(2)

NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 7-88

LIGHT WEIGHT DIVING SYSTEM (LWDS) PROTOTYPE TECHNICAL EVALUATION - HUMAN FACTORS, TRANSPORTABILITY AND SUITABILITY

DAVID G. KIRBY

AUGUST 1988

NAVY EXPERIMENTAL DIVING UNIT

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

(2)

IN REPLY REFER TO

NAVSEA Task 88-04

NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 7-88

LIGHT WEIGHT DIVING SYSTEM (LWDS) PROTOTYPE TECHNICAL EVALUATION - HUMAN FACTORS, TRANSPORTABILITY AND SUITABILITY

DAVID G. KIRBY

AUGUST 1988

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Submitted:

D.G. KIRBY
LT(N), CF
Fleet Support
Project Officer

Reviewed:

M.T. WALLICK
LCDR, MSC, USN
Medical Task Advisor

H.J.C. SCHWARTZ
CAPT, MC, USN
Senior Medical Officer

R.T. MACHASICK
LCDR, USN
Senior Projects Officer

J.C. DEVLIN
CDR, USN
Executive Officer

Approved:

J.D.M. HAMILTON
CAPT, USN
Commanding Officer

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION Unclassified	1b. RESTRICTIVE MARKINGS
2a. SECURITY CLASSIFICATION AUTHORITY	3. DISTRIBUTION/AVAILABILITY OF REPORT Distribution Statement A: Approved for public release; distribution is unlimited.
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) NEDU Report 7-88	5. MONITORING ORGANIZATION REPORT NUMBER(S)
6a. NAME OF PERFORMING ORGANIZ. Navy Experimental Diving Unit 6b. OFFICE SYMBOL (If applicable) NEDU	7a. NAME OF MONITORING ORGANIZATION
6c. ADDRESS (City, State, and ZIP Code) Navy Experimental Diving Unit Panama City, Florida 32407-5001	7b. ADDRESS (City, State, and ZIP Code)
8a. NAME OF FUNDING/SPONSORING ORGANIZATION Naval Sea Systems Command 8b. OFFICE SYMBOL (If applicable) NAVSEA	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
8c. ADDRESS (City, State, and ZIP Code) Naval Sea Systems Command Department of the Navy Washington, DC 20362-5101	10. SOURCE OF FUNDING NUMBERS PROGRAM ELEMENT NO. / PROJECT NO. / TASK NO. NAVSEA 88-04 / WORK UNIT ACCESSION NO.
11. TITLE (Include Security Classification) Lightweight Diving System (LWDS) Prototype Technical Evaluation - Human Factors, Transportability, and Suitability, Diver [illegible], Cm Compressor, Air purifier, Diesel [illegible], [illegible]	
12. PERSONAL AUTHOR(S) David G. Kirby, LT(N), CF	
13a. TYPE OF REPORT Final 13b. TIME COVERED FROM_____ TO_____	14. DATE OF REPORT (Year,Month,Day) August 1988 15. PAGE COUNT 62
16. SUPPLEMENTARY NOTATION	

17. COSATI CODES			18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
FIELD	GROUP	SUB-GROUP	light weight diving system (LWDS); composite flasks; enclosed space diving system (ESDS); human engineering; human factors; control console.

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A prototype light weight diving system was evaluated for compliance with Mil Standards and human factors considerations. The supporting software was also evaluated. Over two days, 13 dives were conducted and applicable observations made. The system adequately supplied air to a single working diver at 20 FSW. Upon resolution of identified problems and discrepancies, the LWDS should prove acceptable to the fleet. The LWDS is a simple design using fundamental equipment and procedures. It is recommended that further development be pursued to lighten the components to bring it into conformance with Mil Standards.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS	21. ABSTRACT SECURITY CLASSIFICATION Unclassified
22a. NAME OF RESPONSIBLE INDIVIDUAL NEDU Technical Librarian	22b. TELEPHONE (Include Area Code) 904-234-4351 22c. OFFICE SYMBOL

CONTENTS

ABBREVIATIONS

EODMU-4	Explosive Ordnance Disposal Mobile Unit Four
EP	emergency procedure
ESDS	enclosed space diving system
FADS	fly away diving system
FSW	feet of seawater
HP	high pressure
ID	inside diameter
LP	low pressure
LWDS	light weight diving system
NAVSEA	Naval Sea Systems Command
NCSC	Naval Coastal Systems Center
NEDU	Navy Experimental Diving Unit
O&M	operation and maintenance
OP	operating procedure
OD	outside diameter
UBA	underwater breathing apparatus

ABSTRACT

A prototype light weight diving system was evaluated for compliance with Mil Standards and human factors considerations. The supporting software was also evaluated. Over two days, 13 dives were conducted and applicable observations made. The system adequately supplied air to a single working diver at 20 FSW. Upon resolution of identified problems and discrepancies, the LWDS should prove acceptable to the fleet. The LWDS is a simple design using fundamental equipment and procedures. It is recommended that further development be pursued to lighten the components to bring it into conformance with Mil Standards.

KEY WORDS:

light weight diving system (LWDS)
composite flasks
enclosed space diving system (ESDS)
human engineering
human factors
control console

I. INTRODUCTION

Per reference 1, the Navy Experimental Diving Unit (NEDU) was tasked in February 1988 to support the Naval Coastal Systems Center (NCSC) in the technical evaluation of the prototype Light Weight Diving System (LWDS). This system is an easily transported, self-contained surface supplied diving system, intended to provide air for two working divers and a standby diver to 60 FSW. The system has two configurations. Configuration 1 utilizes a small diesel-compressor unit to supply primary air for up to 200 minutes. Configuration 2 utilizes nine composite HP air flasks to supply primary air for up to 100 minutes. Both configurations use three composite HP air flasks to supply secondary air. Divers utilize the Enclosed Space Diving System (ESDS) and a light weight umbilical. After discussions with NCSC, NEDU developed the test plan of Appendix A to evaluate human factors, transportability, and suitability of the LWDS during its initial open water trials. In addition, the preliminary O&M Manual and preliminary OP/EP Manual were evaluated. The LWDS was then sent to Explosive Ordnance Disposal Mobile Unit 4 (EODMU-4) in Key West, Florida, for further evaluation by NCSC during actual operations.

II. FUNCTIONAL DESCRIPTIONS OF EQUIPMENT

The layout and air flow of the LWDS is shown in Figure 1. The diver worn equipment is the ESDS currently in use. Configuration 1 utilizes a small diesel-compressor unit to supply primary air and a rack of three composite HP air flasks to supply secondary air. Configuration 2 utilizes the same components except that the diesel-compressor is replaced by nine composite HP air flasks to supply primary air. Each component is described as follows:

NOTE: All specifications and descriptions are taken from the draft LWDS Operations and Maintenance Manual.

A. DIESEL-COMPRESSOR UNIT

1. Diesel Engine. The engine is a two-cylinder Lister LV2, air cooled engine connected to the compressor unit by a belt drive (Figure 2). The LV2's fuel supply is a 6 gallon plastic tank mounted to the frame of the diesel-compressor unit above the compressor inlet. The fuel consumption of this engine, under load, is 0.5 gallons per hour.

2. Compressor. The compressor is an air cooled, belt driven Atlas Copco Model 18AT8BE (Figure 2). It has two cylinders that provide two stage compression. An unloader pilot valve senses pressure at the volume tank and controls the compressor unloaders mounted on the compressor heads. The pilot valve thus controls compressor cut-in and cut-out pressures. An interstage pressure relief valve protects the compressor in case of blockage between the first and second stages. The total weight of the diesel-compressor unit is 600 pounds.

