Chapter 5 – Noise

1. General

a. This chapter provides the basic information necessary to evaluate and document employee noise exposure and to assist with determining compliance with Department of Defense (DoD) noise instructions. For more detailed information, see references.

b. Documentation for noise surveys, noise dosimetry, and audiometric test booth surveys are listed in Appendix E, Appendix F, and Appendix M.

c. Information on enrollment into and execution of a Hearing Conservation Program can be found in references 5-1, 5-2, and 5-3.

2. Definitions

a. Continuous Noise. Noise where intervals between impulses are less than 0.5 seconds, except for short rapid bursts of automatic weapons fire, which are considered impulse noise (reference 5-1).

b. Crest Factor. For steady–state repetitive sound wave form, it is equal to the ratio of peak acoustic pressure to the root-mean-square (RMS) sound pressure level (SPL) for a given noise measurement situation. The crest factor characterizes a sound measuring instrument's ability to accurately average or integrate repetitive waveforms with elevated peak levels but does not rate the capability to measure true instantaneous peak values, or isolated impulses (reference 5-4).

c. Criterion Level. The continuous equivalent A-weighted SPL which constitutes 100 percent of an allowable exposure. For DoD purposes, this is 85 dBA as an 8-hour time-weighted average (TWA) in a 24-hour period (reference 5-1). The dosimeter readout can be used to calculate both the continuous equivalent A-weighted SPL (L_A) and the 8-hour TWA for the time sampled, using the following equations:

$$L_A = 85 + \left(10 \times \log\left[\frac{D}{12.5 \times T}\right]\right)$$

Equation 5-1

$$TWA = 85 + \left(10 \times \log\left[\frac{D}{100}\right]\right)$$

Equation 5-2

Where:
L_A = continuous equivalent A-weighted SPL, in decibels, for the time sampled, if the Criterion Level is 85 dBA as an 8-hour TWA exposure and the Exchange Rate is 3 dB

D = dosimeter read-out in percent noise dose
T = sampling time in hours
For impact or impulse noise, the criterion level is 140 dB peak (dBP) SPL (reference 5-1).

d. Decibel (dB). The unit of measurement for SPL. The SPL, in dB, is equal to 20 times the common logarithm of the ratio of the existing sound pressure to a reference sound pressure of 20 micro-pascals.
   (1) A-Weighted Sound Level (dBA). SPL (in decibels) measured using a sound level meter with an A-weighting network. The A-weighted response is maximum at 2500 Hz and drops rapidly as frequency decreases below 1000 Hz and gradually decreases above 4000 Hz, thereby approximating the frequency dependent human response to moderate sound levels (reference 5-5). See reference 5-6 for definition of A-weighting filter characteristics.
   (2) C-weighted Sound Level (dBC). SPL (in decibels) measured using a sound level meter with a C-weighting network. It is generally used to limit the low and high frequency response of the instrument so that the instrument will not respond to signals outside the human hearing frequency range at high sound levels (reference 5-5). See reference 5-6 for definition of C-weighting filters.
   (3) Decibel, Peak (dBP). Instantaneous SPL when measured by a sound level meter (SLM) using an impulse or peak hold circuit having a rise time constant not exceeding 35 milliseconds. See also the discussion of SLM and peak SPLs in chapter 3 of reference 5-4.

e. Dosimeter. An instrument worn by personnel for determining their accumulated workplace noise exposure regarding SPL and time according to a pre-determined integration formula. This instrument shall meet the requirements of reference 5-7.

f. Dosimeter Threshold Level. Threshold level is the A-weighted SPL at which a noise dosimeter begins to integrate the noise into the measured exposure. For DoD purposes this is 80 dBA. All sound levels from 80 dBA to 130 dBA, at a minimum, are integrated (reference 5-1).

g. Exchange Rate. The exchange rate is a trade-off between the SPL in dB and the duration of exposure in hours. The DoD exchange rate is 3 dB (reference 5-1). Each 3 dB increase in SPL (above the 85 dBA 8-hour TWA criterion level) can be balanced by a 50% reduction in unprotected exposure duration.

h. Impact Noise. Noise produced by a single collision of one mass in motion with a second mass, generally less than one second in duration and which repeats no more than once per second (reference 5-4).

i. Impulse Noise. Impulse noises are usually considered to be singular noise pulses, each less than one second in duration, or series of repetitive noise pulses that may last longer than 1 second (reference 5-5). Also defined as a change of sound pressure of 40 dB or more within 1 second (reference 5-1).

j. Intermittent Noise. Noise which starts and stops, usually at varying intervals (e.g., use of a drill press or the start and stop of a forklift).

k. Meter Response. The motion of the SLM's needle or digital output resulting from an excitation (stimulus). To allow the user to follow the movement of the results, "slow" and "fast" averaging circuits are built into the sound level meter. In practical terms, the "slow" circuit allows visual tracking of the average SPL and the "fast" circuit allows visual tracking of the variability of the SPL. SLMs should usually be set for "slow" response, which has an exponential time constant of 1,000 milliseconds. Type 0, 1 and 2 SLMs are also equipped with a "fast" response setting which has an exponential time constant of 125 milliseconds. Some SLMs are equipped with an "impulse" response setting which has an exponential rise time constant of 35 milliseconds. The "impulse" setting also has a decay constant of 1,500 milliseconds which is sufficiently slow to allow a user to manually record the maximum reading before it disappears from the display. The "impulse" response setting is not sufficiently fast to measure true peak SPLs due to impulse or impact noise (reference 5-4). See Section 3 Noise Measurement Instruments, for instruments needed to measure impact and impulse noise.

