Positive Displacement Pumps—Reciprocating

API STANDARD 674
THIRD EDITION, DECEMBER 2010

ERRATA, MAY 2014
ERRATA 2, APRIL 2015

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*

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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*

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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 Varembé, 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.

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[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, Pittsburg, 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 a 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^2K/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 μin.) 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 μm/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 mm^2 (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 mm^2/s (65 cSt).

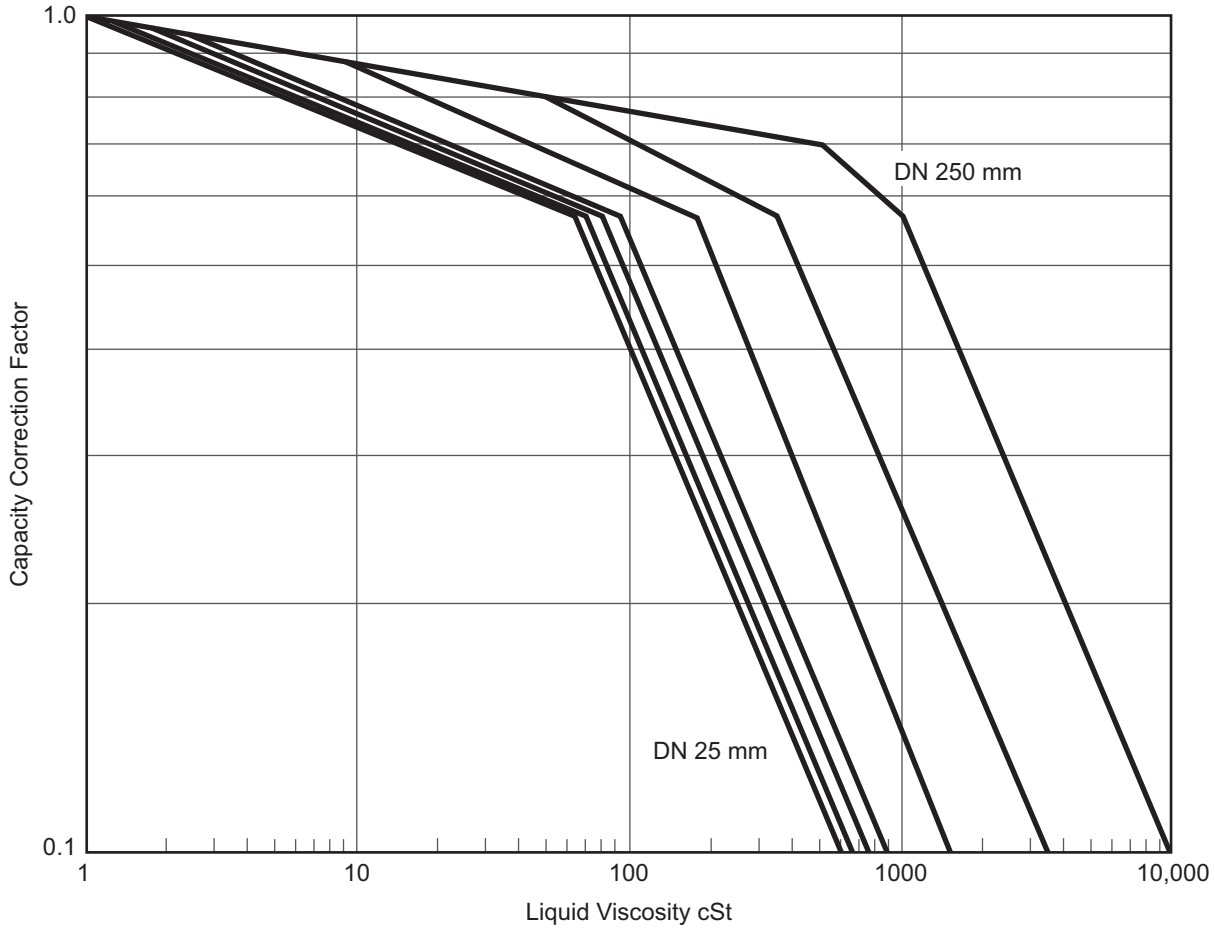


Figure 1—Kinematic Vicosities

- **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 $^{3}/_{4}$) 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 $1^{1}/_{4}$, NPS $2^{1}/_{2}$, NPS $3^{1}/_{2}$, 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 $1^{1}/_{2}$) 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 ($1^{1}/_{2}$ 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 $1^{1}/_{2}$).

