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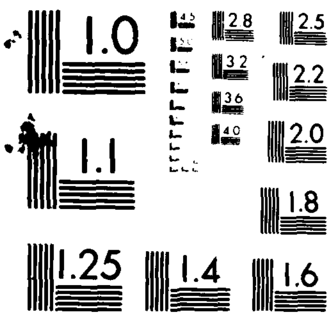

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BUOYANT LIFT SYSTEMS FOR THE SALVAGE NAVY

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September 1981

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ADMINISTRATIVE INFORMATION

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Presently the Navy's buoyant lift capability is centered around the 8.4-ton salvage pontoons. Purchased in the mid 60's, these pontoons have been reliable tools, but due to natural deterioration they are reaching the end of their usefulness and must be replaced.

Recent technological advancement in materials and buoyant lift systems designs suggest that an increase in operational capability and flexibility can be achieved through lift bags. Modern lift bags are light in weight, easily handled by two persons (up to 10-ton capacity) and require minimal storage space and maintenance. Their advantages make them ideal for shipboard deployment and salvage application.

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These lift bags are proposed as replacements for the 8.4-ton pontoons. Some questions remain as to the best materials and design for Navy salvage application. The subsequent phases of this project will attempt to answer these questions.

It is recommended that commercial bags be tested, evaluated, and if they meet Navy requirements, procured.

OBJECTIVE

Document the requirements of buoyant lift capability in the Navy, identify available commercial lift bag technology, and evaluate the extent to which commercial bags meet the Navy's requirements.

RESULTS

This report addresses phase I of the objective, documenting the Navy's buoyant lift requirements and identifying commercially available lift bags which, upon initial survey, appear to meet those needs.

RECOMMENDATIONS

1. Commercial bags should be evaluated.

2. Conduct an engineering analysis of available commercial lift bag configurations, fabrication techniques and fabric/seam strength.

3. Obtain and analyze airflow test data for various relief valves used on commercial lift bags.

4. Operational testing in fleet salvage or closely simulated fleet salvage conditions should be conducted to ensure the lift bag's apparent advantages are valid, and to ensure they can withstand salvage evolutions.

5. Evaluate the various buoyancy control systems available and based on Navy needs determine the extent to which a buoyancy control system is required.

6. An instruction manual should be written which outlines the various types of buoyancy devices available.

7. Further lift bag application in underwater construction, ships husbandry, and other related fields should be evaluated.

A

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INTRODUCTION

The objective of this program is to document the requirements of buoyant lift capability in the Navy, identify available commercial lift bag technology, and evaluate the extent to which commercial bags meet the Navy's requirements. To accomplish the objective a three-phase approach has been taken.

This paper is the final report for phase one. It documents the Navy's buoyant lift requirements and identifies commercially available lift bags which, upon initial survey, appear to meet those needs. In phase two, a group of commercial lift bags will be procured, tested, and evaluated to determine the extent to which they meet salvage force requirements. Phase three will recommend, based upon these findings, to either procure commercial lift bags for the salvage fleet or identify a further developmental approach for lift bag refinement.

BACKGROUND

Since the onset of World War II a continually increasing emphasis has been placed on buoyant lift devices in the salvage community. Many new devices have been developed, but not until very recently, with the advent of lift bags, has there been a marked improvement in lift-to-weight ratio. Throughout the 1940s, 1950s and 1960s, collapsible pontoons generally were made of a heavy rubber and nylon cord resembling tire material. This resulted in pontoons being very heavy and difficult to handle. Sizes ranging from 3.5 to 250 tons were developed and tested, but due to many drawbacks few were adopted for use. Table 1 summarizes lift pontoon development through 1970 (ref. 1).

In 1964, testing began on new lighter weight and smaller capacity pontoons. This resulted in the 1967 Navy purchase of the 8.4-ton salvage pontoons, which are still operational today. Two hundred originally were procured and are presently stored at the Navy ESSM pools.

In 1972, the Naval Civil Engineering Laboratory conducted a fabric study to determine the suitability of these pontoons for use at 600-foot depths. The results of the study showed that, due to inherent material weaknesses, the pontoons should not be used at depths greater than 350 feet (ref. 2). Additionally, many recommendations were made for future designs of collapsible pontoons. These pontoons are the primary buoyant lift system in the Navy today, and are compared with modern lift bags in table 2.

