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TEST AND EVALUATION OF MAKO HIGH-PRESSURE BREATHING AIR COMPRES--ETC(U)
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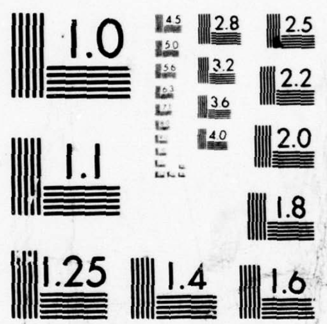

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EXPERIMENTAL DIVING UNIT
UNITED STATES NAVY

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

(14) NEDU-

NAVY EXPERIMENTAL DIVING UNIT
REPORT NO. 21-78

(6) **TEST AND EVALUATION OF MAKO HIGH-PRESSURE BREATHING AIR COMPRESSOR KA-51-DF.**

(10) D. E. DODDS

(11) December 1978

(12) 37 p.

(9) Test rept.

Approved for public release; distribution unlimited

Submitted:	Reviewed:	Approved:
D. E. DODDS	J. T. HARRISON	C. A. BARTHOLOMEW
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T&E Department	T&E Department Head	Commanding Officer

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

A diesel engine driven high-pressure breathing air compressor, MAKO model KA-51-DF, was evaluated by the Navy Experimental Diving Unit to determine its suitability for Navy use. Results of the 100-hour endurance test showed that the portable compressor delivers breathing air at an average charge rate of 4.8 CFM, charging twin 71.2 cu. ft. and twin 90 cu. ft. scuba tanks in 25 and 31 minutes respectively. The unit is easily maintained, sturdily constructed, and economical in diesel fuel consumption. (Continued)

20. ABSTRACT--Continued

Modified to NEDU recommendations, the MAKO high-pressure breathing air compressor (KA-51-DFN) is recommended for placement on the list of equipment Approved for Navy Use (ANU).

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ABSTRACT

A diesel engine driven high-pressure breathing air compressor, MAKO model KA-51-DF, was evaluated by the Navy Experimental Diving Unit to determine its suitability for Navy use. Results of the 100-hour endurance test showed that the portable compressor delivers breathing air at an average charge rate of 4.8 CFM, charging twin 71.2 cu. ft. and twin 90 cu. ft. scuba tanks in 25 and 31 minutes respectively. The unit is easily maintained, sturdily constructed, and economical in diesel fuel consumption. Modified to NEDU recommendations, the MAKO high-pressure breathing air compressor (KA-51-DFN) is recommended for placement on the list of equipment Approved for Navy Use (ANU).

1. INTRODUCTION

1.1 OBJECTIVES

By direction of the Commander, Naval Sea Systems Command (reference 1), the MAKO high-pressure breathing air compressor, model KA-51-DF, was tested by the Navy Experimental Diving Unit to determine whether the compressor produces satisfactory breathing air and has a service life which meets the requirements of scuba diving activities throughout the Navy.

1.2 SCOPE

1.2.1 Compressor Operation

Compressor testing simulated field operation to intermittently fill scuba cylinders to 2250 psig and 3000 psig until a total 100 hours of compressor operation had been completed. The test included subjective operational evaluation but was not intended to incorporate detailed mechanical considerations.

1.2.2 Air Quality Analysis

Testing provided an analysis of air produced by the compressor.

1.3 BACKGROUND

The Experimental Diving Unit previously has evaluated several portable high-pressure air compressors (references 2 through 4). None were fully accepted. Mechanical failures in the compressor or prime mover, low capacity, or poor quality of breathing air produced, were cited as reasons for nonacceptance. At the time of this report, U.S. industry markets three portable high-pressure air compressors which have been Approved for Navy Use, all of which are gasoline engine driven.

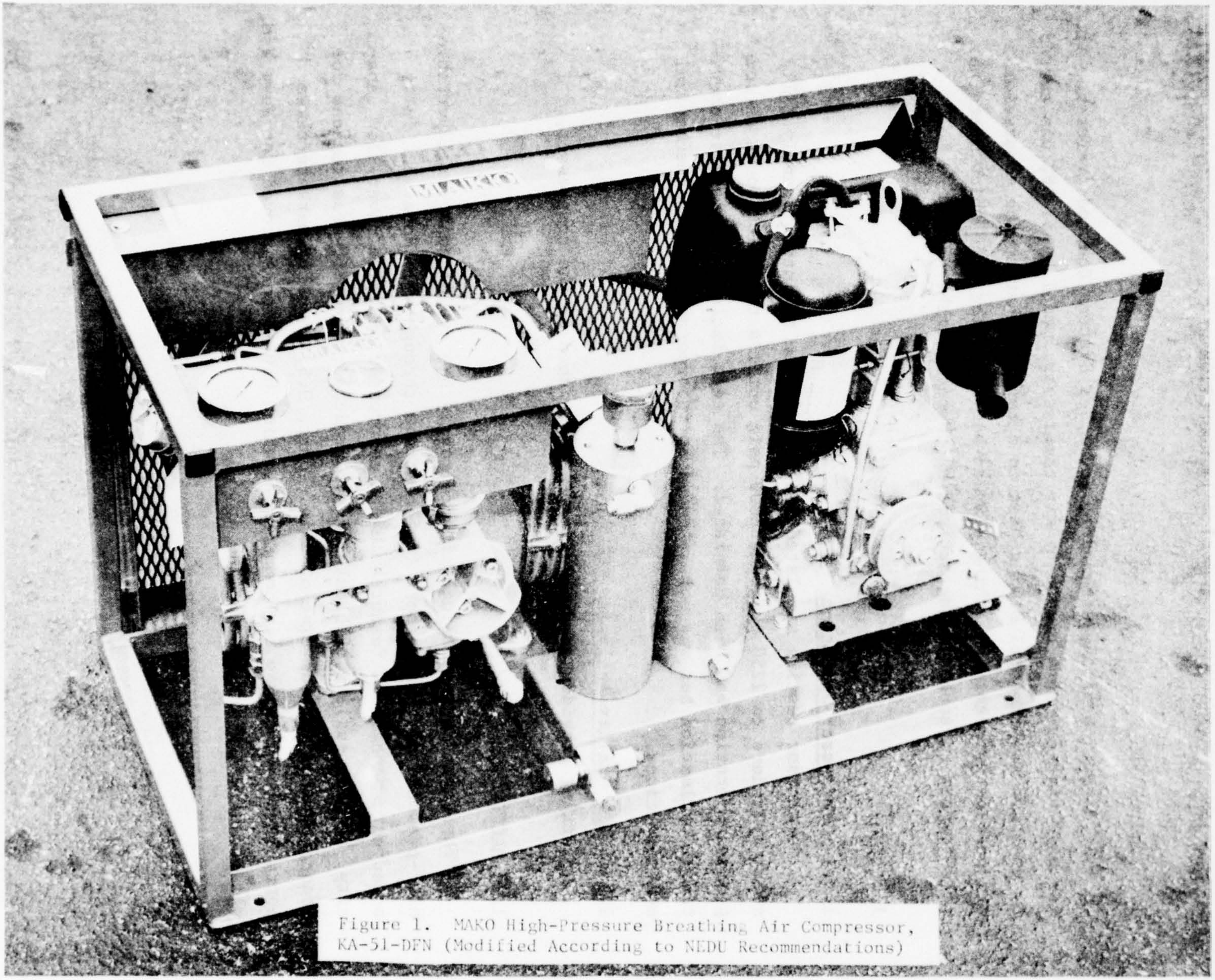

Figure 1. MAKO High-Pressure Breathing Air Compressor, KA-51-DFN (Modified According to NEDU Recommendations)

2. DESCRIPTION

2.1 GENERAL DESCRIPTION

The MAKO KA-51-DF high-pressure breathing air compressor (figure 1) is manufactured by MAKO Compressors Incorporated, 1634 S.W. 17th Street, Ocala, Florida 32670.

