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Summary

Noise is becoming pervasive. It causes accidents, is annoying, and interferes with communication (1). Attempts are being made to reduce noise through both legislation and technical control. This introductory bulletin defines the unit usually used to quantify sound intensity, the A-weighted decibel, and illustrates its meaning with familiar examples.

Introduction

Noise is easily described as any unwanted sound. Scientific investigations require numerical data and use total sound rather than unwanted sound since instruments are generally unable to distinguish wanted from unwanted. Since sound can be measured using instruments which emphasize or weight various portions of the frequency spectrum (2), various measuring scales are in use. Further mathematical manipulation of the data coming from the instrument may also be performed to generate values which approximately indicate various effects of the sound on humans, such as loudness, annoyance or speech interference (2). There are consequently a number of systems used for quantifying these effects. The system which is generally used involves simply the direct measure of sound pressure using a meter with an"A" filtering system. This A filter approximates the sensitivity of the human hearing system to various frequencies (2). Measurements are made in units called decibels (db) and usually with the A filter, resulting in A-weighted decibels (dbA).

This A-weighted decibel will be illustrated by giving values for familiar sounds, but an explanation of the technical basis of the measure will be useful in understanding some of the problems of controlling noise. A simple explanation follows. The range of human ability to hear is extremely wide, with the maximum tolerable sound pressure being approximately 10^9 times the pressure of the minimum detectable sound (2). A logarithmic measuring system helps reduce this range. Furthermore, human hearing is approximately logarithmic in nature (2). For example, a person judges one sound to be a certain amount louder than another sound, but instruments measure the sound pressure to be ten times stronger. To make another sound which will be judged to be this same amount louder than the second sound (or twice this amount louder that the first sound) one might at first assume that it would be only 10 plus 10 larger on the instrument but actually it will require a sound pressure 10 times 10 larger according to the meter. Thus relationships which appear additive to the human ear are multiplicative for a physical measuring instrument. Consequently the human hearing system is most conveniently described in logarithmic terms.

Hearing measurements, historically originating in telephone research, use the "bel", or one tenth of it, the decibel, as the fundamental unit of the logarithmic measure. The reference, or zero, for bels and decibels is the very weak sound which a young person of very good hearing would just be able to detect in an extremely quiet location. This is zero decibels and is a sound pressure of only 2.9×10^{-9} lbs. per square inch (3). Sound measurements are usually made relative to this slight sound which most persons could not hear. The measure of any sound, in decibels, is twenty times the logarithm to the base ten of the ratio of the pressure of the sound being measured to the pressure of the reference sound. Thus,

$$\text{sound (decibels)} = 20 \log_{10}\left(\frac{\text{pressure of sound measured}}{\text{pressure of reference sound}}\right).$$

Notice that every twenty-decibel increase on a sound level meter means that the actual physical sound pressure has increased by a factor of ten. Mufflers or sound absorbing material will have to reduce the physical sound intensity to 10% of its original level in order to reduce the meter reading by 20 decibels.

The discussion above was concerned with the actual physical sound and its measurement on instruments. These are the quantities specified by laws and building codes and affected by changes such as putting up acoustical tile. To see how much we will benefit by a given reduction in sound level we have to change from physical measurements to loudness, thus involving human hearing judgements. As mentioned earlier, human hearing was long thought to be nearly logarithmic but more accurate measurements of loudness indicate that it is only approximately logarithmic. Sones are a unit used for measuring human judgements of loudness. Loudness, in sones, can be related to sound pressure level, in decibels, by the formula below.

$$\text{Loudness(sones)} = \left[20 \log_{10}\left(\frac{\text{pressure of sound meas.}}{\text{pressure of ref. sound}}\right) - 40\right]^{0.6}.$$

This system is arbitrarily biased by 40 db. so that 40 decibels of physical sound intensity is called zero loudness. If hearing were perfectly logarithmic the exponent in the formula would be unity rather than the value of 0.6. This value is an average obtained from experiments on many subjects. It actually varies with both the frequency (pitch) and the duration of the sound. Using the exponent 0.6, which is the average for a somewhat changing value, indicates that each increase in sound pressure by a ratio of ten will cause a sound's loudness to a person hearing it to change by approximately a ratio of four.

