

Positive Displacement Pumps— Reciprocating

API STANDARD 674
THIRD EDITION, DECEMBER 2010

ERRATA, MAY 2014
ERRATA 2, APRIL 2015

REAFFIRMED, NOVEMBER 2016



AMERICAN PETROLEUM INSTITUTE

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Downstream Segment

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Positive Displacement Pumps—Reciprocating

1 Scope

This standard covers the minimum requirements for reciprocating positive displacement pumps and pump units for use in the petroleum, petrochemical, and gas industry services. Both direct-acting and power-frame types are included. Controlled-volume pumps, hydraulically driven pumps, and rotary pumps are not included.

Note: See API 675 for controlled-volume pumps and API 676 for rotary pumps.

2 Normative References

2.1 The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

API Specification 5L: 2004, *Specification for Line Pipe*

API Standard 526:2002, *Flanged Steel Pressure Relief Valves*

API Standard 541:2002, *Form-wound Squirrel Cage Induction Motors — 250 Horsepower and Larger*

API Standard 546:1997, *Brushless Synchronous Machines — 500 kVA and Larger*

API Standard 611:1997, *General-purpose Steam Turbines for Petroleum, Chemical, and Gas Industry Services*

API Standard 677:1997, Reaffirmed: 2000, *General-purpose Gear Units for Petroleum, Chemical and Gas Industry Services*

API Recommended Practice 500A, *Classification of Locations for Electrical Installations in Petroleum Refineries*

API Recommended Practice 686:1996, *Machinery Installation and Installation Design*

ANSI/ABMA 7:1995 ¹, *Shaft and Housing Fits for Metric Radial Ball And Roller Bearings (Except Tapered Roller Bearings) Conforming To Basic Boundary Plan*

ANSI/AGMA 2015-1:2001 ², *Accuracy Classification System — Tangential Measurements for Cylindrical Gears*

ANSI/AGMA 6010:2003, *Standard for Spur, Helical, Herringbone, and Bevel Enclosed Drives*

ANSI/AGMA 6009:2000, *Standard for Gearmotor, Shaft Mounted, and Screw Conveyor Drives*

ANSI/AGMA 9002:2001, *Bores and Keyways for Flexible Couplings (Inch Series)*

ASA S2.19:1999 ³, *Mechanical Vibration — Balance Quality Requirements of Rigid Rotors — Part 1: Determination of Permissible Residual Unbalance, Including Marine Applications*

ASME Boiler and Pressure Vessel Code ⁴, Section V:2001, *Non-destructive Examination*

ASME Boiler and Pressure Vessel Code, Section VIII:2001, *Rules for Construction of Pressure Vessels, Division 1*

¹ American Boiler Manufacturers Association, 8221 Old Courthouse Road, Suite 207, Vienna, Virginia 22182, www.abma.com.

² American Gear Manufacturers Association, 500 Montgomery Street, Suite 350, Alexandria, Virginia 22314, www.agma.org.

³ Acoustical Society of America, 35 Pinelawn Road, Suite 114 East, Melville, NY 11747, <http://asa.aip.org>.

⁴ ASME International, 3 Park Avenue, New York, New York 10016-5990, www.asme.org.

ASME Boiler and Pressure Vessel Code, Section IX:2001, *Welding and Brazing Qualifications*

ASME B1.1:2003, *Unified Inch Screw Threads, UN and UNR Thread Form*

ASME B16.1:1998, *Cast Iron Pipe Flanges and Flanged Fittings Classes 25, 125, and 250*

ASME B16.5:2003, *Pipe flanges and flanged fittings NPS 1/2 through NPS 24*

ASME B16.11:2001, *Forged Fittings Socket Welding and Threaded*

ASME B16.42:1998, *Ductile Iron Pipe Flanges and Flanged Fittings Classes 150 and 300*

ASME B16.47:1996, *Large Diameter Steel Flanges NPS 26 Through NPS 60*

AWS D1.1:2003 ⁵, *Structural Welding Code — Steel*

DIN 910:2004 ⁶, *Heavy-duty Hexagon Head Screw Plugs*

EN 287:1997 (all parts) ⁷, *Qualification Test of Welders — Fusion Welding*

EN 288:1997 (all parts), *Specification and Approval of Welding Procedures for Metallic Materials*

EN 13445:2002 (6 parts), *Unfired Pressure Vessels*

HI 6.6:2000 ⁸, *Reciprocating Pump Tests*

HI 8.1-8.5:2000, *Direct Acting (Steam) Pumps — Nomenclature, Definitions, Applications, and Operation*

IEC 60034 (all parts: latest editions published prior to June 1, 2004) ⁹, *Rotating Electrical Machines*

IEC 60079 (all parts: latest editions published prior to June 1, 2004), *Electrical Apparatus for Explosive Gas Atmospheres*

IEEE 841:2001 ¹⁰, *Standard for the Petroleum and Chemical Industry — Severe Duty Totally Enclosed Fan-cooled (TEFC) Squirrel Cage Induction Motors — Up To and Including 370 kW (500 hp)*

ISO 7; part 1:1994; part 2: 2000 ¹¹, *Pipe Threads Where Pressure-tight Joints are Made On the Threads*

ISO 228-1:2000, *Pipe Threads Where Pressure-tight Joints are Not Made On the Threads — Part 1: Dimensions, Tolerances And Designation*

ISO 261:1998, *ISO General-purpose Metric Screw Threads — General Plan*

ISO 262:1998, *ISO General-purpose Metric Screw Threads — Selected Sizes for Screws, Bolts, and Nuts*

ISO 281:1990; Amendment 1:2000; Amendment 2:2000, *Rolling Bearings. Dynamic Load Ratings, and Rating Life*

⁵ American Welding Society, 550 NW LeJeune Road, Miami, Florida 33126, www.aws.org.

⁶ Deutsches Institut für Normung E.V., Burggrafenstrasse 6, 10787 Berlin, Germany.

⁷ European Committee for Standardization, Avenue Marnix 17, B-1000, Brussels, Belgium, www.cen.eu.

⁸ Hydraulic Institute, 6 Campus Drive, First Floor North, Parsippany NJ, 07054-4406, www.pumps.org.

⁹ International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, CH-1211, Geneva 20, Switzerland, www.iec.ch.

¹⁰ Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, New Jersey 08854, www.ieee.org.

¹¹ International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, www.iso.org.

ISO 286-2:1998, *ISO System of Limits and Fits — Part 2: Tables of Standard Tolerance Grades and Limit Deviations For Holes and Shafts*

ISO 724:1993, *ISO General-purpose Metric Screw Threads — Basic Dimensions*

ISO 965:2000 (5 parts), *ISO General-purpose Metric Screw Threads — Tolerances*

ISO 1328-1:1995, *Cylindrical Gears — ISO System of Accuracy — Part 1: Definitions and Allowable Values of Deviations Relevant To Corresponding Flanks of Gear Teeth*

ISO 1940-1:2003, *Mechanical Vibration — Balance Quality Requirements of Rigid Rotors — Part 1: Determination of Permissible Residual Imbalance*

ISO 3448:1992, *Industrial Liquid Lubricants — ISO Viscosity Classification*

ISO 3744, *Acoustics — Determination of Sound Power Levels of Noise Sources Using Sound Pressure — Engineering Method in an Essentially Free Field Over a Reflecting Plane*

ISO 5753:1991, *Rolling bearings — Radial Internal Clearance*

ISO 6708:1995, *Pipework Components — Definition and Selection of DN (nominal size)*

ISO 7005-1:1992, *Metallic Flanges — Part 1: Steel Flanges*

ISO 7005-2:1998, *Metallic Flanges — Part 2: Cast Iron Flanges*

ISO 8501-1:1988 (supplement:1994), *Preparation of Steel Substrates Before Application of Paints and Related Products — Visual Assessment Of Surface Cleanliness — Part 1: Rust Grades and Preparation Grades of Uncoated Steel Substrates and of Steel Substrates After Overall Removal of Previous Coatings*

ISO 10438:2003 (all parts), *Petroleum and Natural Gas Industries — Lubrication, Shaft-sealing and Control-oil Systems and Auxiliaries*

ISO 15649:2001, *Petroleum and Natural Gas Industries — Piping*

NACE MR0175/ISO15156:2003 (3 parts) ¹², *Petroleum and Natural Gas Industries — Materials for Use in H₂S-Containing Environments In Oil and Gas Production*

NFPA 70:2002 ¹³, *National Electrical Code*

SSPC SP 6:2000 ¹⁴, *Commercial Blast Cleaning*

2.2 All referenced standards, to the extent specified in the text, are normative.

2.3 Notes following a paragraph are informative.

2.4 The editions of standards, codes, and specifications that are in effect at the time of 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 inquiry shall be mutually agreed upon by the Purchaser and the Vendor.