BLANK PAGE

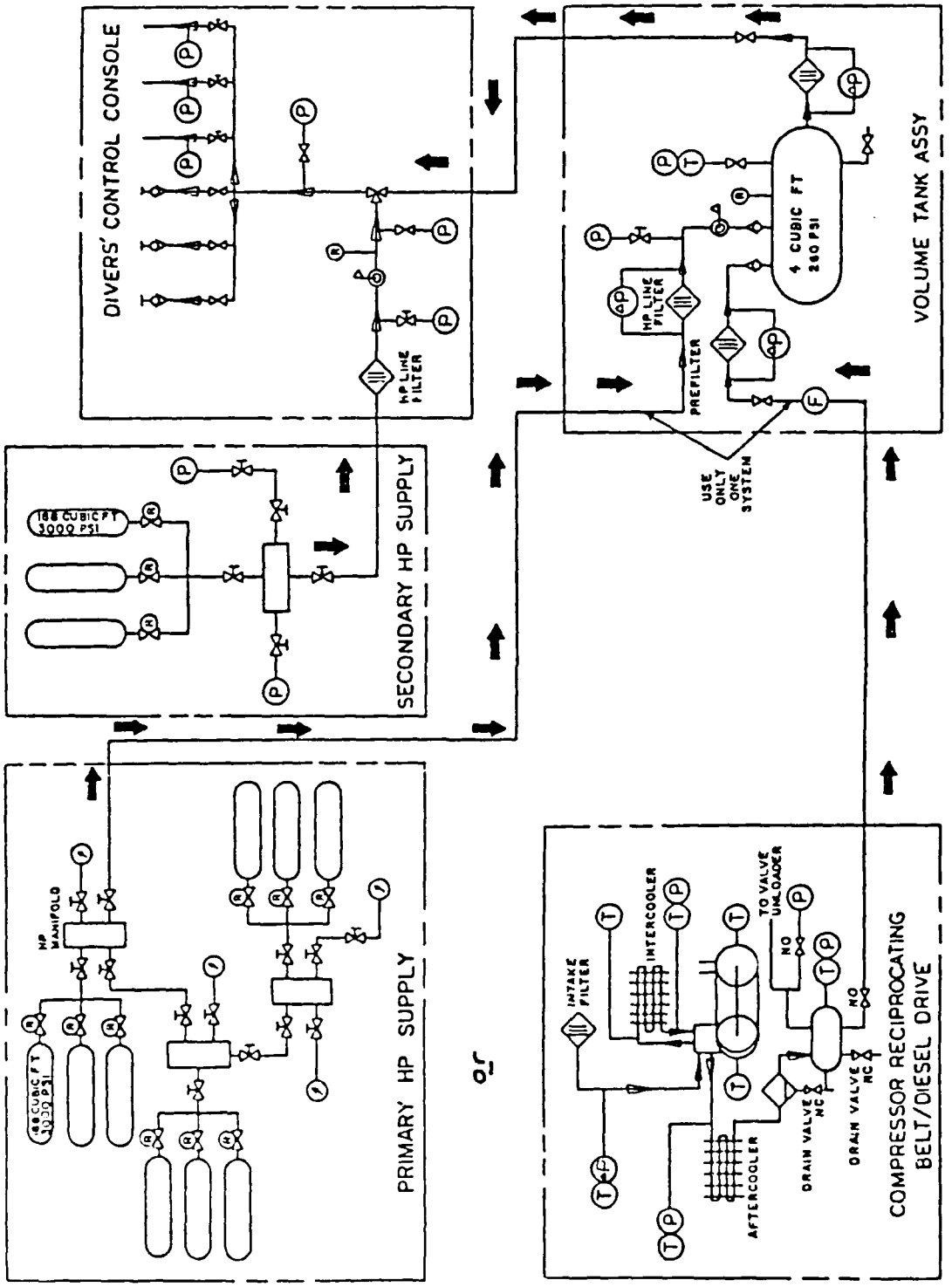


Figure 1. LWDS Layout and Air Flow

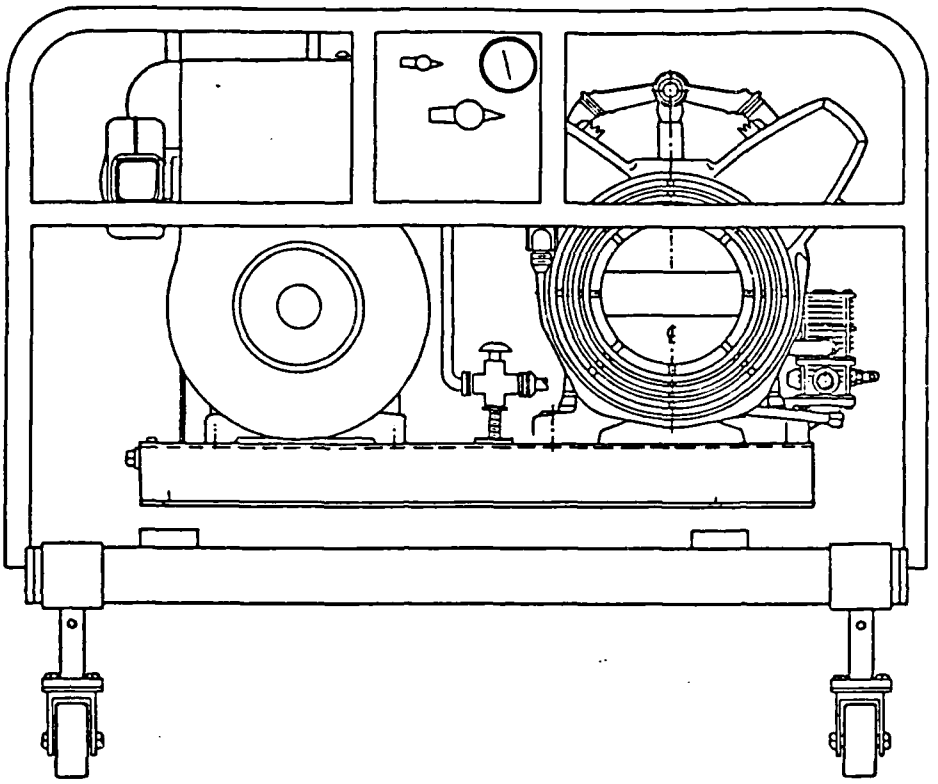


Figure 2. Diesel-Compressor Unit

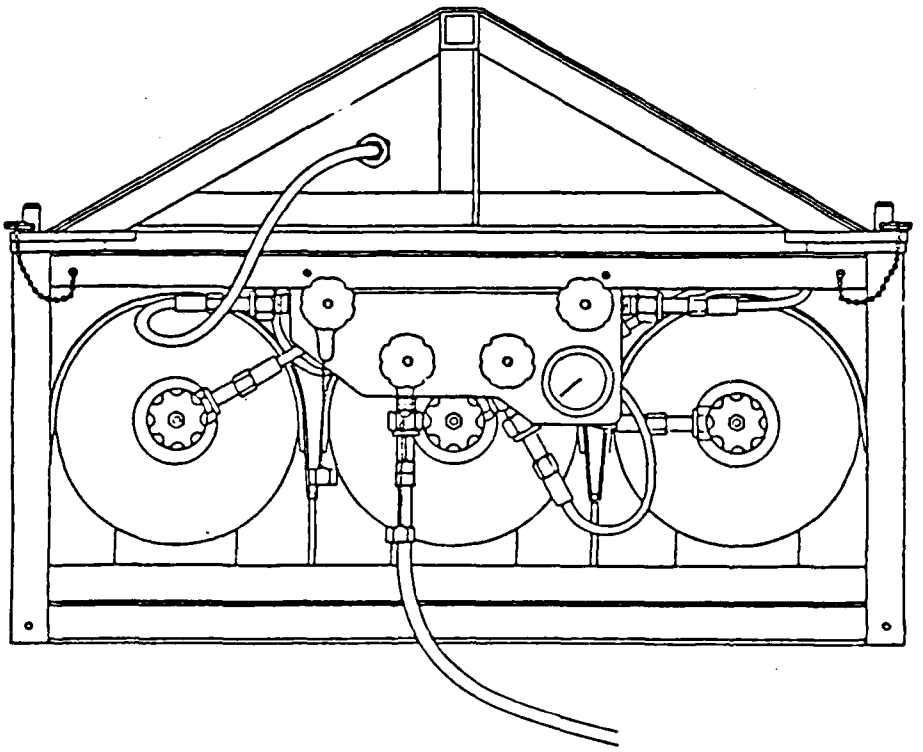


Figure 3. Secondary HP Air Supply

B. SECONDARY HP AIR SUPPLY

The secondary HP air supply of 188 scf at 3000 psig is contained in three KEVLAR-wrapped aluminum flasks (Figure 3). The secondary air supply is always connected to the divers' control console, where it is reduced to LP air. In the event there is a system failure prior to the divers' control console, the secondary air supply may be directed to the divers' breathing hoses by switching the three-way selector valve on the divers' control console to "SECONDARY SUPPLY". The secondary air supply is calculated sufficient for three divers to complete a 60 foot, 200 minute bottom time decompression schedule. The secondary supply rack weighs 200 pounds.

C. PRIMARY HP AIR SUPPLY

The primary HP air supply may be used in place of the diesel-compressor unit when a scheduled dive does not exceed a maximum dive of 60 FSW for 100 minutes (Figure 4). This air supply consists of three racks with three KEVLAR-wrapped aluminum flasks in each rack. Each rack is identical to the secondary air supply. Primary air from the flasks is directed to the bottom rack manifold and then by interconnecting hose to a manually adjustable regulator on the volume tank unit. Each 3-flask rack contains 188 scf at 3000 psig. A peaked roof fits over the top-most rack and contains an HP pressure gauge that faces the operator when in use. Each rack weighs 150 pounds when charged, and the single roof unit weighs 50 pounds.

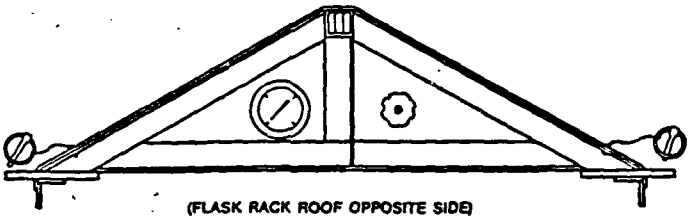
D. VOLUME TANK UNIT

1. Volume Tank. The volume tank serves as a supply reservoir of LP compressed air (Figure 5). It also removes most of the moisture from the incoming air by condensation through natural cooling. The water collected in the tank is removed through a manually operated tank drain valve. The tank also serves to dampen pressure pulsations in air supplied by the compressor. Incoming air to the volume tank flows through a non-return check valve to prevent loss of pressure due to a rupture in the interconnecting hose or from failure of the diesel-compressor unit. The unit weighs 250 pounds.

2. Filters. The volume tank unit contains two identical filters; one a prefilter, the other a final filter. The filters are designed to remove entrained hydrocarbons, liquid water, and particulate matter, greater than 0.1 micron in size from the air. Each filter element is equipped with a moisture drain valve. The status of the filters is monitored by two pressure drop sensing units whose indicators are located on the Instrument Panel. The indicators will gradually change from green to red as the pressure drop across the filter increases to 5 psi.

E. DIVERS' CONTROL CONSOLE

Control of life support and pneumofathometer air flow in the LWDS is provided by the divers' control console (Figure 5). Low pressure air from the volume tank unit, and high-pressure air from the secondary air supply enter the divers' control console through color-coded, marked fittings. Air from



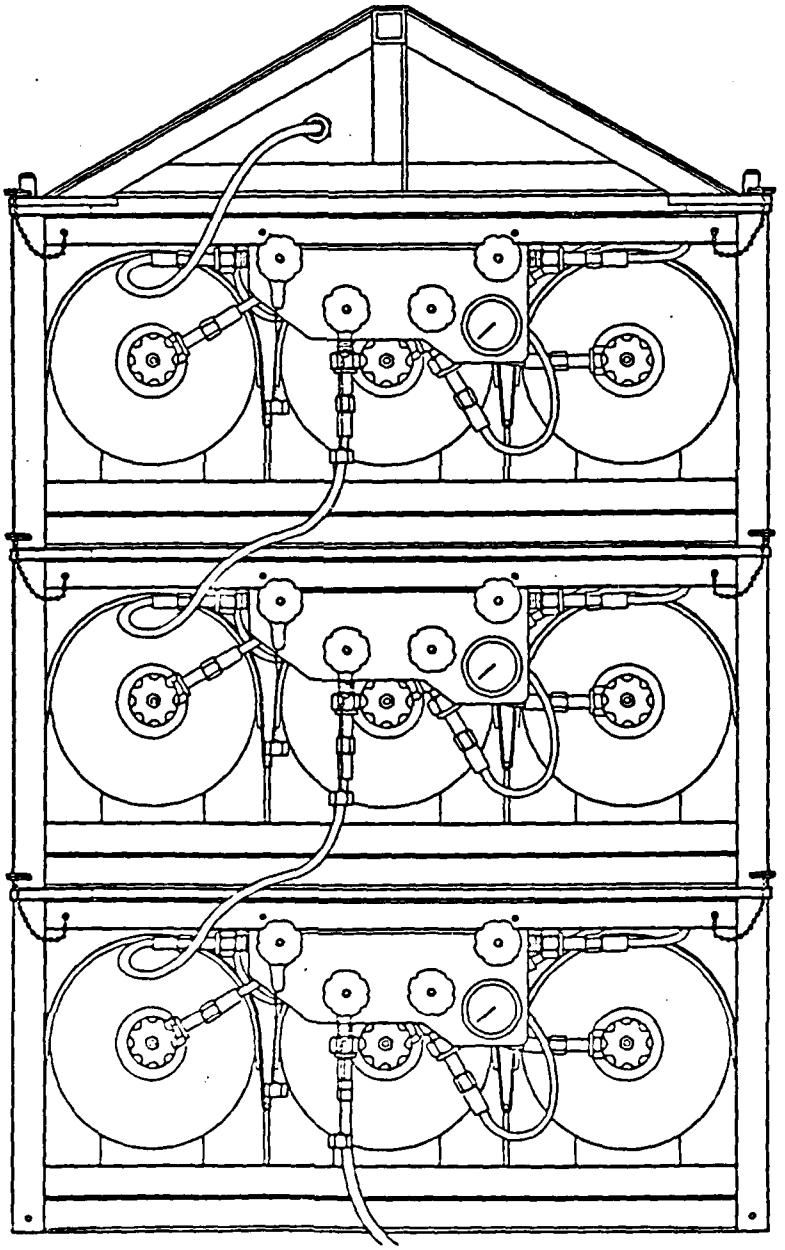
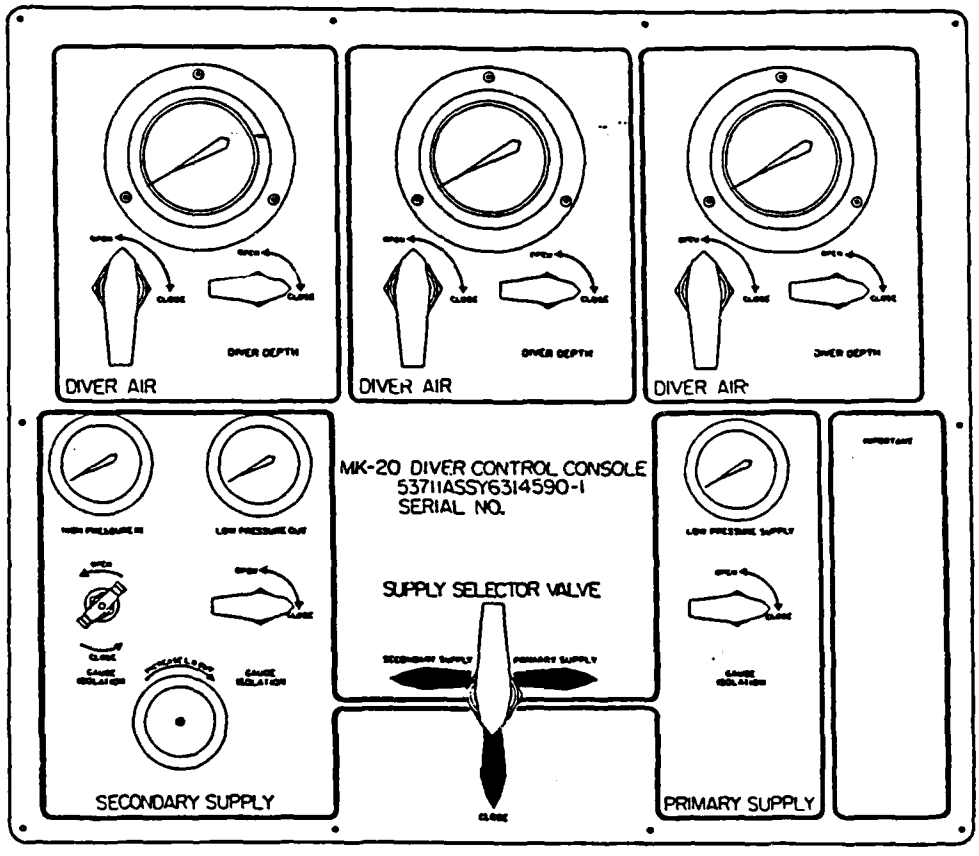


