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**EFFECTS OF XM-40 CHEMICAL PROTECTIVE MASK ON  
REAL-EAR ATTENUATION AND SPEECH INTELLIGIBILITY  
CHARACTERISTICS OF THE SPH-4 AVIATOR HELMET**

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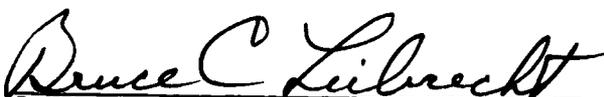
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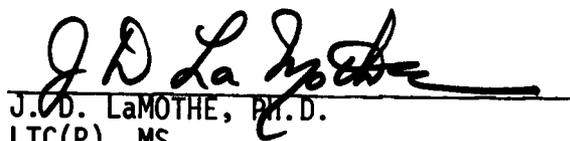
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## ABSTRACT:

Chemical Defense (CD) measures depend primarily on the use of protective clothing and equipment. Adequate protection only can be achieved if each item in the CD ensemble is compatible with every other item. The design or modification of each component must give consideration to its impact on the performance of all items. This study investigated the effects of the XM-40 Chemical Protective (CP) Mask on the protective functions of the SPH-4 aviator helmet. Based on the results it was concluded that the XM-40 compromised the noise attenuation and speech communication functions of the SPH-4.

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## INTRODUCTION

The use 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 three prototype versions of the XM-40 Chemical Protective (CP) mask on the hearing protective and communicative functions of the SPH-4 aviator helmet. The effects of the masks on hearing protection were determined by a comparison of the real-ear attenuation for the SPH-4 with and without the mask. The effects of the masks on communication were assessed in terms of speech intelligibility in two modes. They were (1) a comparison of the listener's ability to discriminate words with and without the mask when the speaker used the standard SPH-4 with its standard boom microphone; and (2) a comparison of the listener's ability to discriminate words while wearing a standard SPH-4 when the speaker was wearing each of the three prototype masks. The primary difference between the three masks was in the configuration of the microphone within the mask.

The request for this evaluation was initiated by the US Army Aviation Board.

## METHODS AND INSTRUMENTATION

### REAL-EAR ATTENUATION

The real-ear attenuation of the SPH-4 helmet, when worn in combination with one of the three CP masks, was measured using the ANSI Standard S3.19-1974. Since the principle difference between the three prototypes was the microphone configuration inside the mask and since in this case the microphone position does not affect attenuation. It was deemed appropriate to test only one mask prototype for attenuation. Ten listeners were college students with normal hearing. They were required to have hearing thresholds for both ears not greater than 10 dB at the 250-1000 Hertz test frequencies and no higher than 20 dB at any other test frequency as measured on a standard audiometry (ANSI S3.6-1969). The same listeners were used to evaluate the real-ear attenuation characteristic of the same SPH-4 with and without the mask.

The real-ear attenuation measurement was conducted in a custom-built Tracoustics Corporation Audiometric Examination Room\* measuring 10'X9'4"X6'6" (1XwXh) located at the Acoustical Sciences Research Group Laboratory, Sensory

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\*See Appendix B.

Research Division, United States Aeromedical Research Laboratory, Fort Rucker, Alabama. This room had been modified to give the reverberant characteristics specified in the standard.

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 one 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. Also it extended the useable range of the recording attenuator. This is useful especially 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. This is related directly 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 photoelectric switch. For each test sound, the listener controlled the signal level in the fashion described by Von Bekesy (1947) to determine the threshold of audibility. At each reversal point of the tracking process, the potentiometer output was input into the microprocessor control system where it was processed. The system summed 10 reversal points, computed the average, and this output was sent to a printer. The real-ear attenuation was determined by taking the differences between hearing threshold values measured under two conditions. A free-field reference threshold was obtained for all test signals with the listener's head position fixed by the use of a chin rest. An attenuated threshold measurement then was made under identical conditions except the listener wore an SPH-4 with or without a CP mask. A full standard real-ear attenuation test (three attenuation values for each test frequency for each of the 10 listeners) was run for both conditions.

## INTELLIGIBILITY

Appendix A shows various views of the masks evaluated in this experiment. The speech intelligibility of each prototype XM-40 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 five test conditions which are summarized in Table 1.

