Desk Reference to NOISE DESCRIPTORS

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Objective

Sound is considered noise when it is "unwanted". There are different opinions on whether a particular sound is noise based on some description of the sound's characteristics, including whether the sound is appropriate for the circumstances. A number of noise descriptors have been developed because of the difficulty in fitting an objective sound description with a subjective determination of the wantedness of the sound. This paper will outline the descriptors and categorize them according to their use.

Noise can be described in many ways - from laymen's onomatopoetic words, like "hiss", "rat-a-tat", "boom", "kachunk", "bang", "ring", "purr" - to technical terms like "a pure-tone sound of 1000 Hz, at 80 dB, for 3 seconds." This paper will show the appropriate descriptor for the circumstance.

The use of the data will determine the proper noise descriptor. The same source of sound can be measured by different techniques and described in different terms. For example, suppose the source is an air compressor. To compare this air compressor with others, the sound power level would be useful. To enforce a community regulation on air compressors, the maximum sound pressure level (A-weighted) would be used, but circumstances would be considered such as time of day, length of operation, and proximity to the nearest residence. If a survey on the noise characteristics of the area were to be done, the compressor noise might be measured with a time weighted average like Equivalent Sound Level (Leq) or Day-Night Sound Level (Ldn). In a trend analysis, the noise would be described in terms of people affected. The descriptor might be the number of people affected by an Leq greater than 60 dB in 1977 versus the number in 1982. The subjective response of people to compressor noise could be measured in noys. All of these techniques are used to describe the same sound.

One descriptor cannot be used in all of these instances because sources vary in frequency, intensity, temporal characteristics, and spacial variation. Receivers vary in their subjective response to the sound source. Circumstances vary. There are descriptors for each combination of source, receiver and circumstance. This paper will group the descriptors by use categories.

Some descriptors will be in many categories; some will be specific . Where possible, an equation will be given to allow for approximate conversions between descriptors. The paper should allow persons in the field of noise control to analyze use of the noise data, and then select the correct descriptor for the source, situation, and the receiver.

Fundamentals of Sound

Sound is created when an object is set into vibratory motion. The molecules in an elastic medium surrounding the object are set in motion producing a sound wave which is the oscillation of the molecules in the medium. Sound is heard when the characteristics of the wave fall within the sensitivity limits of the human ear. For sound to be heard, a source, medium, and receiver are all necessary. For this paper, the medium will be air; the receiver, human.

Sound is a result of oscillations in pressure, particle displacement, and particle velocity in the air between the source and the ear. An object in motion bumps the air molecules surrounding it, disturbing them and pushing them closer together. This can be seen as an instantaneous increase in pressure or compression. The molecules react by trying to return to their original position, but they overshoot, causing an instantaneous decrease in pressure called rarefaction. The sound wave is propagated away from the source by successive collisions of air molecules, causing successive compressions and rarefactions, on the way to the receiver. It is the sound energy and not the air molecules that travel from the source through the air.

A. Intensity

a. Sound Pressure Level

The increase or decrease in pressure caused by sound is small in comparison with ambient or atmospheric pressure. Normal atmospheric pressure can be expressed as 1 bar. Pressure changes created by sound are expressed in microbars (ubar) or 1/1,000,000 of a bar. The normal human ear is sensitive to a range from 0.0002 ubars to 2000 ubars. Because of the size of the scale, logarithms are used. Intensity is expressed as a ratio of the actual change in pressure to the smallest pressure that the human ear can sense.

Sound waves consist of alternating positive and negative pressures with respect to atmospheric pressure. The mean value is zero. To express average sound pressure, a root-mean-square is used. The values of the sound pressures are squared and averaged over a certain time period. The square root of the average is found.

The formula for expressing the sound pressure level in decibels is:

dB SPL = 20 log P/Pref

Where: P is the root-mean-square pressure of the sound
P ref is the reference pressure, 0.0002 ubars, roughly equivalent to the threshold of hearing. This reference can also be expressed as 20 micro pascals, 0.00002 newtons/square meter or 0.0002 dynes/sq cm.

Figure 1 relates the common sounds in everyday life to their sound pressure levels in decibels and sound pressure in ubars.

b. Sound Power Level

Another way to describe the intensity of sound is by sound power. Instrumentation is not available to measure the sound power directly, but it can be calculated from sound pressure level measurements. the sound power is the amount of energy passing through a unit area. the reference for acoustic power is in watts/cm^2. Thus, the formula for expressing sound power levels is:

dB IL = 10 log W/Wref

where: W/Wref = (P/Pref)^2

W is the power output of the source in watts/cm^2
Wref is the reference power of 10^-16 watts/cm^2

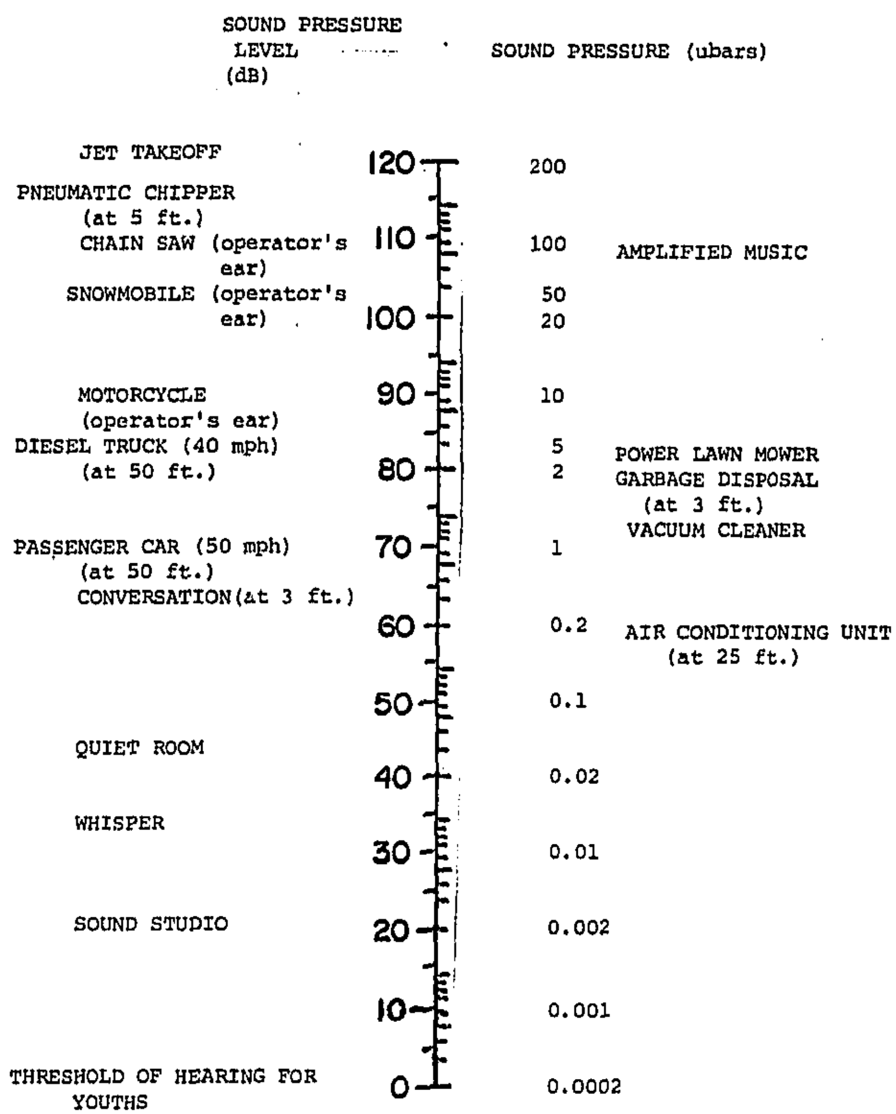
IL stands for intensity level. Sound Power Level can also be expressed as PWL (dB) or LW (dB), when using watts/cm^2 as the reference.

B. Frequency, Velocity, Wavelength

Frequency is defined as the number of complete pressure variations, (compression and rarefaction) or cycles, per second. The unit for expressing frequency is cycles per second or Hertz (Hz). If a sound source vibrates 50 times a second, it produces a sound with a frequency of 50 cycles per second or 50 Hz.

The human ear is sensitive to frequencies from 20 to 20,000 Hz. However, sounds of equal sound pressure

Figure 1: Relationship of Common Sounds to their Sound Pressure Levels and Sound Pressure



levels but different frequencies are not perceived with equal loudness. The ear is most sensitive to sounds between 1000 and 4000 Hz.

The distance between two successive compressions or two successive rarefactions is called the wavelength.

The speed of sound in air is dependent on temperature. At room temperature (21 degrees C) the velocity of sound in air is 344 meters/sec (1128 ft/sec). The relationship between the speed of sound and temperatures normally encountered in community noise situations is (22):

$$c = 1087.42 + 1.99t \quad \text{ft/sec}$$

$$c = 1052.03 + 1.106F \quad \text{ft/sec}$$

$$c = 331.45 + .607t \quad \text{cm/sec}$$

where: c = velocity of sound
t = temperature in degrees centigrade
F = temperature in degrees fahrenheit.

Frequency (f), velocity (c) and wavelength (lambda) are related by the formula:

$$c = f(\text{lambda})$$

Table I relates frequency to wavelength.

Table I: Relationship of Frequency to Wavelength
(c = 344 m/sec or 1128 ft/sec)
(Temperature = 21°C)

Frequency (Hz)	Wavelength (m)	Wavelength (ft)
25	13.76	45.13
100	3.44	11.28
200	1.72	5.64
400	0.86	2.82
800	0.43	1.41
1000	0.34	1.12
2000	0.17	0.55
4000	0.08	0.26
8000	0.04	0.13
10,000	0.03	0.09
16,000	0.02	0.06
20,000	0.017	0.05

Health Effects of Noise

A. Hearing Measurements

a. Hearing Level

The human ear perceives different frequencies of equal sound pressure level with different loudness levels. The decibel hearing level (dB HL) uses the sensitivity of the average human ear with no otological history, normallized for aging, at various frequencies as its reference. It can be related to dB SPL at specific frequencies. Prior to 1964, different countries had their own standards for normal hearing. The 1951 standards of the American Standards Association (ASA) are shown in Table II. The American and British standards differed by over 10 dB. In 1964 the International Standards Organization (ISO) issued a recommended standard based on threshold experiments by American, British, French, Russian and West German laboratories. In 1969, the American National Standards Institute (ANSI) gave its specification for audiometers in S.3.6-1969. Clinical audiometers are more commonly equipped with Telephonics TDH-39 earphones which differ slightly from ANSI. These values are shown in Table II.

b. Minimum Audible Pressure, Minimum Audible Field

To describe the sound intensity necessary for a normal hearing person (with no otological history) to just detect the presence of a sound stimulus, two methods of measurement are used. One involves testing the individual through earphones to yield minimum audible pressure (MAP). The other approach involves seating the individual in the sound field and presenting the stimulus through loudspeakers, yielding minimum audible field (MAF) thresholds. The values chosen represent a measure of the central tendencies of a group of normal hearing subjects. MAP and MAF yield different values. The MAF curve consistently falls below the MAP curve, showing that hearing thresholds are lower when both ears are used in the sound field.

Upper limits of hearing have also been established. They are referred to as the threshold of feeling, tickle, touch, tolerance, or pain. Uncomfortable loudness occurs with sound pressure levels of more than

Table II: Standard Reference Levels for OdB HL reference: dB SPL

Frequency (Hz)	ASA 1951(1)	ISO 1964(1)	ANSI S3.6 1969(2)	Telephonics TDH-39 (3)
125	54.5	45.5	45.5	45.0
250	39.6	24.5	24.5	25.5
500	24.8	11.0	11.0	11.5
1000	16.7	6.5	6.5	7.0
2000	17.0	8.5	8.5	9.0
3000			7.5	10.0
4000	15.1	9.0	9.0	9.5
6000			8.0	15.5
8000	21.0	9.5	9.5	13.0

100 dB for the normal hearing population. Lower levels can be uncomfortable to people exhibiting the phenomenon of recuritment.

Figure 2 shows the MAP and MAF thresholds, and the upper limits of hearing for the normal hearing population.

c. Compensation Formulae

One of the normal consequences of aging is hearing loss. The term "presbycusis" is used to describe the gradual hearing loss associated with advancing age. However, a study of primitive tribesmen in Africa who had no exposure to noise, did not show any appreciable hearing loss as they got older(4). The term "sociocusis" was suggested by Glorig (5) to describe the gradual loss of hearing due to noise exposure as well as aging.

A sudden loss of hearing due to noise is called "acoustic trauma". It can be caused by a single loud blast or explosion. The tympanic membrane can be ruptured, the ossicles displaced, or the hair cells in the cochlea can be damaged. The gradual loss of hearing due to noise exposure is called "noise-induced hearing loss", and is characterized by damage to the hair cells in the cochlea. In its beginning stages it is reversible damage, and the hair cells can recover after a period of rest in a quiet environment. During this stage, when the hair cells have not been destroyed by noise but merely fatigued, the hearing loss is known as a temporary threshold shift (TTS). Repeated noise exposures resulting in repeated TTS will eventually damage the hair cells permanently. This loss of hearing is so gradual that the affected individual probably will not notice a change in hearing. The first evidence of damage occurs in frequencies above the speech range, so the individual will not be aware of any difficulty in communication, in good listening conditions. In poor listening conditions where there may be other noise, competing speech, or reverberation, speech will seem garbled as if the speaker were not enunciating clearly.