Figure 4. Primary HP Air Supply



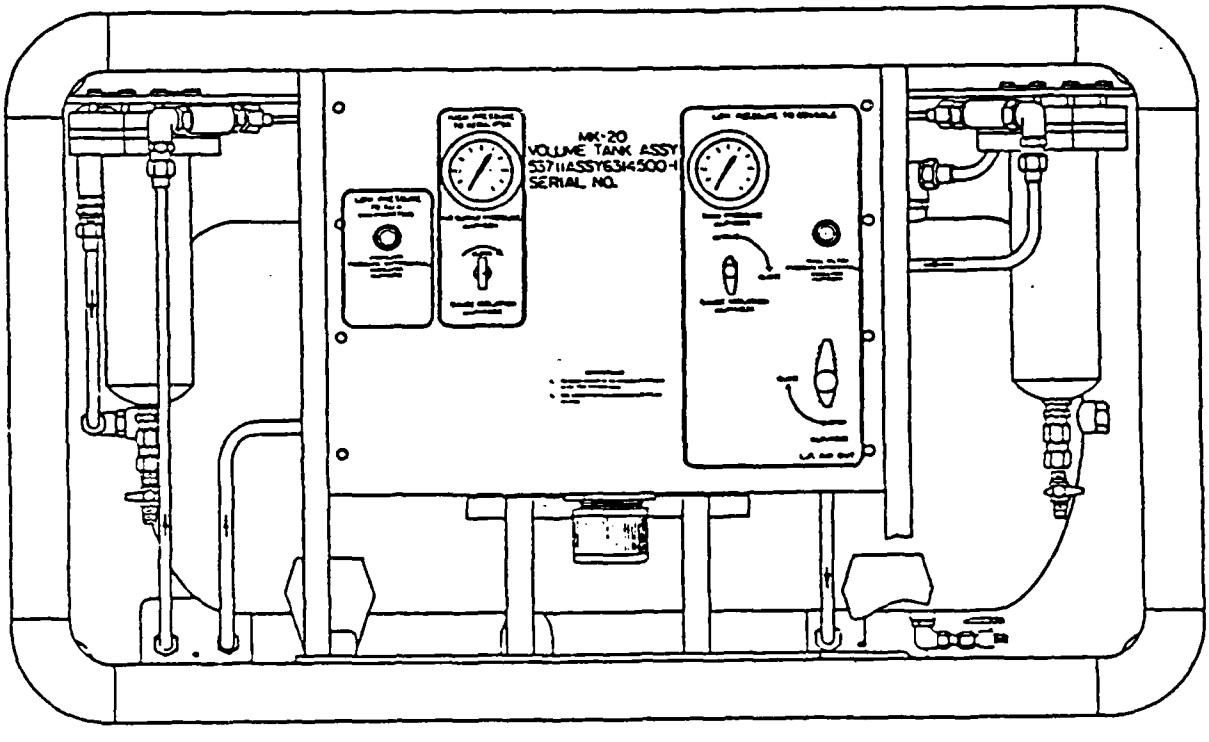


Figure 5. Divers' Control Console and Volume Tank Unit

the secondary HP air supply is directed from the flask racks to the divers' control console through a regulator in the console. The air is regulated as necessary, and directed to the diver's air supply hose through control valves. The console contains pressure gauges to allow the operator to monitor divers' air supply systems. Also contained in the console is the pneumofathometer (pneumo) system which provides a depth readout for each diver. Air to the pneumofathometer hose is supplied from the primary and secondary air supplies. The console weighs 150 pounds.

F. INTERCONNECTING HOSE ASSEMBLIES

The interconnecting hose assemblies connect the LWDS in either an LP air compressor supplied configuration or an HP air flask supplied configuration. A flow diagram of the interconnecting hose assemblies in both configurations is shown in Figure 1. These consist of:

1. Diesel-Compressor Unit to Volume Tank Unit. Air from the compressor outlet passes through a 50-foot, ½-inch ID rubber diver's hose to the volume tank prefilter inlet. This hose is equipped with 7/8-inch 37° flare fittings to preclude its use between the volume tank unit and the control console. If it is desired to locate the compressor unit more than 50-feet from the divers' control console, a maximum of three 50-foot hoses can be joined with 37°-to-37° unions. A 1/8-inch OD stainless steel restraining line is strapped to the hose for safety. A ¼-inch ID hose is used to feed back volume tank pressure to the pilot valve to cycle the compressor.

2. Volume Tank Unit to Divers' Control Console. The volume tank unit is connected to the divers' control console by a 15-foot, ½-inch ID rubber diver's hose. This hose is equipped with 3/4-inch 37° flare fittings to preclude its use between the diesel-compressor unit and the volume tank unit.

3. Secondary HP Air to Divers' Control Console. A 30-foot long, 3/8-inch ID stainless steel overbraided TEFLON hose is connected between the secondary air manifold and the divers' control console. A 1/8-inch OD stainless steel restraining line is strapped to the air hose for safety.

4. Primary HP Air to Volume Tank. When the primary HP air supply is used, a 30-foot long, 3/8-inch ID stainless steel overbraided TEFLON hose is connected between the primary HP manifold and the manually adjustable regulator on the volume tank. A 1/8-inch OD stainless steel restraining line is strapped to the air hose for safety.

5. Flask Rack to Flask Rack to Roof. When HP air is used as the primary air supply for the LWDS, nine HP air flasks mounted in three racks provide the divers' air. These racks are interconnected by a rack manifold and 24-inch long, 3/8-inch ID stainless steel overbraided TEFLON hoses. The top rack is connected to the rack roof pressure gauge in the same manner. Each HP flask is connected to their rack manifold by a 24-inch long, ¼-inch ID stainless steel overbraided TEFLON hose.

6. Umbilical from Divers' Control Console to Diver. See the ESDS Operation and Maintenance Manual, 56560 AF-OMP-010 ESDS, (paragraph 1-4.1) for a description of the diver's umbilical. The LWDS uses a combination strength/communication Noreco cable vice a separate communication cable and lifeline as described in the ESDS Manual.

The various hoses together weigh approximately 250 pounds.

III. TEST PROCEDURES

The evaluation was conducted per the test plan of Appendix A. The LWDS was picked up at the NCSC work area by a NEDU team and transported to the NCSC pier in two pick-up trucks. NCSC personnel instructed two NEDU six-man teams in the operation of the system; then a series of 13 dives was conducted over 2 days. The test plan was modified to include a break-down questionnaire to compliment the set up questionnaire. Also, emergency endurance trials were conducted. The length of time a diver at rest, at 20 FSW, could breathe air contained only in the umbilical was measured. An indication of duration for the volume tank only under the same criteria was obtained. Throughout, human factors observations were made using dive team questionnaires and other notes taken by the Dive Officer, Master Diver, and the NEDU Medical representative.

IV. TEST RESULTS

The results of the dive team questionnaires are contained in Appendix B. The human engineering checklist completed by the Dive Officer, Master Diver, and the NEDU Medical representative is contained in Appendix C. A list of additional observations and recommended improvements noted during the evaluation are contained in Appendix D. All the collected data was provided to NCSC (Code 5110) to assist refinement of the system.

The LWDS proved to be an acceptable diving system.

A. PRIMARY SAFETY OBSERVATIONS WERE:

1. Pneumofathometer hose and fuel supply hose connections must be more secure. The fitted band-it clamps were not fully compressed.

2. The various gauges must display calibration stickers.

3. The HP regulators should have bypasses in case of regulator failure.

4. All heavy equipment should have carrying handles.

B. PRIMARY HUMAN FACTORS OBSERVATIONS WERE:

1. It was a simple system to operate.

2. The diesel-compressor unit is an extremely heavy, awkward lift for four men, that significantly exceeds MIL STD 1472C recommended limits.

3. The diesel was very noisy.

4. The team was uncomfortable with the fuel tank mounted over the compressor inlet and the compressor oil filter co-centric with the inlet filter housing. Failure of the filter housing seal could result in air contamination.

C. PRIMARY OPERATIONAL OBSERVATIONS WERE:

1. Topside to diver communications were very good.

2. The 150 foot umbilicals were too short.

3. There is no way within the system to charge the HP flasks.

4. Due to the LWDS size, LCM 6 or 8 craft would be required to operate the system afloat in either configuration.

D. PUBLICATIONS REVIEW:

Review of the publications for the LWDS prove them to be very good preliminary drafts. The various checklists need to be in the proper format and recent equipment changes must be reflected in the manuals. Detailed observations were placed directly in the manuals and the publications returned to NCSC (Code 5110) for action.

