20 November 2017

Department of Veterans Affairs
Evidence Intake Center
P.O. Box 4444
Janesville, WI 53547-4444

Sir or Ma'am,

This is a NOTICE OF DISAGREEMENT to appeal an adverse decision that was rendered on 2 April 2016 for

Claimant's name:
Claimant's VA case number:

The adverse decision being appealed is:

**The rating of "Not Service Connected" for Hearing Loss**

Attached with the VA Form 21-0958 are the following documents – this cover letter, VA NOD form, supporting evidence to link hearing loss with my job as a missile combat crew member in an acoustically-reflective environment.

I would also like to request a **Statement of the Case**, so I may appeal to the BVA at the appropriate time.

Respectfully,

**DEPARTMENT OF VETERANS AFFAIRS**
**Veterans Benefits Administration**
**Washington, D.C. 20420**

September 2, 2010

Director (00/21)
All VA Regional Offices

In Reply Refer To: 211B
Fast Letter 10-35

SUBJECT: Modifying the Development Process in Claims for Hearing Loss and/or Tinnitus

## Purpose

This letter introduces the Duty MOS Noise Exposure Listing, a rating job aid for determinations regarding service connection of hearing loss and/or tinnitus. The Duty MOS Noise Exposure Listing is a compilation of Department of Defense-verified lists of military occupational specialties (MOSs) and the corresponding probability of hazardous noise exposure. Use of a single listing of duty position and probability of exposure to hazardous noise will help to standardize processing of these claims.

## Background

Each branch of the Armed Services has reviewed and endorsed lists of military occupational specialties and the corresponding probability of hazardous noise exposure related to an individual's occupational specialty. The Duty MOS Noise Exposure Listing is available at http://vbaw.vba.va.gov/bl/21/rating/docs/dutymosnoise.xls.
See above link for Air Force, Navy and Coast Guard.
Direct service connection may not be granted without medical evidence of a current disability; medical or, in certain circumstances, lay evidence of in-service incurrence or aggravation of a disease or injury; and medical evidence of a nexus between the claimed in-service disease or injury and the present disease or injury. See *Caluza v. Brown*, 7 Vet. App. 498, 506 (1995) aff'd, 78 F.3d 604 (Fed. Cir. 1996).

A Veteran is competent to report symptoms of hearing loss and/or tinnitus as a disability because symptoms of hearing loss and tinnitus are capable of lay observation. See *Charles v. Principi*, 16 Vet. App. 370 (2002); *Espiritu v. Derwinski*, 2 Vet. App. 492 (1992). Consequently, a Veteran's testimony regarding hearing loss and/or tinnitus is sufficient to serve as evidence that the disability(ies) currently exists.

Director (00/21)

## Instructions

Effective immediately, when a claim for hearing loss and/or tinnitus is received, the decision maker must review the claim for:

- Sufficient evidence of a current disability (including lay evidence); and
- Evidence of hearing loss and/or tinnitus in service; or
  records documenting an event, injury, disease, or symptoms of a disease potentially related to an audiological disability.

If there is no documented evidence of an in-service illness, injury, or event with which the claimed conditions could be associated, the Duty MOS Noise Exposure Listing will be considered. Based on the Veteran's records, each duty MOS, Air Force Specialty Code, rating, or duty assignment documented will be reviewed for a determination as to the probability of exposure to hazardous noise on the Duty MOS Noise Exposure Listing. If the duty position is shown to have a **"Highly Probable"** or **"Moderate"** probability of exposure to hazardous noise, exposure to such noise will be conceded for purposes of establishing the in-service event.

In such cases, where there is sufficient evidence of a current disability and the in-service exposure to hazardous noise is conceded based on the Duty MOS Noise Exposure Listing, we would be obligated to request a VA examination and opinion to determine if there is a medical nexus. The level of probability of exposure conceded, such as "Highly Probable" or "Moderate," should be included in the information provided to the examiner in the body of the examination request.

Additionally, in other cases where an examination and opinion request are otherwise warranted, the probable level of exposure to hazardous noise associated with the Veteran's documented duty position will be provided in the examination request remarks.

Finally, the Duty MOS Noise Exposure Listing is not an exclusive means of establishing a Veteran's in-service noise exposure. Claims for service connection of hearing loss must be evaluated in light of all evidence of record in each case, including treatment records and examination results.

## Questions

Questions should be e-mailed to VAVBAWAS/CO/21Q&A.

/S/
Thomas J. Murphy
Director
Compensation and Pension Service

All entries were approved by the Service Department,
and all entries in Red were provided by the Service Department

AIR FORCE OFFICER SPECIALTIES

| AFSC | JOB TITLE | HIGHLY PROBABLE | MODERATE | LOW |
|---|---|---|---|---|
| 10C0 | Operations Commander | X | | |
| 11AX | Airlift Pilot | X | | |
| 11BX | Bomber Pilot | X | | |
| 11EX | Test Pilot | X | | |
| 11FX | Fighter Pilot | X | | |
| 11GX | Generalist Pilot | X | | |
| 11HX | Helicopter Pilot | X | | |
| 11KX | Trainer Pilot | X | | |
| 11RX | Recce/Surv/Elect Warfare Pilot | X | | |
| 11SX | Special Operations Pilot | X | | |
| 11TX | Tanker Pilot, C-12 CTP | X | | |
| 12AX | Airlift Navigator | X | | |
| 12BX | Bomber Navigator | X | | |
| 12EX | Test Navigator | X | | |
| 12FX | Fighter Navigator | X | | |
| 12GX | Generalist Navigator | X | | |
| 12KX | Trainer Navigator | X | | |
| 12RX | Recce/Surv/Elect Warfare Navigator | X | | |
| 12SX | Special Operations Navigator | X | | |
| 12TX | Tanker Navigator | X | | |
| 13AX | Astronaut | X | | |
| 13BX | Air Battle Manager | X | | |
| 13DX | Combat Control | X | | |
| 13MX | Airfield Operation | X | | |
| 13SX | Space & Missile | | X | |
| 14NX | Intelligence | | X | |
| 15WX | Weather | | | X |
| 16FX | Foreign Area | | | X |
| 16GX | Air Force Operations Staff Officer | | X | |
| 16PX | Intl Politico-Military Affairs | | X | |
| 16RX | Planning & Programming | | | X |
| 20C0 | Logistics Commander | | | X |
| 21LX | Logistician | | | X |
| H21BX | Maintenance | X | | |
| 21MX | Munitions and Missile Maintenance | X | | |

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MMR MILITARY MEDICAL RESEARCH

REVIEW Open Access

# Impact of noise on hearing in the military

Jenica Su-ern Yong* and De-Yun Wang


## Abstract

Hearing plays a vital role in the performance of a soldier and is important for speech processing. Noise-induced hearing loss is a significant impairment in the military and can affect combat performance. Military personnel are constantly exposed to high levels of noise and it is not surprising that noise induced hearing loss and tinnitus remain the second most prevalent service-connected disabilities. Much of the noise experienced by military personnel exceeds that of maximum protection achievable with double hearing protection. Unfortunately, unlike civilian personnel, military personnel have little option but to remain in noisy environments in order to complete specific tasks and missions. Use of hearing protection devices and follow-up audiological tests have become the mainstay of prevention of noise-induced hearing loss. This review focuses on sources of noise within the military, pathophysiology and management of patients with noise induced hearing loss.


**Keywords:** Hearing loss, Noise-induced, Military personnel, Ear protective devices

## Introduction

Noise-induced hearing loss is a major preventable disease. It can be caused by an acute exposure to an intense impulse of sound or by a continuous steady-state long-term exposure with sound pressure levels higher than 75–85 dB (Table 1).

Noise remains a large public health problem with an estimated 1.3 billion people being affected by hearing loss [1]. It ranks 13th globally as the cause of years lived with disability (YLD). YLD is estimated by multiplying the number of incident cases in that period with the duration of disease and the weight factor which measures disease severity. In North America, it ranks 19th as the cause of YLD, in Central Asia, it ranks 15th and in Southeast Asia it ranks 9th.

The prevalence of hearing loss and tinnitus in military population are greater than in the general public. Almost every soldier, sailor, airman or marine will be exposed to hazardous noise levels at some point in their career [2-4]. The two most prevalent service connected disabilities for veterans in the United States at the end of fiscal year 2012 remain tinnitus and hearing loss, with tinnitus affecting 115,638 veterans (9.7%) and hearing loss affecting 69,326 veterans (5.8%) [5]. In Finland, despite the increasing use of hearing protection devices, a large proportion of professional soldiers experience disabling tinnitus and hearing loss [6].

Hearing acuity is a key component of a soldier's effectiveness in the battlefield. The presence of tinnitus and hearing loss can significantly impair a soldier's ability to hear important acoustic cues or communication signals from the unit or the enemy [2]. Hearing problems can also be a reason for disruption of their military service. In a study by Muhr et al., 33 soldiers (3.9%) had interrupted training as a result of their hearing problems [7].

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## Review

### Sources of noise-induced hearing loss

#### *Land force*

Sources of noise within the military vary with soldier's designation. Within the Belgian military, Fighting in Built-Up Area (FIBUA) training, shooting with large calibre weapons and participation in military exercises were the strongest determinants of hearing loss [4].

Within the infantry, weapons emit high levels of noise. Table 2 depicts the amount of permissible noise allowed and Table 3 depicts the typical noise level emitted by different weapons. Many weapons emit sounds that exceed the maximum achievable protection that double hearing protection can offer. Double hearing protection means both earmuffs and ear plugs are used. The US Department of Defense published a medical surveillance monthly report on noise-induced hearing loss and it was found that

**Table 1 Glossary of terms used**

| Terms | Descrption |
|---|---|
| **Sound pressure level (SPL)** | Sound intensity is expresses the pressure caused by a sound wave and is indicated by sound pressure level. The unit of measurement is the decibel (dB SPL) |
| **dB Scale** | A logarithmic scale to measure sound pressure level |
| **dBA** | To measure noise, A-weighted SPL (dBA) can be used. In contrast to SPL which represents a physical dimension, A-weighted SPL represents a perceptual dimension. The dB SPL will be different from dBA for different for different frequencies as low frequency sounds and high frequency sounds tend to be less loud than mid-frequency sounds |
| **$L_{Aeq}$** | This refers to the average level of sound pressure within a certain time period with the A-filter used for frequency weighting. The A-filter is a frequency-weighting of sound pressure levels that mimics the sensitivity of the auditory system of humans (eg, low-frequency sounds contribute little to the A-weighted dB level) |

noise-induced hearing injuries were more prevalent among combat-specific occupations (41.2 per 1000 person-years of active component military service) [8].