A typical progression for a noise-induced hearing loss is shown in Figure 3. After one year of exposure to noise above 90 dBA, the loss is only at 4000Hz. In 5 - 9 years, the notch widens but the greatest dip is at 30 dB HL at 4000Hz. It is only after 35 - 39 years that the loss influences the speech frequencies (500 - 2000Hz) significantly.

Figure 2: Minimum audible pressure (MAP) and minimum audible field (MAF) thresholds, and upper limits of hearing (3).

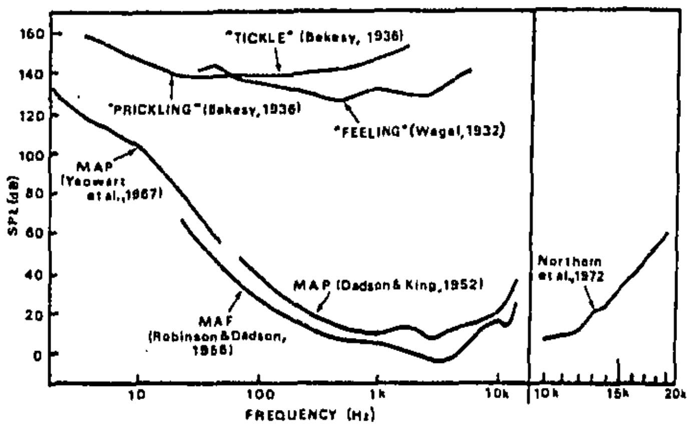
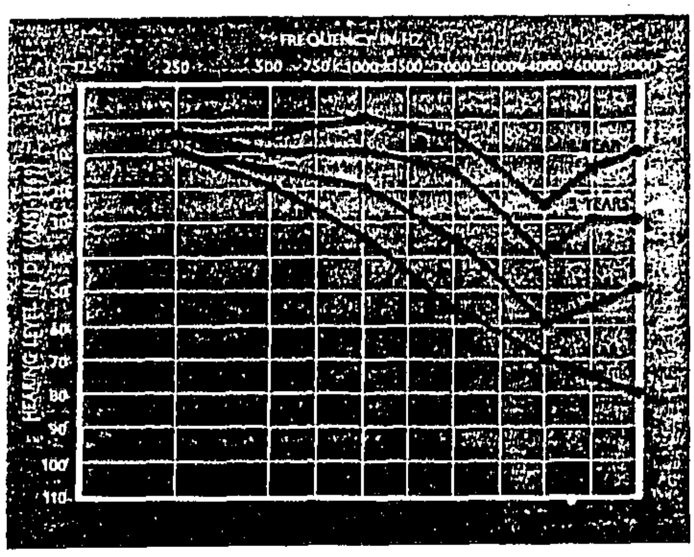


Figure 3: Typical progression in Hearing Loss as Function of Years of Exposure to Industrial Noise of High Intensity (2).



By 1949, all states in the U.S. had enacted some form of workmen's compensation legislation. At first only accidental injuries were covered. Subsequently, the laws were expanded to include occupational disease, which includes noise induced hearing loss. Several formulae were developed to determine the degree of hearing loss which was compensable.

The American Academy of Opthamology and Otolarynglolgy set forth a guide for the evaluation of hearing impairment in 1959(6). The American Medical Association adopted it in 1961(7). The criteria can be summarized as follows:

Monaural Loss:
Average the thresholds at 500, 1000, and 2000 Hz. Subtract 25 dB as the low fence. (A low fence is the average hearing level below which there is assumed to be no handicap.) Multiply by a weighting factor of 1.5 to find the % monaural impairment.

Binaural Loss:
Find the % loss in both ears. Multiply the % loss in the better ear by 5, then add the % loss in the poorer ear. Divide by 6 to find the % binaural impairment. The binaural impairment is the handicap of a person listening with both ears.

The National Institute for Occupational Safety and Health (NIOSH) suggested a different formula in 1972(8). The only change from the AAOO/AMA criteria is the frequencies used in computing the average. NIOSH recommends averaging thresholds at 1000, 2000, and 3000Hz. The importance of 3000 Hz for speech intelligibility under difficult listening conditions such as high background noise has been established since the 1960's.(9)

In 1975, the National Research Council Committee on Hearing, Bioacoustics and Biomechanics released their compensation formula(10). They averaged thresholds at 1000, 2000, and 3000 Hz as did NIOSH, but used a low fence of 35 dB HL and multiplied by a 1.75 weighting factor. The computation method was the same as those previous. The higher low fence meant that a greater hearing loss was allowed before awarding compensation.

In 1976, the chief judge of compensation of the New Jersey Department of Labor and Industry handed down a ruling on the compensation formula for NJ(11). His formula was the most lenient in granting compensation for hearing loss and was computed in the following manner.

Monaural:
From thresholds at 500, 1000, 2000, 3000(if available), and 4000 Hz subtract a low fence of 25 dB HL. Find the average and multiply by the 1.5 weighting factor. This gives the % monaural impairment.

Binaural:
Add the % loss in the better ear and the % loss in the poorer ear, then divide by 2. This yields the % binaural impairment.

In 1980, NJ passed a law, S3362, defining the formula for compensation for hearing loss. By law, these are the criteria:

Monaural:
Average thresholds at 1000, 2000, and 3000 Hz. Subtract a 30 dB HL low fence, and multiply by a weighting factor of 1.5. This results in the % monaural loss.

Binaural:
Multiply the % loss in the better ear by 5, then add the % loss in the poorer ear. Divide by 6. The result is the % binaural loss.

The various methods for calculating hearing loss for compensation are compared in Table III. A fictional person with decreased hearing thresholds was used to show the differences in the compensation awards.

5. Health and Welfare Effects

Noise affects health in many ways other than hearing loss. These include hypertension, stress, sleep disruption, startle effects, and effects on a fetus. Noise can interfere with speech, making it impossible to hear warning signals, or just masking enough of the speech sounds so that the message is misunderstood. This can especially affect children during the time they are learning language and may be referred to as a "welfare" effect of noise. The following descriptors are used to relate the level of sound to health and welfare effects.

a. A-weighted Sound Pressure Level

The human ear is not equally sensitive at all frequencies. It is most sensitive to frequencies in the range of 1000 to 4000 Hertz, least sensitive to low frequencies. In relating health effects to noise, the

Table III: Comparison of Compensation Formulae

Year	Society	Average Thresholds (Hz)	Low Fence (dB HL)	Weighting	% loss RE	% loss LE	%binaural loss
1959 1961	AAOO AMA	500, 1000, 2000	25	1.5	0	18	3
1972	NIOSH	1000, 2000, 3000	25	1.5	15	38	19
1975	NRC-CHBB	1000, 2000, 3000	35	1.75	0	26	4
1976	NJ-DLI	500, 1000, 2000, 3000, 4000	25	1.5	17	35	26
1980	NJ-S3362	1000, 2000, 3000	30	1.5	8	30	11

For a person with the following thresholds:

	500	1000	2000	3000	4000	8000
RE	15	20	35	50	60	50
LE	20	35	55	60	70	80

human ear's sensitivity must be approximated. Several frequency weighting networks were developed to simulate the way the ear behaves in different dynamic conditions. The A-scale was an approximation of the human ear response to sound less then 55 dB, the B-scale from 55 to 85 dB, and the C-scale for sound above 85 dB. These weighting scales are built into the electronic circuitry of a sound level meter. By convention, the A-scale is the weighting network used for all community noise measurements. Also, the standards set by OSHA use the A-weighting. The weightings are shown in Figure 4.

The A-weighting is used in the following two descriptors. If used by itself, the A-weighted sound pressure level denotes either the sound level at a given instant, a maximum level, or a steady-state level.

b. Time Weighted Average

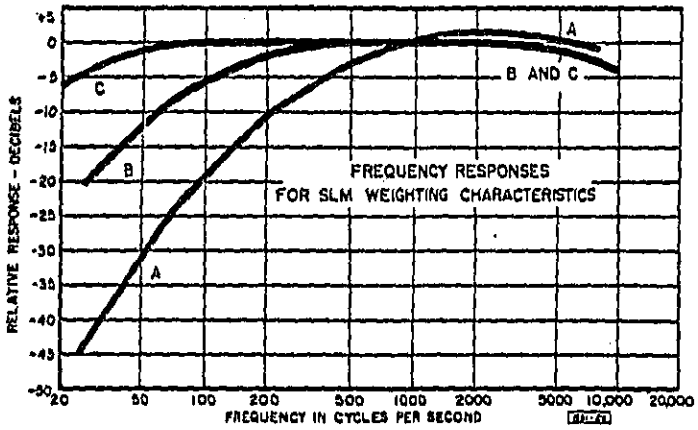
The effect of noise on hearing is correlated to the intensity and duration of sound. There are two hypotheses relating noise exposure and hearing loss. 1. The "equal-energy" hypothesis states that the hearing hazard is determined by the total energy that the ear is subjected to on a daily basis. This total energy is a product of sound level and duration. 2. The "equal temporary effect" hypothesis states that the long-term effect of steady-state noise exposure is predicted by the average temporary threshold shift produced by the same daily noise. However, it has been observed that intermittent noise is less harmful than unbroken exposure to steady-state noise at the same level.

A descriptor that relates sound intensity and duration is the time-weighted average or TWA. It is used to calculate compliance with the OSHA standard. If Cn is the total time of exposure at a specified noise level, and Tn is the total time of exposure permitted at that level, the TWA is equal to the sum of the fractions: C1/T1 + C2/T2 + ...+ Cn/Tn. If the TWA exceeds 1, the noise exposure is above the specified limit of the OSHA standard.

c. Equivalent Sound Level

A measure accounting for both the duration and the intensity of sound during a given period of time is the equivalent continuous noise level or Leq. It is defined as the level of a steady-state continuous sound having the same energy as the actual time varying

Figure 4: A, B, and C weighting scales



sound.

The major virtue of the Leq is that it correlates well with the effects of noise on people, including hearing loss, annoyance, and long term effects like hypertension. It is useful when relating the duration and intensity of sound, but not the conditions surrounding the noise. It does not correct for time of occurrence (day or night.)

The major problem of the Leq is that as an average it does not show the absolute value of the high and low levels. High levels of noise have different effects than the energy average. As an example, consider airplane noise. The level of one overflight may be 112 dB SPL yielding an Leq for the day of only 50 dB, if other sources are relatively quiet. While the averaged level of 50 dB would not cause autonomic changes like the startle response, those effects would certainly occur during the 112 dB overflight.

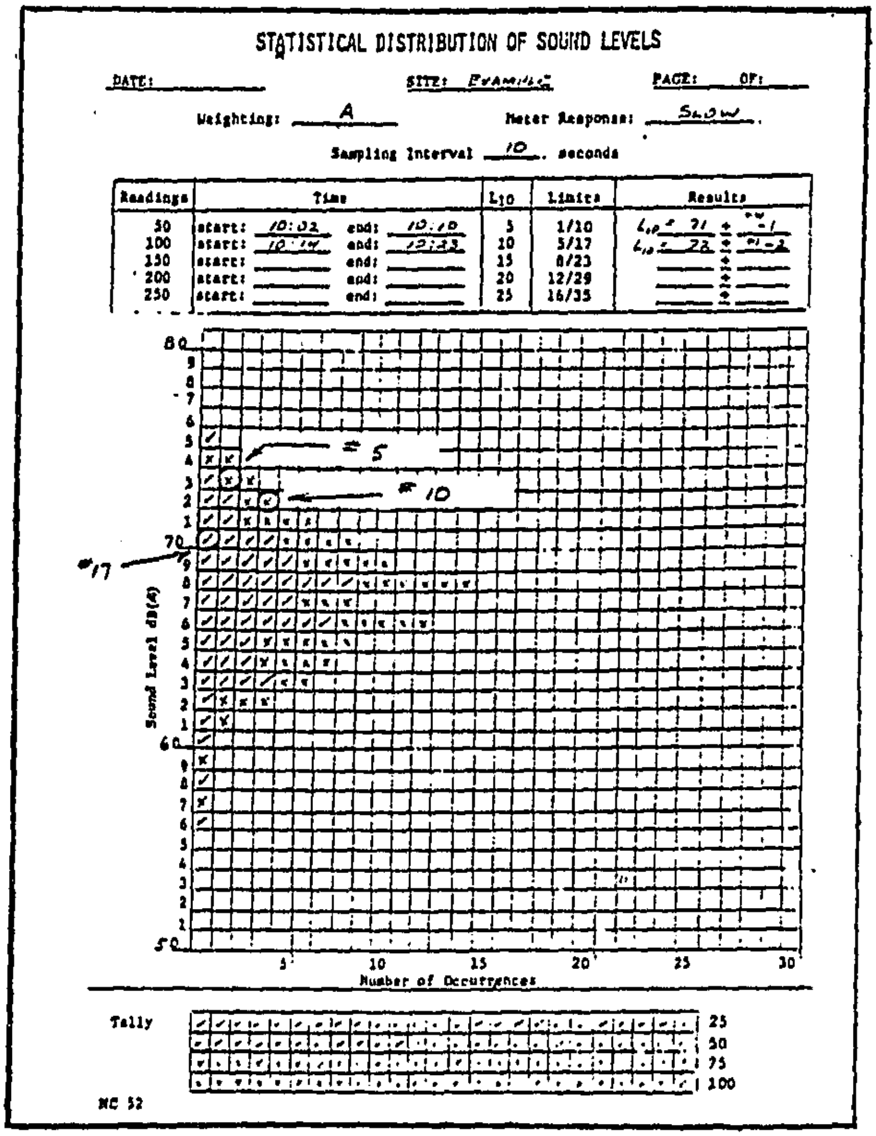
The determination of the Leq may be manual or instrumental. Instruments are available to read the Leq directly. If the distribution of levels is Gaussian, the manual method of determining the Leq can be used from obtaining the L10 and L50 values. If the level distribution is not Gaussian, or if there are impulsive sounds present, the manual method is not valid and the insturmental method must be used. The formula for the manual determination is:

$$Leq = L50 + 0.07\ (L10 - L50)^2$$

The L10 is the A-weighted sound level that is exceeded 10% of the time. The L50 is the A-weighted sound level that is exceeded 50% of the time. A simple procedure involving a sound level meter, stopwatch, and data sheet is available for their calculation. Every 10 seconds record the instantaneous A-weighted sound level. A sample data sheet is shown in Figure 5. After 50 samples have been taken, look at the range of levels measured. Multiply this range by 10 to compute the total number of samples required for statistical significance. After the appropriate number of samples have been taken, find 10% and 50% of this total. Starting at the highest entry, count down to the 10% number entry. This is the L10 value. The L50 value is the median entry. Use these numbers in the Leq formula.

