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INTERNATIONAL ASSOCIATION OF FIRE FIGHTERS  
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NIOSH INVESTIGATOR:  
Randy L. Tubbs, Ph.D.

## I. SUMMARY

The National Institute for Occupational Safety and Health (NIOSH) was contacted by the health and safety department of the International Association of Fire Fighters (IAFF) in 1987 and requested to conduct medical screening tests on the approximately 800 fire fighters who would be attending their convention in Anaheim, California. During October 18-22, 1987, NIOSH conducted audiometric testing on 333 fire fighters attending the Ninth Redmond Symposium on Occupational Health and Hazards of the Fire Service. Pulmonary function tests (PFT) were also conducted on an equal number of fire fighters attending the symposium. The results of the PFT examinations were sent to the individual fire fighters who had participated in the screening, but further population analyses of the PFT data were not conducted, based on a determination by NIOSH medical personnel.

Pure-tone hearing threshold data were obtained from the fire fighters using screening audiometric procedures outlined in the Department of Labor's noise regulation. Of the 333 fire fighters tested at the symposium, 163 (49%) were found to have normal hearing patterns as defined by a single frequency, hearing impairment criterion proposed by Eagles, *et al.*<sup>5</sup> The 170 fire fighters defined as having some degree of hearing loss fell into the mild (79 [46%]) or moderate (46 [27%]) hearing loss categories. The hearing levels in the left ears of the fire fighters were statistically poorer than the hearing levels in the right ears. No statistical relationship was found between hearing loss and time employed as a fire fighter.

This survey did not document an occupational etiology to the hearing loss present in half the participants. However, the study was limited by the self-selection of participants and the audiograms were generally more suggestive of noise-induced hearing loss than presbycusis (hearing loss due to aging). Other research data point to a need for continued medical surveillance of fire fighters' hearing ability with routine audiometric examinations during their careers. Recommendations to establish these surveillance programs for hearing loss, as well as other aspects of a hearing conservation program are presented in Section VII of this report.

**KEYWORDS:** SIC 9224 (Fire departments, including volunteer), hearing loss, hearing conservation programs.

## II. INTRODUCTION AND BACKGROUND

The International Association of Fire Fighters (IAFF) was organized in 1918 to advance and protect the interest of professional (career) fire fighters. The IAFF has over 167,000 members who belong to more than 1,900 affiliated local unions. One activity of the Safety and Health Department of the IAFF is the John P. Redmond Symposium on occupational health and hazards of the fire service, which is convened every other year. Union officers, safety committee representatives, and other interested parties from local unions attend this symposium to learn about current safety and health finding concerning the fire service. At the request of the IAFF, the National Institute for Occupational Safety and Health (NIOSH) offered audiometric examinations and pulmonary function testing (PFT) to the 800 participants at the Ninth Redmond Symposium in Anaheim, California, on October 18-22, 1987. Each individual's results of his or her examination(s) were sent to them with a letter of explanation shortly after the symposium. Further analysis of the group's PFT's was determined to be unjustified by NIOSH medical personnel. Therefore, the remainder of this report deals only with the audiometric test results and the analysis of them.

## III. METHODS

All fire fighters attending the symposium were eligible to participate in the NIOSH audiometric screening program. Each individual was given a voluntary consent form to sign in front of a NIOSH witness prior to being allowed to continue in the testing program. A self-administered questionnaire was also provided to each fire fighter. The questionnaire asked several basic demographic questions concerning the fire fighter's name, age, sex, address, and years of employment.

The audiometric screening tests were administered by NIOSH personnel certified as Occupational Hearing Conservationists by the Council for Accreditation in Occupational Hearing Conservation (CAHOC). Three audiometric testing booths were set up in a meeting room at the symposium's hotel to accommodate the hearing tests of the fire fighters. Audiometric screening was conducted on either two Grason-Stadler Model 1703B Tracking Audiometers or one Tracor RA-400 Microprocessor Audiometer. Pure-tone hearing thresholds were obtained at 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hertz (Hz) separately for each of the fire fighter's ears. The total test time was approximately 7-10 minutes in the audiometric booth following a brief instructional explanation of the hearing test procedures. The project officer offered a brief explanation of the results immediately following the test procedure. All audiometers had been exhaustively calibrated by an authorized audiometer dealer just prior to the symposium, and they underwent daily biological calibration procedures during the test period.

