NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 7-86

EVALUATION OF AGA DIVATOR II LIGHTWEIGHT UMBILICAL SUPPLIED ENCLOSED SPACE DIVING SYSTEM AND UNMANNED TESTING OF WIDOLF DF 400 AND PROTOTYPE DSI EXO-26 FULL FACE MASKS

CHRISTOPHER J. TARMEY

JUNE 1986

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

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Divator II	Ryan 26	NEDU Test Plan 85-29

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

Between August and December 1985 NEDU evaluated the AGA Divator II lightweight enclosed space diving system. Both manned and unmanned tests were conducted. The purpose of this series of tests was to determine the suitability of the AGA to replace the existing lightweight mask (Jack Browne) for diving in enclosed spaces. The Widolf DF-400 and Ryan 26 prototype underwent comparative unmanned tests.

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Abbreviations

BPM	breaths per minute
cmH_2O	centimeters of water (pressure)
cu ft	cubic feet
°F	degree farhenheit
DIVEX	Diver's Exchange of Harvey, LA
DSI	Diving Systems International
EBS	emergency breathing system
EDF	Experimental Diving Facility
FSW	feet of seawater
ft	foot
HP	high pressure
ID	inside diameter
in	inches
J/L	joules per liter (unit respiratory work)
kg·m/L	kilogram-meters per liter (unit respiratory work)
kPa	kilopascals
lpm	liters per minute (flow rate)
MOD	modified
NAVSEA	Naval Sea Systems Command
NEDU	Navy Experimental Diving Unit
ΔP	pressure differential
psi	pounds per square inch
psid	pounds per square inch differential
psig	pounds per square inch gauge

QD	quick disconnect
RMV	respiratory-minute-volume in liters-per-minute
SCUBA	self-contained underwater breathing apparatus
SI	System International (units of measure)
TV	the tidal volume in liters of air breathed in and out of the lungs during normal respiration
UBA	underwater breathing apparatus

To Convert From	To	Multiply By
kg·m/L	joules per liter (J/L)	9.807
psi	kilopascals (kPa)	6.895
feet	meters (m)	0.305
FSW	meters of seawater (MSW)	0.305
FSW	kilopascals (kPa)	3.065

Abstract

Between August and December 1985 NEDU evaluated the AGA Divator II lightweight enclosed space diving system. Both manned and unmanned tests were conducted. The purpose of this series of tests was to determine the suitability of the AGA to replace the existing lightweight mask (Jack Browne) for diving in enclosed spaces. The Widolf DF-400 and Ryan 26 prototype underwent comparative unmanned tests.

KEY WORDS: AGA
Lightweight
Enclosed Space
Divator II
Open circuit demand
Umbilical supplied
DSI EXO-26
Ryan 26
Widolf DF-400
NEDU Test Plan 85-19
NEDU Test Plan 85-28
NEDU Test Plan 85-29

PART I - UNMANNED TESTING

I. INTRODUCTION

Reference (a) tasked Navy Experimental Diving Unit (NEDU) to identify a lightweight system to replace the lightweight (Jack Browne) mask for diving operations in enclosed spaces such as submarine mud tanks.

The first system evaluated in 1982 was an AGA Divator 324 mask, already approved for SCUBA use, but modified by Divex for an umbilical supply. The results were published in reference (b). Shortcomings in this rig were identified during human factors testing which prevented its service use.

Interspiro, the manufacturer of AGA diving equipment, then provided their own umbilical-supplied full face mask with a harness and umbilical connection assembly for evaluation. It had a small capacity chest or thigh-worn bailout bottle. This mask came fitted with the latest AGA second stage regulator, the Divator II. Unmanned testing demonstrated that this mask and regulator met all the performance goals established in reference (c) for both surface umbilical-supplied and SCUBA equipment. The results were published in 1983 in reference (d), and the regulator subsequently became approved for Navy use for SCUBA, replacing the Divator 324. Once again, however, there were some human factors objections which prevented the whole rig from being recommended for use with an umbilical supply even though the concept was well received by diver-subjects during manned dives, as reported in reference (e).

In response to NEDU suggestions and recommendations, Interspiro then made a number of changes to the harness, mask, and pony bottle configuration and enlarged the ports in the umbilical connection block. Evaluation of this latest system (Figure 1) has now been completed.

During the latest testing, two other full face masks were introduced into the evaluation at the request of Naval Coastal Systems Center (NCSC) in conjunction with a separate task to develop a complete, mobile, lightweight diving package. The first was the Divematics Widolf DF 400 mask, and the second a prototype Diving Systems International mask, the Ryan 26. The Ryan 26 has since been renamed the EXO (Exoskeleton) 26.

The Widolf DF 400 failed to meet any of the NEDU performance goals. Following unmanned testing, it was withdrawn from further evaluation. The EXO 26 was withdrawn from the evaluation after unmanned testing by the manufacturer in spite of its promising performance. The unmanned tests results for both these masks will be shown.

A summary of the test results was first published in reference (f). This report provides the full technical information requested by reference (a).

Figure 1. AGA Divator II Lightweight Enclosed Space Diving System

II. FUNCTIONAL DESCRIPTION OF THE AGA DIVATOR II LIGHTWEIGHT ENCLOSED SPACE DIVING SYSTEM

The system consists of a full face mask with second stage regulator, a gas distribution block with non-return valve, an emergency gas supply, a harness assembly, and a communications system. It does not include a special umbilical or a gas supply but is intended to operate with existing U.S. Navy surface supplied umbilicals.

A. Full Face Mask and Second Stage Regulator

Breathing gas is supplied to the second stage regulator at 110-150 psi over ambient (135 psi was used during all tests). The regulator is fitted with a double diaphragm safety pressure device which consists of a spring loaded assembly and second diaphragm. This creates a positive pressure to the mask of approximately 2 cm of water (0.20 kPa) and is intended to prevent mask flooding or ingress of contamination.

The positive pressure feature is activated by the diver taking his first breath or by actuating the purge button. The mask is held in place by an adjustable spider band. A seal is achieved by the positive pressure acting on a reversed lip around and inside the skirt of the mask. This feature is designed to ensure a comfortable fit and seal without the need to cinch down hard on the spider band.

During inhalation, the gas flows from the second stage through two de-mister ports, across the face plate and then into the oral nasal through two mushroom valves (Figure 2).

During exhalation, gas is expelled to the ambient water through the exhalation valve. Inhalation and exhalation gasses pass through separate channels in the second stage to avoid mixing. This separation of the gas flow is also designed to minimize the chance of regulator freeze up during diving operations in freezing conditions.

B. Gas Supply (Figure 3)

Gas at the correct overbottom pressure can be supplied through any service umbilical. However, the divers mask USN MK 1 MOD 0 adaptor whip is needed when 1/2-inch ID umbilical is used.

The umbilical should terminate in a female oxygen connection which is screwed to a double action quick disconnect provided with the AGA rig.

The quick disconnect (QD), which has a nonreturn valve to prevent gas escaping when released, is connected to a gas distribution block attached to the harness on the diver's right hip or waist. This gas distribution block has four ports: one to receive the umbilical Q.D., one for emergency gas supply, one to receive an intermediate whip to the mask, and a spare for a suit inflation whip. The umbilical supply port is fitted with a nonreturn valve.

