NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 2-88

THROUGH-WATER DIVER COMMUNICATION SYSTEM TEST AND EVALUATION

JERRY D. PELTON

MARCH 1988

NAVY EXPERIMENTAL DIVING UNIT

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DEPARTMENT OF THE NAVY
NAVY EXPERIMENTAL DIVING UNIT
PANAMA CITY, FLORIDA 32407-5001

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In September 1987, the Navy Experimental Diving Unit (NEDU) tested and evaluated wireless diver communications equipment [NAVSEA Task 86-29 (revised)] in the Panama City, Florida area Gulf of Mexico. The systems, furnished by the following manufacturers, were found to provide acceptable overall performance and are recommended for Authorized for Navy Use (ANU) status.

1. Safare-Crouzet SA, Nice-cedex-France
   Model: ERUS-2B4D/ERUS-2A3
2. Ocean Technology Systems, Santa Ana, Ca. (U.S.A.)
   Model: Aquacom SSB-1000, SSB-1000D and CDK-3
3. Orcatron Manufacturing Ltd., Delta, B.C. Canada
   Model: Scubaphone ORCA RT-2000

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Abbreviations

ANU	Authorized for Navy Use
NEDU	Navy Experimental Diving Unit
NAVSEA	Naval Sea Systems Command
DCIEM	Defense & Civil Institute of Environmental Medicine
FSW	Feet of Sea Water
FFM	Full Face Mask
MRT	Modified Rhyme Test
SCUBA	Self Contained Underwater Breathing Apparatus
VOX	Voice Operated Transmission
kHz	Kilohertz
RMS	Root Mean Square
VDC	Volt Direct Current
VAC	Volt Alternating Current
AGC	Automatic Gain Control
°C	Degrees Celsius(centigrade)
°F	Degrees Fahrenheit
LED	Light Emitting Diode
dB	Decibel(s)
%	Percent

Abstract

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I. INTRODUCTION

As directed by NAVSEA Task 86-29, NEDU tested and evaluated three through-water diver communication systems, the Safare-Crouzet ERUS-2B4D and ERUS-2A3, Ocean Technology Systems Aquacom SSB-1000 and Aquacom SSB-1000D, and Orcatron Manufacturing Ltd. Scubaphone. The main areas covered were, word intelligibility, diver-to-diver during hull inspections, pier and piling inspections, distance test between the surface units and the diver units, bench checks for maintainability and quality control, and human engineering of systems overall.

II. EQUIPMENT DESCRIPTION

The following descriptions were mainly taken from the manufacturers manuals.

A. Safare-Crouzet ERUS-2B4D and ERUS-2A3: The ERUS-2B4D apparatus is a surface transceiver (see Figures 1 & 2) which enables telephonic communications to be established with other ERUS-2B4D units, divers equipped with an ERUS-2A3 transceiver. Transmission is carried out by means of high frequency (35 kHz) ultrasonic waves, transmission is omnidirectional. It consists of, a metal cabinet containing the transceiver unit which includes the electronic circuits, the watertight storage battery and battery charging device. The front panel carries the control knobs, the loudspeaker, the socket for the transducer connector, a meter for checking the batteries (surface and diver units), a three conductor socket for connecting the diver units to the battery charging circuit and a tape recorder/external speaker outlet. The hand held microphone with push-to-talk switch and the headset/earphones are connected to the front panel by their cables and are stored in a special compartment below the front panel, with a fold down cover. A removable cover, which can be placed on the back where matching holders are in place, protects the controls and accessories when the equipment is not in use. The surface container/cabinet dimensions are: width, 35cm (13.8 inches); height, 26cm (10.24 inches); depth, 25cm (9.8 inches); and total weight, 12kg (26.45 pounds).

The transducer (Figure 3) with its connecting cable to the transceiver [length 50 meters (164 feet)] wound on a portable wooden reel protected by a removable metal cover (Figure 3) has the following dimensions: diameter, 22cm (8.7 inches); height, 24cm (9.4 inches); and weight, 6kg (13.2 pounds)

The ERUS-2-A3 units consist of a transceiver (Figures 4, 5, and 6), a mask with microphone installed and an earphone. The transceiver's case (Figure 7) has a diameter of 80mm (3.14 inches) and a length of 340mm (13.4 inches) and weighs 3kg (6.6 pounds) dry, in water weight not known. This unit is powered by cadmium-nickel storage batteries that are recharged via the surface unit, when not in use. This unit is worn by the diver and it is recommended that it be fastened along the thigh by its straps. The microphone was placed in an AGA Divator MK II mask for the purpose of this evaluation. The earphone was held in place by a lightweight skull cap (instead of a wet suit hood due to the water temperature).

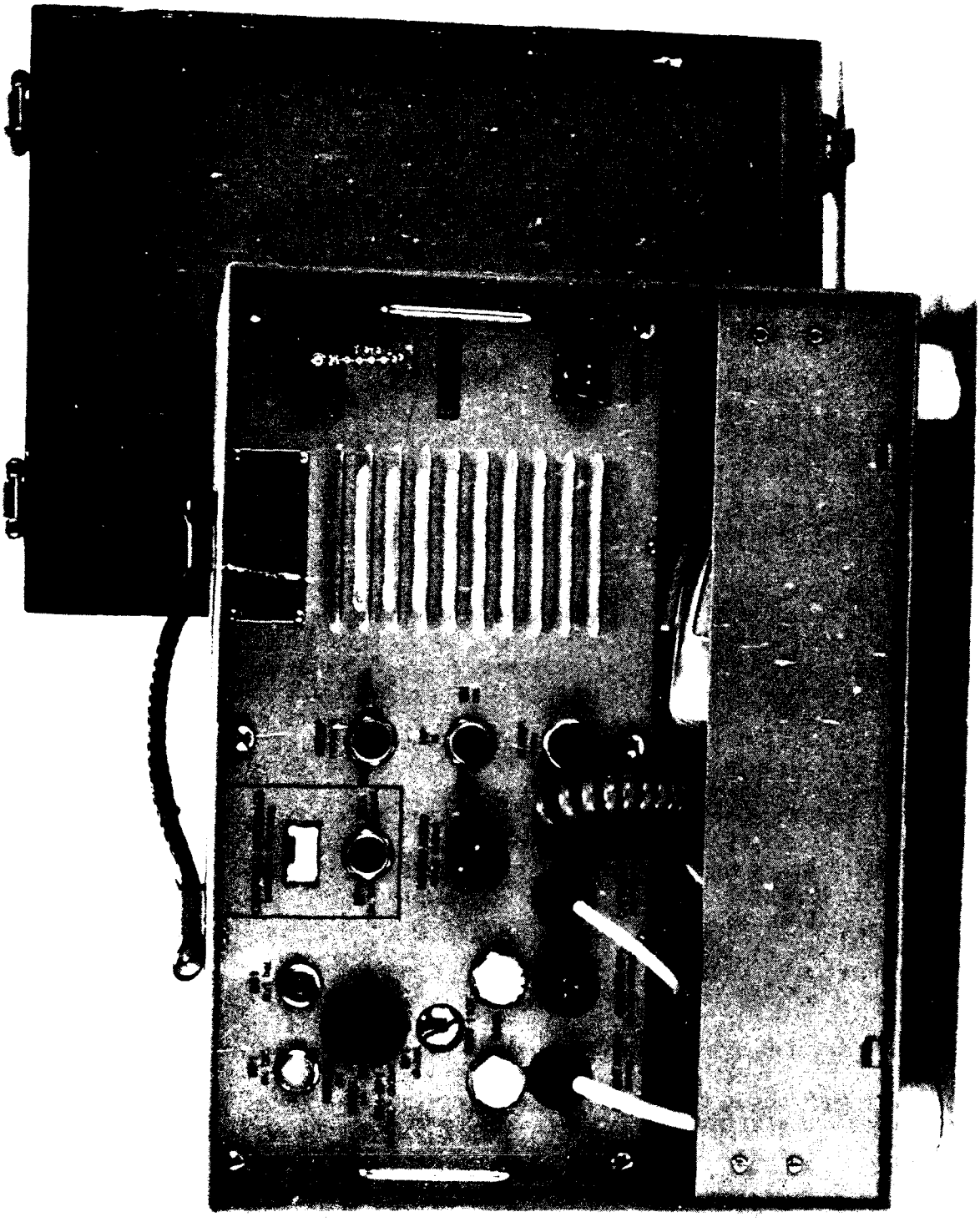

Figure 1. Sperry Gyrozet EKUS 2B4D Surface Control Unit (Storage Compartment Closed)

