undercurrent®

P. O. Box 1658, Sausalito, California 94965
Cable Address: Gooddiving

THE PRIVATE, EXCLUSIVE GUIDE FOR SERIOUS DIVERS

Vol. 12, Nos. 11/12 November/December 1987

U.S. Navy 1987 Tests Of 51 Regulators

--Including Cold Water Tests And Test Of 1980 Models

In September, 1987, the United States Navy Experimental Diver Unit released the results of its manned and unmanned tests of commercially available regulators. The Navy not only tested regulators under standard diving conditions, but also tested several regulators under simulated cold water conditions.

Undercurrent has edited and condensed the 1987 U.S. Navy tests into a usable form for our subscribers. In addition we have added the results of 1980 tests, since many divers still dive with older regulators and will find it useful to compare them with newer models.

THE BASIC 1987 TESTS

The U.S. Navy Experimental Dive Unit tested the breathing resistance and work of breathing of 51 commercially available regulators produced or distributed in the United States by 19 manufacturers. The regulators tested were purchased from various commercial distributors. Only one complete regulator of each model was purchased.

Each regulator was calibrated to the manufacturers' specifications for first stage static pressure (the pressure measured at the mouthpiece of the second stage when the air is turned on at the tank), the intermediate pressure (the pressure measured in the hose of the air delivered from the first stage to the second stage) and the second stage cracking pressures (the effort required to start the flow upon inhalation).

Years ago breathing resistance (i.e., peak respiratory pressure on inhalation and exhalation) at a moderate work rate (40 RMV, a measurement of respiratory volume in liters per minute) was used as the primary specification for regulator evaluation, and these criteria still form the basis of the military specifications.

In the late 1970's the Navy determined that breathing resistance did not provide as complete a definition of total regulator performance as did "work of breathing." While peak pressures on two different regulators may be identical, the actual respiratory work required from the diver can be significantly different. In addition, how "hard" or "easy" a regulator breathes is a direct function of whether the diver has to maintain the peak inhalation and exhalation pressure for the entire cycle.

Table Of Content

So, in 1980 more refined standards were developed. These standards require that under specific conditions – a depth of 132 fsw (feet of sea water), a supply pressure of 1000 psi, and a moderately heavy work rate (62.5 RMV, i.e., respiratory volume in liters per minute) -- the maximum respiratory work of breathing level for a regulator should not exceeded 0.14 kg.m/l.

Regulators meeting these standards in 1980 were considered "superior" performance regulators and were authorized for Navy use to a maximum depth of 130 fsw.

The 1987 U.S. Navy standards modify only one variable; the standard has been changed from 132 to

1987 GROUP A SUPERIOR REGULATORS

87 Legend: Regulators which met or exceeded the 1986 upgraded work of breathing requirement up to 198 fsw, a moderately heavy work rate, and 1000 psi supply pressure.

AGA MP / USD Royal SL

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	●	●	●
Heavy	●	●	●	●	●	○
Extreme	●	●	●	◐	○	○

AGA Divator MK II / USD Royal SL

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	●	●	◐
Heavy	●	●	●	◐	○	○
Extreme	●	●	○	○	○	○

Poseidon Cyklon 5000
(1986 Model distributed by Pos Dive)

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	●	●	●
Heavy	●	●	●	●	●	○
Extreme	●	●	●	●	○	○

Poseidon Odin
(1986 Model distributed by Pos Dive)

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	●	●	●
Heavy	●	●	●	●	○	○
Extreme	●	●	●	○	○	○

Poseidon Thor
(1986 Model distributed by Pos Dive)

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	●	●	●
Heavy	●	●	●	●	●	●
Extreme	●	●	●	●	●	●

Scubapro MX/G-250

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	●	●	●
Heavy	●	●	●	●	○	○
Extreme	●	●	●	○	○	○

US Divers Conshelf SE2

Work rate At 3000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	●	●	◐
Heavy	●	●	●	◐	○	○
Extreme	●	●	○	○	○	○

US Divers Pro Diver

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	●	●	◐
Heavy	●	●	●	●	○	○
Extreme	●	●	●	○	○	○

These charts represent the results of regulator tests from light to extreme workloads, defined by the Navy as ranging from 22.5 RMV (respiratory minute volume in liters per minute) to 90 RMV. The supply pressure is 1000 psi and the depths range from 33 feet of sea water to 198 fsw. A solid circle (●) indicates the regulator's performance was acceptable. A semicircle (◐) indicates the regulator's performance was marginal. An empty circle (O) indicates the regulator's performance was unacceptable.

198 fsw because Navy divers today work to 190 feet on scuba.

Test Procedures

All test regulators were calibrated to manufacturers' specifications. Manufacturers' representatives were invited to observe the testing of their regulators, and they monitored and assisted in calibrations. Upon completion of testing, six regulators from the group were selected at random for separate evaluations to confirm repeatability of data. These regulators were bench tested and recalibrated to the specifications of the original evaluation. From these six regulators, 10 separate and complete breathing resistance evaluations were conducted.

For the purpose of understanding the USN results, the most important of the parameters is the so-called work of breathing, which was controlled as follows:

Breathing Rate	Tidal Volume	RMV	Simulated Diver's Work Rate
15 BPM	1.5 Liters	22.5	Light
20 BPM	2.0 Liters	40.0	Moderate
25 BPM	2.5 Liters	62.5	Moderately Heavy
30 BPM	2.5 Liters	75.0	Heavy
30 BPM	3.0 Liters	90.0	Extreme

Test Results

Regulator performance was analyzed and data obtained at several supply pressures, RMVs and depths

1987 GROUP B: Regulators which met or exceeded the same requirements as Group A, but only up to a depth of 132 fsw.

AGA Divator MK II (FFM) Complete With Cylinders

Work rate At 3000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	●	●	○
Heavy	●	●	●	○	○	○
Extreme	●	●	○	○	○	○

AGA Divator MK II (FFM) / USD Conshelf XIV

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	●	●	○
Heavy	●	●	●	○	○	○
Extreme	●	●	○	○	○	○

Dacor Pacer XL 950

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	○	○	○
Heavy	●	○	○	○	○	○
Extreme	●	○	○	○	○	○

Dacor Pacer XLE 360

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	●	◕	○
Heavy	●	●	○	○	○	○
Extreme	●	○	○	○	○	○

Oceanic Omega II Maxflo

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	◕	○	○
Heavy	●	○	○	○	○	○
Extreme	○	○	○	○	○	○

Poseidon Cyklon 300
(1986 Model distributed by Pos Dive)

Work rate At 3000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	◕	●	○
Heavy	●	●	●	●	○	○
Extreme	●	●	◕	○	○	○

Scubapro MK X/D 300

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	●	◕	○
Heavy	●	●	●	○	○	○
Extreme	●	○	○	○	○	○

Sherwood Magnum II SRB-3300

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	○	○	○
Heavy	●	●	○	○	○	○
Extreme	●	◕	○	○	○	○

US Divers Conshelf 21

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	○	○	○
Heavy	◕	◕	◕	○	○	○
Extreme	○	○	○	○	○	○

up to the point at which breathing resistance became excessive.

Two regulator models, the Sea Sport Zepher ZR-01 and the Tekna 2100BX, displayed specific inhalation characteristics that prohibited the *objective* analysis and accurate data reduction of breathing pressure and work of breathing. Rather than publish inaccurate or faulty data, these results are not included, but they were evaluated under cold water conditions.

By circumstance, Poseidon pre-1986 models were supplied by Parkway, while Poseidon 1986 models were supplied by Pos Dive.

The AGA Divator MK II full face mask, used by the U.S. Navy when through-water communications are required, was evaluated combined with another manufacturer's first stage regulators as a *system*.

From the analysis of the data and subsequent grouping of performance levels in relation to established criteria, five performance levels were identified. They are presented alphabetically within those performance levels.

Group A. **Regulators which met or exceeded the 1987 upgraded work of breathing requirement up to 198 FSW, a moderately heavy work rate, and 1000 psi supply pressure.**

1. AGA Divator MK II FFM with U.S. Divers Royal SL first stage regulator.
2. AGA Divator MK II breathing valve with AGA mouthpiece and U.S. Divers Royal SL first stage.
3. Poseidon Cyklon 5000 (distributed by Pos Dive, Poseidon 1986 model)
4. Poseidon Odin (distributed by Pos Dive, Poseidon 1986 model)
5. Poseidon Thor (distributed by Pos Dive, Poseidon 1986 model)
6. Scubapro MK X/G-250
7. U.S. Divers Conshelf SE-2
8. U.S. Divers Pro Diver

Group B. **Regulators which met or exceeded the same requirements as Group A, but only up to a depth of 132 FSW.**

1. AGA Divator MK II (FFM) complete with first and second stages with AGA cylinders.
2. AGA Divator MK II (FFM) used with U.S. Divers Conshelf XIV first stage.
3. Dacor Pacer XL 950
4. Dacor Pacer XLE 360
5. Oceanic Omega II Max Flow
6. Poseidon Cyklon 300 (1986 model distributed by Pos Dive)
7. Scubapro MK X/D-300
8. Sherwood Magnum II SRB-3300
9. U.S. Divers Conshelf 21

Group C. **Regulators which meet or exceed military specifications for breathing resistance, but do not meet the superior performance standards up**

1987 GROUP C

Regulators which meet or exceed military specifications for breathing resistance, but do not meet the performance standards up to 132 fsw in Group B.

