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EFFECTS OF CHEMICAL PROTECTIVE AND OXYGEN MASKS ON ATTENUATION AND INTELLIGIBILITY WHEN WORN WITH THE SPH-4 HELMET

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March 1984

U.S. ARMY AEROMEDICAL RESEARCH LABORATORY
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ABSTRACT: The utilization of protective equipment by today's soldier is essential to enhance and ensure his ability to perform on the battlefield. However, a given personal protective system may influence the performance of another. This investigation evaluated the effects of three chemical defense masks on speech intelligibility and real-ear attenuation characteristics of the SPH-4 aviator helmet. The effects of two oxygen masks on speech intelligibility also were investigated.

ACKNOWLEDGEMENT

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INTRODUCTION

The utilization of protective equipment by today's soldier is essential to enhance and ensure his ability to perform on the battlefield. The soldier's protective equipment must be designed with its effect on the total system being a primary consideration. This study investigated the effects of Chemical Protective (CP) masks on the hearing protective and communication components of the SPH-4 aviator helmet.

Speech intelligibility of an electrically-aided voice communication system is a measure of the suitability of a system for voice message interchange between individuals. The system may be divided into several parts which perform specific functions in the overall interchange process. We investigated two components of the process which may be influenced by wearing a CP mask. The first was the conversion of sound waves produced by the speaker's voice into electrical speech signals which are transmitted to the listener. The second was the conversion of the speaker's electrical speech signals into sounds which are heard by the listener. The effects of the former process will be defined as a measure of the speaker's intelligibility while effects of the latter process will be defined as listener's intelligibility.

Three CP masks (M-24, XM-33, the British AR-5) and two oxygen masks (the P/Q and MBU-12) were evaluated to determine how they interact with the SPH-4 aviator helmet in terms of speech intelligibility and real-ear attenuation. All of the masks were evaluated to determine their effects on the speaker's intelligibility. The CP masks were evaluated to determine their effects on the listener's intelligibility and the real-ear attenuation while wearing the SPH-4 aviator helmet.

Request for the evaluation of these masks came from two sources. The Biomedical Applications Research Division, USAARL, requested evaluation of the M-24 and AR-5 CP masks and the British P/Q and MBU-12 oxygen masks in terms of their effects on real-ear attenuation and intelligibility of the SPH-4 helmet. The US Army Aviation Development and Test Activity (ADTA) requested an evaluation of the attenuation characteristics of the SPH-4 helmet when worn with the XM-33 or M-24 CP masks.

METHOD AND INSTRUMENTATION

INTELLIGIBILITY

Appendix A shows various views of the mask conditions evaluated in this experiment. The speech intelligibility of each mask worn in combination with the SPH-4 helmet was measured using Phonetically Balanced (PB) words. The list of words used in this experiment is described in ANSI S3.2-1960 (R1971). Each list consisted of 50 PB words. A different PB word list was assigned to each of nine test conditions which are summarized in Table 1.

TABLE 1

CONDITIONS USED IN THE EVALUATION OF SPEECH INTELLIGIBILITY

Test Condition	Speaker Conditions	Listener Conditions
1	Wearing SPH-4	Wearing SPH-4
2	Wearing SPH-4 & M-24	Wearing SPH-4
3	Wearing SPH-4 & XM-33	Wearing SPH-4
4	Wearing SPH-4 & AR-5	Wearing SPH-4
5	Wearing SPH-4 & MBU-12	Wearing SPH-4
6	Wearing SPH-4 & P/Q	Wearing SPH-4
7	Wearing SPH-4	Wearing SPH-4 & M-24
8	Wearing SPH-4	Wearing SPH-4 & XM-33
9	Wearing SPH-4	Wearing SPH-4 & AR-5

All speaker conditions utilized PB words recorded by a single speaker in the simulated UH-60A aircraft noise environment are shown in Table 2. The speech samples used in this experiment were recorded on a Nagra* Model SJ magnetic tape recorder. The sample lists were reproduced and adjusted in level with a Grason-Stadler* 1701 diagnostic audiometer. Each list was presented to the subject in the simulated aircraft noise environment through the SPH-4 communication system at a level which was 10 dB above Speech Reception Threshold (SRT). The SRT was determined with a "high quality" speech signal presented to the listener for each of the test conditions. The SRT was used to equalize the speech level at the listener's ear for all of the test conditions. This provides for a measure of intelligibility of each device relative to the other devices in the sample at equal listener levels. The order of the nine test conditions was randomized for each subject. It must be understood that the percentage scores may not represent those achievable for conditions different from those tested.

