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EAR PROTECTION PROVIDED BY SEVERAL STANDARD AIR FORCE DEVICES

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FOREWORD

This research was conducted in the Noise and Hearing Conservation Function of the Otolaryngology Branch, Clinical Sciences Division, under task No. 775508 from November 1970 through February 1971. The manuscript was submitted for publication on 22 February 1971.

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This report has been reviewed and is approved.

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Commander

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I. INTRODUCTION

Interest in noise and its potentially harmful effect on hearing is increasing rapidly. This increase can be attributed to the growth in intensity and duration of noise, the increasing awareness of various forms of pollution (including noise), and efforts by various agencies to control harmful effects of noise.

Many criteria for potentially harmful exposure to noise have been described (1). These criteria (usually pertaining to unprotected human ears) allow conclusions as to whether or not ear protectors should be worn. Attenuation provided by the ear protectors in question must be known in order to make computations required to assess degrees of auditory risk for protected exposures.

Attenuation values for specific ear-protective devices are not always readily available, particularly when combinations are used. Although attenuation values can be found for a wide assortment of devices and for some combinations, exact identification is often difficult. Items procured through the Air Force supply system may be identified by federal stock number, federal nomenclature, or manufacturer-model designation. A single stock number and nomenclature may include items from several manufacturers.

The goal in this study was to determine attenuation values for several ear protectors procured through usual Air Force supply channels.

II. PROCEDURE

The testing apparatus, diagrammed in figure 1, was similar to that used by Nixon et al. (2), Sutherland and Endicott (3), and Sommer et al. (4). Pure tone from an oscillator was fed to an electronic switch, then to a 3-watt amplifier, and then to an attenuator with a 110-dB range in 1-dB steps. The signal then went into an anechoic chamber and into a second attenuator with 110-dB range in 1-dB steps. From here the signal went through a transformer and to the loudspeaker. An electronic counter constantly monitored pure tone frequency from the oscillator. A vacuum tube voltmeter monitored signal level at output from the 3-watt amplifier. A talkback system was provided for subject response, and a closed circuit TV permitted visual monitoring of the subject. A plumb bob was suspended from the ceiling for positioning the subject's head.

