Sound Attenuation Techniques and Technology

By Scott Hansen, President
Hansen Consulting, State College, Pennsylvania

Sound is an important issue that must be understood by proprietors of shooting ranges if they want to survive in today's ever-changing world. Populations are migrating from the city to the quiet of the countryside. Ranges that have existed peacefully for several decades are being encroached upon by new developments and find themselves fighting to stay in operation. This paper will discuss techniques to control sound on ranges, their benefits and limits.

Sound Fundamentals

Sound and noise are perceptually different. Sound is influential in the information and emotion it conveys. For instance, a person subjectively judges a sound to be noisy. Noise can be described as sound which may disturb a community, interfere with sleep and communication, and may be hazardous to a person's health. Noise is sound that may be too loud, unexpected, uncontrollable or occurs at inappropriate times. Even the sound of a dripping faucet is considered noisy and bothersome. Many involved in development or maintenance of shooting facilities are unfamiliar with the science of sound. A short discussion of sound and how it is measured is an appropriate place to begin.

The two major characteristics of a sound that determine its acceptability are intensity and frequency. Intensity is a measure of the magnitude of sound and is directly related to the sound pressure level. The human ear is capable of sensing a wide range of pressure fluctuations, from 0.00002 Pascals (the threshold of hearing) to over 5,000 Pascals. It is convenient to use a logarithmic scale with units of decibels (dB) to report sound pressure levels, because the logarithmic scale converts a range of 1 million in pressure to a range of 120 in decibels. An increase of 10 on the decibel scale represents a 10-fold increase in intensity. Sound intensity cannot easily be measured, but it is proportional to the square of sound pressure, which can be measured. The sound pressure level in decibels is defined as $10\log(P/P_{ref})^2$ where p is the measured pressure and pref is the reference sound pressure of 20Pa (20 microPascals).

Frequency is a measure of the tonal quality of a sound. Because the human ear is not equally sensitive to all frequencies and responds differently at different sound pressure levels, it is difficult to present a simple, single numeric measurement that accurately represents what the ear will hear. This sensitivity led to the use of different frequency weightings. The A and C weightings (see Figure 1) are most commonly used and represent the sensitivities of the ear at low and high sound levels, respectively.

Scott D. Hansen is a 5th-year Ph.D. Candidate at The Pennsylvania State University. He holds a Masters in acoustics, also from Pennsylvania, and a Bachelors in electrical engineering from Syracuse. Through his firm, Hansen Consulting, Scott has conducted community noise assessments for state and local government agencies, developed noise abatement programs, counseled architects in the design of new facilities, and located and evaluated noise control products for racetracks and shooting ranges.

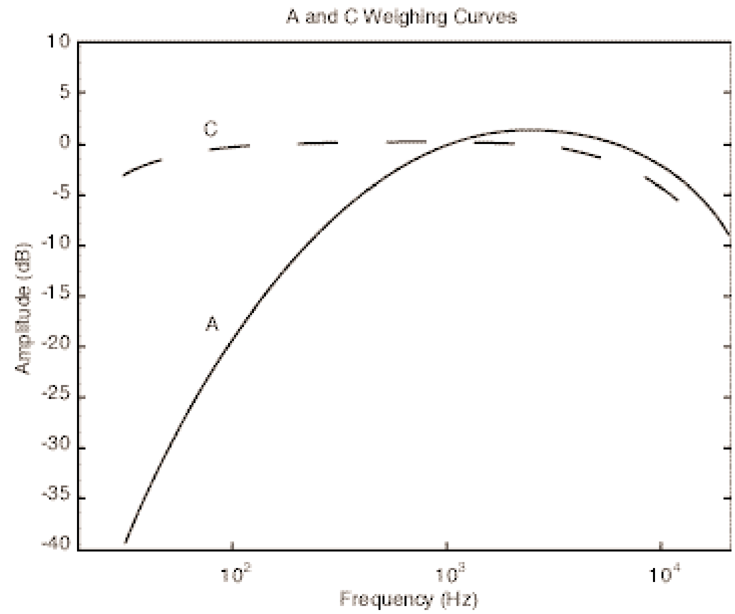

Figure 1. A and C weighting curves.

