NIOSH

TECHNICAL REPORT

A FIELD INVESTIGATION of NOISE REDUCTION AFFORDED by INSERT-TYPE HEARING PROTECTORS

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16. Abstracts This report describes the effectiveness of insert-type hearing protectors (earplugs) as determined by Real-Ear noise attenuation of earplugs. A total of 840 attentuation measurements were made among 168 workers.

The association between the amount of earplug noise attenuation received by workers and earplug design, company policy on earplug use, physical activity of the workers, workplace noise levels, and the effect of numerical test sequence is discussed.

Workers received noise protection ranging from a minimum of about 6dB at 125 Hz to a maximum of about 20 dB at 3150 Hz. Comparison of these results to laboratory and manufacturers data indicated that half of the workers tested were afforded less than one-third of the potential noise reduction. Additional tests demonstrated that reduced protection did not depend significantly on intensity of workplace noise level, earplug design, or company policy regarding earplug use.

It is suggested that earplugs of other designs be tested and that a study be conducted to determine how workers can improve the degree of protection afforded by the earplugs they use.

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ABSTRACT

To determine the effectiveness of insert-type hearing protectors (earplugs) as worn in the workplace, an audiometric van specially instrumented to determine the Real-Ear noise attenuation of earplugs was taken to six industrial sites where a total of 840 attenuation measurements were made among 168 workers. The workers were removed from their workplaces in a completely candid fashion, i.e., without prior knowledge of when they were to be tested and without re-adjusting the fit of their plugs.

The study was designed to investigate the associations between the following parameters and the amount of earplug noise attenuation received by the workers: different earplug designs, company policy with respect to earplug usage, physical activity of the workers, workplace noise levels, and the effect of numerical test sequence.

Results indicate that, on the average, workers were receiving noise protection ranging from a minimum of about 6 dB at 125 Hz to a maximum of approximately 20 dB at 3150 Hz. (Test frequency range was 125 to 8000 Hz.) Comparison of these results to corresponding data established in the laboratory, and reported by the earplug manufacturers, shows that half of the workers tested were receiving less than one-third of the potential attenuation of the hearing protectors in terms of noise reduction in dBA. Additional special testing demonstrated that this reduced performance probably was due to the workers using the wrong size earplugs for their ear canals and/or improperly inserting the earplugs. The degree of protection was not found to depend significantly upon intensity of workplace noise level, earplug design, or company policy regarding earplug usage; however, a significant difference was found between the attenuation received in the first test of all workers and in the four subsequent tests. A slight difference was also demonstrated between workers having an "active" job task compared to those with a more "passive" job activity.

The results of this study suggest the need to test earplugs of other designs, as well as to determine how workers can consistently improve the degree of protection afforded by the earplugs they use.

ACKNOWLEDGEMENTS

The field survey reported herein was performed under NIOSH Contract No. 210-76-0139. The authors extend their sincere appreciation to Mr. Roy Fleming of NIOSH and Dr. Terry Henderson and Mr. Robert Nozza, both formerly with NIOSH, for their contributions in developing this project; and to Mr. Roy Fleming for preparation of the Appendices. Statistical consultation was provided by Dr. D.F. McCoy, Associate Professor of Psychology at the University of Kentucky. The excellent cooperation of Ms. Mary C. Smith, Mr. Randall Greer, and Mr. Ron Toy, Certified Audiometric Technicians, is gratefully acknowledged, as is the splendid cooperation from the six industrial plants participating in the study. Finally, the assistance from the Acoustics Branch of the U.S. Air Force Aerospace Medical Research Laboratory, Biodynamics and Bionics Division, Wright-Patterson Air Force Base, was deeply appreciated.

CONTENTS

INTRODUCTION

Insert-type hearing protectors (earplugs) are commonly used by industrial workers who perform jobs in noisy areas. Although hearing protectors are not the permanent answer to noise exposure reduction, the Occupational Safety and Health Administration (OSHA) at both the Federal and state level recognizes their use as an interim solution until permanent engineering controls eliminate noise hazards. It is therefore important to document the effectiveness of these devices since great numbers of workers rely on them for hearing protection.

Distributors of hearing protectors provide attenuation data derived from laboratory testing which presents the sound attenuation values of the protectors as a function of frequency. In addition, in 1975 the National Institute for Occupational Safety and Health (NIOSH) published a "List of Personal Hearing Protectors and Attenuation Data" (6), a compilation of the data available in this field. The American National Standards Institute (ANSI) standardized the precise methodology that established the reported data and published it under the title "Method for the Measurement of the Real-Ear Attenuation of Ear Protectors at Threshold." ANSI established the first such standard, ANSI Z24.22-1957 (1) in 1957. A more recent version, ANSI 3.19-1974 (also ASA STD1-1975) (2), appeared in 1974. However, attenuation data based on the new standard are available for only a few hearing protectors.

Many investigators have studied the effectiveness of earplugs by making both quantitative and qualitative measurements. Both types of measurements are important because the ear protectors' potential attenuating capabilities obviously are not achieved if either the worker refuses to wear the protectors or he wears them improperly. The comfort, sizes available, ease of insertion and removal, durability, etc., are all very important considerations in the final analysis of the earplugs' effectiveness. The following paragraphs review some recent studies of these and other factors.

Flugrath and Turbeville (5) evaluated six different earplug designs by measuring the attenuation and by obtaining subjective evaluations. They concluded that "the wide inter-individual variation in attenuation for particular earplugs indicates that perhaps the primary consideration should be given to the selection of an earplug that fits properly. It is indicated that if any earplug is properly fitted and is sealed well, it will attenuate well." Botsford (3) presented a good review of ear protectors' characteristics: "Successful ear protection programs have been established in industrial plants through ingenuity and perseverance. . . ."

These studies and others have demonstrated that adequate protection from noise is possible through the proper use of earplugs. More recent studies have been initiated to examine the effectiveness of earplugs as worn in the workplace. Regan (9) collected ear protection data by taking subjects directly from their work station to a nearby audiometric van and performing attenuation tests using the ANSI Z24-22-1957 procedure. Thirty-two subjects from a steel stamping plant were each tested four times. Regan concluded: "Results of this study indicate that attenuation provided to the worker is significantly less than manufacturers' specifications. These results indicate that manufacturers' specifications do not reflect the amount of protection actually provided to the worker while on the job line daily for the ear protective devices investigated in this study. In fact, these protectors provided an inefficient means of protecting the employee from intense noise exposure."

Padilla (8) studied ear plug performance in industrial field conditions by using a modified set of large circumaural ear muffs with TDH 39 earphones attached so that standard audiometry equipment could be used in the field to obtain both data on occluded and unoccluded threshold hearing levels in particular, and data on earplug attenuation in general. His test method was compared and correlated to the standard ANSI test procedure. As stated by the author, "The tests were conducted at 500 Hz under the common knowledge that the real ear attenuation of an earplug tends to increase with an increase in frequency, so that if the attenuation was found acceptable at 500 Hz it was assumed to also be acceptable at higher frequencies."

The following were among Padilla's findings:

1. "The study revealed that while some individuals were protected, many were not, since the overall mean attenuation recorded was only 12 dB at 500 Hz.

2. "The analysis also indicates that laboratory tested standard ear plug data do not represent the actual field conditions studied. Consequently, the effectiveness of the device under field usage may be grossly overestimated.

3. "An analysis of the standard type ear plug revealed that in comparing the potential attenuating capability of the V51-R ear plug (as tested in various laboratories) with the potential capability of standard ear plugs (as tested in the field when the analyst inserted the ear plug correctly and retested the subject) a significant difference was still found. This difference is suggestive that the fitting technique used was ineffective. Also in comparing the attenuation of the standard ear plug after the ear plugs were re-tested (mean = 13 dB) with the actual field attenuation for the same group of subjects (mean = 8 dB), a highly significant difference ($p<0.001$) was found between means, indicating that the average ear plug was worn incorrectly."

P. L. Michael et al., of the Environmental Acoustics Laboratory (EAL) of the Pennsylvania State University developed a field test method similar to that of Padilla for measuring the real-ear sound attenuation of insert-type hearing protectors as they are worn in workplaces. This work was performed under a contract with NIOSH in preparation for the present study, and the results were published under the title, "A Real-Ear Method for the Measurement of the Noise Attenuation of Insert-Type Hearing Protectors" (7). This study included the collection of attenuation data derived from the field test method and the ANSI S3.19-1974 methodology. Results of the study provided a means of correcting values of attenuation obtained using the field method to values that would have been obtained had the standard ANSI methodology been used. The need for such a field method arises because of the impracticability of duplicating the ANSI methodology in a mobile facility. As the authors stated, "This method is intended primarily as a technique for documenting the variability of hearing protector performance in the workplace, rather than as a replacement for the existing ASA/ANSI Standard in rating the performance of a given protector."

The present investigation used the EAL methodology to study the actual attenuation of earplugs as they were used in the workplace. Using a medium-sized audiometric van equipped by NIOSH to perform the EAL-type test, investigators tested 168 workers from 6 industrial plants a total of 840 times. They took care to ensure that all testing was candid, i.e. that the workers were unaware of the time they would be tested until asked to leave their work station. The investigators studied possible factors influencing earplug effectiveness: workplace noise level, company hearing conservation policy, type of earplug design, temporal variations, and worker activity levels.

EQUIPMENT

The audiometric test van used in this study is equipped with a dual test unit to permit the testing of two persons simultaneously. It contains a 5' x 7' soundproof chamber equipped with special headphones developed by EAL. The circumaural headphone set consists of a muff-type hearing protector fitted with earphone drivers. It can be worn while earplugs are inserted without touching the earplugs or disturbing their fit. Testing with the headphones is binaural with parallel (in-phase) input to the headphone set. (The development and performance of this method is documented in the NIOSH publication "A Real-Ear Field Method for the Measurement of the Noise Attenuation of Insert-Type Hearing Protectors" (7).) The two recording audiometer units are modified Grayson-Stadler Model 1703's. The audiometers control the amplitude of the signal to the headphone set and record the hearing levels. As illustrated in the schematic of Figure 1, the signal to the audiometer passes through the output of a third octave filter set; thus a narrow band output replaces the usual pure tone output of the audiometer. The electronic switching circuit interrupts the output, producing a "pulsing" signal of 300 milliseconds "on" and 500 milliseconds "off." NIOSH personnel developed and assembled this system. Appendix A presents a more detailed description of the audiometric test equipment and the modifications to the audiometers.

Workplace noise levels were recorded with a General Radio Model 1933 precision sound level meter. Permanent tape recordings were made simultaneously by feeding the output from the sound level meter to a General Radio Model 1935 recorder.

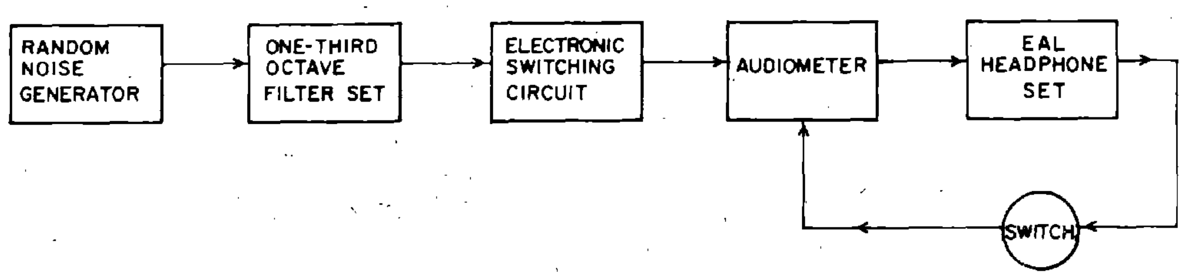

Figure 1. Schematic of Instrumentation

EXPERIMENTAL DESIGN

Figure 2 is a schematic presentation of the experimental design which involved 5 primary factors and 168 subjects, 28 subjects from each of the 6 plants surveyed. The following outlines the 5 factors of the design:

TYPES OF EARPLUGS

Three different types of earplugs were used at the selected plants. In Plant I employees wore a preformed, twin-flanged plug made of a rubber-like, pliable material (Figure 3). In Plants III and VI employees used a moldable, "cotton-like" material frequently called "Swedish Wool."* In Plants II, IV, and V they wore preformed earplugs of the V-51R design. Note: the V-51R earplugs used in Plant II and the V-51R earplugs used in Plants IV and V were from different distributors.

EMPLOYER POLICY TOWARD EARPLUG USE

The study also involved determination of employer policy toward voluntary or mandatory use of earplugs. Plants II, V, and VI provided earplugs for their employees, but did not require their use. Plants I, III, and IV specifically required earplug use.

NOISE EXPOSURE LEVELS

At each plant the subjects were divided into two groups, depending on their workplace noise exposure levels. Half (14) of the selected employees at each plant were normally exposed to "higher" workplace noise levels than the other half. For convenience, designations of "high" and "low" noise levels were used. The workplace noise levels that correspond to each group of workers represent <u>averages</u> of octave band sound level measurements obtained over the course of a typical workday.

EMPLOYEE PHYSICAL ACTIVITY

Investigators categorized the degree of employee physical activity as either "active" or "passive." An "active" employee was generally a production-line type worker whose physical activity was almost continuous.

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* In this study, the term "Swedish Wool" refers to an acoustic wool matting (in bulk form) which is shaped by the user. Later developments of the acoustic wool-type hearing protectors have been neither evaluated nor included in this test; therefore, no conclusions can be made about their effectiveness.

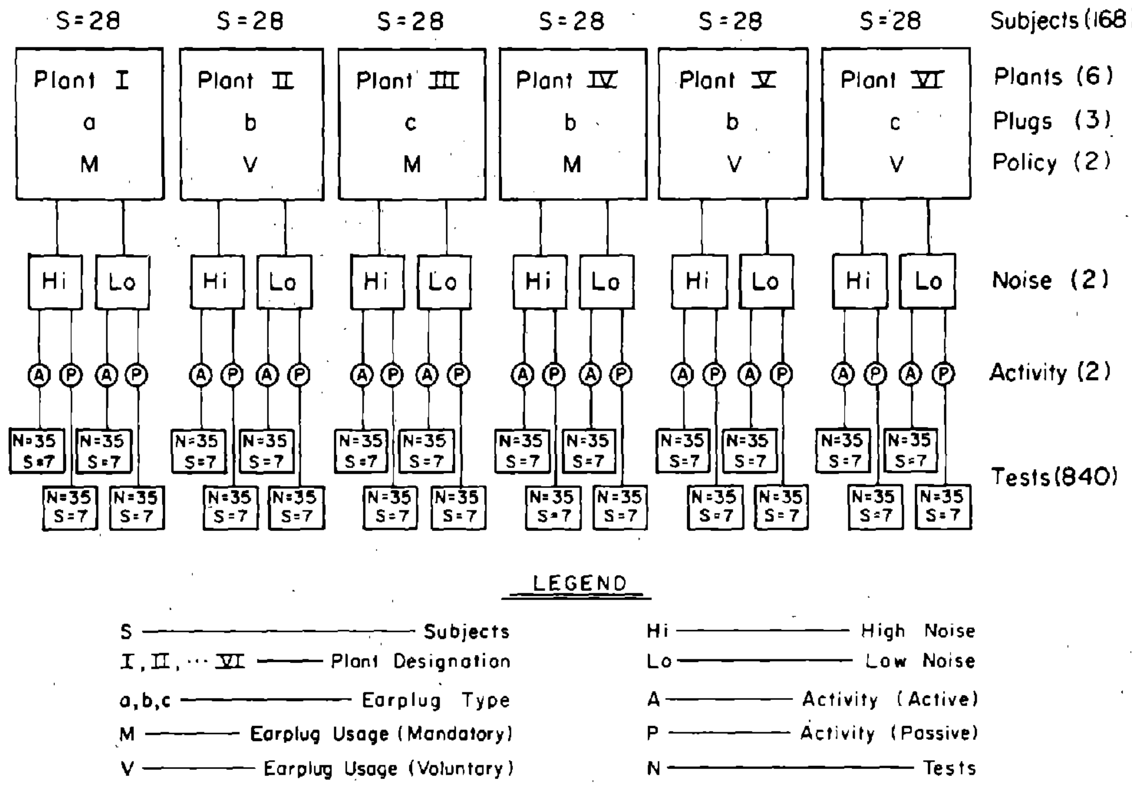


Figure 2. Schematic of Experimental Design

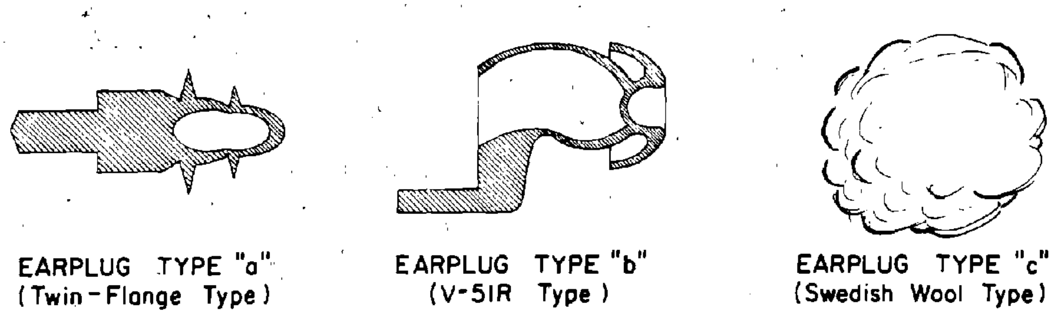


Figure 3. Three Types of Earplug Designs Evaluated in Study

A "passive" employee performed assignments that did not require continuous physical activity, e.g. supervisors, janitors, materials handling personnel.

NUMBER OF TESTS

Each worker was tested five times. At each of the six plants, 140 tests were performed (7 subjects per group x 4 groups x 5 tests per subject), a total of 840 tests for the entire study.

PROCEDURES

SELECTION OF PLANTS

Six factories, representing a cross-section of industrial manufacturers, volunteered to participate in the study. The companies were engaged in metal stamping and forming (Plant I), small electrical components production (Plant II), electronic power generation (Plant III), the production of steel bearings (Plant IV), a tool and die operation (Plant V), and the manufacture of rubber seals (Plant VI). All plants had hearing conservation programs established prior to their selection in the current study. Table 1 contains descriptive information and summarizes several aspects of the hearing conservation programs for each plant.

Table 1. Pertinent Information Regarding Plants Participating in Study

	Plant I	Plant II	Plant III	Plant IV	Plant V	Plant VI
1. How old is plant (years)?	3	18	47	4	16	26
2. No. of shifts per workday.	2	3	3	3	2	3
3. No. of employees.	150	900	35	60	250	600
4. Is there a plant nurse?	yes	yes	no	no	no	no
5. Is there a plant physcian?	no	no	no	no	no	no
6. Is annual audiometry performed as part of the hearing conservation program?	yes	yes	yes	no	yes	no
7. When was the hearing consertion program started?	1973	1974	1972	1973	1970	1951
8. Are the earplugs fitted?	no	yes	NA*	no	yes	NA*
9. Are the employees instructed in how to properly insert the earplugs?	yes	yes	yes	no	yes	no

* Not required (Swedish Wool)

NOTE: See Appendix B for additional information on plants included in this study.

SCHEDULING

The testing was conducted over a period of five days at each plant. Thus, each participating employee was tested an average of once each day, i.e. every employee was tested a total of five times.

