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An American National Standard

Standard Specification for Centrifugal Pump, Shipboard Use[1]

This standard is issued under the fixed designation F 998; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

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

1.1.1 Class 1—Boiler feedwater and other freshwater applications with temperatures above 212°F (100°C),

1.1.2 Class 2—Condensate water,

1.1.3 Class 3—Freshwater except Classes 1 and 2,

1.1.4 Class 4—Seawater in which total head produced per stage does not exceed 50 psi (345 kPa),

1.1.5 Class 5—Seawater in which total head produced per stage exceeds 50 psi (345 kPa), and

1.1.6 Class 6—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.

2. Referenced Documents

2.1 *ASTM Standards:*

A 193/A 193M Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service[2]

A 216/A 216M Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service[3]

A 276 Specification for Stainless Steel Bars and Shapes[4]

A 494/A 494M Specification for Castings, Nickel and Nickel Alloy[3]

A 743/A 743M Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion-Resistant, for General Application[3]

B 148 Specification for Aluminum-Bronze Sand Castings[5]

B 164 Specification for Nickel-Copper Alloy Rod, Bar, and Wire[6]

B 369 Specification for Copper-Nickel Alloy Castings[5]

B 505 Specification for Copper-Base Alloy Continuous Castings[5]

B 584 Specification for Copper Alloy Sand Castings for General Applications[5]

F 467 Specification for Nonferrous Nuts for General Use[7]

F 467M Specification for Nonferrous Nuts for General Use[7]

F 468 Specification for Nonferrous Bolts, Hex Cap Screws, and Studs for General Use[7]

F 468M Specification for Nonferrous Bolts, Hex Cap Screws, and Studs for General Use[7]

F 1511 Specification for Mechanical Seals for Shipboard Pump Applications[8]

2.2 *ANSI Standards:*

B1 ISO Metric Screw Threads (ANSI-B1 Report)[9]

B1.1 Unified Screw Threads[9]

B16.1 Cast Iron Pipe Flanges and Flange Fittings[9]

B16.5 Steel Pipe Flanges, Flanged Valves and Fittings, 150, 300, 400, 600, 900, 1500 and 2500 lb.[9]

B16.11 Forged Steel Fittings, Socket Welding and Threaded[9]

B16.24 Bronze Flanges and Flanged Fittings, 150, 300lb[9]

2.3 *Hydraulic Institute Standards:*

ANSI/HI 1.1-1.5 American National Standard for Centrifugal Pumps for Nomenclature, Definitions, Applications and Operation[9]

ANSI/HI 1.6 American National Standard for Centrifugal Pump Tests[9]

ANSI/HI 9.1-9.5 American National Standard for Pumps—General Guidelines for Types, Definitions, Applications and Sound Measurements[9]

2.4 *AFBMA Standards:*

9 Load Ratings and Fatigue Life for Ball Bearings[10]

11 Load Ratings and Fatigue Life for Roller Bearings[10]

2.5 *ISO Standards:*

ISO 9001 Quality Systems and Quality Assurance—Design/Development, Production, Installation and Service[9]

3. Terminology

3.1 *Definitions:*

[1] This specification is under the jurisdiction of Committee F-25 on Ships and Marine Technology and is the direct responsibility of Subcommittee F25.11 on Machinery.

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[2] *Annual Book of ASTM Standards*, Vol 01.01.

[3] *Annual Book of ASTM Standards*, Vol 01.02.

[4] *Annual Book of ASTM Standards*, Vol 01.03.

[5] *Annual Book of ASTM Standards*, Vol 02.01.

[6] *Annual Book of ASTM Standards*, Vol 02.04.

[7] *Annual Book of ASTM Standards*, Vol 15.08.

[8] *Annual Book of ASTM Standards*, Vol 01.07.

[9] Available from American National Standards Institute, 11 W. 42nd St., 13th Floor, New York, NY 10036.

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

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.

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 4 and 5 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.

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)_____

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 (0-RING, ETC…)

☐ DRAIN/VENT _____ _____

☐ INLET GAGE _____ _____

☐ DISCHARGE GAGE _____ _____

☐ 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

ADDED REQUIREMENTS

COMMENTS (OEM & PURCHASER DEFINED)

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:

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 (PURCHASUER-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 : _____

_____

_____

_____

☐ TEST REPORTS REQUIRED

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	_____	_____

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:

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/002)

FIG. 2 Centrifugal Pump Ordering Data (Metric)

Purchaser approval must be obtained for the use of nonmetallic materials.

TABLE 1 Material Specifications

	Class 1 (Boiler Feedwater)	Class 2 (Condensate)	Class 3 (Fresh Water)	Class 4 (Seawater (< 50 psi/stage)	Class 5 (Seawater (> 50 psi/stage)	Class 6 (Hydrocarbon)
Casing	12 % chrome steel (Specification A 743/A 743M, Grade CA15)	copper-nickel (70-30) (Specification B 369, UNS C96400)	bronze (Specification B 584, Alloy 905 or 922)	copper-nickel (70-30) (Specification B 369, UNS C96400)	copper-nickel (70-30) (Specification B 369, UNS C96400)	bronze (Specification B 584, Alloy 905 or 922)
Shaft	12 % chrome steel (Specification A 276, Grade 410)	nickel-copper alloy (Specification B 164, Class A or B, UNS N04400 or N04405)	nickel-copper alloy (Specification B 164, Class A or B, UNS N04400 or N04405)	nickel-copper alloy (Monel) (Specification B 164, UNS N04400)	nickel-copper alloy (Monel) (Specification B 164, UNS N04400)	nickel-copper alloy (Specification B 164, Class A or B, UNS N04400 or N04405)
Impeller	12 % chrome steel (Specification A 743/A 743M, Grade CA15)	nickel-copper alloy (Specification A 494/A 494M, S22, Comp M30C with S22)	bronze (Specification B 584, Alloy 905 or 922)	nickel-aluminum bronze (Specification B 148, Alloy 955)	nickel-aluminum bronze (Specification B 148, Alloy 955)	bronze (Specification B 584, Alloy 905 or 922)
Shaft sleeves	12 % chrome steel (Specification A 276, Grade 410)	nickel-copper alloy (Specification B 164, Class A or B, UNS N04400 or N04405)	stainless steel (Specification A 276, Type 304 or 316)	nickel-copper alloy (Monel) (Specification B 164, N04400)	nickel-copper alloy (Monel) (Specification B 164, N04400)	stainless steel (Specification A 276, Type 304 or 316)
Wear rings	12 % chrome steel (Specification A 743/A 743M, Grade CA15 and CA6NM)	nickel-copper alloy (Specification A 494/A 494M, Comp M25S, with S10 and S21 or M30H)	bearing bronze III (Specification B 505, UNS C91000)	nickel-copper alloy (Specification A 494/A 494M, Comp M25S, with S10 and S21 or M30H)	nickel-copper alloy (Specification A 494/A 494M, Comp M25S, with S10 and S21 or M30H)	bearing bronze III (Specification B 505, UNS C91000)
Base	structural steel	structural steel	structural steel	carbon steel (Specification A 216/A 216M, Grade WCB)	carbon steel (Specification A 216/216M, Grade WCB)	structural steel
Casing bolts	corrosion-resisting steel (Specification A 193/A 193M)	Monel (Specification F 468, Alloy 400)	Monel (Specification F 468, Alloy 400)	Monel (Specification F 468, Alloy 400)	Monel (Specification F 468, Alloy 400)	Monel (Specification F 468, Alloy 400)

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. 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.

6.3 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.

6.4 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.

6.5 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.

6.6 Bedplates for Class 6 pumps shall be equipped with driprims and drain connections.

6.7 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.

6.8 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.

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

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

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

6.12 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.

6.13 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.

6.14 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 small 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 Table 1 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 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 m^3/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