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NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 01-91

EVALUATION OF MAKO 5436 HIGH PRESSURE BREATHING AIR COMPRESSOR

GEORGE D. SULLIVAN

NAVY EXPERIMENTAL DIVING UNIT

91 3 12 142

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

IN REPLY REFER TO:

NAVSEA TASK 91-003

NAVY EXPERIMENTAL DIVING UNIT

REPORT NO. 01-91

EVALUATION OF MAKO 5436 HIGH PRESSURE BREATHING AIR COMPRESSOR

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FEBRUARY 1991

Approved for public release; distribution unlimited

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

In response to reference (1) and as outlined in reference (2) the Navy Experimental Diving Unit (NEDU) tested the MAKO 5436 diesel powered high pressure, breathing air compressor from 1 Oct 89 to 14 Feb 91. The purpose of this test was to determine if the equipment was suitable for use by the United States Navy (USN) diving community and if so, added to the Approved for Navy Use (ANU) Procurement List.The MAKO 5436 met manufacturers specifications for quanity of air produced with a quality which met or exceeded purity standards in reference (3).The design and engineering was determined to be adequate.With the inclusion of the recommendations in section V the MAKO 5436 compressor is considered suitable for USN requirements for compressors of this size and type.

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CONTENTS

ILLUSTRATIONS

I. INTRODUCTION

Two MAKO 5436 compressors were purchased by NEDU and evaluated as directed by reference (1). The test was to verify that the compressors discharged suitable breathing air and had a service life which satisfied the requirements for divers air supply compressors throughout the Navy. If satisfactory the MAKO model 5436 would be recommended for ANU, reference (2).

There are various methods of testing compressor capacities. For the purposes of this compressor test, NEDU chose testing consisting of charging a single 78.8 cubic foot (floodable volume) high pressure air flask from 0 to 2400 psig. This method closely simulates the use a compressor would experience in the field. To date the compressors have been operated a total of 236 hours. The testing included subjective evaluation of the system operation but did not include detailed mechanical review of the individual components of the system.

II. EQUIPMENT DESCRIPTION

A. GENERAL

The MAKO 5436 compressor (Figure 1) is a four stage, single acting, 90 degree Vee configuration, which provides complete primary balance.

Air enters the machine through a filter/silencer and is compressed by the first stage piston, after which it passes through cooler tubes to the second stage for further compression. Cooled again, the process is repeated through the third stage, after which it is cooled again before entering the final stage compression. After further cooling the air is delivered at the designed pressure to the system.

Cooling is by water through the jackets and passages, either from the mains or by a self contained, radiator cooled, system. Sea water cooling may be used for marine applications.

Drive is by either a flange mounted motor or by a v-belt transmission from a suitable power source, such as electric motor or internal combustion engine. For this particular installation the prime mover was a Baldor 75 horsepower, three phase 460/220 volt, electric motor. Rotational torque was transferred to the compressor by 5 v-belts.

Cylinders are bolted to the crankcase in a 90 degrees Vee formation and the second, third and fourth stage cylinders are fitted with liners.

Main bearings bushes, big end bearings halves and small end bearings are all replaceable.

First and second stage pistons are of conventional design and, the third stage has an integral piston and crosshead assembly. The fourth stage has a floating solid plunger fitted to a crosshead. All pistons are fitted with plain piston rings.

Multi-stage coolers are fitted after each compression stage and are maintained by four access doors. First, second and third stage coolers are fixed, while the fourth stage has a removeable tubestack.

All stage valves are of the flat plate, low lift, multi-ported type and combine both suction and delivery functions. Ease of access, one valve cover per cylinder and good flow characteristics are a feature of this reliable valve design.

B. LUBRICATION

The manufacturer recommends the compressor be "run-in" on normal mineral type oils (i.e. 2190 TEP) for approximately 100 hours, then accomplish an oil change to synthetic oil. One of the recommended synthetic oils is Anderol 500, which is stocked in the Federal Supply System.

A forced lubrication system is utilized, conveying oil to the big end and main bearings via a filter and crankshaft passages. The connecting rods are drilled to supply small end bearings/bushes. Oil is forced through the bearing clearance an thrown off the rotating crankshaft to ensure and adequate supply to cylinders, pistons and crossheads. Return flow oil is drawn through a strainer and excess pressure regulated by a spring loaded relief valve. Oil pressure is gauge indicated and sight feed glasses allow observation of the feed rate of the third and fourth stage mechanical lubricator.

The crankcase is filled through the filler fixing on the main bearing housing and the oil level is indicated in a sight glass on the crankcase end plate. The cylinder lubricator tank has a lifting cap on top for filling purposes, except when automatic top-up system is out fitted.

Lubricating oil to the recommended specification must be used at all times to ensure safe and efficient operation with minimum wear and protection against moist air corrosion. Recommendations are the result of extended research at Reavel Works and all responsibility for the use of an oil other than that recommended is placed on the purchaser and his oil supplier.

C. CONTROLS

For starting purposes, automatic or manual unloaders/drains are fitted to all stages. Automatic unloaders provide initial venting when starting and close as the compressor attains operational speed, opening again for condensate draining when the machine is shut down.

A timer may be incorporated in the unloading circuit to effect timed drainage (compatible with environmental and operating conditions). High humidity requires more frequent draining.

Pressure safety valves are fitted at each stage.

Oil and air pressure gauges for each stage are mounted on a common panel.

Low oil pressure and high temperature switches are standard equipment.

A bursting disc is installed to relieve excessive pressure build up or freezing water in the water passages. Excessive pressure or freezing will rupture specified pressure disc to relieve internal pressure.

III. TEST PROCEDURE RESULTS

The compressor was received and set up in accordance with the manufacturer's instructions, reference (3). The unit was installed in the Ocean Simulation Facility (OSF) high pressure air system. APPENDIX A contains the complete test plan and the pass/fail criteria used during the evaluation. APPENDIX B is the test log and contains the recorded data.

A. ENDURANCE TEST

The compressors have been successfully operated for a total of 236 hours to charge the OSF high pressure air system per APPENDIX A.

