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NAVY EXPERIMENTAL DIVING UNIT PANAMA CITY FL

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EVALUATION OF COMMERCIALY AVAILABLE SUBMERSIBLE PRESSURE GAUGE--ETC(U)

MAR 79 J R MIDDLETON

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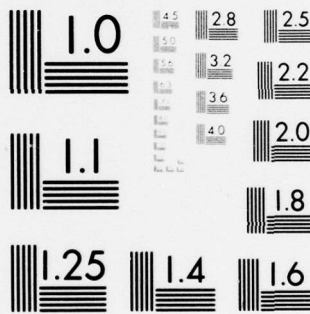
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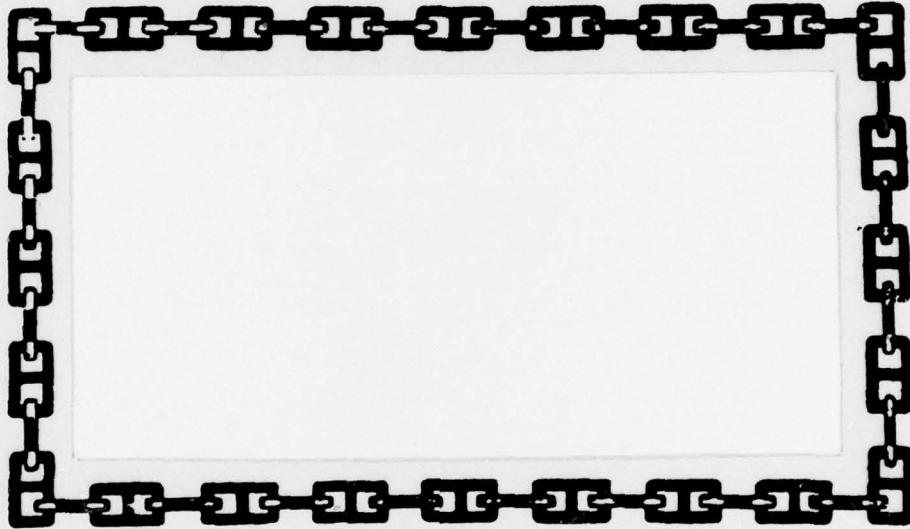
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DEPARTMENT OF THE NAVY
 NAVY EXPERIMENTAL DIVING UNIT
 Panama City, Florida 32407

NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 3-79

EVALUATION OF
 COMMERCIALY AVAILABLE SUBMERSIBLE
 PRESSURE GAUGES

JAMES R. MIDDLETON

March 1979

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Fourteen commercially available submersible pressure gauges were evaluated by the Navy Experimental Diving Unit to determine accuracy and watertight integrity. The gauges tested represent a realistic survey of the market. While not every gauge currently sold in the U.S.A. was tested, the results of this test are felt to represent the general state-of-the-art in gauge design and manufacturing technique. As a result of unmanned testing, and due to the overall quality of design and construction, it is		

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recommended that submersible pressure gauges be designated as open purchase items on the list of equipment Approved for Navy Use (ANU). It should be emphasized to all divers that submersible pressure gauges should be given the same care as that given other life supporting equipment.

