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Assessments of Firearm Noise Exposures and Hearing Loss Prevention

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Disclaimer

- The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the Centers of Disease Control and Prevention, the National Institute for Occupational Safety and Health. Products mentioned in this presentation do not constitute an endorsement by the CDC or NIOSH

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Learning Objectives

After this course, participants will be able to:

- Identify the typical peak sound pressure levels produced by shotguns, pistols and rifles used by law enforcement personnel.
- Describe the expected level of protection that earplugs alone can provide for small-caliber firearms.
- Describe how noise treatments affect the direct and reverberant noise exposures for persons firing weapons within the firing range.
- Identify other health hazards to the hearing that might be found in the firing range.

Presentation Outline

- Prevalence of Hearing Loss
- Magnitude of Exposures
- Effectiveness of Hearing Protection
- Noise Control on the Range
- WPAFB Case Study
- Practical Recommendations

How big is the problem in the US?

- Noise-induced hearing loss (NIHL) is the most common occupational illness in manufacturing
- 22 million people exposed occupationally (Tak et al 2009)
- 27.5 million people have speech frequency hearing impairment (Hoffman et al. 2016)
- Hearing loss accounts for about 10% of non-fatal recordable occupational illnesses in manufacturing

Manufacturing Sector Occupationally-Induced Hearing Loss NIOSH 2010-136
Tak et al [2009] Am J Indust Med 52:358-371
Hoffman et al [2016]. JAMA Otolaryngol Head Neck Surg 143:274-285

Veterans Affairs Hearing Loss Compensation

Veteran Disability

Hearing Loss and Tinnitus

- In FY16 there were a total of 1,610,911 and 1,084,069 disability compensation awards for Veterans for tinnitus and hearing loss, respectively. This is a 9% increase from FY15.
- Tinnitus is the most prevalent service-connected disability for Veterans. In FY16, 10% of new compensation recipients were awarded disability compensation for tinnitus.
- The next most prevalent disability in FY16 for new awardees is hearing loss (5.1% of veterans).

Most prevalent SC disabilities of new compensation recipients

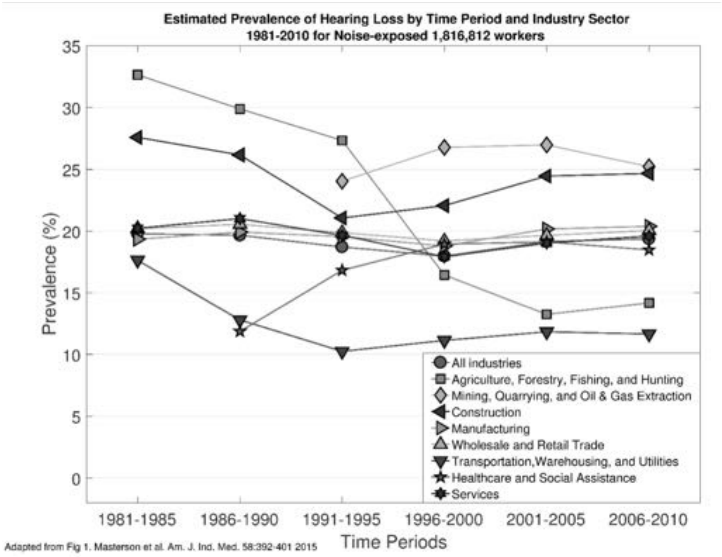
Disability	Body system	Male	%	Female	%	Total	%Total
Tinnitus	Auditory	135,599	10.8%	9,881	4.5 %	149,429	10.0%
Hearing loss	Auditory	72,333	5.8%	1,599	0.7%	77,622	5.2%
Limitation of flexion, knee	Musculoskeletal	61,455	4.9%	10,526	4.8%	72,270	4.8%

Most prevalent SC disabilities of all compensation recipients

Disability	Body system	Male	%	Female	%	Total	%Total
Tinnitus	Auditory	1,499,066	8.1%	80,299	3.2%	1,610,911	7.5%
Hearing loss	Auditory	1,035,336	5.6%	19,128	0.8%	1,084,069	5.1%
Post-traumatic stress disorder	Mental	803,136	4.3%	70,175	2.8%	887,899	4.2%
Lumbosacral or cervical strain[23]	Musculoskeletal	704,552	3.8%	132,218	5.3%	844,353	3.9%
Scars, general	Skin	713,811	3.8%	97,732	3.9%	827,459	3.9%
Limitation of flexion, knee	Musculoskeletal	646,058	3.5%	103,745	4.2%	755,204	3.5%
Paralysis of the sciatic nerve	Neurological	528,197	2.8%	43,097	1.7%	580,986	2.7%
Limitation of motion of the ankle	Musculoskeletal	446,556	2.4%	60,814	2.5%	511,300	2.4%
Diabetes mellitus	Endocrine	419,036	2.3%	5,621	0.2%	438,572	2.1%
Migraine*	Neurological	322,916	1.7%	109,981	4.4%	436,339	2.0%
Total most prevalent disabilities[24]		**7,118,664**	**38%**	**772,810**	**29%**	**7,977,092**	**37%**
Total number of disabilities[25]		**18,573,196**	**100%**	**2,476,504**	**100%**	**21,382,399**	**100%**

