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USAARU REPORT NO. 67-8

SOUND ATTENUATION CHARACTERISTICS OF THE NAVY SPH-3 (MODIFIED) (LS) HELMET

By

Robert T. Camp, Jr., DAC
and
Robert L. Keiser, SP-4

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U. S. ARMY AEROMEDICAL RESEARCH UNIT
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U. S. Army Medical Research and Development Command

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ABSTRACT

An evaluation of the real-ear sound attenuation characteristics of the Navy SPH-3 (Modified) (LS) Helmet was done with procedures and equipment specified by ASA Z24.22 - 1957. The results show that the SPH-3 (Modified) (LS) is a relatively efficient attenuator of sound throughout the audio spectrum. In view of the poor sound attenuation characteristics of the Army APH-5, it has been recommended that this helmet be replaced by the SPH-3 (Modified) (LS).

APPROVED: ROBERT W. BAILEY
LTC., MSC
Commanding

SOUND ATTENUATION CHARACTERISTICS
OF THE NAVY SPH-3 (MODIFIED) (LS) HELMET

INTRODUCTION

Analyses of acoustic spectra in Army aircraft have shown that the sound pressure levels are usually much greater than the Army Technical Bulletin T. B. Med 251, 25 January 1965, criterion for the initiation of a hearing conservation program. The deleterious effects of high sound pressure level acoustic noise on military personnel are manifest in various ways. For example, there may be masking or interference with voice communications to the extent that the efficiency of military operational groups is impaired. Also, the noise may jeopardize the health and efficiency of Army personnel by causing permanent or temporary hearing losses. The gravity of the noise problem in Army aviation is indicated by the fact that there is a frequent occurrence of permanent and temporary high frequency hearing loss of various degrees among Army aviation personnel.

The Army does provide earplugs for ear protection. However, this type of ear protective device is inadequate for all personnel under all operational conditions. There is a need for more sound attenuation in some environments of high sound pressure levels. Also, it is estimated that a large number of personnel avoid the use of earplugs because of discomfort and other reasons. In view of the inadequacy of earplugs alone as a universal ear protector and their lack of acceptance by the user, it is imperative that efficient sound attenuation devices be an integral part of the flight crash protective helmet.

In USAARU Report 67-6, it has been reported that the APH-5 helmet has relatively poor sound attenuation characteristics between 75 and 2,000 Hz. The inefficient sound attenuation characteristics of this standard helmet and the inadequacy of the earplugs as a universal protector of ears provide a basis for the argument that Army aviation personnel are presently without sufficient ear protection. Therefore, there is a need for a helmet with improved sound attenuation characteristics. The conclusions of USAARU Report 67-6 were that if changing earphone muffs in order to achieve the desired attenuation levels is not feasible, then the APH-5 should be replaced by another helmet that has the required high sound attenuation characteristics.

To determine the acoustic characteristics of commercial helmets and those presently available from other services, this Laboratory investigated the real-ear attenuation characteristics of a helmet presently used by the U. S. Navy. It is designated as the SPH-3 (Modified). See Figure 1.

A preliminary test of this SPH-3 helmet disclosed the problem of obtaining a seal of the earphone cushion with a number of listeners. With an inadequate acoustic seal, the helmet offered the average wearer little acoustic protection. During informal discussions of this problem with representatives of the manufacturer, these findings and certain recommendations were made concerning a solution of the seal problem. The manufacturer responded by modifying the SPH-3. Two adjustable elastic straps, approximately 4.75 inches in length and 0.8 inches in width, were mounted in the earphone cavities of the helmet, as is shown in Figure 2. A retest of the SPH-3 with this modification indicated that the elastic straps provided sufficient pressure and freedom of earphone cushion placement to yield good fit for most wearers. The probability of fitting heads of various sizes seems to be increased greatly by this modification so that no fitting problems were experienced by the ten subjects of this study. Preliminary test data showed a significant improvement of mean real-ear attenuation values so that a complete test in accord with standard methods was indicated. This report is concerned with a complete evaluation of the sound attenuation characteristics of the SPH-3 (Modified) with liquid-filled earphone cushion seals subsequent to the modifications discussed above.

The helmet tested was a standard sized SPH-3 with the above modification. The manufacturer's designation is DH-110 with Type 4 earcups. The volume of an earcup is 135 cc. Figures 3 and 4 show the earcup and earcup seals.

PROCEDURE AND EQUIPMENT

The evaluation of the sound attenuating characteristics of the SPH-3 (Modified) (LS) helmet was accomplished with procedures, equipment and physical requirements specified in The Standard Method for the Measurement of the Real-Ear Attenuation of Ear Protectors at Threshold, ASA Z24.22-1957.

One additional low frequency test tone (75 Hz) was added to nine standard frequencies 125, 250, 500, 1000, 2000, 3000, 4000, 6000 and 8000 Hz. The tones were generated by a Hewlett Packard 241A oscillator. See block diagram of instruments in Figure 5. The output of the oscillator was connected to a step attenuator set, a Hewlett Packard 350D with a range of 110 db in one db steps. This attenuator provided the experimenter with a calibrated control of

