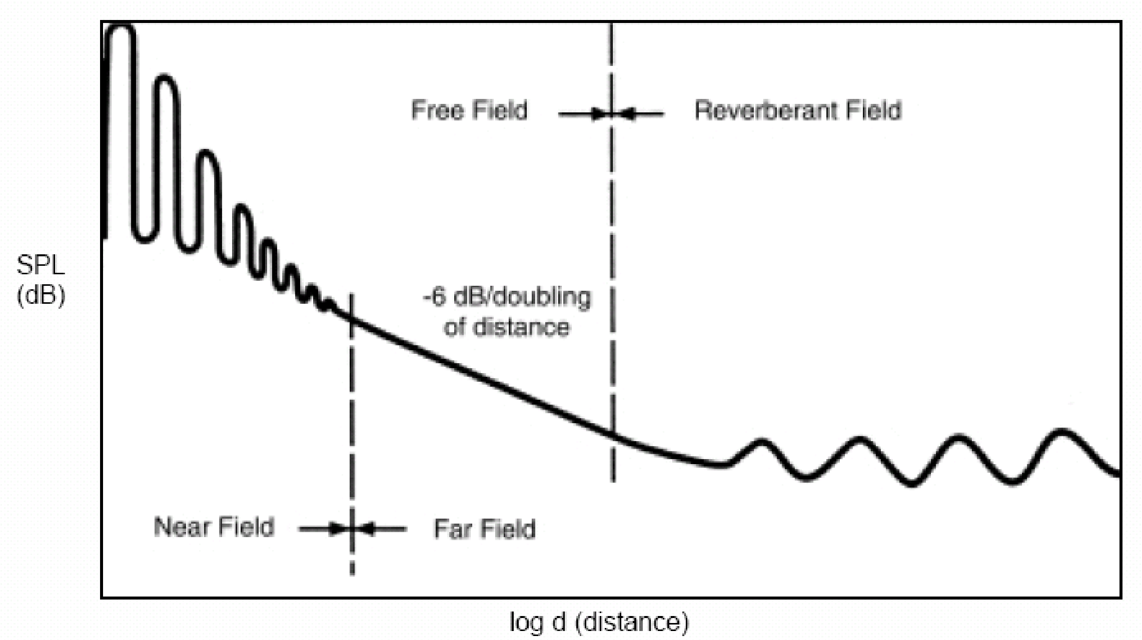
Technical Discussion

Defining Sound Fields

Near Field	The near field is the region close to a sound source usually defined as ¼ of the longest wave-length of the source. Near field noise levels are characterized by drastic fluctuations in levels as much as 10 dBA for small changes in distance from the source. Near field references can pertain to both indoor and outdoor environments.
Far Field	The far field describes a sound field beyond the near field limits described above where the sound pressure level (SPL) drops off at the theoretical rate of 6 dB fore very doubling of distance from the source. This rule of thumb is called the Inverse Square Law. Please note that if the far field does not meet the criteria for a free field as described below, then less than the theoretical drop rate will pertain. In such case doubling the distance from the source may yield a drop rate of 3-4 dB.
Free Field	To be considered free field there can be no obstructing surfaces in the sound path of spherical wave propagation. Free field conditions are characterized by SPL loss rates following the Inverse Square Law. Free field references pertain to large open outdoor spaces or in rooms where walls and other surfaces are almost completely absorptive. Anechoic (without echoes) acoustical test chambers simulate free field conditions where omnidirectional sound wave propagation exists.
Direct Field	The direct sound field is also used to describe far field conditions that follow the Inverse Square Law SPL loss rate of 6dB for every doubling of the distance. The actual formula used to make calculations at various distances in the far/direct field is as follows: SPL_1 [20x log (d2/d1)] = SPL_2 where SPL_1 is the noise level at the location closer to the source at a distance of d1 from the source and SPL_2 is the noise level at a location farther from the source at a distance of d2.
Diffuse Field	In a diffuse field there are so many reflections contributing to the total sound field that sound levels measured virtually anywhere in the sound field are the same. Diffuse fields usually pertain to indoor environments. Rooms that are categorized as “live” have larger diffuse fields than free fields. “Dead” rooms have much larger free fields than diffuse fields.
Reverberant Field	The reverberant field is essentially the same as the diffuse field. For indoor sound field discussions it is used to contrast direct fields. Reverberation test chambers have all room surfaces almost completely reflective so that total sound energy remains constant throughout the environment and sound levels can be measured independent of location and distance.