2.1.1 Air Compressor

The air compressor is a portable, three-stage, reciprocating piston, high-pressure machine that delivers breathing air to fill air receptacles at a rated volume of 140 liters per minute (5 CFM) at 3200 psi.

2.1.2 Prime Mover

The prime mover for the air compressor is a four-cycle, single cylinder, L-head diesel engine which, according to the manufacturer's rating, produces 6 hp at 3600 rpm. The compressor, engine, and filling hose are interconnected and comprise an integrated high-pressure compression system mounted on a square metal framework.

2.1.3 Purification System

Modified in accordance with NEDU recommendations, the compressor was equipped with a MAKO MK-1-C purification system, consisting of a moisture separator and purifier with replaceable cartridge. At an operating temperature of 80°F and compressor output of 300 CFH, the cartridge has a rated life span of 24.5 hours.

2.2 FUNCTIONAL DESCRIPTION

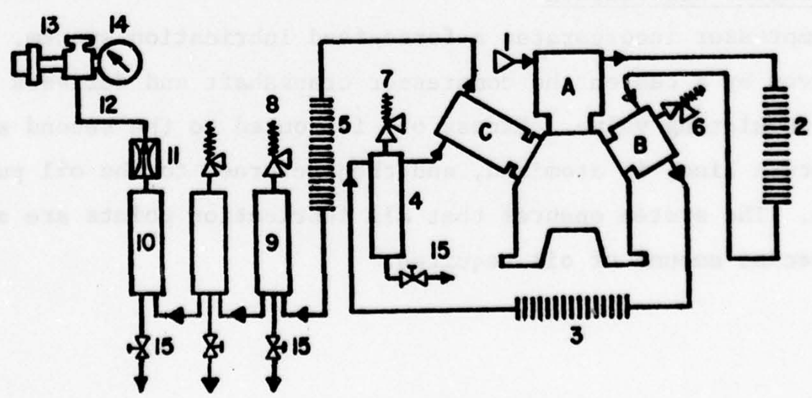

Figure 2. Compressor Air Flow

2.2.1 Compressor Air Flow (Figure 2)

Air is taken into the compressor through the micronic intake filter (1) and flows to stage 1 (A). The stage 1 piston compresses the air to approximately 87 psi before it enters the second cylinder stage (B). Prior to entering stage 2, air is cooled by intercooler (2) to nearly ambient temperature. (All intercoolers and cylinders are located in the direct flow of the axial fan.) The second stage piston then compresses the air to approximately 650 psi. Air then flows to intercooler (3) and intermediate filter (4), which cleanses the air of oil and water. The sintered metal filter of intermediate filter (4) also traps other foreign matter such as solid particles, chips, etc. The precleaned air enters stage 3 (C). Stage 3 compresses the air to its final pressure of approximately 3260 psi. Leaving stage 3, the air flows through aftercooler (5) where it is again cooled to approximately 10° to 15°C above ambient temperature. Each compressor stage is protected by a safety valve (6), (7), and (8). From aftercooler (5), the air flows through the final oil and water separator (9) where any remaining contaminating oil or water is removed. The precleaned air then flows through purifier (10), which has an activated charcoal cartridge which removes any oil vapor odor or moisture remaining. Condensate drain cocks (15) permit removal of accumulated moisture. Downstream of purifier (10) is the pressure maintaining valve (11) which ensures a minimum pressure in the purifier of approximately 1160 psi. The air then flows through the filling hose (12) to the filling valve (13) and pressure gauge (14), registering the pressure to the scuba cylinders being filled.

2.2.2 Compressor Lubrication

The compressor incorporates a force-feed lubrication system. The oil pump is driven by a cam on the compressor crankshaft and delivers oil through a pressure regulating valve. Excess oil is routed to the second stage cylinder by a return line, is atomized, and then returned to the oil pump for recirculation. The system ensures that all lubrication points are supplied with the precise amount of oil required.

