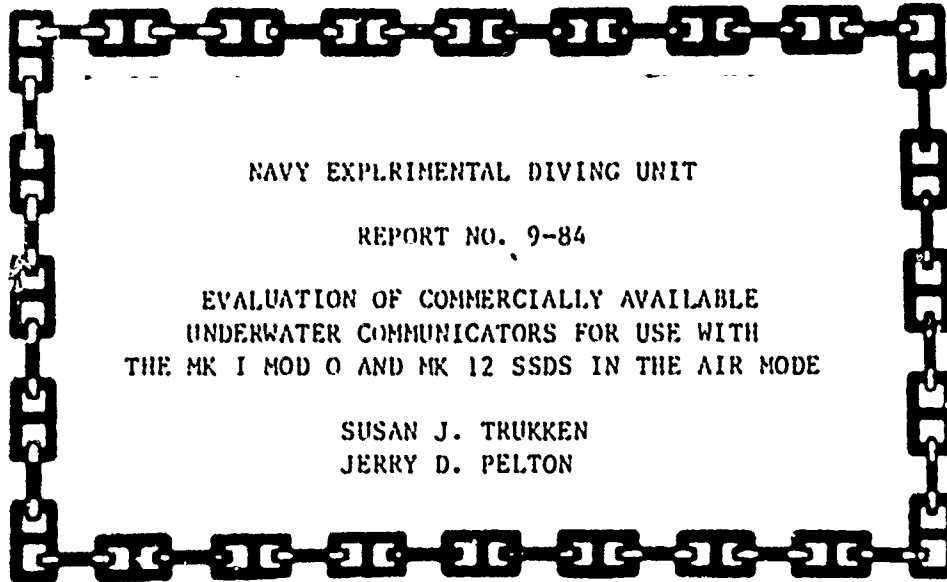




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NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 9-84

EVALUATION OF COMMERCIALY AVAILABLE
UNDERWATER COMMUNICATORS FOR USE WITH
THE MK I MOD 0 AND MK 12 SSDS IN THE AIR MODE

SUSAN J. TRUKKEN
JERRY D. PELTON

NAVY EXPERIMENTAL DIVING UNIT



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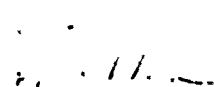
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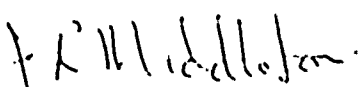
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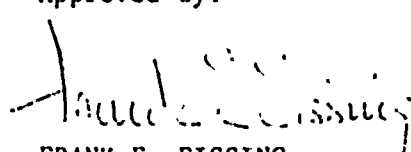
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BLOCK NO. 20 CONTINUED

- a. EFCOM HSU-1500
- b. HELLE Model 3315
- c. HYDROCOM UDC-225
- d. AMCOM III Model 2830H

Only the HYDROCOM, manufactured by Hydro Products, satisfied required communication intelligibility using the Modified Rhyme Test (MRT) as the evaluation criteria during shallow manned in-water testing. Human engineering aspects were satisfactory. The HYDROCOM unit suffered no material failures during testing.

The Hydro-Products, HYDROCOM UDC 225 is considered to be a reliable and effective means of communication for surface supported diving operations.

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Glossary

AC	alternate current
AM	amplitude modulated
AMPS	amperes seawater
boom microphone	microphone on the end of a boom attached to a headset
CB	circuit breaker
cm	centimeters
db	decibel(s)
°F	degrees Fahrenheit
FSW	feet of seawater
ft.	foot
GFI	ground fault indicator
HSU	helium speech unscrambler
in.	inch(es)
INAC	inhalation noise attenuation circuitry
Kg	kilogram
KHz	kilohertz
MIC	microphone
MILSPEC	military specification
MILSTD	military standard
MRT	modified rhyme test
NCSC	Naval Coastal Systems Center
NDSTC	Naval Diving and Salvage Training Center
NEDU	Navy Experimental Diving Unit
PA	public address
PCB	printed circuit board
PE	polyester

Glossary (cont'd)

%	percent
preamp	pre-amplifier
PV	pressure vessel
lbs	pound(s)
RMS	root mean square
round-robin	intercommunications between all parties on the system
SD	standard deviation
SSB	single side band
SSDS	surface supplied diving system
V	volt(s)
VDC	volts direct current
VOX	voice actuated microphone
W	watts

Abstract

✓ In March and April 1984, the Navy Experimental Diving Unit tested four, three diver, four wire, helium speech unscrambler (HSU) capable commercial underwater communicators. The goal was to recommend one or more of the following commercial communicators for Navy approval for use in the the air mode only:

- a) EFCOM HSU-1500;
- b) HELLE Model 3315;
- c) HYDROCOM UDC-225;
- d) AMCOM III Model 2830H.

Only the HYDROCOM, manufactured by Hydro Products, satisfied required communication intelligibility using the Modified Rhyme Test (MRT) as the evaluation criteria during shallow manned in-water testing. Human engineering aspects were satisfactory. The HYDROCOM unit suffered no material failures during testing.

The Hydro-Products, HYDROCOM UDC 225 is considered to be a reliable and effective means of communication for surface supported diving operations.

KEY WORDS: Hardwire Communicators,
MK 12 Communications,
MK I Communications.

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I. INTRODUCTION

In March and April 1984, NEDU conducted a manned in-water evaluation of four, three diver, four wire, HSU capable commercial communication units. Testing was conducted in accordance with NAVSEA Task No. 83-13 and NEDU Test Plan No. 83-56 to determine their suitability for communications in surface supplied diving systems. This report addresses use of these communicators in the air mode only. Follow-on testing will be conducted at a future date in the HSU mode.

An announcement published in "Commerce Business Daily" on 30 December 1983 resulted in the following four companies contacting NEDU for test and evaluation of their unit:

<u>Company</u>	<u>Unit</u>
AMRON International Diving Supply Company 751 West Fourth Avenue Escondido, CA USA 92025 (619) 746-3834	AMCOM III Model 2830 H
EFCOM Communication Systems 1540 So. Lyon Street Santa Ana, CA 92705 (714) 543-0677	EFCOM Model HSU 1500
Helle Engineering, Inc. 7198 Convoy Court San Diego, CA 92111 (619) 278-3521	Helle Model 3315
Hydro Products P.O. Box 2528 San Diego, CA 92112 (714) 453-2345	HYDROCOM Model UDC-225

All four units were evaluated for intelligibility, reliability, maintainability and human engineering.

II. EQUIPMENT DESCRIPTION

A. AMRON International, AMCOM III Model 2830H

1. The AMCOM III (APPENDIX A, Figures A1 through A3) provides round-robin underwater communication between a surface tender and one, two or three divers. The system has a separate HSU that is mounted in the unit's lid and plugs into the front panel. The air or helium selector switch is mounted on the front panel.

2. The unit is powered by internal rechargeable batteries, 115 VAC 50/60 Hz power supply or an external 12 VDC power source. Separate volume controls adjust the audio level of the tender and divers.

3. The AMCOM III can be used in the two wire and/or four wire (SIMULCOM) mode. The AMCOM III has independent voice controls, push to talk to all divers and separated isolated inputs for each diver. This unit can also be used with a remote "walk and talk" module, consisting of a headset on a 25 ft. extension cable and with a boom microphone.

4. Connecting the AMCOM III in the four wire configuration is described in APPENDIX A (Figure A4). Two steps per diver is required.

5. A complete set of manufacturer specifications on the AMCOM III is provided in Table 1.

B. EFCOM Communication Systems, EFCOM Model HSU-1500

1. The EFCOM HSU-1500 (APPENDIX B, Figures B1 through B3) provides round-robin underwater continuous open line communications between up to five divers and a surface tender in a four wire mode. The unit receives to depths of approximately 1000 FSW when used with a high quality noise cancelling microphone. The EFCOM HSU-1500 works with a headphone with a boom microphone, or the front speaker can act as a transmitter and receiver.

2. The HSU-1500 can be operated from the internal rechargeable 12 VDC battery, an external 12 VDC supply or from 110/220 VAC power.

3. The HSU-1500 can be used in the two wire and/or four wire mode. All earphones are connected in parallel so the diver volume control sets the volume level for all earphones.

4. To use the EFCOM HSU 1500 in a four wire configuration, connect the earphones and microphones as described in APPENDIX B (Figure B4).

5. A complete set of manufacturer specifications for the EFCOM HSU-1500 is provided in Table 1.

C. Helle Engineering, Helle Model 3315

1. The Helle Model 3315 (APPENDIX C, Figures C1 through C3) provides underwater communications between a surface tender and one, two or three divers. The system has, as an integral part, a helium speech unscrambler (HSU). Use of the HSU is controlled by an in-out switch. The variable depth voice compensation switch is also an integral part of the circuitry.

2. The unit is powered by using either the 115 VAC power cord or the internal rechargeable battery pack.

3. The unit is equipped with a speaker which functions as a two way communicator in the two wire mode. In the four wire mode the tender must wear a headset to communicate with the divers. A switch on the front panel turns off the speaker when the headset is used. The tender volume control is the only adjustment for the audio level of the tender and divers. The surface tender must actuate the tenders volume control on the front panel for surface to diver communications.

TABLE 1

	ANCOM III MODEL 2830H	EFCON MODEL HSU 1500	HELJE MODEL 3315	HYDRO COM UDC 225
Size	9" wide, 14.5" long, 10" high	10" wide, 16" long, 7.5" high	9.5" wide, 17" long, 9.25" high	12" wide, 16" long, 11" high
Weight	20.5 lbs.	21.5 lbs.	24 lbs.	25 lbs.
Power Supply	12 VDC internal re-chargeable batteries, external VDC source, 115 VAC 50/60 Hz	12 VDC internal re-chargeable battery, 110/220 VAC, 50/60 Hz external power	internal battery re-chargeable battery 115 VAC	internally sealed, re-chargeable battery pack, 115 VAC, 50/60 Hz, external 12 VDC
Power Output	12 watts total	16 watts total	2 watts total	10 watts total
Battery Life	15 hours	15 hours	8 hours	12 hours
Battery Condition Indicator	light/steady=OK, blink=low level (3 hr) 0 light=out	LED	light illuminates when battery voltage drops below 11 VDC	Meter
Battery Charge Indicator	NONE	LED	NONE	LED
Frequency Response	300-12000 Hz	300-15000 Hz	300-1200 Hz	300-17000 Hz

TABLE 1 (continued)

	AMCON III MODEL 2830H	EFCON MODEL HSU 1500	HELLE MODEL 3315	HYDRO CON UDC 225
Input Imped.	100 ohms per unit (mic. inputs of 1-600 ohms)	2-600 ohms	3-16 ohms	2-600 ohms
Output Imped.	< 1 ohm	4-16 ohms	3-16 ohms	4-16 ohms, 8 ohms best
Depth Rating	> 1200 FSW (HSU)	1000 FSW	0-2000 FSW (HSU)	0-2000 FSW
Additional Features	individual input and output controls for each diver	isolation transformer coupling divers to the system	isolation coupling divers to the system, insulation over connectors in area of AC power/battery terminals	ground fault indicator, isolation power transformer, input and output audio, transformers to isolate the divers cable from power equipment, phone jacks for ext. speaker, auxiliary mic. input
Additional Requirements		4-wire = 2-8 gauge twisted pairs, unconnected shields	4-wire mode = 2 twisted shielded pairs per diver	

4. Helle recommends the hookup for four wire round-robin communications described in APPENDIX C (Figure C4). Unlike the other communicators tested, all divers' and tenders earphones are also "ganged" to the EXT SPKR banana jack on the front panel. All divers' and tenders microphones are "ganged" to the Diver 1 banana jack on the front panel. The only volume control is the TENDER VOL control, and only 2 watts of power are available for this collective hookup. Helle does not recommend this type of hookup with cable lengths greater than 300 feet.

5. A complete set of manufacturer specifications for the Helle 3315 is provided in Table 1.

D. Hydro Products, HYDROCOM UDC-225

1. The HYDROCOM UDC-225 (APPENDIX D, Figures D1 and D2) provides round-robin communication between three divers and a surface tender. The UDC-225 is designed to operate in a helium environment with the addition of the optional HSU printed circuit board (PCB). The board can be bypassed or removed for air operation.

2. The unit is powered by internal rechargeable batteries, 115 VAC 50/60 Hz power supply or an external 12 VDC power source. The battery charger will charge when the unit is used in the 115 VAC mode.

3. The HYDROCOM unit is used in the 4-wire mode. It has independent diver voice controls, headphone communications to all divers and separated isolated inputs for each diver. It also has a connection for an auxiliary speaker.

4. To use the HYDROCOM unit, three front panel connectors must be constructed to connect the divers umbilical to the front panel (APPENDIX D, Figure D3).

