FAN ENGINEERING

AEROVENT
INDUSTRIAL VENTILATION SYSTEMS

Information and Recommendations for the Engineer FE-300

Fan Sound & Sound Ratings

Introduction

Small, repetitive pressure disturbances imparted to the air are an unavoidable by-product of the process of moving air. These pressure fluctuations rapidly propagate through the air (at approximately 1100 ft./sec.) to fill the surrounding media. When these pressure disturbances are sensed by a hearing mechanism (your ear), we have created sound. When the receiver of sound deems it undesirable, we call it noise. Another definition for noise is "an objectionable sound that other people make."

The phenomena of both sound and vibration are very similar and related. The term "sound" is used for air or other gas while "vibration" is used for a similar disturbance of motion in a solid. The sound pressure disturbance impacting on a solid can impart a vibration while the vibration of a solid can result in sound. Some prefer to call the concept of vibration which results in sound "structure borne noise."

There are two important characteristics associated with sound. One is amplitude and the other is frequency.

Sound Amplitude

Air at sea level has an ambient pressure of approximately 29.92 in. Hg. (or 407 inches of water). A pressure disturbance adds and subtracts from the ambient level in a repetitive manner. If the sound creates a pressure oscillation up to 408 inches of water, then down to 406, back to 408, etc., we call this a peak amplitude of 1 inch of water since it deviates by one inch about the mean pressure. A loud turbo-pressure blower can achieve pressure oscillations near this amplitude.

The world of sound begins at much lower amplitudes. It is possible for the human ear to sense peak amplitudes as low as .0000001 inch of water or 100-billionth of an inch of water. The maximum achievable amplitude is one atmosphere (or 407 inches of water).

To deal with numbers which vary so widely in magnitude, science has developed some special techniques. For sound pressure amplitudes, this is what is done:

1. Establish a reference level at the pressure where sound begins P_{REF} = 20 micro Pascals.
2. Establish the RMS sound pressure level = P_{RMS}. (For typical sound pressures the RMS level is about 71% of the peak amplitude.)
3. Find the sound pressure level (in decibels) by using the following formula:

   Sound Pressure = $L_P = 10 \text{ LOG}_{10} (P_{RMS} / P_{REF})^2$ (in dB)

One of the difficulties of using this form of amplitude is that it is a very localized value. If we move a couple of feet and remeasure the pressure, we may get an entirely different value. This makes it impractical as a means of establishing sound ratings for fans. To get around this problem, a different technique is required. By combining all of the pressures emanating from the fan in all directions, we can establish the total amount of energy being dissipated as sound. By knowing this amplitude (as well as the frequency to be discussed later), the sound power output level can be determined.

Sound power levels are ideal for creating sound ratings since they are independent of environment. The common analogy used is to compare sound power levels with the "watt" rating of a light bulb. Using a lamp with a 100-watt bulb does not tell you how much light will hit the paper you wish to illuminate since this depends on many variables. However, knowing the characteristics of the reflector, the distance from the light bulb to the paper, the reflectance of the walls, etc., one skilled in the art can make a pretty accurate estimate. Therefore, using published fan sound power levels and the appropriate environmental considerations, the sound power level can yield an estimate of the sound pressure level at any location.

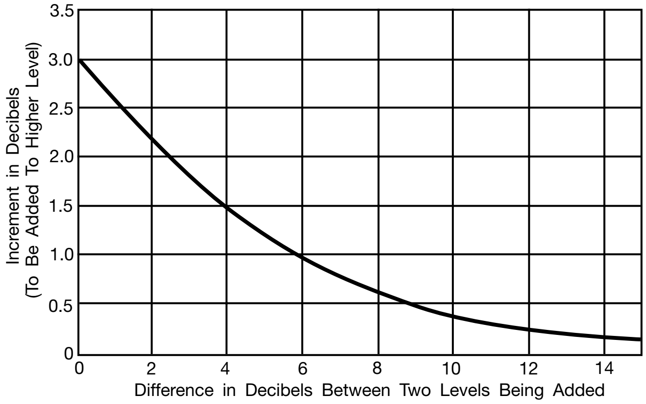
Since sound power levels cover a wide range of amplitudes, the decibel concept is appropriate. For power, a reference level of 10^{-12} watts is used. Therefore, sound power level =

$$L_W = 10 \text{ LOG}_{10} (\text{Sound Power} / 10^{-12} \text{ watts}) \text{ dB}$$

Using this relationship, a fan rated at a sound power of 130 dB is approximately equivalent in power to a 100 watt light bulb.

