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VITAL and HEALTH STATISTICS
DATA EVALUATION AND METHODS RESEARCH

Loudness Balance Study of Selected Audiometer Earphones

Determination of the characteristics of three configurations of TDH-39 earphones used in the first three cycles of the Health Examination Survey and the newer TDH-49 earphone, by the method of loudness balance on human subjects.

U.S. DEPT. OF HEALTH, EDUCATION, AND WELFARE
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FOREWORD

Determination of auditory threshold by air conduction testing has been included as part of the standardized examination in studies of the noninstitutional population of the United States by the Health Examination Survey (HES) since 1960. During the first study among adults the total of 6,672 examined in 1960-62 out of the sample of 7,710 were chosen to represent the 111 million adults 18-79 years of age in the civilian, noninstitutional population. In the second study among children 6-11 years of age, 7,119 were examined in 1963-65 out of the sample of 7,417 selected to represent the 24 million children of that age. In 1966-70 the study dealt with a representative sample of adolescents 12-17 years of age.

During the first two studies a total of 14 standard commercially available pure-tone audiometers with standard earphones (receivers) were used. These were all electronic instruments which generate pure tones of controllable intensity and frequency. The audiometers were calibrated on standard couplers in terms of the sound pressure at auditory threshold for people with normal unimpaired hearing as defined in the 1951 American Standard reference values insofar as was possible. These reference values had been fairly rigorously determined for several types of earphones which were no longer commercially available at the start of the Health Examination Survey. The corresponding reference values for the earphones used in the Health Examination Survey had been determined only in part at two frequencies by loudness balance on human subjects as recommended by the American Standards Association. The latter process takes into account the additional acoustic load due to compliance of flesh and leakage of sound between the ear and the cap of the earphone which have not yet been adequately simulated on the standard coupler used for calibration.

It also became apparent during the course of these HES studies as additional equipment was needed that some of the newer earphones available under the identical instrument number differed somewhat in design from those originally obtained. Consequently, the National Center for Health Statistics (NCHS) contracted with the University of Pittsburgh to have a rigorous loudness balance study made at their acoustics laboratory of the three identifiable types of earphones used in the first two studies of the Health Examination Survey so that the reliability of the data collected with the various audiometers used could be determined.

A panel of experts in the field of acoustics and statistics consisting of Alfred DiMattia of CBS Laboratories and Joan Rosenblatt and Pearl Weissler of the National Bureau of Standards was created to advise on the methods to be used in the loudness balance study.

As the NCHS project officer for this study, I worked with the project director in assuring that the study design was adequate for the purposes of NCHS, advising on analytic methods to be used, supervising portions of the statistical analyses, and reviewing the manuscript for publication.

Jean Roberts
Acting Chief, Medical Statistics Branch
Division of Health Examination Statistics

SYMBOLS

Data not available------------------------	---
Category not applicable-------------------	...
Quantity zero----------------------------	-
Quantity more than 0 but less than 0.05----	0.0
Figure does not meet standards of reliability or precision-----------------	*

CONTENTS

THIS REPORT CONTAINS the characteristics of three different configurations of Telephonics TDH-39 audiometer earphones and a newer design, the TDH-49 earphone, as determined by loudness balance on 12 human subjects. The TDH-39 earphones were ones used for determining auditory threshold in the Health Examination Surveys of 1960-1965.

The audiometers used in these surveys were all calibrated on standard couplers in terms of the sound pressure at auditory threshold for people with normal unimpaired hearing as defined in the 1951 American Standard reference values. However, these reference values had been fairly rigorously determined only for the Western Electric 705-A audiometer earphone and several other types of earphones which were no longer commercially available at the start of the Health Examination Survey. The corresponding reference values for the audiometer earphones used in the surveys had been determined only in part at two frequencies by loudness balance on human subjects as recommended by the American Standards Association. The latter process takes into account the additional acoustical load due to compliance of flesh and leakage of sound between the ear and the cap of the earphone which had not been adequately simulated on the standard coupler used for calibration.

The purpose of this study was to determine more exactly the characteristics of these four types of earphones by loudness balance on human subjects against a standard Western Electric 705-A earphone. The determination of these characteristics made possible a more rigorous assessment of the reliability of the hearing threshold data collected in the surveys.

The report describes the equipment and general experimental design used in the study.

LOUDNESS BALANCE STUDY OF SELECTED AUDIOMETER EARPHONES

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INTRODUCTION

This study was undertaken to determine the characteristics and extent of agreement among several different configurations of Telephonics TDH-39 earphones used in the Health Examination Survey and the Telephonics TDH-49 earphone employing the technique of loudness balance on human subjects.

Prior to the present study, a preliminary trial was made to test the design and technique to be used in the major project. A panel of experts in the fields of acoustics and statistics evaluated the adequacy of the preliminary trial. The majority of the members of this panel also made site visits to Pittsburgh to observe the equipment design and procedures. The data from the preliminary trial demonstrated the general adequacy of the design, equipment, and procedures. However, certain improvements were made on the basis of observations during the preliminary phases and suggestions from the panel. The description of experimental procedures presented in this report were those used in the regular study and include the modifications which were agreed upon after the preliminary investigation.

OBJECTIVES OF THE STUDY

The purpose of this study was to loudness balance, on human subjects, five "experimental" earphone configurations against the "standard" Western Electric 705-A earphone, for the purpose of establishing the sound pressures in the National Bureau of Standards 9-A coupler corresponding to the normal threshold for the experimental phones. The study of the experimental phones was made at the frequencies of 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 cycles per second (cps). The experimental phones included the three different configurations of TDH-39 phones used in the Health Examination Survey (identified by their serial numbers—7727, 7742, and 3523), the newer TDH-49 phones, and a WE 705-A phone which was included as a control to evaluate the precision with which the subjects performed the loudness balance task.

BACKGROUND OF THE PROBLEM OF AUDIOMETRIC CALIBRATION

The purpose of this loudness balance study was to obtain reliable data previously not available for pressure calibration of audiometer earphones in use in the United States today. The present deficiency arises from the following facts: (1) the National Bureau of Standards has never obtained loudness balance data for the majority of earphones employed on audiometers available at present; (2) it is difficult, without destroying the earphone itself, to identify the earphones on which some loudness balance data are available; and (3) the loudness balance data which are available for some of the earphones in use are inadequate for calibration purposes as indicated below.

Loudness balance data on human subjects are necessary because standard coupler pressures which include biological variation as a parameter cannot be determined for a given earphone without such data. For example, the heads and ears of different individuals have different physical configurations. Also the mass of the head and the compliance of the flesh varies among individuals. This means that the biological variation associated with this type of measurement must be a part of the measurement data, and one of the best ways to account for this biological variation is by employing a loudness balance technique with a group of human subjects. The eventual coupler pressure which corresponds to the mean loudness balance value for the subjects will not necessarily be equal to the mean of the ear canal pressures. However, the mean pressure in the coupler does correspond to the real loudness balance judgment and provides a means of calibrating audiometers, provided all the physical characteristics of a given earphone are retained. Hence the American Standards Association recommends the use of a loudness balance method to establish threshold pressure in the NBS-9-A coupler (Z24.5-1951),[1] (Z24.12-1952).[2]

The loudness balance data on human subjects which enabled the determination of standard coupler pressures corresponding to normal threshold for the Western Electric Type 705-A earphones was obtained by the National Bureau of Standards from hearing thresholds determined for a group of normal subjects in the 1935-36 National Health Survey.[3] This survey provided normative data which has been in use since that time. The Western Electric Type 705-A has since been employed as a standard by the National Bureau of Standards for loudness balance comparisons for several types of Permaflux earphones, thus enabling the coupler pressures to be determined for these phones.[2] However, none of these earphones were supplied with currently available commercial audiometers.

The earphone most widely used today is the TDH-39, the type used in the first three cycles of the Health Examination Survey. Some transfer characteristics for the TDH-39 with MX-41-AR cushions were determined by Cox and Bilger in 1960.[4] The standard coupler pressures which they provided were obtained by averaging data from their own loudness-balance study with data from Beltone and Allison laboratory studies.[4,5] Cox and Bilger conducted a loudness balance on six subjects and six different TDH-39 phones at two frequencies, 4000 and 8000 cycles per second. They suggested the use of the average of data from the two other laboratories for frequencies 125, 250, 500, 1000, and 2000 cycles per second. They also suggested that their own data be averaged with the data from the two other laboratories at frequencies of 4000 and 8000 cycles per second.

Since 1960 the Telephonics Corporation, manufacturers of the TDH-39 earphones, have changed the design of these earphones on at least two separate occasions but retained the TDH-39 label on them. An additional complicating factor is the fact that many audiometers in current use utilize TDH-39 earphones with cushions other than MX-41-AR. Thus, for some types of TDH-39 earphones and for those used with cushions other than an MX-41-AR, no loudness balance data are available. Telephonics Corporation is now producing a new earphone (TDH-49) for which no transfer characteristics are yet available.

Thus it is evident that there is real need to establish more adequate loudness balance data for the purpose of audiometer calibration. Some indication of the extent of the differences in characteristics of the various designs of TDH-39 phones was discovered in testing the earphones (TDH-39) utilized in the Health Examination Survey. This present study was conducted primarily to provide reliable transfer characteristics that can be used in evaluating the data collected in the first three cycles of the survey and for later use.

EXPERIMENTAL DESIGN

Subjects

Subjects selected for the study included six male and six female young adult listeners. The ages of the subjects ranged from 20 years through 29 years. All subjects were given an initial pure tone threshold hearing test at all frequencies for which loudness balance data was to be obtained. No subject was used whose threshold at any of these frequencies exceeded 5 decibels (dB) re normal threshold (ASA Z24.5-1951).[1] Appendix I provides the sex, age, and pure tone threshold of each subject.

The 12 subjects contributing data for this study were selected after hearing threshold was determined and after extensive training indicated an ability to enable, on test-retest, the replication of loudness balances within ± 3 dB. None of the subjects contributed data until he reached this level of test-retest consistency on two complete loudness balances for one phone.

Procedures for Loudness Balance Experiment

All listening was done in the anechoic chamber at the University of Pittsburgh.

Loudness balance was accomplished by the subject matching the variable tone (in the experimental phone) presented to one ear three times against the standard tone at 20 dB hearing level[a] re normal threshold (ASA Z24.5-1951)[1] in the standard WE 705-A earphone presented to the other ear, then reversing the standard and experimental phones and again balancing the variable to the standard tone three times.

The first half balance (with the standard phone on one ear and the experimental phone on the other) was accomplished for all eight test frequencies—250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 cps. The second half of a loudness balance was accomplished by switching the experimental and standard phones with the subjects again balancing the experimental to the standard phone at all test frequencies. It is possible that any threshold shift in either ear of a subject, if it occurred between the first and second halves of a given balance, could influence the obtained results. Therefore precautions were taken to obtain both halves of a given balance within a period of one-half to 1 hour. Each half-balance required 20 to 30 minutes. A rest period was therefore allowed between each half balance. The two halves of each complete balance, for each subject, were separated by about 20 minutes but not longer than 1 hour. Three complete balances were obtained by each subject at each of the eight frequencies.

