DEPARTMENT OF THE AIR FORCE
AIR FORCE INSTITUTE FOR OPERATIONAL HEALTH (AFMC)
BROOKS CITY-BASE TEXAS

27 Aug 04

MEMORANDUM FOR 28 MDOS/SGOAB

FROM: AFIOH/RSHI
2513 Kennedy Circle
Brooks City-Base, TX 78235-5123

SUBJECT: Consultative Letter, IOH-RS-BR-CL-2004-0090, Acoustical Evaluation of Firing Ranges, Ellsworth AFB, SD

1. INTRODUCTION

a. *Purpose*: From 19 – 22 July 2004, the Industrial Hygiene (IH) Branch of the Air Force Institute for Operational Health (AFIOH/RSHI), conducted an acoustical evaluation of the M9/M16 and the M240/M249 firing ranges located at Ellsworth AFB, SD. This survey was requested by Ellsworth AFB Bioenvironmental Engineering to help them determine noise exposures for instructors and students. This letter provides the results of our evaluation and recommends appropriate controls for reducing noise exposures.

b. *Survey Personnel*:

Capt Ian Rybczynski, Industrial Hygiene Consultant
Mr. Andrew Wells, Industrial Hygiene Consultant

c. *Personnel Contacted*:

Maj Wenzel, 28 MDOS/SGOAB
1Lt Orcutt, 28 MDOS/SGOAB
SSgt Tucker, 28 MDOS/SGOAB
TSgt Vesperman, 28 SFS/SFTC
SSgt Nichols, 28 SFS/SFTC
SSgt Skuta, 28 SFS/SFTC

d. *Equipment Used*:

High Techniques Digital Oscilloscope (Models FW 7633P and FW 8000-500)
Norsonic Front End Power Supply (Model 336, S/N 20570/20566)
Norsonic Pre-amplifier (Model 1201; S/N 19143/19145)
Brüel & Kjær ¼” Microphone (Model 2530; S/N 1030/1123)

e. Description of Operation:

(1) Combat Arms personnel use the new semi-enclosed firing range to train personnel to fire M9 pistols (9mm) and M16 rifles (5.56 mm). This firing range has 20 firing stations. Typically, one weapon training class is conducted per day with twenty students in each class. There are three to four instructors present for the shooting portion of the classes and they have roughly equivalent noise exposures. During a class, twenty students will fire 90 rounds each with the M9 or 100 rounds each with the M16. Instructors sit at the control desk located behind the firing line and walk behind the students while directing the class through the public address system.

(2) Adjacent to the semi-enclosed range is the M240/M249 range, which is used for Security Forces (SF) training approximately 6 times a year. During these training sessions, up to 5 SF personnel will fire either a M240 or a M249 while 3 instructors observe directly behind the shooters. Typically, instructors position themselves on one knee along the side and a few inches behind the heads of the prone shooters. During the firing portion of the classes, students will fire 1200 M240 rounds or they will fire 570 M249 rounds.

f. *Source of Exposure*: Instructors and trainees have the potential of being exposed to hazardous noise during the firing of weapons. Additionally, the public address system is a noise source in the semi-enclosed range, but this source was not evaluated as part of this survey.

g. *Description of Facilities:*

(1) Semi-Enclosed Range: This firing range has an enclosed area for the firing stations, observer areas, and the control desk. This entire area is secured when the range is not in use with roll-up doors (Figure 1). When the range is being used, all of the roll-up doors are opened. Once in the open position, the doors are directly over the shooters' heads (Figure 2). The wall behind the shooters is made out of wood with a few windows and entry doors mixed in as well (Figure 3). Downrange, there are four sectional concrete walls on each side of the range. The sectional sidewalls are angled so that they slightly taper the width of the range (Figure 4). The tapering pattern of the walls also allows for air gaps that aren't visible from the shooter's position. A 'v'-shaped steel bullet trap is at the end of the range. The roof between the shooters and end of the range is constructed with wood and metal segments that are angled downward so that they slowly taper the height of the range (Figure 5). The concrete floor and the sidewalls were constructed with a smooth finish and are acoustically reflective. The ceiling baffles have been painted and they are also acoustically reflective.