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 228-1shall 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 l6.42. 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)

	Forces		Moments	
Pipe size (DN)	$F_{[x,y,z]}$ 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)

	Forces		Moments	
Pipe size (in.)	$F_{[x,y,z]}$ 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 µin.) 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 µin.) 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 µin.) (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.

6.11.1.5 Plate used in fabrications shall be inspected prior to starting fabrication in accordance with the ASTM standard to which the plate was purchased.

6.11.1.6 Cast and Nodular iron may be inspected only in accordance with magnetic particle and liquid penetrant methods.

6.11.1.7 Spot radiography shall consist of a minimum of one 150 mm (6 in.) spot radiograph for each 7.6 m (25 ft) of weld on each casing. As a minimum, one spot radiograph is required for each welding procedure and welder used for pressure-containing welds.

6.11.1.8 For magnetic particle inspections, linear indications shall be considered relevant only if the major dimension exceeds 1.6 mm ($^1/_{16}$ in.). Individual indications that are separated by less than 1.6 mm ($^1/_{16}$ in.) shall be considered continuous.

6.11.1.9 Cast steel parts shall be examined by magnetic particle methods. Acceptability of defects shall be based on a comparison with the photographs in ASTM E 125 Code. For each type of defect, the degree of severity shall not exceed the limits specified in Table 8.

Table 8—Maximum Severity of Defects in Steel Castings

Type	Defect	Degree
I	Linear discontinuities	1 (Code all)
II	Shrinkage	2
III	Inclusions	2 (Code 3)
IV	Chills and Chaplets	1
V	Porosity	1
VI	Welds	1

6.11.1.10 If specified, the Purchaser may inspect for cleanliness of the equipment and all piping and appurtenances furnished by or through the Vendor before assembly.

• **6.11.1.11** If 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 agreed upon by the Purchaser and the Vendor.

6.11.2 General

6.11.2.1 The materials of construction shall be the Manufacturer's/Supplier's standard for the operating conditions specified, except as required by the data sheet or this standard.

6.11.2.2 The materials of construction of all major components shall be clearly stated in the Vendor's proposal. Materials shall be identified by reference to applicable international standards, including the material grade (Annex A may be used for guidance). If no such designation is available, the Vendor's material specification, giving physical properties (chemical composition), and test requirements shall be included in the proposal.

• **6.11.2.3** If specified, copper or copper alloys shall not be used for parts which are in contact with process fluids. Nickel-copper alloy (UNS NW 4400 or UNS N04400), bearing babbitt, and copper-containing precipitation-hardened stainless steels are excluded from this requirement.

Warning—Certain corrosive fluids in contact with copper alloys have been known to form explosive compounds.

6.11.2.4 The Vendors' response to the inquiry shall specify the optional tests and inspection procedures that are necessary to ensure that materials are satisfactory for the service (see 6.11.1.2). Such tests and inspections shall be listed in the proposal.

NOTE The Purchaser may specify additional optional tests and inspections, especially for materials used for critical components or in critical services.

6.11.2.5 External parts that are subject to rotary or sliding motions (such as control linkage joints and adjustment mechanisms) shall be of corrosion-resistant materials suitable for the site environment.

6.11.2.6 Minor parts such as nuts, springs, washers, gaskets, and keys shall have corrosion resistance at least equal to that of specified parts in the same environment.

• **6.11.2.7** The Purchaser shall specify any erosive or corrosive agents (including trace quantities) present in the process fluids and in the site environment, including constituents that may cause stress-corrosion cracking or attack elastomers.

NOTE Typical agents of concern are hydrogen sulfide, amines, chlorides, bromides, iodides, cyanides, fluorides, naphthenic acid, and polythionic acid. Other agents affecting elastomer selection include ketones, ethylene oxide, sodium hydroxide, methanol, benzene, and solvents.

6.11.2.8 If austenitic stainless steel parts exposed to conditions that may promote inter-granular corrosion are to be fabricated, hard-faced, overlaid or repaired by welding, they shall be made of low-carbon or stabilized grades.

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

• **6.11.2.9** If specified, the Vendor shall furnish material certificates that include chemical analysis and mechanical properties for the heats from which the material is supplied for pressure-containing castings and forgings and shafts. Unless otherwise specified, piping nipples, auxiliary piping components, and bolting are excluded from this requirement.