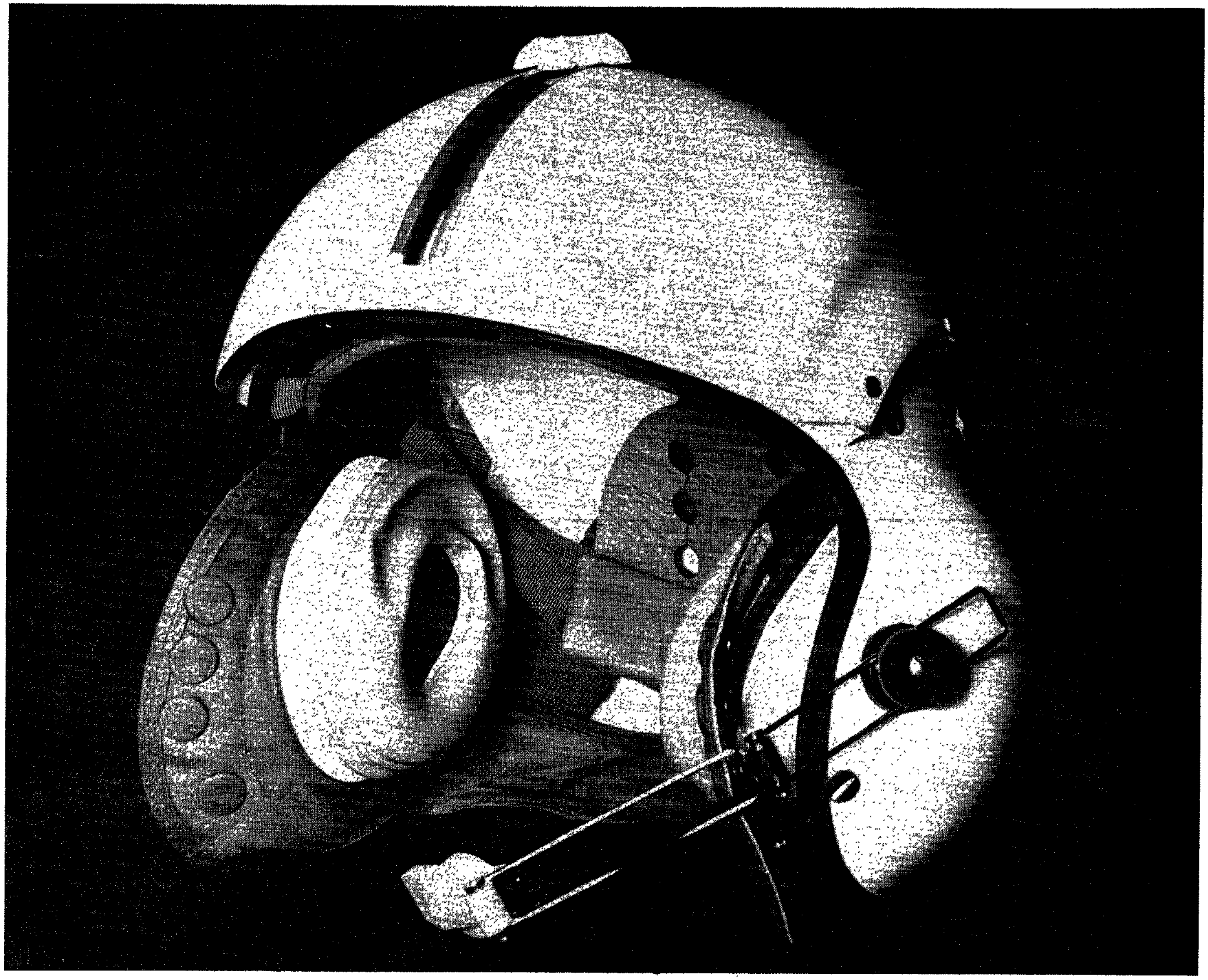


Figure 1. The Navy SPH-3 (Modified) Helmet

Figure 2. Elastic Straps in the Navy SPH-3 (Modified) Helmet

