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USAARL REPORT NO. 73-8

REAL-EAR SOUND ATTENUATION CHARACTERISTICS OF THE DH-132 HELMET FOR ARMORED VEHICLE CREWMEN

By

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February 1973

Biophysics Division
U. S. ARMY AEROMEDICAL RESEARCH LABORATORY
Fort Rucker, Alabama

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U. S. Army Medical Research and Development Command

ABSTRACT

The U. S. Army Aeromedical Research Laboratory was requested by the Preventive Medicine Division of The Office of The Surgeon General to test "off-the-shelf" helmets that would be suitable for replacement of the standard T-56-6 CVC helmet. Audiometric data taken from samples of tank crewmen revealed hearing losses which indicated that there is an urgent need for the development of a helmet that would protect against the adverse acoustic environments associated with tank operations. Previous evaluation by real-ear tests of sound attenuation established the T-56-6 to be an inadequate acoustic protective device for armored vehicle crewmen.

Three "off-the-shelf" helmets were tested and recommended as suitable for consideration as a possible replacement for the standard CVC helmet. The DH-132 was identified by the Armor Center as their choice of the three presented as most appropriate for the armor environment.

A Materiel Need (MN) document was prepared and staffed to procure the DH-132. The first group procured for engineering and service test DH-132-1 was found less efficient than the original DH-132. This identified deficiency was corrected in a second prototype DH-132-2. Data in this report confirms the DH-132-2 meeting or exceeding all acoustic attenuation requirements of the MN and medically acceptable as an acoustic protector for armored vehicle crewmen. Therefore type classification Standard A is recommended for the DH-132-2 helmet.

APPROVED: ROBERT W. BAILEY
COL, MSC
Commanding

REAL-EAR SOUND ATTENUATION CHARACTERISTICS OF THE DH-132 HELMET FOR ARMORED VEHICLE CREWMEN

INTRODUCTION

The Aeromedical Research Laboratory was requested by the Preventive Medicine Division of The Office of The Surgeon General, in 1970, to provide information about the attenuation characteristics of some "off-the-shelf" helmets that might replace the standard T-56-6 CVC helmet. Previous tests of the real-ear attenuation of the T-56-6 helmet revealed that the attenuation characteristics did not protect adequately against the high sound pressure levels within the U. S. Army tanks.

From the data collected on various types of helmets during the development of the SPH-4 helmet, the U. S. Army Aeromedical Research Laboratory selected and recommended three types of helmets that fulfilled the acoustic protection requirements of the U. S. Army tank crewmen. This was reported in USAARL Letter Report of 25 May 1970, "Real-Ear Sound Attenuation Characteristics of Three Brands of Ear Protective Devices Proposed for Armored Vehicle Crewmen," that described the real-ear attenuation data on three brands of helmets with ear protective devices, namely: 1) the David Clark HPG-9A; 2) the CBS MARK III; and 3) the Gentex DH-132. Of these three proposed helmets, the DH-132 was selected by Armor Center representatives as the most suitable for the tank crewmen. Since that time, materiel need requirements and specifications were written and samples from the vendor obtained for engineering and service tests. This Laboratory was responsible for evaluating the medical aspects of bump protection, thermal protection and acoustic protection. Measurement of the real-ear attenuation characteristics of the samples, and recommendations are the subject of this report.

