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HIGH NOISE LEVEL MICROPHONES USED IN AIRCRAFT

Edward Joseph Hintz

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THESIS

HIGH NOISE LEVEL MICROPHONES
USED IN AIRCRAFT

by

Edward Joseph Hintz, Jr.

June 1974

Thesis Advisor: G. D. EWING

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

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High Noise Level Microphones used in Aircraft

by

Edward Joseph Hintz Jr
Lieutenant, United States Navy
B.S., United States Naval Academy, 1968

Submitted in partial fufillment of the requirements for the degree of

MASTER OF SCIENCE IN ELECTRICAL ENGINEERING

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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.

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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 comlexity while airborne and these roles may impose conflicting requirements in personal equipment. The VTAS (Visual Target Acquisition System) concept applied to air combat manuvering 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 inconveniece of a boom microphone would detract from or prevent mission performance or where slipstream or rotor downwash effects would render conventional air conduction

tranducers unusuable. 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 thur 1-4 show in greater detail the manufacturers patented method of mounting the microphone in a helmet. The manufacturer clearly points out that the HNL microphone is a vibration sensitive bone conduction tranducer and preamp combination.

SETCOM does a lot of frequency shaping in its preamp to overcome the loses 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 simularity is shown in figure 1-5 and 1-6. These figures are the results of playing two different tape recordings into a "Bruel Jaer Type 3347 Real-Time 1/3 Octave Band Analysiser". 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 make 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 "Kreul 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.

