US ARMY MEDICAL RESEARCH LABORATORY

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REPORT NO. 680

EXPLORATORY STUDY OF THE EFFECT OF PULSE DURATION ON TEMPORARY THRESHOLD SHIFT PRODUCED BY IMPULSE NOISE

Final Report

by
LTC John L. Fletcher, MSC
and
Michel Loeb, Ph. D.

13 January 1967

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Fort Knox, Kentucky 40121

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Traumatic Origins of Hearing Loss
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ABSTRACT

EXPLORATORY STUDY OF THE EFFECT OF PULSE DURATION ON TEMPORARY THRESHOLD SHIFT PRODUCED BY IMPULSE NOISE

OBJECTIVE

To determine the effect of varying impulse duration upon temporary threshold shifts (TTS) in hearing while holding pulse intensity constant.

RESULTS

The two pulse durations studied were approximately 36 and 92 μsec. It was found that almost three times as many pulses were necessary to induce TTS to the desired criterion with the 36 μsec pulses as with the 92 μsec pulses. The TTS's observed were most pronounced at 4 KHz and above, with a broad pattern of frequencies affected.

CONCLUSIONS

Pulse duration is a significant determinant of TTS from impulses. Further research is necessary to determine the interrelationships holding among pulse duration, intensity, and rise time as determiners of TTS from impulse sound.

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EXPLORATORY STUDY OF THE EFFECT OF PULSE DURATION ON TEMPORARY THRESHOLD SHIFT PRODUCED BY IMPULSE NOISE

INTRODUCTION

Although there now exist reasonably adequate criteria as to what constitutes a safe exposure to continuous and intermittent noise (4), there are no comparable safety standards by which one can regulate exposure to short duration, high intensity impulsive noise. Although the problem has been recognized for some time, there have been relatively few studies of the problem. One of the earliest was by Murray and Reid (6) who exposed subjects to impulses produced by small arms, mortar, and artillery. They reported considerable temporary threshold shifts over a number of test frequencies with maximum shifts occurring between 4096 and 8192 Hz and increasing in magnitude, especially at lower frequencies, as the number of rounds increased. They also reported large individual differences, as well as a decrease in susceptibility with repetitive exposures. Their data indicated that the chief determiner of temporary threshold shift (TTS) was the peak pressure per round rather than integral pressure, but admittedly their measures were approximate. They also reported that when a series of impulses was presented in rapid succession, the increase in TTS was not proportionately large, an effect confirmed by Ward (8) and attributed to the action of the acoustic reflex (AR).

More recent studies do not generally support the idea that peak level rather than some combination of peak and duration determines TTS. Ward (9) reported more TTS following 25 pulses with a measured peak of 150 db than Fletcher (1) did with 700-1400 pulses with a nominal value of 170 db. Ward suggested that the difference probably was due to the wave shape; it is also possible that the fact that his pulses were in a relatively open field and Fletcher's in a small cavity around the ear may have been important. Rice and Coles (7) employed two kinds of gunfire in open and reverberant environments and concluded that pulse duration is an important factor determining TTS, such that longer pulse durations are appreciably more hazardous. In a recent experiment by Kryter and Garinther (3) the effects of gunfire from four kinds of small arms were compared. Analysis indicated similar spectra for all weapons. The TTS was reportedly comparable to that to be expected from continuous noise of comparable character.

In short, though there have been several experiments in which impulse duration has been considered, the only temporal characteristic of impulse noise which has been systematically manipulated has been number of impulses. This latter characteristic apparently increases TTS (in db) linearly (10), but it does not follow that the relationship between pulse exposure time and TTS will be a similar function. A systematic study of this relationship has not been made for two principal reasons: (1) Most commercial transducers employed for noise measurement do not have the dynamic range or the rise time and frequency response necessary for adequate impulse noise measurement. (There are those who feel that a frequency response above the audio range is unnecessary since the hair cells do not respond to such energy, but this position obviously rests upon a number of improved assumptions.) (2) An apparatus which will produce impulses with peak-intensities comparable to those of gunfire noise and of comparable variable durations has not been available.

