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sound level prediction for installed rotating electrical machines

NEMA

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Sound Level Prediction for Installed Rotating Electrical Machines

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SOUND LEVEL PREDICTION FOR INSTALLED ROTATING ELECTRICAL MACHINES

(Approved as Authorized Engineering Information 7-17-1974.)

I. FOREWORD

In recent years noise has had an increasing influence on users of machines. Exposure to excessive noise levels may cause permanent hearing damage and, also, affect people's efficiency, moods, temperament and comfort. Local, State and Federal Governments have enacted legislation to control noise level exposure.

Due to the recent emphasis on health and safety considerations, a large number of people with no special training in sound have had noise control problems thrust upon them. This booklet provides a method of predicting approximate sound pressure levels in industrial and commercial areas.

The method is intended for estimating sound pressure levels and should not be construed as a guarantee of results. It requires a knowledge of the sound levels, location of all sound sources, and room characteristics. Throughout this booklet, for simplicity, emphasis is placed on the use of overall *dBA*. A more detailed analysis can be obtained by using the same method for each octave band sound level as shown in the Appendix.

Machine sound level data are normally expressed as single *dBA* levels or in full octave band *dB* levels, unweighted, in terms of sound pressure or sound power.*

An example is included to assist the reader in understanding the method described in this publication. Instructions for calculation and corresponding sample calculations are presented in a parallel fashion for convenient cross reference.

Comments will be welcomed. They should be sent to:

Technical Director
Manager, Engineering and Safety
Regulations Dept.
National Electrical Manufacturers Association
155 East 44th Street
New York, N.Y. 10017

II. ABBREVIATIONS

A —Total area of room surfaces (sq ft) ($A_1 + A_2 + A_3 + \ldots A_n = A$)

d —Distance from the sound source center to the point of interest (ft).

dB —Decibels, unweighted scale.

dBA—Decibels, A-weighted scale.

$d_{(eff)}$—Effective distance from the sound source to the point of interest, allowing for reflective surfaces.

Lp —Sound pressure level (*dB*) (reference pressure is 0.0002 microbars or 0.0002 dynes/cm^2).

Lw —Sound power level (*dB*) (reference power is 10^{-12} watts).

R —Room constant (sq ft).

X —Point of interest for sound level determination.

α —Absorption coefficient of material of interest.

$\bar{\alpha}$ —Effective sound absorption coefficient of the room being considered.

ΔL —Sound level attenuation (*dB*).

* The NEMA "Standards Publication for Motors and Generators," MG 1, has for a number of years included sound levels for Design A, B and C alternating-current squirrel-cage induction motors, 1 through 250 horsepower, in terms of sound power levels as measured in accordance with the IEEE *Test Procedure for Airborne Sound Measurements on Rotating Electric Machinery*, Publication No. 85.

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III. DEFINITIONS OF TERMS

Absorption Coefficient (α)—The ratio of energy absorbed by a surface to the energy incident upon that surface.

Ambient Sound Pressure Level—The sound level existing in a room with all identified sources removed.

Anechoic (Free) Field—A room whose boundaries absorb effectively all sound incident thereon.

Attenuation (ΔL)—A reduction in sound pressure level in *dB*. It is a function of distance, room constant and location of the source with respect to reflecting and absorbing surfaces.

Machine—In this publication, a rotating electrical device. (In general, it is any sound source.)

Noise—Undesired sound.

Reflecting Surfaces—In this publication, all large surfaces of the room; i.e., walls, floor and ceiling. The indicated corrections to the effective distance for the nearness of major reflecting surfaces do not apply to the floor, unless the motor is at least 5 ft above the floor; such corrections have been incorporated in the curves.

Room Constant (R)—A number rating a room according to its size and the sound absorption properties of the enclosing surfaces.

Sound Power Level (Lw)—A measure of sound power (w) radiated from a source ratioed with a reference power of 10^{-12} watts.

$$Lw = 10Log_{10}\left(\frac{w}{10^{-12}}\right)$$

Sound Pressure Level (Lp)—A measure of the pressure (p) at a distance from the source ratioed with a reference pressure of 0.0002 microbars.

$$Lp = 20Log_{10}\left(\frac{p}{0.0002}\right)$$

IV. STEPS REQUIRED TO DETERMINE SOUND LEVELS*

* The paragraph identification used for each step corresponds to the related explanation in the subsequent text (see pages 3 through 10).

A. Define the problem (example included in text).

B. Measure or estimate the "room effect" in terms of the room constant determined by one of the following methods:
   1. Measured with a sound source of unspecified sound power level.
   2. Computed from architectural materials.
   3. Measured with a specified white sound source.