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ABSTRACT

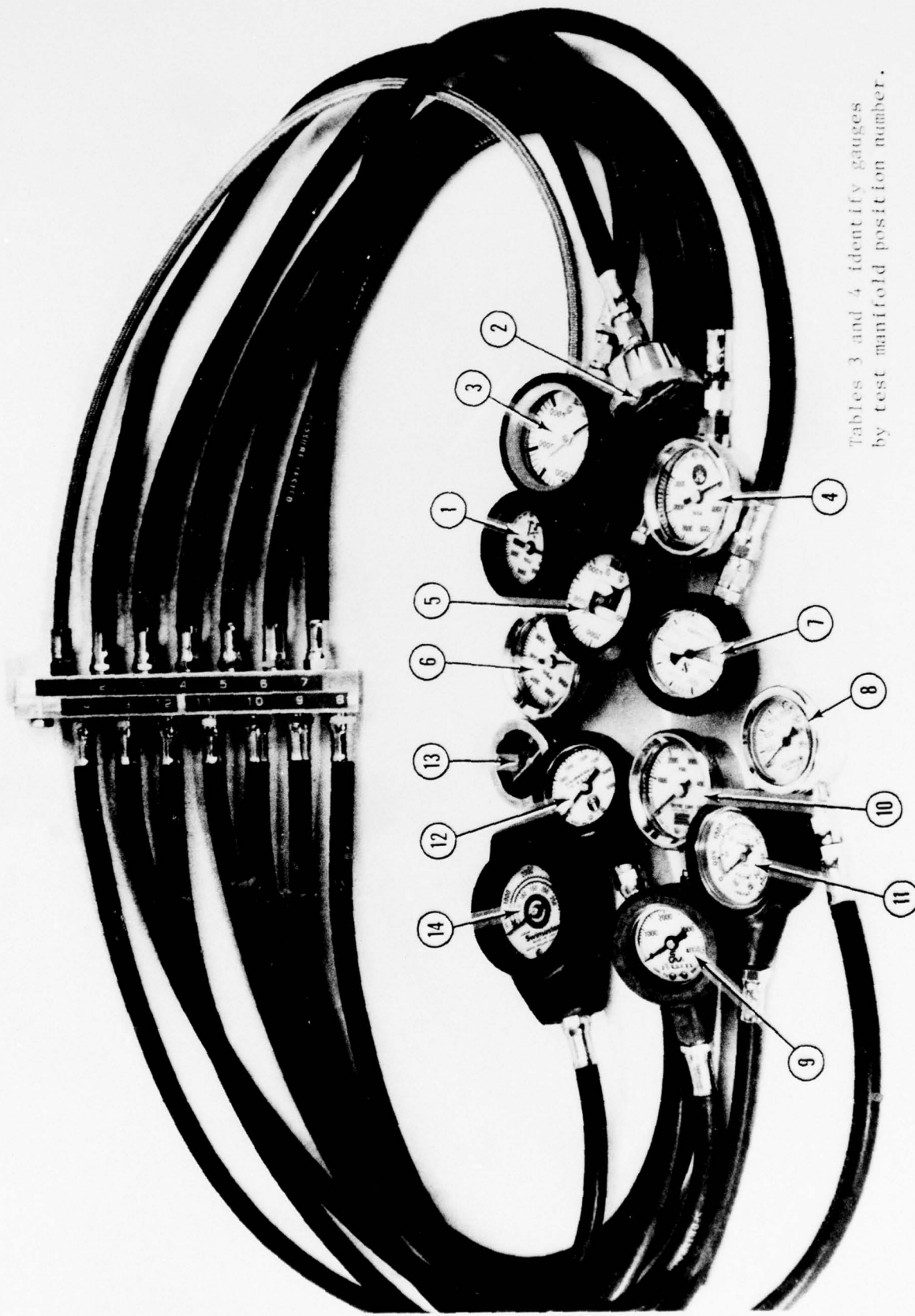
Fourteen commercially available submersible pressure gauges were evaluated by the Navy Experimental Diving Unit to determine accuracy and watertight integrity. The gauges tested represent a realistic survey of the market. While not every gauge currently sold in the U.S.A. was tested, the results of this test are felt to represent the general state-of-the-art in gauge design and manufacturing technique. As a result of unmanned testing, and due to the overall quality of design and construction, it is recommended that submersible pressure gauges be designated as open purchase items on the list of equipment Approved for Navy Use (ANU). It should be emphasized to all divers that submersible pressure gauges should be given the same care as that given other life supporting equipment.

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GLOSSARY

Bourdon tube	a pressure measuring device with either a "C" shaped or spiral "helical" shaped tube which is flattened and sealed at the tip
FSW	feet of seawater
NEDU	Navy Experimental Diving Unit, Panama City, Florida
psig	pounds per square inch gauge
watertight integrity	ability to prevent water leaks into and/or air leaks out of
kg/cm ²	kilograms per square centimeter



Tables 3 and 4 identify gauges
by test manifold position number.

