NIOSH HEALTH HAZARD EVALUATION REPORT

HETA #2000-0191-2960
Immigration and Naturalization Service (INS)
National Firearms Unit (NFU)
Altoona, Pennsylvania

May 2005

DEPARTMENT OF HEALTH AND HUMAN SERVICES
Centers for Disease Control and Prevention
National Institute for Occupational Safety and Health

PREFACE

The Hazard Evaluation and Technical Assistance Branch (HETAB) of the National Institute for Occupational Safety and Health (NIOSH) conducts field investigations of possible health hazards in the workplace. These investigations are conducted under the authority of Section 20(a)(6) of the Occupational Safety and Health (OSHA) Act of 1970, 29 U.S.C. 669(a)(6) which authorizes the Secretary of Health and Human Services, following a written request from any employers or authorized representative of employees, to determine whether any substance normally found in the place of employment has potentially toxic effects in such concentrations as used or found.

HETAB also provides, upon request, technical and consultative assistance to federal, state, and local agencies; labor; industry; and other groups or individuals to control occupational health hazards and to prevent related trauma and disease. Mention of company names or products does not constitute endorsement by NIOSH.

ACKNOWLEDGMENTS AND AVAILABILITY OF REPORT

This report was prepared by Joshua Harney, Bradley King, and Randy Tubbs of HETAB, Division of Surveillance, Hazard Evaluations and Field Studies (DSHEFS), and Keith Crouch, Charles Hayden, Chucri Kardous, Amir Khan, Leroy Mickelson, and Robert Willson of the Engineering and Physical Hazards Branch (EPHB), Division of Applied Research and Technology (DART). Field assistance was provided by Melissa Finley. Analytical support was provided by Ardith Grote and DataChem Laboratories. Desktop publishing was performed by Shawna Watts. Review and preparation for printing were performed by Ellen Galloway.

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Highlights of the NIOSH Health Hazard Evaluation

Evaluation of Lead and Noise Exposures at an Indoor Firing Range

The National Institute for Occupational Safety and Health (NIOSH) received a management request for a health hazard evaluation (HHE) at the US Immigration and Naturalization Service (INS) National Firearms Unit (NFU) in Altoona, Pennsylvania. The request cited management concerns about officers' potential exposure to noise and lead in an indoor firing range at the facility. The request resulted in several site visits over the course of more than 2 years to conduct lead and noise exposure assessments during training and qualification rounds.

What NIOSH Did

- April 5, 2000: Performed an industrial hygiene inspection and qualitative smoke testing for air flow patterns.
- April 19–20, 2000: Assessed lead and noise exposures during firearms qualification exercises, and captured the firearm-specific sound frequency signatures made by weapons commonly used by the INS.
- March 15, 2001: Identified the acoustical environmental parameters, conducted preliminary noise measurements, and provided noise abatement recommendations.
- June 6, 2001: Conducted a more complete assessment of the worst-case noise environment during a typical training.
- March 26, 2002: Performed sampling for airborne lead during qualification rounds after the removal of a roll-top door on one wall of the range.
- September 25, 2002: Conducted additional lead and noise assessment after ventilation improvements had been implemented.

What NIOSH Found

- During these surveys, NIOSH investigators found excessive levels of lead and noise exposures. An inadequate ventilation system and certain design characteristics of the range were found to be contributing factors to the lead exposure.

What INS NFU Managers Can Do

- Investigate the feasibility of using a completely lead-free practice round.
- Install new diffusers on lanes near the end of the firing range shown to be areas of higher lead and carbon monoxide exposure. New diffusers installed at a lower height equal to diffusers in the other lanes will improve laminar airflow across the firing line.
- Train employees in the proper use of hearing protection. Observations of earplugs that barely entered the ear canal and of earmuffs placed on officers' legs or heads when not in use show that the users of these devices need to be instructed on proper use.

What INS NFU Employees Can Do

- Wash their face and hands thoroughly upon leaving the range and before eating, drinking, or smoking.
- Use double hearing protection during qualification rounds to reduce noise exposure in the firing range to a safer level.

What To Do For More Information:
We encourage you to read the full report. If you would like a copy, either ask your health and safety representative to make you a copy or call 1-513-841-4252 and ask for HETA Report #2000-0191-2960

CDC Workplace Safety and Health

NIOSH

Health Hazard Evaluation Report 2000-0191-2960
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SUMMARY

On March 17, 2000, the National Institute for Occupational Safety and Health (NIOSH) received a management request for a health hazard evaluation (HHE) at the US Immigration and Naturalization Service (INS) National Firearms Unit (NFU) in Altoona, Pennsylvania. The request resulted in several site visits over the course of more than 2 years to conduct lead and noise exposure assessments during training and qualification rounds at the facility. During these surveys, NIOSH investigators sampled for lead and noise and found excessive levels of both. An inadequate ventilation system and certain design characteristics of the range were found to be contributing factors to the lead exposure. Recommendations were made for ventilation and design improvements, and for noise exposure reduction.

Over several site visits conducted at the facility, NIOSH investigators concluded that health hazards existed at the times of the evaluations. The facility has since taken several steps to mitigate these hazards, including implementing of many of the recommendations proposed by the NIOSH investigators. Recommendations in the final interim letter have not yet been implemented due to lack of funding. However, NFU management has expressed a desire to continue working with NIOSH investigators before implementing any new controls should funding become available. The contents of this document present no new information; rather, it is a compilation of the letters and reports already sent individually to INS NFU management over the course of the investigation.

Keywords: Firing ranges, lead, noise, shooting ranges, HVAC, ventilation, carbon monoxide (Police Protection). Sic: 9221, NAICS: 922120

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INTRODUCTION

In March 2000, the National Institute for Occupational Safety and Health (NIOSH) received a request for a health hazard evaluation (HHE) from the Eastern Region office of the US Department of Justice, Immigration and Naturalization Service (INS). The request cited management concerns about officers’ potential exposure to noise and airborne lead in an indoor firing range at the National Firearms Unit (NFU) in Altoona, Pennsylvania.

NIOSH investigators visited the INS NFU on April 5, 2000, to conduct an opening conference, industrial hygiene inspection, and qualitative smoke testing. On April 19 and 20, 2000, NIOSH investigators returned to the NFU to assess lead and noise exposures during firearms qualification exercises, and to capture the firearm-specific sound frequency signatures made by weapons commonly used at the INS. This frequency analysis of the noise made while discharging a firearm was done to determine the attenuation characteristics needed for noise control and hearing protection devices (HPDs). On March 15, 2001, NIOSH investigators conducted a site visit to identify the acoustical environmental parameters, conduct preliminary noise measurements, and provide noise abatement recommendations. The NIOSH investigators returned to the facility on June 6, 2001, to conduct a more complete assessment of the worst-case noise environment during a typical training or simulated session with numerous agents. Interim letters conveyed the results of these evaluations. An interim letter (July 5, 2001) detailed specific recommendations for reducing the lead exposures to the lowest technically feasible levels by improving the performance of the ventilation system of the main indoor firing range. In March 2002, a site visit was conducted after portions of the recommendations had been implemented, specifically removing a roll-top door on one wall of the range. This was followed by a site visit in September 2002 to conduct additional lead and noise assessment after ventilation improvements had been implemented. The results from the September 2002 site visit prompted recommendations for a last round of improvements. However, due to lack of funding, the INS NFU was unable to implement these recommendations.

BACKGROUND

The NFU is comprised of three main buildings. The first houses the INS agents’ offices, the armory from which all weapons are issued to the field, and various workshops where gunsmiths repair and test the weapons. The second building houses a small indoor firing range in which ballistics testing is completed for each lot of ammunition purchased by the NFU. The third building (and focus of this HHE) is the new training facility that houses a training classroom and the 20-lane indoor firing range. Its construction was completed in the fall of 1999. This larger range is ventilated by two rooftop heating, ventilation, and air conditioning (HVAC) units, while the adjacent classroom and storage rooms are served by separate general ventilation units. The bullet trap is directly exhausted by a dust collection unit (DCU) located outside the building.

Housekeeping activities downrange from the firing line (sweeping, mopping, bullet trap waste collection, DCU filter replacement) are done by a hazardous waste disposal contractor, except for shooters collecting spent shell casings. Housekeeping activities uprange of the firing line are performed by onsite personnel. Shooters collect the empty shell casings after each shooting exercise using a floor squeegee, a hand broom, and a dustpan to deposit the casings into 5-gallon buckets. The uprange floor is mopped weekly by housekeeping personnel.

EVALUATION CRITERIA

As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, a pre-existing medical condition, and/or a hypersensitivity (allergy). In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Also, some substances are absorbed by direct contact with the skin and mucous membranes, and thus potentially increases the overall exposure. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH recommended exposure limits (RELs),[1] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®),[2] and (3) the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs).[3] Employers are encouraged to follow the OSHA limits, the NIOSH RELs, the ACGIH TLVs, or whichever are the more protective criteria.

OSHA requires an employer to furnish employees a place of employment that is free from recognized hazards that are causing or are likely to cause death or serious physical harm [Occupational Safety and Health Act of 1970, Public Law 91-596, sec. 5(a)(1)]. Thus, employers should understand that not all hazardous chemicals have specific OSHA exposure limits such as PELs and short-term exposure limits (STELs). An employer is still required by OSHA to protect their employees from hazards, even in the absence of a specific OSHA PEL.

A time-weighted average (TWA) exposure refers to the average airborne concentration of a substance during a normal 8- to 10-hour workday. Some substances have recommended STEL or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

Lead

Lead is ubiquitous in U.S. urban environments due to the widespread use of lead compounds in industry, gasoline, and paints during the past century. Exposure to lead occurs via inhalation of dust and fume and ingestion through contact with lead-contaminated hands, food, cigarettes, and clothing. Absorbed lead accumulates in the body in the soft tissues and bones. Lead is stored in bones for decades, and may cause health effects long after exposure as it is slowly released in the body.

Symptoms of lead exposure include weakness, excessive tiredness, irritability, constipation, anorexia, abdominal discomfort (colic), fine tremors, and "wrist drop."[4,5,6] Overexposure to lead may also result in kidney damage, anemia, high blood pressure, infertility and reduced sex drive in both sexes, and impotence. An individual's blood lead level (BLL) is a good indication of recent exposure to, and current absorption of lead.[7] The frequency and severity of symptoms associated with lead exposure generally increase with the BLL. The overall geometric mean BLL for the U.S. adult population (ages 20–74 years) declined significantly between 1976 and 1991, from 13.1 to 3.0 micrograms per deciliter of blood (µg/dL). This decline is most likely due primarily to the reduction of lead in gasoline. More than 90% of adults now have a BLL of <10 µg/dL, and more than 98% have a BLL <15 µg/dL.[8]

Under the OSHA general industry lead standard (29 CFR 1910.1025), the PEL for airborne exposure to lead is 50 micrograms per cubic meter (µg/m^3) (8-hour TWA).[9] The standard requires lowering the PEL for shifts exceeding 8 hours, medical monitoring for employees exposed to airborne lead at or above the action level of 30 µg/m^3 (8-hour TWA), medical removal of employees whose average BLL is 50 µg/dL or greater, and economic protection for medically removed workers. Medically removed workers cannot return to jobs involving lead exposure until their BLL is below 40 µg/dL. NIOSH has an REL for lead of 50 µg/m^3 averaged over a 8-hour work shift. ACGIH has a TLV for lead of 50 µg/m^3 (8–hour TWA), with worker BLLs to be controlled to or below 30 µg/dL, and designation of lead as an animal carcinogen.[2]

The occupational exposure criteria are not protective for all the known health effects of lead. For example, studies have found neurological symptoms in workers with BLLs of 40 to 60 µg/dL, and decreased fertility in men with BLLs as low as 40 µg/dL. BLLs are associated with increased blood pressure, even at levels less than 10 µg/dL. Fetal exposure to lead is associated with reduced gestational age, low birth weight, and early mental development with maternal BLLs as low as 10 to 15 µg/dL.[10] Men and women who are planning on having children should limit their exposure to lead.

In homes with a family member occupationally exposed to lead, care must be taken to prevent "take home" of lead, that is, lead carried into the home on clothing, skin, hair, and in vehicles. High BLLs in resident children, and elevated concentrations of lead in the house dust have been found in the homes of workers employed in industries associated with high lead exposure.[11] Particular effort should be made to ensure that children of persons who work in areas of high lead exposure receive a BLL test.

Lead-contaminated surface dust represents a potential source of lead exposure, particularly for young children. This may occur either by direct hand-to-mouth contact, or indirectly from hand-to-mouth contact with contaminated clothing, cigarettes, or food. Previous studies have found a significant correlation between resident children's BLLs and house dust lead levels.[12] No current federal standard provides a permissible limit for lead contamination of surfaces in occupational settings. The Environmental Protection Agency (EPA) currently recommends meeting the following clearance levels for surface lead loading after residential lead abatement or interim control activities: floors, 40 micrograms per square foot (µg/ft^2); interior window sills, 250 µg/ft^2; window troughs, 400 µg/ft^2.[13] These levels have been established as achievable through lead abatement and interim control activities, they are not based on projected health effects associated with specific surface dust levels.

Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials. The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, and nausea. These initial symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered. Coma or death may occur if high exposures continue.[6,14,15,16,17,18]

The NIOSH REL for CO is 35 ppm for an 8-hour TWA exposure, with a ceiling limit of 200 ppm that should not be exceeded.[3,19] The NIOSH REL of 35 ppm is designed to protect workers from health effects associated with carboxyhemoglobin (COHb) levels in excess of 5%.[14] The ACGIH recommends an 8-hour TWA TLV of 25 ppm.[2] The OSHA PEL for CO is 50 ppm for an 8-hour TWA exposure.

Ventilation

To minimize exposures to contaminants resulting from weapons fire, ventilation systems of indoor firing ranges should provide favorable conditions with regard to at least four criteria: filtration efficiency, range pressurization, volumetric flow rate, and airflow patterns. Any air filtered and re–circulated through the range must be high-efficiency particulate air (HEPA) filtered. Firing ranges should be under slight negative pressure so that no contaminants escape the range under normal operating conditions. The volumetric flow rate of air supplied to and exhausted from the range should provide a minimum average downrange air velocity at the firing line of 50 feet per minute (fpm), as recommended in ACGIH's Industrial Ventilation manual.[20] Finally, air moving downrange in as laminar (nonturbulent) a flow as possible, especially near the firing line. Even if the range is pressurized correctly and a minimum downrange air velocity of 50 fpm is achieved at the firing line, range users may still receive excessive exposures to lead if large-scale eddies exist that create “backflow” and bring contaminated air back into their breathing zones.

Noise

Noise-induced hearing loss (NIHL) is an irreversible, sensorineural condition that progresses with exposure. Although hearing ability declines with age (presbycusis) in all populations, exposure to noise produces hearing loss greater than that resulting from the natural aging process. NIHL is caused by damage to nerve cells of the inner ear (cochlea) and, unlike some conductive hearing disorders, limited medical treatment is available for acoustic trauma.[21] While loss of hearing may result from a single exposure to a very brief impulse noise or explosion, such traumatic losses are rare. In most cases, noise-induced hearing loss is insidious. Typically, it begins to develop at 4000 or 6000 Hz (the hearing range is 20 Hz to 20000 Hz) and spreads to lower and higher frequencies. Often, material impairment has occurred before the condition is clearly recognized. Such impairment is usually severe enough to permanently affect a person's ability to hear and understand speech under everyday conditions. Although the primary frequencies of human speech range from 300 Hz to 3000 Hz, research has shown that the consonant sounds, which enable people to distinguish words such as "fish" from "fist," have spectral energy out to 6000 and 8000 Hz.[22]

The A-weighted decibel [dBA] is the preferred unit for measuring sound levels to assess worker noise exposures. The dBA scale is weighted to approximate the sensory response of the human ear to sound frequencies near the threshold of hearing. The decibel unit is dimensionless, and represents the logarithmic relationship of the measured sound pressure level to an arbitrary reference sound pressure (20 micropascals, the normal threshold of human hearing at a frequency of 1000 Hz). Decibel units are used because of the very large range of sound pressure levels which are audible to the human ear. Because the dB scale is logarithmic, increases of 3 dB, 10 dB, and 20 dB represent a doubling, a tenfold increase, and a 100-fold increase of sound energy, respectively. It should be noted that noise exposures expressed in decibels cannot be averaged by taking the simple arithmetic mean.

The OSHA standard for occupational exposure to noise (29 CFR 1910.95)[23] specifies a maximum PEL of 90 dBA for a duration of 8 hours per day. The regulation, in calculating the PEL, uses a 5 dB time/intensity trading relationship, or exchange rate. This means that a person may be exposed to noise levels of 95 dBA for no more than 4 hours, to 100 dBA for 2 hours, etc. Conversely, up to 16 hours exposure to 85 dBA is allowed by this exchange rate. The duration and sound level intensities can be combined in order to calculate a worker's daily noise dose according to the formula:

$$\text{Dose} = 100 \text{ X } (C1/T1 + C2/T2 + ... + Cn/Tn),$$

where Cn indicates the total time of exposure at a specific noise level and Tn indicates the reference duration for that level as given in Table G-16a of the OSHA noise regulation. During any 24-hour period, a worker is allowed up to 100% of his daily noise dose. Doses greater than 100% are in excess of the OSHA PEL.

The OSHA regulation has an additional action level (AL) of 85 dBA; an employer shall administer a continuing, effective hearing conservation program when the 8-hour time-weighted average (TWA) value exceeds the AL. The program must include monitoring, employee notification, observation, audiometric testing, hearing protectors, training, and record keeping. All of these requirements are included in 29 CFR 1910.95, paragraphs (c) through (o). Finally, the OSHA noise standard states that when workers are exposed to noise levels in excess of the OSHA PEL of 90 dBA, feasible engineering or administrative controls shall be implemented to reduce the workers' exposure levels.

NIOSH, in its Criteria for a Recommended Standard,[24] and the ACGIH[2] propose exposure criteria of 85 dBA as a TWA for 8 hours, 5 dB less than the OSHA standard. The criteria also use a more conservative 3 dB time/intensity trading relationship in calculating exposure limits. Thus, a worker can be exposed to 85 dBA for 8 hours, but to no more than 88 dBA for 4 hours or 91 dBA for 2 hours.

NIOSH recommends that exposure to peak impulsive noise not exceed 140 dB. The OSHA PEL for impulsive noise is also 140 dB for peak-. However, peak impulse noise is not the sole factor in hearing damage. Other factors such as the duration of the impulse and frequency of exposure also have an effect on hearing loss. In an indoor firing range, reverberation also becomes an important factor.

METHODS AND RESULTS: LEAD, CARBON MONOXIDE, AND VENTILATION

April 2000

At the time of the April 2000 site visit, a corrugated metal overhead roll-top garage door was on the range-right wall of the building, behind the firing line. This door was used to bring in equipment too large to pass through the employee entrance. When the range was in use, the ventilation system kept the range under negative pressure relative to the interior building hallways and to the outdoors. To re-establish pressure equilibrium, the easiest path for outdoor air to enter the range is through the doorframe of the overhead door, which is not sealed tightly. With the HVAC system running at optimum conditions immediately after its construction, the closed overhead door constantly flapped and distracted the range users. Several months before the HHE, the HVAC system was adjusted to supply and exhaust less air through the range in an attempt to stop the overhead door from rattling.