• **6.11.2.10** If mating parts such as studs and nuts of austenitic stainless steel or materials with similar galling tendencies are used, they shall be lubricated with an anti-seizure compound of the proper temperature specification and compatible with the specified process liquid(s).

NOTE The torque loading values to achieve the necessary preload are likely to vary considerably depending upon whether or not an anti-seizure compound is used.

6.11.2.11 The Purchaser shall specify the amount of wet H_2S that may be present, considering normal operation, start-up, shutdown, standby, upsets, or unusual operating conditions such as catalyst regeneration. If the Purchaser has specified the presence of hydrogen sulfide in any liquid, materials exposed to that liquid shall be selected in accordance with the requirements of NACE Standard MRO 175. Ferrous materials not covered by NACE MR0 175 shall not have a yield strength exceeding 620 N/mm^2 (90,000 psi) nor a hardness exceeding Rockwell C 22. Components that are fabricated by welding shall be post-weld heat treated, if required, so that both the welds and the heat-affected zones meet the yield strength and hardness requirements. In addition, the following shall apply.

a) Application of NACE MR0175 is a two-step process. First, the need for special materials is determined and, second, the materials are selected. Specification of this clause assumes the Purchaser has determined the need, and limited hardness materials shall be supplied.

b) In many applications, small amounts of wet H_2S are sufficient to require materials resistant to sulfide stress-corrosion cracking. If there are trace quantities of wet H_2S known to be present or if there is any uncertainty about the amount of wet H_2S that may be present, the Purchaser shall note on the data sheets that materials resistant to sulfide stress-corrosion cracking are required.

6.11.2.12 The Vendor shall select materials to avoid conditions that may result in electrolytic corrosion. If such conditions cannot be avoided, the Purchaser and the Vendor shall agree on the material selection and any other precautions necessary.

NOTE If 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. The NACE Corrosion Engineer's Reference Book is one resource for selection of suitable materials in these situations.

6.11.2.13 Steel made to a coarse austenitic grain size practice (such as ASTM A515) shall not be used. Only fully killed or normalized steels made to fine grain practice shall be used.

6.11.2.14 The Manufacturer's data report forms, as specified in codes such as ASME VIII, are not required.

NOTE For impact requirements refer to 6.11.7.3 and 6.11.7.4.

- **6.11.2.15** The material specification of all gaskets and o-rings exposed to the pumped fluid shall be identified in the proposal. O-rings shall be selected and their application limited in accordance with ISO 21049. O-ring materials shall be compatible with all specified services. Special consideration shall be given to the selection of o-rings for high-pressure services to ensure that they will not be damaged upon rapid depressurization (explosive decompression). It shall be specified on the datasheet if the service is such that there is a risk of rapid depressurization.

NOTE 1 For the purpose of this provision, API Standard 682-2004 is equivalent to ISO 21049.

NOTE 2 Susceptibility to explosive decompression depends on the gas to which the o-ring is exposed, the compounding of the elastomer, temperature of exposure, the rate of decompression, and the number of cycles.

6.11.2.16 The minimum quality bolting material for pressure-retaining parts shall be carbon steel (such as ASTM A 307, Grade B) for cast iron cylinders; and high temperature alloy steel (such as ASTM A 193, Grade B7) for steel cylinders. Carbon steel nuts (such as ASTM A 194, Grade 2H) shall be used, except that case hardened carbon steel nuts (such as ASTM A 563, Grade A) shall be used where space is limited. For temperatures below –29 °C (–20 °F), low-temperature bolting material (such as ASTM A 320) shall be used.

6.11.3 Positive Material Identification (PMI)

- **6.11.3.1** In addition to the components outlined in 6.11.2.15, other materials, welds, fabrications and piping shall be PMI tested as specified.

6.11.3.2 If PMI testing has been specified for a fabrication, the components comprising the fabrication, including welds, shall be checked after the fabrication is complete. Testing may be performed prior to any heat treatment.

6.11.3.3 If PMI is specified, techniques providing quantitative results shall be used.

6.11.3.4 Mill test reports, material composition certificates, visual stamps or markings shall not be considered as substitutes for PMI testing.

6.11.3.5 PMI results shall be within ASTM governing standard limits with allowance for the accuracy of the PMI device as specified by the device Manufacturer.