Figure 1: Secured range

Figure 2: Range with roll-up doors open

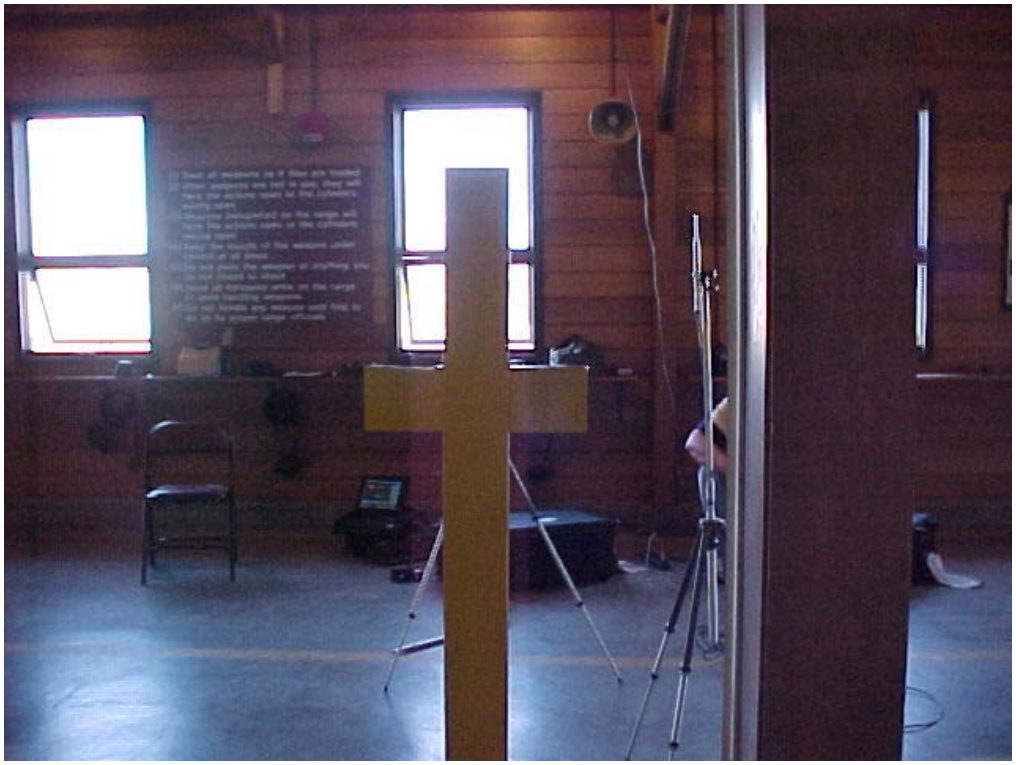

Figure 3: Area behind shooter

Figure 4: Tapered sidewalls

Figure 5: View of sectional roof from bullet trap to shooter

(2) M249 Range: The M249 range is roughly half the size of the semi-enclosed range and only has 5 shooting stations. The wall behind the shooters is nearly identical to the wall behind the shooters in the other range (wood with a regular window pattern). There is a wooden roof that covers the raised concrete shooting dock. The roof extends slightly beyond the shooting dock and has a plastic finish added to the extended area (Figure 6). There are no sidewalls downrange of the shooting dock; however, shooters use 10 meter concrete shooting tubes on this range (Figure 7). Approximately 3 meters past the end of the shooting tube is a steel 'v'-shaped bullet trap (Figure 8). The bullet trap has been installed at the base of a 20' high berm that previously marked the end of this range.