The experimental design required that the participating employees at each plant be divided evenly into four groups according to their workplace noise levels and task activity levels. Table 2 illustrates an example schedule for one plant; the numbers correspond to the sequential test order on a given day. For example, subject S11, in the higher noise exposure group, had a "passive" type of job activity. S11 was in the third group tested on the first day, in the eighth group on the second day, the second and ninth groups on the third day, and in the ninth group on the fourth day.

Table 2. Example of Scheduling at One Plant Visited

Distribution	Name	Designation	Day 1	Day 2	Day 3	Day 4	Day 5
High Noise Active	S1	A1	---	4	10	3, 5	6
	S2	A2	6	---	---	1, 12	2, 9
	S3	A3	7	---	6, 12	5	5
	S4	A4	2	15	5	8, 16	---
	S5	A5	---	13,16	---	4	2, 11
	S6	A6	1, 7	13	---	12,16	---
	S7	A7	4	12	1, 15	---	1
High Noise Passive	S8	B1	14	10	---	2	3, 9
	S9	B2	9, 12	11	10	10	---
	S10	B3	1	7	13	8	7
	S11	B4	3	8	2, 9	9	---
	S12	B5	13, 4	---	5	9	7
	S13	B6	15	12	4, 9	11	---
	S14	B7	9	2	7	10	8
Low Noise Active	S15	C1	---	5	6	1	1, 8
	S16	C2	10	---	2	4	3, 10
	S17	C3	6, 12	3, 9	---	11	---
	S18	C4	---	---	10,15	6	4, 13
	S19	C5	2, 14	1, 14	---	13	---
	S20	C6	8	6	8, 14	13	---
	S21	C7	---	8, 15	14	15,17	---
Low Noise Passive	S22	D1	13	6	1	15,17	---
	S23	D2	5, 8	3	---	---	11,13
	S24	D3	3, 10	4	4	14	---
	S25	D4	11	5	3, 12	7	---
	S26	D5	11	7	---	3	4, 12
	S27	D6	5	11,14	13	14	---
	S28	D7	---	7	8	6	5, 10

Each employee was presented with a copy of the "NIOSH Human Subjects Research Participant Document" which informed him/her of the study's purpose, benefits, procedures, etc. It also secured each employee's signature, certifying that he/she was voluntarily participating in the study.

Since previous audiograms of most employees were available at each of the six selected plants, it was generally possible to use the following two "audiometric criteria" to aid in selection of subjects:

1. A hearing level not greater than 40 dB at any frequency in at least one ear.

2. A difference between left and right ear hearing levels not greater than 20 dB at more than one frequency.

The first criteria insured that the hearing level plus attenuation would be less than the maximum output of the test system. The second criteria screened out persons who might not perform well in this binaural test, in which the test signals are presented to both ears simultaneously. In addition, an audiologist reviewed the available audiograms to eliminate from consideration employees with evidence or histories of hearing problems.

TEST PROCEDURE

The protocol of the investigation required that employees be tested in a completely candid situation. That is:

1. They should be completely unaware of when they would be tested.

2. Once approached and informed that it was time for their test, an escort should accompany them to the audiometric van to insure that their earplug fit was not adjusted.

Therefore, employees were aware only that they would be given several hearing tests at various times during a five day period. Each participant received the following written statement <u>prior</u> to the week of testing:

> Dear Employee:
>
> Your company will participate in a study to determine how well your earplugs are doing their job. About three dozen employees will be asked to volunteer by taking hearing tests during the week of ________. These tests will be very much like the ones you have taken before, except this time you will be tested keeping your ear plugs inserted. At certain times during the week you will be asked to leave your work for the 20 minutes required to be tested. It will be very important that you leave your earplugs inserted just as you normally wear them and that you do not touch either your earplugs or ears on the way to the test van.

The van was always positioned as near as possible to a plant door to provide convenient access, but was located so that noises from the plant were not discernable outside the van. Octave band recordings of sound pressure levels inside the test cell were made to insure that ambient (outside van) noise levels were always sufficiently low to avoid interference with testing. Figure 4 is a graph of typical values. (Note that the circumaural headphone sets provided additional attenuation of ambient noise levels.)

A 240 volt, 5000 watt, gasoline generator provided the power for air conditioning when required. This generator was always placed on the ground approximately 20 feet from the van; thus its noise did not interfere with testing. The typical octave band data described above were gathered inside the test cell with the generator in operation outside. The blower was turned off during measurements below 500 Hertz. However the generator was used only at Plants I and IV. Electric space heaters were used in cold weather.

The contractor used a team of three Certified Audiometric Technicians. Each had experience in administering industrial hearing tests. One technician administered the tests, instructing the subjects and operating the equipment. Another was responsible for bookkeeping tasks, i.e. keeping records of the subjects tested, subjects to be tested, etc. The third technician accompanied the foreman to inform employees that they were to leave their work station and accompany the escort to the test van.

Calibration of equipment was not required, since only differences were desired at each frequency. The technicians listened carefully to the test signal at the start of each day to ascertain that the instrumentation was operating properly.

Testing commenced at least thirty minutes after the start of a work shift. This assured that employees had been performing their regular duties, with earplugs inserted, prior to being tested.

When ready to start testing, the technician responsible for bookkeeping told the escort the names of the two persons scheduled for testing. (Two subjects were tested simultaneously.) The escort then contacted each subject's foreman, who accompanied the escort to the work stations. When the subjects were approached, the escort showed each an 8-1/2" x 11" cardboard sign, which read "Time for Your Hearing Test. Please Do Not Touch Your Earplugs or Ears. Thanks." Each subject then carried the sign as they walked to the van. With the cardboard to occupy their hands, the subjects were less likely to inadvertently reach for their earplugs or ears.

Upon reaching the van, the subjects were seated in the test cell. They sat facing each other, but during testing a curtain was placed between them to minimize distractions. The test was administered first with earplugs inserted and then with earplugs removed.

When the subjects were tested for the first time, they received the following verbal instructions: "You will listen for a pulsing tone. As soon as you hear the tone, please press the button and hold it down until you no longer hear the tone; then release the button. When you again hear the tone, repeat the procedure." A technician then placed the EAL headphone sets on each

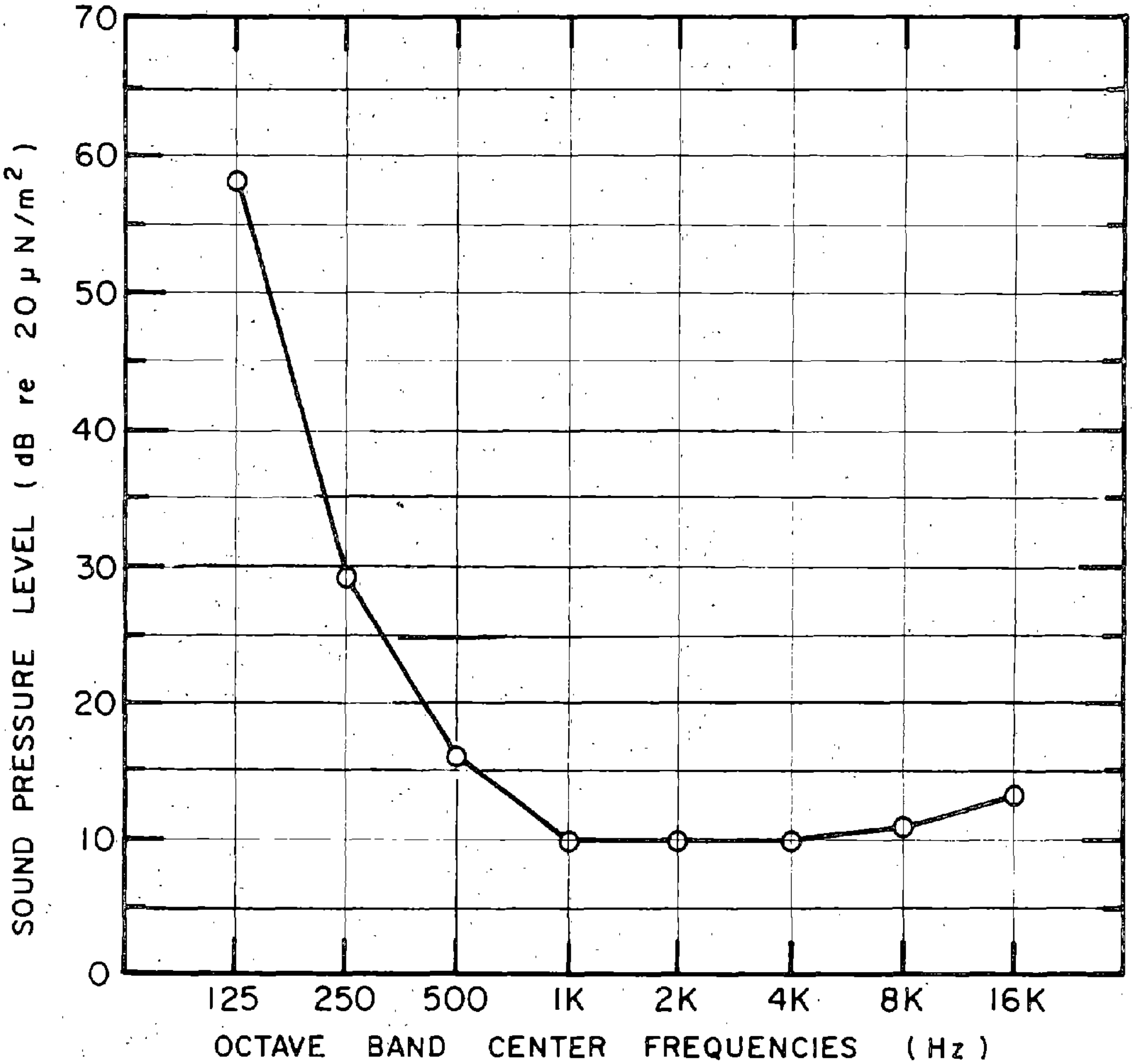


Figure 4. Typical Sound Pressure Levels Inside Audiometric Van Test Cell

subject, taking extreme care in positioning the headphones so not to disturb the earplugs. A 500 Hz tone then sounded, and the subjects practiced the task briefly. Thus, the technicians ensured that the workers understood the procedure before recordings were made.

The operator presented each frequency and made a 30 second recording after determining that the responses were oscillating about threshold. The order of presentation for the third octave band center frequencies was 500, 1000, 2000, 3150, 4000, 6300, 8000, 500, 250, and 125 Hz. Note: 500 Hz was the first frequency presented, and this segment of the test was repeated to demonstrate reproducibility. Separate audiogram cards were used for occluded and unoccluded tests to avoid difficulties in interpretation caused by overlapping traces. The total time required for the two tests was about 15 minutes. Figure 5 illustrates typical data records for one test.

DATA TREATMENT

A two step data reduction technique was conducted for each test:

1. The analogue audiograms corresponding to both the occluded and unoccluded (see Figure 5) cases were digitized, using the midpoints of the pen oscillations at each frequency. This data is contained in Appendix C. By subtracting the respective data for the occluded case from that for the unoccluded, "uncorrected" attenuation values were obtained.

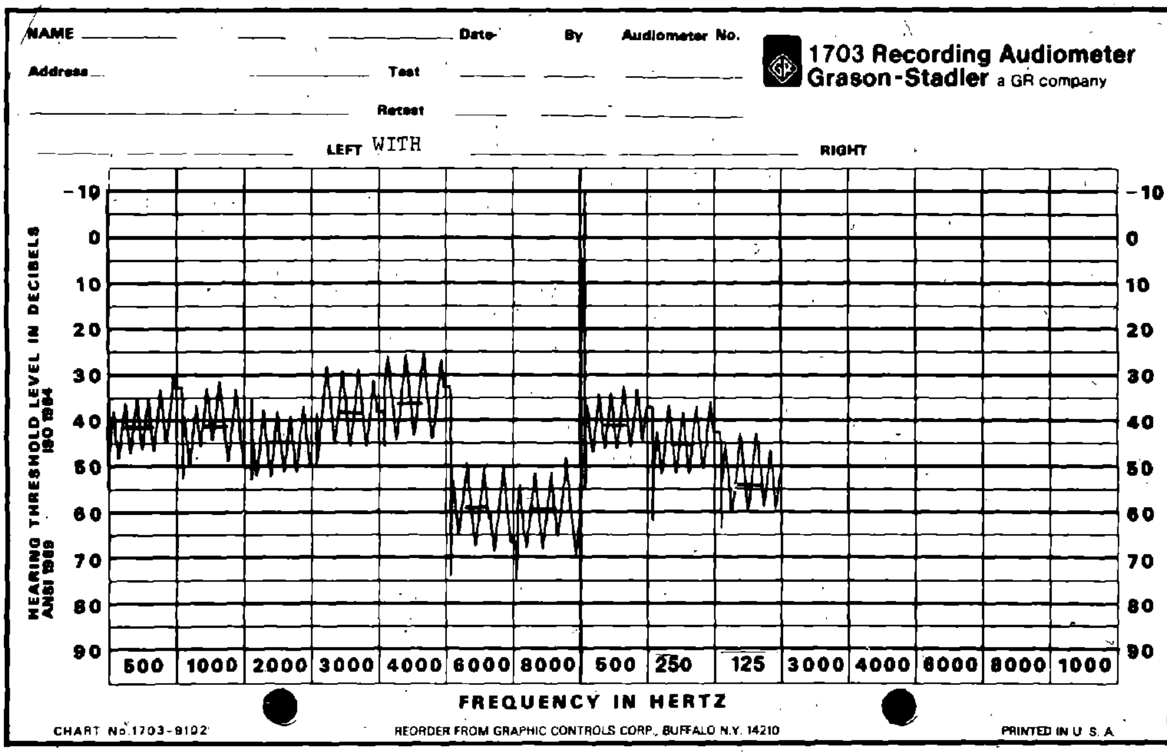
2. The F_n's were then "corrected" to yield the attenuation values in accordance with ANSI S3.19-1974. The procedure for accomplishing this was set forth in the NIOSH publication "A Real-Ear Field Method for the Measurement of the Noise Attenuation of Insert-Type Hearing Protectors" (7) (see discussion in Appendix C).

SPECIAL CORRELATION TESTING

A special test series was arranged after initial field tests showed low attenuation values. This was necessary to document that nothing was inherently wrong with the NIOSH field test system.

The NIOSH mobile audiometric van was taken to Wright-Patterson Air Force Base where the Aeromedical Research Laboratory, Biodynamics and Bionics Division, Acoustics Branch, maintains a wide array of test facilities commonly used to evaluate hearing protectors. One such facility is specially arranged to evaluate insert type hearing protectors in accordance with the ANSI Z24.22-1957 methodology. The same ten subjects were tested three times each with both the ANSI procedure and the NIOSH/EAL procedure in the NIOSH van, which was positioned approximately 50 feet from the Air Force Test Cell. This permitted a direct comparison between the two methods establishing the attenuation values.

The ten subjects in this study were college-aged students. All had some previous experience with audiometric testing, and none had hearing problems.



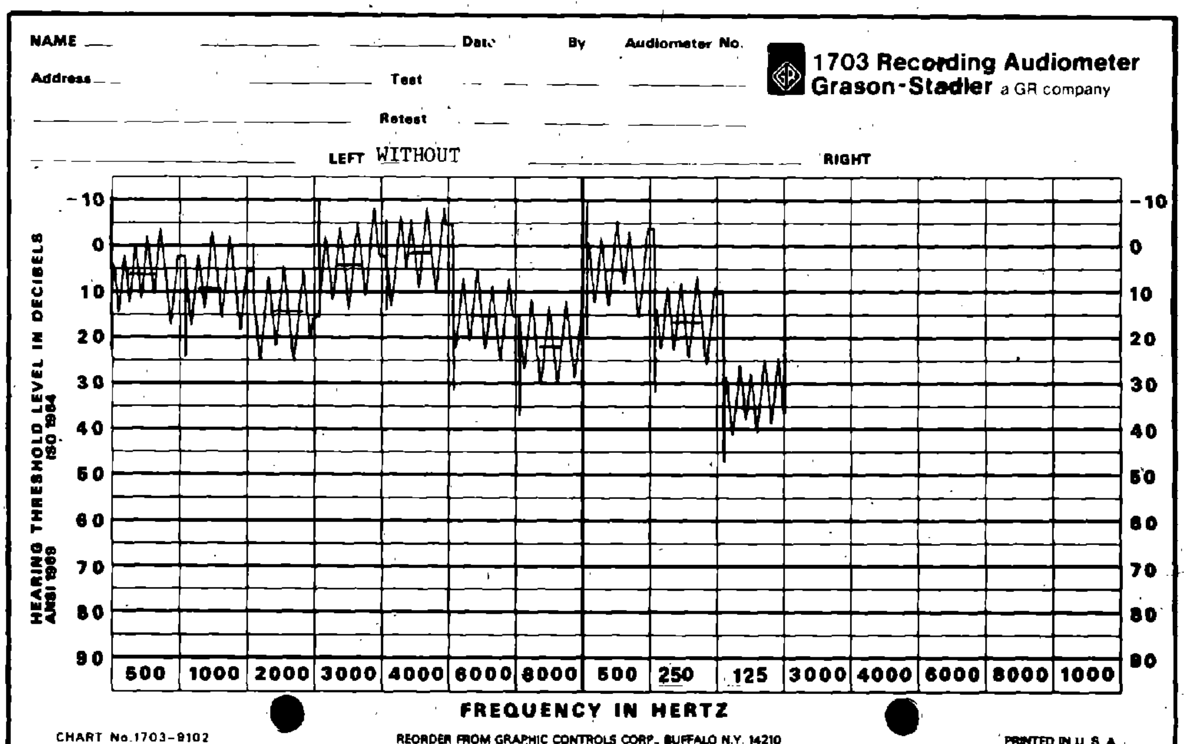


Figure 5. Example audiograms from subject ears occluded (upper) and unoccluded (lower).

An Air Force Audiologist properly fitted and inserted V-51R type hearing protectors. The ten subjects were divided into two groups of five subjects each, designated Group A and Group B. Group A was first tested without earplugs in the NIOSH van. Then the earplugs were inserted by the Air Force Audiologist and the test in the van repeated. With earplugs undisturbed, the Group A subjects were then escorted to the Air Force facility, a distance of about 500 feet. There the Group A subjects were first tested with earplugs still inserted; next the earplugs were removed and the ANSI-type test repeated. This entire procedure was then repeated twice. Group B subjects followed the same procedure, except that testing was first conducted in the Air Force facility and then in the NIOSH van. The following table summarizes the experimental design:

	Group A Subject Test Sequence	Group B Subject Test Sequence
ANSI Test*, Unoccluded	4	1
ANSI Test*, Occluded	3	2
NIOSH/EAL Test**, Occluded	2	3
NIOSH/EAL Test**, Unoccluded	1	4

* - ANSI Z24.22-1957 procedure performed in Air Force facility.
** - NIOSH/EAL procedure performed in NIOSH Audiometric Van.