5. A complete set of manufacturer specifications for the HYDROCOM UDC-225 is provided in Table 1.

6. All of the electronics for the UDC-225 are contained on two printed circuit cards, an audio card and an optional helium speech unscrambler card. The audio card is designed with a differential input stage for each diver to eliminate noise and crosstalk picked up in the umbilical cable. The card uses low noise operational amplifiers to amplify the divers voices and incorporates a ground plane to minimize noise. The HSU uses analog and digital techniques to convert unintelligible helium transmissions into recognizable audio. The UDC-225 also has an inhalation noise attenuation circuitry (INAC).

7. HYDROCOM is designed to interface with both powered and non-powered divers microphones. Each diver has a microphone (MIC) switch so that powered and non-powered microphones can be used on the same dive. When in the powered microphone configuration, DC power is multiplexed onto the divers microphone lines to power the pre-amp in the powered microphone. When in the non-powered microphone configuration, DC power is removed from the

divers microphone lines. An extra stage of amplification is added to boost the signal of the non-powered microphone. The tender has the option of isolating each of the divers input or outputs in event of a cable failure.

III. TEST PROCEDURE

The evaluation of these units consisted of manned in water intelligibility testing, bench testing, human engineering and compatibility with existing equipment. A life cycle cost evaluation was not tested during this evaluation due to time restrictions.

A. Intelligibility Test

1. Intelligibility testing was conducted in two phases. Phase I consisted of dives in the NEDU test pool to 15 FSW. Two MK 12 air divers in the swimmer mode, one MK I MOD 0 air diver and a topside tender were connected to each communications unit. Surface communication checks were made with all three units prior to diving. One MK 12 diver and the MK I diver were put in the water and a modified rhyme test (MRT) was conducted. Each diver and topside tender read a standard NEDU MRT reading list while the other test subjects responded (two diver mode). Finally, both MK 12 divers and the MK I diver were put in the water (three diver mode). Each participant (topside tender and all three divers) read a MRT list and responded to three lists. APPENDIX E provides an example of the standard NEDU MRT list.

2. Phase II consisted of deep air verification dives at the Naval Diving and Salvage Training Center. The purpose of these verification dives was to obtain increased qualitative data since the results of the MRT were expected to be heavily influenced by nitrogen narcosis. These verification dives were conducted with a topside operator and two MK 12 air divers at 200 or 285 FSW and two MK I MOD 0 divers at 130 FSW in NDSTC's hyperbaric wet pot.

3. MRT Scoring Procedure. To determine the percent correct for the NEDU MRT tests, the following formula was utilized (Van Cott and Kinkade, 1972).

$$\% \text{ correct} = 2 \times (\text{number right} - \frac{\text{number wrong}}{4})$$

At NDSTC, a full reading list was not always completed due to the limited bottom time available at the deep depths. To allow for this difference, a correction factor was applied to the above formula so that:

$$\% \text{ correct} = \frac{100}{\text{total number of words completed}} \times (\text{number right} - \frac{\text{number wrong}}{4})$$

B. Bench Test

1. The following bench tests were conducted (the failure criteria for these tests are specified in MILSTD-810C Environmental Test Method):

a. Physical test. Size, weight and volume of each system were tested.

b. Battery current drain measurement:

(1) An operational test was conducted by running the unit for one day of diving on battery power only. The unit was on 100% of the time, and was being keyed approximately twenty minutes per hour.

(2) The batteries were also tested with the transmitter in standby, while transmitting a 1 KHz tone at 30% of maximum output.

(3) A low temperature test was conducted to determine the effects of low temperature on equipment in storage without protective packaging. The system was refrigerated at 32°F for 12 hours. Then the unit was plugged in and operated for an additional two hours in the refrigerated environment.

c. Splash, rain and salt spray test. A splash test was conducted to simulate a wave engulfing the communication unit. This was done by pouring a bucket of salt then fresh water on the unit from a height of 4 feet. A rain and salt spray test was conducted by using a hose and spraying the unit with a fine spray of fresh and salt water for 15 minutes each.

d. Elevated temperature test. This test was conducted to determine the resistance of the equipment to elevated temperatures that may be encountered during service life in either storage or service conditions. The unit was baked at a temperature of 140°F for 24 hours. It was then operated for one hour in the 140°F environment.

e. Bench handling test. Each system was first checked for problem areas pertaining to maintenance, unique parts and inaccessibility to components due to internal arrangement. The units were also checked for their capacity to withstand shock encountered during servicing. Using each edge as a pivot, the unit was lifted until the chassis formed a 45° angle with the bench top and then dropped.

f. System check. The system check consisted of an inspection for possible shock hazards and ground resistance readings on all AC cables. An inspection of each system was also conducted to check components for construction, installation and lay out.

C. Human Engineering Evaluation. Human engineering considerations were addressed via a questionnaire (APPENDIX F) for all divers regarding the unit they used. This questionnaire addressed any operational difficulties encountered with each unit's controls, the control locations, ease of manipulation, clarity of the labels and their location, clarity of sound and operator confidence in the equipment. The bench handling test and system check above also contributed to the human engineering evaluation.

D. General. Compatibility with current surface supplied diving systems (SSDS) was operationally tested during the dives at NEDU and NDSTC. Each communication system was checked and notes made of changes required to connect

it to the existing MK 12 communication cable. Each communication system was tested to insure that the impedances were compatible with existing diving equipment microphones/speakers.

IV. RESULTS AND DISCUSSION

A. Intelligibility Testing

Because intelligibility is the ultimate index of the effectiveness of any voice communication system, an objective means of assessing the intelligibility of the four communication systems was required. The Griffiths (1967) version of the previously developed MRT (House, et al, 1965) was employed for this purpose. It was chosen for its ease of administration and scoring, its stability with respect to learning effects, and because it requires minimal listener training. Gelfand, et al, 1978 report the successful use of the test on a 1600 FSW dive. Although the MRT is not phonetically balanced to represent everyday speech, it is efficient and useful because it requires perception of consonantal sounds (sounds that are difficult to transmit successfully) and are thus more important than vowels to intelligibility.

The MRT consists of 50 sets of words, with five words in each set. In a typical test, a reader reads one specific word from each set in the following way: "number 1, the word is _____, the word is _____, ... number 5, the word is _____, the word is _____, ... number 10, the word is _____," etc. The reader is instructed to pause a couple of seconds between each phrase. The listeners with the corresponding response sheet marked the word they heard from each set. Six different reading and response lists were randomly employed during the course of the testing. The order of the words within each set on the various response word lists were different to counter the tendency of listeners to mark the first word in a set when in doubt or when guessing. Once a word list was completed, the percent correct was calculated using the formulas described in the test procedure.

The intelligibility criteria for military voice communications systems is set forth in MILSTD-1472B. This military standard sets the minimum acceptable intelligibility when using the MRT as the evaluation criteria as 75% correct. A synopsis of the results from each unit follows:

1. AMRON III. The AMRON unit from the beginning was occasionally outstanding but these periods of excellence were marred with ear deafening high frequency emissions. The manufacturer was contacted and the unit returned for modifications to the calibration of the unit to solve the problem. Upon return of the unit to NEDU and the repair of the communications cable, further testing showed the feedback problem improved, but, overall intelligibility, shown in Table 2, was still unacceptable. The AMCOM III was then eliminated as a potential candidate.

2. EFCOM and HELLE. The EFCOM unit had operating problems upon receipt and was returned to the manufacturer for repair before testing began. Neither the HELLE or the EFCOM were able to pass a four wire, three diver round-robin surface communications test using two MK 12 and one MK I MOD 0 helmet. The EFCOM emitted continuous variably ranged feedback and the HELLE also exhibited continuous audio instability.

TABLE 2

AMCOM - NEDU TEST POOL

Intelligibility Score (% Correct)	MK 12		MK 1		TOPSIDE		TOTAL = 81 DIVES	
	# Dives	%	# Dives	%	# Dives	%	Dives	Total %
75 - 100 (Pass)	9	56	6	37	26	53	41	51
0 - 75 (Fail)	7	44	10	63	23	47	40	49

3. HYDROCOM. The Hydro Products, HYDROCOM Model UDC-225, was clearly audible and suffered no feedback problems. The HYDROCOM passed the overall minimum intelligibility requirements of 75% (Table 3). Pool tests produced high overall individual scores for the HYDROCOM with MK 12 SSDS and the topside operator. The individual MK I MOD 0 score fell slightly below the 75% minimum. However, this was due to the poor placement of the earphones over the divers ears in the MK I mask and was not a function of the HYDROCOM communicator.

At the conclusion of the pool test phase of the evaluation, the Hydro Products unit was clearly the only communicator suitable for follow-on testing at deeper depths. This testing was comprised of wet hyperbaric chamber dives to depths of 130 FSW with MK I MOD 0 divers and 200-285 FSW with MK 12 divers. Test subjects were all first class diver trainees unfamiliar with intelligibility testing techniques and not seasoned to the effects of nitrogen narcosis experienced between 200 and 285 FSW. As evidenced by Table 4, the nitrogen narcosis certainly had an effect on intelligibility scores. In fact, Bennett, Ackles and Cripps in "Effects of Hyperbaric Nitrogen and Oxygen on Auditory Evoked Responses in Man" (Aerospace Medicine, May 1969) claim that from 200 to 285 FSW there is a decrement of 15-27% in arithmetic performance. This increment, while not directly applicable to intelligibility testing, gives an indication of the effect narcosis had on test scores. However, the human factors questionnaire displayed in Tables 5A and 5B, answered by all diver-subjects, confirms that despite the low scores at depth the HYDROCOM provided excellent communications. Divers could easily converse with each other and topside, and carry on normal conversation at 200 and 285 FSW with complete confidence in the unit.

NOTE: During testing the MK 12 communications cable was discovered to be wired incorrectly at the divers end. This compounded the problem of crosstalk and feedback between the microphone and earphone by twisting together one microphone and one earphone lead in each polyester (PE) belted pair. This miswiring of the MK 12 communication cable was not discovered earlier because when a two wire system is used, the black leads in the two PE belts are shorted together and the two white leads are shorted together. The affected MK 12 communication cable was rewired and the other MK 12 communication cable as well as the MK I four conductor cable were checked for continuity.

This discovery required that each communicator be retested to see if the cable had negatively affected the earlier testing. Each system was again connected in exact accordance with manufacturers instruction. Although communications did improve with less feedback, neither the Helle or the EFCOM were able to pass a four wire, three diver round-robin surface communications test using two MK 12 and one MK I MOD 0 helmets. The divers could not hear each other or topside even at maximum system gain. After the cable was changed, feedback previously evident in the EFCOM degenerated into occasional high frequency emissions, but the intelligibility did not improve. The Helle unit, although it had not experienced the level of feedback present in the EFCOM, still was not clearly audible to all three divers or the surface unit. Further testing was still not considered appropriate on those units.

TABLE 3
HYDROCOM - GEDU TEST POOL

Intelligibility Score (% Correct)	MK 12		MK I		TOPSIDE		TOTAL = 139 DIVES	
	# Dives	%	# Dives	%	# Dives	%	Dives	Total %
75 - 100 (Pass)	44	88	22	65	48	87	114	83
0 - 75 (Fail)	6	12	12	35	7	13	25	18

NOTE: Intelligibility scoring technique and the requirement for 75% correct to pass are outlined from Van Cott and Kinkade, 1972 and MIL-STD-1472 B respectively.

TABLE 4
HYDROCOM - NDSTC (200 AND 285 FSW DIVES)

Intelligibility Score (% Correct)	MK 12		MK I		TOPSIDE		TOTAL = 87 DIVES	
	# Dives	%	# Dives	%	# Dives	%	Dives	Total %
75 - 100 (Pass)	1	4	4	31	9	18	14	16
0 - 75 (Fail)	27	96	9	69	37	80	73	84

NOTE: Intelligibility scoring technique and the requirement for 75% correct to pass are derived from Van Cott and Kinkade, 1972 and MIL-STD-1472 B respectively.

TABLE 5A

COMMUNICATOR HUMAN FACTORS RATING RESULTS

COMMUNICATIONS UNITS: HYDRO-COM / AMCOM (19-30 MARCH 1984)
TEST SITE: NEDU / NDSTC

	NUMBER OF RESPONSES											
	POOR			BELOW AVERAGE			SATISFACTORY			ABOVE AVERAGE		
	HYDROCOM	AMCOM	NEDU	HYDROCOM	AMCOM	NEDU	HYDROCOM	AMCOM	NEDU	HYDROCOM	AMCOM	NEDU
	NDSTC	NEDU		NDSTC	NEDU		NDSTC	NEDU		NDSTC	NEDU	
Rate the ease of operation of controls on the communicator							2	8		6	7	
												2
Rate the location of controls on the communicator					1		3	6		5	6	
											1	2
Rate the clarity of sound received through the communicator from the helmet (dive-)		4			3		3	3		3	5	
												16
Rate the construction (i.e. materials, craftsmanship)					1			7		7	6	
							4				2	14

NOTE: A total of 8 NEDU test subjects and 24 NDSTC test subjects participated in this phase of the evaluation.