Please refer to the figure on the following page which shows the relationship between sound fields.

Sound Fields Relative To Distances From A Source



Community Reaction To Noise

Listed below are some of the key factors which can reduce the community tolerance level for noise in environmental applications.

- Where there are exceptionally low background ambient noise levels.
- A noticeable fluctuation in sound level which would call attention to the source.
- Pure tones or discrete frequency sounds regardless of the overall intensity.
- Elevated noise sources such as vents, stacks, outdoor cooling towers and other clearly visible noise sources.
- Any noises that disturb or interfere with sleep, communication or recreation.
- Intermittent, impulsive or startling noises.
- Low frequency sound which causes vibrations in windows, walls and other parts of building structures.
- Distracting noise sources, such as breaking of glass at a bottling plant.
- Any changes in noise patterns.

Technical Discussion

Predicting Community Reaction To Noise

1. Plot octave band sound pressure levels on Figure 3 at each frequency 63 Hz to 8000 Hz.
2. Determine the value of N where the plotted data intersects the highest curve.
3. Determine the sum total of all correction factors that apply as outlined in Figure 1. The sum equals value CF. These factors will influence the composite noise rating N1.
4. Calculate the composite noise rating N1 from the formula N1 = N – CF.
5. Refer to Figure 2 for predicted community response based on the calculated composite rating N1.
6. When dealing with sensitive community noise issues it may be necessary to contract the services of an acoustical consultant.

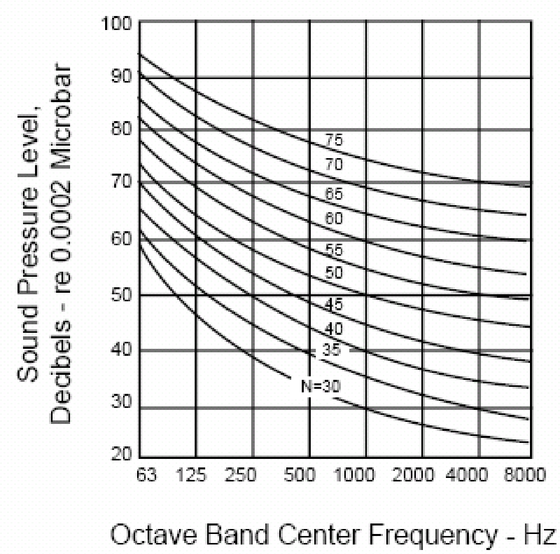
Figure 1

Influencing Factor	Possible Condition	Correction
Noise Spectrum	Pure tone components	-5
	Wide band noise	0
Repetitiveness	Continuous to one/min.	0
	10-60 times/hr.	+5
	1-10 times/hr.	+10
	4-20 times/day	+15
	1-4 times/day	+20
	1 time/day	+25
Time of Day	Daytime only	+10
	Evening	+5
	Nighttime	0
Season	Winter only	+5
	Winter and summer	0
Type of Area	Rural	-10
	Suburban	-5
	Residential (urban)	0
	Residential (some business)	+5
	Area of light industry	+10
	Area of heavy industry	+15
Peak Factor	Impulsive	-5
	Non-impulsive	0

Figure 2

N1	Community Response
Less than 40	No reaction
45	Sporadic complaints
50-55	Widespread complaints
60-65	Threats of community action
70 and above	Vigorous community action

Figure 3



Technical Discussion

Defining Environmental Noise Descriptions

Ambient Level — Noise levels characterized by all sounds in the area including the noise source of interest that is being evaluated.

Background Level — Noise level of all sounds in the area except the noise source of interest that is being evaluated.

