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MAR 80 J R MIDDLETON
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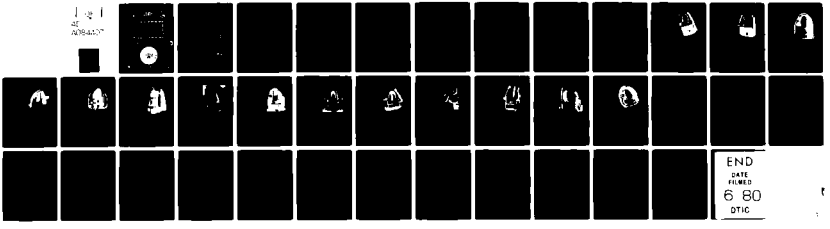

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DEPARTMENT OF THE NAVY
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Panama City, Florida 32407

NAVY EXPERIMENTAL DIVING UNIT
REPORT NO. 1-80

EVALUATION OF COMMERCIALLY AVAILABLE BUOYANCY COMPENSATORS

James R. Middleton

March, 1980

Approved for public release; distribution unlimited

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The Navy Experimental Diving Unit evaluated methods of inflation and performance characteristics of fourteen commercially available buoyancy compensators for use with standard scuba. As a result of manned and unmanned testing, five buoyancy compensators were found to be preferred for use by Navy divers.

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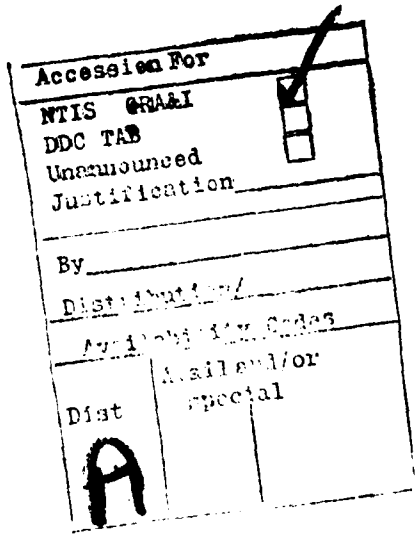
TABLE OF CONTENTS



LIST OF TABLES

GLOSSARY

ANU	Approved for Navy Use
B/C	buoyancy compensator
CO_2	carbon dioxide
fsw	feet of seawater
L.P.	low pressure
NEDU	Navy Experimental Diving Unit
OSF	Ocean Simulation Facility
pony bottle	A small, independent high pressure air cylinder carried in addition to a diver's primary SCUBA.
prone	lying face down
psig	pounds per square inch gauge
scuba	self-contained underwater breathing apparatus
UBA	underwater breathing apparatus
U.S.D.	U. S. Divers Company

ABSTRACT

The Navy Experimental Diving Unit evaluated methods of inflation and performance characteristics of fourteen commercially available buoyancy compensators (B/Cs) for use with standard scuba. As a result of manned and unmanned testing, five buoyancy compensators were found to be preferred for use by Navy divers.

INTRODUCTION

BACKGROUND

By direction of the Commander, Naval Sea Systems Command (reference 1) NEDU evaluated 14 commercially available B/Cs (Table 1) for use with standard open circuit, demand scuba.

After a survey of the market, a representative sample of 14 B/Cs were purchased which included the three styles currently available: backmounted, jacket style, and horsecollar. The backmount has its inflatable bags mounted on the scuba tank backpack, the jacket style serves as a harness with air bags built into the jacket, and the conventional horsecollar style fits around the neck and down the diver's chest. The manufacturer, model and style of each B/C tested are listed in Table 1.

It is important to note that a buoyancy compensator is defined, in U.S. Navy terms, as a diver buoyancy control device incorporating oral inflation, emergency inflation by CO_2 cartridges, and inflation via L.P. air supply. This air supply may be powered from the diver's first stage regulator or an independent pony bottle. A standard life jacket is defined as a horsecollar-style vest which has only CO_2 cartridge and oral inflation capability.

EQUIPMENT DESCRIPTION

The 14 buoyancy compensators tested are described and illustrated on the following pages. The descriptions are those supplied by the manufacturers and represent features which they feel are unique to their design.

TABLE 1

BUOYANCY COMPENSATORS TESTED

MANUFACTURER	MODEL NO.	STYLE
DACOR CORPORATION 161 Northfield Road Northfield, IL 60093 (312)446-9555	SEACHUTE Model No. BC1	Horsecollar
	SEACHUTE Model No. BC4	Horsecollar
SCUBAPRO USA 3105 E. Harcourt Compton, CA 90221 (213)639-7850	BUOYANCY CONTROL PACK Model No. 21-023-000	Backmounted
	STABILIZING JACKET Model No. 21-028-300	Jacket
	BUOYANCY COMPENSATOR VEST Model No. 21-020-000	Horsecollar
SEAPRO 18030 S. Euclid St. Fountain Valley, CA 92708 (714)979-6730	ATPAC Model No. BBC-S	Backmounted
SEATEC Division of Inflatable Systems, Inc. P. O. Box 1109 600 N. Batavia St. Orange, CA 92666 (714)639-6662	BUOYANCY COMPENSATOR Model TD1002	Horsecollar
	SUNFISH 420 Nylon Model No. 10396-31/33	Horsecollar
	SUNFISH TUFF TIGER Model No. 10396-01/04	Horsecollar
AMF Voit Swimaster 3801 South Harbor Blvd. Santa Ana, CA 92704 (714)546-4220	BUOYANCY COMPENSATOR VEST Model No. GBC-1	Horsecollar
U.S. Diver's Co. 3323 West Warner Ave. Santa Ana, CA 92702 (714)540-8010 Telex 67-8414	SEA OTTER Model No. 7776-00	Jacket
	BUOYANCY COMPENSATOR VEST Model No. BC700	Horsecollar
U.S. Navy	MARK IV LIFE JACKET	Horsecollar
WHITE STAG 363 W. Victoria St. Gardena, CA 90248 (213)538-9540	BUOYANSATOR IV Model No. 53962	Horsecollar

DACOR SEACHUTE
Style: Horsecollar
Model No.: BC1
Color: Red, Silver

Design Features:

- Urethane-coated ballistic nylon shell over two internal bladders
- Ultrasonically welded seams and sewn edge bindings
- Single large zippered pocket with sewn-in key ring and plastic diver identification card that fits into its own pocket
- True spiral oral inflation hose, made of bacterial resistant neoprene, for air side inflation and manual deflation
- Lip-stop cold water mouthpiece which prevents confusion with snorkel or regulator
- Surface signal whistle
- Quick drain mesh in bottom panel
- Overpressure relief valve (with quick-purge)
- Separate inflate/deflate hose and overpressure relief valve for CO_2 bladder
- 38-gram CO_2 cartridge for emergency use
- *Dual bladder design
- Oral inflation hose
- Emergency backup inflation (from dual bladder design)
- Optional power inflator
- Complete separation of air and CO_2 bladders (prevents accidental inhalation of CO_2)

*The dual bladders are sandwiched together with the air bladder in the front and the CO_2 bladder in the back of the vest.