Ten subjects, nine males and one female, were used in this study. Each subject had normal hearing which is defined as no more than 10 dB hearing loss (reference ANSI S3.6 1969) (R1973) for the frequencies 250, 500, and 1000 Hertz and no more than 20 dB hearing loss for the frequencies 2000, 3000, 4000, 6000, and 8000 Hertz.

*See Appendix B.

TABLE 2

OCTAVE-BAND SOUND PRESSURE LEVELS OF THE SIMULATED UH-60A NOISE ENVIRONMENT

Octave-Band Center Frequencies in Hertz								
63	125	250	500	1K	2K	4K	8K	16K
97	97	98	95	89	88	82	83	80

REAL-EAR ATTENUATION

The real-ear attenuation of the SPH-4 helmet when worn in combination with each CP mask was measured using ANSI Standard S3.19-1974. The M-24 and XM-33 were evaluated with and without the protective hood in place. The hood was worn under the SPH-4 helmet for the conditions as shown in Figures A-8 and A-10.

The AR-5 mask was evaluated with the blower system not operating. It was determined that the blower system would influence the threshold measurement and produce an unrealistic attenuation value.

The signals used in the test were generated and controlled by the instrumentation shown in Figure 1. The noise generator (Bruel and Kjaer* (B&K) Type 1405) was set to output white noise into the band pass filter, B&K Type 1618. The electronic switch, Grason-Stadler type 1287B, was pulsed with a 1 Hertz symmetric square wave control signal. The rise and fall time of the electronic switch was adjusted to 30 milliseconds to exclude audible transients during on-off or off-on transitions of the test signal. The spectrum shaper was used to provide an equalized output sound pressure level at the listener's head position over the total frequency bandwidth of the test signals. The step attenuator provided the experimenter with a calibrated control of the test signal to check the subject's reliability and extend the usable range of the recording attenuator. This is especially useful for devices which have high efficiency in the low frequencies.

The recording attenuator was modified to include a 0.5% linearity potentiometer with its wiper shaft position directly related to the attenuator level, which is directly related to the output level of the test signal presented to the listener. The recording attenuator's motor direction was controlled by the subject with a noiseless photo-electric switch. For each test sound, the listener controlled the signal level in a Bekesy (1947) type presentation to determine the threshold of audibility. At each reversal point of the tracking process, the potentiometer output was input into