The U.S. Environmental Protection Agency has identified levels that protect public health and welfare with a margin of safety.(11) These levels were derived without concern for technical or economic feasibility,

Figure 5: Example of a Data Sheet for the Manual Procedure for Statistical Descriptors (13).



STATISTICAL DISTRIBUTION OF SOUND LEVELS

DATE: ______ SITE: Example PAGE: ___ OF: ___

Weighting: A Meter Response: Slow

Sampling Interval 10 seconds

Readings	Time		L_{10}	Limits	Results
50	start: 10:02	end: 10:10	5	1/10	L_{10} = 71 ± +4 -1
100	start: 10:14	end: 12:33	10	5/17	L_{10} = 72 ± +1 -2
150	start:	end:	15	8/23	±
200	start:	end:	20	12/29	±
250	start:	end:	25	16/35	±

and contain a margin of safety to insure their protective value, so they should not be viewed as standards, criteria, regulations, or goals. The EPA states that an Leq less than or equal to 70 dBA over a 24 hour period would protect the general population from suffering hearing loss. An Leq less than or equal to 55 dBA over 24 hours would prevent outdoor activity interference and annoyance in outdoor areas where people spend limited amounts of time, such as school yards, or playgrounds. To prevent indoor activity interference and annoyance in indoor areas with human activities such as schools, the EPA suggests an Leq less than or equal to 45 dBA over 24 hours.

1. Impulsive noise

An impulsive noise rapidly rises to a peak and then decays. There are two categories of impulsive noise. A single impulse can occur from a quarry blast. A repetitive impulsive noise would result from a drop hammer, an unmuffled rock drill, a two-stroke motorcycle, or a truck-mounted garbage compactor. There are five physical parameters important for describing impulsive sound. (14) These are illustrated in Figure 6.

(1.) Crest Level

The crest level is defined as the difference in sound pressure level between the peak or maximum sound pressure level, and the root-mean-square (rms) level of the noise. For a noise to be considered impulsive, the crest level should exceed 10 dB.

(2.) Duration

The duration is the amount of time that the instantaneous pressure exceeds the rms value.

(3.) Period

If the sound is repetitive, the time duration between two successive impulses in a train of impulses is called the period.

(4.) Spectrum

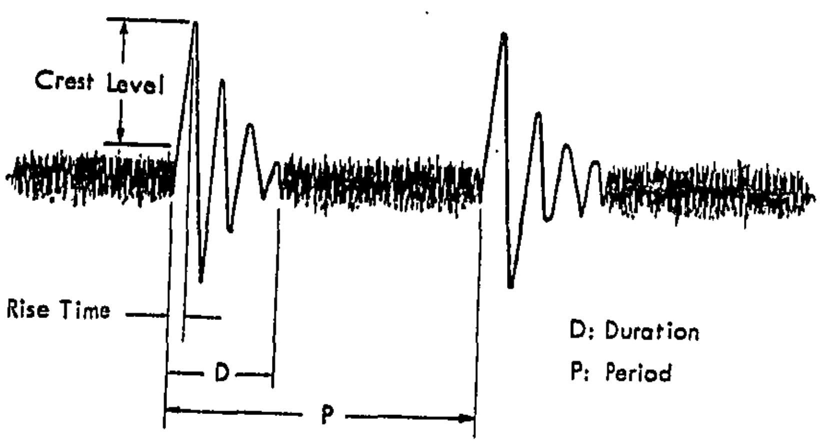
The spectrum is a breakdown of the sound energy into its frequency components.

(5.) Rise Time

The rise time is the time required for the impulse to rise from the background to the peak.

a. Peak

Figure 6: Physical Parameters of a Typical Impulsive Sound (14).



The peak setting of a sound level meter will show the maximum sound pressure level sensed by the microphone. By using the peak hold, the meter will show the highest value until reset. The term "peak sound pressure level" means that no frequency weighting scale is used. The term "peak sound level" means that the A-weighting has been used.

To evaluate hearing loss due to impulsive sound, the peak sound pressure level and the time history of the noise is measured. Both the energy theory and the temporary threshold shift theory support the use of the peak sound level for evaluating the risk of permanent hearing loss.

b. Impulse

The impulse setting on a sound level meter integrates the sound over a very short time period (35 milliseconds). This time period was chosen because it approximates the time the ear needs to perceive an impulse. The time necessary varies with the intensity of the sound. The time increases as the signal is decreased to approach the threshold of hearing. The time also varies slightly with frequency. In different studies (14) the time necessary for perception of an impulsive sound has been measured in values ranging from 13 ms to 200 ms.

Because of the variation in the auditory perception time for impulsive sounds, there is a problem in evaluating the subjective judgement of the annoyance of impulse sounds from any particular measurement scheme. Impulse sound level meters have the 35 millisecond averaging time built into the circuitry as an average time to approximate the ear's perception time.

c. Fast

The averaging time for the fast setting on the sound level meter is 125 milliseconds. This setting is generally used for a source such as a motor vehicle, which is to be measured as it passes by. The fast setting allows the maximum sound level to be read, without a peak hold.

d. Slow

The averaging time for the slow setting on the sound level meter is 1 second. The slow setting is generally used for steady-state sound, but the A-weighted slow response setting of the sound level meter was found to approximate the Leq of impulsive sounds with an accuracy of +- 1.5 dB. (14)

e. Equivalent Sound Level

The Leq is the energy-average of the integrated A-weighted sound level over a specified observation time. In assessing the annoyance of impulsive sound, excluding helicopter noise, a constant subjective correction of +7 dB should be added to the Leq. This means that if impulsive noise is present, 7 dB should be added to the Leq to approximate the annoyance that would be present from a steady-state sound. (14)

2. Speech Interference

Noise interferes with speech signals by masking them. Background noise raises the threshold of hearing to the point where the sounds necessary for speech intelligibility are not audible. Consonants are more readily masked than vowels, and contain most of the information in speech. They are higher in frequency (>2000 Hz) than vowel sounds, and contain less sound energy.

Speech sounds are distributed over the frequency range of 100 to 10,000 Hz. But nearly all the information in speech is between 200 and 6000 Hz. The sound for /s/ is above 3000 Hz; for /sh/ is between 2000 and 4000 Hz; for /f/ is between 6500 and 8000 Hz. (15)

Noise greater than 90 dBA can interfere with speech signals making it difficult to hear directions or warning signals. A level greater than 65 dBA can make it impossible to hear on the telephone and tiring to hold a discussion because more vocal effort is needed.

Speech levels are measured in terms of a long-time (approximately 60 second) rms sound pressure level. This can be approximated by adding 3 dBA to the peak deflections for each word in a sentence with the meter at fast response. If the meter is set at slow response, 8 dBA must be added. (16)

The following descriptors rate noise with respect to its ability to mask speech. All of them assume that the listener has normal hearing. If the listener has a hearing impairment, none of the descriptors is valid. The descriptors also pertain only to steady-state sound. Rapidly varying and fluctuating noises such as those produced by traffic are not considered.

If the masking noise totally drowns out the signal rendering speech inaudible, speech is said to be below the threshold of detectability. If the speech can be detected, but not understood, the speech is said to have poor intelligibility or discriminability. The following descriptors relate to the clarity with which speech can be heard; they measure intelligibility. (17)

a. Articulation Index

The range of 200 to 6000 Hz is of most importance to the understanding of speech. The Articulation Index (AI) breaks noise down this frequency range into a large number of frequency bands and averages the masking in each band to approximate the total masking of the noise.

The Articulation Index is defined as 1/30 of the mean speech-to-noise level in 20 frequency bands in each of which the contribution to intelligibility is equal. The articulation index is often computed from one-third-octave or octave-band levels appropriately weighted according to band-width. (17)

The AI is used to evaluate speech-transmission systems like telephones. It is rarely used in community noise because of the complexity of the computation. The AI was based on intelligibility tests involving male talkers and trained listeners so it cannot be assumed to be valid for female talkers or children.

b. Preferred Speech Interference Level

The Preferred Speech Interference Level (PSIL) is the arithmetic average of the sound pressure levels in the octave bands with center frequencies of 500, 1000, and 2000 Hz. The unit of the PSIL is the decibel.

The PSIL is a simplified approximation for determining whether noise will mask speech. It is related to communication difficulties in Figure 7.

The following chart relates PSIL with telephone usage. (18)

PSIL	TELEPHONE USE
<60 dB	Satisfactory
60-75 dB	Difficult
>80 dB	Impossible

The PSIL can be used for design criteria for buildings. Table IV gives maximum permissible PSIL for various rooms measured with equipment and ventilation systems

Figure 7: Rating chart for determining speech communication capability from speech interference levels (18).

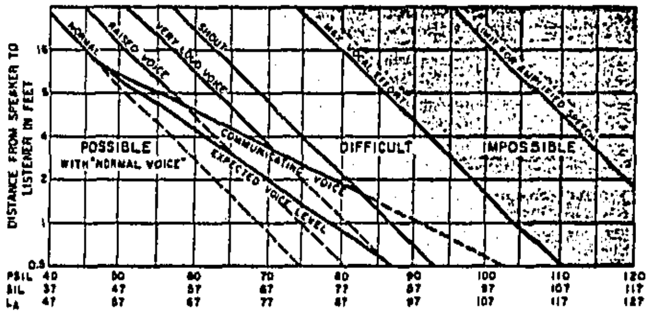


Table IV: Criteria for Noise Control (18).

Type of Room	Maximum Permissible PSIL (measured when room is not in use)
Small Private Office	45
Conference Room for 20	35
Conference Room for 50	30
Movie Theatre	35
Theatres for Drama (500 seats, no amplification)	30
Coliseum for Sports Only (Amplification)	55
Concert Halls (No amplification)	25
Secretarial Offices (Typing)	60
Homes (Sleeping Areas)	30
Assembly Halls (No amplification)	30
School Rooms	30

in use but no people working.

A room can be too quiet. If the background noise is too low, conversation is easily overheard and privacy is threatened.

c. Speech-Interference Level

The Speech-Interference Level (SIL) is the arithmetic average of the sound pressure levels of the interfering noise in the four octave bands centered on the frequencies 500, 1000, 2000, and 4000 Hz. The unit of SIL is the decibel.

There are two possible applications of the SIL: 1. Noises may be ranked with respect to speech interference. 2. The difficulty of face-to-face communication with respect to talker-to-listener distances and voice level required may be related to SIL. This relation is shown in Figure 8. The region below each curve shows the talker-to-listener and noise-level combination for which just reliable face-to-face communication is possible. The parameter on each curve indicates the relative voice level. The A-weighted sound level shown on the abscissa is approximate. The relation between speech-interference level and A-weighted sound level depends on the spectrum of the noise. (19)

The SIL differs from the A-weighted sound level according to the spectrum of the sound. Typically, for many common noises, the A-weighted sound level will equal the SIL + 8dB. (19) The overall C-weighted sound level will equal the SIL + 15 dB. (20)

d. A-weighted Sound Pressure Level

Speech interference can be directly related to the A-weighted sound pressure level of the noise. Figure 9 shows the effects of noise on the percentage that sentences are intelligible to normal hearing people in a typical living room. The speech levels were fairly constant throughout the room beyond 1 meter from the speaker. (12) It should be kept in mind that people unconsciously raise their voices when the background noise is > 45 dB.

Because the A-weighted sound level can be read directly from a sound level meter, it is easier to obtain than the SIL, PSIL, or AI. However, sound level meter measurements tend to overrate the speech-interference properties of high-frequency noise. Caution should be used when there is a significant high frequency

Figure 8: Talker-to-listener distances for just reliable communication (19).