## IV. EVALUATION CRITERIA

The audiometric test results obtained for the fire fighters were combined according to two different criteria to determine the degree of hearing handicap that had been sustained. Additionally, a single-frequency, degree of hearing impairment criterion was used to initially screen the data to determine the amount of hearing loss found in this population. The first criterion was proposed by NIOSH in its criteria document for occupational noise exposure.<sup>1</sup> This criterion, which is intended to determine the amount of handicap in speech perception and communication abilities, averages the hearing level in decibels (dB HL re ANSI S3.6-1969)<sup>2</sup> at the pure-tone frequencies of 1000, 2000, and 3000 Hz for both ears. This measurement will be referred to in this report as the "mid-frequency" variable. The criterion incorporates a 25 dB "low fence" value. This means that the dB HL average value must

exceed 25 dB before a hearing impairment is said to exist. The percentage of impairment is calculated by multiplying each decibel in excess of 25 dB HL by 1.5%. For example, an average dB HL of 40 for the "mid-frequency" variable would represent a 22.5% hearing impairment.

The second variable used in this report has been proposed by the American Academy of Otolaryngology - Head and Neck Surgery.<sup>3</sup> The criterion combines the pure-tone frequencies of 3000, 4000, and 6000 Hz. This combination will be most sensitive to the sensorineural effects on the ear from noise because of the propensity of these frequencies to deteriorate sooner when exposed to loud noises.<sup>4</sup> For this report, the second criterion will be called the "high-frequency" variable.

Finally, a criterion proposed by Eagles, *et al.*<sup>5</sup> for single-frequency hearing impairment determination also uses a low fence of 25 dB HL. With this criterion, any person who had a hearing level of 26 dB HL or greater was classified as having some degree of hearing loss. The degree of loss could range from "mild" (26-40 dB HL) to "profound" (> 90 dB HL). This criterion differs from the other two criteria in that it looks at single test frequencies rather than average hearing levels across several frequencies.

Additional analyses were conducted on the first two criteria after the data had been adjusted for the effects from normal aging processes (presbycusis). In order to do this, the hearing level data were corrected according to the formula described by NIOSH<sup>1</sup> in its criteria document. The formula uses the presbycusis curves for a male population which have been published in the Department of Labor's noise regulation.<sup>6</sup>

## V. RESULTS

Of the 800 symposium participants, 375 (44%) filled out the self-administered questionnaire during the five days of the symposium. Individuals from 35 states and from Canada were included among the people who filled out the questionnaire. Forty of the 375 individuals were omitted from the data analysis because of incomplete or missing audiometric examinations or because they were not fire fighters. Only two females fire fighters participated in the testing, so they were also omitted from the final analyses. The final sample was predominately white, with less than 10% being non-white males. The 333 fire fighters who were included in the data analyses ranged in age from 20 to 65 years, with a mean age of 39 years. Their experiences as fire fighters ranged from less than 1 to 39 years, with a mean of 16 years of service.

A total of 333 male fire fighters completed the audiometric examination and were included in the statistical analyses. The fire fighters' hearing test results were initially compared to the Eagles, *et al.* hearing impairment scale to evaluate the severity of the hearing losses measured in this group. The results of this comparison are given in Table 1. A total of 170 fire fighters, or 51% of the analyzed sample were classified as having some degree of hearing loss in one or both of their ears. Nearly one-half (79 people or 46%) of the group of hearing-impaired fire fighters fell into the "mild" impairment category.

The hearing data were averaged for all fire fighters at each of the seven audiometric test frequencies. The data for each ear are shown in Figure 1. The figure clearly shows a difference between the mean hearing levels in the right and left ears, with the left ear being consistently poorer than the hearing in the right ear. These data were analyzed using paired comparison *t*-tests<sup>7</sup> at each of seven frequencies. All seven *t*-tests showed a significant difference ( $p < 0.05$ ), with the left ear poorer in all cases. Because of this statistical difference

between the two ears, all further analyses were conducted on each of the fire fighters' ears separately.

The audiometric data were categorized into seven groups based on the years of service as a fire fighter. The categories were fire fighters having served (1) less than 5 years, (2) 5-9 years, (3) 10-14 years, (4) 15-19 years, (5) 20-24 years, (6) 25-29 years, or (7) greater than 29 years of fire service. These data are graphically presented in Figures 2 and 3. Two major patterns can be observed in these figures. First, the losses occur predominately in the frequency range above 2000 Hz. Second, the hearing losses generally increase as the age of the fire fighter increases. The 25-29 years group and the greater than 29 years group, however, do not follow this pattern. The amount of hearing loss is reversed for these two groups with the group having less experience showing the greater hearing loss at 2000 Hz and above. These patterns are the same for the left and right ears of the sample.

Age and years of fire service were highly correlated ( $r=0.88$ ,  $p=0.0001$ ). Since hearing loss can be influenced by both aging and the cumulative time of noise exposure, the effects due to aging, or presbycusis, were subtracted from the hearing level scores according to the NIOSH formula.<sup>1</sup> These results after the effects from aging have been eliminated from the data for the seven years of service groups are presented for the left and right ears in Figures 4 and 5.

