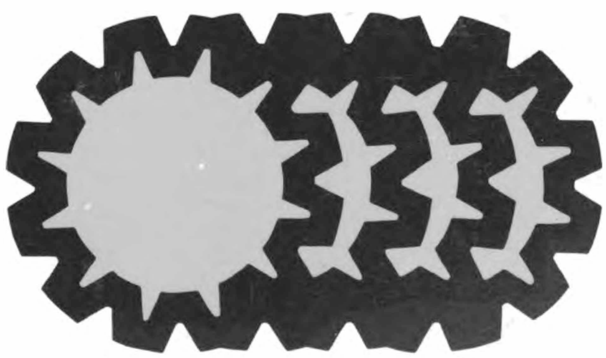
NIOSH

TECHNICAL INFORMATION

Occupational Noise & Hearing

1968–1972



OCCUPATIONAL NOISE AND HEARING

1968 TO 1972

- A NIOSH STUDY -

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INTRODUCTION

The occupational noise and hearing survey (ONHS) was begun in 1968 by the U. S. Public Health Service as a long-range project of what was then called the National Noise Study, with operations based at the Bureau of Occupational Safety and Health in Cincinnati, Ohio. With the creation of the National Institute for Occupational Safety and Health (NIOSH) in December 1970, the survey program was continued by the Noise Section of the NIOSH Physical Agents Branch.

The aim of the occupational noise and hearing survey was to characterize noise exposure levels in a variety of industries, to describe the hearing status of workers exposed to such noise conditions, and ultimately to establish a relationship between occupational noise exposure and hearing loss that would be applicable to general industry. The survey program was informally publicized at industrial hygiene conferences and an outline of the procedures and goals of ONHS was sent to regional offices of the U. S. Public Health Service for distribution. Interested companies were invited to request that they be included in the study. All plants that requested noise and hearing evaluations were considered. Certain priority considerations were applied, however. The existence of factory or occupational noise conditions having critical relevance to the development of noise standards and criteria and the presence of a work force presenting a wide range of years of exposure to such noise were the main factors. Initial discussions with plant management or union officials and preliminary walk-through noise surveys provided the basis for making such judgments.

The four primary types of data collected during the course of an individual noise and hearing study were noise measurements, personal background information, medical and otologic data and audiometric data. Members of the survey team made noise level measurements at different points in the plant and took tape recordings for subsequent laboratory analysis of noise characteristics. A questionnaire form was used to obtain information bearing on each worker's job history, military service, hobbies, and medical history pertinent to ear abnormalities and hearing difficulty. An otoscopic inspection of the ears was made, usually just after the questionnaire was completed. Measurements of the hearing levels for pure tone frequencies in the right and left ears of the workers were accomplished in a mobile audiometric test van. Workers from noisy workplaces were always tested at the beginning of their workshift.

The plan of the study was to concentrate on workers in noisy areas. An attempt was made to test the entire work force at plants having a total of less than 500 employees. In larger plants sampling and selection were done on a random basis. All participation in the hearing survey was strictly voluntary; however, all workers selected for the study were strongly encouraged to participate. Although the study concentrated upon noise exposed workers, employees from each plant who worked in offices or other quiet work areas were also included in the survey in order to provide control data.

The noise and hearing data were sorted and analyzed so as to illuminate the relationship between occupational noise levels and hearing losses in worker groups classified by number of years of occupational noise exposure and age. This report, which provides background information and results of statistical analysis, is intended to complement the data analysis that has already been published in the NIOSH document, "Criteria for a Recommended Standard. . .Occupational Exposure to Noise."*

Dr. Alexander Cohen served as Chief of the National Noise Study and led the occupational noise and hearing survey from the time of its inception until the establishment of the Physical Agents Branch. Herbert H. Jones served as Associate Chief of the National Noise Study and later as Chief of the Physical Agents Branch.

A list of Public Health Service staff members participating in the study program during the years 1968 to 1972 is given below:

Psychoacoustician:	A. Cohen, Ph.D.
Engineers:	H. Jones
	E. Carroll
	P. Carpenter
	S. Cordle
	T. Henderson, Ph.D.
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Industrial Hygienists:	T. Anania
	E. Leininger
Industrial Psychologist:	B. Margolis, Ph.D.
Medical Personnel:	J. Anticaglia, M.D.
	L. Burton, M.D.
	W. Mathews, M.D.
	S. Danziger, M.D.
Technician:	E. Jackson

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NOISE SURVEY

EQUIPMENT AND CALIBRATION

Surveys of environmental noise levels were made using a variety of sound level meters and other instruments. Although efforts focused upon determination of single, representative dBA levels, measurements were also made to determine noise spectra in octave and third-octave bands, statistical distribution of noise levels, temporal characteristics of fluctuating noises, peak pressures of impact or impulsive sounds, repetition rate and duration of impact sounds, directional or position-dependent characteristics, and durations of noise bursts. The following electronic instruments were used at various times during the survey:*

- Bruel-Kjaer Sound Level Meters:
  Types 2203, 2204, 2204S, 2205
- Bruel-Kjaer Octave Filter Sets: Type 1613
- Bruel-Kjaer Piston Phones: Type 4220
- General Radio Sound Level Meter: Type 1565-A
- General Radio Calibrator: Type 1562
- Nagra III Full-track Magnetic Tape Recorder
- General Radio Impact Noise Analyzer: Type 1556-B
- Bruel-Kjaer Level Recorder: Type 2305
- Bruel-Kjaer Statistical Distribution Analyzer: Type 4420
- General Radio 1926 Real-Time Spectrum Analyzer
- Tektronix Storage Oscilloscope: Type 564B, with Camera

Calibration Routine: Sound level meters were acoustically calibrated at least once each day measurements were made. Usually an acoustical calibrator was carried with each sound level meter, and used to provide a calibration check before each measurement series. Battery voltage levels were checked frequently. All of the sound level meters used in the study were found to be quite reliable and consistent, seldom requiring adjustment of more than 1/4 dB. Each tape recording included a pistonphone-generated test tone and a voiced announcement of the attenuator setting of the sound level meter for subsequent calibration of laboratory analysis instruments during playback. Instruments used to measure peak pressure of impact sounds were calibrated using a 127 dB-peak pistonphone tone (124 dB-RMS).

NOISE MEASUREMENT PROCEDURES

Noise level surveys were conducted so as to best assess the daily noise exposures of those workers included in the study. A preliminary

* Mention of commercial products does not imply endorsement by the U. S. Public Health Service.

occupational noise survey often provided the information needed to develop a sampling schedule. Such a survey was a part of the initial inspection of a plant for which a noise and hearing survey had been requested. The following items were obtained, when possible, in each area of a plant: (1) Location and type of operation or work performed; (2) General noise characteristics (e.g., impulsive, steady-state, low frequency, etc.); (3) Temporal characteristics (continuous, fluctuating, intermittent, etc.); (4) Overall noise levels using the "A", "C", and "linear" scales of the sound level meter.

Microphone Placement: To obtain representative and reliable exposure values, noise level measurements were taken alongside workers in the course of their daily job routines. Care was taken to avoid positioning the microphone close to a reflecting or shielding surface. In many cases a worker was asked to stand aside and the sound level meter was positioned at the point normally occupied by the worker's head. Several measurements were made at different locations to determine spatial dependence of noise levels. Estimates of the median and range of levels were recorded whenever the level showed significant variation with position.

Spectrum Measurements: Standard procedures included some measurement of typical noise spectra for each of the noise and hearing surveys in the series, either by field measurement of octave band levels or spectral analysis of recorded tapes, or both. Octave band analyses included bands with mid-frequencies of 31.5, 63, 125, 250, 500, 1000, 2000, 4000, and 8000 Hz. Recorded tapes were played back through an octave band filter set or through a third-octave band, real-time analyzer.

Sequential Sampling

Toward the latter part of the series of individual noise and hearing studies described in this report, a technique was developed for making field measurements of dBA level at intervals of 15 seconds throughout a sample period of ten minutes. This technique was found to be very useful in those areas where the dBA level evidenced significant, random variations with time. The procedure is described briefly as follows: a compact, lightweight sound level meter is selected. A pocket watch or wrist watch having a large sweep-second hand is taped to the face of the sound level meter, either just above or just below the meter dial. The bottom of the sound level meter is then positioned at the top end of an ordinary clipboard. The bottom edge of the clipboard is rested against the belt or hip of the person making the measurements. One hand is used to support the sound level meter/clipboard combination at an angle that is convenient for recording data on the clipboard with the other hand; this also positions the sound level meter for convenient viewing, pointed away from the person's body at an angle of about 45°

above the horizontal. For measurements at 15 second intervals, the sound level meter deflection is noted at precisely each instant that the second-hand crosses 12, 3, 6, or 9 o'clock. The sound level at each instant is recorded by marking a dot at the appropriate location on a special histogram form attached to the clipboard. At the end of a measured 10-minute period, the histogram form will contain 40 dots. The form can be kept for subsequent analysis at a more convenient time or location. It is a fairly simple matter to obtain the mean, median, and quartile levels, and a good estimate can be made of the entire statistical distribution. This measurement technique was found to be quite successful, although a few precautions had to be observed to avoid biasing the data. Analysis of the data was greatly facilitated by programming a Monroe type 1766 electronic calculator to compute the mean and variance of the recorded levels, and also to compute the projected total daily noise exposure according to the formula used in existing Federal regulations.*

Tape Recordings: All tape recordings were made by connecting the signal output from a sound level meter to the input of the Nagra tape recorder. The sound level meter was set to "Linear" response. Tape speeds of 15, 7-1/2, and 3-3/4 inches-per-second were used, depending upon the noise spectrum and the duration desired for the recording. The duration of most recordings ranged from 10 to 60 minutes, depending upon the nature of the noise source. In many cases tape recordings were made simultaneously with other field measurements. Tape recordings were used (a) to obtain octave and third-octave band spectra; (b) to obtain probability distributions of dBA level; (c) to provide a record of the repetition rate of impact sounds; (d) to obtain plots of dBA level vs. time for time-study analyses; and (e) to provide a cross check with field measurements.

Statistical Distribution Analysis: The Bruel-Kjaer (B&K) type 4420 Distribution Analyzer, in conjunction with the type 2305 level recorder, was used to obtain the probability distribution of dBA levels over selected time intervals. Due to the bulk and weight of this equipment, it was not carried into the field. Instead, tape recordings were taken in the field in order to permit analysis in the laboratory.

Analysis for Impact Sounds: Whenever it was apparent that impact sounds were present, measurements of peak-pressure levels were made. If the impacts occurred so rapidly as to blend together, then the noise was regarded as being essentially continuous. The B & K 2204S Impact Meter was the primary instrument used to measure peak pressure levels.

* Occupational Safety and Health Standards. Title 29, Code of Federal Regulations, Section 1910.9 (See Federal Register, Vol. 37, Oct. 18, 1972.)

DETERMINATION OF NOISE EXPOSURE PATTERNS

In order to determine the daily noise exposure for a worker or worker group it was necessary to interview workmen and supervisors to establish the typical workday pattern. In many cases time-study charts were prepared, segmenting the workday into a succession of exposures at specific noise levels and for specified durations.

Discussions with both management and workmen were necessary to determine changes in workmen's noise exposures over the course of many years. Consideration was given to variations in occupational noise conditions due to machinery replacement or relocation and also to changes in work routine and location of workers.

HEARING SURVEY PROCEDURES

EQUIPMENT AND CALIBRATION

All audiometric testing was done in a Rudmose Audiometric Travel Lab Model RA-113. This audiometric van housed an acoustically isolated, sound-deadened chamber in which six persons could be tested simultaneously. The physical layout of the van is shown in Figure 1.

The audiometric test equipment consisted of a Rudmose RA-108 pure tone, air conduction, six-man audiometer which produced test tones at frequencies of 500, 1000, 2000, 3000, 4000, and 6000 Hz, presented first to the left ear and then to the right ear of each listener. The audiometric test sequence provided for 30 seconds of testing at each frequency for each ear. Each test subject, using a button switch, controlled the loudness of the tone so as to oscillate about his threshold level with all such oscillations being traced on individual audiogram cards. Standard procedure included calibration of the audiometer by means of a Bruel-Kjaer artificial ear (Type 4152) and a Bruel-Kjaer precision sound level meter (Type 2203) with octave filter (Type 1613) both before and after a survey. Audiometric frequency checks were performed periodically using a digital frequency counter. Listening tests were performed frequently to detect any miscellaneous audiometer malfunctions.

Test sounds were presented through TDH-39 earphones with MX-41/AR ear cushions enclosed in otocups to eliminate the possibility of masking by ambient noise, although ambient noise levels were within the limits specified in the ANSI S3.1-1960 (R 1971) standard for Background Noise in Audiometer Rooms with the air-conditioning and power generation systems in full operation. (The air-conditioner and electric power generator were always the predominant sources of background noise.) Typical results of an acoustical survey of ambient noise in the audiometric test chamber are shown in Table 1.

HEARING TEST PROCEDURE

The administration of a hearing test began with an instruction session during which each subject was seated at one of the test stations and familiarized with the audiometric procedure. The wording of the instructions varied slightly during the series of surveys; however, the instruction lecture shown below is typical of those used.

> "Take the earphones and black cord off the hook over your seat and hold them in your hands. Different sounds will be heard in the left phone and then in the right phone. Press the switch button (show the switch button) and keep it pressed until the sound fades away. <u>At the instant it disappears</u>, release the switch until you hear the sound again. When the sound reappears, <u>no matter how faint</u>, <u>press the switch and keep it pressed</u> so as to <u>make</u> it fade away again. Do this for all the sounds that you will hear. Are there any questions? (Pause. Ask those wearing glasses or earrings to remove them and those having long hair to pull their hair back behind their ears.) Place the earphones over your ears, being sure that the red earphone is on the right ear and the black one is on the left ear. (Check to make sure that the earphones are correctly placed over the ears.) We will give you a little while to practice, and then if everything is working okay we will go right ahead with the test, which will take about seven minutes. Remember: Whenever you hear the sound press the switch and keep it pressed until the sound fades away. <u>When it disappears</u>, release the switch until you hear it again. When it comes back again, no matter how faint, press the switch and keep it pressed until it fades away."

It should be noted that the test instructor checked each subject's earphones for proper placement and made sure that the ear cushions were adequately sealed against the subject's head. Early during the course of the occupational hearing survey it was decided that a short practice delay should also be given at the beginning of testing in the right ear. The purpose of this delay was to allow time for the audiometer pen to accommodate large differences between the 6000 Hz threshold level just measured in the left ear and the 500 Hz threshold level to be measured in the right ear. This delay was achieved by manual activation of an override switch on the audiometer, and became a part of standard audiometric procedure.

Each noise-exposed subject was tested before the beginning of his work-shift to avoid the possibility of temporary noise-induced hearing loss. Test scheduling usually required subjects to arrive for work 30 to 75 minutes early, depending upon the scheduling sequence for the audiometric test, otoscopic examinations, and individual data questionnaire. Non-noise exposed workers, such as office workers, were tested at any time during the work shift since their pre-test noise exposures were not considered significant enough to produce a temporary threshold shift.

EXCLUSION OF DATA FROM THE SCREENED SAMPLE

For a variety of reasons it was necessary to exclude some of the noise and hearing data from the analysis so that a valid statistical relationship could be developed relating hearing loss and occupational exposure to noise at known levels. The two basic criteria for data exclusion were: (a) uncertainty as to noise exposure history or validity of audiograms and (b) evidence that hearing loss might have been caused by some factor other than occupational noise exposure. The term "exclusion" will be used to indicate deletion of a worker's test data from the analysis.

