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TA 09-08
NEDU TR 11-03
May 2011

UNMANNED EVALUATION OF MARES ABYSS 22 NAVY OPEN CIRCUIT SCUBA REGULATOR FOR COLD WATER DIVING

NAVY EXPERIMENTAL DIVING UNIT

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)* 05-05-2011	**2. REPORT TYPE** Technical Report	**3. DATES COVERED** *(From - To)* October 2010-March 2011

4. TITLE AND SUBTITLE Unmanned Evaluation of Mares Abyss 22 Navy Open Circuit Scuba Regulator for Cold Water Diving	**5a. CONTRACT NUMBER** **5b. GRANT NUMBER** **5c. PROGRAM ELEMENT NUMBER**
6. AUTHOR(S) V. H. Ferris	**5d. PROJECT NUMBER** **5e. TASK NUMBER** 09-08 **5f. WORK UNIT NUMBER**
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Navy Experimental Diving unit 321 Bullfinch Road Panama City, Florida 32407-7015	**8. PERFORMING ORGANIZATION REPORT NUMBER** NEDU TR 11-03
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) Steve Lamphear Mares Diving Division of HEAD USA 902 Clint Moore Road, Suite 208 Boca Raton, FL 33487	**10. SPONSOR/MONITOR'S ACRONYM(S)** **11. SPONSOR/MONITOR'S REPORT NUMBER(S)**

12. DISTRIBUTION / AVAILABILITY STATEMENT

Distribution Statement A: Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Unmanned testing and evaluation of the Mares UBA model Abyss 22 Navy scuba regulator was conducted, and the results were compared to the U.S. Navy performance limits and goals for use in cold water diving applications. The UBA model regulator met or exceeded the U. S. Navy performance limits and goals for use in cold water diving applications.

15. SUBJECT TERMS

resistive effort; work of breathing; unmanned evaluation; open circuit scuba regulator; cold water diving; Mares Abyss 22 Navy; UBA; underwater breathing apparatus; NEDU TR 11-03

16. SECURITY CLASSIFICATION OF:			**17. LIMITATION OF ABSTRACT**	**18. NUMBER OF PAGES**	**19a. NAME OF RESPONSIBLE PERSON** NEDU Librarian
a. REPORT unclassified	**b. ABSTRACT** unclassified	**c. THIS PAGE** unclassified		29	**19b. TELEPHONE NUMBER** 850-230-3170

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

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INTRODUCTION

The Navy Experimental Diving Unit (NEDU) has recently tested commercially available off-the-shelf (COTS) open circuit scuba regulators under the direction of several Naval Sea Systems Command (NAVSEA) tasking directives, primarily to determine which ones meet current Navy performance criteria for cold water diving and to consider these for possible inclusion on the Authorized for Navy Use (ANU) list.[1–6]

To establish statistical significance, Mares, a scuba equipment manufacturer, funded NEDU to perform the same test battery on five units of a specific model of its Abyss 22 Navy (part number 416158) regulator, and then to evaluate its suitability for cold water diving. For the purposes of this testing and evaluation, *cold water* describes water conditions under which a regulator can freeze up, conditions considered to be greater than or equal to 29 °F but less than 38 °F. After testing was completed, NEDU retained these test units.

NEDU Test Plan 09-24 describes the unmanned dive test procedures to which each regulator was subjected.[7] The performance criteria for each regulator included its abilities to provide sufficient breathing air and to avoid sustained free flow in a cold water environment.

With the test plan successfully executed, NEDU informally provided Mares with preliminary results for its Abyss 22 Navy regulator. This technical report includes the detailed results, analyses, comparisons to established performance goals and limits, and conclusions regarding that tested regulator model.

METHODS

ITEM DESCRIPTION

Two-stage, single-hose scuba regulators consist of a first-stage assembly designed to reduce tank pressure to an intermediate level above ambient pressure and a second-stage assembly used to reduce the intermediate pressure to ambient pressure. The first-stage assembly of current production regulators is of either a diaphragm or a piston design. The Mares Abyss 22 Navy regulator uses a diaphragm design. Second-stage assemblies use pneumatic amplification to achieve the low inhalation efforts desired. The second-stage assembly of a regulator includes a main flow valve consisting of a movable poppet within a valve housing located inside the regulator body; a seat, or a pilot valve, mounted within and carried by the main valve poppet; and a pressure sensing diaphragm linked to the poppet. The second-stage assembly of the Mares Abyss 22 Navy regulator uses a downstream valve design incorporating a poppet and seat assembly.

Figure 1. Tested Mares Abyss 22 Navy regulator, with first-stage assembly (left, with dust cap in place), rubber-jacketed intermediate pressure hose (middle), and second-stage assembly (right).

GENERAL METHODS

The evaluation methods are described in an NEDU test plan[7] and are based on parameters set forth in the NEDU technical manual for unmanned test methods for underwater breathing apparatus.[4] All unmanned testing was conducted at the NEDU Experimental Diving Facility (EDF) “Alpha” chamber. Unless otherwise noted, manning and test protocols followed standard operating procedures.[4,7]

NEDU received five Mares Abyss 22 Navy regulators from the manufacturer as test units — a sample size that yields adequate statistical reliability and is typical for NEDU evaluations of equipment for U.S. Navy certification.[1–4] All test units were set up per normal operating procedures, except as noted in each test phase. Before testing began, NEDU documented any minor modifications made to the underwater breathing apparatus (UBA) for testing purposes in the EDF. Such modifications included, but were not limited to, the removal of mouthpieces for routing block interfacing and the addition of adaptors for pressure sensing.

The testing configurations of the five Mares Abyss 22 Navy open circuit regulators, as received from the manufacturer, are listed in Appendix A. The NEDU tracking and manufacturer serial numbers of each test unit (Figure 1) are also listed in Appendix **A**. All regulators were tested upright, with a single second stage attached to the first stage with the standard length intermediate pressure hose supplied by the manufacturer. The first stage was attached to the scuba tank manifold block with a yoke-style attachment provided by the manufacturer. No other intermediate pressure devices (e.g., an inflation whip or a second-stage octopus), submersible pressure gage, or gas-integrated computer were connected to the first stage. As noted in the Test Plan[7] for all phases, an intermediate pressure (IP) sensor transducer was attached to the first stage of each test unit. All regulators were subjected to a hierarchical series of unmanned tests consisting of three sequentially numbered phases. All regulators were tested in the upright position, simulating a diver standing or swimming upright, thus minimizing the hydrostatic loading effects on the regulator encountered in diver orientations other than upright.

