Hearing Protection

Control of hazardous noise at its source in military settings is frequently not possible, so that hearing protection, either through administrative controls (e.g., limiting the time a person can spend in hazardous noise) or with protective devices, has been of vital importance. However, administrative controls are difficult to implement in the military, especially in training and on the battlefield, where operational time frames do not adhere to typical workdays. As a result, protection from hearing loss in the military has essentially equated to issuing hearing protection devices.

Recognition of the need for hearing protection has evolved considerably over the past 60 years, as has the quality and effectiveness of the available equipment. Although hearing protection devices were available prior to 1940 (Acton, 1987; Moritz and Bruce, 1994), utilization was essentially nonexistent throughout World War II. A substantial research effort to devise a suitable hearing protection device concluded in 1945 with the development of the Ear Warden V-51R (Shaw and Veneklasen, 1945), a design used by the military through the 1990s. Shaw and Veneklasen (1945) observed that a common form of hearing protection in use by the military during the 1940s was cotton or cotton waste, as also documented by Walpole (1943). Unfortunately, such air-permeable material was inadequate as a noise attenuator. In fact, according to an early Air Force regulation, even the devices available by 1949 (three-sized V-51R, cotton plugs moistened in petroleum jelly or paraffin, and dental acrylic custom earmolds) were "effective only against minimal exposure" (Department of the Air Force, 1949).

The years since World War II have seen some marked improvements in hearing protection. Resilient materials needed as interfaces with the flesh around the ear or in the ear canal were improved in comfort, durability, and dynamic characteristics. An important advancement in earplug technology was introduced in the 1970s—the roll-down slow-recovery foam and dynamic characteristics. An important advancement in earplug technology was introduced in the 1970s—the roll-down slow-recovery foam earplug, which has become a predominant form of hearing protection for both military and industrial users worldwide. In a one-sized product, it offered increased levels of protection, as well as comfort, for most users (Camp et al., 1972; Bailey and Walker, 1979; Shaw, 1979; Schleifer et al., 1984). Another technological development was the introduction of active noise reduction systems into tanker helmets in the 1980s and into Air Force flight helmets in the 1990s. These systems served to attenuate low-frequency noise and thereby enhanced communications (McKinley and Nixon, 1993; Anderson and Garinther, 1997; Mozo and Murphy, 1997). Other electronic products for communication also appeared, though in some high-noise environments, such as the flight decks of aircraft carriers, the same hearing protection ("cranial earmuffs") and communication technology that was used in the 1950s is still in use today (personal communication, J. Page, Naval Environmental Health Center, March, 2005). Developments in hearing protection from World War II to the present are broadly summarized in Table 5-2.

Although gains have been made in the potential noise reduction of hearing protection devices in the past 60 years, the achievable attenuation values have not changed substantially since the 1970s. Table 5-3 summarizes the potential noise reduction provided by the hearing protection devices in current use. Ranges of attenuation are provided because, even in a laboratory setting, performance is highly dependent on the use and fit of the devices. The ranges also allow for the variation in performance between different brands of the same type of device. The use of earplugs together with earmuffs, called dual protection, provides maximum protection. For well-fitted devices, the average attenuation for dual-protection systems is as much as 40–50 dB at frequencies up to 1000 Hz and can be even greater at frequencies at and above 2000 Hz. The amounts of protection that can be provided are adequate in all but the most severe military exposures, such as carrier flight decks.

Regardless of the data measured in the laboratory, it has become clear that the "real-world" performance of devices is quite different as a result of fit and other factors, such as motivation, training, supervision, and enforcement (Berger et al., 1996; Berger, 2000a). A summary chart of noise reduction ratings versus real-world attenuation is presented in Figure 5-2. The ment (Berger et al., 1996; Berger, 2000a). A summary chart of noise reduction ratings versus real-world attenuation is presented in Figure 5-2. The data were drawn from 22 field studies, including 1 conducted in a military setting (Smoorenburg et al., 1986).

Even more important than the difference between potential attenuation and the real-world performance of hearing protection devices in the field, however, is the impact of wearing the devices at all. The percentage of time a hearing protection device is used in a noisy environment has a much greater effect on hearing protection than even changes of 5 or 10 dB in the amount of noise reduction the devices provide when assessed in a laboratory. A recent study highlights this issue. Neitzel and Seixas (2005) measured the attenuation of the hearing protection devices in use and also developed verified estimates of actual wearing time. For devices with approximately 20 dB of real-world attenuation, the effective protection, taking into account wearing time, was less than 3 dB. Although the environment they studied was construction, it is likely that many of the same factors apply to the military setting.

In intensive military operations, such as training and combat, the motivation to wear hearing protection may be further limited by concerns that hearing protection devices may jeopardize the wearer's safety. Safety could be compromised when using hearing protection devices by impairing communication or causing service members to miss vital auditory warning signals (sounds of enemy troops, ordnance, and the environment).