The audiometric test frequencies do not include 8000 Hz in these figures because presbycusis correction values are not reported for this frequency. Normal hearing on these figures is represented as 0 dB HL. Values less than 0 dB are better than normal, age-corrected hearing. Values greater than zero should be interpreted as hearing decrements that are the results of effects other than aging. Inspection of these figures reveals no consistent pattern of hearing loss as a function of years spent in the fire service. Both the left and right ear groups show a decline in hearing for the 25-29 years of service group. However, the greater than 29 years group has hearing very nearly normal.

Multiple linear regression analyses<sup>7</sup> were conducted on the "mid-frequency" and "high-frequency" variables discussed in the evaluation criteria section of this report. The left and right ear data were also analyzed separately in these statistical tests. In all of the analyses, age was the significant factor in determining the relationship between the hearing data and age or length of fire service. For the mid-frequency variable (1000, 2000, and 3000 Hz), age was significantly related ( $p=0.003$ ) to loss of hearing at these frequencies. A slope of 0.4 dB was calculated in the analyses which can be interpreted as representing a growth of hearing loss of 0.4 dB per year as a result of aging. The high-frequency variable (3000, 4000, and 6000 Hz) was also significantly related to age ( $p=0.0001$ ) in both ears. A slope of 0.9 dB was calculated in this analysis. Years of fire service did not contribute significantly to the hearing data in any analysis.

## VI. DISCUSSION AND CONCLUSIONS

The results of the audiometric testing shows that the fire fighters who took part in the NIOSH survey had high frequency hearing losses that progressively got worse as the years of fire service of the fire fighter increased. The left ears of these fire fighters had poorer hearing than the right ears. The reason for this consistent difference in hearing ability between the two ears cannot be determined from these data. Generally, because noise is ubiquitous in the work place, most occupational noise exposure studies will average the hearing levels for each ear before the data are reported. However, fire fighters can be exposed to directional noise in the vehicles because of the location in the vehicle where they ride. Whether or not this is a consistent finding in fire fighters and paramedics would have to be researched further. The

progression of hearing loss was associated with age in this group of fire fighters and cannot be accounted for by time spent in the fire service.

The audiometric data collected in this hazard evaluation are contrary to data reported in other studies.<sup>8,9,10,11,12</sup> These reports show a progressive loss of hearing for fire fighters and emergency medical personnel that is related to their occupation. This is not the case for the survey participants at the Redmond Symposium in Anaheim, California. The fire fighters at this symposium showed hearing loss which was statistically related to aging. Inspection of Figures 2 and 3, however, do not reveal patterns which are typical of age-related hearing losses. Presbycusis is characterized by high-frequency losses which progressively get worse at higher frequencies.<sup>1</sup> A typical aging curve will not show consistent improvement in hearing as one goes from 6000 Hz to 8000 Hz, as is seen in these figures. This is more typical of noise-induced hearing losses, which have a profile which shows the worst thresholds in the 3000-5000 Hz range, with better thresholds above and below these frequencies.<sup>13</sup>

Although these audiometric data do not suggest that the measured losses are a result of the time spent in the fire service, these fire fighters do exhibit high-frequency hearing losses which are typical in a population which has been exposed to noise. Furthermore, the participants may not be representative of fire fighters generally, since they were self-selected from among participants at a national convention, and this may have accounted for the lack of an association between hearing loss and years in the fire service. Therefore, the recommendation to reduce the amount of noise to which these fire fighters are exposed is still warranted. This recommendation has been incorporated into the language of the National Fire Protection Association's (NFPA) Standard on Fire Department Occupational Safety and Health Program, NFPA 1500.<sup>14</sup> In this standard, maximum noise levels for fire department vehicles and apparatus are stipulated, and the use of hearing protection devices are advocated when these noise levels cannot be met. NFPA 1500 designates that specifications for new fire apparatus should provide maximum sound attenuation so that fire fighters can ride in the vehicles without hearing protection devices. A maximum limit of 85 dB(A) without audible warning devices and 90 dB(A) with warning devices is recommended by the NFPA. The standard also stipulates that fire fighters wear hearing protection devices whenever the noise exceeds 90 dB(A) on vehicles or in the use of power tools or equipment. Regulations have also been promulgated by the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA)<sup>6</sup> for other industries to monitor occupational hearing loss and to help alleviate its progression through noise reduction engineering, hearing protection devices, and worker education. The OSHA regulations need to be followed in the fire service to help to reduce the amount of occupational hearing loss which a fire fighter might accrue. The regulations should be used as guidelines in jurisdictions where state or Federal OSHA regulations are not mandated.