Figure 6: Shooters area of M249 range

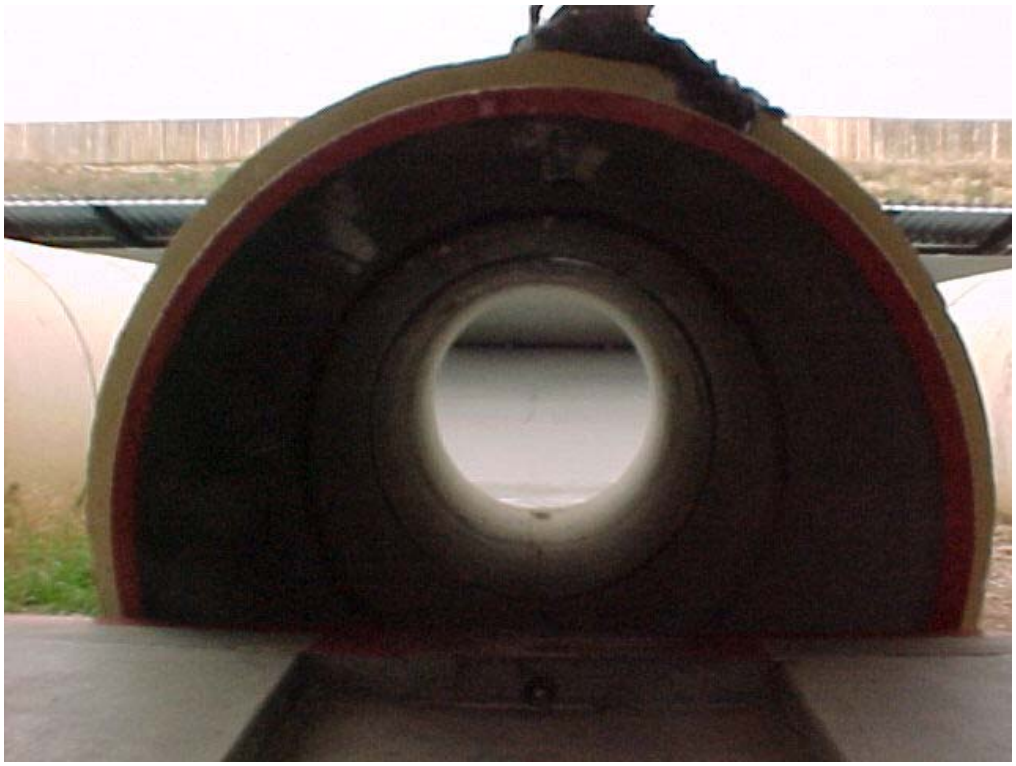

Figure 7: Concrete shooting tubes

Figure 8: M249 bullet trap.

2. SURVEY PROCEDURES

a. *Overview*: A key factor in an acoustical evaluation of a firing range is the decay time for a single shot. Although there are many weapons being fired at once during a class, the acoustical properties of the range are the same for each shot. Noise is categorized as either impulsive or continuous based on the length of time it takes for a shot to attenuate back to background levels. According to AFOSH Standard 48-19, a single shot must attenuate to background levels in less than 1 second in order for the noise to be classified as impulsive. Normally, shots from weapons are classic examples of impulse noise, but enclosing ranges with highly reflective surfaces (acoustically speaking) can cause decay times greater than 1 second. If this is the case, acoustical treatments typically offer the best solution for reducing attenuation time. Additionally, the positioning of the downrange sidewalls added to our concern about reflective surfaces. Since the sidewalls are angled towards the shooters, we were concerned that noise would be reflected directly back to the shooters.

b. *Equipment Set-Up*: We select microphone locations based on the type of facility, the noise sources, and the type of assessment. For this survey, we located one measurement microphone at ear-height approximately at the shooter's position and a second microphone was placed at ear-height at the instructor's position (the yellow line). These microphone positions were used at both ranges. Parameters for the signal processors and other support equipment were established from measuring and storing the signals from on-site weapon discharges.

c. *Data Collection*: A condenser microphone senses pressure fluctuations and converts them into an electrical signal. The electrical output feeds into a pre-amplifier, amplifying the signal to

a front-end unit. The front-end unit provides microphone polarization voltage, frequency selective filters, and additional amplification for the signal. The signal feeds into the digital oscilloscope, which digitizes the analog signal. The oscilloscope displays a voltage-time history signal that corresponds to the decaying random-pressure signal. From the voltage signal, we can determine the peak pressure level and decay time for each round fired. In this acoustical evaluation, filtering and additional amplification were not used or necessary.