The following parameters were recorded:

1. Date.
2. Start Time.
3. Stop Time.
4. Hour Meter Reading.
5. Oil level.
6. Remarks.

B. CHARGE RATES

The volume of air delivered and the time to achieve that volume was logged. 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. Compressor charge rate for the air flasks used during the test is as follows:

TIME	TOTAL VOLUME	CHARGE RATE
161 MINUTES 50 SECONDS	12944 CUBIC FEET	80.00 CFM

C. OIL CONSUMPTION

At the beginning of the test the oil sump was filled with 2190 TEP as per the manufacture's break-in recommendations. Oil level was monitored during operations and consumption logged. During 236.2 hours of operation, the compressors each consumed approximately five quarts of oil. Average consumption was 0.04 pints per hour and is considered acceptable. An oil change was accomplished (as per manufacturer's recommendations) at 112 hours of compressor operation. The oil used for the change was Anderol 750.

D. AIR SAMPLING

The results of air samples taken at 2 hours, 6 months and 12 months of operation are shown in APPENDIX D. The air compressed by these compressors has been used to supply numerous SDV operations, SCUBA dives and used to pressurize the OSF on 12 separate saturation dives. Prior to each saturation dive gas samples were taken on the air system and OSF complex. All samples were within limits established by reference (4).

E. MAINTENANCE

Scheduled maintenance was performed in accordance with the manufacturer's instructions and consisted of a lubricating oil change and cylinder inspection at 112 hours of operation. The MAKO 5436 compressor unit was easily maintained. The maintenance manual for the compressor is considered adequate.

IV. CONCLUSIONS

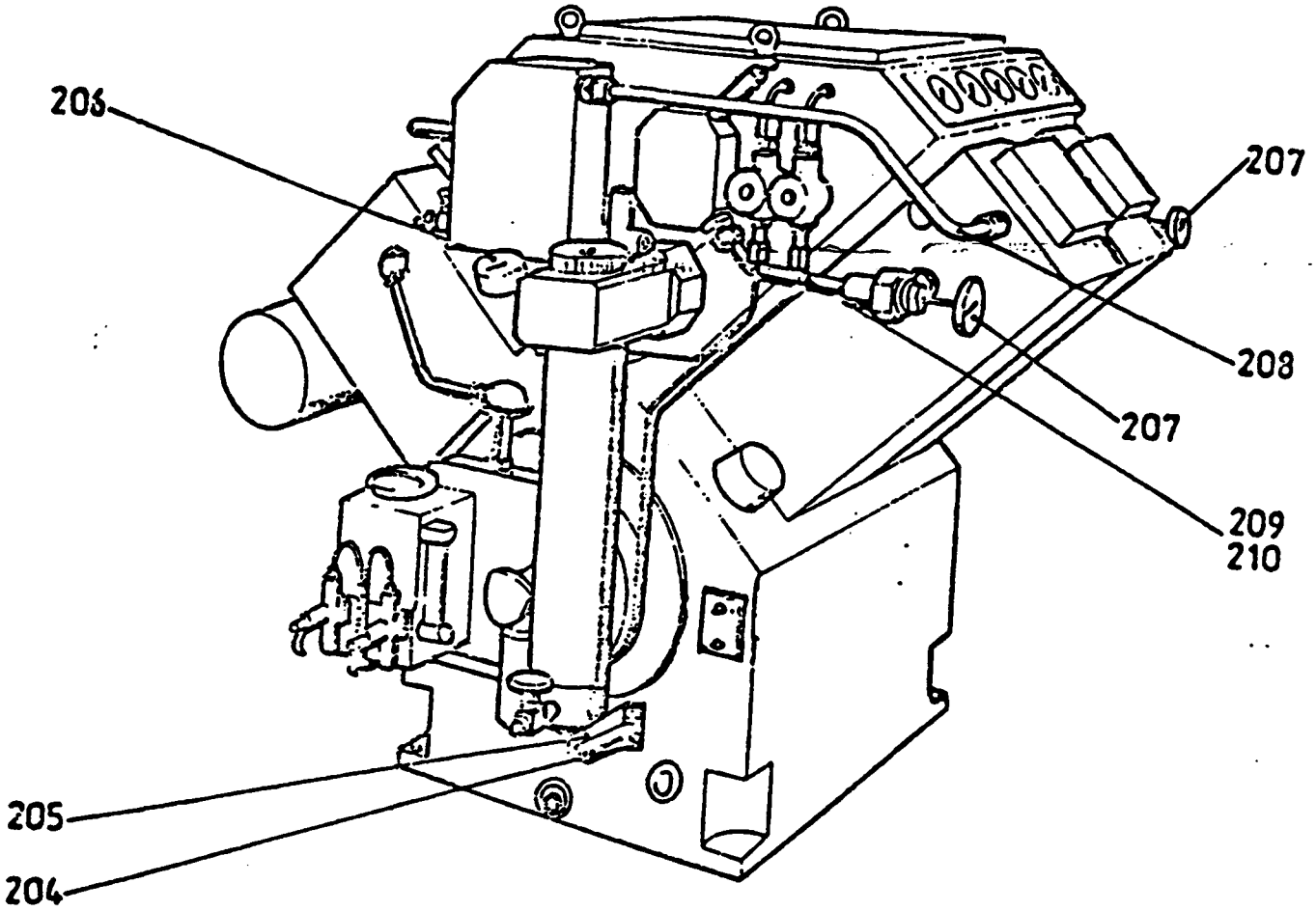
Evaluation of the MAKO 5436 compressor revealed the following:

1. The MAKO 5436 compressor delivers acceptable breathing air at a charge rate and volume which meet's or exceeds the manufacture's specifications.

