To the Graduate Council:

I am submitting herewith a dissertation written by William Scott Wood, III, entitled, "Effects of Three Noise Exposure Patterns with Equivalent Sound Energy on the Auditory System of Chinchilla." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Doctor of Philosophy, with a major in Speech and Hearing Science.

David M. Lipscomb, Major Professor

We have read this dissertation
and recommend its acceptance:

Accepted for the Council:

Vice Chancellor
Graduate Studies and Research

4

EFFECTS OF THREE NOISE EXPOSURE PATTERNS WITH EQUIVALENT SOUND ENERGY ON THE AUDITORY SYSTEM OF CHINCHILLA

A Dissertation

Presented for the

Doctor of Philosophy

Degree

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ABSTRACT

Review of the literature concerned with the equal energy hypothesis and the use of equivalent sound level as a descriptor for assessing oto-hazardous noise exposures was found to lack information regarding long-term noise exposures which simulated a 40-hour work-week schedule. The purpose of this study was to investigate the effects upon the chinchilla's auditory system of three noise exposure patterns with equivalent 24-hour sound levels (Leq_{24}).

Three groups of six animals each were exposed to a one-third octave band noise, centered at 4.0 kHz and set to achieve an Leq_{24} of 85 dB. Group C received a continuous 8-hour exposure of 90 dBA. Groups E and F had time-varying 8-hour exposures such that their mean high sound levels and durations were 105 dBA for 15 minutes and 94.1 dBA for 4 hours, respectively. A 6-month exposure schedule (consisting of 27 weeks of 5-day 8-hour exposures and 2-day, 24-hour quiet periods) was used.

Auditory thresholds were measured by averaging electrical responses from the brain stem elicited by tone bursts. Temporary threshold shifts after the first, fifth, and final 8-hour exposures revealed no statistically significant differences among groups. Threshold shifts measured 30 days after the last exposure (permanent threshold shifts) indicated a statistically significant difference among the three exposure groups for the 4.0 kHz stimulus.

After final auditory thresholds were measured, animals were decapitated. Cochleas were dissected by the surface preparation technique and auditory sensory cell damage was assessed by interference-contrast

microscopy. Results indicated a statistically significant difference for the mean percent of missing hair cells among exposure groups. In addition, there appeared to be no relationship between the percent of missing hair cells for specific regions and the amount of permanent threshold shift for frequencies primarily stimulating those regions.

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CHAPTER I

INTRODUCTION

Noise overexposure, if sustained, can result in damage in the organ of Corti. Specific loci of this damage are sensory cells, supportive cells, and, secondarily, neural fibers (Horton, 1934; Lurie, et al., 1944; Eldredge, et al., 1958; Ades, et al., 1974; and Lipscomb, et al., 1977). Frequent results of severe noise overexposure are widespread sensory cell damage and severely reduced auditory sensitivity (Miller, et al., 1971; Lim and Melnick, 1971; Bredberg, 1973; Ades, et al., 1974; Hunter-Duvar and Bredberg, 1974; Lipscomb, et al., 1977; and Ward, 1978). Whether sensory cell damage is or is not well correlated with auditory sensitivity, the damage (severe or lesser degree) is attributable to the complex interaction of the stimulus' intensity, spectrum, and duration.

It has been demonstrated that reduction of intensity and lengthening of duration for the same stimulus spectrum results in similar degrees of sensory cell damage (Eldredge, et al., 1958). Also, the region of damage in the cochlea varies in accordance to the spectrum of the stimulus, with the greatest damage appearing one-half to one octave above the stimulus' center frequency (Davis, et al., 1950).

Noise overexposure can result from either a steady sound level or a varying sound level of noise if the exposure is long or repeated enough. For the purpose of this study, definitions for steady and non-steady noise are provided by American National Standards Institute, 1973:

1. Steady noise is a noise with the negligible small fluctuations of the level within the period of observance (p. 53).

2. Nonsteady noise is a noise with or without audible tones, for which the level varies substantially during the period of observation (p. 32).

Nonsteady noise has been classified as fluctuant, intermittent, impact, or impluse (Goldstein, 1978). The principle feature by which nonsteady noise is characterized is the variation in the sound pressure level (SPL) within an observation period. Fluctuant noise is a nonsteady noise whose overall level changes but never equals the environment's ambient level during an observation period. An example of fluctuant noise is a circular saw which is turned on and then is used to cut through various thicknesses of wood. As the blade is placed under the various loads, the sound level fluctuates according to the load.

Intermittent noise is characterized by levels which continually exceed and return to the ambient level during the observation period. In the case of the circular saw, turning the saw on followed by turning it off is an example of intermittent noise. It can also be inferred from the above definition that a worker's exposure to a circular saw involves a combination of both fluctuant and intermittent noise.

The remaining two types of nonsteady noise (impact and impulse) are characterized by a rise time to peak intensity of not more than 35 ms and a duration less than 0.5 s (OSHA, 1974). Impact and impulse noise, however, are not under consideration in this study.

In noise measurement the range and sizes of the magnitudes encountered, in absolute units (watts), are extremely large--about one-billion-billion to one (Peterson and Gross, 1972). The immense range and sizes of these magnitudes are not easily handled during everyday use and are converted for convenience into decibels (dB).

Decibels are dimensionless and are expressed as logarithmic ratios of measured magnitudes to an accepted standard, referent magnitude. With sound energy, the referent magnitude (I_0) is 1×10^{-12} watt (Small, 1973). Due to the nature of logarithms to the base ten ($\log_{10}$), ratios of two or one-half equate to +0.3010 or -0.3010, respectively. In acoustics, the formula is applied as follows:

$$\begin{aligned} dB &= 10 \log_{10} I/I_0 \\ &= 10 \log_{10} \frac{2 \times 10^{-12}}{1 \times 10^{-12}} \text{ watt} \\ &= 10 \log_{10} 2 \\ &= 10 \times 0.3010 \\ &= 3.0 \text{ dB} \end{aligned}$$

As can be observed, a two-fold increase results in a 3 dB increase; or, as could be calculated, a halving results in a 3 dB decrease. This doubling and halving will result in a respective 3 dB increase or decrease for any type of magnitude, including time.

If one arbitrarily sets a referent time frame (T_0) of 24 hours and has two different measured time values (T_1 and T_2), 12 hours and 48 hours, for example, the ratio between the referent and measured magnitudes is expressed in dB exactly as the sound energy was. The dB values for T_1/T_0 and T_2/T_0 would be -3 dB and +3 dB, respectively. This universal application of logarithms provides an easy technique of combining several types of magnitudes within one scale.

In some noise overexposure studies, such as studies concerned with the equal energy hypothesis (EEH), logarithms are used to report the product of sound energy and duration of exposure in dB. This application may be observed in the following example.

Given $I_0 = 1 \times 10^{-12}$ watt

$I_1 = 1 \times 10^{-2}$ watt

$T_0 = 24$ hours

$T_1 = 2$ hours

$$dB = 10 \log_{10} \frac{I_1}{I_0} + 10 \log_{10} \frac{T_1}{T_0}$$

$$= 10 \log_{10} \frac{1 \times 10^{-2} \text{ watt}}{1 \times 10^{-12} \text{ watt}} + 10 \log_{10} \frac{2 \text{ hours}}{24 \text{ hours}}$$

$$= 10 \log_{10} [(1 \times 10^{10})(0.083)]$$

$$= 10 \log_{10} (8.3 \times 10^{8})$$

$$= 10 \times 8.919$$

$$= 89.2 \text{ dB}.$$

The result is an easily read index which can be used to compare noise exposure from one study to another.

In noise exposure studies, it is easier to measure the sound pressure than the sound energy of the sound source. The sound energy then can be indirectly obtained from the sound pressure measure. This is possible due to the physical characteristics of the medium through which sound waves must travel. The density of the medium is the primary characteristic which influences the sound wave's energy. The medium's density times the velocity of the sound wave provides the medium's characteristic impedance (CZ) (Green, 1976). Assuming an ideal acoustic environment, the sound energy propagates as a progressive plane wave (Green, 1976). Accepting this ideal makes it possible to relate the sound energy (I) to the square of the sound pressure (P^2) divided by CZ. By substituting the equivalents in the dB equation, one can derive the sound pressure expressed in dB.

$$I = P^2/CZ$$

$$I_o = P_o^2/CZ$$

$$dB = 10 \log_{10} I/I_o$$

$$= 10 \log_{10} \frac{P^2/CZ}{P_o^2/CZ}$$

$$= 10 \log_{10} P^2/P_o^2$$

$$= 10 \log_{10} (P/P_o)^2$$

$$= 10 \times 2 \log_{10} P/P_o$$

$$= 20 \log_{10} P/P_o$$

This difference ($10 \log_{10} I/I_o$ versus $20 \log_{10} P/P_o$) is due to sound energy being spread over an area.

Sound levels experienced in noise environments are most easily measured with a sound level meter. A sound level meter provides the SPL of the measured sound. Sound pressure level, as shown before, is 20 times the logarithm to the base 10 of the ratio of the pressure of a sound to a reference pressure, 20 μPa (ANSI, 1973) and is reported in dB. Several descriptors can be applied to SPL of which two--A-weighted level, expressed as dBA; and equivalent sound level--are important in this study.

The A-weighted level is obtained from a sound level meter using the A-weighted network. This network provides a differential attenuation across frequency which shadows the loudness level contour of the human ear at 40 phons (Peterson and Gross, 1972) and is similar to the perceived noise level (Kryter, 1970). National (OSHA, 1970) and international (ISO,

1971) standards have recommended using the A-weighted network when measuring noise levels for hearing conservation programs.

Equivalent sound level is measured in dBA and accounts for the duration of the sound. It is expressed as Leq and is the average of the total acoustic energy measured during an observation period, such as 24 hours (EPA, 1973).

Sound energy impinging on the auditory mechanism is a dynamic stimulus involving complex interactions of steady and nonsteady noises. These interactions can result in an infinite combination of sound levels and durations. Though each type of noise has been investigated separately--with noise exposure criteria evolving for only steady, intermittent, and impulse noise (Kryter, et al., 1966; NAS-NRC, 1968; and OSHA, 1970)--accepted criteria providing for the interaction of these noises do not exist. Experiments reported in the literature have been designed to investigate each noise type separately as well as the combination of steady and impulse noise. There have been no experiments exploring the effects of the combined exposure to steady, intermittent, and fluctuant noise for a typical work-week schedule. This combined exposure for a typical work-week schedule for a six-month period of time and its effect upon the auditory mechanism of the chinchilla was the subject of this dissertation.

The purpose of this study was to compare audiometric and histologic measures obtained from three groups of chinchilla with each group receiving the same total sound energy, but with different temporal distributions in an eight-hour period. The null hypotheses to be tested and the questions to be answered were as follows:

1. Threshold shifts as measured during the exposure sessions do not differ significantly among the three groups receiving different exposure patterns.
2. Threshold shifts as measured 30 days after the exposure period to not differ significantly among the three groups receiving different exposure patterns.
3. The amounts of hair cell damage do not differ significantly among the three groups receiving different exposure patterns.
4. Does the pattern of hair cell damage differ among the three groups receiving different exposure patterns?
5. Do the thresholds between the exposed and nonexposed chinchilla differ?
6. Is there a relationship between hearing levels and hair cell damage for the noise-exposed chinchilla?

CHAPTER II

REVIEW OF LITERATURE

Investigations using potentially hazardous stimuli to humans typically have used lower animals as experimental subjects. Studies concerned with noise overexposure and its effects upon hearing sensitivity and organ of Corti have most often used guinea pigs (Horton, 1934; Davis, et al., 1935; Lurie, et al., 1944; Eldredge and Covell, 1958; Eldredge, et al., 1959; Abrams, 1980; and Erlandsson, et al., 1980), cats (Miller, et al., 1963, and Elliot and McGee, 1965), and more recently, chinchilla (Mills and Talo, 1972; Mills, et al., 1973; Lipscomb, et al., 1977; Woodford, 1977; and Burdick, et al., 1978). Three key advantages in using lower animals, instead of humans, to study the effects of noise exposure are:

1. One does not need to be concerned with permanently damaging hearing sensitivity.
2. One can obtain access to the sensory tissue relatively quickly and at pre-determined times.
3. In the case of long-term data acquisition, one can better control experimental variables as well as possible contaminating variables.

General Noise Studies

Several studies concerned with noise overexposure are presented in Table 1. These studies did not use Leq, however. The Leq data presented were calculated by this author using the SPL values since the

Table 1. Previous Experiments Concerned with Noise Exposure.

Investigator and Year (Animal)	Stimulus in kHz	Level in dB	Duration	Leq_{24} in dB	Leq_x in dB	TTS in dB	PTS in dB	Damage
Horton, 1934 (G)	1.0	132	10.0 h	128	128	NR	50	NR
Davis, et al., 1935 (G)	2.4	128	15.0 h	93	128	NR	30	+
Lurie, et al., 1944 (G)	0.5	141	3.0 m	114	141	NR	NR	+
	1.0	141	3.0 m	114	141	NR	NR	+
	2.0	139	3.0 m	112	139	NR	NR	+
Smith, 1947 (G)	0.3	134	4.0 m	NA	134	NR	25	-
	1.0	134	4.0 m	NA	134	NR	25	-
	5.0	134	4.0 m	NA	134	NR	25	-
Spoendlin, 1962 (G)	Noise	125	30.0 m	108	125	NR	0	-
	0-10.0	115	5.0 m	90	90	NR	0	-
	0-10.0	100	5.0 m	76	76	NR	0	-
Miller, et al., 1963 (C)	Noise	115	7.5 m	92	89	45	7	NR
	0.3-3.0	105	15.0 m	85	81	37	0	NR
	0.3-3.0	103	15.0 m	83	79	NR	2	NR
	0.3-3.0	115	15.0 m	95	76	NR	11	+
	0.3-3.0	115	30.0 m	98	79	NR	20	+
	0.3-3.0	115	2.0 h	104	85	NR	51	+
	0.3-3.0	115	8.0 h	110	91	NR	52	+
Beagley, 1965 (G)	0.5	128	20.0 m	109	109	51	NR	+
	0.5	128	20.0 m	109	98	51	22	+
	0.5	128	40.0 m	112	112	NR	NR	+

Table 1. (continued)

Investigator and Year (Animal)	Stimulus in kHz	Level in dB	Duration	Leq_{24} in dB	Leq_x in dB	TTS in dB	PTS in dB	Damage
Peters, 1965 (Ch)	1/2 OB @ 1.9	90	40.0 m	74	72	NR	0	NA
	OB @ 3.1	90	110.0 m	79	74	NR	0	NA
	OB @ 3.1	80	110.0 m	69	73	NR	0	NA
	OB @ 3.1	70	110.0 m	62	72	10	0	NA
Stockwell, et al., 1969 (G)	1.0	130	60.0 m	116	100	NR	NR	+
	1.0	130	4.0 h	122	106	NR	NR	+
	2.0	130	60.0 m	116	100	NR	NR	+
	2.0	130	4.0 h	122	106	NR	NR	+
	4.0	130	60.0 m	116	100	NR	NR	+
	1.0	150	60.0 m	136	120	NR	NR	+
	1.0	150	4.0 h	142	126	NR	NR	+
	2.0	150	60.0 m	136	120	NR	NR	+
	2.0	150	4.0 h	142	126	NR	NR	+
Spoendlin, 1971 (G)	Noise	138	1.0 m	106	138	NR	NR	+
	0-10.0	130	3.0 m	103	130	NR	NR	+
	0-10.0	130	60.0 m	116	130	NR	NR	+
	0-10.0	130	60.0 m	116	124	NR	NR	+
	0-10.0	130	60.0 m	116	122	NR	NR	+
	0-10.0	130	60.0 m	116	116	NR	NR	+
	0-10.0	130	60.0 m	116	111	NR	NR	+
	0-10.0	130	60.0 m	116	110	NR	NR	+
	0-10.0	130	60.0 m	116	108	NR	NR	+
	0-10.0	130	60.0 m	116	98	NR	NR	+
	0-10.0	125	60.0 m	111	125	NR	NR	+
	0-10.0	120	60.0 m	106	120	NR	NR	+
	0-10.0	115	60.0 m	101	115	NR	NR	+
	0-10.0	110	2.0 h	99	110	NR	NR	+
	0-10.0	100	24.0 h	100	100	NR	NR	+

Table 1. (continued)

Investigator and Year (Animal)	Stimulus in kHz	Level in dB	Duration	Leq_{24} in dB	Leq_x in dB	TTS in dB	PTS in dB	Damage
Miller, et al., 1971 (Ch)	OB @ 0.4	100	7.0 d	100	93	40	3	+
Carder and Miller, 1972 (Ch)	OB @ 0.5	85	7.0 d	85	78	30	0	NR
	OB @ 0.5	75	7.0 d	75	76	5	0	NR
	OB @ 0.5	95	7.0 d	95	84	48	0	NR
	OB @ 0.5	85	21.0 d	85	82	30	0	NR
	OB @ 4.0	65	7.0 d	65	82	30	0	NR
Mills and Talo, 1972 (Ch)	OB @ 4.0	57	6.0 d	57	57	20	0	NR
	OB @ 4.0	65	6.0 d	65	63	30	0	NR
	OB @ 4.0	72	6.0 d	72	68	40	0	NR
	OB @ 4.0	80	6.0 d	80	75	53	0	NR
Benitez, et al., 1972 (Ch)	OB @ 0.5	95	48-72 h	95	95	NR	NR	NR
	OB @ 0.5	95	48-72 h	95	90-94	NR	NR	NR
	OB @ 0.5	95	48-72 h	95	92-93	NR	NR	NR
Mills, et al., 1973 (Ch)	OB @ 4.0	57	3.0 d	57	57	NR	15	NR
	OB @ 4.0	72	3.0 d	72	62	NR	15	NR
	OB @ 4.0	80	3.0 d	80	68	NR	20	NR
Mills, 1973 (Ch)	OB @ 4.0	80	9.0 d	80	74	50	0	NR
	OB @ 4.0	86	9.0 d	86	80	63	10	NR
	OB @ 4.0	92	9.0 d	92	86	75	25	NR
	OB @ 4.0	98	9.0 d	98	92	86	35	NR

Table 1. (continued)

Investigator and Year (Animal)	Stimulus in kHz	Level in dB	Duration	Leq_{24} in dB	Leq_x in dB	TTS in dB	PTS in dB	Damage
Ades, et al., 1974 (G)	4.0	120	1.0 h	106	NR	NR	5	+
	4.0	125	1.0 h	111	NR	NR	35	+
	4.0	130	1.0 h	116	NR	NR	35	+
Clark, et al., 1974 (Ch)	Noise	123	15.0 m	103	95	94	75	+
	0.7-2.8	123	15.0 m	103	89	94	55	+
Hunter-Duvar and Bredberg, 1974 (G)	1.0	120	12.0 m	99	84	NR	45	+
	OB @ 1.6	123	15.0 m	103	88	NR	15	+
Mills, 1976 (Ch)	OB @ 4.0	80	90.0 d	80	79	58	28	NR
Woodford, 1977 (Ch)	OB @ 4.0	80	4.0 d	80	76	36	0	NR
Lipscomb, et al., 1977 (Ch)	Noise 0.63-4.0	110	8.0 h	105	93	88	32	+
Burdick, et al., 1978 (Ch)	OB @ 0.63	100	3.0 d	100	90	0	-8	NR
	OB @ 0.63	110	3.0 d	110	100	4	0	NR
	OB @ 0.63	120	3.0 d	120	110	20	2	NR
	OB @ 1.0	75	3.0 d	75	66	20	0	NR
	OB @ 1.0	85	3.0 d	85	76	43	0	NR
	OB @ 1.0	95	3.0 d	95	86	60	8	NR

Table 1. (continued)

Investigator and Year (Animal)	Stimulus in kHz	Level in dB	Duration	Leq_{24} in dB	Leq_x in dB	TTS in dB	PTS in dB	Damage
Erlandsson, et al., 1980 (G)	1.33	102	6.0 h	96	81	NR	NR	+
	1.33	108	6.0 h	102	87	NR	NR	+
	1.33	114	6.0 h	108	93	NR	NR	+
	1.33	117	6.0 h	111	96	NR	NR	+
	1.33	120	6.0 h	114	99	NR	NR	+
	3.85	102	6.0 h	96	81	NR	NR	+
	3.85	108	6.0 h	102	87	NR	NR	+
	3.85	114	6.0 h	108	93	NR	NR	+
	3.85	117	6.0 h	111	96	NR	NR	+
	3.85	120	6.0 h	114	99	NR	NR	+

Key: NR - not reported
NA - not applicable
OB - octave band of noise followed by @ indicating the center frequency of the noise band
G - guinea pig
C - cat
Ch - chinchilla

acquisition of dBA values was not possible. Included are: animal (s); type of stimulus (tone or noise band); stimulus level in SPL; duration of exposure in days (d), hours (h), or minutes (m); calculated Leq_{24}; an estimated Leq (by this author)--including recovery--for the duration of the experiment (Leq_x); the amount of temporary and permanent threshold shift (TTS and PTS, respectively) for 4.0 kHz, 6.0 kHz, 8.0 kHz; and whether (+) or not (-) histologic damage to the organ of Corti was observed. An Leq_{24} smaller than Leq_x means the animal was terminated or the experiment ended before a 24-h period had elapsed. If Leq_{24} is greater than Leq_x, it indicates the animal was terminated or the experiment ended after the 24-h period. This table demonstrates the confusing array of experimental variables among these studies, most of which are not replicated. In addition, it should be kept in mind that these studies used different species of animals and tested for TTS at different times after exposure (2 m, 4 m, 11 m, 15 m, or 60 m). Most authors did not report the ambient levels during the recovery periods. Since the ambient levels were not reported, Leq_x was based on an assumed ambient SPL of 60 dB, a value measured in the vivarium at the University of Tennessee.

Although the studies differed widely, general conclusions regarding noise overexposure and its effects on the auditory mechanism can be made:

1. The greater the intensity of a stimulus and/or the longer the exposure, the more extensive the histologic damage and the larger the increase in threshold shift (Miller, et al., 1963; and Carder and Miller, 1972).
2. High frequency tones and high frequency narrow bands of noise damage the organ of Corti more in the basal half of the cochlea (Lurie, et al., 1944; and Stockwell, et al., 1969),

whereas low frequency stimuli cause more damage in the apical half of the cochlea (Lurie, et al., 1944; Miller, et al., 1963; and Stockwell, et al., 1969). More widespread damage occurs for low frequency than for high frequency stimuli (Carder and Miller, 1972).

3. The greater the electrophysiologic threshold shift, the greater the probability of related histologic damage, especially when the threshold shift equals or exceeds 80 dB (Davis, et al., 1935; and Eldredge, et al., 1958).
4. There is a critical SPL (123 dB) which mandates histologic damage (Spoendlin, 1971 and 1976; and Erlandsson, et al., 1980).
5. Decreased histologic variation between an animal's ears for less intense levels and longer exposures is seen (Spoendlin, 1976).
6. If an animal is exposed long enough, a threshold shift limit will be achieved. This limit, for specific exposure parameters, is called an asymptotic threshold shift (ATS) (Carder and Miller, 1972; and Mills, et al., 1973).
7. For a given stimulus level, the ATS will be the same whether an animal is exposed from baseline (i.e., no previous exposure), a lower pre-existing ATS, or a higher pre-existing ATS, providing PTS has not occurred (Mills and Talo, 1972).
8. Auditory electrical responses have demonstrated that ATS is a peripheral (cochlear) phenomenon (Benitez, et al., 1972).
9. Auditory electrical responses are adequate measures of ATS (Woodford, 1977), are generally consistent with behavioral

audiometric thresholds (Benitez, et al., 1972), and can be better correlated to histologic damage than behavioral audiometric thresholds (Benitez, et al., 1972; and Eldredge, et al., 1973).

10. The relationship of histology to audiometric data for noise-exposed animals has not been resolved as evidenced by studies supporting high correlations (Miller, et al., 1963; Hunter-Duvar and Bredberg, 1974; and Ryan and Dallos, 1975) and by studies revealing a poor correlation (Mills, et al., 1970; Ward and Duvall, 1971; Eldredge, et al., 1973; Lipscomb, et al., 1977; and Abrams, 1980).

Although the majority of these studies have not reported exposures in Leq values, a few more recent studies have used equal energy, upon which Leq is based. As with the studies presented in Table 1, replication of the various parameters has not been evident.

Equal Energy Studies

An early investigation of the EEH was conducted by Eldredge and Covell (1958). They studied the effects of reciprocal changes of duration and intensity for a noise overexposure which caused the same degree of threshold shift in the guinea pig. Two stimuli, a 0.5 kHz tone and a 0.3-0.6 kHz band of noise, were used. Tonal exposures consisted of six durations ranging from 1.0 to 160.0 m and ten SPLs ranging from 112 to 144 dB. Noise exposures consisted of six durations ranging from 5.0 to 320.0 m and four SPLs ranging from 115 to 133 dB. The criterion measure was a 40 to 60 dB threshold shift as measured with the cochlear microphonic.

Eldredge and Covell (1958) concluded that tonal exposures caused threshold shifts which followed the EEH for durations between 5.0 m and 160.0 m. Threshold shifts caused by the band of noise were related more strongly to the peak pressure of the stimulus and not the exposure energy. This study was followed by one employing intermittent exposures (Eldredge, et al., 1959).

To investigate the effects of intermittent exposures, Eldredge et al. (1959), used a 0.5 kHz stimulus tone having total on-times of 5.0 m, 40.0 m, and 80.0 m for SPLs of 120 dB, 123 dB, 127 dB, and 133 dB. The on- and off-time in each cycle was 20.0 ms and 51.0 ms, respectively.

Results were similar to the Eldredge and Covell (1958) study in that equal exposure energy yielded equal threshold shifts. In addition, the degree of damage to the organ of Corti was similar for the intermittent and continuous exposures (Eldredge, et al., 1959). The interpretation of these results to daily occupational exposure is difficult because of the tonal nature of some of the exposures, the intense levels of the stimuli, and the brevity of the intermittent exposures.

Since only a small proportion of occupational noise sources exceed sound levels of 115 dBA, it is apparent that the levels used in the above studies were overly intense to allow generalization to the workplace. Also, the above studies have been primarily concerned with equal exposure; that is, they were concerned only with sound energy impinging upon the auditory system during the exposure rather than within a 24-h period. This is a real concern when one considers

acoustical variability in the typical work situation--eight hours a day, five days a week, for a number of years.

The effects of intermittent exposures was also investigated by Miller, et al. (1963). Miller, et al. (1963), specifically studied the effects of interspersed quiet periods on the hearing sensitivity of cats exposed to a band of noise ranging from 0.9 to 9.0 kHz. This noise was presented at a SPL of 115 dB for a total on-time of 2.0 h. Quiet periods (ambient level undefined) of various durations were interspersed in the exposures thereby presenting three on-off exposure patterns and one continuous exposure. The four groups of cats (I, II, III, and IV) and their respective exposure patterns are presented in Table 2.

Table 2. On-Off Exposure Patterns (Miller, et al., 1963) and Calculated Leqs by Group.

Group	Duration of Exposure Cycle		Repetitions	Total Duration in Hours			Leq_y in dB	Leq_z in dB
	On	Off		On	Off	On+Off		
I	2.0 h	0.0 m	1.0	2.0	0.0	2.0	115	115
II	7.5 m	52.5 m	16.0	2.0	14.0	16.0	115	106
III	7.5 m	5.8 h	16.0	2.0	94.0	96.0	115	98
IV	7.5 m	23.8 h	16.0	2.0	382.0	384.0	115	92

The duration of the exposure cycle is expressed either in hours (h) or minutes (m). The columns labeled Leq_y and Leq_z represent equivalent sound level for the total on-time only and for the total on+off-time (total cycle), respectively. These data were calculated by this

author. In calculating off-times, it was assumed that the ambient SPLs were 60 dB. As can be observed, all groups received equal exposure energy (Leq_y).

Results indicated that behaviorally measured threshold shifts decreased as the off-time increased with essentially no threshold shift occurring for an off-time of 23.8 h (Miller, et al., 1963). Threshold shifts at 2.0 kHz approximately one hour after the final exposure were greater than 70 dB for groups I and II, were about 40 dB for group III, and were less than 5 dB for group IV. Recovery occurred more rapidly for groups with smaller threshold shifts. After 84 d of recovery, persistent threshold shifts at 2.0 kHz were as follows: 50 dB for Group I, greater than 20 dB for group II, approximately 15 dB for Group III, and 0 dB for group IV. Miller, et al. (1963), further reported that histologic damage and behavioral thresholds were in agreement. It was concluded that interspersed quiet periods in an exposure reduce the persistent threshold shift, but if elimination of the persistent threshold shift is desired, then quiet periods between 6 h and 24 h are required.

This study is of interest when considering the two ways Leq can be presented--Leq_y and Leq_z. In this regard, it appears that due to unequal threshold shifts Leq_y is not appropriate when using threshold shift as a criterion measure. However, when Leq is based upon the total cycle (Leq_z) one can observe a decrease in the value of Leq_z (see Table 2) which corresponds with the reported decrease in the threshold shift. This observation directs attention to which variable is important: the on-time of exposure or the level of exposure. Ward, et al. (1976), reported a sound level of 75 dBA to be a level which

effectively protects individuals from receiving TTS as well as the level which does not inhibit recovery from TTS. This level is called effective quiet (Ward, et al., 1976). For chinchilla, a pre-exposure ambient level of 40 dBA vs. 70 dBA resulted in less threshold shift.

If exposure above a critical level is the more important, then data reported by Mills and Talo (1972) have demonstrated that effective quiet for the chinchilla is lower than 57 dBA. Their results suggest that the effective quiet level should be considered when investigating EEH and effects of noise overexposure upon the auditory system. Thus far it has not. In such a consideration, a very complex level-duration pattern results. This complex pattern can be reduced to a single number descriptor, Leq, a distinct advantage in comparing studies.

Ward and Duvall (1971) were interested in the correlation between behavioral audiometric thresholds and gross and subtle cochlear sensory cell damage for chinchilla. Four experiments were designed: experiment I used an SPL of 123 dB for 2.0 h; experiment II used four exposures of equal energy with SPLs ranging from 114 dB to 123 dB and respective durations ranging from 4.0 h to 0.5 h; experiment III used an SPL of 114 dB for 2.0 h; and experiment IV used an SPL of 123 dB for 15.0 m. A 0.25 kHz to 16.0 kHz band of noise with its maximum energy between 1.0 kHz and 2.0 kHz served as the stimulus.

Exposure energies were equal within experiment II and between experiments III and IV. Ward and Duvall (1971) reported that after 40 d of recovery, PTSs for 1.0 kHz, 2.0 kHz, 4.0 kHz, and 8.0 kHz were 60 dB for experiment I, 40 dB for experiment II, less than 10 dB for experiment III, and were 0 dB for experiment IV. These results

present contradictory evidence. Equal energy in experiment II presented equal loss and similar damage, but equal energy between experiments III and IV did not.

Histology revealed the organ of Corti to be missing in the first two turns with the inner hair cells (IHC) normal in appearance and the outer hair cells (OHC) being occasionally distorted in the third turn for experiment I. These observations were similar for animals in experiment II, with the exception that more OHCs were damaged in the third turn.

Experiment III was unique in that the termination of the animals occurred at 4 m, 24 h, 7 d, 14 d, or 28 d after exposure. Histology revealed distorted OHCs in the first two turns for animals terminated at 4 m after exposure. Animals terminated 28 d after exposure had missing OHCs in the first two turns. The number of distorted OHCs was greater for animals killed 4 m post exposure than the number of missing OHCs for animals killed 28 d post exposure, suggesting some repair function occurring in the cochlea (Ward and Duvall, 1971). Ward and Duvall (1971) concluded from this study that different exposures of equal energy did not result in similar TTS or equal damage to the cochlea. With regard to this conclusion, the results reported by Ward and Duvall indicate that the EEH may not hold when a critical level-duration combination (123 dB for 15 m) is reached.

In a study using PTS as the criterion measure, Ward and Nelson (1971) provided evidence in support of the EEH. Four groups of chinchilla were exposed to a 0.7 kHz to 2.8 kHz band of noise equated in total energy: 114 dB for 4 h, 117 dB for 2 h, 120 dB for 1 h, and 123 dB for 0.5 h. These exposures were all greater than an exposure

which just produced a PTS (114 dB for 2 h). Results upon auditory thresholds at and above 2.0 kHz were similar, but below 2.0 kHz the EEH was not supported. Ward and Nelson (1971) summarized that EEH was ". . . tenable for determining equivalent single uninterrupted daily exposure to noise."

Dolan, et al (1976), using chinchilla, studied the effect of four different time patterns: A. one hour per day for eight days; B. one hour on and one hour off over a 15 h period; C. eight hours on; and D. one hour on. Noise passed through a 0.6 kHz to 2.0 kHz filter served as the stimulus for all animals. Five SPLs (114 dB, 117 dB, 120 dB, 123 dB, and 126 dB) were used for time patterns B and C; three SPLs (117 dB, 120 dB, and 123 dB) were used for time pattern D; and two SPLs (117 dB and 126 dB) were used for time pattern A. Behavioral threshold shifts and histological damage were criterion measures.

It was concluded that all exposures to 123 dB and 126 dB levels resulted in similar behavioral and histologic findings. For the 117 dB level as compared to the lower levels the steady exposure caused greater threshold shifts in the high frequencies and more extensive sensory cell damage in the basal half of the cochlea.

Weaknesses in the Dolan, et al. (1976), study were:

1. data concerning the growth and recovery of threshold shifts were not reported; and
2. time patterns and levels used did not approximate typical time patterns or levels as found in industry; i.e., an interaction of steady, fluctuant, and intermittent noise for eight hours a day, five days a week.

Saunders, et al. (1977), studied the effects of intermittent noise exposure upon the chinchilla's auditory system. An octave-band noise centered at 4.0 kHz served as the stimulus. Two groups of four chinchilla each were exposed to either SPLs of 57 dB, 65 dB, and 92 dB, or SPLs of 72 dB, 80 dB, and 86 dB. Exposures always proceeded from the lowest to highest values with a ten day minimum rest period between recovery of behavioral auditory thresholds and presentation of the successive exposures. The exposure schedule consisted of 6 h of exposure and 18 h of recovery for each of 9 d.

Asymptotic threshold shifts were reported to occur after the first or second day of exposure for all levels. Only the threshold shifts from SPL of 57 dB demonstrated complete recovery, while threshold shifts from SPLs of 86 dB and 92 dB exhibited incomplete recovery even after the ten day rest period.

In view of the purposes of this study, the Saunders, et al. (1977), study suffers the following shortcomings:

1. Contamination of threshold shift and recovery data due to the use of succeeding levels of noise exposure for the same animals. This is important in view of the results of Eldredge, et al. (1973), who reported that histologic damage can result even though behavioral thresholds demonstrate complete or near complete recovery. With regard to results of Saunders, et al. (1977), one cannot be assured that PTSs reported are solely attributable to exposure levels of 86 dB and 92 dB. It is possible that the PTSs were due to the combined effect of the higher and lower levels received by each group.

2. The effects of exposure to the combination of steady, fluctuant, and intermittent noise were not investigated.
3. Histologic data were not obtained.
4. The problem of long-term (six months) exposures and two-day recovery periods were not addressed; a work day or week schedule was not used.
5. Documentation of the ambient levels during the 18-h recovery period and the 10-d rest period was not provided.

A third study involving steady, intermittent, and fluctuant noise was reported by Hétu and Trémolière in 1977. Hétu and Trémolière (1977) investigated the effect of temporal distribution of sound energy upon the growth and recovery of TTSs in humans. Two groups of ten subjects (Ss) each were exposed to a broad-band noise with equivalent sound levels (96 dBA) in each of nine conditions.

Hétu and Trémolière (1977) reported that fluctuant and steady exposures with equivalent sound energy produced equal amounts of TTSs. Furthermore, TTSs were greater for steady noise exposures as compared to intermittent exposures even after 125 m of recovery.

Regarding the purposes of this study, Hétu and Trémolière's (1977) study had the following deficiencies:

1. Effects of a combined exposure to steady, intermittent, and fluctuant noise were not considered.
2. Long-term effects of their exposures were not addressed. This is important in light of Ward's 1970 study in which he used an eight-hour exposure to a band-passed noise of 1.4 kHz to 2.0 kHz to investigate TTSs. Exposures of this duration for levels of 85 dB resulted in TTSs which did not

fully recover after 16 h in quiet. They indicated that threshold shifts remaining after 16 h of quiet could play an important role in the development of PTS when repeated daily exposures are considered. Due to the brief total exposure time used by Hétu and Trémolière (1977), the effects of incomplete recovery upon repeated exposures were not studied.

3. The use of human Ss precludes the introduction of durations long enough or levels intense enough to cause PTSs. In addition, with human Ss, the acquisition of histologic data from the cochlea is impossible.
4. A typical work schedule was not used.

Erlandsson, et al. (1980), investigated the relationship between noise exposure and inner ear damage. Several levels used were comparable to those measured in occupational settings. Sound levels and/or durations of exposure were varied such that in some of the experiments the EEH was involved. Sound stimuli used were dependent upon the specific experiment and involved continuous pure-tones, impulse sounds, or a combination of the continuous pure-tones and impulse sounds. Since the present study is concerned with non-impulse noise, only the experiments involving the tonal stimuli are reviewed.

In one aspect of their study two tones (1.3 kHz and 3.8 kHz) were presented to five groups of guinea pigs for six hours at five SPLs ranging from 102 dB to 120 dB. Histology revealed losses to OHCs for all groups. Groups receiving higher SPLs also had IHC losses and neural degeneration. The OHC damage pattern for both tonal stimuli was in good agreement with the frequency map of the guinea pig's cochlea; i.e.,

the 1.0 kHz to 3.5 kHz region for the 1.3 kHz stimulus and the 4.0 kHz to 8.0 kHz region for the 3.8 kHz stimulus. For either stimulus, as SPL increased the percent damage of OHC increased and spread towards the apical portion of the cochlea. In addition, individual variation in percent damaged OHCs increased among animals. When the total percentage of OHCs was analyzed, it was revealed that damage to the cochlea was constant through exposures to 114 dB and sharply increased for exposures to 117 dB and 120 dB.

This result suggests the existence of a critical value above 114 dB for increased damage. Furthermore, this increased damage is dependent on frequency. For the 1.3 kHz stimulus, SPLs causing an increase in damage ranged between 114 dB and 117 dB. For the 3.8 kHz stimulus, the SPLs causing an increase in damage ranged from 117 dB to 120 dB.

When the OHC damage from the two stimuli (equal in energy) for SPLs above 114 dB were observed, a difference in the amount of damage was revealed. The higher frequency stimulus yielded more damage. The authors concluded that the use of the EEH does not appear to be accurate unless the frequency of the stimulus is considered. As with most other studies reviewed, this specific one dealt only with the energy of exposure and did not consider a typical work schedule.

Summary

For the studies reviewed, information concerning the effects of long term intermittent noise overexposure upon the auditory mechanism is lacking. There is a paucity of information concerning the effects of noise overexposure upon the cochlea for temporal patterns which

approximate a typical 40 h per week work schedule. And, finally, there has not been a systematic investigation of Leq_{24} as a means of determining the effects of noise overexposure upon the auditory mechanism.

CHAPTER III

PROCEDURES

The following procedures were used to investigate the effects of three noise exposure patterns with equivalent sound levels upon the auditory mechanism.

Subjects

Twenty-seven standard gray chinchilla (chinchilla langeria) in good health and between 9 months and 12 months of age were selected from the Noise Research Laboratory's chinchilla population. The chinchilla was chosen for this thesis for the following reasons:

1. Its auditory sensitivity and frequency range are similar to that of the human (Miller, 1970).
2. It is relatively healthy and free from middle ear disease (Eldredge, et al., 1973).
3. It has been used extensively in recent noise exposure studies (Peters, 1965; Carder and Miller, 1972; Dolan, et al., 1976; and Saunders, et al., 1977).
4. Its thin shelled bulla permits relatively easy access to the middle ear cavity (Eldredge, 1965; Strother, 1967; Hunter-Duvar and Bredberg, 1974) and cochlea (Ades, et al., 1974; and Lipscomb, et al., 1977).
5. Auditory evoked responses (Rothenberg and Davis, 1967; and Woodford, 1977) and early auditory evoked brain stem responses (Benitez, et al., 1972) have been measured.

6. Information concerning the SPL differences at the eardrum of the chinchilla and free field has been reported by von Bismark (1967).

From the 27 chinchilla, three chinchilla were maintained as replacements should some chinchilla die. Of the remaining 24 chinchilla, each was randomly assigned to one of four groups. Group A served as the non-noise exposed control group, while groups C, E, and F served as experimental groups. Binaural hearing was maintained through the course of the experiment.

Auditory Threshold Testing

All chinchilla were tested electrophysiologically by means of an auditory evoked response (AER) technique. The AER instrumentation is diagrammed in Figure 1. A tone burst program was written for a mini-micro-processor (E & L Instruments, Incorporated, Model MMD-1/MI 133). The processor interlocked a tone generator, the scan of a signal averager, the sweep of an oscilloscope, and controlled the on-off cycle of the test stimulus. A Wave-Tek digital wave generator (Model 159) served as the tone generator whose frequency was monitored with a GenRad electronic counter (Model 1192). The processor also controlled tone burst polarity, rise-, and fall-time (1 ms). On-time and off-time were programmed for 10 ms and 90 ms, respectively. In its "on" phase the tone burst passed to the transducer, a Koss electrostatic earphone (Model ESP-9), through a Hewlett-Packard attenuator (Model 350C), and power amplifier (McIntosh, Model 250). The acoustic spectra of these tone bursts are presented in Figure 2.

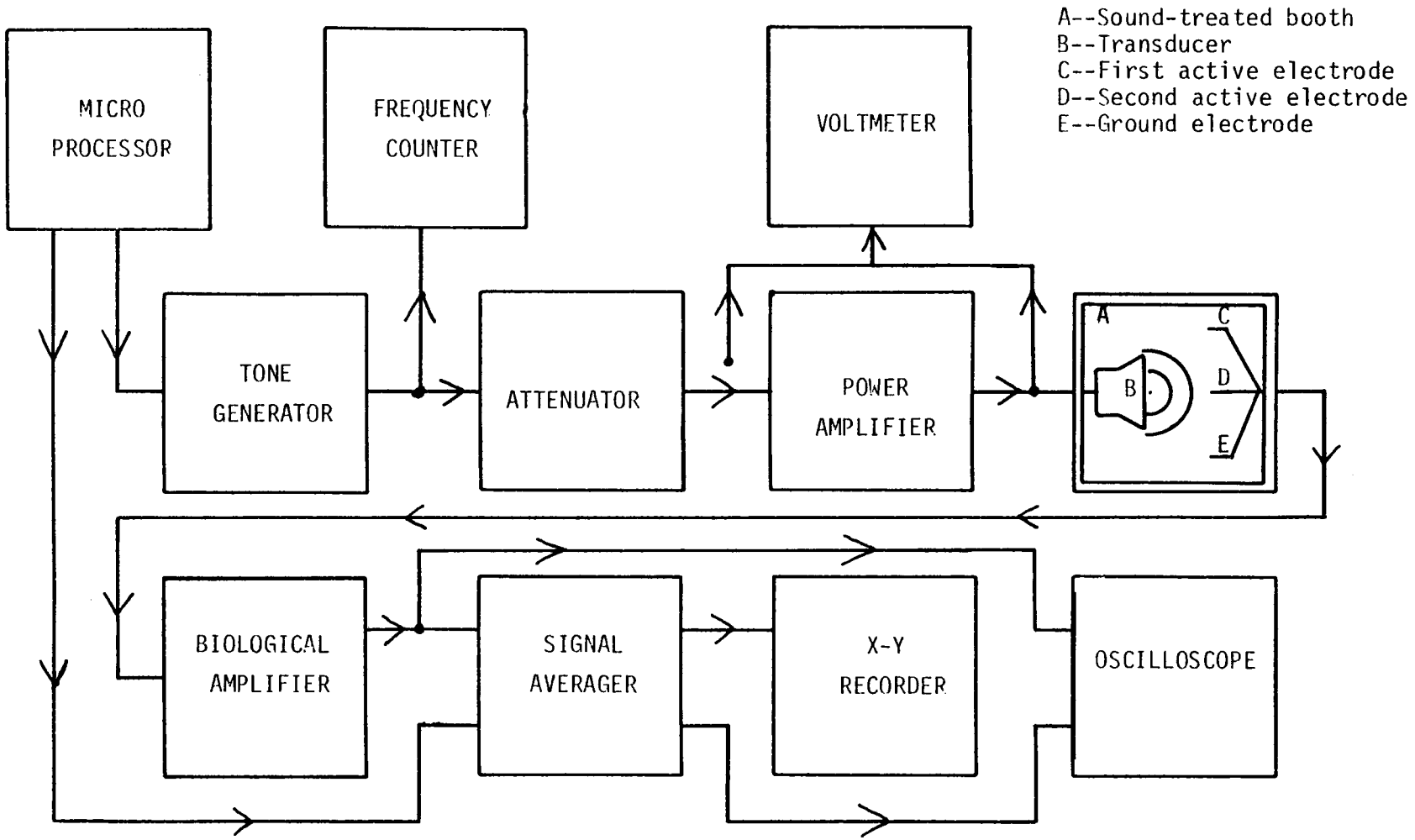


Figure 1. Block diagram of the auditory evoked brain-stem response system.