2.3 PHYSICAL DIMENSIONS

Weight	280 pounds
Length	40 inches
Width	20 inches
Height	24½ inches

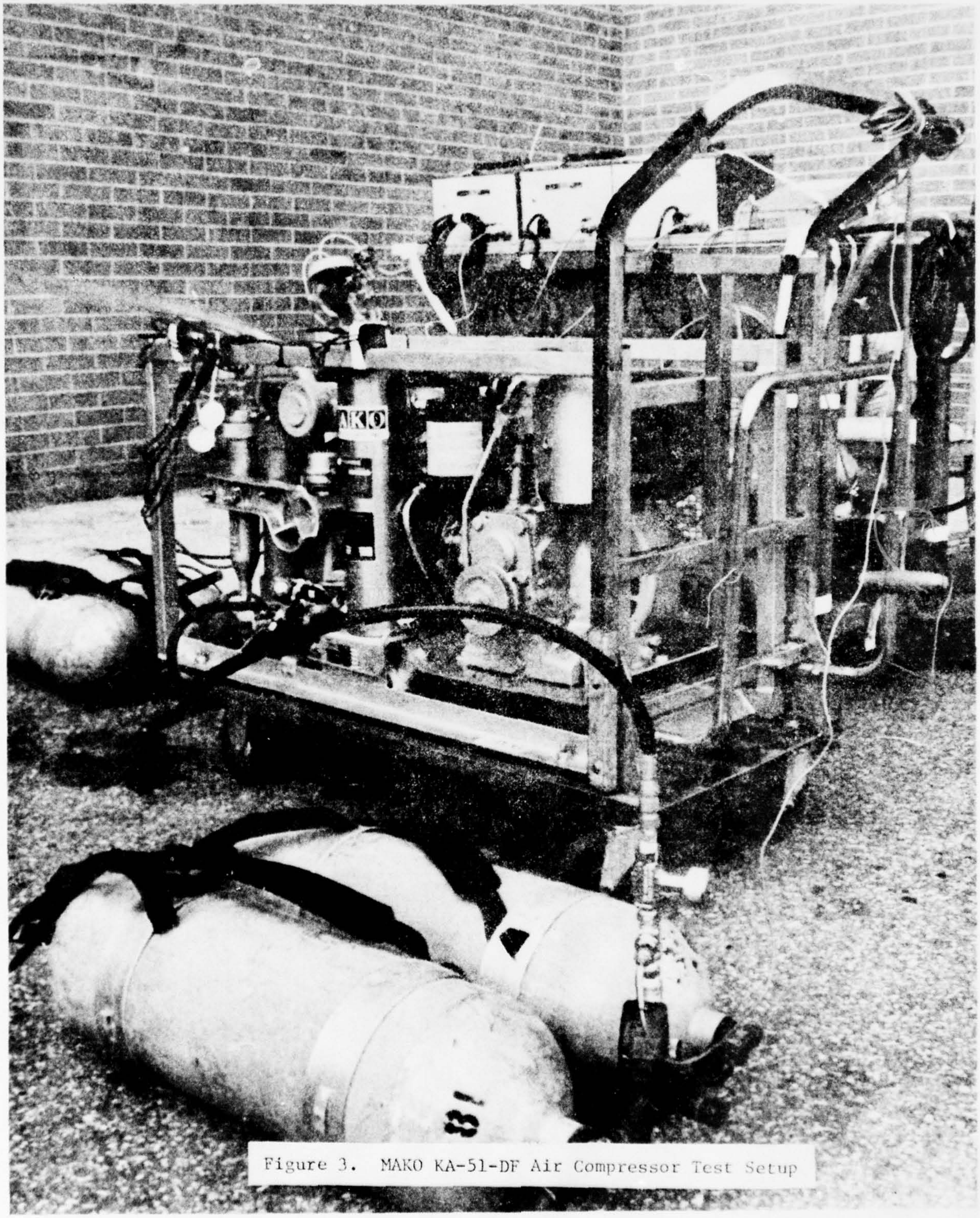

Figure 3. MAKO KA-51-DF Air Compressor Test Setup

3. TEST PROCEDURE

3.1 PRELIMINARY ARRANGEMENTS

A MAKO KA-51-DF air compressor (serial number 8/2090/6) provided by the manufacturer on a loan basis was received on 27 June 1978. The unit was prepared for operation in accordance with instructions in the manufacturer-furnished technical manual.

3.2 TEST PLAN

3.2.1 <u>Test Setup</u>

The compressor was set up as shown in figure 3. Test equipment was attached as shown schematically in figure 4. Appendix B describes the actual test plan and test equipment used.

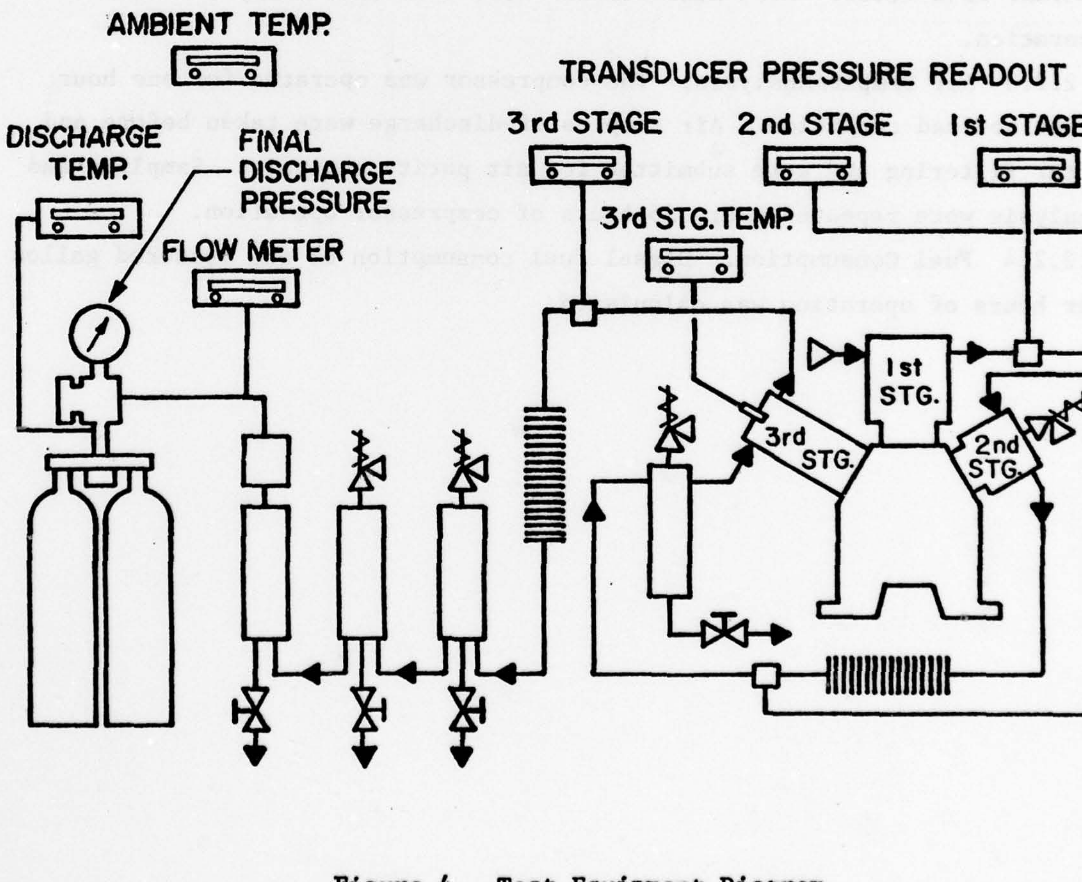

Figure 4. Test Equipment Diagram

3.2.2 <u>Test Parameters</u>

3.2.2.1 Endurance Test. The compressor was operated daily for 6 hours to alternately charge twin 72 cu. ft. and twin 90 cu. ft. scuba tanks until 100 hours of operation were logged. The following measurements were logged every five minutes of operation:

(a) First stage discharge pressure

(b) Second stage discharge pressure

(c) Third stage discharge pressure

(d) Final discharge pressure

(e) Ambient temperature

(f) Third stage discharge temperature

(g) Final discharge temperature

(h) Accumulated hours and minutes of operation

(i) Actual time

3.2.2.2 Flow Test. Flow rate was measured under no-load condition with laminar flow meter. Flow measurements were then made every 25 hours of operation.

3.2.2.3 Air Sample Analysis. The compressor was operated for one hour under no-load condition. Air samples of discharge were taken before and after filtering and were submitted for air purity analysis. Sampling and analysis were repeated every 25 hours of compressor operation.

3.2.2.4 Fuel Consumption. Diesel fuel consumption of one measured gallon per hours of operation was calculated.

4. RESULTS AND DISCUSSION

4.1 ENDURANCE TEST

4.1.1 Location

The unit was placed near a high bay work area with its air intake hose facing into the prevailing wind. Except for repositioning the air intake hose due to changing wind direction and the four hours of MAKO plant compressor operation, the test site remained unchanged.

4.1.2 Startup and No-Load Operation

Procedures outlined in the manufacturer's technical manual were followed to prepare the compressor for operation. A comparison of the unit with the requirements of enclosure 1 to reference 1 showed the compressor incorporated all essential features, except a flywheel safety cover.

4.1.3 Test Initiation

The 100-hour endurance test commenced on 11 August 1978. One and one-half hours of no-load operation were accomplished before dual charging of tanks commenced.

4.1.4 Charge Cycle

During its 100 operating hours, the compressor accumulated 174 charging cycles, alternately charging pairs of standard U.S. Navy 72 cu. ft. and 90 cu. ft. scuba tanks. Throughout compressor operation, data (as shown in paragraph 3.2.2.1) was recorded in the operational log every five minutes. Figure 5 is a typical log sheet, covering charge cycle number 80. Data derived from the log was used to graph each charge cycle (figure 6). The operational log and charge cycle graphs are filed in the NEDU library.

4.2 DATA COMPUTATION

4.2.1 Charge Cycle Data Summary

The charge cycle table (reference appendix C), summarizing test data points for each charge cycle, is the basis for computing and evaluating test results.