1. NCEL TR R-524, Survey of Collapsible Pontoons, D. Taylor and J. J. Bayles, April 1967.
2. NCEL TN-1241, Tests for Fabric Characteristics 8.4-Ton Lift Capacity Collapsible Salvage Pontoon, J. J. Bayles, 1972.

Development Date	Manufacturer	Height ft	Diameter ft	Nominal Capacity tons	Nominal Weight lb	Capacity to Weight Ratio
1943	Cook	16	15	59	4,000	29.5:1
1943	Brizay	21	12	30	-	-
1944	Pneumelevator	-	27	250	24,000	20.8:1
1945	Shep	-	-	3.5	400	17.5:1
1945	Firestone	-	10	16.5	-	-
1948	Goodyear	14.5	12	25	840	59.5:1
1948	Goodyear	18	13	40	1,000	80.0:1
1951	Goodyear	15	10	15	600	50.0:1
1957	Fujibura Rubber Industries Co.	17	16.5	40	1,540	52.0:1
1964	U.S. Rubber	8	7	10	800	25.0:1
1966	Uniroyal	27	13	25	1,500	33.3:1
1967	B.F. Goodrich	7.25	7	8.4	750	25.2:1

Table 1. Characteristics of modern collapsible pontoons.

Comparison Parameter	5-Ton Lift Bag (Open Bottom-Teardrop Shape)	10-Ton Lift Bag (Open Bottom-Teardrop Shape)	8.4-Ton Pontoon
Estimated Cost (1980)	$2,000.00	$2,400.00	$5,000.00
In-Air Weight (lbs)	150	185	750
Stowed Volume (Cu Ft)	8.5	15	75
Ratio Lift Capacity to weight	74:1	121:1	25:1
Ratio Lift Capacity to Stowed Volume	1317:1	1493:1	250:1

Table 2. 8.4-ton salvage pontoon, modern lift bag characteristics comparison.

FLEET STATUS

The ability of the working diver to utilize a buoyant lift force in salvage operations has been an important factor for many years. Through a review of the past decade's salvage reports (ref 3-9) and interviews with 40 Pearl Harbor-based salvage divers, the importance of this ability has been documented.

Information gained from the diver interviews has not been formally listed or summarized; however, it is used throughout the paper and the main conclusions are included in the Navy Requirements section. The salvage reports reviewed have been summarized and are presented in appendix A. While a great number of reports were reviewed and many summaries submitted, they do not cover all salvage operations performed. Additionally, it should be noted that lift bags offer many applications in other fields, such as underwater construction team (UCT), explosive ordnance disposal (EOD) and underwater demolition team (UDT) work. These areas have not been investigated. Their applications, along with the rapidly increasing underwater ships husbandry effort being put forth by the Navy, make lift bag procurement for the working diver increasingly important.

The reports reviewed have been divided into three categories and summarized as situations in which buoyancy devices were used as designed, those in which modified buoyancy devices were used, and finally, those in which a lift bag could have been used to advantage. In addition to the tabulated summary in the appendix, the following paragraphs present a brief discussion of the review conclusions.

BUOYANT DEVICES USED AS DESIGNED

Standard buoyancy devices being used as designed in the last 10 years include commercial lift bags, submarine salvage pontoons and the 8.4-ton salvage pontoons. In the salvage reports reviewed, all have been used effectively but not frequently.

The device utilized most often has been the 8.4-ton salvage pontoon, documented by eight salvage reports. On these jobs its main advantages were durability and towability. This was especially true in Vietnam on "brown water" salvage operations when small salvage tugs would rescue sinking or grounded riverine warfare craft. With an 8.4-ton pontoon securely connected to each side of the craft, it could be floated and towed to safety for repair. Though not frequently reported in writing, interviews with the 40 Pearl Harbor-based divers indicated this type of operation occurred often.

3. NAVSEA 0994-LP-012-6020, SALVOPS 70.
4. NAVSEA 0994-LB-011-2010, The Squaw.
5. NAVSEA 0994-LP-012-6030, SALVOPS 71.
6. NAVSEA 0994-LP-012-6040, SALVOPS 72.
7. NAVSEA 0994-LP-012-6050, SALVOPS 73.
8. Commander Service Squadron Five, Salvage Report Files, 1970-1979.
9. Harbor Clearance Unit One, Salvage Report Files, 1970-1979.

