



Standard Specification for Sealless Lube Oil Pump with Oil Through Motor for Marine Applications¹

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^{ε1} NOTE—The Keywords Section was editorially added in November 2014.

1. Scope

1.1 This specification defines the requirements applicable to design, construction and testing of sealless, rotary positive displacement pumps with oil-through motors for ship lubricating oil service. The complete pump and motor assembly is referred to as canned lube oil pump (CLP). This specification applies to CLPs pumping oil with a SAE rating of 20–50.

1.2 The values stated in inch-pound units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

2. Referenced Documents

2.1 ASTM Standards:²

- A27/A27M Specification for Steel Castings, Carbon, for General Application
- A159 Specification for Automotive Gray Iron Castings
- A193/A193M Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications
- A194/A194M Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
- A216/A216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service
- A395/A395M Specification for Ferritic Ductile Iron

Pressure-Retaining Castings for Use at Elevated Temperatures

A449 Specification for Hex Cap Screws, Bolts and Studs, Steel, Heat Treated, 120/105/90 ksi Minimum Tensile Strength, General Use

A536 Specification for Ductile Iron Castings

A563 Specification for Carbon and Alloy Steel Nuts

A564/A564M Specification for Hot-Rolled and Cold-Finished Age-Hardening Stainless Steel Bars and Shapes

A574 Specification for Alloy Steel Socket-Head Cap Screws

A582/A582M Specification for Free-Machining Stainless Steel Bars

B23 Specification for White Metal Bearing Alloys (Known Commercially as “Babbitt Metal”)

B148 Specification for Aluminum-Bronze Sand Castings

B152/B152M Specification for Copper Sheet, Strip, Plate, and Rolled Bar

B187M Specification for Copper Bar, Bus Bar, Rod and Shapes [Metric] (Withdrawn 2002)³

B271 Specification for Copper-Base Alloy Centrifugal Castings

B505/B505M Specification for Copper Alloy Continuous Castings

B584 Specification for Copper Alloy Sand Castings for General Applications

D2000 Classification System for Rubber Products in Automotive Applications

D3951 Practice for Commercial Packaging

F912 Specification for Alloy Steel Socket Set Screws

F1510 Specification for Rotary Positive Displacement Pumps, Ships Use

2.2 ASME/ANSI Standards:⁴

ASME/ANSI B16.5 Pipe Flanges and Flanged Fittings

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² For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

³ The last approved version of this historical standard is referenced on www.astm.org.

⁴ Available from American Society of Mechanical Engineers (ASME), ASME International Headquarters, Two Park Ave., New York, NY 10016-5990, <http://www.asme.org>.

2.3 *Hydraulic Institute Standards*.⁵

ANSI/HI 3.6 Rotary Pump Tests

2.4 *AISI Standards*.⁶

1018 Carbon Steel

1045 Carbon Steel

1141 Carbon Steel

1144 Carbon Steel

4140 Chromium-molybdenum steel

4150 Chromium-molybdenum steel

4340 Nickel-chromium-molybdenum steel

2.5 *AIA Standards*.⁷

NASM 17829

2.6 *API Standards*.⁸

API Standard 676 Positive Displacement Pumps—Rotary

3. Terminology

3.1 *Definitions of Terms Specific to This Standard*:

3.2 *canned lube oil pump unit*—a unit, which when assembled as a pump and motor, is completely sealed from leakage to the environment. Lubrication and cooling of motor bearings and primary cooling of motor windings and insulation are achieved by circulating a portion of the fluid being pumped (oil) through the motor.

3.3 *capacity*—the quantity of fluid actually delivered per unit of time at the rated speed, including both the liquid and dissolved or entrained gases, under stated operating conditions. In the absence of any gas or vapor entering or forming within the pump, the capacity is equal to the volume displaced per unit of time, less slip, motor bearing lubrication and motor cooling flows.

3.4 *displacement*—the volume of fluid displaced per revolution of the rotor(s).

3.5 *rated condition point*—the required capacity at speed, pressure, viscosity and power as specified by the purchaser.

3.6 *slip*—the quantity of fluid that leaks through internal clearances of a pump per unit of time.

4. Classification

4.1 Pumps will be classified as follows:

4.1.1 *Type II*—Screws with timing gears.

4.1.2 *Type III*—Screws without timing gears.

4.1.3 *Type X*—Vane (sliding).

4.1.4 *Type XI*—Sliding shoe.

4.2 *Motor Types*—Oil-through type that uses the oil to cool the motor and lubricate the bearings.

5. Ordering Information

5.1 The ordering activity shall provide manufacturers with the following information:

⁵ Available from Hydraulic Institute, 6 Campus Drive, First Floor North, Parsippany NJ 07054-4406, <http://www.pumps.org>.

⁶ Available from American Iron and Steel Institute (AISI), 1140 Connecticut Ave., NW, Suite 705, Washington, DC 20036, <http://www.steel.org>.

⁷ Available from Aerospace Industries Association of America, Inc. (AIA), 1000 Wilson Blvd., Suite 1700, Arlington, VA 22209-3928, <http://www.aia-aerospace.org>.

