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By J.P Kunsemiller and S.A. Black

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Engineering Command

SEAWATER HYDRAULICS: A MULTI-FUNCTION TOOL SYSTEM FOR U.S. NAVY CONSTRUCTION DIVERS

ABSTRACT A set of three rugged divers' tools - a rotary impact tool, a bandsaw, and a rotary disk tool - each powered by an interchangeable 3-horsepower seawater hydraulic motor, have been developed for the construction diver. The tools are supplied hydraulic power by a high-pressure seawater pump driven by a diesel engine. This pump provides filtered seawater at 14 gpm and 2,000 psi in an open circuit system. The objective for developing the Multi-Function Tool System (MFTS) was to provide Underwater Construction Teams (UCTs) with a tool system to meet their operational needs and operate safely without contaminating the environment. This MFTS is environmentally neutral, and the single hose requires less physical effort to control, particularly in ocean currents. The diver tools are made of materials that resist the aggressive seawater environment and they require little field maintenance.

NAVAL CIVIL ENGINEERING LABORATORY PORT HUENEME CALIFORNIA 93043-5003

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

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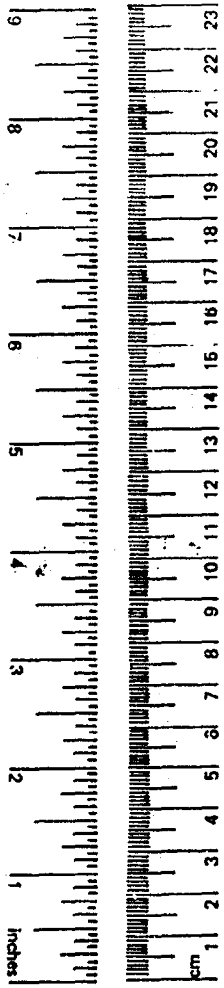
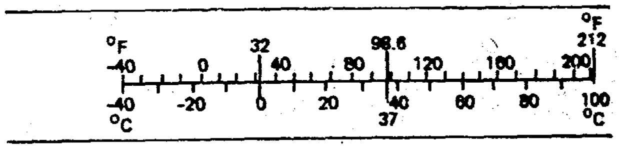
*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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13. ABSTRACT *(Maximum 200 words)*

A set of three rugged divers' tools - a rotary impact tool, a bandsaw, and a rotary disk tool - each powered by an interchangeable 3-horsepower seawater hydraulic motor, have been developed for the construction diver. The tools are supplied hydraulic power by a high-pressure seawater pump driven by a diesel engine. This pump provides filtered seawater at 14 gpm and 2,000 psi in an open circuit system. The objective for developing the Multi-Function Tool System (MFTS) was to provide Underwater Construction Teams (UCTs) with a tool system to meet their operational needs and operate safely without contaminating the environment. This MFTS is environmentally neutral, and the single hose requires less physical effort to control, particularly in ocean currents. The diver tools are made of materials that resist the aggressive seawater environment and they require little field maintenance.

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CHAPTER 5. **SEAWATER HYDRAULIC BANDSAW**

CHAPTER 1. INTRODUCTION

This report documents the development of a seawater hydraulic Multi-Function Tool System (MFTS). The objective of the MFTS development was to demonstrate a seawater-powered tool system to provide improved capability for Underwater Construction Team (UCT) divers. The UCTs are a highly specialized component of the Naval Construction Force (NCF). The UCT mission is to construct, inspect, maintain, and repair fixed ocean facilities in support of Navy and Marine Corps operations.

Tools for the MFTS were selected based on discussions with UCT personnel, analysis of past deployments, and UCT experience with using oil hydraulic tool systems (Ref 1). The tools selected for development were a rotary disk tool, a rotary impact tool, a bandsaw, and a rock drill. The tools, powered by a 3.5-horsepower seawater hydraulic motor, were optimized for both the diver and the environment. The rock drill did not complete the development cycle and therefore is not included in the system.

Basic to the development of the MFTS system was the satisfaction of logistics and reliability requirements. Because the UCTs are highly mobile, the MFTS is designed to be transported by aircraft, truck, or ship. The system was designed and tested to have a minimum reliability* of 0.80. Each tool was designed so that it can be repaired in a minimum time. Tool maintenance at the end of the day is satisfied by a freshwater rinse. Each MFTS package includes spare parts for one operational season and a complete Operation and Maintenance Manual.

The MFTS is intended to replace the existing oil hydraulic tool system currently in use by the UCTs. While oil hydraulic tool systems have extended the capability of the UCT diver to do useful underwater work, there are disadvantages to their use (Ref 2). Oil leaks from the system can cause environmental contamination, pose a fire hazard, or threaten personal safety. Seawater leaks into the system can destroy system components, resulting in excessive maintenance and down time. In addition, the unwieldy dual transmission hoses burden the diver, particularly in a current or surge.

Since 1976, NCEL has been developing a hydraulic tool system that uses seawater instead of oil as the power transmission fluid (Ref 2, 3, 4). The open loop seawater hydraulic system provides the diver with easy to handle, single hose tools that are compatible with their environment. The system has all the benefits of oil hydraulic systems, and yet it does not present a health or fire hazard.

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*Reliability is calculated from the formula $R = e^{-t/MTBF}$, based on a required mission time, t (daily operational time), of 8 hours and a mean time between failure (MTBF) of not less than 36 hours.

While seawater is an attractive alternative to oil from an application point of view, it provided many challenges in mechanical design. Aside from promoting corrosion in metals, seawater's low viscosity offers minimal lubrication and high leakage rates compared to oils. These factors complicate hydraulic machinery design by limiting materials selection to those satisfying corrosion and lubrication criteria. In addition, close tolerance machining was necessary to maintain reasonable operating efficiencies.

The MFTS development described herein includes: design, fabrication, test, and UCT evaluation of a prototype system. The test program was conducted in three phases: (1) operability, safety, and human factors tests, (2) reliability, maintainability, and availability tests, and (3) logistic supportability analysis. Minor design changes were made during testing, where appropriate, to effect improvements and correct failures. These improvements are discussed in this report as they occurred during each phase.

The comments received following the UCT evaluation and the recommendations generated during the laboratory test phases were combined, as appropriate, into design changes for the production models.

Chapters 2, 3, 4, and 5 of this report discuss in detail the complete development process for the power source and each tool. The chapters begin with a description of the prototype and the design requirements. This is followed by a discussion of the test results for each of the laboratory test phases, and then a summary of the significant findings. This report does not include discussions of the field tests conducted by the UCTs. Each chapter concludes with a final description of the production model component.

CHAPTER 2. SEAWATER HYDRAULIC POWER SOURCE

The design requirements for the MFTS seawater hydraulic power source are given in Table 1.

Table 1. Power Source Design Requirements

Item	Design Requirement Threshold
Suction lift	50 ft
Pressure[a]	2,000 psi
Flowrate[a]	14 gpm
Weight with hose	<3,000 lb
Operate two tools simultaneously	Yes
Temperature	-1 to +40 °C
Reliability	0.98
MTBF	369 hr
Mean Time To Repair (MTTR)	4 hr
Availability	0.80
Maintenance	
Daily	0.5 hr
End of project	1 hr
Annually	4 hr

[a] Able to power two tools simultaneously.

COMPONENT DESCRIPTION

The prototype seawater hydraulic power source, Figure 1, uses a 30-horsepower diesel engine to drive a high-pressure seawater pump. The diesel engine also powers a small oil hydraulic system to drive a centrifugal low-pressure seawater pump. A flow controller on the oil hydraulic system is used to regulate the speed of the centrifugal pump.

The centrifugal pump supplies 200 psi water to a jet eductor pump suspended in the ocean. The jet eductor pump returns a larger volume of water to fill the 50-gallon reservoir. The seawater output from the jet eductor pump is passed through a 10-micron basket filter before filling the seawater reservoir. From the reservoir, filtered seawater is gravity fed to the high-pressure pump and distributed to the tools through

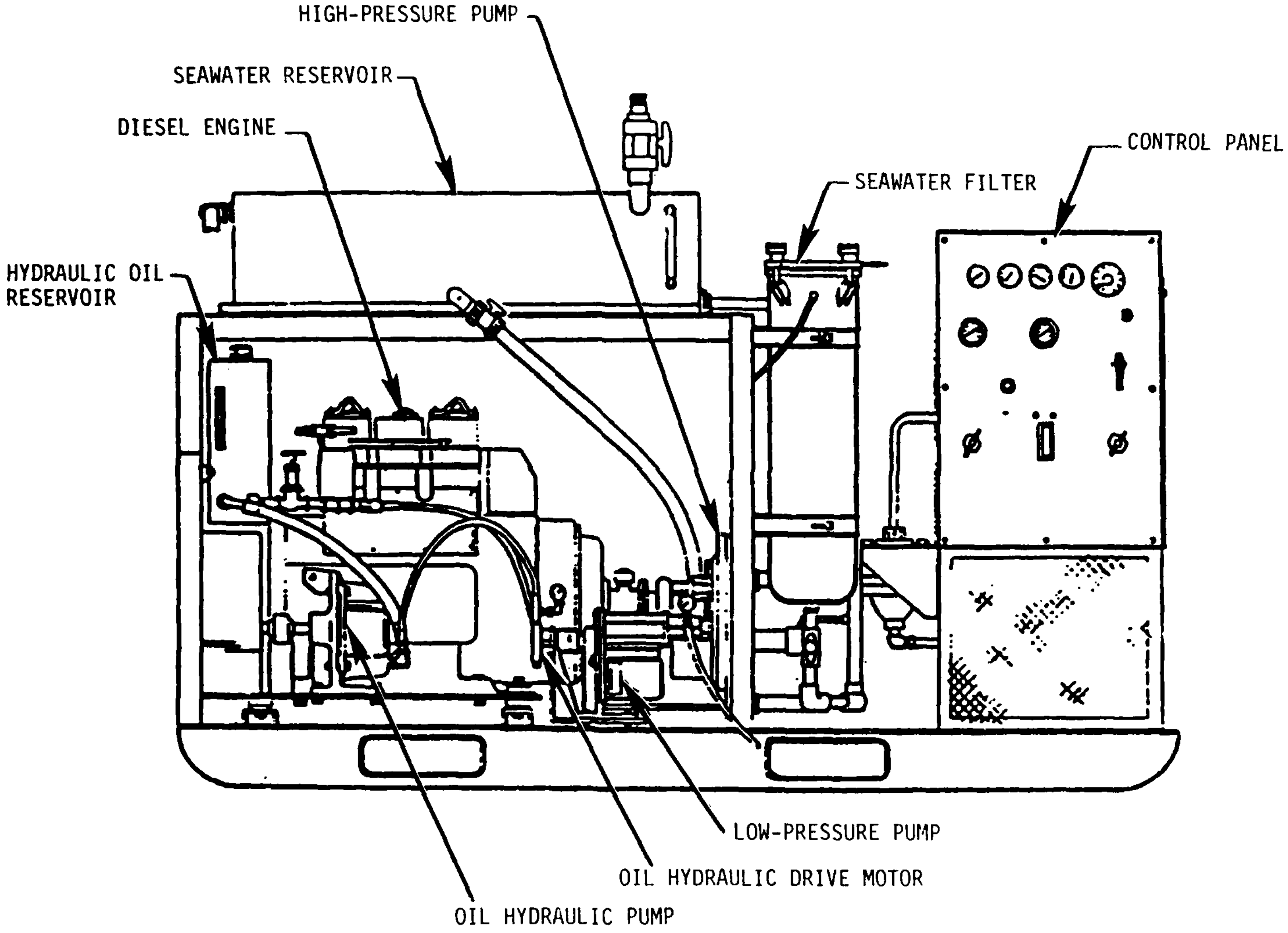


Figure 1. Prototype seawater hydraulic power source.

250 feet of 1/2-inch-diameter hose. One hose reel is attached to the power unit. A second hose reel is separate from the main power unit. The hydraulic circuit diagram is shown in Figure 2.

The power source instrumentation and control panel includes a system pressure relief valve, a tool pressure relief valve, a pressure compensated flow controller, a flowmeter, pressure gauges, and a filter differential pressure gauge. The instrumentation for the diesel engine, also located on this control panel, includes a tachometer, oil pressure gauge, ammeter, and start button.

TEST AND EVALUATION

The laboratory tests and evaluation of the seawater power source were conducted at the Ocean Systems Test Facility by NCEL personnel. Laboratory data collected during the following tests are available from Reference 5.

Operability, Safety, and Human Factors Tests

High-Pressure Pump Performance Test. This test was performed to determine the flowrate of the high-pressure pump at various diesel engine speeds and pump discharge pressures. The data were obtained from reading the system gages and plotted as the performance curves in Figure 3, with flow as a function of engine speed and pump discharge pressure.

The output flowrate of the pump increased linearly with an increase in diesel engine speed, decreasing slightly with an increase in pressure. The maximum flowrate of the pump was found to be 16 gpm at 500 psi at an engine speed of 2,600 rpm. The diesel engine speeds required to operate one tool (7 gpm) or two tools simultaneously (14 gpm) were 1,100 rpm and 2,400 rpm, respectively. At 14 gpm and 2,000 psi, the diesel was operating near maximum design horsepower with little reserve capacity available.

Lift Capability of the Jet Eductor Pump. This test was performed to determine the lift capability of the jet eductor pump system as a function of engine rpm and output head. The flow control valve controlling the speed of the centrifugal pump was set fully open so that the flowrate to the jet eductor pump was maximum at selected engine speeds. The discharge head of the jet eductor pump was adjusted using a restrictor valve while the flowrate of the eductor pump was measured using an in-line flowmeter.

Although the design requirement is to lift water to a 50-foot height, the jet eductor pump was tested at an equivalent head of 55 feet to account for line losses. The resulting data, plotted in Figure 4, show the net flow output of the jet eductor pump as a function of pump head and diesel engine speed. From the data obtained, the engine speeds required for the jet eductor pump to lift 7 gpm and 14 gpm against a 50-foot head were determined.

At 1,400 rpm and a discharge head of 25 feet, the lift capacity of the eductor pump was 12.5 gpm. At a discharge head of 55 feet, this net flow dropped to 3.6 gpm.

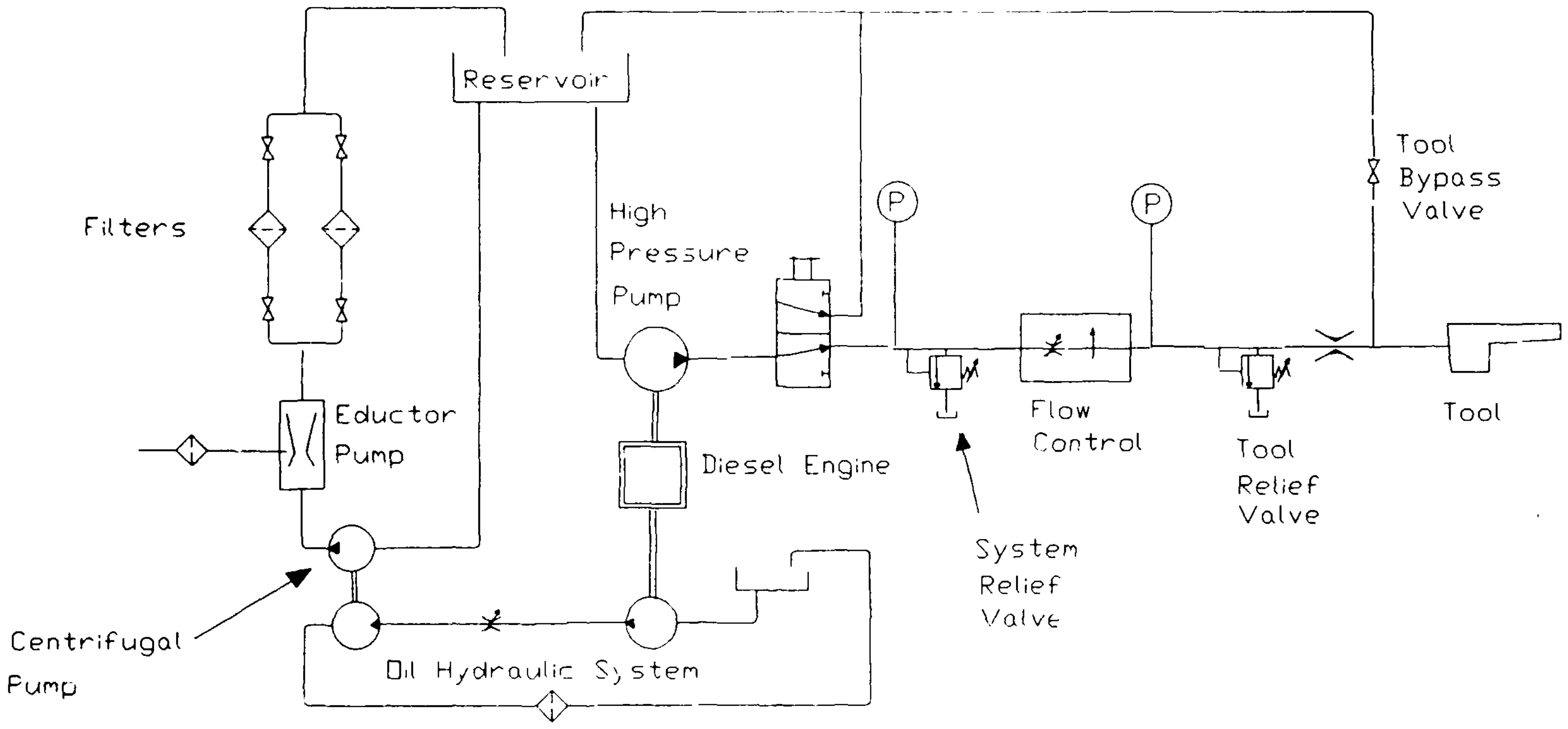


Figure 2. Seawater hydraulic power source flow diagram.

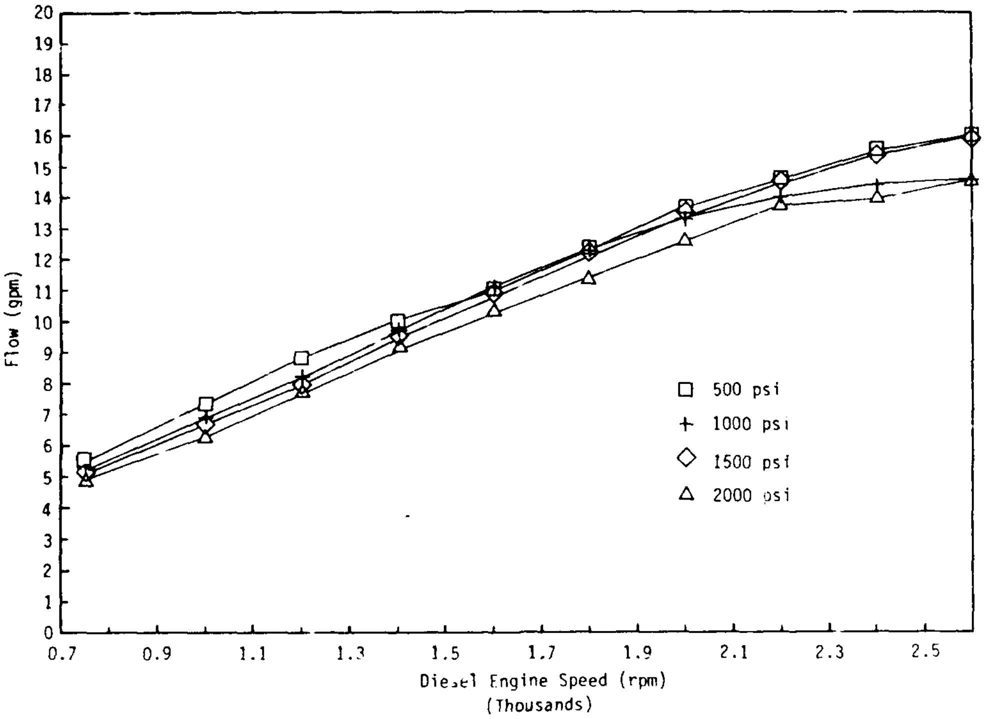


Figure 3. High-pressure pump performance.

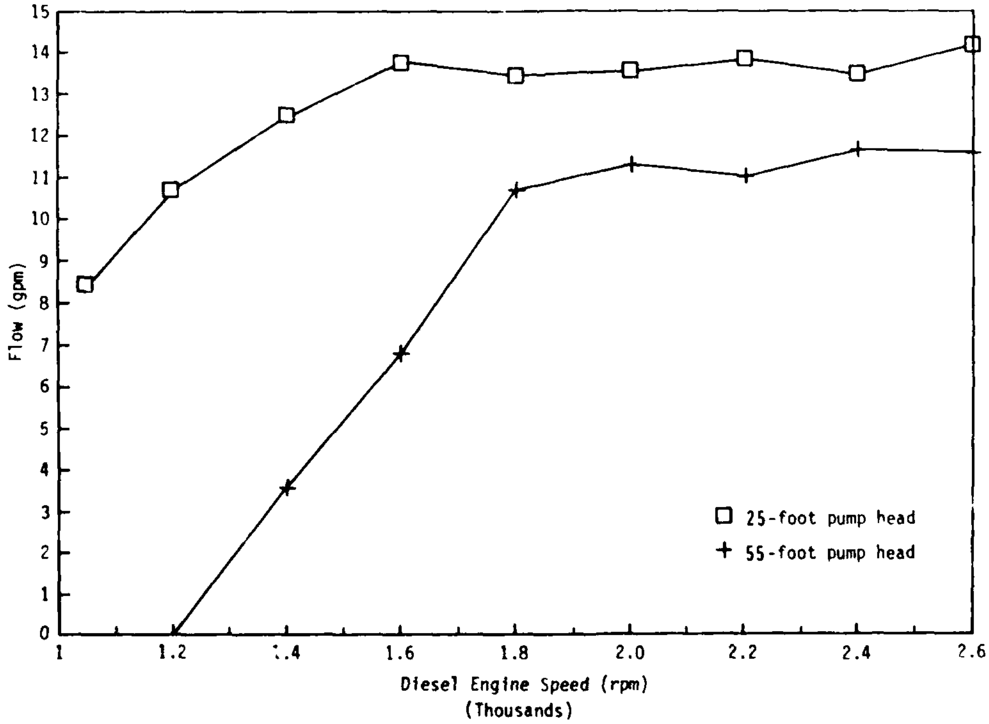


Figure 4. Jet eductor pump performance.

The engine rpm required for the jet eductor pump to lift a net 7 gpm against a 55-foot pump head was about 1,600 rpm. The maximum net flowrate against a 55-foot discharge head was 11 gpm at diesel speeds above 2,000 rpm.

As seen in Figure 4, at a 55-foot lift, the jet eductor pump was not able to meet the design requirements even at a maximum engine speed of 2,600 rpm.

Filter Load Test. This test was performed to determine the requirements for cleaning and replacing the filter elements. This test was conducted in three parts.

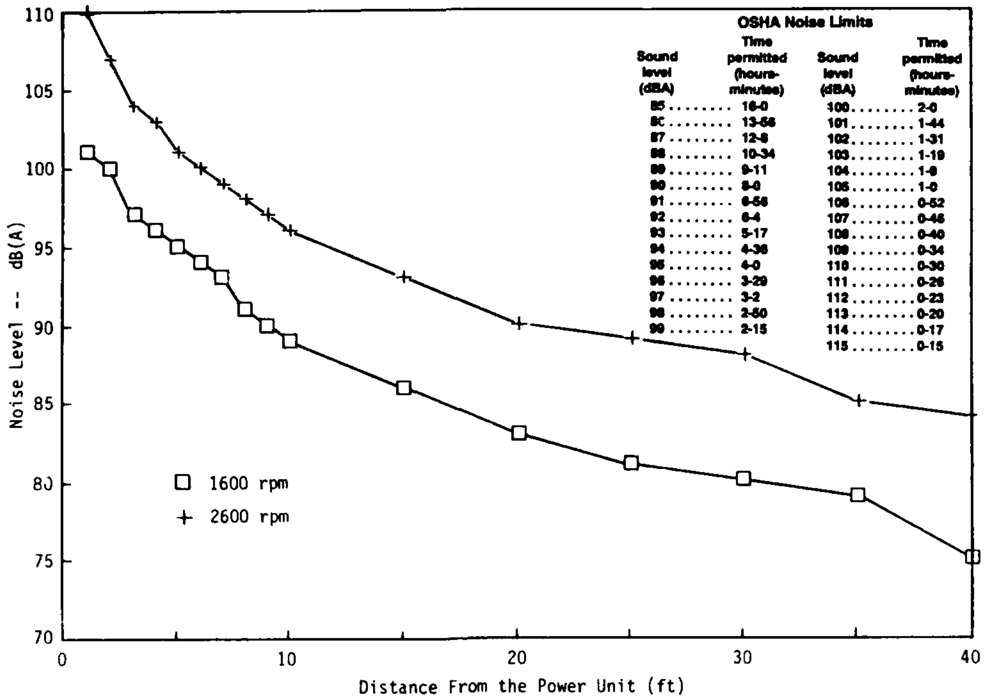
In the first part of the test, a flow restriction valve, placed in line between the jet eductor pump and the 10-micron filters, was adjusted to simulate a dirty filter. Pressure gages were placed on either side of the valve to measure the pressure differential. This test was conducted at engine speeds of 1,600 and 2,600 rpm. It was found that a 10-psi differential would result in a low flowrate. Therefore, the filter elements should be changed when the pressure differential reaches 10 psi. At this pressure difference across the filters, the flow through the filters decreases because of the limitations of the jet eductor pump to overcome the increased head.

In the second part of the test, a new clean filter was compared to a used clean filter. After recording the pressure drop across the new filter, it was partially filled with silt and sand until the pressure differential across the filter was 10 psi. The filter element was then removed, rinsed out, and reinstalled. The power unit was restarted and the pressure differential was noted and compared with the earlier reading. No difference in pressure drop across a new or used clean filter was noted. It was found that dirty filters could be emptied, rinsed clean, and reinstalled. Extremely dirty filters can be cleaned in a conventional washing machine.

In the third part of the test, a filter element was placed in unfiltered seawater for 30 days to see if biological fouling would clog the filter. This filter was later installed and the filter pressure differential recorded. After the 30 days, algae was present but did not clog the filter enough to cause any operational problems. It is not recommended that this become common practice, because the filter element will decay faster under these conditions. Rather, the element should be flushed with fresh water.

Noise level. Noise levels of the power source were measured using an integrated sound level meter on an "A" weighted scale at operating speeds of 1,600 and 2,600 rpm. The noise levels were plotted as a function of the distance from the power unit, and are shown in Figure 5. Occupational Safety and Health Administration (OSHA) noise limitations are also shown in Figure 5.

The noise level ranged from a minimum of 75 dB(A) at 40 feet from the power unit with the engine running at 1,600 rpm, to a maximum of 114 dB(A) at 1 foot from the power unit with the engine running at 2,600 rpm. Background noise level was 71 dB(A). The safe allowable exposure limits can be determined by using the OSHA table in Figure 5. For example, for individuals working within 5 feet of the power unit, the noise



Sound level (dBA)	Time permitted (hours-minutes)	Sound level (dBA)	Time permitted (hours-minutes)
85	16-0	100	2-0
86	13-56	101	1-44
87	12-8	102	1-31
88	10-34	103	1-19
89	9-11	104	1-8
90	8-0	105	1-0
91	6-58	106	0-52
92	6-4	107	0-46
93	5-17	108	0-40
94	4-36	109	0-34
95	4-0	110	0-30
96	3-29	111	0-26
97	3-2	112	0-23
98	2-50	113	0-20
99	2-15	114	0-17
		115	0-15

Figure 5. Power unit noise output.

level is 100 dB(A) at 1,600 rpm and 105 dB(A) at 2,600 rpm. The OSHA table shows the length of time allowed without ear protection is 2 hours at 100 dB(A) and 1 hour at 105 dB(A). It is recommended that hearing protection be used at all times when working in close proximity to the power unit.

Human Factor Evaluation. During testing, power source features pertaining to human factors were evaluated for ease of operation. In general, the unit was easy to operate, and maintenance items were accessible. An observed deficiency was the inadequate labeling of valves and engine controls. This made operation of the power source difficult for an untrained operator. A second deficiency was that the system hydraulic controls and the tool hydraulic controls were located in a noisy environment. Placement of the tool hydraulic controls could be located separate from the system controls. As an example, a hose reel and the tool hydraulic controls could be positioned at a distance from the main power unit. This would allow tool adjustments during operation in a quieter environment. System hydraulic controls would remain at the power source.

Reliability, Maintainability, and Availability Analysis

The results of the individual tests conducted in this evaluation are described below. The reliability was demonstrated to 0.98 at a 90 percent confidence level at the completion of the endurance test.

Endurance Test. The power source was operated at 1,600 rpm with a flowrate of 10 gpm for 750 hours and 2.5 gpm for 161 hours, for a total of 911 hours of testing. Pressure at the tool was maintained at 650 psi. The test was conducted during normal working hours and shut down at night. All system repairs and maintenance actions were recorded in the test log.

Table 2 summarizes the repairs that were required during testing. None of the items required longer than 1/2 hour to repair. With the power source completing 911 hours of testing without a chargeable failure as defined by the failure criteria, the point estimate of the power source reliability is 0.98 at a 90 percent confidence level. The Mean Time To Repair (MTTR) is estimated to be 0.4 hours. The Mean Time Between Failure (MTBF) for a mission of 8 hours can be calculated using exponential distribution to be 369 hours at the lower limit of the 90 percent confidence interval. Using this MTBF of 369 hours and a MTTR of 0.4 hours, the inherent availability (A_i) is 0.998. This is substantially greater than the 0.80 design requirement.

Table 2. Power Source Failures During Testing

Test Time (hr)	Failed Item	Cause of Failure	Redesign Action	Type of Failure (MIL-STD-7891C)	Repair Time (hr)
30	Drive belt	Improperly installed	None	Nonrelevant	0.30
300	Oil hydraulic motor	Defective	None	Nonrelevant	0.50
310	Tachometer	Corroded terminals	None	Nonrelevant	0.30
350	Relief valve	Worn seat	Installed accumulator	Nonrelevant	0.30
675	Reservoir leaking	Vibrations fatigued welded seams	Strong welds	Nonrelevant	0.50
800	Internal components	Used beyond service life of Harben pump	None	Nonrelevant	0.50

Improper Maintenance Test. This test was performed concurrently with the endurance test. The power unit was used without rinsing it off or flushing the seawater out of the system for 30 days. The oil levels were checked regularly. The amount of corrosion, hose decay, and salt crystals was recorded at the end of the 30 days.

Corrosion developed at the electrical connections and wires leading to the alternator and the electrical gauges and switches. They were replaced or cleaned as described in the life test results. Salt crystal growth appeared all over the unit, especially on the water system components. However, this did not cause any operational problems. The only other component impacted by improper maintenance was the high-pressure pump. The lubricating oil became a milky color due to contamination with seawater. The wear in the rubber compression tubes may have allowed the seawater to seep by. This problem will be eliminated if the maintenance schedule for replacing the high-pressure pump tubes and oil is followed. Following this test the power unit was cleaned and rinsed thoroughly. Some crevice corrosion and surface corrosion was present on all the power unit components. However, this did not adversely affect performance during further testing.

Required Maintenance. Maintenance was performed for each component of the power source according to manufacturer's recommendations. The engine oil and filter were changed at 100 hours and every 250 hours thereafter. Engine valves were adjusted on the same schedule. The hydraulic oil filter and the fuel filter were changed every 250 hours. The power source must be rinsed and flushed with fresh water at the end of the day. Other important maintenance is summarized in the maintenance schedule shown in Table 3.

Logistic Supportability Analysis

The MFTS seawater power source will be delivered to the user with an operation and maintenance kit. Some parts will be in the form of maintenance kits. The remainder will be used as replacements in case of premature failure of a component. The items in the operation and maintenance kits are recommended based on the results of the testing that has been completed to date. Regular maintenance parts for the power source such as drive belts and replacement filter elements will be included. No special tools are required to perform any of the maintenance outlined in the Operation and Maintenance Manual.

All spare parts will be transportable in a permanent storage case. There are no special prerequisites for shipping the power source other than the usual requirement to drain the fuel and battery electrolyte. All training required to operate the power source is covered in the Operation and Maintenance Manual.

FINDINGS

The following findings are based on the results of the development tests:

1. The prototype power source met or exceeded the design requirements except for flowrate at maximum suction lift. The jet eductor pump limited system performance as it was only able to lift 11.2 gpm at 50 feet compared to the required 14 gpm. In the present configuration with a 14-gpm demand, a full reservoir will drain in 7 minutes.

Table 3. Scheduled Maintenance Requirements

Action	Daily[a]	125 Hours[a]	250 Hours[a]	1,000 Hours[a]
Diesel Engine				
Fuel supply	C			
Lube oil level	C			
Air cleaner	C			
Oil and fuel leaks	C			
Battery level	C			
Engine oil and filter			R	
Belt tension		C		
Fuel filter			R	
Engine valves adjustment			C	
Condition of belts				C
Condition of electrical terminals	C			

Action	Daily[a]	Weekly	500 Hours[a]	1,000 Hours[a]
High-Pressure Pump				
Crankcase oil	C			R
Inlet valves			R	
Diaphragms			R	
Fittings/hoses/pipes		C		
Low-Pressure Pump				
Gear case oil	C		R	
Filter Elements	C	RM/CL		
Low-Pressure Pump				
Hoses and fittings		C		
Gear oil case	C			
Overall Power Unit				
Exterior of power unit		CL		
Seawater hydraulic system (flush)	CL			

[a] Note: C = Check, CL = Clean with freshwater, R = Replace, RM = Remove.