2. The unit is sturdy, reliable and readily maintained

3. The operating and maintenance manuals for the compressor are adequate.

4. The MAKO 5436 compressor is suitable for use by the US. NAVY.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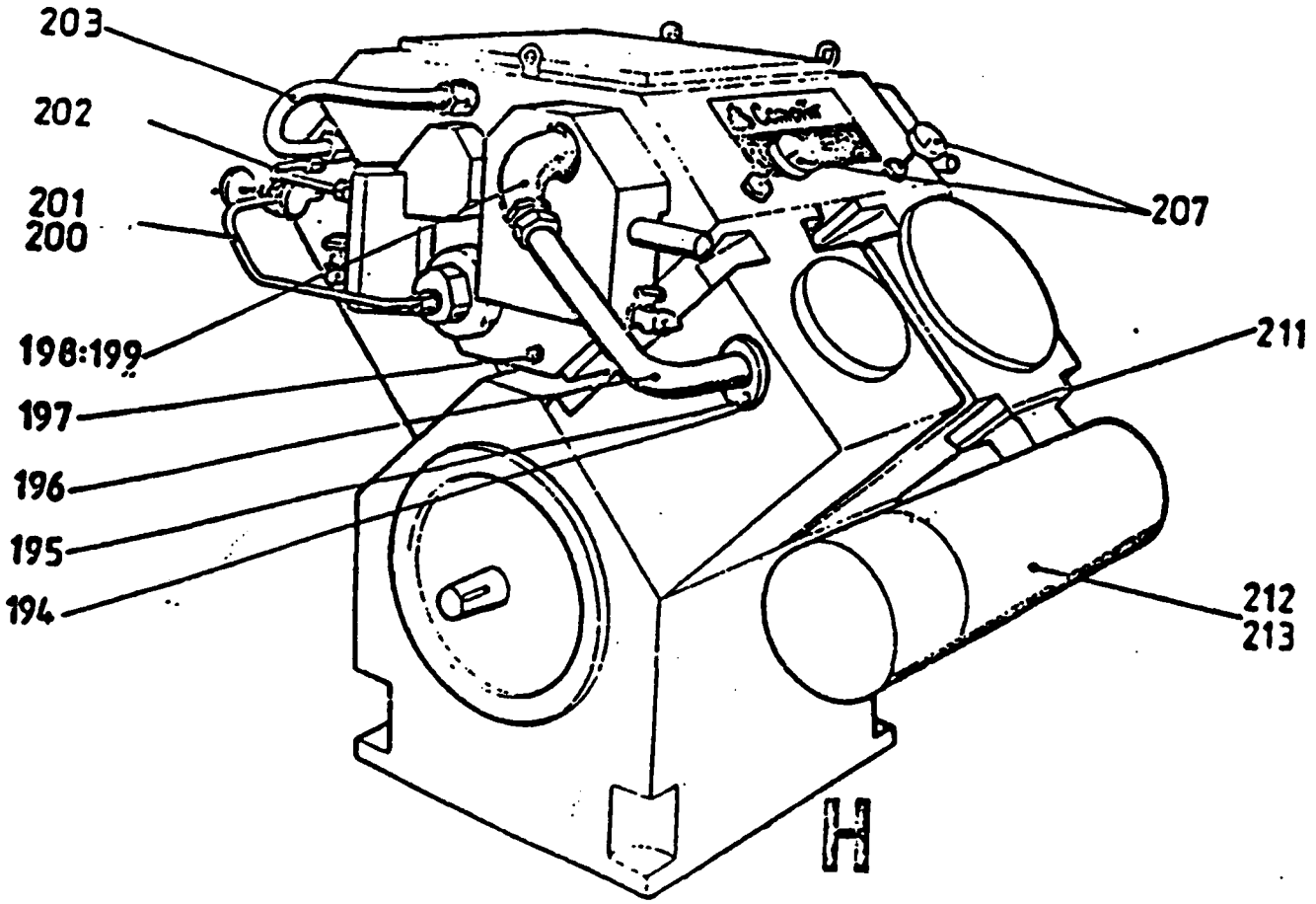
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ITEM NO	DESCRIPTION	NO. OFF	PART NUMBER	SUPPLIED WITH
194	SECOND STAGE SUCTION FLANGE JOINT	1	C.200118	224
195	SCREW	4	95000/0284	
196	SECOND STAGE SUCTION PIPE WITH FLANGE AND UNIONS	1	C.200099	
197	CORROSION ROD complete	1	U.753C	
198	ELBOW	1	95405/0008	
199	NIPPLE	1	95414/0168	
200	FOURTH STAGE DELIVERY PIPE WITH UNIONS	1	C.200100	
201	FOURTH STAGE DELIVERY PIPE WITH UNIONS AND POCKET (if fitted)	1	C.200101	
202	FOURTH STAGE SUCTION PIPE WITH UNIONS	1	C.200102	
203	WATER TRANSFER PIPE	1	C.200103	
204	SCREW	4	95000/0282	
205	BRACKET	1	C.200111/S	
206	FINAL DELIVERY TEMPERATURE GAUGE (if fitted)	1	98268/1007	
207	FIRST, SECOND, THIRD AND FOURTH STAGE TEMPERATURE GAUGES (if fitted)	4	98288/1005	
208	THIRD STAGE SUCTION PIPE WITH UNIONS	1	C.200104	
209	THIRD STAGE DELIVERY PIPE WITH UNIONS	1	C.200105	
210	THIRD STAGE DELIVERY PIPE WITH UNIONS AND POCKET (if fitted)	1	C.200106	
211	FIRST STAGE SUCTION FLANGE JOINT	1	PS.1813/20	224
212	SUCTION FILTER/SILENCER with item 213 (standard)	1	98262/1010	
213	SUCTION FILTER/SILENCER ELEMENT (standard)	1	98262/1015	

V. REFERENCES

1. NAVSEA Task 91-003; Evaluation of commercially available divers air compressors.

2. Authorized for Navy Use NAVSEAINST 10560.2

3. MAKO publication number 5436/VHP36, for Model 5436 Electric Drive High Pressure Air Compressor.

4. NAVSEA 0994-LP001-9010, U S Navy Diving Manual Vol 1 Para 5.3.2. Air purity standards.

5. Test Plan Number 91-04; Operational Evaluation of Divers High Pressure Air Compressor.

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

IN REPLY REFER TO:

NAVSEA Task 91-003

Except as directed [illegible] changes will be made only

NAVY EXPERIMENTAL DIVING UNIT

STANDARD TEST PLAN

EVALUATION OF MAKO MODEL 5436 HIGH PRESSURE AIR COMPRESSOR

TEST PLAN NUMBER: 91-04

JANUARY 1991

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RECORD OF CHANGES

Except as provided for herein, changes will be made only on the authority of the Commanding Officer, NEDU. A dark vertical line in the left-hand margin indicates the coverage of change.