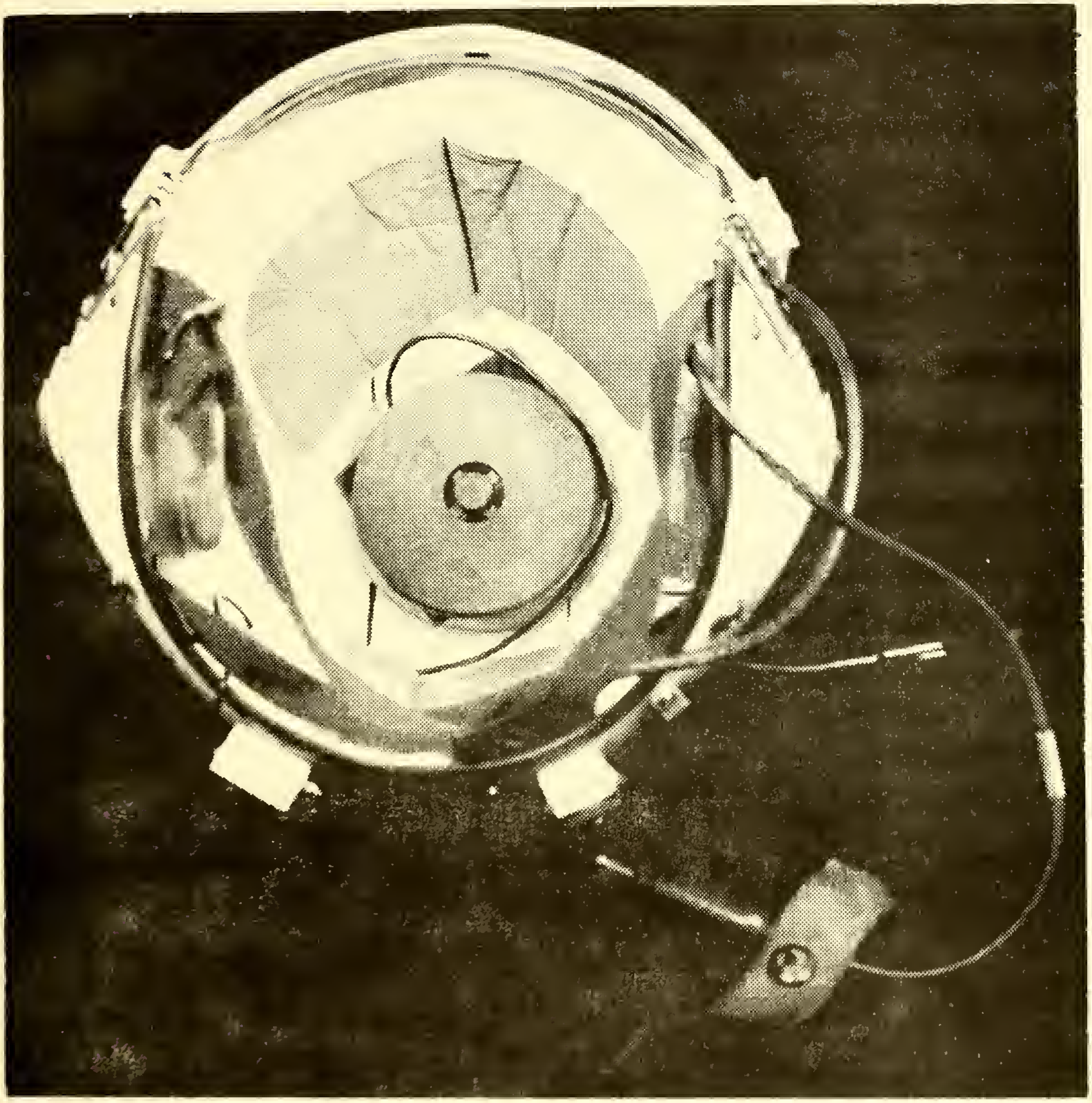

Figure 1-1. HNL Microphone Mounted in an APH-6D

Figure 1-2. Side View of Patented Mounting