## VII. RECOMMENDATIONS

The possibility of fire fighters having an increase in high-frequency hearing loss as a result of an occupational exposure leads to the following recommendations. These recommendations are based on other research data which has documented excessive noise exposures in the fire service, as well as audiometric data which shows an association between years in the fire service and hearing loss.

1. Implement hearing conservation programs for individual fire departments. These programs can be tailored to meet the requirements of the individual departments, but

should meet the minimum requirements set forth by the U.S. Department of Labor, OSHA.<sup>6</sup>

2. The hearing conservation program should include audiometric testing. Pre-employment physical examinations should include a hearing test which will serve as a baseline audiogram. Additionally, fire fighters should be tested on an annual basis throughout their fire service career. These audiometric data should be evaluated according to recent developments in audiometric data base analysis which will give feedback to the department on the efficiency of their hearing conservation program.<sup>15</sup>
3. The use of hearing protection devices should be mandated for fire fighting operations that exceed a noise level of 90 decibels on an A-weighted scale [dB(A)]. A 90 dB(A) criterion puts this recommendation in line with the NFPA 1500 Standard on Fire Department Occupational Safety and Health Program. The NFPA 1500 specification is favorable over the NIOSH Recommended Exposure Level (REL) of 85 dB(A) because the NIOSH REL is based on an 8-hour time-weighted average rather than instantaneous levels which is more typical of fire service noise exposures. This includes riding on fire vehicles during emergency and non-emergency responses, during training activities, equipment usage, and other fire ground operations. The hearing protection devices should be furnished to the fire fighters by the department in the same manner as other safety and fire fighting equipment is issued.
4. Routine noise surveys should be conducted to document events which have the potential for excessive noise exposures.
5. New vehicle and equipment purchases should include specifications on maximum noise exposure levels to the fire fighters which can be allowed in the operation of this equipment. If at all feasible, a "not to exceed" level of 90 dB(A) should be stipulated to meet NFPA 1500 specifications for vehicles operating with audible warning devices and 85 dB(A) for vehicles operating with no warning devices.<sup>14</sup>
6. Fire fighters should be trained about the effects of noise exposure and hearing loss. They should be encouraged to reduce both occupational and recreational noise to help prevent the occurrence of permanent, noise-induced loss of hearing.

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IX. AUTHORSHIP AND ACKNOWLEDGEMENTS

Report Prepared By: Randy L. Tubbs, Ph.D.  
Senior Research Scientist Officer  
Hazard Evaluation and Technical  
Assistance Branch

Evaluation Assistance: Lynette K. Hartle  
Occupational Hearing Conservationist  
Industrial Hygiene Section

Patricia E. McKinzie  
Occupational Hearing Conservationist  
Hazard Evaluation and  
Technical Assistance Branch

Beverly Dotson  
Occupational Hearing Conservationist  
Office of the Director

Nancy L. Zumwalde  
Occupational Hearing Conservationist  
Office of the Director

Originating Office: Hazard Evaluation and  
Technical Assistance Branch  
Division of Surveillance, Hazard  
Evaluations, and Field Studies

Report Typed By: Linda Morris  
Clerk Typist  
Industrial Hygiene Section

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1. International Association of Fire Fighters
2. NIOSH Boston Office