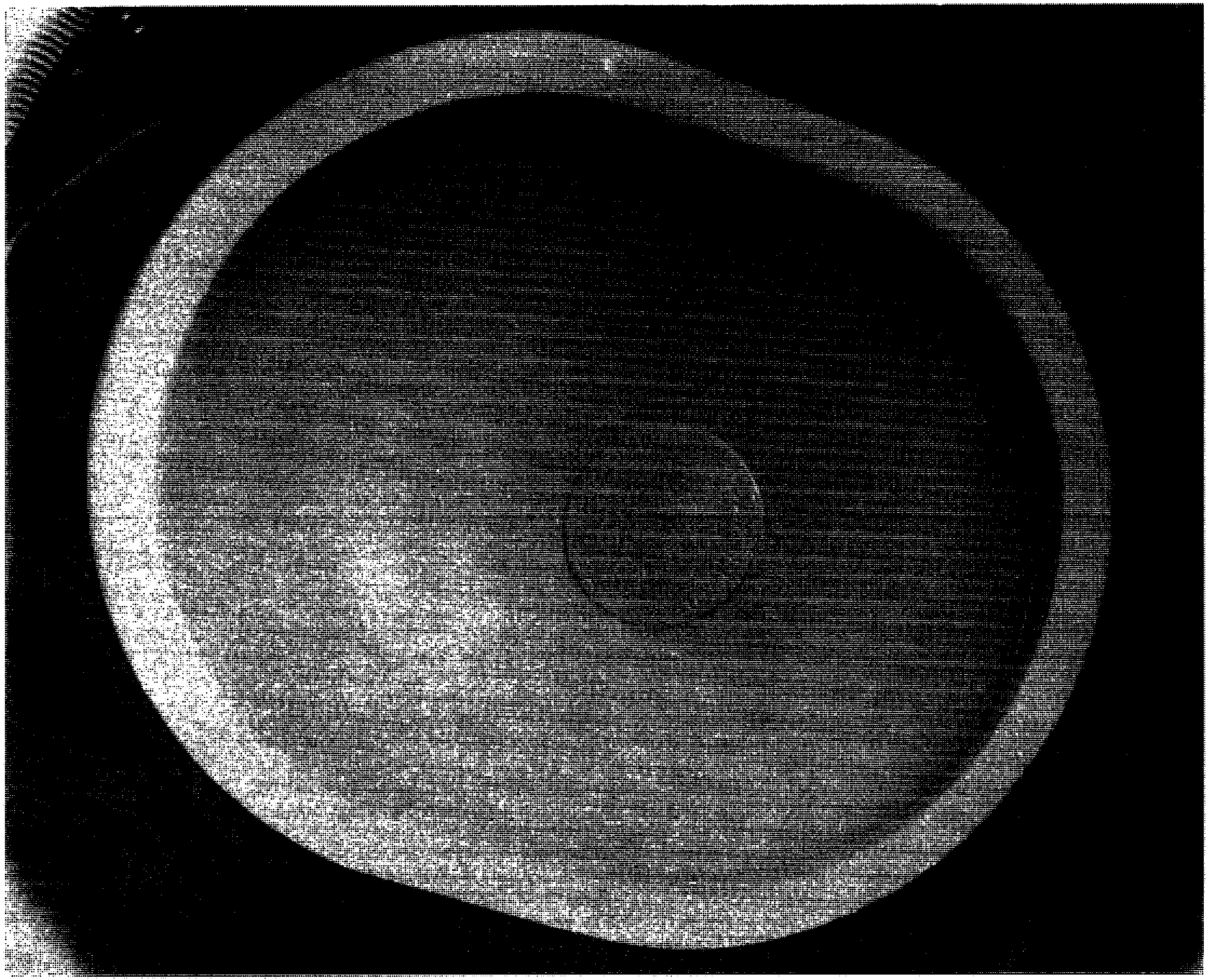


Figure 3. The Type 4 Earcup in the Navy SPH-3 (Modified) Helmet

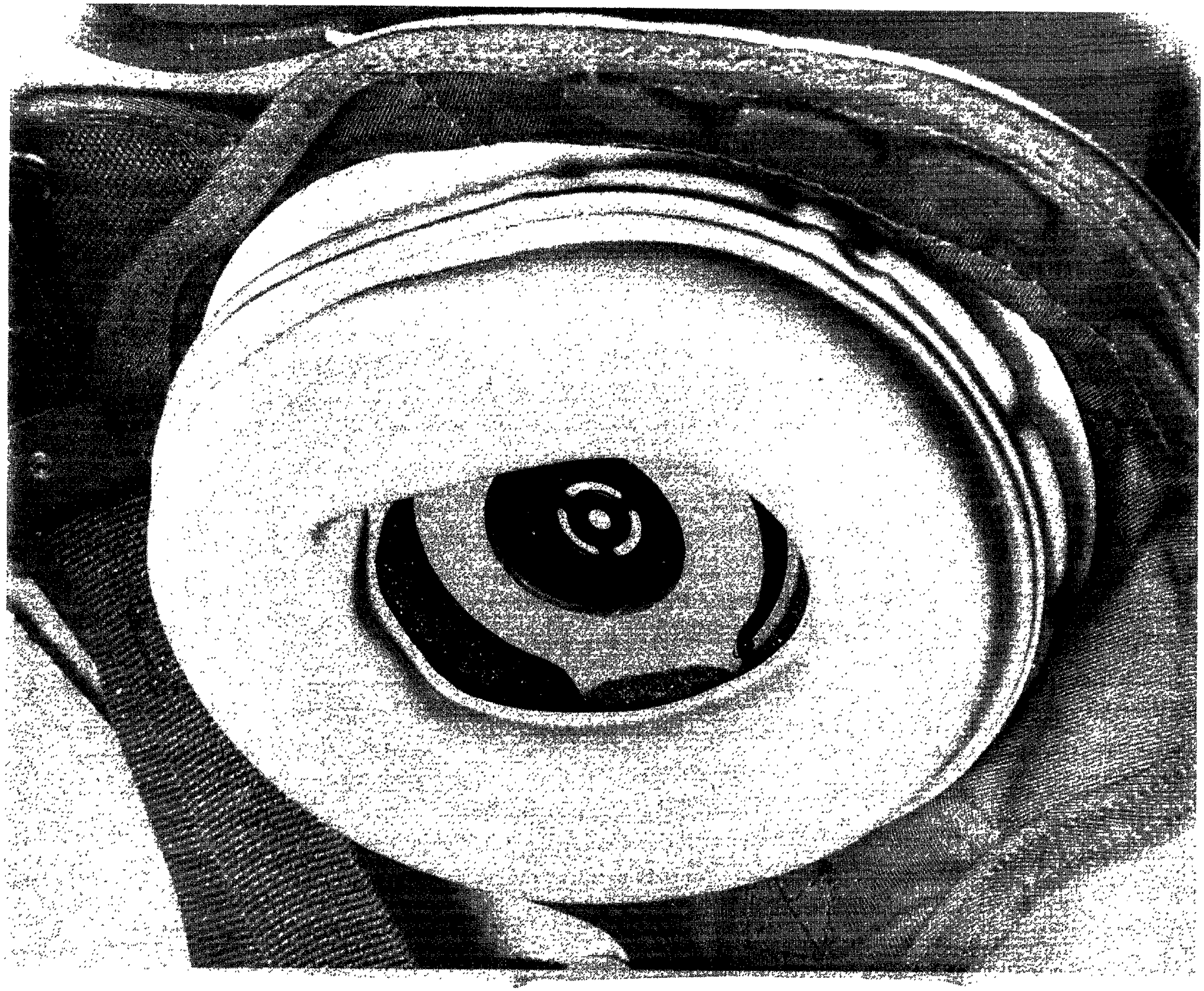
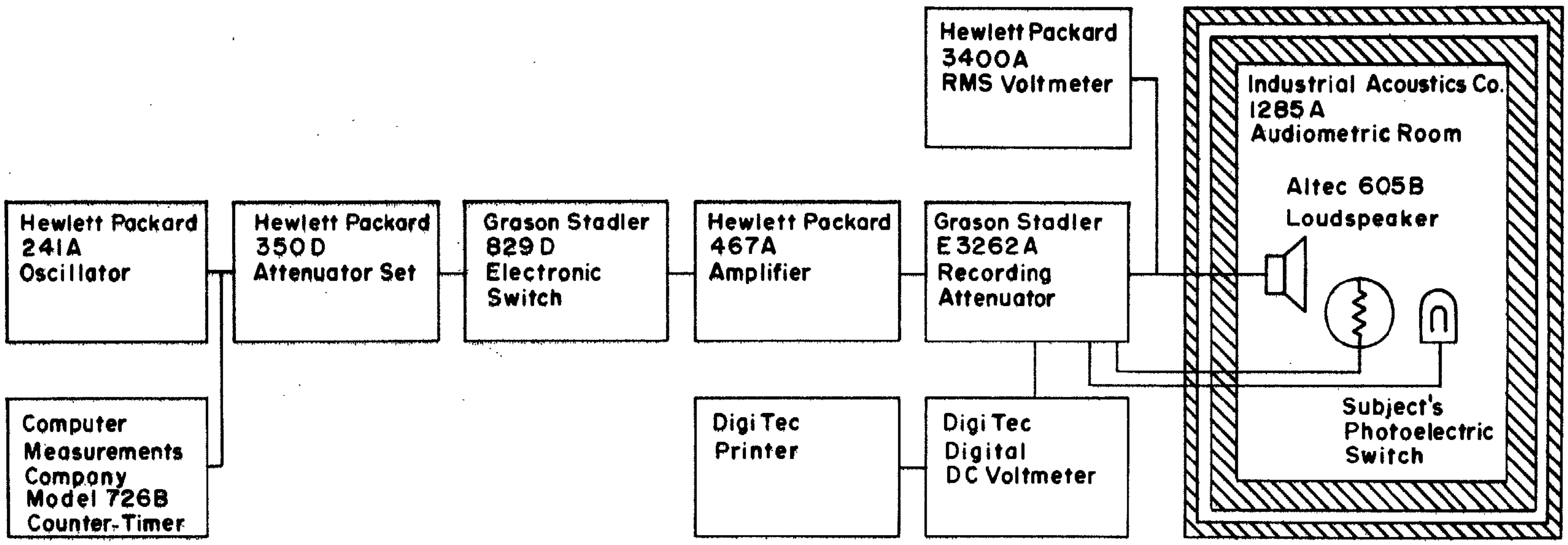