In a 1975 survey of 3,000 enlisted men from U.S. Army infantry, armor, and artillery branches, 64 percent reported that they routinely used hearing protection, while 90 percent reported that hearing protective devices were readily available to them (Walden et al., 1975). Nearly half of the soldiers reported that they disliked wearing hearing protection. A smaller study observed only 14 of 34 (41 percent) Army drill instructors using hearing protection on a given day (Loeb et al., 1973). A study of submariners, submarine force workers, and support personnel in the early 1980s found that more than 50 percent of personnel surveyed who worked in noisy environments reported never using hearing protection, with officers less likely to report use of hearing protection (Gwin and Lacroix, 1985). More recently, a study on the use of hearing protection devices in one of the most hazardous noise environments in any industrial or military setting, the aircraft carrier flight deck (where noise levels routinely exceed 140 dBA), found that 47 percent of those surveyed reported *never* wearing double hearing protection even though they were working in dBA), found that 47 percent of those surveyed reported *never* wearing double hearing protection even though they were working in

TABLE 5-2 Available Hearing Protection from World War II to the Present

Time Frame	Typical Devices	Comments
World War II	Cotton	Minor amounts of noise reduction
	Fingers	Effective but inconvenient; used by artillery crews to some extent
	Nothing	The standard of the day
1945–late 1950s	Vaseline-impregnated cotton	Messy, modestly effective, better for water protection than noise protection
	V-51R earplug	Initially produced in three sizes; developed just at the end of World War II
	Hard custom earmolds	Easily lost seal, not widely used
	Early circumaural earmuff designs	Initial designs had inadequate cushions and modest attenuation (around 20 dB or less) up to 1000 Hz
	Navy "cranial earmuffs" introduced in mid-1950s and still in use today (circa 2005)	Plastic earmuff cups held in place by fabric head cap with a plastic shell covering the fabric but not enclosing the earmuff cups; inadequate fitting and modest protection
1960s	V-51R earplug	An extra-small and extra-large size added to fit a wider range of ear canals
	Triple-flange earplug	Alternative easier-to-fit design introduced as a two-sized version
	Canal caps (pods on light-weight band)	Modest protection for intermittent environments

	light-weight band)	environments
	Malleable putty earplug	Not widely used, and ergonomic problems due to required kneading and messiness
	Improved earmuffs	Higher attenuating designs introduced with better cushions and headbands
1970s	Conventional plugs and muffs same as 1960s	Technology essentially mature by this time, but some material improvements such as newer three-sized silicone version of triple-flange plug. Also, color-coded sizing introduced.
	Roll-down slow-recovery foam earplugs	New-concept earplug that provided better protection and comfort, but limited use in military initially
	Tanker helmets and aircraft flight helmets with internal earcups for noise attenuation	Helmets began to provide not only impact protection, but acoustical protection too. Low-frequency attenuation not as good as conventional earmuffs.
1980s	Conventional plugs and muffs same as 1960s and 1970s	No technology advances
	Tanker helmets began to appear with ANR included	ANR in this environment improved communication and protection
1990s	Same as prior decades	Minor technology advancements especially in cosmetics, but performance essentially unchanged
	Widespread use of roll-down slow-recovery foam ear plugs	Most commonly used hearing protection device
	Communication earplugs	Use of earphone in foam earplugs for use in tanker and helicopter

	Communication earplugs	Use of earphone in foam earplugs for use in tanker and helicopter applications for enhanced communication under helmet and increased protection
	Widespread use of ANR for tanker helmets and limited application of ANR for aircraft flight helmets	The advantages of ANR began to appear in aircraft applications too
2000–present	Same as prior decades	As before, except that V-51R plug dropped from inventory
	Level-dependent "combat arms" earplugs	New technology provides the ability to protect against weapons and blast noise, but still allow communication and signal detection of lower-level sounds when the impacts are not present

NOTE: ANR = active noise reduction.
SOURCES: Shaw and Veneklasen (1945); Department of the Air Force (1949); Blackstock and Von Gierke (1956); Guild (1966); Gardner and Berger (1994); Mozo and Murphy (1998); Ohlin (2005c); Schulz (2005a); Personal communication, D. Gauger, Bose Corporation, April 2005; personal communication, D. Ohlin, USACHPPM, April 2005.

TABLE 5-3 Representative Minimum and Maximum Mean Attenuation Values of Well-Fitted Hearing Protectors Under Laboratory Conditions, in dB

	Octave-Band Center Frequency (Hz)						
Type of Hearing Protector	125	250	500	1000	2000	4000	8000
Inserted Hearing Protectors							
Foam earplugs (attenuation varies with depth of insertion)	20–40	20–40	25–45	25–45	30–40	40–45	35–45
Premolded earplugs	20–30	20–30	20–30	20–35	25–35	30–45	30–45

Premolded earplugs	20–30	20–30	20–30	20–35	25–35	30–45	30–45
Formable (fiberglass/mineral wool)	20–30	20–30	20–30	25–30	25–30	35–40	35–40
Formable (wax-impregnated cotton or silicone)	20–25	20–25	20–25	25–30	30–35	40–45	40–45
Custom-molded earplugs	15–35	15–35	15–35	20–35	30–40	35–45	30–45
Semi-insert earplugs	15–30	15–30	10–30	15–30	25–35	25–45	30–45
Circumaural, Helmet, and Combined							
Earmuffs (with or without communications components)	5–20	10–25	15–40	25–45	30–40	30–40	25–40
Military helmets	0–15	5–15	15–25	15–30	25–40	30–50	20–50
Dual protection (earplugs + earmuffs)	20–40	25–45	25–50	30–50	35–45	40–50	40–50
Active noise reduction (closed-cup systems; identical to conventional muffs above 1 kHz)	15–25	15–30	20–45	25–40	30–40	30–40	25–40
Other Types							
Cotton balls	0–5	0–10	5–10	5–10	10–15	10–20	10–20
Motorcycle helmets	0–5	0–5	0–10	0–15	5–20	10–30	15–35
Air-fed shotblasting helmets	0–5	0–5	0–5	0–15	15–25	15–30	15–25
Finger tips in ear canals	25–30	25–30	25–30	25–30	25–30	30–35	30–35

NOTE: Data are intended to account for brand and testing variability; however, not all manufacturers' reported data or values referenced in the literature will necessarily fall within the ranges cited. All data are from E·A·RCAL Laboratory as reported by Berger (2000a), except for the shotblasting helmets (Price and Whitaker, 1986) and fingers (Holland, 1967).