Table 1

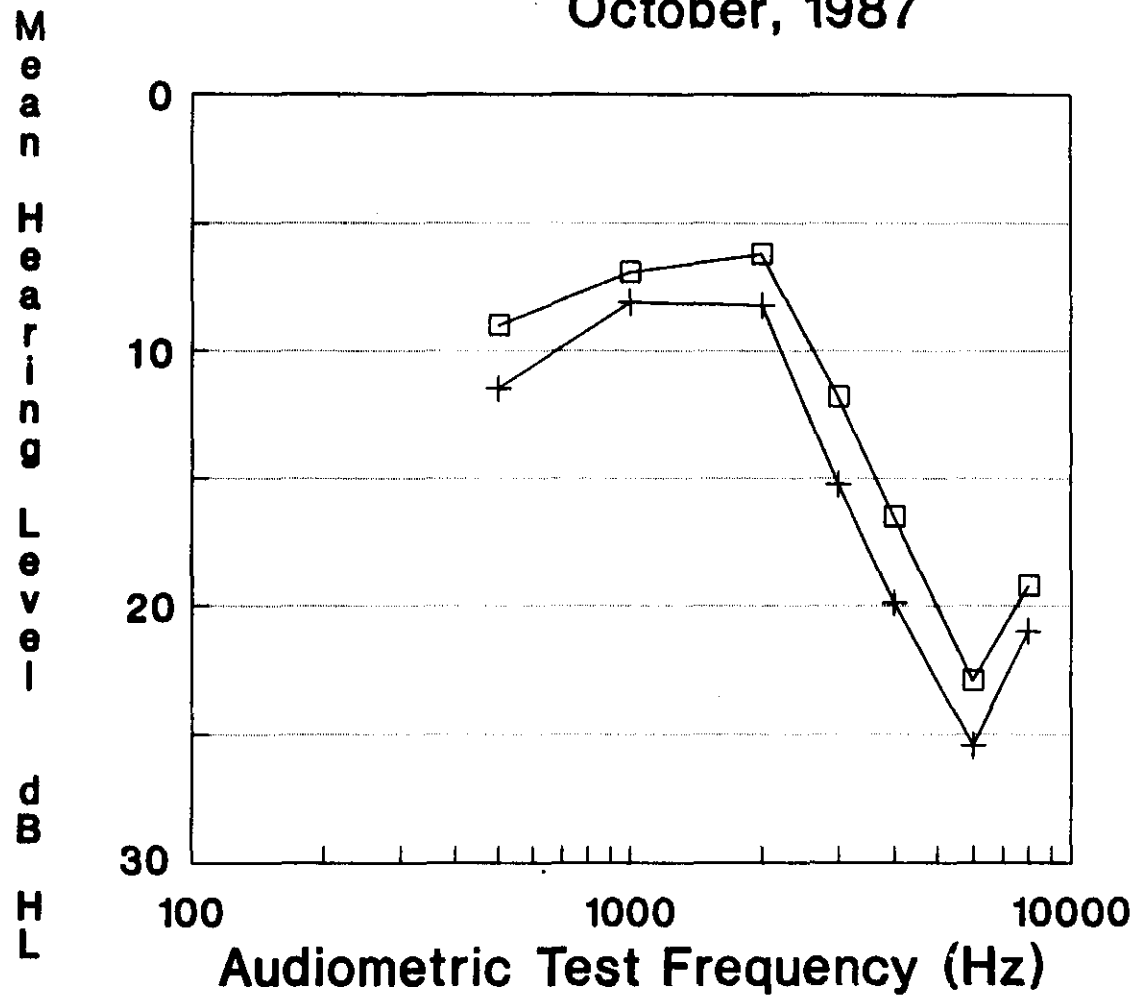
Number of Fire Fighters in Each Hearing Impairment Category

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International Association of Fire Fighters  
Anaheim, California  
October 18-22, 1987

Impairment Category	Number of Fire Fighters	Hearing Level Range