The following procedures were used in obtaining loudness balance judgments from the subjects. The two attenuators in the "experimental" line (subjects' and experimenter's) were connected in series so that the voltage to the subject's attenuator could be controlled by the experimenter's attenuator. With the phones now in place, sound pressure level to the standard phone was set to equal 20 dB re normal threshold (ASA Z24.5-1951).[1] The experimenter's attenuator (outside the chamber) was set to an arbitrary value. The subject was then told to adjust his attenuator until the loudness of the tones to each ear was the same. He was asked to make this judgment as rapidly as possible while retaining a positiveness about the final judgment. (This instruction was intended to reduce fatiguing effects.) When the subject's judgment was made, the experimenter's attenuator was set to a new sound pressure level which either raised or lowered the perceived loudness of the tone in the unknown phone. The subject then changed his attenuator to again achieve balance of loudness. The signal was alternated between the ears and never appeared in both ears simultaneously. The order of presentation of the frequencies was randomized. A complete loudness balance was obtained when the same procedure was followed with the earphones reversed on the head. The ear on which the standard phone was placed for the initial trial was alternated among subjects. For any single subject, the ear on which the standard was initially placed was alternated for each complete balance.

Extreme care was used in placing the earphone directly over each subject's ear canal. This task, as well as all other aspects of the experimental procedure not controlled by the subject, was accomplished by one or the other of the two investigators.

Equipment Design

The equipment required to perform the loudness balance experiment on test subjects is diagrammed in figure 1.

The pure tone oscillator was a Hewlett Packard type 201-C audio-oscillator which had a frequency range from 20 cps to 20,000 cps. The

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[a]Slight variations from a hearing level 20 dB re normal threshold (ASA Z24.5-1951)[1] in the standard phone resulted from drift in the phone from morning till evening. These variations were highly consistent and could be specified reasonably well. They are accounted for in the analysis (see "Results and Discussion," p. 7).

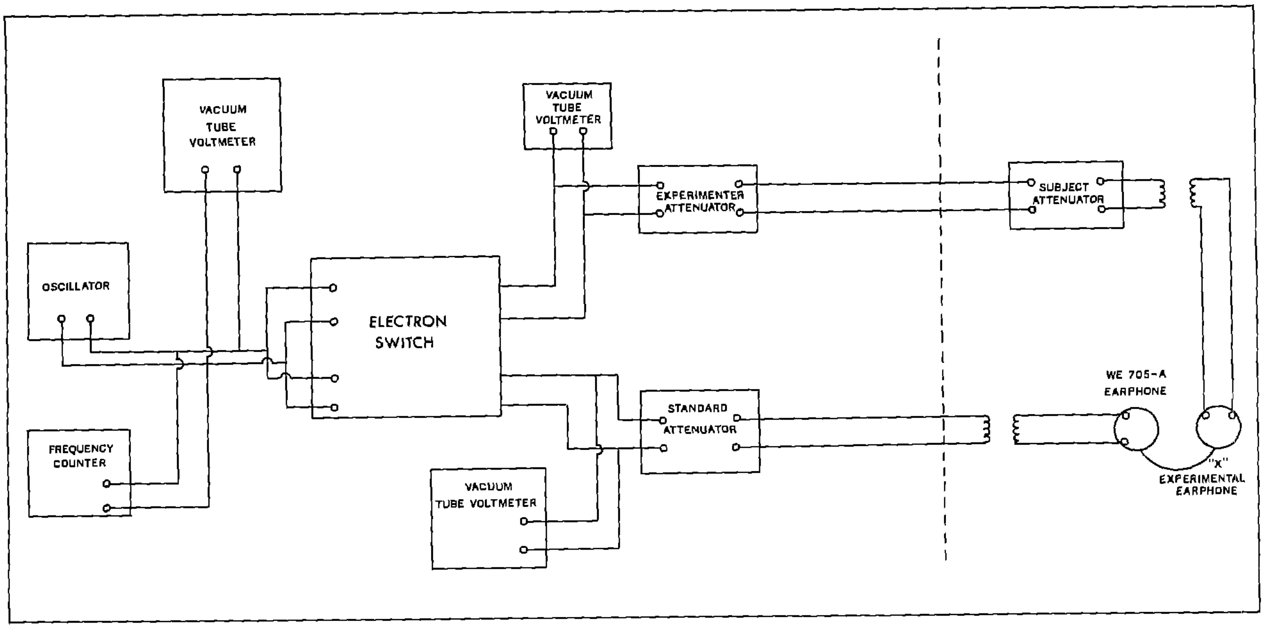

Figure 1. Equipment design for loudness balance.

frequency counter was a Hewlett Packard type 5212-A and measured frequency to an accuracy of ± 1 cps. The Grason Stadler electron switch was type 829-C and provided automatic switching of the stimulus presented to the two earphones worn by the subject. The "on" time of the stimulus was 1.5 seconds and the "off" time about 50 milliseconds. It was necessary to have "on" time sufficient for tonal judgment and "off" time sufficient for switching between the ears. Onset and offset was adequate to prevent the simultaneous perception of the stimulus in both ears. The voltmeter connected to the input terminals of the Grason Stadler electron switch was a Ballantine type 302-C and monitored input voltage to the switch. Input voltage to the switch was 1 volt.

A voltmeter, Ballantine 302-C, was employed to monitor each output channel of the Grason Stadler switch. These voltmeters were calibrated against a standard, and they maintained a constant (1 volt) signal level which eventually provided the basis for the threshold pressure in the NBS-9-A coupler.

The standard signal delivered to the standard WE 705-A phone was controlled by the "T" network labeled "standard attenuator" in figure 1. The dial settings of this attenuator required to produce 20 dB above normal threshold pressure[1] in the NBS-9-A coupler were determined by placing the standard WE 705-A phone on the NBS-9-A coupler employing the exact arrangement shown in figure 1. This assured that differences in length of connecting leads and contact resistance of connections were not a factor in altering the actual signal level delivered to the standard (WE 705-A) phone. The "T" network was a Daven three decade unit and accurate to ± 0.1 dB.

The line to the unknown phone (TDH-39, TDH-49, or experimental WE 705-A) had two "T" attenuators in series, but, otherwise, this line was similar to the standard WE 705-A line. Only equipment to the right of the dashed line in figure 1 was located in the anechoic chamber where the subject was seated.

Procedures and Equipment for Determining Sound Pressures in the NBS-9-A Coupler

The sound pressures in the NBS-9-A coupler, which correspond to normal threshold pressures[1] for each frequency and for each phone, were obtained upon completion of the loudness balance data gathering phase of the experiment.

The test arrangement shown in figure 1 indicates a calibrated voltmeter connected to the input terminals of the experimenter and subject attenuators. There are necessarily certain contact connections and lengths of wire leading from the electron switch terminals to the input terminals of the experimenter attenuator. Similarly, certain lengths of leads and contact connections exist between the experimenter and subject attenuator. These leads are long enough to pass from the anechoic test chamber to the equipment located outside the chamber. All of the leads were shielded. It was necessary to keep all of these connections and leads intact when the transfer from earphone voltage to sound pressure in the NBS-9-A coupler was accomplished. Specifically, from the data gathered in the loudness balance experiment, mean attenuator settings which correspond to a loudness balance to the standard WE 705-A phone were determined. These mean attenuation settings provided certain voltages to the phone terminals. Phone terminal voltage is a function of the attenuator setting, all leads, contact resistances, transformer, resistance networks, and the voltage applied to the input terminals of the experimenter attenuator. This input voltage was maintained at 1 volt as determined by a calibrated voltmeter. The entire system employed in the line to the unknown phone was maintained intact when the unknown phone was placed on the NBS-9-A coupler for pressure determination. This means that the phone voltage and hence pressure in the NBS-9-A coupler was determined by a setting on a precision attenuator the input voltage of which was 1 volt as established by a Weston Thermocouple Voltmeter. This voltmeter was calibrated using a Leeds Northrup Potentiometer. A block diagram of the setup employed for pressure determination in the NBS-9-A coupler is shown in figure 2. The procedure used for determining normal threshold pressure is described below.

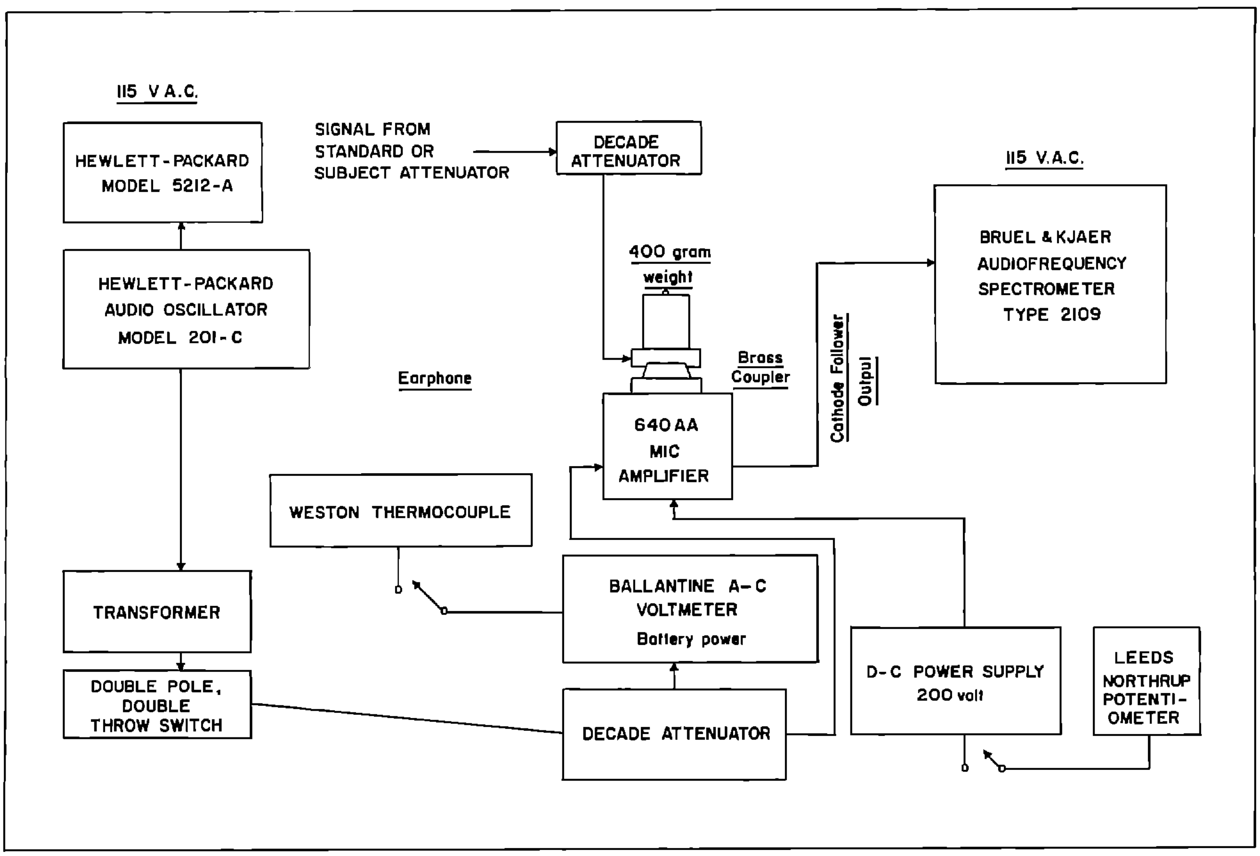

Figure 2. Diagram of the acoustic calibration equipment employed during loudness balance study.