DACOR SEACHUTE
Style: Horsecollar
Model No.: BC4
Color: Red, Silver

Design Features:

- Urethane coated ballistic nylon shell over two internal bladders
- Ultrasonically welded seams and sewn edge bindings
- Single large zippered pocket with sewn-in key ring and plastic diver identification card that fits into its own pocket
- True spiral oral inflation hose, made of bacterial resistant neoprene, for air side inflation and manual deflation
- Lip-stop cold water mouthpiece which prevents confusion with snorkel or regulator
- Surface signal whistle
- Quick drain mesh in bottom panel
- Overpressure relief valve (with quick-purge)
- Separate inflate/deflate hose and overpressure relief valve for CO_2 bladder
- 38-gram CO_2 cartridge for emergency use
- *Dual bladder design
- Oral inflation hose
- Emergency backup inflation (from dual bladder design)
- Optional power inflator
- Complete separation of air and CO_2 bladders (prevents accidental inhalation of CO_2)

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*The BC4 dual bladders are arranged above and below each other. The CO_2 bladder occupies the volume around the diver's neck/chest, and the air bladder is located beneath it on the diver's stomach.

SCUBAPRO BUOYANCY CONTROL PACK

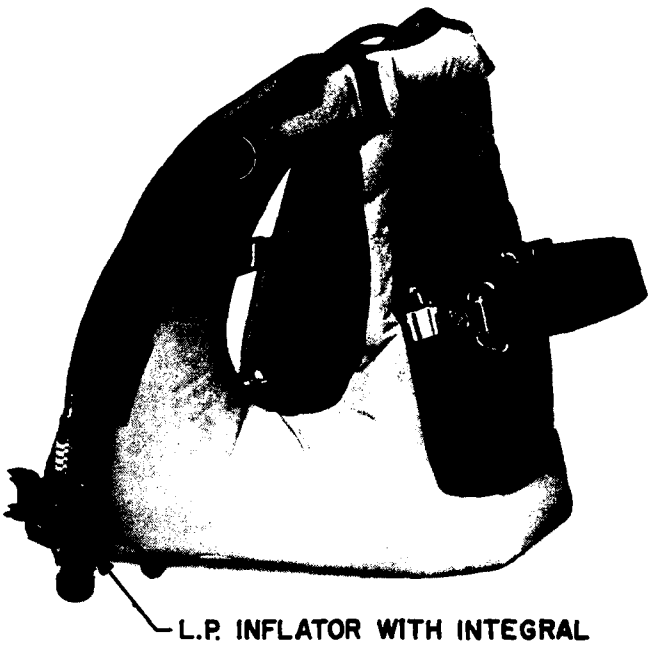
Style: Backmounted
Model No.: 21-044-000
Color: High visibility orange

Design Features:

- Combines Scubapro Contour Scuba Pack and the Scubapro Buoyancy Compensator
- Unrestricted view with flotation out of sight
- Two 38-gram CO_2 cartridges for emergency use
- Quick-release tank band for easy removal
- Surface signal whistle
- Quick-release shoulder and waist strap buckles for quick and easy don and doff, in or out of the water

SCUBAPRO STABILIZING JACKET

Style: Jacket
Model No.: 21-048-000
Color: High visibility orange

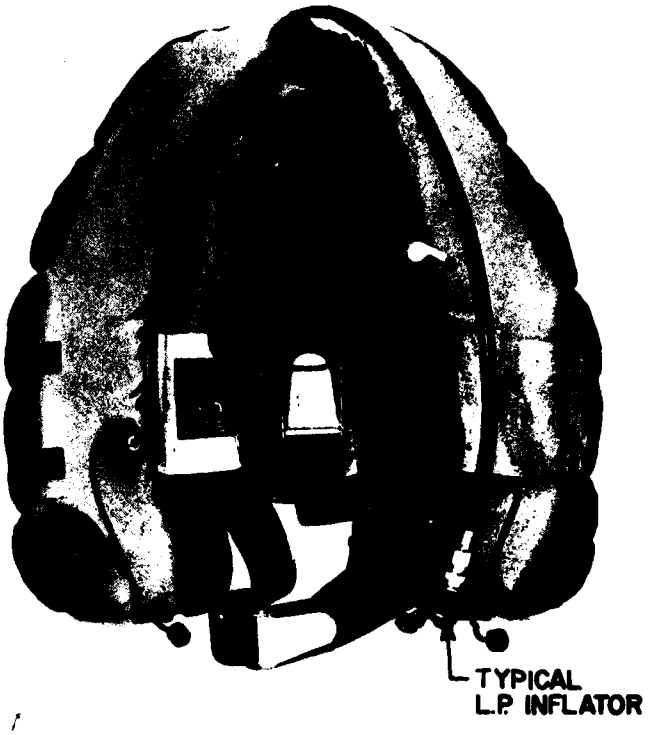


Design Features:

- Combines B/C flotation with back-flotation backpack
- Keeps entire torso buoyant
- Easy entry or exit, in or out of water
- Compact
- Rides surface diver high in the water
- Automatic or manual overpressure relief valve
- Manual dump valve
- Two 38-gram CO_2 cartridges for emergency use
- Available in four sizes

SCUBAPRO VEST

Style: Horsecollar
Model No.: 21-020-000
Color: High visibility orange



Design Features:

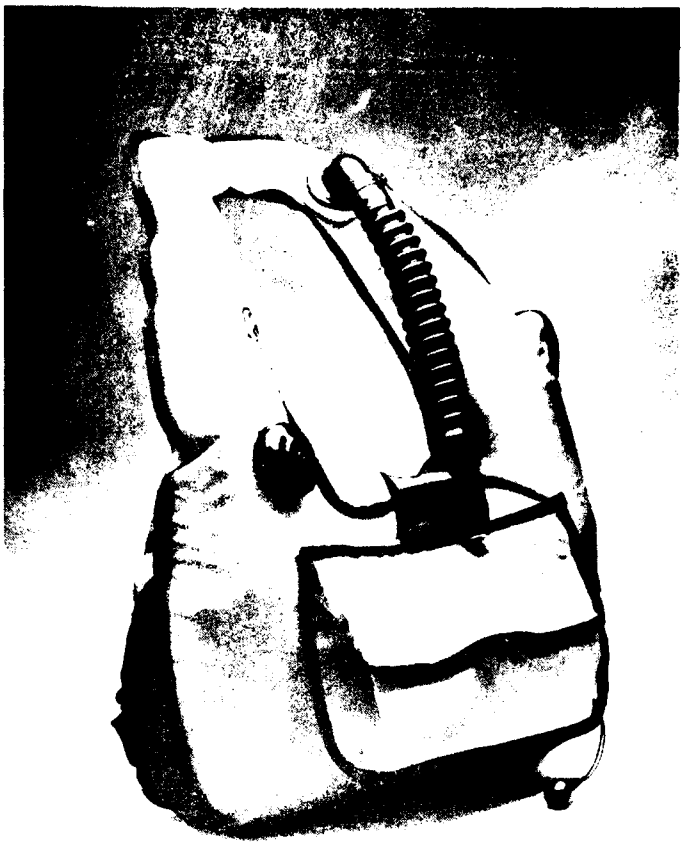
- Buckled waist and crotch strap
- Two 38-gram CO_2 emergency inflators
- Large inflator hose
- Overpressure valve
- Combined inlet/exhaust valves and mouthpiece
- Quick-release connection
- Push-button inflation/deflation

SEAPRO ATPAC

Style: Backmounted
Model No.: BBC-S
Color: Blue, Orange

Design Features:

- Foam padded integral shoulder straps
- No belts, no buckles
- Velcro waist closure
- Cordura nylon material
- Retractable bladder cover
- Internal bladder
- Airway and extra-short quick disconnect L.P. supply hose
- Fits most backpacs
- Integral weight pocket built into the backpac to eliminate the need for a separate weight belt



SEATEC BUOYANCY COMPENSATOR

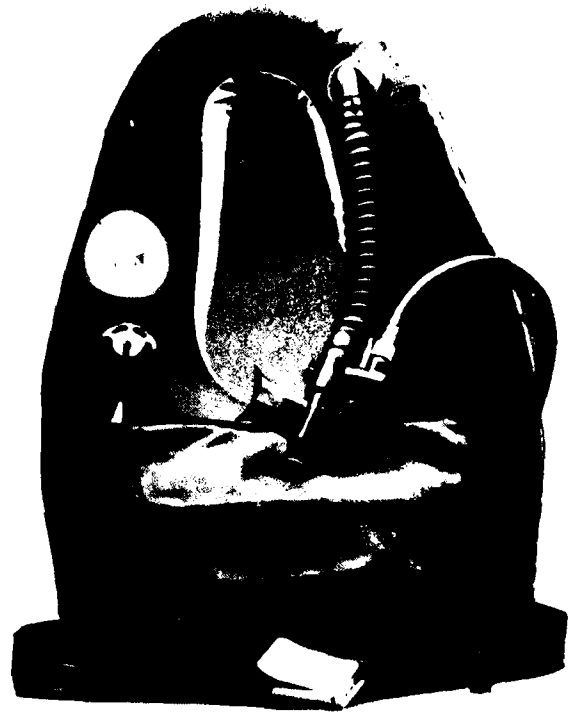
Style: Horsecollar
Model No.: TD1002
Color: Yellow, Black, Orange

Design Features:

- Three dimensional design
- Urethane-coated nylon outer bag with urethane inner bladder
- Large oral inflation hose
- 38-gram CO_2 cartridge for emergency use
- Large pocket
- Overpressure relief valve

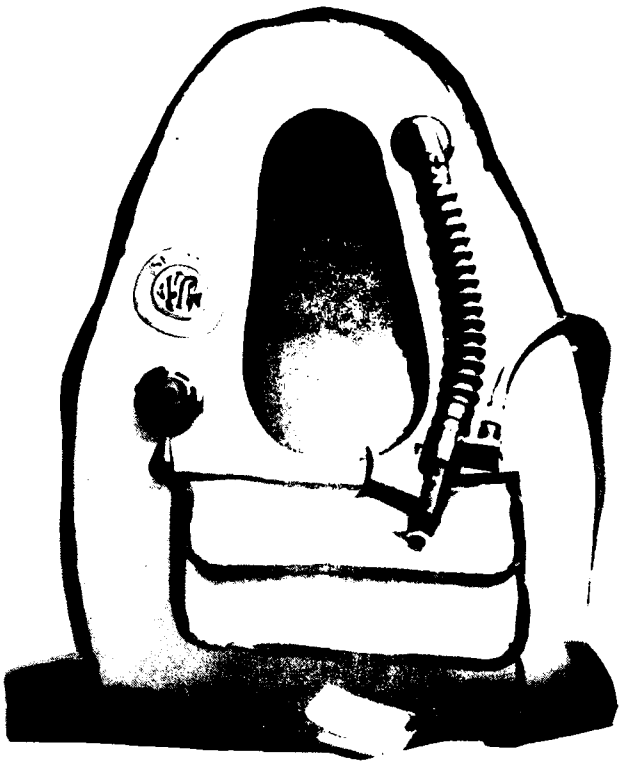
SEATEC SUNFISH TUFF TIGER

Style:	Horsecollar
Model No.:	10396-01/04
Color:	Orange w/Blue
	Blue w/Yellow
	Navy w/Tan
	Yellow w/Orange



Design Features:

- Inner bag
- Tuff Tiger Threads or 420 nylon fabric outer bag
- 38-gram CO_2 cartridge for emergency use
- Overpressure relief valve with quick-dump override
- Mesh drainage panels at top and bottom
- Front utility pocket
- Diamond shaped harness system