NORMAL	163	0 - 25 dB HL
MILD	79	26 - 40 dB HL
MODERATE	46	41 - 55 dB HL
MODERATELY SEVERE	25	56 - 70 dB HL
SEVERE	12	71 - 90 dB HL
PROFOUND	8	Over 90 dB HL

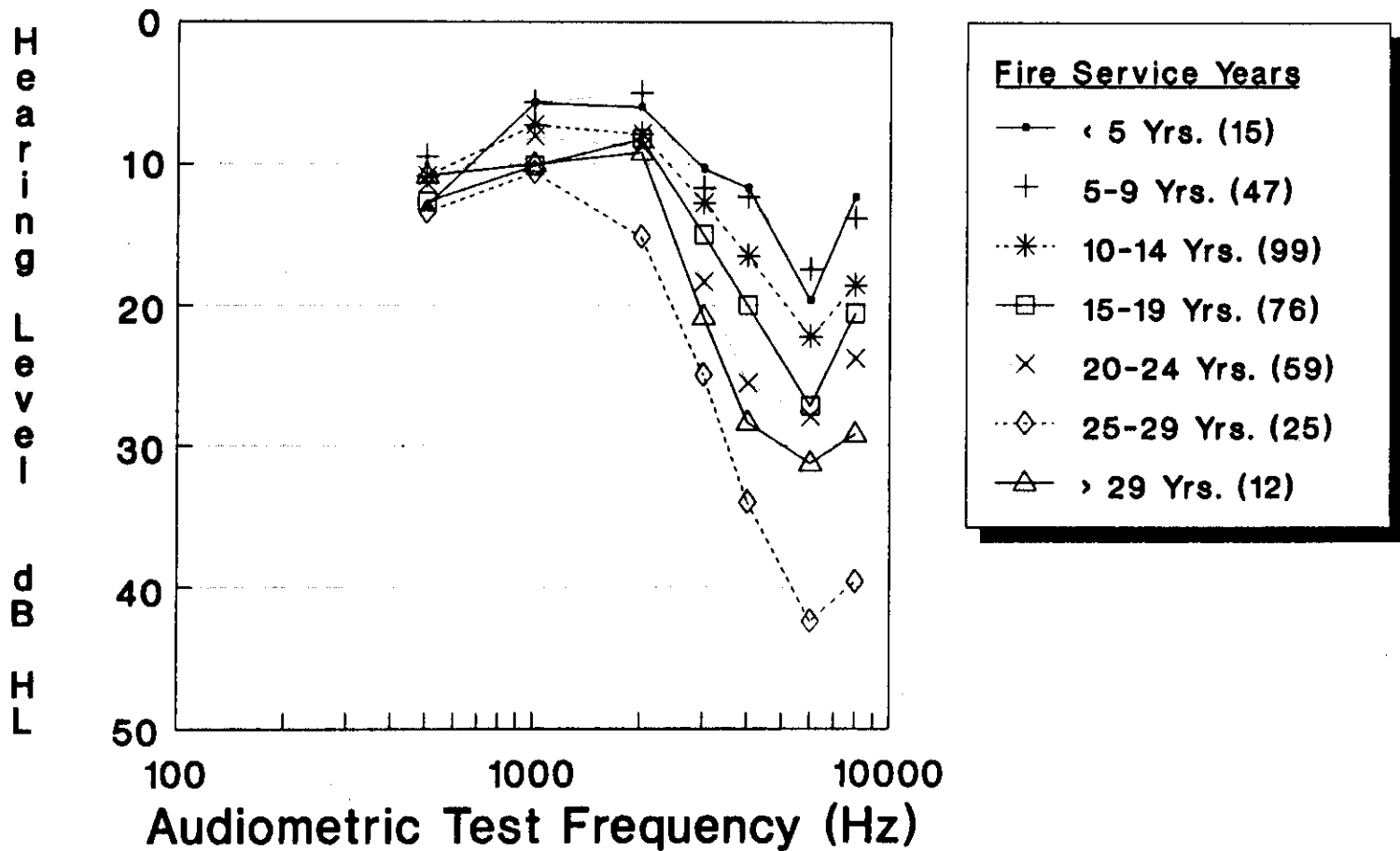
Mean Hearing Levels  
HETA 87-352  
Anaheim, CA IAFF Redmond Symposium  
October, 1987