An INS contractor conducted air sampling for lead under these sub-optimum ventilation conditions. During that evaluation, area air samples were collected at each firing station during three consecutive shooting qualification exercises (two pistol exercises, one shotgun exercise) completed by 19 shooters, taking 3 hours. Under these conditions, five of the 19 samples exceeded the OSHA action level of 30 µg/m^3 as an 8-hour TWA. The contractor simulated 'worst case' conditions by using a course of fire more rigorous than what is typical of training at the NFU. Typically, agents training at the NFU undergo 1 to 2 hours of indoor range use per day, and would not conduct three consecutive qualification exercises.

During the April 2000 site visit by NIOSH investigators, all 20 firing stations were used at once. Shooters and observers within the range were required to wear ear plugs, ear muffs, and safety glasses. Each pistol qualification exercise consisted of each agent firing 73 rounds of 155 grain jacketed hollow point .40 Smith and Wesson (S&W) ammunition at targets of varying distances. The shotgun proficiency exercise consisted of each agent firing 30 rounds using 12 gauge shotguns, 25 rounds of 2¾" 00 Buck and five 2¾" slugs. During all firing exercises, the motors controlling the target distance on lanes 19 and 20 were not working. The shooters using these lanes crossed the firing line and manually moved their targets to the correct distance downrange at the beginning of each portion of the exercise. The shooters using the other 18 lanes did not move downrange at any time.

Air sampling for lead was conducted during three separate periods of time. During the morning of April 19, 2000, 20 shooters completed a single pistol qualification exercise; personal breathing zone samples (PBZs) were collected on 10 of them. That afternoon, the same shooters completed two consecutive pistol qualification exercises while PBZs were collected. On the morning of April 20, 2000, the 20 shooters completed a single shotgun qualification exercise; 10 PBZs were collected from those not sampled the previous day.

Air samples for lead were collected using battery-operated personal sampling pumps calibrated at a nominal flow rate of 3 liters per minute (Lpm) to draw air through a sampling train consisting of a length of Tygon™ tubing and a 37-millimeter (mm) mixed cellulose ester filter in a 3-piece cassette. The filter samples were analyzed according to NIOSH Manual of Analytical Methods (NMAM) Method 7082.[25] Each filter was digested with nitric acid and analyzed using a Varian FS 220 Flame Atomic Absorption Spectrometer. The limit of detection (LOD) for this method is 7 micrograms (µg) per sample, and the limit of quantitation (LOQ) is 20 µg/sample. Samples for which the lead concentration was below the LOQ were subsequently analyzed using a Perkin-Elmer Model 5100 Graphite Furnace Atomic Absorption Spectrometer with Zeeman background correction, according to NMAM Method 7105.[26] The LOD for this second analysis was 0.07 µg/sample and the LOQ was 0.2 µg/sample. A 250 L sample volume yields a minimum detectable concentration (MDC) of 0.3 micrograms per cubic meter of air (µg/m^3) and a minimum quantifiable concentration (MQC) of 0.8 µg/m^3 for graphite furnace atomic absorption analysis.

Six Wash'n Dri™ wipe samples collected from floors, diffusers, and tabletops were analyzed by flame atomic absorption spectrometry using a Varian FS 220 Flame Atomic Absorption Spectrometer according to NIOSH Method 9100.[27] The LOD for this method was 3 µg/sample, and the LOQ was 8 µg/sample.

During the initial NIOSH evaluation, airflow patterns in the range were observed using a fog machine (Roscoe Model 1500™) to generate a visible, non-toxic "smoke." Smoke was released at different heights from the floor to shoulder height at the firing line at different shooting lanes, as well as downrange. Observations were made regarding airflow patterns within the range and whether the range was under positive or negative pressure. A visual inspection of the air handling units (AHUs) was made.

Table 1 lists the air sampling results from the single pistol qualification exercise. No sample collected during this exercise exceeded the OSHA PEL or action level, the NIOSH REL, or the ACGIH TLV. During this time period, PBZ samples ranged in average concentration (the concentration during the time sampled) from 4 µg/m^3 (shooters on lanes 3, 5, and 7) to 89 µg/m^3 (shooter on lane 19). Assuming that the shooters received no further exposure to airborne lead during that work shift, these results equate to 8–hr TWAs ranging from 0.4 µg/m^3 to 10 µg/m^3. Lead was not detected in the PBZ sample collected on the range master working in the control room or on the area sample collected near the West rooftop AHU exhaust (the unit to the left as one faces the AHUs from the top of the roof hatch). The area sample collected in the range before beginning the shooting exercise detected only trace amounts of lead. The area sample collected inside the range near the rear range wall during the shooting exercise had 3 µg/m^3 lead, indicating that small amounts of airborne lead could migrate behind the firing line.

The results from samples collected during two consecutive pistol qualifications are shown in Table 2. No sample collected during these exercises exceeded the OSHA PEL or action level, the NIOSH REL, or the ACGIH TLV. Average PBZ sample concentrations ranged from 4 µg/m^3 (shooter on lane 5) to 159 µg/m^3 (shooter on lane 19). Assuming the shooters received no other exposure to airborne lead during the work shift, these concentrations translate into 8-hr TWAs ranging from 1 µg/m^3 to 25 µg/m^3. The average concentration detected by the sampler near the rear range wall was the same as during the single qualification exercise: 3 µg/m^3. The range master's PBZ sample collected in the control room detected lead, but at levels too low to accurately quantify. The line safety officer's 8-hr TWA was 3 µg/m^3.

Table 3 shows the results of air sampling done on April 20, 2000. During the shotgun qualification exercise, average lead concentrations ranged from trace (shooter on lane 6) to 718 µg/m^3 (shooter on lane 20). Assuming that shooters received no other airborne lead exposure during their work shift, this equates to 8-hour TWAs ranging from trace to 84 µg/m^3. Two samples exceeded the OSHA action level of 30 µg/m^3 on an 8-hr TWA basis; one of these was over the REL and PEL of 50 µg/m^3 8-hr TWA. No lead was detected on the sample collected on the range master in the control room, and the line safety officer's 8-hr TWA was 2 µg/m^3. Only a trace amount of lead was detected near the East rooftop AHU exhaust. One sample, collected in the PBZ of the ballistics lab worker in the smaller of the two indoor ranges (while evaluating .40 S&W handgun ammunition), had an 8-hr TWA of 3 µg/m^3. This level is similar to that of the range users, who had a much higher rate of fire during a comparable amount of time.

There are two likely reasons for the shooters on lanes 19 and 20 receiving a much higher exposure than their colleagues. First, the inflow of air through the overhead roll-top garage door immediately behind these firing stations resulted in stronger eddies near the firing line and more backflow along the adjacent range-right wall compared to the range-left wall adjacent to Lane 1. The second explanation is that these shooters had to move downrange several times during each qualifier to adjust their target to the proper distance from the firing line. This caused them to walk through an area of the range with more lead aerosol than the area at the firing line, and which is not typical of an exposure during normal range use.

All three of the pistol qualification exercises were conducted on one day. Therefore, the shooters' total exposure to lead that day was greater than the levels listed in either Table 1 or 2. The shooters' combined exposures are calculated in Table 4. Assuming the agents did not receive any other lead exposure beyond that of the three pistol qualifications that day, the 8-hr TWAs ranged from 1 µg/m^3 (shooters on lanes 5 and 7) to 35 µg/m^3 (shooter on lane 19). The shooter on lane 19 received the only combined exposure above the OSHA action level.

The levels of surface lead loading in various parts of the range building are shown in Table 5. Three of the six samples resulted in non-detectable levels of lead: a supply air diffuser in the range, the control room tabletop, and a classroom tabletop. The floor at lane 1, and between lanes 10 and 11, and the hallway leading from the range to the outside door had 2.9, 8.1, and 1.6 µg/ft^2 lead, respectively. These levels are much lower than both the most conservative federal limits in residential settings and other indoor firing ranges investigated by NIOSH.[28,29,30] This reflects both the limited use of the range thus far and that good housekeeping practices are being used.

In general, without shooters standing at the firing line, the supply air effectively pushed the smoke emitted by the smoke machine at the firing line toward the downrange exhaust plena. When the smoke machine was used at Lanes 1 and 20, the smoke flowed downrange a short distance before a portion of it began to migrate uprange along the walls. This backflow continued to the firing line before it was again pushed downrange by the air supplied from the rear of the range. This effect was more pronounced near lane 20 where the inflow of air from the overhead door created air currents that drew smoke from downrange of the firing line to the uprange side. The smoke machine was not used while people were standing at the firing line. Immediately before the air sampling was done for this HHE, the INS ventilation contractor balanced the ventilation system and set it as close as possible to its design specifications.

March 2002

After the roll-top door in the wall of the range was replaced with brick, NIOSH conducted a lead exposure assessment on March 26, 2002. Three shooting periods were monitored: (1) a single shotgun qualification; (2) two immediately consecutive pistol qualifications (double pistol qualification); (3) one single pistol qualification. The number of rounds fired per qualification was the same as those during the April 2000 exposure assessment reported above. PBZ samples were collected on shooters in the same manner as the previous evaluation. Area air samples were also collected along the rear range wall behind lanes 3, 9, and 19. The same methods were also used in the analysis of these samples.

Air samples for lead were collected using battery operated personal sampling pumps calibrated at a nominal flow rate of 3 Lpm to draw air through a sampling train consisting of a length of Tygon™ tubing and a 37-mm mixed cellulose ester filter in a 3-piece cassette. The filter samples were analyzed according to NIOSH NMAM Method 7300 modified for microwave digestion.[31]

The results from air sampling conducted March 26, 2002 are listed in Tables 6, 7, and 8. Table 6 shows the PBZ exposures received during a shotgun qualification and the area air sampling results collected during the entire shooting day. Eight-hour TWA PBZ levels ranged from 0.72 µg/m^3 to 9.37 µg/m^3 for shotgun users. Area samples collected at the rear of the range all had quantifiable amounts of lead on them. Table 7 shows the 8-hr TWA exposures to shooters during consecutive pistol qualifications; all exposures were less than 1 µg/m^3. Table 8 shows that during the last sampling period of the day, the single pistol qualification, 8-hr TWA exposures were all below 5 µg/m^3.

September 2002

After a horsepower upgrade of the fan's electric motor had been made to improve the airflow past the firing line, NIOSH investigators collected PBZ and area air samples for lead during two sessions of qualification exercises on September 25, 2002. The first session consisted of fifteen shooters completing a single pistol qualification round in lanes 2 through 9 and 11 through 17. PBZ samples were collected on each of the shooters and the qualification instructor. Area air samples were collected at the firing line of two unoccupied lanes (lanes 10 and 18) and at the doorway entrance to the range. A second round of sampling was performed while shotguns were used during the second qualification exercise using the same sampling protocol.

Air samples for lead were collected using battery operated personal sampling pumps calibrated at a nominal flow rate of 3 Lpm to draw air through a sampling train consisting of a length of Tygon™ tubing and a 37-mm mixed cellulose ester filter in a 3-piece cassette. The filter samples were analyzed according to NIOSH NMAM Method 7300 modified for microwave digestion.[31] The MDC was 0.28 micrograms per cubic meter (µg/m^3) calculated using the analytical LOD, reported as 0.05 micrograms per filter (µg/filter), and a 180-liter sample volume. An MQC of 1.1 µg/m^3 was calculated using the analytical LOQ of 0.2 µg/filter and a 180-liter sample volume.

Additionally, PBZ samples for carbon monoxide (CO) were collected using real-time monitoring equipment placed on six of the shooters. A Biosystems Inc. ToxiUltra Gas Detector recorded CO concentrations in the PBZ of the shooters every 20 seconds during the qualification exercises. The recorded measurements were then downloaded to a computer. The monitor measures CO concentrations from 0–500 parts per million (ppm).

The results from the lead sampling performed on September 25, 2002, during a typical pistol qualification exercise (consisting of each agent firing 72 rounds of 155 grain jacketed hollow point .40 S&W ammunition) are summarized in Table 9. Calculating an 8-hour TWA from these results with the assumption that they were the sole lead exposures experienced during the 8-hour work shift allows comparison to the OSHA PEL and the NIOSH REL. Accordingly, the 8-hour TWA results for these individuals due to exposures solely received during the pistol qualification exercise ranged from 0.14 µg/m^3 to 4.04 µg/m^3. Therefore, a single pistol qualification round during an 8-hour shift appears to cause lead exposure well below applicable exposure limits. The performance of a single pistol qualification exercise during an officer's shift is a typical scenario. However, if individuals were to perform more than one pistol qualification exercise during a shift under these same conditions, the exposure would be expected to increase correspondingly.

The results from the lead sampling performed during a typical shotgun qualification exercise (consisting of each agent firing 25 rounds of

2¾" 00 Buck and five 2¾" slugs rounds) are summarized in Table 10. Again, assuming no other lead exposures were experienced during the 8-hour work shift besides that from the shotgun qualification exercise, 8-hour TWA results for these individuals ranged from 1.0 $\mu g/m^3$ to 59.9 $\mu g/m^3$. The performance of a single shotgun qualification exercise during the shift is also a typical scenario. Although performing shotgun qualification exercises for a full 8-hour shift would be rare, if individuals were to perform more than one shotgun qualification exercise during a shift, or combinations of shotgun and pistol qualification exercises, the exposure would be expected to increase correspondingly. The results returned from sampling performed during the single shotgun qualification exercise were considerably higher than those returned during the pistol exercise, with one sample returning an 8-hour TWA result higher than the OSHA PEL and two other samples above the OSHA AL of 30 $\mu g/m^3$ as an 8-hour TWA.

Figures 1 through 6 show the results of CO monitoring conducted on six individuals during the qualification rounds. On each figure, two identifiable periods of exposure are visible. The first period, approximately 2:05 pm to 2:25 pm, corresponds to the pistol qualification exercise. The second period, corresponding to the shotgun qualification exercise, runs from 2:40 pm to 2:55 pm. Exposure to CO was considerably higher during rounds of shooting with the shotgun versus the pistol. Although the 8-hour TWA exposures for all individuals sampled would be quite low, peaks of CO exposure were highest in lane 17, with one peak of 294 ppm, surpassing the NIOSH-recommended ceiling limit of 200 ppm (a level that should not be exceeded at any time during a workday).

Methods and Results: Noise

April 2000

On April 19–20, 2000, NIOSH investigators conducted a noise exposure assessment at the firing range. Quest® Electronics Model Q-300 Noise Dosimeters were worn by two officers during each of the two pistol qualification rounds and one shotgun qualification round. The noise dosimeters were attached to the wearer's belt, and a small remote microphone was fastened to the wearer's shirt at a point midway between the ear and the outside of the officer's shoulder. At the end of a weapons qualification round, the dosimeters were removed and paused to stop data collection. Additionally, dosimeters were placed in the range master's control room and in the adjacent classroom during qualification rounds to collect area measurement. The information stored in the dosimeters was downloaded to a personal computer for interpretation with QuestSuite for Windows® computer software. The dosimeters were calibrated before and after the measurement periods according to the manufacturer's instructions.

Two officers were asked to wear a noise dosimeter during a qualification round for either a pistol or shotgun. The pistol qualifications consisted of one or two complete rounds of weapon firing; the shotgun qualification was only one complete round of shooting. All 20 firing stations were used at once.

The officers were centrally located on the firing line, either in Lanes 7 or 8 and Lanes 12 or 13. The dosimeter was placed on the officer shortly before the qualification began. For the double set of pistol qualifications, the dosimeter remained on the officer and recorded noise levels for both rounds and the period between them.

The Quest dosimeters collect data so that one can directly compare the information with the two noise criteria used in this survey, the OSHA PEL and Action Level (AL), and the NIOSH REL. The OSHA criteria use a 90 dBA criterion and 5 dB exchange rate for both the PEL and AL. The difference between the two is the threshold level employed, with a 90 dBA threshold for the PEL and an 80 dBA threshold for the AL. The threshold level is the lower limit of noise values included in the calculation of the criteria; the dosimeter ignores values less than the threshold. The NIOSH criterion differs from OSHA's in that the criterion is 85 dBA, the threshold is 80 dBA, and it uses a 3 dB exchange rate.

The personal noise dosimeter results are shown in Table 11. All data are presented as the accumulated dose percentage for the time necessary to complete the qualification round and as an 8-hr TWA that assumes that the remainder of the 8-hour day is spent in noise less than 80 dBA. The noise exposure for both officers exceeded all the evaluation criteria when shooting the pistol either for one or two qualification rounds. When the shotgun was fired on the range, the TWA levels were less than 90 dBA when calculated according to the OSHA PEL. However, the recorded levels of 87 dBA and 88 dBA did exceed the OSHA AL of 85 dBA. The NIOSH REL was exceeded by 18–25 dBA for all qualification conditions.

The noise levels from the weapons in the control room and adjacent classroom were much less than for the officers on the firing line. The control room noise average ranged from 83 dBA to 87 dBA during the qualifications using the most conservative evaluation criteria (REL). The 1-minute noise averages for pistol and shotgun qualifications are graphically displayed in Figures 7–10 for the control room and classroom. The highest level approaches 95 dBA in the control room and 80 dBA in the classroom.

During weapons qualification, all officers on the firing line and all observers behind the line in the range wore double hearing protection, i.e., earplugs under earmuffs. The National Firearms Unit provided Moldex Purafit® earplugs (6800) and Peltor® earmuffs (H7A) at the range. Personnel assigned to the Altoona facility had been fitted with custom-molded earplugs. Also, some of the officers who participated in qualification shooting brought their own HPDs with them, including sound restoration earmuffs. The instructions from the range master were delivered to the firing line through an amplification system with a microphone in the control room and loudspeakers in the range. The amplification system was set near or at the maximum output level during the weapons firing exercise.

The noise produced by gunfire has sufficient intensity to permanently damage the unprotected ear in a very short period of time. The damage can occur in minutes rather than the days or years typical of industrial noise exposure. Because of the noise levels in this environment, the INS practice of wearing double hearing protection is justified. Research has reported that double hearing protection can provide the additional noise reduction needed in high noise-level environments.[32] This same research reported that the earplug was the more important component of the double protection, with greater attenuation afforded when the earplug was properly inserted into the ear canal. Some of the participants of weapons qualification and the INS officials observing the evaluation had not deeply inserted the earplugs before placing the earmuffs over their ears.

Some officers were wearing sound restoration earmuffs over earplugs on the firing line. They reported that this combination helped them hear instructions from the range master while wearing double protection. The earmuffs amplified the instructions to the wearer as long as no weapons were fired. As soon as the firing commenced, the amplification system shut off and the earmuffs acted as passive, noise-attenuating devices. Many of the officers wearing the double protection issued by the INS were unable to hear directions from the control room, even with the amplification system at or near the maximum level. The range master attempted to overcome this condition by raising his voice and speaking directly into the microphone with his mouth nearly touching it.