TESTING AGAINST PERFORMANCE GOALS AND LIMITS

Phase 1:

Visual inspection and dry bench testing (Surface)

The intermediate pressure and the breathing effort required to initiate the flow of air (negative or “cracking” pressure) in each test unit were measured with supply pressures of 500 psi, 1500 psi, and 3000 psi.

Phase 2:

Freeze-up testing

A low compliance, computer-controlled breathing machine (Reimers Systems, Inc.; Lorton, VA) was used to simulate the ventilation process of a diver at a respiratory minute volume (RMV) of 62.5 L/min, a rate considered a “heavy” workload. Water with a salinity range of 35–40 parts per thousand (ppt) and at a temperature range of 29 $\pm$ 1°F (-1.7 $\pm$ 0.6°C) was maintained to simulate the ocean environment. Real-time video monitors were used to visually determine the possible development of a regulator “freeze-up,” indicated by a sustained flow of bubbles from the exhaust port. At various time intervals, the overbottom pressure and resistive effort (analysis of the oral pressure and volume displacement [PV] variables) were monitored and recorded.

Phase 3:

<u>Cold water resistive effort testing</u>

To evaluate open circuit UBA breathing performance, NEDU uses both physiologically derived resistive effort “Limits” and “Performance Goals”.[4–6] Acceptable limits of resistive effort as a function of operating depth have been established for RMVs up to 90 L/min.[5,6] Performance goals for resistive effort as a function of RMV, have been established for RMV’s up to 62.5 L/min for depths not exceeding 198 fsw utilizing air as a breathing medium.[4] For cold water resistive effort testing, a regulator’s breathing performance is considered to be acceptable if the mean resistive effort during testing does not exceed these limits or the performance goals. As in Phase 2, the breathing machine was used to simulate the ventilation of a diver at various RMVs. Water in a salinity range of 35–40 ppt and a temperature range of 38 ± 1 °F (3.3 ± 0.6 °C), was maintained to simulate the ocean environment. The resistive effort (analysis of the PV variables) were monitored and recorded for various depth and breathing rate combinations. After this phase was completed, the test units were reevaluated on the test platform used in Phase 1 to determine whether, during Phase 2 or Phase 3 testing, the intermediate pressure at the three different supply pressures was affected. These results were logged and included as part of the Phase 1 documentation.

TERMINATION CRITERIA

Criteria for both individual unit and regulator model termination of regulator testing were established for each phase of testing. In addition, dive termination criteria were established for both regulator operation and safety.

<u>Individual Regulator Termination</u>

Any regulator test unit not meeting all of the following criteria within each phase was said to have ***failed*** that phase; otherwise, the individual test unit ***passed***.

Phase 1:

- Sustained free flow or failure to deliver gas
- Occurrence of any event for which the EDF test supervisor determined that continued testing was undesirable or unsafe

Phase 2:

- Inhalation or exhalation oral pressure, referenced to suprasternal notch, exceeding 7 kPa
- Sustained free flow or failure to deliver sufficient breathing gas
- Occurrence of any event for which the EDF test supervisor determined that continued testing was undesirable or unsafe

Phase 3:

- Inhalation or exhalation oral pressure, referenced to suprasternal notch, exceeding 7 kPa at a specific RMV and depth (These results terminated that set of test conditions only; the remaining battery of tests was to be attempted.)
- Sustained free flow or failure to deliver sufficient breathing gas
- Occurrence of any event for which the EDF test supervisor determined that continued testing was undesirable or unsafe

Model Termination

Phase 1:

- If two of the five regulators failed the Phase 1 bench test, further testing was to be terminated, and the regulator model was to be excluded from Phase 2 tests. All regulators had their intermediate pressure checked after all tests were completed.

Phase 2:

- If three failures occur, the cumulative failure rate was to be determined. If the cumulative failure rate was greater than 33%, testing was to be terminated and the regulator model was to be excluded from Phase 3 tests. Otherwise, testing was to continue, the cumulative failure rate was recalculated, and the termination criteria were to be reevaluated at the end of each dive.

Phase 3:

- No failure criteria were established. Having successfully passed Phase 2, regulators were to be subjected to resistive effort tests in this phase.

Operational and Safety Termination (All Phases)

An individual test unit or dive could be terminated at the discretion of the test supervisor exercising any of his concerns, including:

1. Safety of personnel
2. Damage to the test equipment or UBA
3. Failure of the test UBA

The operational or safety reasons for terminating any dive were to be noted, and corrective measures were to be taken to reduce the probability of subsequent terminations due to similar conditions.

EXPERIMENTAL DESIGN AND ANALYSIS

Phase 1 was conducted on a platform designed for testing open circuit scuba regulators at atmospheric pressure. As part of this dry bench evaluation, the ability of each regulator to hold intermediate pressure was determined and recorded. In addition, the cracking pressure was observed and recorded.