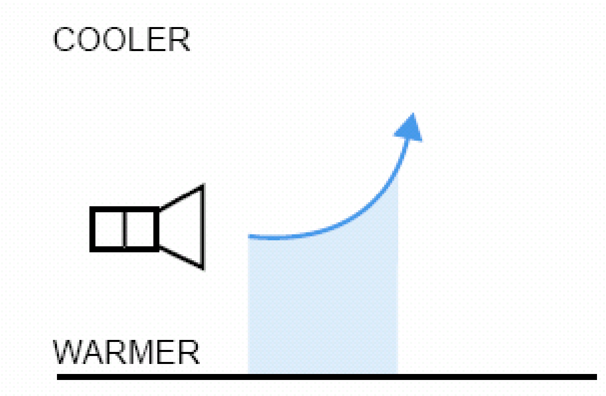
L_{eq} — An energy average continuous equivalent sound level. L_{eq} is the SPL decibel value representing the sum total sound energy of all measured fluctuations for the source applied uniformly over the time period in question. $L_{eq(24)}$ denotes for example a 24 hour measurement period.

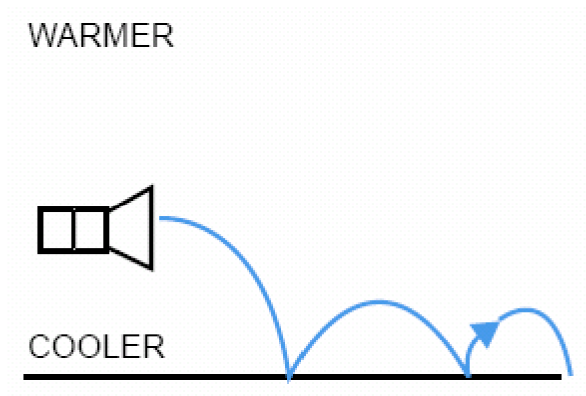
L_{dn} — The A-weighted day-night equivalent sound level L_{dn} is defined as a continuous 24 hour L_{eq} with 10 dBA added to all signals recorded between the hours of 10:00 p.m. and 7:00 a.m. The 10 dBA weighting accounts for the heightened noise sensitivity of people during night sleeping hours.

L_n — The L_n descriptor is a percentile level where "n" is a number between 0 and 100 corresponding to the percentage of the sampling time period by which the specified sound level value has been exceeded. For example, L_{10} = 60 dBA denotes that SPL measurements exceeded 60 dBA for 10% of the time during the sampling period.

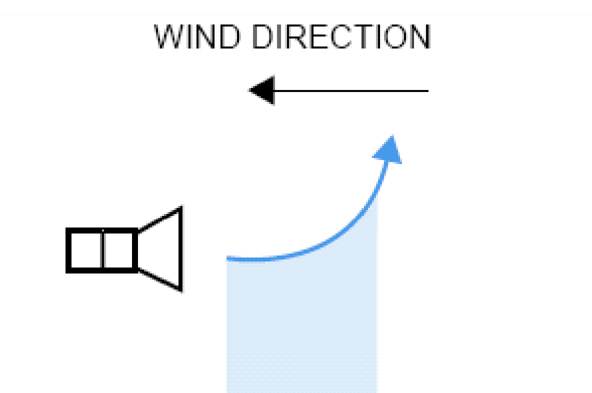
All Environmental Noise Descriptors are dBA Weighted.