The roll top garage door on the wall of the firing range rattled whenever the ventilation system was set for range use. Air leakage around the door frame caused the door to bang into the metal frame and the door housing on the top of the opening. The intensity of this door noise was much less than that from the weapons. By itself the door noise is not hazardous to the hearing of individuals on the range, but it can annoy and distract officers attempting to be very accurate in their shooting. Similarly, noise from the range, while not hazardous may annoy and distract control room and classroom users. This finding is more critical for the classroom if the INS intends to use it for training simultaneously with use of the indoor firing range. The shots on the range were audible in the classroom; an instructor would probably have to stop lecturing until firing stopped.

March 2001

NIOSH investigators visited the NFU on March 15, 2001, to conduct a noise exposure assessment. The purpose of this visit was to identify the acoustical environment parameters, conduct preliminary noise measurements, and provide noise abatement recommendations. Sound reaches a shooter's ears by two paths: the direct field and the reverberant (reflected) field. The direct field is emitted directly from the sound source. The reverberant field is the sound echo. The direct sound field dominates near the noise source (pistol, rifle, etc.) and is independent of the room properties (geometry, absorption, etc.). Direct field diminishes with distance from the source. The reverberant field dominates far from the source, depends on room properties, and does not vary with distance from the source.[33] While INS's initial request focused on the potential for noise reduction on the firing range (direct field), NIOSH investigators were also asked to comment on the potential for reducing sound levels in the adjacent spaces (control room, cleaning room, office, and classroom).

The noise assessment of the firing range consisted of: (1) conducting reverberation measurements to identify the acoustical parameters that may contribute to increased noise levels in the firing range and (2) conducting SPL measurements in the firing range and the adjacent areas. The equipment used to document SPLs and reverberation characteristics were factory calibrated within the previous year by the respective manufacturer. Field calibration was conducted on the survey date by NIOSH investigators. The sound level meters (SLMs) conform to the American National Standards Institute (ANSI) Specification for Sound Level Meters.[34]

Measured reverberation times were obtained using a Model 2900B real time analyzer/sound level meter (RTA/SLM) (Larson Davis, Provo, Utah). The RTA/SLM with built-in building acoustics software was operated in accordance with manufacturer recommendations.[35] The firing range was acoustically excited using pink noise. Pink noise (noise with equal energy across octave bands) was generated from the RTA/SLM. The noise signal was boosted through an Electro Voice (Buchanan, Michigan) P1250 amplifier and played into the room through an Electro Voice S_x 80 speaker. The RTA/SLM was set to allow a noise build up time of 5 seconds prior to triggering the pink-noise generator to off. Reverberation decay time (time required for levels to fall 60 dB after signal cutoff) measurements were set to 6 seconds after the noise generator triggered to off.

Peak SPLs were measured using a 1/4" type 4135 microphone (Bruel & Kjaer, Decatur, Georgia). The SPLs were recorded on digital audio tape (DAT) using a DAT recorder Model SV 255 (Panasonic, Secaucus, New Jersey). The B&K 4135 Microphone operates without distortion to a level of 167 dB. The microphone was located approximately 6–7 feet behind the shooter at ear level.

Area measurements were conducted using a Model 1800 SLM (Quest, Oconowoc, Wisconsin). The SLM was set to operate in the "80–140 dB" range with response set to "Peak".

Peak SPLs were obtained at several locations when one shooter was using either a 0.40 caliber Beretta pistol or a Remington 12 gauge shotgun.

Reverberation measurements are summarized in Table 12. The maximum reduction of SPLs in a best case scenario (all current surfaces offering "perfect" absorption) would be 12 dB. Given measured peak SPLs of 147–153 dBA, there is no opportunity to lower the noise to acceptable levels through sound absorption techniques of current surface areas and geometries. In fact, removing the walls and ceiling (i.e., outdoor conditions) would not achieve the desired reduction. Double hearing protection would still be required at this level. Given the lack of benefit and the high cost associated with absorption treatment of these surfaces, no change would be recommended regarding treatment of the reverberant environment of the indoor firing range.

The measured peak SPLs from the B&K 4135 microphone and the Quest 1800 SLM are shown in Table 13 for the firing range, control room, cleaning room, office, and classroom. The maximum exposure times at NIOSH RELs and the ACGIH TLVs are also noted in Table 13. The data reflect measurements collected using one shooter only. A typical training session involves 15–20 shooters firing multiple weapons for an extended period of time. The preliminary data show levels that exceed the OSHA maximum allowable exposure level of 140 dB inside the firing range. Measurements in the control room and cleaning room show personnel should not be exposed to more than 3 minutes during an 8-hour work shift. Even in the office area, INS personnel may be exposed to harmful levels when multiple shooters use the range. Without regard to the need for hearing protection, the classroom and office areas cannot be used for their intended purpose during a shooting session.

June 2001

NIOSH researchers returned on June 15, 2001, to conduct an additional noise exposure assessment. The equipment used to document SPLs and reverberation characteristics had been factory calibrated within the previous year by the respective manufacturer. Field calibration was conducted on the survey dates by NIOSH investigators. The SLMs conform to the ANSI Specification for Sound Level Meters.[34] The noise dosimeters conform to the ANSI Specification for Personal Noise Dosimeters.[36]

Noise measurements were obtained at 11 different positions throughout the firing range and adjacent areas as outlined in Figure 11. The positions were primarily chosen to measure a typical INS officer's noise exposure in the firing range and the noise reductions afforded by the current building structure in the adjacent areas. The B&K 4136 microphone and dosimeters microphones were placed at the height of an average officer's ear when firing (approximately 5 feet above the floor). Ten INS officers conducted a typical firing session that lasted approximately 1 hour using three different weapons (Remington 870 Shotgun, M4 Rifle, Beretta Pistol). Three INS officers wore personal dosimeters for the entire session. DAT recordings were obtained for 3 to 5 minute intervals at each of the 11 positions.

The measured peak SPLs and equivalent levels from the B&K 4136 microphone are shown in Table 14 for the firing range, control room, cleaning room, classroom, and office. The data show levels that exceed the OSHA maximum allowable exposure level of 140 dB inside the firing range. Interestingly, the data collected from the B&K4136 microphone and DAT setup measured peak sound levels more accurately than the dosimeters because of the limitations of the Q400 dosimeter microphone. The data collected from the Q400 dosimeters were not included in this report because they did not give an accurate representation of the sound pressure levels in the firing range.

The data in Table 14 show the maximum time durations that an INS officer can be exposed to noise. Dual hearing protection must be worn at all times during a firing session, especially in the firing range and control room. While the data collected in the classroom and office areas show average sound pressure levels that are considered acceptable according to NIOSH noise exposure criteria, measured peak levels indicate the presence of impulses that might be considered hazardous to hearing. There are also non-auditory noise effects such as physiologic changes, fatigue, increased reaction time, reduced concentration, and irritability.[37,38,39] The data shown in Table 14 clearly indicate that the classroom and office areas cannot be used successfully for their intended purposes during training.

The calculated noise reductions in octaves for the cleaning room, control room, classroom and office are shown in Table 15. The noise reductions are presented in octave bands because transmission loss of materials used in noise controls is normally specified according to their octave band absorption coefficients. One-third octave band spectra of the firing range and the adjacent areas are shown in Figures 12–16. The one-third octave data provide information on the frequency spectra for each of the positions. The data can be used to assess how to provide the necessary noise reductions and to choose the right transmission loss materials in case INS decides to modify to the range to achieve their intended goals for hearing loss prevention and improved conditions in the adjacent spaces during firing sessions. The average A-weighted sound pressure levels in the cleaning room and control room are 91 dBA and 94 dBA respectively. Currently, the noise reductions in the cleaning room and control room are 33 dBA and 30 dBA. To achieve the NIOSH-recommended exposure limit of 85 dBA in the cleaning room and control room, substantial additional noise reductions (6 dBA to 9 dBA) will be needed.

September 2002

The noise exposure assessment consisted of (1) personal exposure monitoring of officers during a live-fire session, (2) measuring sound levels in the firing range, and (3) assessing the effectiveness of various HPDs.

Personal exposure measurements were made using Quest 400 and Larson-Davis 706 dosimeters. Peak sound levels were measured using a B&K 4136 1/4" microphone, B&K 2615 pre-amplifier, and B&K 2807 power supply, and were recorded on Panasonic SV-255 and Tascam DA-P1 DAT recorders at 48,000 samples per second. The maximum sound pressure for the 4136 microphone was rated at 172 decibels (dB SPL). Area measurements were made using a Larson-Davis 824A sound level meter. Hearing protectors were evaluated using an artificial head mannequin built specifically for measuring impact and impulse noise. The mannequin consists of Head Acoustic pinnae and ear canals, Bruel and Kjaer 4157 middle ear simulator, and a Bruel and Kjaer 4165 ½" microphone. The maximum peak sound pressure level that could be measured with the mannequin was 148 decibels (dB SPL re 20 µPa). Because all mannequin measurements were performed under hearing protection, the maximum sound pressure level was not exceeded. Figure 17 shows the mannequin setup. The mannequin microphone and the external microphone were calibrated with a Bruel and Kjaer 4228 piston-phone that produced a 124 dB SPL tone at 250 Hz. The sound level meters and dosimeters conformed to the American National Standards Institute (ANSI) specifications.[34,36] The equipment was calibrated before the visits by the manufacturers. Field calibrations were conducted before and after measurements.

Sound level measurements were obtained throughout the firing range while shooting occurred. Three officers and a NIOSH researcher wore personal noise dosimeters. The mannequin was set up in lane 10, and protected measurements were recorded to the DAT. The B&K 4136 microphone was set up to the right of the mannequin head to measure the unprotected impulses. Fifteen INS officers conducted a typical live-fire exercise that lasted approximately 1 hour using two different weapons (Remington 870 Shotgun and Beretta 9mm Pistol). Because noise dosimeters were suspected to overload under such extreme conditions, backup measurements were made using the B&K 4136 microphone and DAT recorder as well as sound level meters. Microphones were positioned at an average officer’s ear height (approximately 5 ft above ground). Data from the dosimeters were downloaded and analyzed using the Larson-Davis Blaze software and QuestSuite software. Data from the sound level meter were downloaded and analyzed using the Larson-Davis 824 Utility 3.0 software. Data from the DAT were digitally transferred to a computer as ‘.wav’ files via a AUDIOTRAK Waveterminal U2A 24 bit audio card and CoolEditPro 6.0 software. Spectral analysis was performed using MATLAB software routines to obtain peak levels, equivalent levels (Leq), time durations, frequency, octave, and one-third octave band spectra.

Table 16 shows average and peak sound level measurements obtained throughout the firing range and adjacent areas. The measurements were obtained using the B&K4136/DAT setup. As shown, minor differences appeared between the pistol and shotgun firing exercises in terms of sound energy and overall time-weighted average noise exposures.

Figure 18 shows a frequency spectrum comparison between the pistol and the shotgun firing exercises. As the figure shows, firing shotguns produces more low-frequency energy than firing pistols. Studies have shown that exposure to weapons with low frequency energy (shotgun) is less harmful to hearing than weapons with spectral peaks at the higher frequencies (pistol and M4 rifle).[40,41]

The effectiveness of the hearing protection used by INS officers was evaluated by measuring sound levels outside and inside the same hearing protectors on the artificial head fixture during both firing exercises (pistols and shotguns), and separately using the three different weapons most commonly tested at the range (Beretta pistols, Remington shotguns, and M4 rifles). Three different protectors were evaluated—EAR earplugs, Bilsom 707 earmuffs, and Peltor H10 earmuffs—as representative samples to examine peak reductions. The earplugs and earmuffs were evaluated separately and in combination. Table 17 shows the results of various measurements conducted using double hearing protection. Figure 19 shows the peak reduction performance of various HPDs when using the Beretta pistol.

DISCUSSION AND CONCLUSIONS

Lead

Based on the limited wipe sample results, current housekeeping practices at the firing range appear to be effective in both keeping the range clean and minimizing the migration of lead dust from the range to areas outside the range.

The air sampling results demonstrate that when pistols are used, the lead exposures remain low even after consecutive qualifiers. The potential remains for shotgun users to receive airborne lead exposure above the OSHA action level in the main indoor firing range under the conditions experienced during the April 2000 site visit. The exposures received by shooters in the lanes nearest the walls were consistently among the highest of the data set. This was likely due at least in part to the migration of air along the walls from downrange back toward the firing line. Because the shooters in lanes 19 and 20 also moved downrange at times during the shooting exercises, it is not possible to accurately estimate what portion of their exposure is due solely to the increased backflow created by air entering through the roll-top door entrance adjacent to their shooting station. The two highest exposures documented during this site visit occurred during the shotgun qualifier. One of these samples collected during the shotgun qualifier exceeded the OSHA PEL.

While the population of shooters at the NFU changes throughout the year as different agents come for short-term training, on-site personnel such as the range master and line safety officers are likely to receive the most frequent exposures. Based on the results from this site visit, these individuals do not appear to be at significant risk. The highest exposure documented in this group was 3 $\mu g/m^3$.

Results from the September 2002 lead sampling continued to reveal a pattern of increased exposures to individuals shooting in lanes 14–18 relative to the exposures received by individuals at other lanes during the respective qualification exercises. These patterns can best be seen graphically in Figures 20 and 21.

Results from the sampling for CO show a similar pattern of increased exposure for individuals in the lanes where lead exposure was highest.

The results from the lead and carbon monoxide sampling reinforce the results from smoke release tests performed during the site visit. In the area of lanes 15–18, smoke released at the firing line revealed a high level of turbulence and the presence of eddies and backflow of air that circulated the smoke back into the breathing zone of the individual at each position on the firing line.

Disturbances at the firing line of these lanes may be the result of poor distribution of air due to the size, type or position of the supply air diffusers located at the ceiling level of the back wall of the range. These diffusers are smaller and located at a higher position than those behind other firing lanes. During a conference call on October 21, 2002, the recommendation for new diffusers to improve the laminar flow of air across the firing line of all the lanes was discussed with INS officials. The diffusers would decrease exposure levels of lead and CO for individuals at the firing line, particularly in the lanes of concern.

BULLET TRAP DESIGN

Traditional bullet trap design typically involves the bullet striking an inclined metal surface, removing kinetic energy from the projectile as it guides the bullet into a collection device. Smashing of the bullet onto the bullet trap surface contributes to the ambient airborne lead concentration. Because this occurs far downrange from the shooters, typically this does not increase the lead exposure of range occupants. It can, however, accelerate lead loading on HVAC and dust collection unit filters, decreasing their service life and increasing the rate at which they must be cleaned and/or replaced. The feasibility of rubber bullet traps should be investigated for future range development and modification. In decreasing the total amount of lead aerosol created in the range (by limiting the lead aerosol produced to that coming directly from the firearm when it is fired), the INS may realize long-term cost savings in both filter replacement costs and other maintenance activities. Decreasing lead aerosol would also help alleviate the high airborne lead concentrations in access areas behind the bullet trap, as documented in the survey done by Berger and Associates at the AIFR in 1999.

Ventilation

The objective for the Altoona indoor firing range study is to reduce the lead exposures in the facility to the lowest technically feasible levels. The recommendations associated with these strategies can be phased-in in order of their expected increasing cost until the lead exposure issues in the AIFR have been adequately resolved. These recommendations can be implemented in three phases. In Phase I, the least costly recommendations associated with fixing major air leaks and operational variables contributing to increased air turbulence can be implemented. If implementing Phase I fails to lower airborne lead to acceptable levels, then Phase II recommendations associated with optimizing the ventilation systems should be implemented. If Phase II fails to adequately lower the lead exposures in all of the firing lanes, then Phase III recommendations associated with upgrading the ventilation systems for the AIFR should be implemented.

PHASE I

Leaks

All major leaks in the range must be closed to ensure successful ventilation in indoor firing ranges. Because these leaks are difficult to characterize, they are typically not accounted for in the overall design of the ventilation system. These leaks overburden the range ventilation system, and negatively affect its overall performance. Large leaks in the building can (1) prevent the range from being maintained at a negative pressure, (2) create temperature and humidity variations throughout the facility, (3) influence the formation of eddy currents that disturb the range airflow, making it more turbulent, and (4) reduce the amount of air flowing past the firing line.

The identification process for leaks in the range consists of leak testing all the entrances followed by leak testing the overall structure of the range.

All direct entrances into the range should be leak proofed. Doors opening directly into the range should be individually tested for leaks and repaired to make them airtight. The overhead door located behind the firing line on the east wall of the AIFR should be replaced with an airtight door. The doors leading directly into the range, including the door behind the bullet trap, should also be made airtight.

The building structure of the AIFR should be visually examined for major leaks. Minor leaks can be identified using smoke tubes and fog generation machines. All identified leaks should be repaired.

Turbulence

Ideally, airflow within the range should be uniformly laminar, flowing smoothly without swirling or turbulence. Introduction of any turbulence, particularly behind or at the firing line, can compromise the safe operation of the range. During future range design, all sources potentially capable of enhancing turbulence in the range should be identified so that appropriate actions can be taken to resolve them prior to the start up of the range. In the AIFR currently there are two sources responsible for increased turbulence in the range:

1) Leaks negatively affect overall range operation because they tend to reduce the airflow near the firing line and influence the formation of eddy currents throughout the range. If not eliminated, these eddy currents can cause lead-contaminated air to stop moving downrange away from shooters, swirl in a circular motion, and move back up range to the firing line. Fixing these leaks as described in the previous section is critical for ensuring proper airflow at the firing line, and for keeping turbulence to a minimum.

2) The widest section of the lane partition should always be installed parallel to the airflow to minimize the obstruction of the range airflow. Currently, in the AIFR the widest section of the partitions are installed perpendicularly to the airflow, partially obstructing range airflow. This induces the formation of eddy currents and thus creates more turbulence near the firing line. This may become important especially when shooters use the firing line ahead of the lane partitions, if turbulence is created behind them by the partitions.

PHASE II

Optimization

The optimization process should be executed as follows:

1) The first step involves verifying whether equal airflow is discharged from all of the supply diffusers. If not, then the supply airflow dampers should be appropriately adjusted until the airflow is equally distributed to all of the diffusers.

2) The second step is twofold. The first part is optimizing the exhaust airflow between the midrange exhaust and the downrange exhaust. The second part is ensuring equal distribution of exhaust airflow to all the inlets in each location. The balancing of the exhaust among inlets at each location should be implemented using the same procedure employed in balancing the supply airflow.

3) The third step involves determining the recirculation fan speed at which the air velocity for all of the lanes at the firing line can be maintained at a minimum of 75 feet per minute (fpm) (recommended in NIOSH Document No.76-130, entitled "Lead Exposure and Design Consideration for Indoor Firing Ranges"). This is accomplished by increasing the speed of the recirculation fans for system 1 and system 2 in fixed increments until the desired air velocity across each lane is attained. If the amperage on the 30 horsepower (HP) electric motor peaks out prior to achieving the desired air velocity in each lane, then phase III should be implemented.