DATE	TIME	LOCATION	1ST STAGE PSI	2ND STAGE PSI	3RD STAGE PSI	AMBNT TEMP C°	DISCHG TEMP C°	TANK PSI	OPERATOR	TOTAL TIME RUN	REMARKS
Charge Cycle #80 8-30-78	0912	Inside High Bay	54	300	725	29.1	29.1	0	Dodds	46:09	35.6 Started Comp
	0915		58	340	1125	29.1	25.9	250	Dodds	46:12	60.6
	0920		57	340	1250	29.2	27.1	690	Dodds	46:17	68.9
	0925		57	330	1100	29.3	30.3	1100	Dodds	46:22	66.0 Drained Cond
	0930		60	360	1510	29.3	32.0	1560	Dodds	46:27	73.3
	0935		60	390	2000	29.6	32.7	2050	Dodds	46:32	81.1
	0940		64	420	2500	29.4	32.6	2520	Dodds	46:37	88.8 Drained Cond
	0945		65	440	3000	29.5	33.0	3000	Dodds	46:42	95.2
Charge Cycle #81	0947		55	300	600	29.7	29.2	0	Dodds	46:44	69.0 Shifted Flasks Drained Cond
6 Minute Reading	0953		56	310	710	29.6	30.4	600	Dodds	46:49	58.1
	0958		57	330	1000	29.7	32.2	1010	Dodds	46:54	62.6
	1003		60	360	1425	29.8	33.1	1480	Dodds	46:59	70.8 Drained Cond

Figure 5. Operational Log

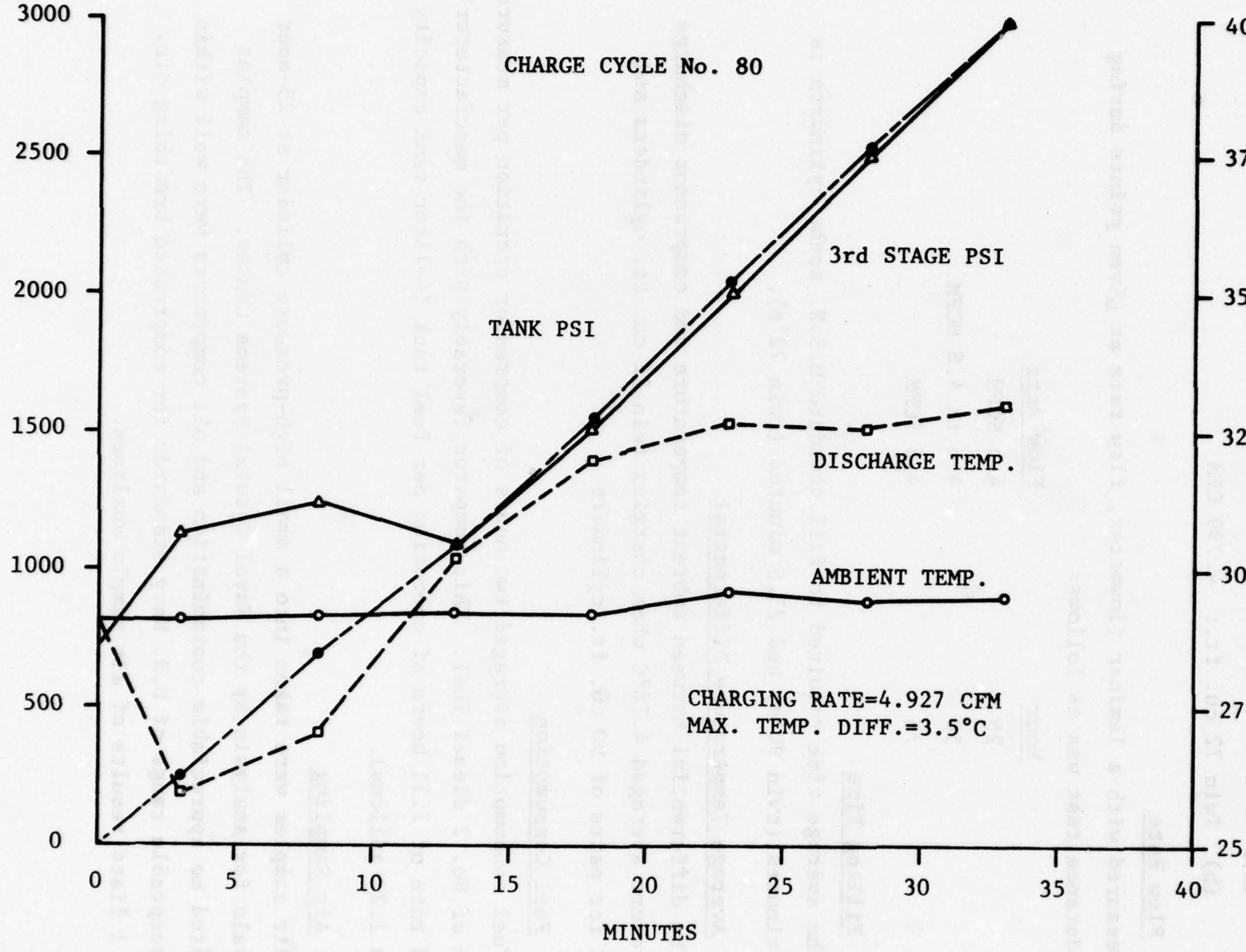

Figure 6. Charge Cycle Graph

4.2.2 Average Charge Rate

Average compressor charge rates for two types of scuba cylinders were as follows:

(a) Twin 90 cu. ft.: 4.83 CFM

(b) Twin 72 cu. ft.: 4.799 CFM

4.2.3 Flow Rate

Measured with a laminar flowmeter, flow rate at given points during the endurance test was as follows:

Hour	Flow Rate
25	4.5 SCFM
50	4.6 to 4.8 SCFM
75	4.6 SCFM

4.2.4 Filling Time

The average time required to fill standard U.S.N. scuba cylinders is 31.27 minutes (twin 90's) and 25.5 minutes (twin 72's).

4.2.5 Average Temperature Differential

The differential between ambient temperature and compressor discharge temperature averaged 4.18°C when charging twin 72 cu. ft. cylinders and 4.99°C for pairs of 90 cu. ft. cylinders.

4.2.6 Fuel Consumption

Fuel consumption averaged two hours of compressor operation per measured gallon of No. 2 diesel fuel. This compares favorably with the manufacturer's stated rate of 2.11 hours of operation per fuel tank (4-liter tank capacity equals 1.22 gallons).

4.2.7 Air Sampling

Air samples were taken into a small high-pressure cylinder at 25-hour intervals for analysis by the Naval Coastal Systems Center. The samples indicated no appreciable contamination and all components were well within the acceptable range of U.S. Navy standards for compressed breathing air. Table 1 lists results of air sample analyses.