The first problem is being solved with the appearance of several commercially available transducers. A start toward the solution of the second problem has been made with the development of a multiple spark-gap apparatus which will produce several overlapping or immediately successive impulses, the combined durations of which will approach the durations of gunfire and will equal (or even exceed) its peak levels.

The present report is a description of an exploratory experiment in which peak intensity was kept constant and subjects were exposed to two different durations of impulses.

PROCEDURE

Subjects. Subjects were 67 enlisted men temporarily assigned to the US Army Medical Research Laboratory. All were volunteers in that they could, without prejudice, decline to participate. All subjects had undergone screening audiometry with a Rudmose ARJ-5 audiometer calibrated to ISO standards and none of those participating in the experiment had hearing levels as great as 20 db at or below 4,000 Hz.

Apparatus. Impulses were generated by a spark-gap generator manufactured by R. W. Benson and Associates. An earlier version of this apparatus has been described in a previous article (5); this one differs in that, rather than having a single spark-gap generator that produces an impulse of constant duration, it could sequentially fire, from one to six gaps, producing six different durations of impulse.

In this preliminary experiment two settings of the apparatus--three gaps and six gaps--were employed. Subjects were seated in an anechoic chamber with one ear 6" (for the three gap setting) or 15 1/2" (for the six gap setting) from the gaps. According to measurements made with an LTV specially constructed microphone, with a nominal response flat to 500 KHz, the peak intensity at either position was 166 db SPL.* Pictures showing the first positive and negative pulse (the output of the microphone fed through a Brüel and Kjaer preamplifier into a Type 549 Tektronix scope) are shown in Figures 1 and 2. The duration of the positive pulse at three gaps is approximately 36 μsec; at six gaps it is approximately 92 μsec. (Duration is here defined as time from first positive deflection to first zero crossing.) By comparison the first positive pulse produced at the ear of a rifleman firing a M-14 rifle is approximately 160 db, 220 μsec (Fig. 3).