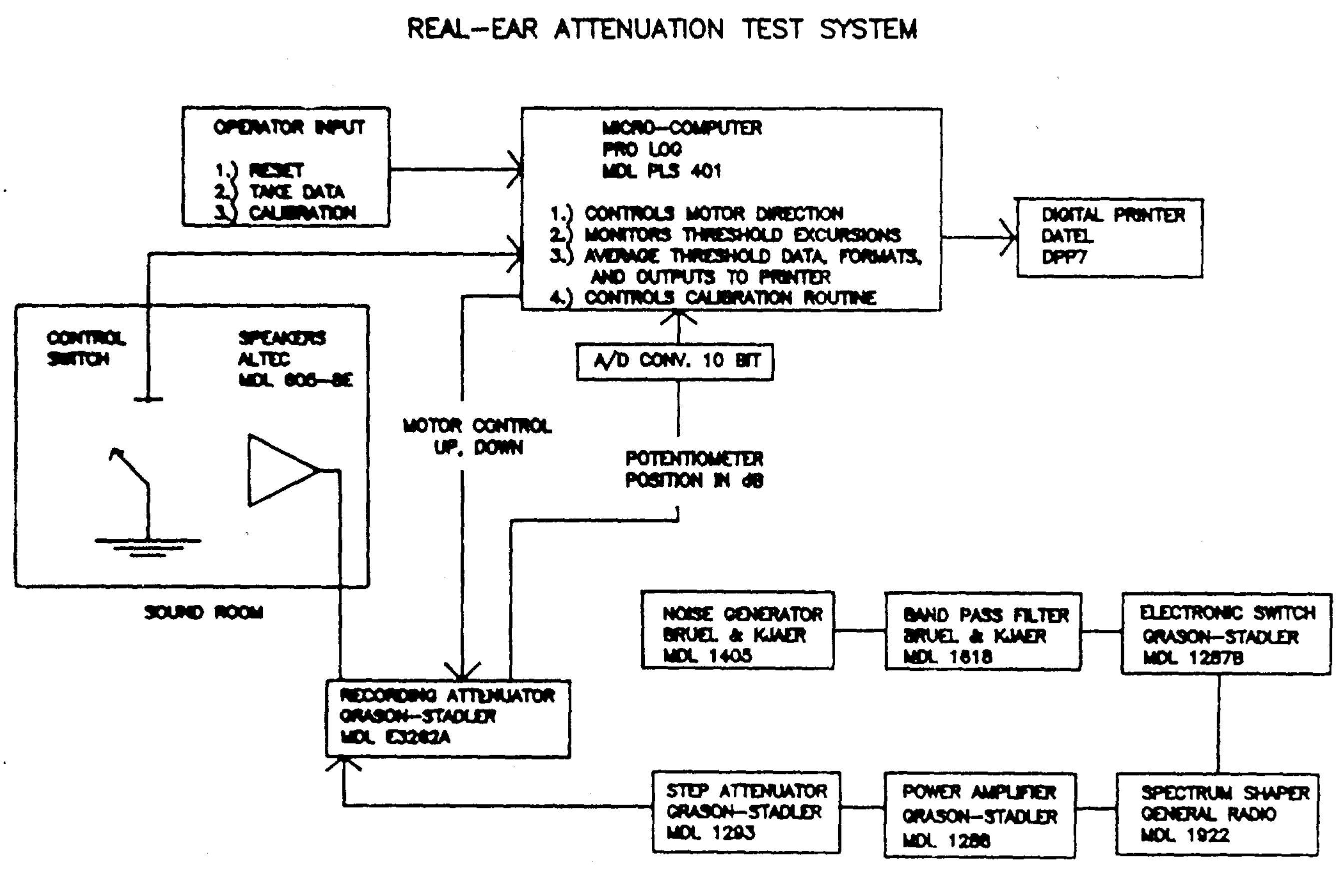

FIGURE 1. Real-Ear Attenuation Test System

the microprocessor control system where it was processed and printed. The system summed ten reversal points, computed the average, and printed the output. Thresholds for each of the test frequencies, with and without the device under test being worn, were determined. The difference in threshold between the with and without condition in each test band gives the real-ear attenuation values of the device. During the threshold measurements the subject maintained his head position by placing his chin in a fixed rest.

RESULTS AND DISCUSSION

INTELLIGIBILITY

The mean and standard deviation of the intelligibility scores, expressed as percentage of correct responses, for each test condition are shown in Tables 3 and 4. Table 3 describes the intelligibility of the mask when used by a speaker and received with an SPH-4 helmet in the UH-60A noise environment. Table 4 describes the intelligibility when the mask is used by a listener from speech initiated with an SPH-4. In all conditions, for both speaker and listener, tests were conducted in a sound field which simulated the UH-60A noise environment.

The mean data in Table 3 indicate the XM-33 is very deficient from an intelligibility standpoint when used for the speaker condition. The MBU-12 oxygen mask did not exhibit a high level of intelligibility due primarily to a lower speech signal-to-noise ratio. The M-24, AR-5, and P/Q masks appear to provide good intelligibility in the UH-60A aircraft noise environment. Table 4 indicates the masks, when used by the listener, degrade the speech intelligibility of the SPH-4.