TABLE 5B

COMMUNICATOR HUMAN FACTORS QUESTIONNAIRE RESULTS

COMMUNICATIONS UNITS: HYDRO-COM / AMCOM (19-30 MARCH 1984)
 TEST SITE: NEDU / NDSTC

	NUMBER OF RESPONSES							
	HYDRO-COM				AMCOM			
	YES		NO		YES		NO	
	NEDU	NDSTC	NEDU	NDSTC	NEDU	NDSTC	NEDU	NDSTC
1. Do your fingers ever slip off of any of the controls?	1		13	24	1		10	
2. Do the controls on the communicator give a positive indication of activation (i.e. snap, audible click)?	13	24	1		9		2	
3. Do the communicator labels clearly and correctly describe the equipment?	14	24			11			
4. Are the labels of the communicator located on or near the items which they identify, so as to eliminate confusion with other items or labels?	14	24			10		1	
5. Did you ever reach for, or operate, the wrong switch or knob?		1	14	23	10		1	
6. Do you have confidence in the performance of this equipment?	14	24					11	

NOTE: Fourteen divers rated the HYDRO-COM while 11 rated the AMCOM. Twenty-four NDSTC divers answered the HYDRO-COM questionnaire.

B. Bench Tests:

1. Preliminary Test. All four units underwent a preliminary bench test and technical manual verification prior to any in-water testing. This was done to ensure there were proper safety devices to prevent an electrical safety hazard to the diver and to ensure that Navy personnel could repair the equipment on station if necessary. With the exception of the HYDROCOM the detailed results of this survey are compiled in APPENDIX G. A synopsis of the results for each unit follows:

a. AMCOM III. The AMCOM III unit is sturdily built inside and out. It did have a fuse holder connection exposed so that it could short to the chassis. This was fixed prior to diving. The AMCOM III technical manual used easily understood drawings and schematics, a troubleshooting section, and a parts list. The unit will be easily maintainable with this technical manual.

b. EFCOM. The EFCOM arrived damaged. It is suspected that the weight of the power transformer mounted on the back side of the card cage caused the legs of the card cage to break at the screws. The unit also suffered from poor quality control and was immediately returned to EFCOM for repair. The EFCOM technical manual was thorough but was only a preliminary draft for the Model HSU-1500. Essentially it was a hastily revised Model HSU-1000 manual. The manual is well organized, easy to read, has a maintenance and troubleshooting section, drawings and schematics and parts list.

c. HELLE. The Helle unit was not damaged in any manner upon receipt and is a standard unit familiar to the U.S. diving Navy. The technical manual's latest publication date was 29 November 1974 and is a Navy publication. Instructions for wiring this unit in the four wire mode came under separate cover and were not part of the manual. The manual was not adequate either with or without the additional instructions provided.

d. HYDROCOM. The HYDROCOM arrived in good condition. The technical manual provided was a preliminary manual. It is well organized with an easily understood maintenance and troubleshooting section. Drawings and schematics are provided but the parts list is incomplete. The manufacturer will forward a final copy of the technical manual for review by NEDU.

2. The Hydro Products HYDROCOM is the only unit to pass in-water intelligibility testing and consequently is the only unit to undergo the following full series of bench testing including the preliminary test.

a. Physical Test Results: The HYDROCOM UDC-225 is 12 inches wide, 16 inches long, 11 inches high and weighs 25 pounds.

b. Battery Current Drain Measurement:

(1) Operationally, the HYDROCOM UDC-225 internal battery pack lasts five hours and twenty minutes under continuous diving with at least twenty minutes of conversation per hour at ambient temperature.

(2) When tested with the transmitter in standby at ambient temperature, while transmitting a 1-KHz tone at 30% carrier modulation the internal batteries lasted in excess of 12 hours.

(3) Before low temperature testing, an externally applied digital voltmeter reading was 12.3 VDC. After twelve hours at 32°F the HYDROCOM's voltage meter indicated slightly over 12 VDC. The unit, still at 33°F, was then set up for a diver #1 microphone, diver #2 and #3 earphone and a topside tender headset. The speaker was turned on and all volume controls were set at 50% gain. A signal of 1 KHz was introduced into the diver #1 microphone for one hour. For a second hour the system was operated with ambient noise as the signal to the microphone. After the additional two hours of testing the installed voltmeter read 12 VDC and an externally applied digital voltmeter read 12.1 volts. The unit was then allowed to return to ambient temperature. A final digital voltmeter reading of 12.2 VDC was measured. After 14 hours of 32°F temperature the batteries dropped only 0.1 VDC and the unit functioned flawlessly throughout the test.

c. Splash, Rain and Salt Spray Test: A splash, rain and salt spray test was conducted on the HYDROCOM unit first in the storage (closed) configuration (Figure 4a) and then in the "in-use" (open) configuration (Figure 4b). There was no leakage into the box in the storage configuration and no leakage into the inner workings in the "in-use" configuration. The unit functioned properly before and after this test.

d. Elevated Temperature Test: For the elevated temperature test, it was placed in a chamber heated to 140°F and left for 24 hours. Upon removal a strong odor of baked varnish was evident. This is normal for PCB's with a varnish coating. A complete system check of communications was conducted. The unit was completely operable and no physical damage was apparent.

e. Bench Handling Test: This test was conducted to determine the capability of the unit to withstand the shock encountered during servicing. The chassis was removed from its enclosure and placed on a horizontal, solid wooden bench top.

(1) Part 1. General Comments: Initially the HYDROCOM was inspected for ease of maintenance, unique parts and inaccessibility to components due to internal arrangement.

(a) The HYDROCOM is easily removed from its case by removing 12 screws from the face of the panel and lifting the unit out of the case with handles provided on the front panel. The 12 screws that hold this unit in the casing do not have any washers between the screw head and the panel facing. This causes damage to the paint and could cause corrosion or amodizing problems later.

(b) The components on the printed circuit boards (PCB) are clearly marked. Test points are easy to find and use via posts provided for connecting test equipment.

(c) DC power from the battery can be secured to the system without removing the internal battery via an internal switch or by removing two power fuses. To remove the battery, a strap approximately four inches wide must be removed by unscrewing four paired screws. The inside set of screws are somewhat difficult to reach.

(2) Part 2. Drop Test: The second part of the bench handling test consisted of the drop test. The drop test was conducted by dropping the unit on each side with one edge on the bench and the bottom edge forming a 45° angle with the bench.

(a) When the HYDROCOM is dropped on either end (see Figure 1), the wiring harness connecting to a Berg 50 pin ribbon type connector on the PCB edge is jammed between the unit and the table. No damage was detected during this test, but it is possible that with several drops the wires could be damaged or the PCB cracked. A reasonable solution would be to add a protective plate on both ends, held in place by screws already available for the stand offs between the front panel and the circuit mounting plate. NOTE: Hydro Products was contacted concerning this problem and has already initiated this change in their production units.

(b) It was noticed that the large size of the audio printed circuit board (6" x 12") allows flexing in the center of the board when dropped (Figure 2). This could cause the board to eventually crack. To strengthen the PCB it is recommended that another support spacer be added. However, this is not considered a critical design problem.

f. System Checks for Shock Hazards and Grounds: During the system check ground readings were taken. The AC power cord was checked using a 500 VDC megger and found acceptable.

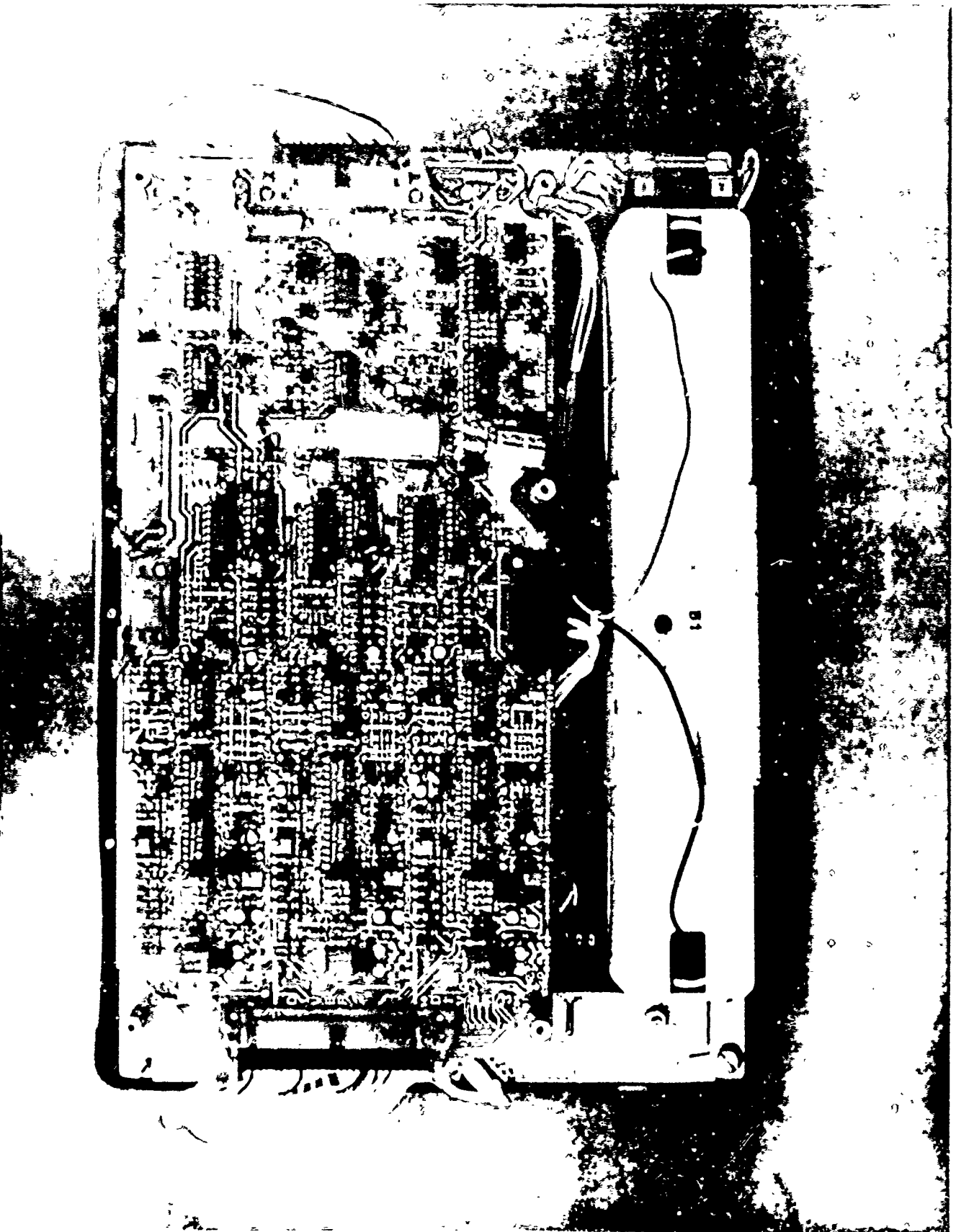
The ground fault indicator (GFI) was tested with the system plugged into a 115 VAC source and worked according to specifications.

The HYDROCOM unit has excluded the problem of electrical shocks to the operator and decreased it to the diver in the following manner:

(1) The 115 VAC is stepped down to 17 and 15 VAC through an isolation transformer. This transformer incorporates a Faraday shield grounded to the chassis ground. This ensures the diver never sees 115 volts by sending the 115 VAC to ground if the transformer fails.

(2) The operator and divers are afforded further protection by the in-line thermal overload circuit breaker that opens both sides of the line when tripped or set in the off position. Additional protection is provided by a ground fault protection circuit. All of this is well coupled and matched to afford good protection to the operator and divers.

C. Human Factors Tests (APPENDIX F). The human factors communicator evaluation sheet was the main source of information for this testing. The results of this evaluation are displayed in Tables 5A and 5B. The evaluation was filled out by each diver and each topside tender and listeners for every dive. Only the Amron and Hydro Products units were evaluated via APPENDIX F since they were the only units to actually be tested in water.