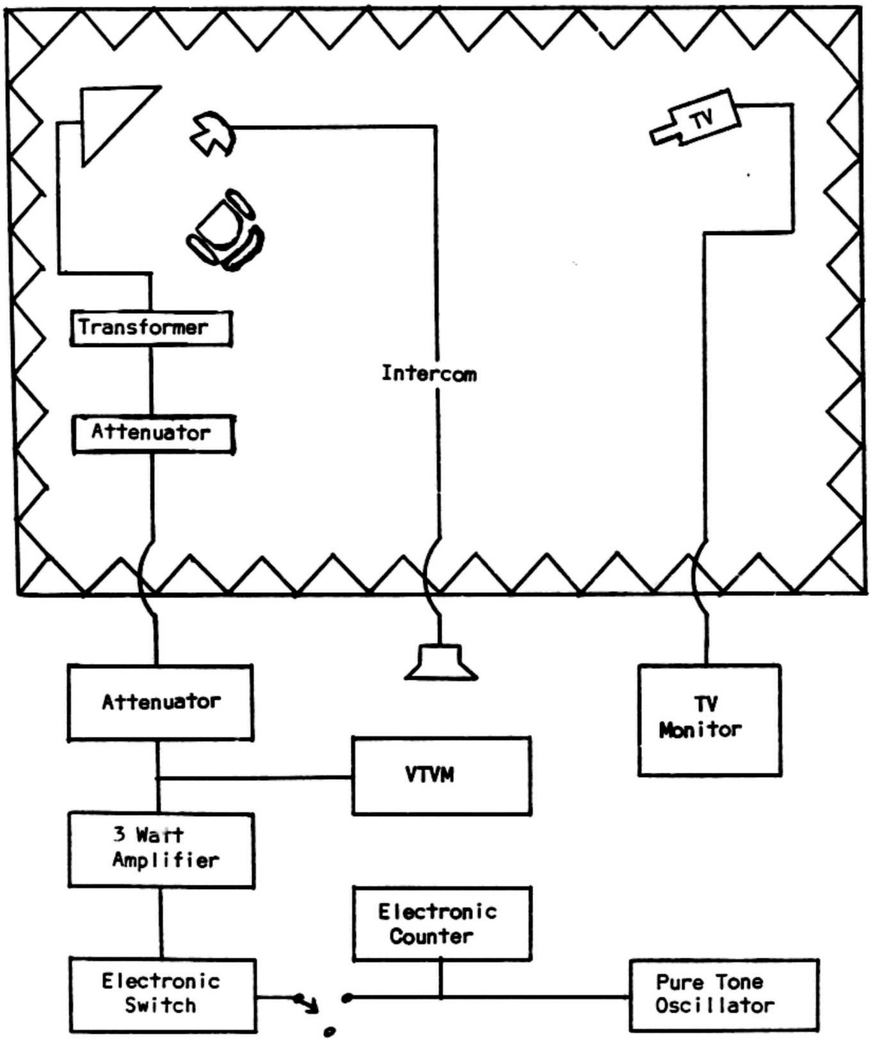

FIGURE I

Block diagram of apparatus used to determine sound attenuation.

Subjects were 10 volunteer Air Force enlisted men, ranging in age from 18 through 21, who had just completed their basic training.

Ear protectors selected for evaluation were:

1. Plug, ear, noise protection, (size), single flange. (U.S. Plastic Molding, Inc.):

Federal Stock No.	Size
6515-664-7858	Extra small
6515-299-8290	Small
6515-299-8289	Medium
6515-299-8288	Large
6515-664-7859	Extra large

2. Aural protector, sound attenuation, type PRU-1A/P. (David Clark Co., Inc., model 117): Federal Stock No. 4240-691-5617.

3. Headset, microphone, H-157/AIC. (Roanwell Corp.): Federal Stock No. 5965-755-4656.

4. Ball, absorbent, viscose rayon, 1¼-inch diameter: Federal Stock No. 6510-201-4100.

The earplugs used (No. 1 above) are commonly referred to as the V-51R (5, 6). Each subject was fitted with the most appropriate size plug for each ear. One earmuff set (No. 2) and one headset-microphone (No. 3) were used for all subjects. The absorbent rayon ball (No. 4), practically always referred to as "dry cotton," is a convenient size for placing in the ear canal. This item was selected for study because of the frequent recommendation that flyers use "dry cotton" in their ears when wearing a flight helmet or communications headset. The experimenter inserted the earplugs and the "dry cotton" when used in testing.

The experiment was divided into two parts, with items 1 and 2 (fig. 2) from the above list included in the first part and items 3 and 4 (fig. 3) in the second part.

In the first part, threshold was determined for (a) open ear, (b) single-flange earplugs, (c) earmuffs, and (d) the same plugs and muffs in combination. Attenuation was determined by a method similar to that recommended in ANSI Z24.22-1957 (real ear attenuation at threshold) (7). Each subject's threshold for free-field pure tone (125, 250, 500, 1000, 2000, 3000, 4000, 6000, and 8000 Hz) was found twice with each of the three forms of ear protection and with no protection. Ear-protector attenuation is the difference between the unprotected and protected threshold values. Threshold was obtained by the method of adjustment. The experimenter set a random amount of attenuation on his attenuator,