TABLE 3

MEANS AND STANDARD DEVIATIONS OF PERCENTAGE SCORES OF INTELLIGIBILITY FOR TEST CONDITIONS ONE THROUGH SIX

	TEST CONDITION					
	1 SPH-4	2 M-24	3 XM-33	4 AR-5	5 MBU-12	6 P/Q
Mean	59.6	76.4	14.6	75.8	44.0	79.8
S.D.	9.9	9.5	6.8	11.4	10.4	7.3

TABLE 4

MEANS AND STANDARD DEVIATIONS OF PERCENTAGE SCORES OF INTELLIGIBILITY FOR TEST CONDITIONS ONE AND SEVEN THROUGH NINE

	TEST CONDITION 1 SPH-4	7 M-24	8 XM-33	9 AR-5
Mean	59.6	32.8	45.6	46.6
S.D.	9.9	11.3	9.7	12.2

The intelligibility scores for the listener and speaker test conditions were subjected to a one-way analysis of variance. The results of these analyses are shown in Tables 5 and 6. In both cases the analyses indicate there are significant intelligibility differences among the test conditions. The differences may be attributed to various factors such as signal-to-noise ratio of the speech signal and/or effects on attenuation of the SPH-4 helmet.

TABLE 5

ONE-WAY ANALYSIS OF VARIANCE OF SPEECH INTELLIGIBILITY SCORES FOR TEST CONDITIONS ONE THROUGH SIX

SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	F-RATIO	F-PROB
Mean	59	36867.93			
Speaker Intelligibility	5	32119.53	6423.92	73.05	<.01
Error	54	4748.40	87.93		

TABLE 6

ONE-WAY ANALYSIS OF VARIANCE OF SPEECH INTELLIGIBILITY FOR TEST CONDITIONS ONE AND SEVEN THROUGH NINE

SOURCE	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	F-RATIO	F-PROB
Mean	39	7803.10			
Listener Intelligibility	3	3596.30	1198.77	10.26	<.01
Error	36	4206.80	116.86		

Tables 7 and 8 show the statistically separated levels for the listener and speaker means computed with Tukey's (1949) Honestly Significant Difference (HSD) multiple comparison procedure. The multiple comparison was computed using an alpha level of .05. The letters represent factor levels which are statistically different from one another. The lowest level or mean is represented by the letter "A" with subsequent letters representing higher levels or means with statistically significant differences. These values can be compared with the corresponding tables of means, Tables 4 or 5, to gain an insight into the significance of the differences in the mean values.

TABLE 7

TUKEY'S (HSD) MULTIPLE COMPARISON OF SPEAKER INTELLIGIBILITY WITH TEST CONDITION USING ALPHA = .05.

	TEST CONDITION					
	1 SPH-4	2 M-24	3 XM-33	4 AR-5	5 MBU-12	6 P/Q
Level of Separation	C	D	A	D	B	D

TABLE 8

TUKEY'S (HSD) MULTIPLE COMPARISON OF LISTENER INTELLIGIBILITY WITH TEST CONDITION USING ALPHA = .05.

	TEST CONDITION			
	1 SPH-4	7 M-24	8 XM-33	9 AR-5
Level of Separation	C	A	AB	B

ATTENUATION

The mean values of real-ear attenuation in dB are shown in Table 9. The objective of the real-ear evaluation was to determine the effect of the mask on the attenuation of the SPH-4. Comparisons of the mask attenuation with that of the SPH-4 indicate a significant reduction in attenuation for all masks except the AR-5. The M-24 and XM-33 mask produced a significant decrease in attenuation for the test frequencies below 1000 Hertz. The test condition which included the protective hood worn under the SPH-4 revealed a significant reduction in real-ear attenuation for all of the frequencies evaluated.

A repeated measure ANOVA was completed with frequency and mask conditions being the factors evaluated for their effects on attenuation. Table 10 shows the results of the analysis.