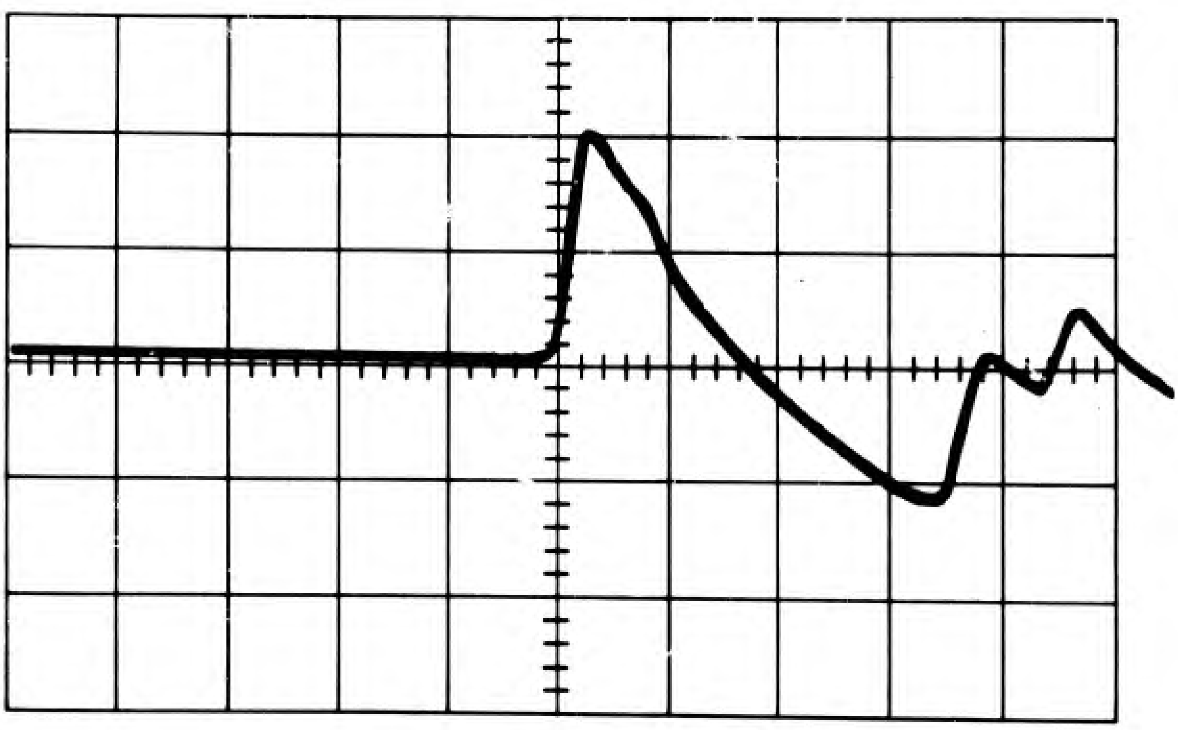

Fig. 1. Tracing of oscillogram of three gap impulse noise. Each horizontal division = 20 μsec; peak = 166 db.

*The measurements were made by Mr. Robert Camp, US Army Aeromedical Research Unit, Fort Rucker, Alabama, for whom the microphone was constructed.

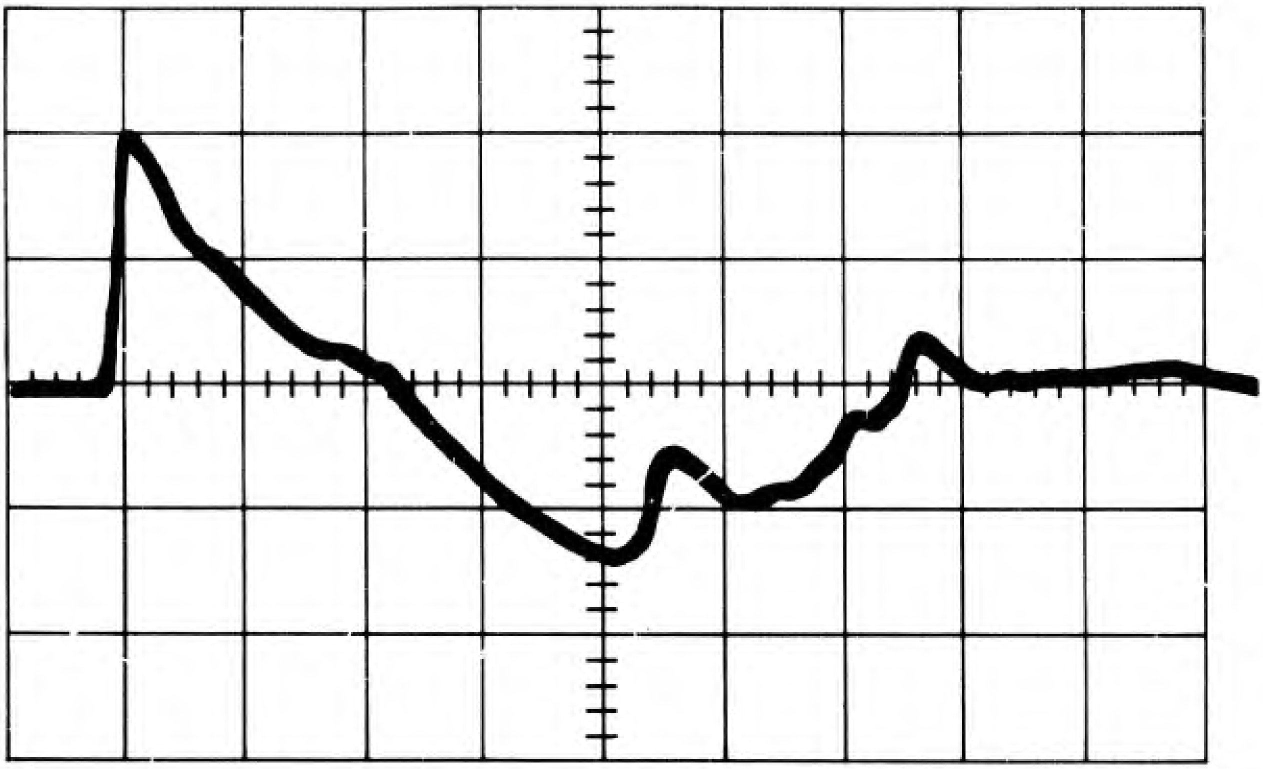

Fig. 2. Tracing of oscillogram of six-gap impulse noise. Each horizontal division = 40 μsec; peak = 166 db.