¹² NACE International (formerly the National Association of Corrosion Engineers), 1440 South Creek Drive, Houston, Texas 77218-8340, www.nace.org.

¹³ National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169-7471, www.nfpa.org.

¹⁴ The Society for Protective Coatings, 40 24th Street, 6th Floor, Pittsburgh, Pennsylvania 15222, www.sspc.org.

3 Terms and Definitions

For the purposes of this document, the following definitions apply.

3.1

acoustical simulation

Process whereby the acoustical characteristics of fluids and the reciprocating pump dynamic flow influence are modeled.

3.2

alarm point

Preset value of a measured parameter at which an alarm is activated to warn of a condition that requires corrective action.

3.3

anchor bolt

Bolt used to attach the mounting plate to the support structure (concrete foundation or steel structure).

Refer to 3.6 for definition of hold down bolt.

3.4

direct-acting pump

Reciprocating pump consisting of a piston-powered drive end connected directly to a liquid end to which power is directly transmitted by the action of the motive fluid on the piston.

NOTE A direct-acting pump may use steam, air, or gas as the motive fluid.

3.5

flammable liquid

Liquid that has a closed-cup flash point below 37.8 °C (100 °F), as determined by recommended test procedures and apparatus.

NOTE Suitable test procedures are e.g., those set forth in NFPA 30.

3.6

hold down bolt

mounting bolt

Bolt holding the equipment to the mounting plate.

3.7

inlet reference point

Position, upstream of any pulsation suppression device, at which the Purchaser's connection is made.

NOTE Point at which the specified inlet conditions, such as inlet pressure, inlet temperature, and NPIP apply.

3.8

local

<of a device>

Mounted on the equipment mounting plate.

3.9

maximum allowable speed

Highest speed permitted by the Manufacturer's design for continuous operation.

NOTE cf. speed (3.40).

3.10**maximum allowable temperature**

Maximum continuous liquid temperature permitted by the Manufacturer's design when handling the specified liquid at the specified maximum operating pressure.

3.11**maximum allowable working pressure (MAWP)**

Maximum continuous pressure permitted by the Manufacturer's design when handling the specified liquid at the specified maximum operating temperature.

3.12**maximum continuous speed**

Highest speed at which the machine, as built and tested, is capable of continuous operation with the specified liquid at each of the specified operating conditions.

NOTE cf. speed (3.40).

3.13**minimum allowable liquid temperature**

Lowest liquid temperature permitted by the Manufacturer's design.

3.14**minimum allowable speed**

Lowest speed at which the Manufacturer's design permits continuous operation.

NOTE This is measured in revolutions per minute for power pumps and strokes per minute for direct acting pumps.

3.15**mounting plate**

Baseplate, skid, or soleplate on which the equipment is mounted.

NOTE See 7.4 for mounting plate specifications.

3.16**net positive inlet pressure****NPIP**

Minimum instantaneous pressure determined at the pump inlet reference point during pulsating pressure, minus the vapor pressure of the liquid at the maximum operating temperature.

3.17**net positive inlet pressure available****NPIPA**

NPIP determined by the Vendor from the NPSHA and system data.

3.18**net positive inlet pressure required****NPIPR**

Minimum NPIP required by the pump to achieve the required performance with the specified liquid.

3.19**NPIPR test**

Running test conducted to validate the NPIPR.

3.20**net positive suction head****NPSH**

Total absolute suction pressure determined at the underside of the mounting plate, minus the vapor pressure of the liquid.

NOTE It is expressed as head of water, in meters (ft).

3.21**net positive suction head available****NPSHA**

Minimum value of NPSH determined to be available under any specified operating condition at the underside of the mounting plate, based on steady state flow.

NOTE NPSHA is a value provided by the Purchaser and which the Supplier will use to calculate the NPIPA (see 3.17). NPSHA is a function only of the system upstream of the pump and the operating conditions, and is independent of pump design.

3.22**observed [test]**

Inspection [test] for which the Purchaser is notified of the timing, and the inspection [test] is performed as scheduled irrespective of whether the Purchaser or Purchaser's representative is present.

3.23**panel**

Enclosure used to mount, display and protect gauges, switches and other instruments.

3.24**performance test**

Running test conducted to confirm the pump's mechanical and volumetric efficiency.

3.25**piston pump**

Reciprocating pump having a seal attached to the piston and moving within a cylinder.

3.26**piston load****plunger load**

Force acting on one piston or plunger during any portion of the pumping cycle.

3.27**plunger pump**

Reciprocating pump having a uniform-section plunger that moves in a static seal.

3.28**power pump**

Reciprocating pump consisting of a power end and a liquid end connected by a frame or distance piece.

NOTE 1 The power end of a power pump transmits energy from a rotating shaft to pistons or plungers by means of a crankshaft, connecting rods, and crossheads.

NOTE 2 The liquid end of a power pump consists of the cylinders, the pistons or plungers, and the valves.

3.29**preliminary anticipated system acceleration head**

The estimated pressure change due to changes in velocity in the piping system.

NOTE This is an important factor in the application of reciprocating pumps because of the pulsating nature of the flow in the pump suction line. For additional information on acceleration head, refer to Hydraulic Institute standards. For additional information on acceleration head, see Annex E.

3.30**pressure-containing part**

Part that acts as a barrier between process or motive fluid and the atmosphere

EXAMPLE Liquid cylinder, discharge manifold, suction manifold, the stuffing box, cylinder plugs and covers (when in contact with process fluid), valve seats (when a portion is in contact with the atmosphere), the power cylinder, the gas cylinder head, the valve chest, and the valve chest cover and heads.

3.31**pressure-limiting valve accumulation pressure**

Pressure at which a pressure-limiting valve discharges the pump rated flow.

3.32**pressure-limiting valve set pressure**

Pressure at which a pressure-limiting valve starts to release pressure.

3.33**pressure-retaining part**

Part whose failure would allow process or motive fluid to escape to the atmosphere.

EXAMPLE Liquid and gas cylinder bolting, stuffing box bolting, gland bolting, glands, and covers that constrain plugs and valve stops, but not parts such as packing, gaskets, pistons, plungers, piston rings, rods, valves, seats (when completely surrounded by pressure-containing parts), and internal bolting.

3.34**pump efficiency****pump mechanical efficiency**

Ratio of the pump's hydraulic power to its power input.

3.35**Purchaser**

Issuer of the order and specification to the Vendor.

NOTE The Purchaser can be the Owner of the plant in which the equipment is to be installed or the Owner's appointed agent.

3.36**rated flow**

Total volume of liquid actually delivered per unit time at rated operating conditions normalized to inlet conditions.