Nemrod Saturn Pro

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	◐	○
Moderately Heavy	●	◐	○	○	○	○
Heavy	●	○	○	○	○	○
Extreme	○	○	○	○	○	○

Parkways Atlas

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	○	○
Moderately Heavy	◐	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

ProSub Max Air I

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	○	○
Moderate	●	●	●	◐	○	○
Moderately Heavy	◐	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Scubapro MK IX / A.I.R. I

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	○	○	○	○
Heavy	●	○	○	○	○	○
Extreme	○	○	○	○	○	○

Scubapro MK X / ADJ

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	○
Moderately Heavy	●	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Scubapro MK X / HP

Work rate	Depth in feet of sea water					
At 3000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	◐	○	○
Moderately Heavy	●	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Dacor Pacer Aero 950A

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	◐
Moderately Heavy	●	●	○	○	○	○
Heavy	●	○	○	○	○	○
Extreme	○	○	○	○	○	○

Ocean Dynamics RB 3000

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	◐	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Poseidon Cyklon 300
(Pre-1986 Model distributed by Parkways)

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	◐
Moderately Heavy	●	●	○	○	○	○
Heavy	●	○	○	○	○	○
Extreme	○	○	○	○	○	○

ProSub Pro Air I

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Scubapro MK IX BAL ADJ

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	○	○	○	○
Heavy	●	○	○	○	○	○
Extreme	○	○	○	○	○	○

Scubapro MK X / A.I.R. I

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	○	○	○	○
Heavy	●	○	○	○	○	○
Extreme	◐	○	○	○	○	○

Sea Pro FSDS—50

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	○	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

IDI Super Star II

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	◐	○
Moderately Heavy	●	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Oceanic Omega II

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	◐	○	○	○
Heavy	●	○	○	○	○	○
Extreme	●	○	○	○	○	○

Poseidon Cyklon Maximum II
(Pre-1986 Model distributed by Parkways)

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	◐	○	○	○
Heavy	●	○	○	○	○	○
Extreme	◐	○	○	○	○	○

Scubapro MK III/HP

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	○	○
Moderately Heavy	●	◐	○	○	○	○
Heavy	●	○	○	○	○	○
Extreme	○	○	○	○	○	○

Scubapro MK IX / HP

Work rate	Depth in feet of sea water					
At 3000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	○	○
Moderately Heavy	◐	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Scubapro MK X / BAL ADJ

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	○	○	○	○
Heavy	◐	○	○	○	○	○
Extreme	○	○	○	○	○	○

Sea Quest AMF Mares MR 12-II

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

1987 GROUP C

Sherwood Brut SRB 2100

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	◕	○	○	○	○
Moderately Heavy	◕	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Sherwood Magnum Blizzard SRB-3200

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	◕	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Sportsways X-2

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Sportsways X3

Work rate At 3000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	○
Moderate	●	◕	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Tabata TR-100

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

US Divers Conshelf XIV

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	◕	○
Moderately Heavy	◕	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

to 132 fsw in Group B.

1. Dacor Pacer Aero 950 A
2. International Divers Inc Super Star II
3. Nemrod Saturn 300 Pro
4. Ocean Dynamics RB-3000
5. Oceanic Omega II
6. Parkways Atlas
7. Poseidon Cyklon 300 (pre 1986 model distributed by Parkways)
8. Poseidon Cyklon Maximum II (pre 1986 model distributed by Parkways)
9. Pro Sub Max Air I
10. Pro Sub Pro Air I
11. Scubapro MK III/High Performance
12. Scubapro MK IX/Air I
13. Scubapro MK IX/Balanced Adjustable
14. Scubapro MK IX/High Performance
15. Scubapro MK X/Adjustable
16. Scubapro MK X/Air I
17. Scubapro MK X/Balanced Adjustable
18. Scubapro MK X/High Performance
19. Sea Pro FSDS-50
20. Sea Quest AMF MR 12-III
21. Sherwood Brut SRB-2100
22. Sherwood Magnum Blizzard SRB-3200
23. Sportsways X-2
24. Sportsways X-3
25. Tabata TR-100
26. U.S. Divers Conshelf XIV

Group D. **Regulators which did not meet the military specifications for breathing resistance established in Group C.**

1. Cressi Sub Galaxie 105
2. Cressi Sub Polaris IV
3. International Divers Inc. Star II
4. Nemrod Saturn 300
5. Scubapro MK X/Air II (NOTE: A buoyancy compensator inflator/mouthpiece *not a primary regulator*.)
6. Sea Pro FSDS-10

Group E. **Regulators that could not be objectively evaluated by breathing resistance vs depth and work of breathing vs depth due to second stage inhalation pressure patterns incompatible with data analysis systems.**

1. Sea Sport Zepher ZR-01
2. Tekna 2100 BX

Conclusions

From these evaluations, the USN has identified eight reliable regulators for operational use to 198 fsw. The new performance criteria are a natural progression of the 1980 standards from 132 fsw to 198 fsw. These performance achievements are directly attributable to manufacturers' improvements in the design and operation of commercially available open circuit regulators.

Additionally it should be noted that the establishment of performance criteria at 198 FSW is solely a Navy requirement and is not an endorsement that casual dives be conducted to such depths.

While eight regulators/systems met the upgraded 1987 NEDU performance requirement, regulators that meet or exceed the 1980 standards are considered to be safe and effective. The 1987 NEDU performance criteria at 198 FSW was specifically designed to identify the highest performance equipment available.

Unmanned breathing resistance and work of breathing evaluation, although considered to be a severe test of regulator performance, is not a lifecycle/mechanical failure study.

1987 GROUP D: Regulators which did not meet the specifications for breathing resistance in Group C, as well as USN performance standards.

Cressi Sub Galaxie 105

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	O
Moderate	●	O	O	O	O	O
Moderately Heavy	O	O	O	O	O	O
Heavy	O	O	O	O	O	O
Extreme	O	O	O	O	O	O

Cressi Sub Polaris IV

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	◐	O	O	O
Moderate	O	O	O	O	O	O
Moderately Heavy	O	O	O	O	O	O
Heavy	O	O	O	O	O	O
Extreme	O	O	O	O	O	O

IDI Star II

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	O	O	O	O
Moderately Heavy	O	O	O	O	O	O
Heavy	O	O	O	O	O	O
Extreme	O	O	O	O	O	O

Nemrod Saturn 300

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	◐	O	O
Moderate	◐	O	O	O	O	O
Moderately Heavy	O	O	O	O	O	O
Heavy	O	O	O	O	O	O
Extreme	O	O	O	O	O	O

Scubapro MKX/A.I.R. II

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	O	O
Moderate	●	O	O	O	O	O
Moderately Heavy	O	O	O	O	O	O
Heavy	O	O	O	O	O	O
Extreme	O	O	O	O	O	O

Seapro FSDS-10

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	◐	O
Moderate	●	O	O	O	O	O
Moderately Heavy	O	O	O	O	O	O
Heavy	O	O	O	O	O	O
Extreme	O	O	O	O	O	O

1987 TESTS WITH LOWERED SUPPLY PRESSURE

The spring/valve mechanism of most second stage regulators is designed to function with minimum inhalation effort when supplied with 125 to 150 psi from the first stage. Upon inhalation, this pressure drops as the air flows from the first to the second stage. As a diver descends and increases his work rate, the increased flow from the first stage to the second stage causes the pressure to drop and the initial setting to increase dramatically. Consequently, the second stage may no longer receive air at a pressure and volume sufficiently high to meet the diver's inhalation demands, so the diver must increase his inhalation effort. Depending upon the regulator, some combination of low psi, high work rate, and depth make it difficult or even impossible for the diver to breathe air from the tank, even though some air remains. This phenomenon begins to increase when the supply pressure to the first stage is below 500 psi and can have serious implications for the diver at 300 psi.

At a moderately heavy work rate, a depth of 99 feet and 300 psi supply pressure, some regulators showed a substantial drop in performance, while others maintained relatively strong performance at even higher work rates. In practice that low performance can mean that a diver low on air -- with 300 psi or less -- at 99 feet of depth, employing a moderately heavy work rate due to a current or even to panic induced heavy breathing, may have difficulty getting air.

The Navy tested each of the regulators at a supply pressure of 300 psi. Although it provided no written evaluation of the tests, it did provide performance charts which *Undercurrent* has interpreted.

