# پیشگامان صنعت و ایمنی پرگاس

## PISHGAMAN SANAAT & IMENI PERGAS

## طراح، مشاور و مجری سیستم‌های ایمنی و تاسیساتی

**دارای صلاحیت سازمان آتش‌نشانی تهران**

**اخذ تاییدیه آتش‌نشانی**

برای اطلاعات بیشتر اسکن کنید

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## مشاوره و طراحی

اطفا حریق . اعلام حریق
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PERGAS
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# Centrifugal Pumps for Petroleum, Heavy Duty Chemical, and Gas Industry Services

API STANDARD 610
EIGHTH EDITION, AUGUST 1995

**American Petroleum Institute**
1220 L Street, Northwest
Washington, D.C. 20005

# Centrifugal Pumps for Petroleum, Heavy Duty Chemical, and Gas Industry Services

**Manufacturing, Distribution and Marketing Department**

API STANDARD 610
EIGHTH EDITION, AUGUST 1995

American
Petroleum
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# FOREWORD

This standard covers the minimum requirements for centrifugal pumps, including pumps running in reverse as hydraulic power recovery turbines, for use in petroleum, heavy-duty chemical, and gas industry services.

This standard is based on the accumulated knowledge and experience of manufacturers and users of centrifugal pumps. The objective of this standard is to provide a purchase specification to facilitate the manufacture and procurement of centrifugal pumps for use in petroleum, chemical, and gas industry services.

The primary purpose of this standard is to establish minimum mechanical requirements. This limitation in scope is one of charter as opposed to interest and concern. Energy conservation is of concern and has become increasingly important in all aspects of equipment design, application, and operation. Thus, innovative energy-conserving approaches should be aggressively pursued by the manufacturer and the user during these steps. Alternative approaches that may result in improved energy utilization should be thoroughly investigated and brought forth. This is especially true of new equipment proposals, since the evaluation of purchase options will be based increasingly on total life costs as opposed to acquisition cost alone. Equipment manufacturers, in particular, are encouraged to suggest alternatives to those specified when such approaches achieve improved energy effectiveness and reduced total life costs without sacrifice of safety or reliability.

This standard requires the purchaser to specify certain details and features. Although it is recognized that the purchaser may desire to modify, delete, or amplify sections of this standard, it is strongly recommended that such modifications, deletions, and amplifications be made by supplementing this standard, rather than by rewriting or incorporating sections thereof into another complete standard.

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Suggested revisions are invited and should be submitted to the director of the Manufacturing, Distribution, and Marketing Department, American Petroleum Institute, 1220 L Street, N.W., Washington, D.C. 20005.

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# Centrifugal Pumps for Petroleum, Heavy Duty Chemical, and Gas Industry Services

## SECTION 1—GENERAL

### 1.1 Scope

**1.1.1** This standard covers the minimum requirements for centrifugal pumps, including pumps running in reverse as hydraulic power recovery turbines, for use in petroleum, heavy duty chemical, and gas industry services.

Note: A bullet (●) at the beginning of a paragraph indicates that either a decision or further information is required. Further information should be shown on the data sheets (see Appendix B) or stated in the quotation request and purchase order.

**1.1.2** The pump types covered by this standard can be broadly classified as overhung, between bearings, and vertically suspended (see Figure 1-1). To aid the use of this standard, Sections 2, 3, 4, and 6 cover requirements that are applicable to two or more of these broad classifications. Section 5 is divided into 3 subsections and covers requirements unique to each of the broad classifications. Figure 1-2 shows the various specific pump types within each broad classification and lists the identification assigned to each specific type.

**1.1.3** The pump types listed in Table 1-1 have special design characteristics and shall be furnished only when specified by the purchaser and when the manufacturer has proven experience for the specific application. Table 1-1 lists the principal special considerations for these pump types and shows in parentheses the relevant paragraph(s) of API Standard 610.

**1.1.4** For nonflammable, nonhazardous services not exceeding any of the limits below, purchasers may wish to consider pumps that do not comply with API Standard 610.

| | | |
|---|---|---|
| Maximum discharge pressure | 1900 kPa | (275 psig) |
| Maximum suction pressure | 500 kPa | (75 psig) |
| Maximum pumping temperature | 150°C | (300°F) |
| Maximum rotative speed | 3600 RPM | |
| Maximum rated total head | 120 m | (400 ft.) |
| Maximum impeller diameter, overhung pumps | 330 mm | (13 in.) |

Note: Pumps that do not comply with API Standard 610 shall, as a minimum, meet the requirements of the standard for service life, materials, shaft stiffness, mechanical seals, bearing, and auxiliary piping. The purchaser shall state in the inquiry those requirements that can be relaxed.

### 1.2 Alternative Designs

**1.2.1** The vendor may offer alternative designs.

● **1.2.2** The purchaser will specify whether pumps supplied to this standard shall have SI dimensions and comply with applicable ISO standards or have U.S. dimensions and comply with applicable U.S. standards.

### 1.3 Conflicting Requirements

In case of conflict between this standard and the inquiry or order, the information included in the order shall govern.

### 1.4 Definition of Terms

Terms used in this standard are defined in 1.4.1 through 1.4.56.

**1.4.1 axially split:** Casing or housing joint that is parallel to the shaft centerline.

**1.4.2 barrel pump:** A horizontal pump of the double-casing type.

**1.4.3 barrier fluid:** Fluid introduced between pressurized dual (double) mechanical seals to completely isolate the pump process liquid from the environment. Pressure of the barrier fluid is always higher than the process pressure being sealed.

**1.4.4 BEP:** Abbreviation for *best efficiency point*; the point or capacity at which a pump achieves its highest efficiency.

**1.4.5 buffer fluid:** Fluid used as a lubricant or buffer between unpressurized dual (tandem) mechanical seals. The fluid is always at a pressure lower than the process pressure being sealed.

**1.4.6 critical speed:** Rotative speed corresponding to a lateral natural frequency of a rotor.

**1.4.7 critical speed, dry:** A rotor natural frequency calculated assuming that the rotor is supported only at its bearings and that the bearings are of infinite stiffness.

**1.4.8 critical speed, wet:** A rotor natural frequency calculated considering the additional support and damping produced by the action of the pumped liquid within internal running clearances at the operating conditions and allowing for flexibility and damping within the bearings.

**1.4.9 design:** Term used by the equipment designer and manufacturer to define various parameters, for example, design power, design pressure, design temperature, or design speed. Purchaser's specifications should avoid using this term.

**1.4.10 double casing:** Type of pump construction in which the pressure casing is separate from the pumping elements (such as, diffuser diaphragms, bowls, and volute inner casings) contained in the casing.

**1.4.11 drive train components:** Items of equipment, such as motor, gear, turbine, engine, fluid drive, and clutch, used in series to drive the pump.

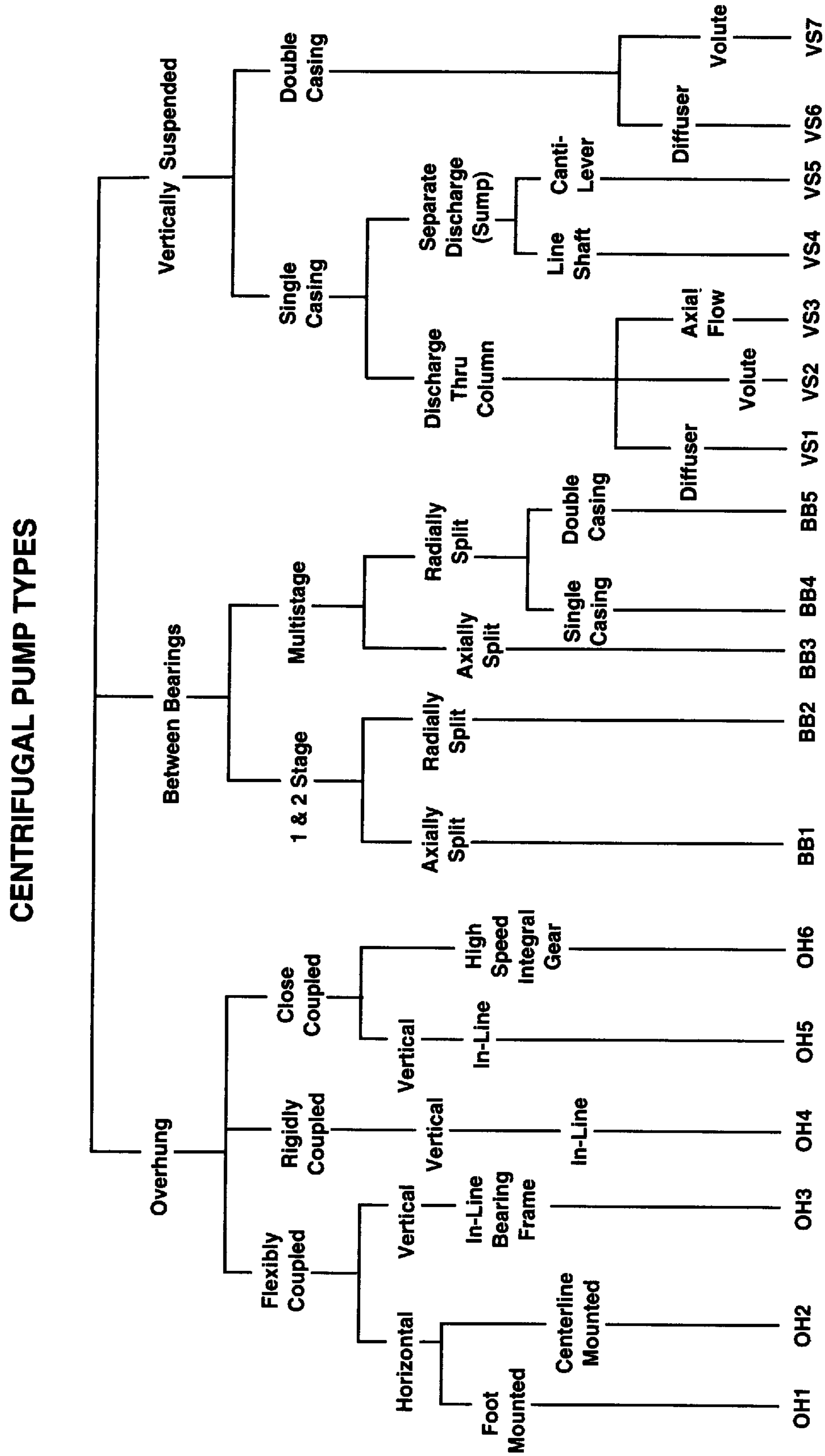
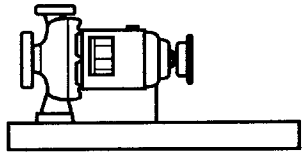
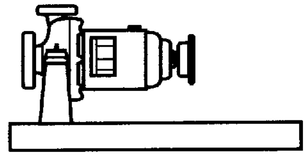
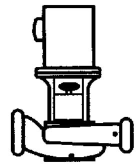
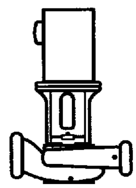
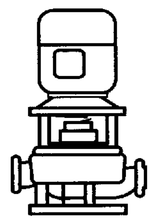



Figure 1-1—Pump Classification Type Identification

| BASIC TYPE (ROTOR) | CODE | SPECIFIC CONFIGURATION | ILLUSTRATION |
|---|---|---|---|
| **Overhung** | OH1[a] | Foot mounted |  |
| | OH2 | Centerline mounted |  |
| | OH3 | Vertical in-line separate bearing frame |  |
| | OH4[a] | Vertical in-line rigidly coupled |  |
| | OH5[a] | Vertical in-line closed coupled |  |
| | OH6 | High speed integral gear |  |

[a] See 1.1.3.

Figure 1-2—Basic Pump Types

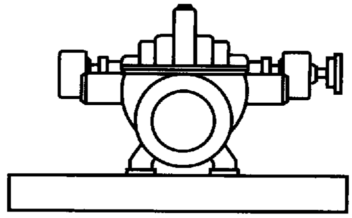
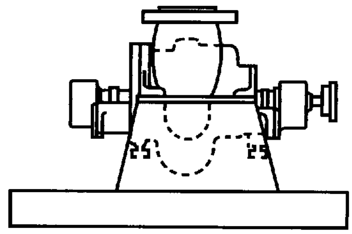
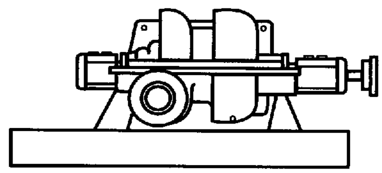
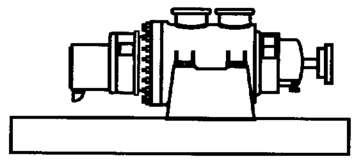
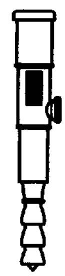
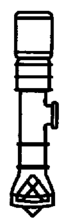
| BASIC TYPE (ROTOR) | CODE | SPECIFIC CONFIGURATION | ILLUSTRATION |
|---|---|---|---|
| **Between Bearings** | BB1 | Axially split, 1 and 2 stage |  |
| | BB2 | Radially split, 1 and 2 stage |  |
| | BB3 | Axially split, multistage |  |
| | BB4<br>BB5 | Radially split, multistage:<br>Single casing<br>Double casing |  |
| **Vertically Suspended** | VS1 | Wet pit, diffuser |  |
| | VS2 | Wet pit, volute |  |

Figure 1-2—Basic Pump Types (Continued)

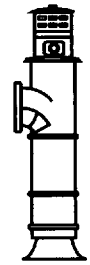
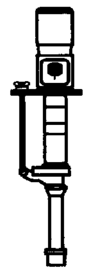
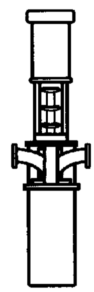
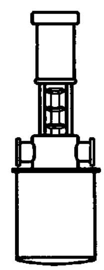
| **BASIC TYPE (ROTOR)** | **CODE** | **SPECIFIC CONFIGURATION** | **ILLUSTRATION** |
|---|---|---|---|
| **Vertically Suspended (continued)** | VS3 | Wet pit, axial flow |  |
| | VS4<br>VS5 | Vertical sump:<br>Line shaft<br>Cantilever |  |
| | VS6 | Double casing diffuser |  |
| | VS7 | Double casing volute |  |

Figure 1-2—Basic Pump Types (Continued)

**1.4.12 element:** The assembly of the rotor plus the internal stationary parts of a centrifugal pump; also known as a *bundle*.

**1.4.13 element, cartridge type:** The assembly of all the parts of the pump except for the casing. For double casing pumps, a cartridge type element includes the casing cover.

**1.4.14 hydraulic power recovery turbine:** A turbomachine designed to recover power from a fluid stream. Power recovery is generally achieved by the reduction of fluid pressure, sometimes with a contribution from vapor or gas evolution during the pressure reduction. A hydraulic power recovery turbine may be a pump operated with re-

## Table 1-1—Special Design Considerations of Particular Pump Types

| Pump Type | Principal Special Considerations |
|---|---|
| Close Coupled (impeller mounted on motor shaft) | 1. Motor construction (3.1.7; 3.1.8)<br>2. Motor bearing and winding temperature at high pumping temperatures<br>3. Seal removal (2.7.3.1) |
| Rigidly Coupled Vertical In-line | 1. Motor construction (3.1.7; 3.1.8)<br>2. Rotor stiffness (2.5.7; 5.1.2.9)<br>3. Product lubricated guide bearing (2.5.7)<br>4. Shaft runout at seal (2.5.6) |
| Horizontal Foot Mounted overhung | 1. Pressure rating (2.2.2)<br>2. Centerline supported casing (2.2.9) |
| Two Stage Overhung | 1. Rotor stiffness (2.5.7; 5.1.1.2) |
| Double Suction Overhung | 1. Rotor stiffness (2.5.7; 5.1.1.2) |
| Ring Section Casing (multistage) | 1. Pressure containment (2.2.7; 2.2.8)<br>2. Dismantling (2.1.25) |
| Built-in Mechanical Seal (no separable seal gland) | 1. Seal removal (2.7.3.1) |

verse flow. Consequently, for the nozzles of such turbines, all references in this standard to suction and discharge apply to the outlet and the inlet, respectively. Appendix E provides additional information on hydraulic power recovery turbines.

**1.4.15 hydrodynamic bearings:** Bearings that use the principles of hydrodynamic lubrication. Their surfaces are oriented so that relative motion forms an oil wedge to support the load without journal-to-bearing contact.

**1.4.16 maximum allowable speed (in revolutions per minute):** The highest speed at which the manufacturer's design will permit continuous operation.

**1.4.17 maximum allowable temperature:** The maximum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified liquid at the specified pressure.

**1.4.18 maximum allowable working pressure (MAWP):** The maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred) when the equipment is operating at the maximum allowable temperature.

**1.4.19 maximum continuous speed (in revolutions per minute):** The speed at least equal to 105 percent of the highest speed required by any of the specified operating conditions.

**1.4.20 maximum discharge pressure:** The maximum suction pressure plus the maximum differential pressure the pump is able to develop when operating with the furnished impeller at the rated speed, and maximum specified relative density (specific gravity).

**1.4.21 maximum dynamic sealing pressure:** The highest pressure expected at the seals during any specified operating condition and during start-up and shut down. In determining this pressure, consideration should be given to the maximum suction pressure, the flush pressure, and the effect of internal clearance changes.

**1.4.22 maximum static sealing pressure:** The highest pressure, excluding pressures encountered during hydrostatic testing, to which the seals can be subjected while the pump is shut down.

**1.4.23 maximum suction pressure:** The highest suction pressure to which the pump is subjected during operation.

**1.4.24 minimum allowable speed (in revolutions per minute):** The lowest speed at which the manufacturer's design will permit continuous operation.

**1.4.25 minimum continuous stable flow:** The lowest flow at which the pump can operate without exceeding the vibration limits imposed by this standard.

**1.4.26 minimum continuous thermal flow:** The lowest flow at which the pump can operate without its operation being impaired by the temperature rise of the pumped liquid.

**1.4.27 minimum design metal temperature:** The lowest mean metal temperature (through the thickness) expected in service. Considerations shall include operation upsets, auto refrigeration, and temperature of the surrounding environment.

**1.4.28 net positive suction head (NPSH):** The total absolute suction head, in meters (feet) of liquid, determined at the suction nozzle and referred to the datum elevation, minus the vapor pressure of the liquid, in meters (feet) absolute. The datum elevation is the shaft centerline for horizontal pumps, the suction nozzle centerline for vertical in-line pumps, and the top of the foundation for other vertical pumps.

**1.4.29 net positive suction head available (NPSHA):** The NPSH, in meters (feet) of liquid, determined by the purchaser for the pumping system with the liquid at the rated flow and normal pumping temperature.

**1.4.30 net positive suction head required (NPSHR):** The NPSH, in meters (feet), determined by vendor testing with water. NPSHR is measured at the suction flange and corrected to the datum elevation. NPSHR at rated and other capacities is equal to the NPSH that produces a 3 percent head drop (first stage head in multistage pumps) due to cavitation within the pump.

**1.4.31 normal operating point:** The point at which the pump is expected to operate under normal process conditions.

**1.4.32 normal wear parts:** Those parts normally restored or replaced at each pump overhaul, typically wear rings, interstage bushings, balancing device, throat bushing, seal faces, bearings, and all gaskets.

**1.4.33 oil mist lubrication:** A lubrication system that employs oil mist produced by atomization in a central supply unit and transported to the bearing housing by compressed air.

**1.4.34 pure oil mist lubrication (dry sump):** The mist both lubricates the bearing and purges the housing.

**1.4.35 purge oil mist lubrication (wet sump):** The mist only purges the bearing housing. Bearing lubrication is by conventional oil bath, flinger, or oil ring.

**1.4.36 operating region:** The portion of a pump's hydraulic coverage over which the pump operates.

**1.4.37 operating region, preferred:** Region over which the pump's vibration is within the base limit of this standard (see 2.1.12).

**1.4.38 operating region, allowable:** Region over which the pump is allowed to operate, based on vibration within the upper limit of this standard or temperature rise or other limitation; specified by the manufacturer (see 2.1.12).

**1.4.39 overhung pump:** Pump whose impeller is cantilevered from its bearing assembly. Overhung pumps may be horizontal or vertical.

**1.4.40 pressure casing:** The composite of all stationary pressure-containing parts of the pump, including all nozzles, seal glands, seal chambers, and other attached parts but excluding the stationary and rotating members of mechanical seals (see Figure D-1, Appendix D).

**1.4.41 purchaser:** Individual or organization that issues the purchase order and specifications to the vendor. The purchaser may be the owner of the plant in which the equipment is to be installed or the owner's appointed agent.

**1.4.42 radially split:** Casing or housing joint that is perpendicular to the shaft centerline.

**1.4.43 rated operating point:** The point at which the vendor certifies that pump performance is within the tolerances stated in this standard (see 4.3.3.3.3).

**1.4.44 relative density:** Property of a liquid; ratio of the liquid's density to that of water at 4°C (39.2°F).

**1.4.45 rotor:** The assembly of all the rotating parts of a centrifugal pump. When purchased as a spare, a rotor usually does not include the pump half coupling hub.

**1.4.46 specific gravity (SG):** Property of a liquid; ratio of the liquid's density to that of water at 4°C (39.2°F).

**1.4.47 specific speed:** An index relating flow, total head, and rotative speed for pumps of similar geometry. Specific speed is calculated for the pump's performance at best efficiency point with the maximum diameter impeller. Specific speed is expressed mathematically by the following equation:

$$n_q = N(Q)^{0.5}/(H)^{0.75}$$

*Where:*

$n_q$ = specific speed.
$N$ = rotative speed in revolutions per minute.
$Q$ = total pump flow in cubic meters per second.
$H$ = head per stage in meters.

Note: Specific speed derived using cubic meters per second and meters multiplied by a factor of 51.6 is equal to specific speed derived using U.S. gallons per minute and feet. The usual symbol for specific speed in U.S. units is *Ns*.

**1.4.48 standby service:** A normally idle or idling piece of equipment that is capable of immediate automatic or manual start-up and continuous operation.

**1.4.49 suction specific speed:** An index relating flow, NPSHR, and rotative speed for pumps of similar geometry. Suction specific speed is calculated for the pump's performance at best efficiency point with the maximum diameter impeller and provides an assessment of a pump's susceptibility to internal recirculation. It is expressed mathematically by the following equation:

$$n_{qs} = N(Q)^{0.5}/(NPSHR)^{0.75}$$

*Where:*

$n_{qs}$ = suction specific speed.
$N$ = rotative speed in revolutions per minute.
$Q$ = flow per impeller eye, in cubic meters per second,
= total flow for single suction impellers,
= one half total flow for double suction impellers.
$NPSHR$ = net positive suction head required (see 1.4.27) in meters

Note: Suction specific speed derived using cubic meters per second and meters, multiplied by a factor of 51.6, is equal to suction specific speed derived using U.S. gallons per minute and feet. The usual symbol for suction specific speed in US units is *S*.

**1.4.50 throat bushing:** A device that forms a restrictive close clearance around the sleeve (or shaft) between the seal (or packing) and the impeller (see Figure D-1, Appendix D).

**1.4.51 throttle bushing:** A device that forms a restrictive close clearance around the sleeve (or shaft) at the outboard end of a mechanical seal gland (see Figure D-1, Appendix D).

**1.4.52 total indicated runout (TIR),** also known as **total indicator reading:** The runout of a diameter or face determined by measurement with a dial indicator. The indicator implies an eccentricity equal to half the reading or an out of squareness equal to the reading.

**1.4.53 trip speed (in revolutions per minute):** The speed at which the independent emergency overspeed device operates to shut down a prime mover.

**1.4.54 unit responsibility:** Refers to the responsibility for coordinating the technical aspects of the equipment and all auxiliary systems included in the scope of order. Factors such as the power requirements, speed, direction of rotation, general arrangement, couplings, dynamics, lubrication, material test reports, instrumentation, piping, and testing of components, etc., shall be included.

**1.4.55 vendor:** The manufacturer of the pump, or the manufacturer's agent.

**1.4.56 vertical in-line pump:** A pump whose suction and discharge connections have a common centerline that intersects the shaft axis. The pump's driver is generally mounted directly on the pump.

**1.4.57 vertically suspended pump:** A vertical axis pump whose liquid end is suspended from a column and mounting plate. The pump's liquid end is usually submerged in the pumped liquid.

## 1.5 Referenced Publications

**1.5.1** Referenced publications, U.S. and SI, are listed in Appendix A. The U.S. publications are the base documents. The corresponding international publications and standards may be acceptable as alternatives with the purchaser's approval. In all cases, the editions that are in effect at the time of the publication of this standard shall, to the extent specified herein, form a part of this standard. The applicability of changes in standards, codes, and specifications that occur after the publication of this standard shall be mutually agreed upon between the purchaser and the vendor.

**1.5.2** The purchaser and the vendor shall mutually determine the measures that must be taken to comply with any governmental codes, regulations, ordinances, or rules that are applicable to the equipment.

**1.5.3** It is the vendor's responsibility to invoke all applicable specifications to each subvendor.

# SECTION 2—BASIC DESIGN

## 2.1 General

**2.1.1** The equipment (including auxiliaries) covered by this standard shall be designed and constructed for a minimum service life of 20 years (excluding normal wear parts as identified in Table 6-1) and at least 3 years of uninterrupted operation. It is recognized that this requirement is a design criterion.

**2.1.2** The vendor shall assume unit responsibility for all equipment and all auxiliary systems included in the scope of the order.

● **2.1.3** The purchaser will specify the equipment's normal and rated operating points. The purchaser will also specify any other anticipated operating conditions. The purchaser will specify when fluids are flammable or hazardous.

**2.1.4** Pumps shall be capable of at least a 5 percent head increase at rated conditions by replacement of the impeller(s) with one(s) of larger diameter or different hydraulic design.

Note: The purchaser may consider the use of variable speed drive capability and/or the use of blank stages (to add impellers in the future) for multistage pumps to meet this requirement.

**2.1.5** Pumps shall be capable of operating continuously up to at least 105 percent of rated speed and shall be capable of operating briefly, under emergency conditions, up to the driver trip speed.

**2.1.6** Pumps shall use throat bushings, wear rings, impeller balance holes and/or flushing line arrangements for the following:

a. To maintain a seal chamber pressure greater than atmospheric pressure.
b. To maintain a seal chamber pressure sufficient to prevent vaporization at the seal faces under all specified operating conditions.
c. To otherwise increase or decrease seal chamber pressure.
d. To isolate the seal chamber fluid.
e. To provide continuous flow through the seal chamber under all specified operating conditions.
f. To otherwise control the flow into or out of the seal chamber.

**2.1.7** The conditions in the seal chamber required to maintain a stable film at the seal faces, including temperature, pressure, and flow, as well as provisions for assuring the adequacy of the design for sealing against atmospheric pressure when pumps are idle in vacuum service, shall be mutually agreed upon by the pump vendor and the seal manufacturer, approved by the purchaser, and noted on the data sheet.

Note: Provision for sealing against atmospheric pressure in vacuum service is especially important when handling liquids near their vapor pressure (such as liquified petroleum gases).

**2.1.8** The vendor shall specify on the data sheets the NPSHR based on water (at a temperature of less than 65°C (150°F)) at the rated capacity and rated speed. A reduction or correction factor for liquids other than water (such as hydrocarbons) shall not be applied.

Note: The purchaser should consider an appropriate NPSH margin in addition to the NPSHR specified in 2.1.8 above. An NPSH margin is the NPSH that exists in excess of the pump's NPSHR (see 1.4.30). It is usually desirable to have an operating NPSH margin that is sufficient at all flows (from minimum continuous stable flow to maximum expected operating flow) to protect the pump from damage caused by flow recirculation, separation, and cavitation. The vendor should be consulted about recommended NPSH margins for the specific pump type and intended service.
In establishing NPSHA (see 1.4.29), the purchaser and the vendor should recognize the relationship between minimum continuous stable flow and the pump's suction specific speed. In general, minimum continuous stable flow, expressed as a percentage of flow at the pump's best efficiency point, increases as suction specific speed increases. However, other factors, such as the pump's energy level and hydraulic design, the pumped liquid, and the NPSH margin, also affect the pump's ability to operate satisfactorily over a wide flow range. Pump design that addresses low-flow operation is an evolving technology, and selection of suction specific speed levels and NPSH margins should take into account current industry and vendor experience.

● **2.1.9** When specified by the purchaser, the pump suction specific speed shall be limited as stated on the data sheet.

**2.1.10** Pumps that handle liquids more viscous than water shall have their water performance corrected in accordance with the Centrifugal Pump Section of the *Hydraulic Institute Standards*.

● **2.1.11** Pumps that have stable head/capacity curves (continuous head rise to shutoff) are preferred for all applications and are required when parallel operation is specified. When parallel operation is specified, the head rise shall be at least 10 percent of the head at rated capacity. If a discharge orifice is used as a means of providing a continuous rise to shutoff, this use shall be stated in the proposal.

**2.1.12** Pumps shall have a preferred operating region (see 2.8.3, Vibration) of 70–120 percent of best efficiency capacity of the furnished impeller. Rated capacity shall be within the region of 80–110 percent of best efficiency capacity of the furnished impeller.

Note: Setting specific limits for the preferred operating region and the location of rated capacity is not intended to lead to the development of additional sizes of small pumps or preclude the use of high specific speed pumps. Small pumps, which are known to operate satisfactorily at flows outside the specified limits, and high specific speed pumps, which may have a narrower preferred operating region than specified, should be offered where appropriate, and their preferred operating region clearly shown on the proposal curve.

**2.1.13** The best efficiency point for the furnished impeller shall preferably be between the rated point and the normal point.

● **2.1.14** Control of the sound level of all equipment furnished shall be a joint effort of the purchaser and the vendor. The equipment furnished by the vendor shall conform to the maximum allowable sound level specified by the purchaser.

Note: ISO Standards 3740, 3744, and 3746 may be consulted for guidance.

**2.1.15** Pumps with heads greater than 200 m (650 ft) per stage and with more than 225 kW (300 hp) per stage may require special provisions to reduce vane passing frequency vibration and low-frequency vibration at reduced flow rates. For these pumps, the radial clearance between the diffuser vane or volute tongue (cutwater) and the periphery of the impeller blade shall be at least 3 percent of the maximum impeller blade tip radius for diffuser designs and at least 6 percent of the maximum blade tip radius for volute designs. The maximum impeller blade tip radius is the radius of the largest impeller that can be used within the pump casing (see paragraph 2.1.4). Percent clearance is calculated as follows:

$$P = 100\,(R_3 - R_2)/R_2$$

*Where:*

$P$ = percent clearance.
$R_3$ = radius of volute or diffuser inlet tip.
$R_2$ = maximum impeller blade tip radius.

The impellers of pumps covered by this paragraph shall not be modified after test to correct hydraulic performance by underfiling, overfiling, or "V" cutting without notifying the purchaser prior to shipment. Any such modifications shall be documented in accordance with 6.3.5.1.

**2.1.16** Pumps of significantly higher energy levels than those specified in 2.1.15 may require even larger clearances and other special construction features. For these pumps, specific requirements should be mutually agreed upon by the purchaser and the vendor, considering actual operating experience with the specific pump types.

● **2.1.17** The need for cooling shall be mutually agreed upon by the purchaser and the vendor. When cooling is required, the type, pressure, and temperature of the cooling liquid will be specified by the purchaser. The vendor shall specify the required flow (see Appendix D).

Note: To avoid condensation, the minimum inlet water temperature to bearing housings should be above the ambient air temperature.

**2.1.18** Cooling jackets, if provided, for seal chambers and bearings shall have clean out connections arranged so that the entire passageway can be mechanically cleaned, flushed, and drained.

**2.1.19** Jacket cooling systems, if provided, shall be designed to positively prevent the process stream from leaking into the coolant. Coolant passages shall not open into casing joints.

**2.1.20** Unless otherwise specified, cooling water systems shall be designed for the following conditions:

| | | |
|---|---|---|
| Velocity over heat exchange surfaces | 1.5-2.5 m/s | (5-8 ft/s) |
| Maximum allowable working pressure (MAWP) | ≥650 kPa | (≥100 psig) |
| Test Pressure | ≥ 1.5 × MAWP | (≥ 1.5 × MAWP) |
| Maximum pressure drop | 100 kPa | (15 psi) |
| Maximum inlet temperature | 30°C | (90°F) |
| Maximum outlet temperature | 50°C | (120°F) |
| Maximum temperature rise | 20°C | (30°F) |
| Minimum temperature rise | 10°C | (20°F) |
| Fouling factor on water side | 0.35 $m^2 \cdot$ °C/kW | (0.002 hr · $ft^2$ · °F/Btu) |
| Shell corrosion allowance | 3.0 mm | (0.125 in.) |

Provisions shall be made for complete venting and draining of the system.

Note 1: The vendor shall notify the purchaser if the criteria for minimum temperature rise and velocity over heat exchange surfaces result in a conflict. The criterion for velocity over heat exchange surfaces is intended to minimize waterside fouling; the criterion for minimum temperature rise is intended to minimize the use of cooling water. The purchaser will approve the final selection.

Note 2: See Appendix R for key to abbreviations.

**2.1.21** The arrangement of the equipment, including piping and auxiliaries, shall be developed jointly by the purchaser and the vendor. The arrangement shall provide adequate clearance areas and safe access for operation and maintenance.

● **2.1.22** Motors, electrical components, and electrical installations shall be suitable for the area classification (class, group, division, or zone) specified by the purchaser and shall meet the requirements of local codes (such as NFPA 70, Articles 500, 501, and 502) specified by the purchaser.

**2.1.23** Oil reservoirs and housings that enclose moving lubricated parts (such as bearings, shaft seals, highly polished parts, instruments, and control elements) shall be designed to minimize contamination by moisture, dust, and other foreign matter during periods of operation or idleness.

**2.1.24** All equipment shall be designed to permit rapid and economical maintenance. Major parts such as casing components and bearing housings shall be designed (shouldered or doweled) and manufactured to ensure accurate alignment on reassembly. The mating faces of the pump casing and the bearing housing assembly shall be fully machined to allow the parallelism of the assembled joint to be gauged. If fully machined mating faces cannot be achieved in the design, four mating machined areas with a minimum arc length of 25 mm (1 in.) located 90 degrees apart shall be provided.

**2.1.25** Except for vertically suspended pumps, casings shall be designed to permit removal of the rotor or inner element without disconnecting the suction or discharge piping or moving the driver.

**2.1.26** The pump and its driver shall perform on their test stands and on their permanent foundation within the acceptance criteria specified in 2.8.3. After installation, the performance of the combined units shall be the joint responsibility of the purchaser and the vendor.

● **2.1.27** Many factors (such as piping loads, alignment at operating conditions, supporting structure, handling during shipment, and handling and assembly at the site) may adversely affect site performance. When specified, to minimize the influence of these factors, the vendor shall do one or more of the following:

a. Review and comment on the purchaser's piping and foundation drawings.
b. Observe a check of the piping, performed by parting the flanges after installation.
c. Be present during the initial alignment check of the pump and drive train.
d. Recheck the alignment of the pump and drive train at the operating temperature.

**2.1.28** Spare and all replacement parts for the pump and all furnished auxiliaries shall, as a minimum, meet all the criteria of this standard.

● **2.1.29** The purchaser will specify whether the installation is indoors (heated or unheated) or outdoors (with or without a roof), as well as the weather and environmental conditions in which the equipment must operate (including maximum and minimum temperatures, altitude, unusual humidity, and dusty or corrosive conditions). The unit and its auxiliaries shall be designed for operation under these specified conditions.

## 2.2 Pressure Casings

**2.2.1** The stress used in design for any given material shall not exceed the values given for that material in Section II of the ASME Code. For cast materials, the factor specified in Section VIII, Division 1, of the ASME Code shall be applied. Pressure casings of forged steel, rolled and welded plate, or seamless pipe with welded cover shall comply with the applicable design rules of Section VIII, Division 1, of the ASME Code. Manufacturers' data report forms, third party inspections, and stamping, as specified in the code, are not required.

**2.2.2** The pressure casing and flanges shall be designed for the maximum discharge pressure plus allowances for head increases (see 2.1.4 and 2.1.5) at the pumping temperatures. Unless otherwise specified, the pressure casing, as a minimum, shall be designed for the following:

a. For axially split one- and two-stage between bearings pumps and single casing vertically suspended pumps: a pressure rating equal to that of an ISO 7005-2 PN20 (ANSI /ASME B16.1 Class 125) cast iron or ISO 7005-1 PN20 (ANSI/ASME B16.5 Class 150) steel flange of a material grade corresponding to that of the pressure casing.
b. For overhung and between bearings radially split pumps, multistage horizontal pumps and double casing vertically suspended pumps: a pressure rating equal to that of an ISO 7005-1 PN50 (ANSI/ASME B16.5 Class 300) flange of a material grade corresponding to that of the pressure casing or 4 MPa (600 psig), whichever is less.

**2.2.3** The pressure casing shall be designed with a corrosion allowance to meet the requirements of 2.1.1. Unless otherwise specified the minimum corrosion allowance shall be 3 mm (0.12 in.).

● **2.2.4** The maximum allowable working pressure shall apply to all parts referred to in the definition of pressure casing (see 1.4.40) except for vertically suspended, double-casing, and horizontal multistage pumps (pumps with three or more stages). Regions of these pumps that are subject only to suction pressure need not be designed for the maximum allowable working pressure. (The purchaser should consider installation of relief valves on the suction side of such installations.) The purchaser will specify whether these pump regions are to be designed for the maximum allowable working pressure.

**2.2.5** The inner casing of double-casing pumps shall be designed to withstand the maximum differential pressure or 350 kPa (50 psig), whichever is greater.

**2.2.6** Pumps with radially split casings are required if any of the following operating conditions are specified:

a. A pumping temperature of 200°C (400°F) or higher. (A lower temperature limit should be considered when thermal shock is probable.)
b. A flammable or hazardous pumped liquid with a relative density (specific gravity) of less than 0.7 at the specified pumping temperature.
c. A flammable or hazardous pumped liquid at a rated discharge pressure above 10 MPa (1450 psi).

**2.2.7** Radially split casings shall have metal-to-metal fits, with confined controlled compression gaskets, such as an O-ring or a spiral wound type.

**2.2.8** The pump's pressure casing shall be capable of withstanding twice the forces and moments in Table 2-1A (2-1B) applied simultaneously to the pump through each nozzle, plus internal pressure, without distortion that would impair operation of the pump or seal.

Note: This is a pump casing design criterion and is not to be used for piping design nozzle loads.

**2.2.9** Centerline supported pump casings shall be used for horizontal pumps.

**2.2.10** O-ring sealing surfaces, including all grooves and bores, shall have a maximum surface roughness average value ($R_a$) of 1.6 µm (63 µin.) for static O-rings and 0.8 µm (32 µin.) for the surface against which dynamic O-rings slide. Bores shall have a minimum 3 mm (0.12 in.) radius or a minimum 1.5 mm (0.06 in.) chamfered lead-in for static O-rings and a minimum 2 mm (0.08 in.) chamfered lead-in for dynamic O-rings. Chamfers shall have a maximum angle of 30 degrees.

**2.2.11** Cylindrical dowels or rabbeted fits shall be employed to align casing components, or the casing and cover, and to facilitate disassembly and reassembly.

**2.2.12** Jackscrews shall be provided to facilitate disassembly of the casing. One of the contacting faces shall be relieved (counter bored or recessed) to prevent a leaking joint or an improper fit caused by marring of the face.

**2.2.13** Bolting shall be furnished as specified in 2.2.13.1 through 2.2.13.7.

**2.2.13.1** The details of threading shall conform to ISO 262 (ANSI/ASME B1.1).

**2.2.13.2** The use of tapped holes in pressure parts shall be minimized. To prevent leakage in pressure sections of casings, metal, equal in thickness to at least half the nominal bolt or stud diameter, in addition to the allowance for corrosion, shall be left around and below the bottom of drilled and tapped holes. The depth of the tapped holes shall be at least 1.5 times the nominal bolt or stud diameter.

**2.2.13.3** Internal bolting shall be of a material fully resistant to corrosive attack by the pumped liquid.

**2.2.13.4** Studs shall be supplied on all main casing joints unless cap screws are specifically approved by the purchaser.

**2.2.13.5** Adequate clearance shall be provided at bolting locations to permit the use of socket or box wrenches.

**2.2.13.6** Internal socket-type, slotted-nut, or c-type spanner bolting shall not be used unless specifically approved by the purchaser.

**2.2.13.7** Metric fine and UNF threads shall not be used.

## 2.3 Nozzle and Pressure Casing Connections

### 2.3.1 CASING OPENING SIZES

**2.3.1.1** Openings for nozzles and other pressure casing connections shall be standard nominal pipe sizes (NPS). Openings of 1¼, 2½, 3½, 5, 7 and 9 NPS shall not be used.

**2.3.1.2** Casing connections other than suction and discharge nozzles shall be at least ½ NPS for pumps with discharge nozzle openings 2 NPS and smaller. Connections shall be at least ¾ NPS for pumps with discharge nozzle openings 3 NPS and larger, except that connections for seal flush piping, lantern rings and gauges may be ½ NPS regardless of pump size.

### 2.3.2 SUCTION AND DISCHARGE NOZZLES

**2.3.2.1** Suction and discharge nozzles shall be flanged. One- and two-stage pumps shall have suction and discharge flanges of equal rating (2.2.2).

**2.3.2.2** Cast iron flanges shall be flat face and shall, as a minimum, conform to the dimensional requirements of ISO 7005-2 (ANSI/ASME B16.1).

**2.3.2.3** Unless otherwise specified, flanges other than cast iron shall as a minimum conform to the dimensional requirements of ISO 7005-1 (ANSI/ASME B16.5).

**2.3.2.4** Flat face flanges with full raised face thickness are acceptable on casings of all materials. Flanges in all materials that are thicker or have a larger outside diameter than that required by ISO (ANSI) are acceptable.

**2.3.2.5** Flanges shall be full or spot faced on the back and shall be designed for through bolting.

**2.3.2.6** Raised face flange finish shall have serrated spiral or concentric grooves machined with a 0.8 mm (0.03 in.) nominal radius round-nosed tool to produce a groove pitch of 0.35 to 0.45 mm (0.014 to 0.018 in.). The resulting surface roughness shall be between $R_a$ 3.2 and 6.3 μm (125 and 250 μin.) and shall be judged by visual and tactile comparison against a surface finish comparator block (ANSI/ASME B46.1). The gasket contact surface shall not have mechanical or corrosion damage which penetrates the root of the grooves for a radial length of more than 30 percent of the gasket contact width.

### 2.3.3 PRESSURE CASING CONNECTIONS

**2.3.3.1** For nonflammable and nonhazardous liquids, auxiliary connections to the pressure casing may be threaded.

**2.3.3.2** Unless otherwise specified, pipe threads shall be tapered threads conforming to ANSI/ASME B1.20.1. Tapped openings and bosses for pipe threads shall conform to ANSI/ASME B16.5.

● **2.3.3.3** If specified, cylindrical threads conforming to ISO 228, Part 1 may be used. If cylindrical threads are used, they shall be sealed with a contained face gasket, and the connection boss shall have a machined face suitable for gasket containment (see Figure 2-1).

**2.3.3.4** For flammable or hazardous liquids, auxiliary connections to the pressure casing shall be socket welded, butt welded, or integrally flanged. Field connections shall terminate in a flange.

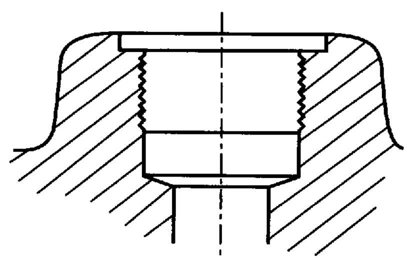


Figure 2-1—Machined Face Suitable for Gasket Containment When Using Cylindrical Threads

**2.3.3.5** Connections welded to the casing shall meet the material requirements of the casing, including impact values, rather than the requirements of the connected piping.

**2.3.3.6** Pipe nipples welded to the casing should not be more than 150 mm (6 in.) in length and shall be a minimum of Schedule 160 seamless for sizes 1 NPS and smaller and a minimum of schedule 80 for sizes 1 1/2 NPS and larger.

**2.3.3.7** Tapped openings not connected to piping shall be plugged. Plugs shall conform to paragraph 3.5.1.14.

**2.3.3.8** Machined and studded customer connections shall conform to the facing and drilling requirements of ISO 7005-1 or 2 (ANSI/ASME B16.1 or B16.5). Studs and nuts shall be furnished installed. The first 1.5 threads at both ends of each stud shall be removed.

**2.3.3.9** All connections shall be suitable for the hydrostatic test pressure of the region of the casing to which they are attached.

**2.3.3.10** Unless otherwise specified, all pumps shall be provided with vent and drain connections. Vent connections may be omitted if the pump is made self-venting by the arrangement of the nozzles.

Note: As a guide, a pump is considered self-venting if the nozzle arrangement and casing configuration permit adequate venting of gases from the first-stage impeller and volute area to prevent loss of prime during the starting sequence.

● **2.3.3.11** When specified, pressure gauge connections shall be provided.

## 2.4 External Nozzle Forces and Moments

**2.4.1** Steel and alloy steel horizontal pumps, and their baseplates, and vertically suspended pumps shall be designed for satisfactory performance when subjected to the forces and moments in Table 2-1A (2-1B). For horizontal pumps, two effects of nozzle loads are considered: Distortion of the pump casing (see 2.2.8) and misalignment of the pump and driver shafts (see 3.3.5).

**2.4.2** Allowable forces and moments for vertical in-line pumps shall be twice the values in Table 2-1A (2-1B) for side nozzles.

**2.4.3** For pump casings constructed of materials other than steel or alloy steel or for pumps with nozzles larger than 16 NPS, the vendor shall submit allowable nozzle loads corresponding to the format in Table 2-1A (2-1B).

**2.4.4** The coordinate system(s) shown in Figures 2-2 through 2-6 shall be used to apply the forces and moments in Table 2-1A (2-1B).

Note: The coordinate systems have changed since the 7th Edition of this standard.

**2.4.5** Appendix F defines the method used by the piping designer to determine allowable piping loads.

## 2.5 Rotors

**2.5.1** Unless otherwise approved by the purchaser, impellers shall be of the fully enclosed type and constructed as single piece castings. Fabricated impellers require the purchaser's specific approval.

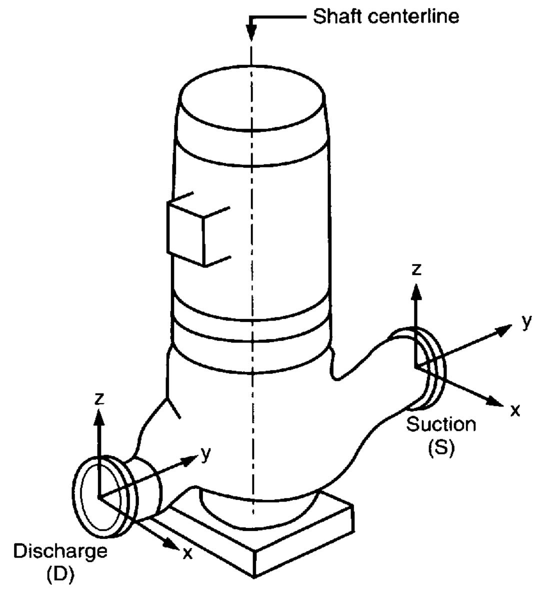



Figure 2-2—Coordinate System for the Forces and Moments in Table 2.1A (2.1B) Vertical In-Line Pumps

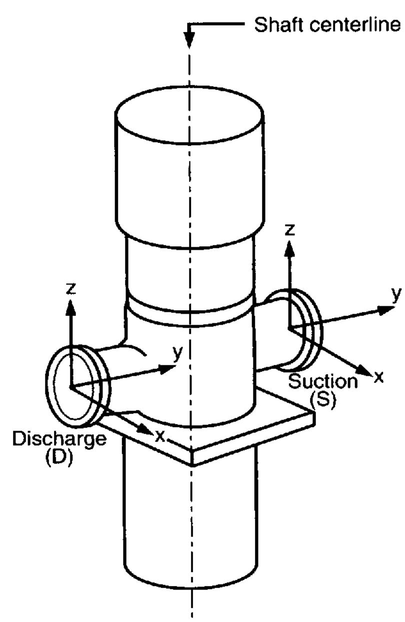



Figure 2-3—Coordinate System for the Forces and Moments in Table 2.1A (2.1B) Vertically Suspended Double-Casing Pumps

## Table 2-1A—Nozzle Loadings (SI Units)

Note: Each value shown below indicates a range from minus that value to plus that value; for example 710 indicates a range from –710 to +710.

| Force/Moment | Nominal Size of Flange (NPS) 2 | 3 | 4 | 6 | 8 | 10 | 12 | 14 | 16 |
|---|---|---|---|---|---|---|---|---|---|
| Each Top Nozzle | | | | | | | | | |
| *FX* | 710 | 1070 | 1420 | 2490 | 3780 | 5340 | 6670 | 7120 | 8450 |
| *FY* | 580 | 890 | 1160 | 2050 | 3110 | 4450 | 5340 | 5780 | 6670 |
| *FZ* | 890 | 1330 | 1780 | 3110 | 4890 | 6670 | 8000 | 8900 | 10230 |
| *FR* | 1280 | 1930 | 2560 | 4480 | 6920 | 9630 | 11700 | 12780 | 14850 |
| Each Side Nozzle | | | | | | | | | |
| *FX* | 710 | 1070 | 1420 | 2490 | 3780 | 5340 | 6670 | 7120 | 8450 |
| *FY* | 890 | 1330 | 1780 | 3110 | 4890 | 6670 | 8000 | 8900 | 10230 |
| *FZ* | 580 | 890 | 1160 | 2050 | 3110 | 4450 | 5340 | 5780 | 6670 |
| *FR* | 1280 | 1930 | 2560 | 4480 | 6920 | 9630 | 11700 | 12780 | 14850 |
| Each End Nozzle | | | | | | | | | |
| *FX* | 890 | 1330 | 1780 | 3110 | 4890 | 6670 | 8000 | 8900 | 10230 |
| *FY* | 710 | 1070 | 1420 | 2490 | 3780 | 5340 | 6670 | 7120 | 8450 |
| *FZ* | 580 | 890 | 1160 | 2050 | 3110 | 4450 | 5340 | 5780 | 6670 |
| *FR* | 1280 | 1930 | 2560 | 4480 | 6920 | 9630 | 11700 | 12780 | 14850 |
| Each Nozzle | | | | | | | | | |
| *MX* | 460 | 950 | 1330 | 2300 | 3530 | 5020 | 6100 | 6370 | 7320 |
| *MY* | 230 | 470 | 680 | 1180 | 1760 | 2440 | 2980 | 3120 | 3660 |
| *MZ* | 350 | 720 | 1000 | 1760 | 2580 | 3800 | 4610 | 4750 | 5420 |
| *MR* | 620 | 1280 | 1800 | 3130 | 4710 | 6750 | 8210 | 8540 | 9820 |

Note 1: *F* = force in Newtons; *M* = moment in Newton meters; *R* = resultant. See Figures 2-2 – 2-6 for orientation of nozzle loads (*X*, *Y*, and *Z*).
**Note 2: Coordinate system has been changed from API Standard 610, 7th Edition, convention to ISO 1503 convention.**

## Table 2-1B—Nozzle Loadings (U.S. Units)

Note: Each value shown below indicates a range from minus that value to plus that value; for example 160 indicates a range from –160 to +160.

| Force/Moment | Nominal Size of Flange (NPS) 2 | 3 | 4 | 6 | 8 | 10 | 12 | 14 | 16 |
|---|---|---|---|---|---|---|---|---|---|
| Each Top Nozzle | | | | | | | | | |
| *FX* | 160 | 240 | 320 | 560 | 850 | 1200 | 1500 | 1600 | 1900 |
| *FY* | 130 | 200 | 260 | 460 | 700 | 1000 | 1200 | 1300 | 1500 |
| *FZ* | 200 | 300 | 400 | 700 | 1100 | 1500 | 1800 | 2000 | 2300 |
| *FR* | 290 | 430 | 570 | 1010 | 1560 | 2200 | 2600 | 2900 | 3300 |
| Each Side Nozzle | | | | | | | | | |
| *FX* | 160 | 240 | 320 | 560 | 850 | 1200 | 1500 | 1600 | 1900 |
| *FY* | 200 | 300 | 400 | 700 | 1100 | 1500 | 1800 | 2000 | 2300 |
| *FZ* | 130 | 200 | 260 | 460 | 700 | 1000 | 1200 | 1300 | 1500 |
| *FR* | 290 | 430 | 570 | 1010 | 1560 | 2200 | 2600 | 2900 | 3300 |
| Each End Nozzle | | | | | | | | | |
| *FX* | 200 | 300 | 400 | 700 | 1100 | 1500 | 1800 | 2000 | 2300 |
| *FY* | 160 | 240 | 320 | 560 | 850 | 1200 | 1500 | 1600 | 1900 |
| *FZ* | 130 | 200 | 260 | 460 | 700 | 1000 | 1200 | 1300 | 1500 |
| *FR* | 290 | 430 | 570 | 1010 | 1560 | 2200 | 2600 | 2900 | 3300 |
| Each Nozzle | | | | | | | | | |
| *MX* | 340 | 700 | 980 | 1700 | 2600 | 3700 | 4500 | 4700 | 5400 |
| *MY* | 170 | 350 | 500 | 870 | 1300 | 1800 | 2200 | 2300 | 2700 |
| *MZ* | 260 | 530 | 740 | 1300 | 1900 | 2800 | 3400 | 3500 | 4000 |
| *MR* | 460 | 950 | 1330 | 2310 | 3500 | 5000 | 6100 | 6300 | 7200 |

Note 1: *F* = force in pounds; *M* = movement in foot-pounds; *R* = resultant. See Figures 2-2 – 2-6 for orientatin of nozzle loads (*X*, *Y*, and *Z*).
**Note 2: Coordinate system has been changed from API Standard 610, 7th Edition, convention to ISO 1503 convention.**

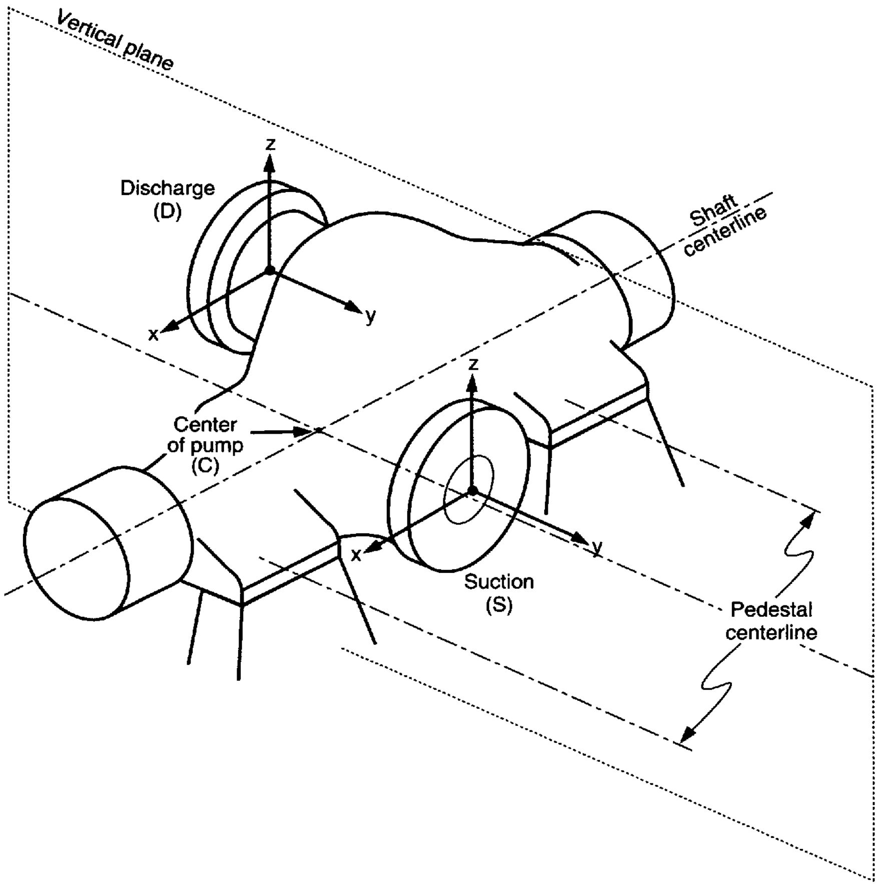



Figure 2-4—Coordinate System for the Forces and Moments in Table 2.1A (2.1B) Horizontal Pumps with Side Suction and Side Discharge Nozzles

**2.5.2** Impellers shall be keyed to the shaft; pinning of impellers is not acceptable. With the purchaser's approval, collets may be used on vertically suspended pumps. Overhung impellers shall be secured to the shaft by a cap screw or cap nut that does not expose shaft threads. The securing device shall be threaded to tighten by liquid drag on the impeller during normal rotation, and a positive mechancial locking method (for example, a staked and corrosion resistant set screw or a tongue-type washer) is required. Cap screws shall have fillets and a reduced diameter shank to decrease stress concentrations.

**2.5.3** Impellers shall have solid hubs. Impellers made from a cored pattern are acceptable if the core is completely filled with a suitable metal that has a melting point of not less than 260°C (500°F) for pumps with cast iron casings and not less than 540°C (1000°F) for pumps with cast steel casings.

Note: The requirement to fill cored impeller hubs is intended to minimize the danger to personnel when impellers are removed by heating.

**2.5.4** For shafts that require sleeve gaskets to pass over threads, at least 1.5 mm (0.06 in.) radial clearance shall be provided between the threads and the internal diameter of the gasket, and the diameter transition shall be chamfered in accordance with 2.2.10.

**2.5.5** Shaft sleeves shall be positively secured to the shaft, shall have a minimum radial thickness of 2.5 mm (0.1 in.) and shall be relieved along the bore leaving a locating fit at or near each end.

**2.5.6** Except for vertically suspended pumps (see 5.3.2.2), shafts shall be machined and finished throughout their length so that the TIR is not more than 25 μm (0.001 in.).

**2.5.7** To obtain satisfactory seal performance, the shaft stiffness shall limit the total deflection under the most severe dynamic conditions over the allowable operating range of the pump—with maximum diameter impeller(s) and the specified speed and fluid—to 50 μm (0.002 in.) at the primary seal faces. This shaft deflection limit may be achieved

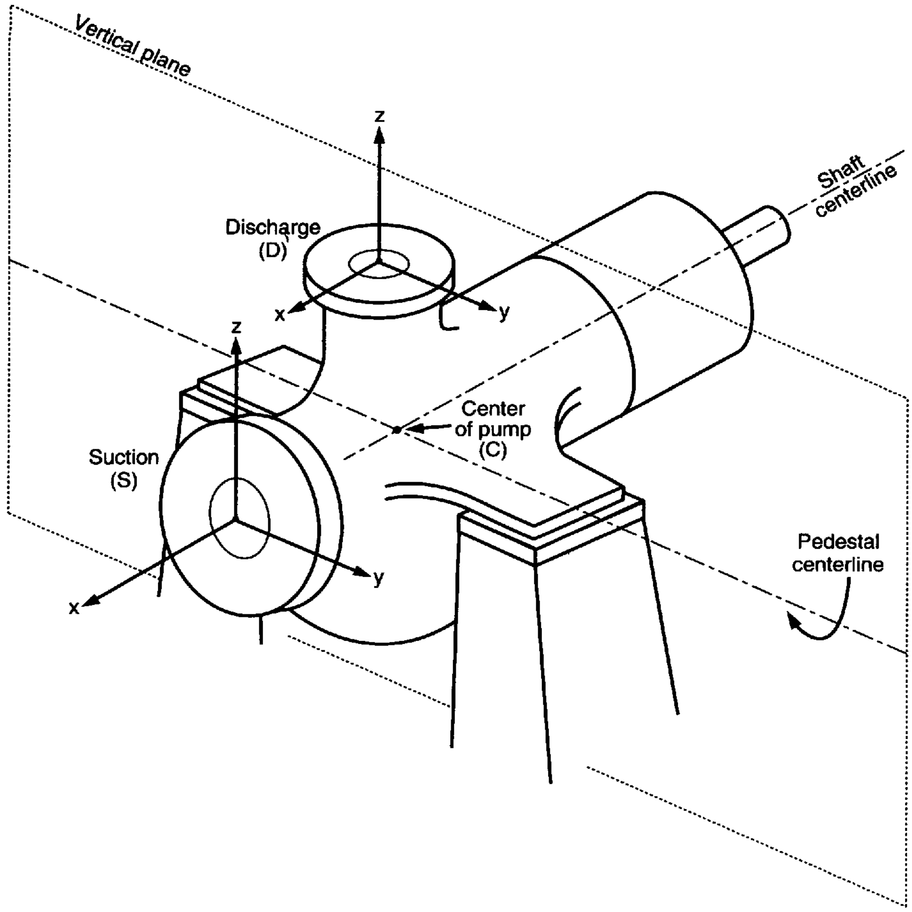



Figure 2-5 —Coordinate System for the Forces and Moments in Table 2.1A (2.1B) Horizontal Pumps with End Suction and Top Discharge Nozzles

by a combination of shaft diameter, shaft span or overhang, and casing design (including the use of dual volutes or diffusers). For one and two stage pumps, no credit shall be taken for the fluid stiffening effects of impeller wear rings. For multistage pumps, fluid stiffening effects shall be considered and calculations shall be performed at both one and two times the nominal design clearances. The fluid stiffness of product lubricated bearings and bearing bushings shall be calculated at both one and two times the nominal design clearances.

**2.5.8** When noncontacting vibration probes are furnished in accordance with 3.4.3.1, the rotor shaft sensing areas to be observed by radial vibration probes shall be concentric with the bearing journals. All shaft sensing areas (both radial vibration and axial position) shall be free from stencil and scribe marks or any other surface discontinuity, such as an oil hole or a keyway, for a minimum distance of one probe tip diameter on each side of the probe. These areas shall not be metallized, sleeved, or plated. The final surface finish shall be a maximum of 1.0 µm (32 µin.) $R_a$, preferably obtained by honing or burnishing. These areas shall be properly demagnetized to the levels specified in API Standard 670, or otherwise treated so that the combined total electrical and mechanical runout does not exceed the following:

a. For areas to be observed by radial vibration probes, 25 percent of the allowed peak-to-peak vibration amplitude or 5 µm (0.25 mil), whichever is greater.
b. For areas to be observed by axial position probes, 15 µm (0.5 mil).

**2.5.9** Electrical and mechanical runout of the rotor surfaces to be observed by vibration probes shall be determined and recorded. The runout shall be determined by rolling the rotor supported by V-blocks positioned at the centerline of the bearing journals while measuring runout with a noncontacting vibration probe and a dial indicator simultane-

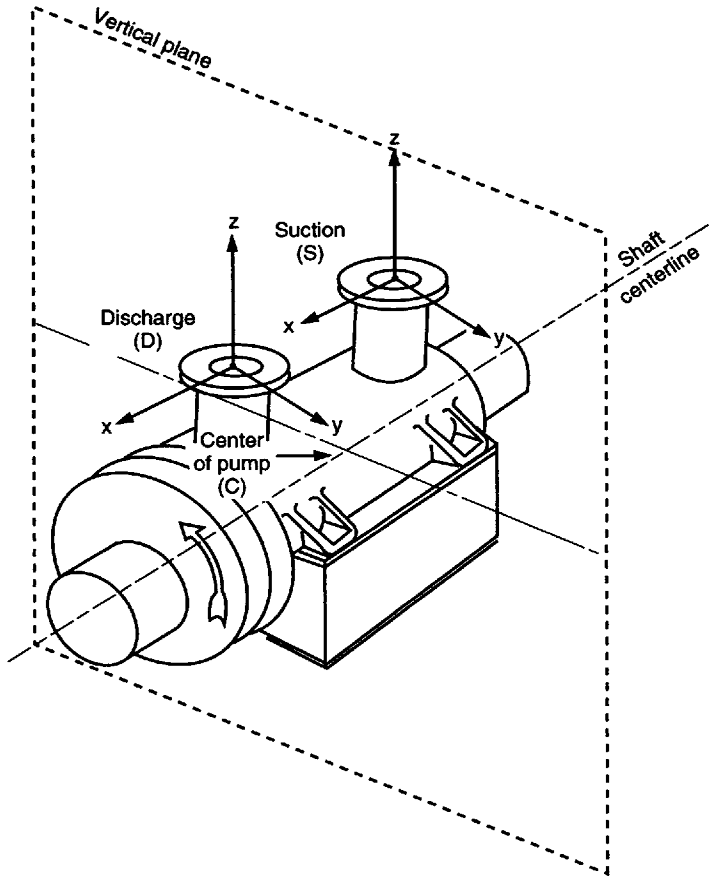



Figure 2-6—Coordinate System for the Forces and Moments in Table 2-1A (2-1B) Horizontal Pumps with Top Nozzles

ously. The measurements shall be taken at the centerline of the installed probe location and one probe tip diameter to either side.

**2.5.10** When noncontacting vibration probes are furnished, accurate records of electrical and mechanical runout for the full 360 degrees at each probe location shall be included in the mechanical test report.

## 2.6 Wear Rings and Running Clearances

**2.6.1** Unless otherwise specified, renewable wear rings shall be furnished on both the casing and the impeller. Front and back wear rings shall be furnished, if required, for axial balance. Pumping vanes shall not be used to establish axial balance.

Note: Integral impeller wear surfaces may be supplied with purchaser's approval.

**2.6.2** Mating wear surfaces of hardenable materials shall have a difference in Brinell hardness number of at least 50 unless both the stationary and the rotating wear surfaces have Brinell hardness numbers of at least 400.

**2.6.3** Renewable wear rings shall be held in place by a press fit with locking pins or threaded dowels (axial or radial) or by flanged and screwed methods. Other methods, including tack welding, require the purchaser's approval. The diameter of a hole in a wear ring for a radial pin or threaded dowel shall not be more than one third the width of the wear ring.

**2.6.4** Running clearances shall meet the requirements of 2.6.4.1 and 2.6.4.2.

Table 2-2—Minimum Running Clearances

| Diameter of Rotating Member at Clearance (mm) | Minimum Diametral Clearance (mm) | Diameter of Rotating Member at Clearance (in.) | Minimum Diametral Clearance (in.) |
|---|---|---|---|
| <50 | 0.25 | <2.000 | 0.010 |
| 50 to 64.99 | 0.28 | 2.000 to 2.499 | 0.011 |
| 65 to 79.99 | 0.30 | 2.500 to 2.999 | 0.012 |
| 80 to 89.99 | 0.33 | 3.000 to 3.499 | 0.013 |
| 90 to 99.99 | 0.35 | 3.500 to 3.999 | 0.014 |
| 100 to 114.99 | 0.38 | 4.000 to 4.499 | 0.015 |
| 115 to 124.99 | 0.40 | 4.500 to 4.999 | 0.016 |
| 125 to 149.99 | 0.43 | 5.000 to 5.999 | 0.017 |
| 150 to 174.99 | 0.45 | 6.000 to 6.999 | 0.018 |
| 175 to 199.99 | 0.48 | 7.000 to 7.999 | 0.019 |
| 200 to 224.99 | 0.50 | 8.000 to 8.999 | 0.020 |
| 225 to 249.99 | 0.53 | 9.000 to 9.999 | 0.021 |
| 250 to 274.99 | 0.55 | 10.000 to 10.999 | 0.022 |
| 275 to 299.99 | 0.58 | 11.000 to 11.999 | 0.023 |
| 300 to 324.99 | 0.60 | 12.000 to 12.999 | 0.024 |
| 325 to 349.99 | 0.63 | 13.000 to 13.999 | 0.025 |
| 350 to 374.99 | 0.65 | 14.000 to 14.999 | 0.026 |
| 375 to 399.99 | 0.68 | 15.000 to 15.999 | 0.027 |
| 400 to 424.99 | 0.70 | 16.000 to 16.999 | 0.028 |
| 425 to 449.99 | 0.73 | 17.000 to 17.999 | 0.029 |
| 450 to 474.99 | 0.75 | 18.000 to 18.999 | 0.030 |
| 475 to 499.99 | 0.78 | 19.000 to 19.999 | 0.031 |
| 500 to 524.99 | 0.80 | 20.000 to 20.999 | 0.032 |
| 525 to 549.99 | 0.83 | 21.000 to 21.999 | 0.033 |
| 550 to 574.99 | 0.85 | 22.000 to 22.999 | 0.034 |
| 575 to 599.99 | 0.88 | 23.000 to 23.999 | 0.035 |
| 600 to 624.99 | 0.90 | 24.000 to 24.999 | 0.036 |
| 625 to 649.99 | 0.95 | 25.000 to 25.999 | 0.037 |

Note: For diameters greater than 649.99 mm (25.999 in.) the minimum diametral clearances shall be 0.95 mm (0.037 in.) plus 1 μm for each additional 1 mm of diameter or fraction thereof (0.001 in. for each additional in.).

**2.6.4.1** When running clearances are established between wear rings and between other moving parts, consideration shall be given to pumping temperatures, suction conditions, the character of the liquid handled, the thermal expansion and galling characteristics of the materials, and pump efficiency. Clearances shall be sufficient to assure dependability of operation and freedom from seizure under all specified operating conditions.

**2.6.4.2** For cast iron, bronze, hardened 11–13 percent chromium steel, and materials with similarly low galling tendencies, the minimum clearances given in Table 2-2 shall be used. For materials with higher galling tendencies and for all materials operating at temperatures above 260°C (500°F), 125 μm (0.005 in.) shall be added to these diametral clearances.

## 2.7 Mechanical Shaft Seals

**2.7.1** Mechanical seals shall be furnished unless otherwise specified. When packing is specified for nonflammable or nonhazardous services, refer to Appendix C.

**2.7.2** Unless otherwise specified, seals and sealing systems shall be furnished in accordance with API Standard 682.

● **2.7.3** When it is specified that seals not comply with API Standard 682, seals shall meet the requirements of 2.7.3.1 through 2.7.3.23.

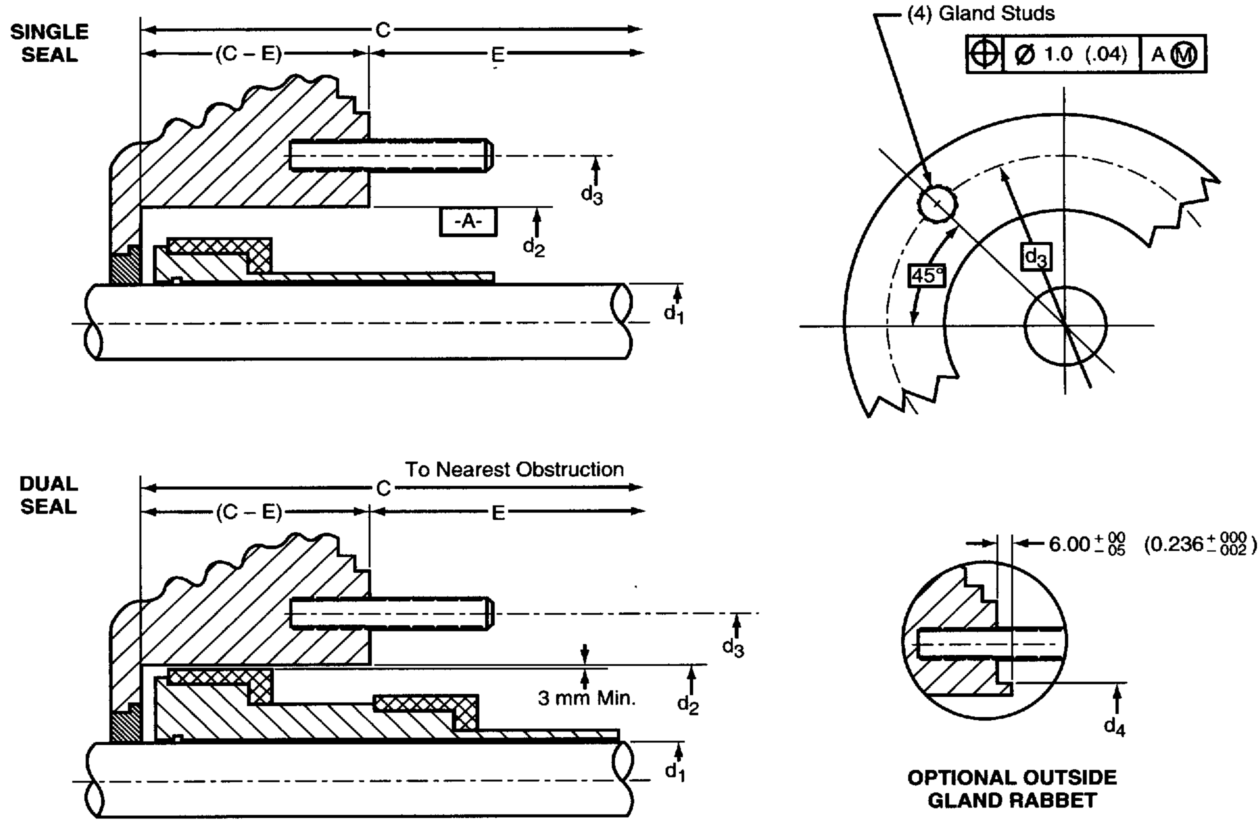
**2.7.3.1** Unless otherwise specified, all standard mechanical seals, regardless of type or arrangement, shall be of the cartridge design. For this standard, a cartridge design consists of a mechanical seal unit, including sleeve, gland, primary seals, secondary seals, etc., that can be tested as a unit and installed as a unit. Hook sleeve cartridge units are not considered to be a cartridge seal for this standard. The seal cartridge shall be removable without disturbing the driver.

**2.7.3.2** The standard single (one rotating face per seal chamber) mechanical seal shall be an inside balanced seal.

**2.7.3.3** The standard unpressurized dual mechanical seal (previously referred to as a tandem mechanical seal) shall be a balanced seal (with two flexible elements and two mating rings in series). Unpressurized dual mechanical seals shall be designed to withstand pressurization of the buffer fluid to 275 kPa (40 psig).

**2.7.3.4** The standard pressurized dual mechanical seal (previously referred to as a double mechanical seal) shall be

## Table 2-3—Standard Dimensions for Seal Chambers, Seal Gland Attachments and Cartridge Mechanical Seal Sleeves (mm/in.)




| Seal Chamber Size | (Note 1) Shaft Diameter (Maximum) ($d_1$) mm/in. | (Note 2) Seal Chamber Bore ($d_2$) mm/in. | Gland Stud Circle ($d_3$) mm/in. | (Note 2) Outside Gland Rabbet ($d_4$) mm/in. | (Note 3) Total Length (Minimum) (C) mm/in. | (Note 3) Clear Length (Minimum) (E) mm/in. | Stud Size (SI Std) | Stud Size (U.S. Std) |
|---|---|---|---|---|---|---|---|---|
| 1 | 20.00/0.787 | 70.00/2.756 | 105/4.13 | 85.00/3.346 | 150/5.90 | 100/3.94 | M12 × 1.75 | 1/2"–13 |
| 2 | 30.00/1.181 | 80.00/3.150 | 115/4.53 | 95.00/3.740 | 155/6.10 | 100/3.94 | M12 × 1.75 | 1/2"–13 |
| 3 | 40.00/1.575 | 90.00/3.543 | 125/4.92 | 105.00/4.134 | 160/6.30 | 100/3.94 | M12 × 1.75 | 1/2"–13 |
| 4 | 50.00/1.968 | 100.00/3.937 | 140/5.51 | 115.00/4.528 | 165/6.50 | 110/4.33 | M16 × 2.0 | 5/8"–11 |
| 5 | 60.00/2.362 | 120.00/4.724 | 160/6.30 | 135.00/5.315 | 170/6.69 | 110/4.33 | M16 × 2.0 | 5/8"–11 |
| 6 | 70.00/2.756 | 130.00/5.118 | 170/6.69 | 145.00/5.709 | 175/6.89 | 110/4.33 | M16 × 2.0 | 5/8"–11 |
| 7 | 80.00/3.150 | 140.00/5.512 | 180/7.09 | 155.00/6.102 | 180/7.09 | 110/4.33 | M16 × 2.0 | 5/8"–11 |
| 8 | 90.00/3.543 | 160.00/6.299 | 205/8.07 | 175.00/6.890 | 185/7.28 | 120/4.72 | M20 × 2.5 | 3/4"–10 |
| 9 | 100.00/3.937 | 170.00/6.693 | 215/8.46 | 185.00/7.283 | 190/7.48 | 120/4.72 | M20 × 2.5 | 3/4"–10 |
| 10 | 110.00/4.331 | 180.00/7.087 | 225/8.86 | 195.00/7.677 | 195/7.68 | 120/4.72 | M20 × 2.5 | 3/4"–10 |

Note 1: Dimensions to tolerance grade G7/h6. Reference: ISO 286 (ANSI/ASME B4.1).
Note 2: Dimensions to tolerance grade H7/h6; for axially split pumps, an additional tolerance to allow for gasket thickness: ± 75 µm / 0.003 in.
Note 3: Shaft deflection criteria (see 2.5.7) may require (C) and (E) dimensions on size 1 and 2 seal chambers to be reduced below the minimum values listed, depending on specific pump construction and casing design.

a balanced seal (with two flexible elements and two mating rings in series). The inner seal shall have an internal (reverse) balance feature designed and constructed to withstand reverse pressure differentials without opening.

**2.7.3.5** This standard does not cover the design of the component parts of the mechanical seals; however, the design and materials of the component parts shall be suitable for the specified service conditions. The maximum allowable working pressure shall apply to all parts referred to in the definition of pressure casing. The seal manufacturer shall state when pressure ratings of seals do not meet this requirement, and shall advise the purchaser of the maximum sealing pressure and the seal's maximum dynamic and static pressure ratings.

**2.7.3.6** The seal chamber shall conform to the minimum dimensions shown in Table 2-3. With these dimensions, the minimum radial clearance between the rotating member(s) of the mechanical seal and the bore of the seal chamber and gland shall be 3 mm (0.12 in.) (see Appendix U).

Note: For pumps with flange and pressure ratings in excess of the minimum values in 2.2.2, the gland stud size and circle may increase. Larger studs shall be furnished only if required to meet the stress requirements of Section VIII or Section II of the ASME Code, or to sufficiently compress spiral wound gaskets in accordance with manufacturer's specifications.

**2.7.3.7** Mechanical seal materials shall be furnished in accordance with Appendix H. Seal faces and gaskets shall be coded in accordance with Tables H-4 and H-5.

**2.7.3.8** Mechanical seal sleeves shall meet the following criteria:

a. Be of wear, corrosion, and erosion resistant material.
b. Be sealed at one end.
c. Extend beyond the outer face of the seal gland (so leakage between the shaft and the sleeve cannot be confused with leakage across the seal faces).
d. Be of one-piece design.
e. Have a shaft-to-sleeve diametral clearance corresponding to G7/h6 to allow easy assembly and removal while providing required runout control.

Note: G7/h6 is nominally equivalent to 25 to 75 µm (0.001 to 0.003 in.) but varies as a function of diameter.

**2.7.3.9** Unless otherwise specified, seal chambers and seal glands shall be designed for the same pressure and temperature as the pump pressure casing and shall have sufficient rigidity to avoid any distortion that would impair seal operation, including distortion that may occur during tightening of the bolts to set gasketing.

**2.7.3.10** Seal glands shall be provided with bolt holes rather than slots, except where the ease of dismantling pumps with axially split casings makes slotted construction desirable.

**2.7.3.11** Provisions shall be made for centering the seal gland and/or chamber with either an inside or outside diameter register fit. The register fit surface shall be concentric to the shaft and shall have a total indicated runout of not more than 125 µm (0.005 in.) (Appendix K). Centering of mechanical seal components by the use of seal gland bolts is not acceptable.

**2.7.3.12** A shoulder at least 3 mm (0.12 in.) thick shall be provided in the seal gland to prevent the stationary element of the mechanical seal from dislodging as a result of chamber pressure.

**2.7.3.13** Mechanical seal performance depends on the runout conditions at the mechanical seal chamber. Seal chamber face runout is a measure of the perpendicularity of this face to the pump shaft axis. This runout (TIR) shall not exceed 10 µm per 20 mm (0.0005 in./in.) of seal chamber bore (Appendix K).

**2.7.3.14** Specified seal and pump connections shall be identified by symbols permanently marked into the component (such as stamped, cast, or chemically etched) and shown on the seal drawing. The symbols shown in Appendix D shall be used. The suffix letters shall be used in conjunction with these markings where appropriate. When a steam quench is specified by the purchaser, the inlet connection (QI) shall be located in the top quadrant of the seal gland, and the outlet connection (QO) shall be located to prevent the formation of liquid pockets.

**2.7.3.15** Seal glands and seal chambers shall have provision for only those connections required by the seal flush plan. If additional tapped connection points are specified and are not used, they shall be plugged with solid round or solid hexagon head plugs furnished in accordance with the requirements of ANSI/ASME B16.11. When cylindrical threads are specified in 2.3.3.3, pipe plugs shall be solid hexagon head plugs furnished in accordance with DIN 910. These plugs shall be of the same material as the seal gland or seal chamber. An anaerobic (or other suitable high temperature) lubricant/sealant shall be used to ensure that the threads are vapor tight.

**2.7.3.16** The seal chamber shall be provided with an internal passage or external connection to permit complete venting of the chamber before start-up.

● **2.7.3.17** When specified, jackets or cooling inserts shall be provided on seal chambers. Cooling (or heating) requirements shall be mutually agreed upon by the purchaser, vendor, and seal manufacturer.

Note: The use of water cooling is discouraged because of the danger of fouling and subsequent loss of effectiveness during operation. Forced-air cooling should be considered as an alternative. As a guide, cooling or heating may be considered for the conditions and services listed in the following items a through e. If provided, piping requirements shall be mutually agreed upon by the purchaser, vendor, and seal manufacturer. No specific piping plan is listed in Figure D-4 for seal chamber cooling (or heating).

a. Pumping temperatures above 150°C (300°F), depending on mechanical seal materials selected.
b. Boiler feed pumps.
c. Dead-ended seal arrangements.
d. Low-flash-point liquids.
e. High-melting-point products (heating).

**2.7.3.18** Throat bushings shall be provided unless otherwise specified by the purchaser or otherwise recommended by the vendor. Throat bushings can be used for the following purposes:

a. To function as a replaceable wearing part.
b. To establish differential hardness between rotating and stationary parts.

● **2.7.3.19** The vendor shall furnish all mechanical seal piping and appurtenances specified by the purchaser. Mechanical seal piping shall be in accordance with the appropriate plan of Appendix D, and the plan shall be indicated on the data sheets. During operation, the pressure at the seal faces shall be maintained at or above atmospheric pressure. In vacuum service, the seal design shall be adequate to seal against atmospheric pressure when the pump is not operating.

● **2.7.3.20** For single seals, and when specified for dual seals, a non-sparking floating throttle bushing shall be installed in the seal gland and positively retained against pressure blowout to minimize leakage if the seal fails. The diametral clearance at the bushing bore shall be as specified in Table 2-4. Floating throttle bushings shall have a minimum radial displacement capability of at least 0.75 mm (0.030 in.).

● **2.7.3.21** Where seal face leakage of the pumped fluid to the atmosphere must be controlled, one of the following arrangements may be utilized (see Appendix D):

a. Auxiliary sealing devices, such as a close-clearance floating throttle bushing (see 2.7.3.20). (Auxiliary sealing devices may require a quench or sealing fluid; see Appendix D.)
b. Dual seals which use a buffer fluid maintained at a pressure lower than the pressure being sealed.
c. Dual seals which use a barrier fluid maintained at a pressure higher than the varying pressure being sealed.
d. Dual seals which use a dry running outer seal with no buffer or barrier liquid. The space between the seals shall be piped to a suitable vapor recovery system.

Table 2-4—Floating Throttle Bushing Diametral Clearance

| Sleeve Diameter | Maximum Clearance |
|---|---|
| 0–50 mm (0–2.00 in.) | 180 µm (0.007 in.) |
| 51–80 mm (2.01–3.00 in.) | 225 µm (0.009 in.) |
| 81–120 mm (3.01–4.75 in.) | 280 µm (0.011 in.) |
| over 120 mm (4.75 in.) | 2.5 µm/1.0 mm diameter (0.0025 in./in. diameter) |

Note: Bushings must be sized to allow for thermal growth of the shaft. The clearances in Table 2-4 are based upon carbon bushings at pumping temperature. Other materials may require other clearances. Axial space limitations may make it impractical to fit floating bushings on dual seals.

The purchaser will specify the characteristics of the barrier or buffer fluid. Where the required flow, pressure, and temperature are factors, they shall be jointly established by the vendor and the seal manufacturer and shall be noted on the data sheets. When dual seals (as in Items b and c above) are provided, the barrier or buffer fluid shall be circulated by means of a circulating device such as a pumping ring or a flow-through system from an external source (see Appendix D).

**2.7.3.22** Mechanical seals and glands for all pumps, except vertically suspended pumps shipped without drivers mounted, shall be installed in the pump before shipment and shall be clean and ready for initial service. On pumps whose seals require final adjustment or installation in the field, the vendor shall attach a metal tag warning of this requirement.

**2.7.3.23** The mating joint between the seal gland and the seal chamber face shall incorporate a confined gasket to prevent blowout. The gasket shall be of the controlled compression type (for example, an O-ring or a spiral wound gasket) with metal-to-metal joint contact. Where space or design limitations make this requirement impractical, an alternative seal gland design shall be submitted to the purchaser for approval.

## 2.8 Dynamics

**2.8.1** The topics of critical speed and lateral analysis are covered in each specific pump type section.

### 2.8.2 TORSIONAL ANALYSIS

**2.8.2.1** Unless otherwise specified, a torsional analysis shall be performed by the manufacturer having unit responsibility when the driver is one of the following:

a. Electric motor, or turbine, through gear rated 1500 kW (2000 hp) or higher.
b. Internal combustion engine rated 250 kW (335 hp) or higher.
c. Synchronous motor rated 500 kW (670 hp) or higher.
d. Electric motor with variable frequency drive (VFD) rated 1000 kW (1350 hp) or higher.

The analysis shall be for the train as a whole unless the train includes a device that has weak dynamic coupling, for example, a hydraulic coupling or torque converter.

**2.8.2.2** Excitation at the following frequencies shall be evaluated:

| | |
|---|---|
| a. Train with gear(s): | 1 and 2 × RPM of either shaft |
| b. Engine drive: | *n* × RPM |
| c. Synchronous motor: | *n* × slip frequency, 1 and 2 × line frequency |
| d. Variable frequency drive: | *n* × RPM, 1 and 2 × line frequency |

*Where:*
*RPM* = Rotor speed.

$n$ = An integer determined by the drive manufacturer:
—for engines: derived from the number of power strokes per revolution.
—for motors: derived from the number of poles.

The excitation frequencies for motor drives, items c and d, include transient and steady state conditions.

**2.8.2.3** The undamped torsional natural frequencies of the complete train shall be at least 10 percent above or 10 percent below any possible (steady state) excitation frequency within the specified operating speed range (from minimum to maximum continuous speed).

**2.8.2.4** When torsional natural frequencies are calculated to fall within the margin specified in 2.8.2.3 (and the purchaser and the vendor have agreed that all efforts to remove the critical from within the limiting frequency range have been exhausted), a stress analysis shall be performed to demonstrate that the resonances have no adverse effect on the complete train. The acceptance criteria for this analysis shall be mutually agreed upon by the purchaser and the vendor.

**2.8.2.5** Whenever a torsional analysis is performed, a Campbell diagram shall be furnished to the purchaser for information only.

● **2.8.2.6** When specified, the manufacturer shall furnish a detailed report of the analysis. The report shall include the following:

a. A description of the method used to calculate the natural frequencies.
b. A diagram of the mass elastic system.
c. A table of the mass moment and torsional stiffness of each element of the mass elastic system.
d. A Campbell diagram.
e. A mode shape diagram with peak stresses shown for each resonant frequency.

Note: Item e is required only when a stress analysis is performed; see 2.8.2.4.

### 2.8.3 VIBRATION

Note: Centrifugal pump vibration varies with flow, usually being a minimum in the vicinity of best efficiency point flow and increasing as flow is increased or decreased. The change in vibration as flow is varied from best efficiency point flow depends upon the pump's energy density, its specific speed, and its suction specific speed. In general, the change in vibration increases with increasing energy density, higher specific speed, and higher suction specific speed.

With these general characteristics, a centrifugal pump's operating flow range can be divided into two regions, one termed the *best efficiency or preferred operating region*, over which the pump exhibits low vibration, the other termed the *allowable operating region*, with its limits defined as those capacities at which the pump's vibration reaches a higher but still "acceptable" level. Figure 2.7 illustrates the concept. (Note that factors other than vibration, for example, temperature rise with decreasing flow or NPSHR with increasing flow, may dictate a narrower allowable operating region).

**2.8.3.1** The preferred operating region and location of rated capacity shall be as specified in 2.1.12. The allowable operating region shall be stated in the proposal. When the allowable operating region is limited by a factor other than vibration, that factor shall also be stated in the proposal.

**2.8.3.2** During the performance test, unfiltered vibration measurements and a Fast Fourier Transform (FFT) spectrum shall be made at each test point except shutoff. The measurements shall be as follows:

a. The bearing housing(s) or equivalent location(s) of all pumps, at the positions shown on Figures 2.8A and 2.8B.
b. The shaft of pumps with hydrodynamic journal or guide bearings and furnished with proximity probes, at a position adjacent to the bearing. Measurements made using a shaft stick are not acceptable.

**2.8.3.2.1** The FFT spectra shall include the range of frequencies from 5 Hz to 2$Z$ times running speed (where $Z$ is the number of impeller vanes; in multistage pumps with different impellers, $Z$ is the highest number of impeller vanes in any stage).

Note: The discrete frequencies 1.0, 2.0, and $Z$ times running speed are associated with various pump phenomena, and are therefore of particular interest in the spectra.

**2.8.3.2.2** The plotted spectra shall be included with the pump test results.

**2.8.3.3** Bearing housing overall vibration measurements shall be made in root mean square (RMS) velocity and, when U.S. dimensions are specified, in both RMS and True Peak velocity, mm/sec (in./sec).

**2.8.3.4** Instrumentation used to measure bearing housing vibration shall meet the following requirements:

**2.8.3.4.1** RMS velocity shall be determined by a circuit which performs the square of the waveform, averages the result, then computes the square root of that value, mathematically described as:

$$RMS = \left[\frac{1}{T}\int^{T} f(t)^2 dt\right]^{\frac{1}{2}}$$

Verification that the instrument is measuring RMS velocity shall be carried out in accordance with Appendix S.

**2.8.3.4.2** True peak velocity shall be determined by dividing the true peak-to-peak value of the vibration (velocity) signal by two. The true peak-to-peak value of the vibration signal shall be measured by an instrument having positive and negative peak detector circuits. These circuits shall determine the maximum positive and negative excursion of the signal during four consecutive shaft revolutions. Measurement of a shaft revolution shall be determined from consecutive pulses from the phase reference transducer (API 670). The charging time constant of these detectors shall not exceed 30 microsec-

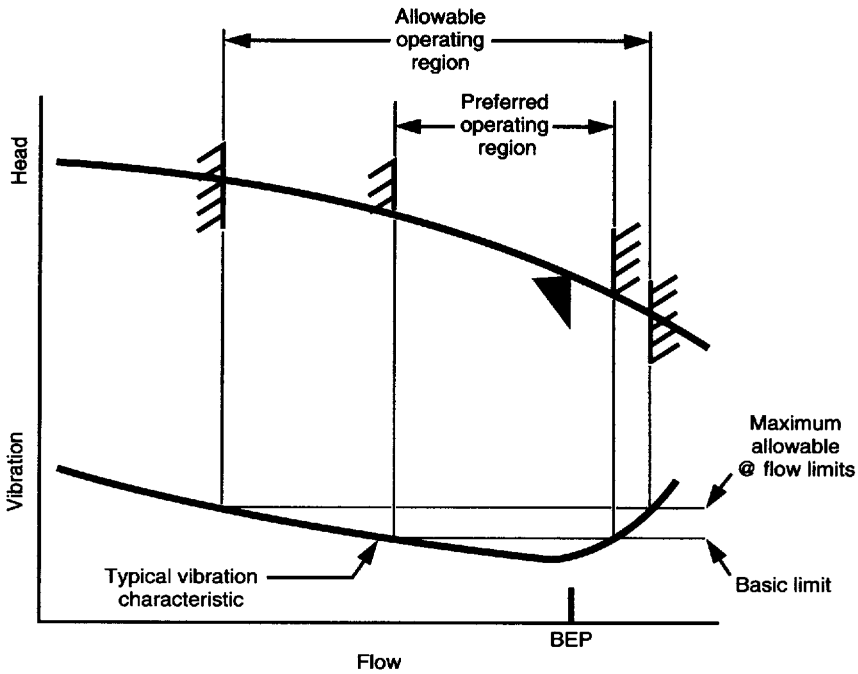



Figure 2-7—Relationship Between Flow and Vibration

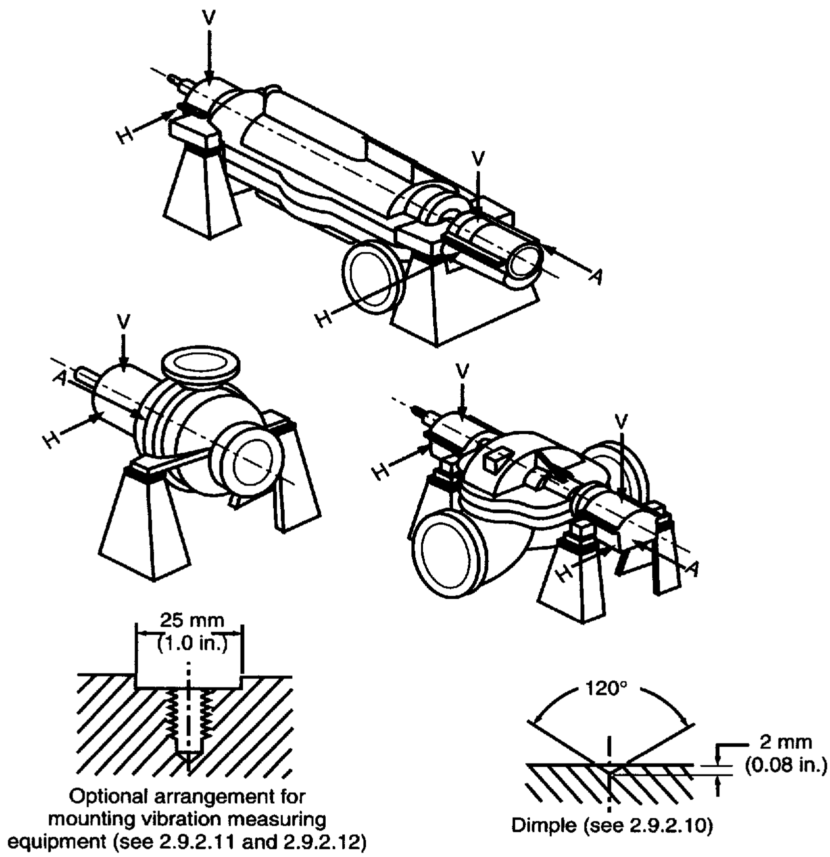



Figure 2-8A—Locations for Taking Vibration Readings on Horizontal Pumps

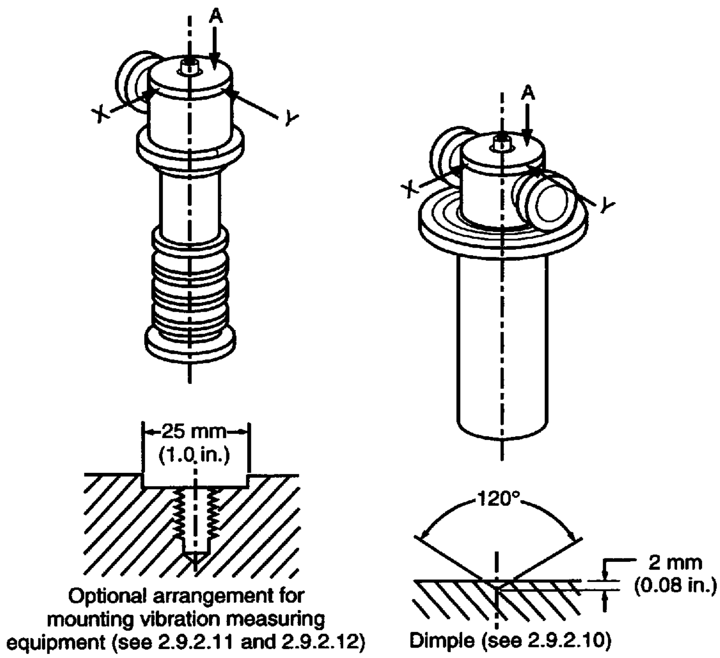



Figure 2-8B—Locations for Taking Vibration Readings on Vertical Pumps

onds. The outputs of the peak detectors shall be sampled, held and then reset at the end of each four shaft revolutions. Verification that the instrument is measuring true peak velocity shall be carried out in accordance with Appendix S.

**2.8.3.5** The units for shaft vibration measurement shall be peak-to-peak displacement in µm (mils).

**2.8.3.6** If the vendor can demonstrate that there is electrical or mechanical runout of the rotor surfaces at the proximity probes (see 2.5.9), a maximum of 25 percent of the measured value or 6 microns (0.25 mils), whichever is greater, may be vectorially subtracted from the vibration signal measured during the shop test.

**2.8.3.7** The vibration measured during the performance test shall not exceed the values shown in the following:

a. Table 2-5 for overhung and between bearing pumps.
b. Table 2-6 for vertically suspended pumps.

Pumps furnished with proximity probes shall meet both bearing housing and shaft vibration limits.

Note: Bearing housing overall vibration limits are defined for RMS measurements only. True peak values are for information and diagnostic purposes only and are not to be used to determine the acceptability of the equipment.

**2.8.3.8** At any speed greater than the maximum continuous speed, up to and including the trip speed of the driver, the vibration shall not exceed 150 percent of the maximum value recorded at the maximum continuous speed.

**2.8.3.9** Variable speed pumps shall operate over their specified speed range without exceeding the vibration limits of this standard.

### 2.8.4 BALANCING

**2.8.4.1** Impellers, balancing drums, and similar major rotating components shall be dynamically balanced to grade G1.0 of ISO 1940 ($4W/N$) or 7 g•mm (0.01 oz-in.), whichever is greater. The weight of the arbor used for balancing shall not exceed the weight of the component being balanced.

Note: Unbalance is expressed in U.S. units as the following:

$$U = KW/N$$

*Where:*

$U$ = unbalance per plane, oz-in.
$K$ = constant.
$W$ = component weight, when balancing components, pounds.
= load per balancing machine journal when balancing rotors, pounds.
$N$ = rotative speed, RPM.

or in ISO terms as a balance quality grade of ISO 1940. Each of the ISO balance quality grades covers a range of unbalance. The nominally equivalent U.S. unit limits given throughout this standard correspond approximately to the midpoint of the ISO range.

With modern balancing machines, it is feasible to balance components mounted on their arbors to $U = 4W/N$ (nominally equivalent to ISO grade G1.0), or even lower depending upon the weight of the assembly, and to verify the unbalance of the assembly with a residual unbalance check. However, the mass eccentricity, $e$, associated with unbalance less than $U = 8W/N$ (nominally equivalent to ISO grade G2.5) is so small (e.g. $U = 4W/N$ gives $e$ = 0.000070 in. for an assembly intended to run at 3600 RPM) that it cannot be maintained if the assembly is dismantled and remade. Balance grades below $8W/N$ (G2.5) are, therefore, not repeatable for components.

**2.8.4.2** Component balancing may be single plane when the ratio $D/B$ (see Figure 2.9) is 6.0 or greater.

**2.8.4.3** Rotor balancing shall be performed as required in the specific pump sections.

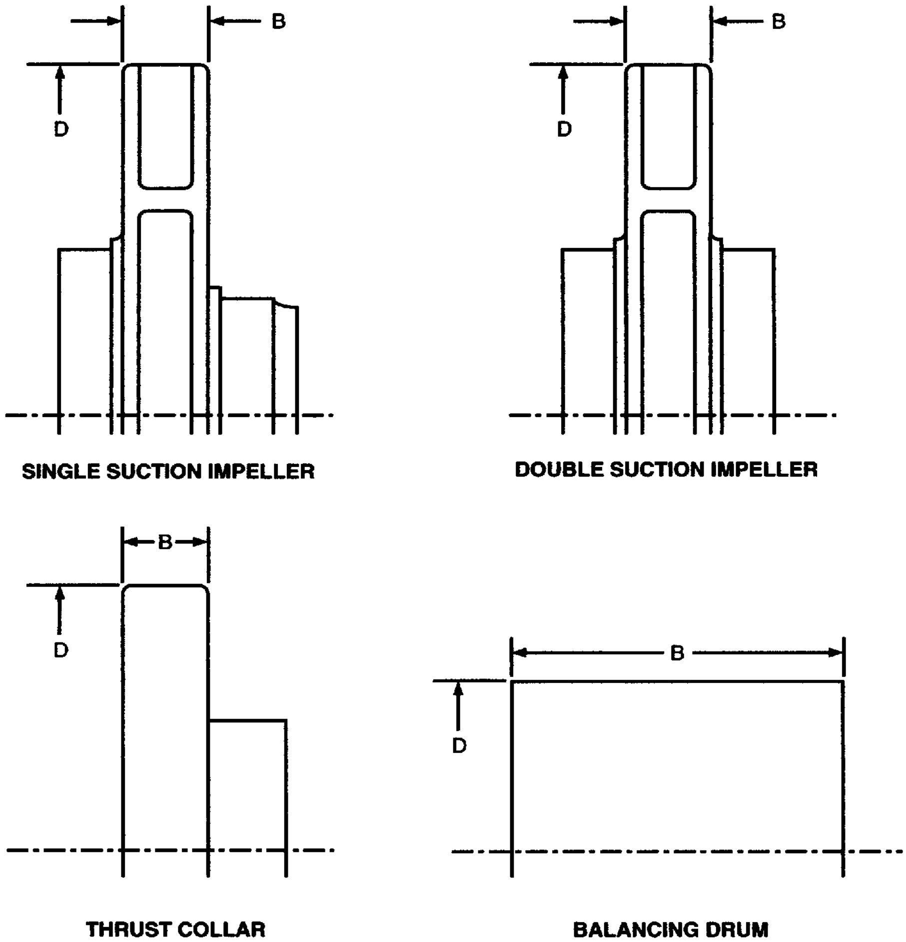



Figure 2-9—Rotating Component Dimensions to Determine When Single Plane Balancing Is Allowable

## 2.9 Bearings and Bearing Housings

### 2.9.1 BEARINGS

**2.9.1.1** Bearings shall be one of the following arrangements: rolling element radial and thrust, hydrodynamic radial and rolling element thrust, or hydrodynamic radial and thrust. Unless otherwise specified, the bearing type and arrangement shall be selected in accordance with the limitations in Table 2-7.

**2.9.1.2** Thrust bearings shall be sized for continuous operation under all specified conditions, including maximum differential pressure. All loads shall be determined at design internal clearances and also at two times design internal clearances. In addition to thrust from the rotor and any internal gear reactions due to the most extreme allowable conditions, the axial force transmitted through flexible couplings shall be considered a part of the duty of any thrust bearing. Thrust bearings shall provide full load capabilities if the pump's normal direction of rotation is reversed.

**2.9.1.2.1** For gear-type couplings, the external force shall be calculated from the following formula:

$$F = \frac{(0.25)\,(9{,}550)\,P_r}{(N_r D)}$$

In U.S. units:

$$F = \frac{(0.25)\,(63{,}000)\,P_r}{(N_r D)}$$

*Where:*

$F$ = external force, kN (lbs)
$P_r$ = rated power, kW (hp)
$N_r$ = rated speed, in revolutions per minute.
$D$ = shaft diameter at the coupling, mm (in.)

Note: Shaft diameter is an approximation of the coupling pitch radius.

## Table 2-5—Vibration Limits for Overhung and Between Bearings Pumps

| Item | Location of Vibration Measurement: Bearing Housing (see Figure 2-8A) | Location of Vibration Measurement: Pump Shaft (adjacent to bearing) |
|---|---|---|
| Pump bearing type | All | Hydrodynamic journal bearings |
| Vibration at any flow within the pump's preferred operating region: | | |
| Overall | $V_u <$ 3.0 mm/sec RMS (0.12 in./sec RMS) | $A_u < \left(\frac{5.2\text{x}10^6}{N}\right)^{0.5}$ µm pk/pk ($(8000/N)^{0.5}$ mils pk/pk) **Not to exceed:** $A_u <$ 50 µm pk/pk (2.0 mils pk/pk) |
| Discrete frequencies | $V_f <$ 2.0 mm/sec RMS (0.08 in./sec RMS) | for $A_f \geq N$: 75% of $A_u$; for $A_f < N$: 33% of $A_u$ |
| Increase in allowable vibration at flows beyond the preferred operating region but within the allowable operating region | 30% | 30% |

Note: Values calculated from the basic limits shall be rounded off to two (2) significant figures.

*Where:*

- $V_u$ = unfiltered velocity.
- $V_f$ = filtered velocity.
- $A_u$ = unfiltered displacement determined by FFT.
- $A_f$ = filtered displacement determined by FFT.
- $N$ = rotational speed (RPM).

## Table 2-6—Vibration Limits for Vertically Suspended Pumps

| Item | Location of Vibration Measurement: Pump Thrust Bearing Housing or Motor Mounting Flange (see Figure 2-8B) | Location of Vibration Measurement: Pump Shaft (adjacent to bearing) |
|---|---|---|
| Pump bearing type | All | Hydrodynamic guide bearing adjacent to accessible region of shaft |
| Vibration at any flow within the pump's preferred operating region: | | |
| Overall | $V_u <$ 5.0 mm/sec RMS (0.20 in./sec RMS) | $A_u < \left(\frac{6.5\text{x}10^6}{N}\right)^{0.5}$ µm pk/pk ($(10{,}000/N)^{0.5}$ mils pk/pk) **Not to exceed:** $A_u <$ 100 µm pk/pk (4.0 mils pk/pk) |
| Discrete frequencies | $V_f <$ 3.4 mm/sec RMS (0.13 in./sec RMS) | $A_f$ :75% of $A_u$ |
| Increase in allowable vibration at flows beyond the preferred operating region but within the allowable operating region | 30% | 30% |

Note: Values calculated from the basic limits shall be rounded off to two (2) significant figures.

*Where:*

- $V_u$ = unfiltered velocity.
- $V_f$ = filtered velocity.
- $A_u$ = unfiltered displacement determined by FFT.
- $A_f$ = filtered displacement determined by FFT.
- $N$ = rotational speed (RPM).

Table 2-7—Bearing Selection

| Condition | Bearing Type and Arrangement |
|---|---|
| Radial and thrust bearing speed and life within limits for rolling element bearings<br>and<br>Pump energy density below limit | Rolling element radial and thrust |
| Radial bearing speed or life outside limits for rolling element bearings<br>and<br>Thrust bearing speed and life within limits for rolling element bearings<br>and<br>Pump energy density below limit | Hydrodynamic radial and rolling element thrust<br>or<br>Hydrodynamic radial and thrust |
| Radial and thrust bearing speed or life outside limits for rolling element bearings<br>or<br>Pump energy density above limit | Hydrodynamic radial and thrust |

Note: Limits are as follows:

a. Rolling element bearing speed:
Factor, $Nd_m$ not to exceed 500,000

*Where:*
$d_m$ = mean bearing diameter $(d+D)/2$, mm
$N$ = rotative speed, RPM

b. Rolling element bearing life:
Basic rating $L_{10h}$ per ISO 281 (ANSI/ABMA Standard 9) of at least 25,000 hours with continuous operation at rated conditions, and at least 16,000 hours at maximum radial and axial loads and rated speed.

c. Energy density:
When the product of pump rated power, kW (hp), and rated speed, RPM, is 4.0 million (5.4 million) or greater, hydrodynamic radial and thrust bearings are required.

**2.9.1.2.2** Thrust forces for flexible metal element couplings shall be calculated on the basis of the maximum allowable deflection permitted by the coupling manufacturer.

**2.9.1.2.3** If a sleeve bearing motor (without a thrust bearing) is directly connected to the pump shaft with a coupling, the coupling transmitted thrust will be assumed to be the maximum motor thrust.

**2.9.1.3** Rolling element bearings shall be located on the shaft using shoulders, collars, or other positive locating devices; snap rings and spring-type washers are not acceptable. Rolling element bearings shall be retained on the shaft with an interference fit and fitted into the housing with a diametral clearance, both in accordance with the recommendations of ISO 286 (ANSI/ABMA Standard 7). Bearings shall be mounted directly on the shaft; bearing carriers are not acceptable. The device used to lock ball thrust bearings to shafts shall be restricted to a nut with a tongue-type lock washer.

**2.9.1.4** Except for the angular contact type, rolling element bearings shall have greater than Normal internal clearance according to ISO 5753 Group 3 (ANSI/ABMA Symbol 3, as defined in ANSI/ABMA Standard 20). Single- or double-row bearings shall be of the Conrad type (no filling slots).

**2.9.1.5** Ball thrust bearings shall be of the duplex, single row, 40 degree (0.7 radian) angular contact type (7000 series). Unless otherwise specified, bearings shall be installed back-to-back. The need for bearing clearance or preload shall be determined by the vendor to suit the application and meet the bearing life requirements of 2.9.1.1.

### 2.9.2 BEARING HOUSINGS

**2.9.2.1** Bearing housings shall be arranged so that bearings can be replaced without disturbing pump drives or mountings.

● **2.9.2.2** Bearing housings for oil-lubricated nonpressure-fed bearings shall be provided with tapped and plugged fill and drain openings at least 1/2 NPS. The housings shall be equipped with constant level sight feed oilers at least 0.12 liter (4 oz) in size, with a positive level positioner (not an external screw), heat-resistant glass containers, and protective wire cages. When specified, the oilers shall meet the purchaser's preference. Means shall be provided for detecting overfilling of the housings. A permanent indication of the proper oil level shall be accurately located and clearly marked on the outside of the bearing housing with permanent metal tags, marks inscribed in the castings, or other durable means.

**2.9.2.3** Sufficient cooling, including an allowance for fouling, shall be provided to maintain oil and bearing temperatures as follows, based on the specified operating conditions and an ambient temperature of 43°C (110°F):

a. For pressurized systems, oil outlet temperature below 71°C (160°F) and bearing metal temperatures (when bearing temperature sensors are supplied) less than 93°C (200°F). During shop testing, the bearing oil temperature rise shall not exceed 28°C (50°F).
b. For ring oiled or splash systems, oil sump temperature below 82°C (180°F). During shop testing, the sump oil temperature rise shall not exceed 39°C (70°F).

Note: Pumps equipped with ring oiled or splash lubrication systems may not reach temperature stabilization during hydraulic performance tests of short duration. If the purchaser desires temperature stabilization testing, this requirement should be stated in the inquiry and addressed by the vendor in the proposal.

**2.9.2.4** Where water cooling is required, water jackets shall have only external connections between upper and lower housing jackets and shall have neither gasketed nor threaded connection joints which may allow water to leak into the oil reservoir. If cooling coils (including fittings) are used, they shall be of nonferrous material or austenitic stainless steel and shall have no internal pressure joints. Tubing or pipe shall have a minimum thickness of 1.0 mm (0.040 in.) and shall be at least 12 mm (0.50 in.) outside diameter.

**2.9.2.5** For pumps handling flammable or hazardous liquids, bearing housings, load-carrying bearing housing covers, and brackets between the pump casing or head and the bearing housings shall be steel. Driver supports for vertical pumps which utilize thrust bearings in the driver to support the shaft shall be steel.

**2.9.2.6** Bearing housings shall be equipped with replaceable labyrinth end seals and deflectors where the shaft passes through the housing; lip seals shall not be used. The seals and deflectors shall be made of nonsparking materials. The design of the seals and deflectors shall effectively retain oil in the housing and prevent entry of foreign material into the housing.

**2.9.2.7** Bearings and bearing housings shall meet the requirements of 2.9.2.7.1 through 2.9.2.7.5 when oil mist lubrication is specified (see 2.10.3).

**2.9.2.7.1** An oil mist inlet connection, 1/4 NPS, shall be provided in the top half of the bearing housing. The pure or purge oil mist fitting connections shall be located so that oil mist will flow through rolling element bearings. On pure-mist systems, there shall be no internal passage to short circuit oil mist from inlet to vent.

**2.9.2.7.2** A 1/4 NPS vent connection shall be provided on the housing or end cover for each of the spaces between the rolling element bearings and the housing shaft closures. Alternatively, where oil mist connections are between each housing shaft closure and the bearings, one vent central to the housing shall be supplied. Housings with only sleeve-type bearings shall have the vent located near the end of the housing.

**2.9.2.7.3** Shielded or sealed bearings shall not be used.

**2.9.2.7.4** When pure oil mist lubrication is specified, oil rings or flingers (if any) and constant level oilers shall not be provided, and a mark indicating the oil level is not required. When purge mist lubrication is specified, these items shall be provided and the oiler shall be piped so that it is maintained at the internal pressure of the bearing housing.

Note: At pumping temperatures above 300°C (570°F), bearing housings with pure oil mist lubrication may require special features to reduce heating of the bearing races by heat transfer from the pumpage. Typical features are as follows:

a. Heat sink type flingers.
b. Stainless steel shafts having low thermal conductivity.
c. Thermal barriers.
d. Fan cooling.
e. Purge mist lubrication (in place of pure mist) with oil (sump) cooling.

**2.9.2.7.5** The oil mist supply and drain fittings will be provided by the purchaser.

**2.9.2.8** Housings for ring oil lubricated bearings shall be provided with plugged ports positioned to allow visual inspection of the oil rings while the pump is running.

● **2.9.2.9** When specified, the vendor shall furnish oil heaters.

**2.9.2.10** All bearing housings shall be dimpled at the locations shown on Figures 2-8A and 2-8B to facilitate consistent vibration measurements. The dimples shall be suitable for accurate location of a hand-held vibration transducer with an extension "wand." Dimples may be cast or machined and shall be nominally 2 mm (0.080 in.) deep with an included angle of 120 degrees.

● **2.9.2.11** When specified, bearing housings shall have a threaded connection(s) for permanently mounting vibration transducers in accordance with API 670. When metric fasteners are supplied, the threads shall be M8.

● **2.9.2.12** When specified, a flat surface at least 25 mm (1 in.) in diameter shall be supplied for the location of magnetic based vibration measuring equipment.

## 2.10 Lubrication

**2.10.1** Unless otherwise specified, bearings and bearing housings shall be arranged for hydrocarbon oil lubrication.

**2.10.2** Flingers or oil rings used to deliver oil to the bearings shall have an operating submergence of 3 to 6 mm (0.12 – 0.25 in.) above the lower edge of a flinger or above the lower edge of the bore of an oil ring. Oil flingers shall have mounting hubs to maintain concentricity and shall be positively secured to the shaft.

● **2.10.3** When specified, provisions shall be made for either pure oil or purge oil mist lubrication (see 2.9.2.7 for requirements).

## 2.11 Materials

### 2.11.1 GENERAL

• **2.11.1.1** Materials for pump parts shall be in accordance with Appendix H, except that superior or alternative materials recommended for the service by the vendor shall be listed on the data sheets. Auxiliary piping materials are covered in 3.5. The purchaser will specify the class of pump materials and, for seals not conforming to API Standard 682, the mechanical seal code from Appendix H that is applicable to the service. Table G-1, Appendix G, is a guide showing material classes that may be appropriate for various services. Pump parts designated as *full compliance* materials in Table H-1 of Appendix H shall meet the requirements of the industry specifications listed for materials in Table H-2. Pump parts not designated as *full compliance* materials in Table H-1 shall be made from materials with the applicable chemical composition but need not meet the other requirements of the listed industry specification.

**2.11.1.2** Materials shall be clearly identified in the proposal with their applicable industry standard numbers, including the material grade (see Appendix H). When no such designation is available, the vendor's material specification giving physical properties, chemical composition, and test requirements shall be included in the proposal.

**2.11.1.3** The vendor shall specify the optional tests and inspection procedures necessary to ensure that materials are satisfactory for the service. Such tests and inspections shall be listed in the proposal. The purchaser may consider specifying additional tests and inspections, especially for materials used in critical components.

**2.11.1.4** Classification of pump materials shall be in accordance with the following items a through c:

a. Pressure casing parts of double casing pumps shall be of carbon steel or alloy steel.
b. Pressure casing parts of pumps that are to handle flammable or hazardous liquids shall be of carbon steel or alloy steel.
c. Cast iron construction may be offered for other services.

**2.11.1.5** If austenitic stainless steel parts exposed to conditions that promote intergranular corrosion are to be fabricated, hard faced, overlaid, or repaired by welding, these parts shall be made of low-carbon or stabilized grades.

Note: Overlays or hard surfaces that contain more than 0.10 percent carbon can sensitize both low-carbon and stabilized grades of austenitic stainless steel unless a buffer layer that is not sensitive to intergranular corrosion is applied.

**2.11.1.6** Materials, casting factors, and the quality of any welding shall be equal to those required by Section VIII, Division 1, of the ASME Code. The manufacturer's data report forms, as specified in the code, are not required.

• **2.11.1.7** When specified for pressure casing parts, impellers, and shafts, the vendor shall furnish chemical and mechanical data for the heat from which the material is supplied.

• **2.11.1.8** The purchaser will specify any corrosive agents present in the motive and process fluids and in the environment, including constituents that may cause stress corrosion cracking.

Note: Typical agents of concern are amines, chlorides, cyanide, fluorides, and napthenic acid.

**2.11.1.9** Minor parts that are not identified (such as nuts, springs, washers, gaskets, and keys) shall have corrosion resistance at least equal to that of specified parts in the same environment. Gasket or seal material between the shaft and the shaft sleeve under the packing or mechanical seal shall be verified by the vendor as being satisfactory for the service conditions.

Note: When dissimilar materials with significantly different electrical potentials are placed in contact in the presence of an electrolytic solution, galvanic couples that can result in serious corrosion of the less noble material may be created. If such conditions exist, the purchaser and the vendor should select materials in accordance with *NACE Corrosion Engineer's Reference Book.*

**2.11.1.10** Where mating parts such as studs and nuts of austenitic stainless steel or materials with similar galling tendencies are used, they shall be lubricated with a suitable antiseizure compound of the proper temperature specification and compatible with the contacted liquid(s).

Note: Torque loading values will differ considerably with and without an antiseizure compound.

• **2.11.1.11** The purchaser will specify the presence and concentration of $H_2S$ and water in the process liquid. Materials with a yield strength of more than 620 N/mm$^2$ (90,000 psi) or a hardness of more than Rockwell C22 shall not be used for the following components if they will be exposed to a sour environment (wet $H_2S$) as defined by NACE MR0175:

a. The pressure casing.
b. Shafting (including wetted shaft nuts).
c. Balancing drums.
d. Impellers.
e. Pressure retaining mechanical seal components (excluding seal faces).
f. Wetted bolting.

Items 1 through 4 below apply when $H_2S$ is present:

1. The yield strength and hardness restrictions above may be modified in accordance with NACE MR0175.
2. The inner-casing parts of double-casing pumps, such as diffusers and bowls, are not considered pressure casing parts.
3. Renewable wear rings that must be hardened above Rockwell C 22 for proper pump operation are acceptable. When approved by the purchaser, in lieu of furnishing renewable wear rings, wear surfaces may be hardened by the application of a suitable coating.

4. Wetted parts subject to welding, including fabrication and tack welding (for example, removable wear rings), shall be stress relieved, if required, so that both the welds and the heat-affected zones meet the yield strength and hardness requirements of this paragraph.

**2.11.1.12** Low carbon steels can be notch sensitive and susceptible to brittle fracture at ambient or low temperatures. Therefore, only fully killed, normalized steels made to fine grain practice are acceptable. The use of steel made to a coarse austenitic grain size practice (such as ASTM A515) is prohibited.

### 2.11.2 CASTINGS

**2.11.2.1** Castings shall be sound and generally free from porosity, hot tears, shrink holes, blow holes, cracks, scale, blisters, and similar injurious defects. Surfaces of castings shall be cleaned by sandblasting, shot blasting, chemical cleaning, or any other standard method to meet the visual requirements of MSS-SP-55. Mold parting fins and remains of gates and risers shall be chipped, filed, or ground flush.

**2.11.2.2** The use of chaplets in pressure castings shall be held to a minimum. The chaplets shall be clean and corrosion free (plating permitted) and of a composition compatible with the casting. Chaplets shall not be used in impeller castings.

**2.11.2.3** Ferrous pressure boundary and impeller castings shall not be repaired by welding, peening, plugging, burning in, or impregnating, except as specified in 2.11.2.3.1 and 2.11.2.3.2.

**2.11.2.3.1** Weldable grades of steel castings may be repaired by welding, using a qualified welding procedure based on the requirements of Section VIII, Division 1, and Section IX of the ASME Code. Weld repairs shall be inspected according to the same quality standard used to inspect the casting.

**2.11.2.3.2** Iron castings may be repaired by plugging within the limits of the applicable ISO (ASTM) specification. The holes drilled for plugs shall be carefully examined, using liquid penetrant, to ensure that all defective material has been removed. All repairs that are not covered by ISO (ASTM) specifications shall be subject to the purchaser's approval.

**2.11.2.4** Fully enclosed cored voids, including voids closed by plugging, are prohibited.

● **2.11.2.5** When specified, casting repair procedures shall be submitted for purchaser's approval

### 2.11.3 WELDING

**2.11.3.1** Welding of piping, pressure containing parts, and wetted parts, as well as any weld repairs to such parts, shall be performed and inspected by operators and procedures qualified in accordance with Section VIII, Division 1, and Section IX of the ASME Code.

**2.11.3.2** The vendor shall be responsible for the review of all repairs and repair welds to ensure they are properly heat treated and nondestructively examined for soundness and compliance with the applicable qualified procedures (see 2.11.1.6). Repair welds shall be nondestructively tested by the same method used to originally qualify the part.

**2.11.3.3** Unless otherwise specified, all welding other than that covered by Section VIII, Division 1, of the ASME Code and ANSI/ASME B31.3, such as welding on baseplates, nonpressure ducting, lagging, and control panels, shall be performed in accordance with ANSI/AWS D1.1, or, at the vendor's option, in accordance with the requirements applied to the pressure containing parts of the pump.

**2.11.3.4** Pressure containing casings made of wrought materials or combinations of wrought and cast materials shall conform to the conditions specified in 2.11.3.4.1 through 2.11.3.4.4. These requirements do not apply to casing nozzles and auxiliary connections (see 2.3.2 and 2.3.3).

**2.11.3.4.1** Plate edges shall be inspected by magnetic particle or liquid penetrant examination as required by Section VIII, Division 1, UG-93(d)(3), of the ASME Code.

**2.11.3.4.2** Accessible surfaces of welds shall be inspected by magnetic particle or liquid penetrant examination after back chipping or gouging and again after postweld heat treatment or, for austenitic stainless steels, after solution annealing.

**2.11.3.4.3** Pressure-containing welds, including welds of the case to horizontal and vertical joint flanges, shall be full-fusion, full-penetration welds.

**2.11.3.4.4** Fabricated casings shall be postweld heat treated in accordance with the requirements of Section VIII, Division 1 of the ASME Code. Where dimensional stability of such a casing component must be assured for the integrity of pump operation, then postweld heat treat shall be performed regardless of thickness.

**2.11.3.5** Connections welded to pressure casings shall be installed as specified in 2.11.3.5.1 through 2.11.3.5.6.

**2.11.3.5.1** Attachment of suction and discharge nozzles shall be by means of full-fusion, full-penetration welds. Weld neck flanges are required for pumps handling flammable or hazardous liquids. Dissimilar metal weldments are not allowed.

**2.11.3.5.2** Auxiliary piping welded to alloy steel casings shall be of a material with the same nominal properties as the casing material or shall be of low carbon austenitic stainless steel. Other materials compatible with the casing material and intended service may be used with the purchaser's approval.

**2.11.3.5.3** When heat treatment is required, piping welds shall be made before the component is heat treated.

• **2.11.3.5.4** When specified, proposed connection designs shall be submitted to the purchaser for approval before fabrication. The drawing shall show weld designs, size, materials, and preweld and postweld heat treatments.

**2.11.3.5.5** All welds shall be heat treated in accordance with the methods described in Section VIII, Division 1, UW-40, of the ASME Code.

• **2.11.3.5.6** Suction and discharge nozzle welds shall be inspected in accordance with 2.11.3.4.2. The purchaser will specify when the following additional inspection methods are required:

a. Magnetic particle or liquid penetrant inspection of auxiliary connection welds.
b. Ultrasonic or radiographic inspection of any casing welds.

### 2.11.4 LOW TEMPERATURE

**2.11.4.1** To avoid brittle fracture during operation, maintenance, transportation, erection, and testing, good design practice shall be followed in the selection of fabrication methods, welding procedures, and materials for vendor furnished steel pressure retaining parts that may be subjected to temperature below the ductile-brittle transition point.

**2.11.4.2** All pressure retaining steels applied at a specified minimum design metal temperature (2.11.4.5) below -30°C (-20°F) require a Charpy V-notch impact test of the base metal and the weld joint unless they are exempt in accordance with the requirements of paragraph UHA-51 in Section VIII, Division 1 of the ASME Code. Impact test results shall meet the requirements of paragraph UG-84 of the Code.

**2.11.4.3** Carbon and low alloy steel pressure retaining parts applied at a specified minimum design metal temperature (2.11.4.5) between -30°C (-20°F) and 40°C (100°F) shall require impact testing in accordance with 2.11.4.3.1 and 2.11.4.3.2.

**2.11.4.3.1** Impact testing is not required for parts with a governing thickness (2.11.4.4) of 25 mm (1 in.) or less.

**2.11.4.3.2** Impact testing exemptions for parts with a governing thickness (2.11.4.4) greater than 25 mm (1 in.) shall be established in accordance with paragraph UCS-66 in Section VIII, Division 1 of the ASME Code. Curve B shall be used for all carbon and low alloy steel materials (including castings) which are not specifically listed for curves A, C, or D. Minimum design metal temperature without impact testing may be reduced as shown in figure UCS-66.1. If the material is not exempt, Charpy V-notch impact test results shall meet the minimum impact energy requirements of paragraph UG-84 of the ASME Code.

**2.11.4.4** Governing thickness used to determine impact testing requirements shall be the greater of the following:

a. The nominal thickness of the largest butt welded joint
b. The largest nominal section for pressure containment, excluding:
   1. Structural support sections such as feet or lugs.
   2. Sections with increased thickness required for rigidity to mitigate shaft deflection.
   3. Structural sections required for attachment or inclusion of mechanical features such as jackets or seal chambers.
c. One fourth of the nominal flange thickness, including parting flange thickness for axially split casings (in recognition that the predominant flange stress is not a membrane stress).

• **2.11.4.5** The purchaser shall specify the minimum design metal temperature used to establish impact test requirements.

Note: Normally, this will be the lower of the minimum surrounding ambient temperature or minimum liquid pumping temperature. However, the purchaser may specify a minimum design metal temperature based on pumpage properties, such as autorefrigeration at reduced pressures.

## 2.12 Nameplates and Rotation Arrows

**2.12.1** A nameplate shall be securely attached at a readily visible location on the equipment and on any other major piece of auxiliary equipment.

**2.12.2** The nameplate shall be stamped with the following information:

a. Purchaser's item number.
b. Vendor's size and model number.
c. Pump serial number.
d. Capacity, $m^3/h$ (GPM).
e. Pumping head, in meters (feet).
f. Casing hydrostatic test pressure, kPa (psig).
g. Speed, RPM.
h. Bearing manufacturer's identity numbers.
i. Maximum allowable working pressure (MAWP).
j. Temperature, basis for MAWP, °C (°F).

**2.12.3** In addition to being stamped on the nameplate, the pump serial number shall be plainly and permanently marked on the pump casing.

**2.12.4** Rotation arrows shall be cast in or attached to each major item of rotating equipment at a readily visible location.

**2.12.5** Nameplates and rotation arrows (if attached) shall be of austenitic stainless steel or of nickel-copper alloy (Monel or its equivalent). Attachment pins shall be of the same material. Welding is not permitted.

# SECTION 3—ACCESSORIES

## 3.1 Drivers

● **3.1.1** The type of driver will be specified by the purchaser. The driver shall be sized to meet the maximum specified operating conditions, including bearing, mechanical seal, external gear, and coupling losses, as applicable, and shall be in accordance with the applicable specifications, as stated in the inquiry specification, data sheets, and order. The driver shall be suitable for satisfactory operation under the utility and site conditions specified.

● **3.1.2** Anticipated process variations that may affect the sizing of the driver (such as changes in pressure, temperature, or properties of the liquid handled, as well as special plant start-up conditions) will be specified.

● **3.1.3** The starting conditions for the driven equipment will be specified, and the starting method shall be mutually agreed upon by the purchaser and the vendor. The driver's starting torque capabilities shall exceed the speed-torque requirements of the driven equipment.

**3.1.4** Motors shall have power ratings, including the service factor (if any), at least equal to the percentages of power at pump rated conditions given in Table 3-1. However, the power at rated conditions shall not exceed the motor nameplate rating. Where it appears that this procedure will lead to unnecessary oversizing of the motor, an alternate proposal shall be submitted for the purchaser's approval.

● **3.1.5** The purchaser will specify the type of motor, its characteristics, and the accessories, including the following:

a. Electrical characteristics.
b. Starting conditions (including the expected voltage drop on starting).
c. The type of enclosure.
d. The sound pressure level.
e. The area classification, based on API Recommended Practice 500.
f. The type of insulation.
g. The required service factor.
h. The ambient temperature and elevation above sea level.
i. Transmission losses.
j. Temperature detectors, vibration sensors, and heaters if these are required.
k. Vibration acceptance criteria.
l. Applicability of API Standard 541 or IEEE 841.

Table 3-1—Power Ratings for Motor Drives

| Motor Nameplate Rating kW | hp | Percentage of Rated Pump Power |
|---|---|---|
| < 22 | < 30 | 125 |
| 22-55 | 30-75 | 115 |
| >55 | >75 | 110 |

● **3.1.6** The motor's starting torque requirements shall be met at reduced voltages specified by the purchaser, and the motor shall accelerate to full speed within a period of time agreed upon by the purchaser and the vendor.

Note: For most applications, the starting voltage is typically 80 percent of the normal voltage, and the time required to accelerate to full speed is generally less than 15 seconds.

**3.1.7** Rolling element bearings in the drive systems designed for radial or axial loads transmitted from the pump shall meet the following requirements:

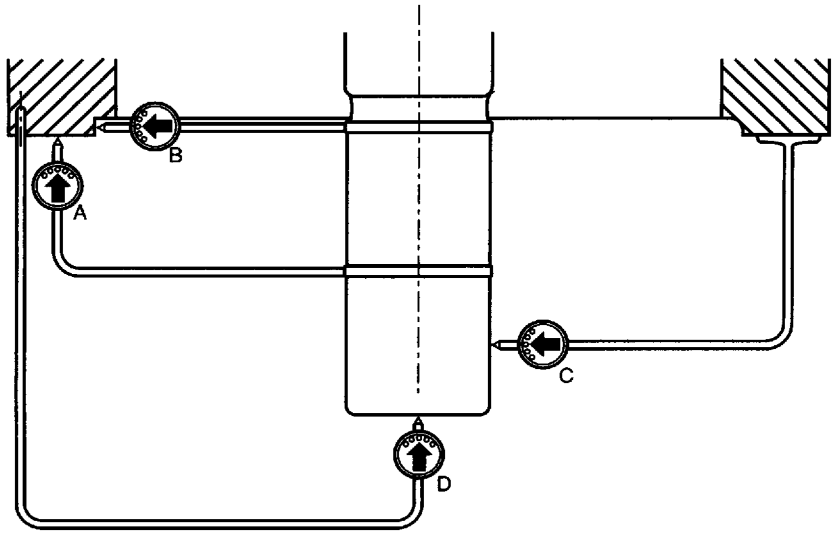
a. Bearings shall be selected to give a basic rating life, $L_{10h}$, in accordance with ISO 281 (ANSI/ABMA Standard 9), of at least 25,000 hours with continuous operation at pump rated conditions.
b. Bearings shall be selected to give a basic rating life, $L_{10h}$, of at least 16,000 hours when carrying the maximum loads (radial or axial or both) imposed with internal pump clearances at twice the design values and when operating at any point between minimum continuous stable flow and rated flow.
c. For vertical motors and right angle gears, the thrust bearing shall be in the nondrive end and shall limit axial float to 125 µm (0.005 in.).
d. Single- or double-row bearings shall be of the Conrad type (no filling slots). Except for angular contact type, bearings shall have greater than Normal clearance according to ISO 5753, Group 3 (ABMA Group 3, as defined in ABMA Standard 20).
e. Thrust bearings shall be designed to carry the maximum thrust the pump may develop while starting, stopping, or operating at any capacity.
f. Hydrodynamic thrust bearings shall be selected at no more than 50 percent of the bearing manufacturer's rating at twice the pump internal clearances specified in 2.6.4.2.

Note: Vertical motors 750 kW (1000 hp) and larger that are equipped with spherical or taper roller bearings may require less than 25,000 hour $L_{10h}$ life to avoid skidding in normal operation. In such cases, the vendor shall state the shorter design life in the proposal.

**3.1.8** Unless otherwise specified, motors for vertical pumps shall have solid shafts. When the pump thrust bearings are in the motor, the motors shall meet the shaft and base tolerances shown in Figure 3-1.

**3.1.9** Unless otherwise specified, steam turbine drivers shall conform to ISO 10436 (API Standard 611). Steam turbine drivers shall be sized to deliver continuously 110 percent of the maximum power required for the purchaser's specified conditions while operating at corresponding speed with specified steam conditions.

**3.1.10** Unless otherwise specified, gears shall conform to API Standard 677.




| | | |
|---|---|---|
| A. | Shaft to driver mating face perpendicularity and surface flatness: | 25 µm (0.001 in.) T.I.R. |
| B. | Shaft to driver register maximum runout: | 100 µm (0.004 in.) T.I.R. |
| C. | Maximum shaft runout with rotor rotating freely: | 25 µm (0.001 in.) T.I.R. |
| D. | Maximum axial float: | 125 µm (0.005 in.) T.I.R. |

Note: All measurements shall be taken with the assembled driver in the vertical position.

Figure 3-1—Vertically Suspended Pump Drivers: Tolerances Required for the Driver Shaft and Base

**3.1.11** For drive train components that weigh more than 450 kg (1000 lbs), the equipment feet shall be provided with vertical jackscrews.

**3.1.12** The equipment feet shall be drilled with pilot holes that are accessible for use in final doweling.

## 3.2 Couplings and Guards

**3.2.1** Unless otherwise specified, couplings and guards between drivers and driven equipment shall be supplied by the vendor.

● **3.2.2** Unless otherwise specified, couplings shall be flexible element. Coupling hubs shall be steel. Flexible disk types shall have disks of corrosion resistant material. The make, model, materials, service factor, and mounting arrangement of couplings will be specified by the purchaser. A spacer coupling shall be used unless otherwise specified. The spacer shall have a nominal length of at least 125 mm (5 in.) and shall permit removal of the coupling, bearings, seal, and rotor as applicable, without disturbing the driver or the suction and discharge piping.

Note: For flexible element couplings, consideration should be given to designs that will retain the spacer if a flexible element ruptures.

**3.2.3** Information on shafts, keyway dimensions (if any), and shaft end movements due to end play and thermal effects shall be furnished to the vendor supplying the coupling.

**3.2.4** Flexible couplings shall be keyed to the shaft. Keys, keyways, and fits shall conform to ISO/R773 (ANSI/AGMA 9002, Commercial Class). Flexible couplings with cylindrical bores shall have the interference fit specified in ISO/R286, Tolerance N8, and shafting in accordance with ISO/R775 (ANSI/AGMA 9002). Where servicing the mechanical seal requires removal of the coupling hub, and the shaft diameter is greater than 60 mm (2.5 in.), the hub shall be mounted with a taper fit. Taper for keyed couplings shall be 1 in 10 "long series conical" in accordance with ISO/R775 or alternately 1 in 16 (0.75 in./ft, diametral) for compliance with U.S. standards. Other mounting methods shall be agreed upon by the purchaser and the vendor. Coupling hubs shall be furnished with tapped puller holes at least 10 mm (3/8 in.) in size to aid in removal.

Note: Appropriate assembly and maintenance procedures must be used to assure that taper fit couplings have an interference fit.

**3.2.5** Couplings and coupling to shaft junctures shall be rated for at least the maximum driver power, including any service factor.

**3.2.6** Couplings shall be manufactured to meet the requirements of ANSI/AGMA 9000 Class 9.

**3.2.7** Couplings operating at speeds of 3800 RPM or less shall be component balanced. Each component such as hubs, sleeves, flexible elements, spacers, and adapters shall be balanced individually. All machining of components, except keyways of single keyed hubs, shall be completed before balancing. Balancing shall be in accordance with 2.8.4.1. Two-plane balancing is preferred; however, single-plane balancing may be used in accordance with 2.8.4.2.

**3.2.8** Couplings operating at speeds in excess of 3800 RPM shall meet the requirements of API Standard 671 for component balancing and assembled balance check.

**3.2.9** Limited end float couplings with maximum coupling end floats as specified in Table 3-2 shall be supplied with horizontal sleeve bearing motors to prevent the motor rotor from rubbing stationary motor parts.

Note: Couplings with axial elastic centering forces are usually satisfactory without these precautions.

Table 3-2—Maximum Coupling End Floats

| Minimum Motor Rotor End Float (mm) | (in.) | Maximum Coupling End Float (mm) | (in.) |
|---|---|---|---|
| 6 | 0.250 | 2 | 0.090 |
| 13 | 0.500 | 5 | 0.190 |

**3.2.10** On vertical pumps equipped with mechanical seals, the coupling shall be a spacer type. The spacer shall be of sufficient length to permit replacement of the seal assembly, including the sleeve, without removal of the driver.

**3.2.11** When the vendor is not required to mount the driver, he shall deliver the fully machined half coupling to the driver manufacturer's plant or any other designated location, together with the necessary instructions for mounting the half coupling on the driver shaft.

**3.2.12** Removable coupling guards shall be furnished and shall be in accordance with requirements of applicable national, industrial, or statutory bodies.

## 3.3 Baseplates

**3.3.1** Single piece drain rim or drain pan baseplates shall be furnished for horizontal pumps. The rim or pan of the baseplate shall be sloped at least 1:120 toward the pump end, where a tapped drain opening at least 2 NPS shall be located to effect complete drainage.

**3.3.2** Unless otherwise specified, the baseplate shall extend under the pump and drive train components so that any leakage is contained within the baseplate. To minimize accidental bumping and damage to components, all pipe joints and pipe flange faces, including pump suction and discharge flanges shall be within the drain pan or drain rim collection area. All other projections of the equipment supplied shall fall within the maximum perimeter of the baseplate. Oversized junction boxes may overhang the perimeter of the baseplate with the purchaser's approval.

**3.3.3** Mounting pads shall be provided for the pump and all drive train components. The pads shall be larger than the foot of the mounted equipment to allow leveling of the baseplate without removal of the equipment. The pads shall be fully machined flat and parallel. Corresponding surfaces shall be in the same plane within 150 µm/m (0.002 in./ft) of distance between the pads. This requirement shall be met by supporting and clamping the baseplate at the foundation bolt holes only.

**3.3.4** All pads for drive train components shall be machined to allow for the installation of shims at least 3 mm (0.12 in.) thick under each component. When the vendor mounts the components, a set of stainless steel shims at least 3 mm (0.12 in.) thick shall be furnished. When the vendor does not mount the components, the pads shall not be drilled, and shims shall not be provided.

**3.3.5** To minimize misalignment of the pump and driver shafts due to piping load effects, the pump and its baseplate shall be constructed with sufficient structural stiffness to limit displacement of the pump shaft at the drive end of the shaft or at the register fit of the coupling hub to the values shown in Table 3-3 during a test in accordance with 3.3.6. Grout or bearing housing supports (wobble plates) shall not be used as a means of obtaining the required stiffness. (It is recognized that grout can significantly increase the stiffness of the baseplate assembly; by neglecting this effect, the adequacy of the baseplate can easily be verified at the vendor's shop.)

● **3.3.6** When specified, the vendor shall test to demonstrate that the pump and its baseplate assembly, when anchored at foundation bolt hole locations with any bearing housing support disconnected, are in compliance with 3.3.5. The pump casing shall be subjected to moments $MY_C$ and $MZ_C$ applied to either nozzle, but not both, such that the corresponding shaft displacements can be measured and recorded. $MY_C$ and

Table 3-3—Stiffness Test Acceptance Criteria

| | Pump Shaft Displacement | | | | |
|---|---|---|---|---|---|
| | Baseplate Intended for Grouting | | Baseplate Not Intended for Grouting | | |
| Loading Condition | µm | in. | µm | in. | Direction |
| $MY_c$ | 175 | 0.007 | 125 | 0.005 | +Z |
| $MZ_c$ | 75 | 0.003 | 50 | 0.002 | –Y |

Note: $MY_c$ and $MZ_c$ equal the sum of the allowable suction and discharge nozzle moments from Table 2.1A (2.1B):

$MY_c = (MY)\text{suction} + (MY)\text{discharge}$
$MZ_c = (MZ)\text{suction} + (MZ)\text{discharge}$

$MZ_C$ shall not be applied simultaneously. The shaft displacement measurements shall be absolute (not relative to the baseplate). For record purposes, the vendor's test data shall include a schematic drawing of test setup, the calculated moment loads ($MY_C$ and $MZ_C$), and the applied moment loads and their corresponding displacements at the drive end of the pump shaft.

**3.3.7** The underside of fabricated baseplates beneath pump and driver supports shall be welded to reinforcing cross members, and the members shall be shaped to lock positively into the grout. All welding shall be continuous. Stitch welding, top or bottom, is unacceptable.

**3.3.8** In addition to the requirements of 3.3.7, anchor studs, such as "J" hooks, shall be welded to the underside of baseplate decks on maximum 300 mm (12 in.) centers to provide additional locking into the grout.

**3.3.9** All baseplates shall be provided with at least one grout hole having a clear area of at least 125 $cm^2$ (19 $in.^2$) and no dimension less than 75 mm (3 in.) in each bulkhead section. These holes shall be located to permit filling the entire cavity under the baseplate without creating air pockets. Where practical, the holes shall be accessible for grouting with the pump and driver installed on the baseplate. Grout holes in the drip pan area shall have 13 mm (0.5 in.) raised lip edges. If the holes are located in an area where liquids could impinge on the exposed grout, metallic covers with a minimum thickness of 1.5 mm (16 gauge) shall be provided. Vent holes at least 13 mm (0.5 in.) in diameter shall be provided at the highest point in each bulkhead section of the baseplate. (Appendix L provides guidelines for grouting.)

**3.3.10** The outside corners of the baseplate in contact with the grout shall have at least 50 mm (2 in.) radii in the plan view (see Figure M-1, Appendix M).

**3.3.11** The bottom of the baseplate between structural members shall be open. When the baseplate is installed on a concrete foundation, accessibility shall be provided for grouting under all load carrying members. The bottom of the baseplate shall be in one plane to permit use of a single level foundation.

**3.3.12** When driver and pump size permits, baseplates shall have standardized dimensions as given in Appendix M and shall be designed for grouting. These baseplates shall be referred to as "API Standard 610 Standard Baseplates, Numbers 0.5-12."

● **3.3.13** When specified, the baseplate and pedestal support assembly shall be sufficiently rigid to be mounted without grouting.

**3.3.14** Transverse alignment positioning jackscrews shall be provided for drive train components weighing more than 200 kg (450 lbs) to facilitate transverse horizontal adjustments. Axial alignment positioning jackscrews shall be provided for drive train components weighing more than 400 kg (900 lbs.) to facilitate longitudinal adjustments. The lugs holding these positioning screws shall be attached to the baseplate so that the lugs do not interfere with the installation or removal of the component. These screws shall be at least the same size as the vertical jackscrews furnished with each component. To prevent distortion, machining of mounting pads shall be deferred until welding on the baseplate in close proximity to the mounting pads has been completed.

**3.3.15** Vertical leveling screws spaced for stability shall be provided on the outside perimeter of the baseplate. They shall be located adjacent to anchor bolts to minimize distortion during the process of installation. These screws shall be numerous enough to carry the weight of the baseplate, pump, and drive train components without excessive deflection, but in no case shall fewer than six screws be provided.

**3.3.16** The height of the pump shaft centerline above the baseplate shall be minimized. Adequate clearance shall be provided between the casing drain connection and the baseplate so that drain piping the same size as the connection can be installed without the use of a street (male-female) elbow.

**3.3.17** Unless otherwise specified, the vendor shall commercially sand blast, in accordance with SSPC SP 6, all grout contact surfaces of the baseplate, and coat those surfaces with inorganic zinc silicate in preparation for epoxy grouting.

● **3.3.18** Baseplates which are specified to be installed with cementitious grout shall have grout contact surfaces left free of paint and primer in order to promote maximum grout adhesion.

**3.3.19** The baseplate shall be provided with lifting lugs for at least a four-point lift. Lifting the baseplate, complete with all equipment mounted, shall not permanently distort or otherwise damage the baseplate or the machinery mounted on it.

**3.3.20** Anchor bolts will be furnished by the purchaser. The vendor shall provide for sufficient anchor bolting to withstand nozzle reaction forces during pump start-up and operation.

## 3.4 Instrumentation

### 3.4.1 TEMPERATURE GAUGES

**3.4.1.1** Dial-type temperature gauges shall meet the following requirements:

a. Heavy duty, corrosion resistant construction.
b. Bimetallic or liquid filled element.
c. 100 mm (4.5 in.) or greater diameter dial.
d. Black printing on white background.

**3.4.1.2** The sensing elements of temperature gauges shall be in the flowing liquid.

Note: This is particularly important for lines that may run partially full.

**3.4.1.3** Temperature gauges shall be furnished with separable threaded solid bar thermowells at least 3/4 NPS in diameter and shall be of austenitic stainless steel or another material more compatible with the liquid.

### 3.4.2 PRESSURE GAUGES

**3.4.2.1** Pressure gauges shall meet the following requirements:

a. Austenitic stainless steel bourdon tubes and movements.
b. 100 mm (4.5 in.) dials for pressures up to 5.5 MPa (800 psi).
c. 160 mm (6 in.) dials for pressures of 5.5 MPa (800 psi) or greater.
d. 1/2 NPS male alloy steel connections.
e. Black printing on white background dials.
f. Normal operating pressure within 50 to 70 percent of the range of the gauge.
g. The maximum reading on the dial shall be less than the applicable relief valve setting plus 10 percent.
h. Provided with a device, such as a disk insert or blowout back, designed to relieve pressure.

● **3.4.2.2** When specified, liquid filled gauges shall be furnished in locations subject to vibration.

### 3.4.3 VIBRATION, POSITION, AND TEMPERATURE DETECTORS

● **3.4.3.1** When specified for equipment with hydrodynamic bearings, provision shall be made for mounting two radial vibration probes in each bearing housing, two axial position probes at the thrust end of each machine, and a one event per revolution probe in each machine. The purchaser will specify whether the vendor is to supply these detectors. The detectors and their mounting and calibration shall be supplied, installed, and tested in accordance with API Standard 670.

● **3.4.3.2** When specified, hydrodynamic thrust and radial bearings shall be fitted with bearing metal temperature detectors. When pressure lubricated hydrodynamic thrust and radial bearings are supplied with temperature detectors, the detectors and their mounting and calibration shall be supplied, installed, and tested in accordance with API Standard 670.

● **3.4.3.3** When specified, monitors with connecting cables to vibration, axial position, or temperature detectors shall be supplied and/or installed in accordance with API Standard 670.

## 3.5 Piping and Appurtenances

### 3.5.1 GENERAL

**3.5.1.1** Auxiliary systems are defined as piping systems that are in the following services:

a. Auxiliary process fluids.
b. Steam.
c. Cooling water.
d. Lubricating oil.

Auxiliary systems shall comply with the requirements of Table 3-4.

Note: Casing connections are discussed in 2.3.2.

**3.5.1.2** Piping systems shall include piping, pipe fittings, isolating valves, control valves, relief valves, pressure reducers, orifices, temperature gauges and thermowells, pressure gauges, sight flow indicators, and related vents and drains as shown in the appropriate plan in Appendix D.

**3.5.1.3** Unless otherwise specified, the piping systems shall be fully assembled and installed.

● **3.5.1.4** When specified, for Plans 52 and 53 (see Appendix D), barrier/buffer fluid reservoirs shall be designed for mounting off the pump baseplate and shall be shipped separately. These reservoirs shall be fully assembled except that the fluid circulation tubing shall not be supplied.

**3.5.1.5** The vendor shall furnish all piping systems, including mounted appurtenances, located within the confines of the baseplate.

**3.5.1.6** The design of piping systems shall achieve the following:

a. Proper support and protection to prevent damage from vibration or from shipment, operation, and maintenance.
b. Proper flexibility and normal accessibility for operation, maintenance, and thorough cleaning.
c. Installation in a neat and orderly arrangement adapted to the contour of the machine without obstructing access.
d. Elimination of air pockets by piping configuration or by provision of vents at high points.
e. Complete drainage through low points without disassembly of piping.
f. Manifolding of each piping system to a single purchaser's inlet or outlet connection at the edge of the baseplate.
g. Nipples threaded into gland in a socket welded piping plan shall terminate with a flange or union (see 3.5.2.10.1) at the first piping joint with no elbow between gland and flange.

**3.5.1.7** Piping design, materials, joint fabrication, examination, and inspection shall be in accordance with ANSI/ASME B31.3.

**3.5.1.8** During assembly of the system before testing, each component (including cast-in passages of these components) and all piping and appurtenances shall be cleaned chemically or by another appropriate method to remove foreign materials, corrosion products, and mill scale.

**3.5.1.9** Piping shall preferably be fabricated by bending and welding to minimize the use of flanges and fittings. Welded flanges are permitted only at equipment connections, at the edge of any base, and for ease of maintenance.

## Table 3-4—Minimum Requirements for Piping Materials

| System | Auxiliary Process Fluid | | Steam | | Cooling Water | | Lubricating Oils | |
|---|---|---|---|---|---|---|---|---|
| | Nonflammable/ Nonhazardous | Flammable/ Hazardous | ≤ 500kPa (≤ 75 psig) | > 500kPa (> 75 psig) | Standard | Optional | ≤ 1 NPS | ≥ 1½ NPS |
| Pipe | Seamless[a] | Seamless[a] | Seamless[a] | Seamless[a] | — | ASTM A53 Type F Schedule 40 galvanized to ASTM A153 | — | ASTM A312 Type 316L stainless steel[b] |
| Tubing | ASTM A269 seamless Type 316 stainless steel[c] | ASTM A269 seamless Type 316 stainless steel[c] | ASTM A269 seamless Type 316 stainless steel[c] | ASTM A269 seamless Type 316 stainless steel[c] | ASTM A269 seamless Type 316 stainless steel[c] | — | ASTM A269 seamless Type 316 stainless steel[c] | — |
| All valves | Class 800 | Class 800 | Class 800 | Class 800 | Class 200 bronze | | Carbon steel Class 800 | Carbon steel Class 800 flanged |
| Gate and globe valve | Bolted bonnet and gland | Bolted bonnet and gland | Bolted bonnet and gland | Bolted bonnet and gland | — | — | Bolted bonnet and gland | Bolted bonnet and gland |
| Pipe fittings and unions | Forged Class 3000 | Forged Class 3000 | Forged Class 3000 | Forged Class 3000 | ASTM A338 and A197 Class 150 malleable iron galvanized to ASTM A153 | | Type 316L Stainless steel | Type 316L Stainless steel |
| Tube fittings | Manufacturer's standard | Manufacturer's standard | Manufacturer's standard | Manufacturer's standard | Manufacturer's standard | — | Manufacturer's standard | — |
| Fabricated joints ≤ 1 NPS | Threaded | Socket welded | Threaded | Socket welded | Threaded | | Threaded | — |
| Fabricated joints ≥ 1½ NPS | — | — | — | — | Purchaser to specify | | — | Welded[d] (see 3.5.5.5) |
| Gaskets | — | Type 316 stainless steel spiral wound | — | Type 316 stainless steel spiral wound | — | — | — | Type 316 stainless steel spiral wound |
| Flange bolting | — | ASTM A193 Grade B7 ASTM A194 Grade 2H | — | ASTM A193 Grade B7 ASTM A194 Grade 2H | — | — | — | ASTM A193 Grade B7 ASTM A194 Grade 2H |

Note: Carbon steel piping shall conform to ASTM A106, Grade B; ASTM A524; or API Specification 5L, Grade A or B. Carbon steel fittings, valves, and flanged components shall conform to ASTM A105 and A181. Stainless steel piping shall conform to ASTM A312, Type 316L. (See Appendix A for corresponding international materials.)

[a] Schedule 80 for diameters from ½ NPS to 1½ NPS. Schedule 40 for diameters 2 NPS and larger.

[b] Schedule 40 for a diameter of 1½ NPS. Schedule 10 for diameters of 2 NPS and larger.

[c] Acceptable tubing sizes are as follows (refer to ISO 4200): 12.7 mm diameter × 1.66 mm wall (½ in. diameter × 0.065 in. wall) 19 mm diameter × 2.6 mm wall (¾ in. diameter × 0.095 in. wall) 25 mm diameter × 2.9 mm wall (1 in. diameter × 0.109 in. wall).

[d] Carbon steel slip-on flanges are permitted.

The use of flanges at other points is permitted only with the purchaser's specific approval. Except for lubricating systems, threaded or slip-on flanges are not acceptable. Other than tees and reducers, welded fittings are permitted only to facilitate pipe layout in congested areas. Threaded connections shall be held to a minimum. Pipe bushings shall not be used.

**3.5.1.10** Pipe threads shall be taper threads in accordance with ANSI/ASME B1.20.1. Pipe threads in accordance with ISO 228 Part 1 are an acceptable alternative when required for compliance with local standards. Flanges shall be in accordance with ISO 7005 (ANSI/ASME B16.5). Slip-on flanges are permitted only with the purchaser's specific approval. For socket welded construction, a 1.5 mm (0.06 in.) gap shall be left between the pipe end and the bottom of the socket (2.3.3.3).

**3.5.1.11** The minimum size of any connection or piping shall be 1/2 NPS.

**3.5.1.12** Connections, piping, valves, and fittings that are 1 1/4, 2 1/2, 3 1/2, 5, 7, and 9 NPS shall not be used.

**3.5.1.13** The bolting requirements of 2.2.12 and 2.11.1.10 apply to auxiliary piping.

**3.5.1.14** Taper threaded plugs shall be (long shank) solid round head bar stock plugs in accordance with ANSI/ASME B16.11 (2.3.3.7). When cylindrical threads are specified in 2.3.3.3, plugs shall be solid hexagon head plugs in accordance with DIN 910. These plugs shall meet the material requirements of the casing. Threads shall be lubricated. Plastic plugs are not permitted. (See 2.7.3.15 for plugs in seal glands.)

### 3.5.2 AUXILIARY PROCESS FLUID PIPING

**3.5.2.1** Auxiliary process fluid piping includes vent and drain lines, balance lines, product flushing lines, and lines for injection of external fluid.

**3.5.2.2** The arrangement of auxiliary process fluid piping shall conform to Figures D-2 and D-3.

**3.5.2.3** Piping components shall have a pressure-temperature rating at least equal to the maximum discharge pressure and temperature of the pump casing, but in no case less than ISO 7005 PN50 (300 pound ANSI Class) flange at ambient temperature (2.2.2)

**3.5.2.4** When the pump casing is of alloy material, piping and components subject to the process fluid shall have a corrosion/erosion resistance equal to or better than that of the casing. Otherwise, all components shall be steel.

**3.5.2.5** All piping components furnished by the vendor that are shown in Figure D-2 and Figure D-3, Plans 52–54, are considered subject to the process fluid.

● **3.5.2.6** The purchaser will specify when chlorides are present in a concentration above 10 parts per million. Caution should then be used when applying stainless steel.

**3.5.2.7** Orifice openings shall not be less than 3 mm (0.12 in.) in diameter.

**3.5.2.8** Unless valves are specified, threaded vent and drain connections shall be plugged. Carbon steel plugs shall be used with cast iron casings.

**3.5.2.9** When heating or cooling is provided, each exchanger component shall be suitable for the process fluid and cooling water to which it is exposed.

**3.5.2.10** In addition to the requirements of 3.5.2.1 through 3..5.2.9, the requirements specified in 3.5.2.10.1 through 3.5.2.10.3 apply to piping containing flammable or hazardous fluids.

● **3.5.2.10.1** The purchaser will specify whether flanges are required in place of socket-welded unions. Threaded connections are permitted at mechanical seal glands.

**3.5.2.10.2** For primary ISO (ANSI) service pressure ratings above PN150 (Class 900), block valves may be of welded-bonnet or no-bonnet construction with a bolted gland; these valves shall be suitable for repacking under pressure.

**3.5.2.10.3** Pressure gauges shall have block and bleed valves.

### 3.5.3 STEAM PIPING

Threaded joints are permitted on cast iron equipment and instruments.

### 3.5.4 COOLING WATER PIPING

**3.5.4.1** The arrangement of cooling water piping shall conform to Figures D-4 and D-5.

**3.5.4.2** The cooling water piping shall be designed as specified in 2.1.20.

**3.5.4.3** Sight flow indicators shall be furnished in each outlet line.

**3.5.4.4** Unless otherwise specified, manifold inlet and outlet valves shall be furnished.

### 3.5.5 LUBRICATING OIL PIPING

**3.5.5.1** Oil drains shall be sized to run no more than half full and shall be arranged to ensure good drainage (recognizing the possibility of foaming conditions). Horizontal runs shall slope continuously, at least 1:50, toward the reservoir. If possible, laterals (not more than one in any transverse plane) should enter drain headers at 45-degree angles in the direction of flow.

**3.5.5.2** Sight flow indicators shall be furnished in each return line.

**3.5.5.3** Piping and tubing shall be cleaned with a suitable solvent. Cleaning shall be performed by the vendor before assembly with the pump.

**3.5.5.4** Any portion of the pressure lubrication systems furnished shall meet the cleanliness requirements of API Standard 614.

**3.5.5.5** Nonconsumable backup rings and sleeve type joints shall not be used. Pressure piping downstream of oil filters shall be free from internal obstructions or pockets that could accumulate dirt. Pipe joints downstream of the oil filter (filter to bearing housing) shall be butt welded. Piping joints in return lines and upstream of the filter (reservoir to filter) may be socket welded. Threaded connections shall be used for instrument connections and where tubing is used.

## 3.6 Special Tools

**3.6.1** When special tools and fixtures are required to disassemble, assemble, or maintain the unit, they shall be included in the quotation and furnished as part of the initial supply of the machine. For multiple unit installations, the requirements for quantities of special tools and fixtures shall be mutually agreed upon by the purchaser and the vendor. These or similar special tools shall be used during shop assembly and post-test disassembly of the equipment.

**3.6.2** When special tools are provided, they shall be packaged in separate, rugged metal boxes and marked "special tools for (tag/item number)." Each tool shall be stamped or tagged to indicate its intended use.

# SECTION 4—INSPECTION, TESTING, AND PREPARATION FOR SHIPMENT

## 4.1 General

**4.1.1** After advance notification of the vendor by the purchaser, the purchaser's representative shall have entry to all vendor and subvendor plants where manufacturing, testing, or inspection of the equipment is in progress.

**4.1.2** The vendor shall notify subvendors of the purchaser's inspection and testing requirements.

**4.1.3** The vendor shall provide sufficient advance notice to the purchaser before conducting any inspection or test that the purchaser has specified to be witnessed or observed.

● **4.1.4** The purchaser will specify the extent of his participation in the inspection and testing and the amount of advance notification required.

**4.1.4.1** When shop inspection and testing have been specified the purchaser and the vendor shall coordinate manufacturing hold points and inspector's visits.

**4.1.4.2** *Witnessed* means that a hold shall be applied to the production schedule and that the inspection or test shall be carried out with the purchaser or his representative in attendance. For mechanical running or performance tests, written notification of a successful preliminary test is required.

**4.1.4.3** *Observed* means that the purchaser shall be notified of the timing of the inspection or test; however, the inspection or test shall be performed as scheduled, and if the purchaser or his representative is not present, the vendor shall proceed to the next step. (The purchaser should expect to be in the factory longer than for a witnessed test.)

**4.1.5** Equipment for the specified inspection and tests shall be provided by the vendor.

● **4.1.6** When specified, the purchaser's representative shall indicate compliance in accordance with the inspector's checklist (Appendix N) by initialing, dating, and submitting the completed checklist to the purchaser before shipment.

**4.1.7** The purchaser's representative shall have access to the vendor's quality program for review.

## 4.2 Inspection

### 4.2.1 GENERAL

**4.2.1.1** The vendor shall keep the following data available for at least 20 years for examination by the purchaser or his representative upon request:

a. Necessary certification of materials, such as mill test reports.
b. Purchasing specifications for all items on bills of material.
c. Test data to verify that the requirements of the specification have been met.
d. Results of documented tests and inspections.
e. Final assembly maintenance and running clearances.

**4.2.1.2** Pressure containing parts shall not be painted until the specified inspection of the parts is completed.

● **4.2.1.3** The purchaser may specify the following:

a. Parts that shall be subjected to surface and subsurface examination.
b. The type of examination required, such as magnetic particle, liquid penetrant, radiographic, and ultrasonic examination.

### 4.2.2 MATERIAL INSPECTION

● **4.2.2.1 General**

When radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection of welds or materials is required or specified, the criteria in 4.2.2.2 through 4.2.2.5 shall apply unless other criteria are specified by the purchaser. Cast iron may be inspected in accordance with 4.2.2.4 and 4.2.2.5. Welds, cast steel, and wrought material may be inspected in accordance with 4.2.2.2 through 4.2.2.5

Note: Regardless of the generalized limits in 4.2.2, it shall be the vendor's responsibility to review the design limits of the equipment in the event that more stringent requirements are necessary. Defects that exceed the limits imposed in 4.2.2 shall be removed to meet the quality standards cited as defined by the inspection method specified.

**4.2.2.2 Radiography**

**4.2.2.2.1** Radiography shall be in accordance with ASTM E94 and ASTM E142.

**4.2.2.2.2** The acceptance standard used for welded fabrications shall be Section VIII, Division 1, UW-51 (100 percent) and UW-52 (spot), of the ASME Code. The acceptance standard used for castings shall be Section VIII, Division 1, Appendix 7, of the ASME Code.

**4.2.2.3 Ultrasonic Inspection**

**4.2.2.3.1** Ultrasonic inspection shall be in accordance with Section V, Articles 5 and 23, of the ASME Code.

**4.2.2.3.2** The acceptance standard used for welded fabrications shall be Section VIII, Division 1, Appendix 12, of the ASME Code. The acceptance standard used for castings shall be Section VIII, Division 1, Appendix 7, of the ASME Code.

**4.2.2.4 Magnetic Particle Inspection**

**4.2.2.4.1** Both wet and dry methods of magnetic particle inspection shall be in accordance with ASTM E709.

**4.2.2.4.2** The acceptance standard used for welded fabrications shall be Section VIII, Division 1, Appendix 6, and Section V, Article 25, of the ASME Code. The acceptability of defects in castings shall be based on a comparison with the photographs in ASTM E125. For each type of defect, the degree of severity shall not exceed the limit specified in Table 4-1.

#### 4.2.2.5 Liquid Penetrant Inspection

**4.2.2.5.1** Liquid penetrant inspection shall be in accordance with Section V, Article 6, of the ASME Code.

**4.2.2.5.2** The acceptance standard used for welded fabrications shall be Section VIII, Division 1, Appendix 8, and Section V, Article 24, of the ASME Code. The acceptance standard used for castings shall be Section VIII, Division 1, Appendix 7, of the ASME Code.

### 4.2.3 MECHANICAL INSPECTION

● **4.2.3.1** When specified, the purchaser may inspect for cleanliness the equipment and all piping and appurtenances furnished by or through the vendor before assembly.

● **4.2.3.2** When specified, the hardness of parts, welds, and heat-affected zones shall be verified as being within the allowable values by testing. The method, extent, documentation, and witnessing of the testing shall be mutually agreed upon by the purchaser and the vendor.

## 4.3 Testing

### 4.3.1 GENERAL

**4.3.1.1** Performance and NPSH tests shall be conducted in accordance with the Hydraulic Institute Standards except that efficiency shall be for information only and not rating (see Table 4-2).

● **4.3.1.2** When specified, at least 6 weeks before the first scheduled running test, the vendor shall submit to the purchaser, for his review and comment, detailed procedures for all running tests and all specified optional tests (4.3.4), including acceptance criteria for all monitored parameters.

**4.3.1.3** The vendor shall notify the purchaser not less than 5 working days before the date the equipment will be ready for testing. If the testing is rescheduled, the vendor shall notify the purchaser not less than 5 working days before the new test date.

Table 4-1—Maximum Severity of Defects in Castings

| Type | Defect | Maximum Severity Level |
|---|---|---|
| I | Linear discontinuities | 1 |
| II | Shrinkage | 2 |
| III | Inclusions | 2 |
| IV | Chills and chaplets | 1 |
| V | Porosity | 1 |
| VI | Welds | 1 |

Table 4-2—Performance Tolerances

| Condition | Rated Point (percent) | Shutoff (percent) |
|---|---|---|
| Rated differential head | | |
| 0–150 m (0–500 ft) | –2 | +10 |
| | +5 | –10[a] |
| 151–300 m (501–1000 ft) | –2 | +8 |
| | +3 | –8[a] |
| Over 300 m (1000 ft) | –2 | +5 |
| | +2 | –5[a] |
| Rated power | +4[b] | |
| Rated NPSH | +0 | |

Note: Efficiency is not a rating value.

[a] If a rising head capacity curve is specified (see 2.1.11), the negative tolerance specified here shall be allowed only if the test curve still shows a rising characteristic.

[b] Under any combination of the above. (Cumulative tolerances are not acceptable.)

**4.3.1.4** Unless otherwise specified, mechanical seals shall not be used during the hydrostatic test but shall be used during all running or performance tests.

### 4.3.2 HYDROSTATIC TEST

**4.3.2.1** All pressure casing components (including seal glands and seal chambers) as defined in 1.4.40 shall be hydrostatically tested with liquid at a minimum of 1.5 times the maximum allowable working pressure, with the special provisions specified below:

a. Double-casing pumps, horizontal multistage pumps (as described in 2.2.4), and other special design pumps as approved by the purchaser may be segmentally tested at 1.5 times the section maximum allowable working pressure.
b. Auxiliary process fluid piping (as described in 3.5.2.1 and 3.5.2.5), if fabricated by welding, shall be tested at 1.5 times the maximum allowable working pressure or section maximum allowable working pressure as applicable in the preceding item a.
c. Cooling passages and components, including jackets for bearings, seal chambers, oil coolers, and seal coolers, shall be tested at a minimum pressure of 975 kPa gauge (150 psig).
d. Steam, cooling water and lubricating oil piping, when fabricated by welding, shall be tested at 1.5 times maximum operating pressure or 975 kPa (150 psig) whichever is greater.
e. The test liquid shall be at a higher temperature than the nil-ductility transition temperature of the material being tested.
f. Gaskets used during hydrostatic testing of an assembled pressure casing, less seal glands, shall be of the same design as those to be supplied with the pump.

**4.3.2.2** If the part tested is to operate at a temperature at which the strength of a material is below the strength of that material at room temperature, the hydrostatic test pressure shall be multiplied by a factor obtained by dividing the allowable working stress for the material at room temperature by that at operating temperature. The stress values used shall conform to those given in ANSI/ASME B31.3 for piping or in Section II of the ASME Code. The pressure thus obtained shall be the minimum pressure at which the hydrostatic test is performed. The data sheets shall list actual hydrostatic test pressures.

**4.3.2.3** The chloride content of liquids used to test austenitic stainless steel materials shall not exceed 50 parts per million. To prevent deposition of chlorides as a result of evaporative drying, all residual liquid shall be removed from tested parts at the conclusion of the test.

**4.3.2.4** Tests shall be maintained for a sufficient period of time to permit complete examination of parts under pressure. The hydrostatic test shall be considered satisfactory when neither leaks nor seepage through the casing or casing joint is observed for at least 30 minutes. Large, heavy castings may require a longer testing period to be agreed upon by the purchaser and the vendor. Seepage past internal closures required for testing of segmented cases and operation of a test pump to maintain pressure are acceptable.

● **4.3.2.5** When specified, the hydrostatic test liquid shall include a wetting agent to reduce surface tension. This wetting agent should be considered when one or more of the following conditions exists:

a. The liquid pumped has a relative density (specific gravity) of less than 0.7 at the pumping temperature.
b. The pumping temperature is higher than 260°C (500°F).
c. The casing is cast from a new or altered pattern.
d. The materials are known to have poor castability.

**4.3.2.6** Austenitic or duplex stainless steel pressure casing components may be hydrostatically tested with an additional amount of material on areas where machining to critical dimensions and tolerances is required. The additional amount of material shall not exceed 1 mm (0.040 in.) material stock or 5 percent of minimum allowable wall thickness, whichever is less.

Any areas which are machined after hydrostatic testing shall be identified on the hydrotest report.

Note: Because of residual stresses resulting from final liquid quenching and relatively low proportional limits inherent in these materials, small amounts of permanent deformation may occur at critical dimensions during hydrostatic testing. By allowing a small amount of material to remain at these critical areas during hydrostatic testing, the need to add material by welding to restore close toleranced dimensions after hydrotest is avoided.

### 4.3.3 PERFORMANCE TEST

Unless otherwise specified, each pump shall be given a performance test on water at a temperature less than 65°C (150°F) in accordance with 4.3.3.1 through 4.3.3.4.

**4.3.3.1** The requirements of 4.3.3.1.1 through 4.3.3.1.7 shall be met before the performance test is performed.

**4.3.3.1.1** Unless otherwise specified, the contract seals and bearings shall be used in the pump for the performance test.

● **4.3.3.1.2** When specified or approved by the purchaser, substitute seals may be used during the performance test if needed to prevent damage to the contract seals or if the contract seals are not compatible with the test fluid.

● **4.3.3.1.3** The acceptable level of seal leakage during testing shall be mutually agreed upon by the purchaser, vendor, and seal manufacturer prior to testing.

Note: When the pump is on the test stand and water is used as the test fluid, seal leakage does not necessarily indicate seal performance under the specified operating conditions. Factors such as test fluid, pressure, temperature, and system cleanliness have an appreciable effect on seal leakage.

**4.3.3.1.4** All lubricating oil pressures, viscosities, and temperatures shall be within the range of operating values recommended in the vendor's operating instructions for the specified unit being tested. For pressure lubrication systems, oil flow rates for each bearing housing shall be determined.

**4.3.3.1.5** Bearings specified to be normally lubricated from a pure oil mist system shall be prelubricated prior to performance testing using a suitable hydrocarbon oil.

**4.3.3.1.6** All joints and connections shall be checked for tightness, and any leaks shall be corrected.

**4.3.3.1.7** All warning, protective, and control devices used during the test shall be checked for proper operation, and adjustments shall be made as required.

**4.3.3.2** Unless otherwise specified, the performance test shall be conducted as specified in 4.3.3.2.1 though 4.3.3.2.4.

**4.3.3.2.1** The vendor shall take test data, including head, capacity, power, and vibration, at a minimum of five points. These points will normally be (a) shutoff (no vibration data required), (b) minimum continuous stable flow, (c) midway between minimum and rated flow, (d) rated flow, and (e) maximum allowable flow (as a minimum, 120 percent of BEP).

Note: In the case of high-energy pumps (see 2.1.15), and multistage pumps, it may not be feasible to test at shutoff.

**4.3.3.2.2** All running tests and mechanical checks shall be completed by the vendor before the purchaser's inspection.

**4.3.3.2.3** Unless otherwise mutually agreed upon, the test speed shall be within 3 percent of the rated speed shown on the pump data sheet (see Appendix B). Test results shall be converted to anticipated results at the rated speed.

**4.3.3.2.4** The vendor shall maintain a complete, detailed log of all final tests and shall prepare the required number of copies, certified for correctness. Data shall include test curves and a summary of test performance data compared to guarantee points (see 6.2.4, 6.3.3.2, and Appendix T).

**4.3.3.3** During the performance test, the requirements of 4.3.3.3.1 through 4.3.3.3.3 shall be met.

**4.3.3.3.1** Vibration values shall be recorded during the test in accordance with 2.8.3.2. Vibration values shall not exceed those given in 2.8.3.7 and 2.8.3.8. When U.S. dimensions are specified, True Peak bearing housing velocities shall also be recorded.

**4.3.3.3.2** Pumps shall operate within bearing temperature limits as defined in paragraph 2.9.2.3 and shall not display signs of unfavorable operation, such as noise caused by cavitation.

**4.3.3.3.3** When operated at rated speed, pumps shall perform within the tolerances given in Table 4-2.

**4.3.3.4** Unless otherwise specified, the requirements of 4.3.3.4.1 through 4.3.3.4.3 shall be met after the performance test is completed.

**4.3.3.4.1** If it is necessary to dismantle a pump after the performance test for the sole purpose of machining impellers to meet the tolerances for differential head, no retest will be required unless the reduction in diameter exceeds 5 percent of the original diameter. The diameter of the impeller at the time of shop test, as well as the final diameter of the impeller, shall be recorded on a certified shop test curve that shows the operating characteristics after the diameter of the impeller has been reduced.

**4.3.3.4.2** If it is necessary to dismantle a pump for some other correction, such as improvement of power, NPSH, or mechanical operation, the initial test will not be acceptable, and the final performance test shall be run after the correction is made.

**4.3.3.4.3** If it is necessary to disturb the mechanical seal assembly following the performance test, or if the test seal faces are replaced with the job seal faces, the final seal assembly shall be air tested as follows:

a. Pressurize each sealing section independently with clean air to a test pressure of 175 kPa (25 psig).
b. Isolate the test setup from the pressurizing source and maintain the pressure for a minimum of 5 minutes, or 5 minutes per 30 liters (1 $ft^3$) of test volume, whichever is greater.
c. The maximum allowable pressure drop during the test is 15 kPa (2 psi).

### • 4.3.4 OPTIONAL TESTS

When specified, the shop tests described in 4.3.4.1 through 4.3.4.5 shall be performed. Test details shall be mutually agreed upon by the purchaser and the vendor.

#### 4.3.4.1 NPSHR Test

**4.3.4.1.1** NPSHR data shall be taken at each test point (4.3.3.2.1) except shut-off.

**4.3.4.1.2** A 3 percent drop in head (first stage head on multistage pumps) shall be interpreted as indicating performance impairment. The first stage head of pumps with two or more stages shall be measured using a separate connection to the first stage discharge whenever possible. If this is not feasible, testing of the first stage only should be considered.

**4.3.4.1.3** NPSHR at the rated point shall not exceed the quoted value (see Table 4-2). Dismantling to correct NPSHR requires a retest (see 4.3.3.4.2).

#### 4.3.4.2 Complete Unit Test

The pump and driver train, complete with all auxiliaries that make up the unit, shall be tested together. When specified, torsional vibration measurements shall be made to verify the vendor's analysis. The complete unit test shall be performed in place of or in addition to separate tests of individual components specified by the purchaser.

#### 4.3.4.3 Sound Level Test

Sound level tests shall be performed as agreed between the purchaser and the vendor.

Note: ISO Standards 3740, 3744, and 3746 may be consulted for guidance.

#### 4.3.4.4 Auxiliary Equipment Test

Auxiliary equipment such as oil systems, gears, and control systems shall be tested in the vendor's shop. Details of the auxiliary equipment test shall be developed jointly by the purchaser and the vendor.

#### 4.3.4.5 Bearing Housing Resonance Test

With the pump unpiped, the bearing housing(s) shall be excited by impact or other suitable means and the natural frequency(ies) shall be determined from the response. A minimum separation margin of 10 percent shall exist between the natural frequency(ies) and the following excitation frequencies:

a. Multiples of running speed (RPM): 1.0, 2.0, 3.0.
b. Multiples of vane passing frequency: 1.0, 2.0.

## 4.4 Preparation for Shipment

• **4.4.1** Equipment shall be suitably prepared for the type of shipment specified, including restraint of the rotor when necessary. Restrained rotors shall be identified by means of corrosion resistant tags attached with stainless steel wire. The preparation shall make the equipment suitable for 6 months of outdoor storage from the time of shipment, with no disassembly required before operation, except for inspection of bearings and seals. If storage for a longer period is contemplated, the purchaser will consult with the vendor regarding the recommended procedures to be followed.

**4.4.2** The vendor shall provide the purchaser with the instructions necessary to preserve the integrity of the storage preparation after the equipment arrives at the job site and before start-up.

**4.4.3** The equipment shall be prepared for shipment after all testing and inspection has been completed and the equipment has been released by the purchaser. The preparation shall include that specified in 4.4.3.1 through 4.4.3.11.

**4.4.3.1** Any packing used in tests shall be removed from the stuffing boxes prior to shipment.

**4.4.3.2** Unless otherwise specified, pumps shall not be disassembled after performance testing, provided the pump, including the seal chamber, is completely drained and dried and all internal parts are coated with a suitable rust preventative within 4 hours of testing.

**4.4.3.3** Exterior surfaces, except for machined surfaces, shall be given at least one coat of the manufacturer's standard paint. The paint shall not contain lead or chromates. Stainless steel parts need not be painted. The undersides of baseplates shall be prepared for grout in accordance with either 3.3.17 or 3.3.18.

**4.4.3.4** Exterior machined surfaces of cast iron and carbon steel parts shall be coated with a suitable rust preventive.

**4.4.3.5** Internal areas of cast iron and carbon steel bearing housings and oil system components shall be coated with a suitable oil soluble rust preventive.

**4.4.3.6** Flanged openings shall be provided with metal closures at least 5 mm (0.19 in.) thick, with elastomer gaskets and at least four full diameter bolts. For studded openings, all nuts needed for the intended service shall be used to secure closures.

**4.4.3.7** Threaded openings shall be provided with steel caps or steel plugs in accordance with 3.5.1.12.

**4.4.3.8** Openings that have been beveled for welding shall be provided with closures designed to prevent entrance of foreign materials and damage to the bevel.

**4.4.3.9** Lifting points and lifting lugs shall be clearly identified.

**4.4.3.10** The equipment shall be identified with item and serial numbers. Material shipped separately shall be identified with securely affixed, corrosion resistant metal tags indicating the item and serial number of the equipment for which it is intended. In addition, crated equipment shall be shipped with duplicate packing lists, one inside and one on the outside of the shipping container.

**4.4.3.11** Exposed shafts and shaft couplings shall be wrapped with waterproof, moldable waxed cloth or volatile-corrosion inhibitor paper. The seams shall be sealed with oil-proof adhesive tape.

**4.4.4** Auxiliary piping connections furnished on the purchased equipment shall be impression stamped or permanently tagged to agree with the vendor's connection table or general arrangement drawing. Service and connection designations shall be indicated. Symbols for all pump connections, including plugged connections shall be in accordance with Appendix D.

**4.4.5** Bearing assemblies shall be fully protected from the entry of moisture and dirt. If vapor phase inhibitor crystals in bags are installed in large cavities to absorb moisture, the bags must be attached in an accessible area for ease of removal. Where applicable, bags shall be installed in wire cages attached to flanged covers. Bag locations shall be indicated by corrosion resistant tags attached with stainless steel wire.

**4.4.6** One copy of the manufacturer's standard installation instructions shall be packed and shipped with the equipment.

# SECTION 5—SPECIFIC PUMP TYPES

Note: See Figures 1.1 and 1.2 for pump classifications and typical illustations.

## 5.1 Single Stage Overhung Pumps

### 5.1.1 HORIZONTAL (TYPE OH2)

**5.1.1.1** Horizontal single stage overhung centerline mounted pumps have a single bearing housing to absorb all forces imposed upon the pump shaft and maintain rotor position during operation. The pumps are mounted on a baseplate and are flexibly coupled to their drivers.

**5.1.1.2** Type OH2 pumps shall be designed such that their first dry lateral critical speed is at least 20 percent above maximum continuous operating speed.

### 5.1.2 VERTICAL IN-LINE (TYPE OH3)

**5.1.2.1** Vertical single stage overhung pumps have a bearing housing integral with the pump to absorb all pump loads. The driver is mounted on a support integral to the pump. The pumps and their drivers are flexibly coupled.

**5.1.2.2** A flat contact surface shall be provided on the bottom of the casing to make the pump stable when free-standing on a pad or foundation. The ratio of the unit center of gravity height to the contact surface width shall be no greater than 3:1. This stability may be achieved through the design of the casing or by a permanent external stand.

**5.1.2.3** Pumps shall be designed to float with the suction and discharge pipe.

● **5.1.2.4** When specified, pumps shall be designed to be bolted to a pad or foundation.

Note: Flange loading on the pump may increase when the unit is bolted down and must be addressed in the piping design.

**5.1.2.5** A minimum 1/2 NPS tapped drain connection shall be provided so that no liquid collects on the cover or driver support.

**5.1.2.6** The pump and seal chamber shall be continuously vented with a high point connection in either the seal chamber or seal flush piping. Systems needing manual venting require purchaser approval.

Note: If venting to atmosphere is not acceptable, the vent must be connected to the process piping at an elevation above the seal chamber.

● **5.1.2.7** Pumps shall be designed to facilitate removal and installation of the back pullout assembly. When specified, a device shall be provided which allows direct rigging or lifting of the back pullout assembly from outside the motor support.

**5.1.2.8** Pumps shall meet the requirements of paragraph 2.5.7 for shaft stiffness.

**5.1.2.9** Pumps shall be designed such that the first dry lateral critical speed is at least 20 percent above the continuous operating speed.

**5.1.2.10** Vibration readings are to be taken on the pump bearing housing at designated locations (see 2.8.3.2 and 2.9.2.10). Vibration readings shall meet the requirements of 2.8.3.

**5.1.2.11** With the purchaser's approval, bearing housings may be arranged for grease lubrication. The stabilized bearing housing temperature shall not exceed 82°C (180°F) when operating at an ambient temperature of 43°C (110°F). Recommended greases shall be suitable for operation at these temperatures.

**5.1.2.12** Coupling hubs may be supplied with a slip fit to the shaft, secured with set screws.

Note: This allows for final coupling hub adjustment required due to variations in distance between shaft ends.

**5.1.2.13** Unless otherwise specified, auxiliary piping systems (Appendix D, Plans 52 and 53) shall not be mounted on the pumps.

### 5.1.3 INTEGRAL GEAR DRIVEN (TYPE OH6)

**5.1.3.1** Integral gear driven pumps have a speed increasing gearbox integral with the pump. The impeller is mounted directly to the gearbox output shaft. There is no coupling between the gearbox and pump; however, the gearbox is flexibly coupled to its driver. Pumps may be oriented vertically or horizontally.

**5.1.3.2** Impellers may be open, semiopen, or fully enclosed. Impellers shall be constructed as single piece castings or weldments. Fabricated impellers require the purchaser's specific approval.

Note: Integral gear pumps are frequently utilized in low specific speed applications, where efficiency is optimized with open type impellers.

● **5.1.3.3** When specified, the vendor shall perform a lateral critical speed analysis for each machine to assure acceptable amplitudes of vibration throughout the anticipated operating speed range. The analysis shall be performed as described in 5.2.4.1.

Note: Lateral critical speeds may be of concern with Type OH6 pumps. Refer to 5.2.4.1 relative to the need for a lateral analysis. Normally pumps of this type are thoroughly investigated during development, and typical rotor dynamics are available and applicable. A lateral analysis should be specified only for unique, new, or critical pumps.

**5.1.3.4** Single piece hydrodynamic radial bearings may be used.

**5.1.3.5** Integral gear pumps may require partial disassembly to permit replacement of the seal assembly.

**5.1.3.6** Unless otherwise specified, auxiliary piping systems (see Appendix D, Plans 52 and 53) shall not be mounted on the pump.

## 5.2 Between Bearings Pumps (Types BB1-BB5)

### 5.2.1 PRESSURE CASINGS

**5.2.1.1** Axially split casings may have a composition sheet gasket or a metal-to-metal joint; the vendor's bid shall state which is being offered.

**5.2.1.2** Pumps for service temperatures below 150°C (300°F) may be foot mounted.

**5.2.1.3** For pumps with axially split casings, lifting lugs or tapped holes for eyebolts shall be provided for lifting only the top half of the casing and shall be so tagged. Methods for lifting the assembled machine shall be specified by the vendor (see 6.2.2.1, Item d).

### 5.2.2 ROTOR

**5.2.2.1** Impellers of multistage pumps shall be individually located along the shaft and positively secured against axial movement in the direction of normal hydraulic thrust. An interference fit is not considered a positive locking method.

● **5.2.2.2** When specified, impellers of multistage pumps shall also be positively locked against axial movement in the direction opposite to normal hydraulic thrust.

**5.2.2.3** The runout of shafts and assembled rotors measured with the shaft or rotor supported on V blocks or bench rollers adjacent to its bearings shall be within the limits given in Table 5-1.

### 5.2.3 RUNNING CLEARANCES

**5.2.3.1** Renewable casing bushings and interstage sleeves or the equivalent shall be provided at all interstage points.

**5.2.3.2** Interstage bushings and thrust-balancing devices on multistage pumps may have the manufacturer's standard clearances, provided these clearances are stated as exceptions to this standard (see 2.6.4.2) in the proposal and are approved by the purchaser. When the manufacturer's standard clearances are based on material combinations exhibiting superior wear characteristics, supporting data shall be included in the proposal.

### 5.2.4 DYNAMICS

#### 5.2.4.1 Lateral Analysis

Note: Depending on pump design, the first or second wet lateral critical speed of multistage and high-speed pumps may coincide with the operating speed, particularly as internal clearances increase with wear. A lateral analysis can predict when this coincidence is likely and whether the resulting vibration will be acceptable.

**5.2.4.1.1** Unless otherwise specified, the need for a lateral analysis of a pump's rotor shall be determined using the process set out in Figure 5-1. For this process, the following definitions apply:

a. *Identical pump:* same size, hydraulic design, number of stages, RPM, clearances, type of shaft seal (axial face or breakdown bushing), type of bearings, coupling weight, coupling overhang, and pumping the same liquid.
b. *Similar pump:* by agreement between purchaser and manufacturer, taking account of the factors listed in the preceding definition (Item a).
c. *Classically stiff:* first dry critical speed (1.4.7) is above the pump's maximum allowable continuous speed by the following:
1. 20 percent for rotors designed for wet running only.
2. 30 percent for rotors designed to be able to run dry.

**5.2.4.1.2** When a lateral analysis is required by the process in 5.2.4.1.1, it shall be carried out and its results assessed in accordance with Appendix I.

Table 5-1—Shaft and Rotor Runout Requirements

| Flexibility factor (see Note 1), $L^4/D^2$, mm² (in²) (see Note 2) | >1.9x10⁹ (3.0x10⁶) | | ≤ 1.9x10⁹ (3.0x10⁶) | |
|---|---|---|---|---|
| Allowable shaft runout, TIR µm (in.) | 40 (0.0015) | | 25 (0.0010) | |
| Component fit on shaft | Clearance | Interference | Clearance | Interference |
| Allowable rotor radial Runout, µm (in.) TIR (see Note 3) | 90 (0.0035) | 60 (0.0025) | 75 (0.0030) | 50 (0.0020) |

Notes:
1. The shaft flexibility factor $L^4/D^2$ is directly related to the static deflection of a simply supported shaft, and is therefore a good indicator of the runout attainable during manufacture and the quality of balance that can be achieved and maintained.
2. $L$ = bearing span; $D$ = shaft diameter (largest) at impeller.
3. Runout of impeller hubs, balancing drum, and sleeves.

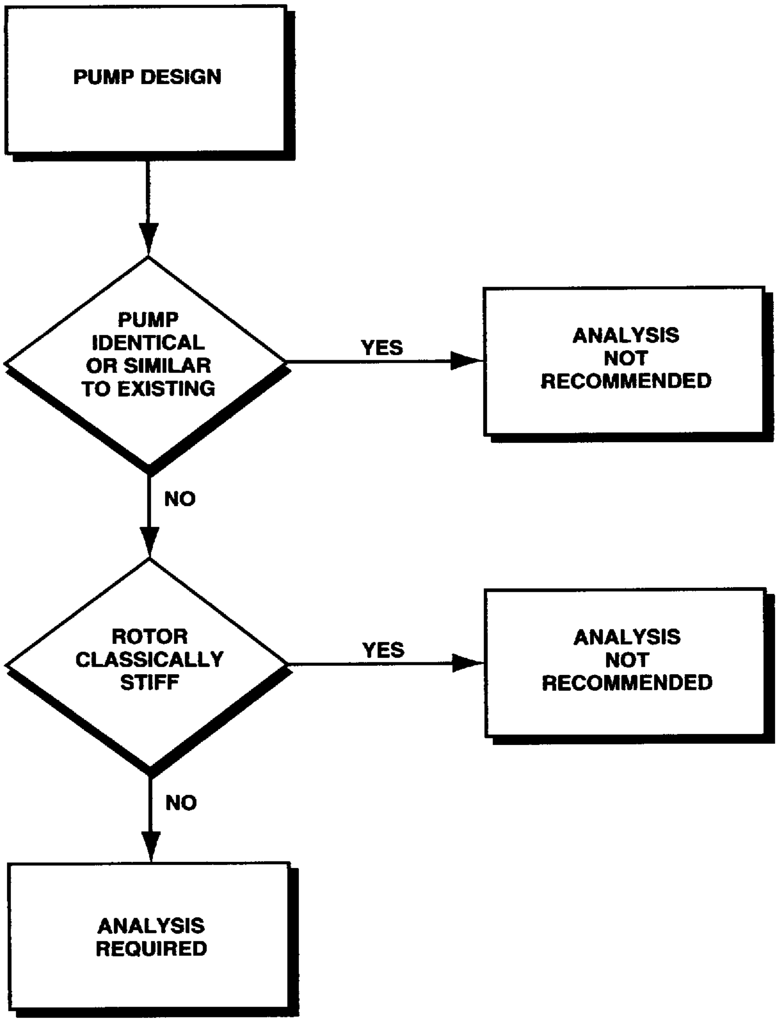



Figure 5-1—Decision Tree for Rotor Lateral Analysis

#### 5.2.4.2 Rotor Balancing

**5.2.4.2.1** Rotors of the categories listed below shall be two-plane dynamically balanced at low speed to the balance grade in Table 5-2:

a. Multistage pumps (three or more stages).
b. One and two-stage pumps whose maximum continuous rotative speed is greater than 3800 RPM.

The sequence of rotor assembly and balance correction shall follow ISO 5406. For balancing, the rotor does not include the pump half coupling hub or the rotary units of the mechanical seals.

Note 1: Table 5-2 shows ISO balance grade G2.5 for all interference fit rotors to speeds of 3800 RPM. This is based on two factors: (a) At 3800 RPM the upper limit of balance grade G2.5 produces a force due to unbalance of 10 percent of rotor weight, which means that unbalance will not have any material effect on the rotor's operating shape; (b) For rotors whose flexibility is high (see Table 5-1), it is not practical to achieve and maintain the rotor straightness necessary for balance grade G1.0.

Note 2: The mass eccentricity associated with balance grade G1.0 is very small; (for example, 0.0001 in. maximum for operation at 3800 RPM). Therefore, the balance quality may not be verifiable if the rotor is disturbed from its position on the balancing stand or disassembled and reassembled. It is normally possible, however, to perform a residual unbalance check to verify the accuracy of the balancing stand.

**5.2.4.2.2** For rotor balancing, any vacant single keyways shall be filled with crowned half keys.

**5.2.4.2.3** Whenever an assembled rotor is balanced, a rotor residual unbalance check shall be performed. The check shall be carried out after final balancing of the rotor, following the procedure given in Appendix J. The weight of all half keys used during final balancing of the assembled rotor shall be recorded on the residual unbalance worksheet.

Table 5-2—Rotor Balance Requirements

| Component Fit on Shaft | Clearance | Interference | |
|---|---|---|---|
| Maximum continuous speed (RPM) | To 3800[a] | To 3800 | Above 3800 |
| Flexibility factor, $L^4/D^2$, $mm^2$ ($in.^2$) | No Limit | No Limit | $\leq 1.9 \times 10^9$ ($3.0 \times 10^6$)[c] |
| Rotor balance grade | [b] | G2.5 (8 *W/N*)[d] | G1.0 (4 *W/N*)[d] |

Note: See Table 5-1 for shaft and rotor runout requirements.

[a]1.05 (3600) for turbine overspeed.
[b]Balance correction during assembly is not feasible because clearance fit will not maintain corrected balance.
[c]When rotors of higher flexibility are used at speeds above 3800 RPM, achieving and maintaining this balance level will require special attention to design, manufacture, and maintenance.
[d]Approximately equal to the midpoint of the corresponding ISO balance quality grade.

## 5.2.5 BEARINGS AND BEARING HOUSINGS

**5.2.5.1** When required by 2.9.1.1, hydrodynamic radial bearings shall be in accordance with 5.2.5.1.1 through 5.2.5.1.3.

**5.2.5.1.1** Bearings shall be split for ease of assembly, precision bored, and of the sleeve or pad type, with steel-backed, babbitted replaceable liners, pads, or shells. The bearings shall be equipped with antirotation pins and shall be positively secured in the axial direction.

**5.2.5.1.2** The liners, pads, or shells shall be in axially split housings and shall be replaceable without having to dismantle any portion of the casing or remove the coupling hub.

**5.2.5.1.3** Bearings shall be designed to prevent installation backwards or upside down or both.

**5.2.5.2** Hydrodynamic thrust bearings shall be in accordance with 5.2.5.2.1 through 5.2.5.2.5.

**5.2.5.2.1** Thrust bearings shall be of the steel-backed, babbitted multiple-segment-type, designed for equal thrust capacity in both directions and arranged for continuous pressurized lubrication to each side. Both sides shall be of the tilting-pad type, incorporating a self-leveling feature that assures that each pad carries an equal share of the thrust load with minor variation in pad thickness.

**5.2.5.2.2** Thrust collars shall be positively locked to the shaft to prevent fretting.

**5.2.5.2.3** Both faces of thrust collars shall have a surface finish of not more than 0.4 µm (16 µin.) $R_a$, and, after mounting, the axial total indicated runout of either face shall not exceed 13 µm (0.0005 in.).

● **5.2.5.2.4** Thrust bearing loading shall be determined as in 2.9.1.2. Bearings shall be selected such that the maximum continuous applied load produces a minimum oil film thickness of 13 µm (0.0005 in.) or a maximum babbit temperature of 88°C (190°F), whichever occurs first. When specified, thrust bearing sizing shall be reviewed and approved by the purchaser.

Note: The limits given above correspond to a design factor of 2 or more based on the bearing's maximum continuous thrust capacity.

**5.2.5.2.5** Thrust bearings shall be arranged to allow axial positioning of each rotor relative to the casing and the setting of the bearing's clearance or preload.

**5.2.5.3** Bearing housings for pressure lubricated hydrodynamic bearings shall be arranged to minimize foaming. The drain system shall be adequate to maintain the oil and foam level below shaft end seals. The rise in oil temperature through the bearing and housings shall not exceed 28°C (50°F) under the most adverse specified operating conditions. The bearing outlet oil temperature shall not exceed 70°C (160°F) (see 2.9.2.3). When the inlet oil temperature exceeds 50°C (120°F), special consideration shall be given to bearing design, oil flow, and allowable temperature rise. Oil outlets from thrust bearings shall be as recommended by the bearing manufacturer for the collar speed and lubrication method involved. Oil connections on bearing housings shall be in accordance with 3.5.

**5.2.5.4** Axially split bearing housings shall have a metal-to-metal split joint whose halves are located by means of cylindrical dowels.

## 5.2.6 LUBRICATION

● **5.2.6.1** When specified or if recommended by the vendor and approved by the purchaser, a pressure lubrication system shall be furnished to supply oil at a suitable pressure to the pump bearings, the driver, and any other driven equipment, including gears and continuously lubricated couplings.

**5.2.6.2** As a minimum, an external pressure lubrication system shall include the following items (see Appendix D, Figure D-6, for a typical schematic):

a. A shaft-driven main oil pump with a suction strainer.

● b. An oil cooler, preferably separate and of the shell-and-tube type, with tubes of inhibited admiralty brass. Internal oil coolers are not acceptable. When specified, to prevent the oil from being contaminated if the cooler fails, the oil-side operating pressure shall be higher than the water-side operating pressure.

c. Unless otherwise specified, an austenitic stainless steel oil reservoir with the following characteristics:

1. The capacity to avoid frequent refilling, to provide adequate allowance for system rundown, and to provide a retention time of at least 3 minutes to settle moisture and foreign matter adequately.
2. Provisions to eliminate air and minimize flotation of foreign matter to the pump suction.

3. Fill connections, reflex-type level indicators, and breathers suitable for outdoor use.
4. Sloped bottoms and connections for complete drainage.
5. Cleanout openings as large as is practicable.
6. A bypass line that returns below the oil level to eliminate aeration and static electricity.

d. A supply and return system.
e. A duplex full-flow filter with replaceable elements and filtration of 25 μm nominal or finer. Filter cartridge materials shall be corrosion resistant. Metal mesh or sintered metal filter elements are not acceptable. The filter shall not be equipped with a relief valve or an automatic bypass.
f. A motor driven auxiliary oil pump with suction strainer and an automatic/manual control system arranged to start automatically on low oil pressure and with manual shutdown only.
g. Sight flow indicators in each bearing drain line.
h. Temperature gauges (with thermowells) in the reservoir, after the oil cooler, and in each bearing drain line.
i. Low-oil-pressure alarm and shutdown switches.
j. A pressure gauge (valved for removal) for each pressure level, and a pressure differential indicator to measure filter pressure drop.

● **5.2.6.3** When specified, a removable steam heating element external to the oil reservoir or a thermostatically controlled electric immersion heater with a sheath of austenitic stainless steel shall be provided for heating the charge capacity of oil before start-up in cold weather. The heating device shall have sufficient capacity to heat the oil in the reservoir from the specified minimum site ambient temperature to the manufacturer's required start-up temperature within 12 hours. If an electric immersion heater is used, the watt density shall not exceed 2.33 watts per sq. cm (15 watts per sq. in.).

**5.2.6.4** The main and standby oil pumps shall have steel casings unless they are enclosed in a reservoir. All other oil containing pressure components shall be steel. (See 3.5.5 for requirements for lubricating oil piping.)

● **5.2.6.5** Where oil is supplied from a common system to two or more machines (such as a pump, a gear, and a motor), the oil's characteristics will be specified on the data sheets by the purchaser on the basis of mutual agreement with all vendors supplying equipment served by the common oil system.

Note: The typical lubricants employed in a common oil system are hydrocarbon oils that correspond to ISO Grades 32 through 68, as specified in ISO 3448.

● **5.2.6.6** When specified, the pressure lubrication system shall conform to the requirements of ISO 10438 (API Standard 614).

### ● 5.2.7 ACCESSORIES

When specified, couplings and coupling mountings shall conform to API Standard 671.

Note: Typically this is necessary only for critical, high speed services.

### 5.2.8 TESTING

**5.2.8.1** For pressure lubricated bearings, test stand oil filtration shall be 25 μm nominal or finer. Oil system components downstream of the filters shall meet the following cleanliness requirements:

a. After 1 hour of oil circulation at 65–70°C (150–160°F), examination of a 100 mesh screen (0.1 mm (0.004 in.)) diameter wire with 0.15 mm (0.006 in.) openings, installed at the bearing housing oil supply connection, shall show the following:
1. Random distribution of particles on the screen.
2. No particle larger than 250 μm (0.010 in.).
3. Total particle count less than that listed in Table 5-3.

b. Freedom from foreign matter (rust, scale, metal shavings, sand) upon visual inspection and no grittiness to the touch.

**5.2.8.2** During the shop test of pumps with pressure lubricated bearings, the oil flow rate to each bearing housing shall be measured and recorded.

**5.2.8.3** All purchased vibration probes, transducers, and oscillator-demodulators shall be in use during the test. If vibration probes are not furnished by the vendor or if the purchased probes are not compatible with shop readout facilities, shop probes and readouts that meet the accuracy requirements of API Standard 670 shall be used. The vibration measured with this instrumentation shall be the basis for acceptance or rejection of the pump (see 2.8.3.7 and 2.8.3.8).

**5.2.8.4** With the purchaser's approval, to accommodate test stand piping constraints, single-stage double-suction pumps may be assembled for testing by driving from the opposite end of the pump when compared to the general arrangement for the contract pump and driver. No retest is required after final assembly.

● **5.2.8.5** When specified, hydrodynamic bearings shall be removed, inspected by the purchaser or his representative, and reassembled after the performance test is completed.

### 5.2.9 PREPARATION FOR SHIPMENT

**5.2.9.1** When a spare rotor or element is purchased, it shall be prepared for unheated indoor storage of 3 years. Storage preparation shall include treatment with a rust preventive and enclosure in a vapor barrier envelope with slow release vapor phase inhibitor. The rotor or element shall be

Table 5-3—Maximum Number of Particles

| Nominal Pipe Size | Particle Count |
|---|---|
| 1 and less | 5 |
| 1½ | 10 |
| 2 | 20 |
| 3 | 40 |

boxed for the type of shipment specified. A rotor shall have a resilient material (but not lead, TFE or PTFE), at least 3 mm (0.12 in.) thick, between the rotor and its support cradle; support shall not be at the rotor's journals. An element shall have its rotor secured to prevent movement within the stator.

● **5.2.9.2** When specified, a spare rotor shall be prepared for vertical storage. The rotor shall be supported from its coupling end with a fixture designed to support 1.5 times the rotor's weight without damaging the shaft. Instructions on the use of the fixture shall be included in the installation, operation, and maintenance manual.

## 5.3 Vertically Suspended Pumps

### 5.3.1 PRESSURE CASINGS

**5.3.1.1** Jackscrews and casing alignment dowels are not required for rabbeted bowl assemblies.

**5.3.1.2** The design of bowl and column bolting shall take into account possible pressure surges during pump start-up.

**5.3.1.3** Unless otherwise specified, pumps shall be provided with vent connections for suction barrels and seal chambers.

### 5.3.2 ROTORS

**5.3.2.1** Unless otherwise specified, impellers shall be fully enclosed and constructed as single-piece castings. Fabricated impellers require the purchaser's approval.

Note: Enclosed (closed) impellers are less sensitive to axial setting and, therefore, preferable for long settings when shaft elongation due to axial thrust is substantial. Similarly, closed impellers should be used for cold or hot liquids due to thermal shaft expansion/contraction. Semiopen impellers offer higher efficiency, due to the elimination of disc friction from one shroud. The running clearances for semiopen impellers are able to be adjusted from the coupling or top of the motor, thus restoring efficiency and pump output without disassembly of pump parts. The open impeller is typically of an axial flow propeller type designed for large capacities at low heads; the open impeller is also used for volute sump pumps with a separate discharge.

**5.3.2.2** Pump shafts less than 100 mm (4 in.) diameter shall be machined or ground and finished throughout their entire length. The total indicated run-out shall not exceed 4 μm per 100 mm (0.0005 in. per ft) of length. Total run-out shall not exceed 80 μm (0.003 in.) over total shaft length.

**5.3.2.3** The pump shaft shall be in one piece unless otherwise approved by the purchaser (because of total shaft length or shipping restrictions).

### 5.3.3 WEAR PARTS AND RUNNING CLEARANCES

**5.3.3.1** Renewable casing bushings shall be provided at all interstage and steady bearing points; however, the interstage pressure differential and the character of the liquid handled (for example, dirty or nonlubricating) should determine the need for corresponding shaft sleeves.

**5.3.3.2** The running clearances specified in 2.6.4.2 do not apply to the clearances of steady bearings or interstage bushings. The clearances used shall be stated in the proposal and approved by the purchaser.

**5.3.3.3** Pumps with semiopen impellers in an erosive service shall have a replaceable casing liner.

### 5.3.4 DYNAMICS

● **5.3.4.1** Vertically suspended pumps are generally flexible structures with running speeds located between natural frequencies. As such, they are susceptible to resonant vibration if their separation margins are not verified during design. When specified, the vendor shall furnish an analysis of the structure to confirm preconstruction design. The purchaser and the vendor shall mutually agree on the extent, method, and acceptance criteria for this analysis.

Note: The basic structural elements typically include the foundation, pump structures and motor frames. Typically the deflection of the foundation will represent less than 5 percent of the total deflection of the structural elements. If foundation data is not available when the analysis is being conducted, a mutually agreed upon value shall be used.

Generally a 20 percent separation margin shall be maintained between the natural frequency of the motor support structure and the operating speed (in other words, below the minimum or above the maximum continuous operating speed).

**5.3.4.2** Pump rotors shall be designed such that their first dry critical speed is the following percentage above their maximum allowable continuous speed:

a. For rotors designed for wet running only, 20 percent.
b. For rotors designed to be able to run dry, 30 percent.

### 5.3.5 GUIDE BUSHINGS AND BEARINGS

**5.3.5.1** Guide bushings shall be suitably corrosion resistant and abrasion resistant for the specified product and temperature. The maximum spacing between shaft guide bushings shall be in accordance with Figure 5-2.

**5.3.5.2** Thrust bearings that are integral with the driver shall meet the requirements of 3.1. Thrust bearings and housings integral with the pump shall meet the applicable requirements of 2.9.1 and 2.9.2. To allow axial rotor adjustment and oil lubrication, the thrust bearing shall be mounted with an interference fit on a slide-fit, key-driven sleeve.

**5.3.5.3** Unless otherwise specified, except for volute sump pumps (Type VS4), the first stage impeller shall be located between bearings.

Note: Although between bearing first stage impellers may result in superior rotor support, certain applications which require superior suction performance may benefit from an overhung first stage impeller arrangement.

### 5.3.6 LUBRICATION

Internal bearings in vertical pumps are normally lubricated by the liquid pumped. Alternate methods of lubrication shall be proposed when the pumped liquid is not suitable.

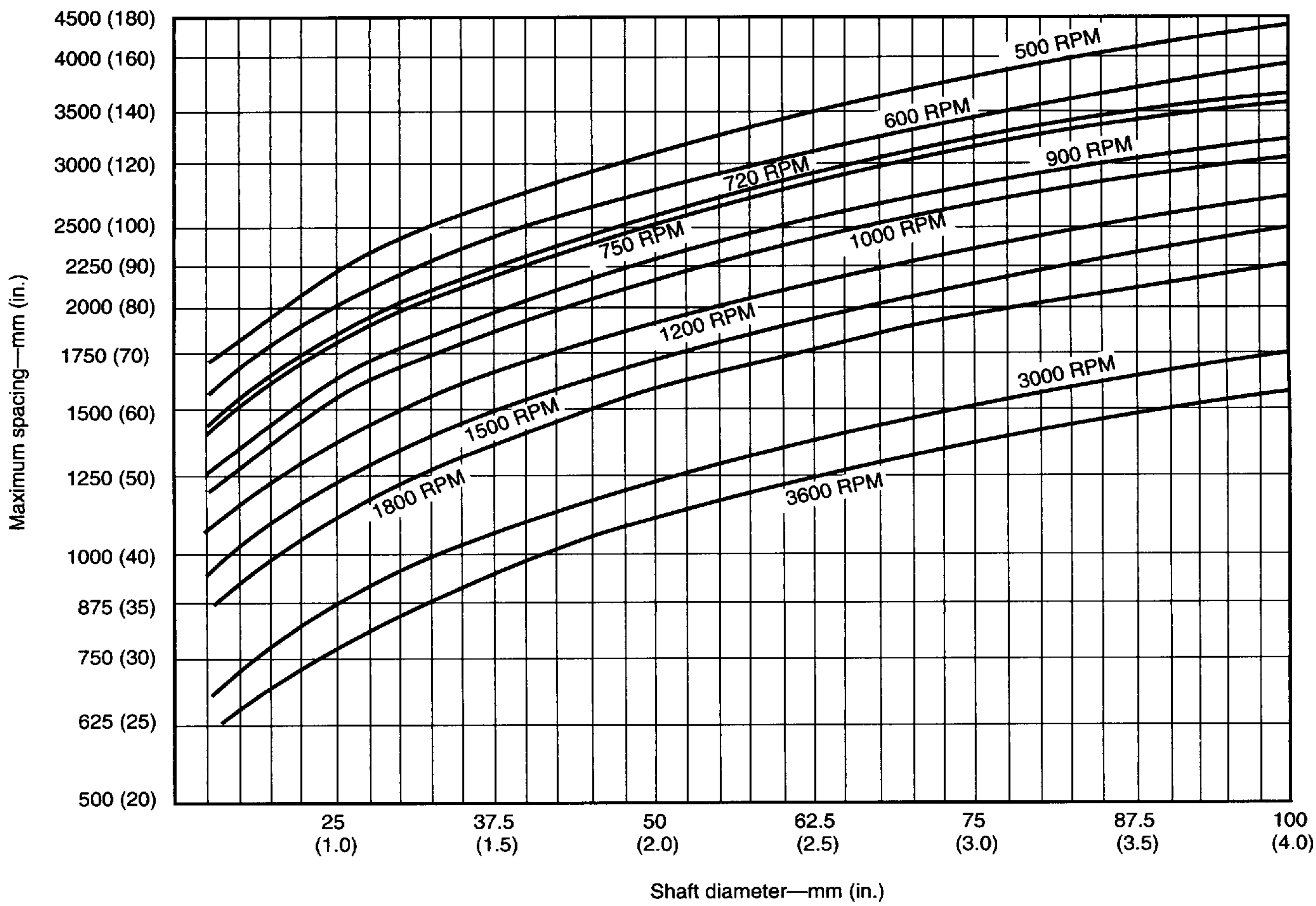



Figure 5-2—Maximum Spacing Between Shaft Guide Bushings

### 5.3.7 ACCESSORIES

#### 5.3.7.1 Drivers

**5.3.7.1.1** The frame of fabricated vertical motors shall be post-weld stress relieved.

**5.3.7.1.2** Pumps and motor assemblies that could be damaged by reverse rotation shall be provided with a nonreverse ratchet or another purchaser-approved device to prevent reverse rotation.

#### 5.3.7.2 Couplings and Guards

Coupling faces shall be perpendicular to the axis of the coupling within 1 µm per 10 mm (0.0001 in. per in.) of face diameter or 13 µm (0.0005 in.) total indicated run-out, whichever is greater.

#### 5.3.7.3 Mounting Plates

**5.3.7.3.1** The mounting plate for double casing pumps shall be separate from the main body flange and located sufficiently below it to permit the use of through bolting on the body flange.

**5.3.7.3.2** Single casing vertical pumps shall have the manufacturer's standard mounting arrangement.

**5.3.7.3.3** The pump-to-motor mounting surface shall contain a rabbeted fit.

**5.3.7.3.4** A minimum of four alignment positioning screws shall be provided for each drive train component that weighs more than 400 kg (900 lbs) to facilitate horizontal adjustment within the rabbeted fit.

● **5.3.7.3.5** When specified, pumps shall be provided with a separate sole plate for bolting and grouting to the foundation. This plate shall be machined on its top surface for mounting of the discharge head, can, or motor support.

#### 5.3.7.4 Piping and Appurtenances

When mechanical seals and drivers are not installed prior to shipment, the seal piping system shall not be fully assembled.

### 5.3.8 INSPECTION, TESTING, AND PREPARATION FOR SHIPMENT

**5.3.8.1** Pumps shall be tested as complete assemblies. Tests using only bowls and impellers are not recommended. In cases where assembled unit testing is impractical, the vendor shall submit alternative testing procedures with the proposal. Suction cans, if supplied, are not required for performance testing.

• **5.3.8.2** When specified, a resonance test with the pump unpiped shall be conducted on the pump structure/driver frame assembly. This assembly shall be excited by an impact on the driver frame, and the natural frequency(ies) shall be determined by the response. This test shall be performed with an impact on the driver in the direction of the discharge flange and repeated at 90 degrees from the discharge flange. The separation margin during these tests shall be 10 percent below the minimum or above the maximum continuous operating speed.

### 5.3.9 SINGLE CASE DIFFUSER (VS1) AND VOLUTE (VS2) PUMPS

**5.3.9.1** Vertically suspended, single casing diffuser pumps with discharge through the column are designated Type VS1.

**5.3.9.2** Vertically suspended, single casing volute pumps with discharge through the column are designated Type VS2.

**5.3.9.3** The components which constitute the pressure casing are the casing (bowls), column, and discharge head.

**5.3.9.4** Line shaft may be open or enclosed. Open line shafting is lubricated by the pumped liquid. When pumped liquid is not suitable as a lubricant, enclosed line shafting may be provided to ensure a clean lubrication supply for line shaft bearings. The type of lubrication will be specified by the purchaser.

**5.3.9.5** The discharge head mounting surface shall be suitable for grouting or mounting on a machined sole plate.

**5.3.9.6** Thrust restraints are required at the pump if an expansion joint is installed on the discharge nozzle. Design review of the proposed installation and piping by the vendor is recommended.

• **5.3.9.7** When specified, line shafting shall be furnished with hardened sleeves under the bearing.

**5.3.9.8** Product lubricated column sections shall incorporate integral bearing spiders and rabbeted fits for column sizes of 300 mm (12 in.) inside diameter pipe or larger.

**5.3.9.9** Unless otherwise specified, bowls shall be flanged and shall have metal-to-metal rabbeted fits.

### 5.3.10 SINGLE CASING AXIAL FLOW (VS3) PUMPS

**5.3.10.1** Vertically suspended, single casing axial flow pumps with discharge through the column are designated Type VS3.

**5.3.10.2** The components which constitute the pressure casing are the casing (bowl), column and discharge head.

**5.3.10.3** Column sections shall incorporate integral bearing spiders and rabbeted fits for column sizes of 300 mm (12 in.) inside diameter pipe or larger.

**5.3.10.4** Bowls shall have metal-to-metal-rabbeted fits.

### 5.3.11 SINGLE CASING VOLUTE LINE SHAFT (VS4) AND VOLUTE CANTILEVER (VS5) PUMPS

**5.3.11.1** Vertically suspended, single casing volute line-shaft driven sump pumps are designated Type VS4.

**5.3.11.1.1** Steady bearings shall be provided to support the shaft and impeller.

**5.3.11.1.2** Thrust bearings shall be designed for either grease or oil mist lubrication. Steady bearings (or bushings) may be lubricated with water, grease, product, or be self-lubricating.

**5.3.11.2** Vertically suspended cantilever sump pumps are designated as Type VS5.

**5.3.11.2.1** The rotor shall be cantilevered from its bearing assembly. Submerged bottom bearings and/or bushings are not used to guide the shaft.

**5.3.11.2.2** The shaft stiffness shall limit total deflection, without the use of a casing bushing, such that the impeller does not contact the pump casing under the most severe dynamic conditions over the complete head capacity curve with a maximum diameter impeller and at the maximum speed and fluid density.

**5.3.11.2.3** Unless otherwise specified, pump bearings shall be grease lubricated. The stabilized bearing housing temperature shall not exceed 82°C (180°F) when operated at an ambient temperature of 43°C (110°F). Recommended greases shall be suitable for operation at these temperatures.

**5.3.11.3** For open system sump pump service, the pressure containing components Types VS4 and VS5 pumps are the volute casing, suction cover, and discharge line. For closed system pressurized or vacuum tank service, the outer stuffing box or seal housing, pump cover plate, and tank cover also become pressure containing components.

**5.3.11.4** For services above 120°C (250°F), the pump must be designed to accommodate differences in thermal expansion between the pipe column and discharge pipe and between the casing and support plate.

**5.3.11.5** Lifting lugs shall be provided in the cover plate for lifting the pump assembly, including the driver.

**5.3.11.6** The discharge nozzle shall be flanged. The discharge nozzle and cover plate shall be designed to withstand twice the forces and moments in Table 2.1.

Note: If the pump is mounted in a vessel, the nozzle of the vessel shall also be designed to withstand these loads. See 2.4 for allowable nozzle loads.

**5.3.11.7** For flammable or hazardous fluids, cover plate joints shall be vapor tight. The cover plate design and mounting shall be mutually agreed to by the purchaser and vendor.

**5.3.11.8** The shaft total indicated runout shall not exceed 50 µm (0.002 in.) as measured on the shaft directly above the mechanical seal or stuffing box.

● **5.3.11.9** When a mechanical seal is specified, it shall be located at the cover plate to seal the vapor in the supply tank or vessel. Mechanical seals normally seal vapor; however, they shall be designed to operate in liquid in the event of tank or vessel overfilling. With purchaser approval, the vendor may supply a seal pressurized by flush from the pump discharge or from an external source. External seal flush must be compatible with the liquid being pumped. The seal chamber shall have provisions for a high point vent.

**5.3.11.10** . Unless otherwise specified, pump out vanes shall be used to reduce leakage back into the sump. The reduction in axial thrust caused by the pump out vanes, however, shall not be considered in sizing axial thrust bearings.

**5.3.11.11** Spacer couplings are not typically required for VS4 and VS5 type pumps. Unless otherwise specified, coupling hubs shall be supplied with a slip fit to the shafts. Coupling hubs and keys shall be secured to the shaft with set screws. This facilitates final coupling adjustment for variations in spacing between shaft ends.

### 5.3.12 DOUBLE CASING DIFFUSER (VS6) AND VOLUTE (VS7) PUMPS

**5.3.12.1** Vertically suspended double casing pumps are designated Type VS6 for diffuser construction and VS7 for volute construction.

**5.3.12.2** The components which constitute the pressure casing of Type VS6 pumps are the discharge head and the suction can.

**5.3.12.3** The components which constitute the pressure casing of Type VS7 pumps are the outer casing (complete with the discharge nozzle), the head plate, and the suction pipe.

**5.3.12.4** Complete outer case venting shall be ensured by means of a high point vent connection.

**5.3.12.5** Provision shall be made to ensure complete venting of the inner assembly within the seal chamber or associated auxiliary process piping.

● **5.3.12.6** When specified, the suction can shall be supplied with a drain piped to the surface.

**5.3.12.7** Column sections shall incorporate integral bearing spiders and rabbetted fits for all column sizes.

# SECTION 6—VENDOR'S DATA

## 6.1 General

**6.1.1** The information to be furnished by the vendor is specified in 6.2 and 6.3. The vendor shall complete and forward the Vendor Drawing and Data Requirements form (see Appendix O) to the address or addresses noted on the inquiry or order. This form shall detail the schedule for transmission of drawings, curves, and data as agreed to at the time of the order, as well as the number and type of copies required by the purchaser.

**6.1.2** The data shall be identified on transmittal (cover) letters and in title blocks or title pages with the following information:

a. The purchaser/user's corporate name.
b. The job/project number.
c. The equipment item number and service name.
d. The inquiry or purchaser order number.
e. Any other identification specified in the inquiry or purchaser order.
f. The vendor's identifying proposal number, shop order number, serial number, or other reference required to identify return correspondence completely.

● **6.1.3** When specified, a coordination meeting shall be held, preferably at the vendor's plant, within 4 weeks after the purchase commitment. An agenda shall be prepared for this meeting and may include the following items:

a. The purchase order, scope of supply, unit responsibility, and subvendor items.
b. The data sheets.
c. Applicable specifications and previously agreed-upon exceptions.
d. Schedules for transmittal of data, production, and testing.
e. The quality assurance program and procedures.
f. Inspection, expediting, and testing.
g. Schematics and bills of material for auxiliary systems.
h. The physical orientation of the equipment, piping, and auxiliary systems.
i. Coupling selections.
j. Thrust-bearing sizing and estimated loadings.
k. The rotor dynamics analysis.
l. Vendor supplied maintenance data.
m. Other technical items.

## 6.2 Proposals

### 6.2.1 GENERAL

**6.2.1.1** The vendor shall forward the original proposal and the specified number of copies to the addressee specified in the inquiry documents. As a minimum, the proposal shall include the data specified in 6.2.2 through 6.2.4, as well as a specific statement that the system and all its components are in strict accordance with this standard. If the system and components are not in strict accordance, the vendor shall include a list that details and explains each deviation. The vendor shall provide details to enable the purchaser to evaluate any proposed alternative designs. All correspondence shall be clearly identified in accordance with 6.1.2

**6.2.1.2** Clearances less than those required by 2.6.4.2 (refer to 5.2.3.2) must be stated as exceptions to this standard in the proposal.

### 6.2.2 DRAWINGS

**6.2.2.1** The drawings indicated on the Vendor Drawing and Data Requirements form (see Appendix O) shall be included in the proposal. As a minimum, the following data shall be furnished:

a. A general arrangement or outline drawing for each major skid or system, showing direction of rotation, size, and location of major purchaser connections; overall dimensions; maintenance clearance dimensions; overall weights; erection weights; maximum maintenance weights (indicated for each piece); and if applicable the Standard Baseplate number (see Appendix M).
b. Cross-sectional drawings showing the details of the proposed equipment.
c. Schematics of all auxiliary systems, including the lube oil, control, and electrical systems. Bills of material shall be included.
d. Sketches that show methods of lifting the assembled machine or machines and major components. (This information may be included on the drawings specified in the preceding Item a.)

**6.2.2.2** If typical drawings, schematics, and bills of material are used, they shall be marked up to show the correct weight and dimension data and to reflect the actual equipment and scope proposed.

### 6.2.3 TECHNICAL DATA

The following data shall be included in the proposal:

a. The purchaser's data sheets, with complete vendor's information entered thereon and literature to fully describe details of the offering.
b. The purchaser's noise data sheet.
c. The Vendor Drawing and Data Requirements form (see Appendix O), indicating the schedule according to which the vendor agrees to transmit all the data specified as part of the contract.
d. A schedule for shipment of the equipment, in weeks after receipt of the order.

e. A list of major wearing components, showing interchangeability with the purchaser's other units.
f. A list of spare parts recommended for start-up and normal maintenance purposes (see Table 6-1). (The purchaser will specify any special requirements for long-term storage.)
g. A list of the special tools furnished for maintenance.
h. An outline of all necessary special weather and winterizing protection required by the pump, its auxiliaries, and the driver (if furnished by the vendor) for start-up, operation, and idleness. The vendor shall list separately the protective items he proposes to furnish. (The purchaser will specify any requirements for long-term storage.)
i. A complete tabulation of utility requirements, such as those for steam, water, electricity, air, gas, and lube oil, including the quantity of lube oil required and the supply pressure, the heat load to be removed by the oil, and the nameplate power rating and operating power requirements of auxiliary drivers. (Approximate data shall be defined and clearly identified as such.)
j. A description of the tests and inspection procedures for materials, as required by 2.11.1.3.
k. A description of any special requirements specified in the purchaser's inquiry and as outlined in 1.2, 2.7.3.5, 2.11.1.2, 2.11.1.3, 3.6.1, 5.2.1.1, 5.2.3.2, 5.3.3.2, and 5.3.8.1.
• l. When specified, a list of similar machines installed and operating under analogous conditions.
m. Any start-up, shutdown, or operating restrictions required to protect the integrity of the equipment.
n. The calculation of suction specific speed, which shall be made for the maximum impeller diameter, at the best efficiency point.
o. Any test facility limitations that may require the vendor to assemble and drive single-stage, double-suction pumps from the opposite end for testing (see 5.2.8.4).

### 6.2.4 CURVES

The vendor shall provide complete performance curves, including differential head, typical efficiency, water NPSHR, and power expressed as functions of capacity. The curves shall be extended to at least 120 percent of capacity at peak efficiency, and the rated operating point shall be indicated. The head curve for maximum and minimum impeller diameters shall be included. The eye area of the first-stage impeller and the impeller identification number shall be shown on the curves. If applicable, the curves shall indicate viscosity corrections. Minimum flow (both thermal and stable), preferred and allowable operating regions, and any limitations of operation shall be indicated.

### • 6.2.5 OPTIONS

When specified, the vendor shall furnish a list of the procedures for any special or optional tests that have been specified by the purchaser or proposed by the vendor.

## 6.3 Contract Data

### 6.3.1 GENERAL

**6.3.1.1** Vendor contract data shall be furnished and maintained as specified in Appendix O. Each drawing, bill of material, and data sheet shall have a title block in its lower right-hand corner that shows the date of certification, a reference to all identification data specified in 6.1.2, the revision number and date, and the title.

**6.3.1.2** The purchaser will promptly review the vendor's data when he receives them; however, this review shall not constitute permission to deviate from any requirements in the order unless specifically agreed upon in writing. After the data have been reviewed, the vendor shall furnish certified copies in the quantity specified.

**6.3.1.3** A complete list of vendor data shall be included with the first issue of the major drawings. This list shall contain titles, drawing numbers, and a schedule for transmission of all the data the vendor will furnish (see Appendix O).

### 6.3.2 DRAWINGS

The drawings furnished shall contain sufficient information so that with the drawings and the manuals specified in 6.3.6, the purchaser can properly install, operate, and maintain the ordered equipment. Drawings shall be legible, identified in accordance with 6.3.1.1, and in accordance with ISO 31 (symbols), ISO 128 (principles of presentation), ISO 129 (dimensioning principles), ISO 3098 (lettering) (ANSI/ASME Y14.2M) or other corresponding standards as agreed upon with the purchaser. Each drawing shall include the details for that drawing listed in Appendix O.

### 6.3.3 TECHNICAL DATA

**6.3.3.1** The data shall be submitted in accordance with Appendix O and identified in accordance with 6.3.1.1. Any comments on the drawings or revisions of specifications that necessitate a change in the data shall be noted by the vendor. These notations will result in the purchaser's issue of completed, corrected data sheets as part of the order specifications.

**6.3.3.2** Certified test curves and data (Appendix T) shall be submitted within 15 days after testing and shall include head, power recalculated to the proper specific gravity, and efficiency, plotted against capacity. If applicable, viscosity corrections shall be indicated. The water NPSHR curve shall be included, drawn from actual test data, for an impeller cast from the same pattern. The curve sheet shall include the maximum and minimum diameters of the impeller design supplied, the eye area of the first-stage impeller, the identification number of the impeller or impellers, and the pump serial number.

### Table 6-1—Recommended Spare Parts

| | | Spares Recommended | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Part | See Note | Start-up | | | Normal Maintenance | | | |
| Number of identical pumps | | 1–3 | 4–6 | 7+ | 1–3 | 4–6 | 79 | 10+ |
| Cartridge | (2) (5) | | | | 1 | 1 | 1 | 1 |
| Element | (2) (6) | | | | 1 | 1 | 1 | 1 |
| Rotor | (3) (7) | | | | 1 | 1 | 1 | 1 |
| Case | (1) | | | | | | | 1 |
| Head (case cover and stuffing box) | | | | | | | | 1 |
| Bearing bracket | (1) | | | | | | | 1 |
| Shaft (w/key) | | | | | 1 | 1 | 2 | N/3 |
| Impeller | | | | | 1 | 1 | 2 | N/3 |
| Wear rings (set) | (8) | 1 | 1 | 1 | 1 | 1 | 2 | N/3 |
| Bearings complete (antifriction, radial) | (1) (9) | 1 | 1 | 2 | 1 | 2 | N/3 | N/3 |
| Bearings complete (antifriction, thrust) | (1) (9) | 1 | 1 | 2 | 1 | 2 | N/3 | N/3 |
| Bearings complete (hydrodynamic, radial) | (1) (9) | 1 | 1 | 2 | 1 | 2 | N/3 | N/3 |
| Bearing pads only (hydrodynamic, radial) | (1) (9) | 1 | 1 | 2 | 1 | 2 | N/3 | N/3 |
| Bearing complete (hydrodynamic, thrust) | (1) (9) | 1 | 1 | 2 | 1 | 2 | N/3 | N/3 |
| Bearing pads only (hydrodynamic, thrust) | (1) (9) | 1 | 1 | 2 | 1 | 2 | N/3 | N/3 |
| Mechanical seal / packing | (4) (8) (9) | 1 | 2 | N/3 | 1 | 2 | N/3 | N/3 |
| Shaft sleeve | (8) | 1 | 2 | N/3 | 1 | 2 | N/3 | N/3 |
| Gaskets, shims, O-rings (set) | (8) | 1 | 2 | N/3 | 1 | 2 | N/3 | N/3 |
| Add for vertical pump | | | | | | | | |
| Bowls | | | | | | | N/3 | |
| Spiders (set) | | | | 1 | 1 | 1 | N/3 | N/3 |
| Bearings, bushings (set) | | 1 | 1 | 2 | 1 | 1 | N/3 | N/3 |
| Add for high speed integral gear | | | | | | | | |
| Gear box | | | 1 | 1 | 1 | 1 | 1 | N/3 |
| Diffuser and cover | | 1 | 1 | 1 | 1 | 1 | 1 | N/3 |
| Splined shaft | | 1 | 1 | 1 | 1 | 1 | 1 | N/3 |
| Gear box housing | | | | | 1 | 1 | 1 | N/3 |
| Oil pump, internal | | | 1 | 1 | 1 | 1 | 1 | N/3 |
| Oil pump, external | | | 1 | 1 | 1 | 1 | 1 | N/3 |
| Oil filter | | 1 | 2 | N/3 | 1 | 2 | 3 | N/3 |

Notes:
N = Number of identical pumps.
(1) Horizontal pumps only.
(2) Vital service pumps are generally unspared, partially spared or multistage. When a vital machine is down, production loss or violation of environmental permits results.
(3) Essential service pumps are required for operation and have an installed spare. A production loss will occur only if main and spare fail simultaneously.
(4) Cartridge type mechanical seals shall include sleeve and gland.
(5) Cartridge consists of assembled element plus discharge head, seal(s) and bearing housing(s).
(6) Element consist of assembled rotor plus stationary hydraulic parts (diffuser(s) or volute(s)).
(7) Rotor consists of all rotating parts attached to the shaft.
(8) Normal wear parts (see 2.1.1).
(9) Per pump set.

### 6.3.4 PROGRESS REPORTS

Unless otherwise specified, the vendor shall submit progress reports to the purchaser at the intervals specified on the Vendor Drawing and Data Requirements form (see Appendix O).

### 6.3.5 PARTS LISTS AND RECOMMENDED SPARES

**6.3.5.1** The vendor shall submit complete parts lists for all equipment and accessories supplied. The lists shall include manufacturer's unique part numbers, materials of construction, and delivery times. Materials shall be identified as specified in 2.11.1.2. Each part shall be completely identified and shown on cross-sectional or assembly-type drawings so that the purchaser may determine the interchangeability of these parts with other equipment. Parts that have been modified from standard dimensions and/or finish to satisfy specific performance requirements shall be uniquely identified by part number for interchangeability and future duplication purposes. Standard purchased items shall be identified by the original manufacturer's name and part number.

**6.3.5.2** The vendor shall indicate on the preceding parts lists which parts are recommended spares for start-up and normal maintenance as referenced in 6.2.3, Item f (Table 6-1). The vendor shall forward the lists to the purchaser promptly after receipt of the reviewed drawings and in time to permit order and delivery of the parts before field start-up. The transmittal letter shall be identified with the data specified in 6.1.2.

### 6.3.6 INSTALLATION, OPERATION, MAINTENANCE, AND TECHNICAL DATA MANUALS

#### 6.3.6.1 General

The vendor shall provide sufficient written instructions and a cross-referenced list of all drawings to enable the purchaser to correctly install, operate, and maintain all of the equipment ordered. This information shall be compiled in a manual or manuals with a cover sheet that contains all reference identifying data specified in 6.1.2, an index sheet that contains section titles, and a complete list of referenced and enclosed drawings by title and drawing number. The manual shall be prepared for the specified installation; a typical manual is not acceptable.

#### 6.3.6.2 Installation Manual

Any special information required for proper installation design that is not on the drawings shall be compiled in a manual that is separate from the operating and maintenance instructions. This manual shall be forwarded at a time that is mutually agreed upon in the order, but not later than the final issue of prints. The manual shall contain information such as special alignment and grouting procedures, utility specifications (including quantities), and all other installation design data, including the drawings and data specified in 6.2.2 and 6.2.3. The manual shall also include sketches that show the location of the center of gravity and rigging provisions to permit the removal of the top half of the casings, rotors, and any subassemblies that weigh more than 135 kg (300 lbs).

#### 6.3.6.3 Operating, Maintenance, and Technical Data Manual

The manual containing operating maintenance and technical data shall be sent at the time of shipment. This manual shall include a section that provides special instructions for operation at specified extreme environmental conditions, such as temperatures. As a minimum, the manual shall also include all of the data listed in Appendix O.

# APPENDIX A— REFERENCED PUBLICATIONS AND INTERNATIONAL STANDARDS

## A.1 Referenced Publications

The following publications are cited in this standard:

ABMA[1]

Standard 7 *Shaft and Housing Fits for Metric Radial Ball and Roller Bearings*

Standard 9 *Load Ratings and Fatigue Life for Ball Bearings*

Standard 20 *Metric Ball and Roller Bearings (Except Tapered Roller Bearings) Conforming to Basic Boundary Plans: Boundary Dimensions, Tolerances, and Identification*

AGMA[2]

9000 *Flexible Couplings—Potential Unbalance Classification*

9001 *Lubrication of Flexible Couplings*

9002 *Bores and Keyways for Flexible Couplings (Inch Series)*

9003 *Flexible Couplings—Keyless Fits*

API

Spec. 5L *Specification for Line Pipe*

RP 500 *Classification of Locations for Electrical Installations at Petroleum Facilities*

Standard 541 *Form-Wound Squirrel-Cage Induction Motors—250 Horsepower and Larger*

Standard 611 *General Purpose Steam Turbines for Refinery Service*

Standard 614 *Lubrication, Shaft-Sealing, and Control-Oil Systems for Special-Purpose Applications*

Standard 670 *Vibration, Axial-Position, and Bearing-Temperature Monitoring Systems*

Standard 671 *Special-Purpose Couplings for Refinery Service*

Standard 677 *General-Purpose Gear Units for Refinery Service*

Standard 682 *Shaft Sealing Systems for Centrifugal and Rotary Pumps*

ASME[3]

B1.20.1 *Pipe Threads, General Purpose (Inch)*

B16.1 *Cast Iron Pipe Flanges and Flanged Fittings*

B16.5 *Pipe Flanges and Flanged Fittings (steel)*

B16.11 *Forged Steel Fittings, Socket-Welding and Threaded*

B31.1 *Power Piping*

B31.3 *Chemical Plant and Petroleum Refinery Piping*

B46.1 *Surface Texture (Surface Roughness, Waviness and Lay)*

*Boiler and Pressure Vessel Code, Section II, "Materials"; Section V, "Nondestructive Examination"; Section VIII, "Pressure Vessels"; and Section IX, "Welding and Brazing Qualifications"*

ASTM[4]

C 531 *Test Method for Linear Shrinkage and Coefficient of Thermal Expansion of Chemical-Resistant Mortars, Grouts, and Monolithic Surfacings*

C 579 *Test Methods for Compressive Strength of Chemical-Resistant Mortars and Monolithic Surfacings*

C 882 *Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete*

C 884 *Test Method for Thermal Compatability Between Concrete and an Epoxy-Resin Overlay*

C 1181 *Test Method for Compressive Creep of Chemical-Resistant Polymer Machinery Groups*

D 638 *Test Method for Tensile Properties of Plastics*

D 2471 *Test Method for Gel Time and Peal Exothermic Temperature of Reacting Thermosetting Resins*

E 94 *Guide for Radiographic Testing*

E 125 *Reference Photographs for Magnetic Particle Indications on Ferrous Castings*

E 142 *Method for Controlling Quality of Radiographic Testing*

E 709 *Practice for Magnetic Particle Examination*

AWS[5]

D1.1 *Structural Welding Code—Steel*

[1]American Bearing Manufacturers Association, 1200 19th Street, N.W., Suite 300, Washington, D.C.20036.

[2]American Gear Manufacturers Association, 1500 King Street, Suite 201, Alexandria, Virginia 22314.

[3]American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017.

[4]American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103-1187.

[5]American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135.

DIN[6]

910 Heavy-Duty Hexagon Head Screw Plugs

HI[7]

The codes, standards, and specifications of the Hydraulic Institute (Centrifugal Pump Section) also form part of this standard.

IEEE[8]

841 *Standard for Petroleum and Chemical Industry Severe Duty TEFC Squirrel Cage Induction Motors—Up To and Including 500 HP*

ISO[9]

31-0 *General Principles Concerning Quantities, Units, and Symbols*

128 *Technical Drawings—General Principles of Presentation*

129 *Technical Drawings—Dimensioning—General Principles, Definitions, Methods of Execution, and Special Indications*

228-1 *Pipe Threads Where Pressure-Tight Joints are Not Made on the Threads—Part 1: "Designation, Dimensions and Tolerances"*

262 *ISO General Purpose Metric Screw Threads—Selected Sizes for Screws, Bolts, and Nuts*

281-1 *Rolling Bearings—Dynamic Load Ratings and Rating Life—Part 1: "Calculation Methods"*

286 *ISO System of Limits and Fits—Part 1: "Bases of Tolerances, Deviations and Fits"; and Part 2—"Tables of Standard Tolerance Grades and Limit Deviations for Holes and Shafts"*

R 773 *Rectangular or Square Parallel Keys and Their Corresponding Keyways*

R 775 *Cylindrical and 1/10 Conical Shaft Ends*

1503 *Geometrical Orientation and Directions of Movements*

1940 *Mechanical Vibration—Balance Quality Requirements of Rigid Rotors—Part 1: "Determination of Permissible Residual Unbalance"*

3098 *Technical Drawings*

3448 *Industrial Liquid Lubricants—ISO Viscosity Classification*

3740 *Acoustics—Determination of Sound Power Levels of Noise Sources—Precision Methods for Broad-Band Sources in Reverberation Rooms*

3744 *Acoustics—Determination of Sound Power Levels of Noise Sources—Engineering Methods for Free-Field Conditions Over a Reflecting Plane*

3746 *Acoustics—Determination of Sound Power Levels of Noise Sources—Survey Method*

5406 *The Mechanical Balancing of Flexible Rotors*

5753 *Rolling Bearings—Radial Internal Clearance*

7005-1 *Metallic Flanges—Part 1: "Steel Flanges"*

7005-2 *Metallic Flanges—Part 2: "Cast Iron Flanges"*

10436 *Petroleum and Natural Gas Industries—General-Purpose Steam Turbines for Refinery Service*

10438 *Lubrication, Shaft-Sealing and Control— Oil Systems For Special-Purpose Applications*

MSS[10]

MSS-SP-55 *Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components—Visual Method*

NACE[11]

MR 0175 *Standard Material Requirements: Sulfide Stress Cracking Resistant Metallic Materials for Oilfield Equipment Corrosion Engineers Reference Handbook*

NFPA[12]

NFPA 70 *National Electrical Code*

SSPC[13]

SP 6 *Surface Preparation Specification*

[6]DIN Deutsches Institut fur Normung, Burggrafenstrasse 6, Postfach 1107, D-1000 Berlin 30, Germany.
[7]Hydraulic Institute, 712 Lakewood Center North, Cleveland, Ohio 44107.
[8]Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York, New York 10017.
[9]International Organization for Standardization publications are available from the American National Standards Institute, 11 West 42nd Street, New York, New York 10036.
[10]Manufacturers Standardization Society, 127 Park Street, N.E., Vienna, Virginia 22180.
[11]National Association of Corrosion Engineers, P.O. Box 218340, Houston, Texas 77218.
[12]National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02269.
[13]Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburgh, Pennsylvania 15213-2683.

U.S. Army Corps of Engineers[14]

CRD C611 *Test Methods for Flow Grout Mixtures (Flowcone Method)*

CRD C621 *Corps of Engineers Specifications for Non-Shrink Grout*

[14]U.S. Army Corps of Engineers, 20 Massachusetts Avenue, N.W., Washington, D.C. 20314

## A.2 Corresponding International Standards

Table A-1 contains international standards corresponding to those listed in A-1. Table A-2 shows U.S. and corresponding international standards for piping components.

## Table A-1—Corresponding International Standards (See Note)

| USA Standard | Subject | Country of Origin and Standard: International ISO | Germany DIN | Great Britain BSI | France AFNOR | Japan JIS |
|---|---|---|---|---|---|---|
| ANSI/ABMA Std 7 | Shaft and housing fits for metric bearings | 286-1<br>286-2 | 5425 | 5646 Part 1<br>5646 Part 2 | NFE 22396 | B0401<br>B1566 |
| ANSI/ABMA Std 9 | Load ratings and fatigue life for ball bearings. | 281<br>76 | 622 | 5512 Part 1 | NF ISO 281 | B1518<br>B1519 |
| ANSI/ABMA Std 20 | Metric bearings: boundary dimensions | 15<br>492<br>5753 | | 6107 Part 3 | NF ISO 5753 | B1512<br>B1513<br>B1514<br>B1520 |
| ANSI/AGMA 9000 | Balance classification flexible couplings | 1940/1<br>8821<br>5406 | VDI 2060<br>740<br>PART A | 6861 Part 1 | NFE 90600 | B0905<br>B0906 |
| ANSI/AGMA 9002 | Bores and keyways flexible couplings | R 773<br>R 774<br>R 775<br>286-1<br>286-2 | 740<br>6885<br>7190 | 3170<br>4235 | NFE<br>02-E22175<br><br>NF ISO 286-1<br>NF ISO 286-2 | B0903<br>B0904<br>B1301<br>B1303 |
| ANSI/ASME B 1.1 | Screw threads | 262<br>(Metric) | | 3643<br>(Metric) | NFE 03-014 | B0205<br>B0207<br>B0209<br>B0211 |
| ANSI/ASME B4.1 | Limits and fits for cylindrical parts | 286 | | | | |
| ANSI/ASME B1.20.1 | General purpose pipe threads | 228 PT.1<br>(Seal on gasket) | | 2779 (Seal on gasket)<br>21 (Seal on thread) | NFE 03.005 | B0202<br>B0203 |
| ANSI/ASME B 16.1 | Cast iron pipe flanges | 7005/2 | 2532<br>2533<br>2534<br>2535 | 4504 | NFE<br>29206 | |
| ANSI/ASME B 16.5 | Steel and alloy pipe flanges | 7005/1 | 2543<br>2544<br>2545<br>2546<br>2547<br>2548<br>2549<br>2550<br>2551 | 4504 | NFE<br>29203/204 | JPI-7S-15-1984 |
| ANSI/ASME B 16.11 | Forged fittings | | 910 | 3799 | NFE 29600 | |

Table A-1—Corresponding International Standards—Continued

| USA Standard | Subject | Country of Origin and Standard: International ISO | Germany DIN | Great Britain BSI | France AFNOR | Japan JIS |
|---|---|---|---|---|---|---|
| ANSI/ASME B 31.3 | Chemical plant and petroleum refinery piping | | | 1600 | | B8270 |
| ANSI/ASME Y 14.2M | Line conventions and lettering | 31<br>128<br>129<br>3098 | | 308 Parts 2 & 3 | NFE 04202/203 | |
| ANSI/AWSE D 1.1 | Structural welding code—steel | | | 4870/1/2 | NFP 22471 | Code of Japan Welding Eng. Society |
| API Std 541 | Motors, squirrel cage induction | IEEE 841 | | | | |
| API Std 611 | General purpose steam turbines | 10436 | 4312 | 132 | | |
| API Std 612 | Special purpose steam turbines | | | | | |
| API Std 614 | Lubrication systems | 10438 | 24425 | 4807 | | |
| | Sound control | 3744<br>3746<br>3740 | 45635P.1<br>45635P.2<br>45635P.8<br>45635P.24<br>45635P.40<br>45645 | 4196 Part 4<br>4196 Part 6<br>4196 Part 0 | NFS 31027<br>NFS 31067<br>(For Sect. 2) | |
| API Std 670 | Vibration position and bearing temperature monitoring | 2372<br>3945 | VDI 2056<br>VDI 2059 | 4675 | NFE 90300<br>NFE 90301 | |
| API Std 671 | Special purpose couplings | | | | | |
| API Std 677 | General purpose gear units | | | | | |
| API Std 682 | Shaft sealing systems for centrifugal and rotary pumps | | | | | |
| API RP 500 | Classification of electrical areas in petroleum refineries | IEC 79 | | 5345 Part 2 | NF-S | RIIS-TR-79-1<br>RIIS-TR-85-1 |
| API Spec 5L | Specification for line pipe | 6708<br>7268 | | | NFE 29.001 | |
| ASME Boiler and Pressure Vessel Code: —Section II | Pressure casing: design and construction:<br><br>Materials | | AD-MERK-BLÄTTER | | | |
| —Section V | Non destructive examination | | SEC. HP 5/3 | 4080 Parts I & II | | G0801<br>Z2343<br>Z2344<br>Z3060 |

Table A-1—Corresponding International Standards—Continued

| USA Standard | Subject | International ISO | Germany DIN | Great Britain BSI | France AFNOR | Japan JIS |
|---|---|---|---|---|---|---|
| | | Country of Origin and Standard | | | | |
| —Section VIII Div. 1 | Rules for construction of pressure vessels | R 831<br>TR 7468 | | 5500 | CODAP | B8270<br>G0565<br>Z2202 |
| —Section IX | Welding and brazing | | SEC. HP 2<br>SEW 110 8560/63 | 4870/1/2 | | Z2242<br>Z3040<br>Z3801<br>Z3881<br>Z3891 |
| ASTM A53 | Zinc coated welded and seamless black and hot dipped steel pipe | | | | | G3452/G3454 |
| ASTM A105 | Carbon steel forgings for piping components | | 1629<br>17155 | 1503 | NFA 49.281 | G3201<br>G3202<br>G4051 |
| ASTM A106 | Seamless carbon steel pipe for high-temperature service | | 17175 | 3602 | NFA 49.211 | G3456 |
| ASTM A120 | Black and hot dipped zinc coated (galvanized) welded and seamless steel pipe for ordinary uses | | | | | G3442 |
| ASTM A153 | Zinc coating (hot dip) on iron and steel hardware | | | 1706 | | B3201 |
| ASTM A181 | Carbon steel forgings for general purpose piping | | 10083 | 1503 | NFA 36.612 | G3202 |
| ASTM A182 | Forged or rolled alloy steel pipe flanges, forged fittings, and valves and parts for high-temperature service | | 17440<br>17175 | 1503 | NFA 36.607 | G3203<br>G3214 |
| ASTM A193 | Alloy steel and stainless steel bolting materials for high-temperature service | | 17240/17440<br>17200/17245<br>17440 | 4882<br>1506 | NFA 35558 | G4107<br>G4303 |
| ASTM A194 | Carbon and alloy steel nuts for bolts for high-pressure and high-temperature service | | 17440 | 4882<br>1506 | | G4051<br>G4303 |
| ASTM A197 | Cupola malleable iron | | | | | G5702 |
| ASTM A216 | Carbon steel castings suitable for fusion welding for high-temperature service | | 17245 | 1504 | NFA 32055/32060 | G5151 |
| ASTM A217 | Martensitic stainless and alloy steel castings for pressure containing parts suitable for high-temperature service | | 17445 | 1504 | NFA 32055 | G5121 |

Table A-1—Corresponding International Standards—Continued

| USA Standard | Subject | Country of Origin and Standard: International ISO | Germany DIN | Great Britain BSI | France AFNOR | Japan JIS |
|---|---|---|---|---|---|---|
| ASTM A269 | Seamless and welded austenitic stainless steel tubing for general service | | 17440 | 3605 | NFA 49117 | G3463 |
| ASTM A276 | Stainless and heat resisting steel bars and shapes | | 17440 | 970 | NFA 35544 | G4303<br>G4317 |
| ASTM A278 | Gray iron castings for pressure containing parts | 185 | 1691<br>AD W 3/1<br>TRD 108 | 1452 | | G5501 |
| ASTM A312 | Seamless and welded austenitic stainless steel pipe | | 17440 | 3605 | NFA 49214/49219 | G3459 |
| ASTM A338 | Malleable iron flanges, pipe fittings, and valve parts for railroad, marine, and other heavy duty service at temperatures up to 650°F (345°C) | | | | | G5702 |
| ASTM A351 | Austenitic steel castings for high-temperature service | | 17445<br>17465<br>SEW 410 | 1504 | NFA 32055 | G5121 |
| ASTM A434 | Quenched and tempered alloy, hot wrought or cold finished steel bars | | EN 10083 | EN10083-1 | NFEN<br>10083-1 | G4104<br>G4105 |
| ASTM A436 | Austenitic gray iron castings | | 1694 | 3468 | NFA 32301 | G5510 |
| ASTM A439 | Austenitic ductile iron castings | | 1694 | 3468 | NFA 32301 | G5510 |
| ASTM A487 | Steel castings suitable for pressure service | | 17245 | 1504 | NFA 32055 | G5121<br>G5151 |
| ASTM A494 | Nickel and nickel alloy castings | | | | | |
| ASTM A516 | Carbon steel plates for moderate and lower temperature pressure vessel service | | | 10028 | | G3106 |
| ASTM A524 | Seamless carbon steel pipe for atmospheric and lower temperatures | | | | | G3460 |
| ASTM A564 | Hot rolled and cold finished age hardening stainless and heat resisting steel bars, wire and shapes | | | | | G4303<br>G4309 |
| ASTM A576 | Special quality hot wrought carbon steel bars | | | 970 PT 3 | NFA 35552 | G4051 |
| ASTM A743 | Iron chromium, iron chromium nickel, corrosion resistant castings for general application | | SEW 410 | | | G5121 |

Table A-1—Corresponding International Standards—Continued

| USA Standard | Subject | Country of Origin and Standard: International ISO | Germany DIN | Great Britain BSI | France AFNOR | Japan JIS |
|---|---|---|---|---|---|---|
| ASTM A744 | Iron chromium nickel and nickel base corrosion resistant castings for severe service | | 17445 | 1504 | | |
| ASTM A747 | Precipitation hardening stainless steel castings | | SEW 410 | | | G5121 |
| ASTM B23 | White metal bearing alloys (known commercially as babbitt metal) | | | 3332 | | H5401 |
| ASTM B148 | Aluminum-bronze castings | | 1714 | 1400-AB2-C | NFA 53709 | H5114 |
| ASTM B164 | Nickel-copper alloy rod, bar and wire | | | 3076-NA13 | | |
| ASTM B473 | Chromium-nickel-iron-molybdenum-copper-columbium stabilized alloy (UNS N08020) bar and wire | | 17751 | | | |
| ASTM B584 | Copper alloy sand castings for general applications | | 17655 | 1400 | NFA 53707-53709 | H510<br>H5102<br>H5111<br>H5112<br>H5115 |
| ASTM D 1418 | Practice for rubber and rubber lattices | | | 6057 | NFT 40002 | |
| ASTM D2422-68 | Standard industrial liquid lubricants—ISO viscosity class | 3448 | | 4231 | NFT 60.141 | |
| ASTM E 94 | Guides for radiographic testing | | 5411/T. 1 & 2 | 2737 (For Castings) | UFA 04160 (For Castings) | G0581<br>Z3104<br>Z3106 |
| ASTM E 125 | Ref. Photographs for magnetic indications | | 1650 | 4080 (For Acceptance Criteria) | | G0565 |
| ASTM E 142 | Controlling quality of radiographic testing | | 54109 | 3971 | | G0581<br>Z3104<br>Z3106 |
| ASTM E 709 | Practice for magnetic particle examination | | 54130 | 6072 | NFA 04193/A09590 | G0565 |
| MSSG-SP-55 | Quality standard for steel castings for valves, flanges, and fittings and other piping components (visual method) | | | | | |

## Table A-1—Corresponding International Standards—Continued

| | | Country of Origin and Standard | | | | |
|---|---|---|---|---|---|---|
| USA Standard | Subject | International ISO | Germany DIN | Great Britain BSI | France AFNOR | Japan JIS |
| NACE MR 0175 | Sulfide stress corrosion cracking resistant metallic materials for oil field equipment | | | | | |
| NEMA SM 23 | Steam turbines for mechanical drive service | | | | | |
| NFPA 70 | National electric code | IEC 79 | | | NFC 02-205U | JEAC8001 |
| SSPC SP 6 | Commercial blast cleaning | | | 7079 | | |

Note: Corresponding international standards may be acceptable as alternatives with the purchaser's approval (see 1.5).

Table A-2—Piping Components—Corresponding International Standards (See Note)

| | Standard Origin | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Component | USA ASTM | UNS | International ISO | Germany DIN 17007 | Germany DIN 17006 | Great Britain BSI | France AFNOR | Japan JIS |
| Bolting ; flange | A193 Grade B7<br>A194 Grade 2H | G41300<br>G10350 | 2604-2-F31<br>683-1-C35e | 1.7258 | 24Cr Mo5 | 1506-661 | 42Cr Mo4<br>2C 35 | G4107 Cl SNB7<br>G4051 Cl S45C |
| Fittings, valves & flanged components; carbon steel | A105<br>or<br>A181 | | | 1.0254 | St 37.0 | 1503 | A48 CP | G4051 Cl S25C |
| Fittings and unions; malleable iron, galvanized | A338 and A197 Class 150 malleable iron galvanized to A153 | | | | | 1706 | | |
| Fittings and unions; stainless steel | A182<br>Type 316L Stainless | S31603 | 683-13-19 | 1.4404 | | 1503<br>316.S.11 | Z6 CN18-09<br>or<br>Z6 WD18-12-03 | G3214<br>GR SUS 316L |
| Gaskets | Type 316 Stainless steel spiral wound | S31600 | | 1.4436 | X.2 Cr Ni 19.11 | 1449 Part 2<br>316.S.11 | Z3 CN18-10<br>or<br>Z3 CND17-12-02 | SUS 316 |
| Pipe; carbon steel | A106<br>Grade B, or<br>A524, or<br>API<br>Specification 5L,<br>Grade A or B | | 2604 | 1.0254 | St 37.0 | 3602 | TU 42C | G5456 Gr<br>STPT<br>370 / 4110 |
| Pipe; carbon steel, galvanized | A53 Type F<br>Sch 40<br>galvanized to<br>A153 | | | | | 1706 | TU26 CH18-12 | |
| Pipe; stainless steel | A312<br>Type 316L<br>stainless | S31603 | 683-13-19 | 1.4404 | X3CrNiMo<br>17 13 2 | 3605 Part 1<br>316.S.11 | TU 26 CN18-12<br>or<br>TU 26 CN17-12 | G3459<br>Gr SUS<br>316LTP |
| Tube; stainless steel | A269 Seamless<br>Type 316 stainless<br>steel | S31600 | 2604 Gr TS61 | 1.4436 | | 3605 Part 1<br>316.S.33 | TU26 CN18-12<br>or<br>TU26 CN17-12 | G3459<br>GR SUS 316J1 |

Note: Corresponding international standards may be acceptable as alternatives with the purchaser's approval.

# APPENDIX B—PUMP DATA SHEETS

# API 610, 8TH EDITION
# CENTRIFUGAL PUMP DATA SHEET
# SI UNITS / ISO STANDARDS (1.2.2)

JOB NO. ______ ITEM NO. ______
REQ / SPEC NO. ______ / ______
PURCH ORDER NO. ______ DATE ______
INQUIRY NO. ______ BY ______
REVISION ______ DATE ______

APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ☐ AS BUILT
FOR ______ UNIT ______
SITE ______ SERVICE ______
NO. REQ ______ PUMP SIZE ______ TYPE ______ NO. STAGES ______
MANUFACTURER ______ MODEL ______ SERIAL NO. ______
NOTE: ○ INDICATES INFORMATION COMPLETED BY PURCHASER ☐ BY MANUFACTURER ☐ BY MANUFACTURER OR PURCHASER

## ○ GENERAL (3.1.1)

PUMPS TO OPERATE IN (PARALLEL) ______ NO. MOTOR DRIVEN ______ NO. TURBINE DRIVEN ______
(SERIES) WITH ______ PUMP ITEM NO. ______ PUMP ITEM NO. ______
GEAR ITEM NO. ______ MOTOR ITEM NO. ______ TURBINE ITEM NO. ______
GEAR PROVIDED BY ______ MOTOR PROVIDED BY ______ TURBINE PROVIDED BY ______
GEAR MOUNTED BY ______ MOTOR MOUNTED BY ______ TURBINE MOUNTED BY ______
GEAR DATA SHEET NO. ______ MOTOR DATA SHEET NO. ______ TURBINE DATA SHEET NO. ______

## OPERATING CONDITIONS

○ CAPACITY, NORMAL ______ ($m^3/h$) RATED ______ ($m^3/h$)
OTHER ______
○ SUCTION PRESSURE MAX/RATED ______ / ______ (kPa)
○ DISCHARGE PRESSURE ______ (kPa)
○ DIFFERENTIAL PRESSURE ______ (kPa)
○ DIFFERENTIAL HEAD ______ (m) NPSHA ______ (m)
○ PROCESS VARIATIONS ______ (3.1.2)
○ STARTING CONDITIONS ______ (3.1.3)
SERVICE: ○ CONTINUOUS ○ INTERMITTENT(START/DAY) ______
○ PARALLEL OPERATION REQ'D (2.1.11)

## SITE AND UTILITY DATA

LOCATION: (2.1.29)
○ INDOOR ○ HEATED ○ UNDER ROOF
○ OUTDOOR ○ UNHEATED ○ PARTIAL SIDES
○ GRADE ○ MEZZANINE ○ ______
○ ELECTRICAL AREA CLASSIFICATION (2.1.22 / 3.1.5)
CL ______ GR ______ DIV ______
○ WINTERIZATION REQ'D ○ TROPICALIZATION REQ'D
SITE DATA (2.1.29)
○ ALTITUDE ______ (m) BAROMETER ______ (kPa abs)
○ RANGE OF AMBIENT TEMPS: MIN/MAX ______ / ______ (° C)
○ RELATIVE HUMIDITY: MIN/MAX ______ / ______ (%)
UNUSUAL CONDITIONS (2.1.23) ○ DUST ○ FUMES
○ OTHER ______
○ UTILITY CONDITIONS:

| STEAM: | DRIVERS | | HEATING | |
|---|---|---|---|---|
| MIN | ______ (kPa) | ______ (° C) | ______ (kPa) | ______ (° C) |
| MAX | ______ (kPa) | ______ (° C) | ______ (kPa) | ______ (° C) |

| ELECTRICITY: | DRIVERS | HEATING | CONTROL | SHUTDOWN |
|---|---|---|---|---|
| VOLTAGE | | | | |
| HERTZ | | | | |
| PHASE | | | | |

COOLING WATER: (2.1.17)
TEMP INLET ______ (° C) MAX RETURN ______ (° C)
PRESS NORMAL ______ (kPa) DESIGN ______ (kPa)
MIN RETURN ______ (kPa) MAX ALLOW DP ______ (kPa)

## SITE AND UTILITY DATA (CONT.)

WATER SOURCE ______
CHLORIDE CONCENTRATION (PPM) ______ (3.5.2.6)
INSTRUMENT AIR: MAX/MIN PRESS ______ / ______ (kPa)

## LIQUID

○ TYPE/NAME OF LIQUID ______
○ PUMPING TEMPERATURE:
NORMAL ______ (° C) MAX ______ (° C) MIN ______ (° C)
○ VAPOR PRESSURE ______ (kPa abs) @ ______ (° C)
○ RELATIVE DENSITY (SPECIFIC GRAVITY):
NORMAL ______ MAX ______ MIN ______
○ SPECIFIC HEAT, Cp ______ (kJ/kg ° C)
○ VISCOSITY ______ (cP) @ ______ (° C)
○ MAX VISCOSITY ______ (cP)
○ CORROSIVE/EROSIVE AGENT ______ (2.11.1.8)
○ CHLORIDE CONCENTRATION (PPM) ______ (3.5.2.6)
○ $H_2S$ CONCENTRATION (PPM) ______ (2.11.1.11)
LIQUID (2.1.3) ○ HAZARDOUS ○ FLAMMABLE
○ OTHER ______

## PERFORMANCE

PROPOSAL CURVE NO. ______ ☐ RPM ______
☐ IMPELLER DIA RATED ______ MAX ______ MIN ______ (mm)
☐ RATED POWER ______ (BHP) EFFICIENCY ______ (%)
☐ MINIMUM CONTINUOUS FLOW:
THERMAL ______ ($m^3/h$) STABLE ______ ($m^3/h$)
☐ PREFERRED OPERATING REGION ______ TO ______ ($m^3/h$)
☐ ALLOWABLE OPERATING REGION ______ TO ______ ($m^3/h$)
☐ MAX HEAD @ RATED IMPELLER ______ (m)
☐ MAX POWER @ RATED IMPELLER ______ (kW)
☐ NPSH REQUIRED AT RATED CAP ______ (m) (2.1.8)
☐ SUCTION SPECIFIC SPEED ______ (2.1.9)
○ MAX SOUND PRESS. LEVEL REQ'D ______ (dBA)(2.1.14)
☐ EST MAX SOUND PRESS. LEVEL ______ (dBA)(2.1.14)
REMARKS ______

# API 610, 8TH EDITION
# CENTRIFUGAL PUMP DATA SHEET
# SI UNITS / ISO STANDARDS (1.2.2)

JOB NO. ____ ITEM NO. ____
REQ / SPEC NO. ____ / ____
PURCH ORDER NO. ____ DATE ____
INQUIRY NO. ____ BY ____
REVISION ____ DATE ____

## CONSTRUCTION

**APPLICABLE STANDARD:**

○ API 610 8TH EDITION
○ OTHER ____ (SEE REMARKS)

**PUMP TYPE: (1.1.2)**

| | | | |
|---|---|---|---|
| ☐ OH2 | ☐ BB1 | ☐ VS1 | ☐ VS6 |
| ☐ OH3 | ☐ BB2 | ☐ VS2 | ☐ VS7 |
| ☐ OH6 | ☐ BB3 | ☐ VS3 | ☐ OTHER |
| | ☐ BB4 | ☐ VS4 | |
| | ☐ BB5 | ☐ VS5 | |

☐ **NOZZLE CONNECTIONS: (2.3.2)**

| | SIZE | RATING | FACING | POSITION |
|---|---|---|---|---|
| SUCTION | | | | |
| DISCHARGE | | | | |
| BALANCE DRUM | | | | |

**PRESSURE CASING CONNECTIONS: (2.3.3)**

| | NO. | SIZE (NPS) | TYPE |
|---|---|---|---|
| ☐ DRAIN | | | |
| ☐ VENT | | | |
| ☐ PRESSURE GAUGE | | | |
| ☐ TEMP GAUGE | | | |
| ☐ WARM-UP | | | |
| ☐ BALANCE / LEAK-OFF | | | |

○ CYLINDRICAL THREADS REQUIRED (2.3.3)

**CASING MOUNTING: (SEE SEPARATE SHEET FOR VERTICALS)**

☐ CENTERLINE ☐ NEAR CENTERLINE
☐ FOOT ☐ SEPARATE MOUNTING PLATE
☐ IN-LINE

**CASING SPLIT:**

☐ AXIAL ☐ RADIAL

**CASING TYPE:**

☐ SINGLE VOLUTE ☐ MULTIPLE VOLUTE ☐ DIFFUSER
☐ OVERHUNG ☐ BETWEEN BEARINGS ☐ BARREL

**CASE PRESSURE RATING:**

☐ MAX ALLOWABLE WORKING PRESSURE ____ (kPa)
@ ____ (°C)
☐ HYDROTEST PRESSURE ____ (kPa)

○ SUCTION PRESS. REGIONS MUST BE DESIGNED FOR MAWP (2.2.4)

**ROTATION: (VIEWED FROM COUPLING END)**

☐ CW ☐ CCW

○ IMPELLERS INDIVIDUALLY SECURED (5.2.2.2)

REMARKS: ____
____
____

○ BOLT OH3 PUMP TO PAD/FOUNDATION (5.1.2.4)

**SHAFT:**

☐ SHAFT DIAMETER AT COUPLING ____ (mm)

## CONSTRUCTION (CONT)

☐ SHAFT DIAMETER BETWEEN BEARINGS ____ (mm)
☐ SPAN BETWEEN BEARING CENTERS ____ (mm)
☐ SPAN BETWEEN BEARING & IMPELLER ____ (mm)

REMARKS ____
____
____

**COUPLINGS: (3.2.2)** DRIVER - PUMP

○ MAKE ____
☐ MODEL ____
☐ CPLG RATING (kW/100 RPM) ____
○ LUBRICATION ____
☐ LIMITED END FLOAT REQUIRED ____
☐ SPACER LENGTH ____ (mm)
☐ SERVICE FACTOR ____

DRIVER HALF COUPLING MOUNTED BY:

○ PUMP MFR. ○ DRIVER MFR. ○ PURCHASER

○ COUPLING PER API 671 (5.2.7)

**BASEPLATES:**

☐ API BASEPLATE NUMBER ____ (APPENDIX M)
○ NON-GROUT (CONSTRUCTION: (3.3.13/5.3.8.3.5)

REMARKS: ____
____
____

## MATERIAL

○ APPENDIX H CLASS ____ (2.11.1.1)
○ MIN DESIGN METAL TEMP (2.11.4.5) ____ (°C)
☐ BARREL/CASE ____ IMPELLER ____
☐ CASE/IMPELLER WEAR RINGS ____
☐ SHAFT ____
☐ DIFFUSERS ____
☐ COUPLING SPACER/HUBS ____
☐ COUPLING DIAPHRAGMS (DISKS) ____

REMARKS ____
____
____

## BEARINGS AND LUBRICATION

**BEARING (TYPE/NUMBER):**

☐ RADIAL ____ / ____
☐ THRUST ____ / ____

○ REVIEW AND APPROVE THRUST BEARING SIZE (5.2.5.2.4)

**LUBRICATION: (2.10)**

☐ GREASE ☐ FLOOD ☐ RING OIL
☐ FLINGER ○ PURGE OIL MIST ○ PURE OIL MIST

○ CONSTANT LEVEL OILER PREFERENCE (SEE REMARKS) (2.9.2.2)
○ PRESSURE LUBE SYS (5.2.6) ○ API-610 ○ API-614
☐ OIL VISC. ISO GRADE (5.2.6.5) ____

# API 610, 8TH EDITION
# CENTRIFUGAL PUMP DATA SHEET
# SI UNITS / ISO STANDARDS (1.2.2)

JOB NO. ______ ITEM NO. ______
REQ / SPEC NO. ______ / ______
PURCH ORDER NO. ______ DATE ______
INQUIRY NO. ______ BY ______
REVISION ______ DATE ______

## BEARINGS AND LUBRICATION (cont)

▣ OIL HEATER REQ'D ○ ELECTRIC ○ STEAM (2.9.2.9/5.2.6.3)
○ OIL PRESS TO BE GREATER THAN COOLANT PRESS (5.2.6.2.b)
REMARKS ______

## MECHANICAL SEAL OR PACKING

**SEAL DATA: (2.7.2)**
○ SEE ATTACHED API-682 DATA SHEET
○ NON-API 682 SEAL (2.7.2)
○ APPENDIX H SEAL CODE ______ (2.11.1.1)
▣ SEAL MANUFACTURER ______
▣ SIZE AND TYPE ______ / ______
▣ MANUFACTURER CODE ______

SEAL CHAMBER DATA: (2.1.6/2.1.7)
▣ TEMPERATURE ______ (° C)
▣ PRESSURE ______ (kPa)
▣ FLOW ______ ($m^3$/h)
☐ SEAL CHAMBER SIZE (TABLE 2.3) ______
☐ TOTAL LENGTH ______ (mm) ☐ CLEAR LENGTH ______ (mm)

**SEAL CONSTRUCTION:**
☐ SLEEVE MATERIAL ______
☐ GLAND MATERIAL ______
○ AUX SEAL DEVICE (2.7.3.20) ______
▣ JACKET REQUIRED (2.7.3.17)

**GLAND TAPS: (2.7.3.14)**
▣ FLUSH (F) ▣ DRAIN (D) ▣ BARRIER/BUFFER(B)
▣ QUENCH (Q) ▣ COOLING (C) ▣ LUBRICATION (G)
▣ HEATING (H) ▣ LEAKAGE ▣ PUMPED FLUID (P)
▣ BALANCE FLUID (E) ▣ EXTERNAL FLUID INJECTION (X)

**SEAL FLUIDS REQUIREMENT AND AVAILABLE FLUSH LIQUID:**
NOTE: IF FLUSH LIQUID IS PUMPAGE LIQUID (AS IN FLUSH PIPING PLANS 11 TO 41), FOLLOWING FLUSH LIQUID DATA IS NOT REQ'D.
○ SUPPLY TEMPERATURE MAX/MIN ______ / ______ (° C)
○ RELATIVE DENSITY (SPECIFIC GRAVITY) ______ @ ______ (° C)
○ NAME OF FLUID ______
○ SPECIFIC HEAT, Cp ______ (kJ/kg ° C)
○ VAPOR PRESSURE ______ (kPa abs) @ ______ (° C)
○ HAZARDOUS ○ FLAMMABLE ○ OTHER ______
☐ FLOW RATE MAX/MIN ______ / ______ ($m^3$/h)
☐ PRESSURE REQUIRED MAX/MIN ______ / ______ (kPa)
☐ TEMPERATURE REQUIRED MAX/MIN ______ / ______ (° C)

**BARRIER/BUFFER FLUID (2.7.3.21):**
○ SUPPLY TEMPERATURE MAX/MIN ______ / ______ (° C)
○ RELATIVE DENSITY (SPECIFIC GRAVITY) ______ @ ______ (° C)
○ NAME OF FLUID ______

## MECHANICAL SEAL OR PACKING (CONT)

○ VAPOR PRESSURE ______ (kPa abs) @ ______ (° C)
○ HAZARDOUS ○ FLAMMABLE ○ OTHER ______
☐ FLOW RATE MAX/MIN ______ / ______ ($m^3$/h)
☐ PRESSURE REQUIRED MAX/MIN ______ / ______ (kPa)
▣ TEMPERATURE REQUIRED MAX/MIN ______ / ______ (° C)

**QUENCH FLUID:**
○ NAME OF FLUID ______
☐ FLOW RATE ______ ($m^3$/h)

**SEAL FLUSH PIPING: (2.7.3.19 AND APPENDIX D)**
○ SEAL FLUSH PIPING PLAN ______
▣ TUBING ▣ CARBON STEEL
▣ PIPE ▣ STAINLESS STEEL
○ AUXILIARY FLUSH PLAN ______
▣ TUBING ▣ CARBON STEEL
▣ PIPE ▣ STAINLESS STEEL
○ PIPING ASSEMBLY: (3.5.2.10.1)
▣ THREADED ▣ UNIONS ▣ SOCKET WELDED
▣ FLANGED ▣ TUBE TYPE FITTINGS
▣ PRESSURE SWITCH (PLAN 52/53) TYPE ______
○ PRESSURE GAUGE (PLAN 52/53)
▣ LEVEL SWITCH (PLAN 52/53) TYPE ______
○ LEVEL GAUGE (PLAN 52/53)
○ TEMP INDICATOR (PLANS 21, 22, 23, 32, 41)
○ HEAT EXCHANGER (PLAN 52/53)
REMARKS ______

**PACKING DATA: (APPENDIX C)**
MANUFACTURER ______
TYPE ______
SIZE ______ NO. OF RINGS ______
☐ PACKING INJECTION REQUIRED
☐ FLOW ______ ($m^3$/h) @ ______ (° C)
☐ LANTERN RING ______

## STEAM AND COOLING WATER PIPING

▣ COOLING WATER PIPING PLAN ______ (3.5.4.1)
☐ COOLING WATER REQUIREMENTS
SEAL JACKET/BRG HSG ______ ($m^3$/h) @ ______ (kPa)
SEAL HEAT EXCHANGER ______ ($m^3$/h) @ ______ (kPa)
QUENCH ______ ($m^3$/h) @ ______ (kPa)
TOTAL COOLING WATER ______ ($m^3$/h)
○ STEAM PIPING: ○ TUBING ○ PIPE
REMARKS ______

# API 610, 8TH EDITION
# CENTRIFUGAL PUMP DATA SHEET
# SI UNITS / ISO STANDARDS (1.2.2)

JOB NO. ________ ITEM NO. ________
REQ / SPEC NO. ________ / ________
PURCH ORDER NO. ________ DATE ________
INQUIRY NO. ________ BY ________
REVISION ________ DATE ________

## INSTRUMENTATION

**VIBRATION:**

○ NONCONTACTING (API 670) ○ TRANSDUCER
○ PROVISION FOR MOUNTING ONLY (2.9.2.11)
○ FLAT SURFACE REQ'D (2.9.2.12)
○ SEE ATTACHED API-670 DATA SHEET
○ MONITORS AND CABLES (3.4.3.3)
REMARKS ________

**TEMPERATURE AND PRESSURE:**

▣ RADIAL BRG METAL TEMP ○ THRUST BRG METAL TEMP
○ PROVISION FOR INSTRUMENTS ONLY
○ SEE ATTACHED API-670 DATA SHEET
○ TEMP GAUGES (WITH THERMOWELLS ) (3.4.1.3)
OTHER ________
○ PRESSURE GAUGE TYPE (3.4.2.2) ________
LOCATION ________
REMARKS ________

## SPARE PARTS (TABLE 6.1)

○ START-UP ○ NORMAL MAINTENANCE
○ SPECIFY ________

## MOTOR DRIVE (3.1.5)

▣ MANUFACTURER ________
☐ ________ (kW) ☐ ________ (RPM)
▣ HORIZONTAL ▣ VERTICAL
☐ FRAME ________
▣ SERVICE FACTOR ________
▣ VOLTS/PHASE/HERTZ ________ / ________ / ________
○ TYPE ________
▣ ENCLOSURE ________
○ MINIMUM STARTING VOLTAGE (3.1.6) ________
○ TEMPERATURE RISE ________
▣ FULL LOAD AMPS ________
▣ LOCKED ROTOR AMPS ________
▣ INSULATION ________
▣ STARTING METHOD ________
▣ LUBE ________
☐ VERTICAL THRUST CAPACITY
UP ________ (N) DOWN ________ (N)
BEARINGS (TYPE / NUMBER):
☐ RADIAL ________ / ________
☐ THRUST ________ / ________

## MOTOR DRIVE (cont) (3.1.5)

REMARKS ________

## SURFACE PREPARATION AND PAINT

○ MANUFACTURER'S STANDARD
○ OTHER (SEE BELOW)

**PUMP:**

○ PUMP SURFACE PREPARATION ________
○ PRIMER ________
○ FINISH COAT ________

**BASEPLATE: (3.3.18)**

○ BASEPLATE SURFACE PREPARATION ________
○ PRIMER ________
○ FINISH COAT ________

**SHIPMENT: (4.4.1)**

○ DOMESTIC ○ EXPORT ○ EXPORT BOXING REQUIRED
○ OUTDOOR STORAGE MORE THAN 6 MONTHS

**SPARE ROTOR ASSEMBLY PACKAGED FOR:**

○ HORIZONTAL STORAGE ○ VERTICAL STORAGE
○ TYPE OF SHIPPING PREPARATION ________
REMARKS ________

## ☐ WEIGHTS

MOTOR DRIVEN:
WEIGHT OF PUMP (kg) ________
WEIGHT OF BASEPLATE (kg) ________
WEIGHT OF MOTOR (kg) ________
WEIGHT OF GEAR (kg) ________
TOTAL WEIGHT (kg) ________

TURBINE DRIVEN:
WEIGHT OF BASEPLATE (kg) ________
WEIGHT OF TURBINE (kg) ________
WEIGHT OF GEAR (kg) ________
TOTAL WEIGHT (kg) ________
REMARKS ________

## OTHER PURCHASER REQUIREMENTS

○ COORDINATION MEETING REQUIRED (6.1.3)
○ REVIEW FOUNDATION DRAWINGS (2.1.27)
○ REVIEW PIPING DRAWINGS
○ OBSERVE PIPING CHECKS
○ OBSERVE INITIAL ALIGNMENT CHECK
○ CHECK ALIGNMENT AT OPERATING TEMPERATURE
○ CONNECTION DESIGN APPROVAL (2.11.3.5.4)

# API 610, 8TH EDITION CENTRIFUGAL PUMP DATA SHEET SI UNITS / ISO STANDARDS (1.2.2)

JOB NO. ______ ITEM NO. ______
REQ / SPEC NO. ______ / ______
PURCH ORDER NO. ______ DATE ______
INQUIRY NO. ______ BY ______
REVISION ______ DATE ______

## OTHER PURCHASER REQUIREMENTS (cont)

○ RIGGING DEVICE REQ'D FOR TYPE OH3 PUMP (5.1.2.7)
○ HYDRODYNAMIC THRUST BRG SIZE REVIEW REQ'D (5.2.5.2.4)
☒ LATERAL ANALYSIS REQUIRED (5.1.4.3/5.2.4.1)
☒ ROTOR DYNAMIC BALANCE (5.2.4.2)
☒ MOUNT SEAL RESERVOIR OFF BASEPLATE (3.5.1.4)
☒ INSTALLATION LIST IN PROPOSAL (6.2.3L)
○ SPARE ROTOR VERTICAL STORAGE (5.2.9.2)
○ TORSIONAL ANALYSIS/REPORT (2.8.2.6)
○ PROGRESS REPORTS REQUIRED (6.3.4)
REMARKS: ______

## QA INSPECTION AND TEST

○ REVIEW VENDORS QA PROGRAM (4.1.7)
○ PERFORMANCE CURVE APPROVAL
○ SHOP INSPECTION (4.1.4)
☒ TEST WITH SUBSTITUTE SEAL (4.3.3.1.2)

| TEST | NON-WIT | WIT | OBSERVE |
|---|---|---|---|
| HYDROSTATIC (4.3.2) | ○ | ○ | ○ |
| PERFORMANCE (4.3.3) | ○ | ○ | ○ |
| NPSH (4.3.4.1) | ○ | ○ | ○ |
| COMPLETE UNIT TEST (4.3.4.2) | ○ | ○ | ○ |
| SOUND LEVEL TEST (4.3.4.3) | ○ | ○ | ○ |
| ○ CLEANLINESS PRIOR TO FINAL ASSEMBLY (4.2.3.1) | ○ | ○ | ○ |
| ○ NOZZLE LOAD TEST (3.3.6) | ○ | ○ | ○ |
| ○ BRG HSG RESONANCE TEST (4.3.4.5.) | ○ | ○ | ○ |
| ○ REMOVE/INSPECT HYDRODYNAMIC BEARINGS AFTER TEST (5.2.8.5) | ○ | ○ | ○ |
| ○ AUXILIARY EQUIPMENT TEST (4.3.4.4) | ○ | ○ | ○ |
| ○ ______ | ○ | ○ | ○ |
| ○ ______ | ○ | ○ | ○ |

○ MATERIAL CERTIFICATION REQUIRED (2.11.1.7)
○ CASING ○ IMPELLER ○ SHAFT
○ OTHER ______
○ CASTING REPAIR PROCEDURE APPROVAL REQ'D (2.11.2.5)
○ INSPECTION REQUIRED FOR CONNECTION WELDS (2.11.3.6)
○ MAG PARTICLE ○ LIQUID PENETRANT
○ RADIOGRAPHIC ○ ULTRASONIC
○ INSPECTION REQUIRED FOR CASTINGS (4.2.1.3)
○ MAG PARTICLE ○ LIQUID PENETRANT
○ RADIOGRAPHIC ○ ULTRASONIC

## QA INSPECTION AND TEST (cont)

○ ADDITIONAL INSPECTION REQUIRED FOR:
______ (4.2.1.3)
○ MAG PARTICLE ○ LIQUID PENETRANT
○ RADIOGRAPHIC ○ ULTRASONIC
○ ALTERNATIVE ACCEPTANCE CRITERIA (SEE REMARKS) (4.2.2.1)
○ HARDNESS TEST REQUIRED FOR:
______ (4.2.3.2)
○ WETTING AGENT HYDROTEST (4.3.2.5)
○ VENDOR SUBMIT TEST PROCEDURES (4.3.1.2/6.2.5)
○ RECORD FINAL ASSEMBLY RUNNING CLEARANCES
○ INSPECTION CHECK-LIST (APPENDIX N) ______ (4.1.6)
REMARKS ______

## GENERAL REMARKS

REMARK 1: ______

REMARK 2: ______

REMARK 3: ______

REMARK 4: ______

REMARK 5: ______

REMARK 6: ______

# API 610, 8TH EDITION
# SUPPLEMENTAL
# VERTICAL PUMP DATA SHEET
# SI UNITS / ISO STANDARDS

JOB NO. ______ ITEM NO. ______
REQ / SPEC NO. ______ / ______
PURCH ORDER NO. ______ DATE ______
INQUIRY NO. ______ BY ______

VERTICAL TYPE (FIG 1.1) ☐ VS1 ☐ VS2 ☐ VS3 ☐ VS4 ☐ VS5 ☐ VS6 ☐ VS7 ☐ OTHER

REMARKS ______

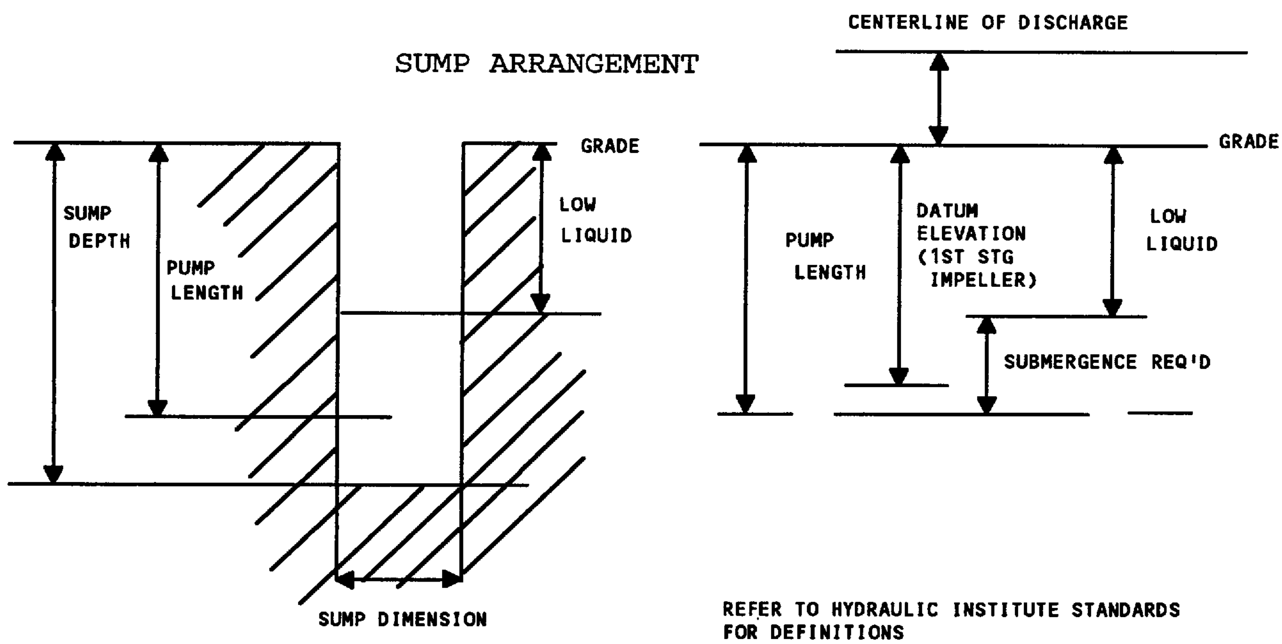
## VERTICAL PUMPS

☐ PUMP THRUST: (+) UP (-) DOWN
AT MIN FLOW ______(N) ______(N)
AT RATED FLOW ______(N) ______(N)
AT MAX FLOW ______(N) ______(N)
MAX THRUST ______(N) ______(N)
☐ SOLEPLATE ______(mm) X ______(mm)
☐ SOLEPLATE THICKNESS ______(mm)
COLUMN PIPE: ☐ FLANGED ☐ THREADED
DIAMETER ______(mm) LENGTH ______(m)
GUIDE BUSHINGS:
☐ NUMBER ______
☐ LINE SHAFT BEARING SPACING ______(mm)
GUIDE BUSHING LUBE:
☐ WATER ☐ OIL
☐ GREASE ☐ PUMPAGE

## VERTICAL PUMPS (CONT'D)

LINE SHAFT: ☐ OPEN ☐ ENCLOSED
☐ LINE SHAFT DIAMETER: ____(mm) ☐ TUBE DIAMETER: ____(mm)
LINE SHAFT COUPLING:
☐ SLEEVE & KEY ☐ THREADED
☐ SUCTION CAN THICKNESS ______(mm)
☐ LENGTH ______(m)
☐ DIAMETER ______(m)
○ SUCTION STRAINER TYPE ______
○ FLOAT & ROD ○ FLOAT SWITCH
○ IMPELLER COLLETS ACCEPTABLE (2.5.2)
○ HARDENED SLEEVES UNDER BEARINGS (5.3.10.7)
○ RESONANCE TEST (5.3.9.2)
○ STRUCTURAL ANALYSIS (5.3.5.1)
○ DRAIN PIPED TO SURFACE (5.3.13.6)

SUMP ARRANGEMENT




REFER TO HYDRAULIC INSTITUTE STANDARDS FOR DEFINITIONS

○ SUMP DEPTH ______(m)
○ SUMP DIMENSION ______(m)
○ LOW LIQUID ______(m)

☐ PUMP LENGTH ______(m)
☐ SUBMERGENCE REQ'D ______(m)
☐ CENTERLINE DISCHARGE HEIGHT ______(m)
☐ DATUM ELEVATION ______(m)

# API 610, 8TH EDITION
# CENTRIFUGAL PUMP DATA SHEET
# US UNITS / US STANDARDS (1.2.2)

JOB NO. ________ ITEM NO. ________
REQ / SPEC NO. ________ / ________
PURCH ORDER NO. ________ DATE ________
INQUIRY NO. ________ BY ________
REVISION ________ DATE ________

APPLICABLE TO: ○ PROPOSAL ○ PURCHASE ▣ AS BUILT
FOR ________ UNIT ________
SITE ________ SERVICE ________
NO. REQ ________ PUMP SIZE ________ TYPE ________ NO. STAGES ________
MANUFACTURER ________ MODEL ________ SERIAL NO. ________

NOTE: ○ INDICATES INFORMATION COMPLETED BY PURCHASER ☐ BY MANUFACTURER ▣ BY MANUFACTURER OR PURCHASER

## ○ GENERAL (3.1.1)

PUMPS TO OPERATE IN (PARALLEL) NO. MOTOR DRIVEN ________ NO. TURBINE DRIVEN ________
(SERIES) WITH ________ PUMP ITEM NO. ________ PUMP ITEM NO. ________
GEAR ITEM NO. ________ MOTOR ITEM NO. ________ TURBINE ITEM NO. ________
GEAR PROVIDED BY ________ MOTOR PROVIDED BY ________ TURBINE PROVIDED BY ________
GEAR MOUNTED BY ________ MOTOR MOUNTED BY ________ TURBINE MOUNTED BY ________
GEAR DATA SHEET NO. ________ MOTOR DATA SHEET NO. ________ TURBINE DATA SHEET NO. ________

## OPERATING CONDITIONS

○ CAPACITY, NORMAL ________ (GPM) RATED ________ (GPM)
OTHER ________
○ SUCTION PRESSURE MAX/RATED ________ / ________ (PSIG)
○ DISCHARGE PRESSURE ________ (PSIG)
○ DIFFERENTIAL PRESSURE ________ (PSIG)
○ DIFFERENTIAL HEAD ________ (FT) NPSHA ________ (FT)
○ PROCESS VARIATIONS ________ (3.1.2)
○ STARTING CONDITIONS ________ (3.1.3)
SERVICE: ○ CONTINUOUS ○ INTERMITTENT (START/DAY) ________
○ PARALLEL OPERATION REQ'D (2.1.11)

## SITE AND UTILITY DATA

LOCATION: (2.1.29)
○ INDOOR ○ HEATED ○ UNDER ROOF
○ OUTDOOR ○ UNHEATED ○ PARTIAL SIDES
○ GRADE ○ MEZZANINE ○ ________
○ ELECTRICAL AREA CLASSIFICATION (2.1.22 / 3.1.5)
CL ________ GR ________ DIV ________
○ WINTERIZATION REQ'D ○ TROPICALIZATION REQ'D

SITE DATA (2.1.29)
○ ALTITUDE ________ (FT) BAROMETER ________ (PSIA)
○ RANGE OF AMBIENT TEMPS: MIN/MAX ________ / ________ (° F)
○ RELATIVE HUMIDITY: MIN/MAX ________ / ________ (%)
UNUSUAL CONDITIONS (2.1.23) ○ DUST ○ FUMES
○ OTHER ________
○ UTILITY CONDITIONS:

STEAM: DRIVERS HEATING
MIN ________ (PSIG) ________ (° F) ________ (PSIG) ________ (° F)
MAX ________ (PSIG) ________ (° F) ________ (PSIG) ________ (° F)

| ELECTRICITY: | DRIVERS | HEATING | CONTROL | SHUTDOWN |
|---|---|---|---|---|
| VOLTAGE | | | | |
| HERTZ | | | | |
| PHASE | | | | |

COOLING WATER: (2.1.17)
TEMP INLET ________ (° F) MAX RETURN ________ (° F)
PRESS NORMAL ________ (PSIG) DESIGN ________ (PSIG)
MIN RETURN ________ (PSIG) MAX ALLOW DP ________ (PSI)

## SITE AND UTILITY DATA (CONT.)

WATER SOURCE ________
CHLORIDE CONCENTRATION (PPM) ________ (3.5.2.6)
INSTRUMENT AIR: MAX/MIN PRESS ________ / ________ (PSIG)

## LIQUID

○ TYPE/NAME OF LIQUID ________
○ PUMPING TEMPERATURE:
NORMAL ________ (° F) MAX ________ (° F) MIN ________ (° F)
○ VAPOR PRESSURE ________ (PSIA) @ ________ (° F)
○ RELATIVE DENSITY (SPECIFIC GRAVITY):
NORMAL ________ MAX ________ MIN ________
○ SPECIFIC HEAT, Cp ________ (BTU/LB ° F)
○ VISCOSITY ________ (cP) @ ________ (° F)
○ MAX VISCOSITY ________ (cP)
○ CORROSIVE/EROSIVE AGENT ________ (2.11.1.8)
○ CHLORIDE CONCENTRATION (PPM) ________ (3.5.2.6)
○ $H_2S$ CONCENTRATION (PPM) ________ (2.11.1.11)
LIQUID (2.1.3) ○ HAZARDOUS ○ FLAMMABLE
○ OTHER ________

## PERFORMANCE

PROPOSAL CURVE NO. ________ ☐ RPM ________
☐ IMPELLER DIA RATED ________ MAX ________ MIN ________ (IN)
☐ RATED POWER ________ (BHP) EFFICIENCY ________ (%)
☐ MINIMUM CONTINUOUS FLOW:
THERMAL ________ (GPM) STABLE ________ (GPM)
☐ PREFERRED OPERATING REGION ________ TO ________ (GPM)
☐ ALLOWABLE OPERATING REGION ________ TO ________ (GPM)
☐ MAX HEAD @ RATED IMPELLER ________ (FT)
☐ MAX POWER @ RATED IMPELLER ________ (BHP)
☐ NPSHR AT RATED CAPACITY ________ (FT) (2.1.8)
▣ SUCTION SPECIFIC SPEED ________ (2.1.9)
○ MAX SOUND PRESS. LEVEL REQ'D ________ (dBA)(2.1.14)
☐ EST MAX SOUND PRESS. LEVEL ________ (dBA)(2.1.14)
REMARKS ________

# API 610, 8TH EDITION CENTRIFUGAL PUMP DATA SHEET US UNITS / US STANDARDS (1.2.2)

JOB NO.____________ ITEM NO.____________
REQ / SPEC NO. ____________ / ____________
PURCH ORDER NO. ____________ DATE ____________
INQUIRY NO. ____________ BY ____________
REVISION ____________ DATE ____________

## CONSTRUCTION

APPLICABLE STANDARD:

○ API 610 8TH EDITION

○ OTHER ____________ (SEE REMARKS)

PUMP TYPE: (1.1.2)

| | | | |
|---|---|---|---|
| ☐ OH2 | ☐ BB1 | ☐ VS1 | ☐ VS6 |
| ☐ OH3 | ☐ BB2 | ☐ VS2 | ☐ VS7 |
| ☐ OH6 | ☐ BB3 | ☐ VS3 | ☐ OTHER |
| | ☐ BB4 | ☐ VS4 | |
| | ☐ BB5 | ☐ VS5 | |

☐ NOZZLE CONNECTIONS: (2.3.2)

| | SIZE (IN) | FLANGE RATING (LBS) | FACING | POSITION |
|---|---|---|---|---|
| SUCTION | | | | |
| DISCHARGE | | | | |
| BALANCE DRUM | | | | |

PRESSURE CASING CONNECTIONS: (2.3.3)

| | NO. | SIZE (NPS) | TYPE |
|---|---|---|---|
| ☐ DRAIN | | | |
| ☐ VENT | | | |
| ☐ PRESSURE GAUGE | | | |
| ☐ TEMP GAUGE | | | |
| ☐ WARM-UP | | | |
| ☐ BALANCE / LEAK-OFF | | | |

○ CYLINDRICAL THREADS REQUIRED (2.3.3)

CASING MOUNTING: (SEE SEPARATE SHEET FOR VERTICALS)

☐ CENTERLINE ☐ NEAR CENTERLINE
☐ FOOT ☐ SEPARATE MOUNTING PLATE
☐ IN-LINE

CASING SPLIT:

☐ AXIAL ☐ RADIAL

CASING TYPE:

☐ SINGLE VOLUTE ☐ MULTIPLE VOLUTE ☐ DIFFUSER
☐ OVERHUNG ☐ BETWEEN BEARINGS ☐ BARREL

CASE PRESSURE RATING:

☐ MAX ALLOWABLE WORKING PRESSURE ____________ (PSIG)
@ ____________ (° F)
☐ HYDROTEST PRESSURE ____________ (PSIG)

○ SUCTION PRESS. REGIONS MUST BE DESIGNED FOR MAWP (2.2.4)

ROTATION: (VIEWED FROM COUPLING END)

☐ CW ☐ CCW

○ IMPELLERS INDIVIDUALLY SECURED (5.2.2.2)

REMARKS:____________

○ BOLT OH3 PUMP TO PAD/FOUNDATION (5.1.2.4)

SHAFT:

☐ SHAFT DIAMETER AT COUPLING ____________ (IN)

## CONSTRUCTION (CONT)

☐ SHAFT DIAMETER BETWEEN BEARINGS ____________ (IN)
☐ SPAN BETWEEN BEARING CENTERS ____________ (IN)
☐ SPAN BETWEEN BEARING & IMPELLER ____________ (IN)

REMARKS ____________

COUPLINGS: (3.2.2) DRIVER - PUMP

○ MAKE ____________
☐ MODEL ____________
☐ RATING (HP/100 RPM) ____________
○ LUBRICATION ____________
☐ LIMITED END FLOAT REQUIRED ____________
☐ SPACER LENGTH ____________ (IN)
☐ SERVICE FACTOR ____________

DRIVER HALF COUPLING MOUNTED BY:

○ PUMP MFR. ○ DRIVER MFR. ○ PURCHASER

○ COUPLING PER API 671 (5.2.7)

BASEPLATES:

☐ API BASEPLATE NUMBER ____________ (APPENDIX M)
○ NON-GROUT (CONSTRUCTION: (3.3.13/5.3.8.3.5)

REMARKS:____________

## MATERIAL

○ APPENDIX H CLASS ____________ (2.11.1.1)
○ MIN DESIGN METAL TEMP (2.11.4.5) ____________ (° F)
☐ BARREL/CASE ____________ IMPELLER ____________
☐ CASE/IMPELLER WEAR RINGS ____________
☐ SHAFT ____________
☐ DIFFUSERS ____________
☐ COUPLING SPACER/HUBS ____________
☐ COUPLING DIAPHRAGMS (DISKS) ____________

REMARKS ____________

## BEARINGS AND LUBRICATION

BEARING (TYPE/NUMBER):

☐ RADIAL ____________ / ____________
☐ THRUST ____________ / ____________

○ REVIEW AND APPROVE THRUST BEARING SIZE (5.2.5.2.4)

LUBRICATION: (2.10)

☐ GREASE ☐ FLOOD ☐ RING OIL
☐ FLINGER ○ PURGE OIL MIST ○ PURE OIL MIST

○ CONSTANT LEVEL OILER PREFERENCE (SEE REMARKS) (2.9.2.2)

○ PRESSURE LUBE SYS (5.2.6) ○ API-610 ○ API-614

☐ OIL VISC. ISO GRADE (5.2.6.5) ____________

# API 610, 8TH EDITION
# CENTRIFUGAL PUMP DATA SHEET
# US UNITS / US STANDARDS (1.2.2)

JOB NO.______________ ITEM NO.______________
REQ / SPEC NO. ______________ / ______________
PURCH ORDER NO. ______________ DATE ______________
INQUIRY NO.______________ BY ______________
REVISION ______________ DATE ______________

**BEARINGS AND LUBRICATION (cont)**

▣ OIL HEATER REQ'D ○ ELECTRIC ○ STEAM (2.9.2.9/5.2.6.3)
○ OIL PRESS TO BE GREATER THAN COOLANT PRESS (5.2.6.2.b)
REMARKS______________

______________

**MECHANICAL SEAL OR PACKING**

**SEAL DATA: (2.7.2)**
○ SEE ATTACHED API-682 DATA SHEET
○ NON-API 682 SEAL (2.7.2)
○ APPENDIX H SEAL CODE______________(2.11.1.1)
▣ SEAL MANUFACTURER______________
▣ SIZE AND TYPE______________ / ______________
▣ MANUFACTURER CODE______________
SEAL CHAMBER DATA: (2.1.6/2.1.7)
▣ TEMPERATURE______________(° F)
▣ PRESSURE______________(PSIG)
▣ FLOW______________(GPM)
☐ SEAL CHAMBER SIZE (TABLE 2.3)______________
☐ TOTAL LENGTH ______________(IN) ☐ CLEAR LENGTH______________(IN)
**SEAL CONSTRUCTION:**
☐ SLEEVE MATERIAL______________
☐ GLAND MATERIAL______________
○ AUX SEAL DEVICE (2.7.3.20)______________
▣ JACKET REQUIRED (2.7.3.17)
**GLAND TAPS: (2.7.3.14)**
▣ FLUSH (F) ▣ DRAIN (D) ▣ BARRIER/BUFFER(B)
▣ QUENCH (Q) ▣ COOLING (C) ▣ LUBRICATION (G)
▣ HEATING (H) ▣ LEAKAGE ▣ PUMPED FLUID (P)
▣ BALANCE FLUID (E) ▣ EXTERNAL FLUID INJECTION (X)
**SEAL FLUIDS REQUIREMENT AND AVAILABLE FLUSH LIQUID:**
NOTE: IF FLUSH LIQUID IS PUMPAGE LIQUID (AS IN FLUSH PIPING PLANS 11 TO 41), FOLLOWING FLUSH LIQUID DATA IS NOT REQ'D.
○ SUPPLY TEMPERATURE MAX/MIN______________ / ______________(° F)
○ RELATIVE DENSITY (SPECIFIC GRAVITY)______________ @ ______________(° F)
○ NAME OF FLUID______________
○ SPECIFIC HEAT, Cp______________(BTU/LB ° F)
○ VAPOR PRESSURE______________(PSIA) @ ______________(° F)
○ HAZARDOUS ○ FLAMMABLE ○ OTHER______________
☐ FLOW RATE MAX/MIN______________ / ______________(GPM)
☐ PRESSURE REQUIRED MAX/MIN______________ / ______________(PSIG)
☐ TEMPERATURE REQUIRED MAX/MIN______________ / ______________(° F)
**BARRIER/BUFFER FLUID (2.7.3.21):**
○ SUPPLY TEMPERATURE MAX/MIN______________ / ______________(° F)
○ RELATIVE DENSITY (SPECIFIC GRAVITY)______________ @ ______________(° F)
○ NAME OF FLUID______________

**MECHANICAL SEAL OR PACKING (CONT)**

○ VAPOR PRESSURE ______________(PSIA) @ ______________(° F)
○ HAZARDOUS ○ FLAMMABLE ○ OTHER______________
☐ FLOW RATE MAX/MIN______________ / ______________(GPM)
☐ PRESSURE REQUIRED MAX/MIN______________ / ______________(PSIG)
▣ TEMPERATURE REQUIRED MAX/MIN______________ / ______________(° F)
**QUENCH FLUID:**
○ NAME OF FLUID______________
☐ FLOW RATE______________(GPM)
**SEAL FLUSH PIPING: (2.7.3.19 AND APPENDIX D)**
○ SEAL FLUSH PIPING PLAN______________
▣ TUBING ▣ CARBON STEEL
▣ PIPE ▣ STAINLESS STEEL
○ AUXILIARY FLUSH PLAN______________
▣ TUBING ▣ CARBON STEEL
▣ PIPE ▣ STAINLESS STEEL
○ PIPING ASSEMBLY: (3.5.2.10.1)
▣ THREADED ▣ UNIONS ▣ SOCKET WELDED
▣ FLANGED ▣ TUBE TYPE FITTINGS
▣ PRESSURE SWITCH (PLAN 52/53) TYPE______________
○ PRESSURE GAUGE (PLAN 52/53)
▣ LEVEL SWITCH (PLAN 52/53) TYPE______________
○ LEVEL GAUGE (PLAN 52/53)
○ TEMP INDICATOR (PLANS 21, 22, 23, 32, 41)
○ HEAT EXCHANGER (PLAN 52/53)
REMARKS______________

______________

______________

**PACKING DATA: (APPENDIX C)**
MANUFACTURER______________
TYPE______________
SIZE ______________ NO. OF RINGS______________
☐ PACKING INJECTION REQUIRED
☐ FLOW______________(GPM) @ ______________(° F)
☐ LANTERN RING______________

**STEAM AND COOLING WATER PIPING**

▣ COOLING WATER PIPING PLAN______________(3.5.4.1)
☐ COOLING WATER REQUIREMENTS
SEAL JACKET/BRG HSG______________(GPM) @ ______________(PSIG)
SEAL HEAT EXCHANGER______________(GPM) @ ______________(PSIG)
QUENCH______________(GPM) @ ______________(PSIG)
TOTAL COOLING WATER______________(GPM)
○ STEAM PIPING: ○ TUBING ○ PIPE
REMARKS______________

______________

______________

# API 610, 8TH EDITION
# CENTRIFUGAL PUMP DATA SHEET
# US UNITS / US STANDARDS (1.2.2)

JOB NO. ______ ITEM NO. ______
REQ / SPEC NO. ______ / ______
PURCH ORDER NO. ______ DATE ______
INQUIRY NO. ______ BY ______
REVISION ______ DATE ______

## INSTRUMENTATION

VIBRATION:
○ NONCONTACTING (API 670) ○ TRANSDUCER
○ PROVISION FOR MOUNTING ONLY (2.9.2.11)
○ FLAT SURFACE REQ'D (2.9.2.12)
○ SEE ATTACHED API-670 DATA SHEET
○ MONITORS AND CABLES (3.4.3.3)
REMARKS ______

TEMPERATURE AND PRESSURE:
○ RADIAL BRG METAL TEMP ○ THRUST BRG METAL TEMP
○ PROVISION FOR INSTRUMENTS ONLY
○ SEE ATTACHED API-670 DATA SHEET
○ TEMP GAUGES (WITH THERMOWELLS ) (3.4.1.3)
OTHER ______
○ PRESSURE GAUGE TYPE (3.4.2.2) ______
LOCATION ______
REMARKS ______

## SPARE PARTS (TABLE 6.1)

○ START-UP ○ NORMAL MAINTENANCE
○ SPECIFY ______

## MOTOR DRIVE (3.1.5)

■ MANUFACTURER ______
☐ ______ (HP) ☐ ______ (RPM)
■ HORIZONTAL ■ VERTICAL
☐ FRAME ______
■ SERVICE FACTOR ______
■ VOLTS/PHASE/HERTZ ______ / ______ / ______
○ TYPE ______
■ ENCLOSURE ______
○ MINIMUM STARTING VOLTAGE (3.1.6) ______
○ TEMPERATURE RISE ______
■ FULL LOAD AMPS ______
■ LOCKED ROTOR AMPS ______
■ INSULATION ______
■ STARTING METHOD ______
■ LUBE ______
☐ VERTICAL THRUST CAPACITY
UP ______ (LBS) DOWN ______ (LBS)
BEARINGS (TYPE / NUMBER):
☐ RADIAL ______ / ______
☐ THRUST ______ / ______

## MOTOR DRIVE (cont) (3.1.5)

REMARKS ______

## SURFACE PREPARATION AND PAINT

○ MANUFACTURER'S STANDARD
○ OTHER (SEE BELOW)
PUMP:
○ PUMP SURFACE PREPARATION ______
○ PRIMER ______
○ FINISH COAT ______
BASEPLATE: (3.3.18)
○ BASEPLATE SURFACE PREPARATION ______
○ PRIMER ______
○ FINISH COAT ______
SHIPMENT: (4.4.1)
○ DOMESTIC ○ EXPORT ○ EXPORT BOXING REQUIRED
○ OUTDOOR STORAGE MORE THAN 6 MONTHS
SPARE ROTOR ASSEMBLY PACKAGED FOR:
○ HORIZONTAL STORAGE ○ VERTICAL STORAGE
○ TYPE OF SHIPPING PREPARATION ______
REMARKS ______

## ☐ WEIGHTS

MOTOR DRIVEN:
WEIGHT OF PUMP (LBS) ______
WEIGHT OF BASEPLATE (LBS) ______
WEIGHT OF MOTOR (LBS) ______
WEIGHT OF GEAR (LBS) ______
TOTAL WEIGHT (LBS) ______
TURBINE DRIVEN:
WEIGHT OF BASEPLATE (LBS) ______
WEIGHT OF TURBINE (LBS) ______
WEIGHT OF GEAR (LBS) ______
TOTAL WEIGHT (LBS) ______
REMARKS ______

## OTHER PURCHASER REQUIREMENTS

○ COORDINATION MEETING REQUIRED (6.1.3)
○ REVIEW FOUNDATION DRAWINGS (2.1.27)
○ REVIEW PIPING DRAWINGS
○ OBSERVE PIPING CHECKS
○ OBSERVE INITIAL ALIGNMENT CHECK
○ CHECK ALIGNMENT AT OPERATING TEMPERATURE
○ CONNECTION DESIGN APPROVAL (2.11.3.5.4)

# API 610, 8TH EDITION
# CENTRIFUGAL PUMP DATA SHEET
# US UNITS / US STANDARDS (1.2.2)

JOB NO. ______ ITEM NO. ______
REQ / SPEC NO. ______ / ______
PURCH ORDER NO. ______ DATE ______
INQUIRY NO. ______ BY ______
REVISION ______ DATE ______

## OTHER PURCHASER REQUIREMENTS (cont)

- O RIGGING DEVICE REQ'D FOR TYPE OH3 PUMP (5.1.2.7)
- O HYDRODYNAMIC THRUST BRG SIZE REVIEW REQ'D (5.2.5.2.4)
- ☒ LATERAL ANALYSIS REQUIRED (5.1.4.3/5.2.4.1)
- ☒ ROTOR DYNAMIC BALANCE (5.2.4.2)
- ☒ MOUNT SEAL RESERVOIR OFF BASEPLATE (3.5.1.4)
- ☒ INSTALLATION LIST IN PROPOSAL (6.2.3L)
- O SPARE ROTOR VERTICAL STORAGE (5.2.9.2)
- O TORSIONAL ANALYSIS/REPORT (2.8.2.6)
- O PROGRESS REPORTS REQUIRED (6.3.4)

REMARKS: ______

## QA INSPECTION AND TEST

- O REVIEW VENDORS QA PROGRAM (4.1.7)
- O PERFORMANCE CURVE APPROVAL
- O SHOP INSPECTION (4.1.4)
- ☒ TEST WITH SUBSTITUTE SEAL (4.3.3.1.2)

| TEST | NON-WIT | WIT | OBSERVE |
|---|---|---|---|
| HYDROSTATIC (4.3.2) | O | O | O |
| PERFORMANCE (4.3.3) | O | O | O |
| NPSH (4.3.4.1) | O | O | O |
| COMPLETE UNIT TEST (4.3.4.2) | O | O | O |
| SOUND LEVEL TEST (4.3.4.3) | O | O | O |
| O CLEANLINESS PRIOR TO FINAL ASSEMBLY (4.2.3.1) | O | O | O |
| O NOZZLE LOAD TEST (3.3.6) | O | O | O |
| O BRG HSG RESONANCE TEST (4.3.4.5.) | O | O | O |
| O REMOVE/INSPECT HYDRODYNAMIC BEARINGS AFTER TEST (5.2.8.5) | O | O | O |
| O AUXILIARY EQUIPMENT TEST (4.3.4.4) | O | O | O |
| O ______ | O | O | O |
| O ______ | O | O | O |

O MATERIAL CERTIFICATION REQUIRED (2.11.1.7)
O CASING O IMPELLER O SHAFT
O OTHER ______

O CASTING REPAIR PROCEDURE APPROVAL REQ'D (2.11.2.5)

O INSPECTION REQUIRED FOR CONNECTION WELDS (2.11.3.5.6)
O MAG PARTICLE O LIQUID PENETRANT
O RADIOGRAPHIC O ULTRASONIC

O INSPECTION REQUIRED FOR CASTINGS (4.2.1.3)
O MAG PARTICLE O LIQUID PENETRANT
O RADIOGRAPHIC O ULTRASONIC

## QA INSPECTION AND TEST (cont)

O ADDITIONAL INSPECTION REQUIRED FOR:
______ (4.2.1.3)
O MAG PARTICLE O LIQUID PENETRANT
O RADIOGRAPHIC O ULTRASONIC

- O ALTERNATIVE ACCEPTANCE CRITERIA (SEE REMARKS) (4.2.2.1)
- O HARDNESS TEST REQUIRED FOR:

______ (4.2.3.2)

- O WETTING AGENT HYDROTEST (4.3.2.5)
- O VENDOR SUBMIT TEST PROCEDURES (4.3.1.2/6.2.5)
- O RECORD FINAL ASSEMBLY RUNNING CLEARANCES
- O INSPECTION CHECK-LIST (APPENDIX N) ______ (4.1.6)

REMARKS ______

## GENERAL REMARKS

REMARK 1: ______

REMARK 2: ______

REMARK 3: ______

REMARK 4: ______

REMARK 5: ______

REMARK 6: ______

# API 610, 8TH EDITION SUPPLEMENTAL VERTICAL PUMP DATA SHEET US UNITS / US STANDARDS



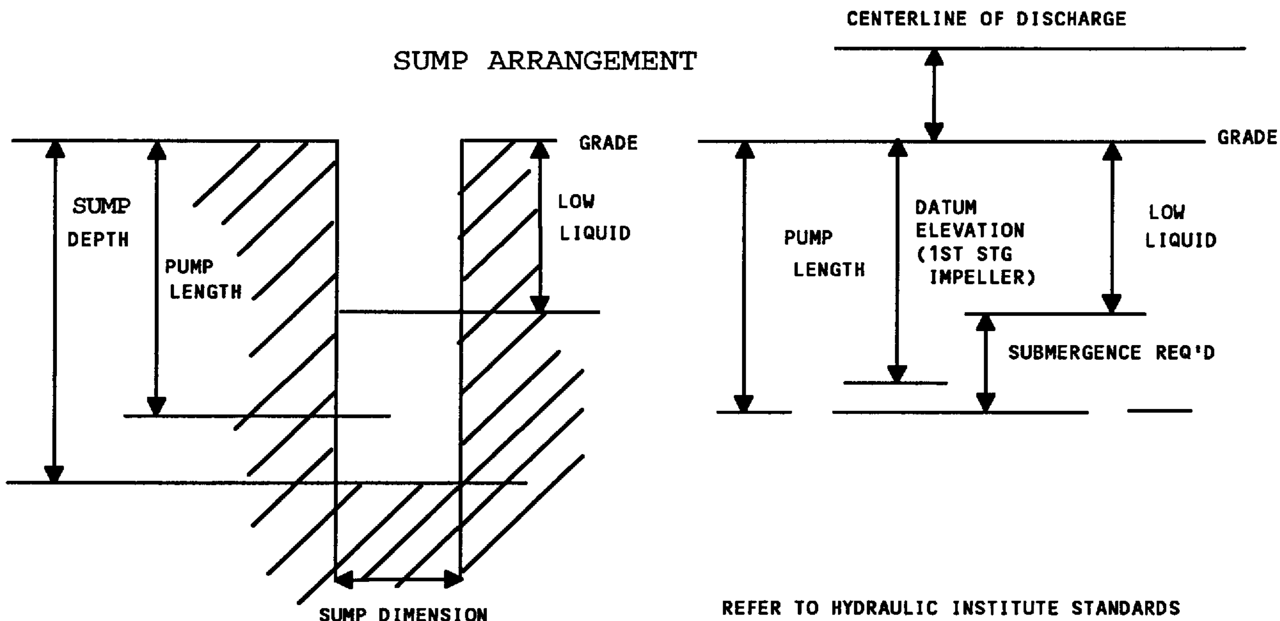
JOB NO.__________ ITEM NO.__________
REQ / SPEC NO. __________ / __________
PURCH ORDER NO. __________ DATE__________
INQUIRY NO.__________ BY __________

VERTICAL TYPE (FIG 1.1) ☐ VS1 ☐ VS2 ☐ VS3 ☐ VS4 ☐ VS5 ☐ VS6 ☐ VS7 ☐ OTHER

REMARKS__________

| VERTICAL PUMPS | VERTICAL PUMPS (CONT'D) |
|---|---|
| ☐ PUMP THRUST: (+) UP (-) DOWN | LINE SHAFT: ☐ OPEN ☐ ENCLOSED |
| AT MIN FLOW ____ (LBS) ____ (LBS) | ☐ LINE SHAFT DIAMETER: ____ (IN) ☐ TUBE DIAMETER: ____ (IN) |
| AT RATED FLOW ____ (LBS) ____ (LBS) | LINE SHAFT COUPLING: |
| AT MAX FLOW ____ (LBS) ____ (LBS) | ☐ SLEEVE & KEY ☐ THREADED |
| MAX THRUST ____ (LBS) ____ (LBS) | ☐ SUCTION CAN THICKNESS ____ (IN) |
| ☐ SOLEPLATE ____ (IN) X ____ (IN) | ☐ LENGTH ____ (FT) |
| ☐ SOLEPLATE THICKNESS ____ (IN) | ☐ DIAMETER ____ (FT) |
| COLUMN PIPE: ☐ FLANGED ☐ THREADED | ○ SUCTION STRAINER TYPE ____ |
| DIAMETER ____ (IN) LENGTH ____ (FT) | ○ FLOAT & ROD ○ FLOAT SWITCH |
| GUIDE BUSHINGS: | ○ IMPELLER COLLETS ACCEPTABLE (2.5.2) |
| ☐ NUMBER ____ | ○ HARDENED SLEEVES UNDER BEARINGS (5.3.10.7) |
| ☐ LINE SHAFT BEARING SPACING ____ (IN) | ○ RESONANCE TEST (5.3.9.2) |
| GUIDE BUSHING LUBE: | ○ STRUCTURAL ANALYSIS (5.3.5.1) |
| ☐ WATER ☐ OIL | ○ DRAIN PIPED TO SURFACE (5.3.13.6) |
| ☐ GREASE ☐ PUMPAGE | |

## SUMP ARRANGEMENT




REFER TO HYDRAULIC INSTITUTE STANDARDS FOR DEFINITIONS

○ SUMP DEPTH ____ (FT)
○ SUMP DIMENSION ____ (FT)
○ LOW LIQUID ____ (FT)

☐ PUMP LENGTH ____ (FT)
☐ SUBMERGENCE REQ'D ____ (FT)
☐ CENTERLINE DISCHARGE HEIGHT ____ (FT)
☐ DATUM ELEVATION ____ (FT)

# APPENDIX C—STUFFING BOXES FOR PACKING

## C.1 Pumps

Pumps designed for packing should be arranged to minimize the pressure in the stuffing box when the rated suction pressure is above atmospheric pressure or the pump developed pressure is greater than 350 kP (50 psi), unless thrust balance requirements dictate otherwise. This can be accomplished with rings on the back of the impeller or with a close fitting throat bushing with bleed back to suction.

## C.2 Stuffing Boxes

Stuffing boxes on packed pumps shall have provision for seal cages (lantern rings) for the introduction of a cooling medium directly into the packing. Inlet and outlet connections shall be provided for the seal cage.

## C.3 Packing

Packing for stuffing boxes shall be a minimum of 10 mm (3/8 in.) square; however, a packing size of at least 12.5 mm (1/2 in.) is preferred.

## C.4 Space

Ample space shall be provided for replacing the packing without removing or dismantling any part other than the gland and, if split, the seal cage.

## C.5 Glands

Glands shall be retained by studs in the pump casing. Where split glands are used, the halves shall be bolted—or positively locked—together.

## C.6 High-Temperature Service

For services in which the liquid's vapor pressure is greater than 100 kPa (14.7 psi) absolute at pumping temperature, glands shall be of the water-smothering type. For high-temperature service, steam may be substituted for water. When cooling water piping is provided by the vendor, the flexible hose or tubing to the quench gland shall have a minimum inside diameter of 6 mm (1/4 in.).

## C.7 Packing Furnished by the Vendor

If pump packing is furnished by the vendor, it shall be packaged separately for installation in the field.

## C.8 Drain

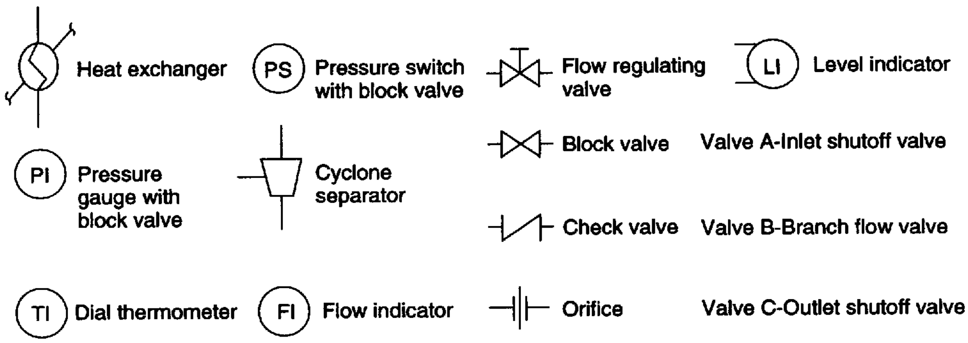
A drain shall be provided on vertical pumps so that no liquid can collect in the driver-support piece.

# APPENDIX D—MECHANICAL SEAL AND PIPING SCHEMATICS

# APPENDIX D—MECHANICAL SEAL AND PIPING SCHEMATICS

This appendix contains schematics for mechanical seals and piping. The notes and key to symbols for Figures D-1 through D-5 are shown below.

**Key to symbols:**

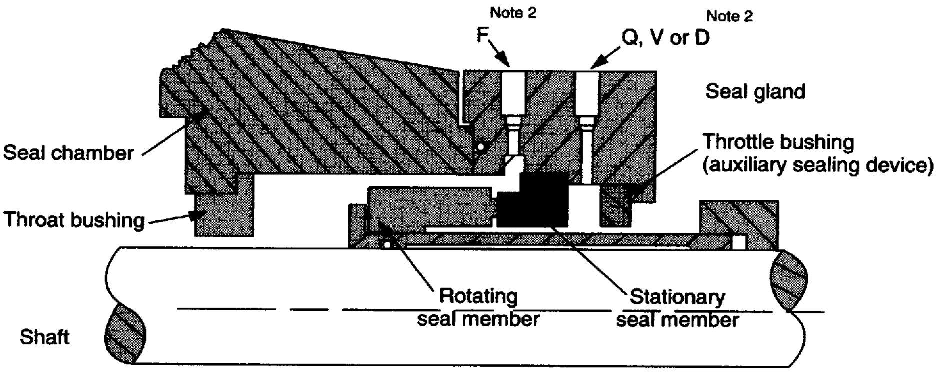



Notes:

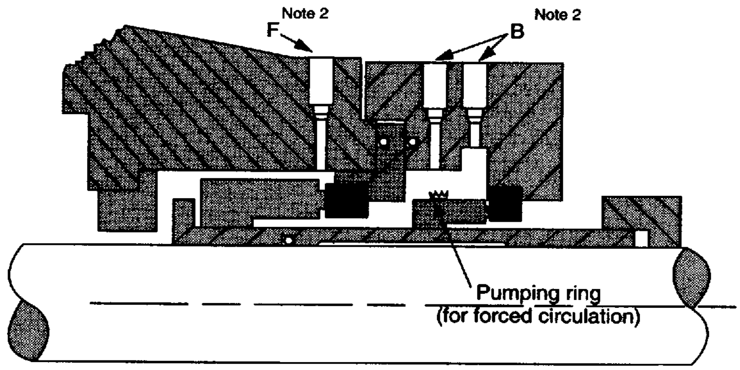
1. These plans represent commonly used systems. Other variations and systems are available and should be specified in detail by the purchaser and mutually agreed upon by the purchaser and the vendor.
2. These plans are for use with the connection "F" on the single and unpressurized dual seal arrangements shown in Figure D-1.
3. For plan 32, the purchaser will specify the fluid characteristics, and the vendor shall specify the volume, pressure, and temperature required.
4. When supplemental seal fluid is provided, the purchaser will specify fluid characteristics. The vendor shall specify the volume, pressure, and temperature required, where these are factors.
5. An asterisk (*) indicates an optional item, furnished only when specified.

Symbols for Pump and Seal Gland Connections

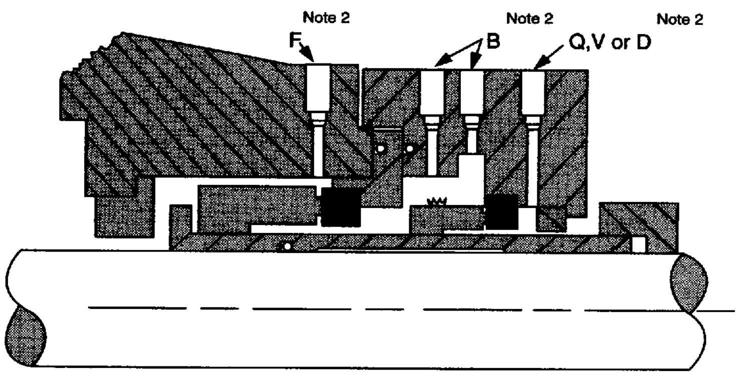
| Symbol | Connections |
|---|---|
| F | Flush |
| L | Leakage |
| B | Barrier/Buffer Fluid Injection |
| X | External Fluid Injection |
| Q | Quench |
| C | Cooling |
| H | Heating |
| G | Lubrication |
| E | Balance Fluid |
| P | Pumped Fluid |
| Suffix | |
| I | Inlet |
| O | Outlet |
| S | Fill |
| D | Drain |
| V | Vent |




SINGLE SEAL




UNPRESSURIZED DUAL SEAL



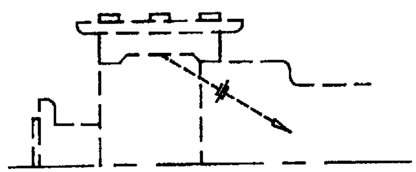

PRESSURIZED DUAL SEAL

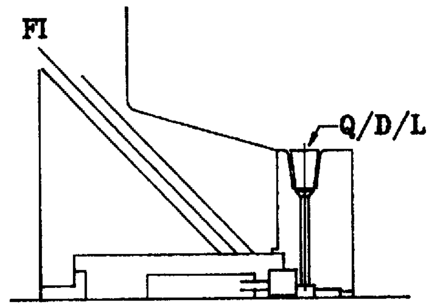
Notes:
1. These illustrations are typical and do not represent any specific design or brand of seal.
2. Refer to appropriate piping plan (Figures D-2 and D-3) for required connections.

**Figure D-1—Typical Mechanical Seal Arrangements**

API PLAN 1

SCHEMATIC | HORIZONTAL | VERTICAL

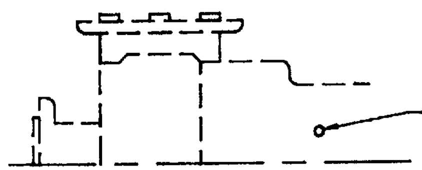


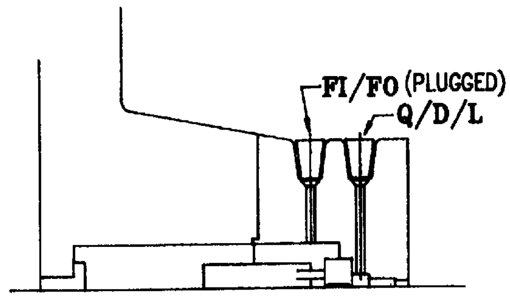



NOT RECOMMENDED ON VERTICAL PUMPS

INTEGRAL (INTERNAL) RECIRCULATION FROM PUMP DISCHARGE TO SEAL. RECOMMENDED FOR CLEAN PUMPAGE ONLY. CARE MUST BE TAKEN TO ENSURE THAT INTEGRAL RECIRCULATION IS SUFFICIENT TO MAINTAIN STABLE CONDITIONS AT THE SEAL FACES.

API PLAN 2



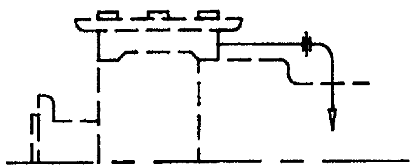

NOT RECOMMENDED ON VERTICAL PUMPS

DEAD-ENDED SEAL CHAMBER WITH NO CIRCULATION OF FLUSHED FLUID.

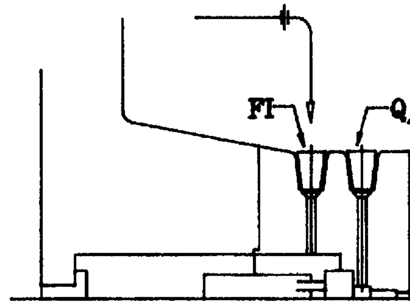
D-2A—Piping for Single Seals and the Primary Seals of Unpressurized Dual Seal Arrangements—Plans 1 and 2

API PLAN 11

SCHEMATIC



HORIZONTAL




VERTICAL

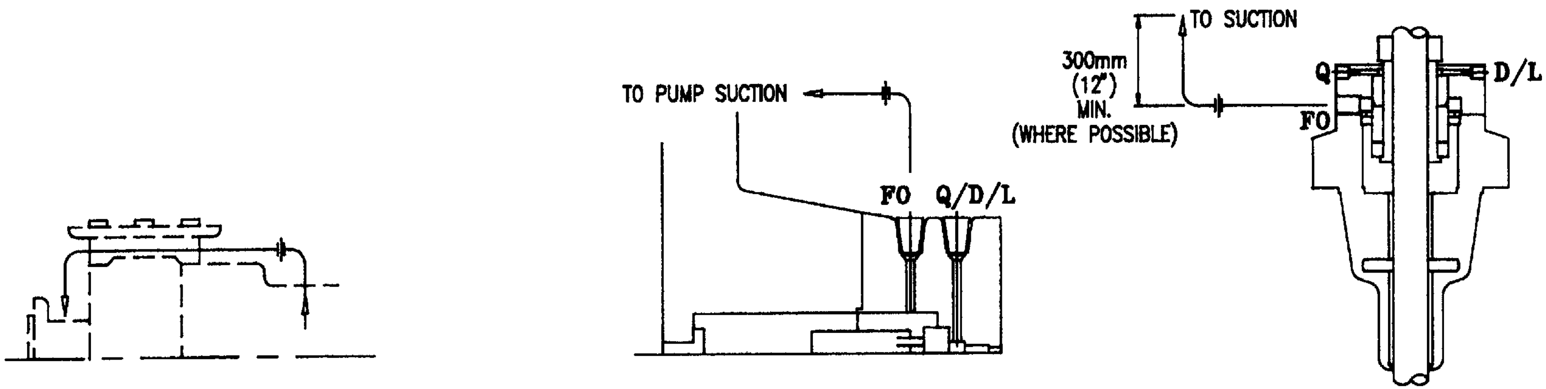
NOT RECOMMENDED ON VERTICAL PUMPS

RECIRCULATION FROM PUMP DISCHARGE THROUGH A FLOW CONTROL ORIFICE, WHEN NECESSARY, TO THE SEAL. THE FLOW ENTERS THE SEAL CHAMBER ADJACENT TO THE MECHANICAL SEAL FACES, FLUSHES THE FACES AND FLOWS ACROSS THE SEAL BACK INTO THE PUMP.

D-2B—Piping for Single Seals and the Primary Seals of Unpressurized Dual Seal Arrangements—Plan 11

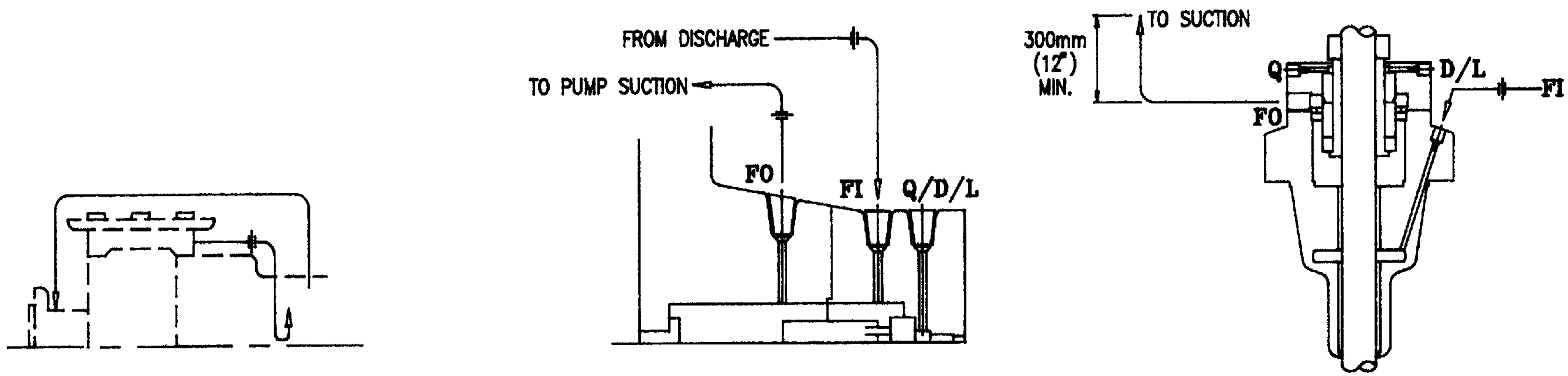
API PLAN 13

SCHEMATIC | HORIZONTAL | VERTICAL




RECIRCULATION FROM SEAL CHAMBER THROUGH A FLOW CONTROL ORIFICE (WHEN NECESSARY) AND BACK TO THE PUMP SUCTION.

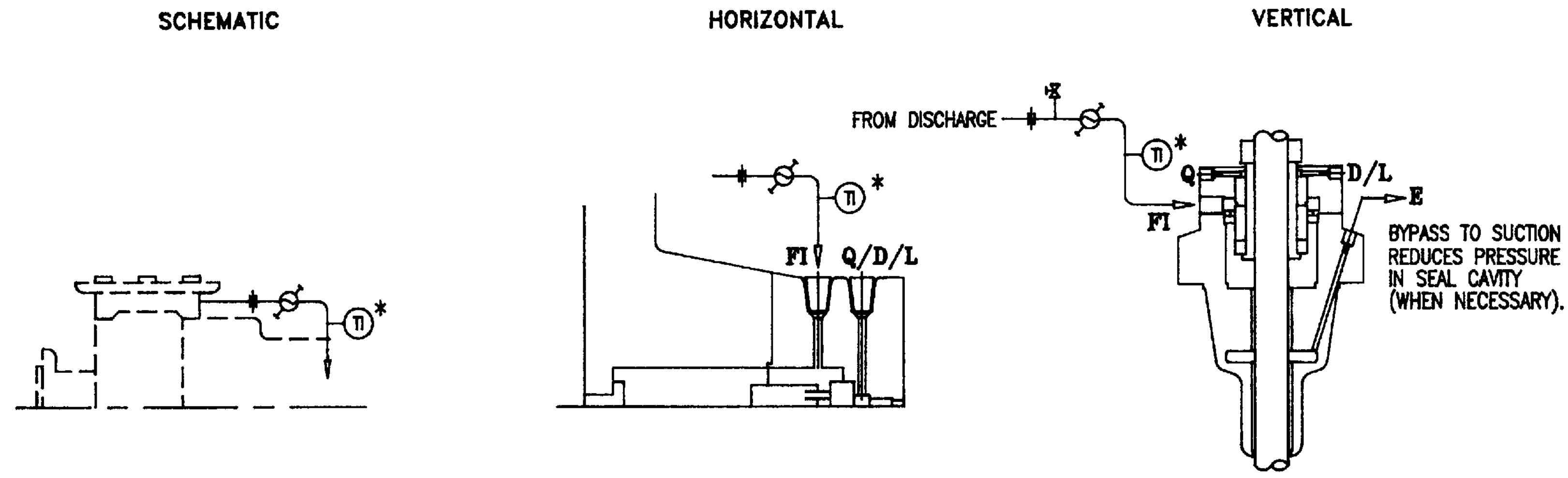
API PLAN 14




RECIRCULATION FROM PUMP DISCHARGE THROUGH A FLOW CONTROL ORIFICE (WHEN NECESSARY) TO THE SEAL AND BACK TO THE SUCTION NOZZLE. THE ORIFICE IS TO BE SIZED IN ACCORDANCE WITH THE THROAT BUSHING AND THE RETURN LINE. SIMILAR TO PLAN 11 BUT FLOW BACK TO SUCTION SIDE WILL EVACUATE VAPORS THAT MAY COLLECT IN SEAL CHAMBER. RECOMMENDED IN LIGHT HYDROCARBON SERVICE.

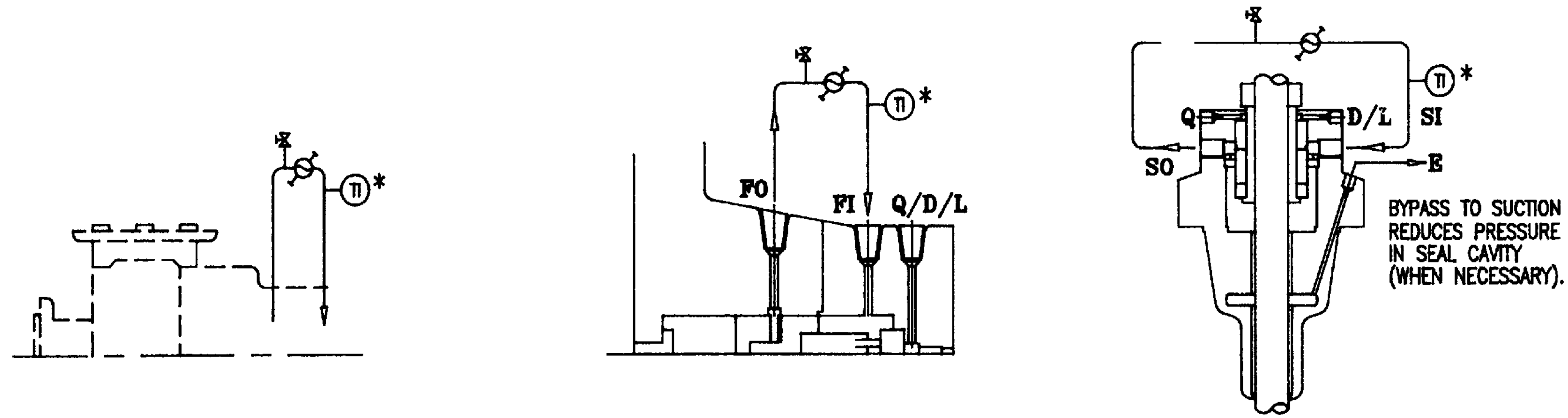
D-2C—Piping for Single Seals and the Primary Seals of Unpressurized Dual Seal Arrangements—Plans 13 and 14

API PLAN 21



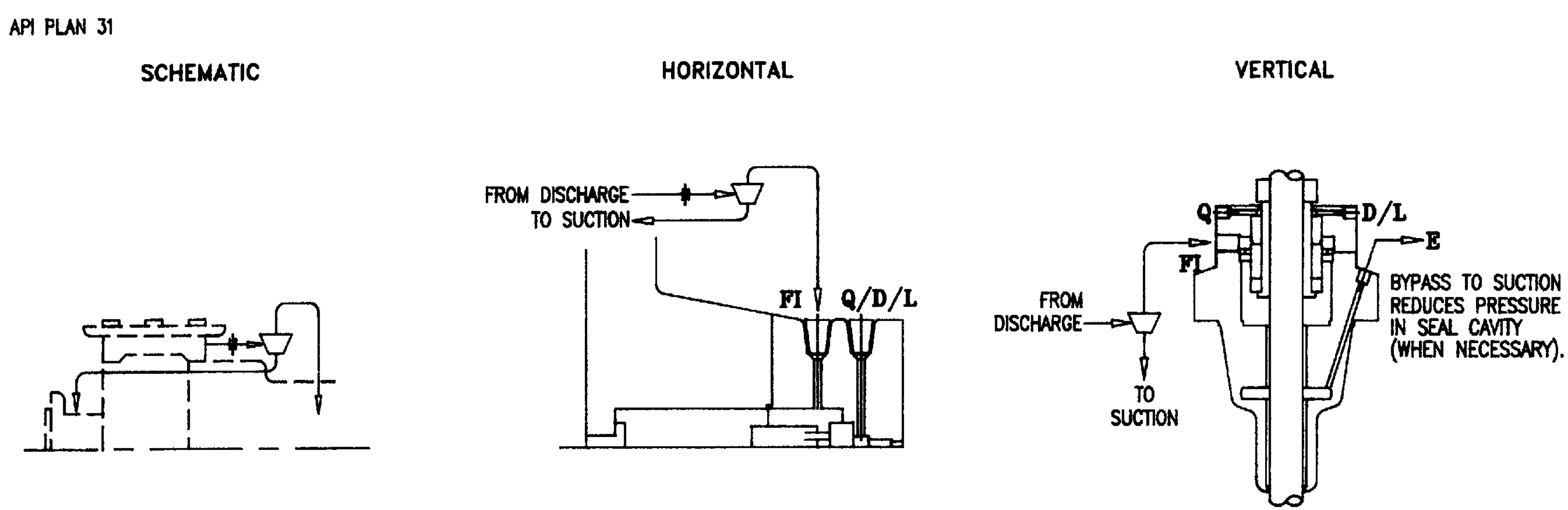

RECIRCULATION FROM PUMP DISCHARGE THROUGH A FLOW CONTROL ORIFICE (WHEN NECESSARY) AND A COOLER AND INTO THE SEAL CHAMBER. (* DIAL THERMOMETER (TI) IS OPTIONAL)

API PLAN 23




RECIRCULATION IS FROM A PUMPING RING IN THE SEAL CHAMBER THROUGH A COOLER AND BACK TO THE SEAL CHAMBER. THIS PLAN CAN BE USED ON HOT APPLICATIONS TO MINIMIZE HEAT LOAD ON THE COOLER BY COOLING ONLY THE SMALL AMOUNT OF LIQUID THAT IS RECIRCULATED. (* DIAL THERMOMETER (TI) IS OPTIONAL)

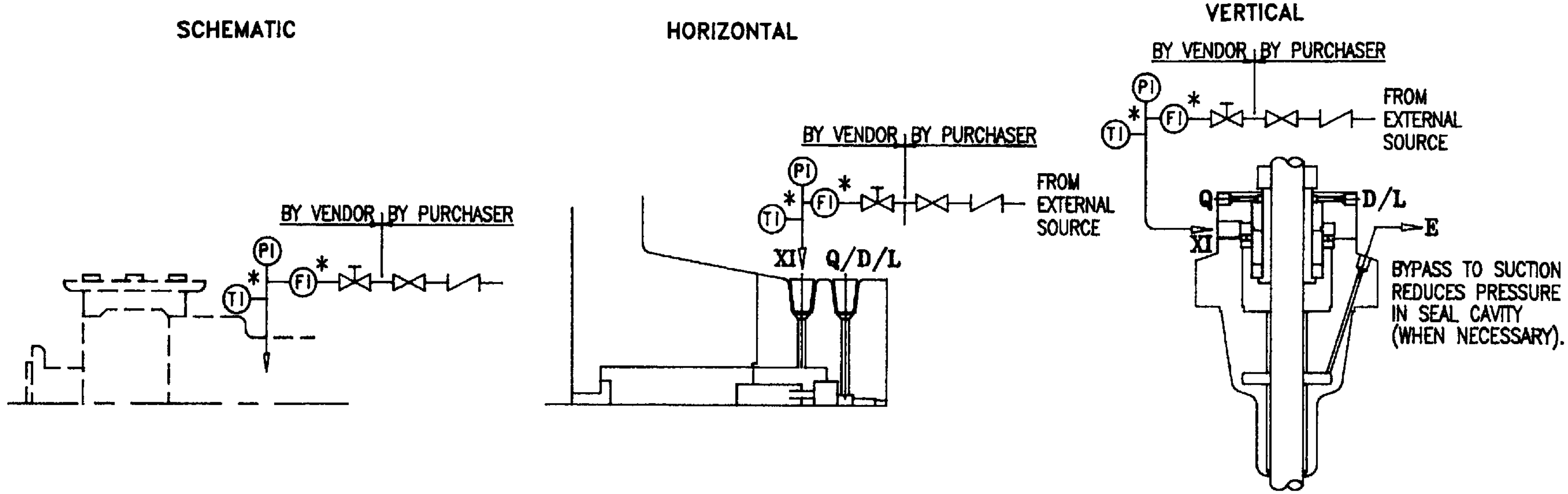
D-2D—Piping for Single Seals and the Primary Seals of Unpressurized Dual Seal Arrangements—Plans 21 and 23




RECIRCULATION FROM PUMP DISCHARGE THROUGH AN ORIFICE (WHEN NECESSARY), TO A CYCLONE SEPARATOR DELIVERING THE CLEAN FLUID TO THE SEAL CHAMBER. THE SOLIDS ARE DELIVERED TO THE PUMP SUCTION LINE.

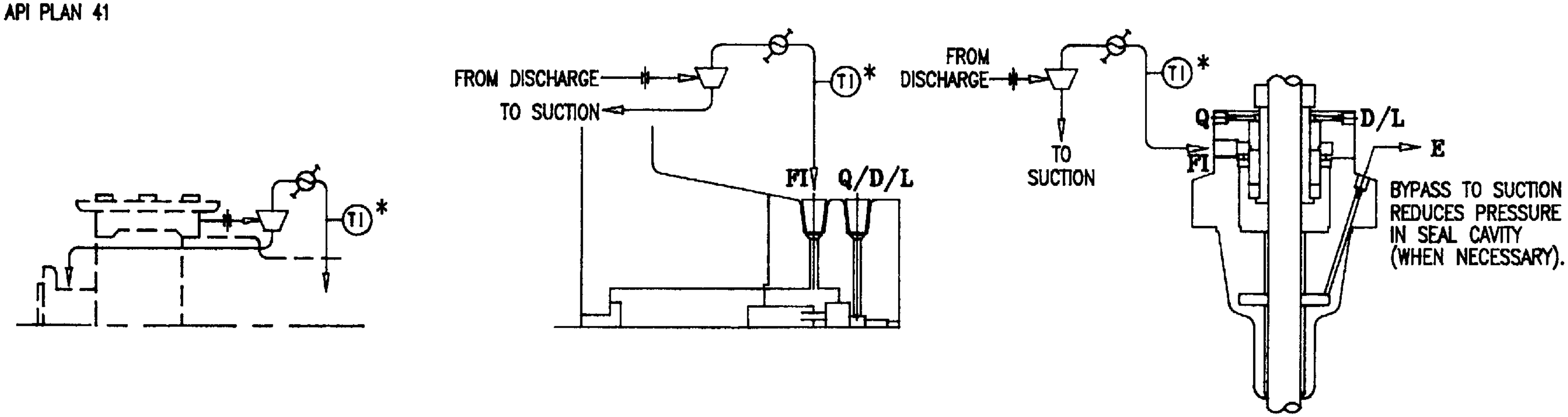
D-2E—Piping for Single Seals and the Primary Seals of Unpressurized Dual Seal Arrangements—Plan 31

API PLAN 32




FLUID IS INJECTED INTO THE SEAL CHAMBER FROM AN EXTERNAL SOURCE. CARE MUST BE EXERCISED IN CHOOSING A PROPER SOURCE OF SEAL FLUSH TO ELIMINATE THE POTENTIAL FOR VAPORIZATION OF THE INJECTED FLUID AND TO AVOID CONTAMINATION OF THE PUMPAGE WITH THE INJECTED FLUSH. (* DIAL THERMOMETER (TI) AND FLOW INDICATOR (FI) ARE OPTIONAL).

API PLAN 41

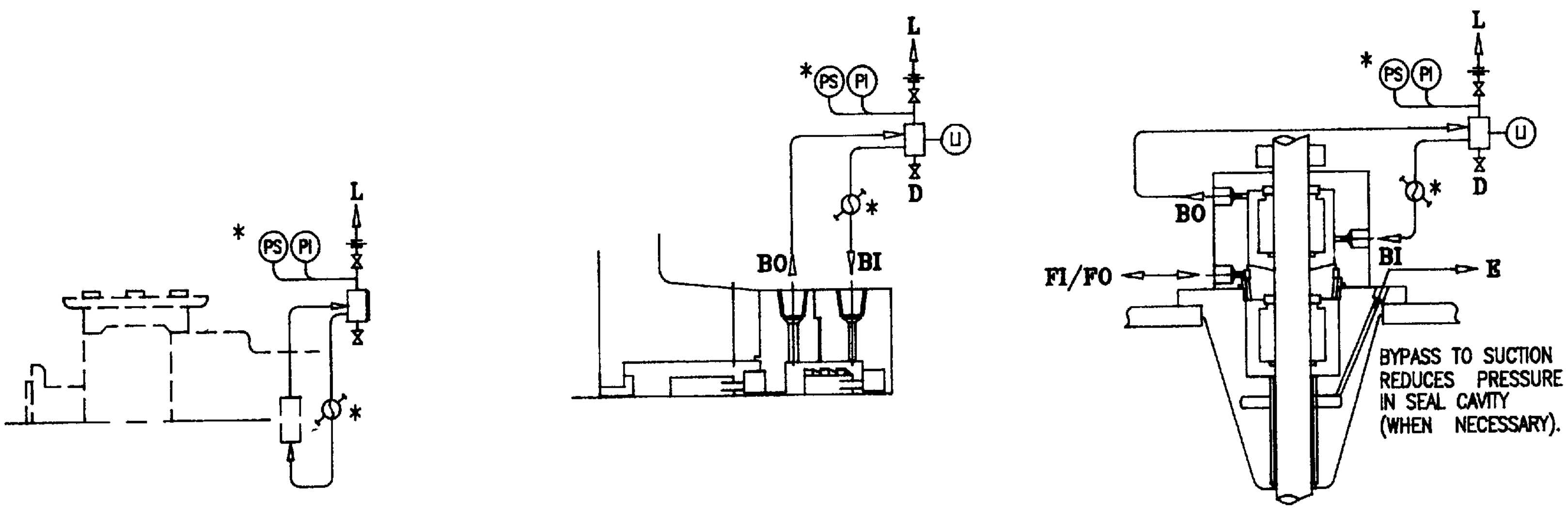



RECIRCULATION FROM PUMP DISCHARGE THROUGH AN ORIFICE (WHEN NECESSARY), TO A CYCLONE SEPARATOR DELIVERING THE CLEAN FLUID TO THE SEAL CHAMBER. THE SOLIDS ARE DELIVERED TO THE PUMP SUCTION LINE. (* DIAL THERMOMETER (TI) IS OPTIONAL).

D-2F—Piping for Single Seals and the Primary Seals of Unpressurized Dual Seal Arrangements—Plans 32 and 41

API PLAN 52

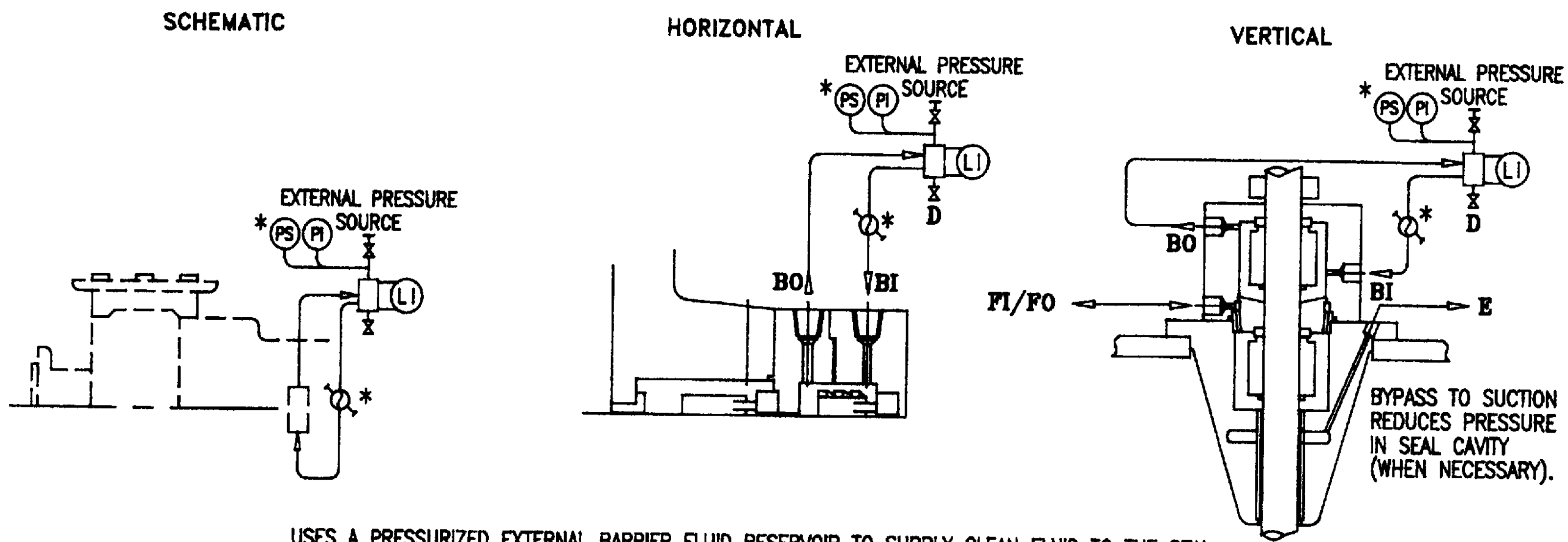
SCHEMATIC HORIZONTAL VERTICAL




USES AN EXTERNAL RESERVOIR TO PROVIDE BUFFER FLUID FOR THE OUTER SEAL OF AN UNPRESSURIZED DUAL SEAL ARRANGEMENT. DURING NORMAL OPERATION, CIRCULATION IS MAINTAINED BY AN INTERNAL PUMPING RING. THE RESERVOIR IS USUALLY CONTINUOUSLY VENTED TO A VAPOR RECOVERY SYSTEM AND IS MAINTAINED AT A PRESSURE LESS THAN THE PRESSURE IN THE SEAL CHAMBER. (* PRESSURE SWITCH (PS) AND HEAT EXCHANGER ARE OPTIONAL).

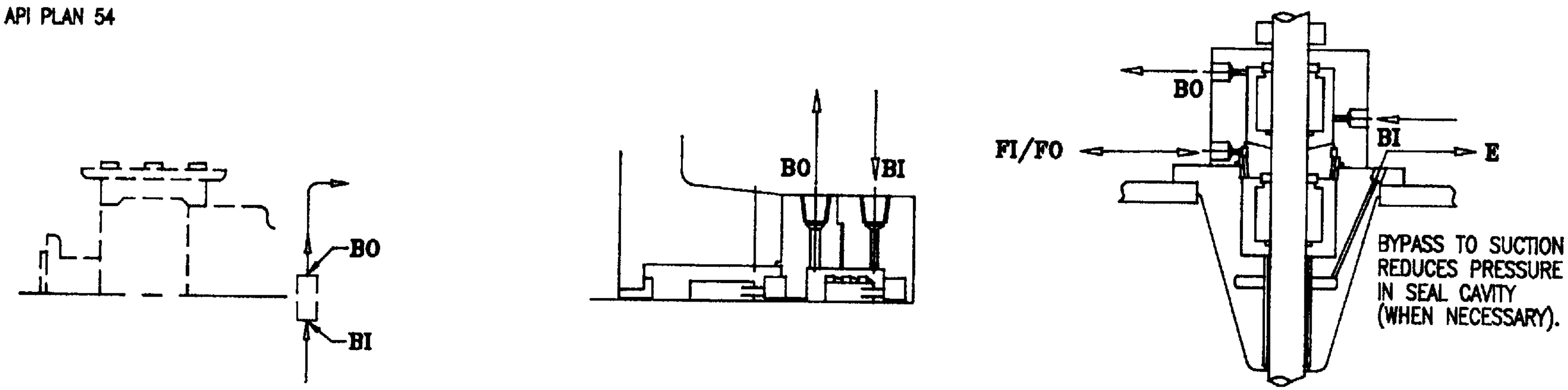
Figure D-3A—Piping for Throttle Bushings, Auxiliary Seal Devices, and Dual Seals—Plan 52

API PLAN 53




USES A PRESSURIZED EXTERNAL BARRIER FLUID RESERVOIR TO SUPPLY CLEAN FLUID TO THE SEAL CHAMBER. CIRCULATION IS BY AN INTERNAL PUMPING RING. RESERVOIR PRESSURE IS GREATER THAN THE PROCESS PRESSURE BEING SEALED. TYPICALLY USED WITH AN ARRANGEMENT 3 PRESSURIZED DUAL SEAL. (* PRESSURE SWITCH (PS) AND HEAT EXCHANGER ARE OPTIONAL).

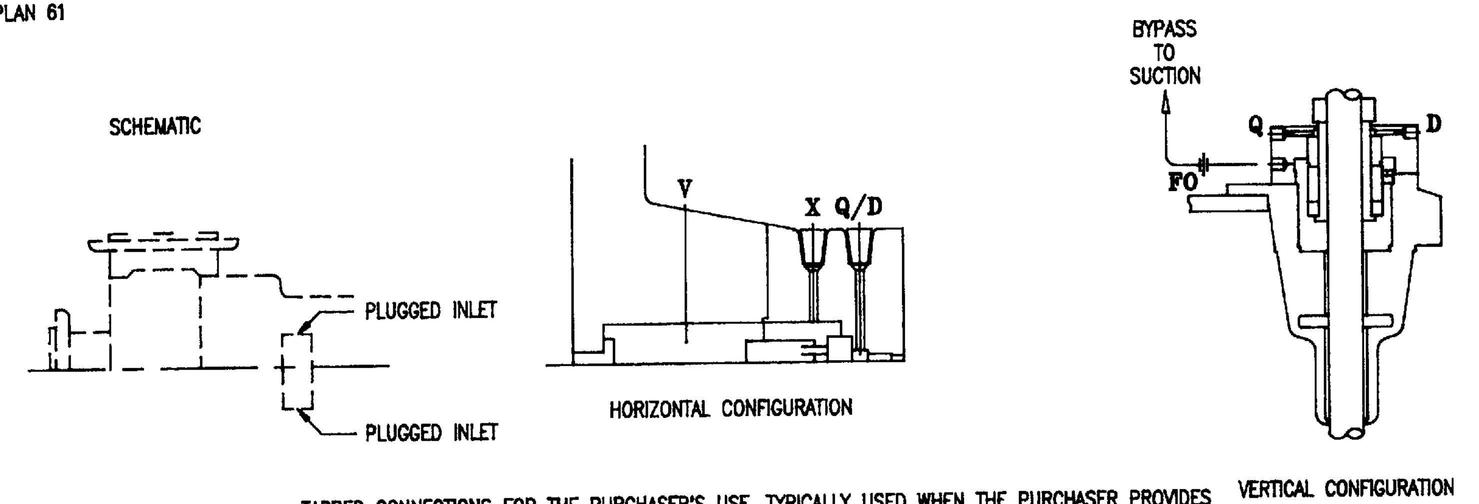
API PLAN 54




USES A PRESSURIZED EXTERNAL BARRIER FLUID RESERVOIR OR SYSTEM TO SUPPLY CLEAN FLUID TO THE SEAL CHAMBER. CIRCULATION IS BY AN EXTERNAL PRESSURE SYSTEM OR PUMP. RESERVOIR PRESSURE IS GREATER THAN THE PROCESS PRESSURE BEING SEALED. TYPICALLY USED WITH AN ARRANGEMENT 3 PRESSURIZED DUAL SEAL.

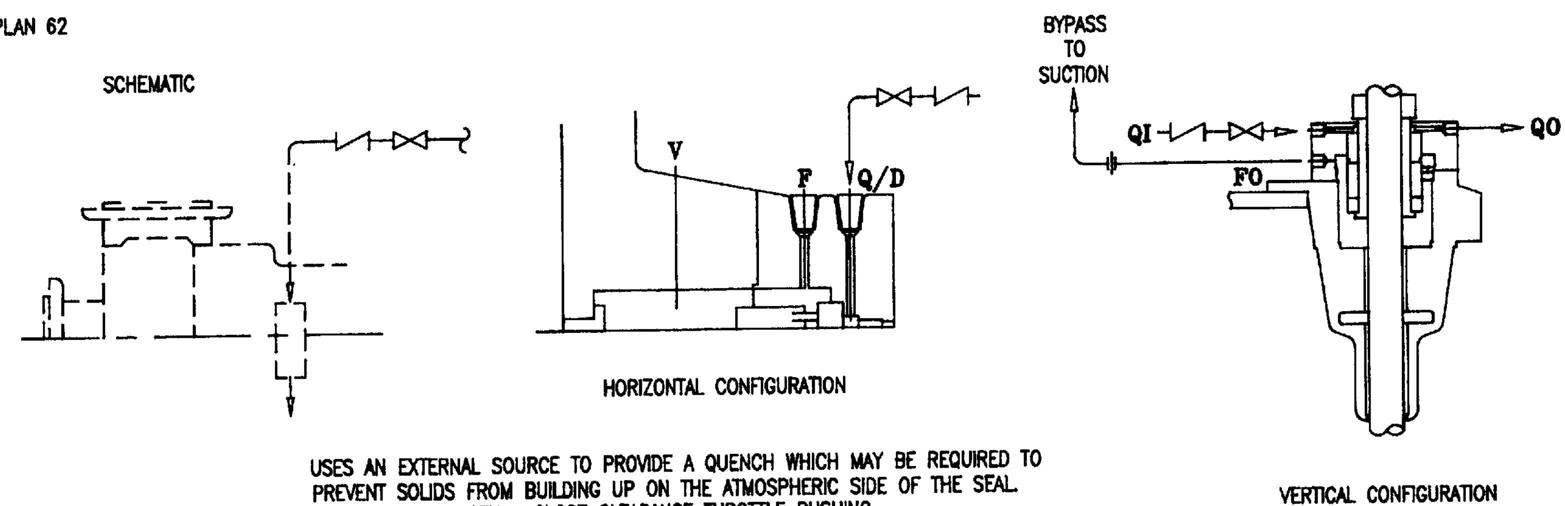
Figure D-3B—Piping for Throttle Bushings, Auxiliary Seal Devices, and Dual Seals—Plans 53 and 54

API PLAN 61




TAPPED CONNECTIONS FOR THE PURCHASER'S USE. TYPICALLY USED WHEN THE PURCHASER PROVIDES FLUID (STEAM,GAS,WATER,ETC.) TO AN AUXILIARY SEALING DEVICE.
NOTE: FOR VERTICAL CONFIGURATION API PLAN 13 1S SHOWN. HOWEVER, OTHER SINGLE AND DUAL SEALING ARRANGMENTS MAY HAVE AN AUXILIARY SEALING DEVICE WHICH CAN BE QUENCHED.

API PLAN 62




USES AN EXTERNAL SOURCE TO PROVIDE A QUENCH WHICH MAY BE REQUIRED TO PREVENT SOLIDS FROM BUILDING UP ON THE ATMOSPHERIC SIDE OF THE SEAL. TYPICALLY USED WITH A CLOSE CLEARANCE THROTTLE BUSHING.
NOTE: FOR VERTICAL CONFIGURATION API PLAN 13 IS SHOWN. HOWEVER, OTHER SINGLE AND DUAL SEALING ARRANGEMENTS MAY HAVE AN AUXILIARY SEALING DEVICE WHICH CAN BE QUENCHED.

Figure D-3C—Piping for Throttle Bushings, Auxiliary Seal Devices, and Dual Seals—Plans 61 and 62

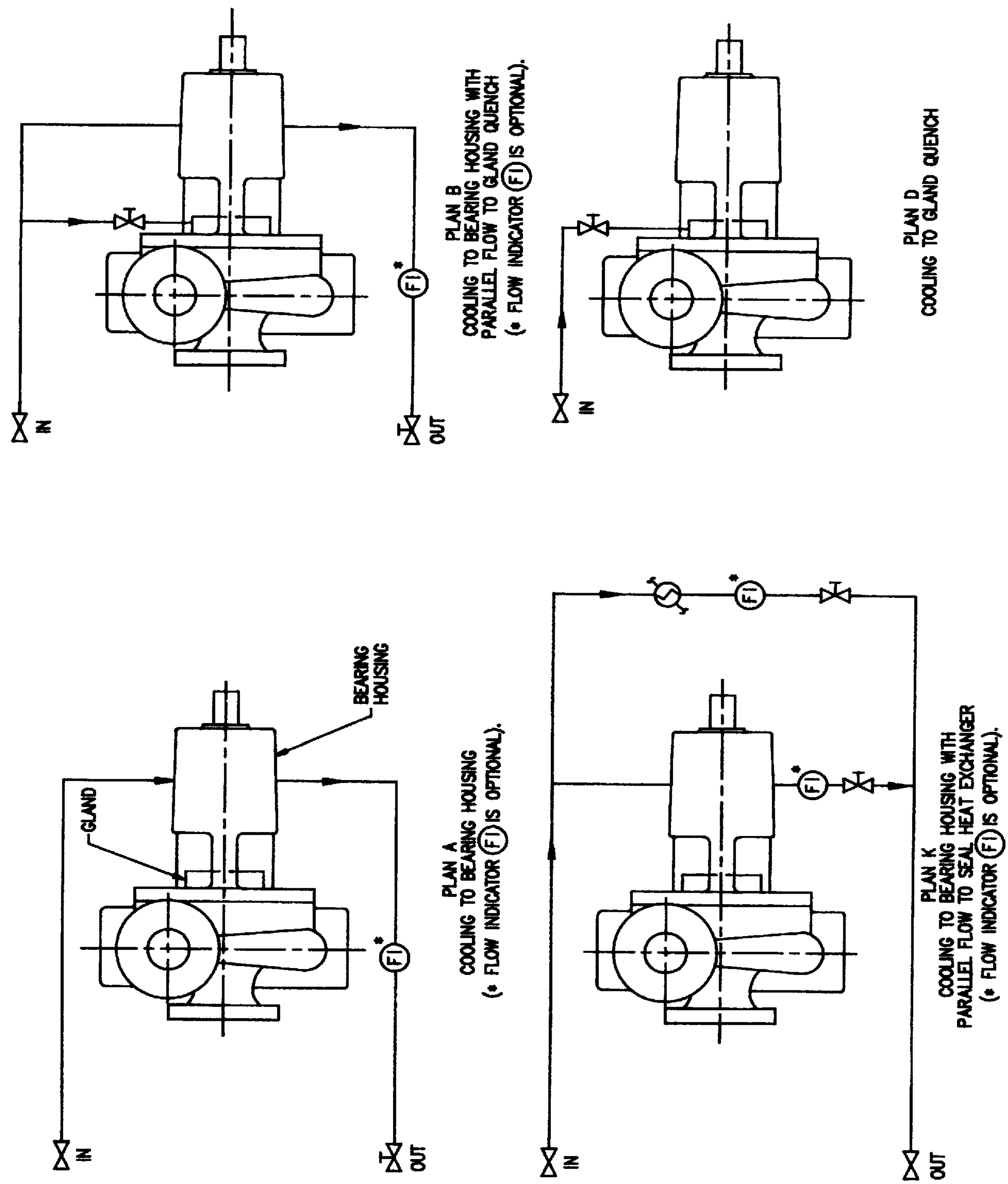
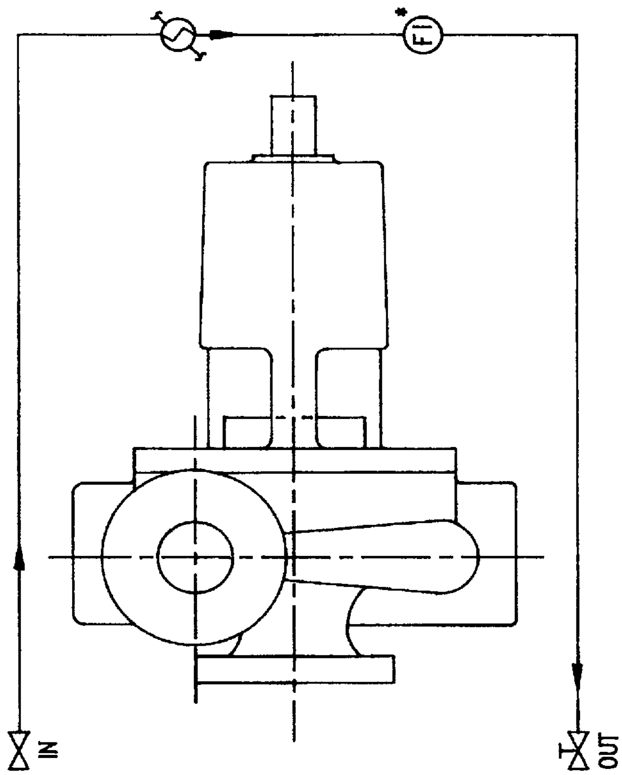



Figure D-4A—Cooling Water Piping for Overhung Pumps—Plans A, B, D, and K




PLAN M
COOLING TO SEAL HEAT EXCHANGER
(* FLOW INDICATOR (FI) IS OPTIONAL).

Figure D-4B—Cooling Water Piping for Overhung Pumps—Plan M

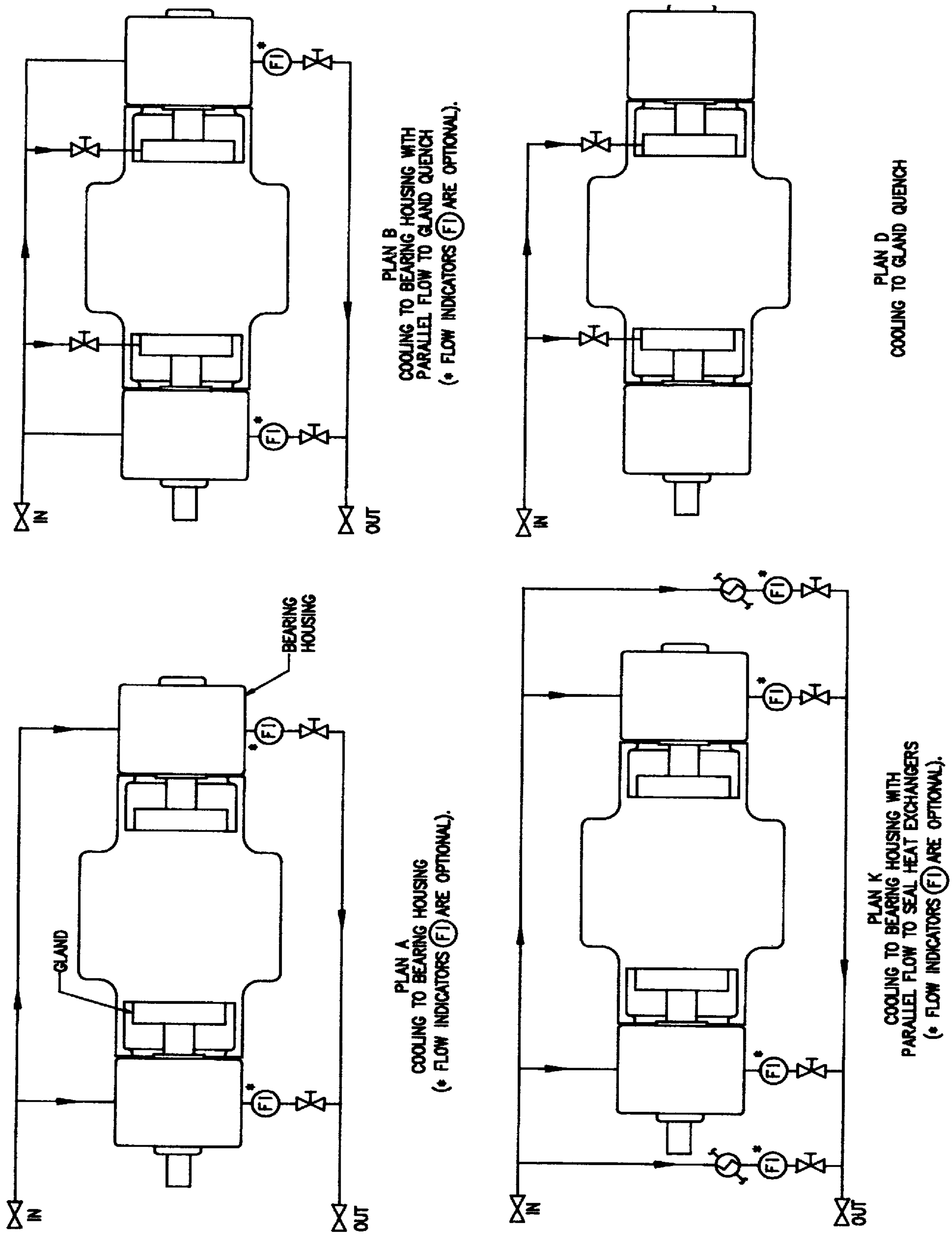



Figure D-5A—Piping for Between Bearings Pumps—Plans A, B, D, and K

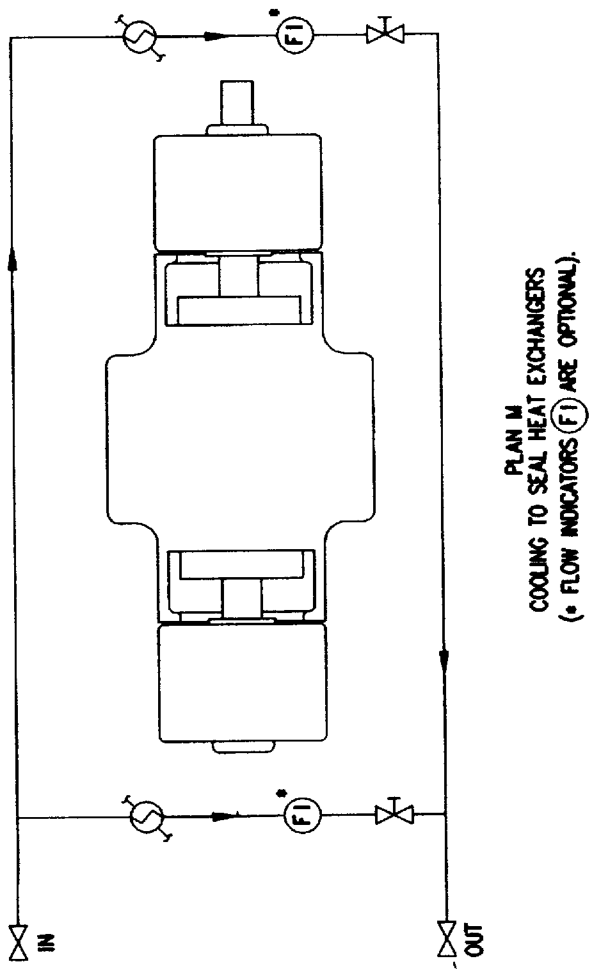
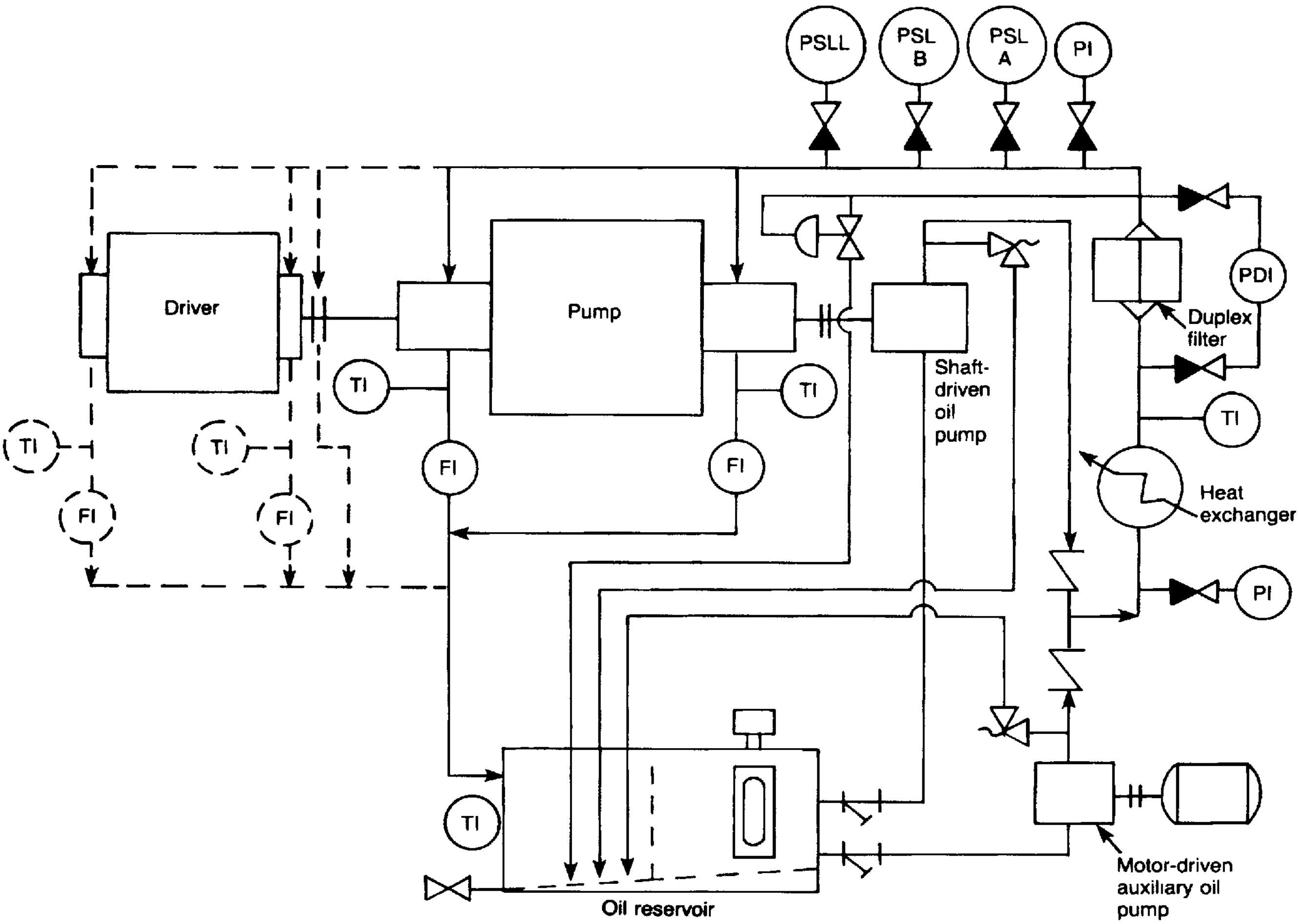



Figure D-5B—Piping for Between Bearings Pumps—Plan M




**LEGEND**

| | |
|---|---|
| FI | Flow indicator |
| TI | Temperature indicator |
| PI | Pressure indicator |
| PDI | Pressure differential indicator |
| PSLA | Low-pressure switch (auxiliary pump start) |
| PSLB | Low-pressure switch (alarm) |
| PSLL | Low-pressure switch (trip) |

Instrument (letters indicate function)
Gate valve
Relief valve
Line strainer
Pressure control valve
Check vale
Block and bleed valve
Reflex-type level indicator

Note: This illustration is a typical schematic and does not constitute any specific design, nor does it include all details (for example, vents and drains).

Figure D-6—Typical Pressurized Lube Oil System

# APPENDIX E—HYDRAULIC POWER RECOVERY TURBINES

## E.1 Scope

This appendix applies to reverse-running hydraulic power recovery turbines (HPRTs) used in the petroleum industry.

## E.2 Terminology

This standard uses terms that need to be changed or deleted when the standard is applied to HPRTs. In such a context, the word *pump* should be interpreted as meaning *HPRT*, the word *suction* should be interpreted as meaning *outlet*, and the word *discharge* should be interpreted as meaning *inlet*. The term *net positive suction head* (*NPSH*) is not applicable to HPRTs.

## E.3 Design

### E.3.1 FLUID CHARACTERISTICS

The purchaser will advise the HPRT manufacturer whether any portion of the process stream entering the HPRT will flash to vapor and whether absorbed gas in the stream will evolve at any pressure less than the inlet pressure. In either case, the purchaser must specify the volume percentage of vapor or gas or both at the turbine outlet and the pressure and temperature at which the vapor will flash off. When known, the fluid composition, and the liquid and vapor (or gas) density versus pressure should also be specified.

### E.3.2 SEAL FLUSHING SYSTEM

To avoid shortening seal life, consideration must be given to evolution of gas and vaporization in seal flushing streams. Where this potential exists, a seal flush from other than the HPRT inlet is generally recommended.

### E.3.3 OVERSPEED TRIP

**E.3.3.1** An overspeed trip should be considered when the HPRT and other equipment in the train cannot tolerate the calculated overspeed (runaway speed). It is important to realize that overspeed with inlet liquids rich in absorbed gas or with liquids that partially flash as they flow through the HPRT can be several times higher than overspeed with water. With such liquids, the overspeed cannot be accurately determined.

**E.3.3.2** The risk of overspeed is reduced when the driven equipment, such as a pump or fan, cannot realistically be expected to lose function. The risk is increased when the driven equipment is a generator, since a sudden disconnection from electric power circuits will unload the HPRT. In the latter case, automatic sensing and dummy-load switching should be provided.

**E.3.3.3** Rotor systems that have low inertia and are subject to accidental unloading should be equipped with a quick-acting brake to prevent damage from overspeed.

### E.3.4 DUAL DRIVERS

When an HPRT is used to assist another driver, the considerations in E.3.4.1 through E.3.4.4 apply.

**E.3.4.1** The main driver should be rated to drive the train without assistance from the HPRT.

**E.3.4.2** An overrunning clutch (that is, a clutch that transmits torque in one direction and freewheels in the other) should generally be used between the HPRT and the train to allow the driven equipment to operate during HPRT maintenance and to permit start-up of the train before the HPRT process stream is lined up.

**E.3.4.3** Flow to the HPRT may vary widely and frequently. When the flow drops to about 40 percent of the rated flow, a drag may be imposed on the main driver. An overrunning clutch will prevent this drag.

**E.3.4.4** The HPRT should never be placed between the main driver and the driven equipment.

### E.3.5 GENERATORS

When a generator is driven by an HPRT on a gas-rich process stream, the generator should be generously sized. The output power of HPRTs can be as much as 20 to 30 percent or more over that predicted by water tests, as a result of the effects of evolved gas or flashed liquid.

### E.3.6 THROTTLE VALVES

For most applications, valves used to control flow to the HPRT should be placed upstream and near the inlet of the HPRT (see Figure E-1). Placement upstream allows the mechanical seals to operate at the outlet pressure of the HPRT and, for gas-rich streams, permits the gas to evolve, which increases the power output.

### E.3.7 BYPASS VALVES

Regardless of the arrangement of the HPRT train, a full-flow bypass valve with modulation capability must be installed. Common control of the modulating bypass valve and the HPRT inlet control valve is normally achieved by means of a split-level arrangement (see Figure E-1).

## E.4 Testing

**E.4.1** The HPRT should receive a performance test at the manufacturer's test facility.

**E.4.2** Figure E-2 shows recommended test performance tolerances for HPRTs. The pump criteria given in the text of this standard are not applicable.

**E.4.3** Vibration levels for HPRTs should meet the criteria for pumps given in this standard.

**E.4.4** It may be useful to verify the overspeed trip setting for the HPRT at the manufacturer's test facility. Determining the runaway speed during a water test may be considered, but this speed can be accurately calculated once performance with water is known. Runaway speed for gas rich-steams cannot be determined by water tests.

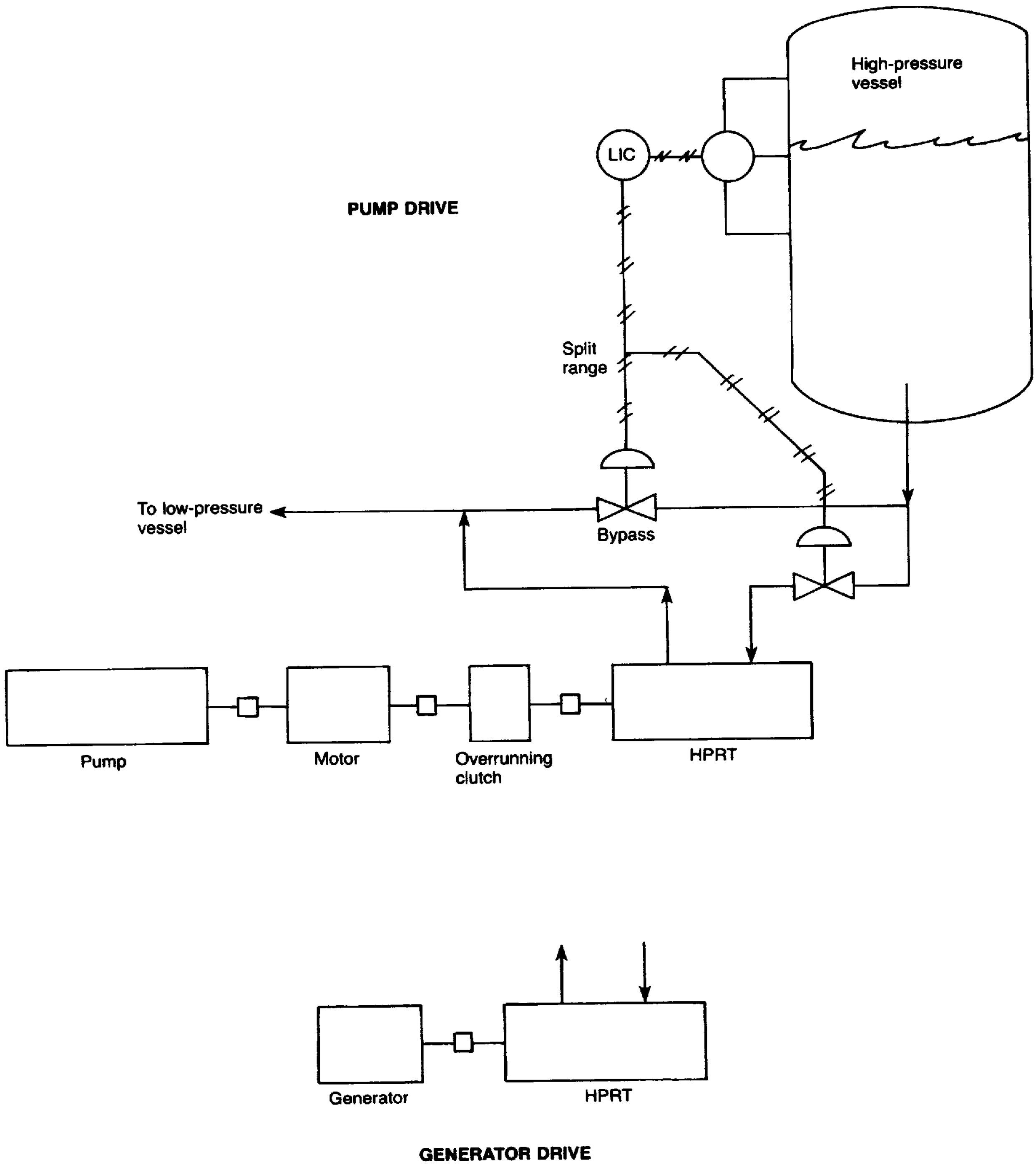
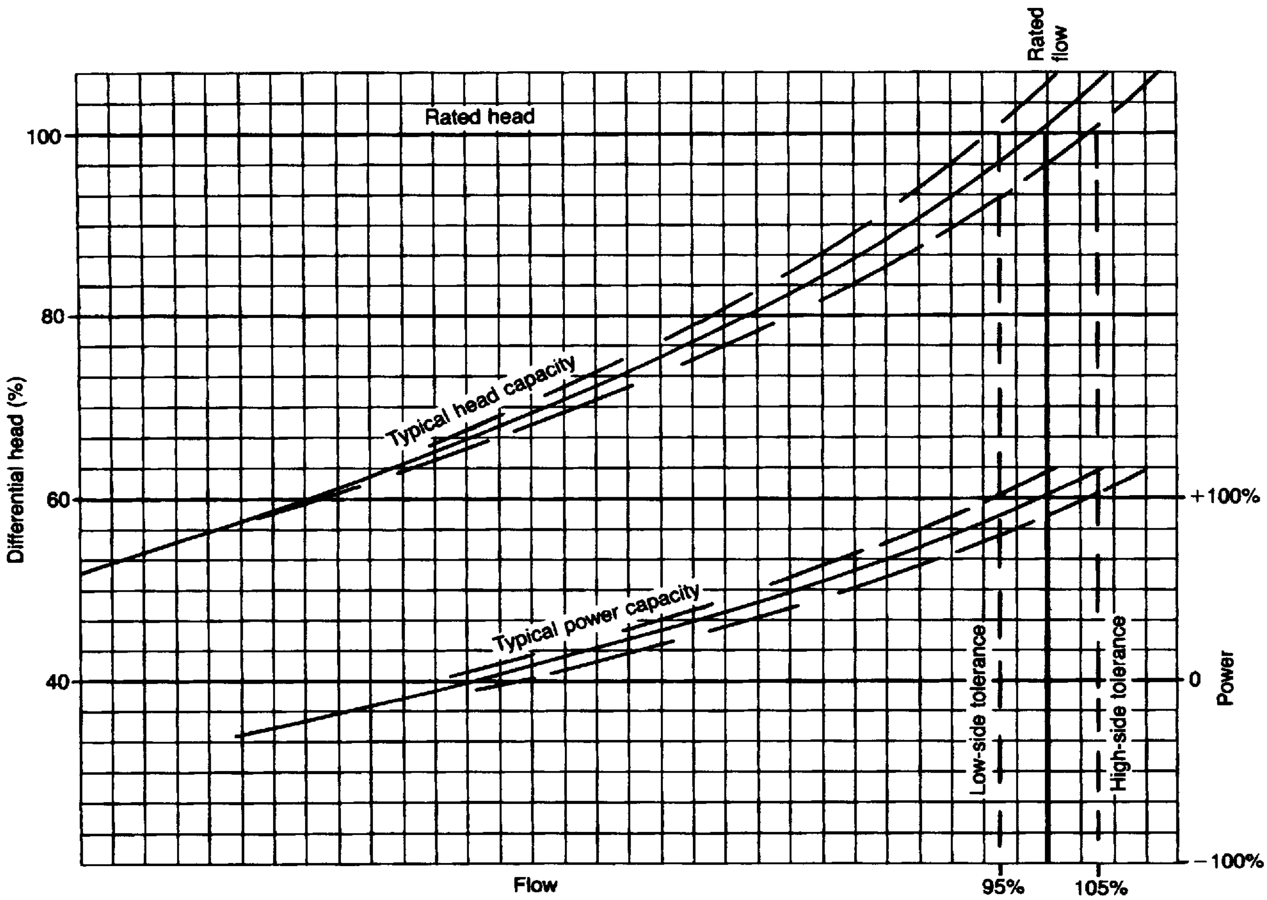



Figure E-1—Typical HPRT Arrangements




Note: When hydraulic power recovery turbines are operated at rated speed, they should achieve their rated power output and rated differential head at a flow within ±5 percent of rated flow.

Figure E-2—HPRT Test Performance Tolerances

# APPENDIX F—CRITERIA FOR PIPING DESIGN

## F.1 Horizontal Pumps

**F.1.1** Acceptable piping configurations should not cause excessive misalignment between the pump and driver. Piping configurations that produce component nozzle loads lying within the ranges specified in Table 2.1A (2.1B) will limit casing distortion to one half the pump vendor's design criterion (see 2.2.8) and will ensure pump shaft displacement of less than 250 µm (0.010 in.).

**F.1.2** Piping configurations that produce loads outside the ranges specified in Table 2.1A (2.1B) are also acceptable without consultation with the pump vendor if the conditions specified in F.1.2.1 through F.1.2.3 are satisfied. Satisfying these conditions will ensure that any pump casing distortion will be within the vendors design criteria (see 2.2.8) and that the displacement of the pump shaft will be less than 380 µm (0.015 in. ). Note: This is a criterion for piping design only.

**F.1.2.1** The individual component forces and moments acting on each pump nozzle flange shall not exceed the range specified in Table 2.1A (2.1B) by a factor of more than 2.

**F.1.2.2** The resultant applied force ($FRS_A$, $FRD_A$) and the resultant applied moment ($MRS_A$, $MRD_A$) acting on each pump nozzle flange shall satisfy the appropriate interaction equation (Equations F-1 and F-2).

$$(FRS_A / 1.5FRS_{T2}) + (MRS_A / 1.5MRS_{T2}) \le 2 \qquad \text{(F-1)}$$

$$(FRD_A / 1.5FRD_{T2}) + (MRD_A / 1.5MRD_{T2}) \le 2 \qquad \text{(F-2)}$$

**F.1.2.3** The applied component forces and moments acting on each pump nozzle flange must be translated to the center of the pump. The magnitude of the resultant applied force ($FRC_A$), the resultant applied moment ($MRC_A$), and the applied moment shall be limited by Equations F-3, F-4, and F-5. (The sign convention shown in Figures 2.2–2.6 and the right hand rule should be used in evaluating these equations.)

$$FRC_A < 1.5(FRS_{T2} + FRD_{T2}) \qquad \text{(F-3)}$$

$$MYC_A < 2.0(MYS_{T2} + MYD_{T2})^{0.5} \qquad \text{(F-4)}$$

$$MRC_A < 1.5(MRS_{T2} + MRD_{T2}) \qquad \text{(F-5)}$$

*Where:*

$$FRC_A = [(FXC_A)^2 + (FYC_A)^2 + (FZC_A)^2]^{0.5}$$

$$FXC_A = FXS_A + FXD_A$$

$$FYC_A = FYS_A + FYD_A$$

$$FZC_A = FZS_A + FZD_A$$

$$MRC_A = [(MXC_A)^2 + (MYC_A)^2 + (MZC_A)^2]^{0.5}$$

$$MXC_A = MXS_A + MXD_A - [(FYS_A)(zS) + (FYD_A)(zD) - (FZS_A)(yS) - (FZD_A)(yD)] / 1000$$

$$MYC_A = MYS_A + MYD_A + [(FXS_A)(zS) + (FXD_A)(zD) - (FZS_A)(xS) - (FZD_A)(xD)] / 1000$$

$$MZC_A = MZS_A + MZD_A - [(FXS_A)(yS) + (FXD_A)(yD) - (FYS_A)(xS) - (FYD_A)(xD)] / 1000$$

Note: When U.S. units are used, the constant 1000 must be changed to 12. This constant is the conversion factor to change millimeters to meters or inches to feet.

**F.1.3** Piping configurations that produce loads greater than those allowed in F.1.2 shall be mutually approved by the purchaser and the vendor.

## F.2 Vertical In-Line Pumps

Vertical in-line pumps that are supported only by the attached piping may be subjected to component piping loads that are more than double the values shown in Table 2.1A (2.1B) if these loads do not cause a principal stress greater than 41 MPa (5950 psi) in either nozzle. For calculation purposes, the section properties of the pump nozzles shall be based on Schedule 40 pipe whose nominal size is equal to that of the appropriate pump nozzle. Equations F-6A (F-6B), F-7A (F-7B), and F-8A (F-8B) can be used to evaluate principal stress, longitudinal stress, and shear stress, respectively, in the nozzles.

$$P = (\sigma / 2) + (\sigma^2 / 4 + \tau^2)^{0.5} < 41 \qquad \text{(F-6A)}$$

$$\sigma = [1.27\, FY / (D_O^2 - D_I^2)] + [1.02 \times 10^4 D_O (MX^2 + MZ^2)^{0.5}] / (D_O^4 - D_I^4) \qquad \text{(F-7A)}$$

$$\tau = [1.27 (FX^2 + FZ^2)^{0.5}] / (D_O^2 - D_I^2) + [0.51 \times 10^4 D_O (MY)] / (D_O^4 - D_I^4) \qquad \text{(F-8A)}$$

For U.S. units, the following equations apply:

$$P = (\sigma / 2) + (\sigma^2 / 4 + \tau^2)^{0.5} < 5950 \qquad \text{(F-6B)}$$

$$\sigma = [1.27\, FY / (D_O^2 - D_I^2)] + [122 D_O (MX^2 + MZ^2)^{0.5}] / (D_O^4 - D_I^4) \qquad \text{(F-7B)}$$

$$\tau = [1.27 (FX^2 + FZ^2)^{0.5}] / (D_O^2 - D_I^2) + [61 D_O (MY)] / (D_O^4 - D_I^4) \qquad \text{(F-8B)}$$

Note: *FX*, *FY*, *FZ*, *MX*, *MY*, and *MZ* represent the applied loads acting on the suction or discharge nozzles; thus, suffixes $S_A$ and $D_A$ have been omitted to simplify the equations. The sign of *FY* is positive if the load puts the nozzle in tension; the sign is negative if the load puts the nozzle in compression. One must refer to Figure 2.2 and the applied nozzle loads to determine whether the nozzle is in tension or compression. The absolute value of *MY* should be used in Equation F-8A (F-8B).

## F.3 Nomenclature

The following definitions apply to the sample problems in F-4:

$C$ = center of the pump. For pump types OH2 and BB2 with two support pedestals, the center is defined by the intersection of the pump shaft centerline and a vertical plane passing through the center of the two pedestals (see Figures 2.5 and 2.6). For pump types BB1, BB3, BB4 and BB5 with four support pedestals, the center is defined by the intersection of the pump shaft centerline and a vertical plane passing midway between the four pedestals (see Figure 2-4).

$D$ = discharge nozzle.

$D_I$ = inside diameter of Schedule 40 pipe whose nominal size is equal to that of the pump nozzle in question, in mm (in.).

$D_O$ = outside diameter of Schedule 40 pipe whose nominal size is equal to that of the pump nozzle in question, in mm (in.).

$F$ = force, in N (lbs).

$FR$ = resultant force. ($FRS_A$ and $FRD_A$ are calculated by the square root of the sum of the squares method using the applied component forces acting on the nozzle flange. $FRS_{T2}$ and $FRD_{T2}$ are extracted from Table 2.1A (2.1B), using the appropriate nozzle size.)

$M$ = moment, in Nm (ft-lb).

$MR$ = resultant moment. ($MRS_A$ and $MRD_A$ are calculated by the square root of the squares method using the applied component moments acting on the nozzle flange. $MRS_{T2}$ and $MRD_{T2}$ are extracted from Table 2.1A (2.1B) using the appropriate nozzle size.)

$P$ = principle stress, in MPa (psi).

$S$ = suction nozzle.

x, y, z = location coordinates of the nozzle flanges with respect to the center of the pump, in mm (in.).

X, Y, Z = direction of the loads (see Figures 2.2–2.6).

$\sigma$ = longitudinal stress, in MPa (psi).

$\tau$ = shear stress, in MPa (psi).

Subscript $A$ = applied loads.

Subscript $T2$ = loads extracted from Table 2-1A (2-1B).

## F.4 Sample Problems

### F.4.1 EXAMPLE 1A ( S.I. UNITS)

#### F.4.1.1 Problem

For an overhung end suction process pump, the nozzle sizes and location coordinates are as given in Table F-1A. The applied nozzle loadings are as given in Table F-2A. The problem is to determine whether the conditions specified in F.1.2.1, F.1.2.2, and F.1.2.3 are satisfied.

#### F.4.1.2 Solution

**F.4.1.2.1** A check of condition F.1.2.1 is as follows:

For the 10NPS end suction nozzle,

$|FXS_A / FXS_{T2}| = |+12{,}900 / 6670| = 1.93 < 2.00$

$|FYS_A / FYS_{T2}| = |0 / 5340| = 0 < 2.00$

$|FZS_A / FZS_{T2}| = |-8852 / 4450| = 1.99 < 2.00$

$|MXS_A / MXS_{T2}| = |-1356 / 5020| = 0.27 < 2.00$

$|MYS_A / MYS_{T2}| = |-5017 / 2440| = 2.06 > 2.00$

$|MZS_A / MZS_{T2}| = |-7458 / 3800| = 1.96 < 2.00$

Since $MYS_A$ exceeds the specified in Table 2.1A by more than a factor of 2, it is not satisfactory. Assume that $MYS_A$ can be reduced to -4879. Then,

$|MYS_A / MYS_{T2}| = |-4879 / 2440| = 1.9996 < 2.00$

For the 8NPS top discharge nozzle,

$|FXD_A / FXD_{T2}| = |+7117 / 3780| = 1.88 < 2.00$

$|FYD_A / FYD_{T2}| = |-445 / 3110| = 0.14 < 2.00$

$|FZD_A / FZD_{T2}| = |+8674 / 4890| = 1.77 < 2.00$

$|MXD_A / MXD_{T2}| = |+678 / 3530| = 0.19 < 2.00$

$|MYD_A / MYD_{T2}| = |-3390 / 1760| = 1.93 < 2.00$

$|MZD_A / MZD_{T2}| = |-4882 / 2580| = 1.89 < 2.00$

Provided that $MYS_A$ can be reduced to –4879, the applied piping loads acting on each nozzle satisfy the condition specified in F.1.2.1.

**F.4.1.2.2** A check of condition F.1.2.2 is as follows:

For the suction nozzle, $FRS_A$ and $MRS_A$ are determined using the square root of the sum of the squares method:

Table F-1A—Nozzle Sizes and Location Coordinates for Example 1A

| Nozzle | Size (mm) | x (mm) | y (mm) | z (mm) |
|---|---|---|---|---|
| Suction | 10NPS | +267 | 0 | 0 |
| Discharge | 8NPS | 0 | –311 | +381 |

**Table F-2A—Applied Nozzle Loadings for Example 1A**

| Force | Value (newtons) | Moment | Value (newton meters) |
|---|---|---|---|
| | | Suction | |
| $FXS_A$ | +12900 | $MXS_A$ | –1356 |
| $FYS_A$ | 0 | $MYS_A$ | –5017[a] |
| $FZS_A$ | –8852 | $MZS_A$ | –7458 |
| | | Discharge | |
| $FXD_A$ | +7117 | $MXD_A$ | +678 |
| $FYD_A$ | –445 | $MYD_A$ | –3390 |
| $FZD_A$ | +8674 | $MZD_A$ | –4882 |

[a]See F.4.1.2.1.

$FRS_A = [(FXS_A)^2 + (FYS_A)^2 + (FZS_A)^2]^{0.5}$

$= [(+12{,}900)^2 + (0)^2 + (-8852)^2]^{0.5} = 15645$

$MRS_A = [(MXS_A)^2 + (MYS_A)^2 + (MZS_A)^2]^{0.5}$

$= [(-1356)^2 + (-4879)^2 + (-7458)^2]^{0.5} = 9015$

Referring to Equation F-1,

$(FRS_A / 1.5FRS_{T2}) + (MRS_A / 1.5MRS_{T2}) \le 2$

$15645 / [1.5(9780)] + 9015 / [1.5(6750)] \le 2$

$1.96 < 2$

For the discharge nozzle, $FRD_A$ and $MRD_A$ are determined by the same method used to find $FRS_A$ and $MRS_A$:

$FRD_A = [(FXD_A)^2 + (FYD_A)^2 + (FZD_A)^2]^{0.5}$

$= [(+7117)^2 + (-445)^2 + (+8674)^2]^{0.5} = 11229$

$MRD_A = [(MXD_A)^2 + (MYD_A)^2 + (MZD_A)^2]^{0.5}$

$= [(+678)^2 + (-3390)^2 + (-4882)^2]^{0.5} = 5982$

Referring to Equation F-2,

$(FRD_A / 1.5FRD_{T2}) + (MRD_A / 1.5MRD_{T2}) \le 2$

$11229 / [1.5(6920)] + 5982 / [1.5(4710)] \le 2$

$1.93 < 2$

The loads acting on each nozzle satisfy the appropriate interaction equation, so the condition specified in F.1.2.2 is satisfied.

**F.4.1.2.3** A check of condition F.1.2.3 is as follows:

To check this condition, the applied component forces and moments are translated and resolved to the center of the pump. $FRC_A$ is determined as follows (see F.1.2.3):

$FXC_A = FXS_A + FXD_A$

$FYC_A = FYS_A + FYD_A$

$FZC_A = FZS_A + FZD_A$

$FRC_A = [(FXC_A)^2 + (FYC_A)^2 + (FZC_A)^2]^{0.5}$

$FXC_A = (+12900) + (+7117) = +20017$

$FYC_A = (0) + (-445) = -445$

$FZC_A = (-8852) + (+8674) = -178$

$FRC_A = [(+20017)^2 + (-445)^2 + (-178)^2]^{0.5} = 20023$

Referring to Equation F-3,

$FRC_A < 1.5(FRS_{T2} + FRD_{T2})$

$20023 < 1.5(9780 + 6920)$

$20023 < 25050$

$MYC_A$ is determined as follows (see F.1.2.3):

$MYC_A = MYS_A + MYD_A + [(FXS_A)(zS) + (FXD_A)(zD) - (FZS_A)(xS) - (FZD_A)(xD)] / 1000$

$= (-4879) + (-3390) + [(+12900)(0.00) + (+7117)(+381) - (-8852)(+267) - (+8674)(0.00)] / 1000 = -3194$

Referring to Equation F-4,

$MYC_A < 2.0(MYS_{T2} + MYD_{T2})$

$-3194 < 2.0(2440 + 1760)$

$-3194 < 8400$

$MRC_A$ is determined as follows (see F.1.2.3):

$MXC_A = MXS_A + MXD_A - [(FYS_A)(zS) + (FYD_A)(zD) - (FZS_A)(yS) - (FZD_A)(yD)] / 1000$

$MYC_A = MYS_A + MYD_A + [(FXS_A)(zS) + (FXD_A)(zD) - (FZS_A)(xS) - (FZD_A)(xD)] / 1000$

$MZC_A = MZS_A + MZD_A - [(FXS_A)(yS) + (FXD_A)(yD) - (FYS_A)(xS) - (FYD_A)(xD)] / 1000$

$MRC_A = [F(MXC_A)^2 + (MYC_A)^2 + (MZC_A)^2]^{0.5}$

$MXC_A = (-1356) + (+678) - [(0)(0.00) + (-445)(+381) - (-8852)(0.00) - (+8674)(-311)] / 1000$
$= -3206$

$MYC_A = -3194$ (see previous calculation)

$MZC_A = (-7458) + (-4882) - [(+12900)(0.00) + (+7117)(-311) - (0)(+267) - (-445)(0.00)] / 1000$
$= -10127$

$MRC_A = [(-3206)^2 + (-3194)^2 + (-10127)^2]^{0.5} = 11092$

Referring to Equation F-5,

$MRC_A < 1.5(MRS_{T2} + MRD_{T2})$

$11092 < 1.5(6750 + 4710)$

$11092 < 17190$

Thus, all of the requirements of F.1.2.3 have been satisfied.

### F.4.2 EXAMPLE 2A (S.I. UNITS)

#### F.4.2.1 Problem

For an 80 × 100 × 178 vertical in-line pump, the proposed applied nozzle loadings are as given in Table F-3A. By in-

Table F-3A—Proposed Applied Nozzle Loadings for Example 2A

| Force<br>Force | Value<br>(N) | Moment<br>4NPS Suction | Value<br>(Nm) |
|---|---|---|---|
| $FXS_A$ | -2224 | $MXS_A$ | +136 |
| $FYS_A$ | -5338 | $MYS_A$ | -2034 |
| $FZS_A$ | +1334 | $MZS_A$ | +1356 |
| | | 3NPS Discharge | |
| $FXD_A$ | +1334 | $MXD_A$ | +2712 |
| $FYD_A$ | -2224 | $MYD_A$ | +271 |
| $FZD_A$ | +445 | $MZD_A$ | +136 |

spection, $FZS_A$, $MZS_A$, and $MXD_A$ are greater than two times the values shown in Table 2.1A . As stated in F.2, these component loads are acceptable provided that the calculated principal stress is less than 41 MPa. The problem is to determine the principal stress for the suction nozzle and the discharge nozzle.

### F.4.2.2 Solution

**F.4.2.2.1** Suction nozzle calculations are as follows: For Schedule 40 pipe with a nominal size of 100 mm, $D_O$ = 114 mm and $D_I$ = 102 mm. Therefore,

$$D_O^2 - D_I^2 = (114)^2 - (102)^2 = 2592$$

$$D_O^4 - D_I^4 = (114)^4 - (102)^4 = 6.065 \times 10^7$$

$$[(FXS_A)^2 + (FZS_A)^2]^{0.5} = [(-2224)^2 + (+1334)^2]^{0.5} = 2593$$

$$[(MXS_A)^2 + (MZS_A)^2]^{0.5} = [(-136)^2 + (+1356)^2]^{0.5} = 1363$$

Equation F-7A is used to determine the longitudinal stress for the suction nozzle, $\sigma_s$.

Note: the applied $FYS_A$ load acting on the suction nozzle is in the negative $Y$ direction and will produce a compressive stress; therefore, the negative sign on $FYS_A$ is used.

$$\sigma_s = [1.27\ FYS_A / (D_O^2 - D_I^2)] + [1.02 \times 10^4 D_O(MXS_A^2 + MZS_A^2)^{0.5}] / (D_O^4 - D_I^4)$$

$$= [1.27(-5338)/ 2592] + [1.02 \times 10^4(114)(1363)] / 6.065 \times 10^7 = 23.52$$

Equation F-8A is used to determine the shear stress for the suction nozzle, $\tau_s$.

$$\tau_s = [1.27(FXS_A^2 + FZS_A^2)^{0.5}] / (D_O^2 - D_I^2)] + [0.51 \times 10^4 D_O(MYS_A)] / (D_O^4 - D_I^4)$$

$$= [1.27(2593) / 2592] + [0.51 \times 10^4(114)(|-2034|)] / 6.065 \times 10^7] = 20.77$$

The principal stress for the suction nozzle, $P_s$, is calculated using Equation F-6A:

$$P_s = (\sigma_s / 2) + (\sigma_s^2 / 4 + \tau_s^2)^{0.5} < 41$$

$$= (+23.52 / 2) + [(+23.52)^2/ 4 + (+20.77)^2]^{0.5}$$

$$= +35.63 < 41$$

Thus, the suction nozzle loads are satisfactory.

**F.4.2.2.2** Discharge nozzle calculations are as follows:

For Schedule 40 pipe with a nominal size of 80 mm, $D_O$ = 89 mm and $D_I$ = 78 mm. Therefore,

$$D_O^2 - D_I^2 = (89)^2 - (78)^2 = 1837$$

$$D_O^4 - D_I^4 = (89)^4 - (78)^4 = 2.573 \times 10^7$$

$$[(FXD_A)^2 + (FZD_A)^2]^{0.5} = [(+1334)^2 + (+445)^2]^{0.5} = 1406$$

$$[(MXD_A)^2 + (MZD_A)^2]^{0.5} = [(+2712)^2 + (+136)^2]^{0.5} = 2715$$

Equation F-7A is used to determine the longitudinal stress for the discharge nozzle, $\sigma_D$.

Note: the applied $FYD_A$ load acting on the discharge nozzle is in the negative $Y$ direction and will produce a tensile stress; therefore, a positive sign on $FYD_A$ is used.

$$\sigma_D = [1.27\ FYD_A / (D_O^2 - D_I^2)] + [1.02 \times 10^4 D_O(MXD_A^2 + MZD_A^2)^{0.5}] / (D_O^4 - D_I^4)$$

$$= [1.27(+2224) / 1837] + [1.02 \times 10^4(89)(2715)] / 2.573 \times 10^7 = 97.33$$

Equation F-8A is used to determine the shear stress for the discharge nozzle, $\tau_D$.

$$\tau_D = [1.27(FXD_A^2 + FZD_A^2)^{0.5}] / (D_O^2 - D_I^2)] + [0.51 \times 10^4 D_O(MYD_A)] / (D_O^4 - D_I^4)$$

$$= [1.27(1406) / 1837] + [0.51 \times 10^4(89)(|+271|)] / 2.573 \times 10^7] = 5.75$$

The principal stress for the discharge nozzle, $P_D$, is calculated using Equation F-6A:

$$P_D = (\sigma_D / 2) + (\sigma_D^2 / 4 + \tau_D^2)^{0.5} < 41$$

$$= (+97.33/2) + [(+97.33)^2/ 4 + (+5.75)^2]^{0.5}$$

$$= +97.67 > 41$$

Thus, the discharge nozzle loads are too large. By inspection, if $MXD_A$ is reduced by 50 percent to 1356 Nm, the resulting principal stress will still exceed 41 MPa. Therefore, the maximum value for $MXD_A$ will be twice $MXD_{T2}$, or 1900 Nm.

### F.5.1 EXAMPLE 1B (U.S. UNITS)

#### F.5.1.1 Problem

For an overhung end-suction process pump, the nozzle sizes and location coordinates are as given in Table F-1B. The applied nozzle loadings are as given in Table F-2B. The

Table F-1B—Nozzle Sizes and Location Coordinates for Example 1B

| Nozzle | Size (in.) | x (in.) | y (in.) | z (in.) |
|---|---|---|---|---|
| Suction | 10 | +10.50 | 0 | 0 |
| Discharge | 8 | 0 | −12.25 | +15 |

problem is to determine whether the conditions specified in F.1.2.1, F.1.2.2, and F.1.2.3 are satisfied.

### F.5.1.2 Solution

**F.5.1.2.1** A check of condition of F.1.2.1 is as follows:

For the 10-in. end suction nozzle,

$|FXS_A / FXS_{T2}| = |+2900 / 1500| = 1.93 < 2.00$

$|FYS_A / FYS_{T2}| = |0 / 1200| = 0 < 2.00$

$|FZS_A / FZS_{T2}| = |-1990 / 1000| = 1.99 < 2.00$

$|MXS_A / MXS_{T2}| = |-1000 / 3700| = 0.27 < 2.00$

$|MYS_A / MYS_{T2}| = |-3700 / 1800| = 2.06 > 2.00$

$|MZS_A / MZS_{T2}| = |-5500 / 2800| = 1.96 < 2.00$

Since $MYS_A$ exceeds the specified in Table 2.1B by more than a factor of 2, it is not satisfactory. Assume that $MYS_A$ can be reduced to –3599. Then,

$|MYS_A / MYS_{T2}| = |-3599 / 1800| = 1.9996 < 2.00$

For the 8-in. top discharge nozzle,

$|FXD_A / FXD_{T2}| = |+1600 / 850| = 1.88 < 2.00$

$|FYD_A / FYD_{T2}| = |-100 / 700| = 0.14 < 2.00$

$|FZD_A / FZD_{T2}| = |+1950 / 1100| = 1.77 < 2.00$

$|MXD_A / MXD_{T2}| = |+500 / 2600| = 0.19 < 2.00$

$|MYD_A / MYD_{T2}| = |-2500 / 1300| = 1.93 < 2.00$

$|MZD_A / MZD_{T2}| = |-3600 / 1900| = 1.89 < 2.00$

Provided that $MYS_A$ can be reduced to –3599, the applied piping loads acting on each nozzle satisfy the condition specified in F.1.2.1.

Table F-2B—Applied Nozzle Loadings for Example 1B

| Force | Value (lbs) | Moment | Value (ft-lbs) |
|---|---|---|---|
| | | Suction | |
| $FXS_A$ | + 2900 | $MXS_A$ | −1000 |
| $FYS_A$ | 0 | $MYS_A$ | −3700[a] |
| $FZS_A$ | −1990 | $MZS_A$ | −5500 |
| | | Discharge | |
| $FXD_A$ | +1600 | $MXD_A$ | +500 |
| $FYD_A$ | −100 | $MYD_A$ | −2500 |
| $FZD_A$ | +1950 | $MZD_A$ | −3600 |

[a] See F.4.1.2.1

**F.5.1.2.2** A check of condition F.1.2.2 is as follows:

For the suction nozzle, $FRS_A$ and $MRS_A$ are determined using the square root of the sum of the squares method:

$FRS_A = [(FXS_A)^2 + (FYS_A)^2 + (FZS_A)^2]^{0.5}$

$= [(+2900)^2 + (0)^2 + (-1990)^2]^{0.5} = 3517$

$MRS_A = [(MXS_A)^2 + (MYS_A)^2 + (MZS_A)^2]^{0.5}$

$= [(-1000)^2 + (-3599)^2 + (-5500)^2]^{0.5} = 6649$

Referring to Equation F-1,

$(FRS_A / 1.5FRS_{T2}) + (MRS_A / 1.5MRS_{T2}) \leq 2$

$3517 / [1.5(2200)] + 6649 / [1.5(5000)] \leq 2$

$1.95 < 2$

For the discharge nozzle, $FRD_A$ and $MRD_A$ are determined by the same method used to find $FRS_A$ and $MRS_A$:

$FRD_A = [(FXD_A)^2 + (FYD_A)^2 + (FZD_A)^2]^{0.5}$

$= [(+1600)^2 + (-100)^2 + (+1950)^2]^{0.5} = 2524$

$MRD_A = [MXD_A)^2 + (MYD_A)^2 + (MZD_A)^2]^{0.5}$

$= [(+500)^2 + (-2500)^2 + (-3600)^2]^{0.5} = 4411$

Referring to Equation F-2,

$(FRD_A / 1.5FRD_{T2}) + (MRD_A / 1.5MRD_{T2}) \leq 2$

$2524 / [1.5(1560)] + 4411 / [1.5(3500)] \leq 2$

$1.92 < 2$

The loads acting on each nozzle satisfy the appropriate interaction equation, so the condition specified in F.1.2.2 is satisfied.

**F.5.1.2.3** A check of condition F.1.2.3 is as follows:

To check this condition, the applied component forces and moments are translated and resolved to the center of the pump. $FRC_A$ is determined as follows (see F.1.2.3):

$FXC_A = FXS_A + FXD_A$

$FYC_A = FYS_A + FYD_A$

$FZC_A = FZS_A + FZD_A$

$FRC_A = [(FXC_A)^2 + (FYC_A)^2 + (FZC_A)^2]^{0.5}$

$FXC_A = (+2900) + (+1600) = +4500$

$FYC_A = (0) + (-100) = -100$

$FZC_A = (-1990) + (+1950) = -40$

$FRC_A = [(+4500)^2 + (-100)^2 + (-40)^2]^{0.5} = 4501$

Referring to Equation F-3,

$FRC_A < 1.5(FRS_{T2} + FRD_{T2})$

$4501 < 1.5(2200 + 1560)$

$4501 < 5640$

$MYC_A$ is determined as follows (see F.1.2.3):

$MYC_A = MYS_A + MYD_A + [(FXS_A)(zS) + (FXD_A)(zD) - (FZS_A)(xS) - (FZD_A)(xD)] / 12$

$= (-3599) + (-2500) + [(+2900)(0.00) + (+1600)(+15) - (-1990)(+10.5) - (+1950)(0.00)] / 12$

$= -2358$

Referring to Equation F-4,

$| MYC_A | < 2.0(MYS_{T2} + MYD_{T2})$

$| -2358 | < 2.0(1800 + 1300)$

$2358 < 6200$

$MRC_A$ is determined as follows (see F.1.2.3):

$MXC_A = MXS_A + MXD_A - [(FYS_A)(zS) + (FYD_A)(zD) - (FZS_A)(yS) - (FZD_A)(yD)] / 12$

$MYC_A = MYS_A + MYD_A + [(FXS_A)(zS) + (FXD_A)(zD) - (FZS_A)(xS) - (FZD_A)(xD)] / 12$

$MZC_A = MZS_A + MZD_A - [(FXS_A)(yS) + (FXD_A)(yD) - (FYS_A)(xS) - (FYD_A)(xD)] / 12$

$MRC_A = [(MXC_A)^2 + (MYC_A)^2 + (MZC_A)^2]^{0.5}$

$MXC_A = (-1000) + (+500) - [(0)(0.00) + (-100)(+15.00) - (-1990)(0.00) - (+1950)(-12.25)] / 12 = -2366$

$MYC_A = -2358$ (see previous calculation)

$MZC_A = (-5500) + (-3600) - [(+2900)(0.00) + (+1600)(-12.25) - (0)(+10.50) - (-100)(0.00)] / 12 = -7467$

$MRC_A = [(-2366)^2 + (-2358)^2 + (-7467)^2]^{0.5} = 8180$

Referring to Equation F-5,

$MRC_A < 1.5(MRS_{T2} + MRD_{T2})$

$8180 < 1.5(5000 + 3500)$

$8180 < 12750$

Thus, all of the requirements of F.1.2.3 have been satisfied.

## F.5.2 EXAMPLE 2B (U. S. CUSTOMARY UNITS)

### F.5.2.1 Problem

For a 3 × 4 × 7 vertical in-line pump, the proposed applied nozzle loadings are as given in Table F-3B. By inspection, $FZS_A$, $MZS_A$, and $MXD_A$ are greater than two times the values shown in Table 2.1B. As stated in F.2, these component loads are acceptable provided that the calculated principal stress is less than 5950 psi. The problem is to determine the principal stress for the suction nozzle and the discharge nozzle.

**Table F-3B—Proposed Applied Nozzle Loadings for Example 2B**

| Force | Value (N) | Moment | Value (Nm) |
|---|---|---|---|
| | | 4NPS | |
| $FXS_A$ | –500 | $MXS_A$ | +100 |
| $FYS_A$ | –1200 | $MYS_A$ | –1500 |
| $FZS_A$ | +300 | $MZS_A$ | +1000 |
| | | 3NPS | |
| $FXD_A$ | +300 | $MXD_A$ | +2000 |
| $FYD_A$ | –500 | $MYD_A$ | +200 |
| $FZD_A$ | +100 | $MZD_A$ | +100 |

### F.5.2.2 SOLUTION

**F.5.2.2.1** Suction nozzle calculations are as follows:

For Schedule-40 pipe with a nominal size of 4 in., $D_O$ = 4.500 in. and $D_I$ = 4.026 in. Therefore,

$D_O^2 - D_I^2 = (4.500)^2 - (4.026)^2 = 4.04$

$D_O^4 - D_I^4 = (4.500)^4 - (4.026)^4 = 147.34$

$[(FXS_A)^2 + (FZS_A)^2]^{0.5} = [(-500)^2 + (+300)^2]^{0.5} = 583$

$[(MXS_A)^2 + (MZS_A)^2]^{0.5} = [(-100)^2 + (+1000)^2]^{0.5} = 1005$

Equation F-7B is used to determine the longitudinal stress for the suction nozzle, $\sigma_s$.

Note: The applied $FYS_A$ load acting on the suction nozzle is in the negative $Y$ direction and will produce a compressive stress; therefore, the negative sign on $FYS_A$ is used.

$\sigma_s = [1.27\,FYS_A / (D_O^2 - D_I^2)] + [212 D_O (MXS_A^2 + MZS_A^2)^{0.5}] / (D_O^4 - D_I^4)$

$= [1.27(-1200)/4.04] + [122(4.500)(1005)] / 147.34$

$= 3367$

Equation F-8B is used to determine the shear stress for the suction nozzle, $\tau_s$.

$\tau_s = [1.27(FXS_A^2 + FZS_A^2)^{0.5}] / (D_O^2 - D_I^2)] + [61 D_O (MYS_A)] / (D_O^4 - D_I^4)$

$= [1.27(583)/4.04] + [61(4.500)(|-1500|)] / 147.34] = 2978$

The principal stress for the suction nozzle, $P_s$, is calculated using Equation F-6B:

$P_s = (\sigma_s / 2) + (\sigma_s^2 / 4 + \tau_s^2)^{0.5} < 5950$

$= (+3367/2) + [(+3367)^2/4 + (+2978)^2]^{0.5}$

$= +5105 < 5950$

Thus, the suction nozzle loads are satisfactory.

**F.5.2.2.2** Discharge nozzle calculations are as follows:

For Schedule-40 pipe with a nominal size of 3 in., $D_O$ = 3.500, and $D_I$ = 3.068. Therefore,

$D_O^2 - D_I^2 = (3.500)^2 - (3.068)^2 = 2.84$

$D_O^4 - D_I^4 = (3.500)^4 - (3.068)^4 = 61.47$

$[(FXD_A)^2 + (FZD_A)^2]^{0.5} = [(+300)^2 + (+100)^2]^{0.5} = 316$

$[(MXD_A)^2 + (MZD_A)^2]^{0.5} = [(+2000)^2 + (+100)^2]^{0.5} = 2002$

Equation F-7B is used to determine the longitudinal stress for the discharge nozzle, $\sigma_D$.

Note: The applied $FYD_A$ load acting on the discharge nozzle is in the negative $Y$ direction and will produce a tensile stress; therefore, a positive sign on $FYD_A$ is used.

$$\sigma_D = [1.27\ FYD_A / (D_O^2 - D_I^2)] + [122 D_O (MXD_A^2 + MZD_A^2)^{0.5}] / (D_O^4 - D_I^4)$$
$$= [1.27(+500) / 2.84] + [122(3.5)(2002)] / 61.47$$
$$= 14131$$

Equation F-8B is used to determine the shear stress for the discharge nozzle, $\tau_D$.

$$\tau_D = [1.27(FXD_A^2 + FZD_A^2)^{0.5}] / (D_O^2 - D_I^2)] + [61 D_O(MYD_A)] / (D_O^4 - D_I^4)$$
$$= [1.27(316) / 2.84] + [61(3.500)(|+200|)] / 61.47] = 836$$

The principal stress for the discharge nozzle, $P_D$, is calculated using Equation F-6B:

$$P_D = (\sigma_D / 2) + (\sigma_D^2 / 4 + \tau_D^2)^{0.5} < 5950$$
$$= (+14131 / 2) + [(+14131)^2 / 4 + (+836)^2]^{0.5} = +14181 > 5950$$

Thus, the discharge nozzle loads are too large. By inspection, if $MXD_A$ is reduced by 50 percent to 1000 ft-lbs the resulting principal stress will still exceed 5950 psi. Therefore, the maximum value for $MXD_A$ will be twice $MXD_{T2}$, or 1400 ft-lbs.

# APPENDIX G—MATERIAL CLASS SELECTION GUIDE

## Table G-1—Material Class Selection Guide

**CAUTION:** This table is intended as a general guide for on-plot process plants and off-plot transfer and loading services. It should not be used without a knowledgeable review of the specific services involved.

| Service | Temperature Range °C | Temperature Range °F | Pressure Range | Material Class | See Reference Note |
|---|---|---|---|---|---|
| Fresh water, condensate, cooling tower water | <100 | <212 | All | I-1 or I-2 | |
| Boiling water and process water | <120 | <250 | All | I-1 or I-2 | 5 |
| | 120–175 | 250-350 | All | S-5 | 5 |
| | >175 | >350 | All | C-6 | 5 |
| Boiler feed water | | | | | |
| Axially split | >95 | >200 | All | C-6 | |
| Double casing (barrel) | >95 | >200 | All | S-6 | |
| Boiler circulator | >95 | >200 | All | C-6 | |
| Foul water, reflux drum water, water draw, and hydrocarbons containing these | <175 | <350 | All | S-3 or S-6 | 6 |
| waters, including reflux streams | >175 | >350 | All | C-6 | |
| Propane, butane, liquefied petroleum gas, and ammonia ($NH_3$) | <230 | <450 | All | S-1 | |
| Diesel oil; gasoline; naphtha; kerosene; gas oils; light, medium, | <230 | <450 | All | S-1 | |
| and heavy lube oils; fuel oil; residuum; | 230–370 | 450-700 | All | S-6 | 6, 7 |
| crude oil; asphalt; synthetic crude bottoms | >370 | >700 | All | C-6 | 6 |
| Noncorrosive hydrocarbons, e.g., catalytic reformate, isomaxate, desulfurized oils | 230–370 | 450-700 | All | S-4 | 7 |
| Xylene, toluene, acetone, benzene, furfural, MEK, cumene | <230 | <450 | All | S-1 | |
| Sodium carbonate, doctor solution | <175 | <350 | All | I-1 | |
| Caustic (sodium hydroxide) concentration of ≤20% | <100 | <210 | All | S-1 | 8 |
| | ≥100 | ≥200 | All | — | 9 |
| Seawater | <95 | <200 | All | — | 10 |
| Sour water | <260 | <470 | All | D-1 | |
| Sulfur (liquid state) | All | All | All | S-1 | |
| FCC slurry | <370 | <700 | All | C-6 | |
| Potassium carbonate | <175 | <350 | All | C-6 | |
| | <370 | <700 | All | A-8 | |
| MEA, DEA, TEA-stock solutions | <120 | <250 | All | S-1 | |
| DEA, TEA-lean solutions | <120 | <250 | All | S-1 | 8 |
| MEA-lean solution ($CO_2$ only) | 80–150 | 175–300 | All | S-9 | 8 |
| MEA-lean solution ($CO_2$ and $H_2S$) | 80–150 | 175–300 | All | — | 8, 11 |
| MEA, DEA, TEA, rich solutions | <80 | <175 | All | S-1 | 8 |
| Sulfuric acid concentration >85% | <38 | <100 | All | S-1 | 6 |
| 85% – <1% | <230 | <450 | All | A-8 | 6 |
| Hydrofluoric acid concentration of >96% | <38 | <100 | All | S-9 | 6 |

General Notes:
1. The materials for pump parts for each material class are given in Appendix H.
2. Specific materials recommendations should be obtained for services not clearly identified by the service descriptions listed in this table.
3. Cast iron casings, where recommended for chemical services, are for non-hazardous locations only. Steel casings (2.11.1.4) should be used for pumps in services located near process plants or in any location where released vapor from a failure could create a hazardous situation or where pumps could be subjected to hydraulic shock, for example, in loading services.
4. Mechanical seal materials: For streams containing chlorides, all springs and other metal parts should be Alloy 20 or better. Buna N and Neoprene should not be used in any service containing aromatics. Viton should be used in services containing aromatics above 95°C (200°F).

Reference Notes:
5. Oxygen content and buffering of water should be considered in material selection.
6. The corrosiveness of foul waters, hydrocarbons over 230°C (450°F), acids, and acid sludges may vary widely. Material recommendations should be obtained for each service. The material class indicated above will be satisfactory for many of these services, but must be verified.
7. If product corrosivity is low, Class S-4 materials may be used for services at 231°–370°C (451°–700°F). Specific material recommendations should be obtained in each instance.
8. All welds shall be stress relieved.
9. Alloy 20 or Monel pump material and dual mechanical seals should be used with a pressurized seal oil system.
10. For seawater service, the purchaser and the vendor should agree on the construction materials that best suit the intended use.
11. Class A-7 materials should be used except for carbon steel casings.

# APPENDIX H—MATERIALS AND MATERIAL SPECIFICATIONS FOR PUMP PARTS

## Table H-1 - Materials for Pump Parts

| Part | Full[b] Compliance Material? | I-1 | I-2 | S-1 | S-3 | S-4 | S-5 | S-6 | S-8 | S-9 | C-6 | A-7 | A-8 | D-1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Material Class and Material Abbreviations[a] | | CI / CI | CI / BRZ | STL / CI | STL / NI-RESIST | STL / STL | STL / STL 12% CHR | STL / 12% CHR | STL / 316 AUS | STL / MONEL | 12% CHR / 12% CHR | AUS / AUS (1&2) | 316AUS / 316 AUS(1&2) | DUPLEX / DUPLEX |
| Pressure Casing | Yes | Cast iron | Cast iron | Carbon steel | Carbon steel | Carbon steel | Carbon steel | Carbon steel | Carbon steel | Carbon steel | 12% CHR | AUS | 316 AUS | Duplex |
| Inner case parts (bowls, diffusers, diaphragms) | No | Cast iron | Bronze | Cast iron | Ni-resist | Cast iron | Carbon steel | 12% CHR | 316 AUS | Monel | 12% CHR | AUS | 316 AUS | Duplex |
| Impeller | Yes | Cast iron | Bronze | Cast iron | Ni-resist | Carbon steel | Carbon steel | 12% CHR | 316 AUS | Monel | 12% CHR | AUS | 316 AUS | Duplex |
| Case wear rings | No | Cast iron | Bronze | Cast iron | Ni-resist | Cast iron | 12% CHR | 12% CHR | Hard Faced 316 AUS (3) | Monel | 12% CHR hardened | Hard Faced AUS (3) | Hard Faced 316 AUS (3) | Duplex (3) |
| Impeller wear rings | No | Cast iron | Bronze | Cast iron | Ni-resist | Cast iron | 12% CHR Hardened | 12% CHR Hardened | Hard faced 316 AUS (3) | Monel | 12% CHR hardened | Hard Faced AUS (3) | Hard Faced 316 AUS (3) | Duplex (3) |
| Shaft (2) | Yes | Carbon steel | Carbon steel | Carbon steel | Carbon steel | Carbon steel | AISI 4140 | AISI 4140 (4) | 316 AUS | K-Monel | 12% CHR | AUS | 316 AUS | Duplex |
| Shaft sleeves, packed pumps | No | 12% CHR hardened | Hard bronze | 12% CHR hardened | 12% CHR hardened or hard faced | 12% CHR hardened or hard faced | 12% CHR hardened or hard faced | 12% CHR hardened or hard faced | Hard Face 316 AUS (3) | K-Monel, hardened | 12% CHR hardened or hard faced | Hard Faced AUS (3) | Hard Faced 316 AUS (3) | Duplex (3) |
| Shaft sleeves, mechanical seals | No | AUS or 12% CHR | AUS or 12% CHR | AUS or 12% CHR | AUS or 12%CHR | AUS or 12% CHR | AUS or 12% CHR | AUS or 12% CHR | AUS or 12% CHR | K-Monel, hardened | AUS or 12% CHR | AUS | 316 AUS | Duplex |
| Throat bushings | No | Cast iron | Bronze | Cast iron | Ni-resist | Cast iron | 12% CHR | 12% CHR | 316 AUS | Monel | 12% CHR hardened | AUS | 316 AUS | Duplex |
| Interstage sleeves | No | Cast iron | Bronze | Cast iron | Ni-resist | Cast iron | 12% CHR hardened | 12% CHR hardened | Hard Faced 316 AUS (3) | K-Monel, hardened | 12% CHR hardened | Hard Faced AUS (3) | Hard Faced 316 AUS (3) | Duplex (3) |
| Interstage bushings | No | Cast iron | Bronze | Cast iron | Ni-resist | Cast iron | 12% CHR hardened | 12% CHR hardened | Hard Faced 316 AUS (3) | K-Monel, hardened | 12% CHR hardened | Hard Faced AUS (3) | Hard Faced 316 AUS (3) | Duplex (3) |
| Seal gland | Yes | 316 AUS (5) | 316 AUS (5) | 316 AUS (5) | 316 AUS (5) | 316 AUS (5) | 316 AUS (5) | 316 AUS (5) | 316 AUS (5) | Monel | 316 AUS (5) | 316 AUS (5) | 316 AUS (5) | Duplex (5) |
| Case and gland studs | Yes | Carbon steel | Carbon steel | AISI 4140 steel | AISI 4140 steel | AISI 4140 steel | AISI 4140 steel | AISI 4140 steel | AISI 4140 steel | K-Monel, hardened (8) | AISI 4140 steel | AISI 4140 steel | AISI 4140 steel | Duplex (8) |
| Case gasket | No | AUS, spiral wound (6) | AUS, spiral wound (6) | AUS, spiral wound (6) | AUS, spiral wound (6) | AUS, spiral wound (6) | AUS, spiral wound (6) | AUS, spiral wound (6) | 316 AUS, spiral wound (6) | Monel, spiral wound, PTFE filled (6) | AUS, spiral wound (6) | AUS, spiral wound (6) | 316 AUS spiral wound (6) | Duplex SS spiral wound (6) |
| Discharge head / suction can | Yes | Carbon steel | Carbon steel | Carbon steel | Carbon steel | Carbon steel | Carbon steel | Carbon steel | Carbon steel | Carbon steel | AUS | AUS | 316 AUS | Duplex |
| Column / bowl shaft bushings | No | Nitrile (7) | Bronze | Filled carbon | Nitrile (7) | Filled carbon | Filled carbon | Filled carbon | Filled carbon | Filled carbon | Filled carbon | Filled carbon | Filled carbon | Filled carbon |
| Wetted fasteners (bolts) | Yes | Carbon steel | Carbon steel | Carbon steel | Carbon steel | Carbon steel | 316 AUS | 316 AUS | 316 AUS | K-Monel | 316 AUS | 316 AUS | 316 AUS | Duplex |

a The abbreviation above the diagonal line indicates the case material, the abbreviation below the diagonal line indicates trim material.
Abbreviations are as follows: BRZ = bronze, STL - steel, 12% CHR = 12% chrome, AUS = austenitic stainless steel, CI = cast iron, 316 AUS = Type 316 austenitic stainless steel

b See 2 11.1.1

Reference and General Notes for Table H- I:

1. Austenitic stainless steels include ISO Types 683-13-10/19 (AISI Standard Types 302, 303, 304, 316, 321, and 347). If a particular type is desired, the purchaser will so state.
2. For vertically suspended pumps with shafts exposed to liquid and running in bushings, the shaft shall be 12 percent chrome, except for Classes S-9, A7, A-8, and D- 1. Cantilever (Type VS5) pumps may utilize AISI 4140 where the service liquid will allow.
3. Unless otherwise specified, the need for hard-facing and the specific hard-facing material for each application shall be determined by the vendor and described in the proposal. Alternatives to hard-facing may include opening running clearances (2.6.4) or the use of non-galling materials, such as Nitronic 60 and Waukesha 88, depending on the corrosiveness of the pumped liquid.
4. For Class S-6, the shaft shall be 12 percent chrome if the temperature exceeds 175°C (350°F) or if used for boiler feed service (see Appendix G. Table G-l).
5. The gland shall be furnished with a non-sparking floating throttle bushing of a material such as carbon graphite or glass-filled PTFE, in accordance with 2.7.3.20. Unless otherwise specified, the throttle bushing shall be premium carbon graphite.
6. If pumps with axially split casings are furnished, a sheet gasket suitable for the service is acceptable. Spiral wound gaskets should contain a filler matrial suitable for the service.
7. Alternate materials may be substituted for liquid temperatures greater than 45°C (110°F) or for other special services.
8. Unless otherwise specified, AISI 4140 steel may be used for non-wetted case and gland studs.

## Table H-2—International Materials for Pump Parts

| Material Class | Applications | U.S.A. | | International | Germany-DIN | | Great Britain | France | Japan |
|---|---|---|---|---|---|---|---|---|---|
| | | ASTM | UNS | ISO | 17007 | 17006 | BSI | AFNOR | JIS |
| Cast Iron | Pressure Castings | A 278 Class 30 | F 12401 | 185/Gr. 250 | 0.6025 | GG - 25 | 1452 Gr. 220 | | G 5501, FC 300 |
| | General Castings | A 48 Class 25/30 | F 11 701/ F 12 101 | 185/Gr. 300 | 0.6030 | GG - 30 | 1452 Gr. 220 | FLG 250/300 | G 5501, FC 250/300 |
| Carbon Steel | Pressure Castings | A216 Gr WCB | J 03 002 | | 1.0619 | GS - C 25 | 1504 161 Gr. 480 | A 480 CP-M | G 5151, Cl SCPH 2 |
| | Wrought/Forgings | A 266 Class 2 | K 03506 | 683-18-C25 | 1.0402 | C 22 | 1503 221 490 | AC 48CP | G 3202, Cl SFVC 2A |
| | Bar Stock: Pressure | A 695 Gr B40 | G 10 200 | 683-18-C 25 | 1.0402 | C 22 | | AC 48CP | G 4051, Cl S25C |
| | Bar Stock: General | A 576 Gr 1045 | G 10 450 | 683-18-C 45e | 1.0503 | C 45 | 970 080 1450 | Z10 C13 | G 4051, Cl S45C |
| | Bolts and Studs | A 193 Gr B7 | G 41 400 | 2604-2-F31 | 1.7258 | 24 Cr Mo 5 | 1506 630 790 | 42 Cr Mo 4 | G 4107, Cl SNB7 |
| | Nuts | A 194 Gr 2H | K 04 002 | 683-1-C35e | 1.1181 | CK35 | 1506 162 | 2C35 | G 4051, Cl S45C |
| | Plate | A 516 Gr 65/70 | K 02 403/ K 02 700 | | 1.0254 | St. 37.0 | 10028 265<br>10028 295 | P295 GH | G 3106, Gr SM400B |
| | Pipe | A 106 Gr B | K 03 006 | | 1.0305 | St. 35.8 | 1501 161 430 | TU 42C | G3456, Gr STPT 370/410 |
| | Fittings | A 105 | K 03 504 | | 1.0308 | St. 35.0 | 1503 221 490 | AF 48N | G 4051, Cl S25C |
| AISI 4140 Steel | Bar Stock | A 434 CLASS BB | G 41 400[c] | 683-2-3 | 1.7225 | 42 Cr Mo 4 | 970 708 M 40 | 42 Cr Mo 4 | G 4105, Cl SCM 440 |
| | Bolts and Studs | A 193 Gr B7 | G 41 400 | | 1.7711 | 40 Cr Mo V 4 7 | 1506 630 790 | 42 CVD 4 | G 4107, Cl SNB16 |
| | Nuts | A 194 Gr 2H | K 04 002 | 2604-2-F31 | 1.7258 | 24 Cr Mo 5 | 1506 162 | 45 D2 | G 4051, Cl S45C |
| 12 % Chrome Steel | Pressure Castings | A 217 Gr CA 15 | J 91 150 | | 1.4008 | G-X 8 Cr Ni 13 | 1504 420 C29 | Z 12 C13 - M | G 5121, Cl SCS 1 |
| | | A 487 Gr CA6NM | J 91 540 | | 1.4313 | G-X 5 Cr Ni 13 4 | 1504 425 C11 | Z 6 CN 1304 - M | G 5121, Cl SCS 6 |
| | Wrought/Forgings: Pressure | A 182 Gr F6a Class 1<br>A 182 Gr F 6 NM | S 41 000<br>S 41 500 | 683-13-3 | 1.4006<br>1.4313 | X 10 Cr 13<br>X 4 Cr Ni 13 4 | 1503 410 S21 | Z10 C13<br>Z 6CN 13-D4 | G 3214, Cl SUS F6 B<br>G 3214, Cl SUS F6 NM |
| | Wrought/Forgings: General | A 473 Type 410 | S 41 000 | 683-13-3 | 1.4313 | X 4 Cr Ni 13 4 | 970 410 S21 | Z 6CN 13-D4 | G 3214, Cl SUS F6 NM |
| | Bar Stock: Pressure | A 479 Type 410 | S 41 000 | 683-13-4 | 1.4006 | X 10 Cr 13 | 1503 420 C29 | Z 10 C13 | G 4303 or 410 |
| | Bar Stock: General | A 276 Type 410 | S 41 400 | | | | | | |
| | Bar Stock/Forgings Wear Parts[a] | A 276 Type 420<br>A 473 Type 416 | S 42 000 | 683-13-4 | 1.4021 | X 20 Cr 13 | 970 420 S37 | Z 20 C13 | G 4303, Grl SUS 403 or 420 |
| | Bolts and Studs[b] | A 193 Gr B6 | S 41 000 | | 1.4923 | X22 Cr Mo V12 1 | 1506 410 S21 760 | Z 13 C13 | G 4303, Gr SUS 403 or 420 |
| | Nuts[b] | A 194 Gr 6 | S 41 000 | | 1.4923 | X22 Cr Mo V 12 1 | 1506 410 S21 760 | Z 13 C13 | G 4303, Gr SUS 403 or 420 |
| | Plate | A 240 Type 410 | S 41 000 | 683-13-3 | 1.4006 | X10 Cr 13 | 970 410 S21 | Z 13 C13 | G 4304 / 4305 or 410 |

## Table H-2—International Materials for Pump Parts (Continued)

| Material Class | Applications | U.S.A. | | International | Germany-DIN | | Great Britain | France | Japan |
|---|---|---|---|---|---|---|---|---|---|
| | | ASTM | UNS | ISO | 17007 | 17006 | BSI | AFNOR | JIS |
| Austenitic Stainless Steel | Pressure Castings | A 351 Gr CF3<br>A 743 Gr CF3 | J 92 500 | 683-13-10 | 1.4306 | G-X 2 Cr Ni N 18 9 | 1504-304-C12 | Z2 CN 18-10M | G 5121, Cl SCSI 3A |
| | | A 351 Gr CF3M<br>A 744 Gr CF3M | J 92 800 | 683-13-19 | 1.4404 | G-X 2 Cr Ni Mo N 18 10 | 1504-316-C12 | Z3 CND 18-12- | G 5121, Cl SCS I 4A 02M |
| | Wrought/Forgings | A 182 Gr F 304L | S 30 403 | 683-13-10 | 1.4306 | X 2 Cr Ni 19 11 | 1503 304 S11 | Z3 CN 18-10 | G 3214, Cl SUS F 304 L |
| | | A 182 Gr F 316 L | S 31 603 | 683-13-19 | 1.4404 | X 2 Cr Ni Mo 17 13 2 | 1503 316 S11 | Z3 CND 17-12-02 | G 3214, Cl SUS F 316 L |
| | Bar Stock | A 479 Type 304 L<br>A 479 Type 316L | S 30 403<br>S 31 603 | 683-13-10<br>683-13-19 | 1.4306<br>1.4404 | X2 Cr Ni 19 11<br>X2 Cr Ni Mo 17 13 2 | 970 304 S11<br>970 316 S11 | Z3 CN 18-10<br>Z3 CND-17-12-02 | G 4303, SUS F 304 L<br>G 4303, SUS F 316 L |
| | | A 479 Type XM19[d] | S 20 910 | | | | | Z3 CN 18-10<br>Z3 CND-17-12-02 | A479 TY X M 19 |
| | Plate | A 240 Gr 304L / 316L | S 30 403<br>S 31 603 | 683-13-10<br>683-13-19 | 1.4306 /<br>1.4404 | X 2 Cr Ni 19 11<br>X 2 Cr Ni Mo 17 13 2 | 970 304 S11<br>970 316 S11 | Z3 CN 18-10<br>Z3 CNP 17-12-02 | G 4304/5, Gr 304L / 316L |
| | Pipe | A 312 Type 304L / 316L | S 30 403<br>S 31 603 | 683-13-10<br>683-13-19 | 1.4306 /<br>1.4404 | X 2 Cr Ni 19 11<br>X 2 Cr Ni Mo 17 13 2 | 3605 304 S11<br>3605 316 S11 | TU22 CN 18-10<br>TU22 CND 17-12-02 | G 3459, Gr 304LTP/316LTP |
| | Fittings | A 182 Gr F304L 316L | S 30 403<br>S 31 603 | 683-13-10<br>683-13-19 | 1.4306 /<br>1.4404 | X 2 Cr Ni 19 11<br>X 2 Cr Ni Mo 17 13 2 | 1503 304 S11<br>1503 316 S11 | Z3 CN 18-10<br>Z3CND-17-12-02 | G 3214, Gr SUS 304L / 316L |
| | Bolts and Studs | A 193 Gr B 8 M | S 31 600 | 683-1-21 | 1.4571 | X 6 Cr Ni Mo Ti 17 12 2 | 1506 316 S31 | Z 6 CN DT 17.12 | G 4303, Grl SUS 316 |
| | Nuts | A 194 Gr B 8 M | S 31 600 | 683-1-21 | 1.4571 | X 6 Cr Ni Mo Ti 17 12 2 | 1506 316 S31 | Z 6 CN DT 17.12 | G 4303, Grl SUS 316 |
| Duplex Stainless Steel | Pressure Castings | A 890 Gr 3A | J933371 | | 1.4468 | G-X 3 Cr Ni Mo N 26 6 3 | | Z6 CND 26-5-02M | G 5121, Cl SCS 11 |
| | | A 351 Gr CD4 MCu | J93370 | | 1.4517 | G-X 3 Cr Ni Mo Cu N 26 6 3 3 | | Z3 CNDU 26-05M | A 351, Gr CO 4 MCU |
| | Wrought/Forgings | A 182 Gr F 51 | S 31803 | | 1.4462 | X 2 Cr Ni Mo N 22 5 | 1503 318 S13 | Z3 CND 22-05AZ | G 4319, Cl SUS 329 |
| | Bar Stock | A276-S31803 | S 31 803 | | 1.4462 | X 2 Cr Ni Mo N 22 5 | | Z3 CND 22-05AZ | G 4303, Grl SUS 329 Gr SUS 329 |
| | Plate | A240-S31803 | S 31 803 | | 1.4462 | X 2 Cr Ni Mo N 22 5 | | Z3 CND 22-05AZ | G 4303, Gr SUS 329 |
| | Pipe | A790-S31803 | S 31 803 | | 1.4462 | X 2 Cr Ni Mo N 22 5 | | Z3 CND 22-05AZ | G 3459, Gr SUS 329 |
| | Fittings | A 182 Gr F 51 | S 31803 | | 1.4462 | X 2 Cr Ni Mo N 225 | 1503-318-S13 | Z3 CND 22-05AZ | |
| | Bolts and Studs | A276-S31803 | S 31 803 | | 1.4462 | X 2 Cr Ni Mo N 22 5 | | Z3 CND 22-05AZ | G 4303, Gr SUS 329 |
| | Nuts | A276-S31803 | S 31 803 | | 1.4462 | X 2 Cr Ni Mo N 225 | | Z3 CND 22-05AZ | G 4303, Gr SUS 329 |

Note: This table lists corresponding (not necessarily equivalent) International Materials which may be acceptable with the purchaser's approval. These materials represent family/type and grade only. Final condition or hardness level (where appropriate) is not specified. Materials listed for pressure applications may be utilized for non-pressure applications. All wear part material combinations must be selected in accordance with the requirements of 2.6.4.2.

[a]Not suitable for shafts.

[b]Special, normally use AISI 4140.

[c]UNS (unified numbering system) designation for chemistry only.

[d]Nitronic 50 or equivalent.

## Table H-3—Miscellaneous Materials

| Material | Typical Description |
|---|---|
| Alloy 20 | ASTM B73, UNS 8020 (wrought), ASTM A744, Grade CN7M (cast) |
| Babbitt | ASTM B23, Grades 1–9, as required by vendor for service conditions |
| Bronze | UNS C87200 (silicon bronze), C90700 or C92200 (tin bronze), C95200 (aluminum bronze) or C95800 (nickel aluminum bronze) |
| Carbon | Suitable mechanical carbon as recommended by vendor for the service conditions |
| Filled carbon | Carbon with an appropriate filler material (usually metal) to enhance its mechanical properties |
| Fluoroelastomer (FKM) | ASTM D1418 FKM elastomer, such as DuPont Viton |
| Flexible graphite | Union Carbide Grafoil (or the equivalent) |
| Hardfacing | Stellite (Cabot Corp.) (or the equivalent), Colmonoy (Wall-Colmonoy Corp.) (or the equivalent), Type 3 tungsten carbide, etc.; overlay-weld deposit of 0.8 mm (0.030 in.) minimum finished thickness, or, if available, a solid cast part of equal material may be substituted.<br><br>Type 1 tungsten carbide—as required for service conditions, with cobalt binder (solid part, not overlay);<br>Type 2 tungsten carbide—as required for service conditions, with nickel binder (solid part, not overlay);<br>Type 3 tungsten carbide—sprayed overlay as required for service conditions, minimum thickness of 0.8 mm (0.030 in.) |
| Low carbon nickel molybdenum chrome alloy | Hastelloy (Cabot Corp.) Alloy C-276 (or the equivalent):<br>ASTM B564, UNS N10276 (forgings)<br>ASTM B574, UNS N10276 (bar and rod)<br>ASTM B575, UNS N10276 (plate, sheet, and strip)<br>ASTM A494, Grade CW-2M (weldable cast) |
| Nickel copper alloy | Monel (Huntington Alloys) Alloy 400 (or the equivalent):<br>ASTM B564, UNS N04400 (forgings)<br>ASTM B164, Class A, UNS N04400 (bar and rod)<br>ASTM B127, UNS N04400 (plate, sheet, and strip)<br>ASTM A494, Grade M30C (weldable cast) |
| Ni resist | ASTM A436, Type 1, 2, or 3, UNS F41000 / F41002 / F41004 respectively (austenitic cast iron);<br>ASTM A439, Type D2, UNS F43000 (austenitic ductile iron) |
| Nitrile | B. F. Goodrich Hycar, Buna N (or the equivalent) |
| Perfluoroelastomer (FFKM) | ASTM D1418 FFKM elastomer, such as DuPont Kalrez |
| Polytetrafluoroethylene (PTFE) | DuPont Teflon or similar material |
| Glass filled PTFE | 25 percent glass filled polytetrafluoroethylene |
| Precipitation hardening nickel alloy | Inconel (Huntington Alloys) Alloy 718 (or the equivalent):<br>ASTM B637, UNS N07718 (forgings and bars)<br>ASTM B670, UNS N07718 (plate, sheet, and strip) |
| Precipitation hardening stainless steel | ASTM A564, Grade 630, UNS S17400 or Grade 631, UNS 17700 (wrought)<br><br>ASTM A747, Grade CB7Cu-1, UNS J92180 (cast) |
| Sheet gasket | Long fiber material with synthetic rubber binder suitable for service conditions, or spiral wound stainless steel and equal gasket material |
| Silicon carbide (SiC) | Reaction bonded silicon carbide (RBSiC) or self sintered silicon carbide (SSSiC)—see API Standard 682 for SiC application guidelines in mechanical seals |

## API Standard 610 Mechanical Seal Materials and Classification Codes

Mechanical seal materials and construction features shall be coded according to the following classification system:

First letter: Balanced (B) or unbalanced (U)

Second letter: Single (S), unpressurized dual (T), or pressurized dual (D)

Third letter: Seal gland type (P = plain, no throttle bushing; T = throttle bushing with quench, leakage and/or drain connections; A = auxiliary sealing device, type to be specified)

Note: See 2.7.3.21.

Fourth letter: Gasket materials (see Table H-4)

Fifth letter: Face materials (see Table H-5)

For example, a seal coded BSTFM would be a balanced single seal with throttle bushing seal gland and would have a fluoroelastomer (FKM) stationary gasket, an FKM seal-ring-to-sleeve gasket, and carbon against tungsten carbide 2 faces. Seal materials other than those listed above should be coded X and defined on the data sheets (see Appendix B).

### Mechanical Seal Notes

1. Unless otherwise specified, the spring material for multiple spring seals shall be Hastelloy C. The spring material for single spring seals shall be austenitic stainless steel (AISI Standard Type 316 or equal). Other metal parts shall be austenitic stainless steel (AISI Standard Type 316 or equal) or another corrosion resistant material suitable for the service, except that metal bellows, where used, shall be of the material recommended by the seal manufacturer for the service. Metal bellows shall have a corrosion rate of less than 50 μm (2 mils) per year.
2. Unless otherwise specified, the gland plate to seal chamber seal shall be a fluoroelastomer O-ring for services below 150°C (300°F). For temperatures 150°C (300°F) and above or when specified, graphite-filled austenitic stainless steel spiral wound gaskets shall be used. The gasket shall be capable of withstanding the full (uncooled) temperature of the pumped fluid.
3. A metal seal ring shall not have sprayed overlay in place of a solid face.
4. When the pumping temperature exceeds 175°C (350°F), the vendor and seal manufacturer should be jointly consulted about using a cooled flush to the seal faces or running the seal chamber dead-ended with jacket cooling.
5. The temperature limits on mechanical seal gaskets shall be as specified in Table H-6.

### Table H-4—Fourth Letter of Mechanical Seal Classification Code

| Fourth Letter | Stationary Seal Ring Gasket | Seal Ring to Sleeve Gasket |
|---|---|---|
| E | FKM | PTFE |
| F | FKM | FKM |
| G | PTFE | PTFE |
| H | Nitrile | Nitrile |
| I | FFKM | FFKM elastomer |
| R | Graphite foil | Graphite foil |
| X | As specified | As specified |
| Z | Spiral wound | Graphite foil |

### Table H-5—Fifth Letter of Mechanical Seal Classification Code

| Fifth Letter | Sealing Ring Face Materials | |
|---|---|---|
| | Ring 1 | Ring 2 |
| L | Carbon | Tungsten carbide 1 |
| M | Carbon | Tungsten carbide 2 |
| N | Carbon | Silicon carbide |
| O | Tungsten carbide 2 | Silicon carbide |
| P | Silicon carbide | Silicon carbide |
| X | As specified | As specified |

### Table H-6—Temperature Limits on Mechanical Seal Gaskets and Bellows

| Gasket Material | Ambient or Pumping Temperature | | | |
|---|---|---|---|---|
| | Minimum | | Maximum | |
| | (°C) | (°F) | (°C) | (°F) |
| PTFE | –75 | –100 | 200 | 400 |
| Nitrile | –40 | –40 | 120 | 250 |
| Neoprene | –20 | 0 | 90 | 200 |
| FKM | –20 | 0 | 200 | 400 |
| Metal bellows[a] | | | | |
| FFKM | –12 | 10 | 260 | 500 |
| Graphite foil | –240 | –400 | 400[b] | 750[b] |
| Glass filled TFE | –212 | –350 | 230 | 450 |
| Mica/graphite | –240 | –400 | 700 | 1300 |
| Ethylene propylene | –57 | –70 | 180 | 350 |

[a]Consult manufacturer for minimum and maximum ambient pumping temperature.
[b]Maximum temperature is 870°C (1600°F) for nonoxidizing atmospheres; consult manufacturer.

# APPENDIX I—LATERAL ANALYSIS

## I.1 Lateral Analysis

### I.1.1 GENERAL

When a lateral analysis is required (see 5.2.4.1), the method and assessment of results shall be as specified in I.1.2 through I.1.5. Figure I.1 illustrates the analysis process. The method and assessment specified are peculiar to liquid handling turbomachines.

### I.1.2 NATURAL FREQUENCIES

Within the frequency range zero to 2.2 times maximum continuous speed, all the rotor's natural frequencies shall be calculated for the speed range 25–125 percent of rated, taking account of the following:

a. Stiffness and damping at internal running clearances, for both new and two times (2×) new clearances with pumped liquid, and for both new clearances with water at the expected test temperature.
b. Stiffness and damping at the shaft seals (if labyrynth type).
c. Stiffness and damping within the bearings for the average clearance and oil temperature; see the note following the lists.
d. Mass and stiffness of the bearing support structure.
e. Inertia of the pump half coupling hub and half the coupling spacer.

The report shall state the following:

a. Those natural frequencies with a damping ratio less than 0.4.
b. The values or the basis of the stiffness and damping coefficients used in the calculation.

Note: The effect of bearing stiffness and damping in pumps is generally minor in comparison to that of the internal running clearances; therefore, it is sufficient to analyze the bearings at their average clearance and oil temperature.

### I.1.3 SEPARATION MARGINS AND DAMPING

For both new and 2× new clearances, the damping factor versus separation margin between any bending natural frequency and the synchronous run line shall be within the "acceptable" region shown on Figure I.2. If this condition cannot be satisfied, the damped response to unbalance shall be determined (see I.1.4).

Note 1: In liquid handling turbomachines, the first assessment of a rotor's dynamic characteristics is based on damping versus separation margin, rather than amplification factor versus separation margin. Two factors account for this basis. First, the rotor's natural frequencies increase with rotative speed, a consequence of the differential pressure across internal clearances also increasing with rotative speed. On a Campbell diagram, Figure I.3, this means the closer separations are between the running speed and natural frequencies rather than between the running speed and the critical speeds. Because the amplification factor at the closer separations is not related to synchronous (unbalance) excitation of the rotor, it can only be developed by an approximate calculation based on the damping. Second, employing damping allows a minimum value to be specified for natural frequency to running speed ratios from 0.8 to 0.4, thereby assuring the rotor of freedom from significant subsynchronous vibration.

Note 2: Damping factor, $\xi$, is related to logarithmic decrement, $\delta$, by the equation:

$$\delta = 2\pi \xi / (1 - \xi^2)^{0.5}$$

For $\xi$ up to 0.4, the following approximate relationships between $\xi$, $\delta$, and amplification factor, AF, are sufficiently accurate for practical purposes:

$$\xi = \delta / 2\pi = 1 / (2\ AF)$$

Critically damped corresponds to the following:

$$\xi \geq 0.2,\ \delta \geq 1.2,\ AF \leq 2.5$$

### I.1.4 DAMPED UNBALANCE RESPONSE ANALYSIS

When the damping factor versus separation margin for a mode or modes is not acceptable by the criteria in Figure I.2, the rotor's damped response to unbalance shall be determined for the mode(s) in question on the following basis:

a. The pumped liquid.
b. Clearances at new and 2× new values.
c. Total unbalance of four times (4×) the allowable value (see 5.2.4.2.1) lumped at one or more points to excite the mode(s) being investigated.

Only one mode shall be investigated in each computer run.

### I.1.5 ALLOWABLE DISPLACEMENT

The peak to peak displacement of the unbalanced rotor at the point(s) of maximum displacement shall not exceed 35 percent of the diametral running clearance at that point.

Note: In centrifugal pumps, the typical damped response to unbalance does not show a peak in displacement at resonance large enough to assess the amplification factor. With this limitation, assessment of the damped response to unbalance is restricted to comparing rotor displacement to the available clearance.

## I.2 Shop Verification of Rotor's Dynamic Characteristics

● **I.2.1** When specified, the rotor's dynamic characteristics shall be verified during the shop test. The rotor's actual response to unbalance shall be the basis for confirming the validity of the damped lateral analysis. This response is measured during either variable speed operation from rated speed down to 75 percent of the first critical speed or during coast down. If the damped response to unbalance was not determined in the original rotor analysis (see I.1.4), this response will need to be determined for a pump with new clearances handling water before proceeding with shop verification. The test unbalances shall be vectorially added in phase with the residual unbalance at locations determined by the manufacturer (usually the coupling and/or thrust collar).

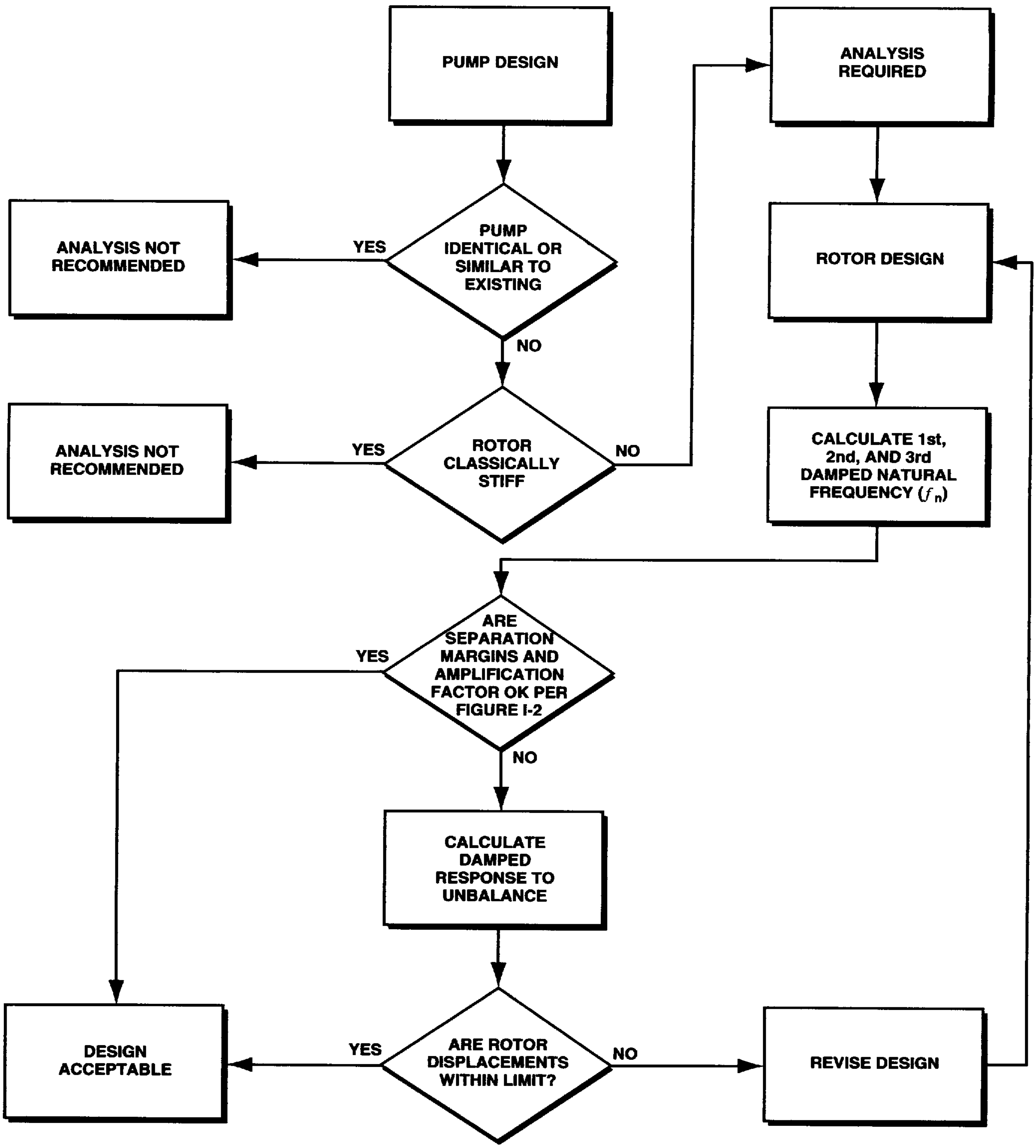



Figure I-1—Rotor Lateral Analysis Logic Diagram

Note: The principal objective of shop verification by response to unbalance is to verify the existence of a critical speed (vibration peak) within tolerance of the calculated value, or if the analysis predicted a highly damped critical speed, the absence of a vibration peak within tolerance of calculated value. Shop verification by this method is feasible only for pumps that have sleeve bearings and are furnished with proximity probe pairs at each journal bearing.

**I.2.2** The magnitude and location of the test unbalance(s) shall be determined from a calibration of the rotor's sensitivity to unbalance. The calibration shall be performed by obtaining the vibration orbits at each bearing, filtered to rotor speed (1X), during two trial runs as follows:

a. With the rotor as built.

b. With trial unbalance weights added 90 degrees from the maximum displacement in run a.

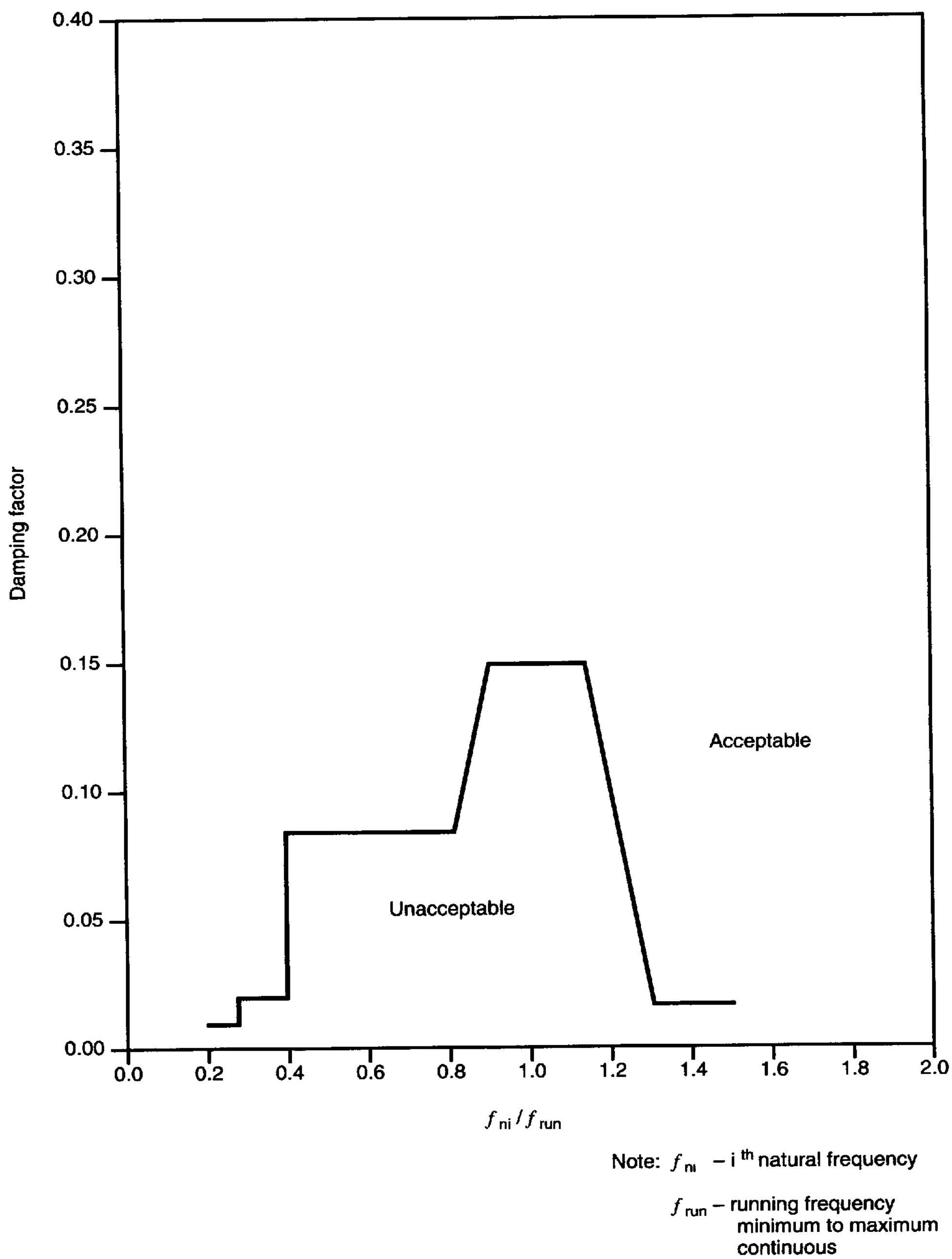



Figure I-2—Damping Factor Versus Frequency Ratio

The magnitude of the test unbalances should be such that the calculated maximum shaft displacement caused by the resultant total unbalance (residual plus test) is 150–200 percent of the allowable displacement from Tables 2.5 or 2.6 at the bearing probes, but shall not exceed eight times the maximum allowable rotor unbalance.

**I.2.3** During the test, the rotor's speed, vibration displacement, and corresponding phase angle, filtered to rotor speed (1X), shall be measured and recorded.

**I.2.4** The rotor's characteristics shall be considered verified if the following requirements are met:

a. Observed critical speed(s) (distinct vibration peak and appropriate phase shift) within ±10 percent of the calculated value(s).
b. Measured vibration amplitudes within ±35 percent of the calculated values.

Note: Highly damped critical speeds will not be observable; therefore, the absence of rotor response in the region of a calculated highly damped critical speed will be verification of the analysis.

**I.2.5** If the acceptance criteria given in I.2.4 are not met, the stiffness or damping coefficients, or both, used in the natural frequency calculation shall be adjusted to produce agreement between the calculated and measured results. The coefficients of one type of element, annular clearances with $L/D < 0.15$, annular clearances $L/D > 0.15$, impeller interaction, and bearings shall be adjusted with the same correction factor. Once agreement is reached, the same correction factors shall be applied to the calculation of the rotor's natural frequencies and damping for the pumped liquid, and the rotor's separation margins versus damping factors rechecked for acceptability.

Note: Of the coefficients used in rotor lateral analysis, those for damping in annular clearances have the highest uncertainty and are therefore usually the first to be adjusted. The stiffness coefficients of annular clearances typically have low uncertainty and, therefore, should be adjusted only on the basis of supporting data. Adjustments of bearing coefficients require specific justification; because the typical values are based on reliable empirical data.

**I.2.6** Alternative methods of verifying the rotor's dynamic characteristics, for example, variable frequency excitation with the pump at running speed to determine the rotor's natural frequencies, are available. The use of alternative methods and the interpretation of the results shall be mutually agreed between the purchaser and manufacturer.

## I.3 Documentation

**I.3.1** The report on a lateral analysis shall include the following:

a. Results of initial assessment (see 5.2.4.1.1).
b. Fundamental rotor data used for the analysis.
c. Campbell diagram (see Figure I-3).
d. Plot of damping ratio versus separation margin.
e. Mode shape at the critical speed(s) for which the damped response to unbalance was determined (see I.1.4).
f. Bode plot(s) from shop verification by unbalance (see I.2.3).
g. Summary of analysis corrections to reach agreement with shop verification (see I.2.5).

Note: Preceding items e through g are furnished only if the activity documented was required by the analysis or specified by the purchaser.

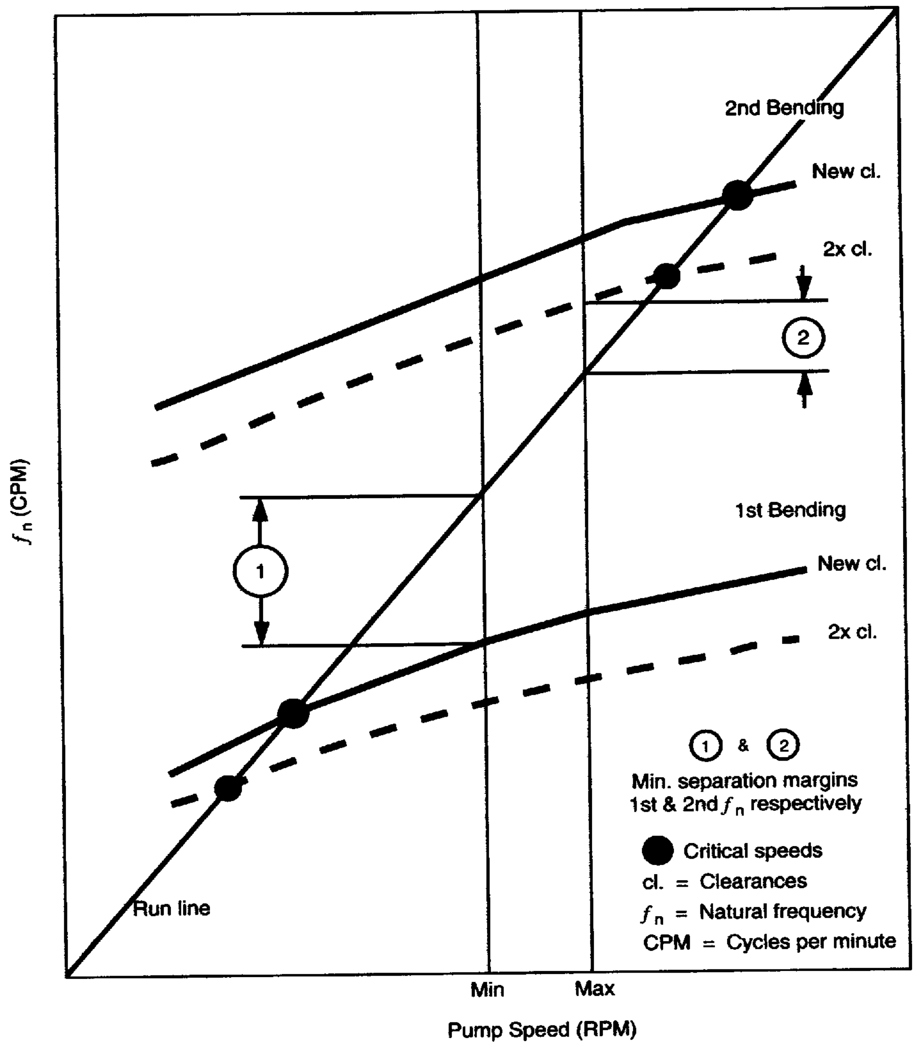



Figure I-3—Typical Campbell Diagram

# APPENDIX J—PROCEDURE FOR DETERMINATION OF RESIDUAL UNBALANCE

## J.1 Scope

This appendix describes the procedure to be used to determine residual unbalance in machine rotors. Although some balancing machines may be set up to read out the exact amount of unbalance, the calibration can be in error. The only sure method of determining residual unbalance is to test the rotor with a known amount of unbalance.

## J.2 Definition

*Residual unbalance* refers to the amount of unbalance remaining in a rotor after balancing. Unless otherwise specified, residual unbalance shall be expressed in g•mm or oz-in.

## J.3 Maximum Allowable Residual Unbalance

**J.3.1** The maximum allowable residual unbalance per plane shall be determined from Table 5.2.2 of this standard.

**J.3.2** If the actual static weight load on each journal is not known, assume that the total rotor weight is equally supported by the bearings. For example, a two bearing rotor weighing 2700 kg (6000 lbs) would be assumed to impose a static weight load of 1350 kg (3000 lbs) on each journal.

## J.4 Residual Unbalance Check

### J.4.1 GENERAL

**J.4.1.1** When the balancing machine readings indicate that the rotor has been balanced to within the specified tolerance, a residual unbalance check shall be performed before the rotor is removed from the balancing machine.

● **J.4.1.2** To check the residual unbalance, a known trial weight is attached to the rotor sequentially in six (or twelve, if specified by the purchaser) equally spaced radial positions, each at the same radius. The check is run in each correction plane, and the readings in each plane are plotted on a graph using the procedure specified in J.4.2.

### J.4.2 PROCEDURE

**J.4.2.1** Select a trial weight and radius that will be equivalent to between one and two times the maximum allowable residual unbalance [that is, if $U_{max}$ is 1440 g•mm (2 oz-in.), the trial weight should cause 1440–2880 g•mm (2–4 oz-in.) of unbalance].

**J.4.2.2** Starting at the last known heavy spot in each correction plane, mark off the specified number of radial positions (six or twelve) in equal (60 or 30 degree) increments around the rotor. Add the trial weight to the last known heavy spot in one plane. If the rotor has been balanced very precisely and the final heavy spot cannot be determined, add the trial weight to any one of the marked radial positions.

**J.4.2.3** To verify that an appropriate trial weight has been selected, operate the balancing machine and note the units of unbalance indicated on the meter. If the meter pegs, a smaller trial weight should be used. If little or no meter reading results, a larger trial weight should be used. Little or no meter reading generally indicates that the rotor was not balanced correctly, the balancing machine is not sensitive enough, or a balancing machine fault exists (i.e., a faulty pickup). Whatever the error, it must be corrected before proceeding with the residual check.

**J.4.2.4** Locate the weight at each of the equally spaced positions in turn, and record the amount of unbalance indicated on the meter for each position. Repeat the initial position as a check. All verification shall be performed using only one sensitivity range on the balance machine.

**J.4.2.5** Plot the readings on the residual unbalance work sheet and calculate the amount of residual unbalance (see Figure J-1). The maximum meter reading occurs when the trial weight is added at the rotor's heavy spot; the minimum reading occurs when the trial weight is opposite the heavy spot. Thus, the plotted readings should form an approximate circle (see Figure J-2). An average of the maximum and minimum meter readings represents the effect of the trial weight. The distance of the circle's center from the origin of the polar plot represents the residual unbalance in that plane.

**J.4.2.6** Repeat the steps described in J.4.2.1 through J.4.2.5 for each balance plane. If the specified maximum allowable residual unbalance has been exceeded in any balance plane, the rotor shall be balanced more precisely and checked again. If a correction is made in any balance plane, the residual unbalance check shall be repeated in all planes.

**J.4.2.7** For stack component balanced rotors, a residual unbalance check shall be performed after the addition and balancing of the first rotor component, and at the completion of balancing of the entire rotor, as a minimum.

Note: This ensures that time is not wasted and rotor components are not subjected to unnecessary material removal in attempting to balance a multiple component rotor with a faulty balancing machine.

Equipment (Rotor) No.: ____________

Purchase Order No.: ____________

Correction Plane (inlet, drive end, etc.—use sketch): ____________

Balancing Speed: ____________ rpm

*N*—Maximum Allowable Rotor Speed: ____________ rpm

*W*—Weight of Journal (closest to this correction plane): ____________ kg (lbs)

$U_{max}$—Maximum Allowable Residual Unbalance =
6350 *W/N* (4 *W/N*)
6350 × ______ kg/______ rpm; 4 × ______lbs/______rpm ____________ g•mm (oz-in.)

Trial unbalance (2 × $U_{max}$) ____________ g•mm (oz-in.)

*R*—Radius (at which weight will be placed): ____________ mm (in.)

Trial Unbalance Weight = Trial Unbalance/*R*

______g•mm/______mm/______oz-in./______in. ____________ g (oz)

Conversion Information: 1 ounce = 28.350 grams

Test Data

| Position | Trial Weight Angular Location | Balancing Machine Amplitude Readout |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |

Rotor Sketch

Test Date—Graphic Analysis

Step 1: Plot data on the polar chart (Figure J-1). Scale the chart so the largest and smallest amplitude will fit conveniently.

Step 2: With a compass, draw the best fit circle through the six points and mark the center of this circle.

Step 3: Measure the diameter of the circle in units of scale chosen in Step 1 and record. ____________ units

Step 4: Record the trial unbalance from above. ____________ g•mm (oz-in.)

Step 5: Double the trial unbalance in Step 4 (may use twice the actual residual unbalance). ____________ g•mm (oz-in.)

Step 6: Divide the answer in Step 5 by the answer in Step 3. ____________ Scale Factor

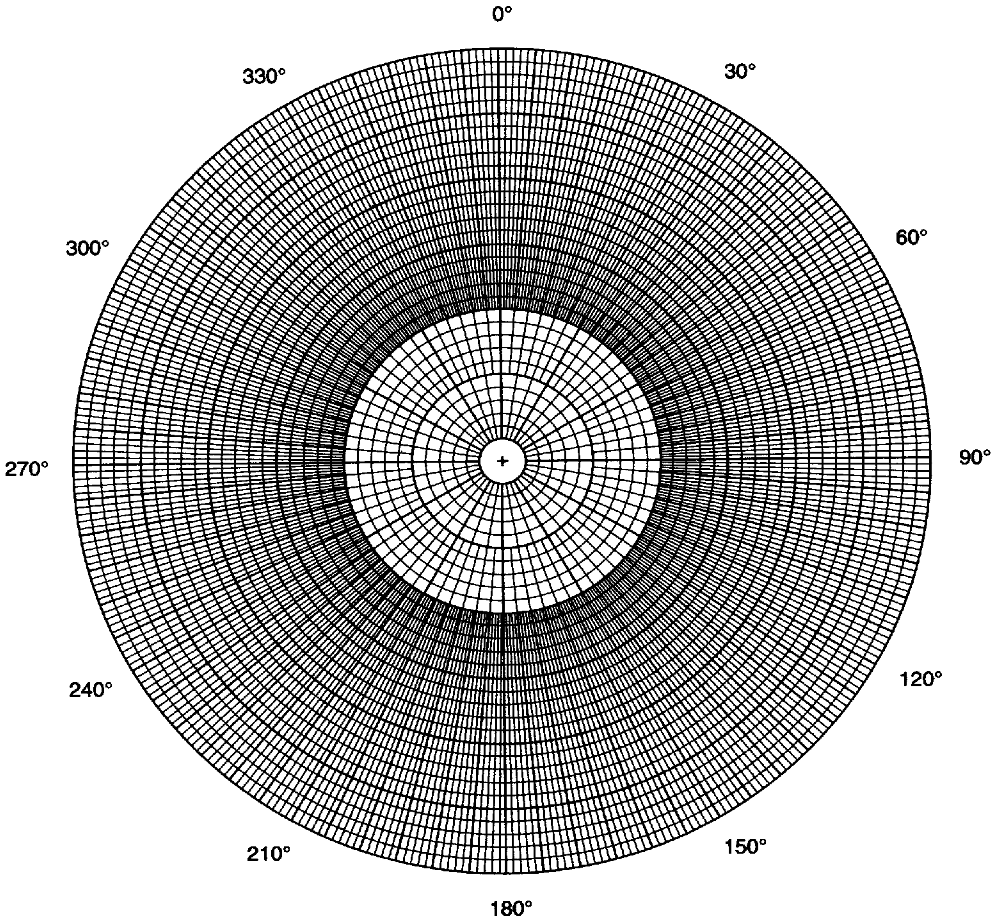
You now have a correlation between the units on the polar chart and the g•in of actual balance.

Notes:

1. The trial weight angular location should be referenced to a keyway or some other permanent marking on the rotor.

2. The balancing machine amplitude readout for position "7" should be the same as position "1," indicating repeatability. Slight variations may result from imprecise positioning of the trial weight.

Figure J-1—Residual Unbalance Work Sheet




The circle you have drawn must contain the origin of the polar chart. If it doesn't, the residual unbalance of the rotor exceeds the applied test unbalance.

NOTE: Several possibilities for the drawn circle not including the origin of the polar chart are: operator error during balancing, a faulty balancing machine pickup or cable, or the balancing machine is not sensitive enough.

If the circle does contain the origin of the polar chart, the distance between origin of the chart and the center of your circle is the actual residual unbalance present on the rotor correction plane. Measure the distance in units of scale you choose in Step 1 and multiply this number by the scale factor determined in Step 6. Distance in units of scale between origin and center of the circle times scale factor equals actual residual unbalance.

Record actual residual unbalance ____________________(g•mm)(oz-in.)

Record allowable residual unbalance (from Figure J-1) ________(g•mm)(oz-in.)

Correction plane __________ for Rotor No. __________ (has/has not) passed.

By ______________________ Date ______________________

Figure J-1—Residual Unbalance Work Sheet (Continued)

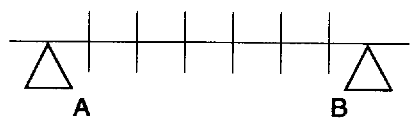
| | | |
|---|---|---|
| Equipment (Rotor) No.: | *C–101* | |
| Purchase Order No.: | | |
| Correction Plane (inlet, drive end, etc.–use sketch): | *A* | |
| Balancing Speed: | *800* | rpm |
| *N*—Maximum Allowable Rotor Speed: | *10,000* | rpm |
| *W*—Weight of Journal (closet to this correction plane): | *908* | ~~kg~~ (lbs) |
| $U_{max}$—Maximum Allowable Residual Unbalance = 6350 *W/N* (4 *W/N*) ~~6350 ×~~ ____ ~~kg/~~ ____ ~~rpm~~; 4 × *908* lbs/ *10,000* rpm | *0.36* | ~~g•mm~~ (oz-in.) |
| Trial unbalance (2 × $U_{max}$) | *0.72* | ~~g•mm~~ (oz-in.) |
| *R*—Radius (at which weight will be placed): | *6.875* | ~~mm~~ (in.) |
| Trial Unbalance Weight = Trial Unbalance/*R* ____ ~~g•mm/~~ ____ ~~mm/~~ *0.72* oz-in./ *6.875* in. | *0.10* | ~~g~~ (oz) |

Conversion Information: 1 ounce = 28.350 grams

Test Data

| Position | Trial Weight Angular Location | Balancing Machine Amplitude Readout |
|---|---|---|
| 1 | *0* | *14.0* |
| 2 | *60* | *12.0* |
| 3 | *120* | *14.0* |
| 4 | *180* | *23.5* |
| 5 | *240* | *23.0* |
| 6 | *300* | *15.5* |
| 7 | *0* | *13.5* |

Rotor Sketch




Test Date—Graphic Analysis

Step 1: Plot data on the polar chart (Figure J-2 continued). Scale the chart so the largest and smallest amplitude will fit conveniently.

Step 2: With a compass, draw the best fit circle through the six points and mark the center of this circle.

Step 3: Measure the diameter of the circle in units of scale chosen in Step 1 and record. *35* units

Step 4: Record the trial unbalance from above. *0.72* ~~g•mm~~ (oz-in.)

Step 5: Double the trial unbalance in Step 4 (may use twice the actual residual unbalance). *1.44* ~~g•mm~~ (oz-in.)

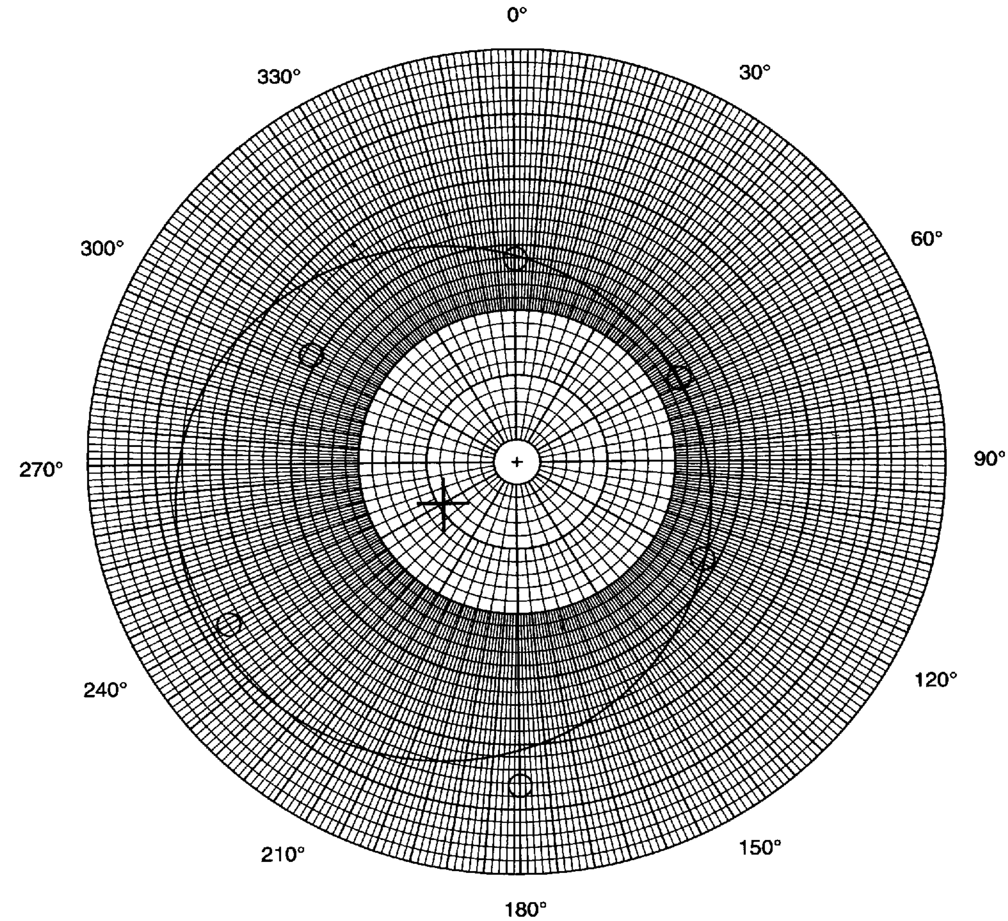
Step 6: Divide the answer in Step 5 by the answer in Step 3. *0.041* Scale Factor

You now have a correlation between the units on the polar chart and the g•in. of actual balance.

Notes:

1. The trial weight angular location should be referenced to a keyway or some other permanent marking on the rotor.
2. The balancing machine amplitude readout for position "7" should be the same as position "1," indicating repeatability. Slight variations may result from imprecise positioning of the trial weight.

Figure J-2—Sample Calculations for Residual Unbalance




The circle you have drawn must contain the origin of the polar chart. If it doesn't, the residual unbalance of the rotor exceeds the applied test unbalance.

NOTE: Several possibilities for the drawn circle not including the origin of the polar chart are: operator error during balancing, a faulty balancing machine pickup or cable, or the balancing machine is not sensitive enough.

If the circle does contain the origin of the polar chart, the distance between origin of the chart and the center of your circle is the actual residual unbalance present on the rotor correction plane. Measure the distance in units of scale you choose in Step 1 and multiply this number by the scale factor determined in Step 6. Distance in units of scale between origin and center of the circle times scale factor equals actual residual unbalance.

Record actual residual unbalance *6.5 (0.041) = 0.27* (~~g-mm~~)(oz-in.)

Record allowable residual unbalance (from Figure J-2) *0.36* (~~g-mm~~)(oz-in.)

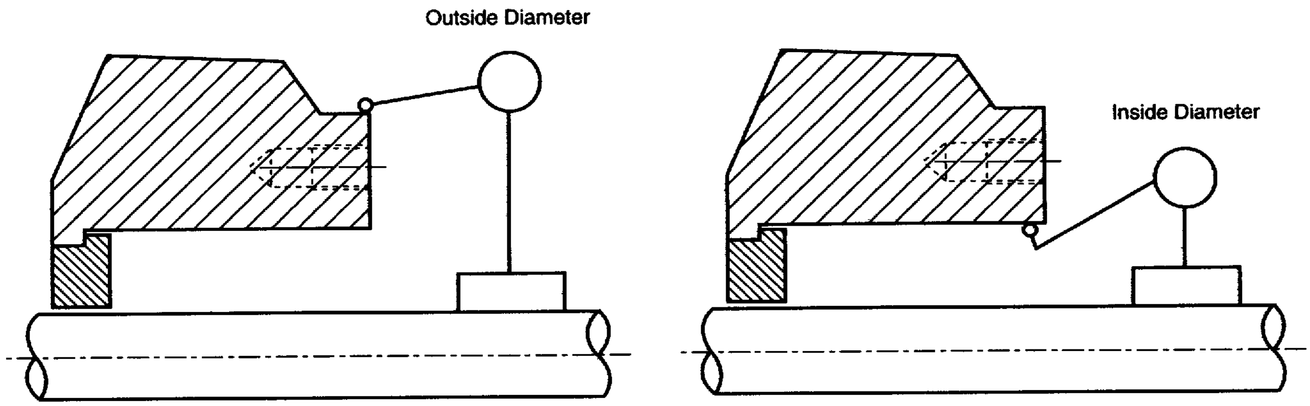
Correction plane *A* for Rotor No. *C-101* (has/~~has not~~) passed.

By *John Inspector* Date *11-31-94*

Figure J-2—Sample Calculations for Residual Unbalance (Continued)

# APPENDIX K—SEAL CHAMBER RUNOUT ILLUSTRATIONS

The schematics in this appendix illustrate the measurements desired, not the method or orientation.




Note: Measure concentricity to register fit to be used, not both.

Figure K-1—Seal Chamber Concentricity (2.7.3.11)

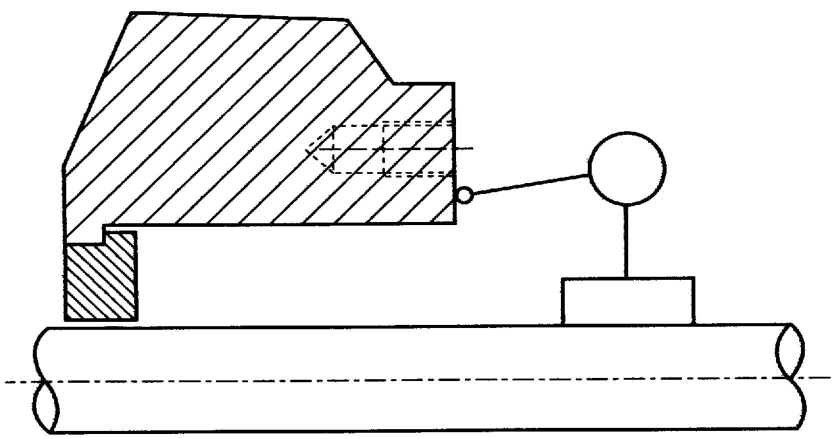


Figure K-2—Seal Chamber Face Runout (2.7.3.13)

# APPENDIX L—BASEPLATE AND SOLEPLATE GROUTING

## L.1 General

Unless otherwise specified, epoxy grout with precision grouting techniques are required when a fully grouted baseplate is specified. Full grouting is defined as the complete filling with grout of the void area under the baseplate or soleplate while supported by a concrete foundation. The epoxy grout shall be applied in accordance with the grout manufacturer's procedure.

## L.2 Minimum requirements

**L.2.1** The creep of the epoxy grout shall be less than 5 μm/mm (0.005 in./in.) when tested by ASTM C 1181 method. The test shall be at 20°C (70°F) and 60°C (140°F) with a load of 2.8 MPa (400 psi).

**L.2.2** Linear shrinkage of epoxy grout shall be less than 0.080 percent and thermal expansion less than $54 \times 10^{-6}$ mm/mm/°C ($30 \times 10^{-6}$ in./in./°F) when tested by ASTM C 531 test method.

**L.2.3** The compressive strength of epoxy grout shall be a minimum of 83 MPa (12,000 psi) in 7 days when tested by ASTM C 579 method 8, modified.

**L.2.4** Bond strength of epoxy grout to concrete grout shall be greater than 14 MPa (2,000 psi) when using ASTM C 882 test method.

**L.2.5** Epoxy grout shall pass the thermal compatibility test when overlayed on cement grout using test method ASTM C 884.

**L.2.6** Tensile strength and modulus of elasticity shall be determined by ASTM D 638. The tensile strength shall not be less than 12 MPa (1,700 psi) and the modulus of elasticity shall not be less than $1.2 \times 10^4$ MPa ($1.8 \times 10^6$ psi).

**L.2.7** Gel time and peak exothermic temperature of epoxy grouts shall be determined by ASTM D 2471. Peak exothermic temperature shall not exceed 45°C (110°F) when a specimen 15 cm (6 in.) diameter × 30 cm (12 in.) high is used. Gel time shall be at least 150 minutes.

## L.3 Placement

**L.3.1** Epoxy grout is very viscous; however, it will flow readily given time and positive hydraulic head. If the epoxy grout is installed below 20°C (70°F) ambient temperature, consult the grout manufacturer to determine if aggregate adjustment is necessary. Generally, it is best to start placing the grout at the center of one end of the baseplate or soleplate and work toward the ends in such manner as to force the air from beneath the baseplate or soleplate and out the vent holes, to eliminate voids.

**L.3.2** Placing of the grout is accomplished in a manner which avoids air entrapment, and a head box is used to aid in pouring the grout into the grout holes. The head box provides a hydraulic head to force the grout to the vent holes. When the head box is moved to the next grout hole, a 15 cm (6 in.) high stand pipe shall be placed over the grout hole and filled with grout. These stand pipes provide a continuous hydraulic head to sweep air from under the baseplate to the vent holes. Never allow the grout to fall below the baseplate level once the grout has made contact with the baseplate. The use of a head box provides a surge volume for the grout as well as providing the critical hydraulic head.

**L.3.3** No push rods, chains, or vibrators shall be used to place epoxy grout under baseplates.

## L.4 General Application

**L.4.1** Grout should be applied only when surrounding temperatures are between 15°C and 32°C (60°F and 90°F).

**L.4.2** Before an epoxy grout is applied, the baseplate temperature should be estimated to ensure that the grout can resist the expected temperature.

**L.4.3** Approximately 10 to 25 mm (0.5 to 1 in.) of the top of the cementitious foundation material should be scarified with a chipping hammer before the grout is applied. This procedure is recommended to remove low-strength, high-porosity concrete in this area. The concrete foundation should be allowed to cure for at at least 7 days prior to this surface preparation.

**L.4.4** All grease, oil, paint, laitance and other undesired materials shall be removed from the surfaces to be grouted. The roughened concrete surface shall be blown with oil-free compressed air to remove all dust and loose particles. When cementitious grout is used, the concrete surface shall be thoroughly soaked with water until absorption stops, and any excess water shall be removed. When epoxy grout is used, all surfaces shall be kept dry before application.

**L.4.5** The baseplate should be located in the desired position by supporting it on shims or leveling screws and securing it with anchor bolts. Approximately 25–50 mm (1–2 in.) of grouting clearance should be allowed between the bottom of the baseplate rim and the top of the scarified foundation.

**L.4.6** All water and foreign materials shall be removed from the anchor bolt sleeves before grouting.

**L.4.7** After the baseplate is installed, the anchor bolt sleeve holes should be filled with a nonbonding material or the chosen grout, depending on the user's preference. This should be done before the main grouting of the baseplate.

**L.4.8** If voids are present after the grouting sequence, epoxy grout may be used to fill them. If cementitious grout is used, a full 28-day cure is recommended before this epoxy is applied. Epoxy grout is usually hand pumped through high-pressure threaded fittings installed in the baseplate where voids have been found. Extreme care should be taken to ensure that excessive pressures do not buckle the baseplate. At least one vent hole should be drilled into each void to help prevent excessive pressures.

## L.5 References

ASTM[1]

C 1181 *Standard Test Method for Creep of Concrete in Compression*

C 531 *Standard Test Method for Linear Shrinkage and Coefficient of Thermal Expansion of Chemical Resistant Mortars, Grouts, and Monolithic Surfaces*

C 579 *Standard Test Method for Compressive Strength of (Method B) Chemical Resistant Mortars and Monolithic Surfacings*

C 882-87 *Standard Test for Bond Strength of Epoxy-Resin Systems Used with Concrete*

C 884-87 *Standard Test Method for Thermal Compatibility between Concrete and an Epoxy-Resin Overlay*

D 638-89 *Standard Test Methods for Tensile Properties of Plastics*

D 2471-88 *Standard Test Method for Gel Time and Peak Exothermic Temperature of Reacting Thermosetting Resins*

Corps of Engineers[2]

CRD C611 *Test Methods for Flow Grout Mixtures (Flowcone Method)*

CRD C621 *Corps of Engineers Specification for Non-shrink Grout*

[1]American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103-1187.

[2]U.S. Army Corps of Engineers, 20 Massachusetts Avenue, N.W., Washington, D.C. 20314.

# APPENDIX M—STANDARD BASEPLATES

## Table M-1—Dimensions of API 610 Standard Baseplates

| Baseplate Number | No. of Holes per Side | Dimensions (mm/in.) A ±13/0.5 | B ±25/1.0 | C ±3/0.12 | D ±3/0.12 | E ±3/0.12 | F ±13/0.5 |
|---|---|---|---|---|---|---|---|
| 0.5 | 3 | 760/30.0 | 1230/48.5 | 465/18.25 | 465/18.25 | 685/27.0 | 140/5.5 |
| 1 | 3 | 760/30.0 | 1535/60.5 | 615/24.25 | 615/24.25 | 685/27.0 | 140/5.5 |
| 1.5 | 3 | 760/30.0 | 1840/72.5 | 770/30.25 | 770/30.25 | 685/27.0 | 140/5.5 |
| 2 | 4 | 760/30.0 | 2145/84.5 | 920/36.25 | 615/24.16 | 685/27.0 | 140/5.5 |
| 3 | 3 | 915/36.0 | 1840/72.5 | 770/30.25 | 770/30.25 | 840/33.0 | 140/5.5 |
| 3.5 | 4 | 915/36.0 | 2145/84.5 | 920/36.25 | 615/24.16 | 840/330 | 140/5.5 |
| 4 | 4 | 915/36.0 | 2450/96.5 | 1075/42.25 | 715/28.16 | 840/33.0 | 140/5.5 |
| 5 | 3 | 1065/42.0 | 1840/72.5 | 770/30.25 | 770/30.25 | 990/39.0 | 165/6.5 |
| 5.5 | 4 | 1065/42.0 | 2145/84.5 | 920/36.25 | 615/24.16 | 990/39.0 | 165/6.5 |
| 6 | 4 | 1065/42.0 | 2450/96.5 | 1075/42.25 | 715/28.16 | 990/39.0 | 165/6.5 |
| 6.5 | 5 | 1065/42.0 | 2750/108.5 | 1225/48.25 | 615/24.12 | 990/39.0 | 165/6.5 |
| 7 | 4 | 1245/49.0 | 2145/84.5 | 920/36.25 | 615/24.16 | 1170/46.0 | 165/6.5 |
| 7.5 | 4 | 1245/49.0 | 2450/96.5 | 1075/42.25 | 715/28.16 | 1170/46.0 | 165/6.5 |
| 8 | 5 | 1245/49.0 | 2755/108.5 | 1225/48.25 | 615/24.12 | 1170/46.0 | 165/6.5 |
| 9 | 4 | 1395/55.0 | 2145/84.5 | 920/36.25 | 615/24.16 | 1320/52.0 | 165/6.5 |
| 9.5 | 4 | 1395/55.0 | 2450/96.5 | 1075/42.25 | 715/28.16 | 1320/52.0 | 165/6.5 |
| 10 | 5 | 1395/55.0 | 2755/108.5 | 1225/48.25 | 615/24.12 | 1320/52.0 | 165/6.5 |
| 11 | 4 | 1550/61.0 | 2145/84.5 | 920/36.25 | 615/24.16 | 1475/58.0 | 165/6.5 |
| 11.5 | 4 | 1550/61.0 | 2450/96.5 | 1075/42.25 | 715/28.16 | 1475/58.0 | 165/6.5 |
| 12 | 5 | 1550/61.0 | 2755/108.5 | 1225/48.25 | 615/24.12 | 1475/58.0 | 165/6.5 |

Note: See Figures M-1 and M-2 for explanation of dimensions.

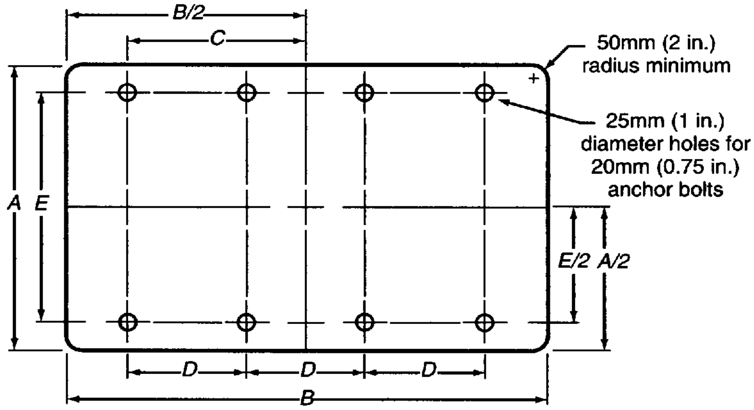



Figure M-1—Schematic for API 610 Standard Baseplates

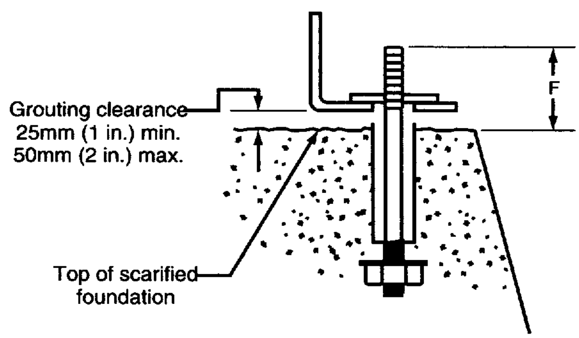



Figure M-2—Anchor Bolt Projection

# APPENDIX N—INSPECTOR'S CHECKLIST

The levels indicated in the following checklist may be characterized as follows: Level 1 is typically used for pumps in general services. Level 2 comprises performance and material requirements and is more stringent than Level 1. Level 3 items should be considered for pumps in critical services.

| Item | API Standard 610 Reference | Date Inspected | Inspected By | Status | Witness Yes/No |
|---|---|---|---|---|---|
| **Level 1 - Basic** | | | | | |
| Casing marking (serial no.) | 2.12.3 | | | | |
| Certified hydrotest | 4.3.2.1 | | | | |
| Performance within tolerance (certified) | 4.3.3.3.3 | | | | |
| NPSHR within tolerance (certified) | 4.3.4.1.3 | | | | |
| Vibration within tolerance | 4.3.3.3.1 | | | | |
| Rotation arrow | 2.12.4[a] | | | | |
| Overall dimensions and connection locations[a] | Appendix O | | | | |
| Nozzle flange dimensions[a] | Appendix O | | | | |
| Anchor bolt layout and size[a] | Appendix O | | | | |
| Auxiliary piping flow diagram | Appendix D | | | | |
| Piping fabrication and installation | 3.5.1 | | | | |
| Equipment nameplate data | 2.12.2 | | | | |
| Rust prevention | 4.4.3.4<br>4.4.3.5<br>4.4.3.11<br>4.4.5 | | | | |
| Painting | 4.4.3.3 | | | | |
| Preparation for shipment | 4.4.1 | | | | |
| Shipping documents and tags | 4.4.3.10 | | | | |

[a]Check against certified dimensional outline drawing.

## APPENDIX N—INSPECTOR'S CHECKLIST (Continued)

| Item | API Standard 610 Reference | Date Inspected | Inspected By | Status | Witness Yes/No |
|---|---|---|---|---|---|
| **Level 2 - Intermediate (Add to Level 1)** | | | | | |
| Casing marking (serial no.) | 2.12.3 | | | | |
| Copies of subvendor purchase order | — | | | | |
| Material certification | 2.11.1.2 | | | | |
| Nondestructive examination (components) | 2.11.1.3<br>4.2.2.1 | | | | |
| Hydrotest witnessed | 4.3.2.1 | | | | |
| Building record (runouts, clearances) | 2.5.6<br>2.5.10<br>2.6.4.2<br>5.2.2.3<br>5.3.2.2<br>5.3.3.2<br>5.3.7.2<br>5.3.11.8 | | | | |
| Performance and NPSH tests witnessed | 4.3.3<br>4.3.4.1 | | | | |
| **Level 3 - Special ( Add to Levels 1 and 2)** | | | | | |
| Material identification | 2.11.1.3 | | | | |
| Welding procedures approved | 2.11.3.1 | | | | |
| Welding repairs approved | 2.11.3.2 | | | | |
| Welding repair maps | — | | | | |
| Impeller/rotor balancing | 2.8.4<br>5.2.4.2 | | | | |
| Bearing inspection after testing | 5.2.8.5 | | | | |
| Nozzle forces and moments test | 3.3.6 | | | | |
| Complete unit test | 4.3.4.2 | | | | |
| Sound level test | 4.3.4.3 | | | | |
| Auxiliary equipment test | 4.3.4.4 | | | | |
| Resonance test (bearing housing) | 4.3.4.5<br>5.3.8.2 | | | | |

# APPENDIX O—VENDOR DRAWING AND DATA REQUIREMENTS

Appendix O consists of a sample distribution record (schedule), followed by a representative description of the items that are presented numerically in the schedule.

# TYPICAL VENDOR DRAWING AND DATA REQUIREMENTS

JOB NO. ______ ITEM NO. ______
PURCHASE ORDER NO. ______ DATE ______
REQUISITION NO. ______ DATE ______
INQUIRY NO. ______ DATE ______
PAGE 1 OF 2 BY ______

FOR ______
SITE ______
SERVICE ______
REVISION ______
UNIT ______
NO. REQUIRED ______

Proposal[a] — Bidder shall furnish ______ copies of data for all items indicated by an X.

Review[b] — Vendor shall furnish ______ copies and ______ transparencies of drawings and data indicated.

Final[c] — Vendor shall furnish ______ copies and ______ transparencies of drawings and data indicated.
Vendor shall furnish ______ operating and maintenance manuals.

**DISTRIBUTION RECORD**

Final—Received from vendor
Final—Due from vendor[c]
Review—Returned to vendor
Review—Received from vendor
Review—Due from vendor[c]

| Proposal[a] | Review[b] | Final[c] | DESCRIPTION | Review—Due from vendor[c] | Review—Received from vendor | Review—Returned to vendor | Final—Due from vendor[c] | Final—Received from vendor |
|---|---|---|---|---|---|---|---|---|
| | | | **Pump** | | | | | |
| | | | 1. Certified dimensional outline drawing. | | | | | |
| | | | 2. Cross sectional drawings and bill of materials. | | | | | |
| | | | 3. Shaft seal drawing and bills of materials. | | | | | |
| | | | 4. Shaft coupling assembly drawing and bill of materials including allowable misalignment tolerances and the style of the coupling guard. | | | | | |
| | | | 5. Primary and auxiliary sealing schematics and bills of materials including seal fluid, fluid flows, pressure, pipe and valve sizes, instrumentation, and orifice sizes. | | | | | |
| | | | 6. Cooling or heating schematic and bills of materials including cooling or heating media, fluid flows, pressure, pipe and valve sizes, instrumentation, and orifice sizes. | | | | | |
| | | | 7. Lube oil schematic and bills of materials. | | | | | |
| | | | 8. Lube oil system arrangement drawing including size, rating, and location of all customer connections. | | | | | |
| | | | 9. Lube oil component drawings and data. | | | | | |
| | | | 10. Electrical and instrumentation schematics, wiring diagrams, and bill of materials. | | | | | |
| | | | 11. Electrical and instrumentation arrangement drawing and list of components. | | | | | |
| | | | 12. Performance curves. | | | | | |
| | | | 13. Vibration analysis data. | | | | | |
| | | | 14. Damped unbalanced response analysis. | | | | | |
| | | | 15. Lateral critical speed analysis. | | | | | |
| | | | 16. Torsional critical speed analysis. | | | | | |
| | | | 17. Certified hydrostatic test data. | | | | | |
| | | | 18. Material certifications. | | | | | |
| | | | 19. Progress reports detailing the cause of any delays. | | | | | |
| | | | 20. Weld procedures. | | | | | |
| | | | 21. Performance test data. | | | | | |
| | | | 22. Optional test data and reports. | | | | | |
| | | | 23. Certified rotor balance data for multistage pumps. | | | | | |
| | | | 24. Residual unbalance check. | | | | | |
| | | | 25. Rotor mechanical and electrical runout for pumps designed to use noncontacting vibration probes. | | | | | |

[a]Proposal drawings and data do not have to be certified or as built. Typical data shall be clearly identified as such.
[b]Purchaser will indicate in this column the time frame for submission of materials using the nomenclature given at the end of this form.
[c]Bidder shall complete these two columns to reflect his actual distribution schedule and include this form with his proposal.

# TYPICAL VENDOR DRAWING AND DATA REQUIREMENTS

JOB NO. ____________ ITEM NO. ____________
PAGE 2 OF 2 BY ____________
DATE ____________ REVISION ____________

Proposal[a] — Bidder shall furnish ______ copies of data for all items indicated by an X.

Review[b] — Vendor shall furnish ______ copies and ______ transparencies of drawings and data indicated.

Final[c] — Vendor shall furnish ______ copies and ______ transparencies of drawings and data indicated.
Vendor shall furnish ______ operating and maintenance manuals.

**DISTRIBUTION RECORD**

Final—Received from vendor
Final—Due from vendor[c]
Review—Returned to vendor
Review—Received from vendor
Review—Due from vendor[c]

| Proposal | Review | Final | DESCRIPTION | Review—Due from vendor | Review—Received from vendor | Review—Returned to vendor | Final—Due from vendor | Final—Received from vendor |
|---|---|---|---|---|---|---|---|---|
| | | | 26. Data sheet applicable to proposals, purchase, and as-built. | | | | | |
| | | | 27. Noise data sheet. | | | | | |
| | | | 28. As-built clearances. | | | | | |
| | | | 29. Instruction manuals describing installation, operation, and maintenance procedures. | | | | | |
| | | | 30. Spare parts recommendations and price list. | | | | | |
| | | | 31. Preservation, packaging, and shipping procedures. | | | | | |
| | | | 32. Material safety data sheets. | | | | | |
| | | | **Motor**<br>33. Certified dimensional outline drawing for motor and all auxiliary equipment. | | | | | |
| | | | 34. Cross sectional drawing and bill of materials including the axial rotor float. | | | | | |
| | | | 35. Data sheets applicable to proposals, purchase, and as-built. | | | | | |
| | | | 36. Noise data sheets. | | | | | |
| | | | 37. Performance data. | | | | | |
| | | | 38. Certified drawings of auxiliary systems including wiring diagrams for each auxiliary system supplied. The drawings shall clearly indicate the extent of the system to be supplied by the manufacturer and the extent to be supplied by others. | | | | | |
| | | | 39. Instruction manuals describing installation, operation, and maintenance procedures. | | | | | |
| | | | 40. Spare parts recommendations and price list. | | | | | |
| | | | 41. Material safety data sheets. | | | | | |
| | | | | | | | | |

[a]Proposal drawings and data do not have to be certified or as-built. Typical data shall be clearly identified as such.
[b]Purchaser will indicate in this column the time frame for submission of materials using the nomenclature given at the end of this form.
[c]Bidder shall complete these two columns to reflect his actual distribution schedule and include this form with his proposal.

Notes:

1. Send all drawings and data to ______________________________

2. All drawings and data must show project, appropriation, purchase order, and item numbers in addition to the plant location and unit. In addition to the copies specified above, one set of the drawings/instructions necessary for field installation must be forwarded with the shipment.

Nomenclature:
______ S—number of weeks prior to shipment.
______ F—number of weeks after firm order.
______ D—number of weeks after receipt of approved drawings.

Vendor ______________________________
Date ______________ Vendor Reference ______________
Signature ______________________________
(Signature acknowledges receipt of all instructions)

# DESCRIPTION

## Pump

1. Certified dimensional outline drawing including:
   a. The size, rating, and location of all customer connections.
   b. Approximate overall and handling weights.
   c. Overall dimensions, and maintenance and dismantling clearances.
   d. Shaft centerline height.
   e. Dimensions of baseplates (if furnished) complete with diameters, number, and locations of bolt holes and the thicknesses of sections through which the bolts must pass.
   f. Grouting details.
   g. Forces and moments for suction and discharge nozzles.
   h. Center of gravity and lifting points.
   i. Shaft end separation and alignment data.
   j. Direction of rotation.
   k. Winterization, tropicalization, and/or noise attenuation details, when required.

2. Cross sectional drawings and bill of materials.

3. Shaft seal drawing and bill of materials.

4. Shaft coupling assembly drawing and bill of materials including allowable misalignment tolerances and the style of the coupling guard.

5. Primary and auxiliary sealing schematic and bill of materials including seal fluid, fluid flows, pressure, pipe and valve sizes, instrumentation, and orifice sizes.

6. Cooling or heating schematic and bill of materials including cooling or heating media, fluid flows, pressure, pipe and valve sizes, instrumentation, and orifice sizes.

7. Lube oil schematic and bill of materials including the following:
   a. Oil flows, temperatures, and pressures at each use point.
   b. Control, alarm, and trip settings (pressure and recommended temperatures).
   c. Total heat loads.
   d. Utility requirements, including electrical, water, and air.
   e. Pipe, valve, and orifice sizes.
   f. Instrumentation, safety devices, control schemes, and wiring diagrams.

8. Lube oil system arrangement drawing including size, rating, and location of all customer connections.

9. Lube oil component drawings and data including the following:
   a. Pumps and drivers.
   b. Coolers, filters, and reservoir.
   c. Instrumentation.
   d. Spare parts lists and recommendations.

10. Electrical and instrumentation schematics, wiring diagrams, and bill of materials including the following:
    a. Vibration alarm and shutdown limits.
    b. Bearing temperature alarm and shutdown limits.
    c. Lube oil temperature alarm and shutdown limits.
    d. Driver.

11. Electrical and instrumentation arrangement drawing and list of connections.

12. Performance curves.

13. Vibration analysis data.

14. Damped unbalanced response analysis.

15. Lateral critical speed analysis.
The required number of lateral critical analysis reports, no later than 3 months after the date of the order. The reports shall be as required by Appendix I. Paragraph I.3.1.

16. Torsional critical speed analysis.
The required number of torsional critical analysis reports, no later than 3 months after the date of the order. The reports shall be as required by Paragraph 2.8.2.6.

17. Certified hydrostatic test data.

18. Material certifications.
The vendor's physical and chemical data from mill reports (or certification) of pressure parts, impellers, and shafts.

19. Progress reports detailing the cause of any delays.
The reports shall include engineering, purchasing, manufacturing, and testing schedules for all major components. Planned and actual dates and the percentage completed shall be indicated for each milestone in the schedule.

20. Weld procedures.

21. Performance test data.
Certified shop logs of the performance test. A record of shop test data (which the vendor shall maintain for at least 20 years after the date of shipment). The vendor shall submit certified copies of the test data to the purchaser before shipment.

22. Optional tests data and reports.
Optional tests data and reports include NPSHR test, complete unit test, sound level test, auxiliary equipment test, bearing housing resonance test, and any other tests mutually agreed upon by the purchaser and vendor.

23. Certified rotor balance data for multistage pumps.

24. Residual unbalance check.

25. Rotor mechanical and electrical runout for pumps designed to use noncontacting vibration probes.

26. Data sheets applicable to proposals, purchase, and as-built.

27. Noise data sheets.

28. As-built clearances.

29. Instruction manuals describing installation, operation, and maintenance procedures. Each manual shall include the following sections:

Section 1—Installation:
   a. Storage.
   b. Foundation.
   c. Grouting.
   d. Setting equipment, rigging procedures, component weights, and lifting diagram.

e. Alignment.
f. Piping recommendations.
g. Composite outline drawing for pump/driver train, including anchor bolt locations.
h. Dismantling clearances.

Section 2—Operation:
a. Start-up including tests and checks before start-up.
b. Routine operational procedures.
c. Lube oil recommendations.

Section 3—Disassembly and assembly:
a. Rotor in pump casing.
b. Journal bearings.
c. Thrust bearings (including clearance and preload on antifriction bearings).
d. Seals.
e. Thrust collars, if applicable.
f. Allowable wear of running clearances.
g. Fits and clearances for rebuilding.
h. Routine maintenance procedures and intervals.

Section 4— Performance curves including differential head, efficiency, water NPSHR, and brake horsepower versus capacity for all operating conditions specified on the data sheets.

Section 5—Vibration data:
a. Vibration analysis data.
b. Lateral critical speed analysis.
c. Torsional critical speed analysis.

Section 6—As-built data:
a. As-built data sheets.
b. As-built clearances.
c. Rotor balance data for multistage pumps.
d. Noise data sheets.
e. Performance data.

Section 7—Drawing and data requirements:
a. Certified dimensional outline drawing and list of connections.
b. Cross sectional drawing and bill of materials.
c. Shaft seal drawing and bill of materials.
d. Lube oil arrangement drawing and list of connections.
e. Lube oil component drawings and data, and bill of materials.
f. Electrical and instrumentation schematics, wiring diagrams, and bills of materials.
g. Electrical and instrumentation arrangement drawing and list of connections.
h. Coupling assembly drawing and bill of materials.
i. Primary and auxiliary seal schematic and bill of materials.
j. Primary and auxiliary seal piping, instrumentation, arrangement, and list of connections.
k. Cooling or heating schematic and bill of materials.
l. Cooling or heating piping, instrumentation arrangement, and list of connections.

30. Spare parts recommendations and price list.

31. Preservation, packaging, and shipping procedures.

32. Material safety data sheets.

**Motor**

33. Certified dimensional outline drawing for motor and all auxiliary equipment including the following:
    a. Size, location, and purpose of all customer connections, including conduit, instrumentation, and any piping or ducting.
    b. ANSI rating and facing for any flanged connections.
    c. Size and location of anchor bolt holes and thicknesses of sections through which bolts must pass.
    d. Total weight of each item of equipment (motor and auxiliary equipment) plus loading diagrams, heaviest weight, and name of the part.
    e. Overall dimensions and all horizontal and vertical clearances necessary for dismantling and the approximate location of lifting lugs.
    f. Shaft centerline height.
    g. Shaft end dimensions, plus tolerances for the coupling.
    h. Direction of rotation.

34. Cross sectional drawing and bill of materials including the axial rotor float.

35. Data sheets applicable to proposals, purchase, and as-built.

36. Noise data sheets.

37. Performance data including the following:
    a. For induction motors 150 kW (200 hp) and smaller:
        1. Efficiency and power factor at one-half, three-quarter, and full load.
        2. Speed-torque curves.
    b. For induction motors larger than 150 kW (200 hp) and larger, certified test reports for all tests run and performance curves as follows:
        1. Time-current heating curve.
        2. Speed-torque curves at 70, 80, 90, and 100 percent of rated voltage.
        3. Efficiency and power factor curves from 0 to rated service factor.
        4. Current versus load curves from 0 to rated service factor.
        5. Current versus speed curves from 0 to 100 percent of rated speed.

38. Certified drawings of auxiliary systems including wiring diagrams for each auxiliary system supplied. The drawings shall clearly indicate the extent of the system to be supplied by the manufacturer and the extent to be supplied by others.

39. Motor instruction manuals describing installation, operation, and maintenance procedures. Each manual shall include the following sections:

Section 1—Installation:
    a. Storage.
    b. Setting motor, rigging procedures, component weights, and lifting diagram.
    c. Piping and conduit recommendations.
    d. Composite outline drawing for motor including locations of anchor bolt holes.
    e. Dismantling clearances.

Section 2—Operation:
    a. Start-up including check before start-up.
    b. Normal shutdown.

c. Operating limits including number of successive starts.
d. Lube oil recommendations.

Section 3—Disassembly and assembly instructions:
a. Rotor in motor.
b. Journal bearings.
c. Seals.
d. Routine maintenance procedures and intervals.

Section 4—Performance data required by Item 37.

Section 5—Data Sheets:
a. As-built data sheets.
b. Noise data sheets.

Section 6—Drawing and data requirements:
a. Certified dimensional outline drawing for motor and all auxiliary equipment with list of connections.
b. Cross sectional drawing and bill of materials.

40. Spare parts recommendations and price list.

41. Material safety data sheets.

# APPENDIX P—PURCHASER'S CHECKLIST

This checklist is to be used to indicate the purchaser's specific requirements when this standard indicates that a decision is required by the purchaser. In this standard, items requiring a decision are indicated by a bullet preceding the paragraph number.

The checklist should be used in conjunction with the data sheets (see Appendix B). In the following list, the purchaser should circle yes or no, or mark the appropriate space with an X.

Note: The use of this checklist is optional where these items are covered by a narrative specification.

| Paragraph | Item | | |
|---|---|---|---|
| | **General:** | | |
| 1.2.2 | Are SI dimensions or U.S. dimensions applicable? (See data sheets.) | | |
| | Are ISO standards or U.S. standards applicable? (See data sheets.) | | |
| | **Basic Design:** | | |
| 2.1.3 | Are there any other anticipated operating conditions? | Yes | No |
| 2.1.9 | Limitation on suction specific speed (see data sheets). | | |
| 2.1.11 | Is parallel operation anticipated? | Yes | No |
| 2.1.14 | Maximum allowable sound pressure level (see data sheets). | | |
| 2.1.17 | Is cooling required (see data sheets)? | Yes | No |
| 2.1.22 | Are local codes applicable? | Yes | No |
| | Have copies been furnished to vendor? | Yes | No |
| 2.1.27 | What additional review of installation factors by vendor is required? | | |
| | Review and comment on purchaser's piping and foundation drawings? | Yes | No |
| | Observe a check of the piping, performed by parting the flanges after installation? | Yes | No |
| | Be present during the initial alignment check of the pump and drive train? | Yes | No |
| | Recheck the alignment of the pump and drive train at the operating temperature? | Yes | No |
| 2.1.29 | Location and environmental conditions (see data sheets). | | |
| 2.2.4 | Is pump suction on multistage pumps to be suitable for maximum allowable working pressure (single pressure casing)? | Yes | No |
| 2.3.3.3 | Are cylindrical threads required? | Yes | No |
| 2.3.3.11 | Are pressure gauge connections required? | Yes | No |
| 2.7.3 | Is API Standard 682 compliance required? | Yes | No |
| 2.7.3.17 | Are jackets required on seal chambers? | Yes | No |
| 2.7.3.19 | Mechanical seal piping plan (see data sheets). | | |
| 2.7.3.20 | Are throttle bushings required with dual seals? | Yes | No |
| 2.7.3.21 | Dual seals and auxiliary shaft sealing devices (see data sheets). | | |
| 2.8.2.6 | Is a torsional analysis report required if driver is in accordance to 2.8.2.1? | Yes | No |
| 2.9.2.2 | Are specific constant level oilers required? | Yes | No |
| 2.9.2.9 | Are oil heaters required? | Yes | No |
| 2.9.2.11 | Are threaded connections required in bearing housings for mounting vibration transducers? | Yes | No |
| 2.9.2.12 | Is a flat surface required on bearing housing for magnetic pick up? | Yes | No |
| 2.10.3 | Are provisions to be made for pure or purge oil mist lubrication? | Yes | No |
| 2.11.1.1 | Have materials of construction been specified? | Yes | No |
| 2.11.1.7 | Shall vendor furnish chemical and mechanical data for materials? | Yes | No |
| 2.11.1.8 | Have all corrosive agents present been specified on the data sheets? | Yes | No |
| 2.11.1.11 | Is $H_2S$ present in pumped fluid? | Yes | No |
| 2.11.2.5 | Shall casting repair procedures be submitted to the purchaser for approval? | Yes | No |
| 2.11.3.5.4 | Shall connection designs be submitted to the purchaser for approval? | Yes | No |

## Purchaser's Checklist (Continued)

| Paragraph | Item | | |
|---|---|---|---|
| | **Basic Design (Continued):** | | |
| 2.11.3.5.6 | Is special inspection of welds required? | Yes | No |
| 2.11.4.5 | Minimum design metal temperature for establishing impact tests (See data sheets) | | |
| | **Accessories** | | |
| 3.1.1 | Has the type of driver been specified on the data sheets? | Yes | No |
| 3.1.2 | Are there process variation or startup conditions that affect driver selection? | Yes | No |
| 3.1.3 | Driver starting conditions and methods (see data sheets). | | |
| 3.1.5 | Motor type and characteristics (see data sheets). | | |
| 3.1.6 | Is it a reduced voltage start? | Yes | No |
| 3.2.2 | Type of coupling (see data sheets). | | |
| 3.3.6 | Is a pump and baseplate stiffness (pipe load) test required? | Yes | No |
| 3.3.13 | Shall pump, baseplate, and pedestal support assembly be sufficiently rigid to be mounted without grouting? | Yes | No |
| 3.3.18 | Are grout contact surfaces to be left free of paint and primer? | Yes | No |
| 3.4.2.2 | Are liquid filled pressure gauges to be furnished? | Yes | No |
| 3.4.3.1 | Shall provision be made for mounting vibration detectors? | Yes | No |
| | Shall detectors be furnished? | Yes | No |
| | Shall detectors be installed? | Yes | No |
| 3.4.3.2 | Shall provision be made for mounting a bearing temperature detector? | Yes | No |
| | Shall a bearing temperature detector be furnished? | Yes | No |
| | Shall a bearing temperature detector be installed? | Yes | No |
| 3.4.3.3 | Shall monitors be furnished? | Yes | No |
| | Shall monitors be installed? | Yes | No |
| | **Piping and Appurtenances** | | |
| 3.5.1.4 | Are seal reservoirs to be mounted off the baseplate and shipped separately? | Yes | No |
| 3.5.2.6 | Is chloride content above 10 parts per million? | Yes | No |
| 3.5.2.10.1 | Are flanges required in place of socket welded unions? | Yes | No |
| | **Inspection and Testing** | | |
| 4.1.4 | Witnessed or observed tests (see data sheets). | | |
| 4.1.6 | Is purchaser's inspector to submit completed inspection checklist before shipment? | Yes | No |
| 4.2.1.3 | Is examination of pressure containing parts required? | Yes | No |
| 4.2.2.1 | Are specific additional material inspection criteria needed? | Yes | No |
| 4.2.3.1 | Will equipment be inspected for cleanliness? | Yes | No |
| 4.2.3.2 | Has hardness test been specified? | Yes | No |
| 4.3.1.2 | Is purchaser review of test procedures required? | Yes | No |
| 4.3.2.5 | Is special hydrostatic test liquid required? | Yes | No |
| 4.3.3.1.2 | Are substitute seals to be used during the performance test? | Yes | No |
| 4.3.4 | What optional tests are required by purchaser (see data sheets)? | | |
| 4.4.1 | Is long-term storage required? | Yes | No |
| | Is type of shipment specified? | Yes | No |
| | **Specific Pump Types** | | |
| 5.1.2.4 | Shall vertical in-line pumps be designed for bolting to a pad or foundation? | Yes | No |

## Purchaser's Checklist (Continued)

| Paragraph | Item | | |
|---|---|---|---|
| | **Specific Pump Types (Continued):** | | |
| 5.1.2.7 | Is a rigging device required to facilitate removal and installation of the back pullout assembly? | Yes | No |
| 5.1.3.3 | Is a lateral critical speed analysis required? | Yes | No |
| 5.2.2.2 | Are impellers for multistage pumps to be positively locked against axial movement in the direction opposite to normal hydraulic thrust? | Yes | No |
| 5.2.5.2.4 | Is purchaser review of thrust bearing sizing required? | Yes | No |
| 5.2.6.1 | Is pressure lubrication system required? | Yes | No |
| 5.2.6.2 | Must oil side pressure be higher than water side pressure? | Yes | No |
| 5.2.6.3 | Is heating of the oil reservoir required? | Yes | No |
| 5.2.6.5 | Is specific oil required? | Yes | No |
| 5.2.6.6 | Does API Standard 614 apply for the pressure lubrication system? | Yes | No |
| 5.2.7 | Shall couplings and coupling mountings comply with API Standard 671? | Yes | No |
| 5.2.8.5 | Must inspection of hydrodynamic bearings after test be witnessed? | Yes | No |
| 5.2.9.2 | Is vertical storage of spare rotor required? | Yes | No |
| 5.3.4.1 | Is natural frequency analysis required for vertically suspended pumps? | Yes | No |
| 5.3.7.3.5 | Is grouting required for vertically suspended pumps (a sole plate shall be provided)? | Yes | No |
| 5.3.8.2 | Is a resonance test required for vertically suspended pumps? | Yes | No |
| 5.3.9.7 | Is line shafting to be furnished with hardened sleeves under the bearings? | Yes | No |
| 5.3.12.6 | Is a piped drain required in the suction can of vertical double case pumps? | Yes | No |
| | **Vendor's Data:** | | |
| 6.1.3 | Is coordination meeting required? | Yes | No |
| 6.2.3 | Is user list required with proposal? | Yes | No |
| 6.2.5 | Is a list of the procedures for any special or optional tests required with the proposal? | Yes | No |

# Appendix Q—Standardized Electronic Data Exchange File Specification

## Q.1 Scope

The purpose of this appendix is to establish a standard format for the storage and transmittal of centrifugal pump data. This standard format is also known as the "neutral data exchange file format."

**Q.1.1** The role of this specification is somewhat different from the "Standardized Electronic Database" in the 7th Edition of API Standard 610. The data exchange file outlined in this specification extends beyond the scope of the API Standard 610 data sheets (Appendix B), such that data fields for virtually all pertinent centrifugal pump information are defined within this specification. This includes data fields that are part of the following:

a. The API Standard 610 centrifugal pump data sheets in the 8th Edition.
b. The API Standard 610 centrifugal pump data sheets in the 7th Edition.
c. Additional data that is an important part of the information exchange between the purchaser and the manufacturer including performance curve data and other detailed technical information.
d. Dimensional information used in equipment general arrangement drawings.
e. Nozzle load data.
f. Multiple operating conditions.

**Q.1.2** Purchasers and manufacturers are encouraged to use this specification to transfer data via electronic methods rather than traditional paper data sheets. Proprietary systems designed to manage centrifugal pump databases may be used, provided import/export capabilities are used that adhere to the data exchange format of this specification The legal ramifications of exchanging data electronically is subject to policy established between purchaser and manufacturer. Data sheets and/or specifications in paper format may be required as approved legal documents.

**Q.1.3** A PC-compatible *API Centrifugal Pump Database Program* that imports from or exports to the data exchange file format will be available in late 1995. This program will allow any purchaser or manufacturer to electronically communicate centrifugal pump data with (a) any other user of the *Program* or (b) any proprietary system with import/export capability. Standard API 610 data sheets may be printed via this *Program*. To register to receive the diskette when it is available, call API Publications and Distribution at 202-682-8375 or fax (202-962-4776) or mail the order form at the end of this book.

**Q.1.4** The data exchange file specification may be revised during the effective period of the 8th Edition. Revisions to the program and data exchange specification will be available to all registered users of the program and through API. Proprietary systems may be affected by these revisions but will be generally protected through the revision control strategy outlined in the specification.

## Q.2 File Format

### Q.2.1 FILE STRUCTURE

The Neutral File format is comprised of a computer file, records, groups, and fields of data. A sample file format is shown below.

```
#CENTRIFUGAL PUMP NEUTRAL FILE EXCHANGE                  {header}
#VERSION 0.0                                             {version number}
#BEGIN: HEADER DATA                                      {start of header group}
----- File Header Data here: {see specification}
#END: HEADER DATA                                        {end of header group}
#RECORD STARTS                                           {start of record}
#BEGIN: PUMP DATA                                        {start of pump group}
---- Pump Data here : [see specification]
#END: PUMP DATA                                          {end of pump group}
#BEGIN: ADDITIONAL DATA                                  {start of additional group}
---- Additional Data here : [see specification]
#END: ADDITIONAL DATA                                    {end of additional group}
#BEGIN: DIMENSIONAL DATA                                 {start of dimensional group}
---- Dimensional Data here : [see specification]
#END: DIMENSIONAL DATA                                   {end of dimensional group}
#BEGIN: NOZZLE LOAD DATA                                 {start of nozzle load group}
---- Nozzle Load Data here : [see specification]
#END: NOZZLE LOAD DATA                                   {end of nozzle load group}
#BEGIN: ADDITIONAL OPERATING CONDITIONS                  {start of additional perating
        DATA                                             conditions group}
---- Additional Operating Conditions Data here : [see specification]
#END: ADDITIONAL OPERATING CONDITIONS DATA               {end of additional operating
                                                         conditions group}
#RECORD ENDS                                             {end of record}
#FILE ENDS                                               {end of file}
```

### Q.2.2 DATA FILES

Data is exchanged as conventional ASCII text *files* supported by all common computer operating systems such as DOS, UNIX, and VAX/VMS. These files may be created and modified using standard text editors such as DOS (edit), UNIX (vi), and VAX/VMS (edit) or via a separate computer program.

The naming convention for the computer *file* is established directly between the trading partners. However, the preferred file format is as follows:

**xxxxxxxx.pxf**

where **xxxxxxxx** is an 8 alphanumeric file prefix

and **pxf** is a 3 digit file extension (pump exchange file)

Each *file* must contain the file header shown below:

| | |
|---|---|
| **#CENTRIFUGAL PUMP NEUTRAL FILE EXCHANGE** | *{header}* |
| **#VERSION 1.0** | *{version number}* |
| **#BEGIN: HEADER DATA** | *{start of header group}* |
| ----- File Header Data here: {see specification} | |
| **#END: HEADER DATA** | *{end of header group}* |

and the end of file identifier

| | |
|---|---|
| **#FILE ENDS** | *{end of file}* |

### Q.2.3 DATA RECORDS

A *record* represents a collection of data about a single pump item (in a conventional inquiry or proposal). The record starts with

| | |
|---|---|
| **#RECORD STARTS** | *{start of record}* |

and ends with

| | |
|---|---|
| **#RECORD ENDS** | *{end of record}* |

Each file contains one or more records.

### Q.2.4 DATA GROUPS

Each record contains any of the following *groups* of field data.

a. Pump Data group. This group is mandatory for each record.
b. Additional Data group. This group is optional for each record.
c. Dimensional Data group. This group is optional for each record.
d. Nozzle Load Data group. This group is optional for each record.
e. Additional Operating Conditions Data group: This group is optional for each record. This group may be repeated one or more times within a record to represent multiple operating conditions.
f. Header Data group: This group is mandatory for each file.

### Q.2.5 DATA FIELDS

The body of the Neutral Exchange file are the data *fields*. Data fields are comprised of the following:

a. **Number:** Field numbers are preceded by a group letter and a sequentially assigned 3 digit number of the form:

**Xnnn**

where **X** is an alpha character and **nnn** is a sequential number from 001 to 999

b. **Delimiter:** The delimiter is a comma (,) to separate the Field Number from the Field Value.
c. **Value:** The value or contents of the field corresponding to the field number.
   - The values are restricted according to the definitions outlined in Q.3, Data Field Definitions.
   - The one character field value, #, denotes a **Required Reply Field**. This indicates to the recipient of the exchange file that the specified field value is currently unknown as is required upon reply by the recipient. This is used to clarify the minimum set of data fields which are required by the sender.
d. **End of Field Delimiter:** Each field is followed by an end of line and carriage return.

### Q.2.6 EXAMPLES

The following examples show proper Neutral Data Exchange File formats.

**Q.2.6.1** Example 1: Single record with only one group (Pump Data). The field values are sample values only and are not intended to represent a true pumping application.

```
#CENTRIFUGAL PUMP NEUTRAL FILE EXCHANGE
#VERSION 1.0
#BEGIN: HEADER DATA
F001,TO:  Company A
F002,FROM:  Company B
F003,DATE:  October 5, 1994
F005,1
#END: HEADER DATA
#RECORD STARTS
#BEGIN: PUMP DATA
A001,JOB21-3454
A002,ITEM01
A003,Requisition number
A005,Purchase order number
A006,19950101
A017,3X8
A018,DA
A019,6
A020,A pump company
A021,12-DA-90874-45-23132
A022,109-132-76123-321984
A023,A
A025,1
A138,#
#END: PUMP DATA
#RECORD ENDS
#FILE ENDS
```

**Q.2.6.2** Example 2: Two records with all four groups in the first record and one group in the second record. The field values are sample values only and are not intended to represent a true pumping application.

```
#CENTRIFUGAL PUMP NEUTRAL FILE EXCHANGE
#VERSION 1.0
#BEGIN: HEADER DATA
F001,TO:  Company A
F002,FROM:  Company B
F003,DATE:  October 5, 1994
F005,2
#END: HEADER DATA
#RECORD STARTS
#BEGIN: PUMP DATA
A001,JOB21-3454
A002,ITEM01
A003,Requisition number
A005,Purchase order number
A006,19950101
A017,3X8
```

A018,DA
A019,6
A020,A pump company
A021,12-DA-90874-45-23132
A022,109-132-76123-321984
A023,A
A025,1
A138,#
#END: PUMP DATA
#BEGIN: ADDITIONAL DATA
B005,6000
B006,1.3209E+03
B007,200.0
B008,C
B009,1
#END: ADDITIONAL DATA
#BEGIN: DIMENSIONAL DATA
C001,1200
C002,1200
C059,1200
#END: DIMENSIONAL DATA
#BEGIN: NOZZLE LOAD DATA
D001,1000
D002,1000
D003,1000
D004,1234
D005,1234
D006,1234
D007,1000
D008,1000
D009,1234
D010,3452
D011,7654
D012,1243
#END: NOZZLE LOAD DATA
#BEGIN: ADDITIONAL OPERATING CONDITIONS DATA
E002,200.1
E008,134.
#END: ADDITIONAL OPERATING CONDITIONS DATA
#BEGIN: ADDITIONAL OPERATING CONDITIONS DATA
E002,252.4
E008,103.
#END: ADDITIONAL OPERATING CONDITIONS DATA
#RECORD ENDS
#RECORD STARTS
#BEGIN: PUMP DATA
A001,JOB21-3455
A002,ITEM02
#END: PUMP DATA
#RECORD ENDS
#FILE ENDS

## Q.3 Data Field Definitions

### Q.3.1 DATA FIELDS

The body of the Neutral Exchange file described in Q.3.2 are the data *fields*. Data field definitinons are comprised of the following:

a. **Number:** Field numbers are preceded by a group letter and a sequentially assigned 3 digit number of the form:

**Xnnn**

where **X** is an alpha character such that:
A = Pump group
B = Additional Data group
C = Dimensional Data group
D = Nozzle Load Data group
E = Additional Operating Conditions group
F = Header Data group
and **nnn** is a sequential number from 001 to 999

b. **Name:** A description of the field. This generally corresponds to a field name in a data sheet.

c. **Field:** A field name is assigned for use in the definition of a computerized database. The field name is not used as part of the neutral exchange file. This is 10 characters or less in length.

d. **Type:** Describes the data field type where:
- **C** is a character field. The contents are any ASCII characters. Note that a comma (,) is an acceptable character and should not be confused with the comma used as a data field delimiter. Special restrictions for the field values are described in the Contents/Units column in Q.3.2.
- **D** is a date field. Dates are represented as 8 character fields of the form YYYYMMDD. For example, October 5, 1994 is represented as 19941005.
- **I** is an integer field. The contents are only whole number values. Examples include 1234 or 2.
- **L** is a logical field. The contents are either:
  Yes (true): 1
  No (false): 0
- **N** is a numeric field. The contents are numeric values that have a field length of 13. Numeric values are represented by a maximum of 7 significant figures when the field is shown in exponential notation. Any of the following notations are also acceptable:
  Integer: 1234
  Floating: 1234.00
  Exponential: +1.234000+E03

e. **Length:** The maximum number of characters allowed.

f. **Contents/Unit:** Fields have the following additional attributes:
- **Contents** are restricted to enumerated lists for certain fields. (Example: A:proposal; B:purchase; C:as built; Z:other)
- **Units** are assigned to certain numeric fields. Units are always stored according to the preferred SI unit standard for centrifugal pumps. The application program is responsible for converting the units into the preferred units of the trading partner.

### Q.3.2 DATA FIELD COMMENTS

The following API 610, 8th Edition Neutral Data Exchange File Specification shows the data fields within each of the 6 data groups.

## Q.3.3 COMMENTS TO THE NEUTRAL DATA EXCHANGE FILE SPECIFICATION

### Q.3.3.1 POLYNOMIAL EQUATIONS

Polynomial equations are used to describe continuous curves of pump flowrate versus head, power, and NPSHR. A 6th order polynomial equation is written in the form:

$$Y = A_1 + A_2Q + A_3Q^2 + A_4Q^3 + A_5Q^4 + A_6Q^5 + A_7Q^6$$

The coefficients of these polynomial equations are used in either Group B, Additional Data or Group E, Additional Operating Conditions such that the $A_1$ term corresponds to the "term 1", the $A_2$ term corresponds to the "term 2" designations ,etc.

The coefficient terms in Group B reference the impeller diameter, pump speed, and liquid conditions described in the Group A, Pump Data. Alternatively, the coefficient terms in Group E reference the impeller diameter in Group A and the pump speed and liquid conditions referenced in Group E.

### Q.3.3.2 REFERENCE TO HYDRAULIC INSTITUTE DIMENSIONAL STANDARDS

The nomenclature selected for the Dimensional Data Group (Group C) was adopted from the *Hydraulic Institute Standards for Centrifugal, Rotary, and Reciprocating Pumps*. For example, the field number C001, "Width of base support", has the field name definition of "HIS_A". This corresponds to dimension "A" in the Hydraulic Institute Standards.

## Q.3.4 REVISIONS TO THE NEUTRAL DATA EXCHANGE FILE SPECIFICATION

**Q.3.4.1** Revisions to this specification are identified by Version Number. As of this writing, the Version Number is 1.0. Those organizations which develop proprietary systems which conform to this data exchange specification are responsible for maintaining compatibility with new Version Numbers.

**Q.3.4.2** Future program revisions are expected to adhere to the file structure outlined in paragraph Q.2.1. New fields will be introduced within each Data Group by issuing new 3 digit sequence numbers. New revisions to the Data Exchange Specification will be made available through the API Publications Office or through an upcoming API electronic bulletin board service.

# API 610, 8th Edition
# Neutral Data Exchange File Specification

*15-Jun-95*

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| **Pump Data** | | | | | |
| **Headings** | | | | | |
| A001 | Job number | JOB_NO | C | 10 | |
| A002 | Item number | ITEM | C | 25 | |
| A003 | Requisition Number | REQ_N | C | 25 | |
| A004 | Specification Number | SPEQ_N | C | 25 | |
| A005 | Purchase Order Number | PO_NO | C | 25 | |
| A006 | Purchase Order Date | DATE | D | 8 | YYYYMMDD |
| A007 | Inquiry Number | INQ_NO | C | 25 | |
| A008 | Inquiry By | INQ_BY | C | 15 | |
| A009 | Revision Number | REV | C | 2 | |
| A010 | Revision Date | REV_DATE | D | 8 | YYYYMMDD |
| A011 | For | FOR | C | 59 | |
| A012 | Applicable To | APPLIC | C | 1 | A:proposal; B:purchase; C:as built; Z:other |
| A013 | Unit | UNIT | C | 20 | |
| A014 | Site | SITE | C | 59 | |
| A015 | Number Required | NO_REQD | I | 5 | |
| A016 | Service | SERVICE | C | 30 | |
| A017 | Pump Size | PUMP_SIZE | C | 30 | |
| A018 | Pump Type | PUMP_TYPE | C | 20 | |
| A019 | Number of Stages | STAGES | I | 5 | |
| A020 | Manufacturer | MFGR | C | 25 | |
| A021 | Model | MODEL | C | 20 | |
| A022 | Serial Number | SERIAL | C | 20 | |
| **General** | | | | | |
| A023 | Operation | OPERATE | C | 1 | A:parallel; B:series;C:both series and parallel; Z:other |
| A024 | ISO Standard | ISO_STD | C | 1 | 1:yes (true); 0: no (false) |
| A025 | US Standard | US_STD | C | 1 | 1:yes (true); 0: no (false) |
| A026 | Other Standard | OTH_STD | C | 1 | 1:yes (true); 0: no (false) |
| A027 | Number Motor Driven | NO_PMPS_M | I | 5 | |
| A028 | Number Turbine Driven | NO_PMPS_T | I | 5 | |
| A029 | With | PUMP_WITH | C | 20 | |
| A030 | Pump Item Number Motor Drive | ITEM_NO_M | C | 24 | |
| A031 | Pump Item Number Turbine Drive | ITEM_NO_T | C | 24 | |
| A032 | Gear Item Number | G_ITEM_NO | C | 24 | |
| A033 | Motor Item Number | M_ITEM_NO | C | 24 | |
| A034 | Turbine Item Number | T_ITEM_NO | C | 24 | |
| A035 | Gear Provided By | G_BY | C | 20 | |
| A036 | Motor Provided By | M_BY | C | 20 | |
| A037 | Turbine Provided By | T_BY | C | 20 | |

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| A038 | Gear Mounted By | G_MTD_BY | C | 20 | |
| A039 | Motor Mounted By | M_MTD_BY | C | 20 | |
| A040 | Turbine Mounted By | T_MTD_BY | C | 20 | |
| A041 | Gear Data Sheet Number | G_DATA_SHT | C | 20 | |
| A042 | Motor Datasheet Number | M_DATA_SHT | C | 20 | |
| A043 | Turbine Data Sheet Number | T_DATA_SHT | C | 20 | |
| **Operating Conditions** | | | | | |
| A044 | Normal Capacity | NORM_CAP | N | 13 | $m^3/h$ |
| A045 | Rated Capacity | RATED_CAP | N | 13 | $m^3/h$ |
| A046 | Other Capacity | OTHER_CAP | N | 13 | $m^3/h$ |
| A047 | Suction Pressure Maximum | SUCT_PRESM | N | 13 | kPa |
| A048 | Suction Pressure Rated | SUCT_PRES | N | 13 | kPa |
| A049 | Discharge Pressure | DISCH_PRES | N | 13 | kPa |
| A050 | Differential Pressure | DIFF_PRES | N | 13 | kPa |
| A051 | Differential Head | HEAD | N | 13 | m |
| A052 | NPSH Available | NPSHA | N | 13 | m |
| A053 | Hydraulic Power | HYD_POWER | N | 13 | kW |
| A054 | Process Variations | PROC_VAR | C | 25 | |
| A055 | Driver Starting Conditions | DR_START_C | C | 25 | |
| A056 | Service | OPER_SERV | C | 1 | A:continuous; B:intermittent; Z:other |
| A057 | Starts per Day | STRTS_PER | I | 5 | |
| A058 | Parallel operation required | PAR_OPER | C | 1 | 1:yes (true); 0: no (false) |
| **Site and Utility Data** | | | | | |
| A059 | Indoor | INDOOR | C | 1 | 1:yes (true); 0: no (false) |
| A060 | Outdoor | OUTDOOR | C | 1 | 1:yes (true); 0: no (false) |
| A061 | Grade | GRADE | C | 1 | 1:yes (true); 0: no (false) |
| A062 | Heated | HEATED | C | 1 | 1:yes (true); 0: no (false) |
| A063 | Mezzanine | MEZZ | C | 1 | 1:yes (true); 0: no (false) |
| A064 | Under Roof | ROOF | C | 1 | 1:yes (true); 0: no (false) |
| A065 | Partial Sides | PART_SIDES | C | 1 | 1:yes (true); 0: no (false) |
| A066 | Other Location | OTHER_SITE | C | 19 | |
| A067 | Electric Area Classification CL | ELECT_CL | C | 6 | |
| A068 | Electric Area Classification GR | ELECT_GR | C | 6 | |
| A069 | Electric Area Classification DIV | ELECT_DIV | C | 1 | |
| A070 | Winterization | WINTER | C | 1 | 1:yes (true); 0: no (false) |
| A071 | Tropicalization | TROPIC | C | 1 | 1:yes (true); 0: no (false) |
| A072 | Altitude | ELEV | N | 13 | m |
| A073 | Barometer | BAR | N | 13 | kPa abs |
| A074 | Ambient Temperature: Min | SITE_TM_MN | N | 13 | °C |
| A075 | Ambient Temperature: Max | SITE_TM_MX | N | 13 | °C |
| A076 | Relative Humidity: Max | SITE_RH_MX | N | 13 | % (0 to 100) |
| A077 | Relative Humidity: Min | SITE_RH_MN | N | 13 | % (0 to 100) |
| A078 | Dust Atmosphere | DUST_ATM | C | 1 | 1:yes (true); 0: no (false) |
| A079 | Fumes Atmosphere | FUME_ATM | C | 1 | 1:yes (true); 0: no (false) |
| A080 | Other Atmosphere | OTHER_ATM | C | 25 | |
| A081 | Steam Drivers Minimum Pressure | D_STM_MNPR | N | 13 | kPa |
| A082 | Steam Drivers Minimum Temperature | D_STM_MNTM | N | 13 | °C |

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| A083 | Steam Drivers Maximum Pressure | D_STM_MXPR | N | 13 | kPa |
| A084 | Steam Drivers Maximum Temperature | D_STM_MXTM | N | 13 | °C |
| A085 | Heating Minimum Steam Pressure | H_STM_MNPR | N | 13 | kPa |
| A086 | Heating Minimum Steam Temperature | H_STM_MNTM | N | 13 | °C |
| A087 | Heating Maximum Steam Pressure | H_STM_MXPR | N | 13 | kPa |
| A088 | Heating Maximum Steam Temperature | H_STM_MXTM | N | 13 | °C |
| A089 | Driver Volts Minimum | DVR_V_MIN | N | 13 | V |
| A090 | Driver Volts Maximum | DVR_V_MAX | N | 13 | V |
| A091 | Driver Hertz | DVR_HERTZ | N | 13 | Hz |
| A092 | Driver Phase | DVR_PHASE | I | 1 | |
| A093 | Heating Volts Minimum | HTG_V_MIN | N | 13 | V |
| A094 | Heating Volts Maximum | HTG_V_MAX | N | 13 | V |
| A095 | Heating Hertz | HTG_HERTZ | N | 13 | Hz |
| A096 | Heating Phase | HTG_PHASE | I | 1 | |
| A097 | Control Volts | CNTL_VOLTS | N | 13 | V |
| A098 | Control Hertz | CNTL_HERTZ | N | 13 | Hz |
| A099 | Control Phase | CNTL_PHASE | I | 1 | |
| A100 | Shutdown Volts | SHDN_VOLTS | N | 13 | V |
| A101 | Shutdown Hertz | SHDN_HERTZ | N | 13 | Hz |
| A102 | Shutdown Phase | SHDN_PHASE | I | 1 | |
| A103 | Cooling Water Temperature Inlet | C_WTR_TMIN | N | 13 | °C |
| A104 | Cooling Water Maximum Return | C_WTR_TMOU | N | 13 | °C |
| A105 | Cooling Water Pressure Normal | C_WTR_PRNO | N | 13 | kPa |
| A106 | Cooling Water Pressure Design | C_WTR_PRDE | N | 13 | kPa |
| A107 | Cooling Water Minimum Return Pressure | C_WTR_PROU | N | 13 | kPa |
| A108 | Cooling Water Maximum Delta P | C_WTR_PRDI | N | 13 | kPa |
| A109 | Cooling Water Source | C_WTR_SOUR | C | 20 | |
| A110 | Cooling water chloride concentration | C_WTR_CHL | N | 13 | parts per million |
| A111 | Instrument Air: Maximum Pressure | AIR_PR_MX | N | 13 | kPa |
| A112 | Instrument Air: Minimum Pressure | AIR_PR_MIN | N | 13 | kPa |
| **Liquid** | | | | | |
| A113 | Name of Liquid | LIQ_NAME | C | 40 | |
| A114 | Pumping Temperature Normal | TEMP_NORM | N | 13 | °C |
| A115 | Pumping Temperature Maximum | TEMP_MAX | N | 13 | °C |
| A116 | Pumping Temperature Minimum | TEMP_MIN | N | 13 | °C |
| A117 | Specific Gravity @ Normal Temperature | SG_NORM | C | 13 | |
| A118 | Specific Gravity @ Maximum Temperature | SG_MAX | C | 13 | |
| A119 | Specific Gravity @ Minimum Temperature | SG_MIN | C | 13 | |
| A120 | Specific Heat | SP_HEAT | N | 13 | kJ/kg°C |
| A121 | Vapor Pressure | VAPOR_PRES | N | 13 | kPa abs |
| A122 | Vapor pressure temperature | VAPOR_TEMP | N | 13 | °C |
| A123 | Viscosity | VISC | N | 13 | cP |
| A124 | Viscosity Temperature | VISC_TEMP | N | 13 | °C |
| A125 | Maximum Viscosity | MAX_VISC | N | 13 | cP |
| A126 | Corrosive/Erosive Agent | CORROSIVE | C | 15 | |
| A127 | Chloride concentration | CH_CON_LIQ | N | 13 | parts per million |
| A128 | H2S Concentration | H2S_CONC | N | 13 | parts per million |

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| A129 | Hazardous (Toxic) | TOXIC | C | 1 | 1:yes (true); 0: no (false) |
| A130 | Flammable | FLAMMABLE | C | 1 | 1:yes (true); 0: no (false) |
| A131 | Other Liquid Hazard | OTHER_HZRD | C | 1 | 1:yes (true); 0: no (false) |
| **Performance** | | | | | |
| A132 | Rated pump speed | PMP_RPM | N | 13 | RPM |
| A133 | Proposal Curve Number | PROP_CRV_N | C | 15 | |
| A134 | Impeller Diameter Rated | IMP_DIA_RA | N | 13 | mm |
| A135 | Impeller Diameter Maximum | IMP_DI_MAX | N | 13 | mm |
| A136 | Impeller Diameter Minimum | IMP_DI_MIN | N | 13 | mm |
| A137 | Rated Power | BHP | N | 13 | kW |
| A138 | Efficiency | EFF | N | 13 | % (0 to 100) |
| A139 | Minimum flow: thermal | MN_FL_THER | N | 13 | $m^3/h$ |
| A140 | Minimum flow stable | MN_FL_STAB | N | 13 | $m^3/h$ |
| A141 | Maximum head rated impeller | MAX_HEAD | N | 13 | m |
| A142 | Preferred operating region (mimimum) | OPER_PREF1 | N | 13 | $m^3/h$ |
| A143 | Preferred operating region (maximum) | PREF_OPER2 | N | 13 | $m^3/h$ |
| A144 | Allowable operating region (minimum) | ALWB_OPER1 | N | 13 | $m^3/h$ |
| A145 | Allowable operating region (maximum) | ALWB_OPER2 | N | 13 | $m^3/h$ |
| A146 | Maximum power rated impeller | MAX_PWR | N | 13 | kW |
| A147 | NPSH required | NPSHR | N | 13 | m |
| A148 | Suction specific speed | SP_SPEED | N | 13 | metric units (see paragraph 1.4.42) |
| A149 | Maximum sound pressure level required | DBA | N | 13 | dBA |
| A150 | Estimated maximum sound pressure level | EST_DBA | N | 13 | dBA |
| A151 | Performance remark | PERF_REMK | C | 140 | |
| **Construction** | | | | | |
| A152 | Pump classification ID | PUMP_CLASS | C | 3 | OVERHUNG TYPE:<br>OH1:foot mounted/horizontal/flexibly coupled<br>OH2:center line mounted/horizontal/flexibly coupled<br>OH3:in-line bearing frame/vertical/flexibly coupled<br>OH4:in-line/vertical/rigidly coupled<br>OH5:high speed integral gear/ridgidly coupled<br>BETWEEN BEARINGS TYPE:<br>BB1:axially split/1 or 2 stages<br>BB2:radially split/1 or 2 stage<br>BB3:axially split/multistage<br>BB4:single case/radially split/multistage<br>BB5:double case/radially split/multistage<br>VERTICAL SUSPENDED TYPE:<br>VS1:single case/discharge through column/diffuser<br>VS2:single case/discharge through column/volute<br>VS3:single case/discharge through column/axial flow<br>VS4:single case/seperate discharge/line shaft<br>VS5:single case/seperate discharge/cantilever<br>VS6:double case (canned)/diffuser<br>VS7:double case (canned)/volute<br>Z:Other |
| A153 | API 610, 8th edition compliance | API610_CMP | C | 1 | 1:yes (true); 0: no (false) |

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| A154 | Other compliance | OTH_COMP | C | 1 | 1:yes (true); 0: no (false) |
| A155 | Other compliance remark | OTH_COMP_R | C | 20 | |
| A156 | Suction Size | SUCT_SIZE | C | 10 | The decimal numeric value is followed by "mm" or "in". Example: 1.5 in or 38 mm |
| A157 | Suction Rating | SUCT_RATE | C | 10 | |
| A158 | Suction Facing | SUCT_FACE | C | 1 | A:flat face; B:raised flange; C:ring type joint; D: threaded; Z:other |
| A159 | Suction position | SUCT_POSIT | C | 1 | A:end; B:top; C:side; D:bottom; E:inline; F:sump; G:can; Z:other |
| A160 | Discharge size | DISCH_SIZE | C | 10 | The decimal numeric value is followed by "mm" or "in". Example: 1.5 in or 38 mm |
| A161 | Discharge rating | DISCH_RATE | C | 10 | |
| A162 | Discharge facing | DISCH_FACE | C | 1 | A:flat face; B:raised flange; C:ring type joint; D:threaded; Z:other |
| A163 | Discharge position | DISCH_POSI | C | 1 | A:top; B:side; C:inline; Z:other |
| A164 | Balance drum size | BAL_DR_SIZ | C | 10 | The decimal numeric value is followed by "mm" or "in". Example: 1.5 in or 38 mm |
| A165 | Balance drum rating | BAL_DR_RAT | C | 10 | |
| A166 | Balance drum facing | BAL_DR_FAC | C | 5 | |
| A167 | Balance drum position | BAL_DR_POS | C | 6 | |
| A168 | Other conn size | OTHER_SIZE | C | 10 | The decimal numeric value is followed by "mm" or "in". Example: 1.5 in or 38 mm |
| A169 | Other conn rating | OTHER_RATE | C | 10 | |
| A170 | Other conn facing | OTHER_FACE | C | 1 | A: flat face; B:raised flange; C:ring type joint; D: threaded; Z:other |
| A171 | Other conn position | OTHER_POSI | C | 6 | |
| A172 | Number of drains | DRN_NO | I | 5 | |
| A173 | Drain size | DRN_SIZE | C | 10 | The decimal numeric value is followed by "mm" or "in". Example: 1.5 in or 38 mm |
| A174 | Drain type | DRN_TYPE | C | 15 | |
| A175 | Number of vents | VENT_NO | I | 5 | |
| A176 | Vent size | VENT_SIZE | C | 10 | The decimal numeric value is followed by "mm" or "in". Example: 1.5 in or 38 mm |
| A177 | Vent type | VENT_TYPE | C | 15 | |
| A178 | Number pressure gauge | P_GAGE_NO | C | 5 | |
| A179 | Pressure gauge size | P_GAGE_SIZ | C | 10 | The decimal numeric value is followed by "mm" or "in". Example: 1.5 in or 38 mm |
| A180 | Pressure gauge type | P_GAGE_TYP | C | 15 | |
| A181 | Number temperature gauge | T_GAGE_NO | I | 5 | |
| A182 | Temperature gauge size | T_GAGE_SIZ | C | 10 | The decimal numeric value is followed by "mm" or "in". Example: 1.5 in or 38 mm |
| A183 | Temperature gauge type | T_GAGE_TYP | C | 15 | |
| A184 | Number warm up | WRMUP_NO | I | 5 | |
| A185 | Warm up size | WRMUP_SIZE | C | 10 | The decimal numeric value is followed by "mm" or "in". Example: 1.5 in or 38 mm |
| A186 | Warm up type | WRMUP_TYPE | C | 15 | |
| A187 | Balance / leak-off number | B_LEAK_NO | I | 5 | |
| A188 | Balance / leak-off size | B_LEAK_SI | C | 10 | The decimal numeric value is followed by "mm" or "in". Example: 1.5 in or 38 mm |
| A189 | Balance / leak-off type | B_LEAK_TY | C | 15 | |
| A190 | Cylindrical threads required | CYLTHR_REQ | C | 1 | 1:yes (true); 0: no (false) |

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| A191 | Casing mounting | CSG_MTG | C | 1 | A:center-line; B:near center-line; C:foot; D:seperate mounting plate; E:vertical; F:sump; G:inline; Z:other |
| A192 | Casing split | CSG_SPLT | C | 1 | A:axial; B:radial; Z:other |
| A193 | Casing type | CSG_TYPE | C | 1 | A: single volute; B:multiple volute; C:diffuser; D:staggered volute; E:barrel; F:vertical double casing; Z:other |
| A194 | Impeller mounted | IMP_MOUNT | C | 1 | A:between bearings; B:over hung; C:vertically suspended; Z:other |
| A195 | Impellers secured against reverse thrust | IMP_IND_SE | C | 1 | 1:yes (true); 0: no (false) |
| A196 | Case pressure | CASE_PRESS | C | 1 | 1:yes (true); 0: no (false) |
| A197 | Maximum allowable working pressure | MAWP | N | 13 | kPa |
| A198 | Reference temperature for MAWP | T_MAWP | N | 13 | °C |
| A199 | Casing hydrotest pressure | CASE_HYD | N | 13 | kPa |
| A200 | Rotation | ROTATION | C | 1 | A: CW; B:CCW per Hydraulic Institute; Z:other |
| A201 | Construction remark | CONST_RMK | C | 140 | |
| A202 | Bolt OH-3 pump to pad/foundation | BOLT_FNDN | C | 1 | 1:yes (true); 0: no (false) |
| A203 | Shaft diameter at sleeve | SH_DI_SLVE | N | 13 | mm |
| A204 | Shaft diameter at coupling | SH_DI_CPLG | N | 13 | mm |
| A205 | Shaft diameter between bearings | SH_DI_BRGS | N | 13 | mm |
| A206 | Span between bearings | SPAN_BRGS | N | 13 | mm |
| A207 | Impeller overhang | SPAN_BR_IM | N | 13 | mm |
| A208 | Shaft remark | SHAF_REMK | C | 140 | |
| A209 | Coupling make | CPLG_MFG | C | 15 | |
| A210 | Coupling model | CPLG_MODEL | C | 10 | |
| A211 | Coupling rating | CPLG_RATE | N | 13 | kW / 1000 RPM |
| A212 | Coupling lubrication | CPLG_LUBE | C | 15 | |
| A213 | Limited end float required | CPLG_ENDF | C | 1 | 1:yes (true); 0: no (false) |
| A214 | Coupling spacer length | CPLG_SPCR | N | 13 | mm |
| A215 | Service factor | CPLG_SERV | C | 13 | |
| A216 | Dynamic balance | CPLG_BAL | C | 1 | 1:yes (true); 0: no (false) |
| A217 | Balance class | CPLG_CLASS | C | 2 | |
| A218 | Driver half coupling mounted by | MTD_CPLG | C | 1 | A:pump mfg; B:driver mfg; C:purchaser; Z:other |
| A219 | Coupling per API 671 | CPLG_671 | C | 1 | 1:yes (true); 0: no (false) |
| A220 | API Baseplate number | BASE_NO | C | 5 | |
| A221 | Non grout construction | NON_GROUT | C | 1 | 1:yes (true); 0: no (false) |
| A222 | Vertical level screws | VERT_SCREW | C | 1 | 1:yes (true); 0: no (false) |
| A223 | Horizontal positioning screws | HORZ_SCRE | C | 1 | 1:yes (true); 0: no (false) |
| A224 | Coupling remark | CPLG_REMK | C | 140 | |
| **Materials** | | | | | |
| A225 | Table H1 material class | MATL_CLASS | C | 5 | |
| A226 | Minimum metal temperature | MATL_MN_T | N | 13 | °C |
| A227 | Barrel/case material | MATL_CASE | C | 20 | |
| A228 | Impeller material | MATL_IMP | C | 20 | |
| A229 | Case wearing material | ML_WR_RI_C | C | 20 | |
| A230 | Impeller wear ring material | ML_WR_RI_I | C | 20 | |
| A231 | Shaft material | MATL_SHAFT | C | 20 | |

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| A232 | Sleeve material | MATL_SLEEV | C | 20 | |
| A233 | Diffusor material | MATL_DIFFU | C | 20 | |
| A234 | Coupling hubs material | MATL_CP_HU | C | 20 | |
| A235 | Coupling spacer material | MATL_CP_SP | C | 20 | |
| A236 | Coupling diaphragm material | MATL_CP_DI | C | 20 | |
| A237 | Baseplate material | MATL_BSEPL | C | 20 | |
| A238 | Material remark | MATL_RMK | C | 140 | |
| **Bearings and Lubrication** | | | | | |
| A239 | Radial bearing type | RAD_BRG_TY | C | 10 | |
| A240 | Radial bearing number | RAD_BRG_NU | C | 10 | |
| A241 | Thrust bearing type | THR_BRG_TY | C | 10 | |
| A242 | Thrust bearing number | THR_BRG_NO | C | 10 | |
| A243 | Review / approve thrust bearing size | APP_THR_BR | C | 1 | 1:yes (true); 0: no (false) |
| A244 | Lubrication | LUBRICATIO | C | 1 | A:grease; B:flood; C:ring oil; D:flinger; Z:other |
| A245 | Oil mist lubrication | OIL_MIST_L | C | 1 | A:none; B:purge oil mist; C:pure oil mist; Z:other |
| A246 | Constant lever oiler | CONST_LVL | C | 1 | 1:yes (true); 0: no (false) |
| A247 | Pressure | PRESS_LUB | C | 1 | 1:yes (true); 0: no (false) |
| A248 | API 610 | API_610_LU | C | 1 | 1:yes (true); 0: no (false) |
| A249 | API 614 | API_614_LU | C | 1 | 1:yes (true); 0: no (false) |
| A250 | Oil viscosity ISO grade | ISO_VIS | C | 15 | |
| A251 | Oil heater required | OIL_HEAT | C | 1 | A:none; B:electric; C:steam; Z:other |
| A252 | Oil pressure greater than coolant | OIL_P_GT_C | C | 1 | 1:yes (true); 0: no (false) |
| A253 | Lubrication remark | LUBE_RMK | C | 140 | |
| **Mechanical Seal or Packing** | | | | | |
| A254 | Seal specification | SEAL_SPEC | C | 1 | A: API 682; B: API 610; C:none; Z:other |
| A255 | API 682 Datasheet attached | SHT_682_AT | C | 1 | 1:yes (true); 0: no (false) |
| A256 | Non API 682 seal | NON_682_SL | C | 1 | 1:yes (true); 0: no (false) |
| A257 | Seal chamber temperature | SEAL_TEMP | N | 13 | °C |
| A258 | Seal chamber pressure | SEAL_PRESS | N | 13 | kPa |
| A259 | Seal chamber flowrate | SEAL_FLOW | N | 13 | $m^3/h$ |
| A260 | API Seal chamber size | SEAL_CHAMB | C | 5 | |
| A261 | Seal chamber bore | SEAL_BORE | N | 13 | mm |
| A262 | Seal total length | SEAL_TOT_L | N | 13 | mm |
| A263 | Seal clear length | SEAL_CLR_L | N | 13 | mm |
| A264 | Appendix H API class code | SEAL_CODE | C | 5 | |
| A265 | Seal manufacturer | SEAL_MFR | C | 15 | |
| A266 | Seal size | SEAL_SIZE | C | 10 | |
| A267 | Seal type | SEAL_TYPE | C | 10 | |
| A268 | Manufacturer code | SEAL_MFR_C | C | 15 | |
| A269 | Cartridge mount | SEAL_CART | C | 1 | 1:yes (true); 0: no (false) |
| A270 | Hooked sleeve / non cartridge | SEAL_NON_C | C | 1 | 1:yes (true); 0: no (false) |
| A271 | No sleeve | SEAL_NO_SL | C | 1 | 1:yes (true); 0: no (false) |
| A272 | Circulating device | CIRC_DEV | C | 1 | 1:yes (true); 0: no (false) |
| A273 | Sleeve material | SLEEVE_MAT | C | 10 | |
| A274 | Gland material | GLAND_MATL | C | 10 | |

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| A275 | Aux seal device | AUX_SEAL_D | C | 15 | |
| A276 | Jacket required | JACKET_REQ | C | 1 | 1:yes (true); 0: no (false) |
| A277 | Flush gland taps | F_GLAND_TA | C | 1 | 1:yes (true); 0: no (false) |
| A278 | Drain gland taps | D_GLAND_TA | C | 1 | 1:yes (true); 0: no (false) |
| A279 | Barrier gland taps | B_GLAND_TA | C | 1 | 1:yes (true); 0: no (false) |
| A280 | Vent gland taps | V_GLAND_TA | C | 1 | 1:yes (true); 0: no (false) |
| A281 | Cooling gland taps | C_GLAND_TA | C | 1 | 1:yes (true); 0: no (false) |
| A282 | Quench gland taps | Q_GLAND_TA | C | 1 | 1:yes (true); 0: no (false) |
| A283 | Heating gland taps | H_GLAND_TA | C | 1 | 1:yes (true); 0: no (false) |
| A284 | Lubricant gland taps | L_GLAND_TA | C | 1 | 1:yes (true); 0: no (false) |
| A285 | Leakage gland taps | LK_GLND_TA | C | 1 | 1:yes (true); 0: no (false) |
| A286 | Pumped fluid gland taps | PF_GLND_TA | C | 1 | 1:yes (true); 0: no (false) |
| A287 | Balance fluid gland taps | BF_GLND_TA | C | 1 | 1:yes (true); 0: no (false) |
| A288 | Fluid injection gland taps | EF_GLND_TA | C | 1 | 1:yes (true); 0: no (false) |
| A289 | Flush supply temperature | FLUSH_TEMP | N | 13 | °C |
| A290 | Flush minimum temperature | FLUSH_T_MI | N | 13 | °C |
| A291 | Flush maximum temperature | FLUSH_T_MA | N | 13 | °C |
| A292 | Specific gravity | FLUSH_SG | C | 13 | |
| A293 | Specific gravity temperature | FLUSH_SG_T | N | 13 | °C |
| A294 | Flush fluid name | FLUSH_FLUI | C | 20 | |
| A295 | Flush specific heat | FLUSH_SP_H | N | 13 | kJ/kg°C |
| A296 | Flush vapor pressure | FLUSH_VP | N | 13 | kPa abs |
| A297 | Flush vapor pressure temperature | FLUSH_VP_T | N | 13 | °C |
| A298 | Flush hazardous | FLUSH_TOXI | C | 1 | 1:yes (true); 0: no (false) |
| A299 | Flush flammable | FLUSH_FLAM | C | 1 | 1:yes (true); 0: no (false) |
| A300 | Flush other | FLUSH_OTHE | C | 15 | |
| A301 | Flush maximum flowrate | FLUSH_MAX | N | 13 | $m^3/h$ |
| A302 | Flush minimum flowrate | FLUSH_MIN | N | 13 | $m^3/h$ |
| A303 | Flush maximum pressure | FLUSH_P_MX | N | 13 | kPa |
| A304 | Flush minimum pressure | FLUSH_P_MN | N | 13 | kPa |
| A305 | Flush maximum temperature | FLSH_T_MX | N | 13 | °C |
| A306 | Flush minimum temperature | FLUSH_T_MN | N | 13 | °C |
| A307 | Barrier minimum temperature | BARR_TM_MN | N | 13 | °C |
| A308 | Barrier maximum temperature | BARR_TM_MX | N | 13 | °C |
| A309 | Barrier SG | BARR_SG | C | 13 | |
| A310 | Barrier SG Temperature | BARR_SG_TM | N | 13 | °C |
| A311 | Barrier liquid name | BARR_FLUID | C | 20 | |
| A312 | Barrier vapor pressure | BARR_VP | N | 13 | kPa abs |
| A313 | Barrier vapor pressure temperature | BARR_VP_TM | N | 13 | °C |
| A314 | Barrier toxic | BARR_TOXIC | C | 1 | 1:yes (true); 0: no (false) |
| A315 | Barrier flammable | BARR_FLAME | C | 1 | 1:yes (true); 0: no (false) |
| A316 | Barrier other | BARR_OTHER | C | 15 | |
| A317 | Barrier flow maximum | BARR_FL_MX | N | 13 | $m^3/h$ |
| A318 | Barrier flow minimum | BARR_FL_MN | N | 13 | $m^3/h$ |
| A319 | Barrier maximum pressure | BARR_PR_MX | N | 13 | kPa |
| A320 | Barrier minimum pressure | BARR_PR_MN | N | 13 | kPa |
| A321 | Barrier temperature maximum | BARR_T_MAX | N | 13 | °C |

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| A322 | Barrier temperature minimum | BARR_T_MIN | N | 13 | °C |
| A323 | Quench fluid | QUENCH_FLU | C | 20 | |
| A324 | Quench flow rate | QUENCH_FLO | N | 13 | m³/h |
| A325 | Seal flush pipe plan | SEAL_PI_PL | C | 1 | A:none; B:API Plan 1; C: API Plan 2; D: API Plan 11; E: API Plan 12; F:API Plan 13; G:API Plan 14; H:API Plan 21; I:API Plan 22; J:API Plan 23; K:API Plan 31; L:API Plan 32; M:API Plan 41; N:API Plan 51; O:API Plan 52; P:API Plan 53; Q:API Plan 54; R:API Plan 61; S:API Plan 62; Z: other |
| A326 | Seal piping construction | SEAL_PIPE | C | 1 | A:tubing; B:pipe; Z:other |
| A327 | Piping material | PIPE_MAT | C | 1 | A:carbon steel; B:stainless steel; Z:other |
| A328 | Other material description | O_MTL_DESC | C | 20 | |
| A329 | Aux piping plan | AUX_PI_PL | C | 1 | A:none; B:API Plan 52; C:API Plan 53; D:API Plan 54;E:API Plan 61; F:API Plan 62; Z: other |
| A330 | Aux piping plan construction | AUX_PLAN_T | C | 1 | A:tubing; B:pipe; Z:other |
| A331 | Aux piping plan material | AUX_PLAN_M | C | 1 | A:carbon steel; B:stainless steel; Z:other |
| A332 | Other aux material description | O_AUX_M_D | C | 20 | |
| A333 | Piping connections | ASSEMBLY | C | 1 | A:threaded; B:socket welded; C:seal welded; Z:other |
| A334 | Piping connections part 2 | ASSEMBLY2 | C | 1 | A:unions; B:flanged; Z:other |
| A335 | Seal piping tube fitting | SEAL_T_ASY | C | 1 | 1:yes (true); 0: no (false) |
| A336 | Seal tube fitting type | SEAL_T_FIT | C | 15 | |
| A337 | Seal flow indicator | SEAL_FI | C | 1 | 1:yes (true); 0: no (false) |
| A338 | Seal pressure switch | SEAL_PS | C | 1 | 1:yes (true); 0: no (false) |
| A339 | Seal pressure switch type | SEAL_PS_TY | C | 15 | |
| A340 | Seal pressure gauge | SEAL_PI | C | 1 | 1:yes (true); 0: no (false) |
| A341 | Seal level switch | SEAL_LS | C | 1 | 1:yes (true); 0: no (false) |
| A342 | Seal level switch type | SEAL_LS_TY | C | 15 | |
| A343 | Seal level gauge | SEAL_LG | C | 1 | 1:yes (true); 0: no (false) |
| A344 | Seal temperature indicator | SEAL_TI | C | 1 | 1:yes (true); 0: no (false) |
| A345 | Seal heat exchanger | SEAL_HX | C | 1 | 1:yes (true); 0: no (false) |
| A346 | Mechanical seal remarks | SEAL_RMK | C | 140 | |
| A347 | Packing manfacturer | PKG_MFR | C | 20 | |
| A348 | Packing type | PKG_TYPE | C | 20 | |
| A349 | Packing size | PKG_SIZE | C | 13 | |
| A350 | Packing no rings | PKG_RINGS | I | 5 | |
| A351 | Packing injection required | PKG_INJ | C | 1 | 1:yes (true); 0: no (false) |
| A352 | Packing injection flow | PKG_FLOW | N | 13 | m³/h |
| A353 | Packing injection pressure | PKG_PRESS | N | 13 | kPa |
| A354 | Packing lantern ring | PKG_LANTER | C | 20 | |

## Cooling Water Piping

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| A355 | Cooling water pipe plan | CW_PIPE_PN | C | 1 | A:Plan A; B:Plan B; C:Plan C; D:Plan D; E:Plan E; F:Plan F; G:Plan G; H:Plan H; J:Plan J; K:Plan K; L:Plan L; M:Plan M; N:none; Z:other |
| A356 | Cooling water sight flow indicator | SIGHT_FLOW | C | 1 | 1:yes (true); 0: no (false) |
| A357 | Cooling water manifold outlet valve | MANIFOLD_V | C | 1 | 1:yes (true); 0: no (false) |

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| A358 | Cooling water piping material | CW_PIP_MAT | C | 1 | A:galvanized pipe; B:copper tube; C:stainless tubing; Z:other |
| A359 | Cooling water/seal jacket flow | SEAL_JKT_Q | N | 13 | $m^3/h$ |
| A360 | Cooling water/seal jacket pressure | SEAL_JKT_P | N | 13 | kPa |
| A361 | Cooling water/bearing housing flow | BRG_H_FL | N | 13 | $m^3/h$ |
| A362 | Cooling water/bearing housing press | BRG_H_PR | N | 13 | kPa |
| A363 | Cooling water/seal heat exchanger flow | SEAL_HX_FL | N | 13 | $m^3/h$ |
| A364 | Cooling water/seal heat exchanger pressure | SEAL_HX_PR | N | 13 | kPa |
| A365 | Cooling water/quench flow | QUENCH_FL | N | 13 | $m^3/h$ |
| A366 | Cooling water/quench pressure | QUENCH_PR | N | 13 | kPa |
| A367 | Total cooling water flow | TOTAL_FLOW | N | 13 | $m^3/h$ |
| A368 | Steam piping | STEAM_PIP | C | 1 | A:tubing; B:pipe; Z:other |
| A369 | Cooling water remark | CW_RMK | C | 140 | |
| **Instrumentation** | | | | | |
| A370 | Vibration non-contact | VB_NONCONT | C | 1 | 1:yes (true); 0: no (false) |
| A371 | Vibration transducer | VB_ACCEL | C | 1 | 1:yes (true); 0: no (false) |
| A372 | Provision for mounting only (Vib) | VB_MTG_ONL | C | 1 | 1:yes (true); 0: no (false) |
| A373 | Flat surface required | VB_FL_SRF | C | 1 | 1:yes (true); 0: no (false) |
| A374 | See attached API-670 data sheet (Vib) | VB_DATA_SH | C | 1 | 1:yes (true); 0: no (false) |
| A375 | Monitors and cables | VB_MON_CB | C | 1 | 1:yes (true); 0: no (false) |
| A376 | Vibration remark | VB_RMK | C | 140 | |
| A377 | Radial bearing metal temperature | TM_RAD_BRG | C | 1 | 1:yes (true); 0: no (false) |
| A378 | Thrust bearing metal temperature | TM_THR_BRG | C | 1 | 1:yes (true); 0: no (false) |
| A379 | Provision for instruments only | TM_INS_ONL | C | 1 | 1:yes (true); 0: no (false) |
| A380 | See attached API-670 data sheet (Temp) | TM_DATA_SH | C | 1 | 1:yes (true); 0: no (false) |
| A381 | Temperature gauges | TEMP_GAGES | C | 1 | 1:yes (true); 0: no (false) |
| A382 | Temperature thermowells | TEMP_WELLS | C | 1 | 1:yes (true); 0: no (false) |
| A383 | Temperature other | TEMP_OTHER | C | 20 | |
| A384 | Pressure gauge type | PR_GAGE_TY | C | 20 | |
| A385 | Pressure gauge location | PR_GAGE_LO | C | 20 | |
| A386 | Pressure switch type | PR_SW_TYPE | C | 20 | |
| A387 | Pressure switch location | PR_SW_LOC | C | 20 | |
| A388 | Instrument remark | INST_RMK | C | 140 | |
| **Spare Parts** | | | | | |
| A389 | Spares start up | SPARE_STAR | C | 1 | 1:yes (true); 0: no (false) |
| A390 | Normal maintance spares | SPARE_NORM | C | 1 | 1:yes (true); 0: no (false) |
| A391 | Spares reconditioning | SPARE_RECO | C | 1 | 1:yes (true); 0: no (false) |
| A392 | Spares critical services | SPARE_CRIT | C | 1 | 1:yes (true); 0: no (false) |
| A393 | Spares specify remark | SPARE_RMK | C | 140 | |
| **Motor Drive** | | | | | |
| A394 | Motor manufacturer | MTR_MFGR | C | 20 | |
| A395 | Motor power | MTR_POWER | N | 13 | kW |
| A396 | Motor speed | MTR_SPEED | C | 13 | RPM |
| A397 | Motor orientation | MTR_ORNT | C | 1 | A:horizontal; B:vertical; Z:other |
| A398 | Motor frame | MTR_FRAME | C | 10 | |
| A399 | Motor service factor | MTR_SERV_F | C | 13 | |

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| A400 | Motor volts | MTR_VLT | C | 10 | V. Dual voltage values are separated with a "/". Example: 230/460 |
| A401 | Motor phase | MTR_PHASE | I | 1 | |
| A402 | Motor hertz | MTR_HERTZ | N | 13 | Hz |
| A403 | Motor type | MTR_TYPE | C | 15 | |
| A404 | Motor enclosure | MTR_ENCL | C | 10 | |
| A405 | Motor explosion proof rating | MTR_EXPL_P | C | 10 | |
| A406 | Motor minimum start volts | MTR_STARTV | N | 13 | V |
| A407 | Motor temperature rise | MTR_TEMP_R | N | 13 | °C |
| A408 | Motor full load amperes | MTR_FL_AMP | C | 13 | A |
| A409 | Motor locked rotor amperes | MTR_LR_AMP | C | 13 | A |
| A410 | Motor insulation | MTR_INSUL | C | 5 | |
| A411 | Motor starting method | MTR_STRT_M | C | 20 | |
| A412 | Motor bearings | MTR_BRGS | C | 20 | |
| A413 | Motor lubrication | MTR_LUBE | C | 20 | |
| A414 | Motor 2x thrust rating | MTR_THRUST | C | 1 | 1:yes (true); 0: no (false) |
| A415 | Motor vertical shaft | MTR_VS | C | 1 | A:solid; B:hollow; Z:other |
| A416 | Motor vertical thrust capacity | MTR_VERT_T | C | 1 | 1:yes (true); 0: no (false) |
| A417 | Motor thrust up | MTR_THR_UP | N | 13 | N |
| A418 | Motor thrust down | MTR_THR_DN | N | 13 | N |
| A419 | Motor radial bearing type | MTR_RB_TY | C | 10 | |
| A420 | Motor radial bearing number | MTR_RB_NU | C | 10 | |
| A421 | Motor thrust bearing type | MTR_TB_TY | C | 10 | |
| A422 | Motor thrust bearing number | MTR_TB_NO | C | 10 | |
| A423 | Motor remark | MTR_RMK | C | 140 | |
| **Vertical Pumps** | | | | | |
| A424 | Up thrust at minimum flow | TH_MN_UP | N | 13 | N |
| A425 | Down thrust at minimum flow | TH_MN_DN | N | 13 | N |
| A426 | Up thrust at rated flow | TH_RTD_UP | N | 13 | N |
| A427 | Down thrust at rated flow | TH_RTD_DN | N | 13 | N |
| A428 | Up thrust at runout flow | TH_RUN_UP | N | 13 | N |
| A429 | Down thrust at runout flow | TH_RUN_DN | N | 13 | N |
| A430 | Maximum up thrust | TH_MAX_UP | N | 13 | N |
| A431 | Maximum down thrust | TH_MAX_DN | N | 13 | N |
| A432 | Seperate mounting plate | SEP_MTG_PL | C | 1 | 1:yes (true); 0: no (false) |
| A433 | Alignment screws | ALGN_SCREW | C | 1 | 1:yes (true); 0: no (false) |
| A434 | Pit / sump depth | PIT_DEPTH | N | 13 | mm |
| A435 | Pump length | PUMP_LENGT | N | 13 | mm |
| A436 | Datum elevation to 1st stage impeller | PUMP_CL | N | 13 | mm |
| A437 | Minimum submergence required | PUMP_SUBME | N | 13 | mm |
| A438 | Column pipe | CLMN_PIP | C | 1 | A:flanged; B:threaded; Z:other |
| A439 | Soleplate length | SOLE_LEN | N | 13 | mm |
| A440 | Soleplate width | SOLE_WID | N | 13 | mm |
| A441 | Soleplate thickness | SOLE_THK | N | 13 | mm |
| A442 | Column pipe diameter | COL_PIP_D | N | 13 | mm |
| A443 | Column pipe length | COL_PIP_L | N | 13 | mm |
| A444 | Number guide bushes | Q_GU_BSH | I | 5 | |

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| A445 | Line shaft bearing spacing | LS_BRG_S | N | 13 | mm |
| A446 | Shaft diameter | SHT_DIA | N | 13 | mm |
| A447 | Line shaft tube diameter | LSHT_TD | N | 13 | mm |
| A448 | Sleeve and key shaft coupling | S_K_SHF_C | C | 1 | 1:yes (true); 0: no (false) |
| A449 | Threaded shaft coupling | TH_SHT_C | C | 1 | 1:yes (true); 0: no (false) |
| A450 | Suction can thickness | SUCT_C_T | N | 13 | mm |
| A451 | Suction can length | SUCT_C_L | N | 13 | mm |
| A452 | Suction can diameter | SUCT_C_D | N | 13 | mm |
| A453 | Suction strainer | SUCT_ST | C | 1 | 1:yes (true); 0: no (false) |
| A454 | Suction strainer type | SUCT_ST_TY | C | 20 | |
| A455 | Float and rod | FLO_ROD | C | 1 | 1:yes (true); 0: no (false) |
| A456 | Float switch | FLO_SWT | C | 1 | 1:yes (true); 0: no (false) |
| A457 | Impeller collets acceptable | IMP_COLLET | C | 1 | 1:yes (true); 0: no (false) |
| A458 | Hardened sleeve under bearings | HARD_BRGS | C | 1 | 1:yes (true); 0: no (false) |
| A459 | Vertical pump resonance test | V_RES_TEST | C | 1 | 1:yes (true); 0: no (false) |
| A460 | Vertical pump structural analysis | V_STR_ANLY | C | 1 | 1:yes (true); 0: no (false) |
| A461 | Drain pipe to surface | D_P_SURF | C | 1 | 1:yes (true); 0: no (false) |
| A462 | Maximum pump external diameter below soleplate | V_DIA_SP | N | 13 | mm |
| A463 | Low liquid level from underside of soleplate for vertical pumps | V_HT_SP | N | 13 | mm |
| A464 | Sump size minimum dimension | V_HT_SS | N | 13 | mm |
| A465 | Centerline of discharge from underside of soleplate | V_DIS_USP | N | 13 | mm |
| A466 | Line shaft | LINE_SHFT | C | 1 | A:open; B:enclosed; Z:other |
| A467 | Guide bushings bowl material | GD_BSHG_BO | C | 15 | |
| A468 | Guide bushings line shaft material | GD_BSHG_SH | C | 15 | |
| A469 | Guide bushings lube | BSHG_LUB | C | 1 | A:water; B:oil; C:grease; D:pumpage; Z:other |
| A470 | Vertical pump remark | VERT_RMK | C | 254 | |

## Applicable Specifications

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| A471 | Vendor having unit responsibilty | VNDR_RESP | C | 50 | |
| A472 | Governing specification | GOVN_SPEC | C | 50 | |
| A473 | Specification remark | SPEC_REMKS | C | 140 | |

## Surface Preparation and Painting

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| A474 | Manufacturer preparation standard | PREP_MFR_S | C | 1 | 1:yes (true); 0: no (false) |
| A475 | Prep other | PREP_OTHER | C | 20 | |
| A476 | Pump surface prep | PMP_PREP | C | 20 | |
| A477 | Pump primer | PMP_PRIMER | C | 20 | |
| A478 | Pump finish | PMP_FINISH | C | 20 | |
| A479 | Baseplate surface prep | BSPL_PREP | C | 20 | |
| A480 | Baseplate prime | BSPL_PRIME | C | 20 | |
| A481 | Baseplate finish coat | BSPL_FINIS | C | 20 | |
| A482 | Baseplate grout | BSPL_GRT | C | 1 | 1:yes (true); 0: no (false) |
| A483 | Baseplate grout surface prep | BSPL_GRT_P | C | 10 | |
| A484 | Baseplate epoxy primer | BSPL_EPOXY | C | 20 | |
| A485 | Grout remark | GROUT_RMKS | C | 20 | |
| A486 | Shipment type | SHP_DEST | C | 1 | A:domestic; B:export; Z:other |

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| A487 | Export boxing required | SHP_EXP_BO | C | 1 | 1:yes (true); 0: no (false) |
| A488 | Outdoor over 6 months | SHIP_OUTDO | C | 1 | 1:yes (true); 0: no (false) |
| A489 | Spare rotor storage | SHP_RT_ST | C | 1 | A:horizontal; B:vertical; Z:other |
| A490 | Type shipping prep | SHP_TYPE | C | 20 | |
| A491 | Surface prep and painting remark | PREP_RMK | C | 140 | |
| **Weights** | | | | | |
| A492 | Weight of pump | WT_PUMP | N | 13 | kg |
| A493 | Weight of baseplate (motor driven) | WT_BAS | N | 13 | kg |
| A494 | Weight of motor (motor driven) | WT_MOTOR | N | 13 | kg |
| A495 | Weight of gear (motor driven) | WT_GEAR | N | 13 | kg |
| A496 | Total weight (motor driven) | WT_TOTAL | N | 13 | kg |
| A497 | Weight baseplate (turbine driven) | WT_BAS_TUR | N | 13 | kg |
| A498 | Weight of turbine (turbine driven) | WT_TURBINE | N | 13 | kg |
| A499 | Weight of gear (turbine driven) | WT_GEA_TUR | N | 13 | kg |
| A500 | Total weight (turbine driven) | WT_TOT_TUR | N | 13 | kg |
| A501 | Weight remark | WT_RMK | C | 140 | |
| **Other Purchaser Requirements** | | | | | |
| A502 | Coordination meeting required | COORD_MTG | C | 1 | 1:yes (true); 0: no (false) |
| A503 | Meeting date | MTG_DATE | D | 8 | YYYYMMDD |
| A504 | Review foundation drawings | R_FOUND_DR | C | 1 | 1:yes (true); 0: no (false) |
| A505 | Review pipe drawings | R_PIPE_DRG | C | 1 | 1:yes (true); 0: no (false) |
| A506 | Observe piping checks | OBS_PIPE_C | C | 1 | 1:yes (true); 0: no (false) |
| A507 | Observe initial alignment check | OBS_ALI_CH | C | 1 | 1:yes (true); 0: no (false) |
| A508 | Check alignment at operating temperature | CHK_ALI_TE | C | 1 | 1:yes (true); 0: no (false) |
| A509 | Connection design approval | CON_APPROV | C | 1 | 1:yes (true); 0: no (false) |
| A510 | Rotor dynamic balance | RTR_BAL_AA | C | 1 | 1:yes (true); 0: no (false) |
| A511 | Rigging device for type OH3 pump | RIG_OHB | C | 1 | 1:yes (true); 0: no (false) |
| A512 | Vendor demo maximum allowable vibration | DEMO_MAXVB | C | 1 | 1:yes (true); 0: no (false) |
| A513 | Hydrodynamic thrust bearing size review | TH_BRG_R | C | 1 | 1:yes (true); 0: no (false) |
| A514 | Lateral critical speed analysis | LAT_RESP | C | 1 | A:pump only; B:all equipment; N:none; Z:other |
| A515 | Spare rotor vertical storage | SP_R_V_S | C | 1 | 1:yes (true); 0: no (false) |
| A516 | Critical speed analysis | CRIT_SP_AL | C | 1 | 1:yes (true); 0: no (false) |
| A517 | Mount seal reservoir off baseplate | MNT_RES_OF | C | 1 | 1:yes (true); 0: no (false) |
| A518 | Installation list in proposal | INST_LST | C | 1 | 1:yes (true); 0: no (false) |
| A519 | Stiffness map rotor | STIFF_MAP | C | 1 | 1:yes (true); 0: no (false) |
| A520 | Torsional analysis | TOR_ANAL | C | 1 | 1:yes (true); 0: no (false) |
| A521 | Progress report required | PROG_RPTS | C | 1 | 1:yes (true); 0: no (false) |
| A522 | Purchase requirements remark | PURCH_RMK | C | 140 | |
| **QA Inspection and Test** | | | | | |
| A523 | Review vendors QA program | REV_QA | C | 1 | 1:yes (true); 0: no (false) |
| A524 | Performance curve approval | APP_PER_CR | C | 1 | 1:yes (true); 0: no (false) |
| A525 | Shop inspection | SHOP_INSP | C | 1 | 1:yes (true); 0: no (false) |
| A526 | Test with substitute seal | T_SUB_SEAL | C | 1 | 1:yes (true); 0: no (false) |
| A527 | Hydrostatic test | HYD | C | 1 | A:non witnessed; B:witnessed; C:observed; D: none; Z:other |

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| A528 | Performance test | PERF | C | 1 | A:non witnessed; B:witnessed; C:observed; D: none; Z:other |
| A529 | NPSH test | NPSH | C | 1 | A:non witnessed; B:witnessed; C:observed; D: none; Z:other |
| A530 | Complete unit test | COMPLETE | C | 1 | A:non witnessed; B:witnessed; C:observed; D: none; Z:other |
| A531 | Sound level test | SOUND | C | 1 | A:non witnessed; B:witnessed; C:observed; D: none; Z:other |
| A532 | Dismantle after test | DISM | C | 1 | A:non witnessed; B:witnessed; C:observed; D: none; Z:other |
| A533 | Cleanliness prior to inspection | CLEAN | C | 1 | A:non witnessed; B:witnessed; C:observed; D: none; Z:other |
| A534 | Hydrodynamic bearing inspection | HYD_BEAR | C | 1 | A:non witnessed; B:witnessed; C:observed; D: none; Z:other |
| A535 | Nozzle load / shaft deflection test | PIPE_LOAD | C | 1 | A:non witnessed; B:witnessed; C:observed; D: none; Z:other |
| A536 | Bearing housing resonance test | BRG_HOUS | C | 1 | A:non witnessed; B:witnessed; C:observed; D: none; Z:other |
| A537 | Auxiliary equipment test | AUX_TEST | C | 1 | A:non witnessed; B:witnessed; C:observed; D: none; Z:other |
| A538 | Other test description 1 | DESC_OTH_1 | C | 20 | |
| A539 | Other test 1 | TEST_OTH_1 | C | 1 | A:non witnessed; B:witnessed; C:observed; D: none; Z:other |
| A540 | Other test description 2 | DESC_OTH_2 | C | 20 | |
| A541 | Other test 2 | TEST_OTH_2 | C | 1 | A:non witnessed; B:witnessed; C:observed; D: none; Z:other |
| A542 | Other test description 3 | DESC_OTH_3 | C | 20 | |
| A543 | Other test 3 | TEST_OTH_3 | C | 1 | A:non witnessed; B:witnessed; C:observed; D: none; Z:other |
| A544 | Other test description 4 | DESC_OTH_4 | C | 20 | |
| A545 | Other test 4 | TEST_OTH_4 | C | 1 | A:non witnessed; B:witnessed; C:observed; D: none; Z:other |
| A546 | Material certificate for casing | MAT_CER_CA | C | 1 | 1:yes (true); 0: no (false) |
| A547 | Material certificate for impeller | MAT_CER_IM | C | 1 | 1:yes (true); 0: no (false) |
| A548 | Material certificate for shaft | MAT_CER_SH | C | 1 | 1:yes (true); 0: no (false) |
| A549 | Material certificate for other | MAT_CER_OT | C | 20 | |
| A550 | Casting repair procedure approval | CAS_REP_PR | C | 1 | 1:yes (true); 0: no (false) |
| A551 | Mag particle inspection of connection welds | NOZZ_MT | C | 1 | 1:yes (true); 0: no (false) |
| A552 | Liquid penetrant inspection of connection welds | NOZZ_LP | C | 1 | 1:yes (true); 0: no (false) |
| A553 | Radiographic inspection of connection welds | NOZZ_RT | C | 1 | 1:yes (true); 0: no (false) |
| A554 | Ultrasonic inspection of connection welds | NOZZ_UT | C | 1 | 1:yes (true); 0: no (false) |
| A555 | Mag particle inspection of castings | CAS_MT | C | 1 | 1:yes (true); 0: no (false) |
| A556 | Liquid penetrant inspection of castings | CAS_LP | C | 1 | 1:yes (true); 0: no (false) |
| A557 | Radiographic inspection of castings | CAS_RT | C | 1 | 1:yes (true); 0: no (false) |
| A558 | Ultrasonic inspection of castings | CAS_UT | C | 1 | 1:yes (true); 0: no (false) |
| A559 | Charpy test required for | CHARPY_FOR | C | 20 | |
| A560 | Additional inspection required | INSP_FOR | C | 20 | |
| A561 | Additional magnetic particle inspection | INSP_MT | C | 1 | 1:yes (true); 0: no (false) |
| A562 | Additional liquid penetrant inspection | INSP_LP | C | 1 | 1:yes (true); 0: no (false) |
| A563 | Additional radiographic inspection | INSP_RT | C | 1 | 1:yes (true); 0: no (false) |
| A564 | Additional ultrasonic inspection | INSP_UT | C | 1 | 1:yes (true); 0: no (false) |
| A565 | Alternative acceptance criteria | ALT_AC_CRI | C | 1 | 1:yes (true); 0: no (false) |

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| A566 | Hardness test required for | HARD_FOR | C | 20 | |
| A567 | Surfactant hydrotest | SURF_HYDRO | C | 1 | 1:yes (true); 0: no (false) |
| A568 | Vendor submit test procedure | TEST_PROC | C | 1 | 1:yes (true); 0: no (false) |
| A569 | Record final assembly running clearances | RUN_CLEAR | C | 1 | 1:yes (true); 0: no (false) |
| A570 | Vendor maintain record 5 years | REC_5_YRS | C | 1 | 1:yes (true); 0: no (false) |
| A571 | Inspection check list | INSP_CHKL | C | 1 | 1:yes (true); 0: no (false) |
| A572 | Q/A inspection and test remark | QA_RMK | C | 140 | |
| **General Remarks** | | | | | |
| A573 | General remark 1 | GEN_RMK1 | C | 254 | |
| A574 | General remark 2 | GEN_RMK2 | C | 254 | |
| A575 | General remark 3 | GEN_RMK3 | C | 254 | |
| A576 | General remark 4 | GEN_RMK4 | C | 254 | |
| A577 | General remark 5 | GEN_RMK5 | C | 254 | |
| A578 | General remark 6 | GEN_RMK6 | C | 254 | |

## Additional Data

### Headings

| | | | | | |
|---|---|---|---|---|---|
| B001 | ** No longer supported ** | ALT_PRO_ID | C | 2 | |
| B002 | Vendor reference number | VENDOR_REF | C | 10 | |
| **General** | | | | | |
| B003 | P & ID Number | P_ID_NO | C | 30 | |
| B028 | Number of pumps operated in parallel | NO_PARALL | I | 5 | |
| B029 | Number of pumps operated in series | NO_SERIES | I | 5 | |
| **Operating Conditions** | | | | | |
| B005 | Maximum working pressure @ 18°C | MAWP_18C | N | 13 | kPa |
| B006 | Maximum power at maximum diameter | MX_PW_MD | N | 13 | kw |
| B007 | Maximum head at maximum diameter | MX_HD_MD | N | 13 | m |
| B030 | Static head | STATIC_HD | N | 13 | m |
| B053 | Closed valve head | CV_HEAD | N | 13 | m |
| **Liquid** | | | | | |
| B025 | Solid description | SOLID_DESC | C | 25 | |
| B026 | Solid dia | SOLID_DIA | N | 13 | mm |
| B027 | Solid % concentration | SOLID_PER | C | 13 | |
| **Performance** | | | | | |
| B049 | First critical speed (dry) | CR_SP_DRY | C | 13 | rpm |
| B050 | First critical speed (wet) | CR_SP_WET | C | 13 | rpm |
| B054 | Rated head term 1 | R_HTERM1 | N | 13 | m |
| B055 | Rated head term 2 | R_HTERM2 | N | 13 | m/(m³/h) |
| B056 | Rated head term 3 | R_HTERM3 | N | 13 | m/(m³/h)^2 |
| B057 | Rated head term 4 | R_HTERM4 | N | 13 | m/(m³/h)^3 |
| B058 | Rated head term 5 | R_HTERM5 | N | 13 | m/(m³/h)^4 |
| B059 | Rated head term 6 | R_HTERM6 | N | 13 | m/(m³/h)^5 |
| B060 | Rated head term 7 | R_HTERM7 | N | 13 | m/(m³/h)^6 |
| B061 | Rated stop capacity | R_STP_CAP | N | 13 | m³/h |
| B062 | Rated power term 1 | R_PTERM1 | N | 13 | kW |

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| B063 | Rated power term 2 | R_PTERM2 | N | 13 | kW/(m³/h) |
| B064 | Rated power term 3 | R_PTERM3 | N | 13 | kW/(m³/h)^2 |
| B065 | Rated power term 4 | R_PTERM4 | N | 13 | kW/(m³/h)^3 |
| B066 | Rated power term 5 | R_PTERM5 | N | 13 | kW/(m³/h)^4 |
| B067 | Rated power term 6 | R_PTERM6 | N | 13 | kW/(m³/h)^5 |
| B068 | Rated power term 7 | R_PTERM7 | N | 13 | kW/(m³/h)^6 |
| B069 | Rated NPSH term 1 | R_NTERM1 | N | 13 | m |
| B070 | Rated NPSH term 2 | R_NTERM2 | N | 13 | m/(m³/h) |
| B071 | Rated NPSH term 3 | R_NTERM3 | N | 13 | m/(m³/h)^2 |
| B072 | Rated NPSH term 4 | R_NTERM4 | N | 13 | m/(m³/h)^3 |
| B073 | Rated NPSH term 5 | R_NTERM5 | N | 13 | m/(m³/h)^4 |
| B074 | Rated NPSH term 6 | R_NTERM6 | N | 13 | m/(m³/h)^5 |
| B075 | Rated NPSH term 7 | R_NTERM7 | N | 13 | m/(m³/h)^6 |
| B076 | Rated NPSH start capacity | R_NSTART | N | 13 | m³/h |
| B077 | Maximum diameter head term 1 | T_HTERM1 | N | 13 | m |
| B078 | Maximum diameter head term 2 | T_HTERM2 | N | 13 | m/(m³/h) |
| B079 | Maximum diameter head term 3 | T_HTERM3 | N | 13 | m/(m³/h)^2 |
| B080 | Maximum diameter head term 4 | T_HTERM4 | N | 13 | m/(m³/h)^3 |
| B081 | Maximum diameter head term 5 | T_HTERM5 | N | 13 | m/(m³/h)^4 |
| B082 | Maximum diameter head term 6 | T_HTERM6 | N | 13 | m/(m³/h)^5 |
| B083 | Maximum diameter head term 7 | T_HTERM7 | N | 13 | m/(m³/h)^6 |
| B084 | Maximum diameter power term 1 | T_PTERM1 | N | 13 | kW |
| B085 | Maximum diameter power term 2 | T_PTERM2 | N | 13 | kW/(m³/h) |
| B086 | Maximum diameter power term 3 | T_PTERM3 | N | 13 | kW/(m³/h)^2 |
| B087 | Maximum diameter power term 4 | T_PTERM4 | N | 13 | kW/(m³/h)^3 |
| B088 | Maximum diameter power term 5 | T_PTERM5 | N | 13 | kW/(m³/h)^4 |
| B089 | Maximum diameter power term 6 | T_PTERM6 | N | 13 | kW/(m³/h)^5 |
| B090 | Maximum diameter power term 7 | T_PTERM7 | N | 13 | kW/(m³/h)^6 |
| B091 | Maximum diameter start flow | T_START | N | 13 | m³/h |
| B092 | Maximum diameter stop flow | T_STOP | N | 13 | m³/h |
| B093 | Minimum diameter head term 1 | B_HTERM1 | N | 13 | m |
| B094 | Minimum diameter head term 2 | B_HTERM2 | N | 13 | m/(m³/h) |
| B095 | Minimum diameter head term 3 | B_HTERM3 | N | 13 | m/(m³/h)^2 |
| B096 | Minimum diameter head term 4 | B_HTERM4 | N | 13 | m/(m³/h)^3 |
| B097 | Minimum diameter head term 5 | B_HTERM5 | N | 13 | m/(m³/h)^4 |
| B098 | Minimum diameter head term 6 | B_HTERM6 | N | 13 | m/(m³/h)^5 |
| B099 | Minimum diameter head term 7 | B_HTERM7 | N | 13 | m/(m³/h)^6 |
| B100 | Minimum diameter power term 1 | B_PTERM1 | N | 13 | kW |
| B101 | Minimum diameter power term 2 | B_PTERM2 | N | 13 | kW/(m³/h) |
| B102 | Minimum diameter power term 3 | B_PTERM3 | N | 13 | kW/(m³/h)^2 |
| B103 | Minimum diameter power term 4 | B_PTERM4 | N | 13 | kW/(m³/h)^3 |
| B104 | Minimum diameter power term 5 | B_PTERM5 | N | 13 | kW/(m³/h)^4 |
| B105 | Minimum diameter power term 6 | B_PTERM6 | N | 13 | kW/(m³/h)^5 |
| B106 | Minimum diameter power term 7 | B_PTERM7 | N | 13 | kW/(m³/h)^6 |
| B107 | Minimum diameter start flow | B_START | N | 13 | m³/h |
| B108 | Minimum diameter stop flow | B_STOP | N | 13 | m³/h |
| B112 | Viscous Cq factor | CQ_FACTOR | N | 13 | dimensionless |

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| B113 | Viscous Ch factor | CH_FACTOR | N | 13 | dimensionless |
| B114 | Viscous Ce factor | CE_FACTOR | N | 13 | dimensionless |
| **Construction** | | | | | |
| B009 | Coupling guard non spark | CP_G_N_SP | C | 1 | 1:yes (true); 0: no (false) |
| B020 | Baseplate drain | BPLATE_DR | C | 11 | A:Rain gutter; B:Drip pan; Z:other |
| B021 | Baseplate drain connection | BPLATE_DC | C | 1 | 1:yes (true); 0: no (false) |
| B022 | Four point lifting lugs | F_LIFT_LG | C | 1 | 1:yes (true); 0: no (false) |
| B040 | Design pressure | DSGN_PRES | N | 13 | kPa |
| B041 | Design temperature | DSGN_TEMP | N | 13 | °C |
| B042 | Test pressure | TEST_PRESS | N | 20 | kPa |
| B043 | Impeller type | IMP_TYPE | C | 20 | |
| B044 | Baseplate type | BASE_TYPE | C | 20 | |
| B052 | Thrust bearing location (pump) | TH_BRG_PUM | C | 20 | |
| B109 | Sealless drive size | MAG_SIZE | C | 10 | |
| B110 | Magnetic drive eddy loss | EDDY_LOSS | N | 13 | kW |
| B111 | Magnetic drive viscous loss | VISC_LOSS | N | 13 | kW |
| **Materials** | | | | | |
| B031 | Inducer material | INDUC_MAT | C | 20 | |
| B032 | Guard material | GUARD_MAT | C | 20 | |
| B033 | Motor frame material | MTR_MATL | C | 20 | |
| B035 | Column material | COLMN_MAT | C | 20 | |
| B036 | Inner Case/Bowl material | BOWL_MAT | C | 20 | |
| B037 | Discharge Head material | DIS_HD_MAT | C | 20 | |
| B038 | Nozzle material | NOZ_MAT | C | 20 | |
| B039 | Flange material | FLANGE_MAT | C | 20 | |
| **Bearings and Lubrication** | | | | | |
| B010 | Material outer magnet | MT_OUT_MG | C | 20 | |
| B011 | Material inner magnet | MT_INN_MG | C | 20 | |
| B012 | Material containment shell | MT_CON_SH | C | 20 | |
| B013 | Material bearings | MT_BEARS | C | 20 | |
| **Mechanical Seal or Packing** | | | | | |
| B008 | Sealing system | SEAL_SYST | C | 1 | A:Mag drive; B:Canned rotor; C:Mechanical seal; D:Packing; Z:other |
| B014 | Secondary piping seal welded | SEC_PI_SEW | C | 1 | 1:yes (true); 0: no (false) |
| B015 | Secondary piping socket welded | SEC_PP_SKW | C | 1 | 1:yes (true); 0: no (false) |
| B016 | Secondary piping threaded | SEC_PP_TH | C | 1 | 1:yes (true); 0: no (false) |
| B017 | Secondary piping flanged | SEC_PP_FL | C | 1 | 1:yes (true); 0: no (false) |
| B018 | Secondary piping unions | SEC_PP_UN | C | 1 | 1:yes (true); 0: no (false) |
| B019 | Secondary tube fittings | SEC_TU_FT | C | 1 | A:Swagelock; B:Parker; Z:other |
| **Instrumentation** | | | | | |
| B023 | Magnetic drive power monitor | M_DRV_MON | C | 1 | A:Low amp relay; B:Power monitor system; Z:other |
| B024 | Containment shell | CON_SHELL | C | 1 | A:Type J thermocouple; B:Type K thermocouple; C:RTD; Z:other |
| **Motor Drive** | | | | | |
| B034 | Motor mounting | MTR_MNTING | C | 1 | A:foot; B:flange; C:foot and flange; D:skirt; Z:other |

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| B051 | Thrust bearing location (motor) | TH_BRG_MOT | C | 20 | |
| B115 | Motor shaft diameter at coupling end | MTR_SFTDIA | N | 13 | mm |
| B116 | Motor IEC safety standard rating | MTR_IECSSR | C | 6 | |
| B117 | Motor sound pressure level | MTR_SNDLEV | N | 13 | dBA |
| **Weights** | | | | | |
| B045 | Shipping spec: Gross weight | SHP_SPEC_W | N | 13 | kg |
| B046 | Shipping spec: cubage | SHP_SPEC_C | C | 13 | cu. m |
| B047 | Weight of Gas Turbine | WT_GT | N | 13 | kg |
| B048 | Weight of Diesel Engine | WT_DIESEL | N | 13 | kg |
| **QA Inspection and Test** | | | | | |
| B004 | Sound Power Level | SND_PW_LV | C | 13 | dBA |

## Dimensional Data

| | | | | | |
|---|---|---|---|---|---|
| C001 | Width of base support | HIS_A | N | 13 | mm |
| C002 | Length of base support | HIS_B | N | 13 | mm |
| C003 | Length of driver | HIS_C | N | 13 | mm |
| C004 | Length of pump | HIS_CP | N | 13 | mm |
| C005 | Vertical height: bottom base support to CL pump | HIS_D | N | 13 | mm |
| C006 | Distance pump CL to bottom drain plug | HIS_DD | N | 13 | mm |
| C007 | Distance CL pump to CL holt down bolts | HIS_E | N | 13 | mm |
| C008 | Distance from CL to CL hold down bolts | HIS_F | N | 13 | mm |
| C009 | Thickness of pads on support, or height of base plate | HIS_G | N | 13 | mm |
| C010 | Diameter of hold down bolt holes | HIS_H | N | 13 | mm |
| C011 | Width of base support | HIS_HA | N | 13 | mm |
| C012 | Length of base support | HIS_HB | N | 13 | mm |
| C013 | Overall length of combined pump and driver when on base | HIS_HC | N | 13 | mm |
| C014 | Vertical height bottom of base support to CL of pump | HIS_HD | N | 13 | mm |
| C015 | Distance from CL pump to CL hold down bolts | HIS_HE1 | N | 13 | mm |
| C016 | Distance from CL pump to CL hold down bolts | HIS_HE2 | N | 13 | mm |
| C017 | Distance from CL pump to CL hold down bolts | HIS_HE3 | N | 13 | mm |
| C018 | Distance from CL to CL of hold down bolts | HIS_HF1 | N | 13 | mm |
| C019 | Distance from CL to CL of hold down bolts | HIS_HF2 | N | 13 | mm |
| C020 | Distance from CL to CL of hold down bolts | HIS_HF3 | N | 13 | mm |
| C021 | Thickness of pads on support, or height of baseplate | HIS_HG | N | 13 | mm |
| C022 | Diameter of hold down bold holes | HIS_HH | N | 13 | mm |
| C023 | Width of pads for hold down bolts | HIS_HJ | N | 13 | mm |
| C024 | Length of support pads for down hold bolts | HIS_HK1 | N | 13 | mm |
| C025 | Length of support pads for down hold bolts | HIS_HK2 | N | 13 | mm |
| C026 | Length of support pads for down hold bolts | HIS_HK3 | N | 13 | mm |
| C027 | Length of support pads for down hold bolts | HIS_HK4 | N | 13 | mm |
| C028 | Length of support pads for down hold bolts | HIS_HK5 | N | 13 | mm |

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| C029 | Length of support pads for down hold bolts | HIS_HK6 | N | 13 | mm |
| C030 | Horizontal distance from suction nozzle face to CL nearest hold down bolt holes | HIS_HL | N | 13 | mm |
| C031 | Height of unit-bottom of base to top of driver | HIS_HM | N | 13 | mm |
| C032 | Vert. dist.-bottom of support to disch. nozzle face or top of case on hor. split pumps | HIS_HO | N | 13 | mm |
| C033 | Length from edge of support, or base plate, to CL of bolt holes | HIS_HP | N | 13 | mm |
| C034 | Horizontal distance-CL discharge flange to CL hold down bolt hole | HIS_HR | N | 13 | mm |
| C035 | Horizontal distance between pump and driving shaft | HIS_HT | N | 13 | mm |
| C036 | Distance from CL of discharge to end of motor | HIS_HW | N | 13 | mm |
| C037 | Width of pads for hold down bolts | HIS_J | N | 13 | mm |
| C038 | Length of support pads for hold down bolts | HIS_K | N | 13 | mm |
| C039 | Horizontal distance from suction nozzle face to CL nearest hold down bolt holes | HIS_L | N | 13 | mm |
| C040 | Length of adaptor piece | HIS_LP | N | 13 | mm |
| C041 | Horizontal distance from CL of discharge flange to CL of suction flange | HIS_M | N | 13 | mm |
| C042 | Distance form face of suction flange to mounting flange of adapter | HIS_MP | N | 13 | mm |
| C043 | Distance end of bearing housing to end of shaft | HIS_N | N | 13 | mm |
| C044 | Vertical distance bottom of support to discharge nozzle face or top of case on hor. split pumps | HIS_O | N | 13 | mm |
| C045 | Vertical distance bottom of support to discharge nozzle face or top of case on hor. split case | HIS_OP | N | 13 | mm |
| C046 | Horizontal distance-CL discharge flange to CL hold down bolt holes | HIS_R | N | 13 | mm |
| C047 | Distance from CL of pump to CL of suction nozzle | HIS_S | N | 13 | mm |
| C048 | Diameter of straight shaft-coupling end | HIS_U | N | 13 | mm |
| C049 | Length of shaft available for coupling of pulley | HIS_V | N | 13 | mm |
| C050 | Vertical height-bottom of base support to CL of discharge nozzle of vertical pumps | HIS_VD | N | 13 | mm |
| C051 | Distance from CL of vertical pump to CL of hold down bolt holes | HIS_VF | N | 13 | mm |
| C052 | Vertical distance-CL of discharge nozzle of CL of suction nozzle on vertical pumps | HIS_VS | N | 13 | mm |
| C053 | Horizontal distance-CL of pump to face of suction elbow of vertical pumps | HIS_VY | N | 13 | mm |
| C054 | Distance from CL of discharge flange to end of pump shaft | HIS_W | N | 13 | mm |
| C055 | Distance from discharge face to CL of pump | HIS_X | N | 13 | mm |
| C056 | Distance from CL of motor hold down bolt to CL of conduit box | HIS_XR | N | 13 | mm |
| C057 | Horizontal distance-CL discharge nozzle to suction face | HIS_Y | N | 13 | mm |
| C058 | Horizontal distance-CL case to suction nozzle face on horizontally split pumps | HIS_YY | N | 13 | mm |

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| C059 | CL discharge nozzle to CL of pump | HIS_Z | N | 13 | mm |

# Nozzle Load Data

## Nozzle Loads

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| D001 | Suction nozzle Fx | LOAD_SFX | N | 13 | N |
| D002 | Suction nozzle Fy | LOAD_SFY | N | 13 | N |
| D003 | Suction nozzle Fz | LOAD_SFZ | N | 13 | N |
| D004 | Suction nozzle Mx | LOAD_SMX | N | 13 | Nm |
| D005 | Suction nozzle My | LOAD_SMY | N | 13 | Nm |
| D006 | Suction nozzle Mz | LOAD_SMZ | N | 13 | Nm |
| D007 | Discharge nozzle Fx | LOAD_DFX | N | 13 | N |
| D008 | Discharge nozzle Fy | LOAD_DFY | N | 13 | N |
| D009 | Discharge nozzle Fz | LOAD_DFZ | N | 13 | N |
| D010 | Discharge nozzle Mx | LOAD_DMX | N | 13 | Nm |
| D011 | Discharge nozzle My | LOAD_DMY | N | 13 | Nm |
| D012 | Discharge nozzle Mz | LOAD_DMZ | N | 13 | Nm |

# Additional Operating Conditions

## Operating Conditions

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| E001 | Additional operating condition remark | AOC_RMK | C | 254 | |
| E002 | Normal Capacity | ENORM_CAP | N | 13 | $m^3/h$ |
| E003 | Rated Capacity | ERATED_CAP | N | 13 | $m^3/h$ |
| E004 | Other Capacity | EOTHER_CAP | N | 13 | $m^3/h$ |
| E005 | Suction Pressure Maximum | ESUC_PRESM | N | 13 | kPa |
| E006 | Suction Pressure Rated | ESUC_PRES | N | 13 | kPa |
| E007 | Discharge Pressure | EDIS_PRES | N | 13 | kPa |
| E008 | Differential Pressure | EDIFF_PRES | N | 13 | kPa |
| E009 | Differential Head | EHEAD | N | 13 | m |
| E010 | NPSH Available | ENPSHA | N | 13 | m |
| E011 | Hydraulic Power | EHYD_POWER | N | 13 | kW |

## Liquid

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| E012 | Name of Liquid | ELIQ_NAME | C | 20 | |
| E013 | Pumping Temperature Normal | ETEMP_NORM | N | 13 | °C |
| E014 | Pumping Temperature Maximum | ETEMP_MAX | N | 13 | °C |
| E015 | Pumping Temperature Minimum | ETEMP_MIN | N | 13 | °C |
| E016 | Specific Gravity @ Normal Temperature | ESG_NORM | C | 13 | |
| E017 | Specific Gravity @ Maximum Temperature | ESG_MAX | C | 13 | |
| E018 | Specific Gravity @ Minimum Temperature | ESG_MIN | C | 13 | |
| E019 | Specific Heat | ESP_HEAT | N | 13 | kJ/kg°C |
| E020 | Vapor Pressure | EVAP_PRES | N | 13 | kPa abs |
| E021 | Vapor pressure temperature | EVAP_TEMP | N | 13 | °C |
| E022 | Viscosity | EVISC | N | 13 | cP |
| E023 | Viscosity Temperature | EVISC_TEMP | N | 13 | °C |
| E024 | Maximum Viscosity | EMAX_VISC | N | 13 | cP |
| E025 | Corrosive/Errosive Agent | ECORROSIVE | C | 20 | |
| E026 | Chloride concentration | ECH_CONC | N | 13 | Parts per million |

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| E027 | H2S Concentration | EH2S_CONC | N | 13 | Parts per million |
| E028 | Hazardous | ETOXIC | C | 1 | 1:yes (true); 0: no (false) |
| E029 | Flammable | EFLAM | C | 1 | 1:yes (true); 0: no (false) |
| E030 | Other Liquid Hazard | EOTH_HZRD | C | 1 | 1:yes (true); 0: no (false) |
| **Performance** | | | | | |
| E031 | Rated Pump Speed | EPMP_RPM | N | 13 | RPM |
| E032 | Closed valve head | ECV_HEAD | N | 13 | m |
| E033 | Rated head term 1 | ER_HTERM1 | N | 13 | m |
| E034 | Rated head term 2 | ER_HTERM2 | N | 13 | m/(m³/h) |
| E035 | Rated head term 3 | ER_HTERM3 | N | 13 | m/(m³/h)^2 |
| E036 | Rated head term 4 | ER_HTERM4 | N | 13 | m/(m³/h)^3 |
| E037 | Rated head term 5 | ER_HTERM5 | N | 13 | m/(m³/h)^4 |
| E038 | Rated head term 6 | ER_HTERM6 | N | 13 | m/(m³/h)^5 |
| E039 | Rated head term 7 | ER_HTERM7 | N | 13 | m/(m³/h)^6 |
| E040 | Rated stop capacity | ER_STP_CAP | N | 13 | m³/h |
| E041 | Rated power term 1 | ER_PTERM1 | N | 13 | kW |
| E042 | Rated power term 2 | ER_PTERM2 | N | 13 | kW/(m³/h) |
| E043 | Rated power term 3 | ER_PTERM3 | N | 13 | kW/(m³/h)^2 |
| E044 | Rated power term 4 | ER_PTERM4 | N | 13 | kW/(m³/h)^3 |
| E045 | Rated power term 5 | ER_PTERM5 | N | 13 | kW/(m³/h)^4 |
| E046 | Rated power term 6 | ER_PTERM6 | N | 13 | kW/(m³/h)^5 |
| E047 | Rated power term 7 | ER_PTERM7 | N | 13 | kW/(m³/h)^6 |
| E048 | Rated NPSH term 1 | ER_NTERM1 | N | 13 | m |
| E049 | Rated NPSH term 2 | ER_NTERM2 | N | 13 | m/(m³/h) |
| E050 | Rated NPSH term 3 | ER_NTERM3 | N | 13 | m/(m³/h)^2 |
| E051 | Rated NPSH term 4 | ER_NTERM4 | N | 13 | m/(m³/h)^3 |
| E052 | Rated NPSH term 5 | ER_NTERM5 | N | 13 | m/(m³/h)^4 |
| E053 | Rated NPSH term 6 | ER_NTERM6 | N | 13 | m/(m³/h)^5 |
| E054 | Rated NPSH term 7 | ER_NTERM7 | N | 13 | m/(m³/h)^6 |
| E055 | Rated NPSH start capacity | ER_NSTART | N | 13 | m³/h |

## Header Data

| No | Name | Field | Type | Length | Contents/Unit |
|---|---|---|---|---|---|
| F001 | To | HDR_TO | C | 40 | |
| F002 | From | HDR_FROM | C | 40 | |
| F003 | Date | HDR_DATE | D | 8 | YYYYMMDD |
| F004 | Time | HDR_TIME | C | 6 | HHMMSS |
| F005 | Number of Records | HDR_RCDS | I | 5 | |
| F006 | Header Comments 1 | HDR_COM1 | C | 254 | |
| F007 | Header Comments 2 | HDR_COM2 | C | 254 | |
| F008 | Header Comments 3 | HDR_COM3 | C | 254 | A:non witnessed; B:witnessed; C:observed; D: none; Z:other |

# APPENDIX R—SI TO U.S. UNITS CONVERSION FACTORS, SYMBOLS, DEFINITIONS, AND ABBREVIATIONS

## Table R-1—SI to U.S. Units Conversion Factors

Multiply the SI unit of measure by the multiplication factor to obtain U.S. units.

| Quantity | Dimension | SI | Unit Abbreviation | Multiplication Factor | U.S. | Unit Abbreviation |
|---|---|---|---|---|---|---|
| Length | L | meter | m | 3.28084 | feet (ft) | ft |
| | | millimeter | mm | 0.03937 | inch | in. |
| | | micrometer | µm | 0.00003937 | inch | in. |
| | | micrometer | µm | 0.03937 | 0.001 inch | mils |
| Area | $L^2$ | square meter | $m^2$ | 10.764 | square feet | $ft^2$ |
| | | square centimeter | $cm^2$ | 0.155 | square inch | $in.^2$ |
| Velocity | $L•T^{-1}$ | meter/second | m/s | 3.28084 | feet/second | ft/sec |
| | | millimeter/second | mm/s | 0.03937 | inches/second | in./sec |
| Volume | $L^3$ | cubic meter | $m^3$ | 264.2 | US Gallons | US Gal. |
| | | liter | l | 33.81 | fluid ounce | fl. oz. |
| Flow Rate | $L^3•T^{-1}$ | cubic meter/hour | $m^3/h$ | 4.4033 | US Gallons/minute | US GPM |
| Mass | M | kilogram | kg | 2.20462 | pounds | lbs |
| | | gram | g | 0.035274 | ounces | oz. |
| Force | $M•L•T^{-2}$ | Newton | N | 0.2248 | pound force | lbf |
| Pressure | $M•L^{-1}•T^{-2}$ | Kilopascal | kPa | 0.145 | pounds/square inch | psi |
| | | Megapascal | MPa | 145.0 | pounds/square inch | psi |
| Stress | $M•L^{-1}•T^{-2}$ | $Newton/mm^2$ | $N/mm^2$ | 145.0 | pounds/square inch | psi |
| Head | L | meter | m | 3.28084 | feet | ft |
| Density | $M•L^{-3}$ | kilogram/cubic meter | $kg/m^3$ | 0.062428 | pounds/cubic foot | $lb/ft^3$ |
| Torque | $M•L^2•T^2$ | Newton•meter | Nm | 0.7376 | pound•foot | lbf•ft |
| Power | $M•L^2•T^3$ | kilowatt | kW | 1.34102 | horsepower | HP |
| Temperature | | Degrees Celsius | C | (1.8 × °C) + 32 | Degrees Fahrenheit | F |
| Heat Energy | $M•L^2•T^{-2}$ | kilojoule | kJ | 0.9478 | British thermal unit | BTU |
| Moment of Inertia | $M•L^2$ | $kilogram•meter^2$ | $kg•m^2$ | 23.73 | pound | $lb•ft^2$ |
| Unbalance | M•L | gram•millimeter | g•mm | 0.001389 | ounce-inch | oz-in. |

Note:
Units of pressure: 100 kPa = 1 bar (nonpreferred unit); units of stress: 1 $Newton/mm^2$ = 1 MPa

## Abbreviations, and Symbols:

| | |
|---|---|
| BTU | British thermal unit |
| cm | centimeter(s) |
| $cm^2$ | square centimeter(s) |
| ft | foot (feet) |
| $ft^2$ | square foot (feet) |
| $ft^3$ | cubic foot (feet) |
| g | gram(s) |
| g•mm | gram • millimeter(s) |
| GPM | gallons per minute |
| H | head in meters (feet) |
| hp | horsepower |
| Hz | hertz |
| in. | inch(es) |
| in./ft | inches per foot |
| in./in. | inches per inch |
| in./sec | inches per second |
| $in.^2$ | square inch(es) |
| kg | kilogram(s) (one thousand grams) |
| kN | kilonewton (one thousand newtons) |
| kPa | kilopascal (one thousand Pa) (100 kPa = 1 bar) |
| kW | kilowatts (one thousand watts) |
| l | liter(s) |
| lb | pound |
| lb/ft | pounds per foot |
| lbf | pound(s) force |
| lbs | pound(s) |
| m | meter(s) |
| m/s | meter(s)/second |
| $m^2$ | square meter(s) |
| $m^3$ | cubic meter(s) |
| $m^3/h$ | cubic meter(s)/hour |
| micron | micrometer (one thousandth of a millimeter – 0.001 mm) |
| mil | One thousandth of an inch (one mil equals 0.001 in.) |
| mm | millimeter(s) |
| µm | micrometer (one thousandth of a millimeter – 0.001 mm) |
| mm/s | millimeter(s)/second |
| MPa | megapascal (one thousand kPa) (1 $N/mm^2$ = 1 MPa) |
| N | Newton |
| Nm | Newton meter |
| $N/mm^2$ | Newton(s)/square millimeter |
| NPS | Nominal pipe size |
| oz | ounce (16 oz = 1 pound) |
| oz-in. | ounce-inch(es) |
| Pa | pascal |
| pk | peak |
| pk/pk | peak to peak |
| psi | pounds per square inch |
| psia | pounds per square inch absolute |
| psig | pounds per square inch gauge |
| Q | total pump flow in $m^3/sec$ (GPM) |
| RMS | root mean square |
| RPM | revolutions per minute |
| W | watts |

## Symbols:

| | |
|---|---|
| $\delta$ | logarithmic decrement |
| $\mu$ | prefix for micro (µm=micrometer) |
| $\xi$ | damping factor |

# APPENDIX S—CALIBRATION AND PERFORMANCE VERIFICATION OF TRUE PEAK AND RMS MEASUREMENT INSTRUMENTS USED FOR TEST STAND ACCEPTANCE

## Required Instruments

The True Peak and RMS verification tests require a pulse/function generator and an oscilloscope.

1. Typical pulse/function generators:
   a. Hewlett Packard 8111A pulse/function generator.
   b. Tektronix PFG 5105.
   c. Stanford Research Systems DS345.
   d. Other equivalent.
2. Typical oscilloscopes:
   a. Tektronix model 2430 A.
   b. Other equivalent.

## True Peak Measurements

Verify a True Peak measurement instrument by first establishing an initial calibration using a sine wave. Then verify the pulse response of the instrument using a nonsymmetrical duty cycle pulse and compare the results to the sine wave calibration. Follow these steps:

1. Set up the instruments as shown in Figure S-1.

Set up the unit under test for the desired full scale amplitude and the sensitivity of the transducer being used. The following example uses a full scale of 10mm/sec. (0.4 in./sec) peak and a transducer scale factor of 20 mV/mm/sec (500 mV/in./sec).

2. Adjust the pulse/function generator with the aid of the oscilloscope to create a sine wave as shown in Figure S-2 with an amplitude accuracy of ±5 percent or better.

3. Verify that the unit under test reads 10 mm/sec (0.4 in./sec) peak ±7 percent.

4. Switch the pulse/function generator from the sine wave to the pulse signal as shown in Figure S-3.

5. Verify that the unit under test still reads 10 mm/sec (0.4 in./sec) peak ±7 percent.

## RMS Measurements

The RMS (as defined in 2.8.3.4.2) measurement calibration shall be verified by using both sine and square waves of the same RMS value.

1. Set up the instruments as shown in Figure S-1.

Set up the unit under test for the desired full scale amplitude

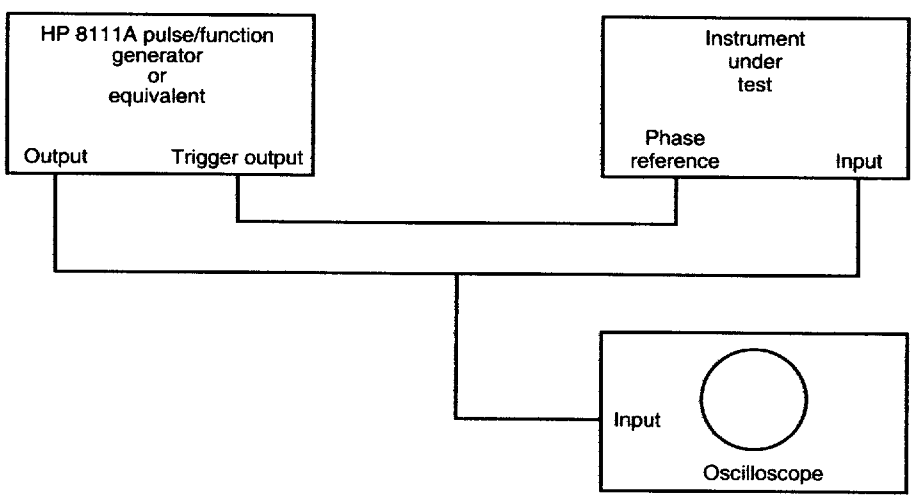



Figure S-1—Instrument Test Setup

and the sensitivity of the transducer being used. The following example uses a full scale of 10 mm/sec (0.4 in./sec) RMS and a transducer scale factor of 20mV/mm/sec (500 mV/in./sec).

2. Adjust the pulse/function generator with the aid of the oscilloscope to create a sine wave as shown in Figure S-4 with an amplitude accuracy of ±5 percent or better.

3. Verify that the unit under test reads 10mm/sec (0.4 in./sec) RMS ±7 percent.

4. Switch the pulse/function generator from the sine wave to a square wave signal as shown in Figure S-5.

5. Verify that the unit under test reads 10mm/sec (0.4 in./sec) RMS ±7 percent.

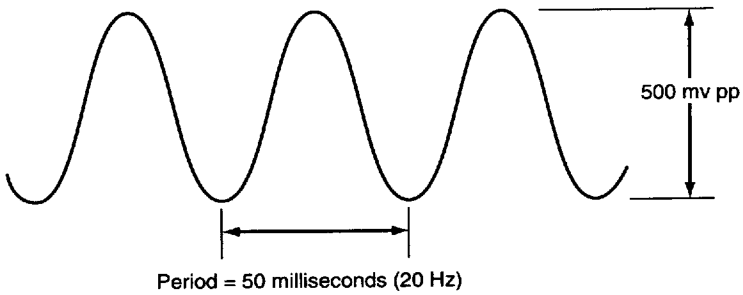



Figure S-2—Sine Wave Signal Showing True Peak

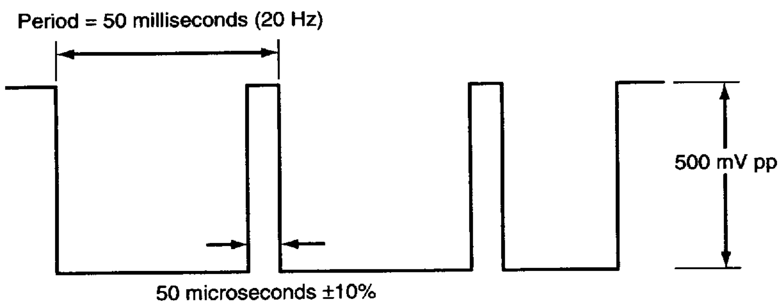



Figure S-3—Pulse Signal Showing True Peak

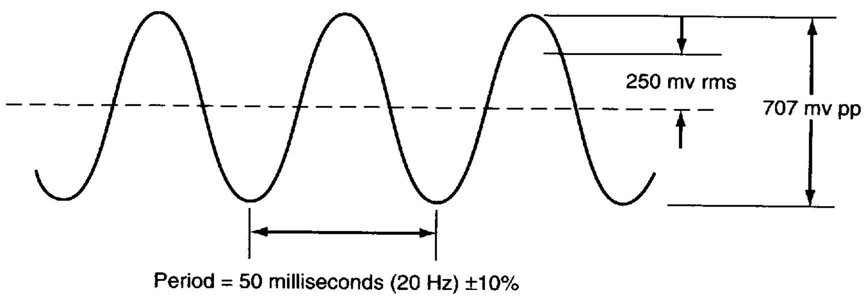



Figure S-4—Sine Wave Signal Showing RMS

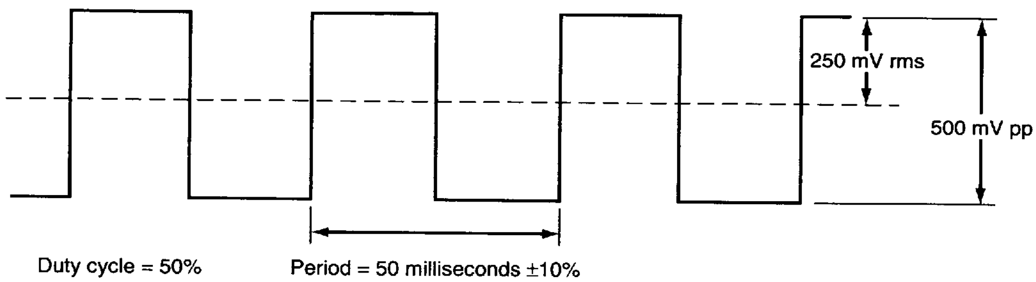



Figure S-5—Pulse Signal Showing RMS

# APPENDIX T—TEST DATA SUMMARY

# APPENDIX T - API 610 TEST DATA SUMMARY

| | | | |
|---|---|---|---|
| Customer | | Curve No. | |
| Purchaser | | Test Date | |
| Purchase Order No. | | | |
| Item No. | | Certified By | |
| Pump Serial No. | | (Vendor Representative) | |
| Size and Type | | Witnessed by | |
| No. of Stages | | (Purchaser Representative) | |

**Hydraulic Performance (Table 4.2)**

| | Rated | Tested | Actual Deviation +/- % | Acceptance Tol. +/- % |
|---|---|---|---|---|
| Flow | | | | |
| Head | | | | |
| Power | | | | |
| NPSHR 3% | | | | |
| Shut off Head | | | | |
| Speed rpm | | | | |

**Pump Construction Data**

| Stage 1 | | Series Stages | |
|---|---|---|---|
| Impeller Diameter | mm (in.) | Impeller Diameter | mm (in.) |
| Impeller Pattern No. | | Impeller Pattern No. | |
| No. of Vanes | | No. of Vanes | |
| Volute/Diffuser Pattern No. | | Volute/Diffuser Pattern No. | |
| Blade Tip Clearance (2.1.15) | % | Blade Tip Clearance (2.1.15) | % |

**Mechanical Performance**

**Maximum Vibration Levels recorded within specified flow region (2.8.3)**

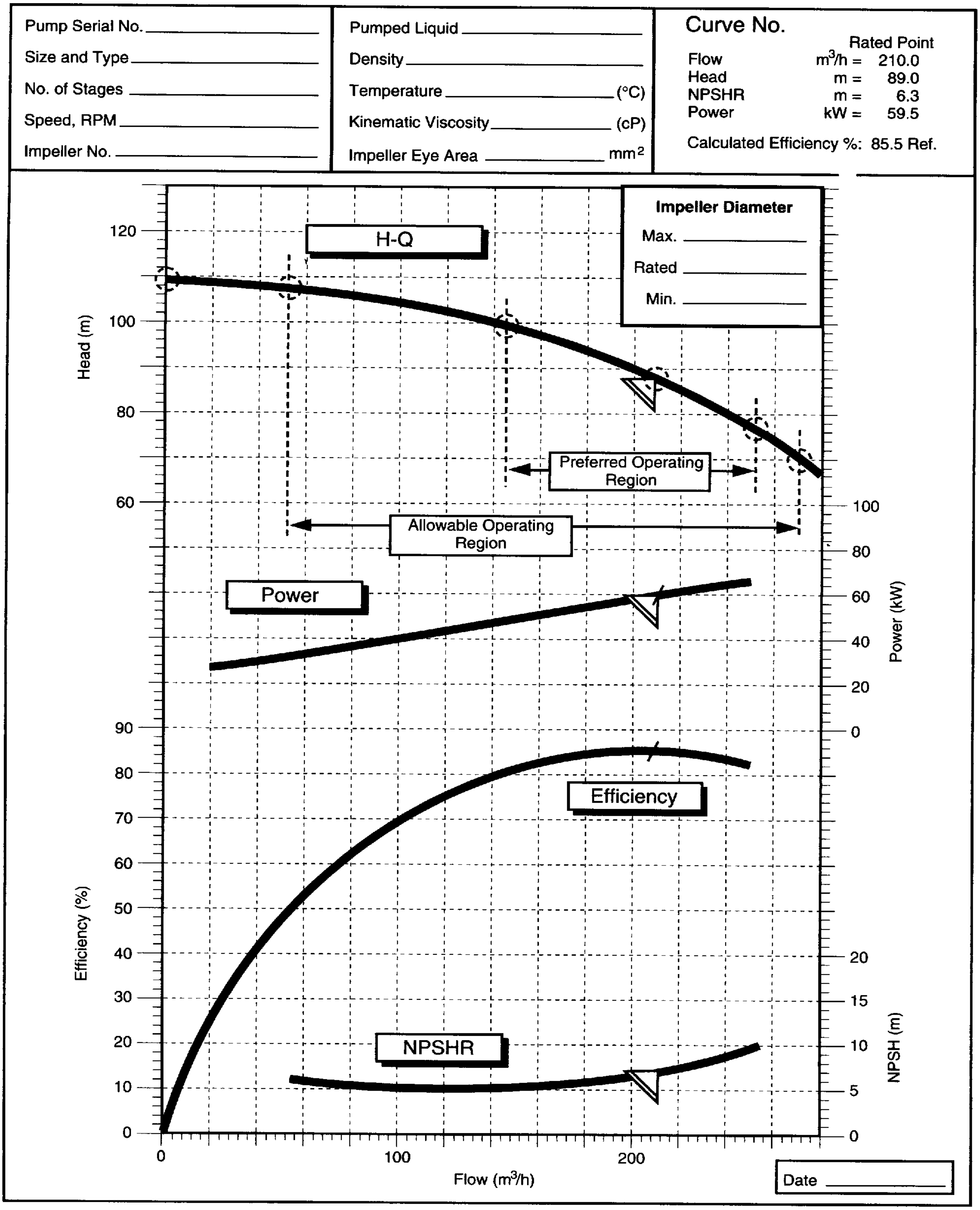
| | Rated Flow | | Preferred Operating Region | | Allowable Operating Region | |
|---|---|---|---|---|---|---|
| | Tested | Specified | Tested | Specified | Tested | Specified |
| Housing Velocity: Drive End: Overall / Filtered | / | / | / | / | / | / |
| Non-Drive End: Overall / Filtered | / | / | / | / | / | / |
| Shaft Displacement: Drive end: Overall / Filtered | / | / | / | / | / | / |
| Non-Drive End: Overall / Filtered | / | / | / | / | / | / |

**Bearing Temperatures °C (°F) (2.9.2.3)**

| Pressurized Lubrication Systems | | Ring Oil or Splash Systems | |
|---|---|---|---|
| Ambient Temp. | | Ambient Temp. | |
| Oil Temp. Rise | | Oil Temp rise | |
| Oil Outlet Temp. | | Oil Sump Temp. | |
| Max. Bearing MetalTemp. Drive End Journal | | | |
| Non Drive End Journal | | | |
| Thrust Bearing | | | |

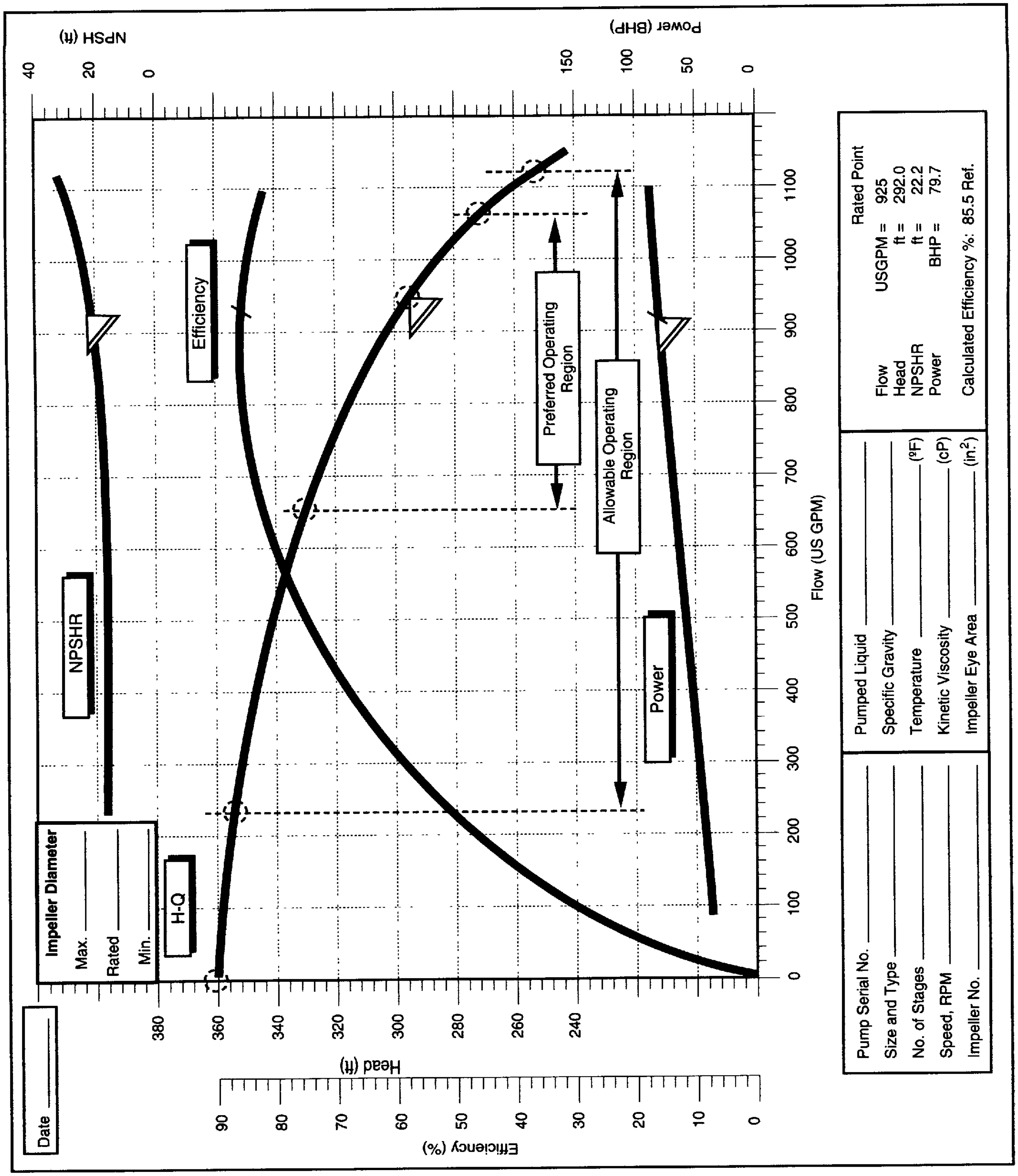
(1) This mechanical performance summary is for recording maximum test levels for each operating region relative to specified values. It is not intended to replace shop test data logs.

(2) Units of measurement shall be mm/sec (in./sec.) RMS for velocity, µm (mils) peak/peak for displacement and °C (°F) for temperature




Note: Values for scales, flow, head, NPSHR, power, efficiency for illustration only.

Figure T-1—Test Curve Format—ISO Style




Note: Values for scales, flow, head, NPSHR, power, efficiency for illustration only.

Figure T-2—Test Curve Format—U.S. Style

# APPENDIX U—SEAL CHAMBER DIMENSIONS: BASIC PHILOSOPHY FOR STANDARDIZATION

The objective of standardization of seal chamber dimensions is to allow standard seals to be developed for API 682 and for API Standard 610 pumps. These dimensions will allow complete standard cartridges to be developed for single stage overhung pumps interchangeable between pump manufacturers. For other types of pumps, custom sleeves and glands may be required, but the basic seal components will be interchangeable.

The standard dimensions (see Table 2.3) have been set to facilitate designs capable of meeting the reliability requirements of API Standards 682 and 610. They recognize the conflict between the desirability of large seal chambers for the seal designer and the desirability of short overhangs for the pump manufacturer. All dimensions are chosen to meet these ends while minimizing the impact on pump manufacturers' existing designs:

a. Seal chamber standard sizes are tabulated from 1 to 10.

b. Shaft dimensions are chosen on 10 mm increments to minimize numbers of seals. Shaft diameter is a maximum dimension. Ultimate standardization on these shaft sizes is desirable.

c. Seal chamber bores are chosen to allow adequate radial space to fit a seal and meet the radial clearance requirements of 610 and 682. These dimensions are slightly larger than the 7th Edition of API Standard 610.

d. Gland stud circles are chosen to allow installation of a 6 mm (1/4 in.) spiral wound gasket in an 8 mm (5/16 in.) gasket pocket and to be compatible with most or all API 610, 7th Edition pump bearing bracket webs. These criteria allow conservative gasket selection and do not force pump manufacturers to redesign their pump bearing brackets.

e. Radial dimension from shaft to seal chamber is chosen for the same reason as seal chamber bores in the preceding item c. These dimensions are slightly larger than in the 7th Edition of API Standard 610. However, the radial dimension has become redundant and has been eliminated from the table in this revision.

f. Total length, C, is established to allow installation of the longest seal arrangement which might be specified, in otherwords, a dual seal with a throttle bushing. Total length is slightly different from the 7th Edition of API Standard 610 due to conversion to metric and graduation with increasing shaft sizes.

g. Chamber depth, C minus E, is free. For existing designs with "traditional seal chambers" this is a finite length. The intent is to place complete responsibility for the design of the seal chamber in the hands of the seal vendor. The C and E dimensions, which are minimum, effectively establish a dimension, C minus E, which for the seal manufacturer is the maximum that seal components can extend into the pump. For pumps with dimensions less than the difference between C and E, either a spacer is required to fit the standard seal or a bolt-on seal chamber is required. A specific chamber depth dimension has, therefore, been deleted from the table in this revision. However, it is necessary for the pump manufacturer to supply the resulting (C minus E) dimension to the seal manufacturer when supplying seal chamber drawings.

While the additional joint incurred by this spacer is not particularly desirable, the reality is that dual seals already require two joints associated with the seal gland. The ability to install a standard seal without a spacer might then become a point of evaluation by users, and the industry might move voluntarily toward fixing a "D" dimension (for single stage overhung pumps) at the difference between C and E in the table. As an alternative, the user can elect to specify custom seal glands which have axial length sufficient to eliminate the need for a spacer.

h. Clear length, E, is a new minimum dimension. API Standard 610 requires that pumps have a separable gland. The gland must have axial space for a seal flush connection (1/2 NPS minimum), quench and drain (3/8 NPS minimum) and a floating throttle bushing. This dimension was chosen from known axial dimensions of existing standard seals.

i. Stud sizes have been chosen basis ASME calculations to meet pressure requirements. Larger stud sizes shall be considered only if required to meet the stress requirements of Section VIII or Section II of the ASME Code, or to sufficiently compress spiral wound gaskets in accordance with the manufacturer's specifications.

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