SEATEC SUNFISH 420 NYLON

Style:	Horsecollar
Model No.:	10396-31/33
Color:	Orange w/Blue
	Blue w/Yellow
	Yellow w/Blue

Design Features:

- Inner bag
- Tuff Tiger Threads or 420 nylon fabric outer bag
- 38-gram CO_2 cartridge for emergency use
- Overpressure relief valve with quick-dump override
- Mesh drainage panels at top and bottom
- Front utility pocket
- Diamond shaped harness system

SWIMASTER BUOYANCY COMPENSATOR VEST

Style: Horsecollar
Model No.: GBC-1
Color: Lime yellow/ Green

Design Features:

- Double bag construction
- Top and bottom mesh drainage
- Front pocket
- Wide straps with noncorrosive buckles
- Overpressure relief valve with manual override for rapid buoyancy adjustments
- 38-gram CO_2 cartridge for emergency use

U.S. DIVER'S SEA OTTER I
Style: Jacket
Model No.: 7776-00
Color: Yellow

Design Features:

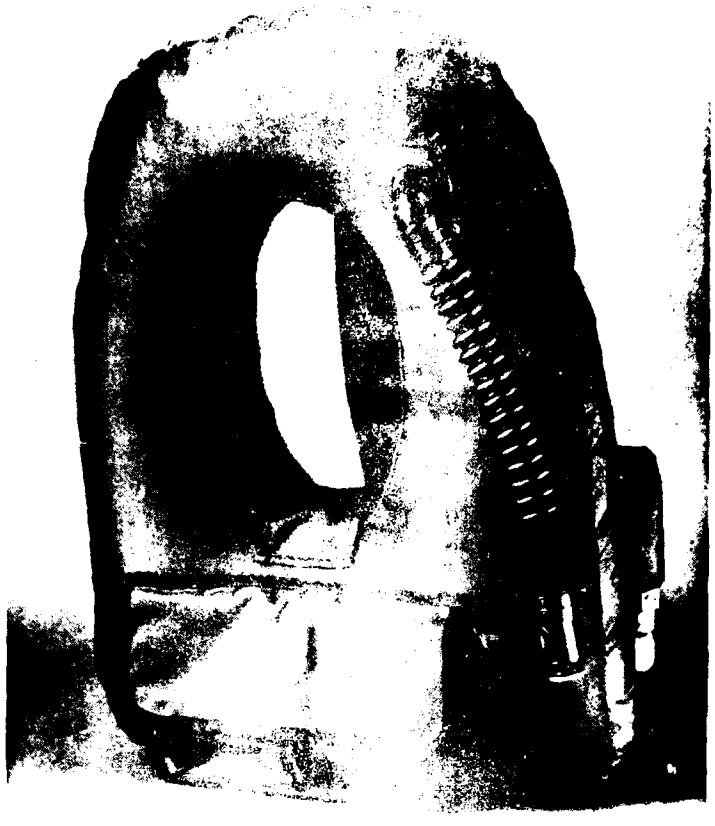
- One hand inflation/deflation with lever dump and L.P. inflator
- Puncture and cut resistant heavy Cordura nylon bag material
- Mariner Kam Bac Pac
- Jacket design for easy donning (only one strap and buckle)
- Inner bladder, removable for repairs
- 38-gram CO_2 cartridge for emergency use
- Oral inflator with Velcro hold-down and attached signal whistle
- Utility pocket
- Mesh drain panels on bottom of bag
- Stainless steel lever cable with swagged fittings
- *Available in two sizes

*SEA OTTER II for smaller divers is designated Model No. 7776-80.

U.S. DIVER'S VEST
Style: Horsecollar
Model No.: 7700-BC700
Color: Yellow

Design Features:

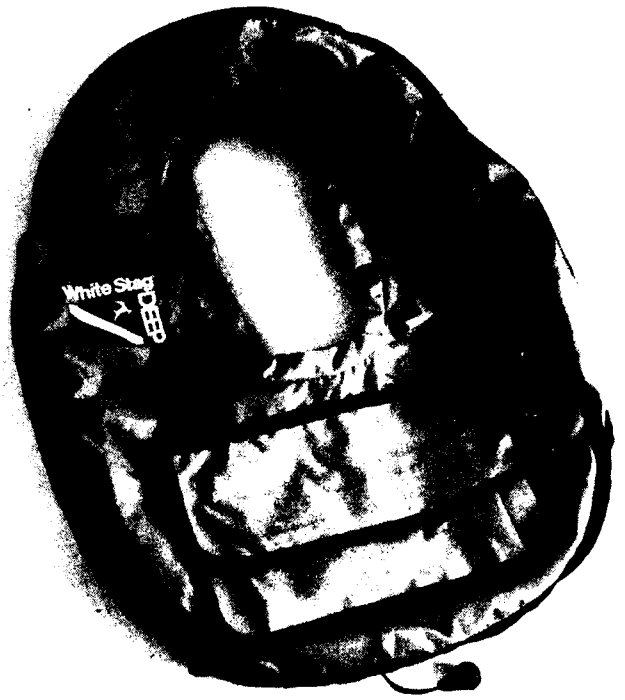
- One hand inflation/deflation with USD lever dump and L.P. inflator
- Puncture and cut resistant heavy Cordura nylon bag material
- Comfort harness for easy diving
- Inner bladder, removable for repairs
- 38-gram CO_2 cartridge for emergency use
- Oral inflator has Velcro hold-down and attached signal whistle
- Utility pocket
- Mesh drain panels on bottom of bag
- Stainless steel lever cable with swagged fittings



U.S. NAVY MARK IV LIFEJACKET
Style: Horsecollar
Model No.: N/A
Color: Black

Design Features:

- Outer fabric envelope with inner bladder
- Crotch/spine and waist straps
- Two dual CO_2 inflation mechanisms
- Oral inflation hose
- Overpressure relief valve
- Oral and manually operated inflators



WHITE STAG BUOYANSATOR IV
Style: Horsecollar
Model No.: 53962
Color: Orange

Design Features:

- Double bag
- Heavy nylon out and tough polyurethane in
- Bellowed sides for compactness
- Flat construction inside neck for comfort
- Extruded neoprene harness
- Noncorrosive plastic quick-release adjustable buckles
- Large utility pocket
- Expandable rubber hose
- Overpressure valve
- Surface signal whistle
- 38-gram CO_2 cartridge for emergency use

TEST PROCEDURE

TEST OBJECTIVE

A series of six manned and two unmanned tests were conducted in the OSF test pool and Gulf of Mexico to evaluate buoyancy compensators for authorized use by Navy divers.

