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HIGH NOISE LEVEL MICROPHONES USED IN  
AIRCRAFT

Edward Joseph Hintz, Jr.

Naval Postgraduate School  
Monterey, California

June 1974

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THESIS

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by

Edward Joseph Hintz, Jr.

June 1974

Thesis Advisor:

G. D. EWING

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High Noise Level Microphones  
used in Aircraft

by

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Submitted in partial fulfillment of the  
requirements for the degree of

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

from the

NAVAL POSTGRADUATE SCHOOL  
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## ABSTRACT

The objective of this paper is to do a comparative analysis of three of the present "State of the Art" high noise level microphones. They are the M-87/AIC and M-87/AIC+ (EV 693) both made by Electro-Voice and the HNL bone conduction microphone made by SETCOM Corporation.

The advantages and disadvantages of using a bone conduction microphone over a boom mounted microphone are also investigated.

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## ACKNOWLEDGEMENT

The author wishes to thank Mr. Ken Schwartzman, president of SETCOM Corporation, who provided the HNL microphone used in this evaluation. His wealth of knowledge and experience regarding the bone conduction microphone was invaluable.

The officers and men of DPT, Aviation Division, Fritzsche Army Air Field, Fort Ord, California, especially Col. Garry Farmer and CW2 Carter Smith for their considerate effort in providing flight time for his experiments.

Dr. Gerald Ewing, my thesis advisor, who directed me to SETCOM Corporation which started me off on the right track. His guidance regarding general organization and the evaluation of my data was essential to the success of my thesis.

The men of Crews System branch, Naval Missile Center, Point Mugu, California, whose testing techniques were of great assistance.

Last, but far from the least, the author would like to thank his wife, Karen, for her help and understanding in the preparation of this paper.

## I. INTRODUCTION

The changing mission objectives and requirements plus new weapons system concepts have generated the need to reevaluate present forms and functions of aviator's personal equipment. Man is being called upon to perform multiple roles of increasing complexity while airborne and these roles may impose conflicting requirements in personal equipment. The VTAS (Visual Target Acquisition System) concept applied to air combat maneuvering requires substantial change in the pilots protective helmet to meet system requirements. Tradeoffs between impact and eye protection, sound attenuation, size, weight, communication efficiency, stability and peripheral visual field are imposed on the flight helmet in the VTAS role [Ref.1]. Changes in the oxygen mask and microphone system are under development to meet the system priorities.

A present day problem has been the inability of the helicopter crew member to have reliable communication with the pilots during VERTREP (Vertical Replenishment) and hoisting operations due to very high outside ambient noise. Improved communication from and within aircraft; specifically, study of intelligibility of present equipment both for helicopter to ground and helicopter to helicopter was recommended to the Navy by CHABA (Committee on Hearing, Bioacoustics and Biomechanics) [Ref.2].

An evaluation of an integrated microphone configuration incorporated within the helmet shell was undertaken, with the foregoing VTAS, VERTREP and hoisting problems in mind. An integrated microphone would be useful when bulk and inconvenience of a boom microphone would detract from or prevent mission performance or where slipstream or rotor downwash effects would render conventional air conduction

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transducers unusable. Foremost consideration was whether Man's performance would be enhanced or degraded with integrated personal equipment.

The evaluation procedures used in this study are essentially a play off between an experimental bone conduction microphone and a standard military air conduction microphone.

The experimental microphone selected for the comparison evaluation was the HNL (High Noise Level) bone microphone as supplied by SETCOM Corporation of San Jose, California. This microphone was described by the manufacturer as a high noise level bone conduction microphone that is designed to "feel" the vibrations of the head when a person speaks and to respond minimally to all other sounds. The manufacturer also states that clear transmissions with good voice recognition and signal-to-noise performance are possible in noise levels as high as 115 dbA [Ref.3]. The HNL was a developed model of an earlier standard bone conduction microphone of the same manufacturer [Ref.4]. The HNL microphone was mounted in the center of a circular crown sizing pad of an APH-6D flight helmet modified in accordance with the manufacturer himself. See figure 1-1. Figures 1-2 thru 1-4 show in greater detail the manufacturer's patented method of mounting the microphone in a helmet. The manufacturer clearly points out that the HNL microphone is a vibration sensitive bone conduction transducer and preamp combination.

SETCOM does a lot of frequency shaping in its preamp to overcome the losses in the higher frequencies (see Chapt. II.D.) so that its output looks much the same as that of the M-87/AIC microphone. This similarity is shown in figure 1-5 and 1-6. These figures are the results of playing two different tape recordings into a "Briel Jaer Type 3347 Real-Time 1/3 Octave Band Analyser". The first recording (figure 1-5) had the word "twenty" recorded on it by the M-87/AIC and the HNL microphone. The second recording

(figure 1-6) was made up of a list of eight different words recorded twice, once with each microphone. Both recordings were made inside a HU-1 helicopter with all the doors closed. The amount of shaping is Company Confidential and SETCOM would not release this information for print in this paper.

The HNL microphone was compared with a standard M-87/AIC boom mounted dynamic lip microphone. The "Kreal Et Al Modified Rhyme Test" word list [Ref.5] was used to evaluate the intelligibility of both systems while being exposed to the interior and exterior helicopter noise as the evaluation criterion.

The M-87/AIC microphone (FSN 5965-755-4643) was developed as a noise cancelling dynamic microphone for the United States Air Force and it is currently being used by all the Armed Forces as their primary aircraft microphone. The M-87/AIC is manufactured by Electro-Voice, Inc.