All speaker conditions utilized PB words recorded by a single speaker in a simulated UH-60A aircraft noise environment 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

# REAL EAR ATTENUATION TEST SYSTEM

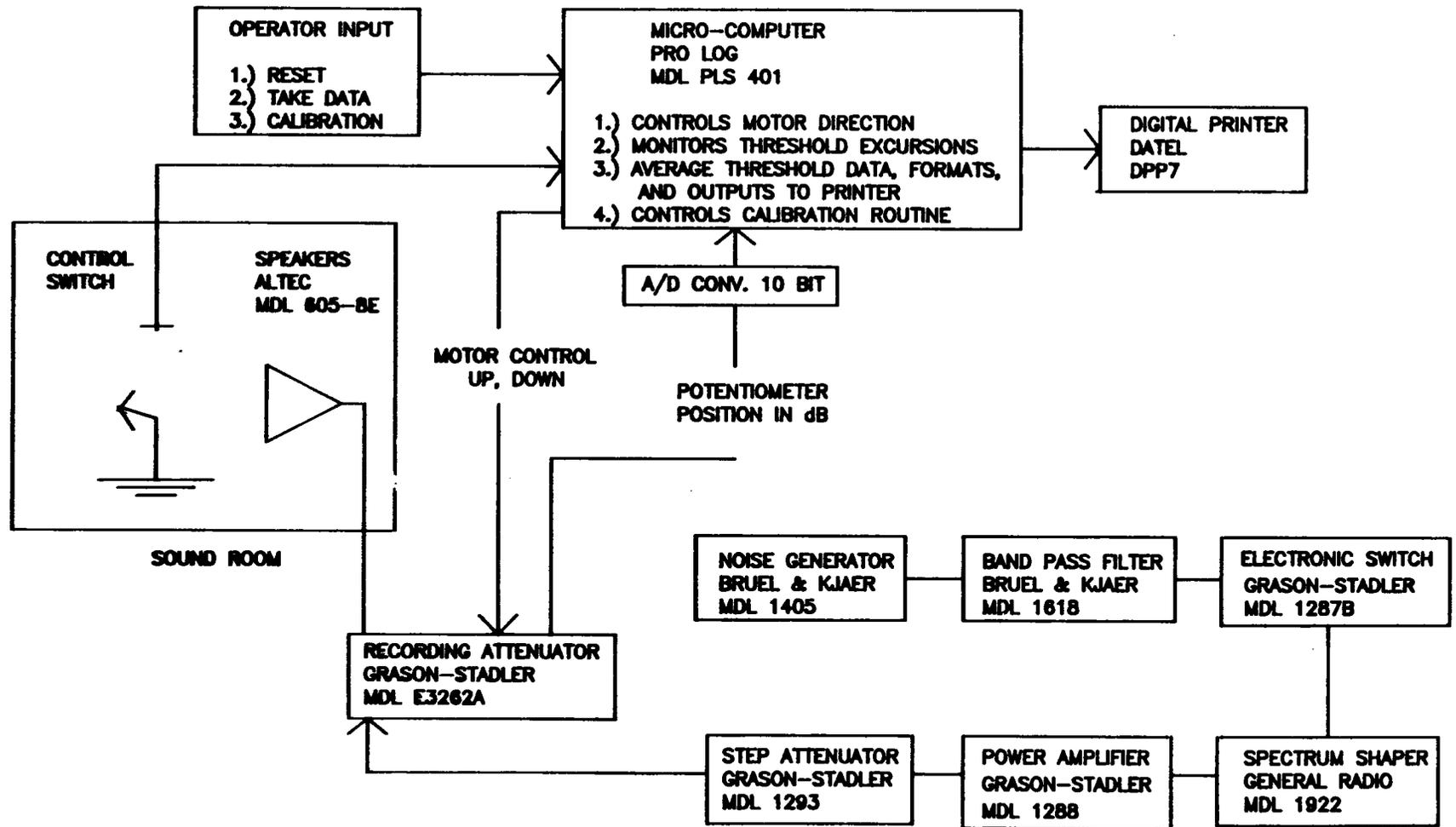


FIGURE 1. Real-Ear Attenuation Test System.

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 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 five 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 were used in this part of the study. Each subject had normal hearing which is defined as no more than 10 dB hearing loss (reference ANSI S3.6-1969) 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.

TABLE 1  
CONDITIONS USED IN THE EVALUATION OF SPEECH INTELLIGIBILITY.