Figure 2. AGA Mask Showing Demister Ports and Inhalation Mushroom Valves

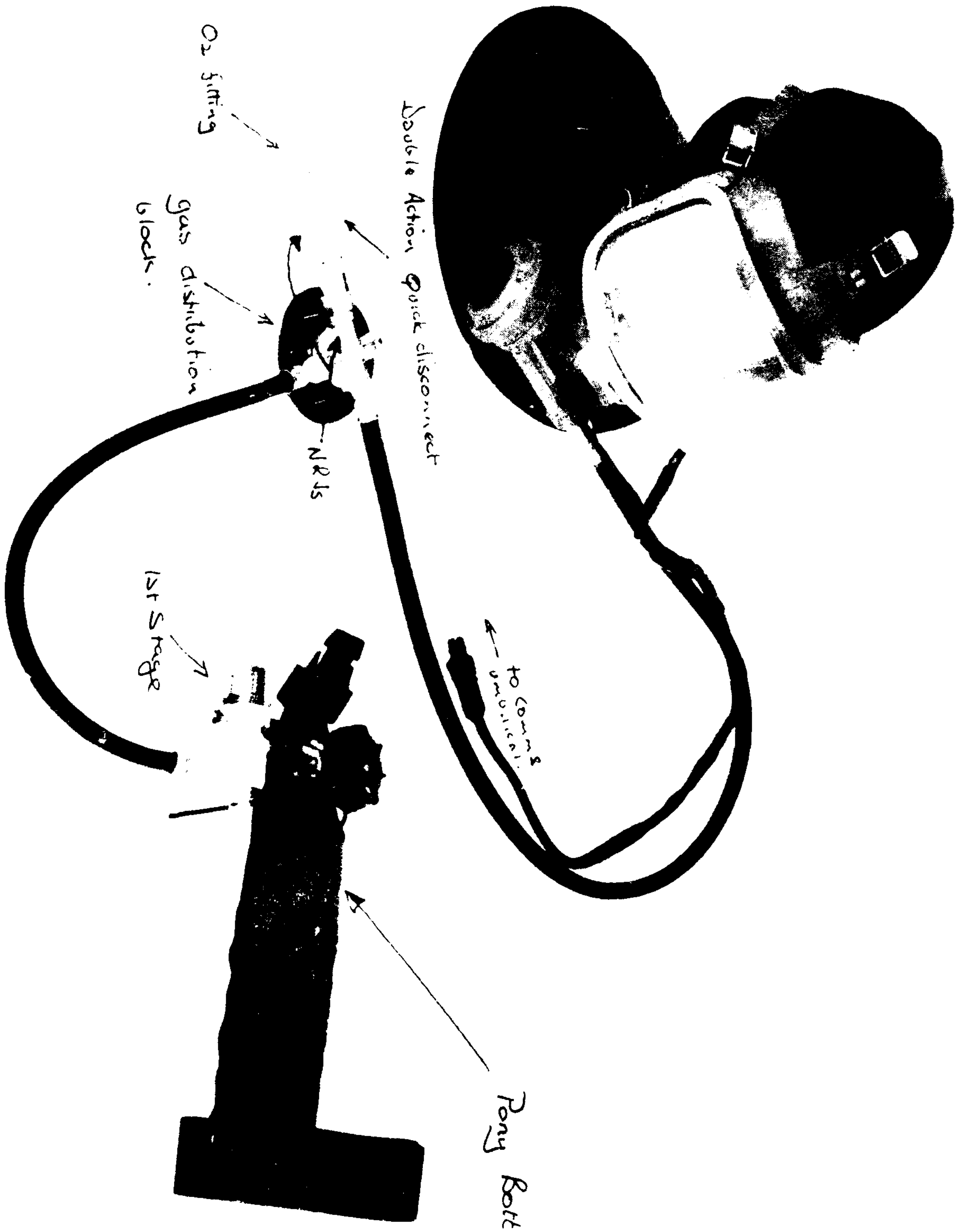


Figure 2. Gas Supply

C. Emergency Gas Supply

An optional emergency gas supply is provided from a small (0.5 liter/0.18 cu.ft.) 3000 psi pony bottle. This bottle is worn on the left thigh in a holster that clips to the harness. Wrap-around velcro fasteners secure the bottle to the thigh.

A first stage regulator at the cylinder reduces the emergency gas which is supplied to the mask via the gas distribution block. A pop-out pressure indicator is fitted at the neck of the cylinder.

If the pony bottle is not fitted, it is necessary to blank the appropriate port at the gas distribution block.

D. Harness

The fully adjustable harness is of the parachute type. It is provided with jocking straps and front and rear lifting points.

E. Communications (Figure 4)

A detachable cover plate is provided above the second stage regulator which provides access to the oral nasal. This can be drilled and fitted with a suitable penetrator, microphone and connector. The earphone must be of the bone conductor type.

The communications provided by AGA were considered unsuitable, being prone to failures when wet. They were replaced with a prototype configuration, assembled and fitted at NEDU, which is compatible with the Hydrocom UDC 225 topside communication unit. This prototype is now a production model and available from Ocean Technology Systems. See Annex A for part numbers and drawing.

III. UNMANNED TEST PROCEDURES

Standardized test procedures were established in reference (c) for the unmanned evaluation of UBAs. In September 1985, the procedures were followed for the testing of the AGA Divator II, Widolf DF 400 and DSI Ryan 26 umbilical-supplied lightweight systems at ambient temperatures. A 300-foot, 3/8-inch ID umbilical was used throughout. The breathing medium was air supplied at 135 psi over bottom pressure. The test plan is in Annex B.

In order to confirm that the AGA Divator II would function without a freeze-up in 29°F water, the test was repeated in December but with the mask and 150 foot of the 300 foot umbilical immersed in 29°F glycol/water solution.

IV. UNMANNED TEST RESULTS

Figure 5 shows a pressure-volume loop obtained during unmanned testing from which work of breathing is computed.