NOTE Rated flow includes liquid and any dissolved or entrained gasses or solids specified.

3.37**remote**

<of a control device>

When located away from the equipment or console, typically in a control room.

3.38**shutdown set point**

Preset value of a measured parameter at which automatic or manual shutdown of the system or equipment is required.

3.39**special tool**

Tool that is not commercially available, e.g. from a catalogue.

3.40**speed**

<power pump>

Number of revolutions of the crankshaft in a given unit of time.

NOTE It is expressed as revolutions per minute.

speed

<direct acting pump>

Number of strokes of the piston in a given unit of time.

NOTE It is expressed in strokes per minute.

3.41**unit responsibility**

Responsibility for coordinating the documentation, delivery, and technical aspects of the equipment and all auxiliary systems included in the scope of the order.

NOTE The technical aspects to be considered include, but are not limited to, such factors as the power requirements, speed, rotation, general arrangement, couplings, dynamics, noise, lubrication, sealing system, material test reports, instrumentation, piping, conformance to specifications and testing of components.

3.42**Vendor****Supplier**

Manufacturer or Manufacturer's agent that supplies the equipment and is normally responsible for service support.

3.43**volumetric efficiency**

Ratio of the pump rated flow to the total piston or plunger displacements per unit time.

NOTE Volumetric efficiency is normally expressed as a percentage.

3.44**witnessed [test]**

Inspection [test] for which the Purchaser is notified of the timing of the inspection [test] and a hold is placed on the inspection [test] until the Purchaser or his representative is in attendance.

4 General**4.1 Units of Measurement**

Drawings and maintenance dimensions of pumps shall be in SI units or U.S. Customary (USC) units. Use of an ISO Standards datasheet (e.g. Annex D, Figure D.1) indicates SI units shall be used. Use of a USC datasheet (e.g. Annex D, Figure D.2) indicates USC units shall be used.

4.2 Subvendor control

The Vendor who has unit responsibility shall ensure that all Subvendors comply with the requirements of the International Standard.

5 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.

6 Basic Design

6.1 General

6.1.1 The equipment (including auxiliaries, but excluding normal maintenance and wear parts as identified in Table 1) shall be designed and constructed for a minimum service life of 20 years and at least 3 years of uninterrupted operation.

It is recognized that these requirements are design criteria, and that service or duty severity, misoperation, or improper maintenance can result in a machine failing to meet these criteria.

The term 'design' shall apply to parameters or features of the equipment supplied by the Manufacturer. The term 'design' should not be used in the Purchaser's enquiry or specification because it can cause confusion in understanding the order.

Table 1—Maintenance and Wear Parts

Item	Life (months)
Packings	4 to 12
Valves	9 to 24
Valve Seats	9 to 24
Plungers	12 to 36
NOTE The Purchaser and Vendor should discuss the frequency of replacement of these parts at the time of inquiry to determine the value added using life cycle cost analysis, delivery, and parts availability.	

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 shall specify the normal operating point and all other required operating points.

6.1.4 Equipment driven by fixed-speed induction motors shall be rated at the actual motor speed for the rated load condition.

- **6.1.5** Control of the sound pressure level (SPL) of all equipment supplied shall be a joint effort of the Purchaser and the Vendor having unit responsibility. The equipment supplied by the Vendor shall conform to the maximum allowable sound pressure level specified. In order to determine compliance, the Vendor shall provide both maximum sound pressure and sound power level data per octave band for the equipment.

6.1.6 Unless otherwise specified, cooling water system or systems shall be designed for the following conditions given in Table 2.

Table 2—Cooling Water System Design Requirements

	SI Units	US Customary Units
Velocity over heat exchange surfaces	1.5 m/sec to 2.5 m/sec	5 f/sec to 8 f/sec
Maximum allowable working pressure (MAWP), gauge pressure	≥ 7.0 barg	≥ 100 psig
Test pressure (≥ 1.5 MAWP)	≥ 10.5 barg	≥ 150 psig
Maximum pressure drop	1 bar	15 psi
Maximum inlet temperature	30 °C	90 °F
Maximum outlet temperature	50 °C	120 °F
Maximum temperature rise	20 K	30 °F
Minimum temperature rise	10 K	20 °F
Fouling factor on water side	0.35 m ² K/kW	0.002 hr-ft ² -°F/BTU
Shell corrosion allowance	3 mm	1/8 in.
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. If such a conflict exists, the Purchaser will approve the final selection. NOTE To avoid condensation, the minimum inlet water temperature to water-cooled bearing housings should preferably be above the ambient air temperature.		

6.1.7 Provision shall be made for complete venting and draining of the pump and systems provided by the Vendor.

6.1.8 Equipment shall be selected to run to the pressure-limiting accumulation pressure and at trip speed without suffering damage.

NOTE There might be insufficient driver power to operate under these conditions.

6.1.9 For direct driven equipment the equipment's maximum continuous operating speed shall be not less than 105 % of the rated speed for variable speed machines and shall be equal to the rated speed for constant speed motor drives.

6.1.10 For gear-driven equipment the gearbox input shaft maximum continuous operating speed shall not be less than 105 % of the rated speed for variable speed machines and shall be equal to the rated speed for constant speed motor drives.

6.1.11 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.

6.1.12 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 the applicable sections of IEC 60079, or NFPA 70, Articles 500, 501, 502, 504, and 505 as specified, as well as any local codes specified and supplied by the Purchaser.

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

6.1.14 All equipment shall be designed to permit rapid and economical maintenance. Major parts such as cylinder components and bearing housings shall be designed to ensure accurate alignment on reassembly. This may be accomplished by the use of shouldering, cylindrical dowels, or keys.

6.1.15 The equipment (machine, driver, and auxiliary equipment) shall perform on the test stand and on its permanent foundation within the specified test tolerances (see 8.3.6). After installation, the performance of the combined units shall be the joint responsibility of the Purchaser and the Vendor who has unit responsibility. The Vendor shall review and comment on the Purchaser's piping and foundation drawings in order to minimize adverse effects.

NOTE Many factors can adversely affect performance of the pump at site. These factors include piping layout, piping connection loads, alignment at operating conditions, support structure, handling during shipment and handling and assembly on site.

- **6.1.16** The equipment, including all auxiliaries, shall be suitable for operation under the environmental conditions specified by the Purchaser. The environmental conditions shall include whether the installation is indoors (heated or unheated) or outdoors (with or without a roof), maximum and minimum temperatures, unusual humidity, dusty, or corrosive conditions, and with available utilities.

6.1.17 Spare and replacement parts for the machine and all supplied auxiliaries shall meet all the criteria of this standard.

6.1.18 Bolting shall conform to 6.1.18.a) through 6.1.18.f).

- a) Details of threading shall conform to ISO 261, ISO 262, ISO 724, and ISO 965, or to ASME B1.1.
- b) Adequate clearance shall be provided at all bolting locations to permit the use of socket spanners (wrenches).
- c) External or internal hexagon head bolting is required unless otherwise agreed.
- d) Mounting bolts shall be not less than 12 mm (0.5 in.) diameter.
- e) Manufacturer's markings shall be located on all fasteners 6mm (¹/₄ in.) and larger (excluding washers and headless screws). For studs, the marking shall be on the nut end of the exposed stud end.

NOTE A set screw is a headless screw with an internal hex opening on one end.

- f) Metric fine and UNF threads shall not be used.

6.1.19 Mounting surfaces shall meet the following criteria.

- a) They shall be machined to a finish of 6.3 μm (250 $\mu\text{in.}$) arithmetic average roughness (Ra) or smoother.
- b) To prevent a soft foot, they shall be in the same horizontal plane within 25 μm (0.001 in.).
- c) Each mounting surface shall be machined within a flatness of 1:24,000. Corresponding surfaces shall be in the same plane within 150 $\mu\text{m/m}$ (0.002 in./ft).
- d) The upper machined or spot faced surface shall be parallel to the mounting surface.