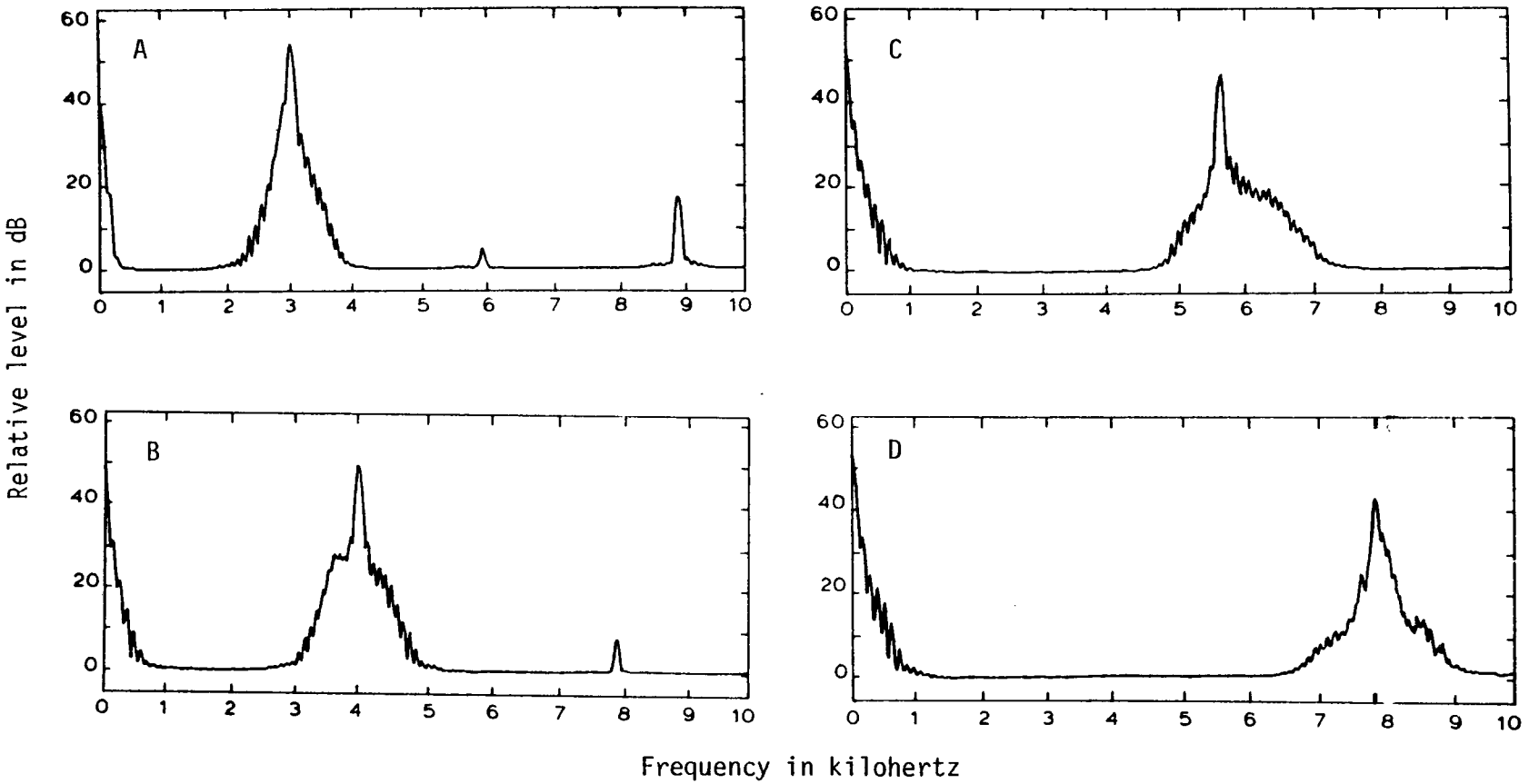


Figure 2. Acoustic spectra of the 3.0 kHz, 4.0 kHz, 5.7 kHz, and 8.0 kHz tone bursts are presented in panels A, B, C, and D, respectively.

While being tested, the animal was situated in a custom fabricated sound-treated and electrically shielded booth of approximately 45 cm in each dimension. In order to maintain body temperature, the animal was placed upon a temperature controlled surface. Ambient SPLs of this booth ranged from 69 dB to 73 dB with the sound levels ranging from 45 dBA to 51 dBA.

Ongoing AERs were amplified by a Coulbourne Instrument wideband bioamplifier (Model S75-02). The amplifier output was monitored on one channel of a Tektronics oscilloscope (Model RM 502A) and directed to a Nicolet Instrument Corporation signal averager (Model 535). Smoothed AERs were directed to the second channel of the oscilloscope and to an X-Y recorder (MFE, Model Explorer II).

Auditory evoked responses were conducted for the left and right ears before and at scheduled times during noise exposure and 30 d after the final exposure session. At all times, the following procedure was used:

1. The animal was anesthetized by injection of Nembutal (0.035 mg per g body weight) into the interperitoneal cavity. A supplemental injection was provided prior to testing the second ear of each animal.
2. Platinum needle electrodes (Grass, Model E2B) were placed subcutaneously over the most salient portion of the bulla for the ear to be tested (first active electrode) and over the vertex (second active electrode). A third needle electrode was inserted into the pinna of the non-test ear.
3. The transducer was connected to the animal's ear via an acoustically damped 30 cm long conical coupler which

included a 4 cm long section of surgical tubing. The tube section of the coupler was inserted into the external ear canal and was held in place with tape--effecting a closed acoustic system.

4. The tone generator was set to the desired frequency and the threshold search was initiated.
5. A descending-ascending technique was used, beginning with a SPL which produced a distinct auditory brain stem response characterized by distinct waves II and IV. At this point the signal level was decreased in 10 dB steps until wave II was just barely recognized. The signal level was then decreased 5 dB below this point and then increased 5 dB above this point. The lowest signal level at which wave II could be clearly recognized was accepted as threshold.
6. The attenuation value yielding threshold was converted to SPL and recorded.

These steps provided a $\pm$ 5 dB measurement variation.

An example of an AER obtained with this procedure is presented in Figure 3. This procedure was used for all test frequencies which were tested in the following sequence: 5.7 kHz, 4.0 kHz, 8.0 kHz, and 3.0 kHz. This fixed test frequency sequence rather than a random or counter-balanced sequence was used throughout the experiment for several reasons:

1. It has been used in previous studies concerning noise over-exposure (Miller, et al., 1971; Carder and Miller, 1972; Woodford, 1977; Hétu and Trémolières, 1977; and Burdick, et al., 1978).

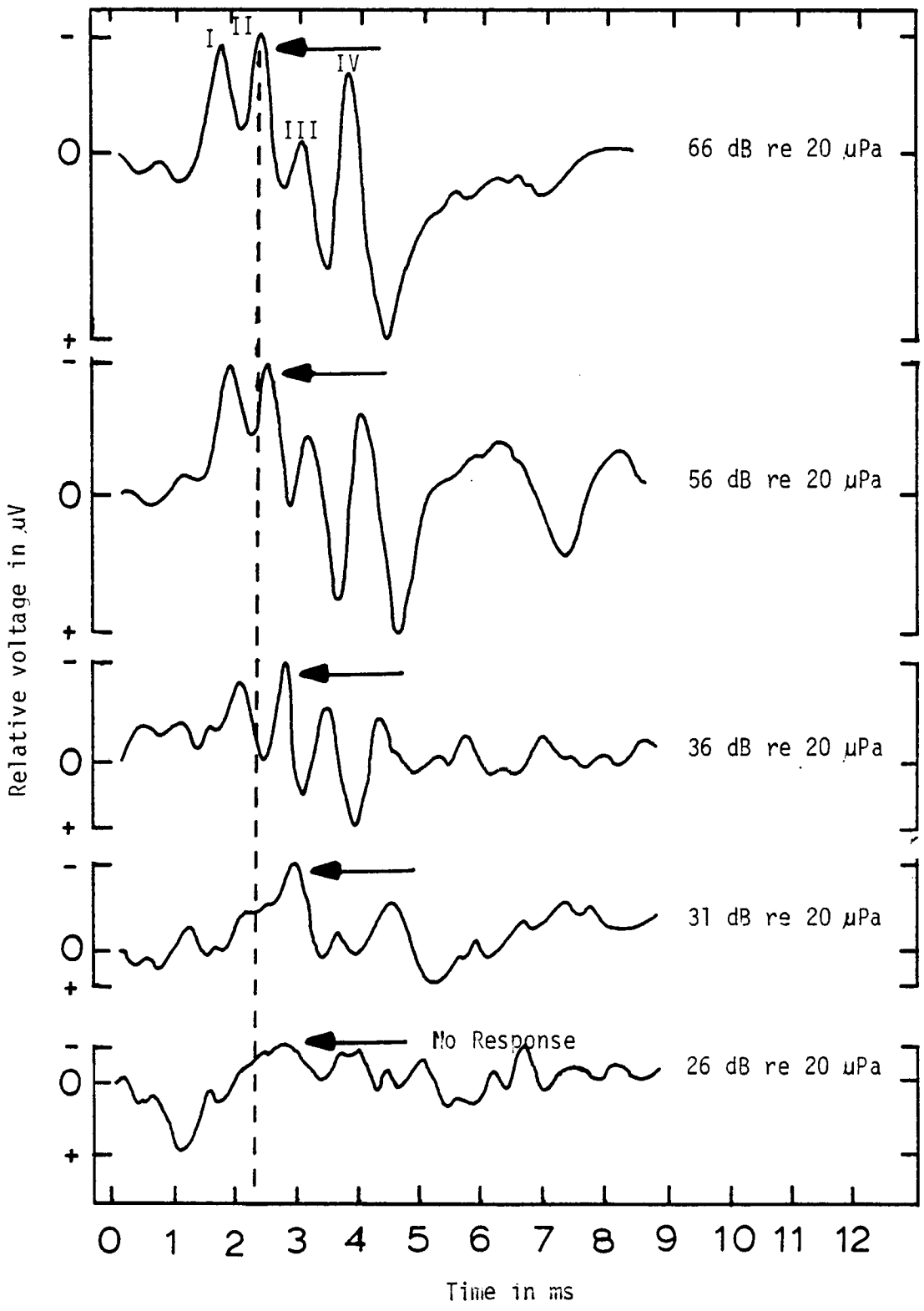


Figure 3. The AER threshold for animal E-2 for an 8.0 kHz tone burst.

2. Review of the literature did not reveal information regarding recovery rates from noise overexposure by frequency for AER determined auditory thresholds.
3. The fixed procedure permitted temporary threshold shifts for 5.7 kHz to be consistently determined at 30 m and 45 m post exposure. For the remaining test frequencies, thresholds were determined after 5.7 kHz at 5 m intervals (± 1.5 m).
4. Data presented by Botsford (1971) indicated recovery occurs more slowly (less than 5 dB over a 30 m period) 20 m post exposure. This would indicate that the expected threshold shift variation attributed to the ± 1.5 m measurement error for 4.0 kHz, 8.0 kHz, and 3.0 kHz would be well within the ± 5 dB threshold variation of the AER procedure.

Noise Exposure

All experimental animals were exposed to a one-third octave band noise in two pentagonal fabricated diffuse sound-field chambers. These chambers were constructed with a volume of 0.75 m^3, non-parallel sides, and reflectant surfaces. Each chamber contained a cage constructed of acoustically transparent hardware cloth. Each cage was partitioned into six sections such that six animals could be held separate from one another. A loudspeaker (Lafayette, number 21A01921) was centered 25 cm above each cage. To insure equivalent sound levels for each of the six animals in each group, the cages revolved at 0.25 rpm. A squirrel cage fan provided ventilation for the animals by blowing air into the bottom of the booth. An exhaust port at the top of the booth provided venting of air and heat. Both booths were always illuminated, as was the animal

holding area. Instrumentation used for the noise exposure is depicted in Figure 4.

A GenRad noise generator (Model 1382) provided a white noise which was passed through a one-third octave band filter centered at 4.0 kHz. This filter was formed by cascading two passive variable filters (Allison, Model AL-2ABR). The one-third octave band noise was used, based on the frequency characteristics of the exposure booths and based on the use of 4.0 kHz octave or one-third octave bands of noise in other investigations. The acoustic spectra of each booth using the stimulus noise are presented in Figure 5.

The filtered noise was directed to a custom designed step-amplifier which provided the level changes required for the three experimental groups. These levels changed via a signal from a custom designed timer. This timer was programmed with the appropriate duration for each group. The noise was then directed to a Heathkit two channel power amplifier (Model AA-1640) which provided the required noise levels for each group.

Noise levels were adjusted so the experimental groups' Leq_{24} was 85 dB for five days per week for six months. The Leq_{24} for each recovery period was 51.5 dB, identical to the Leq_{24} in holding quarters for the control group. This weekly pattern of exposure resulted in a total of 135 d of eight-hour exposure in a 180-d period. The Leq_{24} for these experimental groups was calculated using the ambient level in the holding area and the exposure levels in the booths. An Leq_{24} of 85 dB was selected for the following reasons:

1. Effects of relatively low-level noise exposure have not clearly been documented (Ward, 1978).

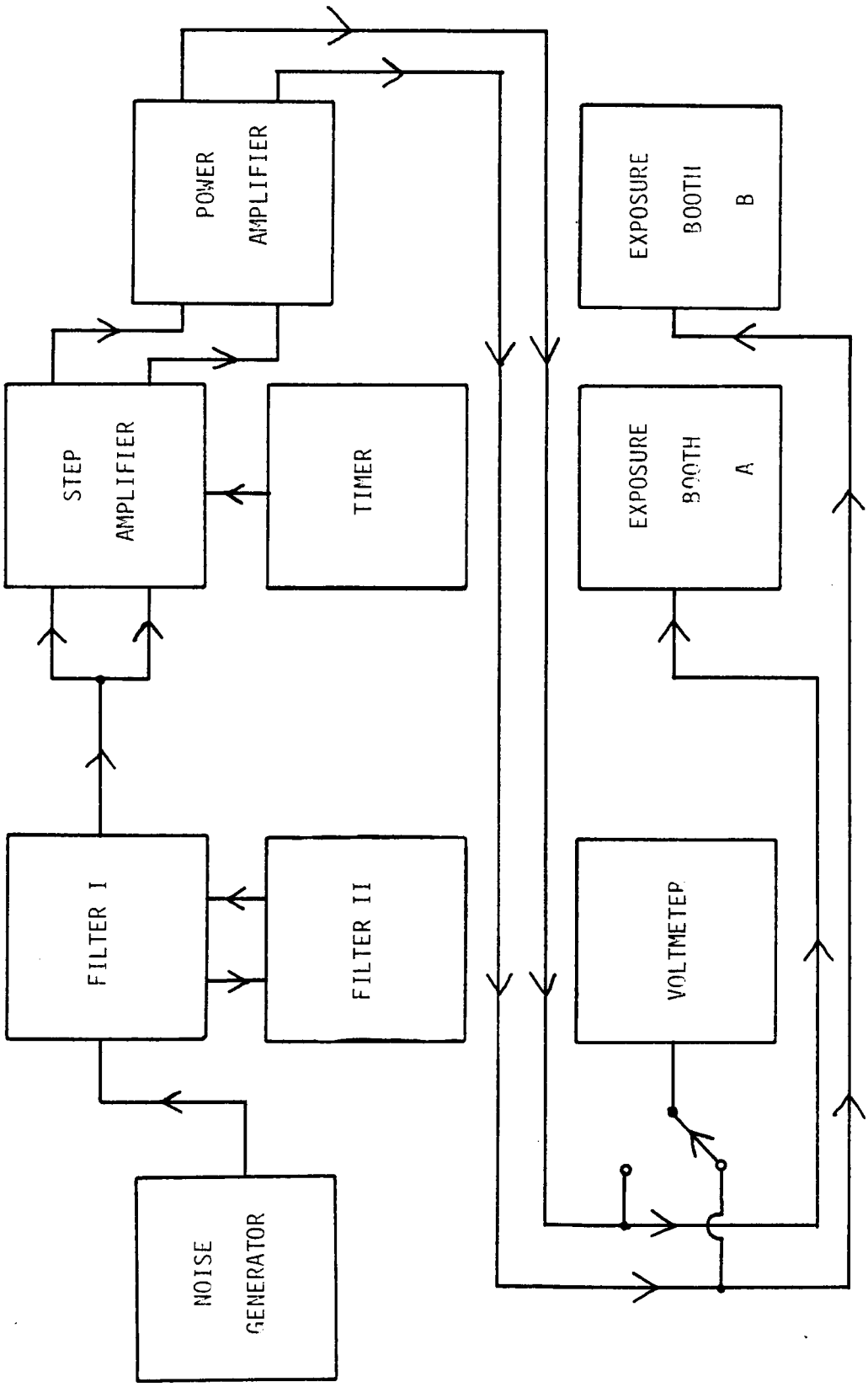


Figure 4. Block diagram of the noise exposure instrumentation.

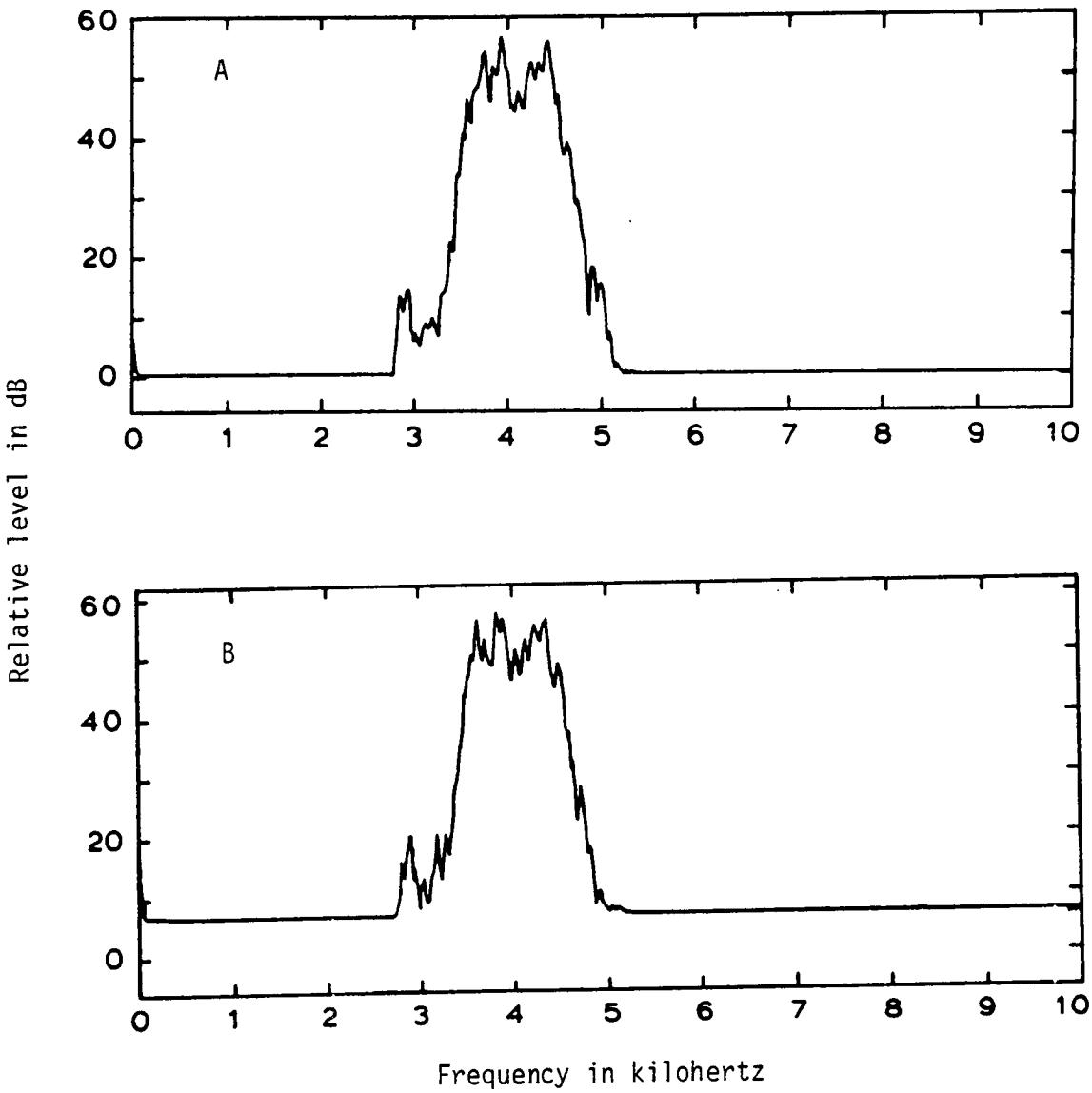


Figure 5. Acoustic spectra of the exposure noise in exposure booths A and B are presented in panels A and B, respectively.

2. This level is in the range reported by Saunders, et al., (1977) to cause PTS in the chinchilla.
3. The exposure levels in the booths do not exceed allotted values for an eight hour work day according to the Occupational Safety and Health Act of 1970.

Exposure patterns for a 24-h period for each group are presented in Figure 6. Each experimental group, with the exception of group C, received the same level of exposure for the last four hours of each eight hour exposure. Group A did not experience noise exposure. Its Leq_{24} was calculated from the ambient noise level in the animal holding area.

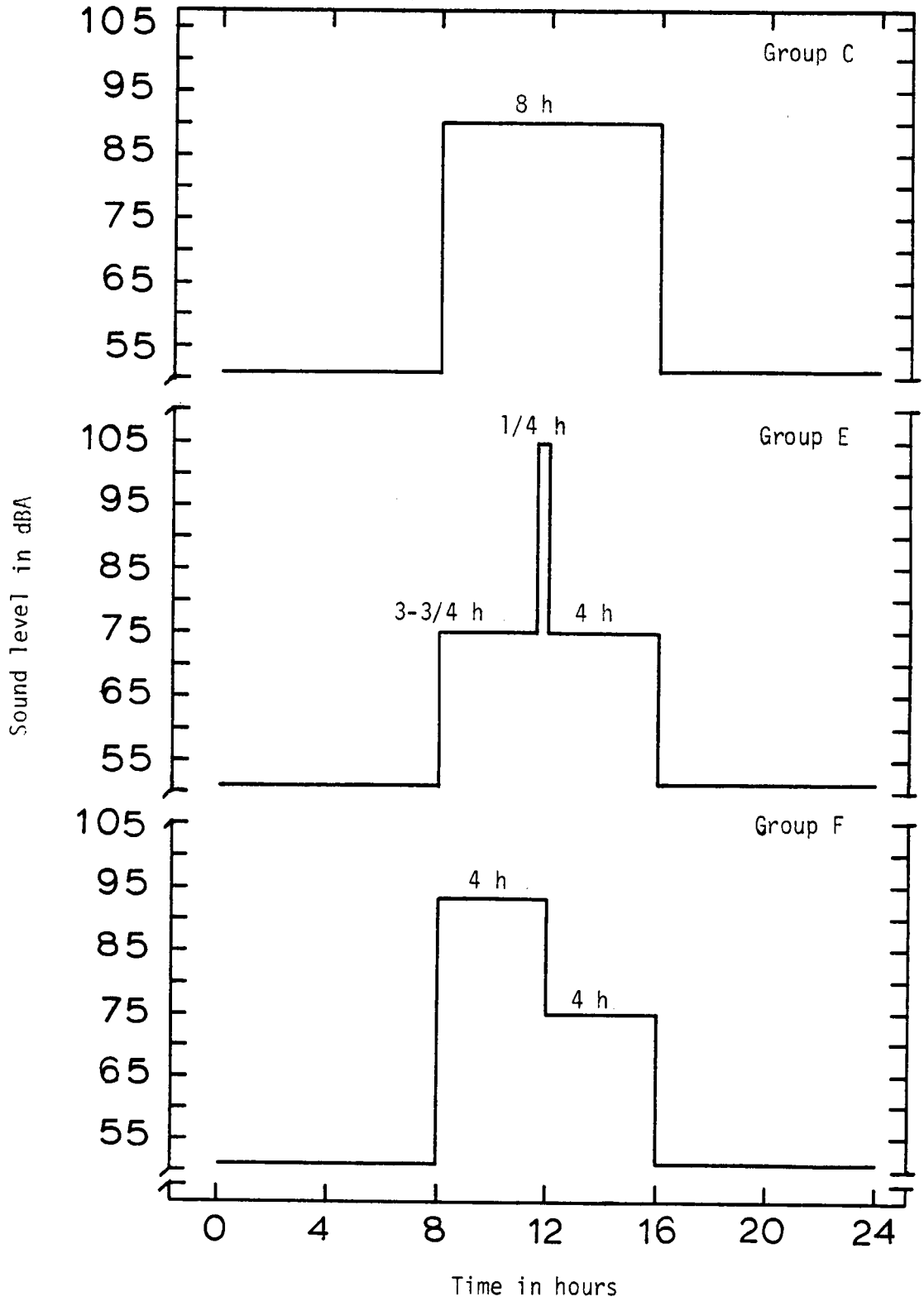


Figure 6. Daily noise exposure patterns for experimental groups C, E, and F--Leq_{24} = 85 dB.

Repeated measures of ambient levels in the holding area and the exposure levels in each booth are presented in Table 3. One-third octave band analysis of the animal holding area is presented in Figure 7 and of the low exposure level for groups E and F and of the exposure level for group C in Figure 8.

Table 3. Three Repeated Measured Sound Pressure Levels and Sound Levels for the Animal Holding Area and Exposure Booths.

	Measure One		Measure Two		Measure Three	
Area	dB	dBA	dB	dBA	dB	dBA
Holding Room	62.0	51.0	66.5	50.5	72.5	53.5
Group C	89.2	90.8	90.8	92.0	88.8	89.6
Group E						
Low Level	76.0	74.8	77.2	75.6	76.0	74.5
High Level	106.2	105.0	106.0	105.0	105.6	105.0
Group F						
Low Level	75.8	74.0	77.0	75.8	74.2	72.2
High Level	94.4	95.2	92.8	93.6	93.0	93.6

Schedule of AER Testing and Noise Exposure

Auditory evoked response testing was scheduled before noise exposure and 30 d after the final exposure period. During the noise exposure period, AER testing was scheduled so that each animal was tested after its first and fifth day of noise exposure. In addition, each animal was tested after the first two-day recovery period. The test/exposure schedule is presented in Appendix A (page 91). An "O" indicates when AER testing was conducted, an "X" when the animal was exposed to noise, and an "-" indicates periods without noise at which time the animal remained in the holding area. When two symbols

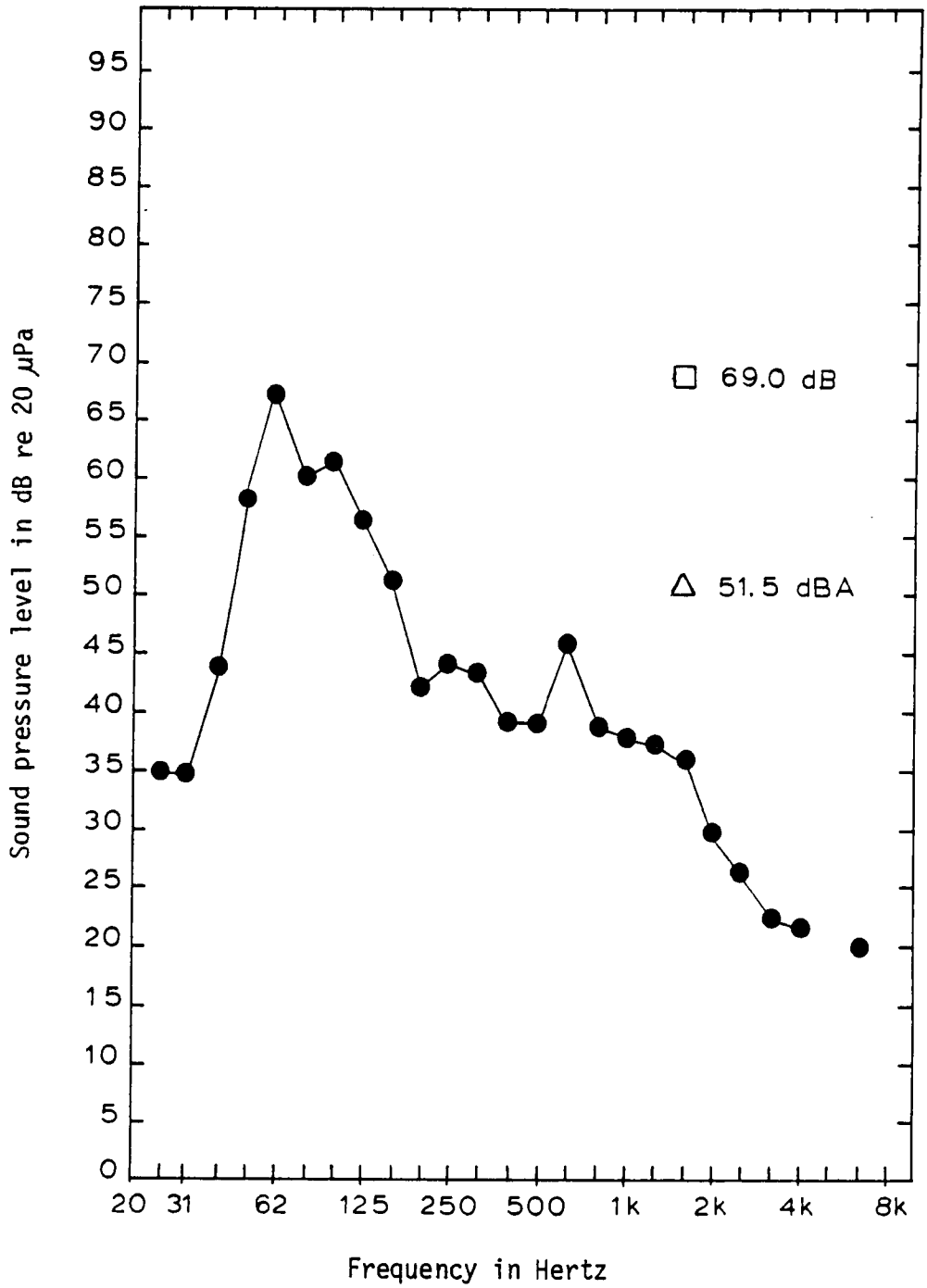


Figure 7. One-third octave band acoustical analysis of the animal holding area.

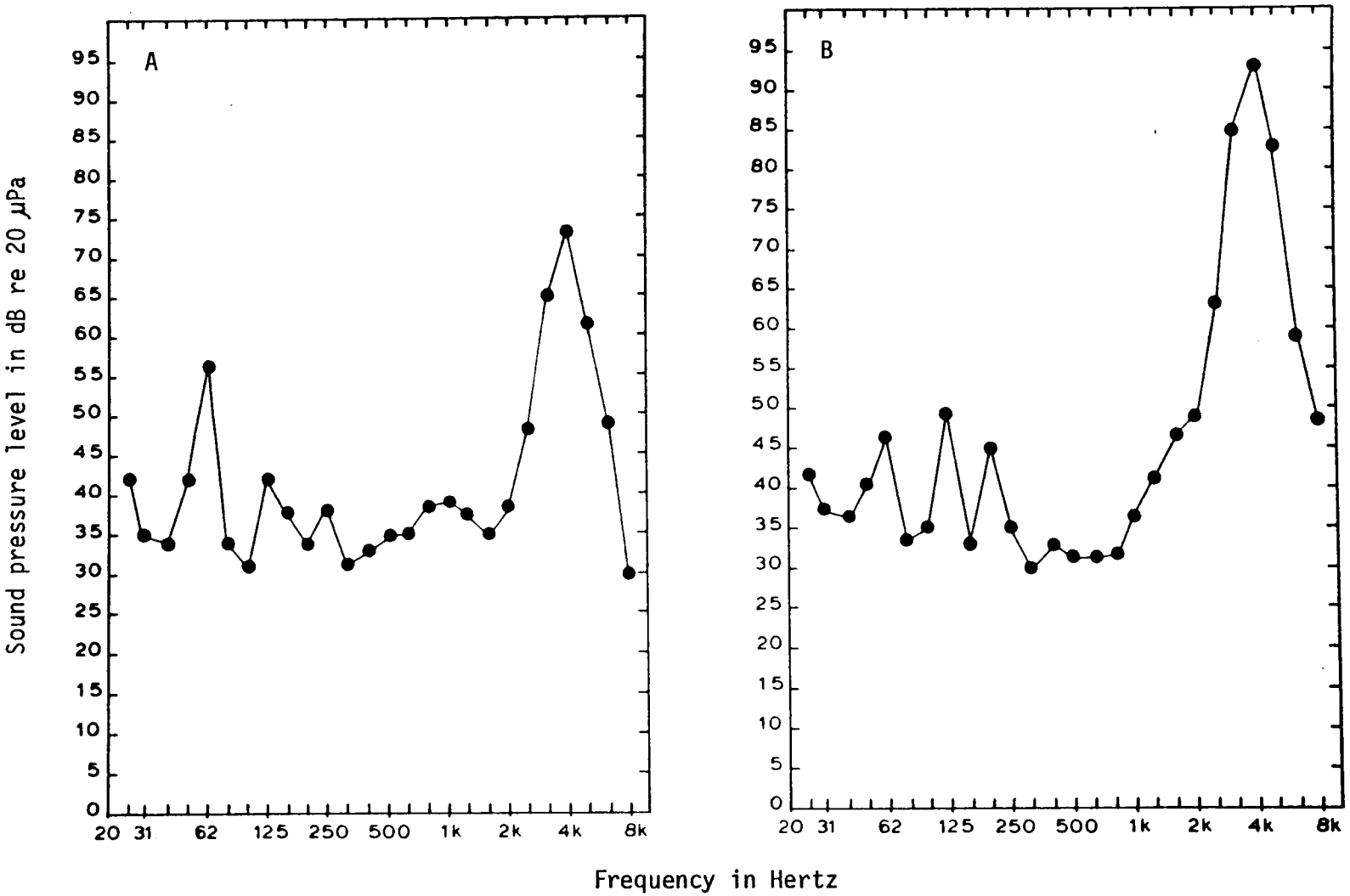


Figure 8. One-third octave band acoustic analysis for the 75 dBA exposure level (panel A) and the 90 dBA exposure level (panel B).

occur in the same block, the right-most symbol indicates the step which was taken first. When more than one animal was to be tested on the same day and shift, priority was given to the animal which had not received a post-exposure test. For example, on day 0, animal C-1 was subjected to AER testing as was the dase on day 4. However, on day 4, animal C-4 was also scheduled for AER testing. In this instance, C-4 was given priority over C-1 and was tested first.

So that each animal could be tested at the same post-exposure time (30 m and 45 m for 5.7 kHz) the exposure schedule was staggered. Upon completion of AER testing for all animals and after the first two-day recovery period, all animals in each group were simultaneously exposed. Three weeks before the final day of exposure, the exposure schedule was again staggered. This schedule can be seen in Appendix A, Table 25 (page 97).

Histology

Upon completion of the final electrophysiologic tests, each animal was terminated and both cochleas were removed, fixed, and dissected in accordance with the surface preparation protocol used in the Noise Research Laboratory (Lipscomb, 1974). This procedure involved four steps: (1) termination and gross dissection, 2) fixation, 3) fine dissection, and 4) slide study.

1. Termination and Gross Dissection
    a. The animal was terminated by decapitation.
    b. The ramus of the mandible was severed from the maxillary portion of the skull to expose the auditory region.
    c. The bullae located slightly anterior and lateral to the spinal column were opened so that the ossicular chain, round window and cochlea were visible.

d. The lateral wall of the temporal bone was removed to improve exposure of the cochlea.

e. The malleus and incus were removed.

f. A small hole was then drilled into the scala tympani at the base of the cochlea to permit injection of a fixative into the cochlea.

g. The stapes was removed from the oval window, permitting the fixative to flow through the cochlea.

2. Fixation

a. Gluteraldehyde (5%) was gently injected through the drilled opening, perfusing the cochlea. (To reduce any artifacts due to the post-mortem tissue changes, the procedures to this point were accomplished so that fixation occurred between two and five minutes after decapitation.)

b. Veronal buffered osmium tetroxide solution (0.5%) was used for post-fixation. This was accomplished as in step 2. a.

c. The cochleas were immersed in the osmic acid fixative in a glass vial and gently agitated for 90 m under refrigeration (4° C).

d. To arrest osmium action the specimens were removed from the fixative and rinsed for one hour in distilled water.

e. After rinsing, the cochleas were prepared for storage by taking them through graduated solutions of alcohol (15%, 40%, and 50%) and storing them in a 70 percent solution of alcohol under refrigeration until time for dissection.

3. Fine Dissection

   a. The specimen to be dissected was stepped-down from the 70 percent alcohol solution to distilled water in the same manner, but in the reverse order to step 2. e.

   b. Excess bone was removed from the cochlea to permit its mounting in a stainless steel dissection holder.

   c. The bony shell of the cochlea was thinned with a 1 mm diamond burr.

   d. Cochlear dissection was begun by gently fracturing the apical portion of the cochlea to expose the apical coil of the membraneous labyrinth.

   e. The exposed soft tissues (stria vascularis, spiral ligament, Reissner's membrane, and tectorial membrane) were then removed in turn, leaving the basilar membrane and its superstructure, the organ of Corti.

   f. Half-turn sections of the basilar membrane and its associated structures were removed. Each half-turn was designated according to the distance from the base of the cochlea. This scheme provides gross orientation as dissection proceeds from apex to base--turns number 3, 2-1/2, 2, 1-1/2, 1, and 1/2.

   g. Each dissected segment of the basilar membrane was placed upright in glycerine on a microscope slide. A cover disc was then placed over each segment.

4. Slide Study. Beginning with the basal coil, half-turn segments were viewed using a Reichart Zetopan research microscope outfitted with interference contrast optics. Magnification was

1000 X for cell counting. Sensory cell damage for each segment was noted by counting visibly damaged cells so that each mm of the organ of Corti could be assessed as to percent cell damage. Sensory cell damage was defined as absence of a sensory cell or notably deformed sensory cell wall, typically having a "X" appearance and called a phalangeal scar (Lipscomb, 1974).

Criterion Measures

In order to test for differences in electrophysiologic threshold shifts among groups, the means for electrophysiologic threshold shifts at 3.0 kHz, 4.0 kHz, 5.7 kHz, and 8.0 kHz were used. The 5.7 kHz and 8.0 kHz frequencies were used due to the greatest threshold shifts occurring at a half to one octave above the center frequency of exposure source (Miller, et al., 1963). The 3.0 kHz and 4.0 kHz frequencies were used to provide assessment of threshold shifts at a half octave below and at the center frequency of the exposure source.

The means for the percent of outer, inner, and total hair cell damage were used to test for differences in percent hair cell damage among groups. These same criteria were used for correlational analyses.

Statistical Design

These procedures provided a two factor design for repeated measures and unequal group sizes. Analyses of the temporary shift data were conducted with six such two-way analyses of variances (ANOVA). Recovery data and histology data were analyzed with one-way ANOVAs. Descriptive statistics were used as an adjunct to the above analyses.

CHAPTER IV

RESULTS AND DISCUSSION

The analysis of data obtained will be according to the following scheme: raw data will be located in Appendices B through E; threshold shift data will be analyzed in three divisions--TTS, recovery, and PTS; and histology data will be reported in four sections--reliability, differences among groups, configuration of hair cell damage, and the relationship between histology and PTS data. Discussion will also occur in the respective sections.

Raw Data

Baseline thresholds for control and experimental animals and shift thresholds for experimental animals are presented in Appendix B, Tables 26 through 52, pages 102 to 128. Examples of the AERs from which these thresholds were obtained are plotted in Appendix C, Figures 14 through 34, pages 130 to 150. The test technique from which these thresholds were taken was previously described in Chapter III, page 32. The ordinate is relative voltage and the abscissa is duration--10 ms for the full-width of the figure. The parameter plotted is the SPL of the tone burst which yielded the AER. In the following pages the terms first-tested ear and second-tested ear refer to the ear tested first and second after exposure for each animal. Figures 14 through 23 are the final TTS data at 8.0 kHz and Figures 24 through 34 are the PTS data at 3.0 kHz for the second-tested ear.

The percent of missing hair cells per millimeter (mm) of basilar membrane, and the final hearing level in SPL for 2 control and 15

experimental animals are reported in Appendix D, Tables 53 through 73, pages 152 to 172. Plots of final hearing level as a function of test frequency and the percent of intact hair cells as a function of distance from the base of the cochlea are depicted in Appendix E, Figures 35 through 57, pages 174 to 196. Figures 35 through 57 present two types of data for comparison--the upper abscissa and left ordinate represent frequency and final hearing level, and the lower abscissa and right ordinate signify the distance from the base of the cochlea and the percent of intact hair cells. To provide some correspondence of frequency with the location of sensory units, the top and bottom scales were aligned according to Eldredge, et al. (1973). The left and right side scales were arbitrarily aligned since the question of the amount of hearing for a percent of intact hair cells has yet to be resolved.

Threshold Shift Analyses

Reliability. Twenty-one animals were used to determine the reliability of the AER procedure and threshold detection criteria. Differences between baseline one and two data were calculated across frequency. The mean differences ($\bar{X}$) and the standard error of the mean differences ($S_{\bar{e}}$) were calculated for each frequency. The $S_{\bar{e}}$ served as the measure of reliability. Table 4 presents $\bar{X}$ and $S_{\bar{e}}$ for each test frequency. Being within the $\pm$ 5 dB measurement variation, these $S_{\bar{e}}$ indicate a reliable AER procedure. The slight differences present may be attributed to the AER procedure (pages 29 to 35), in which 5.7 kHz was tested first and 3.0 kHz was tested last with a supplemental dose of Nembutal occurring between the first-tested and second-tested ears. It is possible that the animals were at different levels of

Table 4. Mean Differences ($\overline{X}$) Between Baseline One and Two Data and Standard Error of the Mean Differences ($S_{\overline{e}}$) Across Frequency

	Frequency in kHz			
Statistic	3.0	4.0	5.7	8.0
$\overline{X}$	2.64	2.93	2.43	1.62
$S_{\overline{e}}$	1.34	0.95	1.41	0.88

anesthesia during baseline one and baseline two data acquisition, as well as at each frequency. This may have resulted in the larger $S_{\overline{e}}$s at 5.7 kHz and 3.0 kHz. A second reason for the higher $S_{\overline{e}}$ at 3.0 kHz may be the synchrony of neural discharge in the acoustic nerve.

Typically, high level, high frequency signals provide better neural discharge synchrony. It is plausible that for chinchilla tone bursts of 3.0 kHz and 4.0 kHz do not provide constant neural synchrony when the stimulus level is varied as compared to tone bursts of 4.0 kHz and 8.0 kHz. A final possibility for asynchronous discharge is tinnitus. The variation in $S_{\overline{e}}$ reported could be attributed to different degrees of tinnitus induced by stress from the test procedure; e.g., sedation and maintenance of the chinchilla's body temperatures.

Temporary threshold shift. Analysis of variance (ANOVA) was used to test for differences in TTS among the exposure groups. Results of six two-way ANOVAs for repeated measures with unequal group sizes (Winer, 1971) are reported in Tables 5 through 10. These ANOVAs also compared exposure days and the interaction between exposure groups and exposure days for each frequency tested. Summary Tables 5, 6, and 7

Table 5. Summary of Analysis of Variance Comparing the Amount of TTS as a Function of Exposure Group and Number of Exposure Days for 5.7 kHz Measured 30 m Post Exposure.

Source of Variance	df	Sum of Squares	Mean Square	F Value
Between Subjects				
Exposure Group (EG)	2	193.57	96.78	2.14
Subjects Within Groups	9	405.96	45.11	
Within Subjects				
Exposure Day (ED)	2	812.65	406.32	11.39*
EG x ED	4	62.84	15.71	0.09
ED x Subjects Within Groups	18	642.31	35.68	

*Significant at or less than the 0.05 level.

Table 6. Summary of Analysis of Variance Comparing the Amount of TTS as a Function of Exposure Group and Number of Exposure Days for 4.0 kHz Measured 35 m Post Exposure.

Source of Variance	df	Sum of Squares	Mean Square	F Value
Between Subjects				
Exposure Group (EG)	2	305.55	152.78	3.11
Subjects Within Groups	8	393.15	49.14	
Within Subjects				
Exposure Day (ED)	2	969.91	484.95	18.84*
EG x ED	4	32.87	8.22	0.32
ED x Subjects Within Groups	16	411.78	25.74	

*Significant at or less than the 0.05 level.

Table 7. Summary of Analysis of Variance Comparing the Amount of TTS as a Function of Exposure Group and Number of Exposure Days for 8.0 kHz Measured 40 m Post Exposure.

Source of Variance	df	Sum of Squares	Mean Square	F Value
Between Subjects				
Exposure Group (EG)	2	57.71	28.86	0.318
Subjects Within Groups	8	723.38	90.42	
Within Subjects				
Exposure Day (ED)	2	72.42	36.21	0.518
EG x ED	4	50.17	12.54	0.179
ED x Subjects Within Groups	16	1118.22	69.89	

present data for 5.7 kHz and 8.0 kHz, respectively, for the first-tested ear (TTS_{30} at 5.7 kHz) with summary values presented for the second-tested ear (TTS_{45} at 5.7 kHz) in Tables 8, 9, and 10. Animals used in these analyses were restricted to those animals which had data points across the entire 155 d of exposure.

The ANOVAs indicated no statistically significant differences in TTS among exposure groups and no significant interaction of TTS between exposure groups and exposure days. Thus the null hypothesis, that threshold shift, measured during the exposure sessions do not differ, was not rejected. Exposure days was the only factor for which there were statistically significant differences. To determine which exposure days contributed to this statistical difference, the Scheffe post hoc procedure was used. Differences for 5.7 kHz measured at 30 m post exposure (first-tested ear) and at 45 m post exposure (second-tested ear), and at 4.0 kHz

Table 8. Summary of Analysis of Variance Comparing the Amount of TTS as a Function of Exposure Group and Number of Exposure Days for 5.7 kHz Measured 45 m Post Exposure.

Source of Variance	df	Sum of Squares	Mean Square	F Value
Between Subjects				
Exposure Group (EG)	2	305.92	152.96	1.54
Subjects Within Groups	7	694.89	99.27	
Within Subjects				
Exposure Day (ED)	2	392.61	196.30	5.88*
EG x ED	4	230.58	57.64	1.73
ED x Subjects Within Groups	14	467.38	33.38	

*Significant at or less than the 0.05 level.

Table 9. Summary of Analysis of Variance Comparing the Amount of TTS as a Function of Exposure Group and Number of Exposure Days for 4.0 kHz Measured 50 m Post Exposure.

Source of Variance	df	Sum of Squares	Mean Square	F Value
Between Subjects				
Exposure Group (EG)	2	88.28	44.14	0.44
Subjects Within Groups	7	698.10	99.73	
Within Subjects				
Exposure Day (ED)	2	264.22	132.11	2.66
EG x ED	4	58.78	14.70	0.30
ED x Subjects Within Groups	14	695.38	49.67	

Table 10. Summary of Analysis of Variance Comparing the Amount of TTS as a Function of Exposure Group and Number of Exposure Days for 8.0 kHz Measured at 55 m Post Exposure.