Those regulators which performed *exceptionally* well at low supply pressures included:

1. AGA Divator II with USD Conshelf XIV
2. AGA Divator II with USD Royal SL
3. Oceanic Omega II Maxflo
4. Poseidon Odin distributed by Pos Dive
5. Scubapro MK IX/Bal Adj
6. Scubapro MK IX/HP
7. Scubapro MK X/D3000
8. Scubapro MK X/G250
9. Scubapro MK X/Bal Adj
10. Scubapro MK X/HP
11. US Divers Conshelf XIV
12. US Divers Conshelf 21
13. US Divers Conshelf SE 2
14. US Divers Pro Diver

Those regulators which *failed* to meet breathing resistance standards with only 300 psi and a moderately heavy work rate include:

1. Cressi Sub Galaxie 105
2. Cressi Sub Polaris IV
3. Poseidon Cyklon 300 (distributed by Pos Dive)
4. Poseidon Thor (distributed by Pos Dive)
5. Pro Sub Max Air I
6. Scubapro MK X/AIR II
7. Sea Pro FSDS-10
8. Sherwood Brut SRB 2100
9. Sherwood Magnum Blizzard
10. Sherwood Magnum II

1987 MANNED OPEN WATER TESTING

NEDU conducted manned human open water studies on 11 commercially available regulators. During the evaluation 156 dives were conducted to a maximum depth of 130 fsw. Diver-subjects completed a regulator questionnaire and entered appropriate remarks on the conclusion of each dive.

Physical Characteristics

Divers rated regulators from not quite adequate to good. Total averaging, however, indicated regulators performed at an adequate or good level.

Highest scores went to the U.S. Divers Conshelf SE-2 and Pro Diver with the AGA Divator MK II breathing valve with AGA mouthpiece and U.S. Divers Royal SL first stage following closely. Lowest marks were assigned to Sea Sport Zepher ZR-01.

Breathing Performance

Total average scores of subjective responses indicated the highest rating assigned to the U.S. Divers Conshelf SE-2 and Pro Diver, followed closely by the AGA Divator MK II with AGA mouthpiece/U.S. Diver Royal SL first stage and the Pro MK X/G-250. The Sea Sport Zepher ZR-01 was rated at the not-quite-adequate level.

General Regulator Function

Overall favorable responses went to the AGA Divator MK II breathing valve with AGA mouthpiece/U.S. Divers Royal SL first stage, Scubapro MK X/G-250 and U.S. Divers Conshelf SE-2 and Pro Divers. The least favorable went to the Sea Sport Zepher ZR-01.

NOTE: Only one mechanical failure was recorded. The piston O-ring on the Scubapro MK X first stage was scored and required replacement. However, the Sea Sport Zepher ZR-01 pressed-in air channel-way on the second stage was removed during the evaluation as it was *considered a safety hazard*. The channel-way could easily separate from the second stage case and possibly become lodged in the diver's airway.

Conclusion:

With the exception of the Sea Sport Zepher ZR-01, the regulators evaluated in this phased operated at the adequate or good levels. The Sea Sport Zepher ZR-01 in normal configuration, with air channel-way installed, was considered unsafe.

High Scores:

1. AGA Divator MK II breathing valve with AGA mouthpiece/USD Royal SL first stage
2. AGA Divator MK II full face mask/USD Royal SL first stage
3. Scubapro MK X/G-250
4. U.S. Divers Conshelf SE-2
5. U.S. Divers Pro Diver

Moderate Scores:

1. Poseidon Cyklon 5000
2. Poseidon Odin
3. Poseidon Thor
4. Sherwood Magnum Blizzard
5. Tekna 2100 BX

Low Scores:

1. Sea Sport Zepher ZR-01.

1987 UNMANNED COLD WATER TESTING

The Navy Experimental Diving Unit conducted unmanned breathing resistance and cold water function evaluations of ten regulators equipped with low temperature conversion kits or standard first stage environmental silicon grease injection to ascertain whether such configurations negatively affected the regulators. Units were selected primarily on their ability to meet the Group A, 198 fsw requirement although some additional regulators were selected.

Common Cold Weather and Cold Water Malfunctions

Both stages of any regulator can mechanically malfunction as a result of cold -- which affects spring tension, and the flexibility of O-rings and diaphragms -- or moisture -- which freezes and forms ice blocks or alters mechanical functions. Such failures occur when regulators are *exposed to cold weather* or during diving operations where subsurface temperatures are below 37 °F.

Rise in first stage overbottom pressure: Overbottom pressure is the pressure of the air delivered from the first stage to the second stage at a given depth (it is determined by adding the pressure of the delivered air to the ambient pressure). In cold water, the regulator may fail to reduce high pressure air to nominal operating low pressures. It's caused by prolonged exposure to cold weather so the first stage component spring and diaphragms become more rigid. This generally leads to a pressure increase on the low pressure side in order to balance the effect of the rigidity and close the high pressure valve seat. Ultimately, static overbottom pressure rises above the specified norm and forces the second stage downstream valve open, driving the regulator into freeflow.

First stage exterior freeze while immersed: Both diaphragm and piston first stages freeze in the open or closed position due to ice formation on the regulator spring and within the spring cavity. Water which enters the spring cavity, via the ambient pressure reference ports, freezes inside the first stage during the reduction of high pressure air to low pressures. As ice begins to form, intermediate pressures rise or drop, and the diaphragm or piston

GENERAL REGULATOR FUNCTION
(MANNED SCUBA REGULATOR EVALUATION)
YES AND NO QUESTIONS

	Number Of Dives	Did The Regulator Ingest Water At Any Time?		During Towed Diver Scenario Did You Experience Excessive Drag?		Did You Experience Water Drag When Free Swimming?		Did The Regulator Free Flow?		Does The 2nd Stage Force Air Excessively To The Diver?		Did You Feel Comfortable Diving With This Regulator?	
		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No	Yes	
AGA Divator MK II W/MP USD Royal SL 1st Stage	15	0	15	0	15	1	N/A	2	13	1	14	14	1
AGA Divator MK II W/FFM USD Royal SL 1st Stage	15	0	15	5	10	N/A	1	6	9	2	13	11	4
Poseidon Cyklon 5000	16	3	13	1	15	1	N/A	2	14	3	13	9	7
Poseidon Odin	13	1	12	4	9	1	N/A	6	7	5	8	9	4
Poseidon Thor	12	3	9	1	11	1	N/A	5	7	4	8	10	2
Scubapro MK X/G-250	14	0	14	0	14	N/A	1	4	10	0	14	14	0
Sea Sport Zepher ZR-01	13	4	9	0	13	N/A	1	1	12	8	5	1	12
Sherwood Magnum Blizzard	14	3	11	0	14	N/A	1	5	9	2	12	12	2
Tekna 2100 BX	12	0	12	1	11	N/A	1	0	12	4	8	8	4
U.S. Divers Conshelf SE-2	15	1	14	0	15	N/A	1	4	11	1	14	15	0
U.S. Divers Pro Diver	17	0	17	0	17	N/A	1	3	14	0	17	17	0

can ultimately freeze open or closed.

First stage interior freeze: The high pressure valve mechanism can freeze open or closed, due to moisture freeze-up inside the first stage. During reduction of air from high to low pressure, temperatures drop and the regulator cools; moisture condenses and freezes on the high pressure valve, its seat, and other components.

Second stage downstream valve failure: Second stage supply valves freeze open or closed as a result of the cold's effect upon moisture that has entered the second stage.

Preventing Mulfunctions

The probability of a malfunction occurring increases as air or water temperature drops. Certain practices can be adopted to lessen the chance of malfunctions:

Prior to cold water diving, regulators should be fully serviced and checked for proper function. First stages should be modified with cold water conversion kits or silicon grease injection.

Supply air should be as dry as possible to prevent internal first stage freeze up and to reduce the probability that the second stage valve of other low pressure devices (e.g. dry suit inflator, buoyancy compensation inflators) will freeze.

Regulators, especially the second stages, should be dry. They should be kept warm as long as possible prior to diving, and have as little exposure as possible to harsh cold surface environments. If snowing, second stages should be covered to prevent entrance of moisture.

Once exposed to cold surface conditions, regulators should not be breathed or exhaled into; nor should they be purged for more than one second while on the surface.

If possible, the diver should enter the water by taking a deep breath, then placing the regulator in the mouth. After entering, exhale and breathe normally with the regulator, keeping it submerged at all times. This is important where surface temperatures are lower than the ambient water. (This method keeps the regulator from flooding during entrance and prohibits excess water moisture from entering the second stage.)

While submerged, breathe normally, and avoid extreme work conditions which demand high air flows through the regulator. High flows will cool the valve mechanisms and produce condensation. Again avoid prolonged purging of the second stage; if equipped with dry suit inflation or buoyancy compensation devices, inflate them with short bursts of air.