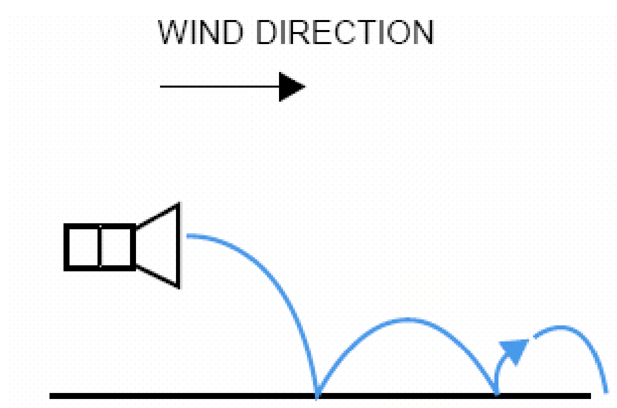
Sound Propagation Outdoors





Sound propagation is affected by changes in atmospheric conditions. Temperature variations will influence sound wave propagation in the direction of cooler air. Above left shows the shadow zone created as sound waves bend toward cooler air at higher altitudes. When this occurs, a noise source may be visible at a distance but quieter than expected. The other extreme shown above right occurs when air is cooler closer to the ground such as at night or over calm ground. If the ground surface is reflective, sound waves will continue to bounce and hop, traveling much farther than otherwise expected.





Wind directions and currents also affect sound propagation outdoors. Noise sources emitting sound in the direction of wind travel (downwind) will tend to propagate farther than expected as shown above right. Conversely, sound emitting in the direction against the wind (upwind) will travel less than expected because of the shadow zone created as illustrated above left. This phenomenon when combined with temperature fluctuations can explain the common occurrence of aircraft noise fading in and out of hearing range while the plane is moving toward the listener.

Predicting Outdoor Sound Levels

Outdoor sound transmission is determined by three categories of natural effects. These are distance effects, atmospheric effects and terrain/vegetation effects. Each natural effect influences the propagation of sound/noise along a different transmission path. The combined distance effects impact the direct path transmission which is where most of the energy flows. Terrain and vegetation effects influence the ground reflected sound transmission path. Typical attenuation values are listed in the table below (right). The refraction or bending (up or down) of sound waves is the third outdoor transmission path variable where natural atmospheric effects such as air temperature, speed, direction, humidity and density alter sound levels at greater distances. Atmospheric effects which include rain, snow and other forms of precipitation are normally short term effects that occur in outdoor sound propagation and measurement.

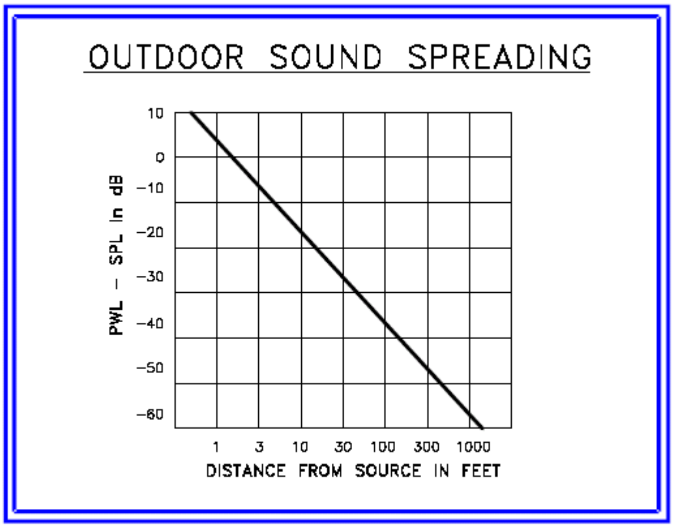
Combined Distance Effects

Combined distance effects include the natural attenuation or drop-off rate for hemispherical radiation of sound outdoors (in accordance with the inverse square law) plus some influence from molecular absorption and anomalous excess attenuation. Page 41 describes the inverse square law in more detail. Molecular absorption is the sound energy absorbed by the air molecules for specific conditions of temperature and relative humidity. Anomalous excess attenuation is the attenuation provided by changes or fluctuations in atmospheric conditions in a manner described in the paragraph above but on a smaller scale. The table below (left) lists the molecular absorption and anomalous excess attenuation values in dB for the frequency bands from 63 to 8000 Hz.