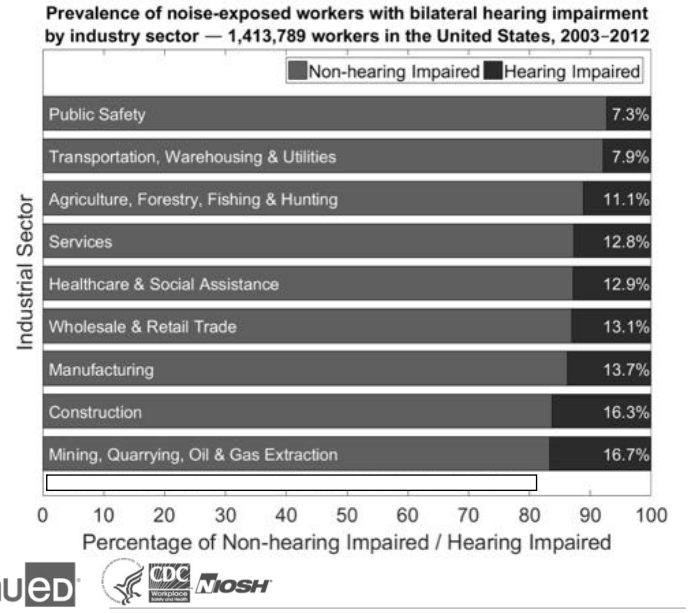
VA FY2016 Compensation Report pp 30,31

Hearing Loss Prevalence by Industrial Sector with Time



Adapted from Fig 1. Masterson et al. Am. J. Ind. Med. 58:392-401 2015

Prevalence of Workers with Hearing Impairment



Masterson et al. [2016]. Hearing Impairment among Noise-Exposed Workers in the US 2003-2012, MMWR 65(15) 389-394

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Firearm noise is hazardous to hearing

NIOSH has an ongoing effort to characterize the risk of hearing loss due to impulse noise exposure.

Risk factors include

- Sound pressure level of impulse peaks
- Duration and number of impulses
- Waveform characteristics such as kurtosis
- Complex (continuous/impulse)
- Mixed exposures to other ototoxic agents

How loud are the exposures?

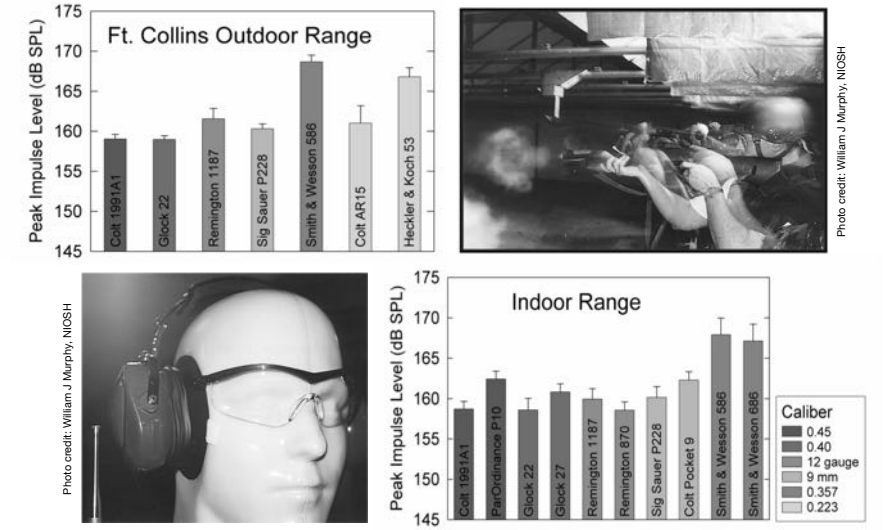
- Small-caliber firearms
  - Pistols (9mm, .40, .45 and .357 caliber)
  - Shotguns (.410, 20 ga, 12 ga)
  - Semi-automatic rifles (5.56, 7.62 mm)
- Large-caliber firearms
  - Large-caliber rifles (.50 caliber)
- Flash-bangs, Grenades, etc.
- Shoulder-fired weapons (LAW, TOW)

Firearms generate high level impulse noise

Firearm type	Peak SPL
Small rifle	140-145 dB
Medium rifle	155-160 dB
Large rifle	160-170 dB
Shotgun	150-170 dB
Small pistol	150-155 dB
Large pistol	160-170 dB

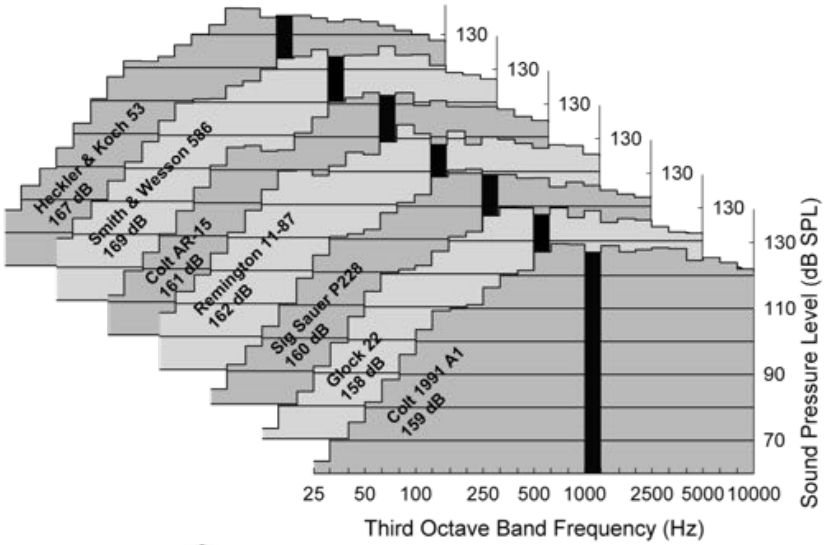
*Add SPL for short barrel, muzzle brake, enclosed area

Schulz, Murphy, Flamme [2013]. Soldier Modernisation, 11:6-8



Tubbs, Murphy, [2003]. HETA #2002-0131-2898 Fort Collins Police Services DHHS-CDC-NIOSH.