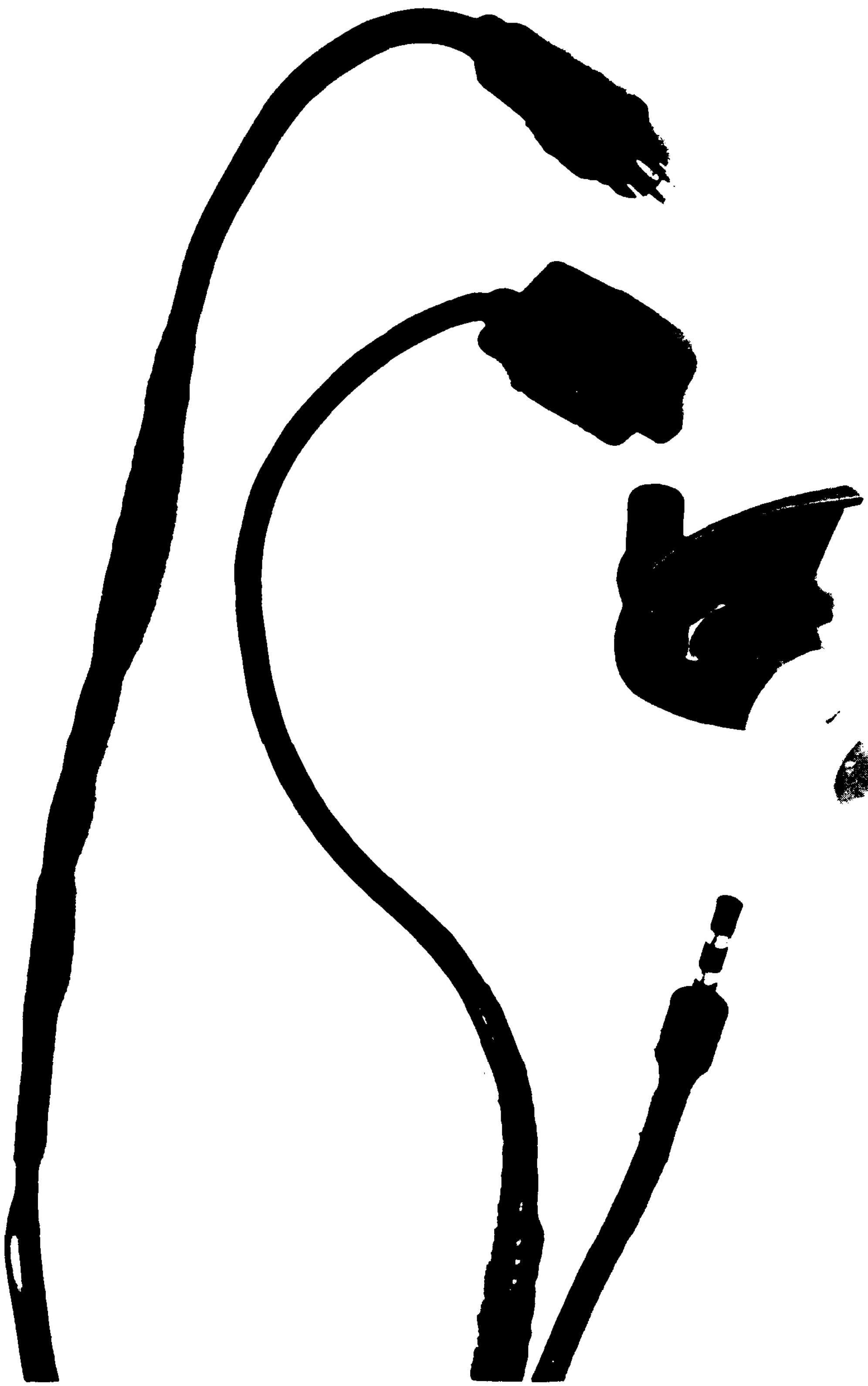
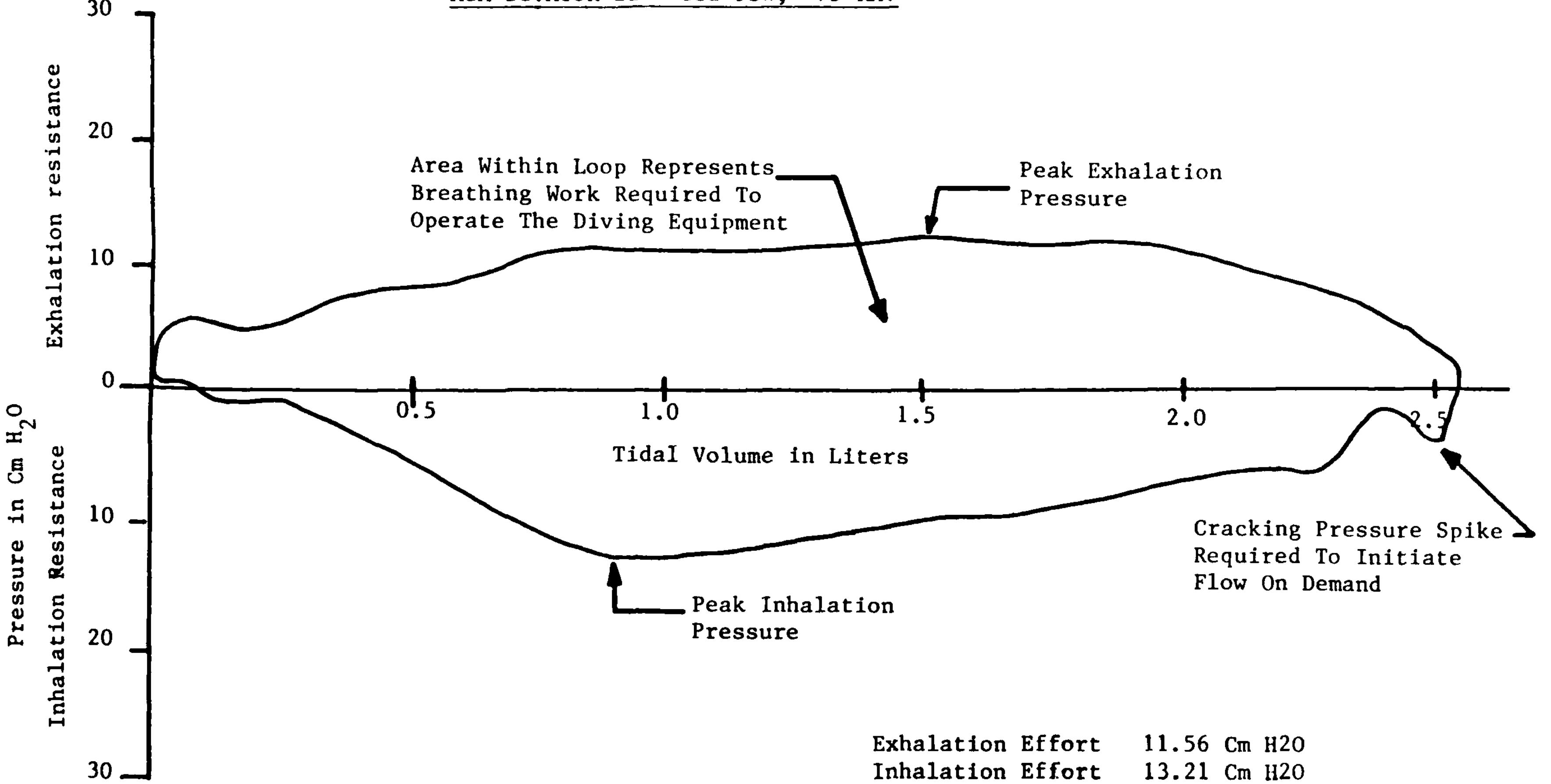


Figure 4. NEDU Comms Fit

AGA DIVATOR II 132 FSW, 75 RMV



Exhalation Effort	11.56 Cm H20
Inhalation Effort	13.21 Cm H20
Work of Breathing	1.53 Joules (0.1539 kg.m/liter)

<u>Breathing Pressure versus Tidal Volume Loop</u>

(Figure 5)

Table 1 shows the measured and computed results of the AGA Divator II test at ambient temperature.

Table 2 shows the same for the AGA in 29°F. No freezing of the second stage regulator was observed.

Tables 3 and 4 show the results of testing of the Widolf DF 400 and DSI Ryan 26 respectively.