Table 1. Results of Air Sample Analyses

COMPONENT AND CONTENT MEASUREMENT	STANDARDS FOR BREATHING AIR QUALITY		AIR SAMPLE ANALYSIS									
			No Load		25 hours		50 hours		75 hours		100 hours	
	US NAVY	ABCA (1)	BEFORE FILTER	AFTER FILTER	BEFORE FILTER	AFTER FILTER	BEFORE FILTER	AFTER FILTER	BEFORE FILTER	AFTER FILTER	BEFORE FILTER	AFTER FILTER
O_2/%	20 to 22%	21 + 1%	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0	21.0
N_2/%		Remainder	78.08	78.08	78.08	78.08	78.1	78.1	78.1	78.1	78.1	78.1
Ar/%			—	—	—	—	0.9	0.9	0.9	0.9	0.9	0.9
CO_2/ppm	1000 ppm	500 ppm	334.0	377.0	526.0	549.0	385.0	333.0	359.0	332.0	370.0	352.0
CO/ppm	20 ppm	10 ppm	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Total hydrocarbons/ppm (methane equivalents)	25 ppm (2)	25 ppm			3.1	1.6	4.7	3.1	6.6	5.9	1.5	1.4
Total halogens/ppm	1.0 ppm (3)				<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Methane/ppm			1.8	1.5	1.8	1.5	2.2	2.1	1.7	1.6	1.4	1.3
Ethane/ppb			1.8 ppm	<20.0 ppb	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0
Acetylene/ppb			<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0
Acetone/ppb			<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0
Benzene/ppb			<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0
C_4+/ppm			<0.6	<0.4	<0.5	<0.5	<0.5	<0.3	1.2	1.1	0.5	0.5
H_2O/ppm			—	—	—	—	—	—	345.0	395.0	—	—

(1) ABCA Naval Quadripartite Standard for Compressed Air
(2) Generally accepted OSHA limits
(3) Limits depend on OSHA limit fer the specific halogenic hydrocarbons detected

4.3 PURIFICATION SYSTEM

4.3.1 Failure of Moisture Separator

At hour 46 (29 August), during a routine check of the third-stage discharge filter, traces of water were detected in the filter housing. At hour 58 (31 August), investigation showed that the filter had become soaked with water and oil. The filter was replaced and less than an hour of operation later (hour 53, 4 September), traces of water and oil were detected in the filter and standing water had accumulated in the filter housing. At the same time, water was found in the scuba charging orifice while the charging hose was being removed from the scuba cylinders. A new filter cartridge was installed, and it became saturated with oil and water after six hours of operation (hour 59, 7 September). Replaced again, the filter cartridge failed after one hour and three minutes of operation (hour 61, 11 September), causing a temporary suspension of the test.

4.3.2 Installation of MAKO MK-1-C Purification System

On 19 September, the unit was returned to the manufacturer's plant in Ocala, Florida where a cyclonic moisture separator was installed. This modification, designated the MAKO MK-1-C Purification System, completely eliminated the moisture problem. No further problems were encountered throughout five hours of test operation at the MAKO plant and for the remainder of the endurance test.

4.4 MAINTENANCE

4.4.1 General

The KA-51-DF compressor is easily maintained. Scheduled maintenance is straightforward and requires a minimum of time.

4.4.2 Scheduled Maintenance

Performed according to the manufacturer's instructions, maintenance during the test period consisted of the following procedures.

4.4.2.1 Draining of Condensate. Condensate was drained at least once each charge cycle.

4.4.2.2 Daily Maintenance. Compressor and engine crankcase oil levels were checked daily. Engine fuel was replenished as required.

4.4.2.3 After 25 Hours Operating Time. Compressor air intake filter was serviced, engine air cleaner washed, and crankcase oil changed.

4.4.3 Corrective Maintenance

Corrective maintenance was limited to back pressure valve adjustment.

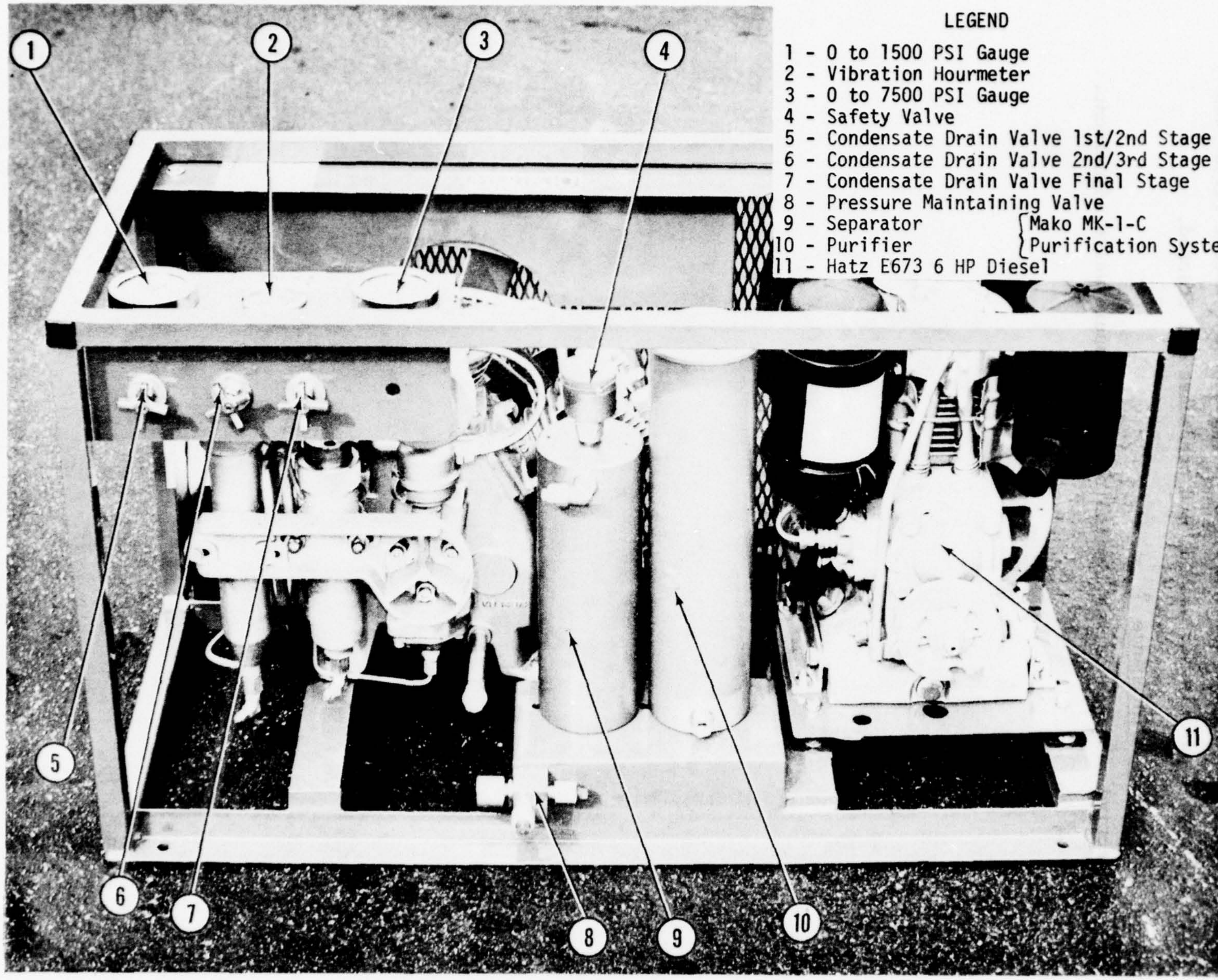

Figure 7. MAKO Model KA-51-DFN

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

5.1.1 The MAKO high-pressure breathing air compressor, modified to incorporate changes recommended by NEDU (figure 7) and designated KA-51-DFN (Navy), is suitable for use by the U.S. Navy.