Octave Frequency Band, Hz	Anomalous Excess Attenuation, dB/1000 ft (dB/300 m)	Molecular Absorption in dB/1000 ft. at 59°F and 70% humidity
63	0.4	0.1
125	0.6	0.2
250	0.8	0.4
500	1.1	0.7
1000	1.5	1.5
2000	2.2	3.0
4000	3.0	7.6
8000	4.0	13.7

Octave Frequency Band, Hz	dB per 100 ft over or through Tall Thick Grass or Shrubbery	dB per 100 ft over or through Medium-dense Woods
63	0.3	1.2
125	2.1	1.5
250	3.7	1.8
500	5.5	2.4
1000	7.0	3.1
2000	8.5	4.0
4000	10.4	4.9
8000	11.9	6.1

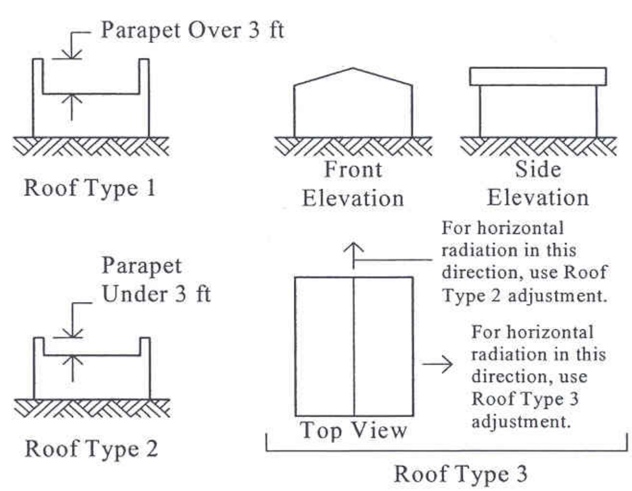
Simplified Method For Converting Sound Power (PWL) and Sound Pressure (SPL) Levels



The graph at left can be used to determine the SPL value at a given distance when the equipment PWL level is known. For example, with a point noise source of know PWL level (90 dB) you can calculate the SPL level at a distance of 30' as follows. Follow the bottom axis of the table out to a distance of 30'. Follow up to the diagonal line and then horizontally across to the left axis which is a PWL- SPL value of 27 dB. Subtract the 27 dB from the original 90 dB PWL to find a corrected SPL value of 63 dB at 30'. Converting from sound pressure (SPL) to sound power (PWL) can be done in a similar manner. The graph can also be used to find the SPL level of a point source at another distance if we know the SPL at a given distance. In the above example we calculated the SPL level at 30' based on an equipment PWL value of 90 dB. We can recalculate the SPL level at another distance such as 100'. To do this find the difference in the PWL-SPL values at 30' (-27 dB) and 100' (-36 dB). The difference (9 dB) is subtracted from the SPL value at the 30' distance. The SPL level at 100' for this example is 63 dB – 9 dB = 54 dB.

Roof-Radiated Sound Reduction Values for Various Roof Types

Octave Frequency Band, Hz	Horizontal Reductions in dB		
	Type 1	**Type 2**	**Type 3**
31	3	2	1
63	5	4	3
125	7	5	4
250	10	8	6
500	12	9	7
1000	15	12	8
2000	18	14	9
4000	20	16	10
8000	22	18	12



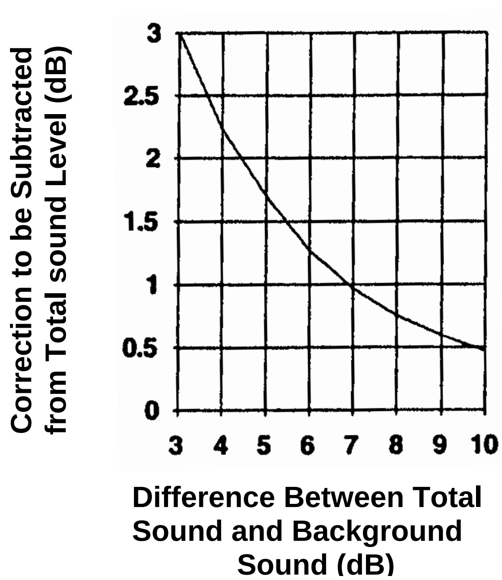
Technical Discussion

Sound Level Corrections to Account for Background Noise Contribution

Equipment Noise
<u>+ Background Noise</u>
= Total Noise

Decibel subtraction can be used to estimate equipment noise when background noise contribution cannot be isolated. Noise measurements are taken with all equipment on. A second noise measurement is taken with the machine in question turned off. The difference in these two levels (total noise – background noise) is used with the figure shown below to determine the correction factor in decibels (dB). The correction factor is subtracted from the total noise level to estimate the machinery noise independent of background contribution. An example calculation is shown below. Reliable corrections cannot be made when total and background levels differ by less than 3 dB.