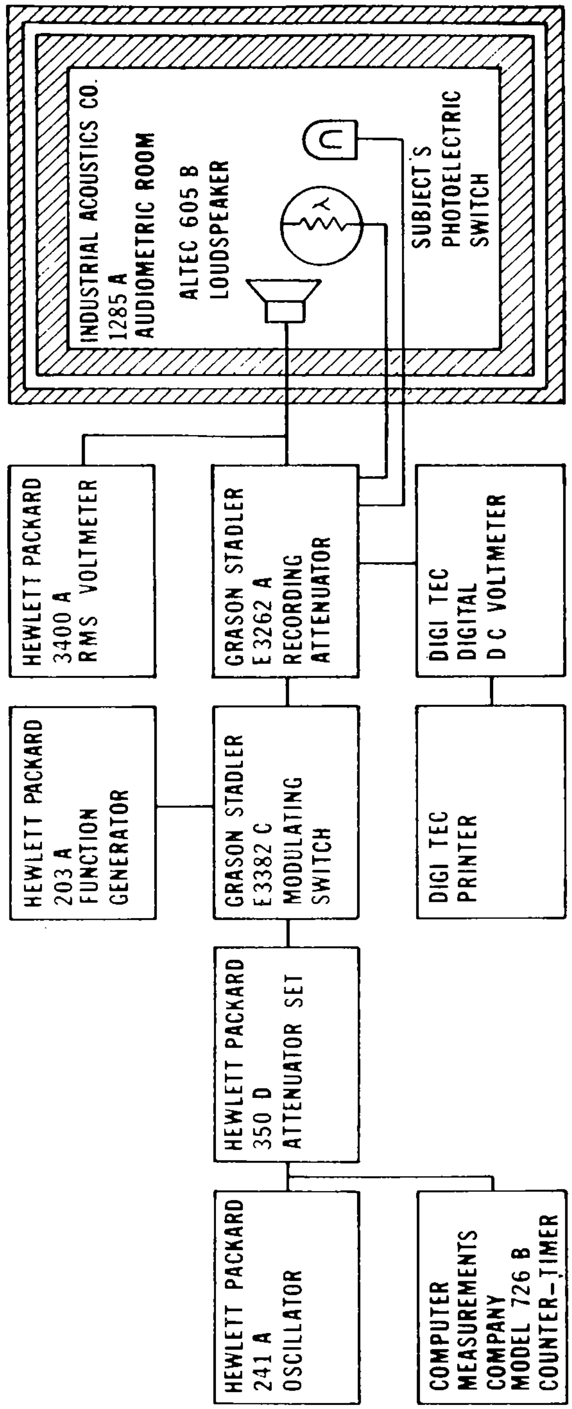
PROCEDURE AND EQUIPMENT

Procedures, equipment and physical requirements specified in the standard method for the measurement of the real-ear attenuation of ear protectors at threshold, ANSI Z24.22-1957, were used for ascertaining the real-ear attenuation characteristics of the DH-132 helmet.

In addition to the standard 125, 250, 500, 1K, 2K, 3K, 4K, 6K and 8K Hz test frequencies, one lower test tone 75 Hz was included. The tones were generated by a Hewlett-Packard 241-A oscillator. See Block Diagram of instruments in Figure 1. The output of the oscillator was connected to a step attenuator set - a Hewlett-Packard 350D with a range of 110 dB in 1 dB steps. This attenuator provided the experimenter with a calibrated control of test tone levels for checking the subjects' reliability; also, the control of the overall 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 the input of a Grason Stadler E-3382C modulating switch. The modulating switch served as a device for interrupting the test tones with a 50 percent duty cycle and with off and on durations of approximately 370 milliseconds which simulates the interruption rate of our Laboratory audiometer. The rise and decay times of the switch were 40 milliseconds each. The E-3382C modulating switch also served as a power amplifier for driving the loudspeaker. The Grason Stadler E-3262A recording attenuator was between the power amplifier and loudspeaker for recording and control of output level of the loudspeaker. The loudspeaker was an Altec 605B, a two-way duplex 15-inch 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 has facilities for changing directions, stopping the attenuator and overriding the subject's control. Having the recording attenuator on the output of the power amplifier provides attenuation of the test signal and the amplifier noise. The voltage to the loudspeaker was measured with a Hewlett-Packard 3400A RMS voltmeter. The circuitry was calibrated with this voltmeter at the beginning of each test.

In addition to recording the information on the recording attenuator, there is a digital printout 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 across the potentiometer yields digital voltage readings that are numerically identical to the attenuation values registered on the recording attenuator. This information was printed by a Digi Tec printer which was connected to the digital voltmeter. This system of representing attenuation values with voltage readings has a resolution equivalent to one-tenth decibel.

The recording attenuator circuitry was provided with a one-shot



BLOCK DIAGRAM OF INSTRUMENTATION FOR REAL-EAR ATTENUATION TEST

Figure 1

monostable multi-vibrator circuit that sent a print command each time the subject changed recording attenuator direction. With a Bakesy type response for constant test tones, there was an oscillation of attenuation 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 printout facility provided digital printout 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 end of ten responses.