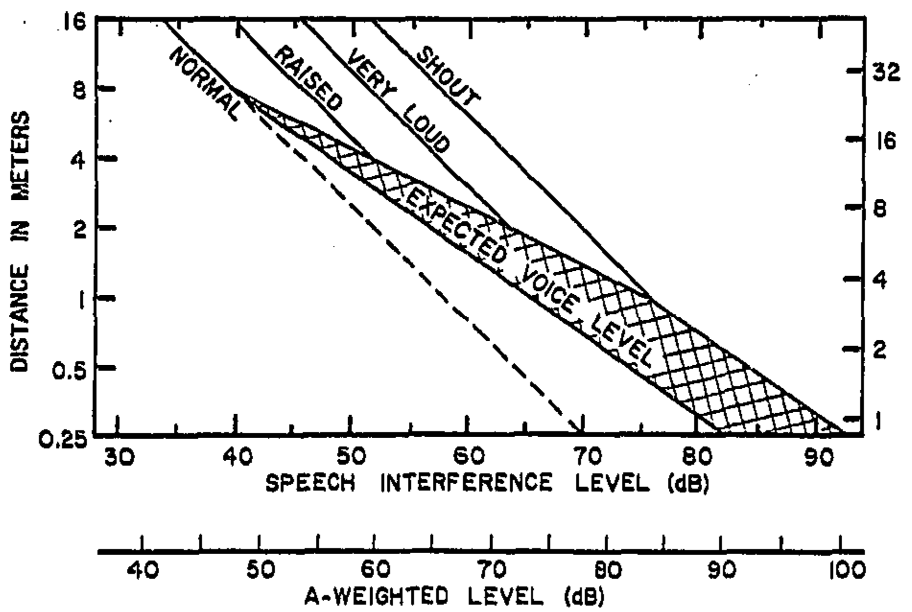
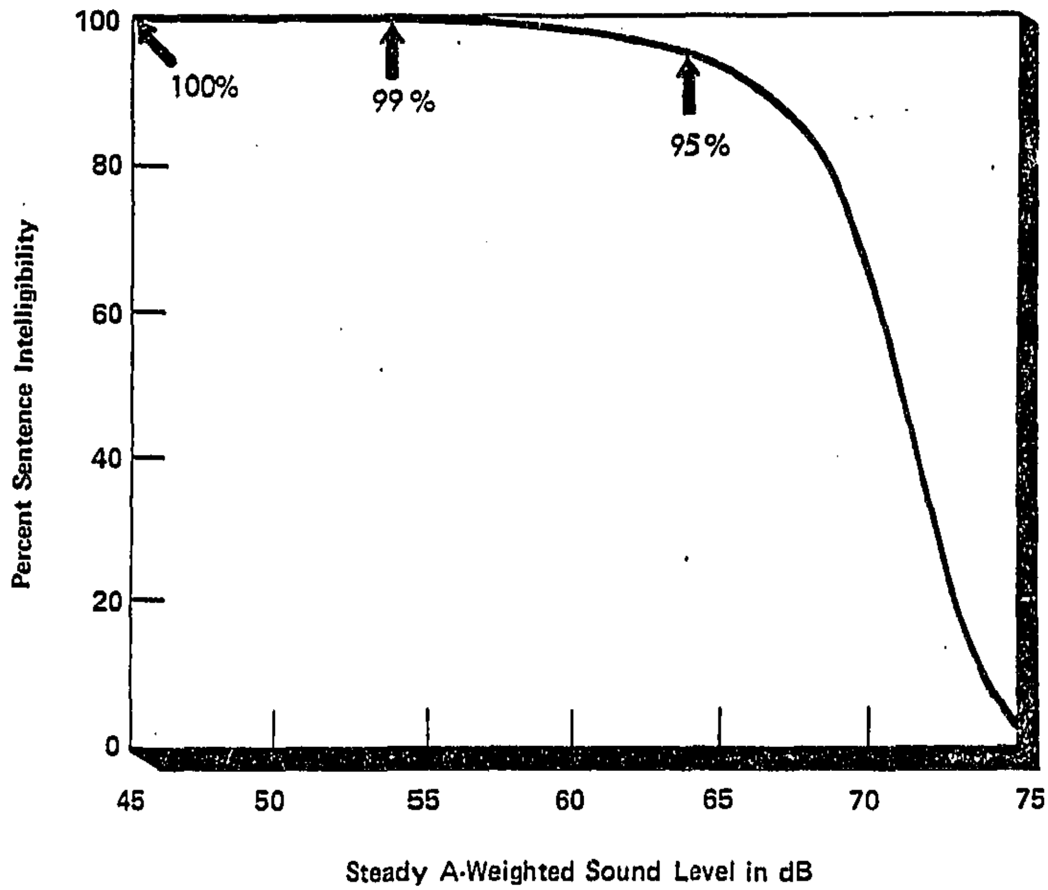


Figure 9: Effects of noise on the percentage of sentences intelligible to normal hearing people in a typical living room (12).

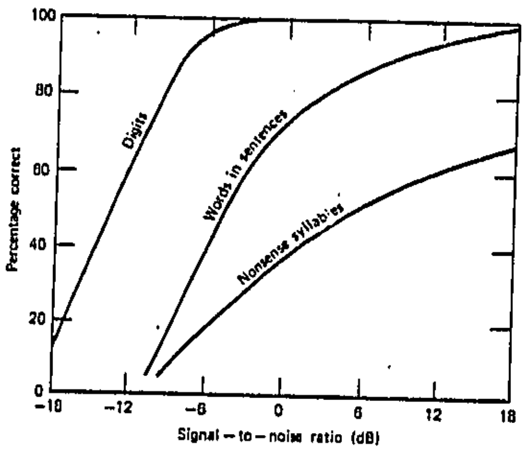


component to the noise. (21)

e. Signal to Noise Ratio

The relative sound pressure level of speech to that of ambient noise is the signal to noise ratio. Speech signals only need to exceed the background noise by 10 to 20 dB to be intelligible in the range of 30 - 110 dB noise. At very high background levels, a deterioration in intelligibility will occur with the same S/N ratio. The intelligibility of digits is 100% even if the signal and the noise are at the same level. The relationship of various types of speech signals and their intelligibility in noise is shown in Figure 10.(22)

Figure 10: Relationship Between Intelligibility Scores and Signal-to-Noise Ratios (22).



Regulations

A. Occupational Safety and Health

The U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) has established a regulation on occupational noise exposure. It applies only to workplace noise. It sets limits on the length of time that a worker may be exposed to a certain intensity of sound. The following table outlines the standard.

Duration per Day, Hours	Sound Level dBA
8	90
4	95
2.	100
1	105
0.5	110
0.25	115
peak	140

The descriptor used to determine compliance with the regulation is a time-weighted average of the noise exposure. The sound level is measured in decibels on the A-weighting scale to approximate the sensitivity of the human ear. However, the length of exposure is also a part of the formula.
The time-weighted average (TWA) can be calculated by summing the quotient of a worker's actual exposure to noise and the amount of time allowed. If the TWA is greater than 1, the worker is exposed to too much noise. For example, suppose a worker is exposed to 90 dBA for 2 hours, 100 dBA for 1 hour, 95 dBA for 2 hours, and 80 dBA for the remaining 3 hours. He is allowed to be exposed to 90 dBA for 8 hours, 100 dBA for 2 hours, 95 dBA for 4 hours, and 80 dBA for an unlimited period. His TWA could be found by:

TWA = actual/allowed at 90 dBA+ actual/allowed at 100 dBA+ actual/allowed at 95 dBA

$$TWA = 2/8 + 1/2 + 2/4 = 1.25$$

Since the TWA is greater than 1, the worker is overexposed to noise.

The TWA can be obtained directly from an instrument called the dosimeter. The worker wears a small microphone at the ear, on a collar, or on the shoulder. An electronic monitor is connected to the microphone and accumulates the dose according to the OSHA standards. After the workday, the monitor is plugged into an indicator, and the TWA is read.

The levels chosen will protect the average worker from suffering hearing loss during his working career. But some people are more sensitive to hearing loss. A safe level of exposure will differ with the individual. OSHA recognized these differences and developed a plan to find those people sensitive to noise and protect them. In legislation effective in 1981, all workers exposed to noise in excess of an 8-hour TWA of 85 dBA must be enrolled in a Hearing Conservation Program. (23)

B. Aviation Noise

The Federal Aviation Administration has jurisdiction over airplane noise. Their regulations cover the operation of the plane, the certification of the plane, and the planning of the airport site. Airport proprietors have jurisdiction over ground operations.

The following descriptors were chosen by the Federal Aviation Administration (FAA) for their regulations. The frequency spectrum from aircraft is so unique that many attempts have been made to relate this type of noise to the annoyance experienced by persons living near airports. The descriptors account for the noise spectrum of single aircraft flyovers and the number of aircraft heard within a certain time-frame.

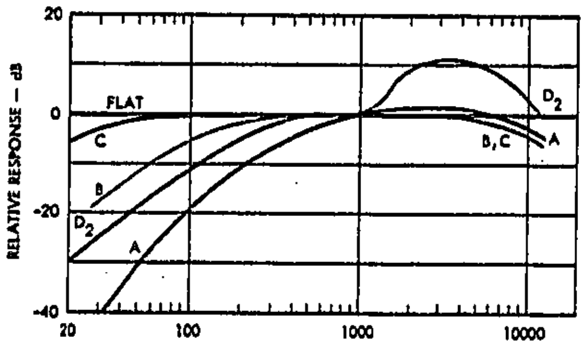
a. Perceived Noise Level

The FAA sets regulations for the operation of airports. These include noise level limits for airplanes on takeoff and landing. The Perceived Noise Level (PNL) is used in the computation of the test data to determine compliance.

The 24 one-third octave bands of sound pressure level are converted to perceived noisiness by means of a noy table. The noy values are combined and then converted to instantaneous perceived noise levels. The unit for PNL is PNdB. (24) In the "Subjective Response" section on page 62 the noy table is shown.

The 40 noy contour has been converted to a frequency weighting network encorporated into the circuitry of the sound level meter. It is called the D-weighting scale and is shown in Figure 11. However, when the level measured with the meter was compared to the calculated PNL, the PNL exceeded the scale by 7 dB.

Figure 11: Frequency Weightings Illustrating the A, B, C, and D Scales (13).



The D-weighted sound level must be corrected by 7 dB to approximate the PNL.

b. Effective Perceived Noise Level

The FAA regulations for airplanes on takeoff and landing are expressed in Effective Perceived Noise Levels (EPNL). The EPNL adjusts the PNL for pure-tones and the duration of the flyover. The PNL varies during the flyover. When the aircraft is directly overhead, the noise from the fan is dominant and as the plane recedes the lower frequency jet noise predominates. The EPNL requires summing 1/3 octave bands for the duration of the flyover in 0.5 second intervals. The maximum values attained in each band during the flyover become most important regardless of whether the peaks occur simultaneously. The unit EPNdB is used instead of the unit dB. (24)

c. A-weighted Sound Pressure Level

Although the FAA regulations require certification of aircraft in units of EPNdB, many airport and community noise analyses utilize a noise rating scale that is based upon A-weighted decibels. Therefore, the FAA has estimated the aircraft noise levels for all the certified aircraft in decibels measured on the A-scale. (25)

d. Day-Night Equivalent Sound Level

The Day-Night Level, Ldn, was introduced by the Environmental Protection Agency so that a single number could measure the community exposure over a specified period. It was designed to predict the effects on a population of the average long-term exposure to environmental noise. Since the EPA used the Ldn for its recommended levels to protect health and welfare, The FAA used the same descriptor for their regulations on airport noise compatibility planning.

The Ldn is the 24-hour average sound level, in decibels, for the period from midnight to midnight, obtained after the addition of ten decibels to sound levels for the period between 10 P.M. and 7 A.M., local time.

The yearly Ldn is used for the analysis and characterization of multiple aircraft noise events and for determining the cumulative exposure of individuals to noise from airports. (26)

e. Sound Exposure Level

The Sound Exposure Level (SEL), also known as the Single Event Noise Exposure Level (SENEL) was chosen by FAA to measure maximum sound level in considering environmental impacts. (27)

If the maximum sound level was graphed during an airplane flyover, the Sound Exposure Level could be thought of as the area under the curve. It is the squared weighted sound pressure, integrated or summed over time, referenced to the standard pressure squared, times one second. For example, a sound of 90 dBA for 1 second has an SEL of 90 dBA. A sound of 90 dBA for 10 seconds, has an SEL of 100 dBA.

f. Composite Noise Rating

For considering cumulative noise, the FAA chose the Compusite Noise Rating (CNR) as one of its descriptors. (27) The CNR corrects the EPNL for the number of day and night flights. Mathmatically, (22)

$$CNR = EPNL + 10 \log (Nd + 10\ Nn) - 12$$

where EPNL = Effective Perceived Noise Level
Nd = number of daytime flights
Nn = number of night flights

The CNR is associated with community response. A public response scale including "no reaction", "sporadic complaints", "widespread complaints", "threats of community action", and "vigorous community action" was the basis for its development. (39) The descriptor was based on a limited number of social surveys and worked best if based on a calibration point for a particular community. If an airport already exists in a community, the CNR is good for predicting changes in community response to changes in the airport.

g. Noise Exposure Forecast

The Noise Exposure Forecast (NEF) was one of the descriptors chosen by the FAA as a cumulative noise measure for considering environmental impacts. NEF contours are the basis of eligibility for Airport Noise Control and Land Use Compatibility (ANCLUC) planning studies.