⁸ Available from American Petroleum Institute (API), 1220 L. St., NW, Washington, DC 20005-4070, <http://www.api.org>.

5.1.1 Title, name and date of specification.

5.1.2 Type and size (see Section 4).

5.1.3 Oil to be pumped (for example, 2190 TEP SAE 40).

5.1.4 *Operating Conditions*—Single speed, two-speed, or variable speed. (See 9.1.)

5.1.5 Capacity in gallons per minute or litres per minute at rated discharge pressure at specified operating condition.

5.1.6 Discharge pressure in pound-force per square inch gauge (psig) or kilopascal (kPa) gauge at specified operating condition.

5.1.7 Inlet pressure conditions (NPIPA).

5.1.8 Oil Viscosity and temperature for minimum and maximum operating conditions.

5.1.9 External motor cooling oil supply, if required. (See 9.4.)

5.1.10 Mounting configuration (vertical, horizontal).

5.1.11 Relief valve cracking pressure. (See 9.1.)

5.1.12 Airborne noise level (if different than 7.4).

5.1.13 Packaging and boxing requirements (immediate use, domestic; storage, domestic; or overseas).

5.1.14 Quantity of pumps.

5.1.15 Quantity of drawings.

5.1.16 Quantity of technical manuals.

5.1.17 Quantity of test reports, if required. (See Section 10.)

5.1.18 Certified test data, if required. (See 10.3.)

5.1.19 IACS (International Association of Classification Societies) classification with applicable notions, if required.

5.1.20 *Motor Characteristics*:

5.1.20.1 *Voltage/Phase/Frequency*:

5.1.20.2 *Duty*—Continuous.

5.1.20.3 *Ambient Temperature*—50°C.

5.1.20.4 *Enclosure*—Totally enclosed, oil through.

5.1.20.5 *Insulation*—Class F, (vacuum pressure impregnation (VPI)).

5.1.20.6 *Conduit Box Orientation*—See 7.6.

6. Material

6.1 Materials of principal pump components shall be in accordance with Table 1.

6.1.1 Materials other than shown in Table 1 are considered exceptions and are subject to approval by the purchaser before usage.

6.2 Materials of principal motor components shall be in accordance with Table 2.

6.2.1 Materials other than shown in Table 2 are considered exceptions and are subject to approval by the purchaser before usage.

7. General Requirements

7.1 CLPs shall be capable of sustained operation during inclinations up to 45° in any direction.

7.2 CLPs shall be capable of withstanding external vibration in the frequency range of 4 to 25 Hz.

7.3 The internally excited vibration levels (displacement, peak to peak) of the CLP shall not exceed the following:

TABLE 1 Materials of Principal Pump Components

Application	Material	Specification
Casings, Covers (Pressure Boundary)	Nodular Iron	ASTM A395/A395M , GR. 60-40-18 or ASTM A536 , GR. 65-45-12
	Bronze	ASTM B505/B505M , B271 , or B584 , UNS C93200 or C93700
	Cast Steel	ASTM A27/A27M , GR. 65-35 or ASTM A216/A216M , GR. WCB
	Aluminum Bronze	ASTM B148 , UNS C95400
Rotor(s), Shaft(s)	Alloy Steel	AISI 4150 RS or AISI 4140-4150
	Gray Iron	ASTM A159 , GR. G3500 or continuous cast equivalents
	Nodular Iron	ASTM A536 , GR. 80-55-06 or continuous cast equivalents
	Carbon Steel	AISI 1045, 1141 or 1144
	Bronze	ASTM B505/B505M , B271 or B584 , UNS C93200 or C93700
	Stainless Steel	ASTM A564/A564M , UNS S17400
		ASTM A582/A582M , UNS S41600
Rotor Housings or Cylinder Liners, Bushings, Thrust Elements, Discs	Bronze	ASTM B505/B505M , B271 or B584 , UNS C93200 or C93700
	Gray Iron	ASTM A159 , GR. G3500 or continuous cast equivalents
	Steel/Babbitt	AISI C1018-12L15/ASTM B23 , ALLOY 2
Hex Head Cap Screws	Aluminum Bronze	ASTM B148 , UNS C95400
	Steel	ASTM A449 , TYPE I or SAE J429, GR. 5
	Alloy Steel	ASTM A574
Hex Socket Head Cap Screws	Steel	ASTM A194/A194M , GR. 2H
Hex Nuts	Alloy Steel	ASTM A563 , GR. DH or SAE GR. 8
Hex Nuts, Slf Lkg	Steel, Zn Plated	NASM 17829 / MS17829
Socket Set Screws	Alloy Steel	ASTM F912
Studs	Alloy Steel	ASTM A193/A193M , GR. B7
O-Rings	Fluorocarbon	ASTM D2000 , TY. HK