4) The design of the supply airflow diffusers plays a critical role in ensuring uniform airflow in each lane. The performance of the supply airflow diffusers can be determined by measuring the air velocity variations within each

lane. Since there are no standards for the maximum air velocity variations permitted, the goal for the AIFR should be to target the variations within 50%. If the air velocity variations in the majority of the lanes of the AIFR exceed 50%, attempts should be made to modify the existing supply airflow diffusers to minimize the turbulence. If these attempts are unsuccessful in reducing air velocity variations below 50%, then the option for replacing the existing supply airflow diffusers with newer commercially available diffusers that are laminar airflow-friendly should be explored.

PHASE III

Ventilation Systems

ScanCo Environmental System Inc. designed the ventilation systems for the AIFR facility. The original design for the ventilation systems called for 40HP recirculation fan motors. However, the roof of the range reportedly could not accommodate the weight of the proposed fans. The fan motors were therefore downsized from 40HP to 30HP to meet the roof's weight limitations.

Noise

The April 2000 exposure assessments show that a hazard to hearing exists at the indoor firing range at the INS facility. Because of this hazard, INS officials need to continue their practice of requiring double hearing protection for officers on the firing line and for any individual in the firing range when weapons are fired.

The June 2001 noise assessment of the NFU firing range showed peak sound pressure levels that exceeded the OSHA maximum exposure limits. INS officers can be exposed to levels that exceed 160 dB during a firing session. The control room roof structure allows for unnecessary noise leakage because of its weak design. While average sound pressure level measurements in the classroom and office area show acceptable average noise levels, NIOSH investigators recorded peak sound pressure levels of 108–110 dB. Hearing protection is warranted throughout the range and dual hearing protection must be worn in the range during firing sessions. INS indicated its intention to explore modifications to the range for noise, ventilation, visibility (more glass in the control room) and reducing of the number of shooting lanes.

The noise levels resulting from shooting activities have rendered the classroom unsuitable for training because the sound isolation between the areas is inadequate. The office, though farther away from the actual range noise, is still essentially unusable as an office during firing. Because the noise environment is far from optimum, conducting telephone conversations or concentrating on tasks is adversely affected by intermittent noise. The control room presents a special problem in that the range officer must use hearing protection while inside the control room. The cleaning room is usable, but high noise levels limits conversation.

Three of the four areas (cleaning room, classroom and office) share common deficiencies: The transmission loss through the existing wall structure is too low, and the leakage and flanking paths other than the wall are significant. While it is possible to build a second wall to alleviate much of the noise intrusion problem, the limitation of the effectiveness of the final result in each room will be leakage and flanking paths that cannot be treated effectively after the fact. The fourth area (control room) has high noise levels because the bullet proof glass does not provide sufficient transmission loss, the roof is essentially a single layer of sheet metal with no absorption, and the door is not acoustically rated. The following paragraphs summarize recommendations to maximize the amount of improvement that can be expected.

Shooting Range

Lowering the noise in the firing range to acceptable levels through sound absorption techniques of current surface areas is not feasible or practical. Double hearing protection would still be required for each shooter and anyone else in the range area. Since INS is considering reducing the number of firing lanes from 21 to 15, absorptive "septum" barriers should be installed between these firing lanes. While this would reduce a shooter's exposure level to the direct sound field of other shooters, it would have limited effect in protecting the shooter from the direct sound field of his/her own activities in the firing range. If barriers are used, care must be taken when placing them to ensure a clear and unobstructed view of each shooter from the control room. Such a design change should include a number of alternative arrangements to allow the selection of a barrier arrangement that provides acceptable visibility from the control room and does not degrade the ventilation requirements.

Adjacent Areas

To significantly reduce noise reduction from the firing range into the adjacent spaces, treat both the direct sound paths and all flanking paths. To improve the transmission loss of an existing wall structure, build a second wall with an air gap between both walls. These measures increase the mass in the sound path, break vibration paths and add cavity absorption.

The results from the September 2002 exposure assessment have shown that noise dosimeters can not provide accurate measures of the impulse sounds commonly encountered in firing ranges. Current noise dosimeters are not designed to handle impulse noise, but rather to provide standard compliance measurements. The electro-acoustic limitations associated with dosimeter use in impulsive noise environments include peak level clipping, dose response uncertainties, and underestimation of the hazard to hearing.[42]

The results show that earplugs generally performed better than earmuffs when used as the only protector. The electronic level-limiting earmuffs (Bilsom 707) performed better than the standard-issue Peltor H10. However, both earmuffs provided the same peak reductions when used in combination with the EAR® earplugs. These results agree with findings from previous studies on hearing protector attenuation against weapon noise.[43,44] These studies have also shown that using personal safety glasses degrades the earmuff performance because safety glasses produce a leak under the earmuff cushion. Special consideration should be given to the proper use and fitting of hearing protectors with safety glasses.

Current impulse noise damage risk criteria[45,46] suffer from a lack of empirical data needed to quantify impulse noise exposures and assess potential damage to hearing. The scientific, occupational, and military communities have not reached a consensus regarding the risk of hearing loss from exposure to impulse noise. NIOSH recommends that exposure to impulse noise not exceed 140 dB peak sound pressure. Based on the above recommendations, NIOSH proposes a simplified formula to evaluate the risk of exposure to impulse noise in terms of the number of impulses to which an officer can be exposed during each firing session:

$$N = 10^{((140 - \mathrm{PI})/10)}$$

where PI is the peak impulsive level in dB SPL under hearing protection. Applying this formula to the peak level of 121 dB from the pistol firing session in Table 17 yields N=80 shots. This conservative formula does not take into account the duration of the impulse, its spectral content, or energy. The Military Standard (MIL-1474D) in contrast, indicates that people wearing double protection can be exposed to 1000 shots a day as long as they do not exceed 162 dB peak sound pressure level. Another method used to examine the hearing hazard from noise impulses is based on the French criterion.[47] This criterion uses the measurement of the integrated A-weighted acoustic energy that enters the cochlea. It reconciles with the current NIOSH recommended exposure limit of Leq/TWA of 85 dBA. Table 17 shows overexposure for officers (wearing double protection) using the Beretta pistol and M4 rifle.

Conclusion

The noise assessment of the firing range showed peak sound levels that exceed the ceiling limits for safe exposure. INS officers were exposed to noise levels that reach 163 dB during a live-fire session. Current damage risk criteria lack the empirical data to establish a quantitative relationship between these levels and hearing damage. Two significant findings have been identified as a result of this study. First, personal noise dosimeters cannot produce accurate measurements in impulsive noise environments nor are they suitable for characterizing the impulse noise hazard. Second, other parameters such as peak pressure, time duration, rise time, energy, spectral content, number and mixture of impulses, and temporal spacing must be considered to understand the full extent of the hearing hazard. Given the poor noise control in the spaces adjacent to the range, hearing protection should be worn throughout the facility, and dual hearing protection must be worn inside the range during firing sessions. The suggested noise abatement techniques reduce airborne sounds by sealing leaks and airtight insulation around doors, windows, and ventilation ducts. Structural-borne transmission and vibration were limited by applying acoustical treatment to walls, windows, doors, and the roof structure.

RECOMMENDATIONS

Lead

- Continue investigating the feasibility of using a completely lead-free practice round.

- Use future wipe sampling results as an indicator of ongoing housekeeping effectiveness.

- Use a HEPA vacuum on the range before it is wet mopped.

- Include range housekeeping personnel, and anyone else with regular occupational exposure to lead, in the blood lead and zinc protoporphyrin monitoring program.

- Investigate the feasibility of rubber bullet traps for future range development and modification.

Ventilation

The NFU should minimize the lead exposures to all range users, especially shooters who may encounter relatively high concentrations of lead for short periods of time. This can in part be accomplished by the following:

- Prohibit shooters from moving downrange.

- Repair or replace the roll-top door.

- Investigate ventilation/engineering solutions that can minimize the amount of backflow along both side walls of the range.

- Require range users to wash their face and hands upon leaving the range and before eating, drinking, or smoking.

Listed below is a summary of the recommendations for overcoming the operational problems associated with leaks and increased turbulence in the AIFR.

- Test all of the doors that provide direct entrance to the range for leaks and repair them to make them leak tight. The overhead roll-top garage door should be replaced with an airtight door.

- Turn the lane partitions so their widest section is parallel with the airflow when shooters use the firing line closest to the bullet trap, ahead of the lane partitions. Turn them approximately 90 degrees from their current position when they are not being used for shooting exercises simulating firing from behind cover.

- Identify and fix all major leaks associated with the range's building structure.

Listed below are recommendations for further reducing the turbulence in the operation of the AIFR. Implementation of these recommendations should result in more laminar airflow throughout the range.

- It is very difficult to maintain uniform laminar airflow in the end lanes. During smoke testing of the range, smoke was first pushed downrange, but then small amounts migrated along the side walls toward the firing line. This creates eddy currents making the end lane airflow more turbulent. As a result of lead contaminated air flowing from downrange back toward the firing line, shooters in the end lanes may receive a higher lead exposure than the shooters in adjacent lanes. Lab Crafters Inc. is conducting research in developing baffles that minimize the end lane effects.

- In many ranges, direct entrances into the range are through air locks. These air locks allow entrance into and exit from the range without disturbing the pressure barrier conditions established inside the range itself. Modify all entrances (excluding the access door behind the bullet trap) to the ranges so that entering the range will be through an airlock to minimize the impact on the pressure barrier conditions maintained in the overall range.

- Reevaluate the design of the supply airflow diffusers and the configuration of the exhaust inlets if there are significant air velocity variations in the breathing zone of the shooter near the firing line of each lane. The current supply airflow diffusers may have to be replaced with diffusers that provide laminar airflow. The exhaust inlets, currently spread over two locations, may have to be consolidated to a single new location, perhaps behind the bullet trap.

Listed below is a summary of recommendations for upgrading the ventilation systems of the AIFR.

- Upgrade the capacities of these fans if the optimization of the ventilation systems with the 30HP fan motors fails to produce 75 fpm airflow across each lane. This may involve substituting the current 30HP electrical motors with larger 40HP electrical motors or replacing the current fans with new fans.

- The installation of larger and heavier 40HP fan motors on to the existing roof may require major renovation and upgrading during reinforcement of the AIFR roof. This process will likely be expensive and time consuming.

Listed below is a recommendation for upgrading the supply diffusers for particular lanes of the AIFR.

- Install new diffusers on lanes near the end of the firing range that showed higher levels of exposure to lead and carbon monoxide during practice rounds. The diffusers cause turbulence and eddies in these lanes, leading to the higher exposures. New diffusers installed at a lower height equal to the other diffusers in the other lanes of the firing range will improve the laminar flow of air across the firing line.

Noise

A full hearing conservation program should be implemented at the NFU.[24,48] The noise intensity on an indoor firing range can cause permanent damage in a very short period of time. Using double hearing protection can attenuate noise to a safer exposure level. However, the use of HPDs is subject to many problems, such as discomfort, incorrect use with other safety equipment, dislodging, deterioration, and abuse.[49] HPDs also perform differently in workplace settings as compared to the laboratories where the noise reduction ratings (NRR) are determined.[50,51] NIOSH recommends conducting monitoring audiograms at least annually.[24] While annual audiometric monitoring identifies persons who have lost hearing or are at risk due to the presence of a noise-induced notch in the audiogram, the INS should consider implementing a more comprehensive hearing protector fit-testing program in addition to audiometry.[52] Fit-testing identifies those persons who have poorly inserted earplugs and therefore are at increased risk of NIHL.

- Conduct training on HPD use at the INS. Earplugs that barely entered the ear canal after insertion and earmuffs that were placed on officers' legs or heads when not in use show that the users of these devices need to be instructed on their proper use. Foam earplugs must be rolled down into a small cylinder before being deeply inserted into the ear canal. Earmuffs should be placed on the floor or tables or in a clip when not in use so that the headbands are not sprung. The pressure necessary to provide a seal with the side of the wearer's head is compromised when the earmuff cups are forced apart for long periods of time.

- Address maintenance of the different kinds of HPDs. The disposable foam earplugs used at the INS should be worn just for the day of weapons qualifications then discarded. The custom-made earplugs that have been issued may deteriorate. This type of HPD should be replaced every 3 to 5 years. The cushions of the earmuff cups may deteriorate and should be inspected every 6 months to see if they are still flexible. Replace them if they become stiff and nonpliant.

- NIOSH investigators provided electronic stereo amplification earmuffs to a few of the officers to wear while they completed a qualification round. Some of the officers reported that these earmuffs helped them to hear the range master better than with the passive earmuffs provided by the NFU. However, not all officers preferred the electronic earmuffs. Provide a limited number of these devices for officers who may need additional amplification to hear commands from the range master. Officers who have pre-existing, high frequency hearing loss may find the amplification beneficial.

- Integrate the amplification system with sound restoration earmuffs capable of local FM communication broadcast and reception. Such earmuffs could be combined with passive earplugs to enhance noise protection and improved communication.

- Some officers were wearing sound restoration earmuffs on the firing line. Test the sound restoration muffs in accordance with EN 352.2 and 352.4, which specify maximum levels under the earmuff.

The following recommendations are suggested to reduce noise levels in the adjacent areas of the control room, cleaning room, classroom, and office:

- Construct a stud wall on the cleaning room and classroom side of common concrete block wall with an air gap, wood or metal stud farming, absorption batts, and a double layer dry wall finish (5/8" type X Gypsum). This measure can provide a transmission loss of upwards of 70 dB in the 500–1000 Hz range.

- Seal the gap between the roof deck and the top of the concrete block wall to eliminate air leakage path.

- Stagger 110 V outlets in the common wall. The existing outlets on the common wall are placed in such a manner that they form a direct acoustic path for the noise. The cavities around the outlets should be caulked to reduce leaks.

- Place absorption batts in the plenum over the ceiling area of the range (approximately 22 feet) to reduce noise by a major flanking path. Adding absorption materials above the dropped ceiling over the classroom and office might also be necessary.

- Design a new ceiling with significant improvement in sound transmission loss over the control room area.

- Place magnetic seals or double sweeps on all doors to seal existing air gaps.

- Place double-paned laminated glass of different thickness to maximize the sound transmission loss everywhere there is glass: Cleaning room, control room, three glass panels to right of control room. Another option is to remove glass where it is not needed and fill in with block (e.g., cleaning room and hallway adjacent to the control room). The control room still needs double glass with maximum air gap possible.

The following recommendations assume that INS is interested in making fundamental structural changes to the shooting range to accomplish several goals including noise reduction. Furthermore, it was understood that the INS is seeking to significantly improve the firing range structure and operations in the following areas:

- Reduce the number of shooting lanes from 20 to 15.

- Improve ventilation system performance so that indoor testing of a wider range of weapons can be achieved than with the present system.

- Alter the control room structure to improve visibility to all shooting lanes.

- Reduce sound levels to accomplish several objectives:

    - Reduce sound levels in the control room so that the range officer can be in the room without hearing protection.

    - Improve sound isolation between the range and the classroom so that classes can be conducted without undue interference while shooting is ongoing.

    - Reduce sound levels in the office are so that it can be occupied and used during shooting sessions with a minimum of speech interference, such as for telephone use.

    - Improve sound levels in the cleaning room so that occupants do not need to wear hearing protection and can converse freely without speech interference from the range.

The following recommendations are suggested to reduce noise levels in the cleaning room, classroom and office:

- Construct a nominal 6-inch stud wall on the cleaning room and classroom side of the existing common block wall, including the hallway area leading from the tower door to the classroom hallway. The stud wall should be set apart from the existing concrete block wall by a minimum of three inches. The stud wall construction should be a double layer unbalanced wall of 2X6" metal stud framing, sound absorption batts, resilient channel, and a dry wall double layer finish (5/8" type X Gypsum, two thicknesses on the quieter side). This measure can provide noise reduction that can increase the Sound Transmission Class of the existing wall to an STC 72 rating. The added stud wall should be non-load bearing and extend up to the roof of the building, including the area over the control room. The top edge of the new wall would be sealed against the corrugated roof system in the same manner as the existing concrete block wall (filled with acoustic fiberglass, drywall piece fit to roof). We recommend replacing the window in the cleaning room wall and the three windows in the short hallway leading to the control room door with the same block construction as the rest of the wall. Windows present special problems in sound reduction, and the likelihood of achieving the intended improvement will be much higher than if these windows are removed.

- Seal the gap between the roof deck and the top of the concrete block wall to eliminate air leakage path. In a like manner, seal the second stud wall at the roof line to prevent sound leakage.

- Remove 110 V outlets that back onto each other in the common wall. The existing outlets on the common wall are placed in such a manner that they form a direct acoustic path for the noise.

- Place absorption batts in the plenum over the ceiling area of the range (over a distance of approximately 22 feet) to reduce noise by a major flanking path. Adding absorption materials above the dropped ceiling over the classroom and office is also necessary to reduce sound through this flanking path to the extent possible.

- Design a new roof with significant improvement in sound transmission loss over the control room area. The roof structure should be specified to provide a minimum of at least STC 60 performance (Sound Transmission Class).

- The existing doors are fire rated without any special acoustical properties. Replace existing doors with sound rated doors having an STC rating of at least 50.

- Install double bullet proof glass with the maximum air gap possible (3 inches minimum is suggested) in the control room. In addition, to minimize vibration transmission form one pane of glass to the next (what is known as inter panel resonance effect), the first and second glass layers should differ in thickness by 30%–50% and the second panel should be installed on a slight angle so that the two panes are not parallel. To make the control room useable without the need for hearing protectors, the total glass area should be minimized and the air space between panes should be maximized (at least 3 inches).