The NEF modifies the CNR by also accounting for the total mix of aircraft flying over a community. Although a computer is required to calculate the NEF ratings for the contours around an airport, the calculations are based on the following formula: (22)

$$NEF_{ij} = EPNL_{ij} + 10 \log (nD_{ij}/20 + nN_{ij}/1.2) - 75$$

where i = specific class of aircraft
j = specific flight path
nD_{ij} = number of operations during the day

The numbers 20 and 1.2 were chosen so that a single night flight contributes as much as 17 day time flights to the total NEF. 75 was chosen so that the numbers for the NEF could not be confused with the CNR. NEF values typically range from 20 to 40. The total NEF number for a certain location is the sum of all the NEF values for each aircraft and flight pattern .

The NEF predictions rely on the interference of noise with speech intelligibility and the importance of speech intelligibility in the activities typical of the use in question. Between the NEF contours of 30 and 40, activities such as schools would not be compatible. Commercial uses would be allowed but office buildings should be sound-insulated. The NEF 40 contour is defined as a "noise saturation" level and noise sensitive uses are discouraged. At NEF 30 to 40, there is a gray area of "noise contamination". An NEF less that 30 is considered compatible with any land use.

C. Defense

The Department of Defense began using the CNR system to describe aircraft noise in its studies of land use near military air bases. They started to replace the CNR with the NEF. Then the Environmental Protection Agency decided to use the Ldn for all studies. The DoD followed the EPA's lead in all new studies, but did not go back and change previous studies with the other descriptors. (28)

The DoD has a correction to be applied when computing helicopter noise levels using data collected from sound level meters. A correction of +7dB is added to the meter readings if blade slap is present. (28)

When measuring impulse noise from bombing and gunnery ranges, the DoD specifies that the C-weighting should be used. (28)

D. General Services Administration

The Federal government sets noise limits in dBA for all construction equipment hired under a government contract. (29)

E. Department of Housing and Urban Development

The Department of Housing and Urban Development (HUD) has a general policy to protect citizens against excessive noise by providing minimum standards for any building activity supported by HUD. They provide exterior and interior noise goals for acceptability of the building site or plans.

The descriptor used by HUD is the Ldn. The EPA used Ldn to recommend levels requisite to protect human health and welfare. HUD uses the same descriptor, and sets levels to evaluate sites as acceptable, normally unacceptable, or unacceptable. The Ldn is the 24-hour average sound level, in decibels, obtained after addition of 10 decibels to sound levels in the night from 10 p.m. to 7 a.m. (30)

If loud impulsive sounds are to be heard on the site, such as those from explosions or sonic booms, 8 dB should be added to the measured Ldn to assess the acceptability of the site. Alternatively, the C-weighted Ldn may be used to assess the site, without the 8 dB penalty. (30)

F. Mine Safety and Health Administration

Regulations for the Mine Safety and Health Administration are the same as those for the Occupational Safety and Health Administration. A TWA is calculated to determine compliance with A-weighted levels. (31)

G. Department of Transportation

The Department of Transportation, Federal Highway Administration set Noise Abatement Criteria for determining traffic noise impacts. They use an hourly A-weighted sound level expressed as Leq or L10.

The Leq is the equivalent steady-state sound level, which, in a stated period of time, contains the same acoustic energy as the time-varying sound level during the same time period. The L10 is the sound level that is exceeded 10 percent of the time for the period under consideration. For DOT purposes, the time is one hour.

The Leq and L10 can be predicted from a highway noise prediction model. When using the model, the worst hourly traffic noise impact for the design year should be used. (32)

The DOT Bureau of Motor Carrier Safety has set limits for vehicles with a gross vehicle weight rating greater than 10,000 pounds using a maximum dBA measured on the fast response of the sound level meter. (33) They use the same descriptor for vehicle interior noise levels. (34)

The DOT Federal Railroad Administration uses the maximum dBA measured on fast response for pass-by testing of trains. (35) For worker safety, the DOT FRA uses the same standards as OSHA. (36)

H. Coast Guard

The noise exposure limits recommended by the Coast Guard are expressed in a 24-hour effective exposure level, or Leff(24). Since workers do not leave the ship after their normal 8-hour day, OSHA standards were not applicable. The 24-hour exposure measurement considers the time after exposure to high noise to see if sufficient quiet time is provided to allow for recovery from temporary threshold shift. The Leff(24) was based on the OSHA standard. By calculating the exposure level resulting from an 8-hour day at 90 dBA and 16 hours at less than 80 dBA, the Coast Guard allows an Leff(24) of 82 dBA. For new ships constructed after 1985, the Coast Guard recommends designing to an Leff(24) of 77 dBA.

Measurements to determine compliance with the standard can be made with a sound level meter or a dosimeter. (37)

I. Community Noise Regulations on State or Local Level

The choice of descriptor for community noise regulations has been debated frequently at meetings of noise control professionals. Various advantages include ease of measurement, validity in court, minimum training required, short measurement time, and low equipment cost. Each descriptor seems to have its trade-offs. The most important consideration in writing a local ordinance or state regulation is to establish levels that sensibly limit the noise source and preserve the health and welfare of the people. It is beyond the scope of this paper to determine the ideal level or the ideal descriptor. However, the following compilation of descriptors and the range of levels set should help determine whether a contemplated level is outrageous or sensible, and whether the descriptor chosen is the proper one for the source.

1. Individual Event Criteria

a. Maximum Sound Level (dBA)

There are two ways to use the Maximum Sound Level (Lmax) descriptor. One way is to set dBA levels not to be exceeded on the property line or at some set distance from the source. The other way is to specify that noise emitted by the source should not exceed the ambient noise by a set limit.

Advantages of the Lmax are that it is easy to measure, the equipment is relatively inexpensive, and people can be quickly trained for enforcement. The issue of the length of measurement time to determine compliance with the regulation has not been resolved. Theoretically, if the source emits sound that violates the standard at any time, the source is not in compliance. In actual enforcement situations, the noise enforcement officer may wish to show that there are repeated violations of the standard, and that his noise measurement was typical of the noise the source emits.

Ambient noise must be determined. The noise measured on the property line is the total noise. To determine the amount of noise due to the source, the ambient (sometimes called background) noise must be measured. This may be found when the source shuts down, by walking away from the source until a steady level is measured from the other neighborhood noise sources, or by going to another neighborhood of similar character and finding the steady-state level. The ambient is then subtracted from the total noise to determine that due to the source. If the ambient is 10 dB or less than the total, all noise measured at the property line is due to the source.

An alternate method of finding the ambient noise is to use the L90. It is described on page 17 .

b. Sound Exposure Level

The descriptor chosen to measure sound from a discrete event such as a truck or airplane pass-by is the Sound Exposure Level or SEL. It is the squared weighted sound pressure integrated or summed over time referenced to the standard pressure squared times one second, and then converted to a level. The best way to explain it is to give an example. A sound of 90 dB for 1 second has an SEL of 90 dB. If the sound is at 90 dB for 10 seconds the SEL is 100 dB. If it persisted for 100 seconds, the SEL would be 110 dB.

The SEL requires sophisticated and expensive noise measurement equipment. This equipment is usually automated so little training is required. The data are collected by the instrument so the noise enforcement officer actually spends very little time in the field. The SEL is used mostly for airplane noise and is accepted in court.

2. Energy Average Criteria

a. Equivalent Sound Level

The equivalent A-weighted sound level (Leq) means the constant sound level that in a given situation and time period, contains the same sound energy as the actual time-varying A-weighted sound.

In the past, equipment to measure the Leq was expensive but several equipment manufacturers have developed more inexpensive units. These Leq meters have different times over which the Leq is calculated and should be carefully selected to conform with the regulation. They are easily operated with minimum training required and may be automated requiring little time in the field. (The security of the instrument must be ensured if it is to be left in the field.) The actual measurement time is specified in the regulation and may be anywhere from 10 minutes to 24 hours. The Leq is accepted in court.

Caution should be used in interpreting Leq data. Remember that it is an energy average and that extreme levels will not be seen. In community noise, frequently it is the burst of sound that occurs for only a short period that is annoying. This type of problem can be averaged out if the measurement period of the Leq is too short.

b. Day-Night Equivalent Sound Level

The day-night average sound level means the 24-hour energy average of the A-weighted sound pressure level, with the levels during the period 10 p.m. to 7 a.m. weighted by 10 dBA before averaging. This procedure helps to account for the sleep interference effects at night.

The Ldn requires expensive equipment and a 24 hour measurement period. It does not consider single intrusive events. It can be used to set guidelines for land use or levels to protect public health and welfare. It is valid in court and with automated equipment it is easy to measure.

c. Community Noise Equivalent Sound Level

The Community Noise Equivalent Sound Level (CNEL) penalizes for the increased effects of noise in the evening hours. It incorporates a 5 dBA penalty between the hours of 7 p.m. and 10 p.m. as well as the 10 dBA penalty of the Ldn.

The preceding averaging noise descriptors, Leq and Ldn, as well as CNEL are adequate to describe the general noise environment. They enable us to make judgements as to the acceptability of the site for various land uses (see HUD standards) but some form of individual event criteria is necessary to insure mitigation of noise intrusion from specific sources.

The CNEL requires a special instrument, and special training for measurement. It yields numbers close to the Ldn. It is used mainly in California.

d. Statistical Methods, L10, L90

The L10 and L90 are statistical methods of describing community noise. The L10 level is the A-weighted sound level that is exceeded 10% of the time and indicates the intrusive noise in the area. The L90 is the a-weighted sound level that is exceeded 90% of the time and indicates the ambient level into which the l10 intrudes.

While there are instruments to calculate the L10 and L90 directly, a simple sound level meter, a stopwatch and a trained person can do as well. (See procedure on page 17.)The descriptor is valid in court if the procedure can be verified. The measurement time is prolonged if the manual method is used. The manual method is tedious, and the enthusiasm of the enforcement official may wane after only a few cases. Te training required is only slightly longer than that for Lmax.

Standards

Institutions promulgate noise standards for two main purposes:

1. DESCRIPTIVE- to describe the loudness of the sound emitted from various pieces of equipment; or to describe the attenuation or absorption capabilities of various materials;

2. PROCEDURAL- to describe the measurement procedures for determining the loudness of sound.

Descriptors used in the descriptive standards will be explained here. Descriptors used for sound measurement procedures are described in the Monitoring and Survey Section of the paper starting on page 44 . The Appendix contains a compilation of standards organizations and associations.

a. Sound Power Level

Since Sound Pressure Levels are influenced by reverberations in the room, a Sound Power Level is used to compare the sound from various pieces of equipment. The Sound Power Level, expressed in dB IL, references the amount of energy, in watts, that is derived from the energy used to power the equipment. To explain, a piece of machinery needs energy for it to work, but it does not use this energy 100% efficiently. Some of the energy is wasted as heat. Less than 1% is wasted as noise. The energy wasted as noise can be expressed in a Sound Power Level. This can then be related to the Sound Pressure Level if characteristics of the installation are considered.

b. Sound Pressure Level

Standards are given which correct the Sound Power Level for the characteristics of the installation of a piece of equipment, including the room size, reverberation, absorption, and other factors. The Sound Pressure Level in A-weighted decibels can then be estimated for that room.

Corrections may also be given to relate Sound Rating Numbers (see section below) to SPL dBA.

Some standards are written directly in SPL dBA. For instance, the Power Saw Manufacturers Association

(PSMA) has established a noise level certification procedure for noise from power saws measured at the operator's ear. The Society of Automotive Engineers (SAE) gives all their standards for pleasure boats, motorcycles, truck tires, construction equipment, snowmobiles, trucks, buses and cars in dBA.

c. Sound Rating Number

A number of organizations who promulgate standards recognized the confusion of the public when faced with complex sound descriptors. A rating scheme which could be used by the average person to compare the sound intensity from several different brands of equipment was devised. The Air-Conditioning and Refrigeration Institute (ARI) rates all outdoor equipment with a single number for the average person to use to compare two air conditioners. The Standard Sound Rating Number is derived from one-third octave band power levels weighted to adjust for psychoacoustic sensitivity.

The Sound Rating Number can then be used to predict the A-weighted sound level after the equipment is installed. Charts to correct for installation factors and distance to the prediction point are provided in another standard by the ARI.

d. Sone Loudness Rating

Sound Ratings are provided for all types of air moving units, including centrifugal fans, axial and propeller fans, roof and wall ventilators, steam and hot water heaters and central heating, ventilating and air conditioning units by the Air Moving and Conditioning Association (AMCA). They use a Sone Loudness Rating which gives the loudness at a distance of 5 feet from the unit in free space with no reflecting surfaces. They provide charts for determining the loudness of the fan once it is installed. Sones are used to describe the subjective perception of the sound. (See section on subjective response.)

e. Sound Power Rating

Standards may use a single-figure rating number based on the Sound Power Level. This is a Sound Power Rating. It is similar to the Sound Rating Number in that it allows comparison of several pieces of equipment with regard to the sound levels they can produce. However it is based solely on Sound Power and does not adjust for psychoacoustic sensitivity.

f. Attenuation of Hearing Protectors

The American National Standards Institute (ANSI) specifies a method for the measurement of physical attenuation of earmuffs by using narrow bands of noise for test stimuli. The muffs are tested by physical means on a dummy head with microphones in place of ears, not in actual use by a person. Only muffs can be tested, not earplugs because of the dummy head configuration.

g. Absorption Coefficient

The American Society for Testing and Materials (ASTM) has standards for measuring the amount of sound that will not be reflected (i.e. absorbed) from building materials. Thus, different types of acoustical ceiling tile, for instance, can be compared by their sound absorption coefficient. Another standard covers the changes in the absorption coefficients of an acoustical ceiling material if it is repainted for maintenance reasons.

h. Sound Transmission Class

ASTM has a standard for the Sound Transmission Loss of building partitions such as wall, floor-ceiling assemblies, and doors. It is expressed as the difference in sound pressure levels in the rooms on opposite sides of the partitions.

