



Standard Specification for Centrifugal Pump, Shipboard Use¹

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1. Scope

1.1 This specification covers the requirements applicable to the design and construction of centrifugal pumps for shipboard application. The three classes of service covered by this specification are as follows:

1.1.1 Class 1—Freshwater,

1.1.2 Class 2—Seawater, and

1.1.3 Class 3—Hydrocarbon pumps (less than 1500 SSU).

1.2 The values stated in inch-pound units are to be regarded as the standard. The values given in parentheses are provided for information purposes only.

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2. Referenced Documents

2.1 ASTM Standards:²

- A 36/A 36M Specification for Carbon Structural Steel
- A 193/A 193M Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service
- A 194/A 194M Specification for Carbon and Alloy Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
- A 276 Specification for Stainless Steel Bars and Shapes
- A 494/A 494M Specification for Castings, Nickel and Nickel Alloy
- A 582/A 582M Specification for Free-Machining Stainless Steel Bars
- A 743/A 743M Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion-Resistant, for General Application
- A 747/A 747M Specification for Steel Castings, Stainless, Precipitation Hardening
- A 890/A 890 Standard Specification for Castings, Iron–Chromium-Nickel-Molybdenum Corrosion Resistant, Duplex (Austenitic/Ferritic) for General Applications
- B 148 Specification for Aluminum-Bronze Sand Castings
- B 164 Specification for Nickel-Copper Alloy Rod, Bar, and Wire
- B 271 Specification for Copper-Base Alloy Centrifugal Castings
- B 369 Specification for Copper-Nickel Alloy Castings
- B 505 Specification for Copper-Base Alloy Continuous Castings
- B 584 Specification for Copper Alloy Sand Castings for General Applications
- F 468 Specification for Nonferrous Bolts, Hex Cap Screws, and Studs for General Use
- F 1511 Specification for Mechanical Seals for Shipboard Pump Applications

2.2 ANSI Standards:

- B1 ISO Metric Screw Threads (ANSI-B1 Report)³
- B1.1 Unified Screw Threads³
- B16.1 Cast Iron Pipe Flanges and Flange Fittings³
- B16.5 Steel Pipe Flanges, Flanged Valves and Fittings, 150, 300, 400, 600, 900, 1500 and 2500 lb.³
- B16.11 Forged Steel Fittings, Socket Welding and Threaded³
- B16.24 Bronze Flanges and Flanged Fittings, 150, 300lb³

2.3 Hydraulic Institute Standards:

- ANSI/HI 1.1-1.5 American National Standard for Centrifugal Pumps for Nomenclature, Definitions, Applications and Operation³
- ANSI/HI 1.6 American National Standard for Centrifugal Pump Tests³
- ANSI/HI 9.1-9.6 American National Standard for Pumps—General Guidelines for Types, Definitions, Applications and Sound Measurements³

2.4 AFBMA Standards:

- 9 Load Ratings and Fatigue Life for Ball Bearings⁴
- 11 Load Ratings and Fatigue Life for Roller Bearings⁴

2.5 ISO Standards:

- ISO 9001 Quality Systems and Quality Assurance—Design/Development, Production, Installation and Service³

3. Terminology

3.1 Definitions:

- 3.1.1 *best efficiency point (BEP)*, *n*—the capacity and head in which the pump efficiency is the highest.
- 3.1.2 *BHP*, *n*—power delivered to the pump from the driver in brake horse power.
- 3.1.3 *capacity*, *n*—the total volume output per unit of time.
- 3.1.4 *centrifugal pump*, *n*—a kinetic machine converting mechanical energy into hydraulic energy through rotating motion.
- 3.1.5 *close coupled pumps*, *n*—in this arrangement, no coupling is provided between the pump and the motor shafts, and the pump housing is flange mounted to the motor. The pump impeller is directly mounted to the motor shaft.
- 3.1.6 *coupled pumps*, *n*—in this arrangement, the pump and the motor must use a coupling to transmit the power from the driver to the pump shaft.
- 3.1.7 *gallons per minute (GPM)*, *n*—U.S. customary unit for capacity.

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*, Vol 01.04, volume information, refer to the standard's Document Summary page on the ASTM website.

Annual Book of ASTM

³ Available from American National Standards, Vol 01.04, Institute, 25 W. 43rd St., 4th Floor, New York, NY 10036.

Annual Book of ASTM Standards, Vol 01.03.

⁴ Anti-Friction Bearing Manufacturers Association, Inc., 1101 Connecticut Ave., N.W., Suite 700, Washington, DC 20036.

3.1.8 *head, n*—the expression of the energy content of the liquid referred to in any arbitrary datum. It is expressed in units of energy per unit of weight liquid. The measuring unit for head is foot (metre) of liquid.

3.1.9 *head, total discharge, n*—the sum of the pump’s discharge gauge head, the velocity head at the gauge connection, and the elevation difference between the pump centerline and the gauge centerline.

3.1.10 *head, total, n*—the measurement of energy increase per unit weight of the liquid, imparted to the liquid by the pump, and is the difference between the total discharge head and the total suction head.

3.1.11 *head, total suction, n*—the sum of the pumps suction gauge head, the velocity head at the gauge connection, and the elevation difference between the pump inlet centerline and the gauge centerline.

3.1.12 *head, maximum rated, n*—the most head a pump can generate with the correct impeller diameter for the service conditions.

3.1.13 *hydrostatic test, n*—applying static pressure to the assembled pump or pressure containing components to determine structural integrity of the unit.

3.1.14 *maximum allowable working pressure, n*— the maximum discharge pressure that could occur in the pump when it is operated at the rated speed and suction pressure for a given application.

3.1.15 *maximum BHP rated impeller, n*—the highest power required by a pump with the correct impeller diameter for the service condition.

3.1.16 *minimum continuous flow, n*—the lowest possible flow rate at which the pump can run without generating excessive heat within the unit or damage to the pump.

3.1.17 *net positive suction head available (NPSHA), n*—the total suction head absolute, determined at the first stage impeller datum, less the absolute vapor pressure of the liquid at a specific capacity.

3.1.18 *net positive suction head required (NPSHR), n*—the amount of suction head over vapor pressure required at the pump to prevent more than a 3 % loss in total head from the first stage of the pump at a specific capacity.

3.1.19 *nonmetallic materials, n*—any material that would not be recognized as a metal. Examples include plastics, fiberglass resins, carbon fiber, fiberglass-reinforced vinyl ester, polytetrafluoroethylene (PTFE), or any similar material.

3.1.20 *non-overloading power characteristics, n*—this characteristic requires that the driver be sized for the highest possible power requirement from the pump.

3.1.21 *OEM, n*—original equipment manufacturer of the pump unit.

3.1.22 *pounds per square inch absolute (PSIA), n*—the U.S. customary measure of pressure with zero as a true absolute zero in pounds per square inch.

3.1.23 *pounds per square inch gauge (PSIG), n*—the U.S. customary measure of pressure with zero being adjusted to atmospheric pressure in pounds per square inch.

3.1.24 *pump efficiency (Eff), n*—the ratio of the energy imparted to the liquid by the pump to the energy supplied to the pump from the driver.

3.1.25 *pump unit, n*—a typical pump unit consists of a separate pump and driver, combined pump and driver (close coupled), coupling, and coupling guard, and may include a gear box and base plate.

3.1.26 *rated point, n*—applies to the capacity, head, net positive suction head, and speed of the pump as specified by the order.

3.1.27 *specific gravity (Sp. Gr.), n*—the ratio of the density of the liquid to the density of water at 64°F (17.8°C).

3.1.28 *vapor pressure, n*—the pressure exerted when a liquid is in equilibrium with its own vapor. The vapor pressure is a function of the substance and of the temperature.

3.1.29 *viscosity, n*—the resistance of a fluid to shear motion, its internal friction.

4. Ordering Information

4.1 Fig. 1 and Fig. 2 are provided for use by the procuring activity and the OEM. The sections of Fig. 1 and Fig. 2 marked “User Defined,” must be completed by the procuring activity and submitted with the request for bid. This will ensure that the potential bidder provides a pump unit that meets all performance, operational, and reliability requirements of the purchaser. The OEM will fill out all sections of Fig. 1 and Fig. 2 marked “OEM Defined,” and return the data sheet to the purchaser upon delivery of the pump.

4.2 For the convenience of the procuring activity, Fig. 1 and Fig. 2 are provided in both U.S. customary and SI versions.

5. Material

5.1 The materials cited in Table 1 are provided as a guide. Other materials may be substituted as approved by the purchasing activity and as specified in Fig. 1 and Fig. 2.

5.2 When selecting material combinations, the pump supplier shall take into consideration the conditions under which the various materials interact with each other. Material hardness shall be such that any rubbing, sliding, or tight clearance parts shall be selected so that no binding or galling occurs. Special care shall be taken with Class 2 pump materials that interact with each other in a seawater environment.

5.3 Consideration shall be given to the use of nonmetallic (composite) pump components where the use of that material can benefit the operation and maintenance of the pump. Purchaser approval must be obtained for the use of nonmetallic materials.

CENTRIFUGAL PUMP ORDERING DATA (ENGLISH)

USER/CUSTOMER _____ OEM/BIDDER _____ DATE _____
 CLASS(1 THRU 6) _____ NO. OF PUMPS _____ NO. OF DRIVERS (MOTORS/TURBINE) _____ ITEM NO. _____

OPERATING CONDITIONS (PURCHASUER-DEFINED)

FLUID _____
 °F RATED _____ °F MAX. _____ (GPM) RATED _____
 SP. GR. AT RATED PT. _____ TOTAL HEAD, (FT) RATED _____
 VAP. PRESS. AT RATED PT. _____ SUCT. PRESS. (PSIG) MAX. _____, RATED _____
 VISCOSITY AT RATED, SSU _____ NPSHA, (PSIG) _____
 AMBIENT CONDITIONS _____
 PITCH _____ ROLL _____ LIST _____ TRIM _____

PERFORMANCE (OEM-DEFINED)

PERFORMANCE CURVE NO. _____
 RPM _____ NPSH (WATER) _____
 EFF. _____ % BHP RATED _____
 MAX. BHP RATED IMPELLER _____
 MAX. HEAD RATED _____
 MAX DISCH. PRESS. (PSIG) _____
 MIN CONTINUOUS (GPM) _____

CONSTRUCTION (PURCHASER REQUIREMENTS)

PUMP TYPE: HORIZ VERT CLOSE COUPLED OEM OPTION (CHECK ONLY
 IF OEM CAN SPECIFY ALTERNATE)
 SPLIT: RADIAL AXIAL
 PAINTING/COATINGS SPECIFICATION: _____
 ACOUSTICS SPECIFICATION: _____, OR
 dBA _____, CENTERBAND VALUES _____
 CONNECTIONS: _____ SIZE _____ TYPE (0-RING, ETC...)
 DRAIN/VENT _____
 INLET GAGE _____
 DISCHARGE GAGE _____

TESTING (PURCHASER-DEFINED)

HYDRO TEST WITNESS NON-WITNESS
 MECH TEST WITNESS NON-WITNESS
 PERF TEST WITNESS NON-WITNESS
 NPSH WITNESS NON-WITNESS
 VIBRATION WITNESS NON-WITNESS
 ACOUSTIC WITNESS NON-WITNESS
 DISMANTLE/INSPECT AFTER TEST
 OTHER : _____

 TEST REPORTS REQUIRED

PUMP DETAILS (OEM-DEFINED)

PRESS: MAX. ALLOW. _____ PSIG _____ °F _____ HYDRO TEST _____ PSIG
 IMPELLER DIA. RATED _____ MAX. _____ IMPELLER TYPE _____
 BEARING TYPES: RADIAL _____ THRUST _____
 LUBE: OIL GREASE PERM. GREASE
 COUPLING: MFR. _____ MODEL _____
 DRIVER HALF MTD. BY: PUMP MRF. DRIVER MFR. PURCHASER
 MECH. SEAL: MFR. & MODEL _____ MATERIAL CODE _____
 EXT. SEAL FLUSH COOLING WATER: GPM _____, PSIG _____, °F _____
 IN ACCORDANCE WITH ASTM F1511

MATERIALS (PURCHASER DEFINED)

CASING _____
 IMPELLER _____
 WEAR RINGS _____
 SHAFT/SLEEVE _____
 GLAND _____
 BASEPLATE _____
 OTHER: _____

INSPECTIONS (PURCHASER-DEFINED)

IN-PROCESS REQUIRED
 FINAL
 ___ DAYS NOTIF. REQ'D

DRIVER (PURCHASER-DEFINED)

MOTOR TURBINE OTHER SUPPLIED BY _____
 BHP _____ RPM _____ FRAME _____ VOLTS/PHASE/HERTZ _____
 MFR. _____ BEARINGS _____ SERVICE FACTOR _____
 TYPE _____ INSULATION _____ AMPS: FL _____ LR _____
 LUBE _____ TEMP. RISE °F _____ ENCL. _____
 ORIENTATION (REL. TO PUMP INLET) _____
 FOR STEAM TURBINE DRIVER:
 INLET PRESS. _____ EXH. PRESS. _____ STEAM TEMP. _____ WATER RATE _____
 OTHER:

ADDED REQUIREMENTS

COMMENTS (OEM & PURCHASER DEFINED)

PUMP DATA (AFTER PRODUCTION BY OEM)

CUSTOMER/USER _____

 LOCATION _____ CUSTOMER P.O. NO. _____
 ITEM NO (S) _____ EQUIP. NO (S) _____
 FACTORY ORDER NO (S) _____ PUMP SERIAL NO (S) _____
 ISSUED BY _____ DATE _____
 REVISION _____ DATE _____

(WORD 6.0, DOCS/FCE/001)

FIG. 1 Centrifugal Pump Ordering Data (English)

CENTRIFUGAL PUMP ORDERING DATA (METRIC)

USER/CUSTOMER _____ OEM/BIDDER _____ DATE _____

CLASS(1 THRU 6) _____ NO. OF PUMPS _____ NO. OF DRIVERS (MOTORS/TURBINE) _____ ITEM NO. _____

OPERATING CONDITIONS (PURCHASER-DEFINED)

FLUID _____
 °C RATED _____ °C MAX. _____ (Lpm) RATED _____
 SP. GR. AT RATED PT. _____ TOTAL HEAD, (bar) RATED _____
 VAP. PRESS. AT RATED PT. _____ SUCT. PRESS. (bar) MAX. _____, RATED _____
 VISCOSITY AT RATED, Centistokes _____ NPSHA, (bar) _____
 AMBIENT CONDITIONS _____
 PITCH _____ ROLL _____ LIST _____ TRIM _____

PERFORMANCE (OEM-DEFINED)

PERFORMANCE CURVE NO. _____
 RPM _____ NPSH (WATER) _____
 EFF. _____ % BHP RATED _____
 MAX. Kw RATED IMPELLER _____
 MAX. HEAD RATED _____
 MAX DISCH. PRESS. (bar) _____
 MIN CONTINUOUS (Lpm) _____

TESTING (PURCHASER-DEFINED)

HYDRO TEST WITNESS NON-WITNESS
 MECH TEST WITNESS NON-WITNESS
 PERF TEST WITNESS NON-WITNESS
 NPSH WITNESS NON-WITNESS
 VIBRATION WITNESS NON-WITNESS
 ACOUSTIC WITNESS NON-WITNESS
 DISMANTLE/INSPECT AFTER TEST
 OTHER : _____

CONSTRUCTION (PURCHASER REQUIREMENTS)

PUMP TYPE: HORIZ VERT CLOSE COUPLED OEM OPTION (CHECK ONLY
 IF OEM CAN SPECIFY ALTERNATE)

SPLIT: RADIAL AXIAL

PAINTING/COATINGS SPECIFICATION: _____

ACOUSTICS SPECIFICATION: _____, OR

dBA _____, CENTERBAND VALUES _____

CONNECTIONS: SIZE TYPE (O-RING, ETC...)

- DRAIN/VENT _____
- INLET GAGE _____
- DISCHARGE GAGE _____

TEST REPORTS REQUIRED

PUMP DETAILS (OEM-DEFINED)

PRESS: MAX. ALLOW. _____ bar _____ °C _____ HYDRO TEST _____ bar

IMPELLER DIA. RATED _____ MAX. _____ IMPELLER TYPE _____

BEARING TYPES: RADIAL _____ THRUST _____

LUBE: OIL GREASE PERM. GREASE

COUPLING: MFR. _____ MODEL _____

DRIVER HALF MTD. BY: PUMP MRF. DRIVER MFR. PURCHASER

MECH. SEAL: MFR. & MODEL _____ MATERIAL CODE _____

EXT. SEAL FLUSH COOLING WATER: Lpm _____, bar _____, °C _____

IN ACCORDANCE WITH ASTM F1511

MATERIALS (PURCHASER DEFINED)

CASING _____

IMPELLER _____

WEAR RINGS _____

SHAFT/SLEEVE _____

GLAND _____

BASEPLATE _____

OTHER: _____

INSPECTIONS (PURCHASER-DEFINED)

- IN-PROCESS REQUIRED
- FINAL
- _____ DAYS NOTIF. REQ'D

DRIVER (PURCHASER-DEFINED)

MOTOR TURBINE OTHER SUPPLIED BY _____

BHP _____ RPM _____ FRAME _____ VOLTS/PHASE/HERTZ _____

MFR. _____ BEARINGS _____ SERVICE FACTOR _____

TYPE _____ INSULATION _____ AMPS: FL _____ LR _____

LUBE _____ TEMP. RISE °C _____ ENCL. _____

ORIENTATION (REL. TO PUMP INLET) _____

FOR STEAM TURBINE DRIVER:

INLET PRESS. _____ EXH. PRESS. _____ STEAM TEMP. _____ WATER RATE _____

OTHER:

PUMP DATA (AFTER PRODUCTION BY OEM)

CUSTOMER/USER _____

LOCATION _____ CUSTOMER P.O. NO. _____

ITEM NO (S). _____ EQUIP. NO (S) _____

FACTORY ORDER NO (S). _____ PUMP SERIAL NO (S) _____

ISSUED BY _____ DATE _____

REVISION _____ DATE _____

ADDED REQUIREMENTS

COMMENTS (OEM & PURCHASER DEFINED)

(WORD 6.0, DOCS/FCE/002)

FIG. 2 Centrifugal Pump Ordering Data (Metric)

TABLE 1 Material Specifications

	Class 1: Freshwater	Class 2: Seawater ^A	Class 3: Hydrocarbon
Casing and Pressure Boundary Parts	Bronze (Specification B 584, Alloy C90500, C92200, or C87500)	Corrosion-resistant Duplex Alloy (Specification A 890/A 890M, Grade CD4MCu)	Bronze (Specification B 584, Alloy C90500, C92200, or C87500)
	Stainless Steel (Specification A 743/A 743M, CF8M)	Ni-Al Bronze (Specification B 148, Alloy C95500 or C95800)	Stainless Steel (Specification A 743/A 743M, CF8M, J92900)
Shaft and Rotor Parts	Stainless Steel (Specification A 582/A 582M, Cond, Alloy S41600)	Stainless Steel (Specification A276, S31600)	Stainless Steel (Specification A58/A 582M A, Alloy S41600)
	Nickel-copper alloy (Specification B 164, UNS N04400 or N04405)	Nickel-copper Alloy (Monel) (Specification B 164, UNS N04400)	
	Composite ^B (shaft sleeves only)	Composite ^B (shaft sleeves only)	
Impellers	Bronze (Specification B 584, Alloy C90500, C92200, or C87500)	Corrosion-resistant Duplex Alloy (Specification A 890/A 890M, Grade CD4MCu)	Bronze (Specification B 584, Alloy C90500, C92200, or C87500)
	Stainless Steel (Specification A 743/A 743M, Grade CF8M or CF8)	Ni-Al Bronze (Specification B 148, UNS C95500 or C95800)	Stainless Steel (Specification A 743/A 743M, Grade CF8M or CF8)
	Composite ^B	Composite ^B	
Wear Rings	Bronze (Specification B 271, B 505 or B 584)	Stainless Steel (Specification A 747, CB7Cu-1, Cond H1150, J92180)	Bronze (Specification B 271, B 505, or B 584)
	Composite ^B	Bronze (Specification B 271, B 505 or B 584) Composite ^B	
Casting Fasteners	Corrosion-resisting steel (Specification A 193/A 193M, Grade B8M and A 194/A 194M, Grade 8M)	Monel (Specification F 468, Alloy 400)	Corrosion-resisting steel (Specification A 193/A 193M, Grade B8M and A 194/A 194M, Grade 8M)
		Corrosion-resisting steel (Specification A 193/A 193M, Grade B8M and A 194/A 194M, Grade 8M)	
Base	Structural Steel (Specification A 36/A 36M)	Structural Steel (Specification A 36/A 36M)	Structural Steel (Specification A 36/A 36M)

^A Materials used for seawater services may also be used for Class 1 and 3 service pumps. Galvanic compatibility must be taken into consideration when choosing allowable materials.

^B Material property of composites must be suitable for pump service life and intended service.

6. General Requirements

6.1 Pumps shall be designed to meet all operational requirements of the intended service and be constructed in such a manner as to allow for reliable operation and maintenance.

6.2 Pumps shall be selected to operate at or near the best efficiency point (BEP) on the head-capacity curve.

6.3 Motors shall have power ratings, including a service factor, if any, at least equal to 125 % of pump brake-horsepower at rated design condition for motors less than 30 hp, 115 % of pump brake-horsepower at rated design condition for motors rated between 30 and 75 hp and 110 % of pump brake-horsepower at pump-rated design condition for motors greater than 75 hp. The power required at pump-rated conditions shall not exceed the motor nameplate horsepower rating.

6.4 Pumps shall be designed for a shipboard environment including both pitch and roll conditions specified by the purchaser in Fig. 1 and Fig. 2. Pumps shall also be capable of sustained operation at the maximum angles of list and trim specified in Fig. 1 and Fig. 2.

6.5 For horizontal pumps, the pump and driver shall be mounted on a common base of sufficient strength and stiffness to allow for proper alignment and operation. Where necessary to maintain proper alignment, dowels or fitted bolts shall be provided.

6.6 All vertical pumps shall be entirely supported by a horizontal foundation or a vertical ship structure, but not both. Where necessary, the upper portion of the pump unit may be bolted to a frame erected on the horizontal foundation.

6.7 Bedplates for Class 3 pumps shall be equipped with driprims and drain connections.

6.8 Horizontal pumps of the coupled type shall be driven through a flexible coupling. Coupled vertical pumps may be connected to their drivers by a flexible or rigid coupling. Couplings between the pump and driver shall be keyed to both shafts.

6.9 All pump units shall incorporate guards over the couplings, belts, and other external rotating parts. The guards shall prevent personnel contact with the rotating elements. Guards shall be rigid enough to support a 200-lb (88-kg) person.

6.10 Pump and driver seating surfaces of mounting bedplates, bracket mounting plates, or other mounting arrangements shall be machined.

6.11 Sufficient means shall be provided for attaching conventional lifting gear for the installation, removal, and maintenance of both the pump and driver.

6.12 Pumps with face-mounted motors shall be arranged such that there are four possible orientations of the motor to pump.

6.13 Shaft alignment between the pump and driver will be specified by the OEM to allow the pump unit to operate within the vibration limits set in Section 8 over the expected service life of the pump.

6.14 Direction of rotation shall be indicated on the pump by either an arrow cast into the pump casing or by a direction arrow plate permanently attached to the pump.

6.15 The driver type and requirements shall be specified in Fig. 1 and Fig. 2.

7. Pump Design

7.1 Pump inlet and outlet connections shall be flanged in accordance with ANSI B16.1, B16.5, B16.11, or B16.24.

7.2 Pump casings, except for close-coupled pumps, shall be arranged so that the rotating components can be removed without disturbing the driver or the suction and discharge connections.

7.3 The pump casings shall be provided with bosses drilled and tapped or socket welded and flanged for suction, discharge pressure gage, and vent and drain connections if specified in Fig. 1 and Fig. 2 (refer to Fig. 1 and Fig. 2 for type and size). All connections shall be plugged or blank flanged using material suitable for design conditions.

7.4 Coupled pumps shall be equipped with radial and thrust bearings to support the rotor and counteract any unbalanced forces in the pump and ensure that the pump will operate satisfactorily over the pump's entire design range.

7.5 Close coupled pumps and rigidly coupled vertical pumps shall have radial and thrust bearings located in the driver that are capable of supporting the rotating assembly and counteracting any unbalanced forces in the pump unit.

7.6 Bearings shall be securely fitted by snap rings, shoulders, or other means to prevent axial movement within the bearing housing. Bearing housings shall be integral or bolted to the pump case to maintain internal alignment of components and external alignment between the pump and driver. Bolted connections require fitted bolts, dowels, or rabbet fit to ensure alignment of the bearing housing to the casing.

7.7 Journal and thrust bearings may be of the fluid film or rolling element (antifriction) type. The bearings may be sealed and self or externally lubricated or may be lubricated by the process fluid.

7.8 Rolling element bearings shall be selected in accordance with AFBMA Standards 9 or 11, or both, and shall have a calculated minimum L10 life of 15 000 h.

7.9 Unless otherwise specified in Fig. 1 and Fig. 2, all pumps shall be equipped with mechanical seals in accordance with Specification F 1511. The installation shall ensure that adequate circulation of liquid at the seal faces occurs to minimize deposits of foreign matter and to provide adequate lubrication of the seal faces.

7.10 Material selection shall be in accordance with Section 5.

7.11 Separate pressure boundary parts such as casing halves, suction heads, and end covers shall be attached to the pump casing using rabbet fits, dowel pins, or fitted bolts to ensure component alignment.

7.12 Screw threads shall conform to ANSI B1.1. Metric screw threads shall conform to ISO Metric Screw Threads (ANSI B1 Report.)

8. Performance Requirements

8.1 The operating conditions of the pump shall be as specified in Fig. 1 and Fig. 2.

8.2 The NPSHR of the pump as determined by the Hydraulic Institute Standards (ANSI/HI 1.1-1.5) shall not exceed the NPSHA that is specified at the rated condition.

8.3 Pumps that handle liquids more viscous than water shall have their water performance corrected in accordance with the Hydraulic Institute Standard (ANSI/HI 1.1-1.5).

8.4 The internally excited vibration levels of the pump unit shall not exceed the requirements of the centrifugal pump test standards of the Hydraulic Institute (ANSI/HI 1.1-1.5).

8.5 The acoustic levels of the pump shall not exceed those specified in Fig. 1 or Fig. 2 when measured in accordance with the centrifugal pump test standards of the Hydraulic Institute (ANSI/HI 9.1-9.5).

8.6 Pressure containing parts shall be capable of withstanding a pressure of at least 1.5 times the maximum allowable design pressure.

9. Painting and Coatings

9.1 *Painting*—External unmachined and nonmating machined surfaces (except for stainless steel) shall be thoroughly cleaned and painted with a hydrocarbon-resistant, anticorrosive (lead and chromate free) primer and topcoat. Heat-resistant paint requirements, if any, will be specified in Fig. 1 and Fig. 2.

9.2 Painting external surfaces of nonferrous parts and components is not required but is permissible to avoid excessive masking. Identification plates shall not be painted or oversprayed.

10. Equipment Identification Plates

10.1 Identification plates shall be made of a corrosion-resistant material that will last throughout the service life of the pump. The identification plate must be securely attached to each pump.

10.2 The pump identification plate shall contain, at a minimum, the following information:

10.2.1 Manufacturer's name,

10.2.2 Manufacturer's model number and size,

10.2.3 Manufacturer's serial number,

10.2.4 ASTM F 998 Class _____, and

10.2.5 Design parameters (expressed in English or SI units):

10.2.5.1 Capacity (rated) (GPM or m³/h),

10.2.5.2 Suction requirements (ft or m),

10.2.5.3 Total developed head (rated) (ft or m),

10.2.5.4 Rated speed (RPM),

10.2.5.5 BHP, and

10.2.5.6 Hydrostatic test pressure (psi or bar).

10.3 Attached accessory units such as the driver, controller, and gearbox shall have an identification plate.

10.4 The manufacturer shall provide necessary safety information in the form of information plates.

11. Testing Requirements

11.1 Testing shall be in accordance with Fig. 1 and Fig. 2.

11.2 Hydrostatic tests shall be performed at a pressure of 1.5 times of design working pressure (or 50 psig minimum) for a minimum of 30 min. The pump shall exhibit no leakage through the pressure boundary material or joints during the hydro test. Mechanical seal leakage criteria shall be in accordance with Specification F 1511.

11.3 The mechanical run test shall consist of a short operation of the pump to ensure there is no abnormal noise, vibration, or excessive mechanical seal leakage from the pump before shipment.

11.4 Performance tests shall be conducted in accordance with the Hydraulic Institute centrifugal pump tests standards (ANSI/HI). The performance tolerance acceptance levels shall be as specified by ANSI/HI.

11.5 Net positive suction head (NPSH) tests, when specified, shall be conducted in accordance with the Hydraulic Institute centrifugal pump tests standards (ANSI/HI). The acceptance level shall be in accordance with ANSI/HI.

11.6 Vibration tests, when specified, shall be conducted in accordance with the Hydraulic Institute centrifugal pump tests standards (ANSI/HI). The acceptance level shall be in accordance with ANSI/HI.

11.7 Acoustic tests, when specified, shall be conducted in accordance with the Hydraulic Institute centrifugal pump tests standards (ANSI/HI). The acceptance level shall be in accordance with ANSI/HI.

11.8 If a test report is required or if tests must be witnessed, the purchaser shall specify the requirements in Fig. 1 and Fig. 2.

12. Technical Documentation

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

12.1.1 Unit description;

12.1.2 Installation instructions;

12.1.3 Operating instructions;

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

12.1.5 Outline dimension drawing, including weight;

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

12.1.7 Performance curve that plots total head, efficiency, NPSH, (if required), and brake horsepower as a function of capacity; and

12.1.8 List of fluids with material safety data sheets (MSDS).

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

12.2.1 Outline dimension drawing with weight and center of gravity;

12.2.2 Typical cross-sectional drawing and list of materials;

12.2.3 Performance curve which plots total head, efficiency, water NPSH, and brake horsepower as a function of capacity; and

12.2.4 List of recommended spare parts.

13. Packaging and Preservation

13.1 All openings shall be sealed with covers. Small piping (1 in. or less) may be sealed with tape. Cover design shall preclude the makeup of connecting piping with covers in place.

13.2 Each unit shall be crated and braced. Small piping shall be secured to prevent damage during shipment.

13.3 Internal surfaces subject to rusting shall be coated with suitable rust preventative.

14. Quality Assurance

14.1 The manufacturer shall have a certified ISO 9001 quality system.

15. Keywords

15.1 bilge and ballast pump; boiler feed pump; centrifugal; centrifugal pump; condensate pump; freshwater pump; hydrocarbon

pump; impeller; marine pump; pump; seawater pump

SUPPLEMENTARY REQUIREMENTS

The following supplementary requirements shall apply only when specified by the purchaser in the contract or order. When the contract or order invokes a supplement item listed in this section and which may be in conflict with the requirements of Specification F 998, the requirements of the supplement shall prevail. The manufacturer and purchaser shall agree upon details of the supplementary requirements. The manufacturer shall perform the specified tests before shipment of the pump.

S1. Referenced Documents

S1.1 *ASTM Standard:*

B 473 Specification for UNS N08020, UNS08024, and UNS N08026 Nickel Alloy Bar and Wire

S1.2 *ANSI Standard:*

S2.19 Balance Quality Requirements of Rigid Rotors, Part 1: Determination of Permissible Residual Unbalance³

S1.3 *ISO Standard:*

281 Rolling Bearings—Dynamic Load Ratings and Rating Life³

S1.4 *Military Standards:*

MIL-STD-167-1 Mechanical Vibrations of Shipboard Equipment (Type I—Environmental and Type II—Internally Excited)⁵

MIL-STD-740 Airborne and Structureborne Noise Measurements and Acceptance Criteria of Shipboard Equipment⁵

MIL-S-901 Shock Tests, H.I. (High Impact) Shipboard Machinery, Equipment and Systems, Requirements for⁵

MIL-C-23233 Couplings for Propulsion Units, Auxiliary Turbines and Line Shafts, Naval Shipboard⁵

NAVSEA Technical Publication T9074-AS-GIB-010/271 Requirements for Nondestructive Testing Methods⁵

S2. Ordering Data

S2.1 *Classification*—Pumps shall be of the following classes:

S2.1.1 *Type C-1*—Pumps with overhung impellers with all bearings on the driver side of the impeller.

S2.1.2 *Type C-2*—Close coupled pumps overhung.

S2.1.3 *Type C-2(a)*—Reference NAVSEA Drawing 803-5773203 “Pump, Fire, 750 to 1000 GPM.”⁶

S2.1.4 *Type C-2(b)*—Reference NAVSEA Drawing 803-6962399 “Navy Standard Titanium Close Coupled Pump – 6 × 6 × 15.”⁶

S2.1.5 *Type C-2(c)*—Reference NAVSEA Drawing 803-6962398 “Navy Standard Titanium Close Coupled Pump – 8 × 6 × 11.”⁶

S2.1.6 *Type C-2(d)*—Reference NAVSEA Drawing 803-6962399 “Pump, Fire, 250 GPM.”⁶

S2.1.7 *Type C-2(e)*—Reference NAVSEA Drawing 803-7014778 “Commercial/Marine Composite Standard Pump (5-875 GPM)”⁶

S2.1.8 *Type C-3*—Pumps with impellers between bearings.

S2.1.89 *Type C-3(a)*—Reference NAVSEA Drawing 803-6397389 “Pump Centrifugal 2000 GPM.”⁶

S2.2 *Requirements*—All pumps in accordance with this Supplement shall have Fig. S2.1 completed by the purchasing activity. The pump supplier shall use Fig. 1 of this specification when identifying their pump.

S3. Design Requirements

S3.1 *Type C-1 and C-2 Pumps:*

S3.1.1 The design shall be of the single-stage, single-suction, and volute type.

S3.1.2 Pumps shall have constantly rising head capacity characteristic curves. Pumps with rated capacities of 50 gal/min or more shall have head capacity characteristic curves such that total head at shutoff is not less than 10 % above the head at rated capacity.

S3.1.3 For pumps with closed impellers, wear rings shall be fitted and shall be secured by means of axially oriented setscrews. Pump out vanes can be used instead of back wear rings when approved by the design agency.

S3.1.4 Pump casing joints shall be made up using compressed sheet gaskets or O-rings.

S3.2 *Type C-3 Pumps:*

Annual Book of ASTM Standards, Vol 01.02:

⁵ Available from Standardization Documents Order Desk, Bldg. 4, Section D, 700 Robbins Ave., Philadelphia, PA 19111-5098, Attn: NPODS.

Annual Book of ASTM Standards, Vol 02.01:

⁶ Available from NAVICP-Mechanicsburg, Code 056, 5450 Carlisle Pike, Mechanicsburg, PA 17055.

PUMP CLASSIFICATION (S1.1) _____

NO. OF PUMPS _____

SERVICE/FLUID: _____ °F RATED _____ °F MAX. _____
 (GPM) RATED _____ TOTAL HEAD, (FT) RATED _____
 NPSHA, (FT) _____

TEST NAVY SUPP.

- | | | |
|---|----------------------------------|--------|
| <input type="checkbox"/> SHOCK | <input type="checkbox"/> WITNESS | S4.1 |
| <input type="checkbox"/> VIBRATION | <input type="checkbox"/> WITNESS | S4.2 |
| <input type="checkbox"/> 1ST ART. QUAL. | <input type="checkbox"/> WITNESS | S5.1 |
| <input type="checkbox"/> HYDRO TEST | <input type="checkbox"/> WITNESS | S5.2.1 |
| <input type="checkbox"/> OVERSPEED | <input type="checkbox"/> WITNESS | S5.2.3 |
| <input type="checkbox"/> MECH/CAPACITY | <input type="checkbox"/> WITNESS | S5.2.4 |
| <input type="checkbox"/> NOISE | <input type="checkbox"/> WITNESS | S5.2.5 |
| <input type="checkbox"/> OTHER : | | |

MOUNTING TYPE: HORIZ VERT OEM OPTION (CHECK ONLY IF OEM CAN SPECIFY ALTERNATE)

CONNECTIONS: TYPE (O-RING, ETC...)

- DRAIN/VENT _____
- INLET PRESSURE GAGE _____
- DISCHARGE PRESSURE GAGE _____

DRIVER (PURCHASER-DEFINED)

- MOTOR
- IEEE _____
- MIL SPEC _____
- OTHER _____

VOLTS/PHASE/HERTZ _____ TYPE _____ ENCL. _____

ORIENTATION (REL. TO PUMP INLET) _____

OTHER:

FIG. S2.1 Ordering Data

S3.2.1 Pumps shall be capable of parallel operation and shall have constantly rising head characteristic curves. Each pump with a total head gage pressure of 100 psig or more shall have a characteristic curve such that at constant rated speed the total head at shutoff will not be less than 10 % nor more than 20 % above total head at rated capacity.

S3.2.2 The preferred design shall be of the single-stage, double-suction, and volute type. Two stages may be used if necessary to provide an acceptable hydraulic design.

S3.2.3 Removable casing wearing rings shall be fitted in all pumps. They shall be designed for anti-rotation. Leakage through the wearing ring clearance shall not impinge directly on the casing.

S3.2.4 Each Type C-3 pump with a total head gage pressure of 100 psig or higher shall have a synthetic rubber seal between the casing wearing ring and casing. The seal may be an O-ring or flat-face type.

S3.2.5 Pump casing joints shall be made up using compressed sheet gaskets. O-rings may be used when approved by the design review agency.

S3.2.6 Suction and discharge connections of split case pumps shall be on the fixed half casing.

S3.3 Casings:

S3.3.1 Casing thickness shall include a minimum 1/8-in. allowance for corrosion and core shift.

S3.3.2 Clearance shall be provided around bolt heads and nuts to permit the use of standard tools.

S3.3.3 Fitted bolts, dowel pins, or rabbets, or combination thereof, shall be provided to ensure alignment of all fitted parts (upper and lower half pump casings, bearing housings to pump casings, and so forth). Dowel pins shall be corrosion resistant and secured against coming adrift under shock loading.

S3.3.4 Forcing (jacking) bolts shall be provided for ease of joint disassembly.

S3.4 Venting—Pump casing shall be self-venting or be provided with casing vents.

S3.5 Impellers:

S3.5.1 Impellers shall be keyed on the shaft and held securely against axial movement by lock nuts. Other means shall be approved by the design review agency.

S3.5.2 Impellers shall not be furnished with wearing rings. Closed impeller hub wearing surfaces shall have sufficient material

thickness to permit reducing the diameter of the impeller hubs as much as 0.050 in. to accommodate undersize casing wearing rings to restore design running clearances.

S3.5.3 Each metal impeller shall be dynamically balanced in accordance with ANSI S2.19, Grade G6.3. Use a density of 0.28 lbm/in.³ to calculate the weight of composite impellers for balancing purposes.

S3.6 Shafts:

S3.6.1 There shall be a maximum shaft deflection of 0.00 ± 2 in. at stuffing box face calculated at shut-off conditions. Use hydraulic radial load calculation from Hydraulic Institute (ANSI/HI 1.1-1.5-1994), Paragraph 1.3.3.7.2. Impeller weight shall be included in radial load calculation for all horizontal pumps. Shaft sleeves shall not be used for determining stiffness of the pump shaft. For overhung impellers, use the inboard bearing as a cantilever fixed point to calculate shaft deflection. Verify deflection at all other close-running clearance locations.

S3.6.2 Screw threads, except for rolling contact bearing locknuts, shall be opposite to the direction of rotation and can be clockwise or counterclockwise.

S3.6.3 Shaft wearing surfaces (local to bushings, water-lubricated bearings and others), shall be fitted with sleeves. O-rings shall be installed between the shaft sleeves and the shaft.

S3.6.4 Shafts of Type C-2 close-coupled pumps shall be of one-piece construction.

S3.7 Rotating Assembly:

S3.7.1 Rotors shall be dynamically balanced with all rotating parts assembled. For common shaft assemblies, or those using rigid coupling, this requires dynamic balance with the rotating element of the driving unit in place. However, rotating parts may be balanced individually, provided that, when assembled, the imbalance shall not exceed the limits specified in ANSI S2.19 Grade G6.3.

S3.7.2 Where balancing is required as a maintenance procedure to maintain proper vibration or noise performance of the pump and driver unit in service, the pump shall be designed such that balancing may readily be performed.

S3.7.3 The pump shall be designed to operate at a speed not exceeding 70 % of the first critical speed.

S3.8 Mechanical Seals:

S3.8.1 Mechanical seals shall be in accordance with S1 of Specification F 1511 except for Type C-2(a), C-2(d), and C-3(a). Split and cartridge seal designs may be used when approved by the design agency.

S3.8.2 Surface ship seawater pumps with a total head of 30 psig or greater shall be fitted with a cyclone separator at each mechanical seal. The separator shall be rigidly mounted on the pump and shall be connected to the suction and discharged piping by means of tubing and fittings. Other means to clean seal flush water, such as a centrifugal force device, can be used when approved by the design review agency.

S3.8.3 Pumps shall be configured so that normal gland leakage from the mechanical seal shall be collected and piped to waste. The collection area shall be tapped for drain connections so that the leakage can be drained away from the pump casing foundation, bearing housings, and driving units.

S3.8.4 A throttle bushing with close clearance shall be used to prevent excessive leakage in case of mechanical seal failure. The diametrical clearance of the throttle bushing bore shall not be more than 0.025 in. for sleeve diameters up to 2.0 in. For larger diameters, the maximum diametrical clearance shall be 0.025 in. plus 0.005 in. for each additional 1.0 in. of diameter or fraction thereof.

S3.8.5 For C-3-type pumps, split mechanical seals shall be incorporated into the pump design. Split mechanical seals (Grade 3 of Specification F 1511) shall not be used for hydrocarbon service pumps.

S3.8.6 Specification F 1511 and Supplement S1 seals shall use an anti-rotation pin with a 1/8-in. diameter and 1/16-in. protrusion for the mechanical seal stationary element.

S3.8.7 The maximum allowable critical tolerancing required: axial shaft movement maximum of 0.003 in., shaft runout maximum of 0.002-in. TIR at impeller fit area and 0.002-in. TIR at seal area (with seal sleeve removed), impeller wear ring runout maximum of 0.004-in. TIR, seal sleeve runout maximum of 0.004-in. TIR, stuffing box face runout of 0.003-in. TIR per inch of shaft diameter (diameter under the seal sleeve), stuffing box bore diameter runout of 0.005-in. TIR (for piloted gland plate), coupling end shaft runout of 0.002-in. TIR.

S3.9 Couplings:

S3.9.1 For horizontal or vertical four-bearing units, a flexible metal coupling shall be installed between the pump and driver. Flexible couplings for pumps for gasoline pumping service or other explosive/flammable liquids shall be nonsparking. Flexible couplings shall be in accordance with MIL-C-23233, Type II, Class 2.

S3.9.2 Coupling hubs shall be keyed to the shaft end. For pump shaft ends 2.5 in. in diameter or larger, the hubs shall be taper fit, keyed, and secured with lock nuts.

S3.10 Bearings:

S3.10.1 Rolling element bearing life shall be calculated for a basic rating L10 h in accordance with ISO 281 (ANSI/ABMA Standard 9) of at least 25 000 h with continuous operation at rated conditions, and at least 16 000 h at maximum radial and axial loads and rated speed.

S3.10.2 For bearing protection, labyrinth or face seals shall be provided adjacent to the gland for all pumps. The wear life of face seals shall be a minimum of 25 000 h. Motors for close-coupled pumps shall have labyrinth or face seals, or both, installed

on the inboard bearing housing. Lip seals are not permitted.

S3.11 Materials:

S3.11.1 For Type C-2(a), (b), (c), and C-3(a) pumps, all materials shall be in accordance with design drawings. Materials for all other pumps shall be in accordance with Table S3.1. Material classes shown in Table S3.1 shall be followed for all pump components to ensure galvanic compatibility.

S3.11.2 All impellers, wear rings, and shaft sleeves for seawater pumps will use a composite material in accordance with NAVSEA Drawing 803-7226047. Wear rings used in freshwater service pumps shall have a hardness difference then the impeller of at least 50 BHN.

S3.11.3 Proposed alternate materials shall be subject to approval by the design review agency. Components of the pump for which the specific materials are not specified shall use materials best suited for the intended service. Materials, which can be sensitized and subjected to heat treatment in the sensitization range during fabrication, shall not be adversely affected by intergranular corrosion-causing mechanisms. Particular attention shall be given to avoiding sensitization of materials during hard-facing, stress-relieving, or repair-welding operations. Use of cadmium-plated parts, fasteners, and washers is prohibited. Galvanic compatibility between dissimilar metals when used in saltwater applications must be considered.

S3.12 *Electric Motors*—The pumps shall have non-overloading power characteristics, and the driver-rated horsepower shall at least equal the maximum power requirements of the pump at the rated speed without allowances for a service factor.

S3.13 Hot Freshwater Services (Greater than 200°F condensate/feedwater service):

S3.13.1 NAVSEA detailed review of pump hydraulic test and design data may be used instead of testing at design pump pressures and temperatures.

S3.13.2 Composite internal components are not permitted.

S3.13.3 Vertical pumps shall have mechanical seal chamber vent.

S3.13.4 Single and multi-stage designs are permitted for these services.

S4. Shock and Vibration Testing

S4.1 Shock Test:

S4.1.1 The pump shall undergo a shock test to ascertain that the pump 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 pump 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.

S4.1.2 Before and 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 subject 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. Shafts, impellers, turbine rotors, motor rotors, and reduction gears shall be inspected by one of the applicable nondestructive test procedures, other than radiography, specified in NAVSEA Technical Publication T9074-AS-GIB-010/271.

S4.1.3 Before and after the shock test, tests in accordance with the Mechanical Soundness and Capacity Test Supplement 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.

TABLE S3.1 Materials

Classes	I (Freshwater)	II (Seawater/Freshwater)	III (Seawater/Freshwater)	IV (Seawater/Freshwater)
Casing and pressure Boundary components	316 stainless CD4Mcu	Ni Al bronze	CD4Mcu	70-30 CuNi
Wetted shaft	316 stainless	Monel	Alloy 20	Monel
Internals	316 stainless CD4Mcu composites	composites NiAl bronze (freshwater)	composites CD4Mcu (freshwater)	composites Ni Al bronze (freshwater)
Mechanical seals	316 stainless alloy 20	Monel	Alloy 20	Monel
Pressure-containing bolts/studs/nuts ^A	stainless steel	Monel	Alloy 20	Monel

^A Pump/motor hold-down bolts shall be Monel or K-Monel. Carbon steel bolts not permitted because of corrosion.

S4.1.4 The unit shall be mounted on the shock machine or barge essentially identical to the actual shipboard installation. 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 with oil lubricated sleeve bearings shall be operated at the minimum speed and pressure required insuring lubrication of bearings and wearing parts. Other pumps shall be operated at the highest rated speed. Pumps shall be operated at as close to the rated condition as possible within the capability of the test facility.

S4.1.5 The pump shall be carefully observed during each shock blow and thoroughly visually examined after each blow. After each blow, the unit shall be operated at as close to maximum rated speed as possible and checked for abnormal noises and vibrations and proper functioning of controls. Turbine driven pumps may be air driven. 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.

S4.1.6 Shock test acceptance criteria shall be as follows:

S4.1.6.1 There shall be no breaking of parts, including mounting bolts.

S4.1.6.2 There shall be no distortion or derangement of any part, which would render the unit incapable of performing as specified.

S4.1.6.3 The amplitude of vibration after test at maximum rated speed shall be less than twice the amplitude measured at the same speed before the test.

S4.1.6.4 Adequate lubrication to all bearings shall be maintained.

S4.1.6.5 Critical dimensions and running clearances shall be maintained.

S4.1.6.6 There shall be no significant change in the head-capacity curve.

S4.1.7 *Postshock Test Procedure*—The shock-tested unit, 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 unit shall successfully pass the Hydrostatic Pressure Test Supplement (S5.2.1), the Mechanical Soundness and Capacity Test Supplement (S5.2.4), and the Noise Test Supplement (S5.2.5), if applicable. Quality conformance test documentation shall certify that the unit 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 unit fully conforms to the specifications for unrestricted service.

S4.1.8 Unless otherwise specified by the contract or purchase order, pump units shall be shock tested with its driver. Flexible coupled pumps shock tested with one driver will not be required to be shock tested again when supplied with a different driver of equal or less weight. Drivers are subject to shock tests in accordance with their applicable equipment specifications.

S4.2 *Vibration Test:*

S4.2.1 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.

S4.2.2 The unit 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 unit 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.

S5. Testing Requirements

S5.1 *First Article Qualification*—One pump 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: S5.1.1, Performance Test; S5.1.2, Endurance Test; and S5.1.3, 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.

S5.1.1 *Performance Test:*

S5.1.1.1 The performance tests shall be conducted and recorded in accordance with the requirements of the test specified in Mechanical Soundness and Capacity Test Supplement (S5.2.4) except that, in addition, a full-performance map for the rated

impeller shall be established. The full-performance map shall be developed by measuring and establishing curves for total head versus capacity, pump efficiency versus capacity, brake horsepower versus capacity, and net positive suction head required versus capacity. For each of those curves, measurements shall be taken at shutoff, rated condition, as close to free delivery as practicable, and at five other capacities approximately evenly spread between these test points. The proposed test procedure for this test shall be submitted to the purchaser for approval approximately at the time of drawing submittal. Test data shall be converted to the specified operating conditions for plotting of all performance curves. The performance curves shall be determined at maximum and minimum operating speed for multispeed pumps. A full net positive suction head (NPSH) curve is required on the lead production unit, and, on subsequent units, the NPSH shall be determined at design rated capacity only.

