Baldwin Report No. AFAC - 23

INVESTIGATION OF CONTACT MICROPHONES FOR USE IN HIGH AMBIENT NOISE FIELDS

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Cincinnati 2, Ohio

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Task 4

Communication and Navigation Laboratory
Wright Air Development Center
Air Research and Development Command
United States Air Force
Wright-Patterson Air Force Base, Ohio

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Foreword

This report was prepared by the Engineering and Research Department of the Baldwin Piano Company, under United States Air Force Contract No. AF33 (616) - 3323, Task No. 4. The task was administered under the direction of Messrs. E. Lazur and T. P. Mountz, Jr., WCLNE-3, Communication and Navigation Laboratory, Wright Air Development Center, WPAFB, Ohio.

The contract was terminated for the convenience of the government on September 13, 1957 by the contracting officer at WADC. This report summarizes all research completed up to the time of contract termination.

Abstract

The vibration spectrum and level of speech from different anatomical locations was measured using contact microphones adapted for this purpose. This information was used to select the optimum anatomical locations for picking up speech in extremely noisy (140 db re. 0.0002 dyne/cm^2) sound fields near jet engines. On the basis of this preliminary research several microphone-noise shield systems for use at selected anatomical locations were developed. Articulation tests of contact microphone-noise shield systems were conducted in a 120 db jet noise spectrum. Unsatisfactory articulation scores were obtained with these systems even with optimum electrical equalization of speech signal, anatomical location and seal around the microphone.

A noise cancelling system employing a pressure gradient microphone (M-76) located in close proximity to the skin provided satisfactory speech intellibibility in a 120 db jet noise spectrum. The contract was cancelled by the contracting officer at WADC before an evaluation of this noise cancelling system was completed. On the basis of available data it appears that this noise cancelling microphone system located on the forehead or neck area would provide satisfactory communication in a 140 db jet noise.

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CINCINNATI 2, OHIO

AF 33 (616)-3323

Table of Contents

Table of Contents
(Continued)

List Of Figures

List Of Tables

CONTACT MICROPHONE INVESTIGATION
Final Engineering Report on
Task 4, conducted under
Contract No. AF 33(616)-3523
PART I

Section A - Purpose

1. The basic contract states the purpose as follows: "Develop improved microphone models for trial intercommunication between ground crews and servicing aircraft in extremely noisy (140 db re .0002 dyne per square centimeter) sound fields near jet engines during engine trim operations." Specifically the requirements of the task called for the measurement of the vibration spectrum and level of speech signals picked up mechanically from logically chosen locations of the human anatomy. On the basis of articulation tests, the optimum location for a contact microphone is to be determined. Knowledge of the speech level at the optimum anatomical location and the noise spectra resulting from ambient acoustical noise, typical of aircraft engines, is to be used in adapting existing types of vibration responsive transducers to the purpose of picking up speech signals. This information will also aid in the design of noise shields to be used in conjunction with the transducer. On the basis of the results obtained with a microphone and noise shield located at the optimum anatomical location, ten microphone models are to be developed for limited trial use by aircraft service personnel. Field tests are to be conducted with the microphone models during jet engine trim operations to determine their effectiveness in providing communication between the engine trim mechanic and the mechanic within the aircraft.

Section B - Identification of Personnel (Total manhours expended on the project shown in parentheses)

2. a) A. B. Bereskin, professor of electrical engineering, University of Cincinnati and electronic consultant for Baldwin. (14)

   b) Harold A. Conklin, Jr., senior electronic engineer, B.S.EE., University of Toledo; seven years experience in communications, ordnance electronics research and development, and acoustical research and development at Philco Corp., National Bureau of Standards (Diamond Ordnance Fuze Labs.), and Baldwin. (88)

   c) Terry Dempsey, acoustical laboratory technician. (52)

   d) Robert K. Duncan, supervising engineer, acoustical research section, B.S.EE. Purdue University, Lt. Cmdr. U.S.N.R. with experience in sonar and electronic equipment. Registered Professional Engineer; LL.B., Attorney at Law, Ohio Bar. Twelve years industrial experience as acoustical and electrical engineer at RCA, Capehart- Farnsworth, and Baldwin. (27)

   e) Roger E. Kirk, senior psychoacoustic engineer, Ph. D. in experimental psychology, Ohio State University; two years experience in psychoacoustics and human engineering. (584)

   f) D. W. Martin, assistant chief engineer and director of research, Ph. D. in physics, sixteen years experience in industrial acoustical research and development at RCA and Baldwin, and as consultant, author and editor in fields of acoustics and audio. (112)

   g) R. L. Murphy, intermediate electrical engineer, B.S., American Television Institute of Technology, six years industrial experience in measurement of acoustical transducer and audio system performance. (467)

h) Donald Patrick, acoustical laboratory technician; 2 years pre-engineering at University of Kentucky and University of Cincinnati, four years industrial laboratory experience. (36)

i) Arthur Pettit, acoustical laboratory technician. (71)

j) D. Borchers, draftsman. (32)

k) The following engineering model shop technicians worked on this task:

P. Engel (12)
W. Fortner (4)
J. Reidinger (13.5)
C. Thueneman (9.5)

l) The first test crew consisted of the following students from the College Conservatory of Music:

W. Hopkins (3)
J. Lankston (3)
A. Loon (3)
A. McClellan (3)
L. Radabaugh (3)
J. Surface (3)
J. Vian (3)

m) The second test crew consisted of the following students from the College Conservatory of Music and the University of Cincinnati

W. Eich (49)
W. Hartz (21)
S. Izenson (49)
R. Lipka (49)
A. McClellan (44.5)
H. Miller (49)
J. Lankston (49)
J. Surface (46)

Section 2 - Survey of Literature Directly Applicable to Problem

3. Noise Levels Encountered in Vicinity of Jet Aircraft

A knowledge of the noise levels which maintenance personnel encounter while jet aircraft ground-run-up engine trimming operations will enable a clearer appreciation of their communication problem. A summary of the noise characteristics of all operational **Air Force** turbo-jet aircraft is contained in a WADC report by Eldred (7).

For aircraft operating with after burners and fighter aircraft at military power, the range of average over-all sound pressure levels in a "general area" about the aircraft is approximately 133 to 138 db re 0.0002 dyne per square centimeter. The maximum over-all level exceeds 150 db in the case of the F100, F[illegible] and [illegible] aircraft for after burner operation. According to Eldred (7), however, the use of the "general area" coverage level will result in a more realistic estimate of the sound pressure level to which personnel may be exposed during the performance of routine maintenance operations. The use of protective devices such as insert type ear-plugs and over-the-ear defenders has markedly increased the time which maintenance personnel may be exposed to noise levels encountered in typical maintenance positions. According to a WADC report by Eldred, Gannon and von Gierke (8), the use of V-51R insert ear-plugs (average seal) with typical over-the-ear defenders increases the maximum permissible exposure time in a 130 db jet noise to approximately 50 minutes as compared to 30 seconds for unprotected ears.

4. Previous Research on Body Contact Speech

During vocalization, vibrations from the vocal cords are distributed over the entire body. The relative amplitudes of these vibrations have been reported by [illegible] ([illegible]). He found that the amplitude of vibration during phonation at a frequency of 13[illegible] cycles per second was greatest in the immediate area of the larynx.

Mullendore (11) also studied the relative amplitude of vowel sounds at various locations on the body. He ranked ten locations in decreasing order of intensity as follows: (1) thyroid cartilage, (2) mandible, (3) nose, (4) top of head, (5) clavicle, (6) vertebra, (7) sternum, (superior end), (8) sternum, (inferior end), (9) mastoid and (10) rib (5th).

A recent investigation (10) of the relative intensities of sound pressures at 1[illegible] anatomical locations on the head and neck during phonation of vowels has been reported by Moser, Dreher and Oyer. Subjects, representing three different body types, intoned vowels for 5 seconds at a level of 75 db re 0.0002 dyne per square centimeter. A Sonotone bone oscillator used as a vibration pickup and an Ampex 350 recorder were used in recording the vowel sounds. An analysis of variance performed on the data indicated a significant difference in intensities among anatomical locations. The findings of the two previously cited experiments of greater intensity of vowel sound near the larynx were borne out in this study. No significant difference in intensity among vowels was found. Listening comparisons of the vowels indicated that the spectrum of various vowels was different at several locations investigated. In general

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[illegible]

[illegible] faithful reproduction of [illegible]

[illegible] investigated the difference in sound pressure [illegible] the lips [illegible] mouth. [illegible] level inside the mouth [illegible] the basis of [illegible]'s research, it would [illegible] could be obtained [illegible] located in front of [illegible] (4) [illegible] located in the mouth [illegible] intelligibility [illegible] described [illegible].

[illegible] located in the ear canal has been investigated (4). A microphone located in the ear canal is [illegible] from the point of view of providing [illegible] communication [illegible] noise attenuation [illegible] in front of the lips [illegible] considerably smaller than the [illegible] microphone [illegible] conclusion that the use of [illegible] conventional [illegible] front [illegible] intense noise [illegible] It is difficult [illegible] of [illegible] equipment.

[illegible]

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[illegible]
[illegible]
[illegible]
Contract No. [illegible]

5. [illegible] vice [illegible] attenuation [illegible]

[illegible] investigated [illegible] Each one [illegible] vibration [illegible] (5) [illegible] that it is impossible to construct ear plugs [illegible] with isolation of more than [illegible] between [illegible] to 9,000 cycles per second. Transmission [illegible] bone conduction [illegible] contributes to [illegible] conduction vibrations. In this connection [illegible] primarily with attempts to isolate the subject [illegible] from his [illegible] conducted [illegible]. In an investigation by Dolan (5), the experimenter attempted to isolate the talker from his own air conducted side tone by placing an acoustically lined box in front of the talker's mouth and acoustically lined boxes around the talker's ears. The volume of the talker's [illegible] physiological noise which occurs [illegible] is enclosed [illegible] cavity. The experimenter reports that he was able to achieve attenuation with the ear boxes of the order of [illegible] db. Attenuation with the voice box in front of the mouth is not as good, being of the order of [illegible] db minimum.