Source of Variance	df	Sum of Squares	Mean Square	F Value
Between Subjects				
Exposure Group (EG)	2	123.77	61.89	0.33
Subjects Within Groups	7	1297.82	185.40	
Within Subjects				
Exposure Day (ED)	2	318.28	159.14	2.86
EG x ED	4	27.14	6.79	0.12
ED x Subjects Within Groups	14	779.78	55.70	

measured at 35 m post exposure (first-tested ear). The results of the Scheffé procedure are summarized in Table 11.

Table 11. Summary of the Scheffé Post Hoc Procedure for TTS Differences Between Exposure Days.

Critical Value	Frequency in kHz	Mean TTS Differences in dB Between Exposure Days		
		Day 5-Day 1	Day 135-Day 1	Day 135-Day 5
7.10	5.7	4.20	11.90*	7.70*
7.26	4.0	7.11	13.66*	6.55
7.48	5.7	8.08*	8.43*	0.35

*Significantly different at the 0.05 level.

For 5.7 kHz measured at 30 m post exposure, TTS for exposure day 135 differed significantly from TTS for exposure days 1 and 5, and TTS for exposure day 5 differed significantly from exposure day 1 TTS. At 4.0 kHz, measured at 35 m post exposure, only TTS for exposure day 135 was significantly different from TTS for exposure day 1. The TTS reported for both test frequencies were from the first-tested ear which had at most 35 m of recovery. The only frequency for which TTS was significantly different for the second-tested ear was 5.7 kHz measured at 45 m post exposure. For this frequency and ear, TTS for exposure days 135 and 5 were significantly different from exposure day 1 TTS, but not from one another.

These results suggest that most of the TTS measured 45 m post-exposure occurs within the first five days of exposure regardless of the time distribution of sound energy. Temporary threshold shift measured at 30 m post exposure appears to increase after the fifth exposure day. Group C, due to five animals dying at some period between the initial baseline thresholds and the second week of daily exposure, offered a closer view of increased TTS after day 5 and before day 135 of exposure.

Two animals (C-3 and C-6) began their exposures at the mid-point of the experiment and therefore provide data for 3 months of exposure. Table 12 presents the mean TTS values across exposure days and frequency for these two animals and the balance of group C. One can also view the effect of the first-tested versus second-tested ear. Mean TTS values do not differ greatly between exposure days for 4.0 kHz and 5.7 kHz for the first-tested ear. However, mean TTS differences between exposure days 5 and 65 at 5.7 kHz for the second-tested ear were less than 5 dB, whereas

between exposure days 65 and 135, TTS differences were greater than 5 dB. It is possible that this TTS difference for the second-tested ear is related to an increased amount of recovery as compared to the first-tested ear. If this is the case, then the thresholds measured for this second-tested ear may be in a slow recovery phase as theorized by Botsford (1971).

Table 12. Descriptive Statistics for TTS in dB for Group C Across Exposure Days and Frequency for the First- and Second-Tested Ears.

Exposure Day	Frequency in kHz	N	First-Tested Ear		Second-Tested Ear	
			Mean	Range	Mean	Range
5	4.0	6	24	11	30	24
	5.7		32	16	24	24
	8.0		23	19	20	21
65	4.0	2	27	15	2	20
	5.7		34	1	23	14
	8.0		8	15	12	5
135	4.0	3	29	9	31	6
	5.7		31	4	30	0
	8.0		19	10	24	9

Botsford (1971) theorized that TTS is comprised of two components, C_2 which recovers quickly and C_1 which recovers more slowly. This phenomenon is commonplace in the recovery data reported in the literature; elgl, Ward (1962); Miller, et al. (1963); and Mills (1976). Though the data presented in Table 12 were not statistically analyzed, they do suggest that as the number of exposure days increased, TTS increased.

This observation has support from the work of Saunders, et al. (1977), in which an increase in the number of noise exposures resulted in increased threshold levels for chinchilla. For the stimulus level and duration combination used by Saunders, et al. (1977), thresholds reached a plateau within three exposure days and did not exhibit additional threshold shift for the duration of their experiment, nine days. This plateau was cited to be analogous to the asymptotic threshold shift (ATS) described by Carder and Miller (1972).

Carder and Miller (1972) indicated that for a given exposure an ATS would occur and suggested that the amount of ATS is the maximum PTS which could be expected from the given exposure. This view may also fit Botsford's theory. If the C_2 component is comprised of a physiological process which recovers relatively quickly and the C_1 component is comprised of some other process or processes, such as suggested by Bohne (1976), which recover more slowly, then the increased TTS observed in this experiment as the number of exposure days increase could represent a decrease in the C_2 component and an increase in the C_1 component. Stated another way, the ATS is actually the C_1 component of the overall TTS. To demonstrate this, the mean TTS values were plotted as a function of the time after exposure day 5 in Figures 9 and 10, representing 4.0 kHz and 5.7 kHz, respectively.

The reversal of the steep sloped segment for group C in Figure 9 is puzzling. The difference between the 35 m and 50 m threshold measures is 6 dB. However, the range present for the first-tested ear (35 m) is 11 dB, while for the second-tested ear (50 m) the range is 24 dB. It is plausible that variation in individual recovery rates and/or difficulty in visualizing the AER threshold because of greater brain stem activity

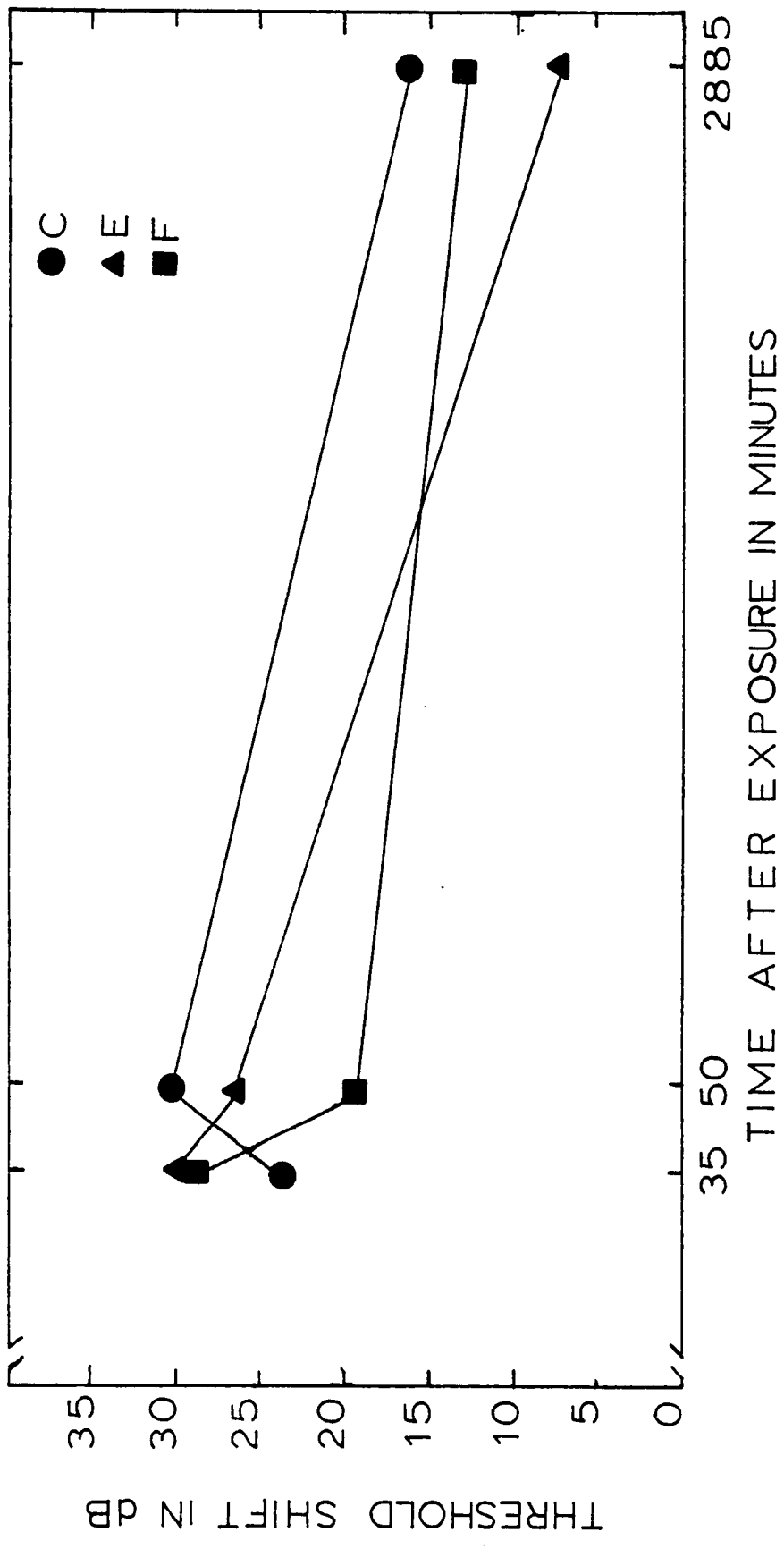


Figure 9. Recovery pattern for 4.0 kHz measured by threshold shift as a function of post-exposure time after five days of eight-hour exposures.

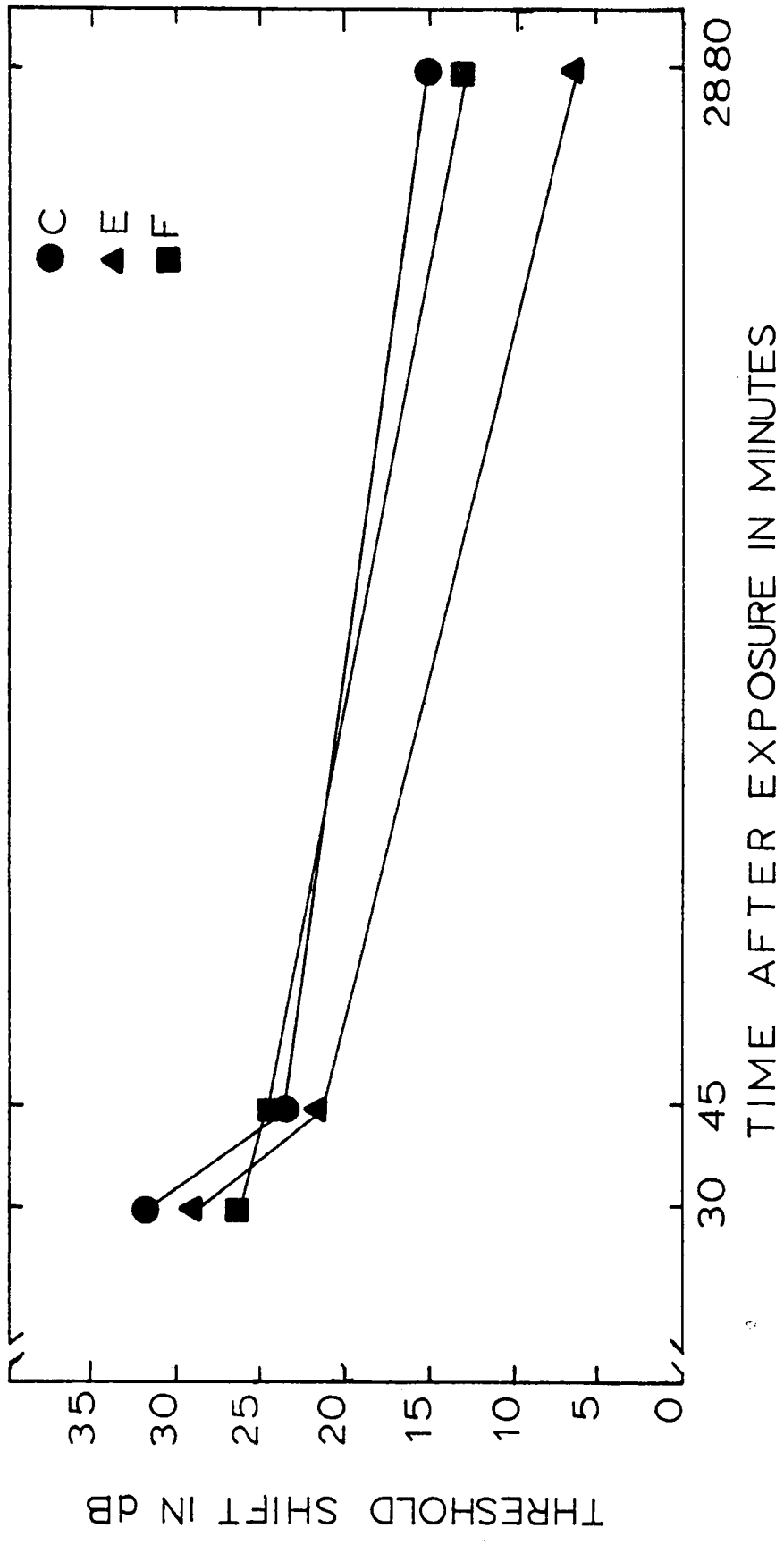


Figure 10. Recovery pattern for 5.7 kHz measured by threshold shift as a function of post-exposure time after five days of eight-hour exposures.

resulted in increased threshold variation. As mentioned earlier, tinnitus or the level of anesthesia could be contributing factors for increased brain stem activity and the resulting threshold variation. In any case, the predominant frequency, 5.7 kHz, Figure 10, fits Botsford's theory very well.

As can be seen in Figure 10, there are two sections to the plot--a steep sloped segment between 30 m and 45 m after exposure day 5 and a less steep sloped segment between 45 m after exposure day 5 and after exposure day 5 and after the first two-day recovery period (2885 m). It is also interesting that group C in Figure 10 had the least slope after exposure day 5. It would appear that if Botsford's theory is correct, the intermittent or varying patterns of exposure for groups E and F permit enough adaptation time to insure the C_1 component is not affected as much as in group C. Whether this holds for PTS as well will be reported in that section of this study.

Since the principle question of this study was concerned with determining if differences were present among three different patterns of noise exposure with equivalent sound energy, and since the number of animals used in the two-way ANOVAs was small, several one-way ANOVAs were conducted to insure no group differences were present. The analysis across exposure days only included animals with data points across all test days (1, 5, and 135). This limited the number of animals, thereby reducing the ANOVAs power. Using one-way ANOVAs permitted the addition of several animals which did not have data points across all test days, thereby increasing the power of the statistical analyses. These ANOVAs did not indicate any significant differences

for TTS among exposure groups. Again, the null hypothesis was not rejected. The mean and range values of TTS used in these analyses are depicted in Figure 11. Panels A, B, and C represent exposure days 1, 5, and 135, respectively, and include threshold data from the first-tested ear. Panels D, E, and F include the same data, but from the second-tested ear.

From this figure, the increase of TTS during exposure can be observed. As with other studies (Miller, et al., 1963; Mills, 1976; Vertes, 1976; and Erlandsson, et al., 1980), the frequencies most affected by a noise stimulus centered at 4.0 kHz and were 4.0 kHz and 5.7 kHz. Variation among the animals should also be noted. To aid in this, a summary of the descriptive statistics are presented in Table 13. Since the major effects of noise exposure were located at 4.0 kHz and 5.7 kHz, 8.0 kHz was not included in Table 13.

Recovery. After every fifth day of exposure, each animal received two days in "quite." Thresholds were measured at the end of the first two-day recovery period. A dependent T-test was conducted between ears and indicated no statistically significant differences. In light of this, both ears for each animal were pooled prior to the analysis for group differences by one-way ANOVAs. The summaries of these ANOVAs are presented in Tables 14 through 16. There were no statistically significant differences for TTS among groups regardless of the test frequency. This means that the amount of TTS present at the beginning of the second exposure week was essentially the same among groups when exposure energy was equivalent; it does not mean that the amount of recovery among groups was the same. Mean TTS values and ranges are presented in Figure 12. The important fact in this figure is

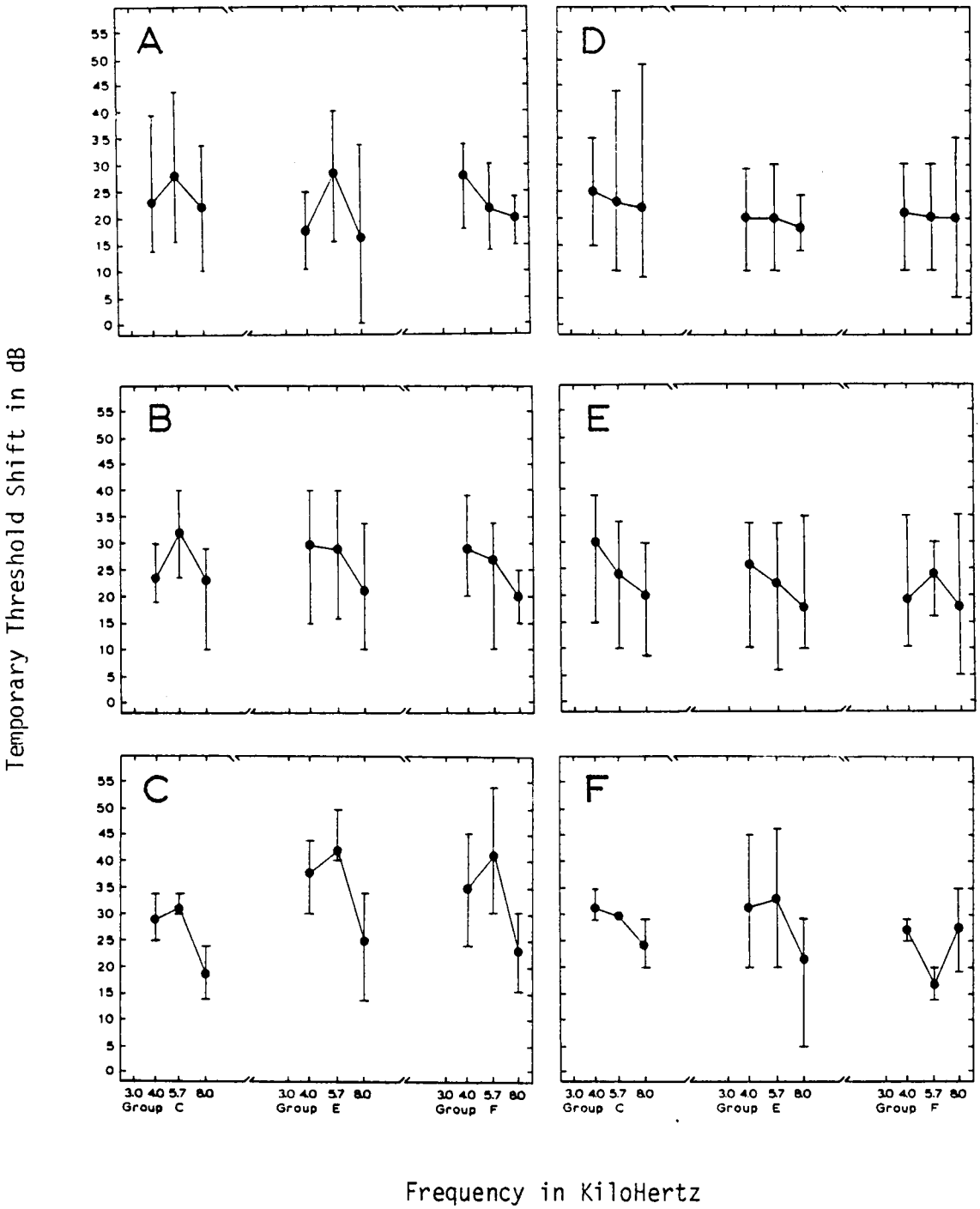


Figure 11. Mean and range TTS values in dB for the first-tested ear (panels A, B, and C) and for the second-tested ear (panels D, E, and F) as a function of exposure group and test frequency. Panels A and D, B and E, and C and F represent exposure days 1, 5, and 135, respectively.

Table 13. Descriptive Statistics of the TTS Data in dB Across Groups, Exposure Day (ED), and Frequency (kHz) for the First- and Second-Tested Ears.

				First-Tested		Second-Tested	
Group	ED	kHz	N	Mean	Range	Mean	Range
C	1	4.0	10	23	25	25	20
	5		6	24	11	30	24
	90		2	27	15	22	16
	135		3	29	9	31	6
E	1	4.0	6	18	15	20	19
	5		6	30	25	26	24
	135		5	38	14	31	25
F	1	4.0	6	28	15	21*	20*
	5		6	29	19	19	25
	135		3	35	21	27*	4*
C	1	5.7	10	28	28	23	34
	5		6	32	16	24	24
	90		2	34	1	23	14
	135		3	31	4	30	0
E	1	5.7	6	29	24	20	20
	5		6	29	24	22	28
	135		5	42	10	33	26
F	1	5.7	6	22	16	20	20
	5		6	27	24	24	14
	135		4	41	24	17*	6*

*The N for these values were less than indicated within this table. See Appendix B, pages 102 to 128, to obtain the number of animals receiving a particular test.

that no group fully recovered from its exposure even though exposure schedules and type varied and included 48 h of "quiet."

Focusing upon 4.0 kHz and 5.7 kHz in Figure 12, group E shows the least residual TTS. Group E had the shortest high-level exposure (15 m). This observation is in agreement with Johnson, et al. (1976),

Table 14. Summary of Analysis of Variance Comparing the Amount of Threshold Shift After Two Days of Recovery for 5.7 kHz.

Group	N	Mean	MS_{among}	MS_{error}	F
C	9	15.89	168.04	62.19	
E	10	7.60			
F	10	12.80			2.70

Table 15. Summary of Analysis of Variance Comparing the Amount of Threshold Shift After Two Days of Recovery for 4.0 kHz.

Group	N	Mean	MS_{among}	MS_{error}	F
C	9	16.44	168.30	72.62	
E	10	8.20			
F	10	13.60			2.32

Table 16. Summary of Analysis of Variance Comparing the Amount of Threshold Shift After Two Days of Recovery for 8.0 kHz.

Group	N	Mean	MS_{among}	MS_{error}	F
C	9	12.22	73.34	66.64	
E	10	6.70			
F	10	9.90			1.10

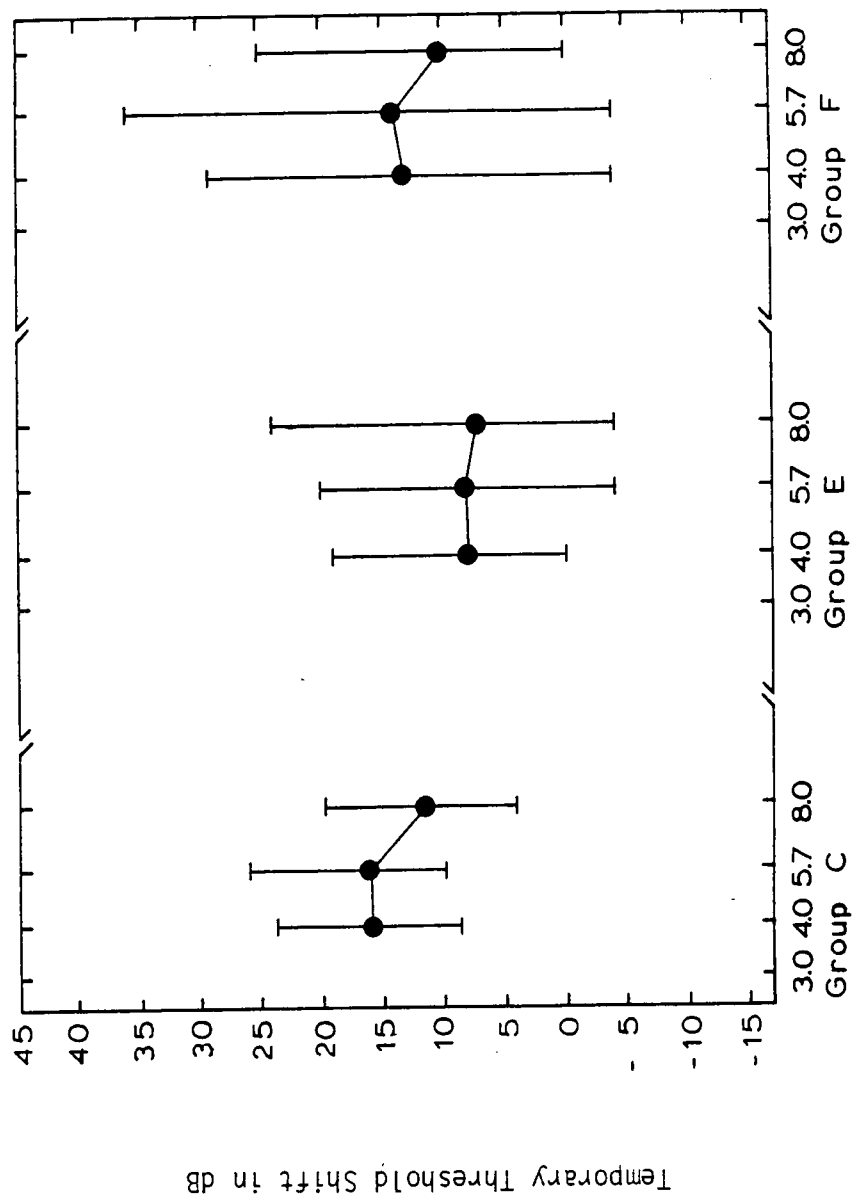


Figure 12. Mean and range TTS values in dB after two days of quiet as a function of exposure group and test frequency.

who reported that TTS was greater for exposures which had longer on-times. The durational parameters used in the present study for the more intense portions of the exposures were 8 h for group C, 4 h for group F, and 15 m for group E--the exact sequence into which the TTS falls after two days of recovery. This observation is maintained when the amount of recovery (the difference between hearing levels measured at day 5 of exposure and after 2 days of quiet) is used.

As was mentioned earlier, Botsford (1971) suggested two components for recovery of TTS. It appears that data from the first two-day recovery also fit his model. If the C_2 component of TTS is based upon an adaptive process which is sensitive to duration, then TTS for group E may primarily consist of this C_2 component. This would result in less TTS after the recovery period. Conversely, the other groups would exhibit more TTS after recovery of two days. If this speculation is true, then the ordering of exposure groups after two days of recovery (E, F, and C) would be accounted for. Apparently, the durational factor may weigh more in TTS than the Leq concept permits.

The mean sound energy measured in an observation period (Leq) does not provide any weighting factors for time of day or for exceeding a critical sound level for a specific period of time. This is the debate underlying the use of various time-intensity trade-offs, e.g., +3 dB versus +5 dB per halving of duration. Johnson (1975) suggested such corrections to the equal energy rule. Though Johnson states that the baseline level is not critical (85 dBA versus 90 dBA), Ward's, et al. (1978) results concerning effective quiet need to be considered. This would indicate that between the sound level for effective quiet and a higher level, a trade-off higher than 3 dB would be used. Above this

higher sound level, a 3 dB trade-off would be used. This same sort of scheme could be proposed for exposures during a 24-h period, necessitating some type of change in Leq calculation or the addition of a correction factor.

If one extends the C_1 concept to ATS and if ATS is related to PTS, then it is possible to project an ordering of PTS from least to most--group C, group F, and group E. If, however, the EEH is true (i.e., equal exposure energy results in equivalent threshold shifts), then there should be no difference in the order of PTS magnitude.

Permanent threshold shift. Permanent threshold shift (PTS) was defined to be the remaining threshold shoft after 30 d of recovery. A dependent T-test was conducted between ears for each test frequency to determine if a statistical difference was present. Results of this test indicated no statistically significant PTS differences existed between ears, therefore, ears were pooled to analyze for group differences.

Four one-way ANOVAs were conducted. Their summary data are reported in Tables 17 through 20. The mean and range values in dB are plotted in Figure 13. The only significant difference in PTS among groups was at 4.0 kHz. Thus the null hypothesis that PTS does not differ among the exposure groups was rejected for 4.0 kHz and was not rejected for the 3.0 kHz, 5.7 kHz, and 8.0 kHz stimuli. The Scheffé post hoc procedure, Table 11 (page 54) revealed group C to be significantly different from group E only. With regard to 4.0 kHz, the difference in PTS between these two groups was 12 dB. This amount of PTS difference was also present at 5.7 kHz.

Table 17. Summary of Analysis of Variance Comparing the Amount of PTS Among Exposure Groups for 3.0 kHz.

Group	N	Mean	MS_{among}	MS_{within}	F
C	6	13.50	176.82	91.16	
E	12	7.92			
F	12	15.42			1.94

Table 18. Summary of Analysis of Variance Comparing the Amount of PTS Among Exposure Groups for 4.0 kHz.

Group	N	Mean	MS_{among}	MS_{within}	F
C	6	24.33	331.89	95.91	
E	12	11.74			
F	12	18.00			3.46*

*Significant beyond the 0.05 level.

Table 19. Summary of Analysis of Variance Comparing the Amount of PTS Among Exposure Groups for 5.7 kHz.

Group	N	Mean	MS_{among}	MS_{error}	F
C	6	27.33	310.06	129.16	
E	12	15.17			
F	12	17.25			2.40

Table 20. Summary of Analysis of Variance Comparing the Amount of PTS Among Exposure Groups for 8.0 kHz.

Group	N	Mean	MS_{among}	MS_{error}	F
C	6	16.00	69.79	89.58	
E	12	11.42			
F	12	10.17			0.78

At 5.7 kHz, however, there were no statistically significant differences because of the large variation in the PTS among animals. Note that the range values for group E in Figure 13 are quite extensive as compared to the other two groups, a factor which decreases the power of ANOVA. Based upon this range, considering the small sample size, and in view of a PTS difference of 12 dB between group C and groups E and F,

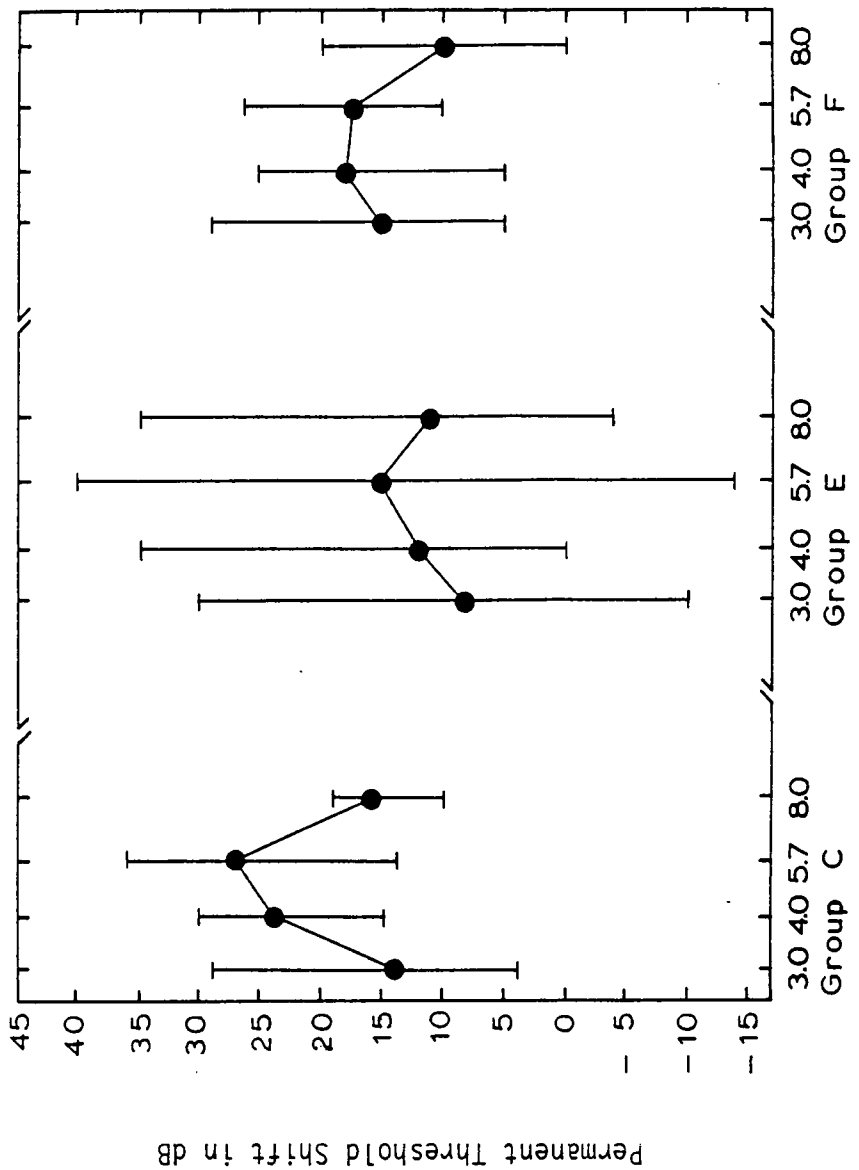


Figure 13. Mean and range PTS values in dB as a function of exposure group and test frequency.

Table 21. Summary of the Scheffé Post Hoc Procedure for Group PTS Differences in dB at 4.0 kHz.

Critical Value	Mean PTS Differences in dB Between Groups		
	F-E	C-F	C-E
6.8	6.2	6.3	12.5*

*Significantly different at the 0.05 level.

it is this author's opinion that the EEH is not supported by the results at 5.7 kHz either, even though PTS among groups was statistically equivalent.

The above results are consistent with the literature in that continuous exposures typically elicit greater hearing loss than intermittent exposures or varying exposures (Miller, et al., 1963; Johnson, 1978). The exposure group with the lowest level and longest exposure developed the most PTS and the exposure group with the highest level and shortest exposure had the least PTS for the predominantly affected test frequencies--4.0 kHz and 5.7 kHz. This sequence is exactly as predicted in the previous sections dealing with TTS and recovery. If Botsford's C_1 concept truly holds, then this provides support for measuring the effects of noise exposure upon the threshold of hearing at a post exposure time which would be within the C_1 component of recovery. This is not a new idea but has been implied by Ward (1970) and suggested by Botsford (1971). Ward thought TTS measured at post exposure times of 45 m or 60 m would be better predictors of PTS than times measured at 2 m to 15 m post exposure.

A second fact which needs to be addressed in the above results is that of the variation. The wide ranges portrayed in Figure 13 suggest a great deal of individual variability. This variability may be related to susceptibility to noise overexposure. In addition, the level of anesthesia and the neural asynchrony could have influenced the variability. The obtained ranges for group E as compared to groups C and F could represent two interacting factors, tinnitus and variability in damage. Tinnitus could provide a masking effect of the AER and increased damage could reduce the AER, thereby decreasing the visual detection of threshold. In either case, the net effect would most likely be the disruption of synchrony in the eighth nerve. Any asynchrony in the eighth nerve would present a problem in obtaining a threshold value when the level of the test stimulus is varied. The asynchrony could be attributed to damage in the sensory generators, a fact which may also be accompanied by tinnitus.

Histology Analysis

Of 23 animals (46 ears) available for dissection, only 23 ears were dissected. The other 23 ears could not be dissected for any one of the following reasons: the cochlea fractured while being removed from the temporal bone (6 cochleas) or when being situated in the dissection holder (10 cochleas); some tissue burned during the fixation and staining process, rendering it too brittle for dissection (6 cochleas); or the specimen was lost during the dissection process (1 cochlea). Five of the 23 ears dissected resulted in missing sections due to dissection error.

Reliability. Five cochleas which were successfully dissected were selected from the 23 dissected cochleas and were subjected to a

second count for missing hair cells. The percent of missing hair cells per mm of basilar membrane was correlated with the first count. Correlations were conducted for IHCs, each of the three rows of OHCs, the total of OHCs, and the total for all hair cells. As presented in Table 22, correlations ranged from a low for the first row of OHCs (R = 0.7694) to a high for the third row of OHCs (R = 0.9911), indicating a strong agreement between the two counts and suggesting good reliability for the counting procedure.

Table 22. Pearson Correlation Coefficients for Missing Hair Cells Across Inner, Outer, Total Outer, and Total Hair Cells of Five Animals.

IHC	OHC_1	OHC_2	OHC_3	TOHC	THC
0.9384	0.7694	0.9904	0.9911	0.9884	0.9876

Histology differences among groups. Histology results were analyzed by obtaining the total percent of missing hair cells in the total cochlea, typically 19 mm to 20 mm in length, and between the second and eleventh millimeter sections, the area most likely to evidence damage from the noise exposure stimulus. An analysis between missing IHCs and OHCs was not conducted since the literature (e.g., Dolan, et al., 1976; Vertes, 1976; and Erlandsson, et al., 1980) has demonstrated that noise exposure causes little IHC damage and inspection of the histology data from this study conforms to the literature in this regard.

Two one-way ANOVAs for unbalanced data (Winer, 1971) were conducted and indicated a significant difference among exposure groups, whether the total basilar membrane or the limited number of sections were used in the analysis. Therefore, the null hypothesis that the amounts of hair cell damage do not differ significantly among exposure groups was rejected. Table 23 presente the summary data of the ANOVA for the total basilar membrane, and Table 24 presents the summary data for the ANOVA using the limited number of sections. In either instance, group F on the basis of inspection was different from groups C and E. The amount of damage experienced by group F was so severe that under the dissection microscope areas of the organ of Corti were observed to be missing. This degree of damage was not observed for the other two groups.

The ordering of damage from most to least, based upon the percent of total hair cells missing, is group F, group E, and group C--the opposite of the PTS results. Obviously, even though all groups received equivalent sound energy for the duration of the experiment, equal damage did not occur.

Individual plots of the percent of intact hair cells as a function of distance from the base of the cochlea are presented in Appendix E - Figures 35 through 57, pages 174 to 196. It is interesting to note the individual variation in each group. Group E provides the most outstanding example. Two animals, E-5 and E-6, have very few missing hair cells. Also in group C, two animals (C-3 and C-6) were exposed for a total of 65 d only, but depict a fair amount of hair cell damage as compared to some of the other animals in this group. These differences

Table 23. Summary Table for the One-Way ANOVA Comparing the Percent of Missing Hair Cells Across Exposure Group for the Total Basilar Membrane.

Group	N	Mean	MS_{among}	MS_{error}	F
C	3	3.13	26.385	6.188	
E	5	3.37			
F	8	6.91			4.264*

*Significant beyond the 0.05 level, $F_{0.95\ (2,13)} = 3.81$.

Table 24. Summary Table for the One-Way ANOVA Comparing the Percent of Missing Hair Cells Across Exposure Group for Basilar Membrane Sections Three Through Ten.

Group	N	Mean	MS_{among}	MS_{error}	F
C	3	3.59	117.49	22.33	
E	5	5.23			
F	8	12.20			5.26*

*Significant beyond the 0.05 level, $F_{0.95\ (2,13)} = 3.81$.

in hair cell damage are probably due to individual variation and susecptability to noise overexposure.

Configuration of hair cell damage. In viewing the figures in Appendix E, page 173, some differences in the configuration of damage are apparent. Group A, the control group, had a flat configuration; whereas, the experimental groups did not. The experimental groups collectively exhibit three areas of insult--2 mm through 6 mm, 7 mm through 10 mm, and 13 mm through 16 mm--and an increasing amount of missing hair cells as one progresses from group C to group F.

Group C had a higher percentage of animals with hair cells missing in the 13 mm to 16 mm sections than the other two groups. In group E, 70 percent of the subjects sustained missing hair cells in the 2 mm to 6 mm sections and no animals had missing hair cells in the 13 mm to 16 mm sections. Group F had a greater percentage of animals with missing hair cells in the 2 mm to 6 mm area and about 40 percent of its animals damage in the other two areas.

For all groups the greatest amount of missing hair cells occurred in the 2 mm to 6 mm sections. Looking closer at these figures, one also observes that groups with the longer durations (groups C and F) exhibited missing hair cells in the 13 mm to 16 mm area. It would appear that as duration increases, the spread of missing hair cells also increases. The percentage of missing hair cells is not related to the equivalent sound energy but most likely is related to a physiological factor, vasoconstriction, for example. If vascular constricture occurs for a long enough time, then hair cell damage can occur in the cochlea (Lipscomb, et al., 1978). The spectrum and intensity of the signal may dictate the locale and degree of insult, but the duration may provide a spread-factor for the damage, such as through vasoconstriction.

Relationship Between Histology and PTS

Missing hair cell data from the 3 mm and 4 mm, 5 mm and 6 mm, 7 mm and 8 mm, and 9 mm and 10 mm sections were respectively collapsed and had their respective means for the percent of total hair cells calculated. These means were used to assess the relationship between total damage and mean PTS. The mean PTS values for each test frequency and for the percent total hair cell damage were rank ordered and subjected to a linear regression routine to calculate the line of best fit. The calculated slope was used as a measure of the relationship, -1.0 being a perfect negative relationship, and +1.0 being a perfect positive relationship. The results were as follows:

1) 3.0 kHz and 9-10 mm section, slope = -0.74;
2) 4.0 kHz and 7-8 mm section, slope = +0.34;
3) 5.7 kHz and 5-6 mm section, slope = -0.05; and
4) 8.0 kHz and 3-4 mm section, slope = -0.08.

As reported by Vertes (1976), Lipscomb, et al. (1977), and Abrams (1980), there appears to be no relation between PTS and missing hair cells. This suggests that a change in the criterion for damage or for a functioning versus a malfunctioning sensory unit is needed. While it is true that a phalangeal scar indicates a missing and therefore non-functioning hair cell, the presence of an "intact" hair cell does not necessarily mean it is functioning properly. Generally, one can say that either missing hair cells or intact hair cells is a poor measure for determining the relationship between hearing thresholds and hair cell "damage."

Control Group

Six chinchilla were assigned to the control group which received an Leq_{24} = 51.5 dB. One animal died for undetermined reasons before baseline measures could be obtained. Observing the baseline measures in Appendix B (page 102) one can see good agreement among the control and three experimental groups. One question of interest was concerned with differences in auditory thresholds between the control group and the experimental groups after noise exposure.

As would be expected, by comparing the control group's baseline measures to the post noise exposure threshold measures of the experimental groups, one can observe large differences. These differences typically exceeded 10 dB indicating poorer hearing for the experimental group. Because of the obvious nature of these differences, formal statistical analyses were not conducted.

In the case of histology data, only two of ten control animals' ears were dissected. Again, the obvious was supported. The control animals exhibited close to 100% intact hair cells. This result was similar to the result of Vertes (1976). The control group results provide evidence that the ambient level (51.5 dBA) does not induce hair cell damage.

CHAPTER V

SUMMARY AND CONCLUSIONS

Studies concerned with the effects of noise exposure upon the auditory mechanism have led to various theories, such as the "damaged-ear theory" (Ward, 1976b), the "micro-trauma theory" (Gravendeel and Plomp, 1960), and the "equal energy hypothesis" (Eldredge and Covell, 1958). Due to the simplicity of the EEH, that is, equal exposure energy yields equal threshold shift, it has become widely accepted (Ward, 1974).

The EEH specifies a 3 dB change in sound energy for each doubling or halving of the exposure duration. To maintain equivalent sound energy, a 3 dB increase in sound energy would necessitate a halving of the exposure duration; while a 3 dB decrease in sound energy would require a doubling of exposure duration. A descriptor, equivalent sound level (Leq), which uses the equal energy rule and accounts for the magnitude and the duration of the total exposure, agrees with many of the physiologic and psychologic effects of noise exposure (Goldstein, 1976). Equivalent sound energy is the average of the total sound energy occurring in a given observation period (Goldstein, 1976). A typical observation period which has become accepted is 24 h (EPA, 1973).

A review of the literature did not disclose EEH studies describing exposures with Leq over a 24 h period (Leq_{24}). In view of Ward, et al.'s 1976 study of effective quiet and Mills and Talo's 1974 results of low level exposure, the use of Leq_{24} as a means of determining the effects of noise overexposure needed to be systematically investigated.

In addition, the literature reviewed did not study the interaction of steady and fluctuant noise overexposure, or the effects of noise exposure upon the cochlea for temporal patterns which approximate a 40 h per week work-schedule.

Purpose and Procedures

The purpose of this study was to investigate the effects upon the auditory system of chinchilla of three noise exposure patterns with equivalent sound energy. The schedule of exposure was typical of a 40 h work-week and was conducted for a total of 6 months. This design resulted in 135 8-h exposures and 16-h quiet periods, as well as 25 48-h periods of recovery for each subject. After the final exposure day, a 30-d recovery period was allowed prior to preparation of ear tissue for histological study.

The exposure stimulus was a one-third octave band of noise centered at 4.0 kHz. The sound level of this stimulus was adjusted such that the Leq_{24} was approximately 85 dB. The specific exposure patterns and sound levels were as follows:

1. Group C - 8.00 h at 90.8 dBA and 16.00 h at 51.5 dBA.
2. Group E - 3.75 h at 75.0 dBA, 0.25 h at 105.0 dBA, 4.00 h at 75.0 dBA, and 16.00 h at 51.5 dBA.
3. Group F - 4.00 h at 94.1 dBA, 4.00 h at 74.0 dBA, and 16.00 h at 51.5 dBA.

Auditory thresholds were measured pre- and post-exposure by averaging electrical activity elicited from the brain stem in response to tone burst stimuli.

Post exposure auditory thresholds were measured after the first, fifth, and final 8-h exposures, as well as after the first 2-d and final

(30-d) recovery periods. Threshold shifts were defined as differences, in decibels, between the pre exposure and post exposure thresholds.

After the final auditory threshold test was administered, the animal was terminated by decapitation. Cochleas were dissected by the surface preparation technique and sensory cell damage was assessed using interference-contrast microscopy. Data from the three exposure groups were compared for TTS, PTS, and histology differences. The EEH and the use of Leq_{24} as an appropriate descriptor for assessing otohazardous exposures were not completely supported.

Temporary Threshold Shifts

Temporary threshold shift (TTS) data supported the EEH and the use of Leq_{24} as an appropriate descriptor of hazardous auditory noise exposures, at least for the animal type and parameters used in this study. For the three noise exposure patterns used, mean TTS among groups were statistically equivalent for all three test frequencies after exposure days 1, 5, and 135. Thus the null hypothesis that there are no significant differences in TTS among groups exposed to different exposure patterns with equivalent sound energy was not rejected. As with other investigations, the amount of TTS increased with the number of exposures. It is concluded that for TTS measured between 30 m and 55 m post exposure and for as many as 135 daily exposures interspersed with 2-d recovery periods, regardless of frequency, EEH is supported.