2. The high-pressure pump provides 14 gpm at 2,000 psi with an engine speed of 2,400 rpm.

3. The filtration system should be serviced when the differential pressure exceeds 10 psi. The filter elements can be cleaned and reused.

4. The maximum noise level of the power source was 114 dB(A) at an engine speed of 2,600 rpm and 1 foot from the power unit. This exposure level can be tolerated for 17 minutes without hearing protection with no permanent hearing loss, according to OSHA standards.

5. The high-pressure pump develops pressure spikes that result in rapid wear in the pressure relief valves. When an accumulator was installed, the wear of the valve seat was reduced.

6. Many of the electrical connections corroded very rapidly when exposed to the salt air environment.

PRODUCTION MODEL

The prototype power source underwent extensive modifications to achieve the required 14-gpm flowrate at the maximum suction lift of 50 feet. The following section describes the nature of these changes and other improvements to the production power source (Figure 6). The assembly drawings are provided in Appendix A.

The jet eductor low-pressure pump system was replaced with an air compressor and a pneumatic diaphragm pump. The diaphragm pump can lift seawater 50 feet at the required 14 gpm. A particular advantage of the diaphragm pump is that it does not require priming. This makes the system easier to operate. In addition, a pneumatic tool can also be used off the air compressor for topside operations. A system flow schematic is shown in Figure 7.

The production power source uses a 41-horsepower air-cooled diesel engine to drive the high-pressure pump and air compressor. The larger horsepower engine enables operation at a fixed speed regardless of system demand. This means that fewer adjustments are required from the operator.

An improvement to handling and operation was achieved by modularizing the hose reels. The modular hose reel (Figure 8) consists of a hose reel containing 250 feet of 1/2-inch hose and a control panel. The control panel has a pressure gauge, pressure regulator, bypass valve, flowmeter, and flowrate controller to distribute high-pressure seawater from the power source to a tool. A 25-foot umbilical hose is used to connect the portable hose reel to the power source.

Because size and weight are critical elements for equipment used by the highly mobile UCTs, the power source size was reduced by careful packaging of the components. This resulted in a small overall weight reduction, even with the larger horsepower engine. The production power source weighs under 2,000 pounds and each of two hose reels weighs 250 pounds.

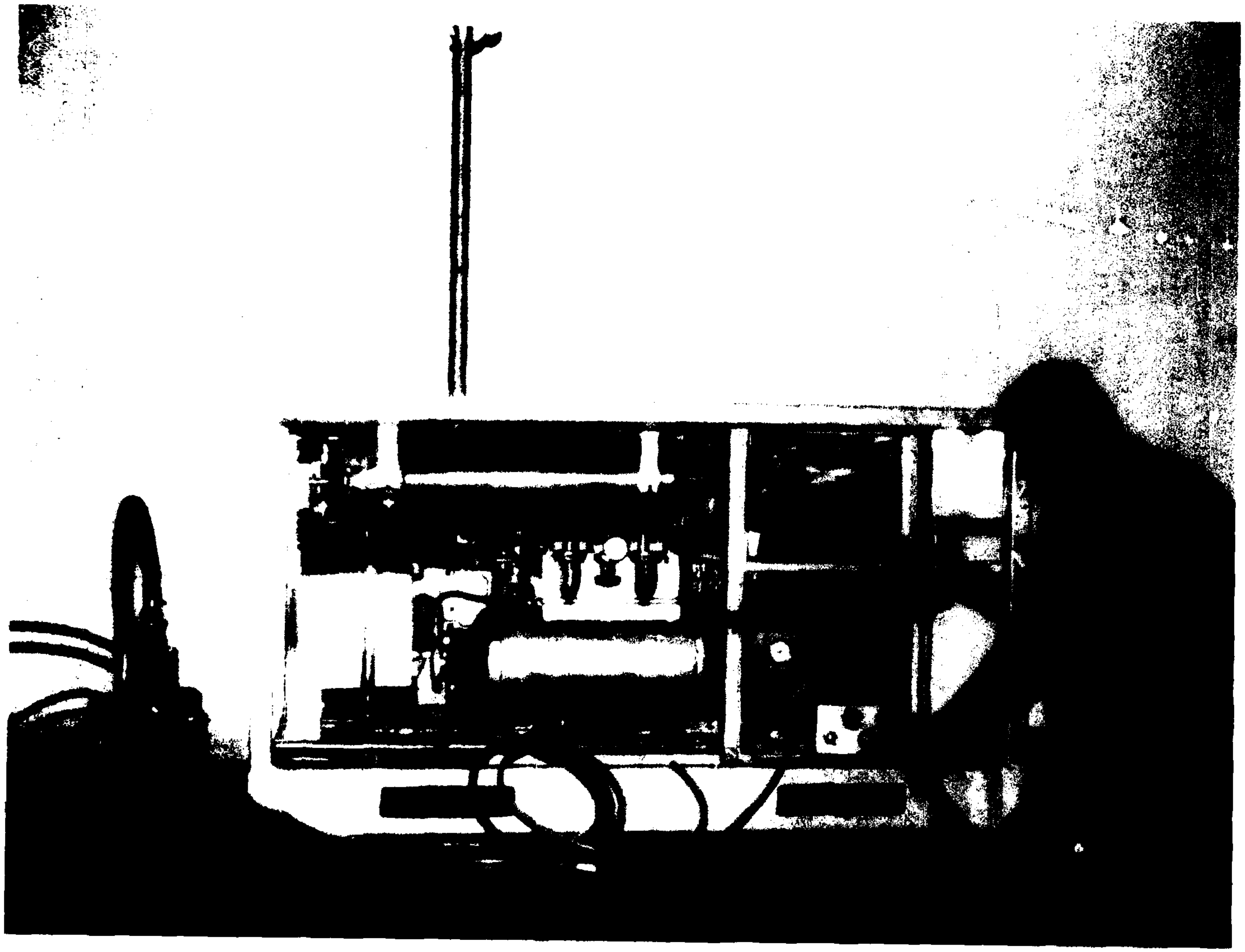


Figure 6. Production power source.

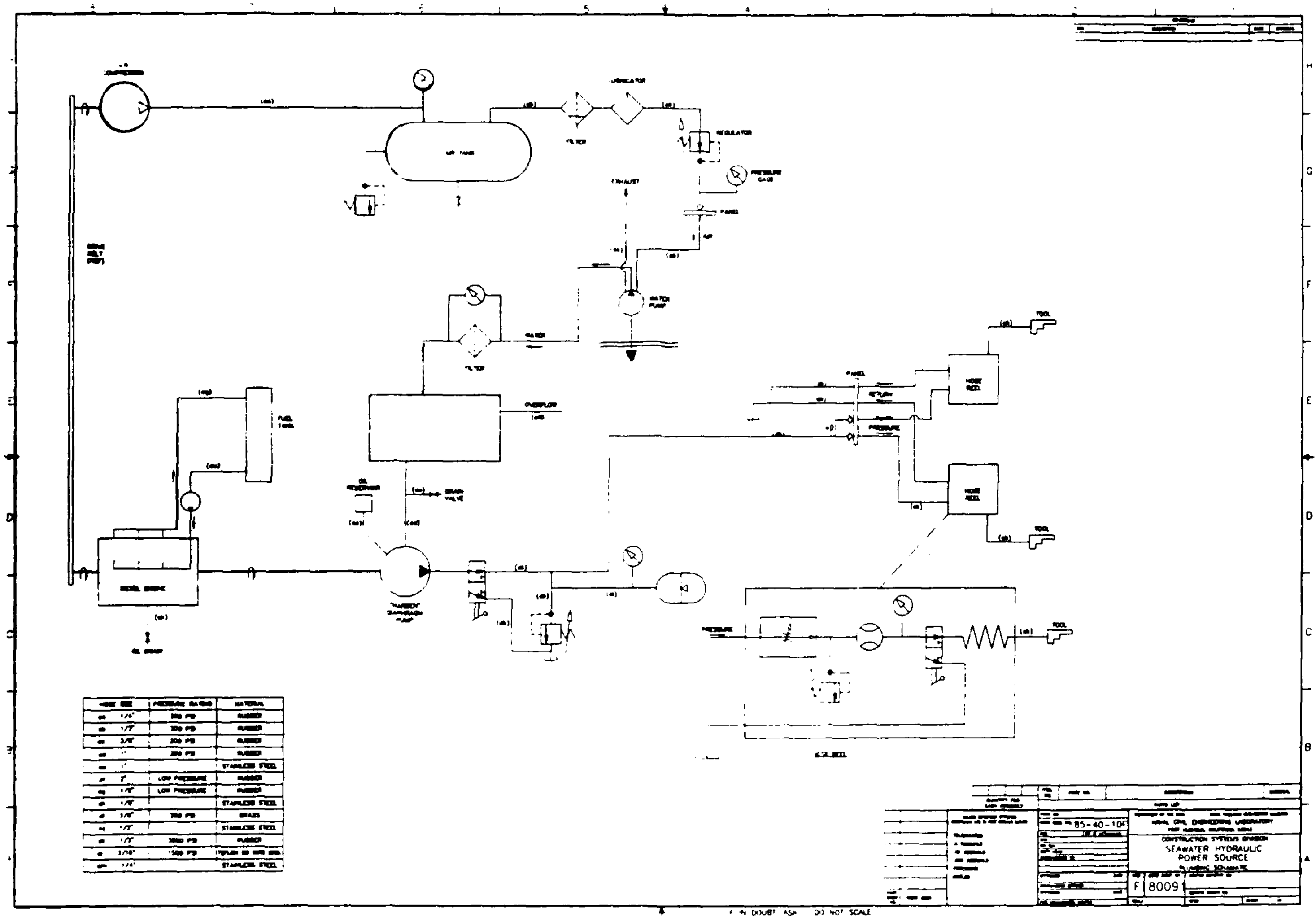


Figure 7. Flow diagram for production power source.

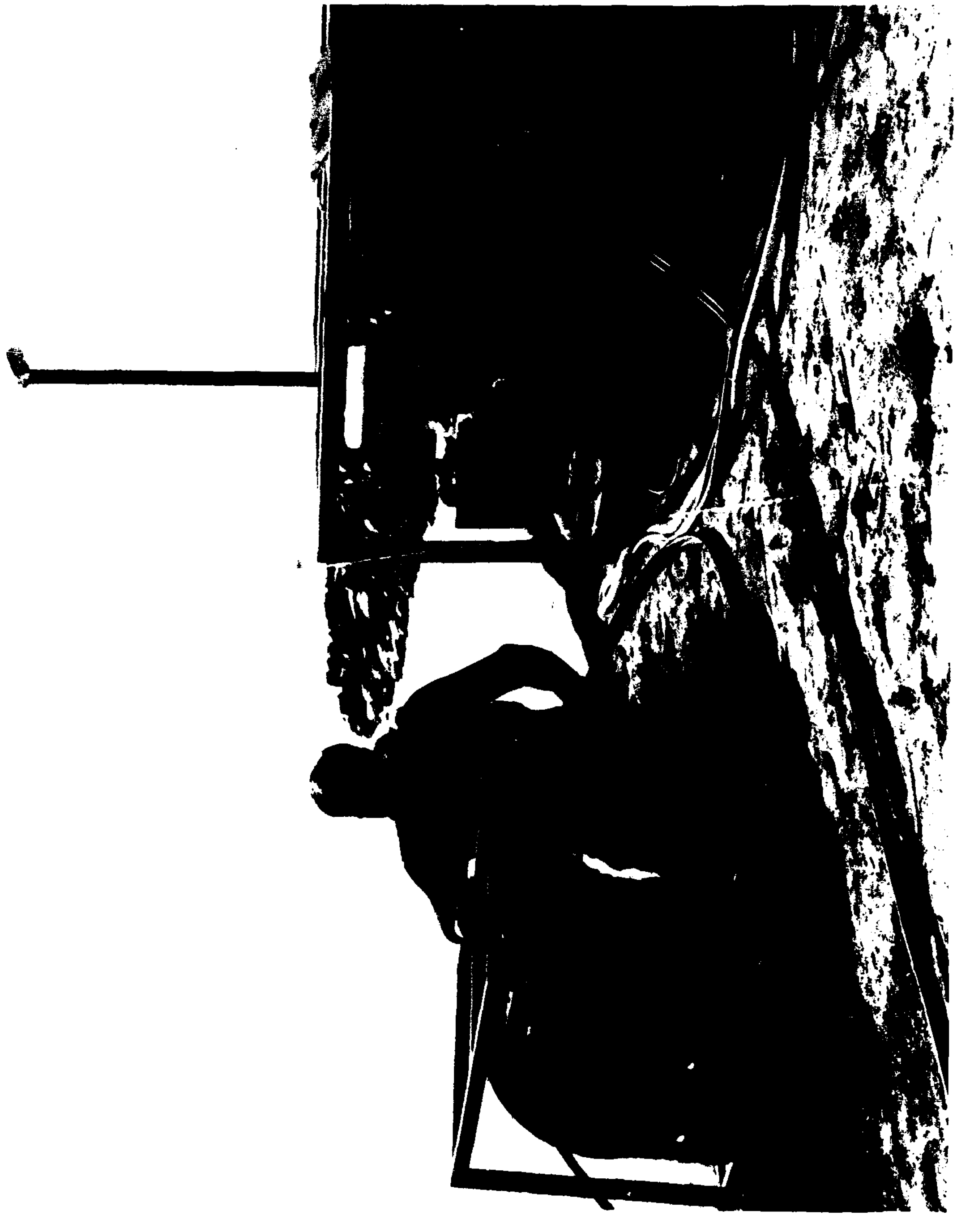


Figure 8. Modular hose reel.

CHAPTER 3. SEAWATER HYDRAULIC ROTARY DISK TOOL

The design requirements for the MFTS rotary disk tool are summarized in Table 4. The RDT can be used as a grinder or as a cutoff tool. As an example, the tool cuts 1-inch rebar, SD List 1 coaxial cable, 1-1/4-inch synthetic line, 5/8-inch bolts, and 1-inch wire rope.

Table 4. Rotary Disk Tool Requirements

Item	Design Requirement Thresholds
Air weight	<15 lb
Forward rotation only	4,500 surface ft/min
Able to cut	Rebar 5/8-in. bolts Wire rope Synthetic line
Interchangeable arbor for abrasive saw, grinding wheel, and cleaning brush	Yes
Operating depth	190 ft
Temperature	-1 to +40 °C
Reliability	0.90
MTBF	76 hr
MTTR	4 hr
Availability	0.80
Maintenance	
Daily	0.5 hr
End of project	1 hr
Annually	4 hr

COMPONENT DESCRIPTION

The rotary disk tool (RDT), Figure 9, is unique in its construction since the majority of the tool is fabricated from an acetal resin. This tough resin is not only used for the body of the tool, but it is also used for the right angle gear set and bearings. The resin is resistant to prolonged exposure to seawater and it is lighter in weight compared to metals. The tool functions as follows:

1. The seawater enters at the base of the handle through the trigger poppet valve to the 3-horsepower seawater hydraulic vane motor.

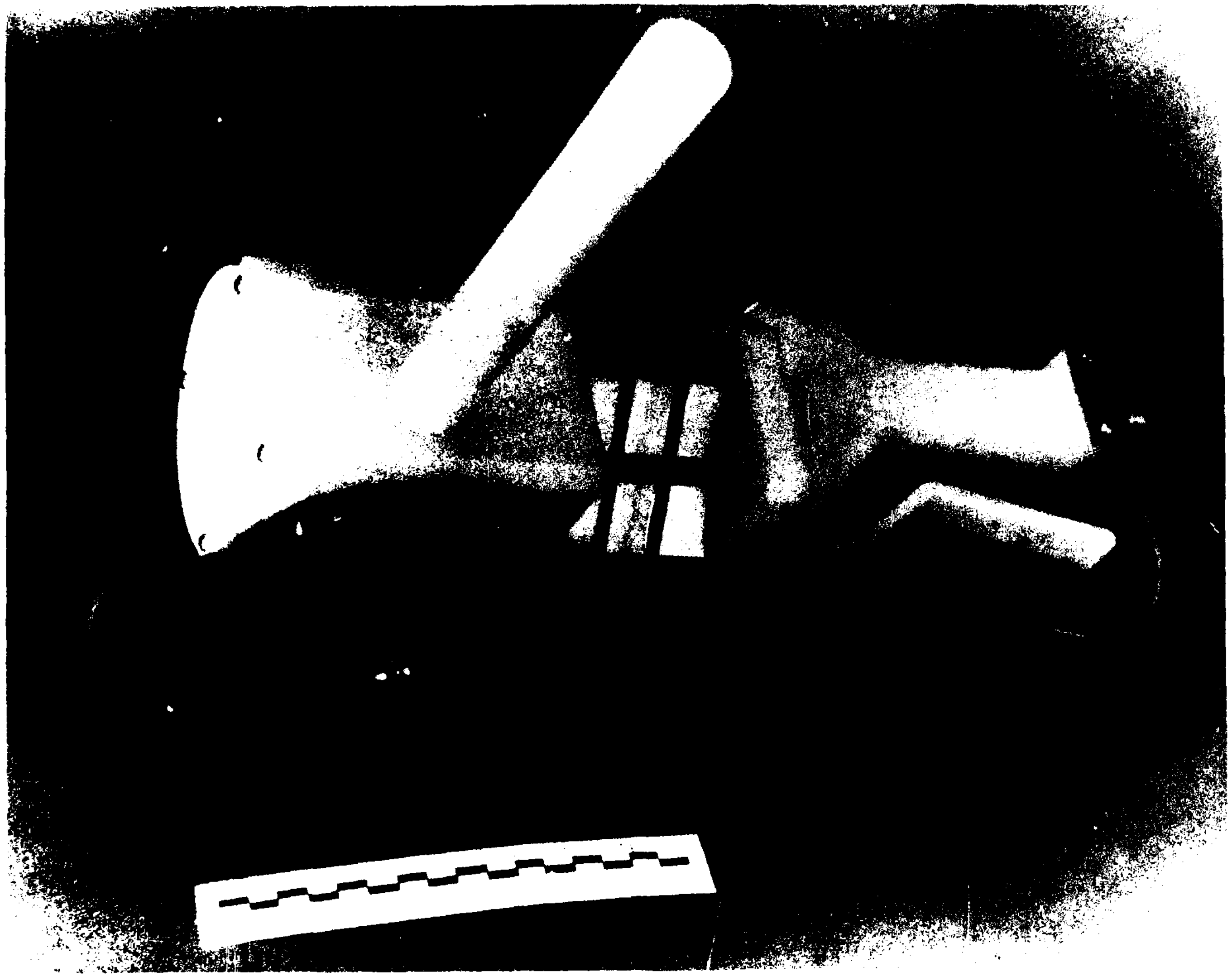


Figure 9. Seawater hydraulic rotary disk tool.

2. The water is exhausted through the seawater motor into the 1:1.4 right angle gear box where it acts as the lubricating fluid for the gear, pinion, and bearings.

3. It is then exhausted as a fan spray directed onto the back of the abrasive disk. This exhaust water serves to reduce the drag of the disk and to flush loose material away from the work surface.

4. A disk guard protects the diver from possible injury.

5. An auxiliary handle can be positioned in one of four threaded ports in the gear box to facilitate tool handling for both left- and right-handed divers.

TEST AND EVALUATION

The laboratory tests and evaluation of the seawater rotary disk tool were conducted at Naval Coastal Systems Center (NCSC), Panama City, Florida and at NCEL. Two rotary disk tools permitted testing simultaneously at both locations. NCSC conducted continuous load tests, while NCEL conducted cyclic testing, human factors evaluation, operational testing, and reliability and maintainability analyses. The laboratory data recorded during these test is available in Reference 6.

Operability, Safety, and Human Factors Tests

Results of the individual tests conducted in this evaluation are given below. The prototype seawater hydraulic RDT met all the design requirements as listed in Table 4. The RDT performance was satisfactory and no safety problems were observed.

Initial Operating Characteristics. The performance of the RDT was measured with the tool installed on a Multi-Purpose Test Apparatus (MPTA), Figure 10. The MPTA provided for submerged measurements of torque and speed. Figure 11 is a plot of shaft torque versus speed for lines of constant flow and constant pressure.

During preliminary testing, the poppet valve failed to operate when the trigger was depressed. An investigation determined that the poppet valve would not completely open because of a buildup of pressure behind the plunger from leakage flow. A small hole, drilled in the valve cap, relieved the plunger chamber and allowed full plunger movement. However, with this modification, the RDT would not completely shut off when the trigger was released. Examination determined that the poppet valve was unbalanced in the open position. The poppet valve was balanced by increasing the area under the valve cap. There were no further problems with operation of the poppet valve.

Noise Level. The RDT is barely audible while underwater and does not present a hearing loss hazard to the diver.

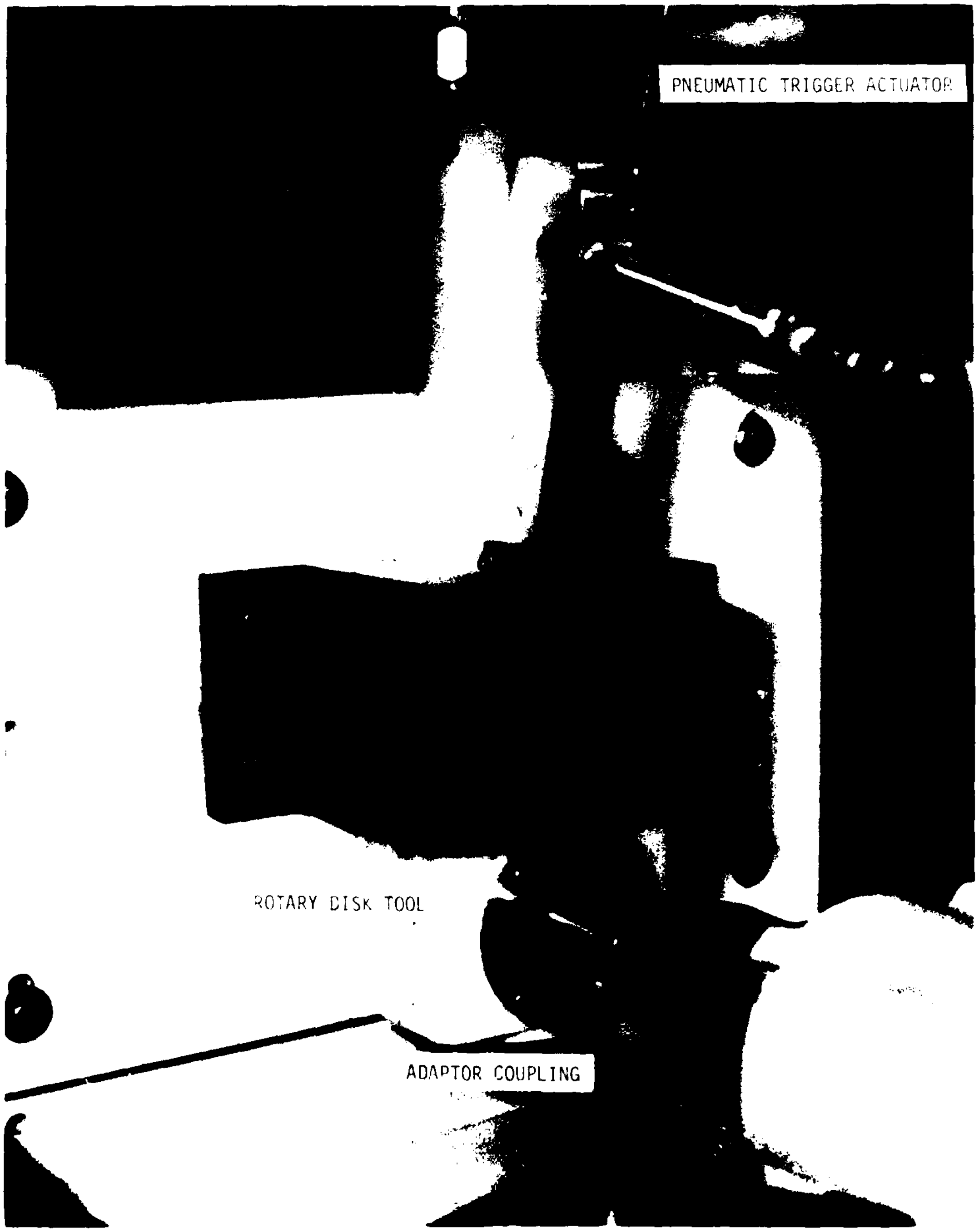


Figure 10. Rotary disk tool mounted in the multi-purpose test apparatus at NCEL, being loaded by an oil-hydraulic pump.

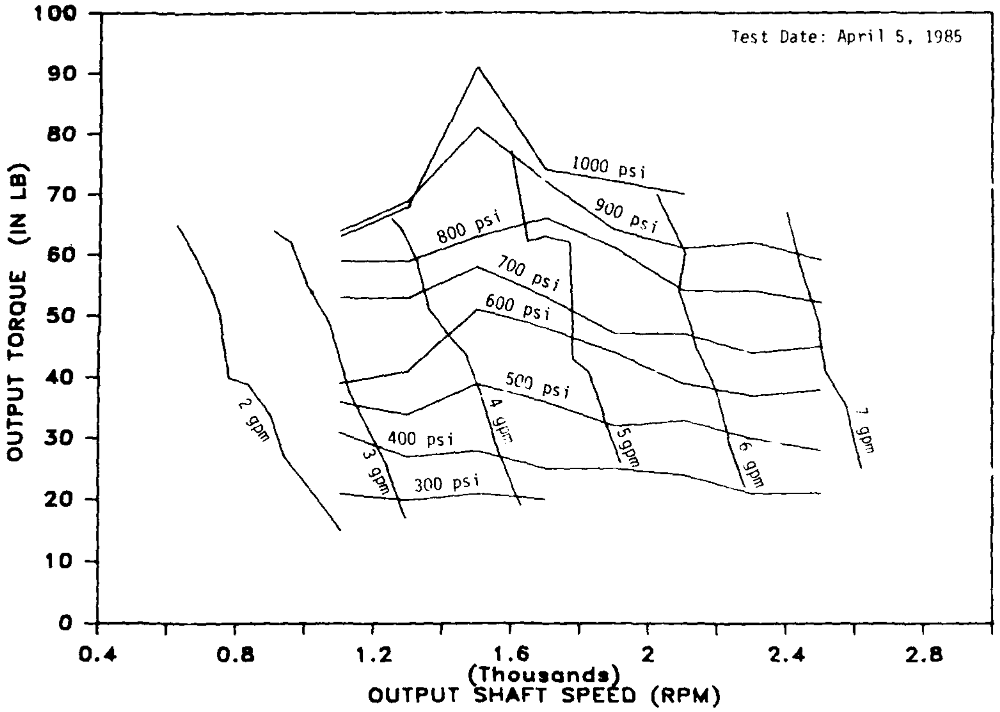


Figure 11. Rotary disk tool: initial performance.

Cutting Tests. The RDT was used to cut SD List 1 coaxial cable, 1-1/4-inch synthetic line, 1-inch rebar, 1-inch wire rope, and 5/8-inch steel bolts. It was also used for grinding operations on steel plate and 5/8-inch bolts. To simulate work tasks, the material was positioned both horizontally and vertically. Table 5 shows representative underwater cutting times. Grinding operations were observed for technique.

The diver was able to quickly cut through all test materials using the RDT. Cutting times in the vertical position were slightly faster than in the horizontal position. The decrease in time required for vertical cuts is attributable to the awkwardness of using the tool on its side when cutting horizontal material.

Human Factors Evaluation. The RDT was evaluated by three divers for handling, ease of use, safety, and other human factors considerations. Interview forms recording diver comments are provided in Appendix B. The results are summarized below:

1. The trigger was too long causing the diver to release the tool handle when releasing the trigger.

2. The auxiliary handle was awkward to use in the available tool head locations when making cuts on horizontal material.

3. The location of the exhaust water around the output shaft was beneficial for clearing debris away from the work area.

4. The disk guard did not extend out far enough to cover the disk.

5. A quick-change disk would improve the diver's ability to change disks while wearing gloves. It also would not require tools.

Valve Leakage Test. A leakage test was performed to determine the rate of water passing through the closed valve to the motor. This test was conducted to assure that water was wetting the motor side plates before motor startup to reduce friction that might damage the motor side plates. The leakage past the valve, approximately 0.07 gpm, was determined to be adequate.

Table 5. Cutting Tests Results

[Note: Flow set at 7 gpm for all tests.]

Material	Material Orientation	Cutting Time (sec)
SD List 1 coaxial cable, 1-1/4-inch diameter	Horizontal	180
	Horizontal	116
	Horizontal	109
1-inch rebar	Vertical	159
	Vertical	293
	Horizontal	346[a]
	Horizontal	393
	Horizontal	218
1-inch wire rope	Vertical	81
	Vertical	171
	Vertical	85
	Horizontal	96
	Horizontal	185
	Horizontal	133
1/8- x 2-inch steel plate (cut and grind)	Horizontal	48[a]
	Horizontal	115
	Horizontal	71
5/8-inch bolt (cut and grind)	Horizontal	104

[a] Partial cut; remaining uncut material was broken off by hand.

Reliability, Maintainability, and Availability Analysis

The results of the individual tests conducted in this evaluation are summarized below. Part of this testing was conducted at NCSC.

Endurance Testing. The endurance testing was conducted in two phases. NCSC performed continuous load testing to evaluate the strength of the gear head assembly. NCEL performed cyclic load testing to determine the durability of the handle and valve subject to repetitive use. To meet a reliability threshold of 0.90 and 76 hours mean time between failure, the rotary disk tool was required to operate 174 hours (Ref 7). The operating cycle for this tool was 6 minutes on, 2 minutes off, for a total "on" time of 130 hours. The reliability criteria specified that a failure requiring less than 30 minutes to repair is not considered a failure chargeable against the reliability threshold.

Continuous Load. The objective of this test was to determine the wear properties of the gear assembly subject to uneven, continuous disk loads. The test apparatus, Figure 12, rigidly supported the RDT during testing. Instrumentation recorded time, flow, speed, temperature, and pressure. Measurements of the critical gear dimensions were recorded throughout the test at 10-hour intervals. The RDT was loaded to 80 percent of the rated motor output using a 1-inch-diameter rod of acetal resin weighted with 10 pounds of lead shot and placed in contact with the outer edge of the simulated grinding disk.

Early results showed rapid wear at the output shaft bearing in the area between the pinion and the thrust collar (Figure 13). The shaft bearing, thrust bearing, and pinion gear were designed as an integral unit. Investigation revealed that the radial bearing surface area was inadequately sized to handle the loads. The bearing was redesigned as a two-piece unit with a larger surface area for carrying the radial shaft loads (Figure 14).

In addition, the bearing surface between the pinion and the thrust collar was not receiving adequate lubrication. The lubrication pressure was increased from 12 psi to 50 psi by blocking three of the existing four motor exhaust holes in the gear box. This provided more flow across the bearing surfaces by forcing exhaust water through the shaft lubrication passages to the bearing surfaces.

Inspection of the redesigned bearing after 50 hours of testing revealed a significant reduction in wear at all bearing surfaces.

At 60 hours of testing, there was evidence that the input shaft bearing collar had seen intermittent rotation. There was no observable damage as a result of this part rotating and therefore, no fix was required. This piece will be retained to prevent rotation in the final design.

There were no further problems encountered and the RDT completed the 130 hours of testing. Once the initial wear-in of the gear teeth had occurred, no additional wear was detected in the tooth meshing area of the gears.

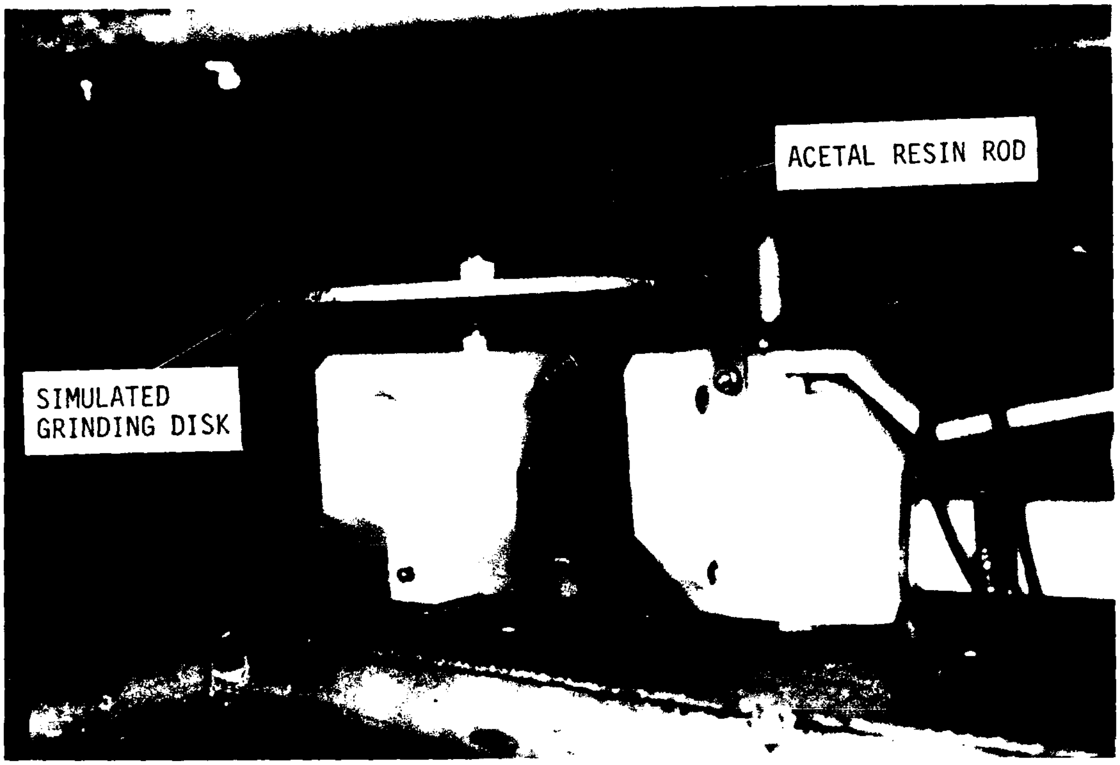


Figure 12. Rotary disk tool in fixture for continuous load test.