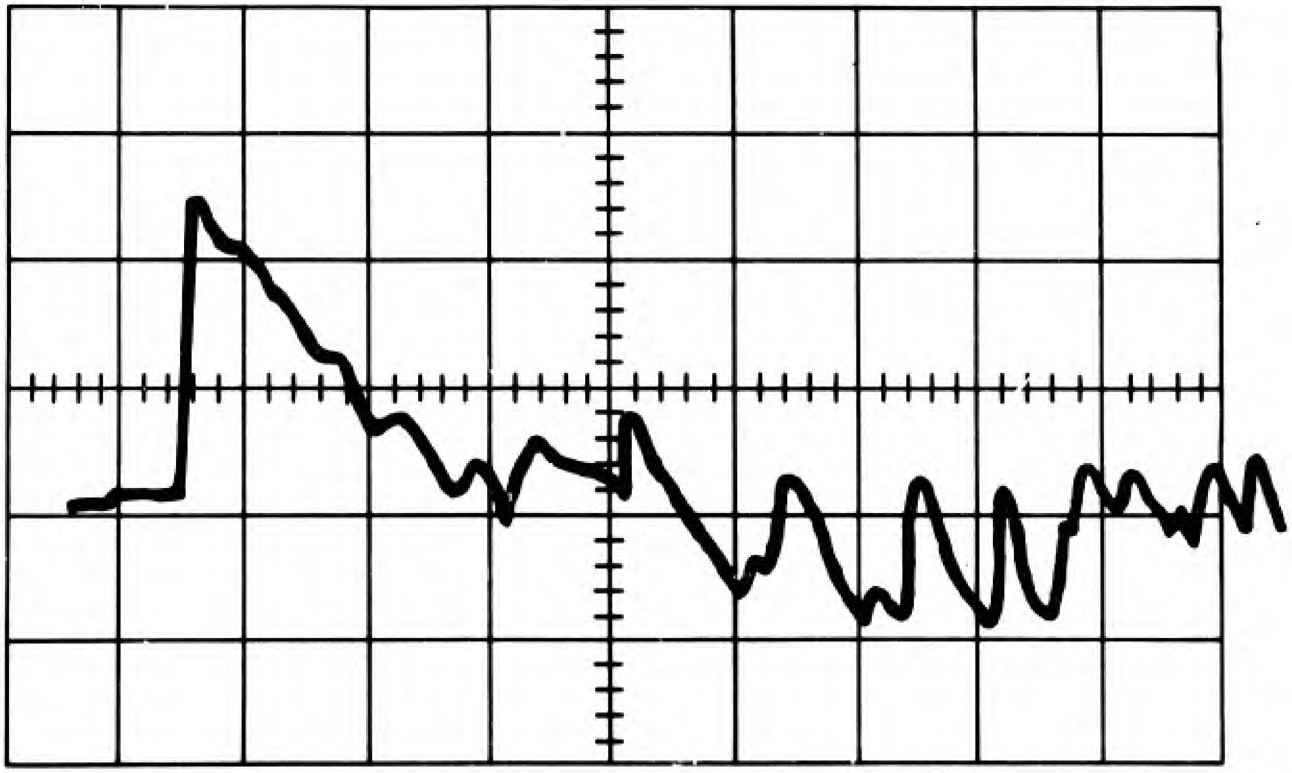

Fig. 3. Tracing of oscillogram of impulse produced by M-14 rifle. Each horizontal division = 100 μsec; peak = 160 db.