V. UNMANNED DISCUSSION

A. AGA Divator II System

The NEDU performance goal for umbilical-supplied open circuit demand systems is a maximum work of breathing of 0.18 kg·m/liter (1.8 joules/liter) at 132 FSW and 62.5 RMV. Under these conditions, the work of breathing of the AGA Divator II was 0.1039 kg·m/L (1.02 J/L) -- well within the performance goal. This is particularly impressive since the umbilical used had an internal diameter of 3/8 inch -- a diameter normally limited by the U.S. Navy Diving Manual to 50 FSW with the USN MK 1 MOD 0 Divers Mask. Indeed, the work of breathing remained within the performance goal to 190 FSW with the 3/8-inch umbilical.

During the 29°F function test the regulator did not freeze and work of breathing was only marginally increased, still remaining well within performance goals.

Prior to 1981, regulator performance was determined by measurement of peak inhalation and exhalation pressure. This was measured for the AGA Divator II system and has been plotted in Table 5 over the results obtained for the USN MK 1 MOD 0 from reference (g) at 62.5 RMV. The AGA Divator II system is by far the superior performer.

B. Widolf DF 400

The Widolf failed to meet any of NEDU's performance goals and was withdrawn from further evaluation following unmanned testing. No freezing tests were conducted.

C. DSI Ryan 26 (EXO-26)

The performance of the DSI Ryan 26 showed promise. It was, however, a prototype mask and the manufacturer withdrew it from further evalaution following the initial tests.

VI. UNMANNED CONCLUSIONS

The AGA Divator II performed well within NEDU performance goals for unit work of breathing at 132 FSW, and remained within 10% of the goals to 190 FSW even in freezing conditions. The regulator is well designed to avoid freeze-up. The function of the UBA will not be a limiting factor in diver performance.

TABLE 1

OPEN CIRCUIT BREATHING LOOP DATA ANALYSIS DATA SHEET

Equipment Tested: AGA Divator II Lightweight Umbilical Supplied

Breathing Gas: Air

Overbottom Pressure Setting: 135 psi

RMV (LPM)	DATA	DEPTH (FSW)							
		0	33	66	99	132	165	198	300
22.5	EXH	2.75	2.96	3.06	3.65	3.71	3.82	3.65	0.00
	INH	-3.44	-3.61	-4.16	-4.16	-4.54	-4.30	-4.81	0.00
	FSPD	1.97	3.09	4.86	6.63	8.20	10.06	12.71	0.00
	WORK	.0355	.0455	.0455	.0509	.0557	.0547	.0578	0.0000
40.0	EXH	3.30	4.92	4.37	4.95	6.09	5.64	7.08	0.00
	INH	-3.89	-3.34	-4.37	-5.02	-4.54	-5.37	-5.09	0.00
	FSPD	3.12	6.58	10.92	15.36	19.61	25.71	32.17	0.00
	WORK	.0408	.0514	.0592	.0616	.0690	.0754	.0807	0.0000
62.5	EXH	4.81	4.13	6.91	8.60	9.87	10.66	11.52	0.00
	INH	-4.54	-5.43	-4.37	-4.51	-5.64	-8.74	-21.84	0.00
	FSPD	5.59	12.77	20.70	30.17	40.87	55.23	64.63	0.00
	WORK	.0474	.0567	.0735	.0888	.1039	.1269	.1930	0.0000
75.0	EXH	6.02	7.94	9.94	8.60	11.56	14.27	0.00	0.00
	INH	-3.92	-4.33	-3.95	-9.39	-13.21	-40.48	0.00	0.00
	FSPD	7.58	17.41	29.35	43.44	57.48	62.58	0.00	0.00
	WORK	.0519	.0709	.0907	.1172	.1539	.3019	0.0000	0.0000
90.0	EXH	6.16	9.46	11.04	15.44	16.89	0.00	0.00	0.00
	INH	-12.97	-5.88	-6.36	-16.44	-58.88	0.00	0.00	0.00
	FSPD	17.23	22.02	39.13	48.53	60.98	0.00	0.00	0.00
	WORK	.0567	.0845	.1144	.1865	.4000	0.0000	0.0000	0.0000

EXH = Exhalation Effort in Centimeters H_2O

INH = Inhalation Effort in Centimeters H_2O

FSPD = Umbilical Pressure Drop in psig

WORK = Unit Work of Breathing in kg•m/liter

<u>NOTE</u>: NEDU Performance Goal for Work is 0.18 kg•m/L (1.8 J/L) at 132 FSW and 62.5 RMV (NEDU Report 3-81)

TABLE 2

UMBILICAL SUPPLIED AGA DIVATOR II LIGHTWEIGHT SYSTEM
WITH 29° AIR SUPPLY AND WATER TEMPERATURE
(300 FT 3/8 INCH ID UMBILICAL, 135 PSI OVERBOTTOM)

Work of Breathing in kilogram·meters/liter (kg·m/L)

RMV (LPM)	DEPTH (FSW)							
	0	33	66	99	132	165	198	300
22.5	0.032	0.038	0.047	0.05	0.055	0.061	0.064	0.068
40.0	0.039	0.051	0.06	0.069	0.077	0.078	0.089	0.115
62.5	0.049	0.065	0.079	0.092	0.11	0.134	0.171	-
75.0	0.055	0.074	0.095	0.12	0.167	0.268	-	-
90.0	0.066	0.075	0.1	0.163	-	-	-	-

Work of Breathing in joules/liter (J/L)

RMV (LPM)	DEPTH (FSW)							
	0	33	66	99	132	165	198	300
22.5	0.31	0.37	0.46	0.49	0.54	0.60	0.63	0.67
40.0	0.38	0.50	0.59	0.68	0.76	0.77	0.87	1.13
62.5	0.48	0.64	0.77	0.90	1.08	1.31	1.68	-
75.0	0.54	0.73	0.93	1.18	1.64	2.63	-	-
90.0	0.65	0.74	0.98	1.60	-	-	-	-

TABLE 3

OPEN CIRCUIT BREATHING LOOP DATA ANALYSIS DATA SHEET

Equipment Tested: Widolf Full Face Mask

Breathing Gas: Air

Overbottom Pressure Setting: 135 psi

RMV (LPM)	DATA	DEPTH (FSW)							
		0	33	66	99	132	165	198	300
22.5	EXH	3.13	3.59	4.01	4.26	4.51	4.96	5.42	0.00
	INH	-7.25	-8.70	-9.75	-10.70	-11.37	-11.58	-11.97	0.00
	FSPD	1.85	2.65	4.25	5.60	6.75	7.90	10.45	0.00
	WORK	.0715	.0796	.0845	.0970	.1040	.1144	.1211	0.0000
40.0	EXH	5.28	5.28	6.34	7.64	8.13	8.38	8.13	0.00
	INH	-9.51	-11.55	-12.85	-13.17	-15.49	-16.34	-18.03	0.00
	FSPD	2.75	5.30	7.90	11.00	15.15	19.50	23.95	0.00
	WORK	.0892	.0975	.1158	.1301	.1504	.1674	.1899	0.0000
62.5	EXH	6.58	8.45	10.74	11.55	12.46	15.14	0.00	0.00
	INH	-11.58	-14.51	-16.41	-19.19	-22.46	-42.18	0.00	0.00
	FSPD	4.20	8.80	14.70	22.15	30.45	37.65	0.00	0.00
	WORK	.1092	.1310	.1599	.1887	.2543	.3633	0.0000	0.0000
75.0	EXH	5.88	9.54	12.18	12.78	14.82	0.00	0.00	0.00
	INH	-15.21	-18.49	-20.92	-25.42	-61.73	0.00	0.00	0.00
	FSPD	6.20	12.70	21.95	29.40	35.70	0.00	0.00	0.00
	WORK	.1233	.1542	.1954	.2524	.4715	0.0000	0.0000	0.0000
90.0	EXH	8.78	10.95	14.75	17.64	0.00	0.00	0.00	0.00
	INH	-14.58	-19.86	-23.84	-39.96	0.00	0.00	0.00	0.00
	FSPD	7.45	16.80	27.20	36.40	0.00	0.00	0.00	0.00
	WORK	.1378	.1766	.2402	.3818	0.0000	0.0000	0.0000	0.0000