6.11.4 Castings

6.11.4.1 Castings shall be sound and free from porosity, hot tears, shrink holes, blow holes, cracks, scale, blisters, and similar injurious defects in excess of that specified in the material specification or any additional specified acceptance criteria.

Surfaces of castings shall be cleaned by sandblasting, shot-blasting, chemical cleaning, or other standard methods to meet the visual requirements of MSS-SP-55. Mold-parting fins and the remains of gates and risers shall be chipped, filed or ground flush.

6.11.4.2 The use of chaplets in pressure castings shall be held to a minimum. If chaplets are necessary, they shall be clean and corrosion free (plating is permitted) and of a composition compatible with the casting.

6.11.4.3 Ferrous pressure-containing castings shall not be repaired by welding, peening, plugging, burning in, or impregnating, except as follows.

a) Weldable grades of steel castings may be repaired by welding in accordance with 6.11.6. Weld repairs shall be inspected according to the same quality standard used to inspect the casting.

b) All other repairs shall be subject to the Purchaser's approval.

6.11.4.4 Fully enclosed cored voids, which become fully enclosed by methods such as plugging, welding, or assembly are prohibited.

• **6.11.4.5** If specified, for casting repairs made in the Vendor's shop, repair procedures including weld maps shall be submitted for Purchaser's approval. The Purchaser shall specify if approval is required before proceeding with repair. Repairs made at the foundry level shall be controlled by the casting material specification ("producing specification").

6.11.4.6 Pressure-retaining castings of carbon steel shall be furnished in the normalized and tempered condition.

6.11.5 Forgings

6.11.5.1 The forging material shall be selected from those listed in Annex A or an equivalent to those in Annex A.

6.11.5.2 Pressure-containing ferrous forgings shall not be repaired except as follows.

a) Weldable grade of steel forgings may be repaired by welding in accordance with 6.11.6. After major weld repairs, and before hydrotest, the complete forging shall be given a post-weld heat treatment to ensure stress relief and continuity of mechanical properties of both weld and parent metal.

b) All repairs that are not covered by the material specification shall be subject to the Purchaser's approval.

6.11.6 Welding

• **6.11.6.1** Welding and weld repairs shall be performed in accordance with Table 9. If specified, alternative standards may be proposed by the Vendor for the Purchaser's approval and, if so, they shall be referenced in the data sheets (see Annex D).

Table 9—Welding Requirements

Requirement	Applicable Code or Standard
Welder/operator qualification	ASME IX or EN287
Welding procedure qualification	Applicable material specification or, where weld procedures are not covered by the material specification ASME IX or EN 288
Non-pressure-retaining structural welding such as mounting plates or supports	AWS D1.1
Magnetic particle or liquid penetrant examination of the plate edges	ASME VIII, Division 1, UG-93(d)(3
Post-weld heat treatment	Applicable material specification or ASME VIII, Division 1, UW 40
Post-weld heat treatment of cylinder fabrication welds	Applicable material specification or ASME VIII, Division I

6.11.6.2 The Vendor shall be responsible for the review of all repairs and repair welds to ensure that they are properly heat treated and nondestructively examined for soundness and compliance with the applicable qualified procedures (see 6.11.6.1). Repair welds shall be nondestructively tested by the same method used to detect the original flaw; however, the minimum level of inspection after the repair shall be by the magnetic particle method in accordance with 8.2.2.1.1 to for magnetic material and by the liquid penetrant method in accordance with 8.2.2.1.1 for nonmagnetic material.

6.11.6.3 Pressure-containing parts made of wrought materials or combinations of wrought and cast materials shall conform to the conditions specified in 6.11.6.2 and 6.11.6.3 a) through c) below. These requirements do not apply to casing nozzles and auxiliary connections.

- a) Accessible surfaces of welds shall be inspected by magnetic particle or liquid penetrant examination after back chipping or gouging and again after post-weld heat treatment or, for austenitic stainless steels, after solution annealing. If specified, the quality control of welds that will be inaccessible on completion of the fabrication shall be agreed on by the Purchaser and Vendor prior to fabrication.

b) Pressure-containing welds, including welds of the cylinder to axial-joint and radial-joint flanges, shall be full-penetration welds.

c) Where dimensional stability of the component must be assured for the integrity of pump operation, post-weld heat treatment shall be performed regardless of thickness.