Figure 4. The Liquid-Filled Earcup Seals in the Navy SPH-3 (Modified) Helmet



BLOCK DIAGRAM OF INSTRUMENTATION FOR REAL-EAR ATTENUATION TEST

Figure 5

test tone levels for checking subject's reliability; also, the control of over-all sound pressure levels of test tones was necessary for subjects with extremely low thresholds and for boosting levels when testing attenuating devices of high efficiency.

The output of the 350D attenuator was fed into a Grason Stadler 829D electronic switch. The electronic switch interrupted the test tones with a 50% duty cycle and with off and on durations of 500 msec. The rise and decay time of the switch was 50 msec. The signal from the electronic switch was amplified with a Hewlett Packard 467A power amplifier.

A Grason Stadler E3262A recording attenuator was inserted between the power amplifier and an Altec 605B loudspeaker. The recording attenuator was provided with control switches that may be operated by the subject and the experimenter. The subject's switch was a photoelectric clickless type. The experimenter's switch had facilities for changing directions, stopping the attenuator and overriding the subject's control. Having the recording attenuator on the output of the power amplifier provided attenuation of the test signal and amplifier noise. The voltage to the loudspeaker was measured by a Hewlett Packard 3400A RMS voltmeter. The circuit was calibrated with this voltmeter at the beginning of each test.

In addition to the recorded information on the recording attenuator paper, there was digital print-out of the attenuation values. A potentiometer was coupled mechanically to the recording attenuator which controlled a DC voltage as a function of attenuator setting. The voltage across the potentiometer was adjusted to indicate 1.000 volt on a Digi Tec digital DC voltmeter when the recording attenuator was set at 100 db attenuation. By arbitrarily moving the decimal point, the voltage indication may be taken as a representation of the attenuation value of 100.0 db. The linear relationship between the change of attenuation of the recording attenuator and the accompanying voltage change across the potentiometer yields digital voltage readings that are numerically identical to attenuation values registered on the recording attenuator. This information was printed by a Digi Tec printer which was connected to the digital voltmeter. This arbitrary system of representing attenuation values with voltage readings had a resolution equivalent to one-tenth decibel.

The recording attenuator circuitry was provided with a one shot mono-stable multivibrator circuit that sent a print command each time the subject changed recording attenuator direction. With a Bekesy type response for constant test tones, there was an oscillation of attenuator values around the subject's threshold. This oscillation is due to the activation and release of the attenuator control switch when the listener perceives and ceases to perceive the acoustic stimuli, respectively. The print-out facility provided digital print-out of minimum and maximum values of the oscillations around the subject's threshold. The printer also provided a sum total of the response values at the command of the experimenter.