If the regulator is removed and flooded, attempt to

PHYSICAL CHARACTERISTICS
(MANNED SCUBA REGULATOR EVALUATION)
NUMERICAL

	Number Of Dives	Mouth-Piece (Comfort)	2nd Stage Buoyancy	2nd Stage Range Of Motion	Bubble Dispersion	Air Hose Length	1st Stage Durability	2nd Stage Durability	Air Hose Durability	Purge Button Operation	2nd Stage Adjustment	1st Stage Adjustment	Dial-A-Breath/ Deflector	Regulator Rating	Total Average
AGA Divator MK II W/MP USD Royal SL 1st Stage	15	4.86	5.06	5.2	4.86	4.86	5.00	4.73	4.93	5.2	N/A	5	N/A	5.1	4.98
AGA Divator MK II W/FFM USD Royal SL 1st Stage	15	N/A	4.06	4.73	4.93	4.73	5.00	4.66	4.86	4.9	N/A	5	N/A	4.66	4.75
Poseidon Cyklon 5000	16	3.6	4.53	3.93	4.46	3.96	4.6	4.53	4.73	4.93	N/A	5	N/A	3.86	4.38
Poseidon Odin	13	4.07	4.38	4.38	4.30	4.53	4.23	4.15	4.53	3.76	N/A	5	N/A	3.5	4.26
Poseidon Thor	12	4.04	4.5	4.25	4.16	4.12	4.29	4.00	4.33	3.66	N/A	5	N/A	3.8	4.20
Scubapro MK X/G-250	14	4.53	4.64	4.71	4.75	4.78	4.85	4.78	4.78	4.85	4	3	4.53	4.89	4.56
Sea Sport Zepher ZR-01	13	4.03	4.38	4.46	4.61	4.46	4.23	3.76	4.46	4.30	N/A	4	N/A	3.03	4.16
Sherwood Magnum Blizzard	14	4.07	4.42	4.71	4.82	4.60	4.42	4.14	4.64	4.57	4	3	N/A	4.00	4.28
Tekna 2100 BX	12	3.25	4.58	4.5	4.83	4.66	4.58	4.25	4.70	4.62	N/A	4	N/A	3.87	4.39
U.S. Divers Conshelf SE-2	15	5.26	5.2	5.00	4.93	4.8	5.13	5.06	5.26	5.2	5	5	N/A	5.43	5.12
U.S. Divers Pro Diver	17	5.05	4.88	5.05	5.00	4.94	5.23	5.11	5.11	5.29	5	5	N/A	5.32	5.08

1. EXTREMELY POOR 2. POOR 3. NOT QUITE ADEQUATE 4. ADEQUATE 5. GOOD 6. EXCELLENT

BREATHING PERFORMANCE RATING
(MANNED SCUBA REGULATOR EVALUATION)
NUMERICAL

	Number Of Dives	Up-Right Position		45° Face Up Position		45° Face Down Position		Full Head Down Position		Prone Position		Supine Position		135° Head Down Position		135° Head Up Position		Average Score		Total Average
		In	Ex	In	Ex	In	Ex	In	Ex	In	Ex	In	Ex	In	Ex	In	Ex	In	Ex	
AGA Divator MK II W/MP USD Royal SL 1st Stage	15	5.13	5.33	5.06	5.33	5.06	5.33	5.00	5.33	5.13	5.33	5.06	5.33	5.2	5.33	5.2	5.33	5.10	5.33	5.22
AGA Divator MK II W/FFm USD Royal SL 1st Stage	15	4.83	4.83	4.76	4.8	4.96	4.9	5.00	5.00	5.06	5.00	4.93	5.00	4.91	4.93	4.93	4.93	4.92	4.92	4.92
Poseidon Cyklon 5000	16	4.68	4.81	4.62	4.62	4.5	4.81	4.43	4.68	4.56	4.75	4.37	4.68	4.37	4.68	4.5	4.68	4.5	4.74	4.62
Poseidon Odin	13	4.15	4.53	4.15	4.53	4.15	4.53	4.00	4.52	4.23	4.61	3.92	4.38	3.92	4.38	3.92	4.38	4.05	4.48	4.27
Poseidon Thor	12	4.36	4.63	4.18	4.63	4.36	4.45	4.27	4.63	4.27	4.63	4.09	4.63	4.00	4.54	4.00	4.54	4.19	4.59	4.39
Scubapro MK X/G-250	14	5.06	5.06	4.8	5.13	5.00	5.13	4.8	5.13	5.06	5.06	4.6	5.13	4.73	5.06	4.66	5.06	4.84	5.09	4.97
Sea Sport Zepher ZR-01	13	3.76	4.15	3.38	4.15	3.38	4.07	3.53	3.92	3.69	4.15	3.33	4.07	3.3	4.15	3.33	4.13	3.44	4.12	3.78
Sherwood Magnum Blizzard	14	4.21	4.57	4.00	4.57	4.21	4.57	4.14	4.5	4.28	4.5	4.07	4.57	3.92	4.64	3.92	4.64	4.09	4.57	4.33
Tekna 2100 BX	12	3.91	4.58	3.91	4.66	4.08	4.66	4.00	4.58	4.00	4.58	4.08	4.66	4.00	4.58	4.00	4.58	3.99	4.61	4.30
U.S. Divers Conshelf SE-2	15	5.26	5.4	5.26	5.4	5.26	5.4	5.2	5.4	5.33	5.4	5.2	5.4	5.26	5.33	5.26	5.4	5.25	5.38	5.32
U.S. Divers Pro Diver	17	5.41	5.29	5.23	5.29	5.23	5.29	5.17	5.29	5.41	5.29	5.05	5.29	5.11	5.29	5.05	5.29	5.21	5.29	5.25

1. EXTREMELY POOR 2. POOR 3. NOT QUITE ADEQUATE 4. ADEQUATE 5. GOOD 6. EXCELLENT

clear the regulator with exhaled air rather than purging. If purging is necessary, again avoid any prolonged bursts of air.

With these in mind, the NEDU tested ten regulators, modified for cold water as follows.

The Regulators:

AGA Divator MK II Breathing Valve with AGA Mouthpiece/U.S. Divers Royal SL First Stage was evaluated *without* the full face mask. The AGA MK II breathing valve (second stage) undergoes no modifications for cold water conditioning. The U.S. Divers Royal SL first stage is modified with a low temperature conversion kit (U.S. Divers part no. 1022-75) consisting of a cotton-backed diaphragm and generic first stage fittings and an antifreeze liquid is used.

Poseidon: Cyklon 5000, Odin and Thor second stages undergo no cold water modification. The first stage is modified by a standard conversion kit (part number Poseidon 1286) consisting of a rubber antifreeze cap and two plastic locking straps. The first stage spring cavity is filled with a nontoxic antifreeze liquid, such as silicon or ethyl alcohol.

Scubapro MK X/G-250 first and second stages undergo no modification for cold water conditioning, except for the injection of environmental silicon (Scubapro part number 41-035-000) into the standard silicon protection environmental cap.

Sea Sport Zepher ZR-01 first and second stages undergo no modification for cold water conditioning, except for the injection of environmental silicon in the first stage piston/spring cavity.

Sherwood Magnum Blizzard SRB 3200 first and second stages are designed for cold water use and undergo no modification or silicon injection.

Tekna 2100 BX first and second stages undergo no modification for cold water, except for the injection of environmental silicon into the first stage piston/spring cavity.

U.S. Divers Conshelf SE-2 second stage undergoes no modification for cold water. The first stage is modified with the emplacement of a low temperature conversion kit, USD part No. 1076-75.

U.S. Divers Pro Diver second stage undergoes no modification for cold water conditioning. The first stage "Royal SL" is modified in identical manner as described under the AGA Divator MK II breathing valve with AGA mouthpiece equipped with U.S. Divers SL first stage.

The Tests

Evaluation of U.S. Divers Cotton-Backed and Nylon-Backed Main First Stage Diaphragms

An evaluation of U.S. Divers cotton-backed vs. nylon-backed main first stage diaphragms used in the "USD Conshelf XIV" first stage regulator was conducted to determine the effects that these diaphragms had on first stage regulator static overbottom pressures once exposed to freezing conditions.

After being frozen for a minimum of 12 hours, each diaphragm was tested for flexibility by placing it edgewise on a counter top and compressing it by index finger pressure to the point of flexing. The nylon-backed diaphragms became very rigid and required significant index finger pressure to flex. Cotton-backed diaphragms were far less rigid than nylon units, requiring significantly less index finger pressure to flex.

For the static pressure (the pressure measured at the mouthpiece of the second stage when the air is turned on) test, four U.S. Divers Conshelf XIV first stages (two with cotton-backed diaphragms and two with nylon) were prepared with cold water conversion kits, set to manufacturers' specifications, and instrumented to monitor first stage intermediate pressure. All four were then frozen for a minimum of 12 hours, then tested for intermediate static pressure. They were warmed to room temperature and checked again.

U.S. Diver's Conshelf XIV first stage static pressures of all units equipped with nylon diaphragms greatly exceeded manufacturers' present static pressure of 145 psi. Readings recorded were 187, 197, 220 and 230 psi.

First stage static pressures of units equipped with cotton-backed diaphragms, although exceeding the preset static pressure of 145 psi, remained consistently close to that value. Readings recorded were 147, 150, 150 and 157 psi.

The test results clearly indicated that the cotton-backed diaphragm became far less rigid than nylon-backed units and had far less effect in raising the Conshelf XIV first stage static overbottom pressure above present pressures for regulators exposed to cold environments. Pressures recorded from nylon units would have been more than sufficient to immediately over-drive a dynamically balanced second stage demand valve into freeflow.