Cyclic Testing. For the cyclic testing, the RDT was operated submerged in fresh water mounted on the MPTA. The cycle time was 6 minutes on, 2 minutes off. The cycle testing was performed on the RDT after the output shaft bearing and the trigger valve problems had been corrected. The test criteria required 1,305 "on/off" cycles. The RDT was operated at 80 percent of the maximum load and the test was completed with no problems.

Table 6 summarizes the failures encountered during endurance testing. The RDT completed 130 hours of the continuous load test, and 1,305 cycles of the cyclic test without a chargeable failure as defined by the failure criteria. The point estimate of the RDT reliability is 0.90 at a 90 percent confidence level. The MTTR is estimated to be 0.40 hours.

The MTBF for a mission of 8 hours was calculated using an exponential distribution to be 76 hours at the lower limit of the 90 percent confidence interval. Using this MTBF of 76 hours and an MTTR of 0.40 hours, the inherent availability (A_I) calculates to be 0.995. This is substantially greater that the 0.80 design requirement.

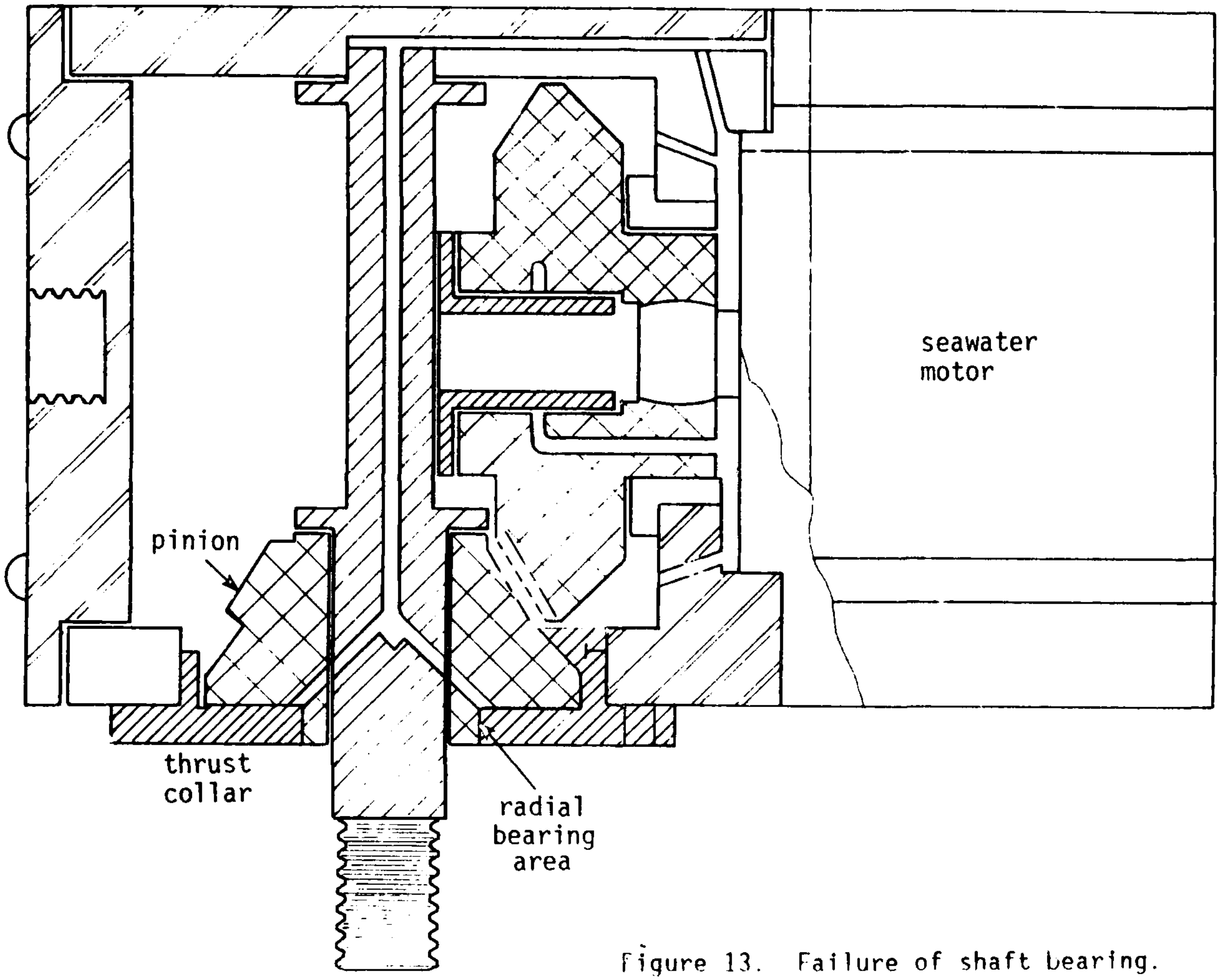


Figure 13. Failure of shaft bearing.

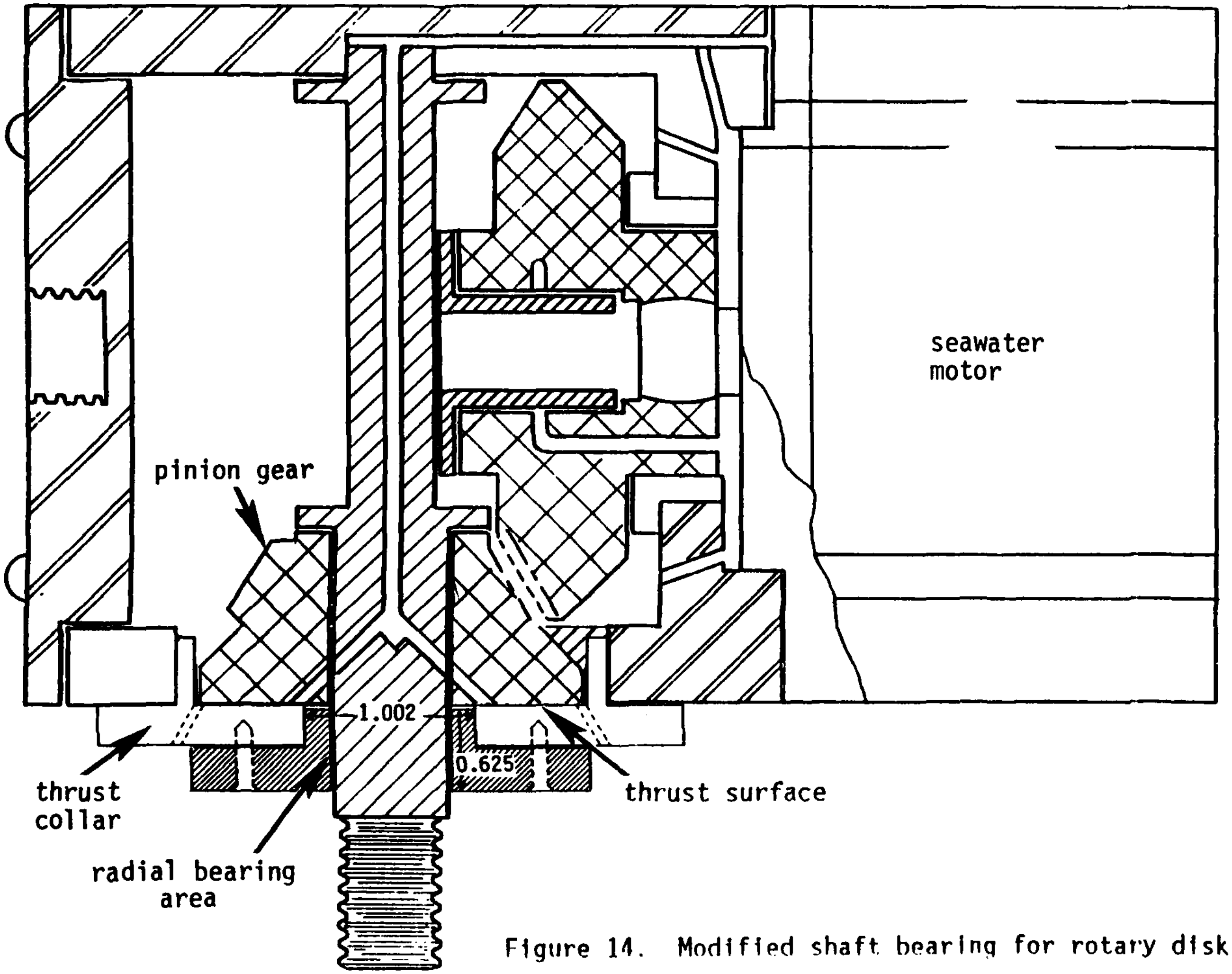


Figure 14. Modified shaft bearing for rotary disk tool.

Table 6. Tool Failure Summary

Equivalent Test Time (hr)	Failed Item	Cause of Failure	Redesign Action	Type of Failure (MIL-STD-781C)	Repair Time (hr)
5	Output shaft radial bearing	Insufficient bearing area	Doubled bearing length	Nonrelevant	0.5
5	Output shaft thrust	Insufficient Lubrication	Increase lubrication flow	Nonrelevant	0.3
135	Trigger valve not operating properly	Unbalanced valve	Balance valve	Nonrelevant	0.3

Post-Life Performance Test. With the endurance test complete, the tool performance was measured to check for any degradation in performance. This test was conducted in the same manner as the initial performance test (Figure 10). The results, displayed in Figure 15, show an insignificant decrease in tool performance when compared to the earlier results of Figure 11. It should be noted that the seawater motor at the end of the tests had only operated for half of its expected life. It is designed to operate for 250 hours at 80 percent of the rated power of 3 horsepower.

Following testing, the RDT was disassembled and the interior components examined. One of the screws that holds the thrust collar to the housing had fallen out but this caused no serious problem. The pinion gear teeth showed minimal wear. There was minimal wear on the output shaft, the thrust collar bearing surface, and on the gear retainer shaft. Wear on these surfaces is expected, and the degree of wear during these tests was found to be of no concern. The tests indicated that the materials are compatible and will provide reliable performance over tool life.

Improper Storage Test. The RDT was operated with seawater and stored without flushing. A severe storage environment was simulated using a wooden box exposed to the elements. The RDT was left in the box for 33 days. At the conclusion of the test, the RDT was removed and completely disassembled. Many of the metal components showed signs of minor corrosion, mostly in the cracks and joints of mating pieces. The acetal resin was stained in places where it contacted rusty metal. The RDT was covered with a salt residue but no hard salt crystals had formed. Some crystals had begun to form in the exhaust ports of the thrust collar but none of the exhaust ports were plugged. There was some minor crevice corrosion on the output shaft. The plugs inserted into the gear box were also corroded. There were no parts that required replacement.

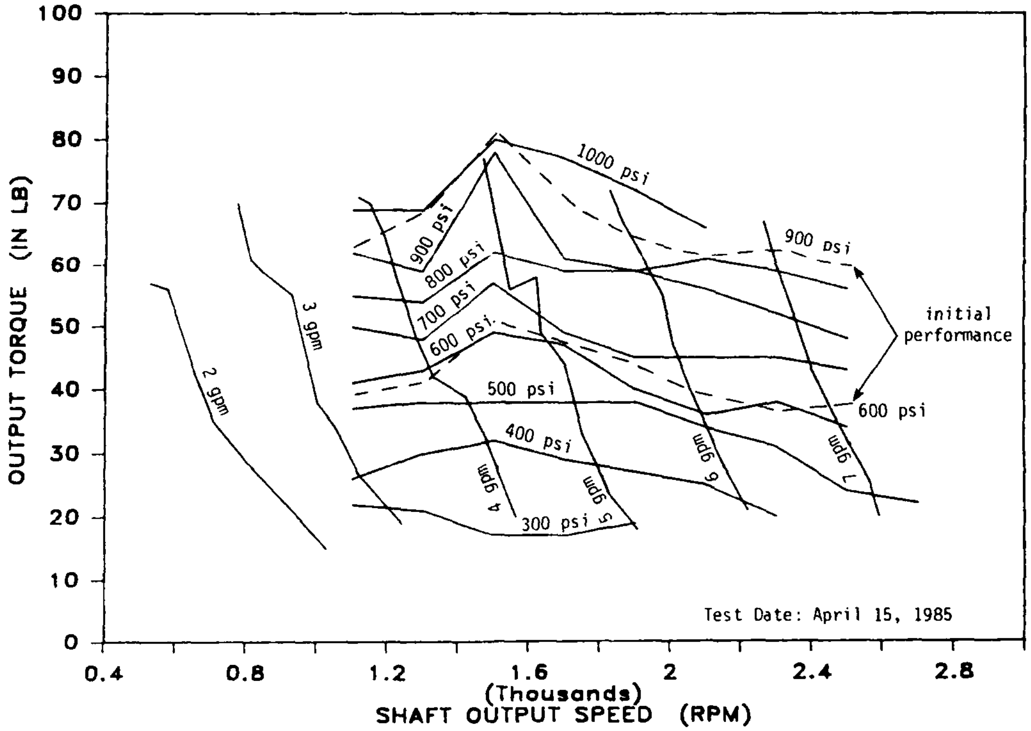


Figure 15. Rotary disk tool: final performance.

Required Maintenance. The maintenance required for the RDT is minimal. A daily fresh-water flushing is all that is required after use. Upon returning from deployment, the RDT O-rings should be checked and lubricated. There are no internal parts in the RDT that require replacing before the end of its useful life. The spare parts kit includes one seawater motor, a complete valve cartridge, bearings, and spare O-rings.

Logistic Supportability Analysis

As part of the MFTS, the RDT will come with an operation and maintenance kit. These parts will include a standardized motor and a standardized valve cartridge. These parts are replacements in case of a premature failure of a component and are recommended based on the results of the testing that has been completed to date. No special tools are required to perform any of the maintenance outlined in the Operation and Maintenance Manual.

All spare parts and the RDT will be transportable in a permanent storage case that is padded to prevent tool damage during transit. There are no special requirements for shipping. All training required for the RDT is covered in the Operation and Maintenance Manual.

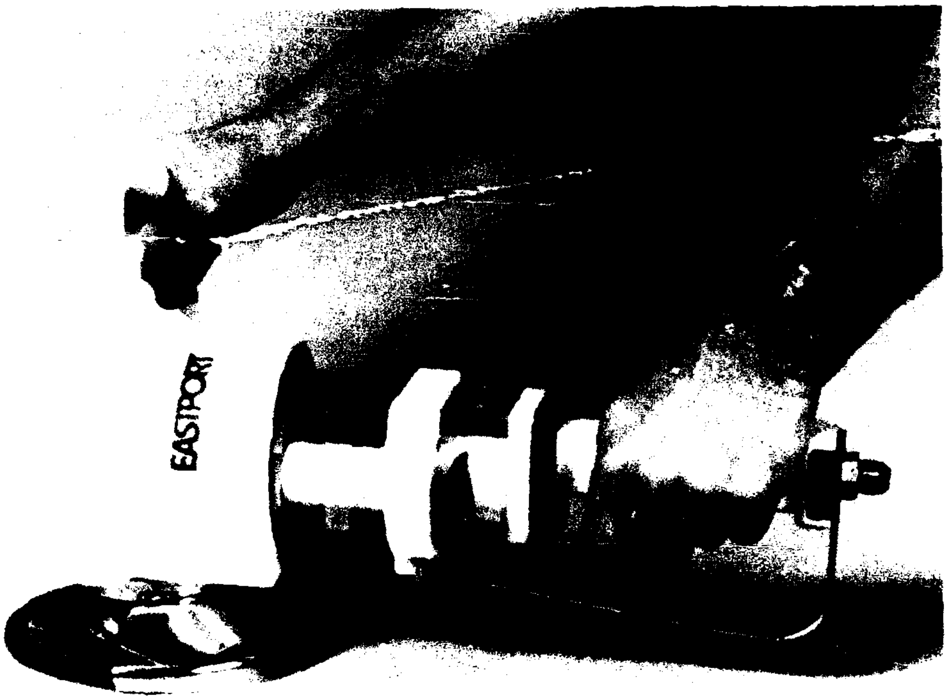


Figure 16. Production rotary disk tool.

FINDINGS

The following findings are based on the results of the development tests:

1. The prototype RDT met or exceeded the design requirements. The tool is suitable for performing the tasks of grinding and cutting a variety of materials.
2. With a 7-inch-diameter abrasive disk, operating at a flowrate of 7 gpm and a pressure of 800 psi, the disk speed is 2,500 rpm submerged.
3. The cutting tests showed the need to improve the design of the auxiliary handle of the tool.
4. The trigger is too long for safe operation.

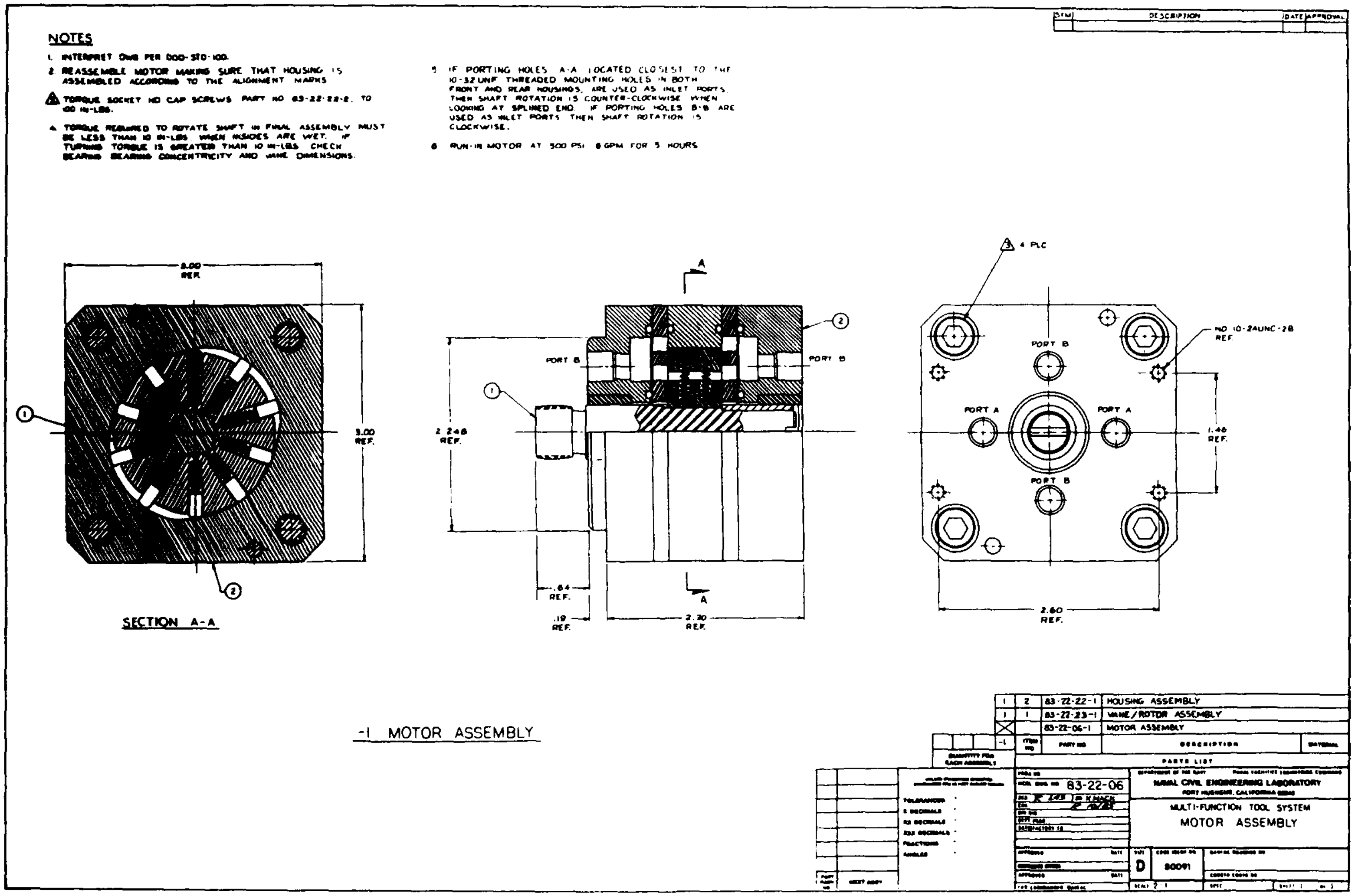
PRODUCTION MODEL

The rotary disk tool was modified to improve handling capabilities. The production rotary disk tool (Figure 16) has a bayonet plate between the motor and tool head. The bayonet plate allows rotation of the tool head in 90-degree increments to accommodate cutting or grinding. In addition, the auxiliary handle was improved to a D-shape to offer convenient hand positions for either a right-handed or left-handed diver.

The rotary disc tool also features a quick-release button on its output shaft that enables installation or removal of the grinding disc underwater without tools. The assembly drawings are provided in Appendix A.

A standardized seawater motor and modular control valve/handle assembly were added to reduce spare parts inventory requirements. The standardized 3.5-horsepower seawater motor (Figure 17) is interchangeable with the tools of the MFTS with the installation of plugs in the unused ports. The balanced vane motor weighs only 3.5 pounds and it has a service life of 250 hours between rebuilds. It features a mounting boss and a short-splined shaft to aid in motor alignment.

The modular control valve and handle assembly (Figure 18) provided a shorter trigger to allow two-finger operation and a full hand guard. The valve design is similar to the valve tested on the prototype rotary impact wrench.


NOTES

1. INTERPRET DWG PER DOD-STD-100.
2. REASSEMBLE MOTOR MAKING SURE THAT HOUSING IS ASSEMBLED ACCORDING TO THE ALIGNMENT MARKS
3. TORQUE SOCKET HD CAP SCREWS PART NO 83-22-22-2, TO 100 IN-LBS.
4. TORQUE REQUIRED TO ROTATE SHAFT IN FINAL ASSEMBLY MUST BE LESS THAN 10 IN-LBS. WHEN INSIDES ARE WET. IF TURNING TORQUE IS GREATER THAN 10 IN-LBS CHECK BEARING BEARING CONCENTRICITY AND VANE DIMENSIONS.
5. IF PORTING HOLES A-A LOCATED CLOSEST TO THE 10-32UNF THREADED MOUNTING HOLES IN BOTH FRONT AND REAR HOUSINGS, ARE USED AS INLET PORTS THEN SHAFT ROTATION IS COUNTER-CLOCKWISE WHEN LOOKING AT SPLINED END. IF PORTING HOLES B-B ARE USED AS INLET PORTS THEN SHAFT ROTATION IS CLOCKWISE.
6. RUN-IN MOTOR AT 500 PSI 8 GPM FOR 5 HOURS

1	2	83-22-22-1	HOUSING ASSEMBLY	
1	1	83-22-23-1	VANE/ROTOR ASSEMBLY	
☒		83-22-06-1	MOTOR ASSEMBLY	
-1	ITEM NO	PART NO	DESCRIPTION	MATERIAL
QUANTITY FOR EACH ASSEMBLY	PARTS LIST			

Figure 17. MFTS 3-horsepower motor assembly.

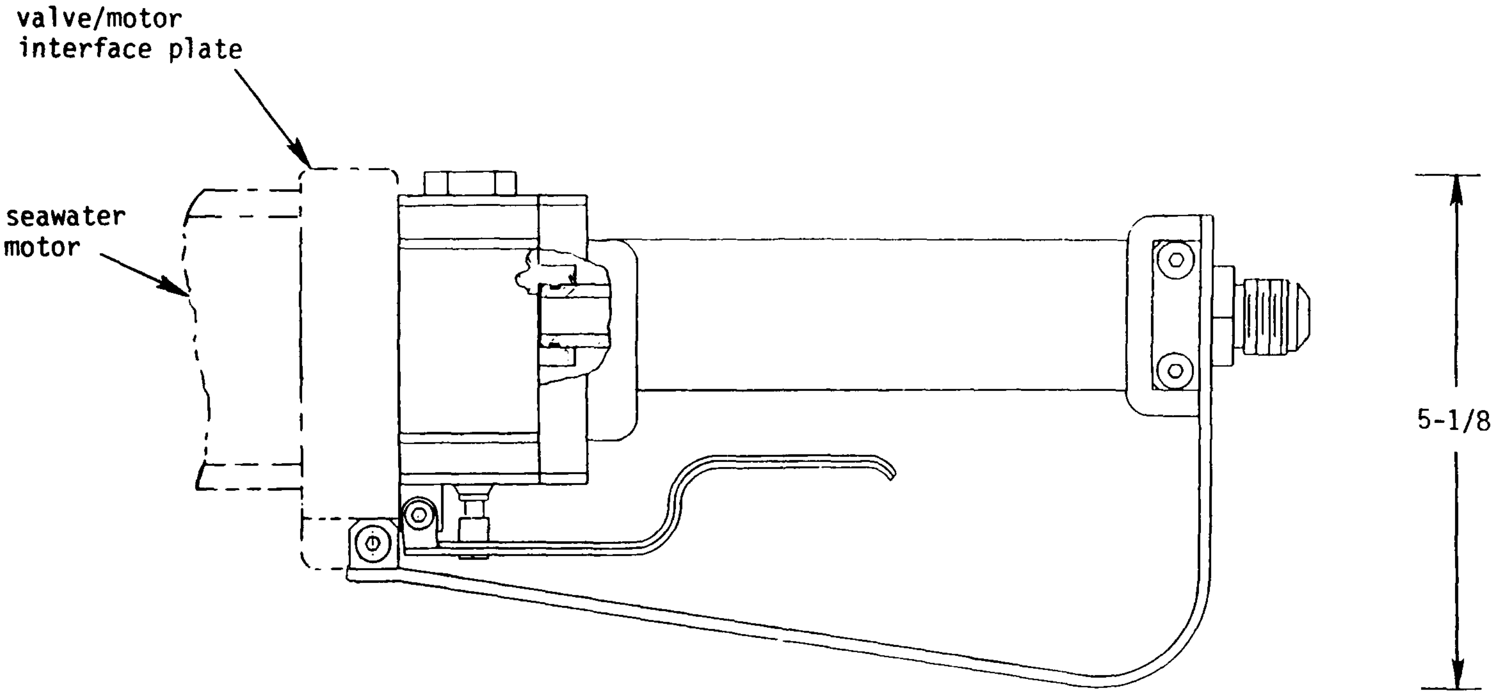


Figure 18. MFTS control handle assembly.

CHAPTER 4. SEAWATER HYDRAULIC ROTARY IMPACT TOOL

The design requirements for the MFTS rotary impact tool are summarized in Table 7. The rotary impact tool can also be used as a drill.

Table 7. Rotary Impact Tool Operating Requirements

Item	Design Requirement Threshold
Torque	400 ft-lb
Bolts	5/8 in.
Drill holes in wood and metal	1/4 to 1 in.
Air weight	15 lb
Forward and reverse operation	Yes
Uses commercial impact sockets and drills	Yes
Operating depth	190 ft
Temperature	-1 to +40 °C
Reliability	0.85
MTBF	49 hr
MTTR	4 hr
Availability	0.80
Maintenance	
Daily	0.5 hr
End of project	1 hr
Annually	4 hr

COMPONENT DESCRIPTION

The seawater hydraulic rotary impact tool (Figure 19) uses a commercially available impact mechanism from a pneumatic impact wrench. The design of the tool centers around a cast Inconel backhead to which the seawater motor, the valve and handle, and the impact housing are attached (Figure 20). Integral with the backhead is the rotary reversing valve and the porting to control the direction of the 3-horsepower seawater motor. The reversing valve rotates 180 degrees and is operated by a handle on the left side of the tool.

Seawater enters at the bottom of the handle and is regulated by a poppet valve at the handle trigger. After being directed by the reversing valve through the seawater motor, the water passes back through the reversing valve and is exhausted just above the handle guard.

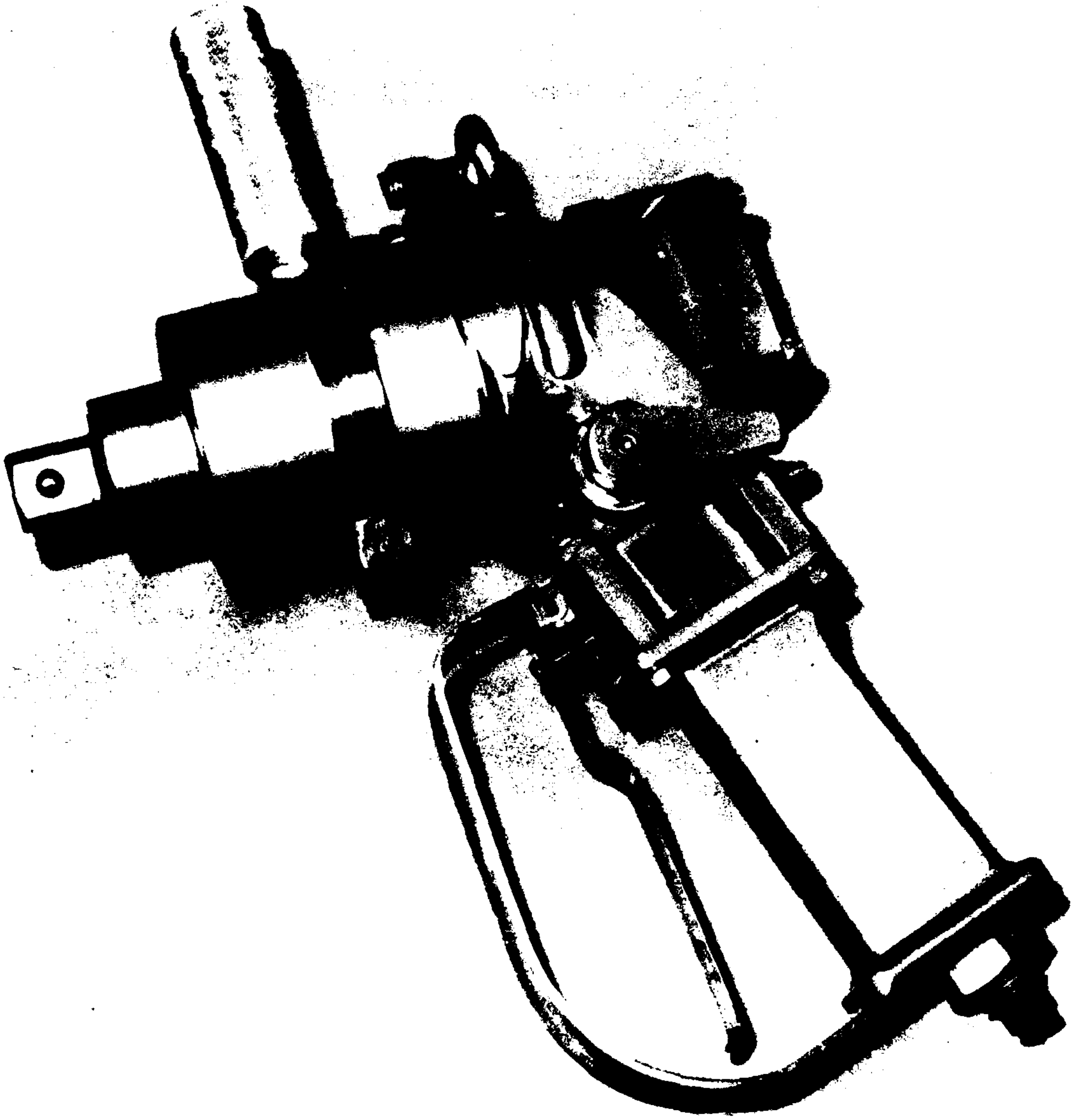


Figure 19. Seawater hydraulic powered rotary impact tool.