When adding two noise sources to obtain a combined effect, it is common to logarithmically add their power. This yields a level 3 dB higher when two equal sources are combined. This works for all practical devices; however, one of the new methods of noise reduction involves the addition of two equal sound sources set up so that they cancel each other out. For most situations, use Figure 1 for addition of amplitudes.

Figure 1. Chart For Combining Decibels



Sound Frequency

The other major characteristic of sound is its frequency. Frequency, measured in Hertz (Hz), is the number of pressure peaks per second that a sound exhibits. The human ear is only sensitive to frequencies between 20 and 20,000 Hz, so this is the entire sound spectrum. For fans, only frequencies between 45 and 11,000 Hz are of interest.

Sound at different frequencies behaves differently, and the human ear responds differently to different frequencies of sound (see Figure 2). For this reason the frequency characteristic of noise ratings is used. Audible sound is divided into eight octave bands. Starting at 63 Hz, each succeeding octave band has a center frequency twice the previous band (see Figure 3). Electrical filters were devised so that frequencies within the desired octave band would pass through while others were blocked. When combined with a microphone and some metering circuitry, the original sound octave band analyzer was constructed.

This method for separating frequencies is an acceptable technique according to AMCA sound test codes. Other methods of separating noise by frequency are also in use today.

Figure 2. Threshold of Hearing for Young Adults with Normal Hearing

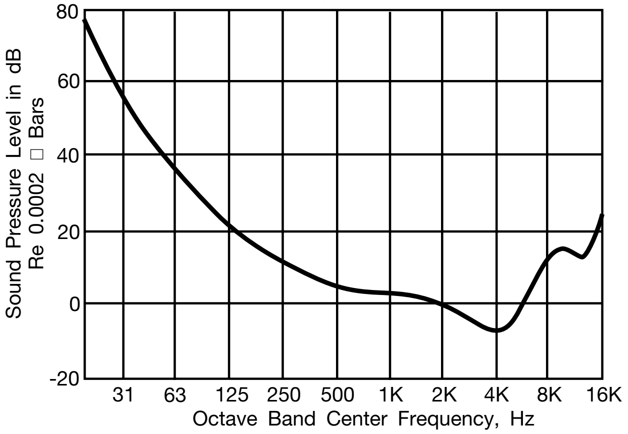


Figure 3. Octave Band Frequencies

OCTAVE BANDS	1	2	3	4	5	6	7	8
FREQUENCY RANGE	45 to 90	90 to 180	180 to 355	355 to 70	710 to 1400	1400 to 2800	2800 to 4600	5600 to 11200
CENTER FREQUENCY	63	125	250	500	1000	2000	4000	8000

Sound Power vs. Sound Pressure

Except for one item we now have the tools in place for establishing sound ratings. We want to rate fans using sound power levels; however, we can only measure sound pressure levels directly. In the early sixties fan engineers devised an accurate method for converting between the two. With some minor changes, it is still in use today. In concept, here is how it works:

1. Calibrate a small noise source which generates relatively high amplitudes at all frequencies of interest. This can be done at a nationally accepted laboratory at low cost. A small, unhoused forward curved fan wheel is suitable for this. The laboratory will measure sound power levels accurate to within one dB.
2. Run the noise source in the room where the fan is to be tested and measure the resulting sound pressure. The difference between the noise source sound power and the measured sound pressure identifies the room characteristic.
3. Run the test fan and measure the sound pressure.
4. Calculate the test fan sound power using the measured sound pressure and the room characteristics obtained in Step 2.
5. Repeat Step 4 for various test RPMs and system resistances and establish base tables.
6. Use established mathematical techniques for extrapolating to other operating points, RPMs, and fan sizes, and generate complete sound ratings.

AMCA Test Code 300 was established on this basis. It was decided to confirm the code by testing the same fan at various test laboratories. The results were very different in the first and second octave band but were within five dB at higher frequencies. AMCA decided to publish the code and allow the manufacturer to add to the tested ratings a value sufficient to ensure that the fan sound would not exceed the rating by the tolerance allowed.