5.1.2 The MAKO compressor delivers acceptable breathing air at a charge rate and volume commensurate with the manufacturer's specifications.

5.1.3 The charging cycle time is considered satisfactory.

5.1.4 Fuel consumption of the diesel engine is very economical and identical to the manufacturer's claim.

5.1.5 The unit is sturdy, reliable, easily maintained and can be handled by three men.

2. RECOMMENDATIONS

It is recommended that the MAKO high-pressure breathing air compressor KA-51-DFN be placed on the list of equipment Approved for Navy Use, enclosure 2 to NAVSEAINST 9597.1 series.

LIST OF REFERENCES

1. Task No. 78-7 from NAVSEA OOC-3 to Commander, NEDU, Subject: Conduct Evaluation MAKO Compressor, Model KA-51 (Diesel-Driven), 24 April 1968 (Appendix A)

2. Navy Experimental Diving Unit Report 6-57, Cornelius Company Gasoline-Driven 2-CFM H. P. Air Compressor, by A. C. van Behren, p. 3, 9 February 1956

3. Navy Experimental Diving Unit Report 5-60, Cornelius Company Scuba Air Compressor Gasoline Driven, 3.5 CFM, by W. L. Marshall and G. M. Janney, p. 11, 10 September 1959

4. Navy Experimental Diving Unit Report 4-65, High Pressure Engineering Co., Inc. H. P. Air Compressor 6-CFM "Hurricane Model HPE 3000-7-L55," by J. V. Harter, p. 6, 31 July 1965

APPENDIX A
NAVSEA TASK No. 78-7

INTER-OFFICE MEMO

TO Commanding Officer, NEDU

DATE 24 April

FROM W. R. Bergman, OOC-3

SUBJECT TA 78-7

MESSAGE Request you conduct evaluation of MAKO compressor, model K-51 (diesel driven). Mr. C. I. McCoy sales manager for MAKO should be contacted to see if they will provide compressor, with o/m manual at no cost for testing or what purchase cost would be quoted. Conduct testing in accordance with attached enclosure. Provide time and cost estimate for this task including final report submission. Point of contact for this task is Mr. Harry Rueter, OOC-32.

W. R. Bergman
Special Assistant for Diving

REPLY

DATE 10 August 1978

Liaison has been established with Mr. McCoy of MAKO, and one compressor with support equipment arrived this command on 5 July 1978. The test plan has been completed, and completion of testing and report submission is estimated NLT 15 October 1978. Upon completion of testing, compressor and support equipment will be returned to MAKO.

J. T. HARRISON

A. Visual Checks

1. Equipment (check to see if the following items are on the compressor: make, model or other description - and that they are securely attached.)

   a. Compressor
   b. Prime Mover
   c. Fuel Tank
   d. Volume Tank
   e. Filter
   f. Gauges
   g. Valves
   h. Aftercooler
   i. Back Pressure Valve
   j. Moisture Separator
   k. Cylinder Drains (automatic or manual)

2. Safety Features (check to see if the following exist)

   a. Pressure Relief Valves
   b. Exhaust Location and Direction
   c. Belt Guard
   d. Battery and Protected Frame
   e. Wiring and Connector Location
   f. Fuel Tank Filler Opening and Location
   g. Inlet to Compressor, Location and Size

B. Operational Checks

1. Can compressor be started using manual?

2. Is compressor easy to start?

3. Is compressor easy to stop?

4. Can compressor perform to manufacturer's claims; such as capacity at RPM, temperature of output, and required HP input?

5. Analyze output air both before the filter and after the filter to determine the quality of the output air.

Enclosure (1)

APPENDIX B

TEST PLAN AND TEST EQUIPMENT

B.1 TEST PLAN

1. Operate compressor for 1 (one) hour under a no-load condition.

2. Take air sample of discharge before filters.

3. Take air sample of discharge after filters.

   (1) Analysis to be repeated at 1, 25, 50, 75 and 100 hours of operation (7b & 7c).

4. Take water condensate sample.

   (1) Sample to be repeated at 50 and 100 hours of operation.

5. Measure flow under a no-load condition with laminar flowmeter.

   (1) Flow measurement to be repeated every 25 hours of operation.

6. Operate compressor daily for 6 hours, charging alternately to two sets of twin 71.2 cu. ft. scuba tanks to a pressure of 2250 psi.

   (1) Repeat daily until 100 hours of operation are logged.

7. Log total charging time for each set of tanks to calculate charging rate.

8. Log the following measurements every 15 minutes of operation.

   (a) 1st stage discharge pressure

   (b) 2nd stage discharge pressure

   (c) 3rd stage discharge pressure

   (d) Final discharge pressure

   (e) Ambient temperature

   (f) Final discharge temperature

9. Measure fuel consumption of one measured gallon per hours of operation.

10. Weigh entire unit to determine portability.

11. Perform maintenance as required.

B.2 TEST EQUIPMENT

1. Sample flasks (air analysis)
2. Sample jars (water condensate)
3. 0-250 psi validyne transducer, SN 12247
4. 0-1000 psi validyne transducer, SN 12248
5. 0-3000 psi validyne transducer, SN 12246
6. Validyne meter (3)
7. Thermisters (2)
8. Digitech thermal readout, SN 87770349
9. Laminar flowmeter
10. Log sheet

APPENDIX C

CHARGE CYCLE DATA SUMMARY

Table C-1. Charge Cycle Data Summary

DATE	CUMULATIVE TIME HRS/MIN	CHARGE CYCLE	CHARGE RATE CFM	TIME REQUIRED TO FILL (MIN): 72's	90's	MAX. TEMP DIFF °C	1st STAGE PSI	2nd STAGE PSI	3rd STAGE PSI	3rd STAGE TEMP°C
14 Aug	2:03	1	4.646	—	35	4.74	65	440	2925	N/A
	2:32	2	5.513	—	29	6.1	65	410	3000	N/A
	3:00	3	4.457	28	—	4.1	65	390	2250	N/A
	3:31	4	5.56	—	29	5.25	64	430	3000	N/A
	4:02	5	5.158	—	36	5.65	62	420	3000	N/A
15 Aug	4:40	6	4.279	—	38	5.5	65	440	3000	N/A
	5:16	7	4.646	—	35	6.75	65	440	3000	N/A
	5:50	8	5.149	—	30	6	63	425	2850	N/A
	6:15	9	5.20	20	—	5.5	56	400	2200	51
	6:48	10	4.927	—	33	5.75	61	440	2950	77.94
	7:23	11	4.893	—	31	5.0	65	440	3000	77.92
	7:53	12	4.336	—	25	5.2	64	435	2900	N/A
	8:34	13	4.968	—	30	5.25	65	420	2900	N/A
	9:02	14	5.42	—	25	6.1	62	420	2700	N/A
	9:34	15	6.059	—	30	5.4	62	430	2900	N/A
16 Aug	10:30	16	4.911	—	33	3.7	62	420	2900	73.81
	11:07	17	5.239	—	30	4	65	425	2925	70.23
	11:40	18	5.158	—	30	5.5	62	429	2950	76.34
	12:22	19	4.395	—	37	5.5	65	429	3000	75.71
	12:55	20	5.239	—	30	4.75	64	430	2900	88.29
	13:25	21	5.312	—	25	4.75	63	425	2850	87.30
	14:00	22	4.878	—	30	5.5	64	435	2950	87.82
	14:30	23	5.42	—	25	5.25	64	435	2900	88.56
	15:00	24	5.203	—	25	4.15	64	420	2800	82.04

