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NAVY EXPERIMENTAL DIVING UNIT  
PANAMA CITY, FLORIDA 32407-5001

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NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 10-91

EVALUATION OF BAUER HIGH PRESSURE  
BREATHING AIR  
P-2 PURIFICATION SYSTEM

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AUGUST 1991

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19. ABSTRACT (Continue on reverse if necessary and identify by block number) In response to NAVSEA tasking, Navy Experimental Diving Unit (NEDU) tested the BAUER P-2 High Pressure, Breathing Air Purification System from 16 July 1991 to 19 July 1991. The purpose of this test was to determine if the P-2 Air Purification System functioned as specified and was suitable for use by the U.S. Navy. Additionally, if the system passed the test criteria a recommendation would be made to add it to the Approved for Navy Use (ANU) list. The BAUER P-2 Purification System met the manufacturer's specifications for quantity of air processed with a quality which met U.S. Navy purity standards. The design and engineering were determined to be adequate. The BAUER P-2 Air Purification System is considered suitable for use with U.S. Navy divers high pressure breathing air compressors			
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## I. INTRODUCTION

In response to NAVSEA tasking<sup>1</sup>, the BAUER P-2 high pressure breathing air purification system, Figure 1, was tested<sup>2</sup> by NEDU. The test determined if the purification system would provide suitable breathing air and a service life satisfying the U.S. Navy requirements for use with divers air supply compressors. Charge rates were taken to calculate total cubic feet of air processed each day.

## II. EQUIPMENT DESCRIPTION

### A. PURIFICATION SYSTEM

The purification system consists of two cylinders. The upstream cylinder contains a molecular sieve and is a coalescing type separator that removes oil and water vapors suspended in the compressed air. The molecular sieve is made to adsorb oil and water vapors. The downstream cylinder contains a cartridge with hopcalite and activated charcoal. The hopcalite converts carbon monoxide (CO) to carbon dioxide (CO<sub>2</sub>). The activated charcoal removes odors, taste and fluorocarbons.

A pressure maintaining/non-return valve is provided downstream from the purification system to ensure that a 2000 psig pressure build-up occurs in the cylinders during compressor start-up. This provides for optimum filtering, moisture separation, and prevents compressed air return from the charged air storage flasks to the compressor during unit shutdown.

A manual condensate drain valve is located on the bottom of the separator cylinder and a relief valve is mounted on top. A system bleed off valve is located next to the pressure maintaining valve.

The P-2 purification system is rated to process 40,000 cubic feet of free air at 70°F. Maximum air flow is 40 cubic feet per minute (cfm) of free air at 5000 psig. The manufacturer provides a correction factor to assist in determining the service life of the cartridge when operated at other than 70°F. Figure 2 is a line graph of the correction factors.

### B. COMPRESSOR

The compressor used for this test was a Bauer K-20 four-cylinder, four-stage, reciprocating, air-cooled unit. The compressor is rated to deliver 20 cfm of free air at 5000 psig.

## III. TEST PROCEDURE

The Bauer Purification System's instruction pamphlet<sup>3</sup> was used to conduct an initial inspection of the equipment to ensure receipt of all parts and material. Inspection consisted of verifying that all instruments and controls were clearly and permanently marked, gauges were easily viewed, and controls easily operated.