E. EMERGENCY ENDURANCE TRIALS DEMONSTRATED THAT:

1. Air trapped in an isolated 300 foot umbilical will support a resting diver at 20 FSW for 90 seconds.

2. The air reserve of the volume tank was depleted from 138 psig to 100 psig by a resting diver at 20 FSW in 10 minutes.

V. DISCUSSION

The LWDS proved to be a good prototype system. Correction of the various shortcomings noted in the appendixes should ensure that it would meet Navy standards. Per MIL STD 1472C, the diesel-compressor unit cannot be considered man-portable, even for six males. This represents a significant failure to achieve Operational Requirement 108-02-87, as detailed in Naval Sea Systems Command TEMP 856-1. Further research into methods of reducing the weight of the diesel-compressor unit should be conducted. Durability and maintainability were not addressed in this report. The results of LWDS use by EODMU-4 should give a good indication of it and provide considerable input into final Navy acceptance. Either configuration can be transported on two full size ½ ton pickup trucks. Transport by aircraft is limited by two factors, weight and dangerous cargo status. Configuration 1 weighs 1,450 pounds. Configuration 2 weighs 1,300 pounds. As both configurations use HP air flasks for secondary air supply, a hazardous cargo waiver would have to be granted prior to air transport. If the flasks were required to be emptied for airlift, there is no method, within the prototype system, to refill the

flasks. A separate HP air compressor weighting 150-250 pounds would be required.

The LWDS design, especially in Configuration 1, is a suitable alternative to the FADS. It is significantly lighter and more manageable and can be transported by a six member dive team (minimum). Configuration 2 however, represents current air supply methods that severely limit flexibility. It is not a system that could be used onboard a Boston Whaler or Zodiac type boat. The requirement for a LP volume tank for reduced HP primary air supply, reference 2, may have been needed for free flow UBA but is not required for modern demand systems. The reserve of air contained in the diver's umbilical is sufficient to allow a safe switch to secondary supply. A weight reduction of 250 pounds is realized with the volume tank unit removed from the configuration. The divers' control console would require modification similar to Figure 6 to add the primary supply regulator removed from the volume tank unit. The use of one, two, or all three Primary HP Air Supply racks should be made optional to allow flexible adaptation to assigned tasks. The addition of a small, portable HP air compressor could greatly expand on-scene duration. The estimated weight of such a configuration is 900 pounds.

The above considerations slightly modify the prototype LWDS. If significant redesign were done, the console could be miniaturized and the HP air racks could be expanded to 4 flasks per rack with one isolated for secondary supply. Similar systems are currently in use in Canada and the United Kingdom and weigh about 400 pounds (without HP compressor).

VI. CONCLUSIONS AND RECOMMENDATIONS

The evaluated prototype LWDS performed very well. Upon resolution of the problems, factors and discrepancies identified in the appendixes, the LWDS should prove acceptable to the fleet. It is recommended that alterations in the LWDS be made. It is recommended that the weight of the diesel-compressor unit be reduced to make it truly man-portable per MIL STD 1472C. It is further recommended that testing be continued during actual operations to identify maintenance and durability problems.

The LWDS in Configuration 1 presents an attractive alternative to the FADS for operations to 60 FSW. For extended operations, an LP compressor is very useful to provide an almost unlimited supply of air. Configuration 2 presents a very attractive alternative to Configuration 1. It is much quieter and in cold weather could reduce the likelihood of regulator freeze up. It could, however, be made much lighter, and in the process, set new standards for HP air supply systems for demand UBA. It is recommended that alternative methods of providing Configuration 2 be considered in the future development of the LWDS. This would extend the Navy's capabilities and provide flexibility to the fleet supervisor while maintaining safety and reliability.

VII. REFERENCES

1. NAVSEA Task 88-04.

2. U. S. Navy Diving Manual, Volume 1

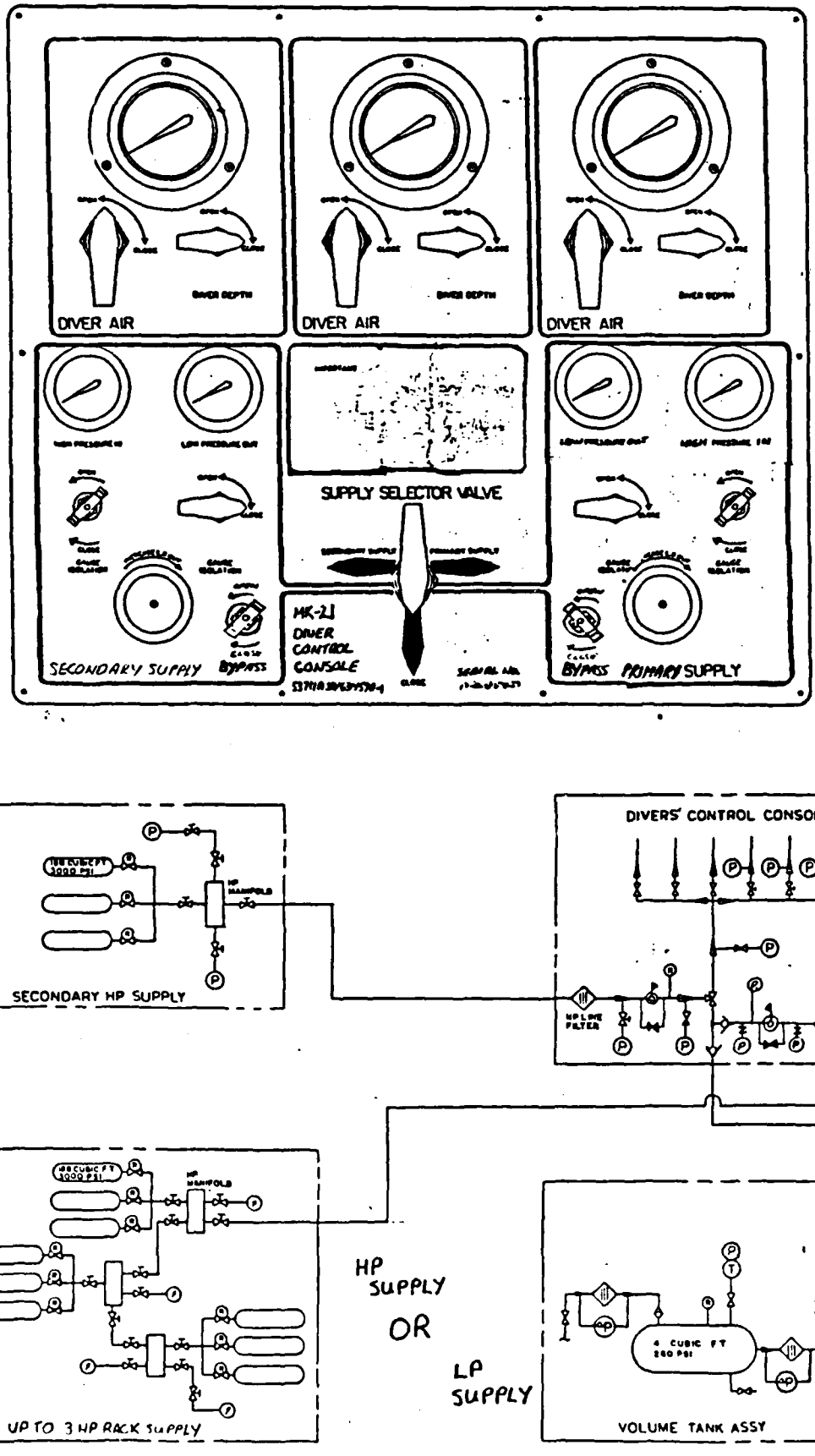


Figure 6. Proposed Changes to the LWDS

BLANK PAGE

APPENDIX A

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

IN REPLY REFER T

NAVY EXPERIMENTAL DIVING UNIT

STANDARD TEST PLAN

LIGHT WEIGHT DIVING SYSTEM (LWDS) TECHNICAL EVALUATION

TEST PLAN NUMBER 88-17

JULY 1988

Submitted:

D.G. KIRBY
LT(N), CF
Fleet Support Projects

M.T. WALLICK
LCDR, MSC, USN
Medical Officer

Reviewed:

J.T. COUCH
LT, CEC, USN
Engineering Officer

D.J. SCHMITT
GM-13
Technical Support Department Head

H.J.C. SCHWARTZ
CAPT, MC, USN
Senior Medical Officer

R.T. MACHASICK
LCDR, USN
Senior Projects Officer

J.C. DEVLIN
CDR, USN
Executive Officer

Approved:

J.D.M. HAMILTON
CAPT, USN
Commanding Officer

DISTRIBUTION: Codes 00, 01, 02, 03, 036, 04, 07
Original to Technical Library

RECORD OF CHANGES

Except as provided for herein, changes will be made only on the authority of the Commanding Officer, NEDU. A dark vertical line in the left-hand margin indicates the coverage of change.

CHANGE NO.	AUTHORITY	INSERTION	SECTION	INITIAL

TABLE OF CONTENTS

BLANK PAGE

References

(a) NAVSEA Task 88-04
(b) NCSC T&E Master Plan 856-1

1. Introduction. The Naval Coastal Systems Center (NCSC) has been tasked to produce a Light Weight Diving System (LWDS). The prototype of this system consists of the Enclosed Space Diving System (ESDS), 3/8 inch umbilical with pneumofathometer and communication/strength members, a volume tank, control panel, diesel powered LP compressor, composite HP storage flasks in racks, and supporting documentation including a draft Operations and Maintenance (O&M) Manual.

Per reference (a), the Navy Experimental Diving Unit (NEDU) is to provide support to NCSC for the technical evaluation of the LWDS to include:

a. Evaluation of the O&M Manual.

b. Evaluation of human factors, transportability and maintainability throughout diving operations.

This test plan will form an annex to reference (b). The scheduled period of testing is 19-20 July 1988.

2. Test Parameters. All diving will be conducted following procedures of the U.S. Navy Diving Manual and the draft LWDS O&M Manual. All diving will be conducted pierside at NEDU in an area of sufficiently deep water. The maximum depth of any dive shall not exceed 60 FSW. The maximum time of any dive shall not exceed the no-decompression limit for the maximum dive depth. Air will be the only breathing medium used.

3. Equipment and Instrumentation. A complete LWDS will be supplied by NCSC (Code 5110). NEDU will not instrument any part of the equipment, but NCSC may have non-obstructive life cycle instrumentation attached. NEDU will provide a suitable vehicle to transport the LWDS. Human factors information will be recorded on the forms of ANNEX B. Each diver will provide his own thermal protection suit, watch, swim fins and weights from equipment issued to him. The dive supervisor shall ensure all other support gear required by the U.S. Navy Diving Manual is procured. For safety, the Fly Away Diving System (FADS) will be used to support the standby diver.

4. Personnel Requirements. The Projects Department shall provide a diving team of six divers. Divers will be provided by all departments as required. Other personnel are as follows:

a. Diving Officer - LT(N) D. G. Kirby, CF

b. Diving Supervisor - QMCS(MDV) T.R. Griggs, USN

c. Project Medical Department Representative - LCDR M. T. Wallick, MSC, USN

d. Duty Medical Officer - per Plan of the Day with Bends Watch

5. Test Procedure. The LWDS will be picked up from NCSC by a four-man NEDU team and transported to NEDU using a vehicle. Notes on transportability will be made. Per the program of ANNEX A, NCSC will instruct the NEDU team in the operation of the LWDS. Initial human factors observations will be made. On completion, a series of dives, per the program, will be conducted pierside. Throughout the diving program, human factors per ANNEX B and other applicable observations will be made. A goal of 10 diving hours will be pursued.