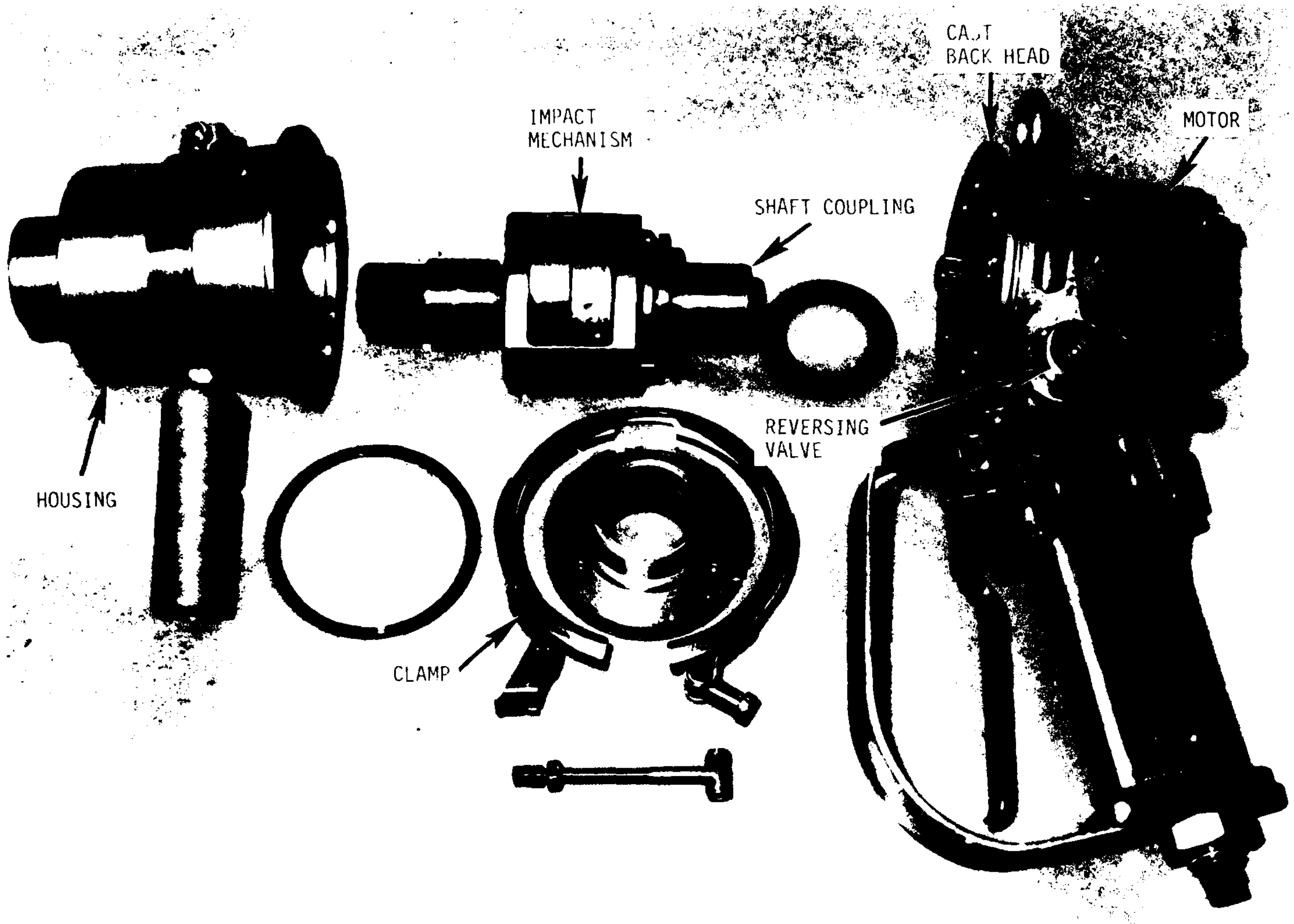


Figure 20. Exploded view of rotary impact tool.

The impact mechanism is mounted in a sealed housing. A water soluble oil solution provides lubrication and cooling for the impact mechanism and bearings.

The impact mechanism is directly coupled to the shaft of the seawater motor. The impact housing is held to the backhead with a flange clamp. The 1-inch-square drive anvil is drilled for the use of socket retainers. By adding a drill chuck, the tool can be used as a drill.

TEST AND EVALUATION

The laboratory tests and evaluation of the seawater rotary impact tool were conducted at NCEL in the Seawater Hydraulics Laboratory and the Ocean Systems Test Facility by NCEL personnel.

The laboratory testing was conducted on a test platform that rigidly supported the tool and test load. Pneumatic actuators were used to control tool operation. A journal brake was connected directly to the impact wrench anvil as the load. This configuration (Figure 21) was submerged in the test tank for extended periods during the life test.

For measuring tool performance, a Skidmore Wilhelm impact tester replaced the journal brake for surface use. The Skidmore Wilhelm impact tester related bolt tension, measured as pressure, to applied torque. Inlet flowrate and pressure were continuously monitored during testing. The laboratory data recorded during testing can be found in Reference 8.

Operability, Safety, and Human Factors Tests

Results of the individual tests conducted in this evaluation are given below. The prototype seawater hydraulic rotary impact tool met the design requirements as listed in Table 7 except for weight. The impact tool performance was satisfactory and no safety problems were observed.

Initial Operating Characteristics. Tool performance was measured using the Skidmore Wilhelm impact tester. Figure 22 is a graph of torque as a function of impact time, in seconds, for five different flowrates. The hydraulic relief pressure was held constant at 750 psi during this test.

The impact wrench achieved the required bolt torque within 3 seconds almost independent of the set flowrate. This is attributed to the accumulator affect of 250 feet of supply hose. For the first seconds of operation, the tool operates with an instantaneous maximum flowrate greater than the set flowrate. This peak flow, a function of the tool relief pressure in this closed center system, is caused by contraction of the hose diameter as the fluid energy stored in the hose is released. As expected, the rate of impacting, measured in beats per second of the hammers, is directly related to the speed of the motor which is a function of the seawater flowrate. During these first seconds, the tool performance is independent of the set flowrate. After this energy has been expended, the tool behaves in the expected load-dependent manner.

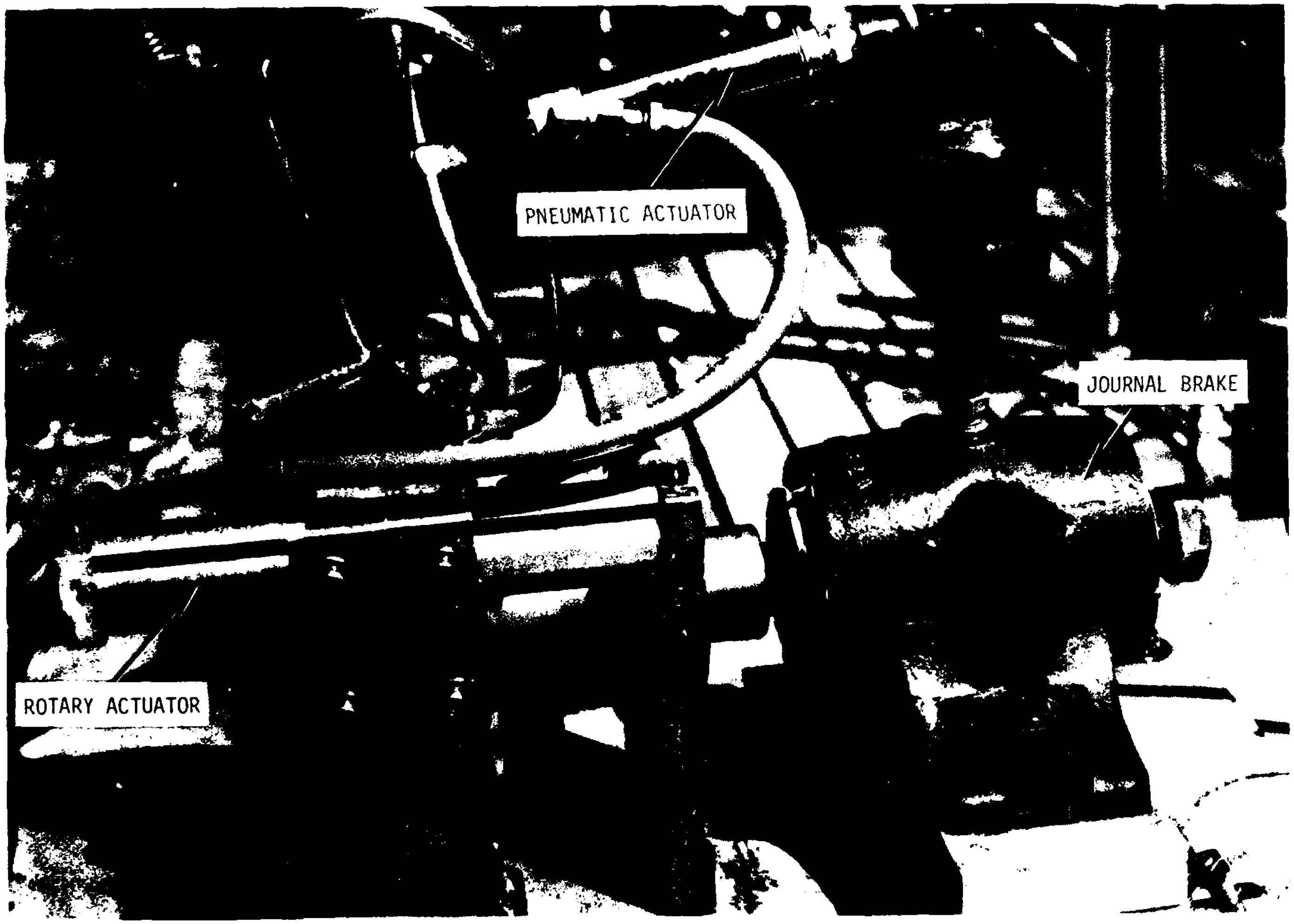


Figure 21. Rotary impact tool mounted on submerged test platform driving a journal brake. The pneumatic linear actuator cycles the trigger, while the rotary actuator controls direction of rotation.

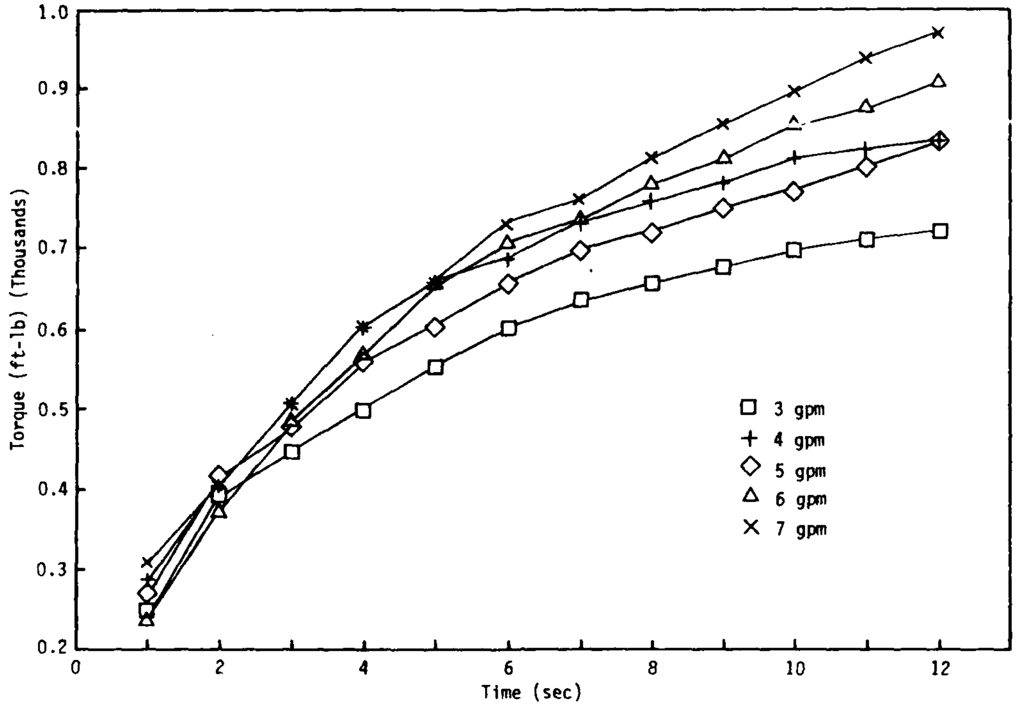


Figure 22. Impact wrench performance curve.

Noise Level. Sound level measurements were conducted in open water with a hydrophone placed near the diver's ear but at a distance from the tool not greater than 2 feet. The data were collected on tape and later analyzed to provide an equivalent sound pressure level in air (Ref 9). The tool produced an adjusted sound pressure level of 74.8 dB referenced to 20 μPa. The permissible exposure level (PEL) is 84 dB for any 8 hours in any 24-hour period. The noise level of the impact tool is within the PEL and is not a hazard to the diver. In addition, hooded divers operating the tool indicated that the impacting noise was not a problem.

Tightening and Drilling Tests. The tightening and drilling tests were performed by Navy divers. The divers used the impact wrench to tighten 5/8-inch bolts and drill 1/4-, 1/2-, 5/8-, and 3/4-inch-diameter holes into 3/8-inch cold rolled steel plate and 4- by 4-inch wood.

The average time required to tighten a series of ten bolts to 400 foot-pounds was less than a minute. Loosening the same ten bolts took slightly longer. The tests were performed with bolts oriented both vertically and horizontally with no significant time difference.

A drill chuck was installed for the drilling tests. The divers were required to drill several hole sizes in steel and wood positioned vertically and horizontally. Times were recorded for each hole drilled. For the drilling tests, tool supply flowrate and pressure were increased from an impact wrench setting of 5 gpm at 750 psi to 7 gpm at 1,000 psi to achieve the proper bit speed.

The average drilling time results are shown in Table 8. Vertical-down drilling times were somewhat better than times recorded for drilling horizontally. This is because the weight of the tool helped in drilling vertical holes. The drilling tests in wood produced comparable drill rates for twist style and auger style drill bits. A sharp increase in horizontal drilling times was noted with the larger bits in steel due to the difficulty of maintaining feed force. These times were satisfactory and comparable to existing tools.

Table 8. Average Drilling Times

Drill Size Diameter (in.)[a]	Material Thickness (in.)	Horizontal Position Time (sec)	Vertical-Down Position Time (sec)
1/4	3/8 Steel	60	13
1/2	3/8 Steel	65	30
5/8	3/8 Steel	130	43
3/4	3/8 Steel	140	--
1/4 T	4 Wood	11	12
1/2 T	4 Wood	24	28
1/2 A	4 Wood	38	15
5/8 T	4 Wood	24	20
5/8 A	4 Wood	21	28
3/4 T	4 Wood	27	25
3/4 A	4 Wood	31	26
1 T	4 Wood	51	29
1 A	4 Wood	32	30

[a] Note: T = Twist drill bit; A = Auger drill bit.

Human Factors Evaluation. During drill and impact tests, the impact tool was evaluated by several divers for handling, ease of use, control, safety, and other human factors considerations. Diver comments can be found in Appendix B. Some specific comments on handling are summarized as follows:

1. The handle was uncomfortably large, creating difficulties in tool positioning and balance.
2. The trigger was considered too long by about two or three finger widths, requiring the divers to release the handle to release the trigger.
3. The divers noted that the tool was heavy and should be lightened.
4. The tool had more than adequate power.

Reliability, Maintainability, and Availability Tests

The results of the individual tests conducted in this evaluation are summarized below. The reliability was demonstrated to 0.85 at an 80 percent confidence level at the completion of the endurance test.

Endurance Test. The endurance test to verify the design requirement of 85 percent reliability at an 80 percent confidence level was 79 hours of cycle testing (Ref 9). A representative operation cycle was chosen at 5 seconds on "forward," 5 seconds on "off," 2 seconds on "reverse," then 5 seconds on "off." Repeating this cycle for the required 79 hours resulted in 10,533 cycles. The control of the tool was performed remotely with a timer and a pneumatic control circuit.

The test cycle was a severe test of the tool for two reasons. First, the reversing valve was operated more frequently than would be expected in field use. Second, the 5-second "off" period between operation was minimal for the lubricant in the impact housing to cool the hammers.

Prior to each test day's operation, the tool was connected to the Skidmore Wilhelm device and performance data were recorded for comparison with the baseline performance data taken at the beginning of the test period. After verifying performance, the Skidmore Wilhelm device was replaced with the journal brake and testing continued.

After 10,374 cycles, just 159 cycles short of completion, the polyamide-imide thrust washers and bearings in the impact housing had deteriorated due to inadequate lubrication. This may have resulted because of too short of an "off" period programmed in the cycle. Also, the bearing surface of the motor-impactor coupling was scored where it contacted the rear housing seal. The following improvements were made to the impact housing assembly to correct these failures:

- The polyamide-imide bearings and thrust washers were replaced with steel flanged bearings in both the front and rear housings.

- The bronze motor-impactor coupling was sleeved with stainless steel to provide better wear properties where it contacted the seal.

- A second O-ring was added to the rear housing to aid in alignment of the rear housing bearing.

- The anvil sleeve was lengthened and four lubrication holes were added to supply the nose bearing with lubricant.

With these improvements, the reliability testing continued. Because the impact housing had been reworked, the cycle count for the housing was reset to zero. The other components of the tool continued from the previous count.

At 15,379 total cycles, the impact wrench would not operate in the reverse direction. Inspection, following disassembly, revealed that the ceramic sleeve of the reversing valve had eroded. Clearance from erosion resulted in excessive leakage of the valve in the reverse position. This leakage was sufficient to stall the motor under load.

From a reliability standpoint, the reversing valve had successfully completed the required 10,533 cycles. The redesigned impact housing was the only component that had not completed the life test, having completed only 5,005 cycles.

To complete testing of the impact housing, a new reversing valve sleeve was fabricated. Bronze was substituted for the ceramic sleeve material because of expected improved wear properties between the stainless steel spool and the bronze sleeve.

At 17,107 cycles (6,574 cycles on the new impact housing), the motor-impactor coupling fractured at undercut for the spline shaft. Examination revealed a cyclic fatigue failure. This part had not been fabricated in accordance with the design as the relief undercut for the spline had not been radiused. Thus, this failure was attributed to improper production of the coupling. It was replaced and testing continued until 10,533 cycles had been completed on the new impact housing. No further problems were encountered. Table 9 summarizes the endurance test on a component basis.

All components of the rotary impact tool completed the required 10,533 cycles without a chargeable failure as defined by the failure criteria. The point estimate of the rotary impact tool reliability was calculated to be 0.85 at an 80 percent confidence level. With the repair times listed in Table 9, the Mean Time To Repair (MTTR) was estimated to be less than 0.60 hours.

The Mean Time Between Failure (MTBF) for a mission of 8 hours was calculated using exponential distribution to be 49 hours at the lower limit of the 80 percent confidence interval. With a MTBF of 49 hours and a MTTR of 0.60 hours, the inherent availability (A_i) is 0.988. This is substantially greater than the 0.80 design requirement.

Post-Life Performance Test. Performance data were taken following life testing and compared with the initial data. A comparison of initial performance with post-life performance at a flowrate of 4 gpm, shown in Figure 23, reveals some deterioration in the performance of the tool. The initial performance data indicated that the 400 foot-pound torque could be achieved in 2 to 3 seconds. Post-life performance shows an increase to 4 to 5 seconds. The deterioration is attributed to increased leakage in the rotary reversing valve.

Improper Storage Test. Several times during the course of the life testing, when it was necessary to wait for improved parts to be fabricated, the rotary impact tool went through informal improper storage tests. These tests ranged from 1 week to 1 month, with the tool left untouched after operation. The tool was not maintained in any way prior to these tests. Salt collected inside the trigger valve block assembly and backhead assembly. None of the deposits were very significant and would not have prevented the tool from performing.

Table 9. Endurance Test Summary

No. of Cycles	Equivalent Test Time (hr)	Failed Item	Cause of Failure	Type of Failure (MIL-STD-781C)	Redesign Action	Repair Time (hr)
10,374	77.8	Impactor bearing	Insufficient lubrication	Nonrelevant	Changed material from Torlon to steel	0.5
15,379	115.3	Reversing valve sleeve	Material breakdown	Nonchargeable	Changed material from ceramic to bronze	1.0
17,107	128.3	Coupling fracture	Improperly manufactured	Nonrelevant	Replaced with properly made part	0.25

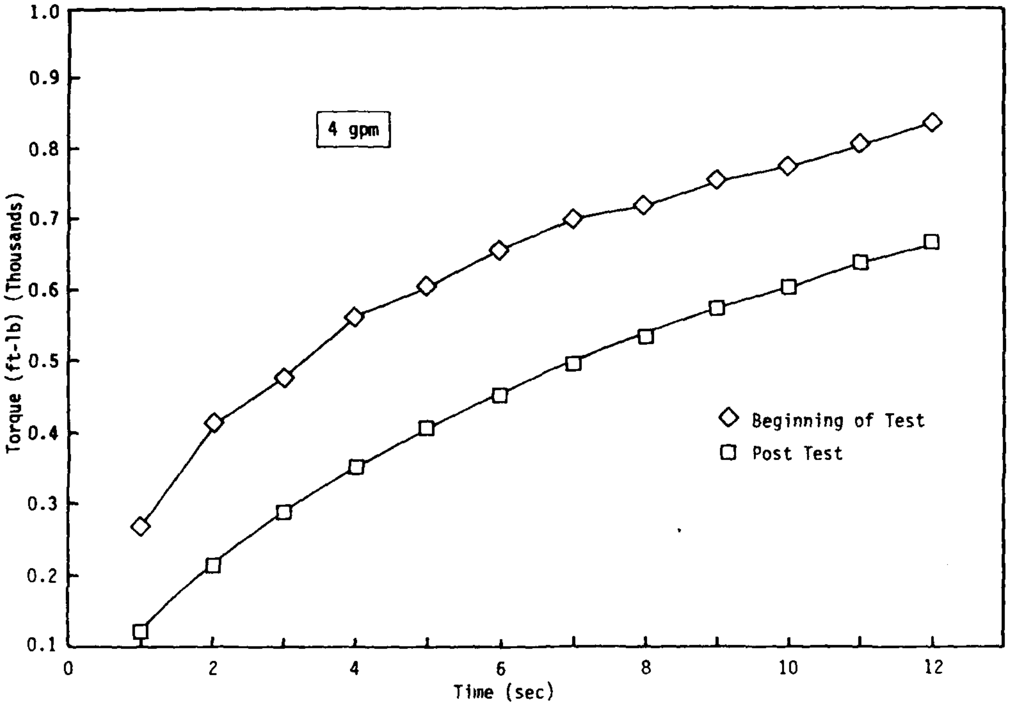


Figure 23. Impact wrench performance.

Two significant observations were noted. The first was the discovery of corrosion around the nuts that hold the clamp flange to the backhead assembly. The aluminum of the clamp flange, where the anodize had been scratched from repeated assembly, had corroded due to galvanic interaction between the anodic exposed aluminum and cathodic system components such as the stainless steel fasteners. This corrosion had penetrated between the threads. After disassembly, small pits were seen in the counter sunk area of the clamp flange. Marine growth was found on the motor mounting bolts where they passed through the backhead assembly. The area where this growth was found had limited access and could not be flushed with fresh water.

The second observation occurred after the new bronze reversing valve sleeve had been installed. Galvanic corrosion between the bronze sleeve and the stainless steel valve spool caused the reversing valve to bind. The very close tolerance between the valve spool and the sleeve makes thorough flushing of the parts difficult short of disassembly. Spraying the valve with oil after each use prevented this corrosion from binding the valve.

Required Maintenance. Aside from the improvements made during the life testing, tool maintenance was limited to replacing the seals and O-rings of the impact housing when it was noticed that they were leaking. The poppet valve seats in the trigger valve block were also replaced after life testing because of leakage.

There was some minor difficulty in assembling the rear housing into the impact housing because of the presence of clearance countersinks in the impact housing. When pressing the rear housing into the impact housing, the O-rings would protrude out at these four locations. If extra care was not taken to guide the O-rings back into their proper position, they would be damaged.

The field maintenance requirements of the seawater rotary impact tool are as follows: (1) the tool must be thoroughly rinsed and flushed with fresh water after daily use, (2) the reversing valve should be sprayed with oil and the valve operated to promote penetration (the oil can be sprayed into the valve area through the exhaust ports of the tool), and (3) after 8 hours of use, the lubricant in the impact housing should be replaced. The lubricant is a 20 percent mixture of soluble oil in water. During testing, it was observed that this oil will come out of solution and coat the internal parts in the impact housing. When the old solution is drained, most of the oil will remain inside. The addition of fresh oil serves to increase the concentration of oil inside the impact housing. The ability of this oil to coat the parts and not get washed away with the leakage of seawater through the impact housing seals helps improve the reliability of the tool. However, after each mission, the impact housing should be disassembled to clean away this buildup for subsequent inspection of the parts.

Depot level maintenance consists of annual disassembly and inspection.

Logistic Supportability Analysis

The impact tool will be delivered to the user with a complement of spare parts. These parts will include a standardized motor, a standardized valve cartridge, and a handle. These parts are intended to be used as replacements in case of premature failure of a component and are recommended based on the results of the testing that has been completed. Regular maintenance parts for the seawater impact tool include water soluble oil, impact housing seals, O-rings, and a reversing valve.

Only two special tools are required to perform the maintenance outlined in the Operation and Maintenance Manual. One is a sleeve for the end of the anvil to guide it through the housing nose seal during assembly of the impact housing. This special tool will be supplied with the impact tool. The other tool required is a hand-operated press used in disassembly and assembly of the rear housing from the impact housing.

The impact tool and all spare parts are transportable in a permanent storage case that is padded to prevent damage during transit. There are no special requirements for shipping. All training required for the impact tool is covered in the Operation and Maintenance Manual.

FINDINGS

The following findings are based on the results of the development tests:

1. The seawater hydraulic impact wrench met or exceeded the design requirements except for weight. The impact tool in-air weight exceeds the design requirement of 15 pounds by 5 pounds.

2. The impact tool provides the required 400 foot-pound torque design requirement in approximately 2 to 3 seconds at 750 psi for flowrates between 3 and 7 gpm.

3. The maximum flowrate for the tool is 7 gpm when used with the drill chuck attached. The minimum flowrate that the tool was operated at was 2 gpm.

4. The handle and trigger configuration requires modification to improve the comfort and reduce diver fatigue. The handle circumference should be reduced to allow gloved divers a firm grip on the tool. In addition, the trigger should be shortened by about two finger widths to allow the diver to release the trigger while maintaining his hold on the handle.

5. The impact housing requires improvement to ease assembly procedures and to prevent damage to the rear housing O-rings.

6. The stainless steel spool and bronze sleeve combination for the reversing valve assembly showed insignificant wear. The bronze sleeve is less expensive to fabricate than the ceramic sleeve. Galvanic corrosion between the stainless steel and the bronze can cause the valve to bind if it is not maintained in accordance with the Operation and Maintenance Manual.

PRODUCTION MODEL

The rotary impact wrench was modified to include the standard seawater motor, and modular control valve and handle assembly. The production rotary impact wrench (Figure 24) now uses the same handle as that of the rotary disk tool and bandsaw. This resulted in a small weight savings. The assembly drawings are provided in Appendix A.

In addition, the materials of the reversing valve were changed to stainless steel for the spool and bronze for the sleeve because of the expected increase in part life and lower fabrication costs.

Finally, the clearance countersinks in the impact housing were removed so that rear housing assembly is easier to perform without damaging the O-rings.

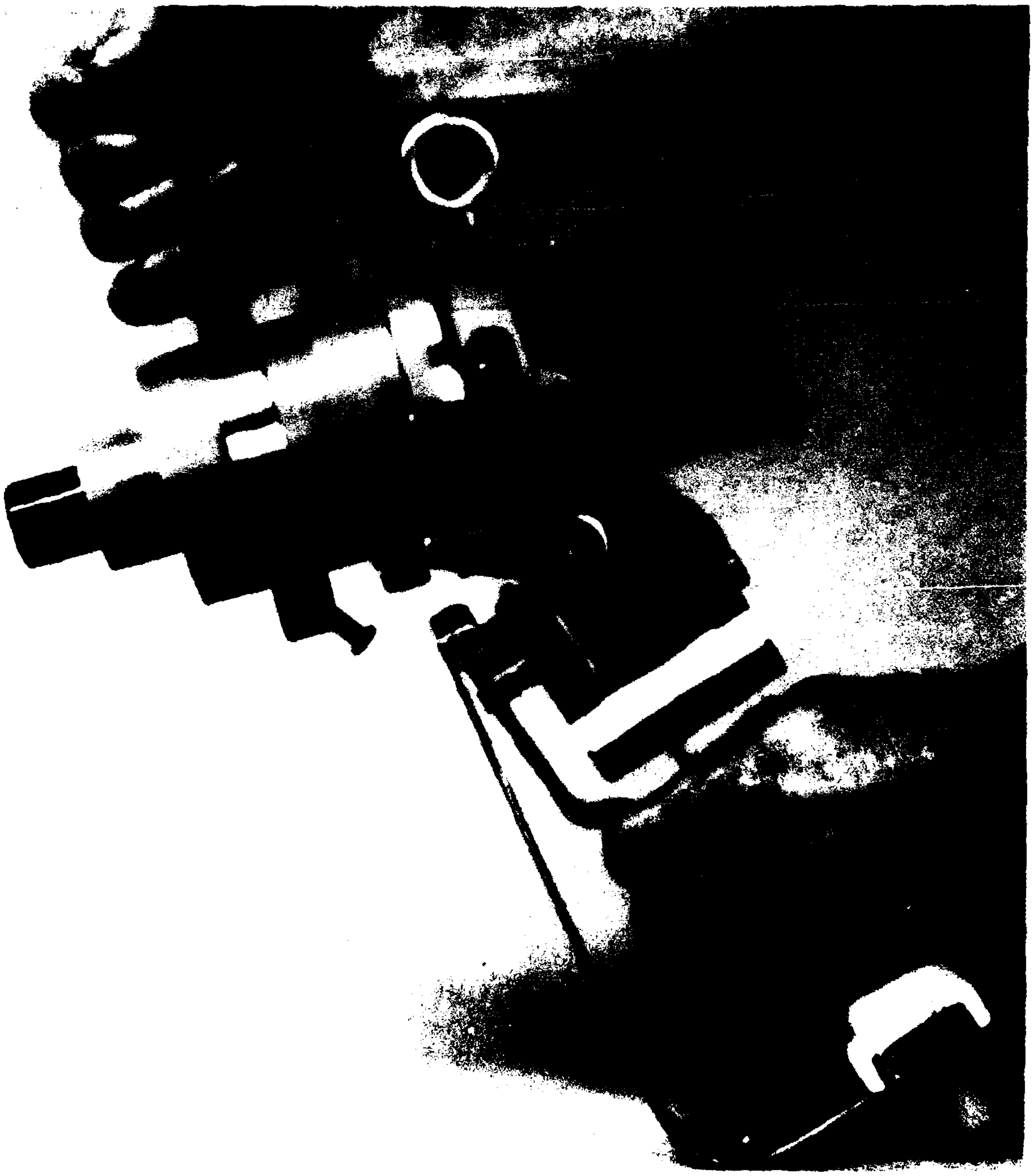


Figure 24. Production rotary impact wrench (RIW).

CHAPTER 5. SEAWATER HYDRAULIC BANDSAW

The design requirements for the MFTS bandsaw are given in Table 10. The seawater hydraulic bandsaw uses some components of an oil hydraulic version of the tool. A new handle, valve, and gear box were required to convert the tool to seawater hydraulic operation.

Table 10. Bandsaw Design Requirements

Item	Design Requirement Threshold
Air weight	30 lb
Forward rotation only	125 surface ft/min
Able to cut	Rebar 1-1/4-in. synthetic line Sheet metal SD list 5 coaxial cable
Operating depth	190 ft
Temperature	-1 to +40 °C
Reliability	0.90
MTBF	36 hr
MTTR	4 hr
Availability	0.80
Maintenance:	
Daily	0.5 hr
End of project	1 hr
Annually	4 hr

COMPONENT DESCRIPTION

The MFTS seawater hydraulic bandsaw (Figure 25) is modeled after the oil hydraulic bandsaw currently used by the UCTs. The seawater bandsaw uses the same cutting section (chain, sprockets, and blade pulleys) as the oil hydraulic bandsaw. This section is taken from the commercially available Rockwell Porta Bandsaw. The gear box and motor are designed especially for seawater hydraulics. The gear box contains three levels of polyamide-imide gears, stainless steel pinions, and graphite bearings for a 20:1 gear reduction.

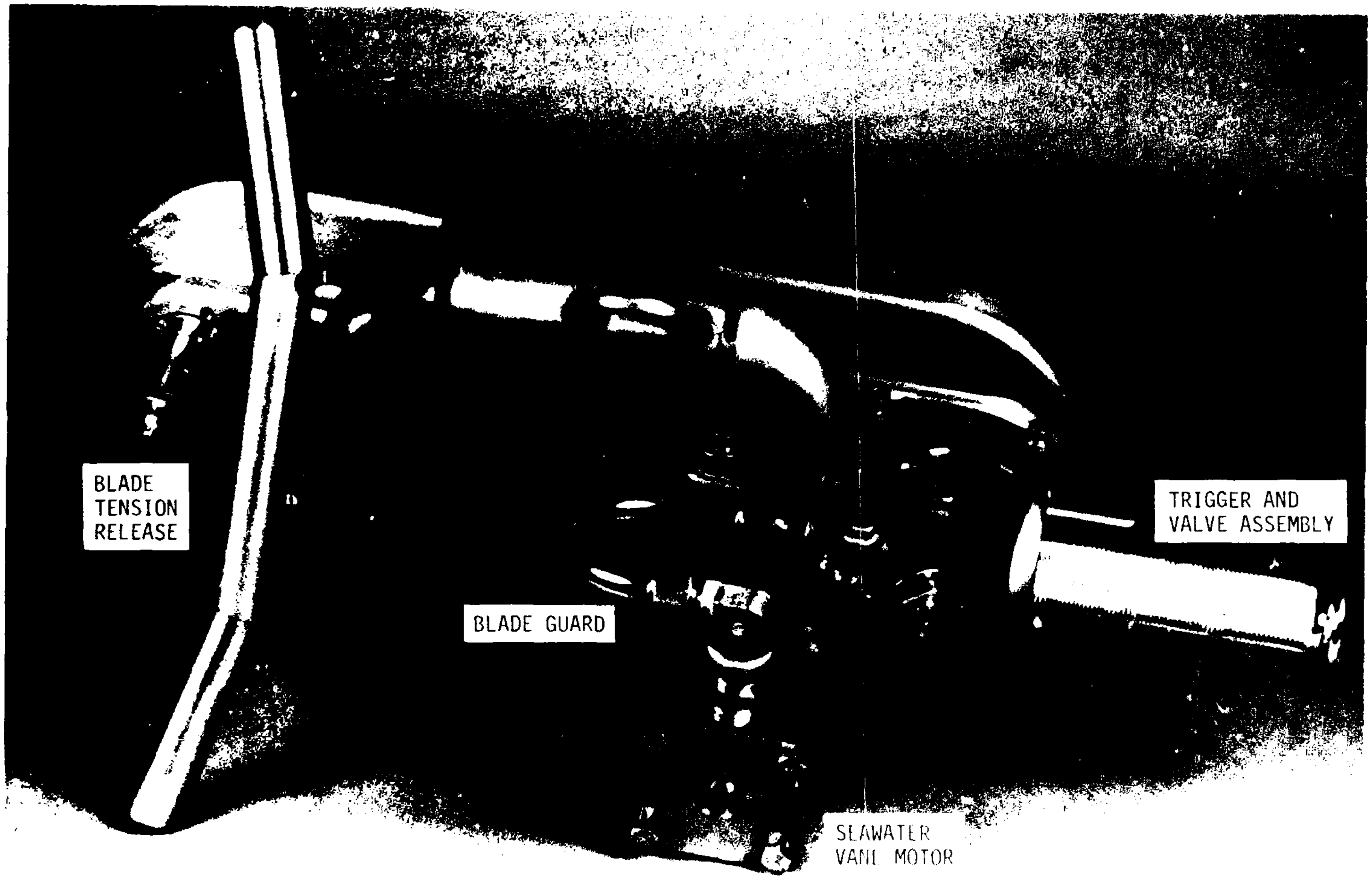


Figure 25. Seawater hydraulic bandsaw.