Recovery Threshold Shift

Throughout the 6-months exposure period, 50 2-d recovery periods were interspersed every sixth and seventh day. Threshold shifts were measured after the first 2-d recovery period and indicated no statistically

significant differences in TTS among the three groups, thus the null hypothesis that threshold shifts as measured during the exposure sessions do not differ, was not rejected. In addition, threshold shifts were present for all groups as the second exposure week began. It is concluded that for chinchilla, daily 16-h quiet periods and 2-d recovery periods do not provide enough time for complete recovery when stimulus Leq_{24} is 85 dB.

Permanent Threshold Shift

Permanent threshold shifts (threshold shifts remaining after 30 d of recovery) were measured at 3.0 kHz, 4.0 kHz, 5.7 kHz, and 8.0 kHz. Statistical analysis revealed the mean PTS at 4.0 kHz to be the only test frequency which was significantly different among the three exposure groups. Additional analysis of data for 4.0 kHz indicated PTS for group C to be significantly different from the PTS for groups E and F, and that PTS for groups E and F was equivalent, thereby rejecting the null hypothesis that PTSs do not differ significantly among the exposure groups. Thus it is concluded that the EEH is not supported by the PTS data of this study.

Histology

The effect of the three noise exposure patterns of equivalent sound energy upon the auditory sensory cells was dissimilar. Statistical analyses indicate that the mean percent of missing hair cells per millimeter of basilar membrane was different among exposure groups. Thus the null hypothesis that the amounts of hair cell damage do not differ significantly among the exposure groups was rejected. Inspection of these mean data revealed group F to be different from groups C and E, and groups C and E to have equivalent damage. It is concluded that when using the criterion of a missing hair cell, the EEH is not supported.

The relationship between the amount of PTS and the mean percent of missing hair cells for each audiometric test frequency was analyzed. No relationship was found. It is concluded that a predictive relationship between PTS and the mean percent of missing hair cells does not exist.

Limitations of this Study

1. Species of animal used limits the extension of the reported results to chinchilla.

2. Individual variability for threshold shifts was not resolved by use of an AER technique. In future studies, a high level stimulus should be used and the latency of one of the peaks in the waveform be set as the criterion measure. The latency and the AER structure could then be used in analyzing the data.

3. There being no statistically significant differences in TTS among groups after the first 2-d recovery period does not mean the results can be applied for later 2-d recovery periods. To determine if these threshold shifts for later 2-d recovery periods remain the same during long-term exposure, additional study of the effect of 2-d recovery periods throughout the duration of the experiment is needed.

4. The assumption that a missing hair cell is the only indicator of a non-functioning hair cell is questioned. Additional study of hair cells is required to define the limits and relation of physical damage and hair cell function.

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APPENDICES

APPENDIX A

TABLE 25. Schedule of AER Testing, Noise Exposure, and Recovery Periods.

Shift	Group	Animal	Day of Experiment								
			-10	-9	-8	-7	-6	-5	-4	-3	-2
Morning	C	1	0	-	-	-	-	-	-	-	-
		2	-	0	-	-	-	-	-	-	-
		3	-	-	0	-	-	-	-	-	-
		4	-	-	-	0	-	-	-	-	-
		5	-	-	-	-	0	-	-	-	-
		6	-	-	-	-	-	0	-	-	-
Evening	E	1	-	-	-	-	-	-	-	-	-
		2	-	0	-	-	-	-	-	-	-
		3	-	-	0	-	-	-	-	-	-
		4	-	-	-	0	-	-	-	-	-
		5	-	-	-	-	0	-	-	-	-
		6	-	-	-	-	-	0	-	-	-
Evening	F	1	0	-	-	-	-	-	-	-	-
		2	-	0	-	-	-	-	-	-	-
		3	-	-	0	-	-	-	-	-	-
		4	-	-	-	0	-	-	-	-	-
		5	-	-	-	-	0	-	-	-	-
		6	-	-	-	-	-	0	-	-	-

Table 25. Continued.

Shift	Group	Animal	Day of Experiment								
			-1	0	1	2	3	4	5	6	7
Morning	C	1	-	OX	X	X	X	OX	-	-	XO
		2	-	-	OX	X	X	X	OX	-	-
		3	-	-	-	OX	X	X	X	OX	-
		4	-	-	-	-	OX	X	X	X	OX
		5	-	-	-	-	-	OX	X	X	X
		6	-	-	-	-	-	-	OX	X	X
Evening	E	1	-	OX	X	X	X	OX	-	-	XO
		2	-	-	OX	X	X	X	OX	-	-
		3	-	-	-	OX	X	X	X	OX	-
		4	-	-	-	-	OX	X	X	X	OX
		5	-	-	-	-	-	OX	X	X	X
		6	-	-	-	-	-	-	OX	X	X
Evening	F	1	-	-	-	-	-	-	-	OX	X
		2	-	-	-	-	-	-	-	-	OX
		3	-	-	-	-	-	-	-	-	-
		4	-	-	-	-	-	-	-	-	-
		5	-	-	-	-	-	-	-	-	-
		6	-	-	-	-	-	-	-	-	-

Table 25. Continued.

Shift	Group	Animal	Day of Experiment								
			8	9	10	11	12	13	14	15	16
Morning	C	1	X	X	X	OX	-	-	X	X	X
		2	XO	X	X	X	OX	-	-	X	X
		3	-	XO	X	X	X	OX	-	-	X
		4	-	-	XO	X	X	X	OX	-	-
		5	OX	-	-	XO	X	X	X	OX	-
		6	X	OX	-	-	XO	X	X	X	OX
Evening	E	1	X	X	X	OX	-	-	X	X	X
		2	XO	X	X	X	OX	-	-	X	X
		3	-	XO	X	X	X	OX	-	-	X
		4	-	-	XO	X	X	X	OX	-	-
		5	OX	-	-	XO	X	X	X	OX	-
		6	C	OX	-	-	XO	X	X	X	OX
Evening	F	1	X	X	OX	-	-	XO	X	X	X
		2	X	X	X	OX	-	-	XO	X	X
		3	OX	X	X	X	OX	-	-	XO	X
		4	-	OX	X	X	X	OX	-	-	XO
		5	-	-	OX	X	X	X	OX	-	-
		6	-	-	-	OX	X	X	X	OX	-

Table 25. Continued.

Shift	Group	Animal	Day of Experiment								
			17	18	19	20	21	22	23	24	25
Morning	C	1	X	X	-	-	X	X	X	X	-
		2	X	X	X	-	-	X	X	X	-
		3	X	X	X	X	-	-	X	X	-
		4	X	X	X	X	X	-	-	X	-
		5	-	X	X	X	X	X	-	-	-
		6	-	-	X	X	X	X	X	-	-
Evening	E	1	X	X	-	-	X	X	X	X	-
		2	X	X	X	-	-	X	X	X	-
		3	X	X	X	X	-	-	X	X	-
		4	X	X	X	X	X	-	-	X	-
		5	-	X	X	X	X	X	-	-	-
		6	-	-	X	X	X	X	X	-	-
Evening	F	1	OX	-	-	X	X	X	X	X	-
		2	X	OX	-	-	X	X	X	X	-
		3	X	X	OX	-	-	X	X	X	-
		4	X	X	X	OX	-	-	X	X	-
		5	XO	X	X	X	OX	-	-	X	-
		6	-	X	X	X	X	OX	-	X	-

Table 25. Continued.

Shift	Group	Animal	Day of Experiment								
			26	27	28	29	30	31	32	33	34
Morning	C	1	-	X	X	X	X	X	-	-	X
		2	-	X	X	X	X	X	-	-	X
		3	-	X	X	X	X	X	-	-	X
		4	-	X	X	X	X	X	-	-	X
		5	-	X	X	X	X	X	-	-	X
		6	-	X	X	X	X	X	-	-	X
Evening	E	1	-	X	X	X	X	X	-	-	X
		2	-	X	X	X	X	X	-	-	X
		3	-	X	X	X	X	X	-	-	X
		4	-	X	X	X	X	X	-	-	X
		5	-	X	X	X	X	X	-	-	X
		6	-	X	X	X	X	X	-	-	X
Evening	F	1	_	X	X	X	X	X	-	-	X
		2	-	X	X	X	X	X	-	-	X
		3	-	X	X	X	X	X	-	-	X
		4	-	X	X	X	X	X	-	-	X
		5	-	X	X	X	X	X	-	-	X
		6	-	X	X	X	X	X	-	-	X

Table 25. Continued.

Shift	Group	Animal	Day of Experiment								
			35	36	37	38	39	179	180	181	182
Morning	C	1	X	X	X	X	-	OX	-	-	-
		2	X	X	X	X	-	X	OX	-	-
		3	X	X	X	X	-	X	X	OX	-
		4	X	X	X	X	-	X	X	X	OX
		5	X	X	X	X	-	X	X	X	X
		6	X	X	X	X	-	-	X	X	X
Evening	E	1	X	X	X	X	-	OX	-	-	-
		2	X	X	X	X	-	X	OX	-	-
		3	X	X	X	X	-	X	X	OX	-
		4	X	X	X	X	-	X	X	X	OX
		5	X	X	X	X	-	X	X	X	X
		6	X	X	X	X	-	-	X	X	X
Evening	F	1	X	X	X	X	-	-	-	X	X
		2	X	X	X	X	-	X	-	-	X
		3	X	X	X	X	-	X	X	-	-
		4	X	X	X	X	-	X	X	X	-
		5	X	X	X	X	-	X	X	X	X
		6	X	X	X	X	-	X	X	X	X

Table 25. Continued.

Shift	Group	Animal	Day of Experiment								
			183	184	185	186	187	188	189	190	191
Morning	C	1	-	-	-	-	-	-	-	-	-
		2	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-
		4	-	-	-	-	-	-	-	-	-
		5	OX	-	-	-	-	-	-	-	-
		6	X	OX	-	-	-	-	-	-	-
Evening	E	1	-	-	-	-	-	-	-	-	-
		2	-	-	-	-	-	-	-	-	-
		3	-	-	-	-	-	-	-	-	-
		4	-	-	-	-	-	-	-	-	-
		5	OX	-	-	-	-	-	-	-	-
		6	X	OX	-	-	-	-	-	-	-
Evening	F	1	X	X	OX	-	-	-	-	-	-
		2	X	X	X	OX	-	-	-	-	-
		3	X	X	X	X	OX	-	-	-	-
		4	-	X	X	X	X	OX	-	-	-
		5	-	-	X	X	X	X	OX	-	-
		6	X	-	-	X	X	X	X	OX	-

Table 25. Continued.

Shift	Group	Animal	Day of Experiment								
			230	231	232	233	234	235	236	237	238
Morning	C	1	0	terminated							
		2	-	0	terminated						
		3	-	-	0	terminated					
		4	-	-	-	0	terminated				
		5	-	-	-	-	0	terminated			
		6	-	-	-	-	-	0	terminated		
Evening	E	1	0	terminated							
		2	-	0	terminated						
		3	-	-	0	terminated					
		4	-	-	-	0	terminated				
		5	-	-	-	-	0	terminated			
		6	-	-	-	-	-	0	terminated		
Evening	F	1	-	-	-	-	-	-	-	0	terminated
		2	-	-	-	-	-	-	-	-	0
		3	-	-	-	-	-	-	-	-	-
		4	-	-	-	-	-	-	-	-	-
		5	-	-	-	-	-	-	-	-	-
		6	-	-	-	-	-	-	-	-	-

Table 25. Continued.

Shift	Group	Animal	Day of Experiment								
			239	240	241	242	243	244	245	246	247
Morning	C	1									
		2									
		3									
		4									
		5									
		6									
Evening	E	1									
		2									
		3									
		4									
		5									
		6									
Evening	F	1									
		2	terminated								
		3	0	terminated							
		4	-	0	terminated						
		5	-	-	0	terminated					
		6	-	-	-	0	terminated				

APPENDIX B

Table 26. Audiometric Data Expressed in dB re 20 μPa for Animal A-1.

Group: A	Leq_{24}: 51.5	Maximum Level: 54.0			Identification: A-1			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	35.0	40.0	20.0	25.0	35.0	30.0	36.0	25.0
Baseline Two	35.0	30.0	30.0	25.0	40.0	30.0	30.0	19.0
First 8-Hour Exposure	*	*	*	*	*	*	*	*
Fifth 8-Hour Exposure	*	*	*	*	*	*	*	*
First 48-Hour Recovery Period	*	*	*	*	*	*	*	*
135th 8-Hour Exposure	*	*	*	*	*	*	*	*
Final Recovery Period (30 Days)	*	*	*	*	*	*	*	*

*Animal was not used in any experimental condition, only as a control.

Table 27. Audiometric Data Expressed in dB re 20 μPa for Animal A-2.

Group: A	Leq_{24}: 51.5	Maximum Level: 54.0			Identification: A-2			
Ear		Left				Right		
Frequency in Kilohertz		3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One		40.0	35.0	36.0	29.0	25.0	35.0	16.0	29.0
Baseline Two		35.0	30.0	36.0	34.0	31.0	30.0	30.0	34.0
First 8-Hour Exposure		*	*	*	*	*	*	*	*
Fifth 8-Hour Exposure		*	*	*	*	*	*	*	*
First 48-Hour Recovery Period		*	*	*	*	*	*	*	*
135th 8-Hour Exposure		*	*	*	*	*	*	*	*
Final Recovery Period (30 Days)		*	*	*	*	*	*	*	*

*Animal was not used in any experimental condition, only as a control.

Table 28. Audiometric Data Expressed in dB re 20 μPa for Animal A-3.

Group: A	Leq_{24}: 51.5	Maximum Level: 54.0			Identification: A-3			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	31.0	35.0	36.0	19.0	35.0	20.0	26.0	25.0
Baseline Two	31.0	26.0	26.0	25.0	40.0	26.0	20.0	29.0
First 8-Hour Exposure	*	*	*	*	*	*	*	*
Fifth 8-Hour Exposure	*	*	*	*	*	*	*	*
First 48-Hour Recovery Period	*	*	*	*	*	*	*	*
135th 8-Hour Exposure	*	*	*	*	*	*	*	*
Final Recovery Period (30 Days)	*	*	*	*	*	*	*	*

*Animal was not used in any experimental condition, only as a control.

Table 29. Audiometric Data Expressed in dB re 20 μPa for Animal A-4.

Group: A	Leq_{24}: 51.5	Maximum Level: 54.0			Identification: A-4			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	25.0	26.0	16.0	19.0	31.0	20.0	30.0	19.0
Baseline Two	31.0	26.0	26.0	25.0	31.0	20.0	26.0	25.0
First 8-Hour Exposure	*	*	*	*	*	*	*	*
Fifth 8-Hour Exposure	*	*	*	*	*	*	*	*
First 48-Hour Recovery Period	*	*	*	*	*	*	*	*
135th 8-Hour Exposure	*	*	*	*	*	*	*	*
Final Recovery Period (30 Days)	*	*	*	*	*	*	*	*

*Animal was not used in any experimental condition, only as a control.

Table 30. Audiometric Data Expressed in dB re 20 μPa for Animal A-5.

Group: A	Leq_{24}: 51.5	Maximum Level: 54.0			Identification: A-5			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	3.7	8.0
Baseline One	40.0	35.0	36.0	25.0	35.0	35.0	36.0	25.0
Baseline Two	31.0	30.0	26.0	19.0	35.0	40.0	20.0	19.0
First 8-Hour Exposure	*	*	*	*	*	*	*	*
Fifth 8-Hour Exposure	*	*	*	*	*	*	*	*
First 48-Hour Recovery Period	*	*	*	*	*	*	*	*
135th 8-Hour Exposure	*	*	*	*	*	*	*	*
Final Recovery Period (30 Days)	*	*	*	*	*	*	*	*

*Animal was not used in any experimental condition, only as a control.

Table 31. Audiometric Data Expressed in dB re 20 μPa for Animal C-1.

Group: C	Leq_{24}: 85.2	Maximum Level: 90.0			Identification: C-1			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	31.0	30.0	26.0	34.0	35.0	26.0	26.0	29.0
Baseline Two	35.0	26.0	30.0	29.0	25.0	26.0	26.0	29.0
First 8-Hour Exposure	**	60.0	50.0	54.0	**	50.0	46.0	49.0
Fifth 8-Hour Exposure	**	50.0	56.0	54.0	**	45.0	50.0	54.0
First 48-Hour Recovery Period	**	40.0	46.0	49.0	**	35.0	40.0	39.0
135th 8-Hour Exposure	I	I	I	I	I	I	I	I
Final Recovery Period (30 Days)	I	I	I	I	I	I	I	I

I - Died prior to these tests.
**This frequency was not tested for TTS data.

Table 32. Audiometric Data Expressed in dB re 20 μPa for Animal C-2.

Group: C	Leq_{24}: 85.2	Maximum Level: 90.0			Identification: C-2			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	35.0	35.0	26.0	34.0	31.0	30.0	30.0	29.0
Baseline Two	35.0	26.0	26.0	25.0	31.0	26.0	26.0	25.0
First 8-Hour Exposure	**	60.0	46.0	44.0	**	40.0	50.0	59.0
Fifth 8-Hour Exposure	**	60.0	50.0	54.0	**	45.0	50.0	54.0
First 48-Hour Recovery Period	**	50.0	46.0	44.0	**	35.0	40.0	29.0
135th 8-Hour Exposure	**	55.0	56.0	49.0	**	55.0	56.0	54.0
Final Recovery Period (30 Days)	40.0	50.0	56.0	44.0	50.0	55.0	60.0	44.0

**This frequency was not tested for TTS data.

Table 33. Audiometric Data Expressed in dB re 20 μPa for Animal C-3.

Group: C	Leq_{24}: 85.2	Maximum Level: 90.0			Identification: C-3			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	DNT	DNT	DNT	DNT	DNT	DNT	DNT	DNT
Baseline Two	25.0	20.0	16.0	15.0	31.0	20.0	16.0	19.0
First 8-Hour Exposure	**	55.0	60.0	64.0	**	55.0	50.0	49.0
Fifth 8-Hour Exposure	**	50.0	56.0	44.0	**	55.0	50.0	49.0
First 48-Hour Recovery Period	III	III	III	III	III	III	III	III
65th 8-Hour Exposure	**	50.0	46.0	39.0	**	55.0	50.0	34.0
Final Recovery Period (30 Days)	31.0	30.0	30.0	19.0	35.0	26.0	26.0	25.0

DNT - Did not test.
III - Weight loss was too great to justify repeated sedation.
**This frequency was not tested for TTS data.

Table 34. Audiometric Data Expressed in dB re 20 μPa for Animal C-4.

Group: C	Leq_{24}: 85.2	Maximum Level: 90.0			Identification: C-4			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	25.0	20.0	30.0	29.0	50.0	35.0	26.0	29.0
Baseline Two	31.0	30.0	26.0	34.0	35.0	26.0	26.0	34.0
First 8-Hour Exposure	**	45.0	46.0	44.0	**	45.0	50.0	44.0
Fifth 8-Hour Exposure	**	45.0	50.0	44.0	**	50.0	56.0	44.0
First 48-Hour Recovery Period	II	II	II	II	**	40.0	40.0	39.0
135th 8-Hour Exposure	**	55.0	60.0	54.0	**	55.0	56.0	54.0
Final Recovery Period (30 Days)	35.0	45.0	40.0	44.0	50.0	45.0	46.0	49.0

II - Came out of sedation prior to conclusion of test session.
**This frequency was not tested for TTS data.

Table 35. Audiometric Data Expressed in dB re 20 μPa for Animal C-5.

Group: C	Leq_{24}: 85.2	Maximum Level: 90.0			Identification: C-5			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	21.0	26.0	16.0	25.0	31.0	26.0	20.0	25.0
Baseline Two	31.0	20.0	26.0	25.0	21.0	26.0	20.0	25.0
First 8-Hour Exposure	**	45.0	40.0	34.0	**	45.0	50.0	39.0
Fifth 8-Hour Exposure	**	50.0	36.0	34.0	**	50.0	56.0	49.0
First 48-Hour Recovery Period	**	40.0	40.0	29.0	**	35.0	46.0	39.0
135th 8-Hour Exposure	**	55.0	56.0	49.0	**	60.0	50.0	39.0
Final Recovery Period (30 Days)	40.0	50.0	56.0	39.0	50.0	55.0	56.0	44.0

**This frequency was not tested for TTS data.

Table 36. Audiometric Data Expressed in dB re 20 μPa for Animal C-6.

Group: C	Leq_{24}: 85.2	Maximum Level: 90.0			Identification: C-6			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	DNT	DNT	DNT	DNT	DNT	DNT	DNT	DNT
Baseline Two	31.0	26.0	15.0	25.0	21.0	16.0	20.0	25.0
First 8-Hour Exposure	**	45.0	46.0	39.0	**	55.0	60.0	54.0
Fifth 8-Hour Exposure	III	III	III	III	III	III	III	III
First 48-Hour Recovery Period	III	III	III	III	III	III	III	III
65th 8-Hour Exposure	**	45.0	50.0	39.0	**	50.0	40.0	44.0
Final Recovery Period (30 Days)	40.0	26.0	26.0	19.0	35.0	30.0	36.0	34.0

DNT - Did not test.
III - Weight loss was too great to justify sedation.
**This frequency was not tested for TTS data.

Table 37. Audiometric Data Expressed in dB re 20 μPa for Animal C-7.

Group: C	Leq_{24}: 85.2	Maximum Level: 90.0			Identification: C-7			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	31.0	26.0	20.0	25.0	31.0	30.0	26.0	29.0
Baseline Two	31.0	26.0	20.0	25.0	35.0	30.0	30.0	25.0
First 8-Hour Exposure	**	45.0	50.0	49.0	**	50.0	46.0	39.0
Fifth 8-Hour Exposure	**	I	I	I	**	I	I	I
First 48-Hour Recovery Period	**	I	I	I	**	I	I	I
135th 8-Hour Exposure	**	I	I	I	**	I	I	I
Final Recovery Period (30 Days)	I	I	I	I	I	I	I	I

I - Died prior to these tests.
**This frequency was not tested for TTS data.

Table 38. Audiometric Data Expressed in dB re 20 µPa for Animal C-8.

Group: C	Leq_{24}: 85.2	Maximum Level: 90.0			Identification: C-8			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	DNT	DNT	DNT	DNT	DNT	DNT	DNT	DNT
Baseline Two	35.0	35.0	40.0	34.0	35.0	30.0	36.0	25.0
First 8-Hour Exposure	**	55.0	50.0	59.0	**	50.0	56.0	49.0
Fifth 8-Hour Exposure	**	I	I	I	**	I	I	I
First 48-Hour Recovery Period	**	I	I	I	**	I	I	I
135th 8-Hour Exposure	**	I	I	I	**	I	I	I
Final Recovery Period (30 Days)	I	I	I	I	I	I	I	I

DNT - Did not test.
I - Died prior to these tests.
**This frequency was not tested for TTS data.

Table 39. Audiometric Data Expressed in dB re 20 µPa for Animal C-9.

Group: C	Leq_{24}: 85.2	Maximum Level: 90.0			Identification: C-9			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	DNT	DNT	DNT	DNT	DNT	DNT	DNT	DNT
Baseline Two	31.0	30.0	26.0	29.0	31.0	26.0	20.0	39.0
First 8-Hour Exposure	**	60.0	50.0	59.0	**	50.0	56.0	54.0
Fifth 8-Hour Exposure	**	I	I	I	**	I	I	I
First 48-Hour Recovery Period	**	I	I	I	**	I	I	I
135th 8-Hour Exposure	**	I	I	I	**	I	I	I
Final Recovery Period (30 Days)	I	I	I	I	I	I	I	I

DNT - Did not test.
I - Died prior to these tests.
**This frequency was not tested for TTS data.

Table 40. Audiometric Data Expressed in dB re 20 μPa for Animal C-10.

Group: C	Leq_{24}: 85.2	Maximum Level: 90.0			Identification: C-10			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	DNT	DNT	DNT	DNT	DNT	DNT	DNT	DNT
Baseline Two	31.0	26.0	26.0	29.0	35.0	30.0	20.0	25.0
First 8-Hour Exposure	**	45.0	46.0	49.0	**	45.0	50.0	54.0
Fifth 8-Hour Exposure	**	65.0	50.0	59.0	**	60.0	56.0	54.0
First 48-Hour Recovery Period	**	40.0	36.0	44.0	**	50.0	40.0	44.0
135th 8-Hour Exposure	**	I	I	I	**	I	I	I
Final Recovery Period (30 Days)	I	I	I	I	I	I	I	I

DNT - Did not test.
I - Died prior to these tests.
**This frequency was not tested for TTS data.

Table 41. Audiometric Data Expressed in dB re 20 μPa for Animal E-1.

Group: E	Leq_{24}: 85.2	Maximum Level: 105.0			Identification: E-1			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	DNT	DNT	DNT	DNT	DNT	DNT	DNT	DNT
Baseline Two	31.0	35.0	30.0	25.0	25.0	26.0	30.0	25.0
First 8-Hour Exposure	**	45.0	56.0	44.0	**	45.0	50.0	49.0
Fifth 8-Hour Exposure	**	60.0	56.0	39.0	**	60.0	60.0	49.0
First 48-Hour Recovery Period	**	II	II	II	**	45.0	36.0	39.0
135th 8-Hour Exposure	**	50.0	56.0	54.0	**	70.0	66.0	49.0
Final Recovery Period (30 Days)	55.0	65.0	40.0	34.0	55.0	45.0	46.0	34.0

DNT - Did not test.
II - Came out of sedation prior to conclusion of test session.
**This frequency was not tested for TTS data.

Table 42. Audiometric Data Expressed in dB re 20 μPa for Animal E-2.

Group: E	Leq_{24}: 85.2	Maximum Level: 105.0			Identification: E-2			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	31.0	26.0	26.0	25.0	45.0	35.0	36.0	34.0
Baseline Two	31.0	30.0	30.0	25.0	31.0	20.0	20.0	25.0
First 8-Hour Exposure	**	50.0	50.0	49.0	**	45.0	60.0	59.0
Fifth 8-Hour Exposure	**	55.0	56.0	39.0	**	60.0	60.0	49.0
First 48-Hour Recovery Period	**	II	II	II	**	35.0	20.0	44.0
135th 8-Hour Exposure	**	65.0	70.0	64.0	**	65.0	66.0	54.0
Final Recovery Period (30 Days)	31.0	35.0	50.0	59.0	45.0	50.0	60.0	44.0

II - Came out of sedation prior to conclusion of test session.
**This frequency was not tested for TTS data.

Table 43. Audiometric Data Expressed in dB re 20 μPa for Animal E-3.

Group: E	Leq_{24}: 85.2	Maximum Level: 105.0			Identification: E-3			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	40.0	26.0	20.0	19.0	40.0	35.0	30.0	25.0
Baseline Two	31.0	26.0	36.0	25.0	31.0	26.0	20.0	25.0
First 8-Hour Exposure	**	50.0	50.0	39.0	**	50.0	60.0	44.0
Fifth 8-Hour Exposure	**	55.0	50.0	44.0	**	55.0	56.0	59.0
First 48-Hour Recovery Period	**	26.0	40.0	39.0	**	35.0	26.0	29.0
135th 8-Hour Exposure	**	60.0	56.0	49.0	**	65.0	60.0	59.0
Final Recovery Period (30 Days)	45.0	35.0	36.0	25.0	35.0	26.0	36.0	34.0

**This frequency was not tested for TTS data.

Table 44. Audiometric Data Expressed in dB re 20 μPa for Animal E-4.

Group: E	Leq_{24}: 87.2	Maximum Level: 105.0			Identification: E-4			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	45.0	45.0	40.0	39.0	40.0	30.0	36.0	34.0
Baseline Two	45.0	40.0	30.0	34.0	35.0	26.0	20.0	39.0
First 8-Hour Exposure	**	50.0	46.0	49.0	**	45.0	46.0	39.0
Fifth 8-Hour Exposure	**	50.0	50.0	49.0	**	55.0	46.0	49.0
First 48-Hour Recovery Period	**	45.0	46.0	34.0	**	30.0	40.0	44.0
135th 8-Hour Exposure	**	70.0	80.0	64.0	**	55.0	60.0	44.0
Final Recovery Period (30 Days)	35.0	40.0	40.0	49.0	40.0	50.0	50.0	44.0

**This frequency was not tested for TTS data.

Table 45. Audiometric Data Expressed in dB re 20 μPa for Animal E-5.

Group: E	Leq_{24}: 87.2	Maximum Level: 105.0			Identification: E-5			
Ear		Left				Right		
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	35.0	26.0	36.0	39.0	40.0	30.0	36.0	34.0
Baseline Two	35.0	30.0	30.0	29.0	31.0	20.0	40.0	29.0
First 8-Hour Exposure	**	40.0	46.0	39.0	**	45.0	50.0	44.0
Fifth 8-Hour Exposure	**	45.0	46.0	44.0	**	50.0	46.0	39.0
First 48-Hour Recovery Period	**	30.0	36.0	25.0	**	30.0	36.0	29.0
135th 8-Hour Exposure	**	IV	IV	IV	**	IV	IV	IV
Final Recovery Period (30 Days)	40.0	30.0	26.0	25.0	31.0	20.0	26.0	25.0

IV - Would not sedate.
**This frequency was not tested for TTS data.

Table 46. Audiometric Data Expressed in dB re 20 μPa for Animal E-6.

Group: E	Leq_{24}: 87.2	Maximum Level: 105.0			Identification: E-6			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	25.0	26.0	30.0	29.0	45.0	35.0	30.0	29.0
Baseline Two	45.0	26.0	26.0	29.0	31.0	30.0	30.0	29.0
First 8-Hour Exposure	**	55.0	56.0	49.0	**	40.0	56.0	44.0
Fifth 8-Hour Exposure	**	60.0	60.0	64.0	**	60.0	50.0	49.0
First 48-Hour Recovery Period	**	40.0	40.0	39.0	**	30.0	40.0	29.0
135th 8-Hour Exposure	**	70.0	66.0	54.0	**	55.0	60.0	49.0
Final Recovery Period (30 Days)	60.0	45.0	60.0	64.0	25.0	30.0	46.0	39.0

**This frequency was not tested for TTS data.

Table 47. Audiometric Data Expressed in dB re 20 μPa for Animal F-1.

Group: F	Leq_{24}: 87.3	Maximum Level: 95.0			Identification: F-1			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	45.0	35.0	36.0	39.0	50.0	45.0	40.0	39.0
Baseline Two	35.0	30.0	20.0	34.0	31.0	30.0	26.0	34.0
First 8-Hour Exposure	**	II	46.0	II	**	60.0	50.0	49.0
Fifth 8-Hour Exposure	**	40.0	46.0	49.0	**	55.0	56.0	49.0
First 48-Hour Recovery Period	**	40.0	56.0	49.0	**	55.0	46.0	39.0
135th 8-Hour Exposure	**	II	II	II	**	65.0	66.0	59.0
Final Recovery Period (30 Days)	40.0	35.0	46.0	34.0	60.0	50.0	50.0	44.0

II - Came out of sedation prior to conclusion of test session.
**This frequency was not tested for TTS data.

Table 48. Audiometric Data Expressed in dB re 20 μPa for Animal F-2.

Group: F	Leq_{24}: 87.3	Maximum Level: 95.0			Identification: F-2			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	35.0	35.0	30.0	44.0	50.0	45.0	50.0	39.0
Baseline Two	31.0	30.0	20.0	29.0	31.0	26.0	26.0	29.0
First 8-Hour Exposure	**	40.0	50.0	54.0	**	60.0	56.0	49.0
Fifth 8-Hour Exposure	**	50.0	50.0	44.0	**	55.0	56.0	44.0
First 48-Hour Recovery Period	**	40.0	26.0	34.0	**	40.0	40.0	34.0
135th 8-Hour Exposure	**	IV	IV	IV	**	IV	IV	IV
Final Recovery Period (30 Days)	45.0	40.0	46.0	34.0	45.0	45.0	46.0	44.0

IV - Would not sedate.
**This frequency was not tested for TTS data.

Table 49. Audiometric Data Expressed in dB re 20 μPa for Animal F-3.

Group: F	Leq_{24}: 87.3	Maximum Level: 95.0			Identification: F-3			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	25.0	30.0	26.0	29.0	31.0	30.0	26.0	25.0
Baseline Two	25.0	26.0	30.0	19.0	25.0	26.0	26.0	19.0
First 8-Hour Exposure	**	50.0	50.0	54.0	**	45.0	50.0	39.0
Fifth 8-Hour Exposure	**	50.0	56.0	44.0	**	50.0	56.0	54.0
First 48-Hour Recovery Period	**	55.0	40.0	44.0	**	45.0	40.0	44.0
135th 8-Hour Exposure	**	55.0	50.0	54.0	**	50.0	56.0	49.0
Final Recovery Period (30 Days)	40.0	50.0	40.0	29.0	45.0	50.0	40.0	39.0

**This frequency was not tested for TTS data.

Table 50. Audiometric Data Expressed in dB re 20 μPa for Animal F-4.

Group: F	Leq_{24}: 87.3	Maximum Level: 95.0			Identification: F-4			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	65.0	40.0	40.0	34.0	25.0	26.0	30.0	34.0
Baseline Two	45.0	40.0	30.0	39.0	35.0	30.0	26.0	25.0
First 8-Hour Exposure	**	60.0	40.0	44.0	**	55.0	46.0	49.0
Fifth 8-Hour Exposure	**	55.0	50.0	44.0	**	65.0	60.0	44.0
First 48-Hour Recovery Period	**	55.0	46.0	29.0	**	35.0	50.0	34.0
135th 8-Hour Exposure	**	85.0	70.0	54.0	**	55.0	40.0	44.0
Final Recovery Period (30 Days)	65.0	65.0	50.0	49.0	50.0	45.0	40.0	44.0

**This frequency was not tested for TTS data.

Table 51. Audiometric Data Expressed in dB re 20 μPa for Animal F-5.

Group: F	Leq_{24}: 87.3	Maximum Level: 95.0			Identification: F-5			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	31.0	26.0	30.0	25.0	25.0	20.0	36.0	34.0
Baseline Two	35.0	30.0	30.0	29.0	31.0	30.0	36.0	29.0
First 8-Hour Exposure	**	II	46.0	II	**	60.0	50.0	44.0
Fifth 8-Hour Exposure	**	40.0	46.0	49.0	**	50.0	46.0	49.0
First 48-Hour Recovery Period	**	26.0	26.0	34.0	**	35.0	36.0	34.0
135th 8-Hour Exposure	**	IV	IV	IV	**	IV	IV	IV
Final Recovery Period (30 Days)	40.0	45.0	50.0	39.0	45.0	55.0	46.0	39.0

II - Came out of sedation prior to conclusion of test session.
IV - Would not sedate.
**This frequency was not tested for TTS data.

Table 52. Audiometric Data Expressed in dB re 20 μPa for Animal F-6.

Group: F	Leq_{24}: 87.3	Maximum Level: 95.0			Identification: F-6			
Ear	Left				Right			
Frequency in Kilohertz	3.0	4.0	5.7	8.0	3.0	4.0	5.7	8.0
Baseline One	31.0	20.0	20.0	25.0	35.0	30.0	20.0	25.0
Baseline Two	31.0	20.0	26.0	29.0	25.0	16.0	26.0	25.0
First 8-Hour Exposure	**	50.0	46.0	44.0	**	45.0	46.0	49.0
Fifth 8-Hour Exposure	**	55.0	50.0	44.0	**	55.0	56.0	49.0
First 48-Hour Recovery Period	**	III	III	III	**	III	III	III
135th 8-Hour Exposure	**	II	80.0	II	**	II	II	II
Final Recovery Period (30 Days)	50.0	30.0	36.0	29.0	40.0	40.0	40.0	44.0

II - Came out of sedation prior to conclusion of test session.
III - Weight loss was too great to justify sedation.
**This frequency was not tested for TTS data.

APPENDIX C

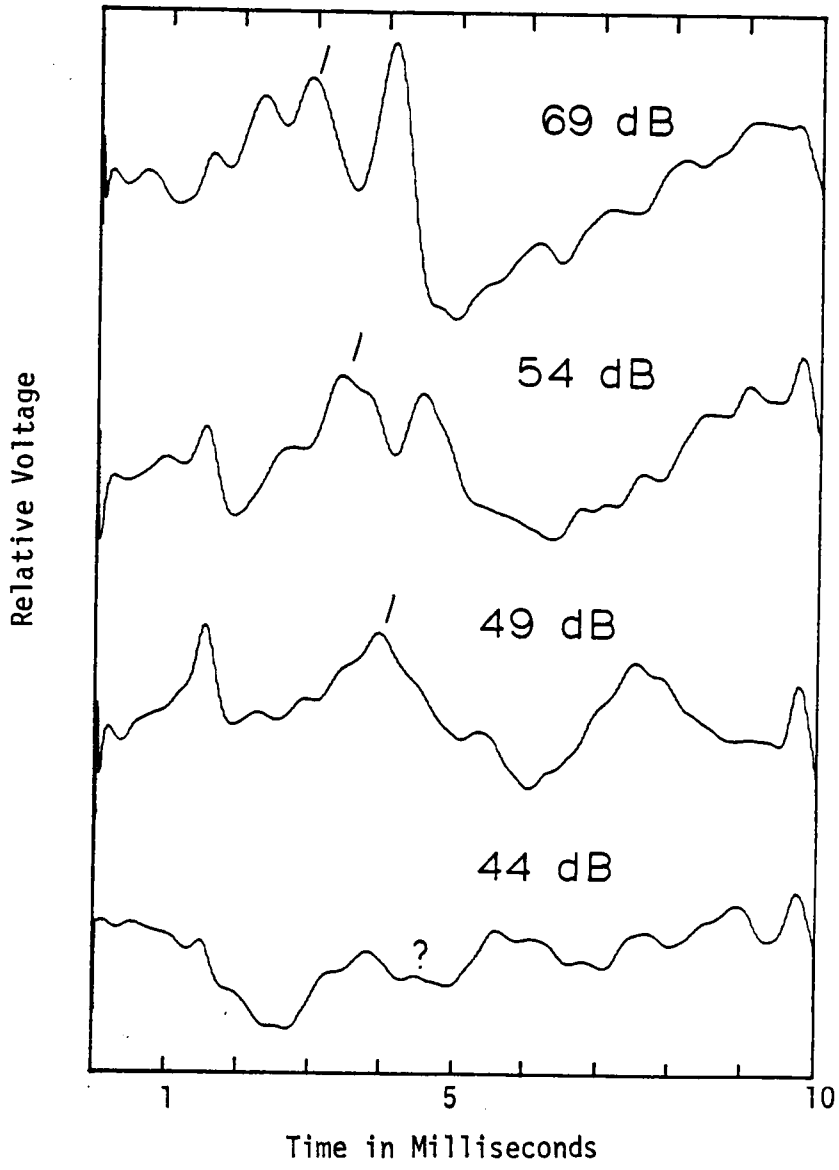


Figure 14. Evoked responses at 8.0 kHz for the left ear of animal C-2.

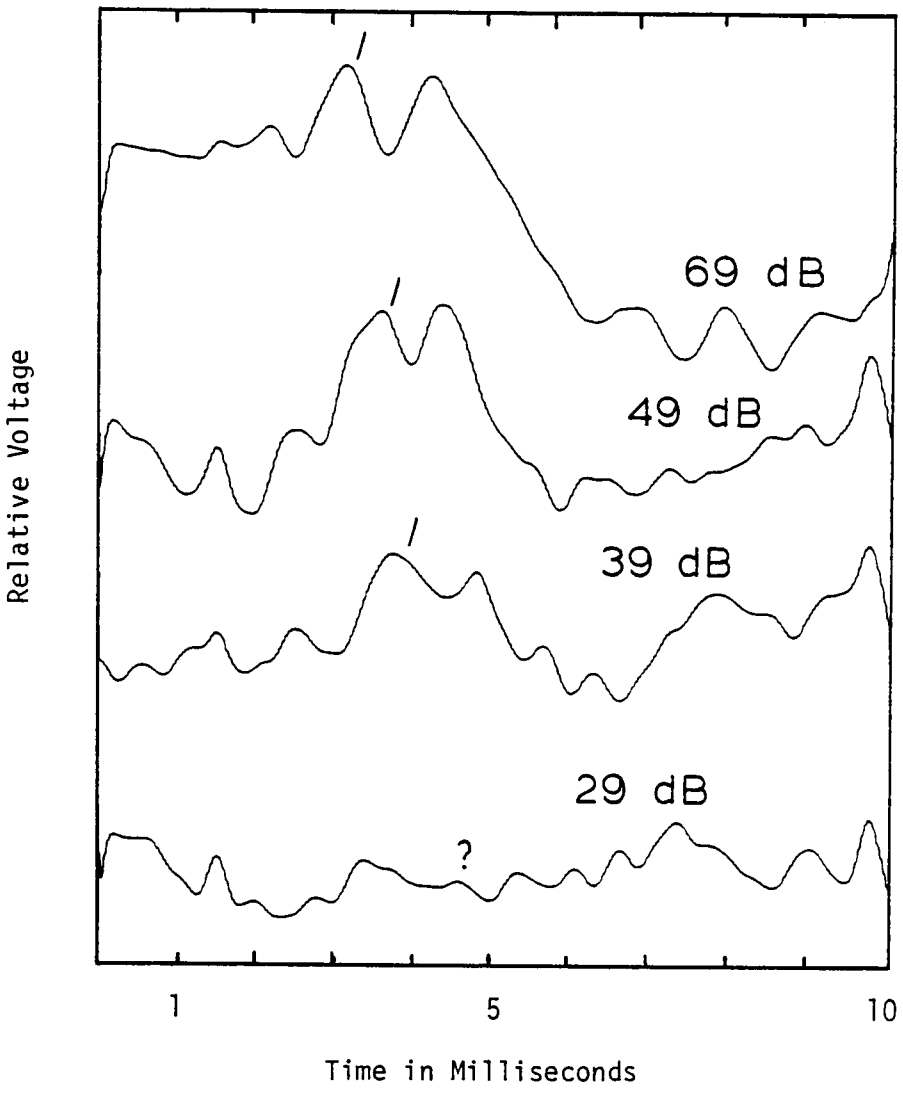


Figure 15. Evoked responses at 8.0 kHz for the left ear of animal C-3.

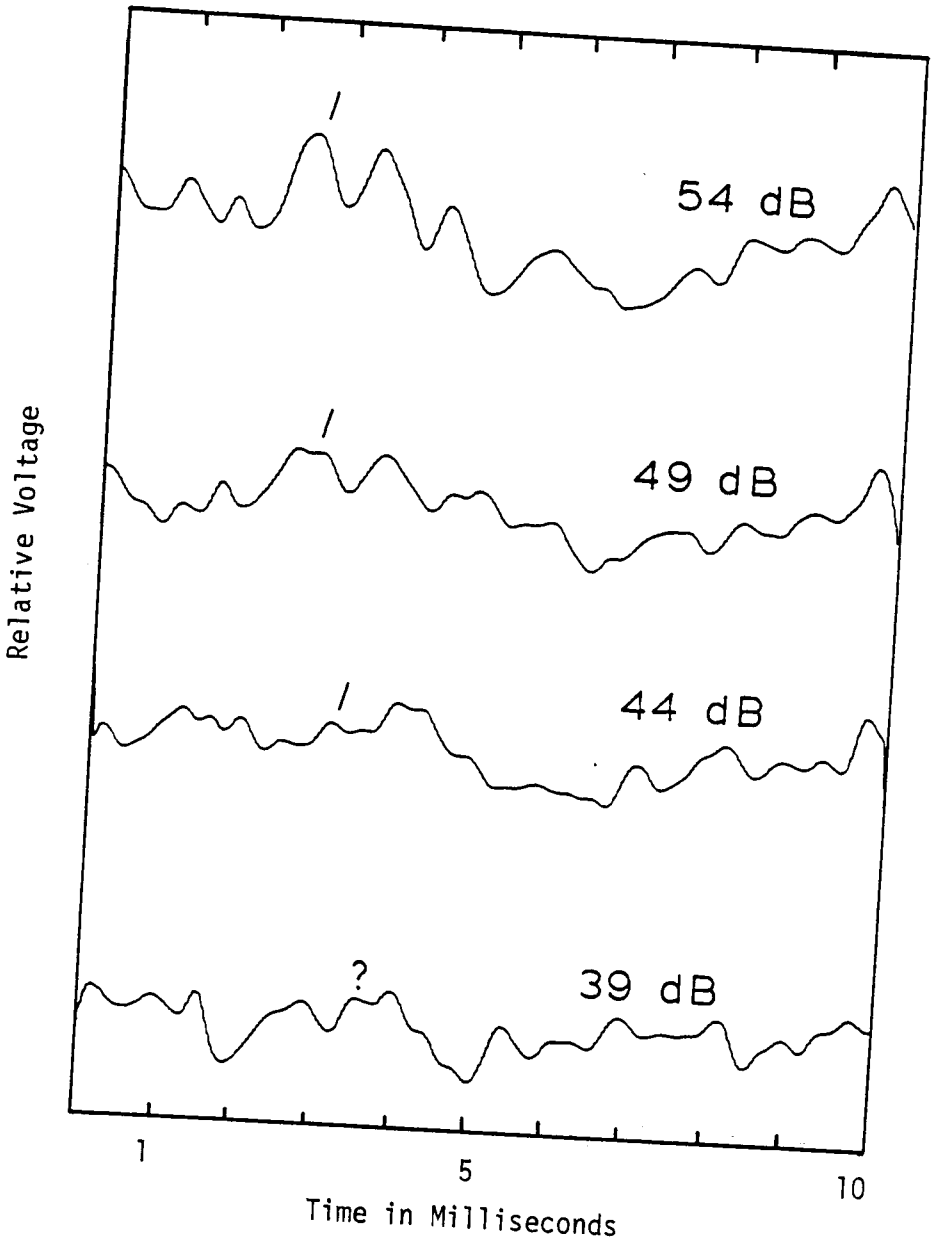


Figure 16. Evoked responses at 8.0 kHz for the right ear of animal C-6.