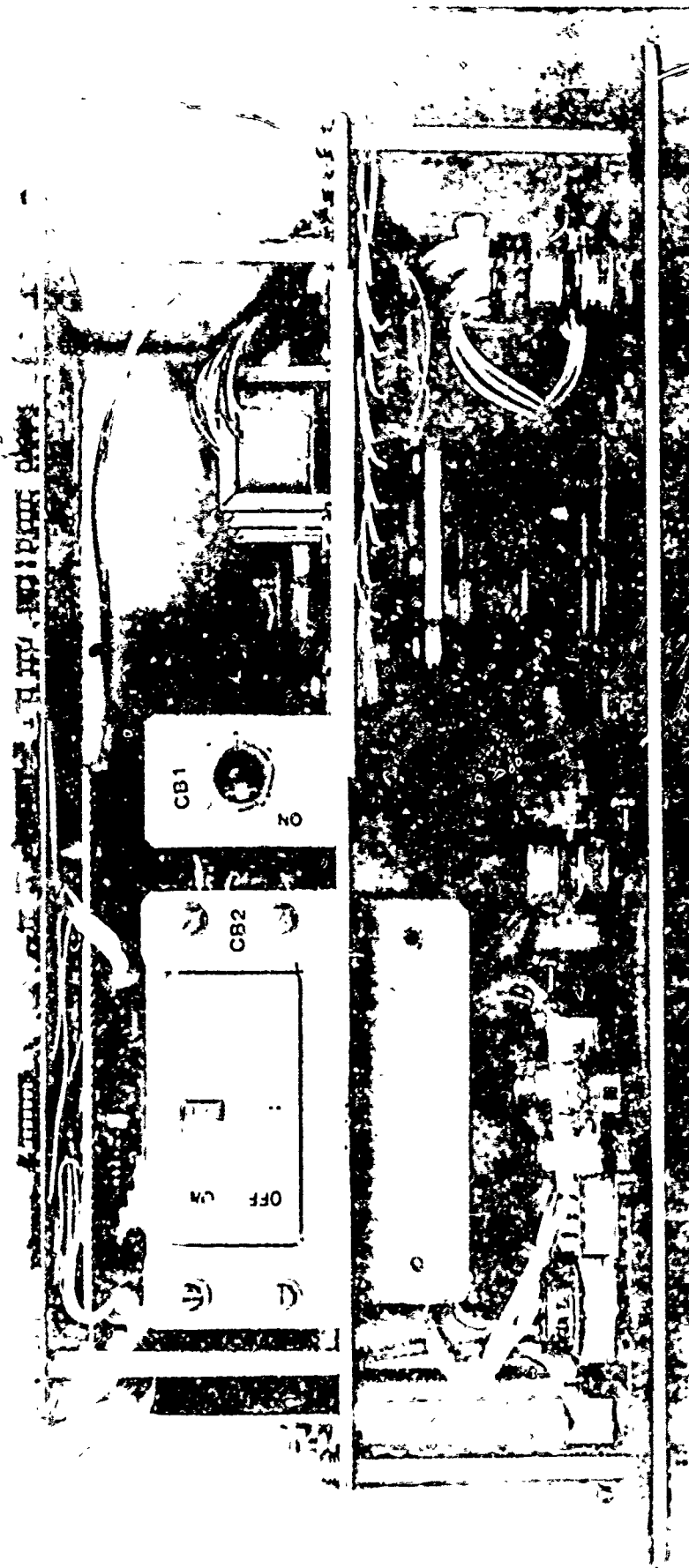


Figure 1. Control Panel of the P-1

Section B, Bench Tests, of this report also contributed information to the Human Factors Evaluation regarding the usefulness of technical manuals and interior layout and its bearing on the ease of maintenance.

The reliability of the HYDROCOM unit during this testing was excellent. It was operable from its receipt by NEDU throughout the testing with no repairs required. The Amcom, Efcorn and Helle all required some repairs before testing could begin.

V. CONCLUSIONS

The EFCOM and Helle units were disqualified from further testing before in-water intelligibility testing began. Neither unit could maintain clear and audible four wire, three diver, round-robin communications during surface checks. The EFCOM unit also suffered from poor quality control. The Helle unit tested was the unit already available to the fleet. This unit is extremely difficult to troubleshoot as most of the parts identification numbers are removed.

Although the AMCOM III provided much better material support and maintainability, it could not pass the minimum intelligibility requirement of 75% correct during in-water testing.

The HYDROCOM UDC-225 passed the overall intelligibility minimum score by a wide margin. Subjective evaluations by the test subjects indicated unanimous full confidence in the performance of this equipment. No significant human engineering problems, material or reliability deficiencies were noted during the evaluation and this unit is sufficiently durable to meet foreseeable U.S. Navy requirements.

The HYDROCOM UDC-225 is considered to be a reliable and effective means of communication for U.S. Navy surface supported diving.

VI. REFERENCES

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2. Griffiths, J.D. Journal of the Acoustical Society of America, 42, 236, 1967
3. Gelfand, R., Rothman, H.B., Hollien, H. and Lambertsen, C.J. Speech Intelligibility in Helium-oxygen at Pressures from 7.1 to 4.9 ATA. Physiologist 21:42 August 1978
4. House, A.S., Williams, C.E., Hecker, M.H.L. and Kryter, K.D. Journal of Acoustical Society of America, 37, 158, 1965
5. MIL-STD-1472-B, Human Engineering Design Criteria for Military Systems, Equipment and Facilities, DOD, Washington, DC June 1972
6. Bennett, P.B., Ackles, K.N., and Cripps, V.J., Effect of Hyperbaric Nitrogen and Oxygen on Auditory Evoked Responses in Man, Aerospace Medicine 40: 521-525, 1969

APPENDIX A
AMRON PICTURES AND WIRING DIAGRAM

(Figures A1 through A4)

