NAVY EXPERIMENTAL DIVING UNIT

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NAVXDIVINGU REPORT 5-73
SOUND LEVEL TESTING OF THE DESCO PROTOTYPE HELIUM-OXYGEN DIVING HELMET

S. D. Reimers

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Submitted:

S.D. Reimers
LT, USNR

Approved:

J. J. Coleman
CDR, USN
Officer-in-Charge

ABSTRACT

A Prototype Helium-Oxygen Diving Helmet developed by the Diving Equipment and Supply Corp. of Milwaukee, Wisc. was subjected to sound level testing on a specially built acoustical manikin at the U.S. Navy Experimental Diving Unit. The helmet was tested in both the semi-closed circuit (venturi) and open-circuit modes. The sound levels existing in the helmet were found to be well into the hearing damage risk levels during all test conditions. The helmet was judged safe for manned use only under restricted laboratory conditions.

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I. INTRODUCTION

In 1970, the Navy Experimental Diving Unit began a program to develop a combination air and helium-oxygen diving helmet that would be an improvement over the traditional MK V air and helium-oxygen helmets. Part of this program was a series of evaluations of commercially available helmets. During these evaluations, several of the divers complained of temporarily muffled hearing subsequent to test dives in some of the helmets. When these temporary hearing decrements were substantiated by audiometric examination (1), it was decided to run sound level tests on all the helmets under consideration prior to any further diving of the helmets.

This report details the results of the sound level testing on the DESCO Prototype Helium Oxygen Diving Helmet.

II. EQUIPMENT TESTED

The helmet tested was a prototype Helium-Oxygen Diving Helm developed by the Diving Equipment and Supply Co. in Milwaukee, W It is intended for use only with a deep sea dress, and its basic design resembles a lightweight version of the standard USN MK V Helium Oxygen Diving Helmet. It is nearly identical to the Japanese (Yokohama) Helium-Oxygen Diving Helmet widely used in Japan and on the U.S. West Coast. The DESCO Prototype $He-O_2$ Helmet is not available on the commercial market at this time.

Figures 1, 2, 3 and 4 show various views of the helmet. The faceplate and side port lenses are made of machined acrylic plastic sealed by "O" rings. The "O" rings show up as black rings around the outer edges of the lenses in Figures 1, 2 and 3.

The cannister assembly is rigidly attached to the helmet by soldered joints as is all of its ambient pressure plumbing. This eliminates the possibility of water leaks into the cannister as sometimes happens with the USN MK V $He-O_2$ helmet. The cannister charge is a standard medical 2½-lb. Soda-Sorb prepacked cartridge. It is inserted from inside the helmet, and held in place by a threaded annular retaining ring. Figure 4 shows the helmet with the cannister element, annular cannister retaining ring and front faceplate removed.

The venturi and its expansion chamber are similar to those on the USN MK V $He-O_2$ helmet. The flow pattern is from the back of the helmet through the cannister, through the venturi chamber, and back through the outer return pipe (top, Fig. 1) to the upper front of the helmet. Supply pressure for the venturi is maintained at 100 psi over bottom pressure by a first stage unit from a standard single-hose open circuit SCUBA regulator. The control valve for the venturi is located at top right on the helmet. See Figures 1 and 4.

The exhaust valve is a standard USN type helmet exhaust valve. The control valve is a globe type valve of unknown origin. During open circuit operation the air or gas discharge into the helmet from the control valve is by means of perforated 3/8" tubing located above the front faceplate (see Fig. 4).

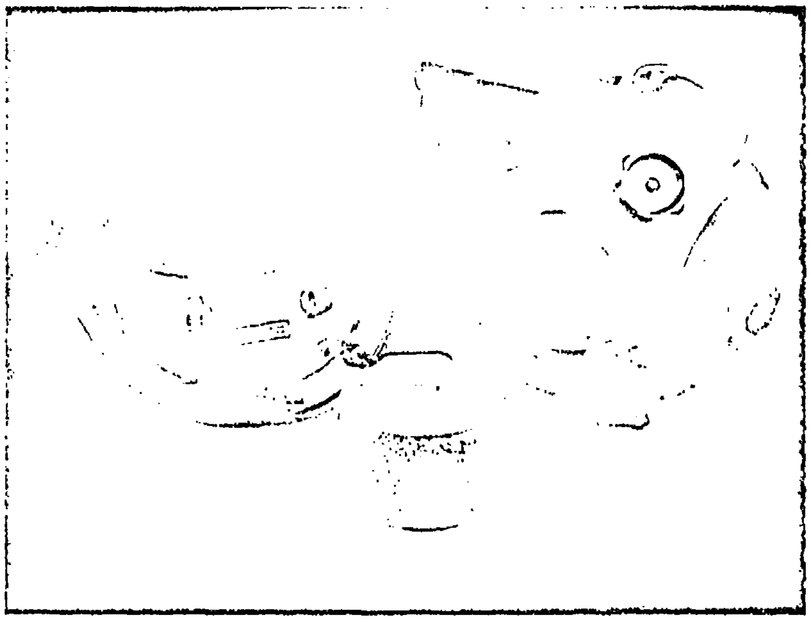


FIGURE 1

DESCO Prototype He-O_2 Diving Helmet
With Breastplate and CO_2 Absorbant
Cannister Element (Soda-Sorb).