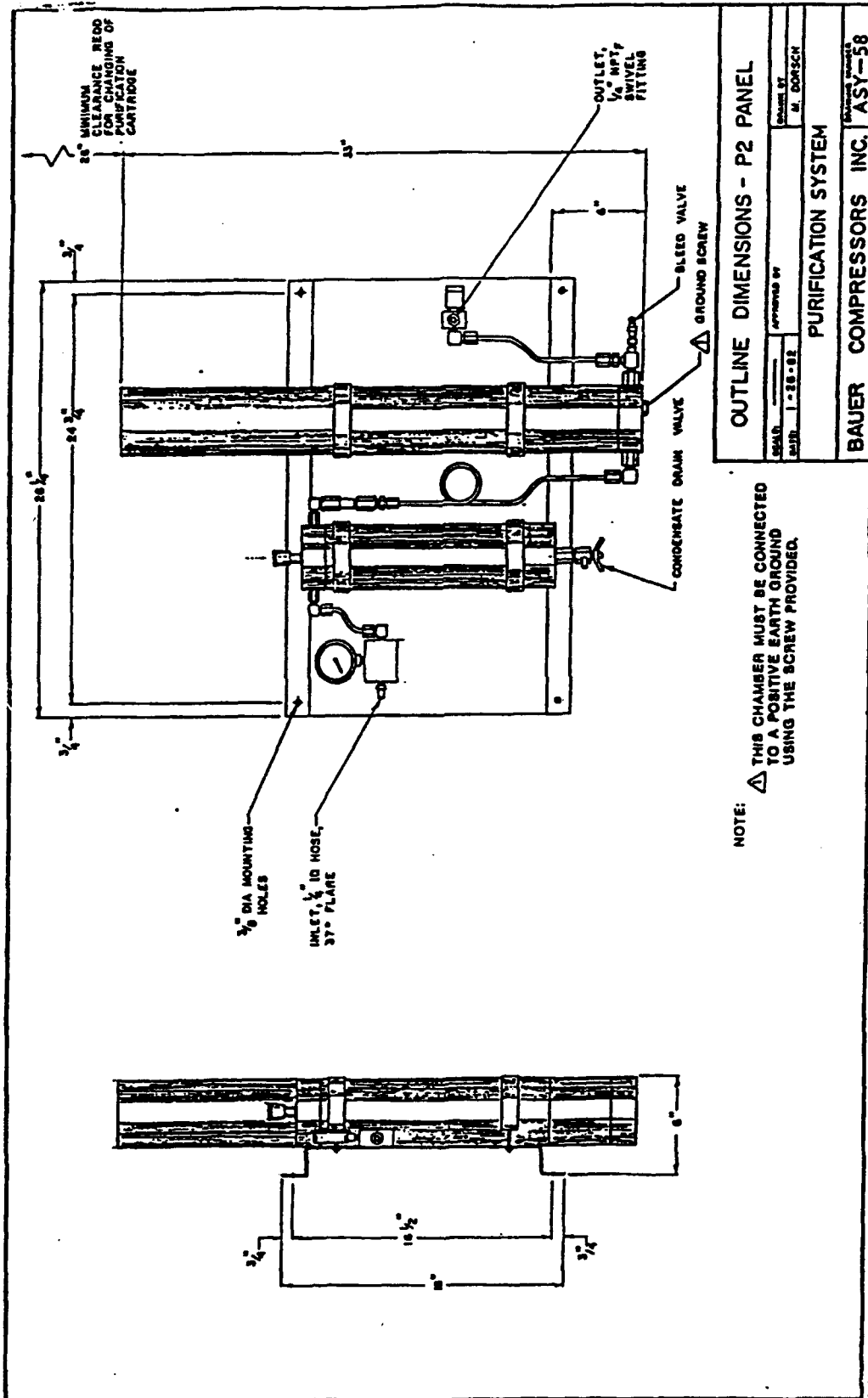


FIGURE 1: P-2 PURIFICATION PANEL VIEW

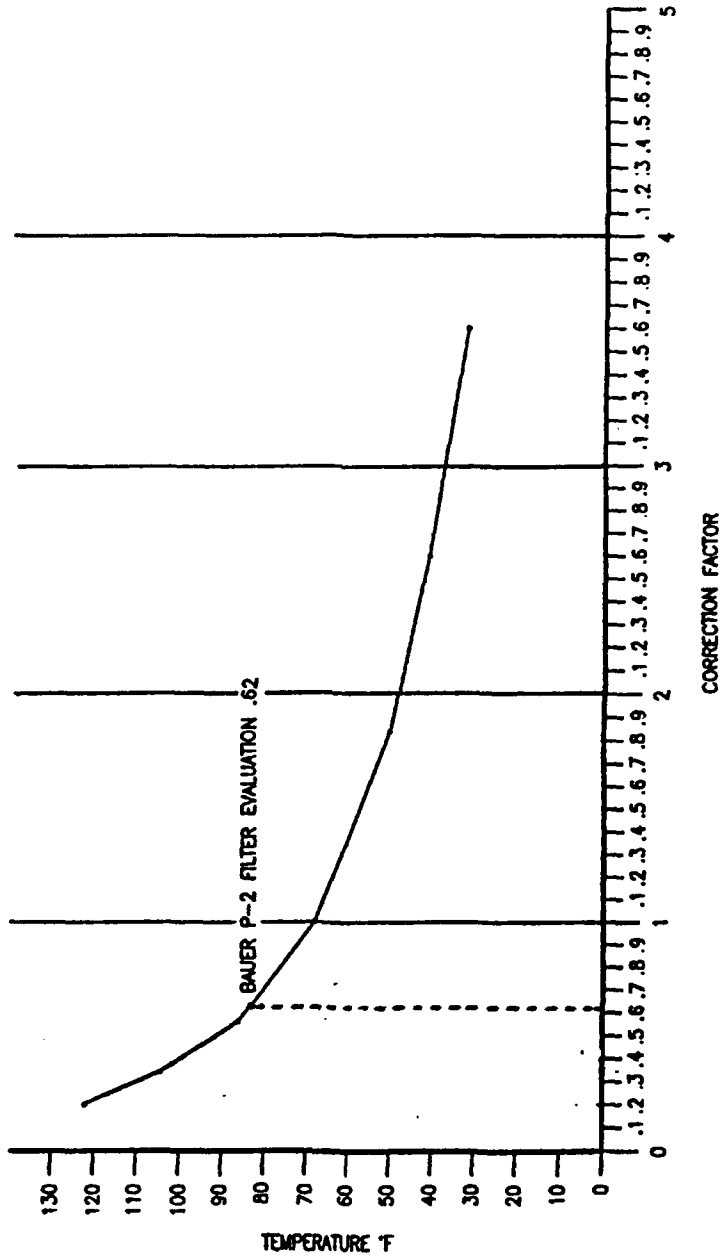


FIGURE 2: BAUER PURIFICATION SYSTEM AMBIENT TEMPERATURE CORRECTION

The compressor configured with the P-2 Purification system was operated at no load prior to starting the actual test. No load conditions were with the vents open and the back pressure valve set at 2000 psig. An air sample was taken at two hours.

The purification unit and ancillary equipment were set up in accordance with the test plan<sup>2</sup>. A line diagram of the test configuration is depicted in Figure 3. The unit was placed in an exterior work area open to ambient temperature but protected by an awning from direct weather. A Digitech HT series, model 5820 temperature monitor and two Yellow Springs Instruments, 6700 series thermistor probes were attached to measure compressor discharge and ambient temperatures. Ambient temperatures were recorded on an hourly basis and averaged each day and again for the overall test period. This overall test period average was used to determine the manufacturer's correction factor in order to calculate corrected life expectancy of the purification cartridge. A Cole Parmer humidity indicator, model 3310-20 was mounted near the compressor unit and the humidity recorded hourly. An MSA Toxgard carbon monoxide (CO) monitor with a flow range from 350 to 900 cc per minute was used to analyze compressor discharge air samples before and after the purification system. One hundred percent nitrogen (N<sub>2</sub>) and 101 parts per million (ppm) CO in air were used to calibrate the monitor on a daily basis. The gases were fed through a Victor Equipment Co. 4000 psig manual regulator to a Fischer/Porter flow meter and into the monitor sensor. Carbon monoxide was introduced directly into the compressor intake through a Victor Equipment Co. 4000 psig manual regulator and Fischer/Porter flow meter. The introduction of CO was adjusted to maintain 50 ppm at the entrance of the filtration system. The compressor and purification system were operated daily to charge four 2250 cubic inch floodable volume cylinders. The four cylinders were interconnected to simulate one large air flask. When 2000 psig flask pressure was reached the vent was adjusted to allow the compressor to maintain the 2000 psig while continuously running. An arrangement of tubing provided a method to supply a gas sample from before or after the filter to the CO monitor. Shifting from clean side to contaminated side of the purification system was done approximately every 30 minutes to allow the monitor time to settle out between readings. Hourly CO readings are in Appendix A.