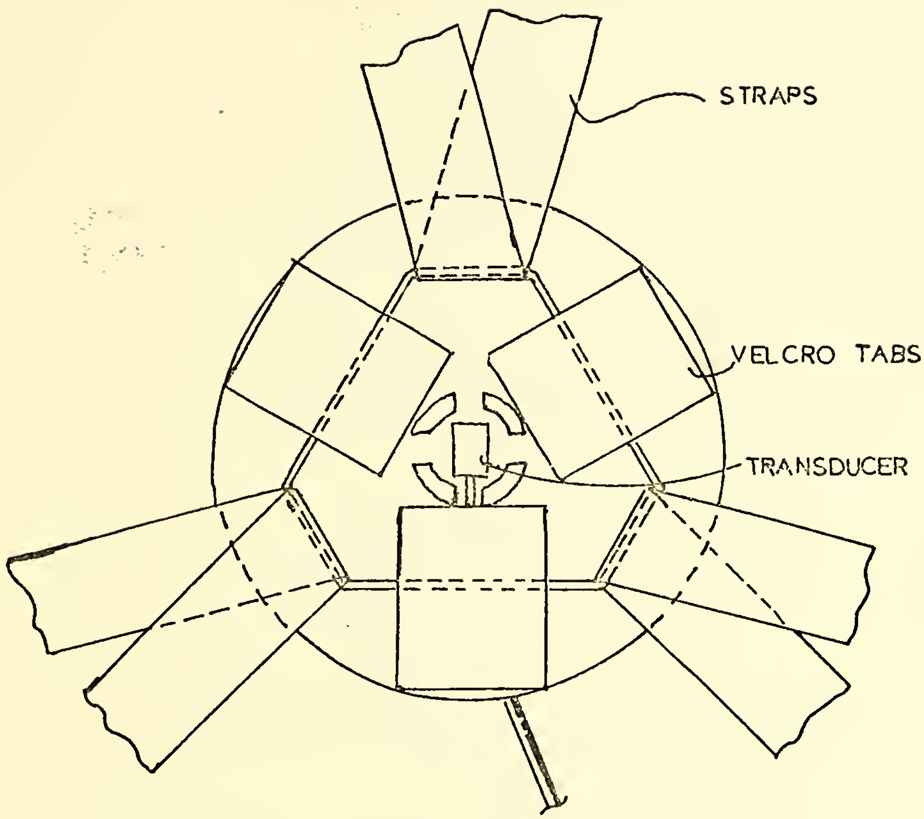

Figure 1-3, Inside View of Patented Mounting

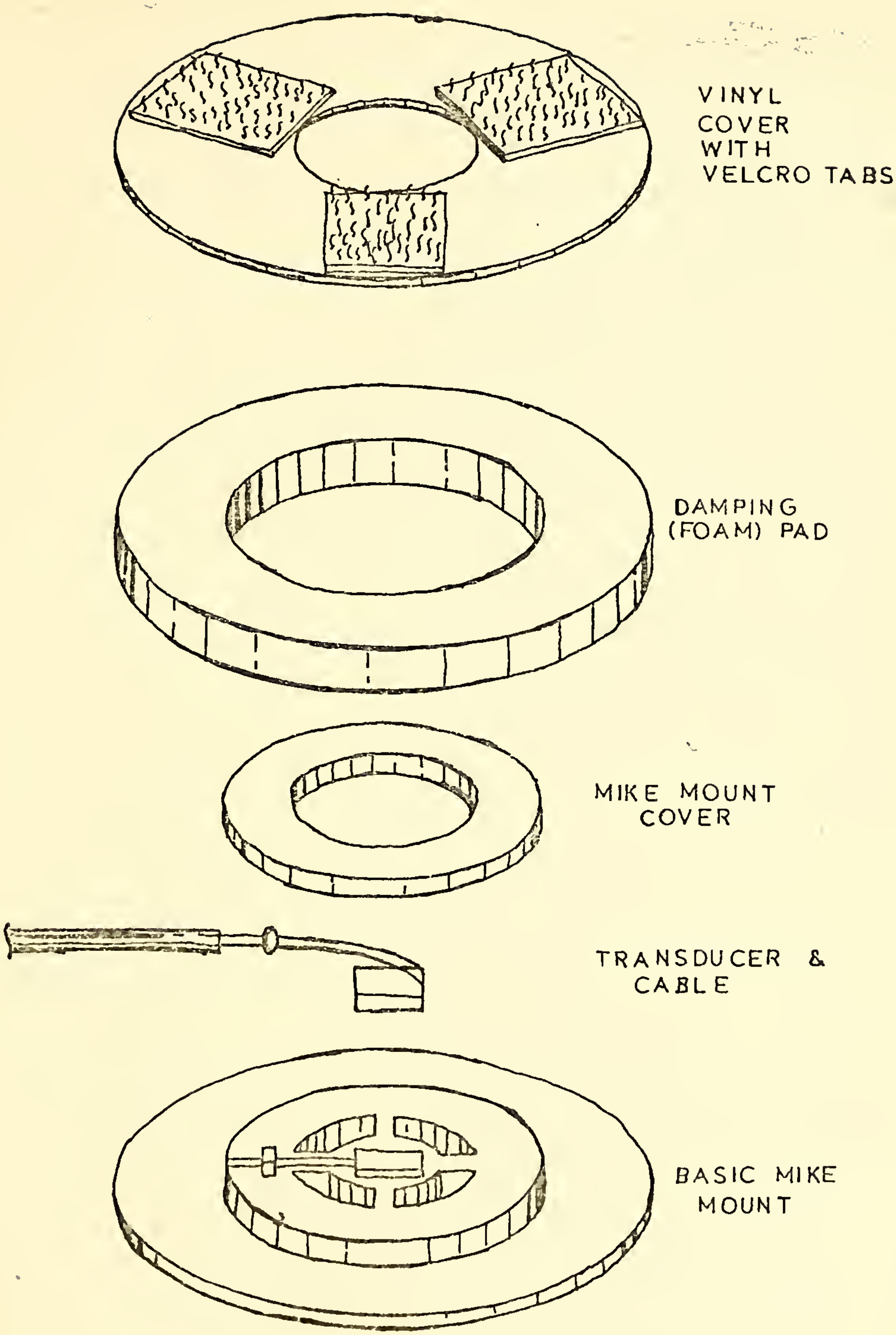