Under the test configuration shown in Figure 2 during Phases 2 and 3, expired gas from the breathing machine was heated and humidified to maintain 100% water saturation at an appropriate temperature (dependent on the water temperature) at the UBA's mouthpiece. The following equation was used to calculate the appropriate expired gas target temperature:

$$T_{expired} = 24°C + 0.32 \cdot T_{inspired}$$

where the temperatures, $T_{expired}$ and $T_{inspired}$, are expressed in °C, and $T_{inspired}$ is defined to be equal to the surrounding water temperature.[8]

As outlined in the test plan, the following parameters were controlled, varied, or recorded:

Testing supply pressure of diver's breathing air	Phases: 1, 2, and 3
Regulator first-stage intermediate pressure	Phases: 1, 2, and 3
Regulator second-stage cracking pressure	Phases: 1, 2, and 3
Ark water salinity and temperature	Phases: 2 and 3
Depth and rates of descent and ascent	Phases: 2 and 3
Breathing rate and volume	Phases: 2 and 3
Exhalation gas humidity and temperature	Phases: 2 and 3
Resistive effort	Phases: 2 and 3

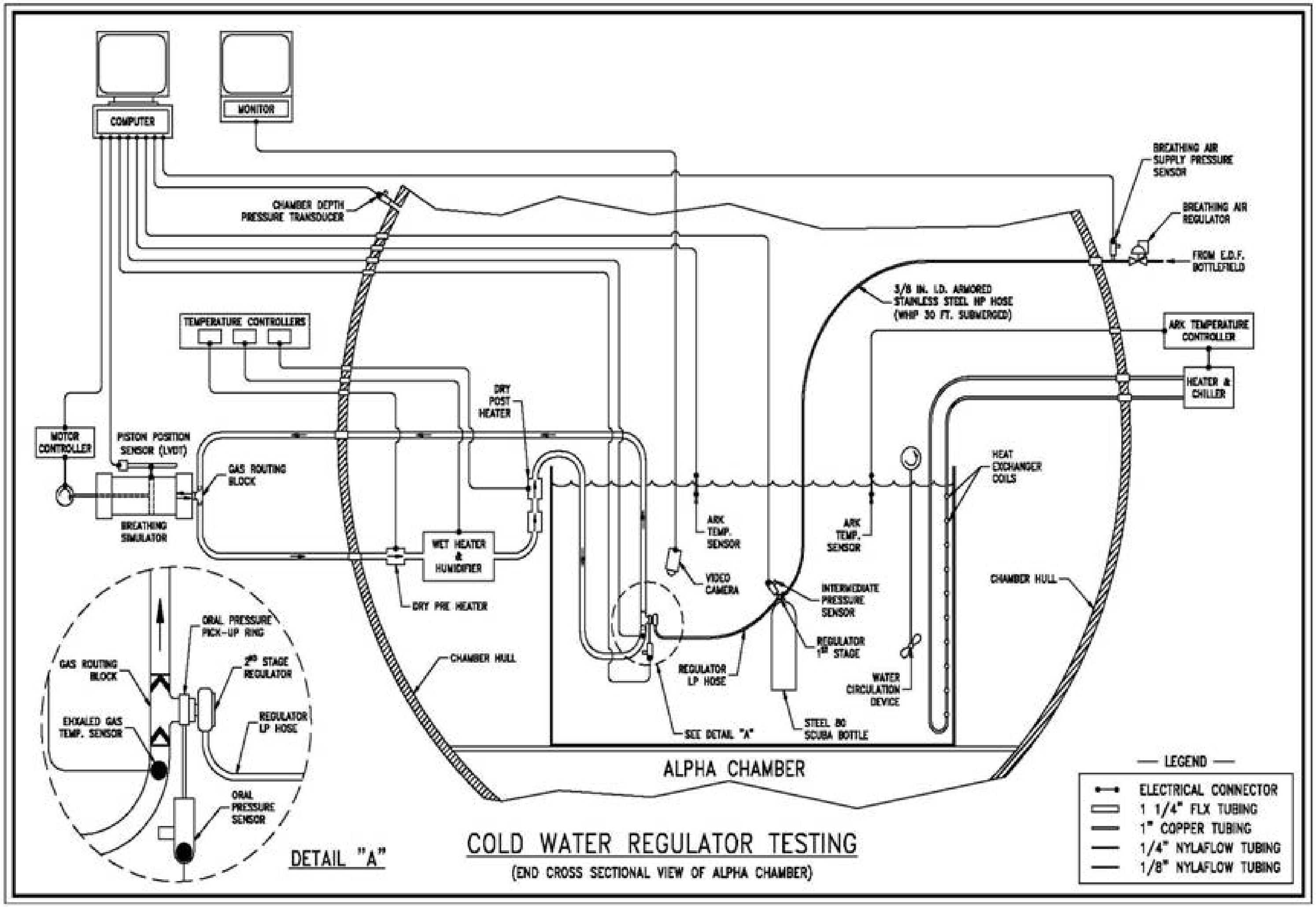

Figure 2. Chamber setup and instrumentation for unmanned regulator testing

TEST PROCEDURES, EQUIPMENT, AND INSTRUMENTATION

A description of the test procedures, equipment, and instrumentation used to conduct the tests is included in the test plan.[7]

RESULTS

All five test units passed Phase 1 of the study and advanced to Phase 2 testing. None of them exhibited freeze-up conditions at 29 °F, and they were thus advanced to Phase 3 tests.

Figures 3 and 4 use values calculated from data collected during the Phase 3 (38 °F) resistive effort evaluation and shown in Tables 1 and 2, respectively. For all five test units, these figures provide scatterplots of the descriptive statistics for the sample arithmetic mean of the resistive effort ensemble average (used as a measure of central tendency) and the sample standard deviation of the data from that arithmetic mean (used as a measure of dispersion). Figure 3 (one plot for all five test units) illustrates the relationship between the resistive effort and the ventilation rate.

Figure 4 (one plot for all five test units) indicates the relationship between resistive effort and depth. Figure 5 provides a representative pressure-volume breathing loop cycle relationship for a randomly selected test unit's single 198 fsw dive at a 62.5 L/min ventilation rate. This figure displays 10 loop cycle iterations, with the ensemble average loop overlaid.

With the results from Phase 3 tests, the regulator's resistive effort was compared to the resistive effort performance limits established by NEDU for underwater breathing apparatus.[5,6] The established resistive effort limits as a function of depth are listed in Table 3 and represented as a black dashed line in Figure 4. If the performance of all five test units are viewed as that of a single product and Table 3's resistive effort limits (independent of ventilation rate) are compared to the resistive effort ensemble average arithmetic means in Table 1 for various depths, the Mares Abyss 22 Navy regulator did not exceed the established resistive effort limits established for ventilation rates at or below 75 L/min for depths up to and including 165 fsw.

Figure 4 also compares the Mares data to NEDU Performance goals cited in NEDU Technical Manual 01-94[4]. For scuba regulators, existing performance goals are far more stringent than performance limits, and are therefore useful for identifying top performing regulators.