Figures 6(a) and 6(b) illustrate the relationship between data obtained by the field method using EAL headphones and by standard ANSI laboratory methods. At each test frequency, means and standard deviations are shown for the 10 subjects tested. Figure 6(a) shows uncorrected results from tests taken in the NIOSH van and Figure 6(b) shows these attenuation values adjusted to correspond to those that would have been obtained had the ANSI S3.19 methodology been used. The results in Figure 6(b) show no statistically significant differences in means at any test frequency at the 0.2 probability level. Figures 7(a) and 7(b) show similar results of the two methods of testing. Values of attenuation are shown for groups A and B discussed above. The small differences between corrected attenuation by the field method and attenuation by the laboratory method for both groups A and B further support the viability of testing using the EAL method in the NIOSH van.

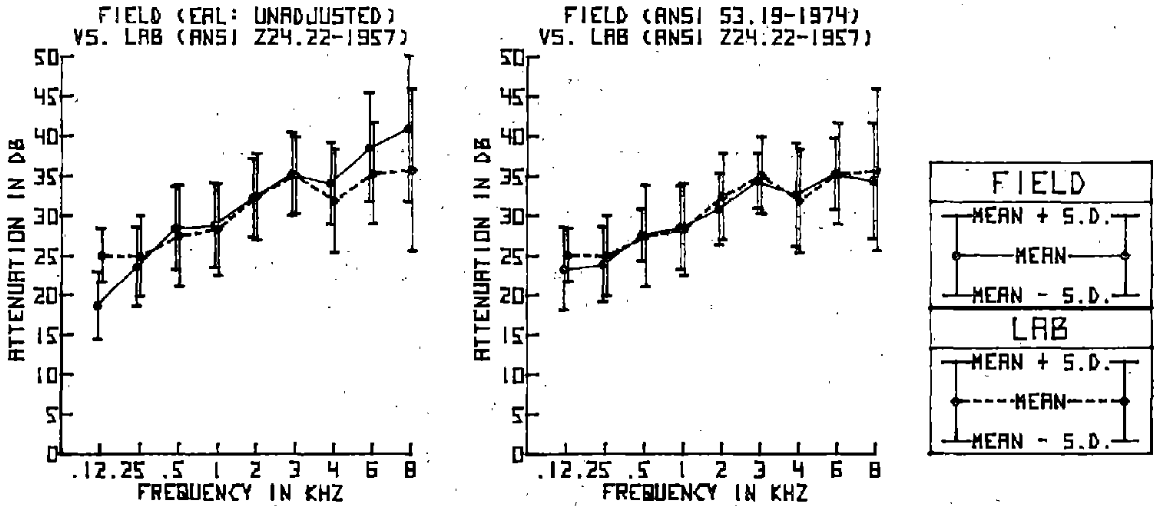


Figure 6a Figure 6b

Figure 6. Attenuation of V-51R earplugs tested at WPAFB: 10 subjects tested 3 times (N=30) by both the field and laboratory methods.

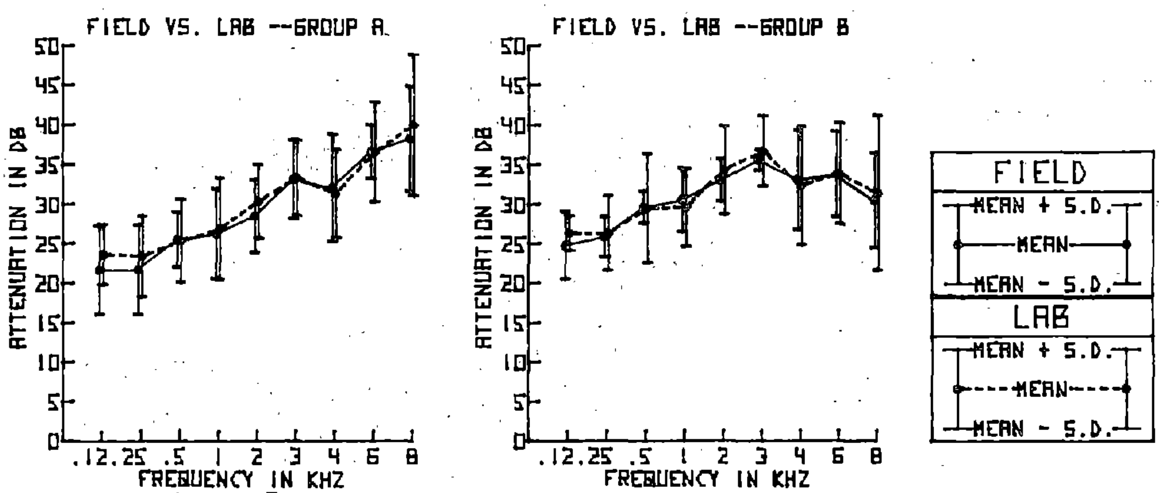


Figure 7a Figure 7b

Figure 7. Attenuation of V-51R earplugs tested at WPAFB:
Group A - 5 subjects tested 3 times (N=15) - first by the field method, then by the lab method;
Group B - 5 subjects tested 3 times (N=15) - first by the lab method, then by the field method.

RESULTS

The graphs of Figures 8 through 14 contain the data of this study. (See Appendix C for a complete tabulation of attenuation data.)

Figure 8 contains graphs for each of Plants I through VI. Earplug attenuation versus frequency is plotted on each graph. The lower plot represents the mean and mean plus or minus one standard deviation for all 140 tests from the 28 subjects at each particular plant. For comparison, the upper plot is of laboratory type data reported by the particular earplug distributor. These graphs reveal substantial differences in the magnitudes of corrected attenuation values recorded in the field when compared to those recorded in the laboratory, even though the field data curves vary with frequency similarly to the curves for the corresponding earplug data established in the laboratory.

Figure 9 shows a comparison of the results from test number one with tests number two, three, four, and five illustrating the potential effects upon attenuation of the sequential test order. At all frequencies the average attenuation for the first test was greater than that for any of the subsequent tests. A pattern of decreasing attenuation from test 1 to test 5 was typical for data from each of the six plants.

A one-way analysis of variance was performed to determine if there was any significant variation due to the tests themselves. A first analysis of data from the 168 subjects included in the survey confirmed this suspicion by revealing a statistically significant test effect ($P<<.01$) at each test frequency. An independent analysis of data from 28 subjects for each plant showed similar results at Plants I, II, III, and V.

Visual inspection of the data suggested that this result may have been primarily attributable to test number one, which for some reason may have been different from the others. (Perhaps anticipation of the first test was enough to influence the results, subsequent tests seeming more routine to the workers.) A second analysis of tests two through five was performed. This analysis did not show significant results. This analysis showed a significant test effect ($P<.05$) on data from Plant III at the 1000 and 2000 Hz test frequencies and Plant V at 500 Hz. However, at all of the other test frequencies for data from each of the six plants, the analysis of variance did not show a statistically significant test effect ($P>.05$), thus supporting the original hypothesis that the first test was different from the others.

Since the data of the subsequent tests two through five were not found to be substantially different, they were combined for further statistical treatment. For the following comparisons of different worker groups and

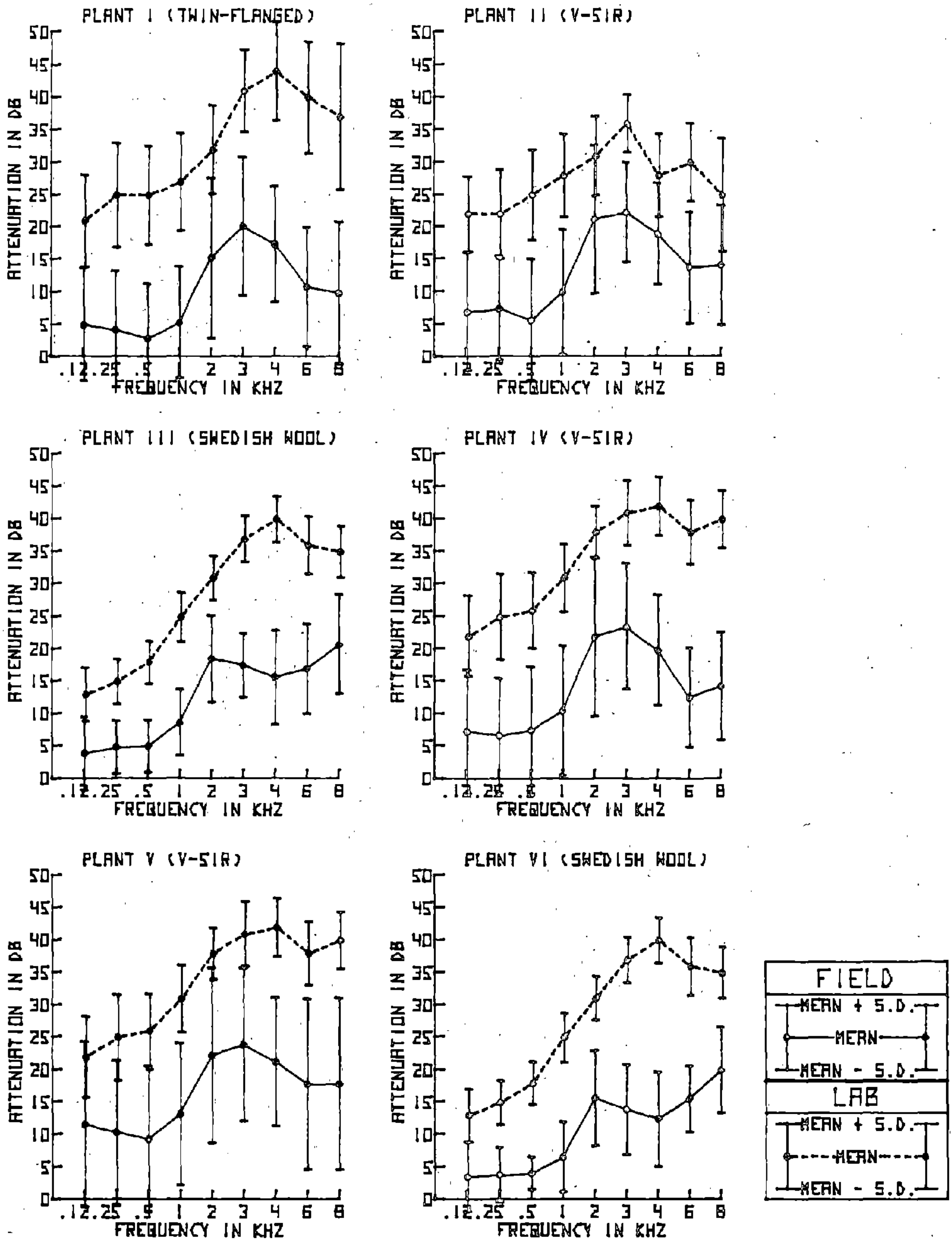


Figure 8. Earplug attenuation versus one-third octave band center frequency: Field data compared to lab data reported by the earplug distributors.

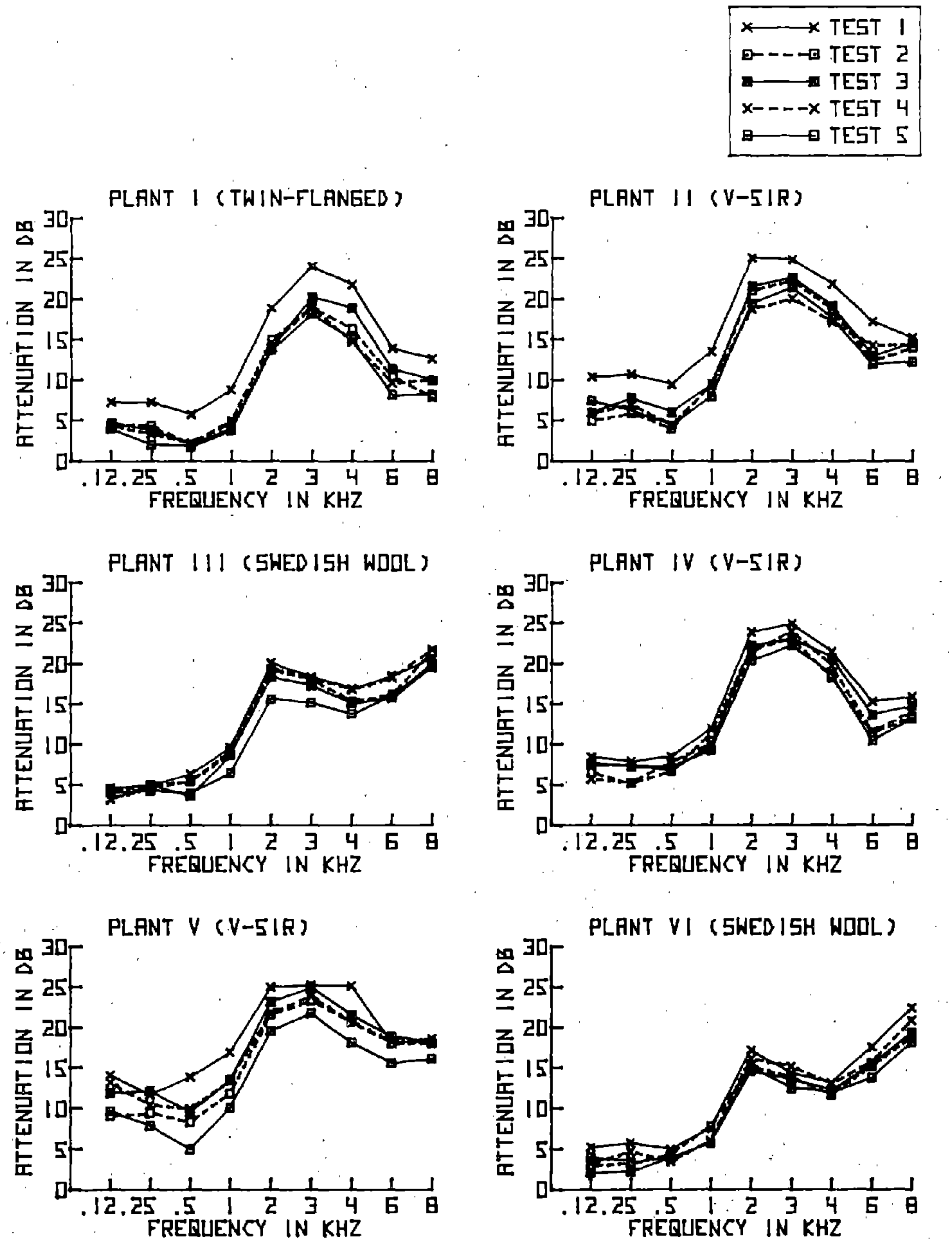


Figure 9. Mean earplug attenuation versus one-third octave band center frequency for each of five sequential tests.

different company policies on earplug usage, a single score was computed for each subject at each test frequency. This score was the mean of tests two through five.

Figure 10 shows the effects upon attenuation of both high and low workplace noise levels with active and passive work patterns. Although the general pattern of decreasing attenuation depicted in Figure 10 was not the same for all of the plants, the "high noise-active" group consistently showed the highest average attenuation and the "low noise-passive" group consistently showed the lowest average attenuation.

Figures 11 and 12 further illustrate comparisons between active and passive and between high and low noise worker groups. In these cases, mean attenuation and mean plus or minus one standard error of the mean (S.E.M.) versus center frequency are plotted. Note that a difference between means equal to approximately 2.8 times the average S.E.M. implies a significant difference at the .05 probability level. Although there were trends toward higher attenuation for the active and high noise worker groups, there were few cases where the differences in average attenuation were significant at the .05 probability level.

Figure 13 shows comparisons of plants using the same earplug design but having different earplug usage policies, i.e., either mandatory or voluntary. The small differences between mandatory and voluntary policies in terms of average attenuation were not statistically significant at the 0.05 probability level.

Octave band sound levels and sound levels in dBA defining the "high" and "low" noise magnitudes for each of the six plants are shown in Figure 14. Attenuation data from workers corresponding to each set of octave band sound levels were used to compute noise reduction values in dBA. This computation simply required reducing the octave band sound levels by the amounts of attenuation provided by the earplugs at each of the corresponding hearing test center frequencies and then computing the reduction in dBA level. Note that attenuation values for 3150 and 4000 Hz center frequencies were averaged and the average value was subtracted from the 4000 Hz octave band sound level; similarly, the average attenuation for the 6300 Hz and 8000 Hz center frequencies was subtracted from the 8000 Hz octave band sound level. The noise reduction value in dBA is the difference between the initial dBA level and the reduced dBA level. Figure 14 illustrates the cumulative percent distributions of noise reduction values for the two worker groups at each plant. These figures also show the comparable distributions of noise reduction values, estimated using mean attenuations and standard deviations obtained from the distributors of the earplugs. Table 3 presents a composite summary of noise reduction factors.

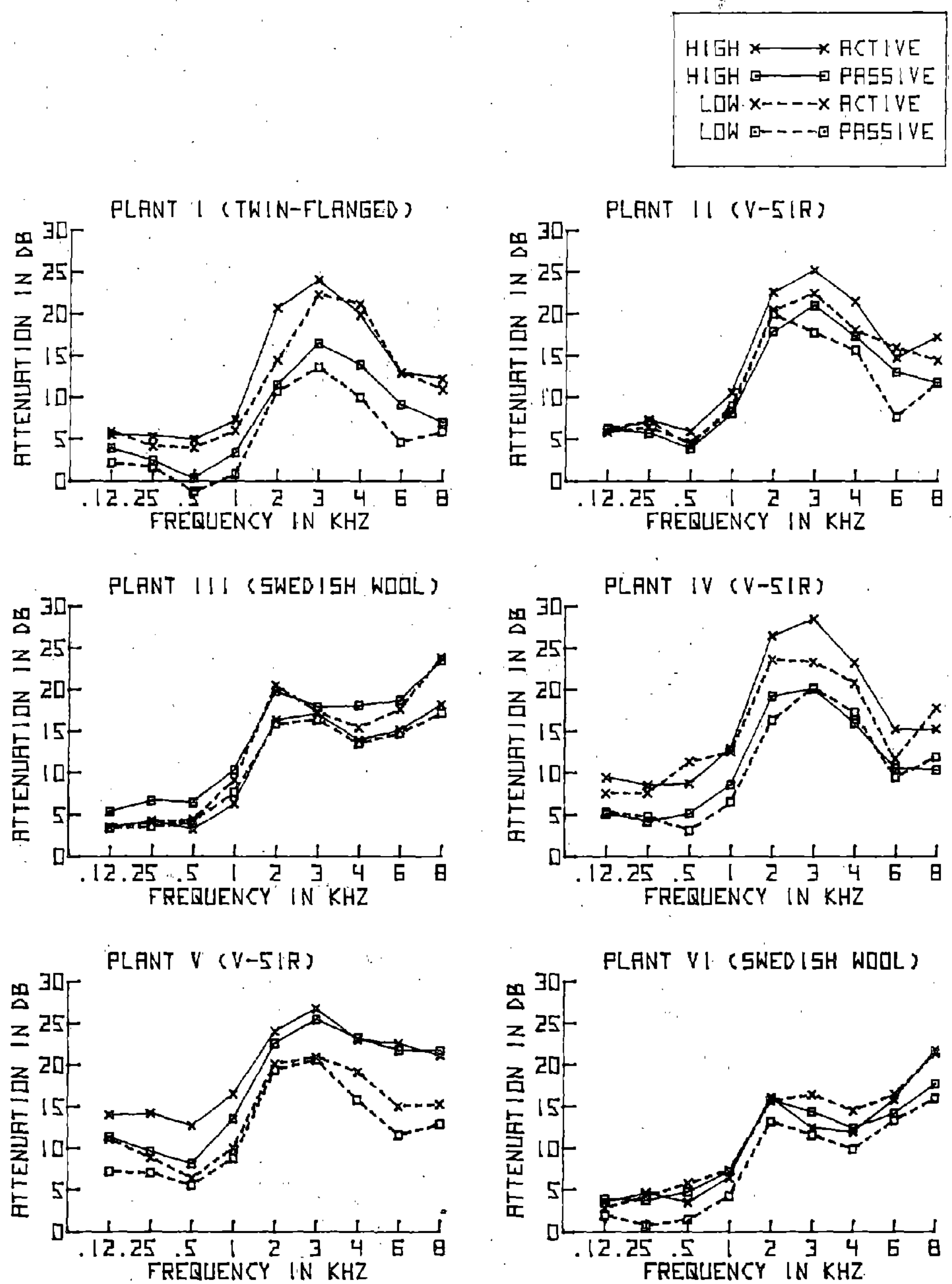


Figure 10. Mean earplug attenuation versus one-third octave band center frequency for workplace exposure ("high" and "low" noise) and job activity ("active" and "passive") groups.