Figure 1. Test Gauge Manifold Setup

INTRODUCTION

GENERAL

During January 1979, the Navy Experimental Diving Unit tested 14 commercially available submersible pressure gauges. Unmanned tests were performed to determine accuracy and watertight integrity of the following pressure gauges. (NOTE: Numbers 1 through 14 keyed to gauges in figure 1)

1. Healthways, Model No. 1629 (0-3500 psig)
2. Sportsways, Model No. 1407 (0-3500 psig)
3. White Stag Deep, Model No. 51159 (0-4000 psig)
4. *Poseidon, Model No. 7324 (0-5000 psig)
5. Farallon, Model No. 04-1008 (0-4000 psig)
6. *Sportsways, Model No. 1408 (0-5000 psig)
7. Scubapro, Model No. 28-132-000 (0-3500 psig)
8. U.S. Cavalero, Model No. p/n 355-000 (0-3500 psig)
9. Sportsways, Model No. 1406 (0-3500 psig)
10. *Selpac, Model No. SPC-5000 (0-5000 psig)
11. Dacor, Model TAG (0-3500 psig)
12. U.S. Divers, Model No. 7036-00 (0-3500 psig)
13. Sportsways, Model No. 1409 (0-4000 psig)
14. AMF Swimaster, Model No. DS-111 (0-4000 psig)

*Same gauge, different brand name

EQUIPMENT DESCRIPTIONS

The submersible pressure gauge, which allows monitoring of air supply at all times, began as a safety accessory and gradually became an indispensable adjunct to the SCUBA cylinder air-reserve mechanism. All 14 pressure gauges tested by NEDU incorporate a Bourdon tube mechanism of spiral-wound or "C"-tube design. Positioned at one end of a high-pressure hose, each gauge employs a chrome-covered brass, stainless steel, or plastic case housing. Tables 1 and 2 provide descriptive data for the 14 pressure gauges.

Many of the pressure gauges tested may also be procured in a composite, console configuration with a depth gauge or other submersible instrument. The test results in this report, however, apply only to the submersible pressure gauge.

Table 1. Common Features of Submersible Gauges

PRESSURE GAUGE	DIAL MARKINGS		MAXIMUM GAUGE READING (psig)	SERVICE PRESSURE (psig)	GAUGE INCREMENTS (psig)	GAUGE GRADUATIONS (psig)	CASE MATERIAL	BOURDON TUBE	HOSE LENGTH (In) / MATERIAL	LIST PRICE (\$)
	BLACK	WHITE								
HEALTHWAYS #1629	BLACK	3500	3500	1000	100	PLASTIC	SPIRAL WOUND	29 3/4 ST. STEEL	67.90	
SPORTSWAYS #1407	WHITE	3500	3000	1000	500	METAL	SPIRAL WOUND	30 1/8 RUBBER	49.50	
WHITE STAG DEEP #51159	BLACK	4000	210 kg/cm ²	70 kg/cm ²	35 kg/cm ²	PLASTIC	SPIRAL WOUND	30 1/4 RUBBER	52.00	
POSELIDON #7324	BLACK	5000	3500	1000	100	METAL	SPIRAL WOUND	30 1/4 RUBBER	52.25	
FARALLON #04-1008	BLACK	4000	1000	1000	100	PLASTIC	NOTE 1	30 1/4 RUBBER	44.95	
SPORTSWAYS #1408	BLACK	5000	3500	1000	100	CHRM PL BRASS	SPIRAL WOUND	30 1/8 RUBBER	62.00	
SCUBAPRO #28-132-000	BLACK	3500	3500	500	100	METAL	"C" SHAPED	34 1/4 RUBBER	65.00	
U.S. CAVALERO p/n 355-000	BLACK	3500	3500	500	100	CHRM PL BRASS	SPIRAL WOUND	34 1/2 RUBBER	59.00	
SPORTSWAYS #1406	WHITE	3500	3500	1000	500	METAL	SPIRAL WOUND	30 1/8 RUBBER	51.50	
SELPAC #SPG-5000	BLACK	5000	3500	1000	100	METAL	SPIRAL WOUND	30 1/4 RUBBER	62.50	
DACOR TAG	BLACK	3500	3500	500	250	LEXAN	"C" SHAPED	31 5/8 RUBBER	50.00	
U.S. DIVERS #7036-00	BLACK	3500	3500	500	100	METAL	SPIRAL WOUND	33 1/4 RUBBER	49.75	
SPORTSWAYS #1409	BLACK	4000	3000	1000	100	PLASTIC	SPIRAL WOUND	29 1/2 RUBBER	44.00	
AMF SWIMASTER #DS-111	BLACK	4000	3000	1000	100	PLASTIC	SPIRAL WOUND	29 1/8 RUBBER	49.95	

NOTE 1: "C" shaped bourdon-tube in units manufactured prior to 1978; spiral-wound from 1978 onward.