l. Noise. An undesired sound may be either intermittent, continuous, or impulse.

m. Noise Dosimeter. An instrument used to measure, store, and integrate SPLs over a time period which meets the requirements of reference 5-7. By integrating the SPL measurements, noise dosimeters can provide a cumulative noise-exposure measurement for a given period of time.

n. Noise Reduction Rating (NRR). A single-number attenuation index for estimating the overall noise exposure reduction of a specific hearing protection device (HPD). The Environmental Protection Agency (EPA) developed this number in 1979, and it is pre-calculated by the HPD manufacturers and provided on their packages (reference 5-4).

NOTE: Although HPDs are recommended for protection against impulse noise, the NRR is based on the attenuation of continuous noise and may not be an accurate indicator of the protection attainable against impulsive noise (reference 5-8).

o. Noise risk assessment code (RAC). A noise RAC can be determined for either steady-state or impulse noise exposures. The exposure level, long-term frequency (consistency), and number of personnel exposed (or specified SEG) are the criteria used to calculate the RAC. Refer to reference 5-9 for further information.

p. Pulse Range. The ability of an instrument to measure average or integrated transient sound pulses. It does not relate to the ability of an instrument to capture true instantaneous peak SPLs (reference 5-4).

q. Peak Sound Pressure Level. The maximum instantaneous SPL that occurs during a specified time interval. The peak detector in Type 0 SLMs provides acceptable

measurements of 50 microsecond duration impulse/impact noise and in Type 1 and 2 SLMs for 100 microsecond duration impulse/impact noise (reference 5-4).

r. Rise Time. The time required for a physical quantity (e.g., sound) to rise from 10% of its final value to 90% of its final value (reference 5-10).

s. Root Mean Square (RMS). Square root of the arithmetic mean of the squares of a set of instantaneous amplitudes, or a set of values of a function of time or another variable.

t. Sound Level Meter (SLM). An instrument used to measure SPLs which meets the requirements of reference 5-6.

u. Sound Pressure Level (SPL). The RMS value of the pressure changes above and below atmospheric pressure when used to measure steady state noise.

v. Time Constant. The time delay for a sound measuring instrument output to reach 63% of the gap between initial and final sound pressure levels.

3. Noise Measurement Instruments

SLMs and noise dosimeters are used to assess an employee's exposure to noise. Octave band analyzers (OBA) are used to identify the frequencies at which the noise is generated and are mainly used to aid in selecting engineering controls.

a. Sound Level Meters (SLM). All SLMs used by the Navy will conform, as a minimum, to the Type 2 requirements cited in reference 5-6, which set performance and accuracy tolerances. SLMs used for measurement of impulse noise have additional performance requirements, as detailed in reference 5-1 and Appendix 5-A of this chapter. The SLM will be electroacoustically calibrated and certified annually. An acoustical calibrator, accurate to within one dB, will be used to calibrate the instrument before each survey and to revalidate the calibration at the conclusion of the survey. Acoustical calibrators will be electroacoustically calibrated and certified annually. See Industrial Hygiene Field Operations Manual (IHFOM) Chapter 8, Equipment Maintenance and Calibration for specifics on calibrating all noise measuring instruments.
   (1) Types of SLMs.
      (a) Type 0. Laboratory standard. Used as a high precision reference in the laboratory; not intended for field use.
      (b) Type 1. Precision SLM. Can be used in the field and laboratory.
      (c) Type 2. General purpose SLM. Designed to have less stringent tolerances than Type 1; used for field measurements.
      (d) Type S. These SLMs may have some but not all the features required of a specified type. They are not generally acceptable for Navy Industrial Hygiene (IH) work.
   (2) Continuous or intermittent noise will be measured in dBA with a SLM set for slow response with the following weighing scales:

(a) The A-weighting scale approximates the equal loudness perception characteristics of human hearing for pure tones relative to a reference of 40dB SPL at 1 KHz (i.e., the 40-phon curve) (references 5-5 and 5-6). This scale discriminates against acoustic energy in the low frequency ranges (reference 5-4).

(b) The C-weighting scale approximates the equal loudness perception characteristics of human hearing for pure tone relative to a reference of 100 dB SPL at 1KHz (i.e., the 100 phone100-phon curve) (references 5-5 and 5-6.) It responds with little discrimination against low frequencies, detects more energy and may result in higher measurements than the A scale. For this reason, C-weighted SPL measurements should be taken and used to determine hearing protector performance (reference 5-4).

(3) Impact or impulse noise from a source other than weapons firing shall be measured as dBP SPLs with SLMs which have a peak hold circuit, a rise time constant not exceeding 35 milliseconds and the capability to measure peak SPLs of at least 140 dBP (reference 5-1).

(4) Impulsive noise from weapons fire in an acquisition program study shall be measured according to the requirements outlined in reference 5-10, which indicates measurement procedures and recording equipment criteria with respect to the kiloPascal (kPa) or dB level.