6. Program. See ANNEX A.

7. Safety Rules and Emergency Procedures. The ESDS, which forms the diver-worn portion of the LWDS is a proven and approved equipment. No additional risks outside those normally incurred in open ocean diving are expected. However, as this is a prototype system, the risk of catastrophic failure of HP and LP air systems is somewhat higher than normal. All reasonable precautions against such an occurrence have been taken, but extra vigilance is required. The FADS I will support the standby diver.

All diving will be conducted per the U.S. Navy Diving Manual. Diver Operating and Emergency Procedures are detailed in the ESDS O&M Manual which forms part of the LWDS manual. Operation of support equipment is contained in the LWDS O&M Manual.

8. Termination Criteria. Diving will be discontinued if, in the opinion of the diving supervisor or diving officer, any unsafe condition exists or is believed to exist. The test will be terminated if, for any reason, diving cannot be continued within the time period programmed for the test.

9. Report Production. A NEDU technical report will be published by LT(N) Kirby by 31 August 1988.

ANNEX A

DAILY SCHEDULE

19 July 1988	0800 -	Pick up LWDS and deliver to NEDU
	o/c -	Conduct transportability study and initial human factors study
	0900 -	NCSC conduct training of NEDU personnel
	1100 -	Begin pierside dives
20 July 1988	0800 -	Conduct pierside dives
	1400 -	Complete pierside dives
	1500 -	Return LWDS to NCSC

BLANK PAGE

ANNEX B

HUMAN FACTORS EVALUATION FOR LWDS

The Enclosed Space Diving System (ESDS) which forms the diver-worn portion of the Light Weight Diving System (LWDS) is proven and approved equipment. No additional formal evaluation of this portion of the LWDS will be conducted.

Evaluation will be carried out on the topside diver support components of the LWDS which include the control panel, diesel powered LP compressor, and composite HP storage flasks in racks. The human factors evaluation will be conducted during the transport, set-up, and operation of these components of the LWDS. Both ease of operation and safety aspects will be considered. The current Military Standard for Human Engineering Design Criteria for Military Systems Equipment, and Facilities (MIL-STD-1472C) will be used in conducting this evaluation.

The Human Engineering Checklist should be filled out by the Project Officer and Human Factors Engineer. Individual questionnaires are provided to be filled out by all divers, tenders, and operators of the LWDS during the evaluation.

HUMAN ENGINEERING CHECKLIST
LIGHT WEIGHT DIVING SYSTEM

INSTRUCTIONS

1. All items appearing in this checklist are extracted from the Military Standard, MIL-STD-1472C: Human Engineering Design Criteria for Military Systems Equipment, and Facilities.

2. This checklist shall be completed by the Project Officer and Human Factors Engineer at an appropriate time during the Operational Phase of the TECHEVAL. The Project Officer will examine the subject of each item on the checklist for conformity or nonconformity with standard cited. Methods employed to complete this checklist may include but are not limited to:

a. Observation of system/equipment.

b. Observation of personnel performing their duties.

c. Questioning operators and maintenance technicians.

d. Making specific measurements.

3. Items not meeting the standards shall be listed on the final summary page of this checklist, together with possible means of improvements/correction. Additional summary pages will be reproduced as required. Below are seven areas cited for consideration when testing the LWDS for human engineering design.

a. Range of acoustic noise, vibration, and impact forces and safe guards against uncontrolled variability beyond safe limits.

b. Adequate space for operator, equipment, and free volume for required movements performed during operation and maintenance tasks under both normal and emergency conditions.

c. Adequate physical, visual, auditory, and other communication links between personnel, and between personnel and their equipment, under both normal and emergency conditions.

d. Efficient arrangement of operation and maintenance workplaces, equipment, controls, and displays.

e. Design feature to assure rapidity, safety, ease and economy of maintenance in normal, adverse and emergency maintenance environments.

f. Satisfactory remote handling provisions and tools.

g. Adequate emergency systems for contingency management, escape, survival and rescue.

4. Human Engineering Considerations per MIL-STD-1472C according to paragraph number:

5.1 Control/display Integration

5.1.1.1 Relationship. The relationships of a control to its associated display and the display to the control shall be immediately apparent and unambiguous to the operator. Controls should be located adjacent to (normally under or to the right of) their associated displays and positioned so that neither the control nor the hand normally used for setting the control will obscure the display.

YES NO

5.1.1.2 Design. Control-display relationships shall be apparent through proximity, similarity of groupings, coding, framing, labeling, and similar techniques.

YES NO

5.1.2.1 Functional Grouping. Functionally related controls and displays shall be located in proximity to one another--arranged in functional groups, e.g., power, status, test.

YES NO

5.2 Visual Displays

5.2.1 General. Visual displays should be utilized to provide the operator with a clear indication of equipment or system conditions for operation under any eventuality commensurate with the operational and maintenance philosophy of the system under design.

YES NO

5.3 Audio Displays

5.3.8.4 Headsets. If listeners will be working in high ambient noise (85 dB(A) or above), binaural rather than monaural headsets shall be provided. Unless operational requirements dictate otherwise, binaural headsets shall be wired so that the sound reaches the two ears in opposing phases. Their attenuation qualities should be capable of reducing the ambient noise level to less than 85 dB(A). Provisions should be incorporated to furnish the same protection to those who wear glasses.

YES NO

5.4 Controls

5.4.1.2.3 Operator-Control Orientation. Controls shall be oriented with respect to the operator.

YES NO

5.4.1.2.4 Valve Controls. Rotary valve controls should open the valve with a counterclockwise motion. Valve controls shall be provided with double-ended arrows showing the direction of operations and appropriately labeled at each end to indicate the functional result (e.g., open and close).

YES NO

5.4.1.3.1 Grouping. All controls which function in sequential operation necessary to a particular task, or which operate together, shall be grouped together along with their associated displays. When several steps of a sequence are selected by one control, the steps shall be arranged by order of occurrence to minimize control movements and prevent cycling through unnecessary steps. Cycling through the control's ON/OFF position shall be avoided.

YES NO

5.4.1.3.2 Sequential Operation. Where sequential operations follow a fixed pattern, controls shall be arranged to facilitate operation (e.g., in a pattern left-to-right and top-to-bottom, as a printed page).

YES NO

5.4.1.3.3 Location of Primary Controls. The most important and frequently used controls shall have the most favorable position with respect to ease of reaching and grasping (particularly rotary controls and those requiring fine settings).

YES NO

5.4.1.3.6 Maintenance and Adjustment. In general, controls used solely for maintenance and adjustment and referred to infrequently shall be covered during normal equipment operation, but shall be readily accessible and visible to the maintenance technician when required.

YES NO

5.4.1.3.7. Spacing. Minimum spacing between controls shall comply with Table VII. Spacing between a control and any adjacent obstruction shall be as shown by the figures referenced by Table VII. Minimum spacing shown shall be increased for operation with gloves or mittens when such operation is a system requirement.

YES NO

5.4.1.8.1 Location and Design. Controls shall be designed and located so that they are not susceptible to being moved accidentally, particularly critical controls whose inadvertent operation might cause damage to equipment, injury to personnel or degradation of system functions.

YES NO

5.5 Labeling

5.5.1.1 Application. Labels, legends, placards, signs or markings, or a combination of these shall be provided whenever it is necessary for personnel to identify, interpret, follow procedures or avoid hazards, except where it is obvious to the observer what an item is and what he or she is to do with it.

YES NO

5.5.2.1 Orientation. Labels and information thereon should be oriented horizontally so that they may be read quickly and easily from left right. Vertical orientation may be used only when labels are not critical for personnel safety or performance and where space is limited. When used, vertical labels shall read from top to bottom.

YES NO

5.5.2.2 Location. Labels shall be placed on or very near the items which they identify, so as to eliminate confusion with other items and labels. Labels shall be located so as not to obscure any other information needed by the operator. Controls should not obscure labels.

YES NO

5.5.2.3 Standardization Labels shall be located in a consistent manner throughout the equipment and system.

YES NO

5.5.5.1 Black Characters. Where the ambient illuminance will be above 10 lux (0.9 ft-c), black characters shall be provided on a light background.

YES NO

5.5.5.4.1 Labels. Labels shall be printed in all capitals; periods shall not be used after abbreviations.

YES NO

5.5.3.1 Equipment Functions. Labels should primarily describe the functions of equipment items. Engineering characteristics or nomenclature may be described as a secondary consideration.

YES NO

5.5.4.3 Visibility and Legibility. Labels and placards shall be designed to be read easily and accurately at the anticipated operational reading distances, vibration/motion environment, and illumination.

YES NO

5.6 Anthropometry

5.6.1 General. Design and sizing shall insure accommodation, compatibility, operability, and maintainability by the user population. Generally, design limits shall be based upon a range from the 5th percentile female to the 95th percentile male values for critical body dimensions, as appropriate.

YES NO

5.7 Workspace Design Requirements

5.7.2.2. Display Placement, Normal. Visual displays mounted on vertical panels and used in normal equipment operation shall be placed between 1.040 m (41 inches) and 1.780 m (70 inches) above the standing surface.

YES NO

5.7.2.4 Control Placement, Normal. All controls mounted on a vertical surface and used in normal equipment operation shall be located in a area between 860 mm and 1.780 m (34 and 70 inches) above the standing surface.

YES NO

5.8 Environment

5.8.3.1. General. Personnel shall be provided an acoustical environment which will not cause personnel injury, interfere with voice or any other communications, cause fatigue, or in any other way degrade over-all system effectiveness. The fact that a component which contributes to the overall noise may be government furnished equipment shall not eliminate the requirement that the total system conform to the criteria herein.

YES NO

5.9 Design for Maintainability

5.9.1.1 Standardization. Equipment shall be designed to incorporate standard parts to the maximum extent feasible. Standard parts should meet the human engineering criteria herein.

YES NO

5.9.1.5. Separate Adjustability. Functions shall be so unitized that it will be possible to check and adjust each unit separately, except where this would be inconsistent with established maintenance concepts.

YES NO

5.9.1.6 Malfunction Identification. Equipment design shall facilitate rapid and positive fault detection and isolation of defective items to permit their prompt removal and replacement.

YES NO

5.9.1.7 Assembly and Disassembly. Equipment design shall facilitate assembly and disassembly.

YES NO

5.9.3.6 Hazardous Locations. Internal controls should not be located close to dangerous voltages, rotating machinery, or any other hazards. If such location cannot be avoided, the controls shall be appropriately shielded and labeled.

YES NO

5.9.4.1 Structural Members. Structural members of units or chassis shall not

prevent access to or removal of items. Replaceable items shall not be placed in a manner which will make them difficult to remove. Where accessibility depend upon removal of panels, cases, and covers, measures shall be taken to insure that such items are not blocked by structural members or other items.

YES NO

5.9.4.2 Large Items. Large items which are difficult to remove shall be so mounted that they will not prevent convenient access to other items.

YES NO

5.9.4.3 Use of Tools and Test Equipment. Check points, adjustment points, test points, cables, connectors, and labels shall be accessible and visible during maintenance. Sufficient space shall be provided for the use of test equipment and other required tools without difficulty or hazard.

