mind typical of forced draft units. For such units, Moore Fans feels confident of the basis on which the program calculations are made. Even with such units, however, the program does not (nor can it) anticipate all the effects of the fan's environment. Surrounding structures and objects may absorb, reflect or mask sound in incalculable ways.

For non-typical forced draft units and for all induced draft units, there is less theoretical basis for sound level prediction due to the wide variety of possible designs and the poorly understood effect of the bundle. For such units, values presented are on a "best guess" basis. Actual testing of the fan in place is recommended.

Sound Attenuation

As sound travels through the atmosphere, it is affected by numerous environmental factors: attenuation (i.e. reduction) by absorption in the air, by rain, sleet, snow, fog and barriers in the path. It is effected by grass, shrubbery, trees, and the changing reflectivity of the ground-to name a few. None of these environmental effects are included in these calculations.

Ground Reflection Information

It is up to the user to estimate the reflectivity of the ground from 0 (perfectly absorbing) to 1 (perfectly reflecting). We offer the following guidelines:

Concrete, poured	.95
Sand, dry	.54
Gravel or soil, loose, moist	.37