Methodology. Before exposure each O was tested on a Rudmose ARJ-5 modified Békésy type audiometer at 250, 500, 750, 1,000, 1,500, 2,000, 3,000, 4,000, 5,000, 6,000, 7,000, and 8,000 Hz. They were also tested with an ARJ-4 modified so that the testing transducer was a condenser earphone and the test frequencies were 4,000, 5,000, 6,000, 7,000, 8,000, 9,000, 10,000, 11,000, 12,000, 13,000, 14,000, 15,000, 16,000, 17,000, and 18,000 Hz. Pulse tone audiometry was employed in every case.

After testing, each O was exposed to impulsive noise, then retested, beginning with the ARJ-5, 90 sec after exposure, going through every frequency, and then continuing with the modified ARJ-4. With these audiometers, test time at each frequency was 30 sec, and it required 30 sec to switch audiometers. All Ss were tested with a minimum number of rounds on the first test day (10 impulses with six gaps and 75 with three gaps). The number of rounds were increased slowly on subsequent test days. Testing was discontinued when a loss greater than 20 db was encountered. The size of the increments in additional rounds was variable in this preliminary study. The initial increment for the six gaps was 10 impulses, and the increment was increased if no effect was apparent. The initial increment for the three gaps condition was 25 which similarly was increased as necessary. Needless to say, only one number of impulses was employed on a test day. On the following test day further exposure was performed only if the residual shift was less than 5 db (which generally was the case). Half the Ss were given three gap exposures first; half, six gap.

RESULTS AND DISCUSSION

The shifts (TTSs) were computed and tabulated for each O employing the ARJ-5 data at 8,000 Hz and below and the modified ARJ-4 data for higher frequencies. It was found that more than 2/3 of the Ss had shifts exceeding 20 db within 10-25 rounds for the six gap setting, shifts being especially pronounced at 4,000 Hz and above. However, one S failed to shift 20 db with 300 impulses. Similarly, approximately half of the Ss shifted 20 db or more when exposed to 75-100 impulses at three gaps, but one S shifted 20 db only with 1200 rounds.

The steps employed were too gross to discuss precise relationships between impulse duration, number of impulses, and TTS, but it is interesting that an approximately equal number of people had comparable TTSs with 10-25 impulses at three gaps (36 μsec) and 75-100 impulses at six gaps (92 μsec).

In order to obtain an idea of the pattern of TTS to be expected, the shifts for each O were computed at the last exposure employed (that producing shifts greater than 20 db); these were converted to estimates of TTS 2 min after exposure (TTS_2) by procedures similar to those described by Kryter (2), averaged for each frequency, and the percentage of Os having shifts of 10, 20, 30, 40, 50, and 60 db at each test frequency were computed. (The values at 40 db and above were derived by extrapolation from Kryter's curves.) The computed percentages are shown in Figures 4 and 5 respectively. Since a number of Os could not hear some very high frequencies, the figures were replotted using only those in the original group with measurable thresholds for every test frequency. These are plotted in Figures 6 and 7. The number of observations on which the data points are based is shown in an inset in each figure; note that due to attrition the Ns are somewhat different for each data point.

It is noteworthy that for both settings TTS is most pronounced at 4 KHz and above, though some subjects shifted at each test frequency and there is more shift at the lower frequencies (especially 2 and 3 KHz) with the six than with the three gap settings.

Also notable is the very broad pattern of frequencies affected. This is in accord with Murray and Reid's (6) findings. However, the TTS does apparently fall off at the very highest frequencies.

Extensive generalization regarding the findings must await the collection of more data at more settings of the spark-gap generator.