TEST PROGRAM

The following tests were conducted to evaluate the various parameters important to Navy use.

Test 1. B/C Surface Floating Attitudes

To determine which B/Cs would function as surface flotation for an unconscious diver (i.e., with diver's head completely out of water in order to breathe), a series of buoyant ascents were conducted with B/Cs partially inflated. In the 15-foot deep OSF Test Pool, two tests, each with a different bottom position assumed by the diver prior to ascent, were performed with each B/C to determine the effect of initial lift position upon surface floating attitudes. Each diver wore a weight belt 20 pounds heavier than normally required. After the diver assumed a bottom position, his B/C was inflated to achieve neutral buoyancy, and the weight belt was ditched. At this time he went completely limp and remained that way until the surface floating attitude was recorded by a topside observer. Prior to ascent, the diver assumed a prone position for the first test, and a head-down/vertical position for the second test. These two bottom positions were chosen to represent the normal position of an unconscious diver and the worst case condition to attain a face-up attitude on the surface, respectively.

Test 2. B/C Inflation and Deflation Rates

The purpose of the Inflation/Deflation Rate tests was to determine how fast a diver could fill or vent his B/C in an emergency situation. The L.P. inflator, normally used for buoyancy control, is used to supplement the CO_2 cartridge's lift capability in an emergency.

The procedures outlined below were conducted to determine powered inflation rates (via the L.P. air supply) and deflation rates (via the oral inflation hose) of each B/C.

Inflation Rate Test Scenario

Step 1 A fully deflated B/C was attached to a spring scale anchored in 60 fsw.

Step 2 The low pressure inflator was activated.

Step 3 The elapsed time was recorded from beginning of step 2 until the B/C overpressure relief valve vented.

Deflation Rate Test Scenario

Step 1 The B/C was attached to a spring scale anchored in 60 fsw.

Step 2 The B/C was inflated until the overpressure relief valve vented.

Step 3 The manual exhaust valve on the oral inflation hose was opened.

Step 4 The elapsed time was recorded from beginning of step 3 until B/C was fully deflated.

Test 3. B/C Buoyancy at 60 fsw

The purpose of this test series was to provide information on the B/C lift capacity available to the diver for use as a tool and its ability to bring an unconscious diver up from the bottom. This test was performed in conjunction with Test 2. Each B/C was attached to a spring scale anchored in 60 fsw, and fully inflated until the overpressure relief valve vented. The maximum upward force, or buoyancy, was measured in pounds of lift from the spring scale reading and recorded.

Test 4. B/C Interface with Scuba Harness

The purpose of this test was to evaluate the buoyancy compensator/scuba interface, which included valve compatibility, evaluation of dressing-out procedure, and interference with scuba harness. Single and double tank units with both contour and harness type backpacks were evaluated. This test was conducted in the OSF Test Pool.

Test 5. B/C Air Consumption

The amount of air used by a buoyancy compensator is critical in determining the air supply source for a low pressure B/C inflator. Therefore, a series of dive profiles in the Gulf of Mexico were conducted to objectively evaluate B/C air consumption.

For this series of tests, each B/C inflator was supplied by a pony bottle (15.5 cubic feet @ 3,000 psig) attached to the diver's scuba tanks. B/C air consumption was determined by gauging pony bottle air pressure before and after each dive.

Each B/C was tested at two depths: 100 fsw for 25 minutes, and 60 fsw for 60 minutes. The following dive profile determined B/C air consumption when interfaced with scuba.

a. Two man teams dressed in full 1/4-inch wet suits descended to the maximum depth (either 100 or 60 fsw) and used the B/C inflator to achieve neutral buoyancy.

b. Divers swam at maximum depth for 1/3 of their maximum no-decompression limit.

c. Each dive team then ascended to a depth equal to 1/2 the maximum depth, achieved and maintained neutral buoyancy, and remained there for 1/3 of their maximum no-decompression limit.

d. Divers then descended back to maximum depth, achieved neutral buoyancy and swam for the remainder of the no-decompression limit.

e. Upon surfacing, each diver inflated his B/C via the L.P. inflator until his buoyancy was sufficient to comfortably support him as he ditched his scuba gear prior to re-entering the boat.

Test 6. B/C Air Supply Source Evaluation

The two sources of air supply evaluated were:

1) direct from first stage mounted on scuba tanks

2) diver carried independent pony bottle (15.5 cubic feet @ 3,000 psig) attached to scuba tanks.

Dives in each configuration with each B/C were conducted with scuba in 60 and 100 fsw. Each diver descended and ascended at will for the duration of the dives. Dressing and undressing problems for each configuration were observed and noted. Diver comments regarding positive and negative points of each air supply source were recorded.

Test 7. B/C Failure Modes

To determine possible effects on diver safety, B/C failure modes were evaluated in the OSF test pool. The purpose of these tests was to determine if a component failure or human engineering problem related to B/C configuration could endanger the diver. The following parameters were evaluated:

a. L.P. Inflator Failing in the Open Position.
A test was conducted in which the L.P. inflator was held in the open position at 15 fsw. As the B/C inflated, the exhaust valve on the oral inflator hose was held open to determine whether or not the B/C could be adequately deflated to prevent uncontrolled ascent from excessive buoyancy.

b. Overpressure Relief Valve Flow Capability.
The ability of each B/C's overpressure relief valve to adequately handle maximum L.P. inflator flow rates with a fully inflated B/C was evaluated. The purpose of this test was to determine whether the B/C would rupture when fully inflated if the L.P. inflator failed in the open position.

c. Human Engineering Evaluation of B/C Controls.

Tests were conducted to evaluate ease of operating all B/C controls. This included operation of the following components (with wet and drysuit mitt-type gloves):

1) L.P. Inflator valve

2) L.P. inflator hose quick disconnect couplings

3) Exhaust valve on the oral inflator hose

4) B/C harness adjustment fittings

Test 8. B/C Swim Characteristics

To evaluate surface and underwater swim characteristics, divers' comments were recorded after tests 5 and 6. Divers were instructed to be aware of overall comfort, mobility, ease of operating inflator/deflator, and ease of attaining neutral buoyancy.

RESULTS AND DISCUSSION

Test 1. B/C Surface Floating Attitudes

Surface floating attitudes for each B/C are recorded in Table 2. Results indicate that 1) diver's position prior to ascent has no effect on surface floating attitude, and 2) surface floating attitude is affected by type of B/C worn by the diver and whether or not it is used according to manufacturer's instructions.

During each test the diver was outfitted in full scuba gear and the surface floating attitude was recorded prior to ditching any equipment other than the diver's weight belt. Table 2 shows that most B/Cs always floated a diver face up with his head out of the water. B/Cs that need their surface floating attitude qualified are starred(*) in Table 2 and explained below:

a. DACOR SEACHUTE BC4*

The unique design of this B/C features two separate bladders — one for CO_2 cartridge inflation and one for oral and L.P. inflation. The L.P. inflated bladder is beneath the CO_2 bladder and is intended strictly for buoyancy compensation. Consequently, because of its position, the attitude in which the lower bladder floats a diver on the surface is not consistent from test to test and may float a diver face down when used by itself. However, the upper CO_2 bladder which encircles the diver's neck, always floats a diver face up on the surface but is intended strictly for emergency use.

b. Scubapro Stabilizing Jacket*

The Scubapro jacket-style buoyancy compensator always floated the diver face up. However, since it is imperative that a Navy diver be able to ditch his scuba gear on the surface without losing his flotation, any jacket style B/C whose harness is integral with the B/C is unsatisfactory. In this light the Scubapro Engineering Department provided NEDU a Stabilizing Jacket with the capability of ditching the scuba tank independently of the B/C. Tests showed this mechanism to work quite well. However, once the scuba tanks were disconnected from the Scubapro Stabilizing Jacket, the B/C floated the diver face down. The weight of the tanks kept the diver's center of gravity and center of buoyancy in the right relationship to float a diver face up. Without the tank weight, this relationship no longer existed.

c. Seapro Atpac*

The Seapro Atpac features a unique weight pocket in the B/C's backpack. This shot-filled pocket replaces the conventional weight belt. The Seapro Atpac floated the diver in a face-up position whenever the lead or copper shot weight was in place (see manufacturer's description). However, when the shot was emptied and replaced by a conventional weight belt, the diver floated face down.

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*Refer to Table 2, Surface Flotation Attitudes

TABLE 2

SURFACE FLOTATION ATTITUDES

POSITION PRIOR TO ASCENT / MODEL / STYLE	DACOR SEACHUTE BC1 Horsecollar	DACOR SEACHUTE BC4 Horsecollar	SCUBAPRO BUOYANCY CONTROL PACK Backmounted	SCUBAPRO STABILIZING JACKET Jacket	SCUBAPRO VEST Horsecollar	SEAPRO ATPAC Backmounted	SEATEC TD1002 Horsecollar
PRONE	Face-Up	Face-Up *	Face-Down *	Face-Up *	Face-Up	Face-Up *	Face-Up
UPSIDE DOWN VERTICAL	Face-Up	Face-Up *	Face-Down *	Face-Up *	Face-Up	Face-Up *	Face-Up

POSITION PRIOR TO ASCENT / MODEL / STYLE	SEATEC SUNFISH 420 NYLON Horsecollar	SEATEC SUNFISH TUFF TIGER Horsecollar	SWIMASTER GBC-1 Horsecollar	USD SEA OTTER I Jacket	USD VEST Horsecollar	USN MARK IV Horsecollar	WHITE STAG BC-IV Horsecollar
PRONE	Face-Up	Face-Up	Face-Up	Face-Down *	Face-Up	Face-Up	Face-Up
UPSIDE DOWN VERTICAL	Face-Up	Face-Up	Face-Up	Face-Down *	Face-Up	Face-Up	Face-Up

*Flotation attitudes of these B/Cs are explained further on Pages 21 and 23.

d. Scubapro Buoyancy Control Pack*

The Scubapro backmounted B/C does not have a weight pocket built into the backpack. During testing, therefore, the diver always floated face down when using a conventional weight belt.

e. U.S. Divers' Sea Otter I*

This U.S.D. Jacket has a large lift capacity due to enlarged bags located on the diver's back and chest. This large air bladder caused the divers to float face down approximately 50 percent of the time during tests performed in the OSF Test Pool. The surface floating attitude was determined by whatever position the diver reached the surface (i.e., if he ascended in a face-down position, he remained in that position on the surface). This problem was eliminated when a diver large enough to comfortably wear the Sea Otter I used the vest. The smaller Sea Otter II is more appropriately sized for most divers.

Test 2. B/C Inflation and Deflation Rates

Inflation/deflation rates are recorded in Table 3. The time range for inflation varied from 6 to 25 seconds; the time range for deflation (vent) varied from 4 to 16 seconds. Variations in fill and vent times were directly related to B/C lifting capacity and the design of the L.P. inflator supplied with each B/C. Tests showed fill and vent times to be adequate for any foreseeable Navy requirements.

Test 3. B/C Buoyancy at 60 fsw

Pounds of upward force (buoyancy) exerted by each completely inflated B/C at 60 fsw are recorded in Table 3. The range varied from 31 to 50 pounds depending on vest volume. It is felt that all B/C lift capacities measured are adequate for Navy requirements when using open circuit scuba.

The Dacor BC-4** had a lift capacity of only 23 pounds. However, this number represents only the lift capacity of the lower air bladder which is supplied via the L.P. inflator. The vest buoyancy is approximately doubled when the separate CO_2 bladder is filled via its CO_2 cartridge and used in conjunction with the L.P. inflated bladder.

Test 4. B/C Interface with Scuba Harness

Pool tests revealed no problem when using any of the B/Cs with conventional scuba. All backpack styles were acceptable with the various B/Cs. The minor problems encountered were quickly solved as divers became accustomed to using the equipment. Proper training in the use of B/Cs was deemed essential.

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*Refer to Table 2, Surface Flotation Attitudes

**Refer to Table 3.

TABLE 3

INFLATION/DEFLATION RATES
AND BUOYANCY AT 60 FSW

AT 60 FSW	DACOR SEACHUTE BC1	DACOR SEACHUTE BC4	SCUBAPRO BUOYANCY CONTROL PACK	SCUBAPRO STABILIZING JACKET	SCUBAPRO VEST	SEAPRO ATPAC	SEATEC TD1002
INFLATION RATE (seconds)	9	6 **	14	14	11	13	11
DEFLATION RATE (seconds)	9	7 **	10	11	9	16	6
BUOYANCY (pounds lift)	42	23 **	41	40	40	45	31

AT 60 FSW	SEATEC SUNFISH 420 NYLON	SEATEC SUNFISH TUFF TIGER	SWIMASTER GBC-1	USD SEA OTTER I	USD VEST	USN MARK IV	WHITE STAG BC-IV
INFLATION RATE (seconds)	13	15	12	17	15	25	12
DEFLATION RATE (seconds)	5	8	7	12	9	9	4
BUOYANCY (pounds lift)	42	42	40	50	46	49	32

**Inflation/deflation rates and buoyancy for this B/C are explained further on page 23.

Test 5. B/C Air Consumption

Each B/C was tested at 100 and 60 fsw to objectively evaluate air consumption. Results are recorded in Table 4.

B/C air consumption range varied from 0.50 to 4.25 cubic feet. No B/C required more than 5.9% of a diver's air supply when using a single 71.2 cubic foot scuba tank and it should be noted that all B/Cs required less air from the L.P. inflator as the divers became accustomed to using the B/Cs. It is important to note that air consumption is not related to B/C design and is solely a function of a diver's experience with this equipment.

A 5.9% air consumption of a single 71.2 cubic foot scuba tank (2.9% for twin tanks) for B/C inflation poses no threat to the diver and does not significantly deplete his air supply. Consumption was also low enough to make feasible a small 8.0 cubic foot pony bottle and first stage regulator mounted to the diver's scuba tanks as an alternate air supply source for B/C use.

Test 6. B/C Air Supply Source Evaluation

During Test #5, all dives were conducted with a 15.5 cubic foot pony bottle secured with stainless band clamps to a single 80 or twin 71.2 cubic foot scuba tanks. Once a diver entered the water, this setup was comfortable and easy to maneuver. However, the logistics of securing a pony bottle to the diver's primary air supply were inconvenient. In addition, connecting an extra first stage regulator to the pony bottle solely to supply L.P. air to the inflator is viable but not expedient.

No problems were encountered with attaching the L.P. inflator hose directly to the diver's primary first stage regulator. This method provided a simple, quick and uncluttered L.P. air supply to the B/C.

Test 7. B/C Failure Modes

Evaluation of various failure modes indicates no potential safety problems for divers familiar with buoyancy compensators. Results of each test mode are:

a. L.P. Inflator Failing in the Open Position.
OSF Pool tests showed all B/C oral inflator exhaust valves adequately vented B/Cs in the event of an L.P. inflator failure. In all tests, divers were able to easily maintain their depth by holding open the exhaust valve under maximum inlet flow conditions.

b. Overpressure Relief Valve Flow Capability.
The overpressure relief valves prevented vest rupture on all B/Cs tested, by sufficiently venting excess air when the fully inflated B/Cs received maximum inlet flow.

TABLE 4

BUOYANCY COMPENSATOR AIR SUPPLY CONSUMPTION

Buoyancy Compensator	Dive No.*	Predive Pressure (psig)	Post Dive Pressure (psig)	B/C Air Consumption (psig)	B/C Air Consumption (cu ft)
DACOR SEACHUTE BC1	1	3025	2600	425	2.13
	2	3100	2900	200	1.0
DACOR SEACHUTE BC4	1	3050	2950	100	0.50
	2	N/A			
SCUBAPRO BUOYANCY CONTROL PACK	1	2850	2100	750	3.75
	2	2900	2750	150	0.75
SCUBAPRO STABILIZING JACKET	1	N/A			
	2	2750	2500	250	1.25
SCUBAPRO VEST	1	3050	2700	350	1.75
	2	3150	2600	550	2.75
SEAPRO ATPAC	1	N/A			
	2	3100	3000	100	0.50
SEATEC SUNFISH TD1002	1	2550	2300	250	1.25
	2	N/A			
SEATEC SUNFISH 420 NYLON	1	3000	2750	250	1.25
	2	N/A			
SEATEC SUNFISH TUFF TIGER	1	3000	2700	300	1.50
	2	2925	2125	800	4.00
SWIMASTER GBC-1	1	2400	2250	150	0.75
	2	2800	2600	200	1.00
USD SEA OTTER I	1	2925	2550	375	1.88
	2	N/A			
USD VEST	1	2800	1950	850	4.25
	2	N/A			
U.S. NAVY MARK IV	1	2600	2100	500	2.50
	2	2900	2300	600	3.00
WHITE STAG BC-IV	1	2700	2325	375	1.86
	2	3050	2800	250	1.25

Average per dive consumption during tests: 1.85 cu ft
Average per dive consumption from twin 71.2 cu ft Scuba Tanks: 2.6%
N/A — No dive made
*Dive No. 1 — 100 fsw
Dive No. 2 — 60 fsw

c. Human Engineering Evaluation of B/C Controls.

Operation of B/C controls was exceptionally easy in all four areas tested, even with gloved hands, and should pose no threat to diver safety or convenience.

Test 8. B/C Swim Characteristics

Divers' comments on comfort, mobility, ease of operating inflator/deflator valves and ease of attaining neutral buoyancy are recorded below.

1) Dacor Seachute BC1

Divers' overall impressions of this B/C were positive. However, the "diamond type" harness was felt to be difficult to learn to use and the lack of a strap running from the neck through the crotch caused the vest to ride up under the diver's chin.

2) Dacor Seachute BC4

The unique upper/lower bladder design of this B/C was liked by all divers. The location of the L.P. inflated bladder under the diver's stomach provides precise and comfortable buoyancy control. The lack of a strap between the neck and crotch was not a problem with this B/C due to the placement of the L.P. air bladder. Difficulty in donning the "diamond style" harness persisted.

3) Scubapro Buoyancy Control Pack

This B/C was compact and easy to don. Lack of straps and an unencumbered chest were well received. Comfort could be increased by adding a crotch strap to prevent the backpack assembly, when inflated, from riding up on a diver. However, the diver's loss of surface flotation, upon ditching his scuba gear with this style B/C, is unacceptable for Navy use.

4) Scubapro Stabilizing Jacket

This jacket style B/C, incorporating the diver's harness as part of the B/C, was well received. No problems were encountered except that placement of the oral inflation hose higher on the jacket would facilitate venting the B/C. No straps to adjust, and in-water comfort were strong points for small to medium divers. This jacket is available in a larger size to accommodate large divers. As with the Scubapro Buoyancy Control Pack, the loss of surface flotation upon ditching the scuba tanks is unacceptable for Navy use.

5) Scubapro Vest

This B/C was functional and easy to operate. However, the stiff rubber impregnated vest material caused neck chafing on some divers. The crotch strap, which runs only from the waist through the crotch, allowed the partially inflated B/C to ride up on the diver. Placement of the oral inflation hose higher on the B/C would aid in exhausting air.

6) Seapro Atpac

The Atpac was well received for the same basic reasons as the Scubapro backmounted unit. Divers liked the L.P. inflator connection position which reduced the free length of hose to snag on objects under water. The contour backpack provided a snug fit although the addition of a crotch strap would help to further secure the tank to the diver in the water. The backpack's weight pocket for shot is a convenient alternative to the conventional weight belt, but it is not suitable for Navy diving operations. The retractable bladder design on this B/C made it one of the most compact units tested. But once again, this style B/C causes a loss of flotation when tanks are ditched on the surface and is therefore unsuitable for Navy use.

7) Seatec TD1002

Divers found this B/C to be compact, easy to don and adjust. The harness was comfortable and prevented the vest from riding up during the dive. No problems with the L.P. inflator or exhaust were noted.

8) Seatec Sunfish 420 Nylon

Divers felt this to be an exceptionally comfortable B/C. Doffing and donning were easy and all controls were functional. This B/C has a rugged ballistic nylon outer bag.

9) Seatec Sunfish Tuff Tiger

This is basically the same B/C as the Seatec 420 Nylon with the exception of a heavier outer bag material. Divers' comments were essentially the same as for the 420 Nylon.

10) Swimaster GBC-1

The Swimaster B/C was seen as functional, rugged and easy to operate. Divers generally liked this B/C and no problems were encountered.

11) U.S. Divers' Sea Otter I

The inflation and exhaust controls are exceptionally well positioned and easy to operate. When swimming, this B/C is comfortable on a large man but is too big for the small to medium-sized diver. The Sea Otter I is available in a smaller size (Sea Otter II) to accommodate medium to small divers.

12) U.S. Divers' Vest

This compensator was very well received. The harness is comfortable, easy to adjust and holds the B/C securely in position. As with the U.S.D. Sea Otter I, the L.P. inflator and exhaust valve location on this B/C were exceptionally well liked. The heavy ballistic nylon outer bag was rugged and should provide good service.

13) U.S. Navy MK-IV

The MK-IV was found to be comfortable, easy to don and adjust. The jocking system was adequate and held the B/C securely in place at all times. Divers found the 4-cartridge CO_2 system to be bulky and unnecessarily large for open circuit scuba.

14) White Stag BC-IV

This B/C was liked by all divers. The compact design and functional harness were mentioned as strong points. No problems were encountered with use.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The buoyancy compensators tested were generally comfortable and well constructed. Problems encountered were due to B/C configuration and style rather than quality control.

Specific conclusions drawn from testing are as follows:

1) The conventional horsecollar style B/Cs will always float a diver face up in an emergency situation.

2) Backmounted and jacket style B/Cs are functional and have application in specific diving situations. However, training and operational requirements preclude Navy use of these type compensators.

3) All compensators tested have inflation and deflation rates adequate to meet Navy operational and safety requirements.

4) Every B/C tested provided adequate buoyancy (lift), via the L.P. inflator, to bring an unconscious diver to the surface.

5) B/C interference with scuba harness is negligible.

6) B/C air consumption is very low and does not threaten a diver by consuming inordinate amounts of his breathing air supply.

7) The B/C's L.P. inflator, supplied via a diver's first stage regulator, is the simplest and most expedient method to use. However, a pony bottle L.P. supply is suitable should the dive supervisor deem it necessary.

8) No B/C failure mode was observed which could make this type of equipment unsuitable for Navy use.

Based on conclusions cited above, the horsecollar style B/Cs are preferred for Navy use.

Since the performance characteristics of all B/Cs tested were adequate and similar, final ANU recommendation is based on the following parameters.

a. Harness Design

The conventional waist strap and neck-through-crotch strap was preferred by all divers. In adddition, this type harness simplifies training and makes practical the use of a single B/C by several different divers.

b. Overall Diver Comfort

Two factors became important during testing: chafing and B/C position on the body. B/C material must be soft enough to prevent neck chafing on a

working diver when no wet suit is used. It is also important that the B/C, when partially inflated, does not ride up under the diver's chin.

c. Durability

B/C outer bag material must be durable enough to withstand the rigors of Navy operational use. Those preferred are the heaviest outer bag materials available which do not interfere with diver comfort or mobility.

RECOMMENDATIONS

The following buoyancy compensators are recommended for Navy use in conjunction with any suitable commercially available L.P. inflator:

a. Seatec Sunfish Tuff Tiger (Model No. 10396-01 through 04)

b. Swimaster Buoyancy Compensator (Model No. GBC-1)

c. U.S. Divers' Vest (Model No. 7700-BC700)

d. U.S. Navy Mark IV Life Jacket

e. White Stag BC-IV (Model No. 53962)

It is further recommended that:

1) the L.P. inflators be supplied primarily via the diver's first stage regulator

2) buoyancy compensators be used only in conjunction with a submersible pressure gauge

3) all buoyancy compensators supplied from the diver's first stage regulator be equiped with at least one 38-gram CO_2 cartridge or equivalent

4) a pony bottle for the L.P. inflator be an optional air supply source

5) a new generation of training be developed for using buoyancy compensators at all training commands

6) appropriate changes be made to the Diving Manual to explain use and function of buoyancy compensators.

The buoyancy compensator is recognized as a useful tool and safety device for the Navy diver when using conventional (i.e., open circuit, demand) scuba. It has the potential of making his job easier and therefore safer.

REFERENCES

1. NAVSEA Code OOC Task Assignment Number 78-29, dtd 12 December, 1978.