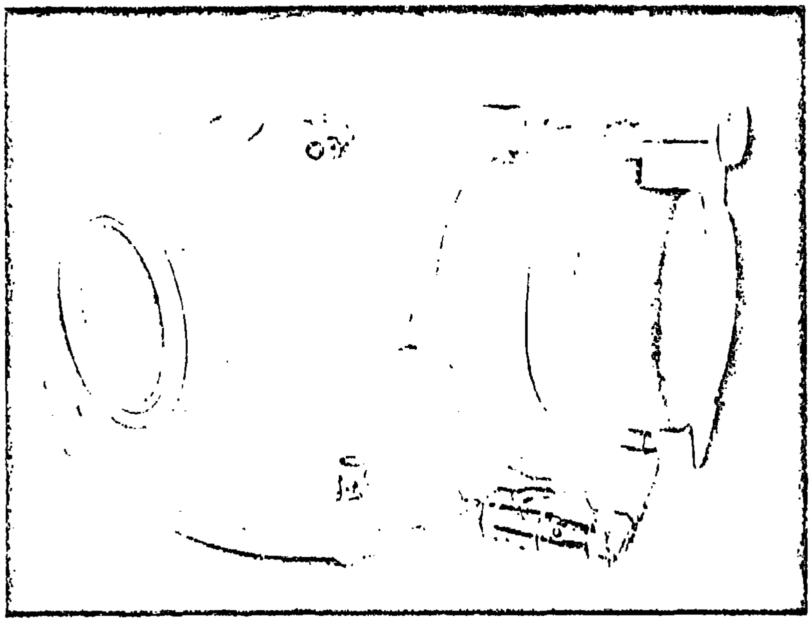


FIGURE 2

DESCO Prototype He-O_2 Diving Helmet
Left Rear View

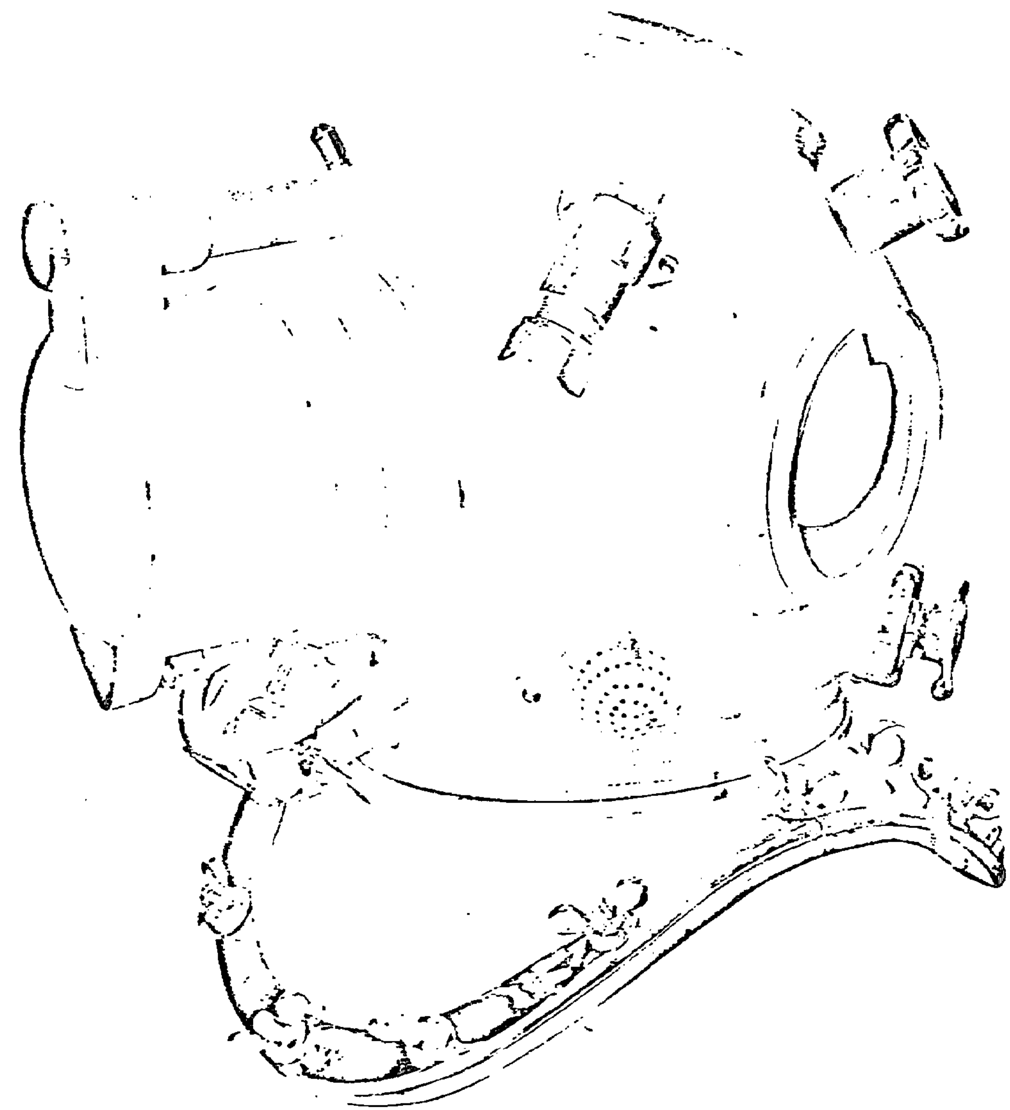


FIGURE 3 DESCO Prototype $He-O_2$ Diving Helmet, Right Rear View
Note capped non-return valve.

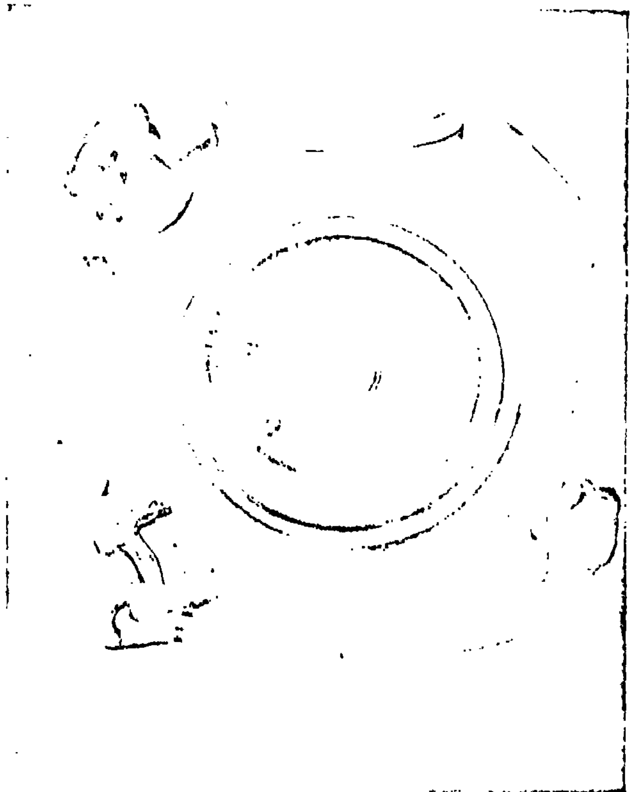


FIGURE 4

DESCO Prototype $He-O_2$, Diving Helmet Front View with Faceplate, Cannister Retaining Ring and Cannister Removed. Center Hole is Plenum Chamber Behind Cannister. Knubbed Annular Ring is Rear Cannister Support. White Foamed Plastic Just Behind Upper Left Portion of Faceplate Opening is Plastic Wrapped Around Gas Discharge Piping to Help Reduce Open Circuit Noise Levels.

III. TEST PROCEDURES

A. Apparatus

A test manikin consisting of a soft rubber head and a fiberglass torso was modified to accommodate a Bruel and Kjaer 1-inch condenser microphone and preamplifier at either the right or left ear position. The microphone head was recessed 1/4 inch from the surface of the manikin ear and was connected through appropriate wiring to a B & K sound level meter outside the chamber. Figure 5 shows a simplified schematic diagram of the complete experimental apparatus.

The DESCO He-O_2 helmet is designed to be used only with a breastplate and standard deep sea diving dress. This necessitated placing the entire manikin inside the dress. To prevent over inflation of the dress, it was clamped tightly against the manikin torso just above its base. This level corresponds roughtly to the hip joint level in a normal man. The excess dress was rolled up and tied off. The sleeves of the dress were clamped closed at the elbows with flat clamps, and the wires from the microphone were brought out through one of the clamps.

The entire apparatus was carefully watched and checked for leaks as these tended to increase the measured sound levels. None were observed to occur.

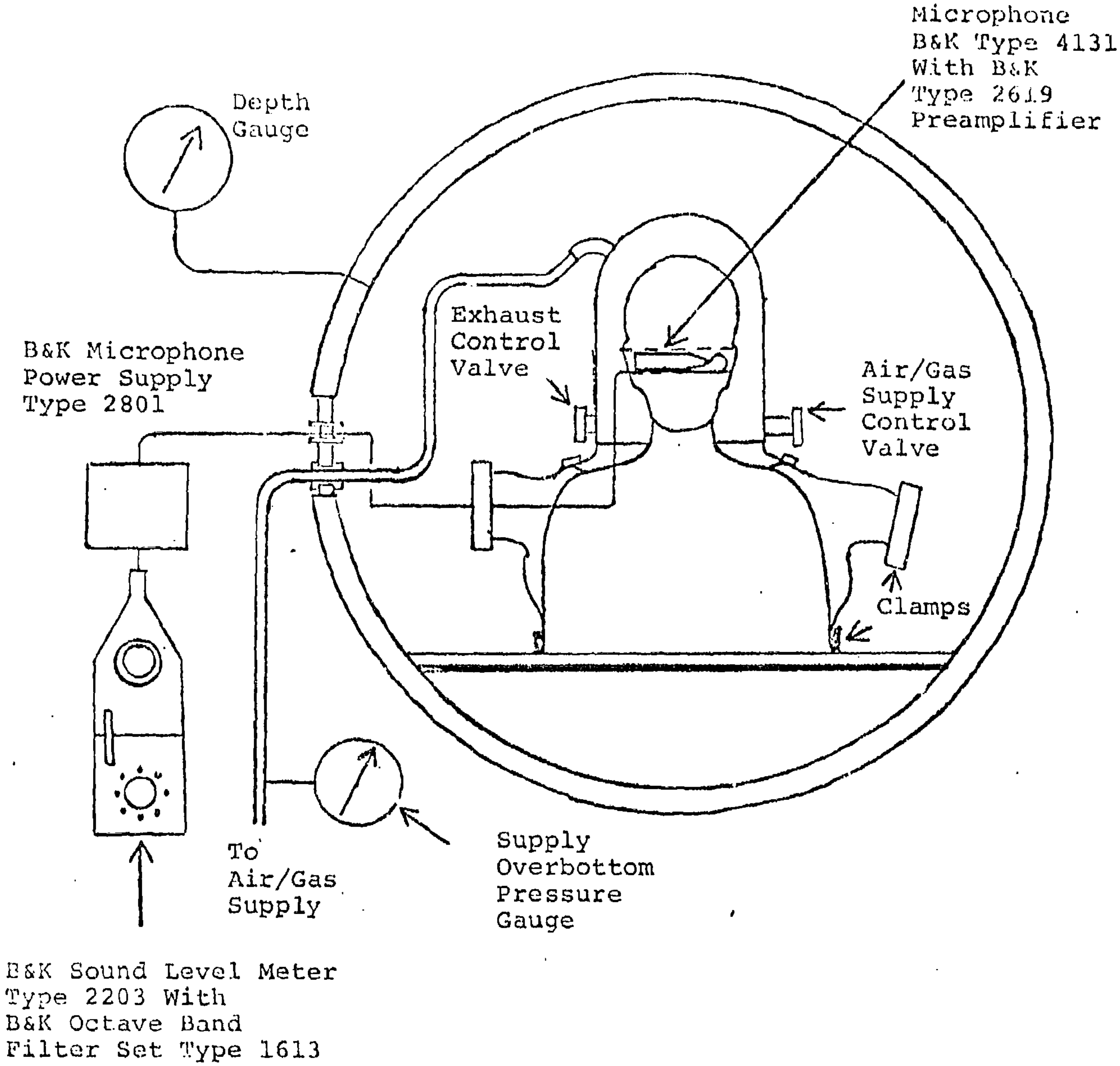


FIGURE 5

Test Set-Up for Measuring
Sound Levels in DESCO
Helium Oxygen Helmet

B. Procedure

The helmet was tested dry in NAVXDIVINGU's #5 recompression chamber.

For tests with the helmet in the venturi mode, the air control and helmet exhaust valves were set at fully closed. The venturi control valve was set at fully open. Venturi mode sound levels were measured using air at 0 and 50 feet sea water at supply pressures of 50 and 100 psi over bottom pressure. They were also measured using pure helium and a mixture of 15% oxygen, 85% helium at 100 psi over bottom pressure at 100, 200 and 300 fsw. Both ear positions were tested.

During the open circuit mode sound level tests, the venturi control valve was closed completely. The helmet exhaust valve was set at fully open and the air control valve was set at 1/4, 1/2 and fully open. Open circuit tests were initially run using air at 100 psi over bottom pressure at both 0 and 50 fsw. Both ear positions were tested.

When examination of the results of the initial tests indicated that the open circuit sound levels were too high, one 1/8 inch thick layer of porous white foamed plastic was wrapped around the perforated air discharge tubing in the helmet. The foamed plastic was the same material used as a particle filter on the effluent side of the CO_2 absorbant cannister in the USN MK 10 Underwater Breathing apparatus. It was held in place by wrapping it with nylon fishing line. The sound level tests were then repeated.

Examination of the results showed the sound levels slightly reduced, but still too high. Consequently, a second layer of foamed plastic was added and the tests were repeated. This time supply pressures of both 50 and 100 psi over bottom pressure were used.

The sound levels measured with two layers of foamed plastic wrapped around the air discharge tubing when the helmet was supplied with air at 50 psi overbottom were judged safe for laboratory applications, and manned diving tests were allowed to be undertaken. The results of those dives will be reported in a Battelle Memorial Institute report covering both the manned tests at NAVXDIVINGU and the unmanned ventilation tests performed at Battelle. That report is in preparation at this time.

Microphone calibration was checked before and after each test run. No changes in calibration were found.

C. Data Handling

The descriptive sound measurement most frequently used to determine noise risk in industry and in the Navy is the A-weighted sound level, dBA. This term also relates closely to the various noise-rating numbers used to describe interference with communications, annoyance and noise fatigue (3)(4)(5). Unfortunately, calibration curves for the A-weighted sound level measurement at increased ambient pressures as read directly from the sound level meter are not available. It was necessary to first correct the octave band sound pressure levels for increased pressure (6)(7) and then determine an equivalent A-weighted sound level (dBA) from the equivalent sound level contours shown in Figure 6.

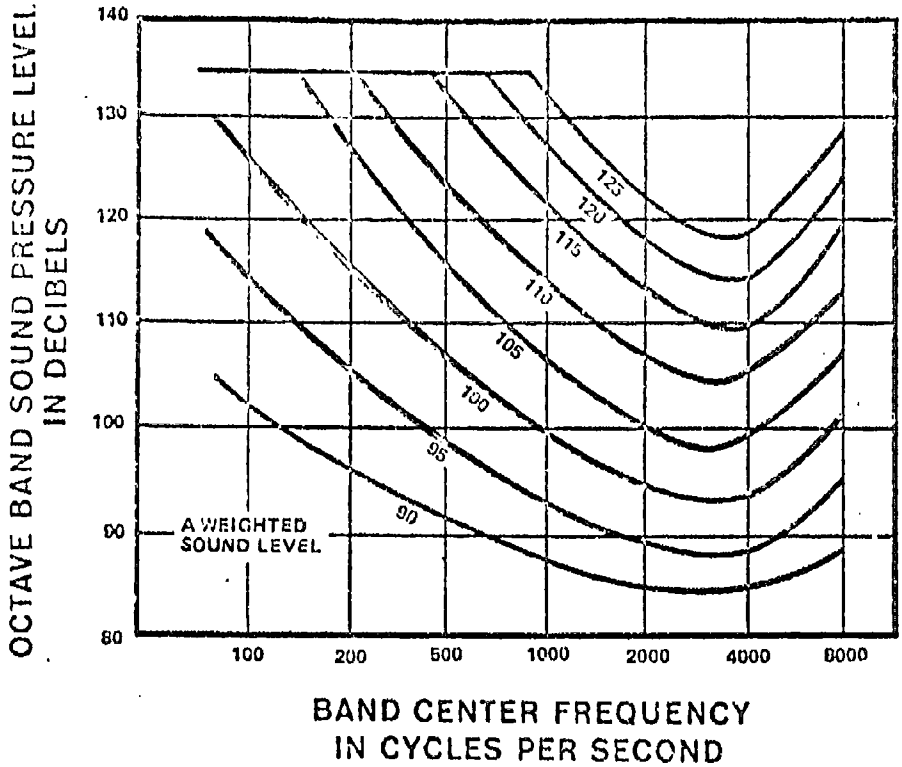


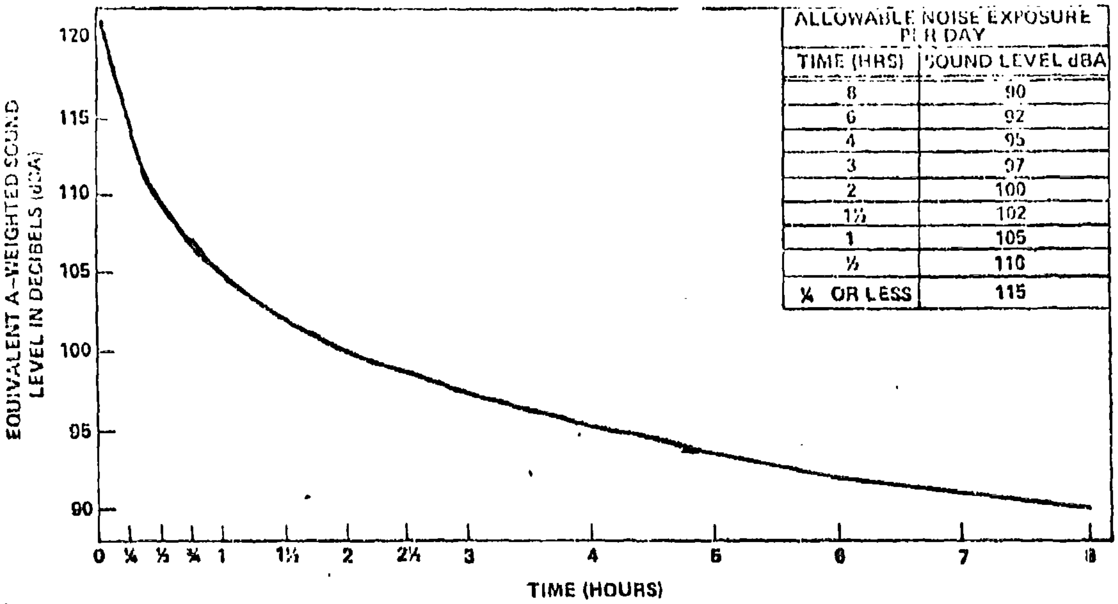
Fig. 6. Equivalent A-Weighted Sound Level Contours. Octave Band Sound Pressure Levels May Be Converted to the Equivalent A-Weighted Sound Level by Plotting Them on This Graph and Noting the A-Weighted Sound Level Corresponding to the Point of Highest Penetration into the Sound Level Contours (2).

IV. RESULTS AND DISCUSSION

Figure 7 presents the currently accepted daily limits for exposure to high environmental noise levels. Tables 1 and 2 present the Equivalent dBA levels obtained for the DESCO $He-O_2$ helmet when operated in the semi-closed circuit and open circuit modes. The detailed octave band sound pressure level results are contained in the Appendix.