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Table 1. Airborne Lead Exposures During One Pistol Qualification Exercise
HETA 2000–0191
U.S. INS–NFU
April 19, 2000

Lane # or area	Sample time [min]	Sample volume [L]	Pb conc. [μg/m^3]	8-hr TWA Pb conc. [μg/m^3]
1	57	169	32	4
3	56	167	4	0.4
5	60	179	4	1
7	64	190	4	1
9	pump failed	pump failed	n/a	n/a
11	58	175	7	1
13	53	158	15	2
15	58	172	37	5
17	55	163	12	1
19	56	168	89	10
6, area, preshooting	88	263	trace	trace
West rooftop exhaust	295	876	ND	ND
rear range wall	40	119	3	0.3
control room PBZ	42	122	ND	ND
NIOSH REL				**50**
ACGIH TLV–TWA				**50**
OSHA PEL				**50**
OSHA action level				**30**

ND = 'not detected,' contaminant was present at levels below the analytical limit of detection
trace = contaminant was detected at levels between the limit of detection and the limit of quantitation

Table 2. Airborne Lead Exposures During Two Consecutive Pistol Qualification Exercises
HETA 2000–0191
U.S. INS–NFU
April 19, 2000

Lane # or area	Sample time [min]	Sample volume [L]	Pb conc. [μg/m^3]	8-hr TWA Pb conc. [μg/m^3]
1	100	297	22	5
3	96	285	18	4
5	75	217	4	1
7	76	225	5	1
9	71	212	6	1
11	73	219	23	4
13	79	236	16	3
15	76	226	58	10
17	79	236	22	4
19	74	221	159	25
line safety officer	79	235	19	3
rear range wall	72	215	3	1
control room PBZ	71	213	trace	trace
NIOSH REL				**50**
ACGIH TLV–TWA				**50**
OSHA PEL				**50**
OSHA action level				**30**

ND = 'not detected,' contaminant was present at levels below the analytical limit of detection
trace = contaminant was detected at levels between the limit of detection and the limit of quantitation

Table 3. Airborne Lead Exposures During Shotgun Qualification Exercises
HETA 2000–0191
U.S. INS–NFU
April 20, 2000

Lane # or area	Sample time [min]	Sample volume [L]	Pb conc. [µg/m^3]	8-hr TWA Pb conc. [µg/m^3]
2	56	169	130	15
4	54	158	11	1
6	47	140	trace	trace
8	56	165	31	4
10	51	151	56	6
12	59	172	44	5
14	54	159	314	35
16	52	155	116	13
18	52	155	97	11
20	56	167	718	84
line safety officer	33	98	21	2
control room PBZ	37	110	ND	ND
ballistics lab worker	79	235	20	3
East rooftop exhaust	147	435	trace	trace
NIOSH REL				**50**
ACGIH TLV–TWA				**50**
OSHA PEL				**50**
OSHA action level				**30**

ND = ‘not detected,’ contaminant was present at levels below the analytical limit of detection
trace = contaminant was detected at levels between the limit of detection and the limit of quantitation

Table 4. Total* Airborne Lead Exposures During Pistol Qualification Exercises
HETA 2000–0191
U.S. INS–NFU
April 19, 2000

Lane #	Sample time [min]	Sample volume [L]	Pb conc. [$\mu g/m^3$]	8-hr TWA Pb conc. [$\mu g/m^3$]
1	157	467	25	8
3	152	452	12	4
5	135	397	4	1
7	140	415	5	1
11	131	394	16	4
13	132	394	15	4
15	134	398	49	14
17	134	399	18	5
19	130	388	129	35
NIOSH REL				**50**
ACGIH TLV–TWA				**50**
OSHA PEL				**50**
OSHA action level				**30**

ND = 'not detected,' contaminant was present at levels below the analytical limit of detection
trace = contaminant was detected at levels between the limit of detection and the limit of quantitation
* = these values were calculated based on the data in Tables 1 and 2; they do not represent discrete samples

Table 5. Surface Lead Concentrations
HETA 2000–0191
U.S. INS–NFU
April 19, 2000

Sample location	Sample number	Surface Pb concentration [µg/ft^2]
Lane 1, floor behind barricade	wipe #1	2.9
Floor between lanes 10 & 11	wipe #2	8.1
Supply–air diffuser, 2nd from left of control room	wipe #3	ND
Control room – tabletop, right side of track control box	wipe #4	ND
Classroom – 3rd row tabletop closest to wall	wipe #5	ND
Hallway from range to outer door, outside classroom door	wipe #6	1.6

ND = 'not detected,' contaminant was present at levels below the analytical limit of detection

Table 6. Airborne Lead Exposures During One Shotgun Qualification Exercise
HETA 2000-0191
U.S. INS-NFU
March 26, 2002

Lane # or area	Sample time [min]	Sample volume [L]	Pb conc. [μg/m³]	8hr TWA Pb conc. [μg/m³]
1	18	52	249.9	9.37
2	18	54.5	86.2	3.23
9	16	47	36.1	1.2
10	16	46.7	59.7	2
11	14	43.3	83.2	2.43
12	15	43.5	23	.72
19	13	37.7	318.3	8.62
20	10	30.1	192.7	4
Area, behind lane 19	75	213.8	28.54	4.46
Area, behind lane 9	75	219	16.9	2.64
Area, behind lane 3	75	228.8	28	4.43
NIOSH REL				**50**
ACGIH TLV-TWA				**50**
OSHA PEL				**50**
OSHA action level				**30**

Table 7. Airborne Lead Exposures During Two Pistol Qualification Exercises
HETA 2000-0191
U.S. INS-NFU
March 26, 2002

Lane #	Sample time [min]	Sample volume [L]	Pb conc. [μg/m^3]	8hr TWA Pb conc. [μg/m^3]
1	47	135.8	2.04	0.2
2	42	127.7	.52	0.05
6	45	131.9	.2	0.02
11	46	142.1	.44	0.04
12	43	126.4	.37	0.03
18	49	147.5	2.65	0.27
19	55	156.8	.96	0.11
20	48	144.5	.81	0.08
NIOSH REL				**50**
ACGIH TLV-TWA				**50**
OSHA PEL				**50**
OSHA action level				**30**

Table 8. Airborne Lead Exposures During One Pistol Qualification Exercise
HETA 2000-0191
U.S. INS-NFU
March 26, 2002

Lane #	Sample time [min]	Sample volume [L]	Pb conc. [$\mu g/m^3$]	8hr TWA Pb conc. [$\mu g/m^3$]
1	18	52	117.3	4.4
2	23	69.7	38.7	1.86
6	16	46.9	27.7	0.92
11	16	47	21.3	0.71
12	19	58.7	37.5	1.48
18	16	48.2	149.5	4.98
19	16	48.2	60.2	2.01
20	16	45.6	52.6	1.75
NIOSH REL				**50**
ACGIH TLV-TWA				**50**
OSHA PEL				**50**
OSHA action level				**30**

Table 9. Airborne Lead Exposures during Single Pistol Qualification
HETA 2000-0191
U.S. INS-NFU
September 25, 2002

Lane # or area	Sample time [min]	Sample volume [L]	Pb conc. [µg/m^3]	8-hr TWA [µg/m^3]
Lane 2	60	177.1	3.50	0.44
Lane 3	50	146.3	1.91	0.20
Lane 4	61	183.6	2.89	0.37
Lane 5	61	180.9	12.16	1.55
Lane 6	53	158.7	5.10	0.56
Lane 7	50	149.5	1.34	0.14
Lane 8	51	152.4	2.36	0.25
Lane 9	49	146.9	3.81	0.39
Lane 10	38	143.6	6.62	0.66
Lane 11	32	95.9	7.61	0.51
Lane 12	47	140.6	7.11	0.70
Lane 13	47	140.4	8.55	0.84
Lane 14	46	137.8	8.71	0.83
Lane 15	44	131.7	10.63	0.97
Lane 16	43	128.1	29.66	2.66
Lane 17	43	128.6	45.10	4.04
Lane 18	36	108.3	43.40	3.25
Qualification instructor	33	98.6	9.13	0.63
Range Entrance Door	34	101.8	2.65	0.19
NIOSH REL				**50**
ACGIH TLV-TWA				**50**
OSHA PEL				**50**
OSHA action level				**30**

Table 10. Airborne Lead Exposures during Single Shotgun Qualification
HETA 2000-0191
U.S. INS-NFU
September 25, 2002

Lane # or area	Sample time [min]	Sample volume [L]	Pb conc. [g/m^3]	8-hr TWA µg [lead/m^3]
Lane 2	26	76.7	69.08	3.74
Lane 3	25	73.2	19.14	1.0
Lane 4	25	75.3	97.01	5.05
Lane 5	24	71.2	252.95	12.65
Lane 6	24	71.9	37.56	1.88
Lane 7	23	68.8	21.81	1.05
Lane 8	24	71.7	33.46	1.67
Lane 9	23	68.9	31.92	1.53
Lane 10	24	71.8	153.24	7.66
Lane 11	29	86.9	57.53	3.48
Lane 12	24	71.8	89.13	4.46
Lane 13	25	74.7	125.88	6.56
Lane 14	25	74.9	333.89	17.39
Lane 15	21	62.9	715.72	31.31
Lane 16	22	65.5	732.40	33.57
Lane 17	19	56.8	1,513.31	59.90
Lane 18	23	69.2	477.15	22.86
Qualification instructor	22	65.7	365.10	16.73
Range Entrance Door	22	65.9	36.42	1.67
NIOSH REL				**50**
ACGIH TLV-TWA				**50**
OSHA PEL				**50**
OSHA action level				**30**

Table 11. Personal Noise Dosimeter Results
HETA 2000-0191
U.S. INS-NFU
April 19-20, 2000

Location/ Qualification	**OSHA - PEL**		**OSHA - AL**		**NIOSH - REL**	
	% Dose	TWA	% Dose	TWA	% Dose	TWA
Lanes 7-8						
Single Pistol	103.98	91.9 dBA	132.01	92.0 dBA	13,326.61	106.2 dBA
Double Pistol	254.75	96.7 dBA	256.00	96.8 dBA	26,005.76	109.1 dBA
Single Shotgun	75.16	87.9 dBA	75.90	88.0 dBA	7,897.97	104.0 dBA
Lanes 12-13						
Single Pistol	160.06	93.4 dBA	161.07	93.4 dBA	18,551.03	107.7 dBA
Double Pistol	249.60	96.6 dBA	251.00	96.6 dBA	24,929.81	109.0 dBA
Single Shotgun	68.68	87.3 dBA	69.59	87.4 dBA	6,784.19	103.3 dBA

Table 12. Reverberation Time Measurements
HETA 2000-0191
U.S. INS-NFU
March 15, 2001

	Frequency (Hz)					
	125	250	500	1000	2000	4000
Measured T_{60} (seconds)	1.97	2.38	2.91	2.81	2.02	1.42
Calculated Sabin Absorptive Area - $A_{current}$ (m^2)	186	119	137	157	163	216
* Sound Level Reductions (dB)	10	12	12	11	11	10

*given A_{new}=1963 m^2 to achieve perfect absorption across octave bands for existing surfaces provides the best case scenario for using sound absorption techniques to reduce the sound pressure level.

Table 13. Peak Sound Pressure Levels
HETA 2000-0191
U.S. INS-NFU
March 15, 2001

Location	Peak SPL (dB) .40 Caliber S&W Beretta	Peak SPL (dB) 12 gauge shotgun	Maximum Exposure Time NIOSH REL/ACGIH TLV**
Firing Range *	147	153	< 1 Second
Control Room	107	110	1 minute 29 seconds
Cleaning Room	101	107	2 min. 59 Seconds
Office	91.2	99	18 min. 59 Seconds
Classroom	103	102	9 min. 27 Seconds

* Firing Range measurements were made using the B&K 4135 microphone and the Panasonic SV-255 Digital Audio Tape recorder approximately 6-7 feet behind the shooter at ear level.

** NIOSH Recommended Exposure Limit (REL)/ACGIH Threshold Limit Value (TLV)

Table 14. Measured Sound Pressure Levels
HETA 2000-0191
U.S. INS-NFU
June 6, 2001

Area*	Peak SPL (dB)	Equivalent Level Leq (dBA)	NIOSH Recommended Exposure Limits
Firing Range	151.4	122	6 Seconds
Control Room	136	93	1 hr 16 minutes
Cleaning Room	115	90	2 hr 31 minutes
Classroom	110.4	79	No Hazard
Office	108	77	No Hazard

*B&K4136 and DAT setup

Table 15. Calculated noise reductions for adjacent areas by octave-band
HETA 2000-0191
U.S. INS-NFU
September 25, 2002

	Octave level	**125**	**250**	**500**	**1000**	**2000**	**4000**	**8000**
Cleaning Room	Outside	110	116	121	119	116	113	110
	Inside	84	87	88	88	84	77	73
	Noise reduction	**26**	**29**	**33**	**31**	**32**	**36**	**37**
Control Room	Outside	111	116	122	119	117	114	111
	Inside	84	89	91	91	86	80	75
	Noise reduction	**27**	**27**	**31**	**28**	**31**	**34**	**36**
Classroom	Outside	109	117	121	119	117	114	111
	Inside	83	86	80	72	70	66	68
	Noise reduction	**26**	**31**	**41**	**47**	**47**	**48**	**43**
Office	Outside	111	116	122	119	117	114	111
	Inside	75	78	73	69	67	66	68
	Noise reduction	36	38	49	50	50	48	43

Table 16. Sound Level Measurements
HETA 2000-0191
U.S. INS-NFU
September 25, 2002

Position	TWA/Leq (dB)	TWA/Leq (dBA)	Peak Level (dB)
Firing Range*	128	126	157
Pistol Exercise*	127.6	126	157
Shotgun Exercise*	126.8	124.4	156
Observation Station	95.5	93	136
Cleaning Room	92	90	115
Classroom	80	79	110
Office	78	77	108

* Measurements taken at ear level, center lane (tripod)

Table 17. Hearing Protectors Noise Reductions
HETA 2000-0191
U.S. INS-NFU
September 25, 2002

	Unprotected				Protected*				Peak Reduction
Weapon	Peak	Leq	Leq A	Leq A (2 hr)	Peak	Leq	Leq A	Leq A (2 hr)**	
Pistol	157	128	126	134	121	95	84	92	36
Shotgun	156	127	124	132	107	92	71	79	49
Rifle	157	128	127	135	127	102	93	101	30

* Protected measurements were made with the Artificial Head and the Peltor H10 earmuffs and EAR Classic earplugs.
** LeqA(2hr) is the A-weighted equivalent sound level for 2 hours of continuous exposure.

Figure 1. Carbon Monoxide Exposure during Qualification Exercises, Lane 5
HETA 2000-0191
U.S. INS-NFU
September 25, 2002

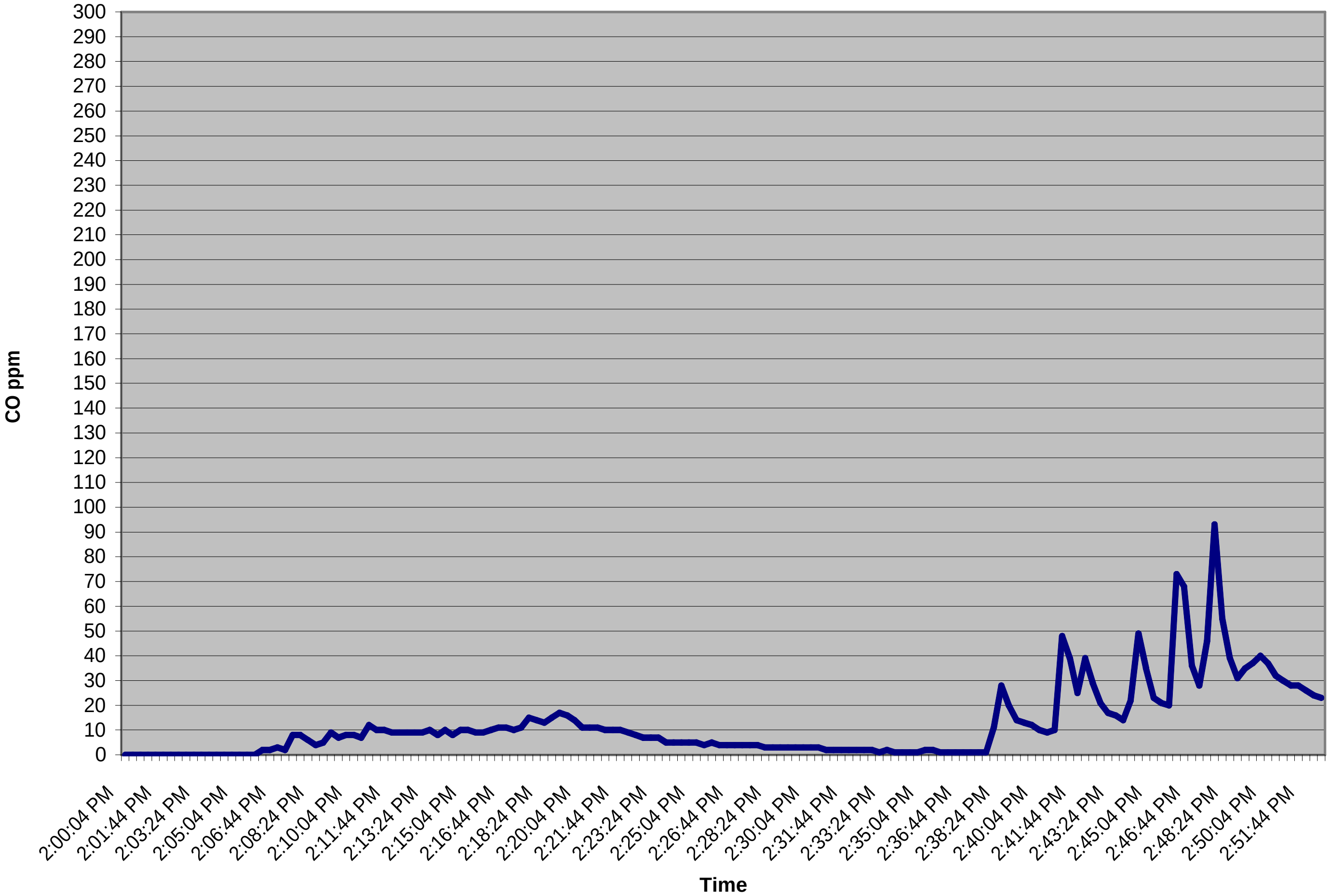

Figure 2. Carbon Monoxide Exposures during Qualification Exercises, Lane 7
HETA 2000-0191
U.S. INS-NFU
September 25, 2002

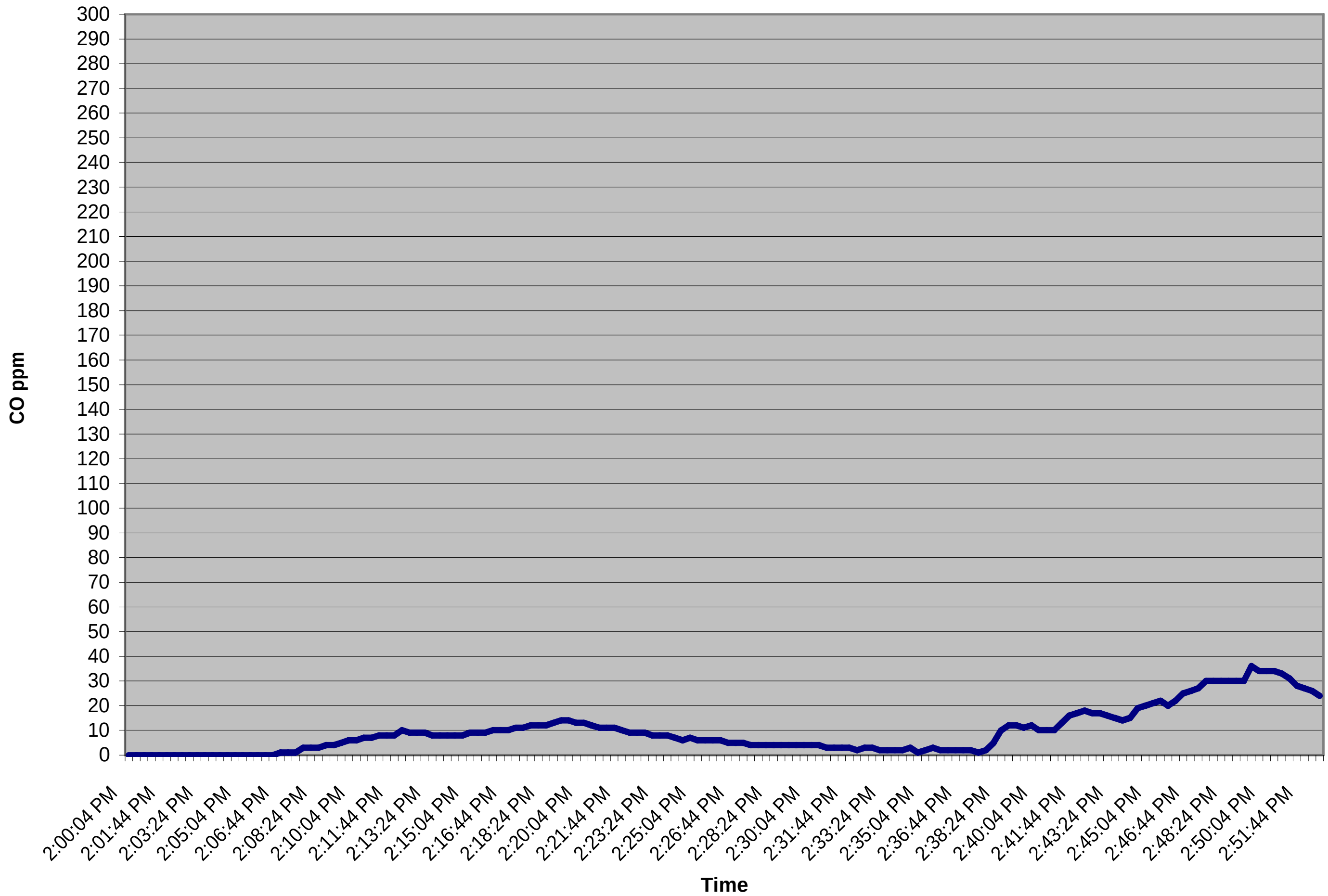

Figure 3. Carbon Monoxide Exposures during Qualification Exercises, Lane 10
HETA 2000-0191
U.S. INS-NFU
September 25, 2002