YES NO

5.9.8.1 Securing of Covers. It shall be made obvious when a cover is not secured, even though it may be in place.

YES NO

5.9.8.2 Instructions. If the method of opening a cover is not obvious from the construction of the cover itself, instructions shall be permanently displayed on the outside of the cover.

YES NO

5.9.9.2 Self-Supporting Covers - All access covers that are not completely removable shall be self-supporting in the open position. Accesses (and covers) should be devoid of sharp edges to preclude hand injury and clothing damage.

YES NO

5.9.10.1 General. The number and diversity of fasteners used shall be minimized commensurate with stress, bonding, pressurization, shielding, thermal and safety requirements. Finger or hand-operated fasteners shall be used when consistent with these requirements, except where scrrews with heads flush with the case or fastening surface are required for NBC survivability. Fasteners requiring non-standard tools shall not be used.

YES NO

5.9.10.2 Hinges and Tongue-and Slot Catches. Optimum use shall be made of hinges and tongue-and slot catches to minimize the number of fasteners required; however, where covers are subject to NBC survivability requirements, interlock clips, rather than hinges, should be used.

YES NO

5.9.11.1 Rests and Stands. When required to support operations or maintenance functions, rests or stands on which units can be placed, including space for test equipment, tools, technical orders and manuals, should be provided. When permitted by design requirements, such rests or stands shall be part of the basic unit, rack or console chassis.

YES NO

5.9.11.2 Extensions. Extensions and connected appurtenances, accessories, utilities, cables, wave guides, hoses and similar items shall be designed for easy removal or disconnection from the equipment before handling.

YES NO

5.9.11.3.1 Lifting Limits. The weight limits in Table XXIV, conditions A and B, shall be used as maximum values in determining the design weight of items requiring one person lifting with two hands. Double the weight limits in Table XXIV shall be used as the maximum values in determining the design weight of items requiring two person lifting, provided the load is uniformly distributed between the two lifters. If the weight of the load is not uniformly distributed, the weight limit applies to the heavier lift point. Where three or more persons are lifting simultaneously, not more than 75 percent of the one-person value may be added for each additional lifter, provided that the object lifted is sufficiently large that the lifters do not interfere with one another while lifting. Where it is not possible to define the height to which an object will be lifted in operational use, the limit wherein the object is lifted to shoulder height shall be used rather than the more permissive bench height value. The values in Table XXIV are applicable to objects with or without handles.

YES NO

5.9.11.3.9 Labeling. Items weighing more than the one-person lift or carry values for Male and Female Population of Table XXIV shall be prominently labeled with weight of the object and lift limitation, i.e., mechanical or two-person lift, three-person lift, etc. Where mechanical or power lift is required, hoist and liftpoints shall be provided and clearly labeled.

YES NO

5.9.11.5.1 General. All removable or carried units designed to be removed and replaced shall be provided with handles or other suitable means for grasping, handling, and carrying (where appropriate, by gloved or mittened hand). Items requiring handling should be provided with a minimum of two handles, or one handle and one grasp area. Items weighting less than 4.5 kg (10 lbs) whose form factor permits them to be handled easily shall be exempt from this requirement unless specifically directed by the procuring activity.

YES NO

5.9.11.5.2 Location. Whenever possible, handles or grasp areas shall be located relative to the center of gravity of the unit to preclude swinging or tilting when lifted. They shall be located to provide at least 50 mm (2 inches) of clearance from obstructions during handling.

YES NO

5.9.14.1 Use of Quick Disconnect Plugs. Plugs requiring no more than one turn, or other quick-disconnect plugs, shall be provided whenever feasible.

YES NO

5.9.14.2 Keying. Plugs are designed so that it is impossible to insert a wrong plug into a receptacle.

YES NO

5.13 Hazards and Safety

5.13.1 General. As a part of system equipment design, safety factors shall be given major consideration, including, as a minimum, the effective application of the human engineering criteria in other sections of this standard, together with the representative safety criteria herein.

YES NO

5.13.2.1 Warning Placards - Conspicuous placards shall be mounted adjacent to any equipment which presents a hazard to personnel (e.g., from high voltage, heat, toxic vapors, explosion, radiation).

YES NO

5.13.2.7 Hand Grasp Areas - Hand grasp areas shall be conspicuously and unambiguously identified on the equipment.

YES NO

5.13.3 Pipe, Hose and Tube Line Identification - Pipe, hose, and tube lines for liquids, gas, steam, etc., shall be clearly and unambiguously labeled or coded as to contents, pressure, heat, cold, or other specific hazardous properties in accordance with MIL-STD-1247.

YES NO

5.13.4.6. Thermal Contact Hazards - Equipment which, in normal operation, exposes personnel to surface temperatures greater than those shown below, shall be appropriately guarded. Surface temperatures induced by climatic environment are exempt from this requirement. Cryogenic systems shall also be appropriately guarded.

YES NO

5.13.5.2 Access. Units shall be so located and mounted that access to them can be achieved without danger to personnel from electrical charge, heat, moving parts, chemical contamination, radiation, or other hazards.

YES NO

5.13.5.4 Edge Rounding. Where applicable, all exposed edges and corners shall be rounded to a minimum of .75 mm (.03 in) radius. Sharp edges and corners that present a personal safely hazard or potential damage to equipment during usage shall be suitably protected or rounded to a minimum radius of 13 mm (1/2 in).

YES NO

5.13.7.2.1 Guards. A guard shall be provided on all moving parts of machinery and transmission equipment, including pulleys, belts, gears, blades, etc., on which personnel may become injured or entangled.

YES NO

HUMAN ENGINEERING CHECKLIST

DEFICIENCY SUMMARY SHEET

MIL-STD-1472C REFERENCE	DEFICIENCY DESCRIPTION	SUGGESTED CORRECTION

HUMAN FACTORS EVALUATION

SET-UP QUESTIONNAIRE

NAME _____ DATE _____

LOCATION: PIERSIDE _____ AFLOAT _____

GRADING CODE: A - Satisfactory
B - Fair: Minor deficiencies, improvement desirable
C - Poor: Considerable deficiencies, improvement needed
D - Unacceptable: Major deficiencies, improvement mandatory

1. How many persons are needed to safely unload and position the largest system component?

2. Are handles and lifting aids correctly positioned to provide easy and balanced carrying for all components? Yes _____ No _____ If not, please describe how these could be improved.

3. How would you rate the ease of set-up of the LWDS? _____

4. Please describe any problems you encountered during the set-up of any of the components of the LWDS.

AFLOAT TESTING ONLY: BOAT USED _____

5. Would you encounter any problems in loading the components onto a boat? Yes _____ No _____ If yes, please describe.

6. How much space should be available to set-up a safe working area for this system? Yes _____ No _____
Comments:

7. How do you rate the stability and safety of the LWDS under motion conditions encountered on a boat? _____
Comments:

HUMAN FACTORS EVALUATION

OPERATOR'S QUESTIONNAIRE

NAME _____ DATE _____

LOCATION: PIERSIDE _____ AFLOAT _____

GRADING CODE: A - Satisfactory
B - Fair: Minor deficiencies, improvement desirable
C - Poor: Considerable deficiencies, improvement needed
D - Unacceptable: Major deficiencies, improvement mandatory

DIESEL PRIME MOVER/COMPRESSOR	GRADE		GRADE
1. Adequacy of controls	_____	3. Operating noise level	_____
2. Adequacy of displays	_____	4. Operating instructions	_____

COMMENTS:

DIVER CONTROL STATION	GRADE		GRADE
5. Adequacy of controls	_____	11. Communications	
6. Control arrangement	_____	Operator to tender	_____
7. Control labels	_____	Tender to operator	_____
8. Adequacy of displays	_____	12. Operation instructions	
9. Display arrangement	_____	Normal operation	_____
10. Display labels	_____	Emergency operation	_____
		HP primary	_____

COMMENTS:

HUMAN FACTORS EVALUATION

OPERATOR'S QUESTIONNAIRE (CONTINUED)

GENERAL

13. Did you notice any potential safety hazards in the Diesel Prime Mover/Compressor or the Diver Control Station? Yes _____ No _____
If yes, please describe.

14. Are the emergency procedures adequate for "worst case" situations?
Yes _____ No _____

15. Does the technical manual support equipment description, function, and operating procedures? Yes _____ No _____

16. Are there any modifications you would like to see in the LWDS?

17. Is there anything else about the LWDS that you want to comment on?

HUMAN FACTORS EVALUATION

TENDER'S QUESTIONNAIRE

NAME _____ DATE _____

ORGANIZATION _____ LOCATION: _____ DIVE NO. _____

GRADING CODE: A - Satisfactory
B - Fair: Minor deficiencies, improvement desirable
C - Poor: Considerable deficiencies, improvement needed
D - Unacceptable: Major deficiencies, improvement mandatory

DIVING EQUIPMENT/LWDS INTERFACE	GRADE
1. Diving hose connections	_____
2. Pneumofathometer	_____

COMMENTS:

COMMUNICATION	GRADE
3. With divers	_____
4. With operator	_____

COMMENTS:

5. Are the emergency procedures adequate for "worst case" situations?
Yes _____ No _____

HUMAN FACTORS EVALUATION

TENDER'S QUESTIONNAIRE (CONTINUED)

6. Does the technical manual accurately support equipment description, function, and operating procedures? Yes _____ No _____

7. Are there any modifications you would like to see in the LWDS?

8. General comments on any part or combination of parts of the LWDS:

HUMAN FACTORS EVALUATION

DIVER'S QUESTIONNAIRE

NAME _____ DATE _____

ORGANIZATION _____ LOCATION: _____ DIVE NO. _____

GRADING CODE: A - Satisfactory
B - Fair: Minor deficiencies, improvement desirable
C - Poor: Considerable deficiencies, improvement needed
D - Unacceptable: Major deficiencies, improvement mandatory

AIR SUPPLY, PRIMARY (HP OR COMPRESSOR)	GRADE		GRADE
1. Adequate flow	_____	4. Gas humidity	_____
2. Odor	_____	5. Taste	_____
3. Gas temperature	_____		

COMMENTS:

AIR SUPPLY, EMERGENCY	GRADE		GRADE
6. Adequate flow	_____	9. Gas humidity	_____
7. Odor	_____	10. Taste	_____
8. Gas temperature	_____		

COMMENTS:

COMMUNICATIONS	GRADE
11. Ambient noise	_____
12. Intelligibility	_____

COMMENTS:

HUMAN FACTORS EVALUATION

DIVER'S QUESTIONNAIRE (CONTINUED)

13. Where there any operations of the LWDS you did not feel secure or safe with? Yes _____ No _____ If yes, please explain.