(5) Impulsive noise from weapons firing in a workplace exposure study or other non-acquisition setting shall be measured as described in paragraph (3), above.

b. Noise Dosimeters. Specifications for noise dosimeters are provided in reference 5-7. For Navy use, the dosimeter must meet, as a minimum, class 2A-85/80-3 where:

(1) "2" means that the dosimeter has tolerances that correspond to those for a Type 2 SLM (reference 5-7).

(2) "A" means the A-frequency weighting network,

(3) "85" means an 85 dBA slow criterion level,

(4) "80" means an 80 dBA threshold level, and

(5) "3" means a 3 dB exchange rate.

(6) Additionally, dosimeters shall be capable of accurately measuring impulse noise between 80 dB and 130 dB (reference 5-1).

(7) Also, when a noise dosimeter requires programming of an upper limit, it shall be set as high as the instrument is capable of reliably measuring but in no case less than 130 dB (reference 5-1).

(8) Although not required, a data-logging capability which will allow collection of time history data is strongly recommended when dosimetry results will be used to devise noise control strategies. The ability to field select different criterion levels and exchange rates is also desirable but not required.

c. Octave Band Analyzers (OBA). OBAs are used to determine where sound energy lies in the frequency spectrum. This is important for recommending engineering controls for

noise. Always follow the manufacturer's instructions when taking OBA measurements. These measurements usually require several minutes to complete; therefore, the sound being measured must be steady state and of a long enough duration to complete the measurements.

4. Noise Measurement Records

reference 5-2 requires that noise measurement records be kept for 40 years after the data is collected. reference 5-3 requires that noise measurement records be kept for 50 years after the data is collected. references 5-1 and 5-11 require that noise measurement records be kept for the duration of employment plus 30 years. Reference 5-12 dictates longer retention times for some records (e.g., Section SSIC 6200.2a dictates some occupational health, industrial and environmental control program records not be destroyed until after 75 years, though they can be archived after 5 years). As a minimum, records must include:

a. Number, type and location of the noise sources.

b. Number and identification of personnel in the work area and their daily noise exposure and duration (dosimetry only).

c. Type, model, serial number of test equipment and calibration data.

d. Location, date and time of noise measurement.

e. SPLs measured in dBA and/or SPLs measured in dBP.

f. Hazard radius (both to 85 dBA and 104 dBA if necessary); if applicable this can be performed for impulse or impact noise (both to 140 dBP and 165 dBP if necessary).

g. 8-hour TWA noise exposure in dBA, if the measurements are sufficient to calculate it (e.g., dosimetry data or many sequential measurements over the work-shift with an SLM).

h. Name and signature of the person(s) who performed the survey.

5. Sampling Protocol

a. Noise measurements will be taken by industrial hygienists, audiologists, IH technicians, workplace monitors or others suitably trained. An industrial hygienist is responsible for making noise exposure assessments, assigning noise risk assessment codes (RACs), designating noise hazardous areas, equipment, and work processes based on noise measurements as well as associated information as part of the IH survey.

b. Types of Surveys:
   (1) General Survey. Conducted to determine the locations and boundaries of hazardous noise areas and equipment. The Type 2 SLM is adequate for this type of survey.
   (2) Noise Control Survey. A Type 1 SLM with an octave band filter is used to obtain engineering-type data to aid in selecting a course of action for noise control (i.e., noise profiles, special surveys) or audiometric testing booth certifications.

(3) Noise Dosimeter Survey. Dosimeters are used to assess individual noise exposure. Noise dosimeters with a data logging capability are typically used to determine which processes during the work shift are the major contributors to noise exposure so noise control efforts can be focused where the most benefit will be derived.

(4) Impulse Noise Survey. Similar to a general survey but conducted to determine the locations and boundaries specific to hazardous impulse noise areas and equipment. Appendix 5-A contains guidance for conducting an impulse noise survey.

c. SLM. Always follow the manufacturer's instructions. For practical purposes, the procedure below would typically be followed for SPL measurements.

(1) Continuous and Intermittent Noise.

(a) SLM should be set to slow response.

(b) Measurements should be taken using the "A" weighting network (dBA).

(c) Additional “C" weighting network dBC measurements can be taken.

(2) Impulse or Impact Noise. Measurements should be taken using the no weighting/Z/peak setting dBP.

(3) Ensure windscreen is used where needed.

(4) Obtain SPL measurements at the noise source.

(a) Record locations of sources on a diagram.

(b) Record the Noise hazard radius.

1. If SPL measurements at the noise source exceed 85 dBA, determine the distance from the noise source where the SPL falls to 85 dBA. Repeat several times and record on the diagram. This is the hazard radius. If SPL measurements at the noise source exceed 104 dBA, the distance from the noise source to where the SPL falls to 104 dBA should also be measured in addition to the hazard radius to 85 dBA.

2. If applicable, this can also be performed for impulse or impact noise sources - for the distance from the noise source where the SPL falls to 140 dBP. If SPL measurements at the noise source exceed 165 dBP, the distance from the noise source to where the SPL falls to 165 dBP should also be measured in addition to the hazard radius to 140 dBP.

(5) Obtain SPL measurements at the worker location.