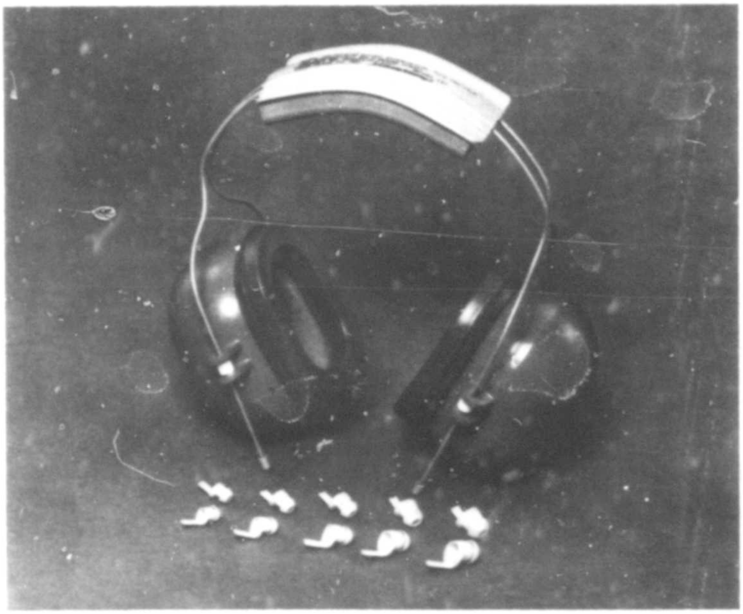

FIGURE 2

Single-flange earplugs and type PRU-1A/P aural protectors.

FIGURE 3

Absorbent rayon balls and H-157/AIC headset-microphone.

and the subject then adjusted his attenuator in 1-dB steps until he found his own threshold. He then orally reported his attenuator setting to the experimenter and prepared to listen again. The sum of the two attenuators was recorded as a threshold adjustment. Three adjustments to threshold were made at each pure tone frequency with each ear-protection condition. The tone was always pulsed at 500 msec. on and 500 msec. off, with rise-decay time of 25 msec. The order of testing the four conditions--open ear, plugs, muffs, plugs and muffs--was randomized.

The second part was done with the same procedure except that there were only three conditions: (a) open ear, (b) headset-microphone, and (c) headset-microphone, with dry absorbent rayon in the ear canals.

III. RESULTS

Individual (the average of two tests) and mean attenuation values, in decibels, are given in the table for all subjects. The individual data are included primarily to illustrate how two subjects seemed different from the others. Subject 3 yielded very poor attenuation, mainly at low frequencies, with both circumaural-type ear protectors (muffs and headset-microphone). Subject 10 showed poor attenuation with the ear-muffs but good attenuation with the headset-microphone. Subjects 8, 9, and 10 yielded noticeably better attenuation than the first seven subjects at frequencies 1000 Hz and below with the headset, both with and without cotton. There was no apparent reason for this occurrence.

Average attenuation for the five types of ear protection is shown graphically in figure 4. The greatest amount of attenuation was obtained with the combination of earplugs and earmuffs, while the poorest was found with the headset-microphone. The dashed line in figure 4 indicates the increase in attenuation with the H-157 headset-microphone when "dry cotton" was placed in the ear canals.

Figures 5, 6, 7, and 8 compare attenuation values found here with similar determinations made at the 6570th Aerospace Medical Research Laboratories (AMRL), Wright-Patterson AFB, Ohio (2, 8, 9). Remarkable agreement is seen for the V-51R-type earplug (fig. 5) even though the plugs were from different manufacturers. Nixon et al. (2) used plugs manufactured by the Mine Safety Appliance Co., while the present study used plugs manufactured by the U.S. Plastic Molding Corp. A substantial difference for the earmuffs is apparent in figure 6. Both USAFSAM and AMRL (8) studied the same make and model earmuffs. It is possible that some differences did exist, such as in headband design and tension or in configuration of the cushion on the muffs. The important factor is that muffs identified as identical did not yield the same attenuation values at the different facilities.

TABLE

Sound attenuation (in dB) for five types of standard Air Force ear-protective devices: individual and mean results from 10 subjects

