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AD-A035 916

ARCTIC ADAPTS

ENGINEERING ANALYSIS, PROTOTYPE DEVELOPMENT AND TESTING

SEAWARD INTERNATIONAL, INCORPORATED
FALLS CHURCH, VIRGINIA

DECEMBER 1976

REPORT NO. CG-D-123-76
TASK NO. 4108.07.02.03

ARCTIC ADAPTS
ENGINEERING ANALYSIS, PROTOTYPE DEVELOPMENT AND TESTING

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David W. Durfee
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December, 1976

FINAL REPORT

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16. Abstract

ADAPTS is a portable pumping system consisting of a diesel/hydraulic power supply and an hydraulic motor powered axial flow, submersible turbine pump equipped with the necessary power and discharge hoses, etc., expressly built by the Coast Guard for off-loading damaged tank ships.

An engineering study to analyze the feasibility of adapting the Coast Guard's ADAPTS pumping systems for use in an arctic environment is presented. Environmental criteria for this study are air temperatures as low as -40°F, cargo temperature as low as +28°F, and winds up to 40 knots.

Results of prototype system testing are discussed, and final recommendations presented, for arctic modification of ADAPTS.

Miscellaneous system modifications, changes in lubricating and operating fluids, and procedural changes are discussed. Drawings, parts list and cost information are included for the modifications recommended.

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Transportation Technology Division
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FOREWORD

This study presents the results of the preliminary engineering analysis, prototype testing, and final analysis for modification of the U. S. Coast Guard's ADAPTS transfer pumping system for use in an arctic environment. Seaward International, Inc., performed the work under Contract DOT-CG-51,864-A during the period 2 June 1975 to 1 December 1976.

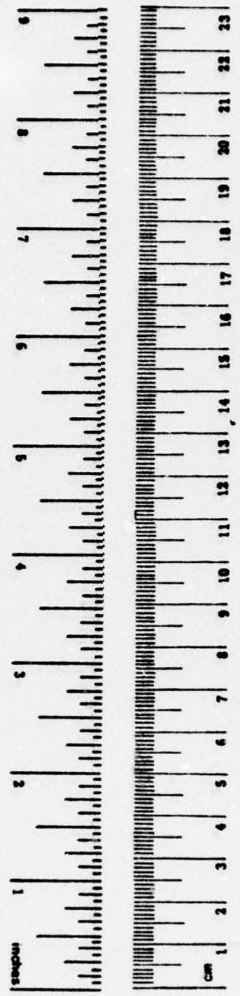
Lt. J. Getman of the U. S. Coast Guard served as Project Officer during this program. S. H. Shaw served as Project Manager for Seaward International, Inc. M. L. Clarke and D. W. Durfee performed the engineering analysis. B. Gierhart, R. P. Bishop, F. March, and M. Krenitsky also contributed to the program.

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 (2000 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

*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 (1000 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

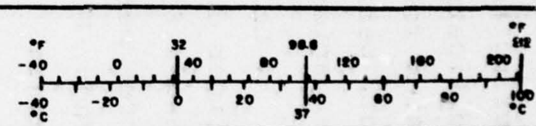


TABLE OF CONTENTS

TABLE OF CONTENTS

TABLE OF CONTENTS
(Cont.)

LIST OF FIGURES

LIST OF FIGURES
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1.0 INTRODUCTION AND SUMMARY

The Air-Deliverable Anti-Pollution Transfer System (ADAPTS) was developed by the U. S. Coast Guard to provide an emergency quick-response method of offloading the cargoes from grounded or disabled tank ships and barges. ADAPTS consists of a hydraulically powered, axial flow, submersible pump powered by a lightweight diesel power unit. Each system includes all necessary rigging gear, fuel containers, hydraulic transmission hoses, and lightweight cargo discharge hoses. The submersible pump, with capacities in excess of 1000 gallons per minute, is sized to be lowered through the Butterworth deck openings into the liquid cargo. The cargo is transported through the discharge hose to intact tanks or into lightering vessels alongside.

Since 1970 the Coast Guard's National Strike Team has operated ADAPTS to prevent and combat tanker spills. With the increasing volume of petroleum products being transported in cold regions of the globe, it has become necessary to modify the ADAPTS equipment to allow it to operate reliably under arctic environmental conditions.

Under contract number DOT-CG-51,864-A, from the U. S. Coast Guard, Seaward International, Inc., of Falls Church, Virginia, conducted an engineering analysis to determine the extent of modifications required to permit reliable arctic operation and modified a complete ADAPTS pumping system accordingly. They then successfully tested the modified system both in an environmental test chamber at $-40^{\circ}F$ and in an actual arctic environment at Fort Wainwright, Fairbanks, Alaska.

This report describes the modifications tested, the test procedures utilized, and the test results. The equipment modifications recommended as a result of the test program are described in full, with both drawing and photographic illustrations.

Modifications to the system operating and maintenance procedures are also described.

2.0 EXISTING ADAPTS SUITABILITY ANALYSIS

2.1 Definition of Criteria

The arctic environmental conditions considered in defining all material and operational problems are the following:

Air Temperature	-40°
Water Temperature	$+28^{\circ}F$
Wind	40 knots
Ice Debris in Pumped Fluid	Size as limited by suction strainer approximately ¼ inch
Type of Oils Pumped	Crude oils, distillate and residual fuel oils

It is assumed the equipment will be required to perform in continuous operation, fully exposed to the above conditions. It is also assumed that any substitutions or modifications allow the components which produce heat in operation, the engine and hydraulic system, to reach equilibrium and operate continuously in the fully warmed condition.

2.2 Method of Analysis

A complete list was compiled of all the component parts used in the assembly of ADAPTS Type I and Type II pumping systems as originally procured and any substitute or additional components known to have been included in the systems.

Information was obtained from each of the component manufacturers in regard to the suitability of their product for the conditions, possible problem areas, arctic use experience, and recommended modifications or substitutions. Materials compatibility and problems with differential expansion and contraction were included in this analysis. This information was reviewed and any unsuitable or questionable components identified. Standard operating procedures were reviewed for suitability. Wherever hardware or procedural incompatibility with arctic operations were found, suitable modifications were determined.

Changes to hardware which would preclude use of the modified ADAPTS in temperate climates were avoided.

2.3 Specific Potential Problems

2.3.1 Prime Mover Unit

The ADAPTS prime mover consists of a 40 HP air-cooled diesel engine driving a variable displacement, piston hydraulic pump in a "closed" hydraulic system. The engine has no electrical system and is provided with an American Bosch hydraulic starter system. This unit is mounted on an aluminum foundation in a watertight fiberglass container.

The fuel, lubricating and hydraulic oils normally used in this unit are unsuitable for use at $-40^{o}F$ and are discussed separately in section 2.3.4. Aside from these temperate climate fluids, few of the basic components of this unit were found to be unsuitable or unreliable at $-40^{o}F$. The major problem in operation of the power unit is the start-up and warming to operating temperature of the engine.

The Avco Lycoming/Bernard W-44 diesel engine, although successfully started and operated at temperatures of $-40^{o}F$ and below in cold chamber tests and in actual cold climate operations, presented special problems in start-up in the ADAPTS application. For safety reasons, the standard electrical system was eliminated precluding the use of the resistance wire preheating of combustion air at the cylinder intakes and the sustained cranking by an electrical starter. The manufacturer's standard operating instructions recommend use of preheaters prior to starting at temperatures below $+40^{o}F$.

These engines had successfully been started at low temperatures using ether dosing as an alternative to preheating.

The only means of dosing the existing ADAPTS engine was by spraying of ether from an aerosol can directed into the air intake filter. This method often results in overdosing and possible damage to connecting rods or "lock-up" of a piston on a pure charge of ether.

The ADAPTS engine is cranked for starting by pumping a 3000 PSI, one gallon charge into an accumulator which then drives the starter motor. This charge is sufficient to rapidly rotate the engine approximately four turns and is effective for ignition in temperate climates. For reliable starting at -40°F, cranking time of greater duration is needed.

This engine is designed for maximum air cooling of the cylinder walls and lube oil by an intake fan belted to the front of the crankshaft. No means is provided to reduce the air cooling to allow warming to and maintenance of a proper operating temperature at -40°F.

At -40°F the standard engine oil temperature gauge fails to register properly due to freeze-up of the capillary tube connecting it to the temperature sensor in the oil sump.

The Jamesbury Double Seal hydraulic starter valve has a carbon steel body which may fail at its operating pressure of 3000 PSI due to embrittlement at -40°F.

The BUNA-N, synthetic rubber lip seals in the Snap-Tite 1-inch and 1/4-inch quick-disconnect couplers used in the main hydraulic system return and in the fuel system supply lines stiffen at -40°F, and according to their manufacturer, may allow leakage. In the hydraulic lines this is not critical; however, in the fuel supply lines, an air-tight seal is essential to operation of the diesel.

The standard V-belts used on the engine governor and hydraulic charge pump stiffen at -40°F and are subject to cracking in use. See Figure #1.

Because of the inaccessible location of the oil sump drain and the watertight fiberglass bottom cover, necessary oil changes can be difficult and time-consuming.

Removal and replacement of the diesel exhaust pipes and mufflers fitted with slip joints can be difficult and result in damage to the exhaust manifolds. This is caused by sticking of the standard clamp-type joints and has been a problem in all systems.

According to the supplier, the hydraulic accumulator used in the diesel starting system has had a history of failures when used after long periods of storage. This is caused by the O-ring piston seal, which tends to stick to the cylinder walls and roll out of place when the piston moves.

The Lucas MAMS-PM-500 main hydraulic pump, with modifications, is used in the British Chieftain tank and has been tested and operated at low temperatures. Due to the high case pressures resulting from high starting viscosities at -40°F, seal failure and external leakage at the shaft and servo ends of the pump can occur at low temperatures if the pump seals are not modified.

The glycerin-filled gauges used in the charge and main hydraulic system are inoperable at -40°F due to the solidification of the glycerin.

2.3.2 Cargo Pump

The standard ADAPTS cargo pump is a two-stage, 10-inch, Byron-Jackson submersible turbine pump powered by a Dennison hydraulic motor directly coupled through a coupling housing fitted with a double tapered roller thrust bearing. Single-stage, 8-inch submersible pumps have also been procured by the Coast Guard to be used with the same ADAPTS Prime Mover Unit. These are similar in construction.

Although the minimum temperature of the liquid to be pumped and in which this pump will be submerged is +28°F, for purposes of this study, it was assumed that during handling on deck and at initial start-up the pump will be at -40°F. On this basis the following problems might occur in the existing pump and require material or operational changes.

The outer edges of the closed-type pump impellers run in a bronze wear ring pressed into the pump body; clearances between impeller and wear ring may be less than .005 inches. If, when the pump arrives in the arctic climate, any water or condensed moisture is present in this space, the impellers could freeze in place; and the motor might not have sufficient torque to start the pump.

The pump body is cast of Meehanite, a cast iron; according to the manufacturer, this material could become brittle at -40°F and subject to fracturing upon impact. This condition would not affect the normal operation of the pump in place in a tank, but may require unusual care in handling on deck and in rigging and lowering the pump.

The Snap-Tite 1-inch quick-disconnect coupler, like that on the prime mover, has a synthetic rubber seal which may allow leakage at -40°F prior to warm-up.

The Dennison motor shaft seal is designed to withstand continuous internal pressures to 50 PSI and momentary surges to 300 PSI. Since this motor case is internally drained, the pressure acting on the shaft seal is equal to the back pressure in the 1-inch hose returning the hydraulic fluid from the motor to the prime mover. With the high viscosities of the hydraulic fluid prior to warm-up of the system, the prime mover is capable of flow rates which can cause return hose pressures to exceed 300 PSI.

The Dodge double-tapered roller thrust bearing is normally lubricated with temperate climate lithium grease which will be a solid at -40°F.

2.3.3 Hoses

Each ADAPTS system is equipped with sets of 80-foot-long, 1-inch hydraulic power hoses to transmit fluid power from the prime mover to the cargo pump. High pressure, double wire braid S.A.E. 100 AR hose is used for both supply and return from the pump motor. The S.A.E. specification for this hose allows for operation at -40°F at its usual working pressure of 2000 PSI and minimum bend radius of 12 inches. The only problem expected in the power hoses is possible leakage at the Snap-Tite quick-disconnect seal due to stiffness, as in the prime mover and cargo pump couplers. Any seal leakage experienced should stop as the hydraulic oil warms up to operating temperature.

The cargo discharge hose used with ADAPTS is 6-inch, lightweight, Mil-H-82127 (MC), equipped with 6-inch aluminum cam action fittings. This Mil Spec requires low temperature flex testing only down to 0°F. Information supplied by Goodyear, a major supplier of this hose, indicates that brittleness at -40°F will cause failure by cracking of the rubber. It is expected that this would occur on unrolling and flexing the hose on deck prior to pumping. If the hose survives the handling in air and start-up of pumping, operation at the minimum cargo temperature of +28°F will present no problem. The standard BUNA-N gasket in the female cam-action couplers is compressed in coupling the 6-inch hoses. Due to stiffness and resulting high-compressive loads, coupling by hand at -40°F may be difficult.

2.3.4 Fluids

Three petroleum fluids are used in ADAPTS in temperate climate operations: number two high speed diesel fuel, Exxon Nuto 47 hydraulic oil, and S.A.E. 30W high detergent motor oil. None of these are suitable for use at -40°F. Standard grades of number two diesel are jellylike at -40°F and may include ice crystals. Nuto 47 is a temperate climate hydraulic oil; its viscosity at -40°F is excessive. The maximum start-up viscosity allowable for both the Lucas hydraulic pump and the Dennison hydraulic motor is 900 centistokes. S.A.E. 30W motor oil has an excessive viscosity at -40°F, and will not allow cranking of the engine.

2.3.5 Auxiliary Equipment

The components considered here are the following:

B. E. Wallace tripod and attachments
Griphoist wire hoist
P. Thompson hydraulic capstan
Uniroyal Sealdrum, fuel container
lifting slings, wire pennants, shackles

The standard grease used to lubricate the internal workings of the Griphoist will not allow proper movement of the gripping jaws at $-40^{\circ}F$.

The hydraulic capstan motor cannot operate with the temperate climate hydraulic oil,and the Snap-Tite coupler seal may allow leakage. Otherwise this equipment can operate at $-40^{\circ}F$.

The Sealdrum fuel container is not suitable for use at temperatures below $0^{\circ}F$. At lower temperatures cracking failures may occur, and the unvented container will not flex to allow filling to capacity,or collapse in use to allow emptying.

2.3.6 Manipulation in Arctic Clothing

The Coast Guard operation of ADAPTS systems in off-loading the SS HILLYER BROWN in Cold Bay, Alaska, provided some experience in operation in arctic gear. Both mittens suitable for $-40^{\circ}F$ and ordinary woolen gloves were worn. Operation and set up of the system, involving manipulation of the starter pump and valves, throttle, hose couplings, hydraulic controls, wirehoist, etc., could be accomplished in arctic mittens with some difficulty, but satisfactorily. Routine maintenance, changing oil, air filter, etc., could also be done in mittens. Disassembly for repair of a component was not practicable.

3.0 CHANGES TESTED

3.1 Equipment Modifications or Additions

3.1.1 Prime Mover Unit

Several additions and modifications were made to the Avco Lycoming/Bernard diesel engine to provide for starting and warming to an adequate operating temperature. These additions allow the prime mover unit to remain non-electric.

Use of ether dosing lowered the fuel/air mixture ignition temperature to approximately 360°F and was essential for starting of the cold engine at temperatures below +40°F. This was done by installing an "off-the-shelf" measured-shot ether injection system. This equipment, when manually actuated, provides a measured dose of ether (3cc for this engine) to an atomizer nozzle mounted in the air intake housing. This system provided even distribution and mixing of the ether and eliminated the hazards of overdosing and piston lockup associated with aerosol can dosing. Also included was an optional metering valve which was used to replace the 3cc dosing valve. This valve provides a metered continuous spray of ether necessary for starting at or below -20°F. See Figures 2 and 6.

In order to provide more sustained cranking, the starter accumulator capacity was doubled. This was done by repiping the existing accumulator to include a plugged tee between the accumulator and the needle valve and providing an additional 1-gallon accumulator (with improved T-ring piston seal) packed separately, which can be connected and simultaneously. See Fig. #3.

This engine's cooling fan provides the large flow of air around the cylinder walls and through the oil cooler needed for operation in hot climates. In very cold climates, it is necessary to greatly reduce this flow to achieve a proper operating temperature under load, and even more reduction is required to maintain the temperature of an idling engine. This could be

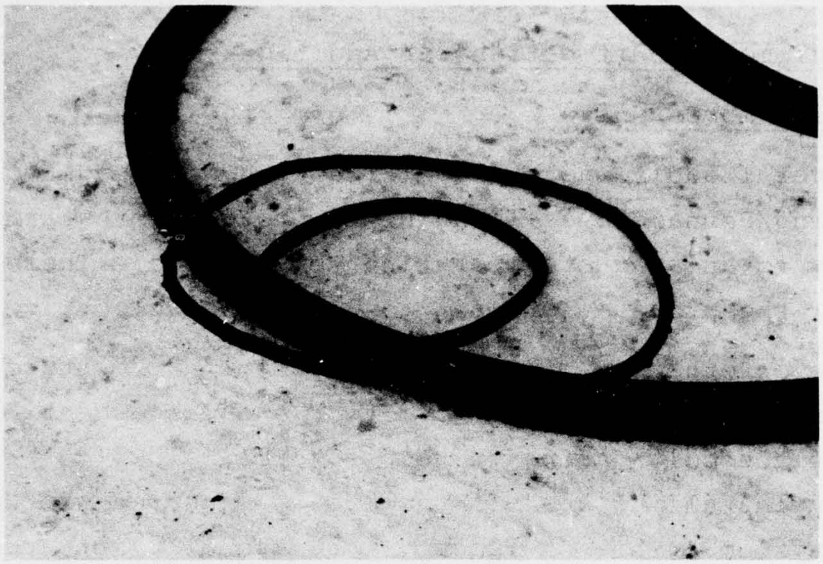

Figure #1: Cracking of Standard V-Belts After Low Temperature Testing

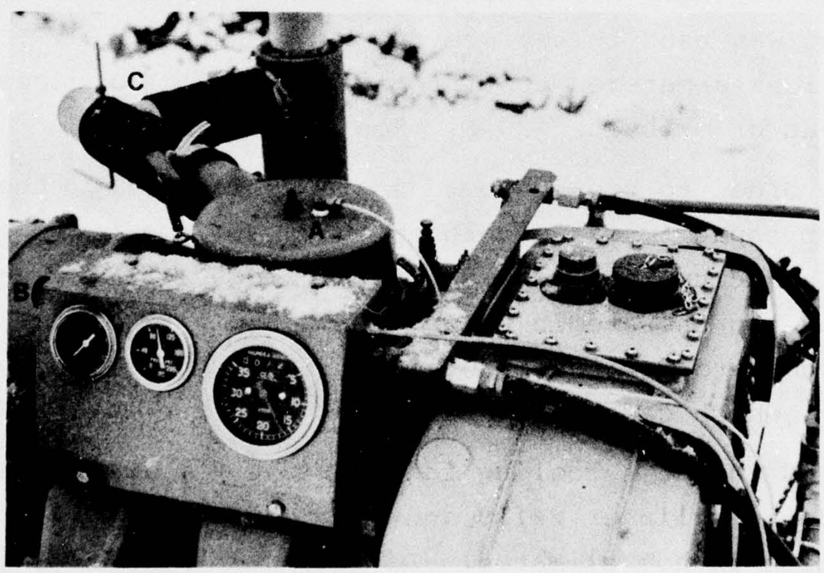

Figure #2: ADAPTS Hydraulic Power Supply

A. Ether Atomizer Injection Nozzle on Air Intake.
B. Ether Injection Control Valve.
C. Intake Air Preheater Ducting.

done simply by blocking the cooling air intake by covering the grill with whatever material is at hand. However, this method does not allow for regulation of temperature and may cause fracturing due to inadvertently dumping -40°F air through a hot engine. The intake restrictor, shown in Figure #4 was fabricated and installed on the front of the engine over the cooling air intake. The cooling air flow was thus regulated from near shutoff to full flow by rotating the outer slotted disc. Although this greatly facilitates control of the flow of cooling air, care must still be used in operation, to avoid sudden changes in air flow.

In order to get an accurate and reliable reading of engine oil temperature under arctic conditions, a direct-mounted oil sump temperature gauge was installed. See Figure #4.

The Jamesbury Double Seal hydraulic starter valve with a carbon steel body was replaced by a Jamesbury SS-HP 36GT stainless steel bodied valve to insure reliability at a working pressure of 3000 PSI at -40°F. See Figure #5.

The manufacturer of the Snap-Tite 1-inch hydraulic disconnect couplers and the 1/4-inch fuel disconnect coupler advised that these couplings be replaced with couplers fitted with softer composition Buna N seals, providing more positive sealing at -40°F. It was thus necessary to replace the 1/4-inch fuel couplers since sealing of these fittings against admission of air to the fuel supply is critical. In the case of the hydraulic system disconnects, which will warm up during system operation, some initial leakage could be tolerated. In order to test and compare the standard couplers with the low temperature units, both types of couplers were used in the test system (the low temperature units being marked by an MHO designation engraved in the coupler body). See Fig. #8.

After initial cold chamber testing with standard V-belts on the charge pump and engine governor, during which the belts cracked, specially compounded low temperature V-belts were installed for further testing. See Figure #1.

FIGURE #3: Modified System During Arctic Testing
(Note: Additional hydraulic starter accumulator connected to system -- indicated by arrow.)

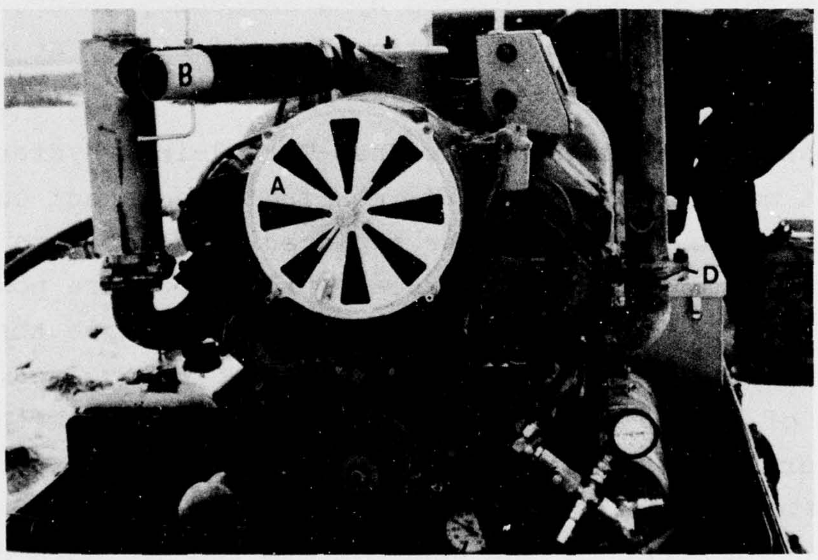

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Figure #4: Modified ADAPTS Diesel Engine

A. Adjustable Cooling Air Restrictor.
B. Intake Air Preheater Ducting with Bypass Valve.
C. Direct Mounted Engine Oil Thermometer.
D. Exhaust System Flanges.

To facilitate changing the engine oil, a hose whip and quick-connect coupling assembly was connected to the lower crankcase drain port.

To raise the engine intake air temperature as quickly as possible after starting, special intake ducting was fabricated. This metal ducting provided a flow of air from around one of the exhaust pipes to the existing intake air filter cover. This system provided the warmest air available after the initial start-up by ether dosing in an attempt to increase the compression heat sufficiently for ignition on straight diesel fuel as quickly as possible. The ducting system was constructed to allow proportioning the warmed air from around the exhaust pipe and cold outside air as the engine warmed to operating temperature. See Figure #4.

Exhaust system flanges were installed in order to facilitate installation and removal of the mufflers and exhaust piping. See Figure #4.

Changes to the Lucas main hydraulic pump to preclude leakage at the startup viscosities of the hydraulic fluid required replacing the drive shaft seal with a Viton seal, replacing the servo and cover "O" ring with an ethylene propylene "O" ring and adding a PTFE back-up ring. The same modifications on this pump were used in the British Chieftain tank for operation at temperatures of -40^{O}F. These modifications were performed by the supplier. See Figure #6.

The glycerin-filled pressure gauges in the charge and main hydraulic systems were replaced by gauges filled with a mixture of 35% water and 65% glycerin. These gauges are operable at -40^{O}F and still perform adequately under temperate conditions.