d. *Data Storage*: The primary oscilloscope has the capability of collecting data at a maximum rate of 0.05 microsecond (μs) per point and can store up to two million data points. If all two million points were collected at the maximum rate, total data collection time would be limited to only 0.1 seconds. It is unlikely that this is enough time to record the entire event. Therefore, sampling rates of 1.0 μs per point (1 million samples per second, for a two-second collection window) were chosen to enable the best evaluation of the entire event with sufficient detail. A second oscilloscope was used during this survey to capture data at an alternate location (the yellow line). Unfortunately, this oscilloscope is an older model and has only half of the data storage capabilities of the primary unit. Therefore, the collection window for the secondary oscilloscope is limited to 1 second at this sampling frequency.

e. *Decay Time*: The period of time between initial sound pressure generation to the attenuation of that energy to background levels at a specific location. According to AFOSH Standard 48-19, this time period must be 1 second or less for the source to qualify as impulse sound. If attenuation time is greater than one second, exposure limits for continuous noise should be used.

f. *Sound Reflections:* To evaluate how sound was reflecting off the sidewalls, a mirror and laser pointer were used. The mirror was taped to each sidewall and a laser pointer was shot at the mirror to indicate the reflective path of sound. The mirror was placed in the middle and on the downrange end on each sidewall. Once the mirror was in place, the laser was fired at the mirror from shooter positions 2, 11, and 19. The steps were repeated until the reflective paths from all shooter positions were determined for each sidewall.

3. RESULTS

a. *Noise Levels:* Decay times were determined in both ranges after CATM personnel fired single shots. A M16 was used in the M240/M249 range because it uses the same rounds as the weapons normally fired in this range. CATM personnel explained shooting single shots was not recommended for the machine guns because doing that could damage these weapons. Table 1, below, lists the results of our decay time evaluations.

Table 1: Firing Range Noise Summary

Range	Microphone Location	Weapon Fired	Number of test shots	Average Time to Decay (s)
M9/16	Shooter	M9	9	0.776
M9/16	Yellow Line	M9	3*	0.782
M240/249	Shooter	M16	8	**1.648**
M240/249	Yellow Line	M16	8	**> 1.0****

* = Due to data collection limitations, not all data files were valid
** = Maximum window for collection device used was 1 s

b. *Reflective Properties:*

(1) Figures 9, 10, and 11 show the data collected from the sound reflection assessment. The large arrow in the shooters box indicates were a shot must be fired to get the illustrated reflective sound paths. The dotted lines with the small arrowheads indicate the reflective path of the sound after it hits the wall. It is assumed that bullet trap at the end of the range ultimately reflects all sound back towards the shooters.