C. Determine the sound pressure level at a desired point due to each noise source. Using Figure 1, locate the room constant curve for the room constant being considered.
   1. If the machine is rated in sound power level, locate the site distance intercept with the R curve selected and read ΔL; then $Lp_{(R)} = Lw - \Delta L$.
   2. If the machine is rated in sound pressure level (Lp) at a specified distance in an anechoic or semianechoic chamber:
      a. Locate the specified distance intercept with curve $R = \infty$, and read ΔL (noted as $\Delta L_{(\infty)}$).
      b. Locate the site distance intercept with the R curve selected, and read ΔL (noted as $\Delta L_{(R)}$).
      c. Sound pressure level due to this source is given by:
      $$Lp_{(R)} = Lp + \Delta L_{(\infty)} - \Delta L_{(R)}$$
   3. If the machine is rated in sound pressure level (Lp) at a specified distance in a room having a room constant of R^1:
      a. Locate the specified distance intercept with curve R^1 and read ΔL (noted as $\Delta L_{(R^1)}$).
      b. Locate the site distance intercept with the R curve selected and read ΔL (noted as $\Delta L_{(R)}$).
      c. Sound pressure level due to this source is given by:
      $$Lp_{(R)} = Lp + \Delta L_{(R^1)} - \Delta L_{(R)}$$

D. Combine the sound pressure levels due to identified sources at the point of interest.

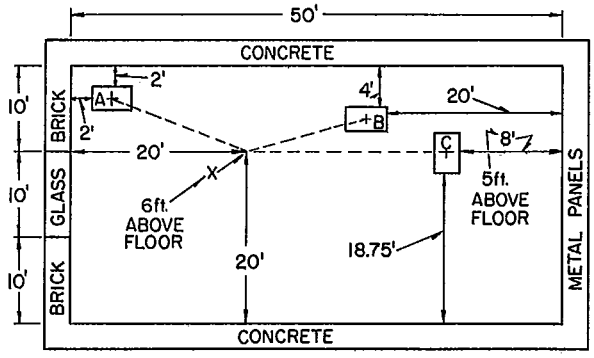
E. Consider the effect of the ambient sound pressure levels.

F. Concluding comments.

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A. DEFINING THE EXAMPLE USED IN THE TEXT.

Predict the sound pressure level at point *X*, 6 feet above the floor, due to three machines placed in a room whose dimensions and material are given.



FLOOR PLAN – TOP VIEW

Floor is of asphalt tile. Ceiling is of acoustical tile, 12 feet above the floor. Machines A and B are mounted on the floor; Machine C is mounted 5 feet above the floor. The ambient sound level of the room = 70 *dBA*.

The dimensions of the machines (supplied by the manufacturer) are:

	Dimensions, Ft		
Machine	Length	Width	Height
A	3	2	2
B	3	2.5	2
C	2.5	1.5	2

The machine sound levels (supplied by the manufacturer) are:

Machine A, sound power level..... 90 *dBA*
Machine B, sound pressure level at 3 ft (from a major machine surface*) $R = \infty$ ..... 85 *dBA*
Machine C, sound pressure level at 5 ft (from a major machine surface*) R = 2000 sq ft. 82 *dBA*

* Exclusive of terminal housing.

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B. ROOM CONSTANT

The use of a quantity known as "room constant" permits simple and realistic corrections for deviations from ideally anechoic conditions. Three alternative methods for determining the room constant are described, but only one need be used.

Strictly speaking, a room constant value should be obtained for each octave band center frequency. Use of the octave band method is recommended primarily if sound spectra of widely differing character are to be combined. The example, therefore, will be worked through first with overall sound levels as a first choice, and then with the octave band sound levels given in the Appendix.

1. *Measured with a Sound Source of Unspecified Sound Power Level*—The sound source is placed as near the center of the room as possible but not less than ¼ wavelength distance from a major reflecting surface for the lowest frequency considered. (Normally 125 Hz is the lowest center frequency to be considered; it corresponds to a minimum of approximately 3 ft.) The ¼ wavelength rule applies to all microphone positions; moreover, no microphone shall be closer to the sound source than a distance equal to the source length.

   Two sound pressure level readings are taken at different distances from the sound source on an approximately straight line passing through the center of the sound source. [See par. C(1) Sound Power Levels.] Distances are from the center of the source and not its surface. Preferably, the distance between the two microphone positions should be equal to the distance from the sound source center to the closer microphone. The difference in sound levels, the two distances involved, and the use of Figure 2 permit the determination of the room constant.

   Sound source is centrally located in the room.

   Sound pressure measured at 5 ft from the center of the source is 80.8 *dBA*. Sound pressure at 10 ft from the center of the machine is 78.2 *dBA*. Therefore, $\Delta L = 80.8 - 78.2 = 2.6$ *dBA*.

   Interpolating from Figure 2, room constant $R =$ ***940 sq ft.***

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2. *Computed from Architectural Materials*— This is done in four steps:

(a) Calculate the surface area (sq ft) of each of the enclosing surfaces in the room; i.e., walls, floor, ceiling, windows, etc.