Test Condition	Speaker's Condition	Listener's Condition
1	Wearing SPH-4	Wearing SPH-4
2	Wearing SPH-4	Wearing SPH-4 with Prototype C
3	Wearing SPH-4 with Prototype A	Wearing SPH-4
4	Wearing SPH-4 with Prototype B	Wearing SPH-4
5	Wearing SPH-4 with Prototype C	Wearing SPH-4

Note: Prototype A was marked XM-43.  
 Prototype B was marked 2A/C.  
 Prototype C was marked M15.  
 The prototype designation was made by the US Army Aviation Board. The above mentioned markings were on the CP masks when received at USAARL.

TABLE 2

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

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Octave-Band Center Frequencies in Hertz

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63	125	250	500	1K	2K	4K	8K	16K
97	97	98	95	89	88	82	83	80

---

## RESULTS AND DISCUSSION

## REAL-EAR ATTENUATION

The objective of the real-ear attenuation test was to assess the effects of the XM-40 CP mask on the noise attenuation ability of the SPH-4. The mean real-ear attenuation values by test frequency are shown in Table 3. A comparison of the attenuation results for the SPH-4 and the SPH-4 in combination with the mask reveals little difference in the attenuation of the SPH-4 with and without the mask except at 2 kHz, 6.3 kHz, and 8 kHz. Evaluation of mean attenuation data by individual T-tests with 58 degrees of freedom and  $\alpha = .05$  indicates significant differences at 2 kHz ( $T=2.05$ ), 6.3 kHz ( $T=4.67$ ), and 8 kHz ( $T=2.84$ ). Although the effects on attenuation are less severe than those noted by Mozo (1984) in a similar test of the M-24 and XM-33 CD masks, the current data indicate that high frequency attenuation is compromised significantly when the XM-40 mask is used with the SPH-4 helmet.

## SPEECH INTELLIGIBILITY

The intelligibility portion of the study was divided into two parts: (1) the effects of XM-40 mask configuration on the listener's ability to understand speech and (2) the effects of the various microphone configurations within the mask on the talker's speech intelligibility.

For the first part of the intelligibility test, only one prototype mask was selected. The average listener's speech intelligibility under the two experimental conditions are contained in Table 4. With both speaker and listener wearing the SPH-4 only, the mean intelligibility was 62.4% and the standard deviation was 10.0%. When the listener donned the XM-40 CP mask, the mean was 44.2% with a standard deviation of 11.6%. A repeated measures one-way analysis of variance (ANOVA) as described by Winer (1962) was done on the intelligibility scores. An *a priori* error rate ( $\alpha$ )

TABLE 3

MEAN AND STANDARD DEVIATIONS OF REAL-EAR ATTENUATION VALUES MEASURED IN dB  
FOR SPH-4 HELMET WITH AND WITHOUT THE XM-40 CP MASK.

	Test Frequencies in Hertz									
	80	125	250	500	1K	2K	3.5K	4K	6.3K	8K
<u>SPH-4</u>										
Mean	16.2	12.7	12.3	21.7	19.4	30.1	42.6	47.4	49.7	48.1
SD	5.4	4.0	3.4	4.3	3.1	2.5	3.5	3.8	5.3	6.0
<u>SPH-4 with Prototype C</u>										
Mean	15.0	12.7	12.8	22.9	19.5	31.5	41.2	46.1	42.5	43.7
SD	5.4	4.3	3.9	4.4	2.8	2.7	3.8	4.9	6.4	5.8
<u>T-values</u>										
	0.85	0.0	0.52	1.05	0.13	2.05*	1.46	1.13	4.67*	2.84*

\*  $p < .05$ ,  $df = 58$

TABLE 4

EXPERIMENTAL LISTENER'S CONDITIONS, TALKER WITH SPH-4 ONLY.

Test Condition	Mean	Standard Deviation
SPH-4	62.40	10.10
SPH-4 with Prototype C	44.20	11.56

of .05 was selected. The result of this analysis indicates the XM-40 CD mask significantly degrades a listener's ability to understand speech when compared with the SPH-4 alone ( $F(1,9) = 21.99, p < .001$ ).

