



**The Communications Earplug: A Logical  
Choice for Voice Communications  
In Aircraft  
(Reprint)**

**By**

**Ben T. Mozo**

**and**

**John E. Ribera**

**Aircrew Protection Division**

**January 1998**

Approved for public release, distribution unlimited.

**U.S. Army Aeromedical Research Laboratory  
Fort Rucker, Alabama 36362-0577**

Notice

Qualified requesters

Qualified requesters may obtain copies from the Defense Technical Information Center (DTIC), Cameron Station, Alexandria, Virginia 22314. Orders will be expedited if placed through the librarian or other person designated to request documents from DTIC.

Change of address

Organizations receiving reports from the U.S. Army Aeromedical Research Laboratory on automatic mailing lists should confirm correct address when corresponding about laboratory reports.

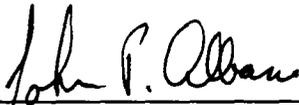
Disposition

Destroy this document when it is no longer needed. Do not return it to the originator.

Disclaimer

The views, opinions, and/or findings contained in this report are those of the author(s) and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by other official documentation. Citation of trade names in this report does not constitute an official Department of the Army endorsement or approval of the use of such commercial items.

Reviewed:

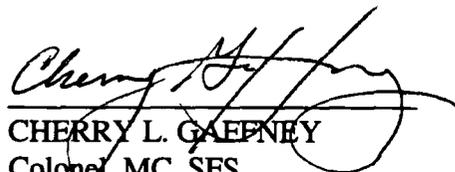


JOHN P. ALBANO  
MAJ, MC, SFS  
Director, Aircrew Protection  
Division

Released for publication:

For 

JOHN A. CALDWELL, Ph.D.  
Chairman, Scientific Review  
Committee



CHERRY L. GAENEY  
Colonel, MC, SFS  
Commanding

## REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified		1b. RESTRICTIVE MARKINGS			
2a. SECURITY CLASSIFICATION AUTHORITY		3. DISTRIBUTION / AVAILABILITY OF REPORT Approved for public release; distribution unlimited			
2b. DECLASSIFICATION / DOWNGRADING SCHEDULE					
4. PERFORMING ORGANIZATION REPORT NUMBER(S) USAARL Report No. 98-09		5. MONITORING ORGANIZATION REPORT NUMBER(S)			
6a. NAME OF PERFORMING ORGANIZATION U.S. Army Aeromedical Research Laboratory	6b. OFFICE SYMBOL <i>(If applicable)</i> MCMR-UAD	7a. NAME OF MONITORING ORGANIZATION U.S. Army Medical Research and Materiel Command			
6c. ADDRESS (City, State, and ZIP Code) P.O. Box 620577 Fort Rucker, AL 36362-0577		7b. ADDRESS (City, State, and ZIP Code) 504 Scott Street Fort Detrick, MD 21702-5012			
8a. NAME OF FUNDING / SPONSORING ORGANIZATION	8b. OFFICE SYMBOL <i>(If applicable)</i>	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER			
8c. ADDRESS (City, State, and ZIP Code)		10. SOURCE OF FUNDING NUMBERS			
		PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO.	WORK UNIT ACCESSION NO.
		63787A	3016287A878	OF	DA360347
11. TITLE (Include Security Classification) (U) The communications earplug: A logical choice for voice communications in aircraft (Reprint)					
12. PERSONAL AUTHOR(S) Ben T. Mozo, and John E. Ribera					
13a. TYPE OF REPORT Final	13b. TIME COVERED FROM TO	14. DATE OF REPORT (Year, Month, Day) 1998 January	15. PAGE COUNT 13		
16. SUPPLEMENTAL NOTATION Originally published by the Advisory Group for Aerospace Research and Development, NATO, in Conference Proceedings CP-596 - Audio Effectiveness in Aviation, June 1997					
17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)		
FIELD	GROUP	SUB-GROUP	earplug, voice communications, noise assessment, hearing protection		
19. ABSTRACT (Continue on reverse if necessary and identify by block number) The U.S. Army aviator works in high levels of noise and routinely faces the challenge of effective voice communication. Existing aviator helmets, while adequate in providing hearing protection, do not provide the signal-to-noise ratio necessary to optimize in-flight voice communications. The Communications Earplug (CEP) is a small device worn by the aviator and provides significant improvements in hearing protection and communication performance. The CEP uses a miniature earphone transducer adapted to a replaceable foam earplug. Attenuation characteristics of the CEP are similar to those of other insert hearing protective devices and provide adequate protection in U.S. Army noise environments. Additional protection results when the CEP is worn with the aviator's helmet. The CEP is comfortable over a period of several hours and, in its current configuration, is considered highly acceptable by seasoned aviators and crewmembers. The CEP is easier to insert and seat in the outer ear canal than other insert protectors available through military channels. Speech intelligibility in simulated helicopter noise is significantly enhanced when using the CEP when compared to the standard SPH-4 and HGU-56/P aviator's <div style="text-align: right;">(continued on next page)</div>					
20. DISTRIBUTION / AVAILABILITY OF ABSTRACT <input checked="" type="checkbox"/> UNCLASSIFIED/UNLIMITED <input type="checkbox"/> SAME AS RPT. <input type="checkbox"/> DTIC USERS			21. ABSTRACT SECURITY CLASSIFICATION Unclassified		
22a. NAME OF RESPONSIBLE INDIVIDUAL Chief, Science Support Center		22b. TELEPHONE (Include Area Code) (334) 255-6907		22c. OFFICE SYMBOL MCMR-UAX-SS	

19. Abstract (continued):

helmets. CEP and active noise reduction (ANR) results are comparable in terms of speech intelligibility. However, there are several differences that should be considered before deciding which is the system of choice. The technology developed for CEP has wide-ranging application in the military and can easily be adapted to communication needs in the civilian community. The CEP is an inexpensive device that can enhance air and ground crewmember voice communications in the operational environment, and should be positively considered for inclusion into all aircraft and vehicular communication helmets as a battlefield multiplier for the 21st century.