(a) The microphone should be held in the person's hearing zone (defined as a sphere within a two-foot diameter surrounding the head) and oriented in accordance with the manufacturer's recommendations (i.e., either perpendicular or parallel to the noise source). When sampling weapons firing, safety rules may require the noise surveyor to be remote from the source. A tripod and/or microphone extension cable can be used to sample at an appropriate location.

(b) Select the ear closest to the noise source. When noise levels measured at each ear for a single individual are different, the higher level should be used for compliance purposes.

(c) Noise levels will vary during the day and between different days as work operations change. Obtain many SLM measurements to determine an actual exposure; noise dosimeters are the instruments of choice for monitoring personal exposure to steady-state noise. Noise dosimeters are not capable of accurately monitoring impulse noise and should not be used for this purpose.

b. Noise Dosimeters. Always follow the manufacturer's instructions. For practical purposes, the procedure below would typically be followed for dosimeter measurements.
   (1) The noise dosimeter should be set to parameters meeting reference 5-1. Ensure windscreen is used where needed.
   (2) Clip the microphone to the employee's collar at the top of the shoulder, as close as possible to the employee's ear that is closest to the noise source. The microphone should be in the person's hearing zone (defined as a sphere within a two-foot diameter surrounding the head). Considerations of practicality and safety for each survey location will dictate the actual microphone placement. Care should be taken to ensure that the microphone is in a vertical position. Placement of ear clips should be in accordance with the manufacturer's instructions.
   (3) Ensure the microphone is not covered, obstructed or brushing against anything.
   (4) Inform the employee that the dosimeter should not interfere with normal duties and emphasize that the employee should continue to work in a routine manner.
   (5) Explain to each employee being surveyed the purpose of the dosimeter and that it is not a speech recording device.
   (6) Instruct the employee being monitored to not remove the dosimeter unless necessary and to not cover the microphone with a coat, other garment, or work equipment.
   (7) Inform the employee when and where the dosimeter will be removed.
   (8) Make sure that the dosimeter is in recording mode before starting the survey.
   (9) The dosimeter should be checked periodically to ensure that the microphone is oriented properly.
   (10) For dosimeter results to be meaningful, a log of the employee's activity along **with respective sound pressure level measurements** shall be maintained by the person conducting the survey so that exposure data can later be correlated with different locations, operations, and activities, thereby identifying noise sources.

   NOTE: Do not leave the dosimeter unattended in the field.

6. Factors That Affect Instrument Performance

a. Temperature. Sound measuring equipment should be used within the manufacturer's design specifications. Store sound measuring equipment in accordance with the manufacturer's recommendations.

b. Humidity. Sound measuring instruments perform accurately as long as moisture does not condense or deposit on the microphone.

c. Atmospheric Pressure. When checking an acoustical calibrator always apply the corrections for atmospheric pressure and temperature as directed in the manufacturer's instructions.

(1) In general, if the altitude of the measurement site is less than 10,000 feet above sea level, the correction is negligible and need not be considered further.

(2) If the measurement site is at an altitude higher than 10,000 feet above sea level, or if the site is pressurized above ambient pressure, use the following equation to correct the instrument reading:

$$C = 10 \times \log\left(\sqrt{\frac{460 + t}{528}} \times \left(\frac{30}{B}\right)\right)$$

Equation 5-3

Where:
C = correction to be added to the measured SPL (dB)
t = temperature (°F)
B = barometric pressure (inches Hg)
NOTE: For high altitude locations, C will be positive; for hyperbaric conditions, C will be negative.

d. Wind. Wind blowing across a microphone produces turbulence which may cause positive error in the measurement. Use a wind screen for all outdoor measurements and where there is significant air movement inside a building (e.g., cooling fans or gusty wind through open windows).

e. Magnetic Fields. Devices such as heat sealers, induction furnaces, generators, transformers, electromagnets, arc welders, radars and radio transmitters generate electromagnetic fields which may induce current in the electronic circuitry of SLMs and noise dosimeters causing erratic readings. If SLMs or dosimeters must be used near such devices, attempt to determine if the effect of the magnetic field is significant. Follow the manufacturer's instructions for use around magnetic fields.

f. Impulse/Impact Levels. The presence of impulse/impact noise in the vicinity of a noise dosimeter may overload the noise dosimeter. Because the noise dosimeter suffers from microphone limitations and lacks measurement parameters that have been associated with characterizing impulse noise and its effect on the auditory system (reference 5-13). When using an SLM for weapons fire measurement, ensure an appropriate SLM and microphone are used for the expected sound level in accordance with reference 5-10. Refer to references 5-13 and 5-14 to understand instrument limitations. The scope of

reference 5-10 is limited to acquisition programs, but the performance criteria it contains for microphones and sound level meters are broadly relevant to impulse noise measurement for other purposes.

g. Microphone Placement. For SLMs and noise dosimeters that use omnidirectional microphones, the effects of microphone placement and orientation are negligible in the typical reverberant environment. As a rule, the SLM should be held at arm's length and not in line with the noise source and the operator to reduce the body-baffling effect. To minimize body shielding effects on microphones, consult the manufacturer for recommended placement. If the measurement site is non-reverberant and/or the noise source is highly directional, consult the manufacturer for recommended microphone placement and orientation. Also, ensure the microphone is not directed toward reflective surfaces. This would result in higher SPL measurements.