TABLE 2 Materials of Principal Motor Components

Application	Material	Specification
Frame	Nodular Iron	ASTM A395/A395M , GR. 60-40-18 or ASTM A536 , GR. 65-45-12
Housings	Nodular Iron	ASTM A395/A395M , GR. 60-40-18 or ASTM A536 , GR. 65-45-12
Shaft	Alloy Steel	AISI 4340
Ball Bearings	Steel	CID A-A-59585
		CID A-A-59584
Bearing Caps	Steel	Commercial
Shrink Ring	Steel	Commercial
Rotor Bar	Copper	ASTM B187M
Rotor End Ring	Copper	ASTM B152/B152M
Rotor Core Plate	Elec. Sheet Steel	Commercial
Stator End Plate	Steel	Commercial
Stator Core Plate	Elec. Sheet Steel	Commercial
Hex Head Cap Screws	Steel	ASTM A449 , TYPE I or SAE J429, GR. 5
Hex Socket Head Cap Screws	Alloy Steel	ASTM A574
Lock Washers	Steel	Commercial

RPM (SYN)	Displacement, Peak to Peak, Mils
3600	0.7
1800	1.4
1200	1.8
900	2.2
600	2.6

flange. Conduit box cable entrance shall be oriented downward, unless otherwise specified. Horizontal pumps shall specify orientation of conduit box.

7.7 The connection between the motor shaft and the pump rotor shall be splined or consist of a rigid connection.

7.8 To facilitate and maintain alignment, the motor bracket to pump joint shall be rabbetted.

7.9 Motor bracket to pump joint shall be o-ring sealed.

7.10 Direction of rotation shall be indicated by an arrow cast into the pump or by a label plate attached to the CLP.

7.11 An internal or separate relief valve is not required to be provided with the CLP.

7.4 At normal operating conditions, the airborne noise level of the pump shall not exceed 85 dBA.

7.5 CLPs shall be designed such that no damage will result from reverse rotations of at least a one-minute duration with no restriction in flow of oil to or from the CLP.

7.6 Unless otherwise specified, vertical CLPs shall be assembled with the conduit box mounted over the pump outlet

8. Pump Design

8.1 Pump inlet and outlet connections shall be flanged. Pump flanges shall mate to ASME/ANSI B16.5 pipe flanges. Cast iron and non-ferrous material case flanges shall be flat face, unless otherwise stated in the ordering data. Flanged connections shall meet the external forces and moments requirements in API Standard 676. Spool piece adapters (threaded and seal-welded, or O-ring sealed to the pump case on one end and flanged on the other end) may be furnished to meet the flanged inlet and outlet requirement.

8.2 Pumps of capacity 100 gpm and greater shall be equipped with vent, drain, inlet, and outlet gage connections. Where threaded connections are used they shall be straight thread with O-ring seal. Tapered pipe thread connections are prohibited. Small capacity pumps (under 100 gpm) do not require vent, drain, and gage connections.

8.3 Pumps shall be designed to counteract radial and axial thrust loads encountered during operation.

8.4 Pumps shall be self-priming and capable of removing air from the suction lines.

8.5 Pumps shall be designed to handle up to 8 % entrained air.

9. Motor Design

9.1 Motors may be single speed, two-speed or single speed with a variable speed drive to support pump operation at various temperatures and viscosities. Single speed motors shall be sized for the maximum flow at the system relief valve cracking pressure at maximum viscosity. If a two speed motor is specified, rating of the low speed winding shall be based on power required at the low speed with maximum viscosity oil during cold startup. The high speed winding rating shall be based on power required at pump rated conditions. Motors driven by variable speed drive units should be sized so that the motor can support pump cold start-up operation and normal rated condition operation without overloading the motor.

9.2 Motors shall be rated for continuous duty for all ratings.

9.3 Motors shall be equipped with a high point fill connection for filling the CLP unit with oil at initial start-up and a low point drain connection. Where threaded connections are used they shall be straight thread with O-ring seal. Tapered pipe thread connections are prohibited.

9.4 A method to supply cooling and lubricating oil to the motor and motor bearings must be provided. The cooling oil shall be supplied by either internal pump passages or an external system connection. When an external cooling method is chosen, supplier shall provide motor cooling oil pressure, temperature and flow requirements to the purchaser. Where threaded connections are used they shall be straight thread with O-ring seal. Tapered pipe thread connections are prohibited.

9.5 Motors shall be equipped with an inspection cover, o-ring sealed, for verification of direction of shaft rotation.

9.6 The motor enclosure shall contain the cooling/lubricating oil pressure. Where external cooling flow is provided, the cooling oil shall be provided at a maximum of 20 psig.

9.7 Motor bearings shall be lubricated by the pumping fluid.

10. Test Requirements

10.1 *General*—All equipment shall be tested in accordance with 10.2.

10.1.1 Equipment for specified tests shall be provided by the manufacturer.

10.2 *Hydrostatic Test:*

10.2.1 Each pump casing shall be tested hydrostatically to a minimum of 150 percent of discharge pressure (see 5.1.6). The hydrostatic test shall be considered satisfactory when no leaks are observed for a minimum of 5 min. Seepage past internal closures required for segmented casing testing and operating of the hydrostatic test pump to maintain pressure will be accepted.

10.2.2 Each motor shall be tested hydrostatically at 50 PSIG. This test may be accomplished by testing the complete CLP.

10.3 *Certification Data and Testing*—Certified performance test data shall be supplied when required. (See 5.1.18.)

