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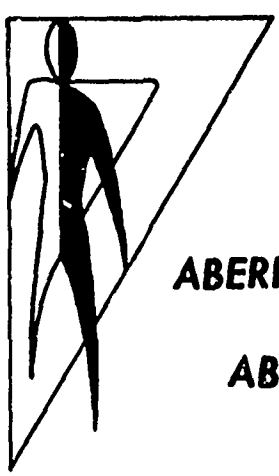

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ENVIRONMENTAL QUALITY CONSIDERATIONS FOR CONTINUOUS OPERATIONS

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INTRODUCTION

For the past ten years we have been investigating the effects of noise and blast on man. The results of these experiments have been applied in the development of acoustical design criteria for new Army equipment. During the past year we have been reviewing the state-of-the-art with respect to noise criteria, to determine where we need to go to be able to meet the requirements of the future Army with respect to continuous operations. One thing we need is exposure limits for long-term noise exposure. However, there are other air-borne pollutants besides noise. In this brief report I would like also to note the current status of design criteria for fumes and vapors and some of the improvements needed in this area as well.

NOISE CRITERIA

Assessment of the potential hazards of noise exposure in military environments is made by means of "damage-risk" criteria (DRC). The best available DRC for steady-state and intermittent noise are those developed by Working Group 46 of the NAS-NRC Committee on Hearing, Bioacoustics and Biomechanics (the "CHABA" committee) (4).

Figure 1 illustrates one damage-risk contour from the CHABA DRC for steady-state noise. This one is for a single daily exposure to bands of noise. The left-hand ordinate is octave-band sound-pressure level (SPL) in 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 Hz. The nine contours show the permissible noise levels for various exposure times from 1-1/2 minutes to 8 hours per day. In practice, the SPLs measured in a particular environment would be plotted on the graph and the highest penetration would define the maximum exposure time permitted by the DRC. If exposed personnel are wearing hearing protection,

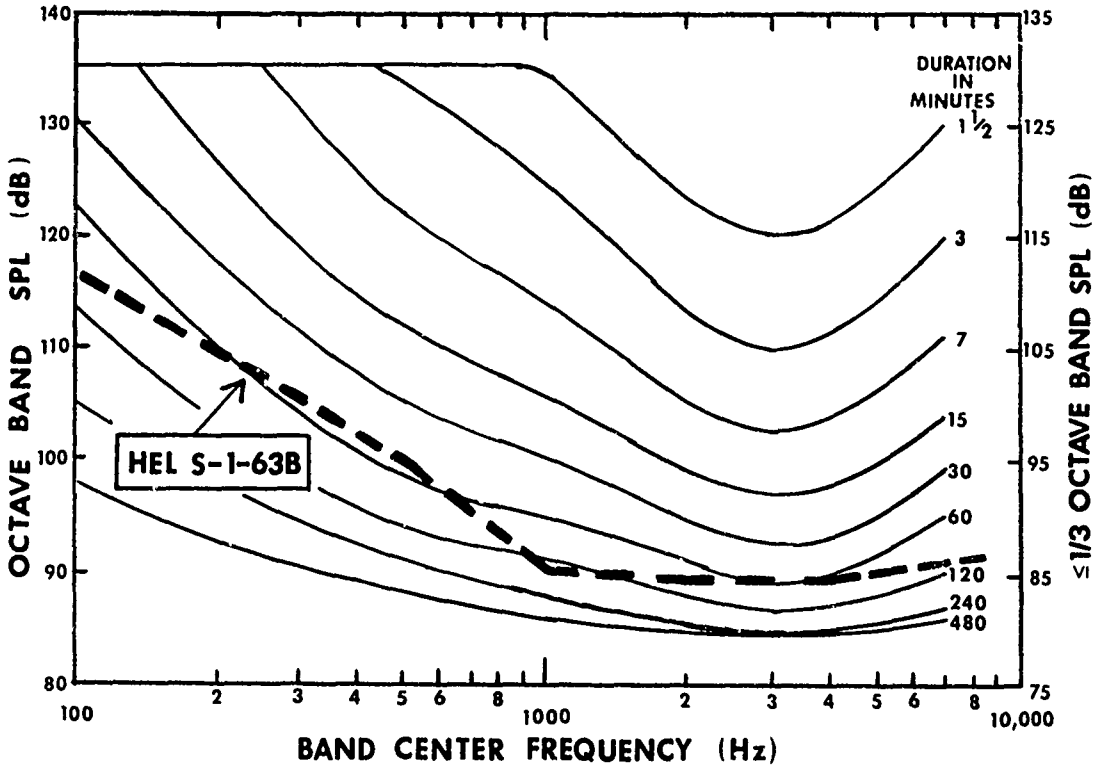

Fig. 1. CHABA DAMAGE-RISK CONTOURS FOR EXPOSURE TO BANDS OF NOISE. DASHED CURVE IS CURRENT AMC EQUIPMENT DESIGN STANDARD.