The "experimental" phone was placed on the NBS-9-A coupler. An attenuator reading which produced 20 dB of signal above that required to produce equal loudness to the standard WE 705-A phone when the standard WE 705-A phone was adjusted to 20 dB above normal threshold (ASA Z24.5-1951)[1] was inserted in the attenuator. (While loudness balancing was accomplished at 20 dB re ASA Z24.5-1951,[1] the coupler transfer was done at 40 dB re ASA Z24.5-1951[1] in order to obtain a favorable signal to noise ratio.) The voltmeter connected to the input of the attenuator was set to the same 1 volt as employed in the data gathering phase of the experiment. The pressure now produced in the NBS-9-A coupler was 40 dB above normal threshold[1] for the particular experimental phone. This coupler pressure produced a certain open circuit voltage at the terminals of the 640-AA condenser microphone. This open circuit voltage in turn produced a reference reading on the Bruel and Kjaer audiofrequency spectrum analyzer 2109. The signal to the subject and experimenter attenuators was then switched off. A voltage was fed through the insert calibration line into the terminals of the 640-AA microphone. This voltage was adjusted by means of an insert attenuator to produce the same (balanced) reading on the spectrum analyzer as was previously produced by the sound pressure from the earphone. Threshold pressure in the NBS-9-A coupler was then determined by calculation. Below is a sample calculation to determine NBS-9-A coupler pressure, dB re 0.0002 dynes/cm^2 corresponding to normal threshold, ASA Z24.5-1951[1] for the TDH-49 phone with MX-41-AR cushion at the frequency of 1000 cycles per second:

640-AA open circuit voltage generated by TDH-49 operating at 40 dB above threshold, ASA Z24.5-1951[1]	-66.0	dB re 1 volt
640-AA pressure calibration, open circuit voltage (subtract)	-50.4	dB re 1 volt/dyne/cm^2
	-15.6	NBS-9-A coupler pressure, dB re 1 dyne/cm^2 corresponding to 40 dB above normal threshold ASA Z24.5-1951[1]
Add -40 dB	-40.0	
	-55.6	NBS-9-A coupler pressure, dB re 1 dyne/cm^2 corresponding to normal threshold (ASA Z24.5-1951)[1]
	74.0	dB corresponding to 1 dyne/cm^2 re 0.0002 dynes/cm^2
	18.4	NBS-9-A coupler pressure, dB re 0.0002 dynes/cm^2 corresponding to normal threshold (ASA Z24.5-1951)[1] (no correction for WE 705-A drift)
WE 705-A correction (dB) due to drift at 1000 cps	-1.1	
	17.3	NBS-9-A coupler pressure, dB re 0.0002 dynes/cm^2 corresponding to normal threshold (ASA Z24.5-1951)[1]

The procedure described above for obtaining coupler pressures corresponding to the subject's mean attenuator settings for loudness balances was replicated three times for each mean attenuator setting.

Checks were made daily during the course of the study, as indicated in appendix II, of the linearity of all attenuators (two in the "variable phone line," one each in the standard line and the coupler line). The Ballantine voltmeters were checked daily against the standard Weston thermocouple voltmeter. This standard voltmeter was calibrated with a Leeds Northrup Potentiometer. Real ear checks were made daily of all earphones and cords. In addition to the above checks, daily routine attenuator settings for 20 dB above normal threshold, ASA Z24.5-1951,[1] were determined for the standard phone by coupler measurements.

In the initial stages of the study all the above checks were routinely made at the *end* of each day's testing. A morning coupler measurement for 20 dB re normal threshold[1] in the standard line was accomplished about the middle of the study. A comparison of this morning check with the evening measurements obtained previously suggested the possibility of drift in the standard phone (which was operated often almost continuously from morning to late evening). Thereafter several morning and one middle-of-the-day coupler measurements were obtained. Those measurement results are presented and analyzed in the "Results and Discussion" section of this report. The daily checks revealed no additional problems which would affect the results of the study. Regular maintenance procedures such as cleaning of attenuators and replacement of batteries were observed. Appendix II contains a copy of the form which was used to record results of the routine daily checks of the equipment.

RESULTS AND DISCUSSION

The objective of this study, as indicated previously, was to determine sound pressures in an NBS-9-A coupler which correspond to normal thresholds (ASA Z24.5-1951)[1] at eight frequencies for three Telephonics TDH-39 earphones and the Telephonics TDH-49 earphone. Coupler pressures were also determined for a Western Electric 705-A phone, primarily as an experimental control to evaluate the subject's loudness balance performance.

Statistical Analyses of the Data

Each of the 12 subjects provided 18 attenuator settings for each frequency and each experimental phone. These were the settings required to balance the loudness of the experimental phone to the loudness of the standard phone at 20 dB re normal threshold.[1] These attenuator settings represent three complete balances. Of the six trials for any balance, three trials were accomplished with the experimental phone on the right ear and the standard phone on the left; they were followed by three trials with the phones reversed. Statistical analyses of the data obtained provide some insight into the performance of the subjects and the validity of the mean attenuator settings which ultimately were utilized to develop normal threshold coupler pressures. An analysis of variance for a completely randomized design involving factorial treatments for the three major variables—phones, balances, and subjects—was performed at each frequency.[b] In computing the F ratios for this analysis, it was assumed that the phones represented a fixed group and that the balances and subjects were samples drawn from a larger population. Hence the F ratios are obtained as follows:

Phones-------------------	MS_p/MS_{pxs}
Balances-----------------	MS_b/MS_{bxs}
Subjects-----------------	MS_s/MS_{bxs}
Phones within balances----	MS_{pxb}/MS_{pxbxs}
Phones within subjects----	MS_{pxs}/MS_{pxbxs}
Balances within subjects--	MS_{bxs}/MS_e
Phones within balances within subjects----------	MS_{pxbxs}/MS_e

Tables 1-8 provide the F ratios resulting from this analysis. Each of these tables provides the F-ratios for the analysis at a given frequency. Approximate values for 5 and 1 percent points in the distribution of F are also presented.[6]

Observation of the data in tables 1-8 indicates that differences among phones were highly statistically significant for all frequencies at the 1-percent probability level. This was expected on the basis of preliminary findings in calibrating the TDH-39 phones. It should be recognized that the significant F-ratios demonstrate nonchance differences among mean attenuator settings required to loudness balance the experimental phones to the standard. Since the earphone variable was of major concern in this study and since differences among phones in terms of loudness judgments appear to be real on the basis of the analysis of the variances,

[b]The University of Pittsburgh IBM 7090 computer and the Analysis of Variance for Factorial Design Program (version of May 20, 1964) from the Biomedical Division, UCLA Health Sciences Computing Facility, were utilized in performing the analysis.

closer inspection of the relationships among phones seemed desirable. As may be seen in table 9, the average settings for the experimental WE 705-A were significantly higher than the average for all other experimental phones ($P<.05$) at the lower four frequencies (250-3000 cps); TDH-39 No.3523 was significantly higher than the average of the remainder at 250 and 500 cps, while the other two TDH-39's were significantly lower than the average of the others at the lower frequencies (250-2000 cps for No.7742 and 500-3000 cps for No.7727) and significantly higher than the average of the remainder at 6000-8000 cps.

It should be emphasized again, however, that differences between mean attenuator settings of any two phones may have little meaning in terms of actual differences in coupler pressures required for calibration of these phones. Statistical tests of the differences between the mean attenuator settings for these phones will enable a determination of the real differences among these phones required for loudness balance to a standard; they will not necessarily demonstrate differences among coupler pressures resulting from the mean attenuator settings.

Differences among subjects were also highly statistically significant at all frequencies ($P<.01$). This result was also expected since humans do exhibit considerable real differences in biological functioning. If this were not the case, a study of this type could logically utilize a single subject. It will be noted in table 9 that subject 9 obtained significantly higher settings than the average for all 12 subjects ($P<.05$) at all frequencies and that subject 7 did so at all but 8000 cps. Subject 12, on the other hand, shows significantly lower settings on the average than the average for all other subjects at all frequencies.

An indication of the variability among subjects themselves and for them on each phone may be obtained from the averages and standard errors shown for the three balances combined in table 9 and again for each balance separately in tables 10-17.

Using Bartlett's test of homogeneity of variance,[7] the intrasubject variability was found to differ significantly among subjects. Hence the average standard errors of the subject means shown in table 9 can only be considered as approximate. This has been taken into consideration in testing the significance of subject differences as indicated above. Subjects 2 and 6 were found to be somewhat more variable in their responses than the others.

Findings from this study show that differences among balances are not statistically significant at any of the test frequencies. As indicated in tables 10-17 the average settings obtained from each balance for the various experimental phones are similar over all test frequencies. This result indicates that the subjects as a group are fairly consistent from one balance to another and hence that these results could probably be replicated satisfactorily among other highly trained listeners with comparable hearing thresholds.

The interaction of *balances* x *subjects* and *phone* x *balances* x *subjects* shows statistically significant differences ($P<.01$) at four frequencies—250, 500, 1000, and 6000 cps. At 8000 cps the differences are significant only at the 5-percent level.

These interactions do not reach statistical significance for frequencies of 2000, 3000, and 4000 cps. The *phone* x *subject* interaction is significant at the 1-percent level for frequencies of 3000 and 4000 cps. This would indicate that, at least for some frequencies, the balancing task differs somewhat from subject to subject and phone to phone.

The residual variation at each frequency tends to be much smaller than that from the phones and subjects, indicating that the principal sources of variation have been accounted for in the fitted model used for the analysis of variance here (tables 1-18).

Relationships Between Experimental Phones and the "Standard" WE 705-A

Mean attenuator settings corresponding to loudness balance with the WE 705-A phone were obtained, as previously indicated, for a new TDH-49 phone with an MX-41-AR cushion and the following TDH-39 phones which were used in Cycles I and II of the Health Examination Survey (the number which identifies the earphone is the serial number of the audiometer on which it was used):

No. 7727 Cushion *not* MX-41-AR
No. 3523 Cushion *not* MX-41-AR
No. 7742 MX-41-AR

Further identification of the cushions which were *not* MX-41-AR was not possible. In addition to these "experimental" phones, mean attenuator settings corresponding to loudness balance with the standard WE 705-A phone were obtained for an "experimental" WE 705-A. These data were obtained for frequencies of 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 cps.