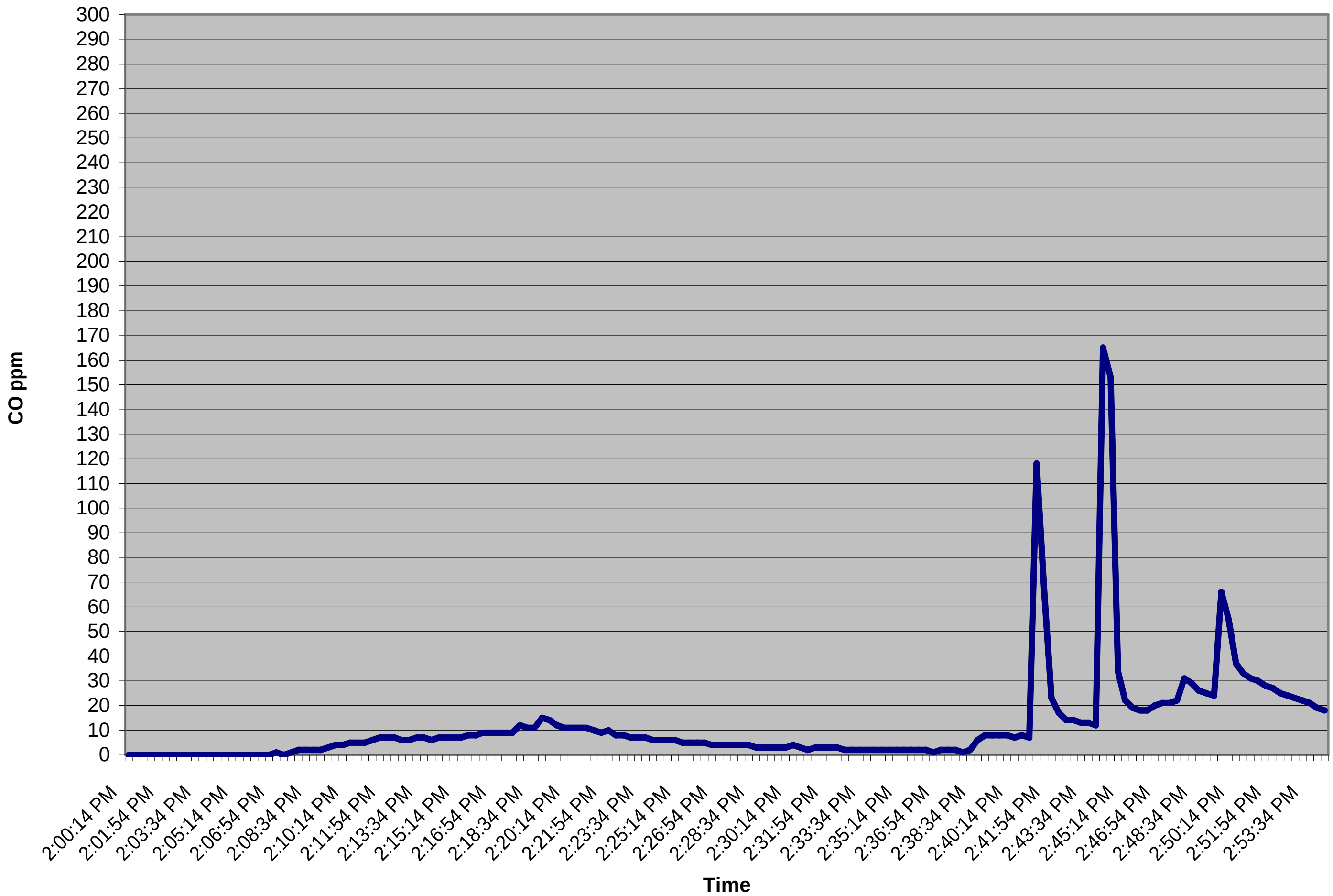

Figure 4. Carbon Monoxide Exposures during Qualification Exercises, Lane 13
HETA 2000-0191
U.S. INS-NFU
September 25, 2002

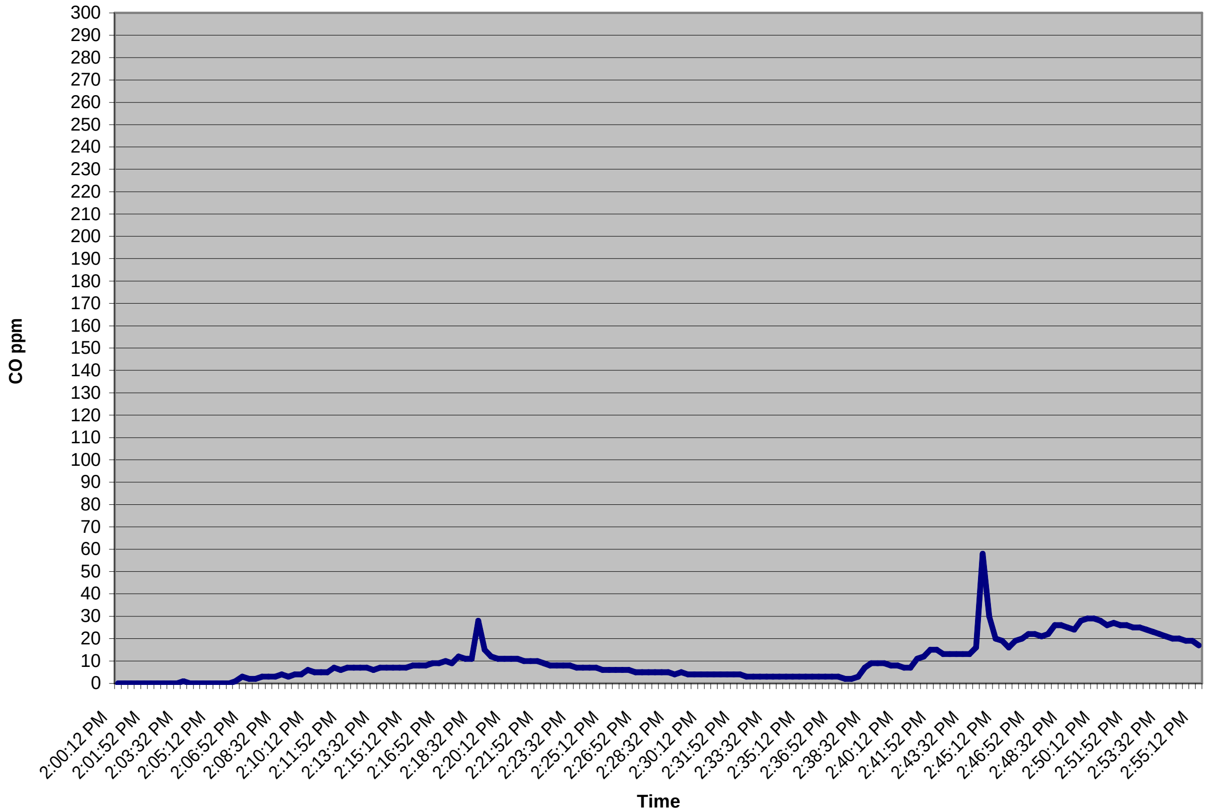

Figure 5. Carbon Monoxide Exposures during Qualification Exercises, Lane 15
HETA 2000-0191
U.S. INS-NFU
September 25, 2002

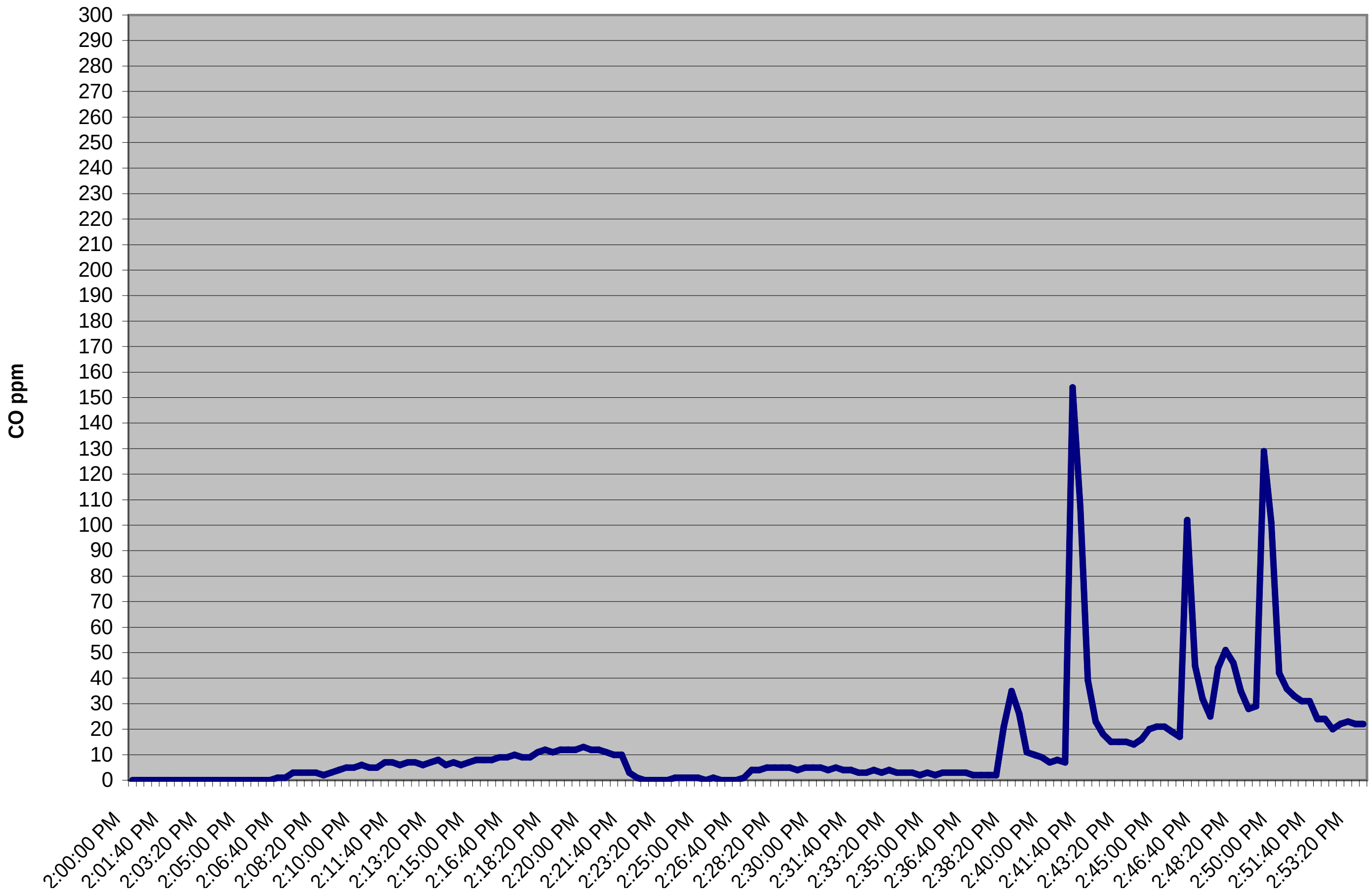

Figure 6. Carbon Monoxide Exposures during Qualification Exercises, Lane 17
HETA 2000-0191
U.S. INS-NFU
September 25, 2002

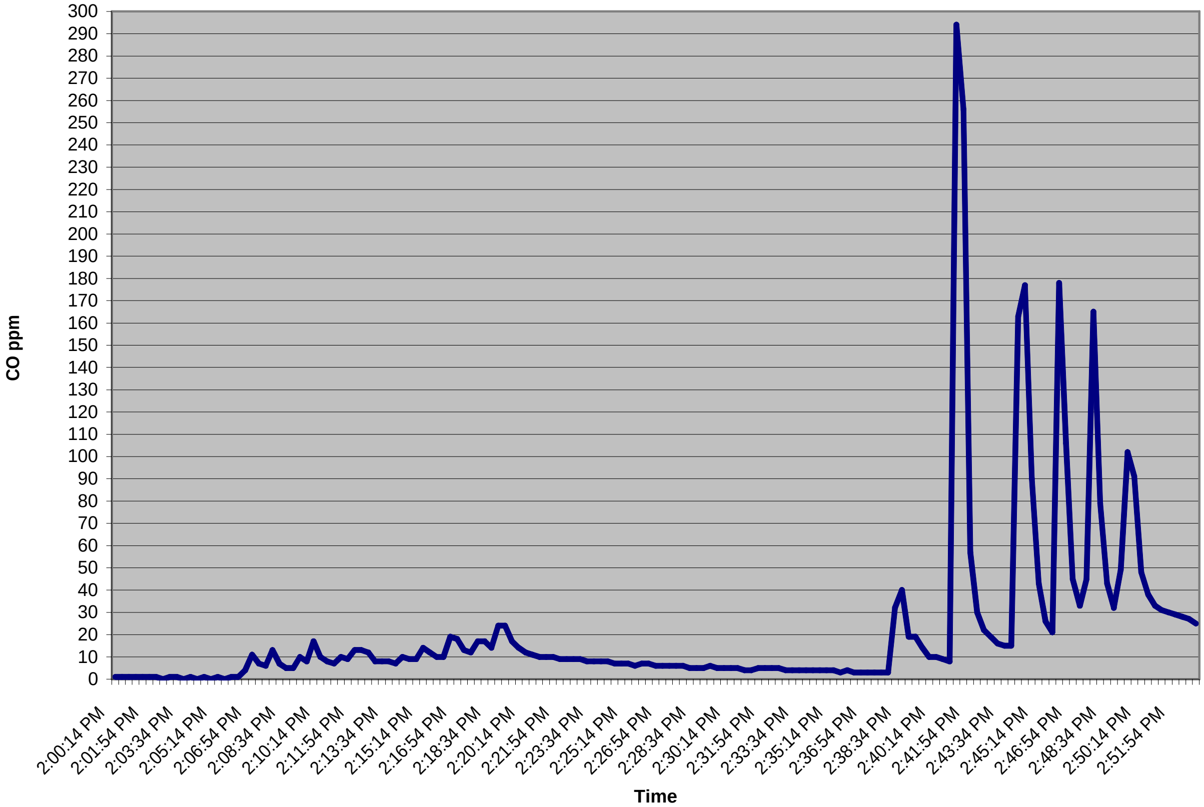

Figure 7. Control Room Noise Levels During Pistol Qualification
HETA 2000-0191
U.S. INS-NFU
April 19-20, 2000

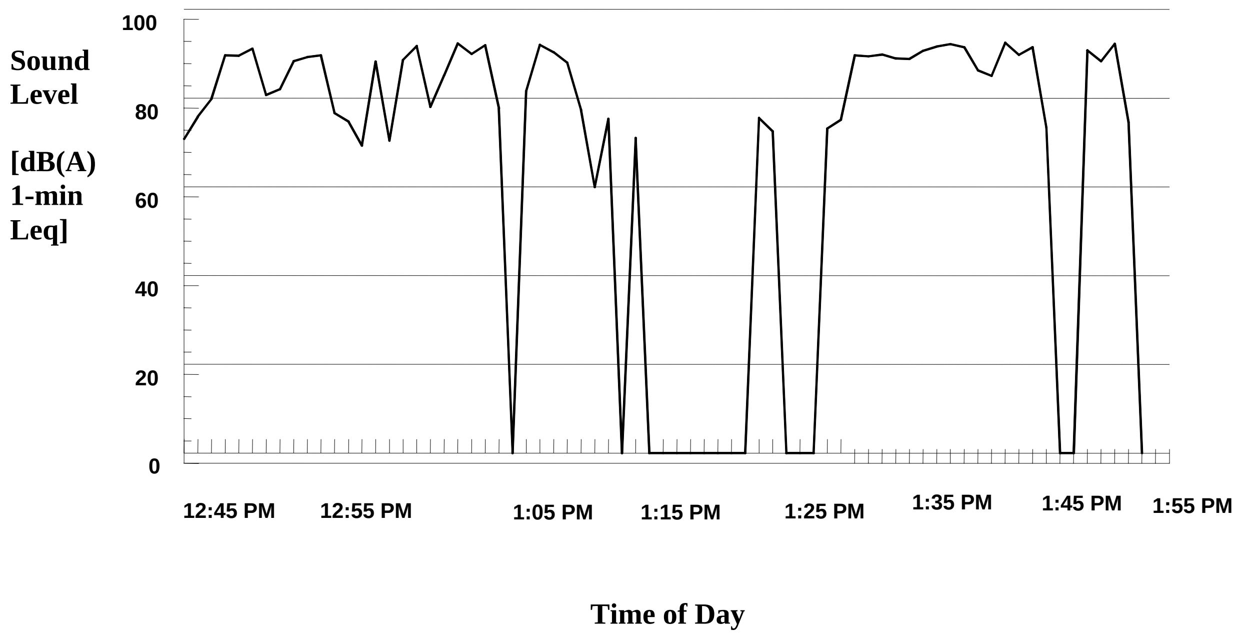

Figure 8. Control Room Noise Levels During Shotgun Qualifications
HETA 2000-0191
U.S. INS-NFU
April 19-20, 2000