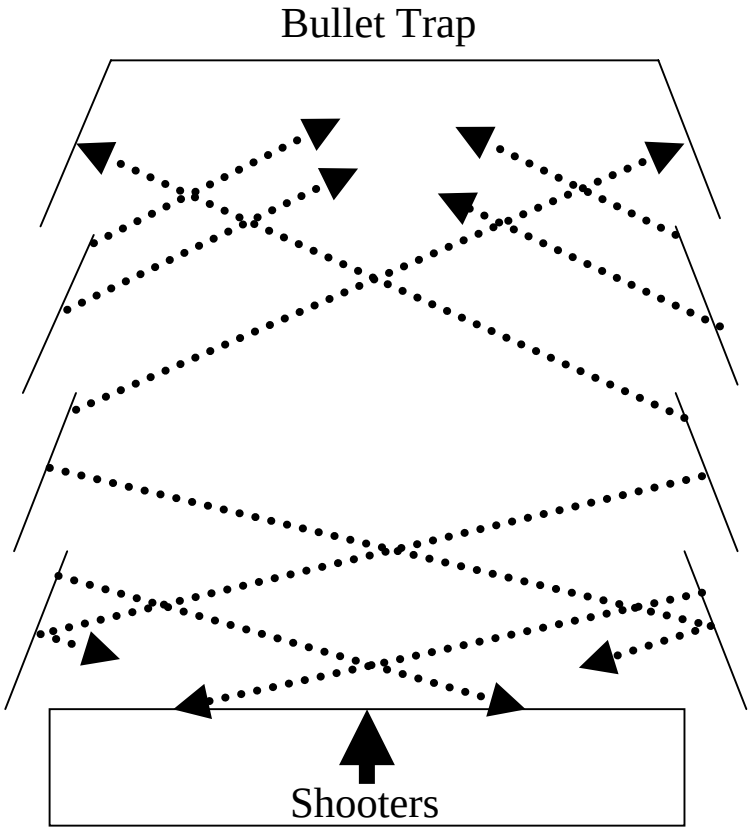

Figure 9: Reflective paths from shooting position #11.

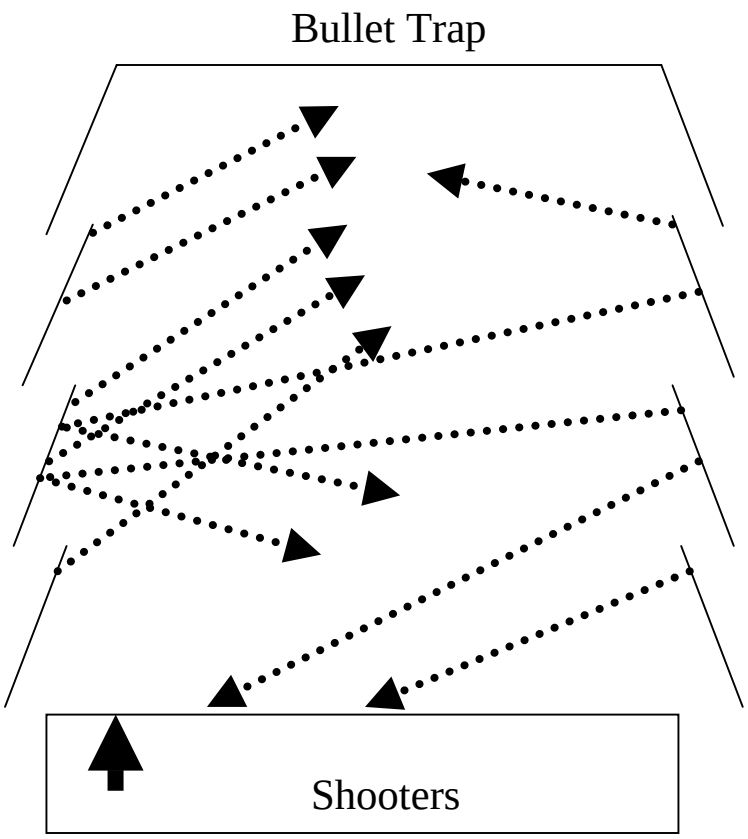

Figure 10: Reflective paths from shooting position #2.