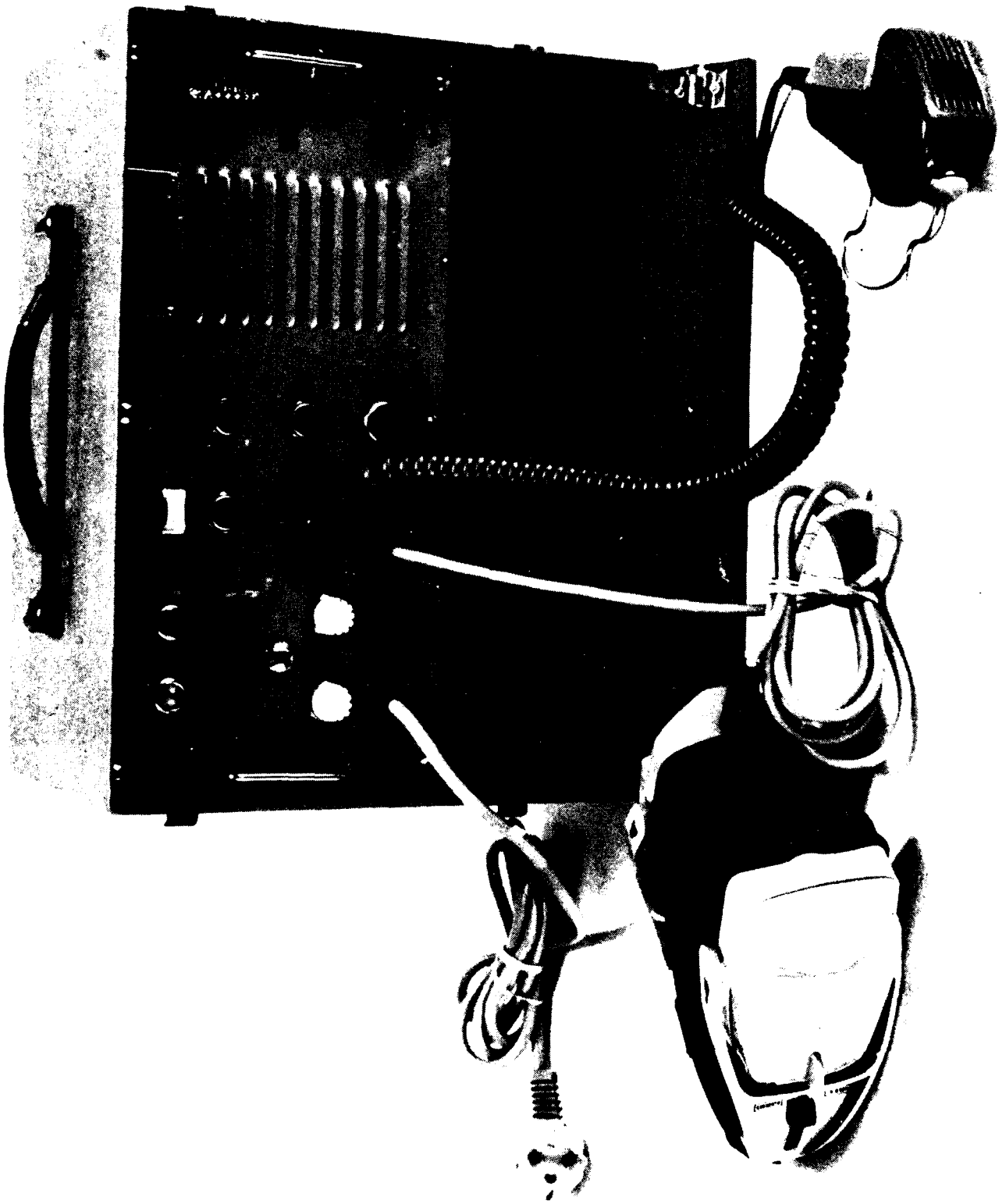

Figure 2. Safare-Crouzet ERUS 2B4D Surface Control Unit
(Storage Compartment Open)

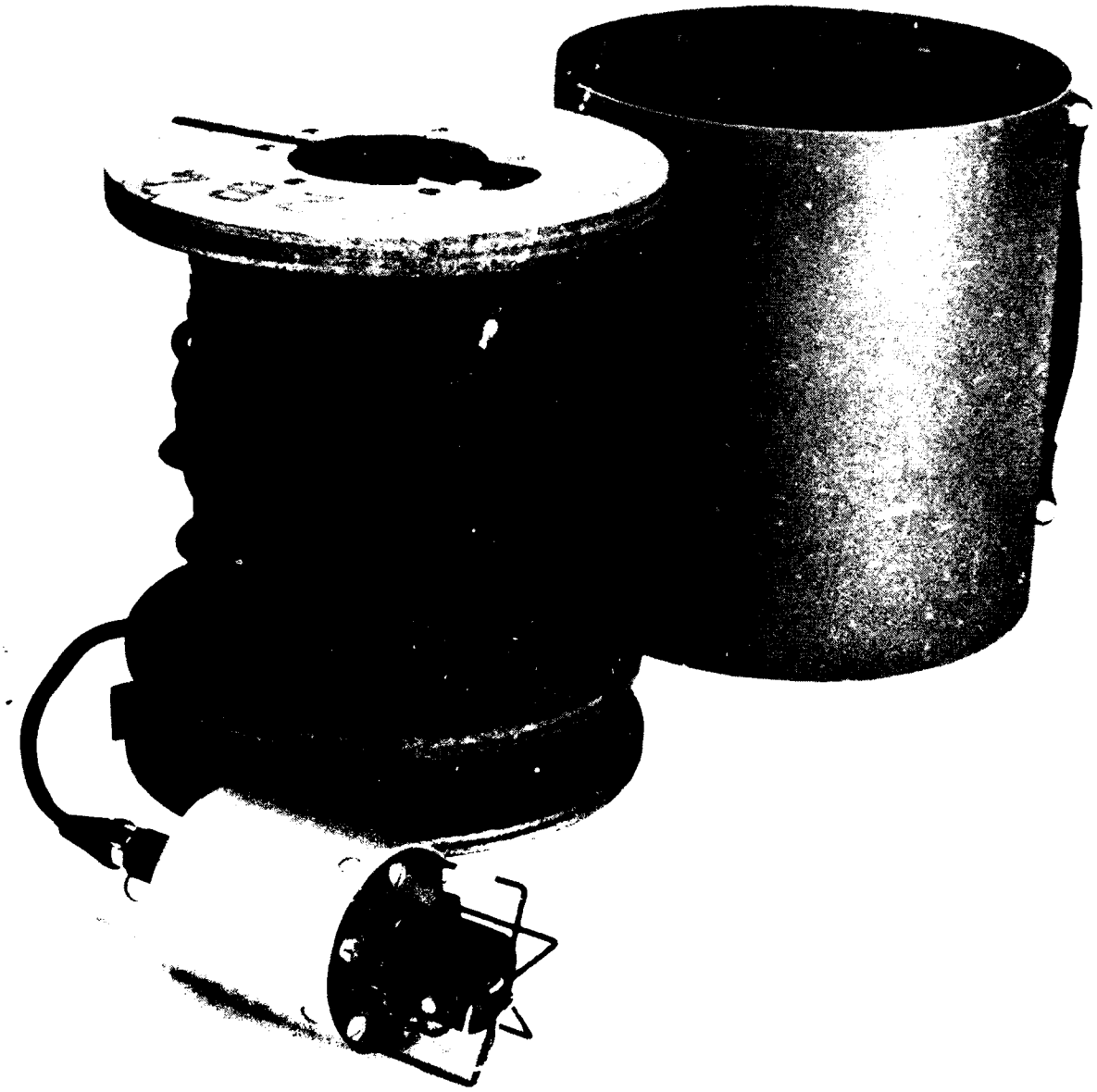

Figure [illegible] Modified Gronzet Surface Transducer
(Steel and Protective Cover)

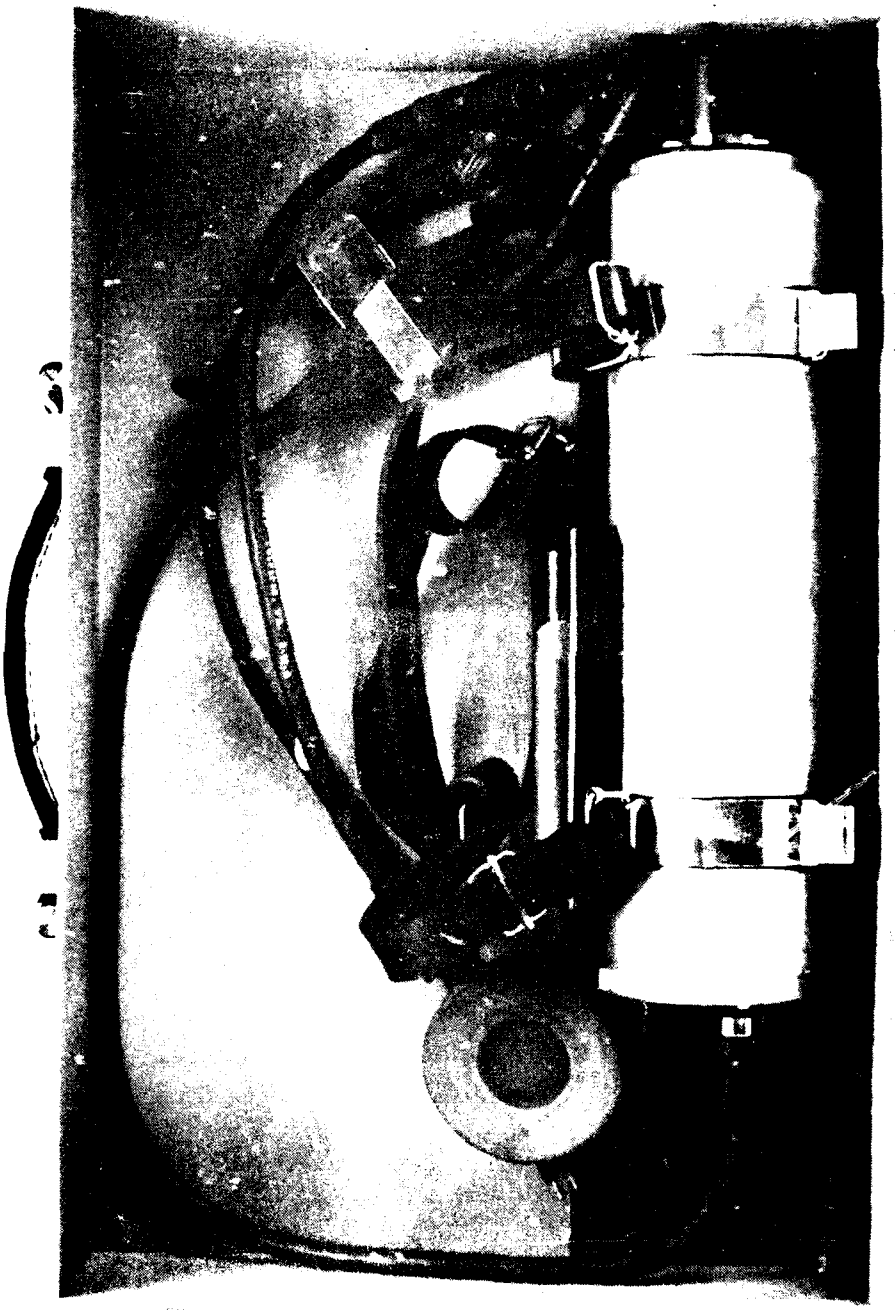

Figure 4. Safare Crouzet [illegible] in Storage/Carrying Case

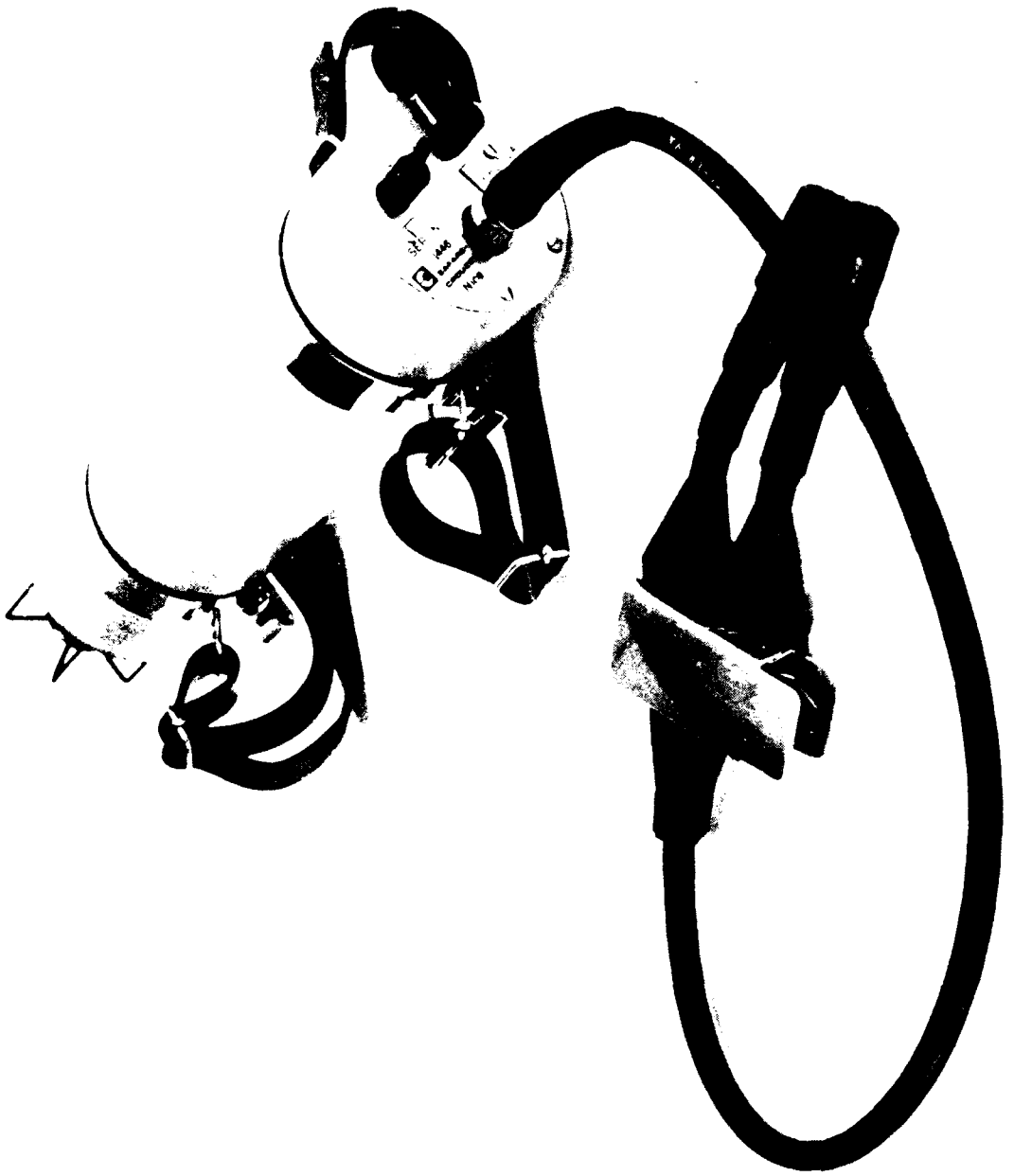

Figure 5. Safare Crouzet ERUS-2A3 Diver Unit (Side/Top View)

Figure 6. Safare-Crouzet ERUS-2A3 Diver Unit (Side/Bottom View)

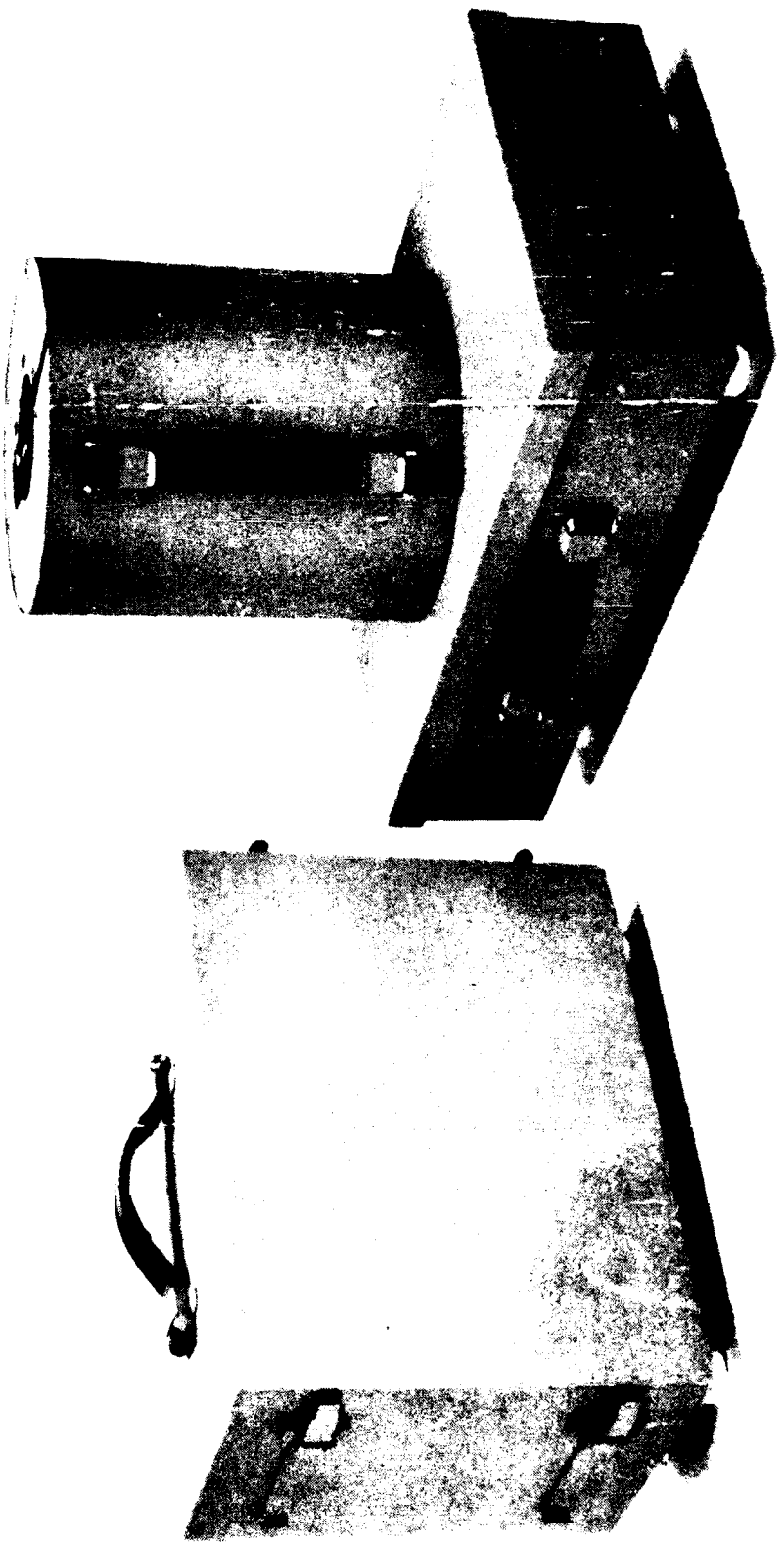

Figure 7. Safare-Crouzet System in Carrying/Storage Cases

In order to facilitate putting the equipment on the diver, the connections for the earphone and microphone with the diver transceiver are made with two watertight connectors, one with two pins and one with three pins. The result is that the transceiver, the earphone and the mask with the microphone in place, can each be put on independently. The cables and connectors are mounted on a clip which can be clipped to any convent strap on the diver. The diver unit is delivered in a metal carrying case (Figure 7), the dimensions of which are: length, 44cm (17.3 inches); width, 28cm (11 inches); height, 11cm (4.3 inches); and total weight is 5kg (11 pounds). This equipment is constructed with non-corrosive materials for all parts exposed to water (either plastic or anodized aluminum). The depth rating is 10 bars (325.9 FSW).

B. Ocean Technology Systems Aquacom SSB-1000 and Aquacom SSB-1000D: The Aquacom SSB-1000D is housed in a water tight enclosure (Figures 8, 9, and 10) designed for belt or tank mounting. The unit may be used as a surface transceiver when operated with the Model #CDK-3 conversion kit. The housing is constructed of high impact polycarbonate plastic which will not corrode when scratched. The housing is divided into two major parts (Figure 9), the upper electronics section and the lower battery section, an o-ring between both sections serves to maintain the housings watertight integrity. Stainless steel latches maintain a constant pressure which pre-loads the o-ring and prevent leakage at shallow depths. This unit contains a squelch and VOX control which are located inside the housing. The squelch control provides a means to limit the background noise heard by the diver. The VOX control provides for the setting of sensitivity (trigger point) of the voice operated transmitter circuit. This unit is activated when submerged in water and turns off when removed from the water. The housing dimensions are: height, 15.3cm (6 inches); width, 8.9cm (3.5 inches); and depth, 4.5cm (1.75 inches).

The Aquacom SSB-1000 (Figure 11) is designed to provide long range through-water communication with free swimming divers equipped with the Aquacom 1000D unit. It is contained in a fiberglass water tight case that contains an internal speaker that can be switched on and off, an auxiliary speaker jack, a frequency select switch that allows for switching between 8.0875 kHz (International Submarine Frequency), 28 kHz [Diver Frequency (this system)], or 37.5 kHz (International Emergency Beacon Frequency), a LED to indicate transmission (comes on when push-to-talk switch on the microphone is on), Power on indicating LED, Battery charging indicating LED, Low battery indicating LED, On/Off volume control switch, front panel connectors for headset/microphone, recorder output and the transducer. The cover is removable, also the battery compartment is removable to allow access to battery for ease of maintenance.

The CDK-3 Surface Conversion Kit allows the Aquacom SSB-1000D unit to be converted to a portable surface. Once converted the surface operator would be able to communicate surface-to-diver, diver-to-surface and/or surface-to-surface with any number of persons equipped with Aquacom transceivers on the same frequency. This kit consists of one 55 ft transducer cable with mating connectors for the SSB-1000D and the transducer (Figure 12), one headset with a noise cancelling boom microphone and mating connector for the SSB-1000D unit.

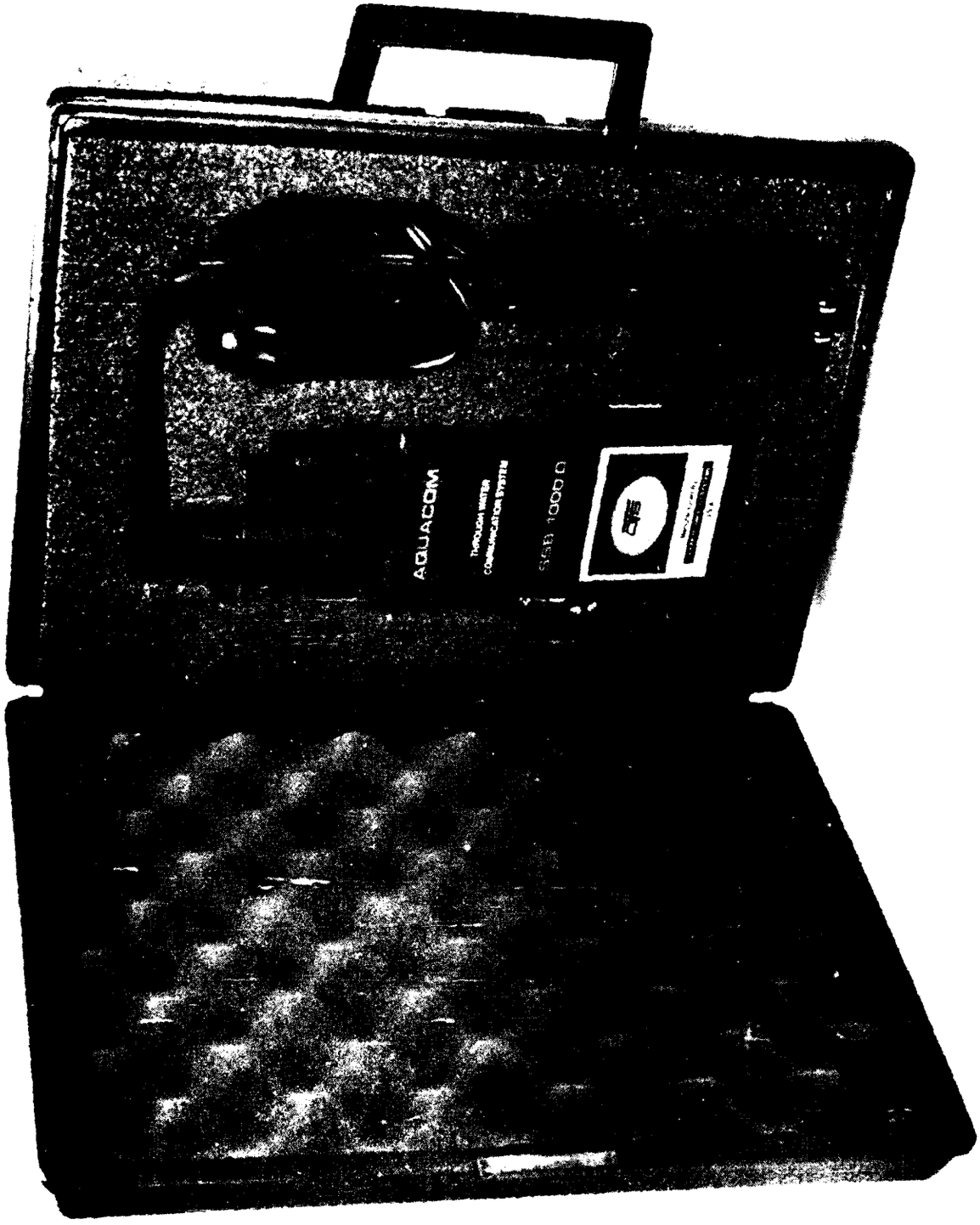

Figure 8. Ocean Technology System Diver Unit in Storage/Carrying Case

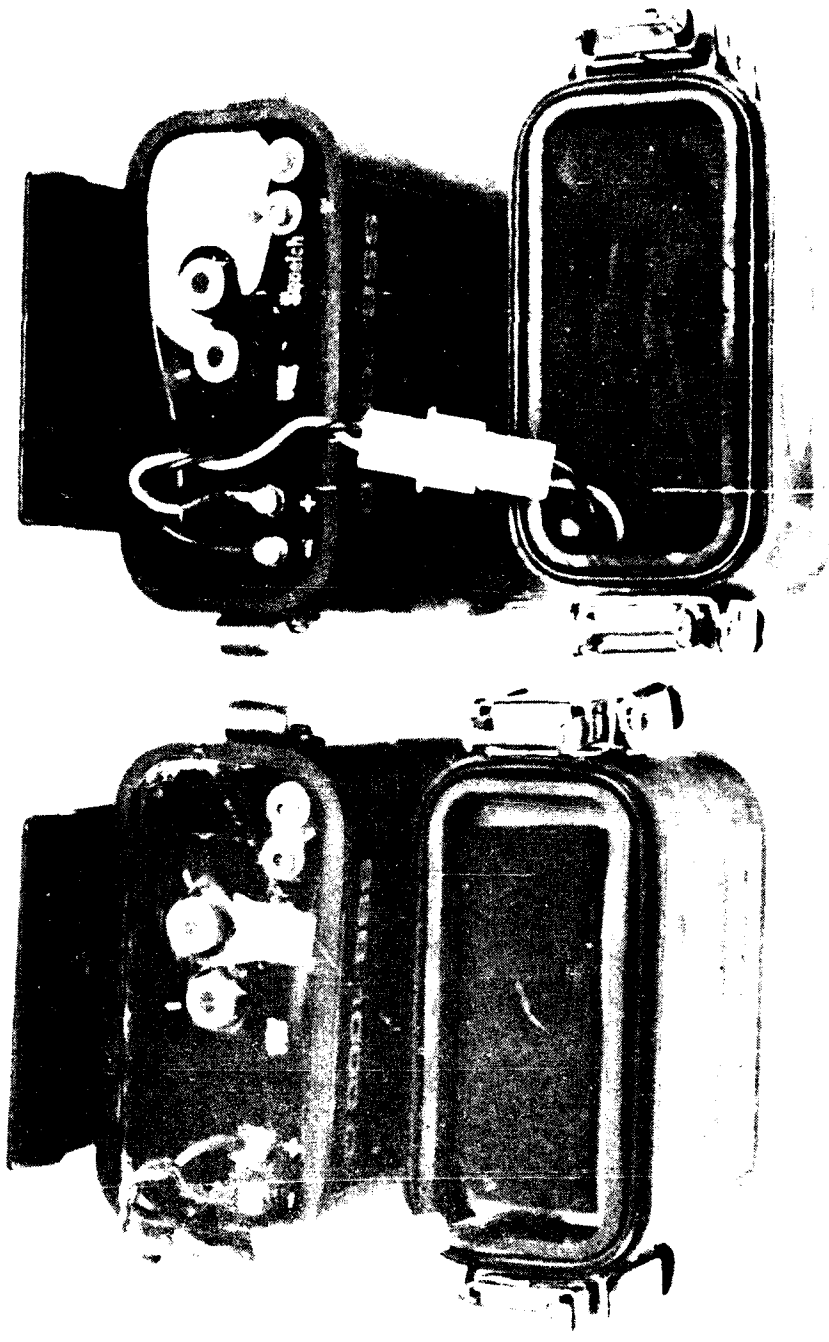

Figure 9. Ocean Technology System Diver Unit (Open)

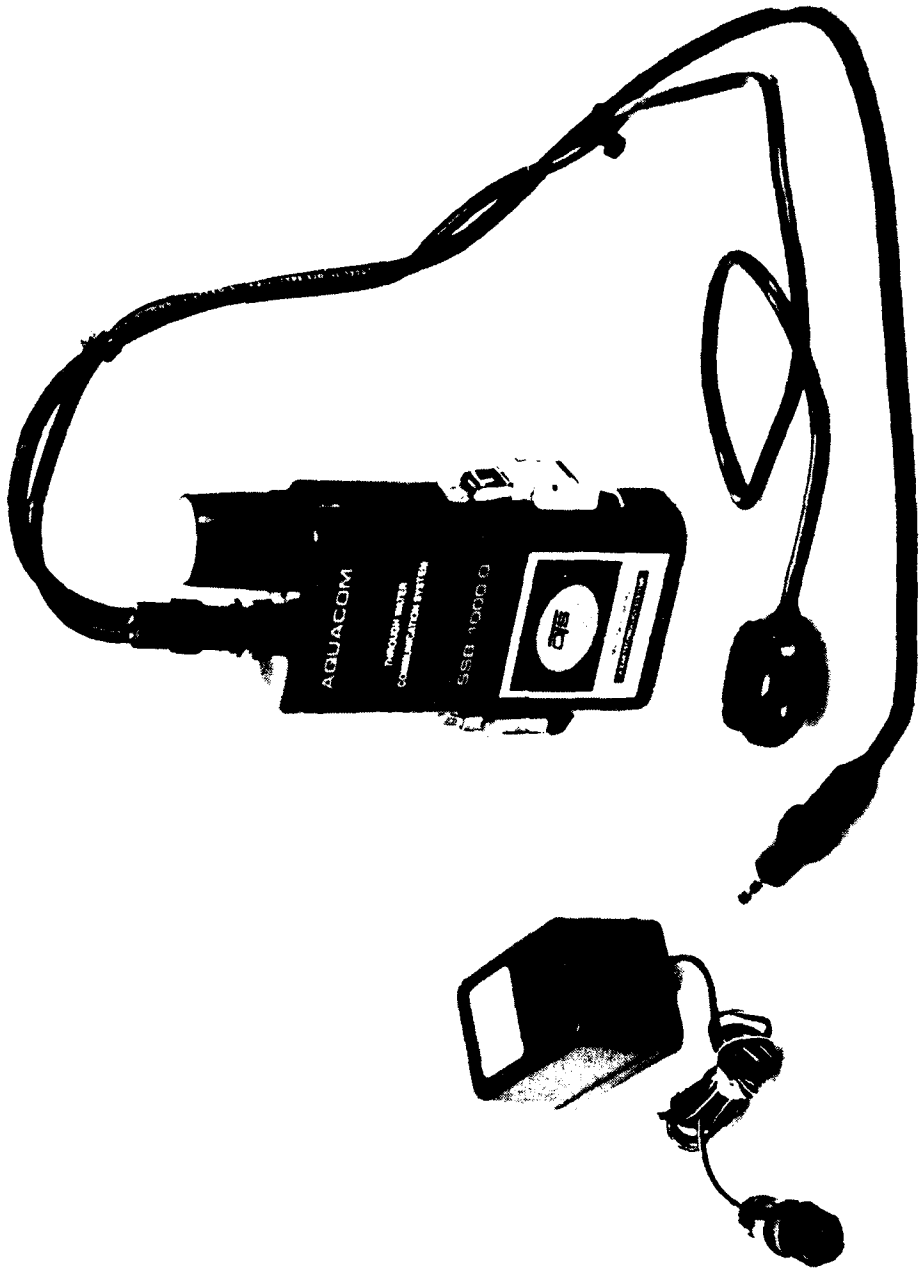

Figure 10. Ocean Technology System Diver Unit and Battery Charger

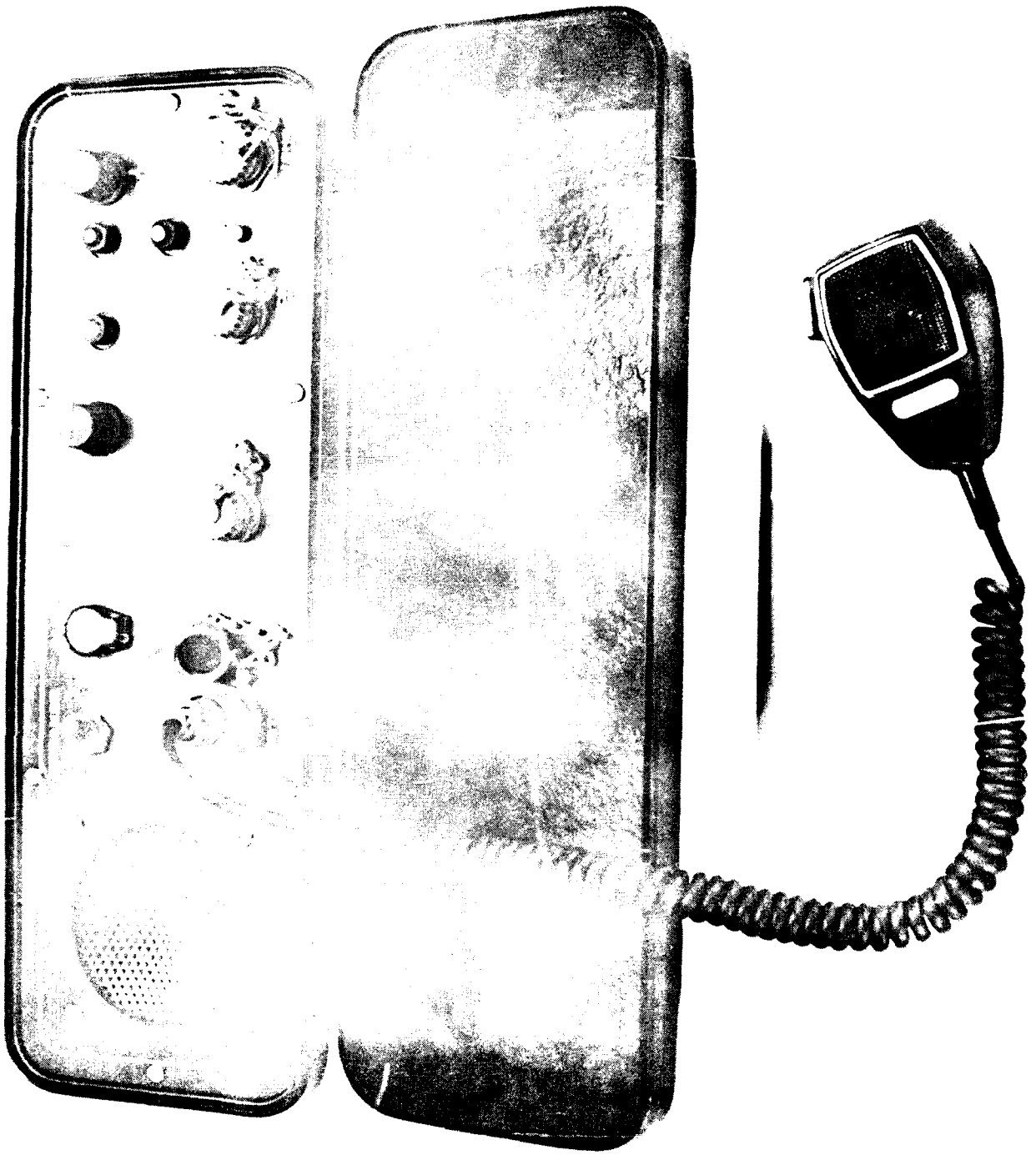

Figure 11. Ocean Technology System Surface Control Unit

Figure 12. Ocean Technology System Surface Transducer

C. Orcatron Manufacturing Ltd. Scubaphone: Surface Phone (topside control box) has the following features (Figures 13, 14, 15, and 16), red light to indicate that the unit is on, a power select switch for selecting either internal or external power, or placing the internal battery on charge via the power input connector also on the front panel, a battery indicator switch for testing the internal battery and the diver units (when they are connected via the battery charge outlets located on the front panel, a gain control switch, volume controls for the internal speaker and the tape recorder output, front panel connectors for the transducer, headset/microphone and tape recorder output. The internal battery is a Lead Acid maintenance free rechargeable (that can be changed in the field).

The Surface Phone is contained in an anodized aluminum carrying case that has a storage compartment in the cover to hold accessories and up to two Diver Phones (Figure 15). This cover can be removed when system is in use.

Diver Phone (diver worn unit) has the following features (Figures 17 and 18), the electronics, the batteries, the earphones, the power on/off switch and microphone connecting cable/push-to-talk switch are all made into one head worn earphone set. The push-to-talk switch is mounted in such a way that it can be depressed by hand or by pressing the mask against an arm or other object, it is equipped with a bayonet lock which, in the locked-in position (push in and twist), locks the Diver Phone into continuous transmission. In this position no receiving is possible. This unit is powered by rechargeable Nickel Cadmium batteries (these batteries are not field replaceable).

III. TEST PROCEDURES

Prior to starting the diving portion of the test and evaluation, all divers and topside personnel were briefed on each system to familiarize them with each systems operation and also to cover the test procedures of the test.

A. Intelligibility Tests

1. Intelligibility tests were conducted utilizing one set of divers in the water and one topside listener/operator for each test on each system, with four test being conducted on each system at 30, 60, and 100 FSW.

2. Topside and in-water test subjects (divers) used the standard NEDU MRT word lists. These word lists provide a reading list for one test subject and response lists (sheets) for the other two test subjects, this allowed for six tests per dive. All test subjects rotated through topside reader/listener and diver reader/listener positions. The MRT consists of 50 sets of words, with five words in each set (APPENDIXES A and B). The test was conducted in the following manner for this type of equipment, due to excessive bubble noise, etc.; the word is lodge, the word is lodge. Pause; the word is badge, the word is badge, etc. The reader was instructed to pause for 2 to 3 seconds between each new word (phrase). The listener who held a response sheet with the same 50 sets of words was instructed to mark the word "heard" out of each set of words. Six different reading lists and response sheets were randomly

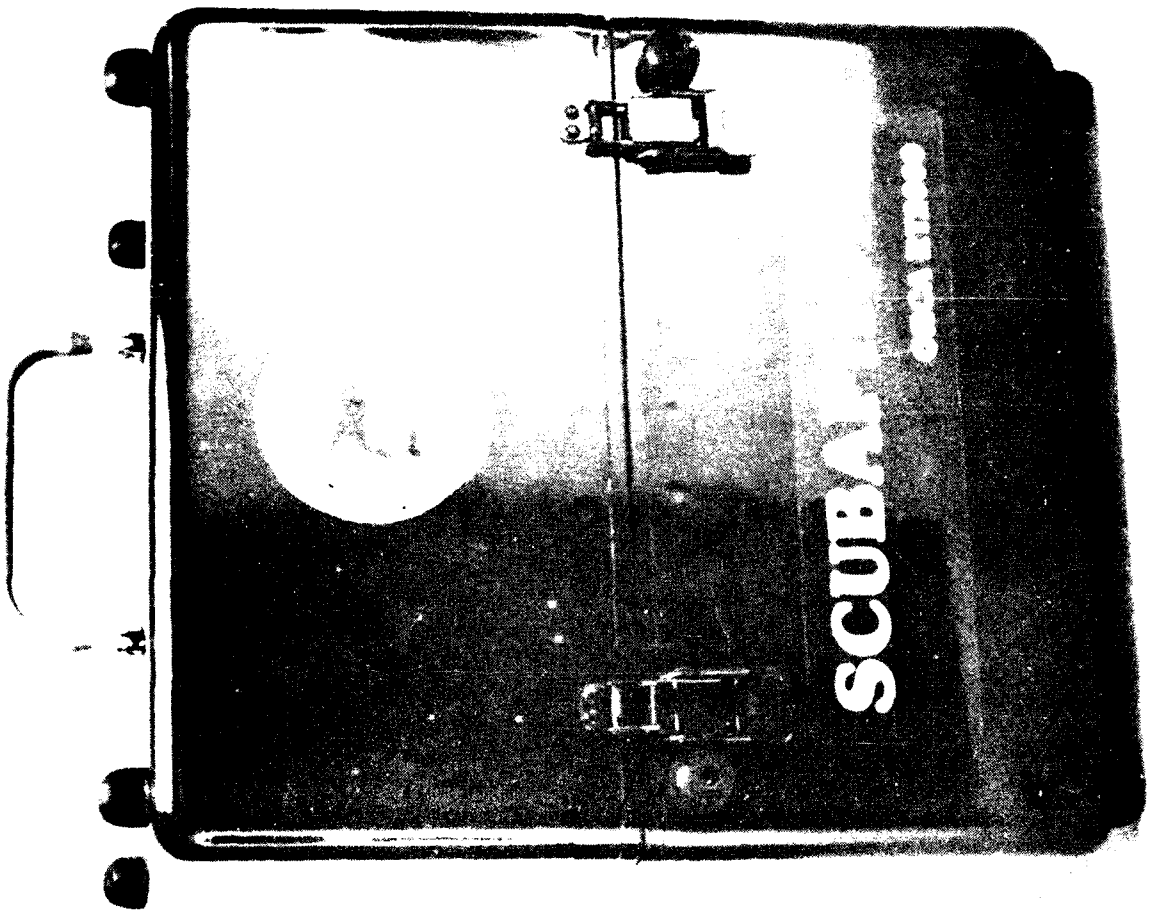

Figure 13. Orcatron Manufacturing SCUBAPHONE System in Carrying/Storage Case

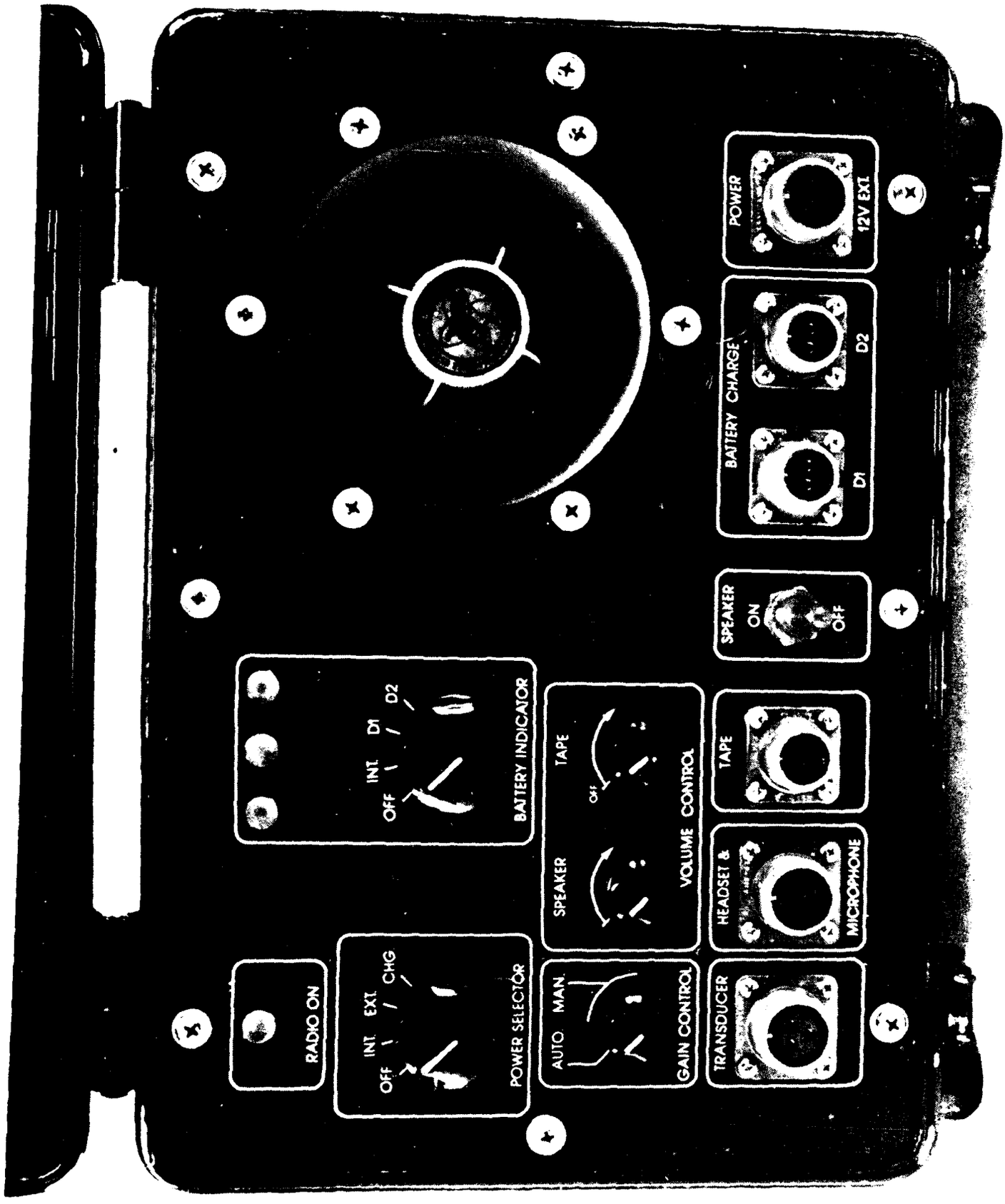

Figure 14. Orcatron Manufacturing SCUBAPHONE Surface Control Unit (Front Panel)

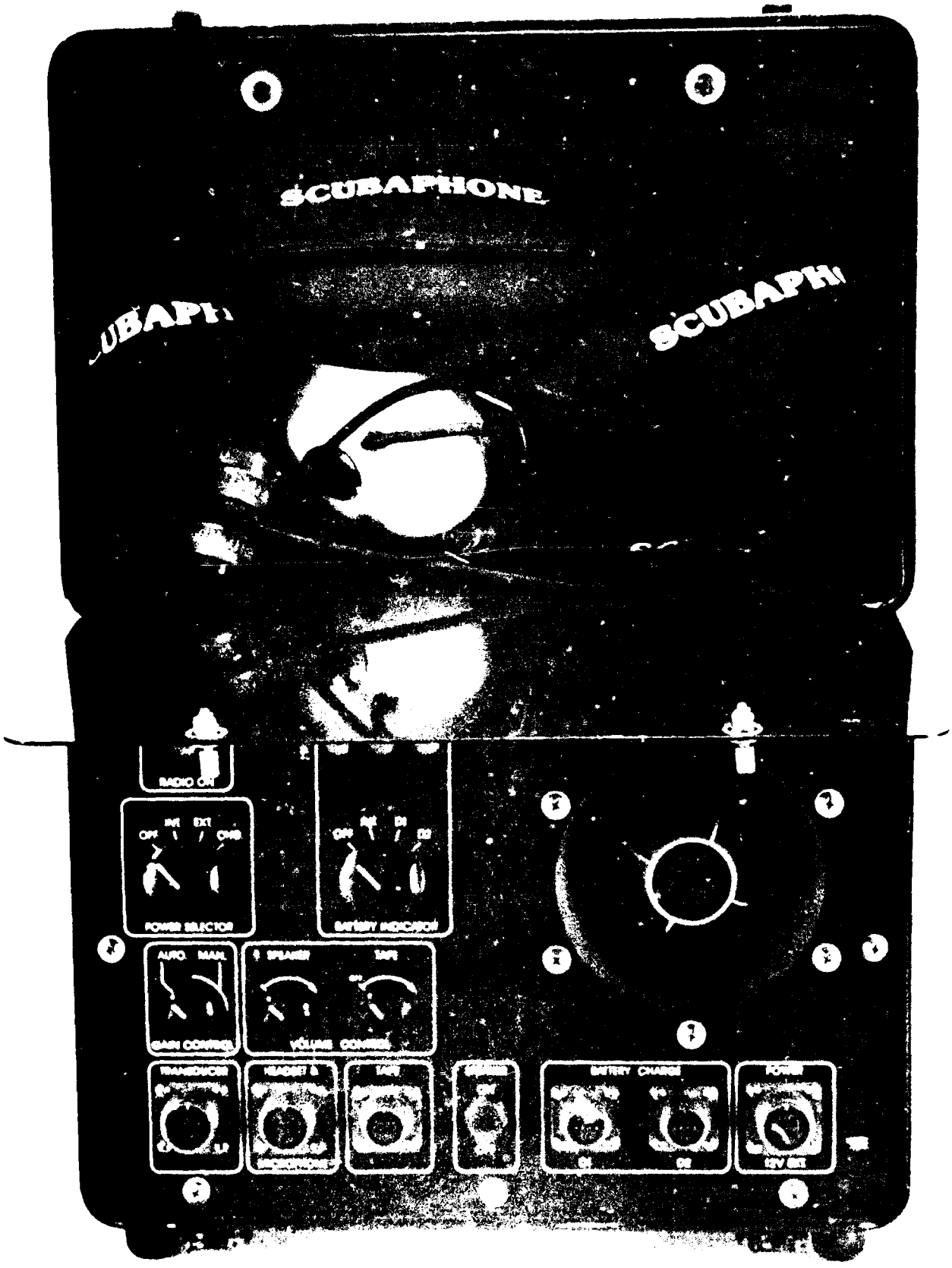

Figure 15. Oceaneering Manufactured SCUBAPHONE Surface Control Unit/Storage Compartment Open

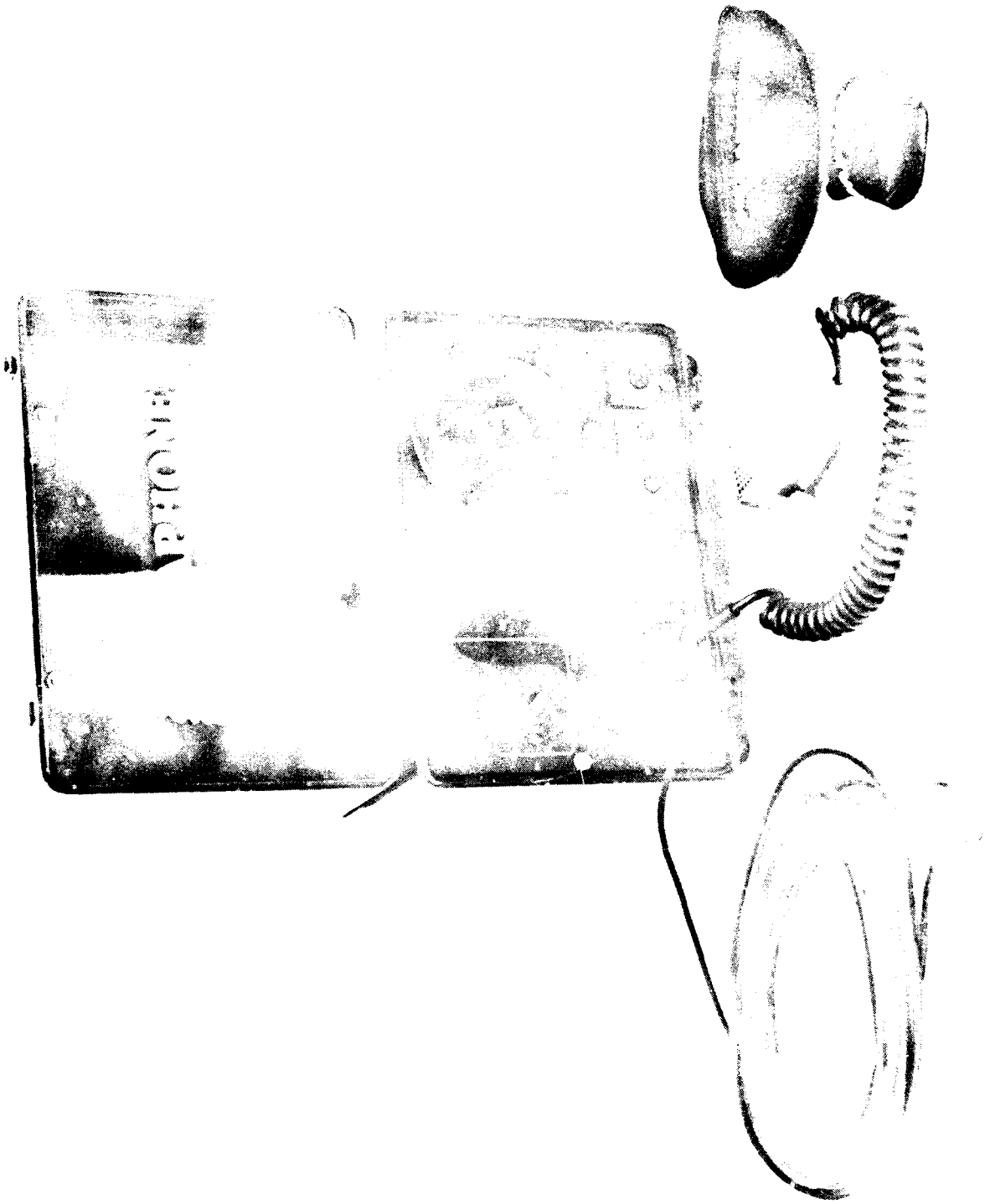

Figure 16. Orcatron Manufacturing SCUBAPHONE Surface Control Unit/Storage Compartment Closed

Figure 17. Orcatron Manufacturing SCUBAPHONE Diver Unit

Figure 18. Orcatron Manufacturing SCUBAPHONE Diver Unit With Mask

employed during the course of the evaluation, this was to insure that the test subjects did not memorize the list as the test progressed. The order of the words within each set on the various response sheets were different to counterbalance the tendency of listeners to mark the first word in a set when in doubt or when guessing. Once the response sheets are completed, the percent correct was calculated using the following formula (from Van Cott and Kincaid, 1972):

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

The result of this formula allows for the guess factor involved in this type of testing. The intelligibility criteria for military voice communications systems is set forth in MIL-STD-1472B. This military standard sets the minimum acceptable intelligibility when using the MRT as the evaluation criteria as 75% correct.

B. Distance/Range Test: Each system was tested out to a maximum distance of 300 yards from the surface controls transducer. This distance was chosen because, as a general rule, dive teams conducting work in SCUBA are not allowed to be further than this from the dive supervisor, even when conducting pier/seawall inspections.

C. Human Engineering Evaluation: Following each test dive, each test subject was required to complete a questionnaire, evaluating the system used for pre-dive, in-water and post-dive aspects of the test systems (APPENDIX C). The manuals and or literature provided with each system was evaluated for ease of locating needed information to operate and maintain the test systems.

D. Maintainability/Bench Tests: Each system was subjected to bench tests using MIL-STD-810C section 507.1, 507.9, and 516.2 as guidelines. The maintainability of each system was evaluated as the test progressed and by studying the furnished material of each manufacturer.

IV. RESULTS AND DISCUSSION

A. Intelligibility Tests: Intelligibility is one of the main deciding factors in placing any communication equipment on the Authorized for Navy Use (ANU) list, an objective means of assessing the intelligibility of the test articles was required. The Griffiths (1967) version of the previously developed Modified Rhyme Test (MRT) (House, et al, 1965) was utilized for this purpose. It was chosen because of its ease of administration and scoring, its stability with respect to learning effects, because it requires minimal user training and it has been used on all test and evaluation efforts on diver communication equipment of this type for several years. 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 systems submitted for testing by Ocean Technology Systems of the United States, Safare-Crouzet of France, and Orcatron Manufacturing Ltd. of Canada, all surpassed the minimum requirement of 75% word intelligibility at all test depths and therefore overall, with less than 2% spread in the overall scores therefore they all are considered equal in this area.

All systems were tested for intelligibility at 30, 60, and 100 FSW. All diver test subjects were checked and found to have acceptable hearing levels to meet all of the U.S. Navy and Canadian Forces requirements with no waived areas.

B. Distance/Range Tests: Each of the test articles were tested for distance/range with dive teams at approximately 15 FSW and at the surface out to a maximum distance of 300 yards from the surface transducer with the surface transducer hanging at 10 FSW, from a small boat, the dive teams were deployed from another small boat every 25 yards out to the maximum range. The depth of water during this phase of the test and evaluation was from 20 to 34 FSW, the dive teams were deployed along a seawall 6 to 10 feet out from it, the surface transducer was hanging over the outboard side of a 25 foot boat that was moored to the seawall.

All of the systems were found to provide good communications out to the maximum range, when the divers were submerged, due to the location of the diver transducer on the Orcatron system, the divers could not receive or transmit when they were on the surface. The systems provided by Safare-Crouzet and Ocean Technology Systems, both provided good diver to diver and diver to surface communication, with the divers on the surface. The Ocean Technology Systems system provided the additional benefit of the divers being able to communicate with both hands free using their VOX option, all of the other systems require the use of a push-to-talk switch. The Orcatron system's PTT was located on the front of the face mask of the test system, however they have several optional locations available, the PTT for the Safare-Crouzet system was located on the diver unit which is intended to be (and was) worn strapped to the diver's thigh.

As part of this portion of the test and evaluation of the test articles, all of which are of the single side band type, a ships hull, a seawall and bridge pilings were inspected to determine if the SSB type systems are better suited for this type work over the presently authorized systems. The following results were noted:

1. Diver-to-Diver communication was possible, with divers on opposite sides of a ships hull, were as with the presently authorized equipment this has not been possible. The only problems noted were that with the Orcatron (Scubaphone) if the divers had their heads out of the water they were not able to communicate due to the fact that the diver's transducer in on top of the diver's head, the communications between divers and from divers to the surface is effected by shadowing caused by objects between the respective transducers but communications were still possible.

2. Diver-to-Diver and Diver-to-surface communications were possible in most cases when the divers were conducting bridge pilings inspections, at times if the divers were completely shielded by being on opposite sides of a solid concrete piling and both divers were at the bottom communications were so weak, on all test systems, that for all practical purposes communications was not possible, however if the divers were off the bottom more than a few feet communications were improved to an acceptable level, even though still diminished from line of sight level of communication.

Another phenomena, of the SSB type systems, that was found/verified during this testing was with all of the test systems there is a varied level of echo effect, this did not create a problem unless the divers talked too fast, then their words would overlap and become unintelligible, this was not a problem in deep water. This echo effect or bouncing of the signal is what allows for communications around/under objects, therefore it is acceptable but divers need to be trained in the proper use of the equipment and in the proper methods for communicating with Single Side Band through-water communication systems. All diver communications equipment requires divers to speak slow and distinctively to achieve the best possible communication link, this is especially true with wireless diver communication equipment and can not be over-stressed.

3. During this phase of the evaluation it became apparent that the VOX option of the Ocean Technology Systems (OTS) system was a real asset, by allowing the divers to have both hands free to work and still have good communications diver-to-diver and diver-to-surface. OTS does, however, offer their system with a push-to-talk switch with a cable long enough to allow it to be strapped to the diver's wrist for easy reach or it can be clipped onto the diver's vest. When submerged completely the divers could activate to push-to-talk switch on the Orcatron (Scubaphone) by pressing the front of their mask against their arm are some other object, but this was awkward. The Safare-Crouzet system requires the diver to activate the push-to-talk switch by using a hand, the only variance is the unit can be strapped to either thigh, thus allowing the use of either left or right hand.

4. The recommended position of the diver units on all three test systems was found to be good with a few exceptions. Body/equipment shadow effect is a concern with both the Safare-Crouzet and the Ocean Technology Systems diver units, the Orcatron diver unit is worn on the diver's head and is not as prone to this problem but is as prone to shadow effect caused by other objects, ships hulls, rocks, pilings, etc.

C. Human Engineering Evaluation:

1. Safare-Crouzet ERUS-2-B4 (Surface Unit). The surface unit for the Safare-Crouzet system is a well designed unit with controls that are clearly marked in both French and English and were easy to operate. The headset and microphone were both hard wired in place this eliminates the need for two connectors but if one of these components fails during an operation especially the microphone it could cause a delay longer than if these components could be

replaced with out removing the front panel of the surface box. The system came with a French A.C. plug on the power cord this had to be adapted to the type used in the U.S., the company representative was contacted and his response was this could be changed in the future at the factory are adapters could be furnished, if specified at the time of procurement. One other short coming of this system was there is only one outlet for charging the divers units (ERUS-2-A3) and since normal diving operations require two divers this will increase the recovery time between dives. One nice feature that this system has, that is not on other systems tested, is a built in tone key that allows transmission of modulated telegraphic signals, this feature was tested as a call system by holding in the key for a few seconds, this would be very useful if a diver is working in a tight space or for just getting divers attention before sending a verbal transmission. The storage compartment at the bottom for the headset and microphone is convenient and helps keep/protect these components, another convenient feature is the method for storing the cover on the back of the surface box. This is a very well thought out system and was well received by the divers/test subjects.

2. Safare-Crouzet ERUS-2-A3 (Diver Unit). The Safare-Crouzet diver worn unit is made to be worn on the diver's thigh this created a problem for short and medium height divers due to it's length, a shorter version is being produced but was not completed at the time of testing except in prototype. It's length appears to be better suited to being worn on the diver's thigh but it has other problems that will not be covered in this report since it was not officially a test article. The controls on the ERUS-2-A3 unit were easy to operate and the dive/test subjects had little to no problems in becoming familiar with their location and functions. One bad feature is that in order to operate the push-to-talk switch the diver must have a free hand this would hamper several types of underwater work. Another item that caused minor problems during testing was the straps that hold tne unit on the diver's thigh, if improperly tightened they can cause some circulation problems and at best when worn on bare legs they cause discomfort by pulling hair and pinching flesh while swimming, dressing and undressing. Also the earphone caused some minor problems due to the divers were not wearing wet suit hoods, this was overcome by the use of a cloth skull cap, but the earphone should come with a better method of attaching/holding it in place.

3. Ocean Technology Systems Aquacom SSB-1000 (Surface Unit). The OTS surface unit's controls were all clearly marked and were easy to operate. The labeling clearly denoted the function of each knob, switch and connector and could be read in dim light with ease. The only misleading item was the battery charge indicating light, it only emits light when the battery requires a high current charge this happens when the battery is approximately 80 percent exhausted. This light's intensity will diminish as the battery charge current is reduced. The Operator's Manual on this unit is well written and easy to follow when basic troubleshooting is needed, it covers the necessary areas for operation and normal maintenance.

4. Ocean Technology Systems Aquacom SSB-1000D (Diver Unit). The OTS diver unit is light weight and clip on to any belt type strap on the diver's apparel, it relatively easy to put on and take off. This unit has no external

controls for the diver to operate, except the push-to-talk button when using the systems in this mode, this can be placed in several covenant locations, i.e arm, vest, belt, etc. The only controls/adjustments are located inside the unit and can be accessed by removing the battery portion of the housing, they clearly marked as to their function and the operators manual gives clear instructions on how to and when to make adjustments. The electronics portion of this unit is not field repairable due to the potting material used to insure waterproofing and reduced damage if the housing should flood (which is the most probable cause for the need to repair). This Unit can also serve as a surface unit when used with the CDK-3 Surface Conversion Kit (This is beneficial when operating from a small boat, but does have less range than the standard surface unit). The Operators Manual on the unit covers the operation and normal maintenance/troubleshooting very well and give a very good explanation of the Basics of Sound in Water.

5. Orcatron Manufacturing Ltd. Scubaphone ORCA RT-2000 (Surface Unit). The Scubaphone surface unit is housed in an aluminum case that has several well designed features and affords good portability. The controls are well laid out, the functions are clearly marked and divided into groups that help in the operation of the systems. The control knobs are good for their design functions, with a few minor exceptions, the Gain control when in the manual mode can be rotated more than 330°, far beyond the marking before it hits its stop, this is also found on the speaker volume control and the tape recorder output control, these control knobs are also small and could cause some difficulty in operating with wet or gloved hands. The storage compartment in the lid allows for storage of key components and is a nice feature for transporting the system. The dark blue finish in hot weather does cause the system to collect heat but did not appear to cause problems in the operation of the system during the test, but if the system were to be used in the tropics the color might need to be changed.

6. Orcatron Manufacturing Ltd., Scubaphone RT-2000 (Diver Unit). The Scubaphone diver unit is housed in a set of plastic earphone cups. The electronics are potted in one and the batteries in the other, the diver unit is not field repairable and the batteries can not be replaced in the field, the unit must be sent back to the factory in Vancouver Canada for this type of service. The package is compact and can be put on and off the diver with ease, but unless a hood is worn are extra rubber added to the earphone area the unit tends to slide off when in the head down mode or when moving about with little more than normal head movement. The method of connecting the diver's microphone/mask to the unit is a very good and easy method, the only problem experienced during the test was the push-to-talk switch was accidently lock on several times and when this happens the diver is in the transmit mode and can not be reached by topside or other divers and this adds steady noise to everyone's earphones making communication with other divers difficult.

The on/off switch is located on one of the earphone cups and is very easy for the diver to turn on or off, in fact it was found that this switch could and was turned of by the brushing against it while in the water also there were time when the unit was left turned on when on the surface and the dive

team thought it was off, the bottom line is this switch is in a good location but needs to be a more positive acting type.

The manual that normally comes with this system is good and is adequate for normal operation and upkeep, a special repair manual can be procured separately if desired and with this manual repairs can be accomplished to the surface unit, but the diver unit still must be returned to the factory for repairs or replacement of the batteries.

D. Maintainability/Bench Tests

1. Safare-Crouzet ERUS-2B4 (Surface Unit) & ERUS-2A3 (Diver Unit). These units are designed in such a manner that they can be maintained by qualified technicians. The Technical Manual, provided on special request, is complete and gives adequate information to allow repairs and planned maintenance, in a format understood by U.S.Navy trained technicians. The parts list for each of these units also includes NATO stock numbers that in several cases can be cross referenced to National Stock Numbers (NSN) this can save allot of time when making repairs. During bench testing no problems were encountered and quality of workmanship and components appear to be of the best commercial level. This system is the only one of the three systems tested that repairs can be made to both the diver unit and the surface unit, in the field, by qualified technicians.

2. Ocean Technology Systems Aquacom SSB-1000 (Surface Unit). The OTS surface unit is designed in such a manner that it can be repaired by qualified technicians, however the manual does not provide adequate information to allow any repairs other than board/assembly replacement using OTS replacement parts. In most cases this is acceptable but a better manual/spare parts list and schematics are needed in order to allow for complete field repairs. During bench testing of this unit no problems were encountered and quality of workmanship and components appear to be of the best commercial level.

3. Ocean Technology Systems Aquacom SSB-1000D (Diver Unit). The OTS diver unit is designed in such a manner that very few field repairs can be made, it does allow for easy replacement of the batteries and repair to the battery connector. The electronics are potted into the upper portion of the housing and are not repairable, this has one advantage, if the housing floods the electronic probably will not suffer any damage but this disadvantage is if damage does occur it can not repaired no matter how slight the damage. Therefore a simply failure would lead to return to manufacture and possible replacement of the unit since repairs even at the factory are limited.

4. Orcatron Manufacturing Ltd. Scubaphone RT-2000 (Surface Unit). The Scubaphone surface unit is designed in such a manner that repairs and maintenance can be accomplished by qualified Navy technicians. The user manual provides information needed for operation and basic troubleshooting. There is also a Repair Manual available that provides information needed to make field repairs, by trained technicians, with complete schematics and parts lists. During Bench testing workmanship and parts were found to be of the

best commercial level, with one small exception the method used to hold the battery could allow the battery to come loose during rough handling experienced during transport via commercial air. Also the internal wiring could be secured better. However no problems were experienced during the bench test portion of the evaluation.

V. CONCLUSIONS

The three systems that were tested and evaluated all passed the intelligibility portion with less than a two (2) percent spread overall. The scores ranged from 77.9% to 79.2%, while these scores are less than previous scores obtain using systems that transmit via Amplitude Modulated (AM) carrier frequencies, these systems provide better means of communication with and between divers, in the type of diving scenario found during day to day diving operations.

The range of all three systems tested is considered to be satisfactory to meet foreseeable U.S.Navy requirements. The range test were limited to U.S.Navy diving scenario and it is felt that all of the test systems have ranges beyond the test range. Also all of the systems tested meet the basic requirements for human engineering, material, maintainability and reliability, with the few exceptions listed in the text of this report.

The three systems were also evaluated for diver/operator preference, based on experience gained during the course of the test and evaluation period. Seventy percent of the diver/operators picked Ocean Technology Systems' Aquacom 1000/1000D system as number one, twenty percent picked the Orcatron Manufacturing Ltd., Scubaphone RT-2000 system and the remaining ten percent picked the Safare-Crouzet ERUS-2A3/ERUS-2B4 system. The major portion of the likes and dislikes expressed by this group were ease of operation, dressing and undressing the diver, plus comfort while diving with the unit attached to the diver. Some of these scores might have changed if the testing had been conducted during cold weather were the divers would be wearing wet suits and hoods.

APPENDIX A

READING LIST 2

	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	dee	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

APPENDIX B

NAME: _____ RIG OR LOCATION: _____ DATE: _____

RESPONSE SHEET 2

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

APPENDIX C

COMMUNICATION EVALUATION FORM

System Used:

Date:

Depth:

Total Time of Dive:

Pre-Dive:

Donning	_____ Easy	_____ Slight Difficulty	_____ Difficult
Check	_____ Good	_____ Marginal	_____ Poor

Remarks: _____

_____

During Dive:

In Water Check	_____ Good	_____ Marginal	_____ Poor
Legibility	_____ Good	_____ Marginal	_____ Poor
Comfort	_____ Good	_____ Marginal	_____ Poor

Distance between divers:

Remarks: _____

_____

Post-Dive:

Doffing	Easy	____ Slight Difficulty	Difficult

Remarks: _____

_____

APPENDIX C

HUMAN FACTORS ASSESSMENT

THIS INFORMATION SHALL BE RECORDED AS NARRATIVE TO CALL PARTICULAR ATTENTION TO THOSE CHARACTERISTICS OF THE TEST ARTICLE WHICH, FROM THE ASPECT OF HUMAN ENGINEERING DESIGN PRINCIPLES, ENHANCE OR IMPEDE THE EFFICIENT USE OF THE TEST ARTICLE TO PERFORM ITS INTENDED FUNCTION.

TEST ARTICLE (NAME, MODEL, NUMBER, ETC.):

_____

_____

THE FOLLOWING AREAS OF INTEREST SHOULD BE CONSIDERED UNDER BOTH NORMAL DAYLIGHT CONDITIONS, AND UNDER DURESS, SUCH AS NIGHT, WHEN WEARING FOUL WEATHER GLOVES, ETC. THOSE CONTROLS WHICH WOULD BE OPERATED BY THE DIVER SHOULD BE ASSESSED WHEN OPERATED BY PERSONNEL WEARING WET SUIT GLOVES.

1. CONTROLS: (A) CONSISTENCY OF MOVEMENT _____

(B) GROUPING _____

(C) LOCATION OF PRIMARY CONTROLS _____

(D) LOCATION OF EMERGENCY CONTROLS _____

2. LABELS: (A) ORIENTATION AND LOCATION _____

(B) VISIBILITY AND LEGIBILITY _____

(C) DURABILITY _____

3. HANDLING: (A) SIZE AND WEIGHT OF MAJOR SUBSYSTEMS _____

(B) SIZE AND LOCATION OF HANDLES _____

4. INTERFACES: (A) EXTERNAL-CONNECTORS PINNED TO PREVENT IMPROPER MATING AND MISALIGNMENT _____

(B) EXTERNAL-CONNECTORS MAY NOT BE INSERTED INTO WRONG RECEPTACLES _____

(C) INTERNAL-SPARE AND REPAIR PARTS MAY NOT BE INSTALLED WITH IMPROPER ORIENTATION INTO MAJOR SUBSYSTEMS _____

DATA RECORDED BY: _____
NAME RATE/RANK/TITLE

DATE: _____

APPENDIX C

MATERIAL SUITABILITY ASSESSMENT

THIS INFORMATION WILL BE RECORDED AS NARRATIVE TO CALL PARTICULAR ATTENTION TO THE SUITABILITY OF THE TEST ARTICLE WITHIN THE FLEET ENVIRONMENT. EXAMPLES OF PARTICULAR AREAS FOR CRITIQUE ARE LISTED BELOW.

TEST ARTICLE: (NAME, MODEL NUMBER, ETC., INCLUDING THAT OF LIGHT SOURCE)

_____

_____

_____

_____

HARDWARE ASSESSMENT: (NARRATIVE TO DESCRIBE THE OVERALL RUGGEDNESS AND QUALITY OF WORKMANSHIP OF THE TEST ARTICLE. COMMENTS REGARDING EASE OF SET-UP AND TEAR-DOWN, MAINTENANCE, AND INTERFACES WITH APPROVED DIVING AND HUSBANDRY EQUIPMENT SHOULD BE ADDRESSED HERE.)

_____

_____

_____

_____

SOFTWARE ASSESSMENT: (NARRATIVE TO DESCRIBE THE CLARITY, COMPLETENESS, AND UTILITY OF THE TECHNICAL DOCUMENTATION PROVIDED BY THE TEST ARTICLE MANUFACTURER. MAINTENANCE DOCUMENTATION SHOULD BE ASSESSED AS EQUAL IN IMPORTANCE TO OPERATIONAL DOCUMENTATION.)

_____

_____

_____

_____

LOGISTIC ASSESSMENT: (NARRATIVE TO DESCRIBE THE COMMERCIAL AVAILABILITY OF SPARE AND REPAIR PARTS FOR THE TEST ARTICLE, AND OTHER CHARACTERISTICS OF THE MANUFACTURER'S MARKETING SCHEME WHICH WOULD PARTICULARLY ENHANCE/IMPEDE SUPPORTING THE TEST ARTICLE WITH REASONABLY HIGH AVAILABILITY AT THE ORGANIZATIONAL LEVEL.)

_____

_____

_____

_____

DATA RECORDED BY: _____

NAME RATE/RANK/TITLE

DATE: _____

APPENDIX C

QUESTIONNAIRE ON THRU-WATER COMMUNICATION EQUIPMENT

THIS QUESTIONNAIRE IS FOR THE PURPOSE OF GRADING THE BELOW LISTED SYSTEMS AS TO DIVER/OPERATOR PREFERENCE. EACH SYSTEM IS TO BE GRADED FROM (1) TO (4) AS TO THE BEST LIKED TO THE LEAST LIKED, WITH (1) BEING THE BEST.

SAFARE-CROUZET ERUS 2A3/ERUS-2B4 UNDERWATER TELEPHONE (1)__ (2)__ (3)__ (4)___

OCEAN TECHNOLOGY SYSTEMS AQUACOM SSB-1000D (1)__ (2)__ (3)__ (4)___

ORCATRON MANUFACTURING LTD. SCUBAPHONE (1)__ (2)__ (3)__ (4)___

MARCONI UNDERWATER SYSTEMS THRU-WATER MODULE (1)__ (2)__ (3)__ (4)___

COMMENTS: _____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

DATA RECORDED BY: _____
NAME RATE/RANK/TITLE

DATE: _____