6.1.20 Glands shall be bolted or threaded to the stuffing box. Gland studs shall pass through holes (not slots) in the gland. Axially-split glands shall be bolted together. Threaded gland bolts in slots are not acceptable.

6.2 Selection of Pump Type

6.2.1 Unless otherwise specified a piston pump shall not be used in applications requiring continuous operation where the differential pressure across the piston is in excess of 15 MPa (150 bar) (2175 psi).

NOTE Operation above these pressures may result in a significant reduction in piston seal and liner life and some reduction in pump performance (due to piston seal leakage).

6.3 Ratings

6.3.1 Table 3 and Table 4 represent the maximum allowable speed ratings for reciprocating pumps in continuous service.

Table 3—Speed Ratings for Power Pumps in Continuous Service

Stroke Length		Speed Rating	
		r/min	
mm	(in.)	Single-acting Pumps	Double-acting Piston-type Pumps
50	(2)	450	140
75	(3)	400	127
100	(4)	350	116
125	(5)	310	108
150	(6)	270	100
175	(7)	240	94
200	(8)	210	88
250	(10)	168	83
300	(12)	140	78
350	(14)	120	74
400	(16)	105	70

For single-acting plunger pumps with five or more cylinders, speeds may be increased by 20 % for continuous operation. For light and intermittent duties (up to 6 h per day), speeds up to 10 % higher are permissible.

Table 4—Speed Ratings for Direct-Acting Pumps in Continuous Service

Stroke Length		Speed Rating
mm	(in.)	Strokes per Minute
100	(4)	52
150	(6)	44
200	(8)	38
250	(10)	34
300	(12)	30
350	(14)	28
400	(16)	26
450	(18)	24
500	(20)	22
600	(24)	20



NOTE 1 Factors such as viscosity, specific gravity, abrasiveness, vapor pressure, gas solubility or evolution in the pumped liquid, specified pressures and temperatures, or system acceleration (resulting NPIP) head may require further speed limitations.

NOTE 2 For installations where the NPIPA is less than 0.15 bar (2.25 psi) above the NPIPR consideration should be given to speeds lower than those in Table 3 and Table 4.

6.3.2 Refer to Figure 1 when using plug and plate valves in services in which the kinematic viscosities are above 65 mm² (65 cSt) (300 Saybolt Seconds Universal) at pumping temperatures. For other valve designs, refer to Manufacturer's data. The speeds given in Table 3 and Table 4 shall be reduced using the correction factors given in Figure 1. These corrections apply only to pumps with plate and plug valves; for other valve designs, refer to Manufacturers' data.

NOTE The correction factors apply only above 65 mm²/s (65 cSt).

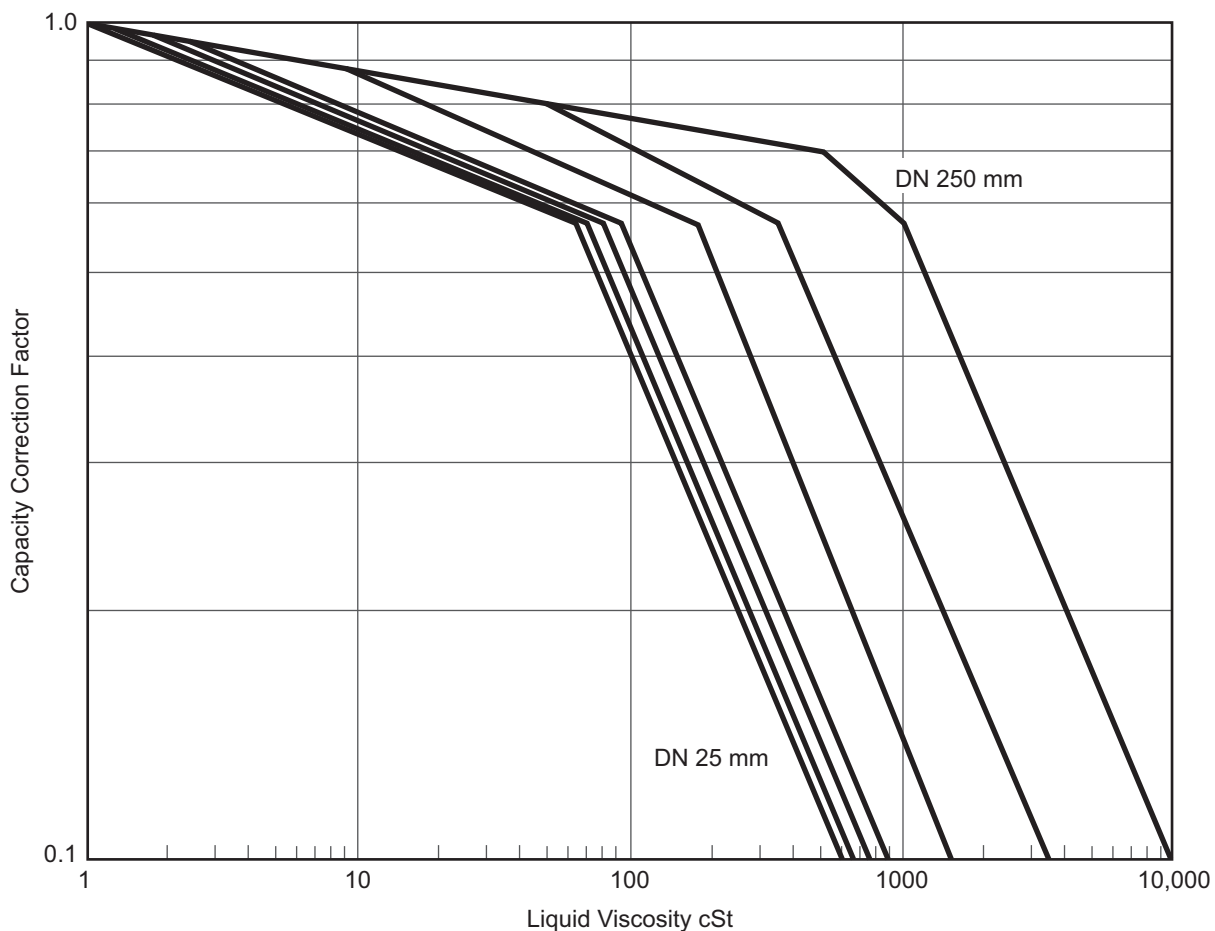


Figure 1—Kinematic Viscosities

- **6.3.3** The Purchaser shall supply liquid properties. Based on these properties, the Vendor shall state the volumetric efficiency.

6.3.4 In the determination of power-pump power requirements, the value of pump efficiency used shall be that value determined by the Vendor for the specified operating conditions.

NOTE The power requirement is used for driver sizing.

6.3.5 For power pumps, the Vendor shall include in the proposal the rated and maximum allowable continuous piston or plunger load. The allowable peak or momentary load, if different from the continuous rating, shall also be specified.

6.3.6 For direct-acting piston pumps, without liquid end tail rods, the Vendor shall include in the proposal the maximum process liquid outlet stall pressure, the maximum of the two values calculated as follows:

$$p_{st} = \frac{(d_m^2 \times p_m) + ((d_p^2 - d_r^2) \times p_1) - ((d_m^2 - d_r^2) \times p_e)}{d_p^2}$$

$$p_{st} = \frac{(d_p^2 \times p_1) + ((d_m^2 - d_r^2) \times p_m) - (d_m^2 \times p_e)}{d_p^2 - d_r^2}$$

where

- d_m is the motive piston diameter,
- d_p is the liquid end piston or plunger diameter,
- d_r is the rod diameter,
- p_e is the lowest motive fluid exhaust pressure,
- p_m is the highest motive fluid supply pressure,
- p_1 is the highest process liquid inlet pressure,
- p_{st} is the maximum process liquid outlet stall pressure.