### *Navy*

In the Navy, the highest indoor noise levels were found in engine rooms [9,10]. Landing ship tanks and patrol vessels typically generated about 98 to 103 dBA of noise, whereas the noise level in missile gun boats were at 120 dBA [9]. The loudest noise generated is on the carrier decks that can range from 130 to 160 dBA [2].

### *Air force*

Military aircraft personnel are not spared, the average noise experienced in service helicopters was found to be 97 dBA for 'Gazelle', 99.8 dBA for the 'Scout', 99.9 dBA for the 'Puma' and 100 dBA for the 'Lynx' [11]. In fighter planes, the noise level ranged from 97 to 104 dBA, in jet trainers the noise level was at 100 to 106 dBA and in transporter aircrafts, the noise level was found to be between 88 to 101 dBA [12]. In such settings, due to chronic noise exposure, pilots were found to exhibit hearing impairment [13].

**Table 2 Amount of permissible noise exposure allowed in theworkplace***

| Duration per day (hour) | Sound level (dBA) |
|---|---|
| 8 | 90 |
| 6 | 92 |
| 4 | 95 |
| 3 | 97 |
| 2 | 100 |
| 1 ½ | 102 |
| 1 | 105 |
| ½ | 110 |
| ¼ or less | 115 |

*Adapted from OSHA 2014. Standards. US Dept Labor: Occupational Noise Exposure [Online]. vailable by Occupational Safety and Health Administration. https://www.osha.gov/SLTC/noisehearingconservation/index.html.

## Pathophysiology

Injury from noise can occur in 2 main ways. First, high level, short duration exposure exceeding more than 140 dB can cause the delicate inner ear tissues to beyond stretch beyond their elastic limits. This causes mechanical disruption of the sterocilia and direct damage to supporting and sensory cells [14]. In such cases, the maximum sound pressure level (SPL) is more important than the duration of the exposure [15]. This type of acoustic trauma can result in immediate and permanent hearing loss.

Second, long term exposure to low level noise damages the cochlea metabolically rather than mechanically. It involves biochemical pathways leading to cell death either through apoptosis or necrosis [16]. There are 2 factors that influence which cell death pathway is activated. The first factor is the sound intensity level. Noises of 105 dB favour necrosis whereas louder noises (120 dB) favour apoptosis [17]. Another factor is the time between noise exposure and morphological analysis. Outer hair cells immediately start dying during the initial acoustic insult and continue to do so for at least 30 days after the event [18,19]. Immediately after the insult, apoptosis is the main cause of cell death. After 4 days, the apoptotic activities start to diminish and by day 30 both apoptosis and cell necrosis contribute equally to cell death [19,20].

Exposure to intense sound can cause auditory thresholds to become elevated permanently or temporarily. Reversible hearing loss is referred to as temporary threshold shift (TTS). Depending on duration of exposure, recovery from TTS can occur over a period of minutes to hours or days. If TTS does not recover, permanent hearing loss results and this is referred to permanent threshold shift (PTS) [21]. These two phenomena, permanent and temporary threshold shifts are still not well understood.

PTSs are postulated to be either due to direct mechanical trauma or metabolic overstimulation of cellular elements within the organ of Corti which is associated with generation of reactive oxygen species [22].

Various mechanisms have been proposed for TTS and include synaptic fatigue, metabolic fatigue of either stria vascularis or hair cells and changes in cochlear blood flow. An important component of noise-induced hearing loss is postsynaptic damage in the afferent dendrites beneath the inner hair cells [23]. Even though hair cells recover normal function, there is rapid extensive and

**Table 3 Peak sound pressure level range of different weapons***

| Type of weapons | Peak sound pressure level range (dB) |
|---|---|
| **Rifles** | |
| .45-70 Rifle | 155.2-159.9 |
| .30-06 Rifle | 158.7-163.1 |
| **Shotguns** | |
| .410 Bore | 151.0- 157.3 |
| 20 Gauge | 154.8 |
| 12 Gauge | 156.1- 161.5 |
| **Pistols** | |
| .22 | 151 |
| 9 mm Luger | 159 163 |
| .45 ACP | 158 |
| **Other Weapons** | |
| Hand grenade | 158 |
| Light anti-tank weapon | 184 |
| Inside armored vehicle, continuous noise | $L_{Aeq}$103 – 107 |

*Adapted from Chen L, Brueck SE. Noise and lead exposure at an outdoor firing range – California. Health Hazard Evaluation report Sept 2011, and from Kramer WL. Gunfire noise and hearing. American Tinnitus Association. June 2002:14–15.

irreversible loss of synapses and delayed and progressive loss of cochlear neurons over many months [24,25]. This resultant cochlear neuropathy has been observed in mice exposed to just 84 dB SPL over a week [26]. It is possible that many people with difficulty in hearing also suffer from noise-induced cochlear neuropathy seen in animal studies.

Noise not only increases hearing threshold, but it can also cause tinnitus and hyperacusis. This can be present in individuals with normal hearing thresholds but with cochlear neuropathy. Indeed, studies have shown that patients with tinnitus have evidence of reduced Wave I at high sound levels [25,27]. The pathogenesis of tinnitus is postulated to be due to a compensatory increase in neural gain to the auditory brainstem as a result of reduced neural output from cochlea [27,28]. The gain can lead to tinnitus due to the amplification of spontaneous activity of auditory neurons.

## Clinical presentation

### *Symptoms and signs*

Exposure to noise can induce several hearing symptoms such as temporary threshold shifts (TTS), tinnitus, hyperacusis, recruitment, distortion or abnormal pitch perception [29]. Tinnitus can occur in the presence or absence of an abnormal audiogram. The tinnitus pitch match is associated with the frequency spectrum of hearing loss [30,31].

Patients may exhibit difficulty in listening to high frequency noise such as whistles or buzzers. They may also have difficulty differentiating some speech consonants, especially if they are in areas where there is significant background noise.

However these symptoms are typically insidious and most patients with noise induced hearing loss may not notice their deficiency until it starts to affect communication.

## Audiometric characteristics

Noise-induced deafness usually occurs at high frequencies with hearing loss beginning around 4 kHz or 6 kHz. However, as the disease progresses, hearing loss will also be seen at the lower frequencies. The expected maximal changes in thresholds are predictable at one-half octave above maximal frequency of the exposure [32].

The audiometric pattern in noise induced hearing loss is usually symmetrical and bilateral. However some asymmetry is not unexpected. The asymmetry in hearing threshold may be partly explained by the position of head during work [33]. Hong et al. studied workers in the American construction industry and it was found that the left ear predominantly experienced more hearing loss than the right. Asymmetry was postulated to be due to the work habit that the operators look over their right shoulder when operating heavy equipment, exposing their left ear to the noise generated by the machines [34]. Hearing loss among rifle shooters also tend to be asymmetrical, as hearing in the ear closest to the barrel tends to be worse as it is closer to the explosion whereas the other ear is protected by the head [12,35]. In the civilian population, this was also seen in musicians who played high string instruments where the left ear was found to be exposed to 4.6 dB more than the right ear [36].

## Management of patients

### *Noise prevention*

Within the military setting, noise exposure may be controlled through isolation (distance and physical barriers), vibration dampening, insulation and proper equipment maintenance [37]. The preferred method of preventing noise induced hearing loss and noise induced tinnitus is engineering controls. Other methods including the use of hearing protection devices such as foam ear plugs, molded insets and sound attenuating ear muffs are limited and can diminish perception of speech. Prevention is also reliant on the individual's compliance to the sound protection devices.

Currently, the Navy considers 85dBA to be the threshold for single hearing protection and 104 dBA for double hearing protection for steady state noise settings [38]. Noise levels on the flight deck during flight and some aircraft maintenance operations are intense and can easily exceed the 104 dBA threshold for double hearing protection [2].

In the British Army Air Corps, pilots of the Lynx have to wear the Mk4 flying helmet and pilots of the Apache wear the Integrated Helmet and Display Sighting System (IHADSS). Circumaural earmuffs are integrated into the aircrew helmet system. Lang *et al.* found that hearing was better than predicted in nearly all frequencies for both ears for both Lynx and Apache pilots, demonstrating that the circumaural earmuffs implemented reduce the risk of noise induced hearing loss [39].

Even the best hearing protection equipment will be ineffective if it is not used properly or if soldiers are not compliant. A focus group study found that main concerns with hearing protection were interference with detection and localization of auditory warning and perception of orders [40]. Bjorn *et al.* conducted a study on the hearing protection equipment use by the crew on the flight deck and found that 79% of flight deck personnel received an estimated 0–6 dB rather than the expected 28–30 dB of noise attenuation from either misuse of earplugs or non-compliance to ear plugs [41].

### Pharmacotherapy

Currently there is no established treatment for patients and it is limited to prevention and follow-up. However recent clinical trials have proved promising.

### Magnesium

Magnesium efficacy was tested in a double-blind study. Test subjects were given either 122 mg of magnesium or a placebo for 10 days and thereafter subjected monoaurally to 90 dB SPL of white noise for 10 minutes. TTS of > 20 dB was found in 28% of the placebo group compared to 12% in the magnesium-supplemented group [42].