Table 2. Special Features of Submersible Gauges

PRESSURE GAUGE	LUMINOUS DIAL FACE	ENGLISH & METRIC DIAL FACE	METRIC MODEL AVAILABLE	LOW PRESSURE WARNING ZONE	SIDE READING	END READING	360° SWIVEL	RUBBER COVER STANDARD	RUBBER COVER OPTIONAL
HEALTHWAYS #1629	X				X		X		X
SPORTSWAYS #1407	X	X		X		X	X		
WHITE STAG DEEP #51159	X			X	X		X	X	
POSEIDON #7324	X		X	X	X		X		
FARALLON #04-1008	X		X		X		X	X	
SPORTSWAYS #1408	X			X	X		X		X
SCUBAPRO #28-132-000	X			X	X		X		X
U.S. CAVALERO p/n 355-000	X		X		X		X		
SPORTSWAYS #1406	X	X		X	X		X		
SELPAC #SPG-5000	X			X	X		X		
DACOR TAG	X	X		X	X		X	X	
U.S. DIVERS #7036-00	X				X		X	X	
SPORTSWAYS #1409	X			X	X		X	X	
AMF SWIMASTER #DS-111	X	X		X	X		X	X	

TEST PROCEDURE

TEST PLAN

Test equipment is listed in Appendix A; the test setup is illustrated in figures 2 and 3.

Accuracy Test

To determine gauge accuracy, all 14 submersible pressure gauges were connected to a test gauge manifold (figure 1) which was connected to a gauge comparator (illustrated in figure 2). A Roylyn precision/direct drive gauge (with 1/4 of one percent accuracy) was the calibrated standard for pressurizing the test manifold at 3500 psig. See Appendix B for Roylyn calibration chart. Beginning with 3500 psig, differences in pressure readings between the submersible gauges and the Roylyn gauge were recorded for each 100 psig increment in pressure reduction. Data was recorded while gauge pressure was continually decreasing, which is the normal mode of operation under actual diving conditions.

Pressure Shift Test

When 0 psig was reached, pressure was again increased to 3500 psig, maintained for 30 minutes, and any shifts in pressure gauge readings were recorded. Accuracy readings were repeated when pressure was reduced to 1000 psig and 500 psig, respectively.

Watertight Integrity Test

To determine watertight integrity, the 14 gauges were placed in a water-filled test box inside a hyperbaric chamber, and connected to a high pressure gas supply via the test manifold and pressure regulator (illustrated in figure 3). The gauges were pressurized to 500 psig at 200 FSW for one hour and were observed for water leaks and/or escaping air. They were then brought to the surface and inspected. The same procedure was repeated at 3500 psig supply pressure at 200 FSW. For all test applications, helium was the gas medium selected for its leak detection properties.

CONTROLLED PARAMETERS

The following parameters were controlled during test procedures.

1. Gas supply pressure
 - a. Accuracy Test: 3500 to 0 psig in 100 psig pressure reduction increments
 - b. Pressure Shift Test: 3500, 1000 and 500 psig
 - c. Watertight Integrity Test: 3500 and 500 psig
2. Test depth: 200 FSW (watertight integrity test only)
3. Gas medium: helium