The questionnaire form presented in the appendix* was administered to each subject who was given a hearing test. The following text summarizes the evaluation procedure used to develop a "screened sample" for each of the occupational noise and hearing surveys.

1. Data were excluded from the screened sample if a subject's previous job history included two or more years of other work assignments in a noisy job.

2. A military history for each subject was obtained to include number of years in the service, number of years in combat, type of job performed, and weapon firing history. Exclusions were based upon: (a) exposure to weapons-type noise for 100 days or more, (b) one or more years of actual combat experience, and (c) routine daily exposure to non-weapon type noise, e.g., noise from aircraft engines or armored vehicles for two years or more. However, those few workers who wore ear protection in such noise fields were not necessarily eliminated in the screening process.

3. Consideration was given to non-occupational noise exposure, including the extent of civilian firearms use and the frequency and duration of participation in such activities as motorbike riding, mechanized farming, piloting an airplane, machine workshop activity, and sport car or drag racing. Firearm shooters exposed to 1000 rounds per year for one or more

* The questionnaire form was revised during the course of the study. The revision was for the purpose of speeding up the questionnaire routine and did not significantly alter the content.

years or 500 rounds per year for five or more years with no use of ear protectors were also excluded. Any subject who participated in a noisy off-job hobby (e.g., rock music) besides shooting was excluded if this participation was at least three times per week for one year or more.

4. Exclusion from the screened sample was made if there was a history of severe head trauma, chronic ear infection, or evidence of hereditary deafness in the family. Exclusions were also predicated upon certain other conditions, e.g., Meniere's disease; use of ototoxic drugs; history of previous ear surgery; concurrent severe head colds; or tinnitus at the time of testing.

5. An otoscopic examination of the aural canal and eardrum was made by a staff physician or trained audiologist to determine the presence of visible abnormalities. Any indication of congenital or acquired ear malformations, almost total occlusion of the ear canal by cerumen, perforated or severely scarred tympanic membrane, or active ear involvement, e.g., otitis media, were grounds for exclusion of subject data from the screened sample.

6. If the subject had not been out of the working environment for 14 hours or more or if he had significant noise exposure prior to taking the audiometric test, he was excluded.

7. Exclusions based on audiometric irregularities included: (a) audiograms revealing as much or greater low frequency hearing loss as high frequency loss (suspected conductive loss) in one or both ears; (b) hearing losses in one ear which were 40 dB greater than in the other ear at two or more test frequencies; or (c) suspected subject response to tinnitus rather than the tone presentation.

Whenever it was determined that one of the above criteria applied, the worker was assigned an appropriate exclusion code. No more than three exclusions were coded for any single worker. Table 2 lists exclusion categories used in coding, and also lists the number of workers who "failed" the criteria for each category, expressed as a percentage of the total number of subjects (3699). Also listed is the percentage of workers who failed at least one of the criteria (listed as "All categories").

The exclusion criteria discussed above were used to develop screened samples of data sufficient to estimate the impact of industrial noise exposures upon the occupational groups included in the individual noise and hearing surveys. However, for the <u>composite</u> occupational noise and hearing survey (ONHS) analysis, which sought to accurately determine the risk to hearing as a function of noise level, additional exclusion criteria were applied. In particular, hearing level data were excluded for workers for whom there was insufficient noise exposure data. Workers exposed to noise consisting of discrete impact sounds, or noise having highly variable and unpredictable levels, were not included in the composite analysis. All maintenance workers were excluded because it was impossible to quantify their noise exposures. Furthermore, only male workers were used in the composite analysis. The consensus expressed by recent literature indicates that statistical differences exist between the prevalence of hearing loss found in male and female populations. For this reason hearing data for males and females were separated for purposes of statistical analysis. Subsequently it was decided that the sample of female noise-exposed workers was too small (110 were available for composite analysis) to permit valid conclusions concerning the relationship between noise level and hearing loss.

EXTENT OF STUDY

Population totals used in the composite occupational noise and hearing survey (ONHS) study are presented in Table 3. The individual survey totals, however, do not include those individuals who were rejected from the sample because of an incomplete questionnaire; an apparent misunderstanding of the procedure of the hearing test; or mechanical failure of the audiometer. From the total of 3699 subjects, 65% were included in the screened samples; and 23% (or 49% of the screened sample) were included in the composite ONHS analysis.

Table 4 contains summary abstracts of the individual noise and hearing surveys conducted during the years 1968-1972. This table includes a tabulation of numbers of tested subjects, classified by job or department, and also lists the numbers of subjects utilized in the composite ONHS study. The numbers listed under the heading, "Number in Screened Group" indicate those workers surviving the screening criteria. Also included are the median dBA levels for the various job groups used in the composite data analysis. Typical octave band spectra are shown in Figures 2 and 3.

HEARING LEVELS OF NON-NOISE EXPOSED PERSONS

In order to use the hearing level statistics of the non-noise exposed persons as baseline statistics for comparison with the noise exposed populations, a mathematical model was developed to generate "non-noise exposed" hearing level statistics for a population having any specified distribution of ages.

Figures 4-8 show a comparison of the model with raw data. The figures illustrate centile distributions of the male, non-noise exposed, raw hearing level data split into five age groups. (This splitting was performed so that each age group contained the same number of workers.) These figures also show centile distributions generated by the mathematical model, based on the actual distributions of ages within each age group. The data generated by the model are termed "Smoothed Data" in the figures.

At the 10%, 25%, and 50% (or median) levels, comparisons of model versus raw data indicate agreement to within 3 dB; at the 75% and 90% levels, agreement is to within 5 dB, except at the 90% level for the 38 to 48 years age group. (A complete presentation of non-noise exposed male and female population statistics will be published in a subsequent report.)

The model was developed after verification of a Gaussian distribution of the logarithm of [hearing level + K], with age as a parameter, where K is a constant which depends upon frequency, i.e., K = K(f) where f is the audiometer test frequency in Hertz. In fact linear regression of log[hearing level + K] on age proved to accurately fit the hearing level data of non-noise exposed workers (i.e., those working in noise levels <80 dBA). For each of the six audiometer frequencies, K was selected to provide homogeneity of the variance of hearing level data about the regression line. Hearing levels were averaged over left and right ears.

The method by which the mathematical model generates "non-noise" hearing level statistics for any sample population of workers is as follows: For each member of the sample population a log-Gaussian probability distribution of hearing level is generated. This distribution, of course, depends upon his age and sex, as well as audiometric frequency, and is derived using the regression line that statistically fits non-noise exposed persons. These distributions are then superimposed to form a single, "mixture distribution" for the entire group. Using this mixture distribution it is possible to derive non-noise statistics of any type, e.g., centile distributions.

All non-noise data presented in this report have been generated by the technique just described. It should be noted that, within the context of this report, "non-noise exposed" does not indicate total lack of exposure to occupational noise, but rather that the noise level was <80 dBA, and thus "not significant" according to most current criteria. Most of the sample was well below this level.

ONHS COMPOSITE ANALYSIS: HEARING LEVEL STATISTICS

HEARING LEVEL DISTRIBUTION GROUPED BY AGE AND dBA

Hearing level distributions for all noise exposed workers included in the occupational noise and hearing survey (ONHS) composite analysis are displayed in Figure 9. Data have been grouped into five age groups and three noise exposure categories classified as 85 dBA (80 to 87 dBA), 90 dBA (88 to 92 dBA), and 95 dBA (93 to 102 dBA). Although it may appear that the 85 dBA and 95 dBA groups include excessively broad ranges of noise levels, in reality only 15% of the 85 dBA group had noise levels of 83 dBA or below, and only 10% of the 95 dBA group had noise levels at 97 dBA or above. The boundaries for the five age groups were selected so as to separate the entire sample of noise-exposed workers into equal blocks. In the figure the solid lines depict median audiograms for the noise-exposed workers. The dashed lines depict median audiograms for comparable non-noise exposed populations. The split "rolling pins" which also appear on the graph are used to indicate the tenth, twenty-fifth, seventy-fifth, and ninetieth percentile points; those on the left side of the data points represent noise-exposed subject data, while those on the right represent non-noise exposed subject data. The mean age, mean exposure (in years), and number of workers are listed for each group. All audiometric data shown are averages of individual right and left ear data. The figure very clearly demonstrates the effect of noise upon hearing, particularly at frequencies of 2000 to 6000 Hz.

(It should be noted that the age and dBA level groupings described in this section were not employed in generating the hearing impairment and risk statistics that were used to support the NIOSH recommended standard for occupational noise exposure.)

COMPARISON OF NIOSH BASELINE DATA WITH OTHER RECENT DATA

Hearing threshold levels of young, non-noise exposed persons may be regarded as benchmark data by which different hearing studies may be compared. Figure 10 illustrates median audiograms obtained during the past few years by several investigators for comparison with non-noise exposed subject data from the NIOSH composite ONHS analysis. The National Physical Laboratory (NPL) data (N = 168; ages 18-25) are reported by Dr. D. W. Robinson in his book, "Hearing and Noise in Industry," 1970. Data from the Eastman Kodak Company (E. K. Co.; N = 6151 for ages 15-24 years) and the National Health Survey (NHS) are discussed in Section III of the NIOSH noise criteria document. The data depicted by Glorig are taken from his report, "Hearing Loss as a Function of Age," 1962. Glorig's screened sample of 74 professional men (mean age = 24.5 years) is presented. Hearing levels at 500 Hz were not given in his article.

The NIOSH data are quite comparable to all the other studies except the NPL study, but even in that single case the curves have the same shape.

CONSEQUENCES OF A 90 dBA STANDARD

Hearing level distributions of "workers exposed to 90 dBA" are presented in Figures 11 to 15. The workers in the ONHS composite study whose daily noise exposure level was in the range 88-92 dBA (N = 222) were separated into five experience categories. The division into experience categories was accomplished as follows: (1) the individual data were placed in ascending order by number of years of job experience, workers with identical numbers of years of experience being additionally sorted into ascending order by age; (2) the resulting set of data was then separated into five contiguous experience groups of equal size; (3) within each of the five groups the data were then placed in ascending order by age, workers with identical ages being additionally sorted into ascending order by experience; (4) each of the five groups was then bisected (at the median age). Thus, ten groups were derived from the original sample. The separation of the worker population into subgroups in this manner was found to be the most efficient method through which the population could be studied in detail without using elaborate smoothing techniques.

Centile distributions of the averaged (left-right) hearing levels of each such group are shown, plotted against hearing level distributions for non-noise exposed workers (generated using the procedure described previously under the heading, "HEARING LEVELS OF NON-NOISE EXPOSED PERSONS"). Inspection of these graphs indicates that the onset of hearing loss resulting from daily exposure to 90 dBA is present after just 2 or 3 years of experience, with noise-induced losses occurring especially at the audiometric frequencies 3000, 4000, and 6000 Hz, increasing with age and experience. These predominantly high frequency noise-induced losses appear to increase until about age 40 and 15-20 years of job experience, at which point additional high frequency losses seem to depend only upon age. However, it is also evident that once the noise-induced components of high frequency loss approach their maximum, significant losses continue to develop at 500, 1000, and 2000 Hz, with losses progressing from the higher to the lower of these frequencies. The curves indicate that one should expect a 15-30 dB noise-induced hearing loss at the higher frequencies (3000, 4000 and 6000 Hz) and 5-15 dB noise-induced hearing loss at the lower frequencies following 15 years of daily exposure to 90 dBA. Within each experience category it is apparent that the hearing level differences between non-noise exposed and noise exposed populations are larger for the older of the two age groups. Remarkably, the "quantity" of noise exposure (i.e., job experience) does not alone determine noise-induced hearing loss; i.e., the effects of noise and presbycusis are apparently not directly additive.

COMPOSITE ONHS ANALYSIS: HEARING IMPAIRMENT

THE 1972 NIOSH RECOMMENDATIONS FOR A NOISE STANDARD

In July 1972 the document, "Criteria for A Recommended Standard. . . Occupational Exposure to Noise"* was published by NIOSH, containing the recommendation that the daily, eight-hour workplace noise limit be reduced to 85 dBA as soon as the Secretary of Labor, in consultation with the Secretary of Health, Education, and Welfare, determines that it is economically feasible to do so.

The NIOSH criteria document was based upon analysis of available literature, consultation with leading authorities on noise exposure control and the effects of noise on hearing, and NIOSH laboratory and field studies. The following sets of available hearing risk data were determined to be appropriate for detailed examination and analysis: (1) the data base used jointly by the American Conference of Governmental Industrial Hygienists, the U. S. Department of Labor, and the Inter-society Committee; (2) that used by the International Organization for Standardization; and (3) that used by the National Physical Laboratory of Great Britain.** The NIOSH occupational noise and hearing survey (ONHS) data described in this report were considered particularly appropriate for inclusion in the data base for the recommended noise standard for the following several reasons:

1. The ONHS data represented a variety of types of occupational noise exposures, requisite to the development of a single comprehensive Federal standard.

2. All ONHS audiometric tests of noise exposed workers were performed prior to the workshift, thus reducing the possibility of contamination by temporary threshold shift.

* See footnote, page iv
** See pages VI-28 through VI-32 and Tables XIV through XVI of the NIOSH criteria document.

3. The ONHS data were screened to eliminate irrelevant factors, and to select only those workers whose occupational noise levels were well known.

4. Noise levels in the ONHS study were concentrated in the crucial range, namely 85-95 dBA.

5. The ONHS study included a large control sample of non-noise exposed workers who were taken from the same work establishments as the noise exposed workers, thus ensuring that the effects of occupational noise could be isolated from possible influences of audiometric test procedure, geographic or cultural differences, and audiometer idiosyncrasies.

6. Raw audiometric data from the ONHS study were available for exhaustive statistical analysis.

HEARING IMPAIRMENT

The criterion that essentially all workers be protected from a significant impairment of their ability to hear and understand speech sounds formed the basis for the protection goal set forth by the NIOSH recommended standard.

Two hearing level indices were utilized as determinants of hearing impairment. The first, termed HLI (1,2,3), was the average of left and right ear audiometric thresholds at 1000, 2000, and 3000 Hz. The second, HLI (.5,1,2), was defined as the average of thresholds at 500, 1000, and 2000 Hz. It was presumed that noise-induced hearing losses were binaural, and that averages taken over both ears would reduce the random error in the analysis without biasing the data. HLI (.5,1,2) utilizes the audiometric frequencies adopted by the American Academy of Ophthalmology and Otolaryngology (AAOO) in 1959 to measure one's ability to hear conversational speech. The other index, HLI (1,2,3), was adopted by NIOSH as the index most highly correlated with ability to discriminate and understand speech, based on investigations currently available in technical journals. In the ONHS composite analysis the first criterion used for existence of a hearing impairment was that HLI (1,2,3) be greater than 25 dB. In order to permit a comparison with other data in the literature a second criterion for hearing impairment was also employed; namely, that HLI (.5,1,2) be greater than 25 dB. It should be noted that the criteria just described define a beginning impairment in hearing ability and do not necessarily imply the presence of extreme impairment in ability to hear speech. A thorough discussion of the basis for these choices of hearing impairment criteria is presented in Section VI of the NIOSH criteria document.

Figures 16 through 19 plot the percentage of workers classified as having hearing impairment, as a function of age, for four noise exposure categories and for both of the hearing impairment criteria just described. The starred data points represent raw data, i.e., they indicate the actual percentages of ONHS workers having hearing impairment. The line graphs and cross-hatched plots represent the hearing impairment statistics presented in Tables XII and XIII of the NIOSH criteria document. Since the NIOSH tables provided a further breakdown of the data into experience groups, it was necessary to use cross-hatched regions here in order to show the range spanned by the tabulated hearing impairment statistics. The hearing impairment statistics tabulated in the NIOSH criteria document were obtained by a statistical smoothing technique which is described on pages VI-26 through VI-28 of that document.