	Area A (Sq Ft)	Effective Absorption Coefficient α (Table 1)	$A\alpha$
Floor—asphalt tile.....	30′ × 50′ = 1500	0.03	45
Ceiling—acoustical tile.....	30′ × 50′ = 1500	0.42	630
Plate glass wall..	10′ × 12′ = 120	0.04	5
Brick wall.....	2″ × 10′ × 12′ = 240	0.02	5
Concrete wall...	2″ × 50′ × 12′ = 1200	0.07	84
Metal panels....	30′ × 12′ = 360	0.03	11
	ΣA = 4920	$\Sigma A\alpha$ =	780

(b) Find the effective sound absorption coefficient for each of the major surfaces in Table 1. In the event that the material is not covered in the table but that the absorption coefficient can be found elsewhere, it may be expressed as a function of frequency; i.e., center frequency octave bands. In this event, take the average of the 250-Hz, 500-Hz, 1-kHz and 2-kHz absorption coefficients to get the effective absorption coefficient.

NOTE—For simplicity, consideration has not been given to the effect of doorways and similar openings. Usually such openings will increase the room constant but will cause no appreciable change in the noise level.

$$\bar{\alpha} = \frac{\Sigma A\alpha}{\Sigma A} = \frac{780}{4920} = 0.16$$

Therefore, room constant R =

$$\frac{A\bar{\alpha}}{1 - \bar{\alpha}} = \frac{4920 \times 0.16}{1 - 0.16} = 937 \text{ sq ft}$$

(c) Calculate the average sound absorption coefficient for the room:

$$\bar{\alpha} = \frac{A_1\alpha_1 + A_2\alpha_2 + A_3\alpha_3 + \ldots + A_n\alpha_n}{A_1 + A_2 + A_3 + \ldots + A_n}$$

$\bar{\alpha}$ = average sound absorption coefficient of room

$A_1, A_2, A_3 \ldots A_n$ = surface area of each major surface area (sq ft)

$\alpha_1, \alpha_2, \alpha_3 \ldots \alpha_n$ = absorption coefficient for each of the major surface areas.

(d) Calculate the room constant:

$$R = \frac{A\bar{\alpha}}{1 - \bar{\alpha}}$$

R = room constant (sq ft)

$A = A_1 + A_2 + A_3 + \ldots + A_n$

$\bar{\alpha}$ = average room sound absorption coefficient.

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3. *Measured with a Specified White Sound Source*—This method requires the use of a specified white sound source* whose sound power level (*Lw*) is known. If the octave band analysis method is used, the octave band levels must also be known. The specified sound source is placed in the room near the expected location of the machine, with the ambient sound level as low as possible. If there is less than a 10 *dB* difference between the sound generated and the ambient sound, the measured sound level must be corrected using Figure 3.

Care must be taken that the microphone is not placed too close to the walls or major reflecting surfaces. The microphone should be no less than ¼ of the largest wavelength of interest from any wall. Normally 125 Hz is the lowest center frequency to be considered; it corresponds to a minimum of approximately 3 ft. Since improper calibration can affect acoustic measurements by several *dB*, care should be taken to assure the desired accuracy of the measuring instruments used.

The distance of the microphone from the sound source and the attenuation for that distance (i.e., the sound pressure level measured subtracted from the sound power level of the specified sound source) are known. The intercepts of these two lines in Figure 1 will give the value of the room constant by interpolation.

*A sound whose spectrum is continuous and uniform as a function of frequency.

The specified sound source has a sound power level of 90 *dBA*. The microphone is placed 10 ft from the specified sound source and measures a sound pressure level of 78.8 *dBA*.

The difference between the sound source level and the ambient sound level = 78.8 − 70 = 8.8 *dBA*.

The correction from Figure 3 = 0.6 *dB*.

The corrected sound level = 78.8 − 0.6 = 78.2 *dBA*.

$\Delta L = 90 - 78.2 = 11.8$ *dBA*.

Referring to Figure 1, the intersection of ΔL = *11.8 dBA* and the distance from the sound source of 10 ft gives a room constant ***R = 940 sq ft.***

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C. SOUND PRESSURE LEVEL AT A DESIRED POINT DUE TO EACH SOUND SOURCE

Sound levels of machines are commonly reported in one of two ways:

(1) *Sound power levels.* It is assumed by the machine manufacturer in determining the sound power level (*Lw*) that the sound originates at a point source located at the center of the machine at its base (from IEEE Publication No. 85). In determining the distance from the sound source to the point of interest (*d*), it is necessary to consider the dimensions of the machine itself.

(2) *Sound pressure levels* at a specified distance from the surface of the machine.

A sound pressure level reported at a specified distance is not really complete unless the room constant of the room in which it was measured is also reported. If the room constant is not specified, it may be assumed that the room constant is infinity. However, to explain the method, an example is included for Machine C with the room constant as a finite number.