The International Conference of Building Officials (ICBO) uses a Sound Transmission Class (STC) as a single-figure rating of the sound transmission loss of partitions. The rating correlates subjective impressions of the sound insulation of the partition against the measured sounds of speech, radio, television, music, and similar sources of noise in dwellings.

i. Impact Insulation Class

ASTM has a standard for measuring Impact Sound Transmission through partitions. ICBO specifies an Impact Insulation Class (IIC) as a single-figure rating. The standards are based on a sound pressure level in the room adjoining the test room, in which a standard tapping machine is operated.

Monitoring and Surveys

There are various reasons for measuring noise in the community. Before a noise ordinance is drafted, community leaders survey a town for an idea of existing levels in the residential, commercial, and industrial zones. In enforcing a noise ordinance, an official monitors the noise attributable to the offending source, and measures the noise present without the source operating. The following descriptors are used for noise measurement.

1. Residual Level

The residual level, sometimes called the ambient level, is the "all-encompassing noise associated with a given environment, being usually a composite of sounds from many sources near and far".(18) It is sometimes called the background level, although acoustitians usually reserve that term for the interference caused by the circuitry or power source of a sound level meter. There are several ways to measure the residual level or the level not attributable to the source in question. One obvious way is to measure the neighborhood noises without the source in operation. Another way is to walk away from the source until the sound level reaches a stable level or begins increasing from the influence of another source. A third way, but the least desirable from an enforcement point of view, is to go to a neighborhood of similar character and obtain a measurement. Similarly, in performing an acoustical survey of a community, the level due to all normal neighborhood sources must be measured.

a. Statistical Method, L90

One way of determining the residual level is to use the statistical method described on page 17, and find the L90 level. In some community noise ordinances, the residual level is defined as the L90. The L90 is the sound level exceeded 90% of the time.

2. Maximum Level

The maximum sound level produced by a source is used in some ordinances as the enforcement limit. It may be correlated to the effect of the noise in terms of startle, communication interference, sleep interference, hearing loss, or annoyance.

a. Maximum Sound Level

Some community noise ordinances are written using the phrase "the sound level shall not exceed 65 dBA". The maximum sound level, Lmax, is the level used for enforcement. The measurement procedures accompanying the ordinance specify the time weighting of the meter (usually slow) for measuring the maximum. Care should be taken that the event measured is typical of the noisy operation causing offense and not an unusual event. The example that has been used is that dropping a can on one side of the property line will surely violate a noise code written with an Lmax. However, the offender is not cited for a violation of the maximum sound level for such an isolated event.

The maximum sound level is used in acoustical surveys to point out a specific source when a range of typical levels is given. The results of the survey may be written "in general the sound varied between 35 and 40 dBA, with a maximum at 45 dBA due to a dog barking." Note that the maximum sound level was attributable to a specific source.

b. Impulse or Peak

When the sound is impulsive, it may cause a startle reaction. The sound should be measured using either the impulse or the peak setting of the sound level meter. The impulse setting integrates the sound over a period of 35 ms. The peak setting will show the maximum sound pressure level sensed by the microphone.

c. Sound Exposure Level

When monitoring sound from discrete events such as an airplane flyover or a truck pass-by, the Sound Exposure Level (SEL or Lse) can be used. (See page 33.) It does not actually describe the maximum sound level due to a source, but the area under the curve of the time-history of a noise event.

d. Statistical Evaluation

The statistical descriptor of the maximum sound level is generally defined as the level exceeded 10% of the time (L10) but it can be the level exceeded 1% of the time (L1). The method for determining the statistical levels is given on page 17.

3. Average Level

In acoustical surveys, to find the character of an area, the sound level of each individual source is not as important as the average level of all of the sources. For this reason, descriptors are used which average the sound over a certain time period. These descriptors cannot be used to enforce a noise ordinance because they do not single out a sound source. They simply compile a time history of the noise, and yield an average number. The one exception is the Leq. Some noise ordinances have been written using an Leq taken over a time period short enough to say that the total sound measured was due to a single source.

a. Equivalent Sound Level

The Equivalent Sound Level (Leq) is the continuous A-weighted level that is equivalent in noise energy to the actual fluctuating noise over the specified time interval. It may be used to characterize the sound over a period of a day (the 24-hour Leq) for an acoustical survey of an area. It quantifies noise exposure under varying conditions over long periods of time. It is closely tied to the health effects of noise. (See page 15.)

The Leq over a shorter period of time may be used for enforcement of a noise ordinance. The ordinance may be written such that "the sound level shall not exceed an Leq of X dBA for a period of 10 minutes." The enforcement officer must then use an integrating sound level meter for his measurement and compute the Leq for a period of 10 minutes. The residual Leq for 10 minutes must be subtracted from the total level to find the level due to the source unless the residual level is 10 dBA less than the total level. In that case, the total sound is said to be due to the source.

For community noise the Leq can be approximated by the L10 - 3 dBA but this should not be used for enforcement.(18)

b. Day-Night Equivalent Sound Level

The Day-Night Equivalent Sound Level (Ldn) is the Leq for a 24-hour period with an additional 10 dB weighting imposed on the levels occurring during nighttime hours. The night is from 10 pm to 7 am. The Ldn is used to characterize average sound levels that people are exposed to during the day and night with a penalty for the night noise which occurs at a more sensitive time, and is therefore more annoying. Health effects are well correlated to the Ldn so it is used for acoustical surveys. It is not used for enforcement monitoring since it takes all sources into its average.

c. Statistical Method, L50

The median noise level from a series of noise level measurements is the L50. The method for finding the L50 is described in the Health Effects section. If the distribution of noise level readings is Gaussian, the L50 level would be (L10 + 190)/2.

Land Use Planning

Land use planning allows a community to accommodate all of its diverse interests and still retain good environmental quality in its residential areas. The purpose of planning is to provide distinct areas compatible for the functions of industry, commerce, residences, and recreation. The environmental impact, including noise, of new developments, highways, and airports is considered before they are built and measures are taken to mitigate the problems.

In developing a comprehensive plan, airports and surface transportation systems should be given special attention since they are the most pervasive noise sources in the typical community. Development in the area surrounding these sources should be closely scrutinized. Compatible land use around a noise source such as an airport might involve one of these approaches: (1) land use involving few people, such as reservoirs, sewage treatment plants; (2) use which is inherently noisy, such as truck repair, printing; (3) indoor use with sound insulation.

1. Noise Contours

If noise is to be considered before a highway or airport is to be built, a method of predicting the noise levels from these sources is necessary. Models have been developed from empirical evidence to predict sound levels from various transportation sources. These models have also been used to show the zone of influence of an existing noise source to plan development around it. Building inspectors may require buildings built within a 65 dB contour to have sound insulation to cause a 15 dB drop in sound level inside. The zoning board may prohibit new building within a 75 dB contour. The descriptors used for noise contours follow.

a. Equivalent Sound Level

The equivalent Sound Level (Leq) is useful for drawing contours of various sound levels because it is designed to give the equivalent steady noise level in a given period. It integrates the fluctuating noise and gives a measure of the total noise exposure from all sources and combinations of sources. Measurement equipment is commercially available. The Leq can be predicted from such basic information as number of events, intensity of one event, distance from source. The Leq is correlated with noise effects and annoyance. It is useful for enforcement purposes as well as planning and monitoring. Because the Environmental Protection Agency has endorsed the Leq for evaluating the environmental impact of noise sources, it is very widely used.

b. Day-Night Equivalent Sound Level

The Day-Night Equivalent Sound Level (Ldn) is used in the same manner as the Leq. However, since the Ldn has a 10 dB penalty for night noise, it is better for predicting effects such as sleep interference in residential neighborhoods.

c. Traffic Noise Index

The Traffic Noise Index (TNI) is a method for summing exposures to traffic noise over a 24-hour period, without taking the traffic volume or traffic mix (% trucks) into account. The TNI is defined as: (22)

$$TNI = 4\ (L10 - L90) + L90 - 30$$

where L10 and L90 are noise levels exceeded 10% and 90% respectively. (The method for determining L10 and L90 levels is described on page .) The first term: 4 (L10 - L90), describes the variability of the noise; the second term: L90, is the residual noise level; and the third term: 30, is just to yield convenient numbers.

A TNI of 74 is used for planning purposes, to restrict the minimum distance that buildings should be located adjacent to highways.(22) This is based on a 1 in 40 chance that the average person would be dissatisfied with the noise from the road.

The main advantage to the TNI as opposed to other descriptors is that it considers the variability of the noise. It is much more annoying for a few vehicles to pass by in a relatively quiet area, than to have steady traffic. The disadvantage is that it applies only to existing roadways, and is not predictable by computer modeling.

2. Interior Building Spaces

The space inside buildings should also be planned with regard to noise. The following descriptors are used both as a means of evaluating existing noise problems and to define design goals.

a. Noise Criteria

The rating scheme used for interior noise levels is the Noise Criteria (NC) set of values. The curves are shown in Figure 12. For existing buildings, the indoor noise is measured in octave bands. The values are graphed on the chart. An office is said to have a noise criterion of 40 if none of the octave band levels for NC-40 are exceeded, but noise at one or more bands exceeds the NC-35.

The NC curves can be used to specify a goal for the design of an interior noise level. The problem with the NC curve is that if the background level is generated with a spectrum that comforms to an NC curve shape, the sound is not pleasant or neutral. It has been described as both "hissy" and "rumbly".

b. Preferred Noise Criteria

The Preferred Noise Criteria (PNC) curves were developed to overcome the objection to the NC curves. They are shown in Figure 13. They are used in exactly the same manner as the NC curves however, if a sound spectrum is generated to fit the PNC curve it has a more neutral sound. The PNC curves are more steeply sloped toward the high frequencies. Table V shows some recommended NC and PNC values for designing different room environments.

3. Trend Analysis

In assessing environmental impacts, comparing alternative designs to diminish noise impacts, and measuring the success of noise control strategies, a long term measure of noise impacts is needed. The number of people affected by airport noise in 1970 can be compared with the number in 1980 to assess the effect of quieter planes. The following descriptors are used.

a. Equivalent Sound Level Contours

Contours can be drawn around an airport showing the areas affected by an Equivalent Sound Level (Leq) greater than 50, 60, 70, and 80 dBA. These contours will change based on the type of airplane landing at the airport. The newer planes are designed to be about 10 dBA quieter. They will change if new runways are constructed or old runways lengthened. The number of flights may change. Thus contours can be used to

Figure 12: Noise Criteria (NC) curves (38).

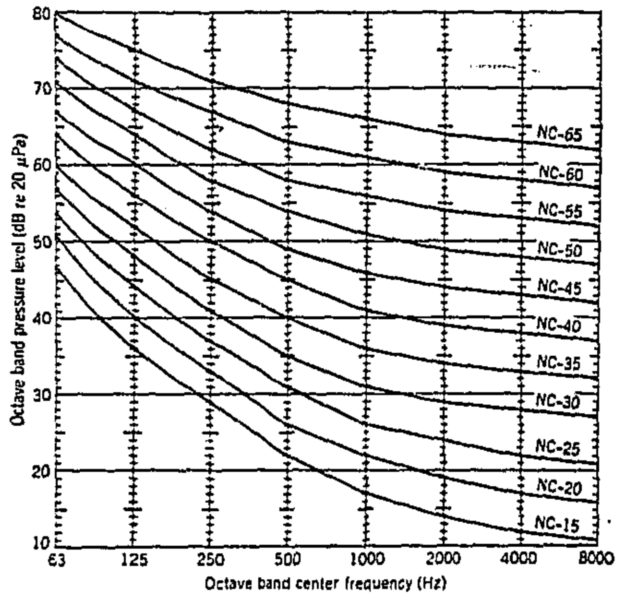


Figure 13: Preferred Noise Criteria (PNC) curves (38).