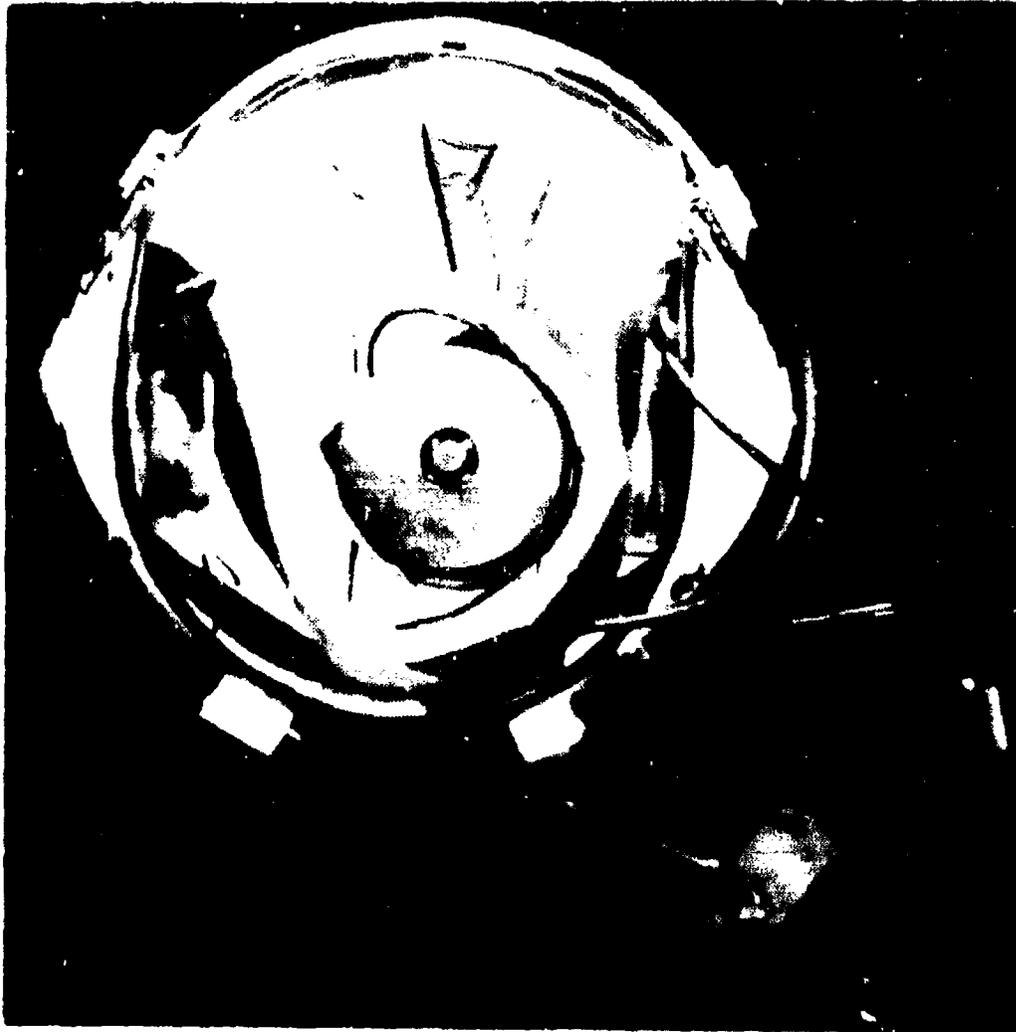


Figure 1-1. HNL Microphone Mounted in an APH-6D

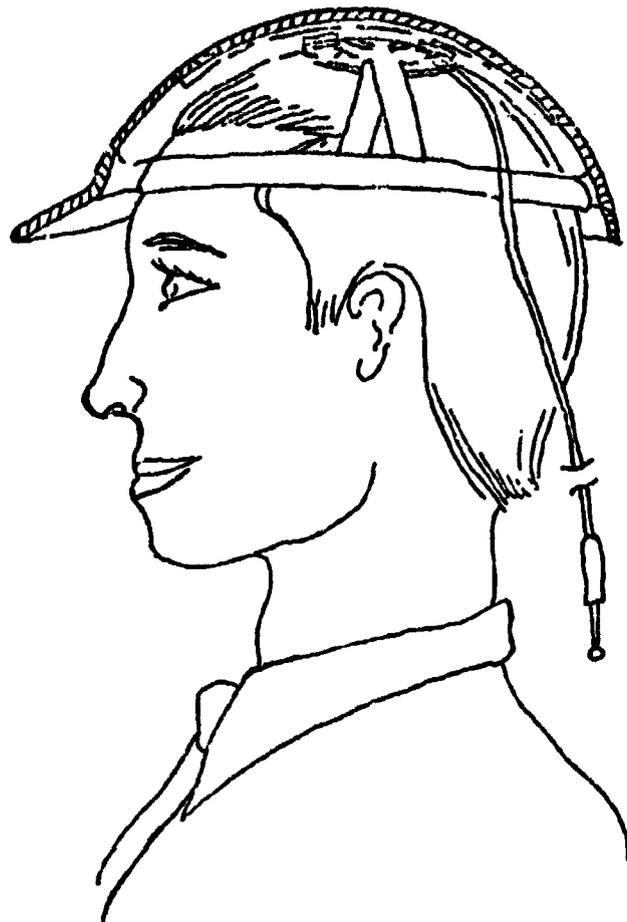


Figure 1-2. Side View of Patented Mounting

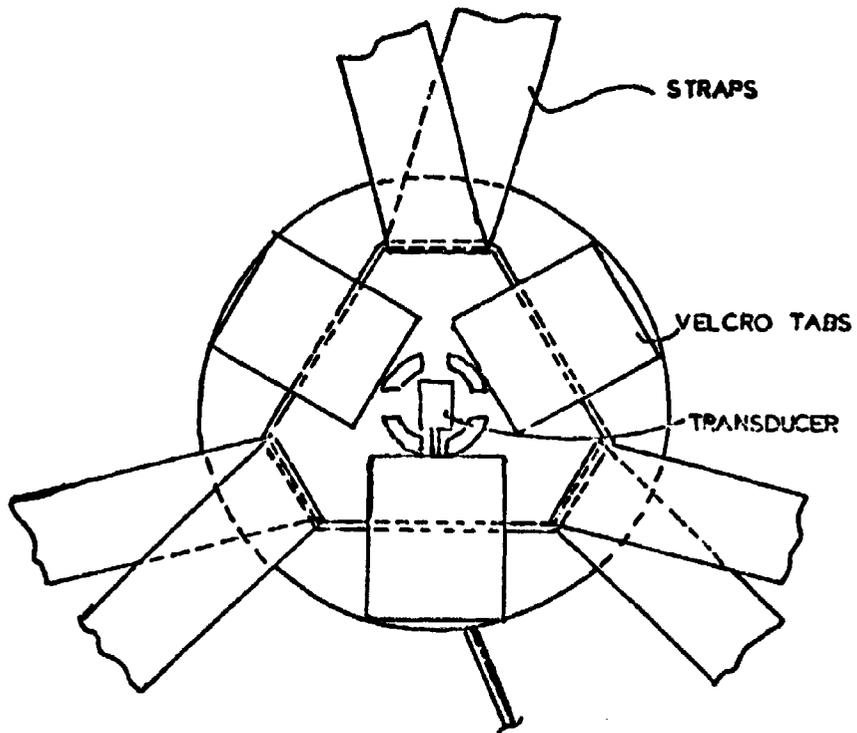


Figure 1-3, Inside View of Patented Mounting

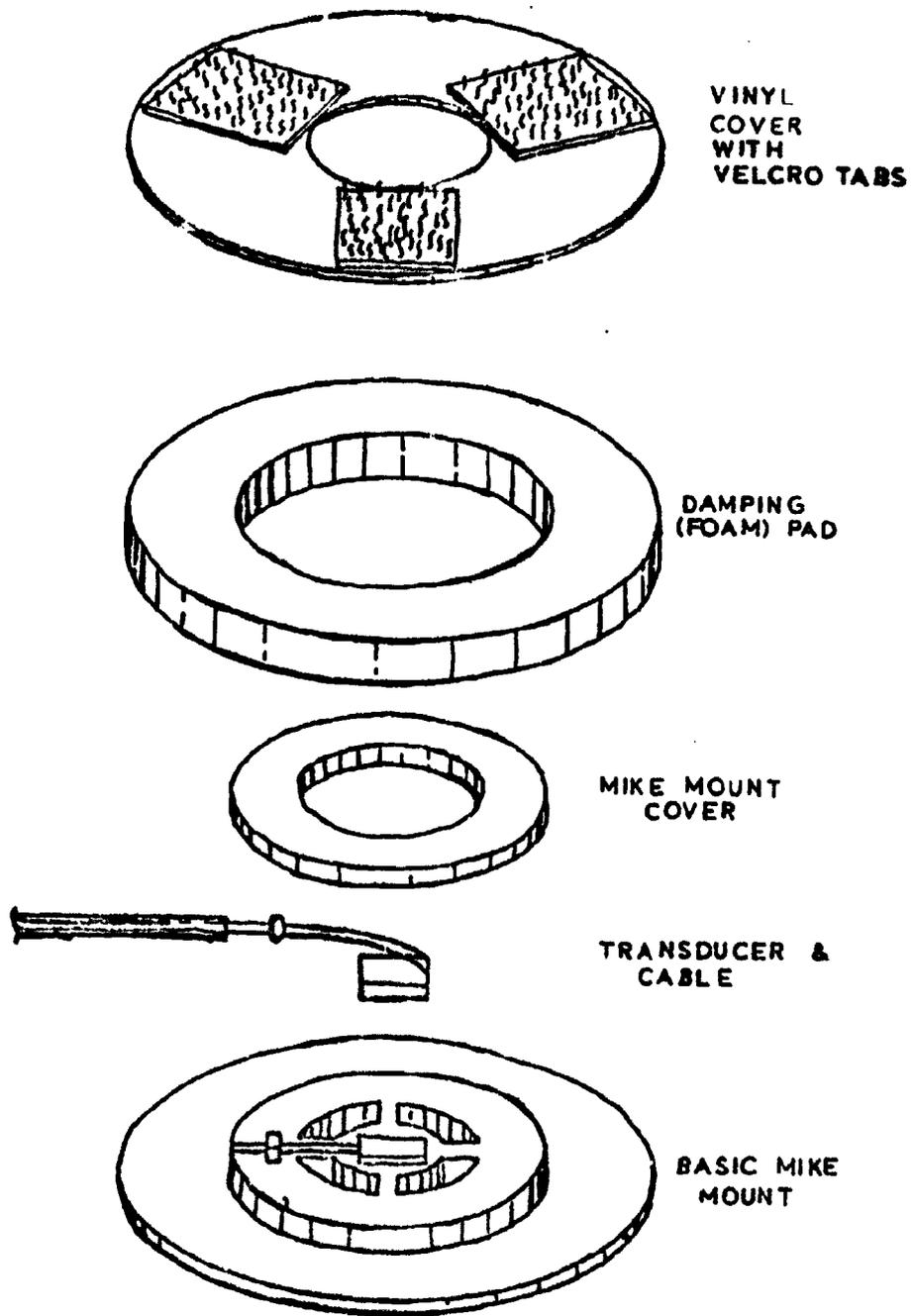


Figure 1-4. Detailed View of HNL Microphone

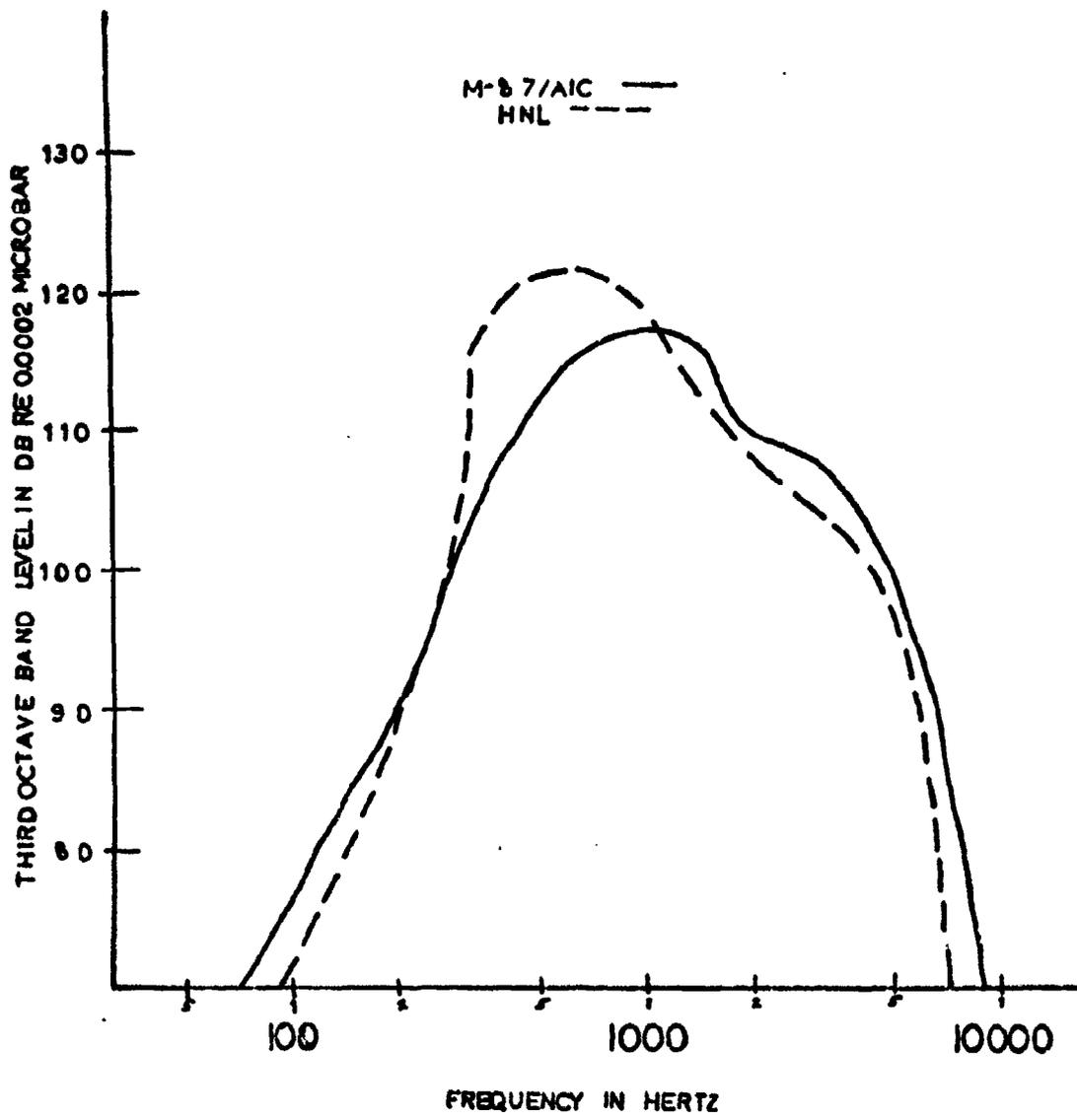


Figure 1-5. Recording of the word "twenty"

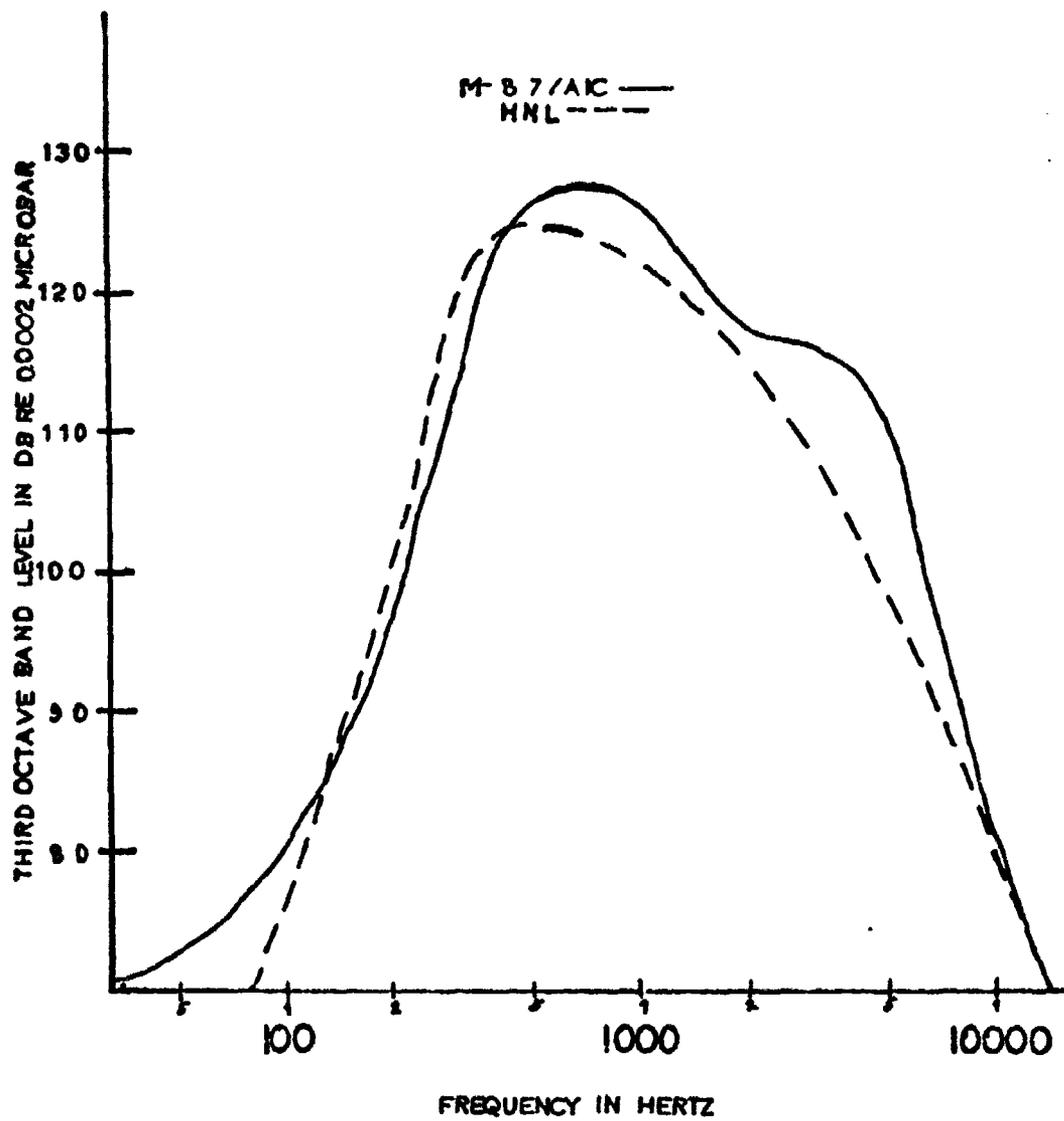


Figure 1-6. Recording of Eight Different Words

## II. PROBLEMS WITH VOICE COMMUNICATIONS

### A. SPEECH INTELLIGIBILITY

Command control of Navy ships and aircraft depends to a major extent on the effectiveness of their communications systems. Demands on these systems increase as new weapons systems and tactics are introduced and ambient noise levels become higher. Too often, voice intelligibility is only marginal to say the least. The factors that affect speech intelligibility can be broken down into four major categories; those associated with (1) the person sending the message, (2) his equipment, (3) his environment, and (4) the message content [Ref.9].

#### 1. PERSONAL

Personal factors known to degrade speech intelligibility include regional dialects, poor enunciation or vocal articulation habits, and inadequate training in the special procedures and phraseologies associated with the equipment or the mission.

#### 2. EQUIPMENT

The design features of present day equipment are known to degrade intelligibility by creating noise and distortion. This plus the requirements of minimum bandwidth does not lend itself to good message transmissions. Reducing noise and increasing bandwidths are expensive, and tradeoffs between expense and intelligibility are a serious consideration. Distortion often results from speech processing schemes which are introduced to overcome noise or to make more efficient use of available power. Distortion of another sort is created by life-support equipment necessary for high-altitude flight, such as the oxygen mask

worn by aircraft crew members. This enclosure over the mouth and nose creates an unnatural cavity in which to talk.