In addition, the nearness (less than 5 ft) of major reflecting surfaces to sound sources must be considered as well as the magnitude of the absorption coefficient (α) of the reflector. If α of reflectors in the immediate vicinity of the machines is greater than 0.5, no other corrections to the distance are required ($d_{(eff)} = d$). However, if α is less than 0.5, the following corrections to the distance have to be made:

Number of Reflecting Surfaces Within 5 Ft of the Sound Source	Typical Configuration of Reflecting Surfaces	$d_{(eff)}$
None	Suspended or supported	$d\sqrt{2}$
One	Floor, wall or ceiling	d
Two	Two adjacent surfaces or two opposite surfaces	$d/\sqrt{2}$
Three	Corner of floor or ceiling	$d/2$

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1. *Machine Rated in Sound Power Level (Lw)*—Read ΔL at the intersection of the effective distance and the room constant curve in Figure 1. The sound pressure at the desired point due to the machine being considered is given by:

$$Lp_{(R)} = Lw - \Delta L_{(R)}$$

2. *Machine Rated in Sound Pressure Level (Lp) at a Specified Distance for a Room Constant of* $R = \infty$—Using Figure 1, locate the intercept of (a) the distance specified from the major surface of the machine plus one half the largest machine dimension and (b) the room constant $R = \infty$ curve, and read $\Delta L_{(R=\infty)}$. Using Figure 1, locate the intercepts of the effective distance, $d_{(eff)}$, from the sound source to the point of interest and of the room constant (R) curve under consideration, and read $\Delta L_{(R=R)}$.
The sound pressure level at the point of interest is:

$$Lp_{(R)} = Lp + \Delta L_{(R=\infty)} - \Delta L_{(R=R)}$$

3. *Machine Rated in Sound Pressure Level at a Specified Distance for a Room Constant of* $R = R^1$—Using Figure 1, locate the intercept of (a) the distance specified from the major surface of the machine plus one half the largest machine dimension and (b) the room constant $R = R^1$ curve, and read $\Delta L_{(R=R^1)}$.

Using Figure 1, locate the intercepts of the effective distance, $d_{(eff)}$, from the sound source to the point of interest and of the room constant (R) curve under consideration, and read $\Delta L_{(R=R)}$.
The sound pressure level at the point of interest is:

$$Lp_{(R)} = Lp + \Delta L_{(R=R^1)} - \Delta L_{(R=R)}$$

Machine A

Machine sound power level (Lw) = *90 dBA* (see par. A, page 3).

Room constant R = *940 sq ft* (see par. B, page 4).

d, distance from sound source in the machine to position $X = \sqrt{7^2 + 16.5^2 + 6^2} = 18.9$ *ft* in a corner less than 5 ft from the walls.

$d_{(eff)} = d/2 = 18.9/2 = 9.45$ *ft.*

From Figure 1, the intercept gives ΔL = *11.7 dB.*

The sound pressure at point X due to Machine A = *90 − 11.7 =* ***78.3 dBA.***

Machine B

Machine sound pressure level at 3 ft, in a room where the reference $R = \infty$, is *85 dBA.*

Actual room constant R = *940 sq ft.*

d, distance from sound source in the machine to position $X = \sqrt{4.75^2 + 8.5^2 + 6^2} = 11.4$ *ft* less than 5 ft from the wall.

$d_{(eff)} = d/\sqrt{2} = 11.4/\sqrt{2} = 8.1$ *ft*

From Figure 1 [using reference $d_{(eff)} = 3 + 1.5 =$ 4.5 ft and $R = \infty$] $\Delta L_{(R=\infty)} = 10.5$ *dB.*

From Figure 1 [using $d_{(eff)}$ = 8.1 ft and R = 940 sq ft] $\Delta L_{(R)} = 11.3$ *dB.*

Therefore, $Lp_{(R)} = Lp + \Delta L_{(R=\infty)} - \Delta L_{(R=940)} =$ *85 + 10.5 − 11.3 =* ***81.2 dBA.***

Machine C

Machine sound pressure level at 5 ft from the surface of the machine, in a room whose room constant R^1 = 2000 sq ft, is 82 *dBA.*

d, distance from the center point in the machine to point $X = \sqrt{21.25^2 + 1^2} = 21.3$ *ft.*

The machine is more than 5 ft from the walls and is suspended 5 ft above the floor. Therefore, $d_{(eff)} = \sqrt{2} \times d = \sqrt{2} \times 21.3 = 30.1$ *ft.*

From Figure 1 [using reference $d_{(eff)} = 5 + 1.25$ = 6.25 ft, and R = 2000 sq ft] $\Delta L_{(R=2000)} = 11.7$ *dB.*

From Figure 1 [using $d_{(eff)}$ = 30.1 ft and R = 940 sq ft] $\Delta L_{(R=R)} = 13.0$ *dB.*

Therefore, $Lp_{(R)} = Lp + \Delta L_{(R=2000)} - \Delta L_{(R=940)}$ *= 82 + 11.7 − 13.0 =* ***80.7 dBA.***

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D. COMBINING SOUND PRESSURE LEVELS AT A POINT DUE TO SEVERAL SOURCES

The separate sound pressure levels (*dBA*) at a point due to several sources are combined as follows:

1. Select any two of the levels to be combined and determine their difference.
2. Locate this difference in Column 1 of Figure 4 and note the corresponding value in Column 2.
3. Add the number from Column 2 to the higher of the two values being combined.
4. Determine the difference between this value and another of the levels to be combined (if more than two) and repeat steps 2 and 3.
5. Repeat step 4 until a single value is obtained.