Third Octave Spectra of Several Weapons



Tubbs, Murphy, [2003]. HETA #2002-0131-2898 Fort Collins Police Services DHHS-CDC-NIOSH.

Elements of the gunshot noise

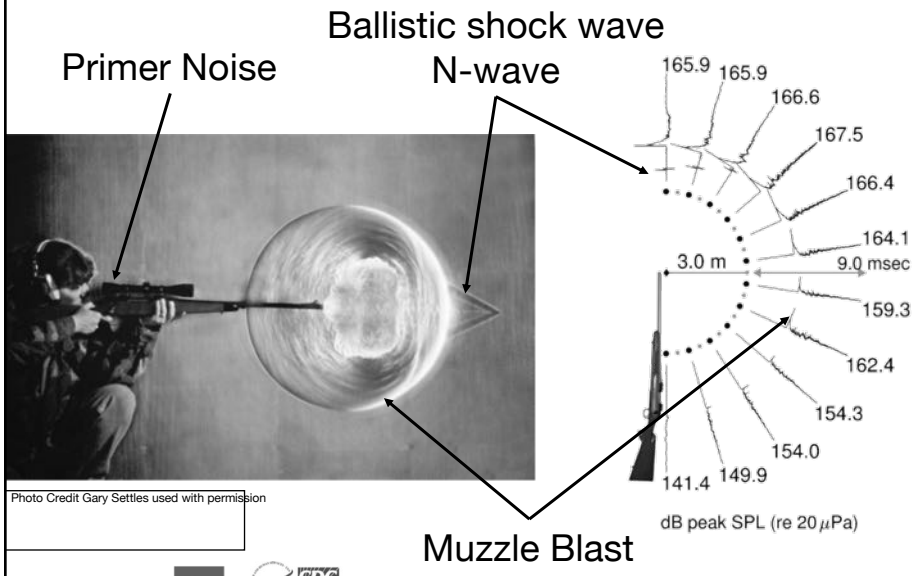
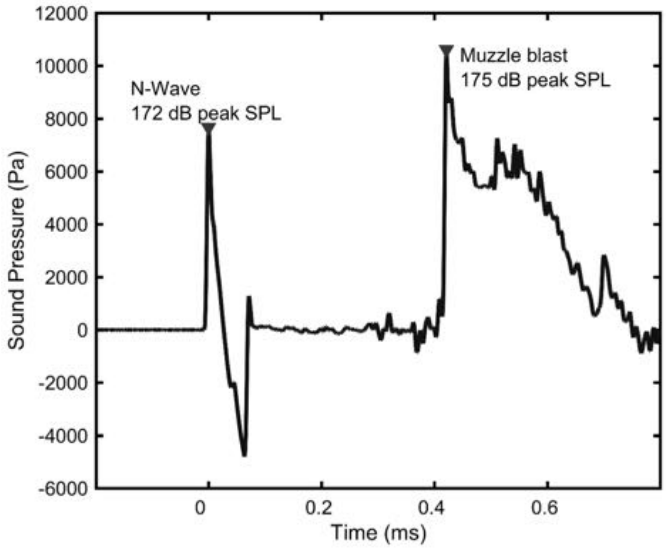


Photo Credit Gary Settles used with permission

Routh & Maher, [2016]. Proceedings of Meetings on Acoustics, 26:030001

Details of the ballistic shock wave (N-wave)



Rasmussen et al. [2009]. Sound & Vibration 14-18

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Effectiveness of Hearing Protection (1 of 4)

Photo credit: Google Public Domain

Effectiveness of Hearing Protection (2 of 4)

Photo credit: Google Public Domain

Effectiveness of Hearing Protection (3 of 4)

Photo credit: William J. Murphy, NIOSH

Effectiveness of Hearing Protection (4 of 4)

Photo credit: Google Public Domain

Attenuation with Insertion Depth

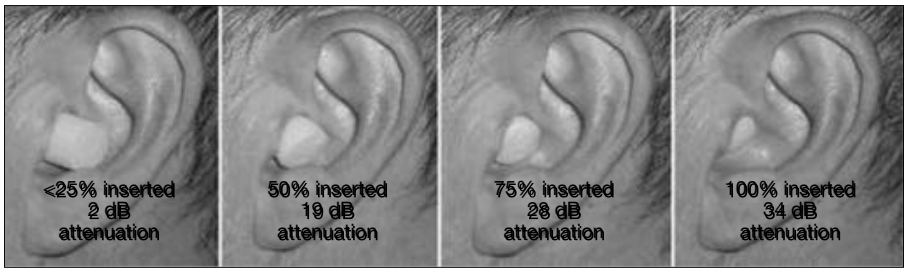


Photo credits: John Hall, USAF WPAFB

Noise Reduction Ratings from earplug insertion depth study completed by the Air Force Research Laboratory using American National Standard S12.6-1997 (R2002) Methods for Measuring the Real-Ear Attenuation of Hearing Protectors,
Method A (Experimenter Supervised / Verbally Coached),
Noise Reduction Statistic for A-weighting - Median

Bjorn et al, US Navy Flight Deck Hearing Protection Use Trends, NATO RTO-MP-HFM-123, 2005

Results: Earplug Use and Insertion Depth

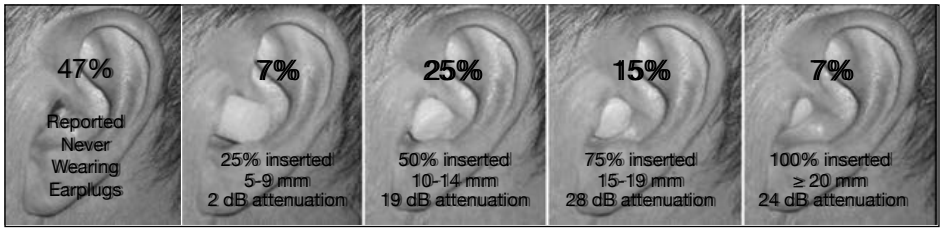


Photo credits: John Hall, USAF WPAFB

- 54% of users achieved 0 to 2 dB attenuation from inadequate use of earplugs.
- 14% of users reported always wearing earplugs
- 7% of users inserted earplugs fully in <u>both</u> ears

[% extrapolated from 202 ears of sometimes & always earplug users]

Bjorn et al, US Navy Flight Deck Hearing Protection Use Trends, NATO RTO-MP-HFM-123, 2005

Ways to reduce firearm noise exposure?