CHANGE NO.	AUTHORITY	INSERTION	SECTION	INITIAL

TABLE OF CONTENTS

TABLE OF CONTENTS

References:

(a) NAVSEA Task 91-003 Evaluation of Commercially Available Divers Air Compressors.
(b) Mako Publication Number 5436/VHP36, for Model 5436 Electric Drive High Pressure Air Compressor
(c) NAVSEA 0994 - LP001-9010, US Navy Diving Manual Volume 1 paragraph 5.3.2 Air Purity Standards

1. Introduction. This test plan provides a series of procedures for standardized evaluation of commercially available divers high pressure air compressors. This test plan and it's associated report are to document results obtained from 16 months of service specifically for the two Mako model 5436 compressors that have been installed in the OSF since October 1989. These compressors have been evaluated and data compiled during 236 hours of operation to determine their suitability and reliability; and possible approval for Navy use (ANU).

Reference (a) directed NEDU to "Survey the commercial domestic market to determine if currently available high and low pressure compressors are applicable for fleet use. If applicable obtain compressor systems as required for evaluation. Make recommendations for inclusion on Approved for Navy Use (ANU) listings".

2. Test Parameters. Evaluation of the compressor will be conducted as follows:

a. Receipt of compressor at NEDU, Panama City.

b. Conduct inspection of compressor using manufacturer's instruction manuals references reference (b) to ensure all parts and material are received and on hand.

c. Using the manufacturer's technical manual reference (b) for the specific air compressor and its components, inspect for and determine if the following items exist and/or comply, and record results and comments in Annex A:

(1) All instruments and controls are clearly and permanently marked according to their functions.

(2) All controls, gauges and indicators necessary for operation of the compressor are visible and convenient to the operator.

(3) Safety devices are provided and audible and/or visual warning functions as specified.

(4) Liquid level indicators accurately display liquid level.

(5) All removable components can be removed and properly re-installed in working conditions using the manufacturer's operating manual i.e. filters.

(6) All drain, trap and safety valve discharge ports will function without splashing, are conveniently located, and are away from operating personnel.

d. Have all instrumentation provided by manufacturer compared and or calibrated, and accompanied with certification.

e. Conduct Testing in accordance with the procedures set forth in section 4.

3. Preliminary Arrangements

a. Arrange for air analysis to be conducted as required per reference (c).

b. Prior to the actual test procedure the air compressor system shall be operated then shut down when the system is at maximum pressure and the following steps accomplished.

(1) Hold pressure.

(2) Allow the system to cool to ambient temperature.

(3) After temperature has stabilized, record the storage flask pressure.

(4) After an eight hour period, record pressure again.

(5) Leak rate shall be zero.

4. Test Procedure. The following test procedures will be conducted as specified, and the results entered in the log sheets, Annex A.

a. Take air samples at hours 2 hours operation, regular PMS intervals and anytime air quality is questioned.

b. Log the following measurements on the log sheet Annex A.

(1) Date

(2) Start Time

(3) Stop Time

(4) Hour Meter Reading

(5) Compressor oil level

(6) Remarks

c. Compute volume output of the compressor by charging a 78.8 cubic foot (floodable volume) storage flask to 2400 psig. Log total charging time and calculate charging rate.

d. Oil consumption shall be measured and recorded during testing, with measurements and additions entered in the log.

e. Perform maintenance as required by the manufacturer's instruction manuals, reference (b).

5. Safety Rules and Emergency Procedures. Safety rules and precautions as outlined in the specific manufacturer's instruction manuals, reference (b).

6. Logistical Support. Air Analysis per reference (c).

7. Report Production. The test report will be written and prepared by the Test Director and submitted for approval to the Commanding Officer via the Task Leader. Estimated and publication date is six (6) weeks following completion of testing. Test Directors will be the point of contact for NEDU concerning this test and will be appointed by the Task Leader.

8. Termination Criteria. The following is Failure Criteria for the suitability for the specific compressor system for ANU:

(1) Failure of any component which cannot be corrected in accordance with the recommended schedule of maintenance.

(2) Failure of the diving air system to operate as specified by the manufacturer's instruction manuals.

(3) Failure of the valves to operate as specified.

(4) Failure of the pressure relief valves to operate as specified.

(5) A decrease in capacity of the compressor during this performance evaluation.

(6) A discharge air temperature from any cylinder in excess of manufacturer's specifications or recommendations.

(7) Failure of the air samples to pass breathing air specifications as listed in reference (e).

MAKO 5436

DATE	START	STOP	HOUR METER	OIL LEVEL	REMARKS

MAKO 5436 NUMBER 1

DATE	HOUR METER	OIL LEVEL	REMARKS
10/02/89	2340:05'00	FULL	
10/10/89	2345.01	FULL	
10/18/89	2348.8	7/8 FULL	
10/25/89	2351.0	3/4 FULL	
11/13/89	2353.5	3/4 FULL	
12/03/89	2363.2	3/4 FULL	
12/05/89			CHANGED OIL AND MOISTURE FILTER
12/28/89	2366.4	FULL	
12/29/89	2366.8	3/4 FULL	
01/02/90	2372.8	3/4 FULLL	
01/05/90	2373.6	3/4 FULL	
01/16/90	2379.1	3/4 FULL	
02/12/90	2385.5	3/4 FULL	
02/13/90	2393.5	2/3 FULL	
02/14/90		3/4 FULL	ADDED 1 QUART OF OIL
02/27/90	2407.2	1/2 FULL	
02/28/90	2411.1	1/2 FULL	ADDED 1 QUART OF OIL
03/06/90	2416.3	3/4 FULL	
03/08/90	2418.4	1/2 FULL	
03/08/90	2424.4	3/4 FULL	