Table C-1. Charge Cycle Data Summary--Continued

DATE	CUMULATIVE TIME HRS/MIN	CHARGE CYCLE	CHARGE RATE CFM	TIME REQUIRED TO FILL (MIN): 72's	90's	MAX. TEMP DIFF °C	1st STAGE PSI	2nd STAGE PSI	3rd STAGE PSI	3rd STAGE TEMP°C
	15:30	25	5.854	—	25	4.45	64	421	2850	89.50
	16:05	26	4.697	—	30	4.6	64	440	3000	92.24
	16:35	27	4.986	—	25	2.85	63	420	2750	85.79
	17:10	28	4.246	—	30	5.1	62	420	2950	84.68
17 Aug	17:43	29	5.129	—	28	3.6	63	420	3000	86.60
	18:13	30	4.986	—	25	3.9	62	425	2800	85.09
	18:43	31	5.312	—	25	5.0	64	420	2650	83.82
	19:03	32	5.051	15	—	5.15	60	400	2275	78.27
	19:58	33	4.986	—	25	4.16	61	420	2800	85.40
	20:33	34	5.239	—	30	3.35	63	440	2990	88.90
	21:08	35	5.059	—	30	2.89	62	430	2800	86.93
	21:48	36	4.568	—	35	2.75	64	435	2950	89.77
	22:15	37	5.42	—	25	2.75	62	420	2700	86.87
	22:50	38	5.059	—	30	2.78	62	420	2850	88.25
18 Aug	23:30	39	4.878	—	25	3.12	62	420	2700	85.79
	24:05	40	4.181	—	35	2.62	64	439	2900	84.29
21 Aug	24:45	41	3.562	—	35	3	61	420	2700	82.53
	25:30	42	4.185	—	30	4.31	62	430	2875	83.70
	26:10	43	3.949	—	35	3.73	68	440	2800	82.35
	26:45	44	5.42	—	30	6.51	65	440	3000	84.70
	27:15	45	5.095	—	25	5.42	62	420	2700	81.90
	28:05	46	4.646	—	35	3.07	63	440	3000	88.50
	28:35	47	5.149	—	25	3.9	60	420	2875	86.10
	29:05	48	5.528	—	25	3.9	60	420	2650	83.2

Table C-1, Charge Cycle Data Summary--Continued

DATE	CUMULATIVE TIME HRS/MIN	CHARGE CYCLE	CHARGE RATE CFM	TIME REQUIRED TO FILL (MIN): 72's	90's	MAX. TEMP DIFF °C	1st STAGE PSI	2nd STAGE PSI	3rd STAGE PSI	3rd STAGE TEMP°C
22 Aug	29:40	49	5.059	—	30	4.7	62	420	2850	79.7
	30:20	50	5.42	—	30	3.01	65	440	2900	71.87
	30:55	51	4.878	—	30	3.1	62	420	2700	84.4
	31:30	52	5.42	—	30	3.6	64	440	3000	88.10
	32:00	53	5.203	—	25	3.93	61	420	2625	85.00
	32:35	54	5.234	—	30	3.42	65	440	2950	90.39
	33:10	55	4.697	—	30	3.97	65	440	3000	91.30
	33:45	56	4.646	—	35	3.66	65	440	2950	93.50
	34:15	57	4.936	—	28	4.3	62	420	2525	87.00
	34:50	58	5.149	—	30	4.81	65	421	2800	83.37
	35:25	59	4.968	—	30	5.1	63	440	3000	93.90
28 Aug	35:56	60	4.645	—	35	4.0	65	440	3000	80.60
	36:26	61	4.568	—	35	3.5	65	440	3000	81.90
	37:00	62	4.568	—	35	3.8	65	440	3000	81.30
	37:27	63	5.081	24	—	4.3	64	405	2250	76.70
	38:02	64	4.910	—	33	4.4	65	440	3000	81.20
	38:29	65	4.732	26	—	4.25	64	410	2250	77.30
	39:03	66	5.081	—	32	3.3	65	440	3000	81.50
29 Aug	39:37	67	4.702	—	34	3.15	65	439	3000	89.14
	40:13	68	4.355	28	—	3.8	65	400	2200	79.60
	40:49	69	4.490		35	2.75	66	440	3000	88.20
	41:18	70	4.878	25	—	3.2	63	400	2250	79.20
	41:52	71	4.996	—	32	3.15	65	440	3000	86.88
	42:20	72	4.878	25	—	3.5	62	400	2175	81.08

Table C-1. Charge Cycle Data Summary--Continued

DATE	CUMULATIVE TIME HRS/MIN	CHARGE CYCLE	CHARGE RATE CFM	TIME REQUIRED TO FILL(MIN): 72's	90's	MAX. TEMP DIFF °C	1st STAGE PSI	2nd STAGE PSI	3rd STAGE PSI	3rd STAGE TEMP°C
	42:56	73	4.662	—	34	3.65	65	440	3000	93.1
	43:23	74	4.516	27	—	2.8	65	400	2250	76.0
	43:56	75	4.845	—	33	3.5	64	440	3000	85.5
	44:30	76	4.996	—	32	3.2	65	440	3000	85.5
	44:57	77	5.203	25	—	3.3	62	405	2400	73.50
	45:32	78	4.615	—	33	3.2	65	430	3000	83.50
	46:09	79	4.966	—	33	3.8	65	440	3000	93.4
30 Aug	46:42	80	4.927	—	33	3.5	65	440	3000	95.2
	47:16	81	4.927	—	33	2.9	65	440	3000	95.0
	47:41	82	4.878	25	—	3.5	63	400	2200	86.2
	48:18	83	4.645	—	35	3.4	65	440	3000	97.5
	48:45	84	5.081	24	—	3.9	62	400	2250	85.6
	49:21	85	4.702	—	34	2.4	65	440	3000	81.5
31 Aug	50:02	86	4.845	—	33	3.9	65	440	3000	95.5
	50:52	87	4.248	—	37	2.9	65	438	3000	89.9
	51:26	88	4.911	—	32	3.5	66	440	3000	89.7
	51:52	89	5.081	24	—	4.5	64	400	2250	81.7
4 Sep	52:26	90	4.911	—	32	5.6	65	440	3000	93.7
	53:01	91	4.845	—	33	5.2	66	440	3000	94.8
	53:35	92	4.911	—	32	4.3	66	440	3000	92.8
7 Sep	54:06	93	5.192	—	31	4.8	65	450	3000	91.7
	54:40	94	4.996	—	32	4.9	66	N/A	3000	94.4
	55:19	95	4.522	—	35	5.5	68	460	3000	94.9
	55:53	96	4.763	—	33	5.7	68	460	3000	95.0