A quiet environment was provided by the Industrial Acoustics Company 1285-A double wall audiometric room. The intensity gradients were measured for certain test tones as required by the ASA Z24.22-1957. Tables I through III contain sound pressure levels measured in one inch increments along three axes from the subject's head. These were the normal maximal sound pressure values of each test tone after calibration. The 1285-A has extremely high attenuation characteristics throughout the audio spectrum. Table IV is a tabulation of a one-third octave-band statistical analysis of the room noise. The system noise of the instrumentation used to measure the room noise is also shown. The noise measurement instrumentation was a calibrated one-inch Brüel & Kjaer microphone, a Brüel & Kjaer Audio Frequency Spectrometer Type 2112, a Brüel & Kjaer Level Recorder Type 2305, and a Brüel & Kjaer Statistical Distribution Analyzer Type 4420. The system noise measurements were done with the microphone cartridge replaced by a 50 pico farad capacitor.

RESULTS AND DISCUSSION

Table V and Figure 6 show the results of the sound attenuation test on the SPH-3 helmet. In addition to the attenuation and standard deviation values obtained with the SPH-3 (Modified) (LS), Table V contains the attenuation characteristics of the APH-5. A comparison of the two sets of data shows that the SPH-3 gives greater attenuation with all test frequencies except two high frequencies. The APH-5 yielded more attenuation at 4,000 and 6,000 Hz by 0.3 db and 2.0 db, respectively. For the six test frequencies between 75 and 2,000 Hz, the SPH-3 had greater attenuation values. The improvement over the APH-5 at 75, 125, 250, 500, 1000 and 2000 Hz was 5.9, 6.0, 9.0, 17.6, 8.0 and 7.3 db, respectively.

In USAARU Report 67-6, the APH-5 was rated in terms of decile values based on data from thirty-six other devices. Tables VI and VII are from USAARU Report 66-6 which give decile values and maximum attenuation values of thirty-six ear protective devices. The method of using decile values is believed to be useful in determining the relative merits of ear protective devices. The absolute attenuation value alone may not be meaningful without some knowledge of the test frequency and the inherent limitations of ear protective devices. Decile ranks of the attenuation values give the relative efficiency of a particular

Table I

Sound Pressure Level Gradient Data Derived from Measurements of Ten Test Tones in the IAC 1285-A Audiometric Room at the Acoustic Laboratory, Fort Rucker, Alabama. The Values are Normal Maximum Sound Pressure Level Output, in Decibels (re 0.0002 Dyne/cm^2), from the Calibrated Instrumentation for Testing Real-Ear Attenuation.

Test Tones in Hz.	Distance in Inches Below the Normal Head Position						Normal Head Position	Distance in Inches Above the Normal Head Position					
	6"	5"	4"	3"	2"	1"	0	1"	2"	3"	4"	5"	6"
75	70.5	70.6	70.8	71.2	71.4	71.6	71.8	71.7	71.8	72.1	72.3	72.3	72.5
125	77.2	77.6	77.8	77.8	78.0	78.2	78.5	78.5	78.7	79.0	79.2	79.4	79.6
250	84.3	84.3	84.1	83.6	83.4	82.9	82.8	82.6	82.4	82.0	81.8	81.6	81.5
500	89.4	89.3	89.1	89.0	88.9	88.6	88.6	88.5	88.5	88.6	88.6	88.7	88.8
1000	84.9	84.8	84.6	84.4	85.2	85.6	86.2	86.2	86.0	85.7	85.4	84.7	84.3
2000	85.6	85.8	85.5	84.6	84.0	84.2	84.8	84.9	84.8	84.4	84.0	84.4	85.0
3000	83.8	83.4	85.6	86.2	85.4	83.4	85.0	86.6	87.3	85.8	84.8	85.0	85.2
4000	84.1	85.0	84.8	85.4	87.8	87.0	85.2	85.4	84.6	84.4	84.8	84.0	82.1
6000	72.6	71.7	72.8	77.8	80.5	84.2	82.0	82.0	80.6	76.4	78.1	77.2	77.3
8000	79.2	78.0	77.9	81.1	81.8	83.4	83.6	84.2	85.1	82.4	84.4	81.1	83.0

Table II

Sound Pressure Level Gradient Data Derived from Measurements of Ten Test Tones in the IAC 1285-A Audiometric Room at the Acoustic Laboratory, Fort Rucker, Alabama. The Values are Normal Maximum Sound Pressure Level Output, in Decibels (re 0.0002 Dyne/cm^2), from the Calibrated Instrumentation for Testing Real-Ear Attenuation.

Test Tones in Hz.	Distance in Inches in Front of the Normal Head Position						Normal Head Position	Distance in Inches Behind the Normal Head Position					
	6"	5"	4"	3"	2"	1"	0	1"	2"	3"	4"	5"	6"
75	76.7	76.1	75.4	74.6	73.9	73.3	72.2	71.4	70.7	70.0	69.2	68.6	68.3
125	81.1	80.6	80.4	80.0	79.6	79.2	78.6	78.4	78.1	77.8	77.2	77.4	76.6
250	80.8	81.5	82.8	81.9	82.6	82.8	83.0	83.2	83.5	83.6	83.7	83.7	83.6
500	87.2	87.8	88.0	88.4	88.5	88.5	88.2	88.1	87.9	87.6	87.3	86.7	86.6
1000	86.0	84.6	83.4	83.7	84.7	86.0	86.6	86.5	85.8	84.6	83.3	82.4	82.5
2000	83.4	84.2	86.7	85.7	81.8	82.9	85.3	84.0	80.0	82.0	84.2	83.4	81.3
3000	82.6	83.8	83.4	83.6	85.3	82.0	82.6	80.2	78.8	83.3	79.5	84.4	85.8
4000	84.9	85.7	85.5	85.3	85.8	84.3	84.5	82.6	85.0	84.1	83.0	83.2	81.2
6000	78.0	81.4	80.6	77.8	79.0	81.2	82.8	72.6	77.8	80.8	82.0	75.0	77.8
8000	79.6	78.6	82.6	82.0	82.0	82.7	82.4	80.1	80.6	80.2	82.1	79.8	80.6