In order to facilitate rapid warm-up of the hydraulic fluid, an adjustable pressure bypass valve was inserted in the high-pressure side of the hydraulic line. The resulting pressure drop across this valve induced a load on the main pump

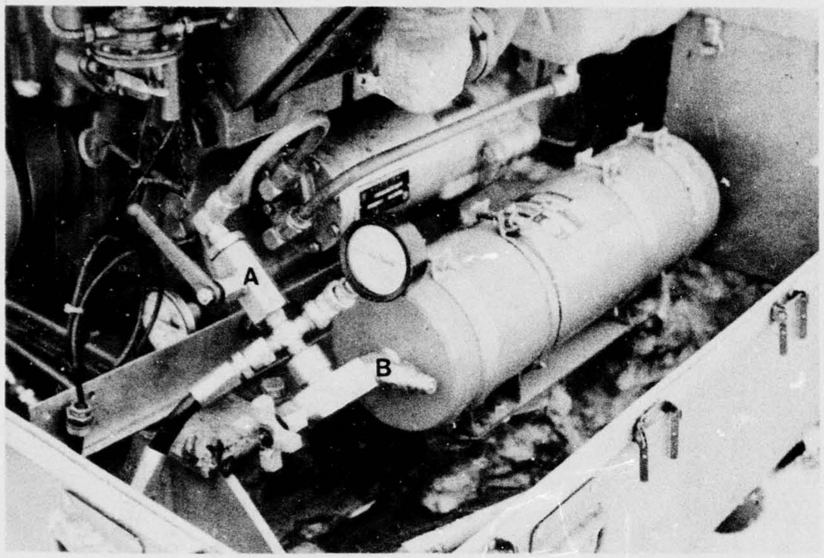


Figure #5: Hydraulic Diesel Starting System As Tested

A. Low Temperature Stainless Steel Starter Valve.
B. Quick-Connect Hydraulic Coupler for Attachment with Second Hydraulic Accumulator (not shown).

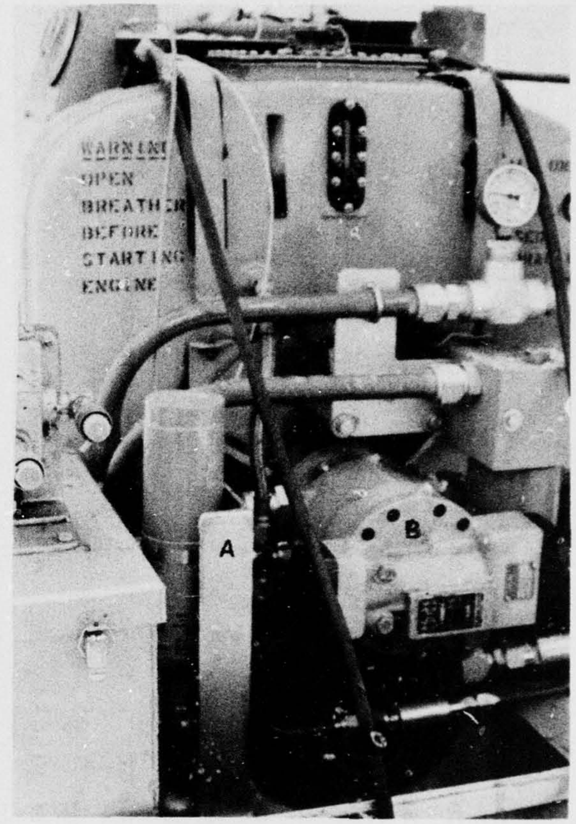


Figure #6: Hydraulic Reservoir and Pump

A. Ether Bottle Mounting Bracket.
B. Lucas Main Hydraulic Pump.

for purposes of initial warm-up. The valve was quick-coupled with Snap-Tite couplings for easy removal if desired, after warm-up. See Figures 7 and 8.

3.1.2 Cargo Pump

In order to test for low temperature brittleness handling problems, three different cargo pumps were tested: a standard meehanite cast iron pump, a meehanite pump coated with a 1/8" coating of urethane elastomer rubber and a special ni-resist alloy pump.

The possibility of freezing and locking up the pump impellers due to the presence of moisture at the wear rings was prevented by drying the pump internal volume and sealing the intake prior to shipment. This required no materials changes.

In order to avoid damage to the Dennison hydraulic motor shaft seal during warm-up, it was necessary to monitor the hydraulic line return pressure and to control the flow rate accordingly, such that motor back pressure was limited to a maximum of 300 psi. For this reason an oil pressure and temperature monitor assembly was fabricated and connected into the hydraulic return line with quick-connect couplers. See Figure 7.

In order to prevent solidification of the bearing grease at -40°F, alternate lubrication was provided for the double-tapered roller thrust bearing. This was done by disassembling the lower end of the pump, removing the bearing, washing and blowing out all of the temperate climate grease, and regreasing with an arctic-grade Conoco Polar Start DN-600 grease. Since the thrust bearing housing freely floods through the pump's lower bronze sleeve bearing, the thrust bearing is normally exposed to the pumped liquids. This requires the frequent disassembly, cleaning, and regreasing of the thrust bearing, coupling, and associated parts, since dilution of the grease by a light cargo or rusting by sea water may occur. To simplify routine maintenance and preparation of a pump for arctic use, the

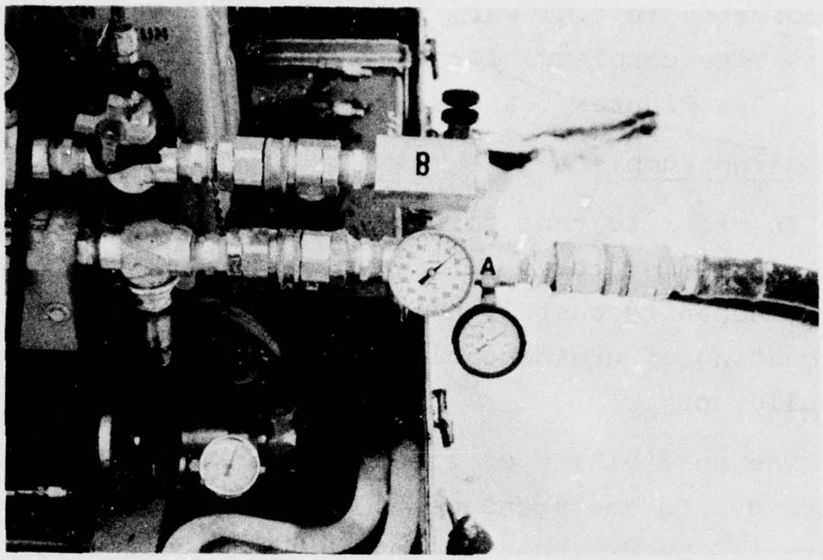


Figure #7: Hydraulic Power Supply
Modifications

A. Return Line Hydraulic Pressure and Temperature Monitor Assembly. (Not in recommended position.)
B. Adjustable Hydraulic Warm-Up Assembly.

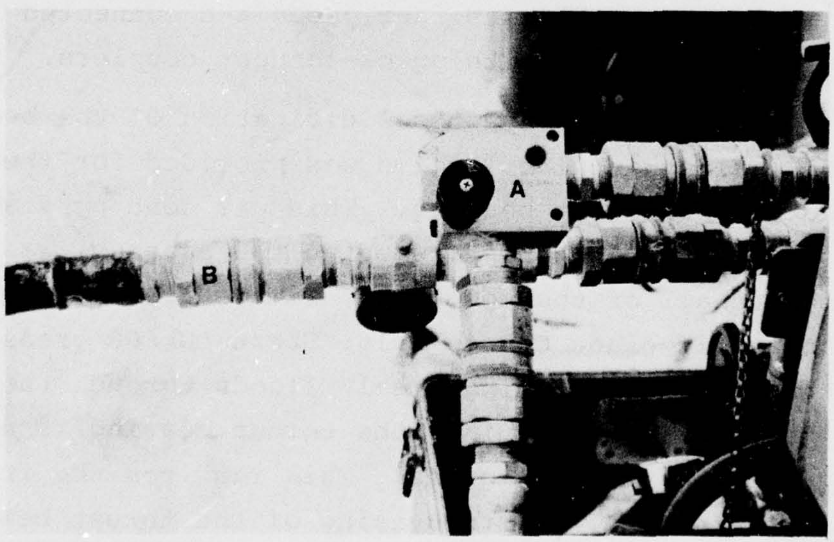


Figure #8: Hydraulic Power Supply
Modifications

A. Adjustable Hydraulic Warm-Up Assembly.
B. Hydraulic Line Coupler with Low Temp. Seals.

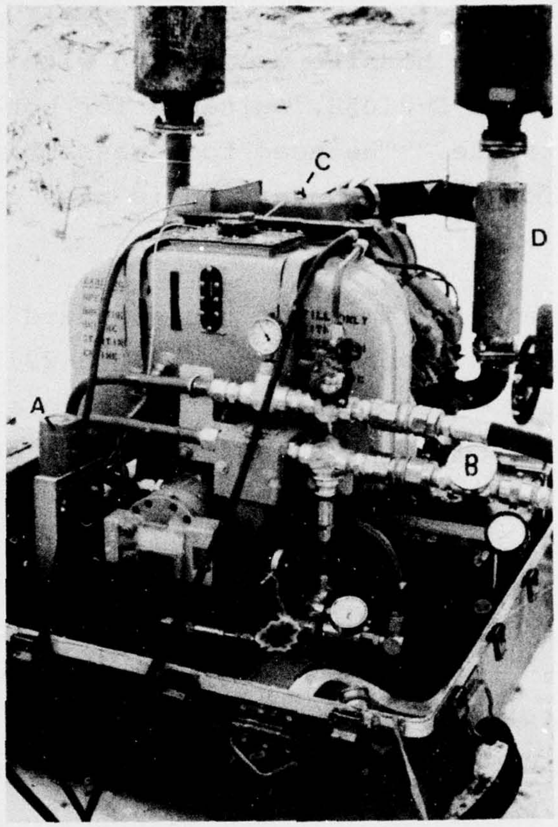


Figure #9: Hydraulic Power Supply System

A. Ether Storage Bottle

B. Hydraulic Return Line Pressure & Temperature Monitor Assembly (not in recommended location)

C. Ether Injection Nozzle.

D. Air Intake Preheater Ducting.

modifications shown in Figure #10 were made (on the ni-resist pump only). This involved machining a cavity in the shaft end of the pump to take a shaft lip seal, gasketing the mating surfaces of the assembly and providing a fill plug in the housing. The bearing housing was filled with arctic-grade SAE 90 gear oil, MIL-L-2105B, suitable for both arctic and temperate climate use. The need to disassemble for routine maintenance or for arctic conversion is thus eliminated.

3.1.3 Hoses

Because embrittlement of the standard ADAPTS lightweight, 6-inch cargo discharge hose, MIL-H-82127 (MC) was anticipated at below zero temperatures, special low temperature hose, produced of specially composed nitrile and neoprene rubbers, and a unidirectional polyester cord fabric was procured for testing. This hose was designed for operation at $-40^{o}F$. Since the cargo hoses will be subject to a temperature as low as $-40^{o}F$ only during handling of the empty hose on deck, then will warm to the minimum cargo temperature of $+28^{o}F$, a section of the existing hose was also tested and evaluated at $-40^{o}F$ to determine its suitability for this application.

Some of the gaskets in the 6-inch aluminum cam action couplers on the cargo hose were replaced with gaskets which remained softer at $-40^{o}F$. Both gaskets were satisfactory at $-40^{o}F$, although coupling was easier in fittings in which the soft gasket was installed.

For purposes of comparison between the standard and low temperature Snap-Tite hydraulic couplers, both types of couplers were used in the 1-inch hydraulic lines for cold chamber and arctic testing.

3.1.4 Fluids

Prior to testing, all the temperate climate lube oil, SAE 20 or 30 H.D., was purged from the diesel engine and the

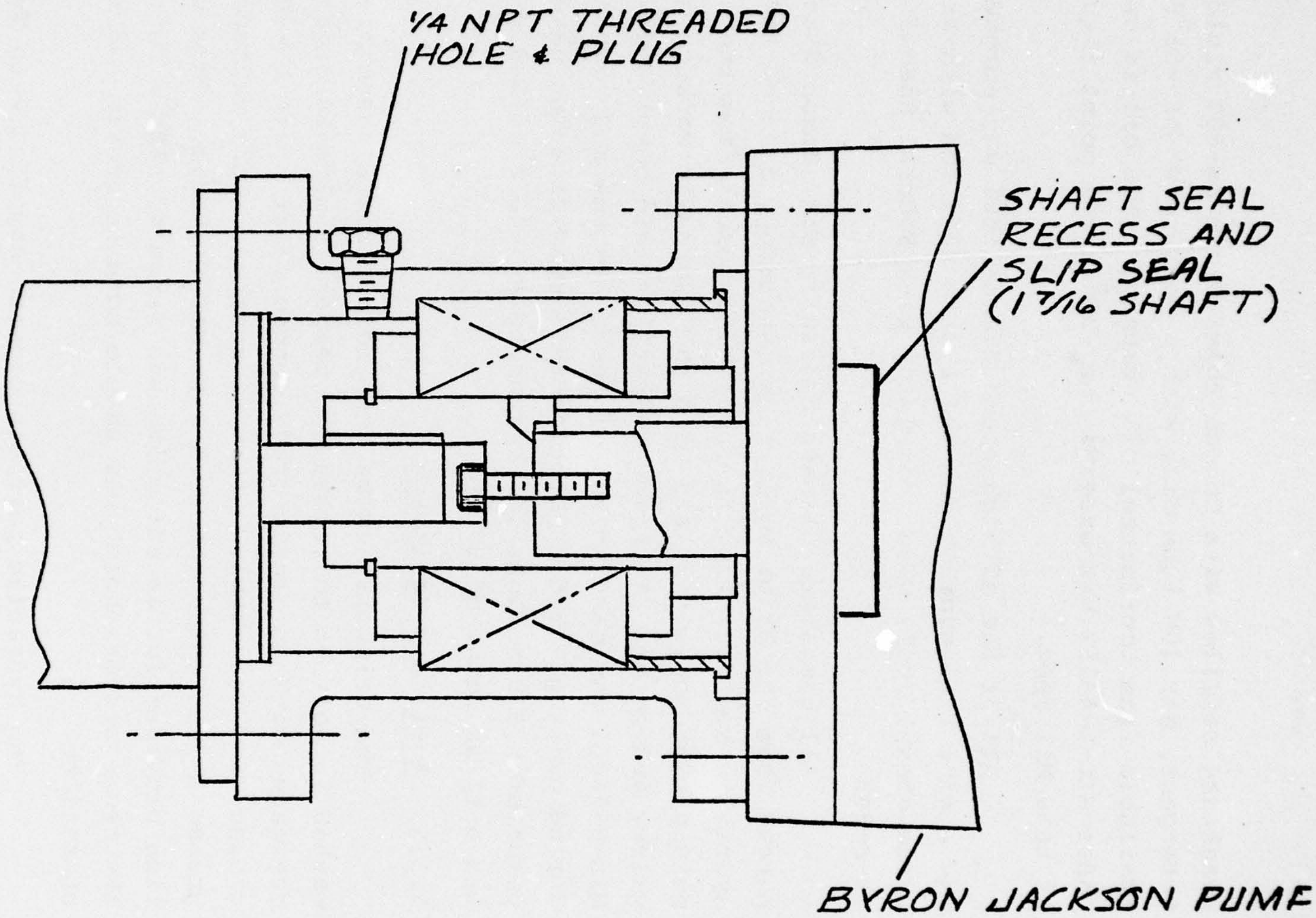


FIGURE #10
CARGO PUMP COUPLING HOUSING SEALING MODIFICATIONS AS TESTED

crankcase refilled with Conoco Polar Start DN-600 Fluid. This detergent, SAE 10W lube oil, with a pour point of -55°F, is available from Continental Oil Company. This oil is qualified under MIL-L-46152 but exceeds the -25°F pour point requirement of this Mil Spec.

All of the #2 high-speed diesel fuel was purged from the engine fuel system, and the system refilled with arctic-grade diesel fuel, DF-A, complying with Federal Specification VV-F-800a.

All temperate climate hydraulic oil, Exxon Nuto 47, was purged from the prime mover tank, starting, charge, and main hydraulic systems; from the hydraulic hoses; from the cargo pump piping and motor; and from the hydraulic capstan hoses, valve, and motor. An Exxon hydraulic fluid complying with MIL-H-5606C was used in all of these systems and components during testing. Fluids meeting this specification have a pour point of -75°F or lower, a viscosity at -40°F of 500 centistokes, and a flash point of 275°F.

3.1.5 Auxiliary Equipment

The Griphoist (wire rope hoist) was disassembled, washed in solvent to remove the temperate climate grease, regreased with an arctic-grade Conoco Polar Start DN-600 SRI grease, and reassembled prior to testing. This recommended grease is one which complies with MIL-G-23827A. This specification provides for an effective use range of -100°F to +250°F so the regreased Griphoist was usable both in arctic and temperate operations.

The hydraulic portable capstan supplied with Type I units was purged of hydraulic fluid and refilled as discussed in Section 3.1.4. The Snap-Tite quick-disconnect couplers, as in the case of the similar couplers on the prime mover, pump, and hoses, were evaluated by testing to determine if seal leakage at start-up necessitated replacement.

The Sealdrum synthetic rubber fuel container was not used in the tests since it is subject to cracking failures and loss of flexibility at -40°F. A fuel drum bung adaptor was fabricated so that the engine fuel supply line could be quick-connected to a standard 55-gallon fuel drum for arctic operation.

3.2 Procedural Changes

Operating procedure in the arctic is expected to differ from that of temperate climates in the special care required in unpacking, handling, and using the synthetic rubber components, special start-up and warming procedures for the diesel engine and hydraulic systems, and allowance for the difficulties in manipulating tools and controls in arctic clothing. Details of special operating procedures used in low temperature testing are described in sections 4.2 and 4.3 and in the test plan and report in Appendix E.

4.0 TESTING

The test program conducted in conjunction with the prototype arctic ADAPTS system was divided into the following three phases:

- Pump Body Materials Impact Strength Tests
- Environmental Chamber Tests
- Arctic Operational Field Tests

These three phases were intended to be a logical progression, with each subsequent series of tests building on the results of the preceeding testing. The purpose of the impact strength tests of the alternate pump body materials was to determine the necessity of using special low temperature alloy steel in constructing the cargo pumps for arctic operations. Unfortunately, the very long lead time required for the procurement of a low temperature ni-resist pump necessitated the ordering of the pump before the impact tests could be conducted, if the overall program schedule was to be maintained. Therefore, the decision to procure a 10-inch, two-stage ni-resist pump was made solely on the recommendation of the manufacturer, Byron Jackson, and not, as originally intended, on the results of the material impact tests.

The environmental chamber tests were designed to test the arctic ADAPTS component modifications, and operating procedures in a controlled environment, convenient to both Coast Guard Headquarters and Seaward International's facilities. Any deficiencies in the system or procedures were to be corrected prior to conducting the actual arctic field operational testing and evaluation.

The arctic operational field tests were intended to test the complete system, including the high volume transfer of oil, under actual field conditions in an environment approximating the maximum design conditions of $-40^{\circ}F$ air temperature and 40-knot wind velocity.

4.1 Pump Body Materials Impact Strength Tests

4.1.1 Background

The standard ADAPTS cargo pump bodies are meehanite cast iron. Byron Jackson, the pump manufacturer, had indicated that this material would have an extremely low impact strength at $-40^{\circ}F$ and therefore recommended the use of a high nickel alloy, ni-resist, with better low temperature properties, for use in ADAPTS pumps for arctic operations. Since the cost of a ni-resist pump was about six times that of a standard meehanite pump, it was decided to conduct Charpy impact tests, at $70^{\circ}F$ and at $-40^{\circ}F$, on both meehanite and ni-resist in an effort to establish the necessity of procuring the more expensive, ni-resist pump for low temperature operations.

Another potential approach to providing greater impact resistance for the standard pump at low temperature was by means of an energy absorbing coating of elatomeric rubber on the pump exterior. Therefore, it was decided to test both coated and uncoated meehanite specimens.

4.1.2 Testing

At the recommendation of the Byron Jackson metallurgist, the standard Charpy notched specimen impact test method was selected for evaluating the relative material impact strength. Three, ASTM-23, Type A specimens of each type were tested to obtain statistically valid results. Uncoated coupons of type I ni-resist and meehanite were tested at $+72^{\circ}F$ and at $-40^{\circ}F$. In addition, meehanite coupons coated with both a 1/16-inch and a 1/8-inch coating of Adiprene polyurethane rubber, 90A durometer, and ni-resist coupons with a 1/16-inch coating of this material were tested at $-40^{\circ}F$.

The testing was conducted on a Tinius Olsen Model 64 Impact Machine in accordance with standard ASTM procedures. The striking velocity was 16.8 ft/sec and the energy at strike was 264 ft.-lb. The testing was carried out under subcontract to Artech Corporation of Falls Church, Virginia.

4.1.3 Test Results

Complete test data is contained in Appendix E. Table #1 shows the anticipated test results based on data provided by the manufacturer. Table #2 shows the actual test results.

TABLE #1

ANTICIPATED CHARPY IMPACT STRENGTH VALUES
(Based on Pump Manufacturer's Data)

	72°F	-40°F
Type 1 Ni-Resist	10 ft-lb	7 ft-lb
Meehanite	10 ft-lb	1-2 ft-lb

TABLE #2

CHARPY IMPACT TEST RESULTS

	72°F	-40°F
Type 1 Ni-Resist (uncoated)	2.17 ft-lb	3.67 ft-lb
Type 1 Ni-Resist (1/16" coating)		4.67 ft-lb
Meehanite (uncoated)	1.17 ft-lb	1.17 ft-lb
Meehanite (1/16" coating)	--	2.17 ft-lb
Meehanite (1/8" coating)	--	8.00 ft-lb

4.1.4 Conclusions

From the test results, it appears that the meehanite material does not undergo a phase transformation at low temperatures which would cause it to lose strength, as indicated by the pump manufacturer. Therefore, it can be concluded that if the ADAPTS pumps in operation have exhibited adequate impact strength at normal temperatures, they will probably perform equally well at $-40^{o}F$.

The ni-resist exhibited higher impact strength than the meehanite at both temperate and low temperatures.

Elastomer coating of the pump body appears to be a cost effective means of greatly increasing the impact resistance of the existing pumps, if this is deemed necessary.

Serious discrepancies exist between the manufacturer's predicted values and the actual values obtained by test. Furthur investigation revealed that for brittle cast materials such as these, ASTM recommends the use of un-notched specimen tests such as Izod.

The uncertainty surrounding the validity of these test results did not significantly effect the test program since, because of the tight program schedule, the decision to order a ni-resist pump for test had already been made before the impact testing was complete.

4.2 Environmental Chamber Testing

4.2.1 Test Plan

The environmental chamber testing was conducted at the General Environments Corporation facilities in Springfield, Virginia, during the period February 12-17, 1976. Figure #11 shows the general arrangement of the ADAPTS equipment in the 12-ft by 22-ft temperature-controlled chamber, prior to cooling the chamber down.

With a few exceptions, the testing was conducted in accordance with the Arctic ADAPTS System Environmental Chamber Test Plan, dated January 26, 1976, and contained in Appendix E .

The purpose of these tests was to determine if the arctic modified ADAPTS system could be started, warmed up, and operated at a temperature of -40°F, and a wind velocity of 40 knots, by operators in arctic dress, using the arctic operating procedures. These tests simulated actual arctic operation in all respects except that actual pumping operations could not be conducted because of the limited chamber size. The results of this testing were intended to establish the adequacy of the system modifications, and what further modifications were required, as well as what modifications, if any, were unnecessary for reliable system operation at -40°F.

4.2.2 Test Sequence

The General Environments test report and complete test data and the chronological record of chamber and system component temperatures is contained in Appendix E. The following summarizes the sequence of significant test events.

Day 1 - February 17th

- Made four unsuccessful attempts to start the diesel engine at -40°F, varying the number of accumulators, cylinder compression release and dosing. Engine fired on two attempts, but ignition could not be sustained. See Figure #12.

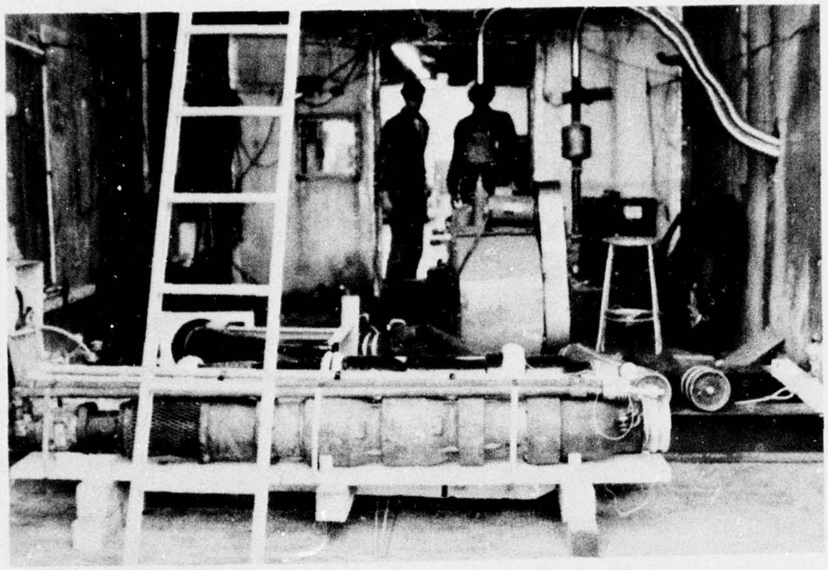


Figure #11: ADAPTS System
Inside Environmental Test Chamber
(At Room Temperature)

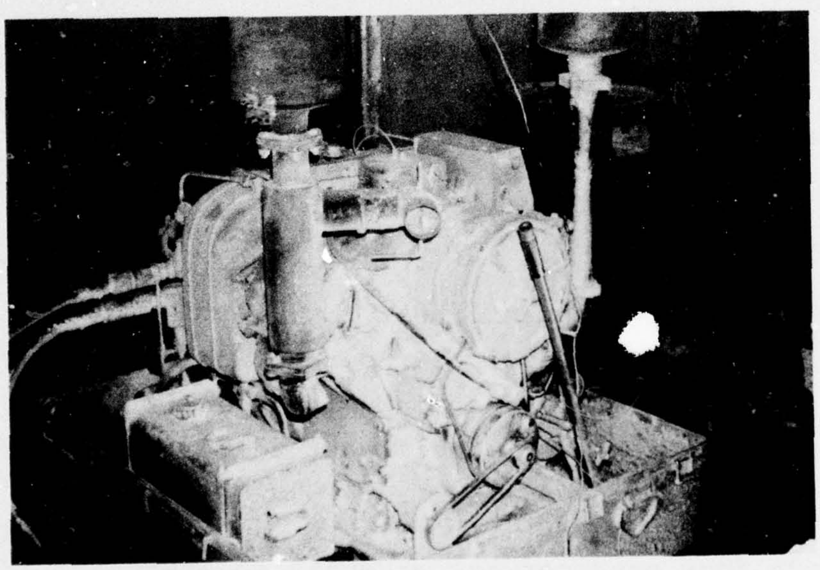


Figure #12: Modified ADAPTS Prime Mover
at -40°F in Environmental Test Chamber

- Recharged leaking accumulator.
- Performed 180° bend test on 6-inch hose sections. See Figure #13.
- Replaced broken fan belt.
- Successfully conducted coupling test of 6-inch quick-connect fitting with both normal and low temperature gaskets.
- Raised chamber temperature to -20°F and made repeated attempts to start the engine until successful.