After a sound is measured and weighted, the root mean square (rms) value of the signal can be determined. The rms is a special kind of mathematical average. The rms value is directly related to the amount of energy in the sound being measured and is regularly used in describing most community noises. Although the perceived loudness of an impulse is lower than a steady continuous sound, the risk of hearing damage is not necessarily reduced. For this reason, the peak value of the sound also may be measured independent of its duration. Some standards require the peak value to be measured, while others ask for maximum rms or peak values of a sound.

It is important to understand the way sound decreases with distance. The attenuation or reduction of sound pressure level in air is 6 dB each time the distance is doubled. The inverse square law states that the sound pressure changes in inverse proportion to the square of the distance. The inverse square law assumes line-of-sight propagation. Obstacles placed between the source and receiver also will decrease the sound pressure level, depending on the type of barrier. Other factors affecting attenuation of sound include ground cover and environmental factors, such as temperature and wind.

Gunshots can result in two distinct noise events: the muzzle blast and the supersonic projectile shock wave. The muzzle blast originates at the end of the muzzle and propagates spherically in all directions. The muzzle blast is very directional, being typically 10 to 15 dB louder in front of the gun than behind the gun.

The shock wave from the projectile propagates supersonically in front of and to the side of the gun. The width of the shock lane is less than the distance from the gun to the target or backstop.

Sound Laws and Regulations

The most common metrics that are used in sound laws are peak sound pressure level (spl), maximum level, equivalent level (L_{eq}), which is an average level over some amount of time, and day-night level, which is a 24-hour average level with a 10 dB penalty for sounds occurring during nighttime.

The U.S. Environmental Protection Agency (EPA) has established guidelines regarding acceptable sound levels for public exposure. This guidelines state that a source that does not exceed a yearly day-night level of 55 dBA is acceptable. The yearly average is to account for day-to-day or seasonal variations.

Many state and local governments go beyond the EPA's regulations, and have developed their own predetermined limits and sometimes state a measurement procedure. For example, Connecticut and New Jersey regulate based on peak levels, whereas Maryland uses maximum levels. The State of Michigan has a state supreme court decision that determines the acceptable amount of sound leaving a range.

Many sound laws are designed to mitigate a current noise source in the community. Those who participate in the development of sound laws must take care to examine the sources of sound throughout the environment. It is common to find sound standards which only state that "no one may exceed a maximum level of 65 dBA at the property line," but do not include any exemptions for lawn care, construction, recreational activities, etc., that frequently exceed the prescribed level. Range owners should be involved in the creation of these laws and, if possible, include exemptions for shooting activity and have the measurement technique described or referenced.

Sound Abatement Techniques

There are many techniques and treatments that reduce the sound levels and exposure on the community surrounding the range. These techniques work best when they are incorporated in the design phase of range construction. However, sound abatement must be reexamined when conditions on or surrounding the range change.

Community Relations

A primary component of an effective noise mitigation program is a proactive and continuous public relations effort. Many people who have problems with neighboring ranges have a "Not in My Back Yard" attitude. They are not against people shooting on a safe range as long as they do not have to hear it. Good community relations are a key and effective strategy in keeping the range open with minimal complaints. A noise mitigation program should include a complaint management procedure. This program should be sensitive to the community's concerns. Invite neighbors and the community to voice their concerns directly to the club, as this allows them to feel that they have some control and that the club is willing to listen. Show them how much you do for the community, e.g., youth training courses, and how shooting competitions translate into money for the community. Communicate what days and hours you are open and when you have competitions.

In addition, it often is helpful to notify the public in advance of particularly noisy events. There may be simple solutions to the problem once you reveal its source. Document all of your public relations efforts and shooting activities. Make members log when and what they shoot. Often, other shooting activity in the area is blamed on your facility.

Barriers

Barriers, such as those found along the highway, can be quite effective in reducing small arms sound. In general, sound can be controlled at the source, receiver or along the transmission paths. Barriers are most effective when they are placed close to the source or receiver and are wider than they are tall. Barriers are very effective in reducing noise to the rear of the range because they can be placed close to the shooters. Barriers along the side of the range are less effective, since they are relatively far from many shooting positions. They also can be placed between firing positions to provide larger attenuation, but this may cause safety and control problems.

Barrier effectiveness is a function of weight (mass), height, length and relative closeness to the source or receiver. These factors will determine the transmission loss through and the amount of sound diffracted around the barrier.