NOTE Direct-acting pumps may require protection by pressure-limiting valves, in the process liquid and motive fluid circuits, if pressures greater than design can occur.

6.3.7 For direct-acting plunger pumps, without liquid end tail rods, the Vendor shall include in the proposal the maximum process liquid outlet stall pressure, the maximum of the two values calculated as follows:

$$p_{st} = \frac{(d_m^2 \times p_m) - ((d_m^2 - d_r^2) \times p_e)}{d_p^2}$$

$$p_{st} = \frac{(d_p^2 \times p_1) + [(d_m^2 - d_r^2) \times p_m] - (d_m^2 \times p_e)}{d_p^2 - d_r^2}$$

where

- d_m is the motive piston diameter,
- d_p is the liquid end piston or plunger diameter,
- d_r is the rod diameter,
- p_e is the lowest motive fluid exhaust pressure,
- p_m is the highest motive fluid supply pressure,
- p_{st} is the maximum process liquid outlet stall pressure.

NOTE Direct-acting pumps may require protection by pressure-limiting valves, in the process liquid and motive fluid circuits, if pressures greater than design can occur.

6.4 Pressure-Containing and Pressure-Retaining Parts

6.4.1 The pressure-containing parts shall be designed in accordance with 6.4.1.1 (or 6.4.1.2, as selected by the Vendor) and 6.4.1.3 to achieve the following:

a) operate without leakage or internal contact between rotating and stationary components (other than bearings and seals) while subject simultaneously to the MAWP (and corresponding temperature) and the worst case combination of maximum allowable nozzle loads applied to all nozzles;

b) withstand the hydrostatic test.

6.4.1.1 The allowable tensile stress used in the design of the pressure-containing parts for any material shall not exceed 0.25 times the minimum ultimate tensile strength for that material at the maximum specified operating temperature and, for castings, multiplied by the appropriate casting factor for the type of non-destructive examination (NDE) as given in Table 5. The Manufacturer shall state which material specification is being used as the source of the material properties, see Annex A, as well as the casting factors applied.

Table 5—Casting Factors

Type of NDE	Casting factor
Visual, magnetic particle, and/or liquid penetrant	0.8
Spot radiography	0.9
Ultrasonic	0.9
Full radiography	1.0
NOTE Application of these criteria seldom results in ultimate tensile strength or yield strength governing the design; fatigue strength usually governs the design.	

6.4.1.2 Pressure-containing parts may be designed with the aid of finite-element analysis. The value of the stress intensity and deflections shall be assessed for acceptability at 150 % of MAWP. The allowable tensile stress used in the design of the pressure components for any material shall not exceed 0.25 times the minimum ultimate tensile strength for that material at the maximum specified operating temperature.

6.4.1.3 The allowable stress for bolts shall be used to determine the total bolting area based on hydrostatic load and gasket preload, as applicable. The preload stress shall not exceed 0.75 times the bolting material minimum yield strength.

NOTE Preloading is performed to prevent bolt fatigue failure under cyclic loading.

6.4.2 The pressure-limiting valve accumulation pressure shall not exceed the maximum allowable working pressure of the cylinder and shall not exceed 110 % of the specified pressure-limiting valve set pressure.

6.4.3 Cylinders and other pressure-retaining parts and supports shall be designed to prevent detrimental distortion caused by the worst combination of temperature, pressure, torque, and allowable external forces and moments based on the specified operating conditions.

6.4.4 The use of threaded holes in pressure-retaining parts shall be minimized. To prevent leakage in these parts, metal, equal in thickness to at least half the nominal bolt diameter, in addition to the allowance for corrosion, shall be left around and below the bottom of drilled and threaded holes. The depth of the threaded holes shall be at least 1.5 times the stud diameter.

6.4.5 Jackscrews, guide rods, cylindrical alignment dowels, and/or appropriate devices shall be provided to facilitate disassembly, if required by pump design. Guide rods shall be of sufficient length to prevent damage to the internals or studs during disassembly and reassembly. If jackscrews are used as a means of parting contacting faces, one of the faces shall be relieved (counter-bored or recessed) to prevent a leaking joint or an improper fit caused by marring of the face.

6.4.6 If cooling of cylinders is necessary, separate non-interconnecting jackets are required for cylinder bodies and cylinder heads. The cylinder cooling system shall be designed to positively prevent process fluid from leaking into the coolant.

6.5 Cylinder Connections

6.5.1 Openings for all piping connections on cylinders shall be standard pipe sizes equal to DN 20 (NPS $\frac{3}{4}$) or larger and shall be in accordance with ISO 6708. The following sizes shall not be used: sizes DN 32, DN 65, DN 90, DN 125, DN 175, and DN 225 (NPS $1\frac{1}{4}$, NPS $2\frac{1}{2}$, NPS $3\frac{1}{2}$, NPS 5, NPS 7, and NPS 9).

6.5.2 All process connections shall be flanged or machined and studded, except where threaded connections are permitted by 6.5.5. All connections shall be suitable for the maximum allowable working pressure as defined in 3.11. Main inlet and outlet process connections shall be oriented as specified. Connections shall be integral with the cylinder or, for cylinders of weldable material, may be welded if agreed by the Purchaser and the Vendor.

6.5.3 Connections welded to the cylinder shall meet the material requirements of the cylinder, including impact values, rather than the requirements of the connected piping [see 6.11.6.4d)]. All welding of connections shall be completed before the cylinder is hydrostatically tested (see 8.3.2).

6.5.4 Butt welded connections, size DN 40 (NPS $1\frac{1}{2}$) and smaller, shall be reinforced by using forged welding inserts or gussets.

6.5.5 For connections other than main process connections, if flanged or machined and studded openings are impractical, threaded connections for pipe sizes not exceeding DN 40 ($1\frac{1}{2}$ NPS) may be used with Purchaser's approval as follows:

- a) on non-weldable materials, such as cast iron;
- b) if essential for maintenance (disassembly and assembly).

6.5.6 Pipe nipples screwed or welded to the cylinders should not be more than 150 mm (6 in.) long and shall be a minimum of Schedule 160 seamless for sizes DN 25 (NPS 1) and smaller and a minimum of Schedule 80 for DN 40 (NPS $1\frac{1}{2}$).

6.5.7 The nipple and flange materials shall meet the requirements of 6.5.3.

6.5.8 Unless otherwise specified, pipe threads shall be tapered threads conforming to ISO 7-1. Openings and bosses for pipe threads shall conform to ASME B16.5.

NOTE For purposes of this provision, ASME B1.20.1 is equivalent to ISO 7-1.

6.5.9 If specified, cylindrical threads conforming to ISO 228-1 shall 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.

6.5.10 Machined and studded connections that connect to the Purchaser's piping require specific Purchaser approval. If approved, they shall conform to the facing and drilling requirements of ISO 7005-1, 7005-2, or ASME

B16.1, B16.5, B16.42, B16.47, as specified. Studs and nuts shall be provided installed, and the first 1.5 threads at both ends of each stud shall be removed.

6.5.11 Threaded connections shall not be seal welded.

6.5.12 Threaded openings not connected to piping shall be plugged. Taper-threaded plugs shall be long-shank solid round-head, or long-shank hexagon-head bar stock plugs in accordance with ASME B16.11. If cylindrical threads are specified, plugs shall be solid hexagon-head plugs in accordance with DIN 910. These plugs shall meet the material requirements of the pressure cylinder. A lubricant that is suitable for the contained fluid and for the service temperature shall be used on all threaded connections. Thread tape shall not be used. Plastic plugs shall not be used.