Day 2 - February 18th

- With chamber at -40°F, conducted pull tests on cargo hose sections. See Figure #14.
- Tried repeatedly to start engine without success.
- Raised chamber temperature to -30°F.
- On third attempt started engine at -30°F. Engine ran rough, on only two cylinders. After one hour of operation, engine oil temperature reached 160°F and hydraulic oil reached 80°F by using warm-up assembly.
- After cooling engine back to -30°F, the engine was restarted on third try with two accumulators.

Day 3 - February 19th

- Unsuccessfully attempted to start engine at -40°F.
- Hydrostatically proof tested all cargo hose test sections. The mil-spec hose sections subjected to the 180° bend and to the 90° pull test both failed.
- Started engine at -30°F after several attempts. Warmed up hydraulic system and ran both the standard and the ni-resist pumps at full speed.
- Conducted impact tests on all three pump bodies, with hammer blows up to 16 ft lb without damage. See Figure #15 for test set-up.

Figure #13: Cargo Hose 180° Bend Test

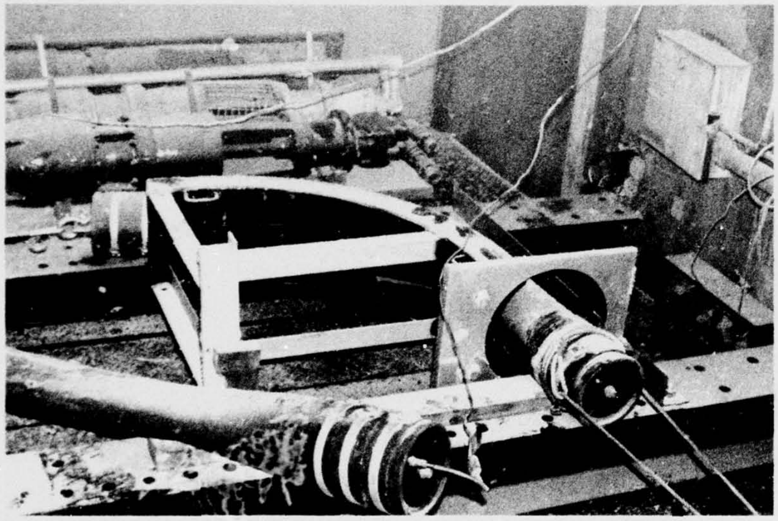


Figure #14: Cargo Hose 90° Saddle Bend Pull Test

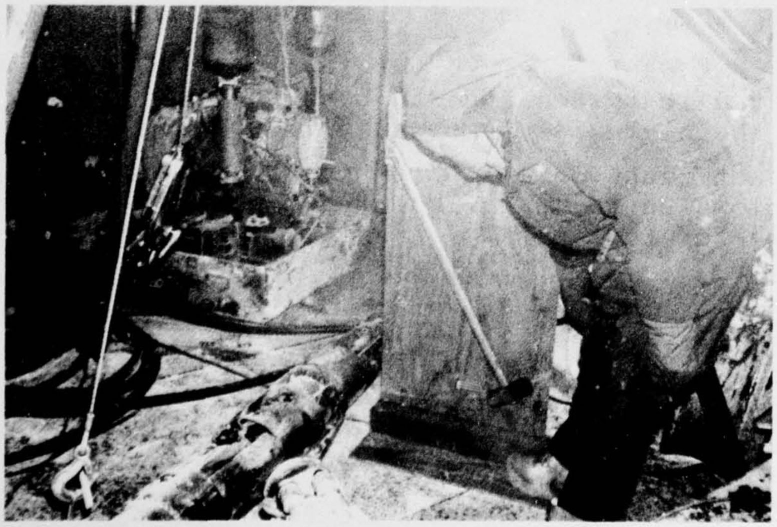


Figure #15: Hammer Blow Pump Impact Test

Day 4 - February 20th

- Installed new design atomizer nozzle and high purity ether bottle.
- Attempted unsuccessfully to start engine at -40°F.
- Modified ether control valve for continuous flow.
- Started engine on third attempt. At -40°F, engine ran rough on only two cylinders, then stalled due to excessive fuel buildup in non-firing cylinders. This was corrected by releasing compression while running to blow out excess fuel.

4.2.3 Test Results

In general, the modifications made to the system and to the system operating procedures proved to be useful. In a few instances, modifications which were made proved to be unnecessary. A few components which had been expected to operate at -40°F failed to do so. Only these discrepancies are discussed in detail in this section.

Those modifications which appeared unnecessary as a result of the environmental test chamber test include: the special ni-resist alloy cargo pump, the elastomer coated cargo pump, the special low temperature gasketed quick-connect couplings on the main hydraulic hoses and on the capstan hydraulic system, the special combustion air preheater, and the special low temperature gaskets in the cargo hose couplings.

The standard, uncoated meehanite ADAPTS cargo pump, the meehanite pump with a 1/8-inch elastomer coating, and the ni-resist pump, in that order, were all subjected, at -40°F, to increasingly severe hammer blows from a 6-pound sledge hammer pendulum, to test their impact resistance. In all cases the blows were struck on a thin section of the impeller bowl. The intended grip hoist pump lowering tests were not done since the lowering speed was too slow to be useful.

Since the severe impact blow did not damage the standard meehanite pump and since the laboratory low temperature impact tests, previously described, indicated that the meehanite was as tough at -40°F as at +72°F, it was concluded that the expense of special ni-resist low temperature pumps was not warranted.

During the environmental chamber testing, hydraulic system quick-connect fittings with both standard and low temperature gaskets were used. In no case was any leakage observed from any couplings under pressure, leading to the conclusion that special low temperature hydraulic hose couplings are not necessary.

No difference in engine starting performance could be observed when the engine was started with the combustion air preheater butterfly valve open or closed. In all cases, the engine became self-sustaining on diesel fuel and no ether before any significant heat could be provided to the intake air by this heat exchanger. It was concluded that this was an unnecessary complexity.

The low temperature, 6-inch, quick-connect coupling gaskets were noticeably more pliable at -40° than were the standard gaskets. However, the coupling joint was successfully coupled and uncoupled with both gaskets at -40°F.

Unanticipated problem areas encountered during the environmental chamber testing included: inability of the ether injection system to provide sufficient combustion to start the engine;cracking of the "V" belts; failure of the engine oil temperature gauge to register; sluggish operation of the engine oil pressure gauge; rough, uneven running of the engine after starting; and failure of the hydraulic accumulators to hold precharge pressure.

Investigation into the ether injection system inadequacy revealed several shortcomings. The ether cannisters originally procured were filled with a low purity ether which, although satisfactory for most engine starting applications, would not vaporize well at very low temperatures. The ether spray nozzle also was not the best design possible for extreme low temperature use. The ether injection valve was designed to deliver a discontinuous flow of ether at a metered rate which could not cause engine damage. The valve contained a 3 cc chamber which when actuated discharged for about 4 seconds through a capillary tube. This supply rate of less than 1 cc/second was not adequate for the ADAPTS engine at -40°F.

The ether system manufacturer, K.B.I., was most cooperative in supplying high grade ether, a special experimental swirling type atomizing nozzle and a continuous flow ether control valve in time to be used in the chamber test. These changes made possible the reduction in the achievable starting temperature from -30°F to -40°F.

Although, when originally queried, the manufacturer of the two engine "V" belts had indicated that these belts would perform normally at -40°F, they cracked repeatedly when flexed at this temperature. Neither belt failed completely during the test and only minor cracks occurred in the charge pump belt. The cooling fan/governor belt experienced gross cracking, and became so stiff that it slowed the engine cranking speed during starting. In this instance too, the manufacturer, Gates Rubber, was most cooperative. They fabricated special low temperature, mil-spec belts with an operating range good to -65°F.

Throughout the chamber testing, the engine oil temperature gauge remained pegged at the low end of the scale. The cause of this was concluded to be the long length of capillary tubing between the engine sump and the gauge dial on the instrument panel. The low ambient temperature caused excessive heat loss from the liquid in the tubing, preventing a true oil temperature reading. During engine operation in the chamber, the oil temperature was monitored with a thermocouple.

The engine oil pressure gauge experienced a similar problem in that it provided no reading until the engine had warmed up and even then read low. This gauge too, utilizes a capillary tube to transmit the pressure to the gauge dial. This tube still contained SAE 30 engine oil which was extremely viscous at -40°F. By flushing the tube with arctic grade diesel fuel, the gauge performance was improved.

Almost each time the engine was started at very low temperature in the chamber, it initially ran on only two or three cylinders. This situation improved only when the engine warmed up and was placed under load. Since the non-firing cylinders varied each time the engine was started, it was concluded that this was an engine characteristic rather than a correctable malfunction.

The problem encountered with the hydraulic accumulators losing precharge pressure was attributed to displacement of the piston O-ring rolling out of its seat. This is a common problem in the Bosch accumulator at normal temperatures and may possibly have been aggravated at low temperature. The manufacturer has designed a "T" ring modification to replace the "O" ring to solve this problem.

The special low temperature hose was clearly a necessity for operation at -40°F, and care is required even when handling it at this temperature. Some delamination of the outer jacket occurred during the 180° bend test. If handled gently, the standard mil-spec hose may possibly be used at or near -40°F. The mil-spec hose subjected to the 180° bend test suffered serious delamination of the outer jacket and cracking of the inner reinforcement. It leaked but did not fail totally when pressure tested. The specimen subjected to the sharp bend and pull test also leaked when pressure tested. However, the piece pull tested over the 90° saddle passed the 200 psi proof test.

4.3 Arctic Operational Field Tests

Test Plan

The object of the arctic operational field test program was to determine if the arctic modifications to the ADAPTS transfer pumping subsystem components and operating procedures were satisfactory to permit reliable operation of this equipment under actual arctic environmental conditions by Strike Force personnel in arctic dress. These tests were originally scheduled to be conducted at Prudhoe Bay, on the Alaskan North Slope, during March. At this time of the year the temperature at Prudhoe averages -24^{o}F with a daily minimum average of -32^{o}F. Unfortunately adequate housing for test personnel was not available at Prudhoe Bay so the test site was changed to Ft. Wainwright at Fairbanks, Alaska, where comparable temperature conditions were predicted.

Although the original program schedule was strictly adhered to, with the field testing commencing on March 1st, abnormally high temperatures prevailed throughout the entire test period. Two weeks before temperatures at the test sight were as low as -52^{o}F. During the first week of testing, temperatures ranged from 0^{o}F to a balmy +40^{o}F. The tests were extended for an additional five days in an effort to encounter colder weather. However, a minimum operating temperature of -5^{o}F was the coldest achieved. Because of the earlier cold weather, the temperature of the JP-5 fuel pumped during the test varied from -1^{o}F to +4^{o}F.

The testing was conducted at the Ft. Wainwright Petroleum Division tank farm. Figures 16 & 17 show the general test arrangement. The ADAPTS diesel-hydraulic power unit was placed on the dike wall, above any possible vapor pockets, surrounding a 40-foot tall, 25,000 barrel storage tank of JP-5 fuel. The submersible cargo pump was lowered into

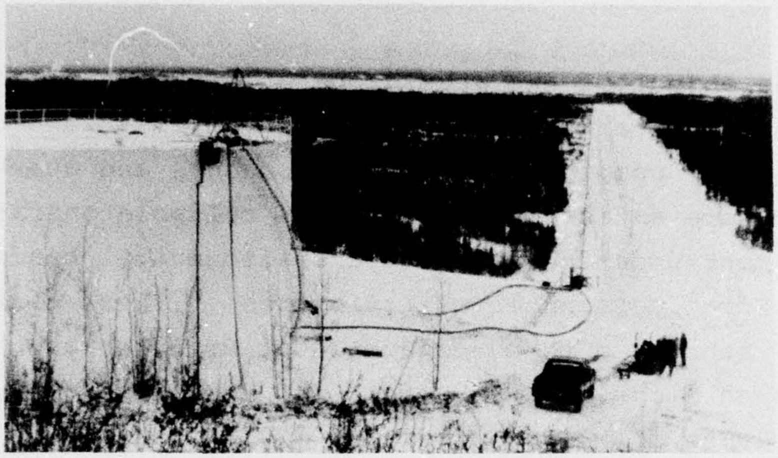


Figure #16: General Test Arrangement

Figure #17: ADAPTS Prime Mover with Hydraulic Transmission Hoses to Cargo Pump on Tank Top the tank through a man-way on top of the tank using the standard tripod and grip hoist, see Figure 18. Two 180-ft sections of hydraulic hose were connected between the power unit and the ni-resist pump. (Although the standard ADAPTS meehanite pump was brought to the test site, it was never carried to the tank top, nor used during the test program.) The 285 feet of low temperature, 6-inch, cargo hose was routed down the tank stairway, then in a large loop and back to the tank bottom discharge connection, see Figures 19 & 20. Two 8-inch gate valves were used to isolate the hose and, as shown in Figure 19, a pressure gauge was inserted into the adaptor to allow measurement of the line pressure.

The electric, turbine flow meter and readout were inserted in the hose line as shown in Figure 21. It was located 185 feet downstream from the pump. As with the diesel engine, this unit was placed on top of the dike as a safety precaution.

With a few exceptions, the test followed the designated test plan contained in Appendix E. As mentioned, only the ni-resist pump was used during the test. Since it was hydraulically identical to the standard ADAPTS pump and since it performed as expected, there seemed no reason to repeat the difficult chore of man handling the second pump to the top of the tank. The second exception to the test plan was the deletion of the long duration, over night, continuous pumping. This was not deemed necessary.

The equipment used in the arctic operational field test was identical to that previously tested in the environmental test chamber, except that the governor/fan V-belt was a special low temperature type and bi-metal dial thermometers were used to measure the engine oil and hydraulic oil temperatures. Thermocouples had been used to measure these temperatures in the chamber tests.

Figure #18: Tripod, Griphoist, and Hose Saddle on Storage Tank Top

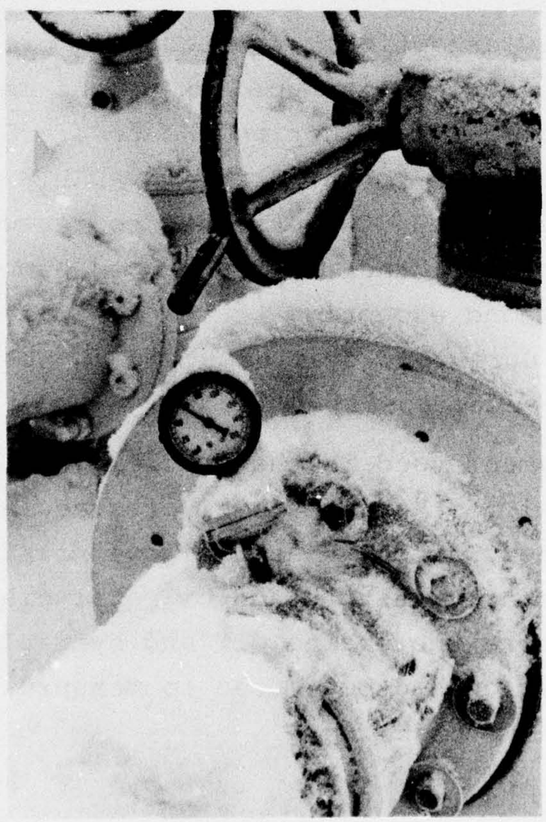


Figure #19: Close-up of Line Pressure Gauge at Pump Shutoff

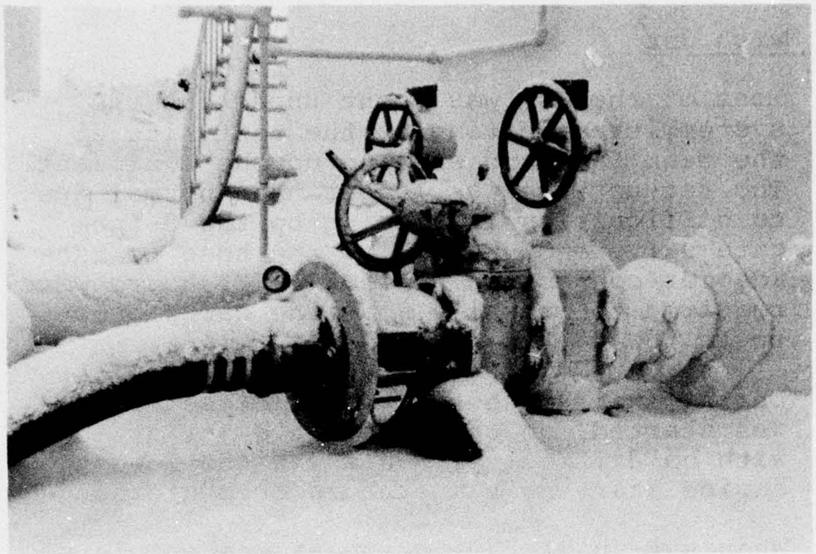


Figure #20: Connection of 6-Inch Hose to the Storage Tank Discharge Connection

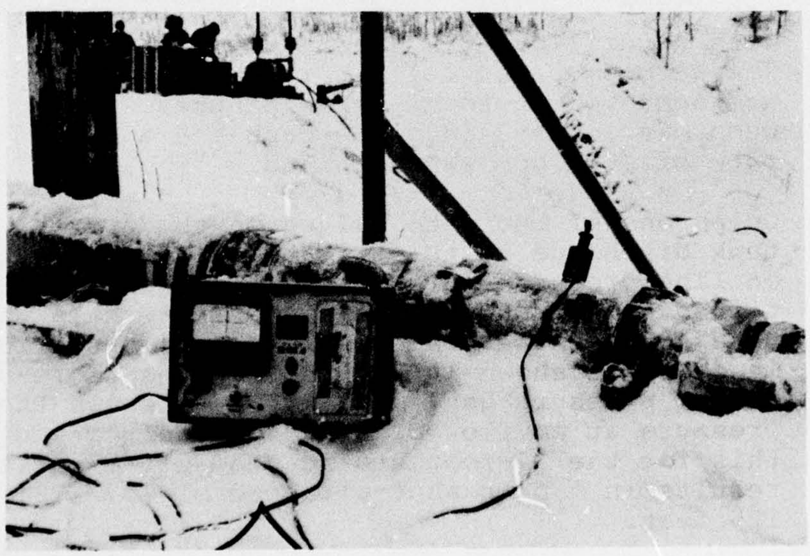


Figure #21: Turbine Flow Meter and Read-out

4.3.1 Test Sequence

Day 1 - March 1st

Most of the day was spent unpacking the system, transporting to the test site at the tank farm and setting up the equipment. The set-up time was longer than normal due to difficulties in freeing up the 8-inch gate valve and installing the hose to tank adapter connection. Also, 2-1/2 hours were required to manually move the cargo pump up to the tank top.

During initial checkout, the diesel engine was started, on the first attempt, at -5°F with no difficulty. This was the lowest engine starting temperature encountered.

When set-up of the equipment was completed, the system was started and warmed up following the designated procedures. Full hydraulic flow was achieved without over-pressurizing the pump motor when the hydraulic oil temperature reached 50°F.

Day 2 - March 2nd

Although the testing was started at 0545 in an effort to obtain the coldest possible ambient temperature, the air temperature was +15°F when the engine was started, again with no difficulty. The hydraulic system was warmed up and full hydraulic oil flow was achieved in twenty-five minutes. The pump was lowered into the tank and a full flow rate of 1600 gpm was obtained.

Using one of the gate valves on the storage tank discharge to throttle the line flow,data on line pressure versus flow rate were obtained at a number of points. These data were used to generate the experimental pump performance curve shown in Figure 22. The close-up of the pressure gauge in Figure 19 shows the pressure at no flow of 56 PSIG. Correcting this for the 37-foot static head differential results in a pump shut-off head of 43.3 PSI or 125 feet.

A second cold start was made at +26°F air temperature and complete warm-up was completed in thirteen minutes.

A total of about 4700 gallons were pumped.

Day 3 - March 3rd

The engine was started at +22°F and required ether injection for about ten seconds. The hydraulic oil was warmed up to 60° in about thirty-five minutes. For this warm-up the hydraulic pressure/temperature gauge assembly was installed on the power unit in the return line rather than at the pump motor. This allowed the submersible pump to remain in the cargo and pumping during warm-up but also gave a less accurate indication of the pressure on the motor seals.

The engine fuel was switched from arctic grade DFA to number 1 diesel with no appreciable change in power or performance.

Because the engine would not reach the normal full speed of 3000 RPM, as indicated on the engine tachometer, a calibrated hand tachometer was used to check the engine speed. This indicated that the installed tachometer readings were 13% low and that the indicated top speed of 2900 RPM was actually 3320 RPM.

A total of 151,000 gallons were pumped for the day.

Days 4-12 - March 4th - 12th

Each day the engine was started using one accumulator, at temperatures ranging from -5°F to +30°F. Ether injection was required for about ten to fifteen seconds before the engine became self-sustaining on diesel fuel.

The hydraulic system was warmed up as on day 3, with the cargo pump immersed and the gauge assembly located at the prime mover. Warm-up times ranged from twenty-five minutes to eighty-five minutes.

The average volume pumped daily during the eight test days was 91,000 gallons.

4.3.2 Test Results

Although the operating temperatures were significantly higher than had been anticipated, these field tests did demonstrate that the complete arctic modified ADAPTS transfer pumping subsystem could easily be erected and operated by Strike Force personnel in arctic dress.

These field tests, which included the pumping of nearly 1 million gallons of oil under a variety of wind, temperature, and snow conditions, when combined with the cold chamber tests at $-40^{\circ}F$, were adequate to demonstrate the ability of the modified system to meet the design goals.

The ability to warm up the hydraulic oil from $-40^{\circ}F$ to where full flow could be accommodated without overpressurizing the pump motor seals, at a hydraulic oil temperature of about $+60^{\circ}F$ was demonstrated. The fastest hydraulic system warm-up was accomplished with the pressure gauge attached at the cargo pump. However, a more cautious, slower warm-up, with the gauge assembly attached at the power unit was considered more convenient by the Strike Force operators.

The pump performance curve generated during these tests, as shown in Figure 22, was in good agreement with the manufacturer's data and, at the low flow rates, far exceeded the performance predicted by the curve in the ADAPTS manual.

No explanation could be offered by the engine manufacturer for the 13% error in the engine tachometer reading.