The use of decibels greatly compresses the scale for sounds but it must be carefully interpreted. A muffling or sound absorbing device which reduces the sound pressure to one half of its previous value will cause a reduction of the sound by only six decibels. Six decibels is only a small part of some of the sounds we hear. Even in the home some sounds exceed 90 dbA. To reduce such a sound to the 45 dbA recommended by the British for a suburban home (1) would require seven successive reductions by half.

To relate the decibel to common experience we cite some typical situations. A soft whisper at 5 feet and a recording studio for records and tapes would both be about 30 decibels (2) (on the A-weighted scale of filtering). An average residence would be approximately 50 decibels; this 50 dbA is still quiet but sounds 4 times louder than the recording studio. Still another 20 dbA additive increase brings us from 50 to 70 dbA, the sound level of the typical home vacuum cleaner at ten feet (6). This is now 4 times louder than the average residence and 16 times louder than the studio. Still another 20 dbA makes 90 dbA, 64 times louder than the studio. This is the value for a subway train at 20 feet (2), a boiler room (2), or a food blender in the kitchen (5).

The values given above were taken from references (2),(3),(5),and(7). They vary from model to model and with locations. The food blender is given by reference (5) as 88 dbA, and by reference (1) as 80 dbA. Reference (5) shows a variation from 84 to 94 dbA for four lawn mowers, with the average being 89 dbA. A further listing of familiar levels, taken from references (1) and (5) is contained in Table 1.

References

(1) The Noise Around Us, U. S. Dept. of Commerce COM 71-00147 pp 35, 67

(2) A.P.G. Peterson and E. E. Gross, Handbook of Noise Measurement, pp 3 - 66

(3) L. L. Beranek, Noise and Vibration Control, McGraw-Hill, New York 1971 p 33

(4) S. S. Stevens, Procedure for Calculating Loudness, J. Acoustic Soc. Amer. 33, 1577-1585 (1961)

(5) A. Cohen, J. Anticaglia and H. H. Jones, "Sociocusis" - Hearing Loss from Non-Occupational Noise Exposure, Sound and Vibration, Nov. 1970, p 13

(6) K. D. Kryter, The Effects of Noise on Man, Academic Press, New York, 1970, p 344

(7) C. R. Bragdon, Noise Pollution, Univ. of Penn. Press, Phil. 1971 p 52

Table 1. Typical A-weighted sound levels. They are in order of loudness from top to bottom with the examples located as close to the correct vertical position as space allows. They are only representative and would vary with distance, type, model, reflectivity of surroundings.

Sones	Relative Loudness (approximate)	Sound Level (dbA)	Typical Community Sound	Typical Home Sound
1/16	1/16 as loud	0 = Threshold of hearing for young person with good hearing in very, very quiet area.		
1/8	1/8 as loud	10		Just audible
¼	¼ as loud	20		
½	half as loud	30 (very quiet)		
1	reference loudness	40	Residential area (Chicago, night)(2)	Bird calls (44dbA)(3)
2	2 times as loud	50 (quiet)	Light traffic 100 feet away(2)	Average residence (2)
4	4 times as loud	60	Near freeway auto traffic (64dbA)(5)	Conversation (60dbA)(5) Air conditioner at 20 ft(60dbA)(5)
8	8 times as loud	70		Washing machine (62dbA) Electric typewriter at 10 ft (3) TV audio (70dbA) and Vacuum cleaner(5) Dishwasher (75dbA)(5)
16	16 times as loud	80 (moderately loud)	Passenger car 65mph at 20 ft(77dbA)(5) Diesel train,40-50mph;100 ft(83dbA)(5)	Clotheswasher (78dbA)(5) Garbage disposal (80dbA)(5)
32	32 times as loud	90	Motorcycle at 25 ft (90dbA)(5)	Food blender (88dbA)(5) Power mower (89 dbA)(5)
64	64 times as loud	100 (very loud)	Farm tractor (98dbA)(5) Snowmobile (100dbA)(7) Jet plane 1000 ft up (103dbA)(5)	
128	128 times as loud	110		Rock and Roll band (108-114dbA)(5)
256	256 times as loud	120 (discomfort)	Chain saw (7)	