the environmental noise spectrum can be reduced by the attenuation of the particular device being worn and the permissible exposure time for protected personnel can thereby be determined.

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 (up to 8 hours) you could determine the permissible octave- or 1/3-octave-band SPL. Also, the DRC provides other contours for evaluating pure tone and intermittent noise exposures.

The risk of hearing damage specified by the CHABA DRC is as follows: maximum permissible temporary threshold shift (TTS) measured two minutes after exposure (TTS_2) is 10 dB at or below 1 kHz, 15 dB at 2 kHz, and 20 dB at or above 3 kHz in 50 percent of exposed ears. These amounts of TTS_2 are designed primarily to preserve man's ability to communicate by speech, since greater emphasis is placed on limiting TTS in the lower, speech frequencies than in

the upper frequencies of hearing.

The design standard for Army materiel is contained in HEL Standard S-1-63B (6). These maximum noise level limits are incorporated into MIL-STD-1472A (10). Figure 1 also shows the noise limits of HEL S-1-63B plotted against the CHABA steady noise DRC. The design standard's limits fall between the 60 and 120 minute exposure contours. In deriving these limits a number of points were considered, including the following:

a. In many cases, Army materiel is not operated for long periods of time (according to present tactical doctrine). Certainly, it is rare to find situations in which personnel are exposed to noise for eight hours a day, five days per week.

b. Hearing protection will be worn by personnel in many situations, or communications gear will be used which provides protection against noise.

c. Noise reduction is expensive and often results in loss of operational effectiveness of materiel. Thus, a realistic tradeoff between desireable and achieveable noise limits is often indicated.

The design standard is an official inclosure to Army procurement actions, and is also incorporated into the Test and Evaluation Command's acceptance criteria (3). Materiel not meeting the S-1-63B limits must be labelled in accordance with Army Regulation 385-30 (9) as follows:

CAUTION

HIGH INTENSITY NOISE

HEARING PROTECTION REQUIRED.

Regarding noise criteria for continuous operations, for steady-state noise we presently 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 experimenting with a 10-hour work day, and the Walsh-Healy Public Contracts Act (11) does not provide for exposures longer than eight hours per day.)

There has been little investigation of the effects of long exposures. The few data which are available are contradictory, and suggest that much needs to be done in this area. Figure 2 shows some results from a recent study by Mills, et al. (12). 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 Fig. 2 indicate that an asymptote in TTS growth was reached after about 12 hours of exposure.