7. Criterion Levels

The DoD criterion levels for occupational exposure to noise, per references 5-1 and 5-3, are:

a. 85 dBA as an 8-hour TWA in a 24-hour period.

b. For periods of less than 16 hours in any 24-hour period, the allowable exposure in dBA, can be determined from the following equation:

$$dBA = 3\left(\frac{log\frac{16}{T}}{\log 2}\right) + 82$$

Equation 5-4

Where:
T = exposure time (hours)

c. For a given SPL, the allowable exposure period follows:

$$T = 8 \times 2^{\left(\frac{85-L}{3}\right)}$$

Equation 5-5

Where:
T = permissible exposure time in hours (decimal)
L = Measured SPL in A-weighted decibels dBA

d. When the daily noise exposure is composed of two or more periods of noise exposure of different levels, their combined effect must be considered. If the sum of the following expression exceeds one, then the combined exposure exceeds the DoD criterion level:

$$\frac{C_1}{T_1} + \frac{C_2}{T_2} + \cdots + \frac{C}{T_n}$$

Equation 5-6

Where:
C = total time of exposure at a specified SPL
T = time of exposure permitted at that level

e. 140 dBP SPL for impact or impulse noise.

f. When exposures to steady-state noise below 130 dBA occur simultaneously within the same 24-hour period as exposure to impulse noise above 130 dB C-weighted peak, apply the hazard criteria separately (i.e., the allowable exposure to steady-state noise [e.g., engine noise] shall not be reduced because of exposure to impulse noise [e.g., weapon firing]).

8. Hazardous Noise Areas/Equipment, Use of Hearing Protection, and Assignment of Noise RACs

The designation of hazardous noise areas and equipment and use of hearing protection is based on the following criteria:

a. Any work area or equipment where the SPL is 85 dBA or above (continuous or intermittent) shall be considered noise hazardous (reference 5-1).

b. Any work area or equipment where the SPL is 140 dBP or greater (impulse or impact) shall be considered noise hazardous (reference 5-1).

c. The administrative control of limiting exposure time (i.e., implementing a stay time) shall be used when HPDs do not provide sufficient attenuation to reduce exposures below the occupational exposure limit (OEL) (references 5-1 and 5-2).

d. In accordance with references 5-1, 5-2 and 5-3, areas or equipment where the SPLs are 85 dBA or greater, but less than 104 dBA, shall be labeled and shall require the use of single hearing protection (approved ear plugs or circumaural muffs). Areas or equipment where the SPLs are 104 dBA or greater shall be labeled and shall require the use of double hearing protection (approved ear plugs and circumaural muffs). Labels should include the type of hearing protection to wear (i.e., single or double), and administrative maximum stay times if hazardous noise exceeds hearing protection NRRs.

e. In accordance with references 5-1, 5-2, and 5-3, areas or equipment where the SPLs are 140 dBP or greater, but less than 165 dBP, shall be labeled and shall require the use of single hearing protection. Areas or equipment where the SPLs are 165 dBP or greater shall be labeled and shall require the use of double hearing protection. Labels should include the type of hearing protection to wear (i.e., single or double), and administrative maximum stay times if hazardous noise exceeds hearing protection NRRs.

f. In accordance with references 5-1, 5-2 and 5-3, all personnel exposed to gunfire or artillery fire in test or training environments (e.g., weapons qualifications, simulated combat sounds, artillery, or missile fire) shall wear HPDs.

g. In accordance with reference 5-9, assign a noise RAC to all potentially hazardous noise operations.

h. Maintain a current inventory of all potentially hazardous noise areas, equipment, and work processes to include, as a minimum, noise levels, RACS, and the types of control measure(s) used.

9. Types of Hearing Protection

references 5-1, 5-2, 5-3 and 5-15 provide guidance and requirements for hearing protection.

a. Fitted Inserts.
   (1) Most are elastomeric.
   (2) Sized non-disposable insert devices can only be fitted and stocked by trained medical department personnel.
   (3) Sizing gauge is useful but does not take the place of actual fitting.
   (4) They are available in various sizes, depending upon the type. Occasionally, a different size must be fitted to each ear.
   (5) Attenuation is approximately 20 dB. NRR varies by manufacturer and product, and in real world situations is rarely as high as the manufacturer's label.

b. Disposable Type Inserts.
   (1) Moldable does not require fitting, provides a very good seal if properly inserted, conforms to the shape of the ear canal.
   (2) Attenuation is approximately 20 dB. NRR varies by manufacturer and product; it may not reach the level measured under laboratory conditions.

c. Circumaural Muffs.
   (1) Cup-like plastic domes that cover the entire ear, connected by a spring band.
   (2) Attenuation varies between manufacturers and products and is approximately 20-30 dB.

d. Canal Caps.
   (1) Block the ear canal only.
   (2) Attenuation is low, typically 12-18 dB. Primary value lies in portability and ease of insertion/removal for intermittent exposures.