Figure 1-4. Detailed View of HNL Microphone

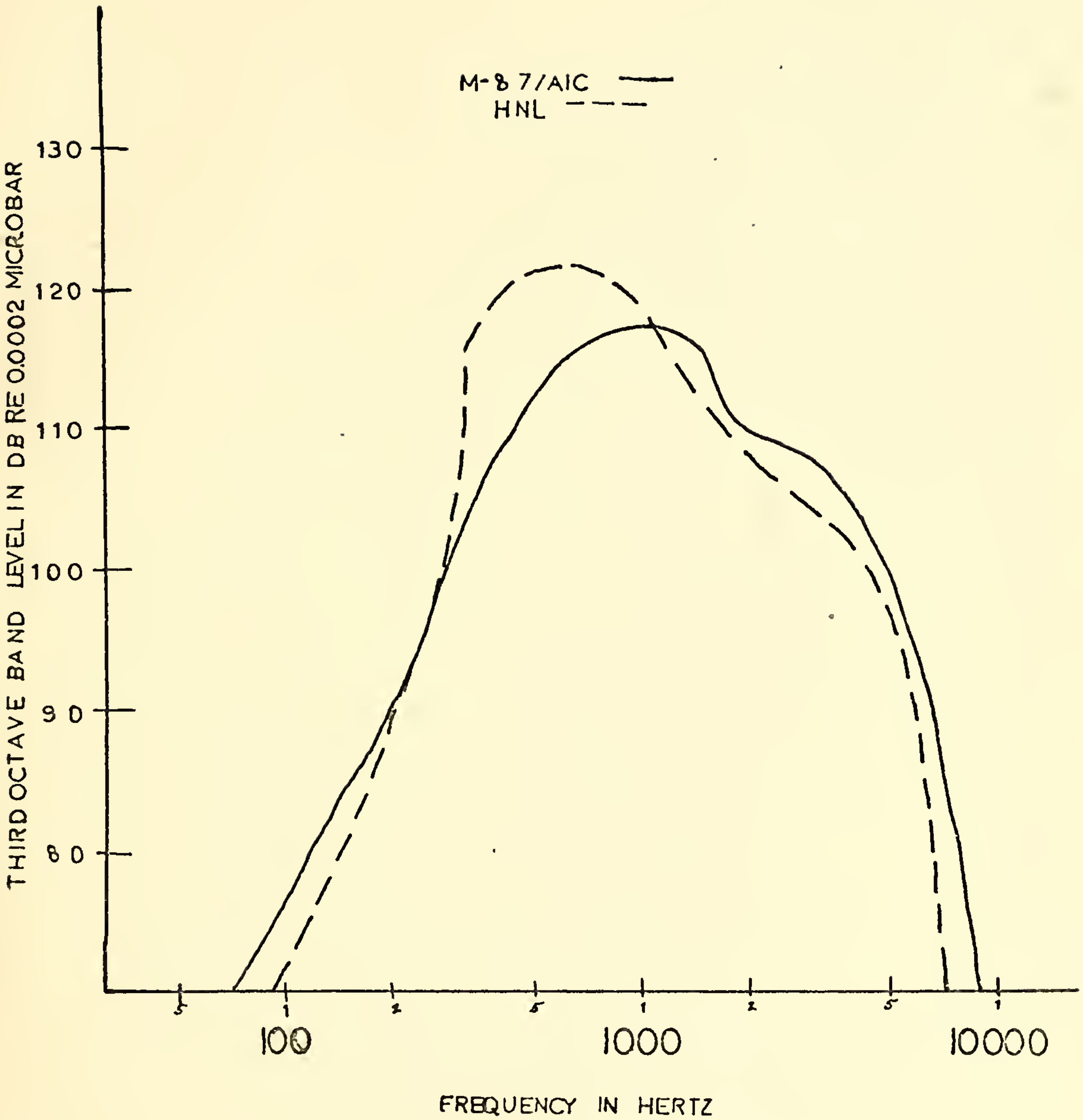

Figure 1-5. Recording of the Word "Twenty"