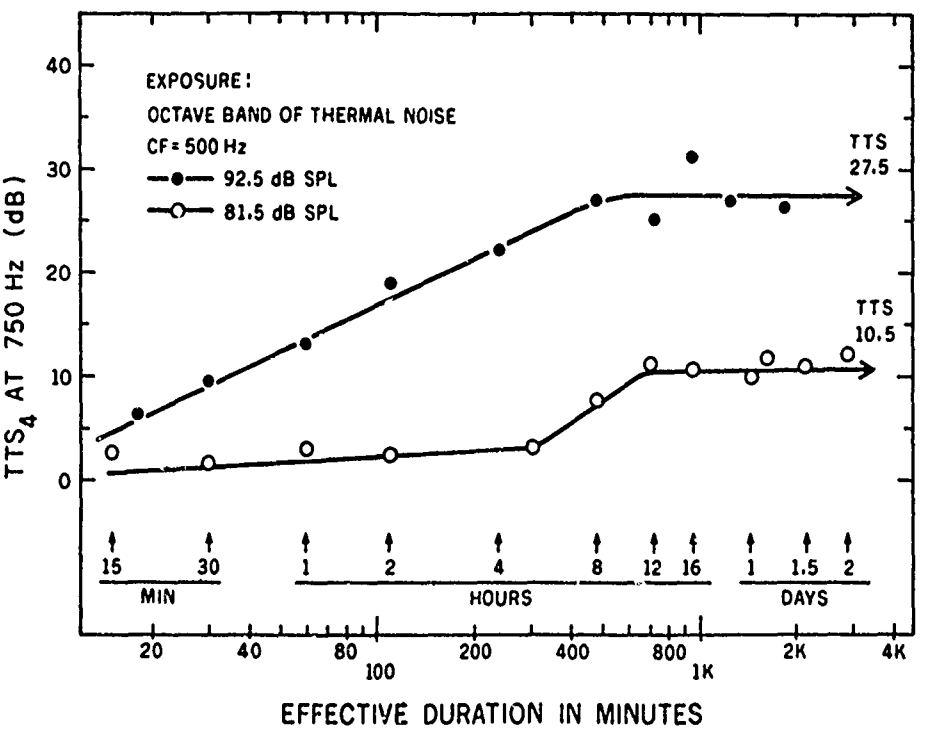

Fig. 2. GROWTH OF TEMPORARY THRESHOLD SHIFT FOR A LONG EXPOSURE AS REPORTED BY MILLS, ET AL. (12).

Figure 3 shows some results from an experiment conducted by Yuganov, et al. (15) in the Russian astronautics program. Here, several astronauts were exposed to broad-band noise at 75 dB SPL for 30 days continuously (720 hours). The figure shows the reported "average TTS" values. These data suggest that for a broad-band noise exposure TTS continues to grow linearly in the logarithm of time over the entire course of the exposure. The contradictory nature of the data reported by Mills, et al., vs those of Yuganov, et al., indicate that further research is needed on the effects of long-term noise exposure.

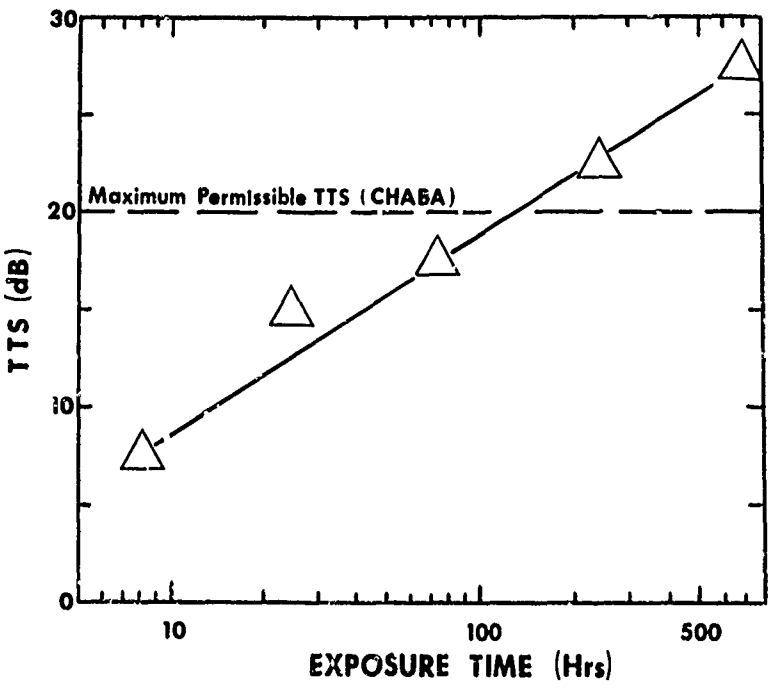

Fig. 3. GROWTH OF TEMPORARY THRESHOLD SHIFT FOR A LONG EXPOSURE AS REPORTED BY YUGANOV, ET AL. (15).

Another aspect of long-term noise exposure requires evaluation: the characteristics of recovery from TTS induced by long exposures. Both Mills and Yuganov indicated that recovery took much longer than for the same amount of TTS resulting from shorter exposures. Figure 4 is from Mills' paper and shows the recovery functions for his one subject. The dashed lines has been added to show the TTS recovery functions implicit in the CHABA DRC. TTS induced by the lower SPL should have, according to the CHABA DRC, recovered within about 45 minutes; it took four days. For the upper curve, recovery should have been complete within about eight hours; it took six days. This matter requires investigation because one of the most critical questions in the continuous operations area is: "How long does it take the soldier to recover from the effects of long-term performance, including long-term exposure to various environmental pollutants?"