Low Temperature Work of Breathing Evaluation

In all cases, the use of low temperature conversion kits for diaphragm or silicon injection for piston first stages, reduced the performance of the regulator when tested at 70°F. As depth and RMV levels increased, regulators equipped for cold water had inhalation resistance and work of breathing values higher in comparison to their normal configuration. The Scubapro MK X/G-250, a first stage piston regulator, was affected less than those regulators equipped with diaphragm first stages. No further increase in work of breathing was noted when converted regulators were subsequently tested in the freezing environment.

The 1987 performance goal of moderately heavy work at 1000 psi supply pressure and depths up to 198 FSW was attained by the AGA Divator MK II with AGA mouthpiece/USD Royal SL first stages and the Scubapro MK X/G-250.

The goal could not be attained by Poseidon Cyklon 5000, Poseidon Odin, Poseidon Thor, U.S. Divers Conshelf SE2 and U.S. Divers Pro Diver. However, in all cases exhalation/inhalation values were well within the established values of the 1980 Military Specifications.

Cold Water Function Evaluations

All test regulators were equipped with applicable cold water conversion or silicon injection, calibrated to manufacturers' specifications, and frozen for 12 hours at 0°F. They were then tested for one hour or until malfunction occurred. If malfunction occurred, the regulator was removed and inspected. Ten separate evaluations were scheduled to provide a statistical data base.

Although a number of test parameters were controlled, only a one needs mentioning here: breathing rate -- 20 BPM; tidal volume -- 2.0; RMV -- 40.0 (or the equivalent of a moderate work rate).

AGA Divator MK II, Breathing Valve with AGA Mouthpiece/USD Royal SL First Stage: Three runs were completed without a malfunction. One run was completed, although 12 minutes into the evaluation a minor freeflow came from the second stage and continued throughout the evaluation.

Initial first stage overbottom pressure after freezing: preset pressure was 155 psi; recorded pressures 156, 176, 173, and 180 psi. First stage intermediate pressure control during one-hour immersion: the first stage intermediate overbottom pressures rose from 139 to 153 psi maximum and dropped from 117 to 112 psi minimum.

Analysis: Despite severe exterior first stage freezing, the regulator controlled first stage pressure satisfactorily. Work of breathing did not vary from previous nonfreezing analysis. The cause of minor freeflow could not be identified.

Poseidon Cyklon 5000: Four runs were completed successfully. In a fifth run the regulator initially freeflowed when supplied with high pressure air. Upon dunking, the freeflow stopped, so the evaluation was continued. At 30 minutes freeflow began in the second stage and increased so much the test was stopped.

Initial first stage overbottom pressure after freezing: Preset pressure was 168 psi; recorded pressure 160, 161, 172, 174, 183 psi. First stage intermediate pressure control during one-hour immersion: The first stage intermediate overbottom pressures rose from 156 to 171 psi maximum, and dropped from 135 to 112 psi minimum.

Analysis: Despite exterior freezing on both stages, the regulator controlled first stage pressures satisfactorily. Work of breathing did not vary from previous nonfreezing analysis. Freeflow at second stage was caused by ice formation between the link/ejector sleeve prohibiting second stage low pressure valve piston from fully seating.

Poseidon Odin: Four runs were completed successfully. On a fifth run the regulator freeflowed when the first stage was supplied with high pressure air. Upon dunking, the freeflow stopped and the test was continued. One run could not be completed because the regulator went into unstoppable severe freeflow when the first stage was supplied with high pressure air.

Initial first stage overbottom pressure after freezing: Preset pressure was 130 psi; recorded pressures 112, 125, 130, 128, 130 psi. The 112 psi reading coincided with the regulator that initially freeflowed then stopped. The first stage intermediate pressure rose from 118 to 137 psi maximum, and dropped from 98 to 78 psi minimum.

Analysis: Despite exterior freezing on the first stage, first stage pressure was controlled satisfactorily. Work of breathing did not vary from previous nonfreezing analysis. Both freeflow situations were attributed to the second stage, but the specific malfunctioning component could not be determined.

Poseidon Thor: Four runs were completed successfully.

The initial first stage overbottom pressure after freezing: Preset pressure was 130 psi; recorded pressures: 160, 160, 164, 167 psi. The first stage intermediate pressures rose from 123 to 127 psi maximum, and minimum values held at approximately 103 psi.

Analysis: Despite severe exterior freezing on the first stage components, the first stage pressures were controlled satisfactorily. Work of breathing did not vary from previous nonfreezing analysis. No malfunctions occurred.

Scubapro MK X/G-250: Three runs were successfully completed. One run was completed despite a slight freeflow from the second stage which began 12 minutes into the evaluation and continued throughout. On another run the second stage went into a severe freeflow 3 minutes into the evaluation.

Initial first stage overbottom pressure after freezing: Preset pressure 118 psi; recorded pressures 138, 146, 117, 141, 142. First stage intermediate control rose from 140 to 176 psi maximum, and dropped from 110 to 80 psi minimum.

Analysis: Exterior freezing occurred on all regulators which completed evaluation. First stage over bottom pressure consistently increased throughout the period of immersion to pressures well beyond the preset value. Cause of the minor malfunction was attributed to ice forming over the interface between the demand lever and the poppet valve. The severe freeflow was caused by substantial ice forming over the interface between the demand lever and poppet valve, keeping the demand lever depressed. Additionally, ice had formed on the inhalation diaphragm and the area immediately adjacent to the exhaust valve.

Sea Sport Zepher ZR-01: No runs were completed successfully. During two runs, the second stage immediately went into unstoppable freeflow when the first stage was supplied with high pressure air. During the third run the second stage went into severe freeflow 10 minutes into the evaluation.

Initial first stage overbottom pressure after freezing: Preset pressure was 150 psi; recorded pressures at 160, 164 psi. One pressure reading could not be accurately attained. First stage intermediate pressures were only attainable during the first 10 minutes of one study. Maximum over bottom pressure rose from 164 to 174 psi, minimum over bottom held at 138 psi prior to entering a freeflow condition.

Analysis: No specific cause of the two severe freeflow cases could be identified. During the one test that resulted in freeflow after 10 minutes of the immersion analysis, ice had formed in the first stage spring cavity and on the first stage piston O-ring despite the pressure of silicon grease. In the second stage, ice had formed on the defector plate and poppet assembly. The tests could not be completed.

Sherwood Magnum Blizzard: Four runs were completed successfully.

Initial first stage overbottom pressure after freezing: Preset value was 133; recorded pressure at 130, 130, 133, 133. Regulators initially began the immersion with maximum first stage intermediate pressure of 142, pressures remained relatively constant throughout the period only rising briefly to a maximum 163 psi. Minimum values remained consistent throughout, fluctuating between 120 and 115 psi.

Analysis: Despite external freezing on first stage, the regulator satisfactorily maintained first stage pressure, work of breathing did not vary from previous nonfreezing analysis.

Tekna 2100 BX: One run was completed successfully, however, first stage overbottom pressure increased dramatically from 137 to 185 psi over the one-hour period. Fifty minutes into another run, the second stage commenced a minor freeflow. Again first stage overbottom pressure increased dramatically over the immersion period to 190 psi. Twelve minutes into a third evaluation, the second stage went into severe freeflow.

Preset first stage overbottom pressure after freezing was set at 118 psi; recorded pressures were 119, 121, 127 psi. After one-hour immersion, the first stage intermediate overbottom pressure rose from 140 to 190 psi maximum, and minimum values held at approximately 115 psi.

Analysis: The first stage regulator exterior freezing occurred on all completed evaluations. First stage overbottom pressures dramatically increased throughout the period of immersion. Analysis of the second stages showed ice formation about pilot valve stem. Relative breathing work of Tekna remained consistent throughout the evaluation.

U.S. Divers Conshelf SE-2: One run was completed without any malfunction. On another run, the second stage went into slight freeflow at 56 minutes into the evaluation. First stage overbottom pressure had consistently risen from 138 psi to maximum of 190 psi, then dropped and held at 170 psi. On two runs, the regulator's second stage went into severe free flow at 17 and 22 minutes into the evaluations, and increased in severity. First stage pressure remained within normal operating pressures.

The overbottom pressures after freezing: Preset pressure was 138; recorded pressures were 156, 145, 148, 164 psi. First stage intermediate pressure control during one-hour immersion: Regulator initially began the immersion period with a maximum overbottom pressure of 140 psi. Pressure varied up to 190 psi but then returned to 170 psi. Minimum values began at 130 psi and then dropped to 105 psi.

Analysis: First stage exterior icing occurred in all cases. First stage pressures were often erratic. The severe freeflow was caused when ice formed on the second stage between the horseshoe valve and the poppet valve, on the inhalation diaphragm, and immediately adjacent to and in the exhaust valve. In the minor freeflow incident small quantities of ice had formed on the interface between the horseshoe valve and the poppet; freeflow was evidently caused by high overbottom pressure. Work of breathing did not vary from previous nonfreezing analysis.

U.S. Divers Pro Diver: No run was completed successfully. On three runs the evaluation was stopped after the regulators went into severe freeflow when the first stage was supplied with high pressure air.