# THE COMMUNICATIONS EARPLUG: A LOGICAL CHOICE FOR VOICE COMMUNICATIONS IN AIRCRAFT

Ben T. Mozo, B.S.  
U.S. Army Aeromedical Research Laboratory  
Fort Rucker, AL 36362-0577, USA

John E. Ribera, Ph.D.  
Brooke Army Medical Center  
San Antonio, TX 78234-6200, USA

## SUMMARY

The U.S. Army aviator works in high levels of noise and routinely faces the challenge of effective voice communication. Existing aviator helmets, while adequate in providing hearing protection, do not provide the signal-to-noise ratio necessary to optimize in-flight voice communications. The Communications Earplug (CEP) is a small device worn by the aviator and provides significant improvements in hearing protection and communication performance. The CEP uses a miniature earphone transducer adapted to a replaceable foam earplug. Attenuation characteristics of the CEP are similar to those of other insert hearing protective devices and provide adequate protection in U.S. Army noise environments. Additional protection results when the CEP is worn with the aviator's helmet. The CEP is comfortable over a period of several hours and, in its current configuration, is considered highly acceptable by seasoned aviators and crewmembers. The CEP is easier to insert and seat in the outer ear canal than other insert protectors available through military channels. Speech intelligibility in simulated helicopter noise is significantly enhanced when using the CEP when compared to the standard SPH-4 and HGU-56/P aviator's helmets. CEP and active noise reduction (ANR) results are comparable in terms of speech intelligibility. However, there are several differences that should be considered before deciding which is the system of choice. The technology developed for CEP has wide-ranging application in the military and can easily be adapted to communication needs in the civilian community. The CEP is an inexpensive device that can enhance air and ground crewmember voice communications in the operational environment, and should be positively considered for inclusion into all aircraft and vehicular communication helmets as a battlefield multiplier for the 21st century.

## 1 Introduction

Noise levels found in military helicopters exceed noise exposure limits required by U.S. DOD Instruction 6055.12, "Department of Defense Hearing Conservation Program." [1] Noise levels in helicopters with higher load capacities such as the CH-47 and H-53 are extremely intense and sometimes exceed the helmet's protective capabilities. Figure 1 shows a distribution of noise levels found in U.S. Army aviation, along with estimates of noise exposure for crewmen wearing the standard protectors. Figure 2 shows the same distribution in cumulative percent for estimating the overall protection for the user population. The data show protection is adequate in all but the top 15 percent of the noise conditions while wearing the SPH-4 or HGU-56/P and in 99

percent of the cases while wearing the yellow foam earplug. Combination protection, earplugs in addition to the helmet, is a technique commonly used to provide additional hearing protection, but this technique generally decreases the aviator's ability to communicate.

The U.S. Army Aeromedical Research Laboratory (USAARL) is investigating two techniques which may be used to reduce noise exposure and improve communications. One technique, active noise reduction (ANR), uses electronic circuitry to manipulate and reduce the noise found inside the earcup. The other technique, CEP, relies on passive sound attenuation of the earplug in combination with the earcup to achieve the required noise reduction. Both systems show significant improvements in voice communications over the standard helmet by simple improvement in the speech signal-to-noise ratio.

Recent technological advances have made application of the ANR practical. ANR is a means used to reduce noise levels in a personal hearing protector by measuring the noise in the earcup and reinserting a processed and out-of-phase noise signal back into the earcup through an earphone. The reinserted sound signal combines with the noise originally measured and causes it to be canceled. This out-of-phase canceling technique usually is very effective for low frequencies, below 800 Hertz, but generally is ineffective for higher frequencies. In some designs, the ANR device increases the noise level inside the earcup in the region where ANR crosses zero attenuation. Total protection provided by the ANR system consists of the passive hearing protection provided by the earcup, and the ANR noise reduction provided by the electronic system.

The CEP is a device which incorporates a miniature earphone coupled with a replaceable foam earplug tip, and may be used to improve hearing protection and speech communications. [2] It can be worn in combination with the aviator's helmet providing protection similar to when using the yellow foam plug. The device consists of a miniature receiver encapsulated in a plastic housing, which includes a threaded adapter used for attaching the replaceable earplug. The earplug tip has an internally threaded insert channel that extends through the center from the base to tip, and mates with the threaded adapter on the transducer housing, shown schematically in Figure 3. The speech signal is delivered directly from the receiver into the occluded portion of the ear canal. The small wire used to connect the CEP into the communications system is highly flexible for comfort and small enough to reduce the potential for leakage when the wire is routed between the

earseal and the wearer's head. [3] This approach provides sound attenuation and speech intelligibility as good as any technique observed to date.