10.3.1 *Mechanical Running Test*—The manufacturer shall conduct a test on each CLP to ensure that rated capacity is achieved at the rated condition. Such tests may be performed with other than the specified liquid and with viscosity up to 50 SSU greater than the minimum specified viscosity. Differential pressure may be measured in place of specified inlet and discharge pressures.

10.3.2 *Performance Test*—When required and as specified by the ordering document, the manufacturer shall operate a CLP at the manufacturing facility or approved test facility to obtain complete mechanical, hydraulic and electrical test data. The pump shall meet rated capacity at this condition and shall meet the airborne noise levels in 7.4.

11. Technical Documentation

11.1 Unless otherwise specified, each pump shall include an instruction book that shall be composed of the following:

11.1.1 CLP description;

11.1.2 Installation instructions;

11.1.3 Operating instructions;

11.1.4 Maintenance procedures (including complete pump disassembly and assembly);

11.1.5 Outline dimension drawing, including weight;

11.1.6 Typical cross-sectional assembly drawing and list of materials;

11.1.7 Motor outline drawing.

11.2 *Submittal Documents*—Proposal documents shall consist of the following:

11.2.1 Outline dimension drawing with estimated, calculated or actual weight and center of gravity

11.2.2 Typical cross-sectional drawing and list of materials.

11.2.3 Performance curve which plots differential pressure, efficiency, and brake horsepower as a function of capacity

11.2.4 List of recommended spare parts.

12. Packaging and Preservation

12.1 Pumps, pump units, and accessories shall be packaged and preserved in accordance with Practice D3951, and the following:

12.1.1 *Preservation*—Items susceptible to deterioration or damage from environmental elements shall be preserved. Non-coated ferrous surfaces shall be preserved.

12.1.2 *Cushioning and Bracing*—Items susceptible to damage during shipment and handling shall be cushioned or shall be securely braced or blocked, or both, within the shipping container, to avoid damage.

12.1.3 *Container Marking*—Containers, boxes, or packages shall be clearly marked with the ship to address, contract or purchase order number, shipping point address, and item nomenclature.

13. Keywords

13.1 lube oil pump; marine pump; sealless pump

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements established by the U.S. Navy, Commander Naval Sea Systems Command (NAVSEA) shall apply when specified in the contract or purchase order. When there is a conflict between the specifications and this section, requirements of this section shall take precedence.

S1. Referenced Documents

S1.1 *ASTM Standard:*

D2519 Standard Test Method for Bond Strength of Electrical Insulating Varnishes by the Helical Coil Test

S1.2 *Underwriters Laboratories:*

984 Hermetic Refrigerant Motor-Compressors

S1.3 *Military Standards:*

Mil-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I-Environmental and Type II-Internally Excited

MIL-STD-740 Airborne and Structure borne Noise Measurements and Acceptance Criteria of Shipboard Equipment

MIL-S-901 Shock Tests, H.I. (High Impact Shipboard Machinery, Equipment and Systems, Requirements, for

MIL-DTL-2212 Contactors and Controllers, Electric Motor AC or DC and Associated Switching Devices

MIL-M-17060 Motors, 60-Hertz, Alternating Current, Integral Horsepower, Shipboard Use

MIL-PRF-32168 Variable Speed Drive System for Induction and Synchronous Machines

NAVSEA Technical Publication T9074-AS-GIB-010/271 Requirements for Nondestructive Testing Methods

S2. Applicability

S2.1 This CLP is part of the US Navy ships' lube oil system and must meet all system requirements for cleanliness, pressure and temperature.

S3. Ordering Data

S3.1 *Requirements*—All CLPs in accordance with this Supplement shall have [Fig. S1.1](#) completed by the purchasing activity.

S4. Design Requirements

S4.1 Motor shall be Service A in accordance with MIL-M-17060 and the following:

S4.1.1 A motor master drawing per MIL-M-17060 shall be provided.

S4.1.2 The motor shall have a means of visually verifying unit direction of rotation for each speed.

S4.1.3 The method of connecting terminal leads shall ensure that no external strains shall be transmitted to the motor internal wiring.

S4.1.5 The CLP may not meet the efficiency requirements of MIL-M-17060. Any specific efficiency requirements and testing for such requirements shall be detailed in the ordering document.

S4.1.6 Motor insulation shall undergo the following testing to prove the compatibility of the insulation system with oil. Test results shall be noted on the motor master plan. These tests only have to be performed once for each insulation design.

S4.1.6.1 Perform an Electrical Insulation Varnish Bond Strength test in accordance with ASTM D 2519. Twelve specimens shall be tested; six specimens in oil and six specimens in air. Specimens shall be tested at 150°C. The reduction in bond strength between the oil specimens and air specimens shall not exceed 50 percent

S4.1.6.2 Perform a compatibility test in accordance with paragraph 41 of UL 984. The test shall be modified to include oil only. A test plan shall be submitted to US Navy for approval prior to start of testing.

S4.1.7 The CLPs shall have non-overloading power characteristics, and the driver-rated horsepower shall at least equal the maximum power requirements of the pump at the maximum rated speed without allowances for a service factor.