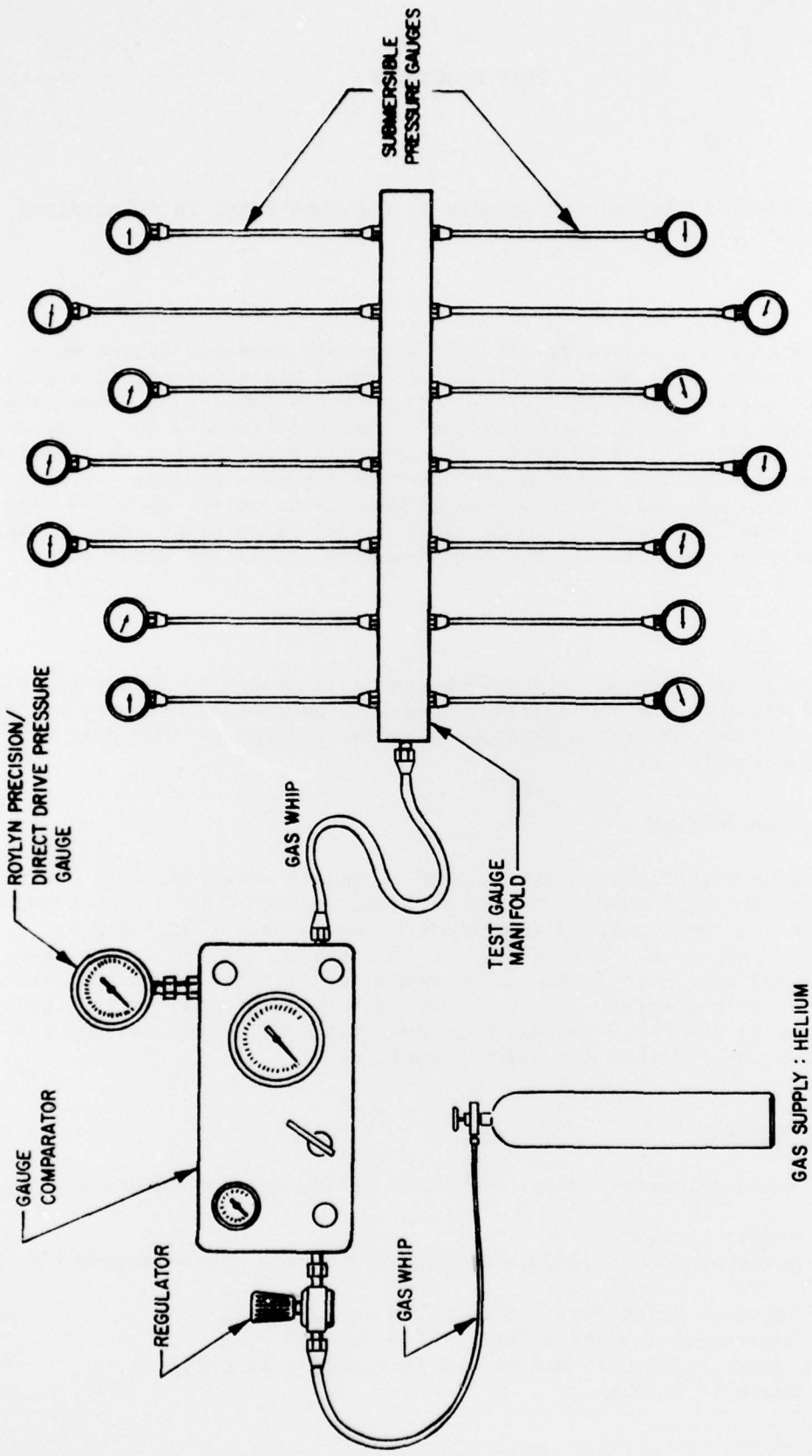


Figure 2. Accuracy Test Setup

MEASURED PARAMETERS

The following parameters were used during the test.

1. Gauge accuracy: Pressure readings of each test gauge were recorded to the nearest 25 psig at each 100 psig incremental pressure reduction.
2. Watertight integrity: Any water leaking into or gas escaping from test gauges was noted.