Hearing Protection Devices

- Muffs/Plugs
- Active/Passive

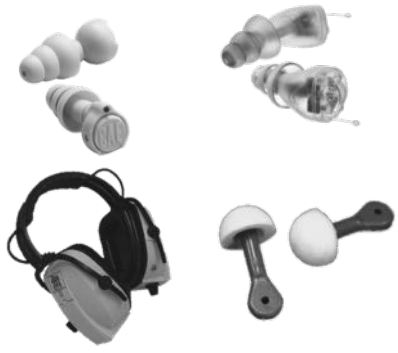


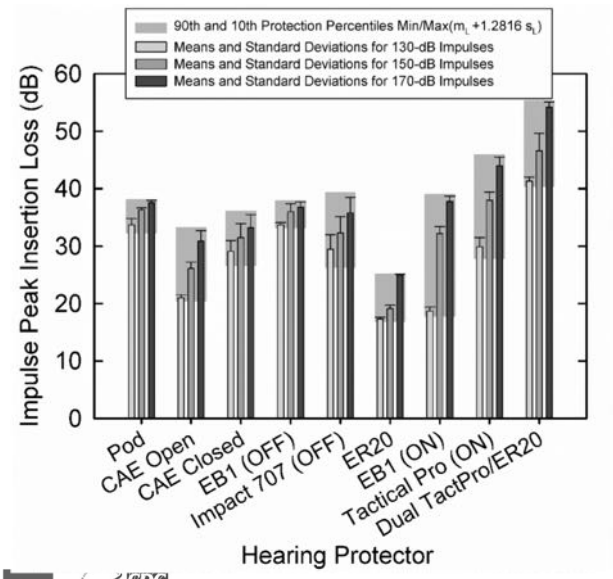
Photo credits: 3M, Etymotic Research, Bilsom, 3M

Reduces Noise at the Ear

- Must have appropriate HPD for specific shooting activities
- Must wear devices consistently
- Research has shown that firearm users do not consistently use HPDs, even during target practice

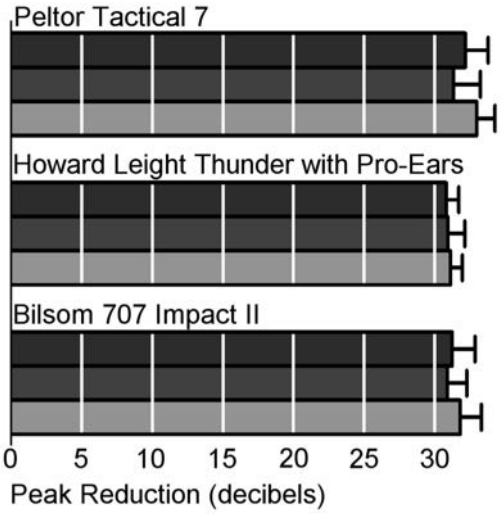
NHCA [2017]. NHCA Position Statement: Recreational Firearm Noise
Stewart M., et al. [2009]. Shooting habits of waterfowl hunters. Noise Health, 11, 8-13.
Stewart M., et al. [2011]. Shooting habits of recreational firearm users. Audiology Today, 23, 38-52.
Stewart M., et al. [2014]. Shooting habits of youth recreational firearm users. Int J Audiol, 53, S26–S34.

Comparison of Impulse Peak Insertion Loss



Meinke et al. [2012]. Audiology Now!, Boston MA, March 28-31

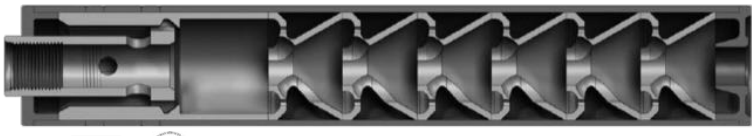
Peak Reduction of Level-limiting Ear muffs



Murphy, Byrne, Franks, [2007]. Hearing Review, pp. 36, 38, March.

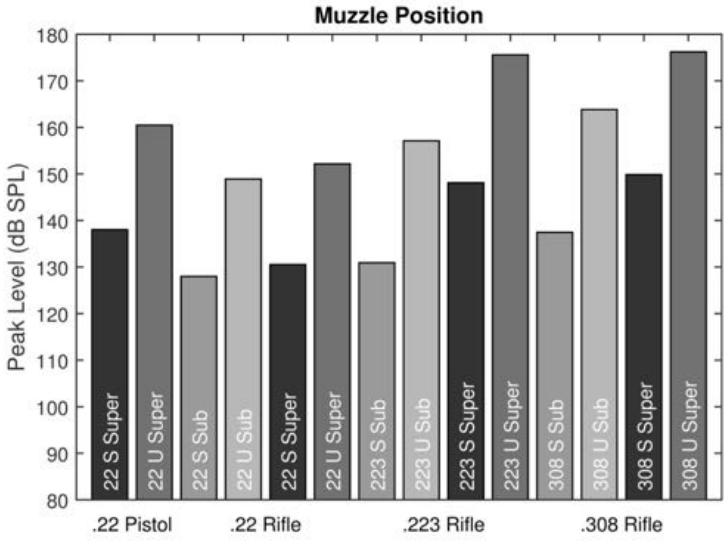
How suppressors work

- High level impulses are generated by sudden release of high pressure gases that accelerate the projectile
- Pressure is reduced by coupling a chamber with larger volume to end of barrel
- Baffles within the chamber act as a muffler
- Suppressors cannot reduce the noise caused by supersonic flight of projectile