Protector	Subj. No.	125	250	500	1000	2000	3000	4000	6000	8000
		Frequency (Hz)								
Plugs	1	30	29	28	31	29	38	35	44	41
	2	25	27	27	29	38	33	42	47	42
	3	20	21	21	29	38	41	32	31	37
	4	16	17	18	23	28	26	21	24	21
	5	24	26	24	25	36	41	36	42	33
	6	22	22	23	26	34	29	30	30	51
	7	27	28	29	31	31	34	31	37	32
	8	14	13	18	18	31	30	24	23	35
	9	27	28	26	26	38	47	59	37	31
	10	25	22	26	28	31	27	22	17	35
	Mean	23	23	24	27	33	35	33	33	36
Muffs	1	18	22	32	40	29	37	32	25	25
	2	10	21	33	41	30	36	41	30	27
	3	-2	2	15	26	18	27	31	14	24
	4	15	21	31	39	26	38	42	22	37
	5	17	22	30	39	27	36	36	32	25
	6	7	15	24	34	26	31	37	28	41
	7	13	19	30	35	23	26	38	31	29
	8	9	12	24	32	28	30	37	22	22
	9	12	14	23	26	29	26	39	19	25
	10	1	7	22	31	29	20	32	23	35
	Mean	10	16	26	34	27	31	37	25	29
Plugs and Muffs	1	38	39	43	51	51	52	53	46	42
	2	27	40	42	38	43	49	58	50	53
	3	18	27	37	40	51	53	48	37	37
	4	26	35	34	45	41	41	55	41	53
	5	33	36	37	39	46	51	47	48	45
	6	21	35	41	42	51	55	44	45	54
	7	34	40	47	52	48	49	55	56	54
	8	24	29	32	42	41	49	43	36	44
	9	29	30	32	28	45	48	52	40	34
	10	25	35	43	44	42	41	45	40	49
	Mean	28	35	39	42	46	49	50	44	47

TABLE (cont.)

Protector	Subj. No.	Frequency (Hz) 125	250	500	1000	2000	3000	4000	6000	8000
Headset-microphone	1	8	10	14	26	26	29	33	22	25
	2	6	10	22	32	34	34	35	25	17
	3	0	1	5	20	29	27	29	9	8
	4	6	11	19	23	28	29	45	23	33
	5	6	10	14	19	27	32	45	29	23
	6	5	5	7	20	29	29	33	19	30
	7	6	7	17	21	34	29	35	28	27
	8	17	28	39	39	32	38	36	17	39
	9	19	27	36	33	33	30	39	23	35
	10	14	29	38	36	34	36	43	25	44
	Mean	9	14	21	27	31	31	37	22	28
Headset-microphone with rayon balls	1	8	8	13	25	35	48	43	36	41
	2	12	18	31	33	49	61	62	48	54
	3	1	1	14	30	48	43	48	33	34
	4	7	13	27	34	37	45	52	47	52
	5	7	7	17	29	40	44	43	47	40
	6	5	8	12	31	51	49	54	35	51
	7	4	10	22	31	48	45	50	47	49
	8	17	30	36	47	41	58	44	44	50
	9	21	32	35	33	39	47	50	52	44
	10	19	36	49	40	44	43	49	40	51
	Mean	10	16	26	33	43	48	50	43	47

A surprising development is seen in figure 7 where the two facilities found very similar attenuation when the earplugs and earmuffs were used in combination. The difference seen for muffs alone (fig. 6) would suggest that a difference would also appear with the earplug-earmuff combination.

Attenuation found at USAFSAM and at AMRL (9) for the headset-microphone (fig. 8) is about the same, except at 6000 and 8000 Hz. (However, if data from subjects 8, 9, and 10 are excluded, a difference appears for 125 through 1000 Hz.) Attenuation data from another facility for the headset-microphone in combination with dry cotton were not available.