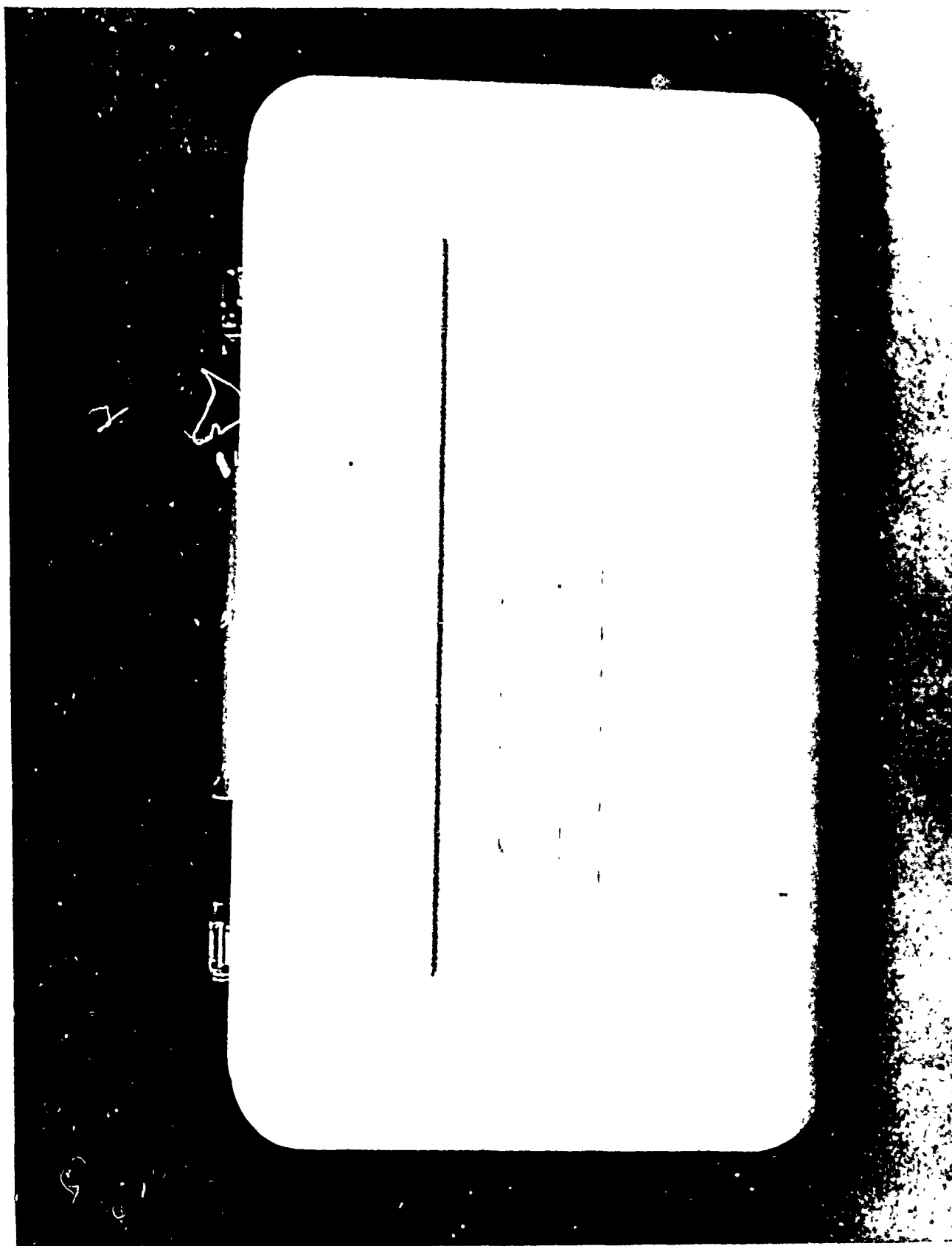


Figure A1. Amron Case Top

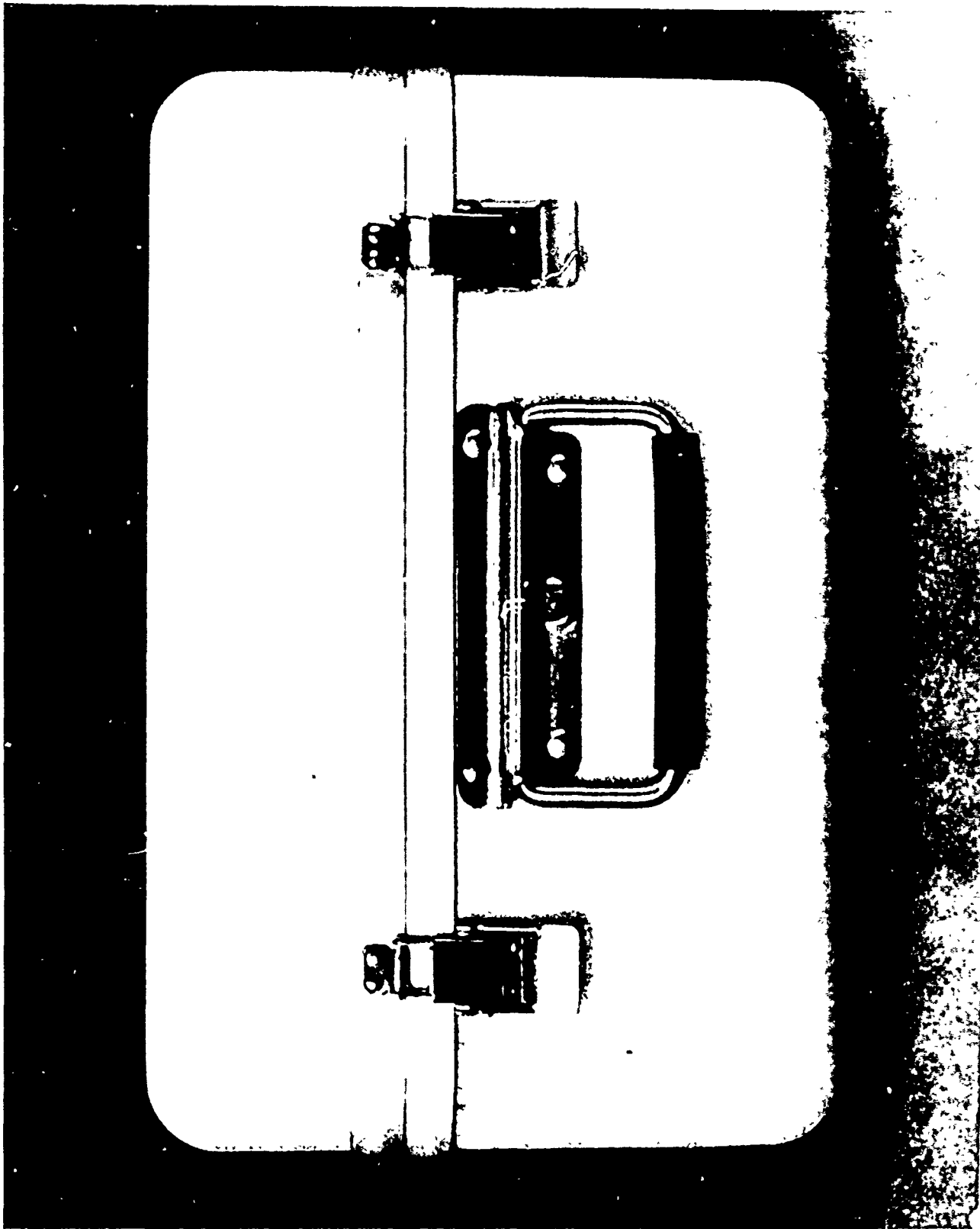


Figure A2. Amron Case Front

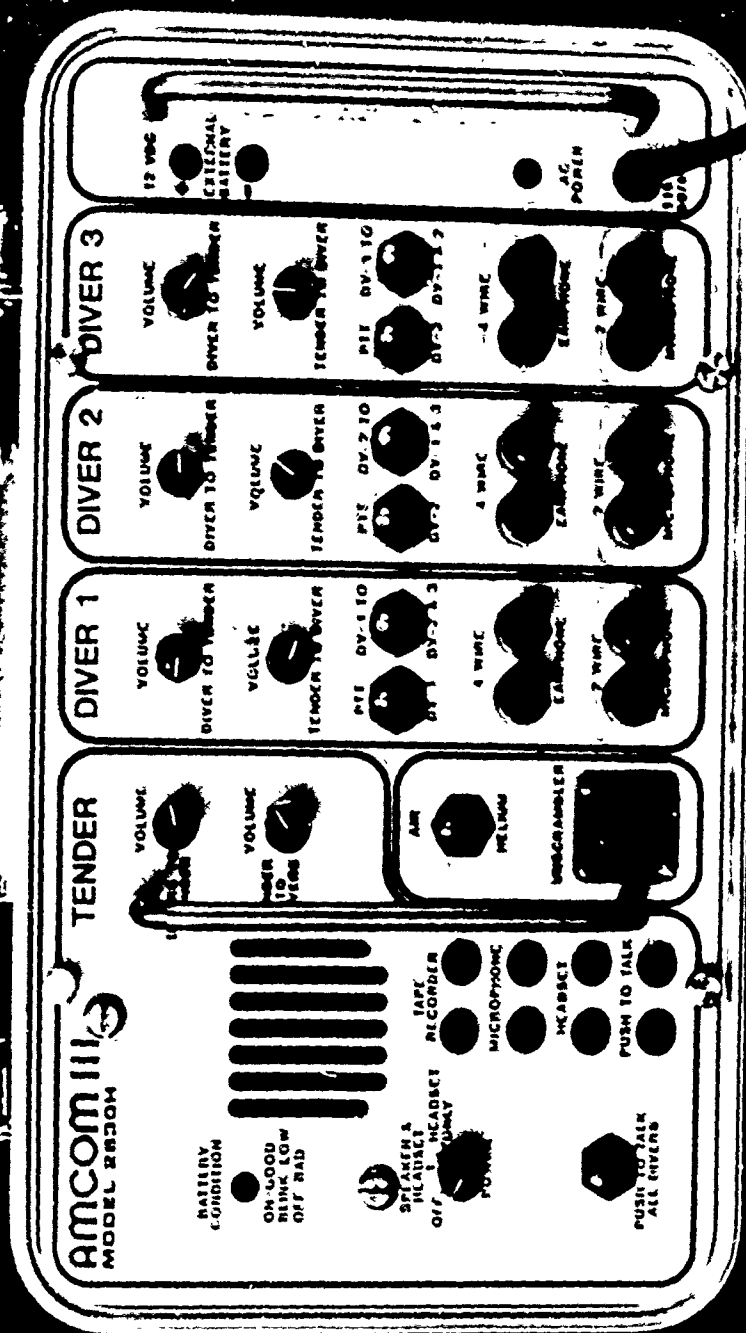


Figure A3. Amron Front Panel

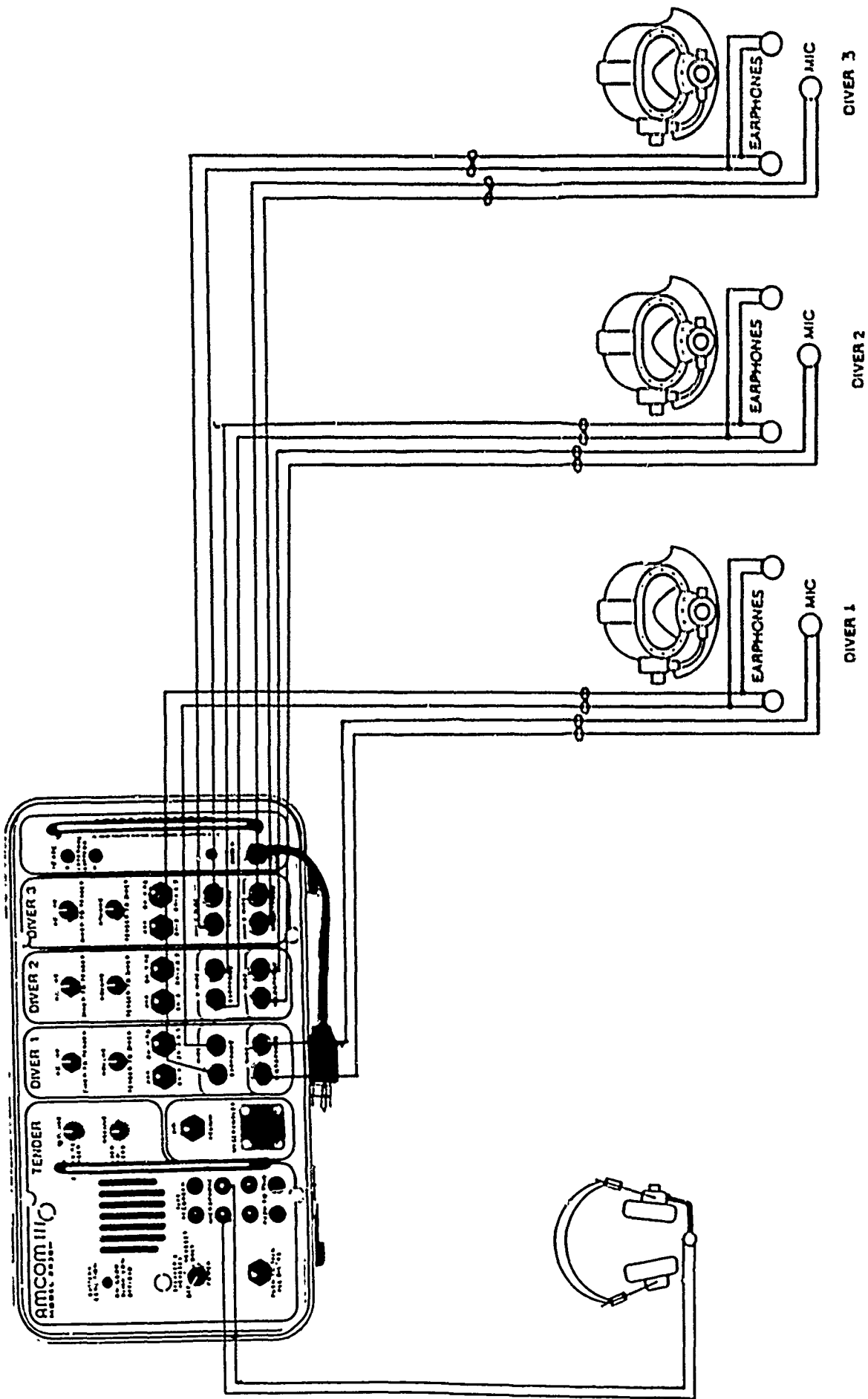


Figure A4. Amron Wiring Diagram

APPENDIX B
EFCOM PICTURES AND WIRING DIAGRAM

(Figures B1 through B4)