EXH = Exhalation Effort in Centimeters H_2O

INH = Inhalation Effort in Centimeters H_2O

FSPD = Umbilical Pressure Drop in psig

WORK = Unit Work of Breathing in kg·m/liter

NOTE: NEDU Performance Goal for Work is 0.18 kg·m/L (1.8 J/L) at 132 FSW and 62.5 RMV (reference (c))

TABLE 4

OPEN CIRCUIT BREATHING LOOP DATA ANALYSIS DATA SHEET

Equipment Tested: Ryan 26 Prototype (EXO-26)

Breathing Gas: Air

Overbottom Pressure Setting: 135 psi

RMV (LPM)	DATA	DEPTH (FSW) 0	33	66	99	132	165	198	300
22.5	EXH	3.99	4.41	4.37	4.34	3.56	4.30	4.09	0.00
	INH	-6.10	-5.15	-5.89	-6.07	-6.56	-6.70	-6.63	0.00
	FSPD	.95	2.15	4.70	4.80	7.05	9.05	11.86	0.00
	WORK	.0715	.0522	.0637	.0513	.0360	.0387	.0318	0.0000
40.0	EXH	5.71	5.33	5.54	6.21	7.55	6.77	7.48	0.00
	INH	-6.31	-4.59	-5.75	-3.92	-4.02	-4.55	-5.29	0.00
	FSPD	2.65	5.05	10.00	9.90	14.61	17.96	23.56	0.00
	WORK	.0709	.0488	.0478	.0462	.0525	.0605	.0780	0.0000
62.5	EXH	7.13	5.43	9.52	11.15	11.99	10.26	10.76	0.00
	INH	-7.02	-6.84	-5.64	-6.45	-9.95	-13.93	-17.21	0.00
	FSPD	3.85	8.45	12.26	19.01	26.91	37.37	44.27	0.00
	WORK	.0809	.0715	.0847	.1091	.1345	.1542	.1848	0.0000
75.0	EXH	8.18	11.50	11.85	9.88	12.42	11.78	13.93	0.00
	INH	-7.65	-4.69	-7.76	-13.97	-14.18	-29.03	-58.94	0.00
	FSPD	6.05	11.81	17.46	25.56	37.27	42.57	45.82	0.00
	WORK	.0910	.0946	.1234	.1583	.1767	.2523	.3857	0.0000
90.0	EXH	11.78	12.70	11.08	14.32	16.54	0.00	0.00	0.00
	INH	-4.34	-7.80	-12.38	-13.02	-42.65	0.00	0.00	0.00
	FSPD	6.90	14.36	22.96	36.17	43.02	0.00	0.00	0.00
	WORK	.0989	.1271	.1616	.1901	.3422	0.0000	0.0000	0.0000

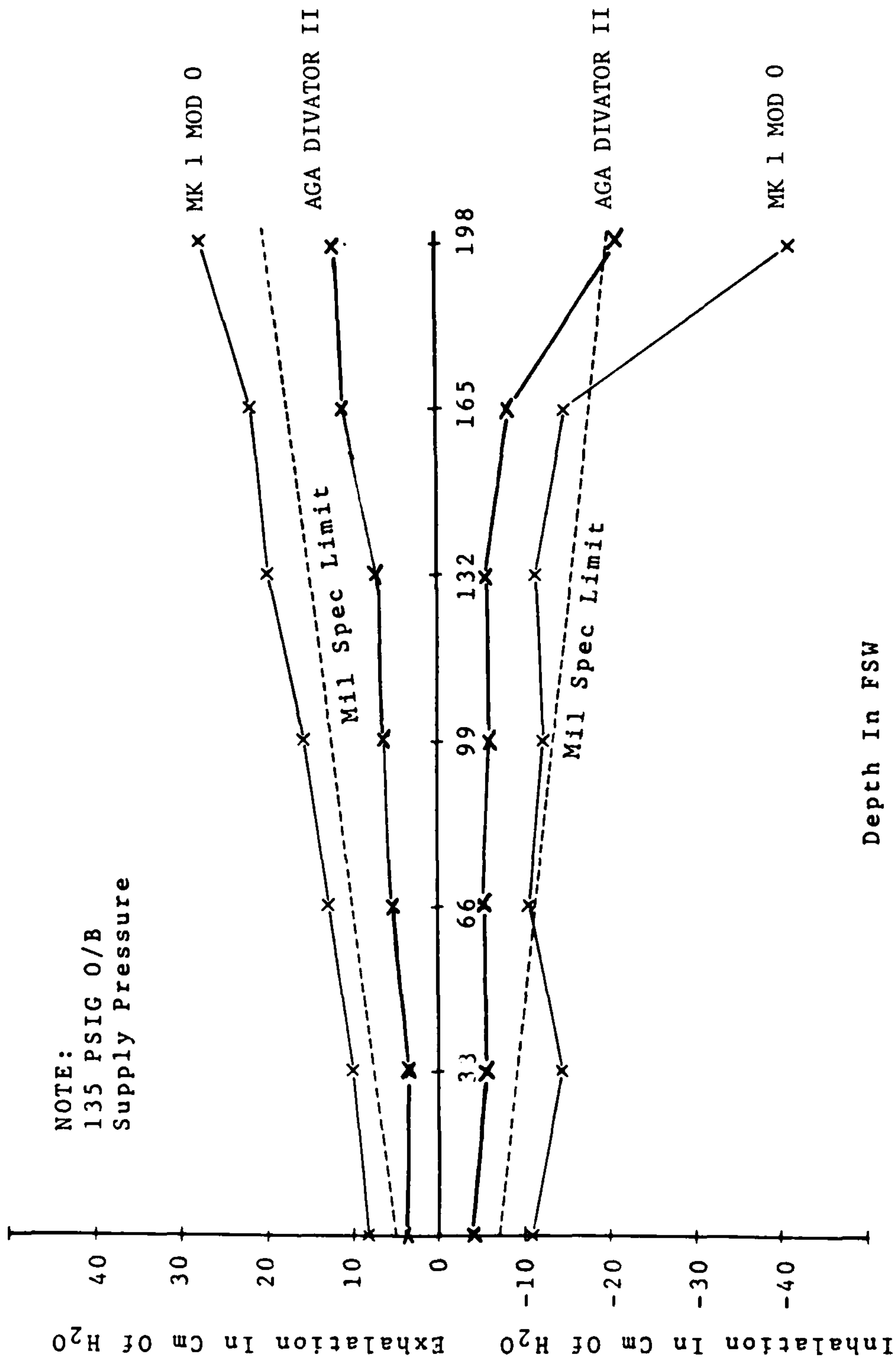
EXH = Exhalation Effort in Centimeters H_2O