The raw data percentages (starred data points) were obtained in the following manner: the ONHS workers were divided into three dBA level groups as has been described previously under the heading, "ONHS COMPOSITE ANALYSIS: HEARING LEVEL STATISTICS." The non-noise exposed workers were used as a fourth group. Each of these four groups was then segmented into five age groups of equal size, and the percentages of workers having hearing impairment were calculated. Slight inconsistencies in the results of this analysis are evident; however, the basic findings are well in line with the more rigorous analysis presented in the NIOSH criteria document. In fact, the ability of rather sophisticated statistical tools to enhance the basic aspects of data analyses is thus illustrated.

CONCLUSIONS

The relationship between hearing-loss risk and noise level has been roughly defined for employees who work 8 hours a day in relatively simple, or "ordinary" noise environments. The results of the analysis of NIOSH data included in this report and in the NIOSH criteria document generally substantiate the results of other similar investigations. However, the effects of fluctuating levels, "quiet" rest periods, shortened exposures at higher levels, administrative controls, ear protectors, impact or impulsive noise, lengthened exposures, seasonal exposures, high frequency noise, and infrasonic noise cannot be quantified until further research and evaluation are performed. Additional work is also needed to enhance the effectiveness of audiometric monitoring and noise measurement techniques and to develop better indicators and criteria for hearing loss.

Although this report describes only noise and hearing studies which were performed between 1968 and 1972, research of this type constitutes a continuing effort. During fiscal year 1973 an audiometric survey of over 1000 coal miners was conducted by NIOSH, but data analysis has not as yet been completed. Several improvements have already been or are in the process of being implemented in order to improve the quality of the NIOSH data gathering system. Among these are: (1) Acquisition of new audiometric test equipment that is more reliable and more amenable to routine calibration; (2) Development of flexible computer analysis programs; (3) Establishment of more consistent routines for noise level measurement, audiometric calibration, and data coding; and (4) acquisition of improved instrumentation for noise level monitoring and audiometric calibration. Furthermore, NIOSH is seeking external sources of audiometric data, and has already obtained copies of several thousand audiograms. Although there is good reason to believe that it will be possible to obtain more and better data in the near future, there are two factors which may impede progress toward this goal, namely: (1) Reluctance of private industry to become involved in NIOSH noise surveys (because the data might be used later in standards which may be applied and enforced by another agency of the government) may affect the quantity of data becoming available, and (2) In future noise and hearing studies the noise measurements may not accurately reflect the workers' long term noise exposures, due to ear protector usage or noise control efforts to comply with existing Federal regulations.

APPENDIX

Form approved
Budget Bureau No. 68-S68039

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
National Center for Urban and Industrial Health
Occupational Health Program
Cincinnati, Ohio 45202

OCCUPATIONAL NOISE AND HEARING STUDY

ASSURANCE OF CONFIDENTIALITY

The U. S. Public Health Service hereby gives its assurance that your identity and your relationship to any information obtained by reason of your participation in the Occupational Noise and Hearing Study will be kept confidential in accordance with PHS regulations (42 CFR 1.103(a)) and will not otherwise be disclosed except as specifically authorized below. A copy of this regulation will be made available to you upon request.

Jerome H Svore
Director, National Center for
Urban and Industrial Health,
BDPEC: USPHS

CONSENT

I hereby voluntarily agree to participate in the Occupational Noise and Hearing Study which will be conducted by the U. S. Public Health Service. It has been explained to me that in addition to my answering a questionnaire, there will be a routine medical examination of my ears and a standard hearing test. I have been advised that I may withdraw from this study at any time if I so desire.

____
Signature Date

AUTHORIZATION TO RELEASE MEDICAL INFORMATION

I hereby request the U. S. Public Health Service to inform my personal physician should there be any evidence from this study of an active ear disorder.

Dr.______________________________

____
Street

____
City State Zip Code

____
Telephone

____
Signature Date

NCUI-78 (Cin)
(6-68)

Plant Name___________________________
Worker Number_________________________

(Note: Questions 1-7 below are to be completed by staff interviewer anytime before hearing exam).

(1) Name:____

(2) Address:____

(3) Age:_________________________________ (4) Sex:__________________________________

	Job History	Location in Plant	Occupation: Describe kind of work	Dates (Mo.Yr.) From------To	Average Number wks per yr on job	Average Number hrs work per week
a.	Present Job			Present		
b.	Last Job	———				
c.	Previous Job	———				

(6) Military Service:
 (a) Were you in military service? Yes_____ No_____
 (b) What was your unit assignment? (e.g., infantry, armored)____________________
 (c) Did you fire weapons? Yes_____ No_____
 (d) If so, what kinds?____
 (e) For how long?_________________________________
 (f) Were you exposed to weapon noise even if you did not fire them? Yes_____ No____
 (g) If so, for how long?_________________________________
 (h) Were you exposed frequently to noise from aircraft, armored vehicles or large engines? Yes_____ No_____
 (i) If so, for how long?_________________________________

(7) Non-Occupational Noise Exposure:
 (a) Have you used firearms as a civilian? Yes_____ No______
 (b) If so, what kind(s) of weapons?____
 (c) When (e.g., childhood, 10 years ago, currently)?___________________________
 (d) For how many years have you used such weapons?____________________________
 (e) How frequently?_____________________________________
 (f) How many rounds per year?_________________________________
 (g) Do you routinely wear ear protectors when you fire weapons? Yes_______ No_______
 (h) Do you participate in hobbies or other off-job activities that are typically noisy or have loud sounds (e.g., motorbike racing, rock-roll music playing, machine work, etc.)? Yes_______ No_________
 (i) If so, specify?_________________________________
 (j) For how many years have you taken part in this hobby or activity?_______________
 (k) How frequently? (daily, weekly, monthly)___________________________________

NCUI-78 (Cin)
(6-68)

Plant Name______________________
Worker Number____________________

(Note: Questions 8 and 9 below will be completed by staff medical doctor 2-3 days before scheduled hearing test).

(8) Relevant Medical History:
Have you had any of the following:

	Yes	No		Yes	No
(a) Head noises	( )	( )	(e) Running ears	( )	( )
(b) Deafness in family	( )	( )	(f) Earaches	( )	( )
(c) Hearing test	( )	( )	(g) Hearing aid	( )	( )
(d) Treatment by MD for ear trouble	( )	( )	Elaborative Comments______		

(h) Do you think you have normal hearing? Yes_____ No_____

(9) Otologic Check: Normal ( ) Abnormal ( )

(a) Perforation of drum head	R(ight)	L(eft)	Elaborative Comments:______
(b) Drainage from ear	R	L	______
(c) Malformation or growth in ear	R	L	______
(d) Ear occlusion	R	L	______
(e) Ear disease	R	L	______
(f) Other (specify)	R	L	______

(Note: Question 10 below will be completed by audiometrist just before worker takes hearing exam).

(10) Time and Duration of Last Notable Exposure:
(a) What was your most recent exposure to loud noise (specify, e.g., horn, airplane, work place, gunshot, etc.)? ______________
(b) How long ago did this exposure take place?______________(in days)
(c) How long did the exposure last?______________(minutes or hours)

(11) Hearing Level Data:

Pure Tone I

Date:	Tester:	
Time:	Station:	
Freq.	R	L
250		
500		
1000		
1500		
2000		
3000		
4000		
6000		
8000		

Pure Tone II (optional)

Date:	Tester:	
Time:	Station:	
Freq.	R	L
250		
500		
1000		
1500		
2000		
3000		
4000		
6000		
8000		

Speech Reception (Optional)

Date:	Tester:
Time:	Station:
Type of Test:	
Score =	

NCUI-78 (Cin)
(6-68)

TABLE 1

AMBIENT NOISE LEVELS IN AUDIOMETRIC TEST CHAMBER (1-22-71)

STATION	AIR BLOWER	SOUND PRESSURE LEVELS IN dB (re. 0.0002 dynes/cm^2) OCTAVE BAND CENTER FREQUENCY IN HERTZ 500	1000	2000	4000	8000
2	ON	32	31	30	30	30
4	ON	37	30	30	--	--
4	OFF	14	12	10	10	10
MAXIMUM ALLOWABLE SPL (re. ANSI S3.1)		(40)	(40)	(47)	(57)	(67)

TABLE 2

EXCLUSION CATEGORIES

CATEGORY	FACTOR	WORKERS EXCLUDED
Exposure History	Previous Job History	11.9%
	Military Weapon Noise	8.6%
	Military History	4.4%
	Civilian Weapon Noise	3.6%
	Civilian History	1.5%
	Pre-test Noise Exposure	0.9%
Medical History	History of Trauma/Fracture	1.9%
	Recent Middle Ear Infection	2.0%
	Ear Surgery	2.7%
	Tinnitus/Labyrinthine Disorder	2.3%
	Family History	0.7%
Otological Examination	Severe Occlusion	1.4%
	Perforation	0.5%
	Scar Tissue	0.7%
	Calcerous Deposits	0.1%
	Inflamed Drum	0.1%
	Malformation/Growth	0.7%
	Other**	5.0%
All Categories		35.0% *

* The percentage listed here is not equal to the sum of the percentages listed for each individual category, because many of the workers failed more than one of the exclusion criteria.

** "Other" includes miscellaneous factors, e.g., mechanized farming, use of various forms of medication, audiometric irregularities, etc.

TABLE 3

MAKEUP OF COMPOSITE ONHS STUDY

				Subjects in Composite ONHS Study		
			Subjects	Non-Noise Exposed		Noise Exposed
Survey	Company	Subjects Tested	in Screened Sample	Males	Females	Males
I	Steel Fabricating & Processing	605	471	110	19	122
II	Paper-Bag Making	194	158	6	10	17
III	Printing	154	133	31	20	63
IV	Aluminum Fabricating & Processing	138	95	10	13	64
V	Quarry	96	63	3	10	42
VI	Woodworking	308	177	20	11	113
VII	Hydro-Electric Power	340	204	7	3	0
VIII	Steel Fabricating	368	266	32	5	8
IX	Tunnel Patrol	173	121	16	22	48
X	Printing and Engraving	185	100	41	23	29
XI	Printing	800	403	104	70	203
XII	Tunnel Patrol	306	201	--	--	63
XIII	Trucking	32	20	--	--	20
	Totals	3699	2412	380	206	792

Survey I: Steel Fabricating and Processing

Notes: Some of the hearing test subjects worked in areas for which no noise surveys could be performed, and thus were not included in the composite ONHS study. Typical octave band spectra are shown in Figure 2.

TABLE 4

INDIVIDUAL SURVEY DATA

Job (Department)	Number of Subjects Tested	Number in Screened Group	Composite ONHS Study: Number of Subjects	Composite ONHS Study: Median Sound Level (dBA)
Office	180	151	110	<80
Maintenance	86	65		
Open Hearth	30	24	16	82
T & L	9	7		
Shipping	16	11		
Processing	42	37	7	92
			2	93
			6	94
			3	95
Hot Strip Mill	94	75		
Zinc Grip	26	22	1	83
			2	86
			14	88
			3	89
Strip Pickler & Cold Reduction	17	14	4	89
			4	95
Galvanizing	9	7		
Blast Furnace	49	39	38	92
			12	94
Power	19	14	4	88
			1	91
Round House	12	9		
Basic Oxygen	10	9	5	80
Totals	605	490	232	

Survey II: Paper-Bag Making Company

Notes: Workers in bag making are generally exposed to noise from repeated impacts of many cutting knives which produce a steady-state background noise. Typical octave band spectra are shown in Figure 2.

Survey III: Printing Company

Notes: The configuration of the presses and other noise sources was known to have remained unchanged over a period of many years, thus prividing well-controlled, long-term exposures to steady state noise. Typical octave band spectra are shown in Figure 2.

TABLE 4

Continuation (2)

Job (Department)	Number of Subjects Tested	Number in Screened Group	Composite ONHS Study: Number of Subjects	Composite ONHS Study: Median Sound Level (dBA)
Office	18	16	6	<80
Bag & Handle Making	36	27	5	95
Square Bag	19	11	5	92
Handle Insertion	68	58	2	90
			2	80
Shipping & Pkg.	28	24		
Preprinting & Twisting	25	22		
Totals	194	158	23	
Office	49	42	23	< 80
Press	38	35	35	94
Bailing	2	2	2	93
Bindery No. 1	21	19	6	85
Bindery No. 2	8	7	7	86
Maintenance	8	6		
Mailing	17	13	13	81
Composing; Warehouse	11	9	8	< 80
Totals	154	133	94	

Survey IV: Aluminum Fabricating and Processing Plant

Notes: All workers at this location were given audiometric tests. There was very little variation in dBA level and noise spectrum. Typical octave band spectra are shown in Figure 2.

Survey V: Quarry

Notes: Noise levels remained rather constant during the 8-hour day. Typical octave band spectra are shown in Figure 2.

TABLE 4

Continuation (3)

Job (Department)	Number of Subjects Tested	Number in Screened Group	Composite ONHS Study: Number of Subjects	Composite ONHS Study: Median Sound Level (dBA)
Office	33	23	10	< 80
Press Operators	14	9	9	93
Asst. Pressmen	16	10	10	94
Stretchers; Sawyers	35	23	23	93
Dummy Block Men	15	14	14	94
Tailstock	11	8	8	88
Crane Operators & Misc.	14	8		
Totals	138	95	74	
Office	21	13	3	< 80
Burner Op's.	5	3		
Ledgermen	21	13	13	102
Quarry Workers	7	5	5	96
Wire Saw Op's.	11	7	7	81
Saw Shed Workers	14	10	10	98
Shed Workers	10	7	7	94
Maintenance	7	5		
Totals	96	63	45	

Survey VI: Woodworking Company

Notes: Although dBA-slow sound level measurements varied in some areas, statistical analysis indicated high repeatability or median levels. Typical octave band spectra are shown in Figure 2.

Survey VII: Hydroelectric Power Plant

Notes: Unfortunately, because of the highly intermittent nature of the noise and changing locations of the workers, the noise-exposed workers could not be included in the Composite ONHS Study.

TABLE 4

Continuation (4)

Job (Department)	Number of Subjects Tested	Number in Screened Group	Composite ONHS Study: Number of Subjects	Composite ONHS Study: Median Sound Level (dBA)
Office	37	24	13	< 80
Warehouse, Yard, & Kiln Workers	38	23	7	77
Door, Ladder, & Lamination Section	94	49	39	88
Rough & Finish Mill	139	81	74	94
Totals	308	177	148	
Office	60	43	7	< 80
Shift & Ass't. Shift Engineers	16	13		
Unit & Ass't. Unit Op's	36	28		
Auxiliary Operators	11	9		
Laborers	43	15		
Coal Foremen, Conveyor & Heavy Equip't. Operator	20	9		
Electricians	19	6		
Machinist & Instrument Mech's.	40	32		
Boilermakers & Boiler Welders	29	15		
Steam Filters	34	18		
Switchboard Op's.	6	5		
Janitors, Painters, Misc.	26	11		
Totals	340	204	7	

Survey VIII: Steel Fabricating Company

Notes: A very substantial amount of noise survey data was gathered, including many tape recordings. Third-octave band spectrum analyses and dBA-level probability distribution analyses were performed. Additionally, 78 steelworkers were given post exposure audiometric exams to determine the presence of temporary threshold shift. Of all noise-exposed workers tested, only the welders could be included in the composite ONHS study because of the highly intermittent nature of the other noise. Typical octave band spectra for the welders are shown in Figure 3.