Initial first stage overbottom pressure after freezing: Preset pressure was 140 psi. During these three evaluations accurate first stage pressures could not be attained. The regulators were subsequently monitored in a static condition, pressures recorded were at 200, 200, 220 psi. During the first stage intermediate pressure control one-hour immersion test, the overbottom pressure rose to such an extreme as to immediately overpower the dynamically balanced second stage valve.

Analysis: Regulator malfunction was directly attributed to high first stage intermediate pressure.

Cold Water Function Discussion

First stage external spring cavity freeze: The cold water conversion kits used on the diaphragm first stage regulators proved to be totally effective in preventing first stage exterior freeze of the spring cavity. No exterior freezes of diaphragm first stage regulators were recorded. The dry air bleed system on the Sherwood Magnum Blizzard also proved totally effective in protecting its first stage from spring cavity freeze.

Environmental silicon grease proved effective in preventing spring cavity freezing. However, the exterior of the first stage of the Sea Sport Zepher ZR-01 froze when silicon grease was forced out of spring cavity through the first stage ambient sensing ports by piston action and water entered. The extrusion of silicon grease is a common problem with piston regulators. It can be *limited,* but not prohibited, via the adaptation of smaller ambient sensing ports as found on the Scubapro MKX environmental standard silicon protection environmental cap.

First stage interior freeze. No occurrence was recorded.

First stage intermediate pressures immediately after freezing: Relatively excessive first stage intermediate static pressures were recorded with AGA Divator II with USD Royal SL first stage and the U.S. Diver Pro Diver also equipped with the Royal SL first stage. The AGA breathing valve, a balanced pilot second stage, never went into freeflow.

However, the USD Pro Diver second stage, a dynamically balanced downstream poppet valve, went into freeflow on every evaluation. The Royal SL first stage did have cotton diaphragms installed, but its performance after freezing was not as controlled as USD Conshelf (XIV) first stage used with the USD SE2. All other first stage regulators' static pressures remained near preset standards. The most precise intermediate static pressure control was demonstrated by the Sherwood Magnum Blizzard.

First stage intermediate pressure control during one-hour immersion: Once the breathing machine was started, all first stage intermediate pressure returned to optimum, with the exception of the Sea Sport Zepher ZR-01. In this case intermediate pressure increased from a preset 150 to 175 psi and the first stage froze and the regulator freeflowed.

The AGA Divator MK II/USD Royal SL, the Poseidon Cyklon 5000, the Odin, the Thor and the Sherwood Blizzard continued to operate within preset first stage pressure ranges.

The USD SE2 operated normally but on one instance pressure increased to 190 psi, then dropped and maintained at 170 psi. This coincided with a slight freeflow, but the evaluation was completed. Both the Scubapro MK X/G-250 and Tekna 2100 BX had consistent increases in overbottom pressure with MK X/G-250 rising to 174 psi and the Tekna to 190 psi. The design characteristics of both second stages (the Scubapro, a balanced adjustable, the Tekna, a pilot) prevent the second stages from freeflowing as a direct result of excessive first stage overbottom pressures.

Second Stage failure due to excessively high first stage overbottom pressure: The USD Pro Diver was the only regulator that malfunctioned due to excessive first stage pressure. The U.S. Diver Conshelf SE-2 (identical second stage to the Pro Diver) did attain a slight freeflow when pressure went as high as 190 psi. However, pressures returned to 170 psi and the regulator completed the evaluation without attaining a severe freeflow.

Second stage failure, due to freezing of valve assembly: this occurred once in the Poseidon 5000, twice with the Scubapro MK X/G-250, the Sea Sport Zepher ZR 01, the Tekna 2100 BX and three times with the U.S. Diver Conshelf SE-2. It was due to icing on second stage demand valve mechanisms. Both the Scubapro MK X/G-250 and U.S. Diver SE-2 second stages had ice form on demand diaphragms immediately adjacent to the exhaust valve (in the case of the SE-2 on the interior surface of the exhaust valve) which suggests some moisture may have splashed back from the exhaust valve.

Cold water performance based on second stage design:

Unbalanced/dynamically balanced demand poppet: Comparing the performance of two structurally similar regulators -- the Sherwood Magnum Blizzard second stage to the U.S. Divers Conshelf SE-2 (same as Pro Diver) -- would indicate the Sherwood Magnum Blizzard to be the superior of the two. The Sherwood teflon-coated components and heat retention system were effective in preventing second stage malfunction. The Poseidon Cyklon 5000 second stage design (side mount inhalation/exhalation diaphragms, operation device linkage with ejector) was also effective.

Pneumatically balanced, demand poppet Scubapro MK X/G-250: The Scubapro G-250 second stage malfunctioned due to second stage icing. Its relative performance, being the only second stage in this category, is considered moderate. Its balanced design was considered to have played an important role in preventing freeflow, as first stage pressures rose from a preset value of 118 psi to as high as 176 psi during the immersion study.

Pilot/Servo: The Sea Sport Zepher-01 and the Tekna 2100 BX second stages both malfunctioned due to icing. The AGA MK II breathing valve, the Poseidon second stage in the Poseidon Odin and the Thor clearly out-performed the Sea Sport Zephyr and Tekna and are considered to be effective.

Total Performance Rating in Cold Water

Based on performance during cold water function evaluations, the regulators tested are grouped alphabetically in the following performance categories:

Superior Performance

AGA Divator MK II Breathing Valve with AGA mouthpiece/U.S. Divers Royal SL First Stage

Poseidon Cyklon 5000

Poseidon Odin

Poseidon Thor

Sherwood Magnum Blizzard

Moderate Performance

Scubapro MK X/G-250

Unacceptable

Sea Sport Zephyr ZR-01

Tekna 2100 BX

U.S. Divers Conshelf SE-2

U.S. Divers Pro Diver

Conclusion

Cotton-backed diaphragms substantially enhanced the control of intermediate pressures after exposure to cold conditions.

In all cases breathing resistance and the work of breathing values of regulators equipped with cold water conversion kits or silicon grease, increased as a direct result of the modifications. Although total effects varied, all units evaluated were considered to be functionally safe at all depths up to 198 FSW.

The results indicated a strong interdependence between first and second stage performance. In instances where first stage intermediate pressures rose excessively, immediately after freezing or during the immersion, the use of *pneumatically balanced* second stages prevented total system failure.

During immersion studies, diaphragm first stage regulators provided greater consistency of control on overbottom pressures in comparison to piston regulators that use environmental silicon grease. Additionally, diaphragm units recorded no external freezes while silicon injected units did. Piston regulators required continuous checks and maintenance for extrusion of grease while diaphragm units suffered no extrusions. Materials used in the manufacture of main first stage diaphragms should be specifically selected to provide maximum flexibility and minimum rigidity during exposure to cold.

Second stage regulators of a conventional design (U.S. Divers and Scubapro and exempting Sherwood), were consistently out-performed by regulators of unconventional design (AGA, Poseidon) that utilized balanced pilot/servo assist mechanisms. These units also incorporated features that lessened the effects of moisture and cold via the use of plastics, rubber valve sleeves, check valves, reduced area of exposed mechanical linkage, and removal of primary second stage actuation devices from the immediate and direct path of exhaled gases and splash back from exhaust valves.

Overall, five regulators were considered superior performers, one considered moderate, and four unacceptable. Regardless of a regulator's superior performance, proper standard operating procedures for cold water operations should always be followed.

Undercurrent Travel Questionnaire

Response Requested

Location being evaluated? ______________________ Would you return? ________

Hotel/Liveaboard boat ______________________ Dive shop ______________________

Date of your trip ______________________ What are best diving months? ______________________

Where else have you dived? ______________________

tropical fish	☐abundant	☐not bad	☐sparse
fish size	☐large ones plentiful	☐a few big ones	☐only tropicals
hard coral	☐plenty and colorful	☐o.k.	☐kind of a bore
soft coral, gorgonia	☐plenty and colorful	☐o.k.	☐kind of a bore
the wall	☐beautiful and exciting	☐a decent dive	☐no wall at all
caves, ledges...	☐good variety	☐some of interest	☐none worth diving
wrecks	☐exciting	☐worth a tank or two	☐none
sharks	☐a couple for fun	☐none	☐too many
beach diving	☐as good as the boats	☐fair possibilities	☐no way
snorkeling from beach	☐quite interesting	☐not bad	☐none or nothing to see
water temperature	☐80° +	☐74°-79°	☐less than 74°
visibility	☐90 ft. or more	☐50-90 ft.	☐less than 50 ft.

rules for experienced divers	☐no restrictions	☐a little tight	☐treated as a novice
guides for new divers	☐top-rated	☐acceptable	☐lousy
decompression computers	☐o.k. to use freely	☐only with guide	☐Navy Tables only
dive personnel	☐help with all gear and tanks	☐assist if asked	☐you tote the tanks
day time diving frequency	☐3 or more tanks/day	☐2 tanks per day	☐one per day
night diving	☐frequent	☐1-2 times/week	☐none
air quality	☐no problems	☐I wondered	☐I worried
air fills	☐3000 psi +	☐2250 psi +	☐short-changed often
rental gear	☐everything you need	☐tanks, wt. belts...	☐bring everything
repair capability	☐can handle anything	☐some repair capacity	☐pray nothing breaks
overnight ektachrome development	☐on premises	☐nearby stores	☐not available

hotel food	☐gourmet	☐not bad	☐ugh!
accommodation	☐luxury	☐o.k., decent	☐far below par
nightlife	☐swinging	☐enough	☐dead
locals	☐helpful, friendly	☐no complaints	☐hostile
weather	☐great every day	☐o.k.	☐many bad days
insects	☐none	☐now and then	☐too many bites