These results indicate there are significant differences in attenuation among the mask conditions. Tukey's HSD Multiple Comparison Test was used to evaluate the significance of the main effects of masks on attenuation at an alpha level of .05. The comparison is shown in Table 11. The letters represent factor levels which are statistically different from one another. The lowest level or mean is represented by the letter A with subsequent letters representing higher levels or means with statistically significant differences. The comparison indicates the means of the mask conditions involved in the investigation are separated into 4 levels which are significantly different. The XM-33 and M-24 with and without the protective hood do not provide attenuation which is equal to that of the SPH-4 or the AR-5. A multiple comparison also was made on the interaction effects of masks and each test frequency (Table 12). The SPH-4 and AR-5 are equivalent at all test frequencies as shown in Table 10 and they are within the same level, indicating their means are not statistically different.

TABLE 9

MEANS AND STANDARD DEVIATIONS OF REAL-EAR ATTENUATION VALUES MEASURED IN DB. EACH DEVICE WAS WORN IN COMBINATION WITH THE SPH-4 HELMET.

		TEST FREQUENCIES IN HERTZ									
		80	125	250	500	1K	2K	3.15K	4K	6.3K	8K
SPH-4	Mean	15.9	18.2	12.5	21.0	22.0	29.5	38.9	44.6	46.1	46.3
	S.D.	4.4	4.0	2.3	3.0	3.1	3.2	3.1	3.5	4.4	6.9
M-24	Mean	11.6	10.4	6.3	16.6	21.0	27.1	33.7	36.7	37.9	39.9
	S.D.	5.5	5.1	4.0	4.6	4.3	4.3	4.8	4.4	4.1	4.9
XM-33	Mean	15.4	14.4	8.9	19.4	21.0	28.6	35.4	39.5	35.2	37.3
	S.D.	6.7	7.5	6.3	5.0	3.5	4.3	6.1	7.9	6.0	7.3
AR-5	Mean	18.1	16.7	14.8	24.5	22.1	29.3	41.4	45.1	50.9	50.6
	S.D.	7.4	7.0	7.0	7.2	6.7	6.5	7.5	8.7	11.1	8.0
M-24 W/Hood worn under SPH-4 (Reg)	Mean	7.2	6.8	1.6	13.4	13.5	19.2	31.4	35.3	39.8	38.3
	S.D.	6.1	4.6	4.7	4.5	5.8	6.2	6.3	6.8	7.9	7.1
XM-33 W/Hood worn under SPH-4 (Reg)	Mean	11.4	9.6	4.6	15.4	15.6	21.7	30.2	34.3	40.0	38.9
	S.D.	5.4	5.4	5.5	5.8	6.6	6.2	7.0	8.1	6.9	7.2

NOTE: Each device was evaluated with 10 subjects (9 males, 1 female) 3 times each.

TABLE 10

ANALYSIS OF VARIANCE OF ATTENUATION CHARACTERISTICS OF THE DEVICES EVALUATED

SOURCE (NAME)	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARES	DEVICES	F-PROB
TOTAL	599	115805.30	193.33		
A frequency	9	91283.08	10142.56	393.12	<.01
B mask	5	8662.26	1732.45	67.15	<.01
AB	45	1925.85	42.80	1.659	<.01
Sampling Error	540	13934.12	25.80		

TABLE 11

TUKEY'S (HSD) MULTIPLE COMPARISONS OF THE FACTOR MASK ON ATTENUATION FOR EACH TEST CONDITION. ALPHA = .05.

DEVICE	MEAN	SEPARATION
SPH-4	29.49	D
M-24	24.13	BC
XM-33	25.51	C
AR-5	31.34	D
M-24 w/Hood	22.16	AB
XM-33 w/Hood	20.65	A

TABLE 12

TUKEY'S (HSD) MULTIPLE COMPARISON OF ATTENUATION MEANS FOR THE FACTORS FREQUENCIES AND MASKS WITH FREQUENCY HELD CONSTANT. ALPHA = .05.