Survey IX: Tunnel Patrol

Notes: Patrolmen typically spent 6-7 hours per day in protective booths at various locations inside the tunnel. Typical octave band spectra are shown in Figure 3.

TABLE 4

Continuation (5)

Job (Department)	Number of Subjects Tested	Number in Screened Group	Composite ONHS Study Number of Subjects	Composite ONHS Study Median Sound Level (dBA)
Office	48	37	32	<80
Shear Operators	51	39		
Asst. Shear "	31	21		
Bender "	51	32		
Asst. Bender "	48	35		
Hookers, Loaders, Checkers	43	34		
Welders	9	8	8	88
Supervisors	44	30		
Crane Operators	43	30		
TOTALS	368	371	40	

Office	50	37	16	<80
Tunnel Patrol	61	48	48	86
Toll Collectors	58	34		
Maintenance	4	2		
TOTALS	173	121	64	

Survey X: Printing and Engraving Company

Notes: Most operators of high noise level machinery used this machinery only for short periods during the day, and were not included in the composite ONHS study. Typical octave band spectra are shown in Figure 3.

Survey XI: Printing Company

Notes: Noise survey data gathered from many different locations indicated a very constant, steady-state environment in the press rooms. Typical octave band spectra are shown in Figure 3.

TABLE 4

Continuation (6)

Job (Department)	Number of Subjects Tested	Number in Screened Group	Composite ONHS Study: Number of Subjects	Composite ONHS Study: Median Sound Level (dBA)
Computer Services	20	12	11	<80
Negative Engravers	33	23	8	<80
Photographers	31	17	12	<80
Compositors	13	4	3	<80
Relief Map Makers	18	7	7	<80
Pressmen	42	25	25	90
Shredder Operators	4	3		
Carpenters	8	4		
Relief Model Reproducers	7	1	1	92
Bindery Workers	9	4	3	81
Totals	185	100	70	
Office	281	174	104	<80
Bindery Workers	133	50	37	86
Offset Pressmen	115	39	39	87
Main Press	195	86	86	87
Postal Card Section	4	0		
Carpentry	18	13		
Monocasting	54	41	41	91
Totals	800	403	307	

Survey XII: Tunnel Patrol

Notes: Similar to Survey IX. A large quanity of dBA level probability distribution data was obtained. Typical octave band spectra are shown in Figure 3.

Survey XIII: Trucking Company

Notes: Drivers indicated that they usually traveled 7-9 hours per day. Spaced-sample measurements of in-cab noise levels were made to obtain probability distribution of dBA levels. Typical octave band spectra are shown in Figure 3.

TABLE 4

Continuation (7)

Job (Department)	Number of Subjects Tested	Number in Screened Group	Composite ONHS Study: Number of Subjects	Composite ONHS Study: Median Sound Level (dBA)
Tunnel Patrol	87	63	63	86
Tunnel Patrol & Service Garage Work	38	25		
Office Workers (& mixed jobs)	40	32		
Electricians	1	0		
Toll Collectors	117	64		
Maintenance	23	17		
Totals	286	201	63	
Drivers	32	20	20	89