DECIBEL SUBTRACTION EXAMPLE



Equipment Noise
<u>+ Background Noise</u>
= Total Noise

Total Noise Measured by Sound Meter = 62 dBA

Sound Level with Equipment Turned Off (Background Sound) = 58 dBA

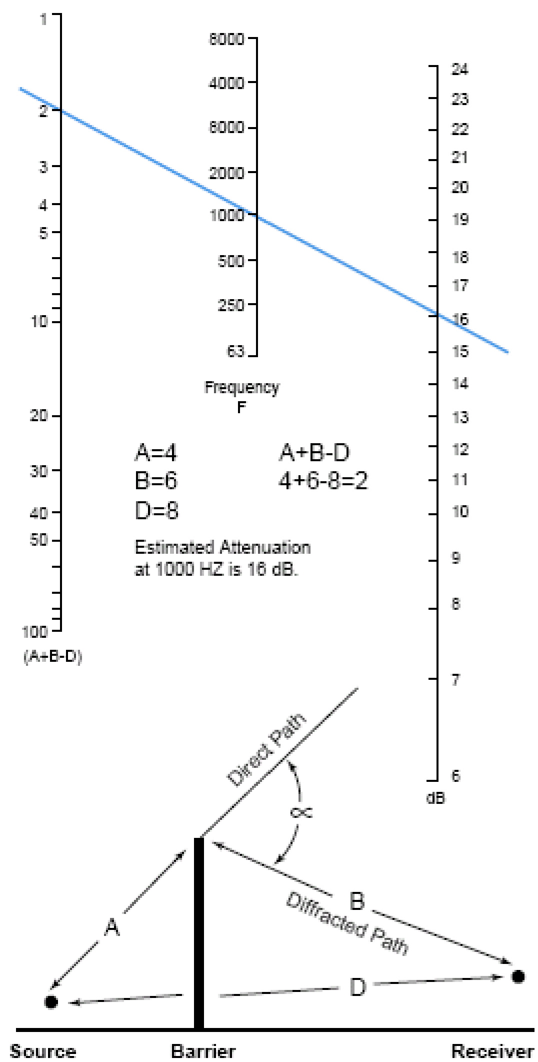
Difference = 4 dBA

From Chart: Subtract 2 dBA
Equipment Noise = 60 dBA

Technical Discussion

Predicting Acoustical Barrier Wall Performance

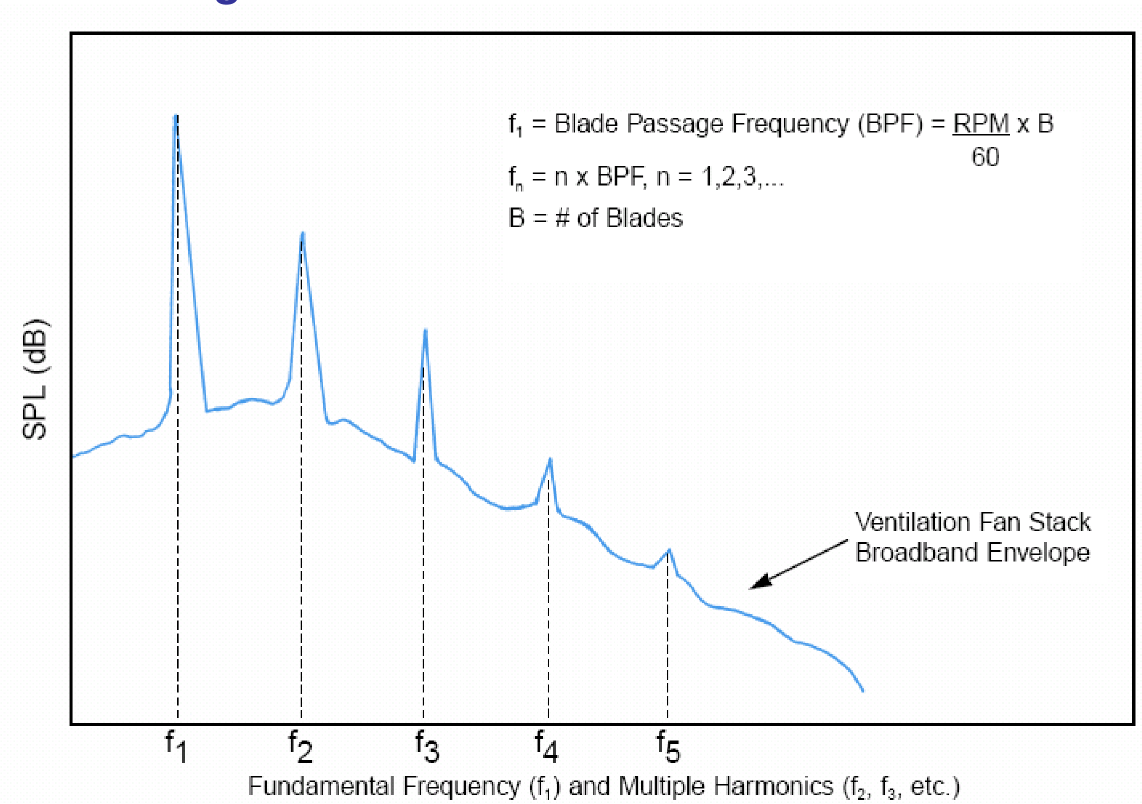
The nomogram at right can be used to describe acoustical barrier sound attenuation. Transmission loss or sound blocking through a freestanding partition or barrier wall will be determined in part by the acoustical properties of the barrier. The second factor affecting barrier wall performance is spillover noise following the diffracted path as illustrated in the figure at right. Sound waves will have a tendency to bend or diffract over the top and around the sides of a barrier wall especially in the lower frequencies. In the higher frequencies sound waves diffract less and are much more directional in nature. The shielding effect of the acoustical barrier and resultant noise shadow area beyond it are determined by the geometric relationship between the source, the receiver and the barrier height.



How To Use The Nomogram

In the figure at right, distances A, B and D should be determined as follows. Distance A is from the point noise source (not the height) of the equipment to the top of the acoustical barrier. Distance B is from the top of the barrier to the receiver position (figure ear/head level). Distance D is from the source to the receiver (straight line). In the example at right the path length difference (A+B-D) equals 2 ft. Plotting a