Figure 7 indicates the external icing typically experienced by a first-stage assembly during Phase 2 testing, and Figure 8 indicates such icing experienced by a second-stage assembly during that same test phase. As viewed from the mouthpiece adaptor (shown in blue) inward into the second-stage assembly, Figure 9 indicates typical internal second-stage icing experienced during Phase 2 testing. Since all five test units exhibited some degree of both first- and second-stage assembly icing, this ice buildup does not provide a useful basis for predicting the onset of second-stage free flow conditions.

All test articles were returned to their *as received* configuration at the completion of testing.

In summary, all five Mares Abyss 22 Navy test regulators performed satisfactorily in all three phases of NEDU's cold water evaluation protocol.[7] After satisfactorily completing these tests, all individual units retained their factory-set nominal intermediate pressure values after cold water exposure.

Table 1. Resistive effort (kPa) arithmetic mean for various ventilation rates and depths for the Mares Abyss 22 Navy regulator in 38 ºF water.

Ventilation (L/min)	**Depth (fsw)**						
	0	**33**	**66**	**99**	**132**	**165**	**198**
22.5	0.77	0.85	0.89	0.92	0.93	0.94	0.95
40.0	0.86	0.98	1.06	1.08	1.07	1.06	1.05
62.5	0.98	1.13	1.16	1.18	1.14	1.10	1.13
75.0	1.04	1.19	1.18	1.18	1.16	1.19	1.27
90.0	1.10	1.23	1.22	1.20	1.26	1.98	NA

Each value represents the arithmetic mean of the ensemble averages for the five test units at each ventilation rate and depth specified. The supply pressure was maintained at 1500 psi. "NA" indicates that the oral pressure limit (7 kPa) was exceeded by all five units and thus the arithmetic mean calculation was not performed for that ventilation rate and depth.

Table 2. Resistive effort (kPa) standard deviation from the arithmetic mean for various ventilation rates and depths for the Mares Abyss 22 Navy regulator in 38 ºF water.

Ventilation (L/min)	**Depth (fsw)**						
	0	**33**	**66**	**99**	**132**	**165**	**198**
22.5	0.04	0.04	0.04	0.03	0.01	0.02	0.02
40.0	0.03	0.04	0.04	0.04	0.06	0.06	0.07
62.5	0.03	0.06	0.08	0.07	0.09	0.12	0.13
75.0	0.04	0.09	0.11	0.10	0.16	0.16	0.21
90.0	0.06	0.13	0.15	0.15	0.19	0.36	NA

Each value represents the standard deviation from the arithmetic mean of the ensemble averages for the five test units at each ventilation rate and depth specified. The supply pressure was maintained at 1500 psi. "NA" indicates that the oral pressure limit (7 kPa) was exceeded by all five test units and thus the standard deviation from the arithmetic mean calculation was not performed for that ventilation rate and depth.

Table 3. Resistive effort (kPa) performance limits as a function of depth and independent of ventilation rate for UBA.

Depth (fsw)						
0	**33**	**66**	**99**	**132**	**165**	**198**
2.99	2.78	2.57	2.36	2,15	1.94	1.73

Resistive effort is expressed as the average work of breathing per unit volume (WOB/V_T) and calculated with the resistive effort for a respiratory load acting alone.[5,6] Using units of kPa is more succinct and physically correct than using the archaic units of J/L.