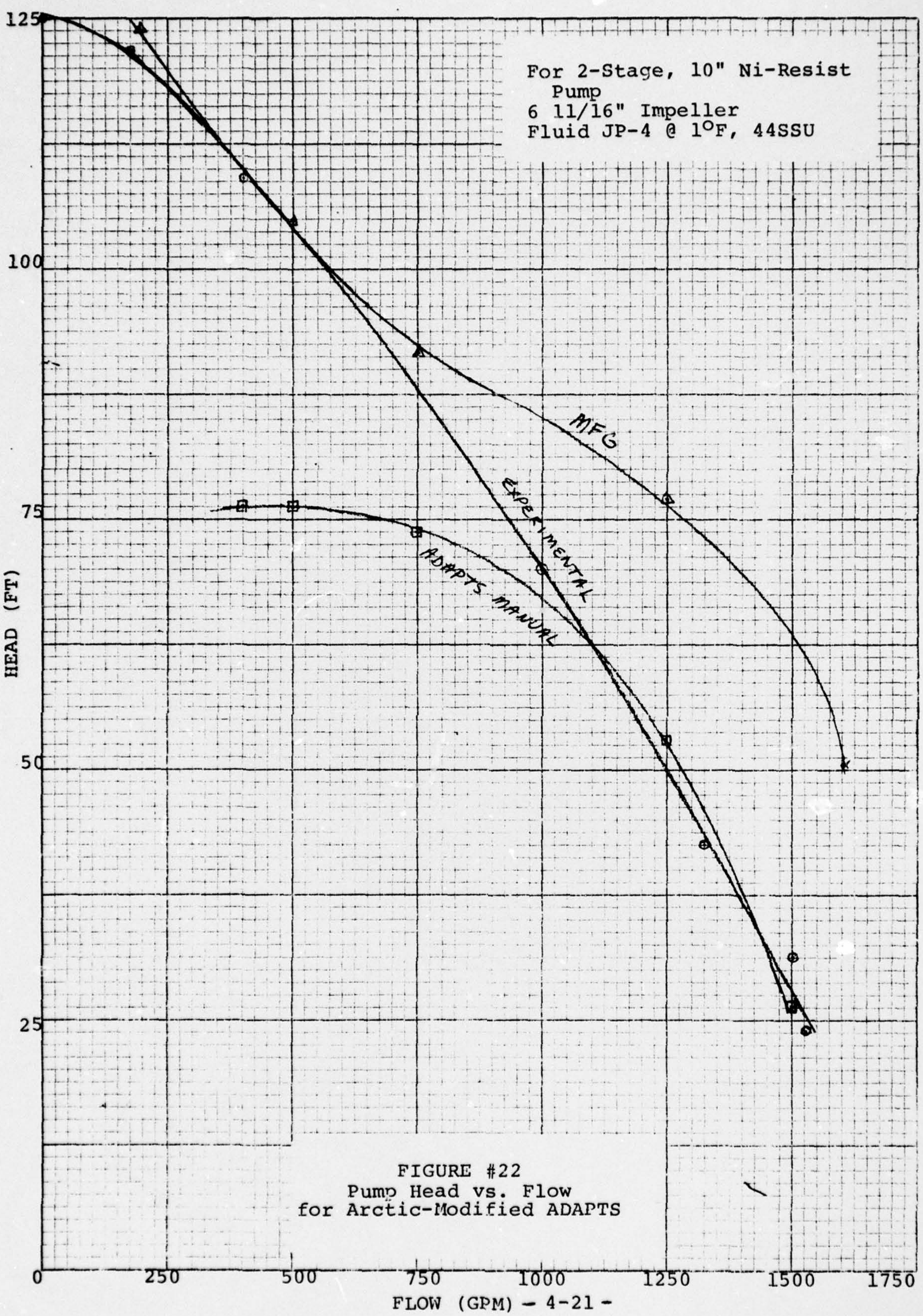


FIGURE #22
Pump Head vs. Flow
for Arctic-Modified ADAPTS

5.0 SUMMARY OF FINAL RECOMMENDATIONS

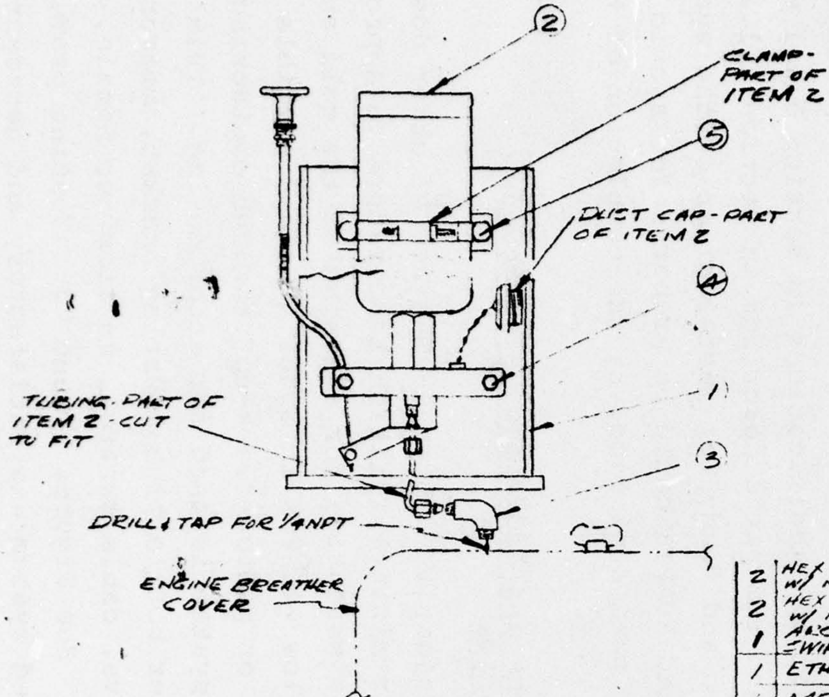
5.1 Recommended Equipment Modifications or Additions

Based on cold chamber and arctic testing of the modified test system, as well as engineering analysis of the suitability of the existing ADAPTS, the following modifications are recommended for arctic operation. These modifications have been divided into two categories. Category 5.1.1 contains those modifications which are recommended to be made on all systems. These modifications are not detrimental, and in some cases are beneficial, to the operation under temperate and tropical conditions. Category 5.1.2 contains those modifications which are recommended only for arctic operation and, in some cases, could be detrimental to normal temperature operations if misused.

Assuming that all modifications in section 5.1.1 were done previously, and the parts described in section 5.1.2 were previously procured and ready for installation on the system, a partially modified ADAPTS could be prepared for arctic use in a relatively short period of time, by the completion of those modifications.

5.1.1 Modifications and Additions Recommended for All Systems

- Ether Injection System -- The use of ether dosing lowers the fuel/air mixture ignition temperature to approximately 360°F and is essential for starting of the cold engine at temperatures below +40°F. In order to avoid possible damage to connecting rods or piston "lock-up" through overdosing, a metered injection system is used for ether dosing. This system consists of an ether bottle with mounting bracket, measured dose injection valve, cable control, an atomizer nozzle, and connecting tubing. See Figures 9 and 23. Testing proved that the recommended system was satisfactory and necessary for low temperature starting.



NOTES
1. REFER TO INSTRUCTION BOOK SUPPLIED WITH KIT FOR STARTING TROUBLE SHOOTING ETC.

QTY REQD	DESCRIPTION	IDENTIFYING OR PART NO.	DRAWING OR SPECIFICATION NO.	MATERIAL OR NOTE	ITEM NO.
2	HEX HD BOLT 5/16-18 X 3/4 LG W/ NUT & L'WSHR			AD PL STL	5
2	HEX HD BOLT 1/4-20 X 3/4 LG W/ NUT & L'WSHR			CAD PL STL	4
1	ARCTIC ATOMIZER SWIRL TYPE NOZZLE	20388		KRUBER INC	3
1	ETHER INJECTION KIT	MOD 20152	NOTE 1	KRUBER INC	2
1	MOUNTING BRACKET		5C-00553	AL	1

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES. TOLERANCES ON: FRACTIONS DECIMALS ANGLES
MATERIAL:
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TITLE: ETHER INJECTION SYSTEM ASSEMBLY ARCTIC ADAPTS

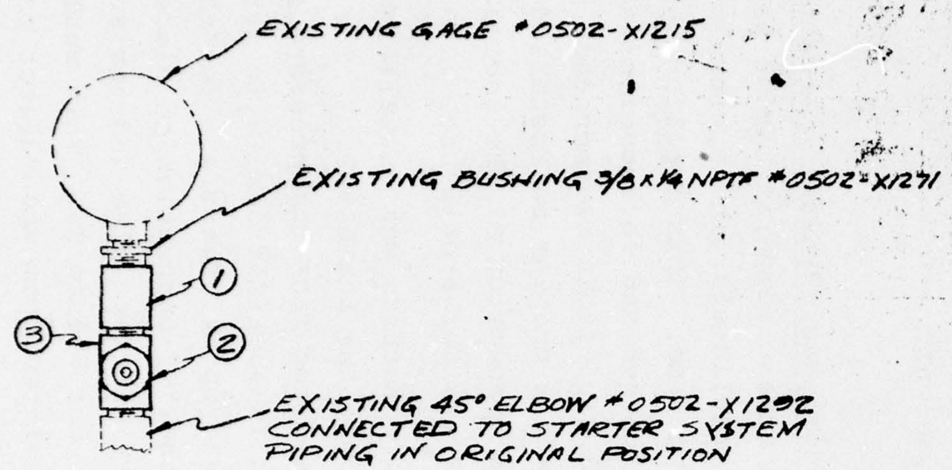
SIZE | CODE IDENT NO. | DRAWING NO. 5C00559
SCALE: NONE | REF: | SHEET

FIGURE 23
ETHER INJECTION SYSTEM
ASSEMBLY

The recommended atomizer nozzle is a special swirling-mist nozzle which extended the low temperature starting to -40°F. For operation at temperatures of -20°F and above, the standard discontinuous ether injection valve should be used. This valve provides a measured (3cc) dose of ether each time the control is actuated. This is the safest system to use to prevent overdosing of the cylinders. Testing also proved the necessity of using high-purity ether bottles; it is recommended that only high-purity ether be used for arctic operation. For starting at temperatures below -20°F, the discontinuous metering valve should be replaced by a continuous spray valve which meters the steady dose of ether needed for starting. This valve is recommended for arctic use only.

- <u>"T" Connection for Additional Hydraulic Accumulator</u> -- For reliable engine starting at arctic temperatures, a second hydraulic accumulator in the hydraulic starting system is necessary to obtain a greater cranking time. This 1-gallon accumulator need not be permanently attached and is recommended for arctic use only (see section 5.1.2). It is recommended, however, that a "T" connection with Snap-Tite coupler be installed on all systems. This would allow quick connection of the second accumulator assembly, when necessary for arctic use.

On the test system a "T" connection was installed between the first hydraulic accumulator and the angle valve. The quick-connect coupling could not be isolated from the pressure in the hydraulic accumulator, resulting in some difficulty in making a connection while the coupler was under pressure. For this reason, it is recommended that the "T" connection be placed in all systems between the Jamesbury starter valve and the angle valve on the first accumulator. See Figure 24. This would allow the quick-connect to be isolated from accumulator pressure, resulting in easier connection of the second accumulator.



QTY ROD	DESCRIPTION	IDENTIFYING OR PART NO.	DRAWING OR SPECIFICATION NO.	MATERIAL OR NOTE	ITEM NO.
1	H.P. ALL MALE TEE 3/8"			STL	3
1	QUICK DISCONNECT NIPPLE 3/8 NPTF	#M-372-EZ		BRUNING	2
1	PIPE COUPLING 3/8 NPTF H.P.			STL	1

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MATERIAL:

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FALLS CHURCH, VA. 22044

TITLE
QUICK DISCONNECT SUB-ASSY
INSTALLATION ON PRIME MOVER
FOR ADDITIONAL HYDRAULIC ACCUM.

SIZE | CODE IDENT NO. | DRAWING NO. SB00641

SCALE: 1/2 | REF: | SHEET

FIGURE 24
QUICK DISCONNECT
SUB-ASSY.

• <u>T-Ring Hydraulic Accumulator Modification</u> -- Due to a history of standard piston seal failures, it is recommended that the O-ring piston seal in the hydraulic accumulators of all systems be replaced with a T-ring seal kit recommended by the manufacturer.

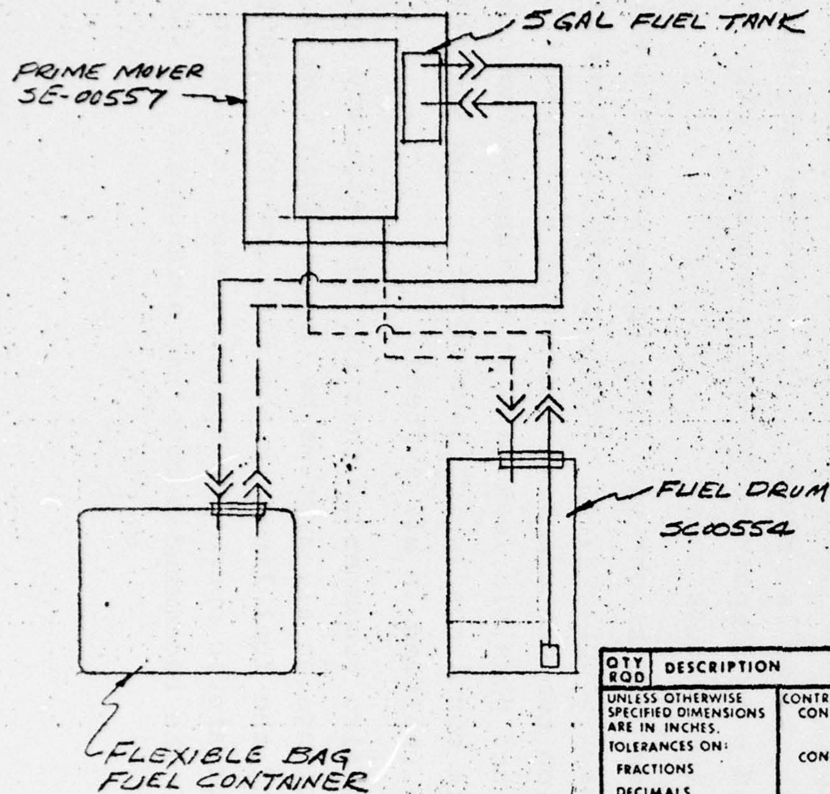
• <u>Low Temperature Hydraulic Starter Valve</u> -- The standard Jamesbury Double Seal hydraulic starter valve has a carbon steel body which may fail at its operating pressure of 3000 PSI due to embrittlement at low temperature. It is thus necessary to replace the valve by a Jamesbury SS-HP 36 GT stainless steel bodied valve to insure reliability at a working pressure of 3000 PSI at $-40^{\circ}F$. This modification proved satisfactory during testing and is recommended for all systems. See Figure 5.

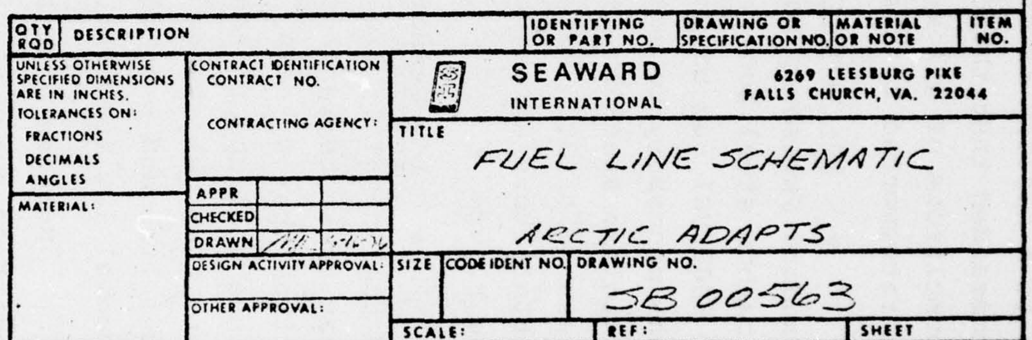
• <u>Low Temperature Fuel Couplers</u> -- The manufacturer of the Snap-Tite 1/4-inch fuel disconnect couplings advises that these be replaced by couplings fitted with softer composition Buna N seals, providing more positive sealing at $-40^{\circ}F$. Since sealing of these couplings against the admission of air into the fuel system is critical, it is recommended that the fuel line and bung adaptor couplings be replaced with the special low temperature units.

Because of a slight variation between the old units and these newer couplings, an old-style male coupling plugged into a new low temperature female coupling will result in cutting of the seal and possible leakage. It is thus recommended that both the male couplings (which have no seal) and the female couplings be replaced in all systems.

It is also recommended that the fuel line and bung adaptor couplings on all systems be sexed, such that proper connection of the fuel lines to the fuel drum bung adaptor (critical for arctic operation and discussed in section 5.1.2) is insured. The recommended coupling arrangement is shown in Figure 25.

FIGURE 25
FUEL LINE SCHEMATIC




QTY RQD | DESCRIPTION | IDENTIFYING OR PART NO. | DRAWING OR SPECIFICATION NO. | MATERIAL OR NOTE | ITEM NO.

UNLESS OTHERWISE SPECIFIED DIMENSIONS ARE IN INCHES.
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INTERNATIONAL
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FALLS CHURCH, VA. 22044

TITLE
FUEL LINE SCHEMATIC
ARCTIC ADAPTS

SIZE | CODE IDENT NO. | DRAWING NO. SB 00563
SCALE: | REF: | SHEET

• <u>V-Belts</u> -- Cold chamber testing proved that the standard V-belts, used for the small hydraulic charge pump drive, diesel fan, and governor drive are not satisfactory for arctic use, being subject to stiffening and cracking at -40°F. Specially compounded V-belts good to -65°F, as well as normal temperature use, are available on special order. Sample belts provided by the manufacturer were tested and performed satisfactorily in use. There is a minimum order of 297 & 255 units respectively for the charge pump and governor drive belts. It is recommended that they be procured, installed, and stocked as replacements for all systems.

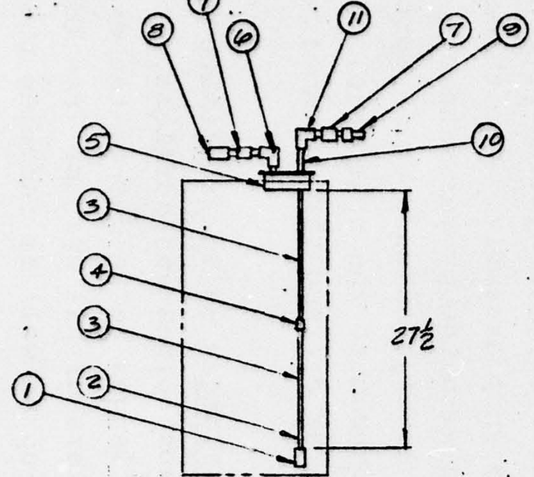
• <u>Oil Drain Modification</u> -- Because of the fiberglass bottom cover and inaccessible location of the crankcase oil drain plug on the standard ADAPTS, draining the engine oil can be very difficult. To facilitate rapid changing of the engine oil, it is recommended that a quick-change oil drain kit with quick-connect couplings be permanently installed on all systems. This kit is an "off-the-shelf" item consisting of a crankcase drain adaptor plug and hose whip assembly. The threads on the adaptor plug must be chased with the proper size die (10mm x 1.5mm) in order to fit the lower crankcase drain port. By simply attaching a quick-connect to the hose whip, the crankcase can be gravity drained or drained through an auxiliary pump or vacuum line.

• <u>Exhaust System Flanges</u> -- To facilitate removal and replacement of the exhaust pipes and mufflers, it is recommended that two-bolt flanges be welded to the exhaust manifolds, pipes, and mufflers of all systems (See Figure 26.) This simplifies system set-up as well as reducing the chance of accidental damage to the cast exhaust manifolds during disassembly.

• <u>Fuel Drum Bung Adaptor</u> -- Because the standard collapsible fuel containers become stiff and cannot be used at low temperatures, a fuel drum bung adaptor is necessary to adapt to a standard 55-gallon fuel drum. The recommended adaptor assembly includes a two-piece fuel pickup line with foot valve, and

FIGURE 27

FUEL DRUM BUNG ADAPTOR



NOTES
1. "MHO" DESIGNATION TO BE PERMANENTLY MARKED ON PART (ITEM 8 & 9) INDICATING COUPLER HAS SPECIAL LOW TEMPERATURE SEALS.

QTY REQD	DESCRIPTION	IDENTIFYING OR PART NO.	DRAWING OR SPECIFICATION NO.	MATERIAL OR NOTE	ITEM NO.
1	STREET ELBOW 3/8NPT			BLK STL	11
1	CLOSE NIPPLE (2") 3/8NPTM			BLK STL	10
1	QUICK DISCONNECT - MALE	VHN4-4F MHO		SNAPTITE NOTE 1	9
1	QUICK DISCONNECT FEMALE	VHC4-4F MHO		SNAPTITE NOTE 1	8
2	REDUCING CONNECTOR 3/8NPTF TO 1/4NPTM			BLK STL	7
1	90° PIPE ELBOW 3/8NPTM				6
1	THREADED BUNG ADAPTER FOR 55 GAL DRUM W/3/8 NPTF HOLES				5
1	PIPE COUPLING 3/8 NPTF				4
2	PIPE 3/8 NOM SCH 40				3
1	REDUCER 1/2NPTM x 3/8NPTF			BLK STL	2
1	FOOT VALVE 1/2NPTF (FUEL)			BRASS	1

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ANGLES ~
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OTHER APPROVAL:

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6269 LEESBURG PIKE
FALLS CHURCH, VA. 22044

TITLE
FUEL DRUM-BUNG ADAPTER
ARCTIC ADAPT...

SIZE | CODE IDENT NO. | DRAWING NO. SC-00554
SCALE: | REF: | SHEET

is fitted with low temperature quick-connect couplers, sex coded in such a way that proper connection of the fuel supply and return lines is insured. Also necessary is a small fuel drum vent cap. This modification could be useful in normal operations and is recommended for all systems. See Fig. 27.

- Modification of the Main Hydraulic Pump --

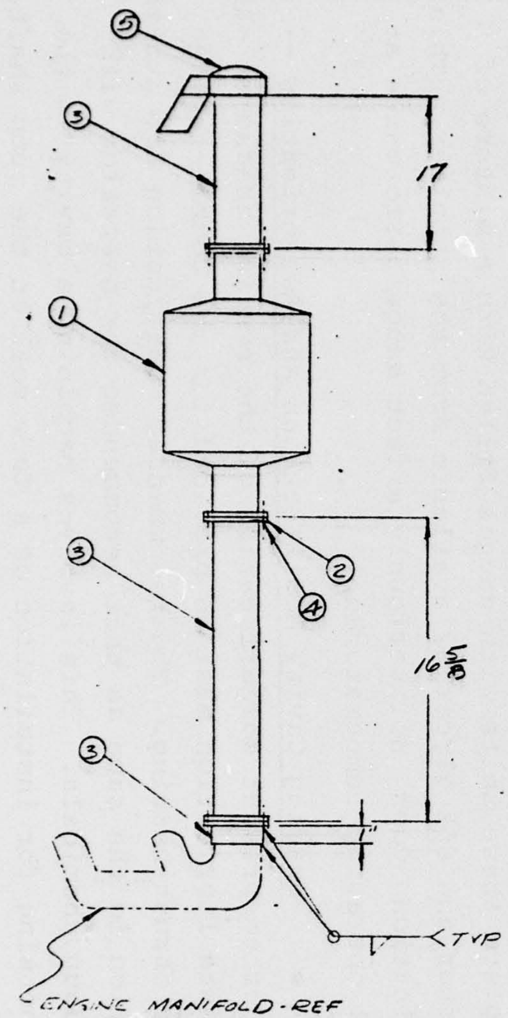
The Lucas MAMS-PM-500 main hydraulic pump, with modifications has been tested and used successfully at low temperatures. Due to the high case pressures resulting from the high starting viscosities of the hydraulic oil at $-40^{\circ}F$, certain modifications to the stock pump are necessary. Changes include replacing the drive shaft seal with a Viton seal, replacing the servo and cover "O" ring with an ethylene-propylene "O" ring, and adding a PTFE back-up ring. These changes are not detrimental to operation of the pump at normal temperatures. It is recommended that these modifications be made on all systems, by the pump supplier.

- Glycerin-Filled Gauges -- In order to prevent low temperature solidification of the damping fluid (100% glycerin) within the hydraulic system pressure gauges, it is necessary to replace these units with gauges filled with a mixture of 35% water and 65% glycerin, available from the supplier. This modification does not seriously affect gauge performance at normal operating temperatures.

- Bearing Cavity Modifications and Relubrication -- In order to prevent solidification of the bearing grease at $-40^{\circ}F$, alternate lubrication must be provided for the double-tapered roller thrust bearing. The recommended modification for arctic operation is the same as that recommended for operation with hazardous chemicals. This involves machining a cavity in the pump housing for installation of a face seal on the pump shaft, gasket sealing between mating surfaces of the pump casing,

FIGURE 26

EXHAUST SYSTEM MODIFICATIONS



QTY RQD	DESCRIPTION	IDENTIFYING OR PART NO.	DRAWING OR SPECIFICATION NO.	MATERIAL OR NOTE	ITEM NO.
1	RAIN CAP			STL	5
12	HEX HD BOLT 1/2-13UNC x 1" LG W/NUT & L'WSHR			SST	4
A/R	TUBING 2 1/2 OD x 2 3/8 ID (EXISTING)			STL	3
6	RIKER FLANGE	R962		RIKER MFG	2
1	MUFFLER (EXISTING)			[illegible]	1

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FRACTIONS ± 1/16
DECIMALS
ANGLES
MATERIAL:

CONTRACT IDENTIFICATION CONTRACT NO.
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OTHER APPROVAL

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6269 LEESBURG PIKE FALLS CHURCH, VA. 22044

TITLE: EXHAUST SYSTEM MOD.
ARCTIC ADAPTS

SIZE | CODE IDENT NO. | DRAWING NO. 5C00561

SCALE | REF | SHEET

machining of cavity fill and drain ports, and installation of plugs. The bearing cavity should then be kept filled with an arctic-grade gear oil (Conoco Polar Start DN-600 Gear Oil).

This modification helps prevent contamination of the bearing by the cargo fluid and simplifies normal maintenance of the submersible pump. See Figure 28.