Sound pressure level at *X* due to:

Machine A = 78.3 *dBA*
Machine B = 84.2 *dBA*
Machine C = 80.7 *dBA*

Combining sound pressure levels due to Machine A and Machine B, *84.2 − 78.3 = 5.9 dBA.*

Referring to Figure 4, locate 5.9 *dBA* in Column 1, read off 1.0 *dB* in Column 2, and add this result to the higher number of the two being combined, *84.2 + 1.0 = 85.2 dBA.*

Therefore, the combination of *84.2 dBA* and *78.3 dBA = 85.2 dBA.*

Now combine this result with the sound pressure level of Machine C, *85.2 − 80.7 = 4.5 dBA.*

Referring to Figure 4, locate 4.5 *dB* in Column 1, read off 1.3 *dBA* from Column 2, and add this result to the higher number of the two being combined, *85.2 + 1.3 = 86.5 dBA.*

Therefore, the combined sound pressure level of three machines (*78.3 dBA and 84.2 dBA and 80.7 dBA*) = ***86.5 dBA.***

E. THE EFFECT OF AMBIENT SOUND PRESSURE LEVEL

The foregoing result does not include the effect of the ambient sound pressure level which is the sound pressure level present in the room if all identifiable sound sources have been considered. Ambient sound may be produced by lighting fixtures in the room, air conditioning systems, water pipes, etc., but probably the largest portion will be from extraneous sources penetrating the walls and entering doors, windows, etc. The ambient sound is treated as though it is an additional sound source and should be combined with the combined sound pressure level calculated in par. D, using the same procedure.

Room ambient = 70 *dBA.*

Combined sound pressure level at point *X* due to the three machines = 86.5 *dBA.*

Room ambient sound pressure level at point *X* = 70.0 *dBA.*

Combining the two pressure levels, *86.5 − 70.0 = 16.5 dBA.*

Referring to Figure 4, 16.5 *dBA* exceeds Column 1.

The effect of the ambient, in this instance, is negligible. Thus, the expected sound pressure level at point *X* remains at ***86.5 dBA.***

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F. CONCLUDING COMMENTS

For most purposes, the overall sound pressure level approximated in accordance with the foregoing will yield reasonable accuracy. The following is a partial list of factors which were not taken into consideration and which may have some effect on accuracy:

1. Source data is subject to some tolerance, depending upon the measuring instruments and their calibration and upon room conditions.

2. Operating conditions of the machine:
   (a) Variation of speed per se, as well as consequential changes in cooling air flow.
   (b) Load on the motor and its effect on magnetic and slot noises.
   (c) Variation of applied voltage which can affect noise generation (magnitude and harmonic content).
   (d) Mounting means and alignment.
   (e) Directional sound characteristics.
   (f) Pure tones (i.e., noise dominated by one particular frequency) which produce standing waves. Pure tones also influence the "quality of the sound" to the extent that a high pure tone content may be more objectionable to the ear than a higher sound level with a less pure tone content.

3. Some rooms are more complex than the example. For instance, they can contain partitions, pipes, openings, columns, people, desks, chairs, etc., all of which may change the room constant and may influence sound pressure levels. These factors should be considered on an individual basis and may have to be dealt with in light of past experience.

Since combined sound levels are affected by many factors, there is no substitute for experience in the use of the method described, especially if backed by experimental verification.

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Table 1
Sound Absorption Coefficients of General Architectural Materials