6.5.13 There shall be no openings (other than suction or discharge ports) in the pumping chamber sides of the liquid end or in other highly stressed areas subject to cyclic loading unless they are essential for pump operation or performance monitoring.

6.5.14 Flanges:

6.5.14.1 Flanges shall conform to ISO 7005-1:1992, Series 1, including Annex D and E, or 7005-2 Series 1 or ASME B16.1, B16.5, B16.42, or B16.47 Series B, as specified.

NOTE 1 ISO 7005-1 (steel flanges) PN 20, 50, 110, 150, 260, 420 are designed to be interchangeable with ASME B16.5 and MSS SP-44 flanges – ISO 7005-1 flanges are not identical to ASME B 16.5 and MSS SP 44 flanges but are deemed to comply with the dimensions specified in the ASME B 16.5 and MSS SP 44.

ISO 7005-2 (cast iron) flanges PN 20, 50 are designed to be interchangeable with ANSI/ASME B16.1 (gray cast iron) and B 16.42 (ductile cast iron) but they are not identical. They are deemed to comply with dimensions specified in ASME B16.1 (gray cast iron) and B 16.42 (ductile cast iron).

NOTE 2 ISO PN 2.5 and 6 do not have a corresponding ASME class and ASME Class 75, 400, and 800 do not have corresponding ISO PN designation. The use of these PN and Class flange ratings are therefore not recommended.

6.5.14.2 If ISO 7005-1 has been specified, materials shall be in accordance with ISO 7005-1:1992, Table D.1 (DIN) or Table D.2 (ASTM), as specified. The pressure/temperature ratings in ISO 7005-1:1992, Annex E shall correspond to the materials specified.

NOTE ISO 7005-1:1992, Tables E.1 to E.4 cover materials in Table D.1 and Table E.5 to E.21 covers materials in Table D.2.

- **6.5.14.3** If specified, ASME B 16.47 Series A flanges shall be provided.

6.5.14.4 Cast iron flanges shall be flat-faced and, except as noted in 6.5.14.5, conform to the dimensional requirements of ISO 7005-2 and the flange finish requirements of ASME B16.1 or B16.42. Class 125 flanges shall have a minimum thickness equal to Class 250 for sizes DN 200 (NPS 8) and smaller.

6.5.14.5 Flanges other than those covered in 7005-2 shall conform to the dimensional requirements of 6.5.14.1.

6.5.14.6 Flat-face flanges with full raised-face thickness are acceptable on cylinders of all materials. Flanges in all materials that are thicker or have a larger outside diameter than required by ISO or ASME are acceptable. Non-standard (oversized) flanges shall be completely dimensioned on the arrangement drawing. If oversized flanges require studs or bolts of non-standard length, this requirement shall be identified on the arrangement drawing.

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

6.5.14.8 Machined and studded connections and flanges that connect to the Purchaser's piping and which are not in accordance with ISO 7005-1 or 7005-2 or ASME B16.1, B16.5, B16.42, or B16.47 require Purchaser's approval. Unless otherwise specified, the Vendor shall supply mating flanges, studs, and nuts for these nonstandard connections.

6.5.14.9 To minimize nozzle loading, and facilitate installation of piping, machine flanges shall be parallel, or perpendicular, to the plane shown on the general arrangement drawing to within plus or minus 0.5 degrees. Studs or bolt holes shall straddle centerlines parallel to the main axes of the equipment.

6.5.14.10 All of the Purchaser's connections shall be accessible for disassembly without requiring the machine, or any major part of the machine, to be moved.

6.5.14.11 For all steel flanges, imperfections in the flange facing finish shall not exceed that permitted in ASME B 16.5 or ASME 16.47, as applicable.

6.5.14.12 The concentricity of the bolt circle and the bore of all flanges shall be such that the area of the machined gasket-seating surface is adequate to accommodate a complete standard gasket without protrusion.

6.6 External Forces and Moments

The Vendor shall specify, in the quotation, the magnitude of forces and moments which may be applied, simultaneously, to the inlet and outlet connections at the rated operating conditions.

Pumps shall be designed for satisfactory performance if subjected to the forces and moments in Table 6.

Table 6a—Forces and Moments on Process Connections (SI)

Pipe size (DN)	Forces		Moments	
	$F_{[x,y,z]}$ max (N)	$F_{[total]}$ max (N)	$M_{[x,y,z]}$ max (Nm)	$M_{[total]}$ max (Nm)
40	255	360	115	170
50	295	420	145	210
80	425	600	215	315
100	505	720	260	385
125	610	870	325	480
150	720	1020	385	565
200	930	1320	500	735
250	1140	1620	625	920
300	1355	1920	740	1090
350	1565	2220	865	1270
400	1775	2520	980	1445
450	1980	2815	1095	1615
500	2200	3125	1220	1795
NOTE $F_{[total]} = \sqrt{F_x^2 + F_y^2 + F_z^2}$ and $M_{[total]} = \sqrt{M_x^2 + M_y^2 + M_z^2}$ Values shown indicate a range, – value to + value.				

Table 6b—Forces and Moments on Process Connections (US Customary)

Pipe size (in.)	Forces		Moments	
	$F_{[x,y,z]}$ max (lbf)	$F_{[total]}$ max (lbf)	$M_{[x,y,z]}$ max (ft-lbf)	$M_{[total]}$ max (ft-lbf)
1½	57	81	85	125
2	66	94	107	155
3	96	135	159	232
4	114	162	192	284
5	137	196	240	354
6	162	229	284	417
8	209	297	367	542
10	256	364	461	679
12	305	432	546	804
14	352	499	638	937
16	399	567	723	1066
18	455	633	808	1191
20	495	703	890	1324

NOTE $F_{[total]} = \sqrt{F_x^2 + F_y^2 + F_z^2}$ and $M_{[total]} = \sqrt{M_x^2 + M_y^2 + M_z^2}$
 Values shown indicate a range, – value to + value.

6.7 Liquid End Features

6.7.1 Liners

6.7.1.1 Unless otherwise specified, piston-type liquid end non-replaceable cylinders shall be provided with liners as described in 6.7.1.2 through 6.7.1.6.

6.7.1.2 For piston diameters of 100 mm (4 in.) or less, the liner may be pressed into the cylinder.

6.7.1.3 Liners for piston diameters larger than 100 mm (4 in.) shall be attached to the cylinder by one of the following methods:

- a) flanged and bolted,
- b) clamped,
- c) held in place by jack bolts,
- d) held in place by followers and set screws.

6.7.1.4 Liners which are not pressed into the cylinder shall have gaskets or o-rings for sealing.

6.7.1.5 The liner bore shall be machined to a surface finish of 0.4 µm (16 µin.) Ra or smoother.

6.7.1.6 Replaceable cylinders shall seal at each end with a gasket or o-ring and have an inside diameter finished to 0.4 µm (16 µin.) Ra or smoother.

6.7.2 Pistons, Plungers, and Piston Rods

6.7.2.1 Surfaces of metallic rods or plungers in contact with packing shall be hardened or coated. All rods and plungers in contact with the packing shall have a minimum hardness of Rockwell C35. Surface finish shall be 0.4 µm

(16 $\mu\text{in.}$) Ra or smoother. When packing is supplied as complete rings that must be installed over the crosshead end of the rod or plunger, the design shall ensure that packing lips shall not be damaged by threads or shoulders.

6.7.2.2 Piston rods, both liquid and drive end, shall be of corrosion-resistant material. For direct-acting pumps, valve rods shall also be of corrosion-resistant material.