S5.1.1.2 Acceptance Criteria—The acceptance criteria specified in the Mechanical Soundness and Capacity Test Supplement (S5.2.4) shall be met. The performance map shall exhibit the specified pump performance characteristics. The net positive suction head required shall not exceed the minimum suction head available specified by the contract or order. Controls and safety devices shall function reliably as intended throughout the full operating ranges of capacity and speed.

S5.1.2 Endurance Test:

S5.1.2.1 The pump shall be operated for a period of not less than 500 h of actual running time with a minimum of 60 starts to ascertain reliability of performance and operation. The start/stop cycle requires that the pump be at rest for 5-min minimum before restarting.

S5.1.2.2 Before commencement of the endurance test and immediately after completion of the 500-h 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 impellers 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.

S5.1.2.3 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.

S5.1.2.4 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. During the latter part of the endurance test, the pump shall be operated as near shutoff as possible for 12 h continuously. The remainder of the endurance tests shall be run at maximum rated speed and within +20°F, -0°F of maximum specified liquid temperature. The pump shall be operated at one-third, two-thirds, and rated capacity in approximately equal time intervals. Operations at rated capacity shall be at minimum specified net positive suction head available or maximum specified suction lift or vacuum, as applicable.

S5.1.2.5 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.

The Endurance Test acceptance criteria shall be as follows:

(1) Head-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) Unit performance and operation after 500 h of operation shall be unchanged and normal and meet all specification requirements.

(3) Unit 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 11.6 or MIL-STD-167-1. if S4.2 is invoked.)

(4) Lubrication shall have remained satisfactory throughout the test period. Bearing temperatures shall have remained normal and shall be consistent with their respective bearing clearances and oil and grease limitations.

(5) Leakage rate from a mechanical shaft seal or pump packing shall have performed as specified. The leakage shall be of a quantity such that it can drain from the pump cavity without overflowing.

(6) Running clearances shall be normal.

(7) Components subject to attack from corrosion, erosion, cavitation, and so forth shall be in a condition commensurate with 500 h of service.

(8) 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.

(9) No relevant failures shall have occurred throughout the 500-h test.

S5.1.2.6 *Postendurance Test Procedures*—The unit 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 unit shall successfully pass the Hydrostatic Pressure Test Supplement, Mechanical Soundness, and Capacity Test Supplement, (S5.2.4.1 (1)), and Noise Tests Supplement (S5.2.5), if applicable. The quality conformance test documentation shall indicate that the unit 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.

S5.1.3 *Inclined Operation Test*—This test shall only be required for pumps with oil lubricated bearings and as a check for oil leakage while inclined at an angle from the normal equal to the combination of the maximum permanent list and trim as specified in the contract or purchase order. Operation in the inclined position shall be as close to rated speed and capacity as practicable. The performance point shall be indicated in the test report.

S5.2 *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.

S5.2.1 *Hydrostatic Pressure Test*—All pressure boundary parts, excluding the mechanical seal, 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.

S5.2.1.1 *Acceptance Criteria*—The pump shall exhibit no leakage through the pressure boundary material or joints.

S5.2.2 *Assembled Pump Pressure Test*—The assembled pump shall be tested at a pressure equal to or greater than the sum of the shutoff pressure plus the design suction pressure.

S5.2.2.1 *Acceptance Criteria*—The pump shall exhibit no leakage from the joint and the pressure boundary. Leakage from the mechanical seal shall be in accordance with Specification F 1511.

S5.2.3 *Overspeed Test*—Each pump driven by a variable speed driver that can overspeed shall be operated continuously for 30 min at a speed of 25 % above maximum design operating speed. The pump need not be under load except as necessary to prevent damage or injury. Continuous shaft and rigid coupled pumps shall be tested with the driver. Units separately driven through flexible couplings and geared units may be tested using a different driver capable of reaching the overspeed condition. The dynamic balance shall be checked using a vibration instrument capable of measuring vibration amplitude of 0.001 in. (peak to peak). Neither the pump nor driver shall exhibit abnormal noises or roughness of operation. Vibration shall not exceed the vibration limits for this equipment in accordance with 11.6 (or MIL-STD-167-1, Type II if S4.2 is invoked).

S5.2.4 *Mechanical Soundness and Capacity Test*

S5.2.4.1 This test shall be conducted, recorded, and reported in accordance with the Centrifugal Pump Rating Standard and Test Code of the Hydraulic Institute, 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) Identification of the diameter of the impellers tested in the pump;

(3) A dimensioned sketch of the test loop showing location of the pump, location of all instrumentation, distance (vertical and along the pipe axis) from the suction and discharge gage taps to the pump suction and discharge flanges, vertical distance from the gage(s) to the elevation datum to which they are calibrated, azimuthal location of the gage taps on the pipe circumference, and location and orientation of any elbows in the pump suction piping;

(4) The test loop water temperature during the test;

(5) 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 gages are calibrated for if a gage is calibrated in feet of water rather than in lb/in.²;

(6) The data sheets of all recorded data, with the unit of measurement identified for all data;

(7) A sample calculation of each type of calculation converting the raw data into specified conditions and showing the conversion in sufficient detail to permit an independent reviewer to verify the calculations, including all temperature and density corrections;

(8) A copy of the specific table of water properties used in the calculations and a reference to the source of that table; and

(9) A plot of the measured head-capacity curve, corrected to the specified operating conditions following the method described in the sample calculations.

S5.2.4.2 The test shall be performed as follows:

(1) Operate the pump and its driver, if motor driven continuously at the rated speed and capacity, with the pumped fluid at ambient temperature until bearing temperatures (not including water-lubricated bearings) stabilize. Stabilization is defined as three consecutively recorded readings taken over intervals of at least 15 min that fall within 3°F band when adjusted for ambient. The three consecutive readings shall not be constantly rising. The pump operation shall be monitored for proper functioning of safety devices, bearing lubrication, and for smooth running.

(a) *Acceptance Criteria*—Unit operation shall be free of abnormal vibrations and noises. Oil temperature rise in force-feed lubricated bearings shall not exceed 50°F with inlet cooling water to the oil cooler at 85°F. Controls and attached instruments shall function as specified and are in calibration. There shall be no abnormal leakage of water or oil.

(2) Operate the pump at the maximum rated speed with the pumped fluid at maximum normal temperature from recirculation flow to 130 % of the rated capacity specified and with the minimum specified suction pressure. The unit shall be operated at shutoff rated condition, 130 % of rated capacity and at five other capacities approximately evenly spaced between these points. The unit shall be operated at each test point until the test values being measured stabilize.

(a) *Acceptance Criteria*—The pump shall deliver the rated capacity, head and efficiency. The head-capacity characteristic curve at maximum rated speed shall satisfy the specified requirements. The total head at all capacities from 0 to 120 % of rated capacity on the curve shall not deviate by more than +5 % or –5 % of rated head at the corresponding capacity on the head-capacity characteristic curve at maximum rated speed established during initial design testing of the pump. If more than one performance test has been performed for a given pump design for use in a given ship class, then an average of all performance head-capacity characteristic curves established is the one to which the preceding sentence refers. In no case shall the pump deliver less than the rated head at rated flow. The required net positive suction head shall not exceed the minimum net positive suction head available as specified in the contract

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

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

S5.2.5 *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 units.

S5.2.5.1 *Acceptance Criteria*—The unit shall meet the noise level limits specified in the contract.

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