INH = Inhalation Effort in Centimeters H_2O

FSPD = Umbilical Pressure Drop in psig

WORK = Unit Work of Breathing in kg·m/liter

NOTE: NEDU Performance Goal for Work is 0.18 kg·m/L (1.8 J/L) at 132 FSW and 62.5 RMV (reference (c))



Breathing Resistance Versus Depth

USN MK 1 MOD 0/AGA DIVATOR II COMPARISON
at 62.5 RMV

Table 5

The AGA Divator II system offers a number of advantages over the Jack Browne:

a. A demand breathing system that conserves the use of air, requiring approximately 1.5 ACFM, as opposed to the 6 ACFM required for free flow diving operations.

b. Work of breathing characteristics that offer the potential when suitably configured for working dives to 190 FSW, breathing air.

c. Extrapolating the results of testing using air, and using the gas density ratio for air: HeO_2 of 6:1, one can predict that the mask will function to 300 FSW using mixed gas, or even deeper for use in saturation diving.

PART II - MANNED TESTING

I. INTRODUCTION

In December 1985, NEDU performed manned testing of the AGA Divator II lightweight enclosed space diving system onboard an operational submarine tender. Testing provided human factors and operational suitability data.

II. MANNED TEST PROCEDURE

The AGA Divator II system was to be used over a five day period on tasks that were to include but not be limited to submarine mud tank work. Test subjects were fully briefed before diving on the function of the rig, and following their dives they were required to complete a human factors questionnaire.

III. MANNED RESULTS AND DISCUSSION

Eight divers performed eight working ship husbandry dives of durations between 17 and 90 minutes. Five of these dives were within submarine mud tanks. The average number of previous dives carried out by each diver in Jack Browne was 43 (the least was five). All divers claimed to have more than 100 dives experience in the USN MK 1 MOD 0.

The AGA lightweight enclosed space diving system was enthusiastically received, gained high marks for comfort, ease of operation, and general performance. Without exception it was preferred to the Jack Browne, for which the AGA was being evaluated as a potential replacement, and to the USN MK 1 MOD 0, to which it could be considered an alternative (and which is also approved for use in confined spaces).

The only area of criticism was the small thigh-worn pony bailout cylinder. The endurance of this cylinder when fully charged to 3000 psi is approximately one minute at 30 FSW. It cannot therefore be considered a substitute for the requirement of an emergency breathing system (EBS) as described in Chapter 6 of the U.S. Navy Diving Manual. All diver-subjects were able to enter and exit the mud tank wearing the cylinder, but three considered it to be an unnecessary burden given its limited endurance. All agreed that it had some merit as a come home bottle when diving lightweight equipment across ships' keels.

An early deficiency identified during the progress of this evaluation was the quality of the communications outfit supplied by Interspiro. Microphone failures due to the ingress of water were commonplace. For all manned testing of the AGA lightweight masks, a prototype configuration of approved microphones and bone conductor earphones, assembled at NEDU, was fitted. It was compatible with the recently approved Hydrocom topside unit, and its performance throughout the evaluation was reported as outstanding.

The intermediate hose between the umbilical connection block and second stage was intentionally provided too long by the manufacturer, who requested that NEDU determine the ideal length required. This has been established as 34 inches.

A summary of the questionnaire responses is in Annex C.

IV. MANNED CONCLUSIONS

The AGA Spiro Divator II lightweight enclosed space diving system connected to existing Navy umbilicals offers a number of significant advantages over the Jack Browne:

a. Excellent communications with the NEDU configuration of microphone and earphone connected to the Hydrocom UDC 225.

b. A positive pressure full face mask that prevents ingress of water or waterborne contamination.

c. The positive pressure feature prevents mask flooding.

d. The air flow design across the face plate prevents mask fogging.

e. A streamlined modern design for easy entry into confined spaces.

f. Provision of a bailout facility.

g. A nose clearing device.

The AGA lightweight system offers a number of advantages over the USN MK 1 MOD 0 for surface-supplied air diving, particularly as a lightweight rig:

a. Lighter.

b. Simpler, compact design.

c. No requirement for defogging.

d. Better work of breathing.

e. Positive pressure mask.

V. REFERENCES

(a) NAVSEA Task Assignment 81-03, "Lightweight Enclosed Space Diving System."

(b) NEDU Report 9-83, "Evaluation of Divex AGA Commercial Mask," James R. Middleton, W.A. Evans, M.S. Jantzen, R.C. Maulbeck, June 1983.

(c) NEDU Report 3-81, "Standardized NEDU Unmanned UBA Test Procedures and Performance Goals," James R. Middleton and Edward D. Thalmann, CDR, MC, USN, July 1981.

(d) NEDU Technical Memorandum TM6-83, "Unmanned Testing of AGA Spiro Lightweight Enclosed Space Diving System and New AGA Spiro Open Circuit SCUBA Regulators," K. Wright, LT, MCD, RN, 15 June 1983.

(e) NEDU Technical Memorandum TM10-83, "Human Factors Evaluation of the AGA Spiro Lightweight Diving System in the Umbilical-supplied, Open Circuit Mode," M.D. Curley, LCDR, MSC, USN, 26 July 1983.

(f) NEDU Technical Memorandum TM85-18, "Evaluation of the AGA Spiro Divator II Lightweight Enclosed Space Diving System," C.J. Tarmey, LCDR, MCD, RN, 17 December 1985.

(g) NEDU Report 8-78, "Unmanned Evaluation of the USN MK 1 MOD 0 Mask in Umbilical and Emergency Modes," James R. Middleton, May 1978.

ANNEX A

MANUFACTURERS AND SUPPLIERS

1. AGA Spiro Divator II Umbilical Supplied Lightweight Enclosed Space Diving System.

Manufacturer	AGA Spiro AB S-181 81 Lidingo Sweden Telephone 468-767-9480
Supplier	Interspiro 11 Business Park Drive Blanford, Connecticut 06405 Telephone 203-481-3899

2. Communications Outfit for Above

Manufacturer/ Supplier	Ocean Technology Systems 2610 Croddy Way, Unit H Santa Ana, California 92704 Telephone 714-754-7848