Figure 1



Mean Hearing Levels by Service Years  
 HETA 87-352  
 Anaheim, CA IAFF Redmond Symposium  
 October, 1987

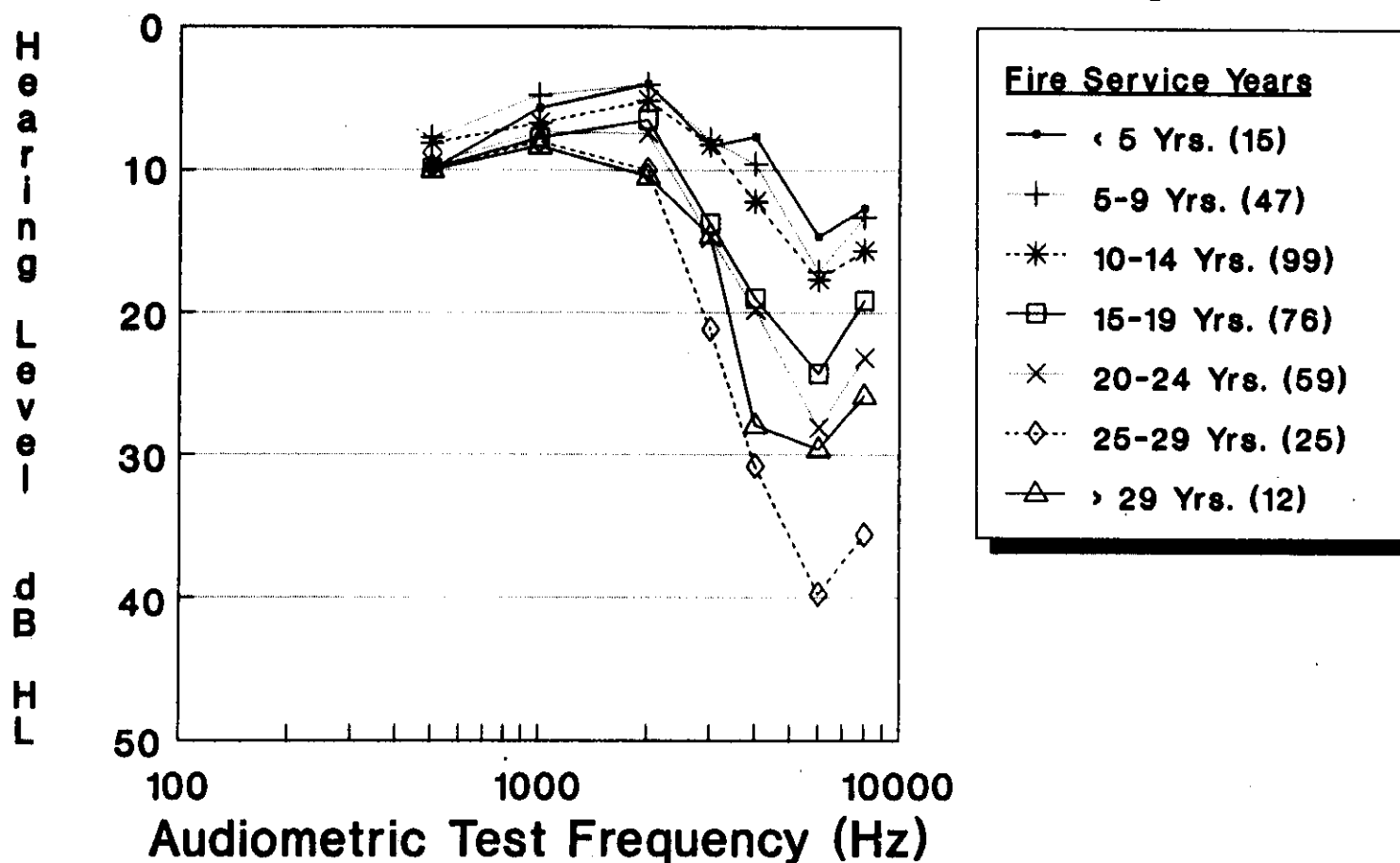
Figure 2



Left Ear

Mean Hearing Levels by Service Years  
 HETA 87-352  
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 October, 1987