10. Personal Attenuation Rating of Hearing Protection

a. Hearing Protective Devices (HPDs). reference 5-1 requires that personal hearing protection be worn to attenuate occupational noise exposure of employees to within the limits of the OEL. The actual effectiveness of any individual hearing protector cannot

be determined under workplace conditions. Hearing protectors are evaluated under rigorous laboratory conditions specified in ANSI/Acoustical Society of America (ASA) S12.6-2016 and ANSI/ASA S12.42-2010. However, Occupational Safety and Health Administration's (OSHA) experience and the published scientific literature indicate that laboratory-obtained real ear attenuation for hearing protectors can seldom be achieved in the workplace. When using the NRR to assess a HPDs adequacy for hearing conservation purposes, the attenuation calculations below should be applied (reference 5-16).

(1) Single Protection (i.e., muffs or plugs):
   (a) Obtain the NRR which is on the packaging of the HPD.
   (b) Subtract 7dB from the NRR to correct for using A-weighted measurements. For C-weighted measurements no correction is needed.
   (c) Exposure estimation for Single Protection:
   Estimated Exposure dBA = TWA dBC - NRR, or
   Estimated Exposure dBA = TWA dBA - (NRR - 7)

(2) Dual Protection (i.e., muffs and plugs).
   (a) Obtain the NRR for the higher rated hearing protector (NRR_h)
   (b) Subtract 7dB from the NRR to correct for using A-weighted measurements. For C-weighted measurements no correction is needed.
   (c) Add 5 dB to the field adjusted NRR to account for the use of the second hearing protector.
   (d) Exposure estimation for Dual Protection:
   Estimated Exposure dBA = TWA dBC - [NRR_h + 5], or
   Estimated Exposure dBA = TWA dBA - [(NRR_h - 7) + 5]

b. Derating NRR. Derating NRRs is the reduction of the NRR by a 50% safety factor. While current guidance (reference 5-17) does not require derating the NRR to assess the adequacy of HPDs for hearing conservation purposes, it is important to do so:

(1) When considering whether engineering controls are to be implemented (reference 5-17), or
(2) When evaluating HPD adequacy for military or civilian personnel who experience an STS (reference 5-2).

If using the NRR to assess a HPDs adequacy in these two situations, the OSHA attenuation and derating calculations below should be applied.

(1) Single Protection (i.e., muffs or plugs):
   Estimated Exposure dBA = TWA dBC - [NRR x 50%], or
   Estimated Exposure dBA = TWA dBA - [(NRR - 7) x 50%]

(2) Dual Protection (i.e., muffs and plugs):
   Estimated Exposure dBA = TWA dBC - [(NRR_h x 50%) + 5], or
   Estimated Exposure dBA = TWA dBA - {[(NRR_h - 7) x 50%] + 5}

11. Noise Control Engineering

a. Noise control engineering is the best means of limiting noise exposure and the primary means of protecting personnel from workplace noise. Administrative controls also can be effective. Hearing protection is considered an interim measure while engineering control measures are being explored, and a permanent measure only if engineering or administrative controls are not feasible. However, most workplace noise continues unabated by engineering controls, due to limited funds and low priority.

b. DoD risk assessment coding is being used to set priorities for noise control projects at a variety of Navy activities. Most of the projects are new construction or modernization of existing buildings where noise control was factored into projects.

12. Audiometric Test Booth Surveys

a. Audiometric test booths require annual field evaluations by qualified professionals, such as industrial hygienists, audiologists, or IH technicians. It's important to note that the evaluation protocols differ depending on whether the booth is used for medical surveillance or clinical testing. Appendix M outlines the requirements for booths used in medical surveillance, physical examinations, and diagnostic testing. A crucial assumption in all booth field evaluation surveys is that the audiologist or examiner will only test down to 0 dB hearing level (HL), even though audiometers are typically calibrated to -10 dB HL. Therefore, if testing down to -10 dB HL with headphones or insert earphones, the ambient noise levels inside the booth must be at least 3 dB lower than the maximum permissible ambient noise levels (MPANLs).

b. All audiometric test booths require a field evalaution survey at least annually (every 365 days). The evaluation must replicate typical operating conditions. For example, a booth certified pier-side cannot be used underway until evaluated under representative underway conditions. New noise sources (internal or external) or booth relocation necessitate a new field evaluation.

c. At a minimum, a Type 1 SLM with a 1/1 octave band filter is required to measure the SPLs inside the booth during normal operational conditions. The SLM, OBA, and microphone's self-noise must be at least 3 dB below the applicable "Max SPL" criteria listed in Appendix M. The SLM, OBA, microphone and calibrator must each have been professionally calibrated within the past year.

d. Audiometric test booth surveys are valid only when interior ambient noise levels are sufficiently low to comply with the “Max SPLs” requirements, as listed in Appendix M. Audiometric test booth surveys are valid only if interior ambient noise levels meet the "Max SPLs" requirements. Exams conducted with noise levels exceeding these limits are invalid.