3 GAP EXPOSURE

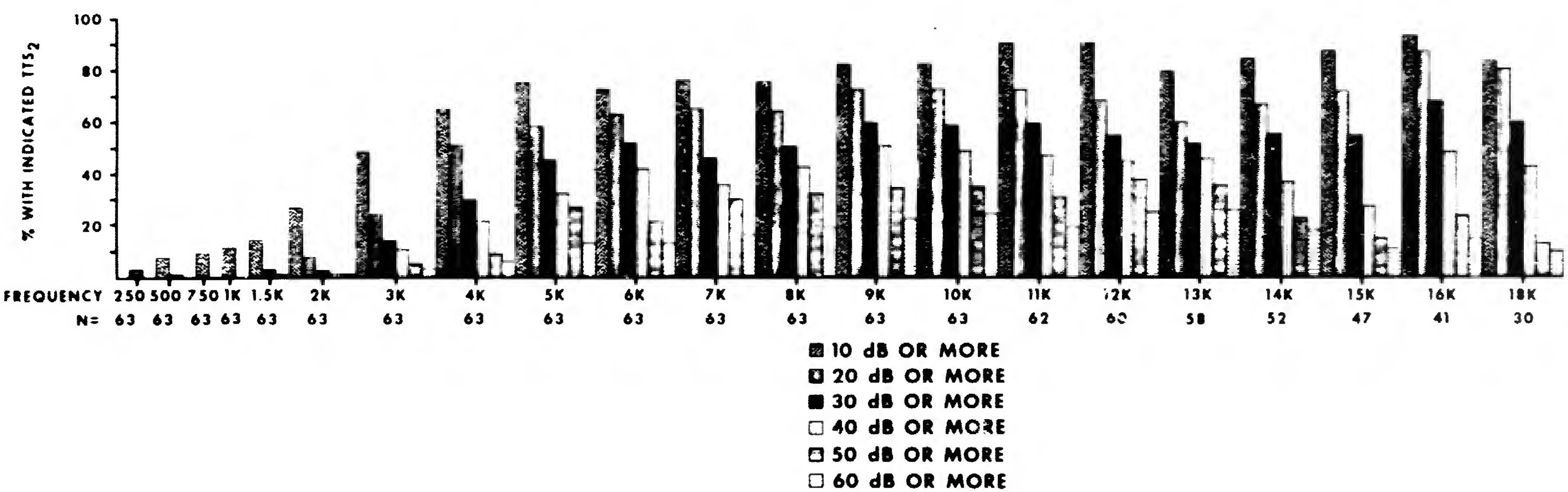

Fig. 4. Histogram showing number of individuals in entire group exhibiting criterion shifts following maximum three-gap exposure.