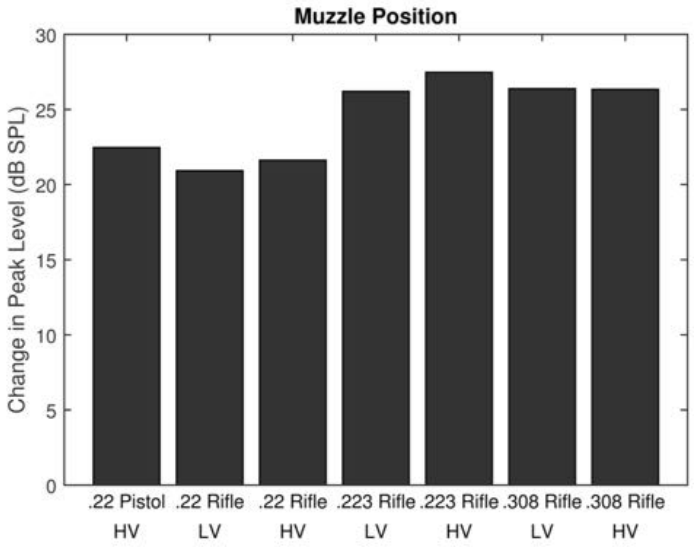
Murphy et al. [2018]. Int. J. Aud. 57:S28-S41.

Reduction of Peak Levels by Firearm Suppressors



Murphy et al. [2018]. Int. J. Aud. 57:S28-S41.

Reduction of Peak Levels by Firearm Suppressors



Murphy et al. [2018]. Int. J. Aud. 57:S28-S41.

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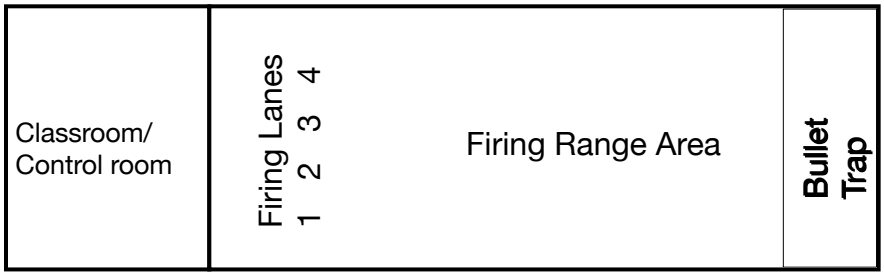
Schematic Indoor Firing Range Layout



Example Indoor Range Layout

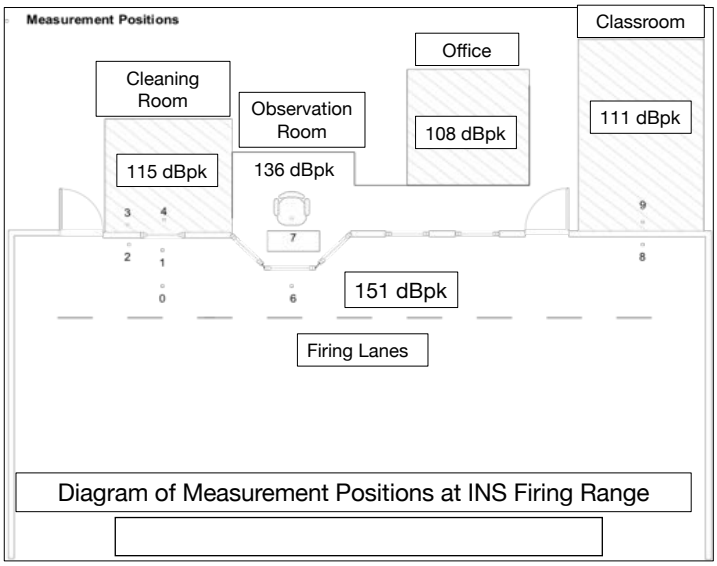


Diagram of Measurement Positions at INS Firing Range

Kardous, et al., [2003]. Noise Exposure Assessment and Abatement Strategies at an Indoor Firing Range, App. Ocup. Env. Hyg. 18:629-636

Noise Control in the Range

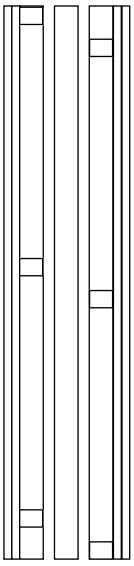
- Limited effectiveness for reflections only
  - Reduction of reverberant field of 10 dB
- Wall elements require an air gap for multiple reflections
- Absorption in the ceiling can reduce the reflected energy within the range.

- Peak sound pressure levels will not be affected
- Focus on the effects of noise transmitted to other spaces.

Kardous, Murphy, [2010]. Noise control solutions for indoor firing ranges, Noise Control Eng. Journal 58(4):345-356

Noise Control for Common Wall

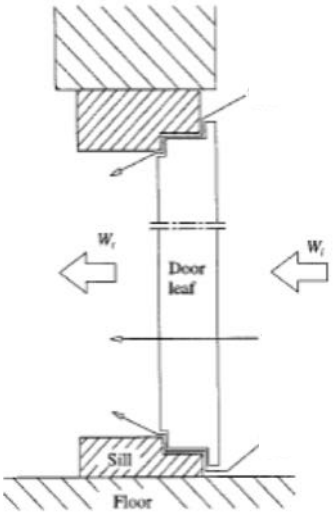
- Normal weight masonry wall with stud walls on either side will provide the greatest transmission loss.
  - The interior range wall will typically be covered with plates (0.25 to 0.5 inch aluminum or steel plating.) can be modeled with thin plate assumptions below 20 kHz.
  - Wall cavity should be insulated (fiberglass and maybe mass-loaded septum)
  - Adjacent spaces should also be insulated
  - The stud walls should be separated from the masonry block wall to reduce direct coupling to adjacent spaces.