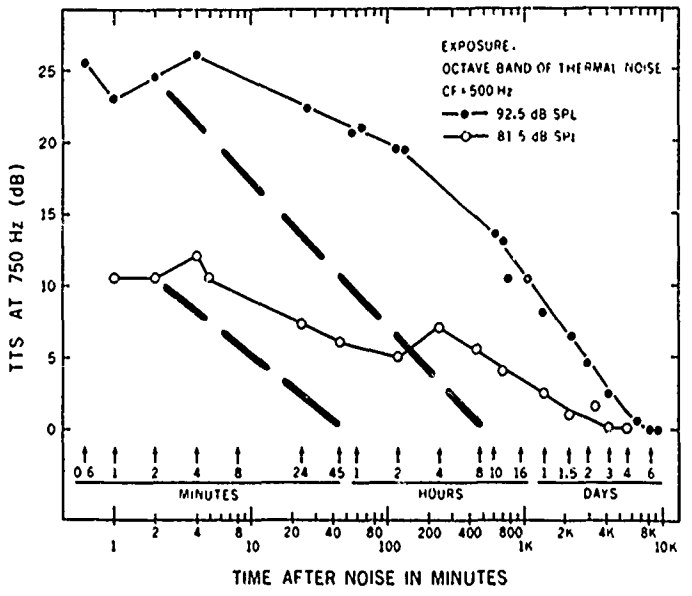

Fig. 4. RECOVERY OF TEMPORARY THRESHOLD SHIFT INDUCED BY LONG-TERM NOISE EXPOSURE, AS REPORTED BY MILLS, ET AL. (12). DASHED LINES HAVE BEEN ADDED TO SHOW RECOVERY FUNCTIONS IMPLICIT IN THE CHABA DAMAGE-RISK CRITERION (4).

We, at the Human Engineering Laboratories, are presently considering these problems and defining an appropriate research program designed to provide the answers. Several aspects will be considered. One goal is the development of "CHABA-DRC-like" exposure contours for exposures longer than eight hours. Another goal is determining the effects of the current eight-hour criterion SPLs on hearing during longer exposures. Then, including the recovery aspect, it may be necessary to establish exposure limits for TTS that will recover within the 16 hours currently implicit in the CHABA DRC.

EXPOSURE LIMITS FOR FUMES AND VAPORS

In thinking about the need for long-term noise exposure criteria it occurred to me that perhaps we need similar criteria for long-term exposures to other atmospheric pollutants such as fumes, vapors, etc. Material which was readily available was surveyed and this brief discussion is the result.

Paragraph 5.13.7.3 of MIL-STD-1472A (10) provides typical design guidance and reads as follows: "Personnel shall not be exposed to toxic substances in excess of the threshold limit values contained in the American Conference of Government Industrial Hygienists -- Threshold Limit Values" (p. 168). Similar instructions may be found in current HEL standards for various types of military equipment (5, 7, 8, 14).

What is a "threshold limit value?" The preface to the 1970 Threshold Limit Values adopted by the ACGIH (1) reads as follows:

> Threshold limit values refer to airborne concentrations of substances and represent conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect.... (p. 1)
>
> Threshold limit values refer to time-weighted concentrations for a 7 or 8-hour workday and a 40-hour workweek. They should be used as guides in the control of health hazards and should not be used as fine lines between safe and dangerous concentrations. (Exceptions are ... those substances with a "C" or Ceiling Value....) (p. 1)

> ... They are not intended for use ... in estimating the toxic potential of continuous uninterrupted exposures.... (p. 2)

Thus the Threshold Limit Values are not appropriate for evaluating working environments under continuous operations conditions, and other guidance must be sought for this purpose.

The problem of long-term exposure to fumes and vapors has been considered by the NRC Committee on Toxicology which published, in 1968, "A Compendium of Recommendations of Safe Concentrations of Atmospheric Contaminants" (2). This document's introduction reads, in part, as follows:

> These values have been recommended by the National Research Council Committee on Toxicology for specific circumstances involving long periods of continuous exposure in confined spaces such as nuclear submarines and spacecraft. They are ... atmospheric concentrations which the Committee believes will produce no toxic effect or discomfort under the intended circumstances of exposure. Each contaminant has been considered separately without regard to possible interactions with other contaminants present simultaneously..... (p. 2)
>
> Ninety-Day Exposures. These recommended levels are average values which ... may be applied to any period of continuous exposure up to ninety days. (p. 2)

In addition to the NRC recommendations, the Naval Submarine Medical Center has published its own set of recommendations and exposure limits for long-term exposure (13).