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[illegible]

PART II

Section A - Experimental Procedure

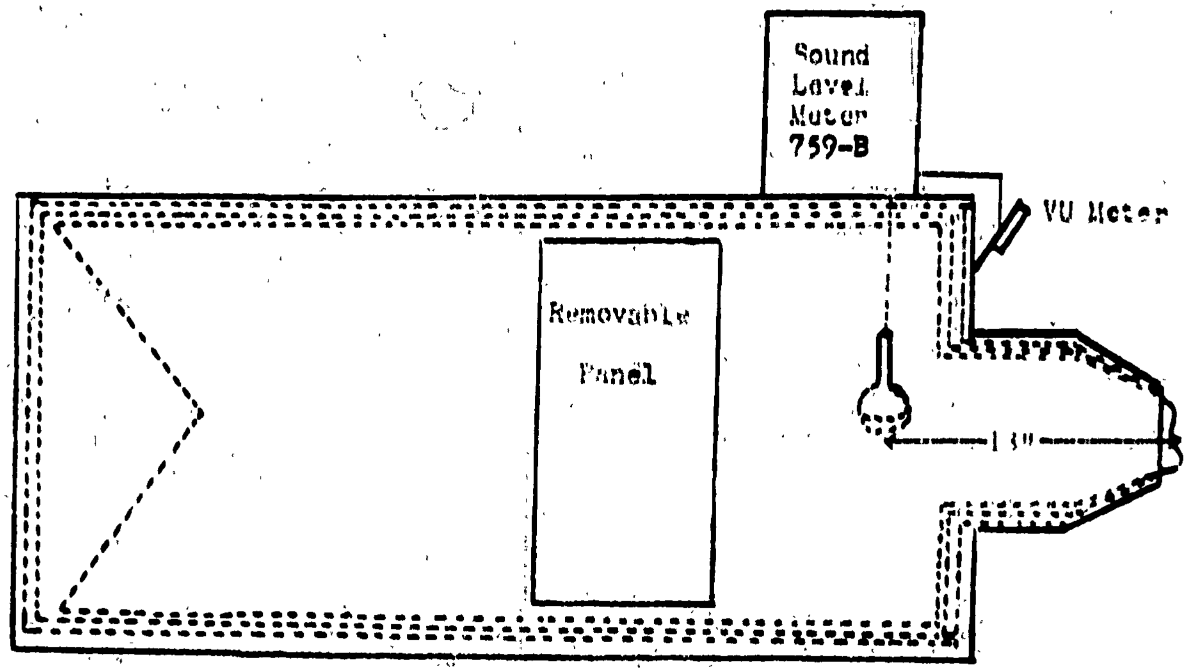
1. Instrumentation

a) Voice Absorber

In order to investigate the vibration spectrum and level of speech signals picked up from logically chosen locations on the anatomy, it was necessary to provide means for isolating the talker's bone conducted speech from his air conducted speech. To this end a voice absorber was adapted from an available box. The design of the voice absorber is shown in Figure 1. The overall-dimensions of the voice absorber were 60 x 36 x 22 inches. The interior of the voice absorber was lined with 3 layers of Aerocor fibre glass. The mouth piece for the voice absorber was designed from a modified A13A oxygen mask. An adjustable head rest held the subject's head firmly in place. A sound level meter microphone was mounted inside the voice absorber approximately 13 inches from the talker's lips. A VU meter was mounted on the front of the voice absorber so that the talker could monitor his speech level while talking into the voice absorber. The voice absorber provided attenuation of sound of the order of 15 to 20 db. It was believed that the acoustic impedance offered to the voice mechanism by the voice absorber was not significantly different than that offered by a free field. In order to ascertain if talking into the voice absorber produced a change in the speech spectrum, the spectrum for a typical talker was measured in an anechoic chamber using a 640AA microphone. Fol-

FIGURE 1

Design of Voice Absorber



----- Layer of Aerocor Fiberglass

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[illegible] to the [illegible] the [illegible] located at the [illegible] in the voice chamber and [illegible] consists of the speech spectrum [illegible] is shown in Figure [illegible]. It can be [illegible] spectrum [illegible] the [illegible] in the voice [illegible] is attributed to the [illegible] treatment [illegible] of the [illegible] in the manner of talking. The speech spectrum shown in Fig. [illegible] determined from the "Jo . . . [illegible]." test sentence.

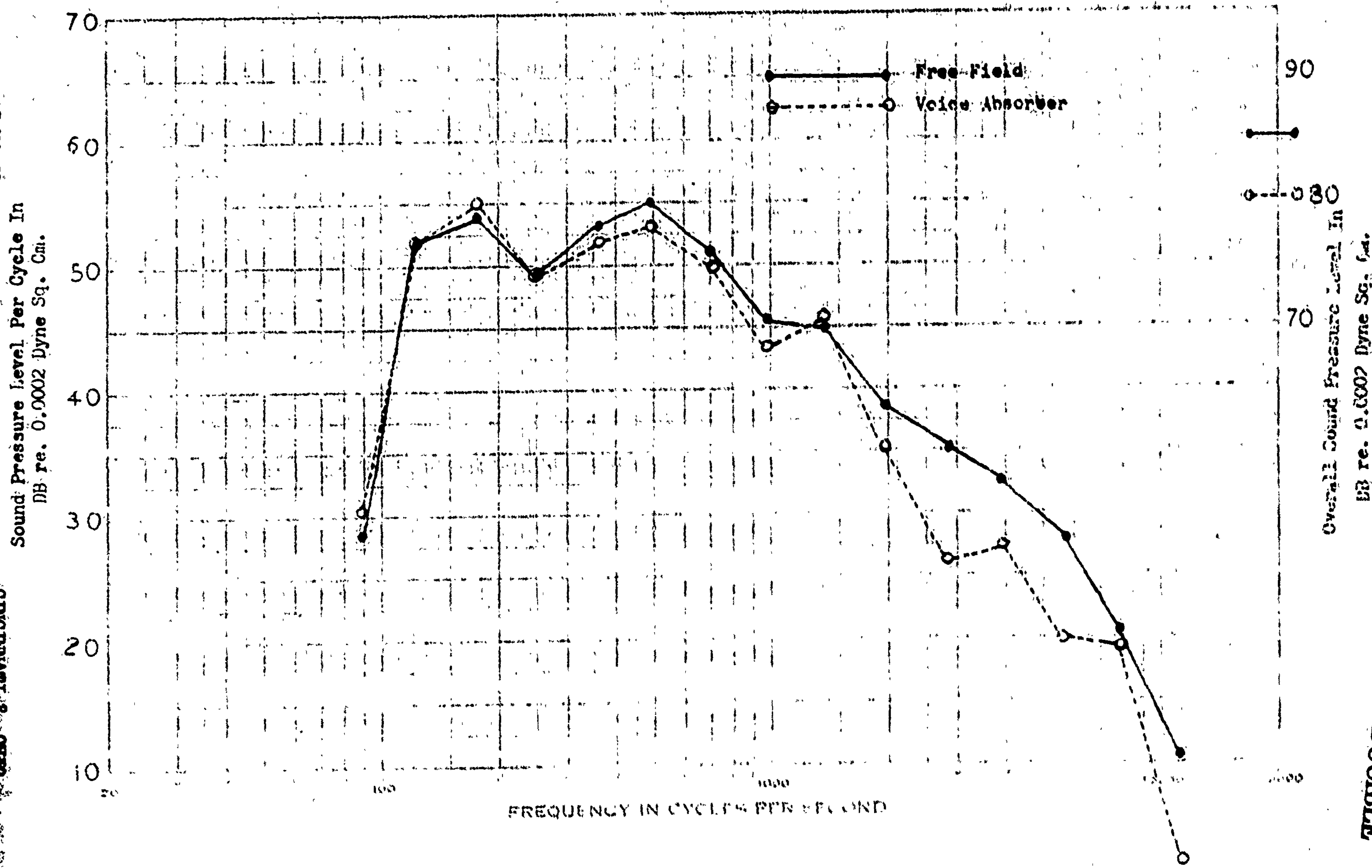
[illegible] Contact microphones

Three commercially available contact microphones were purchased for use in this [illegible]: an Electro-Voice contact microphone Model 8[illegible], [illegible] contact microphone and [illegible] crystal contact microphone.

[illegible] Contact microphone calibration device.