straight line from the path length difference through the frequency of noise in question on line F (1000 Hz) intersects the dB line at 16 in the example. Thus the estimated attenuation for this application would be 16 dB. Please note that the nomogram does not take into consideration the contribution from reflective surfaces. To be conservative in applications where reflective surfaces are present it is recommended that the final dB figure be discounted 20% to 25%. As the angle (□) between the direct and diffracted paths increases, so does the noise reduction.

Treating Pure Tones And Fundamental Harmonics



The above example plotted for an induced fan air system shows a frequency spectrum with spikes at the fan fundamental or blade passage frequency and decreasing spikes at each harmonic or whole number multiple. Most types of rotating equipment such as compressors, engines, blowers and fans generate these pure tone spikes that are elevated above the other frequencies. The tones and harmonics are related to the rotational speed of the equipment and the number of blades, lobes or other driving components. In the example above, the fan tone is a function of the RPM divided by 60 times the number of blades on the fan wheel. For applications such as co-generation (boiler induced draft), dust collectors, scrubber systems, incinerators, etc. the ventilation fan generates its fundamental tone in the 100 to 300 Hz frequency range. This low frequency noise warrants special treatment with tuned silencer designs. Standard packed silencers provide overall A scale reductions but can miss the offending fan tone which is usually the source of neighborhood complaints in the first place.