



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

Manufacturing, Distribution and Marketing Department

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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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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.

CENTRIFUGAL PUMP TYPES

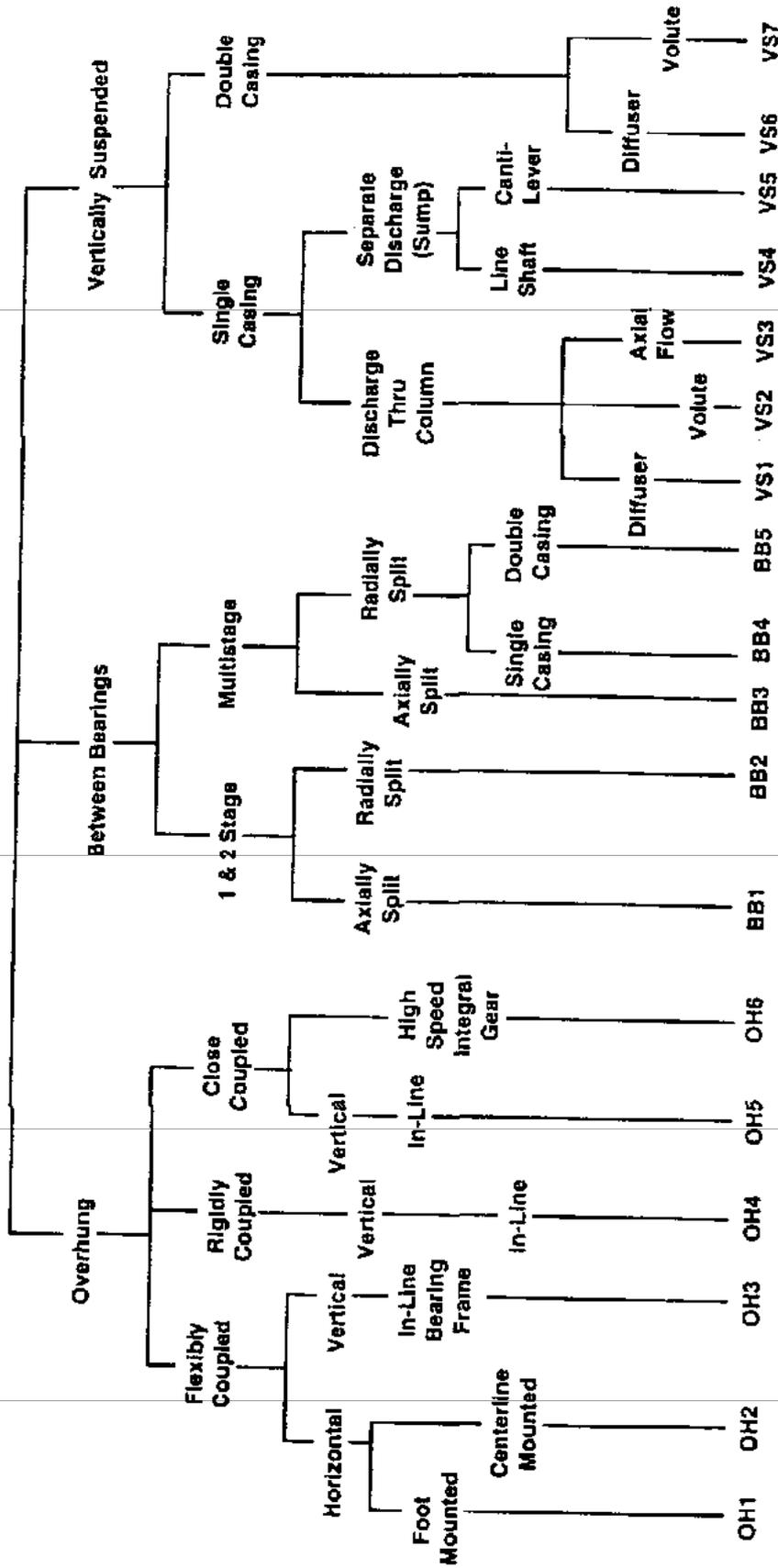


Figure 1-1—Pump Classification Type Identification

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

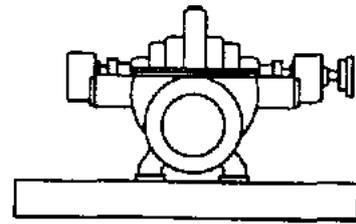
SPECIFIC CONFIGURATION

ILLUSTRATION

**Between
Bearings**

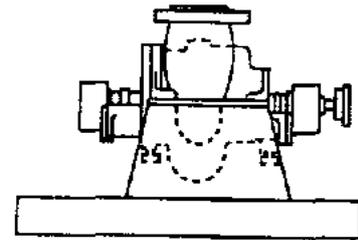
BB1

Axially split, 1 and 2 stage



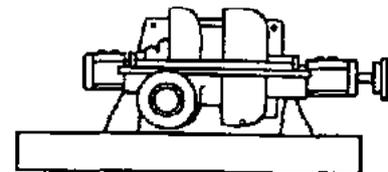
BB2

Radially split, 1 and 2 stage



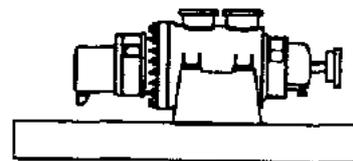
BB3

Axially split, multistage



BB4
BB5

Radially split, multistage:
Single casing
Double casing



**Vertically
Suspended**

VS1

Wet pit, diffuser



VS2

Wet pit, volute



Figure 1-2—Basic Pump Types (Continued)

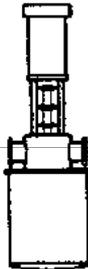
BASIC TYPE (ROTOR)	CODE	SPECIFIC CONFIGURATION	ILLUSTRATION
Vertically Suspended (continued)	VS3	Wet pit, axial flow	
	VS4 VS5	Vertical sump: Line shaft Cantilever	
	VS6	Double casing diffuser	
	VS7	Double casing volute	

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)	<ol style="list-style-type: none"> 1. Motor construction (3.1.7; 3.1.8) 2. Motor bearing and winding temperature at high pumping temperatures 3. Seal removal (2.7.3.1)
Rigidly Coupled Vertical In-line	<ol style="list-style-type: none"> 1. Motor construction (3.1.7; 3.1.8) 2. Rotor stiffness (2.5.7; 5.1.2.9) 3. Product lubricated guide bearing (2.5.7) 4. Shaft runout at seal (2.5.6)
Horizontal Foot Mounted overhung	<ol style="list-style-type: none"> 1. Pressure rating (2.2.2) 2. Centerline supported casing (2.2.9)
Two Stage Overhung	<ol style="list-style-type: none"> 1. Rotor stiffness (2.5.7; 5.1.1.2)
Double Suction Overhung	<ol style="list-style-type: none"> 1. Rotor stiffness (2.5.7; 5.1.1.2)
Ring Section Casing (multistage)	<ol style="list-style-type: none"> 1. Pressure containment (2.2.7; 2.2.8) 2. Dismantling (2.1.25)
Built-in Mechanical Seal (no separable seal gland)	<ol style="list-style-type: none"> 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 N_s .

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 multi-stage 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 reference.

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 impeller 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 · °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 $\mu\text{in.}$) for static O-rings and 0.8 μm (32 $\mu\text{in.}$) 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 1¹/₄, 2¹/₂, 3¹/₂, 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 1/2 NPS for pumps with discharge nozzle openings 2 NPS and smaller. Connections shall be at least 3/4 NPS for pumps with discharge nozzle openings 3 NPS and larger, except that connections for seal flush piping, lantern rings and gauges may be 1/2 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 μ m (125 and 250 μ in.) 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.

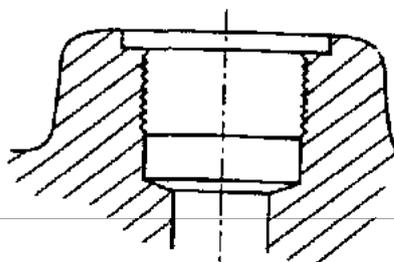


Figure 2-1—Machined Face Suitable for Gasket Containment When Using Cylindrical Threads

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 1½ 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.

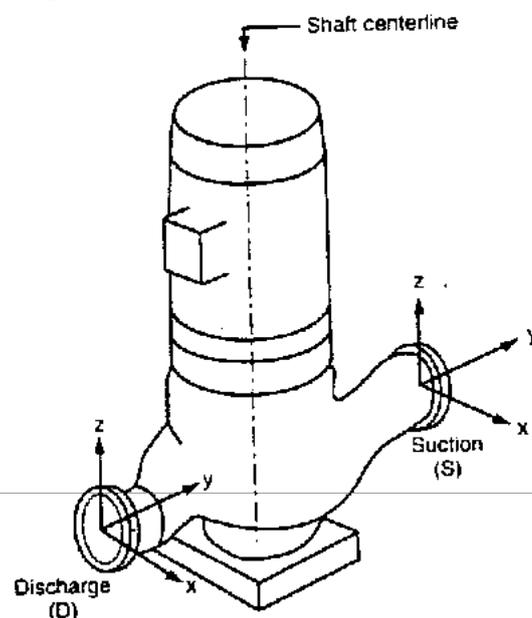


Figure 2-2—Coordinate System for the Forces and Moments in Table 2.1A (2.1B) Vertical In-Line Pumps

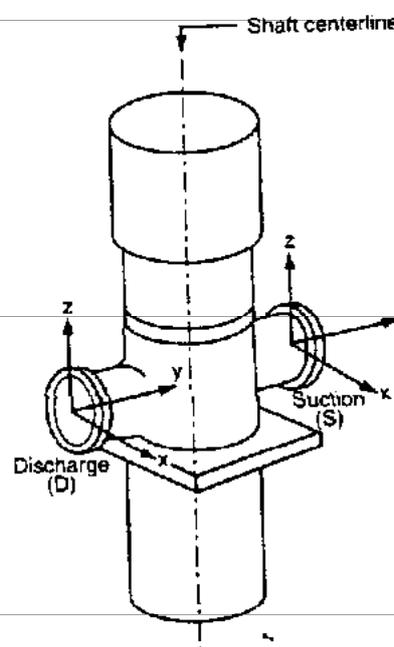


Figure 2-3—Coordinate System for the Forces and Moments in Table 2.1A (2.1B) Vertically Suspended Double-Casing Pumps

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									
<i>FX</i>	710	1070	1420	2490	3780	5340	6670	7120	8450
<i>FY</i>	580	890	1160	2050	3110	4450	5340	5780	6670
<i>FZ</i>	890	1330	1780	3110	4890	6670	8000	8900	10230
<i>FR</i>	1280	1930	2560	4480	6920	9630	11700	12780	14850
Each Side Nozzle									
<i>FX</i>	710	1070	1420	2490	3780	5340	6670	7120	8450
<i>FY</i>	890	1330	1780	3110	4890	6670	8000	8900	10230
<i>FZ</i>	580	890	1160	2050	3110	4450	5340	5780	6670
<i>FR</i>	1280	1930	2560	4480	6920	9630	11700	12780	14850
Each End Nozzle									
<i>FX</i>	890	1330	1780	3110	4890	6670	8000	8900	10230
<i>FY</i>	710	1070	1420	2490	3780	5340	6670	7120	8450
<i>FZ</i>	580	890	1160	2050	3110	4450	5340	5780	6670
<i>FR</i>	1280	1930	2560	4480	6920	9630	11700	12780	14850
Each Nozzle									
<i>MX</i>	460	950	1330	2300	3530	5020	6100	6370	7320
<i>MY</i>	230	470	680	1180	1760	2440	2980	3120	3660
<i>MZ</i>	350	720	1000	1760	2580	3800	4610	4750	5420
<i>MR</i>	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									
<i>FX</i>	160	240	320	560	850	1200	1500	1600	1900
<i>FY</i>	130	200	260	460	700	1000	1200	1300	1500
<i>FZ</i>	200	300	400	700	1100	1500	1800	2000	2300
<i>FR</i>	290	430	570	1010	1560	2200	2600	2900	3300
Each Side Nozzle									
<i>FX</i>	160	240	320	560	850	1200	1500	1600	1900
<i>FY</i>	200	300	400	700	1100	1500	1800	2000	2300
<i>FZ</i>	130	200	260	460	700	1000	1200	1300	1500
<i>FR</i>	290	430	570	1010	1560	2200	2600	2900	3300
Each End Nozzle									
<i>FX</i>	200	300	400	700	1100	1500	1800	2000	2300
<i>FY</i>	160	240	320	560	850	1200	1500	1600	1900
<i>FZ</i>	130	200	260	460	700	1000	1200	1300	1500
<i>FR</i>	290	430	570	1010	1560	2200	2600	2900	3300
Each Nozzle									
<i>MX</i>	340	700	980	1700	2600	3700	4500	4700	5400
<i>MY</i>	170	350	500	870	1300	1800	2200	2300	2700
<i>MZ</i>	260	530	740	1300	1900	2800	3400	3500	4000
<i>MR</i>	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 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.

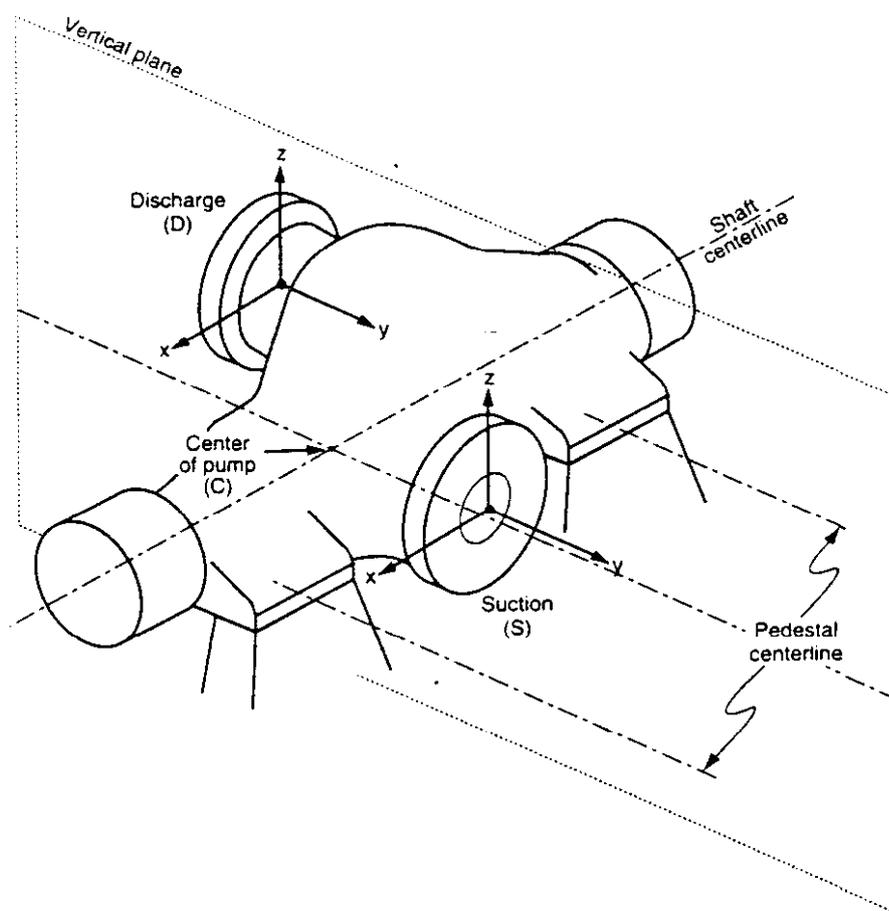


Figure 2-4—Coordinate System for the Forces and Moments in Table 2.1A (2.1B)
Horizontal Pumps with Side Suction and Side Discharge Nozzles

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 mechanical 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 specified speed and fluid—to 50 μm (0.002 in.) at the primary seal faces. This shaft deflection limit may be achieved

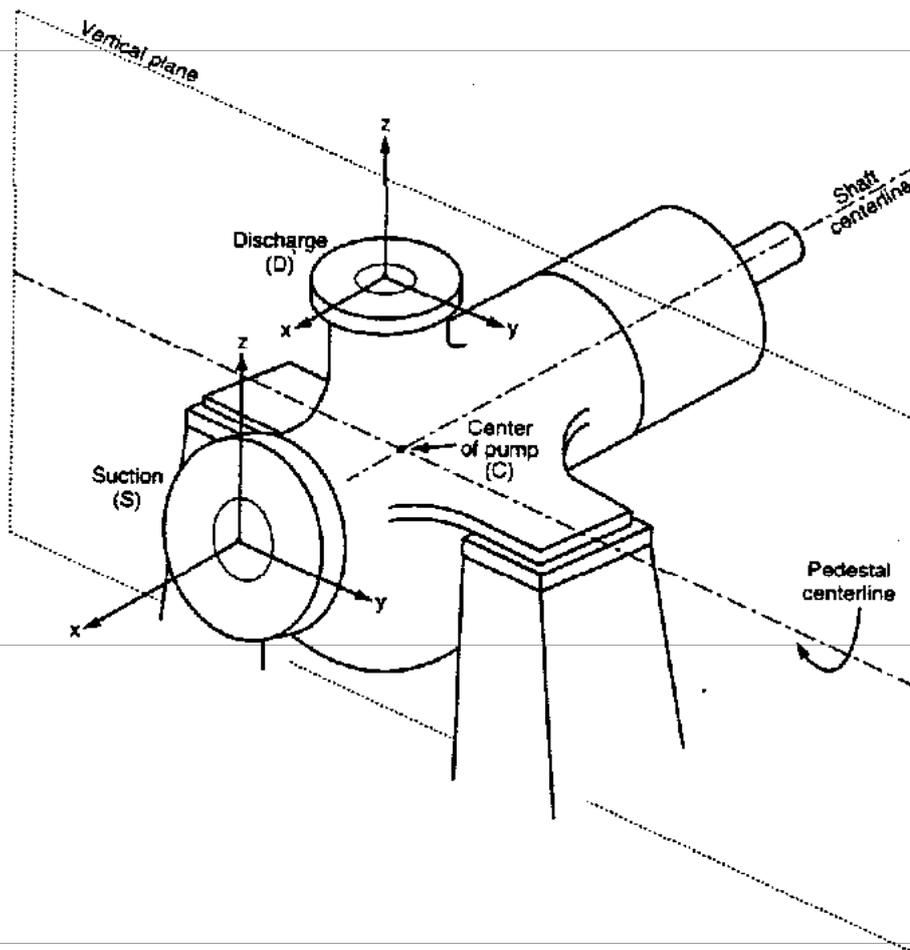


Figure 2-5 —Coordinate System for the Forces and Moments in Table 2.1A (2.1B)
Horizontal Pumps with End Suction and Top Discharge Nozzles

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 $1.0 \mu\text{m}$ ($32 \mu\text{in.}$) 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 $5 \mu\text{m}$ (0.25 mil), whichever is greater.
- b. For areas to be observed by axial position probes, $15 \mu\text{m}$ (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 non-contacting vibration probe and a dial indicator simultane-

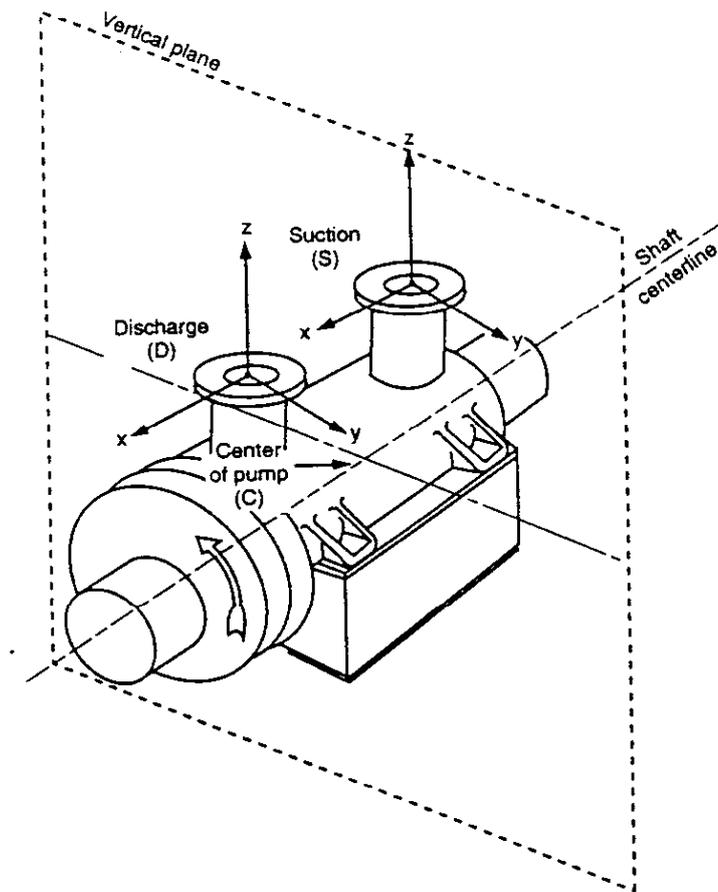


Figure 2-6—Coordinate System for the Forces and Moments in Table 2-1A (2-1B)
Horizontal Pumps with Top Nozzles

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 μ m 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 μ m (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.

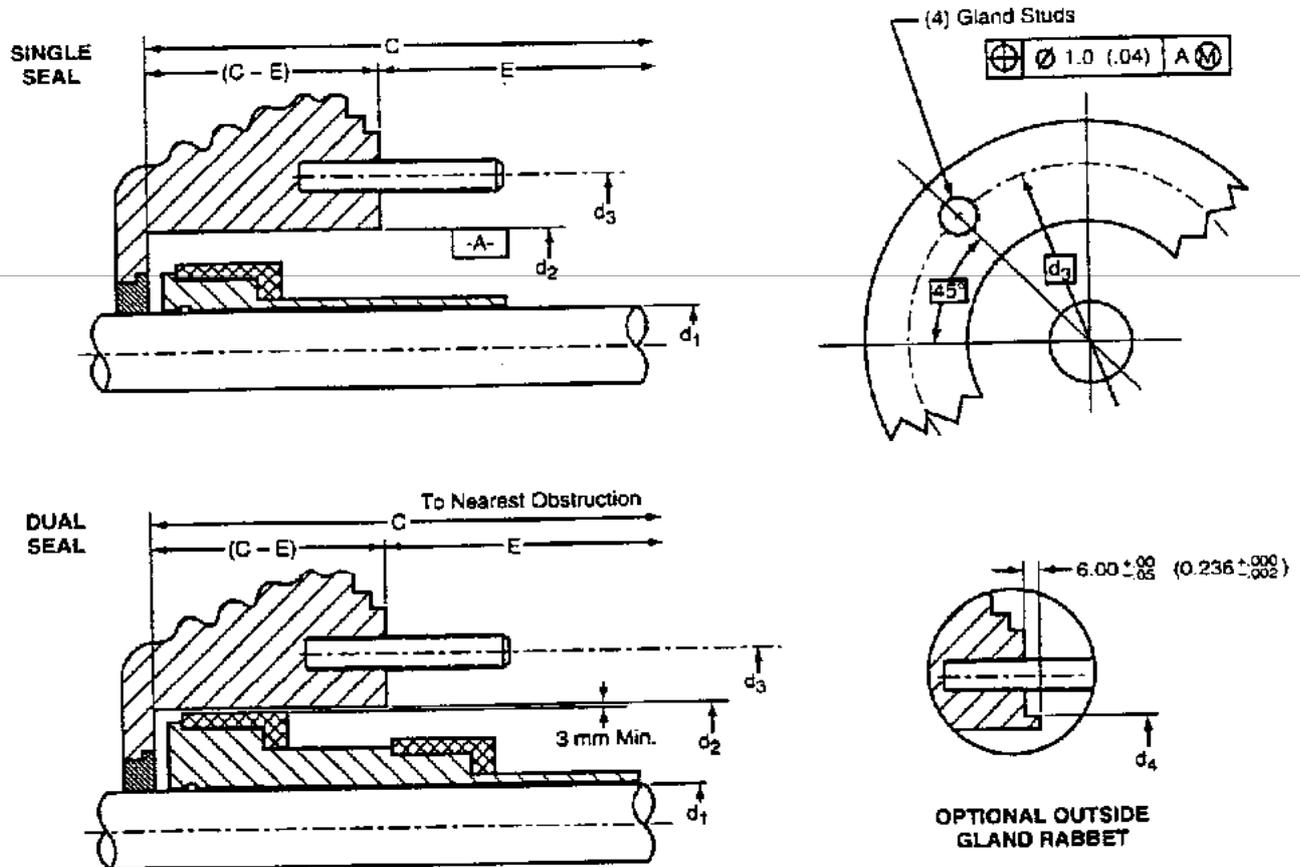
2.7.3.1 Unless otherwise specified, all standard mechanical seals, regardless of type or arrangement, shall be of the cartridge design. For this standard, a cartridge design consists of a mechanical seal unit, including sleeve, gland, primary seals, secondary seals, etc., that can be tested as a unit 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 μ m (0.007 in.)
51–80 mm (2.01–3.00 in.)	225 μ m (0.009 in.)
81–120 mm (3.01–4.75 in.)	280 μ m (0.011 in.)
over 120 mm (4.75 in.)	2.5 μ m/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 $2 \times$ RPM of either shaft
- b. Engine drive: $n \times$ RPM
- c. Synchronous motor: $n \times$ slip frequency, 1 and $2 \times$ line frequency
- d. Variable frequency drive: $n \times$ RPM, 1 and $2 \times$ 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 and PSHR 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 2Z 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:

$$\text{RMS} = \left[\frac{1}{T} \int_0^T f(t)^2 dt \right]^{1/2}$$

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-

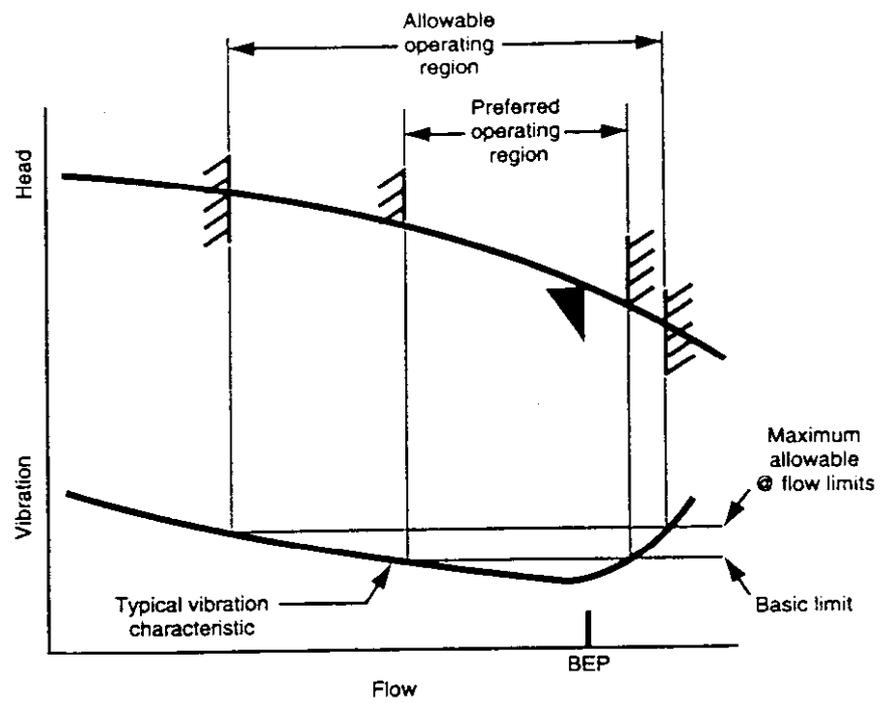


Figure 2-7—Relationship Between Flow and Vibration

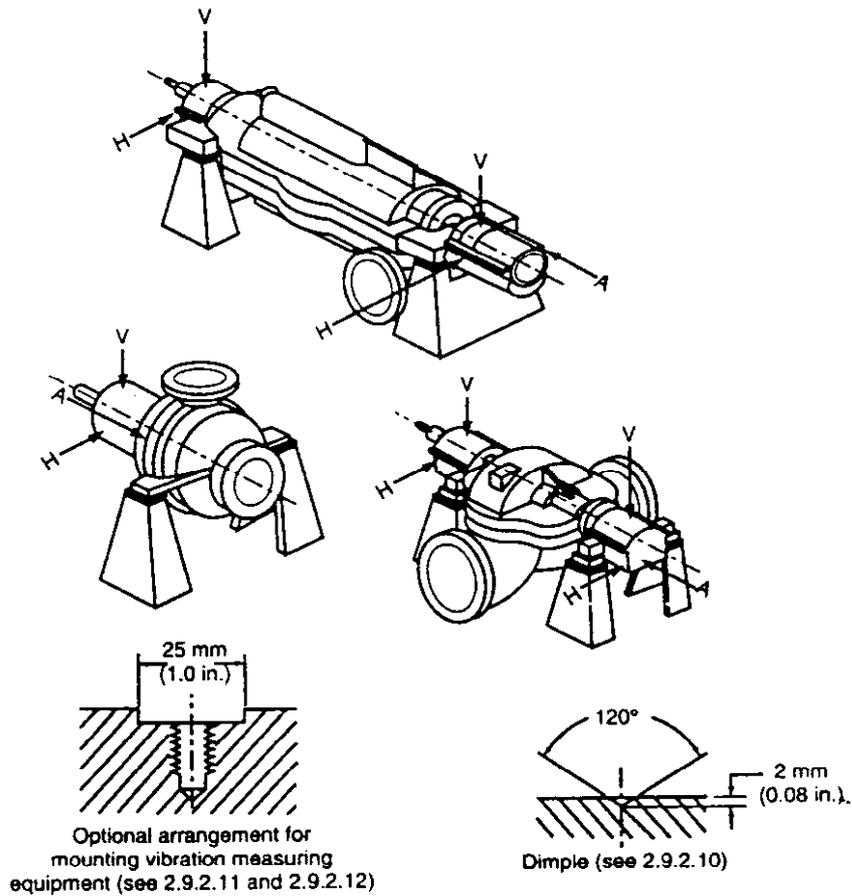


Figure 2-8A—Locations for Taking Vibration Readings on Horizontal Pumps

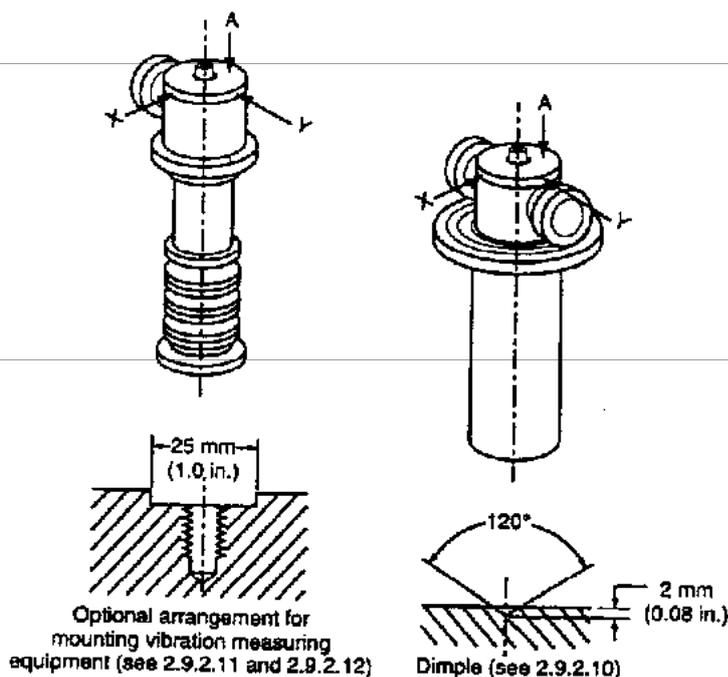


Figure 2-8B—Locations for Taking Vibration Readings on Vertical Pumps

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:

- Table 2-5 for overhung and between bearing pumps.
- 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.

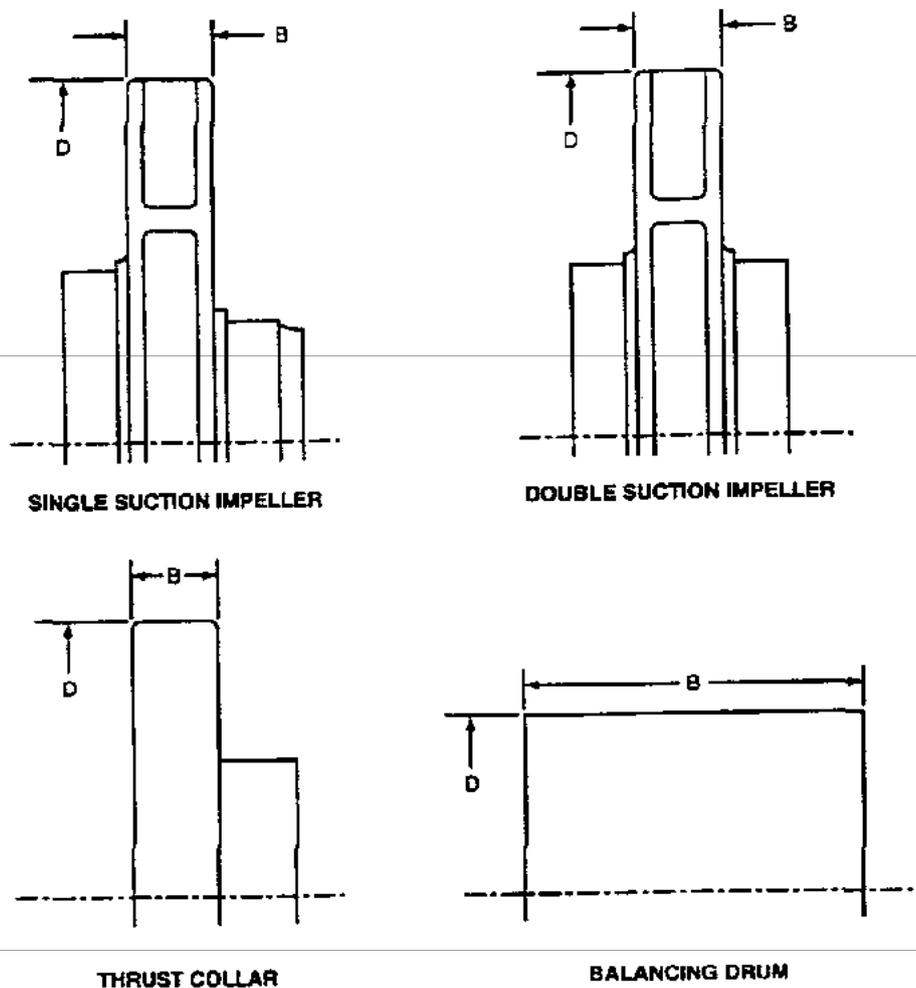


Figure 2-9—Rotating Component Dimensions to Determine When Single Plane Balancing Is Allowable

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)	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)	$A_u < (5.2 \times 10^6)^{0.5} \frac{\mu\text{m pk/pk}}{N}$ ((8000/N) ^{0.5} mils pk/pk) Not to exceed: $A_u < 50 \mu\text{m pk/pk}$ (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)	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)	$A_u < (6.5 \times 10^6)^{0.5} \frac{\mu\text{m pk/pk}}{N}$ ((10,000/N) ^{0.5} mils pk/pk) Not to exceed: $A_u < 100 \mu\text{m pk/pk}$ (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 and Pump energy density below limit	Rolling element radial and thrust
Radial bearing speed or life outside limits for rolling element bearings and Thrust bearing speed and life within limits for rolling element bearings and Pump energy density below limit	Hydrodynamic radial and rolling element thrust or Hydrodynamic radial and thrust
Radial and thrust bearing speed or life outside limits for rolling element bearings or 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 se-

ries). 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 tem-

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:

- Pressure casing parts of double casing pumps shall be of carbon steel or alloy steel.
- Pressure casing parts of pumps that are to handle flammable or hazardous liquids shall be of carbon steel or alloy steel.
- 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 naphenic 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 H₂S and water in the process liquid. Materials with a yield strength of more than 620 N/mm² (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 H₂S) as defined by NACE MR0175:

- The pressure casing.
- Shafting (including wetted shaft nuts).
- Balancing drums.
- Impellers.
- Pressure retaining mechanical seal components (excluding seal faces).
- Wetted bolting.

Items 1 through 4 below apply when H₂S is present:

- The yield strength and hardness restrictions above may be modified in accordance with NACE MR0175.
- The inner-casing parts of double-casing pumps, such as diffusers and bowls, are not considered pressure casing parts.
- 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, $^{\circ}\text{C}$ ($^{\circ}\text{F}$).

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		Percentage of Rated Pump Power
kW	hp	
< 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:

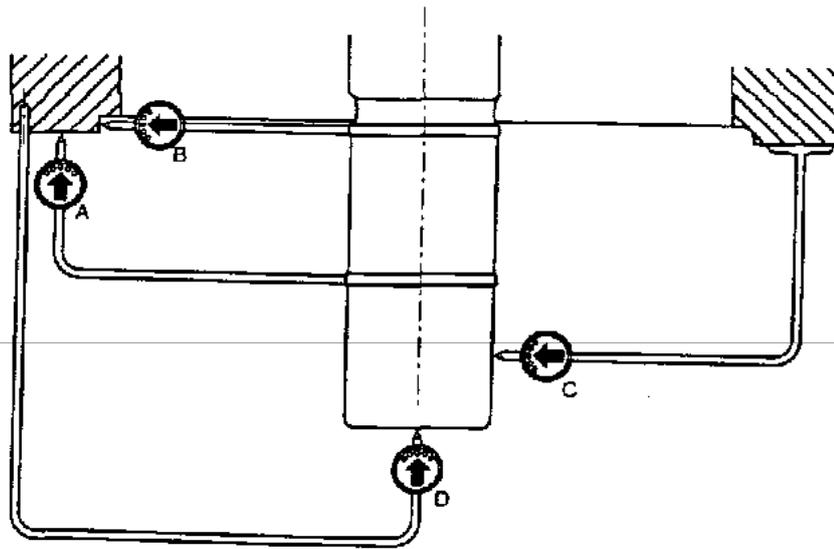
- a. Bearings shall be selected to give a basic rating life, L_{10h} , in accordance with ISO 281 (ANSI/ABMA Standard 9), of at least 25,000 hours with continuous operation at pump rated conditions.
- b. Bearings shall be selected to give a basic rating life, L_{10h} , of at least 16,000 hours when carrying 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		Maximum Coupling End Float	
(mm)	(in.)	(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 $\mu\text{m}/\text{m}$ (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

Loading Condition	Pump Shaft Displacement				
	Baseplate Intended for Grouting		Baseplate Not Intended for Grouting		
	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 cm² (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:

- Heavy duty, corrosion resistant construction.
- Bimetallic or liquid filled element.
- 100 mm (4.5 in.) or greater diameter dial.
- 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 $\frac{3}{4}$ 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. $\frac{1}{2}$ 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	≥ 1 1/2 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	—				
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 ≥ 1 1/2 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 1/2 NPS to 1 1/2 NPS. Schedule 40 for diameters 2 NPS and larger.

^b Schedule 40 for a diameter of 1 1/2 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 x 1.66 mm wall (1/2 in. diameter x 0.065 in. wall); 19 mm diameter x 2.6 mm wall (3/4 in. diameter x 0.095 in. wall); 25 mm diameter x 2.9 mm wall (1 in. diameter x 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:

- Necessary certification of materials, such as mill test reports.
- Purchasing specifications for all items on bills of material.
- 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 and 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 Sec-

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	1
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 al-

lowable 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 through 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 ft³) 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 (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 un piped, 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 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 illustrations.

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 $\frac{1}{2}$ 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 , mm ² (in ²) (see Note 2)	>1.9x10 ⁹ (3.0x10 ⁶)		≤ 1.9x10 ⁹ (3.0x10 ⁶)	
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.

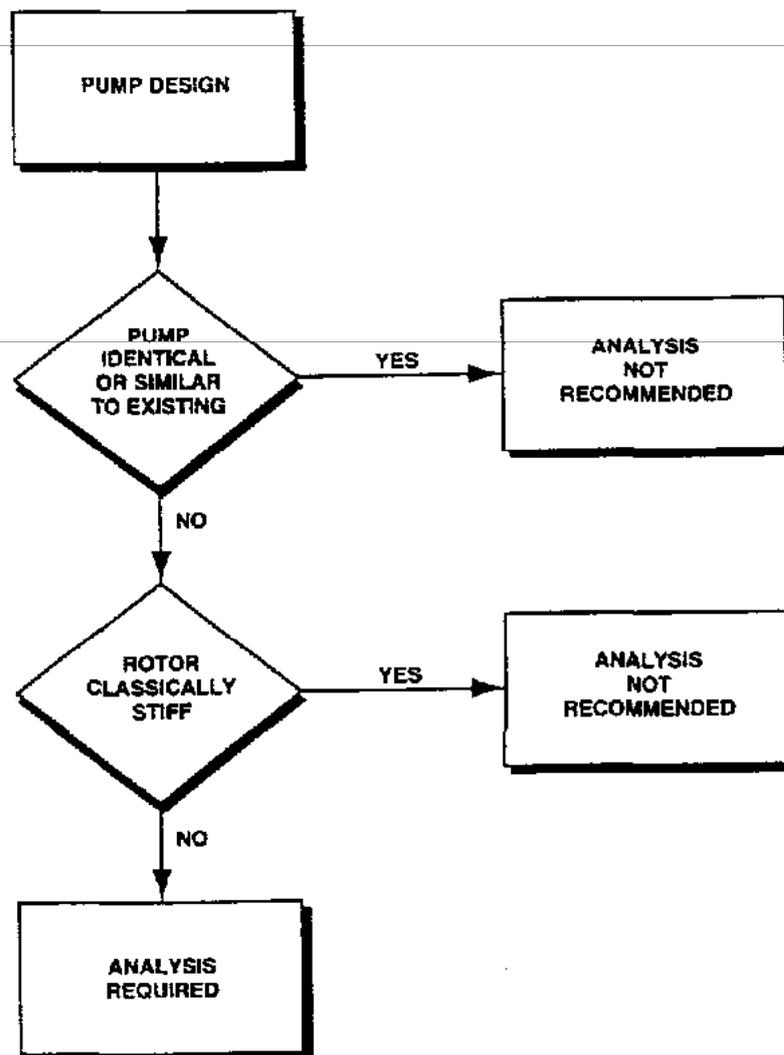


Figure 5-1—Decision Tree for Rotor Lateral Analysis

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	
		To 3800	Above 3800
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	$\leq 1.9 \times 10^9$ (3.0×10^6) ^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.

^a1.05 (3600) for turbine overspeed.

^bBalance correction during assembly is not feasible because clearance fit will not maintain corrected balance.

^cWhen 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.

^dApproximately 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 $0.4 \mu\text{m}$ (16 $\mu\text{in.}$) R_a , and, after mounting, the axial total indicated runout of either face shall not exceed $13 \mu\text{m}$ (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 $13 \mu\text{m}$ (0.0005 in.) or a maximum babbitt 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:

- For rotors designed for wet running only, 20 percent.
- 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.

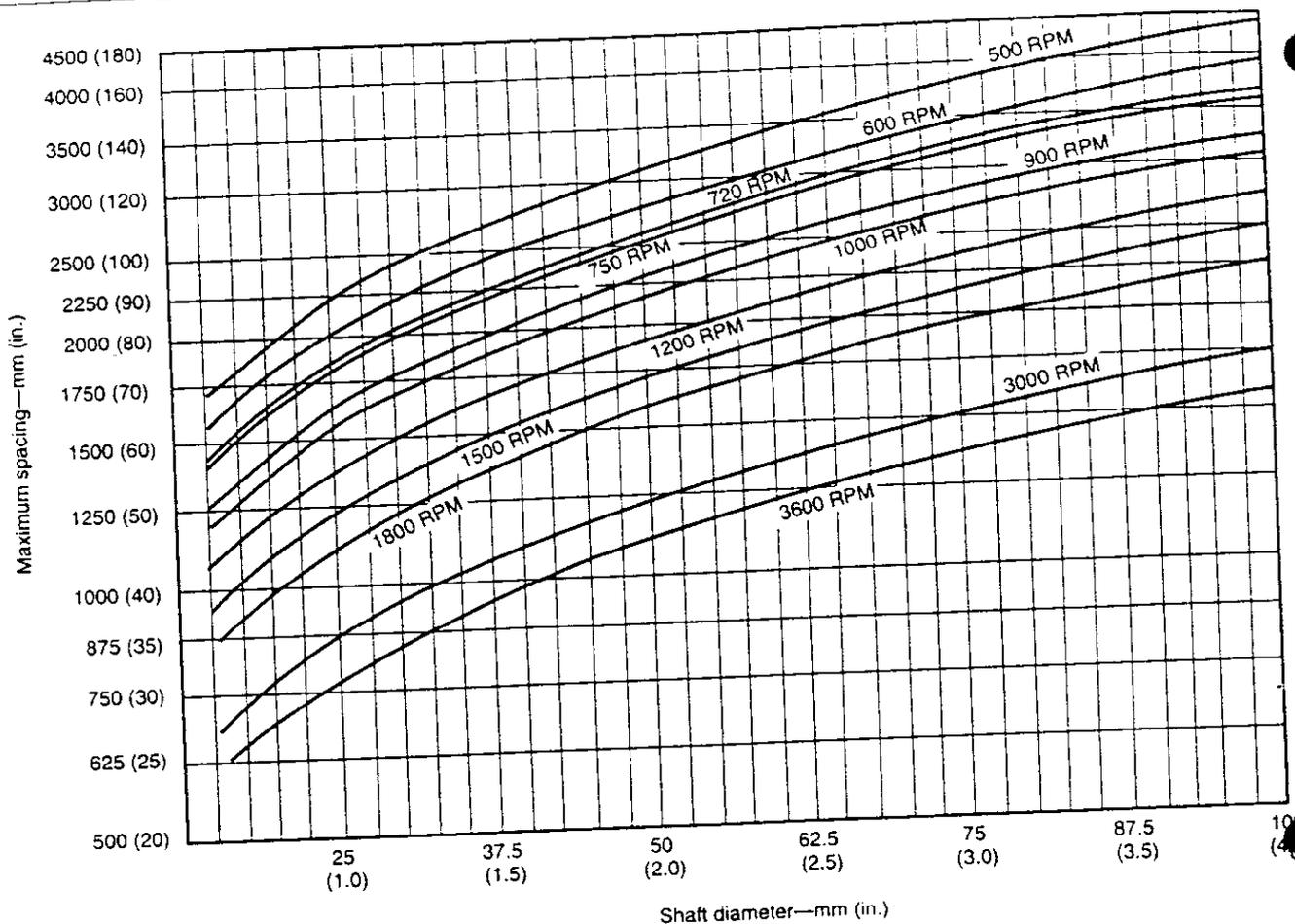


Figure 5-2—Maximum Spacing Between Shaft Guide Bushings

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 $1 \mu\text{m}$ per 10 mm (0.0001 in. per in.) of face diameter or $13 \mu\text{m}$ (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 suf-

ficiently 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 (VSS) 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 VSS.

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 VSS 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 rabbeted 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

Part	See Note	Spares Recommended						
		Start-up		Normal Maintenance			10+	
		1-3	4-6	7+	1-3	4-6		7-9
Number of identical pumps								
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)								2
Impeller								2
Wear rings (set)	(8)	1	1	1	1	1	2	N/3
Bearings complete (antifricition, radial)	(1) (9)	1	1	2	1	2	N/3	N/3
Bearings complete (antifricition, 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		N/3
Bearings, bushings (set)				2		2		N/3
Add for high speed integral gear								
Gear box				1		1		N/3
Diffuser and cover				1		1		N/3
Splined shaft				1		1		N/3
Gear box housing				1		1		N/3
Oil pump, internal				1		1		N/3
Oil pump, external				1		1		N/3
Oil filter				2		2		N/3

Notes:

N = Number of identical pumps.

(1) Horizontal pumps only.

(2) Vital service pumps are generally spared, 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 consists 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 pur-

chaser 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:

ABMA¹

- 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*

AGMA²

- 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*

ASME³

- 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"

ASTM⁴

- C 531 *Test Method for Linear Shrinkage and Coefficient of Thermal Expansion of Chemical-Resistant Mortars, Grouts, and Monolithic Surfacing*
 C 579 *Test Methods for Compressive Strength of Chemical-Resistant Mortars and Monolithic Surfacing*
 C 882 *Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete*
 C 884 *Test Method for Thermal Compatibility 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 Peel 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*

AWS⁵

- D1.1 *Structural Welding Code—Steel*

¹American Bearing Manufacturers Association, 1200 19th Street, N.W., Suite 300, Washington, D.C. 20036.

²American Gear Manufacturers Association, 1500 King Street, Suite 201, Alexandria, Virginia 22314.

³American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017.

⁴American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103-1187.

⁵American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135.

DIN ⁶	910	Heavy-Duty Hexagon Head Screw Plugs			"Determination of Permissible Residual Unbalance"
HI ⁷		The codes, standards, and specifications of the Hydraulic Institute (Centrifugal Pump Section) also form part of this standard.		3098	Technical Drawings
IEEE ⁸	841	Standard for Petroleum and Chemical Industry Severe Duty TEFC Squirrel Cage Induction Motors—Up To and Including 500 HP		3448	Industrial Liquid Lubricants—ISO Viscosity Classification
ISO ⁹	31-0	General Principles Concerning Quantities, Units, and Symbols		3740	Acoustics—Determination of Sound Power Levels of Noise Sources—Precision Methods for Broad-Band Sources in Reverberation Rooms
	128	Technical Drawings—General Principles of Presentation		3744	Acoustics—Determination of Sound Power Levels of Noise Sources—Engineering Methods for Free-Field Conditions Over a Reflecting Plane
	129	Technical Drawings—Dimensioning—General Principles, Definitions, Methods of Execution, and Special Indications		3746	Acoustics—Determination of Sound Power Levels of Noise Sources—Survey Method
	228-1	Pipe Threads Where Pressure-Tight Joints are Not Made on the Threads—Part 1: "Designation, Dimensions and Tolerances"		5406	The Mechanical Balancing of Flexible Rotors
	262	ISO General Purpose Metric Screw Threads—Selected Sizes for Screws, Bolts, and Nuts		5753	Rolling Bearings—Radial Internal Clearance
	281-1	Rolling Bearings—Dynamic Load Ratings and Rating Life—Part 1: "Calculation Methods"		7005-1	Metallic Flanges—Part 1: "Steel Flanges"
	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"		7005-2	Metallic Flanges—Part 2: "Cast Iron Flanges"
R 773		Rectangular or Square Parallel Keys and Their Corresponding Keyways		10436	Petroleum and Natural Gas Industries—General-Purpose Steam Turbines for Refinery Service
R 775		Cylindrical and 1/10 Conical Shaft Ends		10438	Lubrication, Shaft-Sealing and Control—Oil Systems For Special-Purpose Applications
1503		Geometrical Orientation and Directions of Movements	MSS ¹⁰		
1940		Mechanical Vibration—Balance Quality Requirements of Rigid Rotors—Part 1:	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

⁶DIN Deutsches Institut für Normung, Burggrafenstrasse 6, Postfach 1107, D-1000 Berlin 30, Germany.

⁷Hydraulic Institute, 712 Lakewood Center North, Cleveland, Ohio 44107.

⁸Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York, New York 10017.

⁹International Organization for Standardization publications are available from the American National Standards Institute, 11 West 42nd Street, New York, New York 10036.

¹⁰Manufacturers Standardization Society, 127 Park Street, N.E., Vienna, Virginia 22180.

¹¹National Association of Corrosion Engineers, P.O. Box 218340, Houston, Texas 77218.

¹²National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02269.

¹³Steel Structures Painting Council, 4400 Fifth Avenue, Pittsburgh, Pennsylvania 15213-2683.

U.S. Army Corps of Engineers¹⁴

CRD C611 *Test Methods for Flow Grout Mixtures
(Flowcone Method)*

CRD C621 *Corps of Engineers Specifications for
Non-Shrink Grout*

¹⁴U.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	286-1 286-2	5425	5648 Part 1 5646 Part 2	NFE 22396	B0401 B1566
ANSI/ABMA Std 9	Load ratings and fatigue life for ball bearings.	281 76	622	5512 Part 1	NF ISO 281	B1518 B1519
ANSI/ABMA Std 20	Metric bearings: boundary dimensions	15 492 5753		6107 Part 3	NF ISO 5753	B1512 B1513 B1514 B1520
ANSI/AGMA 9000	Balance classification flexible couplings	1940/1 8821 5406	VDI 2060 740 PART A	6861 Part 1	NFE 90600	B0905 B0906
ANSI/AGMA 9002	Bores and keyways flexible couplings	R 773 R 774 R 775 286-1 286-2	740 6885 7190	3170 4235	NFE 02-E22175	B0903 B0904 B1301 B1303
ANSI/ASME B 1.1	Screw threads	262 (Metric)		3643 (Metric)	NFE 03-014	B0205 B0207 B0209 B0211
ANSI/ASME B4.1	Limits and fits for cylindrical parts	286				
ANSI/ASME B1.20.1	General purpose pipe threads	228 PT.1 (Seat on gasket)		2779 (Seat on gasket) 21 (Seat on thread)	NFE 03.005	B0202 B0203
ANSI/ASME B 16.1	Cast iron pipe flanges	7005/2	2532 2533 2534 2535	4504	NFE 29206	
ANSI/ASME B 16.5	Steel and alloy pipe flanges	7005/1	2543 2544 2545 2546 2547 2548 2549 2550 2551	4504	NFE 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 BS	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	31 128 129 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	4563SP.1	4196 Part 4	NFS 31027	
		3746	4563SP.2	4196 Part 6	NFS 31067	
		3740	4563SP.8	4196 Part 0	(For Sect. 2)	
			4563SP.24			
			4563SP.40			
			45645			
API Std 670	Vibration position and bearing temperature monitoring	2372 3945	VDI 2056 VDI 2059	4675	NFE 90300 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	NFS	RIIS-TR-79-1 RIIS-TR-85-1
API Spec 5L	Specification for line pipe	6708 7268			NFE 29.001	
ASME Boiler and Pressure Vessel Code—Section II	Pressure casing design and construction; Materials		AD-MERK-BLÄTTER			
—Section V	Non destructive examination		SEC. IIP 5/3	4080 Parts I & II		G0801 Z2343 Z2344 Z3060

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
—Section VIII Div. 1	Rules for construction of pressure vessels	R 831 TR 7468		5500	CODAP	B8270 G0565 Z2202
—Section IX	Welding and brazing		SEC. HP 2 SEW 110 8560/63	4870/172		Z2242 Z3040 Z3801 Z3881 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 17155	1503	NFA 49.281	G3201 G3202 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 17175	1503	NFA 36.607	G3203 G3214
ASTM A193	Alloy steel and stainless steel bolting materials for high-temperature service		17240/17440 17200/17245 17440	4882 1506	NFA 35558	G4107 G4303
ASTM A194	Carbon and alloy steel nuts for bolts for high-pressure and high-temperature service		17440	4882 1506		G4051 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 G4317
ASTM A278	Gray iron castings for pressure containing parts	185	1691 AD W 3/1 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 17465 SEW 410	1504	NFA 32055	G5121
ASTM A434	Quenched and tempered alloy, hot wrought or cold finished steel bars		EN 10083	EN10083-1	NFEN 10083-1	G4104 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 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 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 (BS)	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 babbit 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 H5102 H5111 H5112 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 60141	
ASTM E 94	Guides for radiographic testing		5411/T, 1 & 2	2737 (For Castings)	UFA 04160 (For Castings)	G0581 Z3104 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 Z3104 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

USA Standard	Subject	Country of Origin and Standard			
		International ISO	Germany DIN	Great Britain BS	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
SSPC SP 6	Commercial blast cleaning			7079	JEAC800

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)

Component	Standard Origin						
	USA ASTM	International ISO	Germany DIN 17007	Germany DIN 17006	Great Britain BSI	France AFNOR	Japan JIS
Bolting; flange	A193 Grade B7 A194 Grade 2H	2604-2-F31 683-1-C35c	1.7258	24Cr Mo5	1506-661	42Cr Mo4 2C 35	G4107 CI SNB7 G4051 CI S45C
Fittings, valves & flanged components; carbon steel	A105 or A181		1.0254	St 37.0	1503	A48 CP	G4051 CI S25C
Fittings and unions; malleable iron, galvanized	A338 and A197 Class 150 malleable iron galvanized to A153				1706		
Fittings and unions; stainless steel	A182 Type 316L Stainless	683-13-19	1.4404		1503 316.S.11	Z6 CN18-09 or Z6 WD18-12-03	G3214 GR SUS 316L
Gaskets	Type 316 Stainless steel spiral wound	S31600	1.4436	X-2 Cr Ni 19.11	1449 Part 2 316.S.11	Z3 CN18-10 or Z3 CND17-12-02	SUS 316
Pipe; carbon steel	A106 Grade B, or A524, or API Specification 5L, Grade A or B	2604	1.0254	St 37.0	3602	TU 42C	G5456 Gr STPT 370/4110
Pipe; carbon steel, galvanized	A53 Type F Sch 40 galvanized to A153				1706	TU26 CN18-12	
Pipe; stainless steel	A312 Type 316L stainless	S31603	1.4404	X3CrNiMo 17 13 2	3605 Part 1 316.S.11	TU 26 CN18-12 or TU 26 CN17-12	G3459 Gr SUS 316LJTP
Tube; stainless steel	A269 Seamless Type 316 stainless steel	S31600	1.4436		3605 Part 1 316.S.33	TU26 CN18-12 or TU26 CN17-12	G3459 GR SUS 316JI

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 _____

1	APPLICABLE TO: <input type="radio"/> PROPOSAL <input type="radio"/> PURCHASE <input checked="" type="radio"/> AS BUILT	UNIT _____
2	FOR _____	SERVICE _____
3	SITE _____	NO. STAGES _____
4	NO. REQ _____ PUMP SIZE _____ TYPE _____	
5	MANUFACTURER _____ MODEL _____ SERIAL NO. _____	
6	NOTE: <input type="radio"/> INDICATES INFORMATION COMPLETED BY PURCHASER <input type="checkbox"/> BY MANUFACTURER <input checked="" type="checkbox"/> BY MANUFACTURER OR PURCHASER	
7	<input type="radio"/> GENERAL (3.1.1)	
8	PUMPS TO OPERATE IN (PARALLEL) _____ NO. MOTOR DRIVEN _____ NO. TURBINE DRIVEN _____	
9	(SERIES) WITH _____ PUMP ITEM NO. _____ PUMP ITEM NO. _____	
10	GEAR ITEM NO. _____ MOTOR ITEM NO. _____ TURBINE ITEM NO. _____	
11	GEAR PROVIDED BY _____ MOTOR PROVIDED BY _____ TURBINE PROVIDED BY _____	
12	GEAR MOUNTED BY _____ MOTOR MOUNTED BY _____ TURBINE MOUNTED BY _____	
13	GEAR DATA SHEET NO. _____ MOTOR DATA SHEET NO. _____ TURBINE DATA SHEET NO. _____	
14	OPERATING CONDITIONS	SITE AND UTILITY DATA (CONT.)
15	<input type="radio"/> CAPACITY, NORMAL _____ (m ³ /h) RATED _____ (m ³ /h)	WATER SOURCE _____
16	OTHER _____	CHLORIDE CONCENTRATION (PPM) _____ (3.5.2.6)
17	<input type="radio"/> SUCTION PRESSURE MAX/RATED _____ (kPa)	INSTRUMENT AIR: MAX/MIN PRESS _____ / _____ (kPa)
18	<input type="radio"/> DISCHARGE PRESSURE _____ (kPa)	LIQUID
19	<input type="radio"/> DIFFERENTIAL PRESSURE _____ (kPa)	<input type="radio"/> TYPE/NAME OF LIQUID _____
20	<input type="radio"/> DIFFERENTIAL HEAD _____ (m) NPSHA _____ (m)	<input type="radio"/> PUMPING TEMPERATURE:
21	<input type="radio"/> PROCESS VARIATIONS _____ (3.1.2)	NORMAL _____ (°C) MAX _____ (°C) MIN _____ (°C)
22	<input type="radio"/> STARTING CONDITIONS _____ (3.1.3)	<input type="radio"/> VAPOR PRESSURE _____ (kPa abs) @ _____ (°C)
23	SERVICE: <input type="radio"/> CONTINUOUS <input type="radio"/> INTERMITTENT (START/DAY) _____	<input type="radio"/> RELATIVE DENSITY (SPECIFIC GRAVITY):
24	<input type="radio"/> PARALLEL OPERATION REQ'D (2.1.11)	NORMAL _____ MAX _____ MIN _____
25	SITE AND UTILITY DATA	<input type="radio"/> SPECIFIC HEAT, Cp _____ (kJ/kg °C)
26	LOCATION: (2.1.29)	<input type="radio"/> VISCOSITY _____ (cP) @ _____ (°C)
27	<input type="radio"/> INDOOR <input type="radio"/> HEATED <input type="radio"/> UNDER ROOF	<input type="radio"/> MAX VISCOSITY _____ (cP)
28	<input type="radio"/> OUTDOOR <input type="radio"/> UNHEATED <input type="radio"/> PARTIAL SIDES	<input type="radio"/> CORROSIVE/EROSIVE AGENT _____ (2.11.1.8)
29	<input type="radio"/> GRADE <input type="radio"/> MEZZANINE <input type="radio"/> _____	<input type="radio"/> CHLORIDE CONCENTRATION (PPM) _____ (3.5.2.6)
30	<input type="radio"/> ELECTRICAL AREA CLASSIFICATION (2.1.22 / 3.1.5)	<input type="radio"/> H ₂ S CONCENTRATION (PPM) _____ (2.11.1.11)
31	CL _____ GR _____ DIV _____	LIQUID (2.1.3) <input type="radio"/> HAZARDOUS <input type="radio"/> FLAMMABLE
32	<input type="radio"/> WINTERIZATION REQ'D <input type="radio"/> TROPICALIZATION REQ'D	<input type="radio"/> OTHER _____
33	SITE DATA (2.1.29)	PERFORMANCE
34	<input type="radio"/> ALTITUDE _____ (m) BAROMETER _____ (kPa abs)	PROPOSAL CURVE NO. _____ <input type="checkbox"/> RPM _____
35	<input type="radio"/> RANGE OF AMBIENT TEMPS: MIN/MAX _____ / _____ (°C)	<input type="checkbox"/> IMPELLER DIA RATED _____ MAX _____ MIN _____ (mm)
36	<input type="radio"/> RELATIVE HUMIDITY: MIN/MAX _____ / _____ (%)	<input type="checkbox"/> RATED POWER _____ (BHP) EFFICIENCY _____ (%)
37	UNUSUAL CONDITIONS (2.1.23) <input type="radio"/> DUST <input type="radio"/> FUMES	<input type="checkbox"/> MINIMUM CONTINUOUS FLOW:
38	<input type="radio"/> OTHER _____	THERMAL _____ (m ³ /h) STABLE _____ (m ³ /h)
39	<input type="radio"/> UTILITY CONDITIONS:	<input type="checkbox"/> PREFERRED OPERATING REGION _____ TO _____ (m ³ /h)
40	STEAM: DRIVERS HEATING	<input type="checkbox"/> ALLOWABLE OPERATING REGION _____ TO _____ (m ³ /h)
41	MIN _____ (kPa) _____ (°C) _____ (kPa) _____ (°C)	<input type="checkbox"/> MAX HEAD @ RATED IMPELLER _____ (m)
42	MAX _____ (kPa) _____ (°C) _____ (kPa) _____ (°C)	<input type="checkbox"/> MAX POWER @ RATED IMPELLER _____ (kW)
43	ELECTRICITY: DRIVERS HEATING CONTROL SHUTDOWN	<input type="checkbox"/> NPSH REQUIRED AT RATED CAP _____ (m) (2.1.8)
44	VOLTAGE _____	<input checked="" type="checkbox"/> SUCTION SPECIFIC SPEED _____ (2.1.9)
45	HERTZ _____	<input type="radio"/> MAX SOUND PRESS. LEVEL REQ'D _____ (dBA) (2.1.14)
46	PHASE _____	<input type="checkbox"/> EST MAX SOUND PRESS. LEVEL _____ (dBA) (2.1.14)
47	COOLING WATER: (2.1.17)	REMARKS _____
48	TEMP INLET _____ (°C) MAX RETURN _____ (°C)	
49	PRESS NORMAL _____ (kPa) DESIGN _____ (kPa)	
50	MIN RETURN _____ (kPa) MAX ALLOW DP _____ (kPa)	
51		

**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	CONSTRUCTION (CONT)
1	CONSTRUCTION	
2	APPLICABLE STANDARD:	
3	<input type="radio"/> API 610 8TH EDITION	
4	<input type="radio"/> OTHER _____ (SEE REMARKS)	
5	PUMP TYPE: (1.1.2)	
6	<input checked="" type="checkbox"/> OH2	<input checked="" type="checkbox"/> BB1
7	<input checked="" type="checkbox"/> OH3	<input checked="" type="checkbox"/> BB2
8	<input checked="" type="checkbox"/> OH6	<input checked="" type="checkbox"/> BB3
9		<input checked="" type="checkbox"/> BB4
10		<input checked="" type="checkbox"/> BB5
11	<input type="checkbox"/> NOZZLE CONNECTIONS: (2.3.2)	<input type="checkbox"/> VS1
12		<input type="checkbox"/> VS2
13		<input type="checkbox"/> VS3
14		<input type="checkbox"/> VS4
15		<input type="checkbox"/> VS5
16		<input type="checkbox"/> VS6
17		<input type="checkbox"/> VS7
18		<input type="checkbox"/> OTHER
19		
20		
21		
22		
23		
24		
25		
26		
27		
28		
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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)

SIZE	RATING	FACING	POSITION

NO.	SIZE (NPS)	TYPE

- SUCTION
- DISCHARGE
- BALANCE DRUM
- 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)

**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 _____

<p>1 INSTRUMENTATION</p> <p>2 VIBRATION:</p> <p>3 <input type="radio"/> NONCONTACTING (API 670) <input type="radio"/> TRANSDUCER</p> <p>4 <input type="radio"/> PROVISION FOR MOUNTING ONLY (2.9.2.11)</p> <p>5 <input type="radio"/> FLAT SURFACE REQ'D (2.9.2.12)</p> <p>6 <input type="radio"/> SEE ATTACHED API-670 DATA SHEET</p> <p>7 <input type="radio"/> MONITORS AND CABLES (3.4.3.3)</p> <p>8 REMARKS _____</p> <p>9 _____</p> <p>10 _____</p> <p>11 TEMPERATURE AND PRESSURE:</p> <p>12 <input checked="" type="radio"/> RADIAL BRG METAL TEMP <input type="radio"/> THRUST BRG METAL TEMP</p> <p>13 <input type="radio"/> PROVISION FOR INSTRUMENTS ONLY</p> <p>14 <input type="radio"/> SEE ATTACHED API-670 DATA SHEET</p> <p>15 <input type="radio"/> TEMP GAUGES (WITH THERMOWELLS) (3.4.1.3)</p> <p>16 OTHER _____</p> <p>17 <input type="radio"/> PRESSURE GAUGE TYPE (3.4.2.2) _____</p> <p>18 LOCATION _____</p> <p>19 REMARKS _____</p> <p>20 _____</p> <p>21 _____</p> <p>22 SPARE PARTS (TABLE 6.1)</p> <p>23 <input type="radio"/> START-UP <input type="radio"/> NORMAL MAINTENANCE</p> <p>24 <input type="radio"/> SPECIFY _____</p> <p>25 _____</p> <p>26 _____</p> <p>27 MOTOR DRIVE (3.1.6)</p> <p>28 <input checked="" type="checkbox"/> MANUFACTURER _____</p> <p>29 <input type="checkbox"/> _____ (KW) <input type="checkbox"/> _____ (RPM)</p> <p>30 <input checked="" type="checkbox"/> HORIZONTAL <input checked="" type="checkbox"/> VERTICAL</p> <p>31 <input type="checkbox"/> FRAME _____</p> <p>32 <input checked="" type="checkbox"/> SERVICE FACTOR _____</p> <p>33 <input checked="" type="checkbox"/> VOLTS/PHASE/HERTZ _____ / _____ / _____</p> <p>34 <input type="radio"/> TYPE _____</p> <p>35 <input checked="" type="checkbox"/> ENCLOSURE _____</p> <p>36 <input type="radio"/> MINIMUM STARTING VOLTAGE (3.1.6) _____</p> <p>37 <input type="radio"/> TEMPERATURE RISE _____</p> <p>38 <input checked="" type="checkbox"/> FULL LOAD AMPS _____</p> <p>39 <input checked="" type="checkbox"/> LOCKED ROTOR AMPS _____</p> <p>40 <input checked="" type="checkbox"/> INSULATION _____</p> <p>41 <input checked="" type="checkbox"/> STARTING METHOD _____</p> <p>42 <input checked="" type="checkbox"/> LUBE _____</p> <p>43 <input type="checkbox"/> VERTICAL THRUST CAPACITY</p> <p>44 UP _____ (N) DOWN _____ (N)</p> <p>45 BEARINGS (TYPE / NUMBER):</p> <p>46 <input type="checkbox"/> RADIAL _____ / _____</p> <p>47 <input type="checkbox"/> THRUST _____ / _____</p> <p>48 _____</p>	<p>MOTOR DRIVE (cont) (3.1.6)</p> <p>REMARKS _____</p> <p>_____</p> <p>_____</p> <p>SURFACE PREPARATION AND PAINT</p> <p><input type="radio"/> MANUFACTURER'S STANDARD</p> <p><input type="radio"/> OTHER (SEE BELOW)</p> <p>PUMP:</p> <p><input type="radio"/> PUMP SURFACE PREPARATION _____</p> <p><input type="radio"/> PRIMER _____</p> <p><input type="radio"/> FINISH COAT _____</p> <p>BASEPLATE: (3.3.18)</p> <p><input type="radio"/> BASEPLATE SURFACE PREPARATION _____</p> <p><input type="radio"/> PRIMER _____</p> <p><input type="radio"/> FINISH COAT _____</p> <p>SHIPMENT: (4.4.1)</p> <p><input type="radio"/> DOMESTIC <input type="radio"/> EXPORT <input type="radio"/> EXPORT BOXING REQUIRED</p> <p><input type="radio"/> OUTDOOR STORAGE MORE THAN 6 MONTHS</p> <p>SPARE ROTOR ASSEMBLY PACKAGED FOR:</p> <p><input type="radio"/> HORIZONTAL STORAGE <input type="radio"/> VERTICAL STORAGE</p> <p><input type="radio"/> TYPE OF SHIPPING PREPARATION _____</p> <p>REMARKS _____</p> <p>_____</p> <p>_____</p> <p><input type="checkbox"/> WEIGHTS</p> <p>MOTOR DRIVEN:</p> <p>WEIGHT OF PUMP (kg) _____</p> <p>WEIGHT OF BASEPLATE (kg) _____</p> <p>WEIGHT OF MOTOR (kg) _____</p> <p>WEIGHT OF GEAR (kg) _____</p> <p>TOTAL WEIGHT (kg) _____</p> <p>TURBINE DRIVEN:</p> <p>WEIGHT OF BASEPLATE (kg) _____</p> <p>WEIGHT OF TURBINE (kg) _____</p> <p>WEIGHT OF GEAR (kg) _____</p> <p>TOTAL WEIGHT (kg) _____</p> <p>REMARKS _____</p> <p>_____</p> <p>_____</p> <p>OTHER PURCHASER REQUIREMENTS</p> <p><input type="radio"/> COORDINATION MEETING REQUIRED (6.1.3)</p> <p><input type="radio"/> REVIEW FOUNDATION DRAWINGS (2.1.27)</p> <p><input type="radio"/> REVIEW PIPING DRAWINGS</p> <p><input type="radio"/> OBSERVE PIPING CHECKS</p> <p><input type="radio"/> OBSERVE INITIAL ALIGNMENT CHECK</p> <p><input type="radio"/> CHECK ALIGNMENT AT OPERATING TEMPERATURE</p> <p><input type="radio"/> CONNECTION DESIGN APPROVAL (2.11.3.5.4)</p>
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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 _____

1 **OTHER PURCHASER REQUIREMENTS (cont)**

2 RIGGING DEVICE REQ'D FOR TYPE OH3 PUMP (5.1.2.7)

3 HYDRODYNAMIC THRUST BRG SIZE REVIEW REQ'D (5.2.5.2.4)

4 LATERAL ANALYSIS REQUIRED (5.1.4.3/5.2.4.1)

5 ROTOR DYNAMIC BALANCE (5.2.4.2)

6 MOUNT SEAL RESERVOIR OFF BASEPLATE (3.5.1.4)

7 INSTALLATION LIST IN PROPOSAL (6.2.3L)

8 SPARE ROTOR VERTICAL STORAGE (5.2.9.2)

9 TORSIONAL ANALYSIS/REPORT (2.8.2.8)

10 PROGRESS REPORTS REQUIRED (6.3.4)

11 REMARKS: _____

12 _____

13 _____

14 **QA INSPECTION AND TEST**

15 REVIEW VENDORS QA PROGRAM (4.1.7)

16 PERFORMANCE CURVE APPROVAL

17 SHOP INSPECTION (4.1.4)

18 TEST WITH SUBSTITUTE SEAL (4.3.3.1.2)

TEST	NON-WIT	WIT	OBSERVE
20 HYDROSTATIC (4.3.2)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
21 PERFORMANCE (4.3.3)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
22 NPSH (4.3.4.1)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
23 COMPLETE UNIT TEST (4.3.4.2)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
24 SOUND LEVEL TEST (4.3.4.3)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
25 <input type="checkbox"/> CLEANLINESS PRIOR TO 26 FINAL ASSEMBLY (4.2.3.1)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
27 <input type="checkbox"/> NOZZLE LOAD TEST (3.3.6)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
28 <input type="checkbox"/> BRG HSG RESONANCE 29 TEST (4.3.4.5)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
30 <input type="checkbox"/> REMOVE/INSPECT 31 HYDRODYNAMIC BEARINGS 32 AFTER TEST (5.2.8.5)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
33 <input type="checkbox"/> AUXILIARY EQUIPMENT 34 TEST (4.3.4.4)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
35 <input type="checkbox"/> _____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
36 <input type="checkbox"/> _____	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
37 <input type="checkbox"/> MATERIAL CERTIFICATION REQUIRED (2.11.1.7)			
38 <input type="checkbox"/> CASING <input type="checkbox"/> IMPELLER <input type="checkbox"/> SHAFT			
39 <input type="checkbox"/> OTHER _____			
40 <input type="checkbox"/> CASTING REPAIR PROCEDURE APPROVAL REQ'D (2.11.2.5)			
41 <input type="checkbox"/> INSPECTION REQUIRED FOR CONNECTION WELDS (2.11.3.6)			
42 <input type="checkbox"/> MAG PARTICLE <input type="checkbox"/> LIQUID PENETRANT			
43 <input type="checkbox"/> RADIOGRAPHIC <input type="checkbox"/> ULTRASONIC			
44 <input type="checkbox"/> INSPECTION REQUIRED FOR CASTINGS (4.2.1.3)			
45 <input type="checkbox"/> MAG PARTICLE <input type="checkbox"/> LIQUID PENETRANT			
46 <input type="checkbox"/> RADIOGRAPHIC <input type="checkbox"/> ULTRASONIC			
47			

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) _____ (4.1.5)

REMARKS _____

GENERAL REMARKS

REMARK 1: _____

REMARK 2: _____

REMARK 3: _____

REMARK 4: _____

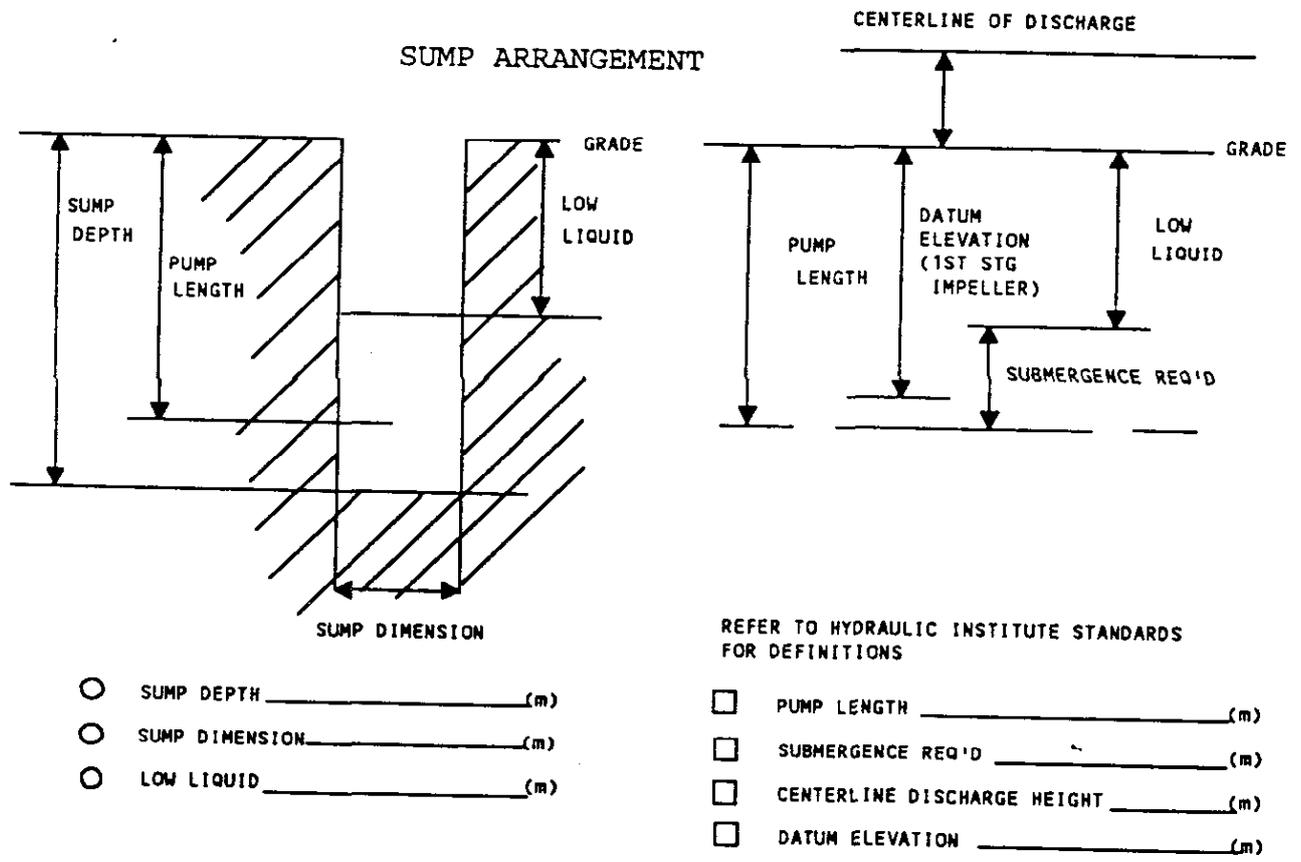
REMARK 5: _____

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 _____

1	VERTICAL TYPE (FIG 1.1) <input type="checkbox"/> VS1 <input type="checkbox"/> VS2 <input type="checkbox"/> VS3 <input type="checkbox"/> VS4 <input type="checkbox"/> VS5 <input type="checkbox"/> VS6 <input type="checkbox"/> VS7 <input type="checkbox"/> OTHER	
2	REMARKS _____	
3	_____	
4	_____	
5	_____	
6	VERTICAL PUMPS	
7	<input type="checkbox"/> PUMP THRUST: (+) UP (-) DOWN AT MIN FLOW _____ (N) _____ (N) AT RATED FLOW _____ (N) _____ (N) AT MAX FLOW _____ (N) _____ (N) MAX THRUST _____ (N) _____ (N)	
8	<input type="checkbox"/> SOLEPLATE _____ (mm) X _____ (mm)	
9	<input type="checkbox"/> SOLEPLATE THICKNESS _____ (mm)	
10	COLUMN PIPE: <input type="checkbox"/> FLANGED <input type="checkbox"/> THREADED DIAMETER _____ (mm) LENGTH _____ (m)	
11	GUIDE BUSHINGS: <input type="checkbox"/> NUMBER _____	
12	<input type="checkbox"/> LINE SHAFT BEARING SPACING _____ (mm)	
13	GUIDE BUSHING LUBE: <input type="checkbox"/> WATER <input type="checkbox"/> OIL <input type="checkbox"/> GREASE <input type="checkbox"/> PUMPAGE	
14	VERTICAL PUMPS (CONT'D)	
15	LINE SHAFT: <input checked="" type="checkbox"/> OPEN <input checked="" type="checkbox"/> ENCLOSED <input type="checkbox"/> LINE SHAFT DIAMETER: _____ (mm) <input type="checkbox"/> TUBE DIAMETER: _____ (mm)	
16	LINE SHAFT COUPLING: <input type="checkbox"/> SLEEVE & KEY <input type="checkbox"/> THREADED	
17	<input type="checkbox"/> SUCTION CAN THICKNESS _____ (mm)	
18	<input type="checkbox"/> LENGTH _____ (m)	
19	<input type="checkbox"/> DIAMETER _____ (m)	
20	<input type="radio"/> SUCTION STRAINER TYPE _____	
21	<input type="radio"/> FLOAT & ROD <input type="radio"/> FLOAT SWITCH	
22	<input type="radio"/> IMPELLER COLLETS ACCEPTABLE (2.5.2) <input type="radio"/> HARDENED SLEEVES UNDER BEARINGS (5.3.10.7) <input type="radio"/> RESONANCE TEST (5.3.9.2) <input type="radio"/> STRUCTURAL ANALYSIS (5.3.5.1) <input type="radio"/> DRAIN PIPED TO SURFACE (5.3.13.6)	



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 _____

1	APPLICABLE TO: <input type="radio"/> PROPOSAL <input type="radio"/> PURCHASE <input checked="" type="radio"/> AS BUILT	
2	FOR _____	UNIT _____
3	SITE _____	SERVICE _____
4	NO. REQ _____ PUMP SIZE _____	TYPE _____ NO. STAGES _____
5	MANUFACTURER _____	MODEL _____ SERIAL NO. _____
6	NOTE: <input type="radio"/> INDICATES INFORMATION COMPLETED BY PURCHASER <input type="checkbox"/> BY MANUFACTURER <input checked="" type="checkbox"/> BY MANUFACTURER OR PURCHASER	
7	<input type="radio"/> GENERAL (3.1.1)	
8	PUMPS TO OPERATE IN (PARALLEL) _____	NO. MOTOR DRIVEN _____ NO. TURBINE DRIVEN _____
9	(SERIES) WITH _____	PUMP ITEM NO. _____ PUMP ITEM NO. _____
10	GEAR ITEM NO. _____	MOTOR ITEM NO. _____ TURBINE ITEM NO. _____
11	GEAR PROVIDED BY _____	MOTOR PROVIDED BY _____ TURBINE PROVIDED BY _____
12	GEAR MOUNTED BY _____	MOTOR MOUNTED BY _____ TURBINE MOUNTED BY _____
13	GEAR DATA SHEET NO. _____	MOTOR DATA SHEET NO. _____ TURBINE DATA SHEET NO. _____
14	OPERATING CONDITIONS	SITE AND UTILITY DATA (CONT.)
15	<input type="radio"/> CAPACITY, NORMAL _____ (GPM) RATED _____ (GPM)	WATER SOURCE _____
16	OTHER _____	CHLORIDE CONCENTRATION (PPM) _____ (3.5.2.6)
17	<input type="radio"/> SUCTION PRESSURE MAX/RATED _____ (PSIG)	INSTRUMENT AIR: MAX/MIN PRESS _____ (PSIG)
18	<input type="radio"/> DISCHARGE PRESSURE _____ (PSIG)	LIQUID
19	<input type="radio"/> DIFFERENTIAL PRESSURE _____ (PSIG)	<input type="radio"/> TYPE/NAME OF LIQUID _____
20	<input type="radio"/> DIFFERENTIAL HEAD _____ (FT) NPSHA _____ (FT)	<input type="radio"/> PUMPING TEMPERATURE:
21	<input type="radio"/> PROCESS VARIATIONS _____ (3.1.2)	NORMAL _____ (°F) MAX _____ (°F) MIN _____ (°F)
22	<input type="radio"/> STARTING CONDITIONS _____ (3.1.3)	<input type="radio"/> VAPOR PRESSURE _____ (PSIA) @ _____ (°F)
23	SERVICE: <input type="radio"/> CONTINUOUS <input type="radio"/> INTERMITTENT (START/DAY) _____	<input type="radio"/> RELATIVE DENSITY (SPECIFIC GRAVITY):
24	<input type="radio"/> PARALLEL OPERATION REQ'D (2.1.11)	NORMAL _____ MAX _____ MIN _____
25	SITE AND UTILITY DATA	<input type="radio"/> SPECIFIC HEAT, Cp _____ (BTU/LB °F)
26	LOCATION: (2.1.29)	<input type="radio"/> VISCOSITY _____ (cP) @ _____ (°F)
27	<input type="radio"/> INDOOR <input type="radio"/> HEATED <input type="radio"/> UNDER ROOF	<input type="radio"/> MAX VISCOSITY _____ (cP)
28	<input type="radio"/> OUTDOOR <input type="radio"/> UNHEATED <input type="radio"/> PARTIAL SIDES	<input type="radio"/> CORROSIVE/EROSIVE AGENT _____ (2.11.1.8)
29	<input type="radio"/> GRADE <input type="radio"/> MEZZANINE <input type="radio"/> _____	<input type="radio"/> CHLORIDE CONCENTRATION (PPM) _____ (3.5.2.6)
30	<input type="radio"/> ELECTRICAL AREA CLASSIFICATION (2.1.22 / 3.1.5)	<input type="radio"/> H ₂ S CONCENTRATION (PPM) _____ (2.11.1.11)
31	CL _____ GR _____ DV _____	LIQUID (2.1.3) <input type="radio"/> HAZARDOUS <input type="radio"/> FLAMMABLE
32	<input type="radio"/> WINTERIZATION REQ'D <input type="radio"/> TROPICALIZATION REQ'D	<input type="radio"/> OTHER _____
33	SITE DATA (2.1.29)	PERFORMANCE
34	<input type="radio"/> ALTITUDE _____ (FT) BAROMETER _____ (PSIA)	PROPOSAL CURVE NO. _____ <input type="checkbox"/> RPM _____
35	<input type="radio"/> RANGE OF AMBIENT TEMPS: MIN/MAX _____ (°F)	<input type="checkbox"/> IMPELLER DIA RATED _____ MAX _____ MIN _____ (IN)
36	<input type="radio"/> RELATIVE HUMIDITY: MIN/MAX _____ (%)	<input type="checkbox"/> RATED POWER _____ (BHP) EFFICIENCY _____ (%)
37	UNUSUAL CONDITIONS (2.1.23) <input type="radio"/> DUST <input type="radio"/> FUMES	<input type="checkbox"/> MINIMUM CONTINUOUS FLOW:
38	<input type="radio"/> OTHER _____	THERMAL _____ (GPM) STABLE _____ (GPM)
39	<input type="radio"/> UTILITY CONDITIONS:	<input type="checkbox"/> PREFERRED OPERATING REGION _____ TO _____ (GPM)
40	STEAM: DRIVERS HEATING	<input type="checkbox"/> ALLOWABLE OPERATING REGION _____ TO _____ (GPM)
41	MIN _____ (PSIG) _____ (°F) _____ (PSIG) _____ (°F)	<input type="checkbox"/> MAX HEAD @ RATED IMPELLER _____ (FT)
42	MAX _____ (PSIG) _____ (°F) _____ (PSIG) _____ (°F)	<input type="checkbox"/> MAX POWER @ RATED IMPELLER _____ (BHP)
43	ELECTRICITY: DRIVERS HEATING CONTROL SHUTDOWN	<input type="checkbox"/> NPSHR AT RATED CAPACITY _____ (FT) (2.1.8)
44	VOLTAGE _____	<input checked="" type="checkbox"/> SUCTION SPECIFIC SPEED _____ (2.1.9)
45	HERTZ _____	<input type="radio"/> MAX SOUND PRESS. LEVEL REQ'D _____ (dBA) (2.1.14)
46	PHASE _____	<input type="checkbox"/> EST MAX SOUND PRESS. LEVEL _____ (dBA) (2.1.14)
47	COOLING WATER: (2.1.17)	REMARKS _____
48	TEMP INLET _____ (°F) MAX RETURN _____ (°F)	_____
49	PRESS NORMAL _____ (PSIG) DESIGN _____ (PSIG)	_____
50	MIN RETURN _____ (PSIG) MAX ALLOW OP _____ (PSI)	_____
51		

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 _____

1 CONSTRUCTION

2 APPLICABLE STANDARD:

3 API 610 8TH EDITION

4 OTHER _____ (SEE REMARKS)

5 PUMP TYPE: (1.1.2)

6 OH2 BB1 VS1 VS6

7 OH3 BB2 VS2 VS7

8 OH6 BB3 VS3 OTHER

9 BB4 VS4

10 BB5 VS5

11 NOZZLE CONNECTIONS: (2.3.2)

SIZE (IN)	FLANGE RATING (LBS)	FACING	POSITION
13 SUCTION			
14 DISCHARGE			
15 BALANCE DRUM			

16 PRESSURE CASING CONNECTIONS: (2.3.3)

NO.	SIZE (NPS)	TYPE
18 <input type="checkbox"/> DRAIN		
19 <input type="checkbox"/> VENT		
20 <input type="checkbox"/> PRESSURE GAUGE		
21 <input type="checkbox"/> TEMP GAUGE		
22 <input type="checkbox"/> WARM-UP		
23 <input type="checkbox"/> BALANCE / LEAK-OFF		

24 CYLINDRICAL THREADS REQUIRED (2.3.3)

25 CASING MOUNTING: (SEE SEPARATE SHEET FOR VERTICALS)

26 CENTERLINE NEAR CENTERLINE

27 FOOT SEPARATE MOUNTING PLATE

28 IN-LINE

29 CASING SPLIT:

30 AXIAL RADIAL

31 CASING TYPE:

32 SINGLE VOLUTE MULTIPLE VOLUTE DIFFUSER

33 OVERHUNG BETWEEN BEARINGS BARREL

34 CASE PRESSURE RATING:

35 MAX ALLOWABLE WORKING PRESSURE _____ (PSIG)

36 @ _____ (°F)

37 HYDROTEST PRESSURE _____ (PSIG)

38 SUCTION PRESS. REGIONS MUST BE DESIGNED FOR MAWP (2.2.4)

39 ROTATION: (VIEWED FROM COUPLING END)

40 CW CCW

41 IMPELLERS INDIVIDUALLY SECURED (5.2.2.2)

42 REMARKS: _____

43 _____

44 _____

45 BOLT OH3 PUMP TO PAD/FOUNDATION (5.1.2.4)

46 SHAFT:

47 SHAFT DIAMETER AT COUPLING _____ (IN)

48 _____

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 _____
 INDUSTRY NO. _____ BY _____
 REVISION _____ DATE _____

1 **BEARINGS AND LUBRICATION (cont)**

2 OIL HEATER REQ'D ELECTRIC STEAM (2.9.2.9/5.2.6.3)

3 OIL PRESS TO BE GREATER THAN COOLANT PRESS (5.2.6.2.b)

4 REMARKS _____

5 _____

6 _____

7 **MECHANICAL SEAL OR PACKING**

8 SEAL DATA: (2.7.2)

9 SEE ATTACHED API-682 DATA SHEET

10 NON-API 682 SEAL (2.7.2)

11 APPENDIX H SEAL CODE _____ (2.11.1.1)

12 SEAL MANUFACTURER _____

13 SIZE AND TYPE _____ / _____

14 MANUFACTURER CODE _____

15 SEAL CHAMBER DATA: (2.1.6/2.1.7)

16 TEMPERATURE _____ (°F)

17 PRESSURE _____ (PSIG)

18 FLOW _____ (GPM)

19 SEAL CHAMBER SIZE (TABLE 2.3) _____

20 TOTAL LENGTH _____ (IN) CLEAR LENGTH _____ (IN)

21 SEAL CONSTRUCTION:

22 SLEEVE MATERIAL _____

23 GLAND MATERIAL _____

24 AUX SEAL DEVICE (2.7.3.20) _____

25 JACKET REQUIRED (2.7.3.17)

26 GLAND TAPS: (2.7.3.14)

27 FLUSH (F) DRAIN (D) BARRIER/BUFFER(B)

28 QUENCH (Q) COOLING (C) LUBRICATION (G)

29 HEATING (H) LEAKAGE PUMPED FLUID (P)

30 BALANCE FLUID (E) EXTERNAL FLUID INJECTION (X)

31 SEAL FLUIDS REQUIREMENT AND AVAILABLE FLUSH LIQUID:

32 NOTE: IF FLUSH LIQUID IS PUMPAGE LIQUID (AS IN FLUSH PIPING

33 PLANS 11 TO 41), FOLLOWING FLUSH LIQUID DATA IS NOT REQ'D.

34 SUPPLY TEMPERATURE MAX/MIN _____ / _____ (°F)

35 RELATIVE DENSITY (SPECIFIC GRAVITY) _____ @ _____ (°F)

36 NAME OF FLUID _____

37 SPECIFIC HEAT, Cp _____ (BTU/LB °F)

38 VAPOR PRESSURE _____ (PSIA) @ _____ (°F)

39 HAZARDOUS FLAMMABLE OTHER _____

40 FLOW RATE MAX/MIN _____ / _____ (GPM)

41 PRESSURE REQUIRED MAX/MIN _____ / _____ (PSIG)

42 TEMPERATURE REQUIRED MAX/MIN _____ / _____ (°F)

43 BARRIER/BUFFER FLUID (2.7.3.21):

44 SUPPLY TEMPERATURE MAX/MIN _____ / _____ (°F)

45 RELATIVE DENSITY (SPECIFIC GRAVITY) _____ @ _____ (°F)

46 NAME OF FLUID _____

47 _____

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 _____

<p>1 INSTRUMENTATION</p> <p>2 VIBRATION:</p> <p>3 <input type="radio"/> NONCONTACTING (API 670) <input type="radio"/> TRANSDUCER</p> <p>4 <input type="radio"/> PROVISION FOR MOUNTING ONLY (2.9.2.11)</p> <p>5 <input type="radio"/> FLAT SURFACE REQ'D (2.9.2.12)</p> <p>6 <input type="radio"/> SEE ATTACHED API-670 DATA SHEET</p> <p>7 <input type="radio"/> MONITORS AND CABLES (3.4.3.3)</p> <p>8 REMARKS _____</p> <p>9 _____</p> <p>10 _____</p> <p>11 TEMPERATURE AND PRESSURE:</p> <p>12 <input type="radio"/> RADIAL BRG METAL TEMP <input type="radio"/> THRUST BRG METAL TEMP</p> <p>13 <input type="radio"/> PROVISION FOR INSTRUMENTS ONLY</p> <p>14 <input type="radio"/> SEE ATTACHED API-670 DATA SHEET</p> <p>15 <input type="radio"/> TEMP GAUGES (WITH THERMOWELLS) (3.4.1.3)</p> <p>16 OTHER _____</p> <p>17 <input type="radio"/> PRESSURE GAUGE TYPE (3.4.2.2) _____</p> <p>18 LOCATION _____</p> <p>19 REMARKS _____</p> <p>20 _____</p> <p>21 _____</p> <p>22 SPARE PARTS (TABLE 6.1)</p> <p>23 <input type="radio"/> START-UP <input type="radio"/> NORMAL MAINTENANCE</p> <p>24 <input type="radio"/> SPECIFY _____</p> <p>25 _____</p> <p>26 _____</p> <p>27 MOTOR DRIVE (3.1.5)</p> <p>28 <input checked="" type="checkbox"/> MANUFACTURER _____</p> <p>29 <input type="checkbox"/> _____ (HP) <input type="checkbox"/> _____ (RPM)</p> <p>30 <input checked="" type="checkbox"/> HORIZONTAL <input checked="" type="checkbox"/> VERTICAL</p> <p>31 <input type="checkbox"/> FRAME _____</p> <p>32 <input checked="" type="checkbox"/> SERVICE FACTOR _____</p> <p>33 <input checked="" type="checkbox"/> VOLTS/PHASE/HERTZ _____ / _____ / _____</p> <p>34 <input type="radio"/> TYPE _____</p> <p>35 <input checked="" type="checkbox"/> ENCLOSURE _____</p> <p>36 <input type="radio"/> MINIMUM STARTING VOLTAGE (3.1.6) _____</p> <p>37 <input type="radio"/> TEMPERATURE RISE _____</p> <p>38 <input checked="" type="checkbox"/> FULL LOAD AMPS _____</p> <p>39 <input checked="" type="checkbox"/> LOCKED ROTOR AMPS _____</p> <p>40 <input checked="" type="checkbox"/> INSULATION _____</p> <p>41 <input checked="" type="checkbox"/> STARTING METHOD _____</p> <p>42 <input checked="" type="checkbox"/> LUBE _____</p> <p>43 <input type="checkbox"/> VERTICAL THRUST CAPACITY</p> <p>44 UP _____ (LBS) DOWN _____ (LBS)</p> <p>45 BEARINGS (TYPE / NUMBER):</p> <p>46 <input type="checkbox"/> RADIAL _____</p> <p>47 <input type="checkbox"/> THRUST _____</p> <p>48 _____</p>	<p>MOTOR DRIVE (cont) (3.1.5)</p> <p>REMARKS _____</p> <p>_____</p> <p>_____</p> <p>SURFACE PREPARATION AND PAINT</p> <p><input type="radio"/> MANUFACTURER'S STANDARD</p> <p><input type="radio"/> OTHER (SEE BELOW)</p> <p>PUMP:</p> <p><input type="radio"/> PUMP SURFACE PREPARATION _____</p> <p><input type="radio"/> PRIMER _____</p> <p><input type="radio"/> FINISH COAT _____</p> <p>BASEPLATE: (3.3.18)</p> <p><input type="radio"/> BASEPLATE SURFACE PREPARATION _____</p> <p><input type="radio"/> PRIMER _____</p> <p><input type="radio"/> FINISH COAT _____</p> <p>SHIPMENT: (4.4.1)</p> <p><input type="radio"/> DOMESTIC <input type="radio"/> EXPORT <input type="radio"/> EXPORT BOXING REQUIRED</p> <p><input type="radio"/> OUTDOOR STORAGE MORE THAN 6 MONTHS</p> <p>SPARE ROTOR ASSEMBLY PACKAGED FOR:</p> <p><input type="radio"/> HORIZONTAL STORAGE <input type="radio"/> VERTICAL STORAGE</p> <p><input type="radio"/> TYPE OF SHIPPING PREPARATION _____</p> <p>REMARKS _____</p> <p>_____</p> <p>_____</p> <p><input type="checkbox"/> WEIGHTS</p> <p>MOTOR DRIVEN:</p> <p>WEIGHT OF PUMP (LBS) _____</p> <p>WEIGHT OF BASEPLATE (LBS) _____</p> <p>WEIGHT OF MOTOR (LBS) _____</p> <p>WEIGHT OF GEAR (LBS) _____</p> <p>TOTAL WEIGHT (LBS) _____</p> <p>TURBINE DRIVEN:</p> <p>WEIGHT OF BASEPLATE (LBS) _____</p> <p>WEIGHT OF TURBINE (LBS) _____</p> <p>WEIGHT OF GEAR (LBS) _____</p> <p>TOTAL WEIGHT (LBS) _____</p> <p>REMARKS _____</p> <p>_____</p> <p>_____</p> <p>OTHER PURCHASER REQUIREMENTS</p> <p><input type="radio"/> COORDINATION MEETING REQUIRED (6.1.3)</p> <p><input type="radio"/> REVIEW FOUNDATION DRAWINGS (2.1.27)</p> <p><input type="radio"/> REVIEW PIPING DRAWINGS</p> <p><input type="radio"/> OBSERVE PIPING CHECKS</p> <p><input type="radio"/> OBSERVE INITIAL ALIGNMENT CHECK</p> <p><input type="radio"/> CHECK ALIGNMENT AT OPERATING TEMPERATURE</p> <p><input type="radio"/> CONNECTION DESIGN APPROVAL (2.11.3.5.4)</p>
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API 610, 8TH EDITION
 SUPPLEMENTAL
 VERTICAL PUMP DATA SHEET
 US UNITS / US STANDARDS

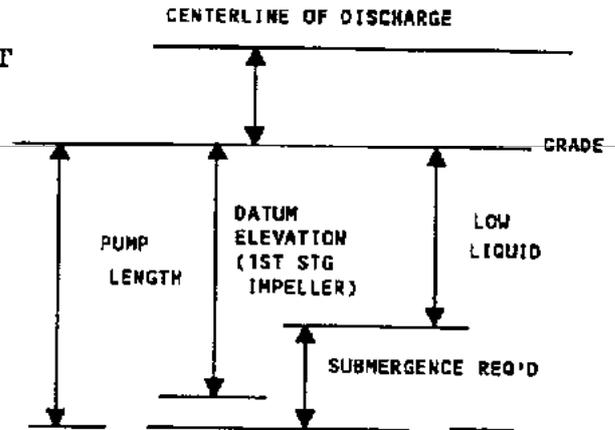
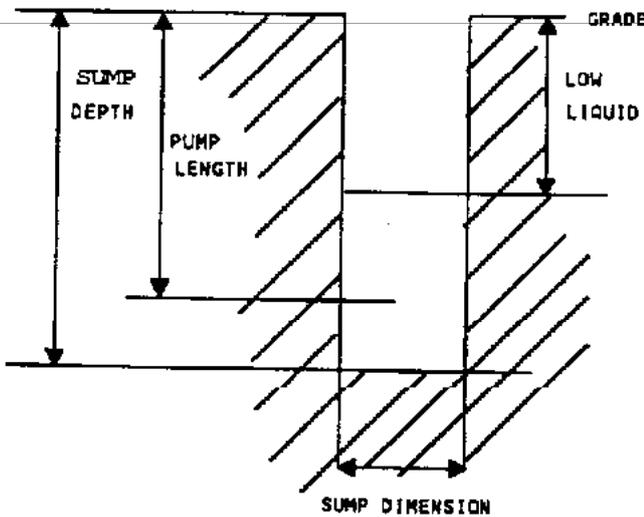
PAGE 1 OF 1

JOB NO. _____ ITEM NO. _____
 REQ / SPEC NO. _____
 PURCH ORDER NO. _____ DATE _____
 INQUIRY NO. _____ BY _____

1	VERTICAL TYPE (FIG 1.1) <input type="checkbox"/> VS1 <input type="checkbox"/> VS2 <input type="checkbox"/> VS3 <input type="checkbox"/> VS4 <input type="checkbox"/> VS5 <input type="checkbox"/> VS6 <input type="checkbox"/> VS7 <input type="checkbox"/> OTHER	
2	REMARKS _____	
3	_____	
4	_____	
5	_____	
6	VERTICAL PUMPS	
7	<input type="checkbox"/> PUMP THRUST: (+) UP (-) DOWN	
8	AT MIN FLOW _____ (LBS) _____ (LBS)	
9	AT RATED FLOW _____ (LBS) _____ (LBS)	
10	AT MAX FLOW _____ (LBS) _____ (LBS)	
11	MAX THRUST _____ (LBS) _____ (LBS)	
12	<input checked="" type="checkbox"/> SOLEPLATE _____ (IN) X _____ (IN)	
13	<input type="checkbox"/> SOLEPLATE THICKNESS _____ (IN)	
14	COLUMN PIPE: <input type="checkbox"/> FLANGED <input type="checkbox"/> THREADED	
15	DIAMETER _____ (IN) LENGTH _____ (FT)	
16	GUIDE BUSHINGS:	
17	<input type="checkbox"/> NUMBER _____	
18	<input type="checkbox"/> LINE SHAFT BEARING SPACING _____ (IN)	
19	GUIDE BUSHING LUBE:	
20	<input type="checkbox"/> WATER <input type="checkbox"/> OIL	
21	<input type="checkbox"/> GREASE <input type="checkbox"/> PUMPAGE	
22		

VERTICAL PUMPS (CONT'D)	
LINE SHAFT: <input checked="" type="checkbox"/> OPEN <input checked="" type="checkbox"/> ENCLOSED	
<input type="checkbox"/> LINE SHAFT DIAMETER: _____ (IN) <input type="checkbox"/> TUBE DIAMETER: _____ (IN)	
LINE SHAFT COUPLING:	
<input type="checkbox"/> SLEEVE & KEY <input type="checkbox"/> THREADED	
<input type="checkbox"/> SUCTION CAN THICKNESS _____ (IN)	
<input type="checkbox"/> LENGTH _____ (FT)	
<input type="checkbox"/> DIAMETER _____ (FT)	
<input type="checkbox"/> SUCTION STRAINER TYPE _____	
<input type="checkbox"/> FLOAT & ROD <input type="checkbox"/> FLOAT SWITCH	
<input type="checkbox"/> IMPELLER COLLETS ACCEPTABLE (2.5.2)	
<input type="checkbox"/> HARDENED SLEEVES UNDER BEARINGS (5.3.10.7)	
<input type="checkbox"/> RESONANCE TEST (5.3.9.2)	
<input type="checkbox"/> STRUCTURAL ANALYSIS (5.3.5.1)	
<input type="checkbox"/> DRAIN PIPED TO SURFACE (5.3.13.6)	

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 kPa (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 ($\frac{3}{8}$ in.) square; however, a packing size of at least 12.5 mm ($\frac{1}{2}$ 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 ($\frac{1}{4}$ 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

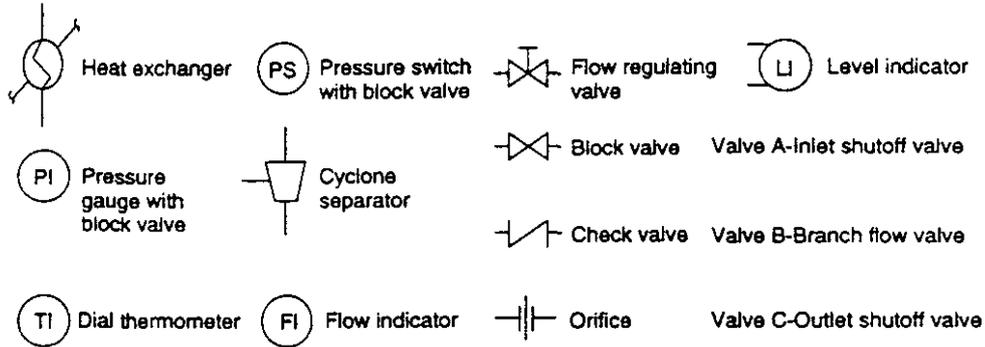
A drain shall be provided on vertical pumps so that no liquid can collect in the driver-support piece.

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:

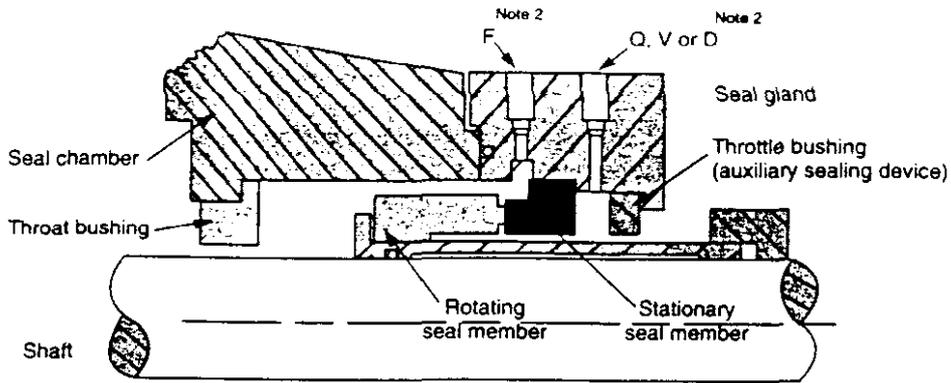


Notes:

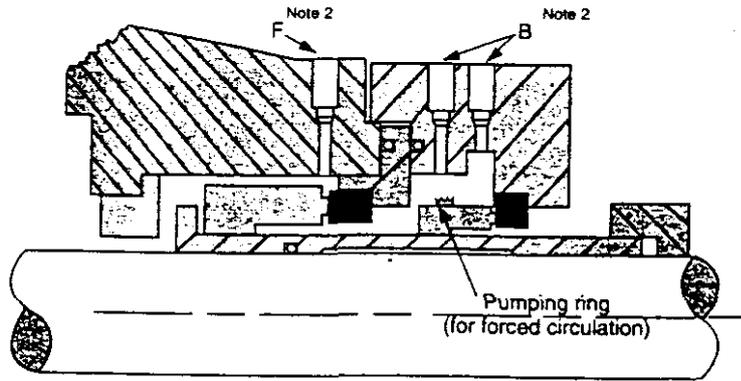
1. These plans represent commonly used systems. Other variations and systems are available and should be specified in detail by the purchaser and mutually agreed upon by the purchaser and the vendor.
2. These plans are for use with the connection "F" on the single and unpressurized dual seal arrangements 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

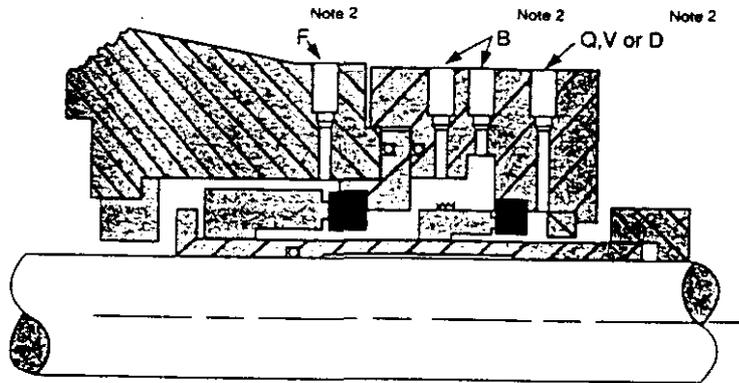
Symbol	Connections
F	Flush
L	Leakage
B	Barrier/Buffer Fluid Injection
X	External Fluid Injection
Q	Quench
C	Cooling
H	Heating
G	Lubrication
E	Balance Fluid
P	Pumped Fluid
Suffix	
I	Inlet
O	Outlet
S	Fill
D	Drain
V	Vent



SINGLE SEAL



UNPRESSURIZED DUAL SEAL



PRESSURIZED DUAL SEAL

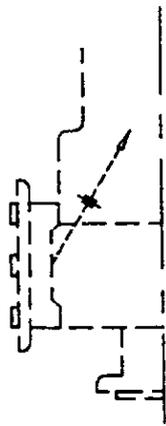
Notes:

- 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.

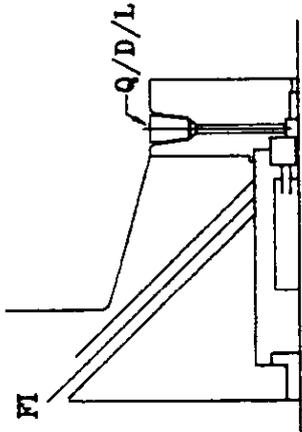
Figure D-1—Typical Mechanical Seal Arrangements

API PLAN 1

SCHEMATIC



HORIZONTAL

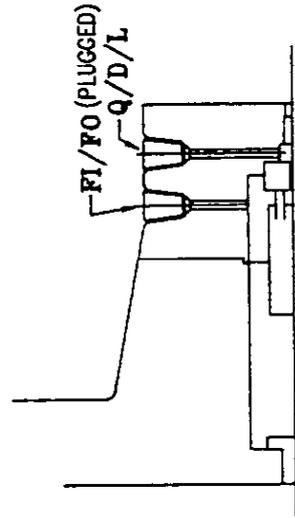
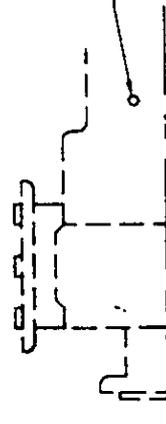


VERTICAL

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



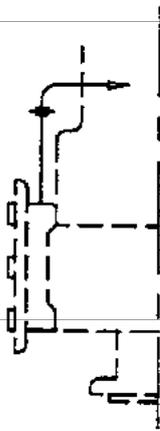
NOT RECOMMENDED
ON VERTICAL
PUMPS

DEAD-ENDED SEAL CHAMBER WITH NO CIRCULATION OF FLUSHED FLUID.

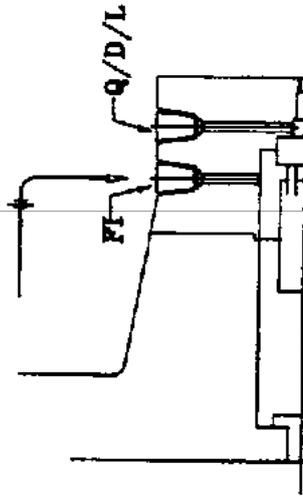
D-2A—Piping for Single Seals and the Primary Seals of Unpressurized Dual Seal Arrangements—Plans 1 and 2

API PLAN 11

SCHEMATIC



HORIZONTAL



VERTICAL

NOT RECOMMENDED
ON VERTICAL
PUMPS

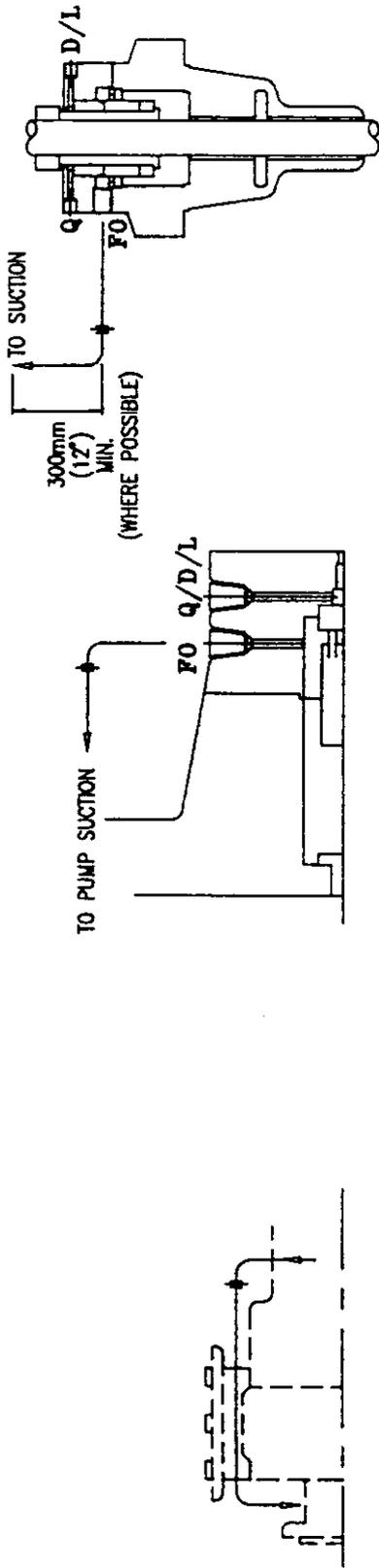
RECIRCULATION FROM PUMP DISCHARGE THROUGH A FLOW CONTROL ORIFICE, WHEN NECESSARY, TO THE SEAL. THE FLOW ENTERS THE SEAL CHAMBER ADJACENT TO THE MECHANICAL SEAL FACES, FLUSHES THE FACES AND FLOWS ACROSS THE SEAL BACK INTO THE PUMP.

API PLAN 13

SCHEMATIC

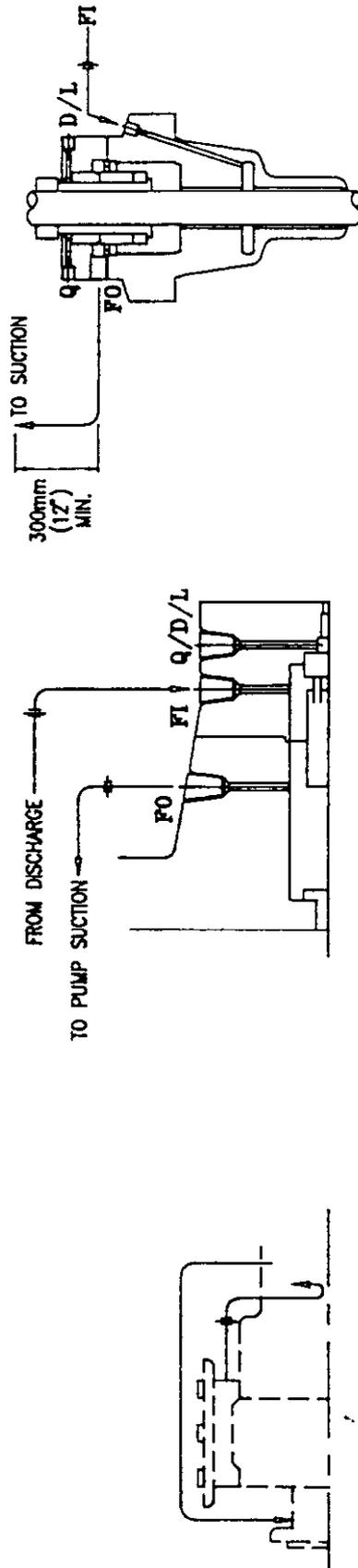
HORIZONTAL

VERTICAL



RECIRCULATION FROM SEAL CHAMBER THROUGH A FLOW CONTROL ORIFICE (WHEN NECESSARY) TO THE SEAL AND BACK TO THE PUMP SUCTION.

API PLAN 14



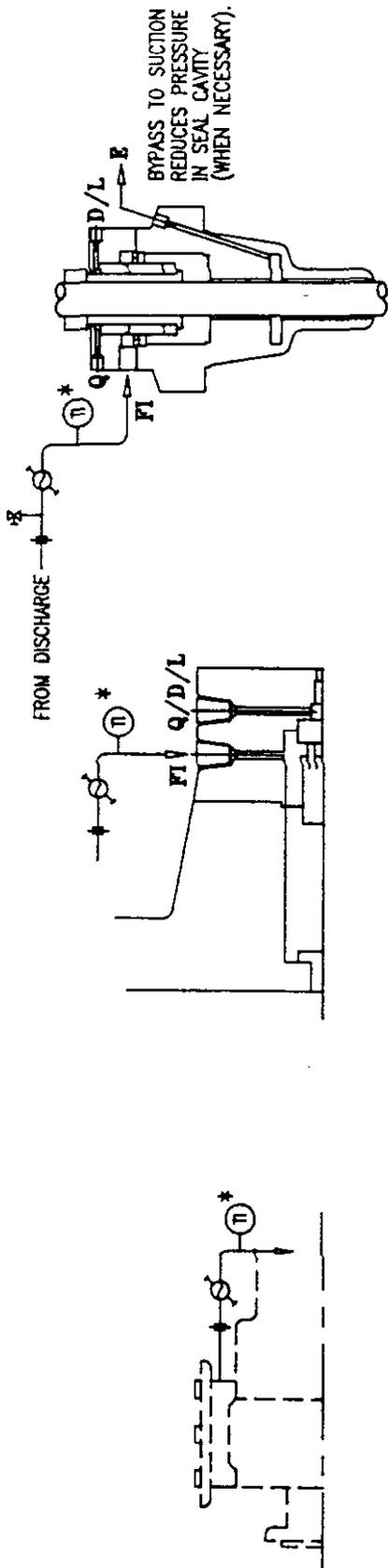
RECIRCULATION FROM PUMP DISCHARGE THROUGH A FLOW CONTROL ORIFICE (WHEN NECESSARY) TO THE SEAL AND BACK TO THE SUCTION NOZZLE. THE ORIFICE IS TO BE SIZED IN ACCORDANCE WITH THE THROAT BUSHING AND THE RETURN LINE. SIMILAR TO PLAN 11 BUT FLOW BACK TO SUCTION SIDE WILL EVACUATE VAPORS THAT MAY COLLECT IN SEAL CHAMBER. RECOMMENDED IN LIGHT HYDROCARBON SERVICE.

PLAN 21

SCHEMATIC

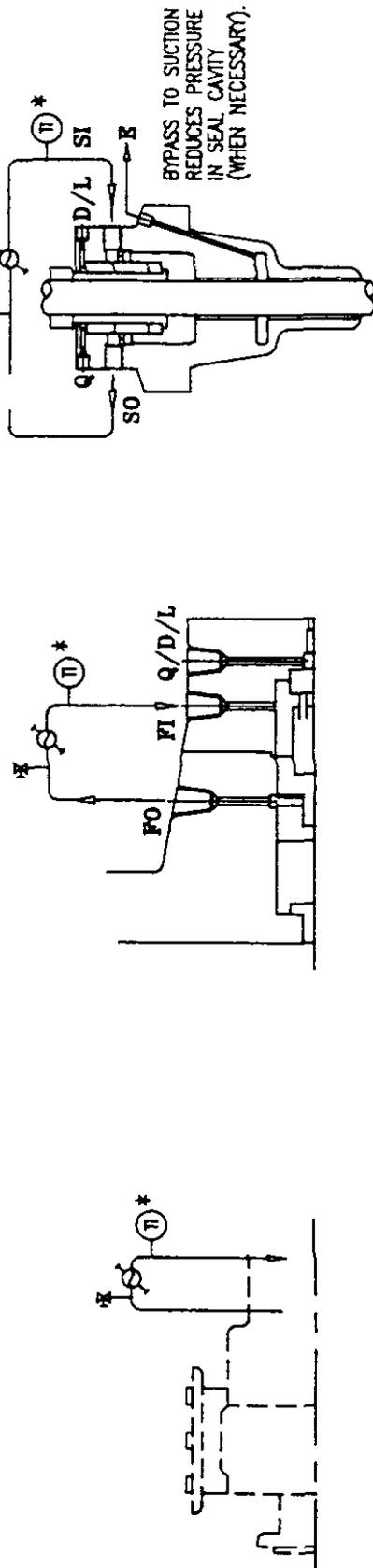
HORIZONTAL

VERTICAL



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

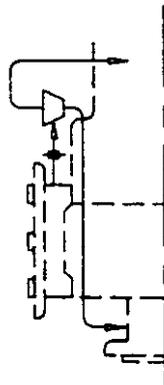


RECIRCULATION IS FROM A PUMPING RING IN THE SEAL CHAMBER THROUGH A COOLER AND BACK TO THE SEAL CHAMBER. THIS PLAN CAN BE USED ON HOT APPLICATIONS TO MINIMIZE HEAT LOAD ON THE COOLER BY COOLING ONLY THE SMALL AMOUNT OF LIQUID THAT IS RECIRCULATED. (* DIAL THERMOMETER (TI) IS OPTIONAL)

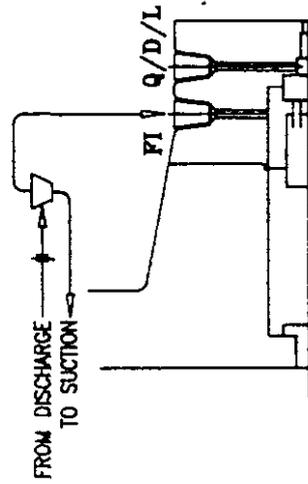
D-2D—Piping for Single Seals and the Primary Seals of Unpressurized Dual Seal Arrangements—Plans 21 and 23

API PLAN 31

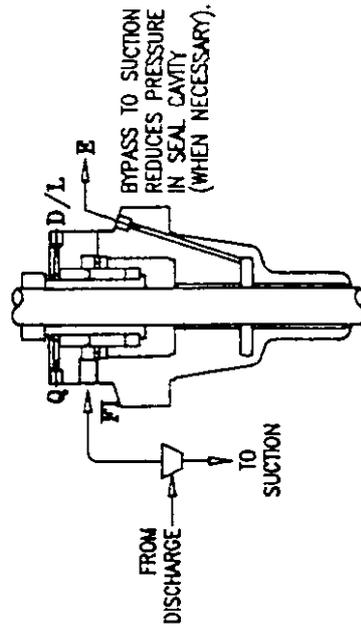
SCHEMATIC



HORIZONTAL

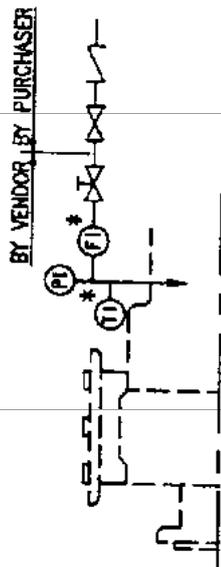


VERTICAL

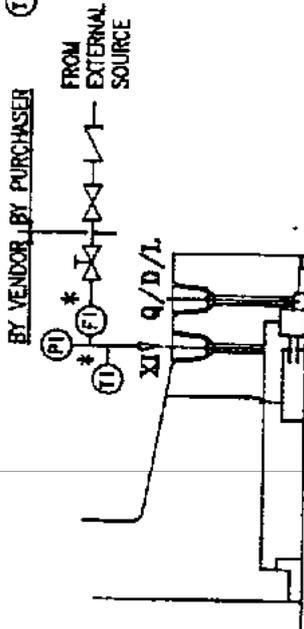


RECIRCULATION FROM PUMP DISCHARGE THROUGH AN ORIFICE (WHEN NECESSARY), TO A CYCLONE SEPARATOR DELIVERING THE CLEAN FLUID TO THE SEAL CHAMBER. THE SOLIDS ARE DELIVERED TO THE PUMP SUCTION LINE.

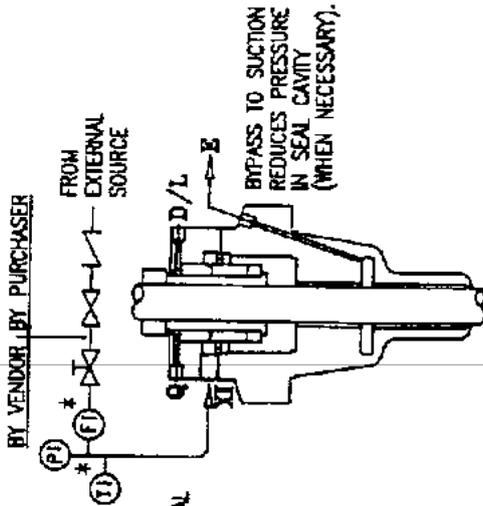
SCHEMATIC



HORIZONTAL

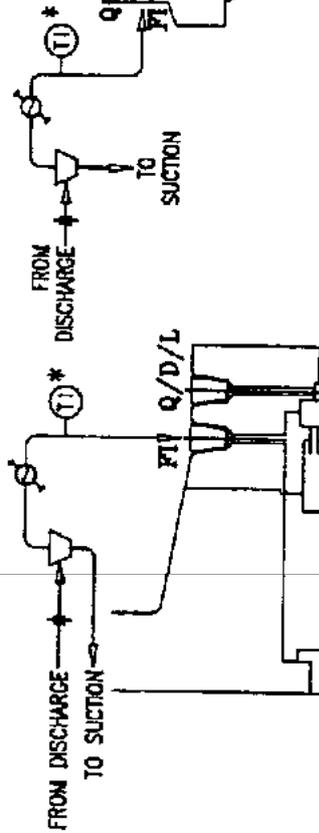
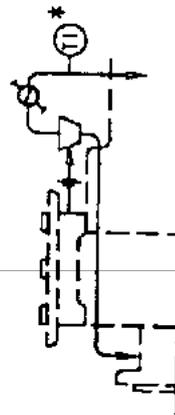


VERTICAL



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. (* DUAL THERMOMETER (TI) AND FLOW INDICATOR (FI) ARE OPTIONAL).

API PLAN 41

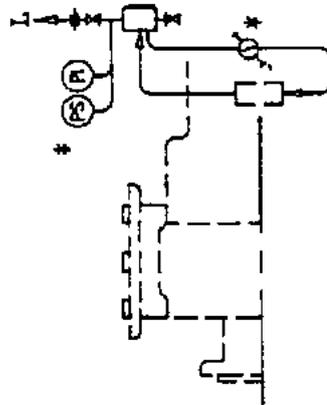


RECIRCULATION FROM PUMP DISCHARGE THROUGH AN ORIFICE (WHEN NECESSARY), TO A CYCLONE SEPARATOR DELIVERING THE CLEAN FLUID TO THE SEAL CHAMBER. THE SOLIDS ARE DELIVERED TO THE PUMP SUCTION LINE. (* DUAL THERMOMETER (TI) IS OPTIONAL).

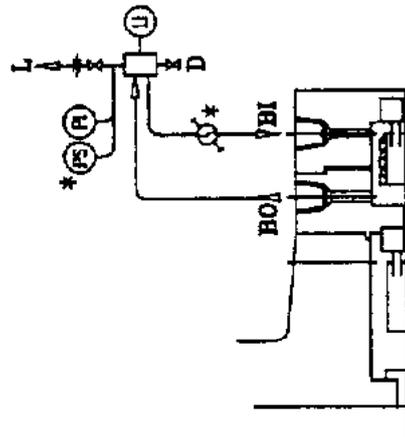
D-2F—Piping for Single Seals and the Primary Seals of Unpressurized Dual Seal Arrangements—Plans 32 and 41

API PLAN 52

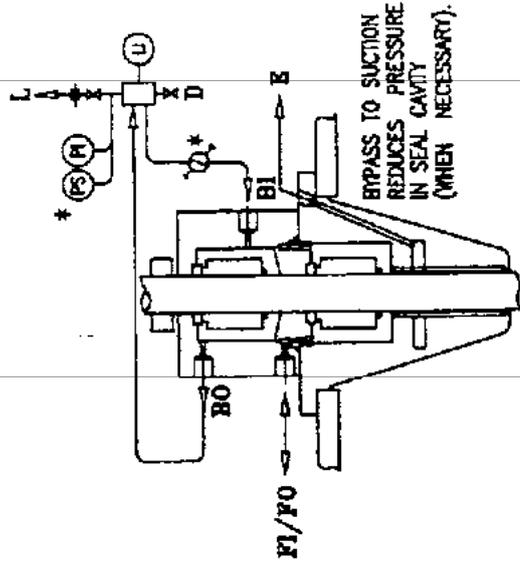
SCHEMATIC



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 (H) ARE OPTIONAL).

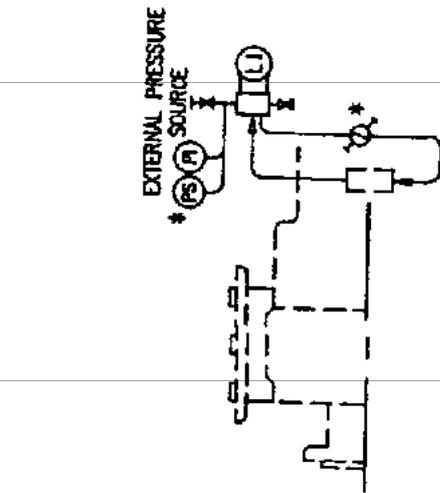
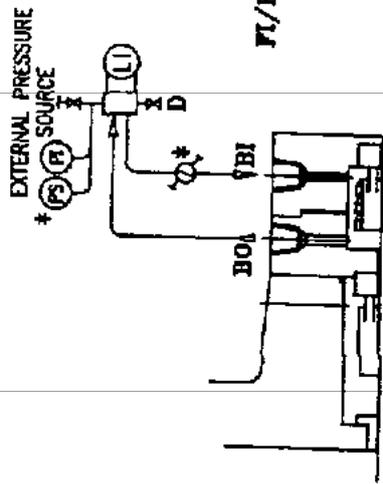
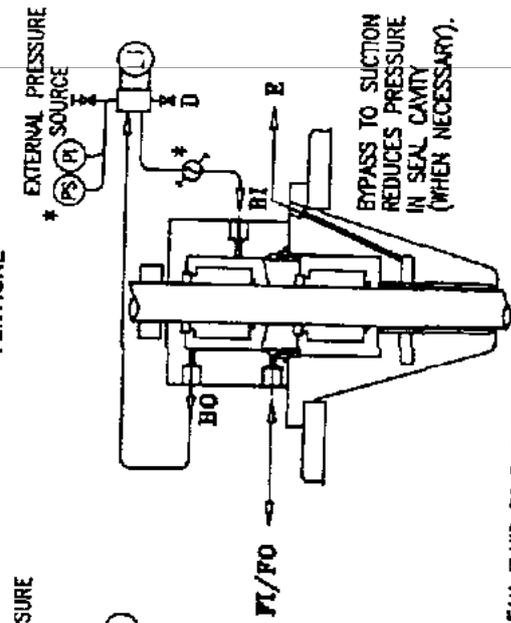
Figure D-3A—Piping for Throttle Bushings, Auxiliary Seal Devices, and Dual Seals—Plan 52

API PLAN 53

SCHEMATIC

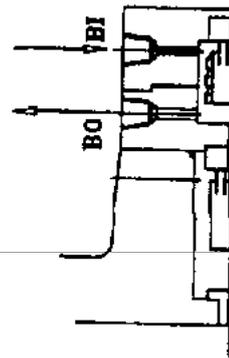
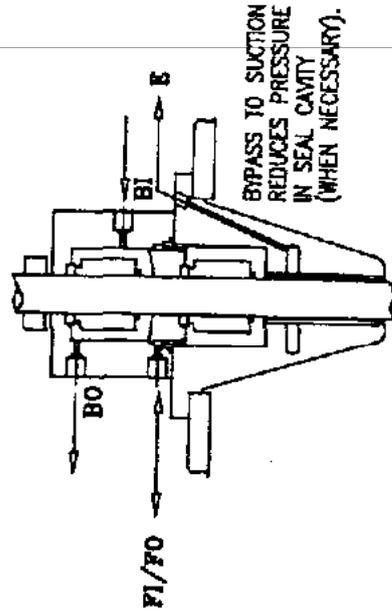
HORIZONTAL

VERTICAL



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 (S) AND HEAT EXCHANGER (Q) ARE OPTIONAL).

API PLAN 54

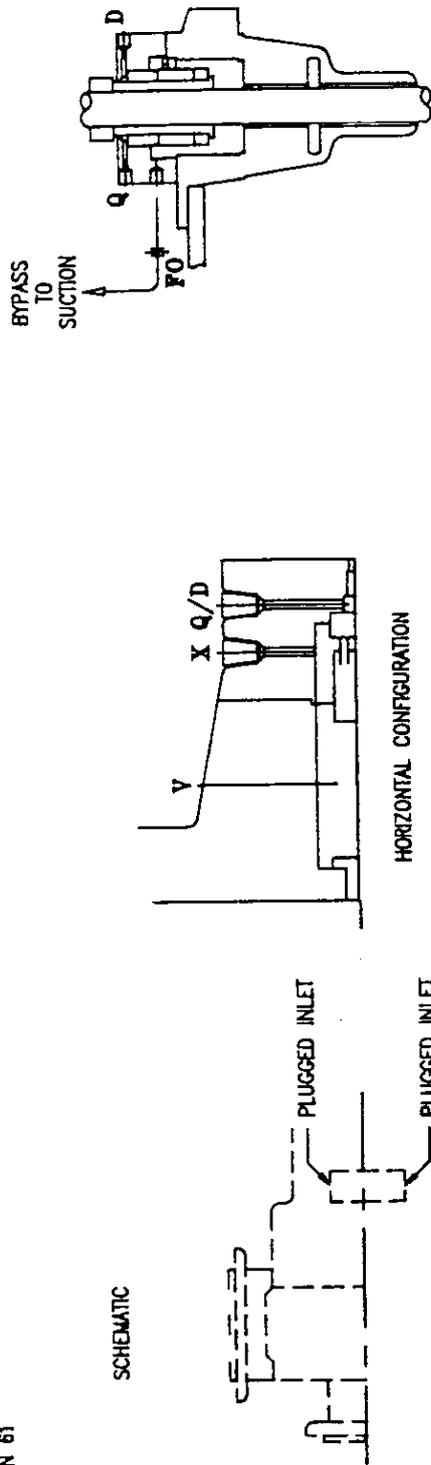


BYPASS TO SUCTION REDUCES PRESSURE IN SEAL CAVITY (WHEN NECESSARY).

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.

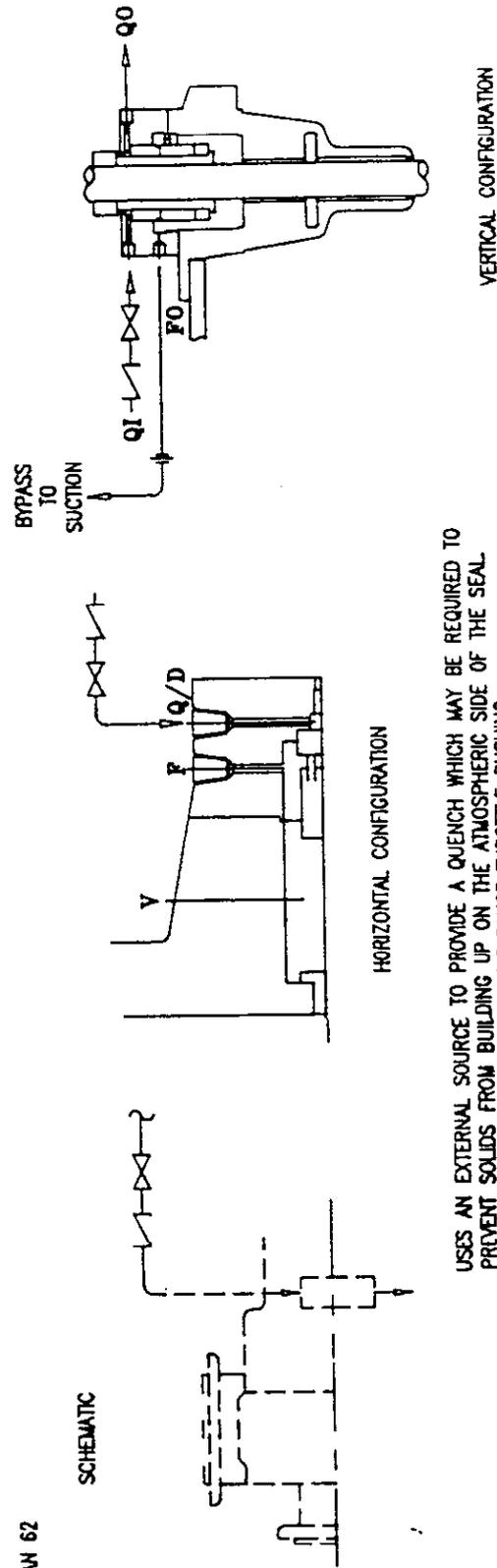
Figure D-3B—Piping for Throttle Bushings, Auxiliary Seal Devices, and Dual Seals—Plans 53 and 54

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 IS SHOWN. HOWEVER, OTHER SINGLE AND DUAL SEALING ARRANGEMENTS 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

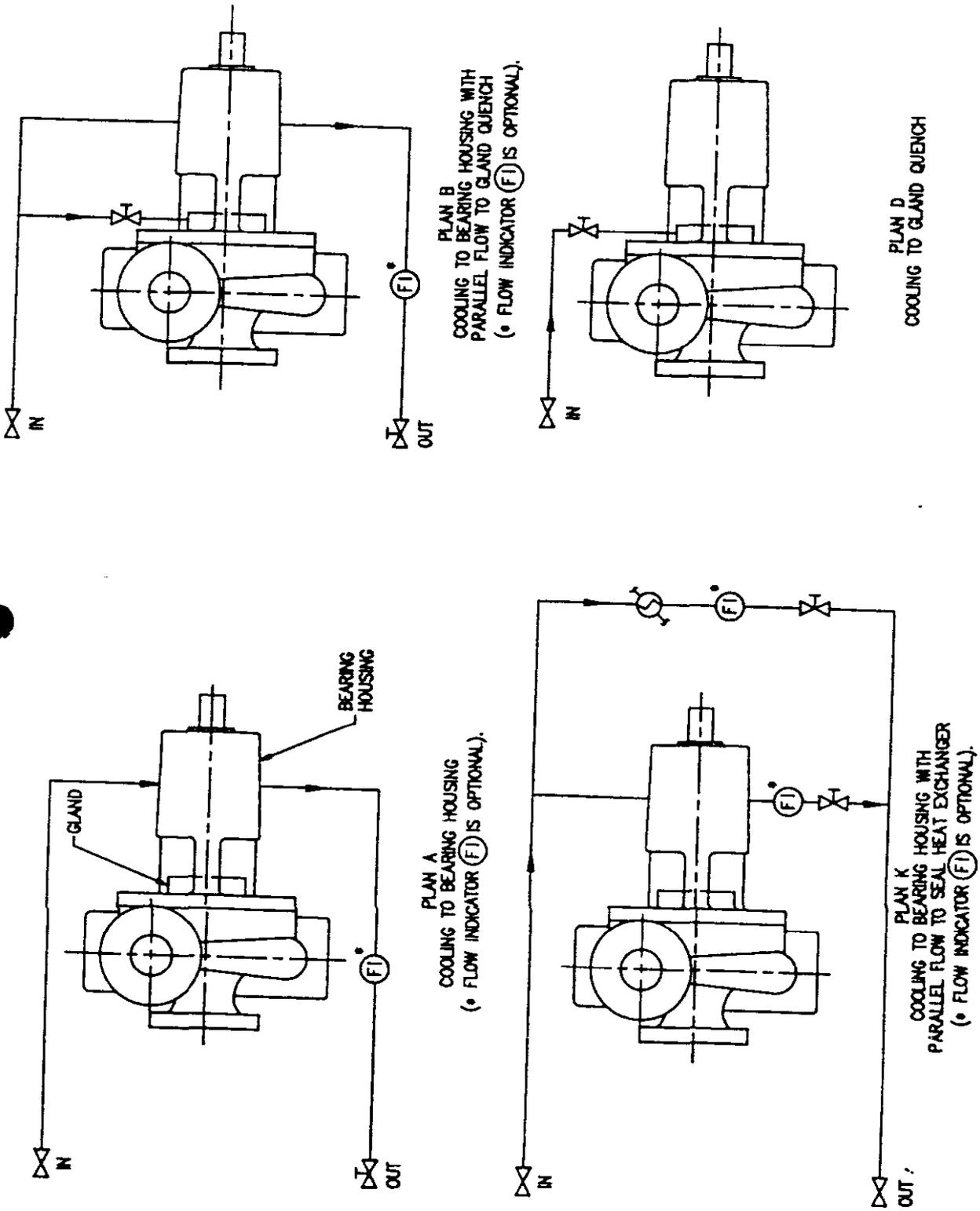
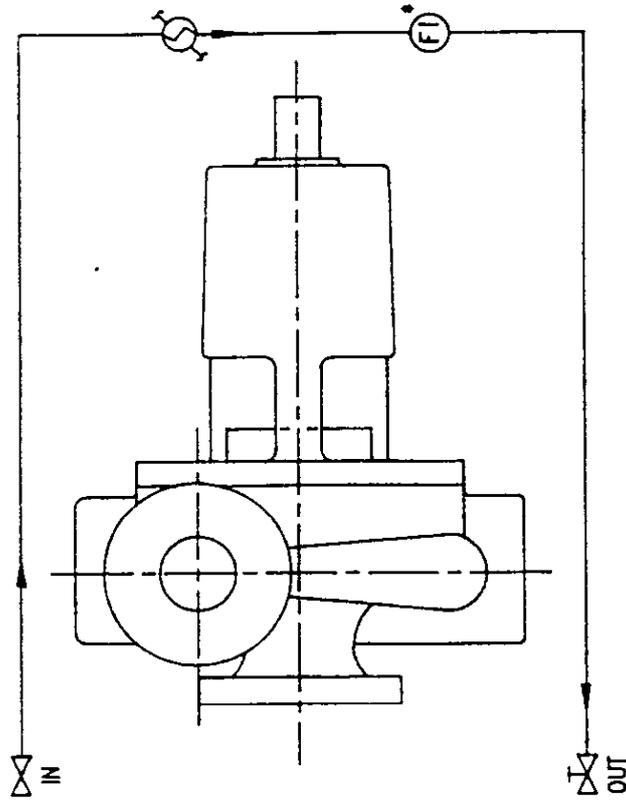
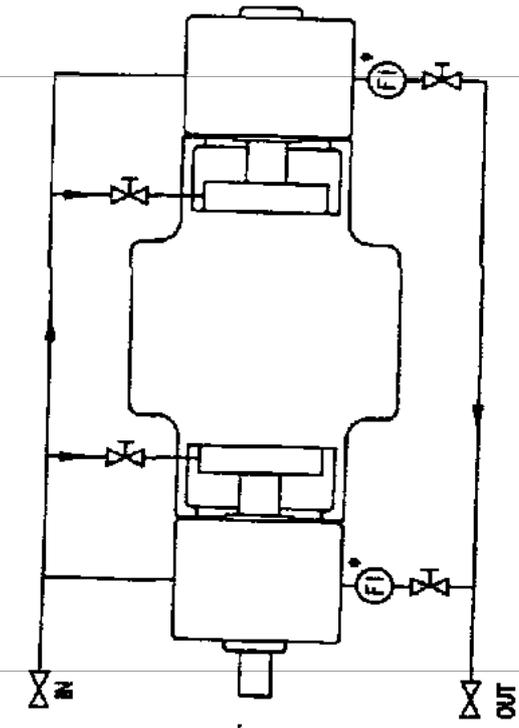


Figure D-4A—Cooling Water Piping for Overhung Pumps—Plans A, B, D, and K

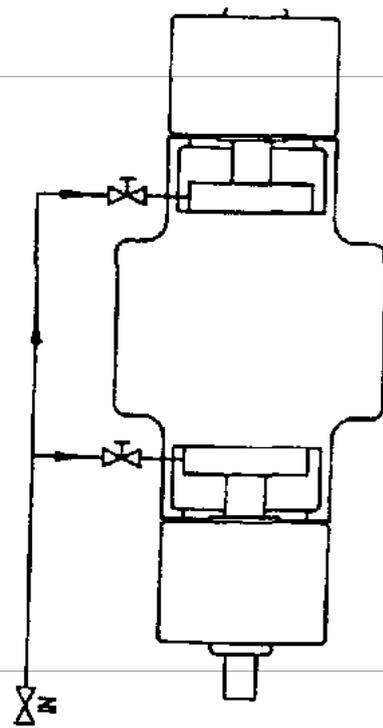


PLAN M
COOLING TO SEAL HEAT EXCHANGER
(• FLOW INDICATOR (FI) IS OPTIONAL).

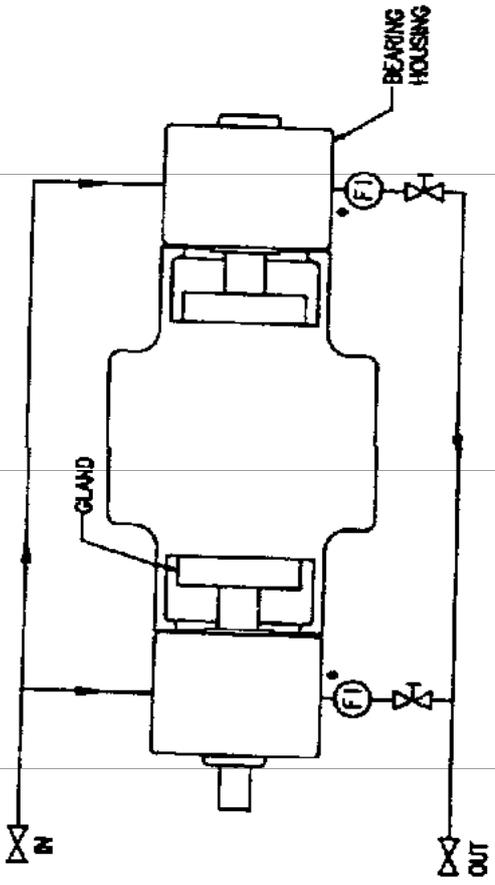
Figure D-4B—Cooling Water Piping for Overhung Pumps—Plan M



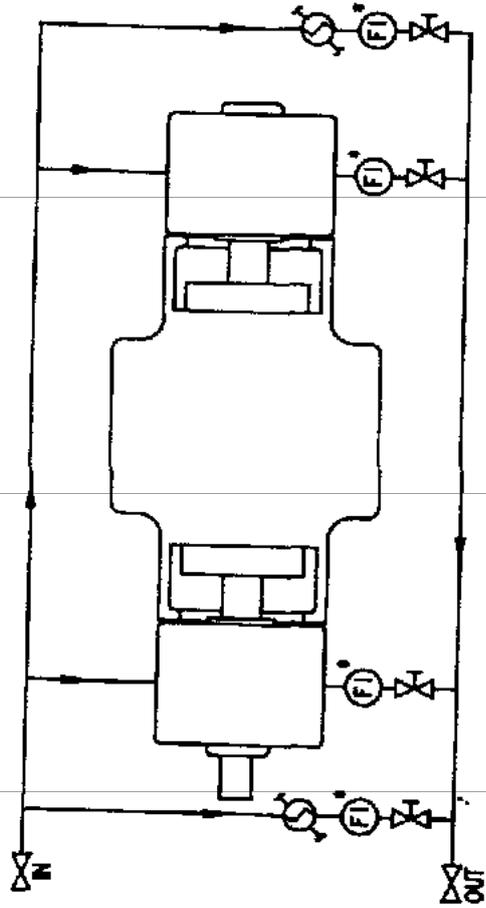
PLAN B
COOLING TO BEARING HOUSING WITH
PARALLEL FLOW TO GLAND QUENCH
(* FLOW INDICATORS (FI) ARE OPTIONAL).



PLAN D
COOLING TO GLAND QUENCH



PLAN A
COOLING TO BEARING HOUSING
(* FLOW INDICATORS (FI) ARE OPTIONAL).



PLAN K
COOLING TO BEARING HOUSING WITH
PARALLEL FLOW TO SEAL HEAT EXCHANGERS
(* FLOW INDICATORS (FI) ARE OPTIONAL).

Figure D-5A—Piping for Between Bearings Pumps—Plans A, D, and K

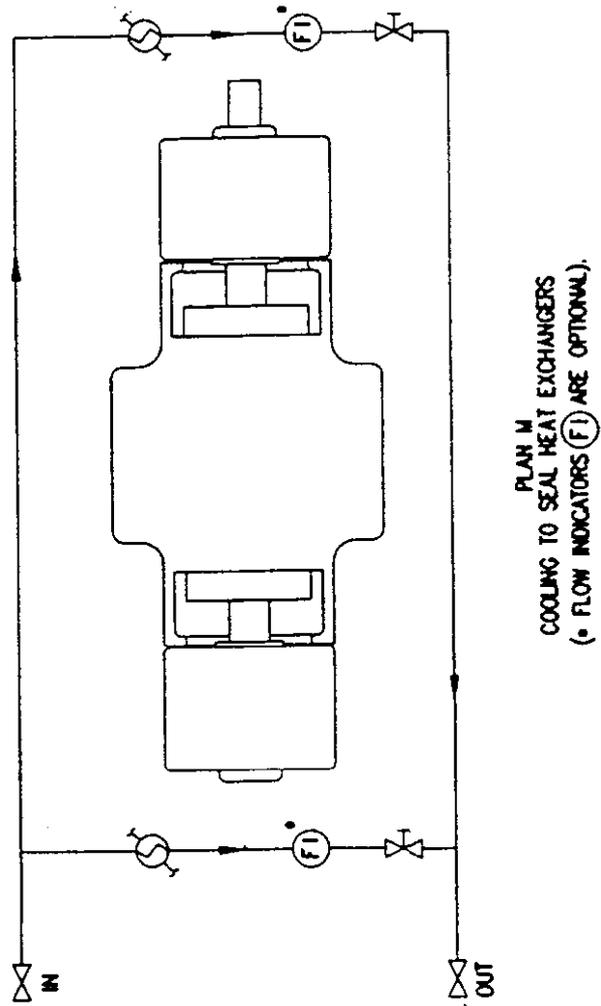
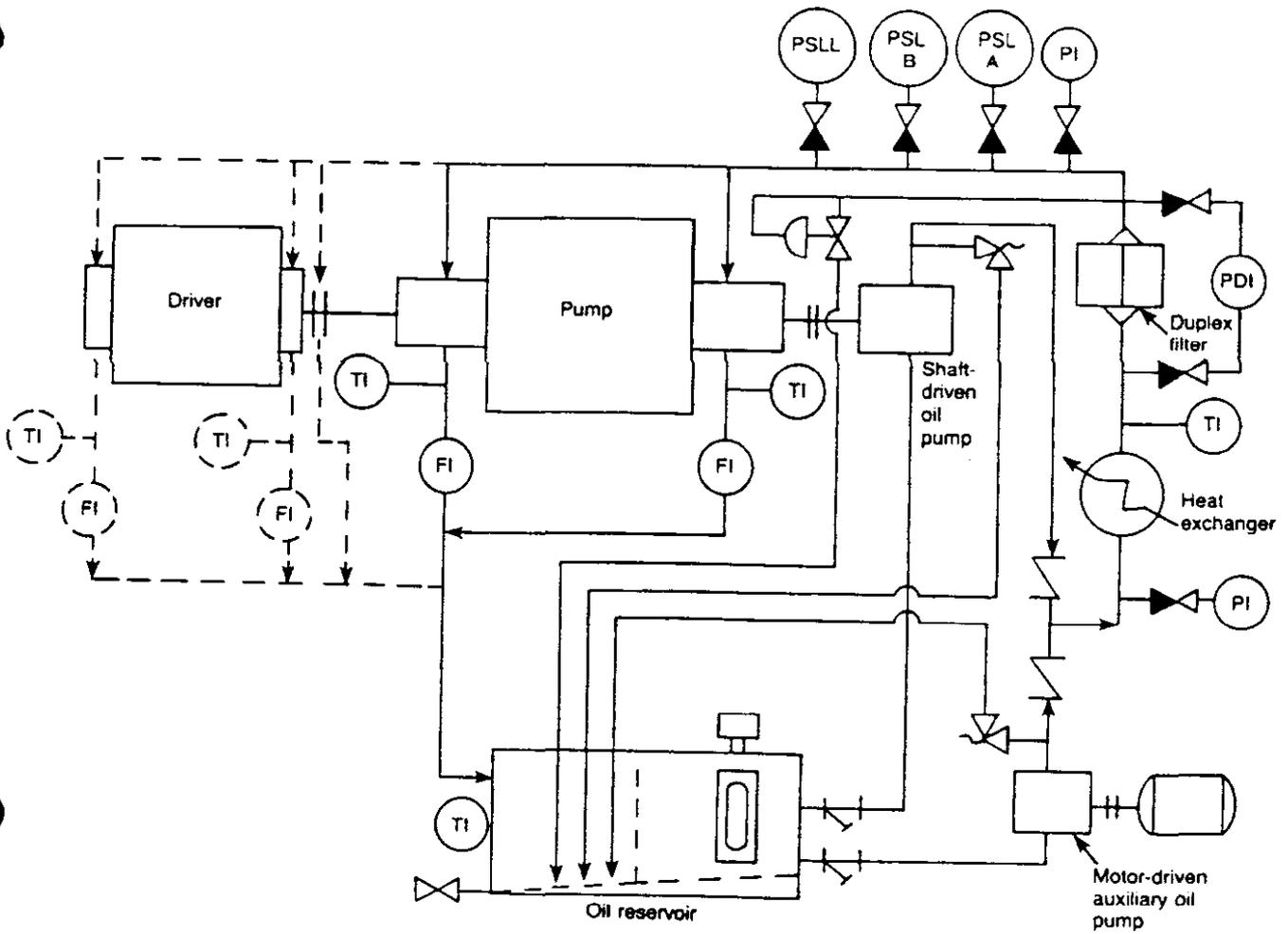


Figure D-5B—Piping for Between Bearings Pumps—Plan M



LEGEND

- | | | | |
|------|--|---|--|
| FI | Flow indicator | ○ | Instrument (letters indicate function) |
| TI | Temperature indicator | ⌵ | Gate valve |
| PI | Pressure indicator | ⌵ | Relief valve |
| PDI | Pressure differential indicator | ⌵ | Line strainer |
| PSLA | Low-pressure switch (auxiliary pump start) | ⌵ | Pressure control valve |
| PSLB | Low-pressure switch (alarm) | ⌵ | Check valve |
| PSLL | Low-pressure switch (trip) | ⌵ | 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.

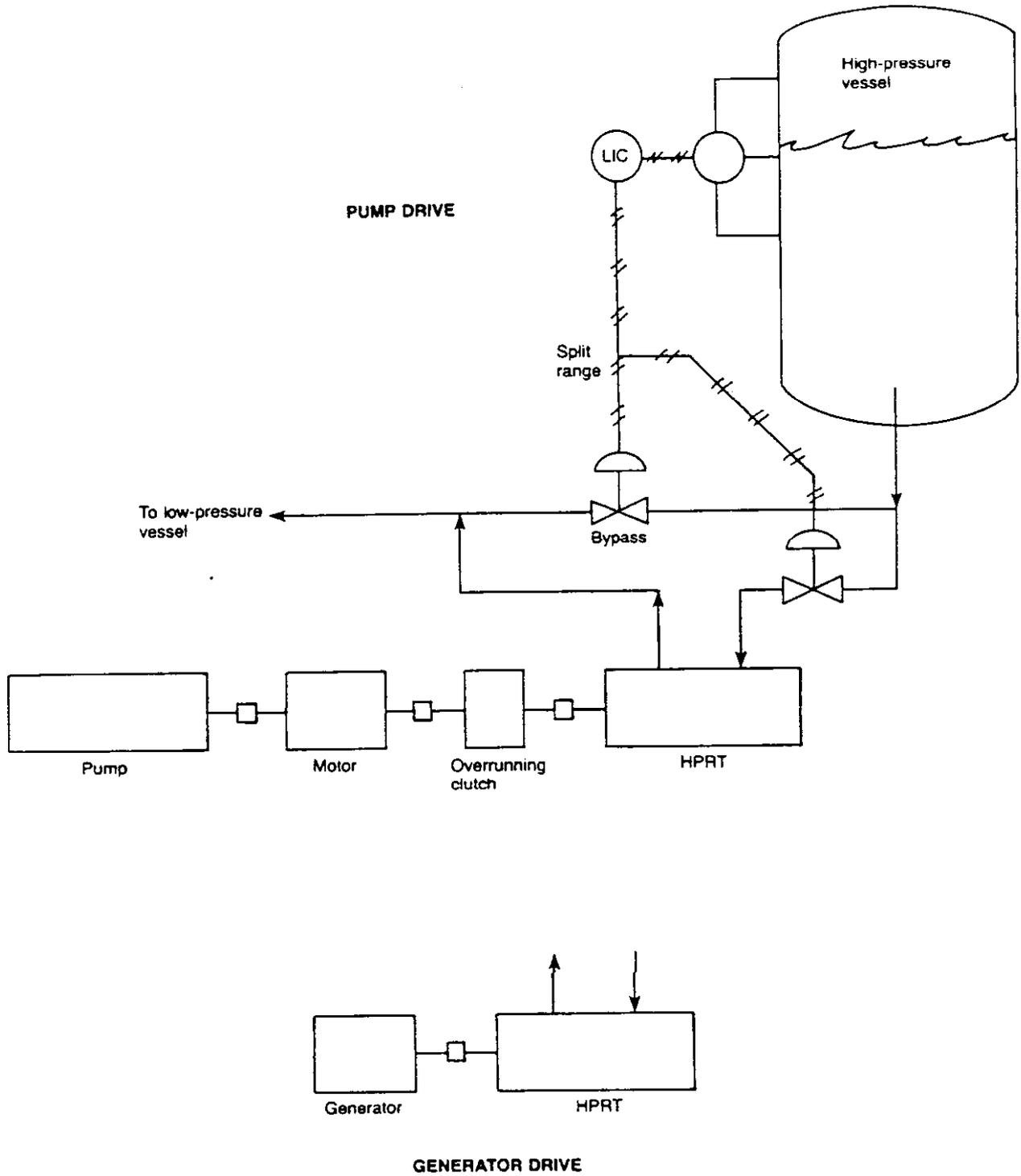
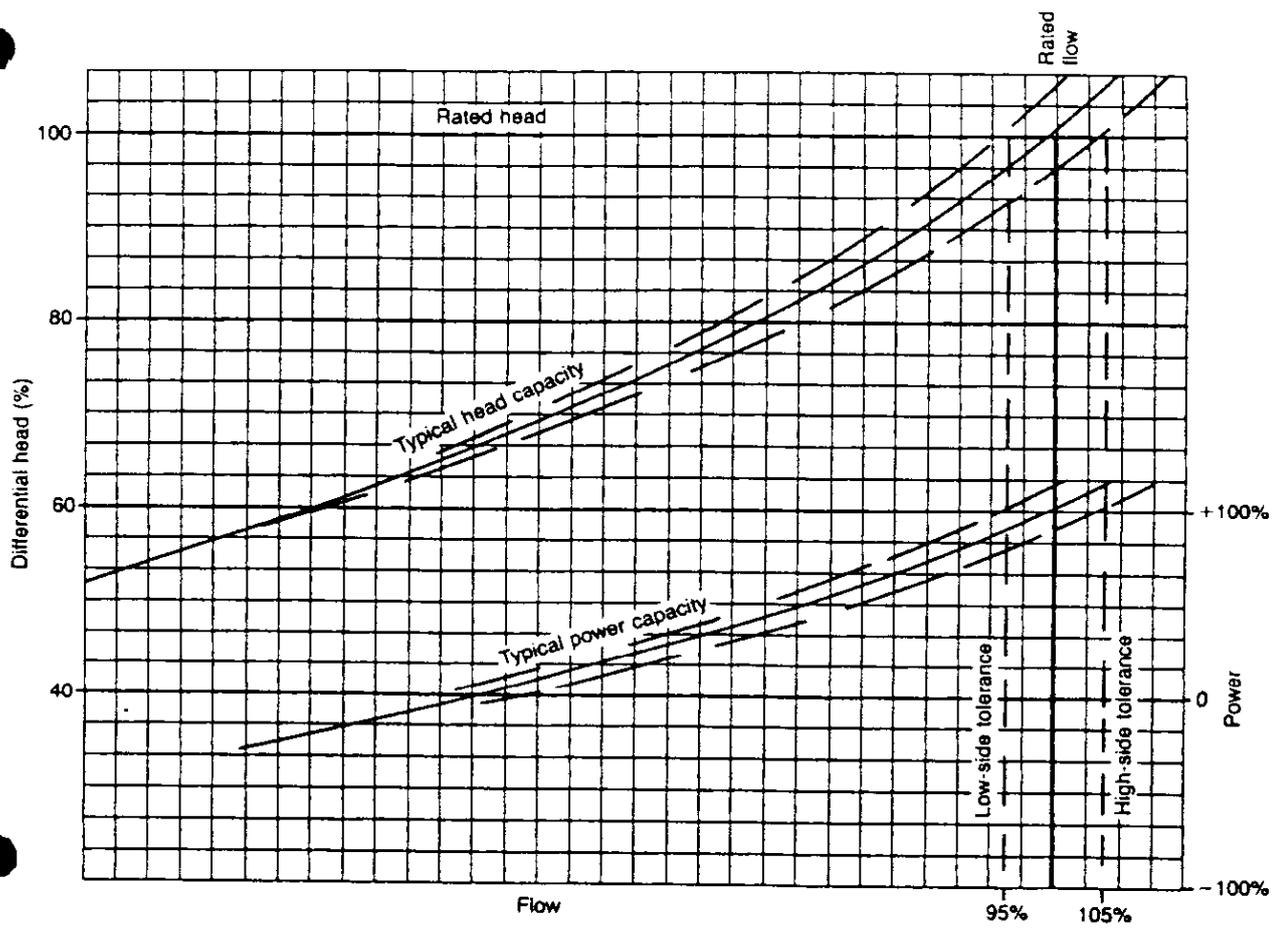


Figure E-1—Typical HPRT Arrangements



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).

$$(FRS_A / 1.5FRS_{T2}) + (MRS_A / 1.5MRS_{T2}) \leq 2 \quad (F-1)$$

$$(FRD_A / 1.5FRD_{T2}) + (MRD_A / 1.5MRD_{T2}) \leq 2 \quad (F-2)$$

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.)

$$FRC_A < 1.5(FRS_{T2} + FRD_{T2}) \quad (F-3)$$

$$MYC_A < 2.0(MYS_{T2} + MYD_{T2})^{0.5} \quad (F-4)$$

$$MRC_A < 1.5(MRS_{T2} + MRD_{T2}) \quad (F-5)$$

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.

$$P = (\sigma / 2) + (\sigma^2 / 4 + \tau^2)^{0.5} < 41 \quad (F-6A)$$

$$\sigma = [1.27 FY / (D_o^2 - D_i^2) + [1.02 \times 10^4 D_o (MX^2 + MZ^2)^{0.5}] / (D_o^4 - D_i^4)] \quad (F-7A)$$

$$\tau = [1.27 (FX^2 + FZ^2)^{0.5}] / (D_o^2 - D_i^2) + [0.51 \times 10^4 D_o (MY)] / (D_o^4 - D_i^4) \quad (F-8A)$$

For U.S. units, the following equations apply:

$$P = (\sigma / 2) + (\sigma^2 / 4 + \tau^2)^{0.5} < 5950 \quad (F-6B)$$

$$\sigma = [1.27 FY / (D_o^2 - D_i^2) + [122 D_o (MX^2 + MZ^2)^{0.5}] / (D_o^4 - D_i^4)] \quad (F-7B)$$

$$\tau = [1.27 (FX^2 + FZ^2)^{0.5}] / (D_o^2 - D_i^2) + [61 D_o (MY)] / (D_o^4 - D_i^4) \quad (F-8B)$$

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_1 = 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).
- σ = longitudinal stress, in MPa (psi).
- τ = 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

^aSee 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,

$$(FRS_A / 1.5FRS_{T2}) + (MRS_A / 1.5MRS_{T2}) \leq 2$$

$$15645 / [1.5(9780)] + 9015 / [1.5(6750)] \leq 2$$

$$1.96 < 2$$

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,

$$(FRD_A / 1.5FRD_{T2}) + (MRD_A / 1.5MRD_{T2}) \leq 2$$

$$11229 / [1.5(6920)] + 5982 / [1.5(4710)] \leq 2$$

$$1.93 < 2$$

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):

$$FXC_A = FXS_A + FXD_A$$

$$FYC_A = FYS_A + FYD_A$$

$$FZC_A = FZS_A + FZD_A$$

$$FRC_A = [(FXC_A)^2 + (FYC_A)^2 + (FZC_A)^2]^{0.5}$$

$$FRC_A = (+12900) + (+7117) = +20017$$

$$FYC_A = (0) + (-445) = -445$$

$$FZC_A = (-8852) + (+8674) = -178$$

$$FRC_A = [(+20017)^2 + (-445)^2 + (-178)^2]^{0.5} = 20023$$

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):

$$MXC_A = MXS_A + MXD_A - [(FYS_A)(zS) + (FYD_A)(zD) - (FZS_A)(yS) - (FZD_A)(yD)] / 1000$$

$$MYC_A = MYS_A + MYD_A + [(FXS_A)(zS) + (FXD_A)(zD) - (FZS_A)(xS) - (FZD_A)(xD)] / 1000$$

$$MZC_A = MZS_A + MZD_A - [(FXS_A)(yS) + (FXD_A)(yD) - (FYS_A)(xS) - (FYD_A)(xD)] / 1000$$

$$MRC_A = [F(MXC_A)^2 + (MYC_A)^2 + (MZC_A)^2]^{0.5}$$

$$MXC_A = (-1356) + (+678) - [(0)(0.00) + (-445)(+381) - (-8852)(0.00) - (+8674)(-311)] / 1000 = -3206$$

$$MYC_A = -3194 \text{ (see previous calculation)}$$

$$MZC_A = (-7458) + (-4882) - [(+12900)(0.00) + (+7117)(-311) - (0)(+267) - (-445)(0.00)] / 1000 = -10127$$

$$MRC_A = [(-3206)^2 + (-3194)^2 + (-10127)^2]^{0.5} = 11092$$

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 Force	Value (N)	Moment 4NPS Suction	Value (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, σ_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.

$$\begin{aligned} \sigma_s &= [1.27 FYS_A / (D_o^2 - D_i^2)] + \\ &\quad [1.02 \times 10^4 D_o (MXS_A^2 + MZS_A^2)^{0.5}] / \\ &\quad (D_o^4 - D_i^4) \\ &= [1.27(-5338) / 2592] + [1.02 \times 10^4 (114) (1363)] / \\ &\quad 6.065 \times 10^7 = 23.52 \end{aligned}$$

Equation F-8A is used to determine the shear stress for the suction nozzle, τ_s .

$$\begin{aligned} \tau_s &= [1.27(FXS_A^2 + FZS_A^2)^{0.5}] / (D_o^2 - D_i^2) \\ &\quad + [0.51 \times 10^4 D_o (MYS_A)] / (D_o^4 - D_i^4) \\ &= [1.27(2593) / 2592] + [0.51 \times 10^4 (114) \\ &\quad (|-2034|)] / 6.065 \times 10^7 = 20.77 \end{aligned}$$

The principal stress for the suction nozzle, P_s , is calculated using Equation F-6A:

$$\begin{aligned} P_s &= (\sigma_s / 2) + (\sigma_s^2 / 4 + \tau_s^2)^{0.5} < 41 \\ &= (+23.52 / 2) + [(+23.52)^2 / 4 + (+20.77)^2]^{0.5} \\ &= +35.63 < 41 \end{aligned}$$

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, σ_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.

$$\begin{aligned} \sigma_D &= [1.27 FYD_A / (D_o^2 - D_i^2)] \\ &\quad + [1.02 \times 10^4 D_o (MXD_A^2 + MZD_A^2)^{0.5}] / \\ &\quad (D_o^4 - D_i^4) \\ &= [1.27(+2224) / 1837] + [1.02 \times 10^4 (89) (2715)] / \\ &\quad 2.573 \times 10^7 = 97.33 \end{aligned}$$

Equation F-8A is used to determine the shear stress for the discharge nozzle, τ_D .

$$\begin{aligned} \tau_D &= [1.27(FXD_A^2 + FZD_A^2)^{0.5}] / (D_o^2 - D_i^2) \\ &\quad + [0.51 \times 10^4 D_o (MYD_A)] / (D_o^4 - D_i^4) \\ &= [1.27(1406) / 1837] + [0.51 \times 10^4 (89) (|+271|)] / \\ &\quad 2.573 \times 10^7 = 5.75 \end{aligned}$$

The principal stress for the discharge nozzle, P_D , is calculated using Equation F-6A:

$$\begin{aligned} P_D &= (\sigma_D / 2) + (\sigma_D^2 / 4 + \tau_D^2)^{0.5} < 41 \\ &= (+97.33 / 2) + [(+97.33)^2 / 4 + (+5.75)^2]^{0.5} \\ &= +97.67 > 41 \end{aligned}$$

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*
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

* 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):

$$\begin{aligned} MYC_A &= MYS_A + MYD_A + [(FXS_A)(zS) + \\ &\quad (FXD_A)(zD) - (FZS_A)(xS) - (FZD_A)(xD)] / 12 \\ &= (-3599) + (-2500) + [(+2900)(0.00) + (+1600) \\ &\quad (+15) - (-1990)(+10.5) - (+1950)(0.00)] / 12 \\ &= -2358 \end{aligned}$$

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):

$$\begin{aligned} MXC_A &= MXS_A + MXD_A - [(FYS_A)(zS) + \\ &\quad (FYD_A)(zD) - (FZS_A)(yS) - (FZD_A)(yD)] \\ &\quad / 12 \end{aligned}$$

$$\begin{aligned} MYC_A &= MYS_A + MYD_A + [(FXS_A)(zS) + (FXD_A)(zD) \\ &\quad - (FZS_A)(xS) - (FZD_A)(xD)] / 12 \end{aligned}$$

$$\begin{aligned} MZC_A &= MZS_A + MZD_A - [(FXS_A)(yS) + \\ &\quad (FXD_A)(yD) - (FYS_A)(xS) - (FYD_A)(xD)] \\ &\quad / 12 \end{aligned}$$

$$MRC_A = [(MXC_A)^2 + (MYC_A)^2 + (MZC_A)^2]^{0.5}$$

$$\begin{aligned} MXC_A &= (-1000) + (+500) - [(0)(0.00) + (-100) \\ &\quad (+15.00) - (-1990)(0.00) - (+1950)(-12.25)] \\ &\quad / 12 = -2366 \end{aligned}$$

$$MYC_A = -2358 \text{ (see previous calculation)}$$

$$\begin{aligned} MZC_A &= (-5500) + (-3600) - [(+2900)(0.00) + (+1600) \\ &\quad (-12.25) - (0)(+10.50) - (-100)(0.00)] \\ &\quad / 12 = -7467 \end{aligned}$$

$$MRC_A = [(-2366)^2 + (-2358)^2 + (-7467)^2]^{0.5} = 8180$$

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, σ_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.

$$\begin{aligned} \sigma_s &= [1.27 FYS_A / (D_o^2 - D_i^2)] \\ &\quad + [212D_o(MXS_A^2 + MZS_A^2)^{0.5} / (D_o^4 - D_i^4)] \\ &= [1.27(-1200) / 4.04] + [122(4.500)(1005)] / 147.34 \\ &= 3367 \end{aligned}$$

Equation F-8B is used to determine the shear stress for the suction nozzle, τ_s .

$$\begin{aligned} \tau_s &= [1.27(FXS_A^2 + FZS_A^2)^{0.5} / (D_o^2 - D_i^2)] \\ &\quad + [61D_o(MYS_A)] / (D_o^4 - D_i^4) \\ &= [1.27(583) / 4.04] + [61(4.500)(-1500)] / 147.34 = 2978 \end{aligned}$$

The principal stress for the suction nozzle, P_s , is calculated using Equation F-6B:

$$\begin{aligned} P_s &= (\sigma_s / 2) + (\sigma_s^2 / 4 + \tau_s^2)^{0.5} < 5950 \\ &= (+3367 / 2) + [(+3367)^2 / 4 + (+2978)^2]^{0.5} \\ &= +5105 < 5950 \end{aligned}$$

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, σ_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.

$$\begin{aligned} \sigma_D &= [1.27 FYD_A / (D_o^2 - D_i^2)] \\ &\quad + [122D_o(MXD_A^2 + MZD_A^2)^{0.5} / (D_o^4 - D_i^4)] \\ &= [1.27(+500) / 2.84] + [122(3.5)(2002)] / 61.47 \\ &= 14131 \end{aligned}$$

Equation F-8B is used to determine the shear stress for the discharge nozzle, τ_D .

$$\begin{aligned} \tau_D &= [1.27(FXD_A^2 + FZD_A^2)^{0.5} / (D_o^2 - D_i^2)] \\ &\quad + [61D_o(MYD_A)] / (D_o^4 - D_i^4) \\ &= [1.27(316) / 2.84] + [61(3.500)(1 + 2001)] / 61.47 = 836 \end{aligned}$$

The principal stress for the discharge nozzle, P_D , is calculated using Equation F-6B:

$$\begin{aligned} P_D &= (\sigma_D / 2) + (\sigma_D^2 / 4 + \tau_D^2)^{0.5} < 5950 \\ &= (+14131 / 2) + [(+14131)^2 / 4 + (+836)^2]^{0.5} = \\ &\quad +14181 > 5950 \end{aligned}$$

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		Pressure Range	Material Class	See Reference Note
	°C	°F			
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	>95	>200	All	C-6	
	>95	>200	All	S-6	
Boiler circulator	>95	>200	All	C-6	
Foul water, reflux drum water, water draw, and hydrocarbons containing these waters, including reflux streams	<175	<350	All	S-3 or S-6	6
	>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, and heavy lube oils; fuel oil; residuum; crude oil; asphalt; synthetic crude bottoms	<230	<450	All	S-1	
	230-370	450-700	All	S-6	6, 7
	>370	>700	All	C-6	6
Noncorrosive hydrocarbons, e.g., catalytic reformat, 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 ₂ S)	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
	<230	<450	All	A-8	6
Hydrofluoric acid concentration of >96%	<38	<100	All	S-9	6

General Notes:

- The materials for pump parts for each material class are given in Appendix H.
- Specific materials recommendations should be obtained for services not clearly identified by the service descriptions listed in this table.
- 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.
- 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:

- Oxygen content and buffering of water should be considered in material selection.
- 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.
- 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.
- All welds shall be stress relieved.
- Alloy 20 or Monel pump material and dual mechanical seals should be used with a pressurized seal oil system.
- For seawater service, the purchaser and the vendor should agree on the construction materials that best suit the intended use.
- 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	Material Class and Material Abbreviations ^a											D-1	
	I-1	I-2	S-1	S-3	S-4	S-5	S-6	S-8	S-9	C-6	A-7		A-8
Pressure Casing	CI	CI	STL	STL	STL	STL	STL	STL	STL	STL	STL	316AUS	DUPLEX
Inner case parts (bowls, diffusers, diaphragms)	CI	BRZ	CI	NI-RESIST	STL	316 AUS (1&2)	DUPLEX						
Impeller	Cast iron	Cast iron	Cast iron	Cast iron	Cast iron	Cast iron	Cast iron	Cast iron	Cast iron	Cast iron	Cast iron	AUS	Duplex
Case wear rings	Cast iron	Bronze	Cast iron	Cast iron	Cast iron	Cast iron	Cast iron	Cast iron	Cast iron	Cast iron	Cast iron	316 AUS	Duplex
Impeller wear rings	Cast iron	Bronze	Cast iron	Cast iron	Cast iron	Cast iron	Cast iron	Cast iron	Cast iron	Cast iron	Cast iron	316 AUS (3)	Duplex (3)
Shaft (2)	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	316 AUS (3)	Duplex (3)
Shaft sleeves, packed pumps	12% CHR hardened	Hard bronze	12% CHR hardened	12% CHR hardened or hard faced	316 AUS (3)	Duplex (3)							
Shaft sleeves, mechanical seals	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	AUS or 12% CHR	AUS or 12% CHR	AUS or 12% CHR	316 AUS	Duplex
Throat bushings	Cast iron	Bronze	Cast iron	Ni-resist	Cast iron	316 AUS	Duplex						
Interstage sleeves	Cast iron	Bronze	Cast iron	Ni-resist	Cast iron	316 AUS	Duplex						
Interstage bushings	Cast iron	Bronze	Cast iron	Ni-resist	Cast iron	316 AUS	Duplex (3)						
Seal gland	316 AUS (5)	316 AUS (5)	316 AUS (5)	316 AUS (5)	316 AUS (5)	316 AUS (5)	316 AUS (5)	316 AUS (5)	316 AUS (5)	316 AUS (5)	316 AUS (5)	316 AUS (5)	Duplex (3)
Case and gland studs	Carbon steel	Carbon steel	AISI 4140 steel	AISI 4140 steel	AISI 4140 steel	AISI 4140 steel	AISI 4140 steel	AISI 4140 steel	AISI 4140 steel	AISI 4140 steel	AISI 4140 steel	AISI 4140 steel	Duplex (5)
Case gasket	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)	AUS, spiral wound (6)	AUS, spiral wound (6)	AUS, spiral wound (6)	AUS, spiral wound (6)	316 AUS spiral wound (6)	Duplex SS spiral wound (6)
Discharge head / suction can	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	316 AUS	Duplex
Column / bowl shaft bushings	Nitride (7)	Bronze	Filled carbon	Nitride (7)	Filled carbon	Filled carbon	Filled carbon						
Wetted fasteners (bolts)	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	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

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 VSS) 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-1).
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 material 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 BSI	France AFNOR	Japan JIS
		ASTM	UNS	ISO	17007	GG-25	17006			
Cast Iron	Pressure Castings	A 278 Class 30	F 12401	183/Gr. 250	0.6025	GG-25	17006	1452 Gr. 220		G 5501, FC 300
	General Castings	A 48 Class 25/30	F 11 701/ F 12 101	183/Gr. 300	0.6030	GG-30		1452 Gr. 220	FLG 250/300	G 5501, FC 250/300
	Pressure Castings	A 216 Gr WCB	J 03 002		1.0619	GS-C25		1504 161 Gr. 480	A 480 CP-M	G 5151, CI SCP11 2
	Wrought/Forgings	A 266 Class 2	K 03506	683-18-C25	1.0402	C 22		1503 221 490	AC 48CP	G 3202, CI SFVC 2A
	Bar Stock: Pressure	A 695 Gr B40	G 10 200	683-18-C25	1.0402	C 22			AC 48CP	G 4051, CI S25C
	Bar Stock: General	A 576 Gr 1045	G 10 450	683-18-C 45e	1.0503	C 45		970 080 1450	Z 10 C13	G 4051, CI 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, CI SNB7
	Nuts	A 194 Gr 2H	K 04 002	683-1-C35e	1.1181	CRK35		1506 162	2C35	G 4051, CI S45C
	Plate	A 516 Gr 65/70	K 02 403/ K 02 700		1.0254	St. 37.0		10028 265 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	G 3456, Gr STPT 370410
AISI 4140 Steel	Fittings	A 105	K 03 504		1.0308	St. 35.0		1503 221 490	AF 48N	G 4051, CI S25C
	Bar Stock	A 434 CLASS BB	G 41 400*	683-2-3	1.7225	42 Cr Mo 4		970 708 M 40	42 Cr Mo 4	G 4105, CI SCM 440
	Bolts and Studs	A 193 Gr B7	G 41 400		1.7711	40 Cr Mo V 4 7		1506 630 790	42 Cr Mo 4	G 4107, CI SNB16
	Nuts	A 194 Gr 2H	K 04 002	2604-2-F31	1.7258	24 Cr Mo 5		1506 162	45 D2	G 4051, CI S45C
	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, CI 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, CI SCS 6
	Wrought/Forgings: Pressure	A 182 Gr F6a Class 1	S 41 000	683-13-3	1.4006	X 10 Cr 13		1503 410 S21	Z 10 C13	G 3214, CI SUS F6 B
	Wrought/Forgings: General	A 473 Type 410	S 41 000	683-13-3	1.4313	X 4 Cr Ni 13 4		1503 410 S21	Z 6 CN 13-D4	G 3214, CI SUS F6 NM
	Bar Stock: Pressure	A 479 Type 410	S 41 000	683-13-4	1.4006	X 10 Cr 13		970 410 S21 1503 420 C29	Z 6 CN 13-D4 Z 10 C13	G 3214, CI SUS F6 NM G 4303 or 410
	Bar Stock: General	A 276 Type 410	S 41 400							
12 % Chrome Steel	Bar Stock/Forgings	A 276 Type 420	S 42 000	683-13-4	1.4021	X 20 Cr 13		970 420 S37	Z 20 C13	G 4303, Gr SUS 403 or 420
	Wear Parts*	A 473 Type 416	S 41 000		1.4923	X22 Cr Mo V12 1		1506 410 S21 760	Z 13 C13	G 4303, Gr SUS 403 or 420
	Bolts and Studs*	A 193 Gr B6	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
	Nuts*	A 194 Gr 6	S 41 000		1.4006	X 10 Cr 13		970 410 S21	Z 13 C13	G 4304 / 4305 or 410
	Plate	A 240 Type 410	S 41 000	683-13-3	1.4006	X 10 Cr 13				

Table H-2—International Materials for Pump Parts (Continued)

Material Class	Applications	U.S.A.		International ISO	Germany-DIN		Great Britain BSI	France AFNOR	Japan JIS
		ASTM	UNS		17007	17006			
Austenitic Stainless Steel	Pressure Castings	A 351 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, CI SCS1 3A
		A 743 Gr CF3			1.4404				
	Wrought/Forgings	A 351 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, CI SCS1 4A 02M
		A 744 Gr CF3M	S 30 403	683-13-10	1.4306	X 2 Cr Ni 19 11	1503 304 S11	Z3 CN 18-10	G 3214, CI SUS F 304 L
	Bar Stock	A 182 Gr F 304L	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, CI SUS F 316 L
		A 479 Type 304 L	S 30 403	683-13-10	1.4306	X 2 Cr Ni 19 11	970 304 S11	Z3 CN 18-10	G 4303, SUS F 304 L
	Plate	A 479 Type 316L	S 31 603	683-13-19	1.4404	X 2 Cr Ni Mo 17 13 2	970 316 S11	Z3 CND-17-12-02	G 4303, SUS F 316 L
		A 479 Type XM19 ^a	S 20 910						A 479 TY X M 19
	Pipe	A 240 Gr 304L / 316L	S 30 403 / S 31 603	683-13-10 / 683-13-19	1.4306 / 1.4404	X 2 Cr Ni 19 11 / X 2 Cr Ni Mo 17 13 2	970 304 S11 / 970 316 S11	Z3 CN 18-10 / Z3 CNP 17-12-02	G 4304/5, Gr 304L / 316L
		A 312 Type 304L / 316L	S 30 403 / S 31 603	683-13-10 / 683-13-19	1.4306 / 1.4404	X 2 Cr Ni 19 11 / X 2 Cr Ni Mo 17 13 2	3605 304 S11 / 3605 316 S11	TU22 CN 18-10 / TU22 CND 17-12-02	G 3459, Gr 304L/TP316L/TP
	Fittings	A 182 Gr F304L	S 30 403	683-13-10	1.4306	X 2 Cr Ni 19 11	1503 304 S11	Z3 CN 18-10	G 3214, Gr SUS 304L / 316L
		A 182 Gr F316L	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 4303, Gr SUS 316
	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, Gr SUS 316
		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, Gr SUS 316
Nuts	A 890 Gr 3A	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, Gr SUS 316	
	A 890 Gr 3A	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, Gr SUS 316	
Pressure Castings	A 890 Gr 3A	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, Gr SUS 316	
	A 351 Gr CD4 MCu	J 933370		1.4468	G-X 3 Cr Ni Mo N 26 6 3		Z6 CND 26-5-02M	G 5121, CI SCS 11	
Wrought/Forgings	A 182 Gr F 51	S 31 803		1.4462	X 2 Cr Ni Mo N 22 5	1503 318 S13	Z3 CND 22-05AZ	A 351, Gr CO 4 MCU	
	A 276-S31803	S 31 803		1.4462	X 2 Cr Ni Mo N 22 5	1503 318 S13	Z3 CND 22-05AZ	G 4319, CI SUS 329	
Bar Stock	A 276-S31803	S 31 803		1.4462	X 2 Cr Ni Mo N 22 5	1503 318 S13	Z3 CND 22-05AZ	G 4303, Gr SUS 329 Gr SUS 329	
	A 276-S31803	S 31 803		1.4462	X 2 Cr Ni Mo N 22 5	1503 318 S13	Z3 CND 22-05AZ	G 4303, Gr SUS 329	
Plate	A 240-S31803	S 31 803		1.4462	X 2 Cr Ni Mo N 22 5	1503 318 S13	Z3 CND 22-05AZ	G 4303, Gr SUS 329	
	A 240-S31803	S 31 803		1.4462	X 2 Cr Ni Mo N 22 5	1503 318 S13	Z3 CND 22-05AZ	G 4303, Gr SUS 329	
Pipe	A 182 Gr F 51	S 31 803		1.4462	X 2 Cr Ni Mo N 22 5	1503 318 S13	Z3 CND 22-05AZ	G 4303, Gr SUS 329	
	A 276-S31803	S 31 803		1.4462	X 2 Cr Ni Mo N 22 5	1503 318 S13	Z3 CND 22-05AZ	G 4303, Gr SUS 329	
Fittings	A 182 Gr F 51	S 31 803		1.4462	X 2 Cr Ni Mo N 22 5	1503 318 S13	Z3 CND 22-05AZ	G 4303, Gr SUS 329	
	A 276-S31803	S 31 803		1.4462	X 2 Cr Ni Mo N 22 5	1503 318 S13	Z3 CND 22-05AZ	G 4303, Gr SUS 329	
Bolts and Studs	A 182 Gr F 51	S 31 803		1.4462	X 2 Cr Ni Mo N 22 5	1503 318 S13	Z3 CND 22-05AZ	G 4303, Gr SUS 329	
	A 276-S31803	S 31 803		1.4462	X 2 Cr Ni Mo N 22 5	1503 318 S13	Z3 CND 22-05AZ	G 4303, Gr SUS 329	
Nuts	A 182 Gr F 51	S 31 803		1.4462	X 2 Cr Ni Mo N 22 5	1503 318 S13	Z3 CND 22-05AZ	G 4303, Gr SUS 329	
	A 276-S31803	S 31 803		1.4462	X 2 Cr Ni Mo N 22 5	1503 318 S13	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 conditions 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.

- ^aNot suitable for shafts.
- ^bSpecial, normally use AISI 4140
- ^cUNS (unified numbering system) designation for chemistry only.
- ^dNitronic 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. Type 1 tungsten carbide—as required for service conditions, with cobalt binder (solid part, not overlay); Type 2 tungsten carbide—as required for service conditions, with nickel binder (solid part, not overlay); 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): ASTM B564, UNS N10276 (forgings) ASTM B574, UNS N10276 (bar and rod) ASTM B575, UNS N10276 (plate, sheet, and strip) ASTM A494, Grade CW-2M (weldable cast)
Nickel copper alloy	Monel (Huntington Alloys) Alloy 400 (or the equivalent): ASTM B564, UNS N04400 (forgings) ASTM B164, Class A, UNS N04400 (bar and rod) ASTM B127, UNS N04400 (plate, sheet, and strip) ASTM A494, Grade M30C (weldable cast)
Ni resist	ASTM A436, Type 1, 2, or 3, UNS F41000 / F41002 / F41004 respectively (austenitic cast iron); 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): ASTM B637, UNS N07718 (forgings and bars) ASTM B670, UNS N07718 (plate, sheet, and strip)
Precipitation hardening stainless steel	ASTM A564, Grade 630, UNS S17400 or Grade 631, UNS 17700 (wrought) 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 sealing-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

- 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.
- 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.
- A metal seal ring shall not have sprayed overlay in place of a solid face.
- 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.
- 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*				
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

*Consult manufacturer for minimum and maximum ambient pumping temperature.

^bMaximum 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:

- 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.
- Stiffness and damping at the shaft seals (if labyrinth type).
- Stiffness and damping within the bearings for the average clearance and oil temperature; see the note following the lists.
- Mass and stiffness of the bearing support structure.
- Inertia of the pump half coupling hub and half the coupling spacer.

The report shall state the following:

- Those natural frequencies with a damping ratio less than 0.4.
- 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 de-

veloped 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, ξ , is related to logarithmic decrement, δ , by the equation:

$$\delta = 2\pi \xi / (1 - \xi^2)^{0.5}$$

For ξ up to 0.4, the following approximate relationships between ξ , δ , 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:

- The pumped liquid.
- Clearances at new and 2× new values.
- 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).

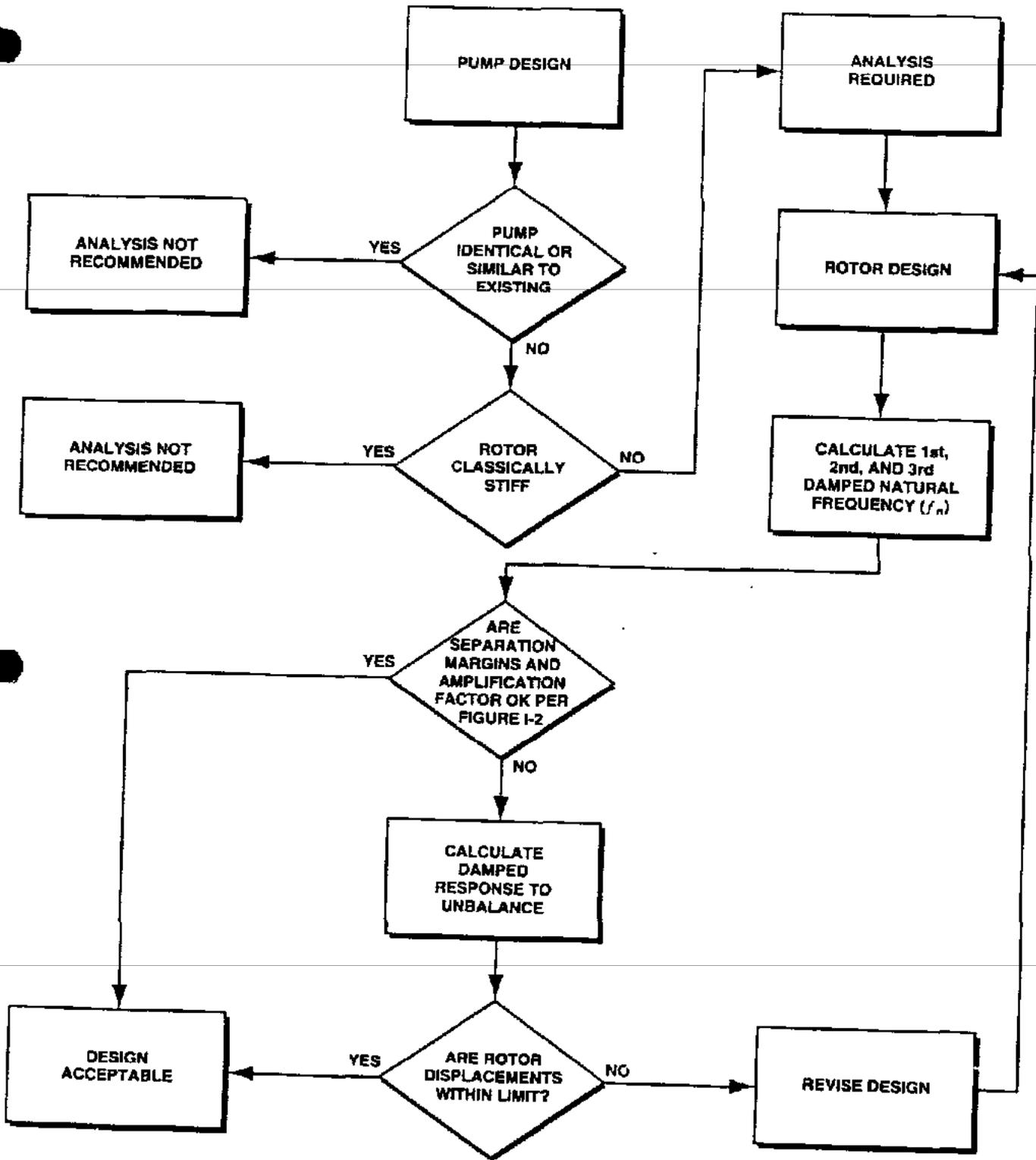


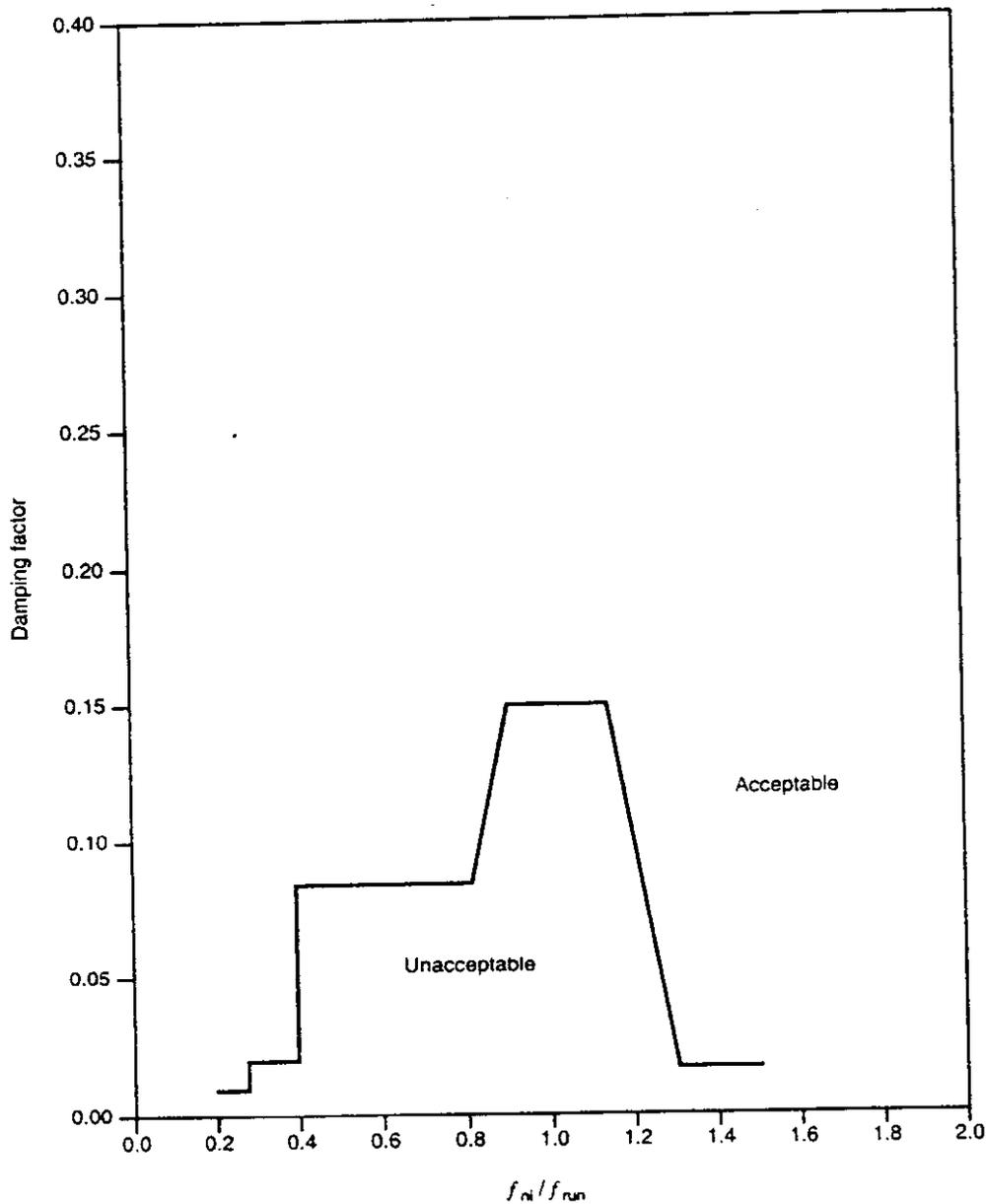
Figure I-1—Rotor Lateral Analysis Logic Diagram

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.

1.2.2 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:

- With the rotor as built.
- With trial unbalance weights added 90 degrees from the maximum displacement in run a.



Note: f_{ni} - i^{th} natural frequency

f_{run} - running frequency
minimum to maximum
continuous

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.

1.2.3 During the test, the rotor's speed, vibration displacement, and corresponding phase angle, filtered to rotor speed (1X), shall be measured and recorded.

1.2.4 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.

1.2.5 If the acceptance criteria given in 1.2.4 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 ro-

tor'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.

1.2.6 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.

1.3 Documentation

1.3.1 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.

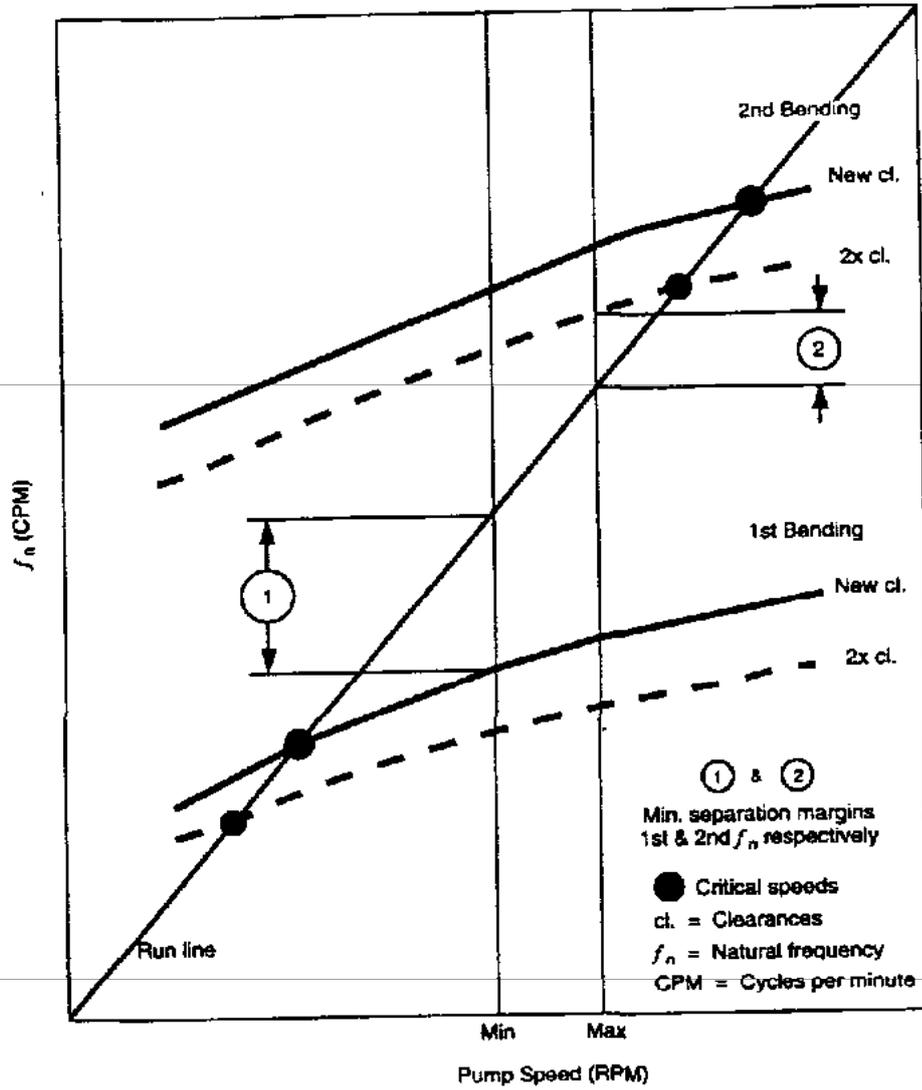


Figure I-3—Typical Campbell Diagram

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 po-

sitions (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)
 $6350 \times$ _____ kg/_____ rpm; $4 \times$ _____ lbs/_____ rpm
 _____ g•mm (oz-in.)

Trial unbalance ($2 \times U_{max}$) _____ 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

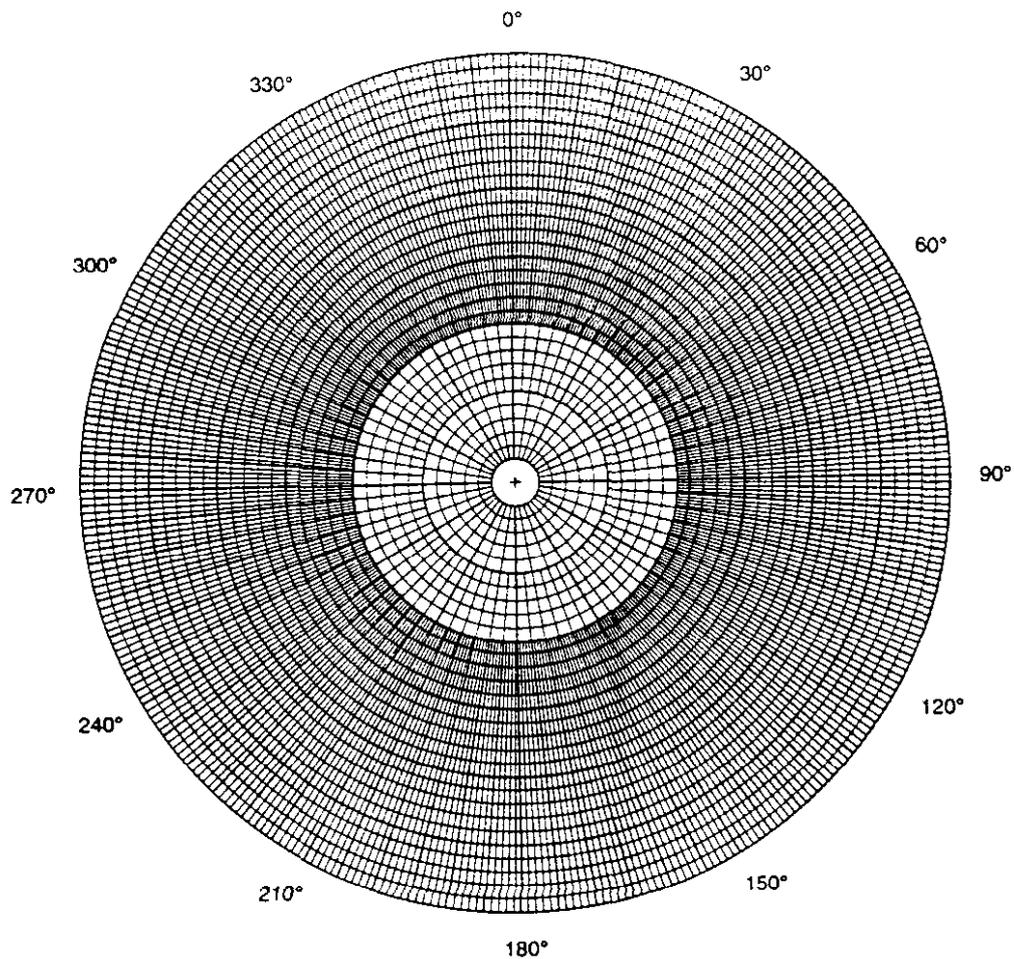
Test Data—Graphic Analysis

- 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:

- The trial weight angular location should be referenced to a keyway or some other permanent marking on the rotor.
- 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 (closest to this correction plane):

908 kg-(lbs)

U_{max} —Maximum Allowable Residual Unbalance =

$6350 W/N$ (4 W/N)

$6350 \times \frac{\text{kg}}{\text{rpm}}; 4 \times \frac{908 \text{ lbs}}{10,000 \text{ rpm}}$

0.36 g-mm (oz-in.)

Trial unbalance ($2 \times U_{max}$)

0.72 g-mm (oz-in.)

R —Radius (at which weight will be placed):

6.875 mm (in.)

Trial Unbalance Weight = Trial Unbalance/ R

$\frac{\text{g-mm}}{\text{mm}}; \frac{0.72 \text{ oz-in.}}{6.875 \text{ in.}}$

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 Data—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.

Step 4: Record the trial unbalance from above.

Step 5: Double the trial unbalance in Step 4 (may use twice the actual residual unbalance).

Step 6: Divide the answer in Step 5 by the answer in Step 3.

35 units

0.72 g-mm (oz-in.)

1.44 g-mm (oz-in.)

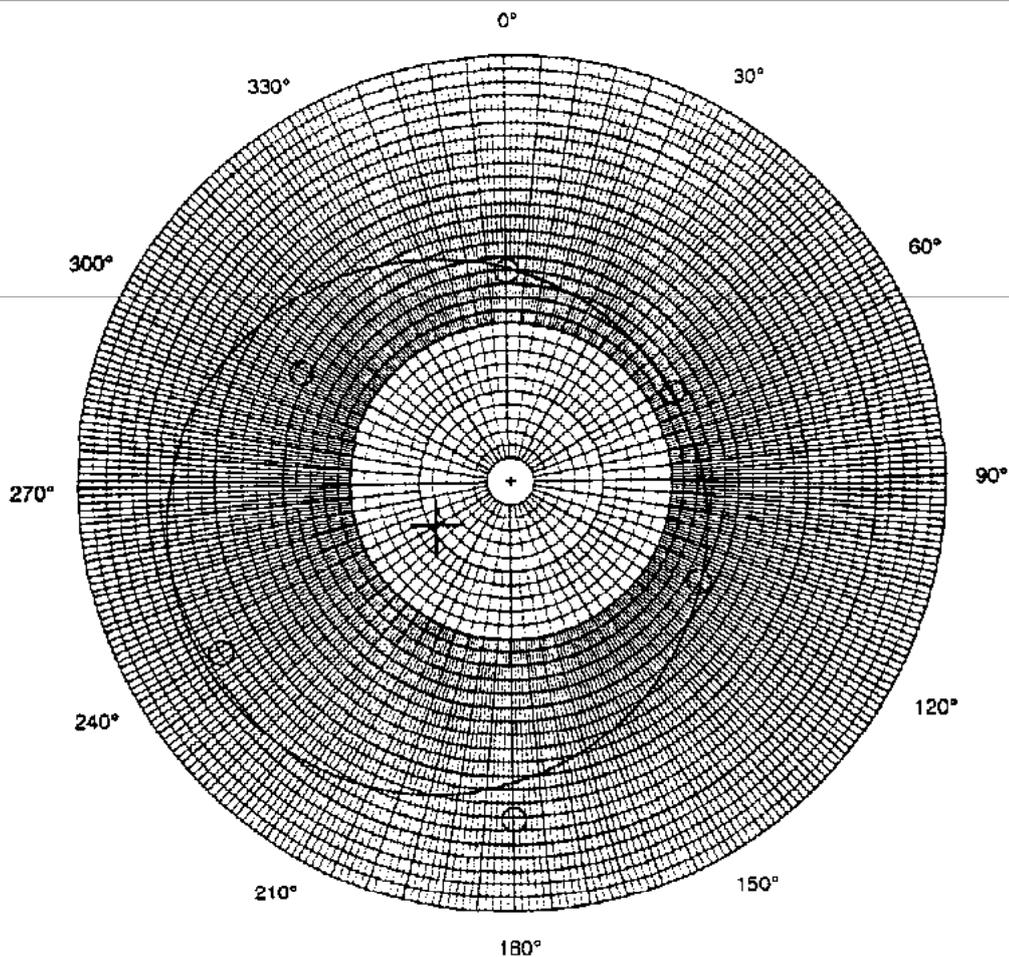
0.041 Scale Factor

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.)

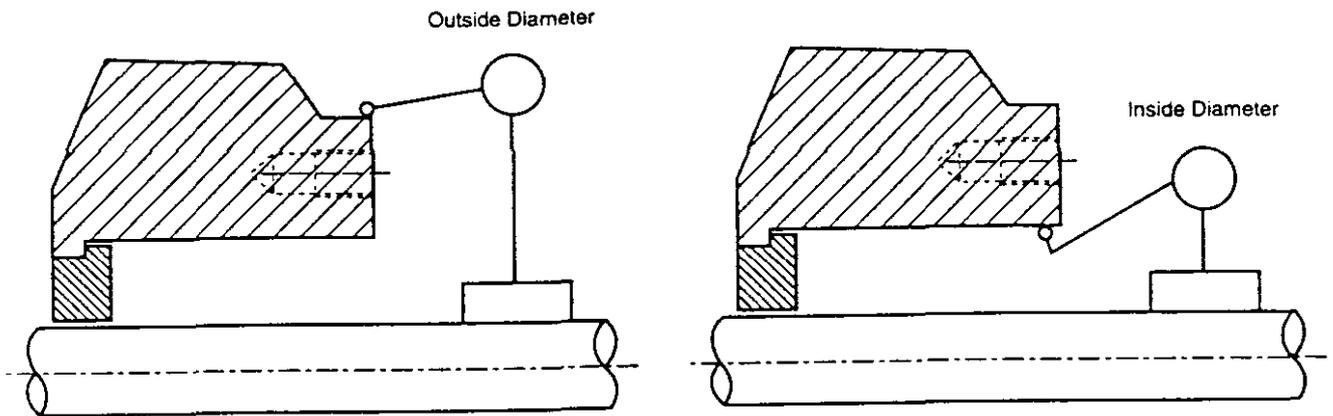
Correction plane A for Rotor No. C-101 (has/has not) passed.

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)

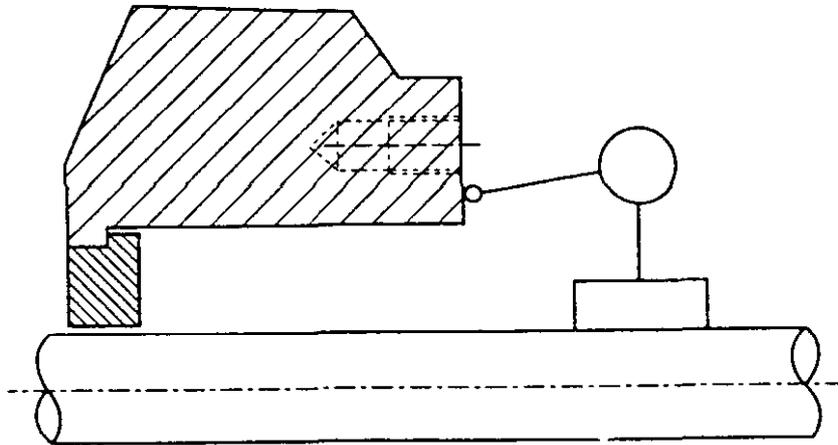


Figure K-2—Seal Chamber Face Runout (2.7.3.13)

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 $5 \mu\text{m}/\text{mm}$ (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 $54 \times 10^{-6} \text{ mm}/\text{mm}/^\circ\text{C}$ ($30 \times 10^{-6} \text{ in.}/\text{in.}/^\circ\text{F}$) 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 overlaid 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 $1.2 \times 10^4 \text{ MPa}$ ($1.8 \times 10^6 \text{ psi}$).

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 \times 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 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

ASTM¹

- 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*

¹American Society for Testing and Materials, 1916 Race Street, Philadelphia, Pennsylvania 19103-1187.

- C 579 *Standard Test Method for Compressive Strength of (Method B) Chemical Resistant Mortars and Monolithic Surfacing*
- 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 Engineers²

- CRD C611 *Test Methods for Flow Grout Mixtures (Flowcone Method)*
- CRD C621 *Corps of Engineers Specification for Non-shrink Grout*

²U.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	840/33.0	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	2755/108.5	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.

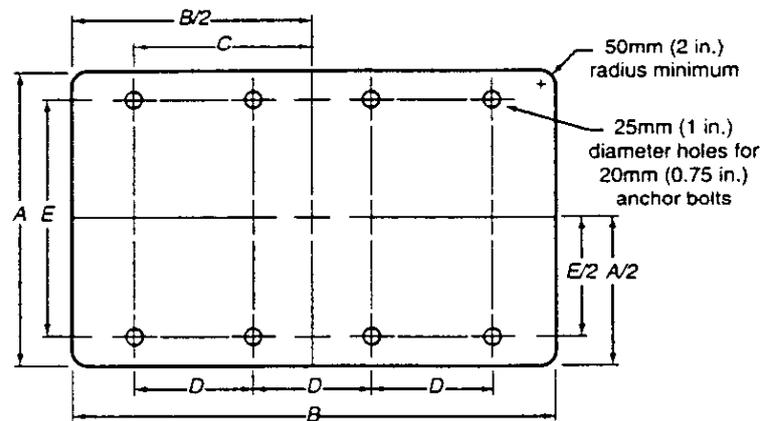


Figure M-1—Schematic for API 610 Standard Baseplates

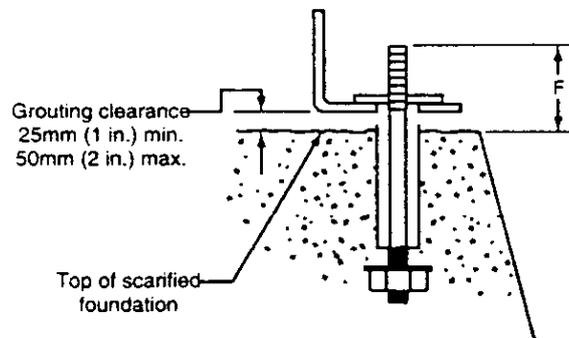


Figure M-2—Anchor Bolt Projection

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 4.4.3.5 4.4.3.11 4.4.5				
Painting	4.4.3.3				
Preparation for shipment	4.4.1				
Shipping documents and tags	4.4.3.10				

^aCheck 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 4.2.2.1				
Hydrotest witnessed	4.3.2.1				
Building record (runouts, clearances)	2.5.6 2.5.10 2.6.4.2 5.2.2.3 5.3.2.2 5.3.3.2 5.3.7.2 5.3.11.8				
Performance and NPSH tests witnessed	4.3.3 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 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 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 _____
 REVISION _____
 UNIT _____
 NO. REQUIRED _____

FOR _____
 SITE _____
 SERVICE _____

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 _____

DESCRIPTION

No.	Description	Final ^c	Review ^b						
	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.								

^aProposal drawings and data do not have to be certified or as built. Typical data shall be clearly identified as such.

^bPurchaser will indicate in this column the time frame for submission of materials using the nomenclature given at the end of this form.

^cBidder 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 _____

DESCRIPTION

		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							
		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.							

^aProposal drawings and data do not have to be certified or as-built. Typical data shall be clearly identified as such.

^bPurchaser will indicate in this column the time frame for submission of materials using the nomenclature given at the end of this form.

^cBidder 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	Yes	No
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 ₂ S 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	Yes	No
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	Yes	No
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 DATA	{start of additional perating 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.

- Pump Data group. This group is mandatory for each record.
- Additional Data group. This group is optional for each record.
- Dimensional Data group. This group is optional for each record.
- Nozzle Load Data group. This group is optional for each record.
- 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.
- 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:

- 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

- Delimiter:** The delimiter is a comma (,) to separate the Field Number from the Field Value.
- 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.
- 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 definitions 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/Errusive 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	<p>OVERHUNG TYPE:</p> <p>OH1:foot mounted/horizontal/flexibly coupled</p> <p>OH2:center line mounted/horizontal/flexibly coupled</p> <p>OH3:in-line bearing frame/vertical/flexibly coupled</p> <p>OH4:in-line/vertical/rigidly coupled</p> <p>OH5:high speed integral gear/rigidly coupled</p> <p>BETWEEN BEARINGS TYPE:</p> <p>BB1:axially split/1 or 2 stages</p> <p>BB2:radially split/1 or 2 stage</p> <p>BB3:axially split/multistage</p> <p>BB4:single case/radially split/multistage</p> <p>BB5:double case/radially split/multistage</p> <p>VERTICAL SUSPENDED TYPE:</p> <p>VS1:single case/discharge through column/diffuser</p> <p>VS2:single case/discharge through column/volute</p> <p>VS3:single case/discharge through column/axial flow</p> <p>VS4:single case/seperate discharge/line shaft</p> <p>VS5:single case/seperate discharge/cantilever</p> <p>VS6:double case (canned)/diffuser</p> <p>VS7:double case (canned)/volute</p> <p>Z:Other</p>
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:separate 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	m³/h
A302	Flush minimum flowrate	FLUSH_MIN	N	13	m³/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	m³/h
A318	Barrier flow minimum	BARR_FL_MN	N	13	m³/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
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					
A471	Vendor having unit responsibility	VNDR_RESP	C	50	
A472	Governing specification	GOVN_SPEC	C	50	
A473	Specification remark	SPEC_REMKS	C	140	
Surface Preparation and Painting					
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/(m ³ /h)
B056	Rated head term 3	R_HTERM3	N	13	m/(m ³ /h) ²
B057	Rated head term 4	R_HTERM4	N	13	m/(m ³ /h) ³
B058	Rated head term 5	R_HTERMS	N	13	m/(m ³ /h) ⁴
B059	Rated head term 6	R_HTERM6	N	13	m/(m ³ /h) ⁵
B060	Rated head term 7	R_HTERM7	N	13	m/(m ³ /h) ⁶
B061	Rated stop capacity	R_STP_CAP	N	13	m ³ /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/(m ³ /h)
B064	Rated power term 3	R_PTERM3	N	13	kW/(m ³ /h) ²
B065	Rated power term 4	R_PTERM4	N	13	kW/(m ³ /h) ³
B066	Rated power term 5	R_PTERM5	N	13	kW/(m ³ /h) ⁴
B067	Rated power term 6	R_PTERM6	N	13	kW/(m ³ /h) ⁵
B068	Rated power term 7	R_PTERM7	N	13	kW/(m ³ /h) ⁶
B069	Rated NPSH term 1	R_NTERM1	N	13	m
B070	Rated NPSH term 2	R_NTERM2	N	13	m/(m ³ /h)
B071	Rated NPSH term 3	R_NTERM3	N	13	m/(m ³ /h) ²
B072	Rated NPSH term 4	R_NTERM4	N	13	m/(m ³ /h) ³
B073	Rated NPSH term 5	R_NTERM5	N	13	m/(m ³ /h) ⁴
B074	Rated NPSH term 6	R_NTERM6	N	13	m/(m ³ /h) ⁵
B075	Rated NPSH term 7	R_NTERM7	N	13	m/(m ³ /h) ⁶
B076	Rated NPSH start capacity	R_NSTART	N	13	m ³ /h
B077	Maximum diameter head term 1	T_HTERM1	N	13	m
B078	Maximum diameter head term 2	T_HTERM2	N	13	m/(m ³ /h)
B079	Maximum diameter head term 3	T_HTERM3	N	13	m/(m ³ /h) ²
B080	Maximum diameter head term 4	T_HTERM4	N	13	m/(m ³ /h) ³
B081	Maximum diameter head term 5	T_HTERM5	N	13	m/(m ³ /h) ⁴
B082	Maximum diameter head term 6	T_HTERM6	N	13	m/(m ³ /h) ⁵
B083	Maximum diameter head term 7	T_HTERM7	N	13	m/(m ³ /h) ⁶
B084	Maximum diameter power term 1	T_PTERM1	N	13	kW
B085	Maximum diameter power term 2	T_PTERM2	N	13	kW/(m ³ /h)
B086	Maximum diameter power term 3	T_PTERM3	N	13	kW/(m ³ /h) ²
B087	Maximum diameter power term 4	T_PTERM4	N	13	kW/(m ³ /h) ³
B088	Maximum diameter power term 5	T_PTERM5	N	13	kW/(m ³ /h) ⁴
B089	Maximum diameter power term 6	T_PTERM6	N	13	kW/(m ³ /h) ⁵
B090	Maximum diameter power term 7	T_PTERM7	N	13	kW/(m ³ /h) ⁶
B091	Maximum diameter start flow	T_START	N	13	m ³ /h
B092	Maximum diameter stop flow	T_STOP	N	13	m ³ /h
B093	Minimum diameter head term 1	B_HTERM1	N	13	m
B094	Minimum diameter head term 2	B_HTERM2	N	13	m/(m ³ /h)
B095	Minimum diameter head term 3	B_HTERM3	N	13	m/(m ³ /h) ²
B096	Minimum diameter head term 4	B_HTERM4	N	13	m/(m ³ /h) ³
B097	Minimum diameter head term 5	B_HTERM5	N	13	m/(m ³ /h) ⁴
B098	Minimum diameter head term 6	B_HTERM6	N	13	m/(m ³ /h) ⁵
B099	Minimum diameter head term 7	B_HTERM7	N	13	m/(m ³ /h) ⁶
B100	Minimum diameter power term 1	B_PTERM1	N	13	kW
B101	Minimum diameter power term 2	B_PTERM2	N	13	kW/(m ³ /h)
B102	Minimum diameter power term 3	B_PTERM3	N	13	kW/(m ³ /h) ²
B103	Minimum diameter power term 4	B_PTERM4	N	13	kW/(m ³ /h) ³
B104	Minimum diameter power term 5	B_PTERM5	N	13	kW/(m ³ /h) ⁴
B105	Minimum diameter power term 6	B_PTERM6	N	13	kW/(m ³ /h) ⁵
B106	Minimum diameter power term 7	B_PTERM7	N	13	kW/(m ³ /h) ⁶
B107	Minimum diameter start flow	B_START	N	13	m ³ /h
B108	Minimum diameter stop flow	B_STOP	N	13	m ³ /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 hold 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 bolt 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 from 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

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

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

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/Errusive 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/(m ³ /h)
E035	Rated head term 3	ER_HTERM3	N	13	m/(m ³ /h) ²
E036	Rated head term 4	ER_HTERM4	N	13	m/(m ³ /h) ³
E037	Rated head term 5	ER_HTERM5	N	13	m/(m ³ /h) ⁴
E038	Rated head term 6	ER_HTERM6	N	13	m/(m ³ /h) ⁵
E039	Rated head term 7	ER_HTERM7	N	13	m/(m ³ /h) ⁶
E040	Rated stop capacity	ER_STP_CAP	N	13	m ³ /h
E041	Rated power term 1	ER_PTERM1	N	13	kW
E042	Rated power term 2	ER_PTERM2	N	13	kW/(m ³ /h)
E043	Rated power term 3	ER_PTERM3	N	13	kW/(m ³ /h) ²
E044	Rated power term 4	ER_PTERM4	N	13	kW/(m ³ /h) ³
E045	Rated power term 5	ER_PTERM5	N	13	kW/(m ³ /h) ⁴
E046	Rated power term 6	ER_PTERM6	N	13	kW/(m ³ /h) ⁵
E047	Rated power term 7	ER_PTERM7	N	13	kW/(m ³ /h) ⁶
E048	Rated NPSH term 1	ER_NTERM1	N	13	m
E049	Rated NPSH term 2	ER_NTERM2	N	13	m/(m ³ /h)
E050	Rated NPSH term 3	ER_NTERM3	N	13	m/(m ³ /h) ²
E051	Rated NPSH term 4	ER_NTERM4	N	13	m/(m ³ /h) ³
E052	Rated NPSH term 5	ER_NTERM5	N	13	m/(m ³ /h) ⁴
E053	Rated NPSH term 6	ER_NTERM6	N	13	m/(m ³ /h) ⁵
E054	Rated NPSH term 7	ER_NTERM7	N	13	m/(m ³ /h) ⁶
E055	Rated NPSH start capacity	ER_NSTART	N	13	m ³ /h

Header Data

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

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	m ³ /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 manufacturer	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	m ³ /h
A353	Packing injection pressure	PKG_PRESS	N	13	kPa
A354	Packing lantern ring	PKG_LANTER	C	20	
Cooling Water Piping					
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)

**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	0.0003937	inch	in.
Area	L^2	micrometer	μm^2	0.03937	0.001 inch square	mils
		square meter	m^2	10.764	square feet	ft^2
Velocity	$L \cdot T^{-1}$	square centimeter	cm^2	0.155	square inch	in^2
Volume	L^3	meter/second	m/s	3.28084	feet/second	ft/sec
		millimeter/second	mm/s	0.03937	inches/second	in./sec
Flow Rate	$L^3 \cdot T^{-1}$	cubic meter	m^3	264.2	US Gallons	US Gal.
		liter	l	33.81	fluid ounce	fl. oz.
Mass	M	cubic meter/hour	m^3/h	4.4033	US Gallons/minute	US GPM
		kilogram	kg	2.20462	pounds	lbs
Force	$M \cdot L \cdot T^{-2}$	gram	g	0.035274	ounces	oz.
		Newton	N	0.2248	pound force	lbf
Pressure	$M \cdot L^{-1} \cdot T^{-2}$	Kilopascal	kPa	0.145	pounds/square inch	psi
		Megapascal	MPa	145.0	pounds/square inch	psi
Stress	$M \cdot L^{-1} \cdot T^{-2}$	Newton/mm ²	N/mm^2	145.0	pounds/square inch	psi
		meter	m	3.28084	feet	ft
Density	$M \cdot L^{-3}$	kilogram/cubic meter	kg/m^3	0.062428	pounds/cubic foot	lb/ft^3
Torque	$M \cdot L^2 \cdot T^{-2}$	Newton-meter	Nm	0.7376	pound-foot	$\text{lb} \cdot \text{ft}$
		kilowatt	kW	1.34102	horsepower	HP
Temperature	$M \cdot L^2 \cdot T^{-2}$	Degrees Celsius	C	$(1.8 \times ^\circ\text{C}) + 32$	Degrees Fahrenheit	F
		kilojoule	kJ	0.9478	British thermal unit	BTU
Moment of Inertia	$M \cdot L^2$	kilogram-meter ²	$\text{kg} \cdot \text{m}^2$	23.73	pound	$\text{lb} \cdot \text{ft}^2$
		gram-millimeter	$\text{g} \cdot \text{mm}$	0.001389	ounce-inch	oz-in.

Note:

Units of pressure: 100 kPa = 1 bar (nonpreferred unit); units of stress: 1 Newton/mm² = 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:

δ	logarithmic decrement
μ	prefix for micro (μm=micrometer)
ξ	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

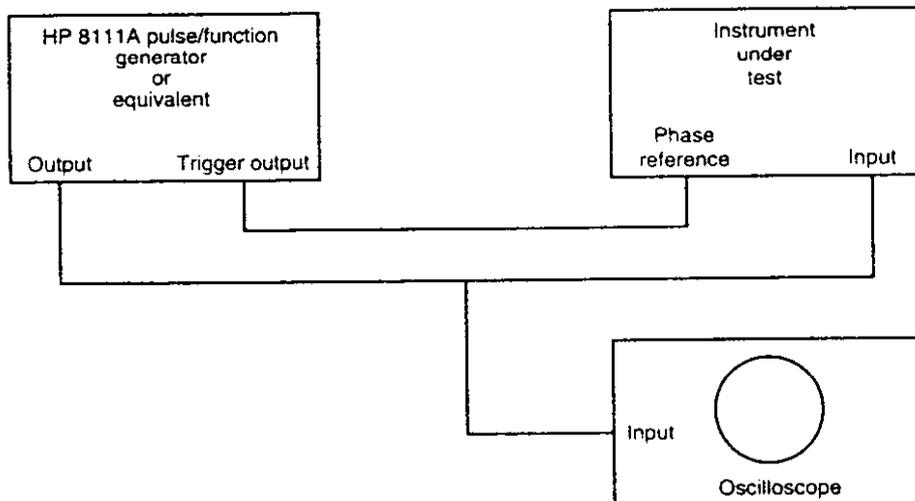


Figure S-1—Instrument Test Setup

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.

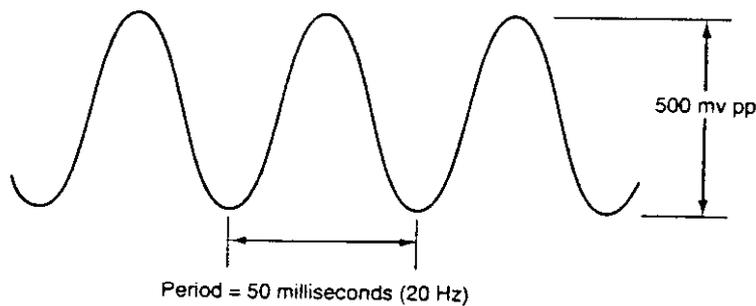


Figure S-2—Sine Wave Signal Showing True Peak

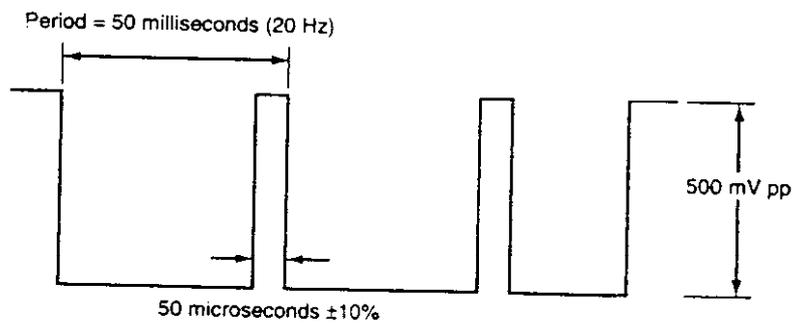


Figure S-3—Pulse Signal Showing True Peak