e. The following measurement procedures are for stationary audiometric test booths only. Mobile Hearing Conservation and Audiometric Trailers (MOHCAT) and Vehicles (MOHCAV) are covered separately.
   (1) Obtain measurements inside the booth during normal operational conditions (lights, ventilation on) and activity levels representative of anticipated use.
   (2) Take readings at all frequencies listed on the survey, measuring one octave below the lowest testing frequency
   (3) Perform pre/post-calibration of the SLM. Document make/model and calibration dates on Appendix M.
   (4) Position the microphone at the center of the seat, where a listener's head would normally be.
   (5) Select the octave band screen, take the sound pressure levels (SPLs) at the required frequencies, and record. (Note: Check levels at seats closest and furthest from the door; record the higher values.)
   (6) Record external levels for informational purposes. Levels can be variable, record typical dBA and dBC levels.
   (7) Have someone talk outside the booth to assess impact on testing. If conversation invalidates testing, annotate this on the survey. This will often be the case with single-wall booths.
   (8) Record all values; complete and post the audiometric test booth survey on the exterior of the booth or on an adjacent wall. Retain a file copy.

f. MOHCATs and MOHCAVs Certification:
   (1) MOHCAV and MOHCAT booths require the same annual field evaluation as stationary booths. Surveys should be conducted at the most frequently used location, with realistic external noise and activity present.
   (2) Mobile booth re-survey after each relocation is generally impractical, take measurements at primary customer locations.
   (3) Current MOHCAVs have a double-walled design (vehicle body) that provides good attenuation. However, traffic, generators, aircraft, and nearby boats can compromise test results. To ensure validity, consider these alternatives:
      (a) Conduct and document booth survey at each prospective test location in worst case conditions. Recertification is not required for subsequent deployments to the same surveyed location

      (b) . Alternatively, perform a self-test audiogram (assuming 0-5 dB HL thresholds) at each location before patient testing, under representative external noise conditions.

g. Documentation. A field evaluation survey for audiometric test booths is detailed in Section 13 Appendix M, below.

13. Appendices

a. Appendix E, Industrial Hygiene Noise Dosimetry Suvey

b. Appendix F, Industrial Hygiene Noise Dosimetry Survey

c. Appendix M, Audiometric Test Booth Survey

14. References

5-1 DoDI 6055.12 Series, DoD Hearing Conservation Program

5-2 OPNAVINST M-5100.23, Chapter 18, Hearing Conservation.

5-3 OPNAVINST 5100.19 Series, Chapter B4, Hearing Conservation Program.

5-4 The Noise Manual, edited by Elliot H. Berger MS, INCE Bd. Cert.; Larry H. Royster, PhD; Dennis P. Driscoll, MS. PE; Julia Doswell Royster, PhD; Martha Layne. AIHA Press. Revised Fifth Edition.

5-5 MIL-HDBK-1908B, Definitions of Human Factors Terms, 1999.

5-6 ANSI/ASA. American National Standard Electroacoustic- Sound Level Meters. ANSI/ASA S1.4-2014/Part 1/IEC 61672:1-2013, ANSI/ASA S1.4-2014/Part 2/IEC 61672:2-2013, and ANSI/ASA S1.4-2014/Part 3/ IEC 61672:3-2013. American National Standards Institute (ANSI), Acoustical Society of America (ASA).

5-7 ANSI/ASA. American National Standard Specification for Personal Noise Dosimeters. ANSI S1.25-1991 (R2017). New York, NY: American National Standards Institute. Reaffirmation 2017. ANSI, ASA.

5-8 40 C.F.R Part 211 Subpart B (§211.204-4) Environmental Protection Agency (EPA).

5-9 DoDI 6055.12 Series, Safety and Occupational Health (SOH) Program

5-10 MIL-STD-1474E, Department of Defense Design Criteria Standard Noise Limits, 2015.

5-11 DoDI 6055.05 Series, Occupational and Environmental Health (OEH)

5-12 SECNAV M-5210.1 Series, Department of Navy Records Management Program.

5-13 C.A. Kardous and R.D Wilson, Limitation, of integrating impulse Noise when using dosimeters, Journal of Occupational and Environmental Hygiene 1(7), 456-462, 2004.

5-14 Measurement of Exposure to Impulsive Noise at Indoor and Outdoor Firing Ranges During Tactical Training Exercises, U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, and National Institute for Occupational Safety and Health, 2014.

5-15 NMPHC TM 6260.51.99-3, Navy Medical Department Hearing Conservation Program Procedures.

5-16 Methods for Estimating HPD Attenuation, Occupational Noise Exposure, 1910.95 Appendix B, OSHA.

5-17 OSHA Technical Manual, Noise. Appendix E. OSHA.

5-18 ANSI/ASA. Maximum Permissible Ambient Noise Levels for Audiometric Test Rooms. ANSI S3.1-1999 (R2023). New York, NY: Reaffirmation 2018. ANSI, ASA.

Appendix 5-A – Standard Operating Procedure (SOP) for Impulse Noise Measurement and Evaluation

1. General

Impulse noise is characterized by a rapid rise in intensity to a level substantially above the background sound level. Impulse noise is generated from a release of pressure. OSHA defines impulse noise as pulses less than one second in duration with a repetition rate of greater than one second. Noise sources with a repetition rate of less than one second between pulses are described as pulsating and will generally be treated as steady-state noise.

Advances in instrumentation and several recent studies have made it clear that conventional sound level meters and noise dosimeters are not capable of accurately measuring impulse noise. Several competing metrics have been proposed for evaluating occupational exposure to impulse noise. This SOP has been drafted to assist Navy IH and audiology professionals in accurately measuring and evaluating occupational exposure to impulse noise specifically for determining peak sound pressure levels.