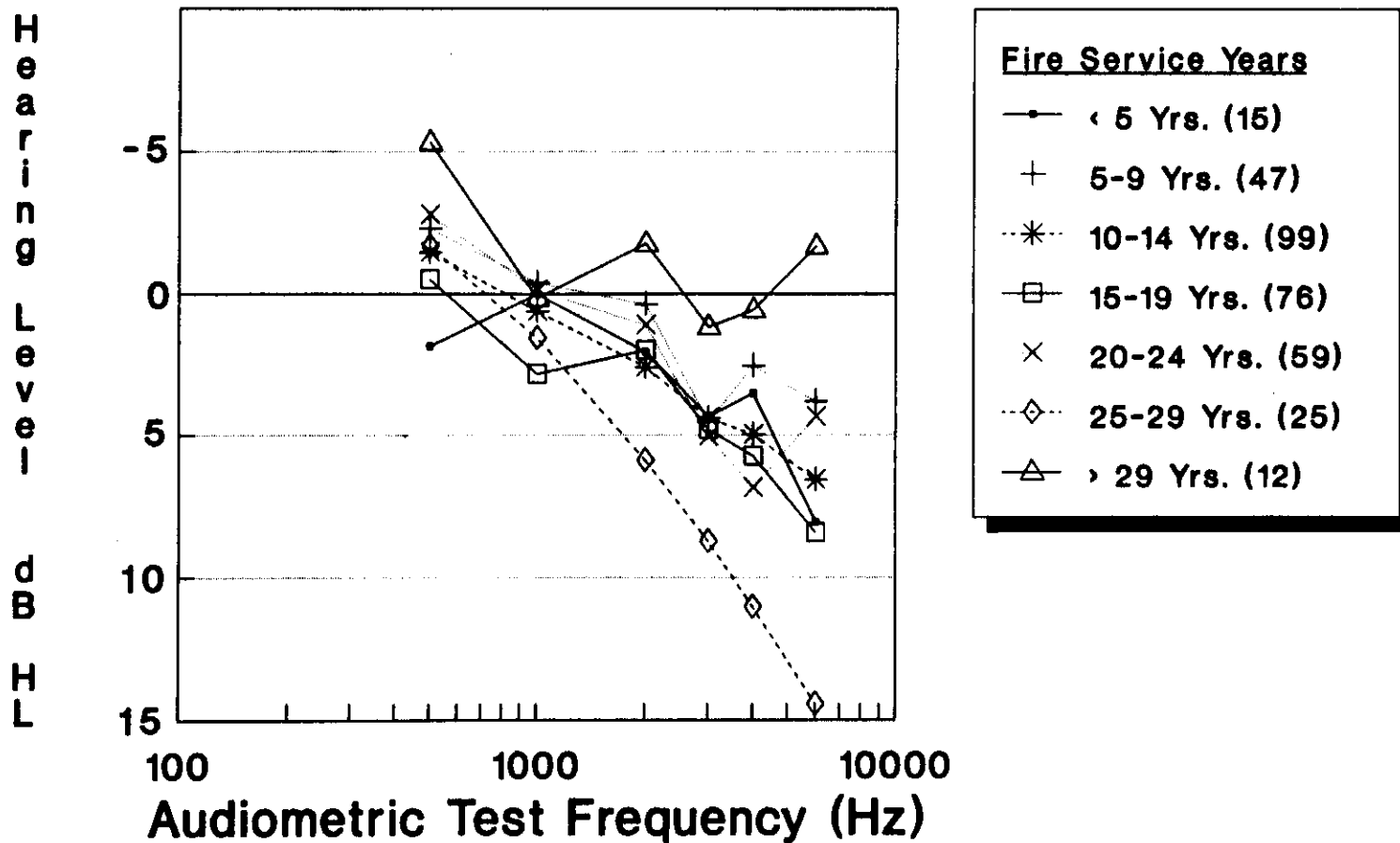
Figure 3



Right Ear

**Age Corrected Mean Hearing Levels**  
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**October, 1987**

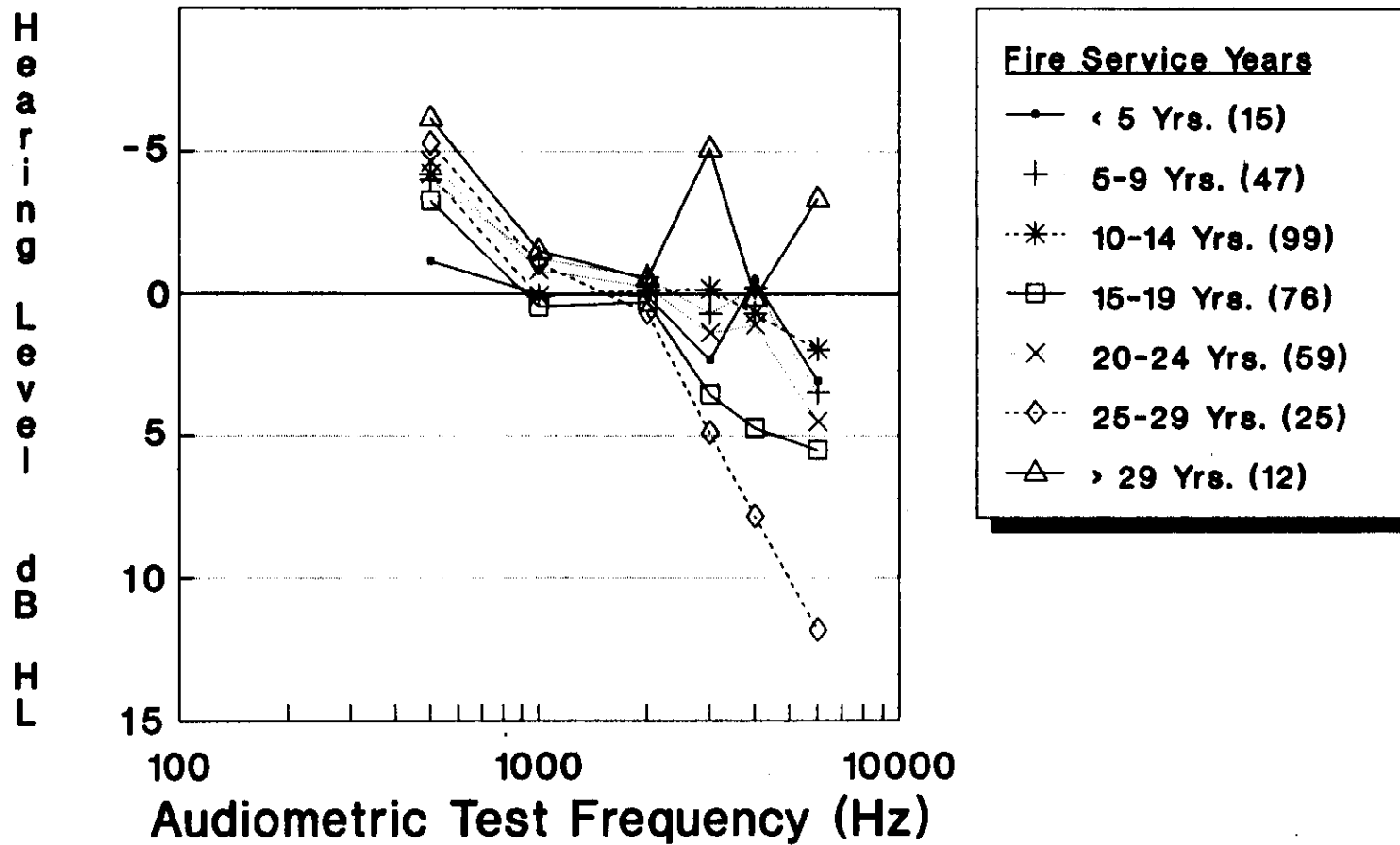
**Figure 4**



Left Ear

**Age Corrected Mean Hearing Levels**  
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**Figure 5**



Right Ear