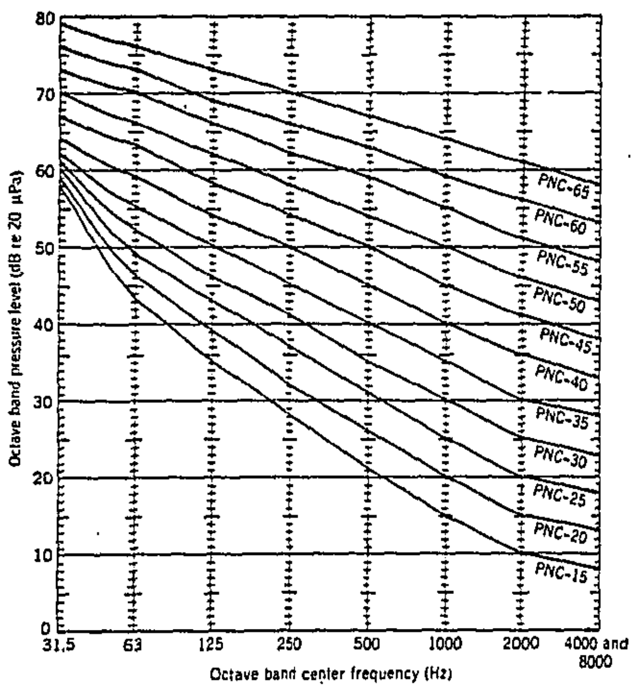


Table V: Interior Building Space and Suggested Noise Criteria Range (38).

Type of Space	PNC	NC
Concert hall	10-20	10-20
Church	< 20	15-20
Conference room	< 35	25-30
Bedroom, hospital	25-40	25-35
Living room	30-40	35-45
Restaurant	35-45	35-50
Shop, garage	50-60	---

illustrate changes in the noise-affected areas surrounding an airport. This does not actually show the changes in the number of people affected by the noise. Flights may have been diverted so that the approach is now over water, or an industrial area. Land surrounding an airport may have been purchased by the airport proprietor so that people are not actually living in the noise-affected area.

b. Sound Level Weighted Population

The Sound Level Weighted Population (LWP) considers the people affected by the noise. Not all people are 100% impacted by noise from the airport. The great majority of people are partially affected by noise of varying intensity. The LWP weights the intensity of the noise and the number of people affected. A few people subjected to loud sound are equivalent to a large number of people affected to a lesser extent. The formula follows: (39)

LWP = SUM P(Ldn)i * W(Ldn)i

where SUM is the summation of successive increments of noise exposure,

P(Ldn)i is the number of people subjected to the increment i

W(Ldn)i is the weighting function for the increment i. The values for the weighting function are given in Table VI. The weighting functions were obtained from the % people highly annoyed by the noise levels.

The LWP is used to measure the total noise impact of a proposed project. It can be used to compare alternatives. It is useful in trend analysis to determine if fewer people are affected by the noise now that abatement procedures are used. Thus it is used to measure the effectiveness of noise abatement programs. Although the example cited was airport noise, the LWP could be used for any noise source affecting people.

for example, suppose two sites were being considered for an airport runway. In one location, 20 people lived close to the site and would be subjected to an Ldn of 85 dB. The alternative site did not have anyone living so close, but a small town of 700 people will be subjected to an Ldn of 50 dB. Using the LWP to assess the alternatives, the first site has an LWP of 14.5, while the second site has 16.1. It would be better to cause a greater impact on those 20 people than to subject the whole town to a lesser amount of noise.

Table VI: Values of the Weighting Function for General Adverse Response (39).

L_{dn}	$W(L_{dn})$	L_{dn}	$W(L_{dn})$	L_{dn}	$W(L_{dn})$
35	0·002	52	0·030	69	0·224
35·5	0·002	52·5	0·032	69·5	0·234
36	0·003	53	0·035	70	0·245
36·5	0·003	53·5	0·037	70·5	0·256
37	0·003	54	0·040	71	0·267
37·5	0·003	54·5	0·043	71·5	0·279
38	0·003	55	0·046	72	0·291
38·5	0·003	55·5	0·049	72·5	0·303
39	0·004	56	0·052	73	0·315
39·5	0·004	56·5	0·056	73·5	0·328
40	0·005	57	0·060	74	0·341
40·5	0·005	57·5	0·064	74·5	0·355
41	0·006	58	0·068	75	0·369
41·5	0·006	58·5	0·072	75·5	0·383
42	0·007	59	0·077	76	0·397
42·5	0·007	59·5	0·082	76·5	0·412
43	0·008	60	0·087	77	0·427
43·5	0·008	60·5	0·092	77·5	0·443
44	0·009	61	0·098	78	0·459
44·5	0·010	61·5	0·104	78·5	0·475
45	0·011	62	0·110	79	0·492
45·5	0·011	62·5	0·116	79·5	0·509
46	0·012	63	0·123	80	0·526
46·5	0·013	63·5	0·130	80·5	0·544
47	0·014	64	0·137	81	0·562
47·5	0·015	64·5	0·144	81·5	0·581
48	0·017	65	0·152	82	0·600
48·5	0·019	65·5	0·160	82·5	0·620
49	0·020	66	0·168	83	0·640
49·5	0·021	66·5	0·176	83·5	0·660
50	0·023	67	0·185	84	0·681
50·5	0·024	67·5	0·194	84·5	0·703
51	0·026	68	0·204	85	0·725
51·5	0·028	68·5	0·214		

Subjective Response

Since noise is defined as "unwanted sound" there is an inherent subjectivity in the decision of classifying some particular sound as noise. There is a relationship between the physically measurable qualities of a sound and the subjective judgment of it. Subjective measurements of noise depend on three parameters:

1. the physiology of the ear (The sound must be detectable.)
2. the psychology of the individual (The nervous sensation of the sound is interpretted by the brain.)
3. the group perception. (The opinion of a statistically significant number of people is averaged.)

A jury cannot go around and listen to each sound and determine if is is noise. Instead studies have been done in laboratories to find out some fundamental relationships between sound and the way it is perceived. From these studies, a number of noise descriptors have been developed to illustrate the way humans respond to sounds of varying intensities, frequencies, and time-scales.

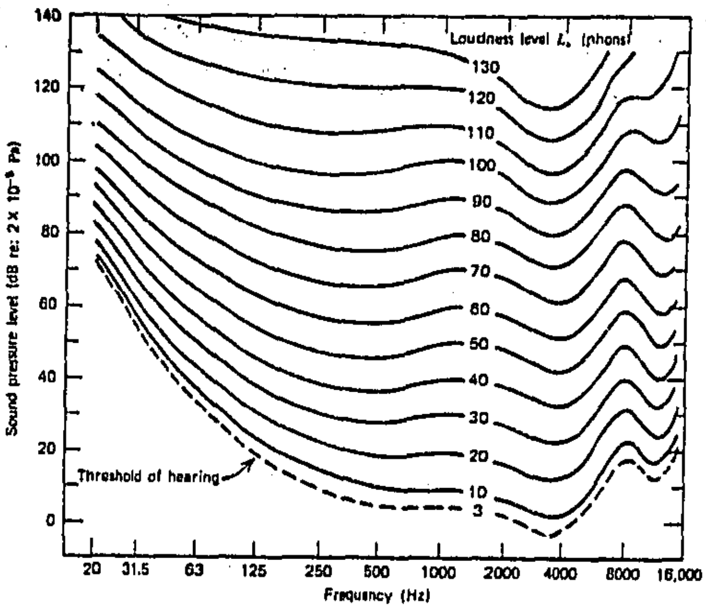
A. Loudness

The subjective correlary of intensity is loudness. Loudness is defined as the magnitude of sensation produced by sound impinging on the eardrum. Certain frequencies are perceived as louder than others even though the sound energy is the same.

a. Phons

In Paris, in 1936, the International Standards Organization adopted 1000 Hz as the standard reference tone.(22) The subjective magnitudes of all other frequencies were then compared to the 1000 Hz tone. The unit, phon, was used to express the equivalent loudness of every decibel at 1000 hz. Loudness level contours were drawn to relate the sensation of loudness vs. frequency. They are shown in Figure 14. The contours were found by having a statistically significant number of people listen to two alternate sounds, one of which was the 1000 Hz reference tone. They judged that a 20 Hz tone at 78 dB was as loud as a

Figure 14: Equal Loudness Level Contours (Phons) Expressed in Decibels Relative to 0.0002 μbars, for Average Listeners for Narrow Band or Pure Tones (22).



1000 Hz tone at 20 dB, and a 4000 Hz tone at 13 dB.

The A and B weighting networks for the sound level meter are based on the equal loudness contours. They are simplified for the electrical network simulation so are not exact duplications of the phon curves.

b. Sones

The problem with the phon scale is that the numbers assigned to the scale do not correspond to the listener's intuitive evaluation of relative loudness. A doubling of loudness only means a change of 10 phons. People intuitively think that a sound that is twice as loud as 40 phons should be twice as much, or 80 phons. Actually, it is only 50 phons. The sone scale was adopted by the International Standards Organization in 1947 (22) to resolve the problem.

A sone is defined as the loudness of a 1000 Hz tone at 40 dB intensity. It is also defined as the loudness of any sound having a loudness level of 40 phons. A doubling of the loudness corresponds to a doubling of sones. Mathematically:

sone = antilog 0.03 (phon - 40)

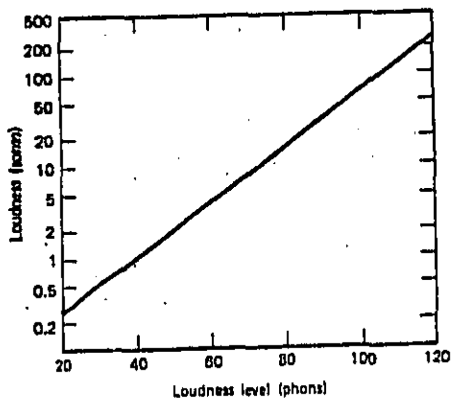
The relationship is shown in Figure 15. Some common sounds are identified in the folowing table in both sones and phons.

LOUDNESS LEVEL PHONS		LOUDNESS SONES
120	jet	256
110		128
100	subway	64
90	truck	32
80		16
70	vacuum cleaner	8
60	conversation	4
50		2
40	quiet room	1
30	whisper	0.5
20	sound studio	0.25

c. Loudness Index

Loudness levels based on sones and phons originated with subjective judgments based on pure tones or narrow frequency bands. The weighted sound level is an estimate of the loudness of a pure tone. However,

Figure 15: Relation Between Sones and Phons (22).



community noise is generally spread over a broad band of frequencies. Use of the weighted sound level to predict loudness of a broad band noise can result in errors of more than 10 phons. (18) The loudness index was developed for broad band noise.

1. Stevens

In 1961, Stevens described the following method for calculating the loudness of broad band noise. (22)

1. Using an octave-band analyzer, record the sound pressure level in each of the eight octave bands having center frequencies of 63, 125, 250, 500, 1000, 2000, 4000, and 8000 Hz.
2. Use the graph (Figure 16) to determine the loudness index of the observed noise for each octave band.
3. The total loudness of the noise in sones (St) is given by:

$$St = Sm + 0.3 (S - Sm)$$

where Sm is the largest of all of the loudness indices and S is the sum of the loudness indices of all of the bands.

4. The total loudness level is then obtained by converting the total loudness (in sones) to a calculated loudness level in phons. (22)

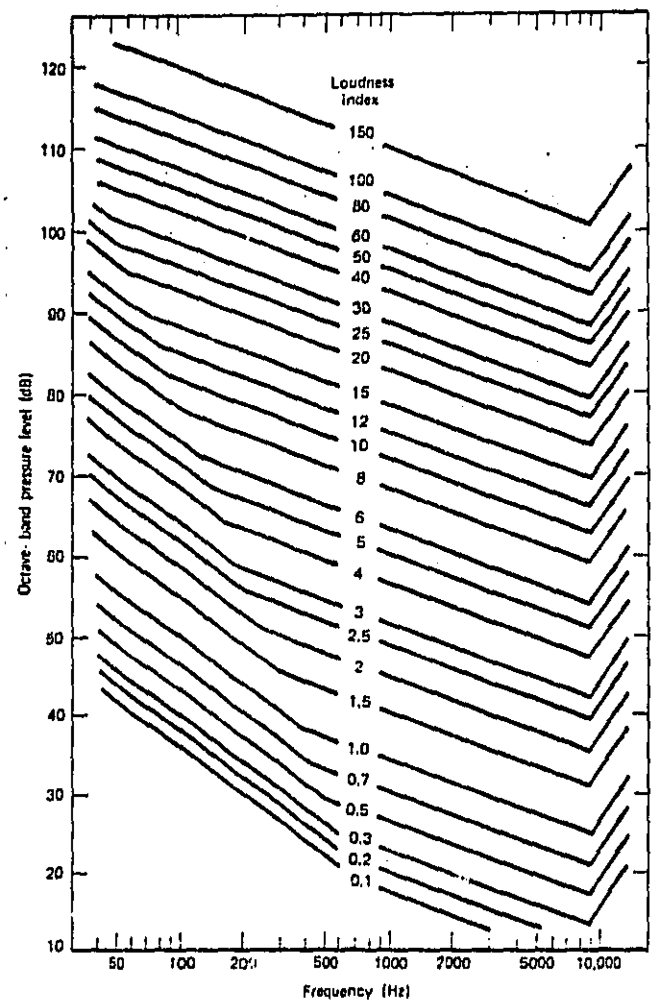
For example, a compressor has the following sound spectrum:

Frequency	SPL	Loudness Index
63Hz	78dB	5
125Hz	84dB	12
250Hz	88dB	20
500Hz	88dB	20
1000Hz	90dB	30
2000Hz	77dB	15
4000Hz	62dB	8
8000Hz	60dB	8

$$St = Sm + 0.3 (S - Sm)$$
$$St = 30 + o.3 (118 - 30)$$
$$St = 56.4 \text{ sones}$$

The factor of 0.3 in the formula accounts for the fact that the loudest band masks the contribution of the other bands. The factor should be changed to 0.15 if the calculation is done for 1/3 octave bands. However, the factor implies that the masking is symmetrical around that frequency. In fact, the loudest band masks

Figure 16: Contours Developed by Stevens. A Loudness Level Index in Sones can be Determined by Measuring the Sound Pressure Level of Eight Octave Bands.



noise of high frequency more than bands of low frequency.