### 3. Environment

Environmental conditions known to degrade intelligibility are ambient acoustic and electrical noise, which create diversions from assigned tasks (like flying an aircraft) and puts more unwanted stress on the performer.

### 4. Message Content

Message parameters which degrade intelligibility include large vocabularies, reports of unusual events with seldom-used words or phrases, and short words or phrases vice grammatical sentences and polysyllabic words.

This study will only address the equipment (mainly microphones) and environmental portions of this critical problem, specifically, those transmissions between crew members of helicopters over the ICS (Internal Communication System).

## B. HIGH NOISE ENVIRONMENT

The primary problem with communications in military vehicles is the high noise environment which they operate in. See Table I. As an example Figure 2-1 shows some typical spectra for two types of military aircraft. The exterior noise spectrum for the OV-1A twin-turbine surveillance aircraft shows that in this case the greatest ambient and also the greatest ear damage risk occurs at low frequencies. However, for the CH-47A helicopter at cruise power the predominant ambient noise occurs in the mid to high frequency region. An estimated envelope of maximum military noise exposure level was obtained by combining the data for the two aircraft [Ref. 10].

### TYPICAL NOISE LEVELS (dBA)

Rustling leaves	10
Whisper	20
Office background noise	50
Conversation	60
Street with moderate traffic	70
Police whistle/vacuum cleaner	80
Five-ton truck	87-101
Street with heavy traffic	90
Motorcycle/gas lawn mower	100-120
CH-47 helicopter/OV-1 Mohawk	102-111
Rock music band	105-111
Armored personnel carrier (M113)	111
M60 tank (not the gun)	114
Jet runway/carrier flight deck	130
.45 caliber pistol (30 feet away)	140
40mm grenade launcher	147
M16 rifle	154-158
3.5-inch rocket	171
81mm mortar	184
90mm tank gun	172-186
105 howitzer	185-191

NOTE: The threshold of physical pain is about 120 to 140 dBA.

Table I

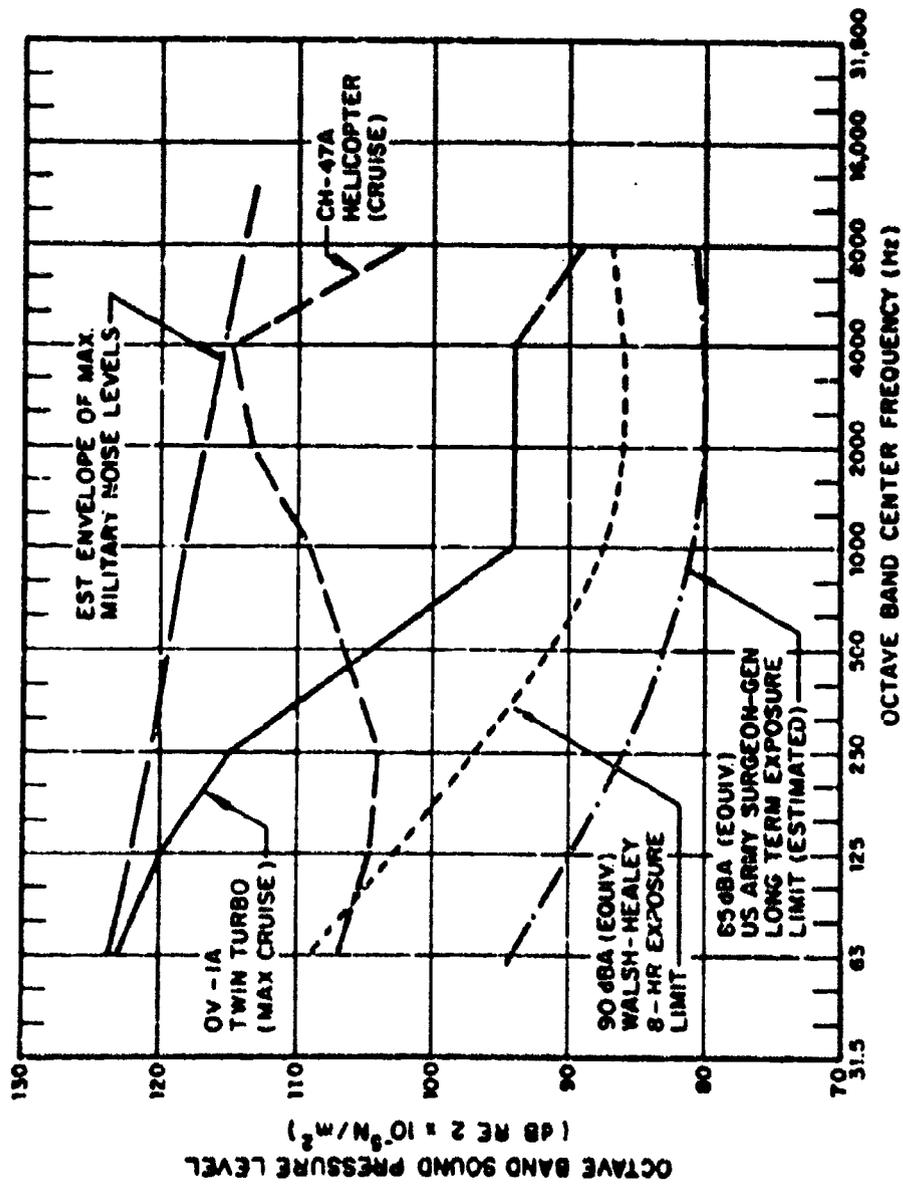


Figure 2-1. Typical Noise Spectra in Military Aircraft (Interiors)

The Walsh-Healey Criterion as applied by the Department of Labor is directed at an eight hour exposure determined by the length of a typical working day. The Army Surgeon General has stated that an 85 dbA (equivalent) level is more appropriate for military personnel because on the average the exposure duration will probably be greater than eight hours. The estimated noise spectrum limits for this criterion are also shown in Figure 2-1.

The problem of high interior noise levels in aircraft is not just peculiar to the Army's inventory, but it is also found in all of the Armed Force's aircraft. In the helicopter this problem is compounded with very high exterior ambient noise caused by the rotor system and other related effects (rotor downwash, slipstream, etc.). One of the main reasons that this is a serious problem to the helicopter community is the missions (VEKREP, hoisting, etc.) that they are tasked with. Communication between crew members is essential to the successful completion of these missions. During these missions at least one crew member is always exposed to the outside ambient noise. This noise level usually exceeds the design limits of his noise cancelling microphone thus making communication difficult if not impossible. The seriousness of this problem is well known to every helicopter pilot and crew member plus it is also on file at the Naval Safety Center, Norfolk, Virginia in the form of aircraft accidents, incidents, and ground accident reports [Ref.6]. This inability to have reliable communication in the environment which helicopters work has cost many lives and dollars throughout the history of aviation.