After five hours of operation, the unit was secured with 1500 psi in the volume tanks. All vents, flowmeters, and blowdown valves were closed. The unit remained secured until 0700 the following day. The pressure drop was less than 100 psig and was considered insignificant when temperature differentials were considered.

The NEDU test plan<sup>2</sup> contains the pass/fail criteria used during the evaluation. Appendix A is the test log and contains the recorded data.



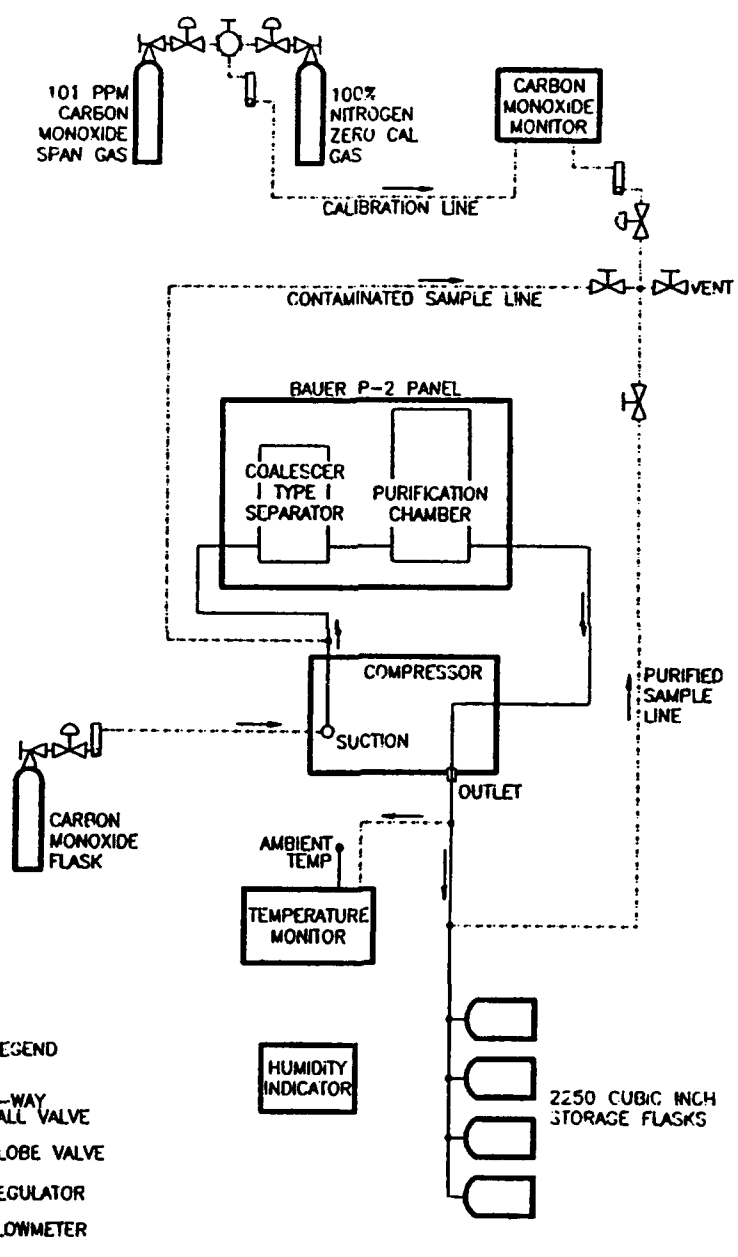


FIGURE 3: BAUER P-2 TEST CONFIGURATION

#### IV. ENDURANCE TEST RESULTS

Total volume of processed air was verified by charging from 1000 to 2000 psig daily. The following parameters were recorded throughout the 26 hours of operation:

- |                             |                                 |
|-----------------------------|---------------------------------|
| (1) Date                    | (9) Amperage                    |
| (2) Time                    | (11) Compressor oil level       |
| (3) Total meter hours       | (12) Compressor oil pressure    |
| (4) Total test hours        | (13) Discharge line pressure    |
| (5) Ambient Humidity        | (13) Discharge line temperature |
| (6) Ambient Temperature     | (14) CO before filter           |
| (7) Engine oil pressure     | (15) CO after filter            |
| (8) Engine head temperature |                                 |

The volume of air delivered and the time to achieve that volume was logged daily (Appendix A). The purification system processed a total of 33,135 cubic feet of air. Using the correction factor provided by the manufacturer, the total cubic feet of air processed equaled 133% of the expected active life of the purifier cartridge. The data collected provided a complete operational and maintenance log for this test and was the basis for computing and evaluating all the test results.

NOTE: On days one and two of the test, the charge rate times were excessive and the throttle was adjusted on the diesel engine to increase the speed and CFM.

Air samples were taken from the purification system discharge at test hours 2, 15 and 26 for purity analysis by Naval Coastal System Center Laboratory, Code 5130. Results are located in Appendix B. All samples were within established limits<sup>4</sup> until the 26 hour sample.

Maintenance consisted of a new purification cartridge, No. 058827, being installed prior to commencing the test. All gauges and indicator readings were checked and considered to be within normal limits. No other maintenance was required.

#### V. CONCLUSIONS

1. The BAUER P-2 Purification System delivers acceptable breathing air at a capacity which exceeds the manufacturer's specifications.
2. The unit is sturdy and readily maintained.
3. The BAUER P-2 Purification System removes carbon monoxide from contaminated air sources and delivers air of a quality that exceeds required purity standards<sup>4</sup> until the 26 hour sample.
4. The BAUER P-2 Purification System is suitable for use by the U.S. Navy.

## VI. RECOMMENDATIONS

The Vendor and NAVSEA should be contacted prior to purchase to ensure the unit meets the user's needs.

If the user is concerned about CO contamination of an air supply, the incorporation of a CO analyzer in conjunction with a purification system should be considered, and is highly recommended by NEDU.

## VII. REFERENCES

1. NAVSEA Task 91-002; Evaluation of commercially available filters for high pressure and low pressure breathing air.
2. NEDU Test Plan No. 91-24 Bauer P-2 Purification system Evaluation.
3. Bauer Compressors Inc. P-2 Purification System Instruction Pamphlet dated November 11 1989 BAUER Compressors Inc 1326 Azalia Garden Road Norfolk Va 23502.
4. U.S. Navy Diving Manual, Vol. 1, NAVSEA 0994-LP-001-9010, Air Purity Standards revision 2 December 15 1988 paragraph 5.3.2.