Even if a barrier is massive enough to have significant transmission loss, the reduction can be severely compromised if there are any holes or openings in the barrier. Large holes will transmit the sound directly to the receiver. At the wall the sound pressure increases, resulting in an amplification of the transmitted sound through any small holes. This results in a serious degradation of the barrier effect. A barrier can reduce high frequencies by 10 to 15 dB but only 2 to 5 dB at lower frequencies.

Trees and Other Vegetation

A natural barrier can be formed by trees, shrubs and other undergrowth. Sound is scattered and absorbed by this type of barrier. Foliage absorbs high frequencies, and low frequencies are reduced through ground absorption. Branches and tree trunks scatter the sound. Still, a barrier of this type must be dense, i.e., no developed canopy for sound to propagate under. A sparse forest offers little resistance to propagating sound.

Studies have shown reductions between 3 and 20 dB per 100 meters of dense forest.

As with all barriers, it is better to situate a natural barrier close to the source to maximize its effectiveness. However, placing trees on top of berms may reduce barrier effectiveness by scattering sound downward along the backside of the berm.

Baffle Systems

Reflections from baffle systems can produce louder sounds behind the shooter than the direct sound due to the directivity of the muzzle blast. Most often, the majority of this sound results from the interaction with the first baffle. Therefore, mitigating noise on the first baffle will reduce the loudest event, which has been correlated to complaints. This venetian blind absorber (Figure 2), designed by Karl W. Hirsh of Germany and tested by Larry Pater at U.S. Army Construction

Engineering Research Labratory, is a series of reflector plates, 4 feet wide at a 45-degree angle. The panels can be constructed of 3/4-inch pressure-treated plywood covered with 2-inch fiberglass boards (6 pounds per cubic foot). Sound is reflected upward or hits sound-absorbing surfaces several times before it reflects back toward the shooter. This sound abatement treatment is designed for a 10 dB reduction or 50-percent loss in loudness.

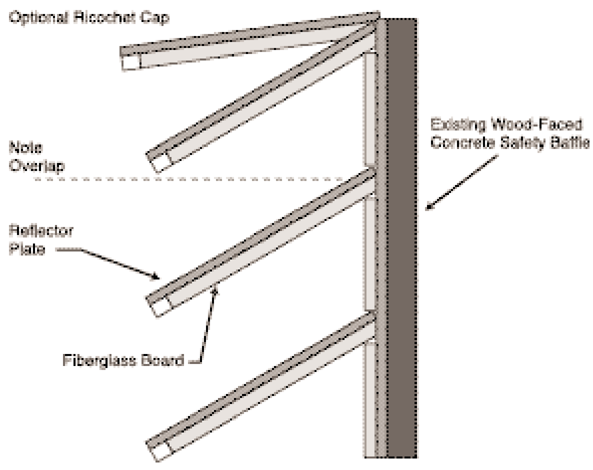

Figure 2. Venetian blind absorber.

Tube Ranges

Tubes, or muzzle blast mufflers, are a relatively new technique used to control small arms sound. The Swiss and U.S. governments have shown that they reduce muzzle blast by 10 to 20 dB. However, the mufflers are not sufficient to stop the projectile shock sound. An additional benefit of reducing the muzzle blast is that it decreases the exposure received by adjacent shooters, limiting the risk of hearing damage.

The 6- to 10-foot long mufflers are constructed of metal, concrete, wood or plastic, with dense insulation attached inside. The muzzle of the small arm is placed inside the tube when discharged.

Shotgun Ranges

Sounds from shotgun ranges, e.g., trap, skeet, five-stand and sporting clays, are more difficult to mitigate than fixed-position shooting of other small arms. Shotguns move to take shots at various angles and elevations. Many of the abatement techniques used on small arms ranges also are applicable to shotgun ranges, such as barriers. However, these techniques also make it difficult to control activities when operating multiple shooting locations.

Conclusion

It is imperative to be prepared for increased pressure from communities as they encroach on ranges. Keeping abreast of any applicable and developing laws and documenting all range activities will maintain a proactive stance to access potential problems before they impact the facility. Several sound abatement techniques have been discussed in this paper. Some design considerations and expected reduction have been discussed where possible. Without totally enclosing the facility, sound will be heard beyond the range property. Community relations are just as vital as implementing sound abatement techniques in a noise mitigation program.