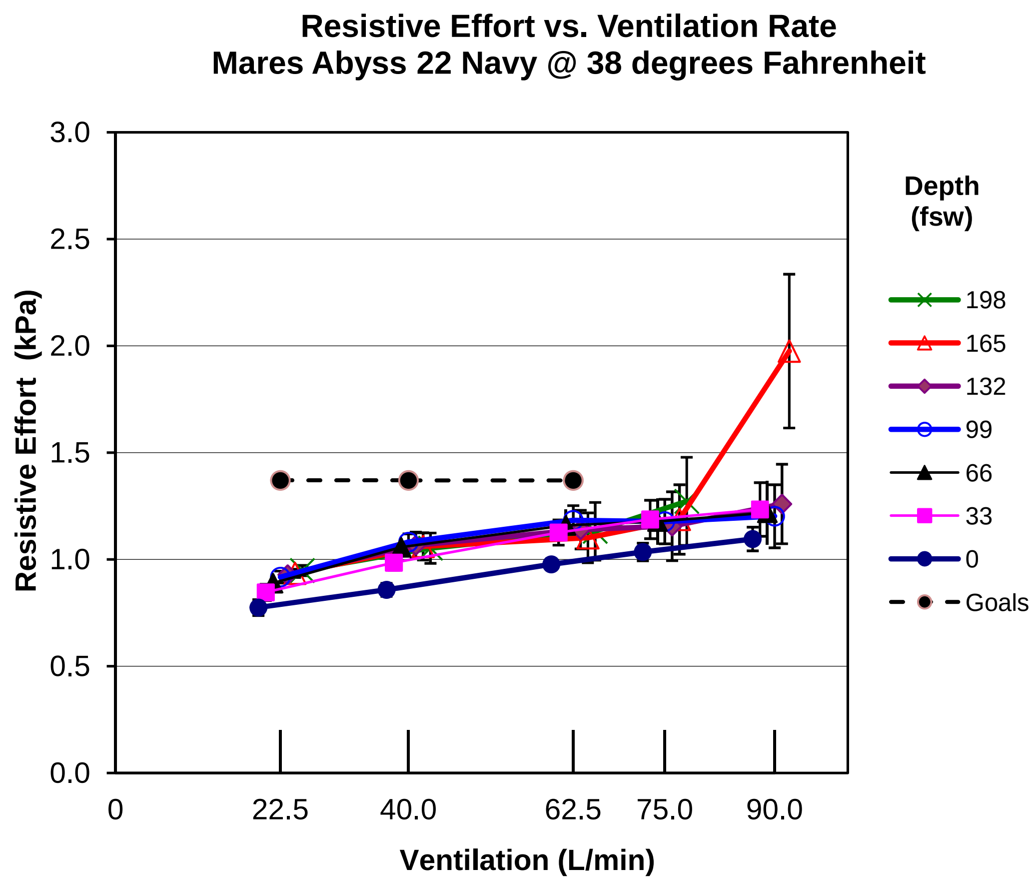

Figure 3. Resistive effort plotted against ventilation rate. The UBA performance goals[4] for Category 1 (0 to 198 fsw, AIR) of 1.37 kPa at ventilation rates of 22.5, 40.0 and 62.5 are indicated with the horizontal black dashed line. From Table 1 data, each point indicates the arithmetic mean of all five test units at various ventilation rates and depths. RMVs of 90 L/min at 198 fsw (green trend line) were not available, since all five test units exceeded the sensor's 7 kPa oral pressure limit. The lines connecting the points for each depth do not represent actual data collected; they are for trending purposes only. With Table 2 data incorporated, error bars for each point indicate the standard deviation from the arithmetic mean. To improve legibility, the symbol indicating each value is slightly offset horizontally.

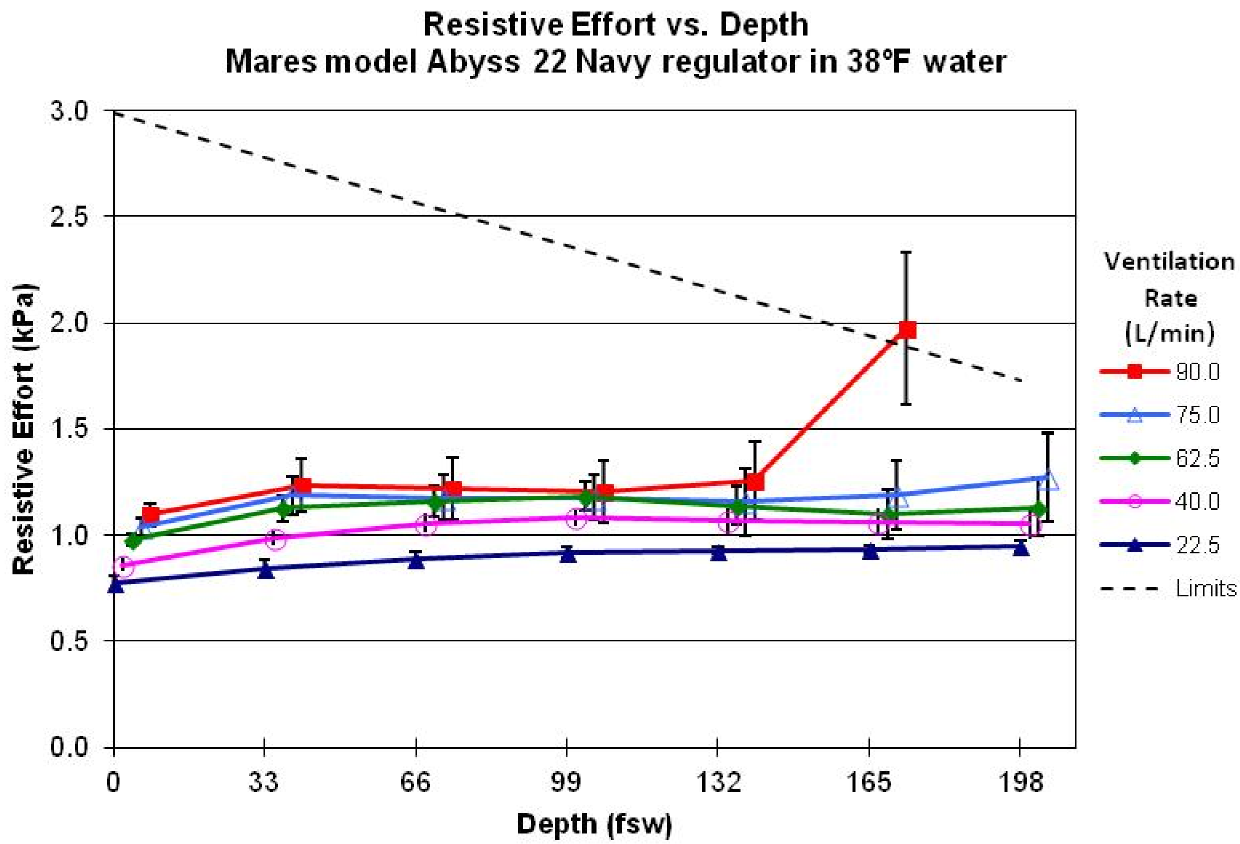

Figure 4. Resistive effort plotted against depth. From Table 1 data, each point indicates the arithmetic mean of all five test units at various depths and ventilation rates. RMVs of 90 L/min at 198 fsw (red trend line) were not available, since one or more test units exceeded the sensor's 7 kPa oral pressure limit. The lines connecting the points for each ventilation rate do not represent actual data collected; they are for trending purposes only. With data from Table 2 incorporated, error bars for each point indicate the standard deviation. To improve legibility, the symbol indicating each value is slightly offset horizontally. With the values calculated from Table 3, "Limits" (dashed line in black) indicates the resistive effort performance limits as a function of depth for ventilation rates up to and including 75 L/min.[5,6]