APPENDIX A  
TEST LOG  
BAUER P-2 PANEL MOUNTED  
PURIFICATION SYSTEM EVALUATION

1991 DATE	DIESEL ENGINE						COMPRESSOR							
	REAL TIME	TOTAL METER HOURS	TOTAL TEST HOURS	AMBIENT HUMIDITY	AMBIENT TEMPERATURE	OIL PRESSURE	ENGINE HEAD TEMPERATURE	AMPERAGE	OIL LEVEL	OIL PRESSURE	DISCHARGE LINE PRESSURE	DISCHARGE LINE TEMPERATURE	CARBON MONOXIDE BEFORE FILTER	CARBON MONOXIDE AFTER FILTER
7-16 0930	105.2	00.0	83.8°F	80%	100	160°F	0	FULL	825	2000	66.0°F	0 PPM	0 PPM	
7-16 1000	105.7	00.30	89.2°F	67%	90	160°F	0	FULL	850	2000	83.5°F	0 PPM	0 PPM	
7-16 1030	106.2	01.00	89.8°F	60%	90	160°F	0	FULL	750	2000	98.2°F	85 PPM	0 PPM	
7-16 1100	106.7	01.30	91.9°F	59%	90	160°F	0	FULL	800	2000	99.1°F	52 PPM	0 PPM	
7-16 1100	SHUT DOWN THE TESTING FOR LUNCH													
7-16 1230	106.7	01.30	85.8°F	74%	90	160°F	0	FULL	850	2000	86.7°F	53 PPM	0 PPM	
7-16 1300	107.2	02.00	91.3°F	64%	90	160°F	0	FULL	800	2000	95.3°F	56 PPM	0 PPM	
7-16 1100	CAPTURED A FILTER DISCHARGE AIR SAMPLE FOR ANALYSIS													
7-16 1330	107.7	02.30	91.2°F	64%	90	160°F	0	FULL	850	1525	98.7°F	58 PPM	0 PPM	
7-16 1330	SECURED TESTING FOR THE DAY													
COMMENTS														
0900 CALIBRATED THE CARBON MONOXIDE MONITOR														
THE COMPRESSOR MOISTURE SEPARATORS AND THE FILTER PANEL COALESCING FILTER MUST BE BLOWN DOWN EVERY 15 MINUTES														
1000 CHARGE RATE WAS TAKEN. IT TOOK 20.4 MINUTES TO CHARGE FROM 1000 PSIG TO 2000PSIG...COMPRESSOR SPEED WAS INCREASED														
1325 CHARGE RATE WAS TAKEN. IT TOOK 19.6 MINUTES TO CHARGE FROM 1000 PSIG TO 2000PSIG...COMPRESSOR SPEED WAS INCREASED AGAIN.														
AVERAGE TEMPERATURE FOR 7-16 - 89.0°F AIR PROCESSED FOR 7-16--18.3 CFM X 1.5 X 60 = 1647 TOTAL CUBIC FEET														



APPENDIX A  
TEST LOG  
BAUER P-2 PANEL MOUNTED  
PURIFICATION SYSTEM EVALUATION

1991 DATE	REAL TIME	TOTAL METER HOURS	TOTAL TEST HOURS	AMBIENT HUMIDITY	AMBIENT TEMPERATURE	DIESEL ENGINE			COMPRESSOR					
						OIL PRESSURE	ENGINE HEAD TEMPERATURE	AMPERAGE	OIL LEVEL	OIL PRESSURE	DISCHARGE LINE PRESSURE	DISCHARGE LINE TEMPERATURE	CARBON MONOXIDE BEFORE FILTER	CARBON MONOXIDE AFTER FILTER
7-18	0630	115.2	10.0	91%	78.5°F	90	150°F	+5	FULL	850	2000	79.2°F	0 PPM	0 PPM
7-18	0730	116.2	11.0	89%	80.3°F	90	150°F	+5	FULL	850	1900	89.5°F	52 PPM	0 PPM
7-18	0830	117.2	12.0	97%	76.3°F	90	150°F	+5	FULL	850	2100	79.3°F	58 PPM	0 PPM
7-18	0930	118.2	13.0	85%	79.6°F	90	150°F	+5	FULL	850	2050	88.5°F	42 PPM	0 PPM
7-18	1030	119.2	14.0	78%	83.3°F	90	150°F	+5	FULL	850	2050	93.5°F	44 PPM	0 PPM
7-18	1130	120.2	15.0	79%	81.0°F	90	150°F	+5	FULL	850	2100	89.8°F	50 PPM	0 PPM
7-18	1230	121.2	16.0	75%	83.4°F	90	150°F	+5	FULL	850	2050	91.9°F	48 PPM	0 PPM
7-18	1330	122.2	17.0	74%	84.3°F	90	150°F	+5	FULL	850	2100	93.9°F	46 PPM	0 PPM
7-18	1430	123.2	18.0	73%	86.0°F	90	150°F	+5	FULL	850	2100	95.6°F	54 PPM	0 PPM
COMMENTS														
0700 CALIBRATED CARBON MONOXIDE MONITOR														
0730 CHARGE RATE WAS TAKEN. IT TOOK 15.7 MINUTES TO CHARGE FROM 1000 PSIG TO 2000 PSIG														
AIR PROCESSED 7-18 = 22.8 CFM X 8 X 60 = 10944														
AIR PROCESSED TO DATE = 10944 CF + 11007 CF = 21951 TOTAL CUBIC FEET														
AVERAGE TEMPERATURE FOR 7-18 = 81.4°F														