The seawater enters through a poppet valve to the 3-horsepower seawater hydraulic vane motor. The water is exhausted through the seawater motor into the gear box. A portion of the water is forced through the gear box to act as the lubricating fluid for the gears, pinions, and bearings. The excess is exhausted through ports in the top of the gear box. The water passing through the gear box is exhausted over the pulley drive chain to help it remain free from foreign particles. The pulleys have friction tape applied to them to allow the blade to slip when binding occurs so that the bandsaw does not twist in the divers hands. A blade guard retracts when the saw is put to the work. A quick-release lever relaxes tension on the following pulley to allow blade replacement. The blade is angled in the throat area to allow cuts up to 8 inches deep on materials up to 4.5 inches wide.

TEST AND EVALUATION

The laboratory tests and evaluation of the seawater bandsaw were conducted at NCEL in the Seawater Hydraulics Laboratory and Ocean Systems Test Facility by NCEL personnel. The laboratory testing was conducted on the Multi-Purpose Test Apparatus (MPTA), a test stand designed to test seawater hydraulic tools submersed in water. The MPTA provided for submerged measurements of torque and speed, and remote operation. A photograph of the bandsaw in the MPTA is shown in Figure 26. The laboratory data can be found in Reference 10.

Operability, Safety, and Human Factor Tests

Results of the individual tests conducted in this evaluation are summarized below. The seawater hydraulic bandsaw met the design requirements, as listed in Table 10, except in weight, where it exceeded the design requirement by 4 pounds. The bandsaw performance was satisfactory and no safety problems were discovered.

Initial Operating Characteristics. The performance of the bandsaw was measured with the tool installed on the MPTA. Figure 27 is a plot of shaft torque of the drive pulley versus speed for lines of constant pressure and constant flow. As expected, blade speed is dependent on flowrate and independent of pressure. This is a very desirable characteristic in the bandsaw where a constant blade speed results in more efficient cutting.

Noise Level. The noise level of the bandsaw is very low while operating underwater and does not present a hearing loss threat to the diver.

Cutting Tests. The cutting tests were performed at NCEL in the Ocean System Test Facility by Navy divers stationed at NCEL. The bandsaw was used to cut 3-inch SD List 5 coaxial cable, 1-1/4-inch SD List 1 coaxial cable, 1-inch rebar, 1-1/2-inch synthetic line, and 1/4-inch mild steel plate. To simulate underwater work tasks, the rebar was cut in both the horizontal and vertical positions. The cutting times were measured by a stopwatch, and are shown in Table 11.

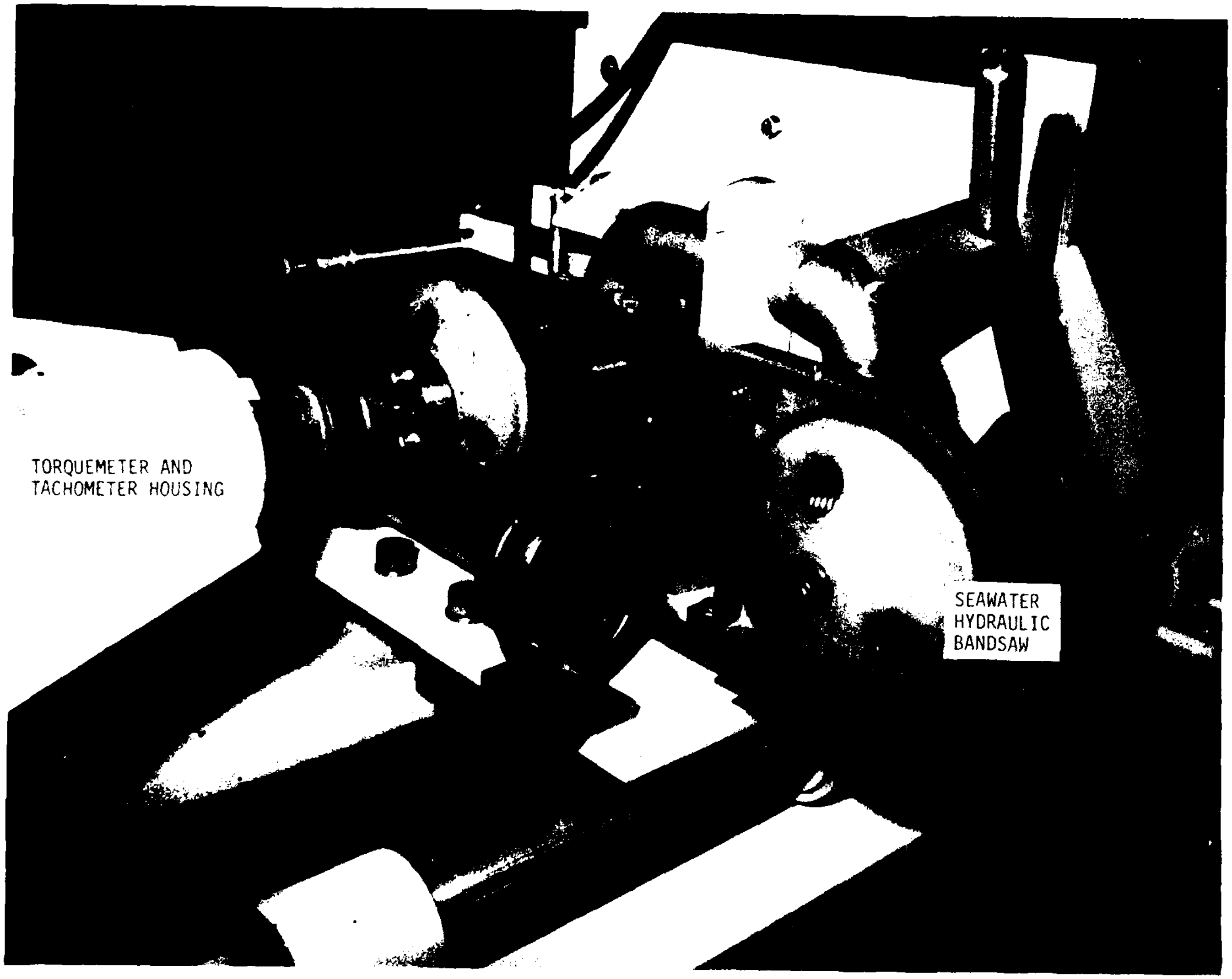


Figure 26. Seawater hydraulic bandsaw mounted on the multi-purpose test apparatus for performance testing.

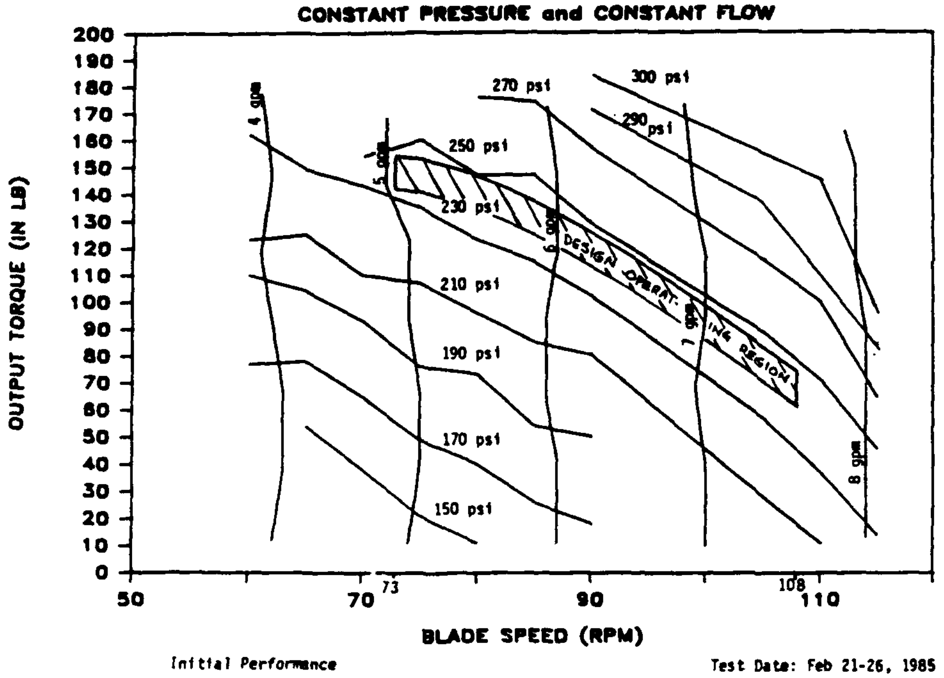


Figure 27. Initial bandsaw performance curves.

An attempt was made to cut SD List 1 cable. However, the hardened steel center strength member of the SD List 1 cable could not be cut with the tool steel blade. The cut was terminated after 5 minutes. A carbide blade is recommended for cutting SD List 1 cable.

Human Factors Evaluation. The bandsaw was evaluated by four Navy divers for handling, ease of use, control, safety, and other human factors considerations. Interview forms recording diver comments are provided in Appendix B. The results are summarized below:

1. The balance and weight of the tool was acceptable.

2. The short valve trigger required only two fingers to operate and allowed the diver to maintain his grip on the tool handle. However, the return spring on the poppet valve made the trigger difficult to hold open and caused forearm fatigue during long cuts.

3. The bandsaw needs a more effective trigger guard to prevent accidental operation during blade replacement.

Table 11. Bandsaw Cutting Tests

Material	Material Orientation	Time (sec)	Blade Speed (fpm)	Blade Teeth (T/in.)	Flowrate (gpm)
Rebar 1-in. diam	Horizontal	135	100	10	4.0
	Vertical	57	100	10	4.0
	Horizontal	88	100	10	4.0
	Vertical	112	100	10	4.0
1-1/2-in.-diam synthetic line	Horizontal	13	100	10	4.0
	Horizontal	13	100	10	4.0
1/4-in. mild steel plate (4 in. thick)	Horizontal	112	100	10	4.0
	Horizontal	64	100	10	4.0
Coaxial cable 3-in.-diam SD List 5	Horizontal	150	175	10	7.5
	Horizontal	154	175	10	7.5
Coaxial cable 1-1/4-in.-diam SD List 1	Horizontal	300[a]	125	18	5.0
	Horizontal	300[a]	125	18	5.0
1-in. rebar	Horizontal	26	175	10	7.5
	Vertical	30	175	10	7.5
	Horizontal	30	175	10	7.5
	Vertical	60	175	10	7.5
	Horizontal	25	175	10	7.5
	Vertical	47	175	10	7.5
1-1/2-in. synthetic line	Horizontal	4	175	10	7.5
	Horizontal	2	175	10	7.5
1/4-in. mild steel plate (4 in. thick)	Horizontal	40	175	10	7.5
	Horizontal	29	175	10	7.5

[a] Never succeeded in cutting through the center strength member of this coaxial cable. Center strength member was hardened steel. Need carbide blade to cut this cable. Tool steel blades were used in this test.

Reliability, Maintainability, and Availability Tests

The results of the individual tests conducted in this evaluation are summarized below. The bandsaw proved its 0.90 reliability factor requirement and completed life testing.

Life Test. The endurance test to verify the design requirement of 0.90 reliability at an 90 percent confidence level required 174 hours of cycle testing (Ref 7). The operating cycle of 2 minutes on, 4 minutes off was modified by reducing the "off" time to 1 minute since there is no wear when the bandsaw is in the "off" position. The bandsaw needed to complete 1,740 cycles to satisfy the reliability requirement.

During the life test of the bandsaw, three components failed and had to be repaired. Table 12 shows when these failures occurred, the cause of failure, the time to repair the item, and subsequent action.

At cycle number 320, the output torque dropped from 45 inch-pounds to 20 inch-pounds. The tool was disassembled and inspected. The steel drive chain had corroded, causing it to bind. The chain was replaced with a used chain from an oil hydraulic bandsaw. The maintenance manual for the oil hydraulic unit calls for daily oiling of the chain and sprocket. Since the seawater bandsaw uses the same assembly, this lubrication procedure was used for the remainder of the test without additional failures.

Table 12. Bandsaw Life Test

No. of Cycles	Failed Item	Cause of Failure	Repair Time (min)	Redesign Action
320	Drive chain	Corrosion/seizing	20	None
320	Wheel bearings	Material too soft	20	Use nylon bearings
595	Roll pin	Pin fatigued and sheared	40	Use keyed shaft or "D" shaft[a]
---[b]	Roll pin	Pin fatigued and sheared	30	Use keyed shaft or "D" shaft[a]

[a] Used in oil hydraulic bandsaw; reliability demonstrated.

[b] This pin sheared during post-life performance testing, equivalent to cycle number 1,775.

While the tool was disassembled at 320 cycles, other components were inspected. The drive wheel graphite bearings had worn considerably allowing the drive wheel to wobble. The graphite bearings were replaced with nylon bearings from the oil hydraulic bandsaw. These nylon drive wheel bearings were used for the remainder of the test without incident.

At cycle 595, the blade stopped moving even though the motor was still operating. Disassembly and inspection revealed that a roll pin used to retain the shaft in the driving gear had sheared. This pin was replaced. A second roll pin was also replaced after shear failure occurred during the post-life performance testing.

The reliability criteria specified that a failed component that required less than 30 minutes to repair was not a failure but rather a maintenance item. By the strict interpretation of this criteria, the bandsaw failed the life test when the repair of the sheared roll pin on the drive shaft exceeded 30 minutes. However, since no roll pins will be used in the final design, this failure is noted but not considered a failure of the tool. The use of a keyed shaft to gear connection to replace the roll pin was verified in the Rotary Disk Tool, which has the same reliability requirements.

Performance data were obtained after the life testing to compare with the initial data. A comparison of Figure 27 and Figure 28 reveals an overall increase in the supply pressure required to yield a given torque. The lines of constant flow on both curves are very close, indicating that blade speed remains constant over the life of the tool.

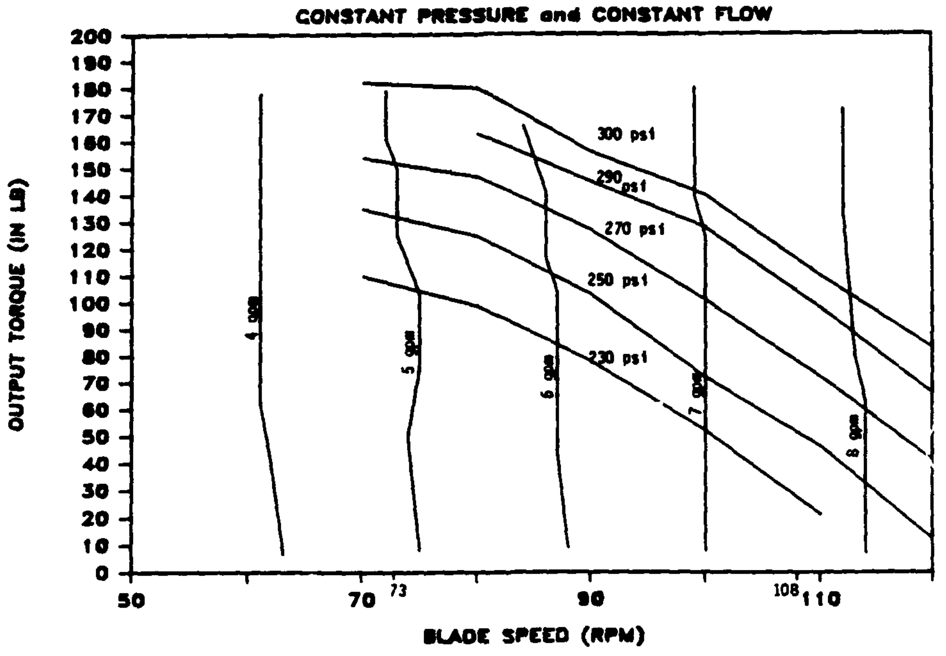
Improper Storage Test. The bandsaw was operated with seawater and stored without flushing or other maintenance. A severe storage condition was simulated using a wooden box exposed to the elements. The bandsaw was left in the box for 33 days. At the end of this period, the bandsaw was removed and completely disassembled. As expected, the tool was covered with a salt residue. Several locations in the gear box, where water had collected, had small accumulations of salt. None of the salt crystals would have prevented the tool from operating.

The formation of rust on the chain sprocket and the drive chain prevented the tool from operating. The sprocket corroded to the output shaft of the bandsaw and they had to be forced apart, while the drive chain had to be replaced.

Galvanic corrosion between the graphite bearings of the gear and pinion shafts and the aluminum gear box caused the adjacent aluminum to oxidize. This oxidation was severe and caused the graphite bearings to collapse on the shaft.

Required Maintenance. The drive chain was repaired because of improper maintenance during the early parts of the test. Subsequent lubrication of the replacement chain resulted in no further problems. Experience with the oil hydraulic bandsaw has shown that with proper lubrication the drive chain is reliable.

The maintenance requirements of the seawater bandsaw are minor. The bandsaw must be rinsed and flushed with fresh water daily. The driving chain must be lubricated with oil after the daily washing. There are no fluids to check or replace. The friction material on the wheels must be checked daily and replaced as needed. At the end of each deployment, the friction material should be replaced. At the beginning of each day, a new blade should be installed. At the end of each day, used blades should be discarded.



Final Performance

Test Date: Mar 20, 1985

Figure 28. Final bandsaw performance curves.

Logistic Supportability Analysis

The MFTS bandsaw will be delivered to the user with its complement of spare parts. These parts will include a standardized motor, a standardized valve cartridge, a drive chain, drive wheel bearings, gear box bearings, and drive wheel tires. These parts are replacements in case of premature failure of a component and are recommended based on the results of the testing that has been completed.

Regular maintenance parts for the seawater bandsaw will include friction tape, tape adhesive, and drive chain lubricating oil. No special tools are required to perform any of the maintenance outlined in the Operation and Maintenance Manual.

All spare parts and the bandsaw will be transportable in a permanent storage case, which is padded to prevent tool damage during transit. There are no special requirements for shipping. All training required for the bandsaw is covered in the Operation and Maintenance Manual.

FINDINGS

The following findings are based on the results of the development tests:

1. The bandsaw met or exceeded the design requirements except for weight. The bandsaw in-air weight exceeds the design requirement of 30 pounds by 4 pounds.

2. The seawater hydraulic bandsaw provides cutting speeds ranging from 125 to 175 feet per minute, suitable for cutting a variety of materials. Tool steel blades can be used to cut all but the hardest materials. A carbide blade is required to cut through SD List 1 cable.

3. The operating pressure at stall is 300 psi. The required flow rate is 5 to 7 gpm.

4. The trigger configuration requires modification to reduce fatigue and lessen the chance of accidental activation.

5. The roll pins used to pin the shafts and gears are a weak point in the design and failed during the life tests.

6. The graphite bearings used in the gear box are cathodic to the aluminum and accelerate the corrosion of the aluminum through galvanic corosion. This leads to bearing failure.

PRODUCTION MODEL

The production bandsaw (Figure 29) required only minor changes to correct the deficiencies of the graphite bearings and the roll pins. The bearing material was changed to nylon on all shaft sleeve bearings. This eliminated the potential for galvanic corrosion between the bearing material and the aluminum housing. Instead of roll pins, the shaft-to-gear connections were keyed. This method was used in the rotary disk tool and it demonstrated durability. The assembly drawings are provided in Appendix A.

Additional changes to the bandsaw included the standard seawater motor, and the modular control valve and handle assembly. This improved the handling of the tool and resulted in a small weight savings.

Figure 29. Production bandsaw.

CHAPTER 6. CONCLUSIONS AND RECOMMENDATIONS

The overall objective of the development described in this report was to demonstrate a seawater hydraulic powered diver tool system that provides improved capability for construction divers. A rotary disk tool, a rotary impact wrench, and a bandsaw were developed and tested. A portable diesel-driven seawater hydraulic power source was also developed and tested. The demonstrated high reliability of the seawater hydraulic MFTS is comparable to conventional oil hydraulic tools. In addition, the MFTS provides the advantages associated with seawater as the working fluid. These advantages include: (1) single transmission hose for improved diver handling, (2) no environmental contamination associated with fluid leaks or spills, and (3) reduced tool maintenance requirements because the tools are compatible with the environment. One production MFTS was delivered to each Underwater Construction Team in 1988.

CONCLUSIONS

1. The capabilities of a seawater hydraulic diver tool system have been clearly demonstrated by the successful development and evaluation of a rotary disk tool, a rotary impact tool, a bandsaw, and a power source.

2. Operational characteristics of each tool and power source met or exceeded the design requirements.

3. The rotary impact wrench and the bandsaw exceeded the weight threshold. The additional weight however, did not detract from tool performance.

4. The production seawater hydraulic power source effectively provides sufficient power for operating two tools simultaneously. Power source controls are conveniently located and easy to operate. Tool settings can be adjusted independently at each hose reel. Overall, the flow circuit operated satisfactorily.

5. The standardized control handle and valve provide an interchangeable assembly between tools and a reduced spare parts inventory. The two-finger trigger allows the gloved diver to release the trigger yet maintain a firm grip on the tool handle. The trigger valve effectively regulates flow to the seawater motor.

6. The standardized seawater motor is well-suited for the diver tools application. By plugging unused fluid ports, the motor can be installed on any of the seawater tools. A kit included with the tool system allows removal of these disposable plugs so that the motor can be installed on any tool. The 3-horsepower motor adequately powers each tool.

RECOMMENDATIONS

The following recommendations are based on conversations with UCT divers during deployments with the MFTS:

1. A rotary impact wrench for the 0- to 400-foot-pound torque range would compliment the MFTS rotary impact wrench for lighter assembly work. An internal hex, quick-change chuck instead of the square drive anvil would improve hole drilling capabilities.

2. UCT diving operations are sometimes conducted using a small inflatable boat (19-foot length). For these operations, a small single tool power source should be developed.

3. A smaller "peanut" grinder specifically designed for cleaning in the webs of "H" pilings would be desirable. The rotary disk tool is too large for this job.

CHAPTER 7. REFERENCES

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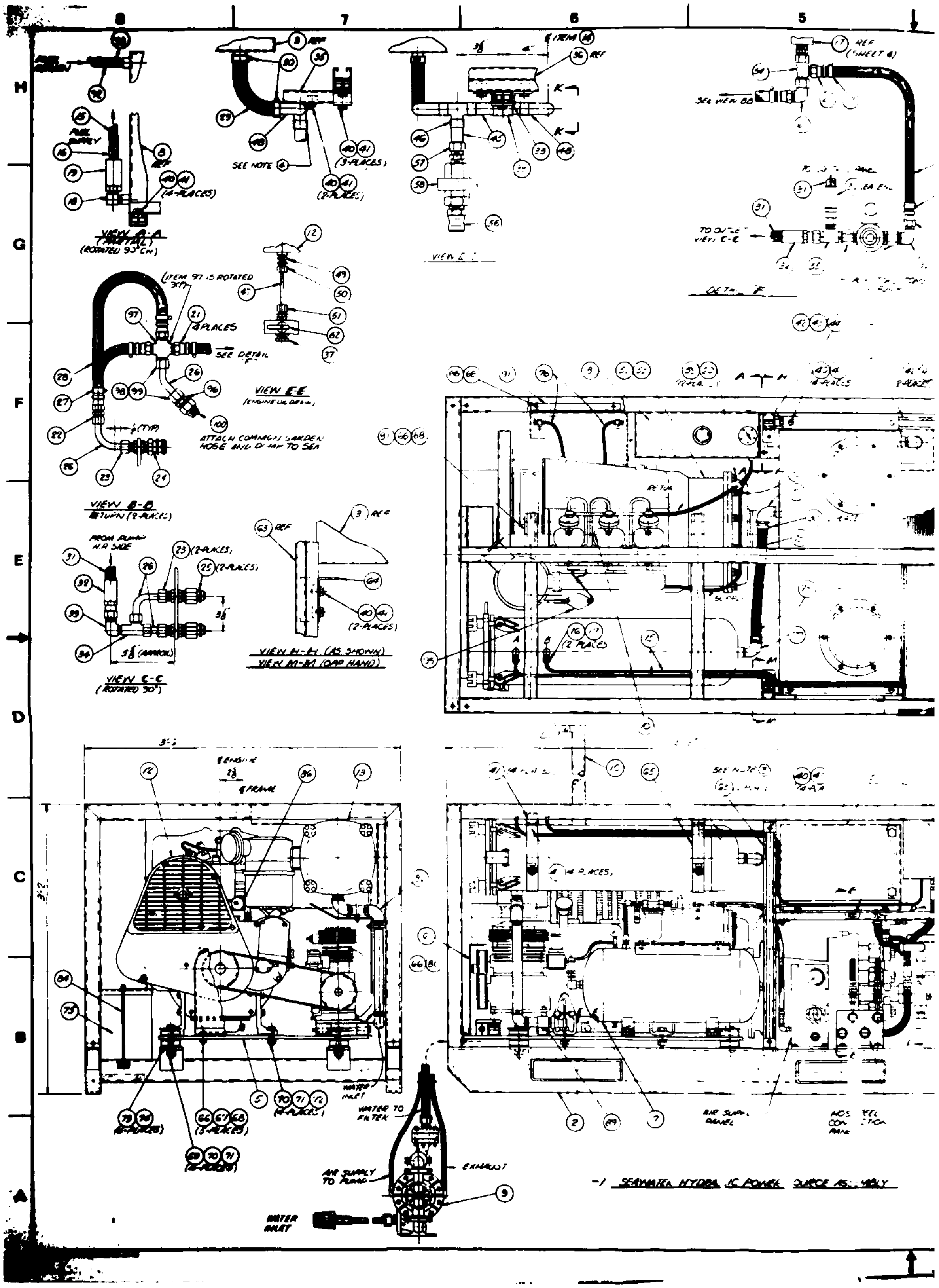
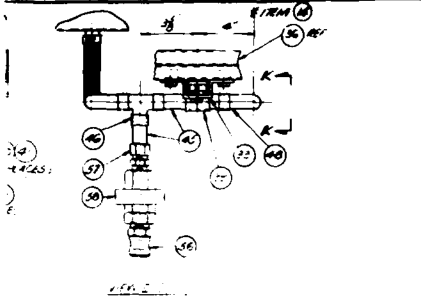
9. NEDU ltr 6420, Ser 404 of 29 Oct 1982. Subj: Diver tool noise conference summary.

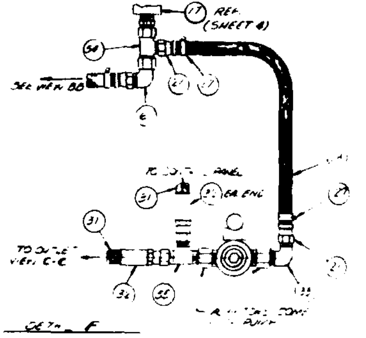
10. Naval Civil Engineering Laboratory. Memorandum to files on the multi-function tool system bandsaw test and evaluation, by S.A. Barradas and B.W. Farber. Port Hueneme, CA, Apr 1986.

Appendix A

PRODUCTION MODEL ASSEMBLY DRAWINGS


8
7
6
5
H
G
F
E
D
C
B
A
FUEL RETURN
FUEL SUPPLY
VIEW A-A (PARTIAL) (ROTATED 90° CW)
(4-PLACES)
SEE NOTE 6
(3-PLACES)
(2-PLACES)
REF
ITEM 18
VIEW E
(ITEM 97 IS ROTATED 30°)
4 PLACES
SEE DETAIL "F"
VIEW E-E (ENGINE OIL DRAIN)
ATTACH COMMON GARDEN HOSE AND DUMP TO SEA
1/8 (TYP)
VIEW B-B RETURN (2-PLACES)
FROM PUMP H.P. SIDE
(2-PLACES)
3 1/8
5 3/8 (APPROX)
VIEW C-C (ROTATED 30°)
VIEW M-M (AS SHOWN)
VIEW M-M (OPP HAND)
(SHEET 4)
SEE VIEW BB
TO OUTLET VIEW C-C
DETAIL F
RETURN
(2 PLACES)
(4 PLACES)
(4-PLACES)
3'-2
ENGINE
2 1/8
FRAME
(3-PLACES)
WATER INLET
WATER TO FILTER
AIR SUPPLY TO PUMP
EXHAUST
WATER INLET
SEE NOTE 8
AIR SUPPLY PANEL
HOSE REEL CONNECTION PANEL
-1 SEAWATER HYDRAULIC POWER SOURCE ASSEMBLY

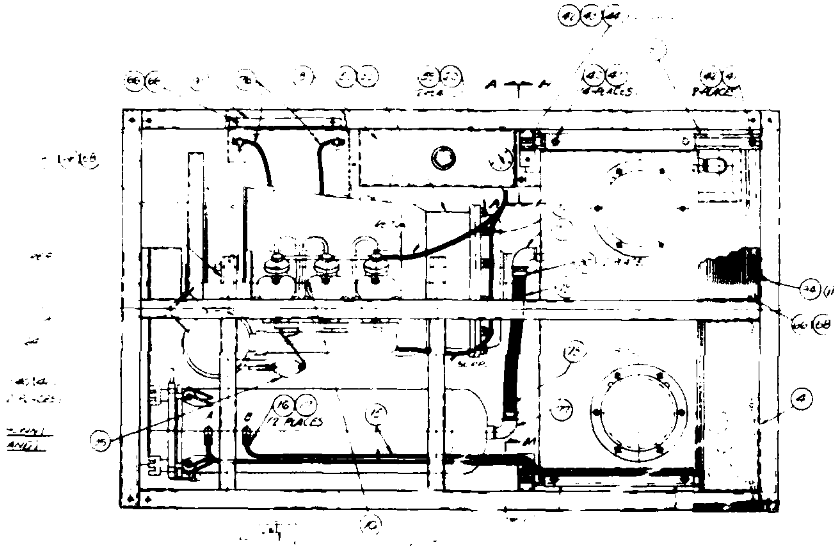


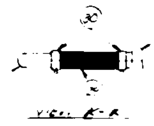


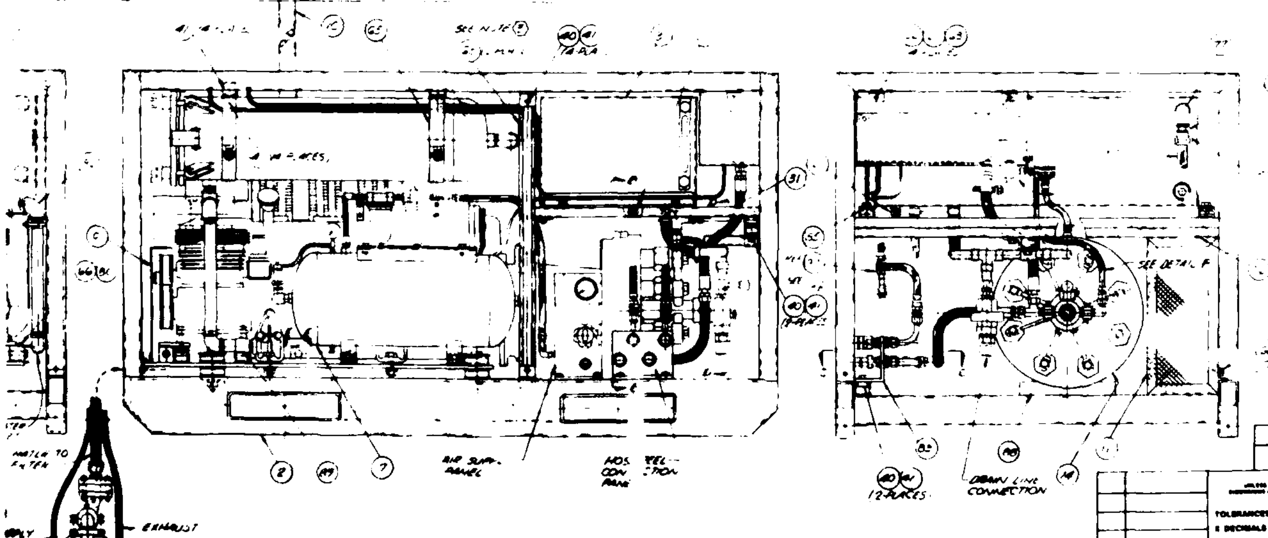
NOTES:

1. DIESEL ENGINE SHALL BE A LOMBARDINI 5LD825-2 WITH STANDARD EQUIPMENT PER GROUP 2 BASIC ENGINE SPECIFICATIONS. DELETE CONTROL PANEL
   ACCESSORIES: SAE 4 HOUSING (9873-0[illegible]), C108 ADAPTOR (9873-0[illegible]) HEAD TEMPERATURE SENSOR (9887-086) CABLE OPERATED THROTTLE ONLY (998[illegible]), SHAFT EXTENSION (9887-9[illegible]), MOUNTED ON #2 PTO, SOLENOID [illegible] (SK 1033 LESS RELAY).
2. [illegible] SHALL BE A HANDEN 8-CYL [illegible] WITH [illegible] PISTONS TO [illegible] 2000 PSI @ 16 GPM. PUMP SHALL HAVE A (2:1) SPEED REDUCER [illegible] THE CRANK [illegible] COVER PLATE. EXPANSION CHAMBER SHALL BE MANUFACTURED IN HARD BLACK ANODIZED ALUMINUM. BLEED SCREW PART NO. D3LO9 SHALL BE STAINLESS STEEL. DELETE PRESSURE GAUGE FITTINGS AND PLUG WITH [illegible] PLUG [illegible] END FITTINGS SHALL BE STAINLESS STEEL. SELECT [illegible] MANIFOLD [illegible] ARE HARD [illegible] NUMBERED [illegible]
3. PLACE [illegible] SECURE [illegible]
4. ALL [illegible] STEEL [illegible] BRAZED [illegible] BAG [illegible] TYPE [illegible]
5. STAINLESS KEY [illegible] 3MM x 7MM [illegible] KEY
6. [illegible] A(2) FLYWHEEL TO ITEM (18) SHAFT
7. SEE [illegible] HOSE [illegible]
8. ALL [illegible] SHALL BE SEALED WITH TEFLON PIPE SEALANT.
9. [illegible]

	99	[illegible]	[illegible]
2	98	[illegible]	[illegible]
1	97	[illegible]	[illegible]
	96	[illegible]	[illegible]
1	95	85-4[illegible]	EXHAUST MUFFLER [illegible]
1	94	85-4[illegible]-94	[illegible]
	93	85-40-1F-93	[illegible]
AR	92	85-40-1F-92	HOSE [illegible]
	91	[illegible]	BATTERY [illegible]
AR	90	85-40-1F-90	HOSE [illegible]
1	89	85-40-3F-357	[illegible] SUPPORT BRACKET
1	88	85-40-1F-88	PUMP [illegible] MOUNT







-1 SEAWATER HYDRAULIC POWER SUPPLY ASSEMBLY

1	87	85-40-3F-90	OVERFLOW AND DRA[illegible]
1	86	85-40-5F-3	PRESSURE GAUGE S[illegible]
2	85	85-40-2F-225	TANK SUPPORT
1	84	85-40-2F-204	BATTERY CLAMP
1	83	85-40-2F-283	BRACKET
1	82	85-40-3F-349	INLET ASSEMBLY
2	81	85-40-[illegible]	EXHAUST PIPE [illegible]
4	80	-80	SPRING NUT [illegible]
1	79	-79	HOSE [illegible]
2	78	-78	NIPPLE SHORT [illegible]
2	77	-77	ELBOW 90° STREET
2	76	-76	BATTERY CABLES [illegible]
1	75	-75	BATTERY 12V [illegible]
4	74	-74	SNUBBING WASHER
4	73	-73	SHOCK MOUNT [illegible]
4	72	-72	[illegible] HEX
	71	-71	[illegible] SPRING [illegible]
	70	-70	[illegible] HEX
4	[illegible]	[illegible]	[illegible]
18	[illegible]	-69	WASHER [illegible]
2	[illegible]	-67	NUT [illegible] HEX
2	[illegible]	[illegible]	[illegible]
2	[illegible]	[illegible]	[illegible] CLAMP [illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	CHANNEL PIPE [illegible]
	[illegible]	[illegible]	BALL VALVE [illegible]
	[illegible]	[illegible]	ELBOW [illegible]
[illegible]	[illegible]	[illegible]	WASHER [illegible]
12	[illegible]	[illegible]	[illegible]
1	[illegible]	-55	BALL VALVE [illegible]
[illegible]	[illegible]	[illegible]	MALE CONNECTOR [illegible]
2	[illegible]	[illegible]	MALE ADAPTER [illegible]
1	[illegible]	[illegible]	MALE RUN TEE [illegible]
1	54	-54	SWIVEL NUT RUN T[illegible]
1	53	-53	COUPLING [illegible]
	52	-52	KEY 3mm x 7mm [illegible]
1	51	-51	MALE CONNECTOR
1	50	-50	MALE CONNECTOR
1	49	-49	ADAPTER [illegible]
1	[illegible]	-48	MALE-FEMALE ELB[illegible]
2	48	-48	MALE CONNECTOR
3	47	-47	O-RING [illegible]
1	46	-46	MALE RUN TEE [illegible]
AR	45	-45	TUBE NUT [illegible]
2	44	-44	WASHER SPRING [illegible]
2	43	-43	NUT HEX [illegible]
4	42	-42	SOCKET HEAD CAP [illegible]
	41	-41	SPRING NUT [illegible]
	40	-40	CAP SCREW HEX [illegible]
	39	-39	TUBING CLAMP [illegible]
	38	-38	U-SUPPORT [illegible]
1	37	-37	PLUG, 1/8 NPT [illegible]
	36	-36	CHANNEL POWER [illegible]
1	35	-35	CHANNEL POWER [illegible]
1	34	-34	FEMALE RUN TEE [illegible]
2	[illegible]	[illegible]	MALE ELBOW [illegible]
4	[illegible]	[illegible]	[illegible] FITTING [illegible]
AR	[illegible]	-31	HOSE [illegible]
6	30	-30	HOSE CLAMP [illegible]
AR	29	-29	HOSE [illegible]
AR	[illegible]	-28	HOSE [illegible]
3	[illegible]	[illegible]	HOSE CLAMP [illegible]
AR	[illegible]	[illegible]	TUBE [illegible]
[illegible]	[illegible]	[illegible]	QUICK DISCONNECT [illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	BULKHEAD [illegible]
[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	HOSE FITTING [illegible]
	[illegible]	-23	PLUG [illegible]
1	[illegible]	[illegible]	[illegible] VALVE [illegible]
	[illegible]	-18	MALE [illegible]
2	[illegible]	-17	STREET ELBOW [illegible]
4	[illegible]	-16	HOSE FITTING [illegible]
AR	[illegible]	-15	HOSE [illegible]
1	14	-14	[illegible]
1	[illegible]	-13	FILTER [illegible]
1	[illegible]	[illegible]-2	ENGINE [illegible]
1	11	85-40-5F-6	STORAGE [illegible]
1	10	85-40-3F-328	EXHAUST [illegible]
1	9	85-40-3F-[illegible]	WATER [illegible]
1	8	85-40-3F-351	FUEL TANK
1	7	85-40-[illegible]F-1	AIR SUPPLY [illegible]
1	6	85-40-3F-382	BELT GUARD
1	5	85-40-[illegible]F-378	ENGINE SU[illegible]
1	4	85-40-4F-1	CONTROL PANEL [illegible]
1	3	85-40-5F-1	WATER STORAGE [illegible]
1	2	85-40-3F-37[illegible]	MAIN FRAME
	1	85-40-1F-1	SEAWATER H[illegible]
-1	ITEM NO	PART NO	

QUANTITY FOR EACH ASSEMBLY

PART DASH NO | NEXT ASSY

TOLERANCES
X DECIMALS
XX DECIMALS
XXX DECIMALS
FRACTIONS 1/16
ANGLES

PROJ NO
DRAWING NO 85-40-1F
APPROVED
APPROVED
F

CON[illegible]
SEAWA[illegible]

IF IN DOUBT, ASK - DO NOT SCALE!

NOTES:

① DIESEL ENGINE SHALL BE A LOMBARDINI 5LD825-2 WITH STANDARD EQUIPMENT [illegible] BASIC ENGINE SPECIFICATIONS. DELETE CONTROL PANEL. ACCESSORIES [illegible] (9973-042) [illegible] (9973-0[illegible]) HEAD TEMPERATURE SENSOR (9987-026) CABLE OPERATED THROTTLE ONLY (998[illegible]) SHAFT EXTENSION (9987-[illegible]) MOUNTED ON #2 PTO SOLENOID [illegible] (SK [illegible] LESS RELAY).

② DIAPHRAGM [illegible] SHALL BE A [illegible] 5-CYLINDER WITH [illegible] PISTONS [illegible] 200 [illegible] GPM, [illegible] SHALL HAVE A (2.3-1) SPEED REDUCER [illegible] THE CRANK [illegible] COVER PLATE [illegible] EXPANSION CHAMBER SHALL BE MANUFACTURED IN [illegible] ALUMINUM [illegible] NO. 0[illegible] SHALL BE STAINLESS STEEL. DELETE [illegible] GAUGE [illegible] AND PLUG WITH [illegible] PLUG [illegible] FITTINGS SHALL BE STAINLESS STEEL SELECT [illegible] MANIFOLD [illegible] MODEL [illegible]

③ [illegible]

④ [illegible] STEEL [illegible] TYPE [illegible]

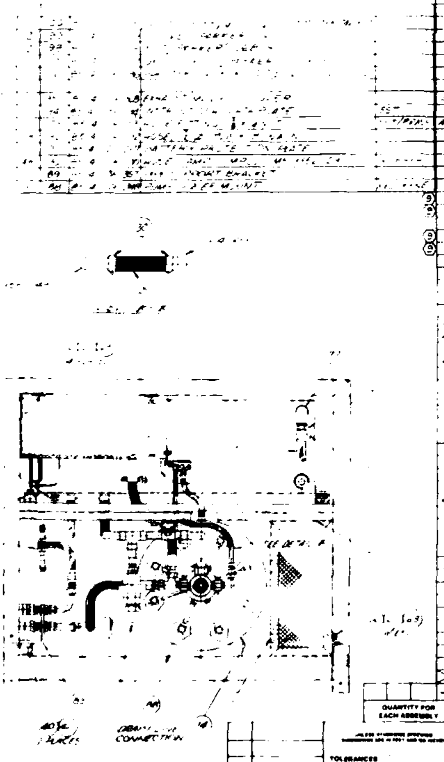
⑤ [illegible]

⑥ [illegible] FLYWHEEL [illegible] SHAF[illegible]

[illegible]

[illegible] SHALL BE [illegible] PIPE SEALER

[illegible]



1	87	85-40-5F-20	OVERFLOW AND DRAIN LINE	
1	86	85-40-5F-3	PRESSURE GAUGE SENDER ASSEMBLY	
2	85	85-40-2F-205	TANK SUPPORT	
1	84	85-40-2F-204	BATTERY CLAMP	
1	83	85-40-1F-283	BRACKET	
1	82	85-40-3F-343	INLET ASSEMBLY	
2	81	85-40-[illegible]	EXHAUST PIPE BRACKET	
4	90	-90	SPRING NUT 1/4-20, "POWER-STRUT", PS-6-[illegible]	GALV
1	79	-79	HOSE 1/4 I.D. × 1-4" GATES, 4G 34CF PLAIN ENDS	
2	78	-78	NIPPLE SHORT, 1" NPT SCH 40	316 SST
2	77	-77	ELBOW 90° STREET, 1" NPT 150#	316 SST
2	76	-76	BATTERY CABLES, LENGTH & TERMINALS AS REQ'D	
1	75	-75	BATTERY, 12V, 80 GROUP SIZE 30H, [illegible] PLATES	
4	74	-74	SNUBBING WASHER BARRY CONTROLS, #9810-45-03	
4	73	-73	SHOCK MOUNT, BARRY CONTROLS, #22003-15	
4	72	-72	BOLT 5/8-11 × 2, HEX HD	316 SST
[illegible]	71	-71	WASHER SPRING LOCK FOR 5/8 BOLT	
[illegible]	70	-70	NUT 5/8 [illegible] HEX	
4	[illegible]	[illegible]	BOLT 3/8 [illegible] HEX HD	
8	[illegible]	[illegible]	WASHER SPRING LOCK FOR 3/8 BOLT	
2	[illegible]	-67	NUT [illegible] HEX	
2	66	[illegible]	[illegible] HEX HD [illegible]	316 SST
[illegible]	[illegible]	[illegible]	SUPPORT CLAMP "ZEMARC", NO. 2MB-85	
[illegible]	[illegible]	[illegible]	CHANNEL ANGLE, POWER-STRUT [illegible]	
[illegible]	[illegible]	[illegible]	CHANNEL, POWER-STRUT PS-[illegible]	
[illegible]	[illegible]	[illegible]	BALL VALVE 1/2 NPT GEMINI 76 SERIES	
[illegible]	6	[illegible]	ELBOW 90° SWIVEL NUT, "PARKER" 3902-8 [illegible]	
[illegible]	[illegible]	[illegible]	WASHER SPRING LOCK FOR 3/8 BOLT	
12	[illegible]	[illegible]	BOLT 3/8-16 × 1/4 HEX HD	
1	[illegible]	[illegible]	BALL VALVE "GEMINI", 1" #96-[illegible]	
1	[illegible]	[illegible]	MALE CONNECTOR SWAGELOK, SS-1610-1-16	
2	56	[illegible]	MALE ADAPTOR [illegible] NPT OPW 633F-[illegible]	
1	55	[illegible]	MALE RUN TEE, PARKER 8-8 R[illegible]	
1	54	-54	SWIVEL NUT RUN T, "PARKER" 363T-8-8[illegible]	
1	53	-53	COUPLING DODGE PARA-FLEX #PF 90E BORE 50mm	⑤⑥
	52	-52	KEY 8mm × 7mm × 45mm LONG	STEEL
1	51	-51	MALE CONNECTOR "PARKER" 6-8 FBTX[illegible]	
1	50	-50	MALE CONNECTOR "PARKER" [illegible]	
1	49	-49	ADAPTER 14MM (MALE) 1/4 NPT	[illegible]
2	48	-48	MALE-FEMALE ELL [illegible] TUBULAR #9CMF-16	
3 ft	47	-47	TUBING 1/4 OD	316 SST
1	46	-46	MALE RUN TEE "TRANS TUBULAR" #8 MF-16	
A.R.	45	-45	TUBING 1" O.D. × .035 WALL	316L SST
[illegible]	44	-44	WASHER SPRING LOCK FOR 1/2 BOLT	316 SST
2	43	-43	NUT HEX 1/2-13	
4	42	-42	SOCKET HEAD CAP SCREW 1/2-13 × 1 1/4	316 SST
[illegible]	41	-41	SPRING NUT 1/2-13 POWER-STRUT, #PS-KTG	GALV
[illegible]	40	-40	CAP SCREW, HEX HD, 1/2-13 × 1 1/4	316 SST
⑨ 1	39	-39	TUBING CLAMP POWER-STRUT, PS-1456	
⑨	38	-38	U-SUPPORT POWER-STRUT, PS-900	
1	37	-37	PLUG, 1/2 NPT, PARKER 8-HP5S	
⑨ 1	36	-36	CHANNEL, POWER-STRUT, PS-400 × 3'-4"	
⑨ 1	35	-35	CHANNEL, POWER-STRUT, PS-400 × 6"	
1	34	-34	FEMALE RUN TEE, SWAGELOK, SS-810-3-8TFT	
2	[illegible]	[illegible]	MALE ELBOW "ALLEN AIRCRAFT" [illegible]-8-8[illegible]	
4	[illegible]	[illegible]	[illegible] FITTING, PARKER #[illegible]-8-8C	
4 ft	[illegible]	[illegible]	HOSE, [illegible] PARKER #[illegible]-8	
6	30	-30	HOSE CLAMP WORM DRIVE RANGE [illegible]	SST
4 ft	[illegible]	-29	HOSE [illegible] GATES [illegible] CF PLAIN END	
[illegible]	[illegible]	-28	HOSE [illegible] PARKER 301-8REL, W/BUNA-N	
5	[illegible]	[illegible]	HOSE CLAMP WORM DRIVE RANGE [illegible]	SST
4 ft	[illegible]	[illegible]	TUBING [illegible] .035 WALL	316 SST
[illegible]	[illegible]	[illegible]	QUICK COUPLING [illegible]	
2	[illegible]	[illegible]	QUICK-[illegible]	
[illegible]	[illegible]	[illegible]	BULKHEAD [illegible] SWAGELOK [illegible]	
[illegible]	[illegible]	[illegible]	UNION SWAGELOK [illegible]-6-9[illegible]	
[illegible]	[illegible]	[illegible]	HOSE FITTING PARKER [illegible]	
[illegible]	[illegible]	-22	PLUG, PARKER [illegible]	
[illegible]	[illegible]	-19	[illegible] MALE FLARE-LINE [illegible]	
[illegible]	[illegible]	-18	MALE [illegible] PARKER 4-4 [illegible]	
2	[illegible]	[illegible]	STREET ELBOW PARKER 4-4 [illegible]-SS	
4	[illegible]	-16	HOSE FITTING PARKER 30182-4-4[illegible]	
4 ft	[illegible]	-15	HOSE [illegible] PARKER 301-4REL, W/BUNA-N	
1	14	-14	DIAPHRAGM PUMP 5 CYLINDER ②	
1	[illegible]	-13	FILTER [illegible]	
1	[illegible]	[illegible]	ENGINE LOMBARDINI, 5LD825-2 ①	
1	[illegible]	85-40-5F-2	STRAINER	
1	10	85-40-3F-[illegible]	EXHAUST ASSEMBLY	
1	9	85-40-[illegible]	WATER PUMP ASSEMBLY	
1	8	[illegible]	FUEL TANK	
1	7	[illegible]	AIR SUPPLY ASSEMBLY	
1	6	[illegible]-F-302	BELT GUARD	
1	5	85-40-[illegible]	ENGINE SUPPORT PLATE	
1	4	85-40-4F-1	CONTROL PANEL ASSEMBLY	
1	3	85-40-5F-1	WATER STORAGE TANK	
1	2	85-40-2F-[illegible]	MAIN FRAME	
	1	85-40-[illegible]	SEAWATER HYDRAULIC POWER SOURCE ASSEMBLY	
-1	ITEM NO	PART NO	DESCRIPTION	MATERIAL

QUANTITY FOR EACH ASSEMBLY

PARTS LIST

TOLERANCES
2 DECIMALS
3 DECIMALS
FRACTIONS
ANGLES

NEXT ASSY

NCEL DWG NO 85-40-1F

DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND

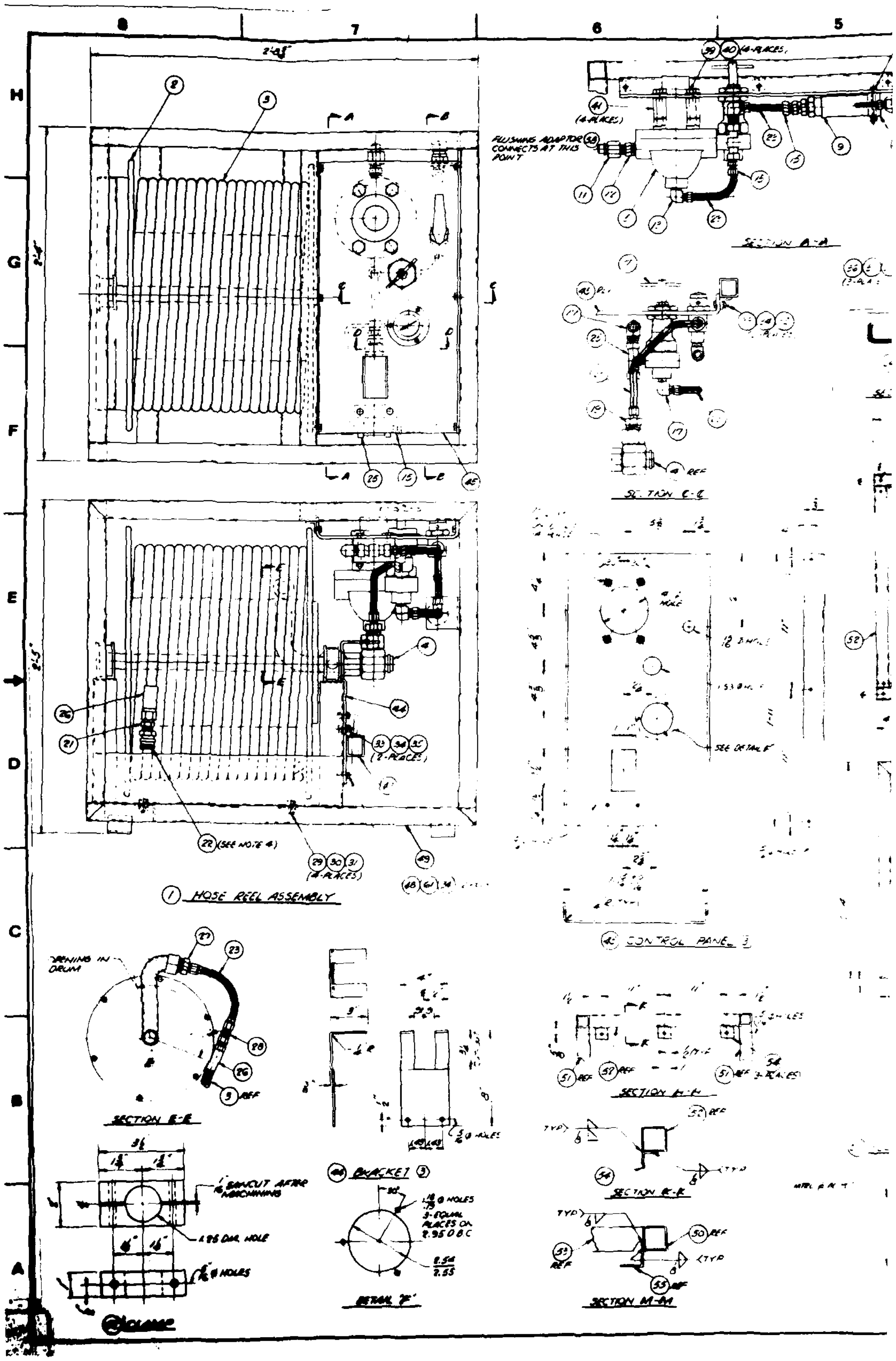
NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME CALIFORNIA 93043

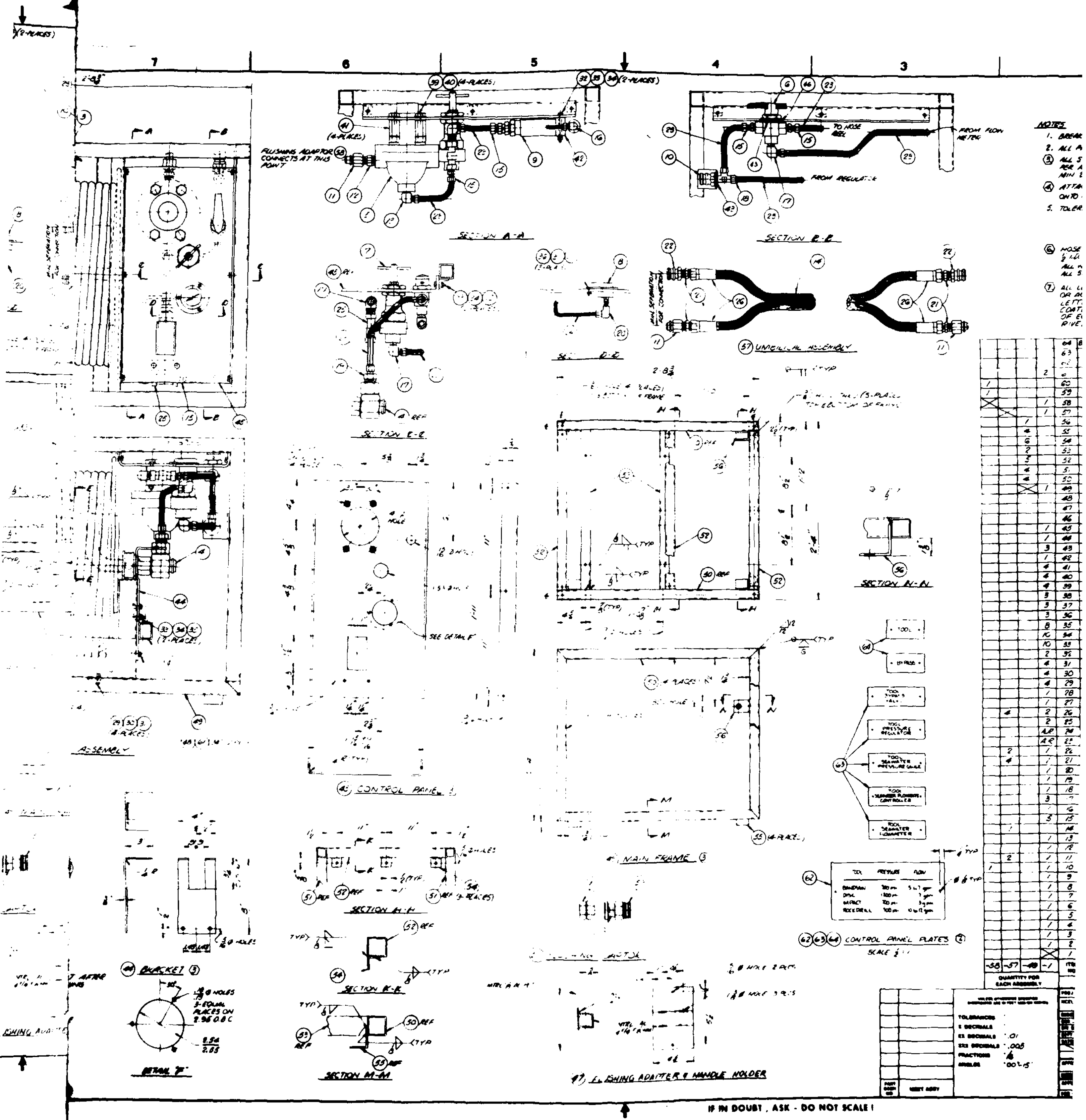
CONSTRUCTION SYSTEMS DIVISION

SEAWATER HYDRAULIC POWER SOURCE ASSEMBLY

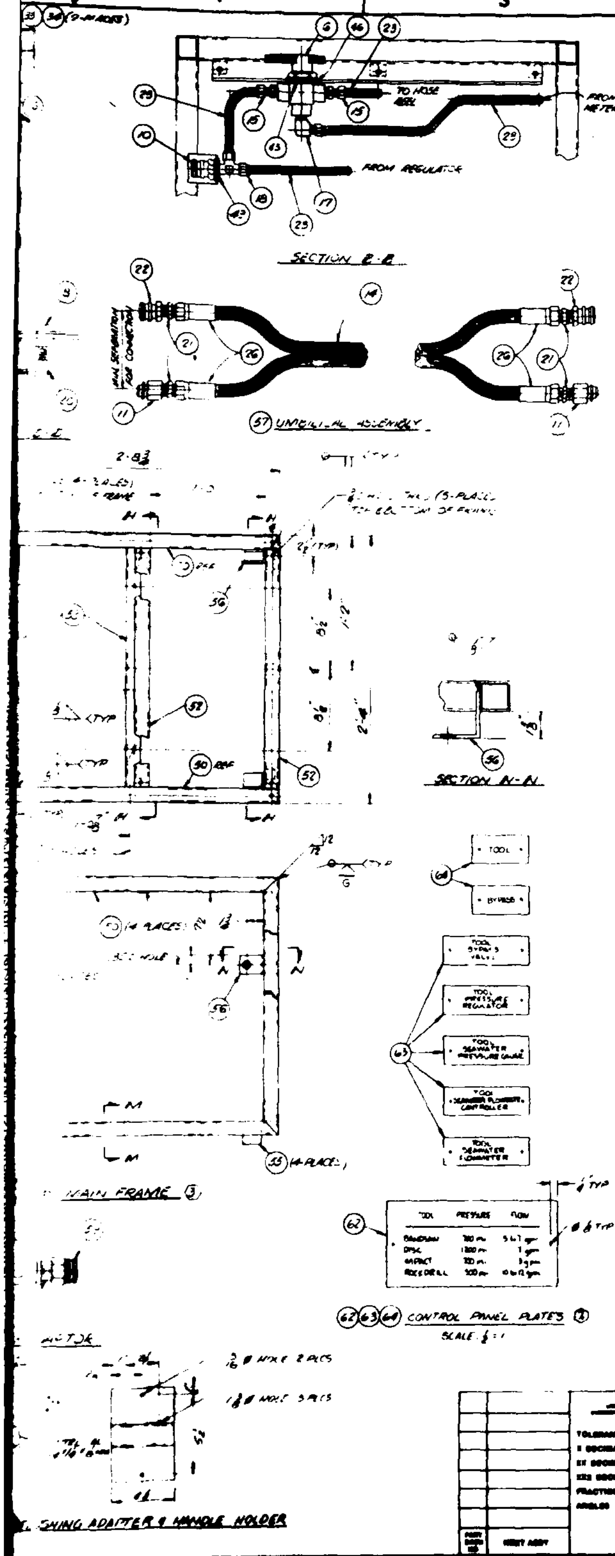
SIZE F
CODE IDENT NO 80091
SHEET 1 OF 10

IF IN DOUBT, ASK - DO NOT SCALE!


8
7
6
5
H
G
F
E
D
C
B
A
FLUSHING ADAPTOR CONNECTS AT THIS POINT
(4-PLACES)
SECTION A-A
SECTION C-C
(22) (SEE NOTE 4)
(29)(30)(31) (4-PLACES)
(33)(34)(35) (2-PLACES)
① HOSE REEL ASSEMBLY
CONTROL PANEL
OPENING IN DRUM
SECTION E-E
(9) REF
SEE DETAIL F
SECTION H-H
SECTION K-K
SECTION M-M
(51) REF
(52) REF
(50) REF
(53) REF
(55) REF
TYP
BRACKET
DETAIL "F"
.19 .15 Ø HOLES 3-EQUAL PLACES ON 2.950 B.C.
2.54 2.55
1/16 SAWCUT AFTER MACHINING
1.95 DIA. HOLE
Ø HOLES
CLAMP



IF IN DOUBT, ASK - DO NOT SCALE!



REVISIONS			
SYM	DESCRIPTION	DATE	APPROVAL

NOTES

1. BREAK ALL SHARP EDGES.
2. ALL PIPE THREADS SHALL BE SEALED WITH PIPE SEALANT
③ ALL STEEL PARTS SHALL BE HOT-DIPPED GALVANIZED PER ASTM SPECIFICATION (A-123) LATEST ISSUE, MIN 2.0 OZ/FT.²
④ ATTACH ITEM (57) UMBILICAL ASSEMBLY TO ITEM (22) AND WIND ONTO REEL FOR STORAGE.
5. TOLERANCE FOR CENTER TO CENTER HOLE SPACING ± 1/64

⑥ HOSE REEL SHALL BE A "HANNAY" MODEL NO. 6024-23-24 FOR 400 FT. 1/2 I.D. × 13/16 O.D HOSE. HAND CRANK REWIND, RT, 1" MNPT INLET × 1" FNPT OUTLET. ALL WETTED PARTS SHALL BE 316 SST WITH 3000 PSI OPERATING PRESSURE. ALL STEEL PARTS SHALL BE HOT-DIPPED GALVANIZED.