This communication problem is also present with aircraft ground handling crews (taxi directors, all aircraft carrier flight deck personnel, etc.) of all types of aircraft.

## C. MICROPHONE HISTORY IN AVIATION

Throughout the history of aviation there have been many attempts to build microphones or a complete communication system to resolve this problem of communication in high ambient noise. For the crew member of a helicopter the greatest portion of the exterior ambient noise is wind noise.

### 1. First Generation Vibration microphones

Air moving over a standard lip microphone is one of the worlds best "White Noise" generators thus making filtering almost impossible. The next concept devised was to shield the microphone from the ambient noise. It was then determined that an easy way to shield the microphone from the wind was to build one that was not pressure sensitive. From this idea came the vibration sensitive microphone. After performing sound surveys of the human skull it was determined that the throat gave the strongest vibration signal, but it did not have a flat frequency response. As a result of this survey and the principle that "the most must be the best", the throat microphone came into being in the late 1940's. As with most new designs the faults in the system are always noted after it's built and the throat microphone was no exception. The two biggest drawbacks were; first, it became uncomfortable to wear for long periods of time because it had to be held tight against the throat in order to operate properly and the second was due to the uneven frequency response of the microphone (no high frequency response) which made it hard to understand the speaker. In human speech the lips is where you get the final forming of words therefore, the further the microphone pick up is from the lips the more unnatural and unclear it is going to sound.

## 2. Second Generation Vibration Microphones

During the development of the second generation of vibration microphones it was noted that the head provided a harder bone structure which in turn provided a better high frequency response than the throat, but the intensity of the vibrations was much less. The best frequency response was found to be from the cheek bone.

These second generation vibration microphones acquired many different names such as "Top of the Head Tissue Microphone", "Bone Knockers", "Head Contact Microphone", and "Bone Conduction Microphone", for the remainder of this paper they all will be referred to as bone conduction microphones.

### D. BONE CONDUCTION MICROPHONES

Bone conduction microphones were first patented in the early 1950's by General Dynamics and are now being produced in all shapes and sizes by numerous companies such as Dyna Magnetic Devices, Inc. and SETCOM Corporation.

Bone Conduction microphones operate from energy generated by auditory vibrations of the bones in the head. The microphone transducer is generally a sensitive, low mass accelerometer in intimate contact with the head to pick up the bone vibrations and generate output signals responsive to the auditory vibrations. In many applications the microphone is used by persons who require the use of both hands and in relatively noisy environments. Normally, in such environment the microphone is used in conjunction with some type of head gear such as industrial hard hats, fire, motorcycle, riot and police helmets.

The early bone conduction microphones had serious limitations in such applications. They were adversely affected by ambient noise transmitted through the air or through the head gear from which they supported. Their size

and shape make it difficult and often impossible to mount the transducers in the head gear and so in many instances when mounted render the head gear uncomfortable. In some instances transducers mounted in the head gear are hazardous in that a hard blow to the head gear may drive the transducer into the head and cause injury. The audio quality is in general, poor because the transducer is not held in intimate contact with the head with sufficient pressure to pick up high frequency vibrations whereby high frequency sound is not effectively reproduced.

NASA, prior to the Apollo Program, did an extensive study on bone conduction microphones. They had planned to use this type of microphone in one of the early space suits. The reason it was not used is that the test results showed that the microphone would not pick up the "s" sound (high frequency) and that there was very little voice recognition.

In May of 1971 the Navy did a comparative intelligibility evaluation with a bone conduction microphone made by Dyna Magnetic Devices, Model D551-100 and a standard Navy noise cancelling dynamic M95A/UR lip microphone [Ref. 7]. The results of this report showed that the bone conduction microphone intelligibility was about thirteen per cent poorer than that of the standard lip microphone. This report, in the discussion section, also pointed out, "While the particular prototype microphone chosen for comparative evaluation did not offer improved intelligibility, further trials of developmental transducers should be undertaken. An integrated contact microphone offers considerable operational appeal for certain applications such as VTAS, if communications performance is at least equal to, if not improved over current Navy dynamic microphones".

### III. EXPERIMENTAL PROCEDURES

Following the recommendations of Ref. 7, a comparative evaluation was conducted between the HNL bone conduction microphone, made by SETCOM Corporation of San Jose, California, and the Armed Forces Standard noise cancelling Dynamic M-87/AIC lip microphone, made by Electro-Voice, Inc. The M-87/AIC was tested with and without a foam wind screen cover.

The evaluation was carried out in accordance with the procedures set forth by the American Standards Association [Ref.8] with exception that the "Kreul Et Al Modified Rhyme Test" was used in place of the PB-50 word list. This modification was done because the conclusions of Ref.9 stated the Modified Rhyme Test of House, et al, was found to be the most acceptable speech intelligibility test for military aircraft. A copy of this word list can be seen in Figure 3-1. There are two reasons for this change; first it takes for less time to train the participants and second a shorter time to conduct the actual test, while the results provide the same accuracy of the PB-50 word list. The test procedures basically consists of two parts: the recording phase and the listening phase.

#### A. RECORDING PHASE

##### 1. Test Conditions

Two comparative microphone test conditions were evaluated: (1) the microphone exposed to outside ambient noise in forward flight and (2) the microphone exposed to a very quiet environment.

### a. Outside Ambient Noise

The conditions of high exterior noise levels was achieved by having the talkers secured by a safety belt in the after station of a UH-1 helicopter with the side door open. This was done so that his head and torso could project out into the airstream and rotor downwash during forward flight, simulating conditions that crewmen experience during hoisting and VERTREP operations. See Figure 3-2. During this test condition the helicopter was operated at 88 percent power, 60 to 65 knots forward speed at 1000 feet altitude. The outside noise level was 110 dBA. The exception Sound Level Surveys for the HU-1 helicopter conducted by Patuxent River Test Center are shown in Table II and Table III.

### b. Quiet Environment

The second condition, a quiet environment, was achieved by using a vacant classroom for the talkers to do their recording.

## 2. Taping

The word lists were recorded on a Magnavox Model 1V9011 tape recorder operated at 3 3/4 per second. An adapter was fabricated to connect the microphone directly to the "mic" input of the tape recorder. This direct connection was used so that only the microphones were being evaluated and not the entire communications system of the aircraft.