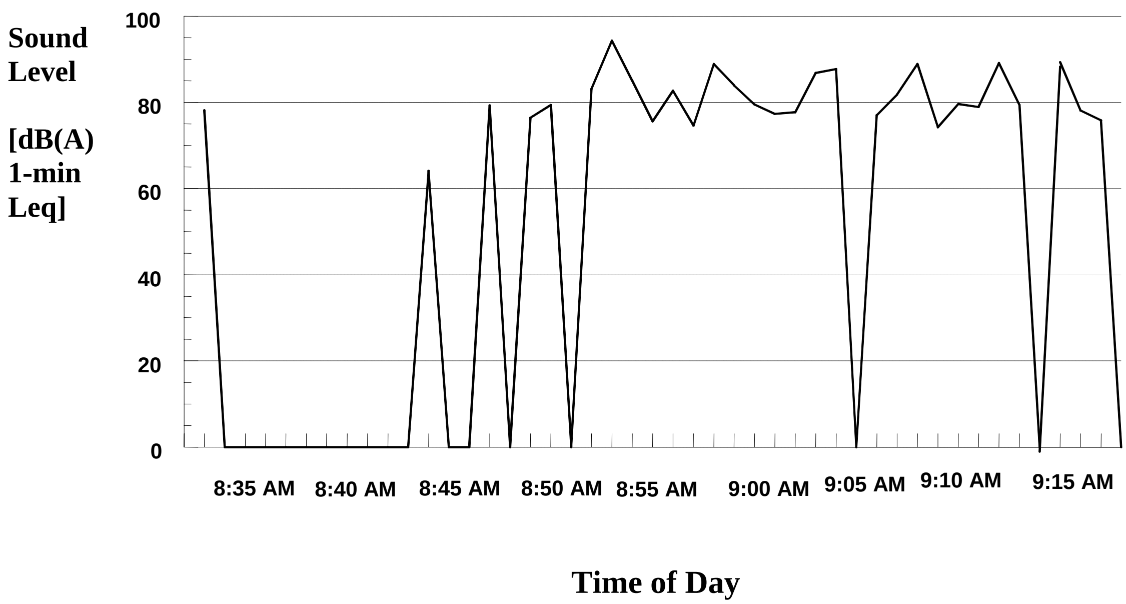

Figure 9. Classroom Noise Levels During Pistol Qualification
HETA 2000-0191
U.S. INS-NFU
April 19-20, 2000

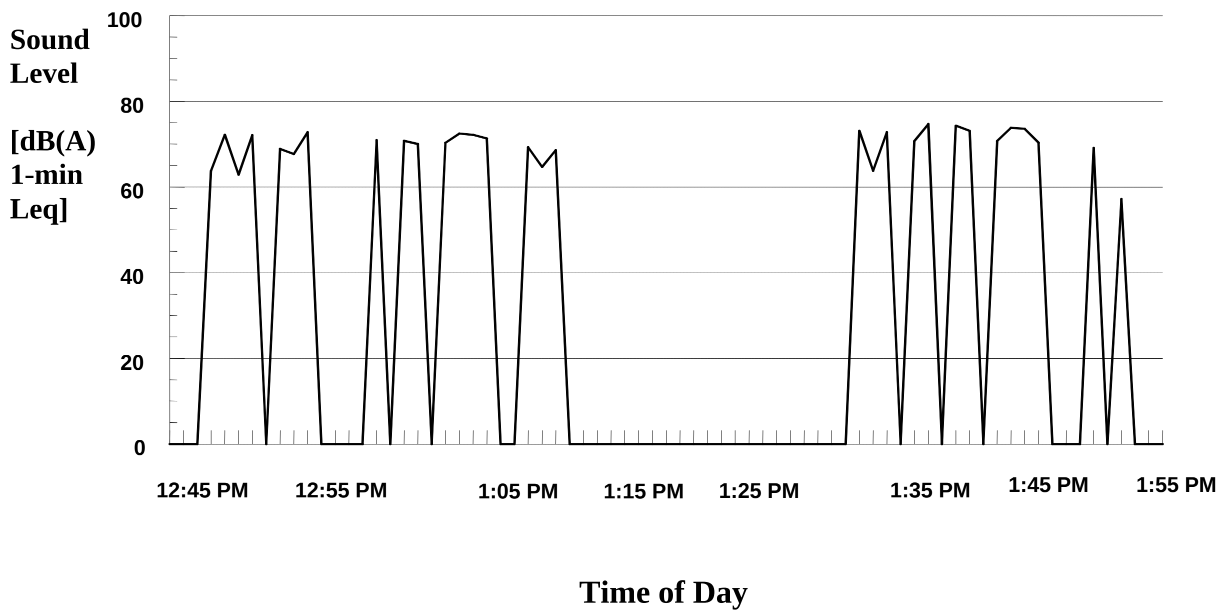

Figure 10. Classroom Noise Levels During Shotgun Qualifications
HETA 2000-0191
U.S. INS-NFU
April 19-20, 2000

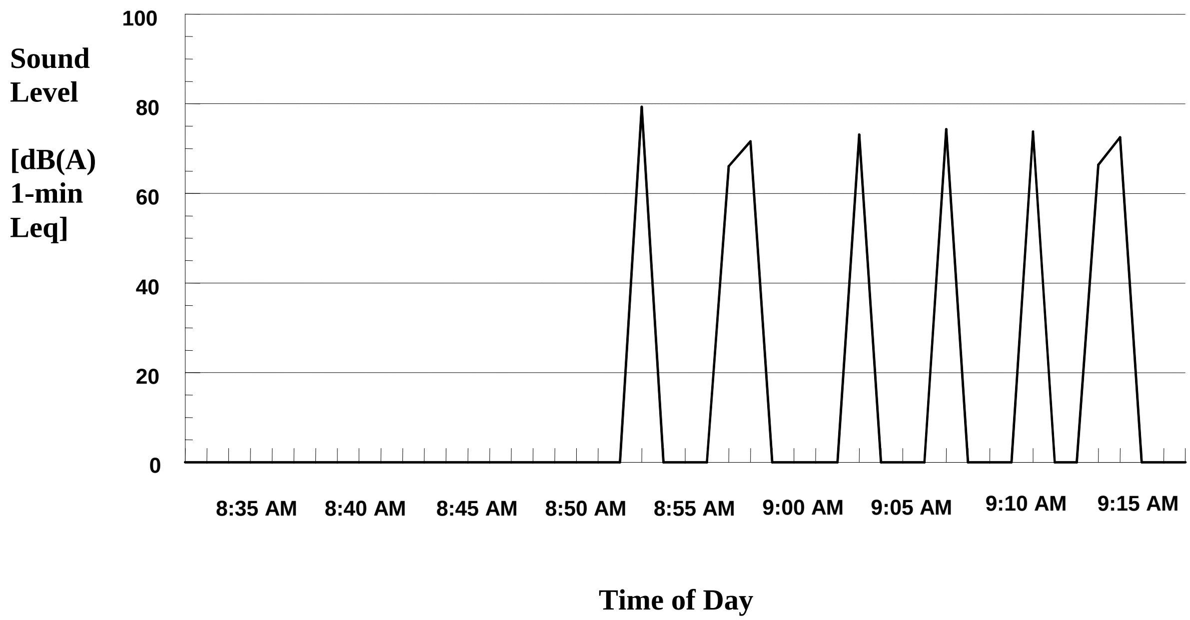

Figure 11. Diagram of Firing Range
HETA 2000-0191
U.S. INS-NFU
June 15, 2001

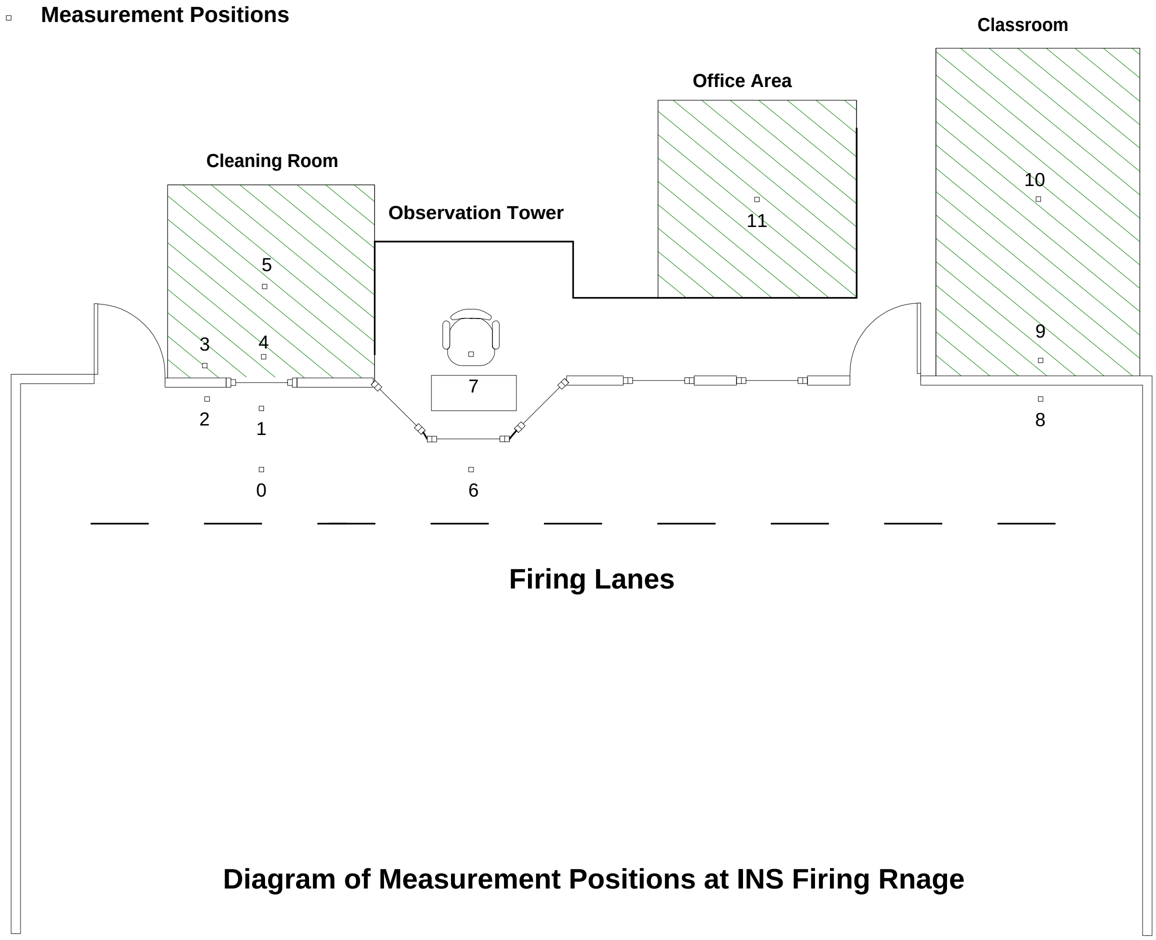

Figure 12. One-Third Octave Spectrum - Position 1 (Firing Range)
HETA 2000-0191
U.S. INS-NFU
June 6, 2001

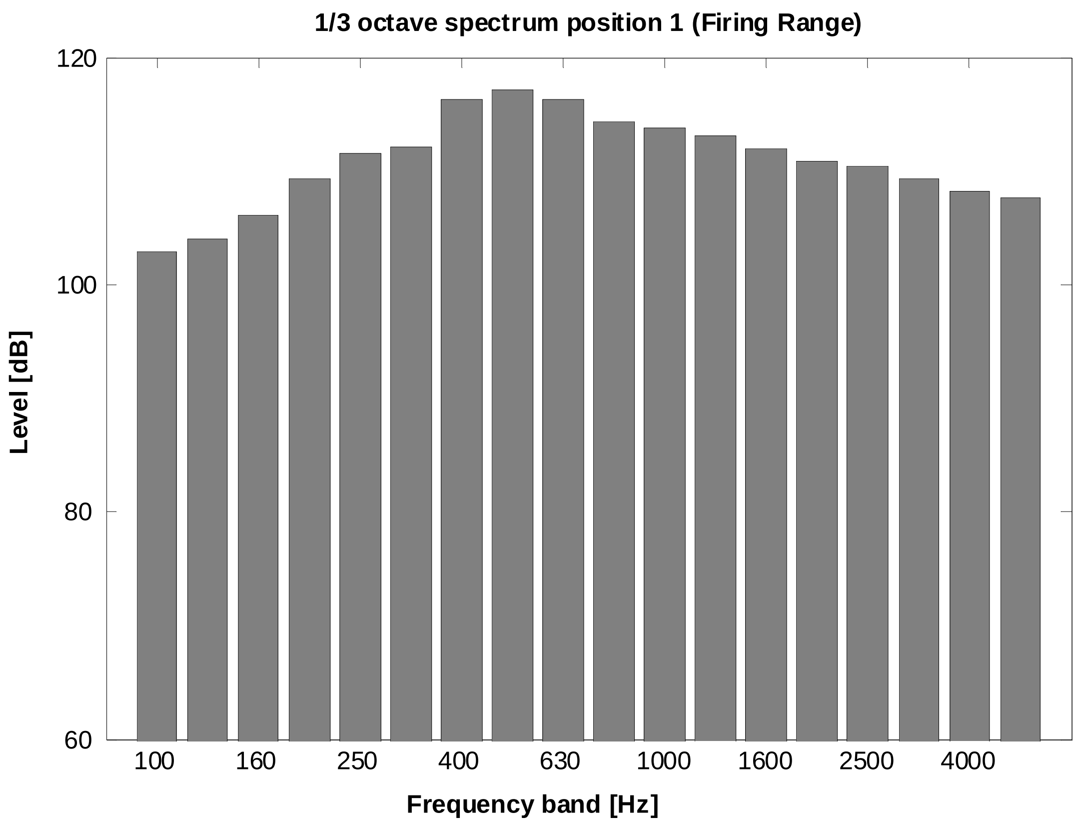

Figure 13. One-Third Octave Spectrum - Position 4 (Cleaning Room)
HETA 2000-0191
U.S. INS-NFU
June 6, 2001

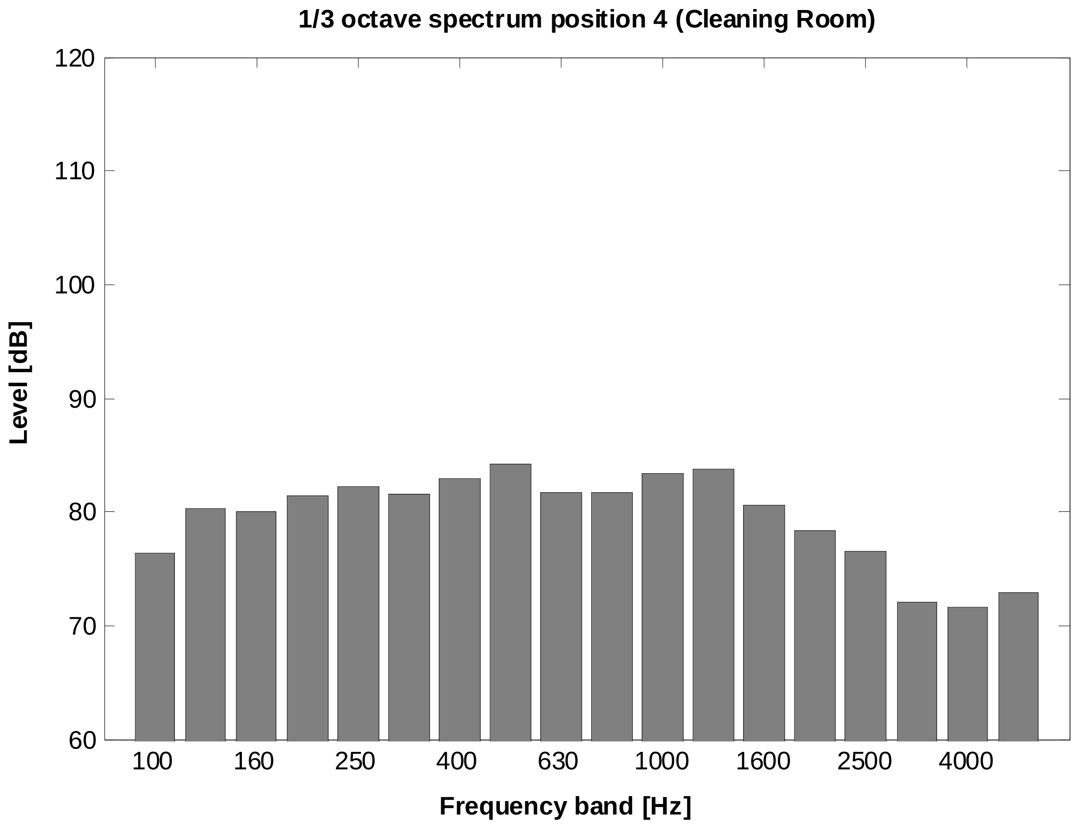

Figure 14. One-Third Octave Spectrum - Position 7 (Control Room)
HETA 2000-0191
U.S. INS-NFU
June 6, 2001

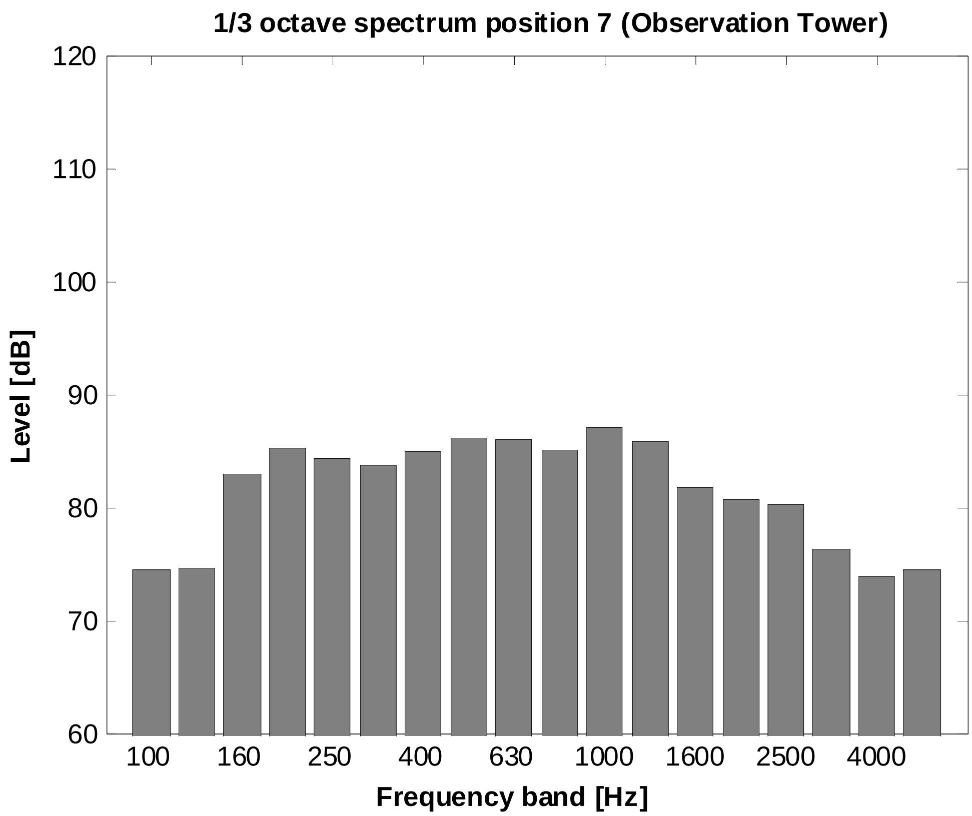

Figure 15. One-Third Octave Spectrum - Position 9 (Classroom)
HETA 2000-0191
U.S. INS-NFU
June 6, 2001