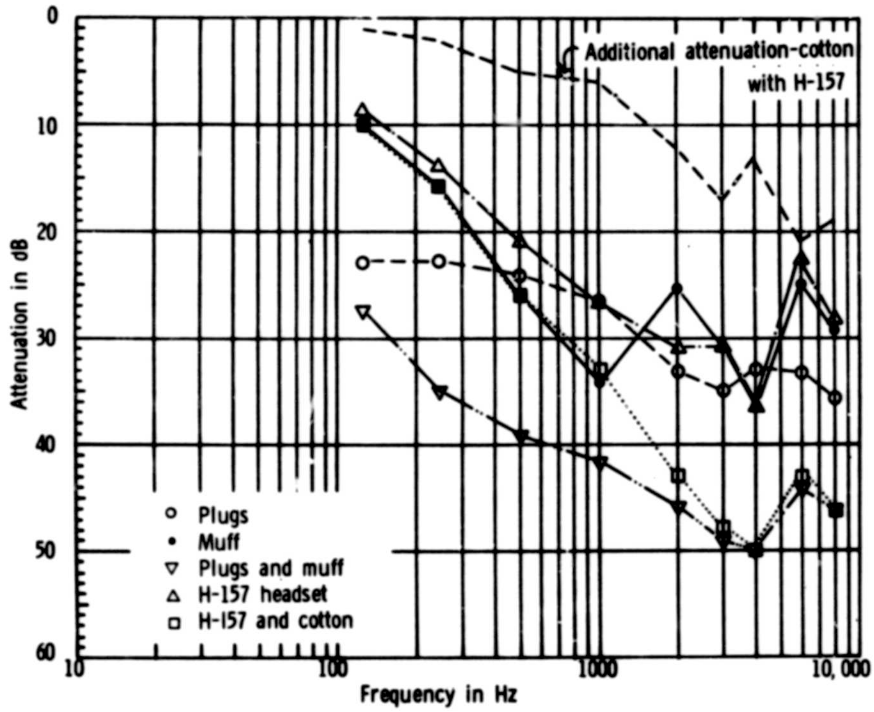

FIGURE 4

Sound attenuation in decibels for five types of standard Air Force devices, mean results from 10 subjects.

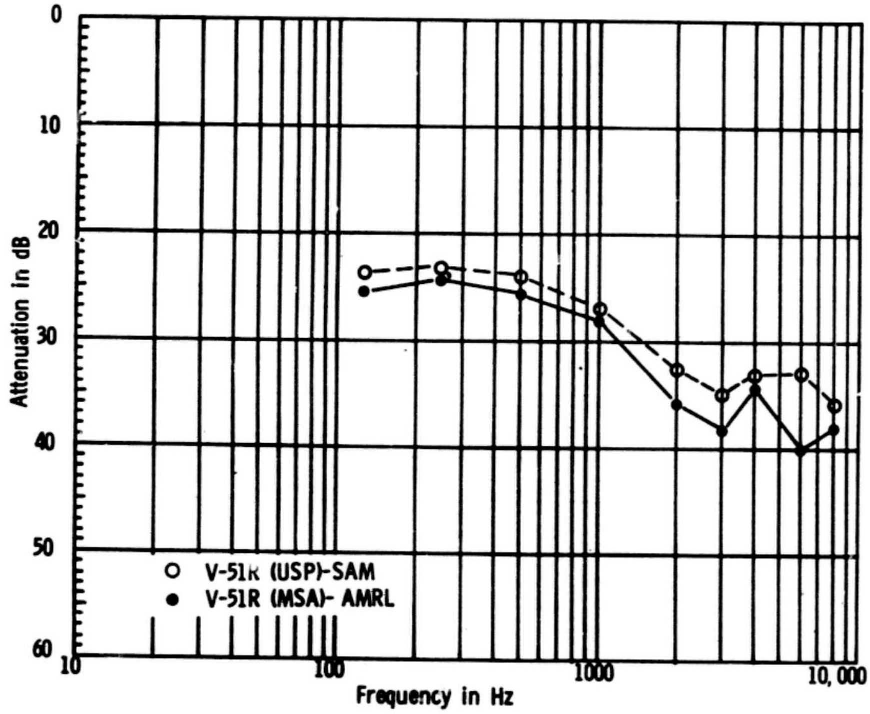

FIGURE 5

Attenuation in decibels for single-flange (V-51R) ear-plugs as determined in this experiment (USAFSAM) and at Wright-Patterson AFB (AMRL).