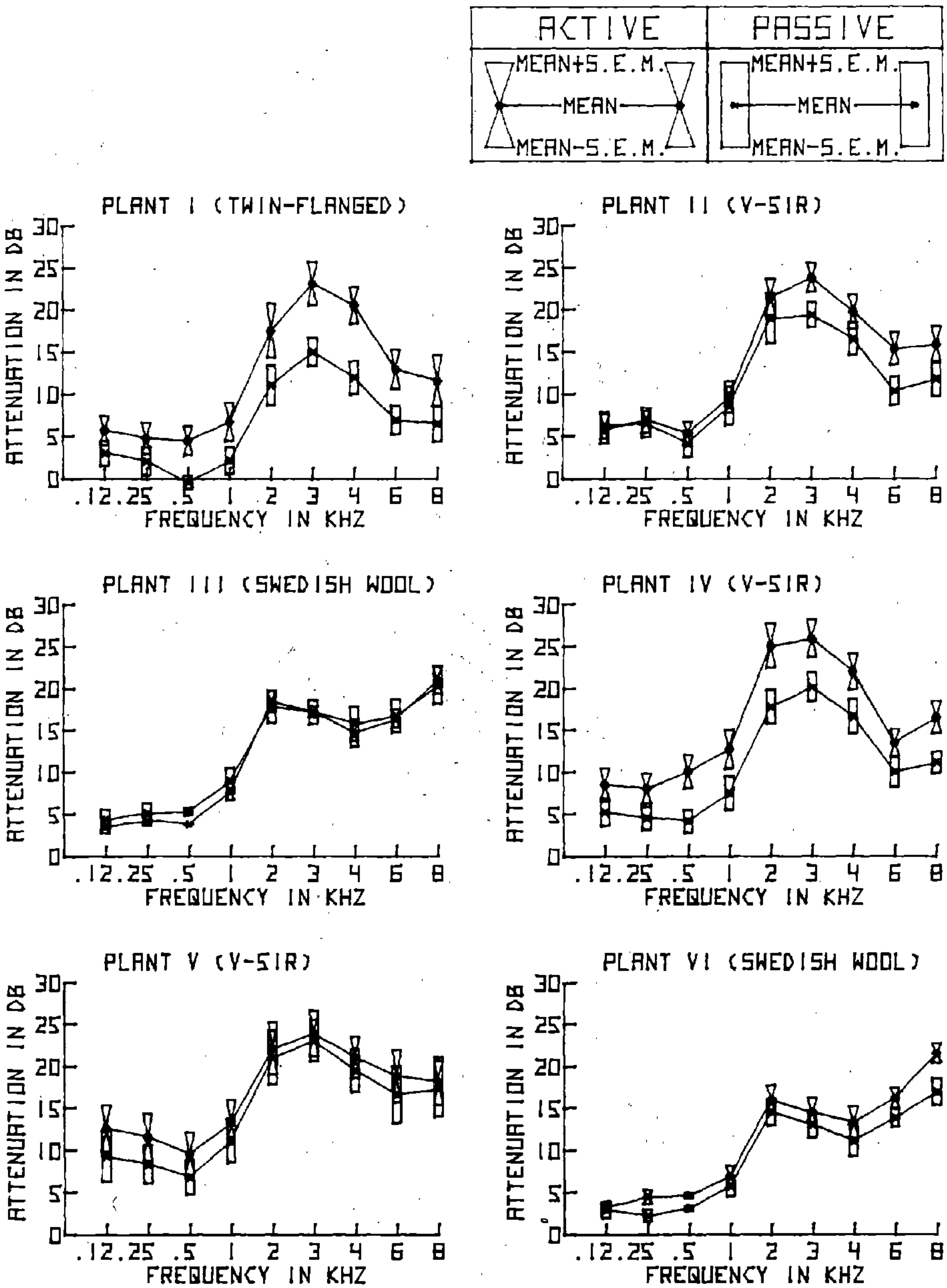


Figure 11. Mean earplug attenuation versus one-third octave band center frequency for workers in "active" compared to "passive" job functions.

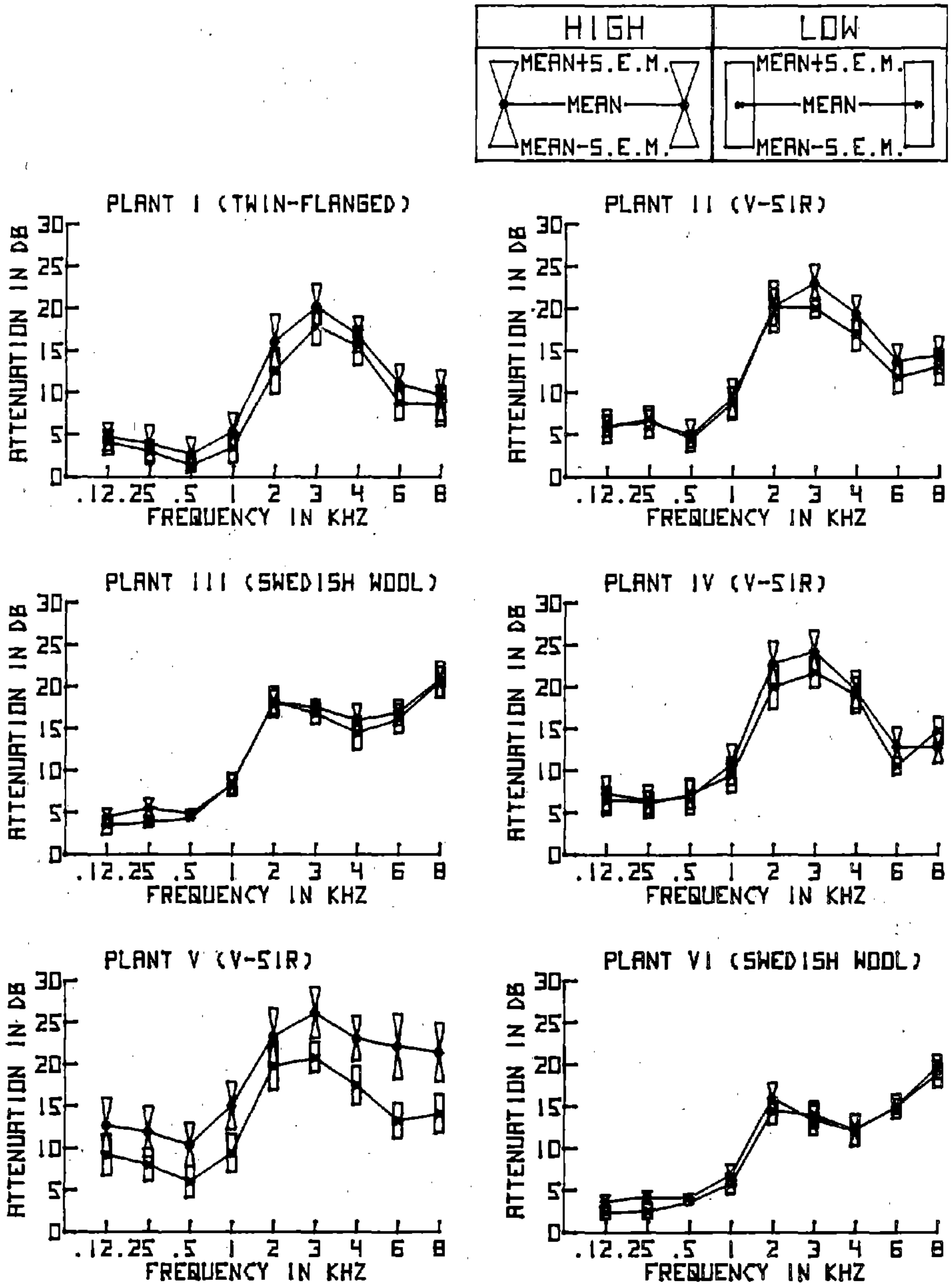


Figure 12. Mean earplug attenuation versus one-third octave band center frequency for workers in "high" compared to "low" plant noise exposures.

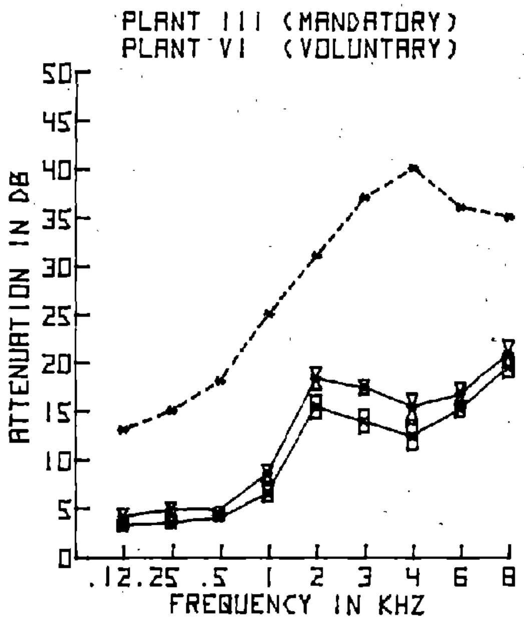


Figure 13a

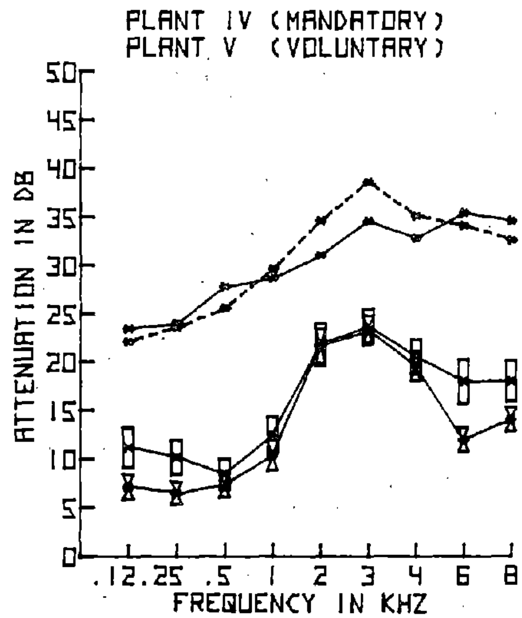


Figure 13b

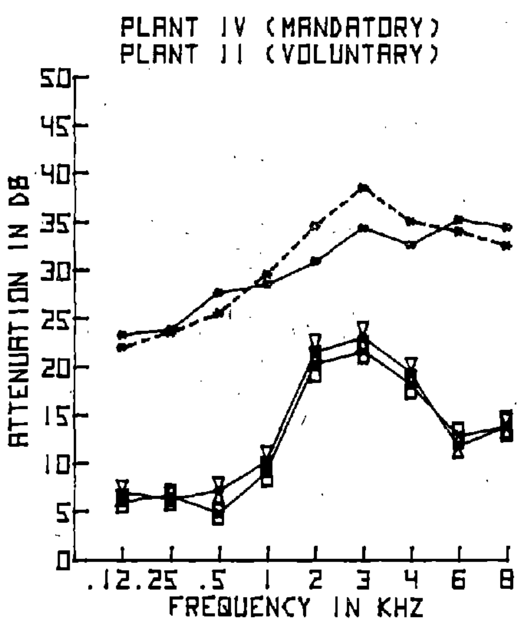


Figure 13c

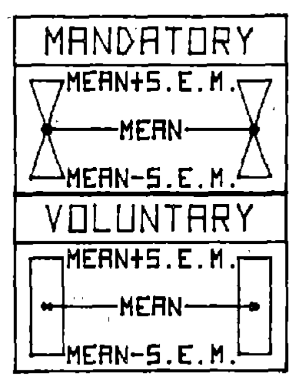


Figure 13. Mean earplug attenuation versus one-third octave band center frequency at plants with mandatory compared to voluntary policies of: (a) Swedish Wool earplug usage; (b) and (c) V-51R earplug usage. Mean attenuation is also shows for lab data reported by the earplug distributors (dashed lines). Also shown in (b) and (c) are similar data (solid line) obtained at WPAFB using the field method of testing.

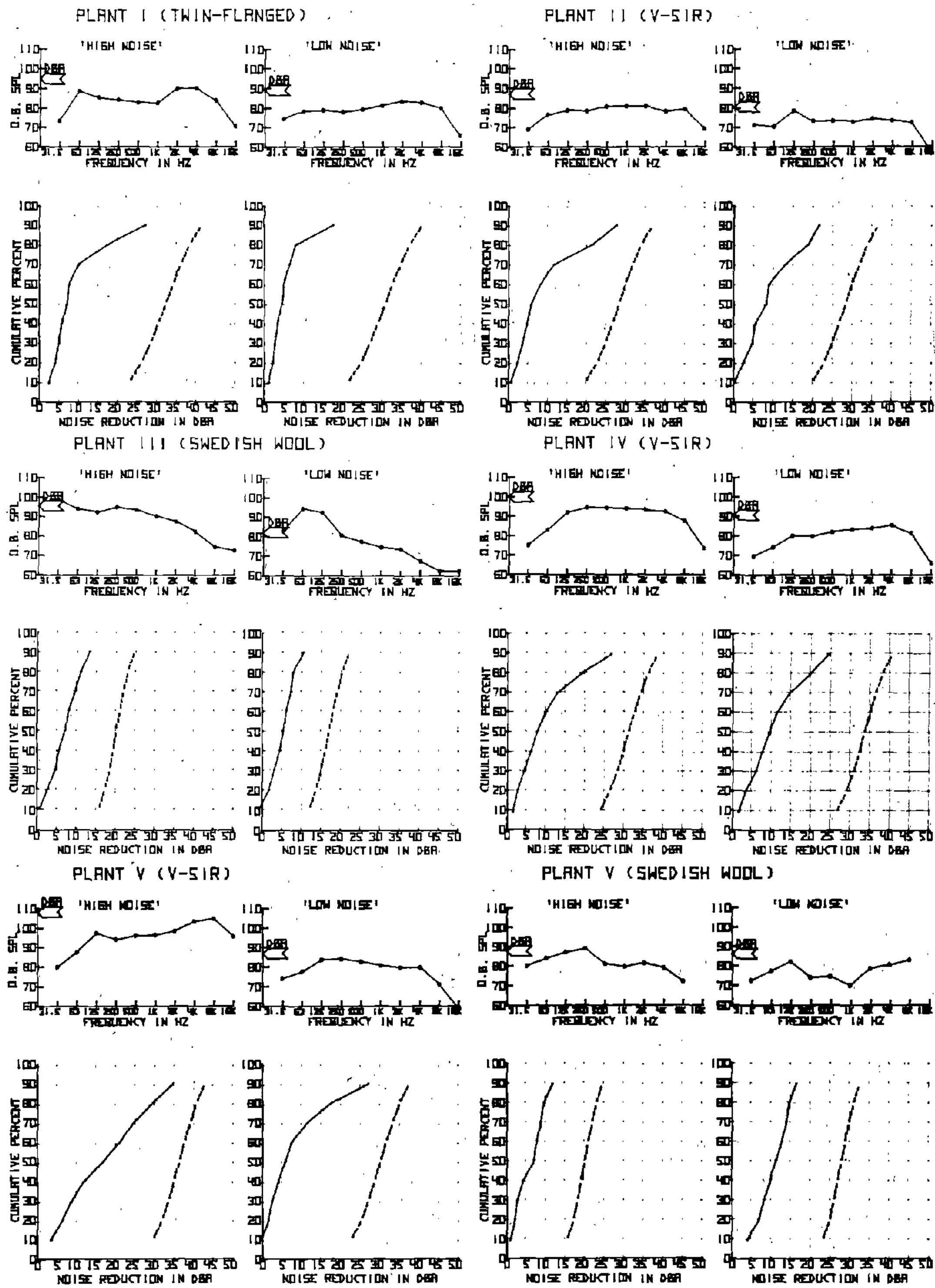


Figure 14. High and Low noise group data: at each plant
top: sound pressure level versus octave band center frequency
bottom: cumulative percent of population versus noise reduction values computed using field data (N=14 subjects x 4 tests; solid line) and using lab data reported by the earplug distributors (dashed line).

Table 3. Noise Reduction Factors, R, in dBA Assuming 'Pink Noise' (Equal Octave Band Sound Pressure Levels in All Frequency Bands)

V-51R EARPLUGS EVALUATED AT NPARB

CUMULATIVE PERCENT(%)	FIELD METHOD(*) TEST NUMBERS 1	2	3	1-3	1-3 EST**	LAB METHOD TEST NUMBERS 1	2	3	1-3	1-3 EST**
10	21.3	23.3	22.9	21.0	23.9	23.0	24.5	24.1	24.1	22.8
25	25.3	27.4	24.8	25.9	26.9	25.8	26.6	24.9	26.1	26.6
50	29.2	29.9	30.5	28.6	30.2	28.3	30.7	29.1	29.0	30.6
75	32.6	32.7	31.6	32.0	33.3	29.9	35.1	31.5	31.8	34.5
90	34.2	33.8	32.5	33.2	36.2	32.7	40.5	33.4	34.7	38.1

EARPLUG DESIGNS EVALUATED IN FIELD SURVEY

TRIPLE-FLANGED EARPLUGS (PLANT I: N=28 X 4 TESTS)

CUMULATIVE PERCENT(%)	FIELD SURVEY(*) TEST NUMBERS (1)	2	3	4	5	(2-5) EST**	2-5	LAB*** EST**
10	(-4.0)	0.1	-0.5	-2.0	-0.9	(-3.4)	-0.1	20.1
25	(3.9)	1.8	2.1	1.0	1.0	(1.9)	1.4	24.9
50	(7.6)	4.0	3.2	4.0	2.4	(7.5)	3.2	29.9
75	(14.0)	8.3	6.4	7.2	7.5	(13.0)	7.1	35.0
90	(28.2)	23.7	24.1	24.5	20.6	(17.9)	22.9	39.7

V-51R EARPLUGS (PLANTS II,IV,V: N=84 X 4 TESTS)

CUMULATIVE PERCENT(%)	FIELD SURVEY(*) TEST NUMBERS (1)	2	3	4	5	(2-5) EST**	2-5	LAB*** EST**
10	(2.2)	2.2	1.7	0.5	0.2	(0.1)	1.0	22.8
25	(6.0)	5.0	4.7	3.5	3.1	(6.1)	3.9	26.5
50	(10.6)	8.0	9.3	8.8	5.7	(12.8)	8.1	30.7
75	(23.7)	17.4	19.4	18.9	16.4	(19.4)	18.5	34.8
90	(31.1)	25.8	25.9	27.3	25.8	(25.4)	26.0	38.5

SWEDISH WOOL EARPLUGS (PLANTS III,VI: N=56 X 4 TESTS)

CUMULATIVE PERCENT(%)	FIELD SURVEY(*) TEST NUMBERS (1)	2	3	4	5	(2-5) EST**	2-5	LAB*** EST**
10	(3.3)	2.8	1.8	2.6	2.5	(3.7)	2.3	20.0
25	(7.6)	6.2	4.8	6.9	4.5	(6.8)	5.4	22.2
50	(10.6)	9.2	9.2	10.3	8.9	(10.0)	9.3	24.6
75	(13.1)	11.6	12.8	12.3	10.9	(12.8)	12.0	26.9
90	(15.7)	17.0	15.1	15.3	13.4	(15.2)	15.2	29.1

* COMPUTATION OF R FOR EACH TEST INCLUDED CORRECTION OF ATTENUATION AT EACH FREQUENCY BY THE METHOD FOR ADJUSTING MEAN ATTENUATION DISCUSSED IN APPENDIX C.