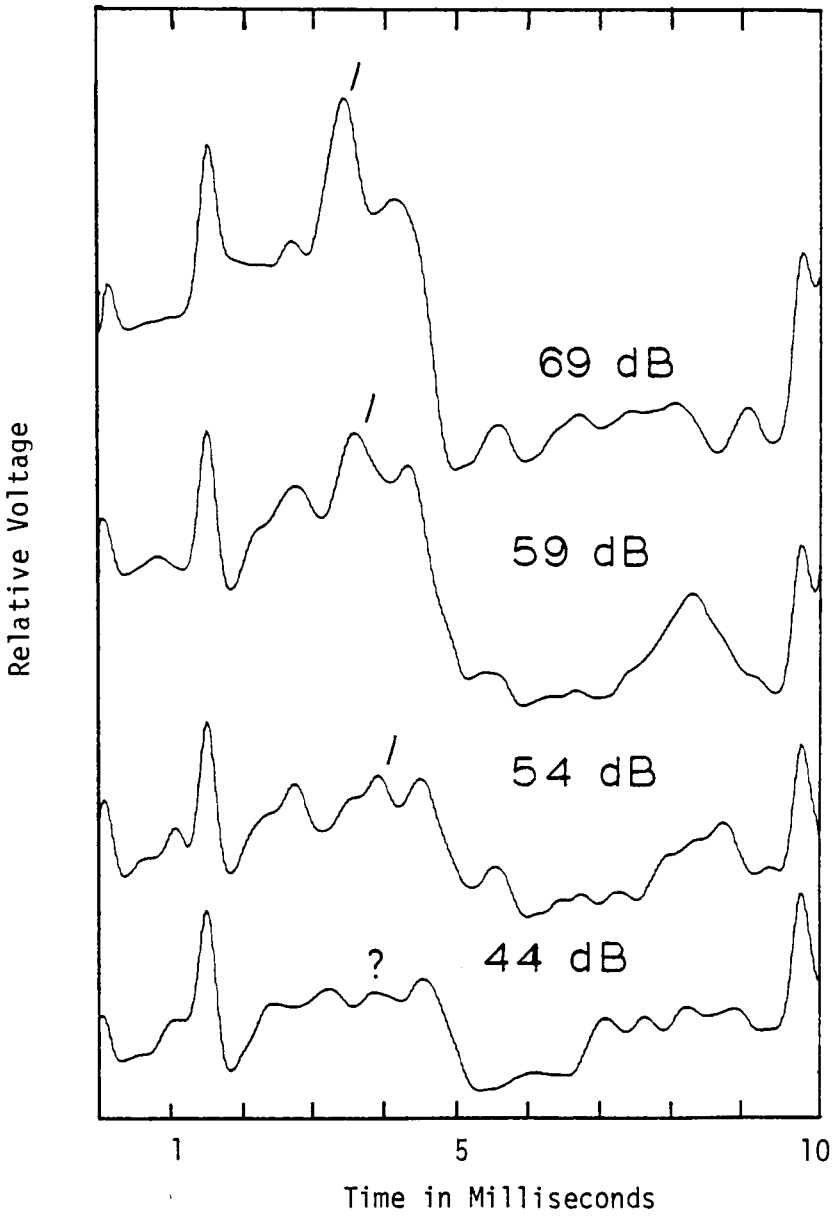


Figure 17. Evoked responses at 8.0 kHz for the left ear of animal E-1.

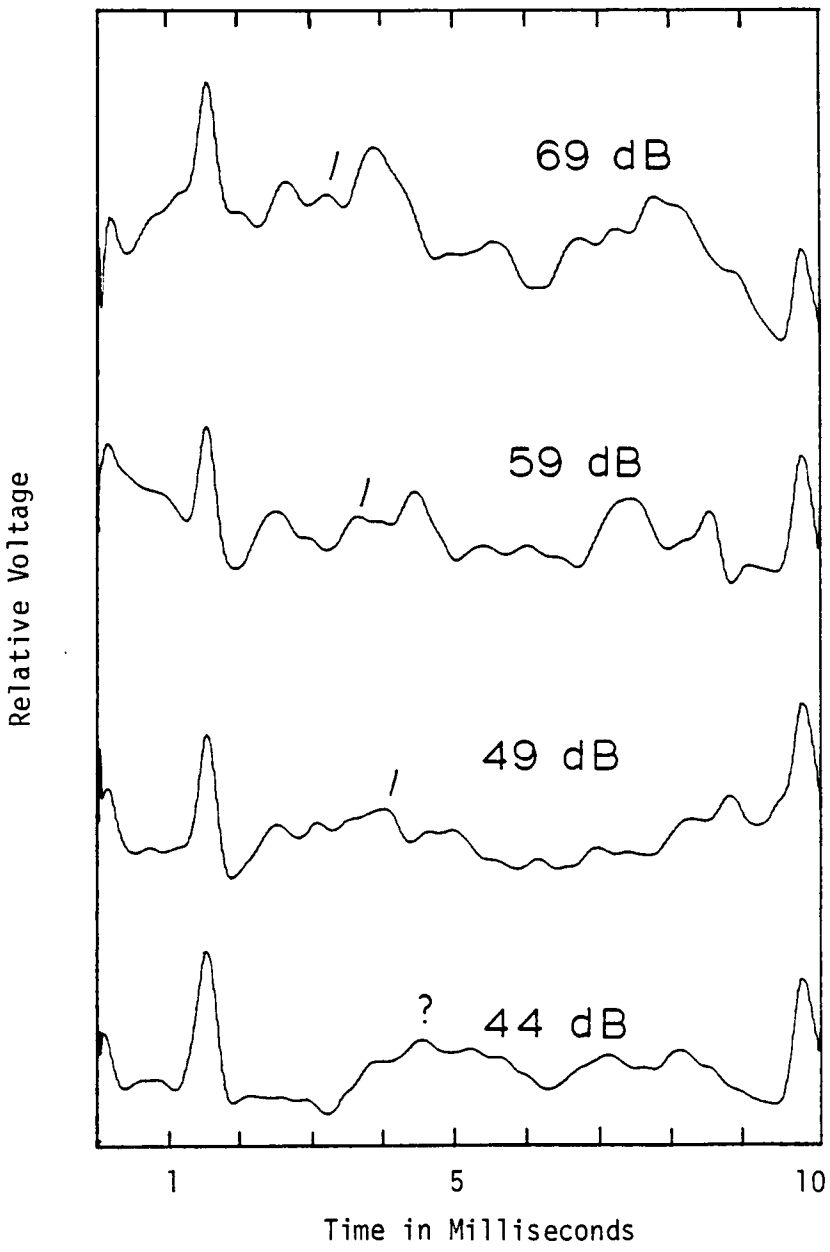


Figure 18. Evoked responses at 8.0 kHz for the left ear of animal E-3.

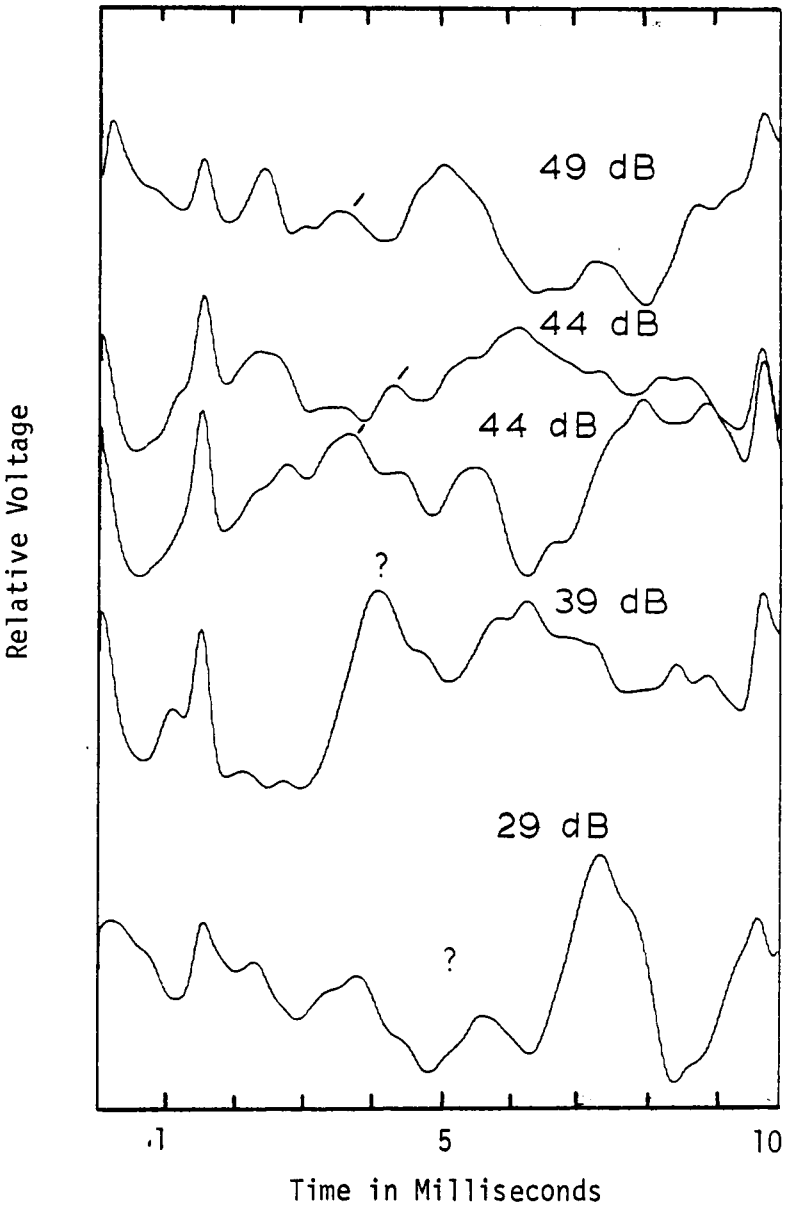


Figure 19. Evoked responses at 8.0 kHz for the right ear of animal E-4.

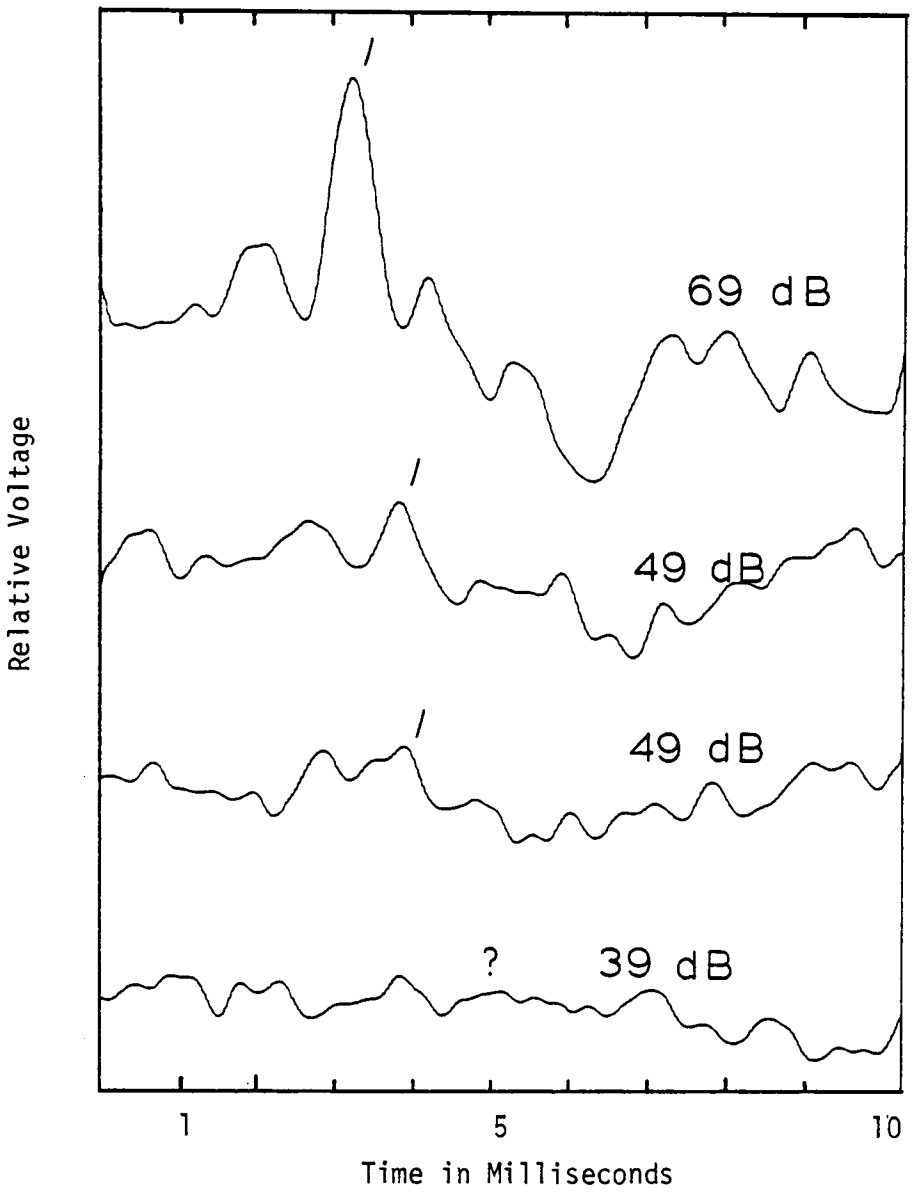


Figure 20. Evoked responses at 8.0 kHz for the right ear of animal E-6.

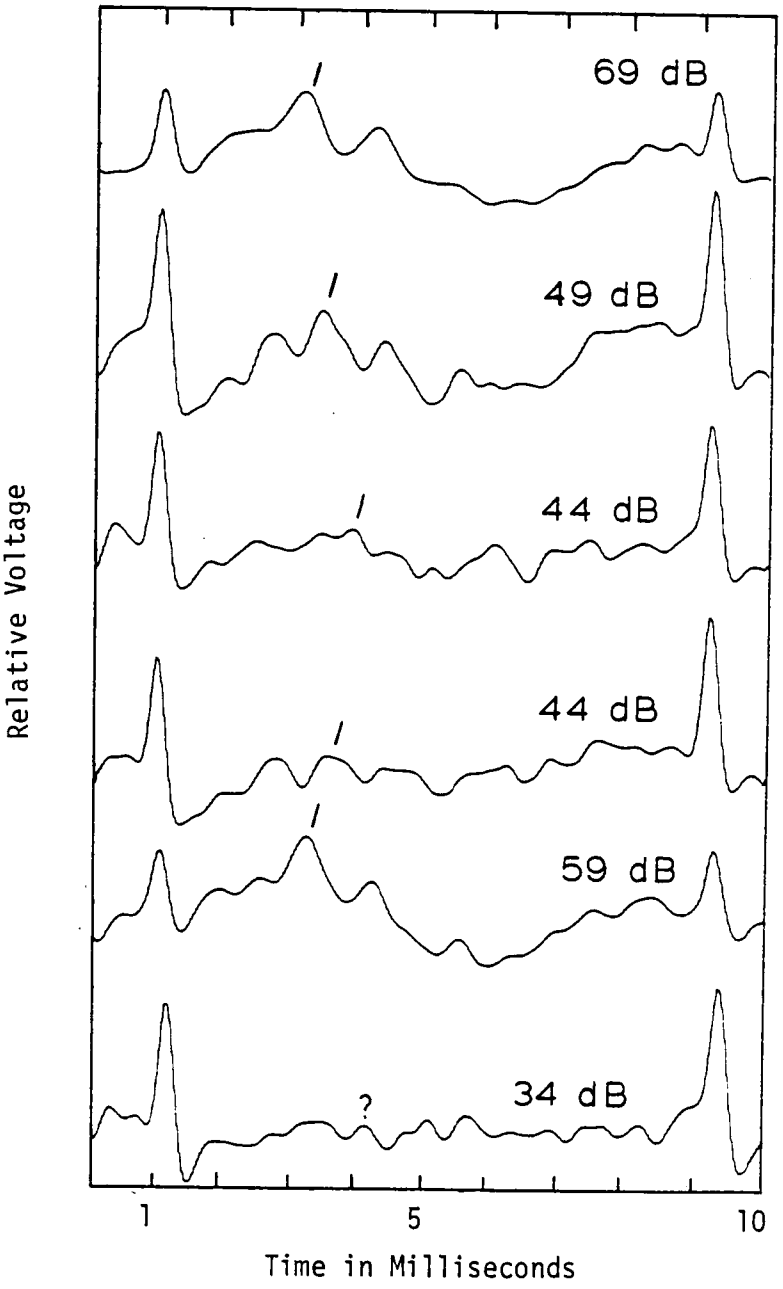


Figure 21. Evoked responses at 8.0 kHz for the right ear of animal F-1.

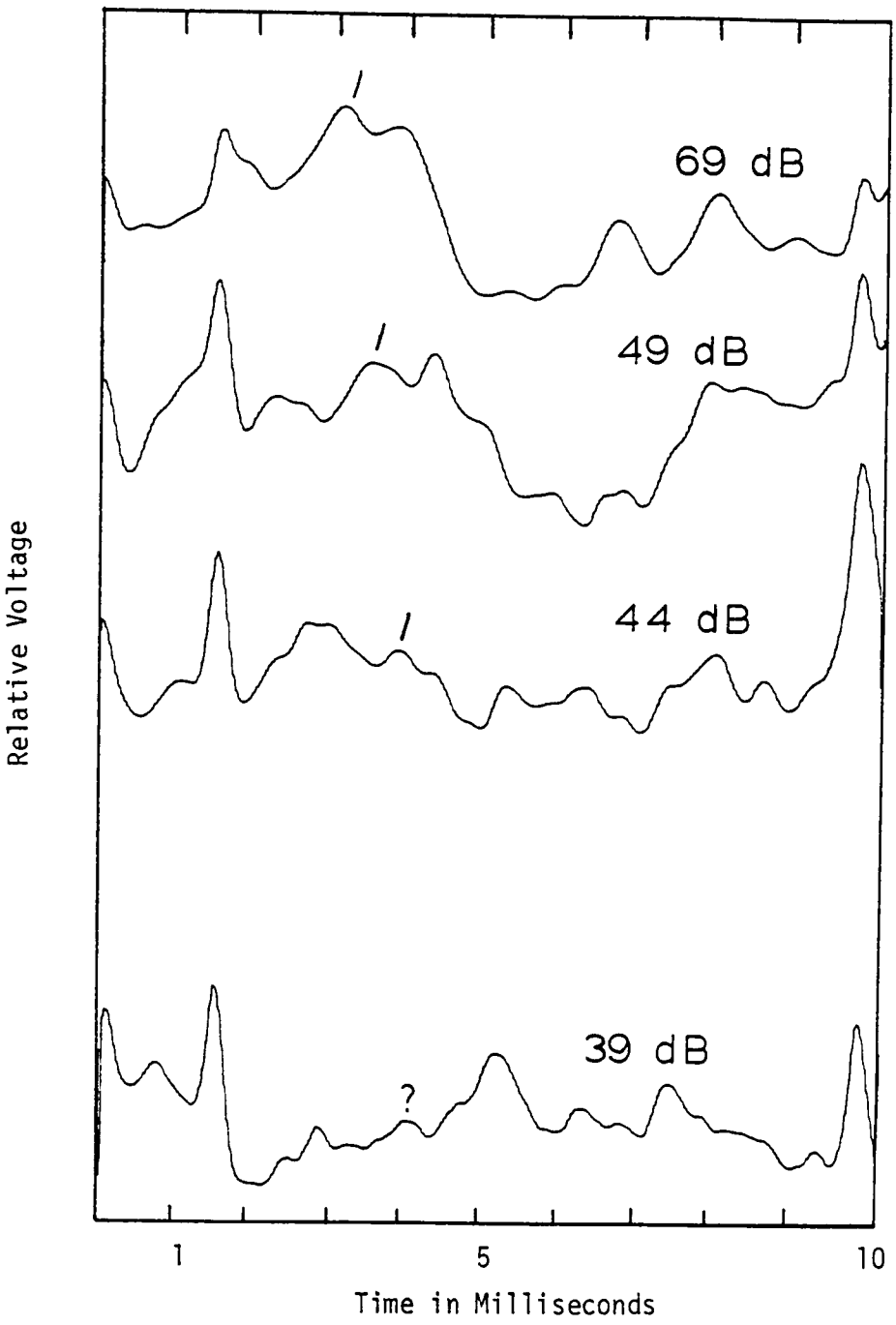


Figure 22. Evoked responses at 8.0 kHz for the right ear of animal F-4.

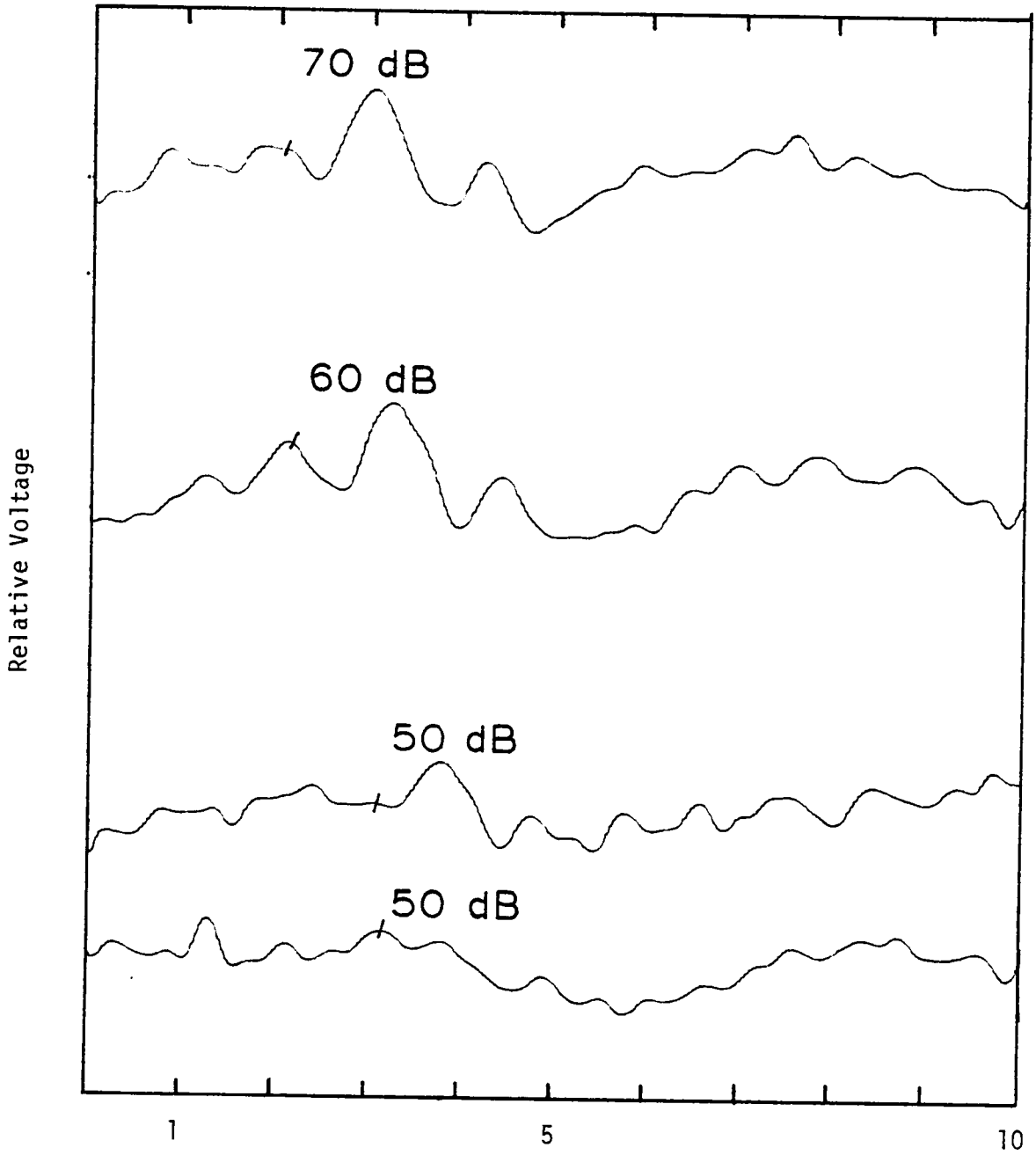


Figure 23. Evoked responses at 3.0 kHz for the right ear of animal C-2.

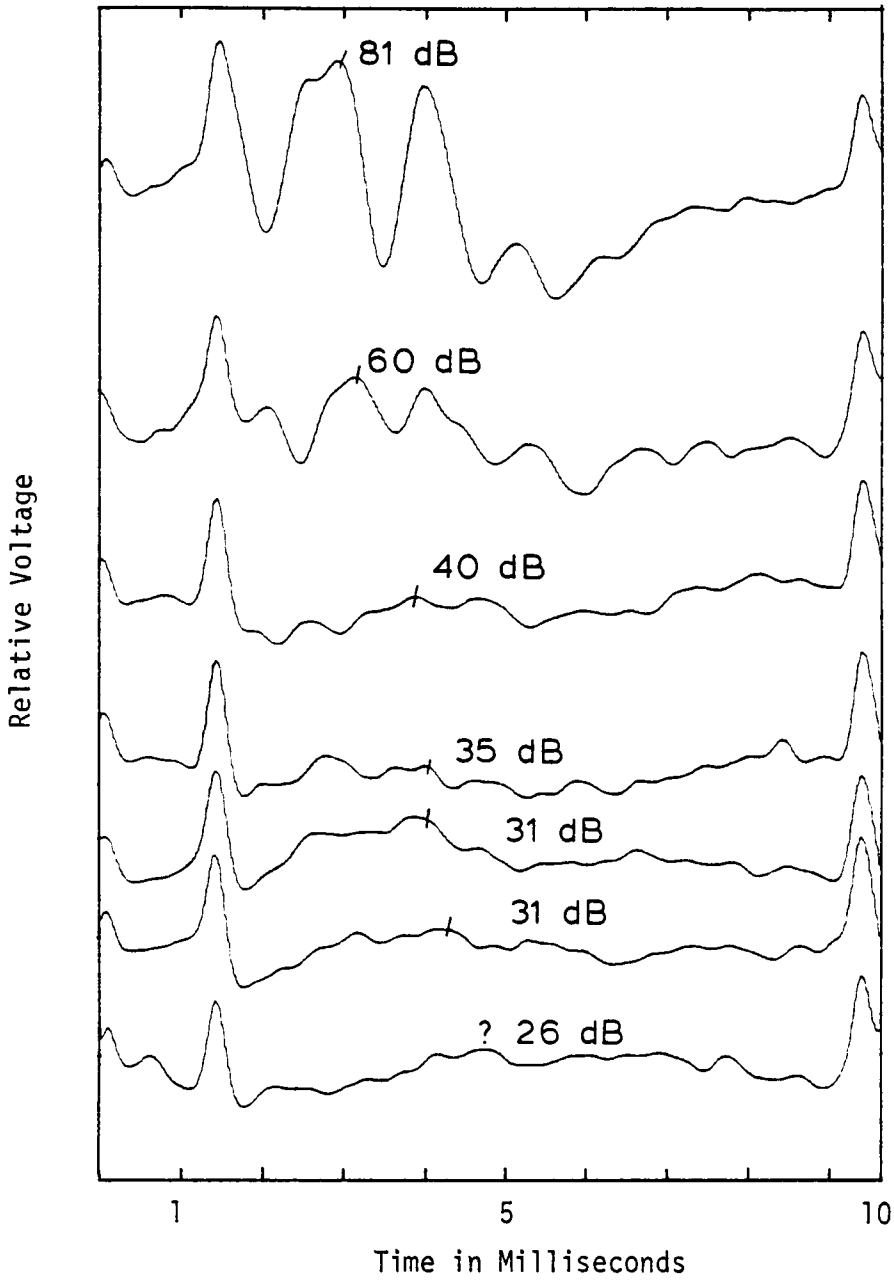


Figure 24. Evoked responses at 3.0 kHz for the left ear of animal C-3.

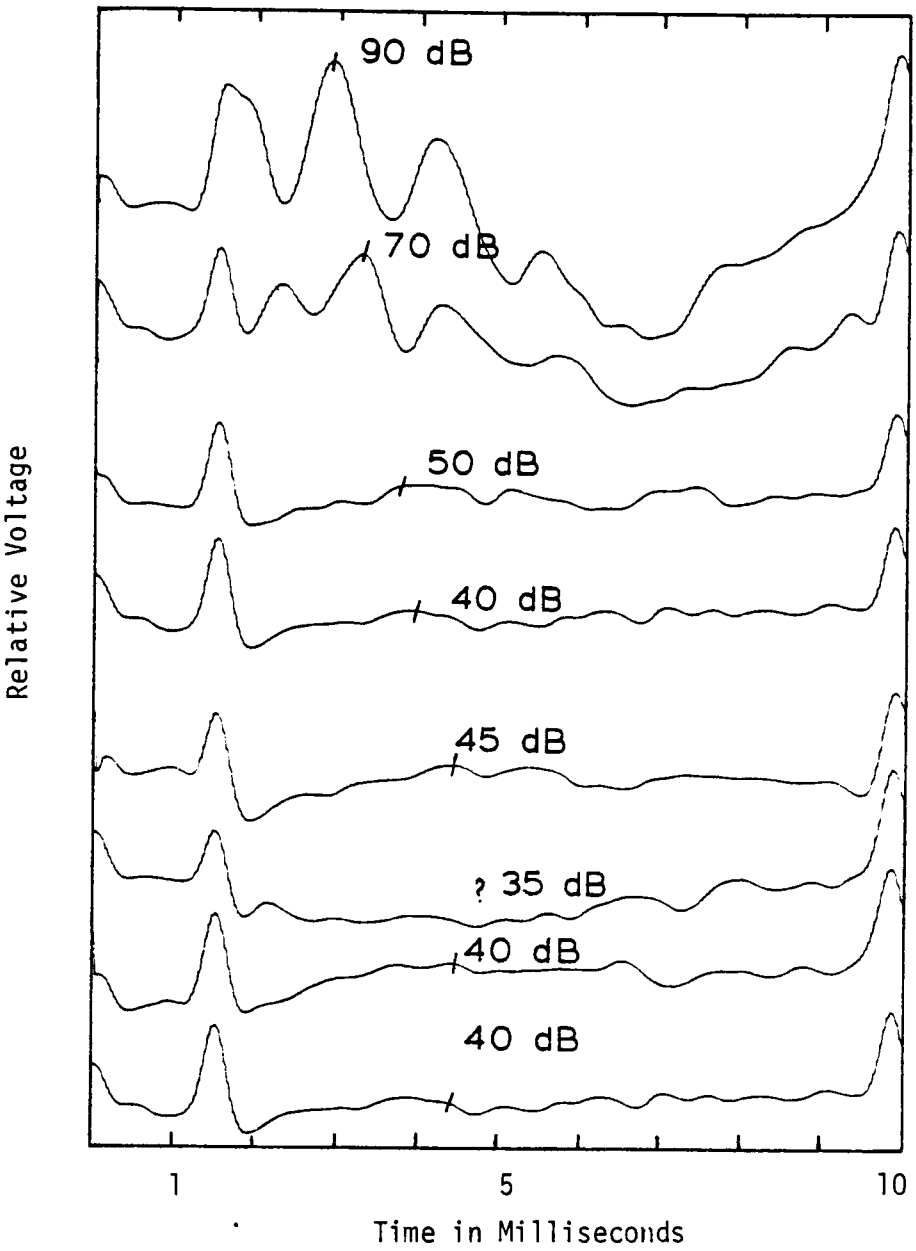


Figure 25. Evoked responses at 3.0 kHz for the left ear of animal C-4.

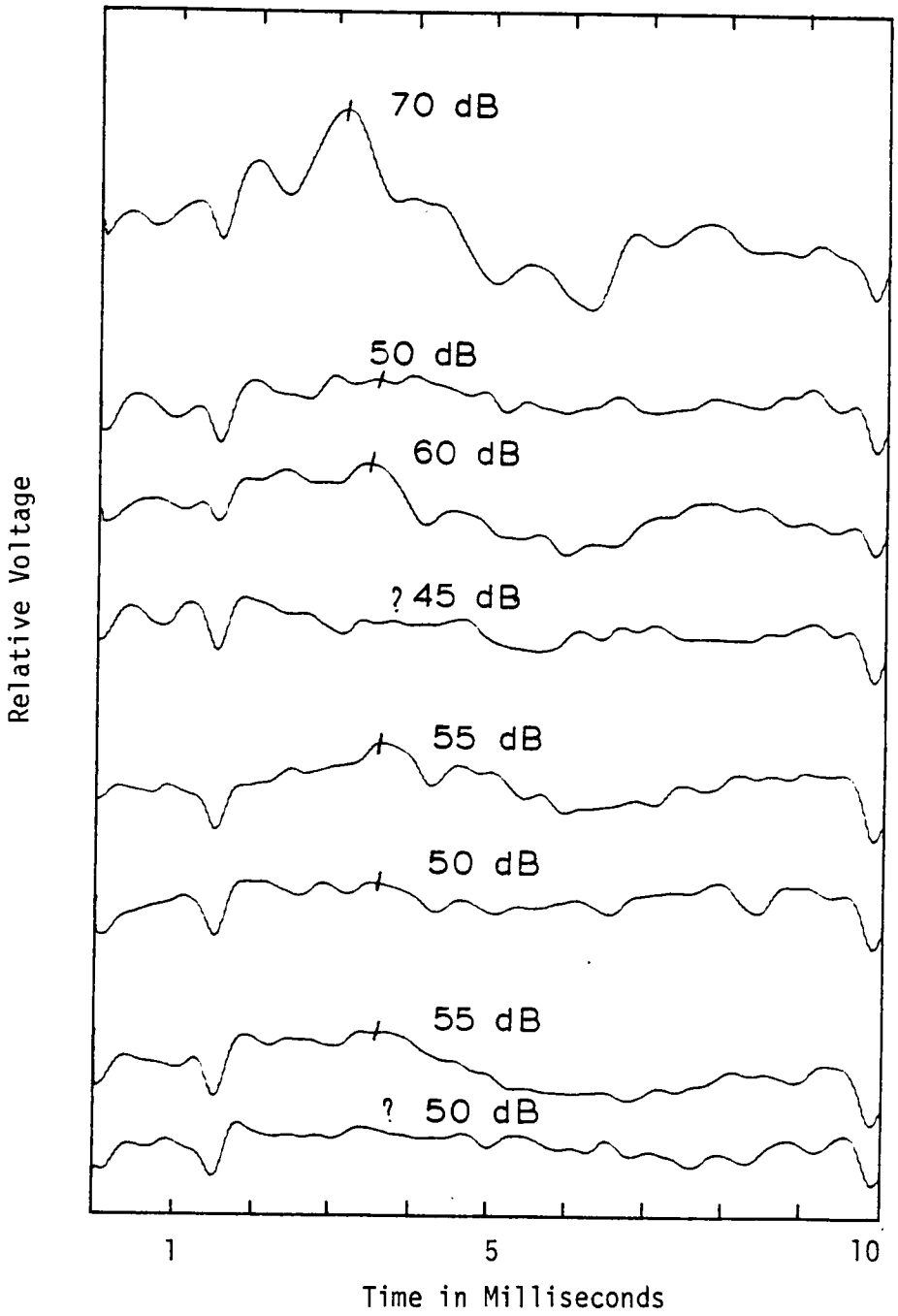


Figure 26. Evoked responses at 3.0 kHz for the right ear of animal C-5.

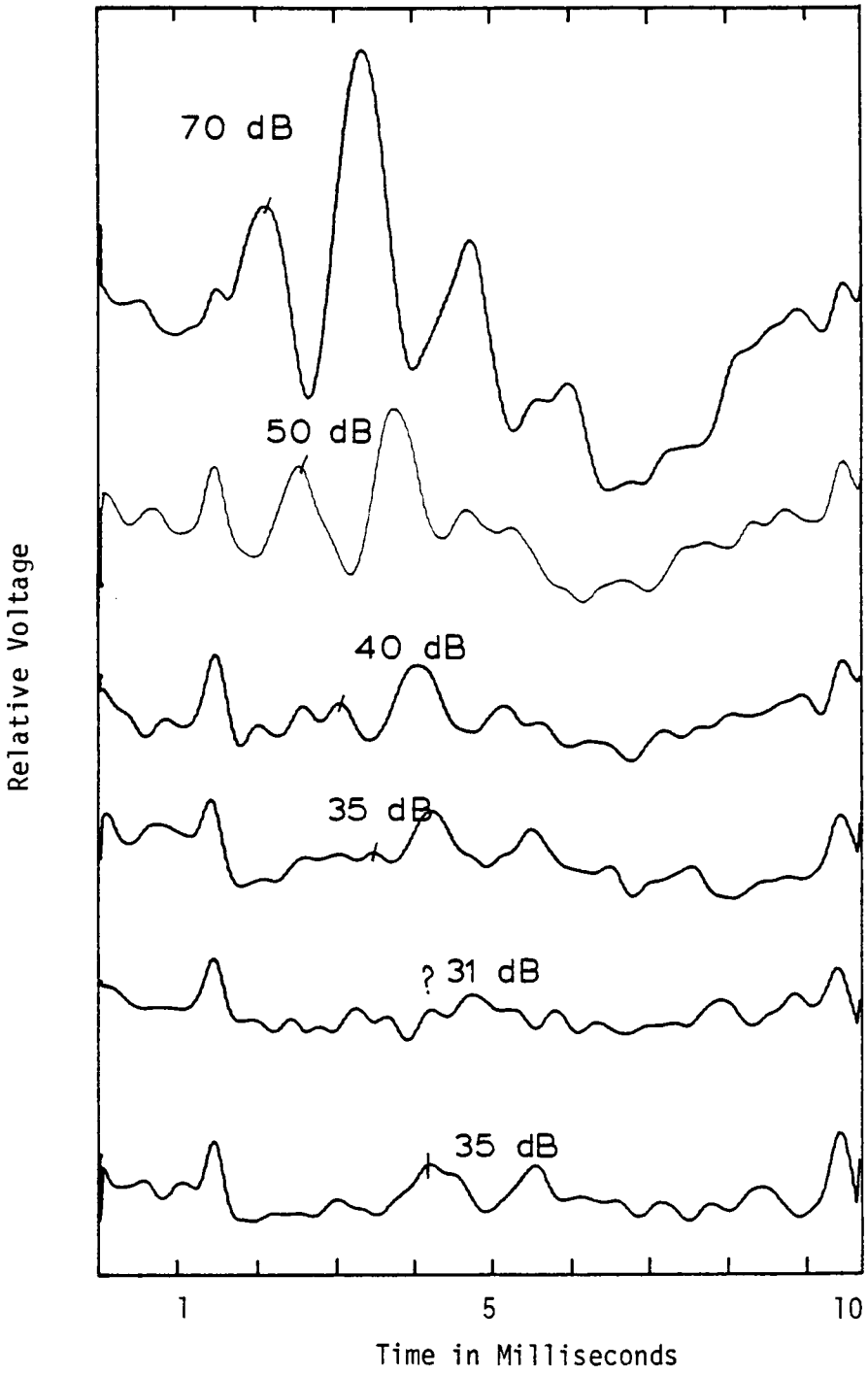


Figure 27. Evoked responses at 3.0 kHz for the right ear of animal C-6.

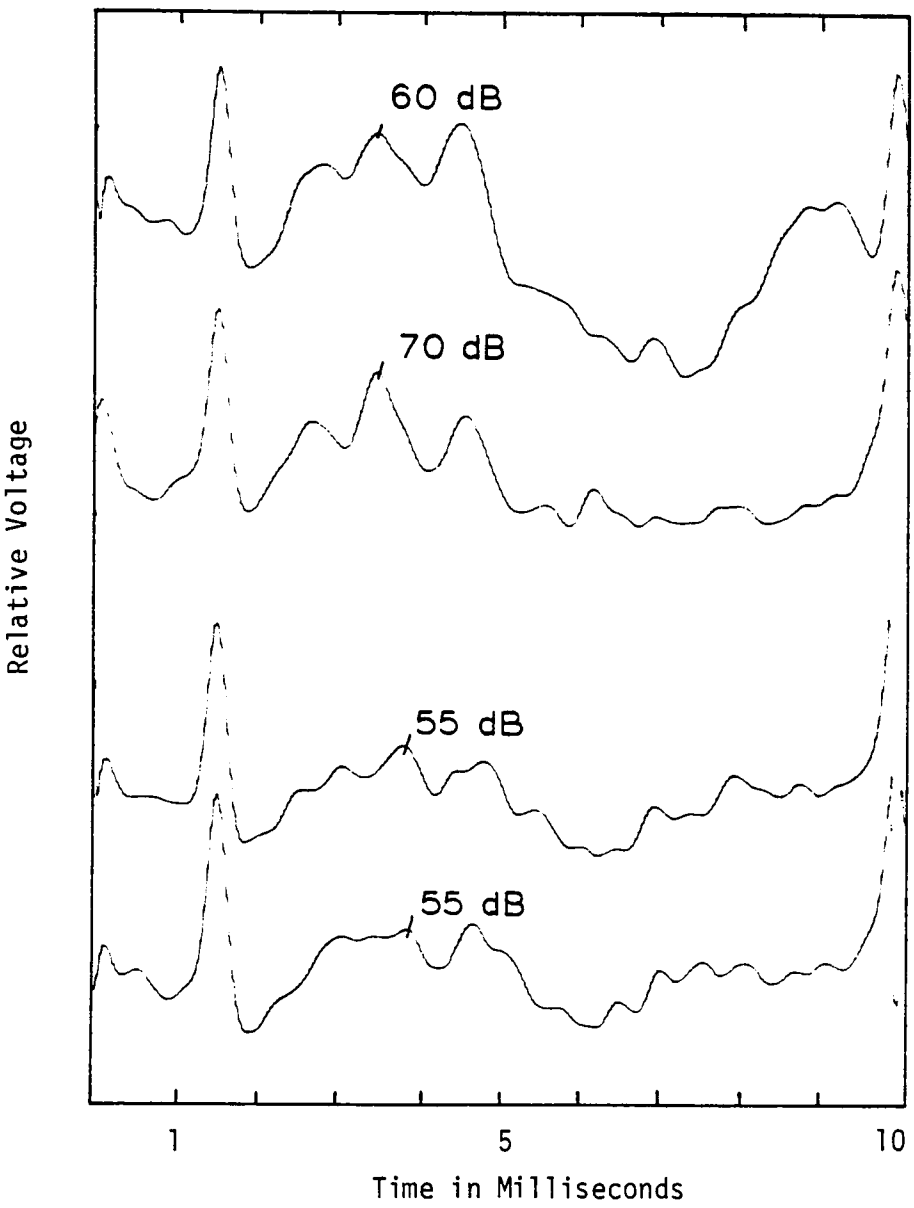


Figure 28. Evoked responses at 3.0 kHz for the left ear of animal E-1.

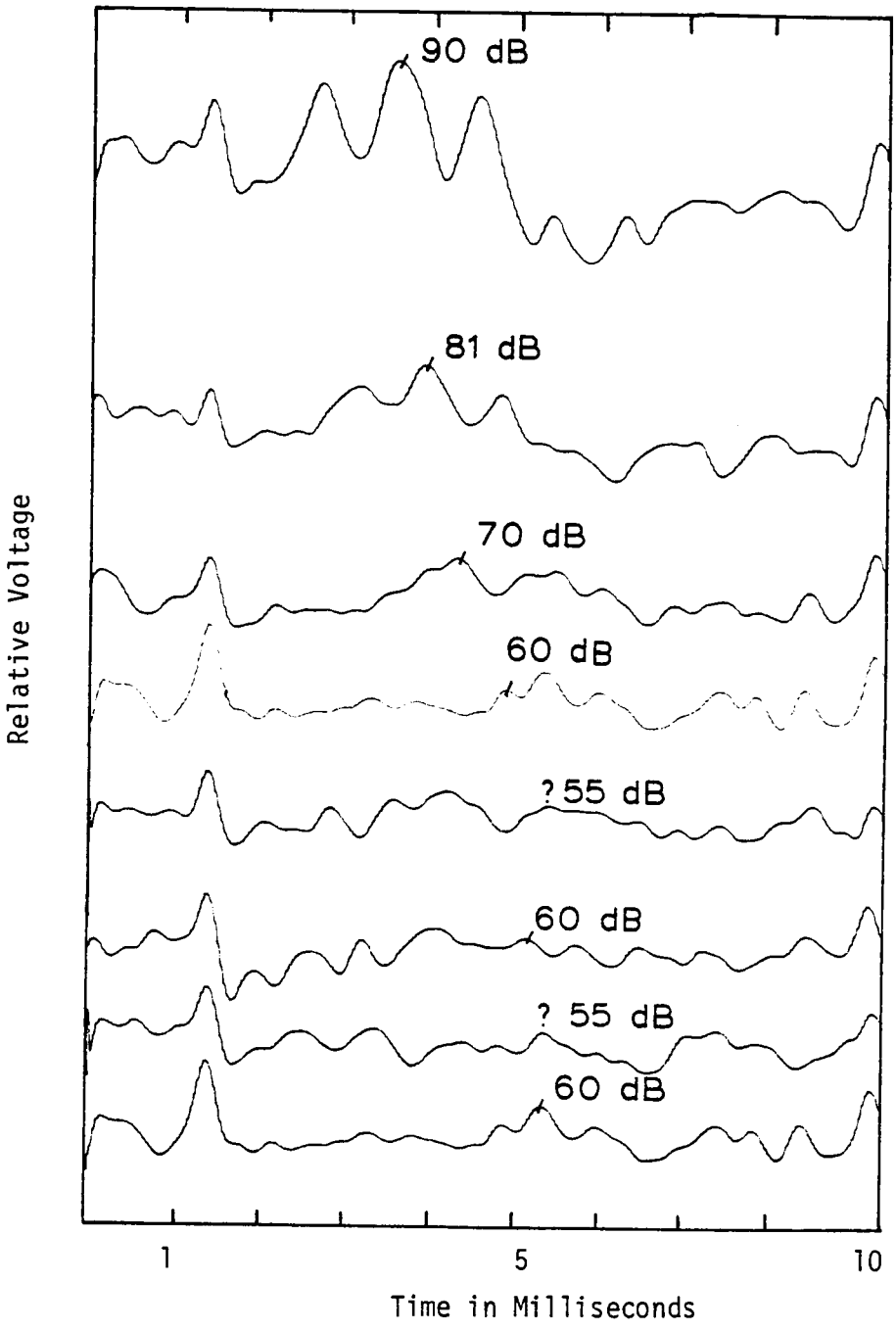


Figure 29. Evoked responses at 3.0 kHz for the left ear of animal E-6.