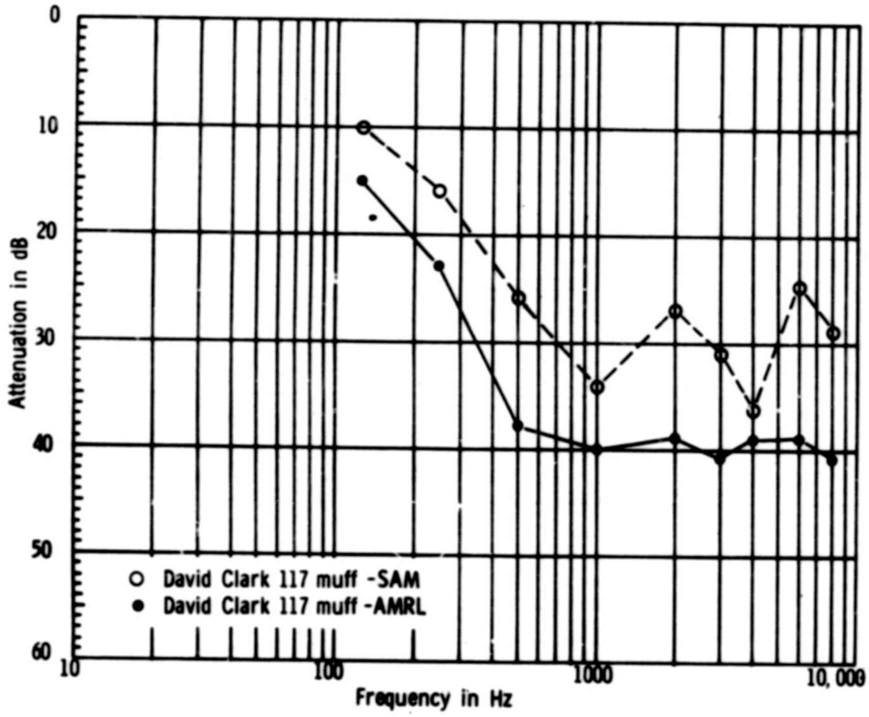

FIGURE 6

Attenuation in decibels for earmuffs (PRU-IA/P) as determined in this experiment (USAFSAM) and at Wright-Patterson AFB (AMRL).

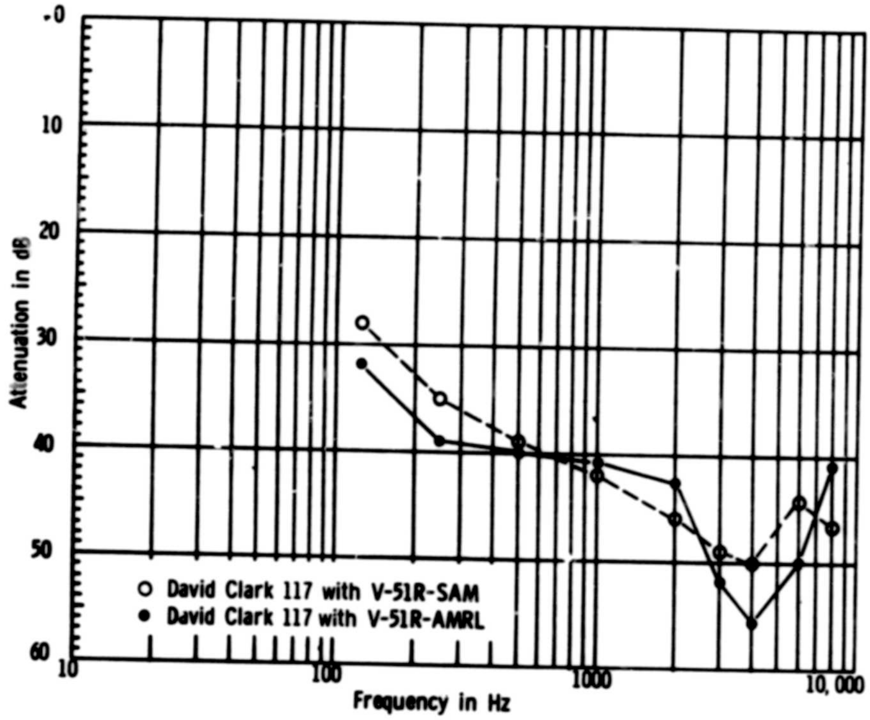

FIGURE 7

Attenuation in decibels for single-flange earplugs worn in combination with PRU-IA/P earmuffs as determined in this experiment (USAFSAM) and at Wright-Patterson AFB (AMRL).