S4.1.8 If required by [Fig. S1.1](#), motor thermal protection shall be in accordance with MIL-M-17060 and the following:

S4.1.8.1 Bearing temperature sensors, thermistor or otherwise, are not required.

S4.1.8.2 All winding sensor leads shall be bought into the terminal box and shall be coiled and restrained to prevent lead damage.

S4.1.8.3 Sensor leads shall be marked. The marking shall be visible in the terminal box. Sensors located in the same winding phase group shall have a common identification.

S4.1.8.4 Thermal protection systems shall meet EMI requirements of MIL-STD-461 after installation in the motor.

S4.1.8.5 Sensors shall be installed so that at least one phase group with sensors is located in an expected or possible hot spot.

S4.1.8.6 If a sensor monitor is required, only one monitor shall be used per motor. The monitor shall be mounted on the motor near the terminal box. The monitor shall provide an output to a visual or audible alarm or ship control system when

US NAVY SUPPLEMENT ORDERING DATA

PUMP TYPE:

Pump Classification (Para 4.1):

Mounting Type: Horizontal Vertical

Pumping Fluid:

Fluid Temperature (Min/Max) (°F):

Viscosity at Minimum Temp:

Viscosity at Maximum Temp:

Operating Conditions (Rotational): Single Speed Two-Speed Variable Speed

Capacity at Rated Discharge Pressure (GPM):

Rated Discharge Pressure (PSIG):

Minimum Suction Pressure (PSIG, PSIA or Inches of Hg as applicable):

Special Efficiency Requirements (Para S4.1.5)

Thermal Protection (Para S4.1.8):

<u>TEST</u>	<u>SPECIFICATION</u>	<u>PARA</u>
<input type="checkbox"/> Motor Test	<input type="checkbox"/> Witness	S5
<input type="checkbox"/> Shock Test	<input type="checkbox"/> Witness	S6.1
<input type="checkbox"/> Vibration Test	<input type="checkbox"/> Witness	S6.2
<input type="checkbox"/> Performace Test	<input type="checkbox"/> Witness	S7.1.1
<input type="checkbox"/> Endurance Test	<input type="checkbox"/> Witness	S7.1.2
<input type="checkbox"/> Inclined Operation Test	<input type="checkbox"/> Witness	S7.1.3
<input type="checkbox"/> Hot Insulation Resistance Test	<input type="checkbox"/> Witness	S7.1.4
<input type="checkbox"/> Production Test	<input type="checkbox"/> Witness	S7.2
<input type="checkbox"/> Hydrostatic Pressure Test	<input type="checkbox"/> Witness	S7.2.1
<input type="checkbox"/> Assembled CLP Pressure Test	<input type="checkbox"/> Witness	S7.2.2
<input type="checkbox"/> Mechanical Soundness and Capacity Test	<input type="checkbox"/> Witness	S7.2.3
<input type="checkbox"/> Noise Test	<input type="checkbox"/> Witness	S7.2.4

CONNECTIONS:

TYPE (O-RING, ETC)

- Drain/Vent
- Inlet Pressure Gage
- Discharge Pressure Gage

MOTOR:

Volts/Phase/Hertz	Type	Encl
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COMMENTS: (volume/weight requirements, special storage instructions, etc.):

FIG. S1.1 US Navy Supplement Ordering Data

sensors get within plus or minus 5 degrees centigrade of the maximum allowable winding temperature.

S4.1.8.7 The motor master drawing shall show the thermal protection system monitor and the approximate locations of the sensors. The parts lists shall identify the monitor and sensors by manufacturer part number or similar description to allow procurement. Notes identifying monitor input power requirements and electrical output characteristics shall be included on the master drawing.

S4.1.9 Motor will be controlled with motor controller manufactured in accordance with MIL-DTL-2212.

S4.2 *Materials*—Materials for the pumps shall be in accordance with Tables 1 of the basic specification. Materials for the motors shall be in accordance with MIL-M-17060. Proposed alternate materials shall be subject to approval by the design review agency. Components of the CLP for which the specific materials are not specified shall use materials best suited for the intended service. Cadmium plating is prohibited. Zinc plating is prohibited in contact with oil.

S.5 Motor Testing

S5.1 *Motor Testing*—Prior to being connected to the pump, the motor shall undergo the following tests for each winding configuration in accordance with MIL-M-17060. Sealed bearings may be used in place of the motor's normal bearings during these tests.

S5.1.1 No-load input test

S5.1.2 Pull-up, breakdown and locked rotor torque and current test

S5.1.3 EMI testing in accordance with MIL-STD 461 after assembly of thermal protection system

S5.2 Heat run test at full load with a CLP. For heat run testing, thermocouples are required in the motor as follows:

S5.2.1 Three per coilhead spaced 120 degrees apart. Locations should be chosen in expected hot spots.

S5.2.2 One per bearing located no further than 1/8 inch from outer ring.

S5.2.3 The heat run test is a first article test that does not need to be repeated unless there is a change to the pump or motor that will affect the temperature rises in the motor.