Attias *et al.* conducted a double-blind placebo controlled study on army recruits and concluded that recruits who had magnesium supplementation had less frequent noise-induced PTS compared to the placebo group [43]. These 300 army recruits underwent basic military training where they were subjected to shooting range noises of an average peak level of 164 dBA and <1 ms duration with the use of ear plugs which reduced noise level by about 25 dBA. PTS was defined as a threshold >25 dB hearing loss in at least 1 frequency and it was found that PTS was higher in placebo group (11.5%) as opposed to the participants in the magnesium group (1.2%).

### N-acetyl-cysteine (NAC)

NAC acts as a reactive oxygen species scavenger and is postulated to reduce noise-induced hearing loss by reducing the exposure of the cochlea to reactive oxygen species. Glutathione S-transferases (GST) are a family of detoxification enzymes which help cells resist oxidative injury. Glutathione detoxification can be affected in individuals with genetic polymorphisms involving deletion of base pairs in the genes like GSTT1 and GSTM1. Patients with these two high-risk genotypes are more prone to have oxidative injury from noise induced hearing loss [44,45]. In a trial conducted on steel manufacturing workers, employees were administered either 1200 mg of NAC or placebo. Trial was conducted in a 2 × 2 crossover design with subjects taking either NAC or placebo for 14 days and with a 14-day wash-out period between treatments. Noise exposure was 88.4 - 89.4 dB as assessed by personal noise monitoring. The difference between the TTS was not found to be significant. However, when the subjects were subdivided based on genetic polymorphisms or GSTT1 and GSTM1, the subgroup with null genotypes in both GSTT1 and GSTM1 experienced protection by NAC [46].

### Methionine (MET)

Another glutathione (GSH) precursor is MET, an essential amino acid that can be converted to cysteine, which is the rate-limiting substrate for GSH production. It has been shown in animal studies to be otoprotective when administered at 200 mg/kg [47]. A major limitation in human studies are high-doses administration, route of administration and bioavailability.

### Ebselen

Ebselen is a potent glutathione peroxidase mimic and neuroprotectant. It also has strong activity against peroxynitrite, a super reactive oxygen species [48,49]. It reduces cytochrome c release from mitochondria and nuclear damage during lipid peroxidation [50]. Since it acts as a catalyst, low does maybe sufficient to prevent or treat noise induced hearing loss [51]. Phase II trials are currently in progress to determine the efficacy of oral ebselen.

## Conclusion

Noise-induced hearing loss is a serious disease burden in the military. Due to the nature of the military profession, hearing is a vital asset during tactical and survival training and exposure to loud noises during training and missions are inevitable. Prevention is still the mainstay of treatment and soldiers need to be educated with regards to the use of hearing protection devices.

**Competing interests**
The authors declare that they have no competing interests.

**Authors' contributions**
JSY made significant contributions in preparing and writing the manuscript. DYW was substantially involved in writing and revising the manuscript for publication. Both authors have read and approved the final manuscipt. In

addition, both authors agree to be accountable for all aspects of the work. Both authors read and approved the final manuscript.

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Government Executive

# Bombs Away

By Louis Jacobson

December 1, 1996

As Lt. Mike Schaffer shows off the cramped, but nuclear-safe, toilet facilities inside his launch control center at the India 01 missile alert facility in Montana, he takes care to point out the flushing mechanism. "This," he deadpans, "is the real button."

When you're baby-sitting the most powerful weapons ever devised, it's hard to forgo a little bathroom humor. For more than 30 years, young men and women at Malmstrom Air Force Base in Montana, where the India 01 facility is located, have had the lonely and mind-numbingly regimented task of guarding and controlling America's intercontinental ballistic missiles (ICBMs).

"Along with submariners, the most conservative people in the world are the people who oversee nuclear missiles," says Lt. Col. Allen Branco, an 18-year ICBM veteran. "There's just no room for error."

But now, as various arms control treaties come into force, Air Force personnel face the daunting task of transporting and decommissioning hundreds of ICBMs. Malmstrom-whose 200 missile silos sprawl over 23,000 square miles of empty, and often frozen, Montana mountain and prairie lands-is at the center of this mission.

The first Strategic Arms Reduction Treaty, which is already in effect, and the second, which is awaiting ratification by the Russian Duma, have mandated such sweeping reductions that the United States is closing half its missile bases. But the number of missiles controlled by Malmstrom's 341st Missile Wing will not decrease.

When the dust settles, Malmstrom will become a major destination for missiles that aren't destroyed or put into treaty-approved deep storage. Since 1991, Malmstrom has been asked to clear out 150 Minuteman II missiles-three-quarters of its total missile capacity-and replace them with improved Minuteman IIIs. Thirty of the newcomers, drawn from stockpiles, are already in place, and the job of installing the remaining 120 is more than half complete.

It's an intricate and highly secure ballet: After being broken down into pieces, each of the last 120 missiles must be shipped to Malmstrom from silos at Grand Forks, N.D. They are hauled on trucks over ordinary roads, including the region's many unpaved (and sometimes snow-covered) routes. Then, after some maintenance on the base, the missiles are shipped to Malmstrom-controlled silos.

Officers at Malmstrom are unfazed by the mission's complexity. Decades of missile upgrades and maintenance have left them with experienced crews and time-tested protocols. "We're used to it," says Col. Wayne N. Hansen, the 341st's vice wing commander.

### The Organization

The 341st Missile Wing has such a sprawling domain that it's broken into four squadrons, each with its own colors, nickname and esprit de corps. Officers say familiarity and trust are the operational bedrock of missileering, and it is unlikely that the four squadrons will be merged anytime soon. A squadron quadruple their size might be unmanageably large.

Each squadron is responsible for 50 missiles stored in launch facilities (commonly known as silos) 120 feet below a 110-ton concrete door. In a true launch situation, the doors would be blasted off by four explosive canisters. In turn, the 50 missiles are controlled from five small, self-contained compounds known as missile alert facilities.

Each of the missile alert facilities-many of them on dirt roads next to farms and ranches-boasts homey quarters, including lodging, cooking and recreational facilities such as satellite television and a pool table. Each facility has a backup generator and, as a last resort, batteries. The duration of these sources of electricity is "classified, but more than long enough," according to one officer.

The facilities' locations aren't secret-"they would be pretty hard to hide," as one officer put it. But missileers have given many of them outrageous nicknames such as "Life's End Missile," "Moral Disorientation Missile" and "Hotel Hell Launch Control Center."

Security is tight. Each launch facility is ringed by a chain-link fence and barbed wire and security officers meticulously verify each visitor's identity and search for contraband. Once inside, movement to sensitive areas is regulated by password codes.

In addition to the roughly 55 missileer officers who control the ICBMs, each squadron includes about 35 enlisted facility managers and chefs and 140 enlisted security police with light infantry-style gear, including M-16s and military vehicles. Missileers themselves used to carry guns, but that ended in 1990 when their gun-training and ammunition costs were targeted by budget cutters, Air Force officials say.

About a year ago, the enlisted personnel began to receive regular assignments to the same facility for three-and-a-half-day shifts and were integrated for the first time into the missileers' same chain of command. Enlisted personnel say the change has boosted morale and moderated the hierarchical distinctions between them and officers.

### Inside the Capsule

The most important part of a missile alert facility is its launch control center, or "capsule," where two-person crews monitor everything about their ICBMs. Crew members become especially familiar with their partners, serving 24-hour shifts in tandem two or three times a week, usually 18 hours awake and 6 hours sleeping (one at a time). Married missileers often say they see their partners more than their families.

In severe weather, missileers may have to work as many as 48 consecutive hours, but the use of four-wheel-drive vehicles and helicopters usually prevents double shifts. Crews are granted unusual autonomy to recommend how to handle the unpredictable local weather.

Capsule crews are ensconced in an environment shielded from nuclear attack. The capsule is literally a big, hollow metal egg with strong shock absorbers. Built at bedrock level, 60 feet to 120 feet below the surface, the capsule has only a single, closely guarded elevator shaft leading to its entrance.

Whether or not this setup is capable of surviving a direct hit, or even a nearby hit, is open to argument. With visitors, the Air Force plays up the capsules' security, but when pressed, officials said survivability specifications are classified. Outside experts are skeptical, suggesting that the main guarantee that the United States could return fire after a nuclear attack owes less to silos' protections than to the likelihood that at least a couple won't get hit at all.

Still, because the capsule is intended to be "hard," nuclear-wise, its 8-ton metal door is supposed to be closed except when changing crews or sending in food or other supplies. While Malmstrom officials say the rule is followed rigorously, the difficulty of yanking the door open and closed has historically made this a popular regulation to ignore. Brookings Institution senior fellow Bruce G. Blair, who was a missileer for more than two years in the 1970s, recalls that he and his crew mate had to scramble to get their door closed when the level of alert was suddenly heightened during the 1973 Yom Kippur war.

Inside, most capsules are predictably snug, though big enough for at least one 6-foot-7, 240-pound missileer in recent memory. India 01-located 35 miles from Great Falls, Mont., the state's second largest city-has room for a toilet, ringed by an insubstantial curtain, and one bed.

Many crew members utilize their quiet hours to study for advanced degrees. The capsules' creature comforts include a television, VCR and refrigerator. (The fridge is not often used, apparently: India 01's chef, Airman Sean M. Ranes, says his cheeseburgers, fries and cheese steaks are the facility's most popular meals.) Recently, technicians improved the carpeting and sound- proofing, which has alleviated long-standing complaints of hearing loss from the drone of electronic equipment. "From our point of reference," said Lt. Col. Thomas Cullen, a onetime capsule crew member, the upgraded capsules "are like the Taj Mahal."

### The Hardware

The most critical feature of the capsules is the equipment that allows crews to carry out their ultimate mission: Communicating with the Pentagon when a launch may be imminent. Each capsule houses several parallel communications systems, in case one is rendered useless after an attack.

Those systems include a satellite receiver, an encrypted fax machine and an ultra-high frequency radio for airplane communications, as well as a mechanism to receive messages by very low spectrum frequencies (which, as officers put it, is particularly useful in a "nuclear environment"). Crews also have access to ordinary telephone lines for personal use (credit card calls only) and a closed-circuit phone system connected to other nearby installations.