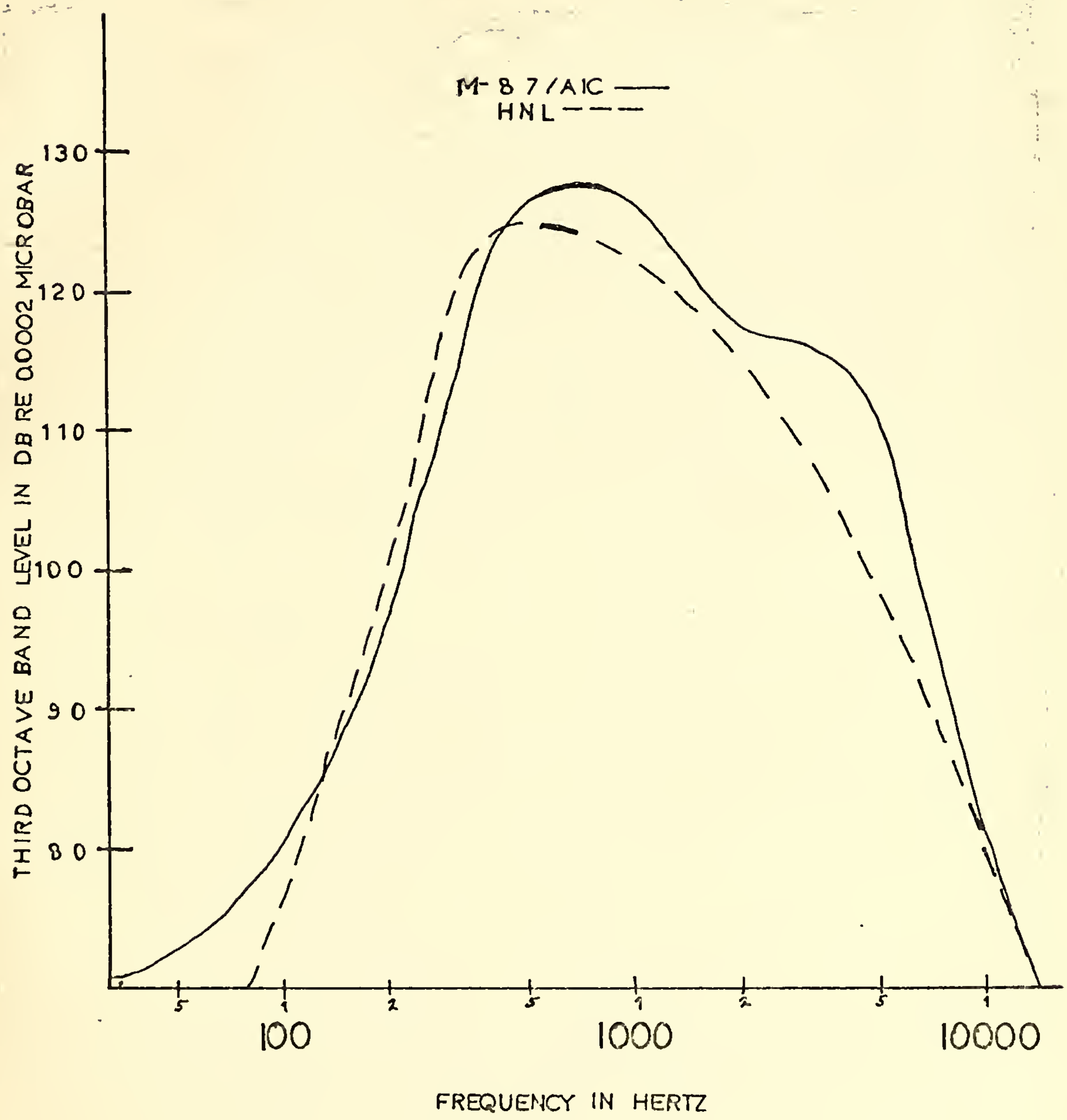

Figure 1-6. Recording of Eight Different Words

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-IA 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 backround 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