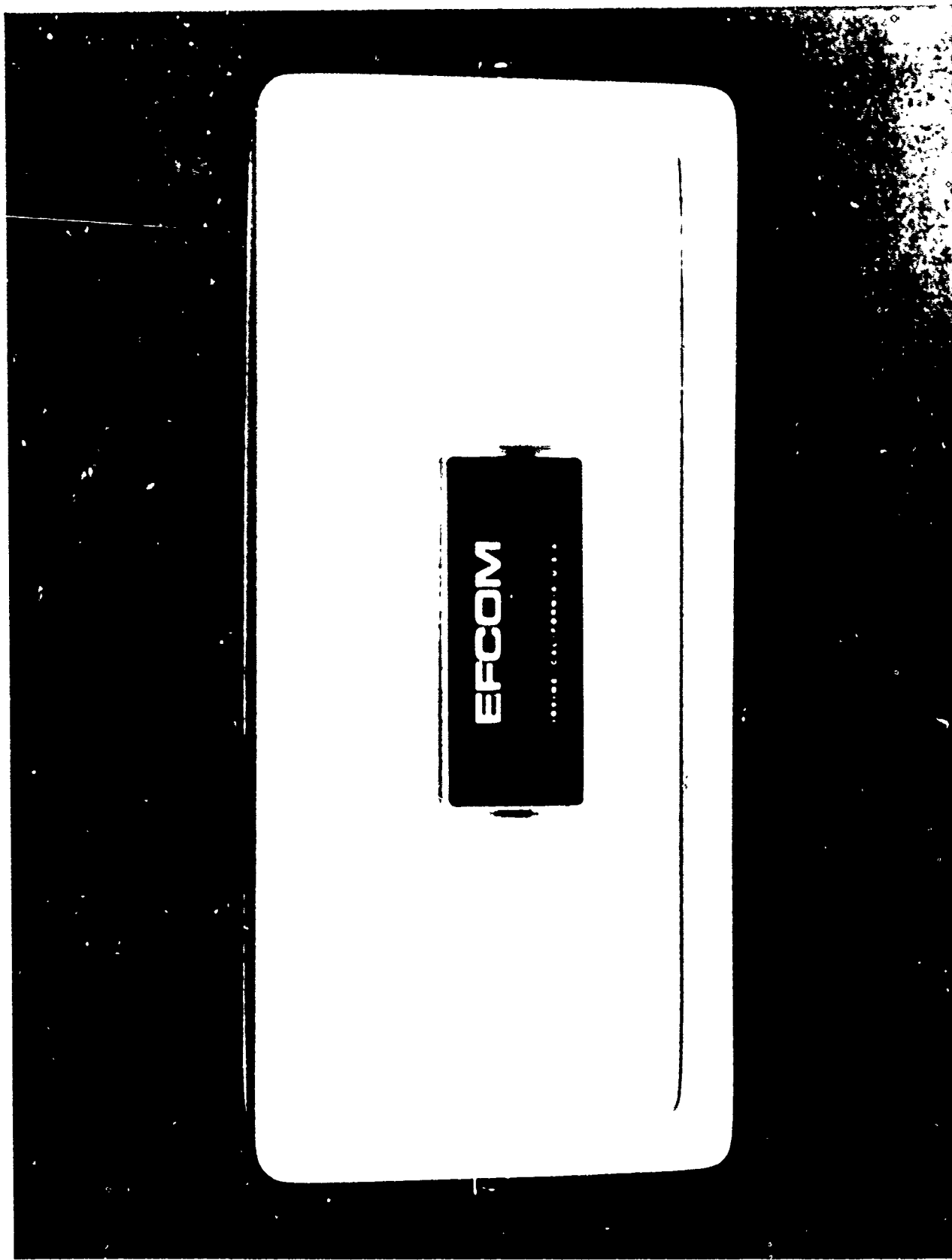


Figure B1. Efcum Case Top

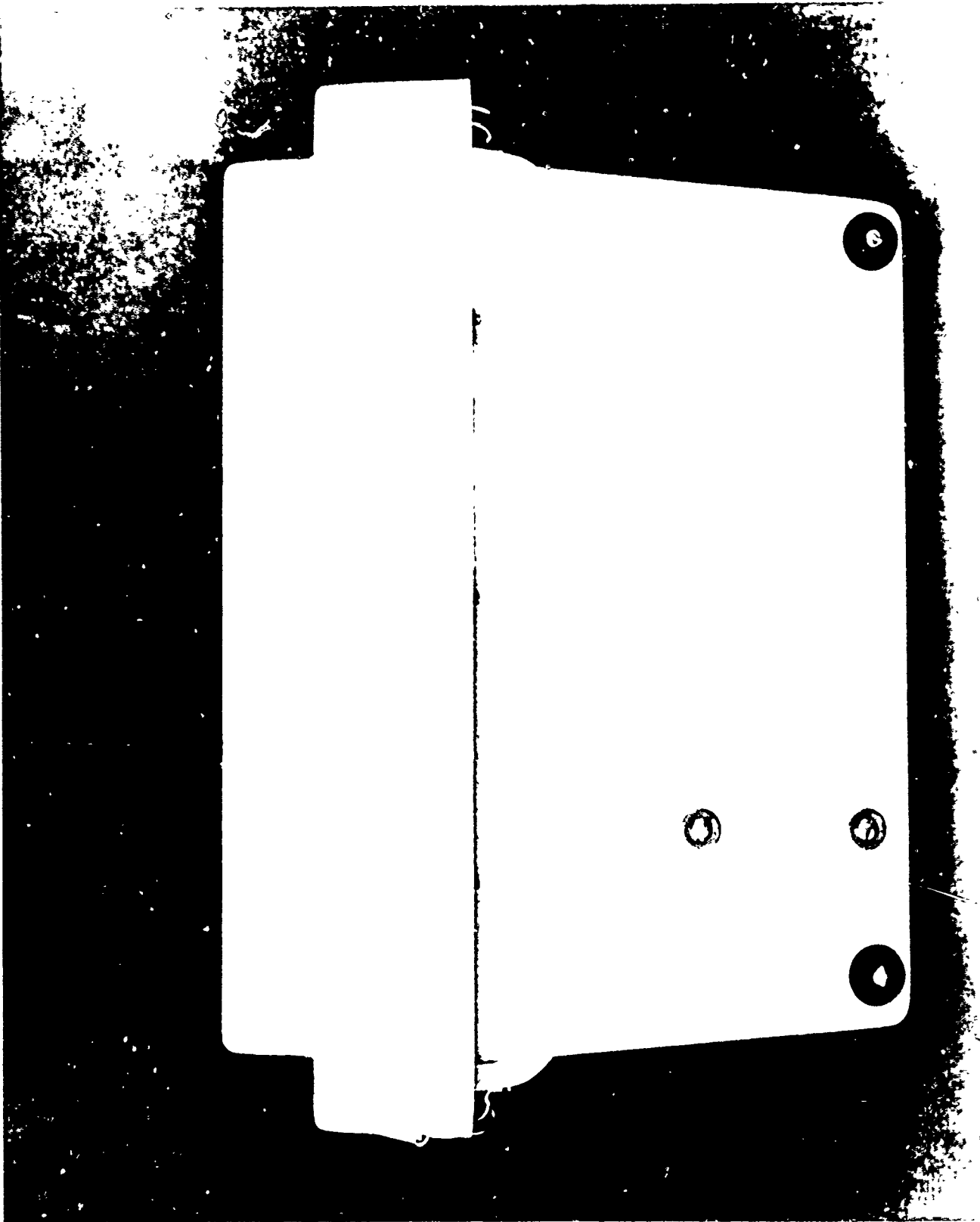


Figure B2. Efcorm Case Front

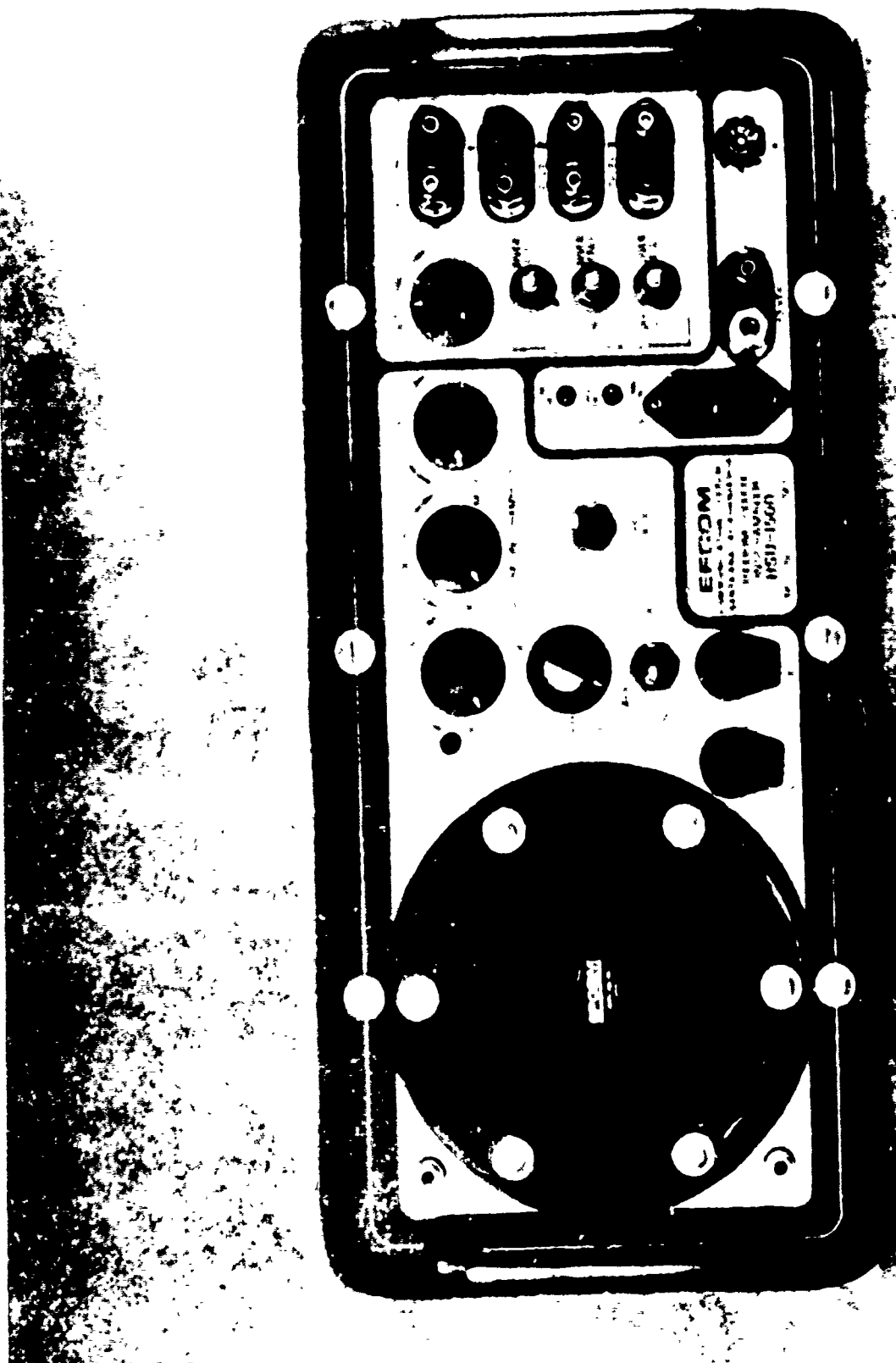


Figure B3. Etcom Front Panel

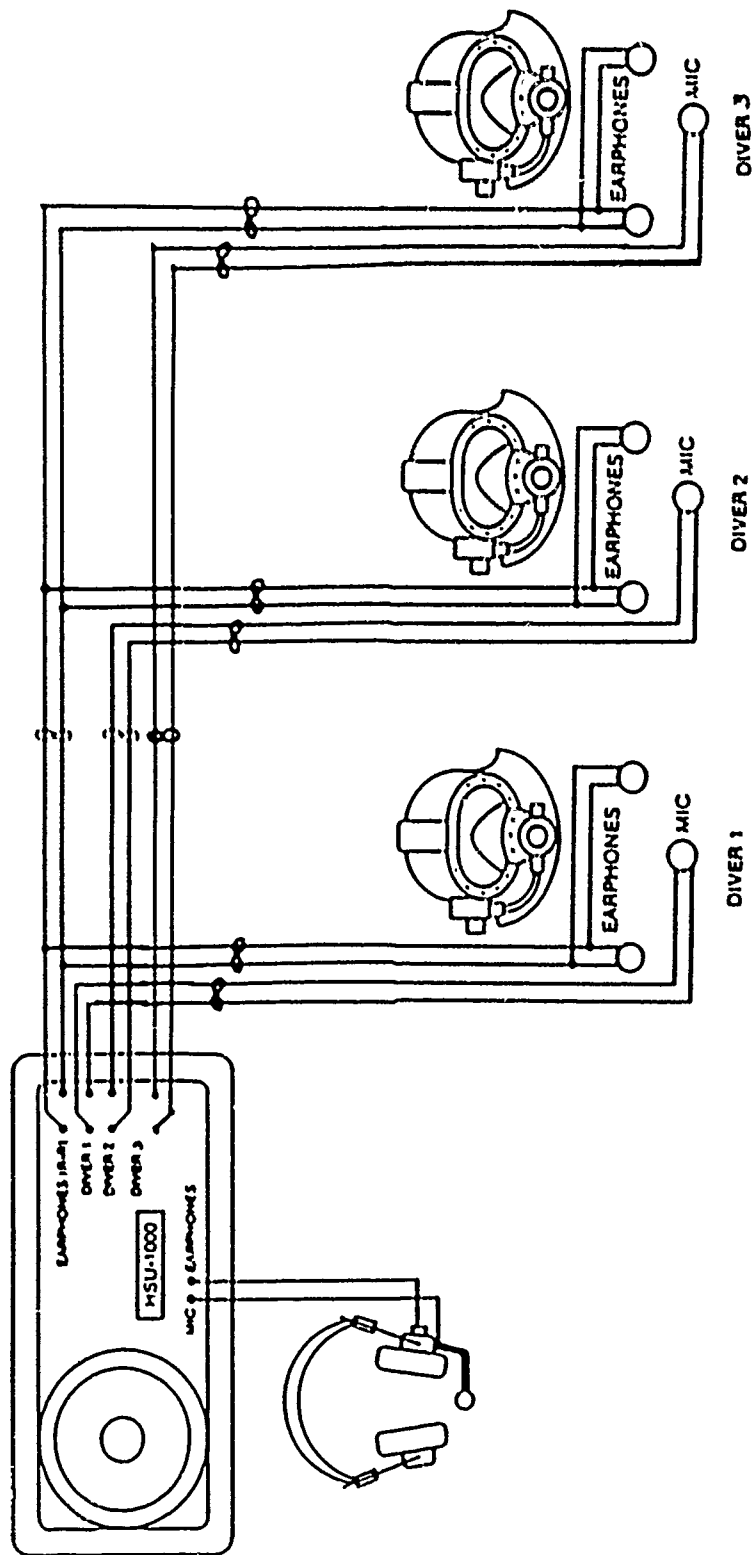


Figure B4. Efcom Wiring Diagram

APPENDIX C
HELLE PICTURES AND WIRING DIAGRAM

(Figures C1 through C4)

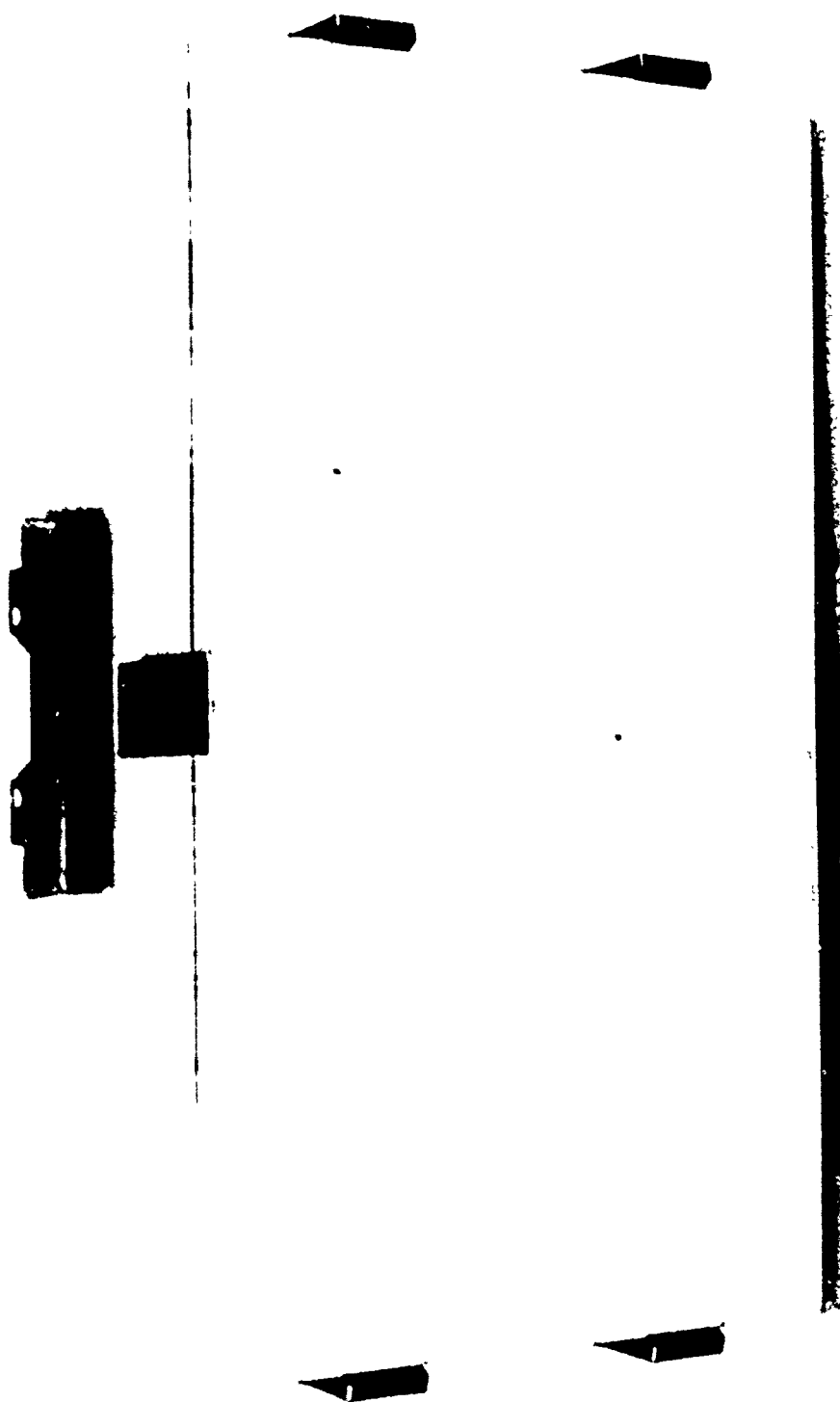


Figure C1. Helle Case Top/Front

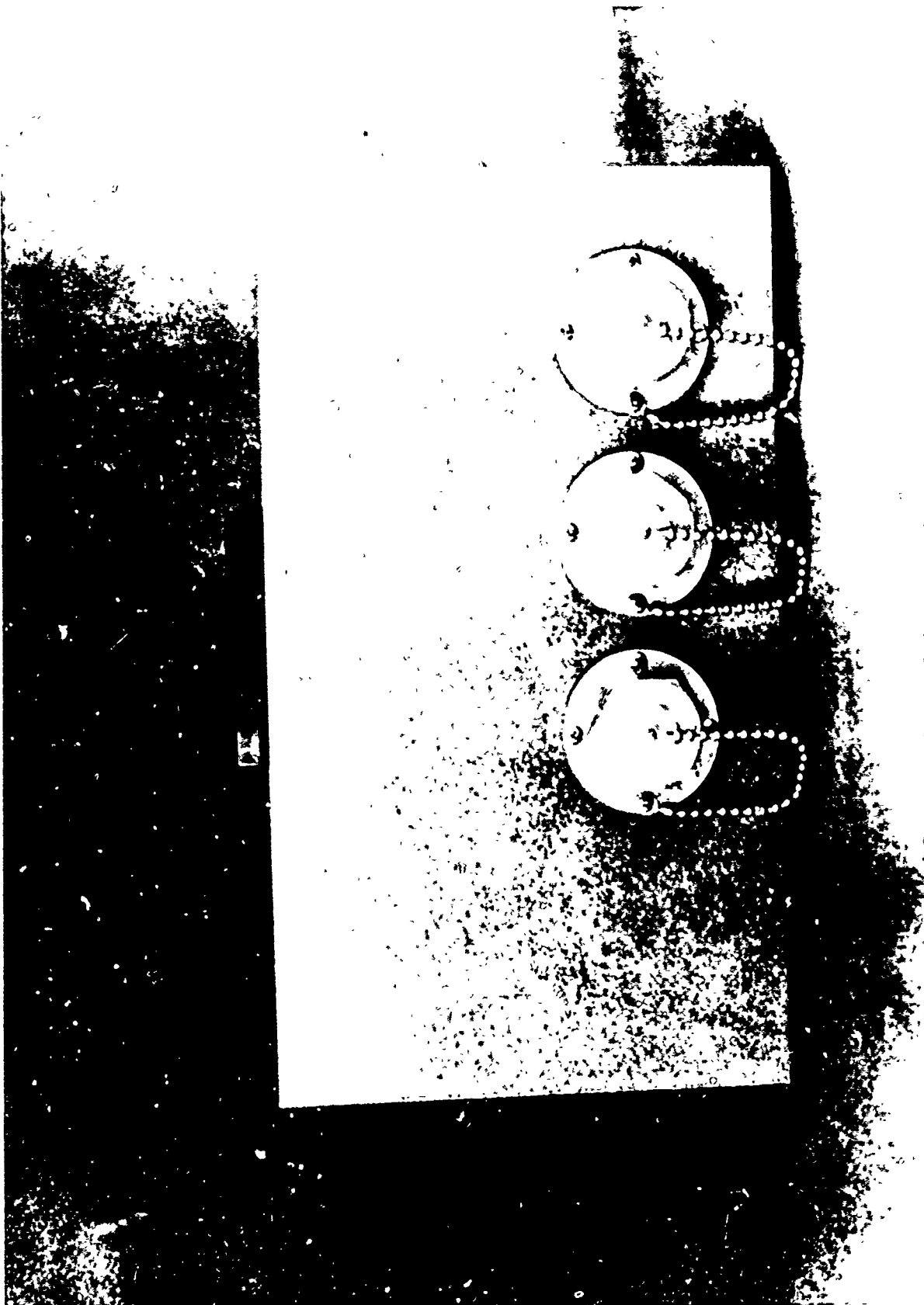


Figure C2. Helle Case Back



Figure C3. Helle Front Panel

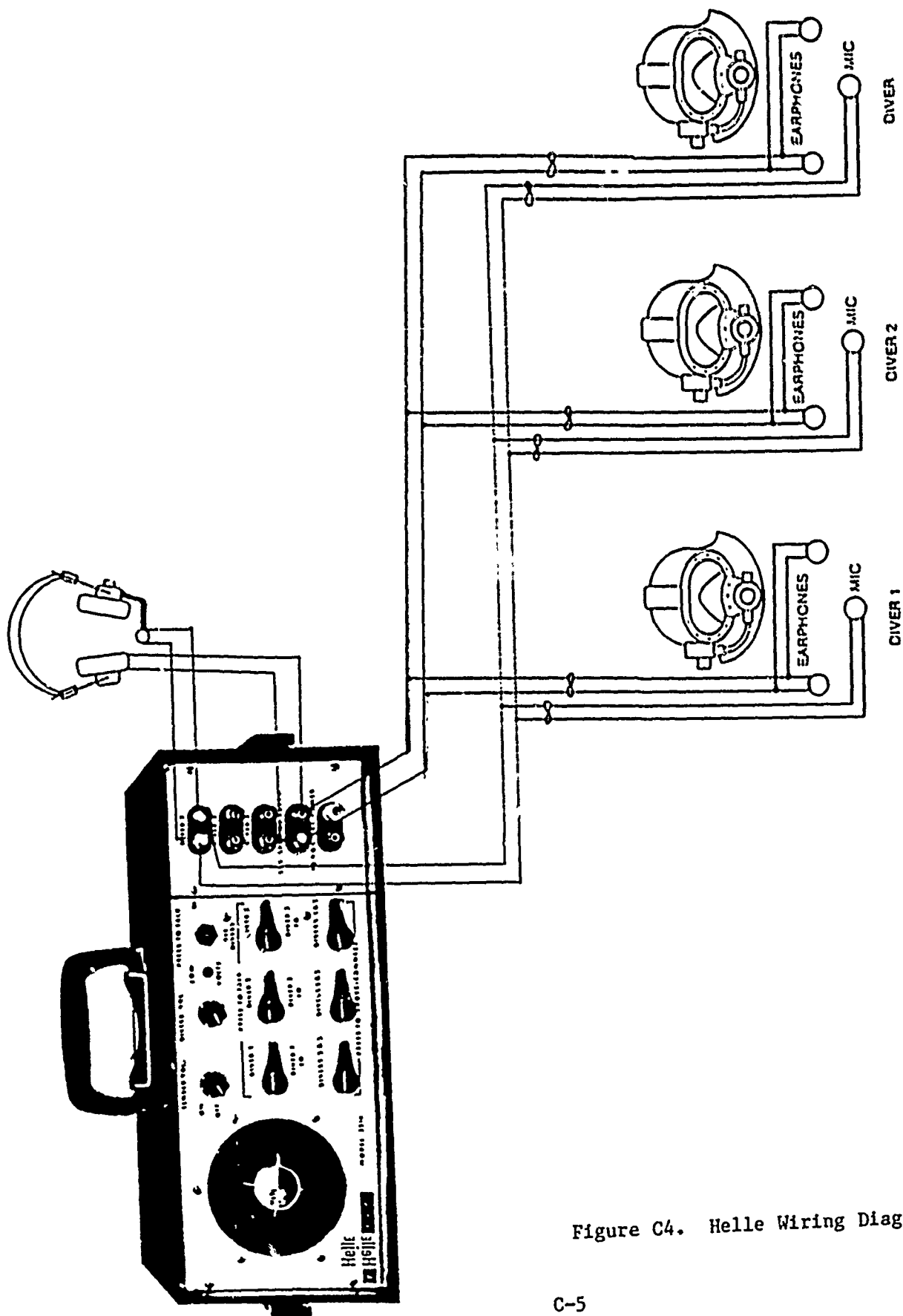


Figure C4. Helle Wiring Diagram

APPENDIX D
HYDROCOM PICTURES AND WIRING DIAGRAM

(Figures D1 through D3)



Figure D1. Hydro Products Case Back

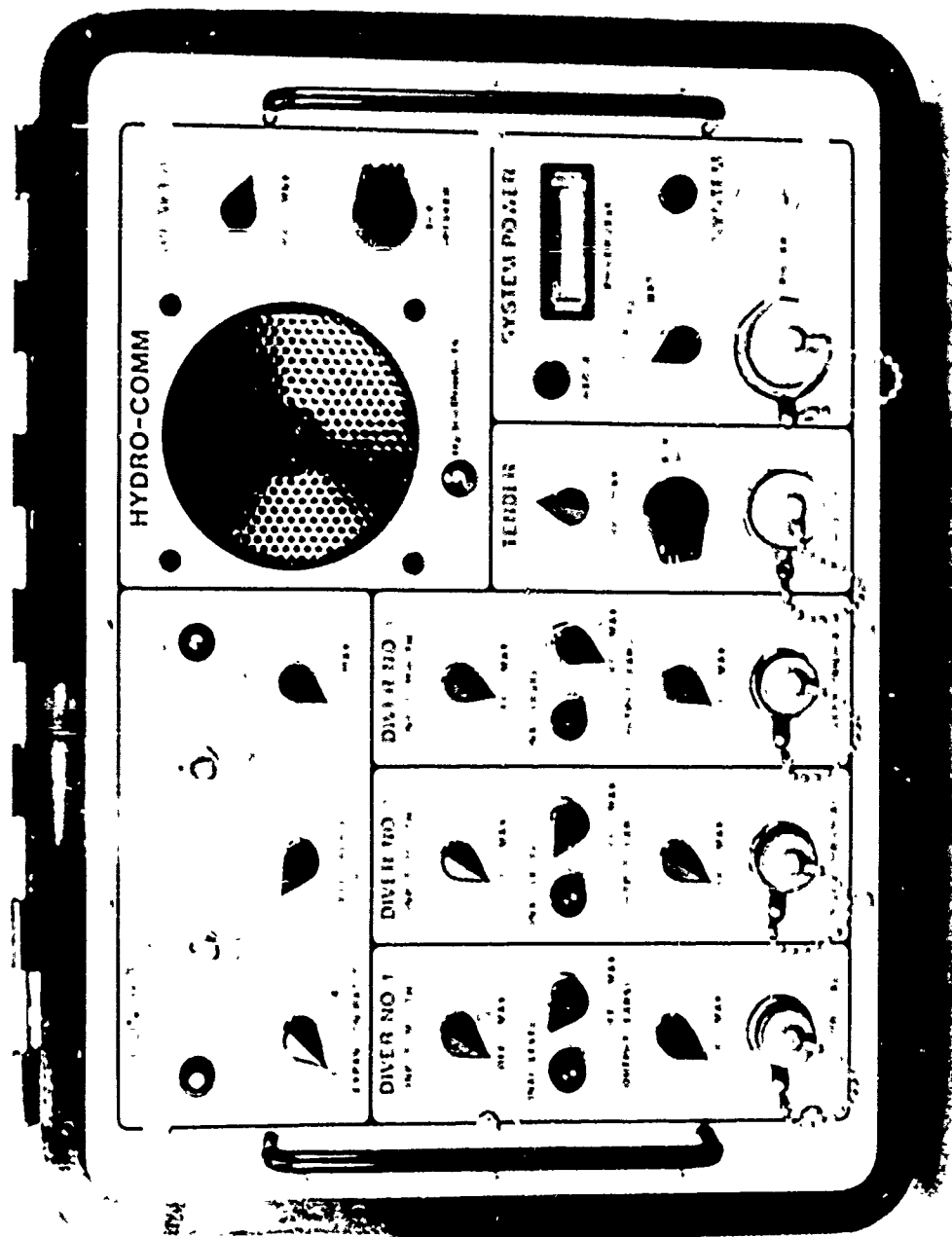


Figure D2. Hydro Products Front Panel

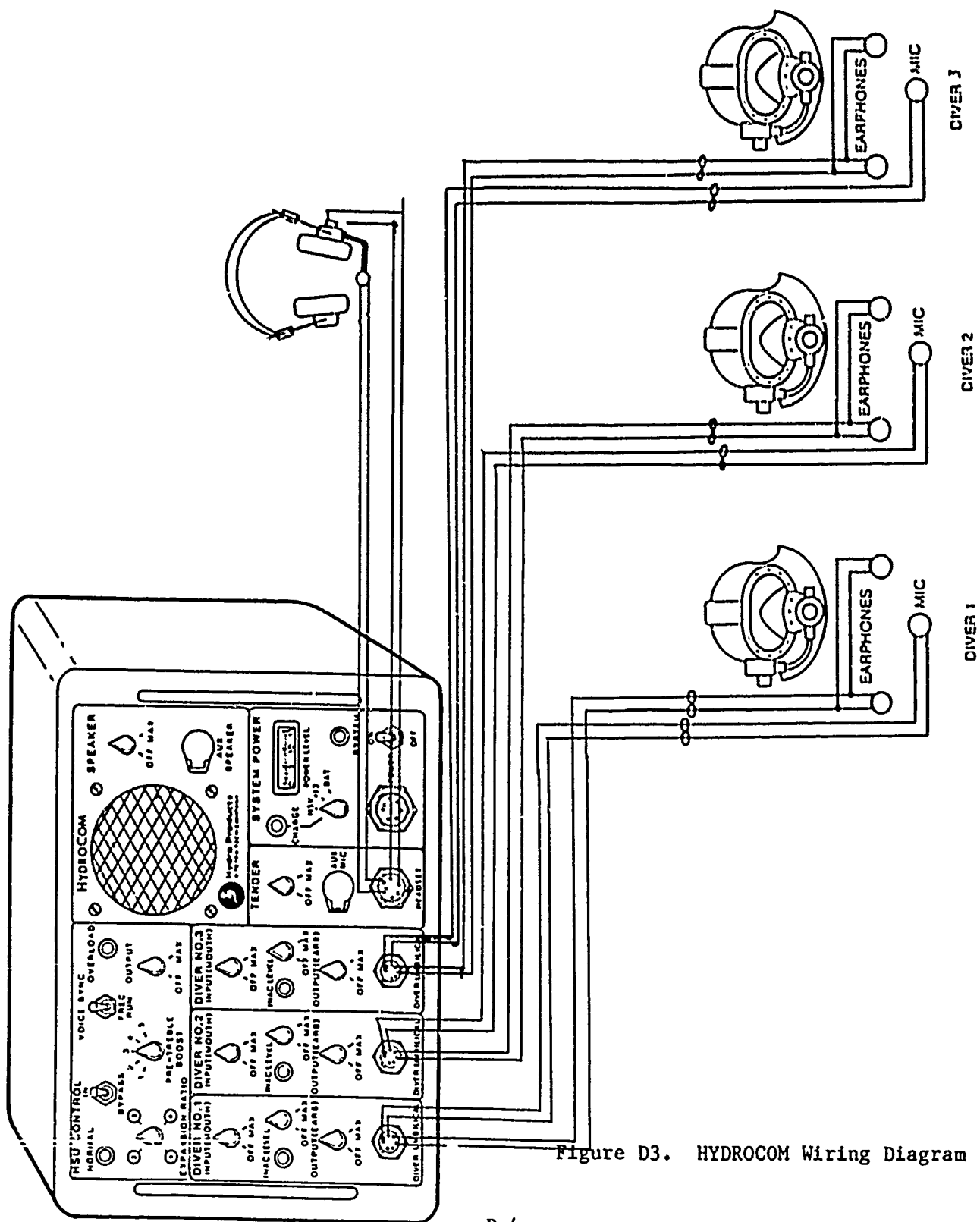


Figure D3. HYDROCOM Wiring Diagram

APPENDIX E

MODIFIED RHYME TEST (MRT)

1. Format. Reading lists 1-6 contain 50 words each (see Figure E1). Each listener will be provided with an MRT response sheet 1-6 (see Figure E2). For each word on the reading list, the listener has five possible words on the response sheet to select from. The listener then circles the word he hears out of the five and goes to the next line.
2. Scoring. The scoring of listener's responses to spoken MRT word lists shall be considered as direct and meaningful indicators of intelligibility characteristics of equipment under test during a military underwater communication (see test program).
3. Talkers. Talkers shall preface each test word with the phrase "The word is ____." This procedure serves to alert the listener and allows the talker to adjust his voice level. Talkers will deliver the words at a rate of one word every five seconds to give listeners sufficient time to make a choice and indicate their response on the MRT answer sheet.

Figure E1
Reading List 1

A	B	C	D	E	A	B	C	D	E
1 bat	batch	bash	bass	badge	26 led	shed	red	wed	fed
2 laws	long	log	lodge	lob	27 sold	cold	hold	told	gold
3 wig	with	wit	witch	wick	28 dig	wig	big	rig	pig
4 dumb	dub	doth	duff	dove	29 kick	chick	thick	pick	sick
5 cuff	cub	cut	cup	cud	30 fin	tin	shin	kin	thin
6 dig	din	dic	dim	dill	31 bark	dark	mark	lark	park
7 dun	dud	dung	dub	dug	32 gale	pale	tale	bale	male
8 fill	fig	fin	fizz	fib	33 peel	feel	eel	heel	keel
9 leave	liege	leach	leash	lead	34 will	hill	kill	till	bill
10 toss	taj	tong	talks	tog	35 feel	reel	seal	zeal	veal
11 lash	lack	lass	laugh	lath	36 shame	game	came	same	tame
12 mat	mad	math	man	mass	37 ten	pen	den	hen	then
13 beige	base	bayed	bathe	bays	38 pin	sin	tin	win	fin
14 pass	path	pack	pad	pat	39 thin	tin	chin	shin	gin
15 peak	peas	peal	peace	peat	40 thee	dec	lee	knee	zee
16 pick	pit	pip	pig	pitch	41 rent	bent	went	dent	tent
17 pup	puff	pub	puck	pus	42 hip	rip	tip	dip	lip
18 hath	hash	half	have	has	43 top	hop	pop	cop	shop
19 we're	weal	weave	weed	wean	44 yore	gore	wore	lore	roar
20 sad	sat	sag	sack	sap	45 vie	thy	fie	thigh	high
21 sheen	sheave	sheathe	sheath	sheaf	46 zip	lip	nip	gyp	slip
22 sing	sip	sin	sit	sick	47 nest	best	vest	rest	west
23 sud	sum	sub	sun	sung	48 bust	just	rust	gust	dust
24 tab	tan	tam	tang	tap	49 mat	vat	that	fat	rat
25 teethe	tear	tease	teel	teeth	50 way	may	gay	they	nay

Figure E2
RESPONSE SHEET 1

NAME: _____ RIG OR LOCATION: _____ DATE: _____

A	B	C	D	E	A	B	C	D	E		
1	bash	bat	bass	badge	batch	26	red	fed	led	wed	shed
2	lodge	laws	lob	log	long	27	told	gold	cold	hold	sold
3	witch	wig	with	wit	wick	28	wig	dig	pig	rig	big
4	duff	dumb	dub	dove	doth	29	thick	sick	pick	chick	kick
5	cud	cup	cut	cuff	cub	30	kin	tin	shin	thin	fin
6	dim	dill	did	din	dig	31	bark	mark	park	lark	dark
7	dud	dung	dug	dun	dub	32	gale	pale	male	tale	bale
8	fin	fig	fib	fizz	fill	33	feel	heel	peel	keel	eel
9	leash	liege	leave	leach	lead	34	till	kill	will	bill	hill
10	taj	tog	toss	tong	talks	35	feel	seal	veal	zeal	reel
11	lath	laugh	lass	lack	lash	36	same	shame	tame	came	game
12	man	mass	math	mad	mat	37	then	hen	pen	den	ten
13	base	bays	bathe	bayed	beighe	38	fin	sin	pin	win	tin
14	pad	pass	path	pack	pat	39	chin	gin	shin	thin	tin
15	peat	peak	peace	peas	peal	40	lee	thee	dee	knee	zee
16	pip	pitch	pit	pick	pig	41	dent	bent	went	rent	tent
17	pus	puck	pup	puff	pub	42	rip	tip	lip	dip	hip
18	have	half	hath	has	hash	43	cop	hop	top	shop	pop
19	weal	we're	weed	weave	wean	44	gore	wore	roar	lore	yore
20	sack	sag	sap	sat	sad	45	thigh	vie	high	thy	fie
21	sheaf	sheave	sheen	sheathe	sheath	46	zip	gyp	lip	slip	nip
22	sip	sick	sit	sing	sit	47	vest	best	west	nest	rest
23	sun	sum	sung	sud	sub	48	gust	rust	dust	bust	just
24	tang	tap	tan	tam	tab	49	vat	that	fat	mat	rat
25	tease	teel	teeth	tear	teethe	50	way	gay	nay	they	may

APPENDIX F

HUMAN FACTORS COMMUNICATOR EVALUATION

Test Number 83-56

Communicator Evaluated (circle):

ANCOM

EFCOM HSU 1500

HELLE 3315

HYDRO PRODUCTS

Date: _____

Name: _____

Operator #: _____ Ambient Noise dBA: _____

Dominant Hand (circle): R L

A. Check the most appropriate answer and make additional comments where necessary.

1. Do your fingers ever slip off any of the controls? YES___ NO___

Comment: _____

2. Do the controls on the communicator give a positive indication of activation (i.e. snap feel, audible click)? YES___ NO___

Comment: _____

3. Do the communicator labels clearly and correctly describe the equipment? YES___ NO___

Comment: _____

4. Are the labels of the communicator located on or near the items which they identify, so as to eliminate confusion with other items or labels? YES___ NO___

Comment: _____

Test Number 83-56 (continued)

5. Did you ever reach for, or operate, the wrong switch or knob? YES___ NO___

Comment: _____

B. Answer the following questions by inserting the number corresponding to the appropriate rating next to the question.

Key:	1	2	3	4	5
	poor	below average	satisfactory	above average	excellent

6. Rate the ease of operation of controls on the communicator: _____

Comment: _____

7. Rate the location of controls on the communicator: _____

Comment: _____

8. Rate the clarity of sound received through the communicator from inside the helmet: _____

Comment: _____

9. Rate the construction (i.e. materials, craftsmanship) of the communicator: _____

Comment: _____

Test Number 83-56 (continued)

C. Comment on how you would improve this communicator: _____

Do you have confidence in the performance of this equipment? YES___ NO___

D. Remarks on any item of importance to you that was not covered by this questionnaire: _____

This image shows a single sheet of white paper with horizontal ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

APPENDIX G

PRELIMINARY BENCH TESTS

1. AMCOM III - In Four Wire Configuration

a. Audio Test: loud and clear

b. System Inspection:

- (1) Front panel: some silk screen letters are smudged out.
- (2) Two different types of volume control were used:
 - (a) Four switches are 50 ohms and tough to turn
 - (b) The other four are 10K ohms and easy to turn
- (3) Power switch is difficult to turn when dry; would be very difficult with wet hands.
- (4) System is easily removed from the container.
- (5) A large percent of components are made in Mexico.
- (6) Interior of components and PCB are well built and sturdy.
- (7) PCB is a little difficult to get to.
- (8) The fuse holders have exposed connections that could short to the chassis. To fix it, rubber tape was applied to the fuse holder.
- (9) The 115V ground lead was not connected. It was corrected.
- (10) The connector for the HSU does not have a protective cap.

2. EFCOM HSU 2500 - In Four Wire Configuration

a. Audio Test: has static noise, the voice comes across as rasping with a heavy bass sound.

b. System Inspection:

- (1) The six retaining screws holding the unit in the container are difficult to reach.
- (2) The PCB "card" cage was broken at three legs and jammed in the container. Unit was returned to the company for repairs.
- (3) The manual indicates a switch for selecting power inside the unit but the switch cannot be found.

(4) The weight of the power transformer mounted on the after side of the card cage was too heavy for the card cage where the mounting screws passed through the legs.

(5) There were several solder splices only two or three inches apart which is indicative of poor quality control.

(6) Major components are held in place with RTV.

3. HELLE 3315 - In Four Wire Configuration

a. Audio Test: The system worked satisfactorily with only one diver connected. However, with more than one diver on the line the solitary volume control, when set so all divers could hear each other, was set so high that it was in continuous feedback.

b. System Inspection:

(1) Ten phillips head screws hold unit in the container.

(2) No handles are provided to lift the unit from the container. The speaker cone and a switch handle were used to lift the unit out.

(3) Most of the identifying numbers/markings are removed from the HSU components. This makes maintenance and repair difficult.

(4) The drawing numbers in the manual, the part numbers, assembly numbers and actual numbers do not match. Newer drawings not in the manual and received under separate cover do match the actual part numbers (that exist), but do not match the part numbers or assembly numbers in the manual. The manual is not current with Helle newsletters or drawings.

(5) Transformer (T2) on 66332 assembly is secured to the PCB with string.

(6) Relay (K1) used to make and break down link communications with the divers is held in place with silicone rubber adhesive (RTV).

(7) Solder joints are good, no unnecessary splices are made in the wiring.