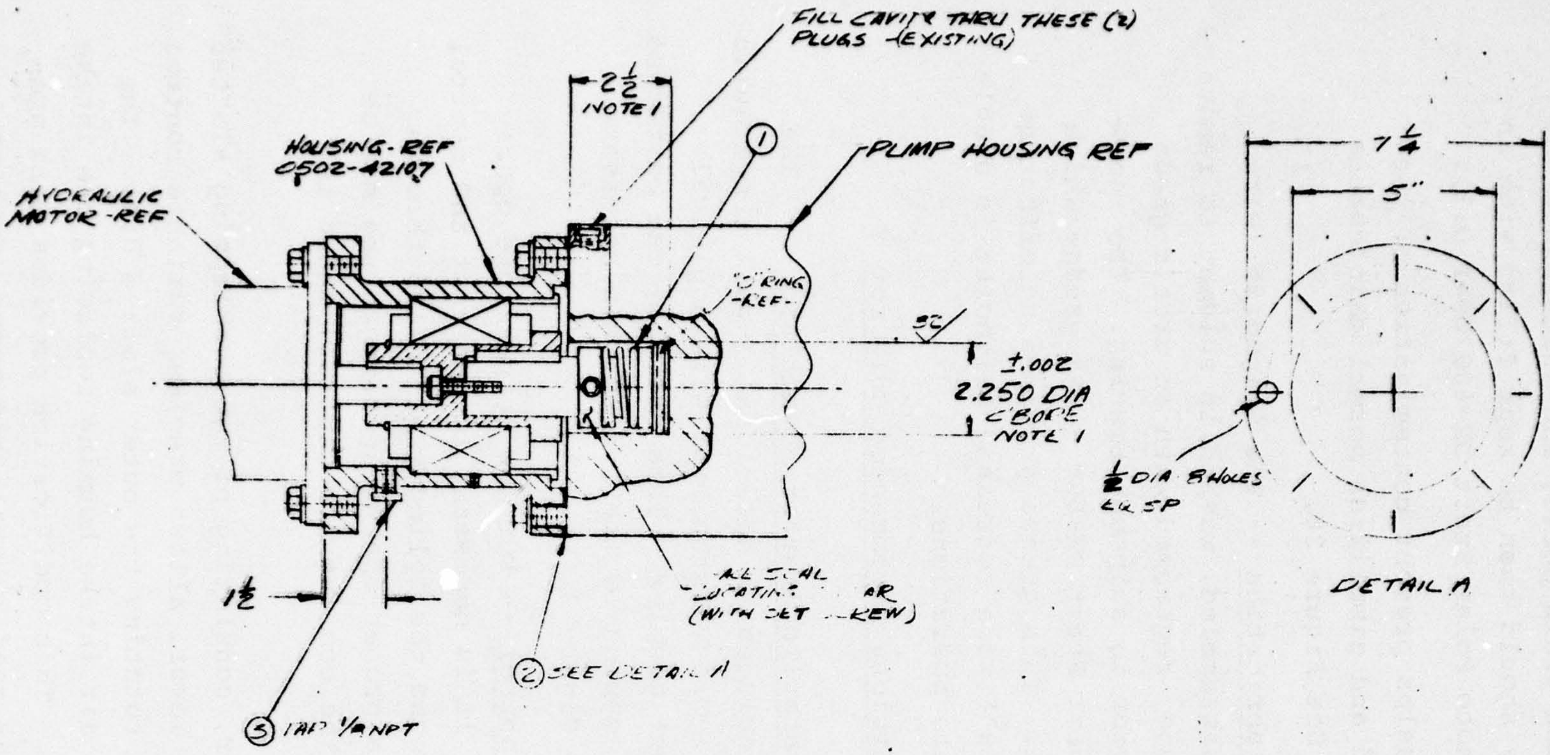
- Griphoist Relubrication -- The Griphoist (wire rope hoists) should be disassembled, washed in solvent to remove the temperate climate grease, regreased with an arctic-grade grease, and reassembled prior to shipment testing. The recommended grease is Conoco Polor Start DN-600 - SRI grease which complies with MIL-G-23827A. This grease provides an effective use range of $-100^{o}F$ to $+250^{o}F$ so a regreased Griphoist is usable both in arctic and temperate operations.

5.1.2 Modifications & Additions Recommended Only for Arctic Use

- Additional Hydraulic Starter Accumulator -- The recommended modification includes an additional 1-gallon hydraulic accumulator with improved T-ring piston seal with angle valve, hose whip, and quick-connect coupler. This assembly can be packed separately if desired and coupled to the system when necessary for arctic operation. See Figure 3.

- Cooling Air Control -- For low temperature operation of the ADAPTS engine, it is necessary to restrict and control the flow of cooling air around the cylinder walls and through the oil cooler, such that a proper operating temperature may be achieved and maintained. The cooling air control, shown in Figure 4 is recommended.

This flow restrictor, consisting of two overlapping slotted aluminum discs and locking lever, allows precise, variable control of the cooling air flow by rotating the outer slotted disc. The flow control fits over the air intake housing replacing the intake grill for arctic operation. This modification provides more precise flow control than other readily available means (such as



NOTES
1. SPECIAL ORDER SEAL-BORE HOLE TO SIZE PER MANUFACTURERS SPECS
PURCHASE FROM:
ROTARY SEAL CORP
7440 W. LAWRENCE AVE
CHICAGO ILL 60656

FIGURE 28

PUMP BEARING

CAVITY MODIFICATIONS

QTY REQD	DESCRIPTION	IDENTIFYING OR PART NO.	DRAWING OR SPECIFICATION NO.	MATERIAL OR NOTE	ITEM NO.
1	PIPE PLUG 1/8 NPTM				3
1	RUBBER GASKET 1/16 THK		OIL RESISTANT	SEE DETAIL A	2
1	FACE SEAL 1 7/16 SHAFT W/COLLAR	TYPE # 1		NOTE 1	1

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TITLE CARGO PUMP BEARING CAVITY MODIFICATIONS ARCTIC ADAPTS

SIZE | CODE IDENT NO. | DRAWING NO. SC 00560

SCALE: 1/2 | REF: | SHEET

covering the intake grill with cardboard) and thus minimizes chances of fracturing of the cylinder walls by inadvertently dumping -40°F air through a hot engine. However, care must still be exercised in use to avoid this. This device if used improperly could be detrimental to normal temperature use and should be used for arctic operation only.

- <u>Direct-Mounted Oil Sump Temperature Gauge</u> -- Due to low-temperature blocking of the capillary tube connecting the standard oil temperature sensor to the gauge, it is necessary to remove the standard sensor and replace it with a direct-reading temperature gauge mounted on the engine block. It is recommended that this modification be performed concurrently with the engine oil change. See Figure 4.

- <u>Change Engine Fuel and Lube Oil</u> -- Prior to arctic operation, all of the #2 high-speed diesel fuel, which is jelly-like at arctic temperatures, must be purged from the engine fuel system, and the system refilled with arctic-grade diesel fuel, DF-A, complying with Federal Specification VV-F-800a.

All the temperate climate lube oil, SAE 20 or 30 H.D., must be purged from the diesel engine, and the crankcase refilled with an arctic-grade lube oil such as Conoco Polar Start DN-600 Fluid. This detergent, SAE 10W lube oil, with a pour point of -55°F, is available from Continental Oil Company. This oil is qualified under MIL-L-46152 but exceeds the -25°F pour point requirement of this Mil Spec. According to the supplier, this lube oil is presently being used successfully for temperate climate use, with a recommended maximum operating oil temperature of 270°F. Possibly, this lube oil could prove applicable to temperate climate use of ADAPTS.

- <u>Change Hydraulic Oil</u> -- Because it is not satisfactory for arctic use, all temperate climate hydraulic oil, Exxon Nuto 47, must be purged from the prime mover tank, starting, charge, and main hydraulic systems; from the hydraulic hoses; from the cargo pump piping and motor; and from the hydraulic capstan hoses, valve, and motor. Hydraulic fluid complying with MIL-H-5606C is recommended for use in all of these systems and components. Fluids meeting this specification have a pour point of -75°F or lower, a viscosity at -40°F of 500 centistokes, and a flash point in closed hydraulic systems, such as ADAPTS, of 275°F. The maximum recommended operating temperature for use in ADAPTS is 120°F.

- Hydraulic Oil Pressure and Temperature Monitor Assembly -- As explained previously, the Dennison hydraulic motor shaft seal on the cargo pump is designed to withstand continuous internal pressures to 50 psi and momentary surges to 300 psig. Since this motor case is internally drained, the pressure acting on the shaft seal is equal to the back pressure in the 1-inch hose returning the hydraulic fluid from pump to the prime mover. With the high viscosities of the hydraulic fluid prior to warm up of the system, the back pressure on the hydraulic motor must be carefully monitored and the flow rate adjusted accordingly, such that the back pressure does not exceed a working pressure of 250 psig. The recommended monitor assembly includes a pressure gauge, temperature gauge, and quick-connect couplers. See Figure 29.

The recommended warm-up procedure, detailed in the operation manual addenda, involves coupling the monitor assembly between the drain side of the hydraulic motor and the hydraulic return hose to the prime mover. The back pressure can thus be directly measured and controlled accordingly. A promising alternate procedure for hydraulic system warmup, which would cut down on the manpower required to monitor the system and the time required for warmup, is described in Appendix A.

Another alternate less desirable method of warming is with the monitor assembly inserted at the return side of the prime mover pump. Through a series of calculations, the theoretical back pressure at the motor drain port could be calculated and adjusted accordingly.

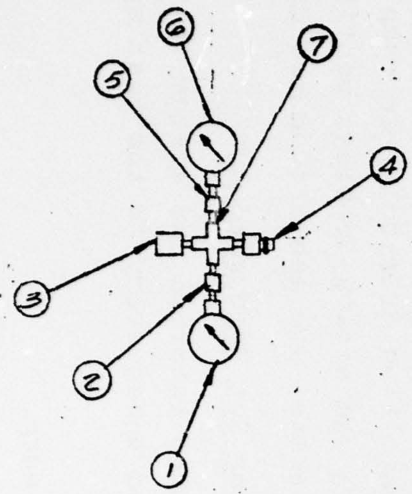

FIGURE 29

HYDRAULIC OIL PRESSURE AND TEMPERATURE MONITOR ASSEMBLY

QTY RQD	DESCRIPTION	IDENTIFYING OR PART NO.	DRAWING OR SPECIFICATION NO	MATERIAL OR NOTE	ITEM NO.
					9
1					8
1	PIPE CROSS 1" NPTF	16 FPC		LENZ	7
1	THERMOMETER (-40 to 160°F)	BC 350R		NOTE 1	6
1	REDUCING BUSH 1" NPTM TO ½" NPTF	16-8 HB		LENZ	5
1	QUICK DISCONNECT-MALE	YPHN16-16M		SNAP TITE	4
1	QUICK DISCONNECT - FEMALE	YPHC16-16M		SNAP TITE	3
1	REDUCING BUSH 1" NPTM TO ¼" NPTF	16-4HB		LENZ	2
1	PRESS GAUGE 0-2000PSI	KE 2\1-25		LENZ	1

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TOLERANCES ON:
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MATERIAL:

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TITLE: HYDRAULIC OIL PRESSURE AND TEMPERATURE MONITOR ASSY ARCTIC ADAPTS

SIZE | CODE IDENT NO. | DRAWING NO. SC-00555

SCALE: | REF: | SHEET

This procedure allows a single operator to monitor warm-up from one location at the prime mover. Unfortunately, the back pressure calculations cannot be accurately applied to field use in any simple, usable way. These calculations are outlined in Appendix A, but should be used with caution.

- Hydraulic Warm-up Assembly -- In order to facilitate rapid warm-up of the hydraulic fluid, it is recommended that an adjustable pressure bypass valve be inserted in the high-pressure side of the hydraulic line, between the main hydraulic pump and hydraulic hose to the cargo pump. The resulting pressure drop across this valve is used to induce a load on the main hydraulic pump, for purposes of initial warm-up. The valve is quick-coupled with Snap-Tite couplings and can easily be removed, if desired, after warm-up. See Figure 8.

- Cargo Hose Replacement -- Because the standard ADAPTS lightweight, 6-inch cargo discharge hose, MIL-H-82127 (MC), is generally unsatisfactory for use at temperatures below $0^{o}F$, it is recommended that it be replaced with Empex low-temperature hose, produced of specially composed nitrile and neoprene rubbers, including a unidirectional polyester cord fabric. This hose is also satisfactory for normal temperature use and could be procured for all systems on a replacement basis. To prevent low temperature stiffening of the seals and resulting difficulty in coupling, it is recommended that the 6-inch cam action couplers be fitted with special softer composition gaskets, available from the manufacturer.

5.2 Equipment Modifications Not Recommended

Based on low temperature material and system testing, the following modifications proved unnecessary in the test system and are not recommended:

- Ni-resist cargo pump.
- Elastomer coating of the cargo pump.
- Hydraulic line couplings with low temperature seals.

- Engine air preheater ducting.

Differences between the test system and that recommended, include those modifications above, and in addition:

- Location of the "T" connection in the hydraulic starter assembly.

- Installation of a lip seal rather than a face seal in the cargo pump bearing cavity housing.

- Fuel system coupler sexing.

- Dial ranges on hydraulic pressure and temperature gauges.

- No T-ring piston seal kit installed in standard hydraulic accumulator.

If the test system is to be used for arctic operation, it is recommended that the system be further modified to conform to the arctic ADAPTS recommendations.

5.3 Arctic Preparation

In preparation of a standard ADAPTS for arctic use, certain of the modifications or additions to the equipment discussed are long lead time items which would have to be done in advance to provide for the preparation of a system or systems for arctic use. These are listed below:

- Procurement of the ether injection system and ether bottles, fabrication of the mounting bracket, and installation.

- Modification of the existing accumulator piping.

- Procurement and piping of the additional accumulator assembly.

- Fabrication of the cooling air intake restrictor.

- Procurement of the oil sump temperature gauge.

- Replacement of the starter valve with a stainless steel valve.

- Replacement of the fuel system quick-connect couplers.

- Procurement and installation of the T-ring piston seal kit in the standard hydraulic accumulator.
- Procurement and replacement of the V-belts.
- Oil Drain Modification.
- Addition of exhaust system flanges.
- Fabrication of the fuel drum bung adaptor.
- Procurement of the 55-gallon drum vent fitting.
- Procurement of sufficient arctic, DF-A, fuel for purging.
- Procurement of arctic-grade hydraulic fluid.
- Procurement of arctic-grade lube oil.
- Modification of the Lucas main hydraulic pump.
- Replacement of glycerin-filled pressure gauges.
- Procurement and assembly of the special hydraulic system warm-up assembly and temperature-pressure monitor assembly.
- Changing the seal lubrication arrangement of the cargo pump thrust bearing.
- Procurement of 6-inch low temperature cargo hose and low temperature hose coupling gaskets.
- Disassembly and regreasing of the Griphoist.

Assuming the advance procurements and modifications listed have been done, an ADAPTS system can be readied for immediate response in a relatively short time. These preparation procedures, which must be followed prior to shipment to the Arctic, are listed below:

- Changing of the engine fuel and lube oil.
- Installation of the engine oil sump temperature gauge.
- Installation of the cooling air control.
- Replacement of the hydraulic oil -- purge and refill the entire hydraulic system.

- Package all arctic accessories -- low temperature cargo hose and seals, hydraulic warm-up assembly and temperature/pressure monitor, fuel drum bung adaptor and vent, extra accumulator assembly, etc.

A cost estimate for all arctic modifications is included in Appendix D.

5.4 Operating and Maintenance Procedural Changes

Operating and maintenance procedures in the arctic are expected to differ from those of temperate climates in the special care required in unpacking, handling, and using the synthetic rubber components, special start-up and warming procedures for the engine and hydraulic systems, and allowance for the difficulities in manipulating tools and controls in arctic clothing. Details of special operating procedures, trouble-shooting, and cautions are best based on actual experience in testing and operating the system at low temperatures, as well as engineering analysis.

6.0 CARGO VISCOSITY CONSIDERATIONS

This study has been primarily concerned with the proper mechanical functioning of the ADAPTS equipment. However, in extending operations to the Arctic, the effect of lower temperatures on the pumpability of petroleum cargoes is also an important consideration.

The factors which control the rate of pumping of a vertical turbine pump apply at any temperature. These are:

Total discharge head or the height of lift plus the dynamic head created by friction losses in hoses or piping.

The positive suction head or height of liquid above the suction inlet.

Viscosity of the pumped liquid.

The viscosity of the cargo affects pump performance directly, and is also a factor in determining the dynamic head developed in hoses and piping. The viscosity of petroleum crudes and products is directly related to temperature. The temperature of the cargo would be determined by the initial temperature at the time of the casualty, time of cooling, ambient sea temperature, air temperature, wind and quantity of cargo. Many of these variables and the effect on pumping rates are discussed in the "Summary Report on Pumping Systems for Transferring High-Viscosity Oils" SUPSALV Report No. 9-74, prepared by Battelle Columbus Laboratories for U. S. Navy Supervisor of Salvage.

The limit of ADAPTS pumping capability is reached when either the cargo cannot flow into the suction inlet or the total head reaches the shut-off point for the pump. Generally, all petroleum distillate products and light crudes are pumpable at the worst expected temperature condition of +28°F. Heavier crudes and residual fuel oils, in which the cargo is heated, are expected to remain pumpable for several days after the loss of the ship's heating capability. A helpful discussion of the thermal decay in the cargo of damaged tankers is available in "Emergency Transfer System for Disabled Tankers," a study performed for U. S. Navy SUPSALV by Murphy Pacific Marine Salvage Company under Contract No. N00024-73-C-0273 (Task 11-74).

APPENDIX A

ALTERNATE PROCEDURES FOR HYDRAULIC SYSTEM WARM-UP

As discussed in the main body of the report, to prevent damage to the motor seals, pressure at the drain port of the Dennison hydraulic motor must not exceed 300 psi. Prior to hydraulic system warm-up, the main hydraulic pump is capable of flow rates sufficient to cause excessive back pressure at the hydraulic motor, which could result in damage to the motor. This back pressure must be constantly monitored during the warm-up procedure, and the flow rate controlled accordingly, so as not to exceed the maximum allowable back pressure.

The recommended procedure involves insertion of a pressure-temperature monitor assembly between the hydraulic motor drain port and the hydraulic hose return line. This allows direct reading of back pressure but requires that the submersible pump be accessible for constant hydraulic pressure monitoring during warm-up.

Normally, this is no problem, as the standard pump can be run on the deck prior to lowering into the cargo hold. However, this procedure (which involves running the submersible pump dry for a period of time), may not be compatible with the proposed future modification of the pump for resistance to hazardous chemicals. Because a self-lubricating bearing could not be used in this design, running the pump dry for an extended period of time could result in damage to the bearing or shaft in a chemical-resistant pump.

An alternative hydraulic fluid warm-up procedure was investigated which would involve less manpower and reduce the warm-up time substantially. This procedure would also eliminate running the submersible pump dry, and would result in improved system reliability due to the simplified and less critical nature of the procedure.

The same hydraulic fluid warm-up accessories (the hydraulic warm-up assembly and the temperature-pressure monitor assembly) could be used, but in a different configuration and procedure than previously discussed. Prior to warm-up, the hydraulic supply and return hoses could be disconnected from the submersible pump and directly coupled to form a loop circuit. The hydraulic warm-up assembly and temperature-pressure monitor assembly (though the pressure gauge is not really necessary) could then be coupled in the line between the prime mover high pressure supply coupling and the hydraulic supply hose.

After the diesel engine has been run for approximately five minutes with the pump controller in the "no flow" position, the flow controller can be slowly advanced to maximum flow, with the engine at 2000 rpm, and the hydraulic warm-up valve adjusted so that the discharge pressure gauge reads 1500 psig. This procedure allows a much greater work load to be applied to the hydraulic system, resulting in faster hydraulic fluid warming, with no chance of accidental damage to the hydraulic motor. When the hydraulic fluid temperature (as read on the thermometer on the temperature-pressure monitor) reaches 60^{o}F, hydraulic fluid viscosity is low enough to prevent excessive back pressure at the pump motor. The warm-up assembly and temperature-pressure monitor can be removed and the submersible pump connected to the hydraulic hoses and lowered into the cargo hold, ready for pumping.

This warm-up procedure offers many advantages, including: cutting down on manpower required for warm-up monitoring, reducing substantially the time required, and improved system reliability.

Discussions with the hydraulic pump and motor manufacturers indicate that this proposed procedure would not result in any system damage. However, this procedure has not been operationally tested.

It is suggested that this procedure be tested in cold chamber or Arctic operational tests and incorporated into the final operating and maintenance manuals.

Another alternative pressure monitoring procedure, which would allow warm-up with the cargo pump submerged, was investigated but found impractical for field use. This procedure involved placing the pressure-temperature monitor assembly at the prime mover unit, and determining the hydraulic motor back pressure theoretically. Because of the number of variables involved, the pressure drop calculations could not be accurately reduced to a simple table format which would be usable in the field.

A summary of the calculation involved is shown below: (Back pressure at the motor drain port) $\cong$ (Gauge pressure at the return side of prime mover) + (Pressure difference due to difference in elevation between the cargo pump and the prime mover) + (Pressure drop across the fittings and couplings in the return line between motor drain port and prime mover pressure monitor) + (Pressure drop due to viscous or turbulent drag in return line).

Based on simplified pressure drop calculations:

$$P_B \cong P_G + (0.37)\,\Delta H + (0.007)F^2(N + 1) + L(dP)$$

Where: $F = (0.00078)TR$

P_B = Back pressure at the Dennison hydraulic motor, (actually the difference between the internal pressure of the hydraulic motor drain port and the external ambient pressure of the motor case) (psig)

P_G = Gauge pressure at the return side of the prime mover hydraulic system, read directly off pressure-temperature monitor assembly (psig)

ΔH= Height of the prime mover unit minus the height of the submersible pump (or the surface of liquid if pump is submerged), (ft.)

F = Flow rate of the hydraulic pump (gpm)

T = Number of turns the pump setting controller is rotated from the no-flow position

R = Engine speed, read directly off tachometer (rpm)

N = Number of lengths of hose between motor drain port and prime mover

L = Hose length between motor drain port and prime mover (ft.)

dP= Differential pressure drop in return line, read from graph showing dP vs. Flow Rate, for various oil temperatures (psi/ft)

The differential pressure drop (dP) in the return line can be determined from Figure A-6, knowing the flow rate and hydraulic oil temperature. This graph is derived from viscosity-temperature curves and from theoretical pressure drop calculations for laminar and turbulent flow. It is based on operation with MIL-H-5606 hydraulic fluid and a 1-inch hydraulic return line.

In summary, while theoretical pressure calculations as shown above could be applied, this method would be impractical for field use, has not been tested, and is not recommended.

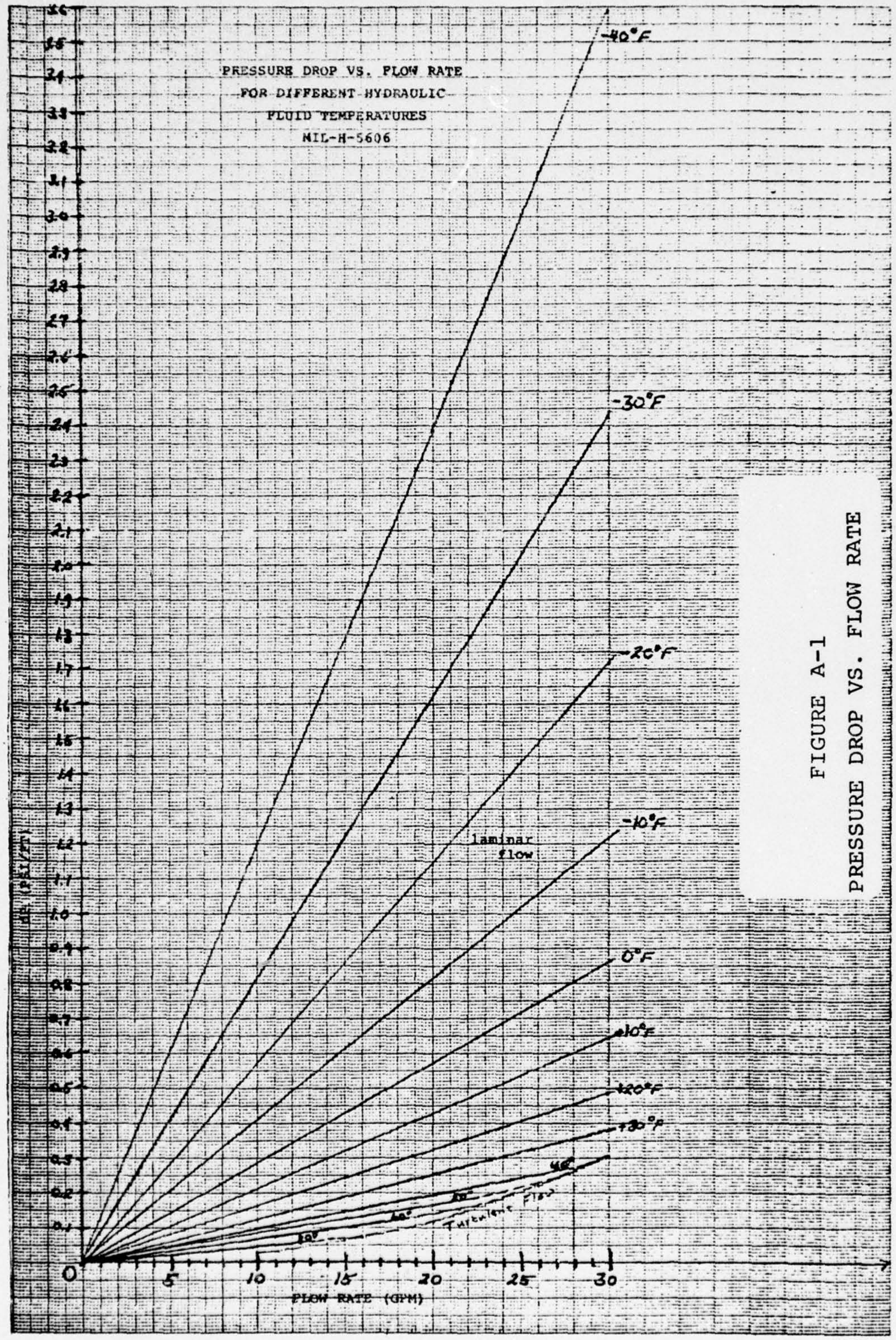

FIGURE A-1
PRESSURE DROP VS. FLOW RATE

APPENDIX B

LIST OF DRAWINGS

Drawing No.	Title
0502-51102 B (two pages)	Prime Mover Mechanical Assembly SII Modification #1
SC-00560	Cargo Pump Bearing Cavity Modifications Arctic ADAPTS
SC-00480	Outside Plate Cooling Air Control Arctic ADAPTS
SD-00479	Inside Plate Cooling Air Control Arctic ADAPTS
SB-00558	Locking Bolt Cooling Air Control Arctic ADAPTS
SC-00561	Exhaust System Modification Arctic ADAPTS
SB-00556	Hydraulic Accumulator Assembly (Add'l) Arctic ADAPTS
SC-00559	Ether Injection System Assembly Arctic ADAPTS
SC-00553	Mounting Bracket Ether Injection System Arctic ADAPTS
SB-00563	Fuel Line Schematic Arctic ADAPTS
SC-00554	Fuel Drum - Bung Adaptor Arctic ADAPTS
SD-00552	Air Preheater Ducting & Butterfly Arctic ADAPTS

LIST OF DRAWINGS
(Cont.)