Table III

Sound Pressure Level Gradient Data Derived from Measurements of Ten Test Tones in the IAC 1285-A Audiometric Room at the Acoustic Laboratory, Fort Rucker, Alabama. The Values are Normal Maximum Sound Pressure Level Output, in Decibels (re 0.0002 Dyne/cm^2), from the Calibrated Instrumentation for Testing Real-Ear Attenuation.

Test Tones in Hz.	Distance in Inches Left of the Normal Head Position						Normal Head Position	Distance in Inches Right of the Normal Head Position					
	6"	5"	4"	3"	2"	1"	0	1"	2"	3"	4"	5"	6"
75	71.6	71.6	71.7	71.7	72.1	72.0	72.3	72.3	72.3	72.4	72.4	72.5	72.3
125	78.1	78.2	78.3	78.4	78.6	78.5	78.6	78.8	78.9	78.9	79.0	79.0	79.0
250	82.4	82.5	82.6	82.7	82.8	82.8	82.9	83.0	83.1	83.1	83.1	83.1	83.2
500	88.2	88.5	88.7	88.9	89.0	88.9	88.9	88.6	88.4	87.9	87.5	87.0	86.4
1000	85.2	85.7	86.1	86.4	86.6	86.3	86.0	85.4	84.7	84.1	83.6	83.4	82.6
2000	83.0	83.2	83.7	84.5	84.7	84.9	85.2	85.1	85.1	84.7	83.3	82.6	84.4
3000	84.7	82.9	82.5	80.9	80.8	82.3	84.6	86.2	85.2	82.6	81.2	82.4	85.0
4000	82.4	82.0	82.4	81.6	82.4	82.8	83.8	84.6	82.6	80.5	82.3	84.3	82.5
6000	82.5	81.3	82.5	82.5	77.1	73.4	82.0	81.7	74.4	79.5	83.0	78.1	84.8
8000	76.4	81.7	79.1	81.7	83.6	83.1	83.1	84.7	79.9	83.7	76.2	81.5	74.2

Table IV

Mean Sound Pressure Level and Standard Deviation Values in Decibels (re 0.0002 Dyne/cm^2) of Ambient Acoustic Noise in the Industrial Acoustics Company 1285-A Audiometric Room at the Acoustic Laboratory, Fort Rucker, Alabama. Also Shown are System Noise Data of the Instrumentation Used in Measuring the Acoustic Noise.

1/3rd Octave-Band Center Frequencies in Hertz	System Noise		Room Noise	
	Mean SPL Equiv.	Standard Deviation	Mean SPL	Standard Deviation
25	18.13	3.15	29.36	2.97
31.5	16.13	2.80	28.68	3.07
40	16.00	2.90	29.48	2.95
50	14.76	2.42	30.36	2.55
63	15.83	2.12	31.97	1.52
80	12.87	2.17	14.36	1.95
100	11.38	1.70	16.81	0.37
125	9.70	1.75	28.93	0.85
160	9.32	1.50	9.88	1.25
200	8.02	1.42	10.99	1.22
250	6.14	1.25	17.81	1.22
310	5.58	1.32	11.56	0.67
400	4.86	1.17	14.21	0.32
500	4.18	0.82	4.58	0.95
630	2.65	1.22	4.46	0.80
800	2.08	0.90	4.55	0.90
1,000	1.59	0.60	2.40	1.12
1,250	2.68	1.20	4.17	0.65
1,600	1.26	1.00	3.22	1.22
2,000	0.96	1.22	2.18	0.95
2,500	0.31	1.27	1.78	0.27
3,150	0.73	1.22	8.97	0.80
4,000	0.58	1.25	4.16	0.47
5,000	1.46	0.80	2.53	1.15
6,300	1.75	0	2.98	1.15
8,000	2.35	1.07	1.90	0.60
10,000	1.75	0	4.30	1.72
12,500	2.49	1.15	4.25	0
16,000	4.25	0	4.26	0.15
20,000	4.25	0	4.62	0.87
A	36.75	0	36.75	0
B	34.25	0	35.65	1.25
C	46.75	0	49.32	0.70
Lin	56.75	0	56.75	0

Table V

Mean Real-Ear Sound Attenuation and Standard Deviation Values Obtained with the Army APH-5 and the Gentex SPH-3 (Modified) Helmets.