** PERCENT DISTRIBUTION OF VALUES OF R WERE DETERMINED USING MEANS AND STANDARD DEVIATIONS OF ATTENUATION (CORRECTED VALUES FOR FIELD METHOD TEST RESULTS) ASSUMING A STATISTICAL NORMAL DISTRIBUTION AT EACH TEST FREQUENCY.

*** VALUES OF R WERE COMPUTED USING DATA REPORTED BY THE EARPLUG DISTRIBUTORS. NOTE THAT THE TWO SETS OF LABORATORY DATA FOR V-51R EARPLUGS (SEE 'EXPERIMENTAL DESIGN' SECTION) WERE POOLED FOR USE IN THIS SUMMARY EVALUATION.

CONCLUSIONS

Industrial workers tested were receiving on the average only 35-50% (depending upon test frequency) of the protection potentially available from the three types of earplug designs evaluated, a finding which is consistent with the results of similar studies by Regan (9) and Padilla (8). Because properly fitted earplugs gave attenuations which were superior by about the same factors to attenuations given by improperly fitted earplugs, it seems probable that the large differences in the protection afforded were attributable to the improper wearing of earplugs in the workplace. The data also indicated that neither differences in workplace noise levels nor differing company policies of earplug usage had a significant effect upon the amount of protection afforded the worker. It is important to point out that these conclusions are the result of studying a limited number of situations. Extrapolation to the general case is not advised without additional testing in other situations and with other types of earplugs.

One finding of this study that should be considered by future investigators performing similar tests is the significantly better performance by workers in the first test when compared with their performance in the four succeeding tests. It might be hypothesized that although extreme care is taken to assure that the workers do not know exactly when they will be tested, the knowledge that they are to be tested sometime during the week is apparently enough incentive for them to wear the plugs somewhat better than usual.

This study also demonstrated that the EAL method of establishing the real-ear noise attenuation of insert-type hearing protectors is viable for use in the field, and that it produces results which do not differ significantly from results obtained with the standard ANSI test methodology.

RECOMMENDATIONS

Results from the present study indicate that:

1. More testing of the same type should be performed on workers using other types (designs) of hearing protectors. It is essential to remember that the results of this study raise serious questions about the practical protection afforded by <u>certain types</u> of earplugs. But, it would be unfair to castigate <u>all</u> earplugs on the basis of these tests. Better fitting, more comfortable types of earplugs should be tried and evaluated.

2. Studies are needed concerning design, comfort, and motivation to establish <u>why</u> earplugs are not being worn correctly in the workplace.

REFERENCES

1. American National Standards Institute, "American Standard Method for the Measurement of the Real-Ear Attenuation of Ear Protectors at Threshold," ANSI Z24.22-1957, New York, 1957.

2. American National Standards Institute and Acoustical Society of America, "Standard Method for the Measurement of Real-Ear Protection of Hearing Protectors and Physical Attenuation of Earmuffs," ANSI S3.19-1974 and ASA STD 1-1975. Standards Section, Acoustical Society of America, 335 E. 45th Street, New York, New York 10017, 1975.

3. Botsford, J. H., "Ear Protectors - Their Characteristics and Uses," Sound and Vibration, pp. 24-29, November 1972.

4. "Criteria for a Recommended Standard. . .Occupational Exposure to Noise," HSM 73-11001, U.S. Government Printing Office, Washington, D.C., 1972.

5. Flugrath, J. M. and J. B. Turbeville, Jr., "The Effectiveness of Earplugs," Sound and Vibration, pp. 32-33, May 1972.

6. Kroes, P., R. Fleming, and B. Lempert, "List of Personal Hearing Protectors and Attenuation Data," HEW Publication No. (NIOSH) 76-120, September 1975.

7. Michael, P. L., R. L. Kerlin, G. R. Bienvenue, J. H. Prout, and J. I. Shampan, "A Real-Ear Field Method for the Measurement of the Noise Attenuation of Insert-Type Hearing Protectors," HEW Publication No. (NIOSH) 76-181, June 1976.

8. Padilla, M., "Ear Plug Performance in Industrial Field Conditions," Sound and Vibration, pp. 33-36, May 1976.

9. Regan, D. E., "Real-Ear Attenuation of Personal Ear Protective Devices Worn in Industry," Audiology and Hearing Education, pp. 16-18, December/January 1977.

10. Tobias, J. V., "Earplug Ranking Based on the Protector-Attenuation Rating (P-AR)," Federal Aviation Administration Report No. FAA-AMA-75-11 (NTIS No. AD-A024-756), October 1975.

Appendix A. Equipment

The audiometric test van used in this study is equipped with a dual test unit to permit the testing of two persons simultaneously. It contains a 5' x 7' x 6' "quiet" chamber mounted on vibration isolators. Additional reduction of ambient noise is provided by the circumaural headphones used to present test signals to subjects. The headphones (Figure 2) were specially designed by the Pennsylvania State University Environmental Acoustics Laboratory (EAL). They consist of a muff type hearing protector (American Optical Model 1200) fitted with earphone drivers (Beyer DT-48S). Details of construction and noise attenuation may be found on pages 9-11 and 12-14, respectively, in reference 7.

The headphones are connected through a jack panel in the chamber wall to a test console just outside the chamber in the cab area of the audiometric van. A schematic diagram of the test system is shown in Figure 3. The noise generator is a General Radio Type 1382 Random Noise Generator, set to the "Pink" noise position and to a "Gain" adjustment that would not overdrive the B & K Type 1616 Third Octave Band Filter. The Type 1616 is externally powered by an R.O. Associates Model 105 power supply set to 4.5 volts D.C. Output from the third octave band filter is fed to both a Grason-Stadler Electronic Switch (1287B) and a Grason-Stadler Ten Second Timer (1223) which pulse the noise signals in a manner similar to some automatic audiometers. Settings are adjusted to produce signals with 50 millisecond rise and fall times, 300 millisecond on times, and 500 millisecond off times. A $\pm$12 volt D.C. power supply (Teledyne Philbrick Model 2235) is used in conjunction with the Grason-Stadler equipment.

The pulsed signal is channeled to a Crown D-60 power amplifier, with the gain set to maximum to prevent an inadvertent gain increase which could overdrive the headphones. However, impedance matching pads are needed to drop the voltages of the dual output signals to levels compatible with the maximum power input of 0.2 watts per headphone. Each headphone has an impedance of 5 ohms, and each pair of earphones is connected in series. The pads consist of a 25 ohm (25 watt) resistor in series with two 1 ohm (25 watt) resistors in parallel. Outputs of the pads are across the parallel-connected 1 ohm resistors, and these outputs are fed to modified Grason-Stadler 1703 automatic audiometers. (The audiometers were modified as described below.) Remote control switches are used to operate the two audiometers together. One switch starts and stops a test, and another switch controls the advancement of the pen across the audiogram card (x-axis). These switches are mounted on a control panel, along with two attenuator switches which can be used to reduce the signal levels to the audiometers by 20 dB when testing persons with better than average hearing acuity.

Modifications made to Grason-Stadler audiometers used in Hearing Protector Survey Instrumentation System:

Mechanical:

1. A hole (approximately 3/8 inch diameter) was drilled in the aluminum frame between the "Phones" jack and the wooden side and a

BNC female connector was mounted using electrical insulation washers.

2. A hole (approximately 3/16 inch diameter) was drilled in the aluminum frame between the "patient switch" and the "continuous-pulsed" switch and a Micro BA1011 double-throw, single-pole toggle switch was mounted.

Electrical:

1. Pin 6 was "lifted" from IC211 to eliminate the 2.5 dB/sec pen rate.

2. Pin 6 of "remote control" connector (previously unused) was connected to the y-axis disable switch at point 16.*

3. Input to slide wire attenuator was broken at point 10* to allow insertion of external noise signal in place of internal pure tone signal. The wiring connections for this purpose were made as follows (reference mechanical modifications): input from BNC to one side of toggle switch; center pin (common) of toggle switch to attenuator input (point 1*, bottom circuit board, below point 10*); other side of toggle switch to attenuator input before the break (point 10*, top circuit board); and BNC ground to point 9* (ground).

4. In order to stop horizontal pen movement at the end of each test frequency interval, a new logic gate was wired to an unused part of IC201; a wire was connected from pin 11 of IC203 to pin 12 (input) of IC201; the output (pin 11) of IC203 was connected to the input (pin 12) of IC201; the output (pin 11) of IC201 was connected to pin 2 of the "remote control" connector by disconnecting the white wire (this wire leads to pin 2) in the audiometer at point 30* of the board and connecting the white wire with the output of IC201.

* Internally labeled points of Grason-Stadler circuit boards.

Appendix B. Background Information on Plants Included in this Study

PLANT I:

The plant is three years old, operates on two shifts a day, and employs 150 people (50-55 had acceptable hearing level characteristics). Noise exposure in this metal fabrication plant is primarily from grinding, welding, and stamping operations. A mandatory hearing protector program was started in 1973; and a selection of earmuffs, earplugs, or band-type earplugs, all from the same manufacturer, is offered. Workers are instructed individually in the use of the hearing protectors by a plant nurse. However, actual fitting of protectors is not done, and workers apparently select their own earplug sizes (small, medium, or large - twin flange type). A strong hearing protector educational program was not evident, but a good audiometric monitoring program is in effect.

PLANT II:

Component parts, such as heat sensors, are manufactured at this 18-year-old plant in a production line type of operation that has three shifts per day. The plant employs 900 people. The process is very clean and the only noisy operations involve plastic molding and light metal punching and pressing work. The noise, however, is not particularly loud and little distinction can be made among the four exposure groups in the study design. In general, active workers have line jobs and passive workers are supervisors or foremen.

Despite the lack of significant noise problems and a company policy of voluntary usage of hearing protectors (since 1974), the plant nurse strongly encourages everyone in noisy areas to wear hearing protectors. Only V51R type earplugs are used, but a sizing device is used by the nurse to select the correct earplug size for each individual. Instruction is given on how to insert the earplugs. A corporate physician in Massachusetts that oversees the plant's program visited the plant during the week of the survey.

Annual audiometric testing was begun in 1976. From these tests it was determined that 75-80 workers had acceptable hearing level characteristics for this study.

PLANT III:

The employees of this small, 47-year-old power plant primarily monitor electricity generating systems in three shifts a day. There is little distinction between active and passive workers. However, two distinct noise exposures groups were identified. Most of the high noise exposure was caused by boiler room noise. All of the 35 employees could be categorized as generally older, easier going, and more cooperative than other groups of industrial workers. Perhaps this situation arose from a long-standing, good safety program which includes (since 1972) mandatory wearing of hearing protectors with the workers choosing the type they want.

Swedish wool has become the sole type of protector used. Each worker has his own supply from which he forms his own earplugs. The plant superintendent is responsible for monitoring the wearing of protectors and everyone consistently wears them. The distributor of the hearing protectors initially provided instructions on inserting the earplugs properly.

This plant had been a client of the contractor for five years, so audiograms were available for screening purposes. However, nearly everyone had to be tested and four employees who exceeded somewhat the hearing level criteria were used. (This fact only means that some data might be lost because of the limits on the output of the test system.)

PLANT IV:

Dirt and poor housekeeping characterize the operations in this 4-year-old ball bearing plant where a total of 70 people work three shifts a day. An important feature of the jobs in this plant is the clear distinction among the four exposure groups in the study.

The hearing conservation program consists solely of the mandatory use of hearing protectors. Only a single size (medium) of V51R type earplugs is issued. There are no personal fittings and no instructions for proper insertion. Although earplugs have been required by the company since 1973, annual audiometric monitoring is not performed.

PLANT V:

Seat belt buckles, parachute hardware, and other component parts are stamped out at this 16-year-old plant, which is fairly clean. Among the 250 employees from two shifts, a variety of job functions provides good distinction among the four exposure categories.

A comprehensive voluntary program of wearing earplugs has been in effect since 1970. Workers were instructed in how to insert V51R type earplugs, and they were fitted by a plant nurse, using a fitting device, with the appropriate size earplug. Otoscopic examinations were also made. The nurse responsible for the program resigned about six months prior to this survey. The program is now handled by the safety and personnel directors. The company has an audiometer and a sound-isolated booth for annual hearing tests administered by a trained audiometric technician; it also has completed an extensive questionnaire on the audiometric history of each worker. About 100 workers among those monitored audiometrically met the hearing level criteria.

PLANT VI:

Air noise from tool blow-offs and hand-held ejector nozzles is the primary reason for the use of earplugs in this 26-year-old plant where a wide range of sizes of "o" rings, or seals, are manufactured in three shifts. Many of the 600 employees are mold press operators and, as such, have a fixed work position. Consequently, little distinction can be made among the four exposure categories.

Hearing conservation has been a company policy for a long time and voluntary use of hearing protectors was started in 1951. Only the Swedish wool type (individual boxes) is issued, so each worker does his own fitting. As might be expected, the use of hearing protectors in this voluntary program was not quite as extensive as in Plant III which has a mandatory program with the same type of earplug.

Appendix C. Field Test Attenuation Data

DATA REDUCTION PROCEDURES

The data reduction procedure initially used when each plant survey was completed was further evaluated after all the field data had been collected because another procedure was deemed more suitable for handling the data. The differences in the procedures are explained below, but it should be noted that average attenuation values were nearly the same for both approaches.

The occluded and unoccluded audiometric measurements were marked as the midpoint of the recorded pen oscillations at each test frequency band. The marks were scored (given a numerical value) by hand, and the differences between the occluded and unoccluded scores were rounded to the nearest 5 dB. Negative attenuation values, which occur due to random sampling variability when little or no attenuation is afforded by a hearing protector, were set equal to zero because of the concern that negative values might be interpreted as amplification of the noise. Since the attenuation data reflected field measurements, they were corrected to estimate attenuation values which would have resulted if the ANSI S3.19-1974 test method had been used. Such corrections were made by applying the equations shown in Section 6.2.4 of reference 7.

Note that the use of regression equations reflects a correlation between a specific field test method and the ANSI 1974 method. Therefore, other field test systems not like the NIOSH system would have to be compared to the ANSI 1974 method independently to determine appropriate regression equations for correcting field data. Furthermore, very little data by the ANSI 1974 procedure was available from manufacturers of hearing protectors. So, the corrected field data (to ANSI 1974) in this report have been compared to laboratory data obtained using the ANSI 1957 procedure. Admittedly, the comparisons are not truly valid because the relationships between the ANSI 1957 and ANSI 1974 values for particular earplugs are not well known, but the relative magnitudes of the attenuation values between the field and the laboratory tests are such that this matter is of small consequence.

The differences between the above procedure and the one described below are in processing the audiogram cards and in correcting the field attenuation values to ANSI 1974 values. An electronic scanning instrument was used for scoring the audiogram cards. This simply required an operator to touch the marked midpoints of the threshold tracings with the tip of a "pen". The coordinates of each touched point on a calibrated electronic grid were then stored in a minicomputer. A checking procedure required the operator to go over all points on an audiogram card twice and the computer was programmed to compare the two sets of numbers for accuracy. If each number pair matched to within 1 dB, the operator could proceed to the next card; otherwise, the operation had to be repeated. After a series of data was entered into the computer, the data group was stored in files on magnetic tapes for subsequent analysis.

Again, several negative values resulted from subtracting the unoccluded thresholds from the occluded thresholds. But it was decided to leave the values negative;

otherwise, the average results would be slightly biased. The original concern about misinterpreting negative attenuation still existed; however, greater accuracy in estimating the true mean attenuation values was judged more important. All of the original field attenuation data are listed in this Appendix to the nearest 1 dB.

The procedure first used to correct the field data was found less suitable than the alternate procedure described by Henderson in Appendix C of reference 7. The procedures in Section 6.2.4 and Appendix C of reference 7 both develop regression equations from the data collected in the correlation study between the ANSI test method and the field test method, however, there is one basic difference between the two procedures. In the former, the equations represent a statistical relationship where average values of field test results are predicted from specific values of lab (ANSI) test results; conversely, the equations described in Appendix C represent a statistical relationship where average values of lab test results are predicted from specific values of field test results.

CODE IDENTIFICATIONS FOR DATA LISTING

Field Survey Test Data (4 groups x 6 plants)

ID = group letter code & subject number within group (1 to 7)

Group Code

- A: high noise/active group
- B: high noise/passive group
- C: low noise/active group
- D: low noise/passive group

= sequential test number (1 to 5)

DY = test day with respect to the number of days testing was performed at the plant

Special Test Data Obtained at WPAFB

Group codes A and B are discussed in section titled "Special Correlation Testing." Note that each subject was tested 3 times by the field (EAL) test method and 3 times by the standard laboratory test method.