Kardous, Murphy, [2010]. Noise control solutions for indoor firing ranges, Noise Control Eng. Journal 58(4):345-356

Noise Control for Passageways

- Double Door passage with 2-meter airlock
  - Doors should be multi-layered (STC-48 for single door)
    - Plate-Absorber-Gap-Absorber-Plate
  - Magnetic Seals to minimize air gaps
  - Absorption in the Passage-way (STC 50 or better)
- Sticky mats for controlling lead dust contamination
- Negative Pressure within the range (lead and CO exposure)



Kardous, Murphy, [2010]. Noise control solutions for indoor firing ranges, Noise Control Eng. Journal 58(4):345-356

Noise Control for Windows

- Laminated (armored windows)
  - Must withstand several impacts
    - Laminated glass 2.9 inches
    - 5 bullet strikes 0.223 caliber
  - Transmission loss of 35-45 dB in 500-1000 Hz
    - 11 mm laminated glass
  - Armored glass could have a thicker constrained layer
- Double glazed and double windows
  - Installed in separate walls
  - Absorptive batting around inner window cavity enhances transmission loss.
  - Nonparallel installation.

Kardous, Murphy, [2010]. Noise control solutions for indoor firing ranges, Noise Control Eng. Journal 58(4):345-356

Noise Control Ventilation System

- Independent ventilation system unconnected to adjacent spaces
  - Large volume velocity capability
  - HEPA Filter for lead dust
  - External exhaust for removal of combustion gases
- Ductwork should not bridge the common wall
- Laminar flow down range across the shooting lanes
- Noise levels from ventilation can be 70-85 dB.
  - Good design practices should minimize the acoustical footprint inside the range
  - Insulated ductwork straight runs

CONTINUED CDC NIOSH

Kardous, Murphy, [2010]. Noise control solutions for indoor firing ranges, Noise Control Eng. Journal 58(4):345-356

Noise Control Flanking Pathways

- Eliminate structural elements that bridge the space between the range and the rest of the building.
- Floor should be isolated with separate foundation and potentially insulated below and around perimeter.
- Mechanical connections (plumbing ventilation and electrical) should be isolated.
- The common wall should be isolate across its thickness with a break in the foundation such that interior range wall is not connected structurally to the adjacent space interior wall(s).
- The roof and exterior walls be isolated with expansion joints to reduce coupling between range and other spaces.

CONTINUED CDC NIOSH

Kardous, Murphy, [2010]. Noise control solutions for indoor firing ranges, Noise Control Eng. Journal 58(4):345-356

Summary

- Noise control is more expensive to retrofit than it is to design/include from beginning.
- Reasonable transmission loss might be in the 70-80 dB range if the isolation techniques are carefully implemented.
- Ideally the impulse noise in the adjacent space should be below 70 dB peaks.

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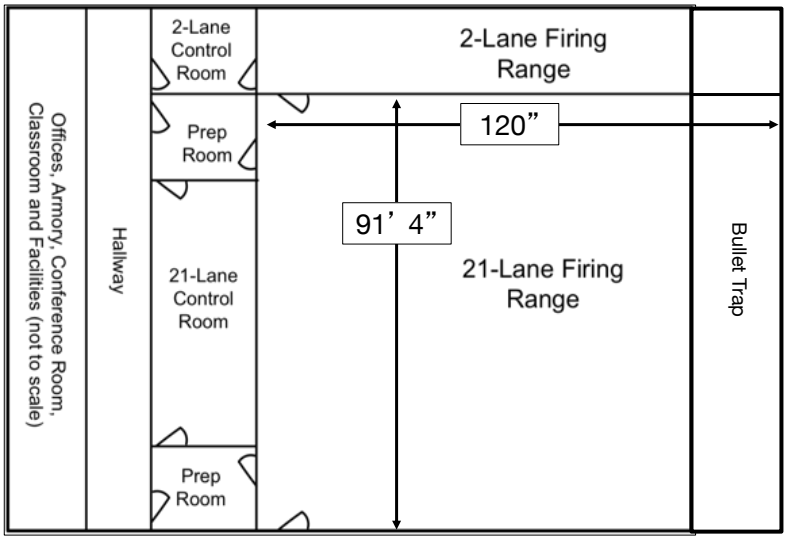
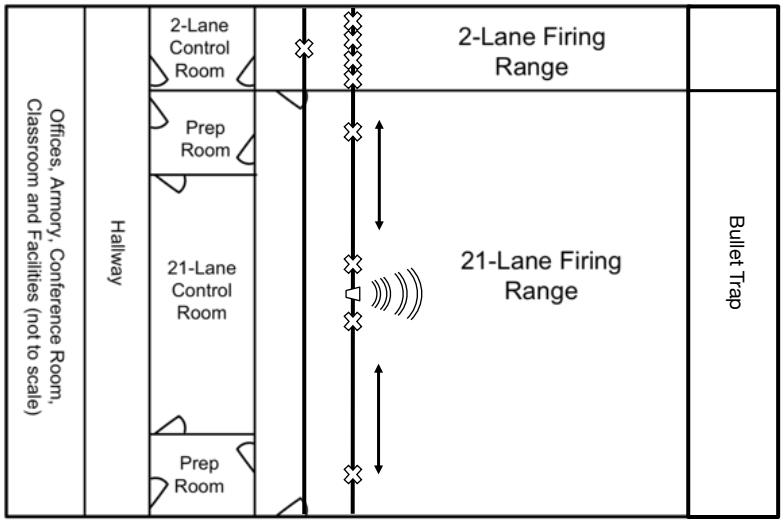
A little history