Drawing No.	Title
SB-00562	Hydraulic Warm-up Assembly Arctic ADAPTS
SC-00555	Hydraulic Oil Pressure and Temperature Monitor Assembly Arctic ADAPTS
SB-00641	Quick Disconnect Sub-Assy. Installation on Prime Mover For Additional Hydraulic Accumulator

APPENDIX C

MATERIALS & PARTS REQUIRED FOR ARCTIC MODIFICATION OF ADAPTS

Following is a list of materials and parts required to make the recommended modifications for arctic use. This list is suitable for procurement of materials and parts, including a detailed description of each part; part or drawing numbers, where applicable; manufacturer; possible supplier, address, and telephone number.

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: Hydraulic Starter System Repiping for Additional Accumulator

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
1	SM-372-E2	3/8" Quick-Disconnect Nipple, 3/8" N.P.T.F.	Bruning	Maryland Rubber Co. 6350 Frankford Ave. Baltimore, MD 21206 (301) 488-8900
1	P.N. 2257 6-6S	3/8" Tee, All Male, N.P.T., High Pressure	Aeroquip	Bearing & Transmission Inc. 2018 Paper Mill Rd. Winchester, VA 22601 (703) 662-5000
1	-	3/8" High Pressure Coupler, N.P.T.	-	same

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: Low Temp - Starter Valve

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
1		Jamesbury Type H.P. Stainless Steel, Manually Operated Valve, 3/8" NPT screwed end, 4500 WOG	Jamesbury	Industrial Supply Corp 209 Key Highway Baltimore, Md. 21230 (301) 727-0777

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: Additional Hydraulic Accumulator Assembly

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
1	ACC-10B-06-PNP	1 gallon Hydraulic Accumulator for petroleum based oil, 3/8" N.P.T.F., 1500 psi precharged with T-ring piston seal	American Bosch	Mar-Oil Hydraulics 113-115 Monroe St. Hoboken, N. J. 07030 (201) 656-8780
1	-	Needle Valve, Type 1900 FFA Angle Pattern, 3/8" N.P.T.	Marsh Instrument	Same as above
1	J4HA06-06MBX 06 MB - 24" O/A	Hydraulic Hose Whip, 24", male pipe threads both ends	Maryland Rubber Co. 6350 Frankford Ave Baltimore, MD 21206 (301) 488-8900	Same as manufacturer
1	SM-371-E2	Female Quick-Disconnect 3/8", 3/8" N.P.T.F.	Bruning	Same as above
1	-	3/8" High Pressure Pipe Nipple	-	Same as above

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: T-Ring Hydraulic Accumulator Modification

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
1	#SE 203 281	T-ring seal kit for American Bosch 1-gallon hydraulic Accumulator	American Bosch	Mar-Oil Hydraulics 113-115 Monroe St. Hoboken, N.J. 07030 (201) 656-8780

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: Low Temp Fuel System Couplings

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
1	VHN4-4M-MHO	¼" Quick-Connect Valved Nipple with male thread, with MHO designation to be permanently marked on part	Snaptite	Airline Hydraulics Co. 107 Beaver Court Cockeysville, Md. 21030 (301) 667-4300
1	VHC4-4M-MHO	¼" Quick-Connect Valved Coupler with male thread, with MHO designation, low temp seal	Snaptite	Same as above
2	VHN4-4F-MHO	¼" Quick-Connect Valved Nipple with female thread, with MHO designation	Snaptite	Same as above
2	VHC4-4F-MHO	¼" Quick-Connect Valved Coupler with female thread, with MHO designation, low temp seals	Snaptite	Same as above

Note: all couplings on sealdrum, fuel lines, and small fuel tank must be replaced

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: Fuel Drum Bung Adapter & Vent Fitting

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
1		Threaded Bung Adapter for 55 gal. drum with (2) 3/8" NPTF holes	-	JNO. SOLENBERGER Industrial Division P.O. Box 765 Winchester, Va. 22601 (703) 667-5900
1		Street Elbow - 3/8" NPT	-	Same
1		Close Nipple - 3/8" NPT, 2" long	-	Same
2		Reducing Connector - 3/8" NPTF to ¼" NPTM	-	Same
1		90° Pipe Elbow - 3/8" NPTM	-	Same
1		Pipe Coupling - 3/8" NPT	-	Same
1		Reducer - ½" NPTM x 3/8" NPTF, Brass, rated for fuel	-	Same

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: continued - Fuel Drum Bung Adaptor & Vent Fittings

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
2	-	Pipe - 3/8" nominal size, schedule 40, 14" length 3/8" NPT on each end	-	local plumbing supply dealer
1	VHN4-4F-MHO	¼" Quick-Connect Valved Nipple with female pipe thread, with MHO designation	Snaptite	Airline Hydraulics Co. 107 Beaver Court Cockeyville, Md. 21030 (301) 667-4300
1	VHC4-4F-MHO	¼" Quick-Connect Valved Coupler with female pipe thread, with MHO designation, low temp. seals	Snaptite	Same
1	BF - 12	Breather Filter for 55 gal. drum, 3/4" NPT	Lenz	Lanier Engineering Sales, Inc. 4703 Ritchie Highway Baltimore, Md. 21225 (301) 789-6800 Mr. Tom Kramer

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: Special Low Temperature V-Belts

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
297 (min. order)	2260 8000 - 5599 - XI	Specially Compounded Low Temp. V-Belt for use to - 65°F (for charge pump drive)	Gates Rubber Co.	Gates Rubber Co. Denver, Colorado Ron Shaw (303) 744-5580
255 (min. order)	8118 3418 - X1	Specially Compounded Low Temp V - Belt (for fan-governor drive)	Same	Same

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: Change Fuel and Lube Oil

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
Variable	-	Arctic-Grade Diesel Fuel Meeting Fed. Spec. VV-F-800 grade DFA, in 55 gal. non-returnable steel drum	-	Howell Refining Co. P. O. Box 2776 San Antonio, Texas (512) 533-8111
Variable	-	Conoco - Lube Oil, Polar Start DNO 600 Fluid in quart cans (24 per case)	Continental Oil Company, Houston, Texas	Basham Oil Inc. 2428 Roamoke Ave., N.W. Roanoke, Va. 24015 (703) 343-0195 or (703) 342-7879 Mr. Coy Bowling

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: Adjustable Cooling Air Intake Assembly

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
1	-	Inside Plate - Cooling Air Control - as per SII drawing # SB00473	Custom-built	Local Machine Shop
1	-	Outside Cover - Cooling Air Control - as per SII drawing #SC-00480	Custom-built	Same
1		Cooling Air Control Locking Bolt, as per SII drawing #SB-00558	Same	Same

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: Oil Sump Temperature Gauge

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
1	BC-350R	Thermometer, type BC-350R, 2½" stem length, with calibrator, 18-8 type 304 Stainless Steel, 3" dial face, range: 50^{o} - 300^{o}F, ½" N.P.T.	TEL-TRU Mfg. Germanow - Simon Machine Co., Inc. 1940 Germanow St. Rochester, N. Y. 14605	Tate Engineering 600 West-West St. Baltimore, Md. 21230 (301) 538-9676

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: Ether Injection System

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
1	Mod. #20152	Ether Injection Kit Mod. 20152 for 140 CID Diesel Engines Containing (1) 24 oz Cylinder of High Purity Ether	Kruber Inc. 900 Ringree Rd. Algonquin, Illinois 60102 (312) 658-8561	Manufacturer
Variable	20,000	Extra Case of 12 - 24 oz Cylinders High Purity Ether	Same	Same
1	20,388	Swirling Atomizer Nozzle for Model 20152 Injection Kit	Same	Same
1	-	Continuous Spray Valve To Replace Metering Valve in Kit #20152	Same	Same
1	-	Ether Injection System mounting bracket - fabricated as per SII drawing #SC-00553	Custom-built	Local Machine Shop

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: Exhaust System Flanges

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
12	P962	Exhaust Flanges	Riker Mfg. Inc. 4901 Stickney Ave. P. O. Box 6468 Toledo, Ohio (419) 729-1626	Same
2	RC 250	Rain Caps	Riker Mfg. Inc.	Same

AD-A035 916 SEAWARD INTERNATIONAL INC FALLS CHURCH VA F/G 13/11
ARCTIC ADAPTS - ENGINEERING ANALYSIS, PROTOTYPE DEVELOPMENT AND--ETC(U)
DEC 76 M L CLARKE, D W DURFEE, S H SHAW DOT-CG51864A
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MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: Replacement of Glycerin-Filled Pressure Gauges

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
1	-	Type 213 Pressure Gauge, 2½" dial, ¼" NPT male, 0-400 psi range, specially filled with 35% water, 65% glycerin	WIKA	International Pressure Co. 230 Newton Road Plainview, N. N. (516) 694-2072 Ms. Doris
1	-	Type 213 Pressure Gauge, 2½" dial, ¼" N.P.T. male, 0-5000 psi range, specially filled with 35% water, 65% glycerin	WIKA	Same as above

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: Oil Drain Modification

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
1	FF 403-24"	Fast Lube Oil Change System, Pan Plug Thread Size 10 x 1mm (to be changed to 10 x 1.5mm), 24" length,	AEROQUIP	Bearings and Transmissions, Inc. 2018 S. Tondsun St. Winchester, Va. 22601 (703) 662-5000 Mr. Mark Kees
1	5600-12-10S	Quick-Connect Coupling Pair, 5/8", with 3/4" N.P.T.F. Threads to fit above hose whip	AEROQUIP	Same as above

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: Lucas Pump Modifications

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
1	-	Installation of special seals and O-rings for operation of pump at - 40°F to be done by supplier, as per recommendations	Lucas	Joseph Lucas N.A. Inc. Industrial Hydraulics Dept. 30 Van Nostrand Ave. Englewood, N. J. 076631 (201) 567-6400 Mr. Clarence Gletow

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: Hydraulic Oil Pressure and Temp. Monitor Assembly

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
1	KE-2M-25	2½" Pressure Gauge, bottom mount model, full range 0-2000 psi, ¼" NPTM connection	Lenz	Lanier Engineering Sales, Inc. 4703 Ritchie Highway Baltimore, Md. 21225 (301) 789-6800 Mr. Tom Kramer
1	BC-350R	Thermometer with calibrator, temp. range -40 to 160°F, stem length 2½", ½" NPTM connection, for pressures up to 2000 psi	TEL-TRU-MFG., Germanow - Simon Machine Co., Inc. 1940 Germanow St. Rochester, N.Y. 14605 (716) 454-3090	Tate Engineering Co. 600 West - West St. Baltimore, Md. 21230 (301) 538-9676
1	16 FPC	1" female pipe cross, high pressure	Lenz	Lanier Engineering Sales, Inc. 4703 Ritchie Highway Baltimore, Md. 21225 (301) 789-6800
1	16-4HB	1" to ¼" Reducing Hex Bushing, high pressure	Lenz	Same as Above

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: continued Hydraulic Oil Pressure and Temp. Monitor Assembly

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
1	16-8HB	1" to ½" Reducing Hex Bushing, high pressure	Lenz	Lanier Engineering Sales, Inc. 4703 Ritchie Highway Baltimore, Md. 21225 (301) 789-6800
1	VPHC16 -16M-MHO	Quick-Disconnect Coupler, 1", with 1" NPTM threads, low temp. seals, MHO designation permanently marked on part	Snaptite	Airline Hydraulics 107 Beaver Court Cockeyville, Md. 21030 (301) 667-4300
1	VPHN16 - 16 M -	Quick Disconnect Nipple, 1", with 1" NPTM threads	Snaptite	Same as Above

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: Replacement of Hydraulic Oil

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
Variable	-	Exxon Arctic-Grade Hydraulic Oil meeting MILH-5606-C (in 55 gallon drum)	Exxon	Exxon Co., USA P. O. Bin "A" Bayonne, N.J. 07002

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: Bearing Cavity Modification & Relubrication

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
1	-	Pump Face Seal, Type #1, for 1 7/16" shaft, with Viton O-Rings and seals, carbon face, and tungsten carbide seat	Rotary Seal Corp.	Rotary Seal Corp. 7440 W. Lawrence Ave. Chicago, Illinois 60656 (312) 867-5000 Mr. Walter Palch
as required	-	Conoco Polar Start DN-600 Gear Oil	Continental Oil Co. Houston, Texas	Basham Oil Inc. 2428 Roanoke Ave., N.W. Roanoke, Va. 24015 (703) 343-0195 Mr. Coy Bowling
as required	-	Oil resistant gasket material, 1/16" thick	-	Jno Solenberger Industrial Division P.O. Box 765 Winchester, Va. 22601 (703) 667-5900
1	-	¼" N.P.T. Steel Pipe Plug	-	Same as above

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: Low Temperature Cargo Hose

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
Variable	-	6" I.D. x 50 ft. length Style WS, Spec. S-598 Low Temp. Fuel Hose Suitable for service at - 40°F, complete with aluminum cam-lock fittings (evertite or equal) attached with S.S. bands. Disconnect coupler gaskets to be low temp. type, minimum burst press. 275 psi	Empex	Empex Industrial Hose Co. 6925 Paramount Blvd. Long Beach, California 90805 (213) 636-9703 Mr. Tony Caduto

MATERIALS & PARTS LIST FOR ARCTIC MODIFICATION OF ADAPTS

MODIFICATION: Hydraulic Warmup Assembly

Quantity	Part No.	Part Description	Manufacturer	Possible Supply Source
1	1AR15-R8-30S (1-76)	Fluid Control Device, 1", adjustable pressure relief valve	Fluid Control Devices	Fluid Power Equipment Co., Inc. Baltimore, Md. (301) 752-7802 Mr. Richard Molhenrich
1	VPHC16-16M-MHO	Quick-Disconnect Coupler, 1", with 1" N.P.T.M. threads, with low temp. seals, MHO designation permanently marked on post	Snaptite	Airline Hydraulics 107 Beaver Court Cockeyville, Md. 21030 (301) 667-4300
1	VPHN16-16M-MHO	Quick-Disconnect Nipple, 1", with 1" N.P.T.M. threads MHO designation	Snaptite	Same as above

Following is a list of materials and parts required for those arctic modifications which were tested, but based on test results are not recommended:

MODIFICATION: Elastomer Coating of Pump

If required, protective coating of ADAPTS two-stage, 10-inch pump.

Send to: Seaward International, Inc.
Clearbrook Industrial Park
Clearbrook, Virginia 22624
(703) 667-5191
Contact: Mr. Louis Brown

MODIFICATION: Hydraulic Line Couplings with Low Temperature Seals

Type I ADAPTS -- Has hydraulic winch requiring six pairs of low temperature quick-connects per unit.

"Bruning" 3/8" SM-371-E2 low temperature coupler

"Bruning" 3/8" SM-372-E2 nipple

None in Type II -- no hydraulic winch

Manufacturer: Bruning

Source: Maryland Rubber Company
6350 Frankford Avenue
Baltimore, Maryland 21206
(301) 488-8900

For Type I & II ADAPTS Systems, as required per system -- 1" quick disconnects.

Coupler VPH C16-16F-MHO

Nipple VPHN16-16F-MHO

Manufacturer: Snap-Tite

Source: Airline Hydraulics
107 Beaver Court
Cockeysville, Maryland 21030
(301)667-4300

MODIFICATION: Ni-Resist Pump

If required, Byron-Jackson two-stage, 10-inch pump, Model 10HQH furnished with 10-inch strainer and special 10-inch strainer adaptor (10-inch HQ to 10-inch strainer, Byron-Jackson Dwg. 167694-1). Pump to be cast of all ni-resist (bronze free). Shaft end to be drilled and tapped 1/2 - 20 ounce.

Source: Byron-Jackson
One Tyson's Corner Center
Suite 207
McLean, Virginia 22101
(703) 790-9191

MODIFICATION: Air Preheater Assembly

Possible fabrication source:

Clearbrook Welding Company
c/o Post Office Clearbrook
Clearbrook, Virginia 22624
(703) 667-1141
Contact: Mr. Eddie Lawrence

All parts and fabrication as per Seaward International, Inc., Dwg. SD-00552 which includes two exhaust flanges Part No. R962X2. These flanges to be sent to fabricator for fabrication of air preheater.

Source: Riker Manufacturing, Inc.
4901 Stickney Avenue
P. O. Box 6468
Toledo, Ohio
(419) 729-1626

APPENDIX D
COST & LABOR ESTIMATES

Introduction:

The following is a breakdown of the materials and labor costs associated with the modification of the Coast Guard's existing ADAPTS pumping equipment for operation in arctic environments, down to -40°F. The complete technical description and rationale for these modifications will be contained in the final report prepared by Seaward International, under contract DOT-CG-51864-A.

The purpose of this document is to provide the Coast Guard planners with the fiscal data required in order to make the decisions on how best to allocate the funds available for the modification of existing ADAPTS and the procurement of new ADAPTS.

An effort has been made to break the costs down into logical elements so that they can be combined in a variety of ways to determine the probable total cost of various alternative options. Five major groupings are provided. These are:

I. Modifications Recommended for All Systems

II. Arctic Modification Accessory Package

III. Variable Quantity Items

IV. Labor to Prepare Arctic Modified Systems for Arctic Operation

V. Modifications Tested But Not Considered Necessary for Arctic Operations

Category I modifications are recommended to be made on all systems. These recommendations are further divided into two categories, General and Low Temperature. The General modifications are those which will benefit system operation, design or performance at all temperatures, including arctic, temperate, and tropical. The Low Temperature modifications are those required to extend the system operating range the last 20° or 30°F down to -40°F. These modifications are not required over the remainder of the operating temperature range. They have no detrimental effect over this range so can safely be made to all systems.

The costs shown do not reflect time spent in ordering and expediting delivery of equipment. The Seaward International labor costs are based on an average loaded labor cost of $15/hr.

Costs are shown for each modification in three ways; for the modifications made on two and eighteen systems by Seaward International, and on a per system basis for the modifications made by Coast Guard personnel. The materials costs, in most cases, do not reflect any decrease in price with quantity, although some savings would be realized through savings in freight charges, minimum order limits and reduced ordering and expediting costs. A further benefit to buying material for all eighteen systems at once will be the standardization of components among all ADAPTS units. In many instances, labor savings are obtained by performing the modifications on multiple units.

Category II contains the materials cost and labor estimate to procure and assemble the additional accessories which must be attached to a previously modified system to equip it for arctic operations. These elements are all capable of being installed quickly. They are not useful for operations at normal temperatures, and in some cases, could have a deleterious effect on normal temperature operations, if misused.

Category III contains the cost estimates associated with the variable quantity items, such as fuel and lubricants, required for arctic operation.

Category IV contains the labor estimates for the preparation of a modified system for arctic operation. It assumes that the modifications of categories I, II, and III have been done concurrently or previously. These are shown for one, two, and six systems, since it is considered unlikely that any more than six systems would be dedicated to arctic use.

Category V contains the cost estimate for the system modifications which were contemplated and, after testing found to be unnecessary.

I. Modifications Recommended for All Systems

General Modifications	Cost for Modifications Done Concurrently by Seaward International				Modifications by USCG Personnel	
	For 2 Systems		For 18 Systems		Per System	
	Materials	Labor	Materials	Labor	Materials	Man Hours
Ether Injection System	$ 80	$ 105	$ 540	$ 600	$ 40	6
'T' Connection on Installed Hydraulic Accumulator	24	60	216	405	12	2
Oil Sump Drain Modification	50	45	400	360	25	2
Exhaust System Flanges	116	180	1044	1200	58	8
Fuel Drum Bung Adapter	50	60	450	270	25	3
Pump Bearing Cavity Modification[3]	300	240	1800	1080	150	12
TOTAL	$ 620	$ 690	$4450	$3915	$ 310	33 MH
Average Cost Per System	$ 655		$465		$ 310	+ 31 MH
Low Temperature Modifications						
Low Temperature Starter Valve	$ 152	$ 75	$1368	$ 472	$ 76	3
Low Temperature Fuel Couplers	45	23	120	120	23	1
V-Belts[1]	5 (623)	30	45 (623)	150	250 (623)	1
Hydraulic Pump Modification[2]	500	240	4320	1620	250	12
Glycerin/Water Filled Gauges	75	45	675	150	38	2
Griphoist Relubrication	5	60	10	240	5	2
LOW TEMP MODIFICATION TOTAL	$1400	$ 473	$7116	$2752	$1015	+ 21 MH
Average Low Temp per System[4]	$ 628		$516		$ 395	+ 21 MH
TOTAL CATEGORY I - Average per System[4]	$1283		$981		$ 705	+ 54 MH

NOTES:
1. Prices are for minimum order quantities of 297 units for the charge pump and 255 units for the governor/fan belt.
2. Labor includes only removal and reinstallation of pump from prime mover. Materials cost includes parts and complete modification by Lucas.
3. Materials cost includes parts and machining.
4. Total per system average cost uses V belt material cost of $2.50 per system so as to give a more reasonable comparison basis.

II. Arctic Modification Accessory Package

Modification	2 Systems		18 Systems	
	Material Cost	Assembly Labor Cost	Material Cost	Assembly Labor Cost
Continuous Ether Injection Valve	$ 20	$ -	$ 180	$ -
Additional Hydraulic Accumulator Assembly	430	60	3870	180
Cooling Air Control	860*	-	5530*	-
Oil Sump Temperature Gauge	40	-	360	-
Hydraulic Warmup Assembly	200	30	1800	120
Hydraulic Oil Pressure & Temperature Monitor Assembly	260	45	2340	150
Total	$1810	$135	$14080	$450
Combined Total per System	$972		$807	

* Material costs include complete cost of fabrication.

III. Variable Quantity Items

Item	Cost Per Unit	Quantity Per System	Cost Per System
Additional 6" Low Temp. Cargo Hose	$670 per 50' Section w/Couplers	6	$4,020
Arctic Grade Lube Oil	$1.50/qt.	13 qts.	20
Arctic Grade Hydraulic Oil	$3.00/gal.	30 gal.	90
Arctic Grade Fuel	$0.75/gal.	variable	-
Additional Ether Bottles	$28/doz.	variable	-
Add'l. Low Temp. 6" Hose Coupling Gaskets	$1.25 ea.	7	8.75
Approximate Total per System			$4,200

NOTE: All prices and quantities approximate and subject to change.

IV. Labor to Prepare System for Arctic Use Assuming Modifications I, II, and III Are Also Accomplished

	Cost for Preparation Done Concurrently By SII		Labor if Done By USCG
	2 Systems	6 Systems	Man Hours Per System
Installation of Cooling Air Control	$ 30	$ 45	1
Change Engine Oil & Install Oil Sump Temp. Gauge	30	60	1
Refill Fuel System with Arctic-Grade Diesel Fuel	25	45	1
Drain & Refill Hydraulic Power Supply	60	120	2
Drain & Refill Hydraulic Hoses (assuming 4-80 ft hoses per system)	180	180	4
TOTAL	$265	$450	9
Average Cost Per System	$133	$ 75	

V. Modifications Not Considered Necessary

	MATERIAL COST	
	2 Systems	18 Systems
#9 Intake Air Preheater	$ 650*	$ 1,000*
#19 Ni-Resist Pump (complete)	24,000	198,000
#20 Elastomeric Coating of Pump, 1/8" Thick	1,300	7,500
#17 Low Temp. Hydraulic Hose Couplings	$35/pair	$35/pair

*Material cost includes complete cost of fabrication.