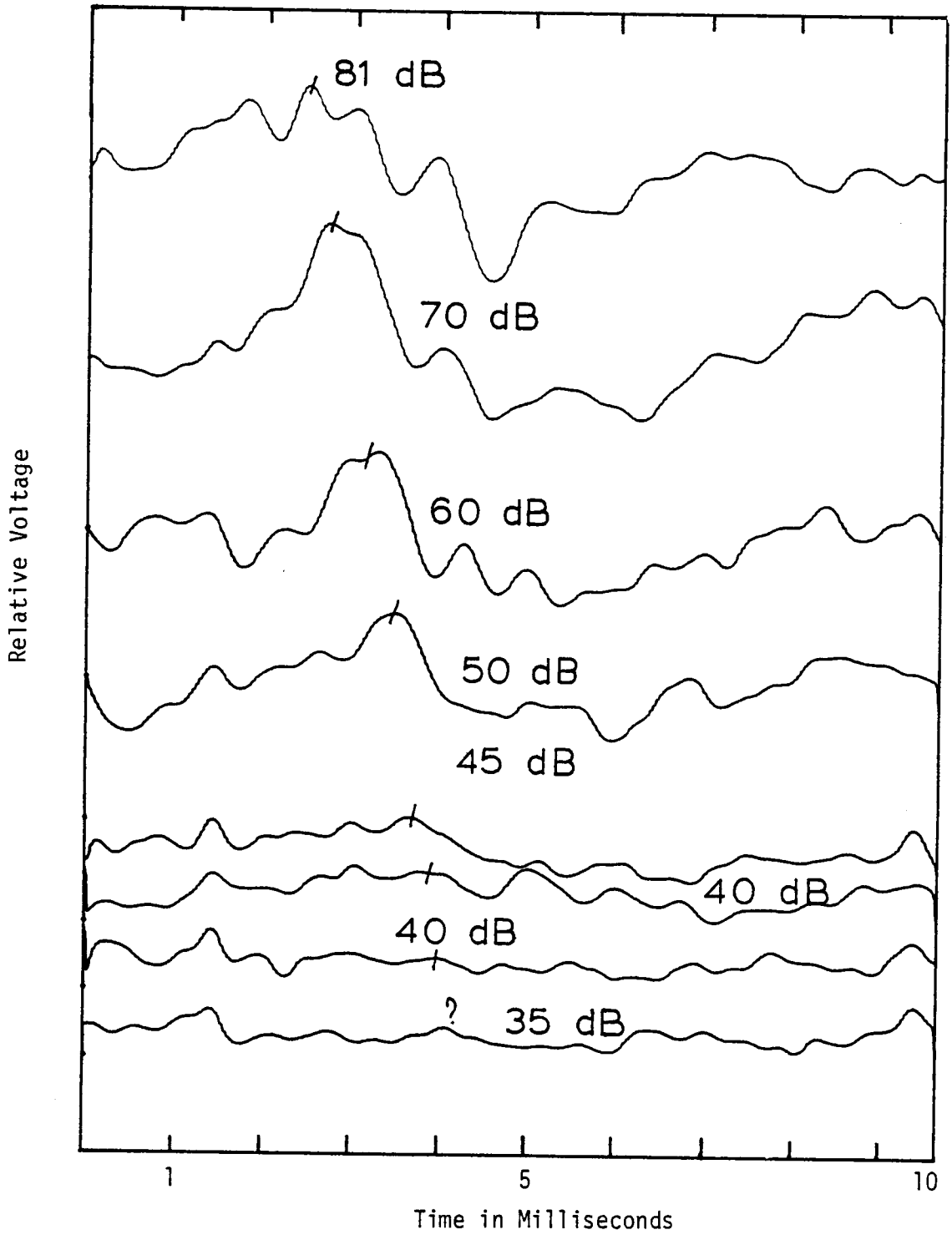


Figure 30. Evoked responses at 3.0 kHz for the left ear of animal F-1.

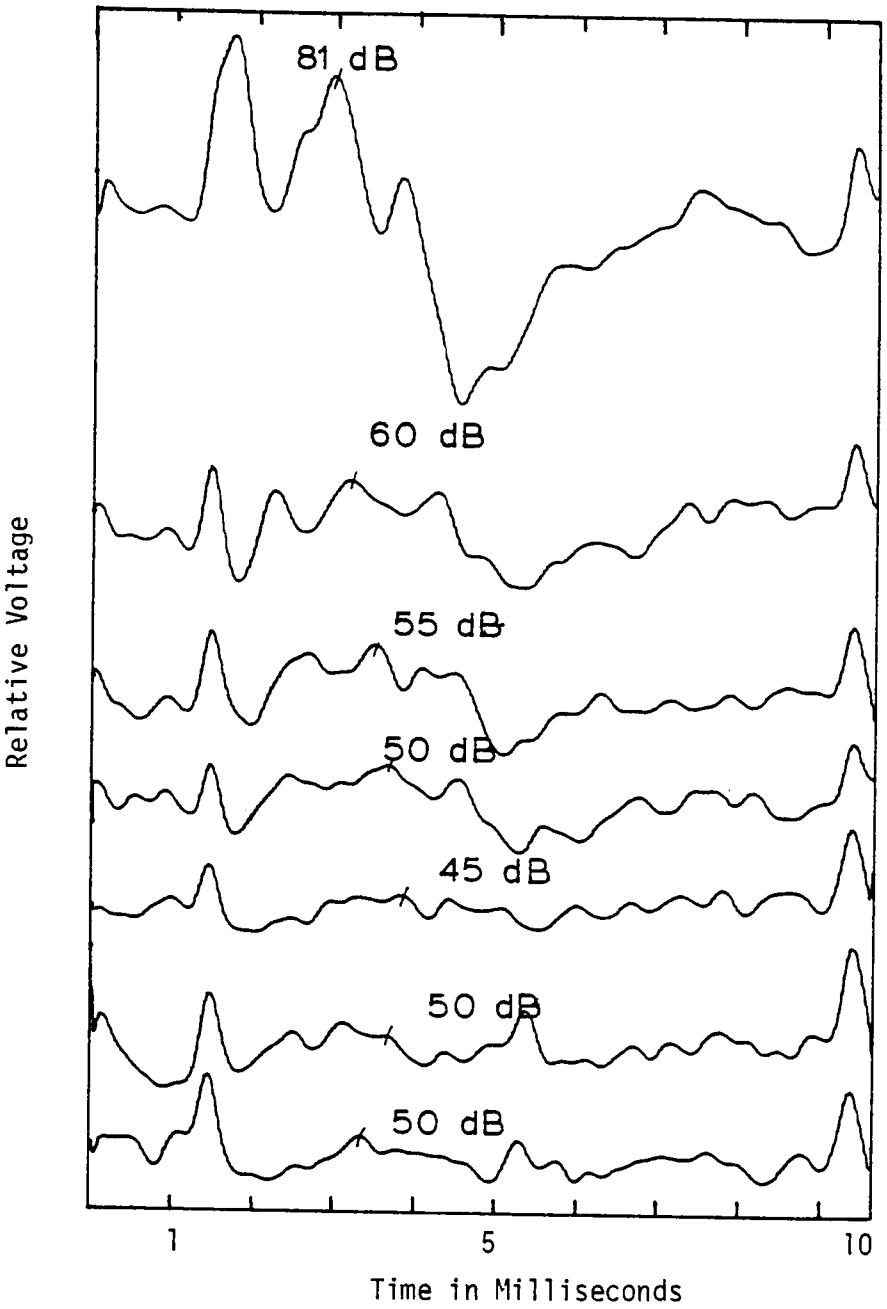


Figure 31. Evoked responses at 3.0 kHz for the right ear of animal F-3.

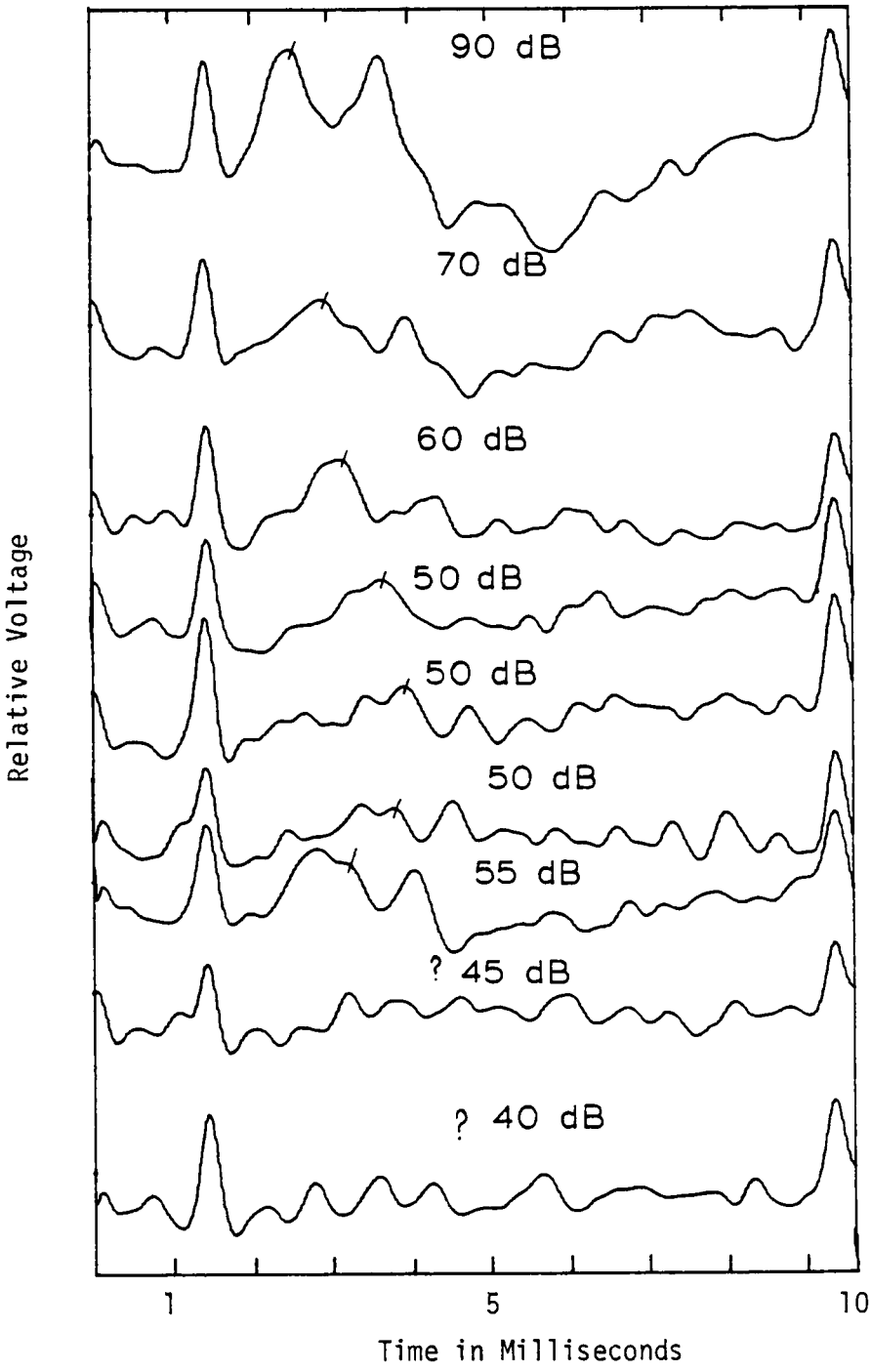


Figure 32. Evoked responses at 3.0 kHz for the right ear of animal F-4.

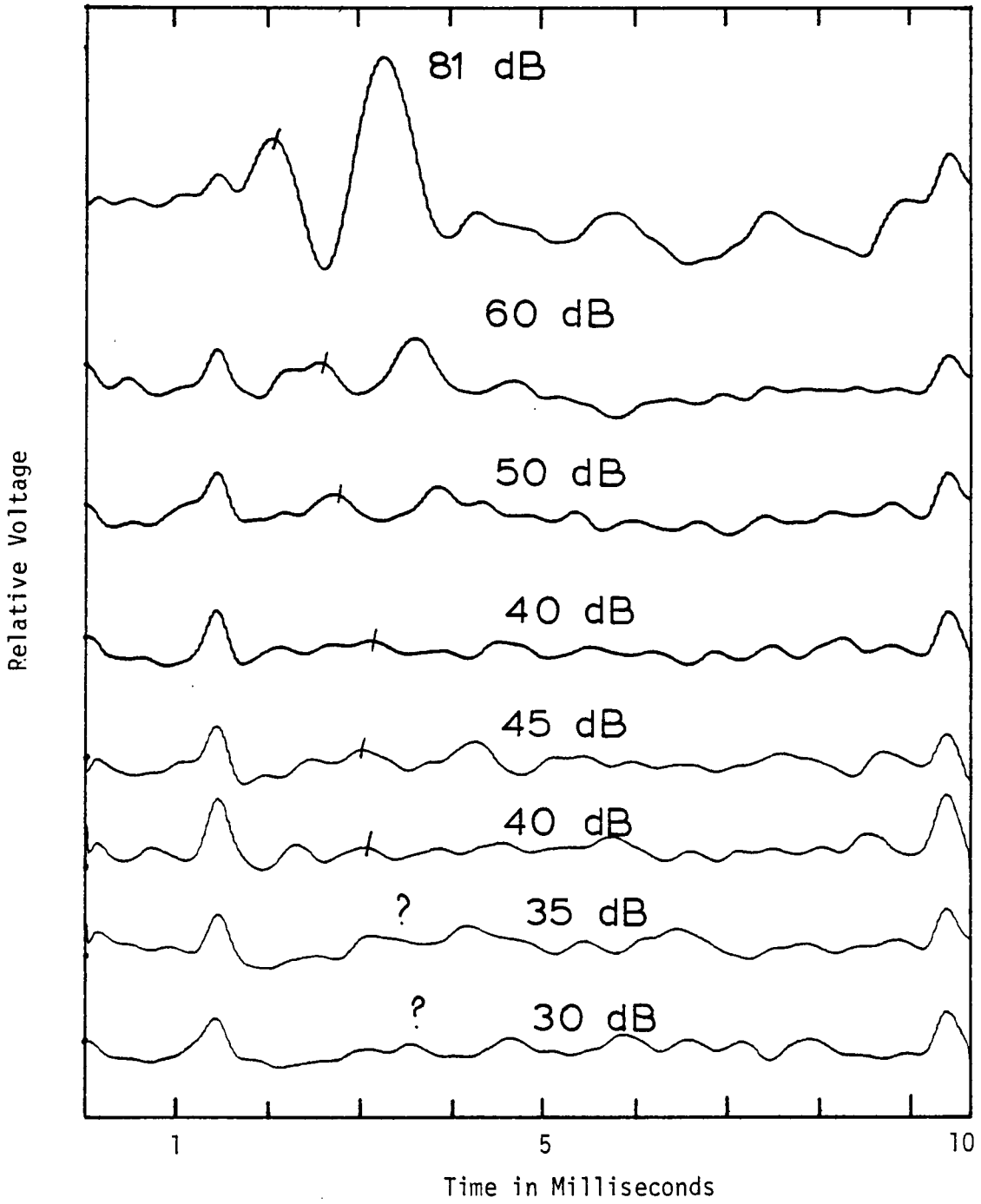


Figure 33. Evoked responses at 3.0 kHz for the left ear of animal F-5.

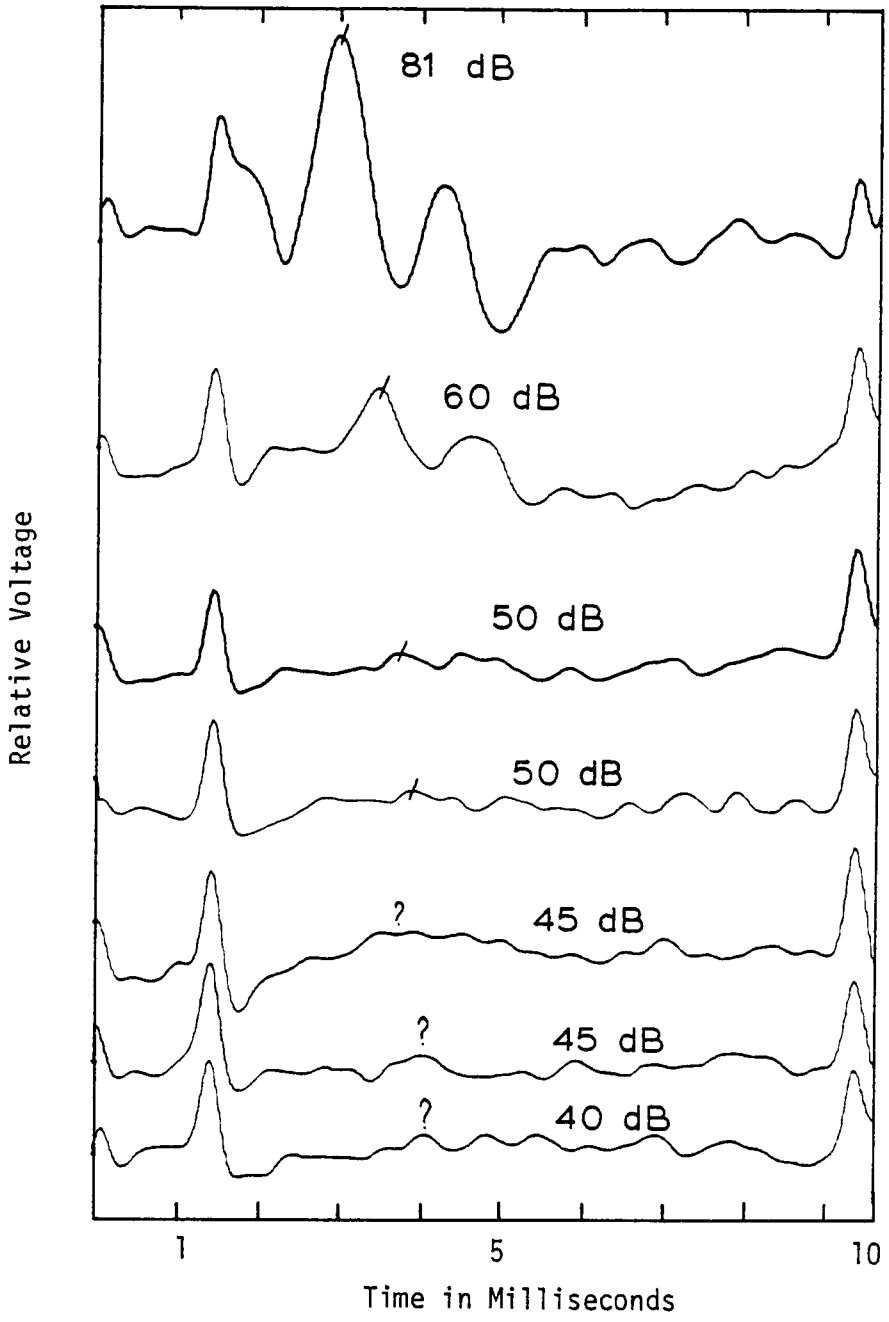


Figure 34. Evoked responses at 3.0 kHz for the left ear of animal F-6.

APPENDIX D

Table 53. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal C-3, Right Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	0.0	0.0	0.0	0.0	0.0	0.0
			2	0.0	0.0	0.0	0.0	0.0	0.0
1/2			3	0.0	0.0	0.0	0.0	0.0	0.0
	8.0	4	4	0.0	0.0	0.0	0.0	0.0	0.0
	5.7	14	5	0.0	0.0	0.0	0.8	0.3	0.2
			6	0.0	0.8	5.6	14.3	6.9	5.2
1	4.0	10	7	0.0	0.0	0.0	0.0	0.0	0.0
	3.0	6	8	0.0	0.0	0.0	0.0	0.0	0.0
			9	0.0	0.0	0.0	0.0	0.0	0.0
1-1/2			10	2.3	0.0	0.0	0.0	0.0	0.6
			11	0.0	0.0	0.0	1.6	0.5	0.4
			12	0.0	0.0	0.0	0.0	0.0	0.0
2			13	0.0	0.0	0.8	2.4	1.1	0.8
			14	0.0	0.0	0.0	0.8	0.3	0.2
			15	0.0	0.0	1.0	2.4	1.3	1.0
2-1/2			16	0.0	0.0	0.0	2.4	0.8	0.6
			17	0.0	0.0	2.3	7.1	3.1	2.4
			18	0.0	0.0	1.3	11.1	4.1	3.1
3			19	.	.	.	.	.	.
			20	.	.	.	.	.	.

*As suggested by Eldredge, et al. (1973).

.Data missing due to the length of the cochlea or due to dissection error.

Table 54. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal C-4, Left Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	0.0	2.8	8.4	2.8	4.7	3.5
			2	1.0	4.7	3.1	0.0	2.6	2.2
1/2			3	1.0	50.4	3.3	3.4	19.0	14.5
	8.0	4	4	0.0	37.8	0.7	2.3	13.6	10.2
	5.7	14	5	0.0	1.6	3.2	2.5	2.4	1.8
			6	0.0	0.0	0.0	0.0	0.0	0.0
1	4.0	10	7	0.0	0.0	0.0	0.0	0.0	0.0
	3.0	6	8	0.0	0.7	0.0	2.3	1.0	0.8
			9	0.0	1.7	0.0	0.0	0.6	0.4
1-1/2			10	0.0	0.0	0.0	0.8	0.3	0.2
			11	0.0	0.0	0.0	0.0	0.0	0.0
			12	0.0	0.7	3.1	0.0	1.3	0.9
2			13	0.0	0.7	3.9	4.7	3.1	2.3
			14	0.0	1.5	6.3	8.7	5.5	4.1
			15	0.0	0.0	0.7	2.3	1.0	0.8
2-1/2			16	0.0	1.6	2.4	2.4	2.1	1.6
			17	0.0	0.0	0.7	7.1	2.6	1.9
			18	0.0	0.7	3.9	7.9	4.2	3.1
3			19	0.0	2.3	7.1	4.7	4.7	3.5
			20	0.0	5.2	12.1	7.6	8.3	6.2

*As suggested by Eldredge, et al. (1973).

Table 55. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal C-4, Right Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	0.0	2.3	0.0	0.0	0.8	0.6
			2	0.0	0.0	0.0	0.0	0.0	0.0
			3	0.0	0.8	0.8	0.8	0.8	0.6
1/2			4	1.0	4.7	0.7	0.0	1.8	1.6
	8.0	4	5	1.2	12.2	4.2	4.2	6.9	5.4
	5.7	14	6	0.0	53.1	0.0	0.7	17.9	13.4
			7	0.0	0.0	0.0	0.0	0.0	0.0
1	4.0	10	8	0.0	0.0	0.0	0.0	0.0	0.0
	3.0	6	9	0.0	2.3	2.3	0.7	1.8	1.3
			10	0.0	0.0	0.0	0.0	0.0	0.0
1-1/2			11	0.0	0.0	0.0	1.5	0.5	0.4
			12	0.0	0.7	3.1	3.9	2.6	1.9
			13	0.0	0.0	8.7	8.7	5.8	4.4
2			14	0.0	0.7	5.5	11.1	5.6	4.3
			15	0.0	0.0	2.5	7.2	3.2	2.4
			16	1.1	0.0	0.0	9.2	3.1	2.6
2-1/2			17	0.0	0.0	5.5	7.1	4.2	3.2
			18	0.0	0.0	3.3	7.1	3.5	2.6
			19	0.0	4.7	6.3	14.2	8.4	6.3
3			20	.	.	.	.	.	.

*As suggested by Eldredge, et al. (1973).

.Data missing due to the length of the cochlea or due to dissection error.

Table 56. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal C-5, Left Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	0.0	0.0	0.8	2.5	1.1	0.8
			2	0.0	0.8	0.8	1.6	1.1	0.8
1/2			3	0.0	0.0	5.5	3.1	2.9	2.2
	8.0	4	4	1.0	3.1	3.9	3.9	3.6	3.0
	5.7	14	5	0.0	1.5	0.7	3.9	2.0	1.5
			6	1.0	10.3	4.7	16.6	10.5	8.2
1	4.0	10	7	1.1	18.2	3.9	10.3	10.8	8.4
	3.0	6	8	0.0	0.8	5.7	3.3	3.3	2.4
			9	0.0	3.9	2.3	1.5	2.6	1.9
1-1/2			10	1.0	0.7	2.3	9.5	4.2	3.4
			11	0.0	2.5	0.8	1.7	1.7	1.2
			12	1.0	7.9	0.0	2.3	3.4	2.8
2			13	0.0	10.3	1.5	4.7	5.5	4.1
			14	0.0	6.4	2.5	6.4	5.1	3.8
			15	0.0	5.5	2.3	7.1	5.0	3.7
2-1/2			16	0.0	4.7	2.3	3.9	3.6	2.7
			17	0.0	7.1	2.3	3.1	4.2	3.1
			18	0.0	2.5	4.0	9.3	5.3	4.0
3			19	0.0	2.3	3.9	11.1	5.8	4.3
			20	0.0	0.0	0.0	0.0	0.0	0.0

*As suggested by Eldredge, et al. (1973).

Table 57. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal C-6, Left Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	4.3	2.2	3.6	0.0	1.9	2.5
			2	0.0	1.5	1.5	1.5	1.5	1.1
1/2			3	0.0	0.0	0.0	0.0	0.0	0.0
	8.0	4	4	0.0	0.0	0.0	0.0	0.0	0.0
	5.7	14	5	0.0	4.4	7.6	14.2	8.7	6.6
			6	0.0	3.1	7.1	11.9	7.4	5.5
1	4.0	10	7	2.1	0.7	0.7	2.3	1.2	1.4
	3.0	6	8	0.0	0.0	0.0	0.7	0.2	0.1
			9	0.0	0.0	1.5	0.0	6.5	0.4
1-1/2			10	0.0	0.0	0.7	0.0	0.2	0.1
			11	0.0	1.6	1.6	2.4	1.9	1.4
			12	0.0	0.0	0.8	2.5	1.1	0.8
2			13	0.0	0.8	0.8	1.6	1.1	0.8
			14	1.0	0.0	5.5	9.5	5.0	4.0
			15	0.0	0.0	5.5	3.9	3.1	2.4
2-1/2			16	0.0	1.5	0.0	2.3	1.3	1.0
			17	0.0	0.8	2.4	4.7	2.6	2.0
			18	0.0	0.0	0.7	5.5	2.1	1.6
3			19	0.0	6.0	0.0	13.7	6.6	4.9
			20	.	.	.	.	.	.

*As suggested by Eldredge, et al. (1973).

.Data missing due to the length of the cochlea or due to dissection error.

Table 58. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal E-2, Left Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	1.0	0.8	1.7	1.6	1.4	1.3
			2	0.0	0.0	2.6	2.6	1.7	1.3
1/2			3	1.0	1.5	1.5	0.7	1.2	1.2
	8.0	4	4	0.0	0.0	0.0	0.8	0.3	0.2
	5.7	14	5	2.1	16.6	33.3	26.1	25.3	19.5
			6	1.0	8.7	7.9	7.1	7.9	6.2
1	4.0	10	7	0.0	4.7	4.7	0.7	3.4	2.5
	3.0	6	8	0.0	1.5	1.5	2.3	1.8	1.3
			9	2.1	3.9	14.2	30.1	16.1	12.6
1-1/2			10	1.0	1.5	12.6	24.6	12.9	9.9
			11	1.0	19.8	14.2	1.5	11.8	9.1
			12	0.0	12.6	14.2	4.7	10.5	7.9
2			13	0.0	18.2	19.0	4.7	14.0	10.5
			14	0.0	5.6	3.2	7.0	5.3	4.0
			15	0.0	0.0	1.5	5.5	2.3	1.8
2-1/2			16	0.0	0.0	0.7	5.5	2.1	1.6
			17	0.0	0.0	0.7	3.1	1.3	1.0
			18	0.0	0.0	1.6	5.6	2.4	1.8
3			19	0.0	0.0	1.5	5.5	2.3	1.8
			20	0.0	0.0	0.0	4.5	1.5	1.1

*As suggested by Eldredge, et al. (1973).

Table 59. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal E-2, Right Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	0.0	0.0	0.0	0.0	0.0	0.0
			2	.	.	.	.	.	.
1/2			3	0.0	0.0	0.0	0.0	0.0	0.0
	8.0	4	4	6.5	0.0	3.9	2.3	2.1	3.2
			5	0.0	19.0	19.2	17.2	18.5	13.8
	5.7	14							
			6	18.6	36.5	30.9	40.4	35.9	31.6
1	4.0	10	7	10.9	20.6	30.1	33.3	28.0	23.7
	3.0	6	8	0.0	0.0	0.7	3.1	1.3	0.8
			9	0.0	0.0	1.5	4.7	2.1	1.6
1-1/2			10	0.0	0.0	0.0	1.5	0.5	0.4
			11	0.0	5.5	10.3	3.1	6.3	4.7
			12	0.0	5.5	8.7	3.1	5.8	4.3
2			13	0.0	1.5	4.7	1.5	2.6	1.9
			14	0.0	0.9	4.4	2.7	2.7	2.0
			15	0.0	0.0	0.7	0.7	0.5	0.4
2-1/2			16	0.0	1.0	3.0	1.0	1.7	1.2
			17	0.0	2.4	4.9	7.8	5.0	3.8
			18	0.0	0.0	0.0	0.0	0.0	0.0
3			19	0.0	0.8	0.0	0.0	0.3	0.2
			20	.	.	.	.	.	.

*As suggested by Eldredge, et al. (1973).

.Data missing due to the length of the cochlea or due to dissection error.

Table 60. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal E-3, Left Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	0.0	1.5	0.0	0.7	0.7	0.6
			2	0.0	0.0	0.0	0.0	0.0	0.0
1/2			3	0.0	0.0	0.0	11.1	3.7	2.8
	8.0	4	4	0.0	2.3	5.5	42.0	16.6	12.4
	5.7	14	5	0.0	0.8	0.0	1.5	0.8	0.6
			6	1.0	0.0	6.3	9.5	5.3	4.2
1	4.0	10	7	0.0	3.1	7.1	11.1	7.1	5.3
	3.0	6	8	0.0	0.0	0.0	1.5	0.5	0.4
			9	0.0	0.0	0.0	0.0	0.0	0.0
1-1/2			10	0.0	1.7	2.6	7.1	3.8	2.8
			11	0.0	0.0	0.0	0.0	0.0	0.0
			12	0.0	0.0	0.0	0.7	0.2	0.2
2			13	0.0	0.0	0.0	0.7	0.2	0.2
			14	0.0	0.0	0.0	0.0	0.0	0.0
			15	0.0	0.0	0.7	0.7	0.5	0.4
2-1/2			16	0.0	0.0	0.0	0.7	0.2	0.2
			17	1.0	0.0	1.5	3.1	1.5	1.4
			18	0.0	1.5	1.5	1.5	1.5	1.4
3			19	0.0	0.0	4.7	4.6	3.1	2.3
			20	.	.	.	.	.	.

*As suggested by Eldredge, et al. (1973).

.Data missing due to the length of the cochlea or due to dissection error.

Table 61. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal E-3, Right Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	.	.	.	.	.	.
			2	.	.	.	.	.	.
1/2			3	.	.	.	.	.	.
	8.0	4	4	.	.	.	.	.	.
	5.7	14	5	.	.	.	.	.	.
			6	.	.	.	.	.	.
1	4.0	10	7	.	.	.	.	.	.
	3.0	6	8	.	.	.	.	.	.
			9	.	.	.	.	.	.
1-1/2			10	.	.	.	.	.	.
			11	0.0	0.0	0.0	1.5	0.5	0.4
			12	0.0	0.0	0.7	0.0	0.2	0.2
2			13	0.0	0.8	0.0	0.0	0.3	0.2
			14	0.0	1.5	2.3	4.7	2.8	2.1
			15	0.0	0.0	0.0	3.1	1.0	0.8
2-1/2			16	0.0	0.7	0.7	0.7	0.7	0.5
			17	0.0	1.7	0.0	0.0	0.6	0.4
			18	0.0	0.7	3.1	3.9	2.6	1.9
3			19	0.0	0.0	2.6	5.1	2.6	1.9
			20	.	.	.	.	.	.

*As suggested by Eldredge, et al. (1973).

.Data missing due to the length of the cochlea or due to dissection error.

Table 62. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal E-4, Right Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	1.5	0.0	0.0	0.0	0.0	0.0
			2	.	.	.	.	.	.
1/2			3	0.0	0.0	3.1	29.3	10.8	8.1
	8.0	4	4	0.0	3.1	7.1	75.3	28.5	21.4
			5	0.0	1.5	5.5	9.5	5.5	4.1
	5.7	14	6	0.0	0.7	2.3	0.0	1.0	0.8
1	4.0	10	7	0.0	0.7	0.7	0.7	0.7	0.5
	3.0	6	8	0.0	0.0	0.0	4.7	1.6	1.2
			9	0.0	0.0	0.0	0.0	0.0	0.0
1-1/2			10	0.0	0.7	0.0	0.0	0.2	0.2
			11	0.0	0.0	0.0	0.0	0.0	0.0
			12	0.0	0.0	0.0	0.0	0.0	0.0
2			13	0.0	0.0	0.0	0.0	0.0	0.0
			14	0.0	0.0	0.0	0.0	0.0	0.0
			15	0.0	0.0	0.0	0.0	0.0	0.0
2-1/2			16	0.0	0.0	0.0	0.0	0.0	0.0
			17	0.0	0.0	0.0	0.0	0.0	0.0
			18	0.0	0.0	3.9	17.4	7.1	5.3
3			19	0.0	0.0	2.3	16.6	6.3	4.7
			20	.	.	.	.	.	.

*As suggested by Eldredge, et al. (1973).

.Data missing due to the length of the cochlea or due to dissection error.

Table 63. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal E-5, Right Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	0.0	2.3	4.8	0.0	2.4	1.8
			2	.	.	.	.	.	.
1/2			3	.	.	.	.	.	.
	8.0	4	4	.	.	.	.	.	.
	5.7	14	5	.	.	.	.	.	.
			6	0.9	1.5	0.0	0.7	0.7	0.8
1	4.0	10	7	1.1	0.0	0.8	0.9	0.6	0.7
	3.0	6	8	0.0	0.0	0.0	3.2	1.1	0.8
			9	0.0	0.0	0.0	0.7	0.2	0.2
1-1/2			10	0.0	0.7	0.0	0.7	0.5	0.4
			11	0.0	0.7	0.0	1.7	0.8	0.6
			12	0.0	0.0	0.8	2.5	1.1	0.8
2			13	0.0	1.5	1.5	0.7	1.2	0.9
			14	1.0	0.7	4.7	2.3	2.6	2.2
			15	0.0	1.5	8.7	3.1	4.4	3.3
2-1/2			16	2.1	3.9	5.5	3.9	4.4	3.8
			17	2.1	3.1	4.7	3.1	3.6	3.2
			18	0.0	0.0	3.1	8.7	3.9	3.0
3			19	0.0	0.0	2.7	5.2	2.6	1.9
			20	.	.	.	.	.	.

*As suggested by Eldredge, et al. (1973).

.Data missing due to the length of the cochlea or due to dissection error.

Table 64. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal E-6, Left Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	0.0	0.0	0.0	0.0	0.0	0.0
			2	0.0	0.0	0.0	0.0	0.0	0.0
1/2			3	0.0	0.0	0.0	0.0	0.0	0.0
	8.0	4	4	0.0	0.0	0.0	0.0	0.0	0.0
	5.7	14	5	0.0	0.0	0.0	0.0	0.0	0.0
			6	0.0	0.0	0.0	0.7	0.2	0.2
1	4.0	10	7	0.0	0.0	0.7	0.0	0.2	0.2
	3.0	6	8	0.0	0.0	0.0	0.0	0.0	0.0
			9	0.0	1.5	1.5	0.7	1.2	0.9
1-1/2			10	2.1	0.0	0.7	0.7	0.5	0.9
			11	0.0	0.0	0.0	0.7	0.2	0.2
			12	0.0	0.0	1.5	1.5	1.0	0.8
2			13	0.0	0.8	1.5	3.8	2.0	1.5
			14	0.0	1.5	1.5	1.5	1.5	1.1
			15	0.0	0.0	0.0	0.0	0.0	0.0
2-1/2			16	1.0	0.0	0.0	0.7	0.2	0.4
			17	0.0	0.0	0.0	2.3	0.8	0.6
			18	0.0	0.0	0.0	6.3	2.1	1.6
3			19	0.0	0.0	0.0	10.0	3.3	2.5
			20	0.0	3.9	3.9	10.3	6.0	4.5

*As suggested by Eldredge, et al. (1973).

Table 65. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal E-6, Right Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	1.0	2.7	0.0	0.8	1.2	1.1
			2	0.0	0.0	0.0	0.0	0.0	0.0
			3	1.2	0.0	0.0	0.0	0.0	0.3
1/2			4	1.0	4.3	2.7	11.5	6.2	4.9
	8.0	4	5	.	.	.	.	.	.
	5.7	14	6	0.0	2.5	1.6	6.2	3.4	2.6
1	4.0	10	7	0.0	1.5	1.5	2.3	1.8	1.3
	3.0	6	8	0.0	0.7	1.5	2.3	1.5	1.1
			9	0.0	0.0	0.0	2.3	0.8	0.6
1-1/2			10	0.0	0.0	0.8	8.7	3.2	2.4
			11	0.0	4.7	3.9	5.5	4.7	3.5
			12	1.1	4.7	0.0	1.5	2.1	1.8
2			13	0.0	4.7	1.5	1.5	2.6	1.9
			14	0.0	0.0	1.5	0.7	0.7	0.6
			15	0.0	0.7	1.5	3.1	1.8	1.3
2-1/2			16	0.0	1.5	2.3	12.6	5.5	4.1
			17	0.0	0.0	0.8	11.2	4.0	3.0
			18	1.0	0.0	8.7	11.9	6.9	5.4
3			19	0.0	1.0	5.1	3.1	3.1	2.3
			20	.	.	.	.	.	.

*As suggested by Eldredge, et al. (1973).

.Data missing due to the length of the cochlea or due to dissection error.

Table 66. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal F-1, Left Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	4.8	1.3	6.5	2.6	3.5	3.8
			2	2.2	2.5	3.4	8.5	4.8	4.2
1/2			3	1.0	7.1	13.5	36.1	18.9	14.4
	8.0	4	4	1.0	3.1	4.8	29.4	12.4	9.6
	5.7	14	5	1.0	0.0	1.6	3.2	1.6	1.4
			6	0.0	0.7	1.6	2.4	1.6	1.2
1	4.0	10	7	0.0	1.6	0.8	3.2	1.6	1.2
	3.0	6	8	1.0	7.1	19.0	27.0	15.9	11.9
			9	2.2	5.6	12.7	26.2	15.3	11.8
1-1/2			10	0.0	0.0	0.7	0.7	2.3	2.3
			11	0.0	0.0	1.6	4.8	2.1	1.6
			12	0.0	0.8	0.0	2.4	0.8	0.6
2			13	0.0	3.2	1.6	0.8	1.1	0.8
			14	0.0	0.7	0.0	4.5	2.6	1.9
			15	0.0	0.8	2.4	9.5	4.2	3.2
2-1/2			16	1.1	0.0	0.8	1.6	1.1	0.8
			17	0.0	0.8	3.2	2.4	2.2	1.9
			18	0.0	0.8	19.8	32.5	17.2	13.2
3			19	1.1	12.7	18.6	14.6	15.3	11.7
			20	.	.	.	.	.	.

*As suggested by Eldredge, et al. (1973).

.Data missing due to the length of the cochlea or due to dissection error.

Table 67. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal F-2, Left Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	0.0	0.0	0.0	0.0	0.0	0.0
			2	0.0	0.0	0.0	0.0	0.0	0.0
1/2			3	0.0	0.0	0.0	2.3	0.8	0.6
	8.0	4	4	0.0	29.1	6.9	33.5	23.2	17.4
	5.7	14	5	1.0	34.1	8.7	48.4	30.4	23.0
			6	0.0	0.7	2.3	2.3	1.8	1.3
1	4.0	10	7	0.0	0.0	1.5	0.7	0.7	0.6
	3.0	6	8	1.0	0.0	0.0	2.3	0.8	0.8
			9	0.0	0.7	2.2	2.9	1.9	1.4
1-1/2			10	1.0	4.7	5.5	4.7	5.0	3.7
			11	0.0	0.7	0.7	1.5	1.0	0.7
			12	0.0	0.7	6.3	4.7	3.9	2.9
2			13	3.2	2.3	1.5	2.3	2.0	2.3
			14	4.3	4.7	0.7	11.1	5.5	5.2
			15	0.0	3.1	8.7	9.5	7.1	5.3
2-1/2			16	0.0	4.7	15.0	10.3	10.0	7.5
			17	0.0	5.1	12.5	6.6	8.1	6.0
			18	3.2	0.0	0.7	7.9	2.9	3.0
3			19	0.0	0.0	3.1	10.3	4.5	3.4
			20	.	.	.	.	.	.

*As suggested by Eldredge, et al. (1973).

.Data missing due to the length of the cochlea or due to dissection error.

Table 68. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal F-2, Right Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	0.0	0.7	0.0	0.7	0.5	0.4
			2	.	.	.	.	.	.
1/2			3	1.1	0.8	4.1	4.0	3.0	2.2
	8.0	4	4	0.0	1.5	1.5	3.1	2.0	1.5
	5.7	14	5	0.0	1.5	2.3	13.4	5.7	4.3
			6	0.0	13.4	7.9	90.4	37.2	27.9
1	4.0	10	7	0.0	96.0	99.2	100.0	98.4	73.8
	3.0	6	8	0.0	42.8	62.6	73.0	59.5	44.6
			9	0.0	0.0	1.5	9.5	3.7	2.8
1-1/2			10	0.0	0.0	0.0	0.7	0.2	0.2
			11	1.0	0.0	0.7	0.0	0.2	0.4
			12	1.0	0.0	0.0	0.0	0.0	0.2
2			13	0.0	1.5	0.7	1.5	1.2	0.9
			14	0.0	1.5	2.3	2.3	2.0	1.5
			15	0.0	0.0	0.7	3.9	1.5	1.2
2-1/2			16	0.0	0.0	1.5	0.0	0.5	0.4
			17	1.0	0.0	0.7	7.9	2.9	2.4
			18	0.0	1.5	13.4	13.4	9.4	7.1
3			19	0.0	2.7	4.1	8.3	5.0	3.8
			20	.	.	.	.	.	.

*As suggested by Eldredge, et al. (1973).

.Data missing due to the length of the cochlea or due to dissection error.

Table 69. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal F-3, Left Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	.	.	.	.	.	.
			2	.	.	.	.	.	.
1/2			3	0.0	0.0	0.8	1.6	0.8	0.6
	8.0	4	4	0.0	6.9	7.5	7.5	7.3	5.5
	5.7	14	5	1.0	33.0	8.7	11.6	17.8	13.6
			6	0.0	46.4	34.9	44.4	41.9	31.4
1	4.0	10	7	1.0	90.4	57.1	89.6	79.0	59.5
	3.0	6	8	3.2	28.9	30.4	42.1	33.8	26.2
			9	0.0	0.7	1.5	3.1	1.8	1.3
1-1/2			10	0.0	3.0	5.4	6.9	5.1	3.8
			11	1.0	0.0	11.9	32.5	14.8	11.4
			12	0.0	1.5	3.9	5.5	3.6	2.7
2			13	0.0	0.7	1.5	10.3	4.2	3.1
			14	0.0	0.0	0.7	0.0	0.2	0.2
			15	0.0	0.0	0.0	7.1	2.4	1.8
2-1/2			16	0.0	0.7	0.7	10.3	3.9	2.9
			17	0.0	6.0	3.7	21.0	10.2	7.7
			18	0.0	0.0	4.8	14.2	6.3	4.8
3			19	3.0	9.2	35.1	24.0	22.8	17.8
			20	.	.	.	.	.	.

*As suggested by Eldredge, et al. (1973).

.Data missing due to the length of the cochlea or due to dissection error.

Table 70. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal F-4, Right Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	0.0	1.6	0.0	0.0	0.5	0.4
			2	0.0	4.9	4.0	9.9	6.3	4.7
1/2			3	13.6	9.5	52.3	100.0	53.9	43.8
	8.0	4	4	2.0	20.0	38.3	100.0	52.8	40.1
	5.7	14	5	2.1	1.5	15.8	86.5	34.6	26.5
			6	2.1	0.7	2.3	10.3	4.4	3.8
1	4.0	10	7	0.0	1.6	0.8	0.8	1.1	0.8
	3.0	6	8	0.0	4.7	0.7	1.5	2.3	1.7
			9	0.0	0.7	0.0	0.0	0.2	0.2
1-1/2			10	0.0	0.0	0.0	8.7	2.9	2.2
			11	3.7	0.0	0.0	1.6	0.5	1.3
			12	0.0	3.9	1.5	0.7	2.0	1.5
2			13	0.0	2.3	0.7	1.5	1.5	1.1
			14	0.0	0.7	1.5	0.7	1.0	0.7
			15	1.0	1.5	0.0	1.5	1.0	1.0
2-1/2			16	0.0	0.0	0.7	2.3	1.0	0.8
			17	0.0	0.0	0.7	0.0	0.2	0.2
			18	0.0	0.0	0.0	0.7	0.2	0.2
3			19	0.0	0.7	0.0	0.7	0.5	0.4
			20	.	.	.	.	.	.

*As suggested by Eldredge, et al. (1973).

.Data missing due to the length of the cochlea or due to dissection error.

Table 71. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal F-5, Right Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	0.0	0.0	0.7	0.7	0.5	0.4
			2	.	.	.	.	.	.
1/2			3	0.0	0.0	0.0	0.0	0.0	0.0
	8.0	4	4	0.0	0.0	0.8	0.0	0.3	0.2
	5.7	14	5	0.0	0.0	3.9	4.7	2.9	2.2
			6	0.0	1.5	3.1	41.3	15.3	11.5
1	4.0	10	7	2.1	0.0	22.2	89.6	37.3	28.5
	3.0	6	8	0.0	0.0	7.9	38.8	15.6	11.7
			9	1.0	0.0	0.0	3.1	1.0	1.0
1-1/2			10	0.0	0.0	0.0	3.1	1.0	0.8
			11	1.0	0.0	0.7	0.7	0.5	0.6
			12	3.2	0.0	0.0	0.7	0.2	1.0
2			13	1.0	0.7	1.5	0.0	0.7	0.8
			14	0.0	0.0	0.7	0.0	0.2	0.2
			15	0.0	0.0	0.0	2.3	0.8	0.6
2-1/2			16	1.0	0.0	0.7	2.3	1.0	1.0
			17	0.0	0.0	0.7	4.7	1.8	1.4
			18	0.0	0.7	2.3	4.7	2.6	1.9
3			19	0.0	16.6	33.3	0.0	16.6	12.5
			20	0.0	.	.	.	.	.

*As suggested by Eldredge, et al. (1973).

.Data missing due to the length of the cochlea or due to dissection error.

Table 72. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal F-6, Left Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	2.4	1.8	6.4	3.8	4.0	3.6
			2	0.0	1.9	6.6	13.3	7.3	5.4
1/2			3	2.2	0.9	0.9	5.4	2.4	2.2
	8.0	4	4	1.2	2.5	9.0	35.7	15.7	12.1
	5.7	14	5	4.9	5.6	17.0	17.9	13.5	11.4
			6	2.5	6.3	31.5	82.2	40.0	30.6
1	4.0	10	7	0.0	17.2	23.0	22.3	20.8	15.6
	3.0	6	8	0.0	0.0	2.3	0.0	0.8	0.6
			9	0.0	2.3	0.0	0.7	1.0	0.4
1-1/2			10	0.0	3.9	0.0	0.7	1.5	1.2
			11	0.0	1.5	0.7	0.7	1.0	0.7
			12	0.0	3.3	1.6	0.0	1.6	1.2
2			13	0.0	0.0	0.0	0.7	0.2	0.2
			14	0.0	0.8	0.8	0.0	0.5	0.4
			15	1.0	0.0	0.0	3.9	1.3	1.2
2-1/2			16	0.0	0.7	0.0	3.9	1.5	1.2
			17	1.1	0.0	0.8	8.5	3.1	2.6
			18	0.0	3.1	7.1	13.4	7.9	5.9
3			19	1.0	0.7	11.9	14.2	8.9	7.0
			20	.	.	.	.	.	.

*As suggested by Eldredge, et al. (1973).

.Data missing due to the length of the cochlea or due to dissection error.

Table 73. Missing Hair Cells in Percent for Inner Hair Cells (IHC), for Row_1, Row_2, and Row_3 of the Outer Hair Cells (OHC_1, OHC_2, OHC_3, respectively), for the Total of Outer Hair Cells (TOHC), and for the Total of All Hair Cells (THC) of Animal F-6, Right Ear.

Cochlear Turn	Frequency* in kHz	PTS in dB	Distance from Base in mm	IHC	OHC_1	OHC_2	OHC_3	Total OHC	Total HC
			1	1.0	1.6	0.0	1.5	1.0	1.0
			2	2.1	1.5	3.1	1.5	2.0	2.0
1/2			3	0.0	2.5	11.5	9.9	8.0	6.0
	8.0	4	4	1.0	12.6	11.1	34.1	19.3	14.7
	5.7	14	5	0.0	0.0	44.4	85.7	43.4	32.5
			6	1.0	0.0	13.4	81.7	31.7	24.0
1	4.0	10	7	0.0	0.8	0.8	6.7	2.8	2.1
	3.0	6	8	0.0	3.2	0.8	3.3	2.4	1.8
			9	0.0	0.7	0.7	1.5	1.0	0.7
1-1/2			10	0.0	0.0	0.7	2.3	1.0	0.8
			11	0.0	0.8	0.8	0.0	0.5	0.4
			12	1.0	6.3	0.0	0.7	2.3	1.8
2			13	0.0	0.0	1.5	1.5	1.0	0.8
			14	4.3	0.0	0.7	0.7	0.5	1.4
			15	0.0	0.0	0.8	4.3	1.7	1.3
2-1/2			16	0.0	0.0	0.0	6.3	2.1	1.6
			17	0.0	0.0	1.5	8.7	3.4	2.6
			18	0.0	0.8	0.0	5.0	1.9	1.4
3			19	0.0	0.0	5.5	7.1	4.2	3.2
			20	1.0	0.0	3.9	1.6	1.8	1.6

*As suggested by Eldredge, et al. (1973).

APPENDIX E

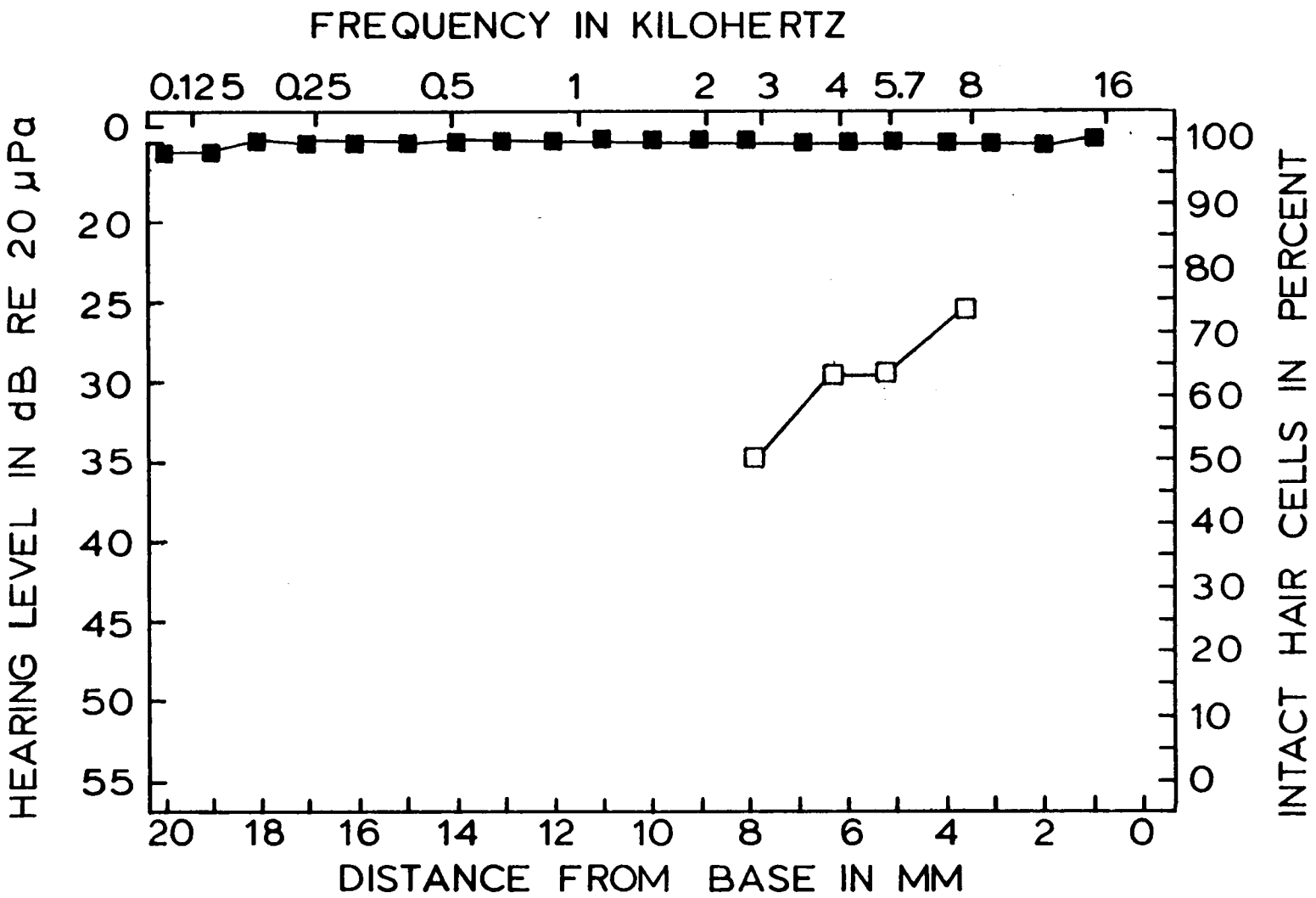


Figure 35. Left ear hearing levels (□) and intact hair cells (■) for animal A-1.

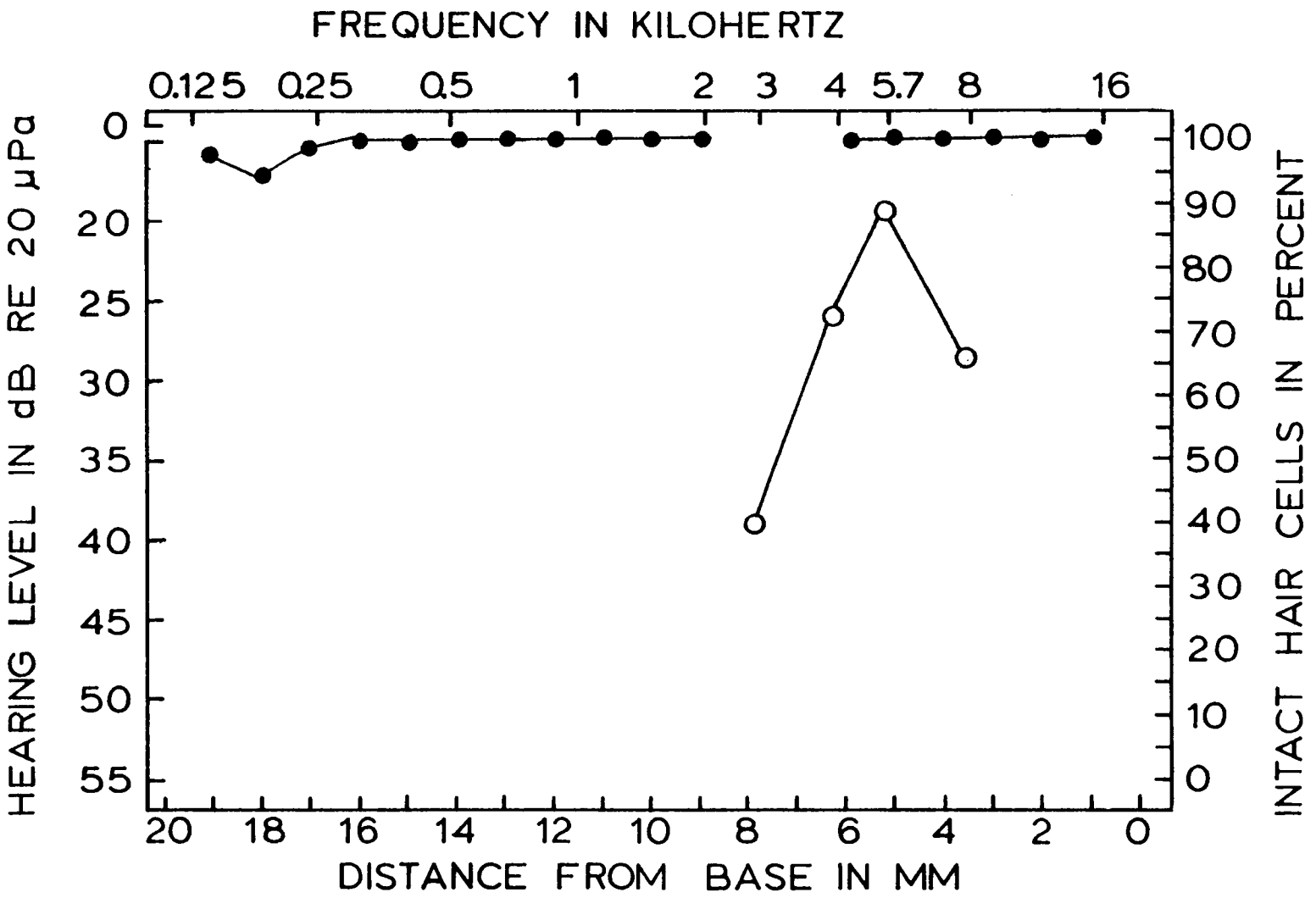


Figure 36. Right ear hearing levels (O) and intact hair cells (●) for animal A-3.

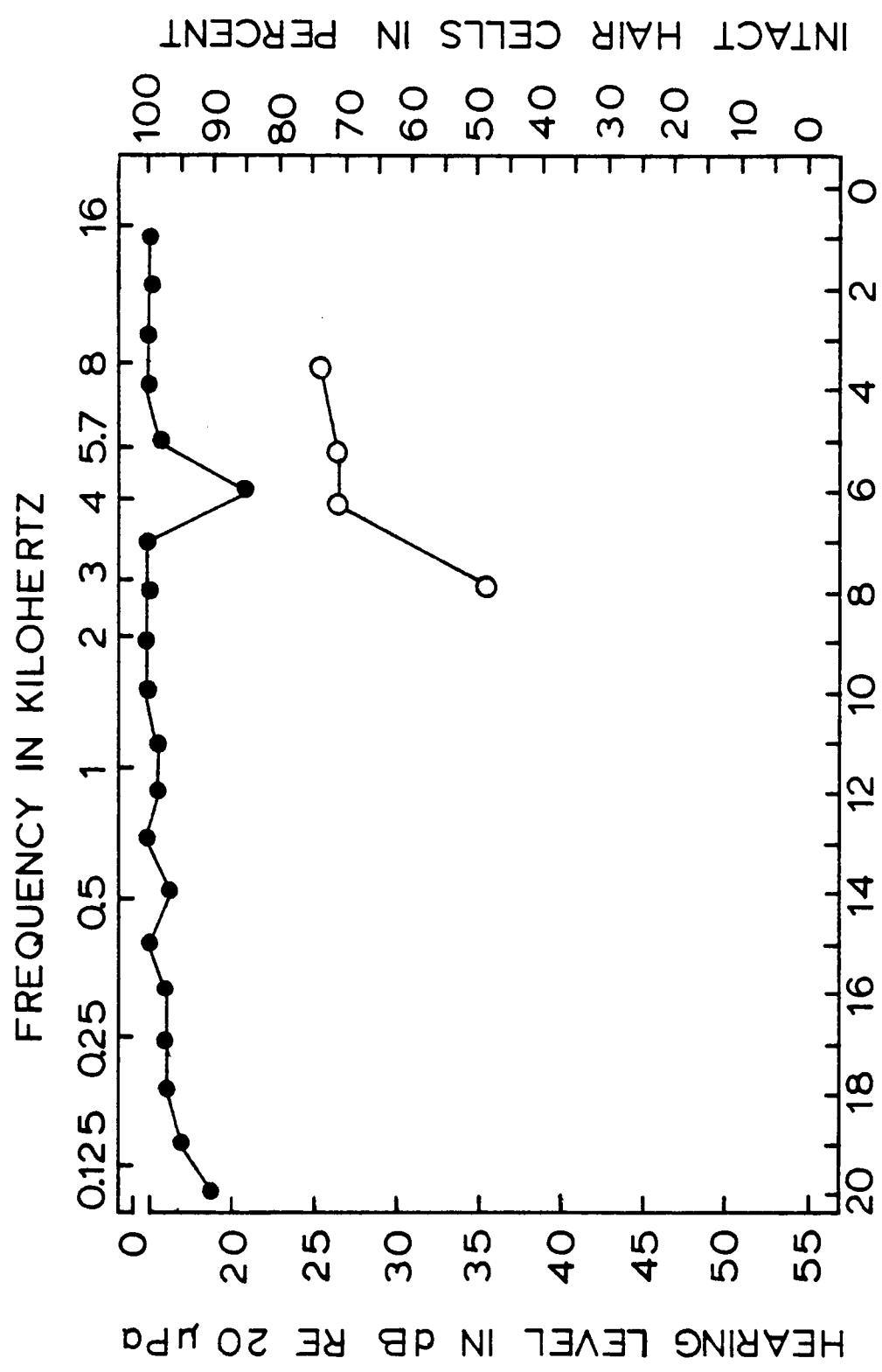


Figure 37. Right ear hearing levels (O) and intact hair cells (●) for animal C-3.

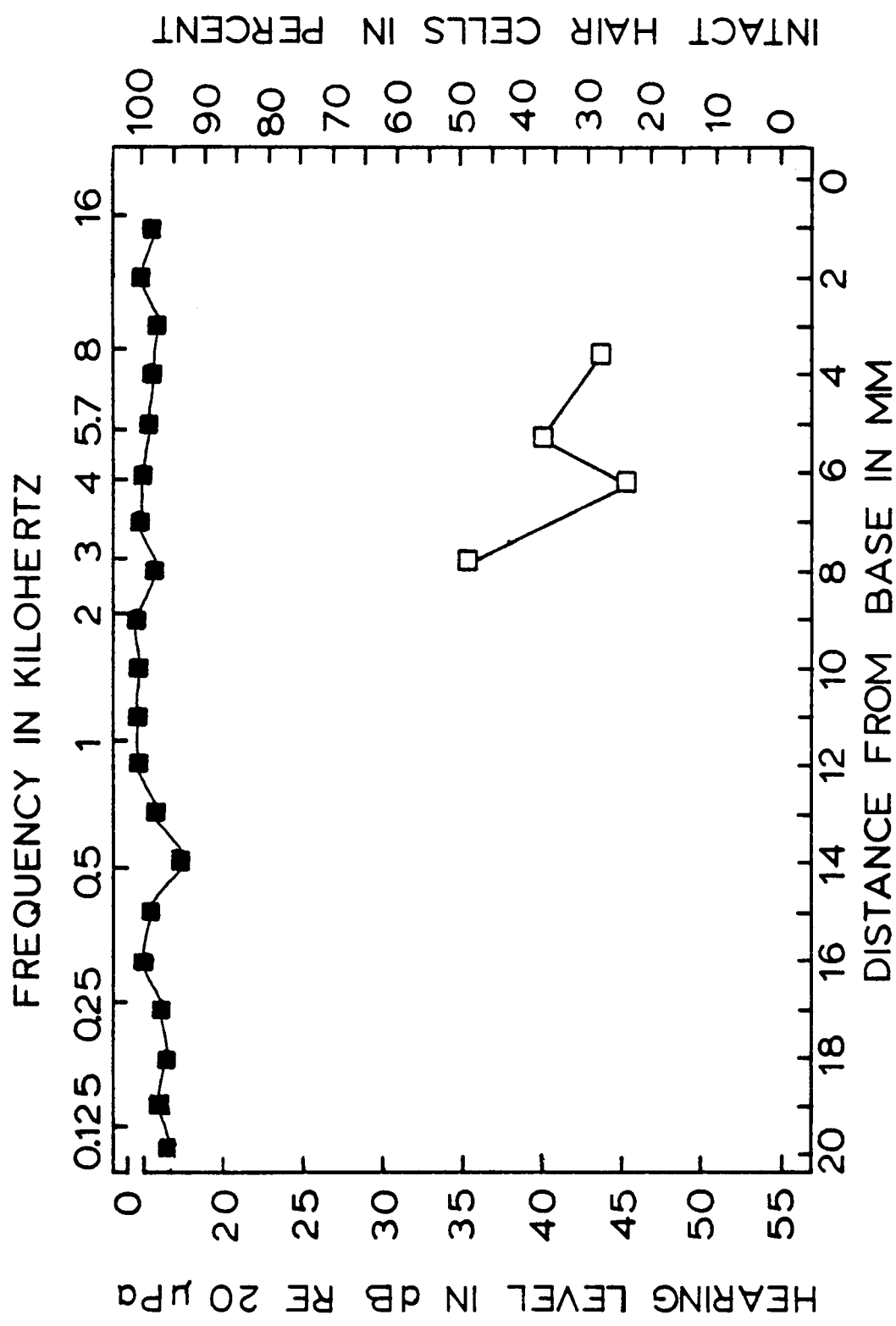


Figure 38. Left ear hearing levels (□) and intact hair cells (■) for animal C-4.

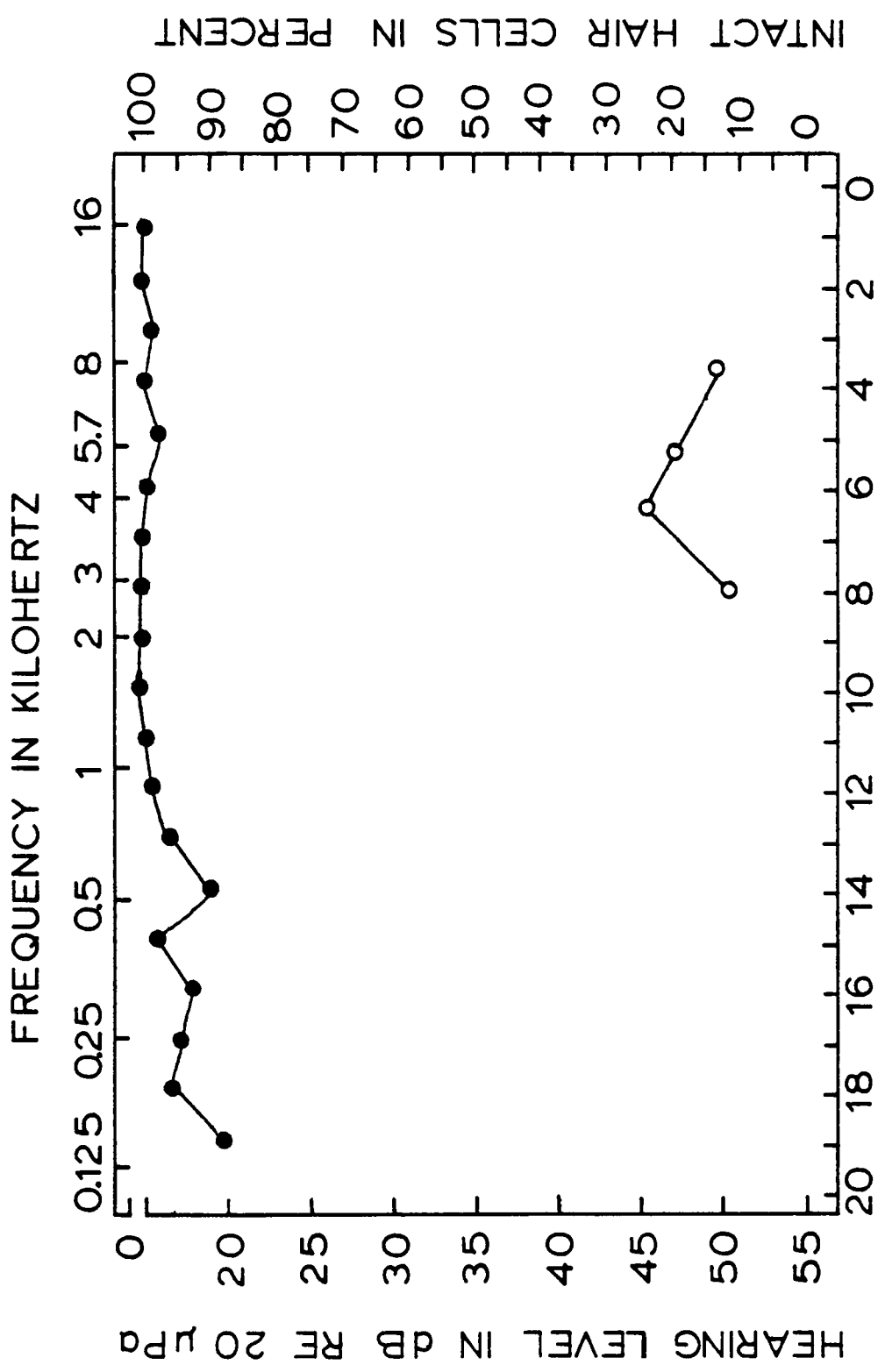


Figure 39. Right ear hearing level (O) and intact hair cells (●) for animal C-4.

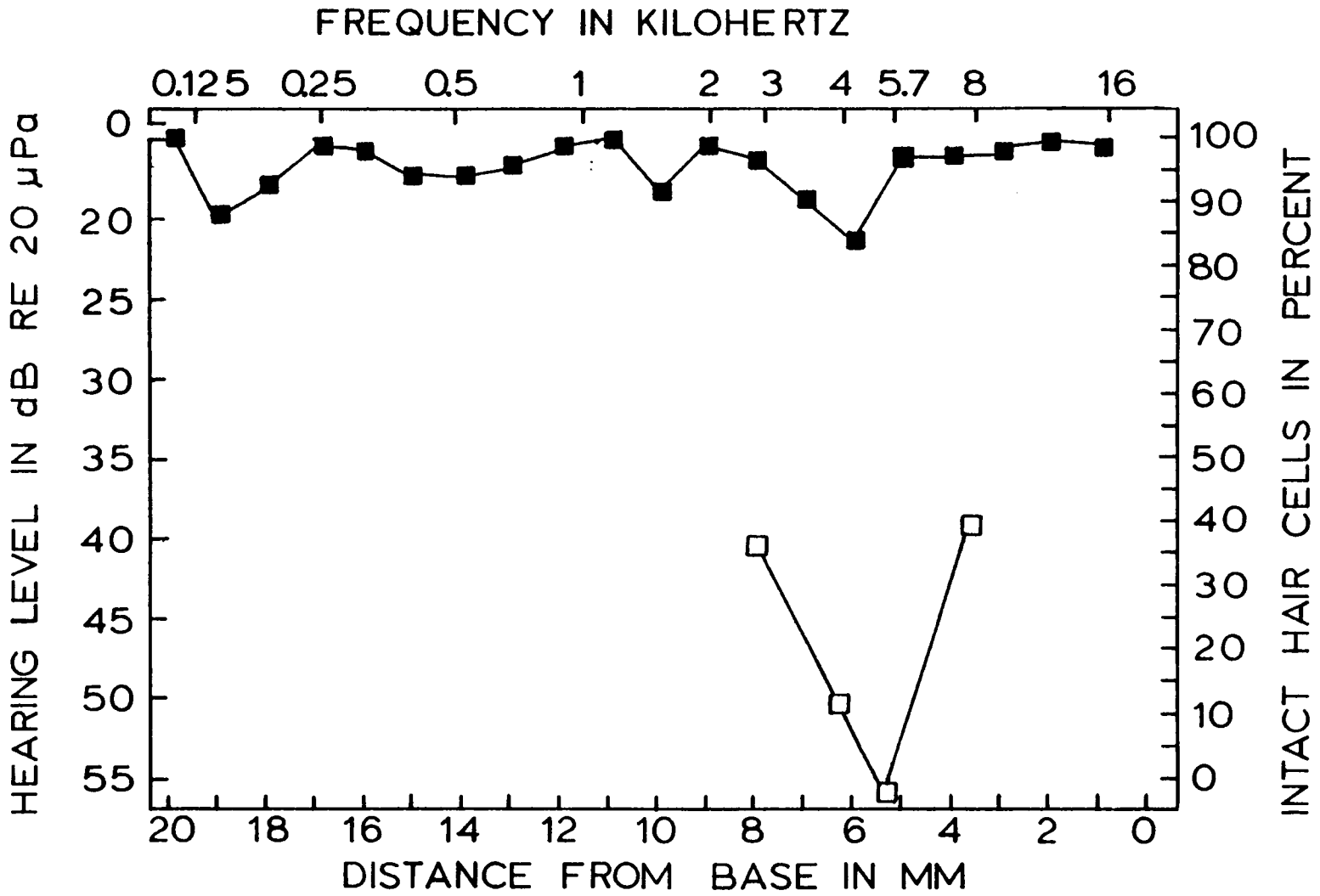


Figure 40. Left ear hearing levels (□) and intact hair cells (■) for animal C-5.

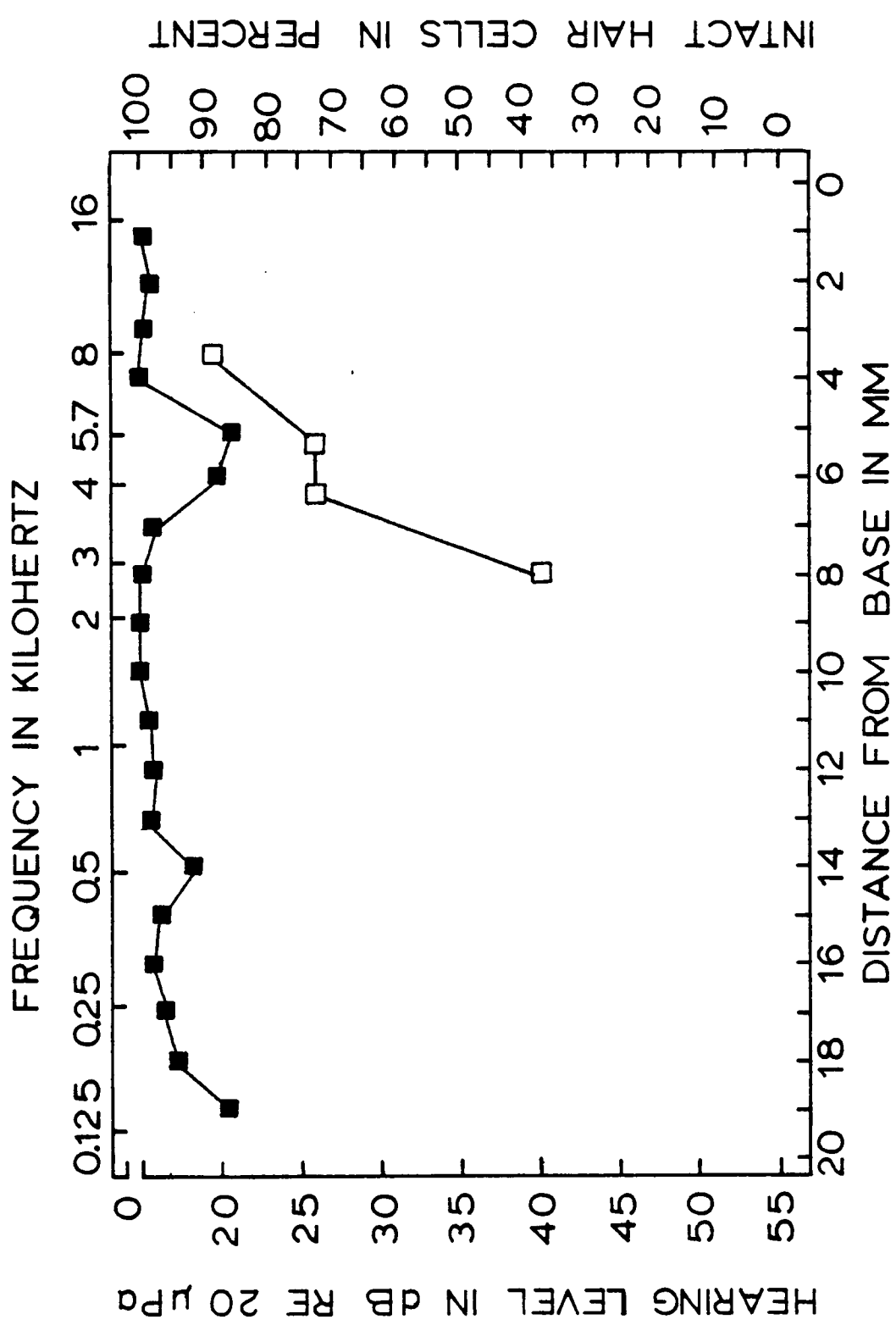


Figure 41. Left ear hearing levels (□) and intact hair cells (■) for animal C-6.

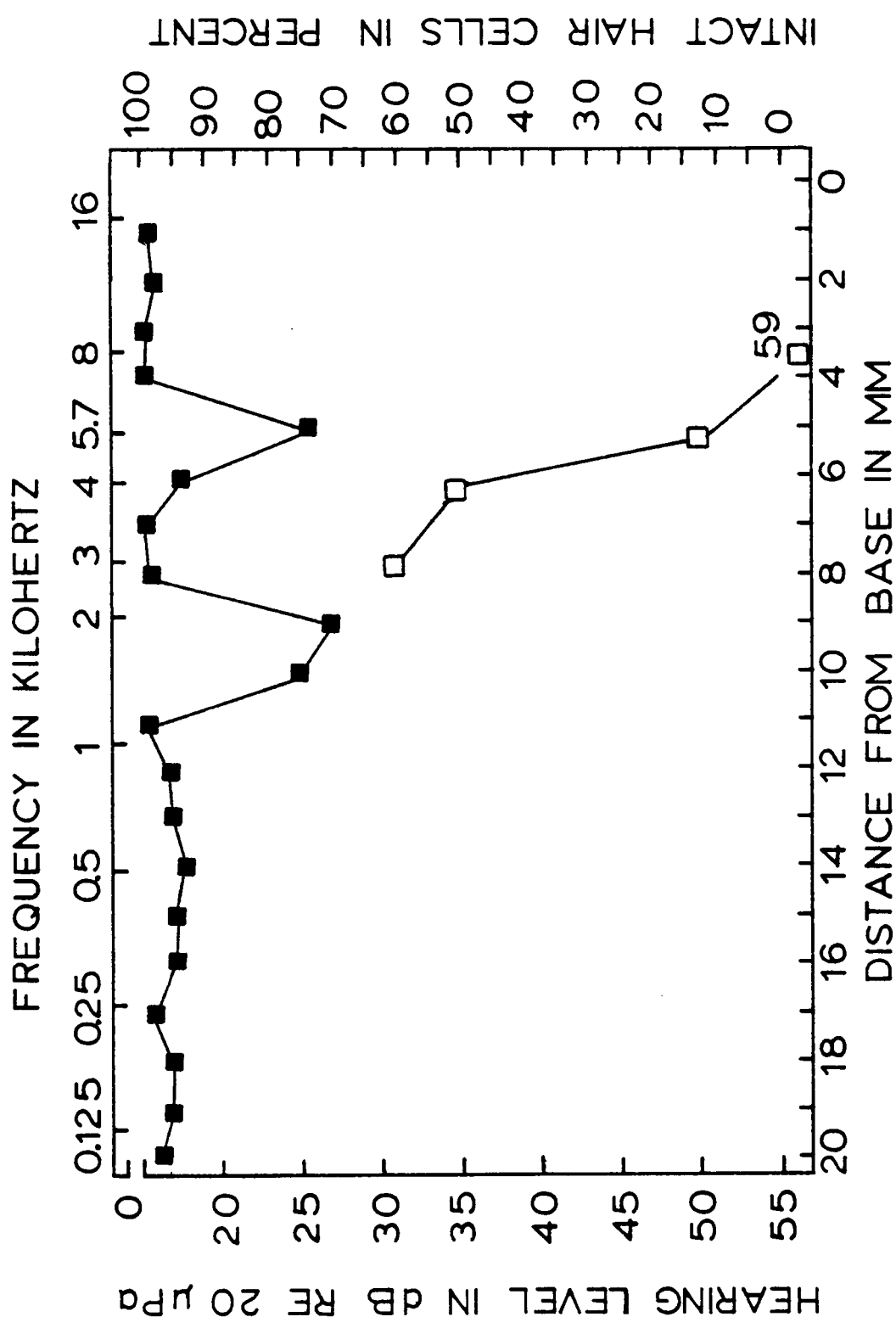


Figure 42. Left ear hearing levels (□) and intact hair cells (■) for animal E-2.

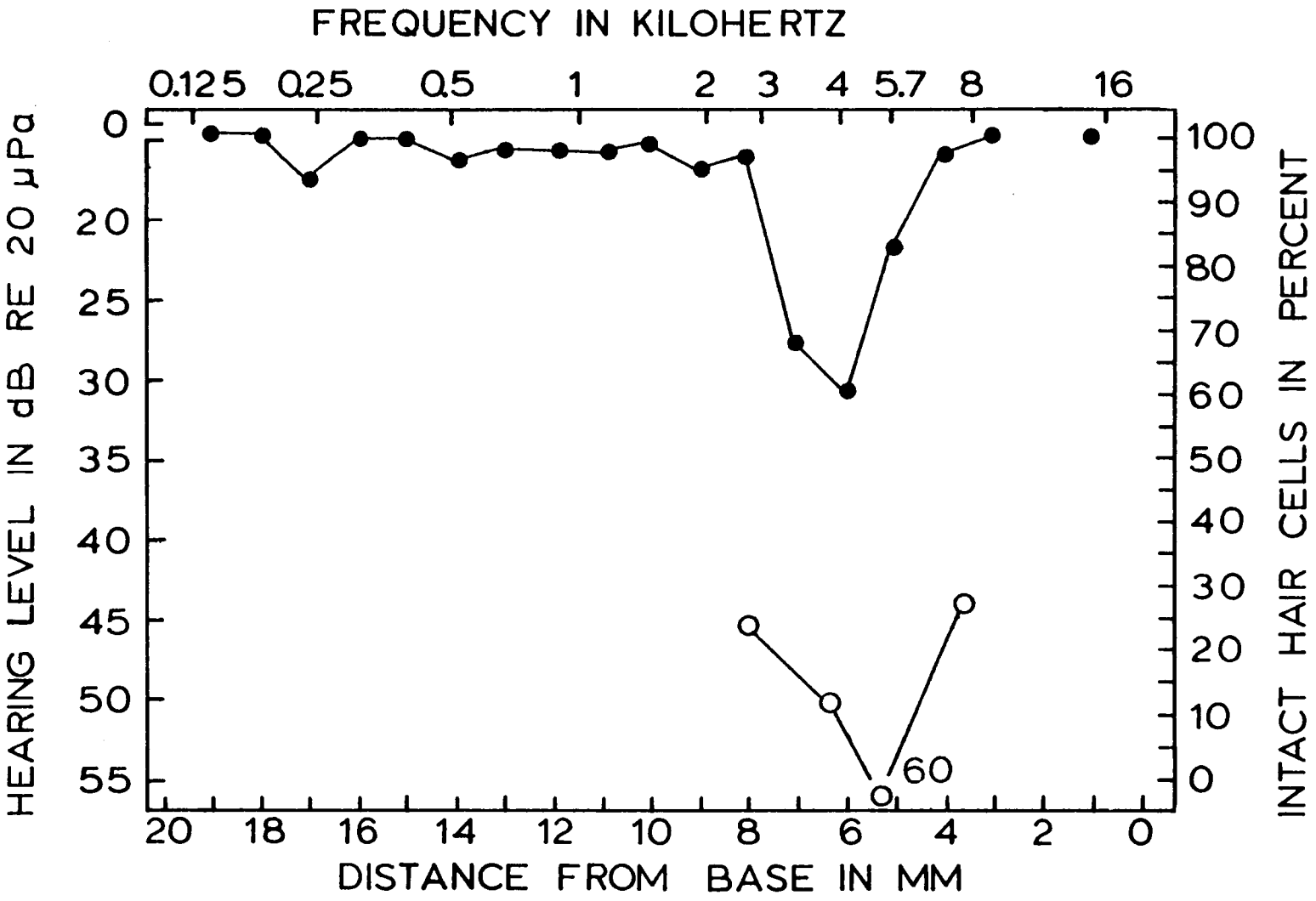


Figure 43. Right ear hearing levels (O) and intact hair cells (●) for animal E-2.

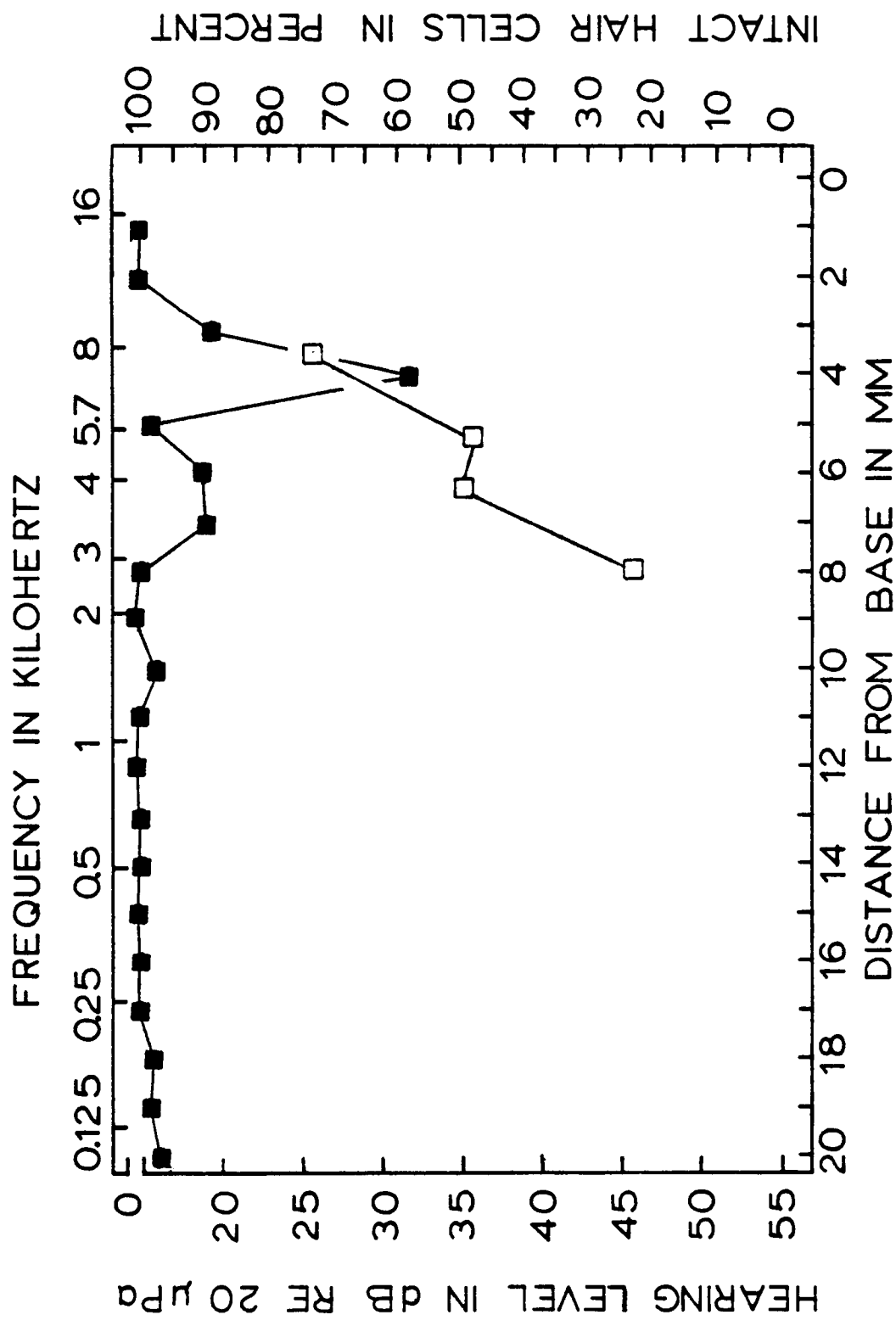


Figure 44. Left ear hearing levels (□) and intact hair cells (■) for animal E-3.

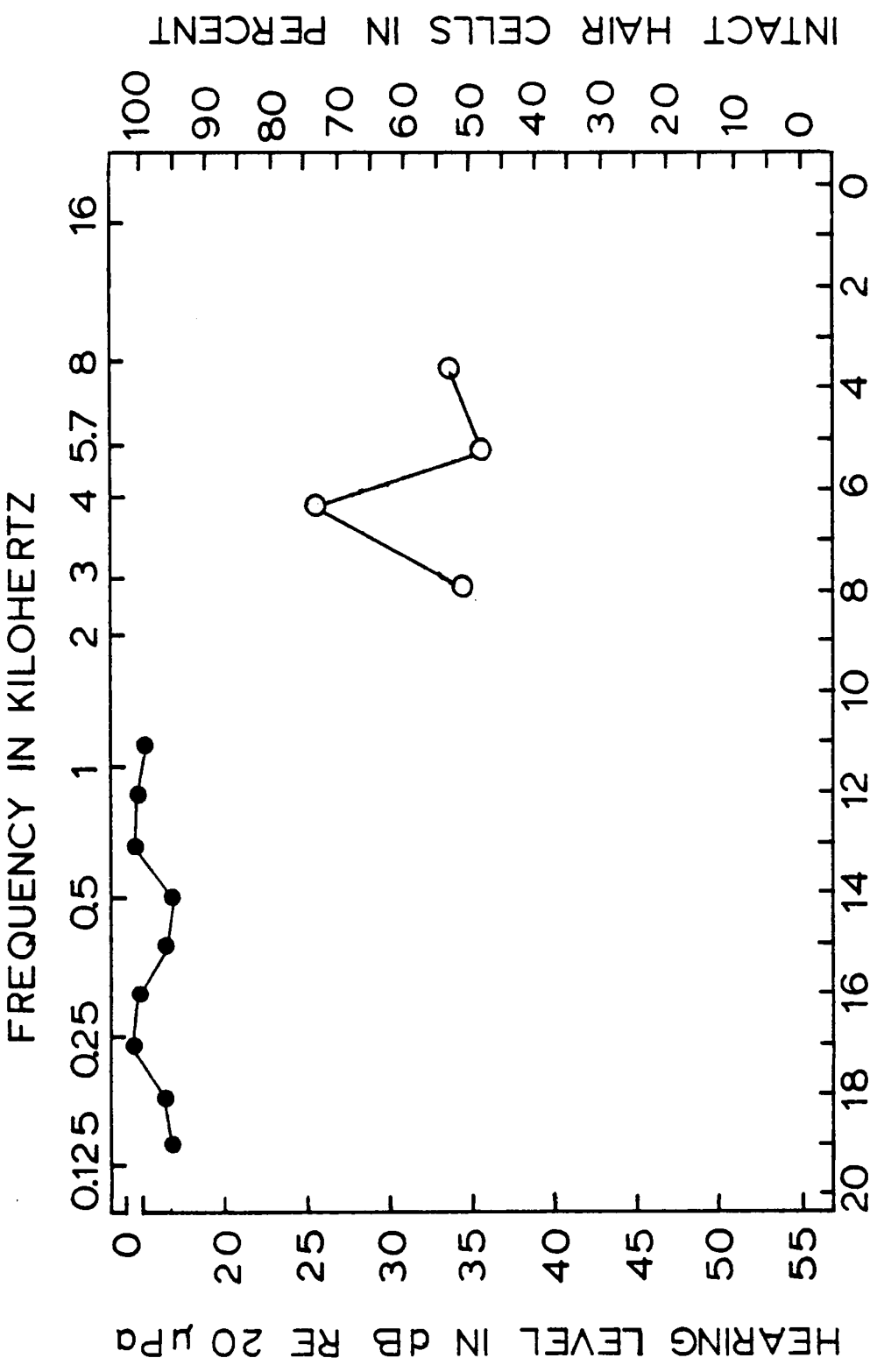


Figure 45. Right ear hearing levels (O) and intact hair cells (●) for animal E-3.