None of these accessories were purchased off the shelf because the Air Force has determined that an ordinary fax machine wouldn't survive the electromagnetic pulse during a nuclear conflict. Indeed, it took 10 years of development at Loral and GTE (including a trip through the Pentagon's acquisitions bureaucracy) before the capsules' computer system could be upgraded. The Russians installed an equivalent system 10 years before the United States did, Blair says.

Despite the wait, the new computer system-which crews have dubbed "Windows for Armageddon"-has been an immense relief to missileers, who find it much easier to use than the blinding array of "idiot lights" typical of its predecessor. The computers are not particularly powerful-120 megabytes, up from 1 megabyte before the upgrade-but officials insist that's all the system needs. In fact, the system's simplicity has been a blessing in at least one regard: The faulty programming that will cause a worldwide crisis once computer clocks hit the year 2000 does not affect ICBM computers, officials say.

That other nuclear guy, Homer Simpson of TV cartoon fame, might find the capsule layout familiar: Big chairs on rails in front of an unpolished, but functional, control panel. The chairs have belt straps for protection from the ultimate shock wave, but these are rarely used. Years ago, veteran missileers say, the job required much sliding back and forth to tear off paper messages. Now, computer screens provide instant updates on the missiles' vital signs much more ergonomically.

Each of the security alerts and emergency action messages that flash regularly across the screen must be investigated. Most alerts are generated by automatic motion sensors at unmanned silos, usually tripped off by maintenance workers or scampering rodents. The messages are generally tests from supervisors to keep missileers on their toes.

Each capsule console monitors not only its own 10 missiles but also the 40 controlled by the squadron's other four crews, who sit in similar capsules dozens of miles away. This feature provides one of the system's best security defenses. A rogue crew member seeking to initiate an unauthorized launch would have to do more than just convince his partner to turn his own two launch knobs simultaneously. One would also have to prevent the other eight off-site squadron members from vetoing their efforts in real time. Even an entire squadron would need to get the nuclear enabling codes first from high-ranking military officials. Flirting with the end of civilization would be no easy task.

Ironically, the system only became this secure in 1977-and only as a cost-cutting measure during post-Vietnam War downsizing. In 1977 the Air Force decided to cut manpower costs by instituting 24-hour shifts during which missileers were allowed to sleep. Previously, crews were rotated in shorter shifts and were forbidden to sleep. To compensate for breaking its traditional two-man-awake rule, the Air Force instituted tighter security controls. Seals were placed on all critical components to prevent tampering, and new coding processes were incorporated into launch directives that are now provided to crews only when needed. Analysts say this has made ICBM control far more secure than it was for Malmstrom's first decade and a half.

**The Missileers**

America's missileers are rigorously trained for eight months. Typically they are lieutenants, 22 to 27 years old, who rotate into missileer duty for four years and then pursue other Air Force careers. Women were first allowed in mixed capsule crews in the 1980s, and they now account for 10 percent of missileers.

The missileer's daily grind is regimented by checklists, but as dulling as the procedures are, missileers say the boredom, particularly between 3 and 6 a.m., can be worse. "I miss seeing the sun," says Lt. Tory Saxe. "You have no sense of time. Even the clocks are in Greenwich Mean Time."

And, of course, serving as the gatekeepers of Armageddon adds a layer of stress. The possibility that a missileer may actually have to launch nuclear weapons "is not only the most obvious question, it's the ultimate question," said Lt. Col. Allen Branco. "I have to sign papers saying that an officer is capable of duty. We ask them whether they have any reservations about the use of nuclear weapons. In two situations, people have come out and said that they didn't think they could do this. We had no ill will. We just sent them off to do other things."

The Air Force says it monitors the mental readiness of its missileers through a "personal reliability program," or PRP, that instructs crews on spotting mental unease. Crew members who are considered emotionally unstable are encouraged-if not forced-to adjust their frame of mind before returning to duty.

"It's the job of every person in this business to watch out for each other and say, 'Hey, why don't you get evaluated,' " says a Malmstrom chaplain. Confidentiality is maintained, he added, but "we don't just say OK. This is a very serious thing."

Former missileers such as Blair recall major breaches in the 1970s, such as dope smoking, as well as widespread frustration at the missileers' rule-bound world (he says he and colleagues "learned shortcuts for our own sanity"). While Blair agrees that the situation is noticeably better today, he says subsequent missileers have told him that "people who rock the boat do suffer from stigma, if not outright punishment."

Even so, Malmstrom's safety message is ubiquitous, sometimes outrageously so. Missileers are reminded (to the point of nagging) about everything from car thefts and drunken driving to basketball injuries. Even in freewheeling Montana, which no longer has daytime speed limits, Air Force vehicles must still drive 55 mph on interstate highways and 25 mph on unpaved roads, despite the long travel times.

But something seems to be working. In June, the 341st Missile Wing spent two weeks under scrutiny by the Air Force Space Command hierarchy, and the wing earned its second highest score since Malmstrom's missiles were installed in the early 1960s. "It was very, very stringent, but we smoked it," Cullen says.

Many agree that even as ICBMs continue to be phased out, the missileers' deadly serious job helps maintain a sense of mission. "There's a certain sense of pride for me every time I come down here," says Saxe. Even Blair, whose skepticism lingers two decades after his missileer duty, agrees that the assignment is highly desirable by military standards.

And because the job is so unique, missileering has a tradition of extraordinary outspokenness. At the meeting before a missileer's final capsule duty-the "last alert"-each outgoing missileer is allowed to speak his or her mind, unreviewed and unedited.

On the day *Government Executive* visited Malmstrom, it was Capt. Jim Sneddon's turn. Though Sneddon began by saying he had no desire to burn his bridges- "the missile community is small," he noted-he still shared some of the cartoons he'd drawn while on duty, many of which lampooned common missileer frustrations.

Missile veterans report that other last alerts possessed even more bite than Sneddon's. "I've seen everything from cussing somebody out to breaking down and crying," says Capt. Michael Jackson, who at 28 is heading off to a combat-planning job after four years as a missileer. "The nature of the job demands a trusting individual. This is the only time I've ever heard of something like this in the military."

**Downsizing Mission**

The rash of arms control agreements between the United States and Russia have already ended the default targeting of many missiles on Russia and closed the book on round-the-clock nuclear bomber runway alerts. The agreements are soon expected to slash each side's arsenal of deployed land-, air- and sea-based strategic weapons from the peak of 10,000 to 13,000 down to 3,500, of which ICBMs will account for only 500 single-warhead missiles.

**Arms control agreements have prompted the closing of three of America's six ICBM facilities.**

ICBMs have survived thanks to support from congressional and Pentagon hawks, Blair says, but the currents of change have still prompted major aftershocks. In May, residents of Sedalia, Mo., watched as a contractor imploded a 30-year-old ICBM silo previously run by missileers at nearby Whiteman Air Force Base. A month later, Defense Secretary William Perry traveled to southern Ukraine to join his Russian and Ukrainian counterparts in planting sunflowers over what had once been Soviet ICBM silos.

Now, thanks to the Pentagon's 1993 nuclear posture review, there will soon be only three remaining ICBM locations on American soil. Malmstrom will house 200 Minuteman IIIs, Minot Air Force Base in North Dakota will host 150 Minuteman IIIs and F.E. Warren Air Force Base in Wyoming will have 150 Minuteman IIIs as well as 50 Peacekeeper missiles (the weapons once called MX missiles, which are to be decommissioned by the Start II treaty).

Of these, Malmstrom may be the most active location for a while. Lt. Col. Dave Noble of Malmstrom's logistics team says that moving a single missile from Grand Forks, N.D., to Malmstrom takes about three weeks of effort by both the Energy Department and Malmstrom personnel.

A missile's lower three propulsive cylinders are shipped first in a special trailer. Following routine maintenance, these stages are inserted into their new silo by a large vehicle called a transporter-erector. Next, the missile's two post-boost control system pieces are moved separately to Malmstrom for maintenance and reassembly. This package includes the rocket engine and guidance system-the missile's "brains."

Last to go is the warhead, which must undergo a week of disassembly and a week of reassembly before it's inserted anew. Once the warhead is in place, the entire missile system must be tested and programmed. On average, Malmstrom says its teams can remove and insert one missile a week. At about 50 missiles a year, that means Malmstrom's great switcheroo should be complete by late 1997.

Though the early missile portions are tightly secured in transit, the warhead is cared for most tightly of all. Officers maintain that it's certified not to explode or cause harmful fallout en route, and the package moves with a convoy of U.S. marshals, helicopters and an undisclosed number of Malmstrom's 1,400 military police officers. Some convoys must drive for four hours or more. Officers say Malmstrom's 1,000-vehicle fleet travels 4 million miles a year.

Security flare-ups are rare, but tracked intently. Though anti-nuclear protesters trespassed onto Whiteman Air Force Base several times in 1987 and 1988, Malmstrom has managed to avoid such problems. Malmstrom officials acknowledge that they feared problems when Freemen sympathizers began visiting the site of the group's anti-government standoff in Jordan, Mont., only 70 miles from some of the base's silos. But such problems never materialized.

In addition to scheduling its missile movements unpredictably, "we have strong shows of force," Hansen says. "We exercise very overtly. You can kill yourself practicing for something that may never happen, but in 34 years we seem to have gotten it right."

Ironically, for such a high-tech maneuver, senior officers say the biggest management challenge is actually as simple (or perhaps as complex) as the weather. The Malmstrom region is so big that it experiences three distinct weather patterns. "The challenge is the wind, tornadoes, ice, snow, hail," says Hansen, the 341st's vice wing commander. "These are critical things that we do not want to put at risk. If Mother Nature wants her way, she wins. We have time to do it right the first time."

### What's Next

Though negotiations are on the back burner, "some people predict that once Start II is done, maybe by the time of a first Gore or Powell Administration, we could be down to about 1,000" strategic weapons, says Reagan-era Pentagon official Lawrence J. Korb, now a Brookings Institution scholar in Washington. And national security specialist Michael Mazarr of the Center for Strategic and International Studies in Washington suggests that the arms control process is at a point where it "may become more of a political issue into early 1997."