References 5-1 and 5-2 require implementation of hearing conservation programs where exposure to impulse noise equals or exceeds 140 dBP. Most of the impulse noise exposure criteria that have been proposed include methods for calculating an Allowable Number of Rounds (ANOR) for a given weapon system or other impulse noise source. The DoD OEL is based on peak sound pressure and does not use ANOR criteria.

Weapons are the most common sources of impulse noise in the Navy and Marine Corps. Access to weapon ranges may require training, special safety equipment, and the presence of authorized range safety personnel. There are typically restrictions as to locations of personnel and equipment (including SLMs) when ranges are active. These issues should be coordinated with the host command prior to monitoring

2. Equipment.

a. Monitoring Instruments. Conventional sound level meters and noise dosimeters are not capable of accurately measuring impulse noise levels. Peak levels shall be measured with SLMs that:
   (1) Meet or exceed the specifications in Parts 1 and 3 of ANSI/ASA Standard S1.4
   (2) Have a peak hold circuit (NOT an impulse circuit)
   (3) Have a rise time not exceeding 35 milliseconds (critical to accurately capture the peak of the short duration impulse)

(4) Are capable of measuring peak SPLs at or above 140 dBP sound pressure. Measurement of SPLs above 130 dB requires a specialty microphone, typically a pressure field design to accurately measure the pressure waves at high intensity
(5) Currently these requirements are met by only a few SLMs and no dosimeters. Some SLMs are equipped with an "impulse" speed setting (in addition to "fast" or "slow"); this circuit is much too slow to capture true peak values and cannot be used for impulse noise surveys.
(6) Unweighted or "Z" weighting is preferred for peak SPL measurements If there is no Z scale, use C or other Flat weighting.
(7) Automated or timed sampling is recommended particularly for weapons firing.
(8) Operational procedures are specific to each model of SLM. Operators must be fully familiar with the instrument, including programming and equipment options, prior to performing surveys.

b. Recommended Accessories.
(1) Microphone extension cable (for remote placement of the microphone away from the operator)
(2) Cable covers
(3) Tripod with standard camera screw mount (1/4-20 thread)
(4) Stakes or sandbags and cords to stabilize tripod
(5) Tape measure(s), optical range finder, or measuring wheel
(6) Pin flags, tape, and markers (for marking measurement locations and safe zones)

3. Sample Locations

a. An impulse noise survey should include samples of peak SPL readings in locations where workers may be exposed at the 140 dB hazard radius which is the level requiring mandatory hearing protection. Measurements of the 140 dB distance should be made at various angles from the noise source, as it may not be uniform. A statistically significant number of each type of sample should be collected. The number of samples will depend on the variability of the noise source; as a general guideline, at least 5-10 measurements should be taken at each location to ensure a representative sample.

b. Personal exposure measurements should be made in the hearing zone of the subject (i.e., within 18 inches of the ear - specifically, at ear level) if feasible. If true personal hearing zone measurements are not possible, select a representative area location that is as close as safely possible to the worker's typical position and likely experiences similar noise levels, and annotate the sample form/notes accordingly. When sampling weapons firing, safety rules may require the noise surveyor to be remote from the source. A tripod and/or microphone extension cable can be used.

c. The body of the industrial hygienist must not be positioned in line with the microphone and noise source to avoid interference (additive or subtractive). Mounting the SLM or remote microphone on a tripod can allow the operator to move farther from the microphone.

4. Microphone Orientation

a. Impulse noise measurements typically use special high intensity microphones and should be oriented as follows (unless the manufacturer indicates otherwise): Microphones should always be oriented according to manufacturer's instructions. Blunt cylinder pressure field microphones shall be oriented at grazing incidence (90°), facing up when not affected by the weather, to reduce ground reflection effects.

b. Pointed transducers shall be pointed directly at the source, with the diaphragm window up.

5. Noise Measurement Records for Impulse Noise

Impulse noise measuring records might require information in addition to that listed in Chapter 5, paragraph 4, Nosie Measurement Records.

a. Detailed drawings and field notes are important to provide context for the sound level measurements. The drawing area provided on the Noise Survey is often too small to record sufficient information. Attach a separate sheet if needed. Distances between significant points should be noted. Photographs if permitted can be useful in preparing a report

b. Notes should include the following information about exposure characteristics:
   (1) Job categories and numbers of personnel exposed
   (2) Frequency and duration of exposures
   (3) Estimated number of noise impulses per event (this can be determined by visual observation, reviewing audio recordings, or consulting with personnel familiar with the operation)

6. Evaluation

Impulse noise exposures may be highly variable in some circumstances, and the number of impulses sampled may be limited. Statistical analysis of the sampling data is strongly recommended, so that potential exposures that exceed the sampled impulses can be identified and quantified.

a. The statistics calculated and reported should include at least the following:
   (1) Range
   (2) Mean
   (3) Standard deviation

(4) 95th percentile

b. The 95th percentile should be compared to the DoD OEL for compliance because it represents the level below which 95% of the measured exposures fall, providing a conservative estimate of typical exposure levels.

c. The Reports should include generic recommendations as to hearing protection devices.