Table C-1. Charge Cycle Data Summary--Continued

DATE	CUMULATIVE TIME HRS/MIN	CHARGE CYCLE	CHARGE RATE CFM	TIME REQUIRED TO FILL (MIN): 72's	90's	MAX. TEMP DIFF °C	1st STAGE PSI	2nd STAGE PSI	3rd STAGE PSI	3rd STAGE TEMP°C
	56:28	97	4.702	—	34	5.7	68	460	3000	95.0
	57:02	98	4.828	—	33	4.7	67	450	3000	96.1
	57:37	99	4.828	—	33	5.5	66	440	3000	97.2
	58.13	100	4.878	—	33	6.6	68	460	3000	96.7
	58:48	101	4.686	—	34	5.2	68	460	3000	94.6
	59:23	102	4.702	—	34	4.2	67	420	3000	95.6
11 Sep	59:59	103	4.622	—	34	6.9	65	440	3000	90.0
	60:29	104	4.516	27	—	4.4	65	400	2250	78.9
	61:02	105	4.622	—	34	5.5	66	440	3000	93.1
19 Sep	61:35	106	4.911	—	32	6.8	66	440	3000	94.9
	62:13	107	4.279	—	38	5.0	67	440	3000	93.9
26 Sep	62:45	108	4.579	—	29	6.6	65	430	3000	96.9
	63.20	109	4.207	—	38	9.3	65	440	3000	95.2
	63:52	110	4.911	—	32	4.4	65	440	3000	97.2
27 Sep	64:27	111	4.568	—	35	9.1	65	430	3000	91.8
	65:03	112	4.702	—	34	10.3	66	440	3000	92.7
	65:37	113	4.845	—	33	10.1	65	440	3000	95.2
	66:12	114	4.702	—	34	9.1	65	440	3000	94.4
2 Oct	66:62	115	4.321	—	37	7.4	65	440	3000	89.1
	67.27	116	4.845	—	33	6.7	66	440	3000	91.4
	68:05	117	4.568	—	35	6.9	66	440	3000	90.0
3 Oct	68:40	118	4.702	—	34	7.6	66	440	3000	91.1
	69.14	119	4.702	—	34	8.2	66	440	3000	91.6
	69.51	120	4.396	—	36	8.4	66	440	3000	N/A

Table C-1. Charge Cycle Data Summary--Continued

DATE	CUMULATIVE TIME HRS/MIN	CHARGE CYCLE	CHARGE RATE CFM	TIME REQUIRED TO FILL(MIN): 72's	90's	MAX. TEMP DIFF °C	1st STAGE PSI	2nd STAGE PSI	3rd STAGE PSI	3rd STAGE TEMP°C
	70:27	121	4.686	—	34	6.2	66	440	3000	95.5
	71:03	122	4.686	—	34	5.7	66	440	3000	95.5
	71:39	123	4.686	—	34	6.7	66	440	3000	96.4
	72:14	124	4.686	—	34	7.3	66	440	3000	95.9
	72:50	125	4.552	—	35	6.9	66	440	3000	94.2
	73.27	126	4.411	—	36	7.1	66	440	3000	101.2
	74:02	127	4.638	—	34	6.4	66	440	3000	101.2
	74:40	128	4.556	—	35	7.1	65	440	3000	100.9
4 Oct	75:34	129	4.945	—	32	5.4	66	440	3000	95.1
	75:47	130				1.6	65	440	3000	90.0
5 Oct	75:55	131	4.336	05	—	1.1	65	400	2400	79.9
	76.31	132	4.654	—	34	7.1	66	440	3000	96.0
	77:07	133	4.654	—	34	5.4	66	440	3000	94.1
	77:42	134	4.645	—	34	5.6	68	440	3000	92.2
11 Oct	78:20	135	4.645	—	35	9.2	65	439	3000	90.7
	78:57	136	4.645	—	35	7.1	65	440	3000	87.7
	80:35	137	4.921	25	—	6.8	65	400	2250	80.3
	81:08	138	5.091	—	33	5.3	65	430	3100	93.8
	81.43	139	4.878	—	33	6.7	65	430	3000	93.3
17 Oct	82.16	140	4.664	—	33	5.4	68	460	3000	93.6
	82.53	141	4.782	—	34	4.0	65	460	3000	85.3
	83.32	142	4.927	—	33	5.2	66	461	3000	86.8
	84:11	143	4.927	—	33	6.0	65	460	3000	84.7
	84:48	144	4.927	—	33	5.6	68	460	3000	82.06

Table C-1. Charge Cycle Data Summary--Continued

DATE	CUMULATIVE TIME HRS/MIN	CHARGE CYCLE	CHARGE RATE CFM	TIME REQUIRED TO FILL(MIN): 72's	90's	MAX. TEMP DIFF °C	1st STAGE PSI	2nd STAGE PSI	3rd STAGE PSI	3rd STAGE TEMP°C
	85:23	145	4.927	—	33	4.9	67	460	3000	85.1
	85.58	146	4.927	—	33	5.5	68	460	3000	81.9
	86:33	147	4.927	—	33	5.9	70	475	3000	83.2
18 Oct	87:08	148	4.779	—	33	5.2	71	460	2950	84.8
	87:42	149	5.047	—	32	8.6	70	460	3000	87.6
	88:17	150	4.979	—	32	4.5	74	453	3000	90.5
	88.52	151	5.030	—	32	4.7	74	460	3000	90.8
	89.28	152	4.927	—	33	6.6	74	460	3000	91.3
	90:03	153	4.927	—	33	4.8	74	460	3000	89.6
	90:41	154	5.245	—	31	4.8	72	460	3000	91.4
	91:20	155	4.645	—	35	5.4	75	460	3000	85.3
19 Oct	91:52	156	4.617	27	—	6.6	61	415	2450	82.9
	92:21	157	4.794	26	—	6.8	67	415	2490	84.4
	92.52	158	4.794	26	—	5.4	66	410	2400	83.1
	93:22	159	4.617	27	—	6.3	67	420	2400	85.1
	93:38	160				4.5	68	420	3000	94.4
	94:12	161	4.827	—	32	5.8	70	445	3000	94.9
	94:46	162	4.895	—	31	4.6	70	440	3000	95.5
	95:10	163	4.661	20	—	6.8	65	380	1800	76.4
20 Oct	95:28	164	4.215	18	—	1.7	65	420	2500	64.6
	95:46	165	4.573	16	—	3.9	62	419	2500	69.4
	96:07	166	4.951	17	—	2.3	63	418	2500	71.1
	96:27	167	4.973	17	—	2.9	63	419	2500	71.3
	96:41	168	4.681	11	—	2.8	62	410	2500	70.9

Table C-1. Charge Cycle Data Summary--Continued

DATE	CUMULATIVE TIME HRS/MIN	CHARGE CYCLE	CHARGE RATE CFM	TIME REQUIRED TO FILL (MIN): 72's	90's	MAX. TEMP DIFF °C	1st STAGE PSI	2nd STAGE PSI	3rd STAGE PSI	3rd STAGE TEMP°C
20 Oct	97:03	169	4.516	18	—	3.2	64	420	2500	72.4
	97:44	170	4.351	—	34	8.0	65	460	3000	83.0
	98:16	171	4.790	—	31	6.3	65	500	3000	82.7
	98:51	172	4.755	—	31	5.2	65	500	3000	82.9
	99:26	173	4.790	—	31	7.6	64	520	3000	86.0
20 Oct	100:00	174	4.733	—	30	7.3	65	520	2900	84.4