From mean attenuator readings corresponding to loudness balance with the standard WE 705-A, root mean square (RMS) sound pressure levels corresponding to normal threshold in an NBS-9-A coupler were developed for each experimental earphone. Coupler pressures were obtained at 40 dB (re normal threshold)[1] —a level above that used for loudness balance. This was necessary to retain an adequate signal-to-noise ratio in this part of the study. Threshold pressures were then calculated from these values. The coupler transfers were accomplished three times for each phone in order to obtain a measure of the reliability of the procedure. Table 18 shows the insert attenuator values for 40 dB re normal threshold[1] for each replication of the transfer for the TDH-49 phone. Tables 19-22 provide the same information for the TDH-39 phones and the experimental WE 705-A. The data in these tables demonstrate that the coupler transfers were made with a high degree of precision. The greatest variation in replications for any phone was 1.8 dB at 2000 cps for the No. 7742 phone. The overwhelming majority of replications on any given phone, however, resulted in variation of two- or three-tenths of 1 dB or less.

The average insert attenuator settings for the three replications were used to calculate the normal threshold values as described previously. The NBS-9-A coupler pressures in dB re 0.0002 dynes/cm^2, which correspond to ASA Z24.5-1951[1] normal threshold, are presented in table A for each of the experimental phones and for the standard phone. The development of the pressures presented for the experimental phones in this table was the objective of this study.

It will be recalled that the task of the listener was to loudness balance a tone in the "experimental" phone to a tone of identical frequency in the "standard" (WE 705-A) phone at 20 dB re normal threshold.[1] Appropriate attenuation was introduced into the standard line at each frequency to produce the 20 dB signal. As indicated earlier, comparison of morning versus evening attenuator settings required in the standard line to produce coupler pressures equivalent to 20 dB normal threshold[1] confirmed a suspicion of some "drift" in the standard WE 705-A phone

Table A. NBS-9-A coupler pressures corresponding to normal threshold (ASA Z24.5-1951[1]) in dB re 0.0002 dynes/cm^2 for each of the phones balanced and for standard WE 705-A phone

Frequency	Standard data WE 705-A#	Experimental WE 705-A	TDH-49 MX-41-AR	TDH-39 not MX-41-AR No. 3523	TDH-39 MX-41-AR No. 7742	TDH-39 not MX-41-AR No. 7727
250 cps---------	39.6	39.3	39.7	38.5	45.4	36.0
500 cps---------	24.8	26.4	25.4	25.0	30.0	23.4
1000 cps---------	16.7	19.0	17.3	17.0	22.6	16.8
2000 cps---------	17.0	19.5	17.8	16.8	21.8	14.0
3000 cps---------	(16.0)	17.9	19.5	19.6	26.7	16.0
4000 cps---------	15.1	17.2	20.4	19.4	16.9	21.2
6000 cps---------	(17.5)	17.1	21.3	25.0	23.9	26.6
8000 cps---------	20.9	17.8	20.0	18.0	26.5	24.0

#Values in parentheses in the WE 705-A standard data were provided by personal communication from one of the consulting panel.

during the course of the day while data were being collected. Table 23 shows the mean of the 16 evening calibrations of the standard phone at each frequency and the mean of the five calibrations obtained in the morning after the phone had been given a night's "rest" together with the standard errors of estimate of these values. The loudness balance task was performed with standard line attenuator settings based upon a calibration performed immediately prior to beginning data collection. These settings correspond almost exactly to the average of the morning calibrations. It seems reasonable to assume that while the loudness balance was begun at 20 dB re normal threshold[1] each day, drift in the standard phone resulted in the balance being accomplished at slight but progressively higher levels above 20 dB re normal threshold— primarily at 250 cps to 1000 cps—as data collection progressed throughout the day. This assumption received further support from the data in table 24, which compares a calibration done at noon (called the midday calibration check) on one of the later days of the study with the average of all morning and evening calibrations. It is apparent from the data in this table that this noon calibration provided attenuator settings for 20 dB re normal threshold[1] that are practically identical to the average of all morning and evening calibrations combined. The data strongly support a progressive and linear drift of the phone during the day. The drift was apparent at frequencies below 2000 cps. It would seem reasonable to use the average of all morning and evening settings as the attenuator settings for 20 dB re normal threshold[1] in the standard line. Since the standard line attenuator settings actually used to set the levels during loudness balance differed from these averages, a correction seemed appropriate when calculating coupler pressure levels corresponding to threshold. Therefore corrections were made at the conclusion of the study when calculating these pressures. The attenuator settings based on the average of all morning and evening calibrations are compared in table 26 with the actual standard line attenuator settings used during loudness balance data collection. The differences between these settings are shown in table 26 as the correction factors which were used when calculating the coupler pressures shown in table A.

A comparison of the experimental WE 705-A data with reported WE 705-A standard data provides information about the reliability of the experimental data obtained in this study (table A). Since a WE 705-A was employed as a standard phone, and since 20 dB re normal threshold[1] pressures for this phone were established in an NBS-9-A coupler for balancing purposes, the experimental phone coupler levels should have conformed closely to WE 705-A standard data. It is noted that the maximum difference in dB between the WE 705-A experimental phone data and the standard data is 3.1 dB at 8000 cps. It might be observed that 8000 cps is widely recognized clinically, as well as experimentally, to be a difficult frequency to test with human subjects.

It is also noteworthy that the differences between standard data and experimental phone balance values obtained in this study are sometimes positive and sometimes negative and that the plus and minus values do not appear to be ordered in any systematic manner. This is further evidence that pressure data obtained in this study are not biased in any one direction. It would appear, from the WE 705-A control data presented in table A, that the loudness balance task was performed with a considerable degree of accuracy.

Coupler pressures corresponding to normal threshold (ASA 1951) in dB re 0.0002 dynes/cm^2 for the TDH-49 phone with MX-41-AR cushion, presented in table A, are of particular interest in view of the current concern for providing calibration data for this phone. The TDH-49 with an MX-41-AR cushion was included in this study for possible future use since no rigorous loudness balance data have been developed for it by any United States laboratory.

It is interesting to note the large differences in coupler pressures corresponding to normal threshold among the various configurations of TDH-39 phones (see table 25). It was mentioned early in this report that TDH-39 phones were changed in design several times and that some equipment manufacturers employ cushions other than the MX-41-AR. These phone differences combined with cushion differences appear to markedly influence the loudness developed by the phone when the coupler pressure is kept constant. This is the reason for conducting a loudness balance

Table B. Comparison of TDH-39 (MX-41-AR cushion) coupler pressures obtained in this study with current standard data for this same phone-cushion combination (pressure in dB re 0.0002 dyne/cm^2 corresponding to normal threshold, ASA Z24.5-1951)[1]

Frequency	Currently used standard TDH-39 data[5]	TDH-39 data from this study	dB differences (study-standard)
250 cps	39.5	45.4	5.9
500 cps	24.1	30.0	5.9
1000 cps	17.2	22.6	5.4
2000 cps	18.0	21.8	3.8
3000 cps	15.6	26.7	11.1
4000 cps	14.3	16.9	2.6
6000 cps	19.5	23.9	4.4
8000 cps	26.8	26.5	-0.3

study on human subjects rather than attempting to establish calibration standards through extrapolation or interpolation of coupler measurement data.

Comparison, for example, between the TDH-39 phone No. 7742 with MX-41-AR cushion and the TDH-39 No. 7727 with a similar cushion but not MX-41-AR indicates a difference in coupler pressure of 9.4 dB on the average at 250 cps to produce the same loudness for human subjects. At this frequency, it can be recalled, the control data indicated a balance (WE 705-A experimental versus WE 705-A standard) accuracy of 0.2 dB on the average. The large difference of 9.4 dB between these two TDH-39 phones at 250 cps must be attributed to differences in phones and/or cushions. At 3000 cps a comparison of these same two phones yields an average difference of 10.7 dB—again, a difference which is considered to be related to phone-cushion differences. If the major differences between TDH-39 phone and cushion combinations occurred primarily at the higher frequencies, 3000 cps and above, several explanations would be available, such as possible erratic resonances at the higher frequency when these phones are placed on an NBS coupler. However, low frequency problems of this nature have not generally been attributed to the phones. The largest differences between these two phones exist at 3000 cps and below.

The differences between the two TDH-39 phones No. 3523 and No. 7727 are small except at 8000 cps, where the average difference is 6.0 dB. This 6.0 dB difference, however, is not severe if one recalls that the WE 705-A differed from standard data by 3.1 dB at this frequency.

Comparisons of the TDH-39 phone with MX-41-AR cushion in this study with currently employed TDH-39 calibration data reveals large differences in coupler pressure values corresponding to normal threshold. These differences are tabulated in table B.

Large differences are observed between the coupler pressures obtained in this study and those currently being employed for calibration purposes. Considering the degree to which the control data in this study verified the accuracy of the results of this loudness balance experiment, it appears that the use of current data for audiometric calibration purposes has serious limitations.

Evidently the change in design of the TDH-39 phone has resulted in a variety of coupler pressures which correspond to normal threshold. The proper coupler pressure depends upon the particular TDH-39 employed as well as upon the cushion.

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DETAILED TABLES

Table 1. Source of variation, degrees of freedom, sums of squares, mean squares, and F ratios for balance at frequency of 250 cycles per second

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F ratio	F .05	F .01
Phones	4	9,052.07	2,263.02	36.48	2.58	3.78
Balances	2	62.70	31.35	0.88	19.44	99.45
Subjects	11	5,483.84	498.53	13.93	2.26	3.18
Phones x balances	8	181.47	22.68	0.51	3.00	5.00
Phones x subjects	44	2,734.86	62.16	1.39	1.54	1.84
Balances x subjects	22	787.03	35.77	4.71	1.60	1.92
Phones x balances x subjects	88	3,940.79	44.78	5.90	1.32	1.47
Residual	900	7,068.92	7.85	-	-	-

Table 2. Source of variation, degrees of freedom, sums of squares, mean squares, and F ratios for balance at frequency of 500 cycles per second

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F ratio	F .05	F .01
Phones	4	5,278.64	1,319.66	37.59	2.58	3.78
Balances	2	9.09	4.54	0.16	19.44	99.45
Subjects	11	9,302.45	845.68	30.39	2.26	3.18
Phones x balances	8	70.63	8.83	0.38	3.00	5.00
Phones x subjects	44	1,544.32	35.10	1.52	1.54	1.84
Balances x subjects	22	612.22	27.83	3.23	1.60	1.92
Phones x balances x subjects	88	2,028.94	23.06	2.68	1.32	1.47
Residual	900	8,136.44	9.04	-	-	-

Table 3. Source of variation, degrees of freedom, sums of squares, mean squares, and F ratios for balance at frequency of 1000 cycles per second

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F ratio	F .05	F .01
Phones------------------------------------	4	8,084.09	2,021.02	57.19	2.58	3.78
Balances----------------------------------	2	19.11	9.55	0.43	19.44	99.45
Subjects----------------------------------	11	17,648.44	1,604.40	71.67	2.26	3.18
Phones x balances-------------------------	8	229.83	28.73	1.11	2.05	2.74
Phones x subjects-------------------------	44	1,555.02	35.34	1.37	1.54	1.84
Balances x subjects-----------------------	22	492.52	22.39	1.94	1.60	1.92
Phones x balances x subjects---------------	88	2,275.98	25.86	2.24	1.32	1.47
Residual----------------------------------	900	10,795.56	12.00	-	-	-