- Wright Patterson Air Force Base (WPAFB) Combat Arms Training Facility (CATF) was built without noise treatments inside the firing range
- 2 Ranges: 2-lane and 21-lane
- Concrete walls, floor, armored bullet trap, baffles and safety ceiling
- In 2009, US Air Force contracted to have Troy Acoustics install the noise treatment

Layout of the WPAFB CATF



Reverb Time Microphone Locations



Troy Acoustics Treatment Materials

- 2” thick Troy Board – Porous cementatious shredded wood
- 1.5” Troy Wool – Basalt mineral wool placed between 2”x4” furring strips
- Armor plate – Bullet trap & last 44’ of range
- Doors – STC 45 (48”x80”)
- Windows
  - STC 47 – 5 panes (96”x36”) 21-lane
  - STC 47 – 1 pane (96”x36”) 2-lane

Which Surfaces were Treated?

- Safety ceiling, baffles and isolation ceiling

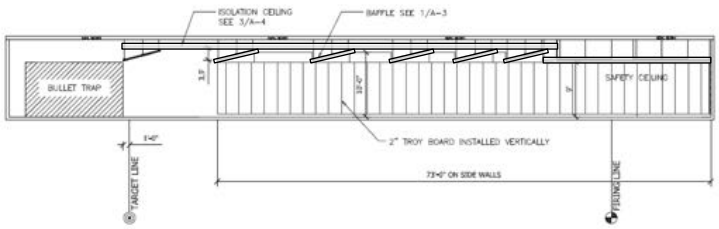


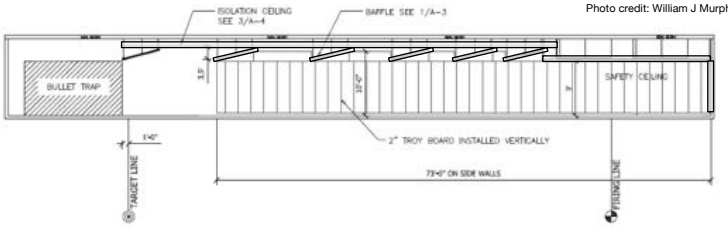
Photo credit: William J Murphy, NIOSH

Drawing used with permission from Troy Acoustics

Which Surfaces were Treated?

- Safety ceiling, baffles and isolation ceiling
- Wall behind shooters

Photo credit: William J Murphy, NIOSH



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Which Surfaces were Treated?

- Safety ceiling, baffles and isolation ceiling
- Wall behind shooters
- Side walls to within 44 feet of end bullet trap

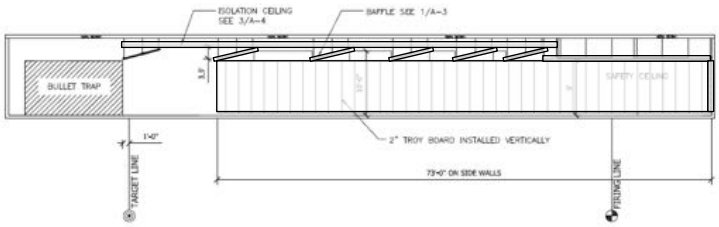

Photo credit: William J Murphy, NIOSH

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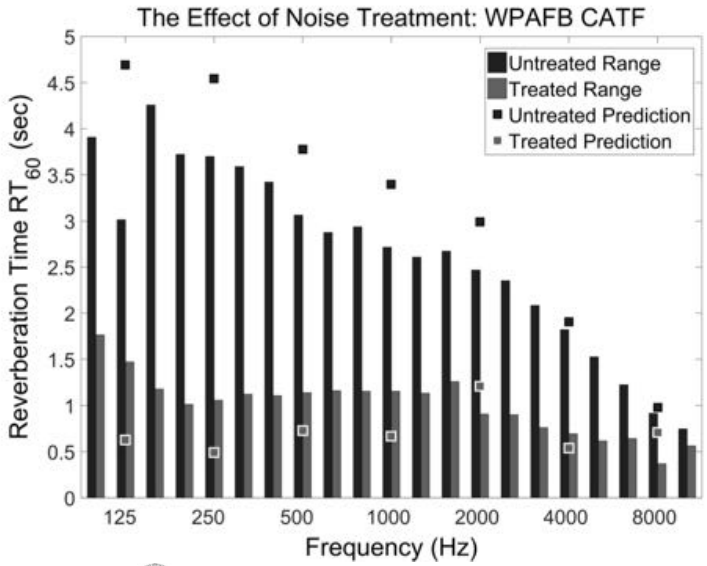
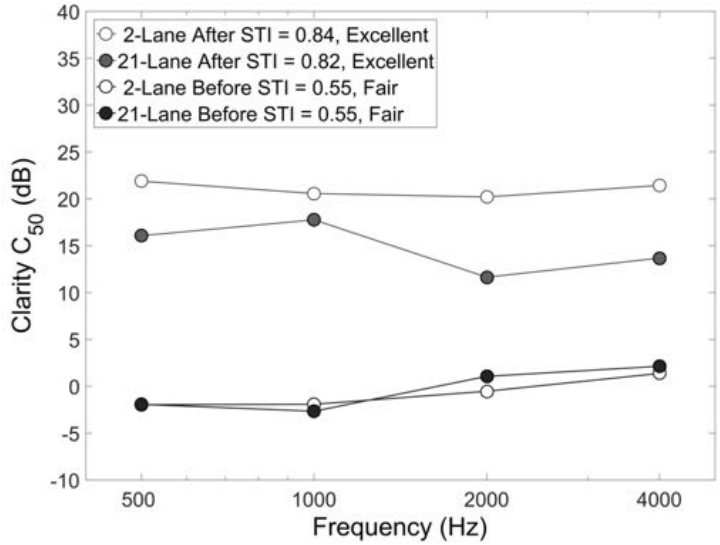
The Effectiveness of WPAFB Noise Treatments