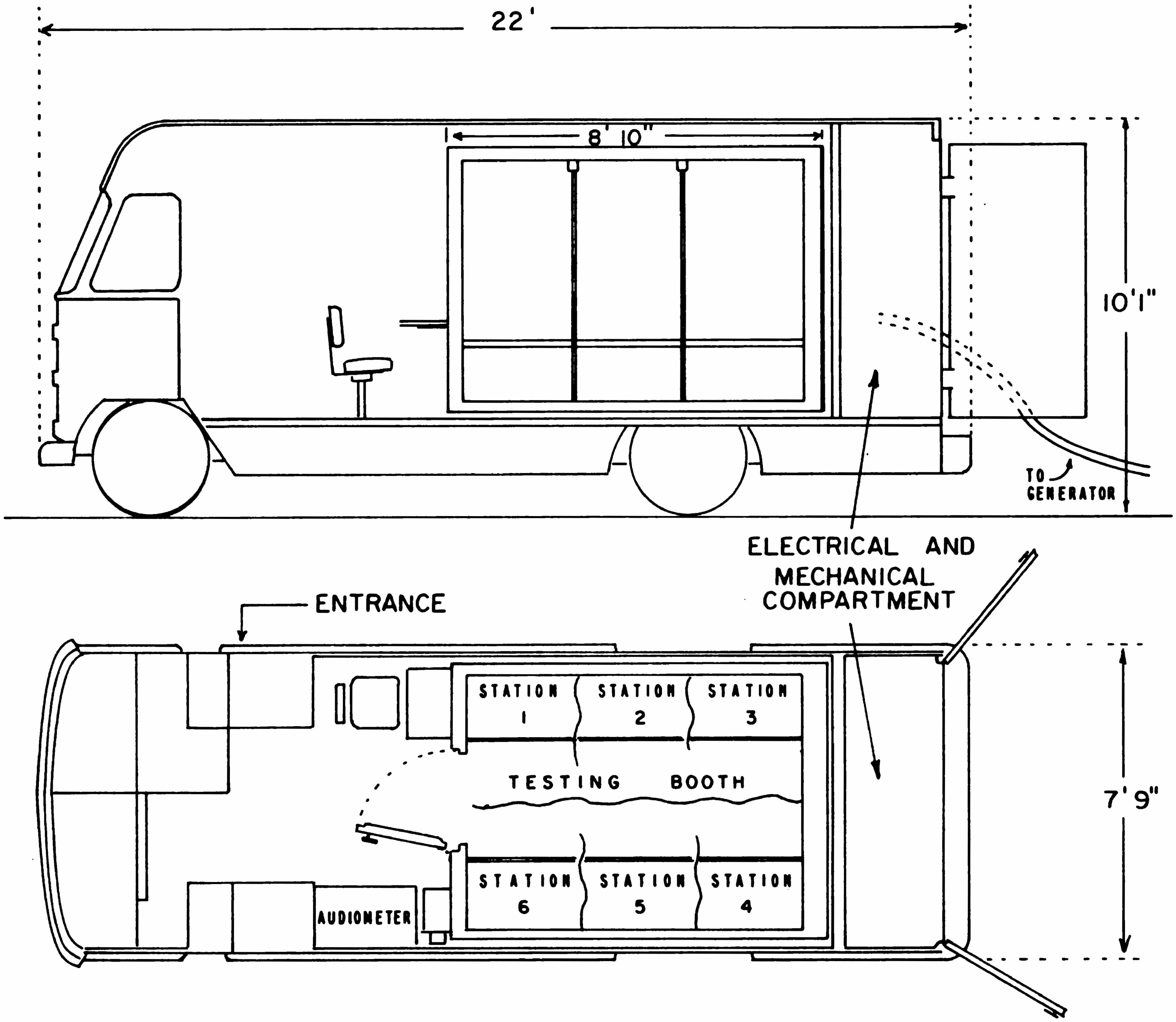


FIGURE 1

AUDIOMETRIC TRAVEL LAB

FIGURE 2

TYPICAL OCTAVE BAND SPECTRA

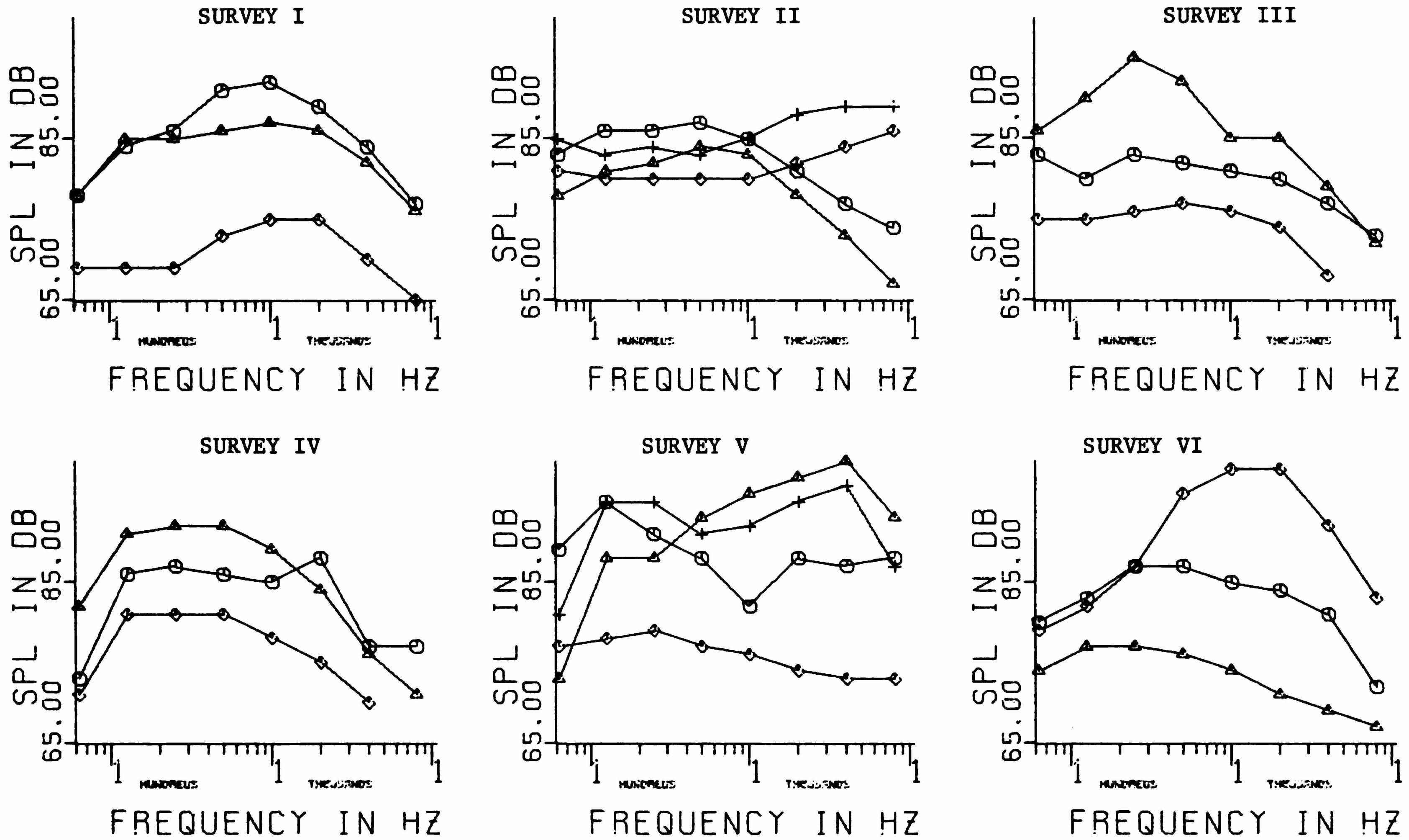


FIGURE 3

TYPICAL OCTAVE BAND SPECTRA

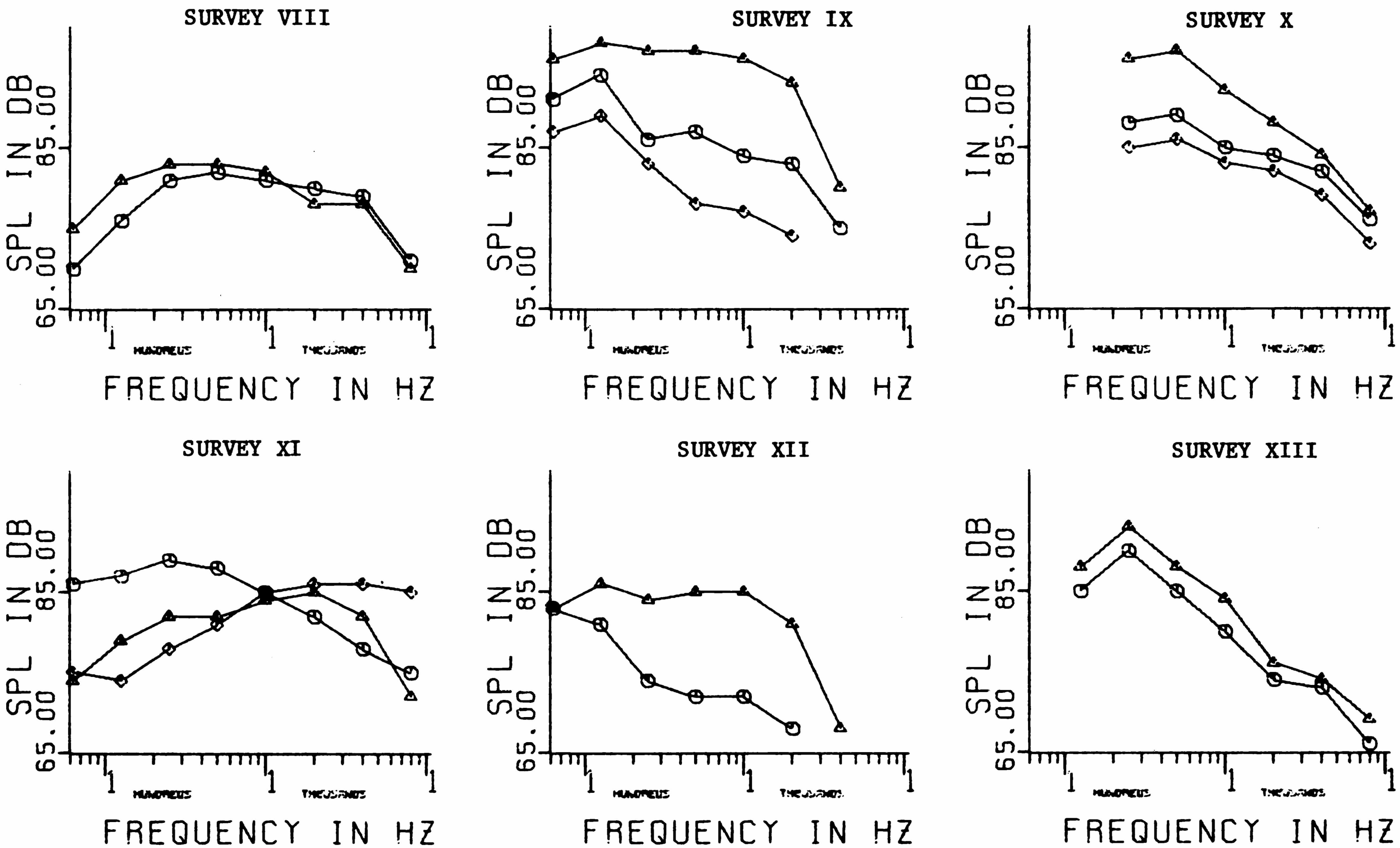


FIGURE 4

ONHS: MALE NON-NOISE EXPOSED WORKERS AGES 17 TO 26 YEARS

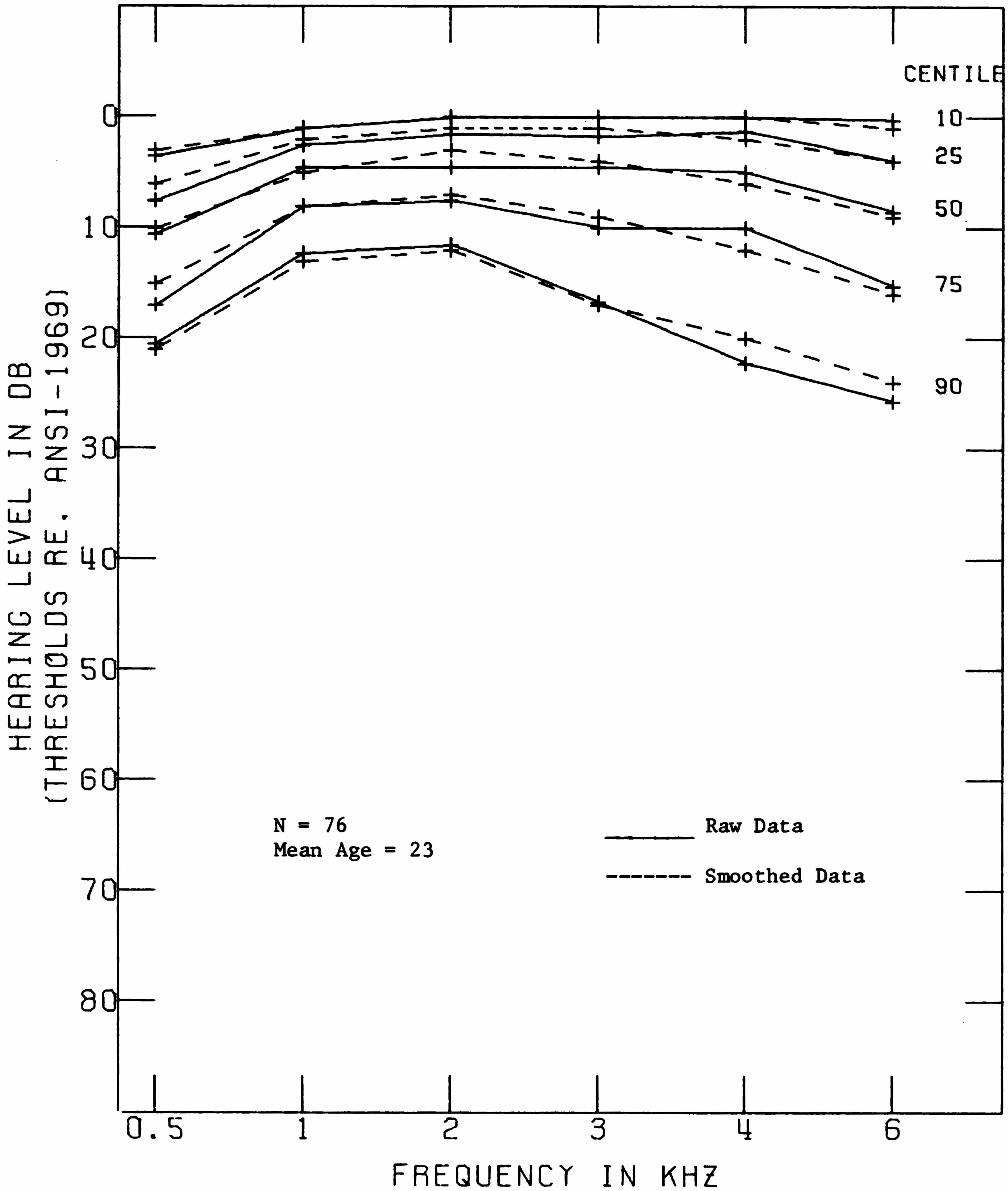


FIGURE 5

ONHS: MALE NON-NOISE EXPOSED WORKERS AGES 26 to 32 YEARS

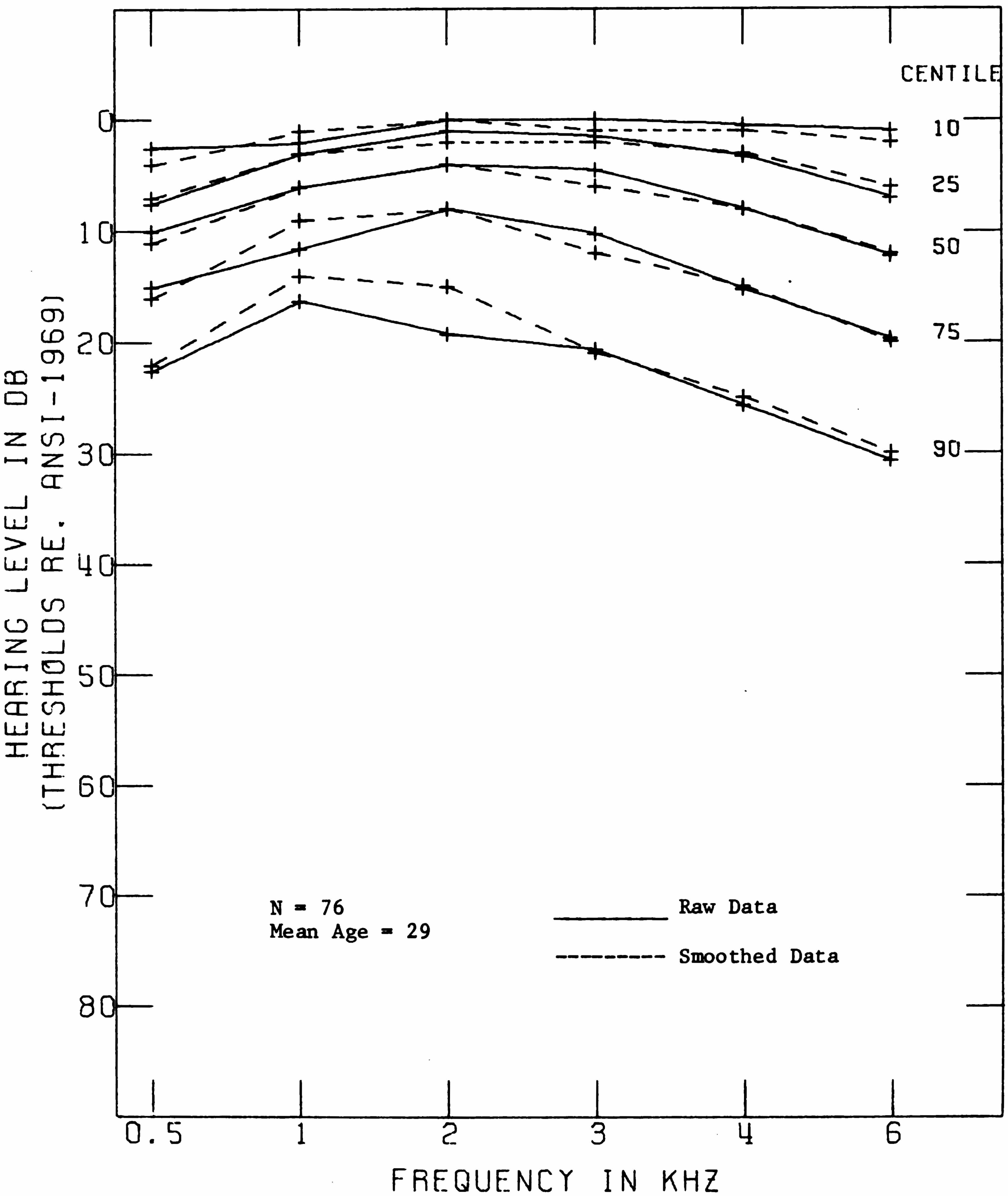


FIGURE 6

ONHS: MALE NON-NOISE EXPOSED WORKERS AGES 32 TO 38 YEARS