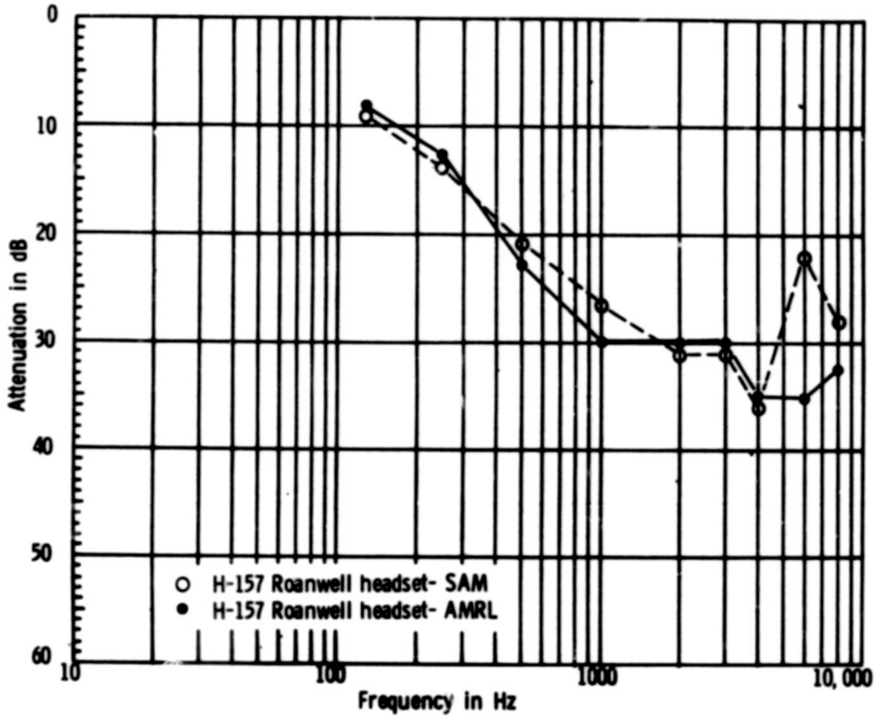

FIGURE 8

Attenuation in decibels for H-157/AIC headset-microphone as determined in this experiment (USAFSAM) and at Wright-Patterson AFB (AMRL).

IV. CONCLUSIONS

Results from this study indicate that ear protectors routinely procured by the Air Force may not yield attenuation equivalent to that reported in studies of compliance with military specifications for aural-protector attenuation (8). Further, the performance of subjects 3 and 10 emphasizes the need for individual attention in ear protection. In general, when noise exposure under ear protection is being computed, the published average attenuation for the particular device is used. If this computation were made for subject 3 with standard earmuffs, the estimated noise exposure would be considerably less than the actual exposure he would receive. This suggests a need for occasionally testing the actual attenuation obtained by an individual with a particular form of ear protection. This procedure would be desirable when (a) extremely intense noise exposure exists, (b) a person is acquiring apparently noise-induced hearing loss even with ear protection, or (c) unusual difficulty is encountered in fitting an ear protector.

The attenuation revealed with the headset-microphone and "dry cotton" combination indicates that the dry cotton does, in fact, achieve the desired goal; that is, a significant reduction in the higher frequency sounds is acquired. This should certainly provide relief from some of the higher frequency pure tone components that are characteristically present near jet engines operating at low r.p.m. However, the abrupt slope in frequency response, a 40-dB drop between 125 and 4000 Hz, may have some implications in speech intelligibility. The greatest effect would be expected if the speech were coming from a free-field source, such as a loudspeaker. Speech generated under the earphone would be modified only by the effect of the cotton. This topic should be subjected to experimentation.

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