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An American National Standard

Standard Specification for Centrifugal Pump, Shipboard Use[1]

This standard is issued under the fixed designation F998; 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 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.

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

A36/A36M Specification for Carbon Structural Steel

A193/A193M Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications

A194/A194M Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both

A276 Specification for Stainless Steel Bars and Shapes

A494/A494M Specification for Castings, Nickel and Nickel Alloy

A582/A582M Specification for Free-Machining Stainless Steel Bars

A743/A743M Specification for Castings, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant, for General Application

A747/A747M Specification for Steel Castings, Stainless, Precipitation Hardening

A890/A890M Specification for Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application

A995/A995M Specification for Castings, Austenitic-Ferritic (Duplex) Stainless Steel, for Pressure-Containing Parts

B148 Specification for Aluminum-Bronze Sand Castings

B164 Specification for Nickel-Copper Alloy Rod, Bar, and Wire

B271 Specification for Copper-Base Alloy Centrifugal Castings

B369 Specification for Copper-Nickel Alloy Castings

B505/B505M Specification for Copper Alloy Continuous Castings

B584 Specification for Copper Alloy Sand Castings for General Applications

F468 Specification for Nonferrous Bolts, Hex Cap Screws, Socket Head Cap Screws, and Studs for General Use

F1511 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 Threads[3]

B16.1 Cast Iron Pipe Flanges and Flange Fittings[3]

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 Threaded[3]

B16.24 Bronze Flanges and Flanged Fittings, 150, 300lb[3]

2.3 *Hydraulic Institute Standards:*

ANSI/HI 1.1-1.5 American National Standard for Centrifugal Pumps for Nomenclature, Definitions, Applications and Operation[3]

ANSI/HI 1.6 American National Standard for Centrifugal Pump Tests[3]

ANSI/HI 9.1-9.6 American National Standard for Pumps—General Guidelines for Types, Definitions, Applications and Sound Measurements[3]

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

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

[3] Available from American National Standards Institute (ANSI), 25 W. 43rd St., 4th Floor, New York, NY 10036, http://www.ansi.org.

2.4 *AFBMA Standards:*
9 Load Ratings and Fatigue Life for Ball Bearings[4]
11 Load Ratings and Fatigue Life for Roller Bearings[4]
2.5 *ISO Standards:*
ISO 9001 Quality Systems and Quality Assurance—Design/Development, Production, Installation and Service[3]

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.

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.

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

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 (PURCHASER-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 ____

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. ____ 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

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:

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: ____

☐ TEST REPORTS REQUIRED

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)

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 (PURCHAUSER-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)

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.

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.

TABLE 1 Material Specifications

	Class 1: Freshwater	Class 2: Seawater[A]	Class 3: Hydrocarbon
Casing and Pressure Boundary Parts	Bronze (Specification B584, Alloy C90500, C92200, or C87500)	Corrosion-resistant Duplex Alloy (Specification A890/A890M or A995/A995M, Grade CD4MCuN)	Bronze (Specification B584, Alloy C90500, C92200, or C87500)
	Stainless Steel (Specification A743/A743M, CF8M)	Ni-Al Bronze (Specification B148, Alloy C95500 or C95800)	Stainless Steel (Specification A743/A743M, CF8M, J92900)
Shaft and Rotor Parts	Stainless Steel (Specification A582/A582M, Cond, Alloy S41600)	Stainless Steel (Specification A276, S31600)	Stainless Steel (Specification A582/A582M A, Alloy S41600)
	Nickel-copper alloy (Specification B164, UNS N04400 or N04405)	Nickel-copper Alloy (Monel) (Specification B164, UNS N04400)	
	Composite[B] (shaft sleeves only)	Composite[B] (shaft sleeves only)	
Impellers	Bronze (Specification B584, Alloy C90500, C92200, or C87500)	Corrosion-resistant Duplex Alloy (Specification A890/A890M or A995/A995M, Grade CD4MCuN)	Bronze (Specification B584, Alloy C90500, C92200, or C87500)
	Stainless Steel (Specification A743/A743M, Grade CF8M or CF8)	Ni-Al Bronze (Specification B148, UNS C95500 or C95800)	Stainless Steel (Specification A743/A743M, Grade CF8M or CF8)
	Composite[B]	Composite[B]	
Wear Rings	Bronze (Specification B271, B505/B505M or B584)	Stainless Steel (Specification A747/A747M, CB7Cu-1, Cond H1150, J92180)	Bronze (Specification B271, B505/B505M, or B584)
	Composite[B]	Bronze (Specification B271, B505/B505M or B584)	
		Composite[B]	
Casting Fasteners	Corrosion-resisting steel (Specification A193/A193M, Grade B8M and A194/A194M, Grade 8M)	Monel (Specification F468, Alloy 400)	Corrosion-resisting steel (Specification A193/A193M, Grade B8M and A194/A194M, Grade 8M)
		Corrosion-resisting steel (Specification A193/A193M, Grade B8M and A194/A194M, Grade 8M)	
Base	Structural Steel (Specification A36/A36M)	Structural Steel (Specification A36/A36M)	Structural Steel (Specification A36/A36M)

[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.

6.4 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 F1511. 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).