S6. Shock and Vibration Testing

S6.1 *Shock Test:*

S6.1.1 The CLP shall undergo a shock test to ascertain that the CLP has the necessary shock resistance. The shock test shall be performed in accordance with MIL-S-901, Grade A, and the specific shock test requirements specified in the contract or purchase order. Only one CLP of each type, design, and size complete with the driver and all appurtenances and controls shall successfully undergo the shock and vibration qualification at a laboratory or testing facility, which is acceptable to the purchaser. Approvals for shock extensions of similar designs already tested and approved are to be obtained from NAVSEA Philadelphia.

S6.1.2 After shock test, the pump and driver and other components susceptible to internal distortion shall be disassembled to the extent necessary and the critical dimensions and running clearances measured, calculated, and recorded. During this disassembly, the critical components and assemblies sub-

ject to shock damage and distortion shall be identified and listed in the inspection record and after completion of the test. The condition of each component and assembly shall be determined and recorded and compared to the same data recorded prior to the shock test.

S6.1.3 Before and after the shock test, tests in accordance with the Mechanical Soundness and Capacity Test Supplement (S7.2.3) shall be performed to determine the changes in performance characteristics of the pump. Vibration measurements shall be taken at the bearing caps or housings of the pump and driver at the same speeds during the initial and final capacity test to determine the changes in mechanical operation.

S6.1.4 The CLP shall be mounted on the shock machine or barge using standard fixtures essentially identical to the actual shipboard characteristics, unless non-standard fixtures are otherwise approved. The purchasing activity will furnish the contractor a drawing of the shipboard mounting arrangement and foundation's stiffness. Horizontal pumps, when tested in the inclined position on the medium weight shock machine, shall be oriented so that the direction of shock is perpendicular to the axis of the pump rotation. The pump shall be in operation during the first, third, and fifth blows of the shock test. Pumps shall be operated at as close to the rated condition as possible within the capability of the test facility.

S6.1.5 The pump shall be carefully observed during each shock blow and thoroughly visually examined after each blow. After each blow, the CLP shall be operated at as close to the rated condition as possible and checked for abnormal noises and vibrations and proper functioning of controls. Tightening of bolts (except for pump/motor hold-down bolts) during shock tests will not be permitted. If any bolt loosens during the test, the equipment manufacturer shall provide a corrective procedure, which must be approved by the purchaser.

S6.1.6 Shock test acceptance criteria shall be as follows:

S6.1.6.1 There shall be no breaking of parts, including mounting bolts.

S6.1.6.2 There shall be no distortion or derangement of any part, which would render the CLP incapable of performing as specified.

S6.1.6.3 The amplitude of vibration after a test measured as close to the rated condition as possible shall be less than twice the amplitude measured at the same speed before the test. The baseline amplitude of vibration shall be taken on the test stand in which the shock test is being performed.

S6.1.6.4 Adequate lubrication to all bearings shall be maintained.

S6.1.6.5 Critical dimensions and running clearances shall be maintained.

S6.1.6.6 There shall be no significant change in the performance curve.

S6.1.6.7 The post shock analysis and the Failure to Perform Principal Functions analysis for the motor shall be in accordance with MIL-M-17060.

S6.1.7 *Postshock Test Procedure*—The shock-tested CLP, if it is to be supplied under a contract or order, shall be restored to the as-new condition by replacement of all parts damaged or distorted beyond the as-new design tolerances. Rolling element bearings shall be replaced regardless of condition. The shock

tested rolling contact bearings shall be rendered unusable. The restored CLP shall successfully pass the Hydrostatic Pressure Test Supplement (S7.2.1), the Mechanical Soundness and Capacity Test Supplement (S7.2.3), and the Noise Test Supplement (S7.2.4), if applicable. Quality conformance test documentation shall certify that the CLP was subjected to the shock test and subsequently restored, tested, and inspected in accordance with contract requirements. A completed parts examination check list shall be supplied and shall identify the parts which were replaced (such as the bearings) and shall certify that the CLP fully conforms to the specifications for unrestricted service.

S6.2 *Vibration Test:*

S6.2.1 The pump shall successfully undergo a vibration test in accordance with the requirements of MIL-STD-167-1, Type I, and as supplemented in the contract or order. The vibration test need not be repeated on subsequent contracts or orders for pumps of identical design to those previously tested, provided the previous tests included the frequencies specified.

S6.2.2 The CLP shall be mounted on typical shipboard foundations during the vibration test or the shipboard mounting arrangement shall be simulated in spring mass characteristics except where this mounting arrangement causes the largest test table capacity to be exceeded. Inability to vibration test the CLP because of excessive weight or size shall not release the contractor from furnishing equipment which can withstand the specified vibration inputs. Vibration test acceptance criteria shall be in accordance with MIL-STD-167-1, Type I.

S6.2.3 Vibration Type I qualification may be performed by analysis and/or extension based on a previously tested CLP with NAVSEA approval.