	APH-5		SPH-3 (Modified)	
Test Frequencies in Hertz	Mean Attenuation Values in Decibels	Standard Deviation in Decibels	Mean Attenuation Values in Decibels	Standard Deviation in Decibels
75	11.34	5.03	17.20	3.50
125	10.86	4.55	16.91	3.70
250	5.98	4.15	14.95	3.36
500	7.11	3.52	24.66	3.07
1000	15.37	4.84	23.38	4.89
2000	29.11	5.61	36.40	5.11
3000	43.00	5.26	47.32	5.86
4000	46.26	7.07	45.94	5.77
6000	45.83	6.92	43.79	5.29
8000	35.97	10.83	36.24	7.82

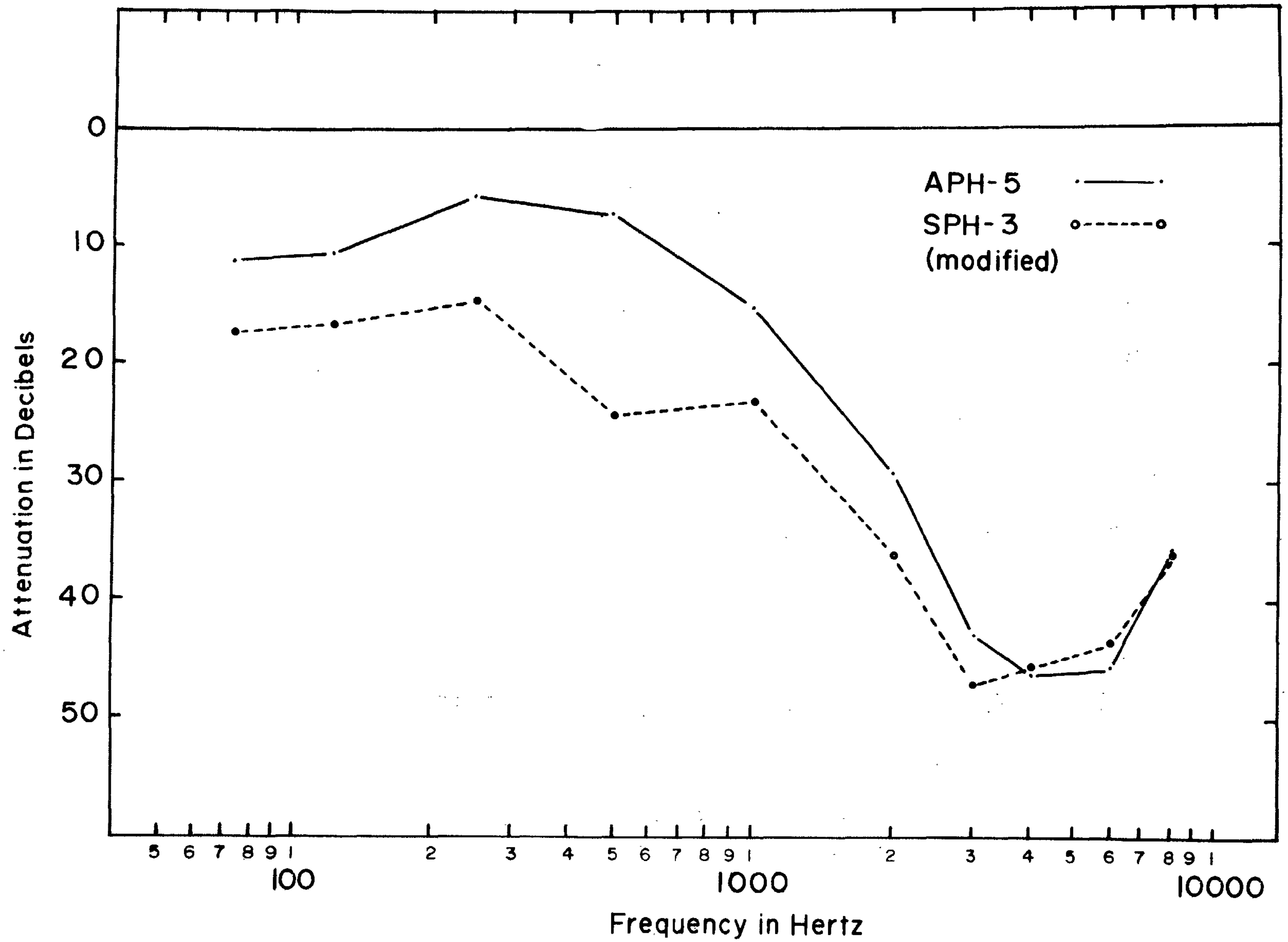

APH-5
SPH-3
(modified)
0
10
20
30
40
50
Attenuation in Decibels
5 6 7 8 9 1
100
2 3 4 5 6 7 8 9 1
1000
2 3 4 5 6 7 8 9 1
10000
Frequency in Hertz

Figure 6

Table VI

Decile Values in Decibels for Mean Real-Ear Attenuation Data of 36 Ear Protective Devices.

Deciles	75 Hz*	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
D_1	2.3	0.3	0.0	3.8	2.4	15.8	27.8	24.8
D_2	4.1	2.9	3.1	7.1	11.7	19.1	29.6	26.6
D_3	5.9	4.4	4.4	10.3	15.4	21.3	31.3	28.4
D_4	7.3	6.9	6.2	13.7	18.9	25.6	32.9	30.2
D_5	9.5	9.0	9.5	16.5	22.0	26.5	34.7	32.5
D_6	10.9	11.1	13.7	18.8	25.8	29.3	35.8	34.0
D_7	13.9	14.1	15.6	24.7	30.2	32.7	37.6	35.9
D_8	15.2	15.4	18.3	29.3	32.3	34.8	38.4	37.4
D_9	17.1	18.7	20.9	30.3	35.6	36.7	41.9	38.3

*Computed from data of 34 ear protective devices.