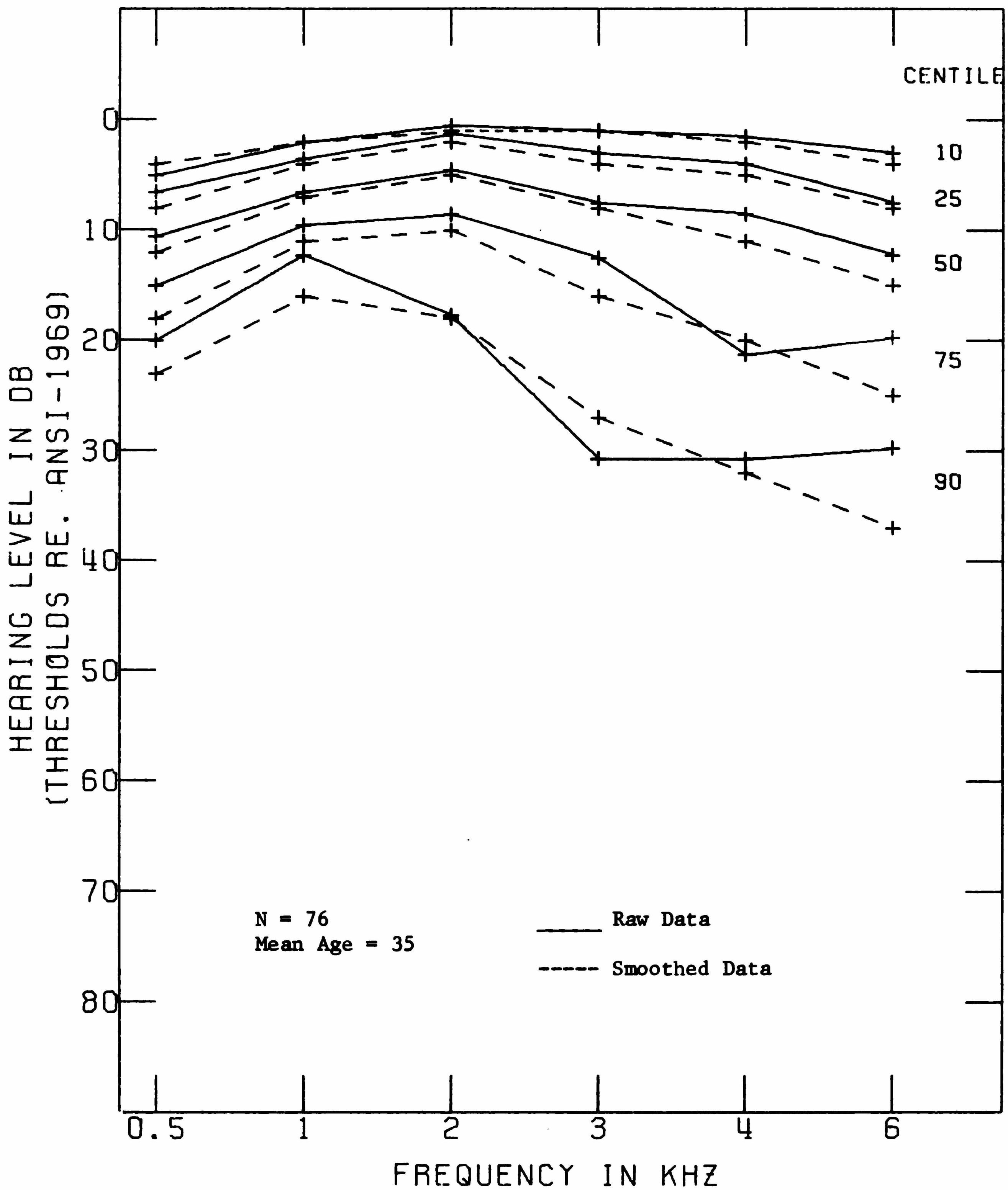


FIGURE 7

ONHS: MALE NON-NOISE EXPOSED WORKERS AGES 38 TO 48 YEARS

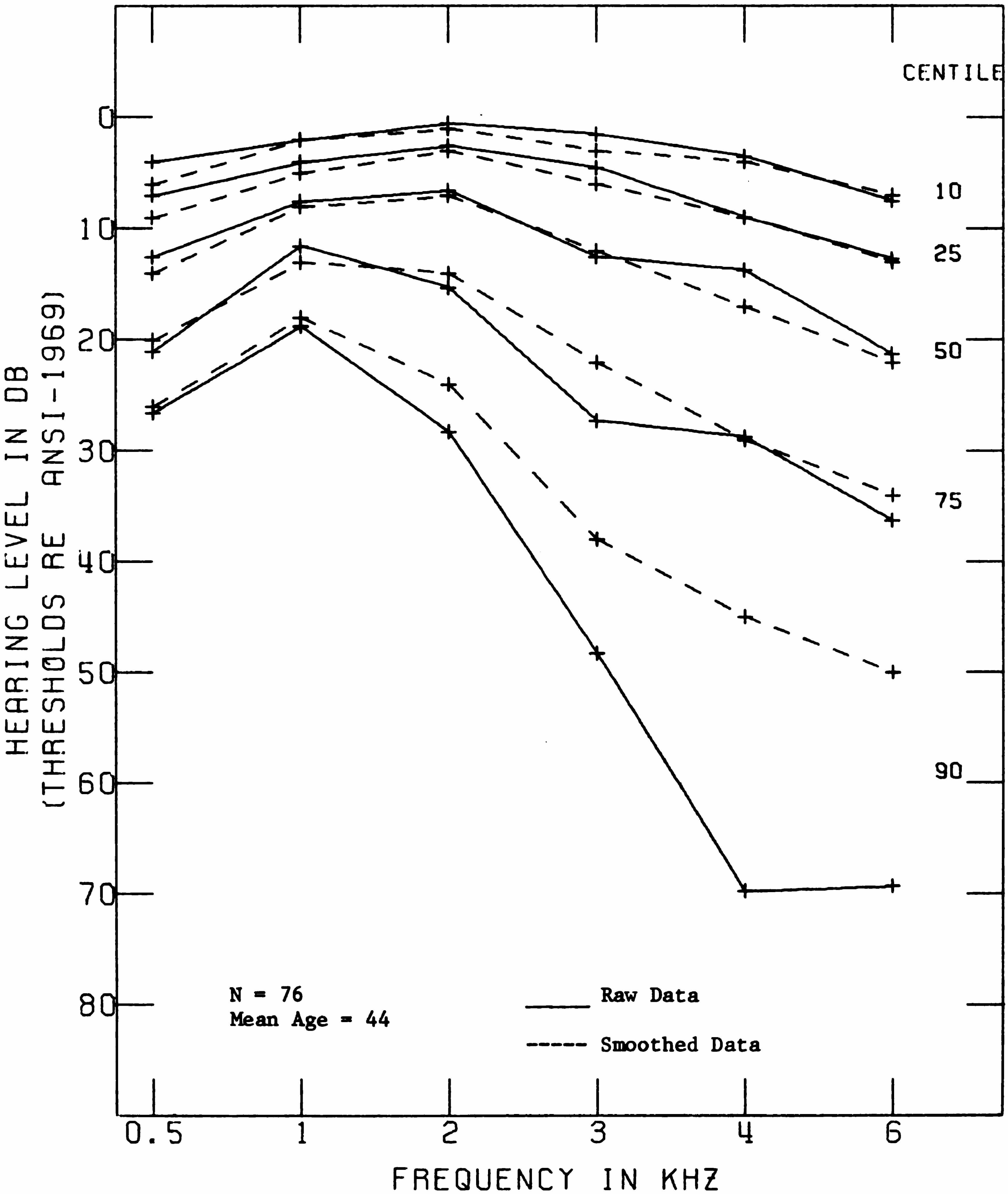


FIGURE 8

<u>ONHS: MALE NON-NOISE EXPOSED WORKERS AGES 48 TO 65 YEARS</u>

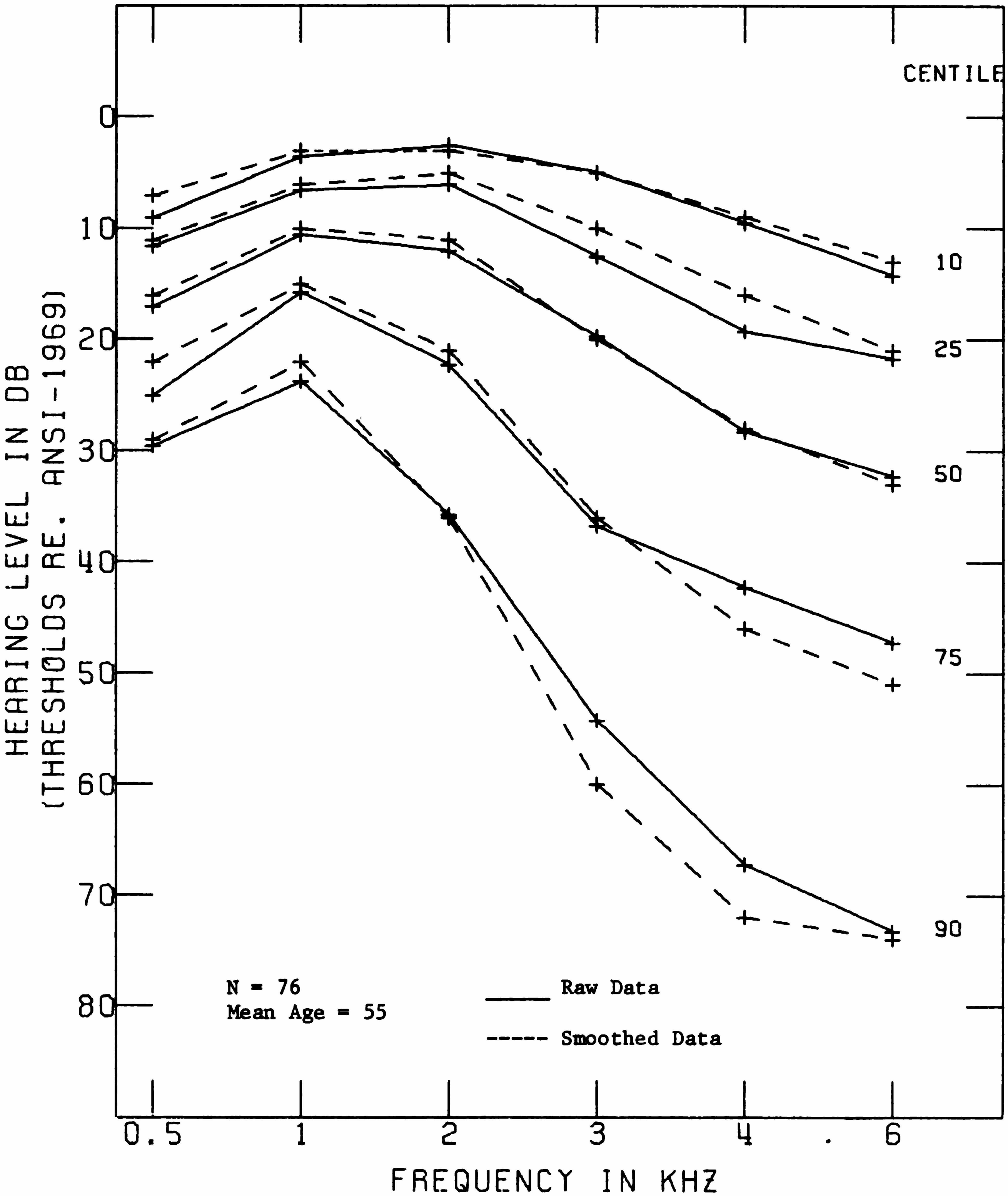


FIGURE 9

ONHS HEARING LEVEL DISTRIBUTION
GROUPED BY AGE AND dBA

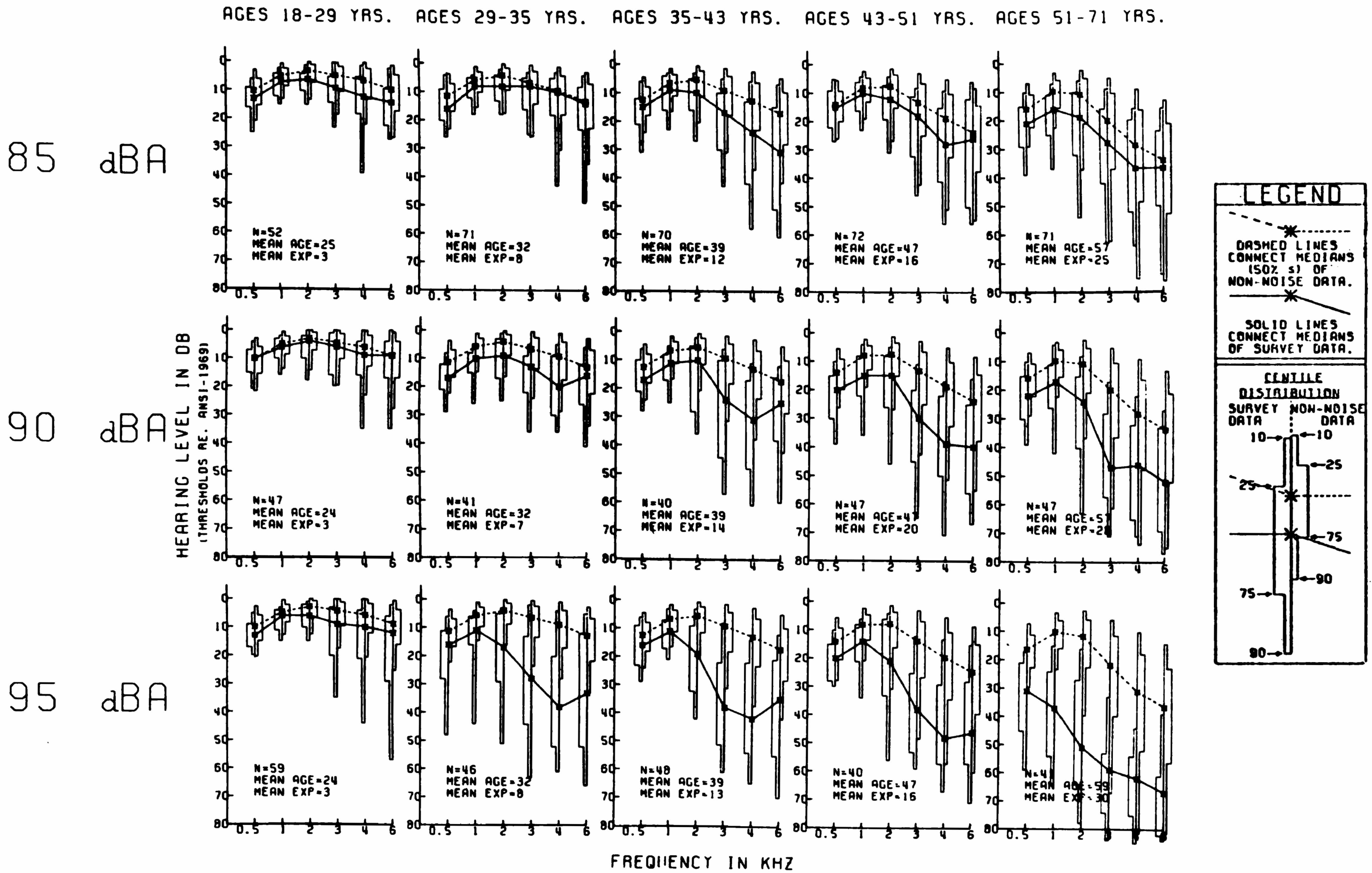


FIGURE 10

MEDIAN HEARING LEVELS OF BASELINE POPULATIONS
AGES 15-24 YEARS

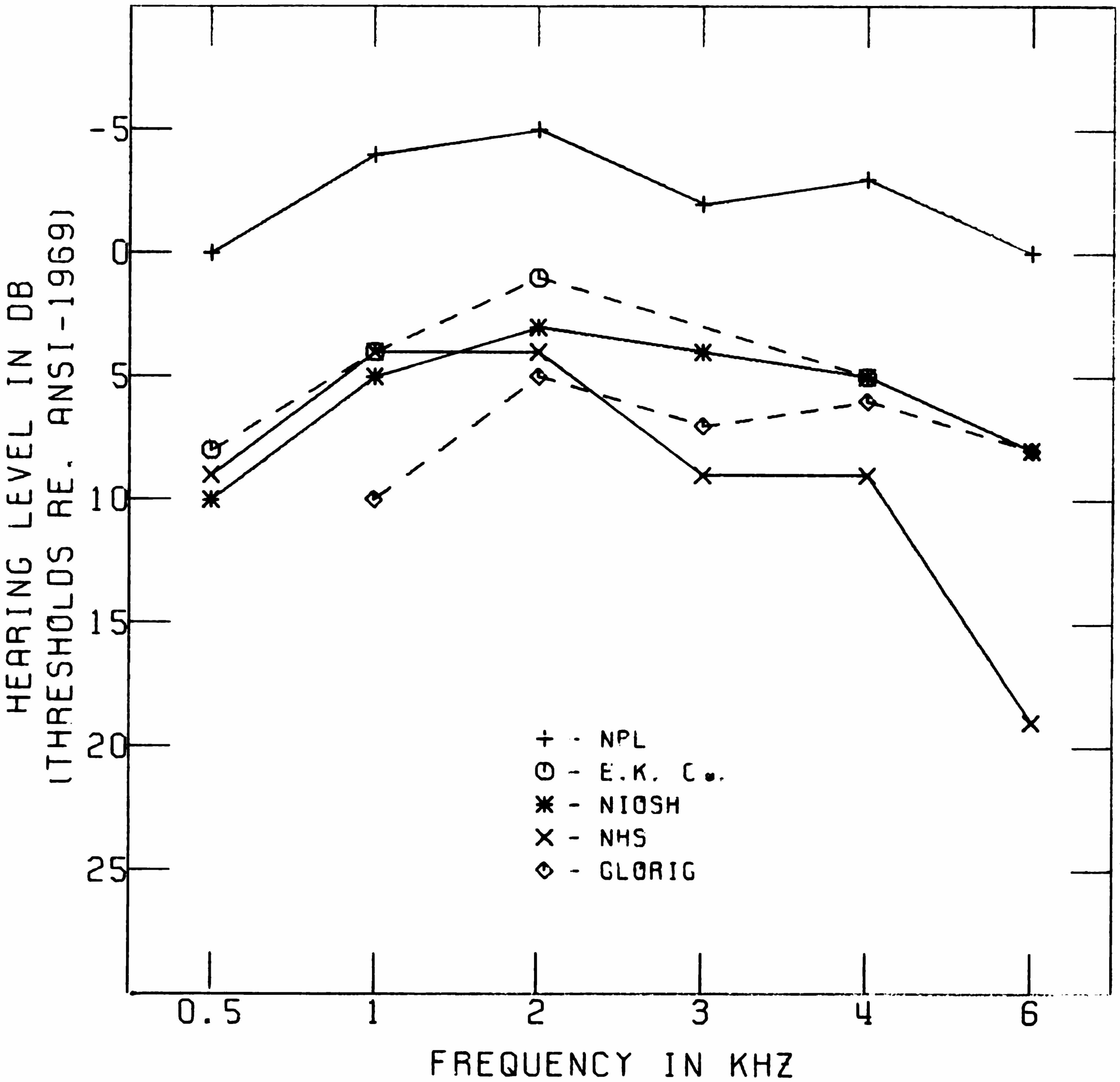


FIGURE 11

ONHS SUMMARY DATA:
Workers Exposed to 90 dBA