6.7.2.3 Pistons or plungers shall be secured to the rods or crossheads with locking methods suitable for the specified service conditions.

6.7.2.4 All compartments of hollow pistons or plungers shall be permanently vented.

6.7.2.5 Tail rods shall be provided if, without the tail rod, the rod load when stroking toward the liquid end exceeds two and one-half times the rod load when stroking toward the gas end.

6.7.3 Valve Seats

Valve seats shall be replaceable. For non-corrosive service, seats may be taper threaded into the cylinder.

If corrosive service is specified, seats shall be:

- a) pressed into tapers in the cylinder,
- b) pressed into valve adaptor tapers, or
- c) positively retained (e.g. by a clamp or plug).

6.7.4 Gaskets

To prevent extrusion, and for operating pressures over 2,400 mPa (24 bar) (350 psi) or temperatures over 180 °C (350 °F), cylinder and valve gaskets shall be of one-piece construction and shall be confined.

6.7.5 Stuffing Boxes, Packing, and Glands

6.7.5.1 If temperature control of the stuffing box is required to maintain the pumped fluid in the liquid phase, cooling or heating jackets are to be supplied and designed for a working gauge pressure of 700 kPa (7 bar) (100 psi).

6.7.5.1.1 Unless otherwise approved by the Purchaser, threaded glands shall be supplied.

6.7.5.1.2 Gland studs shall pass through holes (not slots) in the gland. Headed gland bolts in slots are not acceptable.

6.7.5.1.3 Axially split glands shall be bolted together.

6.7.5.1.4 Threaded glands shall be provided with gland pawls or equivalent devices to ensure positive locking.

- **6.7.5.2** If specified, or recommended by the Vendor, a flush shall be supplied to the stuffing box.

6.7.5.3 A lantern ring or throat bushing shall be provided if:

- a) the rated suction pressure is below atmospheric, a lantern ring shall be supplied to permit injection of a sealing liquid;
- b) the Vendor shall recommend the stuffing box design for the specified liquid at the specified maximum operating conditions;

NOTE Conditions that may be considered are temperature, viscosity control, particulate content of the pumped fluid, control of a hazardous pumped fluid, and environmental reasons.

c) the pumped liquid provides insufficient lubrication the packing shall be lubricated by an external liquid.

6.7.5.4 The liquid end stuffing box bore finish shall be 1.6 μm (63 $\mu\text{in.}$) 63 Ra or smoother.

6.7.5.5 If specified a liquid-tight, non-pressurized collection chamber shall be provided, with minimum DN15 (NPS $1/2$) drain and vent connections, to contain packing leakage.

- **6.7.5.6** If specified, a minimum DN6 (NPS $1/4$) purge connection shall be provided to directly purge fluid to a lantern ring positioned to minimize pumped fluid leakage to the atmosphere.

NOTE It is recognized that this purge fluid may result in increased leakage to the atmosphere. The Purchaser and the Vendor should review any potential leakage collection/containment system to ensure that all applicable environmental, health, and safety regulations are met.

6.8 Power End Running Gear

- **6.8.1** If specified, the provisions of a) to d) of this clause shall apply.

a) Crankshafts shall be wrought or cast in one piece.

b) Forced-lubrication passages in crankshafts shall be drilled.

c) Quintuplex pumps shall have a minimum of three main bearings.

d) Septuplex pumps and larger shall have a minimum of four main bearings.

6.8.2 If rolling element bearings are used, they shall have a basic rating life (L_{10h}) in accordance with ISO 281 of at least 25,000 h with continuous operation at rated conditions, and at least 16,000 h at maximum loads and rated speed.

NOTE 1 ISO 281 defines basic rating life (L_{10}) in units of millions of revolutions. Industry practice is to convert this to hours and to refer to it as L_{10h} .

NOTE 2 For the purposes of this provision, ABMA Standard 9 is equivalent to ISO 281.

6.8.2.1 Rolling element bearings shall be located, retained, and mounted in accordance with the following.

a) Bearings shall be retained on the shaft with an interference fit and fitted into the housing with a diametral clearance, both in accordance with the recommendations of ABMA Standard 7, or as recommended by the bearing Manufacturer.

b) Bearings shall be mounted directly on the shaft. Bearing carriers are acceptable only with Purchaser approval.

c) Bearings shall be located on the shaft using shoulders, collars or other positive locating devices; snap rings and spring-type washers are not acceptable.

d) The device used to lock thrust bearings to shafts shall be restricted to a nut with a tongue-type lock washer.

NOTE This subclause applies to all rolling element bearings, including both ball and roller types. For certain roller bearings, such as cylindrical roller types with separable races, bearing housing diametral clearance may not be appropriate.

6.8.2.2 Single-row deep-groove ball bearings shall have greater than normal initial internal clearance according to ISO 5753 Group 3. Single- or double-row bearings shall not have filling slots.

NOTE 1 Greater internal clearances may reduce the temperature rise of the lubricant. However, vibration velocities may be increased with greater clearances.

NOTE 2 For the purpose of this provision, ABMA 20 Group 3 is equivalent to ISO 5753 Group 3.

6.8.2.3 Ball thrust bearings shall be of the paired single row, 40° (0.7 radian) angular contact type (7000 series) with machined brass cages. Unless otherwise specified, bearings shall be mounted in a paired arrangement installed back-to-back. The need for bearing clearance or preload shall be determined by the Vendor to suit the application and meet the bearing life requirements of Table 7.

NOTE There are applications where alternate bearing arrangements may be preferable particularly where bearings operate continuously with minimal axial loads.

Table 7—Bearing Selection

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

6.8.2.4 If loads exceed the capability of paired angular contact bearings as described in 6.8.2.3, alternative rolling element arrangements may be proposed. Limits to be applied to 6.8.2.3 are as follows:

a) rolling element bearing speed:

Factor, Nd_m shall not exceed 300,000

where

d_m is the mean bearing diameter $(d + D)/2$, expressed in millimeters,

N is the rotative speed, expressed in revolutions per minute.

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

6.8.3 Crossheads on power pumps loaded in excess of 525 kW (700 hp) per cylinder shall have replaceable or adjustable shoes or guides. Crosshead bores for pumps loaded in excess of 75 kW (100 hp) per cylinder shall have renewable liners or sufficient wall thickness for re-boring.

6.8.4 The pump design shall ensure adequate lubrication of the crosshead pin bearings for all specified operating conditions, especially high inlet-pressure applications.

6.8.5 Internal or bolted-on main gearing shall be either single or double helical type, or worm gears when approved by the Purchaser, and shall be manufactured to the tolerances in accordance with ISO 1328-1 Accuracy Grade 7, or the equivalent AGMA 2015-1 Accuracy Grade. Gear ratings and service factors shall be in accordance with AGMA 6010, based on the driver nameplate rating including any driver service factor. Gear and pinion hardness combinations shall be in accordance with the recommended values in AGMA 6010. Hardness combinations of 275 HBW and 320 HBW or more are preferred for gears and pinions, respectively. The calculated values of gear rated horsepower, based on both tooth surface durability and tooth bending strength, shall be included in the Vendor's proposal.

6.8.6 The crankcase shall be a cast or fabricated enclosure that will house the crankshaft, connecting rods, crossheads, and bearings, and internal gearing when provided.

6.8.7 Sealing shall be provided at all openings in the crankcase to prevent contamination of the power end lubricant. All covers shall be gasketed and shall be sufficiently rigid to compress gaskets properly with the bolting supplied.

6.8.8 Internal gearing in the power end shall use the same oil and sump as the crankshaft and connecting-rod bearings. The power end shall be provided with a filtered vent and a DN 6 (NPS $1/4$) minimum connection for purging. An accessible valved drain DN 15 (NPS $1/2$) minimum shall be provided at the lowest point of the sump. If specified, a drilled, tapped, and plugged connection shall be provided for insertion of an oil heater.