	TEST FREQUENCIES IN HERTZ									
	80	125	250	500	1K	2K	3.15K	4K	6.3K	8K
SPH-4	BC	D	CD	BC	BC	C	BC	B	BC	BC
M-24	AB	ABC	ABC	AB	BC	BC	AB	A	A	AB
XM-33	BC	BCD	BCD	ABC	BC	C	ABC	AB	A	A
AR-5	C	CD	D	C	C	C	C	B	C	C
M-24 w/Hood	AB	AB	AB	AB	AB	AB	A	A	AB	A
XM-33 w/Hood	A	A	A	A	A	A	A	A	AB	A

The poorer attenuation obtained with the M-24 and XM-33 appears to be related to the system of straps securing the masks to the head. Figures A-1 and A-3 show the strap arrangements of the M-24 and XM-33 crossing above and below the pinna. These straps interfere with the ability of the SPH-4 earcups to interface with the head properly, thereby creating a leakage path and decreasing the SPH4 attenuation characteristics.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are made: (1) The M-24, AR-5, and the P/Q mask afford improvement of the speaker intelligibility of the SPH-4 helmet system. (2) The MBU-12 oxygen mask degrades the speaker's intelligibility of the SPH-4 system. (3) The XM-33 is not suitable for wear by the speaker in the UH-60A noise environment. (4) All of the masks evaluated degrade the listener's intelligibility of the SPH-4. (5) The M-24 and XM-33 with and without the protective hood degrade the real-ear attenuation characteristics of the SPH-4 helmet.

Methods to improve the XM-33 speaker intelligibility properties should be pursued. The strap system of the M-24 and XM-33 should be modified to provide clearance to allow the SPH-4 earcup to interface properly with the user's head.

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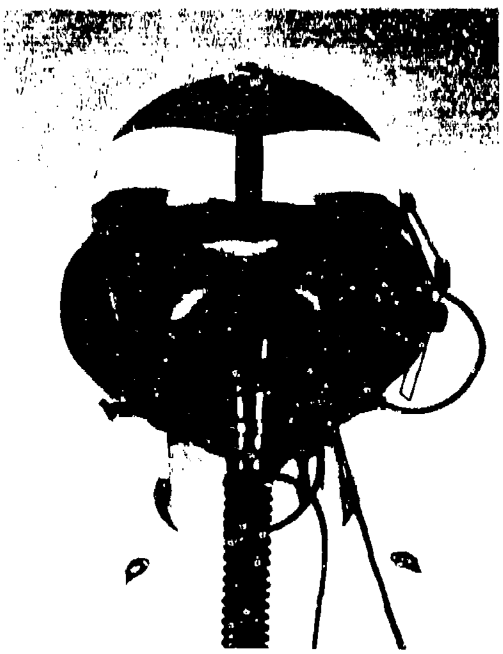
APPENDIX A

Various Views of Mask Conditions

A-1. Front view of M-24 mask.

A-2. Side view of M-24 mask.



A-3. Front view of M-24 mask worn with SPH-4 helmet.

A-4. Side view of M-24 mask worn with SPH-4 helmet.

A-5. Front view of XM-33 mask.

A-6. Side view of XM-33 mask.

A-7. Front view of XM-33 mask worn with SPH-4 helmet.

A-8. Side view of XM-33 mask worn with SPH-4 helmet.

A-9. Front view of AR-5 mask.

A-10. Side view of AR-5 mask.

A-11. Front view of AR-5 mask worn with SPH-4 helmet.

A-12. Side view of AR-5 mask worn with SPH-4 helmet.

A-13. Front view of M-24 mask with hood.

A-14. Side view of M-24 mask with hood.

A-15. Front view of M-24 mask with hood worn under SPH-4 helmet.

A-16. Side view of M-24 mask with hood worn under SPH-4 helmet.

A-17. Front view of XM-33 mask with hood.

A-18. Side view ot XM-33 mask with hood.

A-19. Front view of XM-33 mask with hood worn under SPH-4 helmet.

A-20. Side view of XM-33 mask with hood worn under SPH-4 helmet.

APPENDIX B

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