14. Are there any modifications you would like to see made on the LWDS?

BLANK PAGE

APPENDIX B

Human Factors Questionnaire Results

HUMAN FACTORS EVALUATION

SET-UP QUESTIONNAIRE

NAME 6 MEN DATE 21 JULY 88

LOCATION: PIERSIDE NCSC AFLOAT N/A

GRADING CODE: A - Satisfactory
B - Fair: Minor deficiencies, improvement desirable
C - Poor: Considerable deficiencies, improvement needed
D - Unacceptable: Major deficiencies, improvement mandatory

1. How many persons are needed to safely unload and position the largest system component? 4 - 4 MEN LP COMPRESSOR
1 - 5 MEN,
1 - 6 MEN

2. Are handles and lifting aids correctly positioned to provide easy and balanced carrying for all components? Yes 4 No 2 If not, please describe how these could be improved.
- COMPRESSOR, HP BOTTLE RACK, VOLUME TANK REQUIRES HANDLES
- HP BOTTLE RACK CORNERS AND GOGES NEED TO BE ROUNDED
- VOLUME TANK, COMPRESSOR NEED FORK LIFT POINTS

3. How would you rate the ease of set-up of the LWDS? 3-A 3-B

4. Please describe any problems you encountered during the set-up of any of the components of the LWDS.

AFLOAT TESTING ONLY: BOAT USED N/A

5. Would you encounter any problems in loading the components onto a boat? Yes 1 No ____ If yes, please describe.
LIFTING APPARATUS REQUIRED FOR COMPRESSOR AND VOLUME TANK, POSSIBLY FOR HP BOTTLE RACKS AS WELL.

6. How much space should be available to set-up a safe working area for this system? Yes 1 No ____
Comments:
CONFIGUATION 1: 10'X10' plus 6'x5' FOR COMPRESSOR plus plus 5'x5' FOR INTAKE
CONFIGUATION 2: 10'X10'

7. How do you rate the stability and safety of the LWDS under motion conditions encountered on a boat? B
Comments:
ALL COMPONENTS WOULD HAVE TO BE CASTED IN PLACE.

HUMAN FACTORS EVALUATION

TAKE-DOWN QUESTIONNAIRE

NAME 7 MEN DATE 22 JULY 88

LOCATION: PIERSIDE NCSC AFLOAT N/A

GRADING CODE: A - Satisfactory
B - Fair: Minor deficiencies, improvement desirable
C - Poor: Considerable deficiencies, improvement needed
D - Unacceptable: Major deficiencies, improvement mandatory

1. How many persons are needed to safely load and position the largest system component? 4-4MEN LP COMPRESSOR
3-6 MEN

2. Are handles and lifting aids correctly positioned to provide easy and balanced carrying for all components? Yes 2 No 5 If not, please describe how these could be improved.
ALL COMPONENTS EXCEPT CONSOLE AND HYDROCOM NEED HANDLES

3. How would you rate the ease of take-down? 3-A 3-B

4. Please describe any problems you encountered during the take-down of the components of the LWDS.
- RETAINING PINS FOR COMPRESSOR WHEELS TOO TIGHT A FIT AND HAD TO BE HAMMERED OUT.
- COMPRESSOR IS HEAVY, 600 LBS

AFLOAT TESTING ONLY: BOAT USED N/A

5. Would you encounter any problems in unloading components from a boat? Yes _____ No _____ If yes, please describe.

N/A

6. How much space should be available to set-up a safe working area for this system?
Comments:

N/A

7. How do you rate the stability and safety of the LWDS under motion conditions encountered on a boat? _____
Comments:

N/A

HUMAN FACTORS EVALUATION

OPERATOR'S QUESTIONNAIRE

NAME 11 OPERATORS - 6 TWICE DATE 21-22 JULY 88
TO TOTAL 17 RESPONDENTS - NOT ALL QUESTIONS ANSWERED
LOCATION: PIERSIDE NCSC AFLOAT N/A

GRADING CODE: A - Satisfactory
B - Fair: Minor deficiencies, improvement desirable
C - Poor: Considerable deficiencies, improvement needed
D - Unacceptable: Major deficiencies, improvement mandatory

COMPRESSOR OPERATOR SEPERATE JOB

DIESEL PRIME MOVER/COMPRESSOR	GRADE			GRADE	
				5-A	
1. Adequacy of controls	10-A	3-B	3. Operating noise level	7-B	1-C
2. Adequacy of displays	12-A	1-B	4. Operating instructions	11-A	2-B

COMMENTS: - INSTRUCTIONS ON EQUIPMENT FOR 3.; 4., NOT O;M
- ONE MAN STARTING IS TRICKY (DECOMPRESSOR LEVER)
- MORE NOISE CONTROL FOR EXHAUST REQUIRED
- EXTEND EXHAUST PIPE
- FUEL HOSE LEAKED AT CONNECTOR INSERT

DIFFERENT MAN THAN COMP. OPERATOR

DIVER CONTROL STATION	GRADE			GRADE	
5. Adequacy of controls	11-A	1-B	11. Communications		
6. Control arrangement	12-A		Operator to tender	10-A	
7. Control labels	11-A	1-C	Tender to operator	10-B	
8. Adequacy of displays	12-A		12. Operation instructions		
9. Display arrangement	12-A		Normal operation	7-A	1-B
10. Display labels	11-A	1-B	Emergency operation	3-A	2-B
			HP primary	5-A	1-B

COMMENTS: - GUAGES REQUIRE CALIBRATION
- HYDRO COM. BOX REQUIRES PROPER MOUNT
- CONSOLE INSTRUCTIONS SHOULD BE PLACED IN CENTER OF CONSOLE
- PNEUMOFATHOMETER NEEDS RESTRICTORS
- CHECK VALVES "HUMMED"
- SECONDARY AIR HP REGULATOR "HUMMED"

HUMAN FACTORS EVALUATION

OPERATOR'S QUESTIONNAIRE (CONTINUED)

NOT ALL OPERATORS RESPONDED

GENERAL

13. Did you notice any potential safety hazards in the Diesel Prime Mover/Compressor or the Diver Control Station? Yes 3 No 5
If yes, please describe.

- WITH COMPRESSOR & INTAKE ABLE TO BE REMOTE TEAM MAY NOT NOTICE INTAKE CONTAMINATIO QUICKLY
- SEVERAL BOLTS VIBRATED LOOSE ON COMPRESSOR
- FELT UNCOMFORTABLE WITH COMPRESSOR MOUNTIN BOLTS; COMP. OIL FILL THROUGH INTAKE FILTER; FUEL ABOVE INTAKE FILTER.

14. Are the emergency procedures adequate for "worst case" situations?
Yes 7 No 1

COMPRESSOR NOISE LIMITS COMMUNICATIONS TOPSIDE.

15. Does the technical manual support equipment description, function, and operating procedures? Yes _____ No _____

MANUALS NOT AVAILABLE

16. Are there any modifications you would like to see in the LWDS?

SEE 13.

17. Is there anything else about the LWDS that you want to comment on?

CHANGE PAINT COLOR TO YELLOW

HUMAN FACTORS EVALUATION

TENDER'S QUESTIONNAIRE

NAME 12 TENDERS - 4 TWICE DATE 21-22 JULY 88

ORGANIZATION NEDU LOCATION: NCSC PIER DIVE NO. 13 DIVE

GRADING CODE: A - Satisfactory
B - Fair: Minor deficiencies, improvement desirable
C - Poor: Considerable deficiencies, improvement needed
D - Unacceptable: Major deficiencies, improvement mandatory

DIVING EQUIPMENT/LWDS INTERFACE	GRADE			
1. Diving hose connections	10-A	5-B	1-C	NOT ALL RESPONDED
2. Pneumofathometer	9-A	1-B	1-C	

COMMENTS:
- USE QUICK DISCONNECTS ON CONSOLE END OF UMBILICALS
- PNEUMO FATHOMETER NEEDS A FLOW LIMITER
- PNEUMOFATHOMETER CONNECTORS LEAKED PAST INSERT

COMMUNICATION	GRADE		
3. With divers	14-A	1-B	NOT ALL RESPONDED
4. With operator	12-A	3-B	

COMMENTS:
COMPRESSOR EXHAUST NOISE INTERFERED WITH TOP SIDE COMMUNICATION.

5. Are the emergency procedures adequate for "worst case" situations?
Yes 8 No 1

NO - COMPRESSOR NOISE COULD INTERFERE WITH GETTING ATTENTION OF COMP. OPERATOR

HUMAN FACTORS EVALUATION

TENDER'S QUESTIONNAIRE (CONTINUED)

6. Does the technical manual accurately support equipment description, function, and operating procedures? Yes _____ No _____

MANUALS NOT AVAILABLE

7. Are there any modifications you would like to see in the LWDS?

NONE

8. General comments on any part or combination of parts of the LWDS:

NONE

HUMAN FACTORS EVALUATION

DIVER'S QUESTIONNAIRE

NAME 13 DIVERS DATE 21-22 JULY 88

ORGANIZATION NEDU LOCATION: NCSC PIER DIVE NO. 13 DIVES

GRADING CODE: A - Satisfactory
B - Fair: Minor deficiencies, improvement desirable
C - Poor: Considerable deficiencies, improvement needed
D - Unacceptable: Major deficiencies, improvement mandatory

AIR SUPPLY, PRIMARY (HP OR COMPRESSOR)	GRADE		GRADE
1. Adequate flow	13-A	4. Gas humidity	13-A
2. Odor	13-A	5. Taste	13-A
3. Gas temperature	13-A		

COMMENTS: ONE CASE EYE IRRITATION, NO OTHER SYMPTOMS POSSIBLE CAUSE, SWEAT OR SUNTAN LOTION.

AIR SUPPLY, EMERGENCY	GRADE		GRADE
6. Adequate flow	9-A	9. Gas humidity	9-A
7. Odor	9-A	10. Taste	9-A
8. Gas temperature	9-A		

COMMENTS:

4 DIVERS NOT SHIFTED TO SECONDARY (EMERGENCY)

COMMUNICATIONS	GRADE
11. Ambient noise	11-A ~~1-B~~
12. Intelligibility	11-A ~~1-C~~

COMMENTS:

BUBBLE NOISE IN FACE DOWN POSITION
BONE-PHONE CONDUCTOR DIFFICULT TO KEEP IN PLACE

HUMAN FACTORS EVALUATION

DIVER'S QUESTIONNAIRE (CONTINUED)

13. Where there any operations of the LWDS you did not feel secure or safe with? Yes _____ No 13 If yes, please explain.

HOWEVER, POSITIVE STOPS ON SUPPLY SELECTOR VALVE WOULD ENSURE SUPPLY NOT PARTIALLY CLOSED WHEN SWITCHED.

14. Are there any modifications you would like to see made on the LWDS?

- BYPASS FOR SECONDARY AIR REGULATOR
- HARNESS DOES'NT REDUCE IN SIZE ENOUGH TO FIT SLIM DIVER IN SWIM SUIT
- UMBILICAL TO MASK WHIPS ARE SLIGHTLY TOO LONG AND GET IN THE WAY.
- SIDE BLOCK INTERFERES WITH WEIGHT BELT PLACEMENT - MOVE IT.

APPENDIX C

HUMAN ENGINEERING CHECKLIST

DEFICIENCY SUMMARY SHEET

MIL-STD-1472C REFERENCE	DEFICIENCY DESCRIPTION	SUGGESTED CORRECTION
5.2.1	Air hose disconnect fitting location at compressor provides no indication of hose pressurization status.	Locate guage or red/green indicator for hose pressurization status at location of disconnect fitting on compressor.
5.3.8.4	Headsets provided with Hydrocomm, which will be used with the LWDS to provide diver communications, are monaural only. If field conditions require the compressor to be operated in close proximity to the Diver Control Console, it is expected that noise levels will be high enough to require the use of binaural headsets.	Verify compressor noise levels and ensure that binaural headsets will be available if required
5.4.1.2.4	Valve controls on HP racks are not labelled and open and close arrows are hard to read.	Label appropriately and use black color on directional arrows to improve visibility.