MAKO 5436 NUMBER 1

DATE	START	STOP	HOUR METER	OIL LEVEL	REMARKS
04/04/90	0900	1100	2423.7	1/2 FULL	
04/06/90	1230	1600	2425.3	1/2 FULL	
04/09/90	0545	1400		1/2 FULL	
04/20/90	0850				
04/23/90	0605	1143	2452.9	1/2 FULL	
04/23/90	1505	1700	2454.2	1/2 FULL	
04/30/90	1320			1/2 FULL	
05/03/90	1206	1302	2457.2	1/2 FULL	
05/07/90	1430	1700	2458.1	1/2 FULL	
05/09/90	1625	2463.1	24607	1/2 FULL	
05/15/90	1230	2565.4	2467.1	1/2 FULL	
05/16/90	1225			1/2 FULL	
05/23/90	0830		2467.5	1/2 FULL	
05/24/90	0845		2471.2	1/2 FULL	
05/29/90	0715		2478.0	1/2 FULL	
05/30/90	1300		2480.6	1/2 FULL	
06/21/90	1335		2481.5	1/2 FULL	
06/22/90	0920		2482.0	1/2 FULL	
07/06/90	0715		2483.6	1/2 FULL	
07/09/90	0635		2484.9	1/2 FULL	
07/11/90	0400	1930	2493.2	3/4 FULL	ADD TWO QUARTS OF OIL
07/12/90	0650	1450	2499.8	OK	

MAKO 5436 NUMBER 1

DATE	START	STOP	HOUR METER	OIL LEVEL	REMARKS
07/13/90	0730	1108	2502.9	OK	
07/16/90	0655			OK	
07/17/90	0800	1101	2507.1	OK	
07/17/90	1320	0255	2517.8	OK	
07/18/90	0330	1230	2521.6	SAT	
07/18/90	1330	1429	2521.9	SAT	
07/19/90	0630	0715	2522.5	SAT	
07/19/90	1240	1522	2525.2	SAT	
07/20/90	0615	0806	2577	SAT	
07/23/90	0815	1400	2529	SAT	
07/24/90	0830	1400	2530	SAT	
07/25/90	0855	0925	2531	SAT	
07/26/90	0710	0850	2532.8	SAT	
07/30/90	1320			SAT	
08/02/90	1130	1700	2534.3	SAT	
08/06/90	0528	0646	2535.1	SAT	
08/06/90	1249	1330	2535.7	SAT	
08/07/90	0537	0615	2536.2	SAT	
08/07/90	0822	0900	2536.7	SAT	
08/08/90	0849			SAT	
08/09/90	0540	0620	2537.7	SAT	
08/10/90	0710	0800	2538.3	SAT	

MAKO 5436 NUMBER 1

DATE	START	STOP	HOUR METER	OIL LEVEL	REMARKS
08/14/90	0750	0800	2538.5	SAT	
08/20/90	1100			SAT	
08/22/90	0730		2501.1	SAT	
08/24/90	0710	0910	2542.3	SAT	
08/27/90	1040			SAT	
08/28/90	1345	1410	2543.7	SAT	
08/31/90	1730	1813	2544.4	SAT	
09/10/90	1635	1705	2544.8	SAT	
09/13/90	0545	0600	2545.1	OK	TEST
09/14/90	1755	1822	2545.5	OK	
09/18/90	1920	1940	2545.8	OK	
09/20/90	1040	1100	2546.2	OK	
09/21/90	1248	1307	2546.5	OK	
09/23/90	2240	2300	2546.9	OK	
09/28/90	0740	0857	2548.5	OK	JAM
10/01/90	1405	1510	2549.5	OK	
10/02/90	0650	0820	2550.8	OK	
10/02/90					CHANGED OIL & H20 SEP FIL
10/04/90	0955	1115	2552.2	OK	
10/04/90	1345	1440	2553.1	OK	
10/05/90	0649	1015	2555.9	OK	
10/09/90	1537	1634	2556.9	OK	

MAKO 5436 NUMBER 1

DATE	START	STOP	HOUR METER	OIL LEVEL	REMARKS
10/10/90	0740	0800	2557.2	OK	
10/11/90	1654	1720	2557.7	OK	
10/15/90	0836	0920	2558.5	OK	
10/22/90	0826	0925	2559.4	OK	
10/24/90	1505	1644	2561.1	OK	
10/25/90	0935	1007	2561.6	OK	
11/06/90	0715	1000	2561.6	OK	
11/13/90	0715			OK	
01/07/91	0920		2566.7	OK	
01/10/91	1323		2571.1	OK	
01/11/91	0715		2572.9	OK	ADD 1 QT OIL
01/14/91	1000	1100	2573.5	OK	
02/01/91	0710	0910	2575.8	OK	

MAKO 5436 NUMBER 2

DATE	HOUR METER	OIL LEVEL	REMARKS
10/18/89	1729.06	FULL	
10/22/89	1731.9	FULL	
11/13/89	1733.3	7/8 FULL	
12/04/89	1736.9	7/8 FULL	
12/5/89			CHANGED OIL AND MOISTURE FILTER
12/06/89	1741.6	FULL	
12/07/89		7/8 FULL	
12/08/89	1752.1	7/8 FULL	
12/09/89	1752.8	7/8 FULL	
02/12/90	1757.4	7/8 FULLL	
02/13/90	1765.6	1/2 FULL	
02/14/90		7/8 FULL	ADDED 2 QUARTS OF OIL
02/23/90	1777.6		
02/27/90	1779.0	1/2 FULL	
02/28/90	1781.0	1/2 FULL	
03/06/90	1788.4	3/4 FULL	ADDED 1 QUART OF OIL
03/08/90	1790.5	3/4 FULL	
03/08/90	1792.8		
04/04/90	1796.6	3/4 FULL	
04/06/90	1798.2	1/2 FULL	
06/06/90	1801.0	1/2 FULL	