As noted, when the talker used the boom microphone under these experimental conditions, mean speech intelligibility was 62.4%. Table 5 contains the mean talker speech intelligibility and standard deviation (SD) for the SPH-4 alone and in combination with the three prototype CD masks. When the talkers donned the XM-40 mask identified as prototype A, average talker speech intelligibility was reduced to 46.4% with  $SD = 7.59$ . Prototype B yielded a mean of 52.4% discrimination and a  $SD = 8.2$ . The mask identified as prototype C resulted in a mean of 49.0% and a  $SD = 9.1$ . To determine the significance of differences in speech intelligibility for the various masks, the data were analyzed using a repeated measure one-way ANOVA model with a *a priori* rate ( $\alpha$ ) of .05. The results indicated that the main effect for microphone configuration is significant ( $F(3,27) = 11.40, p < .001$ ). Examination of the results in Table 5 suggest that this significant effect of microphone is a result of the degradation of intelligibility of prototype A and C compared to the SPH-4.

TABLE 5  
EXPERIMENTAL TALKER'S CONDITIONS, LISTENERS WITH SPH-4 ONLY.

Test Condition	Mean	Standard Deviaion
SPH-4	62.40	10.10
SPH-4 with Prototype A	46.40	7.59
SPH-4 with Prototype B	52.40	8.15
SPH-4 with Prototype C	49.00	9.06

It is important to remember the experimental conditions created a very difficult listening situation in order to magnify the differences in performance of the different prototype microphone configurations as compared with the SPH-4 alone. Better results would be expected from all four devices under more optimal listening conditions.

## CONCLUSIONS AND RECOMMENDATIONS

Based on the results of this study, it is concluded that wearing the XM-40 CP mask with the SPH-4 aviator helmet compromises noise attenuation at 2 kHz, 6.3 kHz, and 8 kHz, but that the compromise of attenuation is less than that experienced with the M-24 and XM-33 CP masks. It was further concluded that wearing the XM-40 mask significantly decreased the ability of a listener to understand speech communication received via an SPH-4 helmet.

With regard to talker intelligibility, the independent variable was microphone configuration within the mask. None of the microphone placements resulted in performance as good as the SPH-4 boom microphone, but of the configurations considered, the prototype identified as "B" was best during the present study.

It is recommended that further efforts be made to improve CP mask compatibility with the SPH-4 helmet. It is further recommended that careful attention be given to microphone placement within the mask. The microphone should never be placed outside the mask.

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**APPENDIX A**

**Various Views of Three Prototype XM-40 CP Masks.**



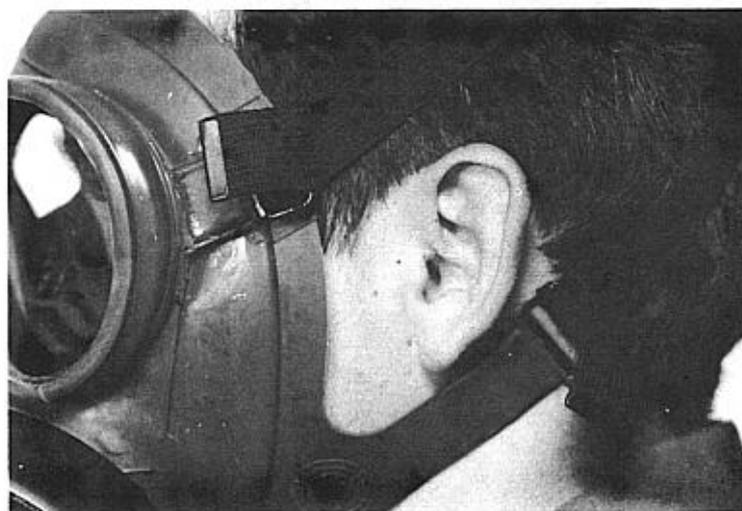
Front views of Prototype XM-40 CP Masks, from left to right, Prototype A, Prototype B, and Prototype C.