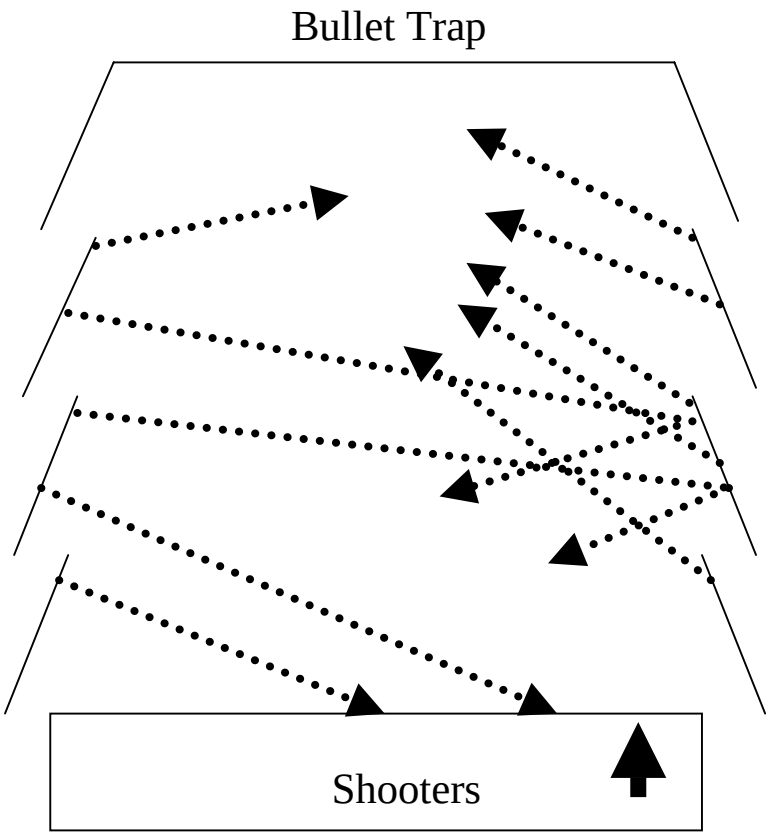

Figure 11: Reflective paths from shooting position #19.

(2) An assessment of the angled ceiling baffles was also performed in a similar manner to the sidewall evaluation. This assessment indicated the ceiling baffles reflected sound downrange.

4. DISCUSSION

a. One of the key issues that must be addressed when studying an Air Force firing range is whether the noise produced when a shot is fired qualifies as impulse noise. As defined in AFOSH Standard 48-19, impulse noise is defined as "a short burst of acoustic energy consisting of either a single burst or a series of bursts. The pressure-time history of a single burst includes a rapid rise to a peak pressure followed by a somewhat slower decay of the pressure envelope to ambient pressure, both occurring within 1 second." If noise can be defined as impulsive, then the impulse standards are applied. Otherwise, the continuous noise standards are used. Since sound pressure generation by the weapons themselves are fairly consistent, failure to meet the definition of impulse noise is indicative of poor acoustical conditions within the range. In this survey, we observed that the pressure-time history decayed within 1 second (s) for the M9/M16 range, but it did not decay within this 1 s time period at the M240/M249. The data sets indicate that the impulse noise standards apply to the M9/M16 range, but continuous noise standards apply to the M240/249 range.

b. The M9/16 range has adequate acoustical properties. This is indicated by the decay of impulses to background within 1 s (Table 1). However, cost effective improvements could still be considered to limit the acoustical energy to which personnel are exposed and to improve speech communication within the range. AFIOH recommends the use of acoustical treatments in any range with attenuation times greater than 0.5 s. Acoustical treatments along the walls behind the shooter (rear and sidewalls) would be beneficial. The noise reflection data also indicated that the downrange sidewalls are also a problem. The data indicated that reflections back towards the shooters are most likely to occur from the first two sets of sidewalls. After considering the data collected and the maintenance issues for treated down range sidewalls, we recommend treating only the first two sets of walls. These walls should be close enough to the shooters that damage from stray bullets is less likely and probably more critical for treatment because of their tendency to reflect sound back at the shooters. Finally, the rollup doors should also be addressed. In the current configuration, the doors are reflecting sound directly back towards the shooter. Treatment options include building a false ceiling above the shooter with acoustically absorptive tile (i.e. the rollup doors are between the current ceiling and the false ceiling), improving the acoustical properties of the doors (through replacement or treatment), and removing the doors from the facility.

c. The M240/M249 range has poor acoustical properties. This is indicated by attenuation times greater than 1 s (Table 1). Ellsworth AFB's Public Health reported that no personnel from this shop have been diagnosed with hearing loss this year (3 of 4 tested) and 1 out of 12 Security Forces personnel had diagnosable hearing loss. We also queried the AF Hearing Conservation Data Repository (DOEHRS-DR) for data from past years, but no information was available. We were concerned about hearing loss because the continuous noise portion of 48-19 requires that exposures over 115 dB(A) not be allowed. Noise exposures for personnel at this range are considered continuous, with peaks of up to 158 dB for the M240 and 160 dB for the M249. The