MATERIALS TEST DATA

Following are several tables presenting data on room-temperature and low-temperature charpy impact testing of specimens of meehanite and ni-resist. This data was used in determining the suitability of the standard ADAPTS cargo pump for arctic operation. Based on this, and low-temperature system testing, a specially built ni-resist cargo pump is not recommended as being necessary for arctic use.

Byron Jackson Pump Division

P.O. BOX 486, MAIN STATION, TULSA, OKLAHOMA 74101 • (918) NAT[illegible]

RECEIVED
DEC 10 1975
SEAWARD INC.

8 December 1975

Mr. Shaw
Seward
6269 Leesburg Pike
Fall Church, Va. 22044

Mr. Shaw:

The numbers 1-15 are on the charpy specimens. Also, those numbers indicate the following heat numbers and tensile strengths.

Heat Number		Tensile Strength (psi)
1.	G5-233	37,371
2.	RM5-65	35,589
3.	RM5-64A	35,660
4.	RM5-68	31,283
5.	RM5-66	32,975
6.	RM5-67B	33,185
7.	G5-228	37,474
8.	G5-292	40,754
0.	G5-239	38,927
10.	G5-225	36,090
11.	G5-237	41,518
12.	G5-223	37,140
13.	G5-227	38,462
14.	G5-230	36,382
15.	RM-5-64C	29,106

Respectfully,

Ron Streetman

RS:ls

DIVISION OF BORG-WARNER CORPORATION

SPECIMEN No.	HEAT No. (G5-)	TENSILE STRENGTH (PSI.)
1	191	40,439
2	195	44,539
3	190	38,051
4	202	36,423
5	217	50,223
6	212	32,339
7	RM5-52B	30,017
8	192	38,095
0	199	40,938
11	207	37,443
12	RM5-59	30,441
13	RM5-57	32,093
14	RM5-52A	29,965
15	RM5-61C	36,276
16	RM5-61D	30,318

NOTE: Ni-resist samples are denoted by RM5-.

10 November 1975

SEAWARD INC.

ARTECH CORP. 2816 Fallfax Drive Falls Church, Virginia 22042 (703) 560-3292

TYPE & MODEL OF MACHINE	Tinius Olsen Model 64 Impact Tester	STRIKING VELOCITY	16.8 ft./sec
TYPE OF SPECIMEN	Charpy, Type A	ENERGY LOSS	0
ROOM TEMPERATURE	72°F	ENERGY AT STRIKE	264 ft.lbs.

SPECIMEN	TEMP-ERATURE	IMPACT VALUE	APPEARANCE OF FRACTURE
1	R.T.	1.0	Meehanite
3	R.T.	1.0	Meehanite
4	R.T.	1.5	Meehanite
13	R.T.	2.0	Ni-Resist
15	R.T.	2.5	Ni-Resist
16	R.T.	2.0	Ni-Resist

(a.) Specimen did not separate.

Number of specimens failing to separate 0

Consumer Protection • Power Sources • Materials • Instrumentation • Testing • Analysis

ARTECH CORP. 2816 Fallfax Drive Falls Church, Virginia 22042 (703) 560-3292

TYPE & MODEL OF MACHINE Tinius Olsen Model 64 Impact Machine

STRIKING VELOCITY 16.8 ft per sec

TYPE OF SPECIMEN - ASTM-23, Type A

ENERGY LOSS - 0

ROOM TEMPERATURE - 73°F

ENERGY AT STRIKE 264 ft lbs

SPECIMEN	TEMP-ERATURE	IMPACT VALUE	SPECIMEN TYPE
0 .5415"	-40°	Machine not reset	1/8" Coated Meehanite
1 .4425		2.0	1/16" Coated Meehanite
2 .4425		6.0	1/16" Coated Ni-Resist
3 .394		3.0	Uncoated Ni-Resist
4 .3935		4.0	Uncoated Ni-Resist
5 .394		4.0	Uncoated Ni-Resist
7 .393		1.0	Uncoated Meehanite
8 .436		2.5	1/16" Coated Meehanite
9 .440		4.0	1/16" Coated Ni-Resist
10 .395		1.0	Uncoated Meehanite
11 .395		1.5	Uncoated Meehanite
12 .5445		8.0	1/8" Coated Meehanite
13 .548		8.0	1/8" Coated Meehanite
14 .438		2.0	1/16" Coated Meehanite
15 .437	↓	4.0	1/16" Coated Ni-Resist

a. Specimen did not break

Number of specimens failing to break 0

ARCTIC ADAPTS SYSTEM
ENVIRONMENTAL CHAMBER
TEST PLAN

TABLE OF CONTENTS

1.0 TEST LOCATION

The tests described in this test plan will be conducted in an environmental test chamber at the General Environments Corporation facility, 6840 Industrial Road, Springfield, Virginia 22151, (703) 354-2000.

2.0 TEST SCHEDULE

It is anticipated that this test program will require one week (five chamber days) and will be performed during the week of February 9-13, 1976.

3.0 <u>TEST PERSONNEL</u>

The following personnel will be responsbile for monitoring and/or performing the test program.

U. S. Coast Guard

Lt. James Getman, USCG - Project Officer (426-1023)
- Strike Team Member

Seaward International

Sidney Shaw - Project Manager (534-3500)

Michael Clarke - Project Engineer (534-3500)

Technician (to be determined)

General Environments (703) 354-2000

Wayne Burnett - Senior Test Engineer
- Chamber Operator
- Technician

4.0 TEST SEQUENCE

4.1 Day 1

- Transport equipment from Clearbrook, Va. to cold chamber.
- Position equipment in cold chamber.
- Rig fixtures for cargohose flex and tension tests.
- Connect engine exhaust system to chamber exhaust ducting.
- Instrument power unit and hoses with thermocouples and recording readouts.
- Begin cold soak at -40°

4.2 Day 2

- Verify that power unit has reached an equilibrium temperature of -40° or below, by reading oil sump thermocouple.
- Conduct engine start-up and operate until engine is running on diesel fuel only, then shut down engine to avoid heating up test chamber.
- Verify that chamber and hose test sections are at temperature of -40°. Conduct hose bending and tensile load tests on both the mil-spec and low temperature hose test sections.
- Couple and uncouple 6" Cam-lok coupling to verify performance and ability to perform in arctic dress.
- Uncoil hydraulic hoses and couple and uncouple quick connect fittings to verify performance and ability to perform in arctic dress.
- Remove test hose sections from the cold chamber and fill with arctic diesel fuel and cap. Replace test hose sections in position for proof testing and install thermocouples.
- If time permits, and engine and chamber temperatures are appropriate, conduct engine start up test, and bring up to operating temperature.

4.3 Day 3

- Verify that power unit has reached equilibrium of -40°.
- Conduct engine start-up only.

- Read hose test section thermocouple temperatures and verify -40°.
- Proof test all hose sections to 200 psi, in the following order:

  1. Low temp hose - saddle pull test section
  2. Mil-spec hose - saddle pull test section
  3. Low temp hose - 180° bend test section
  4. Low temp hose - 90° pull test section
  5. Mil-spec hose - 180° bend test section
  6. Mil-spec hose - 90° pull test section

- If time permits, and engine and chamber temperatures are appropriate, conduct engine start-up and warm-up test.
- Remove hose test sections from chamber and drain.
- Place all three cargo pumps (ni-resist, uncoated and coated meehanite) into the test chamber.

4.4 <u>Day 4</u>

- Verify that power unit is at equilibrium at -40°.
- Couple hydraulic hoses to power unit and cargo pump with warm up valve and gauge assembly on discharge side of the hydraulic motor. Attach unmodified quick connect to hydraulic pump discharge to test adequacy of original connectors.
- Start up engine.
- When engine is running on diesel fuel only (no ether) proceed with hydraulic start-up procedure, continue operating until cargo pump and engine are at full speed and at equilibrium temperature.
- Remove power unit from test chamber.

4.5 <u>Day 5</u>

- Verify that cargo pumps and chamber temperature are -40°F or less.
- Conduct abusive handling tests on all three cargo pumps starting with the uncoated meehanite, followed by the coated pump and then the ni-resist pump. After each "bang" make visual inspection of pump exterior for damage. After each test series, start prime mover and connect each pump to ensure operation.

- Upon conclusion of pump handling tests secure testing, open chamber to return to ambient temperature and remove all equipment.
- Pack up equipment for return to Clearbrook.

5.0 TEST PROCEDURES

5.1 Engine Start-Up

- Read and record all temperatures.
- Check that fuel is connected.
- Set air intake damper to closed position.
- Check that hydraulic pump control is in "no flow" position.
- Dose cylinders through dosing ports with 50/50 fuel and oil mixture and jack over engine.
- Set cooling air control to closed position.
- Check that valve between the two starter accumulators is open.
- Manually charge both accumulators to 3000 psi.
- Inject ether.
- Open starter valve.
- Continue ether injection as required to keep engine turning over until operation is sustained on diesel fuel only.
- If engine dies, repeat above sequence as rapidly as possible to make use of any heat build up in engine.

5.2 Engine Warm-up

- Start-up as in above procedure.
- Monitor engine oil temperature continuously and maintain between 140^{o} to 180^{o}F by means of engine cooling air and combustion air controls.
- Connect hydraulic hoses to power unit and to cargo pump with hydraulic warmup gage assembly installed on the discharge side of the cargo pump motor and the warm-up relief valve assembly at the hydraulic pump discharge.
- Slowly advance the pump flow control lever and monitor the motor discharge pressure and maintain at less than 150 psi. Continue to increase flow control until full flow is reached. Record hydraulic fluid temperature and engine oil temperature as a function of time.

5.3 <u>Hose Bend Test</u>

- While hoses are warm, insert thermocouples and bend hose sections (one of each material) into a sharp 180° bend and tie to hold in place.
- Cap both hose ends.
- Mark location of bend with felt tip marker.
- After thermocouple reads -40°, untie binding strap and straighten hose at a uniform rate, and record the time for straightening.
- Inspect for visual cracks or other damage.
- Fill hose with DF-A through fill connection until cross section is about circular.

5.4 <u>Hose 90° Pull Test</u>

- Attach one end of hose test section to the eyebolt on the chamber 'H' beam by means of a wire bridle.
- Pass the hose through the simulated Butterworth opening in the plate attached to the 'H' beam. Mark the bend location on the hose.
- Attach other end of the hose to a grip hoist by means of a wire bridle.
- Attach the grip hoist to a load cell which is anchored securely.
- Using grip hoist, pull on hose until load cell reads 1000 pounds. Maintain pull for ten minutes, then release.

5.5 <u>Hose Saddle Pull Test</u>

- Repeat procedure in 5.4 above, except with the hose guide saddle installed on the Butterworth plate to give a smooth radius to the bend.

5.6 <u>Hydrostatic Proof Test</u>

- Cap both ends of the hose section.
- Hang the hose vertically at room temperature and fill with DF-A through the 3/4" nipple provided in the upper and cap. When full, cap the 3/4 nipple with pipe cap.
- Place the hose section in the test chamber and suspend vertically from the tripod inside an open topped 55 gal drum.
- Open 3/4 pipe nipple and insert thermocouple.

- When hose interior reaches -40°F, remove thermocouple and cap 3/4" nipple.
- Attach hose from test pump to the 1/4" quick connect on the upper hose cap.
- Using the test pump (outside the chamber) raise the pressure in 25 psi increments until 175 psi. Check for leakage through hose wall or end connections at each increment.
- Increase pressure in 5 psi increments to 200 psi, checking for leakage at each increment.
- Hold 200 psi for 30 seconds and release.

5.7 <u>Pump Abusive Handling Test</u>

- Manually move the pumps across the two 'H' beams on chamber floor.
- Rig pump from tripod, suspended by grip-hoist wire at slight incline with motor end resting on chamber floor.
- Operate grip hoist as rapidly as possible to lower pump onto chamber floor.
- Repeat with all three pumps in order, check for any visual damage to pump or coating.
- Run pump to insure free rotation of shaft and impellers.
- Repeat above, but lower so that upper bowl housing impacts onto the 'H' beam as the pump descends.
- Repeat pump lowering with grip hoist but start with pump one foot above deck so that motor end impacts the chamber floor.
- Hold the pump rigidly in the vertical position and suspend a hammer from a pivot point directly above the pump by means of a line. Mount a protractor to measure the angle of the hammer off vertical. Pull the hammer back 10" and release so that it impacts the pump on the upper bowl casting. Repeat, increasing the angle in increments of 10°.

6.0 TEST EQUIPMENT

6.1 General Environment

- 12'x22' Test Chamber with anchor points capable of withstanding 1000# pull.
- Communications equipment for chamber
- Arctic clothing for G.E. personnel
- Load cell capable of measuring up to 2000#
- Recorder or visual read out for load cell
- Stopwatch
- Multiple thermocouples and 8 channel recorder
- 2000# capacity fork lift
- Dolley or platform truck for transporting filled 5 ft sections of 6" hose
- Dri-rite or other oil sorbent sweeping compound
- Blower for simulating 40 kt. wind in chamber.

6.2 Seaward International/Coast Guard

- Arctic modified ADAPTS pumping system

  Prime mover
  Ni-Resist cargo pump
  Elastomer coated cargo pump
  Standard cargo pump
  Low temperature 6" hose, 1x50', 3 ea x 5' with end caps
  Standard mil-spec 6" hose, 1x50' 3 ea x 5' with end caps
  Hydraulic hoses with modified and one unmodified quick connect
  Tripod and grip hoist
  Special hydraulic warm-up valve assembly

- 55 gal drum of DF-A arctic fuel
- Simulated Butterworth opening
- 6-inch hose guide saddle
- Two hose attachment wire bridles
- In line hydraulic temperature/pressure gage assembly
- Hydrostatic test pump with 25 ft of hose and 1/4 inch quick connect
- Fuel transfer pump
- Arctic clothing for Coast Guard and Seaward personnel
- Still camera and film

- Open topped 55 gal drum and other protective equip to prevent loss of fuel in event of a hose leak during proof testing.
- Additional hydraulic accumulator with valve.
- 5# hammer
- Protractor

ENVIRONMENTAL TEST DATA SHEET

Temperature Tests

Date	Time	Chamber Controller	Engine Ambient	Hose Section Temp.	Hyd. Line Temperature	Engine Oil Sump	Fuel Temp.	Remarks
2/17	0840	-40°F	-39.5C	-39°C	-40°C	-39.5°C	-36°C	Inspect test items. Attempt start. No start.
	0930	-41°F						Attempt start. No Start.
	1020	-41°F						Attempt start. No Start.
	1410	-43°F	-40°C	-41.5°C	-42°C	-41°C	-39°C	Attempt start; Refilled accumulator with N_2.
	1510	-42°F	-39°C	-41°C	-42°C	-40.5°C	-39°C	Attempt start. No Start.
	1600	-43°F						Attempt start. No start.
	1630	-43°F	CHAMBER TO -20°F					
	1635	-20°F						
	1715	-18°F	(-19°F) -28.5°C	(-22°F) -30°C	(-21°F) -29.5°C	(-27°F) -33°C	(-38°F) -39°C	Replacing engine fan belt.
	1840	-18°F	(-16°F) -27°C	(-20°F) -29°C	(-18°F) -28°C	(+77°F) +25°C	(-34°F) -37°C	Started engine.
	1855	-18°F	CHAMBER TO -40°F					
2/18	0810	-42°F	-40.5°C	-40.5°C	-41°C	-41°C	-38.5°C	Engine start; accumulators recharged; belt broke.

1) Yesterday opened two samples of hose that were bent back upon themselves. When opened, both samples cracked the outside sheath.

ENVIRONMENTAL TEST DATA SHEET

Temperature Tests

Date	Time	Chamber Controller	Engine Ambient	Hose Section Temp.	Hyd. Line Temperature	Engine Oil Sump	Fuel Temp	Remarks
2) Today performed pull test on four different samples. Filled all six sections of hose with DFA and checked for leaks.								
	0945	-40°F	-43.5°C	--	-40.5°C	-42°C	-40°C	Attempted engine start.
	1125	-41°F	-40°C	--	-39.5°C	-40°C	-39°C	Chamber to -30°F
3) When checking for leaks in hose sections, the Mil-Spec hose that was bent back on itself leaked; all other okay (room temperature).								
	1400	-31°F	-31.5°C	-15°C -9.5°C	-33°C	-34.5°C	-37.5°C	Accumulators recharged. Attempted engine start.
	1440	-31°F	-37°C	-19.5°C -12.5°C	-34°C		-36.5°C	Engine started.
	1450	-32°F	-34°C	-21°C -14°C	-28.5°C	+37°C	-37°C	Engine runningon two cylinders (1&3) only. Left bank is cold.
	1500	-32°F	-33°C	-20.5°C -14°C	-23°C	+49.5°C	-37°C	
	1510	-32°F	-34.5°C	-21.5°C -15°C	-18°C	+57.5°C	-36.5°C	
	1511	-32°F						Engine off. Putting warm-up assembly on hyd. line to heat up hydraulic oil.

ENVIRONMENTAL TEST DATA SHEET

Temperature Tests

Date	Time	Chamber Controller	Engine Ambient	Hose Section Temp.	Hyd. Line Temperature	Engine Oil Sump	Fuel Temp.	Remarks
	1520	$-32^{\circ}F$	$-32^{\circ}C$	$-21^{\circ}C$ $-15.5^{\circ}C$	$-18^{\circ}C$	$+63^{\circ}C$	$-36^{\circ}C$	Engine started.
	1530	$-32^{\circ}F$	$-34^{\circ}C$	$-21.5^{\circ}C$ $-15^{\circ}C$	$-2^{\circ}C$	$+63.5^{\circ}C$	$-36^{\circ}C$	Still only two cylinders (2&4); switched banks.
	1540	$-32^{\circ}F$	$-29^{\circ}C$	$-21^{\circ}C$ $-16^{\circ}C$	$+32^{\circ}C$	$+73.5^{\circ}C$	$-36^{\circ}C$	
2/19	1525	$-34^{\circ}F$	$-37^{\circ}C$	--	$-0.5^{\circ}C$	$+62.5^{\circ}C$	$-38^{\circ}C$	
	1535	$-32^{\circ}F$	$-32^{\circ}C$	--	$+29^{\circ}C$	$+82^{\circ}C$	$-37.5^{\circ}C$	Started; running on all four cylinders
	1540	$-28^{\circ}F$	$-32^{\circ}C$	--	$+37^{\circ}C$	$+88^{\circ}C$	$-38^{\circ}C$	Engine off. Chamber to -40°
	1635	$-41^{\circ}F$						Setting up to perform handling tests on pumps.
	1750	$-43^{\circ}F$	MAINTAIN $-40^{\circ}F$					
2/20	0845	$-42^{\circ}F$	$-41.5^{\circ}C$	--	$-41.5^{\circ}C$	$-41.5^{\circ}C$	$-39^{\circ}C$	
	1025	$-43^{\circ}F$	$-36^{\circ}C$	--	$-41^{\circ}C$	$-40^{\circ}C$	$-38^{\circ}C$	Attempted engine start.
	1520	$-42^{\circ}F$	$-42^{\circ}C$	--	$-42^{\circ}C$	$-41^{\circ}C$	$-39^{\circ}C$	Attempted engine start.
	1535	$-42^{\circ}F$	$-38^{\circ}C$	--	$-41^{\circ}C$	$-12^{\circ}C$	$-38.5^{\circ}C$	Engine started. Running on 1&3 only.
	1540	$-42^{\circ}F$						Engine off.
	1610	$-42^{\circ}F$	CHAMBER TO ROOM AMBIENT					

General Environments Corporation / Hartwood, Virginia 22471 / (703) 752-5121

REPORT

Client: Seaward International, Inc.
6260 Leesburg Pike
Falls Church, Virginia 22044

Report No. A-5244
Date 3 June 1976

Subject: Low Temperature Testing of Arctic Adapts System in accordance with Seaward P. O. No. 003584 and Seaward Preliminary Test Plan dated 7 January 1976.

1.0 GENERAL

The Arctic Adapts System was subjected to handling and functional tests in a temperature chamber, GEC No. 128D, maintained at -40° ± 5°F (except where otherwise noted). All functional tests were performed by Seaward personnel. All functional test results noted in this report were given to GEC by Seaward personnel. The test program was witnessed by U. S. Coast Guard representatives.

2.0 ENGINE OPERATION

The Arctic Adapts System diesel engine was thermally stabilized, as indicated by a thermocouple installed in the engine oil sump, and the starting system actuated. Attempts to start the engine at -40°F were unsuccessful.

System configuration was changed and the engine started at -40°F. The Seaward representative reported the engine running on two of four cylinders only.

3.0 HOSE BEND TEST

Two hose sections were bent into a sharp 180° bend while at standard ambient temperature and tied to prevent unbending. The two sections were placed in the chamber and allowed to stabilize at -40°F. Stabilization was ascertained by means of thermocouples inserted inside the hose section. After stabilization, the sections were unbent while in the chamber, and visually examined for evidence of cracking.

Test Results

Both sections exhibited cracks in the outer jacket as a result of the bend test.

4.0 HOSE 90° PULL TEST

Four hose sections were subjected to a 1000 lb. pull while being bent 90° through a Butterworth opening (as used on board ships for tank access). After stabilizing at -40°F. Two hoses were pulled with a hose guide saddle to prevent a sharp bend, two without the saddle. The 1000 lb. load was maintained for approximately 10 seconds.

Test Results

There was no visual evidence of damage to the four hose sections as a result of the 90° bend test.

5.0 HOSE HYDROSTATIC PROOF TEST

The hoses subjected to the bend test and the 90° pull test, (6 hoses) were filled with Arctic Grade diesel fuel at standard ambient temperature. The ends of the hoses were sealed and the hose section placed in the chamber. The chamber temperature was maintained at -40°F. A thermocouple in the hose sections was used to determine stabilization at -40°F. Each hose section, individually was pressurized at 200 psig for 30 seconds.

Test Results

1) Bend Test Sections: The "MIL-H" hose section leaked where bent when initially filled and was removed from test. the second hose section did not leak when subjected to 200 psig pressure while at a temperature of -40°F.

2) 90° Pull Test Sections: The "MIL-H" hose section pulled without the saddle, leaked through the hose wall where it was bent around the edge of the Butterworth opening. The 3 remaining sections did not leak.

6.0 PUMP ABUSIVE HANDLING TEST

The pumps were subjected to the handling test at -40°F by the Seaward representatives.

Test Results

The Seaward representatives did not report any damage to the pumps.

GENERAL ENVIRONMENTS CORPORATION

APPROVED L. M. Anstey

BY L. W. Burnett

FORM NO. 120

ARCTIC ADAPTS SYSTEM

FIELD TEST PLAN

TABLE OF CONTENTS

1.0 TEST OBJECTIVE

To determine if the Arctic modifications to the ADAPTS transfer pumping subsystem components and operating procedures are satisfactory to permit reliable operation of this equipment under actual Arctic environmental conditions by strike force personnel in arctic dress.

1.1 Test Goals

- Maximum number of cold engine starts within the time available.
- Maximum hours of system operation within the time available.

Note: Since the two above goals cannot be accomplished concurrently, a balance will have to be struck between them in allocating time.

1.2 Desired Test Results

- Pump performance curve under arctic conditions.
- Evaluation of the arctic modifications adequacy.
- Suggested additional modifications required to enhance system performance or reliability.

2.0 TEST LOCATION

The arctic field tests will be conducted at:

Fort Wainwright
Fairbanks, Alaska

using a 25,000 bbl capacity tank of JP-4 fuel at the base petroleum tank farm.

2.1 Contact Point

Mr. Vern McConnell   Telephone (907) 352-7215
Bldg. 1173
Petroleum Division
Fairbanks Terminal
Ft. Wainwright
Fairbanks, Alaska

2.2 Billeting

Housing during the test period will be at:

Murphy Hall Transient Quarters
Ft. Wainwright
Telephone (907) 353-7291

3.0 TEST SCHEDULE

It is anticipated that this test program will require five operating days and that it will be performed during the week of March 1-5, 1976.

3.1 Equipment Shipment

The arctic-modified ADAPTS system and related equipment will be shipped on Government Bill of Lading L-0919763. It is to be picked up on February 25th by Wilson Trucking at Clearbrook, Virginia, and delivered to Northwest Airlines at Dulles airport for shipment to Anchorage on NW #3 on February 26th and then to Fairbanks on Wein Consolidated on one of their six daily flights.

Shipment will be made on Northwest Airlines air waybill No. 012IAD69732294.

4.0 TEST PERSONNEL

The following personnel will be responsible for monitoring and/or performing the test program.