## 3. Talkers

Two talkers (A and B) were used during both of the environment conditions. Talker A always used word lists 1, 2, and 3 while talker B always used lists 4, 5, and 6, but they did not always use them in that order. The exact order in which they were used is shown in Table IV. It also

listening phase. The talkers were selected and trained in accordance with Ref. 8. The carrier phase which was used with each of the words on the Modified Rhyme Test was "Number \_\_\_\_, would you circle the word \_\_\_\_ now." The phrases were said at a rate of 15 phrases per minute.

#### B. LISTENING PHASE

The listeners were made up of ten people aged 24 through 33 with a mean age of 27.1 years from all walks of life and of both sexes. All subjects were judged to have bilaterally normal hearing in accordance with Ref.8. Each person evaluated the talkers in both of the environments by listening to the tape recording on MX-2508/AIC head set as it was played back on the same tape recorder that was used in the taping phase, in a quiet environment. The MX-2508/AIC head set is the standard Armed Forces head set used by pilots in aircraft where helmets are not required and by maintenance (Avonics) personnel for testing communication equipment. The evaluators were given modified copies of Figure 3-1, see Figure 3-3, to circle their answers on.

EXHIBIT 10: KREUL ET AL MODIFIED RHYME TEST ANSWER SHEETS.

NAME _____		EAR _____		DATE _____	
MODIFIED RHYME HEARING TEST I					
LIST		LIST		LIST	
1. 1. alog 2. ait 3. ain 6. aill 4. aip 5. aich	2. 6. look 3. shook 4. cook 7. took 5. hook 1. book	3. 2. vest 6. rest 1. nest 4. test 5. best 3. west	4. 6. hill 3. hid 4. hit 2. ring 1. hitch 5. hiss	5. 5. putt 2. puff 6. pub 1. pun 3. pup 4. pug	
6. 3. fin 2. fig 6. fit 5. fib 1. fill 4. hiss	7. 5. toil 3. bill 1. foil 6. toll 2. coil 4. oil	8. 3. rust 4. must 2. just 5. guest 6. dust 1. bust	9. 4. rig 3. pig 2. wig 3. big 1. jig 6. fig	10. 4. saw 3. sawn 5. saw 6. same 2. saw 1. sake	
11. 2. bit 6. hit 4. ait 5. wit 3. fit 1. hit	12. 1. cone 2. cone 3. cone 4. cone 5. cone 6. cone	13. 2. hold 6. cold 4. fold 5. gold 2. told 1. acid	14. 5. mass 1. map 3. math 4. man 6. mad 2. mat	15. 5. sale 6. pale 1. gale 4. bale 2. male 3. tail	
16. 1. saw 6. saw 2. paw 5. thaw 4. jaw 3. law	17. 5. rent 3. vent 1. dent 6. sent 4. tent 2. bent	18. 3. pace 5. pale 1. page 4. pay 6. pave 2. pane	19. 3. came 6. game 4. name 1. fame 2. same 5. tame	20. 4. dub 3. du.1 6. dun 1. duck 2. dud 5. dug	
21. 2. rake 1. rave 6. ray 5. read 4. rate 3. race	22. 6. bill 2. bill 5. fill 1. will 3. hill 4. till	23. 6. pan 3. pang 4. pad 1. pass 2. pat 5. path	24. 5. heel 1. peal 2. reel 6. owl 3. feel 4. heel	25. 2. bus 1. bun 4. buff 5. buck 6. bug 2. but	
26. 2. death 5. heat 4. heave 1. hear 3. heal 6. heap	27. 3. sag 4. sack 6. sat 2. saw 5. sap 1. sad	28. 3. gun 2. nun 6. fun 1. sun 5. bun 4. fun	29. 6. tick 4. pick 3. sick 5. wick 2. lick 1. hick	30. 3. cuff 4. cup 5. cud 2. cub 6. cuss 1. cut	
31. 1. peack 3. peak 6. peach 5. peat 4. peal 2. pean	32. 6. pay 1. way 4. gay 2. may 3. say 5. jay	33. 3. den 2. pen 4. hen 6. men 1. ten 5. then	34. 4. seat 5. beat 1. meat 3. heat 2. feat 6. neat	35. 4. dip 3. hip 2. rip 1. sip 6. lip 3. tip	
36. 2. dip 6. din 4. din 3. did 1. dig 5. dill	37. 5. team 6. tank 3. team 2. tear 1. teach 4. teal	38. 3. sub 4. sun 6. sung 5. sup 1. sud 2. sun	39. 4. pig 1. pill 5. pin 2. pick 3. pip 6. pit	40. 5. fed 3. sed 2. shed 6. vend 4. bed 1. led	
41. 5. nap 6. abop 1. top 2. hip 4. cop 3. pop	42. 5. lane 6. lane 4. lace 3. lay 2. lake 1. late	43. 2. beach 3. beat 1. bean 6. beak 5. bead 4. beam	44. 5. bang 6. hang 3. gang 4. bang 1. rang 2. fang	45. 1. soap 4. seed 5. seen 3. seethe 2. seen 6. seek	
46. 5. path 2. path 3. path 6. path 4. path 1. path	47. 1. pin 3. din 2. pin 3. tin 6. pin 4. win	48. 1. tab 4. kang 2. tab 3. tam 5. tab 6. tap	49. 6. bath 3. back 1. bat 5. ban 4. base 2. bad	50. 1. hat 3. eat 6. tot 2. got 3. lot 4. pot	

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Figure 3-1. Kreul Et Al Modified Rhyme Test



Figure 3-2. Talker's Position in a HU-1 Helicopter

GROUND IDLE UH-1

CIRCLE RADIUS FEET	ANGULAR POSITION DEGREES						
	0	30	60	90	120	150	180
12.5	110	112	N.O.	N.O.	N.O.	115	119
25	107	111	114	115	113	115	116
50	102	109	109	109	110	111	113
100	103	104	105	111	110	105	106
200	97	97	100	103	102	101	101

50° HOVER UH-1

CIRCLE RADIUS FEET	ANGULAR POSITION DEGREES						
	0	30	60	90	120	150	180
12.5	106	105	105	106	108	108	108
25	105	105	103	106	104	108	113
50	102	106	108	107	106	107	105
100	103	103	104	108	103	102	105
200	101	97	98	104	103	102	102

Table II. HU-1 External noise levels at  
Ground Idle and 50° Hover (db)

50° HOVER

FREQUENCY	PILOT	COPILOT	FLT ENG	CREWMAN
OVERALL	102	102	102	102
20-75	91	90	94	96
75-150	96	96	92	92
150-300	94	94	92	93
300-600	94	94	94	94
600-1200	93	93	92	91
1200-2400	93	93	92	91
2400-4800	93	93	95	93
4800-10,000	83	84	83	83