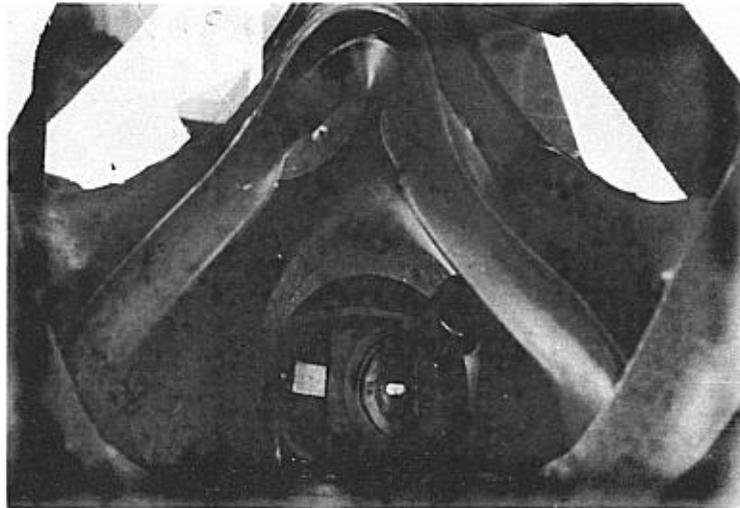
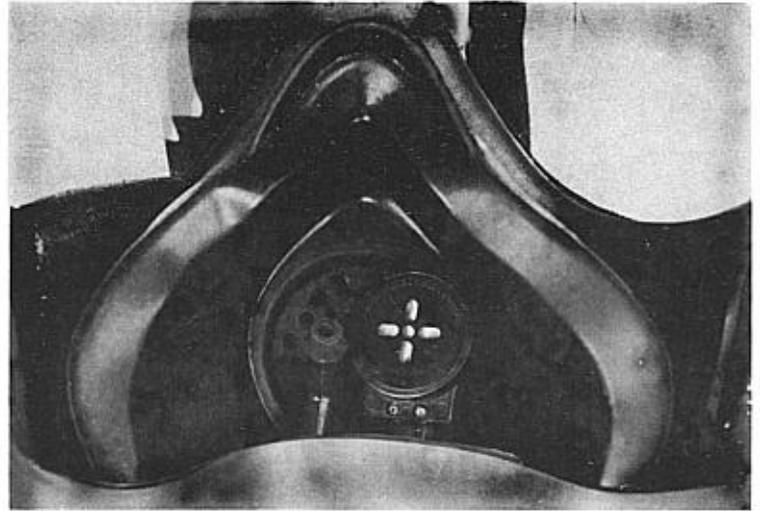
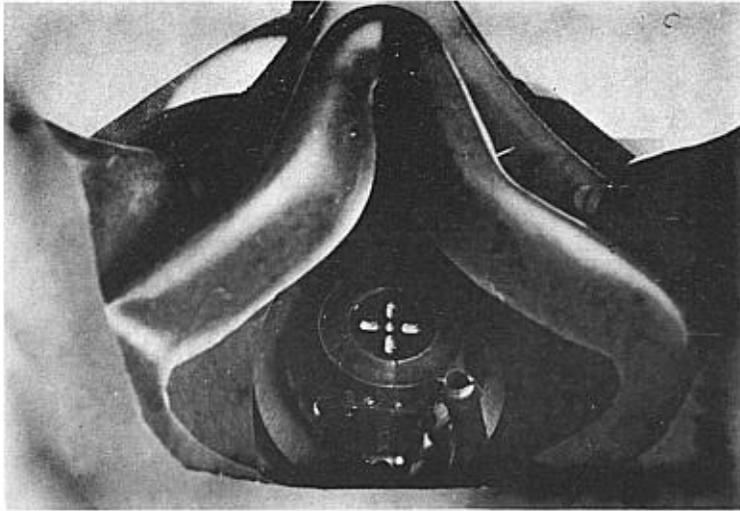
Front views with SPH-4 Helmet, from left to right, Prototype A, Prototype B, and Prototype C.



Side views with SPH-4 Helmet, from left to right, Prototype A, Prototype B, and Prototype C.



Side view of three prototype CP masks showing cross-strap configuration. From left to right, Prototype A, Prototype B, and Prototype C.



Views of nose cone of three prototype CP masks showing microphone configuration. From left to right, Prototype A, Prototype B, and Prototype C.

## APPENDIX B

### List of Manufacturers

Altec Lansing Corporation  
1515 S. Manchester Avenue  
Anaheim, California 92803

Bruel and Kjaer Instruments Incorporated  
185 Forest Street  
Marlborough, Massachusetts 01752

Datel Systems Incorporated  
1020 Turnpike Street  
Canton, Massachusetts 02021

Grason-Stadler  
56 Winthrop Street  
Concord, Massachusetts 01742

Nagra Magnetic Recorders Incorporated  
19 West 44th Street, Room 715  
New York, New York 10036

Pro Log Corporation  
2411 Garden Road  
Monterey, California 93940

Tracoustics Incorporated  
P.O. Box 3610  
Austin, Texas 78764