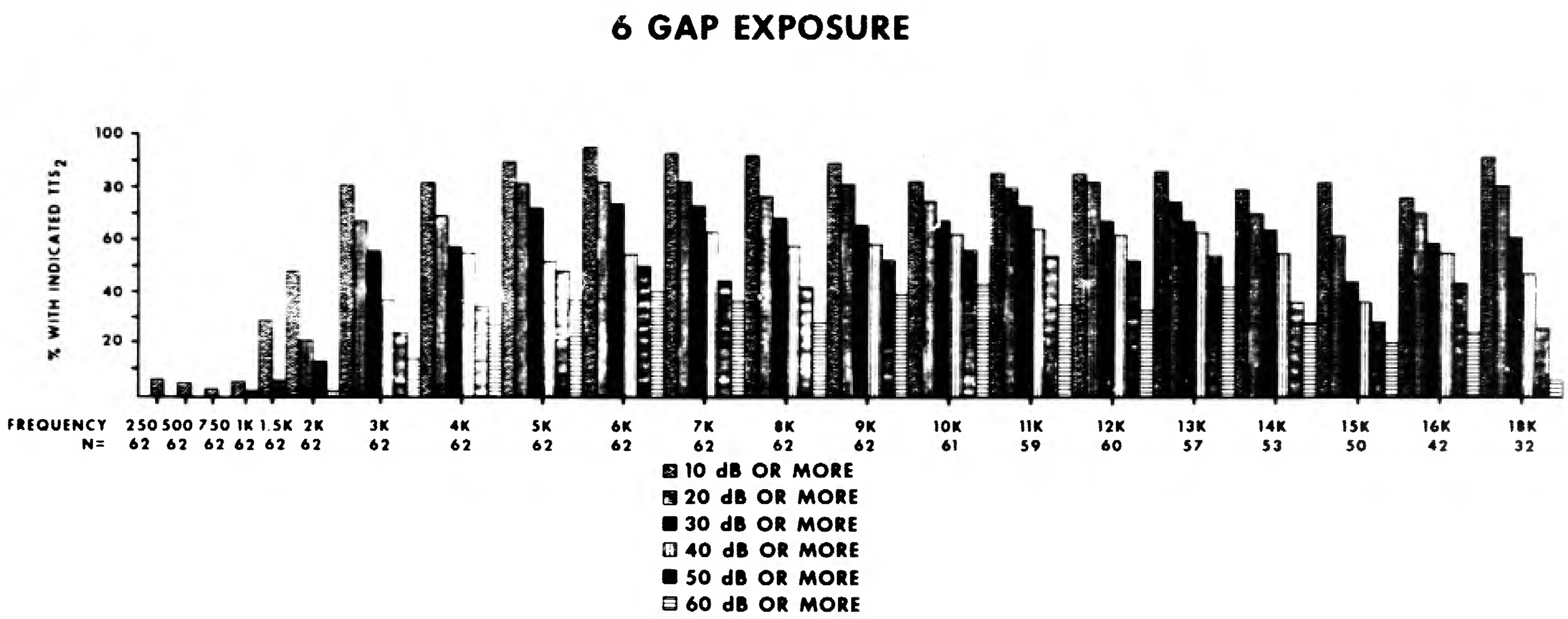

Fig. 5. Histogram showing number of individuals in entire group exhibiting criterion shifts following maximum six-gap exposure.

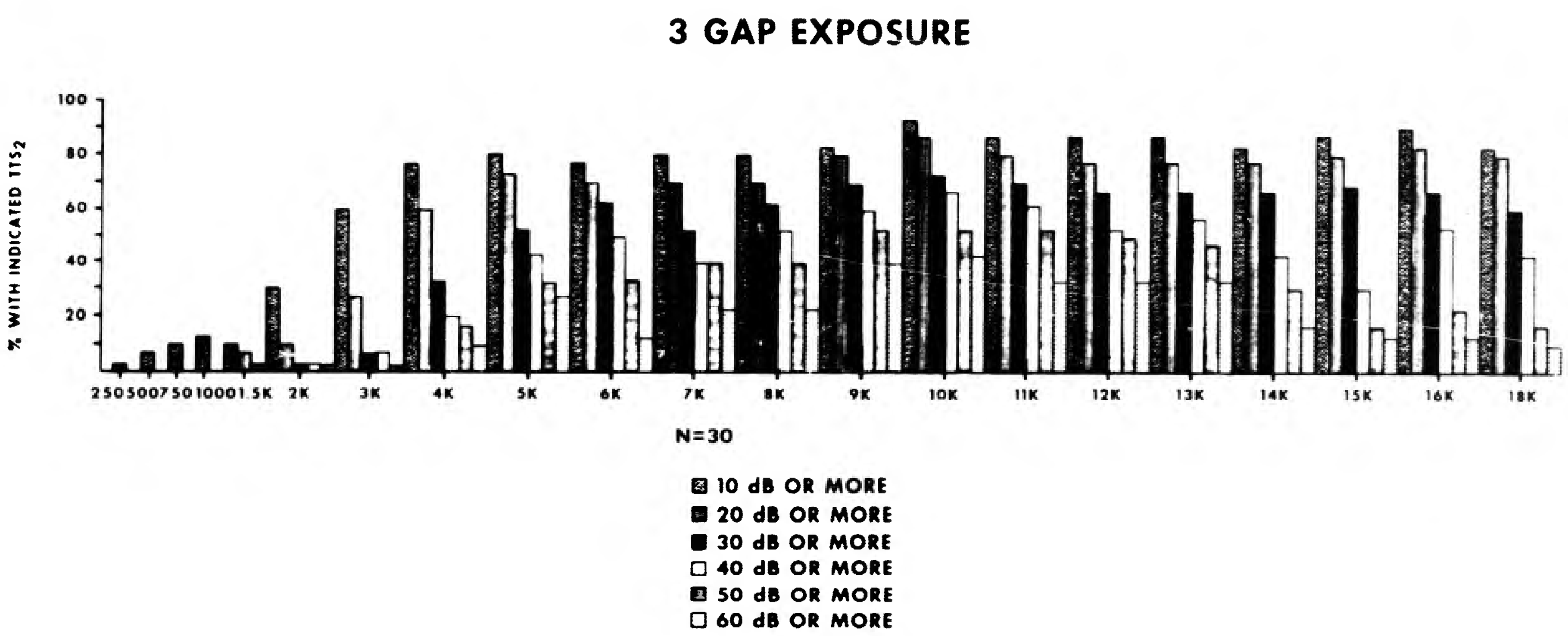

Fig. 6. Histogram showing number of individuals with measurable high frequency thresholds exhibiting criterion shifts following maximum three-gap exposure.