Table 4. Source of variation, degrees of freedom, sums of squares, mean squares, and F ratios for balance at frequency of 2000 cycles per second

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F ratio	F .05	F .01
Phones------------------------------------	4	16,921.27	4,230.32	83.11	2.58	3.78
Balances----------------------------------	2	1.84	0.92	0.04	19.44	99.45
Subjects----------------------------------	11	14,211.38	1,291.94	55.48	2.26	3.18
Phones x balances-------------------------	8	111.56	13.94	0.61	3.00	5.00
Phones x subjects-------------------------	44	2,241.05	50.93	2.23	1.54	1.84
Balances x subjects-----------------------	22	512.27	23.28	0.97	1.78	2.31
Phones x balances x subjects---------------	88	2,012.43	22.87	0.95	1.32	1.49
Residual----------------------------------	900	22,015.36	24.46	-	-	-

Table 5. Source of variation, degrees of freedom, sums of squares, mean squares, and F ratios for balance at frequency of 3000 cycles per second

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F ratio	F .05	F .01
Phones	4	8,633.22	2,158.31	25.43	2.58	3.78
Balances	2	49.40	24.70	0.98	19.44	99.45
Subjects	11	17,952.85	1,632.08	64.55	2.26	3.18
Phones x balances	8	124.76	15.60	0.48	3.00	5.00
Phones x subjects	44	3,734.78	84.88	2.61	1.54	1.84
Balances x subjects	22	556.25	25.28	0.77	1.78	2.31
Phones x balances x subjects	88	2,859.36	32.49	0.99	1.32	1.49
Residual	900	29,871.18	33.19	-	-	-

Table 6. Source of variation, degrees of freedom, sums of squares, mean squares, and F ratios for balance at frequency of 4000 cycles per second

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F ratio	F .05	F .01
Phones	4	2,531.98	633.00	11.46	2.58	3.78
Balances	2	5.03	2.51	0.06	19.44	99.45
Subjects	11	34,555.80	2,141.44	70.02	2.26	3.18
Phones x balances	8	155.84	19.48	0.95	3.00	5.00
Phones x subjects	44	2,429.87	55.22	2.69	1.54	1.84
Balances x subjects	22	986.96	44.86	1.04	1.60	1.92
Phones x balances x subjects	88	1,804.50	20.51	0.48	1.32	1.49
Residual	900	38,797.11	43.11	-	-	-

Table 7. Source of variation, degrees of freedom, sums of squares, mean squares, and F ratios for balance at frequency of 6000 cycles per second

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F ratio	F .05	F .01
Phones	4	42,258.15	10,564.54	84.30	2.58	3.78
Balances	2	374.62	187.31	2.32	3.44	5.72
Subjects	11	27,952.39	2,541.13	31.45	2.26	3.18
Phones x balances	8	552.91	69.11	0.84	3.00	5.00
Phones x subjects	44	5,514.20	125.32	1.53	1.54	1.84
Balances x subjects	22	1,777.61	80.80	2.07	1.60	1.92
Phones x balances x subjects	88	7,203.16	81.85	2.10	1.32	1.47
Residual	900	35,223.17	39.14	-	-	-

Table 8. Source of variation, degrees of freedom, sums of squares, mean squares, and F ratios for balance at frequency of 8000 cycles per second

Source of variation	Degrees of freedom	Sums of squares	Mean squares	F ratio	F .05	F .01
Phones	4	29,857.99	7,464.50	52.05	2.58	3.78
Balances	2	170.16	85.08	0.87	19.44	99.45
Subjects	11	22,209.64	2,019.06	20.64	2.26	3.18
Phones x balances	8	1,192.24	149.03	1.79	2.05	2.74
Phones x subjects	44	6,309.65	143.40	1.72	1.54	1.84
Balances x subjects	22	2,152.42	97.84	1.66	1.60	1.92
Phones x balances x subjects	88	7,315.49	83.13	1.41	1.32	1.47
Residual	900	52,810.84	58.68	-	-	-

Table 9. Mean attenuator settings obtained in the three balances combined, by subjects, phones, and phones for each subject at each test frequency

Subject and frequency	Phones $[\pm SE=(MS_{pbs}/n)^{1/2}]$ WE 705-A	TDH-49	TDH-39 No. 7727	TDH-39 No. 7742	TDH-39 No. 3523	Mean $[\pm SE=(MS_{bs}/n)^{1/2}]$
250 cps	Attenuator setting (dB re 1 volt) (SE=±1.58)					(±1.54)
8	26.44	23.11	22.83	18.78	28.33	24.10
11	27.50	26.28	26.06	21.22	28.44	25.90
10	27.17	24.72	23.78	17.33	26.67	23.93
9	29.22	29.00	27.00	19.78	34.06	27.81
7	32.22	29.67	27.72	21.89	34.17	29.13
6	26.33	24.72	17.89	25.00	26.94	24.18
5	28.22	26.11	21.50	23.06	27.83	25.34
4	29.61	24.39	21.83	22.78	29.89	25.70
3	29.06	24.00	21.67	20.56	25.33	24.12
2	24.11	24.06	21.00	19.89	27.61	23.33
1	26.28	24.67	21.89	18.67	26.94	23.69
12	22.94	19.06	20.61	14.89	21.22	19.74
Mean $[\pm SE=(MS_{ps}/n)^{1/2}=1.32]$	27.43	24.94	22.82	20.32	28.12	24.72
500 cps	Attenuator setting (dB re 1 volt) (SE=±1.13)					(±1.36)
8	41.61	39.33	37.83	36.67	41.28	39.34
11	42.89	42.11	40.61	37.56	42.78	41.19
10	41.50	38.94	36.50	35.22	41.39	38.71
9	44.50	45.22	39.00	39.06	48.33	43.22
7	48.67	47.50	43.17	41.17	49.39	45.98
6	37.72	39.11	33.83	35.39	39.89	37.19
5	39.00	41.00	35.78	37.61	40.17	38.71
4	42.78	40.22	37.56	38.72	40.94	40.14
3	40.17	37.44	32.89	33.67	39.78	36.79
2	37.56	38.94	35.06	37.89	40.61	37.61
1	40.11	39.39	35.89	33.28	39.83	37.70
12	36.56	33.61	36.00	31.28	34.44	34.38
Mean $[\pm SE=(MS_{ps}/n)^{1/2}=\pm 0.99]$	41.09	40.28	36.84	36.34	41.64	39.24
1000 cps	Attenuator setting (dB re 1 volt) (SE=±1.20)					(±1.22)
8	50.28	47.00	43.22	44.28	48.39	46.63
11	53.22	50.00	47.50	45.89	51.00	49.52
10	50.17	46.28	43.00	42.78	48.28	46.10
9	53.83	53.78	47.39	49.17	55.61	51.96
7	59.61	56.83	51.17	47.67	56.78	54.41
6	46.44	46.06	41.39	44.28	47.67	45.17
5	49.28	47.22	40.83	44.33	47.78	46.34
4	53.83	48.61	45.28	46.06	50.06	48.66
3	46.17	43.89	40.78	40.00	45.33	43.23
2	48.89	47.61	41.06	44.28	48.39	46.05
1	49.44	46.56	40.39	42.22	48.22	45.37
12	41.72	37.11	38.17	35.22	36.78	37.82
Mean $[\pm SE=(MS_{ps}/n)^{1/2}=\pm 0.99]$	50.32	47.65	43.35	43.85	48.72	46.78
2000 cps	Attenuator setting (dB re 1 volt) (SE=±1.12)					(±1.24)
8	55.06	48.17	43.50	43.17	47.11	47.40
11	56.67	50.78	46.00	44.33	46.83	48.92
10	54.28	47.39	43.89	43.39	48.33	47.46
9	59.78	56.06	47.94	46.83	55.06	52.93
7	60.22	53.78	47.94	47.33	51.50	52.15
6	51.00	45.17	38.61	46.00	44.39	45.03
5	50.78	46.00	40.72	42.94	45.89	45.27
4	56.00	49.11	42.22	45.44	47.61	48.08
3	53.56	45.72	43.72	41.50	43.44	45.59
2	53.06	50.56	38.78	44.22	50.78	47.48
1	52.94	46.78	38.72	42.06	48.00	45.70
12	45.39	37.72	37.11	35.44	35.72	38.28
Mean $[\pm SE=(MS_{ps}/n)^{1/2}=\pm 1.18]$	54.02	48.08	42.99	43.56	47.06	47.14

Table 9. Mean attenuator settings obtained in the three balances combined, by subjects, phones, and phones for each subject at each test frequency—Con.

Subject and frequency	Phones [$\pm SE=(MS_{pbs}/n)^{1/2}$]: WE 705-A	TDH-49	TDH-39: No. 7727	TDH-39: No. 7742	TDH-39: No. 3523	Mean [$\pm SE=(MS_{bs}/n)^{1/2}$]
3000 cps	Attenuator setting (dB re 1 volt) (SE=±1.34)					(±1.30)
8	54.56	50.89	47.06	47.06	50.56	50.03
11	56.50	53.44	52.22	49.17	52.06	52.68
10	51.83	47.94	46.56	40.94	47.00	46.85
9	59.17	58.33	51.83	49.39	58.06	55.36
7	59.72	55.83	51.89	47.22	54.44	53.71
6	49.83	44.56	36.33	45.56	44.11	45.66
5	48.22	45.06	41.89	45.11	46.61	45.38
4	53.83	50.89	41.89	47.44	48.44	48.40
3	52.22	48.22	43.83	41.44	48.67	46.88
2	50.89	48.33	44.11	47.00	50.33	48.13
1	52.67	44.94	39.61	41.83	46.63	45.14
12	41.94	39.67	42.50	40.17	39.89	40.83
Mean [$\pm SE=(MS_{ps}/n)^{1/2}=\pm$ 1.54]	52.62	49.12	45.03	45.19	48.90	48.17
4000 cps	Attenuator setting (dB re 1 volt) (SE=±1.07)					(±1.73)
8	50.28	47.33	46.72	49.56	49.83	48.74
11	53.67	48.06	47.72	56.00	51.94	51.84
10	49.00	44.28	46.89	51.78	43.39	47.07
9	60.33	57.39	56.33	55.83	62.11	58.40
7	59.78	57.06	56.17	55.89	60.89	57.96
6	46.22	42.06	42.89	46.06	45.00	44.45
5	48.06	42.67	44.39	48.67	47.22	46.20
4	53.78	50.89	51.67	50.89	53.61	52.17
3	50.89	47.28	48.33	51.11	49.61	49.44
2	47.50	46.11	48.06	52.06	49.22	48.59
1	48.44	42.17	41.94	44.33	45.06	44.39
12	36.28	33.78	39.39	39.11	35.56	36.82
Mean [$\pm SE=(MS_{ps}/n)^{1/2}=\pm$ 1.24]	50.17	46.48	47.53	50.11	49.87	48.83
6000 cps	Attenuator setting (dB re 1 volt) (SE=±2.14)					(±1.84)
8	31.67	39.89	46.06	53.83	40.39	42.37
11	35.17	45.83	53.78	51.56	49.39	47.15
10	26.61	37.39	49.06	45.67	45.67	40.88
9	43.22	54.33	61.22	55.17	53.22	53.43
7	42.50	53.28	55.50	51.00	54.94	51.44
6	29.83	36.22	40.50	49.28	40.17	39.20
5	29.39	44.56	43.00	47.72	46.94	42.32
4	33.72	42.83	49.17	52.22	45.56	44.70
3	25.50	41.56	47.83	45.33	43.72	41.90
2	31.56	44.56	52.56	52.67	48.06	45.88
1	29.50	41.94	42.94	44.50	41.50	40.08
12	23.17	32.89	39.67	41.22	36.11	34.61
Mean [$\pm(MS_{ps}/n)^{1/2}=\pm$ 1.87]	31.82	42.94	48.27	49.18	45.47	43.54
8000 cps	Attenuator setting (dB re 1 volt) (SE=±2.15)					(±2.55)
8	17.72	34.33	38.33	43.39	35.67	33.89
11	27.00	38.56	42.50	40.56	40.67	37.86
10	23.17	34.44	37.72	34.17	33.72	32.64
9	35.61	44.89	51.17	45.78	48.11	45.11
7	33.22	39.67	42.44	37.44	39.56	38.57
6	19.83	33.39	37.06	38.78	35.61	32.93
5	22.50	31.39	34.06	37.89	36.11	32.39
4	23.22	31.94	44.33	41.94	34.33	35.25
3	26.11	28.61	37.17	35.28	29.83	31.40
2	23.33	28.56	33.56	36.61	27.33	29.88
1	20.33	27.39	33.78	37.11	33.67	30.46
12	19.89	23.61	32.33	35.44	25.89	27.43
Mean [$\pm SE=(MS_{ps}/n)^{1/2}=\pm$ 1.99]	24.41	33.08	38.75	38.68	35.01	33.99