## 2 Discussion

Both techniques have been shown to reduce noise at the wearer's ear and improve the speech intelligibility characteristics of the aviator's helmet system. A study to determine the effect of these techniques on speech intelligibility for 20 normal and 20 hearing-impaired aviators was completed. Results of the study showed significant improvements over the standard helmet for both groups. Audiometric means of the two subject groups are shown in Figure 4. Speech intelligibility of the hearing-impaired aviators wearing CEP or ANR was compared with the 95 percent confidence interval for the normal aviator wearing the SPH-4 helmet, shown in Figure 5. The hearing-impaired aviators improved from 1 percent while wearing the SPH-4 to 65 percent while wearing the CEP helmet, and 40 percent while wearing the ANR helmet. The results of the study also showed that asymptotic levels of speech intelligibility are reached at much lower speech levels with ANR and CEP, as shown in Figure 6. The net effect should reduce speech levels required for communications and, therefore, reduce the hazardous effects of the speech signal. During field trials we found the intercommunications volume controls are reduced significantly from levels normally used for the standard helmet. [4]

considered when making a fielding decision. The areas concerning performance and safety are of primary importance. While user acceptance and cost may be of secondary importance, they are critical to the decision process. Safety must be considered, not only for the auditory performance enhancements, but for other mechanical factors designed to protect the aviator during normal missions and during unexpected or unplanned events. [5] Side impacts in the helicopter environment have been shown to produce significant head injuries during crashes and, in many cases, are preventable with energy-absorbing earcups. Figure 7 shows results of impact evaluations in the earcup of three ANR systems. The weight of the helmet is a significant factor for increased injury during a crash, and adds to the burden supported by the aviator during flight, as shown in Figure 8. The helmet has become a platform for many weapons system devices which are coupled to the aviator. This adds to the burden supported by the aviator, and techniques to reduce that burden must be explored.

Fielding considerations must include all aspects of how the user wears the helmet system and how various wearer configurations affect the performance of the system. For example, the ANR system is typically installed in a circumaural device, so the effects of equipment which compromise the earseal must be considered. CB protective hoods used by U.S. Army personnel are placed between the head and earseal and cause a significant loss in performance of the protective and communication characteristics of the helmet system. The effects of other ancillary equipment, such as spectacles, are important to the issue of the compromised earseal.

During the past year, USAARL has evaluated ANR systems manufactured by three U.S. corporations. The systems were provided

to the Army under a cooperative research and development agreement for proposed laboratory and field testing. The ANR systems were compared to the standard helmet and to the CEP. Laboratory evaluations included the measurement of sound attenuation and speech intelligibility using 18 normal hearing flight students. The laboratory study included an evaluation of the effects of ancillary equipment, CB masks, and spectacles when used with the helmet. Field tests included questionnaire-based assessments completed by aviators after flying normal missions while wearing the test helmets. Assessments were accomplished in a variety of U.S. Army aircraft, to include the UH-60, OH-58, CH-47, and UH-1.

Results from the laboratory study conducted at USAARL show ANR and CEP produce improvements in speech intelligibility and sound attenuation when compared to the standard helmet. Figures 9 through 14 show results of sound attenuation measurements conducted on the test devices. Measurements for the insert devices, E-A-R and CEP, were conducted using ANSI S12.6, "Method for Measuring the Real-Ear Attenuation of Hearing Protectors," [6] while ANR devices were measured using MIL-STD-912, "Physical Ear Noise Attenuation Test." [7] Decreased sound attenuation or speech intelligibility performance when wearing spectacles with ANR or the standard helmet is minimal. However, wearing the CB mask causes significant reduction in the helmet system performance for the standard and ANR helmet systems. Small effects were observed to be protection provided by the CEP and the yellow foam earplug.

Speech intelligibility measurements were conducted using a wideband reproduction system to provide the speech material to the test device. Speech material consisted of single talker, commercially recorded W-22 word lists. Words were presented to the subject wearing the test device in a sound field of 105 dBA, simulating a UH-60 flying at 120 knot cruise. The test devices and word lists were counterbalanced to reduce learning effects. Results shown in Figures 15 through 17 compare performance of the test devices for each of the ancillary device combinations. Due to inadequate attenuation provided by the two ANR systems and the HGU-56/P helmet, the ambient noise in the test chamber was reduced 10 dB for these devices, while the yellow foam earplug and CEP were held at 105 dBA ambient noise.

While the speech intelligibility for the helmet when worn alone shows little effect, the loss of attenuation while wearing the mask is very significant. The loss of adequate communication with increased noise exposure, while compromising the visual system by wearing the CB mask, leaves the aviator in an uncertain state. Adding night vision goggles to the helmet system further complicates the situation.

Impulse noise hazard becomes an issue when considering the large number of rounds fired from open cockpit aircraft with weapon muzzles located near the crewmember's ear. ANR systems do not show any effect on reducing impulse noise levels encountered in the Army noise environments. Because of the high potential hazard to hearing, insert protection in combination with the helmet has been recommended for training scenarios involving weapons' fire from open cockpit aircraft.