for 0 to 4 years

Ages 18 to 25 yrs | Ages 26 to 46 yrs

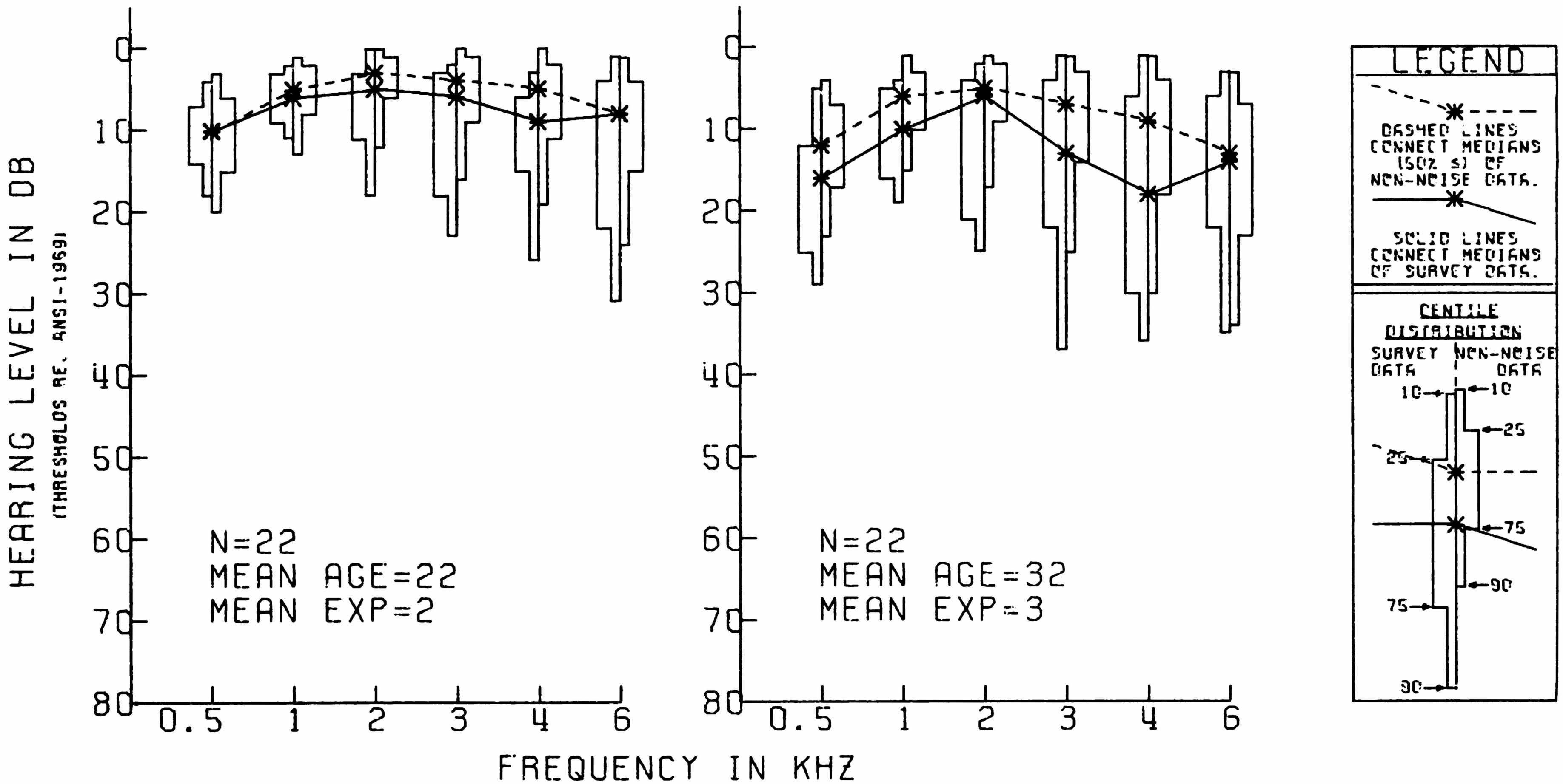


FIGURE 12

ONHS SUMMARY DATA:
Workers Exposed to
90 dBA for 4 to 9 yrs

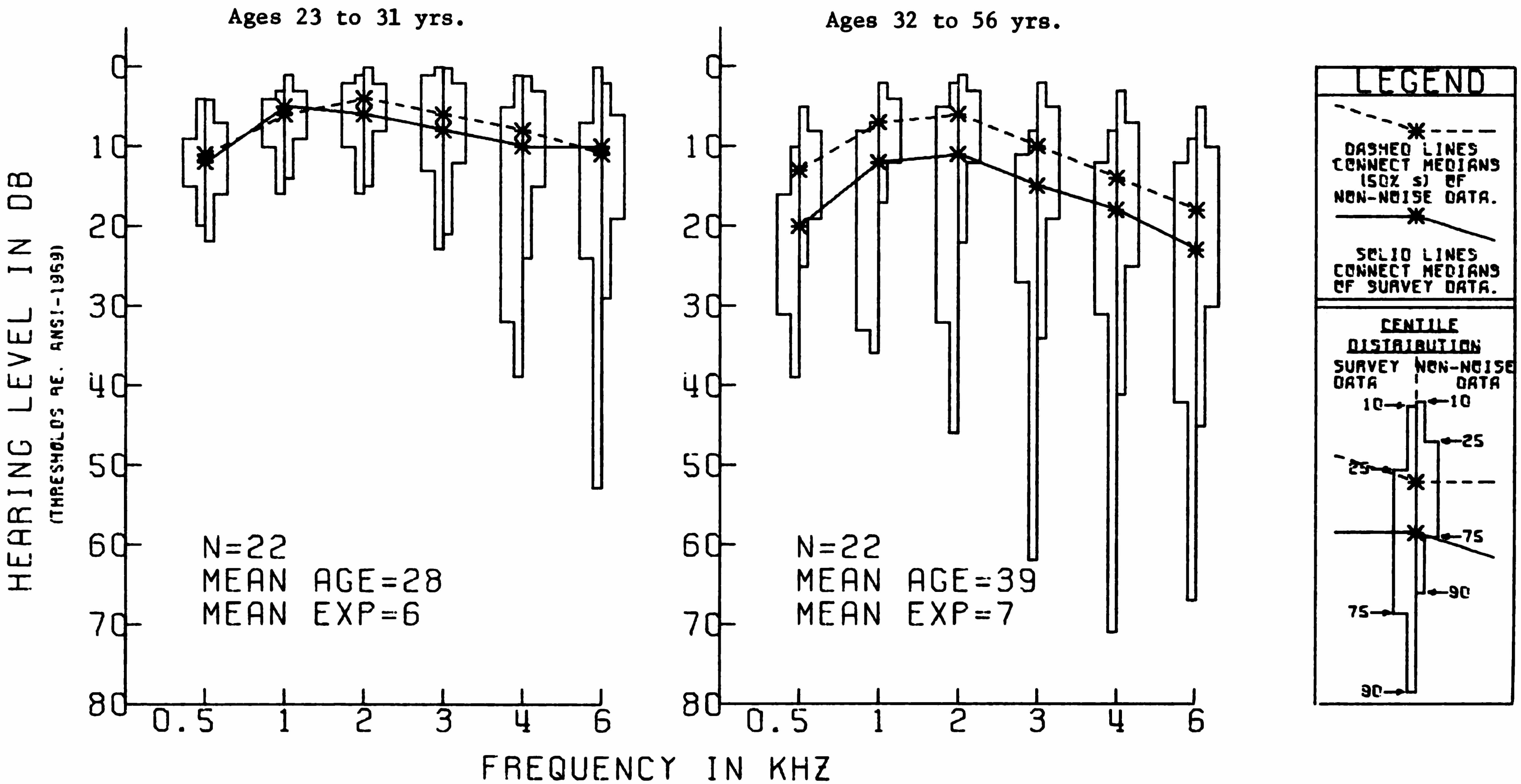


FIGURE 13

ONHS SUMMARY DATA:
Workers Exposed to
90 dBA for 9 to 17 yrs.

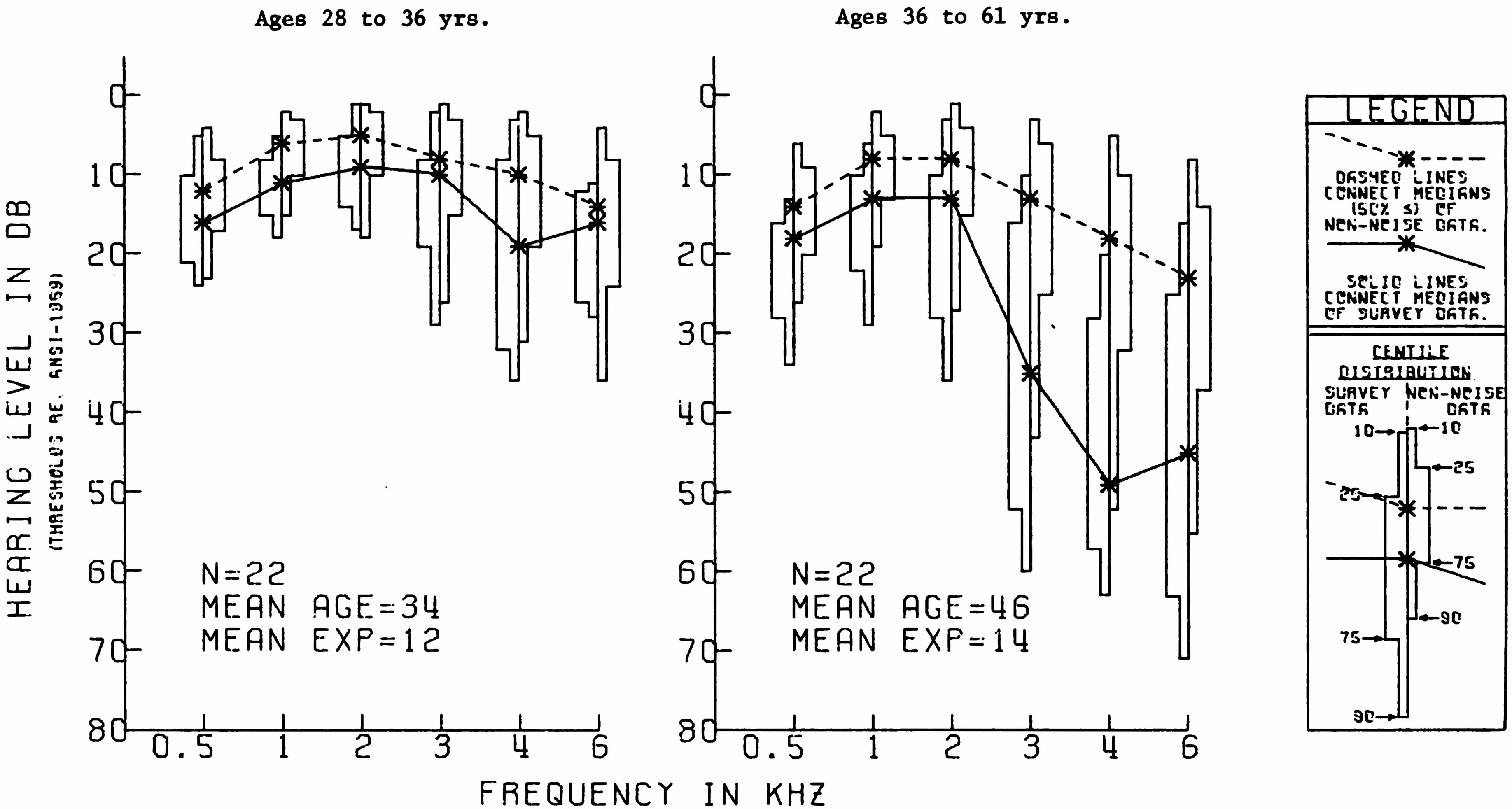


FIGURE 14

ONHS SUMMARY DATA:
Workers Exposed to
90 dBA for 17 to 25 yrs.

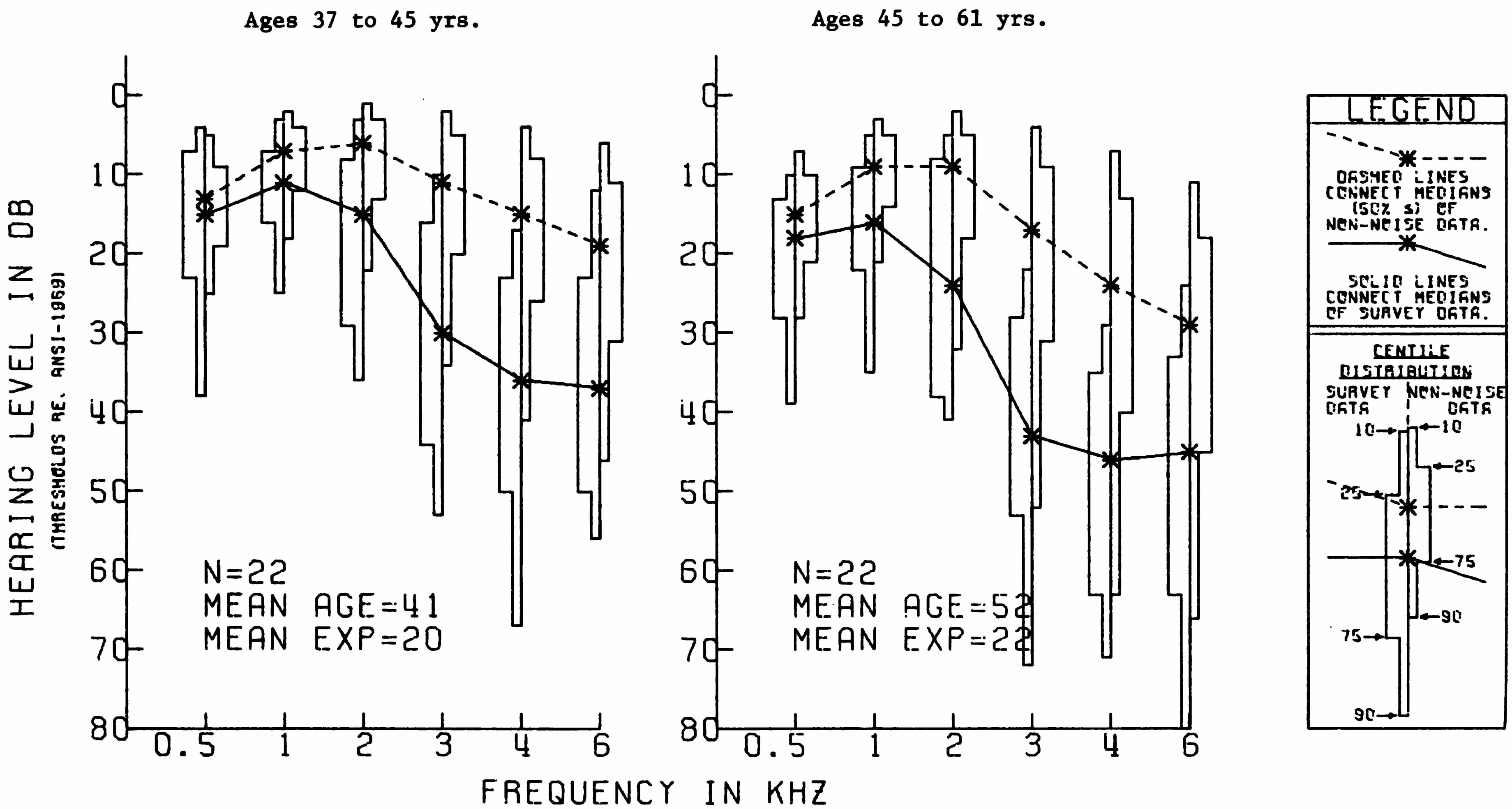


FIGURE 15

ONHS SUMMARY DATA:
Workers Exposed to
90 dBA for 26 to 44 yrs.