That could instigate more nuclear downsizing at Malmstrom and elsewhere. But Malmstrom officers brush off issues of strategy as the purview of Washington policy makers. Even without such a dramatic rebirth of arms control efforts, their mission will continue. Routine maintenance will always be as predictable as death and taxes, and there's also recurring talk of upgrading the propulsion and guidance systems of Malmstrom's Minuteman IIIs.

Because the weapons being installed within the current round of changes should be functional until 2020, there probably won't be a shortage of openings for prospective Malmstrom missileers. "Our job," Hansen says, "never ends."

# U. S. ARMY



Technical Note 1-72

# IMPROVED WEAPON NOISE EXPOSURE CRITERIA

David C. Hodge

February 1972

HUMAN ENGINEERING LABORATORIES

ABERDEEN RESEARCH & DEVELOPMENT CENTER

ABERDEEN PROVING GROUND, MARYLAND

Technical Note 1-72

# IMPROVED WEAPON NOISE EXPOSURE CRITERIA

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February 1972

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## ABSTRACT

The state of the art in noise-exposure criteria is reviewed and it is suggested that such criteria are in need of revision and extension to meet future operational requirements of the Army. Further, existing noise criteria, expressed in terms of "decibels of hearing loss," should be re-stated in terms of predictions about the performance of military personnel after they have been exposed to noise. Such re-statement in performance terms will significantly improve communication about the risk of noise exposure to people who are in a position to utilize such information but who generally do not comprehend the notation of decibels of hearing loss.

# IMPROVED WEAPON NOISE EXPOSURE CRITERIA[1]

## INTRODUCTION

At present, assessment of the potential hazards of noise exposure in military environments is made by means of "damage-risk criteria" (DRC). We are beginning to realize that current DRC are deficient for the solution of many human factors problems. New programs of research will be outlined whose purpose is to resolve these deficiencies.

## THE STATE OF THE ART IN DAMAGE-RISK CRITERIA

There are two DRC which enjoy wide popularity and application at the present time. They are the DRC for steady-state and intermittent noise (1) and the DRC for impulse noise (2) developed by Working Groups 46 and 57, respectively, of the NAS-NRC Committee on Hearing, Bioacoustics and Biomechanics (CHABA). It would be correct to state that, at least in the United States, practically all recent developments in both military and industrial noise-exposure and hearing-conservation criteria are derived, directly or indirectly, from these two basic DRC.

Figure 1 illustrates one set of damage-risk contours from the CHABA steady-state noise DRC (1). This set of contours is for a single daily exposure to bands of noise. The left-hand ordinate is octave-band sound-pressure level (SPL) in decibels (dB) re 20 $\mu N/m^2$, and the right-hand ordinate is 1/3-octave-band SPL. The abscissa is band-center frequency in Hertz (Hz) -- cycles per second is you are old fashioned! The nine contours show the permissible levels for various exposure times from 1½ minutes to 480 minutes per day. Another set of contours in the DRC expresses these same relationships in such a way that if you knew what exposure time was required to perform a particular job (eight hours or less) you could determine the maximum permissible octave- or 1/3-octave-band SPL. Also, other sets of contours are provided for assessing pure-tone exposures and for various types of intermittent-noise exposure.

Figure 2 illustrates the basic exposure limits for impulse noise. The ordinate is peak pressure level in dB re 20 $\mu N/m^2$ and the abscissa is the duration of a single impulse in milliseconds. The basic DRC assumes exposure to 100 impulses per day with the ear at normal incidence, as shown in the lowest curve. Combining the basic DRC with the correction factors for number of impulses per day and ear orientation permits development of a family of exposure curves as illustrated in Figure 2.

[1]Based on a talk presented to the Division 21 Symposium, "New Fellows," American Psychological Association, Washington, D. C., 5 September 1971.

Figures 1 and 2 represent only one aspect of DRC — that aspect which relates to limits on physical exposure parameters. The other important aspect of DRC is the amount of change in hearing which is acceptable, i.e., which the user of the DRC is willing to tolerate as an acceptable maximum. The CHABA DRC (1, 2) state hearing loss limits as decibels of temporary threshold shift (TTS) measured two minutes after exposure ($TTS_2$). The limits are 10 dB at or below 1000 Hz, 15 dB at 2000 Hz, and 20 dB at or above 3000 Hz. The limits apply to 50 percent of ears exposed to intermittent and steady-state noise, and to 95 percent of ears exposed to impulse noise. Less TTS is permitted in the lower frequencies than high, since the primary purpose of current DRC is to preserve man's ability to communicate by speech.

Two additional features of DRC should be mentioned:

1. The actual intent of DRC is to limit permanent hearing loss (i.e., permanent threshold shift — PTS) resulting from years of near-daily exposure. The exact relationship between TTS and PTS is not known, but it is assumed that $PTS_{10\ yr}$ will be equal to or less than $TTS_{2\ min}$.

2. It is implicitly assumed that TTS which is no larger than about 30 dB will recover within 16 hours. More about that later on.

## LIMITATIONS OF CURRENT DAMAGE-RISK CRITERIA

### Criteria for Long-Term Noise Exposure

For steady-state noise we have no systematic criteria at all for exposures longer than eight hours. This may be a problem for industry as well as the Army, since industry is presently experimenting with a 10-hour work day. In the Army, changes in tactical doctrine are expected to provide for deployment of men and materiel for periods of up to 100 hours continuously. This is the doctrine of "continuous operations."

There has been little investigation of the effects of long-term noise exposure. Some results from a recent study by Mills, et al. (4) are shown in Figure 3. A single subject was exposed to an octave-band of noise centered at 500 Hz. Hearing thresholds were monitored at 750 Hz. Two SPLs were used: 81.5 and 92.5 dB. Both curves in Figures 3 indicate that an asymptote was reached in TTS after about 12 hours of exposure.

Figure 4 shows results from an experiment conducted in the Russian astronautics program and reported by Yuganov, et al. (6). Here, several astronauts were exposed to broad-band noise at 75 dB SPL for 30 days continuously (i.e., 720 hours). The data in Figure 4 are the "average TTS" values reported in Yuganov's paper; they suggest that for a broad-band noise exposure TTS may continue to grow linearly in log time for very long exposures. The contradictory nature of the results from Mills and Yuganov suggest that much further research is needed on the effects of long-term exposure.

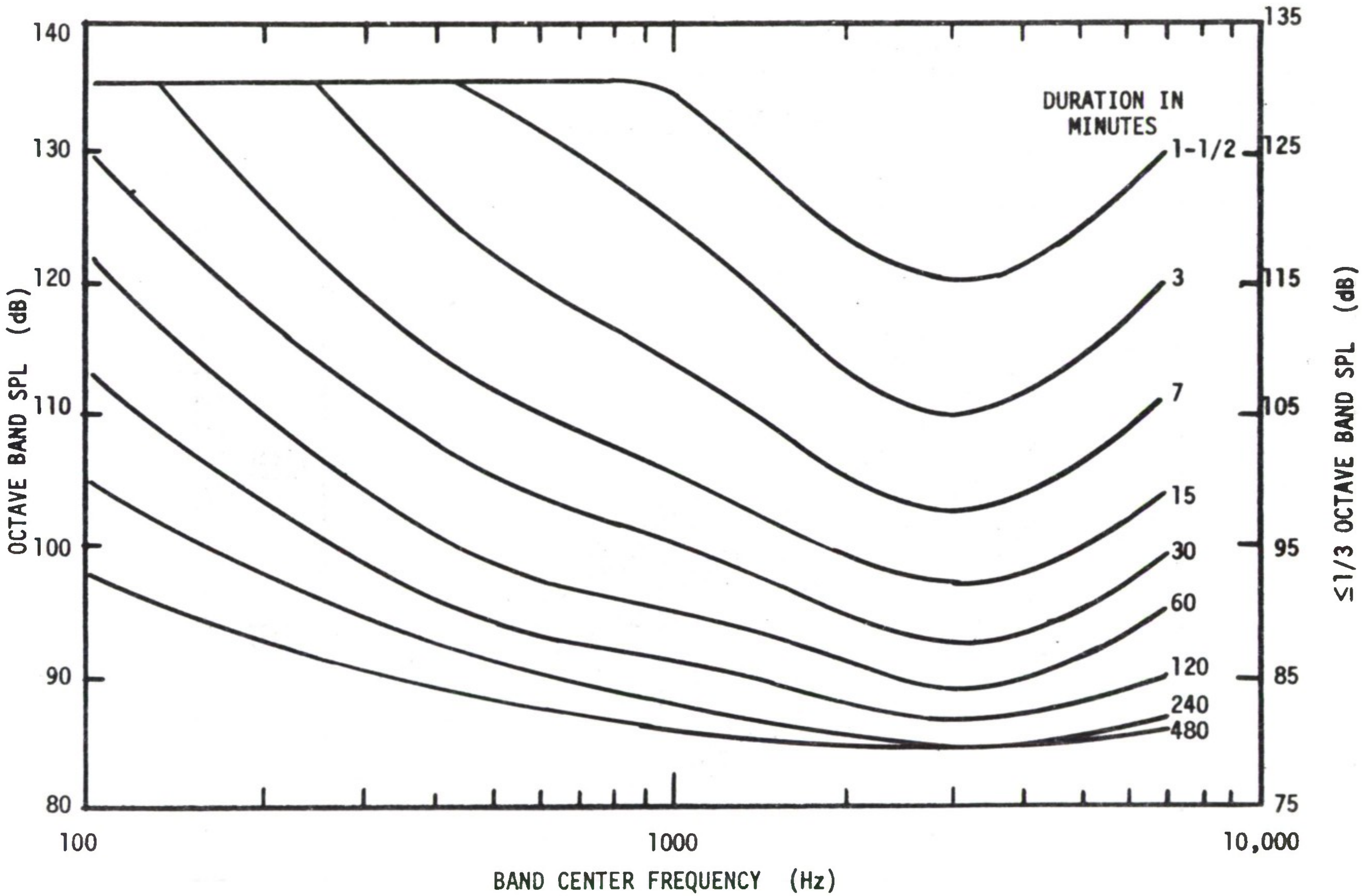


Fig. 1. DAMAGE RISK CONTOURS FOR ONE EXPOSURE PER DAY TO OCTAVE AND ONE-THIRD OCTAVE OR NARROWER BANDS OF NOISE
[This graph can be applied to individual band levels present in broad band noise (From Reference 1.)]

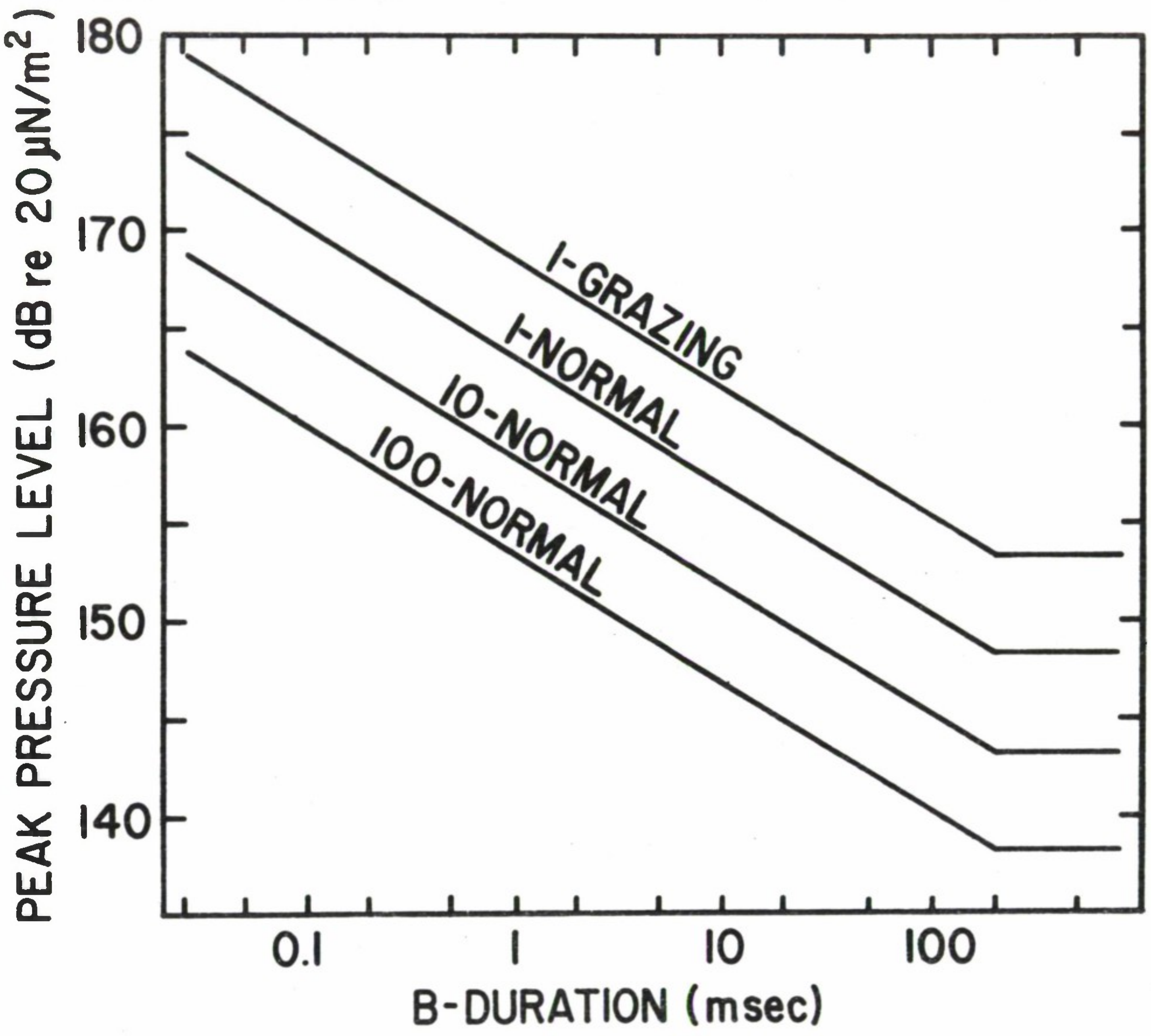


Fig. 2. DAILY EXPOSURE LIMITS FOR IMPULSE NOISE
[Parameters are number of impulses per day and ear orientation.
(From Reference 2)]

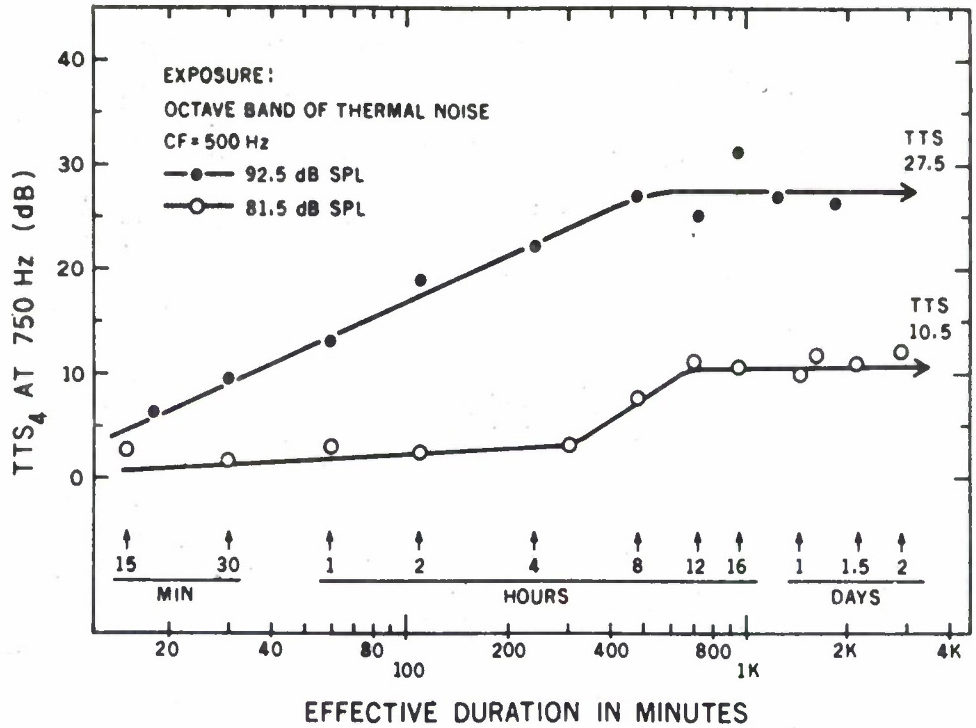


Fig. 3. GROWTH OF TEMPORARY THRESHOLD SHIFT FROM LONG-TERM EXPOSURE TO AN OCTAVE-BAND OF NOISE
(From Reference 4.)

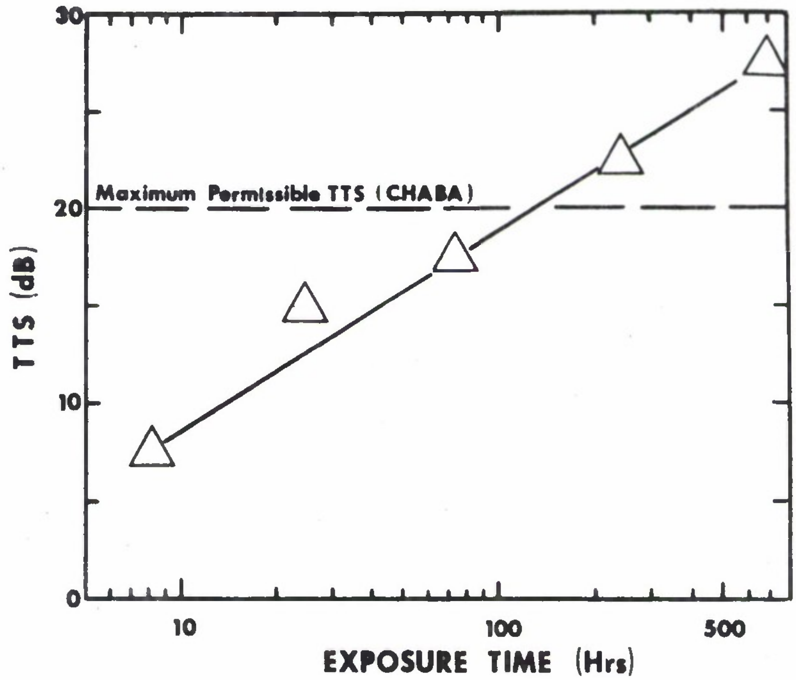


Fig. 4. GROWTH OF TEMPORARY THRESHOLD SHIFT FROM LONG-TERM EXPOSURE TO BROAD-BAND NOISE
(From Reference 6.)

There is another aspect of the long-term exposure problem which should be investigated: the characteristics of recovery from TTS induced by long exposures. Both Mills and Yuganov indicate that recovery took much longer than for the same amount of TTS induced by shorter exposures. Figure 5 shows recovery functions for Mills' one subject. The dashed lines have been added to show the TTS recovery functions implied by the CHABA DRC (1). TTS induced by the lower exposure SPL should have, according to the CHABA DRC, recovered within about 45 minutes; it actually took four days. For the upper curve, recovery should have been complete within about eight hours; it took six days. This matter of recovery requires investigation because one of the most critical questions regarding the whole area of continuous operations is "How long does it take soldiers to recover from long-term performance, including long-term exposure to various environmental pollutants?"

## Intermittent Noise Effects

This aspect of current DRC is already receiving attention. Ward (5) has shown that whereas the CHABA DRC (1) accurately predicted the growth of TTS from steady noise exposure, in some cases the recovery was longer than implied by the DRC. The importance of this problem involves the same considerations raised above.

## Assumptions of DRC

Two of the fundamental, explicit, assumptions of current DRC should be reconsidered.

1. The concept of 50 percent protection against TTS from steady-state noise needs re-evaluation. For impulse noise it was noted that the DRC provides for 95 percent protection. Current DRC based on 50 percent protection may be inadequately protective from a human factors point of view.

2. Currently, DRC permit twice as much TTS at 3000 Hz and above as they permit at 1000 Hz and below. The notion of placing primary emphasis on preservation of the speech frequencies may need revision. This possibility will be explored further later in the paper.

## Impulse-Noise DRC

For impulse noise the current criteria appear to be adequate for the moment. Recent studies have indicated, however, that recovery from impulse-noise-induced TTS varies greatly in the population. Firgure 6 illustrates various recovery-function shapes which have been observed in monkeys and men as reported by Luz and Hodge (3). The upper two curves, labelled "M" and "S," show the recovery functions resulting from two hypothesized TTS mechanisms. The lower four curves show representative examples of recovery functions resulting from combining the two basic mechanisms' functions. All have been observed in experiments on both monkeys and men. These data certainly indicate that we need to examine recovery further. This is particularly true since it was formerly believed that once the value of TTS two minutes after exposure was established the further course of recovery could be predicted with a fair degree of accuracy. This has now been shown not to be necessarily the case.

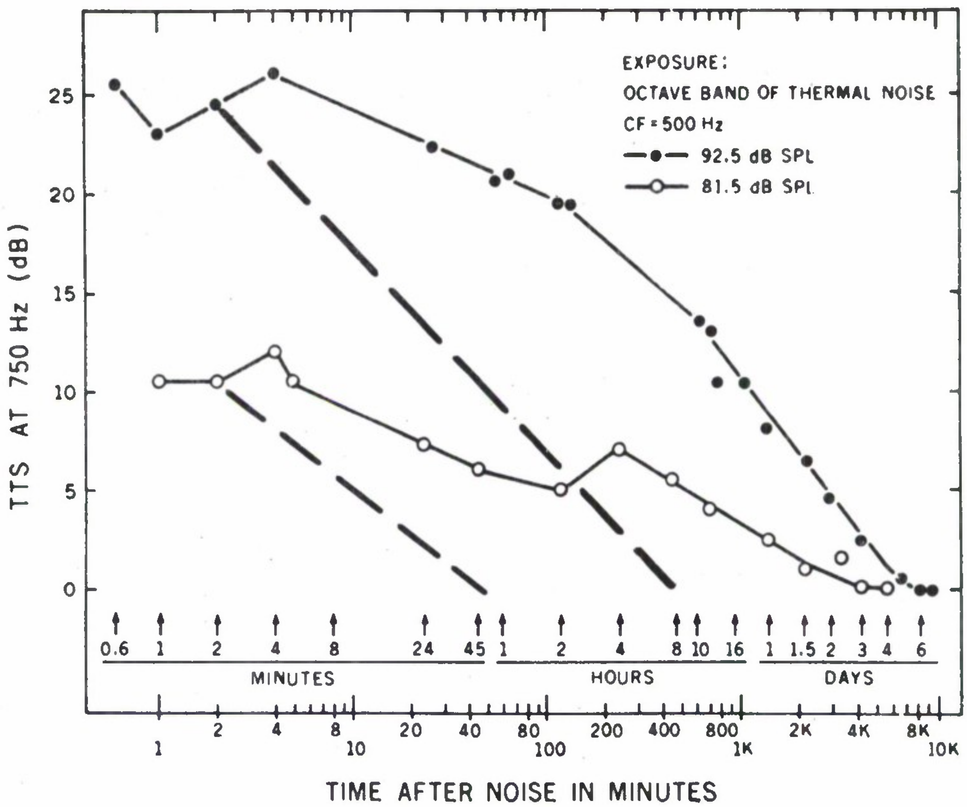


Fig. 5. RECOVERY FROM TEMPORARY THRESHOLD SHIFT INDUCED BY LONG-TERM EXPOSURE (From Reference 4.)
[Dashed lines have been added to show recovery rate implied by CHABA DRC (Reference 1).]

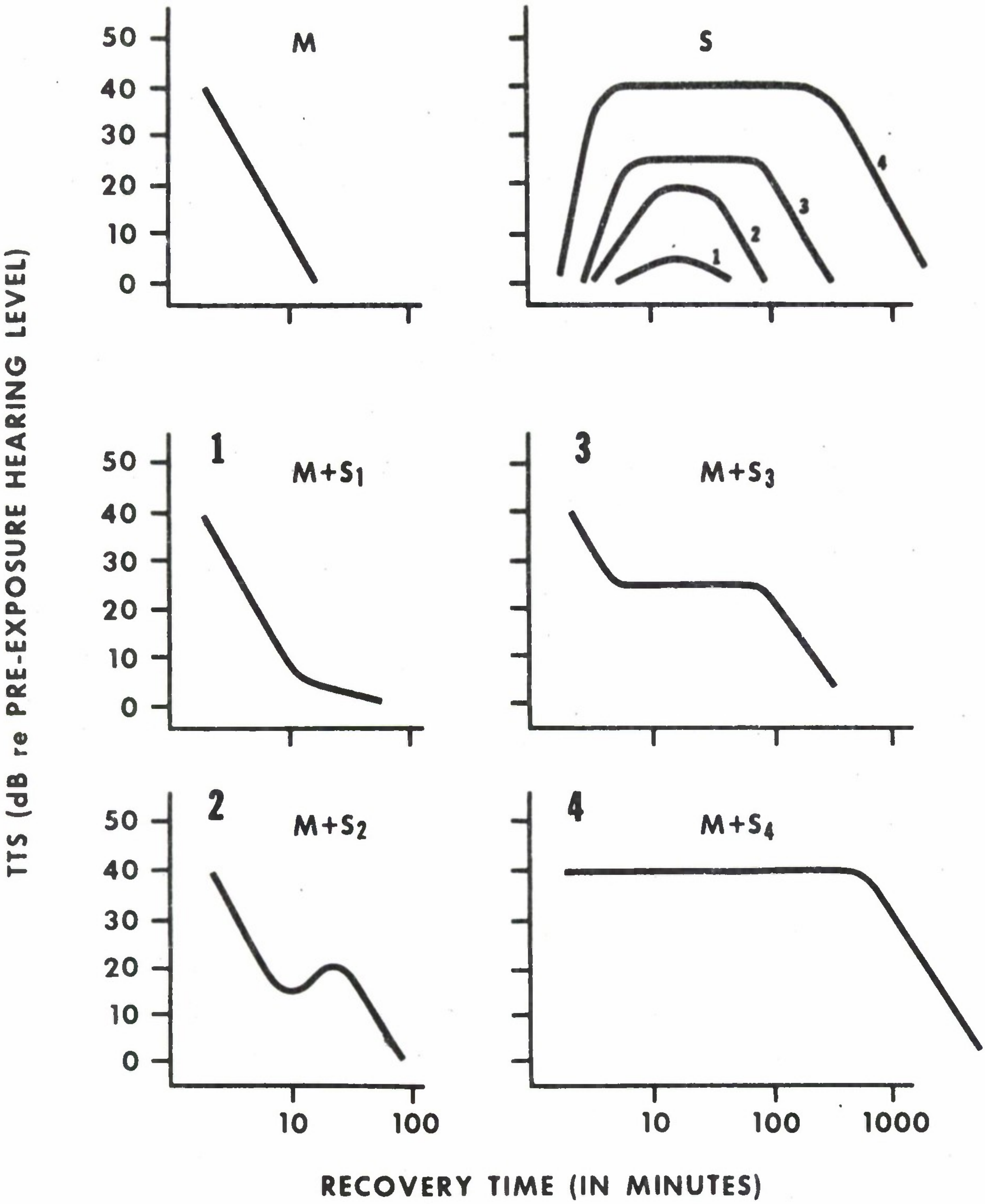


Fig. 6. HYPOTHETICAL RECOVERY FUNCTIONS FOR IMPULSE-NOISE-INDUCED TEMPORARY THRESHOLD SHIFT IN MONKEYS AND MEN (Reference 3)
(The lower four curves have all been seen in both monkeys and human recovery data.)

### Inadequacy of DRC Concept

A fundamental defect of all current DRC will not, we feel, be resolved by extending the state of the art as outlined above. The reason is that current DRC are stated in terms of "decibels of hearing loss" at various frequencies in various percentages of the exposed population. Unless one is knowledgeable in this area, such terminology is relatively unintelligible. It would be much better, we feel, if we had "DRC-like" criteria which relate noise exposure parameters to soldiers' performance.

## WHY PERFORMANCE CRITERIA ARE NEEDED

We have been able to identify three critical areas in which performance criteria for noise exposure would be extremely helpful. They relate to planning research, designing of new materiel and advising field commanders of the tactical risks of noise exposure.

### Research Planning

In designing noise experiments with human subjects, performance criteria are needed for determining when to terminate the exposure. At present, such end-points are derived from humanitarian considerations alone, i.e., we do not want to risk permanent injury to the subjects. Typically, a person is not re-exposed to a larger amount of noise energy once he has shown a TTS of 40 dB or larger at any test frequency. We strongly suspect, however, that performance of tasks requiring acute hearing sensitivity will be significantly degraded long before TTS reaches 40 dB and, if this is so, the experimental noise exposure should be terminated whenever an unacceptable amount of predicted performance decrement has occurred. This will result in more efficient experimental procedures by removing the ambiguity presently involved in setting end-points for exposures.

### Equipment Design Criteria

After the need for a new item of materiel has been conceptualized there is a period of time in which various technological approaches to satisfying the concept are weighed against numerious criteria, including effectiveness and compatibility with the human operator. In weapons, for example, some trade-off has to be reached between those features required to deliver a particular projectile to the target and the risk of noise injury to the operator. At present we have engineering models which permit accurate prediction of the noise characteristics of a new weapon from a knowledge of the intended design parameters. But the best available criteria for the effects of impulse noise on man — the CHABA DRC (2) — are expressed in terms of decibels of hearing loss. Few weapon designers really understand hazards expressed in these terms. However, statements like "exposure to the stated noise parameters for one shot per day will render 25 percent of personnel unfit for sentry duty for up to 12 hours" are readily comprehended since they relate to the effectiveness of soldiers in performing their tasks after noise exposure. Performance criteria would thus aid designers in making more informed decisions and trade-offs between weapon effectiveness and maximum acceptable risk of degraded operator performance.

## Advice to Military Commanders

In many instances field commanders are presently unable to adequately assess the risks involved in noise exposure because the DRC are expressed in unfamiliar terms. As a result, personnel are not required to utilize hearing protective devices in those tactical situations where such protection is desirable and compatible with operations. I have, for example, talked with several Viet Nam veterans who stated that after a 30-minute helicopter airlift to a combat zone they alighted from the aircraft to discover that they could not understand spoken commands because of the TTS induced by helicopter noise. On the other hand, the flight surgeon responsible for medical planning on the Son Tay prison camp raid insisted that all troops wear ear plugs while being airlifted. The result was that the troops arrived at the prison camp, removed their ear plugs, and found their hearing unimpaired by noise-induced TTS. With performance criteria for noise exposure, we think many more instances of this type would be in evidence.

# DEVELOPMENT OF PERFORMANCE CRITERIA

## Hearing Loss vs Performance

We have selected two types of performance for initial consideration which are combat-relevant and critical to survival. One of these is communication by speech, and the other is detection and identification of the presence of the enemy.

We already have a substantial body of information relating noise-exposure parameters to the risk of hearing loss. Therefore, our primary focus will be on determining the relation between hearing loss (or, hearing sensitivity) and performance in these tasks. Figure 7 illustrates the frequency spectra of speech and of combat sounds. (The combat sound data are based on our analysis of Device 5H12, Sound Recognition Tape: Night Sounds, prepared by the Training Devices Center, Orlando, Florida.) Note that the peak energy of male speech is at about 400 Hz, whereas, the combat-sound spectra peak generally in the region of 4000 to 8000 Hz. It should be obvious, then, that the understanding of speech and the detection of combat sounds require quite different hearing acuities.

From an extensive literature review and evaluation of our research data on noise exposure, we have concluded that the most pressing problem is that of hearing-loss effects on detection and identification of combat sounds. There are two reasons for reaching this conclusion:

1. The relation between hearing loss and speech reception has been examined closely already, whereas detection of combat sounds has received little attention. Pure-tone audiometry is much simpler to conduct than tests of speech reception, so there has been considerable clinical interest in the prediction of speech reception from pure-tone hearing loss data. Several predictive schemes have been published, and we feel that one or more of these can be used to develop predictive models of hearing loss effects on speech communications.

2. Noise typically affects the upper frequencies of hearing first. Figure 8 illustrates the effect: the TTSs are from the right and left ears of 26 soldiers who fired one shot with the M72 rocket launcher. The TTSs are 95th percentiles: 95 percent of the ears had shifts of this magnitude or smaller, while five percent of the ears had larger shifts. The CHABA DRC limits on 95th percentile TTS are indicated by the dashed line at the bottom of the graph. Comparison of Figures 7 and 8 leads to the conclusion that typical noise-induced hearing loss profiles will more likely affect detection of combat sounds than the understanding of speech.

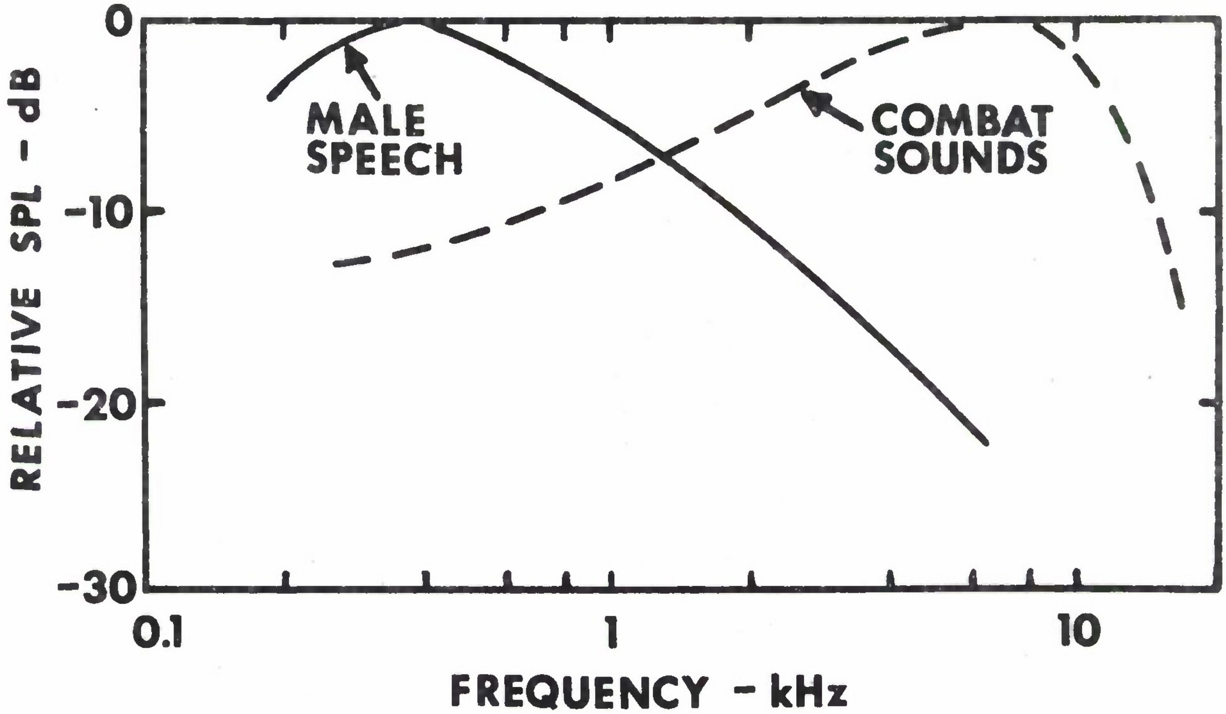


Fig. 7. FREQUENCY SPECTRA OF MALE SPEECH AND COMBAT SOUNDS

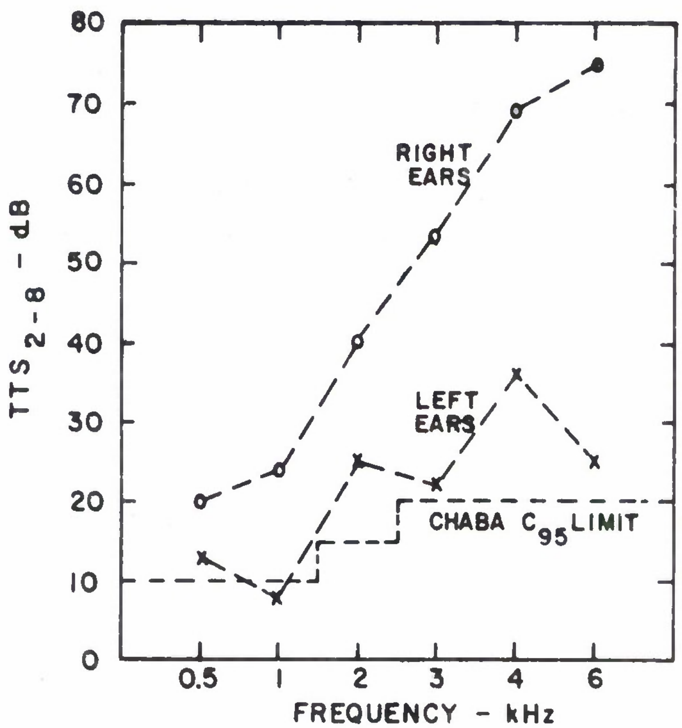


Fig. 8. TEMPORARY THRESHOLD SHIFTS IN RIGHT AND LEFT EARS OF 26 SUBJECTS EXPOSED TO ONE SHOT OF M72 ROCKET NOISE

Tentative Outline of Research Plan

It should be understood that the use of the term "detection" implies and includes the recognition or identification aspect as well. Following is a tentative outline of the steps envisioned to be involved in developing a predictive model of hearing loss effects on detection of combat sounds.

1. An old recipe for rabbit stew starts off: "First you catch a rabbit." The first step in the process is to select a population of combat sounds for use as stimuli in experiments. The population of sounds will likely be developed by reviewing existing documents dealing with combat recognition requirements, including current training plans for Army personnel. An attempt will be made to keep the population definition as broad as possible to assure generality of the empirical data to Army operations under a variety of mission, geographical and terrain situations.

2. In some cases new descriptive parameters must be developed for correlating sound characteristics with detection performance. For some sounds, such as the sound of vehicles operating at great distances, simple octave- or 1/3-octave-band analysis may provide adequate description. In other cases such simple description will not suffice. The masking literature, for example, indicates that sounds of an impulsive character can be detected in steady background noise when the intensity of the signal is below that of the masker. In such instances a more complex form of analysis and description will be required.

3. Instrumentation requirements are being developed. These include instrumentation for recording and playing back stereophonic sounds with minimal distortion. Interfacing requirements to our laboratory programming computer will have to be established.

4. Experimental test procedures may take the form of audiometric-like procedures using real-world sounds. There is little precedent to build on in this area. Rapid testing procedures will be required in some parts of the program.

5. Empirical investigations will include gathering of normative data on subjects having "normal" hearing sensitivity, as well as data from subjects having varying degrees of permanent noise-induced hearing loss. Hypotheses developed from these will be verified with subjects having experimentally-induced TTS. Here, rapid testing methods will be required so detection thresholds can be measured before the TTS recovers.

6. Correlational techniques, among others, will be used to develop predictive models of hearing loss effects on detection of combat sounds.

## SUMMARY

Deficiencies in current hearing damage-risk criteria have been identified and discussed, and the research needed to revise these criteria has been outlined.

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