The field evaluations were completed at three separate Active

Army units. The aircraft types used were the OH-58D, UH-1, UH-60, CH-47, and OH-6. More than 40 aviators participated, wearing each helmet system for a period of 1 week during normal mission scenarios. At the end of each week, they completed a questionnaire about the device they had worn. At the end of the study, they completed a questionnaire that covered all the test devices. The objective was to assess the users' helmet system preferences and solicit their judgment as to operational effectiveness.

At the beginning of the field test, one ANR system was removed from the test because it did not meet the safety requirements. The system did not provide communications capability during loss of battery power. The remaining two ANR systems, along with the standard helmet and the CEP, were included in the evaluation. Results of the evaluation, shown in Table 1, show the CEP and ANR systems provided subjective improvements over the standard helmet for noise reduction and speech clarity. Comfort was considered comparable for all of the helmet systems. Donning of the CEP was considered more difficult since it included an additional step in the process. Previous studies, along with this study, indicate about 80 percent of the U.S. Army aviators normally wear earplugs in combination with the helmet, which may account for the acceptance of the CEP system. The aviators did not feel any of the helmet systems reduced their awareness of the operational noises needed to ensure proper operation of the helicopter. In some cases, instability of the ANR circuitry was annoying but did not detract from successful mission completion. For overall preference, aviators favor the CEP over the other helmet systems.

### 3 Conclusions

ANR and CEP have reached the decision point in their development process and show promise for near term fielding. Besides the selection factors shown in Table 2, there are others which should be considered. Cost of aircraft modification, helmet system cost, logistics, and reliability should be evaluated carefully when considering the use of ANR or CEP in the helicopter environment. It is the authors' opinion that the CEP approach provides the best solution for all aspects of hearing protection, auditory performance, and many other areas of consideration.

### 4 References

1. Department of Defense Instruction 6055.12, 26 Mar 91. Hearing Conservation Program.
2. Ribera, J.E., Mozo, B.T., Mason, K.T., and Murphy, B.A. 1996. Communication and noise hazard survey of CH-47D crewmembers. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Report No. 96-02.
3. Mozo, B.T., Murphy, B.A., and Ribera, J.E. 1995 User acceptability and comfort of the Communications Earplug (CEP) when used in the UH-1 helicopter. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Report No. 95-17.
4. Ribera, J.E., Mozo, B.T., and Murphy, B.A. 1996. Subjective Evaluation of the Communications Earplug with Flexible Harness (CEP/FH) among CH-47D crewmembers. Fort Rucker, AL: U.S. Army Aeromedical Research Laboratory. USAARL Report No. 96-29.
5. Shanahan, D. F., Basilar skull fracture in U. S. Army Aircraft Accidents, USAARL Report No. 85-11, Ft. Rucker, AL, U.S. Army Aeromedical Research Laboratory, 1985.
6. American National Standards Institute. 1984. Method for the measurement of the real-ear attenuation of hearing protectors. 12.6 1984.
7. Department of Defense. 11 December 1990. Physical-ear noise attenuation test. MIL-STD-912.

**Acknowledgements:** This work was funded in part by the U.S. Army Project Managers Office, Aircrew Integrated Systems. The authors are indebted to Ms. Barbara Murphy who did most of the data collection and data entry.

The views, opinions and/or findings contained in this abstract are those of the authors and should not be construed as an official Department of the Army position, policy or decision unless designated by other documents.

Table 1. Mean results of operational assessment. Rank ordered for 1='BEST' to 4='Worst'.

Test Device	Speech Clarity	Noise Reduction	Donning	Comfort	Outside sounds	Stability	Preference (Percent)
HGU-56/P	3.6	3.6	1.4	2.3	3.4	2.4	5
ANR1	1.9	1.9	2.4	2.1	2.6	2.3	33
ANR2	2.8	2.6	2.5	2.8	2.5	2.7	5
CEP	1.7	1.9	3.2	2.6	1.2	2.5	57

Table 2. Factors for consideration during the selection process.

FACTOR	ANR	CEP
Cost:	\$450.00-\$1750.00	<\$100.00
Added Weight:	(90 to 312 gm)	(-28 to 11 gm)
Aircraft modification Cost:	\$1000-\$5000	Not Required
Compatibility:	Reduced Performance	Unaffected