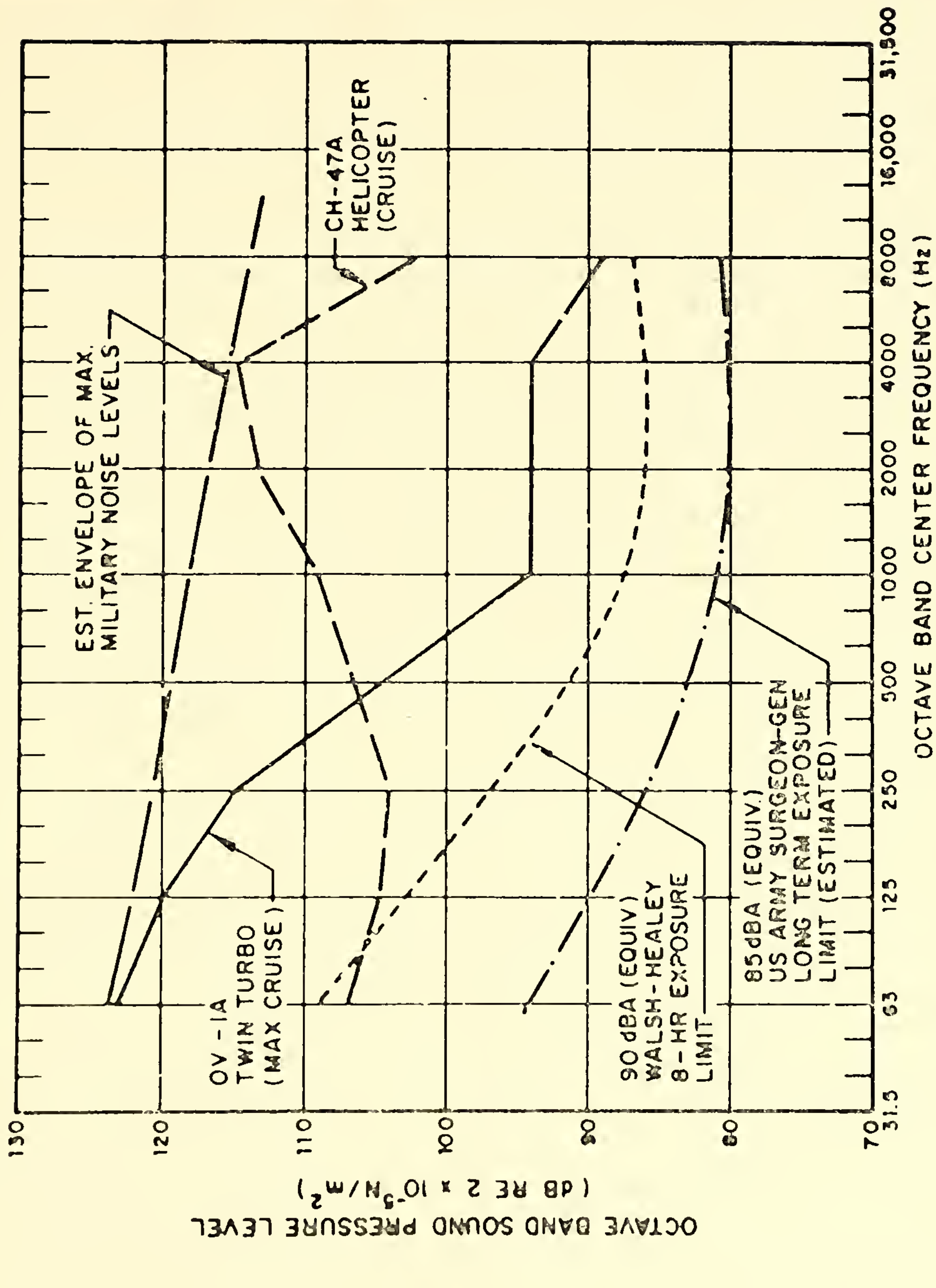

Figure 2-1. Typical Noise Spectra in Military Aircraft (Interiors)

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 crition 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 (VERTREP, 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 helments.

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 ofRef.9 stated the Modified Rhyme Test of House,el 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 acheived 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 exceptence 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 acheived 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 1 LIST ______________