Table VII

Minimum, Median, Maximum, Mean, and Standard Deviation in Decibels of Real-Ear Attenuation Values Obtained from 36 Ear Protective Devices

	75 Hz*	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
Minimum	1	- 1	- 1	2	1	3	14	14
Median	9	9	9	16	22	26	35	32
Maximum	20	20	28	36	41	38	50	41
Mean	10.1	9.5	10.7	17.5	22.3	26.5	34.2	31.8
Standard Deviation	5.48	6.53	7.73	10.19	10.18	8.62	7.0	5.93

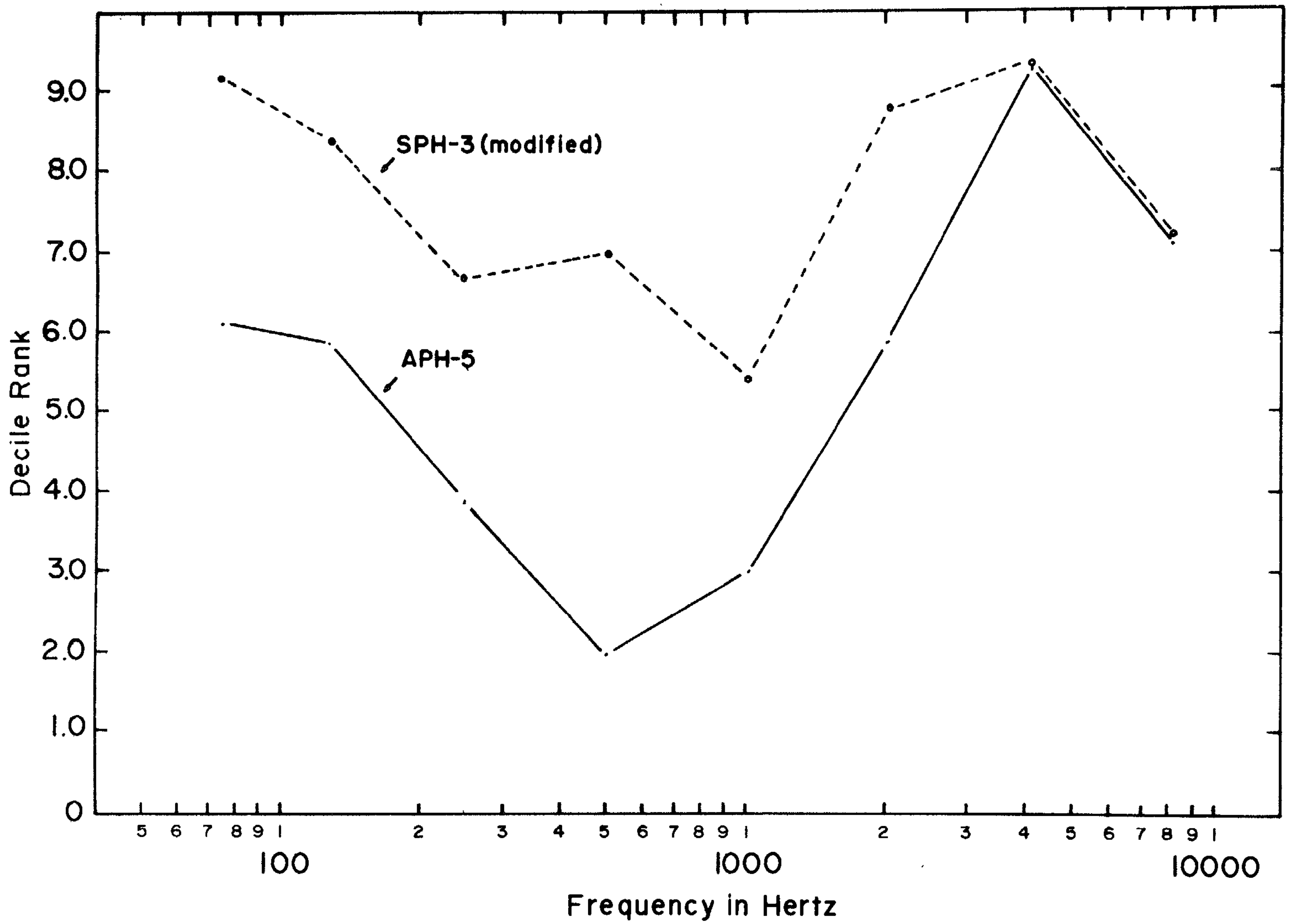
*Computed from data of 34 ear protective devices.

value without additional information. Figure 7 contains curves of the decile rank values yielded by the SPH-3 and APH-5. It may be seen that the SPH-3 varies between approximately 9 and 6 decile rank value and the APH-5 varies between approximately 6 and 2 among the test frequencies below 2,000 Hz. It is interesting to note that the lowest value obtained with the SPH-3 (Modified) (LS) at 1,000 Hz is approximately 6 decile rank which is approximately the same value of the maximum decile rank values of the APH-5 data which occurred at test frequencies 75 and 2,000. With these comparisons, there is no doubt that the SPH-3 is a much more efficient attenuator of sound at test frequencies between 75 and 2,000 Hz.

CONCLUSIONS AND RECOMMENDATIONS

Real-ear sound attenuation characteristics of the Navy SPH-3 (Modified) (LS) helmet were determined by standard procedures and equipment recommended by ASA Z24.22-1957. Ten subjects were tested three times each. This is the minimum amount required by the ASA specifications. Comparisons of the results of these measurements were made with the results obtained from USAARU Report 67-6 on the attenuation characteristics of the Army APH-5. The sound attenuation characteristics of the SPH-3 (Modified) are superior to the sound attenuation characteristics of the APH-5 between 75 and 2,000 Hz.

The test of the SPH-3 has demonstrated that there are helmets available with acoustic characteristics that are superior to those of the APH-5. In view of the manifest need for more ear protection for Army aviation personnel and improved voice communications, it is recommended that the SPH-3 be considered as a standard for Army personnel.



Decile Ranks of Real-Ear Attenuation Values
Obtained with the APH-5 and SPH-3(m) Helmets

Figure 7