limit of 115 dB(A) is after subtractions are made for hearing protection; however, even double protection is unlikely to provide the required attenuation. Therefore, the best solution is to improve the range's acoustical properties. The use of shooting tubes is the primary problem for this range. If tube use is not required, the tubes should be removed from this range. If the tubes cannot be removed, acoustical treatment of the walls behind the shooters (rear and sidewalls) may help; however, acoustical treatment inside the shooting tubes is likely necessary to achieve the desired attenuation. Possibly, adding sandbags to the bottom half of the shooting tubes will reduce the decay times to less than 1 s. A similar survey at F.E. Warren AFB showed their shooting tube attenuation times were less than 1 s and they had sandbags in their shooting tubes. A picture of the FE Warren shooting tube is provided below.

Figure 12: F.E. Warren AFB shooting tube

5. RECOMMENDATIONS

a. Improving the attenuation times of the M240/M249 range should be the top priority. If possible, removal of the shooting tubes will immediately correct the problem. Data were collected from an M16 fired between the tubes and showed the attenuation time dropped from well over 1 s to slightly over 0.5 s. If acoustical treatment is the only possible option, the interior surfaces of the tubes should be as acoustically absorptive as reasonably possible. We have suggested sandbag use as a potential solution; however, if other acoustical treatments will be explored, please contact our office for additional information on the proposed treatments. Although we expect sandbag use will reduce the decay time to less than 1 s, there are other differences in your range (bullet trap, windows/walls behind shooter, etc.) that may limit the effectiveness of this treatment.

b. Double hearing protection should be worn when instructors teach all classes. According to AFOSH Standard 48-19, Attachment 2, all weapons could qualify for single hearing protecting, but this information was developed for exposures to 1000 rounds or less. All full classes at the Ellsworth ranges will exceed 1000 total rounds. Instructors have the highest exposures to hazardous noise at the firing range and they could be exposed during more than one class in a day. Thus, it is particularly important to ensure that adequate hearing protection and guidance for use is provided to instructors. Additionally, since weapons fired at the M240/M249 range do not currently meet the requirements of impulse noise, double hearing protection is recommended. However, even double hearing protection will not sufficiently protect instructors from exposures at this range. Since adequate hearing protection is not possible, changes to the acoustical properties of this range are necessary to reduce the risk of permanent hearing loss.

c. Double hearing protection is also recommended for students on both ranges. As stated above, the AF guidance on impulse noise is limited to exposures of 1000 rounds or less. Since a full M9 class will fire 1800 rounds and a full M16 class will fire 2000 rounds, double hearing protection is recommended. As with the M240/M249 instructors, students at this range are not adequately protected by double hearing protection.

d. Acoustical treatments for the area behind the shooters is recommend for both ranges. Applying quilted fiberglass panels along the wall behind the shooters is typically an effective treatment. We have found that one-inch thick quilted fiberglass, with a 1" air gap behind it, is an effective, durable sound absorber for firing ranges. There are other commercially available treatment options you may wish to explore for practical and/or financial reasons. Our office can provide recommendations regardless of the selected treatment option. Remember, acoustical material must be properly maintained for continued effectiveness. Inspect material regularly for wear, tear, and cleanliness. Repair or replace damaged material as needed.

e. Acoustical treatment for the first two-sets of downrange sidewalls is also recommended. This is recommended because these walls showed a tendency to reflect noise back towards the shooters. Similar to the shooting tubes, avoid the use of porous materials that cannot be cleaned easily. Acoustical foams can accumulate lead dust and mold. If an alternative treatment option is used on the shooting tubes, it is likely that this option will be effective on these sidewalls as well.

f. A treatment option should be explored for the rollup doors on the M9/M16 range. As discussed earlier, the options include removing the doors, treating/replacing the doors, or building an acoustically absorptive compartment for the doors above the shooters.

6. We greatly appreciate the cooperation of CATM and Bioenvironmental Engineering personnel during this survey. If you have any questions concerning this report, please contact me at DSN 240-8441.

/Signed/

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