APPENDIX A  
TEST LOG

BAUER P-2 PANEL MOUNTED  
PURIFICATION SYSTEM EVALUATION

1991 DATE	REAL TIME	TOTAL METER HOURS	TOTAL TEST HOURS	AMBIENT HUMIDITY	AMBIENT TEMPERATURE	DIESEL ENGINE			COMPRESSOR					
						OIL PRESSURE	ENGINE HEAD TEMPERATURE	AMPERAGE	OIL LEVEL	OIL PRESSURE	DISCHARGE LINE PRESSURE	DISCHARGE LINE TEMPERATURE	CARBON MONOXIDE BEFORE FILTER	CARBON MONOXIDE AFTER FILTER
07-19	0630	123.2	18.0	89.0%	79.5°F	100	150°F	+5	FULL	870	2050	79.2°F	48 PPM	0 PPM
07-19	0730	124.2	19.0	82%	77.7°F	90	150°F	+5	FULL	860	2050	87.8°F	51 PPM	0 PPM
07-19	0830	125.2	20.0	96%	74.1°F	90	150°F	+5	FULL	860	2100	81.4°F	52 PPM	0 PPM
07-19	0930	126.2	21.0	89%	80.6°F	90	150°F	+5	FULL	850	2050	85.8°F	46 PPM	0 PPM
07-19	1030	127.2	22.0	76%	85.6°F	90	150°F	+5	FULL	850	2100	85.3°F	56 PPM	0 PPM
07-19	1130	128.2	23.0	70%	85.4°F	90	150°F	+5	FULL	850	2000	95.3°F	49 PPM	+2 PPM
07-19	1230	129.2	24.0	72%	84.9°F	90	150°F	+5	FULL	850	2100	94.8°F	54 PPM	+2 PPM
07-19	1330	130.2	25.0	69%	87.3°F	90	150°F	+5	FULL	860	2150	96.4°F	54 PPM	+7 PPM
07-19	1430	131.2	26.0	69%	86.4°F	90	150°F	+5	FULL	860	2050	95.3°F	56 PPM	+22PPM

COMMENTS

0700 CALIBRATED CARBON MONOXIDE MONITOR  
 AVERAGE TEMPERATURE FOR 7-19 = 82.3°F  
 ADDED 1 PT 9250 TO DIESEL ENGINE.  
 1035 CHARGE RATE WAS TAKEN. IT TOOK 15.4 MINUTES TO CHARGE FROM 1000 PSIG TO 2000 PSIG  
 AIR PROCESSED 7-19 = 22.3 X 8 X 60 = 11184 TOTAL CUBIC FEET AIR PROCESSED FOR TEST= 11184 + 21951 CF = 33135 TOTAL CUBIC FEET  
 OVERALL AVERAGE AIR TEMP = 83°F ± .62 CORRECTION FACTOR 40,000 X .62 = 24800 EXPECTED LIFE =33% OVER EXPECTED LIFE  
 TOTAL AIR PROCESSED DURING THIS TEST WAS 133% OF "CORRECTED" EXPECTED CARTRIDGE LIFE



## APPENDIX B

Memorandum

17 July 1991

To: Dave Sullivan, NEDU  
 From: G. Deason, Code 5130

Subject: Analysis of air sample from NEDU test #91-24. Bauer  
 P-2 panel mounted purification system evaluation.  
 Two hour sample.