PLANT I MANDATORY POLICY TWIN-FLANGED EARPLUGS

ID#	DY	--ATTENUATION/ O.B.CENTER FREQ.(KHZ)-- .5	1	2	3	4	6	8	.5	.25	.12
A11	2	31	[illegible]	52	56	61	57	42†	43	47	27
2	3	6	11	35	21	18	20	16	12	5	7
3	3	37	25	42	53	51	49	37†	30	24	26
4	4	20	19	39	36	25	32	35	15	9	14
5	5	10	13	30	26	18	11	16	10	8	-1
A21	1	21	19	37	32	33	30	27	12	4	-4
2	3	-3	-2	14	23	14	7	10	3	3	-1
3	3	1	6	12	20	18	7	11*	2	-3	-4
4	4	-4	-2	16	20	12	8*	9*	-1	-2*	4*
5	4	0	[illegible]	14	20	19	0	1	-8	-13	-6
A31	1	11	[illegible]	13	16	17	7	-1	7	7	-2
2	4	6	13	20	19	21	20	1	9	-1	0
3	4	-2	2	16	14	16	12	2	3	3	6
4	5	5	5	10	14	17	3	2	7	5	-3
5	5	21	22	24	31	30	22	20	24	15	9
A41	2	10	15	19	23	22	11	10	17	8	5
2	2	-4	-1	11	16	13	8	3	-5	1	4
3	3	3	2	16	22	21	6	13	4	-1	-2
4	4	6	13	13	17	17	10	5	-2	-5	2
5	4	4	8	18	16	10	9	5	4	-2	2
A51	1	23	24	36	45	33	37	47	27	29	18
2	3	28	28	40	48	35	33	38	32	29	16
3	3	30	28	35	45	44	44	47	31	31	19
4	4	8	15	24	35	25	24	39	20	8	1
5	5	21	26	32	45	29	33	51	22	15	11
A61	2	3	1	20	23	17	7	9	3	2	2
2	2	-1	0	15	26	23	0	7	7	-1	--
3	4	-1	2	10*	22	19	10*	8*	-3	2	-2
4	4	0	0	15	18	17	3	12	1	2	-3
5	5	3	-4	15	16	20	3	4	6	7	-5
A71	2	1	7	19	21	21	16	5	5	3	4
2	2	7	12	21	20	20	6	6	1	0	1
3	3	-1	3	13	19	17	10	6	5	-3	1
4	4	2	7	22	19	21	21	2	5	5	5
5	5	3	4	16	21	20	12	-1	1	2	-1
B11	1	-19	-3	2	10	15	33	--	6	7	1
2	2	0	0	6	7	11	19	24	2	-2	-5
3	2	3	9	8	9	8	30	20	6	-2	2
4	3	-1	4	4	3	-4	18	10	1	7	2
5	4	-3	-1	1	-2	5	8	12	-1	-3	1
B21	1	4	7	9	17	16	7	10	4	1	5
2	2	0	3	-2	15	15	7	2	0	1	--
3	3	4	6	1	21	17	3	2	-1	-6	-14
4	4	1	2	-3	13	11	-4	-3	2	-2	3
5	4	0	1	2	17	20	3	-2	-1	-2	-1
B31	1	2	3	13	18	8	10	-6	-4	-4	-4
2	2	1	-1	14	17	19	12	9	0	4	0
3	4	-1	2	5	17	14	5	-3	-3	2	5
4	4	-4	-1	9	13	15	4	-9	0	-15	-6
5	5	3	1	14	18	16	3	2	4	4	8
B41	2	11	8	7	14	6	-1	4	3	5	-3
2	3	0	-1	5	19	14	1	-5	-5	-8	2
3	4	2	1	7	14	15	4	-7	-1	1*	-2
4	4	-3	0	7	17	13	6	7	-1	2	2
5	5	3	1	4	13	12	-1	-7	3	-1	4
B51	3	18	15	32	31	28	18	13	17	11	9
2	4	17	23	39	36	32	33	29	19	15	8
3	4	17	22	32	33	32	36	30	21	27	11
4	5	23	28	47	51	47	45	53	25	25	20
5	5	16	19	33	33	30	26	31	16	15	6
B61	1	2	4	14	23	15	12	4	-1	-1	4
2	1	3	4	7	20	13	14	-3	0	2	4
3	3	1	1	6	20	14	9	4	2	-3	1
4	3	0	1	6	17	14	10	1	-1	1	3
5	4	-1	3	6	14	13	8	3	1	-2	-4
B71	1	5	7	8	23	18	7	14	8	-2	0
2	1	1	4	9	13	9	4	6	1	6	5
3	2	2	3	5	13	11	1	6	-1	-4	7
4	2	-4	-5	6	17	17	6	7	-1	-1	3
5	4	2	4	3	17	14	2	4	2	1	-2

ID#	DY	-ATTENUATION/ O.B.CENTER FREQ.(KHZ)-- .5	1	2	3	4	6	8	.5	.25	.12
C11	1	22	29	42	36	43	42	42	27	21	20
2	1	19	28	36	38	39	36	20	15	17	13
3	2	6	14	20	22	36	29*	12	4	-1	1
4	2	20	29	40	48	62	55	39	26	16	16
5	4	7	12	34	44	36	41	32	10	3	15
C21	1	-19	-4	-4	16	15	6	2	0	0	6
2	2	1	7	1	12	13	9	-4	2	-2	-16
3	3	1	-1	4	21	10	10	10	0	0	-3
4	4	-1	-7	0	12	17	4	-7	1	-1	0
5	5	6	0	-2	7	10	3	-3	-1	-1	9
C31	1	4	8	28	28	29	14	20	6	8	-4
2	2	0	-4	16	19	17	10*	9	7	3	3
3	2	1	0	17	21	--	5	14	3	0	-4
4	5	4	3	19	27	18	2	3	4	6	3
5	5	-1	-2	21	24	15	10	6	0	5	9
C41	3	6	10	4	18	22	10	2	0	0	6
2	4	3	7	1	13	19	10	0	-1	11	3
3	4	0	7	-3	13	19*	9	1	2	-3	11
4	5	2	5	1	10	14	11	11	3	0	-2
5	5	19	14	2	21	17	11	11	5	6	14
C51	1	24	26	34	48	55	33	46	24	20	22
2	2	20	21	33	40	39	23	35	23	18	15
3	3	19	21	33	45	50	34	45	24	19	7
4	4	22	28	33	45	36	24	46	24	14	8
5	5	2	9	23	30	20	17	39	4	1	0
C61	1	8	10	22	26	29	22	12	18	17	4
2	1	6	3	16	23	22	16	11	4	9	8
3	2	4	2	20	23	26	14	1	1	1	3
4	3	6	6	6	10	-7	-5	-1	12	7	-8
5	4	4	2	4	15	23	8	1	1	2	4
C71	1	4	-3	8	26	19	10	6	-3	-2	3
2	1	5	3	0	18	17	13	5	1	0	2
3	2	-1	5	-2	21	12	11	14	-3	-1	-3
4	3	2	-1	3	19	17	8	8	-4	-7	3
5	5	1	-1	1	13	15	6	-4	-3	-12	-1
D11	1	3	1	4	21	19	9	12	4	0	6
2	1	-1	5	8	10	9	-4	3	-2	-5	1
3	3	4	7	13	18	16	4	8	5	12	7
4	5	5	9	8	15	10	12	23	10	15	9
5	5	-3	0	4	10	8	8	13	6	12	9
D21	1	20	18	22	31	27	10	12	7	4	0
2	1	3	4	1	7	9*	-0*	5	5	-3*	-2*
3	2	4	5	16	28	27	11	7	-1	-1	-2
4	3	7	6	8	14	10	6	9	-2	5	-8
5	3	9	7	24	23	28	19	18	-6	-13	-4
D31	2	14	17	25	29	31	12	13	7	3	1
2	3	6	0	11	15	15	12	3	9	1	-1
3	4	-16	-8	-2	16	15	0	6	-2	-2	3
4	5	4	10	15	25	18	2	-2	-1	-6	-4
5	5	-2	3	-5	10	2	-5	-4	3	-5	-16
D41	1	1	12	22	24	26	18	17	8	3	5
2	2	2	1	24	26	23	14	13	5	2	5
3	3	1	2	7	14	11	9	8	1	2	5
4	4	1	3	8	17	13	5	2	0	1	7
5	5	1	-1	10	14	9	11	6	0	0	0
D51	2	14	10	21	29	20	14	--	13	11	5
2	3	3	2	13	23	12*	13*	9	9	3	4
3	4	6	-1	17	15	12	5	13	5	0	3*
4	5	1	2	9	6	1	7	10	16	0	3
5	5	-2	0	9	17	18	9	9	0	0	2
D61	1	2	2	10	8	8	-1	-3	-2	-4	-1
2	1	1	-2	4	7	5	3	4	2	2	2
3	2	0	-4	9	10	9	4	7	-2	1	-2
4	3	2	-1	8	10	8	0	3	-5	-5	-2
5	5	-2	3	1	6	7	0	4	0	-1	-2
D71	1	-2	-7	3	11	8	5	9	1	0	8
2	3	-2	2	6	14	17	11	2	1	6	1
3	4	3	4	5	10	10	6	0	4	7	-1
4	5	7	4	9	14	5	11	8	4	2	0
5	5	-2	3	16	22	14	6	-3	3	--	3

NOTE: '-- ' ATTENUATION COULD NOT BE DETERMINED.
' *' UNOCCLUDED THRESHOLD WAS ESTIMATED USING AVERAGE FROM OTHEP TESTS.
' †' OCCLUDED THRESHOLD WAS >90 DB; VALUE USED WAS 90 DB.

PLANT II VOLUNTARY POLICY V-51R EARPLUGS

ID#	DY	.5	1	2	3	4	6	8	.5	.25	.12
		--ATTENUATION/ O.B.CENTER FREQ.(KHZ)--									
A11	2	10	1	18	20	22	17	13	3	3	4
2	3	5	9	13	21	16	17	18	3	2	1
3	4	3	2	25	19	15	19	17	7	-2	-2
4	4	0	1	13	17	17	20	24	-1	2	-4
5	5	1	3	7	18	18	17	16	1	1	0
A21	1	10	8	22	18	10	2	20	12	10	5
2	4	11	8	25	25	17	12	14	4	7	-5
3	4	-2	12	24	19	17	8	20	-1	-2	-6
4	5	-2	2	15	20	21	10	10	1	5	-1
5	5	-1	8	21	15	15	5	8	3	0	2
A31	1	28	31	34	38	42	30	29	25	20	10
2	3	19	29	35	38	36	28	38	27	15	7
3	3	24	27	32	40	39	35	38	25	15	11
4	4	27	30	33	40	41	42	44	23	18	14
5	5	21	25	35	40	39	36	32	22	28	17
A41	1	16	21	41	37	34	22	11	15	11	7
2	2	6	15	30	32	30	6	15	5	2	3
3	3	10	19	35	36	29	21	20	11	7	-1
4	4	3	12	28	24	20	16	14	11	2	-3
5	4	3	6	28	34	22	12	14	5	5	5
A51	2	32	34	36	46	38	41	35	33	30	25
2	2	22	30	38	38	32	38	36	19	17	26
3	4	2	2	18	25	22	10	13	2	6	4
4	5	-1	10	23	29	25	10	17	12	8	1
5	5	38	27	33	33	28	35	29	21	20	11
A61	1	5	10	23	27	25	16	0	5	2	2
2	1	2	9	23	27	26	16	24	7	3	2
3	2	9	11	29	34	30	13	17	9	4	4
4	4	19	22	28	32	25	30	33	21	21	24
5	4	6	8	23	27	30	14	18	12	11	6
A71	1	2	8	20	25	17	7	9	1	3	5
2	2	1	0	7	17	15	2	11	-3	4	-3
3	3	0	0	16	16	13	6	11	-5	1	3
4	3	2	2	4	9	9	2	10	3	-2	-3
5	5	1	-1	-3	10	5	-2	7	0	0	-5
B11	1	-14	-6	5	11	7	-6	13	15	5	4
2	2	10	13	11	28	19	3	4	3	-2	-3
3	4	-1	0	12	19	14	5	13	-1	-3	-3
4	5	1	4	2	14	8	3	-4	3	2	2
5	5	-4	-5	-1	19	9	6	3	-1	3	-2
B21	1	0	0	4	11	15	18	2	0	2	2
2	1	-1	-1	2	11	10	9	4	-1	0	0
3	2	2	1	5	14	11	7	-1	-2	2	0
4	3	-4	-1	2	11	16	14	3	-0*	0	6
5	4	-1	0	1	13	13	12	3	-2	1	4
B31	2	8	20	35	27	25	5	10	9	7	3
2	3	-2	9	28	19	16	1	17	-1	0	-4
3	3	1	8	29	18	20	14	32	4	-2	0
4	4	15	24	36	24	24	17	26	15	11	6
5	5	7	15	30	19	18	11	20	9	4	3
B41	1	28	32	35	38	32	36	36	35	25	21
2	2	25	33	45	43	40	35	35	26	25	20
3	3	26	27	38	38	29	39	32	29	24	15
4	3	24	28	35	37	30	39	39	19	18	18
5	4	20	25	32	37	38	26	19	23	19	14
B51	1	4	5	20	29	17	19	7	10	6	1
2	1	3	4	14	12	16	17	3	5	2	2
3	3	14	12	19	26	17	16	4	4	5	2
4	4	10	9	16	23	19	11	7	3	4	5
5	5	-1	5	7	20	18	11	6	2	0	3
B61	1	13	19	28	29	30	30	15	16	13	13
2	2	4	3	12	20	19	17	19	5	10	4
3	3	--	4	10	--	--	7	2	2	2	-1
4	3	15	21	31	29	31	24	18	15	13	8
5	4	1	5	22	25	20	16	8	2	-2	7
B71	1	14	17	33	28	29	42	48	14	12	15
2	2	0	10	18	25	23	20	21	6	5	3
3	3	1	5	13	15	13	14	18	3	8	4
4	4	4	2	11	16	14	18	19	-1	6	-2
5	5	-4	0	9	17	12	14	10	2	-1	6

ID#	DY	.5	1	2	3	4	6	8	.5	.25	.12
		--ATTENUATION/ O.B.CENTER FREQ.(KHZ)--									
C11	2	34	33	36	36	43	42	36	26	21	23
2	3	24	23	33	34	25	30	31	19	24	17
3	4	26	19	33	39	40	47	47	24	27	26
4	5	10	16	27	31	25	48	37	9	6	0
5	5	-3	7	17	24	23	26	26	-1	-3	-1
C21	1	3	7	19	24	19	17	15	2	-2	4
2	3	3	5	10	10	9	18	5	-1	-1	3
3	4	5	6	12	23	15	17	8	7	3	0
4	5	3	9	13	23	17	15	6	0	-1	0
5	5	10	13	20	28	23	18	16	5	4	0
C31	1	0	-1	11	14	9	6	2	0	2	0
2	1	1	4	24	25	19	10	-2	3	-1	5
3	2	1	2	3	11	10	2	0	0	2	1
4	2	-2	0	1	8	3	4	-2	3	2	-5
5	4	1	0	15	20	18	12	4	1	0	1
C41	3	4	14	28	32	26	20	16	12	8	0
2	3	21	22	30	35	30	24	25	22	12	14
3	4	16	20	33	31	28	25	28	21	20	16
4	5	4	9	23	24	20	22	16	6	1	0
5	5	4	14	28	26	23	8	3	5	4	3
C51	1	15	19	29	31	25	16	20	9	10	9
2	1	11	20	25	24	23	16	20	18	9	4
3	2	7	8	20	25	23	12	14	9	9	-5
4	2	1	3	21	27	23	13	11	0	6	5
5	4	6	6	19	29	21	15	23	6	0	4
C61	1	1	-4	14	14	10	7	16	-1	0	-2
2	2	-1	2	24	20	18	11	13	3	3	-4
3	3	13	23	41	23	25	25	29	18	19	13
4	3	-2	-3	15	15	13	18	10	0	0	-7
5	4	-1	-1	20	16	11	9	11	-6	0	-2
C71	2	5	6	14	21	23	9	21	6	3	4
2	2	5	10	18	21	17	14	28	-1	5	-1
3	3	2	4	6	18	13	9	6	3	-1	0
4	4	0	7	11	19	20	15	18	3	6	2
5	4	29	23	28	29	26	31	41	24	19	19
D11	1	5	8	12	27	24	17	4	1	2	4
2	2	-3	0	9	15	15	2	2	4	3	-1
3	3	6	8	19	23	21	10	10	12	10	2
4	4	-2	3	0	10	5	1	1	4	2	2
5	4	1	2	2	10	9	3	-4	-1	0	-3
D21	1	20	25	36	26	25	27	32	24	19	11
2	1	4	9	21	21	21	19	26	10	1	-3
3	2	8	13	23	24	23	20	35	15	3	1
4	5	19	15	27	22	23	19	34	12	9	6
5	5	18	19	28	24	23	29	33	19	13	10
D31	1	16	23	42	18	25	17	18	21	20	14
2	1	9	8	20	16	21	8	14	6	6	-3
3	2	19	25	38	27	28	18	12	16	22	14
4	3	16	23	34	22	24	24	20	17	14	8
5	4	23	25	39	30	30	19	13	21	21	15
D41	1	4	2	15	18	14	0	5	5	2	-3
2	2	-4	-3	12	17	14	9	13	-2	-3	-2
3	3	14	1	10	17	19	2	8	6	9	-1
4	3	4	-3	-6	-5	-1	-9	2	4	5	-4
5	4	1	-7	11	15	10	3	10	2	-3	3
D51	1	23	27	34	23	20	44	29	22	19	7
2	2	-4	-4	9	18	8	0	7	3	-2	-1
3	4	-4	7	17	19	17	7	22	1	-1	6
4	5	17	24	34	31	23	15	28	17	20	13
5	5	0	7	15	15	12	1	12	2	3	8
D61	1	18	28	37	25	30	29	18	18	18	7
2	2	3	20	26	21	18	6	5	14	5	-1
3	2	14	25	25	26	16	13	4	14	18	7
4	3	8	19	27	27	28	15	23	16	2	14
5	4	9	27	37	19	21	8	11	10	15	10
D71	2	16	21	38	32	28	20	19	16	22	22
2	3	2	11	27	21	24	17	12	5	7	6
3	4	6	5	22	13	18	4	17	6	5	1
4	5	0	5	12	14	12	6	8	1	6	4
5	5	2	1	17	19	13	-1	5	3	4	7

NOTE: '-- ' ATTENUATION COULD NOT BE DETERMINED.
' *' UNOCCLUDED THRESHOLD WAS ESTIMATED USING AVERAGE FROM OTHER TESTS.
' †' OCCLUDED THRESHOLD WAS >90 DB; VALUE USED WAS 90 DB.