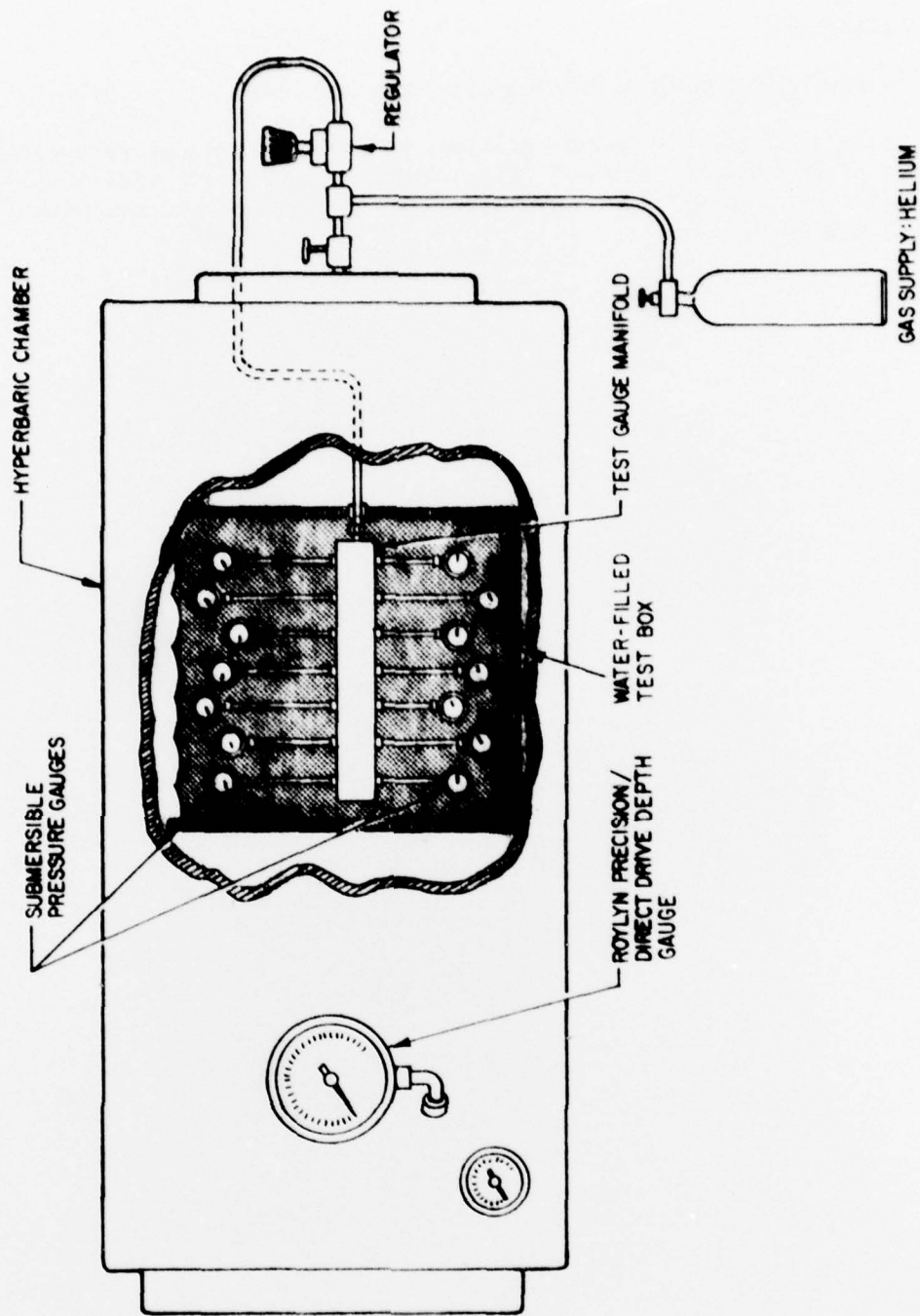


Figure 3. Watertight Integrity Test Setup

RESULTS AND DISCUSSION

ACCURACY TEST

Table 4 represents data plotted during accuracy test. The gauges are numbered according to position on the test manifold (illustrated in figure 1). Positive numbers indicate readings above, and negative numbers indicate readings below the Roylyn precision gauge standard. Blank spaces indicate no variation. Accuracy results from table 4 were averaged for each gauge to determine average variation from the Roylyn precision gauge standard. The pressure gauges are ranked in order of least to greatest average variation in accuracy in table 3, below. It is important to note that the most accurate gauge tested (Poseidon, Model No. 7324) and the next-to-least accurate (Selpac, Model No. SPG-5000) are identical gauges made by the same manufacturer and marketed by two different companies. The average variation in accuracy ranges from 25 psig for the Poseidon and 134.48 psig for the Selpac. This is a good indication of the level of quality assurance that exists in commercially available gauges regardless of brand.

Table 3. Accuracy Ranking

<u>Rank</u>	<u>Gauge</u>	<u>Test Manifold Position No. (ref. table 1)</u>	<u>Average Variation (in psig)</u>
1	Poseidon, Model No. 7324 (0-5000 psig)	* 4	25.00
2	Sportsways, Model No. 1409 (0-4000 psig)	13	30.36
3	Healthways, Model No. 1629 (0-3500 psig)	1	40.00
4	Farallon, Model No. 04-1008 (0-4000 psig)	5	47.32
5	Dacor, Model TAG (0-3500 psig)	11	47.50
6	White Stag Deep, Model No. 51159 (0-4000 psig)	3	49.14
7	Sportsways, Model No. 1407 (end view/0-3500 psig)	2	50.00
8	AMF Swimaster, Model No. DS-111 (0-4000 psig)	14	50.00
9	Sportsways, Model No. 1406 (0-3500 psig)	9	65.91
10	Sportsways, Model No. 1408 (0-5000 psig)	* 6	99.19
11	U.S. Divers, Model No. 7036-00 (0-3500 psig)	12	109.48
12	Scubapro, Model No. 28-132-000 (0-3500 psig)	7	123.57
13	Selpac, Model No. SPG-5000 (0-5000 psig)	* 10	134.48
14	U.S. Cavalero, Model No. p/n 355-000 (0-3500 psig)	8	166.38