⑦ ALL LETTERING FOR DATA PLATES TO BE 3/16" HIGH, ENGRAVED OR ACID ETCHED, CENTERED AND BALANCED AS SHOWN. LETTERS SHALL BE PAINTED BLACK AND ENTIRE PLATE COATED WITH CLEAR LACQUER. LOCATE NEAR PROPER PIECE OF EQUIPMENT, MATCH DRILL MOUNTING HOLES AND SCREW OR RIVET IN PLACE

QUANTITY FOR EACH ASSEMBLY							
-58	-57	-49	-1	ITEM NO	PART NO	DESCRIPTION	MATERIAL
				64	85-38-1F - 64	PLATE, 2 × 1 × 1/16	SST
				63	-63	PLATE, 3 × 1 × 1/16"	SST
				62	-62	PLATE, 3 × 6 × 1/16	SST
			2	61	-61	WASHER, FLAT 1/4	316 SS
1				60	-60	PIPE NIPPLE, 1/2" NPT CLOSE	BRASS
1				59	-59	SWIVEL CONNECTOR "PARKER", 98GHSV-12-8	
☒			1	58	-58	FLUSHING ADAPTOR	
	☒		1	57	-57	UMBILICAL ASSEMBLY	
		1		56	-56	∠ 2 1/2 × 2 1/2 × 1/4 × 2"	ASTM A-36
		4		55	-55	∠ 1 1/2 × 1 1/2 × 1/4 × 2"	"
		6		54	-54	∠ 1 × 1 × 3/16 × 1"	"
		2		53	-53	∠ 1 1/2 × 1 1/2 × 1/4 × 2'-1"	ASTM A-36
		5		52	-52	TUBE 1 1/2 × 1 1/2 × 1/8 × 2'-1"	ASTM A500 GR B
		4		51	-51	TUBE 1 1/2 × 1 1/2 × 1/8 × 2'-4"	"
		4		50	-50	TUBE 1 1/2 × 1 1/2 × 1/8 × 2'-8 1/2	ASTM A500 GR B
		☒	1	49	-49	MAIN FRAME	
				48	-48	BOLT, 1/4-20 × 1" HEX HD	316 SST
				47	-47	FLUSHING ADAPTER & HANDLE HODER ASSY	SEE DETAIL
				46	-46	WASHER ADAPTER 1 3/8 × 2 × 1/4 THK	SS
			1	45	-45	CONTROL PANEL, PL 14 1/2 × 1/4 × 11" (FINISH AS SHOWN)	ASTM A-36
			1	44	-44	BRACKET, BAR 4 × 1/4 × 10 1/2, (FINISH AS SHOWN)	ASTM A-36
			3	43	-43	WASHER, FLAT 1/4 × 2" ⌀	SS.
			1	42	-42	CLAMP, BAR 2 × 1 × 3 1/2, MACHINE AS SHOWN	PVC TYPE I
			4	41	-41	COUPLING NUT, 3/8-10 × 2 1/4", ZINC PLATED	STEEL
			4	40	-40	WASHER, SPRING LOCK, FOR 3/8 ⌀ BOLT	316 SST
			4	39	-39	CAP SCREW, HEX HD, 3/8-10 × 1 1/2	"
			3	38	-38	WASHER, SPRING LOCK, FOR #8 SCREW	"
			3	37	-37	NUT, #8-32, HEX.	"
			3	36	-36	MACHINE SCREW, #8-32 × 3/4" FH SLOTTED	"
			8	35	-35	CAP SCREW, HEX HD, 1/4-20 × 1"	"
			10	34	-34	WASHER, SPRING LOCK, FOR 1/4 ⌀ BOLT	"
			10	33	-33	NUT, 1/4-20, HEX.	
			2	32	-32	BOLT, 1/4-20 × 2 1/2", HEX. HD.	"
			4	31	-31	WASHER, SPRING LOCK, FOR 3/8" ⌀ BOLT	"
			4	30	-30	NUT, 3/8-16, HEX.	"
			4	29	-29	CAP SCREW, HEX. HD. 3/8-16 × 1"	316 SST
			1	28	-28	UNION, "ALLEN AIRCRAFT", AAG 200-8KA	
			1	27	-27	MALE CONNECTOR "ALLEN AIRCRAFT", AAG7006-8-16KA	
	4		2	26	-26	END FITTING "PARKER", #10G55-8-8C	
			2	25	-25	TEE, "CAJON", SS-8-ET	
			A.R.	24	-24	TUBING, 1/2" O.D × .028 WALL	316 SST
			A.R.	23	-23	TUBING, 1/2" O.D × .035 WALL	316 SST
	2		1	22	-22	QUICK-DISCONNECT "SNAP-TITE", SVHC 8-8 F/SL	SLEEVE LOCK
	4		1	21	-21	MALE CONNECTOR "ALLEN AIRCRAFT", AAG7000-8-8K	
			1	20	-20	FEMALE ELBOW, SWAGELOK, SS-400-8-4	
			1	19	-19	MALE CONNECTOR "SWAGELOK", SS-810-1-16	
			1	18	-18	TEE, SWAGELOK, SS-810-3-8TMT	
			3	17	-17	MALE ELBOW, "SWAGELOK", SS-810-2-8	
			1	16	-16	MALE ELBOW, "SWAGELOK", SS-400-2-8	
			5	15	-15	MALE CONNECTOR "SWAGELOK", SS-810-1-8	
	1			14	-14	HOSE, .50 I.D. × 25' "PARKER" #528N-8-8(TWIN-LINE)	
			1	13	-13	MALE ELBOW, "SWAGELOK", SS-810-2-12	
			1	12	-12	REDUCING NIPPLE "CAJON", SS-12-HRN-8	
	2		1	11	-11	QUICK-DISCONNECT, "SNAP-TITE", SVHN 8-8 F	
1			1	10	-10	QUICK-DISCONNECT, "SNAP-TITE", SVHC 8-8 F/SL	
			1	9	-9	FLOW METER "HEDLAND", MODEL 641-016	SCREW LOCK
			1	8	-8	PRESSURE GAGE, "US GAGE", 2135, 0-3000 PSI, 1/4" LBM	
			1	7	-7	REGULATOR "CIRCLE SEAL" BPR31-71-1 1-2P	
			1	6	-6	BALL VALVE "WHITEY", SS45XF8	
			1	5	-5	FLOW RATE CONTROLLER "KATES", NO. C2FA15-30	
			1	4	-4	SWIVEL, "AEROQUIP", BD55015-1616-01	
			1	3	-3	HOSE, .50 I.D × .80 O.D × 250 FT, "PARKER" #528N-8	
			1	2	-2	HOSE REEL ④⑥	
			☒	1	85-38-1F - 1	HOSE REEL ASSEMBLY	

PARTS LIST

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND/OR INCHES
TOLERANCES
X DECIMALS
XX DECIMALS ± .01
XXX DECIMALS ± .005
FRACTIONS ± 1/64
ANGLES ± 00°-15'

PART DASH NO | NEXT ASSY

PROJ NO
NCEL DWG NO 85-38-1F

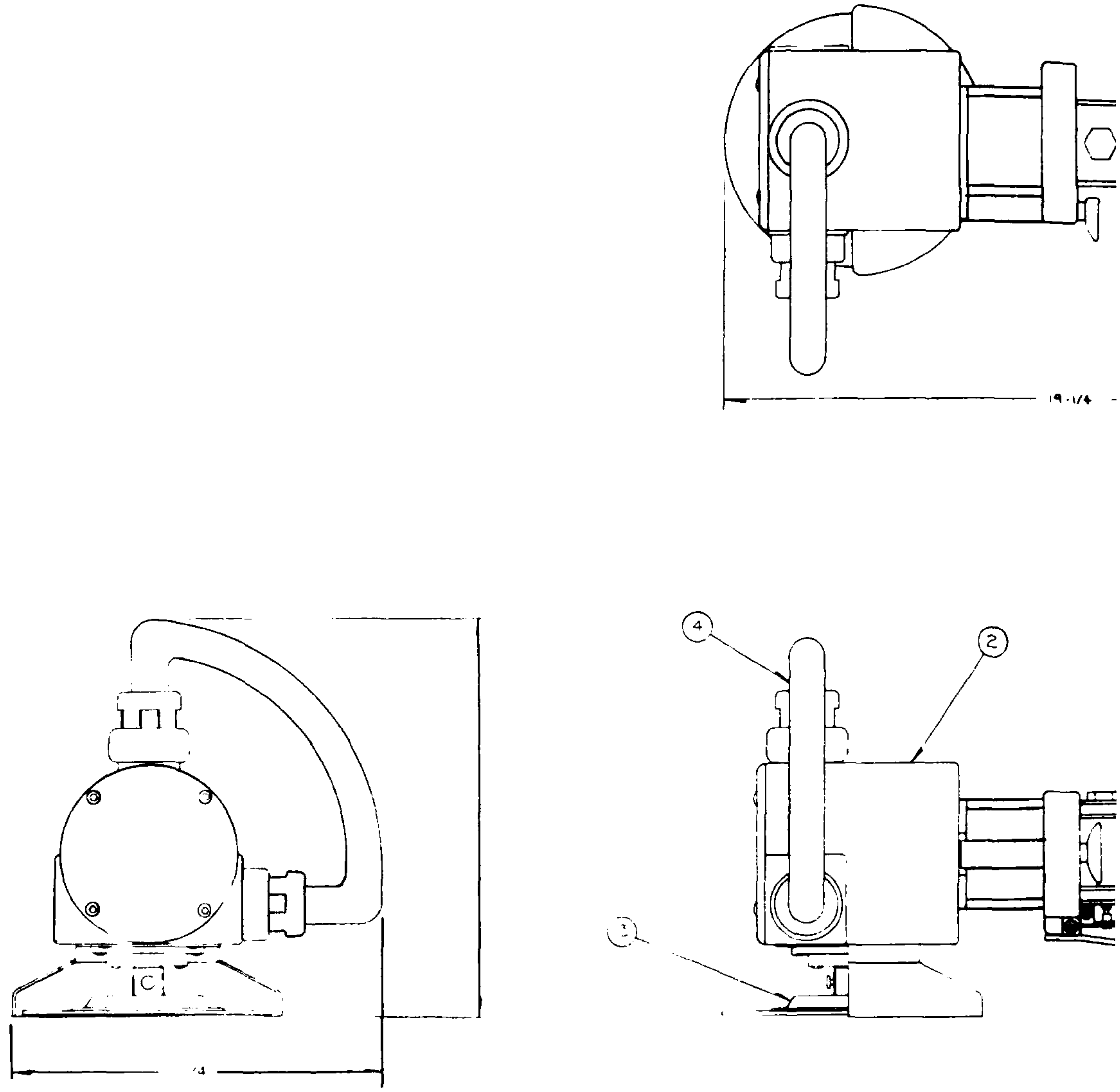
DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND
NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

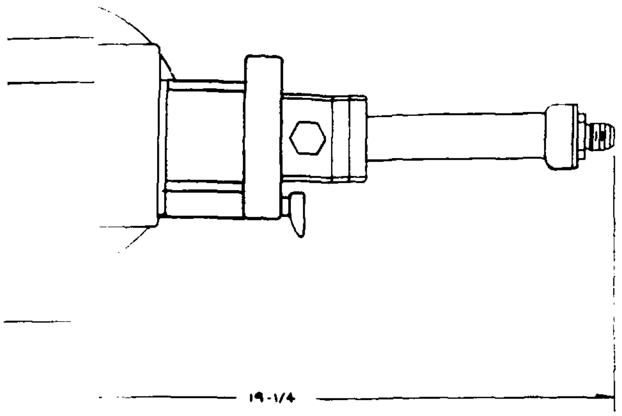
CONSTRUCTION SYSTEMS DIVISION
SEAWATER HYDRAULIC POWER SOURCE
HOSE REEL

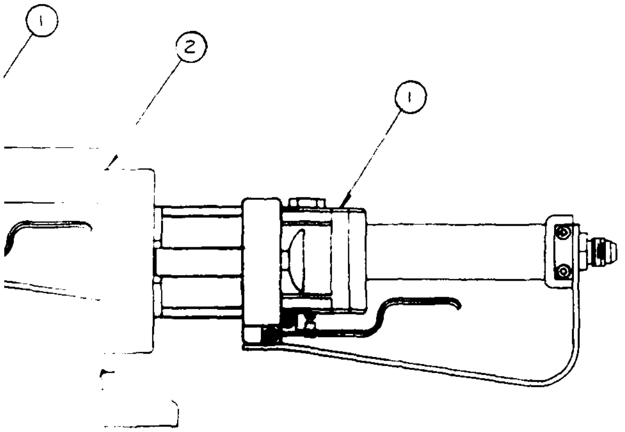
SIZE F | CODE IDENT NO 80091 | NAVFAC DRAWING NO
SCALE NONE | SHEET 1 OF 1

IF IN DOUBT, ASK - DO NOT SCALE!

J85-21(L49280) REV. 1(5-86)


19-1/4
4
2
C





	1	4	EI-2300-0005-AD	FRONT HANDLE ASSEMBLY
	1	3	EI-2300-0004-AD	DISC QUICK-RELEASE ASSEMBLY
	1	2	EI-2300-0003-AD	TOOL HEAD ASSEMBLY
	1	1	EI-2300-0002 AD	HANDLE ASSEMBLY
QUANTITY FOR EACH ASSEMBLY	QTY	ITEM NO.	PART NO.	DESCRIPTION
			PARTS LIST	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND OR INCHES

TOLERANCES :
X DECIMALS :
XX DECIMALS :
XXX DECIMALS :
FRACTIONS :
ANGLES :

PART DASH NO | NEXT ASSY | USED ON
APPLICATION

CONTRACTOR'S DRAWING NO
EI-2300-0001-AD

CONTRACT NO.
N00123-84-D-3130
2214

DR SCOTT CHK HC
ENGR SCOTT ANDERSON
APPROVED DATE 4/7/86
NCEL
MGR
APPROVED DATE

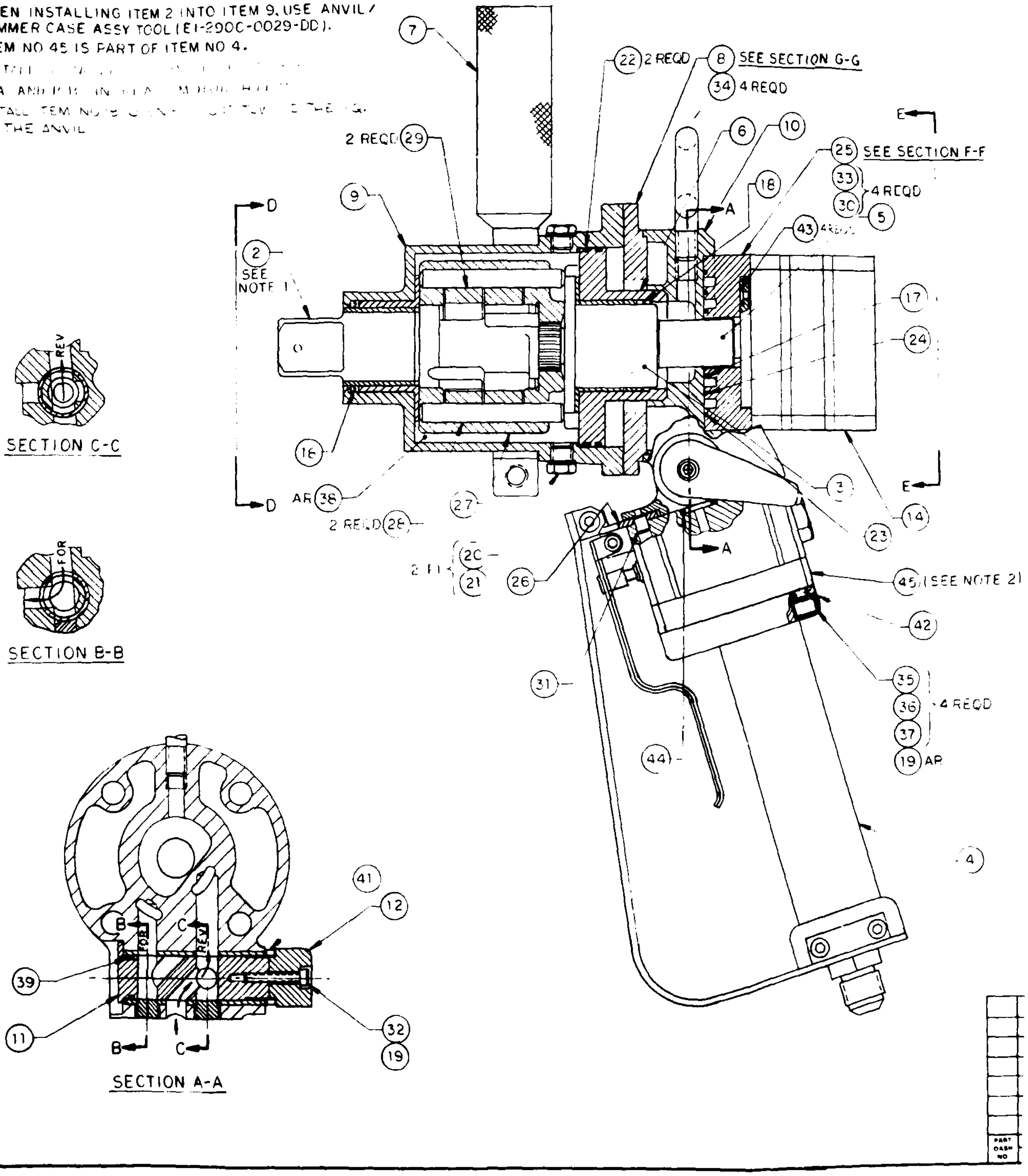
DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING COMMAND
NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

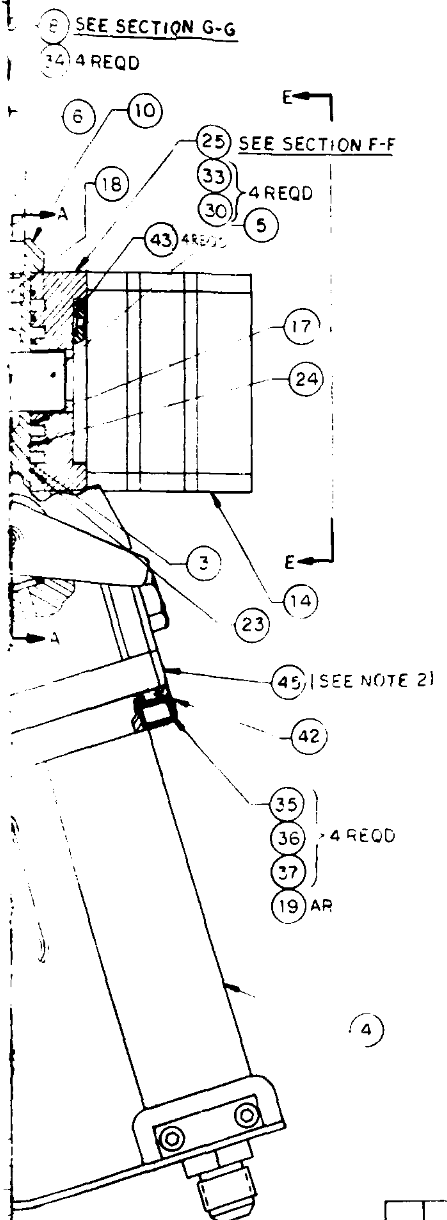
MULTI-FUNCTION TOOL SYSTEM
GRINDER ASSEMBLY
EASTPORT INTERNATIONAL

SIZE D | CODE IDENT NO [illegible] | NAVFAC DRAWING NO
SCALE 1/2 | SPEC | SHEET

NOTES:

1. WHEN INSTALLING ITEM 2 INTO ITEM 9, USE ANVIL/HAMMER CASE ASSY TOOL (E1-2900-0029-DD).
2. ITEM NO 45 IS PART OF ITEM NO 4.
3. INSTALL [illegible] A-A AND [illegible] IN [illegible]
4. INSTALL ITEM NO 5 [illegible] THE [illegible] OF THE ANVIL





(CON'T ON SHEET 2)

-1	FSCM NO	PART NO	DESCRIPTION	MATERIAL	ITEM NO
1		030-3957	O-RING(PRECISION RUBBER PROD)		24
1		036-3957	O-RING(PRECISION RUBBER PROD)		23
2		C42-11647	O-RING(PRECISION RUBBER PROD)		22
2		904-3957	O-RING(PRECISION RUBBER PROD)		21
2		900598-4S-C	O-RING BOSS PLUG(AEROQUIP)		20
AR		SST PIPE SEALANT	PIPE SEALANT(LOCTITE CORP)		19
2		AR10401-126 WC	SEAL, FLUOROCARBON		18
1		022-3957	O-RING(PRECISION RUBBER PROD)		17
1		8891T36	LIFTING LUG(MCMASTER-CARR)	316 CRES	16
6		MS16995-48	SCREW, SKT HD CAP 1/4-20UNC-2A X 1/2 LG	316 CRES	15
1		83-22-C6 (NCEL)	MFTS MOTOR ASSEMBLY		14
1		E1-2900-0012-AD	CLAMP FASTENER ASSEMBLY		13
1		E1-2900-C11-DD	VALVE HANDLE	316 CRES	12
1		E1-2900-0010-DD	REVERSE VALVE	316 CRES	11
1		E1-2900-0009-DD	BACKHEAD ASSEMBLY		10
1		E1-2900-0008-AD	HAMMER CASE ASSEMBLY		9
1		E1-2900-0007-DD	CLAMP FLANGE	316 CRES	8
1		E1-2900-0006-AD	HANDLE STRAP ASSEMBLY		7
1		E1-2900-0005-AD	REAR PLATE ASSEMBLY		6
1		E1-2900-0004-DD	MOTOR SHAFT SLEEVE	INCONEL [illegible]	5
1		E1-2500-C001-AD	MFTS CONTROL HANDLE ASSY		4
1		E1-2900-0003	COUPLING ASSEMBLY		3
1		E1-2900-C002-AD	SLEEVE AND ANVIL ASSEMBLY		2
			IMPACT WRENCH ASSEMBLY		1

QUANTITY FOR EACH ASSEMBLY

PARTS LIST

PART DASH NO	NEXT ASSY	USED ON
	APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND OR INCHES

TOLERANCES
X DECIMALS : ---
XX DECIMALS : —
XXX DECIMALS : —
FRACTIONS : —
ANGLES : —

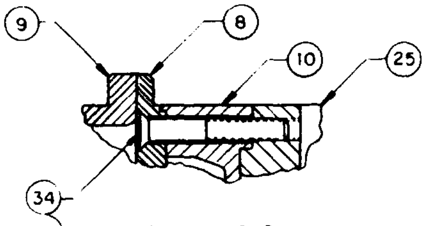
CONTRACTOR'S DRAWING NO: E1-2900-0001-AD

CONTR NO: N00123-84-D-0130 2218
DR PASTORIUS CHK
ENGR
APPROVED DATE
NCEL MGR
RVO DIR
APPROVED DATE
COMMANDING OFFICER
APPROVED DATE
FOR COMMANDER, NAVFAC

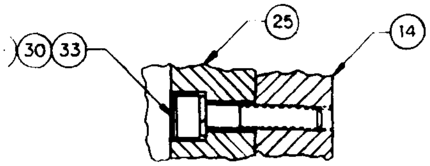
DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING COMMAND
NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME CALIFORNIA 93043

MULTI-FUNCTION TOOL SYSTEM
IMPACT WRENCH ASSEMBLY

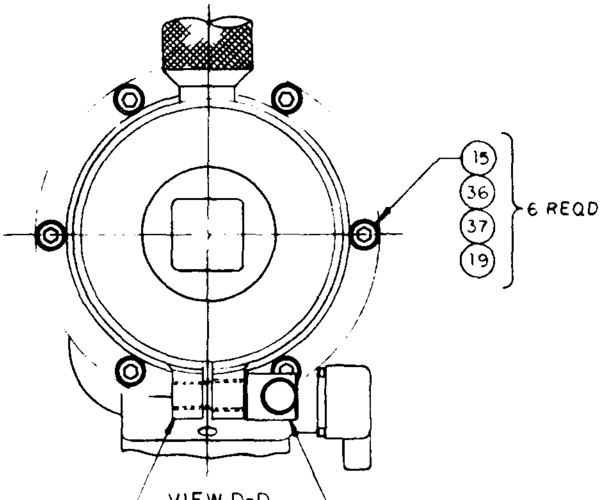
SIZE D
CODE IDENT NO 80091
NAVFAC DRAWING NO
SCALE 1/1
SPEC
SHEET 1 OF 2



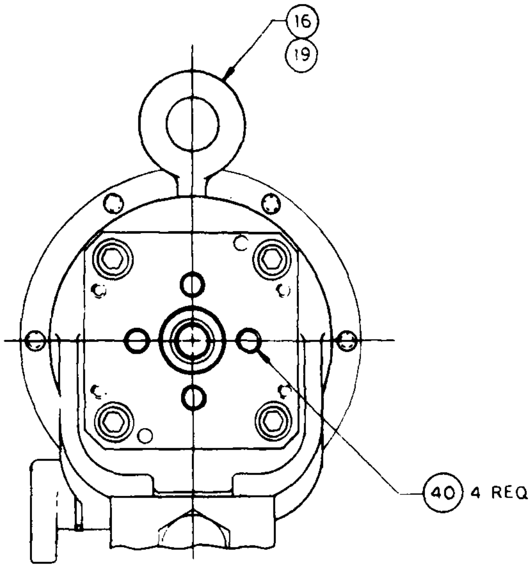
SECTION G-G
TYPICAL 4 PLACES



SECTION F-F
TYPICAL 4 PLACES

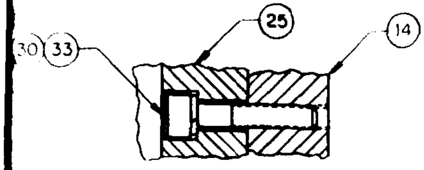


VIEW D-D

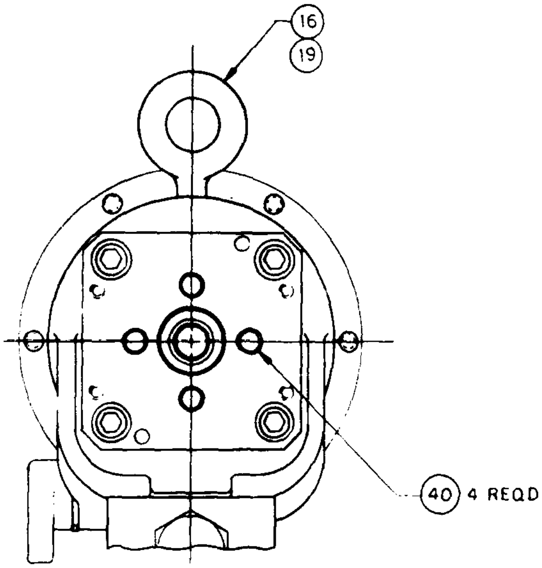


VIEW E-E

PART DASH NO	NEXT ASSY
	APPLICA



SECTION F-F
TYPICAL 4 PLACES



VIEW E-E

-1	FSCM NO	PART NO	DESCRIPTION	MATERIAL	ITEM NO
1			VALVE ASSEMBLY (SEE NOTE 2)		45
1		014-3957	O-RING (PRECISION RUBBER PROD)		44
4		013-3957	O-RING (PRECISION RUBBER PROD)		43
1		E1-2900-0028-DD	HANDLE/VALVE MOUNTING PLATE	316 CRES	42
1		E1-2900-0015-DD	THRUST WASHER	TORLON 4203	41
4			HYDRAULIC INSERT PLUG (LEE COMPANY)	Ti 6Al-4V	40
1		016-3957	O-RING (PRECISION RUBBER PROD)		39
AR		CENTURY 101	IMPACT MECHANISM FLUID (20% RATIO/FRESH WATER)		38
10		NAS620C416L	WASHER, REDUCED O.D.	316 CRES	37
10		MS51848-50	1/4 LOCKWASHER HI-COLLAR HELICAL SPRING		36
4			SCREW, SKT HD CAP, 1/4-20UNC-2A X 2 1/2 LG		35
4		MS24671-45	SCREW, 82° FLAT SKT HD 5/16-18UNC-2A X 2.00 LG		34
4		MS16995-39	SCREW, SKT HD CAP, 10-24UNC-2A X 7/8 LG		33
1		MS16995-40	SCREW, SKT HD CAP, 10-24UNC-2A X 1.00 LG		32
1		39-250-0375	SPRING PIN (REXNORD INC)		31
4		MS51848-49	NO 10 LOCKWASHER HI-COLLAR HELICAL SPRING	316 CRES	30
2		2910-724	HAMMER (INGERSOLL-RAND)		29
2		2910-704	HAMMER PIN (INGERSOLL-RAND)		28
1		2910-A703	HAMMER FRAME (INGERSOLL-RAND)		27
1		E1-2900-0014-DD	GUARD ADAPTER PLATE	316 CRES	26
1		E1-2900-0013-DD	MOTOR INTERFACE PLATE	Ti 6Al-4V	25

QUANTITY FOR EACH ASSEMBLY

PARTS LIST

PART DASH NO	NEXT ASSY	USED ON
	APPLICATION	

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN FEET AND OR INCHES
TOLERANCES
X DECIMALS : —
XX DECIMALS : —
XXX DECIMALS : —
FRACTIONS : -
ANGLES : —

CONTRACTOR & DRAWING NO
E1-2900-0001-AD

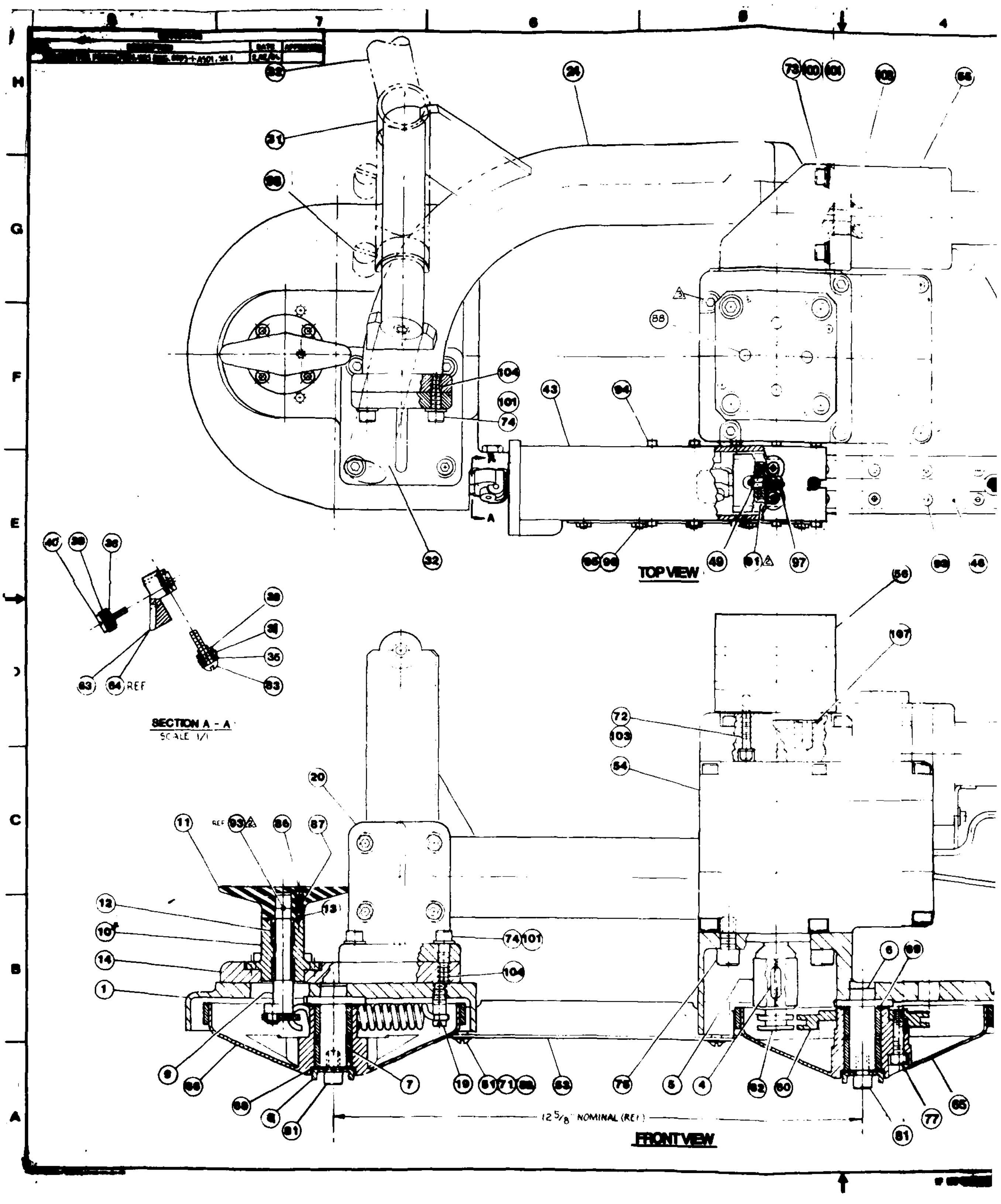
CONTR NO
N00123-84-D-0150
2218

DR PASTORIUS CHK
ENGR
APPROVED DATE 4/1/85
NCEL MGR
RVD DIR
APPROVED DATE
COMMANDING OFFICER
APPROVED DATE
FOR COMMANDER, NAVFAC

DEPARTMENT OF THE NAVY NAVAL FACILITIES ENGINEERING COMMAND
NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME CALIFORNIA 93043

MULTI-FUNCTION TOOL SYSTEM
IMPACT WRENCH ASSEMBLY

SIZE D
CODE IDENT NO 80081
NAVFAC DRAWING NO
SCALE 1/1
SPEC
SHEET 2 OF 2


8
7
6
5
4
H
G
F
E
D
C
B
A
TOP VIEW
SECTION A - A
SCALE 1/1
FRONT VIEW
12 5/8" NOMINAL (REF)
REF
26
31
73
100
101
102
55
88
104
101
74
43
94
32
49
91
97
40
38
36
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35
63
64
58
107
72
103
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11
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60
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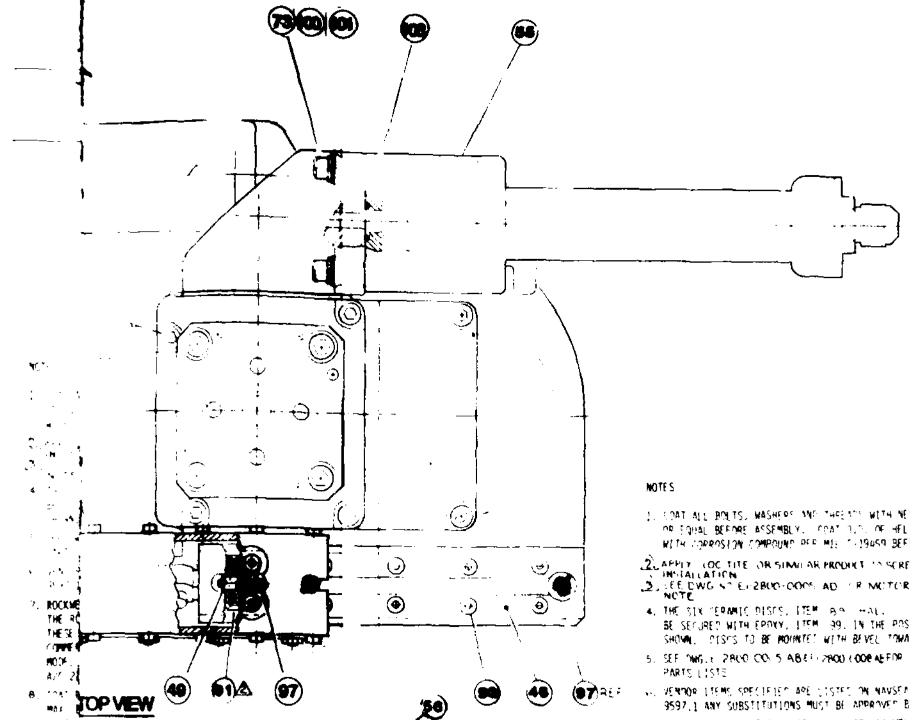
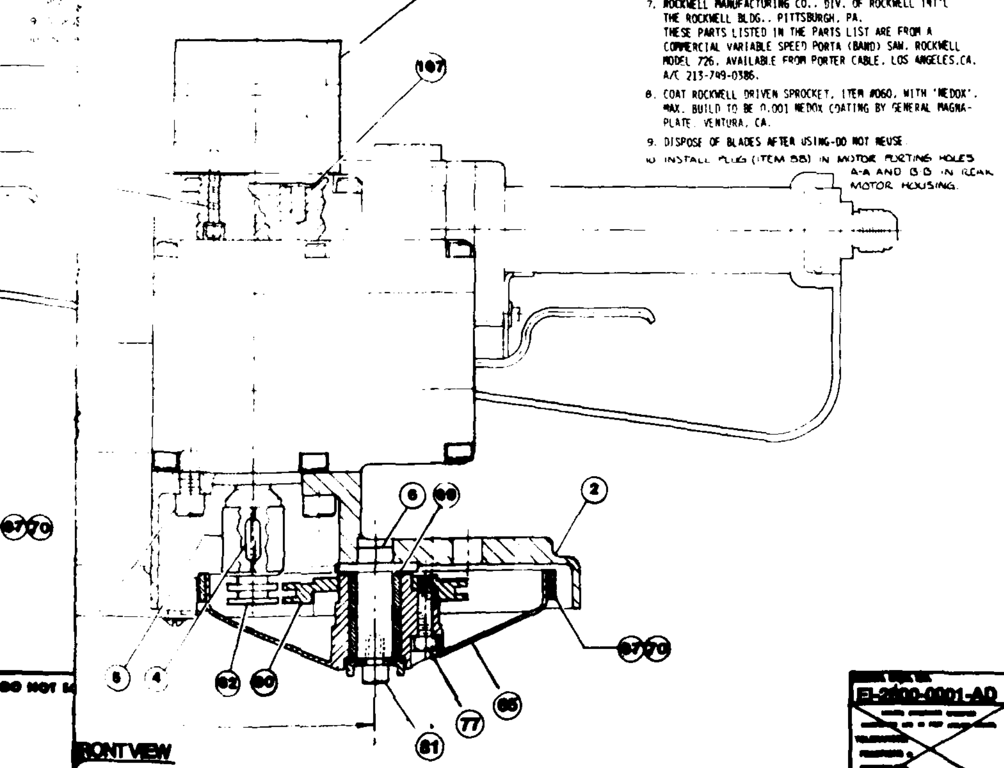
77
65



TOP VIEW



FRONT VIEW

NOTES

1. COAT ALL BOLTS, WASHERS AND THREADS WITH NEVER-SEEZ OR EQUAL BEFORE ASSEMBLY. COAT O.D. OF HELI-COILS WITH CORROSION COMPOUND PER MIL-C-19459 BEFORE INSTALLATION.
2. APPLY LOC TITE OR SIMILAR PRODUCT TO SCREW BEFORE INSTALLATION
3. SEE DWG NO EI-2800-0005 AD FOR MOTOR INSTALLATION NOTE
4. THE SIX CERAMIC DISCS, ITEM 89, SHALL BE SECURED WITH EPOXY, ITEM 99, IN THE POSITIONS SHOWN. DISCS TO BE MOUNTED WITH BEVEL TOWARD BLADE.
5. SEE DWG. EI-2800-0005 AB & EI-2800-0008 AE FOR SEPARATE PARTS LISTS
6. VENDOR ITEMS SPECIFIED ARE LISTED ON NAVSEA INSTRUCTION 9597.1 ANY SUBSTITUTIONS MUST BE APPROVED BY NAVSEA.
7. ROCKWELL MANUFACTURING CO., DIV. OF ROCKWELL INT'L THE ROCKWELL BLDG., PITTSBURGH, PA. THESE PARTS LISTED IN THE PARTS LIST ARE FROM A COMMERCIAL VARIABLE SPEED PORTA (BAND) SAW. ROCKWELL MODEL 726. AVAILABLE FROM PORTER CABLE. LOS ANGELES, CA. A/C 213-749-0386.
8. COAT ROCKWELL DRIVEN SPROCKET, ITEM #060, WITH 'NEDOX'. MAX. BUILD TO BE 0.001 NEDOX COATING BY GENERAL MAGNAPLATE, VENTURA, CA.
9. DISPOSE OF BLADES AFTER USING-DO NOT REUSE.
10. INSTALL PLUG (ITEM 88) IN MOTOR PORTING HOLES A-A AND B-B IN REAR MOTOR HOUSING.