Since the test code remains essentially unchanged, we believe that there are still significant test errors. We estimate that errors of 6 to 8 dB are present in the first octave band while errors of 3 to 4 dB are present in the higher frequencies. This makes it difficult to compare sound ratings since a fan with a sound rating of 8 dB higher than another in the first band may well produce an identical sound level.

In addition, the testing configuration can vary the results by a substantial degree. Therefore, a manufacturer may knowingly (or unknowingly) test a fan in the most favorable (or unfavorable) condition. In essence, with current state of the art, there are uncontrolled variables that have an effect on the sound power levels.

Using Sound Ratings

The object of all the effort that goes into generating noise ratings is to help predict, “Will this fan create a noise problem?” This is a complex question which involves many factors. This paper will only scratch the surface in order to present some of the concepts involved.

The first step is to try to establish what the definition of the “problem” is in the customer’s eyes. For some, the answer is: “A fan which exceeds 85 dBA at 5 feet from the fan.” For others it may be “. . . exceeds 65 dBA at 200 feet from the fan.” There are numerous conditions which may create a problem; but, most often, a problem is defined in terms of dBA level.

What is a “dBA”?

Early sound researchers observed that the human ear was more sensitive to certain frequencies than others. For example, it was observed that a sound amplitude of 80 dB at 1000 Hz was judged (subjectively) to be the same amplitude as a sound of 100 dB at 100 Hz. An A-weighting correction curve was devised to adjust for this condition. By weighting the sound in this manner, a more accurate determination of when “a sound becomes a noise” can be made.

For practical purposes, an A-weighted correction factor is added to each octave band as follows:

Band #	1	2	3	4	5	6	7	8
Correction	–26	–16	–9	–3	0	+1	+1	–1

Although there are other weighting factors which are more appropriate to higher noise levels, they generally are not used.

The individual frequency components may then be combined (logarithmically) to obtain the single dBA value. Since we are often making quick estimates of dBA from our published sound power levels, we also provide an LwA value. The LwA is like an intermediate step in a sound pressure calculation but one which eliminates much of the work. We add the A-weighting correction factor to each of our eight sound power levels, then combine using Figure 1.

What is a "Sone"?

A sone is another unit that takes into account the subjective nature of sound. The sone adjusts both the frequencies and amplitudes to arrive at a "loudness" value.

A 10 dB increase in sound pressure is typically perceived as twice as loud and will have a sone value twice as high. This means it would take twelve equal noise sources in common to be perceived as "twice as loud," not two as you might think.

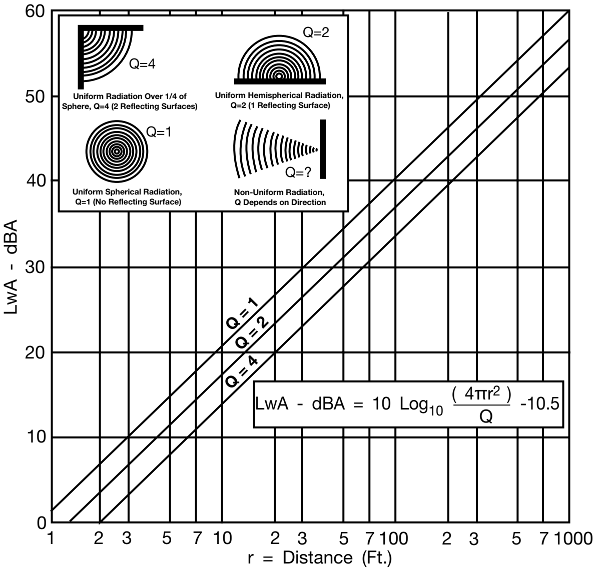
Sones are calculated using sound pressure values (not power levels). To calculate sones, first calculate the sound pressure level for each sound power level based on the conditions specified. Then for each octave band, use Figure 8 to obtain the sone value. The loudness in sones equals the largest of the eight values plus 0.3 times the sum of the other seven sone values.

Free Field vs. Reverberant Field

Noise generated without any walls or reflected surfaces nearby radiates in a spherical manner. Since approximately the same amount of sound energy is dispersed over a larger area, the pressure amplitude decreases at increasing distance. Every doubling of distance results in a 6 dB decrease.