PLANT III MANDATORY POLICY SWEDISH WOOL EARPLUGS

ID#	D	--ATTENUATION/ O.B.CENTER FREQ.(KHZ)--									
	Y	.5	1	2	3	4	6	8	.5	.25	.12
A11	2	6	8	16	22	24	25	19	10	4	4
2	3	8	16	23	29	28	29	39	13	12	-2
3	4	12	13	14	20	19	17	28	14	9	2
4	4	0	8	11	15	15	25	33	0	-1	-12
5	5	3	10	10	13	17	20	28	6	-3	-5
A21	1	5	3	12	12	13	15	21	6	4	-1
2	2	5	-2	19	18	16	18	27	8	4	9
3	2	6	3	13	14	13	16	28	3	2	-2
4	3	8	8	22	26	27	25	34	9	5	9
5	4	1	2	13	21	12	18	24	4	6	1
A31	1	15	15	28	30	25	15	13	13	12	0
2	2	5	14	25	24*	20*	10	11*	9	11*	0
3	3	11	7	23	15	19	8	9	12	7	0
4	4	11	9	25	25	22	12	16	9	7	7
5	5	12	11	21	16	10	7	8	4	9	4
A41	1	8	10	12	12	10	18	31	8	6	1
2	2	5	8	7	9	12	17	22	6	6	3
3	3	0	11	9	14	12	11	20	2	0	-1
4	4	4	7	6	17	16	20	26	7	4	5
5	4	3	2	4	10	11	12	21	2	-1	4
A51	2	13	14	29	29	27	27	30	9	5	2
2	2	7	8	17	15	11	7	14	9	4	2
3	3	9	10	17	19	21	23	21	2	5	2
4	4	11	14	22	19	16	14	24	10	8	2
5	4	8	10	26	20	23	29	38	11	5	0
A61	2	--	9	20	24	20	22	8	6	6	-2
2	3	7	9	19	28	16	16	10	7	3	1
3	4	7	11	16	29	19	16	13	10	6	2
4	4	7	9	18	26	16	17	12	5	3	5
5	5	9	12	18	28	19	15	13	9	7	1
A71	1	42	6	16	17	13	16	29	0	4	-2
2	2	3	6	11	7	7	19	15	8	-2	10
3	2	0	3	19	18	16	30	23	1	-2	4
4	3	-4	-5	14	14	8	23	23	1	-1	2
5	4	1	0	-1	5	8	17	21	5	3	1
B11	1	-17	7	20	26	22	51	31	4	1	0
2	2	6	9	16	22	24	25	32	11	7	9
3	2	3	2	17	19	18	17	30	3	3	2
4	3	11	12	20	24	24	28	25	10	7	2
5	4	2	6	10	17	14	23	26	2	4	1
B21	1	10	17	32	27	23	26	25	11	1	2
2	2	4	8	17	15	16	15	29	10	2	3
3	3	3	9	16	16	13	14	23	3	-1	8
4	4	4	8	13	7	6	12	24	3	-1	2
5	5	1	0	18	7	9	11	17	1	-1	0
B31	2	10	10	15	22	23	16	28	1	-1	0
2	3	7	8	17	19	16	9	28	5	4	5
3	4	5	8	19	12	14	13	25	5	3	-1
4	5	5	5	20	22	14	14	26	4	3	0
5	6	7	7	15	16	19	10	25	3	-1	-4
B41	2	14	20	26	24	17↑	12↑	13↑	17	13	5
2	3	7	9	14	15	13	17↑	13↑	8	5	-1
3	4	6	12	11	15	17↑	12↑	9↑	16	7	6
4	4	12	13	19	19	15↑	11↑	7↑	14	8	4
5	5	4	11	11	10	9	6	3	8	2	1
B51	2	11	10	17	19	22	17	23	8	9	2
2	3	6	12	18	22	24	19	29	6	7	13
3	3	10	14	19	20	20	18	21	10	10	2
4	4	12	15	23	24	29	21	28	13	9	-2
5	5	10	11	21	20	24	26	38	13	8	2
B61	1	4	7	22	13	17	22	22	3	2	1
2	2	19	22	34	28	23	25	33	18	12	3
3	3	14	13	28	22	25	29	39	19	9	-2
4	4	13	20	31	24	34	33	37	14	12	6
5	5	9	12	22	21	18	33	33	11	6	1
B71	1	16	18	24	23	31	34	39	16	11	3
2	2	18	15	21	24	29	38	45	20	12	8
3	3	10	18	24	30	37	35	45	20	17	10
4	4	18	21	36	29	28	46	48	17	18	10
5	5	17	21	21	17	29	34	40	18	12	10
C11	1	10	13	25	14	19	28	25	4	4	0
2	2	5	11	20	17	14	23	35	4	1	-2
3	2	1	11	20	12	8	11	21	2	0	-5
4	3	4	9	19	18	17	26	34	8	6	-2
5	4	3	8	19	12	7	14	22	9	2	5
C21	1	7	7	17	22	15	11	21	6	2	4
2	2	7	10	23	22	16	14	22	9	6	0
3	3	6	8	20	19	18	11	17	6	0	0
4	4	7	11	22	22	19	17	28	8	4	1
5	4	6	11	18	17	17	17	22	8	4	2
C31	1	13	16	15	21	23	21	26	7	1	-5
2	2	11	13	21	17	10	11	14	8	2	3
3	2	2	6	19	14	13	13	18	9	4	4
4	3	7	12	15	16	20	26	28	9	1	2
5	4	0	3	11	14	17	17	19	9	5	3
C41	1	6	11	22	16	16	35	39	7	3	1
2	2	16	16	30	29↑	30↑	39↑	42	12	8	7
3	3	7	13	28	27↑	18↑	36↑	36	10	8	2
4	3	13	16	24	24	27↑	32↑	44	12	3	7
5	4	9	12	23	18	22↑	37↑	37	11	9	7
C51	1	10	15	28	21	27	27	36	10	13	6
2	2	5	8	23	20	22	21	32	8	4	8
3	2	9	15	22	20	21	27	36	13	4	-2
4	3	9	10	20	22	26	24	35	6	5	3
5	4	8	10	17	14	12	15	18	6	5	0
C61	2	13	12	24	17	15	7	24	10	6	1
2	3	3	4	21	14	9	16	31	4	-1	2
3	4	6	15	19	21	18	18	29	4	5	1
4	4	8	11	21	23	17	23	31	10	3	2
5	5	6	8	13	14	15	22	43	7	4	5
C71	2	5	10	28	13	15	16↑	22↑	6	4	-5
2	3	6	9	15	12	17	12↑	27↑	6	4	0
3	3	6	10	25	16	15	16↑	23↑	3	3	2
4	5	13	12*	25	23	23↑	15↑	25↑	13	10	1
5	5	7	6	19	21	21	10↑	22↑	2	3	-1
D11	2	1	4	13	12	9	5	12	4	0	10
2	3	3	5	17	13	6	11	19	7	5	-1
3	4	1	7	8	13	10	5	8	1	-1	1
4	4	8	9	15	8	9	10	14	-1	-4	-1
5	4	-2	7	11	12	4	10	12	2	1	3
D21	1	-4	13	19	17	23	45	34	12	10	4
2	2	10	16	27	21	22	34	37	10	4	5
3	3	10	13	26	27	26	31	36	10	16	21
4	3	6	15	18	22	26	29	32	7	-2	-9
5	3	11	14	24	24	25	30	30	8	3	15
D31	2	13	11	21	25	26	19↑	14↑	6	2	3
2	3	14	13	21	35	22	4	22↑	6	-4	-7
3	4	5	13	22	23	20	18	13↑	6	3	10
4	4	11	16	29	22	27	18↑	15↑	14	4	8
5	5	10	11	19	27	24	15↑	13↑	12	6	3
D41	4	8	13	22	19	20	23	32	12	6	10
2	4	9	13	21	14	16	24	21	18	10	2
3	5	13	14	22	20	14	25	25	12	10	4
4	5	8	12	20	15	18	19	23	7	7	0
5	6	3	8	14	16	15	12	20	9	8	3
D51	2	1	1	12	10	0	0	11	-1	-1	-3
2	3	4	8	11	9	-1	5	9	3	2	-4
3	3	0	4	7	9	3	-1	2	8	0	0
4	4	3	5	8	10	0	16	16	1	2	1
5	4	4	0	11	7	7	15	24	0	3	-2
D61	1	7	7	8	15	12	9	22	7	3	1
2	2	4	-2	-1	5*	16	3	15	4	-2	-9
3	2	-3	-2	-1	8	4	10	17	-1	-3	-2
4	3	2	-1	2	7	11	6	8	5	2	-10
5	4	14	-3	-4	16	12	7	16	4	2	0
D71	1	10	16	17	26	23	28	32	12	6	2
2	2	12	18	25	36	33	40	36	14	9	2
3	3	8	16	22	27	28	29	32	13	10	9
4	3	7	11	18	22	17	20	23	9	2	2
5	4	10	8	12	26	23	33	28	11	2	6

NOTE: '-- ' ATTENUATION COULD NOT BE DETERMINED.
' *' UNOCCLUDED THRESHOLD WAS ESTIMATED USING AVERAGE FROM OTHER TESTS.
' ↑' OCCLUDED THRESHOLD WAS >90 DB; VALUE USED WAS 90 DB.

PLANT IV VOLUNTARY POLICY V-51R EARPLUGS

ID#	D Y	.5	1	2	3	4	6	8	.5	.25	.12
A11	1	13	14	29	31	31	12	25	17	3	2
2	2	10	12	21	30	22	6	36	13	9	7
3	3	7	8	25	28	22	6	20	5	0	3
4	3	6	9	29	27	21	13	16	9	0	4
5	3	1	2	17	22	20	9	16	9	8	6
A21	3	10	16	30	19	15	16	22	7	9	7
2	3	9	17	28	26	11	15	5	15	4	3
3	3	12	12	23	17	18	21	12	8	7	6
4	3	9	21	26	23	16	9	23	11	-4	3
5	3	3	11	20	11	14	14	15	5	1	-1
A31	2	1	2	30	18	12	8	-4	4	1	3
2	3	8	11	33	23	22	9	6	1	4	5
3	3	0	-9	21	15	12	2	7	0	1	-3
4	3	2	11	29	25	25	11	16	1	4	2
5	3	-4	1	27	21	19	6	8	-6	1	2
A41	2	8	2	9	21	19	14	9	1	5	-2
2	2	5	4	17	32	22	9	1	-4	1	-2
3	3	4	2	16	25	16	11	2	0	4	3
4	3	1	2	7	24	13	9	5	6	8	1
5	3	1	0	12	23	21	7	4	4	2	1
A51	2	20	25	35*	39	38	43	22	27	24	19
2	2	8	10	24*	39*	26	16	13	1	2	6
3	3	16	26	35	30	35	23	22	18	13*	9†
4	3	15	20	32	40	30	21	20	8	10	10
5	3	30	22	39	42	33	18	17	16	7	12
A61	3	30	30	46	38	42	35	30	30	23	10
2	3	26	26	35	41	34	21	27	18	18	13
3	3	22	23	40	38	37	28	21	23	25	17
4	-	--	--	--	--	--	--	--	--	--	--
5	-	--	--	--	--	--	--	--	--	--	--
A71	2	11	23	40	41	29	38	31	19	18	14
2	2	17	25	33	40	34	27	35	18	16	12
3	3	7	22	31	34	36	41	30	18	18	13
4	3	--	18	30	34	30	40	33	16	6	13
5	3	19	32	34	39	37	44	39	16	24	23
B11	1	18	18	33	33	35	25	19	14	8	10
2	2	11	8	17	26	22	13	10	8	2	6
3	3	9	9	25	27	23	17	22	12	9	3
4	3	6	10	24	24	19	16	10	10	-1	-1
5	3	6	3	19	26	18	11	10	11	0	1
B21	2	2	8	26	21	18	17	15	0	-2	-2
2	2	0	1	8	12	12	10	2	0	-2	0
3	3	-1	0	19	24	21	13	9	5	4	-4
4	3	0	1	12	17	14	15	6	0	2	0
5	3	-3	-3	5	14	11	11	10	2	2	-3
B31	2	1	6	22	17	10	19	9	8	5	3
2	2	1	7	23	22	13	26	11	3	2	2
3	3	4	5	19	14	12	25	21	5	-1	-2
4	3	-1	2	22	21	17	23	29	4	1	5
5	3	6	15	19	16	9	25	14	6	0	-2
B41	1	11	9	21	25	21	20	6	12	0	6
2	2	33	40	30	43	47	39	35	27	25	20
3	3	27	35	40	49	43	36	22	29	24	23
4	3	34	40	49	49	44	35	29	27	27	19
5	3	7	6	13	24	20	14	3	5	1	5
B51	1	-11	0	7	9	6	-9	-6	-5	-8	-6
2	2	6	3	7	5	10	-2	9	-2	0	1
3	3	9	5	9	19	21	8	14	3	9	3
4	3	6	10	15	19	11	0	-2	0	-7	3
5	3	2	6	18	16	16	-4	2	-2	-2	-2
B61	1	23	29	53	35	32	20	25	16	9	10
2	2	14	19	40	25	20	10	8	14	8	0
3	3	2	12	29	17	16	7	0	5	2	5
4	3	14	22	32	27	26	11	25	16	11	6
5	3	5	-2	13	7	-2	-9	4	-4	-5	2
B71	1	8	6	30	22	12	-1	13	2	0	0
2	2	3	2	4	9	4	-5	10	3	-1	-7
3	3	1	3	13	17	17	11	5	1	-1	3
4	3	7	11	5	16	17	1	8	5	1	2
5	3	2	3	3	10	4	-2	9	1	2	3

ID#	D Y	.5	1	2	3	4	6	8	.5	.25	.12
C11	3	33	32	42	44	37	31	37	32	27	21
2	3	20	25	42	26	31	11	24	1	3	12
3	3	19	19	26	34	35	11	25	12	7	9
4	3	11	5	14	22	15	6	11	-26	-1	-13
5	3	32	38	48	44	32	15	38	29	22	26
C21	1	8	9	19	19	25	12	16	3	1	1
2	3	-7	7	20	18	10	13	15	7	3	2
3	3	4	9	30	13	15	22	19	9	9	7
4	3	6	5	13	15	13	3	11	6	6	9
5	3	26	28	33	28	27	24	33	28	21	11
C31	2	--	--	--	--	--	--	--	--	--	--
2	2	-1	6	12	1	6	12	20	20	-12	-5
3	3	1	-1	2	11	10	3	4	1	5	1
4	3	-4	-4	6	5	5	-5	-7	-7	-10	-1
5	3	13	-1	-4	15	16	10	12	2	8	-18
C41	3	8	0	17	18	21	15	17	13	0	-1
2	3	8	3	13	23	17	18	9	8	2	1
3	3	14	8	16	21	19	19	21	13	7	3
4	3	7	1	26	25	19	14	25	-1	-1	-2
5	3	1	1	9	20	16	12	19	4	4	4
C51	2	26	36	47	49	45	26	43	31	21	12
2	2	27	22	39	37	35	22	35	27	21	18
3	3	34	34	41	38	38	17	30	31	19	21*
4	3	21	23	37	41	38	21	30	22	16	2
5	3	18	24	40	41	40	18	34	20	11	8
C61	1	--	28	29	29	27	27	32	19	10	10
2	2	11	14	21	18	16	13	12	9	3	4
3	3	13	15	26	30	24	15	22	12	7	9
4	3	14	14	19	26	29	17	22	12	7	5
5	3	15	15	22	23	19	8	14	8	5	0
C71	2	40	33	44	36	35	20	22	36	34	28
2	3	--	26	32	27	27	22	28	19	19	12
3	3	20	22	32	25	17	14	38	25	15	9
4	3	22	16	34	35	39	18	25	5	2	5
5	3	7	6	24	22	26	14	16	-2	8	10
D11	2	5	4	17	23	17	16	29	5	4	11
2	2	3	9	24	23	14	18	19	3	5	0
3	3	1	5	22	20	15	7	18	2	0	3
4	3	-3	-1	14	19	12	2	8	0	2	1
5	3	1	0	15	16	15	10	6	3	5	1
D21	3	4	-4	-1	17	14	0	10	4	1	1
2	3	0	-1	4	15	16	1	0	-6	-1	1
3	3	0	3	14	14	10	16	12	3	-1	-5
4	3	-1	7	0	7	14	-2	3	2	-5	5*
5	3	4	0	6	13	16	2	0	2	6	9
D31	2	--	13	6	11	8	10	5	7	1	1
2	2	6	17	16	22	24	23	13	1	-5	6
3	3	5	17	27	25	25	20	18	2	0	-2
4	3	31	19	29	39	41	33	31	33	28	16
5	3	4	13	22	27	24	19	13	7	2	-5
D41	1	3	10	8	28	27	25	35	8	10	16
2	2	6	12	20	14	6	-4	18	12	1	-4
3	3	7	9	4	31	30	19	30	-3	2	0
4	3	17	5	18	26	10	2	5	-1	5	-7
5	3	5	3	10	9	5	2	12	9	0	1
D51	2	-1	6	14	35	25	19	19	4	13	1
2	2	10	16	20	33	25	9	5	0	4	0
3	3	3	8	21	26	34	18	17	8	0	5*
4	3	1	-3*	-2	16	11	10	7*	2*	4*	0
5	3	22	30	35	41	42*	--	--	--	37*	31*
D61	2	-2	0	10	20	28	--	16	3	-2	-1
2	3	-2	1	18	22	25	19	18	0	2	9
3	3	-2	-1	9	19	24	4	9	5	15*	13
4	3	11	13	24	18	21	11	22	18	7	3
5	3	--	--	--	--	--	--	--	--	--	--
D71	3	--	--	--	--	--	--	--	--	--	--
2	3	0	5	13	24	15	5	13	-1	7	3
3	3	12*	8	12	14	8	11	14	-3	-2	1
4	3	3	9	16	21*	17	22	21*	--	--	--
5	3	11	11	14	24	16	18	27	2	2	3

NOTE: '-- ' ATTENUATION COULD NOT BE DETERMINED.
' *' UNOCCLUDED THRESHOLD WAS ESTIMATED USING AVERAGE FROM OTHER TESTS.
' †' OCCLUDED THRESHOLD WAS >90 DB; VALUE USED WAS 90 DB.