PARTS LIST CONTINUED ON SHEET 2

SEE NOTE 6 (items 60–69)

[illegible]	PART NO.	QTY.	[illegible]	[illegible]
90				
89	COMMERCIAL	6	INSERT, CERAMIC KENNAMETAL P/N RNG-42T	SEE NOTE 4 KOBO [illegible]
88		4	PLUG LEE NO PLGA3430020	-
87		1	SPRING, CENTURY P/N S-8N	[illegible]
86		1	SET SCREW, MICRO PLASTICS INC. P/N [illegible]	[illegible]
85		1	SNAP RING, EXT., TRUARC P.N. 5100-25H	CRES
84		3	SCREW, HEX HD., 1/4-20 UNC x 1/2" L.	316 CRES
83		4	SCREW, R.H., 10-24 UNC x 1/2" L.	316 CRES
82		1	SCREW, HEX HD., 1/4-20 UNC x 3/4" L.	316 CRES
81		2	SCREW, CAP, SCH., 5/16-18 UNC x 1/2" L.	316 CRES
80		8	SCREW, F.H., SCH, 82° CSK, 8-32 UNC x 3/8" L.	316 CRES
79		5	SCREW, CAP, SCH, 10-24 UNC x 1/2" L.	316 CRES
78		4	SCREW, F.H., SCH, 82° CSK, 1/4-20 UNC x [illegible] L.	316 CRES
77		2	SCREW, CAP, SCH., 1/4-20 UNC x [illegible] L	316 CRES
76				
75		[illegible]	SCREW, CAP, SCH., 3/8-16 UNC x [illegible]	316 CRES
74		8	SCREW, CAP, SCH, 1/4-20 UNC x 7/8"	316 CRES
73		4	SCREW, CAP, SCH, 1/4 20 UNC X 3" L	316 CRES
72		4	SCREW, CAP, SCH #10 24 UNC X 1 1/4 L	[illegible]
71			WASHER [illegible]	[illegible]
70	COMMERCIAL	A.R.	ABRASIVE STRIP, [illegible]	[illegible]
69	ROCKWELL	[illegible]	PULLEY WASHER, ROCKWELL P.N. [illegible]678	[illegible]
68		[illegible]	PULLEY WASHER, ROCKWELL [illegible]	[illegible]
67		[illegible]	PULLEY TIRE, ROCKWELL P.N. 844868	[illegible]
66		[illegible]	DRIVEN PULLEY, ROCKWELL P.N. 844867	[illegible]
65		[illegible]	DRIVE PULLEY, ROCKWELL P.N. 844866	[illegible]
64		[illegible]	REAR BLADE GUIDE, ROCKWELL P.N. [illegible]	
63	ROCKWELL	1	FRONT BLADE GUIDE, ROCKWELL P.N. [illegible]	[illegible]
62	EI-2800-4062	1	[illegible] (ALTERED), ROCKWELL P.N. [illegible]	
61	ROCKWELL	[illegible]	CHAIN, ROCKWELL P.N. [illegible]	
60	ROCKWELL		DRIVEN [illegible]	SEE NOTE 7
59	EI-2800-3059	1	PLATE, [illegible] AS REQ'D FOR #26	6061-T6 ALUM
58	EI-2800-3058	1	PLATE [illegible] X 2 AS REQ'D FOR [illegible]	6061-T6 ALUM
57	EI-2800-3057	1	PLATE, 3/8" X 2 1/2" AS REQ'D FOR #26	6061-T6 ALUM
56			[illegible] MOTOR NCEL PN 83-22-56-1	
55	EI-2800-0008		VALVE AND HANDLE ASSEMBLY	
54	-0005		GEAR BOX ASSEMB.	
53	-4053	[illegible]	REAR BLADE GUARD, #16 GA. [illegible]	[illegible] T6 ALUM
52	-4052	[illegible]	SHIELD, [illegible] PER [illegible]	[illegible] ALUM
51	-4051	[illegible]	SPACER, .500" O.D. [illegible]	316 CRES
50	-4050	[illegible]	PIN	[illegible]
49	-4049	1	ROLLER	TORLON [illegible]
48	-4048	[illegible]	[illegible]	[illegible]
47	-4047	[illegible]	GUIDE	TORLON [illegible]
46	-4046	1	GUARD SUPPORT	6061 T6 ALUM
45	-4045	[illegible]	PLATE, 1/4" [illegible] PER # [illegible]	6061 T6 ALUM
44	-4044	[illegible]	PLATE, 1/8" [illegible] PER # [illegible]	6061 T6 ALUM
43	-4043	1	SAFETY GUARD ASSEMBLY	6061 T6 ALUM
42	-4042	1	FLUSH CUT GUIDE, #11 GA. (0.120")	316 CRES
41	-4041	2	FLUSH CUT BLADE GUIDE	P.V.C.
40	-4040	2	RETAINING SCREW, 5-40 UNC 2A	316 CRES
39	-4039	2	SPACER	316 CRES
38	-4038	2	ROLLER (DRILL BUSHING)	TUNG.CARB.
37	-4037	2	ROLLER	TUNG.CARB.
36	-4036	2	BEARING	OILITE/[illegible]
35	-4035	2	BEARING	TORLON [illegible]
34	-3034	2	ROD, THR'D, 3/8"-16 UNC-2A, 1 PER # -032	316 CRES
33	-3033	2	ROD, 1" DIA. x 4" L. 1 PER # -032	6061-T6 ALUM
32	-3032	2	EXTENSION HANDLE ASSEMBLY	--------
31	-3031	1	AUXILIARY HANDLE, 1-1/2 IPS PIPE	6061-T6 ALUM
30	-3030	1	ROD, 1" DIA. x 6-1/8" LONG 1 PER # 28	6061-T6 ALUM
29	-3029	2	PLATE, 1/4" x 1-5/8" AS REQ'D FOR # 28	6061-T6 ALUM
28	-3028	1	FRAME HANDLE ASSEMBLY 1 PER #24	--------
27	-3027	----	PIPE, 1 1/2" SCH. 40, AS REQ'D FOR #24	6061-T6 ALUM
26	-3026	1	FRAME SIDE BRACKET, 1 REQ'D FOR #24	6061-T6 ALUM
25	-3025	1	FRAME BRACKET PLATE 3/8" X 2 1/2" 50.1 REQ'D FOR #24	6061 T6 ALUM
24	-3024	1	FRAME ASSEMBLY	6061 T6 ALUM
23	-4023	1	PLATE, 1/4" X 1 1/2", AS REQ'D FOR #20	6061-T6 ALUM
22	-4022	1	PLATE 3/8" X 2 1/2" AS REQ'D FOR #20	6061-T6 ALUM
21	-4021	1	PLATE, 1/2" X 2 7/8" AS REQ'D FOR #20	6061-T6 ALUM
20	-4020	1	FRAME MOUNTING BRACKET	6061-T6 ALUM
19	-4019	2	SPRING ANCHOR	316 CRES
18	-4018	2	EXTENS'N SPRING, #11 GA. (0.1205"), 140 #/IN	CRES
17	-4017	1	TENSION BAR, 1/8" PLATE	316 CRES
16	-4016	2	RETAINER PLATE, 1/8" PLATE	316 CRES
15	-4015	2	GUIDE BAR	316 CRES
14	-4014	1	MOUNTING PLATE	6061-T6 ALUM
13	-4013	1	PLUNGER	17-4 PH
12	-4012	2	BEARING	TORLON 434.
11	-4011	1	TAKEUP HANDLE	DELRIN
10	-4010	1	PEDESTAL	316 CRES
9	-4009	1	TAKEUP SHAFT	316 CRES
8	-4008	2	PULLEY KEEPER	316 CRES
7	-4007	4	PULLEY BEARING	RULON LD
6	-4006	2	SPINDLE	17-4 PH
5	-4005	1	KEY RETAINER, 1"O.D. x 0.035 WALL TUBING	316 CRES
4	-4004	1	KEY	316 CRES
3				
2	2002	1	DRIVE PULLEY HOUSING	6061-T6 ALUM
1	EI-2800-2001	1	DRIVEN PULLEY HOUSING	6061 T6 ALUM

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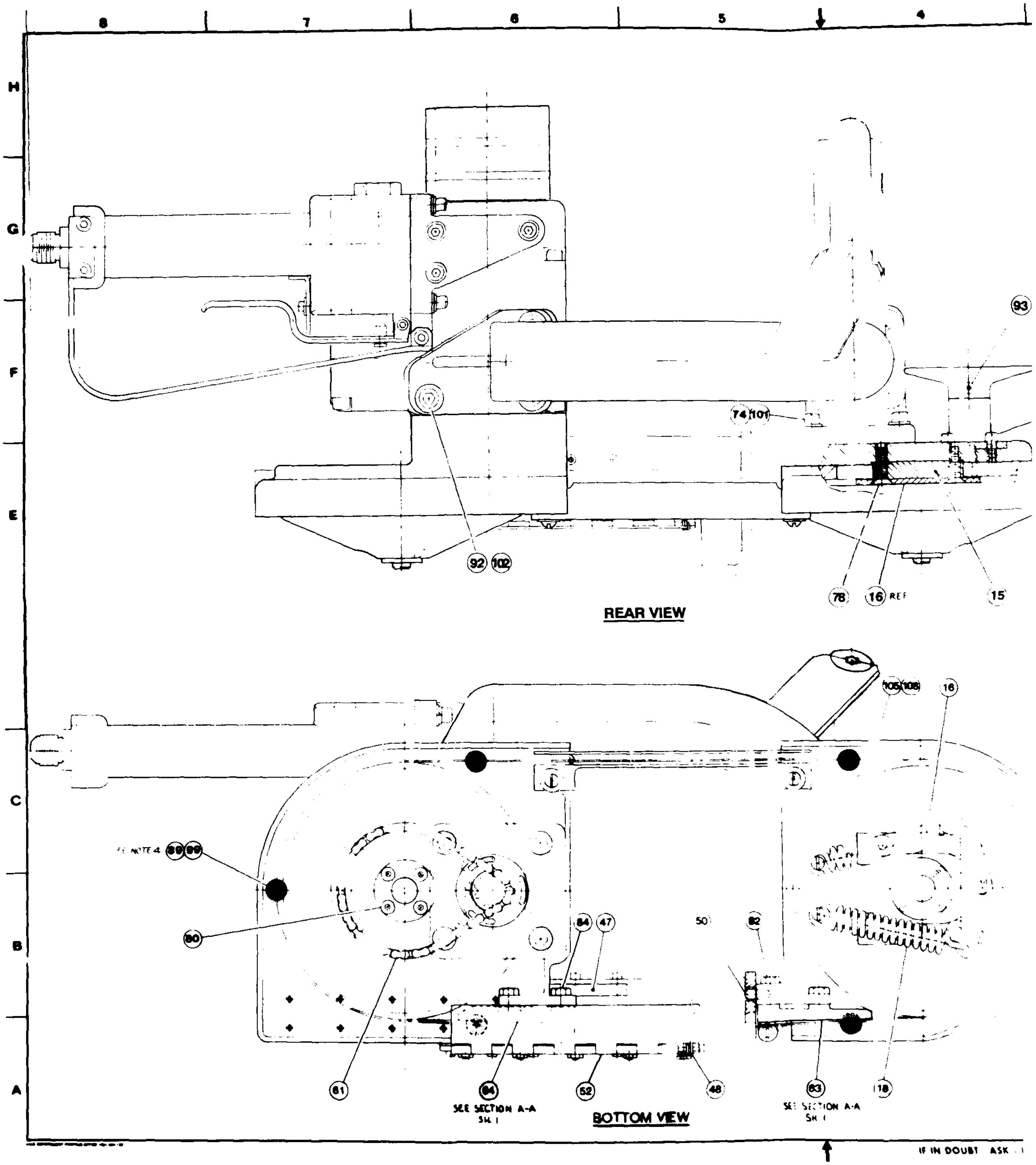
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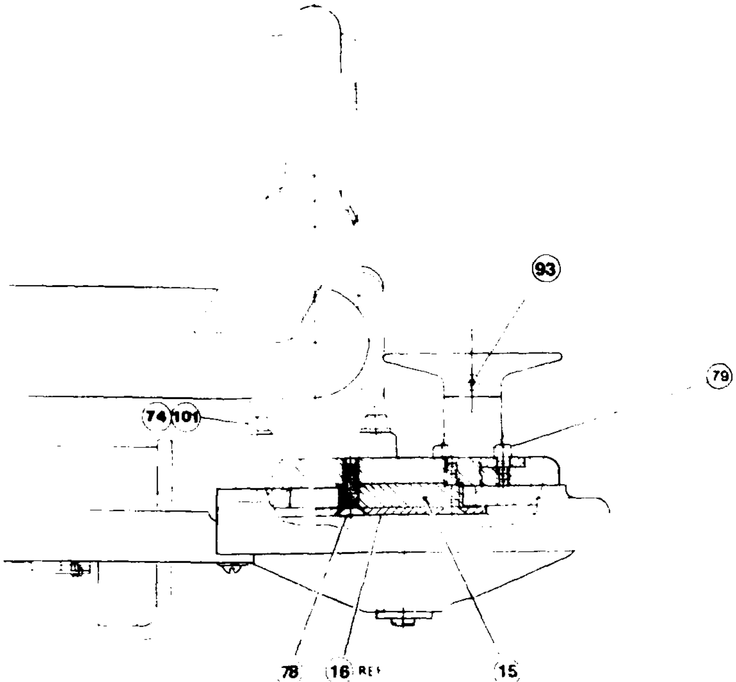

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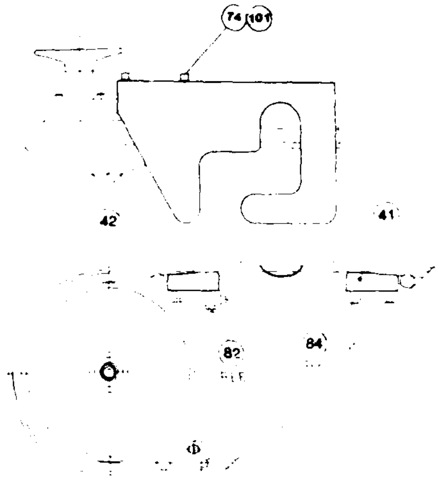

ALTERNATE FLUSH CUTTING ASSEMBLY

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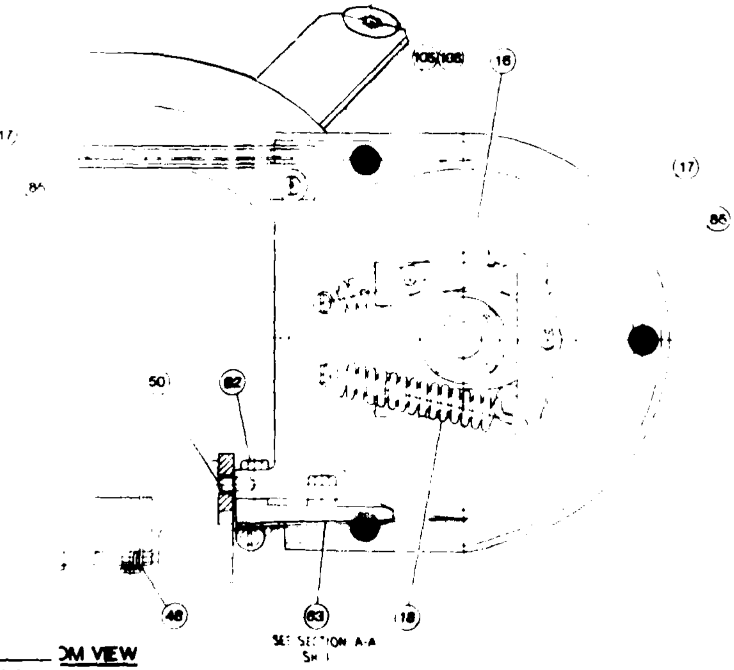

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ITEM | PART NO | QTY | DESCRIPTION | MATERIAL

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FRACTIONS ±
DECIMALS ±
ANGLES ±

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Appendix B

DIVERS' COMMENTS

GRINDER CUTTING TEST -

HUMAN FACTOR COMMENTS

Diver: Tom Conley
Recorded by: R. Arnold

Date: 8 May 1985

Rate the following tool attributes:	Good	Fair	Poor
Trigger mechanism Comments:	X		
Trigger guard Comments:	X		
Trigger comfort Comments: Allows the diver to push with one hand.	X		
Balance of tool Comments: No problems.	X		
Weight of tool Comments: Light	X		
Ease of operation Comments: Can stall it -- this is a good feature. Stops fast.	X		
Location of hose Comments: Ball swivel would be nice. Hose can bind the wheel.			
Location of exhaust ports Comments: No warmth.			
Noise level Comments: Can hear when loading the tool.	X		
Visibility Comments: No cuttings in the way. Work area is clear.	X		
Location of handles Comments: Hoop handle would be better.			

Additional Comments: The tool cuts well but slow. When face grinding, the wheel is sucked down to the grinding surface so the tool has to be held at a steep angle to prevent this from happening.

GRINDER CUTTING TEST -

HUMAN FACTOR COMMENTS

Diver: John Wright
Recorded by: R. Arnold
Date: 8 May 1985

Rate the following tool attributes:	Good	Fair	Poor
Trigger mechanism Comments: Comfortable	X		
Trigger guard Comments:	X		
Trigger comfort Comments:	X		
Balance of tool Comments: Hose tends to throw the tool off balance, otherwise good.	X		
Weight of tool Comments:	X		
Ease of operation Comments: Binds up and stalls if angled in a cut.	X		
Location of hose Comments: Hose causes tool to be off balance.	X		
Water exhaust locaton Comments: No warmth.			
Noise level Comments:	X		
Visibility Comments:	X		
Location of handles Comments: Do not like to change handle.			

Additional Comments: This grinder cuts the same as other grinders I've used.

GRINDER CUTTING TEST -
HUMAN FACTOR COMMENTS

Diver: CDR James Wright
Recorded by: R. Arnold
Date: 8 May 1985

Rate the following tool attributes:	Good	Fair	Poor
Trigger mechanism Comments:	X		
Trigger guard Comments: If it were closer to the trigger you could use the back of your hand to depress the trigger.	X		
Trigger comfort Comments:	X		
Balance of tool Comments: Heavier if using as a cutoff tool.	X		
Ease of operation Comments: Hogged in would be easier. Nice to be able to stall out without so much jerkiness.	X		
Location of hose Comments: Good if tended.	X		
Water exhaust location Comments:	X		
Noise level Comments:	X		
Visibility Comments:	X		
Location of handles Comments: Don't like to switch handle from one side to the other. A wrap-around handle would be nice. Hand slipped after awhile. Deeper knurling needed.	X		

Additional Comments: No suction problem if angled enough. Cuts well.

ROTARY IMPACT WRENCH/DRILL

TOOL ATTRIBUTES:	Good	Fair	Poor
Trigger mechanism	4	3	2

1. Too touchy, hard to start at lower gpm.
2. Should be shortened so that only one finger fits.
3. Trigger is too far away from handle.
4. Handle was bulky, sharp. Try a slimmer, rounder handle closer to trigger. Also would prefer a button-type trigger or shorter lever.
5. Easy to use, but extends too far down. Would rather keep fingers straight rather than all on tool.
6. Comfortable, but gripping handle is too big.
7. Liked moveable handle.
8. Handle should be made rounder and easier to grip.
9. Lever too long, force good.

Trigger operation	5	2	

1. Trigger was easy to pull.
2. Needs variable speeds.
3. Smooth, but more control over drilling speed is needed.

Trigger guard	7		1

1. Sufficed.
2. Too big and too far away from trigger. Only needs enough space to keep hand inside.
3. Big enough, not in the way.

Balance of tool	4	4	

1. Awkward getting into position and moving around in water.
2. Bulky, swivel is worthless. Would prefer to have hose come straight out of bottom. Too unpredictable.
3. Remove 90 degree swivel. Try to go to straight hose.
4. Must keep hose directly under tool for balance.

Weight of tool	4	4	1

1. Heavy.
2. Heavy, could be lightened up.
3. Heavy, but a good heavy.
4. A little on the heavy side.
5. Too heavy.

ROTARY IMPACT WRENCH/DRILL

TOOL ATTRIBUTES:	Good	Fair	Poor
Ease of operation	6		2

1. Poor for drilling, good for impacting. Main handle too big; nuts irritate. Reversing trigger too difficult (tight). Try modeling like IW06.
2. Works wonderfully.
3. Other than drill chuck, worked well.
4. Adjustable handle is good.
5. Once you've got it going, it's great.
6. As an impact tool, no good. Drill screws up hole while impacting and ruins bit. The more it impacts, the harder it is to drill due to "out of roundness" caused by impact.
7. Tool is awkward because of weight.

Water exhaust location	5	1G-/F+	1 Fair

1. Direct it toward the hand.
2. Direct it toward the fingers.
3. Keeps hands warm.
4. Ditto.
5. Did not even notice it.
6. Good for in-water use, lousy for in-air use.

Noise level	6 Low	2 Medium	0 High	0 Too High

1. High while impacting; also noise while drilling.
2. Excellent for an impact wrench.
3. Wasn't aware of any - excellent.
4. Good.
5. Only time it bothered me was when using holesaw.

Do you feel confident that the rotary impact wrench/drill would operate and perform its intended tasks in future operations? If not, please explain.

1. 1/2-inch drill bit froze in chuck - broke teeth key trying to free bit using a 14-inch pipe wrench and soft hammer. NRL - Panama City - same problem with hydraulic impact wrench's Jacob chuck. Redesigned using wide-spaced square threads. Marty Sheehan was engineer-in-charge of hydraulic tools at P.C.

2. For impacting, yes. For drilling, can't see usefulness at all. Either use variable impact adjustment (such as on hydraulic SK-58) tool, or use two separate tools.

3. Yes, if you can fix the problem of drill bit getting stuck in chuck. (I) did not use the tool as an impact mechanism. Sporadic impacting of tool while drilling speeded up the task and helped clear filings and debris away. Did dull drill bits very quickly: try super titanium. Surge in water, but still able to maintain position.

4. Needs "controllable" trigger. Liked impact wrench; fast, good, but heavy. Problem (might) arise working in surf zone with wrench. ****(Later) drilled with holesaw - too loud but good drill****

5. Concerning steel: Drilling motion with anything over 1/4 inch is not smooth. Too much percussion when any force exerted to drill larger holes.

6. Problems: Impacts while drilling. Vibrates alot. Suggestions: Reduce flowrate. Put variable switch on tool: either impacts or drills. Also, lower the rpm. Drilling is too erratic and starts too fast; therefore diver can't get even, continuous drilling.

7. For wood, tool works well. No problem changing bits. Allen head screw no good on moveable handle - too hard to look for. Suggests a wing nut screw. In wood drilling, yes; in steel, doubtful. Impact is very good.

8. Yes, with necessary changes.

SEAWATER HYDRAULIC IMPACT

WRENCH DRILLING TEST

Diver: Tom Conley Date: 22 July 1985
Recorded by: Tony Lightfoot

Rate the following tool attributes:	Good	Fair	Poor
Trigger mechanism Comments: Needs to be shortened so that the hand can be slipped off the trigger and maintained in the trigger guard.	X		
Trigger guard	X		
Trigger/Handle comfort Comments: Uncomfortably fat, gold portion needs to be reduced both ways.			X
Balance of tool Comments: Good for drilling, unstable for impacting overhead or horizontal.		X	
Weight of tool Comments: Heavy for impacting but excellent for drilling.			X
Ease of operation Comments: Reversing switch has poor operating capability.		X	
Location of hose Comments: Recommend a swivel device.	X		
Water exhaust ports	X		
Noise level Comments: Loud but will not affect ears.	X		
Visibility	X		
Handle location Comments: Extra handle was not used for my impacting test. Recommend handle be changed to a 90 degree angle with a wingnut for adjustable purposes.			X

Additional Comments: Drill bits became dull quickly. Needed tighter sockets to reduce vibration and wobbling. Worked better at high speeds. Tom drilled without the second handle.

SEAWATER HYDRAULIC IMPACT
WRENCH DRILLING TEST

Diver: Ken Platt
Recorded by: Tony Lightfoot

Date: 22 July 1985

Rate the following tool attributes:	Good	Fair	Poor
Trigger mechanism Comments: Needs to be shortened about 2 or 3 fingers.	X		
Trigger guard	X		
Trigger/Handle comfort Comments: Too large, needs to be reduced.	X		
Balance of tool Comments: Hard to use for impacting.			X
Weight of tool Comments: Heavy for impacting but excellent for drilling.			X
Ease of operation Comments: Reversing switch has poor operating capability, sometimes falls off and also sticks.			X
Location of hose	X		
Water exhaust ports	X		
Noise Comments: Clicking but not overnoisy.	X		
Visibility	X		
Handle location Comments: Built in an awkward postion	X		

Additional Comments: The second handle helped to stabilize drilling immensely. Having this handle on (forgotten for diver 1 tests) reduced the drill bit wobble, and increased drilling speeds substantially. Recommending having a much tighter socket to drive connection, and a wingnut attached to the second handle for easy handle angle adjustment.

BANDSAW CUTTING TEST -

HUMAN FACTOR COMMENTS

Diver: Ken Platt Date: 28 Feb 1985

Rate the following tool attributes:	Good	Fair	Poor
Trigger mechanism Comments: Hard to squeeze and tiring.			X
Trigger guard Comments: No guard at this time. Could use a guard to keep tool from accidentally being turned on when set on the deck.			
Trigger comfort Comments: Trigger should be longer so all four fingers can grasp it.			X
Balance of tool	X		
Weight of tool Comments: Beneficial for cutting.	X		
Ease of operation Comments: Jumps when starts to cut.	X		
Location of hose Comments: No problems.	X		
Water exhaust location Comments: Certain positions caused visibility problems but they were easy to work around. Warms hands and face.	X		
Noise level Comments· Only hear humming sound.	X		
Visibility	X		
Location of handles Comments: Handles easily, very impressed. Handle did get a little warm.	X		

Additional Comments: Started out with the blade running in the wrong direction and at a slow speed, cutting times were not too fast. Tried later with the blade running in the right direction and at a faster speed, the ease in cutting and cutting times improved markedly.

BANDSAW CUTTING TEST -

HUMAN FACTOR COMMENTS

Diver: Wayne Tausig

Date: 28 Feb 1985

Rate the following tool attributes:	Good	Fair	Poor
Trigger mechanism Comments: Fatiguing.			X
Trigger guard Comments: Should have one.			
Trigger comfort Comments: Be better it if was longer and wider.			X
Balance of tool		X	
Weight of tool Comments: Little heavy.	X		
Ease of operation	X		
Location of hose	X		
Water exhaust location	X		
Noise level Comments: Very quiet.	X		
Visibility Comments: Salt and fresh water mix obstructed vision. Won't happen when seawater is used to power the tool instead of fresh water.	X		
Location of handles	X		

Additional Comments: Started out cutting with the motor running in the wrong direction and at a slow speed, cutting times were slow. Later cut with the motor turning correctly and at a higher speed. Saw then cut like "butter". The saw was a little heavy, and a little large. The blade got stuck (stalled) a few times.

BANDSAW CUTTING TEST -

HUMAN FACTOR COMMENTS

Diver: Jim Butterfield

Date: 28 Feb 1985

Rate the following tool attributes:	Good	Fair	Poor
Trigger mechanism Comments: Hard to squeeze and too short.			X
Trigger guard Comments: Needs one.			
Trigger comfort Comments: Tiring due to short handle and spring being to stiff.			X
Balance of tool	X		
Weight of tool Comments: Just let the saw cut by itself. No need to apply force. Saw should not be any lighter.	X		
Ease of operation	X		
Location of hose	X		
Water exhaust location	X		
Noise level Comments: Not noticeable.	X		
Visibility	X		
Location of handles Comments: Curved handle wouldn't be of much benefit.	X		

Additional Comments:

BANDSAW CUTTING TEST -

HUMAN FACTOR COMMENTS

Diver: Tom Conely Date: 28 Feb 1985

Rate the following tool attributes:	Good	Fair	Poor
Trigger mechanism Comments: Too stiff and too short.			X
Trigger guard Comments: Wouldn't be bad to have one. Would have to be large enough to get your hand out quickly in an emergency.			
Trigger comfort Comments: Tiring and would be better if all four fingers could grasp it.			X
Balance of tool	X		
Weight of tool Comments: Could be a little heavier.	X		
Ease of operation Comments: Let the saw cut on its own. Had to push when cutting material in the vertical position.	X		
Location of hose Comments: Didn't know it was there.	X		
Water exhaust location Comments: Good for warmth.	X		
Noise level Comments: Not noticeable.	X		
Visibility Comments: Able to watch the piece being cut.	X		
Location of handles Comments: Loop type handle is a possibility. Like to see a larger diameter handle next to trigger.		X	

Additional Comments: Would like to see the blade-guard cover the blade during cutting. Trigger no good. Changing the blade was difficult due to the 30 degree offset on the blade guides. Friction material starting to wear off. Blade popped off when cutting the SD List 5 coaxial cable. Blade also stalled a few times.

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