MAKO 5436 NUMBER 2

DATE	START	STOP	HOUR METER	OIL LEVEL	REMARKS
04/06/90	1130	1600	1081.6	1/2	
04/09/90	0545	1400	1812.2	1/2	
04/18/90	-500	1030	1817.7	1/2	
04/23/90	1630	1950	1818.2	1/2	
05/07/90	1431	1818.4	1818.1	1/2	
05/09/90	1626	1819.1	1818.06	1/2	
05/16/90	1230	1420	1820.9	1/2	
05/18/90	0730	0900	1827.9	1/2	
05/24/90	0955			1/2	
05/28/90	0615	1000	1831.4	1/2	
06/04/90	1300	1445	1833.1	1/2	
06/05/90	0800	1015	1835.1	1/2	
06/11/90	0705	0850	1838.9	1/2	
06/21/90	1336	1000	1839.1	1/2	
06/22/90	0920		1839.6	1/2	
07/06/90	0715	0900	1841.2	1/2	
07/09/90	0635		1842.6	1/2	
07/11/90	0400	1930	1853.5	3/4	ADD 2 QT OF OIL
07/12/90	0655	1455	1860.1	OK	
07/12/90	0730	1105	1861.9	OK	
07/16/90				OK	
07/17/90	1320	0250	1875.9	OK	

MAKO 5436 NUMBER 2

DATE	START	STOP	HOUR METER	OIL LEVEL	REMARKS
07/18/90	0330	1230	1883.3	OK	
07/18/90	1330	1400	1883.7	OK	
07/19/90	0630	0715	1884.3	OK	
07/19/90	1240	1330	1889.9	SAT	HIGH TEMP CRUSED NOSE
07/19/90	1350	1522	1886.5	SAT	
07/20/90	0615	0800	1888.1	SAT	
07/23/90	0815	1515	1892.8	SAT	
07/24/90	0830	1330	1894.0	SAT	
07/25/90	0856	0956	1897.0	SAT	
07/26/90	0740	0850	1998.7	SAT	
07/30/90	1320			SAT	
08/02/90	1130	1155	1900.4		
08/06/90	0528	0646	1901.7	SAT	
08/06/90	1240	1404	1902.9	SAT	L/O
08/07/90	0537	0615	1903.4	SAT	
08/08/90	0850	0945	1904.3	SAT	
08/09/90	0540	0715	1905.4	SAT	
08/10/90	0710	0800	1905.9	SAT	
08/14/90	0750	0835	1906.7	SAT	
08/14/90	1350	1415	1907.1	SAT	
08/20/90	1106	1217	1908.1	SAT	
08/22/90	0730	1210	1913.2		

MAKO 5436 NUMBER 2

DATE	START	STOP	HOUR METER	OIL LEVEL	REMARKS
08/24/90	0710	0810	1914.6	SAT	
08/27/90	1040			SAT	
08/28/90	1345	1410	1916.0	SAT	
08/31/90	1730	1813	1916.8	SAT	
09/10/90	1635	1705	1917.1	SAT	
09/13/90	0545	0600	1917.6	OK	TEST
09/14/90	1755	1822	1918.0	OK	
09/18/90	1920	1940	1918.4	OK	
09/20/90	1040	1130		OK	
09/21/90	1248	1335	1920.3	OK	
09/23/90	2240	0013	1921.8	OK	
09/28/90	0740	0845	1922.9	OK	
10/01/90	1405	1510	1923.9	OK	
10/02/90	0650	0820	1925.4	OK	
10/02/90					CHANGED OIL AND FILTER
10/04/90	0955	1140	1927.3	OK	
10/04/90	1345	1440	1928.2	OK	
10/05/90	0645	1030	1931.0	OK	
10/09/90	1537	1630	1932.5	OK	
10/10/90	0740	0800	1932.8	OK	
10/11/90	1654	1714	1933.2	OK	
10/15/90	0835	0920	1934	OK	

MAKO 5436

DATE	START	STOP	HOUR METER	OIL LEVEL	REMARKS
10/22/90	0830	0925	1934	OK	
10/24/90	1505	1540	1935.5	OK	
10/25/90	0935	1007	1936.0	OK	
11/06/90	0715	0950	1936.0	OK	
11/14/90	0845	1138	1941.5	OK	
11/15/90	1000			OK	
11/19/90	0840		1948.3	OK	
01/07/91	0920	1314	1949.2	OK	
01/10/91	1323		1952.9	OK	
01/11/91	0715		1954.7		ADD 2 QT OF OIL
01/14/91	1000		1955.6	OK	
02/05/91	0710	0910	1957.6	OK	
02/11/91	1300	1430	1958.9	OK	
02/12/91	0715	1105	1962.7		

Memorandum 13 Oct 1989

To: ~~J. Schmitt~~ ENGINEERING/NEDU
From: Al Purer: Code 5130

Subject: Results of air sample from NEDU bottle* 71, 1800 psi.

1. In accordance with your request, on 13 Oct 1989 the air sample delivered to the gas analysis lab was analyzed and found to contain:

Component	Air Sample
Oxygen	21.0%
Nitrogen	78.1%
Argon	0.9%
Carbon Dioxide	361 PPM
Carbon Monoxide	0.7 PPM
Total Hydrocarbons*	3.3 PPM
Total Halogens**	<0.5 PPM
Methane	3.4 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
2-Methy-1-Pentene	0.5 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.