If we add reflective surfaces, the pressure decrease may still decline at this rate especially very near the source. Any configuration for which the pressure decreases by 6 dB for each doubling of distance is called a "free field" condition.

Figure 4. Free Field Sound Reduction vs. Distance



In a room there are multiple reflecting surfaces. The pressure will cease to decrease significantly as you move beyond a certain distance. This area of relatively constant sound pressure is called the "reverberant field."

Directivity

If you listen to a speaker directly in front of it, you will likely say it is louder than at the same distance behind it. Fans also will radiate different sounds at different locations around the fan despite being the same distance away. This is one aspect of directivity. Since this effect is difficult to measure, it typically is not dealt with in sound ratings for fans.

Hard surfaces near the fan also affect the directivity and are included in many noise estimates. The assumptions usually made are that all of the sound reflects, and that each additional wall doubles the pressure (adds 3 dB). The directivity is usually assigned to a variable named "Q" and takes on the following values:

Q = 1	No reflecting surfaces
Q = 2	One wall (or floor)
Q = 4	Two walls (or floor and one wall)
Q = 8	Three walls (located in a corner)

When comparing sound estimates from different sources, verify that they are based on the same "Q". The same fan will be 3 dB louder with "Q = 2" vs. "Q = 1".

Estimating Sound Pressure From Sound Power

This process is far more complex than is appropriate to this document. However, one equation will be given with a discussion to identify the complexities of sound:

$$L_P = L_W + 10\ \mathrm{LOG}_{10}\ [(Q / 4\pi r^2) + 4 / R] + 10.5$$

Where:

L_P = Sound pressure
L_W = Sound power
Q = Directivity factor
r = Radius in feet from source
S = Surface area
R = Room const. = $S\bar{\alpha} \div 1 - \bar{\alpha}$
$\bar{\alpha}$ = Average Sabine absorption coefficient

The radius square term in the denominator means that this term will decrease in importance rapidly as one moves away from the fan. But for distances close to the fan, the pressure will decrease by 6 dB for each doubling of the distance. This is the free field condition.

Figure 4 can be used to estimate the sound pressure for fans outside or wherever the free field condition is met.

At some distance the term 4/R dominates. If S is small (small rooms) the value of 4/R is large and the difference between the value of sound pressure and sound power may become very small. Simply put, if you install a fan in a small room with hard walls (typical of many equipment rooms), the sound pressure (dBA) will just about be equal to the sound power (LwA) for almost all locations in the room.

The term α is dependent on both the materials of construction of the wall, floors, etc., as well as the frequency. Values vary from near zero (for hard materials) to almost one (for acoustical tile). Rating charts are available for numerous materials (Figure 5).

For estimation purposes, a value of 0.2 is commonly used for all frequencies. Figure 6 shows a typical plot for establishing the value of [$L_W - L_P$].

dBA Sound Pressure Levels Are Not Guaranteed

In 1998 AMCA published an article on "Fan Sound" as a supplement to the *ASHRAE Journal*. One of the subheadings was titled "Never Ask For a dBA Fan Rating." The point of the article was that similar to a light bulb, sound output is published in power (watts). From the previous discussion, the conversion from sound power to sound pressure is complex and enviromentally dependent. We don't ask the light bulb manufacturer to guarantee how much light reaches our paper, and likewise the fan manufacturer cannot guarantee the "dBA" sound pressure levels that will be measured on site. The job of making accurate estimates of "dBA" from the sound power ratings is one for sound consultants.

Noise Problems

There are two types of noise problems — those that we anticipate from our sound ratings and those emanating from some abnormal condition in the fan. Some of the more common sources of abnormal or unanticipated noise are:

1. Fan wheel unbalance.
2. Resonance of fan or attached components.
3. Rotating components rubbing on stationary parts.
4. Failing, misaligned, or contaminated bearings (on the fan or on the motor).
5. Air leakage. This can allow sound leakage and also generate a whistle-type noise.
6. Belts slipping.
7. Coupling misalignment.
8. Motor noise, especially with improper power supply. Inverter drives may increase motor noise at certain speeds.
9. Air turbulence.
10. Operation in surge.
11. Loose components.
12. High velocity air blowing over fixed components which are not part of the fan.

Although difficult to find, the solution to these problems is often obvious.

The other class of noise problems are those we have anticipated because of normal fan sound ratings. Some cures for these problems are:

1. Select a different fan. Computerized selection routines allow us to examine many fan types looking for the quietest. Use a custom fan design, if required.
2. Relocate the fan to where sound is not a problem.
3. Vibration isolation and flexible connectors on the inlet and discharge will reduce structure-borne noise.
4. Insulate or acoustically enclose the fan housing if housing radiated noise is a problem.
5. Add silencers or duct lining to inlet and/or discharge to reduce sound in these directions. However, a silencer on the outlet does not reduce the housing radiated noise or inlet noise; and an inlet silencer does not affect the housing radiated and/or outlet noise.
6. Look for ways to reduce system resistance since sound output is proportional to fan static pressure.

One final tip which can help to avoid noise problems is to select lower RPM fans. Fans exceeding 3000 RPM are much more likely to tune in to an attached structure resulting in structure borne noise. Structure borne noise easily propagates an entire system and can become a problem at many locations. Also, people tend to become more annoyed with higher frequencies than with lower, increasing the likelihood of a noise problem.

The Future of Sound and Sound Ratings

At the time of this writing, several changes are developing in the technology of fan noise. Some of these are:

1. The latest codes define testing for fan inlet noise, fan outlet noise and noise radiating from the housing (or casing). The inlet noise can no longer be assumed to apply to the outlet and vice-versa.
2. A new test code which uses sound intensity is near adaption. In theory, integrating a series of measured sound intensities over an enclosed area yields the sound power directly.
3. Sound criteria is playing an ever more important role in the selection process. Many fans are insulated for sound or use other sound reduction apparatus.
4. Active noise cancellation continues to be difficult to apply to most fan installations. If it ever proves practical, this technique can cancel fan noise by adding a second pressure wave out of phase with the original.
5. Many more fan specifications are requiring AMCA sound certification. Certified sound ratings mean that AMCA has verified that the ratings are generated in accordance with the codes and that at least one sample has been tested in the AMCA Laboratory to verify the ratings.

Figure 5. Sound Absorption Coefficients of General Building Materials and Furnishings $\bar{\alpha}$

MATERIAL		OCTAVE BAND CENTER FREQUENCY, HZ					
		125	250	500	1000	2000	4000
Brick, Unglazed		0.03	0.03	0.03	0.04	0.05	0.07
Brick, Unglazed, Painted		0.01	0.01	0.02	0.02	0.02	0.03
Carpet, Heavy, On Concrete		0.02	0.06	0.14	0.37	0.60	0.65
Same, on 40 oz. Hairfelt or Foam Rubber		0.08	0.24	0.57	0.69	0.71	0.73
Same, with Impermeable Latex Backing on Hairfelt or Foam Rubber		0.08	0.27	0.39	0.34	0.48	0.63
Concrete Block, Coarse		0.36	0.44	0.31	0.29	0.39	0.25
Concrete Block, Painted		0.29	0.10	0.05	0.04	0.07	0.09
Fabrics	Light Velour, 10 oz. per sq. yd., hung straight, in contact with wall	0.03	0.04	0.11	0.17	0.24	0.35
	Medium Velour, 10 oz. per sq. yd., draped to half area	0.07	0.31	0.49	0.75	0.70	0.60
	Heavy Velour, 10 oz. per sq. yd., draped to half area	0.14	0.35	0.55	0.72	0.70	0.65
Floors	Concrete or Terrazzo	0.01	0.01	0.02	0.02	0.02	0.02
	Linoleum, Asphalt, Rubber or Cork Tile on Concrete	0.02	0.03	0.03	0.03	0.03	0.02
	Wood	0.15	0.11	0.10	0.07	0.06	0.07
	Wood Parquet in Asphalt on Concrete	0.04	0.04	0.07	0.06	0.06	0.07
Glass	Large Panes of Heavy Plate Glass	0.18	0.06	0.04	0.03	0.02	0.02
	Ordinary Window Glass	0.35	0.25	0.18	0.12	0.07	0.04
Gypsum Board, 1/2 in.		0.29	0.10	0.05	0.04	0.07	0.09