Table 10. Mean attenuator settings obtained at each balance, by subject and phone at 250 cycles per second

Subject	WE 705-A balance[a]			TDH-49 balance[a]		
	1	2	3	1	2	3
	Attenuator setting (dB re 1 volt)					
All subjects	28.07	27.31	26.90	24.86	24.47	25.61
8	26.17	25.83	27.33	22.17	22.83	24.33
11	27.67	27.50	27.33	25.67	25.17	28.00
10	26.67	27.67	27.17	24.67	24.33	25.17
9	28.50	28.50	30.67	27.50	27.17	32.33
7	34.17	34.67	27.83	30.50	27.50	31.00
6	27.17	25.00	26.83	23.50	24.67	26.00
5	27.50	28.00	29.17	28.33	25.33	24.67
4	27.33	28.83	32.67	25.17	23.00	25.00
3	34.83	26.50	25.83	23.50	23.33	25.17
2	25.50	25.83	21.00	23.83	25.50	22.83
1	26.17	26.17	26.50	24.67	24.83	24.50
12	25.17	23.17	20.50	18.83	20.00	18.33

[a] ±SE = 0.8 $[1/(3)^{1/2} \times \text{SE phone means}]$

Table 11. Mean attenuator settings obtained at each balance, by subject and phone at 500 cycles per second

Subject	WE 705-A balance[a]			TDH-49 balance[a]		
	1	2	3	1	2	3
	Attenuator setting (dB re 1 volt)					
All subjects	41.21	40.83	41.22	39.75	40.40	40.68
8	41.50	41.67	41.67	39.33	37.67	41.00
11	41.50	42.50	44.67	43.67	41.17	41.50
10	41.33	42.50	40.67	38.33	38.83	39.67
9	42.50	45.33	45.67	43.17	47.00	45.50
7	49.17	50.00	46.83	46.17	48.83	47.50
6	38.33	36.50	38.33	38.67	40.83	37.83
5	40.67	38.67	37.67	40.00	40.67	42.33
4	44.17	40.33	43.83	40.83	39.67	41.67
3	38.17	41.33	41.00	37.83	37.67	36.83
2	38.67	35.83	38.17	36.83	39.83	40.17
1	41.50	38.50	40.33	40.00	39.00	39.17
12	37.00	36.83	35.83	32.17	33.67	35.00

[a] ±SE = 0.6

Table 10. Mean attenuator settings obtained at each balance, by subject and phone at 250 cycles per second—Con.

TDH-39 No. 7727 balance[a]			TDH-39 No. 7742 balance[a]			TDH-39 No. 3523 balance[a]		
1	2	3	1	2	3	1	2	3
Attenuator setting (dB re 1 volt)								
21.97	22.93	23.54	19.88	20.68	20.82	27.61	28.39	28.36
22.83	21.33	24.33	22.50	15.33	18.50	27.83	29.33	27.83
25.67	25.50	27.00	22.00	18.50	23.17	28.17	28.67	28.50
23.50	23.17	24.67	18.83	17.33	15.83	25.17	27.33	27.50
20.67	28.67	31.67	21.00	13.50	24.83	34.17	34.17	33.83
27.33	28.83	27.00	19.00	26.17	20.50	31.83	34.67	36.00
18.17	18.17	17.33	25.83	24.50	24.67	28.50	26.33	26.00
17.83	22.83	23.83	21.50	30.83	16.83	28.00	27.67	27.83
27.33	19.50	18.67	19.67	27.00	21.67	28.33	30.50	30.83
17.67	17.17	30.17	20.17	20.00	21.50	26.33	26.00	23.67
19.17	23.83	20.00	20.17	18.33	21.17	27.50	28.50	26.83
21.50	24.50	19.67	17.00	18.33	20.67	25.83	27.17	27.83
22.00	21.67	18.17	10.83	13.33	20.50	19.67	20.33	23.67

Table 11. Mean attenuator settings obtained at each balance, by subject and phone at 500 cycles per second—Con.

TDH-39 No. 7727 balance[a]			TDH-39 No. 7742 balance[a]			TDH-39 No. 3523 balance[a]		
1	2	3	1	2	3	1	2	3
Attenuator setting (dB re 1 volt)								
36.97	37.08	36.97	36.19	36.69	35.99	41.53	41.81	41.45
40.83	35.33	37.33	39.00	34.67	36.33	42.67	41.17	40.00
42.17	39.50	40.17	35.67	40.00	37.00	43.50	43.50	41.33
35.50	38.00	36.00	35.00	35.33	35.33	42.17	40.50	41.50
35.83	39.17	42.00	39.67	37.33	40.17	48.83	49.00	47.17
41.17	47.33	41.00	36.50	44.67	42.33	48.83	50.67	48.67
34.67	32.33	34.50	35.50	34.83	35.83	38.83	40.17	40.67
33.83	35.50	38.00	38.33	40.67	33.83	38.17	41.83	40.50
41.00	36.50	35.17	37.33	40.33	38.50	38.67	41.17	43.00
29.67	29.50	39.50	35.33	33.67	32.00	41.50	39.67	38.17
36.67	37.17	31.33	37.83	36.17	33.67	41.50	41.83	38.50
35.17	38.00	34.50	31.17	33.33	35.33	39.00	38.83	41.67
37.17	36.67	34.17	33.00	29.33	31.50	34.67	33.33	36.17

Table 12. Mean attenuator settings obtained at each balance, by subject and phone at 1000 cycles per second

Subject	WE 705-A balance[a]			TDH-49 balance[a]		
	1	2	3	1	2	3
	Attenuator setting (dB re 1 volt)					
All subjects	50.49	50.71	49.53	47.39	47.21	48.14
8	50.83	50.67	49.33	45.17	48.17	47.67
11	51.67	53.00	55.00	49.50	50.33	50.17
10	47.67	51.67	51.17	45.00	45.50	48.33
9	53.67	54.17	53.67	53.50	53.33	54.50
7	59.00	60.67	59.17	57.50	56.83	56.17
6	46.83	46.17	46.33	44.83	46.00	47.33
5	50.00	48.00	49.83	47.50	48.50	45.67
4	55.00	53.50	53.00	49.33	47.67	48.83
3	49.33	48.33	40.83	46.17	42.50	43.00
2	49.83	50.50	46.33	47.17	47.83	47.83
1	50.00	49.67	48.67	47.17	43.83	48.67
12	42.00	42.17	41.00	35.83	36.00	39.50

[a] SE=0.6

Table 13. Mean attenuator settings obtained at each balance, by subject and phone at 2000 cycles per second

Subject	WE 705-A balance[a]			TDH-49 balance[a]		
	1	2	3	1	2	3
	Attenuator setting (dB re 1 volt)					
All subjects	53.74	54.25	54.20	48.12	47.90	48.28
8	54.00	54.00	57.17	46.00	48.83	49.67
11	55.17	56.67	58.17	50.50	50.67	51.17
10	53.67	54.50	54.67	46.50	48.17	47.50
9	58.17	62.67	58.50	55.83	55.00	57.33
7	59.00	61.50	60.17	55.67	53.00	52.67
6	49.50	53.33	50.17	45.17	45.83	44.50
5	50.50	49.67	52.17	49.00	45.33	43.67
4	57.17	56.33	54.50	49.50	48.50	49.33
3	53.33	53.50	53.83	45.83	47.00	44.33
2	53.17	52.67	53.33	49.33	51.83	50.50
1	53.33	52.83	52.67	47.00	44.00	49.33
12	47.83	43.33	45.00	37.17	36.67	39.33

[a] SE=0.7

Table 12. Mean attenuator settings obtained at each balance, by subject and phone at 1000 cycles per second—Con.

TDH-39 No. 7727 balance[a]			TDH-39 No. 7742 balance[a]			TDH-39 No. 3523 balance[a]		
1	2	3	1	2	3	1	2	3
Attenuator setting (dB re 1 volt)								
43.00	43.12	43.92	43.56	44.85	43.14	48.58	48.67	48.82
41.83	44.00	43.83	47.17	42.83	42.83	47.50	49.00	48.67
49.50	46.83	46.17	48.50	44.33	44.83	50.00	51.67	51.33
40.00	45.17	43.83	43.33	43.17	41.83	47.00	48.83	49.00
45.17	47.17	49.83	50.67	47.33	49.50	55.67	53.50	57.67
50.50	54.00	49.00	42.33	51.50	49.17	56.17	56.67	57.50
40.83	43.17	40.17	44.33	45.83	42.67	49.17	49.83	44.00
38.83	40.83	42.83	44.50	49.83	38.67	48.67	47.83	46.83
46.50	44.17	45.17	44.83	45.50	47.83	50.50	49.33	50.33
40.17	36.17	46.00	38.33	42.83	38.83	45.17	44.67	46.17
40.67	39.83	42.67	44.17	45.50	43.17	48.67	47.83	48.67
40.67	38.83	41.67	41.67	42.67	42.33	48.33	48.67	47.67
41.33	37.33	35.83	32.83	36.83	36.00	36.17	36.17	38.00

Table 13. Mean attenuator settings obtained at each balance, by subject and phone at 2000 cycles per second—Con.