In order to calibrate the contact microphones, a special driver unit was adapted from available equipment and material to get an electrodynamic device of very high mechanical impedance. Since the device was mass controlled its velocity amplitude decreased at a rate of 6 db/octave. A compensating network for use with the driver unit was designed to increase the voice-coil current with frequency at a rate of 6 db/octave, thus providing

FIGURE 2
Comparison Of Speech Spectrum In
Free Field And In Voice Absorber



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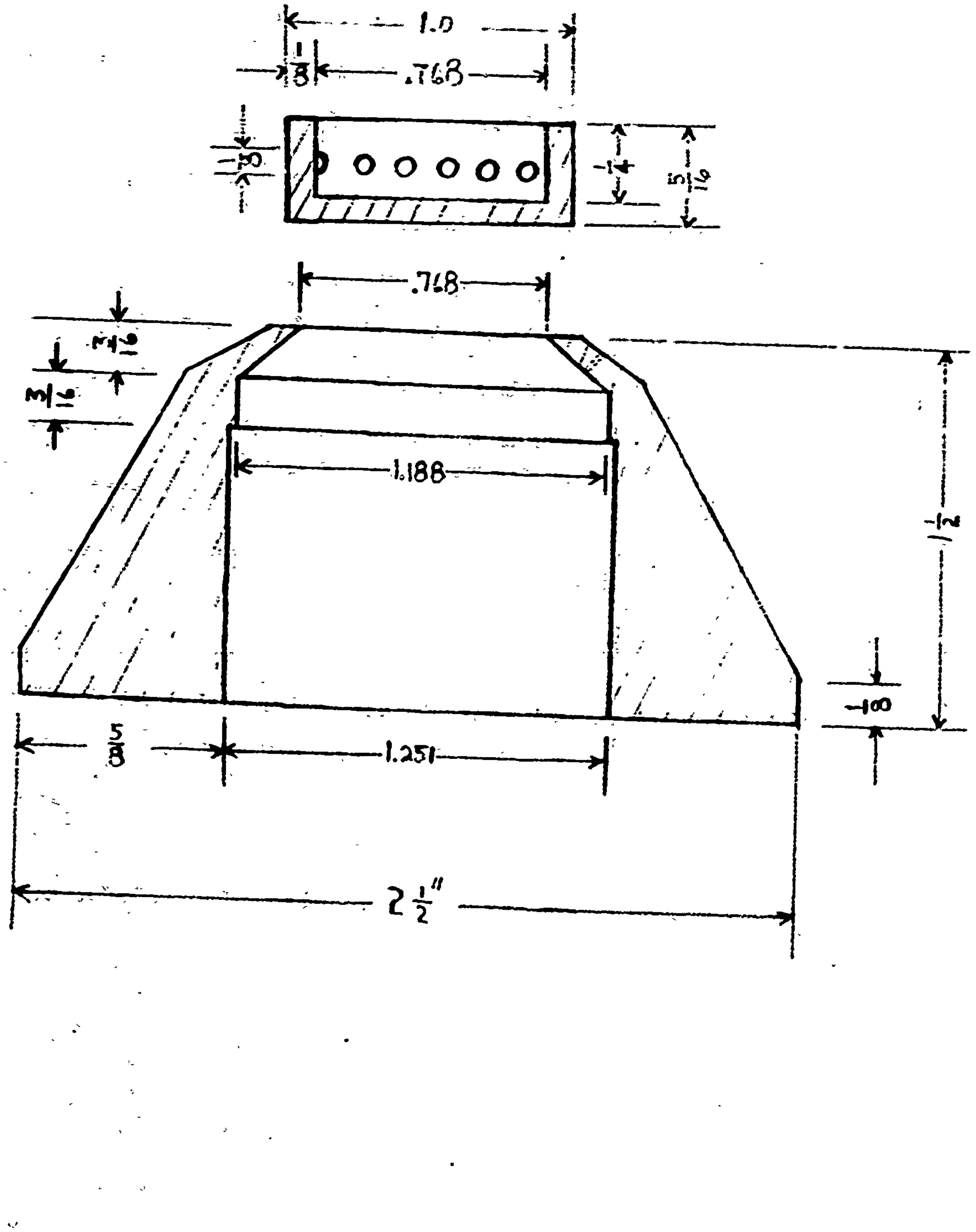
constant velocity amplitude. A description of a device similar in design to the one **adapted** for this investigation can be found in a paper by Martin ([illegible]). Calibration of the driver unit was not made before the termination of the contract. The frequency response of the contact microphone therefore has not been determined **on an absolute basis.**

[illegible] 6cc Coupler Unit

As a subsidiary phase of the investigation, a 6cc coupler for use with a 640-AA microphone was **designed.** The purpose of this coupler was to permit measurement of acoustical energy which was radiated from different areas of the anatomy. The design of the coupler unit is shown in Figure 5. An accessory device for use with the coupler is also shown in Figure 5. This device when attached to the coupler prevents acoustic vibration from activating the diaphragm of the 640-AA microphone. This accessory device was used to determine if the 640-AA microphone was being activated by vibration other than acoustical vibration. Preliminary measurements indicated that the 640-AA microphone was activated only by acoustical vibration radiated from the talker's skin. A block diagram of the equipment used for these measurements is shown in Figure 6. An investigation of the acoustical vibration amplitudes at different anatomical locations was begun. In the course of the measurements, distortion at the output of the Western Electr**oacoustic** **a**mplifier was observed. It appeared that the distortion was due to overloading of the first or second stage**, caused by high sound**

FIGURE [illegible]

[illegible] cc Coupler and Accessory



levels in the 6 c c. coupler. The W. E. amplifier was removed from the equipment setup and an Altec power supply used to provide the polarizing voltage for the 640AA microphone. The microphone output was led directly to the RCA booster amplifier. Measurement of coupler sound pressures at different locations was not completed, but the high levels observed suggested the feasibility of microphone - noise shield systems D and E later tried.

e) Speech equalizer device

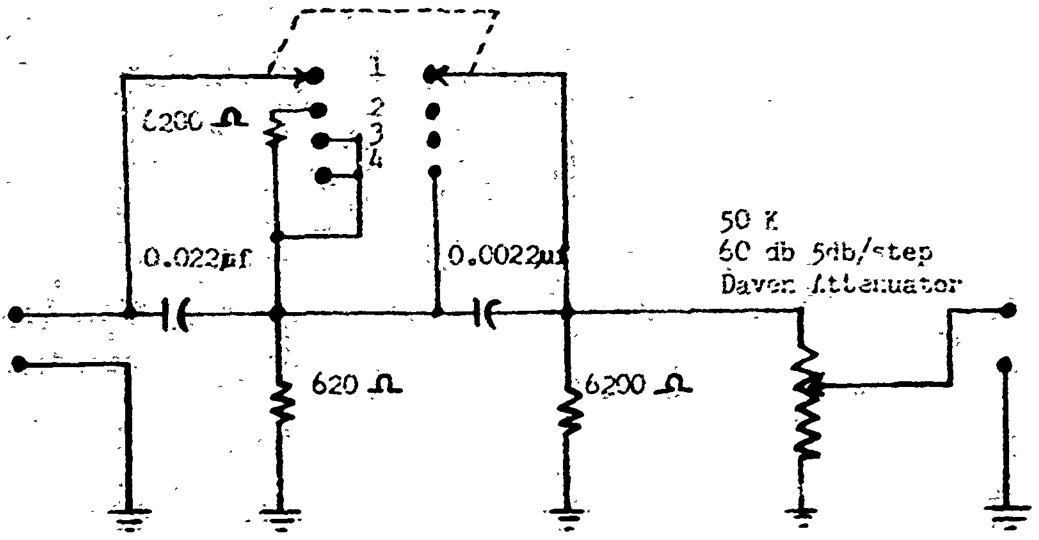
It has been observed by numerous investigators that body conducted speech sounds differ markedly in spectrum from airborne speech sounds emitted from the mouth (2, 3, 8). In general, body conducted speech sounds contain less high frequency energy relative to low frequency energy than do air conducted speech sounds. In order to render body conducted speech sounds maximally intelligible, electrical equalization of the signal after it has been picked up from the anatomy is necessary. To this end a passive equalizer network was developed which provided means for obtaining the following speech equalization slopes: 6 db/octave, 6 db/octave to 1000 cps and 12 db/octave thereafter and 12 db/octave. A circuit diagram of the equalizer network is shown in Figure 4.

f) Low noise transistorized amplifier

The vibration amplitude of speech signals from certain anatomical location, for example the forehead area, is relatively low in level. When equalization of speech signals from the forehead

Figure 4.

Speech Equalizer Network, Four Slopes



Position 1. 12 db/octave rising from 0-10 KC

Position 2. 6 db/octave rising from 0-1 KC and 12 db/octave
beginning about 1 KC
Position 3. 6 db/octave rising from 0-10 KC

Position 4. No equalization

area was attempted, considerable difficulty with electrical noise, T.V. and radio signal interference, was encountered. The T. V. signals, radio signals and hum were found to be entering the system primarily through the contact microphone and microphone cable. In order to minimize these interference effects, a low noise transistorized amplifier was constructed. The circuit developed separately by Bereskin (3) is shown in Figure 5. A block diagram showing all the combinations of equipment used in picking up speech vibrations from different anatomical locations is shown in Figure 6. The system shown in Figure 6 allows for considerable flexibility in the types of microphones used.