Al Purer
Chemist

TMC
Technical Micronics Control Inc.
210 Wynn Drive, N.W.
P.O. Box 1330
Huntsville, Alabama 35807
Phone (205) 837-4480

TECHNICAL MICRONICS CONTROL, INC.
ANALYTICAL REPORT

TO:

COMMANDING OFFICER
NAVAL EXPERIMENTAL DIVING UNIT
BLDG 327, ATTN: MC STEVENS
PANAMA CITY, FL 32407-5001

TMC LOG NO: 20030NS-1
DATE SHIPPED:Feb 15, 1990
DATE RECEIVED:Mar 16, 1990
DATE REPORTED:Mar 19, 1990
ACTIVITY CODE:N146
KIT I.D. NO:061

HP

Sampling time in minutes:3 MINUTES18 SECONDS

Gas #: 123 Source:#2 HPAC
Ambient #: 124 Source:Open air
Filter #: H127

ANALYSIS REQUESTED	SPECIFICATION FOR GAS	RESULTS OF INVESTIGATION		
		Ambient	Gas	
Oxygen	20-22% by Volume	21.0	21.7	%
Carbon Dioxide	1,000 ppm Max.	377	339	ppm
Carbon Monoxide	20 ppm Max.	<5	<5	ppm
Methane	----	---	---	ppm
Total Hydrocarbon as Methane	----			ppm
Total Hydrocarbon - other than Methane	25 ppm Max.	<5	<5	ppm
Particulate and Oil Mist	5 mg/m3 Max.		0.18	mg/m3
Odor and Taste	Not objectionable	not obj	not obj	

This is to certify that the above referenced sample does meet the air purity standards for compressed breathing air per NAVSEA 0994-LP-09010.

Analysis performed by: J.V, J.W

Approved for Distribution: Bharti Ujjani

Bharti Ujjani, Laboratory Director

TMC
Technical Micronics Control Inc.
210 Wynn Drive N.W.
P.O. Box 1389
Huntsville, Alabama 35807
Phone (205) 837-4430

TECHNICAL MICRONICS CONTROL, INC.
ANALYTICAL REPORT

TO:

COMMANDING OFFICER
NAVAL EXPERIMENTAL DIVING UNIT
BLDG 327, ATTN: MC STEVENS
PANAMA CITY, FL 32407-5001

TMC LOG NO: 20030NS-2
DATE SHIPPED:Feb 15, 1990
DATE RECEIVED:Mar 16, 1990
DATE REPORTED:Mar 19, 1990
ACTIVITY CODE:N146
KIT I.D. NO:061

HP

Particulate & Oil Mist Sample: 12 SCFM
Sampling time in minutes:3 MINUTES18 SECONDS

Gas #: 044 Source:#1 HPAC
Ambient #: Source:not used
Filter #: H037

ANALYSIS REQUESTED	SPECIFICATION FOR GAS	RESULTS OF INVESTIGATION		
		Ambient	Gas	
Oxygen	20-22% by Volume		21.2	%
Carbon Dioxide	1,000 ppm Max.		451	ppm
Carbon Monoxide	20 ppm Max.		<5	ppm
Methane	----		---	ppm
Total Hydrocarbon as Methane	----			ppm
Total Hydrocarbon - other than Methane	25 ppm Max.		<5	ppm
Particulate and Oil Mist	5 mg/m3 Max.		<0.09	mg/m3
Odor and Taste	Not objectionable		not obj	

This is to certify that the above referenced sample does meet the air purity standards for compressed breathing air per NAVSEA 0994-LP-09010.

Analysis performed by: J.V, J.W

Approved for Distribution: Bharti Ujjani
Bharti Ujjani, Laboratory Director

TMC

TECHNICAL MICRONICS CONTROL, INC.
ANALYTICAL REPORT

TO:

COMMANDING OFFICER
NAVAL EXPERIMENTAL DIVING UNIT
BLDG 327, ATTN: MC STEVENS
PANAMA CITY, FL 32407-5001

TMC LOG NO: 20030NS-3
DATE SHIPPED:Feb 15, 1990
DATE RECEIVED:Mar 16, 1990
DATE REPORTED:Mar 19, 1990
ACTIVITY CODE:N146
KIT I.D. NO:061

HP

Particulate & Oil Mist Sample: 12 SCFM
Sampling time in minutes:3 MINUTES18 SECONDS

Gas #: 114 Source:SCUBA charging connection
Ambient #: Source:not used
Filter #: H116

ANALYSIS REQUESTED	SPECIFICATION FOR GAS	RESULTS OF INVESTIGATION Ambient	Gas	
Oxygen	20-22% by Volume		21.0	%
Carbon Dioxide	1,000 ppm Max.		384	ppm
Carbon Monoxide	20 ppm Max.		<5	ppm
Methane	----		---	ppm
Total Hydrocarbon as Methane	----			ppm
Total Hydrocarbon - other than Methane	25 ppm Max.		<5	ppm
Particulate and Oil Mist	5 mg/m3 Max.		<0.09	mg/m3
Odor and Taste	Not objectionable		not obj	

This is to certify that the above referenced sample does meet the air purity standards for compressed breathing air per NAVSEA 0994 LP 09010.

Analysis performed by: J.V, J.W

Approved for Distribution: Bharti Ujjani

Bharti Ujjani, Laboratory Director

TMC
Technical Micronics Control, Inc.
210 Wynn Drive, N.W.
P.O. Box 1330
Huntsville, Alabama 35807
Phone: (205) 837-4430

TECHNICAL MICRONICS CONTROL, INC.
ANALYTICAL REPORT

TO:

COMMANDING OFFICER
NAVAL EXPERIMENTAL DIVING UNIT, DET OPS
BLDG 327, ATTN: R. A. WRENN
PANAMA CITY, FL 32407-5001

TMC LOG NO: 100001NS-2
DATE SHIPPED:Oct 1, 1990
DATE RECEIVED:Oct 5, 1990
DATE REPORTED:Oct 17, 1990
ACTIVITY CODE:N146
KIT I.D. NO:090

HP

Particulate & Oil Mist Sample: 12 SCFM
Sampling time in minutes:3 MINUTES18 SECONDS

Gas #: 095 Source:#1 HP compressor
Ambient #: 042 Source:Compressor intake
Filter #: H184

ANALYSIS REQUESTED	SPECIFICATION FOR GAS	RESULTS OF INVESTIGATION		
		Ambient	Gas	
Oxygen	20-22% by Volume	20.8	20.1	%
Carbon Dioxide	1,000 ppm Max.	425	469	ppm
Carbon Monoxide	20 ppm Max.	<5	<5	ppm
Methane	----	---	---	ppm
Total Hydrocarbon as Methane	----			ppm
Total Hydrocarbon - other than Methane	25 ppm Max.	<5	<5	ppm
Particulate and Oil Mist	5 mg/m3 Max.		0.27	mg/m3
Odor and Taste	Not objectionable	not obj	not obj	

This is to certify that the above referenced sample does meet the air purity standards for compressed breathing air per NAVSEA 0994-LP-09010.