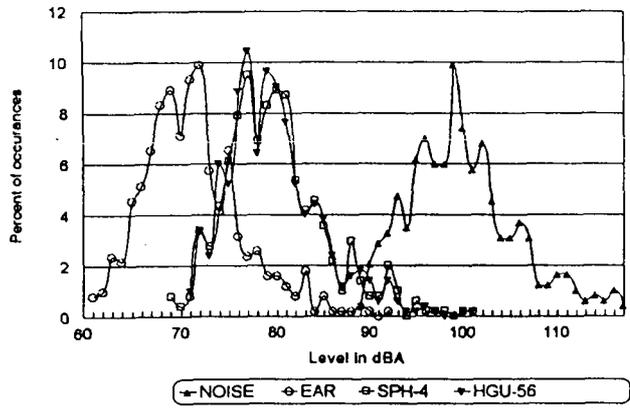


Figure 1. Distribution of noise exposure in U. S. Army Aviation

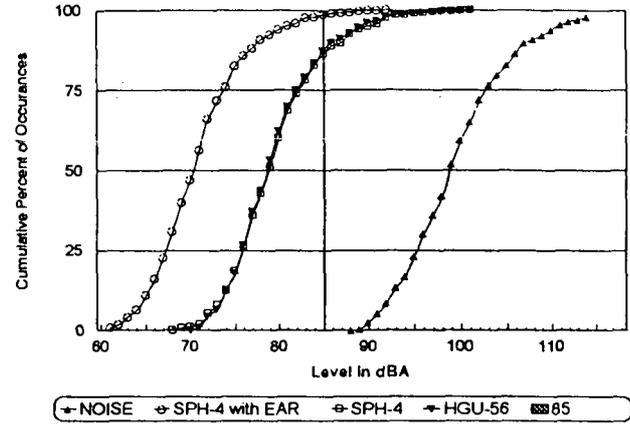


Figure 2. Distribution of noise exposure in U. S. Army Aviation

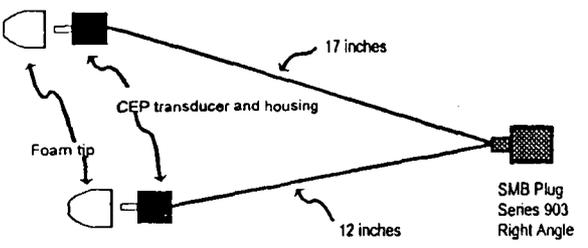


Figure 3. CEP unit schematic diagram

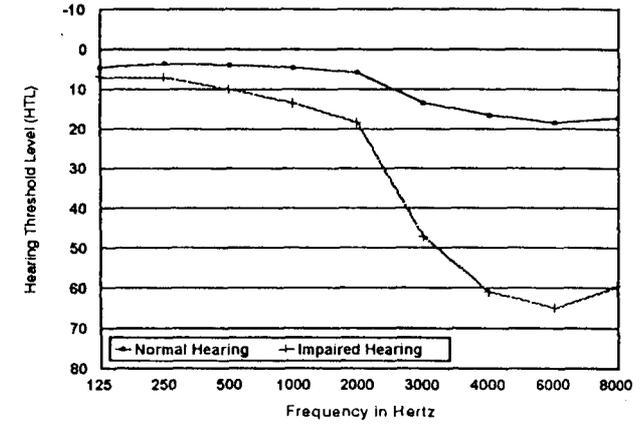


Figure 4. Mean audiometric thresholds of normal and hearing impaired aviators

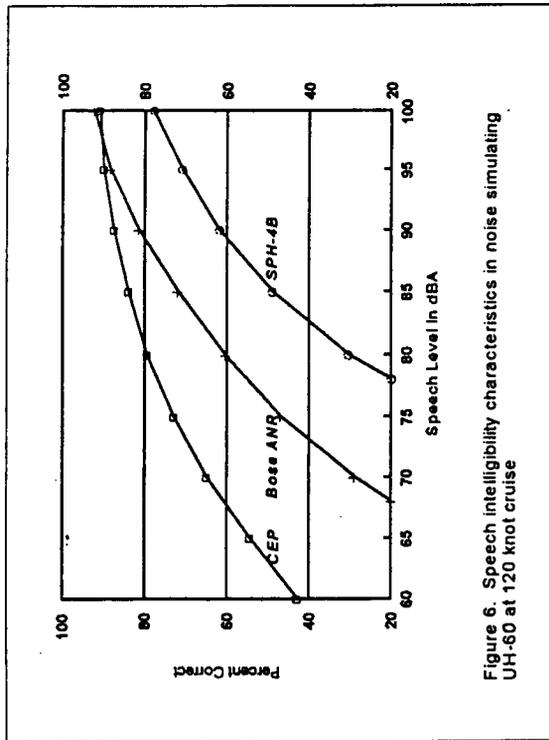


Figure 6. Speech intelligibility characteristics in noise simulating UH-60 at 120 knot cruise

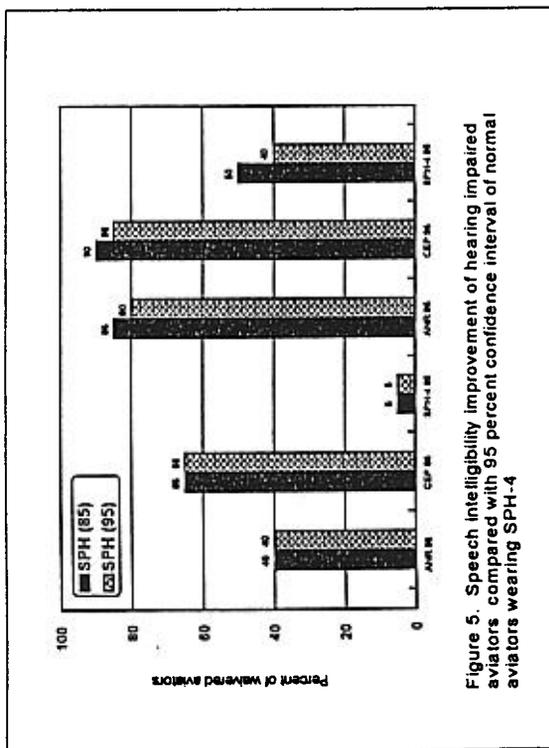


Figure 5. Speech intelligibility improvement of hearing impaired aviators compared with 95 percent confidence interval of normal aviators wearing SPH-4