MILITARY RATED POWER

FREQUENCY	PILOT	COPILOT	FLT ENG	CREWMAN
OVERALL	95	95	100	100
20-75	85	84	88	90
75-150	86	86	86	87
150-300	84	88	87	88
300-600	84	84	88	88
600-1200	84	83	90	89
1200-2400	84	84	92	90
2400-4800	88	90	94	95
4800-10,000	77	77	83	84

Table III. HU-1 Internal Noise Levels at Military Rated Power and 50° Hover (db)

MICROPHONE	TALKERS IN NOISY ENVIRONMENT (Aircraft)		TALKERS IN QUIET ENVIRONMENT (Classroom)	
	A	B	A	B
M-87/AIC	1	5	2	6
M-87/AIC+ <sup>1</sup>	2	4	3	5
HNL	3	6	1	4

<sup>1</sup> M-87/AIC with Foam Wind Screen

Table IV. Random Word List Order

EXHIBIT 10: KREUL ET AL MODIFIED RHYME TEST ANSWER SHEETS.

NAME _____		EAR _____		DATE _____	
MODIFIED RHYME HEARING TEST I				LIST	
1. dig sin cip	all oll nich	2. look cook hook	shook tool hook	3. vest nest best	rest gest west
4. hill hit hith	hid hing hiss	5. putt pub pup	puft pun pug	6. fin fit fill	fig fib fian
7. toll foil coll	boil soil oil	8. rust just dust	must guat bust	9. rig wig jig	pig big fig
10. same safe sole	save same sake	11. hit olt fit	hit olt hit	12. cane cann cave	cape caks cane
13. hold fold told	cold guid suld	14. mass mash had	map man mat	15. male gale male	pale bait tail
16. raw paw faw	saw shaw law	17. rent dent tent	went sent bent	18. pace page pave	pale pay pane
19. come ham saw	game fame tame	20. dub dun dud	duh duch dug	21. cake ray rate	rove rase race
22. bill fill hill	hill will till	23. pan pad pat	pang pahn path	24. keel reel feel	peel eel heel
25. bus buff bug	bun buck but	26. month beave beal	heat hear heap	27. sag sat sap	each sash sad
28. gun fun bun	gun sun fun	29. lick sich lick	pick wich hick	30. cuff cud cuss	cup cub cut
31. peace peach peal	peah peot pean	32. pay gay sav	way may day	33. den hen ten	pen nen then
34. seat meat feat	beat heat neat	35. dtp rip tip	hip sip tip	36. dip din dig	din did dill
37. team tease teach	teah tear teal	38. sub sung sud	sun sup sum	39. pig pin tip	pill pick pit
40. fed shed bed	red wed led	41. mop top pop	shop top pop	42. lark lark lark	lark lark lark
43. teach reach beach	teah leah beah	44. sang gang fang	hang hong fang	45. keep sew seen	seed seeth seek
46. park mark lark	dark hark lark	47. pin sin fin	din tin win	48. tap tap tap	tang tar tarp
49. bath bat base	back ban bad	50. hot tot lot	not got pot		

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Figure 3-3 Test Answer Sheet

#### IV. CONCLUSION

The results of the comparative tests, Table V, shows very clearly that the M-87/AIC+ microphone turned out to be the best microphone because of its high mean score and a small standard deviation in both the quiet and noisy environment.

The foam windscreen of the M-87/AIC+ cuts down on the turbulent airflow over the microphone thus reducing a large amount of the ambient noise while smoothing out the pops and other harsh sounds of the talker and the wind.

The idea of using a foam windscreen over a microphone to reduce outside ambient noise (mainly wind noise) is not original. It has been used by the motion picture industry and TV companies in their outside work for many years.

The M-87/AIC+ microphone is in the supply system under EV 693-8417, FSN 5965-181-0213 and can be ordered from the Defense Electronics Supply Center, Dayton, Ohio. The name M-87/AIC+ is not the official name of this microphone, but the results of Ref. 11 proves that the EV (Electro Voice) 693 microphone is the same as the M-87/AIC plus a foam windscreen, thus the author came up with the nick name of M-87/AIC+.

The EV 693 (M-87/AIC+) costs approximately \$12.00 while the M-87/AIC only costs \$7.00. A M-87/AIC can be easily converted to a EV 693 by simply putting about 50 cents worth of foam rubber over the M-87/AIC. This process will save over \$4.50 per copy.

The results of this test also shows that the HNL microphone remained almost constant during both phases of this test and it's mean in the noise environment was only .3% less than that of the M-87/AIC, but the S.D. was almost one percent greater. The closeness of these results

indicate that further comparative studies and analysis should be performed on the HNL microphone because the bone conduction microphone has many advantages over the standard boom type microphone as already stated in the earlier sections of this paper.

It is further recommended that these further tests be operation type tests and that all the evaluators (listeners) be pilots or aircrew members because they are more accustomed to listening to message traffic in this type of environment and at a faster rate than what the normal person is use to hearing.

TALKERS USING A M-87/AIC MICROPHONE CLASSROOM AIRCRAFT				TALKERS USING A M-87/AIC+ MICROPHONE CLASSROOM AIRCRAFT				TALKERS USING A HNL MICROPHONE CLASSROOM AIRCRAFT															
A	B	A	B	A	B	A	B	A	B	A	B												
0	96	96	92	96	100	98	96	100	92	94	90	94											
1	94	88	92	90	100	96	94	96	86	82	82	92											
2	94	94	92	96	98	100	96	98	82	68	88	96											
3	98	96	92	86	100	96	94	94	94	94	84	92											
4	98	94	92	90	100	100	94	94	94	92	88	96											
5	96	94	90	90	100	98	92	94	88	100	86	92											
6	96	96	94	92	100	98	94	96	88	94	94	96											
7	96	92	96	80	98	98	96	88	92	92	86	96											
8	98	96	96	98	100	100	98	94	96	98	92	94											
9	96	92	92	90	100	96	96	96	94	94	92	98											
MEAN=95.1				MEAN=91.7				MEAN=98.8				MEAN=95.0				MEAN=91.7				MEAN=91.4			
S.D.=2.47				S.D.=3.85				S.D.=1.51				S.D.=2.47				S.D.=4.74				S.D.=4.45			

S.D. - UNBIASED ESTIMATE OF THE TRUE STANDARD DEVIATION

Table V. The Ten Listeners (0-9) Scores (in percent)

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