Two layers of foamed plastic wrapped around the air inlet piping had some beneficial effect in reducing the dBA levels. Reductions of up to 8 dBA were measured. One layer had only a slight effect. Reducing the supply pressure from 100 psi to 50 psi over bottom had as much or more effect (4 to 9 dBA) than did the addition of the foamed plastic. A drop of 5 to 10 dBA in the equivalent dBA levels with a 100 to 50 psi reduction in the over bottom supply pressure is a frequent occurrence in open circuit air helmets (8)(9). The muffling qualities of the foamed plastic are not at all good. The fact that it helped at all indicates that in this helmet at least a considerable reduction in the sound levels is possible with attention to good acoustical design practice.

It is clear from Figure 7 and Tables 1 and 2 that the sound levels occurring in the DESCO prototype $He-O_2$ helmet as it is presently designed, are well into the damage risk levels under all of the conditions tested. The test conditions correspond to nearly all the possible conditions occurring in normal use.



ALLOWABLE NOISE EXPOSURE PER DAY	
TIME (HRS)	SOUND LEVEL dBA
8	90
6	92
4	95
3	97
2	100
1½	102
1	105
½	110
¼ OR LESS	115

FIGURE 7

Currently Accepted Daily Noise Exposure Limits

						dBA EQUIVALENT	
DEPTH FSW	OVER BOTTOM PRES. PSI	GAS	VENTURI VALVE POS.	SUPPLY VALVE POS.	EXHAUST VALVE POS.	RIGHT EAR POS.	LEFT EAR POS.
SURFACE	50	AIR	FULL OPEN	FULL CLOSED	FULL CLOSED	97	
	100	AIR				104	102
50 FEET	50	AIR				88	
	100	AIR				104	103
100 FEET	100	15% HeO_2				99	
	100	100% He					95
200 FEET	100	15% HeO_2				97	
	100	100% He					95
300 FEET	100	15% HeO_2				98	
	100	100% He					95

Table 1

Equivalent dBA Levels Obtained From Octave Band Sound Pressure Levels Measured in the DESCO Prototype Helium Oxygen Helmet During Semi-Closed Circuit (Venturi) Operation

DEPTH FSW	OVER BOTTOM PRES. PSI	SUPPLY VALVE POS.	STANDARD AIR INLET		ONE LAYER OF PLASTIC FOAM		TWO LAYERS OF PLASTIC FOAM	
			RIGHT EAR POS.	LEFT EAR POS.	RIGHT EAR POS.	LEFT EAR POS.	RIGHT EAR POS.	LEFT EAR POS.
SURFACE	50	1/4 OPEN					104	104
		1/2 OPEN					106	106
		FULL OPEN					109	110
	100	1/4 OPEN	116	114	117			
		1/2 OPEN	117	115	118			
		FULL OPEN	121	120	120		113	
50 FEET	50	1/4 OPEN						
		1/2 OPEN						
		FULL OPEN						110
	100	1/4 OPEN	120	116	117			
		1/2 OPEN	121	119	120			
		FULL OPEN	126	123	122		119	

Table 2

Equivalent dBA Levels Obtained
From Octave Band Sound Pressure Levels
Measured in the DESCO Prototype Helium-Oxygen
Helmet During Open Circuit Air Operation

The damage risk levels have been developed for exposures in 14.7 psia air, and their applicability under increased ambient pressures has not yet been substantiated. There are, however, at least three documented cases where maximum exposures (Fig. 7) to damage risk level noise under conditions of high ambient pressures have produced significant temporary hearing impairments (1).