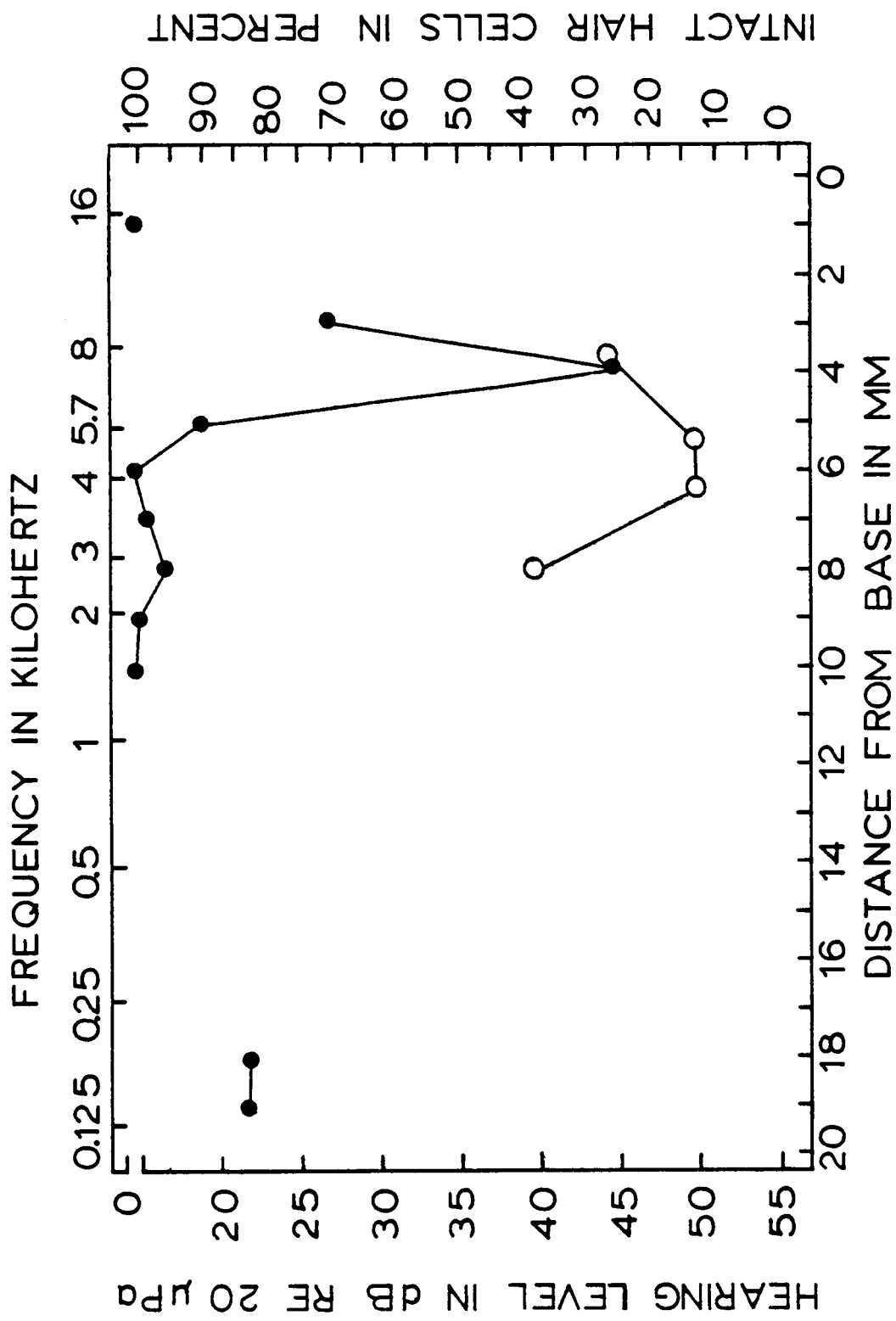


Figure 46. Right ear hearing levels (O) and intact hair cells (●) for animal E-4.

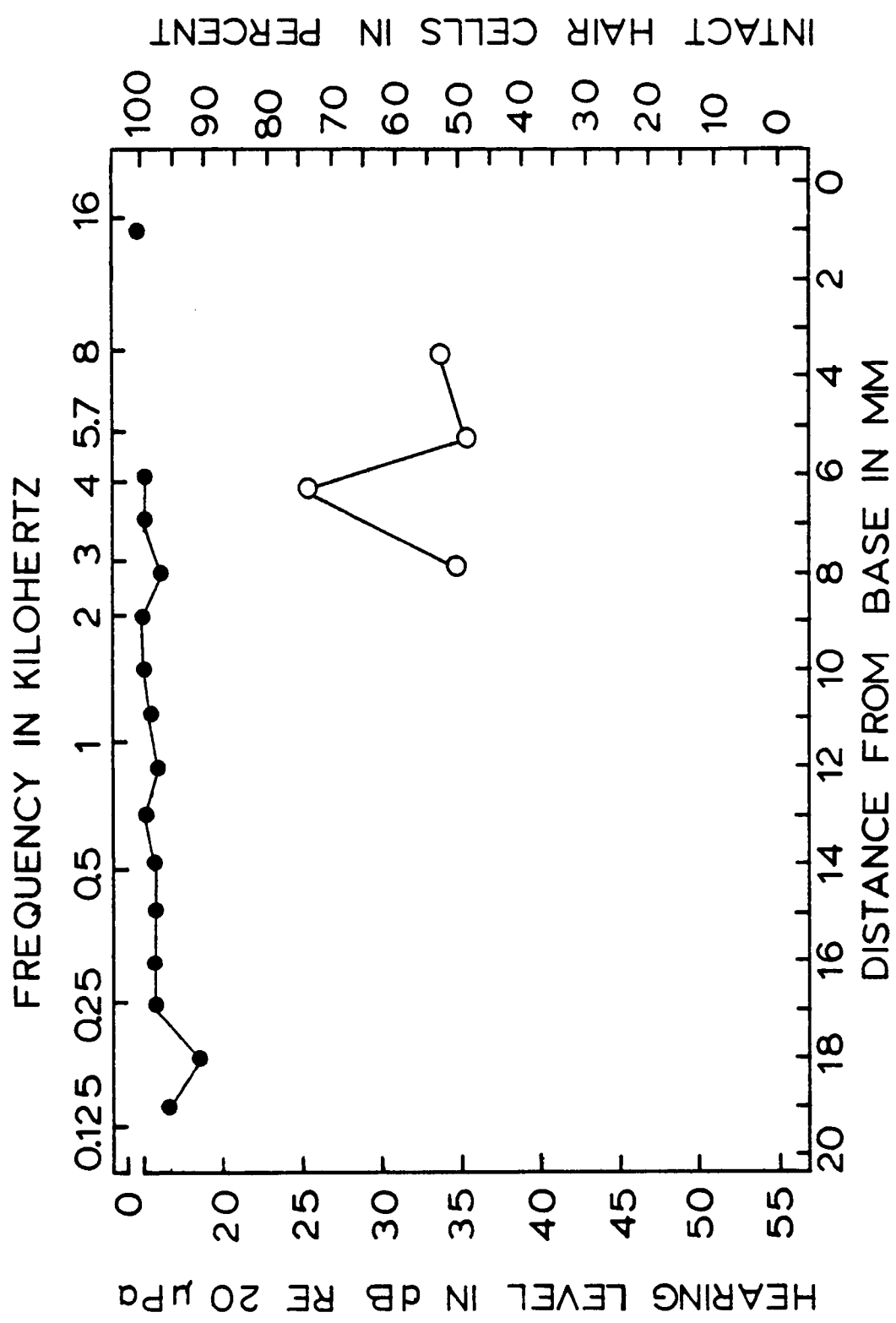


Figure 47. Right ear hearing levels (O) and intact hair cells (●) for animal E-5.

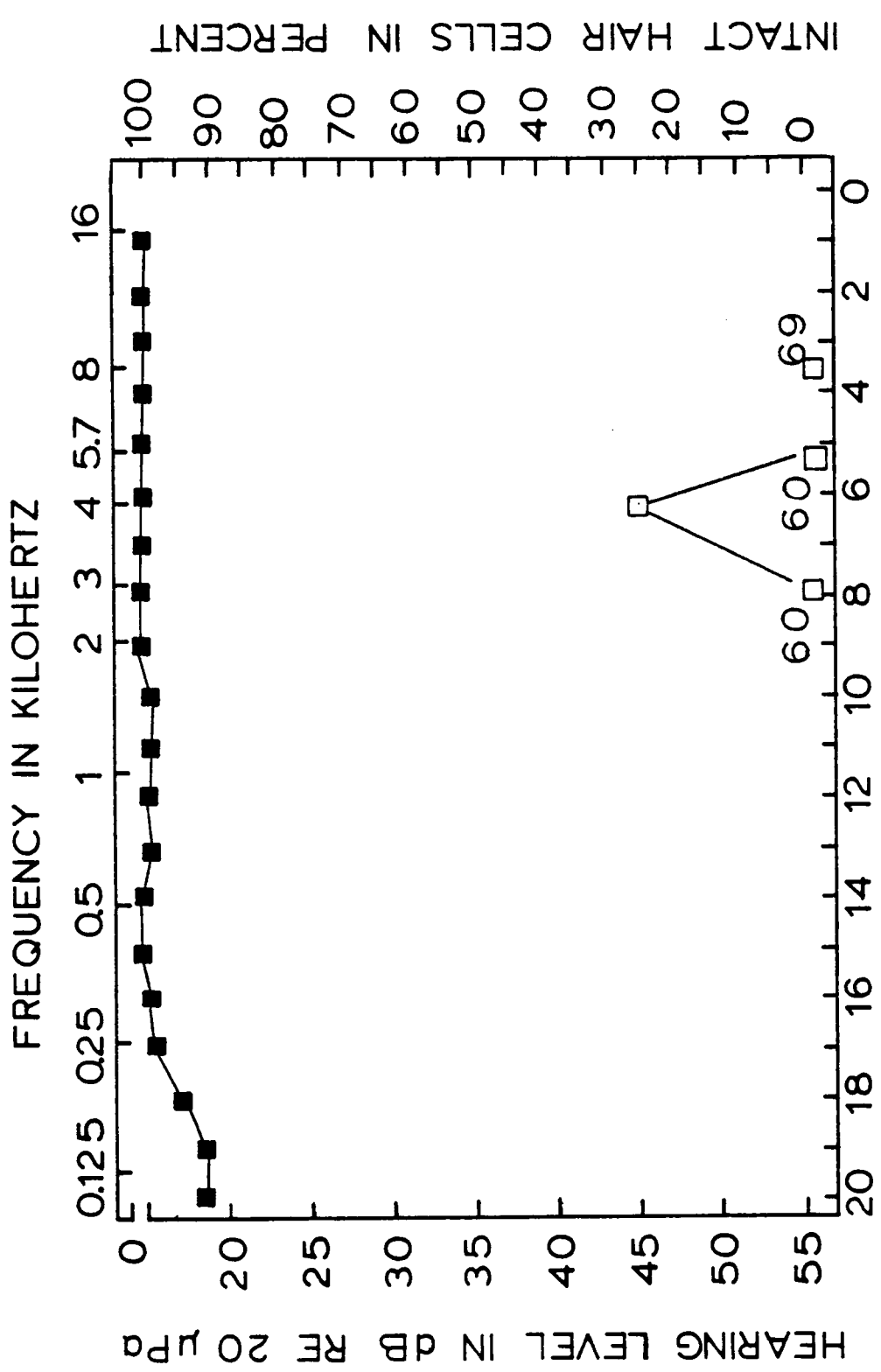


Figure 48. Left ear hearing levels (□) and intact hair cells (■) for animal E-6.

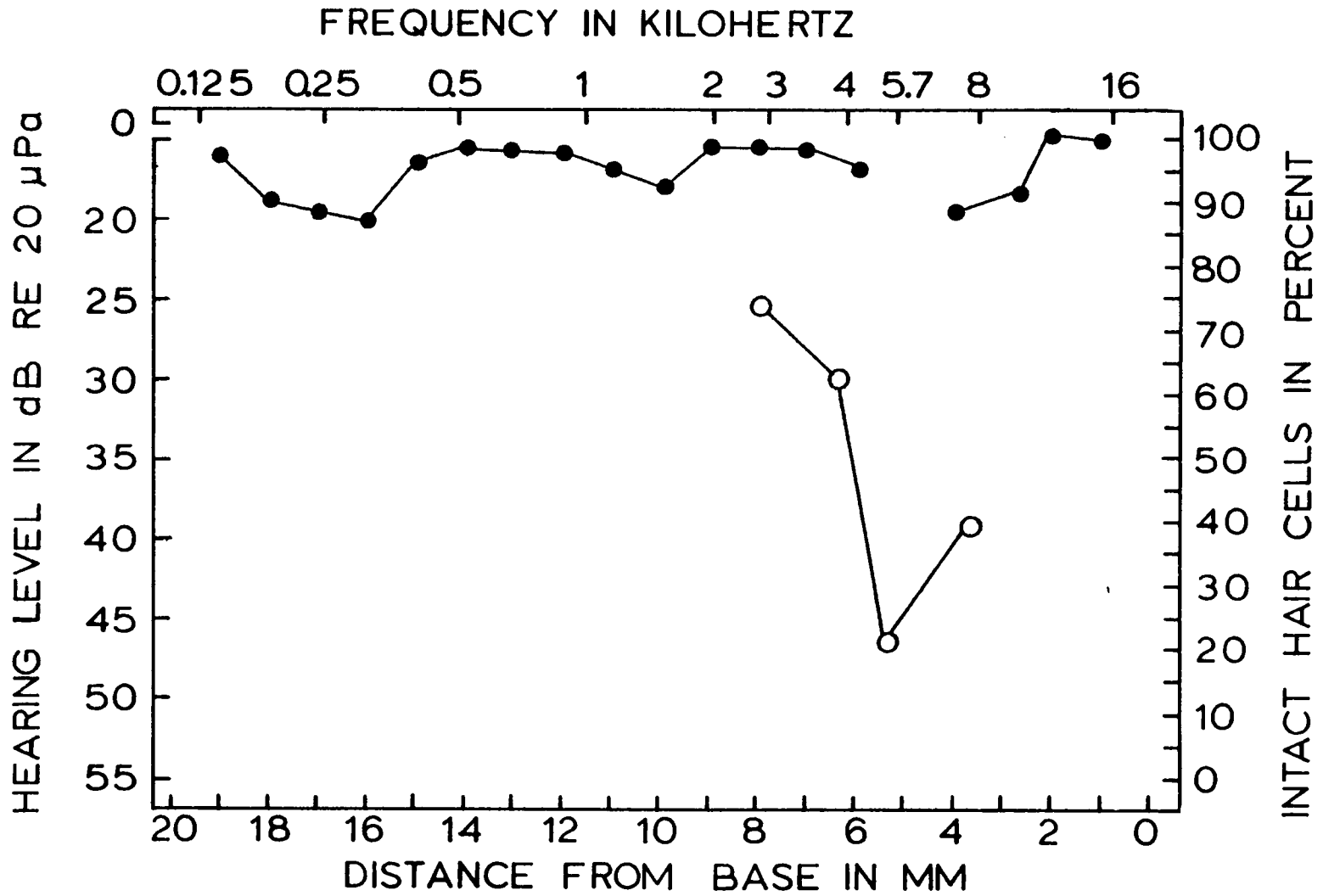


Figure 49. Right ear hearing levels (O) and intact hair cells (●) for animal E-6.

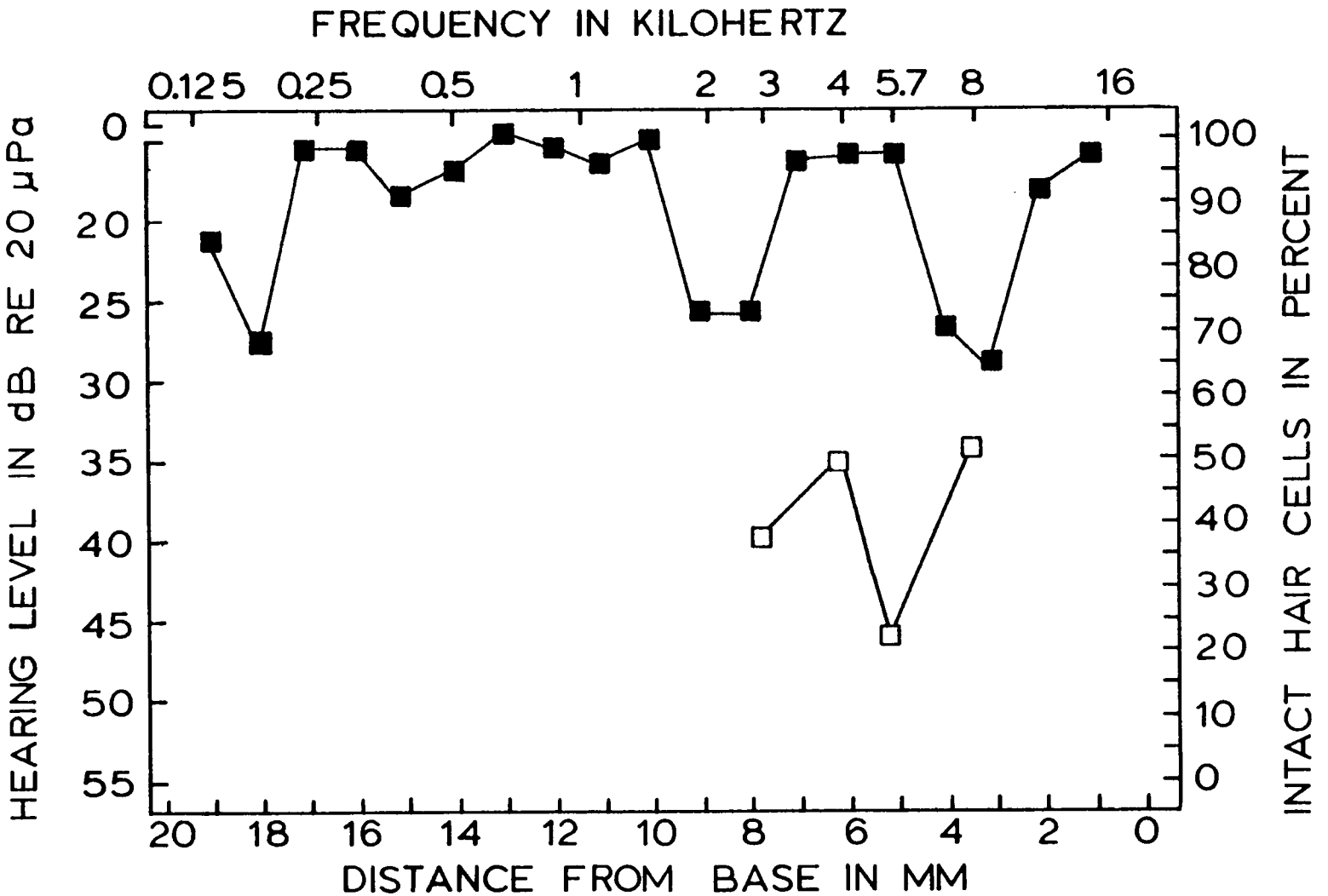


Figure 50. Left ear hearing levels (□) and intact hair cells (■) for animal F-1.

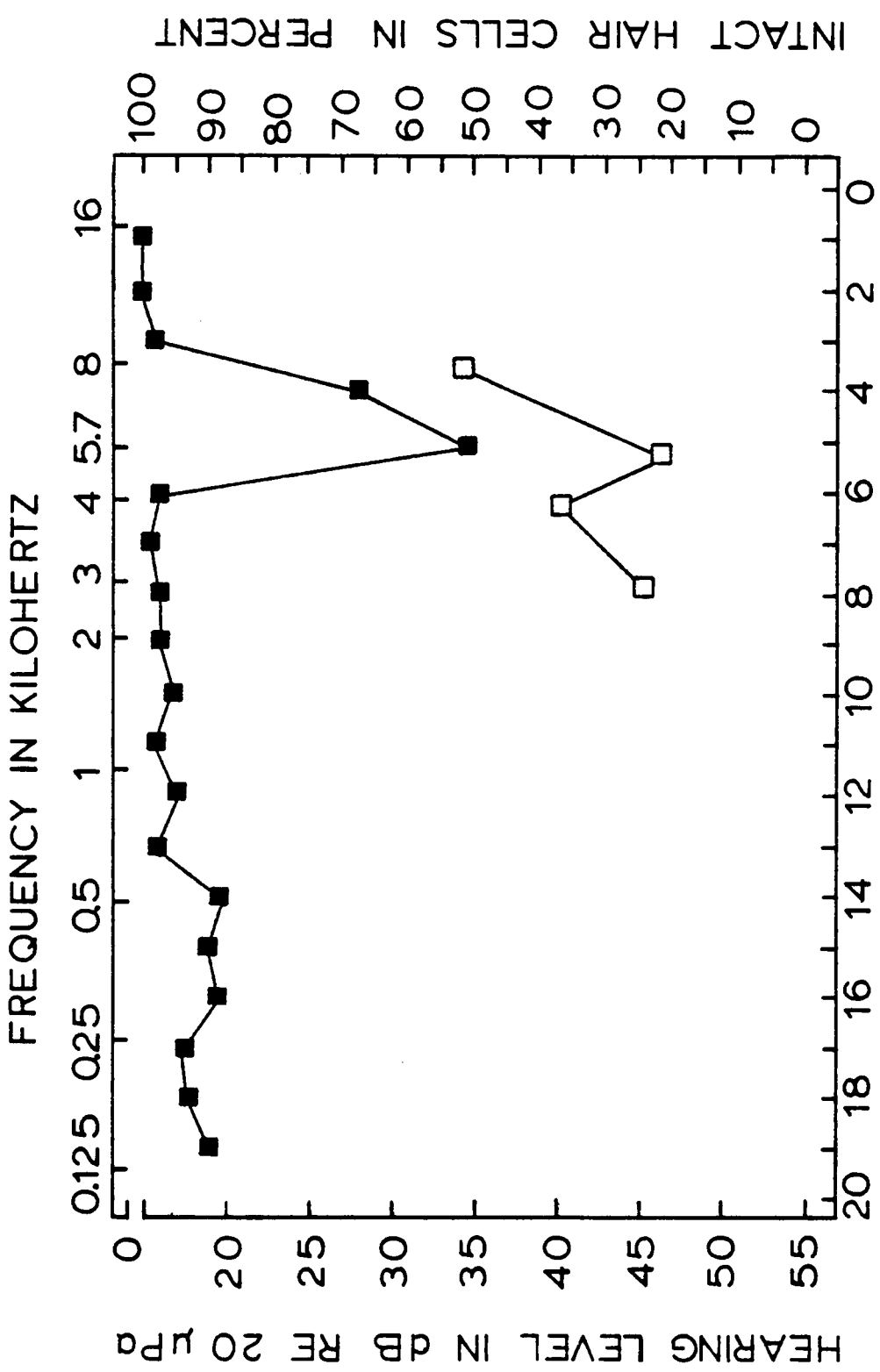


Figure 51. Left ear hearing levels (□) and intact hair cells (■) for animal F-2.

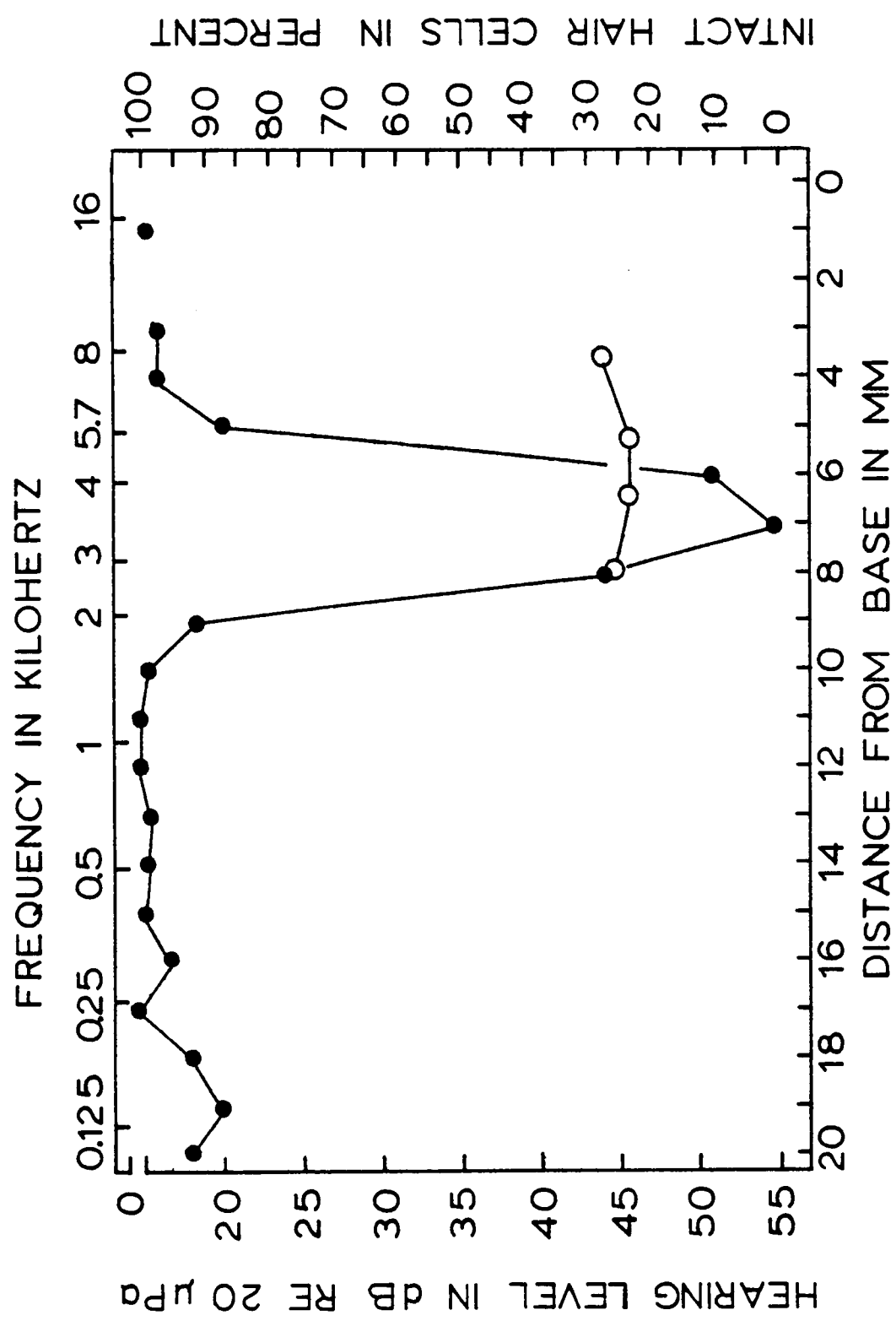


Figure 52. Right ear hearing levels (O) and intact hair cells (●) for animal F-2.

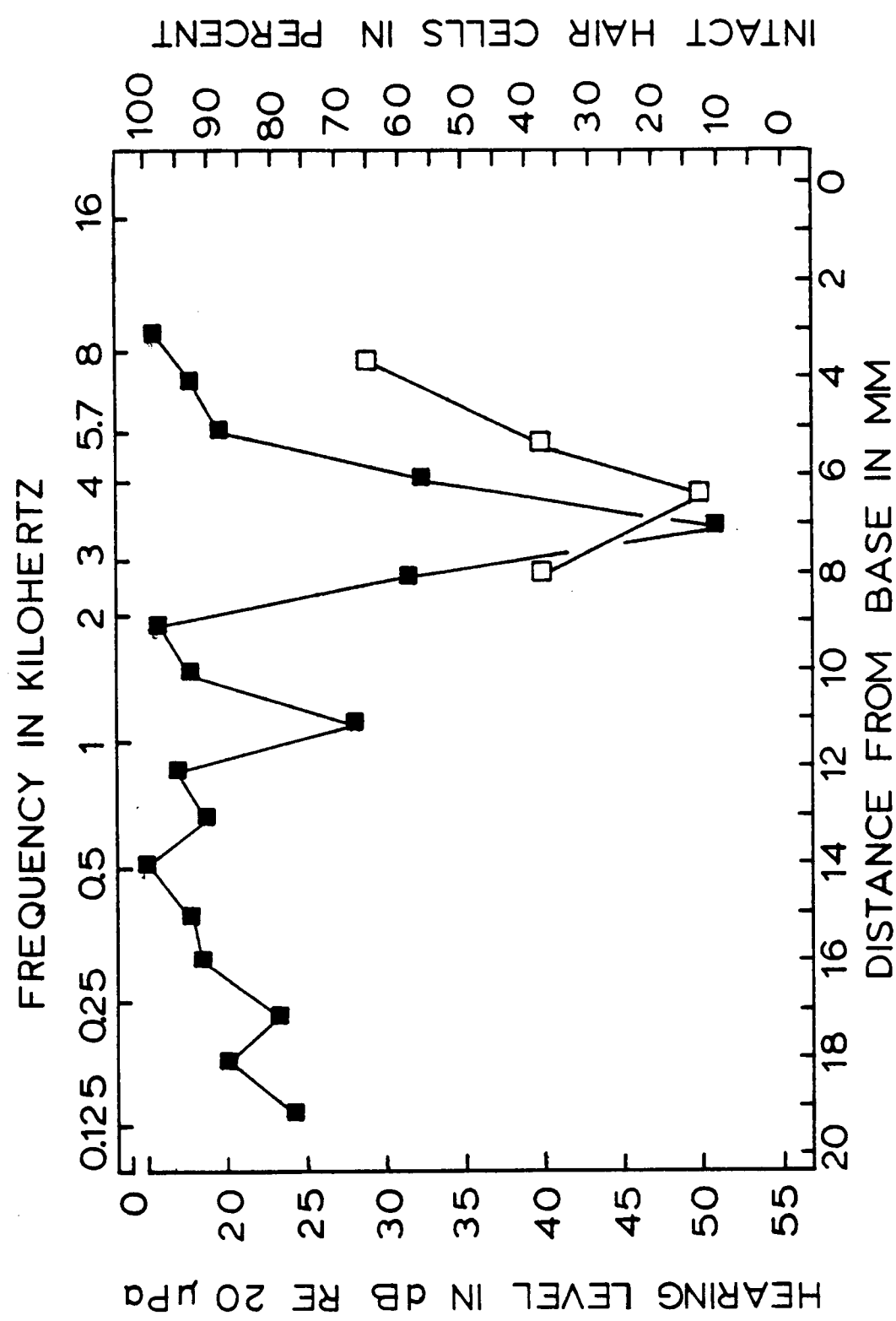


Figure 53. Left ear hearing levels (□) and intact hair cells (■) for animal F-3.

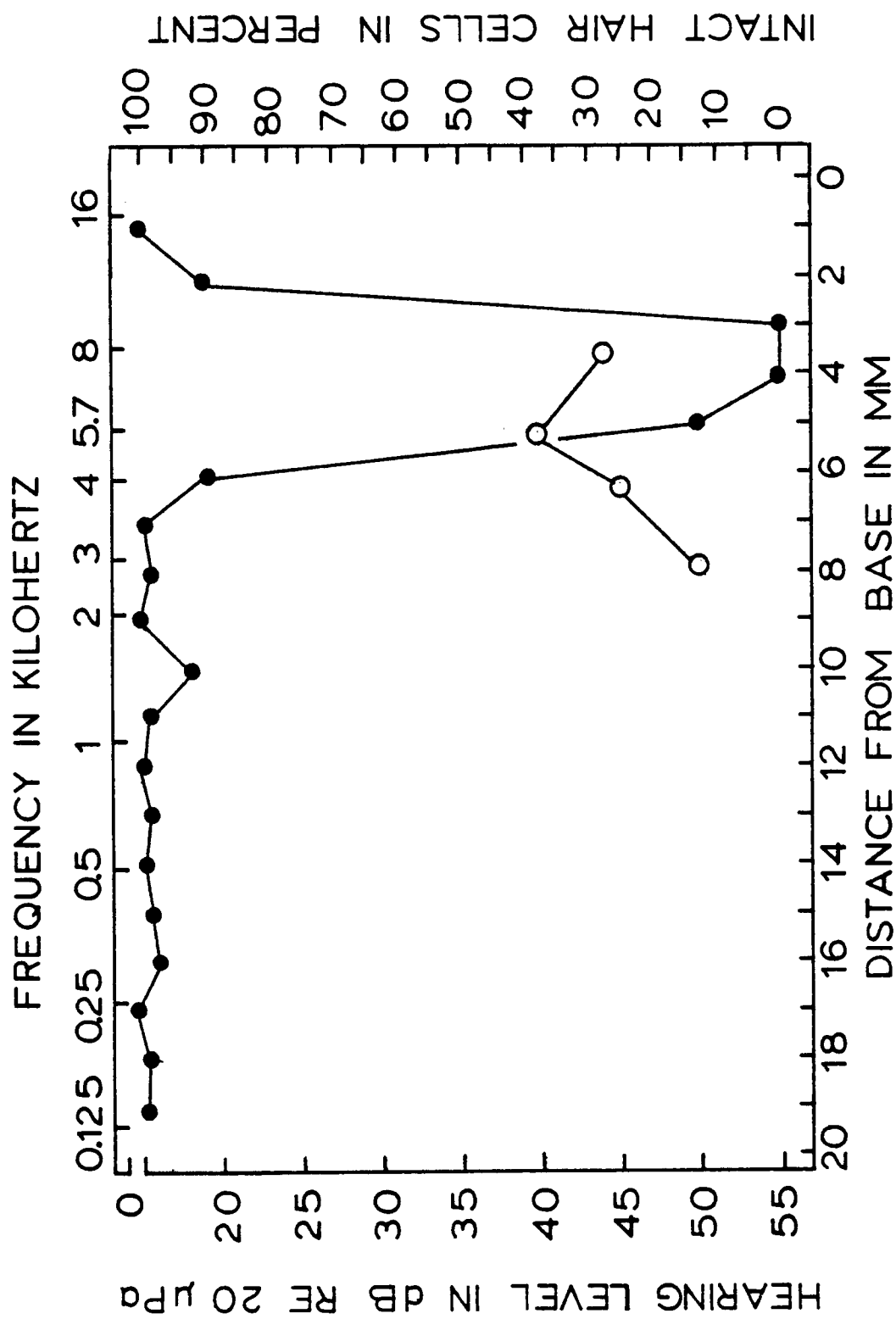


Figure 54. Right ear hearing levels (O) and intact hair cells (●) for animal F-4.

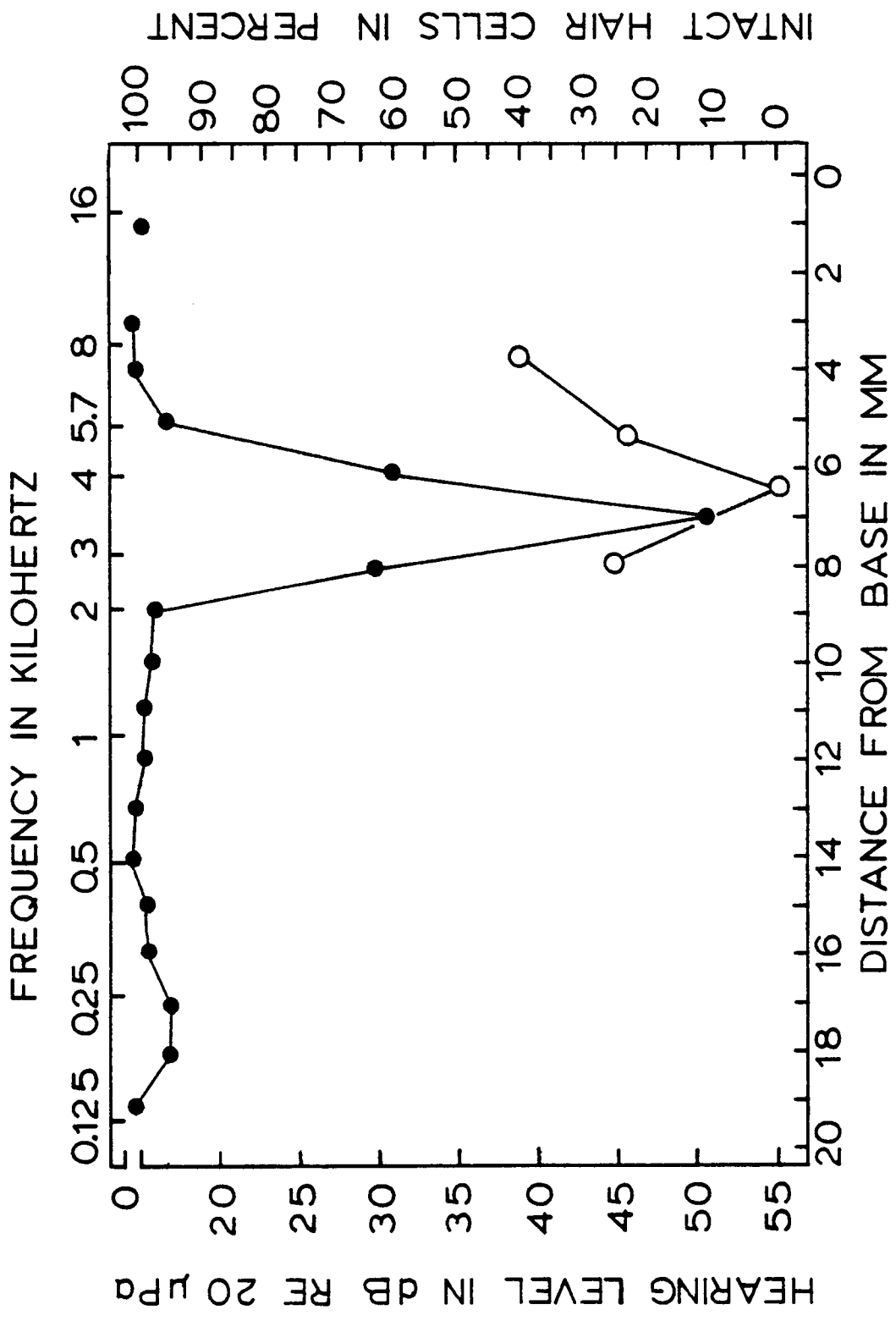


Figure 55. Right ear hearing levels (O) and intact hair cells (●) for animal F-5.

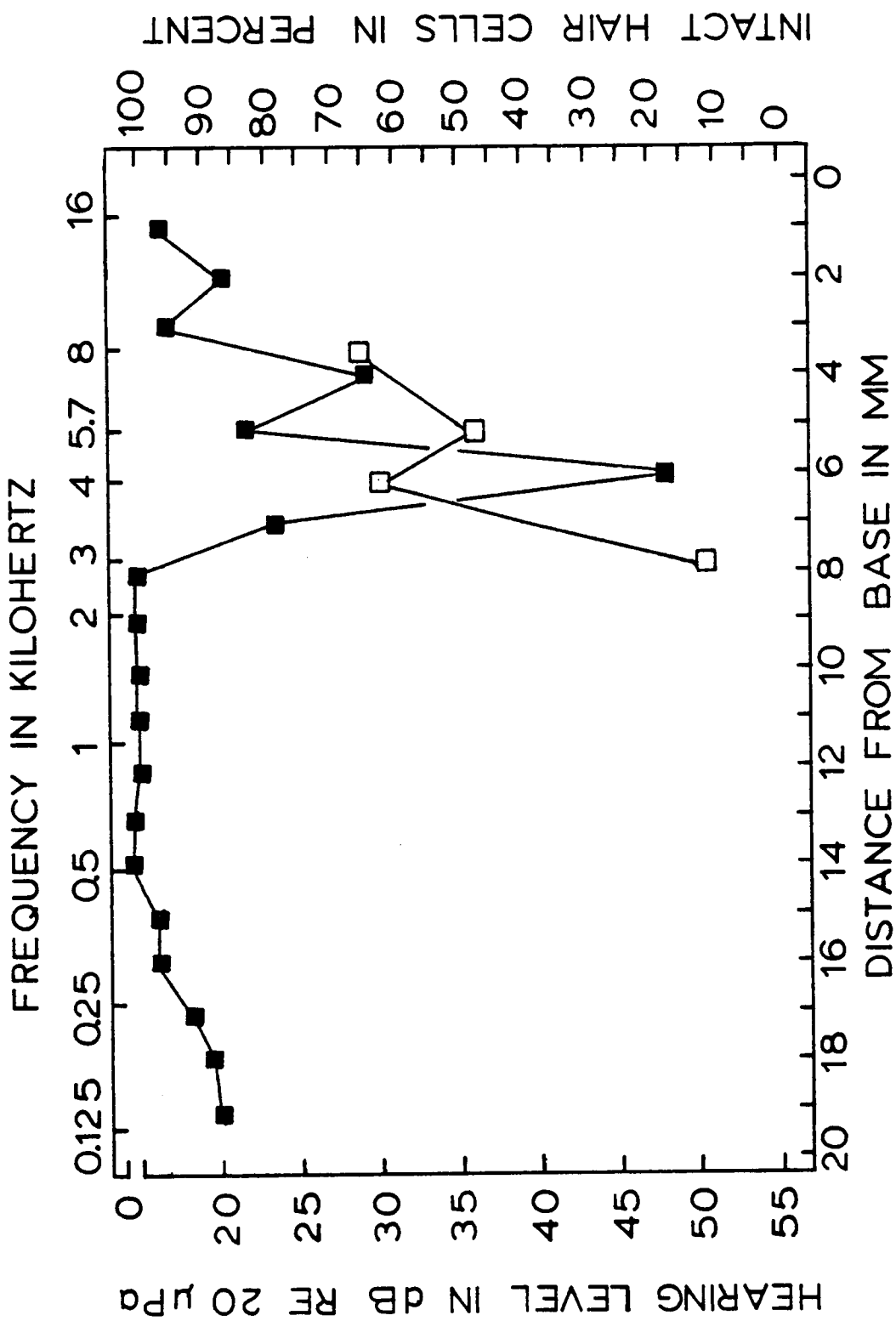


Figure 56. Left ear hearing levels (□) and intact hair cells (■) for animal F-6.

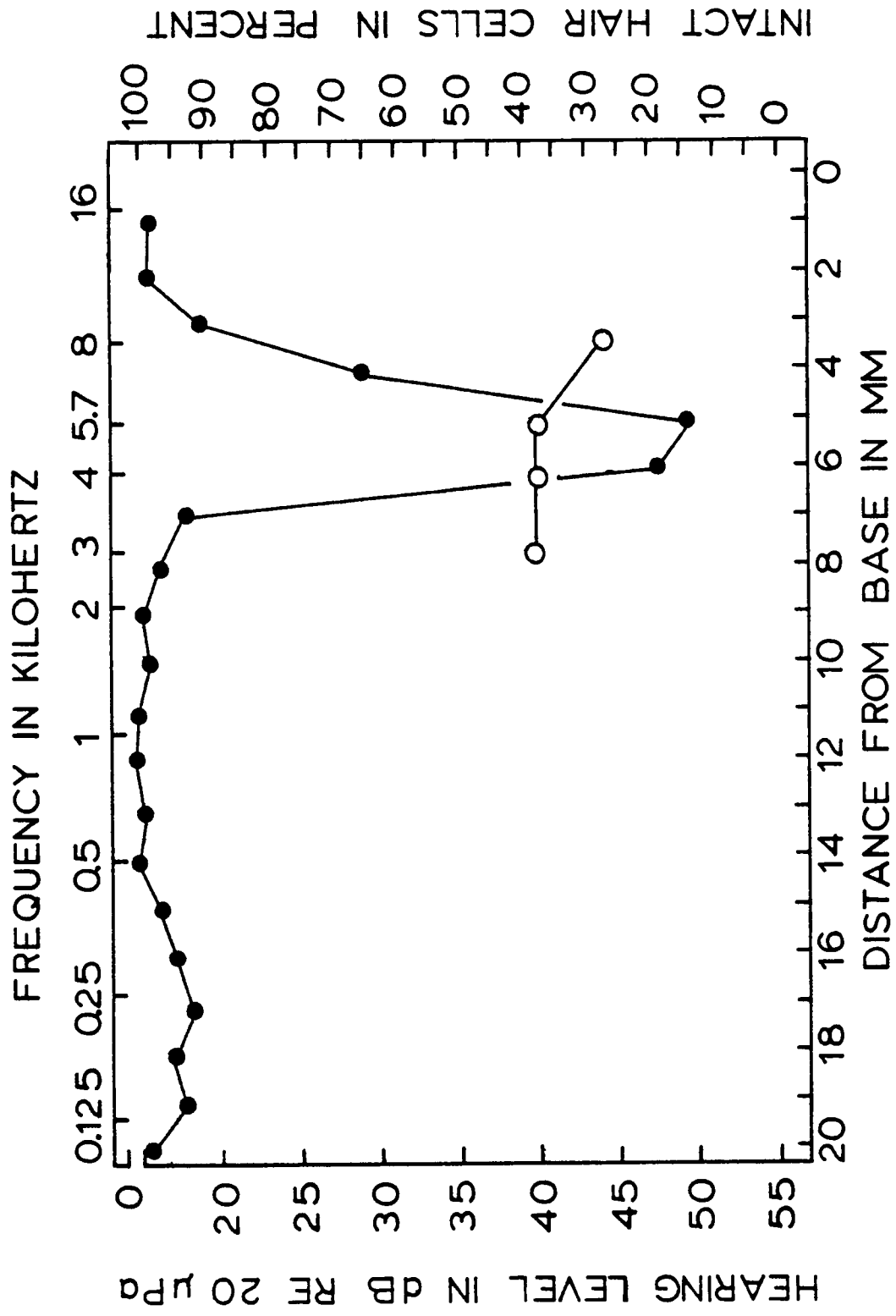


Figure 57. Right ear hearing levels (O) and intact hair cells (●) for animal F-6.

VITA

William Scott Wood, III was born in Syracuse, New York, on August 18, 1947. He attended Narimasu High School in Tokyo, Japan. Scott earned his Bachelor of Science degree in Psychology from Maryville College in Maryville, Tennessee, and his Master of Arts degree in Audiology from the University of Tennessee in Knoxville, Tennessee. In July 1971, he accepted a direct commission into the United States Army Reserves and served three years as a clinical audiologist and two years as a hearing conservation survey officer. Scott resigned his commission and began working toward his doctorate degree in Speech and Hearing Science at the University of Tennessee in September 1976. He received this degree in June 1981.