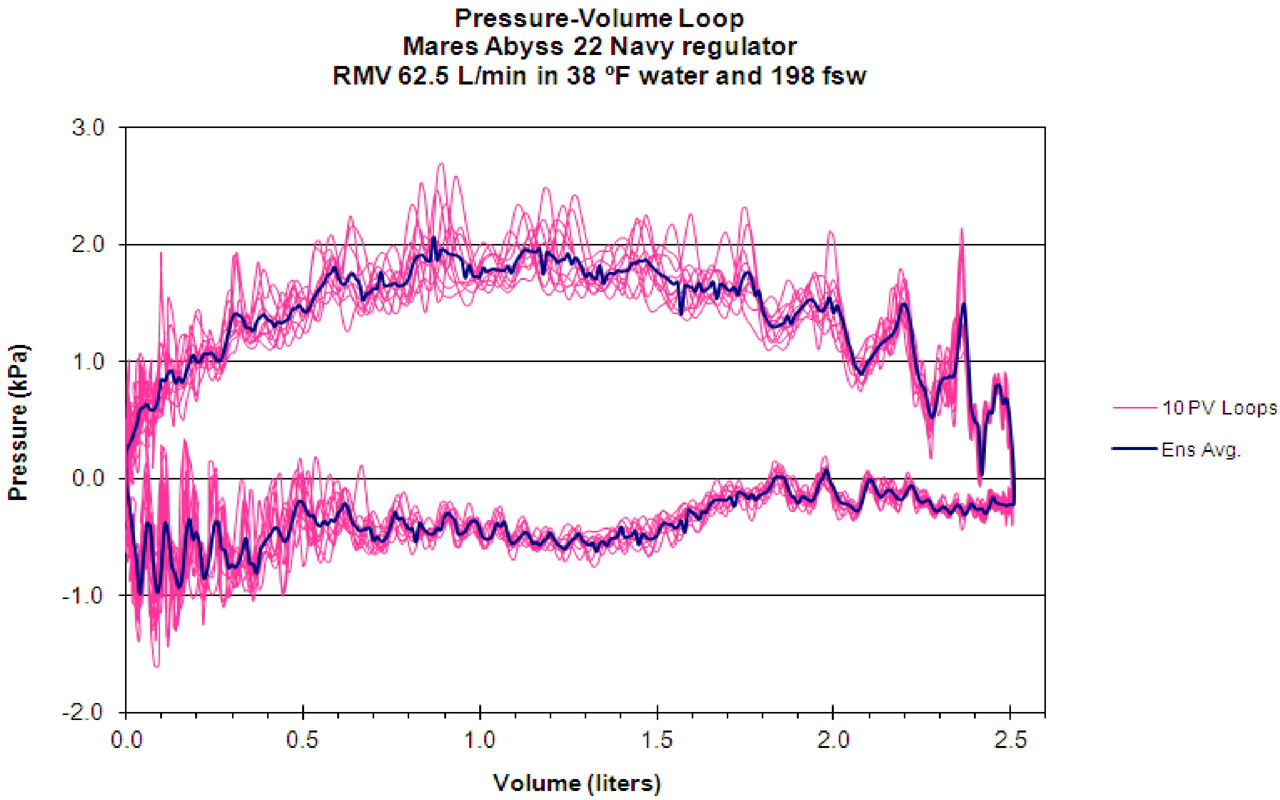

Figure 5. Representative pressure-volume loops in red, for ten individual sequential loops. The pressure-volume loop overlaid in blue represents the ensemble average of the ten sequential loops. The origin (0.0 L, 0.0 kPa) is the initiation of each breathing cycle for the ten breathing loops, with mouth pressure measured relative to the anatomical landmark of the suprasternal notch. Each loop proceeds counterclockwise until the breathing cycle is completed at the origin. Each breathing cycle (loop) takes approximately 2.4 seconds to complete (a RMV of 62.5 L/min is comprised of 25 breathing cycles per minute at a tidal volume of 2.5 liters per breathing cycle). The durations of the inhalation and exhalation portions of each breathing cycle are equal. The sampling rates for both the oral pressure and volume displacement were 250 samples per second (600 samples for each breathing cycle loop, with a duration of 2.4 seconds).