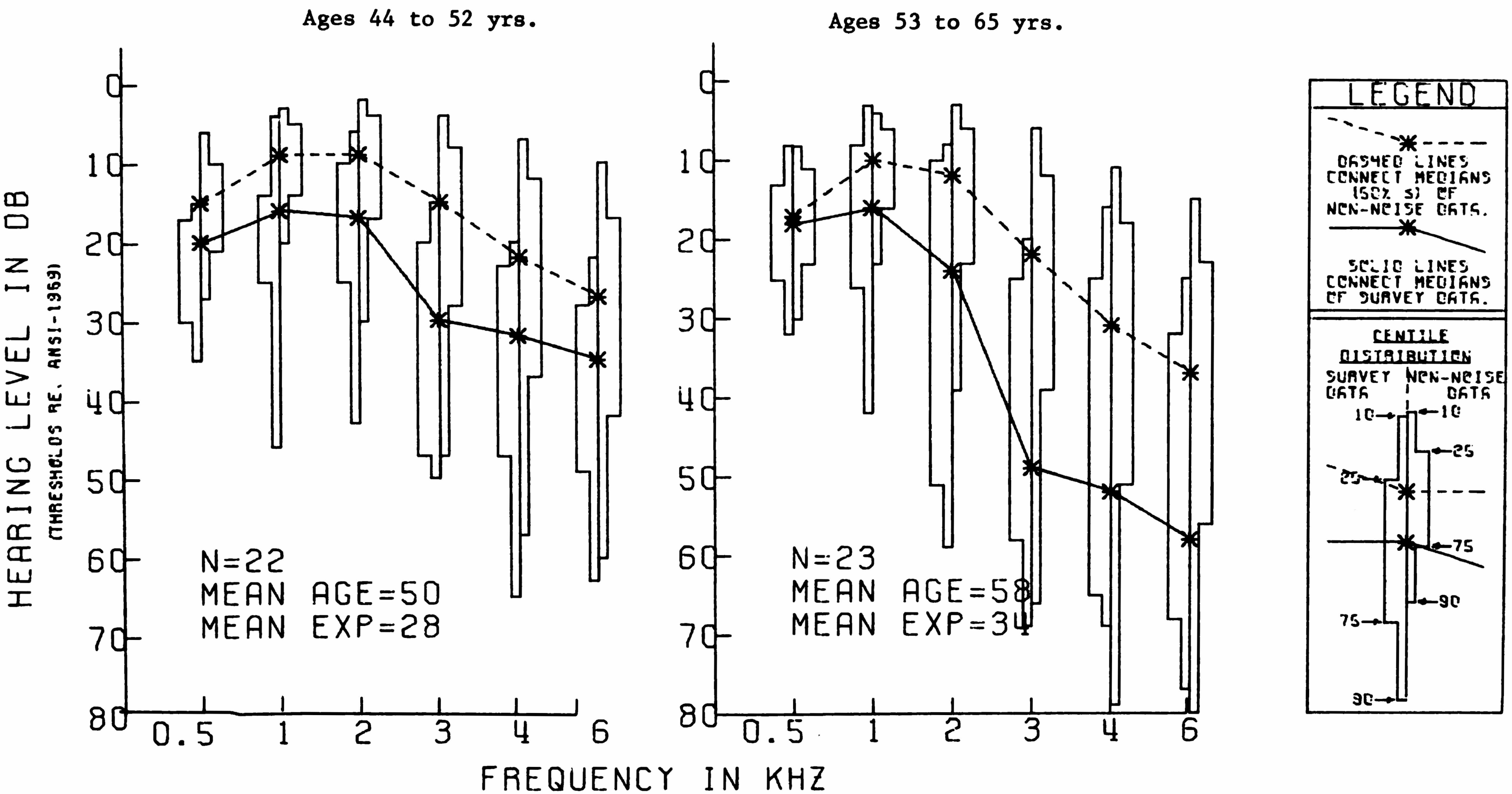


FIGURE 16

PERCENTAGE OF WORKERS HAVING HEARING IMPAIRMENT
USING THE CRITERION HLI (.5,1,2) > 25 dB

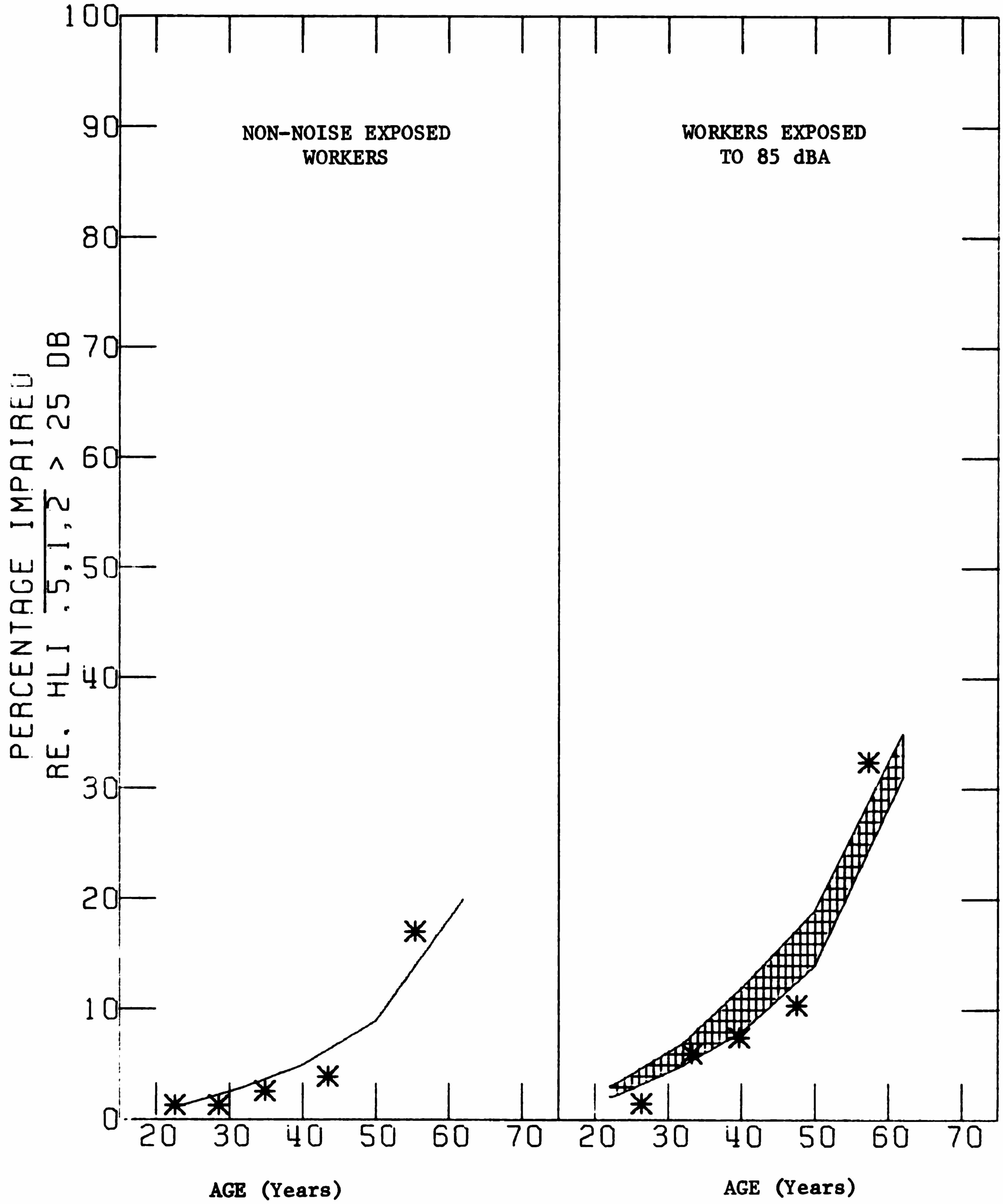


FIGURE 17

PERCENTAGE OF WORKERS HAVING HEARING IMPAIRMENT
USING THE CRITERION HLI $(\overline{.5,1,2}) > 25$ dB

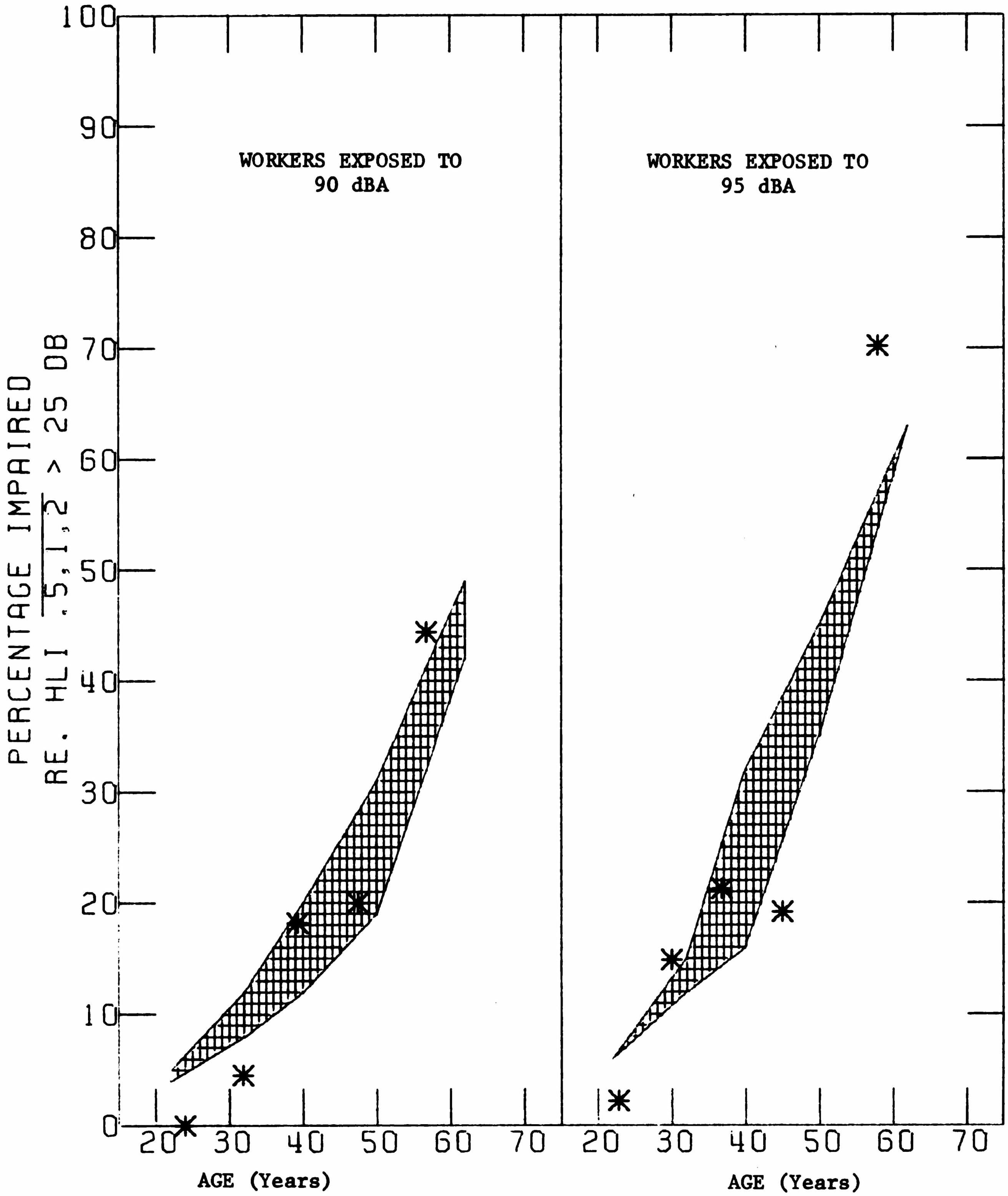


FIGURE 18

PERCENTAGE OF WORKERS HAVING HEARING IMPAIRMENT
USING THE CRITERION HLI $(\overline{1,2,3}) > 25$ dB

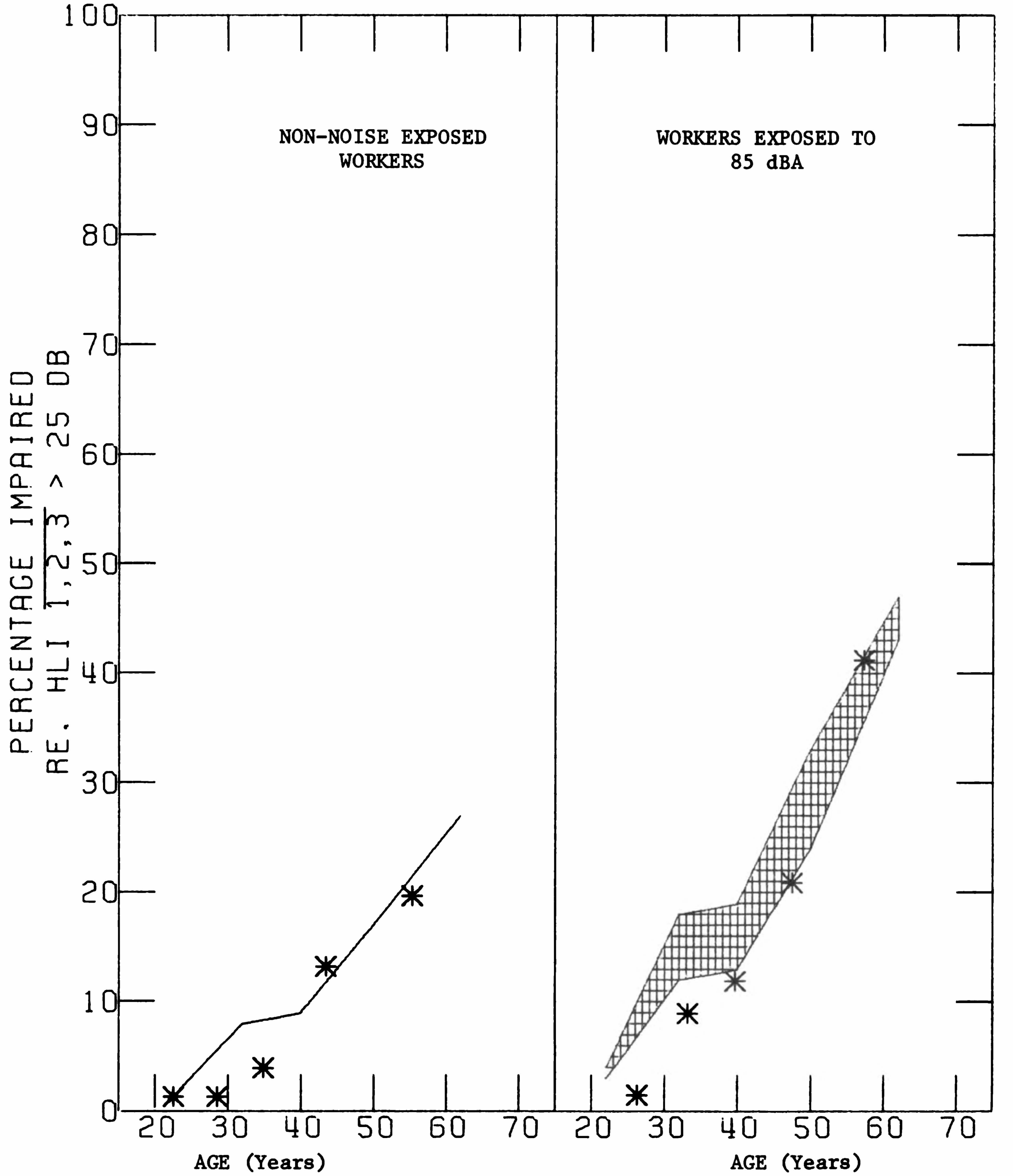
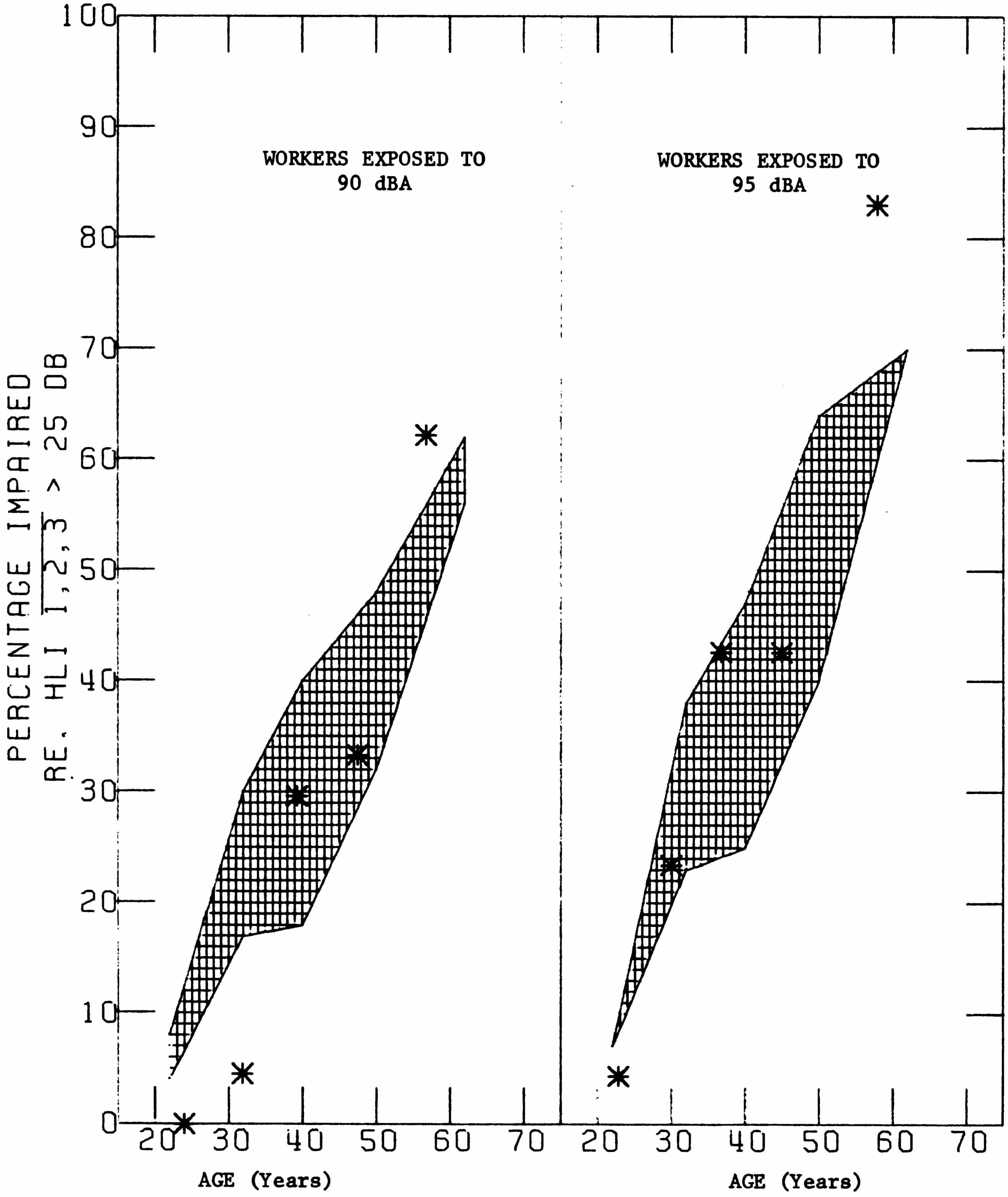


FIGURE 19

PERCENTAGE OF WORKERS HAVING HEARING IMPAIRMENT
USING THE CRITERION HLI $(\overline{1,2,3}) > 25$ dB



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