S7. First Article and Production Testing Requirements

S7.1 *First Article Qualification*—One CLP of each type, design, and size complete with the driver and all appurtenances and controls shall successfully undergo the specified First Article Qualification at a laboratory or testing facility, which is acceptable to the purchaser. The various first article tests on one pump design may be conducted concurrently, if practical. The tests shall fully establish that the product is reliable and is capable of meeting the specified performance. Design changes which, in the opinion of the purchaser, may adversely affect the applicability of a previously tested and accepted pump design shall be cause to require new design evaluation tests in part or in full. The proposed first article qualification procedures shall be submitted for approval to the purchaser before performing the tests. The design evaluation tests shall consist of the following and are detailed in separate paragraphs: S7.1.1, Performance Test; S7.1.2, Endurance Test; and S7.1.3, Inclined Operation Test. Test reports documenting first article qualification shall be prepared in accordance with accepted engineering practice. The test reports shall document test setup, procedure, significant events, test instruments used including calibration data and accuracy, and measured data. The reports shall be accurate and complete and shall present test results in a professional manner to the purchaser for approval. The report shall include certification of conformance to the specified acceptance criteria that the pump is suitable for its intended

application. After approval, test reports shall be distributed as specified in the contract.

S7.1.1 *Performance Test:*

S7.1.1.1 The performance tests shall be conducted and recorded in accordance with the requirements of the test specified in Mechanical Soundness and Capacity Test Supplement (S7.2.3) except that, in addition, a full-performance map shall be established. The full-performance map shall be developed by measuring and establishing curves for discharge pressure versus capacity for a number of discharge pressures. The proposed test procedure for this test shall be submitted to the purchaser for approval approximately at the time of drawing submittal. The test shall include performance testing using the oil as close as possible to the lowest oil temperature shown on the ordering sheet.

S7.1.1.2 *Acceptance Criteria*—The acceptance criteria specified in the Mechanical Soundness and Capacity Test Supplement (S7.2.4) shall be met. The performance map shall exhibit the specified pump performance characteristics.

S7.1.2 *Endurance Test:*

S7.1.2.1 The pump shall be operated for a period of not less than 500 hours of actual running time with a minimum of 60 starts to ascertain reliability of performance and operation.

S7.1.2.2 Before commencement of the endurance test and immediately after completion of the 500-hour operating run, the pump shall be disassembled to the extent necessary and the critical dimensions and running clearance of parts subject to wear, erosion, and derangement shall be measured, calculated, and recorded. Components such as pump rotors and casings subject to erosion, corrosion, cavitation, and wear, the effects of which are not subject to routine measurement, shall be listed in the inspection record and after completion of the test the condition of each component determined and recorded.

S7.1.2.3 During the initial and final hours of the endurance test run, noise, and performance tests (see appropriate paragraphs) shall be performed to determine the changes in pump performance characteristics and noise signature. Vibration measurements shall be taken at the bearing caps or housings of the pump and driver at the same speeds during the initial and final capacity test to determine the changes in mechanical operation.

S7.1.2.4 The endurance test shall not be continuous but shall be interrupted by at least three rest periods of a minimum of 8 h each. The number of starts specified shall be performed at full-line voltage during the course of the test. During an early part of the endurance test, the pump shall be operated continuously for 24 h at a capacity as near free delivery as possible at maximum rated speed and normal specified temperature, submergence, and suction conditions. The remainder of the endurance tests shall be run at maximum rated speed and within $20 \pm 0^\circ\text{F}$ of maximum specified liquid temperature.

S7.1.2.5 The pump shall be monitored during the endurance test to record accurately the conditions of operation, the capacity delivered, the total head developed, the speed at which operated, and the general performance observed. Data shall be collected and the pump inspected at least twice per day of operation. For each periodic inspection, in addition to all

measured data, the record shall indicate the following:

- (1) The conditions of the bearings (by audible noise; by feel; and by bearing temperature by means of a probe if the design includes provisions for a probe, otherwise by means of a surface pyrometer on a normally exposed surface; no disassembly required),
- (2) The airborne noise level (normal-abnormal),
- (3) The vibration level (normal-abnormal),
- (4) The smoothness of operation (normal-abnormal),
- (5) Any other abnormal findings,
- (6) All adjustments made, and
- (7) Changes made in the conditions or method of operation.

S7.1.2.6 Acceptance Criteria—Shall be as follows:

- (1) Capacity curve at maximum rated speed after 500 h of pump operation shall conform to the specification requirements and shall show no abnormal deviations from the curve before the 500-h test.
- (2) CLP performance and operation after 500 h of operation shall be unchanged and normal and meet all specification requirements.
- (3) CLP operation at the end of the endurance test shall be smooth and shall exhibit noise and vibration levels that are normal and in conformance with the specification. (See 7.3 or MIL-STD-167-1 if S6.2 is invoked.)
- (4) Lubrication shall have remained satisfactory throughout the test period. Bearing temperatures shall have remained normal.
- (5) Running clearances shall be normal.
- (6) Components subject to attack from corrosion, erosion, cavitation, and so forth shall be in a condition commensurate with 500 h of service.
- (7) Wear rates for wearing parts, critical for proper operation, shall show a rate of wear for the test period that shall be consistent with the specified design life requirements.
- (8) No relevant failures shall have occurred throughout the 500-h test.