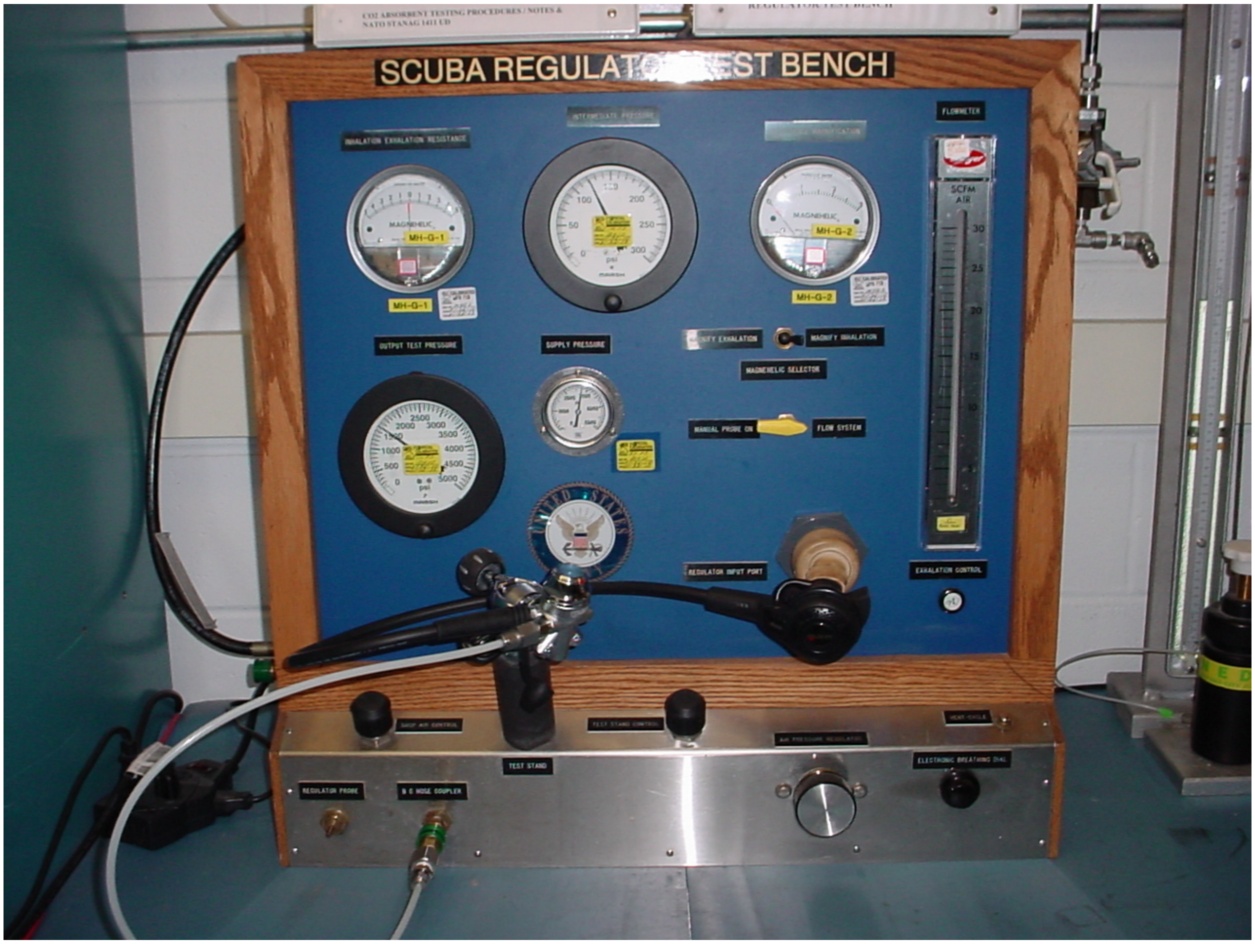

Figure 6. Typical Mares Abyss 22 Navy regulator, attached to the dry bench apparatus for Phase 1 testing.

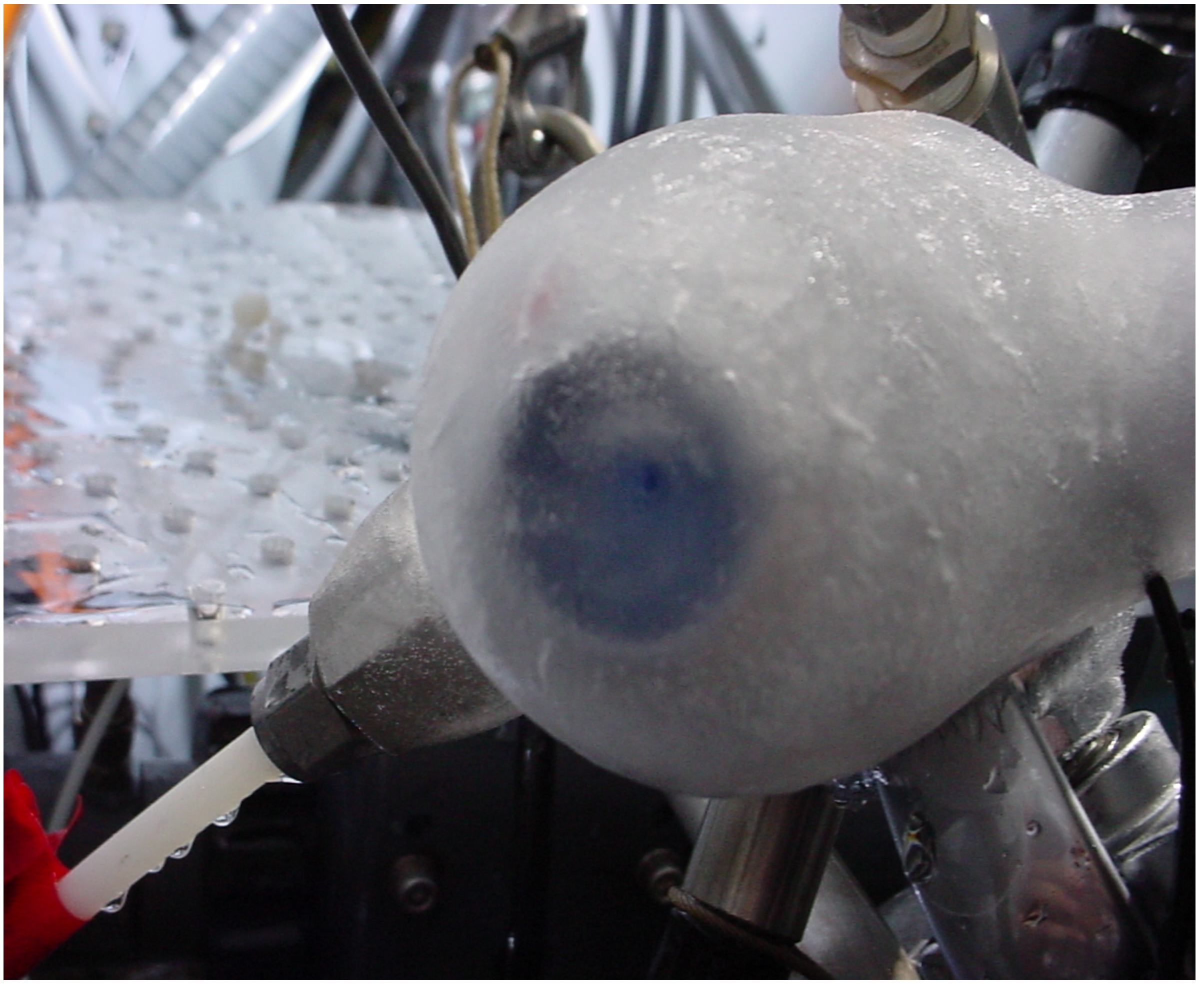

Figure 7. Typical first-stage assembly of the Mares Abyss 22 Navy regulator, with exterior icing after a Phase 2 exposure. The regulator is shown above the water. The first-stage assembly is attached to the tank manifold (not visible) with the intermediate pressure sensor adaptor and hose attached for testing (lower left).

Figure 8. Typical second-stage assembly of the Mares Abyss 22 Navy regulator, with external icing after a Phase 2 exposure. The regulator is shown above the water. Note the blue mouthpiece adaptor, white oral static pressure pick-up ring, and gray routing block attached for testing.

Figure 9. Typical second-stage assembly of the Mares Abyss 22 Navy regulator, with internal icing after a Phase 2 exposure. The regulator is shown above the water. Note the blue mouthpiece adaptor (foreground) installed for testing.

DISCUSSION

The mechanisms by which a second-stage free flow is manifested in cold water are thought to be a combination of (1) the adiabatic cooling resulting from the reduction of high-pressure supply air to the intermediate pressures for subsequent transfer of gas to the second-stage assembly, and (2) the moist gas that the diver exhales into the second-stage exhaust mushroom valve, an exhalation causing ice to precipitate around the mushroom valve that is designed to provide a path for gas flow. Water leakage around poorly sealing exhaust valves (3) can also provide a source for ice buildup. The first two sources in the bibliography discuss these icing mechanisms.