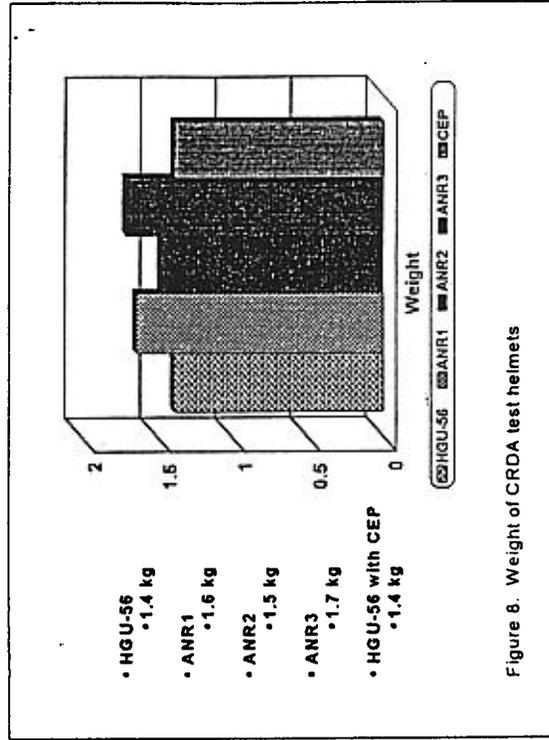


Figure 8. Weight of CRDA test helmets

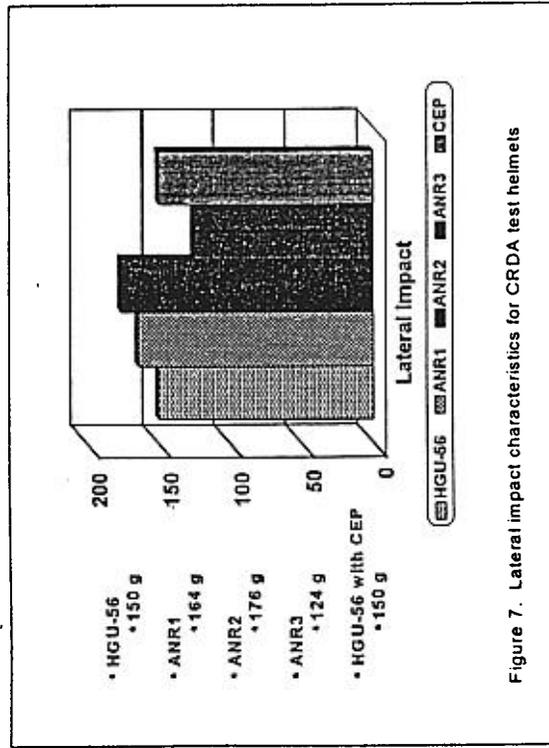
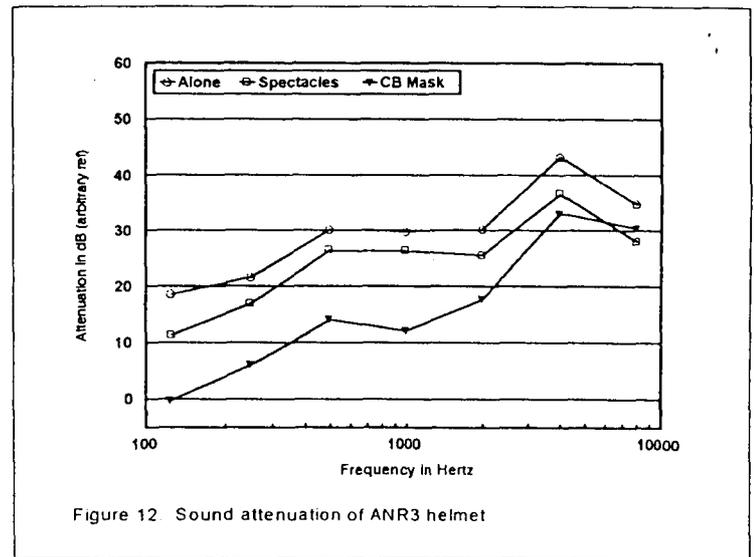