Architectural Material	Effective Absorption Coefficient (α)	Absorption Coefficient (α) Center Frequency, Hz 125	250	500	1000	2000	4000
Acoustical tile	0.42	0.13	0.30	0.33	0.39	0.63	0.70
Brick, unglazed	0.04	0.03	0.03	0.03	0.04	0.05	0.07
Brick, unglazed, painted	0.02	0.01	0.01	0.02	0.02	0.02	0.03
Concrete block, coarse	0.36	0.36	0.44	0.31	0.29	0.39	0.25
Concrete block, painted	0.07	0.29	0.10	0.05	0.04	0.07	0.09
Drape, heavy	0.65	0.24	0.40	0.61	0.79	0.79	0.73
Fiberglass, 1" thick, 2 lb/ft^3	0.75	0.10	0.51	0.63	0.94	0.91	0.87
Glass, large panes of heavy plate	0.04	0.18	0.06	0.04	0.03	0.02	0.02
Glass, ordinary window	0.16	0.35	0.25	0.18	0.12	0.01	0.04
Gypsum board	0.07	0.29	0.10	0.05	0.04	0.07	0.09
Linoleum, asphalt, rubber or cork tile on concrete	0.03	0.02	0.03	0.03	0.03	0.03	0.02
Metal panels	0.03	0.02	0.03	0.03	0.03	0.03	0.03
Wood	0.09	0.15	0.11	0.10	0.07	0.06	0.07
Wood parquet in asphalt on concrete	0.06	0.04	0.04	0.07	0.06	0.06	0.07

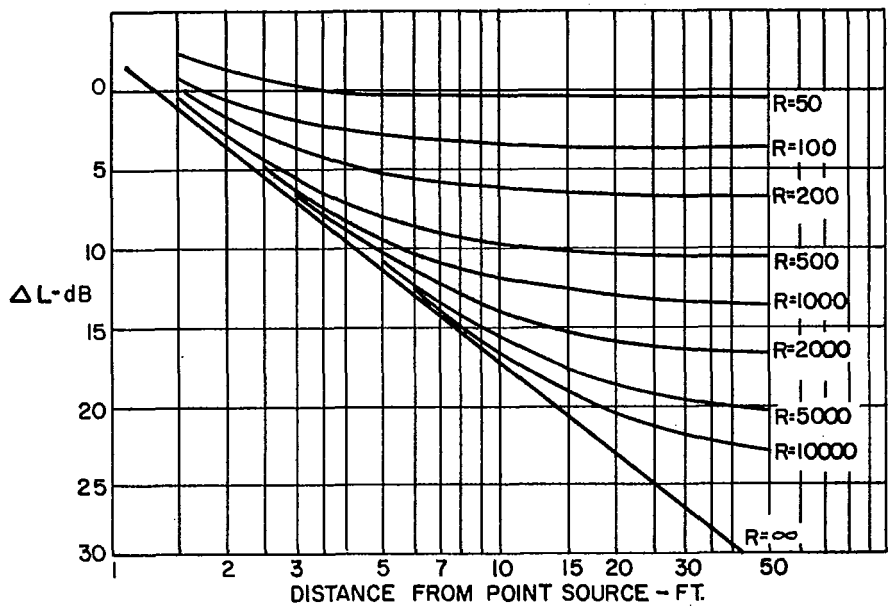


Figure 1
Attenuation of Sound Level (ΔL) as a Function of
Distance and Room Constant Over a Reflection Floor

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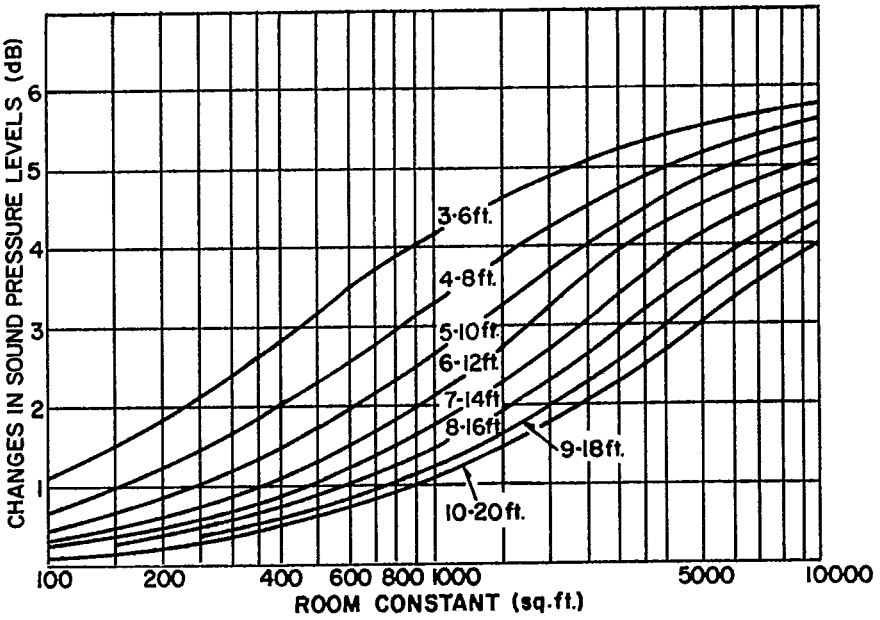


Figure 2
Estimation of Room Constant from Sound Pressure Level Measurements at Two Points