* Same gauge, different brand name

Table 4. Accuracy Test Results

ACCURACY ± PSIG													
1	2	3	4	5	6	7	8	9	10	11	12	13	14
HEALTHWAYS	SPORTSWAYS	WHITE STAG	POSEIDON	FARALLON	SPORTSWAYS	SCUBAPRO	US CAVALERO	SPORTSWAYS	SELPAC	DACOR	US DIVERS	SPORTSWAYS	AMF SWIMMASTER
3500			-25	-25	-125	+100	+200		+200	-25	-125		-100
3400	+50	+50	-25	-25	-200	+100	+200	+50	+200	-50	-125	+25	-100
3300	+50	+50	-25		-175	+125	+225	+100	+200		-200	+25	-75
3200	+50	+50	+25	-25		-75	+125	+225	+150	+175	-200	+25	-75
3100	+50	+50	+25	-25		-75	+125	+225	+150	+200	-200	+25	-50
3000	+25	+50			-150	+125	+200	+100	+175		-200		-50
2900	+50	+50	+50	-25	+25	-150	+125	+200	+50	+175	-175	+25	-25
2800	+50	+50	+50		+25	-150	+125	+200	+50	+175	-175	+25	-50
2700	+50	+50	+50	-25	+25	-150	+150	+200	+50	+200	-150	+50	-25
2600	+50	+50	+50	-25	+25	-125	+150	+200	+50	+175	-150	+25	-25
2500	+25	+50	+50		+50	-125	+125	+175	+50	+150	-150		-25
2400	+50	+50	+50		+50	-125	+125	+175	+50	+175	-125	+50	-25
2300	+50		+50	-25	+50	-100	+125	+175	+50	+175	-125	+25	
2200	+50		+50		+50	-100	+150	+175	+100	+175	+50	-100	+50
2100	+50	+50	+75		+50	-100	+150	+175	+50	+150	+50	-100	+25
2000			+50		+50	-100	+150	+150	+50	+125	+50	-100	+25
1900	+25		+75		+50	-100	+150	+150	+50	+150	-100		-25
1800	+25	+50	+50		+75	-100	+150	+150	+50	+100	-100	+25	
1700	+25		+50	-25	+75	-100	+150	+150	+50	+100	+25	-75	
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1500			+50		+75	-75	+125	+125		+100	+25	-50	
1400	+25		+50		+75	-75	+150	+150	+50	+100	-75		
1300	+25		+50		+50	-50	+150	+150	+50	+100	-50		
1200			+50		+50	-50	+125	+125	+50	+75	-50		
1100			+50		+50	-50	+125	+125		+75	-50		
1000			+50		+50	-50	+100	+100		+50	-50		
900			+50		+50	-50	+100	+100		+50	-25		
800			+50		+25	-50	+125	+125		+50	-25		
700			+25		+25	-50	+125	+125		+50			
600			+25		+25	-50	+100						
500			+25		+25		+100						
400			+25				+100						
300							+100						
200							+100				-50		
100		-50	-100		-100	-100	+50				-100	+25	
0													

PRESSURE SHIFT TEST

After 3500 psig was reached and maintained for 30 minutes, all gauge readings were constant (see table 5); no shifts were evident. After the 30 minute pressure test, accuracy readings (with Roylyn standard) for 1000 and 500 psig, respectively, were not significantly different from readings taken during the previous accuracy test (recorded in table 3).