TDH-39 No. 7727 balance[a]			TDH-39 No. 7742 balance[a]			TDH-39 No. 3523 balance[a]		
1	2	3	1	2	3	1	2	3
Attenuator setting (dB re 1 volt)								
43.46	42.67	42.72	43.78	43.49	43.40	46.32	47.49	47.36
42.83	41.17	46.50	46.00	42.17	41.33	46.00	48.67	46.67
47.33	44.33	46.33	45.50	44.50	43.00	46.83	47.33	46.33
43.17	42.67	45.83	41.83	44.17	44.17	44.67	49.00	51.33
45.00	47.83	51.00	47.33	45.33	47.83	53.67	55.50	56.00
49.50	51.67	42.67	45.50	48.17	48.33	51.00	52.17	51.33
38.83	36.00	41.00	47.67	46.17	44.17	43.50	44.17	45.50
40.33	40.33	41.50	42.17	46.33	40.33	45.83	47.50	44.33
46.67	39.50	40.50	45.33	45.50	45.50	46.67	48.50	47.67
41.33	47.50	42.33	41.67	40.67	42.17	45.00	43.33	42.00
45.00	46.17	43.67	46.50	41.33	44.83	51.50	51.00	49.83
40.50	38.33	37.50	41.50	40.50	44.17	46.50	48.00	49.50
41.00	36.50	33.83	34.33	37.00	35.00	34.67	34.67	37.83

Table 14. Mean attenuator settings obtained at each balance, by subject and phone at 3000 cycles per second

Subject	WE 705-A balance[a]			TDH-49 balance[a]		
	1	2	3	1	2	3
	Attenuator setting (dB re 1 volt)					
All subjects	52.29	52.72	52.83	49.26	48.82	48.94
8	54.83	53.50	55.33	51.33	50.50	50.83
11	54.83	55.83	58.83	54.17	53.83	52.33
10	51.00	52.50	52.00	48.67	46.67	48.50
9	56.83	60.50	60.17	58.00	57.50	59.50
7	59.33	62.33	57.50	56.67	55.33	55.50
6	48.67	51.00	49.83	45.67	44.33	43.67
5	48.50	45.67	50.50	44.67	45.67	44.83
4	53.17	54.50	53.83	50.83	50.50	51.33
3	53.50	51.33	51.83	50.17	47.83	46.67
2	51.17	50.17	51.33	48.50	49.33	47.17
1	53.00	52.67	52.33	43.83	45.67	45.33
12	42.67	42.67	40.50	38.67	38.67	41.67

[a] SE=0.9

Table 15. Mean attenuator settings obtained at each balance, by subject and phone at 4000 cycles per second

Subject	WE 705-A balance[a]			TDH-49 balance[a]		
	1	2	3	1	2	3
	Attenuator setting (dB re 1 volt)					
All subjects	50.61	50.22	49.94	46.81	46.72	46.24
8	50.33	50.67	49.83	48.50	47.17	46.33
11	52.83	54.67	53.50	48.17	47.83	48.17
10	48.33	50.83	47.83	45.83	42.33	44.67
9	58.00	60.83	62.17	55.00	57.83	59.33
7	60.17	61.00	58.17	57.33	56.00	57.83
6	43.67	47.83	47.17	41.67	43.33	41.17
5	49.83	45.83	45.17	44.67	42.33	41.00
4	54.33	54.83	52.17	50.67	51.83	50.17
3	52.17	47.50	53.00	49.33	49.83	42.67
2	48.33	47.83	46.33	45.33	48.00	45.00
1	52.33	44.83	48.17	43.50	42.00	41.00
12	37.00	36.00	35.83	31.67	32.17	37.50

[a] SE=0.7

Table 14. Mean attenuator settings obtained at each balance, by subject and phone at 3000 cycles per second—Con.

TDH-39 No. 7727 balance[a]			TDH-39 No. 7742 balance[a]			TDH-39 No. 3523 balance[a]		
1	2	3	1	2	3	1	2	3
Attenuator setting (dB re 1 volt)								
44.36	44.68	45.89	45.43	44.76	45.39	49.39	48.39	48.81
47.33	45.67	48.17	49.33	47.33	44.50	51.50	49.50	50.67
55.00	52.17	49.50	52.00	47.83	47.67	52.50	51.00	52.67
41.67	49.83	48.17	41.17	40.00	41.67	46.00	48.33	46.67
48.83	49.33	57.33	49.67	47.67	50.83	55.67	59.33	59.17
52.50	54.33	48.83	44.50	48.67	48.50	54.83	54.67	53.83
37.83	33.50	37.67	47.00	43.67	46.00	44.17	41.50	46.67
37.83	40.67	47.17	43.17	49.33	42.83	48.67	45.33	45.83
42.50	41.67	41.50	45.50	51.00	45.83	50.00	48.33	46.50
39.50	41.50	50.50	44.17	41.00	39.17	50.67	48.50	46.83
42.83	45.17	44.33	48.17	45.17	47.67	51.17	50.50	49.33
39.83	40.33	38.67	41.50	37.67	46.33	47.50	45.00	46.50
46.67	42.00	38.83	39.00	37.83	43.67	40.00	38.67	41.00

Table 15. Mean attenuator settings obtained at each balance, by subject and phone at 4000 cycles per second—Con.

TDH-39 No. 7727 balance[a]			TDH-39 No. 7742 balance[a]			TDH-39 No. 3523 balance[a]		
1	2	3	1	2	3	1	2	3
Attenuator setting (dB re 1 volt)								
52.04	47.38	47.52	49.17	50.31	50.85	49.76	50.22	49.62
46.17	47.00	47.00	48.17	50.17	50.33	49.67	51.33	48.50
47.50	50.33	45.33	55.17	58.83	54.00	50.83	53.17	51.83
47.83	47.33	45.50	50.83	52.50	52.00	49.67	47.50	48.00
54.67	54.83	59.50	51.17	57.83	58.50	60.33	62.50	63.50
55.33	53.50	59.67	56.00	54.50	57.17	61.17	60.33	61.17
42.83	42.00	43.83	44.67	46.17	47.33	42.50	48.50	44.00
44.50	44.50	44.17	49.17	49.67	47.17	49.33	45.33	47.00
50.33	52.00	52.67	46.33	51.50	54.83	52.83	52.33	55.67
51.67	45.17	48.17	52.17	50.17	51.00	49.50	51.83	47.50
49.00	49.00	46.17	54.83	50.00	51.33	48.50	48.17	51.00
42.67	41.17	42.00	43.17	42.83	47.00	44.50	47.67	43.00
40.33	41.67	36.17	38.33	39.50	39.50	38.33	34.00	34.33

Table 16. Mean attenuator settings obtained at each balance, by subject and phone at 6000 cycles per second

Subject	WE 705-A balance[a]			TDH-49 balance[a]		
	1	2	3	1	2	3
	Attenuator setting (dB re 1 volt)					
All subjects	31.39	31.86	32.21	41.86	42.04	44.92
8	30.17	31.17	33.67	41.50	36.00	42.17
11	35.83	33.33	36.33	42.67	45.83	49.00
10	22.17	28.67	29.00	38.83	40.00	33.33
9	41.33	46.00	42.33	59.00	48.50	55.50
7	44.00	42.00	41.50	54.00	50.67	55.17
6	26.00	29.67	33.83	35.67	34.17	38.83
5	27.50	27.17	33.50	42.83	46.00	44.83
4	33.17	31.83	36.17	37.67	44.33	46.50
3	28.33	27.17	21.00	39.67	39.83	45.17
2	28.67	35.33	30.67	38.33	48.00	47.33
1	34.17	25.17	29.17	41.33	40.67	43.83
12	25.33	24.83	19.33	30.83	30.50	32.33

[a] ± SE = 1.1

Table 17. Mean attenuator settings obtained at each balance, by subject and phone at 8000 cycles per second

Subject	WE 705-A balance[a]			TDH-49 balance[a]		
	1	2	3	1	2	3
	Attenuator setting (dB re 1 volt)					
All subjects	24.10	25.40	23.74	32.61	33.46	33.13
8	13.67	21.67	17.83	32.33	29.50	41.17
11	26.00	28.67	26.33	37.83	38.00	39.83
10	19.17	28.00	22.33	32.17	32.17	39.00
9	33.67	39.17	34.00	43.67	44.33	46.67
7	31.83	38.83	30.50	37.33	42.83	38.83
6	21.33	19.00	19.17	34.67	34.50	31.00
5	25.17	16.67	25.67	34.83	31.67	27.67
4	31.33	18.67	21.17	28.00	40.17	27.67
3	25.67	25.50	27.17	30.33	27.50	28.00
2	24.50	25.17	20.33	30.67	26.83	28.17
1	17.17	21.67	22.17	26.00	24.50	31.67
12	19.67	21.83	18.17	23.50	29.50	17.83

[a] ± SE = 1.2

Table 16. Mean attenuator settings obtained at each balance, by subject and phone at 6000 cycles per second—Con.

TDH-39 No. 7727 balance[a]			TDH-39 No. 7742 balance[a]			TDH-39 No. 3523 balance[a]		
1	2	3	1	2	3	1	2	3
Attenuator setting (dB re 1 volt)								
46.79	49.44	49.04	49.15	49.90	48.48	44.29	46.24	45.89
43.33	53.17	41.16	55.17	53.00	53.33	46.33	37.00	37.83
51.67	55.50	54.17	51.33	50.50	52.83	46.17	51.33	50.67
42.67	51.00	53.50	47.50	43.00	46.50	37.67	48.00	51.33
60.83	61.83	61.00	55.67	53.17	56.67	54.83	51.17	53.67
54.83	58.33	53.33	40.50	59.17	53.33	52.50	57.17	55.17
39.00	37.50	45.00	53.67	47.00	47.17	40.00	36.33	44.17
38.17	49.00	41.83	49.67	45.67	47.83	45.83	47.67	47.33
50.00	45.00	52.50	52.83	55.50	48.33	47.17	47.83	41.67
47.00	45.33	51.17	45.33	53.17	37.50	43.83	44.83	42.50
49.83	51.83	56.00	54.50	50.50	53.00	44.67	51.83	47.67
48.00	38.83	42.00	44.00	44.00	45.50	39.67	43.00	41.83
36.17	46.00	36.83	39.67	44.17	39.83	32.83	38.67	36.83

Table 17. Mean attenuator settings obtained at each balance, by subject and phone at 8000 cycles per second—Con.