1. 1. sing 2. sit 3. sin 6. sill 4. sip 5. sick	**2.** 6. look 3. shook 4. cook 2. took 5. hook 1. book	**3.** 2. vest 6. rest 1. nest 4. test 5. best 3. west	**4.** 6. kill 3. kid 4. kit 2. king 1. kith 5. kiss	**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. fizz	**7.** 5. toil 3. boil 1. foil 6. soil 2. coil 4. oil	**8.** 3. rust 4. must 2. just 5. gust 6. dust 1. bust	**9.** 4. rig 5. pig 2. wig 3. big 1. jig 6. fig	**10.** 4. sane 3. save 5. safe 6. same 2. sale 1. sake
11. 2. bit 6. hit 4. sit 5. wit 3. fit 1. kit	**12.** 1. came 2. cape 3. cane 4. cake 5. cave 6. case	**13.** 3. hold 6. cold 4. fold 5. gold 2. told 1. sold	**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. tale
16. 1. raw 6. saw 2. paw 5. thaw 4. jaw 3. law	**17.** 5. rent 3. went 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. dull 6. dun 1. duck 2. dud 5. dug
21. 2. rake 1. rave 6. ray 5. raze 4. rate 3. race	**22.** 6. bill 2. hill 5. fill 1. will 3. kill 4. till	**23.** 6. pan 3. pang 4. pad 1. pass 2. pat 5. path	**24.** 5. keel 1. peel 2. reel 6. eel 3. feel 4. heel	**25.** 2. bus 1. bun 4. buff 5. buck 6. bug 3. but
26. 2. heath 5. heat 4. heave 1. hear 3. heal 6. heap	**27.** 3. sag 4. sack 6. sat 2. sass 5. sap 1. sad	**28.** 3. gun 2. nun 6. run 1. sun 5. bun 4. fun	**29.** 6. tick 4. pick 3. sick 5. wick 2. lick 1. kick	**30.** 3. cuff 4. cup 5. cud 2. cub 6. cuss 1. cut
31. 1. peace 3. peak 6. peach 5. peat 4. peal 2. peas	**32.** 6. pay 1. way 4. gay 2. may 3. say 5. day	**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 5. hip 2. rip 1. sip 6. lip 3. tip
36. 2. dip 6. din 4. dim 3. did 1. dig 5. dill	**37.** 5. team 6. teak 3. tease 2. tear 1. teach 4. teal	**38.** 3. sub 4. sun 6. sung 5. sup 1. sud 2. sum	**39.** 4. pig 1. pill 5. pin 2. pick 3. pip 6. pit	**40.** 5. fed 3. red 2. shed 6. wed 4. bed 1. led
41. 5. mop 6. shop 1. top 2. hop 4. cop 3. pop	**42.** 5. lane 6. lame 4. lace 3. lay 2. lake 1. late	**43.** 2. peach 3. beat 1. bean 6. beak 5. bead 4. beam	**44.** 5. sang 6. hang 3. gang 4. bang 1. rang 2. fang	**45.** 1. seep 4. seed 5. seem 3. seethe 2. seen 6. seek
46. 5. park 2. dark 3. mark 6. bark 4. lark 1. hark	**47.** 1. pin 5. din 2. sin 3. tin 6. fin 4. win	**48.** 1. tab 4. tang 2. tan 3. tam 5. tack 6. tap	**49.** 6. bath 3. back 1. bat 5. ban 4. bass 2. bad	**50.** 1. hot 3. not 6. tot 2. got 5. lot 4. pot