Murphy, Zechmann, Kardous, Xiang [2012]. J. Acoust Soc Am 134:2084

Speech Intelligibility



Murphy, Zechmann, Kardous, Xiang [2012]. J. Acoust Soc Am 134:2084

Conclusions

- The Troy System™ acoustic treatment provided a significant reduction of the reverberation time in the firing ranges.
- Speech Intelligibility improved dramatically as a result.
- Reverberation Times were lowered to less than $RT_{60} < 1.5$ sec above 125 Hz.

Firing Range Auralizations

- Untreated 21-lane Firing Range

  21 Shooters firing M16 Rifles
- Untreated 21-lane Range

  Fixed Location Source, Walking around the Range
- Treated 21-lane Range

  Fixed Location Source, Walking around the Range

Murphy, Zechmann, Kardous, Xiang [2012]. J. Acoust Soc Am 134:2084

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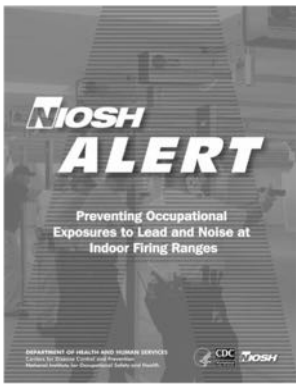
Practical Recommendations

- NIOSH Alert
  - Preventing Occupational Exposures to Lead and Noise at Indoor Firing Ranges
- NIOSH Indoor Firing Ranges Topic Page
  - https://www.cdc.gov/niosh/topics/ranges/
- NIOSH Science Blog
  - Hit the Mark: Firearms training without damaging your hearing
- NIOSH Publications
  - Noise and Hearing Loss Prevention



Effect of training: Modalities of instruction

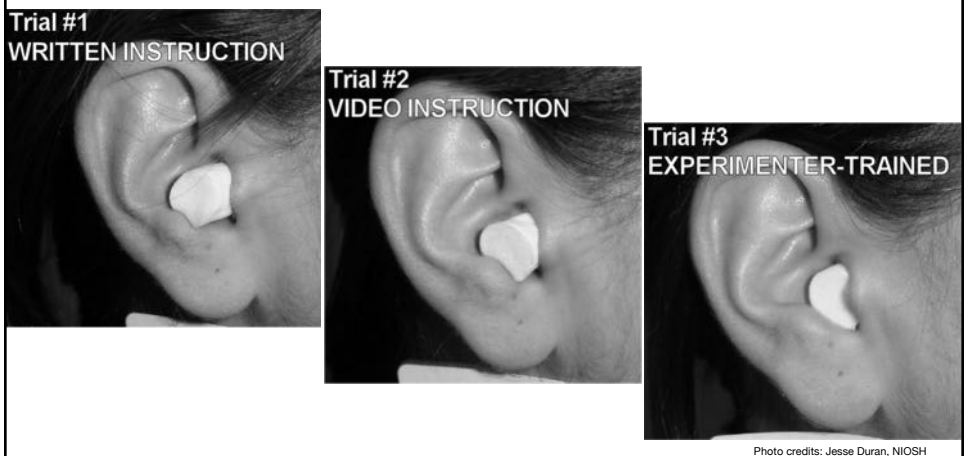
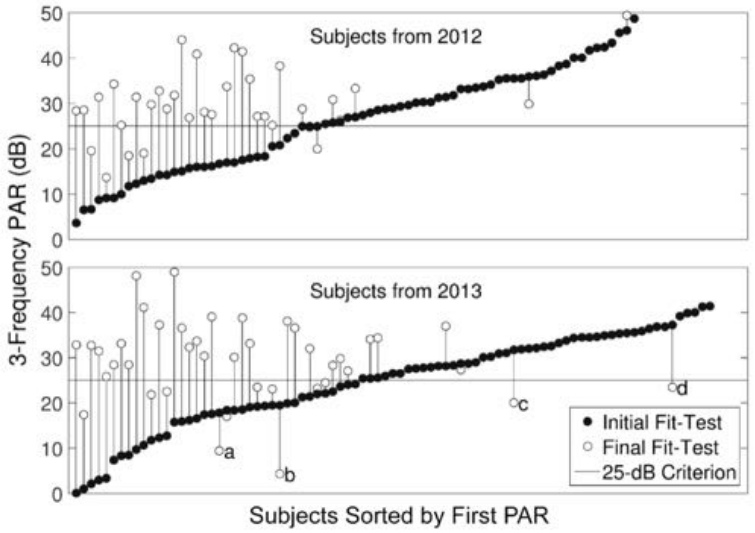


Photo credits: Jesse Duran, NIOSH

Murphy et al., The effects of training on attenuation, Noise & Health, 2011

Effect of training in proper earplug fitting



Murphy et al, (2016). Int. J. Audiol, 55:11, 688-698

Conclusions

- Implement Health and Safety Programs
- Monitor for potential exposures to lead
- Monitor hearing status for workers and shooters
- Provide a wide range of hearing protection devices
- Train people about how to wear hearing protection and other PPE
- Encourage the shooters to use hearing protection in other settings
- Firearm health and safety demands a proactive approach

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Questions?

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