U. S. Coast Guard

Lt. James Getman, USCG - Project Officer (202) 426-1023

MK1 C. MacKnight, USCG - Atlantic Strike Team (919) 338-1100

CWO James Rivera, USCG - Pacific Strike Team (415) 556-1342

MK1 Gary Davis, USCG - same as above

DC1 Phil Jensen, USCG - same as above

Seaward International

Sidney H. Shaw - Project Manager (703) 534-3500

5.0 TEST SEQUENCE

5.1 Day 1

- Check out equipment in protected environment, checking the following points:

  Precharge in all accumulators

  Lube oil level

  Hydraulic fluid level

  Start and run engine, run up to 3000 RPM and ensure all cylinders are firing

  Fill additional hydraulic hoses with Mil 5606C fluid

- Install Kamlok adapter on tank discharge line.
- Transfer equipment to the test tank and locate hoses along spiral stairway while still pliable enough to be routed at will. Lash hoses to stairway if necessary.
- Rig flow meter to hose line and the hose to the tank flange.
- Rig tripod and other lift equipment as required to raise the two submersible pumps to the tank top.
- Shift the tripod to straddle the tank top manhole opening.
- Connect the 6-inch cargo hose and the hydraulic hoses to the standard ADAPTS meehanite pump, with the warm-up pressure gauge installed on the discharge side of the pump motor.
- When engine oil has reached ambient temperature, conduct engine arctic prestart and start procedures.
- When engine is running smoothly on diesel fuel alone, commence hydraulic system warm-up procedure using the relief valve assembly on the Lucas pump discharge and the flow controller.

CAUTION: Never exceed 200 psi indicated pressure on the gauge on the pump motor discharge.

- When full 30 gpm hydraulic flow can be obtained without exceeding 200 psi on the motor return side, remove waterproofing boot and tape from the pump and remove the pressure gauge assembly from the hydraulic line. (Note: the engine will have to be secured for this operation to relieve any pressure in the lines)

- Lower the submersible pump into the tank and commence pumping.

- Check out all instrumentation and other indications for normal operation.

- Once normal operation has been obtained, secure all equipment and allow equipment to cold soak overnight. If the pump is removed from the tank, it should be covered to keep out moisture. Cover prime mover if necessary to keep snow off.

5.2 Day 2

- Record all temperatures

- Check out engine fluid levels and hydraulic accumulator precharge pressures.

- Conduct engine start-up and hydraulic system warm-up as before, monitoring hydraulic system pressure.

- Commence pumping. Vary hose line back pressure by varying gate valve opening. Record flow rate and pressure for each valve setting to generate pump curve.

- Repeat this process using the special Ni-resist pump.

- Secure pumping and inspect all system components. (Inspection to be done either in place or in a heated shop area as deemed appropriate).

- Cold soak equipment overnight as before.

5.3 Day 3

- Repeat Day 2 procedure but with sustained periods of pumping with each pump of several hours duration.

5.4 Day 4

- Early morning - Start engine and warm up system as before.
- When warmed-up commence sustained pumping with gate valve adjusted to give 1000 gpm flow rate.
- Continue pumping all night, recording engine, hydraulic system and cargo flow data.

5.5 Day 5

- Secure pumping. Unrig equipment and drain cargo hose into 55 gal. drum.
- Return equipment to heated shop area, inspect, clean and pack for shipment.

6.0 TEST EQUIPMENT

6.1 Available on Scene

- Vehicle for shelter and transportation
- Standard cylinder of dry nitrogen, pressure above 2000 psig
- Arctic grade diesel in 55 gal. drum
- Mil H 5606C hydraulic fluid
- Storage tank of JP4 with man hole on top and 8" flange connection with gate valve at bottom
- Heated shop area for equipment storage and check out.

6.2 Pacific Strike Team

- 2 each 80 ft. lengths of hydraulic hoses
- Tool kit
- Standard system spares including air, oil, fuel filters and six spare fan belts of each size.
- Flow meter with readout and end connections for inserting in the 6 inch cargo hose line.
- Adapter to mate 6 inch hose line to 8 inch flange, with 0-50 psi pressure gage installed.
- Fuel drum transfer pump

6.3 Seaward International

- Arctic modified ADAPTS pumping system:
  - Prime mover with three hydraulic accumulators and ether start
  - Ni resist cargo pump
  - Standard Meehanite cargo pump
  - 2 each 80 ft. lengths of hydraulic hose with low temperature quick connects

- 6 each 50 ft. lengths of low temperature 6 inch cargo hose with Kamlok fittings with low temperature gaskets
- Tripod and snatch block
- Griphoist with 100 ft. wire
- Special hydraulic warm-up relief valve assembly
- Hydraulic line pressure and temperature assembly.

- Still camera and film
- Data sheets
- Thermometer for recording ambient temperatures
- Charging assembly for hydraulic accumulators
- Graph paper
- 2 each 6 inch female Camlok to 6 inch female pipe thread adapters
- Spare Snap tite couplings
- Spare 'O' rings and back-up rings for hydraulic accumulators

7.0 SUMMARY OPERATING PROCEDURES FOR ADAPTS ARCTIC OPERATIONS

7.1 Preparation Prior to Mobilization (assume modified unit)

- Change engine oil to Polar Start 600 or equal. (While oil is drained, remove oil temperature sensor and install dial thermometer directly into oil sump.)
- Change hydraulic oil in prime mover unit, all hydraulic hoses, piping, motors, accumulators, and hand pump.
- Connect engine to supply of DFA and operate for minimum of ten minutes to remove all #2 fuel.
- Be sure all equipment is dry, cover prime mover; cover intakes, slots and discharge of submersible pumps.

7.2 Operation

- Unpack and locate equipment on deck, unrolling and arranging hose carefully, avoiding short bends, leave submersible pump on deck. If possible, route hoses before they cool to ambient and become stiff.
- Install fuel adapter in drum of DFA and connect engine (high fittings on adapter must go to supply hose). Relieve poppet valve on supply and fill standpipe by tilting drum or by blowing into drum vent hole.
- Connect extra accumulator.
- Connect warm-up valve assembly to prime mover discharge back off hand wheel all the way.
- Connect necessary hydraulic hose to pump motor high pressure in (female fitting).
- Connect warm-up pressure/temperature gauge assembly to pump motor low pressure return (male fitting).
- Connect necessary hydraulic hose from pressure/ temperature gauge assembly to prime mover return.
- Open air bleed needle valve half way to relieve charge pump.

- Close cooling air and combustion air ducting valve.
- Put throttle in full on position.
- Dose engine with DFA/lube oil mix 80/20 and jack over.
- Pump both accumulators to 3000 PSI (3200 with the gauge on prototype which reads low).
- Close off second accumulator.
- Actuate starter.
- Dose with DFA, pump up accumulator and crank.
- Repeat above twice more in rapid succession.
- Bring both accumulators to 3000 (second accumulator valve open).
- Double dose engine with DFA.
- Pull ether knob two seconds prior to cranking, crank with two accumulators.
- If engine does not start, repeat operation. Caution should be exercised so as not to over dose the engine.
- With engine running stop ether injection by pushing knob in, inject ether as needed to maintain operation.
- When engine is running steadily on DFA only, open cooling duct very slightly (1/16 to 1/8 in.) to avoid "hot spots."
- Close air bleed needle valve (do not exceed 150 PSI on a large gauge).
- When engine oil temperature has reached 0 to +10°F bring to 2000 RPM and screw in Lucas controller sufficiently to spin pump.

  Note: Watch charge pressure closely, if air bleed valve is still partly open, close completely as Lucas begins operation.

- Turn in hand wheel on warm-up relief valve, raising main system gauge pressure 500 PSI above that required to operate submersible pump (about 1000 PSI total).

- Monitor return line gauge assembly pressure and begin advancing Lucas controller as hydraulic oil warms, do not exceed 250 PSI return pressure, do not exceed 140°F hydraulic oil temperature.

- When engine oil temperature has reached +50°F open combustion air ducting valve.

- When hydraulic oil has warmed sufficiently to allow full flow of Lucas and full engine RPM bring flow to zero, remove gauge and warm-up valve assemblies (stopping engine if necessary).

- Lower the pump into the oil and proceed by normal procedures to pump cargo.

- Adjust cooling air damper as necessary to maintain loaded engine temperature in range 160-200°F.

ADAPTS
ARCTIC FIELD TEST
DATA SHEET

Date: ____________________

Time	Eng Oil Temp	Eng Oil Pres	Hyd Oil Temp	Hyd Motor Pres (Out)	Lucas Contr Position	Eng RPM	Cargo Flow	Cargo Hose Press	Air Temp	Wind Vel	Comments

ADAPTS
ARCTIC FIELD TEST
DATA SHEET

Date: 2 March 1976

Time	Eng Oil Temp	Eng Oil Pres	Hyd Oil Temp	Hyd Motor Pres (Out)	Lucas Contr Position	Eng RPM	Cargo Flow	Cargo Hose Press	Air Temp	Wind Vel	Comments
0545	13	0	13	0	Out	0	0	0	+13	0	Ready to start up
0625	15	95	15		Out	1800	-		+15	0	Start first time ~40 sec on ether
0628	50	115	-		In 2 Turns	1800			+15	0	Running well on all 4 cyl.
0633	100	108	-	200	In 2 Turns	17.30			+15	0	Open comb. air butterfly
0638	125	102			In 2 Turns	1700			+15	0	Increase to 2000 RPM
0640	130	102			In 2 Turns	2000			+16	0	
0646	150	100			In 2 Turns	2000			+15	0	
0652	150	100	15	150	In 2 Turns	2000			+15	0	Secure
E-39											
0755	95	100			In 2	1700			+19 Snow	0	Restart - ether ~10 sec
0805	125	107	17	150		↓ 2200				5 MPH SE	Start Warmup
0814			30	200							
0819			40	225							
0823			50	200		2000					
0825			60	200		↓ 2600					
0829			70	200							
0831			75	250	Full	3000					Complete Warmup - Lower Pump
0838	175	100	56	-		2450					Start pumping
0842	185	100	54	-	In 1/2	2850	1250	12	+20	SE 5	Open Tank Valve Wid
0846	duct open wide 200	98	54	-	In 1/2/1500 psi	2850	1400				
0848	200	98	58		In Full/1825	2775	1500				Run control in full
0850	200	92	60		Full in 1825	2600	1575	12			
0900	215	85	70		Full in 1825		1600	12			

ADAPTS
ARCTIC FIELD TEST
DATA SHEET

Date: 2 March 1976

Pump Curve

Time	Eng Oil Temp	Eng Oil Pres	Hyd Oil Temp	Hyd Motor Pres (Out)	Lucas Contr Position	Eng RPM	Cargo Flow	Cargo Hose Press	Gate Valve ~~Hand~~-wheel	Wind Vel	Comments
0905							1600	12 1/2	0 Turn In		
							1575	12 1/2	2		
							1525	15	4		
							1500	17 1/2	6		
0909							1325	23	8		
							1000	34	10		
							725	42	11		
							375	50	12		
							175	54	12 1/2		
							0	56	13		
0914							0	57	15 1/2 SHUT		
0915	225	85	71	-	Full in 1825	2525	1600	13	Full Open		
0920											Shut down to fix hose leak
1345	50	120	28	100	Out				+26	SW ~3	Start eng. 10 sec on ether
1350	120	110	30	180	1/3 1000 psi	2000					
1355	160	105	46	225	3/4 1000	2500					
1358			61	250	Full in 1000				+28		
1359			66	260	Full in	2800			+28		
1400	185	105	73	250	Full in 500	2900			+28		
1405			80	250	Full in 1000				+28		Throttle Back & remove gauge
1410	175	105	72	-	Out	2900					Back up to speed no load & no relief valve
1425	190	102	58	-	1/2 in 1000	2850					Put relief warmup valve back in systems to keep hyd. warm while
1445	SECURE		Total Flow 4676 gpm								waiting for repair of flow meter assembly leak

E-40

ADAPTS
ARCTIC FIELD TEST
DATA SHEET

Date: 3 March 1976

Time	Eng Oil Temp	Eng Oil Pres	Hyd Oil Temp	Hyd Motor Pres (Out)	Lucas Contr Position	Eng RPM	Cargo Flow	Cargo Hose Press	Air Temp	Wind Vel	Comments
0803	22								+22		Start eng - 10 sec on ether
0810	115	110	20		2 Turn in/300 psi	2100					Warm up w/gauge on eng. not pump
0817	152	100	22		2 Turns/1000 psi	2100					
0826	165	100	40		5 Turns/1000	2500					
0835	185	98	60		8 Turns/1000	2500					
0840	200	98	83		Full 13 Turns/ 1000	2900			+23		Idle back, remove warmup valve, Lower Pump
0915	165	95	40		1/2 in	2000	900				Had problems w/hose kinking - Commence Pumping
0927	180	95	40		8 Turns/1000	2000	300				Put warmup valve back to heat
0930	185	98	48		8 Turns/1000	2500	500				
0940	210	95	58		10 Turns/1200	2900	950		+24		
0944	210	88	60		Full in/1800	2650	1350				250 gpm reduction in max flow due to warmup valve - Remove it
0948	210	85	65		Full in/1800	2650	1350				
1004	220	82	71		Full in/1775	2525	1600	12.8	+25	0	
1005	220	82	71		Out 1 1/2/ 1810	2650	1600				
					Out 2 1/2/ 1640	2775	1500				
1008	225	82	71		Out 1 3/4/ 1825	2750	1600				Try #1 Diesel Fuel
1037	215	82	70		Out 2 1/2/ 1775	2775	1500				Try #1 Diesel Fuel
					Out 1 1/2/ 1875	2675	1500				Try #1 Diesel Fuel
					Out 2 1/2/ 1750	2775	1500				Try #1 Diesel Fuel
					Full in/1760	2525	1560				
1115	235	81	77		Out 1 1/2/ 1825	2675	1550		+33	0	Still on #1/About 125,000 gal. pumped
1124	235	81	77								Switch back to DFA
1130	SECURE										151,040

ADAPTS
ARCTIC FIELD TEST
DATA SHEET

Tachometer Check

Date: 3 March 1976

Time	Eng Oil Temp	Eng Oil Pres	Hyd Oil Temp	Hyd Motor Pres (Out)	Lucas Contr Position	Eng RPM	Hand Tach.	Speed Error	Air Temp	Wind Vel	Comments
						2000	2300				
						1000	1150				
						2610	3000				
							Calibrated Tachometer				
						1000	1140	12% low			
						1500	1730	13%			
						2000	2320	14%			
						2500	2880	13%			
						2630	3000	12%			
						2900	3320	13%			

ADAPTS
ARCTIC FIELD TEST
DATA SHEET

Date: 4 March 1976

Time	Eng Oil Temp	Eng Oil Pres	Hyd Oil Temp	Hyd Motor Pres (Out)	Lucas Contr Position	Eng RPM	Cargo Flow	Cargo Hose Press	Air Temp	Wind Vel	Comments
~0800	Started engine and warmed up hyd. system										
0900	205	95	68		Out 1 1/2/ 1850	2780	1520	12.8	+31	N 5 Snow	
0920	220	88	74		Out 1 1/2/ 1860	2780	1600	12.8	+30	N 5 Snow	
1000	225	82	77		Out 1 1/2/ 1830	2750	1600	12.8	+29	N 5 Snow	125,000 gal. pumped
1015	Secure check injectors all normal										136,970

ADAPTS
ARCTIC FIELD TEST
DATA SHEET

Date: 5 March 1976

Time	Eng Oil Temp	Eng Oil Pres	Hyd Oil Temp	Hyd Motor Pres (Out)	Lucas Contr Position	Eng RPM	Cargo Flow	Cargo Hose Press	Air Temp	Wind Vel	Comments
0800	Arrive	on scene							+15		
0808	~15	100	18		Out	1700	Act 1840		+18	0	Start, 15 sec ether
0815	100	105	18		in 1	1700			+18	0	Warming up with gauges at eng.
0820	125	100	14		in 6/1500	1700			+13	0 Sun	
0830	165	98	30		in 6/1500	2000					
0835	180	90	40		in 10/1500	2000	800				
0841	180	90	50		in 10/1500	2000	800				
0848	185	90	57		in 12/1500	2000	850				
0850	185	85	61		Out 1 in 14/1500	2000	1060		+15		
0855	190	90	64		Out 1 1/2/Valve backed out 1600	2250	1250		+15		
0900	200	95	72		Out 1 1/2/ 1800	2780 ↑ 3180 actual	1500		+16		Full flow with warmup valve in line
0908	205	98	74		Out 1 1/2/ 1850	2800	1550				Remove restrictor
0926	215	90	80		Out 1 1/2/ 1850	2800	1590	13	+20		67,500 total
0950	215		81	SECURE		2800	1595		+23°		94,950

ADAPTS
ARCTIC FIELD TEST
DATA SHEET

Date: 6 March 1976

Time	Eng Oil Temp	Eng Oil Pres	Hyd Oil Temp	Hyd Motor Pres (Out)	Lucas Contr Position	Eng RPM	Cargo Flow	Cargo Hose Press	Air Temp	Wind Vel	Comments
0749	On Scene								+17	0 Clear &	sunny
0755		105	20		Out	1250					Start ~15 sec ether
0800	70	105	22		In 3/600	1600					
0805	115	101	18		In 6/1200	1600					
0815	160	87	32		In 8/1500	1600	160				
0820	160	100	42		In 8/1500	2000	300				
0823	160	100	48		In 10/1500	2000	510				
0826	160	98	54		In 12/1500	1950	800				
0830	165	95	60		Out 1 1/2 In 14/1500	1900	1040				
					1325 Back off warmup		1050				
0834	180	102	64		Out 1 1/2/ 1800	2750	1450				Full bore with warmup in line
0837	190	100	70		Out 1 1/2/ 1810	2800	1550				
0845	210	95	81		Out 1 1/2/ 1825	2775	1560	29,100 gal.	+26		
0900	210	90	88				1570				Remove warmup valve
		92	82		Out 1 1/2/ 1850	2750	1600		+28		
0912	225	92	82		Out 1 1/2/ 1850	2750	1600	65,460 gal.			Idle down & shutdown

ADAPTS
ARCTIC FIELD TEST
DATA SHEET

Date: 8 March 1976

Time	Eng Oil Temp	Eng Oil Pres	Hyd Oil Temp	Hyd Motor Pres (Out)	Lucas Contr Position	Eng RPM	Cargo Flow	Cargo Hose Press	Air Temp	Wind Vel	Comments
0520									+11	0	
0530									+11	0	Started 15 seconds on ether
0535		110			0	1500	0	12	+11	0	
0538	80	105	14	150	0	1500	0	12	+11	0	
0540	80	105	15	150	0	1800	0	12	+11	0	
0545	125	102	18	150	3/500	1800	0	12	+12	0	
0550	150	100	14	150	5/500	2000	0	12	+12	0	
0555	160	99	22	150	6/500	2000	0	12	+12	0	
0602	170	95	26	125	8/800	2050	400	12	+12	0	
0607	170	95	32	125	8/800	2050	350	12	+12	0	
0610	170	95	35	125	8/800	2100	400	12	+13	0	
0620	185	95	42	100	11/1300	2100	725	12	+13	0	
0625	185	100	54	100	11/500	2550	1000	12	+11	0	
0630	185	100	60	100	11/500	2550	1050	12	+12	0	
0635	185	100	65	100	13/1650	2500	1250	12	+12	0	
0640	195	99	76	100	Full 1800	2800	1500	12	+12	0	
0645	200	95	82	100	Full 1850	2800	1500	12	+14	0	
0650	205	95	85	100	Full 1850	2800	1550	12	+15	0	48720 gallons pumped
0655			87		SECURED						65460 gallons pumped from 3-6-76

ADAPTS
ARCTIC FIELD TEST
DATA SHEET

Date: 3/9/76

Time	Eng Oil Temp	Eng Oil Pres	Hyd Oil Temp	Hyd Motor Pres (Out)	Lucas Contr Position	Eng RPM	Cargo Flow	Cargo Hose Press	Air Temp	Wind Vel	Comments
0530									+ 5	0	
0540									+ 5	0	Started 15 sec. on either
0545		110	10		0	1600	0	12	+ 6	0	
0550	50	110	10	150	0	1600	0	12	+ 6	0	
0600	80	110	18	150	3/400	1600	0	12	+ 6	0	
0606	110	105	20	150	3/400	1600	0	12	+ 6	0	
0610	125	105	20	150	5/500	1600	0	12	+ 6	0	
0615	140	102	25	150	6/700	2000	350	12	+ 6	0	
0620	150	100	31	125	7/900	2000	450	12	+ 6	0	
0625	160	100	36	125	7/900	2000	450	12	+ 6	0	
0630	170	98	40	125	9½/1000	2000	600	12	+ 8	0	
0640	180	95	46	125	11/1250	2200	750	12	+ 8	0	
0650	200	95	58	125	13/1400	2500	1000	12	+ 8	0	
0700	200	95	64	125	Full 1850	2800	1450	12	+ 8	0	
0710	200	95	70	125	Full 1850	2800	1500	12	+ 9	0	
0720	210	95	75	125	Full 1850	2800	1500	12	+10	0	
0730	210	95	81	125	Full 1850	2800	1500	12	+11	0	
0740	210	95	85	125	Full 1850	2800	1500	12	+12	0	59140 pumped this date
0750			85		Secured						

ADAPTS
ARCTIC FIELD TEST
DATA SHEET

Date: 3/10/76

Time	Eng Oil Temp	Eng Oil Pres	Hyd Oil Temp	Hyd Motor Pres (Out)	Lucas Contr Position	Eng RPM	Cargo Flow	Cargo Hose Press	Air Temp	Wind Vel	Comments
0500									+ 6	0	Arrived; installed new
0525	0	105	10	0	Out	1700	0	0	+ 6	0	return psi gauge
0530	100	105	10	0	Out	1700	0	0	+ 6	0	#2 Fuel Oil
0535	120	100	10	120	4/500	1700	0	12	+ 8	0	
0540	140	98	14	110	4/1000	1750	0	12	+ 8	0	
0545	150	90	14	110	4/1000	1750	0	12	+ 8	0	
0550	160	85	14	105	6/1200	1750	0	12	+ 8	0	
0555	175	96	74	100	6/1200	2000	0	12	+ 8	0	
0557	175	96	30	100	8/1000	2000	500	12	+ 8	0	
0600	165	100	36	100	8/1000	2000	500	12	+ 8	0	
0605	160	100	42	100	10/1000	2000	750	12	+ 8	0	
0615	165	95	52	100	13/1500	2000	1200	12	+ 8	0	
0620	175	95	60	100	Full/1850	2700	1450	12	+ 8	0	
0625	210	90	74	90	Full/1850	2700	1500	12	+ 7	0	
0635	215	87	82	90	Full/1900	2700	1500	12	+ 9	0	
0640	215	85	86	90	Full/1900	2750	1550	12	+10	0	
0645				TOOK THE	LOAD OFF ENGINE	RPM	2950	ON #2DF			No load
											50230 gal pumped this date

ADAPTS
ARCTIC FIELD TEST
DATA SHEET

Date: 11 March 1976

Time	Eng Oil Temp	Eng Oil Pres	Hyd Oil Temp	Hyd Motor Pres (Out)	Lucas Contr Position	Eng RPM	Cargo Flow	Cargo Hose Press	Air Temp	Wind Vel	Comments
0520									-5	0	Arrived
0531					Lit Off On 1 Accumulator						
0537	75	110	2	100	Out	1700	0	0	-4	0	
0542	100	100	2	100	3/500	1700	0	0	-4	0	
0545	125	95	4	100	4/1000	1700	0	0	-2	0	
0551	150	85	8	100	7/1000	1650	0	0	-2	0	Flow meter counter
0555	165	95	16	100	7/1000	2000	0	0	-2	0	Stopped
0557	175	90	20	100	7/1000	2000	250	12	-2	0	
0600	175	90	24	100	8/1000	2000	300	12	-2	0	
0604	180	85	30	100	10/1000	2000	650	12	-1	0	
0610	185	80	36	100	12/1300	2000	800	12	-1	0	
0611	205	90	45	100	12/1400	2500	1100	12	-1	0	
0620	210	85	50	100	12/1500	2500	1250	12	-1	0	Flow meter stopped
0627	200	90	58	100	13/1800	2900	1450	12	-1	0	Showing G.P.M.
0635	215	90	66	100	Full 1825	2850	Unknown	12	-1	0	May be machine froze
0645	215	85	80	100	Full 1850	2850	Unknown	12	0	0	
0650	215	85	83	100	Full 1850	2850	Unknown	12	0	0	
0655			83		Secured				0	0	

ADAPTS
ARCTIC FIELD TEST
DATA SHEET

Date: 3/12/76

Time	Eng Oil Temp	Eng Oil Pres	Hyd Oil Temp	Hyd Motor Pres (Out)	Lucas Contr Position	Eng RPM	Cargo Flow	Cargo Hose Press	Air Temp	Wind Vel	Comments
0515			6						+4	0	Snowing; arrived; started
0530			6		5 seconds on	either			+4	0	engine.
0535	90	115	8	0	0	1875	0	12	+4	0	
0540	125	100	8	0	0	1875	0	12	+4	0	
0545	140	99	12	100	5/1000	1850	0	12	+5	0	
0550	165	90	20	100	7/1100	1850	150	12	+5	0	
0555	175	95	28	120	7/1100	2100	300	12	+5	0	
0600	185	90	34	100	8/1200	2150	300	12	+7	0	
0605	185	90	40	100	10/1400	2100	700	12	+5	0	
0610	185	90	47	100	11/1500	2100	800	12	+6	0	
0615	190	95	60	90	11/1650	2500	1000	12	+6	0	
0620	205	95	70	90	Full 1850	2900	1550	12	+6	0	
0525	225	85	78	90	Full 1850	2850	1550	12	+6	0	
0635	225	85	83	90	Full 1850	2850	1550	12	+6	0	3/4" Nipple Cracked
0636	SECURED										on Accumulator Lost
											Charge
											35040 Gal.Pumped

GPO 912-755