Consequently, the maximum safe daily exposure limits for the DESCO prototype helium-oxygen diving helmet are considered to be as follows:

Semi-Closed Circuit Mode -

Helium Oxygen Mixtures at 100 psi over bottom pressure and/or air or oxygen at not more than 50 psi over bottom pressure:	2 hours

Open Circuit Mode -

Air and/or oxygen at not more than 50 psi over bottom pressure and with some type of muffler on the air inlet piping:	30 minutes
with no muffler:	15 minutes

If both modes are used in one dive, the sum of the fractions of the total permissible time the diver is exposed to each condition shall not exceed one; i.e.

$$\frac{\text{venturi time}}{\text{2 hours}} + \frac{\text{open circuit time}}{\text{30 minutes}} \leqq 1$$

These times are short enough so that diving of the helmet is considered prudent only in a laboratory situation where the diver can remove the helmet if for some reason he becomes committed to open circuit operation or to a long decompression schedule. Even in this case, audiometric examination equipment should be available.

V. CONCLUSIONS

1. The sound levels existing in the DESCO Prototype Helium Oxygen Helmet are well into the damage risk levels under all conditions of normal usage.

2. Maximum safe daily exposures in the helmet are 2 hours in the venturi mode and 30 minutes in the open circuit mode subject to the restrictions identified in Section IV.

VI RECOMMENDATIONS

1. The DESCO Prototype Helium Oxygen Helmet is not recommended for manned use except in laboratory situations where the diver can remove the helmet if he becomes committed to open circuit operation or to a long decompression. This recommendation is further subject to the restrictions identified in Section IV.

2. Further U.S. Navy testing of this helmet is not recommended until the sound levels occurring in the helmet are reduced to a maximum of 92 dBA.

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APPENDIX

OCTAVE BAND SOUND PRESSURE LEVELS
AND EQUIVALENT A-WEIGHTED SOUND LEVELS
IN THE DESCO PROTOTYPE HELIUM OXYGEN HELMET

DEPTH FSW	GAS	OVER BOTTOM PRESSURE PSI	OCTAVE BAND SOUND PRESSURE LEVELS IN DB RE 0.0002 MICROBAR AT THE INDICATED CENTER FREQUENCIES IN HERTZ										dBA EQUIV-ALENT
			31.5	63	125	250	500	1000	2000	4000	8000	16000	
							LEFT	EAR					
SURFACE	AIR	100	75	87	92	88	93	98	93.5	96	99	95.5	102
50'	AIR	100	77	88	91	91	96	98	94	97	99	93	103
100'	100% He	100	66	73	83	90	88	88	91	88	95	--	95
200'	100% He	100	71	74	80	88	88	88	90	88	94	--	95
300'	100% He	100	75	73	78	89	88	87	89	88	92	--	95
							RIGHT	EAR					
SURFACE	AIR	50	68	77	82	77	79	87	86	90	91	84	97
	AIR	100	77	87	90	88	89	96	95	98	101	96	104
50	AIR	50	65	64	76	74	75	80	81	83	83	74	88
FEET	AIR	100	78	85	91	91	93	96	94	98	100	91	104
100'	15% HeO_2	100	69	77	83	92	87	89	92	92	99	--	99
200'	15% HeO_2	100	69	77	83	90	88	89	92	90	97	--	97
300'	15% HeO_2	100	69	74	79	88	87	87	90	91	94	--	98

Table A-1. DESCO MIXED GAS HELMET
MODE - VENTURI DATE: 7 NOVEMBER 1970
VALVE SETTINGS: SUPPLY - FULLY CLOSED
VENTURI CONTROL - FULLY OPENED
EXHAUST - FULLY CLOSED