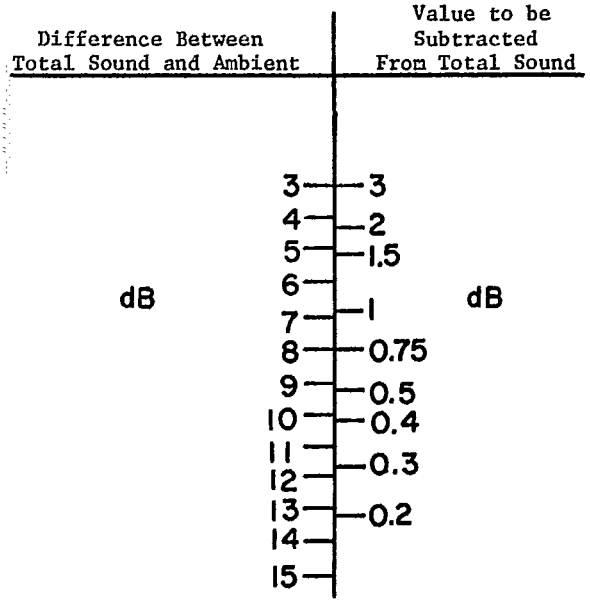


Figure 3
dB Adjustments for Ambient Correction

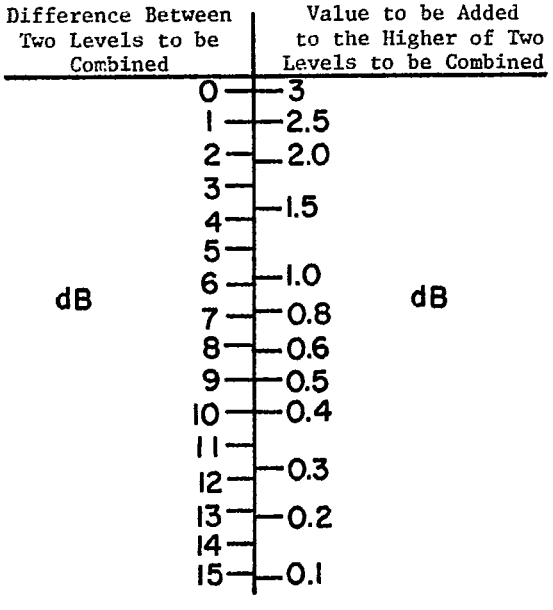


Figure 4
dB Adjustments for Combining Sound Sources

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APPENDIX
ADDITIONAL DATA REQUIRED WHEN USING OCTAVE BAND CENTER FREQUENCIES TO DETERMINE SOUND PRESSURE LEVELS

	Octave Band Center Frequency, Hz						Overall
	125	250	500	1000	2000	4000	*dBA*
I. MACHINE SOUND LEVELS							
Machine A, Lw	82	87	88	85	83	77	90
Machine B, Lp at 3 ft from major machine surface, $R \rightarrow \infty$	67	75	80	80	79	75	85
Machine C, Lp at 5 ft from major machine surface	76	77	80	77	73	67	82
Ambient noise level of room, *dB*	80	70	65	65	60	55	70
Reference room constant, R, for Machine C	500	800	1660	3560	3560	4320	2000
II. TO FIND ROOM CONSTANT FOR EACH OCTAVE BAND CENTER FREQUENCY							
A. Measured With a Sound Source of Unspecified Sound Power Level							
$Lp_{(R)}$ measured 5 ft from center of source	75.6	75.4	75.4	75.0	74.1	74.0	
$Lp_{(R)}$ measured 10 ft from center of source	73.5	73.2	73.2	72.6	70.9	70.6	
$\Delta L = Lp_{(R_5)} - Lp_{(R_{10})}$	2.1	2.2	2.2	2.4	3.2	3.4	
Room constant, R, from Figure 2	650	720	720	830	1430	1630	
B. Computed from Architectural Materials							Area A, Sq Ft
$A\alpha$ in sq ft							
Floor, asphalt tile	30	45	45	45	45	30	1500
Ceiling, acoustical tile	195	450	495	585	960	1050	1500
Plate glass wall	22	7	5	4	2	2	120
Brick walls	2	2	5	5	5	7	240
Concrete walls	348	120	60	48	84	108	1200
Metal panels	7	11	11	11	11	11	360
Σ	604	635	621	698	1107	1208	4920
$\bar{\alpha} = \Sigma A\alpha / \Sigma A$	0.12	0.13	0.13	0.14	0.23	0.25	
Room constant, $R = A\bar{\alpha}/1 - \alpha$	630	690	690	800	1470	1640	
C. Measured with a Specified White Sound Source							
Specified sound source levels, Lw, in *dB*	84	84	84	84	84	84	
$Lp_{(R)}$ measured at 10 ft from the source	73.5	73.2	73.2	72.7	70.8	70.6	
$\Delta L = Lw - Lp_{(R)}$	10.5	10.8	10.8	11.3	13.2	13.4	
Room constant, R, from Figure 1	630	690	690	800	1470	1640	
III. SOUND PRESSURE LEVEL AT A DESIRED POINT DUE TO EACH SOUND SOURCE							
A. Machine Rated in Sound Power (Lw)							
Machine A, Lw	82	87	88	85	82	77	
Room constant	630	690	690	800	1470	1640	
ΔL from Figure 1 when $d_{(eff)} = 9.45$ ft	10.4	10.7	10.7	11.2	13.0	13.2	
$Lp = Lw - \Delta L_{(R)}$	71.6	76.3	77.3	73.8	69.0	63.8	
B. Machine Rated in Sound Pressure Level (Lp) at a Specified Distance for a Room Constant of $R = \infty$							
Machine B, Lp at 3 ft from surface with $R = \infty$	67	75	80	80	89	75	
Reference $\Delta L_{(R=\infty)}$ when $d_{(eff)} = 4.25$ and $R = \infty$, From Figure 1	10.5	10.5	10.5	10.5	10.5	10.5	
Room constant, R, in sq ft	630	690	670	800	1470	1640	
$\Delta L_{(R=R)}$ when $d_{(eff)} = 8.1$, from Figure 1	10.1	10.3	10.3	10.8	12.4	12.6	
$Lp_{(R)} = Lp + \Delta L_{(R=\infty)} - \Delta L_{(R=R)}$	67.4	75.2	80.2	79.7	77.1	72.9	
C. Machine Rated in Sound Pressure Level at a Specified Distance for a Room Constant of $R = R^1$							
(It is necessary that the room constant for each of the octave band center frequencies be known for the original sound pressure level)							
Machine C, Lp at 5 ft from surface of machine	76	77	80	77	73	67	
Room constants for the reported levels	500	800	1600	3560	3560	4320	
$\Delta L_{(R=2000)}$ when $d = 6.25$, from Figure 1	8.7	8.9	11.4	12.3	12.3	12.5	
Room constant, R, in sq ft	630	690	690	800	1470	1640	
$\Delta L_{(R=R)}$ when $d_{(eff)} = 30.1$ ft, from Figure 1	11.4	11.7	11.7	12.4	14.9	15.3	
$Lp_{(R)} = Lp + \Delta L - \Delta L_{(R=R)}$	73.3	75.2	79.7	76.9	70.4	64.2	