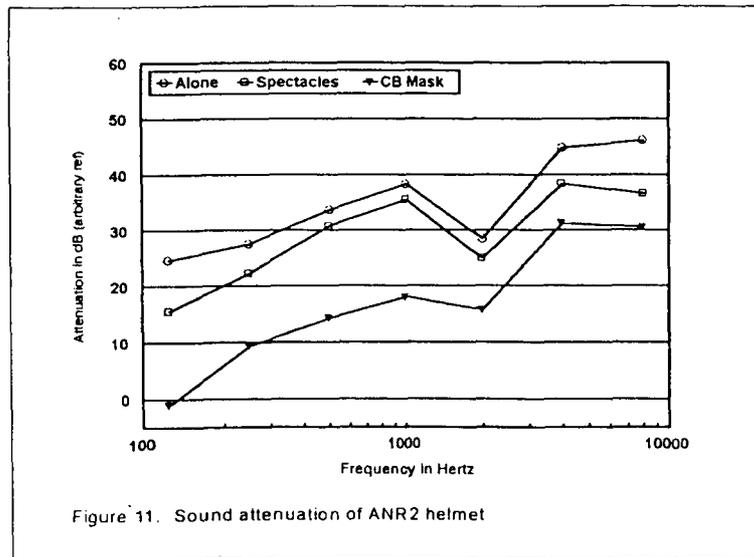
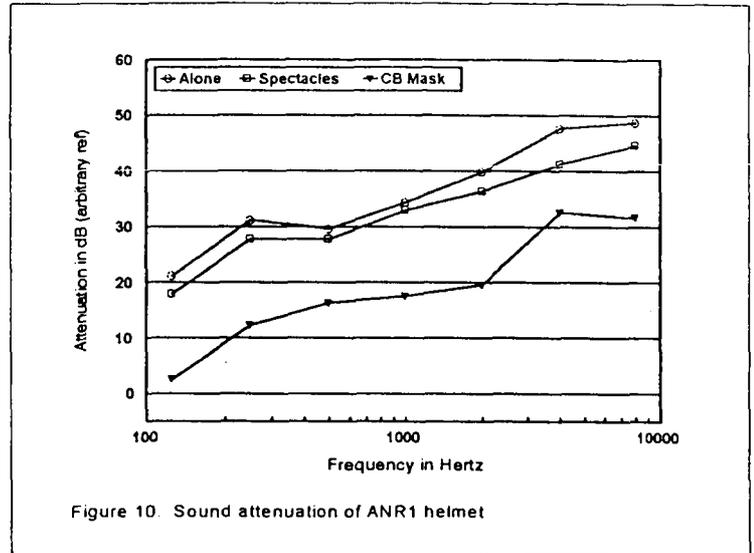
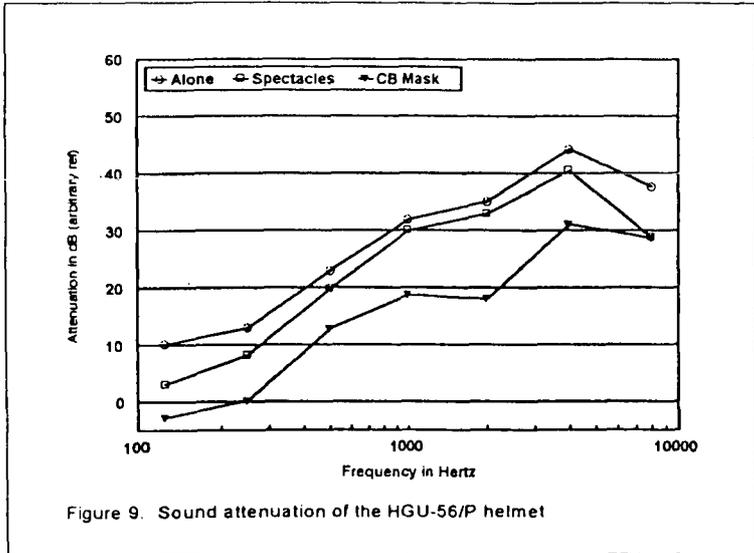