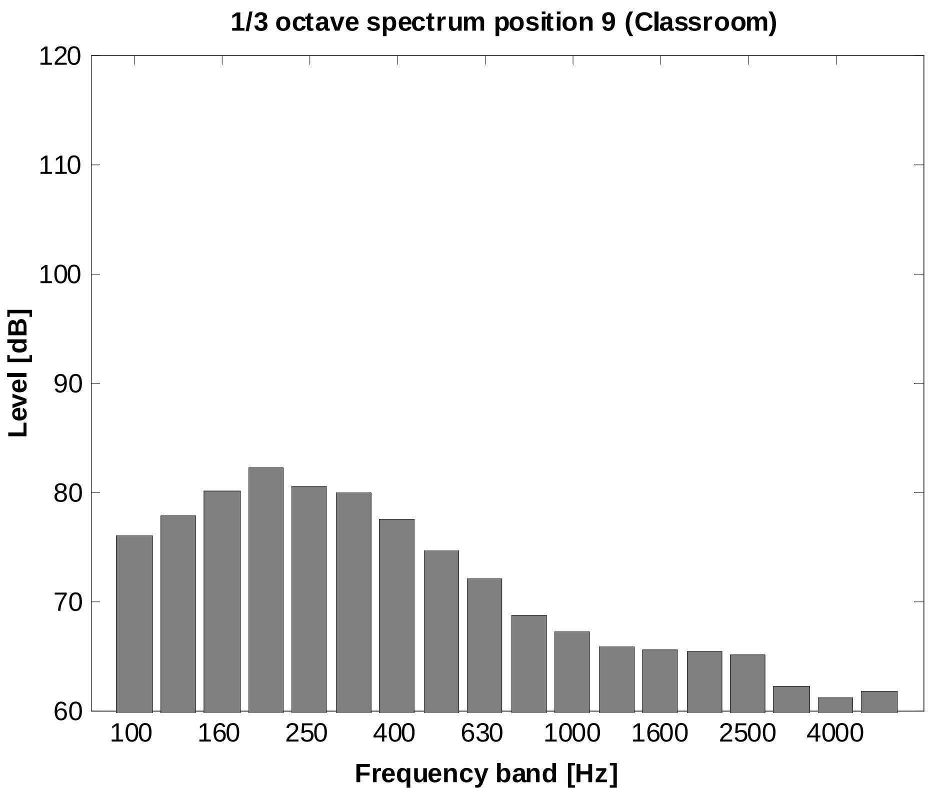

Figure 16. One-Third Octave Spectrum - Position 11 (Office Area)
HETA 2000-0191
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June 6, 2001

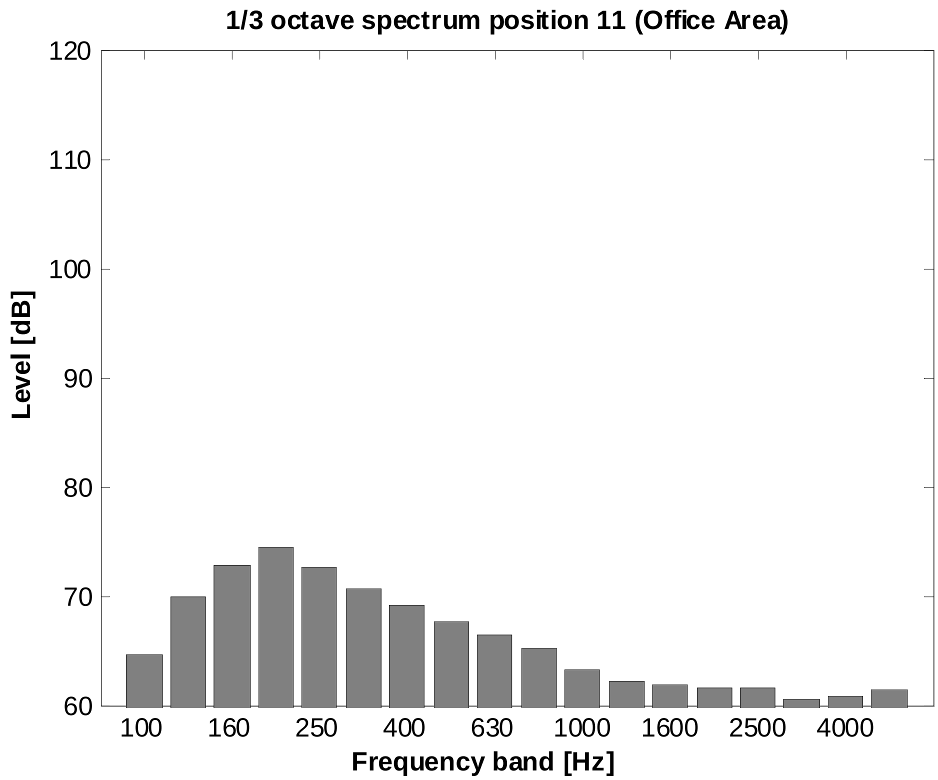


Figure 17. Artificial Head Measurement Setup
HETA 2000-0191
U.S. INS-NFU
September 25, 2002

Figure 18. One-third Octave Spectrum - Pistols vs. Shotguns
HETA 2000-0191
U.S. INS-NFU
September 25, 2002

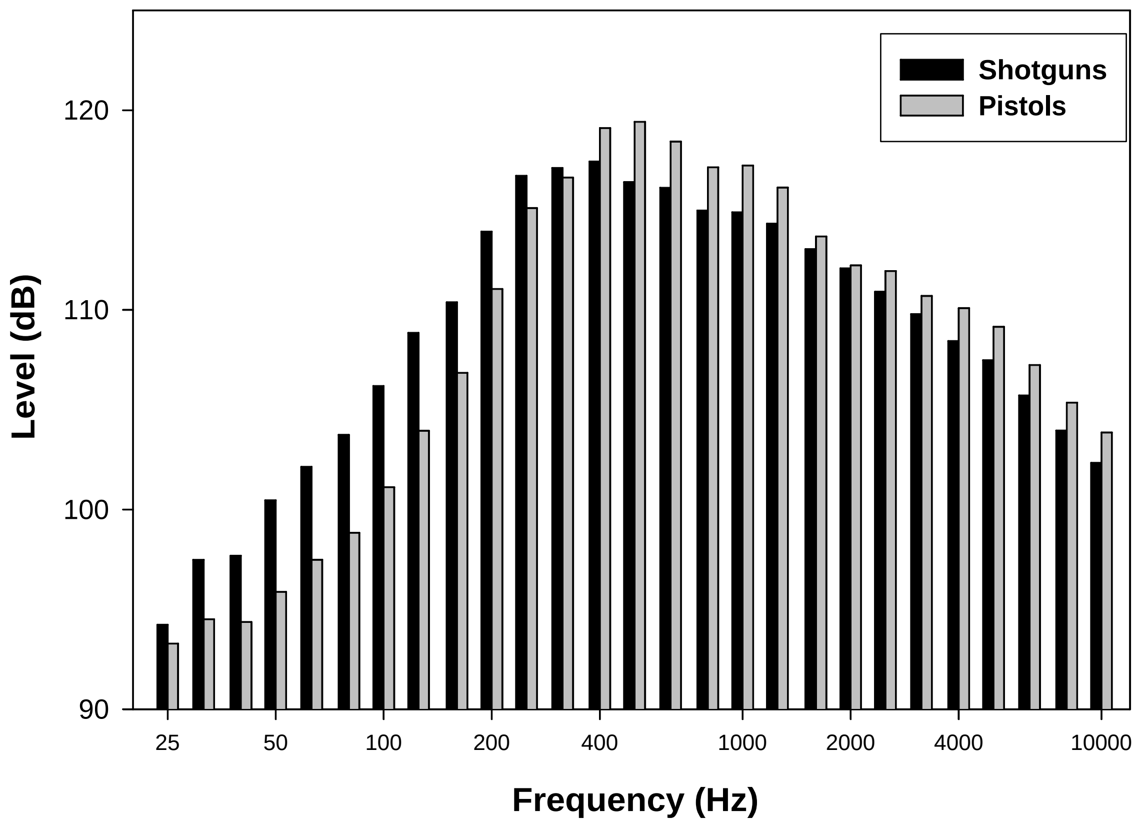


Figure 19. Peak Level Reductions for Hearing Protectors
HETA 2000-0191
U.S. INS-NFU
September 25, 2002

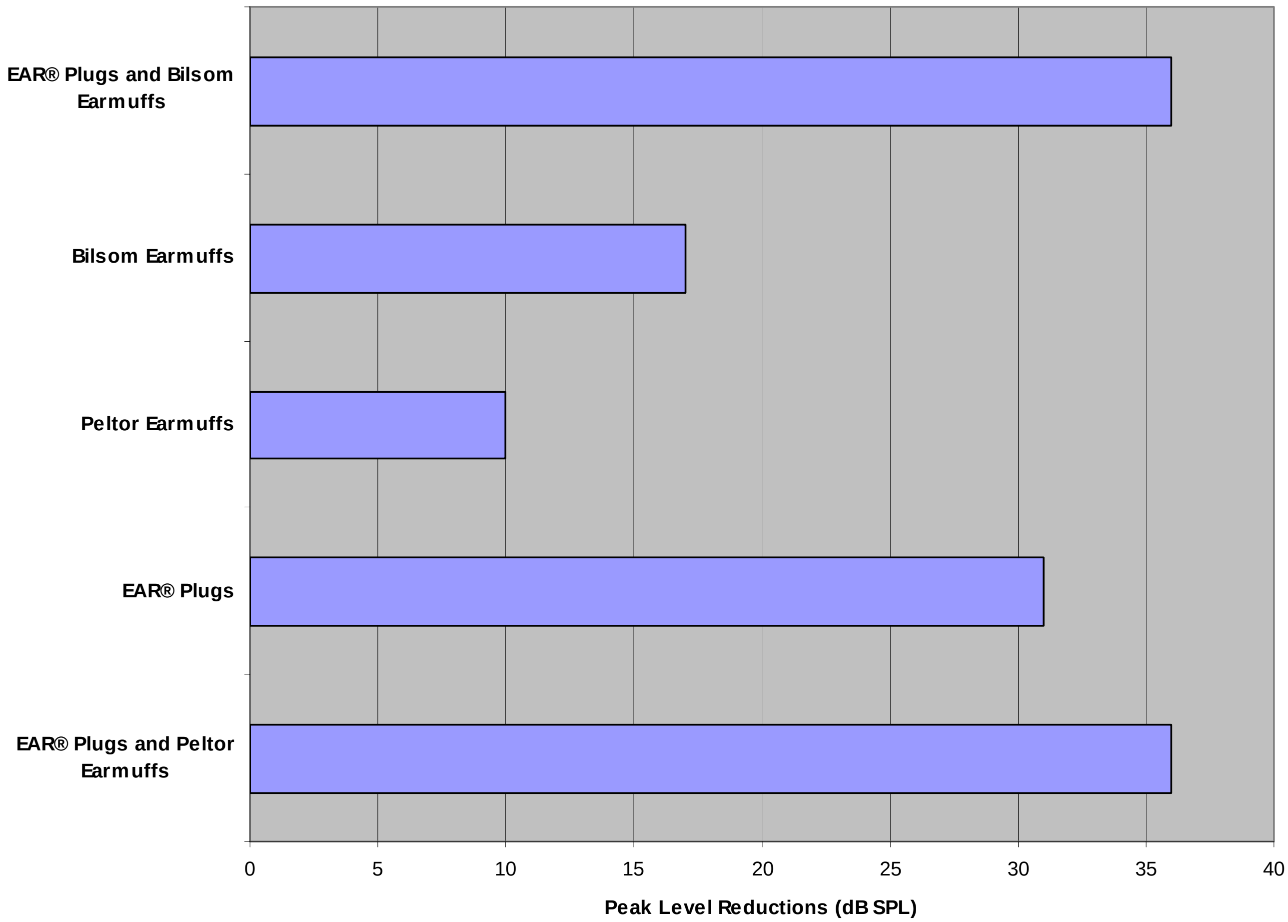


Figure 20. Lead Exposures during Single Pistol Qualification Exercise
HETA 2000-0191
U.S. INS-NFU
September 25, 2002

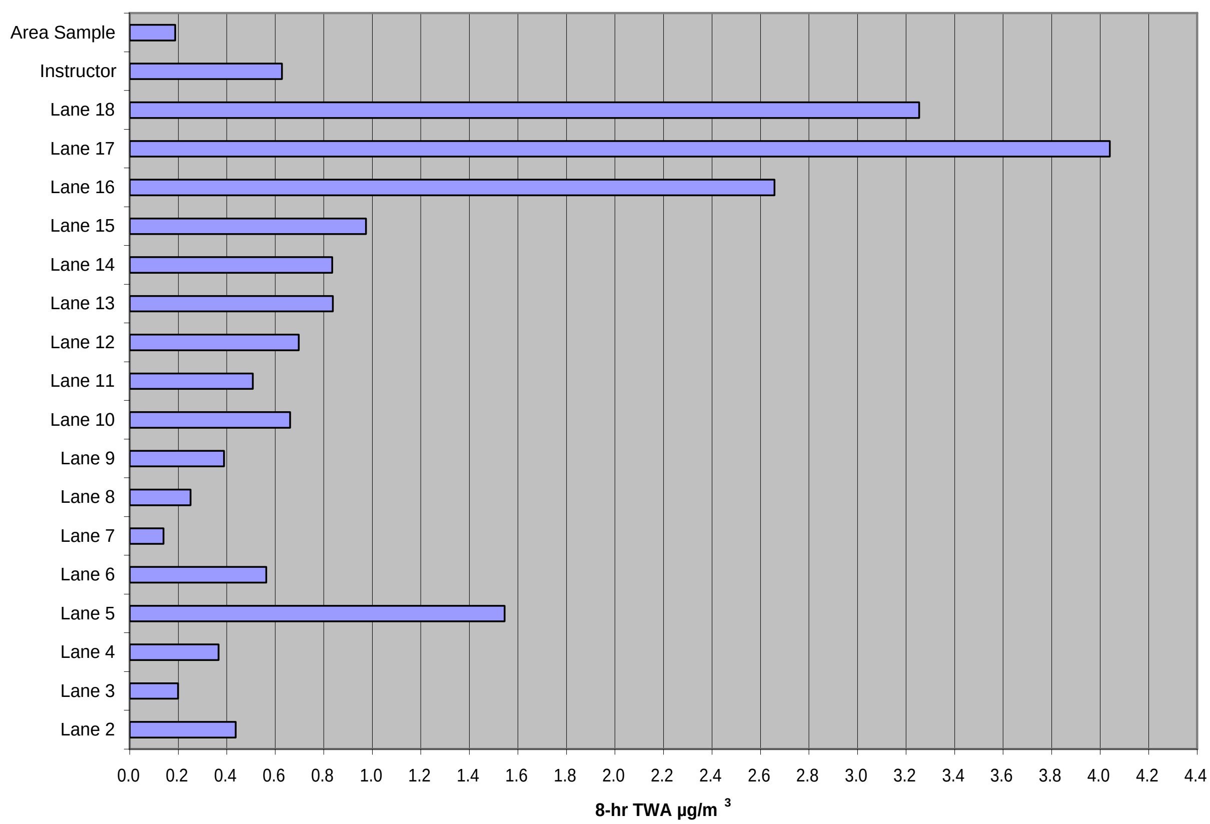
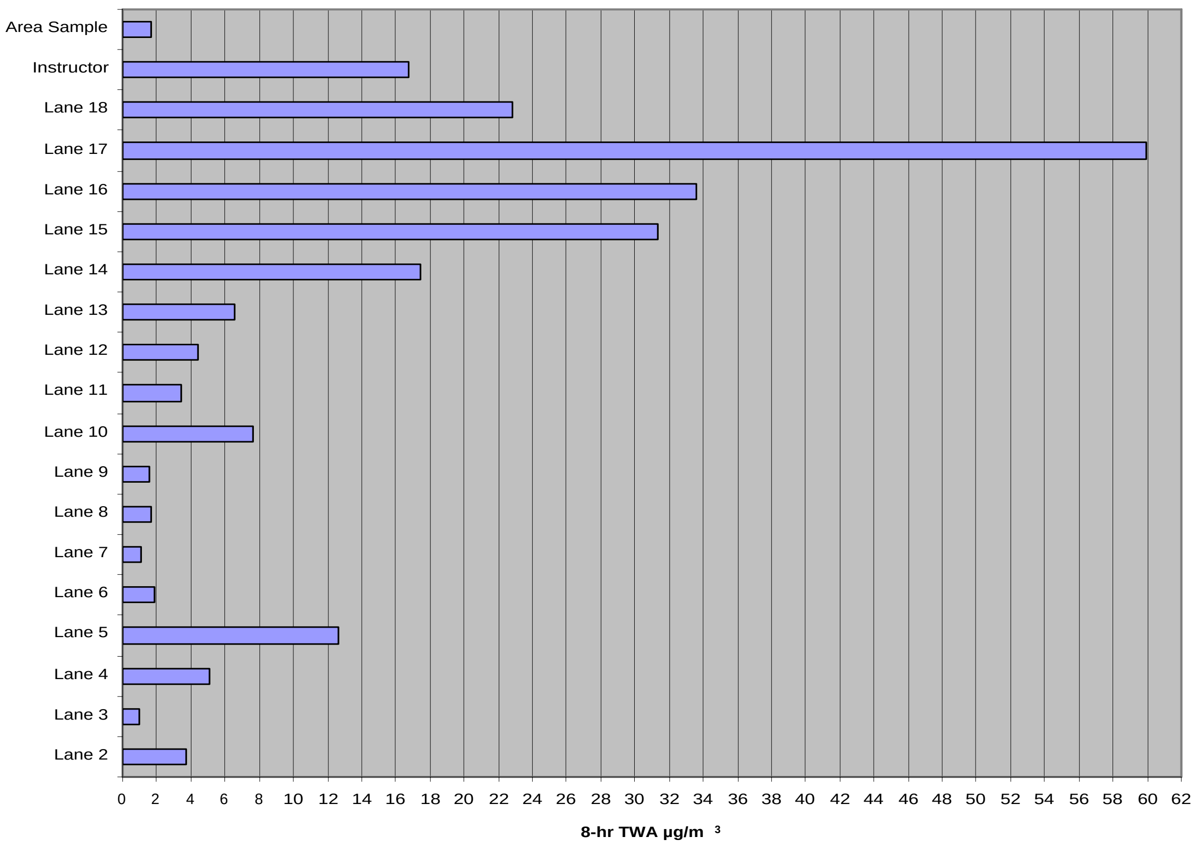


Figure 21. Lead Exposures during Single Shotgun Qualification Exercise
HETA 2000-0191
U.S. INS-NFU
September 25, 2002



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