A quiet environment was provided by an Industrial Acoustic Company 1285-A double wall audiometric room. The intensity gradients were measured for certain test tones as required by ANSI Z24.22 - 1957. Tables I through III contain sound pressure levels measured in 1-inch increments along three axes from the subject's head. These were the normal maximal sound pressure level values of each test tone after calibration. The 1285-A had extremely high attenuation characteristics throughout the audiospectrum. 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 measuring instrumentation was a calibrated one-inch Bruel & Kjaer microphone, a Bruel & Kjaer audiofrequency spectrometer type 2112, a Bruel & Kjaer level recorder type 2305, and a Bruel & Kjaer statistical analyzer type 4420. System noise measurements were done with the microphone cartridge replaced by a 50 pico farad capacitor.

RESULTS AND DISCUSSION

Real-ear attenuation values obtained with the samples of the Gentex DH-132 helmets are shown in Table V. Column 1 contains the original data published in the 1970 Letter Report about the original findings of the attenuation characteristics of the DH-132. The second column contains the attenuation characteristics of the first prototype DH-132-1 and the third column contains the attenuation values of the second prototype DH-132-2. The minimum attenuation characteristics as written in the materiel need specifications for the armored vehicle crewmen helmets are shown in Column 4.

The results from the first test performed on the DH-132 helmets in Column 1 show that all values exceeded the required values in the specifications. However, the second column data shows that the first test sample DH-132-1 did not pass the test. The attenuation was found to have deteriorated considerably at frequencies of 125 Hz, 250 Hz, 500 Hz, 1KHz, and 2KHz. Investigations into the reasons why the DH-132 failed to yield the original values show that there was a modification, required by other Army agencies, which had an adverse effect on the

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, Ft. 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 Mean SPL Equiv.	System Noise Standard Deviation	Room Noise Mean SPL	Room Noise 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 in Decibels Obtained with Gentex DH-132 Helmets

Test Frequencies in Hertz	DH-132 Original Prototype in 1970 (1)		DH-132-1 First Test Samples in 1972 (2)		DH-132-2 Modified Test Samples in 1972 (3)		Mean Attenuation Values Required by Specifications (4)
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation	Mean
75	18.85	5.61	12.09	6.34	21.74	6.31	
125	15.62	3.44	11.65	5.65	16.95	3.63	15
250	16.23	2.54	13.15	6.02	20.41	0.99	14
500	26.81	3.36	21.48	5.29	25.61	2.71	24
1000	31.08	4.16	17.33	5.83	32.12	4.50	28
2000	35.40	3.88	26.44	5.38	30.57	3.66	30
3000	37.95	2.53	37.56	4.81	42.71	3.84	35
4000	41.78	5.37	46.56	7.54	44.31	3.19	35
6000	39.82	8.67	36.90	8.54	37.39	6.06	35
8000	32.11	6.57	33.10	10.86	34.68	7.98	30

(1) Tests performed at USAARL - 3 subjects 3 times each.
(2) " " " " - 10 subjects 3 times each.
(3) " " " " - 3 subjects 3 times each.

sound protective characteristics. It therefore required further modifications to correct the faults induced by these modifications. Column 3 contains the results of the real-ear attenuation test after the correction of induced losses in attenuating efficiency. These values show that the second prototype of the DH-132 (DH-132-2) provided the attenuation characteristics required by the specifications of the MN for an improved armor vehicle crewman's helmet. It is therefore concluded that the DH-132-2 does equal, or exceed the attenuation characteristics required to protect against the high level noise encountered by armor vehicle crewmen.

SUMMARY AND CONCLUSIONS

At the request of the Preventive Medicine Division of The Office of The Surgeon General, the Aeromedical Research Laboratory assumed the task of obtaining a solution to the problem of severe hearing loss among tank crewmen caused by the adverse acoustical environment associated with tank operation. Three "off-the-shelf" helmets were submitted in 1970, one of which - the DH-132 - was selected as suitable for test and consideration as a replacement for the original CVC helmet. Later, this Laboratory received test samples (DH-132-1) and discovered that modifications of the original DH-132 had caused a deterioration of the attenuation characteristics. A second modification was performed to regain the original acoustical integrity of the prototype DH-132-1. This configuration of the DH-132 (DH-132-2) does fulfill the requirements in terms of adequate acoustic protection against the high level tank and weapons noise. It is therefore recommended that this helmet be classified as the Standard A for armored vehicle crewmen.

Dated: 16 February 1973

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2. Audition						
3. Hearing Conservation						

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