Comments and comparison to other places: ______________________

Circle the number of stars applicable to your experience, from 0 to 5 (for the tops)

Diving for beginners	★ ★ ★ ★ ★
Diving for old pros	★ ★ ★ ★ ★
Beach snorkeling	★ ★ ★ ★ ★
Hotel meals	★ ★ ★ ★ ★
Hotel otherwise	★ ★ ★ ★ ★
Money's worth	★ ★ ★ ★ ★

PLEASE RETURN THIS TO:
UNDERCURRENT, P.O. BOX 1658,
SAUSALITO, CA 94965

Name ______________________

Address ______________________

City ____________ State ____________

Zip ____________ Tel. ____________

Undercurrent Travel Questionnaire

Response Requested

Location being evaluated? ______________________ Would you return? ________

Hotel/Liveaboard boat ______________________ Dive shop ______________________

Date of your trip ______________________ What are best diving months? ______________________

Where else have you dived? ______________________

tropical fish	☐abundant	☐not bad	☐sparse
fish size	☐large ones plentiful	☐a few big ones	☐only tropicals
hard coral	☐plenty and colorful	☐o.k.	☐kind of a bore
soft coral, gorgonia	☐plenty and colorful	☐o.k.	☐kind of a bore
the wall	☐beautiful and exciting	☐a decent dive	☐no wall at all
caves, ledges...	☐good variety	☐some of interest	☐none worth diving
wrecks	☐exciting	☐worth a tank or two	☐none
sharks	☐a couple for fun	☐none	☐too many
beach diving	☐as good as the boats	☐fair possibilities	☐no way
snorkeling from beach	☐quite interesting	☐not bad	☐none or nothing to see
water temperature	☐80° +	☐74°-79°	☐less than 74°
visibility	☐90 ft. or more	☐50-90 ft.	☐less than 50 ft.

rules for experienced divers	☐no restrictions	☐a little tight	☐treated as a novice
guides for new divers	☐top-rated	☐acceptable	☐lousy
decompression computers	☐o.k. to use freely	☐only with guide	☐Navy Tables only
dive personnel	☐help with all gear and tanks	☐assist if asked	☐you tote the tanks
day time diving frequency	☐3 or more tanks/day	☐2 tanks per day	☐one per day
night diving	☐frequent	☐1-2 times/week	☐none
air quality	☐no problems	☐I wondered	☐I worried
air fills	☐3000 psi +	☐2250 psi +	☐short-changed often
rental gear	☐everything you need	☐tanks, wt. belts...	☐bring everything
repair capability	☐can handle anything	☐some repair capacity	☐pray nothing breaks
overnight ektachrome development	☐on premises	☐nearby stores	☐not available

hotel food	☐gourmet	☐not bad	☐ugh!
accommodation	☐luxury	☐o.k., decent	☐far below par
nightlife	☐swinging	☐enough	☐dead
locals	☐helpful, friendly	☐no complaints	☐hostile
weather	☐great every day	☐o.k.	☐many bad days
insects	☐none	☐now and then	☐too many bites

Comments and comparison to other places: ______________________

Circle the number of stars applicable to your experience, from 0 to 5 (for the tops)

Diving for beginners	★ ★ ★ ★ ★
Diving for old pros	★ ★ ★ ★ ★
Beach snorkeling	★ ★ ★ ★ ★
Hotel meals	★ ★ ★ ★ ★
Hotel otherwise	★ ★ ★ ★ ★
Money's worth	★ ★ ★ ★ ★

PLEASE RETURN THIS TO:
UNDERCURRENT, P.O. BOX 1658,
SAUSALITO, CA 94965

Name ______________________

Address ______________________

City ____________ State ____________

Zip ____________ Tel. ____________

Undercurrent Comments

So, the truth is out.

There are a handful of super regulators on the market, a slew more of very good regulators, a bunch that are probably alright for most vacation divers, and a handful that, well, a serious diver wouldn't be caught dead with. Or would he?

For cold-water divers -- those who brave the Great Lakes, Long Island Sound, or do any diving where the *surface* temperature is less than 37°F -- there are really four fine regulators to choose from.

At least that's our interpretation of the Navy tests. You see, a superb regulator is so vital to the safety of a diver, that to dive with anything but the best -- or one of the best -- is a risk we prefer to avoid. But, just what is the best? And why should a sport diver, who doesn't push himself like a Navy diver, need the best?

The answer is not complicated. A sport diver, in our book, should be prepared for any contingency that may occur. Only the best regulators permit that. The extra hundred or two hundred dollars they might cost is cheap insurance.

To understand the difference between a top-of-the-line regulator and the rest, simply realize the three external major variables that affect how -- or whether -- a regulator will deliver air.

1. The deeper one goes, the more difficult it is for a regulator to deliver air and the more resistance is offered to exhaled air. Every regulator has an ultimate depth limitation.

2. The lower the air pressure in the tank, the more difficult it is for a regulator to deliver air. Some regulators can pull air from a nearly empty tank, while others will deliver no air at the same psi.

3. The harder a diver works -- that is, the more rapid and deep the diver has to breath -- the more difficult it is for the regulator to deliver air and the more resistance is offered to exhaled air.

In evaluating a regulator, forget all the advertiser's hooey about pistons and balance and servo-assistance and biradial diaphragms. Independently of the conditions under which the regulator will deliver air, the technical specs mean little to the sport diver. The truth is in the test performance.

Surely the regulator manufacturers know just how well their products work. It's just that they have chosen to provide magnificent technical descriptions as substitutes for facts about performance.

The latest ad for the AMF Mares MR 12-III says its "balanced diaphragm design provides consistent intermediate pressure for years of dependable performance" and it has "an ingenious, second stage by-pass tube that creates a swirling, low-pressure vortex. Allowing you to breathe naturally and effortlessly. Even under the toughest diving conditions."

Tabata doesn't even say that. "The new Liberator TR-200 regulator comes in a variety of Tabata's famous hot colors. And it features a purge slide lock which relieves pressure on the demand valve during storage. Rated at 4000 psi, the TR-200 has a 360° swivel top plus two high-pressure and four low-pressure ports."

That's the sort of information manufacturers provide to entice us to buy their regulators. We deserve more than that. Thanks to the Navy tests, we now have it.

But again, why does the typical sport diver need a top-of-the-line regulator. Won't just an ordinary one do?

Suppose you're diving in a tidal flow or a strong current. Or suppose you find yourself with less than 300 psi, strong current or not. If you're at 100 feet, or even 60 feet, several of the regulators the Navy tested do not deliver air with the ease their standards require. Under more severe circumstances, it could mean that you might not even be able to draw air.

As a sport diver you shouldn't get into these circumstances. Hopefully, you won't. But it's important to note that there are scores of sport diver deaths every year where the victim is found with some air left in his tank, but he has drowned. Often the regulator is out of his mouth, as if he couldn't get air. The deaths are chalked up to drowning or in some cases panic, but in many cases the reason for the death is that the diver couldn't get air. Because of some combination of his work or breathing, the depth at which he was diving, and the low air pressure in his tank, his regulator just couldn't deliver.

And if the regulator's failure to deliver air doesn't cause a fatality, it can lead to an embolism or the bends. Too many divers, when a regulator has failed to deliver, have panicked and hightailed it to the surface, only to injure themselves in the process. In many cases, by rising ten or fifteen or twenty feet, the lessened pressure permits the regulator once again to draw air from the tank. Had they tried to inhale once again, they would have found air -- which is one reason why one should leave his regulator in his mouth on free ascent and breath in and out -- not hum.

No one officially attributes these injuries or deaths to regulator failure, although the regulator, in many cases, did fail. When it's tested on the surface it works just fine. But odds are the diver was injured or died when his demand for air exceeded the ability of the regulator to deliver -- when he exceeded the specifications of the regulator ... specifications, the manufacturers don't address in their advertisements or their literature.

So, in our mind we think the serious diver, and even the occasional diver, ought to have one of the top-of-the-line regulators -- just about any of those in Group A or B. The three we might question are the Poseidon Thor and the Poseidon Cyklon 300 (distributed by Pos Dive) and the Sherwood Magnum II SRB-3000. Each of these apparently failed to meet U.S. Navy specs at the low tank pressure of 300 psi.

But plenty of others nicely exceeded those specs, so any of the following are excellent, top-of-the-line choices.