NOTE Emissions control methods may require that the power end be pressurized to a slightly higher pressure than that in the distance piece.

6.8.9 The distance piece shall have access openings of adequate size to permit removal of the packing, stuffing box, and parts associated with the stuffing box if necessary for maintenance.

6.8.10 The distance piece shall be equipped with safety guards, louvered weather covers, or gasketed solid covers, as specified. Access openings for solid covers shall be surfaced and drilled.

6.8.11 If provided with a solid cover, the distance piece shall have a DN 15 (NPS $1/2$) minimum vent.

6.8.12 Each distance-piece compartment shall have a DN 15 (NPS $1/2$) minimum drain connection.

6.8.13 Vertical pumps that have the liquid end attached directly to the power end shall be fitted with a thermal-barrier when the liquid temperature range is liable to cause condensation in the power end.

6.9 Direct-Acting Pump

6.9.1 The power cylinder shall be designed to cushion the piston at the end of the stroke and prevent sudden deceleration and contact between reciprocating and stationary components.

6.9.2 The power cylinder shall be designed to allow a piston diameter increase of 6 mm ($1/4$ in.) minimum.

6.9.3 D-type slide valves with flat seating surfaces may be supplied for operation with steam temperatures through 260 °C (500 °F) and steam gauge pressures through 2100 kPa (21 bar) (300 psi) providing lubricant carried by the steam is adequate. Valve seating surfaces shall be capable of being re-lapped.

6.9.4 If the steam temperature is above 260 °C (500 °F) or if the steam pressure is above a gauge pressure of 2100 kPa (21 bar) (300 psi), the main steam valves shall be the radially balanced piston type with removable liners in the steam chest.

6.9.5 The power piston shall be secured to the rod with a nut. The nut shall be locked to the rod with a cotter pin or with another locking device suitable for the service.

6.9.6 Stuffing boxes, packing, and glands for air and steam shall comply with a) and b):

- a) piston-rod stuffing-box bore finish shall be 1.6 μm (63 $\mu\text{in.}$) (63 Ra) or smoother.
- b) packing requiring lubrication shall be lubricated by oil entrained in gas, by oil fed into the stuffing box on the atmospheric side of the packing, or by oil injected into a lantern ring in the stuffing box.

6.9.7 The power end may be of the non-lubricated design if the drive medium can provide sufficient lubrication, such as wet steam. Non-lubricated construction shall include a piston-type main valve, special piston rings, a honed cylinder bore, suitable rod packing, and any other feature required for non-lubricated operation.

6.10 Lubrication

6.10.1 Lubrication for Power Pumps

6.10.1.1 Unless otherwise specified, bearings and bearing housings shall be designed for oil lubrication using a mineral oil in accordance with ISO 3448.

- **6.10.1.2** If specified, or as recommended by the pump Vendor, the power end may be splash, positive pressure, or gravity lubricated. A sight glass, gauge, or oil-level dipstick shall be provided.

6.10.1.3 Unless otherwise specified, pressurized oil systems shall conform to the requirements of the General Purpose Section (Chapter 3) of ISO 10438.

NOTE For the purposes of this provision API 614, Chapter 3, is equivalent to ISO 10438-3.

- **6.10.1.4** If specified or if recommended by the Vendor and approved by the Purchaser, a pressure lubrication system shall be supplied to supply oil at a suitable pressure to the pump, the driver, and any other driven equipment, including gears.

6.10.1.5 External pressure lubrication systems shall comply with the requirements of ISO 10438-3 and with Annex G.

NOTE For the purposes of this provision API 614, Chapter 3, is equivalent to ISO 10438-3.

6.10.1.6 The oil drain piping shall be sloped 1-in-50 [20 mm/m (0.25 in./ft)].

6.10.1.7 If oil is supplied from a common system to two or more machines (such as a pump, a gear and a motor), the oil's characteristics shall be suitable for all equipment supplied. The Vendor having unit responsibility shall obtain approval of the Purchaser and the other equipment Vendors for the oil selection.

NOTE The typical lubricants employed in a common oil system are mineral (hydrocarbon) oils that correspond to ISO 3448 Grades 32 through 68.

- **6.10.1.8** If specified, the pressure lubrication system shall conform to the requirements of ISO 10438-2 (Special-Purpose Oil Systems). For such a lubrication system, datasheets should be supplied.

NOTE For the purpose of this provision, API Std 614, Chapter 2, is equivalent to ISO 10438-2.

6.10.2 Lubrication for Liquid End and Power End

6.10.2.1 If specified, a mechanical lubricator shall be supplied for stuffing box lubrication and any other points requiring lubrication.

6.10.2.2 The lubricator shall be supplied with a separate compartment for each type of lubricant required. Each lubricant compartment shall be sized for at least 30 hours of operation at the maximum expected pumping rate.

6.10.2.3 All lubricator lines shall be rated for the pressure into which the either the lubricator must pump or the lubricator pump can generate, whichever is higher.

6.10.2.4 A separate lubricant line shall be supplied for each point of lubrication, unless a divider block is supplied to meter lubricant positively to each point.

6.10.2.5 Unless otherwise specified, the lubricator shall be mounted on the pump. On power pumps, the lubricator may be mechanically driven from the crankcase driving mechanism or may be separately driven. On direct-acting pumps, the lubricator shall be ratchet driven by the pump.

6.10.2.6 For lubrication points that are under pressure, a suitable check valve shall be supplied in the lubricant line near the point of lubrication.

6.10.2.7 For injection into a liquid-end stuffing box lantern ring with packing on both sides, each lubricator feed shall be rated at least equal to pump maximum allowable working pressure.

6.10.2.8 For direct-acting pumps, when the point of lubricant entry for the gas end is in a line supplied by the Purchaser, the pump Vendor shall supply the lubricant line and check valve for field installation.

6.11 Materials

6.11.1 Material Inspection of Pressure-Containing Parts

6.11.1.1 Regardless of the generalized limits presented in this section, it shall be the Vendor's responsibility to review the design limits of all materials and welds in the event that more stringent requirements are specified. Defects that exceed the limits imposed in 6.11.1.9 shall be removed to meet the quality standards cited, as determined by additional magnetic particle or liquid penetrant inspection as applicable before repair welding.

- **6.11.1.2** If radiographic, ultrasonic, magnetic particle, or liquid penetrant inspection of welds or materials is required by the ASME *Pressure Vessel Code* or specified, the procedures and acceptance criteria shall apply, except as required by 6.11.1.4. Alternative standards may be proposed by the Vendor or specified by the Purchaser. The welding and material inspection data sheet in Annex D may be used for this purpose.

6.11.1.3 The Purchaser shall be notified before making a major repair to a pressure containing part. Major repair, for the purpose of Purchaser notification only, is any defect that equals or exceeds any of the three criteria defined below:

- a) the depth of the cavity prepared for repair welding exceeds 50 % of the component wall thickness;
- b) the length of the cavity prepared for repair welding is longer than 150 mm (6 in.) in any direction;
- c) the total area of all repairs to the part under repair exceeds 10 % of the surface area of the part.

6.11.1.4 All repairs to pressure containing parts shall be made as required by the following documents:

- a) The repair of plates, prior to fabrication, shall be performed in accordance with the ASTM standard to which the plate was purchased.
- b) The repair of castings or forgings shall be performed prior to final machining in accordance with the ASTM standard to which the casting or forging was purchased.
- c) The inspection of a repair of a fabricated casing or the defect in either a weld or the base metal of a cast or fabricated casing, uncovered during preliminary or final machining, shall be performed in accordance with 6.11.1.2.