Figure 6. Chart for Converting Sound Pressure Level Lp (in dB re 0.0002 microbar) into Power Level Lw (in dB re 10^{-12} watt)

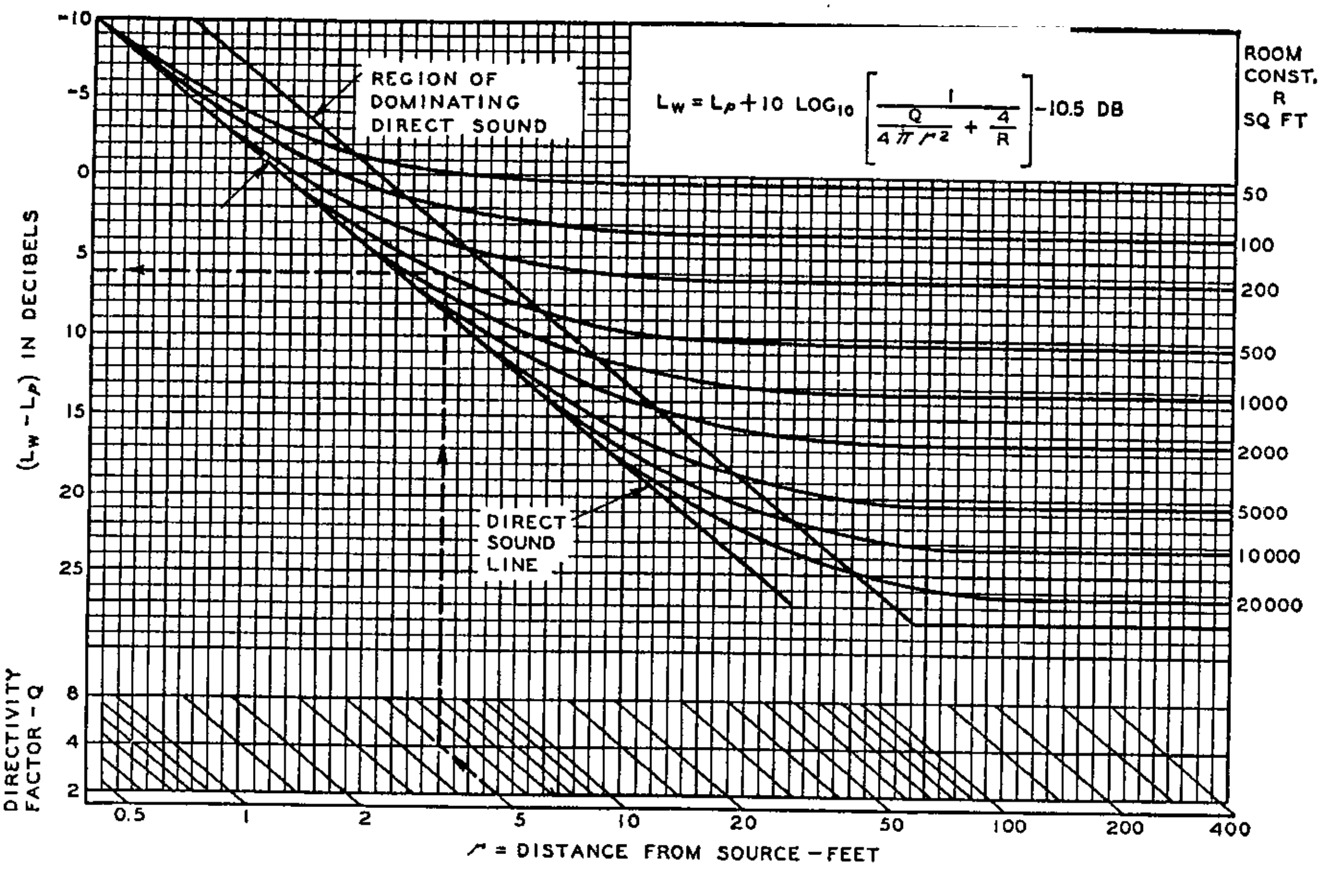


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Figure 7. Sound Level Chart

PRESSURE (MICROBAR)	PRESSURE LEVEL (dB)	SOURCE (LONG TIME AVERAGE)
200,000	180	ROCKET LAUNCH AT PAD (3 PSI)
2,000*	140	JET PLANE *APPROX. 1* H_2O
	130	THRESHOLD OF PAIN
200	120	THRESHOLD OF DISCOMFORT, LOUD BAND, RIVETING
	110	BLARING RADIO, AUTOMOBILE HORN
20	100	STEEL SAW
	90	PUNCH PRESS, AUTOMOBILE AT 40 MPH IN HEAVY CITY TRAFFIC
2	80	RELATIVELY QUIET FACTORY
	70	QUIET AUTOMOBILE, CONVERSATIONAL SPEECH
0.2	60	NOISY RESIDENCE (INSIDE)
	50	QUIET RESIDENCE (INSIDE)
0.02	30	QUIET WHISPER AT 5 FEET
0.002	20	ELECTRIC CLOCK
0.0002	0	THRESHOLD OF HEARING

Figure 8. Loudness Index S (ANSI S3.4-1980)

Lp	OCTAVE BAND							
	63	125	250	500	1000	2000	4000	8000
11								0.18
12							0.10	0.22
13							0.14	0.26
14							0.18	0.30
15						0.10	0.22	0.35
16						0.14	0.26	0.40
17						0.18	0.30	0.45
18					0.10	0.22	0.35	0.50
19					0.14	0.26	0.40	0.55
20					0.18	0.30	0.45	0.61
21					0.22	0.35	0.50	0.67
22					0.26	0.40	0.55	0.73
23				0.12	0.30	0.45	0.61	0.80
24				0.16	0.35	0.50	0.67	0.87
25				0.21	0.40	0.55	0.73	0.94
26				0.26	0.45	0.61	0.80	1.02
27				0.31	0.50	0.67	0.87	1.10
28				0.37	0.55	0.73	0.94	1.18
29			0.12	0.43	0.61	0.80	1.02	1.27