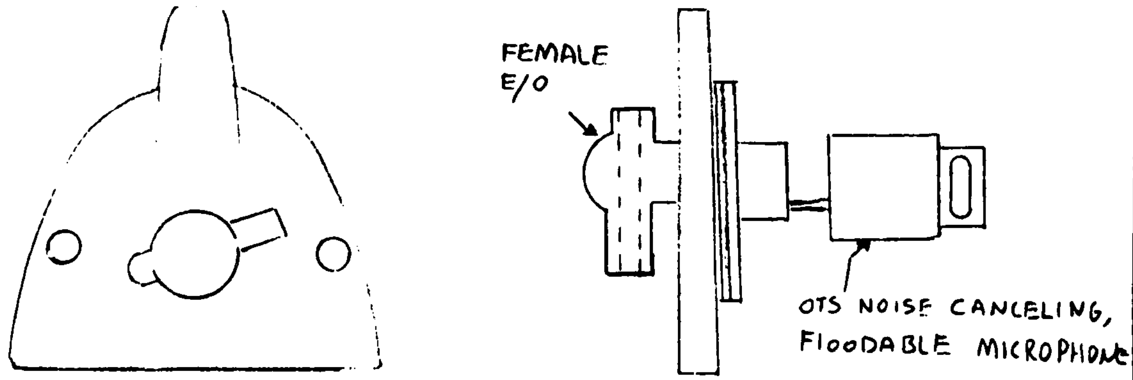
NOTES:

1. Communications outfit comprises:

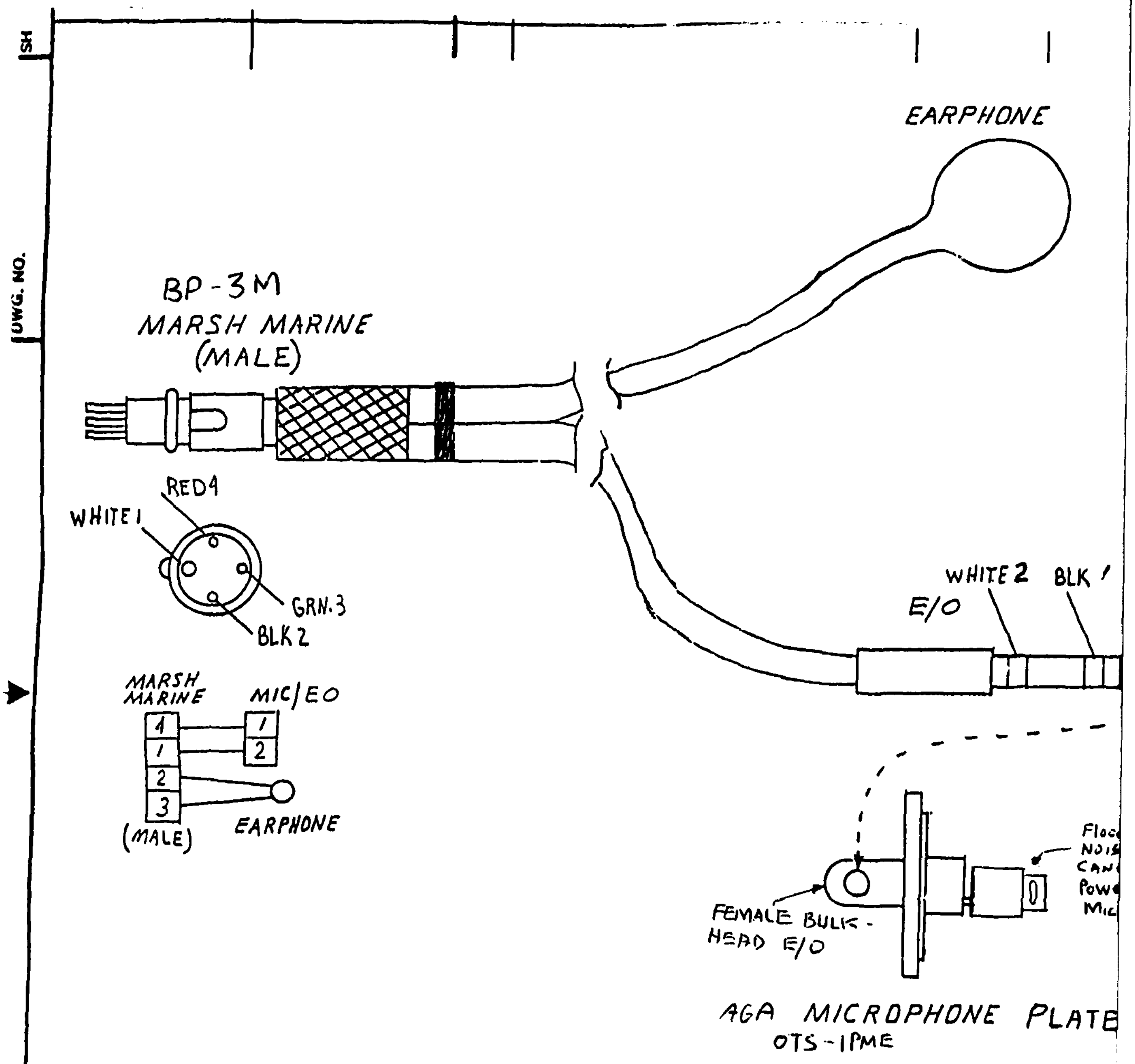
   a. BP-3M Earphone/microphone assembly
   b. OTS-1PME AGA mircorphone plate/noise cancelling -- floodable

2. OTS are also able to provide the AGA Divator II mask assembly complete with communications.

REV.	APPLICATION		REVISIONS			
SH	NEXT ASSY	USED ON	REV.	DESCRIPTION	DATE	APPROVED
DWG. NO.						



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS ± DECIMALS .XX ± .XXX ± ANGLES ±	CONTRACT NO. TELE 28 MAR 86		OCEAN TECHNOLOGY SYSTEMS		
MATERIAL	APPROVALS	DATE	OTS-1PME AGA MICROPHONE PLATE / NOISE CANCELING-FLOODABLE		
	DRAWN M. Pelissier	3-28-86			
FINISH	CHECKED MP	3-28-86	SIZE A	FSCM NO.	DWG. NO. NEDU-86-1
	ISSUED				REV.
DO NOT SCALE DRAWING			SCALE		SHEET



UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES TOLERANCES ARE: FRACTIONS DECIMALS ANGLES .XX ± .XXX ± ±	CONTRACT NO. LETTER 12-12-85		OCEAN TECHNOLOGY SYSTE
	APPROVALS	DATE	BP-3M EARPHONE / MICROPHONE ASSEMBLY
MATERIAL	DRAWN D. ALLISON	1/10/86	
	CHECKED M. Pelissier	3-28-86	
FINISH	ISSUED		SIZE A · FSCM NO. · DWG. NO. NEDU-86-1
DO NOT SCALE DRAWING			SCALE · SHEET

ANNEX B

UNMANNED TEST PLAN

1. Preliminary Arrangements

a. The EDF Charlie Chamber complex will be used to conduct these tests.

b. Divator II and sideblock assembly has been provided by AGA/Interspiro. Code 053 Surface Supplied Officer will provide 300 ft. 3/8 in. ID umbilical.

2. Test Procedure

a. Test equipment:

(1) Breathing machine.

(2) Validyne pressure transducer w/1.00 psid diaphragm for oral pressure (1 ea).

(3) Wet test box.

(4) Validyne pressure transducer w/50 psid diaphragm for ΔP umbilical pressure drop.

(5) X-Y plotter.

(6) Validyne transducer readout (2 ea).

(7) EDF "C" Chamber.

(8) EDF control console supply pressure gauge.

(9) "C" control console depth gauge.

(10) Test regulator: AGA Divator II second stage with AGA lightweight side block assembly.