Table 1 compares the eight-hour TLV (1), 90-day NRC (2) and 90-day USN (13) exposure limits for a selected group of toxic air-borne vapors and fumes. The five compounds indicated by the superscript "d" are known constituents of the exhaust from internal-combustion engines, and thus would definitely be of concern to the Army. In addition, the three Freon compounds are of concern in any environment where air-conditioning or refrigeration equipment is used. The compounds preceeded by an asterisk indicate those for which the 90-day exposure limit is less than the eight-hour limit which,

Table 1

RECOMMENDATIONS FOR ATMOSPHERIC CONTAMINANTS

(ppm by volume unless otherwise noted)

Contaminant	8-hr TLV[a]	90-day Exposure[b]	90-day Exposure[c]
*Acetone[d]	1000	300	---
Ammonia[d]	25	25	25
*Arsine	0.05	0.01	0.01
*Benzene	80 mg/m^3	3 mg/m^3	---
Carbon Dioxide[d]	5000	5000	6-10,000
*Carbon Monoxide[d]	50	25	25
*Chlorine	1 C	0.1	0.5
*Ethanol	1000	100	---
*Freon 11	1000	1000	500
*Freon 12	1000	1000	500
Freon 114	1000	1000	---
*Hydrogen Chloride	5 C	1	0.1
*Hydrogen Fluoride	3	0.1	0.1
*Isopropanol	400	50	---
*Mercury	0.05 mg/m^3	0.01 mg/m^3	---
*Methanol	200	10	3
*Methyl Chloroform	350	200	---
*Nitrogen Dioxide[d]	5 C	0.5	0.5
*Ozone	0.1	0.02	0.05
*Phosgene	0.1	0.05	0.05
*Stibine	0.1	0.01	0.05
*Sulfur Dioxide[d]	5	1	---
*Toluene	750 mg/m^3	10 mg/m^3	20
*Triaryl Phosphates	5 mg/m^3	1 mg/m^3	---
*Xylene	435 mg/m^3	10 mg/m^3	3

[a]American Conference of Governmental Industrial Hygienists, 1970 (1).

[b]NRC Committee on Toxicology, 1968 (2).

[c]USN Submarine Medical Center, 1965 (13).

[d]Known constituents of exhaust from internal combustion engines.

*Contaminants for which 90-day exposure limit is less than 8-hr TLV.

in this case, includes all but three of the listed compounds. It may be worth noting, in addition, that for three compounds to which the ACGIH has assigned a Ceiling Value, which means that they are not to be exceeded under any circumstances, the 90-day exposure limit is significantly lower than the Ceiling Value.

Several types of data and/or recommendations may be needed in this area to evaluate continuous operations problems:

a. Long-term exposure criteria for, say, five days.

b. Estimates of the effect of eight-hour-limit exposure levels experienced for periods longer than eight hours.

c. An Army document which treats the problem of long-term exposure.

An Army agency specializing in toxicity problems, such as the US Army Environmental Health Agency, should be requested to develop the needed recommendations and define any new research which may be required for long-term exposure to toxic fumes and vapors.

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DISCUSSION SESSION

DAVID HODGE

CLAY GEORGE: Are people looking at the effect of noise of sudden onset? This is not exactly the intermittent noise situation, but the unpredictable occurrence in time and type and amount of noise and its accumulative effect on circadian rhythm.

DAVID HODGE: Are you referring to things like "startle?" There is work like this going on, particularly the startling effect of things like the sonic boom. In our own laboratories there is work being conducted on the effect of noise level on performance of tasks like aiming, etc. Yes, there is considerable interest in this particular problem.

BEN B. MORGAN, JR.: This brings to mind, since I am interested basically in performance, the synergistic effects of environmental factors on performance: the problem of the interaction of stressors in continuous operations. For example, you might have your noise or the toxic gases interacting with the stress imposed by the continuous work. This is something that will have to be considered somewhere down the road.

DAVID HODGE: While I was in Miskolc, Hungary, a couple of weeks ago, I talked with a West German scientist who ran an experiment with all the subjects being exposed to the same noise level. One group was a control. Another group got noise as a reward; the third group got noise as a punishment. He reported that he found significant differences in the amount of temporary hearing loss, depending on whether the noise was a reward or punishment. There is certainly a lot of interaction going on.