1. AGA Divator II with US Divers Royal SL
2. Oceanic Omega II Maxflo
3. Poseidon Odin distributed by Pos Dive
4. Scubapro MK X/G-250
5. Scubapro MK X/D 3000
6. U.S. Divers Conshelf SE-2
7. U.S. Divers 21
8. U.S. Divers Pro Diver

And though not all of these were tested underwater, four which were came out on top of the top:

1. AGA Divator MK II with US Divers Royal SL
2. Scubapro MK X/G-250
3. U.S. Divers Conshelf SE-2
4. U.S. Divers Pro Diver

We should point our here that the Sea Sport Zepher and the Tekna 2100 BX were not bench tested because, as an NEDU spokesman told *Undercurrent*, "none of the 'pilot' regulators were studied because of the nature of the test equipment. The testing is designed to show comparisons of breathing resistance and since pilot regulators are positive pressure, there is no breathing resistance to measure. They are almost resuscitators rather than regulators. Once a pilot is activated it throws air at you." Some of the personnel testing the regulators thought this feature was unsafe, although when the Tekna 2100B was tested underwater by divers they found it safe and acceptable. On the other hand, they found the Zepher to be "not quite adequate and unsafe."

Three AGA Divator regulators were tested in combination with a full face mask which is used when underwater communication is required. We did not put these on the recommendation list above since they are impractical for sport divers. The AGA Divator MK II second stage with a U.S. Divers Royal SL first stage is commercially available, although difficult to find.

All the regulators tested were purchased in 1986. Since then, some have disappeared and new models have appeared. But, most often those new models are only modified versions of the older models, and the modifications may do little to improve performance. The switch from chrome plating to plastic so as to reduce weight and permit a variety of colors is the kind of change that does a lot to sell regulators, but does nothing to enhance performance.

But many companies do make internal changes and those changes can affect performance. No doubt there are one or more new models on the market that would make our top eight list if they were put through the tests at the US Navy Experimental Dive Unit. But, until those tests are conducted and released, it is our belief that the serious diver looking for a new regulator ought to select it from one of those which the Navy has already tested.

And there are plenty to choose from.

THE 1980 U.S. NAVY TESTS

In 1980, the U.S. Navy performed similar tests on regulators that were commercially available then, when the report was made available. *Undercurrent* reported the results.

No doubt, many people diving today are using regulators that were covered in those reports. So that one can see how these older models stack up with new regulators, we have decided to reprint the results of those tests. Please note that Group A performance standards at 198 feet were not established by the Navy in 1980, so at that time Group B was considered top of the line.

Group B. **Regulators which met or exceed the work of breathing requirement up to 132 fsw, a moderately heavy work rate, and 1000 psi supply pressure.**

1. Poseidon Cyklon 300
2. Scubamaster Model 7687
3. Scubapro Air I/MK V (4 port swivel)
4. Scubapro Air I/MK V (5 port swivel)
5. Tekna T-2100B
6. U.S. Divers Calypso VI
7. U.S. Divers Conshelf XIV

Group C. **Regulators which meet or exceed military specifications for breathing resistance, but do not meet the work of breathing standards of group B.**

1. AGA Divator 324/USD Conshelf XIV
2. Dacor Pacer 150
3. Dacor Pacer 300
4. Dacor Pacer 600
5. Dacor Pacer 900
6. Jepson Model 200
7. Scubapro Mark V (4 port-swivel)
8. Scubapro Pilot Mark V (4 port swivel)
9. Scubapro Mark V (5-port swivel)
10. Sherwood Selpac SRB 2000
11. Sherwood Selpac SRB 3100
12. Sherwood Selpac SRB 4100
13. Sportsways WL 200
14. Sportsways W-600 Hydronaut
15. Sportsways W-900 Waterlung
16. Sub Aquatic Systems Sub II
17. Sub Aquatic Systems Sub X
18. Swimaster MR 12
19. Swimaster MR 12-II

20. Swimaster R14 Polaris
21. Tekna T-2100
22. U.S. Divers Aquarius
23. White Stag Deep

Group D. **Regulators which did not meet the military specifications for breathing resistance established in Group C.**

1. Dacor C 3NB
2. Scubapro Air II/MK V (a buoyancy compensator inflator mouthpiece; not a primary regulator)
2. Scubapro Air II/MK V (a buoyancy compensator inflator mouthpiece; not a primary regulator)
3. Sea Pro FSDS 10
4. Sea Pro FSDS 50
5. Sportsways 950 Arctic
6. Sportsways 1390

1980 GROUP B: Regulators which met or exceeded the 1986 work of breathing requirement up to 132 fsw, a moderately heavy work rate, and 1000 psi supply pressure.

Scubamaster model 7687

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	●	○	○
Heavy	●	○	○	○	○	○
Extreme	○	○	○	○	○	○

Scubapro Air I/Mk V (4-port swivel)

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	◐	○	○
Heavy	●	●	○	○	○	○
Extreme	●	○	○	○	○	○

Poseidon Cyclon 300

Work rate At 300 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	◐	○	○
Heavy	●	●	◐	○	○	○
Extreme	●	◐	○	○	○	○

Scubapro Air I/Mk V (5-port swivel)

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	●	○	○
Heavy	●	●	●	○	○	○
Extreme	●	●	◐	○	○	○

Tekna T 2100B

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	●	○	○
Heavy	●	●	●	○	○	○
Extreme	●	●	○	○	○	○

U.S. Divers Calypso VI

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	●	○	○
Heavy	●	○	○	○	○	○
Extreme	○	○	○	○	○	○

U.S. Divers Conshelf XIV

Work rate At 1000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	◐	○	○
Heavy	●	◐	○	○	○	○
Extreme	●	○	○	○	○	○

1980 GROUP D: Regulators which failed to meet the specifications for breathing resistance in Group C, as well USN performance standards.

Dacor C 3NB

Work rate At 3000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	○	○
Moderate	○	○	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Scubarpro Air II/MK V

Work rate At 3000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	◐	◐	○	○	○
Moderate	○	○	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Seapro FSDS 10

Work rate At 3000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	◐	○	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Seapro FSDS—50

Work rate At 3000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	●	●	●	◐
Moderate	◐	○	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Sportsways 950 Arctic

Work rate At 3000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	○	○	○	○	○	○
Moderate	○	○	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Sportsways 1390

Work rate At 3000 psi	Depth in feet of sea water 33	66	99	132	165	198
Light	●	●	○	○	○	○
Moderate	○	○	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

1980 GROUP C: Regulators which met or exceeded military specifications for breathing resistance, but do not meet the performance standards up to 132 fsw in Group B.

AGA Divator 324/U.S.D. Conshelf XIV

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	◐	○	○
Moderately Heavy	●	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Dacor Pacer 150

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	◐	○	○
Moderate	◐	○	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Dacor Pacer 300

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	◐
Moderate	●	◐	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Dacor Pacer 600

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	◐
Moderate	●	○	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Dacor Pacer 900

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	○
Moderate	●	○	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Jepson Model 200

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	○
Moderate	●	●	●	◐	○	○
Moderately Heavy	◐	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Scubapro Mark V (4-port swivel)

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	◐	○
Moderately Heavy	◐	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Scubapro Pilot Mark V (4-port swivel)

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	○	○
Moderately Heavy	●	◐	○	○	○	○
Heavy	●	○	○	○	○	○
Extreme	○	○	○	○	○	○

Scubapro Mark V (5-port swivel)

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	◐	○	○
Moderately Heavy	●	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Sherwood Selpac SRB-2000

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	◐	◐	◐	◐
Moderately Heavy	●	◐	○	○	○	○
Heavy	◐	○	○	○	○	○
Extreme	○	○	○	○	○	○

Sherwood Selpac SRB-3100

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	◐	◐	○
Moderately Heavy	●	◐	○	○	○	○
Heavy	◐	○	○	○	○	○
Extreme	○	○	○	○	○	○

Sherwood Selpac SRB-4100

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	◐	◐	○	○
Moderately Heavy	◐	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Sportsways WL-200

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	○	○
Moderate	◐	○	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Sportsways W-600 Hydronaut

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	◐	◐
Moderate	◐	○	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Sportsway W-900 Waterlung

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	◐
Moderate	○	○	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Sub Aquatic Systems Sub II

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	○
Moderate	●	◐	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Sub Aquatic Systems Sub X

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	◐	○	○
Moderately Heavy	●	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Swimaster MR12

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	◐	○	○	○
Moderately Heavy	◐	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Swimaster MR12-II

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	◐	○	○	○
Moderately Heavy	◐	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Swimaster R14 Polaris

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	○	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○

Tekna T-2100

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	●	●
Moderately Heavy	●	●	●	○	○	○
Heavy	●	●	○	○	○	○
Extreme	●	◐	○	○	○	○

U.S. Divers Aquarius

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	●	●	◐	◐
Moderately Heavy	●	◐	○	○	○	○
Heavy	●	○	○	○	○	○
Extreme	◐	○	○	○	○	○

White Stag Deep V

Work rate	Depth in feet of sea water					
At 1000 psi	33	66	99	132	165	198
Light	●	●	●	●	●	●
Moderate	●	●	◐	○	○	○
Moderately Heavy	○	○	○	○	○	○
Heavy	○	○	○	○	○	○
Extreme	○	○	○	○	○	○