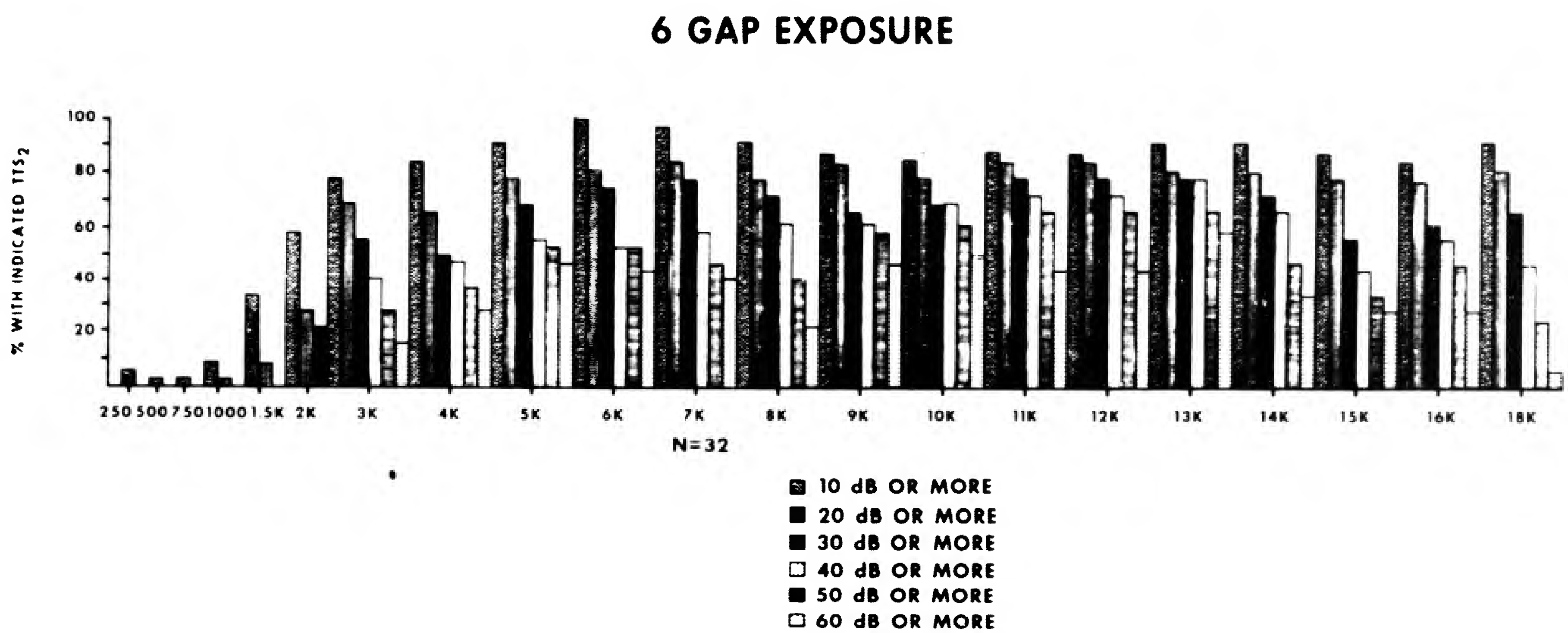

Fig. 7. Histogram showing number of individuals with measurable high frequency thresholds exhibiting criterion shifts following maximum six-gap exposure.

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13 ABSTRACT

Human Ss were exposed to a series of impulses of variable duration. Pre- and post-exposure hearing was examined to determine the differential effect of pulse duration on temporary threshold shift. An apparently linear duration effect was observed. ~~(U)~~

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