Table 5. Results of Pressure Shift Test

PRESSURE PSIG		HEALTHWAYS	SPORTSWAYS	WHITE STAG	POSEIDON	FARALLON	SPORTSWAYS	SCUBAPRO
		1	2	3	4	5	6	7
START	3500	+50	+50				-200	+100
DEVIATION AFTER 30 MINUTES	3500	0	0	0	0	0	0	0
	1000			+50		+50	-50	+125
	500			+25				+100

PRESSURE PSIG		U.S. CAVALERO	SPORTSWAYS	SELPAC	DACOR	U.S. DIVERS	SPORTSWAYS	AMF SWIMASTER
		8	9	10	11	12	13	14
START	3500	+200	+50	+200	-25	-225		-100
DEVIATION AFTER 30 MINUTES	3500	0	0	0	0	0	0	0
	1000	+125		+50		-25		
	500	+100						

KEY

Blank space - no variation from Roylyn standard
 Positive number - reading above Roylyn standard
 Negative number - reading below Roylyn standard
 0 - represents no deviation after 30 minutes

WATERTIGHT INTEGRITY TEST

All submersible pressure gauges maintained watertight integrity at 200 FSW when pressurized at 500 and 3500 psig for one hour at each pressure level. No gas escape was observed, nor did water enter any of the gauge case housings.

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Accuracy of the submersible pressure gauges ranged from 25 to 166 psig in average variation from the Roylyn precision gauge standard. Thus, a diver must not expect these gauges to provide reading accuracy better than ± 250 psig at the upper end of the gauge range and ± 100 psig at the lower end between 500 and 0 psig. Nevertheless, a submersible pressure gauge serves as a valuable diving instrument and should be considered indispensable for mission planning and diver safety.

Pressure shifts experienced after pressurization for 30 minutes at 3500 psig and subsequent pressure reduction to 1000 and 500 psig were negligible.

All gauges tested maintained their watertight integrity at a test depth of 200 FSW when subjected to supply pressures of 3500 and 500 psig, respectively, for one hour.

RECOMMENDATIONS

While gauge accuracy was relatively consistent, a certain tolerance in accuracy is to be expected. A careful diver must be cognizant of the accuracy limitation inherent to the submersible pressure gauge and use it accordingly. Due to the relative merits and overall quality design and construction of the products tested, it is recommended that submersible pressure gauges be designated as diver preference, open purchase items on the list of equipment Approved for Navy Use (ANU), enclosure 2 to OPNAVINST 9597.1 series.

Submersible pressure gauges are designed to withstand heavy wear and tear; it is recommended, however, that they should be afforded the same care as that given to other life supporting equipment.

APPENDIX A

TEST EQUIPMENT

Hyperbaric Chamber

Test gauge manifold

Water-filled test box

External gas supply pressure gauge

Pressure regulator

Chamber depth gauge

Submersible pressure gauges

Gauge comparator, King Pneumatic Amplifier Mod. 3194F, SN 4340
manufactured July 1978 by Nutronics Corp., Woodland Hills,
California

Roylyn Precision/Direct Drive Gauge, 0-4000 psig, SN 785956
manufactured by 3D Instruments, Inc., Huntington Beach,
California (See appendix B for Roylyn gauge calibration
chart.)

CALIBRATION CERTIFICATE

FLUIDIC PRESSURE GAUGE

NO. _____ DATE _____
BY _____

SL. NO.	STANDARD PRESSURE	TESTING PRESSURE	GAUGE READING	PERCENT ERROR	REMARKS

APPENDIX B

GAUGE NO. _____ DATE _____
BY _____

CALIBRATION CERTIFICATE

ROYLYN[®] PRESSURE GAUGE

PART NUMBER 25545-34B41

SERIAL NUMBER 725956

PRESSURE RANGE 0-4000 P.S.I. ACCURACY \pm 1/4 % FULL SCALE (\pm 10.00 P.S.I.)

CALIBRATION

INCREASING PRESSURE			DECREASING PRESSURE		
Applied Press.	Indicated Press.	Difference	Applied Press.	Indicated Press.	Difference
0	0.00	0.00	4000	3998.00	-2.00
500	500.00	0.00	3500	3497.00	-3.00
1500	1497.00	-3.00	2500	2501.00	+1.00
2500	2494.00	-6.00	1500	1502.00	+2.00
3500	3493.00	-7.00	500	503.00	+2.00
4000	3998.00	-2.00	0	0.00	0.00

Calibrated in VERTICAL Position. Temp. 72 ° F.

This is to certify that this gauge has been inspected and tested

against Pressure Standard MUNSFIELD + GREEN D.W.G. # 2654

traceable to the National Bureau of Standards, traceability reference TEST # 4852,
compensated to local acceleration due to gravity.

Special Conditions: _____

DATE OF CALIBRATION 11-3-72

INSPECTOR A. Toudreau

3D Instruments Inc. 15542 Chemical Lane, Huntington Beach, Calif. 92649