Analysis performed by: J.V, J.W

Approved for Distribution: Bharti Ujjani
Bharti Ujjani, Laboratory Director

TMC
Technical Micronics Control, Inc
3110 Wynn Drive, N.W.
P.O. Box 1360
Huntsville, Alabama 35807
Phone (205) 837-4430

TECHNICAL MICRONICS CONTROL, INC.
ANALYTICAL REPORT

TO:

COMMANDING OFFICER
NAVAL EXPERIMENTAL DIVING UNIT, DET OPS
BLDG 327, ATTN: R. A. WRENN
PANAMA CITY, FL 32407-5001

TMC LOG NO: 100001NS-1
DATE SHIPPED:Oct 1, 1990
DATE RECEIVED:Oct 5, 1990
DATE REPORTED:Oct 17, 1990
ACTIVITY CODE:N146
KIT I.D. NO:090

HP

Particulate & Oil Mist Sample: 12 SCFM
Sampling time in minutes:3 MINUTES18 SECONDS

Gas #: 258 Source:#2 HP compressor
Ambient #: 106 Source:Compressor intake
Filter #: H102

ANALYSIS REQUESTED	SPECIFICATION FOR GAS	RESULTS OF INVESTIGATION		
		Ambient	Gas	
Oxygen	20-22% by Volume	20.6	20.8	%
Carbon Dioxide	1,000 ppm Max.	450	209	ppm
Carbon Monoxide	20 ppm Max.	<5	<5	ppm
Methane	----	---	---	ppm
Total Hydrocarbon as Methane	----			ppm
Total Hydrocarbon - other than Methane	25 ppm Max.	<5	<5	ppm
Particulate and Oil Mist	5 mg/m3 Max.		<0.09	mg/m3
Odor and Taste	Not objectionable	not obj	not obj	

This is to certify that the above referenced sample does meet the air purity standards for compressed breathing air per NAVSEA 0994-LP-09010.

Analysis performed by: J.V, J.W

Approved for Distribution: Bharti Ujjani

Bharti Ujjani, Laboratory Director

DESIGN DESIGNATION

Flange mounted motor driven machine 5436

V-belt driven machine, electric or internal combustion powered 5436

TECHNICAL DATA - GENERAL

Type ..... Single acting, four stage, 90° Vee

Cooling ..... Water

Direction of rotation, viewed from drive end ..... Anti-clockwise

Number of Valves ..... One combined suction and delivery per stage

Type of valve ..... Flat plate, low lift

Mounting ..... Three point, anti-vibration mounts

Lifting points ..... Three

TEMPERATURES

Minimum ambient temperature ..... 0°C (32°F)

Maximum compressor air intake temperature ..... 45°C (114°F)

Maximum cooling air temperature (radiator sets) ..... 30°C (86°F)

Maximum water inlet temperature ..... 37°C (99°F)

Temperature rise across machine ..... 10°C-12°C (18°F-22°F)

SPEEDS

Maximum speed ..... 1500 rev/min

Minimum speed ..... 725 rev/min

PRESSURES

Minimum working pressure ..... 140 bar (2030 lbf/in^2)

Maximum working pressure ..... 350 bar (5000 lbf/in^2)

Maximum water pressure ..... 5 bar (75 lbf/in^2)

Oil pressure ..... 2.1 bar (30 lbf/in^2)

LUBRICATION

Crankcase oil capacity ..... 45 litres(80 pints)

Cylinder lubricator capacity ..... 1.0 litre (1.7 pints)

Cylinder lubricator feed rate (3 & 4 Stgs)..... 1 rev every 60 secs ± 10 secs

Recommended oil ..... Mobil Rarus 427

Recommended alternative ..... Shell Turbo T78

Recommended grease (for assembly) ..... Shell Alvania R3

++ Synthetic lubricants

** Carbonisation with these oils may be higher, in which case it may be advisable to reduce time between maintenance operations.

COOLING

Water	Mains or water pump circulation
Cooling water flow @ 15°C (59°F)	75 l/h/kw (12 gal/h/ohp)

INTERNAL DIMENSIONS

Piston stroke	75 mm (2.952 in)
First stage cylinder bore	185 mm (7.283 in)
Second stage cylinder bore	95 mm (3.740 in)
Third stage cylinder bore	45 mm (1.771 in)
Fourth stage cylinder bore	22 mm (0.866 in)

CONNECTIONS

First stage suction	Special flange adaptor Rp3 (3" bsp)
Fourth stage delivery	Rp½ (½" bsp)
Water inlet	Rp1 (1" bsp)
Water outlet	Rp1 (1" bsp)

WATER TEST PRESSURES

First stage cooler	7.6 bar (110 psig)
Second stage cooler	42 bar (610 psig)
Third stage cooler	200 bar (2900 psig)
Fourth stage cooler	525 bar (7600 psig)
Water jacket	7.6 bar (110 psig)

UNIT WEIGHT (approx)

Bare machine	1000 kgs (2200 lbs)
Crankcase	230 kgs (500 lbs)
Cooler body	180 Kgs (400 lbs)

HIGHER AMBIENT AND WATER TEMPERATURES MAY BE ACCEPTABLE WITH RESTRICTIONS ON DUTY – REFER TO REAVELL WORKS

OIL RECOMMENDATIONS ARE BASED ON NORMAL CONDITIONS. IF DIFFICULTY IS EXPERIENCED A CHANGE MAY BE ADVISABLE – REFER TO REAVELL WORKS