Among second-stage assemblies designed with a poppet and seat mechanism to control air flow, such as the Mares Abyss 22 Navy, ice can build around the demand lever or the poppet and seat assembly, eventually prevent the poppet from moving, and subsequently prevent contact between the poppet and the seat. Once a free flow condition is initiated, self-contained gas supplies are quickly depleted. A sustained free flow does not prevent a diver from drawing a breath, but it does increase his exhalation resistive effort as he tries to overcome the increased pneumatic amplification of the free flow. Furthermore, as Antarctic exposures have shown, divers under polar conditions have experienced free flow that cause painful chilling of the mouth and teeth.[9] When ice builds up, induced by free flows in second-stage assemblies, divers can do little — short of shutting off their air supply or immersing themselves in warmer water — to stop those free flows.

Since NEDU has not tested any modifications to the regulator configurations reported herein (e.g., modifications such as those that entail eliminating or substituting for any component, or attaching any ancillary equipment such as an octopus second-stage, a free flow shut-off device/isolator, a first-stage overpressure relief valve, a buoyancy inflation device, a submersible pressure gauge, or a dry suit inflation device), the cold water performance of regulators in any such configuration cannot be known precisely. Furthermore, to comply with standard regulator storage procedures of the U.S. Antarctica Program (USAP) all test articles were blown dry. However, they were ***not*** rinsed with water before being stored at dry room temperature (approximately 72 °F) between dives.[10] This storage procedure represents a realistic case for operational military scenarios. The USAP requires that regulators which are rinsed before being blown dry, must remain at room temperature overnight before being dived again.[9] When practical, the USAP requires the removal of the second-stage diaphragm cover from the second stage body prior to being blown dry.[10] Since the Mares Abyss 22 Navy second-stage diaphragm cover is not designed for simple removal from the second-stage body by end users, it was not removed before the second-stage was blown dry. Also, to avoid free flow conditions and to conform to storage procedures used by U.S. Antarctic divers, NEDU investigators neither breathed nor purged these regulators before submerging them. Regulator performance in cold water cannot be predicted if the usage and storage procedures followed during testing are not strictly adhered to.

CONCLUSION

Under the conditions and regulator configurations tested herein, the Mares Abyss 22 Navy regulator (part number 416158) — consisting of first- and second-stage assemblies with a rubber-jacketed intermediate pressure hose attached — passed without failure NEDU's rigorous unmanned protocol evaluating its performance for use in water conditions of 29 °F and higher.

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GLOSSARY

arithmetic mean	a measure of central tendency, expressed as the quotient of the sum of data values divided by the number of data values
ark	a vat housed within the pressurized testing chamber and used for submerging test articles in water
cracking pressure	the breathing effort required to initiate air flow and expressed in units of inches of water
free flow	a continuous and typically uncontrolled escape of air
freeze-up	a condition in which one or both stages of a regulator has succumbed to the effects of cold water and the regulator either fails to deliver an adequate air supply or free flows
mushroom valve	a valve of flexible material creating a one-directional flow by opening and closing against a seat or a sealing surface with differential pressures between opposing sides of the valve
octopus second-stage	an optional second-stage assembly attached to the first-stage assembly of a two-stage regulator
oral pressure	the pressure at the oral cavity, in reference to the suprasternal notch
pilot valve	a tilt valve that triggers airflow
poppet	a valve that rises perpendicular to or from its seat to permit the controlled flow of air
routing block	a device using mushroom valves to permit directional control of air from the breathing simulator
standard deviation	a measure of the dispersion of data values from their arithmetic mean
suprasternal notch	an anatomical landmark situated above the sternum
tidal volume	the magnitude of the difference between the initial and the final volume of a breathing cycle
unmanned	operated or used without the interaction of humans

LIST OF ABBREVIATIONS

ANU	authorized for Navy use
COTS	commercial off-the-shelf
EDF	Experimental Diving Facility
fsw	feet of seawater
IP	intermediate pressure
kPa	kilopascal (force per unit area of pressure)
L/min	liters per minute
NAVSEA	Naval Sea Systems Command
NEDU	Navy Experimental Diving Unit
ppt	parts per thousand
psi	pounds per square inch (force per unit area of pressure)
PV	pressure and volume relationship
RMV	respiratory minute volume
scuba	self-contained underwater breathing apparatus
UBA	underwater breathing apparatus
V_T	tidal volume
WOB	work of breathing
$T_{expired}$	expired temperature in degrees Celsius
$T_{inspired}$	inspired temperature in degrees Celsius
°C	degrees Celsius
°F	degrees Fahrenheit

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APPENDIX A

TEST ARTICLES and CONFIGURATION

Mares Abyss 22 Navy:
NEDU Tracking Codes: MN1-MN5
Part Number: 416158[12]
Consisting of:

a) Abyss 22 Navy first-stage yoke configuration as standard
b) Abyss 22 Navy second-stage as standard
c) Intermediate pressure hose, 30-inch, rubber-jacketed as standard, part no. 46201109[12]

Notes:

The Mares Abyss 22 Navy regulator, part number 416158, differs from other Mares Abyss regulators. Therefore, the manufacturer service kits listed herein should be used exclusively with the Mares Abyss Navy regulator. No parts for other models of the Mares Abyss regulator should be used as substitutes, since these parts were not evaluated as part of the testing performed by NEDU.

Manufacturer Service Kits:[12]

First-stage assembly: part no. 46201132
Second-stage assembly: part no. 46200912
Service kit first-stage: part no. 46186152
Service kit second-stage: part no. 46200912
Service kit poppets: part no. 46201132 (10 each in kit, not included in first-stage kit)

NEDU CODE	First-Stage Serial	Intermediate Pressure Range[11]	Second-Stage Serial
Mares Abyss 22 Navy, Part number 416158[12]			
MN1	NV10123	127–136 psi	NV10123
MN2	NV10107	127–136 psi	NV10107
MN3	NV10102	127–136 psi	NV10102
MN4	NV10110	127–136 psi	NV10110
MN5	NV10109	127–136 psi	NV10109