Figure 3-1. Kreul Et Al Modified Rhyme Test

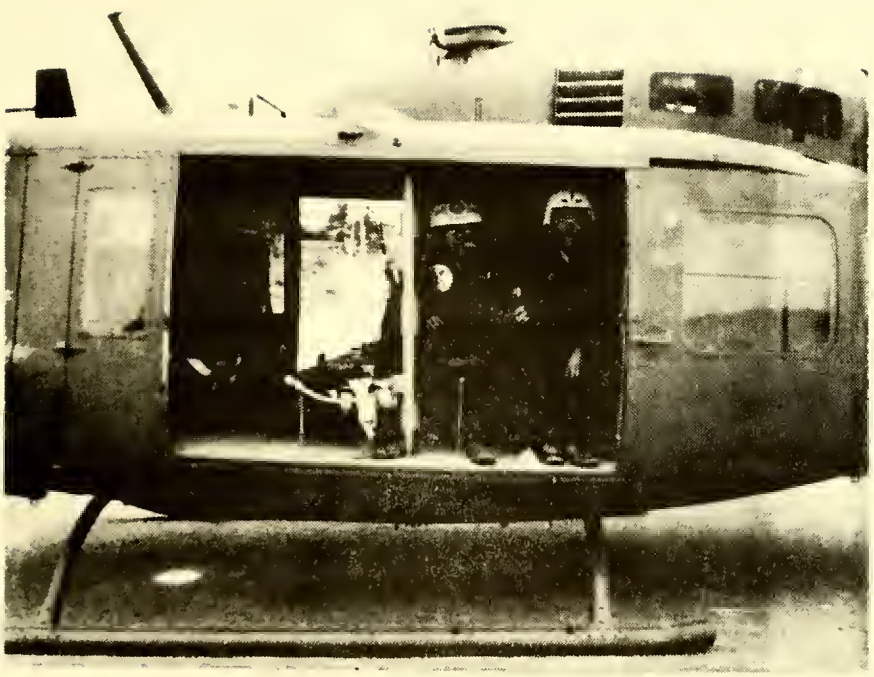

Figure 3-2. Talker's Postion in a HU-1 Helicopter

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) A	B	TALKERS IN QUIET ENVIRONMENT (Classroom) A	B
M-87/AIC	1	5	2	6
M-87/AIC+[1]	2	4	3	5
HNL	3	6	1	4

[1] 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 1 LIST ____________

1.		2.		3.		4.		5.	
sing	sit	look	shook	vest	rest	kill	kid	putt	puff
sin	sill	cook	took	nest	test	kit	king	pub	pun
sip	sick	hook	book	best	west	kith	kiss	pup	pug
6.		**7.**		**8.**		**9.**		**10.**	
fin	fig	toil	boil	rust	must	rig	pig	sane	save
fit	fib	foil	soil	just	gust	wig	big	safe	same
fill	fizz	coil	oil	dust	bust	jig	fig	sale	sake
11.		**12.**		**13.**		**14.**		**15.**	
bit	hit	came	cape	hold	cold	mass	map	sale	pale
sit	wit	cane	cake	fold	gold	math	man	gale	bale
fit	kit	cave	case	told	sold	mad	mat	male	tale
16.		**17.**		**18.**		**19.**		**20.**	
raw	saw	rent	went	pace	pale	came	game	dub	dull
paw	thaw	dent	sent	page	pay	name	fame	dun	duck
jaw	law	tent	bent	pave	pane	same	tame	dud	dug
21.		**22.**		**23.**		**24.**		**25.**	
rake	rave	bill	hill	pan	pang	keel	peel	bus	bun
ray	raze	fill	will	pad	pass	reel	eel	buff	buck
rate	race	kill	till	pat	path	feel	heel	bug	but
26.		**27.**		**28.**		**29.**		**30.**	
heath	beat	sag	sack	gun	nun	tick	pick	cuff	cup
heave	hear	sat	sass	run	sun	sick	wick	cud	cub
heal	heap	sap	sad	bun	fun	lick	kick	cuss	cut
31.		**32.**		**33.**		**34.**		**35.**	
peace	peak	pay	way	den	pen	seat	beat	dip	hip
peach	peat	gay	may	hen	men	meat	heat	rip	sip
peal	peas	say	day	ten	then	feat	neat	lip	tip
36.		**37.**		**38.**		**39.**		**40.**	
dip	din	team	teak	sub	sun	pig	pill	fed	red
dim	did	tease	tear	sung	sup	pin	pick	shed	wed
dig	dill	teach	teal	sud	sum	pip	pit	bed	led
41		**42.**		**43.**		**44.**		**45.**	
mop	shop	lane	lame	beach	beat	sang	hang	seep	seed
top	hop	race	lay	bean	beak	gang	bang	seem	seethe
cop	pop	lake	late	bead	beam	rang	fang	seen	seek
46.		**47.**		**48.**		**49.**		**50.**	
park	dark	pin	din	tab	tang	bath	back	hot	not
mark	bark	sin	tin	tam	tan	bat	ban	tot	got
lark	hark	fin	win	tack	tap	bass	bad	lot	pot

Figure 3-3 Test Answer Sheet

IV. CONCLUSION

The results of the comparitive 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 offical 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 preformed on the HNL microphone because the bone conduction microphone has many advanges 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				TALKERS USING A M-87/AIC+ MICROPHONE				TALKERS USING A HNL MICROPHONE			
	CLASSROOM		AIRCRAFT		CLASSROOM		AIRCRAFT		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	88	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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