PLANT V   VOLUNTARY POLICY   V-51R EARPLUGS

ID#	DY	.5	1	2	3	4	6	8	.5	.25	.12
		--ATTENUATION/ O.B.CENTER FREQ.(KHZ)--									
A11	1	18	27	46	32	31	25↑	31↑	21	20	17
2	2	15	27	28	19	14	21	23↑	14	19	9
3	3	12	27	28	23	22	21↑	25↑	16	23	10
4	4	25	27	34	28	29	17↑	23	37	23	15
5	5	15	30	25	24	20	22↑	32↑	19	24	14
A21	1	31	33	35*	37*	54	--	--	26	22	17
2	2	21	26	30	38	32	21	36	22	17	4
3	3	19	17	23	32	24	28	22	22	14	12
4	4	9	14	26	35	30	15	17	10	-1	6
5	5	13	10	25	28	27	18	2	13	8	-1
A31	1	5	6	5	13	10	7	-4	3	3	1
2	2	4	7	20	14	9	8	17	2	-1	4
3	3	-2	1	3	8	7	-4	0	0	-1	0
4	4	-4	1	1	10	10	7	0	-6	-5	2
5	5	3	3	6	10	-3	8	21	1	-3	5
A41	1	8	13	27	25	23	11	21	8	13	12
2	2	19	26	33	31	28	26	26	19	18	17
3	3	15	20	27	28	26	25	33	19	13	13
4	4	9	7	21	32	25	13	25	28	16	14
5	5	-1	8	21	24	13	19	22	6	8	11
A51	1	30	31	40	43	43	54	38	30	27	22
2	3	17	25	26	35	42	49	30	20	20	20
3	3	20	20	27	38	35	48	31	26	22	12
4	4	25	26	36	33	41	50	40	27	18	12
5	5	21	20	28	24	24	39	38	26	22	13
A61	1	30	31	40	48	44	51	47	27	26	21
2	2	28	22	37	49	42	59	44	29	30	22
3	3	32	30	32	37	33	47	47	31	30	25
4	4	45	41	54	63	69	62	55	46	40	34
5	5	29	37	35	38	29	44	48	34	29	28
A71	1	11	8	12	20	14	8	8	-1	4	3
2	2	6	7	12	12	12	12	7	3	2	1
3	3	0	3	17	21	20	10	4	-1	4	1
4	4	8	7	23	29	24	13	14	-6	1	1
5	5	3	4	9	17	11	10	17	-1	3	1
B11	1	11	13	23	16	14	6	7	9	4	5
2	2	1	5	20	18	14	6	10	3	2	1
3	3	6	6	21	19	11	-1	9	3	-3	-2
4	4	6	8	20	15	13	1	8	-1	-1	2
5	5	17	16	27	29	24	20	19	7	6	2
B21	1	10	20	18	17	12	22	30	10	12	10
2	2	4	8	14	14	11	27	29	1	1	-1
3	3	-1	-3	1	17	15	5	-1	0	-1	-9
4	4	7	21	9	23	19	21	18	9	8	4
5	5	6	6	6	16	6	29	19	6	3	5
B31	1	22	30	42	45	45	48	47	18	16	13
2	2	26	34	43	49	62	51	57	30	26	23
3	3	30	40	55	47	58	57	60	35	37	28
4	4	19	29	39	45	45	45	53	24	20	18
5	5	24	39	41	45	58	51	53	26	22	20
B41	2	28	31	46	23	22	36	47	26	12	13
2	2	15	23	21	21	21	35	30	11	16	15*
3	3	16	24	33	28	26↑	46	36	12	12	17
4	4	12	20	35	26	22	--	49	45	13	33
5	5	--	26	33	37	42	17	16	32	18	27
B51	1	23	36	37	45	46↑	48	58	29	30	21
2	2	10	8	21	28	25	37	39	11	6	3
3	3	30	29	37	44	43↑	52	51	31	31	17
4	4	17	26	34	41	35	55	49	29	21	18
5	5	17	25	53	46	37	57↑	54	25	20	17
B61	1	5	12	26	30	30	12	5	1	0	10
2	2	2	5	13	16	20	8	15	-1	-7	-16
3	4	2	1	17	27	24	9	16	7	3	21
4	5	5	6	-1	-2	2	5	-2	2	10	-4
5	5	0	-4	9	12	11	12	14	-1	2	3
B71	1	1	0	9	21	15	-3	14	-1	1	3
2	2	1	3	7	21	13	1	4	1	0	-1
3	3	3	3	12	21	12	-4	-1	-2	0	0
4	4	1	1	9	19	15	5	5	5	-2	-4
5	5	1	2	12	21	16	3	10	-1	1	4

ID#	DY	.5	1	2	3	4	6	8	.5	.25	.12
		--ATTENUATION/ O.B.CENTER FREQ.(KHZ)--									
C11	1	3	0	10	12	3	10	14	-2	-4	-8
2	2	2	0	15	15	9	9	8	0	-3	-2
3	3	-4	2	11	12	7	7	13	3	-3	-3
4	4	14	11	19	18	14	22	41	12	1	8
5	5	-1	-1	9	11	13	4	20	1	0	-2
C21	1	24	20	31	25	33	32*	26	20	25	25
2	2	25	26	40	37	29	22	28	19	21	11
3	3	12	27	35	35	41	23	18	22	22	8
4	4	24	25	40	36	39	29	28	20	24	25
5	5	3	12	24	29	31	22	7	10	16	20
C31	1	35	33	45	54	61	53	61	35	32	20
2	2	29	25	49	50	63	50	49	29	21	33
3	3	17	26	43	33	29	25	26	26	25	20
4	4	24	30	37	35	34	29	26	17	15	18
5	5	15	21	29	25	28	24	29	16	11	9
C41	1	29	27	39	38	37	38	47	32	19	22
2	2	17	19	27	21	20	37	39	13	12	3
3	3	15	17	26	21	26	29	30	21	16	21
4	4	6	16	16	14	21	26	30	12	5	14
5	5	10	13	24	27	31	38	46	9	5	3
C51	1	8	5	20	16	15	3	3	4	3	6
2	2	7	6	9	12	15	2	1	7	6	9
3	3	5	7	20	24	20	8	13	4	1	9
4	4	5	5	6	13	9	1	8	5	7	2
5	5	-1	3	14	18	16	5	12	3	3	1
C61	1	2	9	11	-11	22	1	-4	1	-3	1
2	2	0	1	4	13	15	3	9	-5	-1	-5
3	3	-1	-9	9	18	6	8	2	-3	-6	-4
4	4	-3	-2	1	12	2	4	4	3	1	6
5	5	-1	0	-3	12	9	7	-5	0	2	1
C71	1	2	4	2	11	18	-3	-1	3	3	3
2	2	3	4	12	19	12	13	3	7	11	9
3	3	14	17	22	23	21	19	17	16	16	9
4	4	5	8	16	21	19	14	4	11	13	8
5	5	0	4	8	16	11	6	-4	0	2	4
D11	1	31	37	41	38	43	25	34	29	27	23
2	2	4	7	21	22	14	14	21	5	-4	0
3	3	29	31	37	38	38	16	27	25	25	18
4	4	32	38	42	39	32	30	36	32	23	22
5	5	16	19	26	29	27	17	22	14	7	9
D21	1	7	6	8	16	15	7	-1	5	0	8
2	2	1	5	11	19	13	5	8	0	3	8
3	3	2	9	23	30	24	14	19	7	5	0
4	4	-1	3	15	18	7	8	11	0	-7	4
5	5	1	4	10	14	11	4	7	2	5	8
D31	1	13	19	35	30	29	19	8	13	5	5
2	2	19	26	42	33	38	26	19	15	17	13
3	3	5	10	33	25	20	22	12	4	4	3
4	4	0	6	19	21	17	15	0	3	2	1
5	5	-1	6	29	24	24	14	5	1	0	5
D41	1	18	18	30	31	29	21	16	6	3	4
2	2	4	7	13	19	18	5	12	3	3	3
3	3	7	8	19	20	14	5	7	7	-1	0
4	4	-1	3	10	11	10	-2	23	0	3	1
5	5	1	5	15	19	10	5	4	-3	1	3
D51	1	--	3	2	12	3	1	3	5	-11	-10
2	2	7	4	14	18	10	9	1	8	8	-9
3	3	4	1	-2	-1	1	-2	2	6	5	-2
4	4	1	-2	12	22	11	14	2	5	5	3
5	5	10	4	11	14	8	-1	10	3	1	-6
D61	1	8	10	11	20	15	7	14	1	4	6
2	2	1	3	12	19	12	7	17	1	11	2
3	3	5	11	22	25	18	36	36	7	9	4
4	4	3	2	8	9	6	8	12	0	-2	-6
5	5	-4	-1	9	15	13	0	13	-3	-2	-7
D71	1	--	--	--	--	--	--	--	37	29	33
2	2	--	8	15	22	19	12	16	3	4	9
3	3	31	31	29	35	35	52	43↑	36	33	25
4	4	41	28	36	33	34	42	37↑	44	34	28
5	5	-1	3	8	18	15	9	0	-1	0	2

NOTE: '-- ' ATTENUATION COULD NOT BE DETERMINED.
' *' UNOCCLUDED THRESHOLD WAS ESTIMATED USING AVERAGE FROM OTHER TESTS.
' ↑' OCCLUDED THRESHOLD WAS >90 DB; VALUE USED WAS 90 DB.

PLANT VI   MANDATORY POLICY   SWEDISH WOOL EARPLUGS

ID#	DY	.5	1	2	3	4	6	8	.5	.25	.12
A11	1	10	11	22	19	26	27	32	13	1	11
2	2	11*	17	27	21	26	32	37	15	14	6
3	3	9	11	22	21	23	20	20	11	5	-2
4	4	2	1	12	15	12	11	31	4	0	2
5	5	2	1	17	14	16	12	26	4	0	-1
A21	1	8	4	12	4	5	17	32	6	1	-2
2	2	-6	-1	7	3	-2	7	23	1	-3	-3
3	3	2	-2	1	2	1	6	18	1	1	2
4	4	0	-1	8	9	8	13	30	4	8	4
5	5	4	3	16	11	4	9	21	3	2	0
A31	1	11	10	26	22	19	29	32	12	7	3
2	2	13	15	29	22	21	25	30	16	7	1
3	3	12	13	25	16	17	31	33	12	8	4
4	4	12	14	31	29	23	28	28	15	9	7
5	5	9	10	23	18	17	17	20	10	7	5
A41	1	15	14	27	21	22	25	36	15	10	0
2	2	15	4	7	9	6	13	13	5	5	3
3	3	7	7	15	14	17	20	20	10	3	1
4	4	6	9	21	12	13	15	29	10	8	0
5	5	14	15	22	25	20	19	30	15	7	3
A51	1	0	-1	-2	0	2	23	18	1	3	2
2	2	5	3	1	0	8	11	11	2	-2	0
3	3	2	2	3	2	12	22	22	2	1	0
4	4	1	5	-1	1	12	15	20	5	1	0
5	5	1	1	4	-1	9	15	23	-1	3	1
A61	1	8	10	22	13	13	25	33	6	3	1
2	2	6	13	19	21	19	28	35	5	0	6
3	3	7	18	29	32	27	29	46	7	7	3
4	4	2	9	22	22	21	27	39	-1	8	5
5	5	6	9	14	13	17	20	28	3	3	1
A71	1	11	12	30	20	17	19	38	12	6	7
2	2	12	15	20	19	17	25	29	11	11	7
3	3	-4	4	9	12	3	11	20	1	0	3
4	4	7	12	19	9	12	13	19	10	7	-3
5	5	8	10	12	14	16	16	17	6	4	-2
B11	1	8	12	17	16	16	18	23	5	3	2
2	2	12	12	23	24	21	14	26	9	7	5
3	3	12	13	19	13	20	21	25	11	4	-2
4	4	13	12	23	21	20	20	19	10	3	2
5	5	6	12	24	15	17	14	24	5	3	-3
B21	1	2	5	5	6	2	6	12	0	1	4
2	2	2	10	14	17	13	14	29	6	9	12
3	4	5	11	22	20	19	16	19	6	4	0
4	4	7	11	23	24	23	23	26	8	6	2
5	5	9	13	24	19	20	19	21	5	3	4
B31	1	3	3	5	9	7	12	14	0	0	-1
2	2	5	7	7	6	-2	5	0	3	4	3
3	3	3	0	2	6	3	9	13	0	-2	-2
4	4	0	1	7	6	3	13	19	0	-1	1
5	5	4	2	5	5	10	10	10	-2	10	6
B41	1	0	-2	10	10	13	17	22	-1	0	1
2	2	1	2	12	16	9	15	25	1	2	-6
3	3	0	-1	12	17	9	21	31	3	-1	-3
4	4	6	5	16	18	11	21	30	3	2	6
5	5	-3	1	12	14	14	19	25	14	5	4
B51	1	8	11	30	25	31	31	34	10	5	7
2	2	9	13	18	26	25	21	28	-4	-5	4
3	3	9	12	17	27	25	8	20	5	1	-2
4	4	6	12	19	28	23	18	25	9	-2	-9
5	5	4	8	17	18	17	13	20	1	-4	0
B61	1	3	3	13	22	10	15	21	4	9	-2
2	2	6	7	10	16	15	23	17	9	10	3
3	3	20	24	22	26	26	24	31	10	3	1
4	4	7	8	20	17	18	26	29	4	8	5
5	5	12	7	18	22	21	23	27	5	4	9
B71	1	-1	4	10	9	15	11	10	19	12	9
2	2	13	15	8	-5	1	9	5	4	6	2
3	3	9	3	7	0	10	7	18	4	1	4
4	4	11	9	11	13	7	23	11	4	8	5
5	5	11	8	10	10	9	13	11	8	11	11

ID#	DY	.5	1	2	3	4	6	8	.5	.25	.12
C11	1	9	12	19	10	16	17	29	10	9	7
2	2	4	6	10	15	10	9	21	6	1	-5
3	3	4	1	5	3	5	3	19	-1	-7	-3
4	4	2	4	5	6	9	9	21	10	1	2
5	5	7	8	8	7	7	11	11	6	0	4
C21	1	9	6	18	18	21	26	26	8	5	5
2	2	5	8	20	23	22	26	31	4	2	4
3	3	9	9	15	21	19	20	28	7	2	2
4	4	5	4	14	26	21	22	29	7	4	2
5	5	6	8	17	21	17	19	22	7	0	1
C31	1	--	14	10	18	10	11	28	14	8	1
2	2	1	6	7	12	14	15	17	6	-3	-2
3	3	6	11	16	19	19	20	21	7	-3	1
4	4	9	6	14	18	16	18	28	7	5	5
5	5	9	10	18	17	17	13	26	11	11	4
C41	1	9	12	23	20	19	29	34	12	9	7
2	2	8	11	22	24	23	24	27	15	5	0
3	3	8	9	19	23	20	30	32	8	5	0
4	4	11	10	19	22	22	31	25	10	8	1
5	5	7	7	17	14	14	24	19	6	3	0
C51	1	10	18	25	30	26	32	39	19	11	7
2	2	12	22	28	31	25	31	36	19	14	4
3	3	11	17	25	26	25	29	31	13	12	2
4	4	15	16	23	29	25	28	38	17	11	7
5	5	19	15	25	27	26	26	33	12	10	5
C61	1	13	16	20	25	25	27	37	12	5	7
2	2	9	3	9	18	19	20	26	5	3	-18
3	3	7	4	10	13	16	19	16	7	2	2
4	4	13	7	13	20	19	23	28	14	10	11
5	5	6	7	10	21	19	19	31	13	4	2
C71	1	15	12	22	20	17	16	27	7	2	-2
2	2	8	14	16	11	3	9	15	5	3	1
3	3	7	1	8	6	10	15	28	5	0	4
4	4	11	14	22	19	18	7	27	9	4	-1
5	5	6	3	4	3	5	9	21	3	7	1
D11	1	3	3	2	7	4	--	--	2	2	0
2	2	1*	0	1	-2	6	--	--	6	-4	2
3	3	0	-2	4	7	5	--	--	1	-2	0
4	4	-1	-4	0	4	8	--	--	0	10	8↑
5	5	3	-1	1	6	4	--	--	0	0	8
D21	1	5	11	19	20	23	31	28	13	7	4
2	2	7	9	16	23	22	26	33	9	-4	-1
3	3	1	10	17	17	19	26	25	4	3	1
4	4	6	12	19	17	21	19	27	6	2	-4
5	5	6	11	19	17	22	26	29	10	3	1
D31	1	4	7	16	15	15	7	10	5	7	1
2	2	4	5	14	5	6	5	4	0	1	4
3	3	0	-1	10	8	10	0	2	1	1	-4
4	4	3	9	16	14	12	6	10	9	3	11
5	5	8	15	15	17	15	7	11	8	7	8
D41	1	4	4	10	12	12	11	21	4	10	-1
2	2	3	10	14	14	9	22	19	1	-2	5
3	3	9	5	8	3	3	11	9	-2	2	3
4	4	-1	0	7	10	10	17	21	9	3	-15
5	5	2	5	9	5	23	28	19	2	-7	-4
D51	1	17	17	20	17	15	23	34	9	10	6
2	2	7	7	13	19	21	14	21	6	1	0
3	3	12	10	19	29	18	22	24	6	4	-3
4	5	10	10	18	18	12	15	29	8	1	2
5	5	4	5	14	18	12	10	24	0	-3	0
D61	1	10	6	11	9	11	14	19	4	3	4
2	2	6	6	5	13	13	8	16	4	0	3
3	3	3	6	6	15	11	14	16	7	1	2
4	4	3	5	12	13	14	10	14	1	-1	-2
5	5	3	2	7	-1	-5	7	9	-3	-6	-5
D71	1	5	12	24	21	14	23	27	6	5	5
2	2	7	14	24	21	17	22	26	8	1	-1
3	3	5	3	16	16	9	26	29	2	1	4
4	4	-2	4	18	19	10	18	14	0	-2	-8
5	5	2	3	17	17	11	15	19	2	2	0

NOTE: '-- ' ATTENUATION COULD NOT BE DETERMINED.
' *' UNOCCLUDED THRESHOLD WAS ESTIMATED USING AVERAGE FROM OTHER TESTS.
' ↑' OCCLUDED THRESHOLD WAS >90 DB; VALUE USED WAS 90 DB.

WPAFB SPECIAL TESTING OF V-51R EARPLUGS

FIELD METHOD

ID#	DAY	.5	1	2	3	4	6	8	.5	.25	.12
A11	1	27	25	26	34	33	47	57	33	16	18
2	1	37	37	31	41	38	45	58	35	32	22
3	1	24	19	24	31	26	39	45	31	27	15
A21	2	34	34	37	32	34	31	43	33	24	25
2	2	30	32	35	42	41	46	49	28	23	17
3	2	33	33	36	35	37	47	38	28	19	22
A31	2	18	28	21	35	34	44	50	26	32	23
2	2	31	26	28	44	33	39	50	28	18	19
3	2	25	22	25	42	30	39	49	22	21	15
A41	2	25	27	27	35	32	42	48	25	23	19
2	2	21	23	32	22	27	35	48	23	13	14
3	2	23	20	34	30	30	39	46	24	21	16
A51	3	22	21	24	24	24	29	27	18	12	8
2	3	24	33	31	30	45	38	36	24	22	11
3	3	23	22	34	33	40	41	37	20	20	17
B11	1	35	37	30	38	39	51	40	30	22	26
2	1	28	25	34	42	29	38	33	28	26	16
3	1	28	31	41	39	40	32	21	25	22	13
B21	1	28	27	34	41	39	37	36	29	25	20
2	1	33	32	37	36	36	49	43	34	24	25
3	1	30	29	40	39	40	40	43	34	29	20
B31	2	40	36	32	33	34	43	44	33	29	24
2	2	31	32	31	33	35	38	40	31	28	18
3	2	35	32	31	35	35	43	38	36	29	19
B41	2	32	35	43	39	36	26	30	33	29	23
2	2	24	27	31	30	35	27	24	20	25	21
3	2	30	33	37	34	35	24	27	29	29	17
B51	3	23	29	35	39	25	37	40	25	24	21
2	3	30	31	36	36	27	38	40	35	27	17
3	3	23	26	33	33	34	33	45	22	21	21

ATTENUATION/CENTER FREQ. (KHZ)

LABORATORY METHOD

ID#	DAY	.12	.25	.5	1	2	3	4	6	8
A11	1	24	25	27	31	28	30	33	38	42
2	1	27	31	34	40	32	37	35	39	51
3	1	21	31	25	27	29	33	29	33	40
A21	2	25	29	31	32	33	34	34	33	46
2	2	31	28	36	38	33	38	40	45	49
3	2	28	27	30	32	34	37	45	42	50
A31	2	22	22	23	23	21	30	33	32	29
2	2	22	20	22	21	28	30	34	42	35
3	2	22	23	21	22	22	33	37	44	39
A41	2	23	23	26	27	27	40	31	33	48
2	2	17	19	22	20	32	32	24	31	45
3	2	19	18	22	20	35	40	27	27	44
A51	3	20	24	18	22	31	22	21	26	33
2	3	27	18	21	26	38	35	29	40	27
3	3	27	14	23	23	33	30	26	41	23
B11	1	26	27	30	25	25	32	37	41	44
2	1	23	21	24	27	31	34	37	40	34
3	1	26	30	26	24	35	32	28	23	30
B21	1	22	20	24	27	31	33	35	31	29
2	1	27	26	34	30	30	37	32	35	30
3	1	23	25	34	30	38	36	32	40	30
B31	2	29	24	30	30	30	30	31	26	18
2	2	27	22	33	29	33	35	25	27	25
3	2	27	27	26	29	33	35	29	39	17
B41	2	25	25	32	34	37	39	38	24	17
2	2	27	40	50	45	50	40	54	40	42
3	2	24	26	25	30	33	39	30	29	25
B51	3	29	28	25	26	33	39	28	32	39
2	3	30	30	32	30	37	42	29	25	40
3	3	27	25	28	29	32	35	31	35	46

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