HUMAN ENGINEERING CHECKLIST

DEFICIENCY SUMMARY SHEET

MIL-STD-1472C REFERENCE	DEFICIENCY DESCRIPTION	SUGGESTED CORRECTION
5.4.1.8.1	Supply Selector Valve on Diver Control Console contains no positive protection to prevent valve handle from being moved to the closed position which turns off the divers' air supply. Currently the level of friction on this valve, combined with the control design, makes this fairly hard to do by accidentally bumping against it.	Provide positive locking detente at each selector position, which must be overridden before switch can be moved. In addition to completely removing risk of turning off divers' air by accident, this would also remove operator uncertainty about whether the selector is properly positioned to provide free air flow to diver.
5.5.1.1	(1) Noise hazard warning placard missing from compressor.	Install warning on each side of compressor unit.
	(2) No set-up instructions provided for Diver Control Console or Volume Tank Unit.	Install on inside lid of Diver Control Console and on removable front cover of Volume Tank Unit.

HUMAN ENGINEERING CHECKLIST

DEFICIENCY SUMMARY SHEET

MIL-STD-1472C REFERENCE	DEFICIENCY DESCRIPTION	SUGGESTED CORRECTION
5.5.1.1 (cont.)	(3) No starting instructions provided for compressor.	Install near starting crank on compressor frame.
	(4) No labels for hose connections on back of Diver Control Console. Connectors are color coded.	Install labelled diagram on inside of attached lid which folds downs to expose connectors. Keep color coding at connectors.
	(5) No label for belt tension bolts on compressor.	Install.
	(6) No instructions for proper lid alignment when closing up Diver Control Console.	Label left and right sides of lid and box to prevent lid from being put on backwards.
5.5.2.2	Instructions for setting up secondary air supply at the start of the dive are located at opposite side of panel from controls and are not clearly identified as a start-up procedure.	Move instructions closer to appropriate controls and improve instruction label wording.

HUMAN ENGINEERING CHECKLIST

DEFICIENCY SUMMARY SHEET

MIL-STD-1472C REFERENCE	DEFICIENCY DESCRIPTION	SUGGESTED CORRECTION
5.5.2.3	The use of color coding for functional areas generally works well, but some confusion is possible with the use of blue for the HP system and orange for the LP system. It is not immediately obvious whether the colors are coding the HP vs. LP systems or the Emergency vs. Primary systems.	If the HP primary guages and controls are moved to the Diver Control Console as recommended in Figure 6 of the report, this distinction in coding may become more obvious. Increased care in labelling might also help eliminate this confusion.
5.5.3.1	(1) All controls and functions labelled on the Diver Control Console as "Secondary Supply" are commonly referred to by the divers as "Emergency Supply" which more appropriately describes their function.	All labels and instructions referring to "Secondary Supply" should be changed to read "Emergency Supply". This change should also be reflected in all manuals.

HUMAN ENGINEERING CHECKLIST

DEFICIENCY SUMMARY SHEET

MIL-STD-1472C REFERENCE	DEFICIENCY DESCRIPTION	SUGGESTED CORRECTION
5.5.4.3	(1) Warning statements on Diver Control Console and Volume Tank Unit panel are embedded within procedural instructions and letter size is too small to read easily.	Separate warnings from procedures and move to a more central location on the panels. Increase the size of the letters to improve visibility and readability.
	(2) Paint used on panels is already chipping and showing signs of wear. This will seriously affect legibility over life of unit.	Improved method for labelling panels or for protecting and prolonging life of current labels.
5.5.5.1	(1) Labels for valves and and guages on compressor panel are etched only and very difficult to read.	Provide black letters for all labels on the compressor panel.
	(2) Color coding of functional areas has been used on the Diver Control Console and Volume Tank Unit panels, with valve handles and label colors matching area borders.	Keep color coded valve handles and borders for the different functional areas on the panels, but use black letters for all labels within the different areas.

HUMAN ENGINEERING CHECKLIST

DEFICIENCY SUMMARY SHEET

MIL-STD-1472C REFERENCE	DEFICIENCY DESCRIPTION	SUGGESTED CORRECTION
5.7.2.2	Guages on Volume Tank Unit are located less than 41 inches above the standing surface. They are extremely difficult to read.	Integrate the HP primary guages and controls into the Diver Control Console as proposed in Figure 6 of the report. This would leave only the filter pressure indicators and the valve control and pressure guage for the Volume Tank on the lower panel.
5.8.3.1	Noise levels from compressor are high enough to require the use of hearing protection and to seriously interfere with voice communication in its immediate vicinity. (See also 5.3.8.4)	(1) Establish a minimum required separation between the compressor and the immediate area of diving operations. This may restrict the use of Configuration 1 in operational settings. (2) Develop a portable noise baffle for use around the compressor.

HUMAN ENGINEERING CHECKLIST

DEFICIENCY SUMMARY SHEET

MIL-STD-1472C REFERENCE	DEFICIENCY DESCRIPTION	SUGGESTED CORRECTION
5.9.1.7	Insufficient clearance exists to make compressor outlet connection when the wheels are off the compressor.	Relocate the outlet position or increase clearance height under the compressor.
5.9.7.1	The method for storing the removable support legs in the lid of the Diver Control Console when not in use was unclear.	Include explanation or diagram with instructions provided for 5.5.1.1 item 2.
5.9.8.2	Pressure venting requirements for Dive Control Console box and lid are displayed, but location and print size make them easy to overlook.	Increase letter size and move to top of case near vent controls.
5.9.9.4.1	Access panel to hose connections at the back of the Diver Control Console is too small and cramped to allow connections and disconnections to be made easily.	Increase size of panel and increase spacing between hose connection points.

HUMAN ENGINEERING CHECKLIST

DEFICIENCY SUMMARY SHEET

MIL-STD-1472C REFERENCE	DEFICIENCY DESCRIPTION	SUGGESTED CORRECTION
5.9.11.2	The side table extensions provided with the Volume Tank Unit were difficult to secure in both the stored and mounted positions. The necessity and method for securing them is not obvious.	Improve securing pin type and mechanism used. Include procedure in the installation procedures placard.
5.9.11.3.1	(1) The compressor weight exceeds the recommended manual lifting limits, even when the more generous "Male Only Population" limits are used (435 pounds with 6 men).	Modify compressor frame for use with forklift and hoist. This manual lifting restriction may cause an unacceptable loss of LWDS flexibility of use, methods for reducing the weight of the compressor unit should be explored.

HUMAN ENGINEERING CHECKLIST

DEFICIENCY SUMMARY SHEET

MIL-STD-1472C REFERENCE	DEFICIENCY DESCRIPTION	SUGGESTED CORRECTION
5.9.11.3.1 (cont.)	(2) The recommended limits for the manual lift and carry of the other components of the LWDS are given below. Personnel required are for Male Only or Male & Female populations. Diver Control Console -- 150 lbs -- 2 or 4 persons Volume Tank Unit -- 250 lbs -- 4 or 8 persons HP Rack Module -- 200 lbs -- 3 or 6 persons	Reduce component weight as much as possible.
5.9.11.3.9	Labels with object weight and lifting limitations missing from all LWDS components.	Install appropriate labels.
5.9.11.5.1	Carrying handles are required for all components except the Diver Control Console.	Install appropriate carrying handles using guidelines from 5.9.11.3 and 5.9.11.5

HUMAN ENGINEERING CHECKLIST

DEFICIENCY SUMMARY SHEET

MIL-STD-1472C REFERENCE	DEFICIENCY DESCRIPTION	SUGGESTED CORRECTION
5.13.2.7	With no separate carrying handles provided for any component but the Diver Control Console, the team used portions of the frames to lift and carry the other components. These were not marked as hand grasp areas and were poorly located for lifting.	Install appropriate carrying handles. (See 5.9.11.5.1)
5.13.4.6	Compressor head at end of the unit is not guarded and presents a possible thermal safety hazard to the operator.	Install guard.
5.13.5.4	Sharp edges and corners on HP bottle rack unit present possible safety hazard when moving and working around the unit.	Round exposed edges and corners as necessary.

APPENDIX D

LWDS OBSERVATIONS AND RECOMMENDED IMPROVEMENTS

Item	Recommendation
Diesel-Compressor Unit:	
Various nuts and bolts vibrated loose	Use lock washers.
Wheel securing pins jammed	Enlarge holes.
Diesel fuel line uses Mercury outboard connections	Use Johnson connections.
LP intake stand is much too big and awkward	Reduce size and allow it to fold up.
Diesel is noisy and exhaust is just below face level	Increase mufflering and extend exhaust pipe (detachable).
Secondary Air Supply:	
Sloped roof cannot be stacked or used as a seat or bench	Make flat
Roof HP gauge not necessary as secondary HP inlet gauge and primary HP inlet gauge on the console and volume tank unit repeat the pressure	Remove gauge and associated plumbing.
Primary Air Supply:	
Same as secondary supply	
Volume Tank Unit:	
HP primary regulator has no bypass	Install bypass.

Item	Recommendation
Divers' Control Console:	
HP secondary regulator has no bypass	Install bypass.
Console must be lashed in place on top of the volume tank unit	Supply straps or mechanical method of making it fast.
Gauges lack calibration	Calibrate gauges.
Regulator and check valves "hummed"	Perform maintenance.
Interconnecting Hoses and Umbilical:	
Volume tank to console hose too long	Shorten 5-10 feet.
Wire restraining lines developing fish hooks, especially at the hard eyes	Whip hard eyes.
Umbilical much too short at only 150 feet	Provide 300 foot umbilical.
Umbilical lashed with polytape at 24 inch intervals	Must be secured at 18 inch intervals per U.S. Navy Diving Manual.
Wire pennants at each end of Noreco communication strength cable are embedded in the potted connecter. If the wire breaks, the cable must be returned to the manufacturer	Have a D-ring or other hard device embedded in the connector.
Potted connectors at each end of Noreco communications/ strength cable are very large	Reduce size if possible.
Diesel-Compressor Unit:	
Starting process very awkward for one man to perform	Extension for decompressor lever to make it easier to reach while cranking.
Air intake stand can be distant from diving ops area and may be affected by different wind pattern created by buildings or terrain features	Install wind flag bracket on air intake stand.

Item	Recommendation
Volume Tank Unit:	
Front panel cover must be supported in correct position to insert securing pins when packing up unit	Redesign cover so that it rests on bottom frame of unit and holes for securing pins are automatically aligned.
Divers' Control Console:	
Pressure Gauges	Consider rotating all gauges so that normal operating pressure is at the "12 o'clock" position. This would simplify operator equipment checks and make deviations from normal operation easier to spot.
Hydrocomm Interface	Tying down comm box face up on side table is awkward and increases exposure of equipment to water entry. Explore alternate locations for comm box. Could a support shelf be added above diver control console?
General:	
Moisture was noticed in several of the pressure gauges	Verify water resistant status and proper maintenance.
Tools	Any tools required for set up of system should be kept with it - perhaps in a storage bracket in lid of diver control console.
Unit frames, panels, and controls become almost too hot to handle when left in direct sunlight for any period of time.	Provide some type of awning to provide shielding from sun.