DEPTH FSW	SUPPLY VALVE POSITION	OVER BOTTOM PRESSURE PSI	OCTAVE BAND SOUND PRESSURE LEVELS IN DB RE 0.0002 MICROBAR AT THE INDICATED CENTER FREQUENCIES IN HERTZ										dBA EQUIVALENT
			31.5	63	125	250	500	1000	2000	4000	8000	16000	
							LEFT	EAR					
SURFACE	1/4 OPEN	100	80	83	82	75	88	90	100	109	114	108	114
	1/2 OPEN	100	68	88	92	85	91	94	102	110	114	110	115
	FULL OPEN	100	86	89	90	81	92	94	103	114	115	110	120
50 FEET	1/4 OPEN	100	77	80	81	77	92	95	102	111	112	105	116
	1/2 OPEN	100	80	92	96	89	95	99	104	113	115	108	119
	FULL OPEN	100	79	86	90	85	93	98	105	117	117	114	123
							RIGHT	EAR					
SURFACE	1/4 OPEN	100	90	89	87	76	85	89	102	111	111	104	116
	1/2 OPEN	100	90	92	91	83	88	91	102	111	110	104	117
	FULL OPEN	100	91	92	89	79	87	91	103	115	112	106	121
50 FEET	1/4 OPEN	100	84	82	80	77	87	91	105	114	110	102	120
	1/2 OPEN	100	87	90	93	87	90	95	107	115	103	105	121
	FULL OPEN	100	91	87	90	85	90	94	108	120	116	110	126

Table A-2. DESCO MIXED GAS HELMET ON OPEN CIRCUIT AIR, EXHAUST VALVE FULLY OPEN
8 November 1970

DEPTH FSW	SUPPLY VALVE POSI-TION	OVER BOTTOM PRES-SURE PSI	OCTAVE BAND SOUND PRESSURE LEVELS IN DB RE 0.0002 MICROBAR AT THE INDICATED CENTER FREQUENCIES IN HERTZ										dBA EQUIV-ALENT
			31.5	63	125	250	500	1000	2000	4000	8000	16000	
							LEFT	EAR					
						NO SOUND LEVELS TAKEN							
							RIGHT	EAR					
SURFACE	1/4 OPEN	100	83	81	83	75	78	88	101	111	110	105	117
	1/2 OPEN	100	84	85	89	84	88	90	101	112	111	107	118
	FULL OPEN	100	84	84	87	85	89	90	102	114	112	107	120
50 FEET	1/4 OPEN	100	81	84	86	90	92	102	115	111	102	104	117
	1/2 OPEN	100	71	75	80	81	82	94	104	114	113	105	120
	FULL OPEN	100	86	88	91	92	95	97	106	119	116	111	122

Table A-3. DESCO MIXED GAS HELMET ON OPEN CIRCUIT AIR WITH ONE LAYER OF GE FOAM ADDED TO THE AIR INLET. EXHAUST VALVE FULLY OPENED

9 November 1970

DEPTH FSW	SUPPLY VALVE POSI-TION	OVER BOTTOM PRES-SURE PSI	OCTAVE BAND SOUND PRESSURE LEVELS IN DB RE 0.0002 MICROBAR AT THE INDICATED CENTER FREQUENCIES IN HERTZ										dBA EQUIV-ALENT
			31.5	63	125	250	500	1000	2000	4000	8000	16000	
X	X	X	X	X	X	X	LEFT	EAR	X	X	X	X	X
SURFACE	1/4 OPEN	50	61	66	68	70	74	78	89	98	97	94	104
SURFACE	1/2 OPEN	50	68	75	80	74	76	79	91	99	100	95	106
SURFACE	FULL OPEN	50	68	75	82	78	80	81	94	105	104	101	110
50'	FULL OPEN	50	72	74	77	77	80	86	94	105	105	95	110
X	X	X	X	X	X	X	RIGHT	EAR	X	X	X	X	X
SURFACE	1/4 OPEN	50	62	64	68	69	75	78	91	98	96	89	104
SURFACE	1/2 OPEN	50	70	80	85	75	77	81	91	99	98	92	106
SURFACE	FULL OPEN	50	67	70	72	74	77	80	95	104	102	95	109
X	X	X	X	X	X	X	RIGHT	EAR	X	X	X	X	X
SURFACE	FULL OPEN	100	74	76	82	75	78	88	96	108	108	101	113
50'	FULL OPEN	100	71	74	78	79	81	92	101	113	112	108	119

Table A-4. DESCO MIXED GAS HELMET ON OPEN CIRCUIT AIR WITH TWO LAYERS OF GE FOAM ADDED TO AIR INLET. EXHAUST VALVE FULLY OPEN.
10 November 1970

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13. ABSTRACT

A Prototype Helium-Oxygen Diving Helmet developed by the Diving Equipment and Supply Corp. of Milwaukee, Wisc. was subjected to sound level testing on a specially built acoustical manikin at the U.S. Navy Experimental Diving Unit. The helmet was tested in both the semi-closed circuit (venturi) and open-circuit modes. The sound levels existing in the helmet were found to be well into the hearing damage risk levels during all test conditions. The helmet was judged safe for manned use only under restricted laboratory conditions.

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
DIVING EQUIPMENT						
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HYPERBARBIC NOISE						
HEARING						
DIVER'S HEARING LOSS						