2. Speech Spectrum Measurement

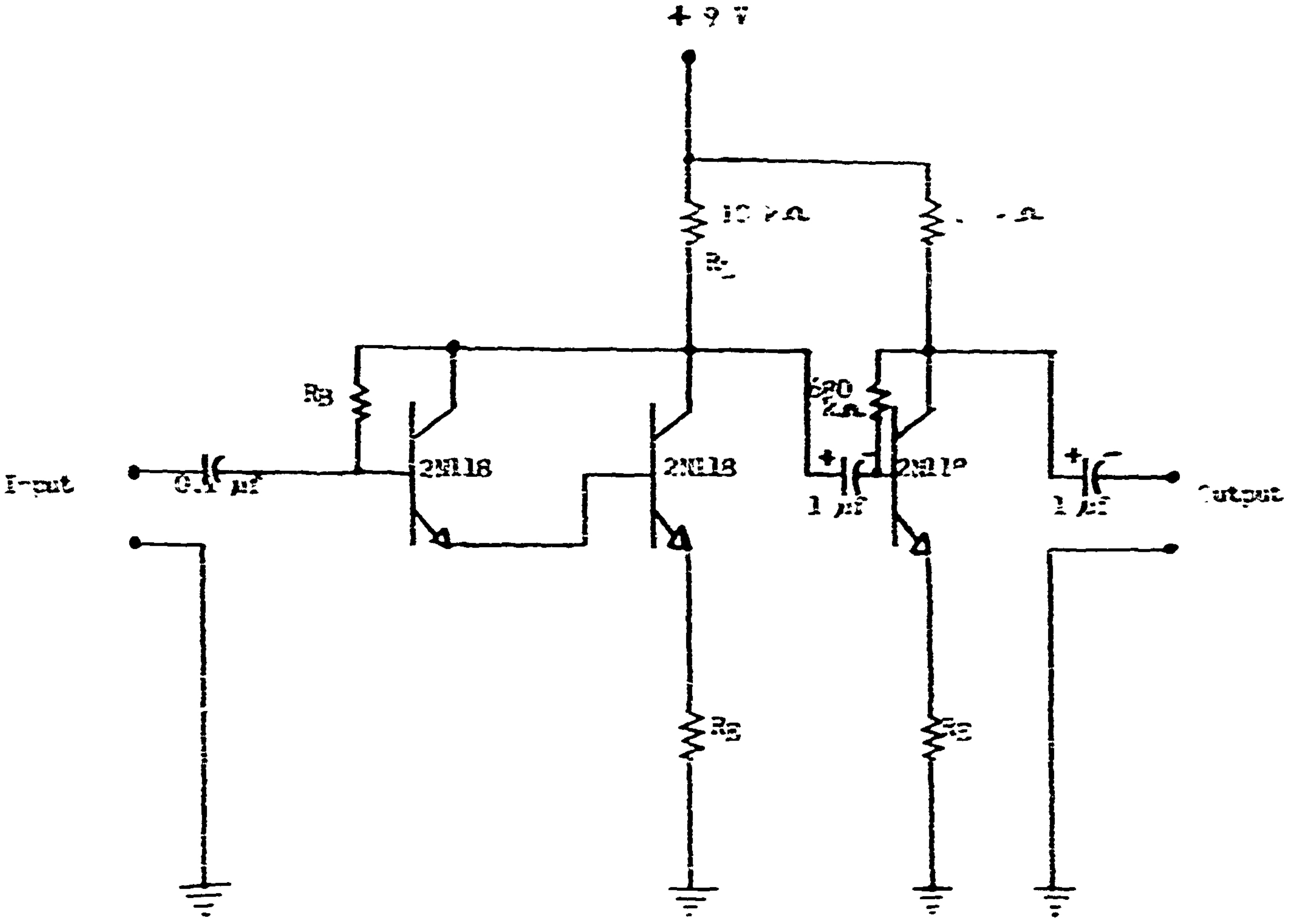
On the basis of preliminary listening comparisons of the speech spectrum from all locations on the head and neck area, six anatomical locations were chosen for more extensive investigation. The six locations were (1) right and left side of neck on plane with larynx, (2) one inch above nasalis, (3) across coronal suture on top and along midline of skull, (4) one inch below occiptial protuberance, (5) great wing of sphenoid and (6) one inch back and below mental protuberance of mandible. Figure 7 shows the 6 locations used in the investigation.

The contact microphone was attached to the anatomical location under investigation by means of an adjustable strap.

The subject's head was positioned in front of the voice absorber so that a good seal around the chin, cheeks and nose was obtained.

[illegible]

Circuit Diagram of Low Noise Transistor Amplifier



(1) RB is approximately 560 k and is selected to produce 4.5 volts drop across R_L
(2) R_E is approximately 680 ohms and is selected to produce a voltage amplication of 10.0.
(3) 2N18 transistors selected.

(4) Overall gain 40 db.

(5) Note: see reference 3.

[illegible]

[illegible] Equipment

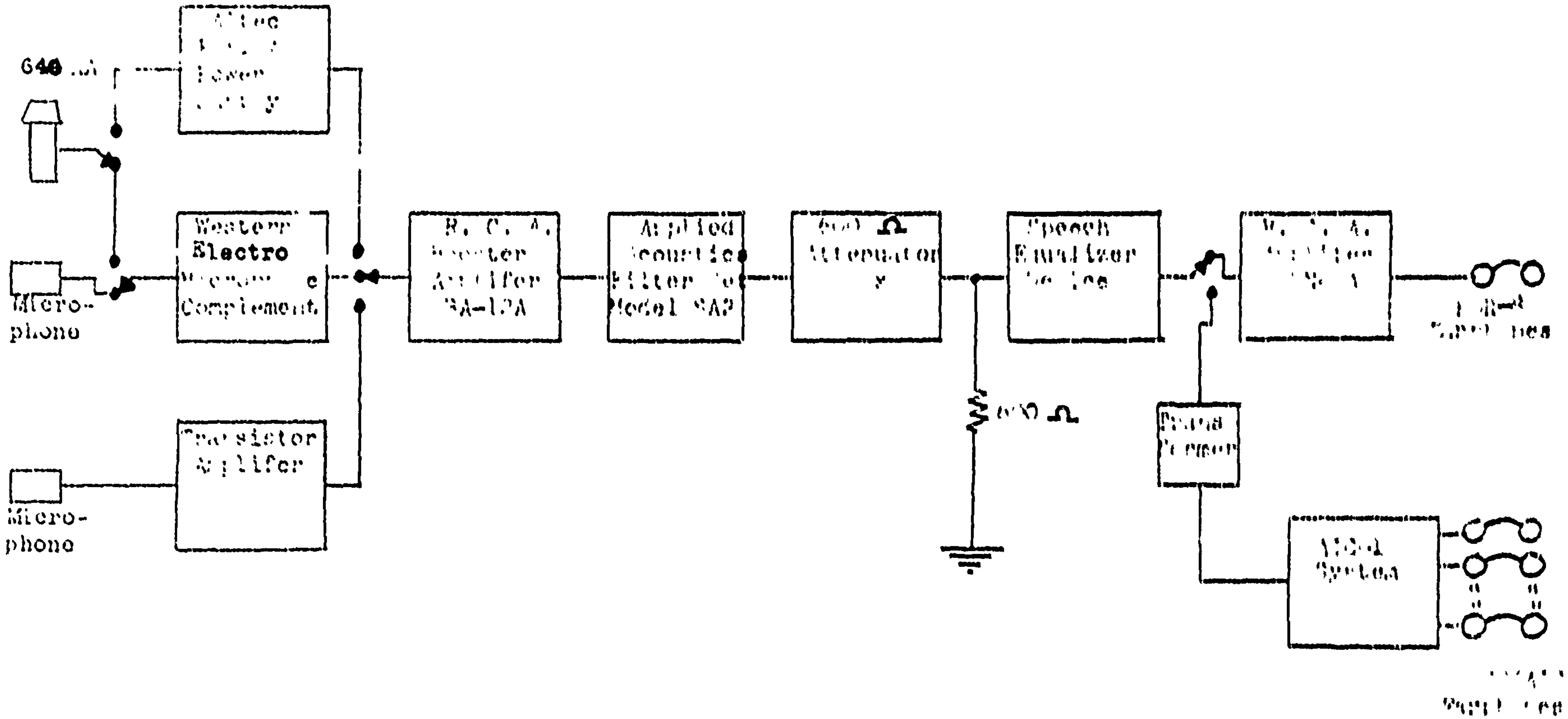
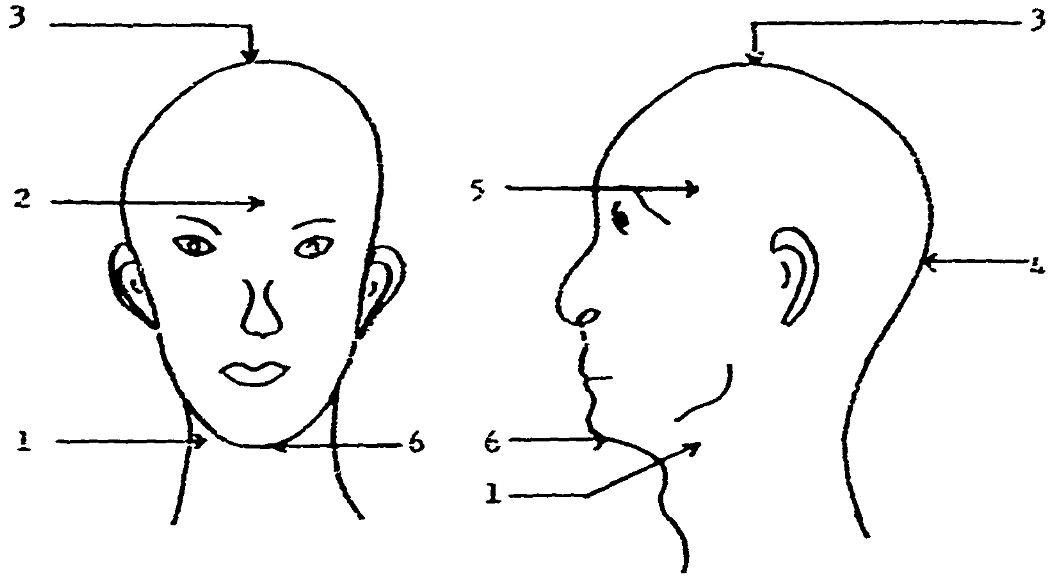

640
Western
Electro
Complement
Micro-
phone
Transistor
Amplifier
Micro-
phone
R. C. A.
Amplifier
BA-12A
Applied
Acoustic
Filter
Model SA
600 Ω
Attenuator
600 Ω
Speech
Equalizer
Trans
former
System

FIGURE 7

Anatomical Locations Used In Investigation



1 Right and left side of neck on plane with larynx

2 One inch above nasalis

3 Across coronal suture on top and along midline of skull

4 One inch below occiptial protuberance

5 Great wing of sphenoid

6 One inch back and below mental protuberance of mandible

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[illegible] Lawn" test [illegible] test [illegible] speech level [illegible] level [illegible] of the voice observer. [illegible] each [illegible] locations was recorded on [illegible] recorder for subsequent spectrum analysis.

[illegible] experiment [illegible] college [illegible] articulation test [illegible] determined by [illegible].

Part III

[illegible] Locations

[illegible] output spectra [illegible] anatomical locations was determined [illegible] the procedures and equipment described earlier. The results of the spectral measurements are shown in Figures 8 [illegible] 9. Of [illegible] interest in Figures 8 and 9 is the in- [illegible] 100 [illegible] each

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FIGURE 8
Output Spectrum At Three
Anatomical Locations

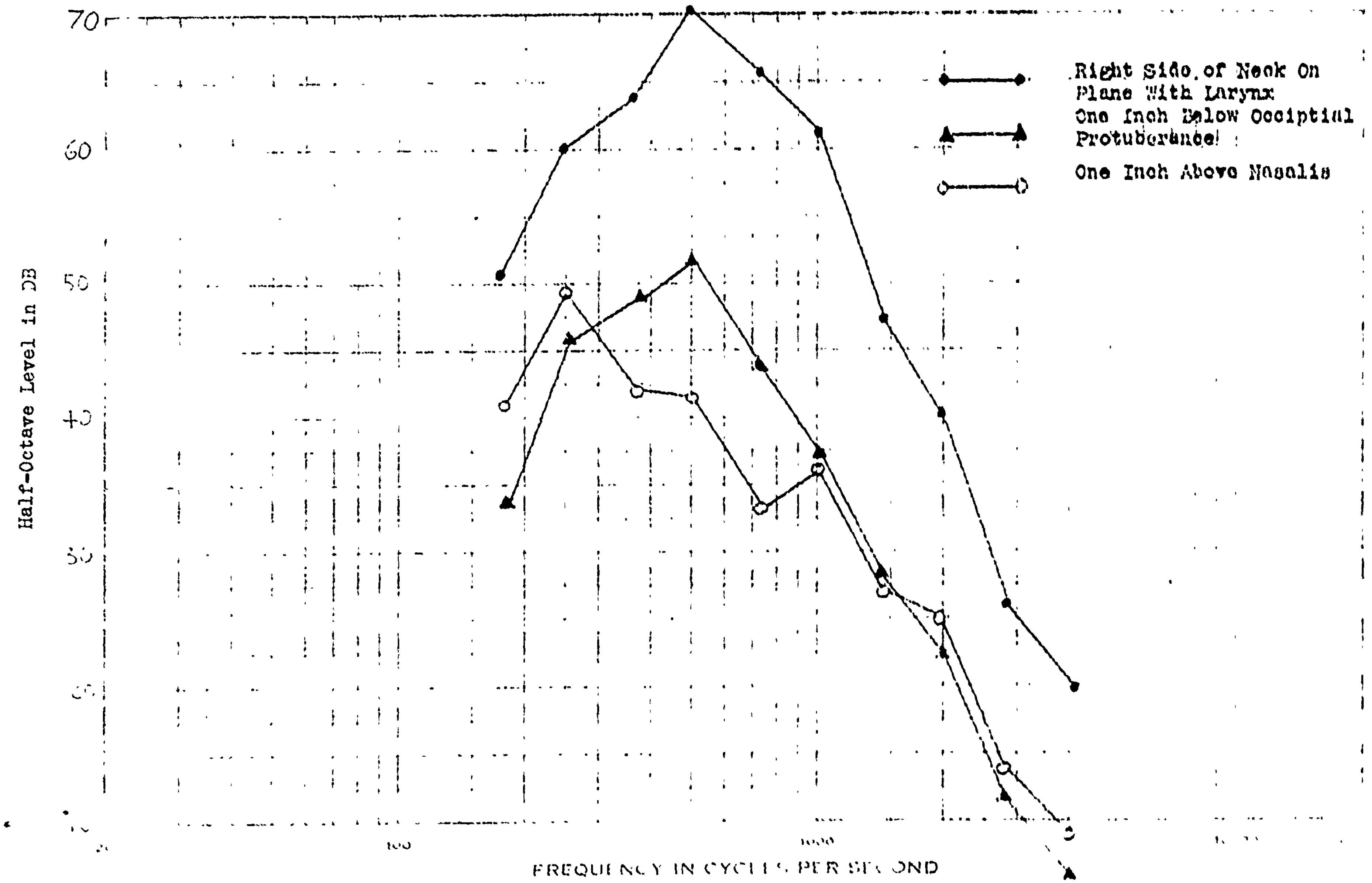

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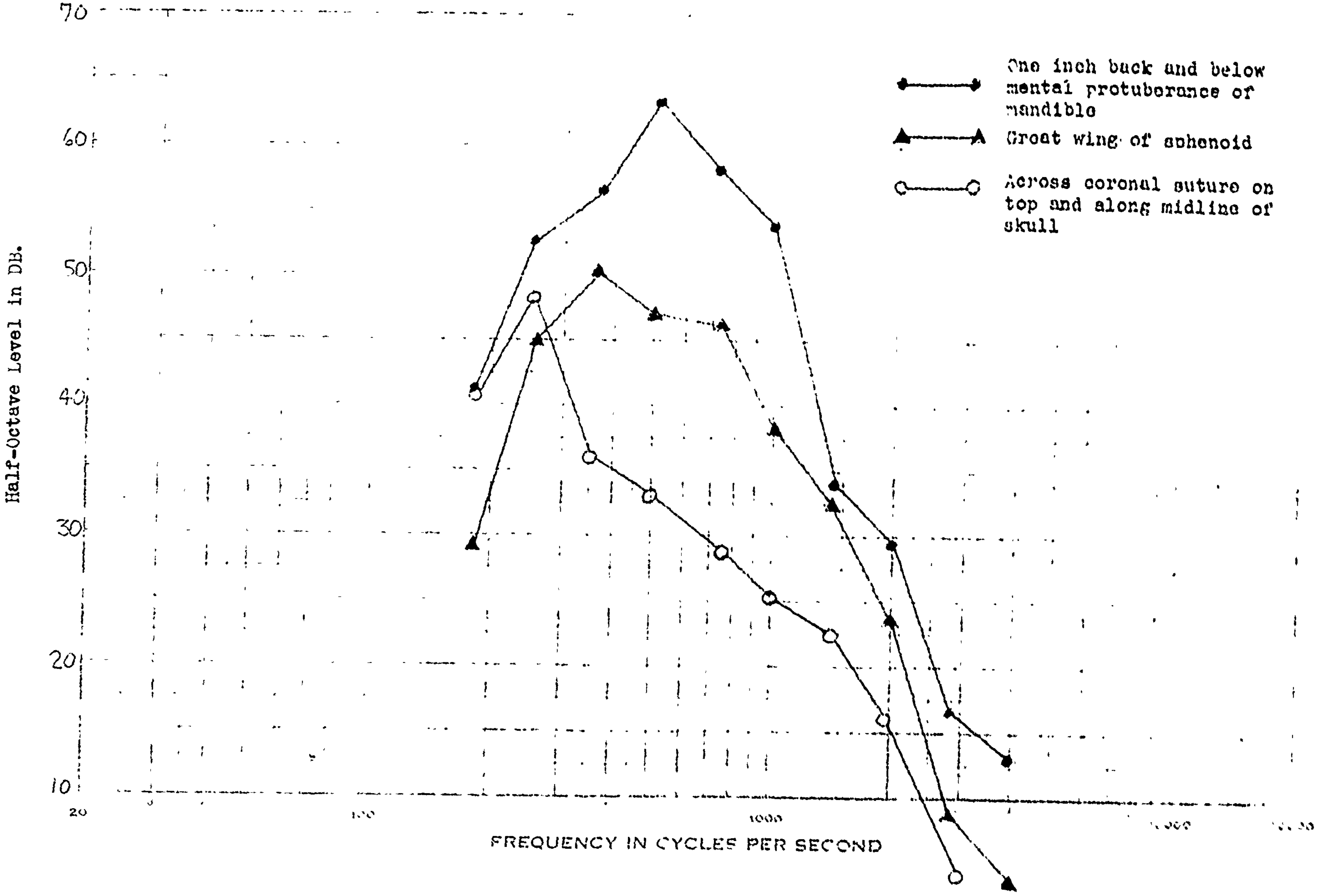
FIGURE 9
Output Spectrum at Three
Anatomical Locations



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energy below 1000 cps. This is of interest since frequencies above 1000 cps contribute disproportionately to speech intelligibility. It should be noted that the data was obtained for one subject only.

The Amperite Kontak Microphone was used to pick up the body conducted speech vibrations. The frequency response of this microphone has not been determined due to termination of the contract and therefore only relative comparisons among the curves can be made. On the basis of listening comparisons of speech from the six anatomical locations, it appeared that best intelligibility could be achieved from the forehead region.

2. Speech Level At Four Anatomical Locations

It is evident from Figures 8 and 9 that there is a considerable difference in speech level at different anatomical locations. In order to make a valid comparison of speech intelligibility among the locations it is necessary to equate the speech levels so that they sound equally loud. This was accomplished by having the subjects monitor their speech on the sound level meter while talking into the voice absorber. In this way the subjects could maintain a constant vocal effort. Loudness balance comparisons were made while the contact microphone was switched to each of the anatomical locations under investigation. The amount of speech signal attenuation necessary for equal loudness was determined while the subjects repeated the "Joe . . . . Lawn" test sentence. The results of the loudness balance tests are shown in Table I. Two sets of loudness balance tests were made for each subject. In this way the variability attributable to factors such as placement of the microphone and errors in loudness balancing the signals could be determined. The average difference between the first and second trials was 1.9 db. This indicates that the reliability of the experimental procedure is satisfactory.

TABLE I

Attenuation Applied To Speech Signals For Equal Loudness

Subject	Right Side of Neck On Plane With Larynx	One Inch Below Occiptial Protuberance	One Inch Above Nasalis	Great Wing Of Sphenoid
WE 1	-21	-7	-1	-2
2	-24	-9	-2	-3
WH 1	-30	-7	-3	-2
2	-27	-10	-5	-6
SI 1	-27	-9	-2	-3
2	-28	-13	-5	-4
JL 1	-27	-8	-3	-3
2	-30	-6	-3	-2
RL 1	-25	-8	-3	-2
2	-25	-6	-1	0
HM 1	-23	-7	-3	-3
2	-26	-7	-3	-2
JS 1	-27	-9	-4	-5
2	-29	-11	-8	-5
M 1	-26.1	-7.9	-2.7	-2.9
M 2	-26.7	-8.9	-3.8	-3.1
σ 1	2.53	.83	.88	.99
σ 2	2.37	2.47	2.17	1.88

It is evident from Table I that speech signals from the throat area required the most attenuation for equal loudness followed by the occiptial protuberance, nasalis and great wing of sphenoid in that order. The results of these loudness balance tests are in agreement with the findings of previous investigators (2, 4, 9 & 10) to the effect that the highest level speech sounds are those in the region of the larynx. In all of the articulation tests reported in the results section, the speech signals were adjusted for equal loudness.

When electrical equalization was applied to the speech signals to render them more intelligible, it was necessary to change the system gain in order to achieve equal speech loudness. The amount of attenuation used with the four speech equalization slopes is shown in Table II. The amount of attenuation applied to each slope for equal loudness was determined by the loudness balance procedure described above.

TABLE II

Attenuation Applied To Four Speech Equalization Slopes for Equal Loudness

Microphone	Slope *			
	0	6 db	6-12 db	12 db
Electro Voice	29	12	3	0
Amperite Kontack	30	14	2	0

* For a description of the different slopes see Part II Section A le

3. Articulation Tests At Three Anatomical Locations

Articulation tests were conducted to determine which anatomical locations provided the best speech intelligibility. Three anatomical locations were used; one inch above the nasalis, one inch below the occiptial protuberance and the right side of the neck on plane with the larynx. An Amperite Kontack microphone and an Electro-Voice microphone were used to pick up the speech vibrations. The listeners and talker were located in quiet. The contact microphones were connected to the AIC-10 Intercommunication System by means of a 600Ω to 5Ω matching transformer at the output of the speech equalizer device as shown in Figure 6. The microphone input to the AIC-10 System was used so that this part of the system could remain constant regardless of the type of microphone used. The subjects listened to PB word lists over H79/AIC earphones. The results of these articulation tests are shown in Table III.

It is evident from Table III that the best speech intelligibility is obtained from the forehead area. It is interesting to note the equalization slopes which provided the best intelligibility at the three anatomical locations. This is an indirect indication of the relative distribution of speech energy along the frequency continuum. We would expect the throat area to require the most equalization since as shown in Figures 8 and 9, it had less high frequency energy relative to low frequency energy than either the back of the head or the forehead. This expectation is confirmed by the data in Table III.

TABLE III

Results of Articulation Tests At Three Anatomical Locations.

Three Equalization Slopes Applied To Speech Spectrum*

Listeners & Talker In Quiet

Talker	Microphone	Right Side Of Neck On Plane With Larynx				One Inch Below Occiptial Protuberance				One Inch Above Nasalis			
		0	6	6-12	12*	0	6	6-12	12	0	6	6-12	12
J.S.	Amperite	88	90	91	84	90	94	96	94	97	96	97	93
J.S.	Amperite	84	91	91	96	92	97	97	91	97	96	93	97
J.S.	Electro-Voice	82	84	78	90	88	91	96	86	93	91	96	94
J.S.	Electro-Voice	81	83	84	87	91	92	96	87	97	98	97	94
J.S.	Electro-Voice	81	84	85	85	87	95	95	89	97	93	93	91
AVE. =		83	86	86	88	90	94	96	89	96	95	95	92
W.E	Amperite	77	83	85	89	88	93	97	92	99	93	91	89
W.E.	Amperite	85	91	90	93	88	91	96	91	99	98	95	96
W.E.	Electro-Voice	84	92	88	80	90	87	87	85	97	92	92	81
W.E.	Electro-Voice	82	79	85	89	91	84	82	81	90	95	93	80
W.E.	Electro-Voice	80	93	79	89	79	85	90	90	95	95	87	80
AVE. =		82	88	85	88	72	88	90	88	96	95	92	85
AVE. (TWO = TALKERS)		83	87	86	88	81	91	93	89	96	95	94	88

* For description of equalization slopes see Section le titled Speech equalization device.

The differences shown in Table III between the equalization slopes are small. We would expect speech intelligibility differences among the slopes to be more evident under conditions of high ambient noise at the talker end of the system.

4. Articulation Tests In A 120 db Jet Noise

Articulation tests were conducted with the talker located in the contractor's noise room with a 120 db jet noise spectrum. Listeners were located in the control room in a relatively low ambient noise field (88 db re. 0.002 dyne/cm^2). Noise shields for use with the contact microphones were obtained by modifying existing ear-muffs. Two types of ear-muffs were used for this purpose; Straight Away Sound Protector AO 372-8 and Safe-T-Ear Muff No. 255. It was possible to achieve ambient noise attenuation of the order of 20 db by using these shielding devices around the microphones. The results of articulation tests conducted under the above conditions are shown in Table IV.

TABLE IV

Results Of Articulation Tests

Talker in 120 db Jet Noise

Listeners In Quiet*

Talker	Microphone	Right Side Of Neck On Plane With Larynx				One Inch Below Occipital Protuberance				One Inch Above Nasalis			
		0	6	6-12	12	0	6	6-12	12	0	6	6-12	12
W.E.	Amperite Kontak					15	19	12	8	21	14	8	6
W.E.	Amperite Kontak					20	18	14	6	22	22	11	8
J.S.	Amperite Kontak	11	20	14	29					43	32	30	28
J.S.	Amperite Kontak	11	19	17	22					30	35	22	20
J.S.	Amperite Kontak					30	33	37	28	39			
J.S.	Amperite Kontak					22	31	33	30	40			
W.E.	M-76 mike (moisture barrier pressed against skin)	12	21	19	28					22	22	18	17
W.E.	M-76 (moisture barrier pressed against skin)	14	16	21	20					25	39	25	22
J.S.	M-76 mike (moisture barrier pressed against skin)									24	35	37	23
J.S.	M-76 (moisture barrier pressed against skin)									14	39	40	25
J.S.	M-76 (moisture barrier removed, mike against skin)	22	25	19	31					29	41	31	22
J.S.	M-76 (moisture barrier removed, mike against skin)									29	40	39	23

* Data not complete due to termination of contract.

It is evident from the results shown in Table IV that speech intelligibility using a contact microphone in a 120 db jet noise was not satisfactory. As might be expected, the problem was poor S/N ratio. It will be recalled that articulation scores in quiet (Table III) were quite satisfactory. Attempts to achieve more than 2[illegible] db of ambient noise attenuation by improving the microphone noise shields were unsuccessful.

The microphone currently in use by mechanics while servicing jet aircraft in a 140 db of noise is the M-55 in a modified M-34 microphone noise shield. A microphone and noise shield typical of units currently in use was obtained and articulation tests conducted. The results of these tests are shown in Table V.

TABLE V

Results Of Articulation Tests With M-55 Microphone
In M-34 Microphone Noise Shield
Talker In 120 db Jet Noise
Listeners In Quiet

Talker	Articulation Score
J.S.	86
J.S.	86
J.S.	89
J.S.	81
J.S.	79
MEAN	84.2

When the results of articulation tests using a contact microphone and a M-55 microphone are compared it is evident that the performance of the contact microphone under optimum conditions (equalization, anatomical location, good seal around shield, etc.) is far inferior to the M-55. Since articulation test scores using a contact microphone in 120 db jet noise were not satisfactory, it was apparent that little chance for success could be expected in 140 db noise as outlined in the task assignment. In view of these findings, it was decided to try a different approach to the problem of picking up speech from the anatomy. These approaches as well as a qualitative evaluation of the two approaches which were reduced to practice are described in Part IV of this report.

PART IV

A. Alternative Methods For Picking Up Speech From The Anatomy

The results presented in Part III of this report indicate that the chief problem encountered with contact microphones in a 120 db jet noise is poor signal to noise ratio. Attempts to achieve greater than 20 db ambient noise attenuation by shielding means around the microphone were unsuccessful. Since adequate shielding around the microphones could not be obtained, the following five alternative approaches to improving S/N ratio were considered. Four of the approaches considered would involve some method of cancelling the noise which entered the system in addition to the use of shielding around the microphone.

1. System A

The first system is illustrated in Figure 10. This system consists of two contact microphones and noise shields located at adjacent places on the anatomy. This system requires that the microphones be located on areas which have the same noise level and spectrum at the surface of the skin but different speech levels. Two possible locations would be the forehead area and the cheek. The ambient noise levels would probably be very similar at both locations. In addition, the noise which is radiated from these areas is probably similar in spectrum. The signal outputs from the two microphones would be led to a mixing circuit. The output of the mixing circuit would be proportional to the difference in signal levels between the microphones. Although the noise levels at the microphones would be similar, the phases would be different at high frequencies, so that the noise signals would not be completely cancelled. This approach was neither reduced to practice nor considered promising.

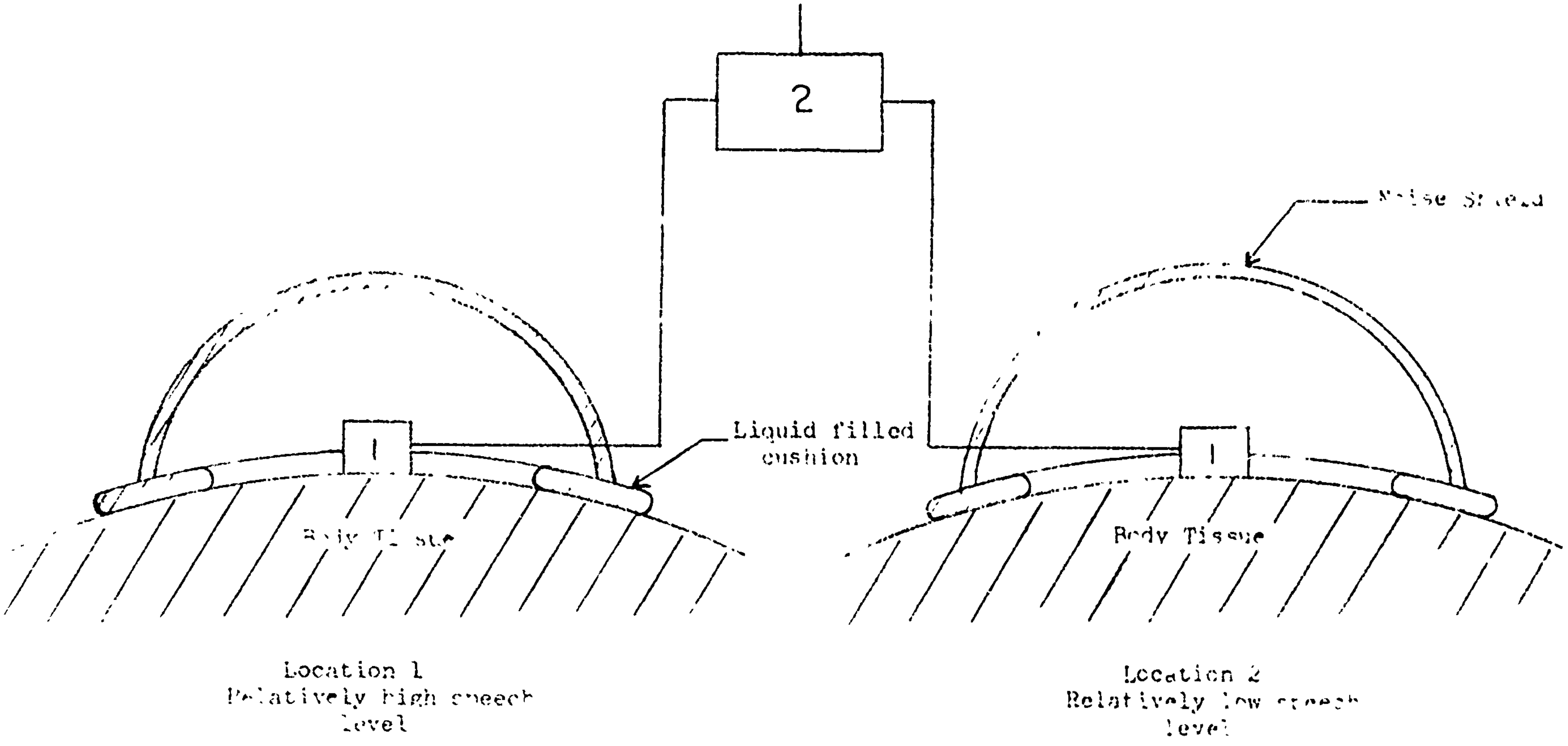
2. System B

The second system is shown in Figure 11. This system consists of a contact microphone located on the skin to pick up speech, and an acoustical microphone located in the same enclosure to pick up noise not attenuated by the noise shield. The acoustic microphone would feed the noise 180° out of phase to a small loudspeaker located in the enclosure. Such a system would effectively cancel noise in the enclosure around the contact microphone. The feasibility of cancelling noise in a small en-

FIGURE -

System [illegible]

Proposed Noise Canceling System



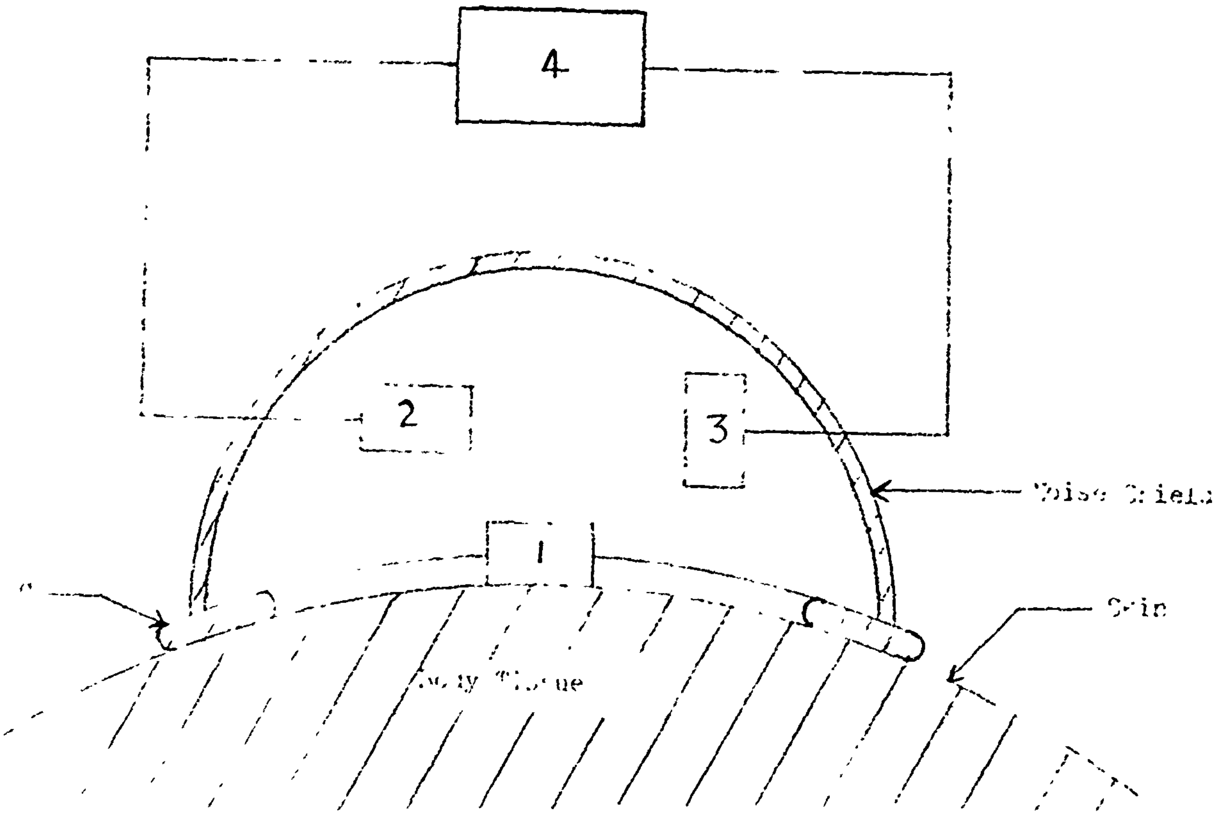
[illegible]

Mixing circuit

FIGURE 11

System 4

[illegible] Noise Cancelling
System



1 Contact Microphone

2 Acoustic Microphone

3 Loudspeaker

4 180 Degree Phase Shifter

closure has been previously demonstrated by Olson (12). Preliminary work on this system was begun but not completed prior to termination of the contract.

A modification of this approach would involve a bridge in the electronic circuit so that the acoustic microphone (2) was always driven in the null direction. This approach was not tried due to termination of the contract.

3. System C

The third system is shown in Figure 12. This system uses a contact microphone located on the skin. This microphone is activated by speech signals as well as noise in the enclosure. The output of the microphone is fed 180° out of phase to a loudspeaker in the enclosure which cancels the noise. The system was not reduced to practice.

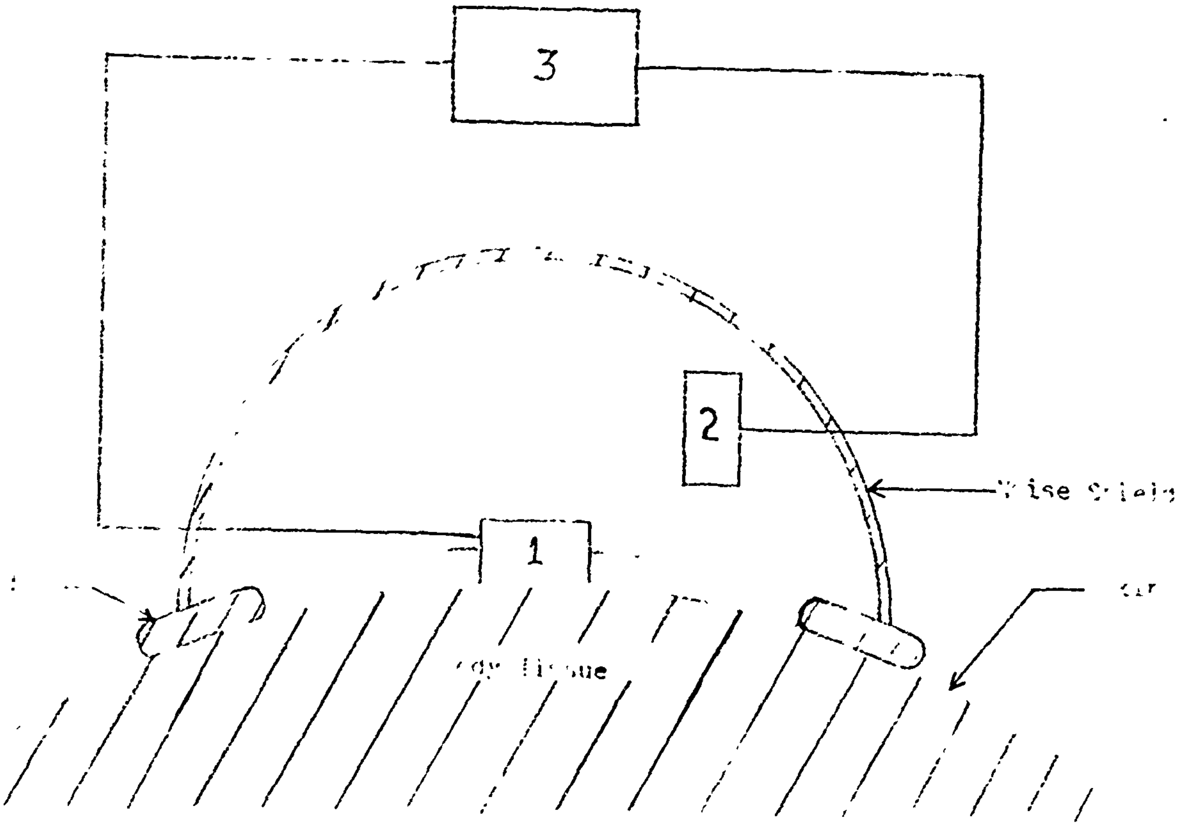
4. System D

The fourth system is shown in Figure 13. This system consists of an acoustic microphone in close proximity to the skin. The microphone would be located so as to achieve a good seal with the skin. An experimental model of this system was constructed. Preliminary tests with this system have shown promise of providing good speech intelligibility in a noise level of 120 db. It is believed that this system would not be satisfactory in a noise level of 140 db.

[illegible]

[illegible]

[illegible] Noise C[illegible] System



1 Contact Microphone

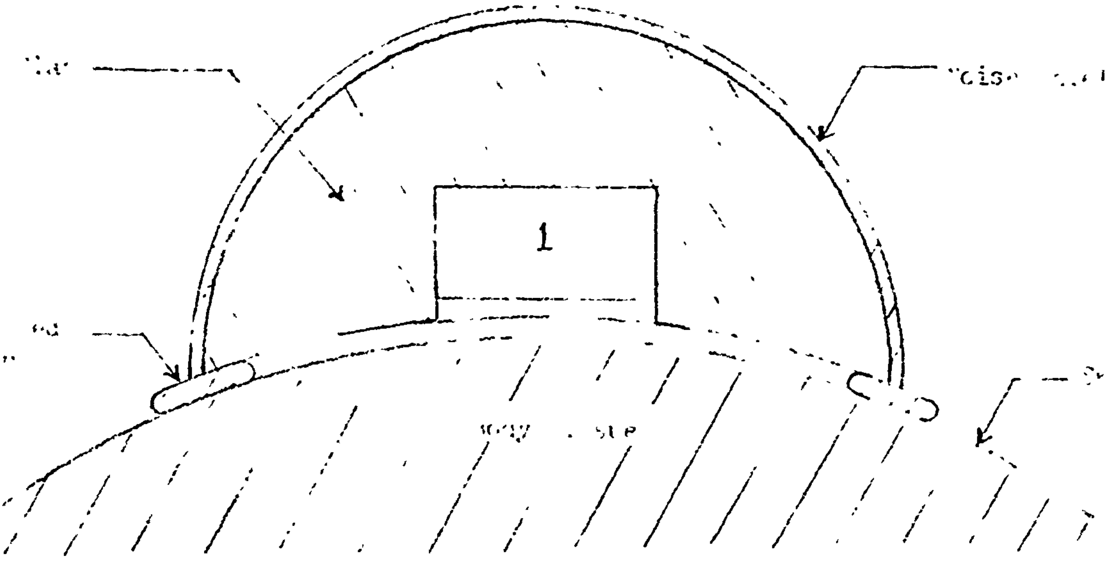
2 Loudspeaker

3 180 Degree Phase Shifter

[illegible]

System

[illegible]



1 - Acoustic Microphone
Microphone diaphragm in
close proximity to skin

5. System E

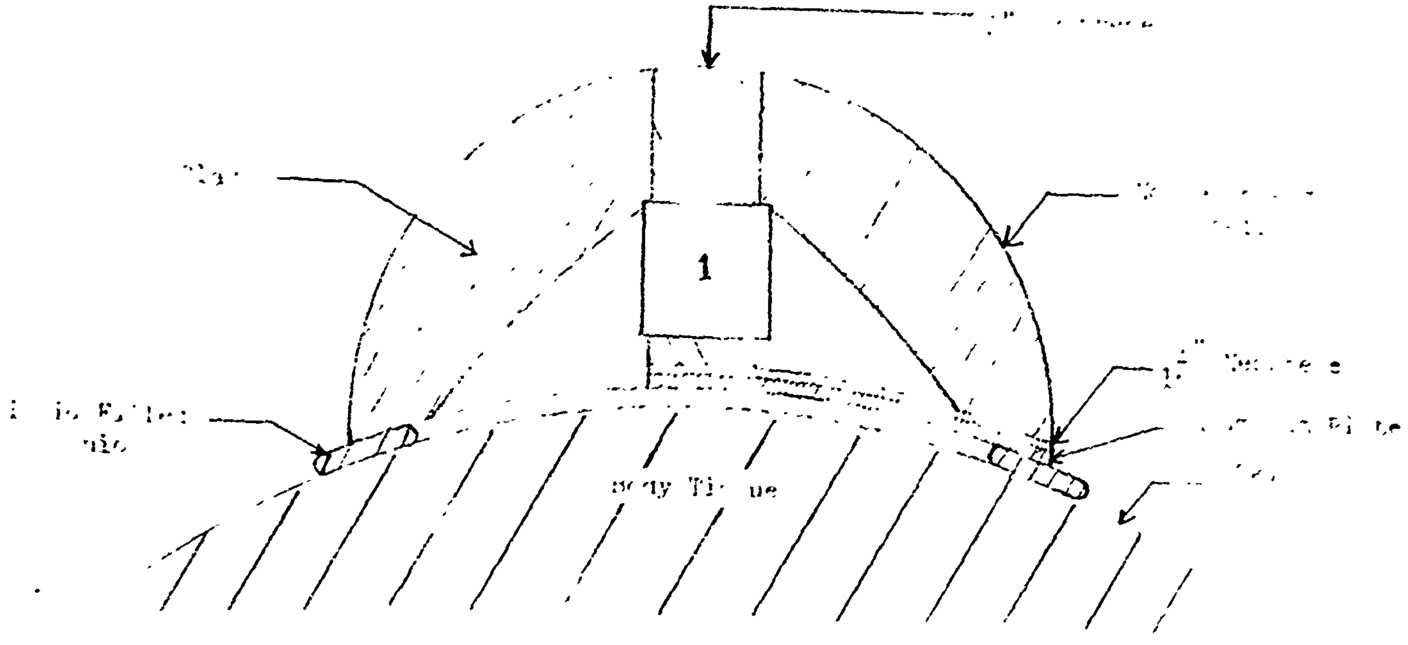
The fifth system is shown in Figure 14. This system consists of an M-76 pressure gradient microphone in a noise shield. One side of the noise cancelling microphone was sealed off from the other side as shown in Figure 14. The diaphragms of the noise cancelling microphone were oriented at right angles to the skin. Speech was permitted to enter one side of the enclosure but was prevented from entering the other side by a rigid metal plate. Thus the speech signals activated only one diaphragm of the pressure gradient microphone. Noise on the other hand could activate both diaphragms of the microphone. The effect of this arrangement was to cancel the noise entering the enclosure while transmitting the speech signal. This system was reduced to practice using an early model of the M-76 microphone in a Safe-T-Muff ear defender. The enclosure was separated into two sections by a half inch sheet of neoprene rubber. The inside of the enclosure was shaped with clay to reduce the internal volume and to produce a horn effect from the skin to the microphone diaphragm. The inside surface of the metal plate,which prevented the speech signal from entering one side of the enclosure,was covered with 1/16 inch neoprene to simulate skin.

On the basis of listening comparisons of this system with the M-55 in a M-34 shield, it is believed that intelligible communication in a 140 db jet noise could be obtained. At the time the experimental model of this system was completed, the contractor's articulation test crew was on vacation. It was planned

[illegible]

[illegible]

Noise Canceling System Using
Pressure Gradient Microphone



1 Pressure Gradient
Microphone

to conduct articulation tests on this noise cancelling microphone system when the articulation test crew returned, but the contract was terminated before this could be accomplished.

The signal to noise ratio of the microphone system was + 18 db in a 120 db jet noise. This figure was obtained with the microphone system located on the side of the throat. This is not the optimum location for the system but was dictated by the shape of the shield enclosure. The speech quality of the system was judged good even in this throat position.

On the basis of the data available it appears that this microphone system would meet the requirements set forth in the task assignment. Specifically these requirements were to: (1) provide intelligible communication in a 140 db jet noise and (2) provide a minimum of restriction of head and body movements of the wearer.

PART V

A. Conclusions

The following conclusions have been drawn from the data presented in this report.

1. The highest intensity level speech sounds are those radiated from the larynx area.
2. Speech intelligibility is best at anatomical locations on the forehead (1 inch above nasalis) and temple area (great wing of sphenoid).
3. There appears to be an inverse relationship for areas on the head between speech intelligibility and speech intensity level.

4. A microphone located on the throat requires more electrical equalization of the speech spectrum than the same microphone located on the forehead or back of the head (one inch below the occiptial protuberance) to achieve maximum intelligibility.
5. The maximum overall noise attenuation which can be achieved by shielding means around a microphone located on the skin is of the order of 20 db.
6. Conventional contact microphones under optimum conditions of shielding, anatomical location, seal between shield and skin and electrical equalization will not provide satisfactory articulation scores in a 140 db jet noise field.
7. Poor signal-to-noise ratio is the chief factor responsible for unsatisfactory performance of contact microphones in a 120 db jet noise system.
8. A noise cancelling system consisting of a pressure gradient microphone (M-76) located in close proximity to the skin in a special shielding device can provide satisfactory speech intelligibility in a 120 db jet noise. It is believed on the basis of S/N measurement in a 120 db noise field that this type of system could provide satisfactory intelligibility in a 140 db jet noise.
9. Some system of noise cancelling is necessary, either by the microphone or in the cavity enclosing the microphone if satisfactory speech communication is to be carried on in jet noise fields of 140 db.

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