(*Continued*)

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(Continued)

	Octave Band Center Frequency, Hz						Overall
	125	250	500	1000	2000	4000	*dBA*
IV. COMBINING SOUND PRESSURE LEVELS AT A POINT DUE TO SEVERAL SOURCES							
(The procedure is the same as that previously described in par. D, page 9, except that only values within the same octave band can be combined)							
Sound pressure level at *X* due to							
Machine A	71.6	76.3	77.3	73.8	69.0	63.8	
Machine B	67.4	75.2	80.2	79.7	77.1	72.9	
Machine C	73.3	75.2	79.7	76.9	70.4	64.2	
Result of combining all three levels using Figure 4	76.2	80.4	84.0	82.2	78.5	73.9	
V. THE EFFECT OF AMBIENT SOUND PRESSURE LEVEL							
(It is more than likely that at this point the overall sound pressure level on the A scale is required. It must be remembered that all of the octave levels are predicted on an unweighted basis; that is, there has been no attentuation as a function of frequency as is the characteristic for the A scale.)							
Resultant sound pressure level at *X* due to the sound source (Machines A, B and C)	76.2	80.4	84.0	82.2	78.5	73.9	
Ambient sound pressure level at *X*, *dBA*	80	70	65	65	60	55	
Resultant sound pressure level at *X* combined with ambient sound pressure level	81.5	80.8	84.1	82.3	78.6	74.0	
Corrections applied to octave levels to convert to equivalent A-scale values	−16.1	−8.6	−3.2	0.0	1.2	1.0	
Resultant sound pressure level at *X* in terms of the A scale	65.4	72.2	80.9	82.3	79.8	75.0	
Combining, using Figure 4:							

A. *A-Weighted*

65.4, 72.2 → 73.0; 80.9, 82.3 → 84.7; 73.0, 84.7 → 85.0; 79.8, 75.0 → 81.0; 85.0, 81.0 → 86.5 *dBA*

B. *Unweighted*

81.5, 80.8 → 84.2; 84.1, 82.3 → 86.3; 84.2, 86.3 → 88.4; 78.6, 74.0 → 79.9; 88.4, 79.9 → 89.0 *dB*

REFERENCES

1. IEEE *Test Procedure for Airborne Sound Measurements on Rotating Electric Machinery*, Publication No. 85.
2. *Handbook of Noise Measurement*, General Radio Company.
3. *Handbook of Noise Control*, by Cyril M. Harris, McGraw-Hill Book Company.
4. *Noise Reduction*, edited by Leo L. Beranek, McGraw-Hill Book Company.
5. NEMA *Standards Publication for Motors and Generators*, Publication No. MG 1

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