30			0.16	0.49	0.67	0.87	1.10	1.35
31			0.21	0.55	0.73	0.94	1.18	1.44
32			0.26	0.61	0.80	1.02	1.27	1.54
33			0.31	0.67	0.87	1.10	1.35	1.64
34			0.37	0.73	0.94	1.18	1.44	1.75
35		0.12	0.43	0.80	1.02	1.27	1.54	1.87
36		0.16	0.49	0.87	1.10	1.35	1.64	1.99
37		0.21	0.55	0.94	1.18	1.44	1.75	2.11
38		0.26	0.62	1.02	1.27	1.54	1.87	2.24
39		0.31	0.69	1.10	1.35	1.64	1.99	2.38
40		0.37	0.77	1.18	1.44	1.75	2.11	2.53
41	0.12	0.43	0.85	1.27	1.54	1.87	2.24	2.68
42	0.16	0.49	0.94	1.35	1.64	1.99	2.38	2.84
43	0.21	0.55	1.04	1.44	1.75	2.11	2.53	3.0
44	0.26	0.62	1.13	1.54	1.87	2.24	2.68	3.2
45	0.31	0.69	1.23	1.64	1.99	2.38	2.84	3.4
46	0.37	0.77	1.33	1.75	2.11	2.53	3.0	3.6
47	0.43	0.85	1.44	1.87	2.24	2.68	3.2	3.8
48	0.49	0.94	1.56	1.99	2.38	2.84	3.4	4.1
49	0.55	1.04	1.68	2.11	2.53	3.0	3.6	4.3
50	0.62	1.13	1.82	2.24	2.68	3.2	3.8	4.6
51	0.69	1.23	1.96	2.38	2.84	3.4	4.1	4.9
52	0.77	1.33	2.11	2.53	3.0	3.6	4.3	5.2
53	0.85	1.44	2.24	2.68	3.2	3.8	4.6	5.5
54	0.94	1.56	2.38	2.84	3.4	4.1	4.9	5.8
55	1.04	1.68	2.53	3.0	3.6	4.3	5.2	6.2
56	1.13	1.82	2.68	3.2	3.8	4.6	5.5	6.6
57	1.23	1.96	2.84	3.4	4.1	4.9	5.8	7.0
58	1.33	2.11	3.0	3.6	4.3	5.2	6.2	7.4
59	1.44	2.27	3.2	3.8	4.6	5.5	6.6	7.8
60	1.56	2.44	3.4	4.1	4.9	5.8	7.0	8.3
61	1.68	2.61	3.6	4.3	5.2	6.2	7.4	8.8
62	1.82	2.81	3.8	4.6	5.5	6.6	7.8	9.3
63	1.96	3.0	4.1	4.9	5.8	7.0	8.3	9.9
64	2.11	3.2	4.3	5.2	6.2	7.4	8.8	10.5
65	2.27	3.5	4.6	5.5	6.6	7.8	9.3	11.1