(11) 300 foot 3/8 inch ID umbilical.

(12) Breathing machine piston position transducer.

(13) Bubble dampening mat.

b. Parameters to be controlled:

(1) Breathing Rate / Tidal Volume / RMV

(a) 15 BPM	1.5 liters	22.50
(b) 20 BPM	2.0 liters	40.0
(c) 25 BPM	2.5 liters	62.5
(d) 30 BPM	2.5 liters	75.0
(e) 30 BPM	3.0 liters	90.0

(2) Exhalation/inhalation time ratio: 1.00/1.00.

(3) Breathing waveform: sinusoid.

(4) Incremental descent stops: 0 to 198 FSW in 33 FSW increments.

(5) Air supply pressure: 135 psig overbottom at all depths.

c. Parameters to be measured:

(1) Inhalation peak pressure in cmH_2O.

(2) Exhalation peak pressure in cmH_2O.

(3) Pressure vs. volume plots.

(4) Umbilical pressure drop at each depth.

d. Parameters to be computed: respiratory work from pressure vs. volume plots (kg·m/L).

e. Data to be printed:

(1) Inhalation max pressure at each depth and RMV.

(2) Exhalation max pressure at each depth and RMV.

(3) Respiratory work at each depth and RMV.

(4) Umbilical pressure drop and RMV.

f. Test plan:

(1) Insure that the Divator II regulator is set to factory specifications and is working properly.

(2) Chamber on surface.

(3) Calibrate transducers.

(4) Open air supply valve to test regulator and set supply pressure at 135 psig.

(5) Adjust breathing machine to 1.5 liters tidal volume and 15 BPM and take data.

(6) Adjust breathing machine to 2.0 liters tidal volume and 15 BPM and take data.

(7) Adjust breathing machine to 2.5 liters tidal volume and 15 BPM and take data.

(8) Adjust breathing machine to 2.5 liters tidal volume and 15 BPM and take data.

(9) Adjust breathing machine to 3.0 liters tidal volume and 15 BPM and take data.

(10) Pressurize chamber to 198 FSW at 33 FSW increments. At each stop adjust O/B pressure to 135 psig. Repeat steps f.(5)-(9).

ANNEX C

LIGHTWEIGHT DIVING EQUIPMENT/MASK QUESTIONNAIRE SUMMARY

Instructions: Please complete this questionnaire carefully for each type of dive that you do during the period of the evaluations. The type of lightweight diving equipment eventually chosen for the U.S. Navy may depend upon your answers. A new questionnaire should be completed for each type of diving, e.g. mud tank, hull survey, etc.

Check the appropriate answer to each question or fill in the blank spaces provided and then add any relevant comments that you may have.

NAME: ______________________ WEIGHT: ________ AGE: ________

PREVIOUS EXPERIENCE IN: MK 1 MOD 0 (approx no. of dives) ____________

Jack Browne (approx no. of dives) ____________

TYPE OF DIVE: Mud Tank 5

Ballast Tank ____________

Hull Survey 1

Other 1 Arrival Swim

1 Removal of WLR Autec Pinger

DURATION: AGA ________

1. Was the mask comfortable during the dive?

	AGA	DSI	WIDOLF
(1) Very Uncomfortable			
(2) Uncomfortable			
(3) OK			
(4) Comfortable			
(5) Very Comfortable	8		

If uncomfortable, explain: ______

AGA: ______

DSI: ______

WIDOLF: ______

2. Did you notice any breathing resistance?

	AGA	DSI	WIDOLF
(1) Excessive			
(2) Moderate			
(3) Slight	1		
(4) None	7		

3. If breathing resistance was noticed was it during:

	AGA	DSI	WIDOLF
(1) Inhalation	1		
(2) Exhalation			
(3) Both			

If so, explain:

AGA: ______

DSI: ______

WIDOLF: ______

4. Did mask fogging occur?

	AGA	DSI	WIDOLF
(1) Yes			
(2) No	8		

5. Any problems defogging mask?

	AGA	DSI	WIDOLF
(1) Yes			
(2) No			

If so, explain:

AGA: ____________________

DSI: ____________________

WIDOLF: ____________________

6. Did you notice any muscular fatigue or strain in your jaws with the full face mask. If so, how long into the dive did it begin?

	AGA	DSI	WIDOLF
(1) Yes			
(2) No	8		
Time into the dive			

7. During your dives did any water enter the mask?

	AGA	DSI	WIDOLF
(1) Yes			
(2) No	8		

If so, how much, could you clear, did you have to abort or surface from the dive? What caused it?

AGA: ____________________

DSI: ____________________

WIDOLF: ____________________

8. When using the communications system could you be clearly understood?

	AGA	DSI	WIDOLF
(1) Yes	8		
(2) No			

9. Could you hear topside clearly?

	AGA	DSI	WIDOLF
(1) Yes	8		
(2) No			

Comments:

AGA: Communications was exceptionally good

DSI:

WIDOLF:

10. How would you rate the ease with which head harness can be adjusted?

	AGA	DSI	WIDOLF
(1) Extremely Poor			
(2) Poor			
(3) Barely Adequate			
(4) Adequate			
(5) Very Good	6		
(6) Excellent	2		

Comments:

AGA:

DSI:

WIDOLF:

11. How would you rate harness comfort?

	AGA	DSI	WIDOLF
(1) Extremely Poor			
(2) Poor			
(3) Barely Adequate			
(4) Adequate	1		
(5) Very Good	1		
(6) Excellent	6		

12. How would you rate the overall comfort of the rig?

	AGA	DSI	WIDOLF
(1) Extremely Poor			
(2) Poor			
(3) Barely Adequate			
(4) Adequate			
(5) Very Good	2		
(6) Excellent	6		

13. How would you rate the ease of donning rig?

	AGA	DSI	WIDOLF
(1) Extremely Poor			
(2) Poor			
(3) Barely Adequate			
(4) Adequate	3		
(5) Very Good	1		
(6) Excellent	3		

14. How would you rate the ease of operation of emergency supply?

	AGA	DSI	WIDOLF
(1) Extremely Poor			
(2) Poor			
(3) Barely Adequate			
(4) Adequate			
(5) Very Good	5		
(6) Excellent	3		

15. How would you rate emergency bottle position?

	AGA	DSI	WIDOLF
(1) Extremely Poor	1		
(2) Poor			
(3) Barely Adequate	1		
(4) Adequate	3		
(5) Very Good	3		
(6) Excellent			

16. How would you rate rig fastenings, fittings, and valves?

	AGA	DSI	WIDOLF
(1) Extremely Poor			
(2) Poor			
(3) Barely Adequate			
(4) Adequate	2		
(5) Very Good	4		
(6) Excellent	2		

17. What is your overall rating of the rigs?

	AGA	DSI	WIDOLF	MK 1 MOD 0	JACK BROWNE
(1) Extremely Poor					
(2) Poor					2
(3) Barely Adequate				3	2
(4) Adequate				5	4
(5) Very Good	2				
(6) Excellent	6				

18. What suggestions would you have for improving each of the rigs:

AGA: a. Dispense with pony bottle (3).

b. Shorten intermediate whip to second stage (to 34 inches).

DSI:

WIDOLF: