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

Downstream Segment

API STANDARD 685
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FOREWORD

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

The primary purpose of API standards for mechanical equipment is to establish minimum mechanical requirements. 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 can be based 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 reduce total life costs without sacrifice of safety or reliability.

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CONTENTS

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CONTENTS

Page

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CONTENTS

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

1 Scope

This standard covers the minimum requirements for sealless centrifugal pumps for use in petroleum, heavy duty chemical and gas industry services. Refer to Appendix U for application information.

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 datasheets (see Appendix B) or stated in the quotation request and purchase order.

Single stage pumps of two classifications, Magnetic Drive Pumps (MDP) and Canned Motor Pumps (CMP), are covered by this standard. Sections 2 through 8 and 10 cover requirements applicable to both classifications. Section 9 is divided into two subsections and covers requirements unique to each classification.

For process services not exceeding any of the limits below, purchasers may wish to consider pumps that do not comply with API Standard 685.

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	3600 rpm
Maximum rated total head	120 m	(400 ft)
Maximum impeller diameter	300 mm	(13 in.)

2 Referenced Publications

2.1 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.

2.2 The purchaser will specify whether equipment supplied to this standard shall comply with the applicable ISO standards or applicable US standards.

2.3 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 between the purchaser and the vendor.

3 Definition of Terms

Terms used in this standard are defined in 3.1 through 3.85.

3.1 air gap: The distance between the outer magnet ring and the containment shell or, the total radial dimension between the stator inside bore and the outside diameter of the basic rotor core (armature) prior to installation of stator liner and rotor liner.

3.2 axial thrust: The net axial load on the pump shaft caused by hydraulic forces acting on the impeller shrouds and rotor or inner magnet ring.

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

3.4 BEP: Abbreviation for best efficiency point, the point or capacity at which a pump achieves its highest efficiency.

3.5 canned motor pump: A type of sealless pump which has a common shaft to link pump and motor in a single sealed unit. The pumped liquid, or a flush fluid, is circulated through the motor rotor chamber, but is isolated from the motor electrical components by a thin corrosion-resistant nonmagnetic stator liner (Figure C-2, Appendix C).

3.6 containment shell: The pressure containing boundary located within the drive end that separates the inner and outer magnet rings of a magnetic drive pump (Figures C-1 and C-3, Appendix C).

3.7 coupling (magnetic): The attraction of the magnets of the Inner Magnet Ring and Outer Magnet Ring allowing both to rotate synchronously or asynchronously in the case of a torque ring drive.

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

3.9 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.

3.10 decouple: To break the magnetic linkage between inner and outer magnet rings of a synchronous coupling resulting in a failure of the magnet assemblies to rotate synchronously.

3.11 demagnetization: The loss of magnetic attraction due to such causes as age, or elevated temperature.

3.12 design: Term used by 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.

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

3.14 eddy current losses: Losses from random electrical currents generated in a conductive material when a mag-

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netic field is rotated around it. These losses are normally dissipated as heat due to the electrical resistance of the material.

3.15 electrical feed-through barrier: The static seal in a canned motor pump through which electrical lines feed the motor stator (Figure C-4, Appendix C).

3.16 hydraulic thrust balance: Axial thrust equalization achieved by means of an impeller design, by impeller balance holes or by thrust balancing through variable orifices in the drive end.

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

3.18 hysteresis: The failure of a magnetic material (that has been changed by an external agent) to return to its original magnetic strength when the cause of the change is removed.

3.19 inner magnet ring: The cylindrical band of magnets operating within the containment shell of a magnetic drive pump, driven by the outer magnet ring. The inner magnet ring contains the same number of magnets as the outer magnet ring, and is mounted on the same shaft as the pump impeller (Figure C-3, Appendix C).

3.20 inner magnet sheathing: The protective covering of the inner magnet ring in a magnetic drive pump (Figure C-3, Appendix C).

3.21 journal sleeve: The renewable component of the journal.

3.22 liquid end: The end of the pump which converts mechanical energy to kinetic energy in the pumped fluid.

3.23 liquid gap: The radial distance between the containment shell inside surface and the outside surface of the inner magnet sheathing or the radial distance between the stator liner inside surface and the rotor liner outside surface.

3.24 locked rotor torque: The maximum torque which a motor will develop at rest for all angular positions of the rotor, with rated voltage applied at rated frequency.

3.25 magnetic drive pump: A type of sealless pump which utilizes magnets to drive an internal rotating assembly consisting of an impeller, shaft and inner drive member (torque ring or inner magnet ring) through a thin, corrosion-resistant containment shell (Figure C-1, Appendix C).

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

3.27 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.

3.28 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.

3.29 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.

3.30 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).

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

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

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

3.34 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.

3.35 minimum design metal temperature: The lowest mean metal temperature (through the thickness) expected in service.

3.36 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.

3.37 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.

3.38 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 is the minimum NPSH at rated capacity required to prevent a head drop of more than 3 percent due to cavitation within the pump.

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

3.40 normal wear parts: Those parts normally restored or replaced at each pump overhaul, typically wear rings, throat bushing, bearings, and all gaskets.

3.41 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.

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

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

3.44 operating region: Portion of a pump's hydraulic coverage over which the pump operates.

3.45 preferred operating region: Region over which the pump's vibration is within the base limit of this standard (see 6.1.13).

3.46 allowable operating region: 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 6.1.13).

3.47 outer magnet ring: The band of permanent magnets securely fixed to a cylindrical frame and evenly spaced to provide a uniform magnetic field. The outer magnet ring rotates about the containment shell, driving the inner magnet ring or torque ring.

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

3.49 pole: The region of a magnet where flux density is concentrated.

3.50 power end: The end of the pump that provides the mechanical energy necessary for the operation of the liquid end.

3.51 primary pressure casing: The composite of all stationary pressure-containing parts of the unit, including the stator liner or containment shell (see Figures C-1 and C-2, Appendix C).

3.52 product lubricated bearings: Bearings and journals that operate in a pumped liquid lubricated environment to support the shaft of the inner magnet ring of a magnetic drive pump or the rotor assembly of a canned motor pump.

3.53 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.

3.54 radial loading: The side load perpendicular to the pump shaft and drive shaft due to unbalanced hydraulic loading on the impeller, mechanical and magnetic rotor unbalance, rotor assembly weight, and forces of the fluid circulating through the rotor chamber.

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

3.56 rated operating point: The point at which the vendor certifies that pump performance is within the tolerances stated in this standard (see 8.3.3.3.3).

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

3.58 rotor: The assembly of all the rotating parts of a centrifugal pump.

3.59 rotor chamber: The liquid filled cavity bounded by the inside diameter of the stator liner and the bearing housings in a canned motor pump or the liquid filled cavity in a magnetic drive pump internal to the containment shell which contains the inner magnet ring, shaft, and bearings.

3.60 rotor chamber temperature rise: The temperature increase of the fluid circulated through the rotor chamber. It is the difference between the temperature of the fluid leaving the rotor chamber and that entering.

3.61 rotor liner: The outer sheathing of the rotor assembly in a canned motor pump (Figure C-4, Appendix C).

3.62 sealless pump: A design that does not require an external dynamic shaft seal. Static seals are the primary method of containing the fluid.

3.63 secondary containment: The confinement of the pumped liquid within a secondary pressure casing in the event of failure of the primary containment shell or stator liner.

3.64 secondary containment system: A combination of devices that, in the event of leakage from the primary containment shell or stator liner, confines the pumped liquid within a secondary pressure casing that includes provisions to indicate a failure of the primary containment shell or stator liner.

3.65 secondary control: The minimization of release of pumped liquid in the event of failure of the containment shell or stator liner.

3.66 secondary control system: The combination of devices (including a secondary pressure casing) that, in the event of leakage from the containment shell or stator liner, minimizes and safely directs the release of pumped liquid. It includes provision(s) to indicate a failure of the containment shell or liner.

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3.67 secondary pressure casing: The composite of all pressure containing parts of the unit which are exposed to pressure resulting from failure of a containment shell or stator liner.

3.68 sleeve bearing: A bearing consisting of a rotating member (journal) and a stationary member (bearing bushing).

3.69 slip: The speed differential between the torque ring and outer magnet ring in a torque ring drive pump.

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

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

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

where

n_q = specific speed,

N = rotative speed in revolutions per minute,

Q = total pump flow in cubic meters per second,

H = head per stage in meters.

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

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

3.73 stator housing: The housing in which a stator assembly is mounted (Figure C-2, Appendix C).

3.74 stator liner: The member that separates the liquid in the rotor chamber from the stator assembly. (Figure C-4, Appendix C).

3.75 suction pressure: The liquid pressure at the suction flange of the pump.

3.76 suction specific speed: An index defining the relationship between 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 3.38) 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 U.S. units is "S."

3.77 throat bushing: A device that forms a restrictive close clearance around the sleeve (or shaft) between the rotor chamber and the impeller (see Figures C-1 and C-2, Appendix C).

3.78 throttle bushing: A secondary control device on a magnetic drive pump that forms a restrictive close clearance around the shaft (or sleeve) of the outer magnet ring (see Figure C-1, Appendix C).

3.79 tolerance ring: A component which acts as an elastic shim to frictionally position mating cylindrical parts.

3.80 torque ring drive: A magnetic coupling consisting of a permanent outer magnet ring and an inner torque ring containing a network of copper rods supported on a mild steel core. The rotating outer magnet ring generates eddy currents in the copper rods which converts the core to an electromagnet. The electromagnet follows the rotating outer magnet ring, but at a slightly slower speed due to slip.

3.81 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.

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

3.83 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, and so forth, shall be included.

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

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3.85 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.

4 General

4.1 UNIT RESPONSIBILITY

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

4.2 NOMENCLATURE

A guide to sealless pump nomenclature can be found in Appendix C.

5 Requirements

5.1 UNITS OF MEASURE

The purchaser will specify whether pumps and vendor data supplied to this standard shall use the SI or U.S. Customary system of measurements.

5.2 STATUTORY REQUIREMENTS

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.

5.3 ALTERNATIVE DESIGNS

The vendor may offer alternative designs.

5.4 CONFLICTING REQUIREMENTS

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

6 Basic Design

6.1 GENERAL

6.1.1 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 is a design criterion.

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

• **6.1.3** 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.

6.1.4 Pumps shall be capable of at least a 5 percent head increase at rated conditions by replacement of the impeller with ones of larger diameter or different hydraulic design.

Note: The purchaser may consider the use of variable speed driver capability to meet this requirement.

6.1.5 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.

6.1.6 Pumps shall use throat bushings, wear rings, impeller balance holes, auxiliary impeller, and/or flushing-line arrangements to maintain a rotor chamber pressure greater than the suction pressure. The pump design shall also ensure that the temperature and pressure in the rotor chamber prevent vaporization at all operating conditions, including minimum flow while providing continuous flow through the rotor chamber for cooling and bearing lubrication.

6.1.7 All internal cavities shall be completely self-venting. When exception must be taken, the vendor shall, as a minimum, include provision for manual venting and provide a "caution" tag attached to the pump to indicate that manual venting is required before and after maintenance.

6.1.8 Unless otherwise specified, all internal cavities, including the rotor chamber, shall be drainable through a single connection to the pump assembly. If fluid will remain in the internal cavities when this drain connection is opened, an additional connection shall be provided for purging/flushing the rotor chamber. The vendor shall include the size and location of this connection in the proposal.

6.1.9 The vendor shall enter on the datasheets 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 4.1.9 above. An NPSH margin is the NPSH that exists in excess of the pump's NPSHR (see 3.38). 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. Consideration should be given to the effects of heated fluid when recirculated back to the pump suction in establishing the NPSH margin. The vendor should be consulted about recommended NPSH margins for the specific pump type and intended service.

Note: In establishing NPSHA (see 3.37), 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 satis-

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factorily 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.

• **6.1.10** When specified, the pump suction specific speed shall be limited as stated on the datasheet.

6.1.11 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. Additional corrections may be necessary for viscous effects on the rotor. These additional corrections shall be highlighted in the proposal.

• **6.1.12** Pumps that have stable head/capacity curves (continuous head rise to shut-off) 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 shut-off, this use shall be stated in the proposal.

6.1.13 Pumps shall have a preferred operating region (see 6.9.3 Vibration) of 70 to 120 percent of best efficiency capacity of the furnished impeller. Rated capacity shall be within the region of 80 to 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.

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

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

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

6.1.16 Pumps with heads greater than 200 m (650 ft) and with power more than 225 kW (300 hp) may require special provisions to reduce vane passing frequency vibration and low-frequency vibration at reduced flow rates. For these pumps, the radial clearance between the diffuser vane or volute tongue (cutwater) and the periphery of the impeller blade shall be at least 3 percent of the maximum impeller blade tip radius for diffuser designs and at least 6 percent of the maximum blade tip radius for volute designs. The maximum impeller blade-tip radius is the radius of the largest impeller that can be used within the pump casing (see 6.1.4). Percent clearance is calculated as follows in equation (1):

$$P = 100\,(R_3 - R_2)/R_2 \qquad (1)$$

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 10.3.5.1.

6.1.17 Pumps of significantly higher energy levels than those specified in 6.1.16 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.

6.1.18 Pumps shall be designed to prevent damage by reverse rotation, including backward rotation on starting.

• **6.1.19** 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.

6.1.20 Cooling jackets, if provided, shall have cleanout connections arranged so that the entire passageway can be mechanically cleaned, flushed, and drained.

6.1.21 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.

6.1.22 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 x MAWP	(≥ 1.5 x MAWP)
Maximum pressure drop	100 kPA	(15 psi)
Maximum inlet temperature	30°C	(90°F)
Maximum outlet temperature	50°C	(120°F)

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Maximum temperature rise	20°K	(30°F)
Minimum temperature rise	10°K	(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 water-side 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.

6.1.23 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.

• **6.1.24** Motors, electrical components, and electrical installations shall be suitable for the area classification (class, group, and division or zone) specified by the purchaser and shall meet the requirements of national codes such as NFPA 70, Article 500, 501, 502, and 504 as well as local codes specified and furnished by the purchaser.

6.1.25 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.

6.1.26 The pump and its driver shall perform on their test stands and on their permanent foundation within the acceptance criteria specified in 6.9.3. After installation, the performance of the combined units shall be the joint responsibility of the purchaser and the vendor.

• **6.1.27** 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 the 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 (magnetic drive pump only).

d. Recheck the alignment of the pump and drive train at the operating temperature (magnetic drive pump only).

6.1.28 The spare and all replacement parts for the pump and all furnished auxiliaries shall, as a minimum, meet all the criteria of this standard.

• **6.1.29** 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.

6.1.30 The requirements of 6.1.30.1 through 6.1.30.4 apply to vertical inline pump designs.

6.1.30.1 A flat contact surface shall be provided on the bottom of the casing to make the pump stable when freestanding on a pad or foundation. The ratio of the unit center of gravity height to 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.

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

• **6.1.30.3** 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.

6.1.30.4 A minimum ½ NPS tapped drain connection shall be provided when necessary to assure that no liquid collects on the cover or driver support.

6.2 CRITICAL DESIGN AND APPLICATION CONSIDERATIONS

• **6.2.1** Properties of the fluid being pumped are critical to the performance of the pump. The purchaser and vendor have a responsibility to transfer information to each other. The purchaser will furnish information including but not limited to the following: NPSHA, temperature/vapor pressure curve, temperature/viscosity curve, specific heat, specific gravity, thermal conductivity, thermal expansion, and polymerization characteristics. The purchaser will also furnish information on any solids present including particle size, percent, and distribution. The vendor shall furnish information including, but not limited to, the following: NPSHR, temperature rise based on fluid being pumped, both during operation and after shutdown, effect of wear, minimum continuous stable flow, and minimum continuous thermal flow.

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• **6.2.2** Proper pump design and selection are dependent on knowledge of the purchaser's system. The purchaser will furnish information including, but not limited to, pump location, suction vessel and piping arrangement.

6.2.3 Since sealless pumps may use product to cool and lubricate the bearings, the product must remain stable as it passes through the bearings. The vendor shall furnish the temperature and pressure profiles of the fluid recirculation flow path through the pump and rotor chamber. Refer to Appendix K.

6.3 PRESSURE CASINGS

6.3.1 Unless deflection criteria dictates lower allowable stresses, the stress values used in design for any given material shall not exceed the values given for that material (at the maximum operating temperature) 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 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. With purchaser approval, alternate stress levels and design methods from other national or local codes may be used.

6.3.2 The pressure casing and flanges (including the secondary pressure casing) shall be designed for the maximum discharge pressure plus allowances for head and/or speed increases (see 6.1.4 and 6.1.5) at the specified pumping temperature. When vacuum conditions at the pump suction are specified, the containment shell or stator liner, as applicable, shall be designed for the resulting external pressure. Unless otherwise specified, the pressure casing, as a minimum, shall be designed to meet a pressure rating equal to that of an ISO7005-1 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.

6.3.3 The pressure casing shall be designed with a corrosion allowance to meet the requirements of 6.1.1. Unless otherwise specified the minimum corrosion allowance shall be 3 mm (1/8 in.), except that containment shells and liners shall be in accordance with 9.1.2.1.1 for magnetic drive pumps and both 9.2.3.1 and 9.2.4.1. for canned motor pumps.

6.3.4 Axially split casings are not allowed. Pumps with radially split casings are required.

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

6.3.6 Casings shall be designed to permit removal of the rotor or inner magnet ring without disconnecting the suction or discharge piping.

6.3.7 The pump's pressure casing shall be capable of withstanding twice the forces and moments in Table 1A (1B) applied simultaneously to the pump through each nozzle, plus internal pressure, without distortion that would impair operation of the pump or cause contact between stationary and rotating parts.

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

6.3.8 Centerline supported pump casings shall be used for horizontal magnetic drive pumps. Centerline supported pump casings shall be used for horizontal canned motor pumps with pumped liquid temperatures of 175°C (350°F) or higher.

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

6.3.10 Jackscrews, guide rods and cylindrical casing-alignment dowels or rabbeted fits shall be provided to facilitate disassembly and reassembly. 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. Guide rods shall be of sufficient length to prevent damage to the internals or casing studs by the casing during disassembly and reassembly.

6.3.11 Bolting shall be furnished as specified in 6.3.11.1 through 6.3.11.8.

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

6.3.11.2 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 tapped holes shall be at least 1.5 times the nominal bolt or stud diameter.

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

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

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

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

6.3.11.7 Metric fine and UNF threads shall not be used.

6.3.11.8 Manufacturer's marking shall be located on all fasteners 6 mm (1/4 in.) and larger (excluding washers and headless set screws). For studs, the marking shall be on the nut end of the exposed stud end.

6.4 NOZZLE AND PRESSURE CASING CONNECTIONS

6.4.1 Casing Opening Sizes

6.4.1.1 Openings for nozzles and other pressure casing connections shall be standard nominal pipe sizes (NPS). Openings of 1 1/4, 2 1/2, 3 1/2, 5, 7 and 9 NPS shall not be used.

6.4.1.2 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 flush piping and gauges may be 1/2 NPS regardless of pump size.

6.4.2 Suction and Discharge Nozzles

6.4.2.1 Suction and discharge nozzles shall be flanged and of equal rating.

6.4.2.2 Flanges shall, as a minimum, conform to the dimensional requirements of ISO 7005-1 (ANSI/ASME B16.5).

6.4.2.3 Unless otherwise specified, flat face flanges with full raised face thickness are acceptable. Flanges in all materials that are thicker or have a larger outside diameter than that required by ISO (ANSI) are acceptable. When flange thickness requires stud-bolts with lengths that are non-standard relative to the flange rating, the vendor shall identify this requirement in the proposal.

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

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

6.4.3 Pressure Casing Connections

6.4.3.1 Auxiliary connections to the pressure casing shall be socket welded, butt welded or integrally flanged. Field connections shall terminate in a flange.

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

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

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

6.4.3.5 All connections shall be suitable for the hydrostatic test pressure.

• **6.4.3.6** When specified, pressure gauge connections shall be provided.

6.4.3.7 All of the purchaser's connections shall be accessible for disassembly without the machine being moved.

6.4.3.8 Unless otherwise specified, auxiliary connections to the secondary casing may be threaded. Threaded connections shall meet requirements of 6.4.3.8.1 through 6.4.3.8.3.

6.4.3.8.1 Plugs shall conform to 7.3.1.13.

6.4.3.8.2 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.

• **6.4.3.8.3** 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 1).

6.5 EXTERNAL NOZZLES FORCES AND MOMENTS

6.5.1 Steel and alloy steel horizontal pumps, and their baseplates, shall be designed for satisfactory performance when subjected to the forces and moments in Table 2A (2B). Two affects of nozzle loads are considered: Distortion of the pump casing (6.3.7) and misalignment of the pump and motor shafts (magnetic drive pumps only) (see 9.1.5.3.5).

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

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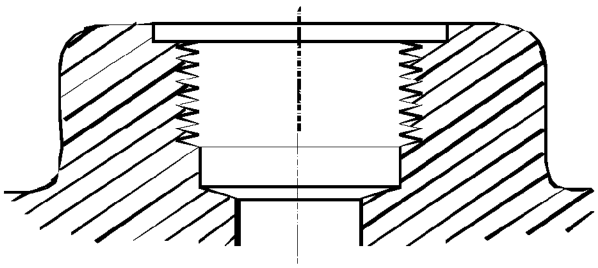

Figure 1—Machined Face Suitable for Gasket Containment When Using Cylindrical Threads

6.5.3 For pump casings constructed of materials other than steel or alloy steel, the vendor shall submit allowable nozzle loads corresponding to the format in Table 1A (1B).

6.5.4 The coordinate system (s) shown in Figures 2 and 3 shall be used to apply the forces and moments in Table 1A (1B).

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

6.6 ROTOR

6.6.1 Unless otherwise approved by the purchaser, impellers shall be of the fully enclosed type and constructed as single-piece castings. Open, semi-open and fabricated impellers require the purchaser's specific approval.

6.6.2 Impellers shall be keyed to the shaft; pinning of impellers is not acceptable. 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.

6.6.3 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 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.

6.6.4 Shafts shall be machined and finished throughout their length so that the TIR is not more than 25 μm (0.001 in.).

Table 1A—Nozzle Loadings (SI Units)

	Nominal Size of Flange (NPS)								
Force/Moment	2	3	4	6	8	10	12	14	16
Each Top Nozzle									
FX	710	1070	1420	2490	3780	5340	6670	7120	8450
FY	580	890	1160	2050	3110	4450	5340	5780	6670
FZ	890	1330	1780	3110	4890	6670	8000	8900	10230
FR	1280	1930	2560	4480	6920	9630	11,700	12,780	14,850
Each Side Nozzle									
FX	710	1070	1420	2490	3780	5340	6670	7120	8450
FY	890	1330	1780	3110	4890	6670	8000	8900	10230
FZ	580	890	1160	2050	3110	4450	5340	5780	6670
FR	1280	1930	2560	4480	6920	9630	11,700	12,780	14,850
Each End Nozzle									
FX	890	1330	1780	3110	4890	6670	8000	8900	10230
FY	710	1070	1420	2490	3780	5340	6670	7120	8450
FZ	580	890	1160	2050	3110	4450	5340	5780	6670
FR	1280	1930	2560	4480	6920	9630	11,700	12,780	14,850
Each Nozzle									
MX	460	950	1330	2300	3530	5020	6100	6370	7320
MY	230	470	680	1180	1760	2440	2980	3120	3660
MZ	350	720	1000	1760	2580	3800	4610	4750	5420
MR	620	1280	1800	3130	4710	6750	8210	8540	9820

Note 1: Each value shown above indicates a range from minus that value to plus that value; for example, 710 indicates a range from – 710 to + 710.

Note 2: *F*= force in Newtons; *M* = moment in Newton meters; *R* = resultant. See Figures 2 and 3 for orientation of nozzle loads (*X*, *Y*, and *Z*).

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Table 1B—Nozzle Loadings (U.S. Units)

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

Note 1: Each value shown above indicates a range from minus that value to plus that value; for example, 160 indicates a range from – 160 to + 160.
Note 2: *F*= force in Newtons; *M* = moment in Newton meters; *R* = resultant. See Figures 2 and 3for orientation of nozzle loads (*X*, *Y*, and *Z*).

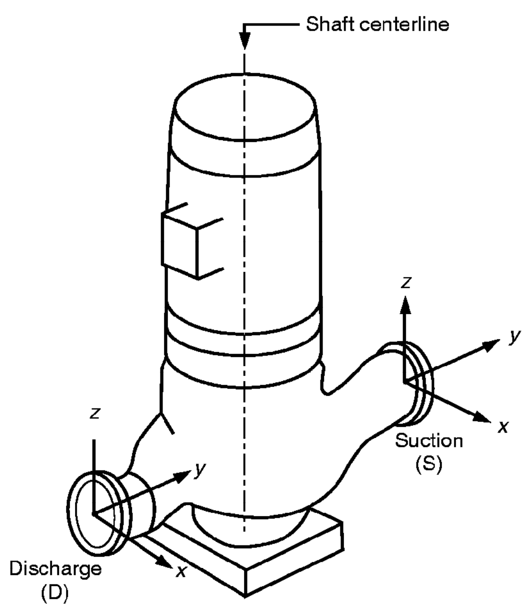

Figure 2—Coordinate System for the Forces and Moments in Table 1A (1B): Vertical Inline Pumps

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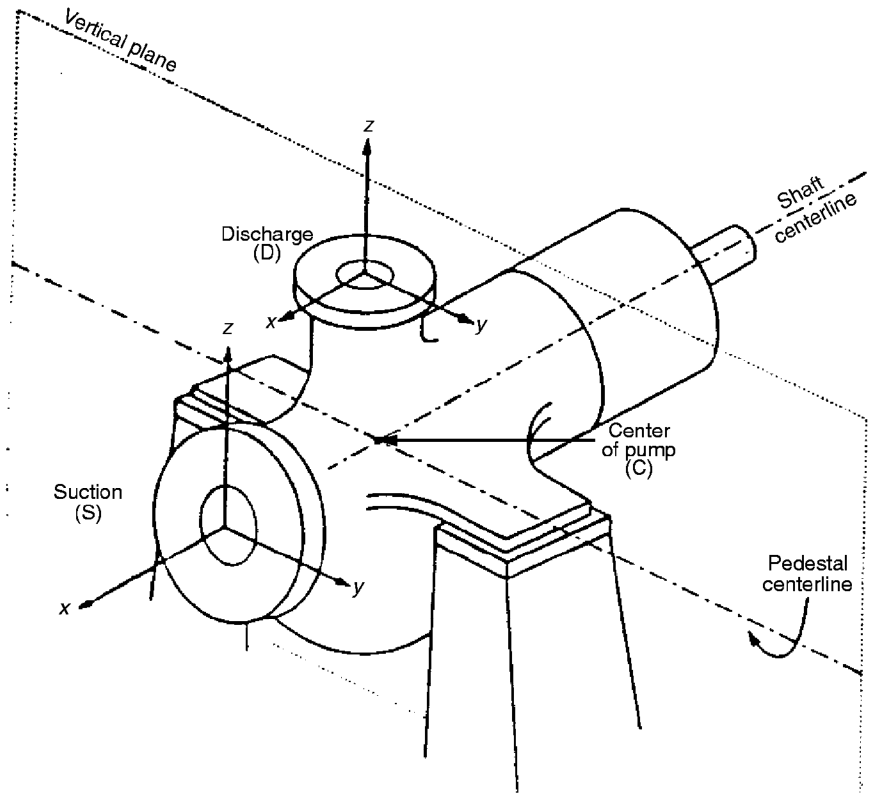

Figure 3—Coordinate System for the Forces and Moments in Table 1A (1B): Horizontal Pumps with End Suction and Top Discharge Nozzles

6.6.5 Shaft stiffness and fluid stiffening of product lubricated bearings shall limit the total impeller displacement under the most severe dynamic conditions over the allowable operating range of the pump—with maximum impeller diameter and the specified speed and fluid—to one half the minimum impeller wear ring clearance. This displacement limit may be achieved by a combination of shaft diameter, shaft span or overhang, bearing design, and casing design (including the use of dual volutes or diffusers). No credit shall be taken for the fluid stiffening effects of impeller wear rings. The fluid stiffening of product lubricated bearings shall be calculated at both one and two times the nominal design clearances.

6.7 WEAR RINGS AND RUNNING CLEARANCES

6.7.1 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. This paragraph does not apply to auxiliary impellers.

6.7.2 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.

6.7.3 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.

6.7.4 Running clearances shall meet the requirements of 6.7.4.1 and 6.7.4.2.

6.7.4.1 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.

6.7.4.2 For hardened 11 to 13 percent chromium steel, and materials with similarly low galling tendencies, the minimum clearances given in Table 2 shall be used. For materials with higher galling tendencies and for all materials operating at

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Table 2—Minimum Running Clearances

Diameter of Rotating Member at Clearance (mm)	Minimum Diametrical Clearance (mm)	Diameter of Rotating Member at Clearance (in.)	Minimum Diametrical 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 mm for each additional 1 mm of diameter or fraction thereof (0.001 in. for each additional in.).

temperatures above 260°C (500°F), 125 µm (0.005 in.) shall be added to these diametral clearances.

6.8 SECONDARY CONTROL/CONTAINMENT

6.8.1 The purchaser will specify which of the following control/containment options the pump shall have:

a. Secondary control design (3.65).
b. Secondary control with leakage monitoring device(s) (Secondary control system 3.66).
c. Secondary containment design (3.63).
d. Secondary containment with leakage monitoring device(s) (Secondary containment system 3.64).

6.8.2 The secondary control system shall have a stand-by life of at least 25,000 hours in a pump operating mode and shall have a functional life of at least 24 hours in the event of containment shell failure.

• **6.8.3** When specified, the vendor shall provide the maximum flow rate from the secondary control system in the event of containment shell or stator liner failure.

6.8.4 The secondary control/containment system shall be rated for the same pressure as the pressure casing. Provisions for monitoring shall be included in the secondary control/containment system.

6.8.5 Material of the secondary pressure casing(s) shall be carbon steel as a minimum.

6.8.6 Secondary pressure casings are by definition pressure containing components and shall meet the requirements of 6.3.

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6.8.7 All secondary control and containment system joints shall be rabbeted and sealed with controlled compression gasket(s), sealed with O-rings of material compatible with the process liquid, or welded.

• **6.8.8** When specified, drain connections shall be provided which completely drain and provide the capability to flush all internal areas of the secondary pressure casing.

6.9 DYNAMICS

6.9.1 Pumps shall be designed such that their first dry lateral critical speed is at least 20 percent above maximum continuous operating speed.

6.9.2 Resonances of structural support systems (base, frame, and bearing housings) may adversely affect rotor vibration amplitude. Therefore, resonance of support systems within the vendor's scope of supply shall not occur within 10 percent of the operating speed of a fixed speed machine, or from 10 percent below to 10 percent above the operating range of a variable speed machine.

6.9.3 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 4 illustrates the concept. (Note that factors other than vibration, for example, temperature rise with decreasing flow or NPSHR with increasing flow, may dictate a narrower allowable operating region).

6.9.3.1 The preferred operating region and location of rated capacity shall be as specified in 6.1.13 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.

6.9.3.2 During the performance test, unfiltered vibration measurements and Fast Fourier Transform (FFT) spectrum shall be taken at each test point except shutoff. The measurements shall be taken on the bearing housing(s) or equivalent location(s) at the positions shown in Figure 5.

6.9.3.2.1 The FFT spectra shall include the range of frequencies from 5 hertz to 2Z times running speed (where Z is the number of impeller vanes).

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

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

6.9.3.3 Bearing housing overall vibration measurements shall be made in root mean square (RMS) velocity, mm/sec (in./sec).

6.9.3.4 The vibration measured during the performance test shall not exceed the values shown in Table 3.

6.9.3.5 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.

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

6.9.3.7 All bearing housings shall be dimpled at the locations shown on Figure 5 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.

• **6.9.3.8** 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.

Table 3—Vibration Limits

	Vibration Measurement
Vibration at any flow within the pump's preferred operating region:	
Overall	$V_u <$ 3.0 mm/sec RMS (0.12 in./sec RMS)
Discrete frequencies	$V_f <$ 2.0 mm/sec RMS (0.08 in./sec RMS)
Increase in allowable vibration at flows beyond the preferred operating region, but within the allowable operating region	30%

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

Where

V_u = unfiltered velocity.

V_t = filtered velocity.

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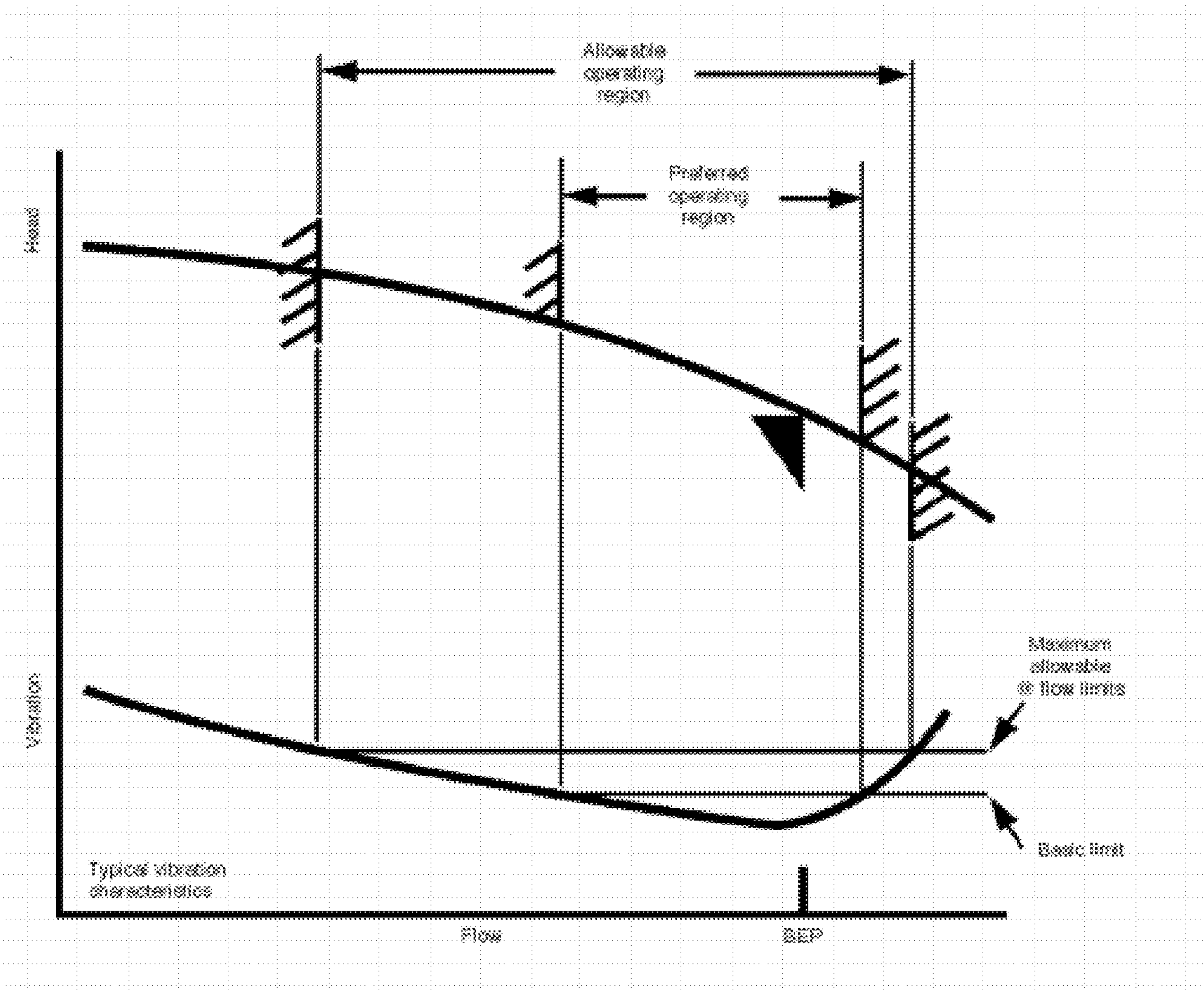

Figure 4—Relationship Between Flow and Vibration

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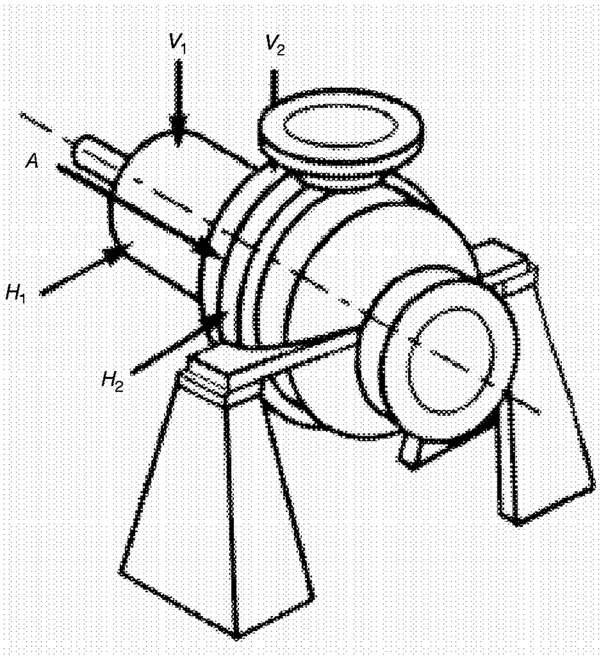
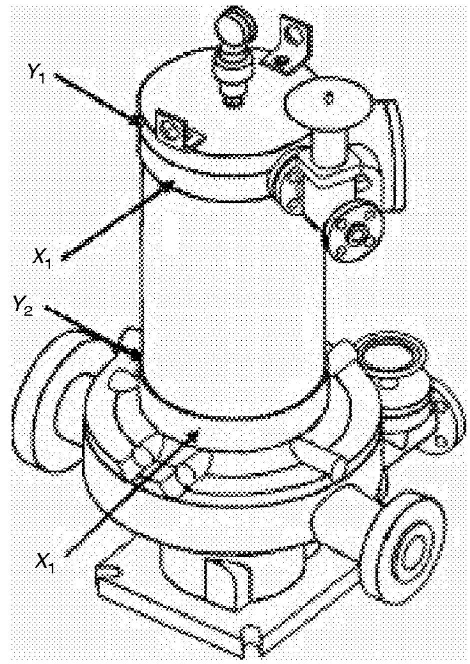
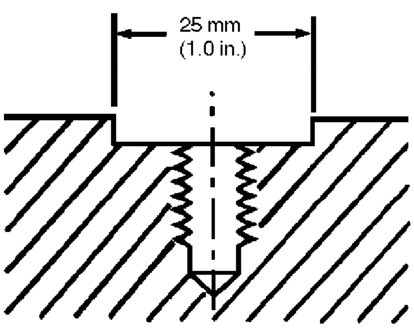
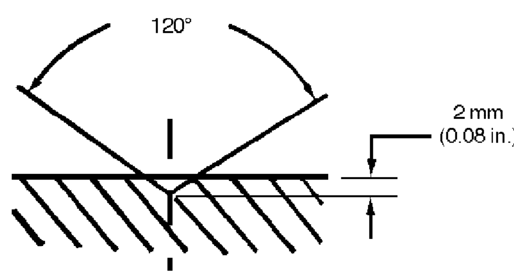






Optional arrangement for mounting vibration measuring equipment (see 6.9.3.8)



Dimple (see 6.9.3.7)

Figure 5—Locations and Provisions for Taking Vibration

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• **6.9.3.9** 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.

6.9.4 Balancing

6.9.4.1 Impellers and similar major rotating components shall be dynamically balanced to grade G1.0 of ISO 1940 (4W/N) or 7 gm-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,

= 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 (for example, $U = 4W/N$ 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.

6.9.4.2 Component balancing may be single plane when the ratio D/B (see Figure 6) is 6.0 or greater.

6.10 PROCESS COOLED/LUBRICATED BEARINGS

6.10.1 Process cooled/lubricated bearings shall be of the precision bored sleeve type. These bearings shall be equipped with anti-rotation devices and be positively secured in the axial direction.

6.10.2 Sleeve bearings and thrust bearings shall have a surface finish of not more than 0.4 μm (16 μin.) R_a.

6.10.3 Bearing materials such as silicon carbide with low coefficients of thermal expansion shall have a radial clearance designed to accommodate relative thermal expansions at the maximum and minimum operating temperature specified on the pump datasheet.

6.10.4 Tolerance rings or similar bearing mounting devices shall be used to allow for relative thermal expansion and provide a resilient mounting surface for the bearings.

6.10.5 Unless otherwise approved by the purchaser, bearings shall incorporate groove(s) for heat removal and flushing of foreign particles.

6.10.6 Pumps using only one radial bearing shall not be used for drive powers above 7.5 kW (10 hp).

6.10.7 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. Thrust bearings shall provide full load capabilities if the normal direction of shaft rotation is reversed.

6.10.8 Thrust bearings shall be designed for thrust capacity in both directions.

6.10.9 Lubrication/cooling of the bearings shall be by the pumped liquid or by a clean liquid from an external source. The use of an external system requires purchaser's approval (see Appendix D).

6.11 MATERIALS

• **6.11.1** 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 datasheets. Auxiliary piping materials are covered in 7.3. The purchaser will specify the class of pump materials from Appendix H that are 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 H-1 shall be made from materials with the applicable chemical composition, but need not meet the other requirements of the listed industry specification.

Note: Appendix H in this standard differs from that in API 610 in both components specified and material class designations.

6.11.2 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.

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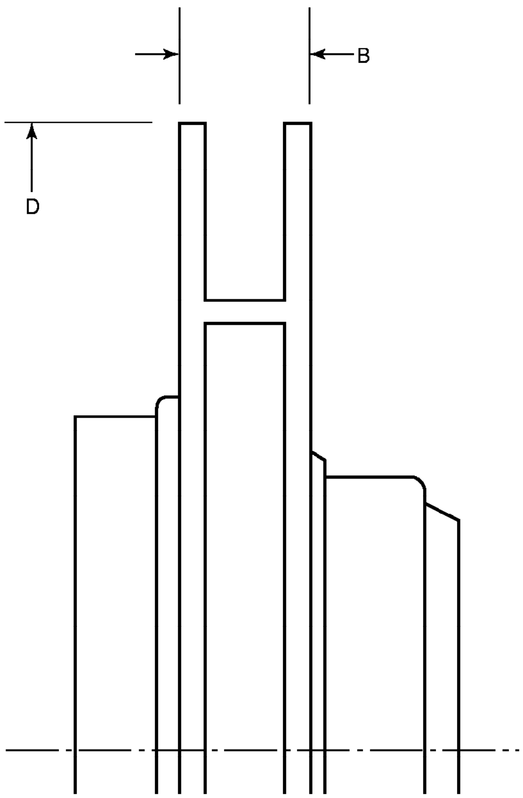
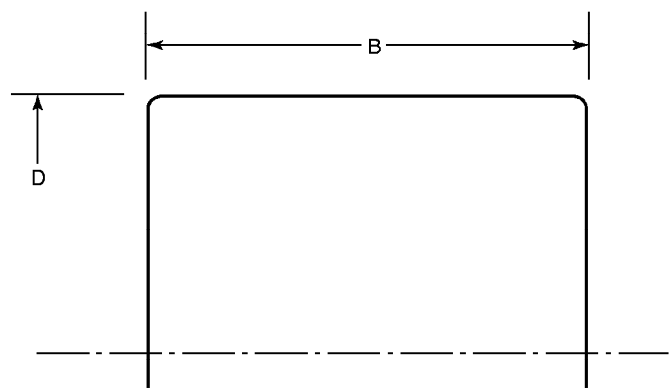


Single Suction Impeller



Inner Magnet/Rotor Assembly

Figure 6—Rotating Component Dimensions to Determine When Single Plane Balancing is Allowable

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6.11.3 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.

6.11.4 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.

6.11.5 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.

• **6.11.6** 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.

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

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

6.11.8 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 the *NACE Corrosion Engineer's Reference Book.*

6.11.9 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 anti-seizure compound.

6.11.10 Extruded components such as containment shells with more than 5 percent of cold work shall be stress-relieved to minimize stress corrosion cracking.

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

a. The pressure casing.
b. Shafting (including wetted shaft nuts).
c. Impellers.
d. Wetted bolting.

Items 1 through 3 below apply when wet H_2S is present:

1. The yield-strength and hardness restrictions above may be modified in accordance with NACE MR0175.
2. Renewable wear rings that must be hardened above Rockwell C22 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.
3. 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.

6.11.12 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 A 515) is prohibited.

6.12 CASTINGS

6.12.1 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 riser shall be chipped, filed, or ground flush.

6.12.2 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.

6.12.3 Ferrous pressure boundary and impeller castings shall not be repaired by welding, peening, plugging, burning in, or impregnating, except as follows:

Weldable grades of steel castings may be repaired by welding, using a qualified welding procedure based on the requirements of the applicable material specification, and qualified in accordance with Section IX of the ASME Code. Weld

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repairs shall be inspected according to the same quality standard used to inspect the casting.

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

• **6.12.5** When specified, casting repair procedures shall be submitted for purchaser's approval.

6.13 WELDING

6.13.1 Welding of piping, pressure-containing parts, and wetted parts, as well as any dissimilar-metal welds and 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 ASME Code.

6.13.2 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 6.11.5 and 6.12.3). Repair welds shall be nondestructively tested by the same method used to originally qualify the part.

6.13.3 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, non-pressure 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.

6.13.4 Pressure-containing casings made of wrought materials or combinations of wrought and cast materials shall conform to the conditions specified in 6.13.4.1 through 6.13.4.4. These requirements do not apply to casing connections (see 6.4.3 and 6.13.5).

6.13.4.1 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.

6.13.4.2 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.

6.13.4.3 Pressure-containing welds, including welds of the case to horizontal-and vertical-joint flanges and the welds of canned motor liner/rotor assemblies or containment shells, shall be full-fusion, full-penetration welds.

6.13.4.4 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 treatment shall be performed regardless of thickness.

6.13.5 Connections welded to pressure casings shall be installed as specified in 6.13.5.1 through 6.1.3.5.6.

6.13.5.1 Attachment of suction and discharge nozzles shall be by means of full-fusion, full-penetration welds. Weld neck flanges are required. Dissimilar-metal weldments are not allowed.

6.13.5.2 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.

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

• **6.13.5.4** 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.

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

Note: High-alloy materials fusion welded in sub-assemblies (i.e., liners in stator assemblies and containment shells) may be exempt from stress relief and post weld heat-treating, per ASME Section VIII.

• **6.13.5.6** 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.

6.14 LOW TEMPERATURE

6.14.1 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.

6.14.2 All pressure retaining steels applied at a specified minimum design metal temperature (6.14.5) 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.

6.14.3 Carbon and low alloy steel pressure retaining parts applied at a specified minimum design metal temperature (6.14.5) between –30°C (–20°F) and 40°C (100°F) shall require impact testing in accordance with 6.14.3.1 and 6.14.3.2.

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6.14.3.1 Impact testing is not required for parts with a governing thickness (6.14.5) of 25 mm (1 in.) or less.

6.14.3.2 Impact testing exemptions for parts with a governing thickness (6.14.4) 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 A shall be used for all carbon and low alloy steel materials (including castings) which are not specifically listed for curves B, 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.

6.14.4 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 as jackets or seal chambers.

c. One fourth of the nominal flange thickness (in recognition that the predominant flange stress is not a membrane stress).

• **6.14.5** The purchaser will 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.

6.15 NAMEPLATES AND ROTATION ARROWS

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

6.15.2 The nameplate shall be stamped with the following information in units consistent with the datasheet:

a. Purchaser's item number.
b. Vendor's size and model number.
c. Pump serial number.
d. Capacity.
e. Pumping head.
f. Casing hydrostatic test pressure.
g. Speed.
h. Maximum allowable working pressure (MAWP).
i. Temperature, basis for MAWP.

Note: Supplemental nameplate data requirements are given in 9.1.1.8 (magnetic drive pump) and 9.2.5 (canned motor pumps).

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

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

6.15.5 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.

7 ACCESSORIES

7.1 MOTORS

Note: The motor requirements in this section apply to both canned motor pumps and magnetic drive pumps. See Section 5.2.2 for additional requirements for canned motor pump motors.

• **7.1.1** The driver shall be sized to meet the maximum specified operating conditions, including all losses, as applicable, and shall be in accordance with the applicable specifications, as stated in the inquiry specification, datasheets, and order. The driver shall be suitable for satisfactory operation under the utility and site conditions specified.

• **7.1.2** 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.

• **7.1.3** 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.

7.1.4 Motors will be sized in accordance with 7.1.4.1 and 7.1.4.2.

7.1.4.1 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 4. 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.

Table 4—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

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• **7.1.4.2** When specified, motor shall be sized to cover maximum power for the rated impeller.

7.1.5 Motors shall be designed to operate under running conditions at rated load and frequency with a voltage variation of 10 percent or less, above or below rated voltage.

7.1.6 Motors shall be designed to operate under running conditions at rated load and voltage with a frequency variation of plus or minus 5 percent of rated frequency.

7.1.7 Motors shall be designed to operate under running conditions at rated load with a combined variation of voltage and frequency up to 10 percent above or below the rated voltage and the rated frequency, provided that the frequency variation does not exceed 5 percent.

• **7.1.8** 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.

7.1.9 For variable speed motors, the vendor shall ensure that the drive characteristics fully meet all requirements, such as motor cooling, supply waveforms/harmonics, rotor mechanical integrity, and torque availability/requirements for acceptable start-up and operating conditions.

7.1.10 For variable speed motors, the vendor shall identify and supply any input/or output line reactors that may be required to ensure reliable operation of the pump and power supply system to which it will be connected, under all operating conditions.

7.2 INSTRUMENTATION AND CONTROLS

7.2.1 General

7.2.1.1 Unless otherwise specified, controls and instrumentation shall be suitable for outdoor installation.

7.2.1.2 Where applicable, controls and instrumentation shall conform to API RP 551.

7.2.1.3 All conduit shall be designed and installed so that it can be easily removed without damage and located as not to hamper removal of bearings or pump internals.

• **7.2.1.4** When specified, a panel shall be provided which shall include all panel-mounted instruments for the driven equipment and the driver. Such panels shall be designed and fabricated in accordance with the purchaser's description. The purchaser will specify whether the panel is to be freestanding, located on the base of the unit, or in another location. A lamp test push button shall be provided. The instruments to be mounted on the panel will be specified by the purchaser.

7.2.1.5 Panels shall be completely assembled, requiring only connection to the purchaser's external piping and wiring circuits. When more than one wiring point is required on a unit for control or instrumentation, the wiring to each switch or instrument shall be provided from a single terminal box with terminal posts mounted on the unit (or its base, if any). Wiring shall be installed in metal conduits or enclosures. All leads and posts on terminal strips, switches, and instruments shall be tagged for identification.

• **7.2.1.6** Unless otherwise specified, all instruments and controls other than shutdown sensing devices shall be installed with sufficient valving to permit their replacement while the system is in operation. When shutoff valves are specified for shutdown sensing devices, the vendor shall provide a means of locking the valves in the open position.

7.2.2 Instrumentation

7.2.2.1 Temperature Detection

7.2.2.1.1 Dial-type temperature gauges shall meet the following requirements:

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

7.2.2.1.2 Temperature sensing element normally in contact with the process or in pressurized or flooded lines shall be furnished with separate solid bar thermowells, 3/4 NPS, and shall be austenitic stainless steel or another material more compatible with the liquid.

7.2.2.1.3 Where practical, the design and location of thermocouple and resistance temperature detectors shall permit replacement while the unit is operating. The lead wires of thermocouple and resistance temperature detectors shall be installed as continuous leads between the thermowell or detector and the terminal box.

7.2.2.1.4 Unless otherwise specified, resistance temperature detectors shall be platinum, 100 Ohm, 6 mm (0.25 inch) 316 SS sheath 3-wire configuration, bayonet spring-loaded.

7.2.2.2 Pressure Gauges

7.2.2.2.1 Pressure gauges shall meet the following requirements:

a. Austenitic stainless steel bourdon tubes and movements.
b. 100 mm (4.5 in.) dials for pressures up to 5.5 MPa (800 psi).
c. 160 mm (6 in.) dials for pressures of 5.5 MPa (800 psi) or greater.
d. 1/2 NPS male alloy steel connections.
e. Black printing on white background dials.

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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.

• **7.2.2.2.2** When specified, liquid-filled gauges shall be furnished in locations subject to vibration.

7.2.2.3 Vibration and Position Detector System

• **7.2.2.3.1** When specified, vibration and axial-position transducers shall be supplied, installed, and tested in accordance with API Standard 670.

• **7.2.2.3.2** When specified, vibration and axial-position monitors shall be supplied and calibrated in accordance with API Standard 670.

• **7.2.2.3.3** When specified, a bearing-temperature monitor shall be supplied, and calibrated in accordance with API Standard 670.

• **7.2.2.3.4** When specified, a mechanical, hydraulic, or electrical bearing wear detector shall be provided inside of the pressure casing which shall externally indicate radial and/or axial wear of the product-lubricated-bearings.

7.2.2.4 Protective Instrumentation

• **7.2.2.4.1** When specified, protective/condition monitoring instrumentation shall be provided. It is recommended that the following items be included:

a. Pump power monitoring to detect pump dry-run condition and magnetic drive decoupling.
b. Leakage monitoring in the secondary containment area to detect containment shell or liner leakage for all pumps handling flammable, hazardous, or highly corrosive fluids (see 7.2.2.4.3).
c. Temperature monitoring of the fluid circulating in the rotor chamber.

• **7.2.2.4.2** When specified, pump power shall be monitored with a motor watt meter. The vendor shall specify normal and recommended alarm and shutdown conditions.

• **7.2.2.4.3** When specified, leakage into the secondary pressure casing shall be monitored with suitable instrumentation mounted and located in accordance with Appendix E.

a. For pumped liquid with relatively low vapor pressure (such that leakage would collect at atmospheric pressure and temperature), an optical moisture sensor and sight glass shall be located in a collection area of the secondary pressure casing.
b. For pumped liquid with a relatively high vapor pressure (such that leakage would not collect at atmospheric pressure and temperature), a pressure switch shall be located in the secondary pressure casing. A secondary sealing device shall be utilized to create back pressure to activate the pressure switch.

7.2.2.4.4 All instrumentation penetrating the secondary pressure casing shall be rated for the maximum design pressure.

7.2.3 Alarms and Shutdowns

• **7.2.3.1** Requirements for the vendor to supply any alarm/shutdown system will be specified.

7.2.3.2 Each alarm switch and each shutdown switch shall be furnished in a separate housing located to facilitate inspection and maintenance. Unless otherwise specified, hermetically sealed, single-pole, double-throw switches with a minimum capacity of 5 amperes at 120 volts AC and 1/2 ampere at 120 volts DC shall be used. Mercury switches shall not be used.

7.2.3.3 Unless otherwise specified, electric switches that open (deenergize) to alarm and close (energize) to trip shall be furnished by the vendor.

7.2.3.4 Alarm and trip switch settings shall not be adjustable from outside the housing. Alarm and trip switches shall be arranged to permit testing of the control circuit, including, when possible, the actuating element, without interfering with normal operation of the equipment. The vendor shall provide a clearly visible light on the panel to indicate when trip circuits are in a test bypass mode. Unless otherwise specified, shutdown systems shall be provided with switches or another suitable means to permit testing without shutting down the unit.

7.2.3.5 Pressure-sensing elements shall be of AISI Standard Type 300 stainless steel. Low-pressure alarms, which are activated by falling pressure, shall be equipped with a valved bleed or vent connection to allow controlled depressurizing so that the operator can note the alarm set pressure on the associated pressure gauge. High-pressure alarms, which are activated by rising pressure, shall be equipped with valved test connections so that a portable test pump can be used to raise the pressure.

7.2.3.6 The vendor shall furnish with the proposal a complete description of the alarm and shutdown facilities to be provided.

7.2.4 Electrical Systems

• **7.2.4.1** The characteristics of electrical power supplies for motors, heaters, and instrumentation will be specified by the purchaser.

7.2.4.2 Electrical wiring within the confines of the baseplate shall be resistant to oil, heat, moisture, and abrasion. Stranded conductors shall be used within the confines of the

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Mon Feb 03 13:40:30 2003

baseplate and in other areas subject to vibration. Measurement and remote-control panel wiring may be solid conductor. Thermoplastic insulation shall be used and shall be covered by a neoprene or equal sheath for abrasion resistance. Wiring shall be suitable for the temperature range to which it will be exposed.

7.2.4.3 All leads on terminal strips, switches, and instruments shall be permanently tagged for identification. All terminal boards in junction boxes and panels shall have at least 5 spare terminal points.

7.2.4.4 To facilitate maintenance, liberal clearances shall be provided for all energized parts (such as terminal blocks and relays) on equipment. The clearances required for 600-volt service shall also be provided for lower voltages. To guard against accidental contact, enclosures shall be provided for all energized parts.

• **7.2.4.5** Electrical materials including insulation shall be corrosion resistant and nonhygroscopic insofar as possible. When a tropical location is specified, materials shall be given the treatments specified in 5.2.4.5.1 and 5.2.4.5.2.

7.2.4.5.1 Parts (such as coils and windings) shall be protected from fungus attack.

7.2.4.5.2 Unpainted surfaces shall be protected from corrosion by plating or another suitable coating.

7.2.4.6 Electrical wiring (including temperature element leads) within the limits of the baseplate shall be installed in rigid metallic conduits and boxes, properly bracketed to minimize vibration and isolated or shielded to prevent interference between voltage levels. Conduits may terminate (and in the case of temperature element heads, shall terminate) with a flexible metallic conduit long enough to permit access to the unit for maintenance without removal of the conduit.

7.2.4.7 For Division 2 locations, flexible metallic conduits shall have a liquid tight thermosetting or thermoplastic outer jacket and approved fittings. For Division 1 locations, an NFPA-approved connector shall be provided.

7.2.4.8 AC and DC circuits shall be clearly labeled, connected to separate terminal blocks, and isolated from each other.

7.3 PIPING AND APPURTENANCES

7.3.1 General

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

a. Auxiliary process fluids.
b. Steam.
c. Cooling water.

Auxiliary systems shall comply with the requirements of Table 5.

Note: Casing connections are discussed in 6.4.3.

7.3.1.2 Piping systems shall include piping, pipe fittings, isolating valves, control 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.

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

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

7.3.1.5 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.

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

7.3.1.7 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. 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. The use of flanges at other points is permitted only with the purchaser's specific approval. 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.

7.3.1.8 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 (6.4.3.8.3). Flanges shall be in accordance with ISO 7005 (ANSI/ASME

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Table 5—Minimum Requirements for Piping Materials

	Auxiliary Process Fluid		Steam		Cooling Water	
System	Nonflammable Nonhazardous /	Flammable/ Hazardous	≤ 500 kPa (≤ 75 psig)	> 500 kPa (> 75 psig)	Standard	Optional
Pipe	Seamless[a]	Seamless[a]	Seamless[a]	Seamless[a]	—	ASTM A53 Type F Schedule 40 galvanized to ASTM A153
Tubing	ASTM A269 seamless Type 316 stainless steel[b]	ASTM A269 seamless Type 316 stainless steel[b]	ASTM A269 seamless Type 316 stainless steel[b]	ASTM A269 seamless Type 316 stainless steel[b]	ASTM A269 seamless Type 316 stainless steel[b]	—
All valves	Class 800	Class 800	Class 800	Class 800	Class 200 bronze	
Gate and globe valve	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	
Tube fittings	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	
Fabricated joints ≥ 1$^1/_2$ NPS	—	—	—	—	Purchaser to specify	
Gaskets	—	Type 316 stainless steel spiral wound	—	Type 316 stainless steel spiral wound	—	—
Flange bolting	—	ASTM A193 Grade B7 ASTM A194 Grade 2H	—	ASTM A 193 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 carbon steel in diameters from $^1/_2$ NPS through 1$^1/_2$ NPS. Schedule 40 for stainless steel in diameters from $^1/_2$ NPS through 1$^1/_2$ NPS.

[b]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).

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.

7.3.1.9 Piping systems furnished by the vendor shall be fabricated, installed in the shop, and properly supported. Bolt holes for flanged connections shall straddle lines parallel to the main horizontal or vertical centerline of the equipment.

7.3.1.10 The minimum size of any connection or piping shall be $^1/_2$ NPS.

7.3.1.11 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.

7.3.1.12 The bolting requirements of 6.3.11 and 6.11.9 apply to auxiliary piping.

7.3.1.13 Taper threaded plugs shall be (long shank) solid round head bar stock plugs in accordance with ANSI/ASME B16.11 (6.4.3.8.1). When cylindrical threads are specified in 6.4.3.8.3, 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.

7.3.2 Auxiliary Process Fluid Piping

7.3.2.1 Auxiliary process fluid piping includes vent and drain lines, balance lines, product flushing lines, and lines for

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injection of external fluid, purge gas, and decontamination flush lines.

7.3.2.2 The arrangement of auxiliary process fluid piping shall conform to Appendix D.

7.3.2.3 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 (6.3.2).

7.3.2.4 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.

7.3.2.5 All piping components furnished by the vendor that are shown in Appendix D are considered subject to the process fluids.

• **7.3.2.6** 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.

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

7.3.2.8 Unless valves are specified, threaded vent and drain connections shall be plugged.

7.3.2.9 When heating or cooling is provided, each exchanger component shall be suitable for the process fluid and heat transfer fluid to which it is exposed.

• **7.3.2.10** The purchaser will specify whether flanges are required in place of socket-welded unions. Threaded connections are permitted at instruments.

7.3.2.11 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.

7.3.2.12 Pressure gauges shall have block and bleed valves.

7.3.3 Steam Piping

Threaded joints are permitted at instruments.

7.3.4 Cooling Water Piping

7.3.4.1 The arrangement of cooling water piping shall conform to Appendix D.

Note: The cooling water piping shall be designed as specified in 6.1.22.

7.3.4.2 Sight flow indicators shall be furnished in each outlet line.

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

7.4 SPECIAL TOOLS

7.4.1 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.

7.4.2 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.

8 Inspection, Testing and Preparation for Shipment

8.1 GENERAL

8.1.1 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.

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

8.1.3 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.

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

8.1.4.1 When shop inspection and testing have been specified, the purchaser and the vendor shall coordinate manufacturing hold points and inspectors' visits.

8.1.4.2 *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.

8.1.4.3 *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.)

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

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• **8.1.6** 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.

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

8.2 INSPECTION

8.2.1 General

8.2.1.1 The vendor shall keep the following data available for at least 20 years for examination by the purchaser or the purchaser's representative upon request:

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

8.2.1.2 Pressure-containing parts shall not be painted until the specified inspection of the parts is completed.

• **8.2.1.3** 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.

8.2.2 Material Inspection

• 8.2.2.1 General

When radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection of welds or materials is required or specified, the criteria in 8.2.2.2 through 8.2.2.5 shall apply unless other criteria are specified. Cast iron may be inspected in accordance with 8.2.2.4 and 8.2.2.5. Welds, cast steel, and wrought material may be inspected in accordance with 8.2.2.2 through 8.2.2.5.

Note: Regardless of the generalized limits in 8.2.2, it is 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 8.2.2 must be removed to meet the quality standards cited as defined by the inspection method specified.

8.2.2.2 Radiography

8.2.2.2.1 Radiography shall be in accordance with ASTM E94 and ASTM E142.

8.2.2.2.2 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.

8.2.2.3 Ultrasonic Inspection

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

8.2.2.3.2 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.

8.2.2.4 Magnetic Particle Inspection

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

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

Table 6—Maximum Severity of Defects in Castings

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

8.2.2.5 Liquid Penetrant Inspection

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

8.2.2.5.2 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.

8.2.3 Mechanical Inspection

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

• **8.2.3.2** 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.

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8.3 TESTING

8.3.1 General

8.3.1.1 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 7).

8.3.1.2 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.

8.3.1.3 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.

8.3.2 Hydrostatic Test

8.3.2.1 All pressure-casing components, including secondary pressure casing(s), as defined in paragraphs 3.51 and 3.67, shall be tested hydrostatically with liquid at a minimum of 1$^1/_2$ times the maximum allowable working pressure, with the special provisions specified below:

a. Special-design pumps as approved by the purchaser may be segmentally tested at 1$^1/_2$ times the section maximum allowable working pressure.

b. Auxiliary process fluid piping (as described in 7.3.2), if fabricated by welding, shall be tested at 1$^1/_2$ 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, and oil coolers shall be tested at a minimum pressure of 975 kPa (150 psig).

d. Steam and cooling water piping, when fabricated by welding, shall be tested at 1$^1/_2$ 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 shall be of the same design as those to be supplied with the pump.

g. The secondary control casing of canned motor pumps may require gas testing in lieu of hydrostatic testing. Procedures shall be developed between the purchaser and vendor.

8.3.2.2 If the part tested is to operate at a temperature at which the strength of a material is below the strength of that material at room temperature, the hydrostatic test pressure shall be multiplied by a factor obtained by dividing the allowable working stress for the material at room temperature by that at operating temperature. The stress values used shall conform to those given in ANSI/ASME B31.3 for piping or in Section II, Division 1, of the ASME Code. The pressure thus obtained shall be the minimum pressure at which the hydrostatic test is performed. The datasheets shall list actual hydrostatic test pressures.

• **8.3.2.3** 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.

8.3.2.4 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 is acceptable.

• **8.3.2.5** 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.

8.3.2.6 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.

8.3.3 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 8.3.3.1 through 8.3.3.4.

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8.3.3.1 The requirements of 8.3.3.1.1 through 8.3.3.1.3 shall be met before the performance test is performed.

8.3.3.1.1 Antifriction bearings (magnetic drive pump) specified to be normally lubricated from a pure oil mist system shall be prelubricated prior to performance testing using a suitable hydrocarbon oil.

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

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

8.3.3.2 Unless otherwise specified, the performance test shall be conducted as specified in 8.3.3.2.1 through 8.3.3.2.5.

8.3.3.2.1 The vendor shall take test data, including head, capacity, power and vibration, at a minimum of 5 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 4.1.16), it may not be feasible to test at shut-off.

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

8.3.3.2.3 The test speed shall be within 3 percent of the rated speed shown on the pump datasheet (see Appendix B). Test results shall be converted to anticipated results at the rated speed. When testing at rated speed is not possible, test speed should not be less than 80 percent or more than 120 percent of rated speed. When testing at other speeds, parasitic losses (e.g., viscous and eddy current) may vary significantly. The purchaser and manufacturer shall agree on corrections to pump power input prior to testing. When applying magnetically coupled or canned motor pumps to very low S.G. fluids (i.e., below 0.5) testing at speeds less than 80 percent of rated may be required to avoid overloading the motor or decoupling a magnetic drive. In such cases mutual agreement between purchaser and manufacturer must be reached prior to testing.

8.3.3.2.4 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 8.2.4, 8.3.3.2, Appendix T).

8.3.3.2.5 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, then 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 6.9.3.4).

8.3.3.3 During the performance test, the requirements of 8.3.3.3.1 through 8.3.3.3.4 shall be met.

8.3.3.3.1 Vibration values shall be recorded during the test in accordance with 6.9.3.2. Vibration values shall not exceed those given in 6.9.3.4 through 6.9.3.6.

8.3.3.3.2 Pumps with antifriction bearings (magnetic drive pumps) shall operate within bearing-temperature limits given in 9.1.4.2.2 and shall not display signs of unfavorable operation, such as noise caused by cavitation.

8.3.3.3.3 When operated at rated speed, pumps shall perform within the tolerances given in Table 7.

Note: Rated power for magnetic drive pumps shall be measured at the pump-to-motor coupling. Rated power for canned motor pumps shall be measured at the motor terminals (i.e., water-to-wire values).

8.3.3.4 Unless otherwise specified, the requirements of 8.3.3.4.1 through 8.3.3.4.3 shall be met after the performance test is completed.

8.3.3.4.1 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.

8.3.3.4.2 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.

Table 7—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	– 2	+ 8
(501 – 1000 ft)	+ 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 4.1.12), 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.)

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• **8.3.3.4.3** When specified, product lubricated bearings shall be removed, inspected by the purchaser or his representative, and reassembled after the performance test is completed. Removal and inspection of bearings shall not require retest unless bearing replacement is required.

• 8.3.4 Optional Tests

When specified, the shop tests described in 8.3.4.1 through 8.3.4.7 shall be performed. Test details shall be mutually agreed upon by the purchaser and the vendor.

• 8.3.4.1 NPSHR Test

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

8.3.4.1.2 A 3 percent drop in head shall be interpreted as indicating performance impairment.

8.3.4.1.3 NPSHR at the rated point shall not exceed the quoted value (see Table 7). Dismantling to correct NPSHR requires a retest (see 8.3.3.4.2).

• 8.3.4.2 Complete-Unit Test

Such components as pumps, drivers, and auxiliaries that make up a complete unit shall be tested together. The complete-unit test shall be performed in place of or in addition to separate tests of individual components specified by the purchaser.

• 8.3.4.3 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.

• 8.3.4.4 Auxiliary-Equipment Test

Auxiliary equipment such as 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.

• 8.3.4.5 Secondary Containment/Control System Hydrotest

When specified, the pressure integrity of the secondary containment system or secondary control system shall be verified by hydrotest using the same criteria as the pressure casing (Reference 8.3.2). Certification shall be provided by the vendor.

• 8.3.4.6 Secondary Containment/Control System Instrumentation Test

When specified, the operability of the instrumentation supplied with the secondary containment system or secondary control system shall be verified. Criteria for the test will be mutually agreed to by the purchaser and the vendor. Certifications shall be provided by vendor.

• 8.3.4.7 Pressure-Temperature Profile Test

When specified, the vendor shall demonstrate the pressure-temperature profile in the recirculation circuit using a fully instrumented pump unit of similar design to the specified unit. Pressures and temperatures at critical points in the circuit shall be measured with the unit pumping water. A pressure-temperature profile shall be developed as defined in Appendix G, with data factored to correspond with the specified fluid and service conditions. Criteria for the test and data presentation shall be agreed to by the purchaser and vendor.

8.4 PREPARATION FOR SHIPMENT

• **8.4.1** 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.

8.4.2 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.

8.4.3 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 8.4.3.1 through 8.4.3.9.

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

8.4.3.2 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 9.1.5.3.17 or 9.1.5.3.18.

8.4.3.3 Exterior machined surfaces of carbon steel parts shall be coated with a suitable rust preventer.

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8.4.3.4 Internal areas of carbon steel bearing housings (magnetic drive pumps) shall be coated with a suitable oil-soluble rust preventer.

8.4.3.5 Flanged openings shall be provided with metal closures at least 5mm (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.

8.4.3.6 Threaded openings shall be provided with steel caps or steel plugs in accordance with 7.3.1.13.

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

8.4.3.8 Lifting points and lifting lugs shall be clearly identified.

8.4.3.9 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.

8.4.4 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.

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

9 Specific Pump Sections

9.1 MAGNETIC DRIVE PUMPS

9.1.1 General

9.1.1.1 Magnetic Drive Pumps are designated as Type MDP. A description of Type MDP pumps is given in Appendix C.

9.1.1.2 The design clearance of the liquid gap and of the air gap shall be sufficient to ensure that contact between the magnet assemblies and the containment shell does not occur due to pressure deformation, nozzle loading, flow variations, thermal expansion or power end bearing wear.

9.1.1.3 The design shall allow for the inspection of the containment shell without disturbing the pressure casing.

• **9.1.1.4** When specified, the design shall provide for the removal of the drive end without disturbing the pressure casing or the pump driver (i.e., adequate spacer coupling provided) (see 4.3.6).

9.1.1.5 Product lubricated bearings shall not be supported by the containment shell.

9.1.1.6 Jackscrews, guide rods, or similar devices shall be incorporated in the design to facilitate installation and maintenance of the magnet coupling.

9.1.1.7 Cooling and lubrication of product lubricated bearings and magnet area shall be in accordance with Appendix D.

9.1.1.8 The torque rating of the magnetic coupling and the antifriction bearing manufacturer's identity numbers shall appear on the pump nameplate or on a supplemental nameplate meeting the requirements of 6.15.2

9.1.2 Pressure Containment

9.1.2.1 Containment Shell

9.1.2.1.1 The containment shell is by definition a pressure containing component and shall meet the requirements of 6.3 except as follows:

a. Section VIII, Division 2, of the ASME Boiler and Pressure Vessel Code may be utilized in lieu of Division 1 for design.
b. The minimum corrosion/erosion allowance shall be 0.4 mm (0.015 in.).
c. The minimum containment shell thickness shall be 1.0 mm (0.040 in.).

9.1.2.1.2 Fabrication of containment shells shall conform with 6.13.

9.1.2.1.3 The containment shell to casing cover joint shall have a metal-to-metal rabbeted fit utilizing a confined controlled compression gasket of material compatible with the process fluids and operating temperatures.

9.1.2.1.4 Alternative containment shell designs are subject to approval by the purchaser.

9.1.2.2 Secondary Control System

9.1.2.2.1 The secondary control system shall protect the antifriction bearings from contamination by the pumped fluid.

9.1.2.2.2 To minimize leakage around the external shaft in the event of a primary containment failure, the secondary control system shall include a replaceable, non-sparking restriction device. Lip seals are not acceptable.

9.1.3 Magnetic Couplings

9.1.3.1 Magnetic coupling assemblies shall be of either synchronous or asynchronous design. Synchronous couplings shall be supplied with rare earth magnets. Torque ring drive couplings may be supplied with either rare earth or aluminum nickel cobalt magnets. The vendor shall state the magnet material on the proposal datasheet (refer to Appendix B).

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Alternate designs and/or materials require purchaser approval for the specific application.

9.1.3.2 Magnets shall be mechanically retained and bonded with a suitable adhesive.

9.1.3.3 The pump shall be designed to prevent the outer drive magnet from contacting the containment shell in the event of a shaft or bearing failure. The design shall utilize a replaceable device of nonsparking material to eliminate any sources of ignition.

9.1.3.4 The outer drive rotor (outer magnet ring) shall be keyed to the power end drive shaft. A taper fit and puller holes are required for shaft sizes equal to or greater than 50 mm (2 in.).

9.1.3.5 The inside surface of the outer magnet ring shall be sheathed with a nonmagnetic material to prevent damage to the magnets or the containment shell upon assembly/disassembly.

9.1.3.6 The inner magnet or torque ring material shall be shielded from the process fluid by a hermetically sealed metallic sheathing. This sheathing material must be compatible with the process fluid to ensure against chemical attack. The minimum inner magnet sheathing thickness shall be 0.40 mm (0.015 in.).

• **9.1.3.7** Magnetic couplings shall be designed to avoid decoupling during start-up and while operating at rated conditions. The following conditions shall be analyzed by the manufacturer when sizing the magnetic coupling:

a. Torque required to accelerate the rotor assembly during start-up with the job driver and specified fluid. Starting conditions will be specified by the purchaser. Across-the-line starting is to be assumed for medium voltage motor drives unless otherwise specified.

b. Torque required to pump the fluid at rated conditions of flow, temperature, specific gravity and viscosity with provision to operate at a 5 percent increase in head for constant speed drivers or 5 percent increase in speed when variable speed drivers are applied.

Table 8—Magnetic Coupling Torque Service Factors

Calculated Torque		Minimum Synchronous Coupling Service Factor	Minimum Torque Ring Coupling Service Factor
(Nm)	(ft-lbf)	(%)	(%)
< 50	< 37	125	110
50 to 150	37 to 111	115	110
> 150	> 111	110	110

c. When specified, torque required to cover end of curve operation, such as transfer pumps, loading pumps, and pumps operating in parallel.

Note: This sizing will result in higher losses, greater heat generation by the magnetic coupling, and an oversized coupling.

• **9.1.3.8** The rated torque of the magnetic coupling shall equal the larger of the torques calculated in 9.1.3.7 (a), (b), or, when specified, (c), with factors applied as shown in Table 8. Where it appears that this will lead to unnecessary oversizing of the magnetic coupling, an alternative proposal shall be submitted for the purchaser's approval.

• **9.1.3.9** When specified, the vendor shall submit a torque versus temperature curve that covers the entire design temperature range of the magnetic coupling.

• **9.1.3.10** When specified, the vendor shall submit a speed-torque curve defining capability of the synchronous magnetic coupling during start-up and operation at the rated temperature. The torque requirements of 9.1.3.7 (a) and (b) are to be shown as well as the rating factor defined in 9.1.3.8. The speed-torque curve shall be presented in the format shown in Figure 7.

9.1.4 Antifriction Bearings, Bearing Housings, and Lubrication

9.1.4.1 Antifriction Bearings

9.1.4.1.1 Antifriction rolling element bearings shall be used to support the external drive shaft such that the following conditions are satisfied:

a. Factor Nd_m shall not exceed 500,000

where

d_m = mean bearing diameter $(d+D)/2$, mm,

N = rotative speed, rpm.

b. Basic rating L_{10} per ISO 281 (ANSI/ABMA Standard 9) shall be at least 25,000 hours with continuous operation at rated conditions, and at least 16,000 hours with maximum radial and axial loads at rated speed.

9.1.4.1.2 Antifriction rolling element bearings selected to support axial thrust loads shall be sized for continuous operation under all specified conditions. In addition to thrust from 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.

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

$$F = \frac{(0.25)(9,550)P_r}{(N_r D)} \qquad (1)$$

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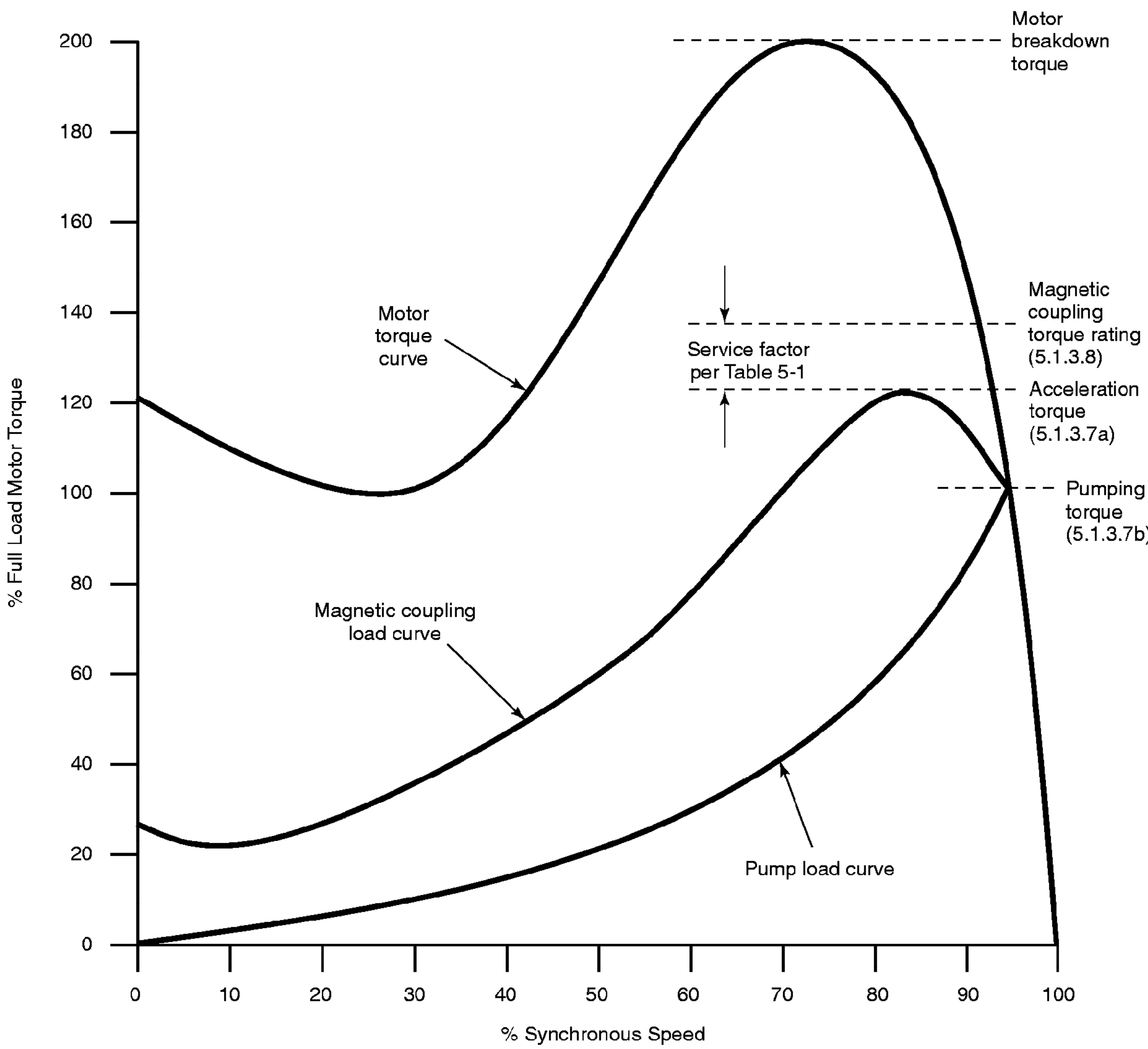

Figure 7—Speed-Torque Curve

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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.

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

9.1.4.1.5 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 diametrical clearance, both in accordance with the recommendations of ISO 286 (ANSI/ABMA Standard 7). sBearings 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.

9.1.4.1.6 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).

9.1.4.2 Antifriction Bearing Housings

• **9.1.4.2.1** 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.

9.1.4.2.2 Sufficient cooling, including allowance for fouling, shall be provided to maintain the oil sump temperature below 82°C (180°F) for ring-oiled or splash systems, based on the specified operating conditions and ambient temperature of 43°C (110°F). During shop testing, the oil sump 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.

9.1.4.2.3 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 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.

9.1.4.2.4 Bearing housings, load-carrying bearing covers, and brackets between the pump casing or cover shall be steel.

9.1.4.2.5 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.

9.1.4.2.6 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.

9.1.4.2.7 Bearings and bearing housings shall meet the requirements of 9.1.4.2.7.1 through 9.1.4.2.7.4 when oil mist lubrication is specified (see 9.1.4.3.3).

9.1.4.2.7.1 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.

9.1.4.2.7.2 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.

9.1.4.2.7.3 Shielded or sealed bearings shall not be used.

9.1.4.2.7.4 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.

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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.

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

9.1.4.3 Antifriction Bearing Lubrication

9.1.4.3.1 Bearings and bearing housings shall be arranged for oil lubrication.

9.1.4.3.2 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.

• **9.1.4.3.3** When specified, provisions shall be made for either pure oil or purge oil mist lubrication (see 7.1.2.2.7 for requirements).

9.1.5 Accessories

9.1.5.1 Drivers

• **9.1.5.1.1** The purchaser will specify the type of driver, 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 500A.
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.

9.1.5.1.2 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.

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

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

9.1.5.1.5 The driver feet shall be drilled with pilot holes that are accessible for use in final doweling.

9.1.5.2 Shaft Couplings and Guards

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

• **9.1.5.2.2** 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 back pullout assembly 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.

9.1.5.2.3 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.

9.1.5.2.4 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 the shaft diameter is greater than 60 mm ($2^1/2$ in.), the hub shall be mounted with a taper fit. Taper for keyed couplings shall be 1:10 long series conical in accordance with ISO/R775, or alternately 1:16 (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.

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

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

9.1.5.2.7 Couplings operating at speeds of 3800 rpm or less shall be component balanced. Components 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 6.9.4.1. Two-plane balancing is preferred; however, single-plane balancing may be used in accordance with 6.9.4.2.

9.1.5.2.8 Limited end float couplings with maximum coupling end floats as specified in Table 9 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 9—Maximum Coupling End Floats

Minimum Motor Rotor End Float		Maximum Coupling End Float	
(mm)	(in.)	(mm)	(in.)
6	0.25	2	0.09
13	0.50	5	0.19

9.1.5.2.9 When the vendor is not required to mount the driver, the vendor 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.

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

9.1.5.3 Baseplates

9.1.5.3.1 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.

9.1.5.3.2 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.

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

9.1.5.3.4 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.

Table 10—Stiffness Test Acceptance Criteria

Loading Condition	Pump Shaft Displacement: Baseplate Intended for Grouting		Pump Shaft Displacement: Baseplate Not Intended for Grouting		Displacement Direction
	µm	in.	µm	in.	
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 movements from Table 1A (1B):

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

9.1.5.3.5 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 10 during a test in accordance with 7.1.5.3.6. 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.)

• **9.1.5.3.6** 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 9.1.5.3.5. 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 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

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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.

9.1.5.3.7 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.

9.1.5.3.8 In addition to the requirements of 7.1.5.3.7, 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.

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

9.1.5.3.10 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).

9.1.5.3.11 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.

9.1.5.3.12 When driver and pump size permit, 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."

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

9.1.5.3.14 Transverse alignment positioning jackscrews shall be provided for drive train components weighing more than 200 kg (450 lb) to facilitate transverse horizontal adjustments. Axial alignment positioning jackscrews shall be provided for drive train components weighing more than 400 kg (900 lb) 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 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.

9.1.5.3.15 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 6 screws be provided.

9.1.5.3.16 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.

9.1.5.3.17 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.

• **9.1.5.3.18** 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.

9.1.5.3.19 The baseplate shall be provided with lifting lugs for at least a 4-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.

9.1.5.3.20 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.

9.1.6 Testing

• **9.1.6.1** Static torque testing data shall be available for each coupling rating, and when specified shall be submitted for purchaser review. When specified, magnetic couplings shall be given a static torque test to verify the rated torque (reference 9.1.3.8) and certification shall be provided. The test shall be performed at ambient temperature and corrected for maximum allowable temperature.

9.1.6.2 Prior to actual performance testing, the pump manufacturer shall advise the shop procedure for quantifying eddy-current losses and for correcting water test results to performance on specified job fluid(s).

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9.1.7 Preparation for Shipment

9.1.7.1 Exposed shafts and shaft couplings (magnetic drive pumps) shall be wrapped with waterproof, moldable waxed cloth or volatile-corrosion inhibitor paper. The seams shall be sealed with oil-proof adhesive tape.

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

9.2 CANNED MOTOR PUMPS

9.2.1 General

Canned Motor Pumps are designated as Type CMP. A description of Type CMP is given in Appendix C.

9.2.2 MOTOR REQUIREMENTS

9.2.2.1 The stator housing of a canned motor pump, including the electrical feed through barrier, shall be designed for the pressure casing maximum allowable working pressure, associated hydrostatic test pressure and operating temperature range.

9.2.2.2 The stator cavity on motors for pumps built for services which have operating temperature of 160°C (320°F) or less shall not be filled with oil. When approved by the purchaser, solid heat transfer material may be used to conduct heat away from the stator windings. Pumps built for services which have operating temperatures in excess of 160°C (320°F), shall have ceramic insulated stators or shall incorporate a cooling system.

9.2.2.3 Electrical feed through barrier to canned motor junction box shall be located above the pump centerline and shall be self-draining into the stator cavity.

9.2.2.4 The connection box shall be sized at least one size larger than the standard IEC (NEMA) size for the motor used.

9.2.2.5 Motors shall be designed for across-the-line starting.

9.2.2.6 Motors rated below 150 kW (200 hp) shall be capable of 3 starts per hour when the initial start is from ambient temperature. Motors rated 150 kW and above shall be capable of 3 starts per hour but limited to 8 starts per day.

9.2.2.7 The stator winding insulation shall be rated to allow the motor to satisfactorily operate for at least 175,000 hours at the maximum rated temperature and flow conditions.

9.2.2.8 Class F is the minimum acceptable class of insulation. Class C insulation shall not be used unless specifically approved by the purchaser.

• **9.2.2.9** When specified, motors shall be designed for the special operating conditions, such as frequent starting and multi-speed operation, of the driven equipment. The vendor shall state the effect of these conditions on the expected operating life.

• **9.2.2.10** When specified, UL, FM or equivalent certification shall be provided.

• **9.2.2.11** When specified, a decontamination flush or purge connection shall be included on the stator assembly.

9.2.3 Stator Liner

9.2.3.1 The stator assembly consisting of the stator, stator liner, liner backing supports, stator housing, and electrical feed-through is by definition a pressure-containing assembly and shall meet the requirements of 4.3 except as follows.

a. The minimum stator liner corrosion allowance shall be 0.15 mm (0.005 in.).
b. The minimum stator liner thickness shall be 0.46 mm (0.018 in.).
c. The stator liner shall be hydrostatically tested in the stator assembly at 1.5 times the maximum allowable working pressure.

9.2.3.2 The stator liner material shall conform to 6.11.

9.2.3.3 Stator liner materials not contained in Appendix H shall be subject to the approval of the purchaser.

9.2.4 Rotor Liners

9.2.4.1 The minimum rotor liner corrosion allowance shall be 0.15 mm (0.005 in.).

9.2.4.2 The rotor liner material shall conform to 6.11.

9.2.4.3 Rotor liner materials not contained in Appendix H shall be subject to the approval of the purchaser.

9.2.5 Additional Nameplate Requirements

9.2.5.1 In addition to the nameplate information required in 6.15.2, canned motor pump nameplates shall also include the following additional information:

a. Rated motor voltage.
b. Full load motor amperes.
c. Motor insulation class
d. Motor rated horsepower.
e. Locked rotor amperes.
f. Maximum allowed pump and motor working pressure at rated temperature.
g. Date of manufacture.

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h. Pump impeller diameter.
i. Pumped liquid identification.
j. Motor thermal protection actuation temperature.

9.2.5.2 For service in Class I, Division 1 Hazardous Areas, the following additional nameplate information is required:

a. Pumped liquid temperature limits (either by NFPA 70 or actual temperature).
b. Label, note or logo indicating approval for use in Class I, Division I area.

9.2.5.3 For variable speed drives, the following additional nameplate information is required: Motor speed range.

9.2.6 Submersible Canned Motor Pumps

When pumps are designed and supplied with a vessel nozzle cover plate, the cover plate shall be designed to the same maximum working pressure and temperature as the vessel on which it is mounted. If the vessel on which it is mounted is a pressure vessel, designed to ASME Section VIII, Division 1, then the cover plate shall be designed to the same criteria. The conduit from the motor to the cover plate is a part of the pressure casing and shall be designed in accordance with all requirements imposed on the pump pressure casing such as corrosion allowance, design pressure, and design temperature.

• 9.2.7 Testing

Motor tests shall consist of resistance measurements of the windings and dielectric tests to confirm the integrity of the winding insulation. The dielectric tests shall include the polarization index ratio measurement based on 1- and 10-minute readings. Tests shall be performed in accordance with IEEE 252 or other standards as agreed to by the purchaser. When specified, certification shall be provided by the vendor.

10 Vendor's Data

10.1 GENERAL

10.1.1 The information to be furnished by the vendor is specified in 10.2 and 10.3. 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.

10.1.2 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.

• **10.1.3** 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 datasheets.
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. Magnetic coupling sizing (MDP only).
j. Temperature-pressure profile.
k. Vendor-supplied maintenance data.
l. Other technical items.
m. Thrust-bearing sizing and estimated loadings.

10.2 PROPOSALS

10.2.1 General

10.2.1.1 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 10.2.2 through 10.2.4, 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 10.1.2.

10.2.1.2 Clearances less than those required by 6.7.4.2 must be stated as exceptions to this standard in the proposal.

10.2.2 Drawings

10.2.2.1 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 loca-

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tion 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 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 above.)

10.2.2.2 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.

10.2.3 Technical Data

The following data shall be included in the proposal:

a. The purchaser's datasheets, with complete vendor's information entered thereon and literature to fully describe details of the offering.
b. The purchaser's noise datasheet.
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 11). (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, and external flush liquid including the quantity of liquid required and the supply pressure. (Approximate data shall be defined and clearly identified as such.) This information may be entered on the datasheets.
j. A description of the tests and inspection procedures for materials, as required by 4.11.1.3.
k. A description of any special requirements specified in the purchaser's inquiry and as outlined in 5.3, 6.1.8, 6.1.11, 6.1.12, 6.4.2.3, 6.9.3.1, 6.11.2, 7.1.4.1, 7.4.1, 9.1.3.8, 9.1.4.2.2.
• 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. Notification when testing at rated speed, per 8.3.3.2.3, is not possible or recommended. A recommendation for correction of pump power from rated to test conditions shall also be included.

10.2.4 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 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.

• 10.2.5 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.

10.3 CONTRACT DATA

10.3.1 General

10.3.1.1 Vendor contract data shall be furnished and maintained as specified in Appendix O. Each drawing, bill of material, and datasheet 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 10.1.2, the revision number and date, and the title.

10.3.1.2 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.

10.3.1.3 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).

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10.3.2 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 clearly legible, identified in accordance with 10.3.1.1, 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 international standards as agreed upon with the purchaser. Each drawing shall include the details for that drawing listed in Appendix O.

10.3.3 Technical Data

10.3.3.1 The data shall be submitted in accordance with Appendix O and identified in accordance with 10.3.1.1. 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 datasheets as part of the order specifications.

10.3.3.2 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 impeller, the identification number of the impeller, and the pump serial number.

10.3.4 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).

10.3.5 Parts Lists and Recommended Spares

10.3.5.1 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 6.11.2. 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.

10.3.5.2 The vendor shall indicate on the preceding parts lists which parts are recommended spares for start-up and normal maintenance as referenced in 10.2.3, Item f (Table 11). 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 10.1.2.

10.3.6 Installation, Operation, Maintenance, and Technical Data Manuals

10.3.6.1 General

The vendor shall provide sufficient written instructions and a cross-referenced list of all drawings to enable the purchaser to correctly install, operate, and maintain all of the equipment ordered. This information shall be compiled in a manual or manuals with a cover sheet that contains all reference identifying data specified in 10.1.2, 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.

10.3.6.2 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 10.2.2 and 10.2.3.

10.3.6.3 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.

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Table 11—Recommended Spare Parts

Parts	See Note	Spare Recommended For:						
		Start-Up			Normal Maintenance			
Number of Identical Pumps		1 – 3	4 – 6	7+	1 – 3	4 – 6	7 – 9	10+
Casing								1
Cover, casing								1
Impeller					1	1	2	N/3
Wear Rings (set)	3	1	1	1	1	1	2	N/3
Bearing Set, Product Lubricated Radial, Inboard	4	1	1	2	1	2	N/3	N/3
Bearing Set, Product Lubricated Radial, Outboard	4	1	1	2	1	2	N/3	N/3
Bearing Set, Product Lubricated Thrust	4	1	1	2	1	2	N/3	N/3
Gasket, Shims, O-rings (Set)	3, 4	1	2	N/3	1	2	N/3	N/3
SPECIFIC TO TYPE MDP PUMPS:								
Rotor Assembly (Driven)	1, 2, 5				1	1	1	1
Bearing Housing, Antifriction								1
Pump Shaft (w/key)					1	1	2	N/3
Drive Shaft (w/key)					1	1	2	N/3
Bearing, Antifriction Radial	4	1	1	2	1	2	N/3	N/3
Bearing, Antifriction Thrust	4	1	1	2	1	2	N/3	N/3
Containment Shell	1, 2				1	1	1	1
SPECIFIC TO TYPE CMP PUMPS:								
Rotor Assembly	1, 2, 5				1	1	1	1
Bearing Housing, Inboard								1
Bearing Housing, Outboard								1

Notes:
N = Number of identical pumps.
[1]Vital service pumps are generally unspared or partially spared. When a vital machine is down, production loss or violation of environmental permits results.
[2]Essential service pumps are required for operation and have an installed spare. A production loss will occur only if main and spare fail simultaneously.
[3]Normal wear parts (see 6.1.1).
[4]Per pump set.
[5]Rotor consists of all rotating parts attached to the shaft.

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APPENDIX A—REFERENCED PUBLICATIONS AND INTERNATIONAL STANDARDS

A.1 Referenced Publications

The following publications are cited in this standard:

ABMA[1]

Standard 7	*Shaft and Housing Fits for Metric Radial Ball and Roller Bearings*
Standard 9	*Load Ratings and Fatigue Life for Ball Bearings*
Standard 20	*Metric Ball and Roller Bearings (Except Tapered Roller Bearings) Conforming to Basic Boundary Plans: Boundary Dimensions, Tolerances, and Identification*

AGMA[2]

9000	*Flexible Couplings — Potential Unbalance Classification*
9002	*Bores and Keyways for Flexible Couplings (Inch Series)*

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 670	*Vibration, Axial-Position, and Bearing-Temperature Monitoring Systems*
Standard 677	*General-Purpose Gear Units for Refinery Service*

ASME[3]

B1.1	*Unified Inch Screw Threads (UN and UNR Thread Form*
B1.20.1	*Pipe Threads, General Purpose (Inch)*
B16.5	*Pipe Flanges and Flanged Fittings (steel)*
B16.11	*Forged Steel Fittings, Socket-Welding and Threaded*
B31.3	*Chemical Plant and Petroleum Refinery Piping*
B46.1	*Surface Texture (Surface Roughness, Waviness and Lay)*
Y14.2M	*Line Conventions and Lettering*
	Boiler and Pressure Vessel Code, Section II, "Materials"; Section V, "Nondestructive Examination"; Section VIII, "Pressure Vessels"; and Section IX, "Welding and Brazing Qualifications"

ASTM[4]

C 531	*Test Method for Linear Shrinkage and Coefficient of Thermal Expansion of Chemical-Resistant Mortars, Grouts, and Monolithic Surfacings*
C 579	*Test Methods for Compressive Strength of Chemical-Resistant Mortars and Monolithic Surfacings*
C 882	*Test Method for Bond Strength of Epoxy-Resin Systems Used With Concrete*
C 884	*Test Method for Thermal 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 Peal Exothermic Temperature of Reacting Thermosetting Resins*
E 94	*Guide for Radiographic Testing*
E 125	*Reference Photographs for Magnetic Particle Indications on Ferrous Castings*
E 142	*Method for Controlling Quality of Radio*
E 709	*Practice for Magnetic Particle Examination*

AWS[5]

D1.1	*Structural Welding Code—Steel*

DIN[6]

910	*Heavy-Duty Hexagon Head Screw Plugs*

HI[7]

The codes, standards, and specifications of the Hydraulic Institute (Centrifugal Pump Section) also form part of this standard.

[1]American Bearing Manufacturers Association, 1200 19th Street, N.W., Suite 300, Washington, D.C.20036.
[2]American Gear Manufacturers Association, 1500 King Street, Suite 201, Alexandria, Virginia 22314.
[3]American Society of Mechanical Engineers, 345 East 47th Street, New York, New York 10017.
[4]American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959.
[5]American Welding Society, 550 N.W. LeJeune Road, P.O. Box 351040, Miami, Florida 33135.
[6]DIN Deutsches Institut fur Normung, Burggrafenstrasse 6, Postfach 1107, D-1000 Berlin 30, Germany.*
[7]Hydraulic Institute, 712 Lakewood Center North, Cleveland, Ohio 44107.

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FM[8]

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IEC[9]

34-1	*Rotating Electrical Machines, Part 1: Rating and Performance*

IEEE[10]

252	*Test Procedure for Polyphase Induction Motors Having Liquid in the Magnetic Gap*
841	*Standard for Petroleum and Chemical Industry Severe Duty TEFC Squirrel Cage Induction Motors—Up To and Including 500 HP*

ISO[11]

31-0	*General Principles Concerning Quantities, Units, and Symbols*
128	*Technical Drawings—General Principles of Presentation*
129	*Technical Drawings—Dimensioning—General Principles, Definitions, Methods of Execution, and Special Indications*
228-1	*Pipe Threads Where Pressure-Tight Joints are Not Made on the Threads—Part 1: "Designation, Dimensions and Tolerances"*
262	*ISO General Purpose Metric Screw Threads—Selected Sizes for Screws, Bolts, and Nuts*
281-1	*Rolling Bearings—Dynamic Load Ratings and Rating Life—Part 1: "Calculation Methods"*
286	*ISO System of Limits and Fits—Part 1: "Bases of Tolerances, Deviations and Fits"; and Part 2—"Tables of Standard Tolerance Grades and Limit Deviations for Holes and Shafts"*
R 773	*Rectangular or Square Parallel Keys and Their Corresponding Keyways*
R 775	*Cylindrical and 1/10 Conical Shaft Ends*
1503	*Geometrical Orientation and Directions of Movements*
1940/1	*Mechanical Vibration—Balance Quality Requirements of Rigid Rotors—Part 1: "Determination of Permissible Residual Unbalance"*
3098	*Technical Drawings*
3448	*Industrial Liquid Lubricants—ISO Viscosity Classification*
3740	*Acoustics—Determination of Sound Power Levels of Noise Sources—Precision Methods for Broad-Band Sources in Reverberation Rooms*
3744	*Acoustics—Determination of Sound Power Levels of Noise Sources—Engineering Methods for Free-Field Conditions Over a Reflecting Plane*
3746	*Acoustics—Determination of Sound Power Levels of Noise Sources—Survey Method*
5406	*The Mechanical Balancing of Flexible Rotors*
5753	*Rolling Bearings—Radial Internal Clearance*
7005-1	*Metallic Flanges—Part 1: "Steel Flanges"*
9905	*Technical Specification for Centrifugal Pumps—Clause 1*
10436	*Petroleum and Natural Gas Industries—General-Purpose Steam Turbines for Refinery Service*

MSS[12]

MSS-SP-55	*Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components—Visual Method*

NACE[13]

	Corrosion Engineers Reference Book
MR 0175	*Standard Material Requirements: Sulfide Stress Cracking Resistant Metallic Materials for Oilfield Equipment Corrosion Engineers Reference Handbook*

NEMA[14]

MG-1	*Motors and Generators*

NFPA[15]

NFPA 70	*National Electrical Code*

SSPC[16]

SP 6	*Surface Preparation Specification*

[8]Factory Mutual, PO Box 9102, Norwood, Massachusetts 02062-9102.

[9]International Electrotechnical Commission, 3 Rue De Varembe, PO Box 131, Geneve, Switzerland, CH-1211*

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

[11]International Organization for Standardization publications, Case Postale 56, Geneva, Switzerland, CH-1211.*

[12]Manufacturers Standardization Society, 127 Park Street, N.E., Vienna, Virginia 22180.

[13]NACE International (formerly the National Association of Corrosion Engineers) 1440 South Creek Drive, P.O. Box 218340, Houston, Texas 77218-8340.

[14]National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1847, Rosslyn, Virginia 22209.

[15]National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02269.

[16]Steel Structures Painting Council, 40 24th Street, Suite 600, Pittsburgh, Pennsylvania 15222.

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UL[17]

Underwriters Laboratories is a testing and certification agency

U.S. Army Corps of Engineers[18]

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

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

[17]Underwriters Laboratories, 333 Pfingsten Road, Northbrook, Illinois 60062-2096.

[18]U.S. Army Corps of Engineers, 20 Massachusetts Avenue, N.W., Washington, D.C. 20314.

Note: AGMA, DIN, IEC and ISO Standards are available from Global Engineering Documents, 15 Inverness Way East, Englewood, Colorado, 80112-9649.

A.2 Corresponding International Standards

Table A-1 contains international standards that cover the topics corresponding to standards listed in A-1. Table A-2 shows U.S. and international standards for piping components that cover the same general topics.

The requirements contained in those standards may be significantly different and determination of equivalence or acceptability is the responsibility of the parties involved.

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Table A-1—Corresponding International Standards (see notes)

		Country of Origin and Standard				
USA Standard	Subject	International ISO	Germany DIN	Great Britain BSI	France AFNOR	Japan JIS
ANSI/ABMA Std. 7	Shaft and bearing fits for metric bearings	286-1 286-2	5425	5646 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	R773 R774 R775 286-1 286-2	740 6885 7190	3170 4235	NFE 02-E22175 NF ISO 286-1 NF ISO 286-2	B0903 B0904 B1301 B1303
ANSI/ASME B1.1	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 Part 1 (seal on gasket)		2779 (seal on gasket) 21n(seal on thread)	NFE 03.005	B0202 B0203
ANSI/ASME B16.5	Steel and alloy pipe flanges	7005/1	2543 2544 2545 2546 2547 2548 2549 2550 2551	4504	NFE 29203/204	IPI-75-15-1984
ANSI/ASME B16.11	Forged fittings		910	3799	NFE 29600	
ANSI/ASME B31.3	Chemical plant and petroleum refinery piping			1600		B8270
ANSI/ASME Y14/2M	Line conventions and lettering	31 128 129 3098		308 Parts 2 & 3	NFE 04202/203	

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Table A-1—Corresponding International Standards (see notes)

USA Standard	Subject	Country of Origin and Standard: International ISO	Germany DIN	Great Britain BSI	France AFNOR	Japan JIS
ANSI/AWSE D1.1	Structural welding code—steel			4870/1/2	NFP 22471	Code of Japan Welding Eng. Society
API Std 541	Motors, squirrel cage induction	IEEE841				
API Std 611	General purpose steam turbines	10436	4312	132		
	Sound control	3746 3744 3740	45635P.1 45635P.2 45635P.8 45635P.24 45635P.40 45645	4196 Part 4 4196 Part 6 4196 Part 0	NFS 31027 NFS 31067 (for Sect. 2)	
API Std 670	Vibration position and bearing temperature monitoring	2372 3945	VDI 2056 VDI 2059	4675	NFE 90300 NFE 90301	
API Std 677	General purpose gear units					
API RP 500	Classification of electrical areas in petroleum refineries	IEC 79		5345 Part 2	NF-S	RIIS-TR-79-1 RIIS-TR-85-1
API RP 686	Machinery Installation and Installation Design					
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-BLATTER			
—Section V	Non destructive examination		SEC.HP 5/3	4080 Parts I & II		G0801 Z2343 Z2344 Z3060
—Section VIII Div. 1	Rules for construction of pressure vessels	R 831 TR 7468		5500	CODAP	B8270 G0565 Z2302
Section IX	Welding and brazing		SEC.HP 2 SEW 110 8560/63	4870/1/2		Z2242 Z3040 Z3801 Z3881 Z3891
ASTM A53	Zinc coated welded and seamless black and hot dipped steel pipe					G3452/G3454

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Table A-1—Corresponding International Standards (see notes)

		Country of Origin and Standard				
USA Standard	Subject	International ISO	Germany DIN	Great Britain BSI	France AFNOR	Japan JIS
ASTM A105/A105M	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/A153M	Zinc coating (hot dip) on iron and steel hardware			1706		B3201
ASTM A181/A181M	Carbon steel forgings for general purpose piping		10083	1503	NFA 36.612	G3202
ASTM A182/A182M	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/A193M	Alloy steel and stainless steel bolting materials for high-temperature service		17240/17440 17200/17245	4882 1506	NFA 35558	G4107 G4303
ASTM A194/A194M	Carbon and alloy steel nuts for bolts for high-pressure and high-temperature service		17440	4882 1506		G4051 G4303
ASTM A216/A216M	Carbon steel castings suitable for fusion welding for high-temperature service		17245	1504	NFA 32055/32060	G5151
ASTM A217/A217M	Martensitic stainless and alloy steel castings for pressure containing parts suitable for high-temperature service		17445	1504	NFA 32055	G5121
ASTM A240/A240M	Heat-Resisting Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Fabrications					
ASTM A266/A266M	Carbon Steel Forgings for Pressure Components					
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 A312/A312M	Seamless and welded austenitic stainless steel pipe		17440	3605	NFA 49214/49219	G3459
ASTM A351/A351M	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	#N10083-1	NFEN 10083-1	G4104 G4105
ASTM A473	Stainless and Heat-Resisting Forgings					
ASTM A479/A479M	Stainless and Heat-Resisting Steel Bars and Shapes for Pressure Components					
ASTM A487	Steel castings suitable for pressure service		17245	1504	NFA 32055	G5121 G5151
ASTM A494/A494M	Nickel and nickel alloy castings					

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Table A-1—Corresponding International Standards (see notes)

USA Standard	Subject	Country of Origin and Standard				
		International ISO	Germany DIN	Great Britain BSI	France AFNOR	Japan JIS
ASTM A515/A515M	Carbon Steel Pressure Parts for Intermediate or Higher-Temperature Service					
ASTM A516/A516M	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/A564M	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 A695	Steel Bars, Carbon, Hot-Wrought, Special Quality , for Fluid Power Applications					
ASTM A 743/A743M	Iron chromium, iron chromium nickel, corrosion resistant castings for general application		SEW 410			G5121
ASTM A744/A744M	ron chromium nickel and nickel base corrosion resistant castings for severe service		7445	I150		
ASTM A747/A747M	Precipitation hardening stainless steel castings		SEW 410			G5121
ASTM A790/A790M	Seamless and Welded Ferritic/Austenitic Stainless Steel Pipe					
ASTM A890/A890M	Castings, Iron-Chromium-Nickel-Molybdenum Corrosion-Resistant, Duplex (Austenitic/Ferritic) for General Application					
ASTM B23	White metal bearing alloys (known commercially as babbit metal)			3332		H5401
ASTM B127	Nickel-Copper Alloy (UNS N04400) Plate, Sheet and Strip					
ASTM B164	Nickel-copper alloy rod, bar and wire			3076-NA13		
ASTM B265	Titanium and Titanium Alloy Strip, Sheet and Plate					
ASTM B333	Nickel-Molybdeum Alloy Plate, Sheet, and Stri					
ASTM B335	Nickel-Molybdenum Alloy Rod					
ASTM B338	Seamless and Welded Titanium and Titanium Alloy Tubes					
ASTM B348	Titanium and Titanium Alloy Bars and Billets					
ASTM B363	Seamless and Welded Unalloyed Titanium and Titanium Alloy Welding Fittings					
ASTM B366	Factory-Made Wrought Nickel and Nickel Alloy Fittings					
ASTM B367	Titanium and Titanium Alloy Castings					
ASTM B381	Titanium and Titanium Alloy Forgings					

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Table A-1—Corresponding International Standards (see notes)

USA Standard	Subject	Country of Origin and Standard				
		International ISO	Germany DIN	Great Britain BSI	France AFNOR	Japan JIS
ASTM B462	Forged or Rolled UNS N08020, UNS N08024, Uns N08026, UNS N09367 and UNS R20033) Pipe Flanges, Forged Fittings and Valves and Parts for Corrosive High-Temperature Service					
ASTM B464	Welded UNS N08020, N08024, N08026 Alloy 20 Pipe					
ASTM B468	Welded UNS N08020, N08024, N08026 Alloy 20 Tubes					
ASTM B473	Chromium-nickel-iron-molybdenum-copper-columbium stabilized alloy (UNS N08020) bar and wire		17751			
ASTM B564	Nickel Alloy Forgings					
ASTM B574	Low-Carbon Nickel-Molybdenum-Chromium, Low-Carbon Nickel-Chromium-Molybdenum and Low-Carbon Nickel-Chromium-Molybdenum-Tungsten Alloy Rod					
ASTM B584	Copper alloy sand castings for general applications		17655	1400	NFA 53707-53709	H510 H5102 H5111 H5112 H5115
ASTM B619	Welded Nickel and Nickel-Cobalt Alloy Pipe					
ASTM B622	Seamless Nickel and Nickel-Cobalt Alloy Pipe and Tube					
ASTM B626	Welded Nickel and Nickel-Cobalt Alloy Tube					
ASTM B729	Seamless UNS N08020, N08024, N08026 Nickel Alloy Pipe and Tube					
ASTM B861	Titanium and Titanium Alloy Seamless Pipe					
ASTM B862	Titanium and Titanium Alloy Welded Pipe					
ASTM D1418	Practice for rubber and rubber latices			6057	NFT 40002	
ASTM D2422-68	Standard industrial liquid lubricants – ISO viscosity class	3448		4231	NFT 60141	
ASTM E94	Guides for radiographic testing		5411/T/1&2	2737 (for Castings)	UFA 04160 (for castings)	G0581 Z3104 Z3106

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Table A-1—Corresponding International Standards (see notes)

		Country of Origin and Standard				
USA Standard	Subject	International ISO	Germany DIN	Great Britain BSI	France AFNOR	Japan JIS
ASTM E125	Ref. Photographs for magnetic indications		1650	4080 (for acceptance criteria)		G0565
ASTM E142	Controlling quality of radiographic testing		54109	3971		G0581 Z3104 Z3106
ASTM E709	Practice for magnetic particle indications		54130	6072	NFA 04193/ A09590	G0565
ASTM F467/F467M	Nonferrous Nuts for General Use					
ASTM F468/F468M	Nonferrous Bolts, Hex Cap Screws, and Studs for General Use					
MSSG-SP-55	Quality standard for steel castings for valves, flanges, and fittings and other piping components (visual method					
NACE MR0175	Sulfide stress corrosion cracking resistant metallic materials for oil field equipment					
NEMA SM 23	Steam turbines for mechanical drive service					
NFPA 70	National electric code		IEC 79		NFC 02-205U	JEAC8001
SSPC SP 6	Commercial blast cleaning			7079		

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Table A-2—Piping Components—Corresponding International Standards (see note)

	Standard Origin							
Component	USA ASTM	UNS	International ISO	Germany DIN 17007	Germany DIN 17006	Great Britain BSI	France AFNOR	Japan JIS
Bolting; flange	A193 Grade B7 A194 Grade 2H	G41300 G10350	2604-2-F31 683-1-C35e	1.7258	24Cr Mo5	1506-661	42Cr Mo4 2C 35	G4107 Cl SNB7 G4051 Cl S45C
Fittings, valves & flanged components; carbon steel	A105 or A181			1.0254	St 37.0	1503	A48 CP	G4051 Cl S25C
Fittings and unions; malleable iron, galvanized	A338 and A197 Class 150 malleable iron galvanized to A153					1706		
Fittings and unions; stainless steel	A182 Type 316L, stainless	S31603	683-13-19	1.4404		1503 316.S.11	Z6 CN18-09 or Z6WD18-12-03	G3214 GR SUS 316L
Gaskets	Type 316 Stainless steel spiral wound	S31600		1.4436	X.2 CrNi 19.11	1449 Part 2 316.S.11	Z3 CN18-10 or Z3CND17-12-02	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 43C	G5456 Gr STPT 370/4110
Pipe; carbon steel, galvanized	A53 Type F Sche 40 galvanized to A153					1706	TU26 CH18-12	
Pipe; stainless steel	A312 Type 316L stainless	S31603	683-13-19	1.4404	X3CrNiMo 17 13 2	3605 Part 1 316.S.11	TU26 CH18-12 or TU 26-CN17-12	G3459 Gr SUS 316LTP
Tube; stainless steel	A269 Seamless Type 316 stainless steel	S31600	2604 Gr TS61	1.4436		3605 Part 1 316.S.11	TU26 CH18-12 or TU 26-CN17-12	G3459 Gr SUS 316JI

Note: Corresponding international standards may be acceptable as alternatives with the purchaser's approval.

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APPENDIX B—SEALLESS PUMP DATA SHEETS

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PAGE ______ OF ______

API 685 SEALLESS CENTRIFUGAL PUMP DATA SHEET SI UNITS

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

APPLICABLE TO: ○ PROPOSALS ○ PURCHASE ■ AS BUILT
FOR ______ UNIT ______
SITE ______ SERVICE ______
NO. REQ ______ PUMP SIZE ______ TYPE ______ NO. STAGES ______
MANUFACTURER ______ MODEL ______ SERIAL NO. ______
DIMENSIONS PER: ○ SI ○ US UNITS EQUIPMENT TO COMPLY WITH APPLICABLE: ○ ISO ○ US STANDARDS
NOTES: INFORMATION BELOW TO BE COMPLETED: ○ BY PURCHASER □ BY MANUFACTURER ▣ BY MANUFACTURER OR PURCHASER

○ GENERAL (5.15.1.1)

PUMPS TO OPERATE IN (PARALLEL) NO. MOTOR DRIVEN ______ NO. TURBINE DRIVEN ______
(SERIES) WITH ______ PUMP ITEM NO. ______ PUMP ITEM NO. ______
GEAR ITEM NO. ______ MOTOR ITEM NO. ______ TURBINE ITEM NO. ______
GEAR PROVIDED BY ______ MOTOR PROVIDED BY ______ TURBINE PROVIDED BY ______
GEAR MOUNTED BY ______ MOTOR MOUNTED BY ______ TURBINE MOUNTED BY ______
GEAR DATA SHT. NO. ______ MOTOR DATA SHT. NO. ______ TURBINE DATA SHT. NO. ______

○ OPERATING CONDITIONS (6.1.3)

CAPACITY, NORMAL ______ (m^3/h) RATED ______ (m^3/h)
OTHER ______
SUCTION PRESSURE MAX./RATED ______ / ______ (kPaG)
DISCHARGE PRESSURE ______ (kPaG)
DIFFERENTIAL PRESSURE ______ (kPa)
DIFF. HEAD ______ (m) NPSHA ______ (m)
PROCESS VARIATIONS (7.1.2) ______
STARTING CONDITIONS (7.1.3) ______
SERVICE: ○ CONT. ○ INTERMITTENT (STARTS/DAY) ______
○ PARALLEL OPERATION REQ'D (6.1.12)

○ SITE DATA

LOCATION: (6.1.29)
○ INDOOR ○ HEATED ○ UNDER ROOF
○ OUTDOOR ○ UNHEATED ○ PARTIAL SIDES
○ GRADE ○ MEZZANINE ○ ______
○ ELECTRIC AREA CLASSIFICATION (6.1.24)
CL ______ GR ______ DIV ______
○ WINTERIZATION ○ TROPICALIZATION REQ'D.(7.2.4.5)
SITE DATA (6.1.29)
○ ALTITUDE ______ (m) BAROMETER ______ (kPa)
○ RANGE OF AMBIENT TEMPS: MIN/MAX. ______ / ______ (°C)
○ RELATIVE HUMIDITY: MIN / MAX ______ / ______ (%)
UNUSUAL CONDITIONS: (6.1.29) ○ DUST ○ FUMES
○ OTHER ______

○ LIQUID

TYPE OR NAME OF LIQUID ______
PUMPING TEMP., (°C) NORMAL ______ MAX. ______ MIN. ______
VAPOR PRESSURE ______ (kPa) @ ______ (°C)
TEMPERATURE-VAPOR PRESSURE CURVE NO.: ______
RELATIVE DENSITY (SPECIFIC GRAVITY):
NORMAL ______ MAX ______ MIN ______
SPECIFIC HEAT, Cp ______ (kJ/kg °K)
VISCOSITY ______ (Cp) @ ______ (°C)
MAX. VISCOSITY ______ (Cp) @ ______ (°C)
TEMPERATURE-VISCOSITY CURVE NO.: ______
THERMAL EXPANSION: ______ (mm/m/°K)
THERMAL CONDUCTIVITY: ______ (W/m°K)
CORROSIVE / EROSIVE AGENT ______ (6.11.7)
CORROSION ALLOWANCE (6.3.3) ______ mm
○ CHLORIDE PRESENT; CONCENTRATION (PPM) ______ (7.3.2.6)
○ WET H_2S PRESENT; CONCENTRATION (PPM) ______ (6.11.11)
○ SOLIDS PRESENT (6.2.1); CONCENTRATION (% by wt.) ______
PARTICLE SIZE ______ HARDNESS ______
SIZE DISTRIBUTION: ______
LIQUID (6.1.3) ○ HAZARDOUS ○ FLAMMABLE
POLYMERIZATION CHARACTERISTICS (6.2.1): ______
○ OTHER ______
REMARKS: ______

○ UTILITY CONDITIONS:

STEAM: DRIVERS HEATING
MIN. ______ (kPaG) ______ (°C) ______ (kPaG) ______ (°C)
MAX. ______ (kPaG) ______ (°C) ______ (kPaG) ______ (°C)
ELECTRICITY DRIVERS HEATING CONTROL SHUTDOWN
VOLTAGE: ______ / ______ ______ ______ ______
HERTZ: ______ ______ ______ ______
PHASE: ______ ______ ______ ______
COOLING WATER: (6.1.22) SOURCE ______
TEMP. INLET ______ (°C) MAX. RETURN ______ (C)
PRESS. NORM ______ (kPaG) DESIGN ______ (kPaG)
MIN RETURN ______ (kPaG) MAX ALLOW DP ______ (kPa)
CHLORIDE CONCENTRATION (PPM) ______ (7.3.2.6)
INSTRUMENT AIR: MAX/MIN PRESS ______ / ______ (kPaG)

○ SYSTEM DESCRIPTION (6.2.2)

SUCTION VESSEL: ○ VENTED TO ATMOS. ○ CLOSED
PUMP LOCATION: ○ BELOW LIQUID LEVEL ○ ABOVE LIQ. LEVEL
SUCTION VESSEL ON LEVEL CONTROL? ○ YES ○ NO
PRESSURE SENSOR ON SUCTION VESSEL ○ YES ○ NO
SUCTION VESSEL PRESSURE MAINTAINED BY: ______
IF FLUID LEVEL OR TANK PRESSURE DROPS TOO LOW, WILL
SYSTEM AUTOMATICALLY STOP THE PUMP? ○ YES ○ NO
WILL THE PUMP RUN DRY IN NORMAL OPERATION? ○ YES ○ NO
REMARKS: ______

09/99 SHT 1 OF 5 685DSSI.XLS REV 1

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API 685 SEALLESS CENTRIFUGAL PUMP DATA SHEET SI UNITS

PAGE ______ OF ______
JOB NO. ______ ITEM NO. ______
REQ / SPEC NO. ______ / ______
PURCH ORDER NO. ______ DATE ______
INQUIRY NO ______ BY ______
REVISION ______ DATE ______

PERFORMANCE

PROPOSAL CURVE NO. ______ RPM ______
IMPELLER DIA ; RATED ______ MAX. ______ MIN. ______ (mm)
HYD. EFFICIENCY AT RATED ______ (%)
HYSTERESIS & MECH. LOSSES ______ kW)
OVERALL EFF.(%) ______ RATED POWER ______ (kW)
MAX POWER @ RATED IMPELLER ______ (kW)
MINIMUM CONTINUOUS FLOW:
THERMAL ______ (m^3/h) STABLE ______ (m^3/h)
ROTOR CHAMBER TEMP. RISE OPERATING (6.2.1) ______ (°C)
ROTOR CHAMBER TEMP. RISE ON SHUTDOWN ______ (°C)
PREFERRED OPER. REGION ______ TO ______ (m^3/h)
ALLOWABLE OPER. REGION ______ TO ______ (m^3/h)
LIMITED BY: VIBRATION OTHER ______
MAX HEAD @ RATED IMPELLER ______ (m)
PERCENT RISE TO SHUTOFF (6.1.12) ______
ORIFICE USED TO STEEPEN CURVE OR GIVE CONT. RISE (6.1.12)
NPSHR AT RATED CAPACITY (6.1.19) ______ (m)
MAX. SUCTION SPECIFIC SPEED ALLOWED (6.1.10) ______
SUCTION SPECIFIC SPEED QUOTED ______
MAX. SOUND PRESS. LEVEL REQ'D (6.1.15) ______ (dBA)
EST MAX SOUND PRESS. LEVEL ______ (dBA)
REMARKS: ______

CONSTRUCTION

APPLICABLE STANDARD:
API 685 OTHER ______ (SEE REMARKS)
ROTATION: (VIEWED FROM COUPLING END) CW CCW
PUMP TYPE:
OH1 OH2 OH5 OTHER ______
CASING MOUNTING:
CENTERLINE NEAR CENTERLINE
FOOT IN-LINE OTHER ______
CASING TYPE:
SINGLE VOLUTE MULTIPLE VOLUTE DIFFUSER
CASE PRESSURE RATING:
MAX ALLOWABLE WORKING PRESSURE ______ (kPaG)
@ ______ (°C)
HYDROTEST PRESSURE ______ (kPaG)
DESIGN PUMP FOR : FULL ______ (kPaG VACUUM)
REMARKS: ______

ROTOR:
OPEN SEMI-OPEN FAB'D IMPELLERS ARE ACCEPT
RENEWABLE CASE WEAR RINGS ARE NOT REQUIRED (6.7.1)
RENEWABLE IMP. WEAR RINGS ARE NOT REQUIRED (6.7.1)
NON-GROOVED BEARINGS ARE ACCEPTABLE (6.10.5)
SHAFT DIAMETER BETWEEN BEARINGS ______ (mm)
SPAN BETWEEN BEARING CENTERS ______ (mm)
SPAN BETWEEN BEARING & IMPELLER ______ (mm)
REMARKS: ______

CONSTRUCTION - CONT'D

NOZZLE CONDITIONS: (6.4.2)

	SIZE (NPS)	FLANGE RATING (kg)	FAC'G	POSITION
SUCTION				
DISCHARGE				

PRESSURE CASING AUX. CONNECTIONS: (6.4.3)

	NO.	SIZE (NPS)	TYPE
DRAIN			
VENT			
PRESS. GAUGE			
TEMP GAUGE			
WARM-UP			
EXT. FLUSH / LEAK-OFF			
PURGE/FLUSHOUT			

VENDOR SUPPLY VALVES FOR: (7.3.2.8) VENT(S) DRAIN(S)
ROTOR CAVITY DRAINABLE THRU SECONDARY DRAIN (6.1.8)
CYLINDRICAL THREADS REQ'D FOR AUX. CONN'S (6.4.3.8.3)
FLANGE THICKNESS REQ'S NON-STD. BOLT LENGTH (6.4.2.3)
THD. CONN. TO SECONDARY CASING IS NOT ACCEPT. (6.4.3.8)
SECONDARY CASING HAS: (6.8.8)
DRAIN CONN. & FLUSH PROVISION

AUXILIARY PIPING (7.3)

AUXILIARY PIPING PLAN: ______
CIRC. PIPING MATERIALS:
TUBING CARBON STEEL
PIPE STAINLESS STEEL
CIRC. PIPING ASSEMBLY: (7.5.2.10)
THREADED UNIONS SOCKET WELDED
FLANGED TUBE FITTINGS ______
COOLING WATER PIPING PLAN (7.3.4) ______
C.W. PIPING ASSEMBLY:
PIPE TUBING; FITTINGS ______
C.W. PIPING MATERIALS.
STAINLESS STEEL C. STEEL GALVANIZED
COOLING WATER REQUIREMENTS.
JACKET BEARING HOUSING ______ (m3/h)
HEAT EXCHANGER ______ (m3/h)
TOTAL COOLING WATER ______ (m3/h)
STEAM PIPING: TUBING PIPE OTHER
REMARKS: ______

MATERIALS

APPENDIX H CLASS (6.11.1) ______
MIN DESIGN METAL TEMP (6.11.4.5) ______ (°C)
CASE ______ IMPELLER ______
CASE/IMPELLER WEAR RINGS ______
SHAFT ______
CONTAINMENT SHELL / STATOR LINER ______
INNER MAG. SHEATHING / ROTOR LINER ______
BEARINGS ______
OTHER ______

09/99 SHT 2 OF 5 685DSSI.XLS REV 1

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PAGE ____ OF ____

API 685 SEALLESS CENTRIFUGAL PUMP DATA SHEET SI UNITS

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

SECONDARY CONTROL / CONTAINMENT

O SECONDARY CONTROL (6.8.1)
O MAX LEAKAGE ON PRIMARY FAILURE: ____ (m^3/h)
O SECONDARY CONTAINMENT (6.8.1)
AUX. SEAL DEVICE: O MECHANICAL SEAL O BUSHING
O OTHER: ____
DEVICE IS: O DRY RUNNING O WET RUNNING
O INSIDE O OUTSIDE OF BEARINGS (MAG-DRIVE)
O OTHER: ____

MECHANICAL SEAL DATA:
O APPENDIX H SEAL CODE ____
O SEAL MANUFACTURER ____
O SIZE AND TYPE ____ / ____
O MANUFACTURER CODE ____
O REMARKS ____

MAG-DRIVE SPECIFIC

O DESIGN FOR REMOVAL OF DRIVE END WITHOUT DISTURBING THE PRESSURE CASING OR DRIVER (9.1.1.4)
MAGNETIC COUPLING: O SYNCHRONOUS O TORQUE RING

MAGNETS:	OUTER	INNER
O MAG. MATERIAL		
☐ MOUNT. METHOD		
☐ TEMP. LIMIT, (°C)		
☐ HERMETIC. SEALED		
☐ NO. OF MAGNETS		

O SOFT START REQ'D ☐ HARD START CAPABILITY
☐ TORQUE RATING (DECOUPLING), Nm ____
☐ MAX TORQUE REQ'D ON STARTING, Nm (9.1.3.7a) ____
☐ PUMP TORQUE AT RATED (+ 5%), Nm (9.1.3.7b) ____
☐ ACTUAL SERVICE FACTOR (9.1.3.8) ____ (%)
☐ TORQUE REQ'D FOR FULL CURVE, Nm (9.1.3.7c) ____
O DESIGN FOR FULL CURVE TORQUE REQUIREMENTS (9.1.3.7c)
O SUBMIT MAG-COUPLING TORQUE - TEMP. CURVE (9.1.3.9)
O SUBMIT SPEED VS TORQUE CURVE(9.1.3.10)
O ____

EXTERNAL BEARING (TYPE/NUMBER):
☐ RADIAL ____ / ____
☐ THRUST ____ / ____
LUBRICATION: (9.1.4.3)
O RING OIL O FLINGER O FLOOD
O PURGE OIL MIST O PURE OIL MIST O OTHER ____
O CONSTANT LEVEL OILER PREF. (SEE REMARKS) (9.1.4.2.1)
O OIL VISC. ISO GRADE ____

MAG-DRIVE SPECIFIC - CONT'D

SHAFT COUPLINGS: (DRIVER-TO-PUMP)
O MAKE ____ O MODEL ____
O NON-LUBE O LUBRICATED: (SEE REMARKS)
☐ RATING (kW/100 RPM) ____ O SERVICE FACTOR ____
O LIMITED END FLOAT REQUIRED ____
O SPACER, LENGTH ____ (mm) O NOT REQUIRED
O MATERIAL: HUBS ____ SPACER ____
ELEMENTS ____
☐ SHAFT DIAMETER AT COUPLING ____ (mm)
DRIVER HALF COUPLING MOUNTED BY:
O PUMP MFR. O DRIVER MFR. O PURCHASER
REMARKS ____

SEPARATE MOTOR DRIVE
APPLICABLE SPEC: O IEEE841 O API541 O OTHER. ____
☐ FRAME ____ O ENCLOSURE ____
O LUBE ____
BEARINGS (TYPE / NUMBER):
☐ RADIAL ____ / ____
☐ THRUST ____ / ____
REMARKS ____

BASEPLATES (9.1.5.3):
☐ API BASEPLATE NUMBER ____ (APPENDIX M)
O NON-GROUT CONSTRUCTION: (9.1.5.3.13)
O BASEPLATE MATERIAL ____
O BOLT V-INLINE PUMP TO PAD / FOUNDATION (6.1.30.3)
REMARKS ____

CANNED MOTOR SPECIFIC

O SOLID MEDIA POTTING ALLOWED IN STATOR (9.2.2.2)
O CERAMIC INSULATION ACCEPTABLE (9.2.2.8)
O DESIGN MOTOR FOR FREQUENT STARTS (9.2.2.9)
O ____ STARTS PER ____ ☐ IMPACT ON LIFE (REMARKS)
O DESIGN MOTOR FOR: (9.2.2.9) O TWO-SPEED
O VARIABLE SPEED ____
O UL, FM OR EQUIVALENT REQ'D (9.2.2.10) ☐ UL ☐ FM ☐ OTHER
O CERTIFICATION OF IEEE 252 TEST REQUIRED (9.2.7)
O DECONTAMINATION CONNECTION ON STATOR (9.2.2.11)
REMARKS ____

ADDITIONAL REMARKS: ____

09/99 SHT 3 OF 5 685DSSI.XLS REV 1

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PAGE ____ OF ____

API 685 SEALLESS CENTRIFUGAL PUMP DATA SHEET SI UNITS

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

INSTRUMENTATION (7.2)

O INSTRUMENT PANEL REQ'D (7.2.1.4) O FREESTANDING
O ON BASEPLATE O OTHER: ____
REMARKS: ____

O MONITOR LEAKAGE INTO SECONDARY CASING (7.2.2.5.3)
O OPTICAL MOISTURE SENSOR O SIGHT GLASS
O PRESSURE SWITCH O CONDUCTIVITY PROBE
O LOCAL O ON PANEL O ALARM O SHUTDOWN
REMARKS: ____

O PUMP POWER MONITORED (7.2.2.5.1/2) O WATTS O AMPS
O LOCAL O ON PANEL O IN PURCHASER MCC
O ALARM O SHUTDOWN
SENSOR BY: O PURCHASER O VENDOR
REMARKS: ____

O TEMPERATURE MONITOR OF: O ROTOR CAVITY FLUID
O CONTAINMENT SHELL/LINER O INTERNAL BEARING(S)
READOUT: O LOCAL O PANEL O ALARM O SHUTDOWN
O PROVISION FOR INSTRUMENTS ONLY
SENSOR BY: O PURCHASER O VENDOR
TYPE: ____
O MONITOR AND CABLES BY: O PURCHASER O VENDOR

O PRESSURE MONITOR OF: O ROTOR CAVITY
O SECONDARY CASING O OTHER: ____
READOUT: O LOCAL O PANEL O ALARM O SHUTDOWN
O PROVISION FOR INSTRUMENTS ONLY
SENSOR BY: O PURCHASER O VENDOR
TYPE: ____
REMARKS: ____

O VIBRATION (7.2.2.4.1-3) O READOUT O ALARM O S/DN
O PROVISION FOR INSTRUMENTS ONLY
O FLAT SURFACE REQ'D (6.9.3.11) O THREADED CONN (6.9.3.10)
SENSOR BY: O PURCHASER O VENDOR
O TYPE: ____
MONITORS AND CABLES BY: O PURCHASER O VENDOR
REMARKS: ____

O BEARING WEAR DETECTOR (7.2.2.4.4) ☐ MECHANICAL
☐ ELECTRICAL ☐ HYDRAULIC ☐ OTHER (see remarks)
O ALARM O S/DN O READOUT O LOCAL O PANEL
REMARKS: ____

GENERAL
O LIQUID FILLED GAUGES FOR VIB. SERVICES(7.2.3.2)
O REPLACE INSTRUMENT WHILE RUNNING NOT REQ'D (7.2.1.6)
O PROVISION FOR TESTING OF SHUTDOWN SYSTEMS WHILE RUNNING IS NOT REQUIRED (7.2.3.4)

SWITCHES (7.2.3.3)
ALARM CONTACTS: O OPEN O CLOSE TO SOUND ALARM
AND BE NORMALLY: O ENERGIZED O DE-ENERGIZED
S/D CONTACTS SHALL: O OPEN O CLOSE TO SOUND ALARM
AND BE NORMALLY: O ENERGIZED O DE-ENERGIZED

DRIVE MOTOR (7.1)

MANUFACTURER ____
____ (kW) ____ (RPM)
HORIZONTAL VERTICAL SERVICE FACTOR ____
VOLTS/PHASE/HERTZ ____ / ____ / ____
O TYPE ____
O MINIMUM STARTING VOLTAGE (7.1.8) ____
INSULATION ____ O TEMPERATURE RISE ____ °K
FULL LOAD AMPS ____
LOCKED ROTOR AMPS ____
STARTING METHOD (7.1.3) ____

O SIZE MOTOR FOR MAX POWER OF RATED IMPELLER (7.1.4.2)
O MAXIMUM ACCELERATION TIME (SEC) ____ ☐ QUOTED ____
REMARKS: ____

SPARE PARTS (TABLE 11)

O START-UP O NORMAL MAINTENANCE
O SPECIFY ____

SURFACE PREPARATION AND PAINT

O MANUFACTURER'S STANDARD
O OTHER (SEE BELOW)
PUMP:
O PUMP SURFACE PREPARATION ____
O PRIMER ____
O FINISH COAT ____
BASEPLATE: (6.1.5.3)
O BASEPLATE SURFACE PREPARATION ____
O PRIMER ____
O FINISH COAT ____
SHIPMENT: (8.4.1)
O DOMESTIC O EXPORT O EXPORT BOXING REQUIRED
O OUTDOOR STORAGE MORE THAN 6 MONTHS
REMARKS ____

OTHER PURCHASER REQUIREMENTS FOR VENDOR

O COORDINATION MEETING REQUIRED (10.1.3)
O REVIEW & COMMENT ON PURCHASER'S PIPING DWGS (6.1.27a)
O OBSERVE PIPING CHECKS AFTER INSTALLATION (6.1.27b)
O OBSERVE INITIAL ALIGNMENT CHECK (6.1.27c)
O CHECK ALIGNMENT AT OPERATING TEMPERATURE (6.1.27d)
O CONNECTION DESIGN APPROVAL (6.11.3.5.4)
O INSTALLATION LIST IN PROPOSAL (10.2.3L)
O PROGRESS REPORTS ARE NOT REQUIRED (10.3.4)
REMARKS: ____

09/99 SHT 4 OF 5 685DSSI.XLS REV 1

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PAGE ____ OF ____

API 685 SEALLESS CENTRIFUGAL PUMP DATA SHEET SI UNITS

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

QA INSPECTION AND TEST

- O REVIEW VENDORS QA PROGRAM (8.1.7)
- O PERFORMANCE CURVE APPROVAL
- O SHOP INSPECTION (8.1.4)

TEST	NON-WIT	WIT	OBS
HYDROSTATIC (8.3.2)	O	O	O
PERFORMANCE (8.3.3)	O	O	O
O NPSH (8.3.4.1)	O	O	O
O COMPLETE UNIT TEST (8.3.4.2)	O	O	O
O SOUND LEVEL TEST (8.3.4.3)	O	O	O
O SECONDARY CONTAINMENT SYSTEM HYDROTEST (8.3.4.5)	O	O	O
O CLEANLINESS PRIOR TO FINAL ASSEMBLY (8.2.3.1)	O	O	O
O NOZZLE LOAD TEST (7.3.6)	O	O	O
O SECONDARY CONTAINMENT / CONTROL SYSTEM INST. TEST (8.3.4.6)	O	O	O
O REMOVE/INSPECT INTERNAL BEARINGS AFTER TEST (9.2.8.5)	O	O	O
O DISASSEMBLY / INSPECT AFTER TEST (8.4.3.1)	O	O	O
O AUXILIARY EQUIPMENT TEST (8.3.4.4)	O	O	O
O PRESS-TEMP PROFILE TEST(8.3.4.7)	O	O	O
O ____	O	O	O
O ____	O	O	O

- O MATERIAL CERTIFICATION REQUIRED (6.11.6)
  - O CASING O IMPELLER O SHAFT
  - O OTHER ____
- O CASTING REPAIR PROCEDURE APPROVAL REQ'D (6.11.2.5)
- O INSPECTION REQUIRED FOR CONNECTION WELDS (6.11.3.5.6)
  - O MAG PARTICLE O LIQUID PENETRANT
  - O RADIOGRAPHIC O ULTRASONIC
- O INSPECTION REQUIRED FOR CASTINGS (8.2.1.3)
  - O MAG PARTICLE O LIQUID PENETRANT
  - O RADIOGRAPHIC O ULTRASONIC
- O ADDITIONAL INSPECTION REQUIRED FOR: (6.11.3.5.6) (8.2.1.3)
  ____
  - O MAG PARTICLE O LIQUID PENETRANT
  - O RADIOGRAPHIC O ULTRASONIC
- O ALTERNATE ACCEPTANCE CRITERIA (SEE REMARKS) (8.2.2.1)
- O HARDNESS TEST REQUIRED FOR: (8.2.3.2)
  ____
- O WETTING AGENT HYDROTEST (8.3.2.5)
- O VENDOR SUBMIT TEST PROCEDURES (8.3.1.2/10.2.5)
- O RECORD FINAL ASSEMBLY RUNNING CLEARANCES
- O INSPECTION CHECK-LIST (APPENDIX N) ____ (8.1.6)
- O SUBMIT DATA FOR MODEL STATIC TORQUE TEST (9.1.8.1)
- O JOB SPECIFIC STATIC TORQUE TEST REQUIRED (9.1.8.1)

REMARKS ____

☐ WEIGHTS

MOTOR DRIVEN:
- WEIGHT OF PUMP (kg) ____
- WEIGHT OF BASEPLATE (kg) ____
- WEIGHT OF MOTOR (kg) ____
- TOTAL WEIGHT (kg) ____

DIMENSIONS OF PLOT: (LxWxH) ____

TURBINE DRIVEN:
- WEIGHT OF BASEPLATE (kg) ____
- WEIGHT OF TURBINE (kg) ____
- WEIGHT OF GEAR (kg) ____
- TOTAL WEIGHT (kg) ____

DIMENSIONS OF PLOT: (LxWxH) ____

GENERAL REMARKS

REMARK 1: ____

REMARK 2: ____

REMARK 3: ____

REMARK 4: ____

REMARK 5: ____

REMARK 6: ____

09/99 SHT 5 OF 5 685DSSI.XLS REV 1

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Mon Feb 03 13:40:35 2003

API 685 SEALLESS CENTRIFUGAL PUMP DATA SHEET U.S. CUSTOMARY UNITS

PAGE ____ OF ____
JOB NO. ____ ITEM NO. ____
REQ / SPEC NO. ____ / ____
PURCH ORDER NO. ____ DATE ____
INQUIRY NO ____ BY ____
REVISION ____ DATE ____

1	APPLICABLE TO: ○ PROPOSALS ○ PURCHASE ○ AS BUILT	
2	FOR ____	UNIT ____
3	SITE ____	SERVICE ____
4	NO. REQ ____ PUMP SIZE ____	TYPE ____ NO. STAGES ____
5	MANUFACTURER ____	MODEL ____ SERIAL NO. ____
6	DIMENSIONS PER: ○ SI ○ US UNITS	EQUIPMENT TO COMPLY WITH APPLICABLE: ○ ISO ○ US STANDARDS
7	NOTES: INFORMATION BELOW TO BE COMPLETED: ○ BY PURCHASER	□ BY MANUFACTURER ○ BY MANUFACTURER OR PURCHASER
8	○ GENERAL (6.16.1.1)	
9	PUMPS TO OPERATE IN (PARALLEL) NO. MOTOR DRIVEN ____	NO. TURBINE DRIVEN ____
10	(SERIES) WITH ____ PUMP ITEM NO ____	PUMP ITEM NO. ____
11	GEAR ITEM NO. ____ MOTOR ITEM NO. ____	TURBINE ITEM NO. ____
12	GEAR PROVIDED BY ____ MOTOR PROVIDED BY ____	TURBINE PROVIDED BY ____
13	GEAR MOUNTED BY ____ MOTOR MOUNTED BY ____	TURBINE MOUNTED BY ____
14	GEAR DATA SHT. NO. ____ MOTOR DATA SHT. NO. ____	TURBINE DATA SHT. NO. ____
15	○ OPERATING CONDITIONS (6.1.3)	○ LIQUID
16	CAPACITY, NORMAL ____ (gpm) RATED ____ (gpm)	TYPE OR NAME OF LIQUID ____
17	OTHER ____	PUMPING TEMP., (°F) NORMAL ____ MAX. ____ MIN. ____
18	SUCTION PRESSURE MAX./RATED ____ / ____ (psig)	VAPOR PRESSURE ____ (psia) @ ____ (°F)
19	DISCHARGE PRESSURE ____ (psig)	TEMPERATURE-VAPOR PRESSURE CURVE NO.: ____
20	DIFFERENTIAL PRESSURE ____ (psi)	RELATIVE DENSITY (SPECIFIC GRAVITY):
21	DIFF. HEAD ____ (ft) NPSHA ____ (ft)	NORMAL ____ MAX ____ MIN ____
22	PROCESS VARIATIONS (7.1.2) ____	SPECIFIC HEAT, Cp ____ (BTU/lb-°F)
23	STARTING CONDITIONS (7.1.3) ____	VISCOSITY ____ (Cp) @ ____ (°F)
24	SERVICE: ○ CONT. ○ INTERMITTENT (STARTS/DAY) ____	MAX. VISCOSITY ____ (Cp) @ ____ (°F)
25	○ PARALLEL OPERATION REQ'D (6.1.12)	TEMPERATURE-VISCOSITY CURVE NO.: ____
26	○ SITE DATA	THERMAL EXPANSION: ____ (in/in/°F)
27	LOCATION: (6.1.29)	THERMAL CONDUCTIVITY: ____ (BTU/ft-°F)
28	○ INDOOR ○ HEATED ○ UNDER ROOF	CORROSIVE / EROSIVE AGENT ____ (6.11.7)
29	○ OUTDOOR ○ UNHEATED ○ PARTIAL SIDES	CORROSION ALLOWANCE (6.3.3) ____ min
30	○ GRADE ○ MEZZANINE ○ ____	○ CHLORIDE PRESENT: CONCENTRATION (PPM) ____ (7.3.2.6)
31	○ ELECTRIC AREA CLASSIFICATION (6.1.24)	○ WET H_2S PRESENT; CONCENTRATION (PPM) ____ (6.11.11)
32	CL ____ GR ____ DIV ____	○ SOLIDS PRESENT (6.2.1); CONCENTRATION (% by wt.) ____
33	○ WINTERIZATION ○ TROPICALIZATION REQ'D.(7.2.4.5)	PARTICLE SIZE ____ HARDNESS ____
34	SITE DATA (6.1.29)	SIZE DISTRIBUTION: ____
35	○ ALTITUDE ____ (ft) BAROMETER ____ (psia)	LIQUID (6.1.3) ○ HAZARDOUS ○ FLAMMABLE
36	○ RANGE OF AMBIENT TEMPS. MIN/MAX. ____ / ____ (°F)	POLYMERIZATION CHARACTERISTICS (6.2.1). ____
37	○ RELATIVE HUMIDITY: MIN / MAX ____ / ____ (%)	○ OTHER ____
38	UNUSUAL CONDITIONS: (6.1.29) ○ DUST ○ FUMES	REMARKS: ____
39	○ OTHER ____	
40	○ UTILITY CONDITIONS:	○ SYSTEM DESCRIPTION (6.2.2)
41	STEAM: DRIVERS HEATING	SUCTION VESSEL: ○ VENTED TO ATMOS. ○ CLOSED
42	MIN.: ____ (psig) ____ (°F) ____ (psig) ____ (°F)	PUMP LOCATION: ○ BELOW LIQUID LEVEL ○ ABOVE LIQ. LEVEL
43	MAX.: ____ (psig) ____ (°F) ____ (psig) ____ (°F)	SUCTION VESSEL ON LEVEL CONTROL? ○ YES ○ NO
44	ELECTRICITY DRIVERS HEATING CONTROL SHUTDOWN	PRESSURE SENSOR ON SUCTION VESSEL ○ YES ○ NO
45	VOLTAGE: ____ / ____ ____ ____ ____	SUCTION VESSEL PRESSURE MAINTAINED BY: ____
46	HERTZ: ____ ____ ____ ____	____
47	PHASE: ____ ____ ____ ____	IF FLUID LEVEL OR TANK PRESSURE DROPS TOO LOW, WILL
48	COOLING WATER: (6.1.22) SOURCE ____	SYSTEM AUTOMATICALLY STOP THE PUMP? ○ YES ○ NO
49	TEMP. INLET ____ (°F) MAX. RETURN ____ (°F)	WILL THE PUMP RUN DRY IN NORMAL OPERATION? ○ YES ○ NO
50	PRESS. NORM ____ (psig) DESIGN ____ (psig)	REMARKS: ____
51	MIN RETURN ____ (psig) MAX ALLOW DP ____ (psi)	____
52	CHLORIDE CONCENTRATION (PPM) ____ (7.3.2.6)	____
53	INSTRUMENT AIR: MAX/MIN PRESS ____ / ____ (psig)	____

09/99 SHT 1 OF 5 685DSUS.XLS REV 1

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API 685 SEALLESS CENTRIFUGAL PUMP DATA SHEET U.S. CUSTOMARY UNITS

PAGE ______ OF ______

JOB NO. ______ ITEM NO. ______

REQ / SPEC NO. ______ / ______

PURCH ORDER NO. ______ DATE ______

INQUIRY NO ______ BY ______

REVISION ______ DATE ______

PERFORMANCE

PROPOASAL CURVE NO. ______ ☐ RPM ______

☐ IMPELLER DIA.; RATED ______ MAX. ______ MIN. ______ (in)

☐ HYD. EFFICIENCY AT RATED ______ (%)

☐ HYSTERESIS & MECH. LOSSES ______ (hp)

☐ OVERALL EFF (%) ______ RATED POWER ______ (hp)

☐ MAX POWER @ RATED IMPELLER ______ (hp)

☐ MINIMUM CONTINUOUS FLOW:

THERMAL ______ (gpm) STABLE ______ (gpm)

☐ ROTOR CHAMBER TEMP. RISE OPERATING (6.2.1) ______ (°F)

☐ ROTOR CHAMBER TEMP. RISE ON SHUTDOWN ______ (°F)

☐ PREFERRED OPER. REGION ______ TO ______ (gpm)

☐ ALLOWABLE OPER. REGION ______ TO ______ (gpm)

LIMITED BY: ☐ VIBRATION ☐ OTHER ______

☐ MAX HEAD @ RATED IMPELLER ______ (ft)

☐ PERCENT RISE TO SHUTOFF (6.1.12) ______

☐ ORIFICE USED TO STEEPEN CURVE OR GIVE CONT. RISE (6.1.12)

☐ NPSHR AT RATED CAPACITY (6.1.16) ______ (ft)

○ MAX. SUCTION SPECIFIC SPEED ALLOWED (6.1.10) ______

☐ SUCTION SPECIFIC SPEED QUOTED ______

○ MAX. SOUND PRESS. LEVEL REQ'D (6.1.15) ______ (dBA)

☐ EST MAX SOUND PRESS. LEVEL ______ (dBA)

REMARKS: ______

CONSTRUCTION

APPLICABLE STANDARD:

○ API 685 ○ OTHER ______ (SEE REMARKS)

ROTATION: (VIEWED FROM COUPLING END) ☐ CW ☐ CCW

PUMP TYPE:

OH1 OH2 OH5 OTHER ______

CASING MOUNTING:

CENTERLINE ☐ NEAR CENTERLINE

FOOT IN-LINE ☐ OTHER ______

CASING TYPE:

☐ SINGLE VOLUTE ☐ MULTIPLE VOLUTE ☐ DIFFUSER

CASE PRESSURE RATING:

☐ MAX ALLOWABLE WORKING PRESSURE ______ (psig)

@ ______ (°F)

☐ HYDROTEST PRESSURE ______ (psig)

DESIGN PUMP FOR : ○ FULL ○ ______ (psig VACUUM)

REMARKS: ______

ROTOR:

○ OPEN ○ SEMI-OPEN ○ FAB'D IMPELLERS ARE ACCEPT

○ RENEWABLE CASE WEAR RINGS ARE NOT REQUIRED (6.7.1)

○ RENEWABLE IMP. WEAR RINGS ARE NOT REQUIRED (6.7.1)

○ NON-GROOVED BEARINGS ARE ACCEPTABLE (6.10.5)

☐ SHAFT DIAMETER BETWEEN BEARINGS ______ (in)

☐ SPAN BETWEEN BEARING CENTERS ______ (in)

☐ SPAN BETWEEN BEARING & IMPELLER ______ (in)

REMARKS: ______

CONSTRUCTION - CONT'D

NOZZLE CONDITIONS: (6.4.2)

	SIZE (NPS)	FLANGE RATING (lb)	FAC'G	POSITION
SUCTION				
DISCHARGE				

PRESSURE CASING AUX. CONNECTIONS: (6.4.3)

	NO.	SIZE (NPS)	TYPE
DRAIN			
VENT			
PRESS. GAUGE			
TEMP GAUGE			
WARM-UP			
EXT. FLUSH / LEAK-OFF			
PURGE/FLUSHOUT			

VENDOR SUPPLY VALVES FOR: (7.3.2.8) ○ VENT(S) ○ DRAIN(S)

ROTOR CAVITY DRAINABLE THRU SECONDARY DRAIN (6.1.8)

○ CYLINDRICAL THREADS REQ'D FOR AUX. CONN'S (6.4.3.8.3)

○ FLANGE THICKNESS REQ'S NON-STD. BOLT LENGTH (6.4.2.3)

○ THD. CONN. TO SECONDARY CASING IS NOT ACCEPT. (6.4.3.8)

SECONDARY CASING HAS: (6.8.8)

DRAIN CONN. & FLUSH PROVISION

AUXILIARY PIPING (7.3)

○ AUXILIARY PIPING PLAN: ______

CIRC. PIPING MATERIALS:

TUBING CARBON STEEL

PIPE STAINLESS STEEL

CIRC. PIPING ASSEMBLY: (7.3.2.10)

THREADED UNIONS SOCKET WELDED

FLANGED TUBE FITTINGS ______

COOLING WATER PIPING PLAN (7.3.4) ______

C.W. PIPING ASSEMBLY:

PIPE TUBING; FITTINGS ______

C.W. PIPING MATERIALS:

STAINLESS STEEL C. STEEL GALVANIZED

COOLING WATER REQUIREMENTS:

☐ JACKET ☐ BEARING HOUSING ______ (GPM)

HEAT EXCHANGER ______ (GPM)

TOTAL COOLING WATER ______ (GPM)

STEAM PIPING: ○ TUBING ○ PIPE ○ OTHER

REMARKS: ______

MATERIALS

○ APPENDIX H CLASS (6.11.1) ______

○ MIN DESIGN METAL TEMP (6.11.4.5) ______ (°F)

☐ CASE ______ IMPELLER ______

☐ CASE/IMPELLER WEAR RINGS ______

☐ SHAFT ______

☐ CONTAINMENT SHELL / STATOR LINER ______

☐ INNER MAG. SHEATHING / ROTOR LINER ______

☐ BEARINGS ______

○ OTHER ______

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API 685 SEALLESS CENTRIFUGAL PUMP DATA SHEET U.S. CUSTOMARY UNITS

PAGE ______ OF ______
JOB NO. ______ ITEM NO. ______
REQ / SPEC NO ______ / ______
PURCH ORDER NO. ______ DATE ______
INQUIRY NO ______ BY ______
REVISION ______ DATE ______

SECONDARY CONTROL / CONTAINMENT

- O SECONDARY CONTROL (6.8.1)
  - O MAX LEAKAGE ON PRIMARY FAILURE: ______ (gpm)
- O SECONDARY CONTAINMENT (6.8.1)
- AUX. SEAL DEVICE: O MECHANICAL SEAL O BUSHING
  - O OTHER: ______
- DEVICE IS: O DRY RUNNING O WET RUNNING
  - O INSIDE O OUTSIDE OF BEARINGS (MAG-DRIVE)
  - O OTHER: ______

MECHANICAL SEAL DATA:

- O APPENDIX H SEAL CODE ______
- ▣ SEAL MANUFACTURER ______
- ▣ SIZE AND TYPE ______ / ______
- ▣ MANUFACTURER CODE ______
- O REMARKS ______

MAG-DRIVE SPECIFIC

- O DESIGN FOR REMOVAL OF DRIVE END WITHOUT DISTURBING THE PRESSURE CASING OR DRIVER (9.1.1.4)
- MAGNETIC COUPLING: O SYNCHRONOUS O TORQUE RING

MAGNETS:	OUTER	INNER
▣ MAG. MATERIAL		
☐ MOUNT. METHOD		
☐ TEMP. LIMIT. (°F)		
☐ HERMETIC. SEALED		
☐ NO. OF MAGNETS		

- O SOFT START REQ'D ☐ HARD START CAPABILITY
- ☐ TORQUE RATING (DECOUPLING), ft-lb ______
- ☐ MAX TORQUE REQ'D ON STARTING, ft-lb (9.1.3.7a) ______
- ☐ PUMP TORQUE AT RATED (+ 5%), ft-lb (9.1.3.7b) ______
- ☐ ACTUAL SERVICE FACTOR (9.1.3.8) ______ (%)
- ☐ TORQUE REQ'D FOR FULL CURVE, Nm (9.1.3.7c) ______
- O DESIGN FOR FULL CURVE TORQUE REQUIREMENTS (9.1.3.7c)
- O SUBMIT MAG-COUPLING TORQUE - TEMP. CURVE (9.1.3.9)
- O SUBMIT SPEED VS TORQUE CURVE(9.1.3.10)
- O ______

EXTERNAL BEARING (TYPE/NUMBER):

- ☐ RADIAL ______ / ______
- ☐ THRUST ______ / ______

LUBRICATION: (9.1.4.3)

- ▣ RING OIL ▣ FLINGER ▣ FLOOD
- O PURGE OIL MIST O PURE OIL MIST ▣ OTHER ______
- O CONSTANT LEVEL OILER PREF. (SEE REMARKS) (9.1.4.2.1)
- ▣ OIL VISC. ISO GRADE ______

MAG-DRIVE SPECIFIC - CONT'D

SHAFT COUPLINGS: (DRIVER-TO-PUMP)

- O MAKE ______ ▣ MODEL ______
- O NON-LUBE O LUBRICATED: (SEE REMARKS)
- ☐ RATING (hp/100 RPM) ______ ▣ SERVICE FACTOR ______
- ▣ LIMITED END FLOAT REQUIRED ______
- ▣ SPACER, LENGTH ______ (IN) O NOT REQUIRED
- ▣ MATERIAL: HUBS ______ SPACER ______
  - ELEMENTS ______
- ☐ SHAFT DIAMETER AT COUPLING ______ (in)

DRIVER HALF COUPLING MOUNTED BY:

- O PUMP MFR O DRIVER MFR. O PURCHASER

REMARKS ______

SEPARATE MOTOR DRIVE

- APPLICABLE SPEC: O IEEE841 O API541 O OTHER: ______
- ☐ FRAME ______ ▣ ENCLOSURE ______
- ▣ LUBE ______

BEARINGS (TYPE / NUMBER):

- ☐ RADIAL ______ / ______
- ☐ THRUST ______ / ______

REMARKS ______

BASEPLATES (9.1.5.3):

- ☐ API BASEPLATE NUMBER ______ (APPENDIX M)
- O NON-GROUT CONSTRUCTION: (9.1.5.3.13)
- O BASEPLATE MATERIAL ______
- O BOLT V-INLINE PUMP TO PAD / FOUNDATION (9.1.30.3)

REMARKS ______

CANNED MOTOR SPECIFIC

- O SOLID MEDIA POTTING ALLOWED IN STATOR (9.2.2.2)
- O CERAMIC INSULATION ACCEPTABLE (9.2.2.5)
- O DESIGN MOTOR FOR FREQUENT STARTS (9.2.2.9)
  - ▣ ______ STARTS PER ______ ☐ IMPACT ON LIFE: (REMARKS)
- O DESIGN MOTOR FOR: (9.2.2.9) O TWO-SPEED
  - O VARIABLE SPEED ______
- O UL, FM OR EQUIVALENT REQ'D (9.2.2.10) ☐ UL ☐ FM ☐ OTHER
- O CERTIFICATION OF IEEE 292 TEST REQUIRED (9.2.7)
- O DECONTAMINATION CONNECTION ON STATOR (9.2.2.11)

REMARKS ______

ADDITIONAL REMARKS: ______

09/99 SHT 3 OF 5 685DSUS.XLS REV 1

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API 685 SEALLESS CENTRIFUGAL PUMP DATA SHEET U.S. CUSTOMARY UNITS

PAGE ______ OF ______

JOB NO. ______ ITEM NO. ______

REQ / SPEC NO. ______ / ______

PURCH ORDER NO. ______ DATE ______

INQUIRY NO ______ BY ______

REVISION ______ DATE ______

INSTRUMENTATION (7.2)

○ INSTRUMENT PANEL REQ'D (7.2.1.4) ○ FREESTANDING

○ ON BASEPLATE ○ OTHER: ______

REMARKS: ______

○ MONITOR LEAKAGE INTO SECONDARY CASING (7.2.2.5.3)

○ OPTICAL MOISTURE SENSOR ○ SIGHT GLASS

○ PRESSURE SWITCH ○ CONDUCTIVITY PROBE

○ LOCAL ○ ON PANEL ○ ALARM ○ SHUTDOWN

REMARKS: ______

○ PUMP POWER MONITORED (7.2.2.5.1/2) ○ WATTS ○ AMPS

○ LOCAL ○ ON PANEL ○ IN PURCHASER MCC

○ ALARM ○ SHUTDOWN

SENSOR BY: ○ PURCHASER ○ VENDOR

REMARKS: ______

○ TEMPERATURE MONITOR OF: ○ ROTOR CAVITY FLUID

○ CONTAINMENT SHELL/LINER ○ INTERNAL BEARING(S)

READOUT: ○ LOCAL ○ PANEL ○ ALARM ○ SHUTDOWN

○ PROVISION FOR INSTRUMENTS ONLY

SENSOR BY: ○ PURCHASER ○ VENDOR

☐ TYPE: ______

○ MONITOR AND CABLES BY: ○ PURCHASER ○ VENDOR

○ PRESSURE MONITOR OF: ○ ROTOR CAVITY

○ SECONDARY CASING ○ OTHER: ______

READOUT: ○ LOCAL ○ PANEL ○ ALARM ○ SHUTDOWN

○ PROVISION FOR INSTRUMENTS ONLY

SENSOR BY: ○ PURCHASER ○ VENDOR

☐ TYPE: ______

REMARKS: ______

○ VIBRATION (7.2.2.4.1-3) ○ READOUT ○ ALARM ○ S/DN

○ PROVISION FOR INSTRUMENTS ONLY

○ FLAT SURFACE REQ'D (6.9.3.11) ○ THREADED CONN. (6.9.3.10)

SENSOR BY: ○ PURCHASER ○ VENDOR

○ TYPE: ______

MONITORS AND CABLES BY: ○ PURCHASER ○ VENDOR

REMARKS: ______

○ BEARING WEAR DETECTOR (7.2.2.4.4) ☐ MECHANICAL

☐ ELECTRICAL ☐ HYDRAULIC ☐ OTHER (see remarks)

○ ALARM ○ S/DN ○ READOUT ○ LOCAL ○ PANEL

REMARKS: ______

GENERAL

○ LIQUID FILLED GAUGES FOR VIB. SERVICES(7.2.2.3.2)

○ REPLACE INSTRUMENT WHILE RUNNING NOT REQ'D (7.2.1.6)

○ PROVISION FOR TESTING OF SHUTDOWN SYSTEMS WHILE RUNNING IS NOT REQUIRED (7.2.3.4)

SWITCHES (7.2.3.3)

ALARM CONTACTS: ○ OPEN ○ CLOSE TO SOUND ALARM

AND BE NORMALLY: ○ ENERGIZED ○ DE-ENERGIZED

S/D CONTACTS SHALL: ○ OPEN ○ CLOSE TO SOUND ALARM

AND BE NORMALLY: ○ ENERGIZED ○ DE-ENERGIZED

DRIVE MOTOR (7.1)

☐ MANUFACTURER ______

☐ ______ (hp) ☐ ______ (RPM)

☐ HORIZONTAL ☐ VERTICAL ☐ SERVICE FACTOR ______

☐ VOLTS/PHASE/HERTZ ______ / ______ / ______

○ TYPE ______

○ MINIMUM STARTING VOLTAGE (7.1.8) ______

☐ INSULATION ______ ○ TEMPERATURE RISE ______ °K

☐ FULL LOAD AMPS ______

☐ LOCKED ROTOR AMPS ______

☐ STARTING METHOD (7.1.3) ______

○ SIZE MOTOR FOR MAX POWER OF RATED IMPELLER (7.1.4.2)

○ MAXIMUM ACCELERATION TIME (SEC) ______ ☐ QUOTED ______

REMARKS: ______

SPARE PARTS (TABLE 11)

○ START-UP ○ NORMAL MAINTENANCE

○ SPECIFY ______

SURFACE PREPARATION AND PAINT

○ MANUFACTURER'S STANDARD

○ OTHER (SEE BELOW)

PUMP:

○ PUMP SURFACE PREPARATION ______

○ PRIMER ______

○ FINISH COAT ______

BASEPLATE: (8.1.5.3)

○ BASEPLATE SURFACE PREPARATION ______

○ PRIMER ______

○ FINISH COAT ______

SHIPMENT: (8.4.1)

○ DOMESTIC ○ EXPORT ○ EXPORT BOXING REQUIRED

○ OUTDOOR STORAGE MORE THAN 6 MONTHS

REMARKS ______

OTHER PURCHASER REQUIREMENTS FOR VENDOR

○ COORDINATION MEETING REQUIRED (10.1.3)

○ REVIEW & COMMENT ON PURCHASER'S PIPING DWGS (6.1.27a)

○ OBSERVE PIPING CHECKS AFTER INSTALLATION (6.1.27b)

○ OBSERVE INITIAL ALIGNMENT CHECK (6.1.27c)

○ CHECK ALIGNMENT AT OPERATING TEMPERATURE (6.1.27d)

○ CONNECTION DESIGN APPROVAL (6.11.3.5.4)

○ INSTALLATION LIST IN PROPOSAL (10.2.3L)

○ PROGRESS REPORTS ARE NOT REQUIRED (10.3.4)

REMARKS: ______

09/99 SHT 4 OF 5 685DSUS.XLS REV 1

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PAGE ______ OF ______

API 685 SEALLESS CENTRIFUGAL PUMP DATA SHEET U.S. CUSTOMARY UNITS

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

QA INSPECTION AND TEST

O REVIEW VENDORS QA PROGRAM (8.1.7)
O PERFORMANCE CURVE APPROVAL
O SHOP INSPECTION (8.1.4)

TEST	NON-WIT	WIT	OBS
HYDROSTATIC (8.3.2)	O	O	O
PERFORMANCE (8.3.3)	O	O	O
O NPSH (8.3.4.1)	O	O	O
O COMPLETE UNIT TEST (8.3.4.2)	O	O	O
O SOUND LEVEL TEST (8.3.4.3)	O	O	O
O SECONDARY CONTAINMENT SYSTEM HYDROTEST (8.3.4.5)	O	O	O
O CLEANLINESS PRIOR TO FINAL ASSEMBLY (8.2.3.1)	O	O	O
O NOZZLE LOAD TEST (7.3.6)	O	O	O
O SECONDARY CONTAINMENT / CONTROL SYSTEM INST. TEST (8.3.4.6)	O	O	O
O REMOVE/INSPECT INTERNAL BEARINGS AFTER TEST (8.2.8.5)	O	O	O
O DISASSEMBLY / INSPECT AFTER TEST (8.4.3.1)	O	O	O
O AUXILIARY EQUIPMENT TEST (8.3.4.4)	O	O	O
O PRESS-TEMP PROFILE TEST(8.3.4.7)	O	O	O
O ______	O	O	O
O ______	O	O	O

O MATERIAL CERTIFICATION REQUIRED (6.11.6)
O CASING O IMPELLER O SHAFT
O OTHER ______
O CASTING REPAIR PROCEDURE APPROVAL REQ'D (6.11.2.5)
O INSPECTION REQUIRED FOR CONNECTION WELDS (6.11.3.5.6)
O MAG PARTICLE O LIQUID PENETRANT
O RADIOGRAPHIC O ULTRASONIC
O INSPECTION REQUIRED FOR CASTINGS (8.2.1.3)
O MAG PARTICLE O LIQUID PENETRANT
O RADIOGRAPHIC O ULTRASONIC
O ADDITIONAL INSPECTION REQUIRED FOR: (6.11.3.5.6) (8.2.1.3)
______
O MAG PARTICLE O LIQUID PENETRANT
O RADIOGRAPHIC O ULTRASONIC
O ALTERNATE ACCEPTANCE CRITERIA (SEE REMARKS) (8.2.2.1)
O HARDNESS TEST REQUIRED FOR: (8.2.3.2)
______
O WETTING AGENT HYDROTEST (8.3.2.5)
O VENDOR SUBMIT TEST PROCEDURES (8.3.1.2/10.2.5)
O RECORD FINAL ASSEMBLY RUNNING CLEARANCES
O INSPECTION CHECK-LIST (APPENDIX N) ______ (8.1.6)
O SUBMIT DATA FOR MODEL STATIC TORQUE TEST (9.1.6.1)
O JOB SPECIFIC STATIC TORQUE TEST REQUIRED (9.1.6.1)
REMARKS ______

☐ WEIGHTS

MOTOR DRIVEN:
WEIGHT OF PUMP (lb) ______
WEIGHT OF BASEPLATE (lb) ______
WEIGHT OF MOTOR (lb) ______
TOTAL WEIGHT (lb) ______
DIMENSIONS OF PLOT: (LxWxH) ______
TURBINE DRIVEN:
WEIGHT OF BASEPLATE (lb) ______
WEIGHT OF TURBINE (lb) ______
WEIGHT OF GEAR (lb) ______
TOTAL WEIGHT (lb) ______
DIMENSIONS OF PLOT: (LxWxH) ______

GENERAL REMARKS

REMARK 1: ______

REMARK 2: ______

REMARK 3: ______

REMARK 4: ______

REMARK 5: ______

REMARK 6: ______

09/99 SHT 5 OF 5 685DSUS.XLS REV 1

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APPENDIX C—SEALLESS PUMP NOMENCLATURE

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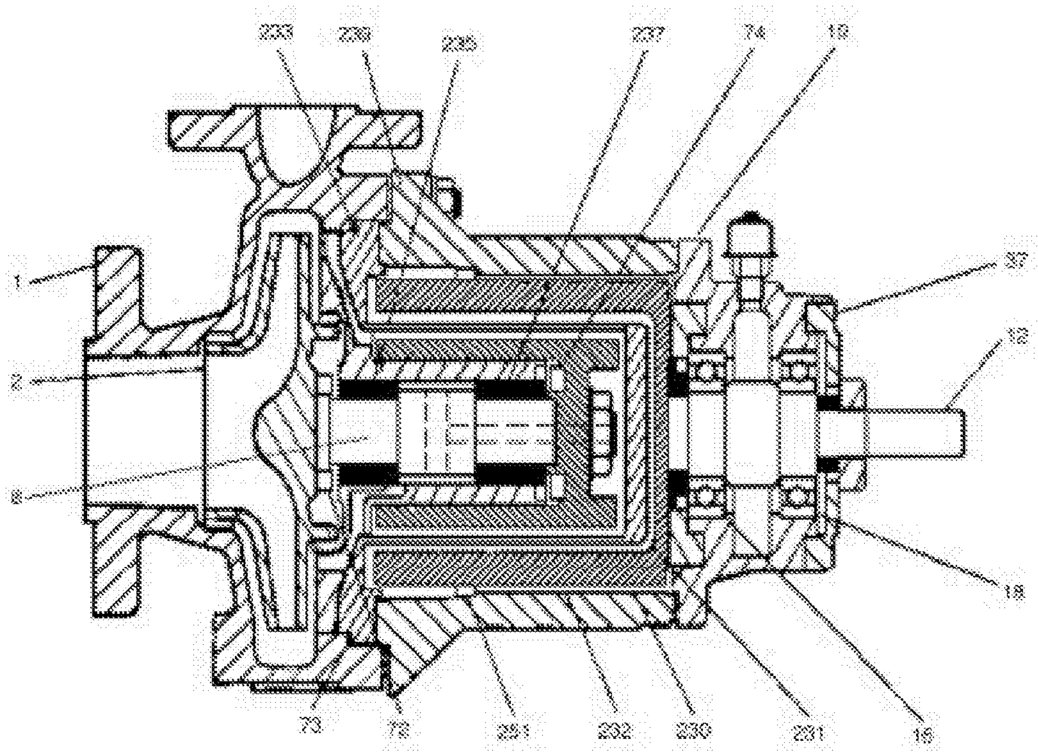

1 Casing
2 Impeller
8 Shaft, pump
12 Shaft, drive
16 Bearing, inboard
18 Bearing, outboard
19 Frame
37 Cover, bearing outboard
72 Collar, thrust inboard
73 Gasket
74 Collar, thrust outboard
230 Magnetic assembly, inner
231 Shell, containment
232 Magnet assembly, outer
233 Housing, bearing
235 Bushing, bearing inboard
237 Bushing, bearing outboard
238 Cover, casing
251 Ring, rub

Figure C-1—Magnetic Drive Pump, Separately Coupled

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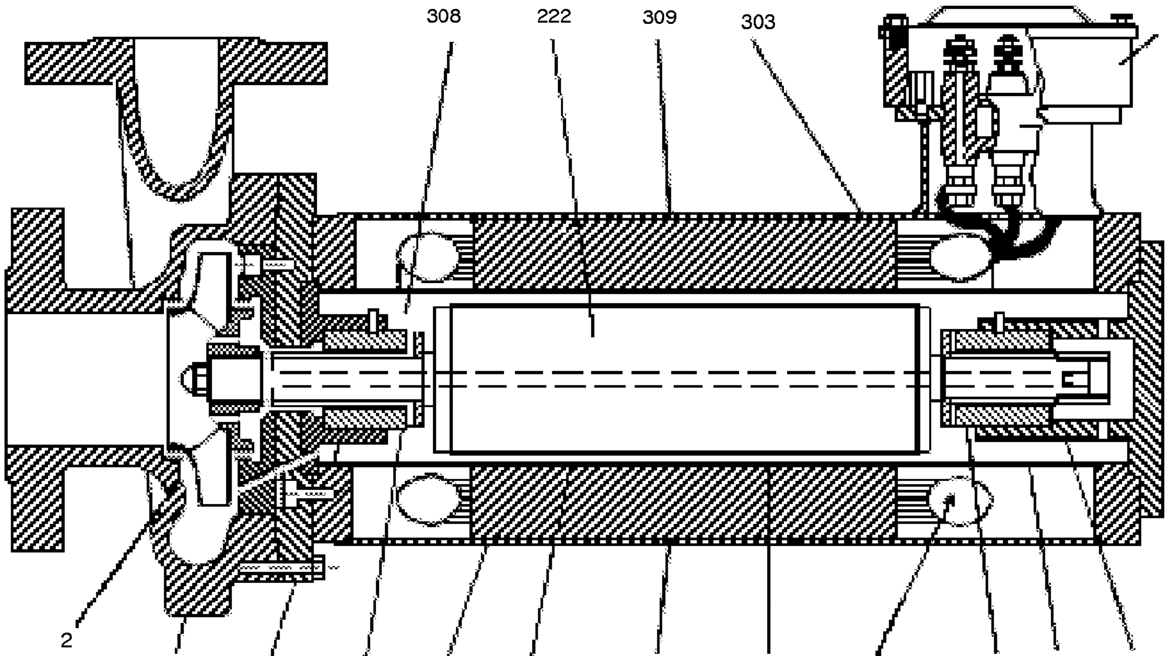

1 Casing
2 Impeller
8 Shaft, rotor assembly
201 Stator housing (secondary containment)
217 Stator liner
221 Rotor liner
222 Assembly, rotor
223 Assembly, stator
235 Bushing, bearing, inboard
237 Bushing, bearing, outboard
243 Box, electrical connection
300 Switch, thermal
301 Feed through barrier
303 Bearing, thrust
305 Sleeve, backup
306 Journal sleeve
308 Rotor chamber
309 Liquid gap

Figure C-2—Canned Motor Pump

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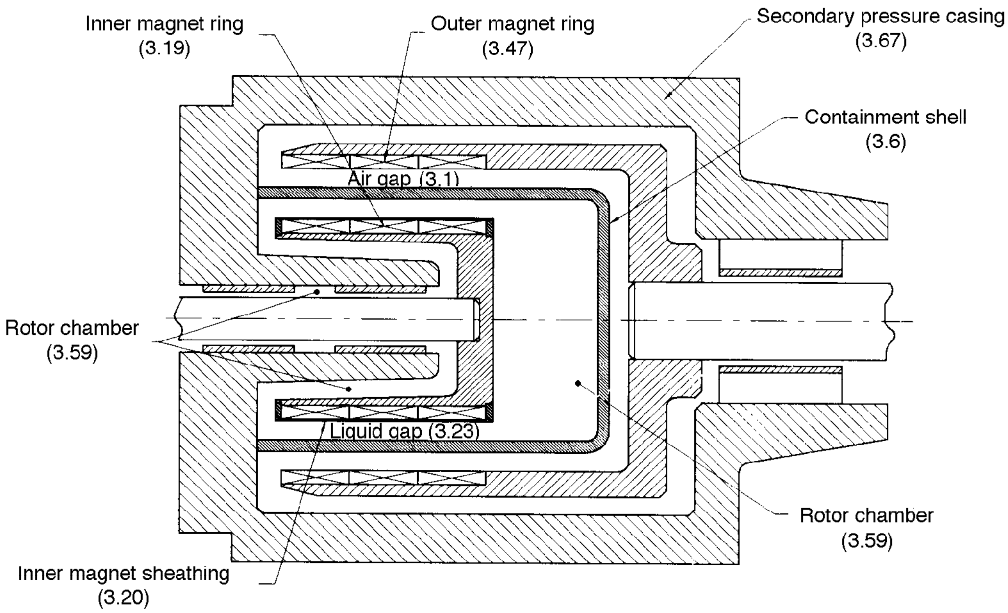

Figure C-3—Magnetic Drive Pump Terms Defined in Section 3

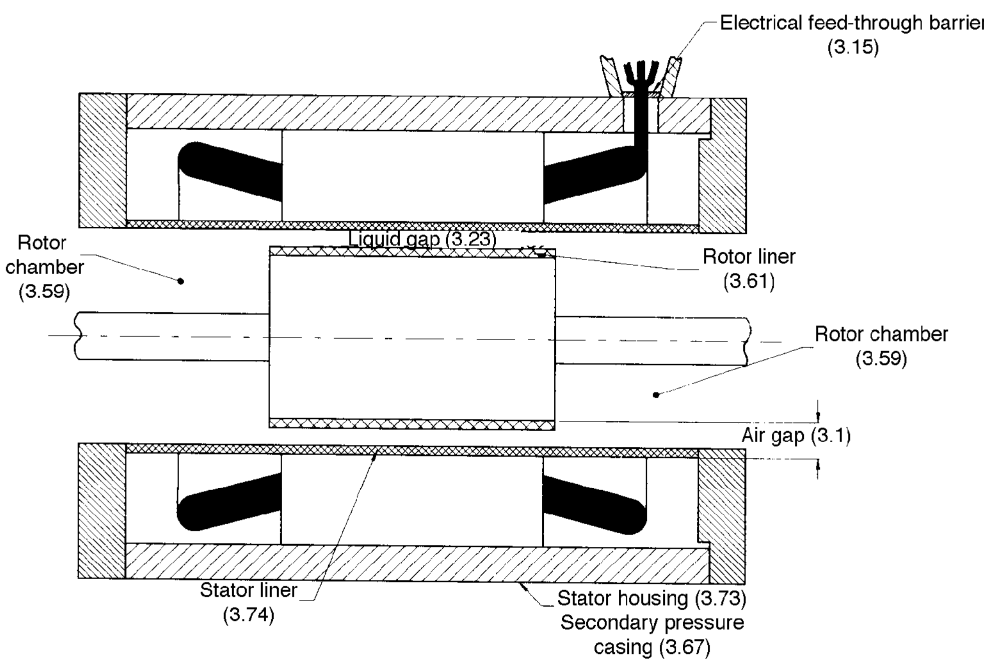

Figure C-4—Canned Motor Pump Terms Defined in Section 3

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APPENDIX D—CIRCULATION AND PIPING SCHEMATICS

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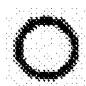
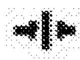
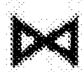
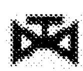
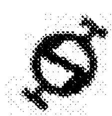
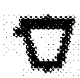
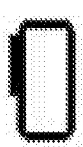
FI	Flow Indicator
TI	Temperature Indicator
PI	Pressure Indicator
*	Option must be specified by the purchaser
	Instrument (letters indicate function)
	Orifice
	Block and bleed valve
	Gate valve
	Throttle valve
	Heat exchanger
	Separator
	Circ pot with level gauge

Figure D-1—Appendix D Legend

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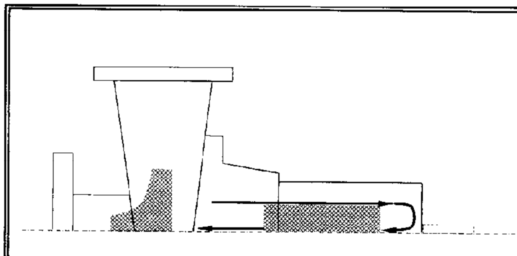
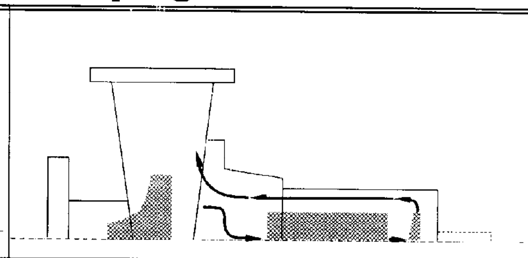
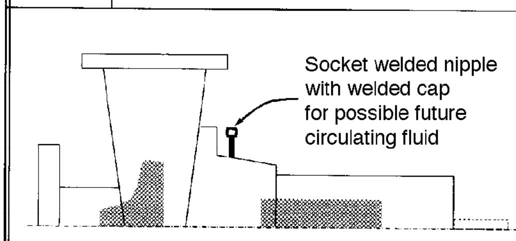
Clean Pumpage



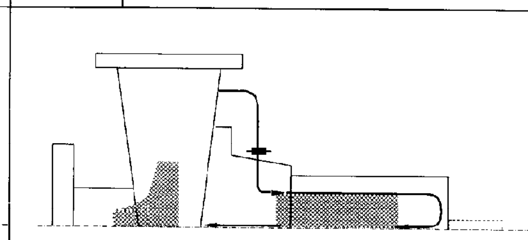
PLAN 1-S Internal recirculation through drive chamber back to suction.



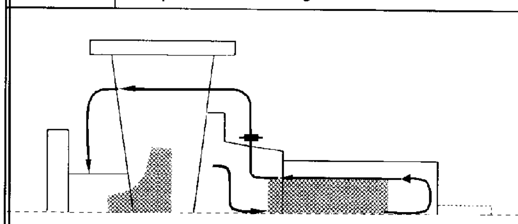
PLAN 1-SD Internal recirculation from high pressure through the rotor chamber to an auxiliary impeller and back to pump discharge.



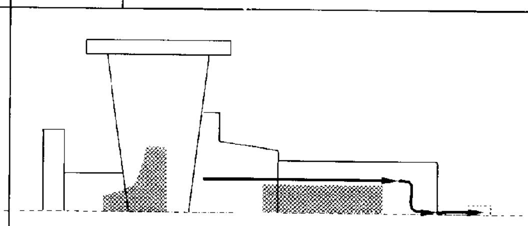
PLAN 2-S Dead-ended rotor chamber with no circulation of flushed fluid (used for temperature thinning viscous fluids.



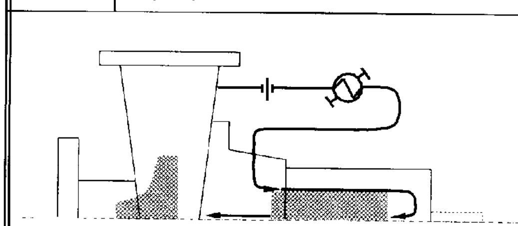
PLAN 11-S Recirculation from pump discharge through an orifice to the rotor chamber and back to suction.



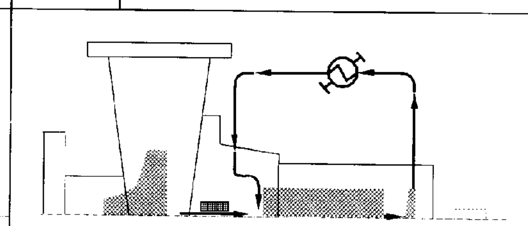
PLAN 13-S Recirculation from pump discharge to the rotor chamber, through an orifice and back to pump suction.



PLAN 13-SE Reverse circulation from pump discharge through the rotor chamber to an external suction vessel.



PLAN 21-S Recirculation from pump discharge through an orifice and cooler to the rotor chamber and back to pump suction.



PLAN 23-S Recirculation from rotor chamber through a cooler back to rotor chamber using an auxiliary pumping device.

Figure D-2—Circulating Fluid Arrangements

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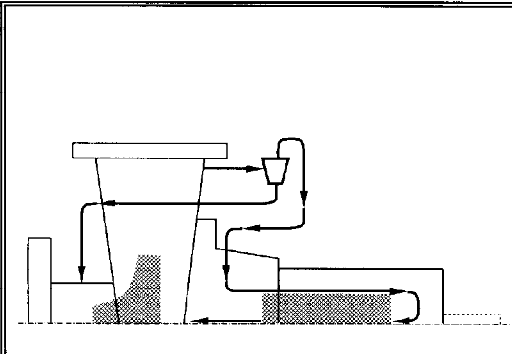
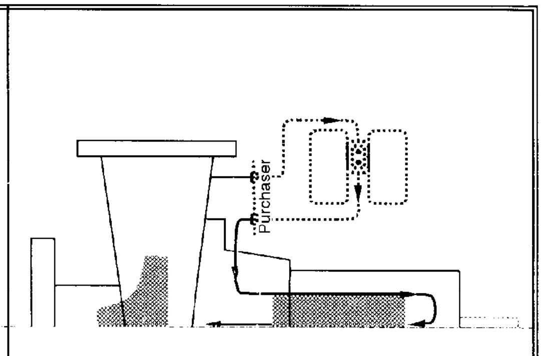
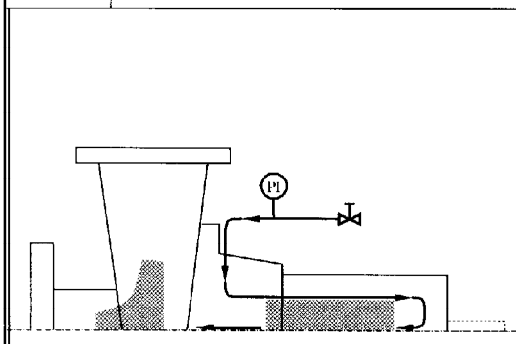
Dirty or Special Pumpage



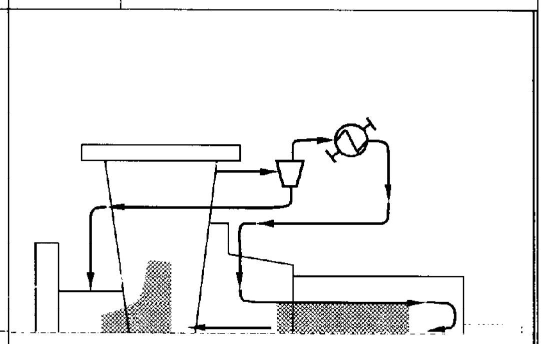
PLAN 31-S — Recirculation of cleaned fluid from a separator through the rotor chamber.



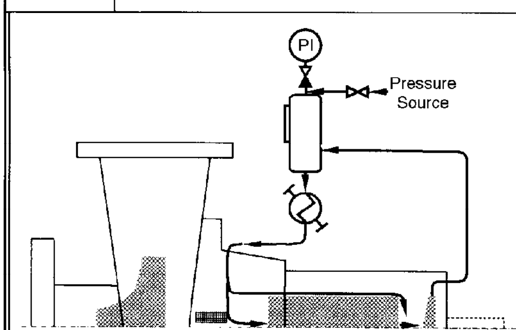
PLAN 31-SE — Circulation from pump discharge through Purchaser's filter system to rotor chamber.



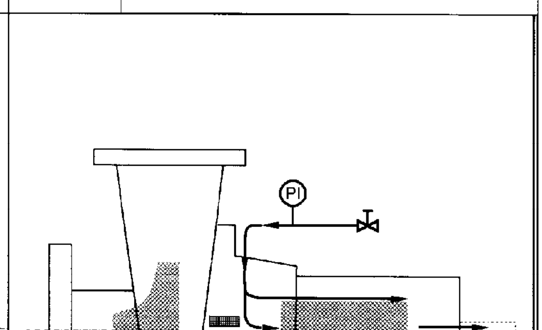
PLAN 32-S — Injection to rotor chamber from external source.



PLAN 41-S — Recirculation from pump discharge of cleaned fluid from a separator through a cooler to the rotor chamber.



PLAN 53-S — Circulation of an externally pressurized fluid through a cooler and the rotor chamber using an auxiliary impeller.



PLAN 54-S — Circulation of external source fluid through the rotor chamber, and back to the fluid source using an auxiliary pumping device.

Figure D-3—Circulating Fluid Arrangements

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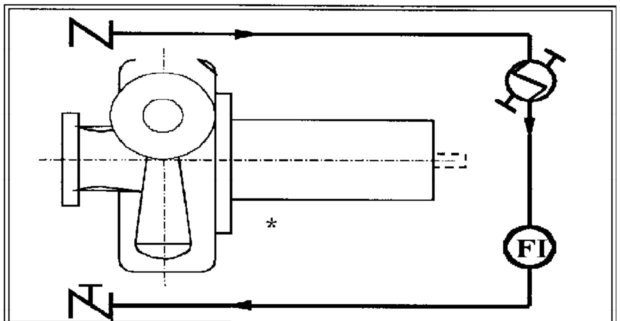
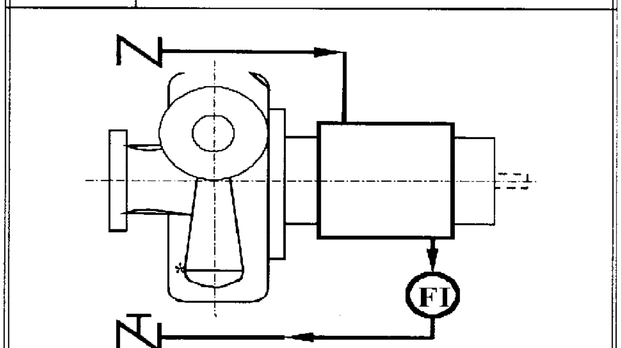
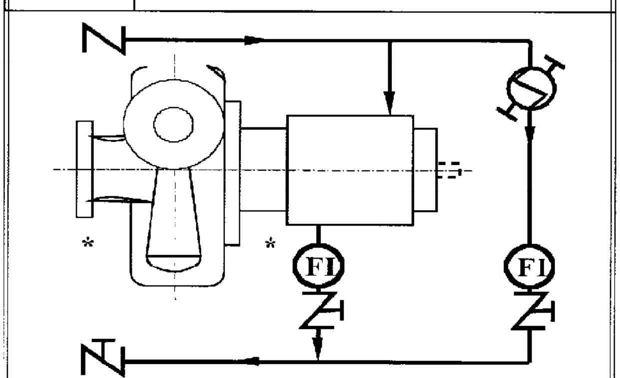
COOLING WATER PIPING



PLAN MS	Cooling water to rotor chamber circulating fluid heat exchanger.



PLAN BS	Cooling water to rotor housing jacket



PLAN KS	Cooling to rotor housing jacket with parallel flow to circulating fluid heat exchanger

Figure D-4—Cooling Water Piping Arrangements

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APPENDIX E—INSTRUMENTATION AND PROTECTIVE SYSTEMS

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Table E-1—Instrumentation and Protective Systems

Tag Number	Description	Location	Function
CE	Conductivity Sensor	Low point of secondary containment area	Shutdown on detection of a conductive media indicating a failure of the primary containment
IE	Current Sensor	Motor	Indication or alarm/shutdown on falling current due to pump dry-run condition or magnetic drive decoupling
JE	Power Sensor	Motor Wiring	Indication or alarm/shutdown on high or low power due to dry running, excess load, or single phasing
LE	Level Sensor	Pump suction or discharge piping	Permissive/shutdown on absence of liquid level to avoid dry- run
ME	Optical Moisture Sensor	Low point of secondary containment area	Shutdown on optical detection of liquid in the secondary containment casing indicating a failure of the primary containment
PS	Pressure Switch	Secondary pressure casing	Shutdown on rising pressure due to containment shell leakage
TE1	Thermal cutout device	Motor stator windings	Alarm/shutdown on excessive temperature in windings due to loss of circulating fluid or over load.
TE2	Temperature sensor with thermowell	Circulation flow path	Indication or alarm/shutdown on increasing temperature due to loss of circulation or magnetic drive decoupling
TE3	Temperature sensor – directly applied	On containment shell/ can	Indication or alarm/shutdown on increasing temperature due to loss of circulation or magnetic drive decoupling
VE	Vibration sensor	On pump (near) bearing housing	Indication or alarm/shutdown on excessive vibration
ZE	Shaft position sensor	On pump housing	Indication or alarm/shutdown on excessive change in shaft position. May be either radial or axial and indicates the wear on the product lubricated bearings.
D1	Primary Casing Drain	Low point of primary casing	Remove all fluids from primary casing for decommissioning.
D2	Secondary Casing Drain	Low point of secondary containment casing	Remove all fluids from secondary casing for decommissioning.
D3	Secondary Control Drain	Low point of area just outside of secondary control barrier	Controlled leakage path for liquids from the secondary control casing
V1	Primary Casing Vent	High point of primary casing	Venting of vapors from primary casing.
V2	Secondary Casing Vent	High point of secondary casing	Venting of vapors from secondary casing.

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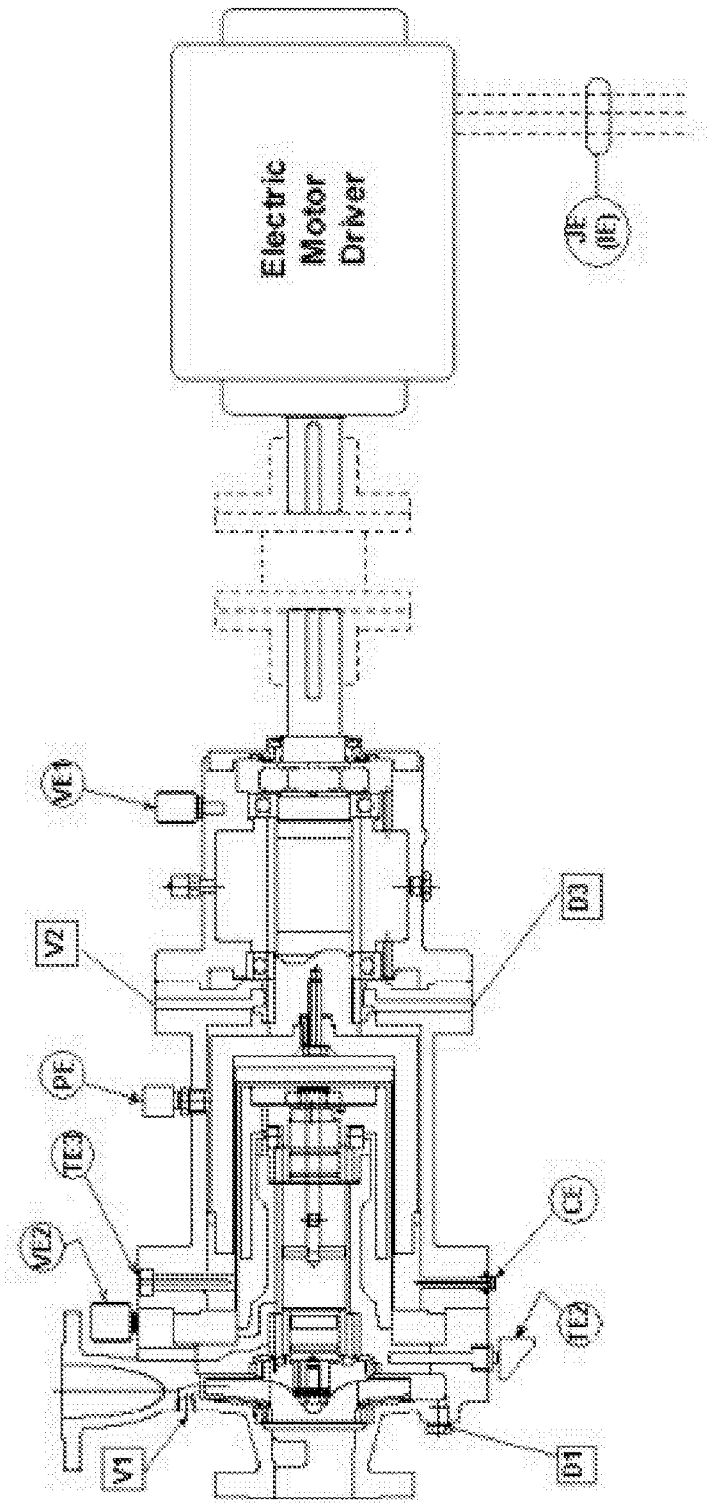

Figure E-1—Magnetic Drive Pump

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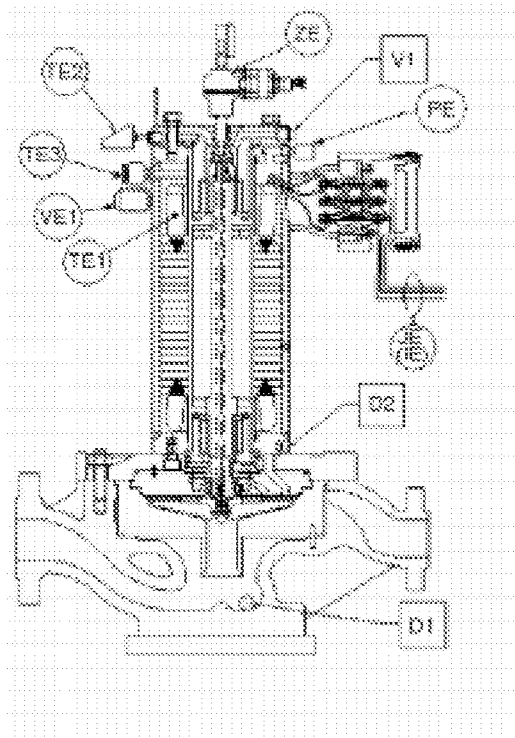

Figure E-2—Vertical In-Line Canned Motor Pump

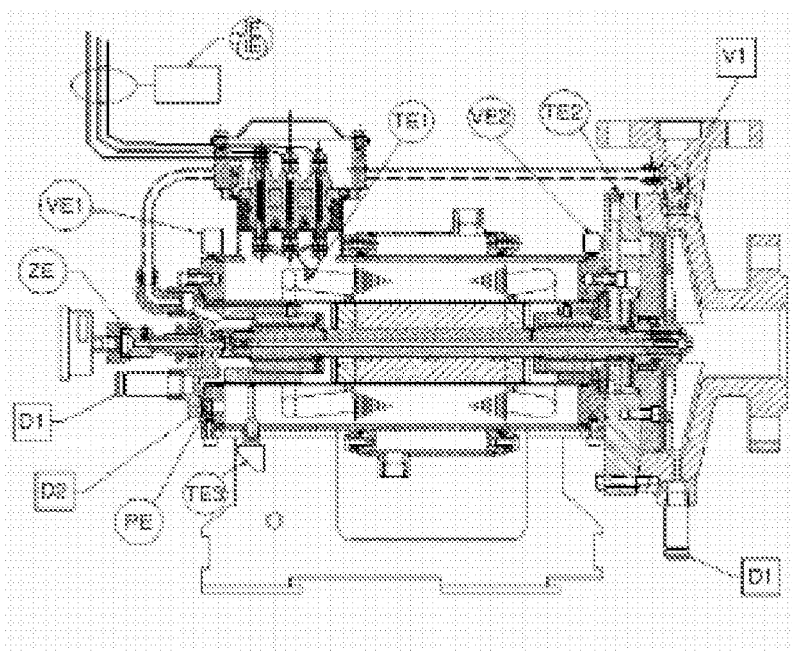

Figure E-3—Horizontal Canned Motor Pump

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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 1A (1B) will limit casing distortion to one half the pump vendor's design criterion (see 6.3.7) 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 1A (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 6.3.7) 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 1A (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).

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

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

F.1.2.3 The applied component forces and moments acting on each pump nozzle flange must be translated to the center of the pump. The magnitude of the resultant applied force (FRC_A), the resultant applied moment (MRC_A), and the applied moment shall be limited by Equations F-3, F-4, and F-5. (The sign convention shown in Figures 2 and 3 and the right hand rule should be used in evaluating these equations.)

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

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

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

where

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

$$FXC_A = FXS_A + FXD_A$$

$$FYC_A = FYS_A + FYD_A$$

$$FZC_A = FZS_A + FZD_A$$

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

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

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

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

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 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.

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

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

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

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

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

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

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

Note: *FX*, *FY*, *FZ*, *MX*, *MY*, and *MZ* represent the applied loads acting on the suction or discharge nozzles; thus, suffixes S_A and D_A have been omitted to simplify the equations. The sign of *FY* is positive if the load puts the nozzle in tension; the sign is negative if the load puts the nozzle in compression. One must refer to Figure 2 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 Figure 3).

D = discharge nozzle.

D_I = inside diameter of Schedule 40 pipe whose nominal size is equal to that of the pump nozzle in question, in mm (in.).

D_O = outside diameter of Schedule 40 pipe whose nominal size is equal to that of the pump nozzle in question, in mm (in.).

F = force, in N (lbs).

FR = resultant force (FRS_A and FRD_A are calculated by the square root of the sum of the squares method using the applied component forces acting on the nozzle flange. FRS_{T2} and FRD_{T2} are extracted from Table 1A (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 1A (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 & 3).

σ = longitudinal stress, in MPa (psi).

τ = shear stress, in MPa (psi).

Subscript *A* = applied loads.

Subscript *T2* = loads extracted from Table 1A (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,

$$|FXS_A/FYS_{T2}| = |+12{,}900/6670| = 1.93 < 2.00$$

$$|FYS_A/FYS_{T2}| = |0/5340| = 0 < 2.00$$

$$|FZS_A/FZS_{T2}| = |-8852/4450| = 1.99 < 2.00$$

$$|MXS_A/MXS_{T2}| = |-1356/5020| = 0.27 < 2.00$$

$$|MYS_A/MYS_{T2}| = |-5017/2440| = 2.06 < 2.00$$

$$|MZS_A/MZS_{T2}| = |-7458/3800| = 1.96 < 2.00$$

Since MYS_A exceeds the specified in Table 1A by more than a factor of 2, it is not satisfactory. Assume that MYS_A can be reduced to -4879. Then,

$$|MYS_A/MYS_{T2}| = |(-4879)/2440| = 1.9996 < 2.00$$

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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	+ 1,2900	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

Note: See F.4.1.2.1.

$$FRS_A = [(FXS_A)^2 + (FYS_A)^2 + (FZS_A)^2]^{0.5}$$

$$= [(+12,900)^2 + (0)^2 + (-8852)^2]^{0.5} = 15645$$

$$MRS_A = [(MXS_A)^2 + (MYS_A)^2 + (MZS_A)^2]^{0.5}$$

$$= [(-1356)^2 + (-4879)^2 + (-7458)^2]^{0.5} = 9015$$

Referring to Equation F-1,

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

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

$$1.96 < 2$$

For the discharge nozzle, FRD_A and MRD_A are determined by the same method used to find FRS_A and MRS_A:

$$FRD_A = [(FXD_A)^2 + (FYD_A)^2 + (FZD_A)^2]^{0.5}$$

$$= [(+7117)^2 + (-445)^2 + (-8674)^2]^{0.5} = 11,229$$

$$MRD_A = [(MXD_A)^2 + (MYD_A)^2 + (MZD_A)^2]^{0.5}$$

$$= [(+678)^2 + (-3390)^2 + (-4482)^2]^{0.5} = 5982$$

Referring to Equation F-2,

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

$$11,229/[1.5(6920)] + 5982/[1.5(4710)] \leq 2$$

$$1.93 < 2$$

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):

$FXC_A = FXS_A + FXD_A$

$FYC_A = FYS_A + FYD_A$

$FZC_A = FZS_A + FZD_A$

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

$FXC_A = (+12,900) + (+7117) = +20,017$

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

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

$FRC_A = [(+20,017)^2 + (-445)^2 + (-178)^2]^{0.5} = 20,023$

Referring to Equation F-3,

$FRC_A < 1.5(FRS_{T2} + FRD_{T2})$

$20,023 < 1.5(9780 + 6920)$

$20,023 < 25,050$

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MYC_A is determined as follows (see F.1.2.3):

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

$$= (-4879) + (-3{,}390) + [(+12{,}900)(0.00) + (+7117)(+381) - (-8852)(+267) - (+8674)(0.00)] / 1000 = -3194$$

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):

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

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

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

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

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

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

$$MZC_A = (-7458) + (-4882) - [(+12{,}900)(0.00) + (+7117)(-311) - (0)(+267) - (-445)(0.00)] / 1000 = -10{,}127$$

$$MRC_A = [(-3206)^2 + (-3194)^2 + (-10{,}127)^2]^{0.5} = 11{,}092$$

Referring to Equation F-5,

$$MRC_A < 1.5(MRS_{T2} + MRD_{T2})$$

$$11{,}092 < 1.5(6750 + 4710)$$

$$11{,}092 < 17{,}190$$

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 inspection, FZS_A, MZS_A, and MXD_A are greater than two times the values shown in Table 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.

Table F-3A—Proposed Applied Nozzle Loadings for Example 2A

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

F.4.2.2 Solution

F.4.2.2.1 Suction nozzle calculations are as follows:

Schedule 40 pipe with a nominal size of 100 mm, $D_O = 114$ mm and $D_I = 102$ mm. Therefore,

$$D_O^2 - D_I^2 = (114)^2 - (102)^2 = 2592$$

$$D_O^4 - D_I^4 = (114)^4 - (102)^4 = 6.065 \times 10^7$$

$$[(FXS_A)^2 + (FZS_A)^2]^{0.5} = [(-2{,}224)^2 + (+1334)^2]^{0.5} = 2593$$

$$[(MXS_A)^2 + (MZS_A)^2]^{0.5} = [(-136)^2 + (+1356)^2]^{0.5} = 1363$$

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.

$$\sigma_S = [(1.27 FYS_A)/(D_O^2 - D_I^2)] + [1.02 \times 10^4 D_O (MXS_A^2 + MZS_A^2)^{0.5}]/(D_O^4 - D_I^4)$$

$$= ([1.27(-5{,}338)/(2{,}592)] + [1.02 \times 10^4 (114)(1{,}363)])/6.065 \times 10^7 = 23.52$$

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

$$\tau_S = [1.27(FXS_A^2 + FZS_A^2)^{0.5}/(D_O^2 - D_I^2)] + [0.51 \times 10^4 D_O (MYS_A)]/(D_O^4 - D_I^4)$$

$$= [1.27(2593)/(2592)] + [0.51 \times 10^4 (114)(|-2034|)]/6.065 \times 10^7 = 20.77$$

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

$$P_S = (\sigma_S/2) + (\sigma_S^2/4 + \tau_S^2)^{0.5} < 41$$

$$= (+23.52/2) + [(+23.52)^2/4 + (+20.77)^2]^{0.5}$$

$$= +35.63 < 41$$

Thus, the suction nozzle loads are satisfactory.

F.4.2.2.2 Discharge nozzle calculations are as follows:

For Schedule 40 pipe with a nominal size of 80 mm, D_O = 89 mm and D_I = 78 mm. Therefore,

$D_O^2 - D_I^2 = (89)^2 - (78)^2 = 1837$

$D_O^4 - D_I^4 = (89)^4 - (78)^4 = 2.573 \times 10^7$

$[(FXD_A)^2 + (FZD_A)^2]^{0.5} = [(+1334)^2 + (+445)^2]^{0.5} = 1406$

$[(MXD_A)^2 + (MZD_A)^2]^{0.5} = [(+2712)^2 + (+136)^2]^{0.5} = 2715$

Equation F-7A is used to determine the longitudinal stress for the discharge nozzle, 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.

$$\sigma_D = [(1.27FYD_A)/(D_O^2 - D_I^2)]$$

$$+ [1.02 \times 10^4 D_O(MXD_A^2 + MZD_A^2)^{0.5}]/(D_O^4 - D_I^4)$$

$$= ([1.27(+2224)/(1837)] + [1.02 \times 10^4 (89)(2715)])/2.573 \times 10^7 = 97.33$$

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

$$\tau_D = [1.27(FXD_A^2 + FZD_A^2)^{0.5}/(D_O^2 - D_I^2)]$$

$$+ [0.51 \times 10^4 D_O(MYD_A)]/(D_O^4 - D_I^4)$$

$$= ([1.27(1406)/(1837)] + [0.51 \times 10^4 (89)(|+271|)])/2.573 \times 10^7 = 5.75$$

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

$$P_D = (\sigma_D/2) + (\sigma_D^2/4 + \tau_D^2)^{0.5} < 41$$

$$= (+97.33/2) + [(97.33)^2/4 + (+5.75)^2]^{0.5}$$

$$= +97.67 < 41$$

Thus, the discharge nozzle loads are too large. By inspection, if MXD_A is reduced by 50 percent to 1356 Nm, the resulting principal stress will still exceed 41 MPa. Therefore, the maximum value for MXD_A will be twice MXD_{T2}, or 1900 Nm.

F.5

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 problem is to determine whether the conditions specified in F.1.2.1, F.1.2.2, and F.1.2.3 are satisfied.

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

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,

$|FXS_A / FXS_{T2}| = |+2900 / 1500| = 1.93 < 2.00$

$|FYS_A / FYS_{T2}| = |0 / 1200| = 0 < 2.00$

$|FZS_A / FZS_{T2}| = |-1990 / 1{,}000| = 1.99 < 2.00$

$|MXS_A / MXS_{T2}| = |-1000 / 3700| = 0.27 < 2.00$

$|MYS_A / MYS_{T2}| = |-3700 / 1800| = 2.06 > 2.00$

$|MZS_A / MZS_{T2}| = |-5500 / 2800| = 1.96 < 2.00$

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 – 3,599. 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.

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Table F-2B—Applied Nozzle Loadings for Example 1B

Force	Value (lbs)	Moment	Value (ft-lbs)
		Suction	
FXS_A	+ 2900	MXS_A	–1000
FYS_A	0	MYS_A	–3700[a]
FZS_A	– 1990	MZS_A	– 5500
		Discharge	
FXD_A	+ 1600	MXD_A	+ 500
FYD_A	– 100	MYD_A	– 2500
FZD_A	+ 1950	MZD_A	– 3600

Note: See F.4.1.2.1

F.5.1.2.2 A check of condition F.1.2.2 is as follows:

For the suction nozzle, FRS_A and MRS_A are determined using the square root of the sum of the squares method:

$$FRS_A = [(FXS_A)^2 + (FYS_A)^2 + (FZS_A)^2]^{0.5}$$

$$= [(+2900)^2 + (0)^2 + (-1990)^2]^{0.5} = 3517$$

$$MRS_A = [(MXS_A)^2 + (MYS_A)^2 + (MZS_A)^2]^{0.5}$$

$$= [(-1000)^2 + (-3599)^2 + (-5500)^2]^{0.5} = 6649$$

Referring to Equation F-1,

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

$3517 / [1.5(2200)] + 6649 / [1.5(5000)] \leq 2$

$1.95 < 2$

For the discharge nozzle, FRD_A and MRD_A are determined by the same method used to find FRS_A and MRS_A:

$$FRD_A = [(FXD_A)^2 + (FYD_A)^2 + (FZD_A)^2]^{0.5}$$

$$= [(+1600)^2 + (-100)^2 + (+1950)^2]^{0.5} = 2524$$

$$MRD_A = [(MXD_A)^2 + (MYD_A)^2 + (MZD_A)^2]^{0.5}$$

$$= [(+500)^2 + (-2500)^2 + (-3600)^2]^{0.5} = 4411$$

Referring to Equation F-2,

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

$2524 / [1.5(1560)] + 4411 / [1.5(3500)] \leq 2$

$1.92 < 2$

The loads acting on each nozzle satisfy the appropriate interaction equation, so the condition specified in F.1.2.2 is satisfied.

F.5.1.2.3 A check of condition F.1.2.3 is as follows:

To check this condition, the applied component forces and moments are translated and resolved to the center of the pump. FRC_A is determined as follows (see F.1.2.3):

$FXC_A = FXS_A + FXD_A$

$FYC_A = FYS_A + FYD_A$

$FZC_A = FZS_A + FZD_A$

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

$FXC_A = (+2900) + (+1600) = +4500$

$FYC_A = (0) + (-100) = -100$

$FZC_A = (-1990) + (+1950) = -40$

$FRC_A = [(+4500)^2 + (-100)^2 + (-40)^2]^{0.5} = 4501$

Referring to Equation F-3,

$FRC_A < 1.5(FRS_{T2} + FRD_{T2})$

$4501 < 1.5(2200 + 1560)$

$4501 < 5640$

MYC_A is determined as follows (see F.1.2.3):

$$MYC_A = (MYS_A + MYD_A + [(FXS_A)(zS) + (FXD_A)(zD) - (FZD_A)(xD)])/12$$

$$= = (-3599) + (-2500) + [(+2900)(0.00) + (+1600)(+15) - (-1990)(+10.5) - (+1950)(0.00)]/12$$

$$= 2358$$

Referring to Equation F-4,

$|MYC_A| < 2.0(MYS_{T2} + MYD_{T2})$

$|-2358| < 2.0\ (1800 + 1300)$

$2358 < 6200$

MRC_A is determined as follows (see F.1.2.3):

$$MXC_A = MXS_A + MXD_A - [(FYS_A)(zS) + (FYD_A)(zD) - (FZS_A)(yS) - (FZD_A)(yD)]/12$$

$$MYC_A = MYS_A + MYD_A + [(FXS_A)(zS) + (FXD_A)(zD) - (FZS_A)(xS) - (FZD_A)(xD)]/12$$

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$$MZC_A = MZS_A + MZD_A - [(FXS_A)(yS) + (FXD_A)(yD) - (FYS_A)(xS) - (FYD_A)(xD)]/12$$

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

$$MXC_A = (-1000) + (+500) - [(0)(0.00) + (-100)(+15.00) - (-1990)(0.00) - (+1950)(-12.25)]/12 = -2366$$

MYC_A = – 2,358 (see previous calculation)

$$MZC_A = (5500) + (-3600) - [(+2900)(0.00) + (+1600)(-12.25) - (0)(+10.50) - (-100)(0.00)]/12 = -(7467)$$

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

Referring to Equation F-5,

$MRC_A < 1.5(MRS_{T2} + MRD_{T2})$

$8{,}180 < 1.5(5000 + 3500)$

$8{,}180 < 12{,}750$

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.

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.

$$\sigma_s = [(1.27FYS_A)/(D_O^2 - D_I^2)]$$

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

$$[212D_O(MXS_A^2 + MZS_A^2)^{0.5}]/(D_O^4 - D_I^4)$$

$$= [1.27(-1200)/4.04] + [122(4.500)(1005)]/147.34$$

$$= 3367$$

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

$$\tau_s = [1.27(FXS_A^2 + FZS_A^2)^{0.5}]/D_O^2 - D_I^2$$

$$+ [61D_O(MYS_A)]/(D_O^4 - D_I^4)$$

$$= [1.27(583)/4.04] + [61(4.500)(|-(1500)|)]/147.34 = 2978$$

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

$$P_s = (\sigma_s/2) + (\sigma_s^2/4 + \tau_s^2)^{0.5} < 5950$$

$$= (+3367/2) + [(+3367)^2/4 + (+2978)^2]^{0.5}$$
$$= +5105 < 5950$$

Thus, the suction nozzle loads are satisfactory.

F.5.2.2.2 Discharge nozzle calculations are as follows:

For Schedule-40 pipe with a nominal size of 3 in., D_O = 3.500, and D_I = 3.068. Therefore,

$D_O^2 - D_I^2 = (3.500)^2 - (3.068)^2 = 2.84$

$D_O^4 - D_I^4 = (3.500)^4 - (3.068)^4 = 61.47$

$[(FXD_A)^2 + (FZD_A)^2]^{0.5} = [(+300)^2 + (+100)^2]^{0.5} = 316$

$[(MXD_A)^2 + (MZD_A)^2]^{0.5} = [(+2000)^2 + (+100)^2]^{0.5}$
$= 2002$

Equation F-7B is used to determine the longitudinal stress for the discharge nozzle, σ_D.

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Note: The applied FYD_A load acting on the discharge nozzle is in the negative Y direction and will produce a tensile stress; therefore, a positive sign on FYD_A is used.

$$\sigma_D = [1.27FDA/(D_O^2 - D_I^2)] + [122D_O(MXD_A^2 + MZD_A^2)^{0.5}]/(D_O^4 - D_I^4)$$

$$= [1.27(+500)/2.84] + [122(3.5)(2002)]/61.47$$

$$= 14{,}131$$

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

$$\tau_D = [1.27(FXD_A^2 + FZD_A^2)^{0.5}]/(D_O^2 - D_I^2) + [61D_O(MYD_A)]/(D_O^4 - D_I^4)$$

$$= [1.27(316)/2.84] + [61(3.500)(|+200|)]/61.47$$

$$= 836$$

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

$$P_D = (\sigma_D / 2) + (\sigma_D{}^2 / 4 + \tau_D{}^2)^{0.5} < 5950$$

$$= (+14{,}131 / 2) + [(+14{,}131)^2 / 4 + (+836)^2]^{0.5}$$

$$= +14{,}181 > 5950$$

Thus, the discharge nozzle loads are too large. By inspection, if MXD_A is reduced by 50 percent to 1000 ft-lbs the resulting principal stress will still exceed 5950 psi. Therefore, the maximum value for MXD_A will be twice MXD_{T2}, or 1400 ft-lbs.

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APPENDIX G—MATERIAL CLASS SELECTION GUIDE

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Table G-1 Material Classes for Centrifugal Pump Services

Service	Temperature Range Degrees C	Degrees F	Pressure Range	Material Class	See Reference Note
Boiling water and process water	<120	<250	All	S-1	4
	120 – 175	250 – 350	All	S-5	4
	> 175	> 350	All	C-6	4
Boiler circulator	> 95	> 200	All	C-6	
Foul water, reflux drum water, water draw, and hydrocarbons containing these	< 175	> 350	All	S-3 or S-6	5
waters, including reflux streams	> 175	> 350	All	C-6	5
Propane, butane, liquefied petroleum gas, and ammonia (NH_3)	< 230	< 450	All	S-1	
Diesel oil; gasoline; maphtha; kerosene; gas oils; light, medium,	< 230	< 450	All	S-1	
and heavy lube oils; fuel oil; residuum; crude oil; asphalt; synthetic	230 – 370	450 – 700	All	S-6	5, 6
crude bottoms	> 370	> 700	All	C-6	5
Noncorrosive hydrocarbons, e.g., catalytic reformate, isomaxate, desulfurized oils	230 – 370	450 – 700	All	S-4	6
Xylene, toluene, acetone, benzene, furfural, MEK, cumene	< 230	< 450	All	S-1	
Sodium carbonate, doctor solution	< 175	< 350	All	S-1	
Caustic (sodium hydroxide)	< 100	< 210	All	S-1	7
concentration of ≤ 20%	≥ 100	≥ 200	All		
Sour water	< 260	< 470	All	D-1	
Sulfur (liquid state)	All	All	All	S-1	
FCC slurry	< 370	< 700	All	C-6	
Potassium carbonate	< 175	< 350	All	C-6	
	< 370	< 700	All	A-8	
MEA, DEA, TEA-stock solutions	< 120	< 250	All	S-1	
DEA, TEA-lean solutions	< 120	< 250	All	S-1	8
MEA-lean solution (CO_2 only)	80 – 150	175 – 300	All	S-9	8
MEA-lean solution (CO_2 and H_2S)	80 – 150	175 – 300	All		7,8
MEA, DEA, TEA, rich solutions	< 80	< 175	All	S-1	8
Sulfuric acid concentration > 85%	< 38	< 100	All	S-1	5
85% – < 1%	< 230	< 450	All	A-8	5
Hydrofluoric acid concentration of > 96%	< 38	< 100	All	S-9	5

General Notes:
1. The materials for pump parts for each material class are given in Appendix H.
2. Specific materials recommendations should be obtained for services not clearly identified by the service description listed in this table.
3. Caution should be used when considering the use of nickel containing stainless steel in applications where various concentrations of chloride containing liquids exist. Generally, nickel does not withstand chlorides well.

Reference Notes:
4. Oxygen content and buffering of water should be considered in material selection.
5. 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.
6. 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.
7. All welds shall be stress relieved.
8. Class A-7 materials should be used except for carbon steel casings.

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APPENDIX H—MATERIALS AND MATERIAL SPECIFICATIONS FOR CENTRIFUGAL PUMP PARTS

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Table H-1—Materials for Sealless Centrifugal Pumps

Part	Full Compliance Materials[b]	S-1	S-3	S-4	S-5	S-6	S-8	S-9	C-6	A-7	A-8	D-1	H-1	H-2	T-1	A-9
							Material Class and Material Abbreviations[a]									
		STL CI	STL Ni-Resist	STL STL	STL STL 12% CHR	STL 12% CHR	STL 316 AUS	STL Monel	12%CHR 12%CHR	AUS AUS (1 & 2)	316AUS 316AUS (1 & 2)	Duplex Duplex	Hast B Hast B	Hast C Hast C	Titanium Titanium	Alloy 20 Alloy 20
Pressure Casing (Pump case, cover)	Yes	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	12% CHR	AUS	316AUS	Duplex	Hast B	Hast C	Titanium	Alloy 20
Secondary Pressure Casing	Yes	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel
Impeller	Yes	Cast Iron	Ni-Resist	Carbon Steel	Carbon-Steel	12% CHR	316 AUS	Monel	12% CHR	AUS	316AUS	Duplex	Hast B	Hast C	Titanium	Alloy 20
Case Wear Rings	No	Cast Iron	Ni-Resist	Cast Iron	12% CHR	12% CHR	Hard-faced316 AUS (3)	Monel	12% CHR Hardened	Hard-faced AUS (3)	Hard-faced AUS (3)	Duplex (3)	Hast B	Hast C	Titanium	Alloy 20
Impeller Wear Rings	No	Cast Iron	Ni-Resist	Cast Iron	12% CHR Hardened	12% CHR Hardened	Hard-faced 316AUS (3)	Monel	12% CHR Hardened	Hard-faced AUS (3)	Hard-faced AUS (3)	Duplex (3)	Hast B	Hast C	Titanium	Alloy 20
Shaft (CMP)	Yes	Carbon Steel	Carbon Steel	Carbon Steel	AISI 4140 Steel	AISI 4140 Steel	316 AUS	K-Monel	12% CHR	AUS	316 AUS	Duplex	Hast B	Hast C	Titanium	Alloy 20
Shaft (Mag Drive) Wet End	Yes	Carbon Steel	Carbon Steel	Carbon Steel	AISI 4140 Steel	AISI 4140 Steel	316 AUS	K-Monel	12% CHR	AUS	316 AUS	Duplex	Hast B	Hast C	Titanium	Alloy 20
Shaft (Mag Drive) Drive End	No	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel
Shaft Sleeves or Spacers	Yes	Cast Iron	Ni-Resist	Cast Iron	12% CHR	12% CHR	316 AUS	K-Monel	12% CHR	AUS	316 AUS	Duplex	Hast B	Hast C	Titanium	Alloy 20

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Table H-1—Materials for Sealless Centrifugal Pumps

Part	Full Compliance Materials[b]	Material Class and Material Abbreviations[a] S-1	S-3	S-4	S-5	S-6	S-8	S-9	C-6	A-7	A-8	D-1	H-1	H-2	T-1	A-9
		STL / CI	STL / Ni-Resist	STL / STL	STL / STL 12% CHR	STL / 12% CHR	STL / 316 AUS	STL / Monel	12%CHR / 12%CHR	AUS / AUS (1 & 2)	316AUS / 316AUS (1 & 2)	Duplex / Duplex	Hast B / Hast B	Hast C / Hast C	Titanium / Titanium	Alloy 20 / Alloy 20
Stator & Rotor Liner	Yes	316L AUS	316L AUS	316L AUS	316L AUS	316L AUS	316L AUS	316L AUS	316L AUS	316L AUS	316L AUS	Duplex	Hast B	Hast C	Titanium	Alloy 20
Containment Shell	Yes	316L AUS	316L AUS	316L AUS	316L AUS	316L AUS	316L AUS	316L AUS	316L AUS	316L AUS	316L AUS	Duplex	Hast B	Hast C	Titanium	Alloy 20
Inner Magnet Sheathing	Yes	316L AUS	316L AUS	316L AUS	316L AUS	316L AUS	316L AUS	316L AUS	316L AUS	316L AUS	316L AUS	Duplex	Hast B	Hast C	Titanium	Alloy 20
Throat Bushings	No	Cast Iron	Ni-Resist	Cast Iron	12% CHR	12% CHR	316 AUS	Monel	12% CHR Hardened	AUS	316 AUS	Duplex	Hast B	Hast C	Titanium	Alloy 20
Magnets (Mag Drive)	No	See Appendix I, Magnet Materials														
Motor Materials (CMP)	No	Note 5	Note 5	Note 5	Note 5	Note 5	Note 5	Note 5	Note 5	Note 5	Note 5	Note 5	Note 5	Note 5	Note 5	Note 5
Case Studs	Yes	AISI 4140 Steel	AISI 4140 Steel	AISI 4140 Steel	AISI 4140 Steel	AISI 4140 Steel	AISI 4140 Steel	K-Monel Hardened (8)	AISI 4140 Steel	AISI 4140 Steel	AISI 4140 Steel	Duplex (8)	304 AUS	304 AUS	AISI 4140 Steel	304 AUS
Case Gasket	No	AUS, Spiral Wound (6)	AUS, Spiral Wound (6)	AUS, Spiral Wound (6)	AUS, Spiral Wound (6)	AUS, Spiral Wound (6)	AUS, Spiral Wound (6)	Monel, Spiral Wound, PTFE Filled (6)	AUS, Spiral Wound (6)	AUS, Spiral Wound (6)	316 AUS, Spiral Wound (6)	Duplex SS Spiral Wound (6)	Graphoil or Teflon	Graphoil or Teflon	Graphoil or Teflon	Graphoil or Teflon
Wetted Fasteners(Bolts)	Yes	Carbon Steel	Carbon Steel	Carbon Steel	316 AUS	316 AUS	316 AUS	K-Monel	316 AUS	316 AUS	316 AUS	Duplex	Hast B	Hast C	Titanium	Alloy 20

General Notes:
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. Cantilever 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 nongalling 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. Alternate materials may be substituted for liquid temperatures greater than 45°C (110°F) or for other special services.
6. Unless otherwise specified, AISI 4140 steel may be used for nonwetted case and gland studs.

Notes:
[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).
[b]See 6.11.1.

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Table H-2—International Materials for Pump Parts

Material Class	Applications	USA		International ISO	Germany		Great Britain BSI	France AFNOR	Japan JIS
		ASTM	UNS		17007	17006			
Carbon Steel	Pressure Castings	A216 Gr WCB	J 03 002		1.0619	GP240GH	1504 161 Gr. 480	A 480 CP-M	G 5151, C1 SCPH 2
	Wrought/Forgings	A 266 Class 2	K 03506	683-18-C25	1.0402	C 22 C 22.8	1503 221 490	AC 48CP	G3202, C1 SFVC 2A
	Bar Stock: Pressure	A 695 Gr B40	G 10 200	683-18-C 25	1.0402	C 22	970 055 M15	AC 48CP	G 4051, C1 S25C
	Bar Stock: General	A 576 Gr 1045	G 10 450	683-18-C 45e	1.0503	C 45	970 080 1450	Z10 C13	G 4051, C1 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, C1 SNB7
	Nuts	A 194 Gr 2H	K 04 002	683-1-C35e	1.1181	CK35	1506 162	2C35	G 4051, C1 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 GrB	K 03 006		1.0305	St. 35.8	1501 161 430	TU 42C	G3456, Gr. STPT 370/410
	Fittings	A 105	K 03 504		1.0308	St. 35.0	1503 221 490	AF 48N	G 4051, C1 S25C
AISI 4140 Steel	Bar Stock	A 434 CLASS BB A 434 CLASS BC	G 41 400[c]	683-2-3	1.7225	42 Cr Mo 4	970 708 M 40	42 Cr Mo 4	G 4105, C1 SCM 440
	Bolts and Studs	A 193 Gr B7	G 41 400		1.7711 1.7709	40 Cr Mo V 4 7 21 Cr Mo V 5 7	1506 630 790	42 CVD 4	G 4107, C1 SNB16
	Nuts	A 194 Gr 2H	K 04 002	2604-2-F31	1.7258	24 Cr Mo 5	1506 162	45 D2	G 4051, C1 S45C
12% Chrome Steel	Pressure Castings	A 217 Gr CA 15	J 91 150		1.4107	G-X 8 Cr Ni 12	1504 420 C29	Z 12 C13 - M	G5121, C1 SCS 1
		A 487 Gr CA6NM	J 91 540		1.4317	G-X 4 Cr Ni 13 4	1504 425 C11	Z 6 CN 1304-M	G5121, C1 SCS 6
	Wrought/Forgings: Pressure	A 182 Gr F6a Class 1 A 182 Gr F 6 NM	S 41 000 S 41 500	683-13-3	1.4006 1.4313	X 10 Cr 13 X 4 Cr Ni 13 4	1503 410 S21	Z10C13 Z6CN 13-D4	G3214, C1 SUS F6 B G3214, C1 SUS F6 NM
	Wrought/Forgings: General	A 473 Type 410	S 41 000	683-13-2	1.4313	X 4 Cr Ni 13 4	970 410 S21	Z 6CN 13-D4	G3214, C1 SUS F6 NM
	Bar Stock: Pressure	A 479 Type 410	S 41 000	683-13-3	1.4006	X 10 Cr 13	1503 420 C29	Z 10 C13	G4303 or 410
	Bar Stock: General	A 276 Type 410	S 41 400	683-13-3	1.4006	X10 Cr 13	970 410 S21	X 12 Cr 13	G4303, Grl SUS 403 or 420

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Table H-2—International Materials for Pump Parts

Material Class	Applications	USA ASTM	USA UNS	International ISO	Germany 17007	Germany 17006	Great Britain BSI	France AFNOR	Japan JIS
	Bar Stock/Forgings Wear Parts[a]	A 276 Type 420 A 473 Type 416	S 42 000	683-13-4	1.4021	X 20 Cr 13	970 420 S37	Z 20 C13	G4303, Grl SUS 403 or 420
	Bolts and Studs[b]	A 193 Gr B6	S 41 000		1.4923	X22 Cr Mo V 12 1	1506 410 S21 760	Z 13 C13	G4303, Gr SUS 403 or 420
	Nuts[b]	A 194 Gr 6	S 41 000		1.4923	X22 Cr Mo V 12 1	1506 410 S21 760	Z 13 C13	G4303, Gr SUS 403 or 420
	Plate	A 240 Type 410	S 41 000	683-13-3	1.4006	X10 Cr 13	970 410 S21	Z13 C13	G4304/4305 or 410
Austenitic Stainless Steel	Pressure Castings	A 351 Gr CF3 A 743 Gr CF3	J 92 500	683-13-10	1.4306 1.4581	G-X 2 Cr Ni N 18 9 G-X 5 Cr Ni Mo Nb 18 10	1504-304-C12 1504-347-C17	Z2 CN 18-10M	G 5121, C1 SCSI 3A
		A 351 Gr CF3M A 744 Gr CF3M	J 92 800	683-13-19	1.4409 1.4408	G-X 2 Cr Ni Mo 19-11-2 G-X6 Cr Ni Mo 18 10	1504-316-C12 1504-318-C17	Z3 CND 18-12	G 5121, C1 SCS I 4A 02M
	Wrought/Forgings	A 182 Gr F 304L	S 30 403	683-13-10	1.4306	X2 Cr Ni 19 11	1503 304 S11	Z3 CN 18-10	G 3214, C1 SUS F 304 L
		A 182 Gr F 316L	S 31 603	683-13-19	1.4404 1.4571	X2 Cr Ni Mo 17 13 2 X 6 Cr Ni Mo Ti 17 12 2	1503 316 S11	Z3 CND 17-12-02	G 3214, C1 SUS F 316 L
	Bar Stock[c]	A 479 Type 304L A 479 Type 316L	S 30 403 S 31 603	683-13-10 683-13-19	1.4306 1.4404 1.4571	X2 Cr Ni 19 11 X2 Cr Ni Mo 17 13 2 X 6 Cr Ni Mo Ti 17 12 2	970 304 S11 970 316 S11	Z3 CN 18-10 Z3 CND-17-12-02	G 4303, SUS F 304L G 4303, SUS F 316L
		A 479 Type XM19[d]	S 34 565		1.3974	X3CrNiMnMoNNb 23-17-6-3			
	Plate	A 240 Gr 304L / 316L	S 30 403 S 31 603	683-13-10 683-13-19	1.4306/1.4404 1.4571 1.4301	X 2 Cr Ni 19 11 X 2 Cr Ni Mo 17 13 2 X 6 Cr Ni Mo Ti 17 12 2 X 5 Cr Ni 18 10	970 304 S11 970 316 S11	Z3 CN 18-10 Z3 CNP 17-12-02	G 4304/5, Gr 304L/ 316L
	Pipe	A 312 Type 304L/ 316L	S 30 403 S 31 603	683-13-10 683-13-19	1.4306/1.4404 1.4436	X 2 Cr Ni 19 11 X 2 Cr Ni Mo 17 13 2 X 3 Cr Ni Mo Ti 17 13 3	3605 304 S11 3605 316 S11	TU22 CN 18-10 TU22 CND 17-12-02	G 3459, Gr 304 LTP/ 316LTP
	Fittings	A 182 Gr F304L 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	1503 304 S11 1503 316 S11	Z3 CN 18-10 Z2CND-17-12-02	G 3214, Dr SUS 304L/ 316L
	Bolts and Studs	A 193 Gr B 8 M	S 31 600	683-1-21	1.4571	X 6 Cr Ni Mo Ti 17 12 2	1506 316 S31	Z 6 CN Dt 17. 12	G 4303, Grl SUS 316
	Nuts	A 194 Gr B 8 M	S 31 600	682-1-21	1.4571	X 6 Cr Ni Mo Ti 17 12 2	1506 316 S31	Z6 CN DT 17.12	G 4303, Grl SUS 316
Duplex Stainless Steel	Pressure Castings	A 890 Gr 3A	J93371		1.4468	G-X 2 Cr Ni Mo N 26 6 3		Z6 CND 26-5-02M	G 5121, C1 SCS 11

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Table H-2—International Materials for Pump Parts

Material Class	Applications	USA		International ISO	Germany		Great Britain BSI	France AFNOR	Japan JIS
		ASTM	UNS		17007	17006			
		A 351 Gr CD4 MCu	J93370		1.4517	G-X 2 Cr Ni Mo Cu N 26 6 3 3		Z3 CNDU 26-05M	
	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	G 4319, C1 SUS 329
	Bar Stock	A276-S31803	S 31 803		1.4462	X 2 Cr Ni Mo N 22 5		Z3 CND 22-05AZ	G 4303, Grl SUS 329 Gr SUS 329
	Plate	A240-S31803	S 31 803		1.4462	X 2 Cr Ni Mo N 22 5		Z3 CND 22-05AZ	G 4303, Gr SUS 329
	Pipe	A790-S31803	S 31 803		1.4462	X 2 Cr Ni Mo N 22 5		Z3 CND 22-05AZ	G 3459, Gr SUS 329
	Fittings	A 182 Gr F 51	S 31 803		1.4462	X 2 Cr Ni Mo N 22 5	1503-318-S13	Z3 CND 22-05AZ	
	Bolts and Studs	A276-S31803	S 31 803		1.4462	X 2 Cr Ni Mo N 22 5		Z3 CND 22-05AZ	G 4303, Gr SUS 329
	Nuts	A276-S31803	S 31 803		1.4462	X 2 Cr Ni Mo N 22 5		Z3 CND 22-05AZ	G 4303, Gr SUS 329
Hastelloy B	Pressure Castings	A494 Gr N-12MV A494 Gr N-7V			2.4810	G-NiMo 30			
	General Castings	A743 Gr N-12M							
	Wrought/Forgings		N10001		2.4617	NiMo 28			
	Bar Stock Rod	B335							
	Plate	B333							
	Pipe/Tube	B622 B626 B619							
	Fittings	B366							
	Bolts and Studs	F468	N10001						
	Nuts	F467	N10001						
Hastelloy C	Pressure Castings	A494 Gr 12MW A494 Gr CW-7M			2.4686	G-NiMo 17 Cr			
	General Castings	A743 Gr CW-7M							
	Wrought/Forgings Hastelloy C276	B564 Gr N10276	N10276		2.4610	NiMo16Cr16Ti			
	Bar Stock Rod	B574 Gr N10276	N10276						
	Plate Hastelloy C276	B564 Gr N10276	N10276						

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Table H-2—International Materials for Pump Parts

Material Class	Applications	USA		International ISO	Germany		Great Britain BSI	France AFNOR	Japan JIS
		ASTM	UNS		17007	17006			
	Pipe Hastelloy C276	B619 Gr N10276	N10276						
	Fittings Hastelloy C276	B366 Gr N10276	N10276						
	Bolts and Studs	F468	N10002						
	Nuts	F467	N10002						
Titanium	Pressure Castings	B367 Gr C-3			3.7031	G-Ti 99.4			
	General Castings								
	Wrought/Forgings	B381	R50400 R56400 R58640		3.7035	Titan Gr. 2			
	Bar Stock	B348 Gr 2 B348 Gr 5	R50400 R56400						
	Plate	B265							
	Pipe Tube	B337 B338							
	Fittings	B363							
	Bolts and Studs	F467 F468 Alloy 5 or Gr 5	R56400						
	Nuts	F467 F468 Alloy 5 or Gr 5							

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Table H-2—International Materials for Pump Parts

Material Class	Applications	USA		International ISO	Germany		Great Britain BSI	France AFNOR	Japan JIS
		ASTM	UNS		17007	17006			
Alloy 20	Pressure Castings					G-X5NiCrMoCu 36 20			
	General Castings	A743 Gr CN7M							
	Wrought/Forgings	B473 Gr N08020	N08020		1.4458	X2NiCrAlTi 32 20			
	Bar Stock	B473 Gr N08020	N08020						
	Plate	B473 Gr N08020	N08020						
	Pipe	B464 B729							
	Fittings	B462 B468 Gr N08020	N08020						
	Bolts and Studs		N08020						
	Nuts		N08020						

Note: This table lists corresponding (not necessarily equivalent) International Materials which may be acceptable with the purchaser's approval. These materials represent family/type and grade only. Final condition or hardness level (where appropriate) is not specified. Materials listed for pressure applications may be utilized for non-pressure applications. All wear part material combinations must be selected in accordance with the requirements of 6.7.4.2.

[a]Not suitable for shafts in the hardened condition (over 302HB).

[b]Special, normally use AISI 4140.

[c]UNS (unified numbering system) designation for chemistry only.

[d]Nitronic 50 or equivalent.

[e]For shafts, standard grades of 304 and 316 may be substituted in place of low carbon (L) grades.

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APPENDIX I—MAGNET MATERIALS FOR MAGNETIC COUPLINGS

I.1 General

The magnet alloys discussed within this appendix represent present technology at time of publication. As the state-of-the-art in permanent magnet materials advance (i.e., temperature stability, coercive force, energy product, and corrosion resistance) higher magnet operating temperatures than those in Table I-1 may be achieved. It should be noted that higher magnet operating temperatures may require advancements in the adhesives and epoxies used to bond and hold the magnets within the inner and outer magnet rings. Selected adhesives and epoxies should have long-term working temperatures comparable to that of the maximum magnet operating temperatures. Purchaser shall approve the use of advanced grades of permanent magnet materials.

I.2 Magnet Materials

To obtain high torque transmission values in synchronous magnetic couplings, while keeping the coupling drive radius and length to a minimum (reduce eddy current losses), the strongest available magnets need to be used. The strongest commercial permanent magnet materials today all stem from the "Rare Earth" family of compounds. Rare Earth magnets are so termed because they are alloys of the Rare Earth group of elements such as Samarium or Neodymium.

These magnet alloys are commercially available as Samarium Cobalt (SmCo) and Neodymium Iron Boron (NdFeB). Properties for commercially available grades of SmCo and NdFeB are listed in Table I-1.

With torque ring couplings, magnets can be of the Rare Earth type or Aluminum Nickel Cobalt (Alnico). Alnico magnet materials exhibit coercivity values and maximum BH products that are significantly lower than values for the Rare Earth magnet alloys. However, Alnico magnets are characterized by excellent temperature stability and are generally used in high temperature sealless pumps with torque ring couplings. Properties for several commercially available grades of Alnico magnet material are listed in Table I-1.

I.3 Magnet Alloy Notes

a. The properties and temperature limits reflect "modified" or "temperature compensated" SmCo Alloys exhibiting high coercivity values and greater temperature stability. Traditionally, Sm_2Co_{17} grades exhibit better temperature characteristics and corrosion resistance than that of grade Sm_1Co_5. Samarium Cobalt magnet alloys are manufactured by a process of pressing and sintering. These alloys are brittle in nature and require great care in handling. SmCo magnet alloys contain appreciable quantities of cobalt giving this alloy good corrosion resistance.

b. The properties and temperature limits reflect NdFeB alloys that have been alloyed and processed to produce high coercivity values and temperature stability. NdFeB alloys contain iron and are very susceptible to oxidation in the presence of moisture. It is highly recommended that magnets made from NdFeB alloys be coated (i.e., epoxy sealer) or metal plated during the manufacturing process. Prior to coating or plating NdFeB magnet alloys should be baked at low temperature in order to drive out any remnant moisture. Neodymium Iron Boron magnet alloys are manufactured by a process of pressing and sintering. NdFeB alloys exhibit higher mechanical strength than those of the SmCo alloys and tend to be less brittle.

c. Alnico magnet alloys are manufactured through either a casting or sintering process. Sintered Alnico materials offer slightly lower magnetic properties but better mechanical characteristics than the cast Alnico alloys. Alnico alloys are very hard and brittle. These alloys are cast or sintered as closely as possible to required sizes so that grinding to finished dimensions is minimized. Corrosion resistance range from "fair" for castings to "good" for the sintered forms. Alnico magnets exhibit excellent high temperature stability.

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Table I-1—Magnetic Materials Properties Overview & Temperature Limits

Magnetic Alloys	Typical Values				Maximum Magnet Operating Temp. (°C)[d]	Related Notes (See I.3)
	Commercial Grades	Remanence B_r (Mt)[a]	Coercivity H_{CB}(K/m)[b]	Maximum BH Product $(BH)_{max}$ (Kj/M3)[c]		
Samarium Cobalt (SmCo)	Sm1Co5	850 – 870 (8.5 – 8.7 kG)	637 – 684 (8.0 – 8.6 kOe)	143 (18 MGOe)	200 (392°F)	a
	Sm2Co17	950 – 1060 (9.5 – 10.6 kG)	716 – 796 (9.0 – 10.0 kOe)	175 – 223 (22 – 28 MGOe)	260 (500°F)	
Neodymium Iron Boron (NdFeB)	NdFeB	1040 – 1210 (10.4 – 12.1 kG)	796 – 923 10.0 – 11.6 kOe)	207 – 279 (26 – 35 MGOe)	150 (302°F)	b
Aluminum Nickel Cobalt (Alnico)	Alnico 5	1090 – 1210 (10.9 – 12.8 kG)	49 – 51 (0.62 – 0.64 kOe)	32 – 44 (4.0 – 5.5 MGOe)	150 (302°F)	c
	Alnico 8	740 – 820 (7.4 – 8.2 kG)	119 – 131 (1.5 – 1.7 kOe)	32 – 42 (4.0 – 5.3 MGOe)	450 (842°F)	

Notes:

[a]Br—represents the remanence of maximum magnetic flux density remaining in the material after the magnetizing force has been removed.

[b]HCB—represents coercivity or the coercive force which is the demagnetizing force necessary to remove all the magnetic lines of force to a flux density of zero.

[c](BH)max—represents the energy product, a measure of overall magnetic strength and is the product of the induction and demagnetizing forces.

[d]Maximum Magnet Operating Temperature—is based on long-term thermal aging of less than 4% irreversible loss in flux density.* Operating above this temperature can result in long-term irreversible loss in flux density that could affect coupling performance. For synchronous magnetic couplings, the maximum magnet operating temperature will be that temperature indicated on the outer surface of the containment shell during operation and at maximum pumpage temperature. For torque ring couplings, which carry the permanent magnets in the outer magnet ring and not directly in contact with the pumpage, the maximum magnet operating temperature will relate to the maximum pumpage temperature as follows: For Sm2Co17 = 350°C (662°F) pumpage temperature, for Alnico = 450°C (842°F) pumpage temperature.

* "Some Properties of High Coercivity 2-17 Magnet Materials" By W. Ervens, International Rare Earth Symposium, Paper No. IV-2.

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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 Umax is 1440 g•mm (2 oz-in.), the trial weight should cause 1440–2880 g•mm (2–4 oz-in.) of unbalance].

J.4.2.2 Starting at the last known heavy spot in each correction plane, mark off the specified number of radial positions (six or twelve) in equal (60 or 30 degree) increments around the rotor. Add the trial weight to the last known heavy spot in one plane. If the rotor has been balanced very precisely and the final heavy spot cannot be determined, add the trial weight to any one of the marked radial positions.

J.4.2.3 To verify that an appropriate trial weight has been selected, operate the balancing machine and note the units of unbalance indicated on the meter. If the meter pegs, a smaller trial weight should be used. If little or no meter reading results, a larger trial weight should be used. Little or no meter reading generally indicates that the rotor was not balanced correctly, the balancing machine is not sensitive enough, or a balancing machine fault exists (i.e., a faulty pickup). Whatever the error, it must be corrected before proceeding with the residual check.

J.4.2.4 Locate the weight at each of the equally spaced positions in turn, and record the amount of unbalance indicated on the meter for each position. Repeat the initial position as a check. All verification shall be performed using only one sensitivity range on the balance machine.

J.4.2.5 Plot the readings on the residual unbalance work sheet and calculate the amount of residual unbalance (see Figure J-1). The maximum meter reading occurs when the trial weight is added at the rotor's heavy spot; the minimum reading occurs when the trial weight is opposite the heavy spot. Thus, the plotted readings should form an approximate circle (see Figure J-2). An average of the maximum and minimum meter readings represents the effect of the trial weight. The distance of the circle's center from the origin of the polar plot represents the residual unbalance in that plane.

J.4.2.6 Repeat the steps described in J.4.2.1 through J.4.2.5 for each balance plane. If the specified maximum allowable residual unbalance has been exceeded in any balance plane, the rotor shall be balanced more precisely and checked again. If a correction is made in any balance plane, the residual unbalance check shall be repeated in all planes.

J.4.2.7 For stack component balanced rotors, a residual unbalance check shall be performed after the addition and balancing of the first rotor component, and at the completion of balancing of the entire rotor, as a minimum.

Note: This ensures that time is not wasted and rotor components are not subjected to unnecessary material removal in attempting to balance a multiple component rotor with a faulty balancing machine.

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Equipment (Rotor) No.: ______________

Purchase Order No.: ______________

Correction Plane (inlet, drive end, etc.—use sketch): ______________

Balancing Speed: ______________ rpm

N—Maximum Allowable Rotor Speed: ______________ rpm

W—Weight of Journal (closest to this correction plane): ______________ kg (lbs)

U_{max}—Maximum Allowable Residual Unbalance =
6350 *W/N* (4 *W/N*)
6350 · ______ kg/______ rpm; 4 · ______lbs/______rpm ______________ g•mm (oz-in.)

Trial unbalance (2 · U_{max}) ______________ g•mm (oz-in.)

R—Radius (at which weight will be placed): ______________ mm (in.)

Trial Unbalance Weight = Trial Unbalance/*R*

______g•mm/______mm/______oz-in./______in. ______________ g (oz)

Conversion Information: 1 ounce = 28.350 grams

Test Data

Position	Trial Weight Angular Location	Balancing Machine Amplitude Readout
1		
2		
3		
4		
5		
6		
7		

Rotor Sketch

Test Date—Graphic Analysis

Step 1: Plot data on the polar chart (Figure J-1). Scale the chart so the largest and smallest amplitude will fit conveniently.
Step 2: With a compass, draw the best fit circle through the six points and mark the center of this circle.
Step 3: Measure the diameter of the circle in units of scale chosen in Step 1 and record. ______________ units
Step 4: Record the trial unbalance from above. ______________ g•mm (oz-in.)
Step 5: Double the trial unbalance in Step 4 (may use twice the actual residual unbalance). ______________ g•mm (oz-in.)
Step 6: Divide the answer in Step 5 by the answer in Step 3. ______________ Scale Factor

You now have a correlation between the units on the polar chart and the g•in of actual balance.

Notes:
1. The trial weight angular location should be referenced to a keyway or some other permanent marking on the rotor.
2. The balancing machine amplitude readout for position “7” should be the same as position “1,” indicating repeatability. Slight variations may result from imprecise positioning of the trial weight.

Figure J-1—Residual Unbalance Work Sheet

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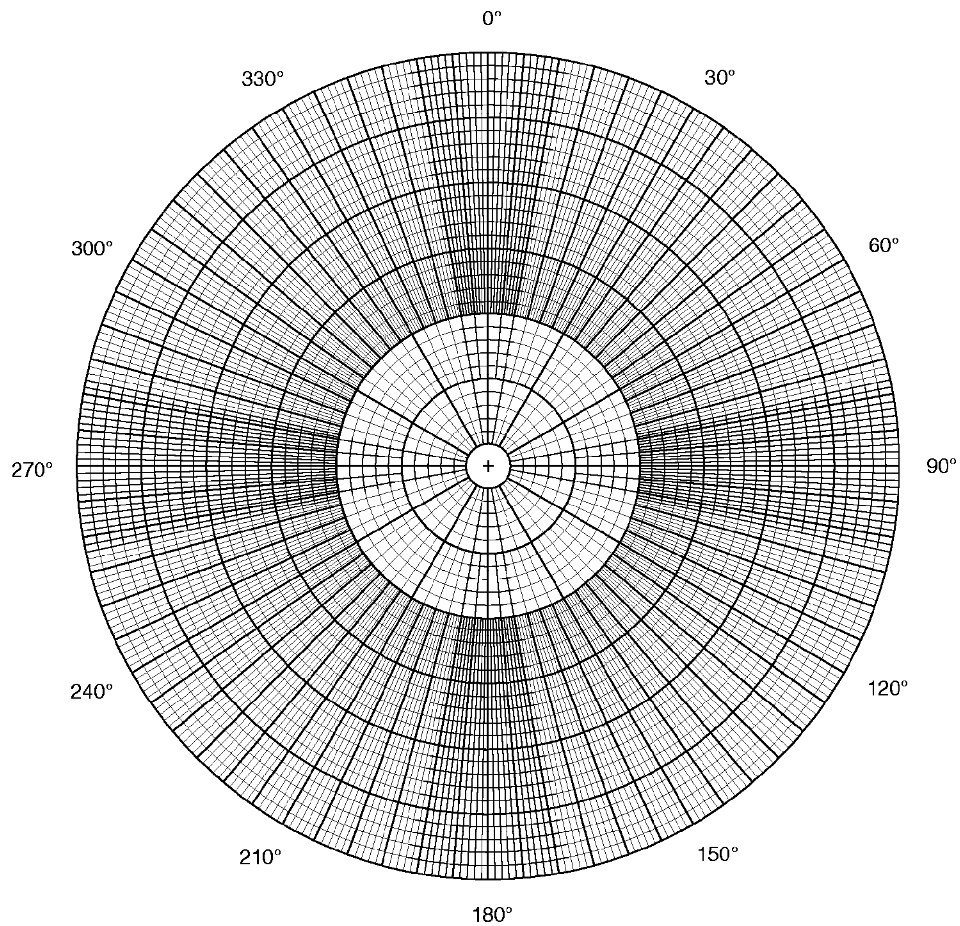

The circle you have drawn must contain the origin of the polar chart. If it doesn't, the residual unbalance of the rotor exceeds the applied test unbalance.

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)

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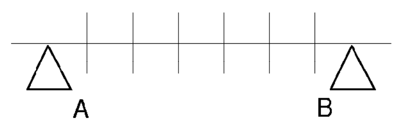
Equipment (Rotor) No.:	*C–101*	
Purchase Order No.:		
Correction Plane (inlet, drive end, etc.–use sketch):	*A*	
Balancing Speed:	*800*	rpm
N—Maximum Allowable Rotor Speed:	*10,000*	rpm
W—Weight of Journal (closet to this correction plane):	*908*	~~kg~~ (lbs)
U_{max}—Maximum Allowable Residual Unbalance = 6350 *W/N* (4 *W/N*) ~~6350 · ______ kg/______ rpm~~; 4 · *908* lbs/ *10,000* rpm	*0.36*	~~g•mm~~ (oz-in.)
Trial unbalance (2 · U_{max})	*0.72*	~~g•mm~~ (oz-in.)
R—Radius (at which weight will be placed):	*6.875*	~~mm~~ (in.)
Trial Unbalance Weight = Trial Unbalance/*R* ~~______ g•mm/______ mm~~/ *0.72* oz-in./ *6.875* in.	*0.10*	~~g~~ (oz)

Conversion Information: 1 ounce = 28.350 grams

Test Data

Position	Trial Weight Angular Location	Balancing Machine Amplitude Readout
1	*0*	*14.0*
2	*60*	*12.0*
3	*120*	*14.0*
4	*180*	*23.5*
5	*240*	*23.0*
6	*300*	*15.5*
7	*0*	*13.5*

Rotor Sketch



Test Date—Graphic Analysis

Step 1: Plot data on the polar chart (Figure J-2 continued). Scale the chart so the largest and smallest amplitude will fit conveniently.

Step 2: With a compass, draw the best fit circle through the six points and mark the center of this circle.

Step 3: Measure the diameter of the circle in units of scale chosen in Step 1 and record.	*35*	units
Step 4: Record the trial unbalance from above.	*0.72*	~~g•mm~~ (oz-in.)
Step 5: Double the trial unbalance in Step 4 (may use twice the actual residual unbalance).	*1.44*	~~g•mm~~ (oz-in.)
Step 6: Divide the answer in Step 5 by the answer in Step 3.	*0.041*	Scale Factor

You now have a correlation between the units on the polar chart and the g•in. of actual balance.

Notes:

1. The trial weight angular location should be referenced to a keyway or some other permanent marking on the rotor.
2. The balancing machine amplitude readout for position "7" should be the same as position "1," indicating repeatability. Slight variations may result from imprecise positioning of the trial weight.

Figure J-2—Sample Calculations for Residual Unbalance

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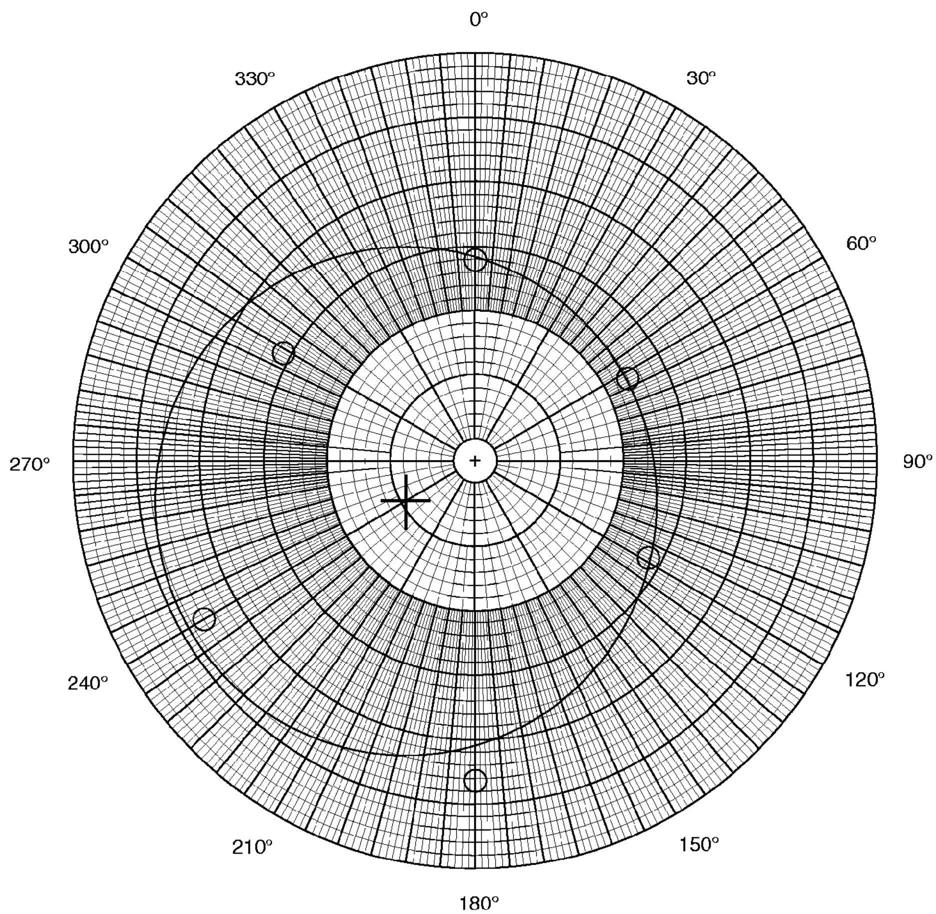

The circle you have drawn must contain the origin of the polar chart. If it doesn't, the residual unbalance of the rotor exceeds the applied test unbalance.

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)

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APPENDIX K—PRESSURE TEMPERATURE PROFILES IN THE RECIRCULATION CIRCUIT

K.1 General

In general, pumpage from the pump casing enters the recirculation circuit to provide cooling and lubrication to the product lubricated bearings and cooling to the primary containment shell (MDP). Heat is added to the pumpage as it passes through the recirculation circuit. If sufficient pressure is not provided in the circuit, flashing of the pumpage will occur, and bearing failure could result. Flashing at the containment shell (MDP) could result in excessive temperature rise of the shell and subsequent cavitation or vapor lock in the recirculation circuit. To avoid these occurrences, the pressure temperature profile for the proposed pump unit is to be analyzed by the manufacturer for the rated conditions and pumpage to assure that an adequate pressure margin exists at all points in the recirculation circuit.

K.2 Profile Diagram

K.2.1 A pressure temperature profile diagram, defining all critical points in the recirculation circuit should be provided as a part of the vendor proposal and/or data package. Rated conditions and pumpage should be used to construct the profile. Figure K-1 shows a typical diagram for a magnetic drive pump. Figure K-2 shows a typical diagram for a canned motor pump.

K.2.2 Temperature rise through the recirculation circuit is plotted on the profile. Pressure should be plotted in absolute units. Vapor pressure of the pumpage should be plotted on the profile diagram for each critical point in the circuit for direct comparison to the circuit pressure.

K.2.3 Temperature rise through the pump must be calculated to determine the recirculation circuit inlet temperature, if the circuit is designed to use discharge volute pumpage. Alternative designs that utilize a heat exchanger require calculation of the temperature at the circuit inlet by the vendor. Circuits which are to be flushed from any outside source require the purchaser to supply flush liquid temperature.

K.2.4 Temperature rise and absolute pressure characteristics of the recirculation circuit should be based on qualification testing of a unit of similar design and construction when running on water. The qualification test records should be retained by the vendor as documentation of recirculation circuit assumptions.

K.2.5 Temperature rise in the recirculation circuit is a function of pumpage specific gravity and specific heat. The temperature rise data developed on water must be factored to account for pumpage properties.

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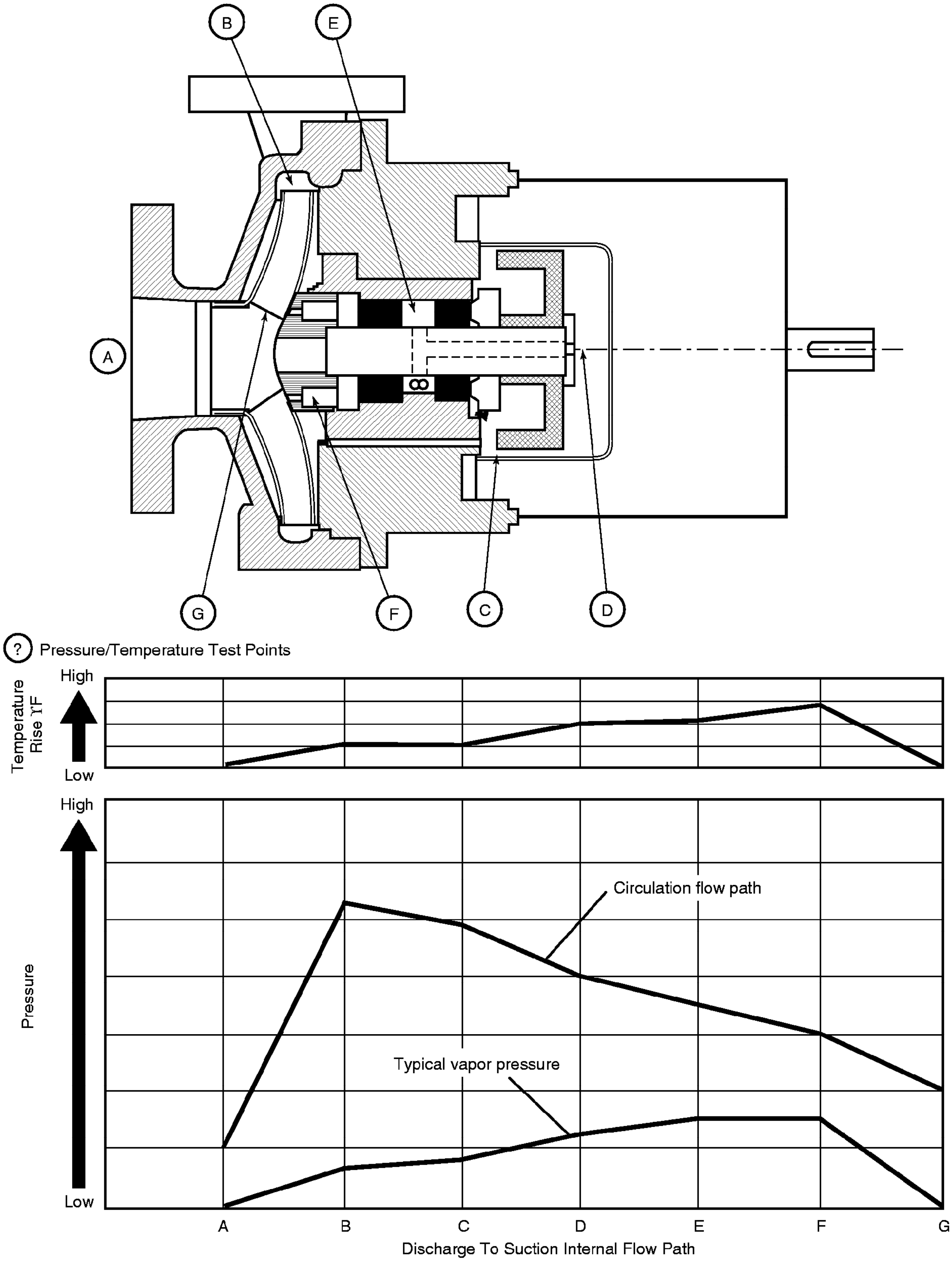

Figure K-1—Typical Pressure-Temperature Profile in Magnetic Drive Pump

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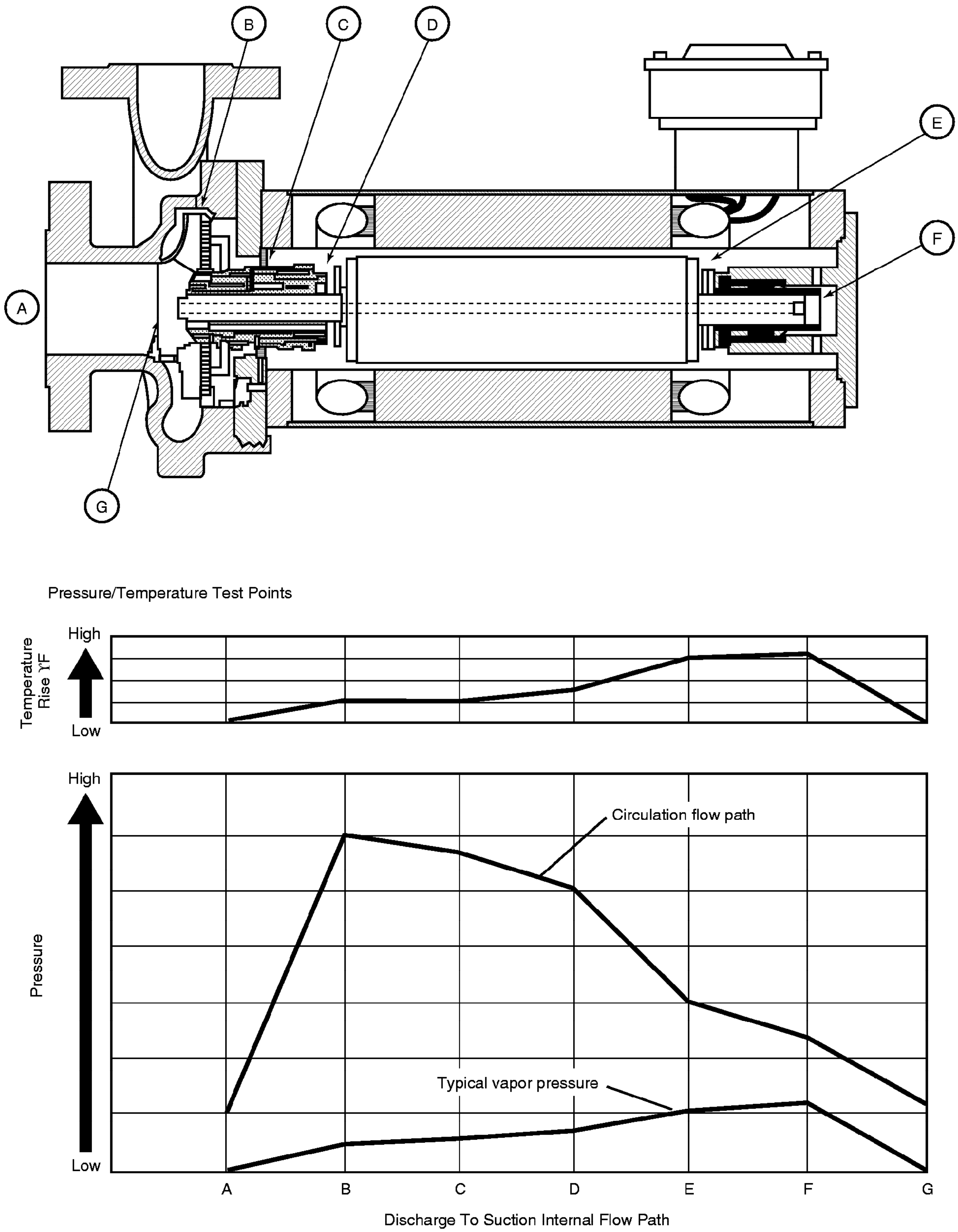

Figure K-2—Typical Pressure-Temperature Profile in Canned Motor Pump

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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 mm/mm (0.005 in./in.) when tested by the 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 x 10-6 mm/mm/°C (30 x 10^{-6} in./in./°F) when tested by the 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 the 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 the ASTM C 882 test method.

L.2.5 Epoxy grout shall pass the thermal compatibility test when overlayed on cement grout using the test method of 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 (1700 psi) and the modulus of elasticity shall not be less than 1.2 x 104 MPa (1.8 x 106 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 x 30 cm (12 in.) high is used. Gel time shall be at least 150 minutes.

L.3 Placement

L.3.1 Epoxy grout is very viscous; however, it will flow readily given time and positive hydraulic head. If the epoxy grout is installed below 20°C (70°F) ambient temperature, consult the grout manufacturer to determine if aggregate adjustment is necessary. Generally, it is best to start placing the grout at the center of one end of the baseplate or soleplate and work toward the ends in such manner as to force the air from beneath the baseplate or soleplate and out the vent holes, to eliminate voids.

L.3.2 Placing of the grout is accomplished in a manner which avoids air entrapment, and a head box is used to aid in pouring the grout into the grout holes. The head box provides a hydraulic head to force the grout to the vent holes. When the head box is moved to the next grout hole, a 15 cm (6 in.) high stand pipe shall be placed over the grout hole and filled with grout. These stand pipes provide a continuous hydraulic head to sweep air from under the baseplate to the vent holes. Never allow the grout to fall below the baseplate level once the grout has made contact with the baseplate. The use of a head box provides a surge volume for the grout as well as providing the critical hydraulic head.

L.3.3 No push rods, chains, or vibrators shall be used to place epoxy grout under baseplates.

L.4 General Application

L.4.1 Grout should be applied only when surrounding temperatures are between 15°C and 32°C (60°F and 90°F).

L.4.2 Before an epoxy grout is applied, the baseplate temperature should be estimated to ensure that the grout can resist the expected temperature.

L.4.3 Approximately 10 to 25 mm (0.5 to 1 in.) of the top of the cementitious foundation material should be scarified with a chipping hammer before the grout is applied. This procedure is recommended to remove low-strength, high-porosity concrete in this area. The concrete foundation should be allowed to cure for at at least 7 days prior to this surface preparation.

L.4.4 All grease, oil, paint, laitance and other undesired materials shall be removed from the surfaces to be grouted. The roughened concrete surface shall be blown with oil-free compressed air to remove all dust and loose particles. When cementitious grout is used, the concrete surface shall be thoroughly soaked with water until absorption stops, and any excess water shall be removed. When epoxy grout is used, all surfaces shall be kept dry before application.

L.4.5 The baseplate should be located in the desired position by supporting it on shims or leveling screws and securing it with anchor bolts. Approximately 25 to 50 mm (1 to 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.

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L.4.8 If voids are present after the grouting sequence, epoxy grout may be used to fill them. If cementitious grout is used, a full 28-day cure is recommended before this epoxy is applied. Epoxy grout is usually hand pumped through high-pressure threaded fittings installed in the baseplate where voids have been found. Extreme care should be taken to ensure that excessive pressures do not buckle the baseplate. At least one vent hole should be drilled into each void to help prevent excessive pressures.

L.5 References

ASTM[19]

C 1181	*Standard Test Method for Creep of Concrete in Compression*
C 531	*Standard Test Method for Linear Shrinkage and Coefficient of Thermal Expansion of Chemical Resistant Mortars, Grouts, and Monolithic Surfaces*
C 579	*Standard Test Method for Compressive Strength of (Method B) Chemical Resistant Mortars and Monolithic Surfacings*
C 882-87	*Standard Test for Bond Strength of Epoxy-Resin Systems Used with Concrete*
C 884-87	*Standard Test Method for Thermal Compatibility between Concrete and an Epoxy-Resin Overlay*
D 638-89	*Standard Test Methods for Tensile Properties of Plastics*
D 2471-88	*Standard Test Method for Gel Time and Peak Exothermic Temperature of Reacting Thermosetting Resins*

Corps of Engineers[20]

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

[19]American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959.

[20]U.S. Army Corps of Engineers, 20 Massachusetts Avenue, N.W. Washington, D.C. 20314.

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APPENDIX M—STANDARD BASEPLATE

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	2750/108.5	1225/48.25	615/24.12	990/39.0	165/6.5
7	4	1245/49.0	2145/84.5	920/36.25	615/24.16	1170/46.0	165/6.5
7.5	4	1245/49.0	2450/96.5	1075/42.25	715/28.16	1170/46.0	165/6.5
8	5	1245/49.0	2755/108.5	1225/48.25	615/24.12	1170/46.0	165/6.5
9	4	1395/55.0	2145/84.5	920/36.25	615/24.16	1320/52.0	165/6.5
9.5	4	1395/55.0	2450/96.5	1075/42.25	715/28.16	1320/52.0	165/6.5
10	5	1395/55.0	2755/108.5	1225/48.25	615/24.12	1320/52.0	165/6.5
11	4	1550/61.0	2145/84.5	920/36.25	615/24.16	1475/58.0	165/6.5
11.5	4	1550/61.0	2450/96.5	1075/42.25	715/28.16	1475/58.0	165/6.5
12	5	1550/61.0	2755/108.5	1225/48.25	615/24.12	1475/58.0	165/6.5

Note: See Figures M-1 and M-2 for explanation of dimensions.

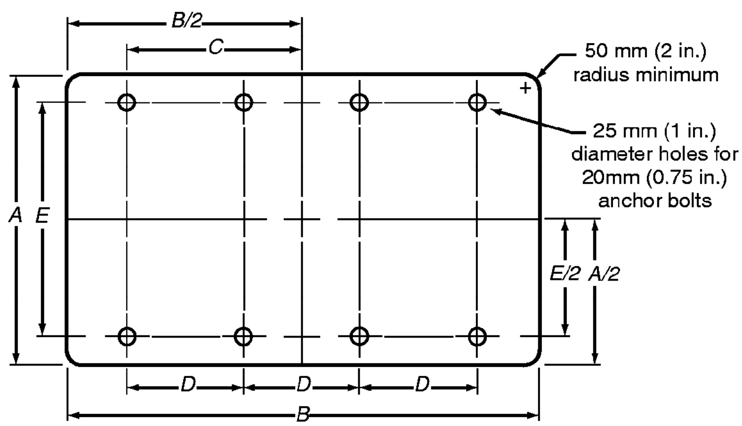

Figure M-1—Schematic for API 610 Standard Baseplates

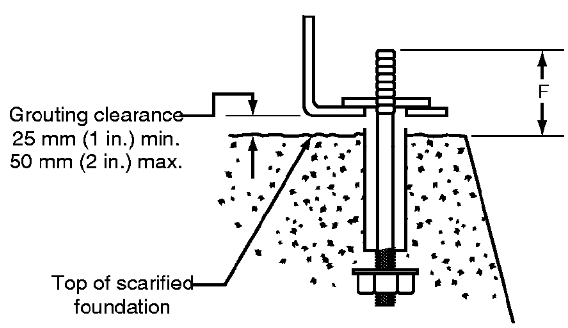

Figure M-2—Anchor Bolt Projection

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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	Standard 685 Reference	Date Inspected	Inspected By	Status	Witness Yes/No
Level 1—Basic					
Casing marking (serial no.)	6.15.3				
Certified hydrotest	8.3.2				
Performance within tolerance (certified)	8.3.3.3.3				
NPSHR within tolerance (certified)	8.3.4.1.3				
Vibration within tolerance	8.3.3.3.1				
Rotation arrow	6.15.4[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	7.3				
Equipment nameplate data	6.15.2				
Rust prevention	8.4.3.3 8.4.3.4				
Painting	8.4.3.2				
Preparation for shipment	8.4.1				
Shipping documents and tags	8.4.3.9				
Level 2—Intermediate (Add to Level 1)					
Copies of subvendor purchase order	—				
Material certification	6.11.6				
Nondestructive examination (components)	6.2.2.1				
Hydrotest	8.3.2				
Building record (runouts, clearances)	6.6.4 6.7.4				
Performance and NPSH tests	8.3.3 8.3.4.1				
Level 3—Special (Add to Levels 1 and 2)					
Material identification	6.11.2				
Casting repairs approved	6.12.5				
Impeller/rotor balancing	6.9.4				
Bearing inspection after testing	8.3.3.4.3				
Nozzle forces and moments test	9.1.5.3.6				
Complete unit test	8.3.4.2				
Sound level test	8.3.4.3				
Auxiliary equipment test	8.3.4.4				
Secondary Containment/Control System Hydrotest	8.3.4.5				
Secondary Containment/Control System Instrumentation Test	8.3.4.6				
Pressure-Temperature Profile Test	8.3.4.7				

Note: [a] Check against certified dimensional outline drawing.

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APPENDIX O—VENDOR DRAWING AND DATA REQUIREMENTS

This appendix consists of a distribution record (schedule), followed by a representative description of the items that are presented numerically in the schedule.

Description

Pump

1. Certified dimensional outline drawing including:
   a. The size, rating, and location of all customer connection.
   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 (magnetic drive pumps only).
   j. Direction of rotation.
   k. Winterization, tropicalization, and/or noise attenuation details, when required.
2. Cross-sectional drawings and bill of materials.
3. Shaft coupling assembly drawing and bill of materials including allowable misalignment tolerances and the style of the coupling guard (magnetic drive pumps only).
4. Auxiliary flush piping schematic and bill of materials including fluid flows, pressure, pipe and valve sizes, instrumentation, and orifice sizes.
5. Cooling or heating schematic and bill of materials including cooling or heating media, fluid flows, pressure, pipe and valve sizes, instrumentation, and orifice sizes.
6. Electrical and instrumentation schematics, wiring diagrams, and bill of materials including:
   a. Vibration alarm and shutdown limits.
   b. Bearing temperature alarm and shutdown limits.
   c. Lube-oil temperature alarm and shutdown limits.
   d. Driver.
7. Electrical and instrumentation arrangement drawing and list of connections.
8. Performance curves.
9. Breakaway torque (magnetic drive pumps only).
10. Speed torque curve (magnetic drive pumps only).
11. Temperature-Pressure profile.
12. Vibration analysis data.
13. Damped unbalanced response analysis.
14. Lateral critical speed analysis.

    The required number of lateral critical analysis reports, no later than 3 months after the date of the order.
15. Certified hydrostatic test data.
16. Material certifications.

    The vendor's physical and chemical data from mill reports (or certification) of pressure parts, impellers, and shafts.
17. 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.
18. Weld procedures.
19. Performance test data.

    Certified shop logs of the performance test. A record of shop test data (which the vendor shall maintained 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.
20. 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.
21. Residual unbalance check.
22. Rotor mechanical and electrical runout for pumps designed to use non-contacting vibration probes.
23. Data sheets applicable to proposals, purchase, and as-built.
24. Noise data sheets.
25. As-built clearances.
26. 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 (magnetic drive pumps only).
    f. Piping recommendations.
    g. Composite outline drawing for pump/driver train, including anchor bolt locations (magnetic drive pumps only).
    h. Dismantling clearances.

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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. Thrust collars, if applicable.
e. Allowable wear of running clearances.
f. Fits and clearances for rebuilding.
g. Routine maintenance procedures and intervals.
h. Safety concerns.

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.

Section 6—Technical data:

a. Breakaway torque (magnetic drive pumps only).
b. Speed-torque (magnetic drive pumps only).
c. Temperature-pressure profile.

Section 7—As-built data:

a. As-built datasheets.
b. As-built clearances.
c. Rotor balance data for multistage pumps.
d. Noise data sheets.
e. Performance data.

Section 8—Drawing and data requirements:

a. Certified dimensional outline drawing and list of connections.
b. Cross-sectional drawing and bill of materials.
c. Electrical and instrumentation schematics, wiring diagrams, and bills of materials.
d. Electrical and instrumentation arrangement drawing and list of connections.
e. Coupling assembly drawing and bill of materials (magnetic drive pumps only).
f. Cooling or heating schematic and bill of materials.
g. Cooling or heating piping, instrumentation arrangement, and list of connections.

27. Spare parts recommendations and price list.
28. Preservation, packaging, and shipping procedures.
29. Material safety datasheets.

Motor

30. Certified dimensional outline drawing for motor and all auxiliary equipment including:
    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.
31. Cross-sectional drawing and bill of materials including the axial rotor float.
32. Data sheets applicable to proposals, purchase, and as-built.
33. Noise data sheets.
34. Performance data including:
    a. For induction motors 250 horsepower and smaller:
        1. Efficiency and power factor at one-half, three-quarter, and full load.
        2. Speed-torque curves.
    b. For induction motors over 250 horsepower, 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.
35. 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.
36. Instruction manuals describing installation, operation, and maintenance procedures. Each manual shall include the following sections:

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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 34.
Section 5—As-built datasheets.

a. 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.

37. Spare parts recommendations and price list.
38. Material safety datasheets.

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TYPICAL VENDOR DRAWING AND DATA REQUIREMENTS

JOB NO. ______ ITEM NO ______
PURCHASE ORDER NO. ______ DATE ______
REQUISITION NO ______ DATE ______
INQUIRY ______ DATE ______
PAGE ______ OF ______ BY ______
FOR ______
REVISION ______
SITE ______
UNIT ______
SERVICE ______
NO. REQUIRED ______

Proposal[a] Bidder shall furnish ______ copies of data for all items indicated by an X.

review[b] Vendor shall furnish ______ copies and ______ transparencies of drawings and data indicated

final[c] Vendor shall furnish ______ copies and ______ transparencies of drawings and data indicated.
Vendor shall furnish ______ operating and maintenance manuals.

DISTRIBUTION RECORD

Final -- Received from vendor
Final -- Due from vendor[c]
Review -- Returned to vendor
Review -- Received from vendor
Review -- Due from vendor[c]

Proposal	Review	Final	DESCRIPTION	Review -- Due from vendor	Review -- Received from vendor	Review -- Returned to vendor	Final -- Due from vendor	Final -- Received from vendor
			Pump					
			1. Certified dimensional outline drawing					
			2. Cross sectional drawings and bill of materials.					
			3. Shaft coupling assembly drawing and bill of materials(mag drive pumps only).					
			4. Auxiliary flush piping schematics and billsof materials.					
			5. Cooling or heating schematic and bill of material					
			6. Electrical and instrument schematics, wiring diagrams, and bill of material					
			7. Electrical and instrument arrangement drawing and list of connections					
			8. Performance curves					
			9. Breakaway torque (magnetic drive pumps only)					
			10. Speed-torque curve (magnetic drive pumps only)					
			11. Temperature - pressure profile					
			12. Vibration analysis data					
			13. Damped unbalanced response analysis					
			14. Lateral critical speed analysis					
			15. Certified hydrostatic test data					
			16. Material certifications					
			17. Progress reports					
			18. Weld procedures					
			19. Performance Test data					
			20. Optional tests data and reports					
			21. Residual unbalance check					
			22. Rotor mechanical and electrical runout					
			23. Data sheets applicable to proposals, purchase and as-built					
			24. Noise data sheets					
			25. As built clearances					
			26. Installation, operation, and maintenance manuals					
			27. Spare parts recommendations and price list					
			28. Preservation, packaging, and shipping procedures					
			29. Material safety data sheets					
			MOTOR					
			30. Certified dimensional outline drawing (magneric drive pumps only)					
			31. Cross-sectional drawing and bill of materials					
			32. Data sheets applicable to proposals, purchase and as-built					

[a]Proposal drawings and data do not have to be certified or as-built. Typical data shall be clearly identified as such

[b]Purchaser will indicate in this column the time frame for submission of materials using the nomenclature given at the end of this form.

[c]Bidder shall complete these two columns to reflect his actual distribution schedule and include this form with his proposal.

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TYPICAL VENDOR DRAWING AND DATA REQUIREMENTS

JOB NO ____________ ITEM NO ____________
PAGE ______ OF ______ BY ____________
DATE ____________ REVISION ____________

Proposal[a] Bidder shall furnish ______ copies of data for all items indicated by an X.

Review[b] Vendor shall furnish ______ copies and ______ transparencies of drawings and data indicated

Final[c] Vendor shall furnish ______ copies and ______ transparencies of drawings and data indicated.
Vendor shall furnish ______ operating and maintenance manuals.

DISTRIBUTION RECORD

Final -- Received from vendor
Final -- Due from vendor[c]
Review -- Returned to vendor
Review -- Received from vendor
Review -- Due from vendor[c]

Proposal	Review	Final	DESCRIPTION	Review -- Due from vendor	Review -- Received from vendor	Review -- Returned to vendor	Final -- Due from vendor	Final -- Received from vendor
			MOTOR - cont'd					
			33. Noise data sheets					
			34. Performance data					
			35. Certified drawings of auxiliary systems					
			36. Installation operation and maintenance manuals					
			37. Spare parts recommendations and price list					
			38. Material safety data sheets					

[a]Proposal drawings and data do not have to be certified or as-built. Typical data shall be clearly identified as such

[b]Purchaser will indicate in this column the time frame for submission of materials using the nomenclature given at the end of this form.

[c]Bidder shall complete these two columns to reflect his actual distribution schedule and include this form with his proposal.

Notes:

1. Send all drawings and data to ____________________

____

2. All drawings and data must show project, appropriation, purchase order, and item numbers in addition to the plant location and unit. In addition to the copies specified above, one set of the drawings/instructions necessary for field installation must be forwarded with the shipment.

Nomenclature:

______ S -- number of weeks prior to shipment.
______ F -- number of weeks after firm order.
______ D -- number of weeks after receipt of approved drawings.

Vendor ____________________
Date __________ Vendor Reference ____________________
Signature ____________________
(Signature acknowledges receipt of all instructions)

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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, these items requiring a decision are indicated by a bullet preceding the paragraph number.

The checklist should be used in conjunction with the data sheets (see Appendix B). In the following list, the purchaser should circle yes or no, or mark the appropriate space with an X.

Note: The use of this checklist is optional where these items are covered by a narrative specification.

Paragraph	Item		
	General		
5.1	Are metric dimensions or U.S. dimensions applicable? (see data sheets)	Yes	No
2.2	Are ISO standards or U.S. standards applicable? (see data sheets)	Yes	No
	Basic Design		
6.1.3	What are the operating conditions?		
	Is the fluid flammable or hazardous?	Yes	No
6.1.10	Limitation on suction specific speed (see data sheet).		
6.1.12	Is parallel operation anticipated?	Yes	No
6.1.15	Maximum allowable sound pressure level (see data sheets).		
6.1.19	Cooling plan, pressure and temperature of cooling fluid (see data sheet)?		
6.1.24	What is the electrical area classification (see data sheet)?		
6.1.27	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 piping and drive train?	Yes	No
	Recheck the alignment of the pump and drive train at the operating temperature?	Yes	No
6.1.29	Location and environmental conditions (see data sheet).		
6.1.30.3	Is pump to be bolted to a pad or foundation?	Yes	No
6.3.2	Are vacuum conditions present in pump suction?	Yes	No
6.4.3.6	Are pressure gauge connections required?	Yes	No
6.4.3.8.3	Are cylindrical threads permitted?	Yes	No
6.8.1	Type of secondary control/containment (see data sheet).		
6.8.3	Is vendor to provide maximum flow rate from secondary control system?	Yes	No
6.8.8	Are secondary pressure casing drain (s) connections required?	Yes	No
6.9.3.8	Are threaded connections required on bearing housings for mounting vibration transducers?	Yes	No
6.9.3.9	Is a flat surface required for magnetic pick up?	Yes	No
6.11.1.	Has the materials class been specified?	Yes	No
6.11.6	Shall vendor furnish chemical and mechanical data for materials	Yes	No
6.11.7	Have all corrosive agents present been specified on the data sheets?	Yes	No
6.11.11	Is H2S and water present in the pumped fluid?	Yes	No
6.12.5	Shall casting repair procedures be submitted to the purchaser for approval?	Yes	No
6.13.5.4	Shall connection designs be submitted to the purchaser for approval?	Yes	No
6.13.5.6	Is special inspection NDT of welds required?	Yes	No
6.14.5	Minimum design metal temperature for establishing impact tests (see data sheet).		
	Accessories		
7.1.1	Has the type of driver been specified on the data sheets?	Yes	No
7.1.2	Are there process-variation or start-up conditions that affect drive size?	Yes	No

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7.1.3	Driver starting conditions and methods (see data sheet).		
7.1.4.2	Is motor sized for max power with rated impeller a requirement?	Yes	No
7.1.8	Reduced voltage for motor starting specified?	Yes	No
7.2.1.4	Is a panel required?	Yes	No
	Is a panel mounting location specified?	Yes	No
7.2.1.6	Are shutoff valves required for shutdown sensing devices?	Yes	No
7.2.2.2.2	Are liquid-filled pressure gauges required?	Yes	No
7.2.2.3.1	Are vibration transducers to be furnished?	Yes	No
7.2.2.3.2	Are vibration monitors to be furnished?	Yes	No
7.2.2.3.3	Is a bearing temperature monitor to be furnished?	Yes	No
7.2.2.3.4	Is a bearing wear detector to be furnished?	Yes	No
7.2.2.4.1	Is protective/condition monitoring to be furnished?	Yes	No
7.2.2.4.2	Is a pump power monitor to be furnished?	Yes	No
7.2.2.4.3	Shall leakage into secondary pressure casing be monitored?	Yes	No
7.2.3.1	What are requirements for alarm/shutdown system?		
7.2.4.1	Are characteristics of electrical power specified?	Yes	No
7.2.4.5	Is this a tropical location?	Yes	No
7.3.2.6	Is chloride content above 10 parts per million?	Yes	No
7.3.2.10	Are flanges required in place of socket-welded unions?	Yes	No

Inspection and Testing

8.1.4	Extent of purchaser participation in inspection (see data sheets).		
	Amount of advance notification required (see data sheet)		
8.1.6	Is purchaser's inspector to submit completed inspection checklist before shipment?	Yes	No
8.2.1.3	Which parts shall be subjected to examination (see data sheet).		
	Type of parts examination required (see data sheet).		
8.2.2.1	Are specific additional material inspection criteria needed?	Yes	No
8.2.3.1	Is cleanliness inspection required before assembly?	Yes	No
8.2.3.2	Has hardness test been specified?	Yes	No
8.3.1.2	Is pre-test submittal of test procedures required?	Yes	No
8.3.2.5	Is wetting agent required in hydrotest liquid?	Yes	No
8.3.3.4.3	Is bearing inspection required after performance test?	Yes	No
8.3.4	What optional tests are required by purchaser (see data sheets)?		
8.3.4.1	Is NPSHR test required?	Yes	No
8.3.4.2	Is complete unit test required?	Yes	No
8.3.4.3	Is sound level test required?	Yes	No
8.3.4.4	Is auxiliary equipment test required?	Yes	No
8.3.4.5	Is a secondary containment/control system hydrotest required?	Yes	No
8.3.4.6	Is a secondary containment/control system instrumentation test required?	Yes	No
8.3.4.7	Is a pressure-temperature profile test required?	Yes	No
8.4.1	Is type of shipment specified?	Yes	No
	Is long-term storage required?	Yes	No

Specific Pump Types

9.1.1.4	Is removal of drive end without disturbing driver required?	Yes	No
9.1.3.7	Is end of curve torque coverage required?	Yes	No
9.1.3.9	Is a torque vs. temperature curve required?	Yes	No
9.1.3.10	Is a speed-torque curve required?	Yes	No
9.1.4.2.1	Is a preferred oiler specified?	Yes	No

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9.1.4.3.3	Are pure or purge oil mist provisions required (see data sheet)?	Yes	No
9.1.5.1.1	Are motor requirements specified (see data sheet)?		
9.1.5.2.2	Are coupling requirements specified (see data sheet)?	Yes	No
9.1.5.3.6	Is a pump casing deflection test required?	Yes	No
9.1.5.3.13	Is baseplate & pedestal rigidity without grout required?	Yes	No
9.1.5.3.18	Is baseplate preparation for cementitious grout required?	Yes	No
9.1.6.1	Is a magnetic coupling static torque test required?	Yes	No
9.2.2.9	Have special operating conditions for motor been specified?	Yes	No
9.2.2.10	Is UL or FM certification required?	Yes	No
9.2.2.11	Are stator flush or purge connections required?	Yes	No
9.2.7.1	Is test motor test certification required?	Yes	No

	Vendor's Data		
10.1.3	Is coordination meeting required?	Yes	No
10.2.31	Is list of similar installations required with proposal?	Yes	No
10.2.5	Is a list of the procedures for any special or optional tests required with the proposal?	Yes	No

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APPENDIX Q—STANDARD 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 for sealless pumps. This standard format is also known as the "neutral data exchange file format."

Q.1.1 The data exchange file outlined in this specification extends beyond the scope of the 8th Edition of API Standard 610 (Appendix Q), such that data fields for all additional sealless centrifugal pump information are defined within this specification. This includes all additional data fields that are part of the sealless pump data sheets (Appendix B).

Q.1.2 Purchasers and manufacturers are encouraged to use this format 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 is available from API. 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 and PIP RESP73H data sheets may be printed via this *Program*, and it should include API 685 data sheet by the time of publication of this standard. 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 this standard. 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 #RECORD STARTS	*(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 group)*
—Nozzle Load Data here: *[see specification]*	
#END: NOZZLE LOAD DATA	*(end of nozzle load group)*
#BEGIN: ADDITIONAL OPERATING CONDITIONS DATA	*(start of additional operating 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)*

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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 VAXNMS. These files may be created and modified using standard text editors such as DOS (edit), UNIX (vi), and VAX/VMS (edit) or via a separate computer program.

The naming convention for the computer file is established directly between the trading partners. However, the preferred file format is as follows:

xxxxxxxx.pxf

where

xxxxxxxx is an 8 alphanumeric file prefix, and pxf is a 3-digit file extension (pump exchange file).

Each file must contain the file header shown below:

#CENTRIFUGAL PUMP NEUTRAL FILE EXCHANGE	*(header)*
#VERSION 1.0	*(version number)*
#BEGIN: HEADER DATA	*(start of header group)*
—File Header Data here: [see specification]	
#END: HEADER DATA	*(end of header group)*

and the end of file identifier

#FILE ENDS	*(end of file)*

Q.2.3 DATA RECORDS

A record represents a collection of data about a single pump item (in a conventional inquiry or proposal). The record starts with

#RECORD STARTS	*(start of record)*

and ends with

#RECORD ENDS	*(end of record)*

Each file contains one or more records.

Q.2.4 DATA GROUPS

Each record contains any of the following *groups* of field data:

a. Pump Data group. This group is mandatory for each record.
b. Additional Data group. This group is optional for each record.
c. Dimensional Data group. This group is optional for each record.
d. Nozzle Load Data group. This group is optional for each record.
e. Additional Operating Conditions Data group: This group is optional for each record. This group may be repeated one or more times within a record to represent multiple operating conditions.
f. Header Data group: This group is mandatory for each file.

Q.2.5 DATA FIELDS

The body of the Neutral Exchange file are the data fields. Data fields are comprised of the following:

a. *Number:* Field numbers are preceded by a group letter and a sequentially assigned 3 digit number of the form:

Xnnn

where X is an alpha character and nnn is a sequential number from 001 to 999.

b. *Delimiter*: The delimiter is a comma (,) to separate the Field number from the Field Value.

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c. *Value*: The value or contents of the field corresponding to the field number.
   1. Values are restricted according to the definitions outlined in Q.3. Data Field Definitions.
   2. 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 that are required by the sender.

d. *End of Field Delimiter*: Each field is followed by an end of line and carriage return.

Q.2.6 EXAMPLES

The following examples show proper Neutral Data Exchange File formats.

Q.2.6.1 Example 1: Single record with only one group (Pump Data). The field values are sample values only and are not intended to represent a true pumping application.

```
#CENTRIFUGAL PUMP NEUTRAL FILE EXCHANGE
#VERSION 1.0
#BEGIN: HEADER DATA
FOO1,TO: Company A
F002,FROM: Company B
F003,DATE: October 5,1994
F005,2
#END: HEADER DATA
#RECORD STARTS #BEGIN: PUMP DATA
A001,J0B21-3454
A002,ITEM01
A003,Requisltion 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
F00I,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
```

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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
#BEGIN: ADDITIONAL DATA
B005,6000
B006,1.32E+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
D012,1234
#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

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```
#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 is 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 datasheet.

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:

1. C is a character field. The content:s 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.
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.
3. I is an integer field. The contents are only whole number values. Examples include 1234 or 2.
4. L is a logical field. The contents are either:
   Yes (true): 1
   No (false): 0
5. 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:

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1. Contents are restricted to enumerated lists for certain fields. (Example: A: proposal; B: purchase; C: as built; Z: other)
2. 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 A1 term corresponds to the "term 1", the A2 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 the Neutral Data Exchange File 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 Q.2.1. New field 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.

No.	Name	Field	Type	Length	Contents/Unit
		General			
G001	SI Dimensions	ISO_DIM	L	1	1:yes (true); 0:no (false)
G002	US Dimensions	US_Dim	L	1	1:yes (true); 0:no (false)
Site and Utility Data					
G003	Unheated	UNHEATED	L	1	1:yes (true); 0:no (false)
Liquid					
G004	Temperature-Vapor Pressure Curve No.	T_VP_CRV_N	C	15	
G005	Max. Viscosity Temperature	MAX_VISC_T	N	13	°C
G006	Temperature-Viscosity Curve No.	T_VISC_CRV	C	15	
G007	Thermal Expansion	THERM_EXP	N	13	mm3/mm3/°C
G008	Thermal Conductivity	THERM_COND	N	13	
G009	Corrosion Allowance	CORR_ALLOW	N	13	mm
G010	Hardness of Solids	HARDNESS	C	15	

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No.	Name	Field	Type	Length	Contents/Unit
G011	Size Distribution	SIZE_DIST	C	40	
G012	Polymerization Characteristics	POLY_CHAR	C	40	
G013	Liquid Remarks	LIQ_REMK	C	140	
System Description					
G014	Suction Vessel Vented to Atmosphere	SUCT_VENTD	L	1	1:yes (true); 0:no (false)
G015	Suction Vessel Closed	SUCT_CLOSE	L	1	1:yes (true); 0:no (false)
G016	Pump Location Below Liquid Level	PUMP_BELOW	L	1	1:yes (true); 0:no (false)
G017	Pump Location Above Liquid Level	PUMP_ABOVE	L	1	1:yes (true); 0:no (false)
G018	Suction Vessel on Level Control	SUCT_L_CTL	L	1	1:yes (true); 0:no (false)
G019	Pressure Sensor on Suction Vessel	PS_SUC_VES	L	1	1:yes (true); 0:no (false)
G020	Suction Vessel Pressure Maintained by	SV_PRES_BY	C	15	
G021	Auto Stop on Low Level	LL_A_STOP	L	1	1:yes (true); 0:no (false)
G022	Dry Run in Normal Operation	DRY_RUN	L	1	1:yes (true); 0:no (false)
G023	System Remarks	SYST_REMK	C	140	
Performance					
G024	Rated Hydraulic Efficiency	HYD_EFF_R	N	13	% (0 to 100)
G025	Hysteresis & Mechanical Losses	HYST_LOSS	N	13	kW
G026	Percent Rise to Shutoff	RISE_TO_SO	N	13	%
Construction					
G027	Description of Other Pump Type	OTHER_PUMP	C	15	
G028	Design Pump for vacuum	VAC_DESIGN	C	1	A:full; B:partial
G029	Partial vacuum design pressure	VAC_PRESS	N	13	kPa
G030	Other Acceptable Impellers	OTHER_IMP	C	3	A:open; B:semiopen; C:fabricated
G031	Case Wear Rings NOT Required	NO_CASE_WR	L	1	1:yes (true); 0:no (false)
G032	Impeller Wear Rings NOT Required	NO_IMP_WR	L	1	1:yes (true); 0:no (false)
G033	Non-grooved Bearings Acceptable	ACC_NG_BRG	L	1	1:yes (true); 0:no (false)
G034	Ext. Flush / Leak-off Connection	E_FLSH_LO	L	1	1:yes (true); 0:no (false)
G035	Number Ext.Flush / Leak-off	FLSH_LO_NO	I	5	
G036	Ext. Flush / Leak-off Size	EF_LO_SIZE	N	10	The decimal numeric value is followed by "mm" or "IN". Example: 1.5 in or 38 mm
G037	Ext. Flush / Leak-off Type	EF_LO_TYPE	C	15	
G038	Purge / Flushout Connection	PRG_FO_CONN	L	1	1:yes (true); 0:no (false)
G039	Number Purge / Flushout	PRG_FO_NO	I	5	
G040	Purge / Flushout Size	PRG_FO_SIZE	N	10	The decimal numeric value is followed by "mm" or "IN". Example: 1.5 in or 38 mm
G041	Purge / Flushout Type	PRG_FO_TYPE	C	15	
G042	Other Aux. Connection	O_AUX_CONN	C	25	Description
G043	Number Other Aux.	O_AUX_NO	i	5	
G044	Other Aux. Size	O_AUX_SIZE	N	10	The decimal numeric value is followed by "mm" or "IN". Example: 1.5 in or 38 mm
G045	Other Aux. Type	O_AUX_TYPE	C	15	
G046	Vendor to supply valves for vents	VENT_VALVE	L	1	1:yes (true); 0:no (false)
G047	Vendor to supply valves for drains	DRN_VALVE	L	1	1:yes (true); 0:no (false)
G048	Rotor cavity drainable through secondary drain	CAV_DRAIN	L	1	1:yes (true); 0:no (false)
G050	Non-standard bolt length	N_STD_BOLT	L	1	1:yes (true); 0:no (false)
G051	No threaded conn. on secondary casing	NO_THR_2ND	L	1	1:yes (true); 0:no (false)
G052	Secondary Casing has drain connection	2CASE_DRAIN	L	1	1:yes (true); 0:no (false)
G053	Secondary Casing has flush provision	2CASE_FLSH	L	1	1:yes (true); 0:no (false)

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No.	Name	Field	Type	Length	Contents/Unit
Auxiliary piping					
G054	Auxiliary Circulation Plan	CIRC_PLAN	C	1	A:Plan 1S; B:plan 1SD; C: plan 2S; D: plan 11S; E: plan 13S; F: plan 13SE; G: plan 21S; H: plan 23S; I: plan 31S; J: plan 41S; K: plan 53S; L: plan 54S
G055	Cooling water piping plan	CW_PLAN_S	C	1	A:Plan BS; B:Plan MS; C:Plan KS
G056	Other CW user	CW_OTHER	C	15	
G057	Other CW user flow	CWFLO_OTH	N	13	M^3/h
G058	Steam piping other description	STM_PIPE_O	C	15	Description
Materials					
G059	Inner magnet sheathing/rotor liner	RTR_LINER	C	15	
G060	Other part	OTHER_PART	C	15	Description
G061	Other part material	OTH_PT_MTL	C	15	
Secondary Control / Containment					
G062	Secondary Control required	SECD_CTRL	L	1	1:yes (true); 0:no (false)
G063	Secondary control leakage on primary fail	S_CTR_LEAK	N	13	M^3/h
G064	Secondary containment required	SECD_CTN	L	1	1:yes (true); 0:no (false)
G065	Secondary aux seal device	S_AUX_SEAL	C	15	
G066	Aux seal device type	AUX_SEAL_T	C	1	A:dry running; B:wet running
G067	Aux seal location	AUX_SEAL_L	C	1	A:Inside; B:Outside of bearings; C:Other
G068	Aux seal other location	AUX_LOC_O	C	40	
G069	Secondary cont. remarks	S_CONT_REM	C	140	
Mag-drive Specific					
G070	Design for removal of drive end	REM_DR_END	L	1	1:yes (true); 0:no (false)
G071	Mag coupling type	MAG_CLP_TP	C	1	A:synchronous: B:Torque ring
G072	Magnet mounting method—outer	MAG_MT_OUT	C	15	
G073	Magnet mounting method—inner	MAG_MT_INN	C	15	
G074	Temperature limit-outer	TEMP_LMT_O	N	13	ºC
G075	Temperature limit-inner	TEMP_LMT_I	N	13	ºC
G076	Outer magnet hermetically sealed	HERM_SL_O	L	1	1:yes (true); 0:no (false)
G077	Inner magnet hermetically sealed	HERM_SL_I	L	1	1:yes (true); 0:no (false)
G078	Number of magnets—outer	NO_MAG_O	N	13	
G079	Number of magnets—inner	NO_MAG_I	N	13	
G080	Soft start required	SFT_START	L	1	1:yes (true); 0:no (false)
G081	Hard start capability	HD_STRT	L	1	1:yes (true); 0:no (false)
G082	Decoupling Torque (Torque Rating)	DCPL_TRQ	N	13	Nm
G083	Max torque required on starting	START_TRQ	N	13	Nm
G084	Pump torque at rated point with +5%	PUMP_TRQ	N	13	Nm
G085	Actual service factor	ACTUAL_SF	N	4	
G086	Torque required for full pump curve	FL_CRV_TRQ	N	13	Nm
G087	Design coupling for full curve torque	FULL_CURVE	L	1	1:yes (true); 0:no (false)
G088	Submit torque vs temp curve	TRQ_TEMP	L	1	1:yes (true); 0:no (false)
G089	Submit speed vs torque curve	SPD_TRQ	L	1	1:yes (true); 0:no (false)
G090	Other mag-coupling requirement	MAG_REQMT	C	40	
G091	Constant level oiler preference	CLO_PREF	L	1	1:yes (true); 0:no (false)
G092	Applicable motor spec	MTR_SPEC	C	1	A:IEEE 841; B:API 541; C:Other
G093	Other motor spec	MTR_OTHER	C	15	
G094	Baseplate remarks	BASE_RMKS	C	90	

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No.	Name	Field	Type	Length	Contents/Unit
Canned Motor Specific					
G095	Solid media potting allowed	MTR_POTG	L	1	1:yes (true); 0:no (false)
G096	Ceramic insulation acceptable	CRMC_INSUL	L	1	1:yes (true); 0:no (false)
G097	Design motor for frequent starts	FREQ_STRT	L	1	1:yes (true); 0:no (false)
G098	No starts for motor	NO_STRTS	I	5	
G099	Start period units	STRT_UNIT	C	15	
G100	Lift impacted by start frequency	LIFE_IMPKT	L	1	1:yes (true); 0:no (false)
G101	Speed design of motor	MTR_SPD	C	1	A:Two speed; B:Variable speed
G102	Agency certification required	CERT_MTR	L	1	1:yes (true); 0:no (false)
G103	Agency certification provided	MTR_CERT	C	1	A:UL; B:FM; C:Other provided
G104	Certification per IEEE 252 required	IEEE_CERT	L	1	1:yes (true); 0:no (false)
G105	Canned motor specific remarks	CMP_RMKS	C	500	
Instrumentation					
G106	Instrument panel required	INST_PNL	L	1	1:yes (true); 0:no (false)
G107	Instrument panel mounting	I_PNL_MTG	C	1	A:On base by vendor; B:Separate by purchaser
G108	Instrument panel remarks	I_PNL_RMKS	C	140	
G109	Monitor leakage into secondary casing	LEAK_MON	L	1	1:yes (true); 0:no (false)
G110	Leakage monitor type	LK_MON_TYP	C	1	A:Optical; B:Sight glass; C:Pressure switch; D:Conductivity
G111	Leakage monitor location	LK_MON_LOC	C	1	A:Local; B:On panel
G112	Leakage monitor initiates alarm	L_MON_ALRM	L	1	1:yes (true); 0:no (false)
G113	Leakage monitor initiates shutdown	L_MON_SDN	L	1	1:yes (true); 0:no (false)
G114	Leakage monitor remarks	L_MON_RMKS	C	140	
G115	Pump power monitored	PWR_MON	L	1	1:yes (true); 0:no (false)
G116	Power monitor provided by	PWR_MON_BY	C	1	A:Vendor; B:Purchaser
G117	Electrical characteristic monitored	PWR_CHAR	C	1	A:Power (watts); B:Current (amps)
G118	Power monitor location	PW_MON_LOC	C	1	A:Local; B:On panel; C:In MCC
G119	Power monitor initiates alarm	PW_MON_ALM	L	1	1:yes (true); 0:no (false)
G120	Power monitor initiates shutdown	PW_MON_SDN	L	1	1:yes (true); 0:no (false)
G121	Power monitor remarks	PW_MON_RMK	C	140	
G122	Temperature monitor required	TEMP_MON	L	1	1:yes (true); 0:no (false)
G123	Monitor temperature of	T_MON_WHAT	C	1	A:Containment shell/liner; B:Rotor cavity fluid; C:Bearings
G124	Temperature monitor location	T_MON_LOC	C	1	A:Local; B:On panel
G125	Temperature monitor initiates alarm	T_MON_ALRM	L	1	1:yes (true); 0:no (false)
G126	Temperature monitor initiates shutdown	T_MON_SDN	L	1	1:yes (true); 0:no (false)
G127	Provision for temperature instrument only	T_MON_PROV	L	1	1:yes (true); 0:no (false)
G128	Temperature sensor provided by	T_MON_SEN	C	1	A:Vendor; B:Purchaser
G129	Temperature sensor type	T_SEN_TYPE	C	40	
G130	Temperature monitor and cables by	T_MON_BY	C	1	A:Vendor; B:Purchaser
G131	Pressure monitor required	PRESS_MON	L	1	1:yes (true); 0:no (false)
G132	Monitor pressure of	P_MON_WHAT	C	1	A:Rotor cavity; B:Secondary casing
G133	Pressure monitor location	P_MON_LOC	C	1	A:Local; B:On panel
G134	Pressure monitor initiates alarm	P_MON_ALRM	L	1	1:yes (true); 0:no (false)
G135	Pressureonitor initiates shutdown	P_MON_SDN	L	1	1:yes (true); 0:no (false)
G136	Provision for pressure instrument only	P_MON_PROV	L	1	1:yes (true); 0:no (false)
G137	Pressure sensor provided by	P_MON_SEN	C	1	A:Vendor; B:Purchaser
G138	Pressure sensor type	P_SEN_TYPE	C	40	

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No.	Name	Field	Type	Length	Contents/Unit
G139	Pressure monitor remarks	P_MON_RMK	C	140	
G140	Vibration will be monitored	VIB_MON	L	1	1:yes (true); 0:no (false)
G141	Vibration has readout	VIB_RD_OUT	L	1	1:yes (true); 0:no (false)
G142	Vibration monitor initiates alarm	V_MON_ALRM	L	1	1:yes (true); 0:no (false)
G143	Vibration monitor initiates shutdown	V_MON_SDN	L	1	1:yes (true); 0:no (false)
G144	Vibration provision for instrument only	V_MON_PROV	L	1	1:yes (true); 0:no (false)
G145	Vibration provision required	V_PROV_TYP	C	1	A:Flat surface; B:Threaded connection
G146	Vibration sensor provided by	V_MON_SEN	C	1	A:Vendor; B:Purchaser
G147	Vibration sensor type	V_SEN_TYPE	C	40	
G148	Monitor and cables by	V_MON_BY	C	1	A:Vendor; B:Purchaser
G149	Vibration monitor remarks	VIB_RMKS	C	140	
G150	Bearing wear monitored	BW_MON	L	1	1:yes (true); 0:no (false)
G151	Bearing wear monitor type	BW_MON_TYP	C	1	A:Mechanical; B:Electrical; C:Hydraulic; D:Other
G152	Bearing wear has readout	BW_RD_OUT	L	1	1:yes (true); 0:no (false)
G153	Bearing wear monitor initiates alarm	BW_MON_ALM	L	1	1:yes (true); 0:no (false)
G154	Bearing wear monitor initiates shutdown	BW_MON_SDN	L	1	1:yes (true); 0:no (false)
G155	Bearing wear monitor location	BW_MON_LOC	C	1	A:Local; B:On panel
G156	Bearing wear monitor remarks	BW_MON_RMK	C	140	
G157	Liquid filled gauges to resist vibration	FILL_GAUGE	L	1	1:yes (true); 0:no (false)
G158	Not replace instrument while running	REPLC_RUN	L	1	1:yes (true); 0:no (false)
G159	No test of shutdown while running	NTEST_RUN	L	1	1:yes (true); 0:no (false)
G160	Alarm switch action	ALARM_ACT	C	1	A:Open; B:Close to alarm
G161	Alarm switch normal condition	ALARM_NOR	C	1	A:Energized; B:De-energized
G162	Shutdown switch action	SD_ACT	C	1	A:Open; B:Close to alarm
G163	Shutdown switch normal condition	SD_NORM	C	1	A:Energized; B:De-energized
Drive Motor					
G164	Size motor for max power	MTR_MAX	L	1	1:yes (true); 0:no (false)
G165	Max acceleration time required	ACEL_REQD	N	13	seconds
G166	Acceleration time quoted	ACEL_QOTD	N	13	seconds
G167	Motor remarks	MTR_RMKS	C	140	
QA Inspection and Test					
G168	Secondary containment system hydrotest	CONT_HYDRO	C	1	A:Non-witness; B:Witness; C:Observe
G169	Secondary cont. system instrument test	C_INST_TST	C	1	A:Non-witness; B:Witness; C:Observe
G170	Press-temp profile type test	P_T_PROFIL	C	1	A:Non-witness; B:Witness; C:Observe
G171	Certification of static torque test	TRQ_CERT	L	1	1:yes (true); 0:no (false)
G172	Testing remarks	TEST_RMKS	C	140	
G173	Plot dimensions—motor drive	L_W_H_MTR	C	40	
G174	Plot dimensions—steam turbine drive	L_W_H_ST	C	40	

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APPENDIX R—METRIC TO U.S. UNITS CONVERSION FACTORS*

Quantity	Dimension	Metric	Unit Abbreviation	Multiplication Factor	U.S.	Unit Abbreviation
Length	(L)	meter	m	3.28084	feet (ft)	ft
		millimeter	mm	0.03937	inch	in.
		micrometer	µm	0.00003937	inch	in.
		micrometer	µm	0.03937	0.001 inch	mlls
Area	(L^2)	square meter	m^2	10.764	square feet	ft^2
		square centimeter	cm^2	0.155	square inch	$in.^2$
Velocity	$(L \bullet T^{-1})$	meter/second	m/s	3.28084	feet/second	ft/sec
		millimeter/second	mm/s	0.03937	inches/second	in./sec
Volume	(L^3)	cubic meter	m^3	264.2	U.S. gallons	US Gal
		liter	l	33.81	fluid ounce	fl. oz.
Flow Rate	$L^3 \bullet T^{-1}$	cubic meter/hour	m^3/h	4.4033	U.S. gallons/minute	US GPM
Mass	(M)	kilogram	kg	2.20462	pounds	lbs
		gram	g	0.035274	ounces	oz.
Force	$(M \bullet L \bullet T^{-2})$	Newton	N	0.2248	pound force	lbf
Pressure	$(M \bullet L^{-1} \bullet T^{-2})$	Kilopascal	kPa	0.145	pounds/square inch	psi
		Megapascal	MPa	145.0	pounds/square inch	psi
Stress	$(M \bullet L^{-1} \bullet T^{-2})$	Newton/mm^2	N/mm^2	145.0	pounds/square inch	psi
Head	(L)	meter	m	3.28084	feet	
Density	$M \bullet L^{-3}$	kilogram/cubic meter	kg/m^3	0.062428	pounds/cubic foot	lb/ft^3
Torque	$(M \bullet L^2 \bullet T^2)$	Newton•meter	Nm	0.7376	pound•foot	lbf•ft
Power	$(M \bullet L^2 \bullet T^3)$	kilowatt	kW	1.34102	horsepower	HP
Temperature		Degrees Celsius	C	(1.8 x °C) + 32	Degrees Farenheit	F
Heat Energy	$(M \bullet L^2 \bullet T^{-2})$	kilojoule	k	0.9478	British thermal unit	BTU
Moment of Inertia	$(M \bullet L^2)$	kilogram•meter^2	kg•m^2	23.73	pound	lb•ft^2
Unbalance	(M•L)	gram•millimeter	g•mm	0.001389	ounce•inch	oz•in
Magnetic Coercivity		kiloampere/meter	kA/m	0.012566	kiloOersted	kOe
Magnetic Remanence		millitesla	mT	0.01	kilogauss	kG
Magnetic BH Product		kilojoule/meter^3	kJ/m^3	0.125664	MegaGauss•Oersted	MGOe

Notes:
*Multiply the metric unit of measure by the multiplication factor to obtain U.S. units.
Units of Pressure: 100 kPa = 1 bar (Non Preferred Unit)
Units of Stress: 1 newton/mm^2 = 1 MPa

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APPENDIX S—WITHDRAWN

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APPENDIX T—API 685 TEST DATA SUMMARY

Customer	Curve No.
Purchaser	Test Date
Purchase Order No.	
Item No.	Certified By:
Pump Serial No.	(Vendor Representative)
Size and Type	Witnessed by:
No. of Stages	(Purchaser Representative)

Overall Pump Performance (Table 7)

	Rated	Tested	Actual Deviation +/- %	Acceptance Tolerance +/- %
Flow				
Head				
Power				
NPSHR 3%				
Shutoff Head				
Speed, rpm				

Pump Construction Data

Stage 1		Series Stages	
Impeller Diameter	mm (in.)	Impeller Diameter	mm (in.)
Impeller Pattern No.		Impeller Pattern No.	
No. of Vanes		No. of Vanes	
Volute/Diffuser Pattern No.		Volute/Diffuser Pattern No.	
Blade Tip Clearance (6.1.16)	%	Blade Tip Clearance (6.1.16)	%

Mechanical Performance

Maximum Vibration Levels recorded within Specified Flow Region (6.9.3)

	Rated Flow		Preferred Operating Region		Allowable Operating Region	
	Tested	Specified	Tested	Specified	Tested	Specified
Housing Velocity: Drive End: Overall/Filtered	/	/	/	/	/	/
Non-Drive End: Overall/Filtered	/	/	/	/	/	/
Shaft Displacement: Drive End: Overall/Filtered	/	/	/	/	/	/
Non-Drive End: Overall/Filtered	/	/	/	/	/	/

Bearing Lubrication / Circulated Fluid Temperatures °C (°F) (8.3.3.3.2 & 9.1.4.2.2)

Circulated Fluid	Ring Oil or Splash Lubrication
Fluid Supply Temp.	Ambient Temp.
Fluid Temp. Rise	Oil Temp. Rise
Fluid Return Temp.	Oil Sump Temp.

(1) This Mechanical performance summary is for recording test levels for each operating region relative to specified values. It is not intended to replace shop test data logs.

(2) Units of measurement shall be mm/sec (in./sec.) RMS for velocity, mm (mils) peak/peak for displacement, and °C (°F) for temperature.

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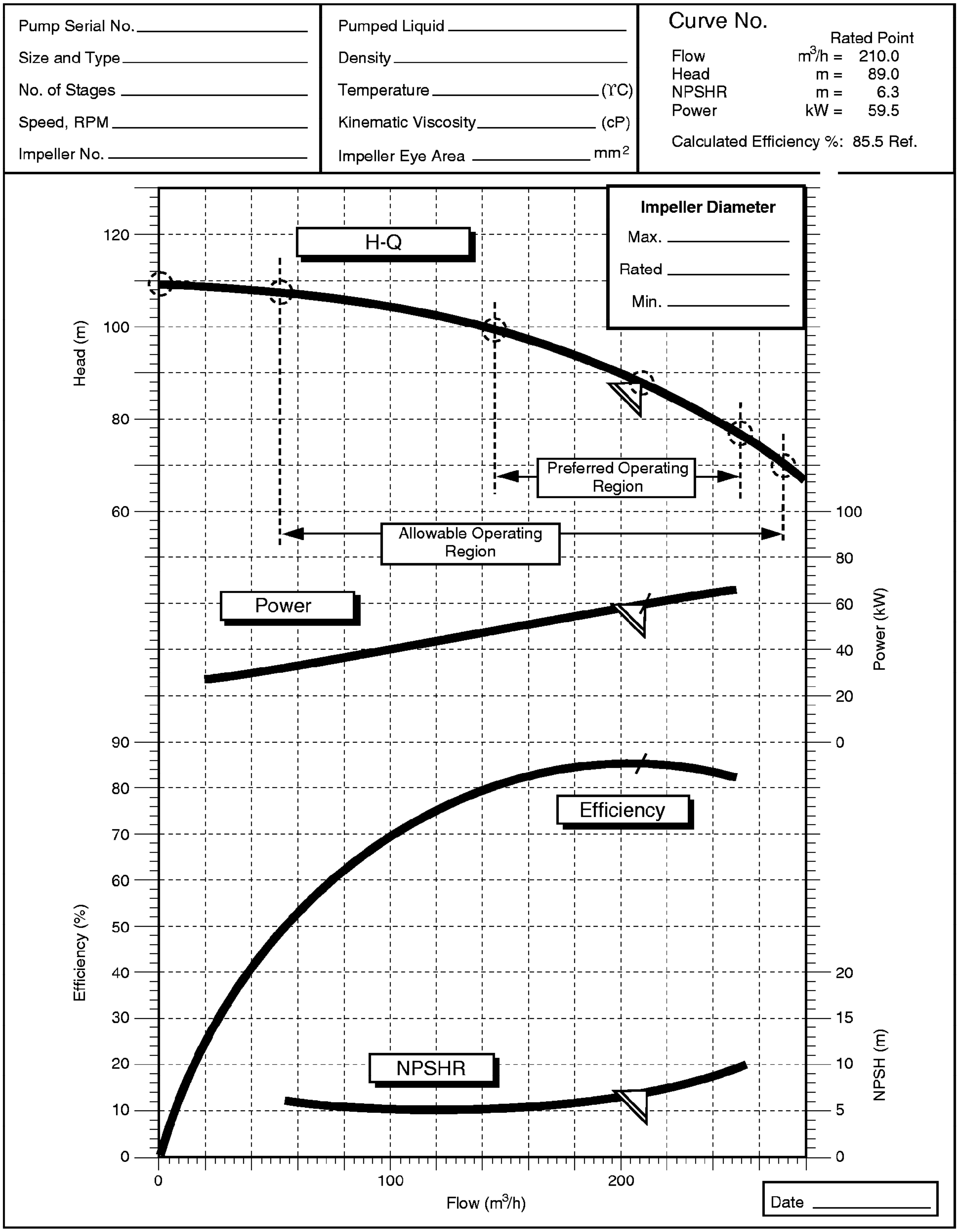

Note: Values for scales, flow, head, NPSHR, power, efficiency for illustration only.

Figure T-1—Test Curve Format—ISO Style

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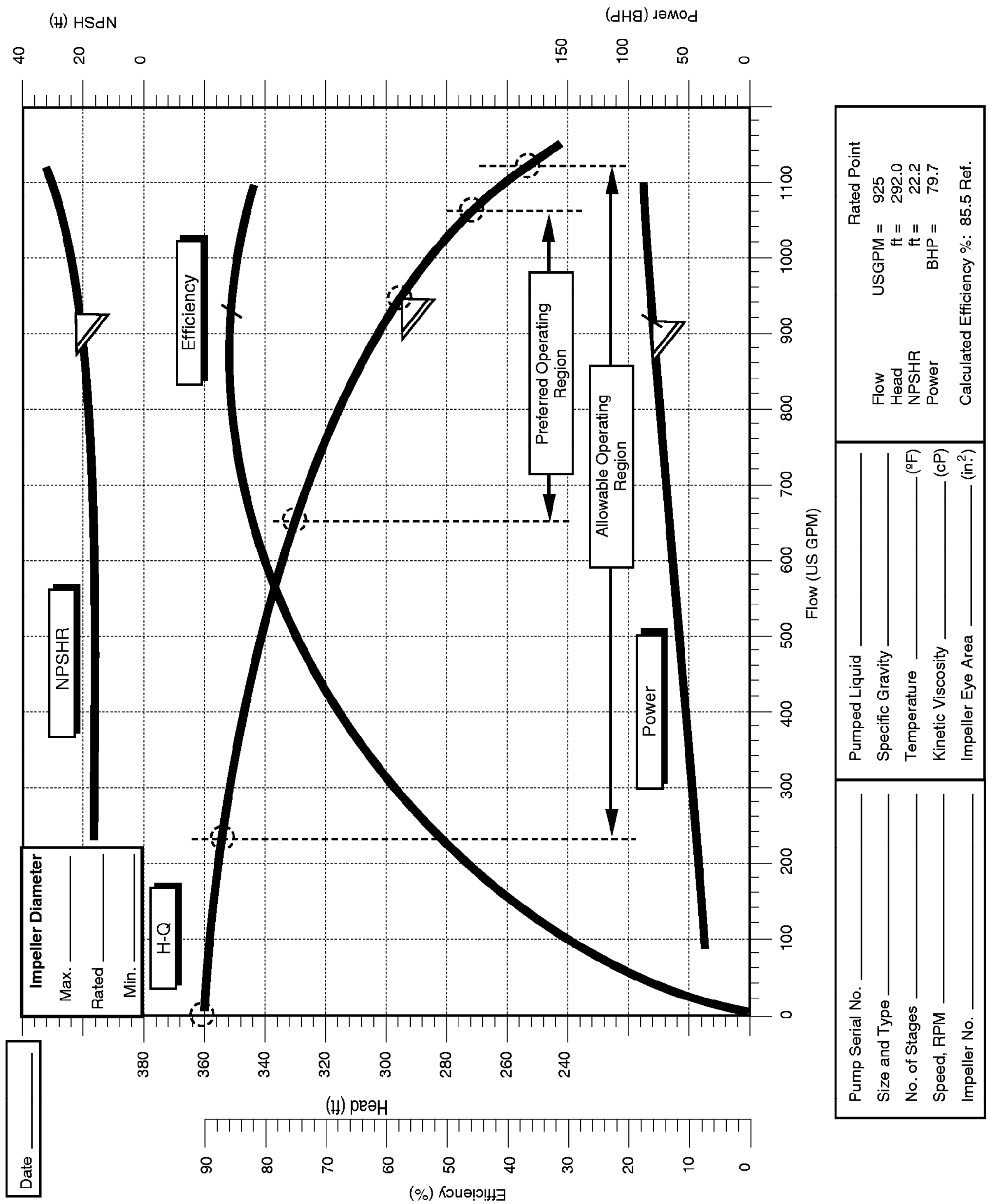

Note: Values for scales, flow, head, NPSHR, power, efficiency for illustration only.

Figure T-2—Test Curve Format—U.S. Style

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APPENDIX U—APPLICATION INFORMATION

U.1 General

Some additional understanding of differences between sealless pumps and mechanically sealed centrifugal pumps is necessary for proper application. Information is presented within this section to point out factors which need to be considered in application, and identify factors which are different from considerations for centrifugal pumps with shaft seals.

U.2 Circulation Plan Selection and Application

(See Appendix D)

It is recognized that the product lubricated bearings design and application considerations are essentially the same for canned motor pumps and magnetic drive pumps.

Selection of an appropriate circulation plan depends upon knowledge of fluid properties such as cleanliness, volatility, specific heat, toxicity, melting point, and tendency to form solids or polymerize. Also to be considered are intended operation, flow rates, NPSH, frequency of starts, and cooling or heating availability.

Factors internal to the unit design such as pressures, temperatures, flows and heat transfer characteristics within the drive section as well as hydraulic performance of the pump end must be understood in order to properly select circulation plans and assess application questions. Possible advantages and limitations of available plans must also be understood.

The circulation plans shown in Appendix D coupled with detailed knowledge of individual unit design allow for the handling of most applications.

Comments on individual considerations are as follows:

U.2.1 *Clean, non-volatile, moderate temperature* fluid with sufficient NPSH. This description fits the majority of sealless pump applications and can be handled by variations of circulation plans shown.

U.2.2 *High Temperature.* Temperature of motor windings or magnetic drive components can be controlled by a variety of circulation plans shown in the grouping for high temperature.

U.2.3 *Volatile Fluids/limited NPSH Available.* Reverse circulation and pressurized circulation plans may be used to avoid the thermal effect of drive heating on pump NPSH requirements. Consideration of vapor pressure increase with temperature and of specific heat of fluid is required. Use of a separate low volatility drive buffer fluid is also possible.

U.2.4 *Venting and Cool Down.* When pumping cold fluids which are volatile at atmospheric temperature use of a separate vent line back to the supply vessel is necessary to cool the pump and piping to near pumping temperature prior to start-up.

U.2.5 *Fluids Containing Abrasive Particles* may cause objectionable wear. Centrifugal separation, mechanical filtration, or separate, clean buffer fluid may be used to remove particles from the circulation fluid.

U.2.6 *Jacketed designs may be required for high melting point* fluids and easily polymerizing or crystallizing fluids. Buffer fluids may also be used.

U.2.7 *High Viscosity.* Viscosities which would cause objectionable drag losses in the drive section or inadequate bearing lubrication (generally above 100 CP) may be handled with an external source of circulation fluid. (CPS = CS x SG, SSU = 4.64 x CS). Start-up as well as operating viscosity needs consideration.

U.3 Pump Performance Selection

Pump selection is the same as for a shaft sealed, centrifugal pump with additional attention to the following:

U.3.1 *Hydraulic Sizing.* Caution should be used when sizing the pumps. Oversizing the pump can cause excessive heat build up. The excessive heat can be caused by magnetic-drive eddy currents or efficiency losses in canned motors.

U.3.2 *Driver Sizing for Canned Motor Pumps.* The effect of load on winding temperature and rotational speed needs to be considered over anticipated performance range allowing for any projected future change in requirements. Motors must conform to required area classification.

U.3.2.1 *Canned Motor Pump Electrical Feeder Cable Sizing.* Due to the integral nature of the canned pump impeller and motor construction, the motor rating required for a given duty is directly affected by the temperature of the fluid being pumped and the power rating is stated as motor input electric power, not shaft power. Due to the process fluid operating temperatures, derating of the motor winding in many cases may be required to maintain the winding insulation temperature within the limits of the class of insulation used. In these cases, the motor rating under ambient temperature conditions will be higher than that required at rated conditions.

Both of these factors need to be considered when calculating the motor feeder cable size, and associated voltage drop when starting the motor. For example, if a 40 HP motor rating is selected for a 30 HP pump duty to meet the winding temperature rise limitations, its starting current is limited to 6.5 times the full load current of the 40 HP rating, not relative to the 30 HP duty rating. The starting current would therefore be 8.7 times an equivalent 30 HP full load current value. When converting the power value into amperes, it is not required to account for the motor inefficiencies as the power value already includes the effect of the motor losses.

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The correct value of starting current must be used when calculating the appropriate size of feeder cable.

U.3.2.2 *Area Classification Considerations.* If a canned pump is located in an area defined as Division 1 or 2 because of other process equipment in that area, then the canned pump design and construction must meet the appropriate regulations and authority requirements. Attention is drawn to the motor surface temperature limitation requirements in NFPA 70, especially for service in Division 1 and 2 areas having high operating temperatures.

U.3.2.3 *Electrical Protection.* In addition to the circuit breakers, overcurrent sensing elements, proper sizing of the feeder cable and other protection devices used with standard motors, the canned motor windings include a thermal switch which is imbedded in the motor windings to sense the temperature of the motor windings during operation.

This switch is normally rated to limit the motor winding temperature based on temperature rating of the insulation system. However, it should also be rated based on the application data provided. If the process fluid stream is interrupted in the motor cooling circuit, this switch will sense the temperature rise and either shut the motor off or provide an alarm. This will occur even if the motor is not overloaded. In the case of process fluids with low boiling points, low auto-ignition temperatures, tendency to polymerize at elevated temperatures or other sensitivity to temperature rise, the thermal switch should be sized accordingly based on discussions between the purchaser and vendor.

U.3.3 *Drive and Driver Sizing—Magnetic Drive Pumps.* Rapid over heating may occur if the inner and outer magnets decouple during operation. Excessively large drives may have higher losses and fluid heating. The drive motor needs to be selected to cover projected operating range, but oversizing may be a factor in decoupling during acceleration. Motors must conform to required area classification.

U.3.4 *Thermal Effects on NPSH.* Heat from the drive section of a sealless pump can cause cavitation and loss of suction if fluid is recirculated to the pump suction. Circulation to intermediate or discharge points or recirculation to supply tank minimizes this problem and may be used to avoid flashing at bearings. Heating of fluid at the suction eye can also occur by internal recirculation within the pump impeller at low flow rates. Volatile fluids may require higher minimum flows and use of appropriate circulation plans.

Cavitation at pump impeller may also result in excessive thrust and should be avoided.

The design and circulation system should provide the margin of safety between pressure and vapor pressure within the drive area over the projected operating range.

U.3.5 *Low Specific Gravity Performance.* Pumps pumping low specific gravity fluids (0.5) may perform differently than pumps pumping fluids with specific gravities close to 1.0 (water). Different specific gravities may affect thrust balance, mechanical stability, temperature rise, and power required. Purchaser should verify with vendor start-up and commissioning conditions including the use of start-up strainers.

U.3.6 *Material selection* is the responsibility of the purchaser but the vendor has a responsibility as well to inform user of unusual corrosion requirements such as effect on pressure containment shells and rotor encapsulation.

The purchaser shall identify any potentially corrosive agents such as chlorides or hydrogen sulfide which need to be given special consideration.

The vendor shall identify materials of construction so that purchaser has sufficient information to ascertain proper selection.

Allowance should also be made for the temperature rise within the drive section when corrosive characteristics vary significantly with temperature.

U.3.7 *Entrained, Non-Condensable Gas.* Collection of vapors at pump suction and at fluid lubricated bearing area must be avoided by use of an appropriate circulation plan.

0.0.1 *Efficiency.* The efficiencies of magnetic drive and canned motor pumps should consider overall efficiency from power input to hydraulic work output. Power input is measured at the pump-to-motor coupling for magnetic drive pumps and at the motor terminals for canned motor pumps. This overall efficiency must also include energy used for auxiliary piping, seals, or other optional components. It is necessary to know pump hydraulic efficiency for proper drive selection. It is also necessary to know efficiency of the drive section as well as for separate motors (when used) to predict overall efficiency for comparison between magnetic drive and canned motor pumps.

U.4 Canned Motor or Magnet Component Temperature

Temperature capabilities for magnet materials are shown in Appendix I. Operating conditions must be evaluated along with vendor knowledge of temperature rises to assure that the proper sizing and use of circulation plans will result in satisfactory drive component temperatures. Magnet strength and motor insulation life decreases rapidly above the rated temperatures.

U.4.1 *Magnetic permeability* is a measure of the degree a material changes the flux in a magnetic field, the level of flux produced in a material by a given magnetizing field, and the relative eddy current losses per unit material thickness for various containment shell materials.

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U.4.2 *Parasitic hydraulic loss* is the energy lost due to internal fluid friction from the rotation of the inner magnet ring within the liquid filled containment shell of a magnetic drive pump or similar losses due to the liquid circulating between the stator and rotor liners of a canned motor.

U.5 Installation, Operation, and Maintenance

U.5.1 GENERAL

U.5.1.1 Avoid dry bearing operation. The sleeve bearings in sealless pumps are usually lubricated by the pumped liquid. If operated dry, the bearings can fail quickly due to lack of lubrication. Some bearing materials have self-lubricating properties and can tolerate dry running under some conditions.

U.5.1.2 Avoid air entrainment. Air entrainment in the pumped liquid can have the same effect on the pumped liquid lubricated bearings as running dry. The pump casing and containment shell must be fully primed and properly vented prior to pump start-up.

U.5.1.3 The frequency of inspection will depend on the corrosive and erosive nature of the pumped liquid. The manufacturer's manual shall recommend a schedule of inspection, and shall recommend inspection of certain parts based on some abnormal event.

U.5.1.4 The manufacturer's manual shall detail the method of review of individual parts to evaluate their wear and recommend they should be replaced. The manufacturer should be consulted when unusual or abnormal wear or corrosion is observed.

U.5.2 SPECIAL CONSIDERATION FOR MAGNETIC DRIVE PUMPS

U.5.2.1 The magnets in magnetically driven centrifugal pumps may create very strong magnetic fields. The following cautions should be observed at distances within 1 meter (3 feet) of pump while servicing or maintaining the pump:

a. Pacemakers—magnets can upset the timing of pacemakers.

b. Credit cards—magnets can erase magnetic tape on credit cards.

c. Computers, computer disks and tapes—magnets can erase information stored on computer disks and tapes, or any computer memory device.

d. Watches—magnets can damage mechanical spring-driven and electronically controlled watches.

e. Magnetic implants—can be attracted to the magnets.

Note: Extreme caution should be used when reassembling a magnetically driven pump. Magnets can cause parts and tools to slam together with force enough to injure the parts and the parts handler. The jackscrews and/or guides provided on the transition or containment shell cartridge flange should be used. Refer to the manufacturer's maintenance manual for procedures or special tools. Use of nonmagnetic tools, where practical, is recommended.

U.5.2.2 Shipping of magnets and magnet assemblies, especially by air, may require special precautions. Note: Usually the shipment of an assembled pump is not a problem; however, consultation between the pump manufacturer, the user and the freight company is advisable.

U.5.2.3 Avoid decoupling magnets. Decoupling of the inner and outer magnets can result in demagnetization of the inner magnets in a short period of time. Decoupling can also result in rapid temperature rise of the liquid in the containment shell. Decoupling can be caused by jamming of the impeller or overloading from rubbing, high viscosity or air entrainment. Decoupling can also occur if an oversized motor accelerates too fast for the magnetic coupling. A wattmeter (or kW) sensor on the motor can detect and shut off the pump is decoupling occurs.

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