Lp	OCTAVE BAND							
	63	125	250	500	1000	2000	4000	8000
66	2.44	3.7	4.9	5.8	7.0	8.3	9.9	11.8
67	2.61	4.0	5.2	6.2	7.4	8.8	10.5	12.6
68	2.81	4.3	5.5	6.6	7.8	9.3	11.1	23.5
69	3.0	4.7	5.8	7.0	8.3	9.9	11.8	14.4
70	3.2	5.0	6.2	7.4	8.8	10.5	12.6	15.3
71	3.5	5.4	6.6	7.8	9.3	11.1	13.5	16.4
72	3.7	5.8	7.0	8.3	9.9	11.8	14.4	17.5
73	4.0	6.2	7.4	8.8	10.5	12.6	15.3	18.7
74	4.3	6.6	7.8	9.3	11.1	13.5	16.4	20.0
75	4.7	7.0	8.3	9.9	11.8	14.4	17.5	21.4
76	5.0	7.4	8.8	10.5	12.6	15.3	18.7	23.0
77	5.4	7.8	9.3	11.1	13.5	16.4	20.0	24.7
78	5.8	8.3	9.9	11.8	14.4	17.5	21.4	26.5
79	6.2	8.8	10.5	12.6	15.3	18.7	23.0	28.5
80	6.7	9.3	11.1	13.5	16.4	20.0	24.7	30.5
81	7.2	9.9	11.8	14.4	17.5	21.4	26.5	33.0
82	7.7	10.5	12.6	15.3	18.7	23.0	28.5	35.3
83	8.2	11.1	13.5	16.4	20.0	24.7	30.5	38
84	8.8	11.8	14.4	17.5	21.4	26.5	33.0	41
85	9.4	12.6	15.3	18.7	23.0	28.5	35.3	44
86	10.0	13.5	16.4	20.0	24.7	30.5	38	48
87	10.8	14.4	17.5	21.4	26.5	33.0	41	52
88	11.7	15.3	18.7	23.0	28.5	35.3	44	56
89	12.6	16.4	20.0	24.7	30.5	38	48	61
90	13.6	17.5	21.4	26.5	33.0	41	52	66
91	14.7	18.7	23.0	28.5	35.3	44	56	71
92	16.0	20.0	24.7	30.5	38	48	61	77
93	17.3	21.4	26.5	33.0	41	52	66	83
94	18.7	23.0	28.5	35.3	44	56	71	90
95	20.0	24.7	30.5	38	48	61	77	97
96	21.4	26.5	33.0	41	52	66	83	105
97	23.0	28.5	35.3	44	56	71	90	113
98	24.7	30.5	38	48	61	77	97	121
99	26.5	33.0	41	52	66	83	105	130
100	28.5	35.3	44	56	71	90	113	139
101	30.5	38	48	61	77	97	121	149
102	33.0	41	52	66	83	105	130	160
103	35.3	44	56	71	90	113	139	171
104	38	48	61	77	97	121	149	184
105	41	52	66	83	105	130	160	197
106	44	56	71	90	113	139	171	211
107	48	61	77	97	121	149	184	226
108	52	66	83	105	130	160	197	242
109	56	71	90	113	139	171	211	260
110	61	77	97	121	149	184	226	278
111	66	83	105	130	160	197	242	298
112	71	90	113	139	171	211	260	320
113	77	97	121	149	184	226	278	
114	83	105	130	160	197	242	298	
115	90	113	139	171	211	260	320	
116	97	121	149	184	226	278		
117	105	130	160	197	242	298		
118	113	139	171	211	260	320		
119	121	149	184	226	278			
120	130	160	197	242	298			

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