S7.1.2.7 Postendurance Test Procedures—The CLP subjected to the 500-h test, if it is to be supplied under an order or contract, shall be restored to the as-new condition by replacement of all parts worn beyond the as-new design tolerances. The restored CLP shall successfully pass the Hydrostatic Pressure Test Supplement, Mechanical Soundness, and Capacity Test Supplement, (S7.2.4.1 (I)), and Noise Tests Supplement (S7.2.5), if applicable. The quality conformance test documentation shall indicate that the CLP was subjected to the endurance test and subsequently restored and tested, and that it shall be certified as fully conforming to the specification for unrestricted service.

S7.1.2.8 Approvals for 500 hour endurance qualification of similar design already tested may be extended based on a previously tested CLP with NAVSEA approval.

S7.1.3 Inclined Operation Test—One pump of each design shall undergo an inclined operation test to prove CLP can operate under all ships operating scenarios. Operate the pump at a 45° inclination in each of pump's planes (fore-aft and port-starboard). A mechanical soundness test shall be performed under each of these conditions. The pump shall meet its design capacity at each of the inclined conditions.

S7.1.4 Hot Insulation Resistance Test—The CLP shall be operated for four hours at full load in order to determine hot insulation resistance. Resistance readings shall be corrected for temperature.

S7.2 Production Tests—The purchasing activity or its representatives, or both, shall have the right to examine the facilities at the manufacturer's plant and at his subcontractor's plants and to witness all tests specified in the contract to the extent specified in the ordering data. Failures, deficiencies, and discrepancies revealed during the performance of the specified tests and the corrective measures taken should be recorded and fully documented in the applicable test records and test reports. After correction of any deficiency, tests shall be repeated to the full extent necessary to determine acceptability for the modified pump. Failures indicative of a design deficiency (as distinguished from shop error or faulty workmanship) shall be reported to the purchaser before a correction is made.

S7.2.1 Hydrostatic Pressure Test—All pump pressure boundary parts shall be tested hydrostatically to a pressure one and one half times the maximum design working pressure at maximum submergence, but in no case less than 50 psig. The hydrostatic test pressure shall be maintained for at least 30 min or longer as necessary for examination of entire casing.

S7.2.1.1 Acceptance Criteria—The pump shall exhibit no leakage through the pressure boundary material or joints.

S7.2.2 Assembled CLP Pressure Test—The assembled CLP shall be tested at a pressure equal to the maximum design pressure of the CLP but in no case less than 50 psig.

S7.2.2.1 Acceptance Criteria—The CLP shall exhibit no leakage from the joint and the pressure boundary.

S7.2.3 Mechanical Soundness and Capacity Test:

S7.2.3.1 This test shall be conducted, recorded, and reported in accordance with the Hydraulic Institute Standard ANSI/HI 3.6 Rotary Pump Tests, to the extent that these standards are applicable and are not in conflict with the contract requirements. The test record for each pump shall include the following as a minimum:

- (1) Certification of the major pump components (pump, gear assembly, driver) by the manufacturer's drawing number and serial number that were tested;
- (2) A sketch of the test loop showing location of the pump and all instrumentation.
- (3) A list of the test instruments including date of last calibration, advertised accuracy, size, (for example, 0.25 lb/in.²) of the smallest graduation on the readout scale, range of the readout scale (for example, from 0 to 100 lb/in.²), and unit (for example, lb/in.²) of measurement including the water temperature the gauges are calibrated for if a gauge is calibrated in feet of water rather than in lb/in.²;
- (4) The data sheets of all recorded data, with the unit of measurement identified for all data;

S7.2.3.2 The test shall be performed as follows:

- (1) Operate the CLP at the rated speed and capacity, with the pumped fluid at ambient temperature. The pump operation shall be monitored for proper functioning of safety devices, bearing lubrication, and for smooth running.
 - (a) **Acceptance Criteria**—CLP operation shall be free of abnormal vibrations and noises.

TABLE S1.1 Acceptable Octave Band Sound Pressure Levels (in dB re 20 μPa)

		Octave Band Center Frequency, Hz						
31.5	63	125	250	500	1000	2000	4000	8000
91	88	85	82	79	76	73	70	67

(2) Operate the CLP at the each of the design rated speeds with the pumped fluid at maximum normal temperature specified in and with the minimum specified suction pressure (see Fig. S1.1). The test should be run at rated capacity.

(a) *Acceptance Criteria*—The pump shall deliver the rated capacity at the rated discharge pressure. The characteristic curve at maximum rated speed shall satisfy the specified requirements.

(3) Operate the electric motor-driven CLP for a minimum of 1 min in reverse rotation at maximum rated speed.

(a) *Acceptance Criteria*—The CLP shall not be damaged by the reverse rotation test.

S7.2.4 *Noise Tests*—Airborne and structure-borne noise tests when specified shall be conducted and reported in accordance with MIL-STD-740. Noise test details, instrumentation, and testing techniques identified in MIL-STD-740 shall be submitted to the purchaser before testing for approval. Noise tests shall be performed with the driver furnished with pump, and tests shall be conducted on all CLPs.

S7.2.4.1 *Acceptance Criteria*—The CLP shall meet the airborne noise level limits of Table S1.1 or as specified in the contract. Structure-borne limits shall be specified by the contract.

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