Figure 7. Lateral impact characteristics for CRDA test helmets



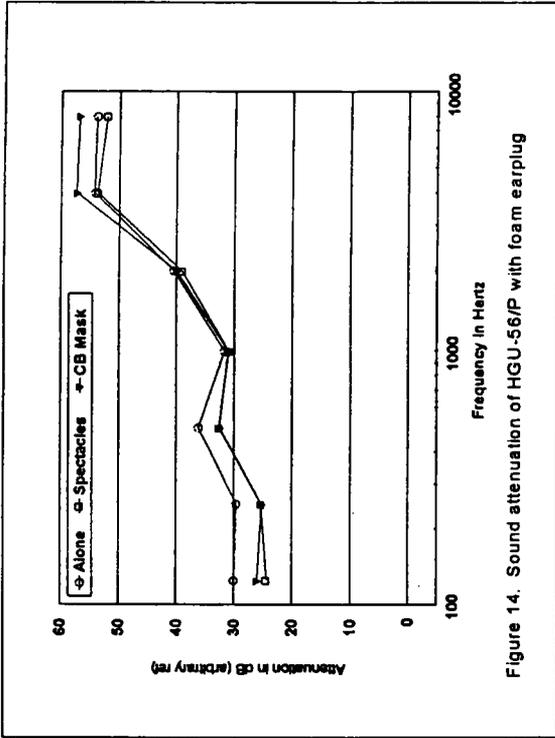


Figure 14. Sound attenuation of HGU-56/P with foam earplug

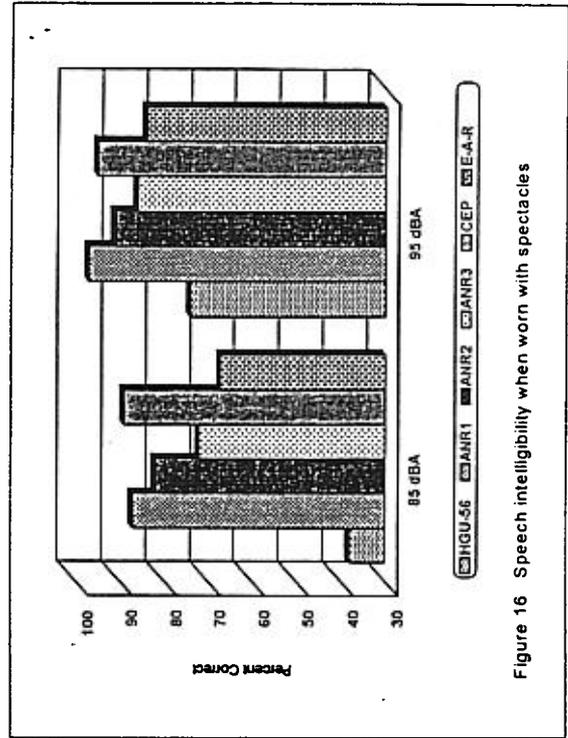


Figure 16. Speech intelligibility when worn with spectacles

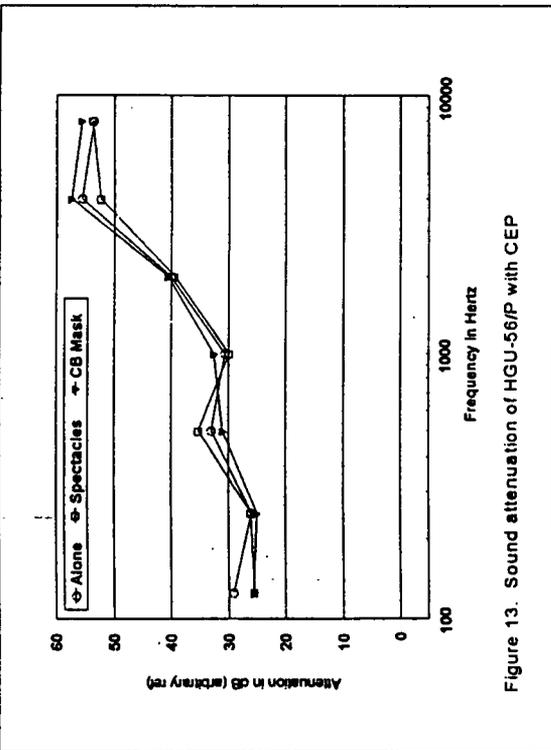


Figure 13. Sound attenuation of HGU-56/P with CEP

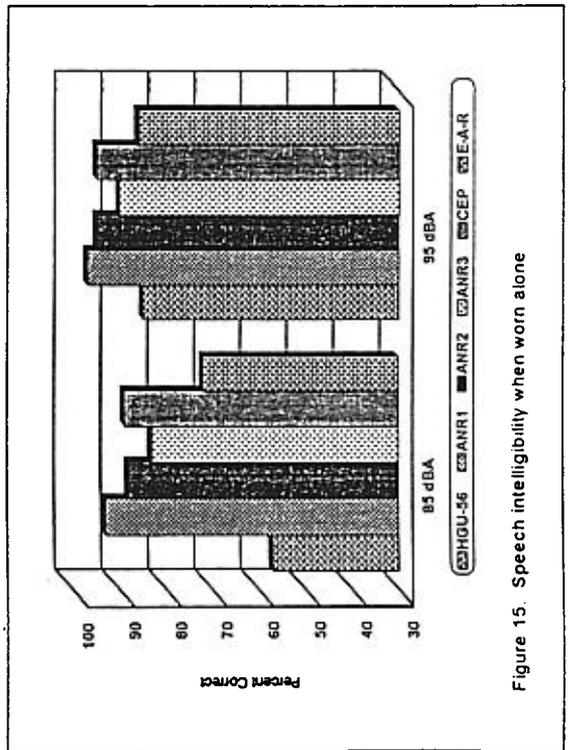
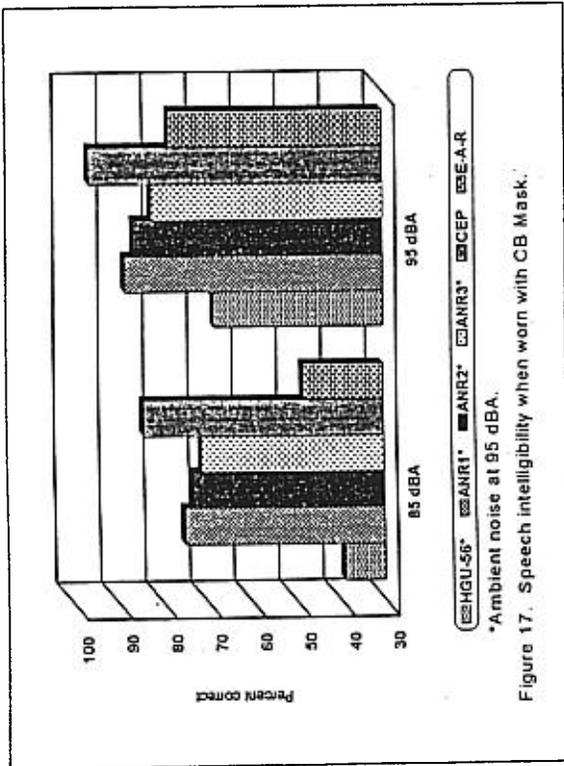


Figure 15. Speech intelligibility when worn alone



\*Ambient noise at 95 dBA.  
Figure 17. Speech intelligibility when worn with CB Mask.