2. Zwicker

Zwicker developed a complicated calculation which accounted for the upward spread of masking. The calculation has been adapted for use on a computer as the calculations are too tedious to be done by hand. Typically, results calculated by the Zwicker method are 5 dB higher than Stevens loudness level.(40)

3. Robinson

Robinson modified Stevens' Method to account for Zwicker's asymmetry of masking. Robinson's adaptation (40) is to add the loudness indices from Figure 15 starting from the lowest band. The loudness index is taken at full value if it is greater than or equal to the preceeding band. If it is less that the preceding band, it is added at 0.3 times the value. With this modification, the values are about equal to Zwicker's.

d. Perceived Noise Level

The annoying quality of noise is more than just the loudness. There are various psychological effects. The following considerations relate to the degree of annoyance of noise. (22)

(1.) High frequency sounds are more annoying than those of low frequency.

(2.) Continuous noise is more annoying than noise of short duration if it occurs infrequently. However, there may be a "startle" effect for intense sounds.

(3.) Noise of moderate intensity is not found objectionable unless the source can be identified or at least the direction associated with the sound.

(4.) Any judgment of annoyance is based on the situation, (the time of day or the activity of the listener.)

(5.) If both sounds are of equal loudness, machine noise is considered more annoying than natural sounds like wind, rain, waterfalls, or the ocean.

(6.) Even loud sounds are not too annoying if they do not occur often (jets) and sleep is not interrupted.

Kryter introduced a method for determining the annoyance due to noise. It is called the Percieved Noise Level.(22) It is based on contours of equal noisiness called "noys" which are shown in Figure 17.

Figure 17: Kryter's Contours of Perceived Noisiness (NOYS) That are Used to Determine Annoyance (22).

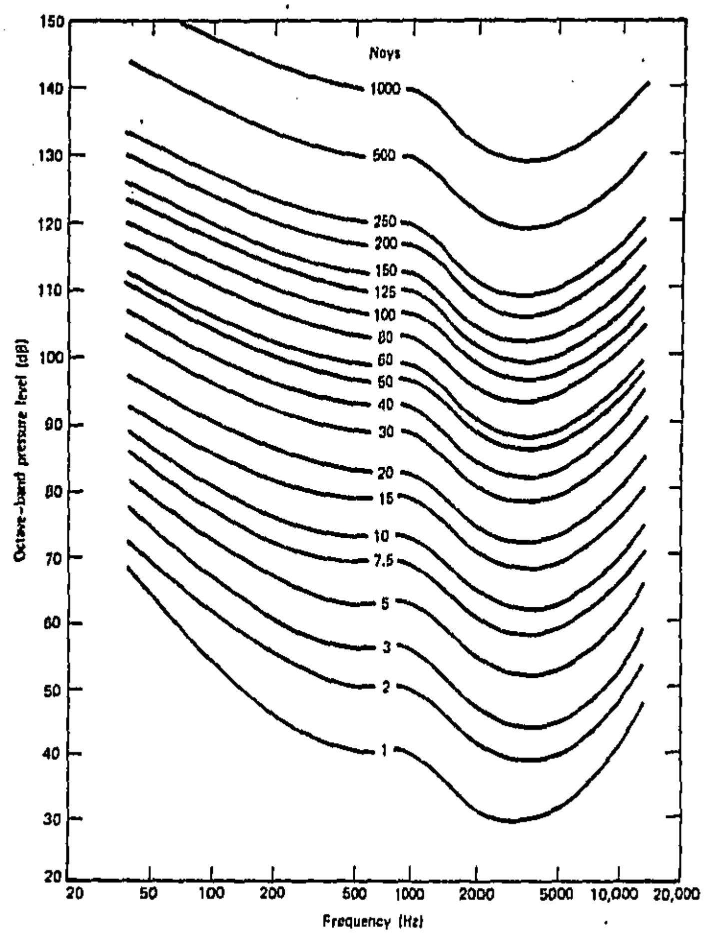


Figure 4 Kryter's contours of perceived noisiness (noys) that are used to determine annoyance. The total annoyance is determined by measuring the sound pressure level in various octave bands. [From K. D. Kryter, *J. Acoust. Soc. Am.*, *31*, 1415 (1959).]

These were obtained by relative annoyance judgments of narrow bands of noise. The approach is similar to Stevens' Loudness Level. The noise is analyzed by octave bands and each is assigned a contour of noys. These are substituted into the formula:

$$Nt = Nm + 0.3\ (N - Nm)$$

where Nt = total noisiness in noys
N = sum of all noys
Nm = maximum noy level

The total noisiness (Nt) in noys is then converted to Perceived Noise Level (PNdB) by the formula:

$$PNdB = 40 + 0.03 \log Nt$$

Noys are limited to sounds of equal duration since for two equally loud sounds, the one lasting longer is judged to be more annoying for levels exceding the annoyance threshold.

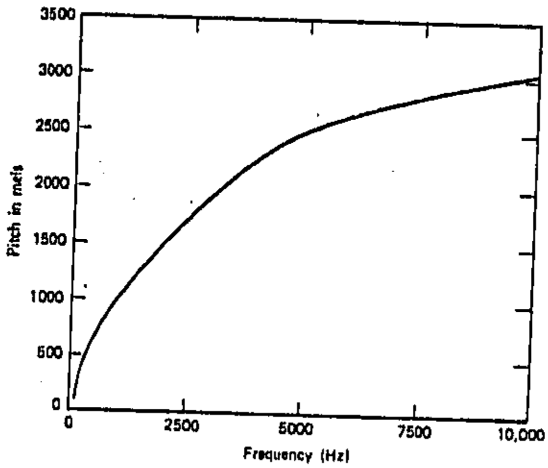
The Perceived Noise Level, PNdB, is approximately equal to the D-weighted sound level + 7 dB.(40)

B. Pitch

a. Mels

The descriptor for the subjective perception of frequency is the mel. A tone of 1000 Hz is defined as having a pitch of 1000 mels. A pitch that is perceived as twice as high as 1000 mels is 2000 mels. Figure 18 shows the relationship between frequency and mels.

Figure 18: Relationship Between Pitch in Mels and Frequency



Summary

Table VII: List of noise descriptors and how they are used, as outlined in this paper.

Descriptor	Health Effects	Regulations	Standards	Monitoring Surveys	Land Use Planning
dBA	X	X	X	X	
TWA	X				
Leq	X	X		X	X
Peak/ Impulse	X			X	
AI, S/N	X				
SIL, PSIL	X				
PNL		X			
EPNL		X			
dBD		X			
Ldn		X		X	X
SEL		X		X	
CNEL		X			
NEF		X			
CNR		X			
L10, L90		X		X	
SPowerL			X		
SPL			X		
Rating Numbers			X		
Attenuation			X		
AC			X		
STC, IIC			X		
TNI					X
NC					X
PNC					X
LWP					X

Discussion

As a noise regulating body, the Environmental Protection Agency has had a tremendous impact on the descriptors which are accepted. The Leq and Ldn met the EPA's criteria for correlation with health effects and annoyance. Because of the EPA's advocacy of these descriptors, they are in widespread use today in the monitoring and regulation of noise, as well as land use planning. Although the EPA has dropped out of the noise abatement field, much of the noise data already collected is in terms of Leq. Since the Leq is an energy average, this has effectively smoothed out all the peaks and valleys of noise exposure. In traffic and aircraft noise, it is the peak levels that bring the most complaints. And it is the peaks that noise enforcement personnel can ticket for loud mufflers or retrofit the airplanes. There is very little change in the Leq or Ldn with rigorous enforcement activity, so these descriptors are not useful for evaluating the effectiveness of noise control programs.

While the EPA has declared the Leq the descriptor for noise regulation, they have proposed regulations that only eliminate the peak sounds. The truck regulation is estimated to only catch the top 5% noisiest trucks. Measuring the success of the truck regulation in terms of the Leq shows no change in the noise environment with an aggressive noise enforcement program. (Preliminary results from a study by the National Association of Noise Control Officers support this statement.) Yet it is the noise peaks that the people along highways find most annoying. They are grateful for the noise abatement programs.

This is different from the predicament of people living near an airport. Although the newer airplanes are designed to be quieter, any flyover that wakes them is a problem. The Leq or even Ldn contours (or any average level) is not important. The peak level is what they focus on.

Much time and energy has gone into finding the descriptor which correlates best with what the "average" person perceives as noise. Once again the "average" is important. Yet there are peaks and valleys of people, and their perception of noise. Many noise regulations are designed to protect the "reasonable person of normal sensitivities". The extra-sensitive person is ignored. To give an example from another field, suppose one were to hit a person with hemophilia. That person would be protected to a greater extent by law, than someone who would not bleed to death from a scratch. Why are noise sensitive individuals ignored?

Because the EPA no longer has an Office of Noise Abatement and Control, the regulation of noise has been turned over to the state and local governments. One possible outcome is that this will cause a change in the use of noise descriptors to those that are more specific to an individual's response to the noise. The opposite scenario may take place, however, where international organizations will control which descriptors will be accepted. The third possibility is that the EPA's influence has already been so great that the Leq and Ldn will remain the descriptors of choice for just about every situation.

It is my opinion that local government has the responsibility to protect the individual's right to a quiet environment so should use the descriptor that would show the most annoying peaks of an individual's noise exposure. The international standards organizations are so far removed from people, they should use noise descriptors that are the best, technically, to draw specifications for equipment. Engineering is their prime concern, with human response only in the abstract - from psychoacoustical studies. The federal government which has to have the greater good of the nation as its goal, should continue using averaging descriptors such as Leq and Ldn for their noise abatement goals. If the EPA resurrects its Office of Noise Abatement and Control, they should be concerned with the reasonable person of normal sensitivities.

Conclusion

In this paper noise descriptors have been categorized according to their uses. Some descriptors (like the Leq) are used for multiple purposes. Others (like the LWP) are very specific. When analyzing noise, the wrong descriptor can make the data useless. This paper has shown the correct descriptor for the circumstance. Where possible an equation has been given to allow approximate conversions between descriptors.

Suggestions have been given for the most appropriate descriptor for the level of government. The federal government should use descriptors such as the Leq or Ldn which correlate with the average person's response to the noise. International standards organizations should use engineering descriptors to technically specify the noise from various pieces of equipment. But state and local governments should have the health of the individual in mind when setting noise regulations. They should use terms, like maximum A-weighted sound level, which show the peaks that individuals find so annoying.

APPENDIX

Compilation of Standards Organizations and Associations (41)

Acoustical and Board Products Association
205 West Touhy Avenue
Park Ridge, IL 60068

Acoustical Society of America
335 East 45th Street
New York, NY 10017

Air Conditioning and Refrigeration Institute
1815 North Fort Meyer Drive
Arlington, VA 22209

Air Diffusion Council
435 North Michigan Avenue
Chicago, IL 60611

Air Moving and Conditioning Association
30 West University Drive
Arlington Heights, IL 60004

American Gear Manufacturers Association
1330 Massachusetts Ave. NW
Washington, DC 20005

American National Standards Institute
1430 Broadway
New York, NY 10018

American Petroleum Institute
Refining Department
2101 L Street, NW
Washington, DC 20037

American Society for Testing and Materials
1916 Race Street
Philadelphia, PA 19103

American Society of Heating, Refrigerating and Air-Conditioning Engineers
345 East 47th Street
New York, NY 10017

American Textile Machinery Association
1730 M Street, NW

Washington, DC 20036

The Anti-Friction Bearing Manufacturers Association, Inc.
60 East 42nd astreet
New York, Ny 10017

Association of Home Appliance Manufacturers
20 North Wackjer Drive
Chicago, IL 60606

Compressed Air and Gas Institute
2130 Keith Building
Cleveland, OH 44115

Diesel Engine Manufacturers Association
2130 Keith Building
Cleveland, OH 44115

Home Ventilating Institute
230 North Michigan Ave.
Chicago, IL 60601

Industrial Silencer Manufacturers Association
c/o Burgess Industries
P.O. Box 47146
Dallas, TX 75247

Institute of Electrical and Electronic Engineers
445 Hoes Lane
Piscataway, NJ 08854

Instrument Society of America
400 Stanwix Street
Pittsburgh, PA 15222

International Conference of Building Officials
5360 South Workman Mill Road
Whittier, CA 90601

International Electrotechnical Commission
(available from ANSI)

International Organization for Standardization
(available from ANSI)

National Electrical Manufacturers Association
845 15th Street, Suite 438
Washington, DC 20005

National Fluid Power Association
3333 N. Mayfair Road

Milwaukee, WI 53222

National Machine Tool Builders Association
7901 West Park Drive
McLean, VA 22101

Power Saw Manufacturers Association
Box 7256, Belle View Station
Alexandria, VA 22307

Society of Automotive Engineers
400 Commonwealth Drive
Warrendale, PA 15096

Woodworking Machinery Manufacturers Association
1900 Arch Street
Philadelphia, PA 19103

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