TDH-39 No. 7727 balance[a]			TDH-39 No. 7742 balance[a]			TDH-39. No. 3523 balance[a].		
1	2	3	1	2	3	1	2	3
Attenuator setting (dB re 1 volt)								
36.54	39.04	40.53	39.10	36.89	39.93	34.82	36.49	33.82
38.17	35.33	41.50	45.67	43.33	41.17	32.33	37.00	37.67
51.00	37.00	39.50	42.83	39.83	39.00	43.33	39.83	38.83
34.17	42.50	36.50	35.50	29.00	38.00	32.33	34.67	34.17
49.00	53.00	51.50	44.67	44.00	48.67	49.00	48.67	46.67
35.17	48.67	43.50	36.83	37.33	38.17	35.33	43.83	39.50
38.33	32.83	40.00	38.67	37.33	40.33	35.83	35.17	35.83
30.50	35.83	35.83	36.83	39.33	37.50	37.17	36.33	34.83
44.33	39.50	49.17	47.17	39.17	39.50	37.00	37.67	28.33
33.17	38.17	40.17	32.00	32.83	41.00	29.67	32.83	27.00
27.17	34.17	39.33	34.00	35.17	40.67	26.67	33.33	22.00
26.17	38.00	37.17	35.33	39.17	34.67	33.00	33.67	34.33
31.33	33.50	32.17	39.67	26.17	40.50	26.17	24.83	26.67

Table 18. Replications of insert attenuator readings,range, and average of three replications for TDH-49 phone with MX-41-AR cushion (attenuator readings, dB re 1 volt)

Frequency	Transfer			Range	Average of three repli-cations
	1	2	3		
250 cps	43.8	43.8	43.7	0.1	43.8
500 cps	58.1	58.1	58.1	0.0	58.1
1000 cps	65.9	66.0	66.0	0.1	66.0
2000 cps	66.1	66.0	66.1	0.1	66.1
3000 cps	64.6	64.6	64.7	0.1	64.6
4000 cps	63.3	63.4	63.4	0.1	63.4
6000 cps	62.6	62.6	62.7	0.1	62.6
8000 cps	64.4	64.3	64.5	0.2	64.4

Table 19. Replications of insert attenuator readings, range, and average of three replications for TDH-39 phone No. 7727 not MX-41-AR cushion (attenuator readings, dB re 1 volt)

Frequency	Transfer			Range	Average of three repli-cations
	1	2	3		
250 cps	47.4	47.5	47.5	0.1	47.5
500 cps	61.0	61.0	60.9	0.1	61.0
1000 cps	66.5	66.5	66.4	0.1	66.5
2000 cps	69.9	69.9	70.1	0.2	69.9
3000 cps	68.1	68.2	68.0	0.2	68.1
4000 cps	62.6	62.6	62.5	0.1	62.6
6000 cps	57.4	57.2	57.2	0.2	57.3
8000 cps	60.3	60.5	60.3	0.2	60.4

Table 20. Replications of insert attenuator readings, range, and average of three replications for TDH-39 phone No. 7742 with MX-41-AR cushion (attenuator readings, dB re 1 volt)

Frequency	Transfer			Range	Average of three replications
	1	2	3		
250 cps	38.1	38.3	38.1	0.1	38.1
500 cps	53.6	53.5	53.5	0.1	53.5
1000 cps	60.7	60.7	60.8	0.1	60.7
2000 cps	62.7	60.9	62.7	1.8	62.1
3000 cps	57.5	57.4	57.4	0.1	57.4
4000 cps	66.8	66.9	66.9	0.1	66.9
6000 cps	59.9	60.0	60.1	0.2	60.0
8000 cps	57.8	58.0	57.9	0.2	57.9

Table 21. Replications of insert attenuator readings, range, and average of three replications for TDH-39 phone No. 3523 not MX-41-AR cushion (attenuator readings, dB re 1 volt)

Frequency	Transfer			Range	Average of three replications
	1	2	3		
250 cps	44.9	45.0	45.1	0.2	45.0
500 cps	58.4	58.6	58.5	0.2	58.5
1000 cps	66.2	66.3	66.3	0.1	66.3
2000 cps	67.2	67.2	67.0	0.2	67.1
3000 cps	64.5	64.4	64.5	0.1	64.5
4000 cps	64.2	64.4	64.5	0.3	64.4
6000 cps	59.1	59.0	58.7	0.4	58.9
8000 cps	66.5	66.3	66.4	0.2	66.4

Table 22. Replications of insert attenuator readings, range, and average of three replications for experimental WE 705-A phone (attenuator readings, dB re 1 volt)

Frequency	Transfer			Range	Average of three repli-cations
	1	2	3		
250 cps	44.4	44.2	44.1	0.3	44.2
500 cps	57.3	57.0	57.1	0.3	57.1
1000 cps	64.3	64.3	64.2	0.1	64.3
2000 cps	64.5	64.5	64.4	0.1	64.4
3000 cps	66.3	66.2	66.1	0.2	66.2
4000 cps	66.6	66.5	66.6	0.1	66.6
6000 cps	66.9	66.8	66.8	0.1	66.8
8000 cps	66.6	66.6	66.6	0.0	66.6

Table 23. Morning and evening standard (WE 705-A) line attenuator values for 20 dB above normal threshold (attenuator values in dB re 1 volt)

Frequency	Evening attenuator values (N=16)		Morning attenuator values (N=5)	
	Mean	Standard error of mean	Mean	Standard error of mean
250 cps	28.7	0.04	27.2	0.16
500 cps	43.6	0.04	41.9	0.16
1000 cps	54.0	0.06	52.2	0.14
2000 cps	53.4	0.03	52.8	0.05
3000 cps	55.3	0.02	55.2	0.02
4000 cps	52.8	0.05	52.5	0.09
6000 cps	29.5	0.02	29.4	0.02
8000 cps	20.3	0.02	20.3	0.04

Table 24. Comparison of the morning and evening average of standard line attenuator values with midday values (attenuator values in dB re 1 volt)

Frequency	Average of morning and evening attenuator values	Midday attenuator values
250 cps	28.0	28.0
500 cps	42.8	42.8
1000 cps	53.1	53.1
2000 cps	53.1	53.1
3000 cps	55.2	55.3
4000 cps	52.7	52.4
6000 cps	29.4	29.4
8000 cps	20.3	20.1

Table 25. Coupler pressure correction in dB, and comparison of standard phone line attenuator values actually used in the study with the average of all morning and evening values (attenuator values in dB re 1 volt)

Frequency	Average of morning and evening attenuator settings	Attenuator settings actually employed in loudness balance	Coupler pressure correction in dB
250 cps	28.0	27.1	0.9
500 cps	42.8	41.9	0.9
1000 cps	53.1	52.0	1.1
2000 cps	53.1	52.8	0.3
3000 cps	55.2	55.2	0.0
4000 cps	52.7	52.5	0.2
6000 cps	29.4	29.3	0.1
8000 cps	20.3	20.0	0.3

APPENDIX I

SUBJECT HEARING THRESHOLDS IN dB re NORMAL THRESHOLD (AUDIOMETRIC ZERO) (AMERICAN STANDARD, 1951)

Subject	Age in years	Sex	Ear	Frequency 250 cps	500 cps	1000 cps	2000 cps	3000 cps	4000 cps	6000 cps	8000 cps
1	23	M	R	-20	-15	-15	-5	-5	-5	0	-10
			L	-20	-15	-10	-5	-10	0	0	-10
2	25	F	R	-15	-15	-20	-5	-10	-10	-5	-5
			L	-10	-15	-20	-10	-10	-15	5	5
3	25	M	R	-10	-15	-10	-5	-5	-10	0	-5
			L	-10	-15	-15	-10	0	-5	-5	-15
4	20	M	R	-10	-10	-15	-10	-15	0	0	-5
			L	0	-5	-5	0	0	5	-5	-5
5	23	F	R	-20	-15	-5	-10	-15	-5	0	0
			L	-15	-10	-10	-15	-5	-5	-10	-20
6	25	M	R	-15	-10	-10	-20	-5	0	-5	-20
			L	-10	-15	-10	-15	-5	-5	0	-20
7	24	F	R	-10	-15	-20	-15	-5	-5	-5	-5
			L	-10	-15	-15	-10	-10	-5	-5	-15
8	25	F	R	-10	-20	-15	-10	-10	-10	-10	-15
			L	-10	-15	-15	-10	-15	-10	-10	-20
9	20	M	R	-10	-5	-5	-5	-10	-5	-5	-20
			L	-10	-5	0	-15	-10	-10	-10	-20
10	23	F	R	-15	-10	-10	-5	-15	0	-10	0
			L	-15	-20	-10	-5	-10	-10	-15	-10
11	29	F	R	-15	-15	-15	-15	-10	-5	-5	-15
			L	-20	-15	-10	-10	-15	-5	-5	-15
12	21	M	R	-20	-20	-20	-10	-15	-15	-15	-20
			L	-20	-15	-15	-10	-15	-10	-10	-15

APPENDIX II

RECORDING FORMS FOR INSTRUMENT CHECKS AND LOUDNESS BALANCE

DAILY ROUTINE CHECKS

Date ____________________

Time ____________________

1. Attenuator Linearity	10 dB Scale	1 dB Scale	0.1 dB Scale
Standard Line Attenuator			
Variable Line			
Attenuator 1			
Attenuator 2			
Coupler Line Attenuator			

2. Attenuator Settings for 20 dB H.L. (re: ASA Z24.12-1952[2]) Standard.

Freq.
250
500
1K
2K
3K
4K
6K
8K

3. Real Ear Check of Earphone and Cords

Standard Line

Variable Line

4. Voltmeter Checks

(WE 705-A) SAMPLE FORM USED FOR LOUDNESS BALANCE (SUBJECT NO. 1)

FIRST BALANCE- Oct. 12, 1967

Standard on		Frequency							
Trial		2K	4K	6K	250	3K	500	8K	1K
Right ear	1	50	58	31	21	61	44	13	50
	2	51	60	29	24	55	39	14	48
	3	49	58	28	24	61	70	14	53
Trial		250	500	2K	3K	8K	1K	4K	6K
Left ear	1	31	43	58	53	17	51	43	31
	2	28	43	57	49	12	52	43	31
	3	29	40	59	50	12	51	40	31

SECOND BALANCE-Oct. 16, 1967

Standard on		Frequency							
Trial		2K	8K	250	3K	1K	4K	500	6K
Left ear	1	59	21	28	48	47	49	44	37
	2	59	19	27	46	46	45	45	37
	3	59	18	27	47	49	41	42	33
Trial		2K	250	500	6K	4K	3K	1K	8K
Right ear	1	49	24	40	28	60	60	54	26
	2	48	23	40	28	57	59	54	23
	3	50	24	39	24	57	61	54	23

(WE 705-A) SAMPLE FORM USED FOR LOUDNESS BALANCE (SUBJECT NO. 1)—Con.

THIRD BALANCE-Oct. 17, 1967

Standard on		Frequency							
Trial		8K	4K	3K	2K	6K	1K	500	250
Right ear	1	24	61	63	56	32	50	40	26
	2	25	61	66	52	30	50	38	27
	3	21	61	64	55	28	51	39	25
Trial		3K	4K	8K	250	1K	500	6K	2K
Left ear	1	47	39	13	27	48	46	36	61
	2	48	38	13	28	50	43	38	59
	3	44	34	14	31	47	44	38	60

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