1. In accordance with your request, the air sample delivered to the gas analysis lab was analyzed and found to contain:

Component	Sample
Oxygen	21%
Nitrogen	78.1%
Argon	0.9%
Carbon Dioxide	439 PPM
Carbon Monoxide	<0.5 PPM
Total Hydrocarbons*	2.3 PPM
Total Halogens**	<0.5 PPM
Methane	2.3 PPM
Acetylene	<0.1 PPM
Acetone	<0.1 PPM
Freon 113	<0.1 PPM
Methyl Ethyl Ketone	<0.1 PPM
Ethylene	<0.1 PPM
Toluene	<0.1 PPM
Benzene	<0.1 PPM
Formaldehyde	<0.1 PPM
C4+	<0.1 PPM

\*Expressed as methane equivalents.

\*\*Expressed as methyl chloride equivalents.

2. The above sample showed no appreciable contamination; all components were within the acceptable range of the U.S. Navy Diver's Air Purity Standards.



Glen Deason  
 Chemist

APPENDIX B

Memorandum

19 July 1991

To: Dave Sullivan, NEDU  
 From: G. Deason, Code 5130

Subject: Analysis of air sample from NEDU test #91-24. Bauer  
 P-2 panel mounted purification system evaluation.  
 Fifteen hour sample.

1. In accordance with your request, the air sample delivered to the gas analysis lab was analyzed and found to contain:

Component	Sample
Oxygen	21%
Nitrogen	78.1%
Argon	0.9%
Carbon Dioxide	496 PPM
Carbon Monoxide	1.6 PPM
Total Hydrocarbons*	1.6 PPM
Total Halogens**	<0.5 PPM
Methane	1.6 PPM
Acetylene	<0.1 PPM
Acetone	<0.1 PPM
Freon 113	<0.1 PPM
Methyl Ethyl Ketone	<0.1 PPM
Ethylene	<0.1 PPM
Toluene	<0.1 PPM
Benzene	<0.1 PPM
Formaldehyde	<0.1 PPM
C4+	<0.1 PPM

\*Expressed as methane equivalents.

\*\*Expressed as methyl chloride equivalents.

2. The above sample showed no appreciable contamination; all components were within the acceptable range of the U.S. Navy Diver's Air Purity Standards.



Glen Deason  
 Chemist

## APPENDIX B

Memorandum

22 July 1991

To: Dave Sullivan, NEDU  
 From: Glen Deason, Code 5130

Subject: Analysis of Air Sample from NEDU test #91-24. Bauer  
 P-2 panel mounted purification system evaluation.  
 Twenty five hour sample.

1. In accordance with your request, the air sample delivered to the gas analysis lab was analyzed and found to contain:

Component	Results
Oxygen	21%
Nitrogen	78.1%
Argon	0.9%
Carbon Dioxide	365 PPM
Carbon Monoxide	46.0 PPM
Total Hydrocarbons*	1.6 PPM
Total Halogens	<0.5 PPM
Methane	1.6 PPM
Ethane	<0.1 PPM
Acetone	<0.1 PPM
Acetylene	<0.1 PPM
Methyl Ethyl Ketone	<0.1 PPM
Freon 113	<0.1 PPM
Benzene	<0.1 PPM
Toluene	<0.1 PPM
C4+	<0.1 PPM

\*Expressed as methane equivalents

2. The above sample showed appreciable contamination; all components were not within the acceptable range of the USN Diver's Air Purity Standards.

  
 Glen Deason  
 Chemist