Salvage reports show the pontoons also have been used in submarine salvage exercises as floatation devices to buoy off wire ropes and cables, and for controlling the sinking and placement of bottom structures for at-sea platforms. The jobs reported have shown minimal equipment failure on the pontoons, with the only reported incident being the failure of a tandem leg on the 1971 Subsalves. Operations using the 8.4-ton pontoons were all in the early 1970s. More recently, either modified devices or commercial lift bags have been employed.

Three jobs in particular, in 1975, 1977, and 1978, illustrate the advantages of new lightweight lift bags. Though the jobs were small and the lifts relatively light (maximum lift 7000 lbs), the bags' flexibility, ease of handling, and speed of deployment were very evident. Additionally, the ability to utilize these lift bags while towing a floated object was demonstrated.

A problem encountered on the 1975 MILS junction box placement was buoyancy control. While some degree of control was available through the use of a manual diver-controlled dump valve, the position of the valve on top of the lift bag required a diver to depress it physically for air release. This greatly limited the bag's controllability and placed the diver in a dangerous situation. A more positive buoyancy control system, especially for use on jobs where delicate equipment or explosives are being handled, could be of great benefit.

MODIFIED BUOYANCY DEVICE USED

Throughout diving history one of the trademarks of a good working diver has been his ability to improvise. He will create tools, patches and such for a particular job when none of the standard equipment available will work. While this skill has enabled many jobs to be accomplished much quicker and more efficiently than otherwise would have been possible, it can also result in dangerous or hazardous situations. This is most noticeable with buoyant devices where everything from crown buoys to strawberry buoys to 55-gallon drums have been substituted for lift bags. Many jobs have been done successfully, but an additional hazard is always present since it cannot be accurately determined exactly how a handmade or modified device will react when under pressure.

The 55-gallon drum rig, whether single or tandem, has been the technique most often employed. The maximum lift recorded was approximately 1000 lb and was done with a tandem rig. Modifications have gone as far as putting standard kitchen faucets on top of the drums to act as controllable relief valves for fine buoyancy control. The advantages of adapting devices to act as lift bags are (1) their availability, (2) they are small and easy to handle, and (3) they are inexpensive both to modify and to replace if necessary.

Disadvantages include the previously-mentioned safety factor due to questionable durability and under-pressure performance, and the high expenditure rate since equipment modified for use is most often either damaged during use or unable to perform its designed function after modification.

LIFT BAGS COULD HAVE BEEN USED TO ADVANTAGE

Using surface craft lift lines, shore based lines or even helicopter lifts can be practical and reliable methods. However, there are many situations such as bad weather, high seas, or shallow, treacherous waters which would make a buoyant device more advantageous. Time, safety and effectiveness are factors which must be considered when deciding upon the lift techniques.

The case histories illustrate examples where a great deal of time and expense were spent repositioning the ship for a line lift due to the object being out of a lifting radius of the ship. In these cases, buoyant lift bags could easily have been attached to the objects, raised, and towed to the ship's side. Additionally, on jobs when positioning the ship directly over the object is not feasible, compounded damage has been done to the equipment salvaged as it is dragged over the bottom until directly under the salvage vessel. This, too, can be avoided by swimming a bag to the equipment, lifting it to the surface, and then towing it to the salvage ship.

These examples involve an important factor of safety. Whether the factor is the ship's safety as it maneuvers in tight waters or personnel and equipment safety as surface lines are used under heavy tension while dragging the object, with the use of buoyant lift devices these hazards often would be reduced.

NAVY BUOYANT LIFT REQUIREMENTS

The review of salvage reports brings forth many conclusions concerning the strengths and weaknesses of past and present buoyant lift systems. Additionally, it indicates many areas in which these systems must be improved if they are to meet the future needs of the Navy salvage community adequately. In looking toward the procurement of a new buoyant lift system, these areas must be identified and validated through operational/material testing prior to being accepted as required specifications. An initial list of buoyant systems requirements, as based on anticipated future Navy requirements, is presented in the following paragraphs.

LIFT BAG CAPACITY

The lift capacity must be determined by the anticipated magnitude of the operations in which lift bags are planned to be used. As an example, a civilian salvage firm, EUROSLAVE, accomplished an 800-ton lift in salvaging the Dutch owned vessel Nordzee using 80 10-ton lift bags. However, the salvage reports reviewed indicate a 5-ton bag is more suitable for lifting aircraft and small craft, which are the jobs for which the lift bags seem most ideal. Since the primary focus of this project is replacement of the 8.4-ton salvage pontoons, the recommendation is to put the 5-ton bags on salvage ships for ready access on small jobs, and have the larger, 10-ton bags available through ESSM pools for major salvage efforts. Smaller, 2- to 3-ton bags should also be considered in the future but are not considered as an adequate replacement for the 8.4-ton pontoon.

LIFT BAG DURABILITY

Probably the single outstanding feature of the 8.4-ton pontoon and a very questionable factor in lift bags is durability. The heavy construction of the salvage pontoons allowed them to withstand scrapes against coral and jagged metal, chafing against line, and many other hazards associated with the salvage environment. This factor is still very important, as the salvage environment has not changed. For future systems, maximum durability while staying within the lift bag concept must be attained. Durability in lift bags will vary greatly with the differing fabrics and coatings used. In order to find the optimum combination of durability and operability the available materials should be tested.

BUOYANCY CONTROL

One recent advancement in lift bag development has been buoyancy control. Full control of the lift bag can enable a single diver to use the buoyant force as an underwater crane, lifting, lowering, and even hovering objects in a water column without risk of the bag rocketing to the surface. This positive control adds a safety factor for the divers as well as a great deal of operational flexibility. Control systems presently available include manual diver controlled dump valves, controllable standpipe configurations, and a fixed displacement system which uses water ballast. Since this is one of the main advantages of lift bag systems, and an important consideration as brought forth in the salvage report review, these systems must be tested in a salvage environment.

HANDLING AND STORAGE

Two of the major advantages of lift bags over pontoons are their relative light weight and handling ease for equal lift capacities. An 8.4-ton pontoon has a storage weight of approximately 750 lb and a volume of 75 ft^3. A 10-ton lift bag will weigh close to 175-185 lb and have a 15-ft^3 storage volume. These facts make lift bags very adaptable to salvage ship use where storage space is at a premium. Equally important is the ease of handling of the lift bags. Two divers can handle a lift bag and associated hoses easily, both on the surface and in the water, while the 8.4-ton salvage pontoons require crane support. This weight factor should be maintained during any subsequent procurement effort. It can make buoyancy devices much more available through shipboard deployment and it will make handling of the buoyancy system easier and safer.

DISTRIBUTION

Shipboard deployment of lift bags will add a great deal of flexibility to the salvage diver's capabilities. The 8.4-ton pontoons have been located solely at the ESSM pools, and due to this relative unavailability their use has been minimal. The interviews with 40 Pearl Harbor-based salvage divers indicated an overwhelming lack of training and experience with buoyancy devices (only three of the divers had ever used 8.4-ton pontoons). With lift bags onboard ships, at Harbor Clearance Units, and at diver training commands, fleet salvage readiness can be greatly increased through an on-hand, deployable buoyancy system and an aggressive training program. There are excellent salvage training exercises conducted on both coasts and lift bag training could easily be included. In order to optimize diver training and salvage fleet readiness in the area, the distribution listed in table 3 is recommended.

Command Type	Qty 10-Ton	Qty 5-Ton
ARS/AT	0	4
TATF (as part of FADS)	0	2
ATF	0	2
ASR	0	2
HCU	2-4	8-10
Training Commands	0	2
ESSM Pools	*	0

*Quantity to be determined by available funding and total buoyant lift capability required by the Navy.

Table 3. Recommended lift bag distribution.

STANDARDIZATION

In order to make the system as efficient as possible and to eliminate many potential logistic and supply problems, standardization of all fittings, hoses, and surface support equipment is necessary. On any subsequent lift bag procurement this should include standardization to existing Navy air and water fittings.

MAINTENANCE

To be operational on salvage ships the entire system must require as little maintenance as possible. Austere manning levels and the vast amount of salvage and diving equipment already being handled will make extensive maintenance nearly impossible. Quick PMS checks prior to use, *after use*, *and prior* to storage should be identified.

MISCELLANEOUS REQUIREMENTS

The following paragraphs list possible requirements to be considered.

Towing

The lift bags should be capable of floating an object, and then continuing to be used as floatation while the object is towed to its destination.

Air Holding

The bags must be able to hold or maintain buoyancy over extended periods of time without additional air being supplied.

Recovery Liftability

The ability to lift an object out of the water by attaching the crane to the top of the lift bag would be a convenient feature. A lift plate and shackle on top, with either internal or external strength members connecting it to the lifting bridle, would satisfy this requirement.

CURRENT TECHNOLOGY

COMMERCIAL DEVELOPMENT

In order to determine the present status of commercially available lift bags, twelve companies known to have experience in the buoyant lift field were contacted. Of the twelve, three responded favorably with specifications and information of their standard lines of lift bags. These responses indicate many improvements have been made in the past few years.

The three major lift bag manufacturers are Canflex Manufacturing Inc. of North Vancouver, B.C., J. W. Automarine of Mt Kisco, N. Y., and Subsalve Industries of Providence, R.I. Each offers an extensive line of lift bags of varying designs and types of materials.

Table 4 summarizes the large lift bags (1 ton and larger) offered by the three companies. Table 5 lists the nine companies contacted who do not have standard lines. Additionally, the following is information provided in the companies' sales brochures:

o Each company offers some form of buoyancy control. These include standpipe systems with electric motors for push button control, diver controlled manual dump valves, and fixed displacement bags using seawater ballast. The standpipe with motor and the fixed displacement bag are said to offer the diver complete underwater crane capabilities with raise, lower and hover control.

o Major design and shape characteristics of the large lift bags vary somewhat from company to company, but generally fall into one of two categories: open bottom bags which are an inverted teardrop or parachute shape, and totally enclosed bags which are cylindrical. An exception to this is the enclosed or fixed displacement lift bag that Subsalve offers, which is teardrop shaped. Other design differences include strength members (internal vs external) relief valve types and locations, load attaching points and fittings, and differing materials.

o Each company has a standard material which it utilizes and recommends. Polyester and nylon are the standard materials, with others, such as Kevlar, available at extra cost. PVC is the most common coating, but neoprene and urethane also are available. The weights of material and hence overall specifications also vary greatly between companies. One offers polyester cloth at 7.5 oz per square yard, uncoated. Another offers a similar polyester but it is 28 oz per square yard, uncoated. The third standardizes nylon at 13 oz per square yard. With this spread, the strengths and weaknesses of lift bags will be vastly different.

Company	Lift Bag Capacities (tons)	Lift Bag Types (designs)	Standard Materials	Approximate Cost (5-ton bag)	Comments
SUBSALV Industries P. O. Box 9287 Providence, R.I. 02940	1, 3, 6 and 10	Teardrop shape open and enclosed bottom	Nylon fabric Neoprene coating. Kevlar is also available (recommended on fixed displacement model)	Open: $1550 Enclosed: $2450 Add $900 for Kevlar	o 100% seam strength o Capable of fixed displacement mode using water ballast o Internal Kevlar strength member o 5-to-1 material strength factor
CANFLEX MAN 1406-8 Charolette Rd. North Vancouver, B.C. V7J1HZ	1, 3, 5 and 10	Teardrop shape open and cylindrical shape enclosed	Polyester scrim fabric, PVC coating bottom	Open: $1875 Enclosed: $2175 Add $365 for CABCO Option	o 100% seam strength o *CABCO option with standpipe* available for controlled buoyancy o External strapping strength members o No air wicking o 5-to-1 material strength factor
J. W. Automarine Old Road Lane Mt Kisco, N.Y. 10549	1, 2, 3, 5 and 10	Parachute shape Open bottom cylindrical shape enclosed	Polyester fabric PVC Coating	Open: $2375 Enclosed: $2300	o 80% seam strength o Diver controlled (lanyard) manual dump valve for lift control o External strapping strength members o 5-to-1 material strength factor

NOTE: Materials listed are companies' standard production materials. Others, such as Kevlar fabric and urethane coatings, are available at additional cost.

Table 4. Commercial lift bags presently available.

PROTEUS INC.
Box 74
Malton Lanes, NJ 07046

CARTER BAG CO
29500 Green River Gourge Road
Enumclaw, WA 98022

VETTERS SYSTEMS
605 Parkway View Drive
Pittsburgh, PA 15205

GOODYEAR AEROSPACE CORP
P. O. Box 92-78-T
Akron, OH 44318

UNIROYAL PLASTIC PRODUCTS
Div UniRoyal Inc.
Eng Syst Dept
Mishawara, IN 46544

B. F. GOODRICH
General Products Div
500 S. Main Street
Akron, OH 44318

MARAVIA CORP
857 Thornton Street
P. O. Box 395
San Leandro, CA 94577

SUBMARINE AND SAFETY ENG LIMITED
Daux Road
Billingshurst,
Sussex, England

SEI INDUSTRIES LTD
P. O. Box 86430
North Vancouver, B.C.
Canada V7L4K6

Table 5. Commercial firms contacted, without standard stock lift bag lines.

NAVAL LAB DEVELOPMENT

As with the commercial firms, many new developments have been made in the lift bag field by Navy laboratories, with the bulk of attention being directed toward controllable buoyancy. In this regard the zipper bag, Jack-in-the-Bag, and fixed displacement lift bag have been developed recently.

To date, the zipper bag (ref 10), with roughly a 900-lb lift capacity, is the only bag authorized for Navy use. Cylindrical in shape and vertically oriented, the zipper bag uses a zipper to control the size of the air bubble within the bag. Originally, it was designed for UCT use but now it is planned for FY 82 distribution with the standard diver's underwater tool package as part of the hot tap system. Another light lift device recently developed is the Jack-in-the-Bag (ref 11). The prototype has a lift capacity of approximately 500 pounds and is a totally self-contained unit. The original model is roughly the size of a 55-gallon drum, with rigid end plates and a collapsible midsection. It utilizes a scuba bottle air source which is supplied through a scuba regulator. A standpipe system from the top of the bag, and again through the regulator, acts as the air relief valve. In order to maintain fixed volume, a salt water inlet/exhaust valve is installed on the bottom of the bag along with a hand water pump, used for fine ballast adjustments. The tests conducted with the bag have had very positive results, giving a single diver an easy-to-handle lift bag with precise buoyancy control. The possibility of enlarging this system's lift capacity looks very promising.

An offspring of the Deep Ocean Technology program has been the fixed displacement lift bag (ref 12). Originally designed to be used with an unmanned recovery vehicle and microprocessor control unit, it has been proven effective on controlled lifts of up to five tons. Since its original testing it has been used on several test programs by NOSC, Hawaii Laboratory personnel and has proven to be equally effective with a diver controlled manifold utilizing surface supplied air and water. Water ballasting and an internal air pressure of slightly greater than ambient combine to maintain the fixed displacement and buoyancy control. The amount of water ballast controls the maximum volume for air and also the lift capacity. As the lift proceeds, expanding air is vented through relief valves in the top of the bag. Utilizing the manifold, which has water inlet and exhaust valves as well as the air inlet valve, one diver can control an ascent, descent and even hover the bag with full or partial load. This is the bag that seems to hold the most promise for the future. Its features give it innumerable applications for underwater salvage, construction and specialty work, and its light weight and compact storage make it attractive for shipboard applications.

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10. Phonecon LT L. W. Carithers of NOSC Hawaii Laboratory and Mr. M. Sheehan of NCSC Panama City, Fla. of 17 Mar 81.
11. NOSC TR 657, The Jack-in-the-Bag, Fixed Volume Lift Device, R. W. Buecher, February 1981.
12. NUC TN 1743, Fixed Volume, Collapsible Lift Bag, A Progress Report, R. T. Hoffman, Sep 1976.

CONCLUSIONS

The Navy's primary buoyancy devices, the 8.4-ton salvage pontoons, have been in service for approximately 14 years. Due to material fatigue, wear, and natural dry rot they are nearing the end of their usefulness.

There exists a definite need in the salvage Navy for a working, usable buoyancy system. Therefore, the 8.4-ton pontoons must be replaced.

The 8.4-ton pontoons are big, bulky and difficult to handle, both on deck and in the water. This, combined with their inconvenient location at the ESSM pools, has made their use quite minimal. New, lightweight lift bags, deployed on salvage ships and at all other diving commands, could eliminate these problems.

Lightweight lift bags are the devices which should replace the 8.4-ton salvage pontoons. Their many advantages make them ideal for shipboard application and their added capabilities, such as positive buoyancy control, will give the salvage diver a very flexible lift system. Their deployment to all diving commands will aid diver training, eliminate the danger of using modified devices, and make many previously difficult operations much simpler and quicker.

A sufficient quantity of lift bags must be available to afloat salvage units to allow bags to be used for training and on smaller jobs. While some bags may also be stored at the ESSM pool, consideration must be given to ensure that enough bags can be collected rapidly for larger lifts (100 tons and larger).

In order to maintain the handling, weight and storage advantages, 5- and 10-ton bags are the most advantageous bags to replace the 8.4-ton pontoons.

The commercial lift bag market has expanded and made many recent improvements. From the initial survey, commercial firms appear to manufacture several lines of bags which meet basic Navy needs.

RECOMMENDATIONS

1. Given that (1) the Navy does need a buoyant lift capability, and (2) lift bags are the devices which look best as a buoyant lift system, commercial bags should be evaluated.

2. Conduct an engineering analysis of available commercial lift bag configurations, fabrication techniques and fabric/seam strength.

3. Obtain and analyze airflow test data for various relief valves used on commercial lift bags.

4. Operational testing in fleet salvage or closely simulated fleet salvage conditions should be conducted to ensure the lift bag's apparent advantages are valid, and to ensure they can withstand salvage evolutions.

5. Evaluate the various buoyancy control systems available and based on Navy needs determine the extent to which a buoyancy control system is required.

6. An instruction manual should be written which outlines the various types of buoyancy devices available from 55-gallon drums to commercial lift bags. It should include: recommended uses, techniques for use, safety factors, and any other factors which have been discovered through use.

7. Since this report has dealt solely with salvage operations, further lift bag application in underwater construction, ships husbandry, and other related fields should be evaluated. A group representing the diverse users within the Navy community should be convened to determine a comprehensive set of requirements for buoyant lift devices.

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APPENDIX A: CASE HISTORIES

BUOYANT DEVICES USED AS DESIGNED

Device Used	Date	Object and Weight	Depth	Comments (Pros and Cons)
8.4-ton pontoon	Apr 70	LCM-6, 28-ton displacement	35 ft	o Reliable, rapid deployment system in war zone. o Buoyancy used for raising ship and during towing. o Durable during towing, rugged.
8.4-ton pontoon	Mar 70	F-4J Aircraft, 15-ton air wt	75 ft	o Versatile: can be used from work-boat. o Good backup system for shipboard lift.
8.4-ton pontoon	Nov 70	Barge, 200-ton displacement	104 ft	o Useful on a controlled sinking for buoyancy control. o Pontoons lack total buoyancy control, which could be of great value.
8.4-ton pontoon	Nov 70	Squaw Mooring Legs, 9-ton air weight	3500 ft	o Used as a floatation system for mooring legs. o Extended air holding capability very important.
8.4-ton pontoon	Jul 71	Acoustic range, 9-ton air wt	Surface	o Ability to hold air pressure over extended period important.
8.4-ton pontoon	Aug 71	ex USS HAKE, 2000-ton displacement	100 ft	o Relief valve failure during free ascent. o Internal strength member failure.
8.4-ton pontoon	Nov 72	PGH-20, 221-ton displacement	3 ft	o Rugged durability very important here, the pontoons were severely ripped by coral but held air.

8.4-ton pontoon	Jul 73	Buoy and anchor sys – 4-ton air wt	2200 ft	o Used as a buoy to float bitter end of moor, air holding important.
EOD lift bladder	Aug 75	LARP, 4-ton air wt	320 ft	o Lightweight, easily deployed. o 1000-lb lift per bag; 5 bladders. o Expended due to chafing. Not rugged enough for normal salvage use.
Lift bag	Sep 75	MILS cable junction box, 500-lb air wt	80 ft	o Easy to deploy and use by 2 men. o Usable away from ship's mooring radius. o Some buoyancy control available with manual relief valve. However, danger is involved as valve was operated from above the bag.
Lift bags	Jul 77	Pontoon, 5000 lb	30 ft	o 4 lift bags, 2000-lb capacity each were used for the lift and as floatation during subsequent towing of pontoon to port. o Speed and ease of deployment and lift bags towability were important.
Lift bag	Jun 77	Antenna couplers, 390 lb	45 ft	o 390-lb couplers raised with 500-lb capacity lift bag. o 2 scuba divers used scuba bottle air supply to inflate bag.

MODIFIED DEVICES USED

Device Used	Date	Object and Weight	Depth	Comments
Salvage balloons (strawberries)	Sep 70	A-6A aircraft engine, unk	12 ft	o 20 strawberry buoys were used to raise the A-6A engine. o No relief system, only usable in very shallow depths.
55-gal drums	Jul 77	Underwater pipeline, 8-ton per 160 ft	50 ft	o Drums used to position sections on bottom, filled until section had neutral buoyancy.
Crown buoy	Mar 78	Hawking anchor rig, wt unk	210 ft	o Crown buoy used to float hawk rig overnight. Due to rig fouling, unexpected weight was hanging from the buoy. As a result, the system failed and the buoy went down. No larger floatation devices were available.
55-gal drums	Jul 79	Buoyancy modules	20 ft	o Buoyancy modules made negative with cement clumps. Drums were used to control the modules, making them neutral for installation. o Sink type faucets installed for relief and buoyancy control.
55-gal drum	Aug 79	Anchors (4)	90 ft	o 3 drums welded together in triangular formation to provide 1500-lb lift force. o Surface compressor and hose supplied air to manifold at site which simultaneously filled all three drums.

LIFT BAGS COULD HAVE BEEN USED TO ADVANTAGE

Device Used	Date	Object and Weight	Depth	Comments
Coast Guard lift craft	Jun 72	Hovercraft (ACV-3) 10-ton displacement	110 ft	o An initial attempt in Nov 71 terminated due to bad weather and seas. Sufficient lift bag capacity readily available. May have enabled job completion in Nov. o Specific I-beam bridle was constructed for lift. Not required with lift bags.
Ship's boom	Dec 74	F-4B aircraft, 15-ton	65 ft	o The wreckage was scattered over a large area and while it was recovered using the ship's boom, considerable time and effort was expended *repositioning the ship.* o This was an ideal job for lift bags. The entire system could be loaded into a work boat and the job completed without moving the ship.
Ship's boom and capstan	Jan 75	HU-1H aircraft, 3-ton air weight	90 ft	o Ship was unable to moor over wreckage so helo was dragged over bottom until under the ship and then raised, adding a great deal of damage to the aircraft. o Lift bags could have raised the helo, and enabled its towing on the surface to the ship for pickup, eliminating compiled damages.
Barge A frame and lines	Feb 76	Eells anchor, 8000 lb	85 ft	o Considerable time, expense, and effort expended rigging barge, A-frame, and block and tackle system. o Being very close to port, a work boat and 5-ton lift bag system with 4 scuba divers could raise the anchor and tow it to port for pickup.

Ship's boom	Jul 76	LST bow ramp	205 ft	o Extreme current made passing lift line to ramp very difficult, and the ship was forced to reposition. While this current would have made lift bags ineffective for the lift, one could have been used with a fairlead at the ramp to pass the lift line.
Shorelines	May 78	Amphib beach mats	60 ft	o 165 beach mat sections were scattered over a rock bottom. Due to traffic and bottom terrain, the salvage ship could not anchor over site. o Dragging of mats up onto shore damaged mats, the lines, and increased safety risks. o Lift bags would have been ideal to raise mats and tow to shore.
Ship's boom and capstan	Apr 78	TS-2A aircraft	80 ft	o The main wreckage was directly under moored recovery craft and quickly salvaged. One engine was outside of moored radius so a line was attached and it was dragged across the bottom until under the craft, causing additional damage.
Ship's boom and support craft lines	Mar 79	TA-4J aircraft	160 ft	o Recovery ship moored and salvaged all but the tailpipe section, which was outside moored radius. A support craft was called in and recovered tailpipe.

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