6.11.6.4 Connections welded to cylinders shall be installed as follows.

a) Attachment of suction and discharge nozzles shall be by means of full-fusion, full-penetration welds. Weld neck flanges shall be used for pumps handling flammable or hazardous liquids. Welding of dissimilar metals shall not be performed.

b) If specified, proposed connection designs shall be submitted for approval before fabrication. The drawings shall show weld designs, size, materials, and pre and post-weld heat treatments.

c) Post-weld heat treatment, if required, shall be carried out after all welds, including piping welds, have been completed.

d) Unless otherwise specified, auxiliary piping welded to alloy steel cylinders shall be of a material with the same nominal properties as the cylinder material.

6.11.7 Low Temperature Service

- **6.11.7.1** The Purchaser shall specify the minimum design metal temperature the pump will be subjected to in service. This temperature shall be used to establish impact test requirements. Normally, this will be the lower of the minimum surrounding ambient temperature or minimum fluid pumping temperature; however, the Purchaser may specify a minimum design metal temperature based on properties of the pumped fluid, such as auto-refrigeration at reduced pressures.

6.11.7.2 To avoid brittle failures, materials and construction for low temperature service shall be suitable for the minimum design metal temperature in accordance with the codes and other requirements specified. The Purchaser and the Vendor shall agree on any special precautions necessary with regard to conditions that may occur during operation, maintenance, transportation, erection, commissioning, and testing.

NOTE Good design practice should be followed in the selection of fabrication methods, welding procedures, and materials for Vendor-supplied steel pressure retaining parts that may be subject to temperatures below the ductile-brittle transition temperature. The published design-allowable stresses for materials in internationally recognized standards such as the ASME Code and ANSI standards are based on minimum tensile properties. Some standards do not differentiate between rimmed, semi-

killed, fully killed, hot-rolled, and normalized material, nor do they take into account whether materials were produced under fine- or course-grain practices. Therefore the Vendor should exercise caution in the selection of materials intended for services between –29 °C (–20 °F) and 40 °C (100 °F).

6.11.7.3 The Purchaser shall specify whether EN 13445 (all parts) or ASME VIII, Division 1, shall apply with regard to impact-testing requirements.

6.11.7.4 If ASME VIII, Division I is specified (see 6.11.7.3), the following shall apply:

a) all pressure-retaining steels applied at a specified minimum design metal temperature below –29 °C (–20 °F) shall have a Charpy V-notch impact test of the base metal and the weld joint unless they are exempt in accordance with ASME VIII, Division 1, UHA-51;

b) carbon steel and low alloy steel pressure-retaining parts applied at a specified minimum design metal temperature between –29 °C (–20 °F) and 40 °C (100 °F) shall require impact testing as follows.

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

   — Impact testing exemptions for parts with a governing thickness greater than 25 mm (1 in.) shall be established in accordance with paragraph UCS-66 in Section VIII, Division 1 of the ASME Code. 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.

6.11.7.5 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 deflection;

   3) structural sections required for attachment or inclusion of mechanical features such as jackets or seal chambers.

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

6.12 Nameplates and Rotation Arrows

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

6.12.2 Rotation arrows shall be cast-in or attached to each major item of rotating equipment at a readily visible location if direction of rotation affects performance and/or reliability.

6.12.3 Nameplates and rotation arrows (if attached) shall be of austenitic stainless steel or nickel-copper alloy (UNS N04400). Attachment pins shall be of the same material. Welding is not permitted.

6.12.4 The following data (if relevant) shall be clearly stamped or engraved on the nameplate:

a) Vendor's name,

b) serial number,

c) size, type, and model,

d) rated capacity,

e) minimum and maximum rated pressures,

f) minimum and maximum rated temperatures,

g) rated speed,

h) rated power,

i) MAWP,

j) maximum allowable temperature,

k) Purchaser item number or other reference,

l) pumped liquid.

6.12.5 Power pumps shall be provided with a plate mounted in a conspicuous place on the crankcase to specify the type and quantity of lubricant required for the power end.

7 Accessories

7.1 Drivers

7.1.1 General

7.1.1.1 The driver shall be of the type specified, shall be sized to meet the maximum specified operating conditions, including external gear and coupling losses, and shall be in accordance with applicable specifications, as stated in the inquiry. The driver shall operate under the utility and site conditions specified in the inquiry.

7.1.1.2 The driver shall be sized to meet all process variations such as changes in the pressure, temperature or properties of the liquid handled, and conditions specified in the inquiry, including plant start-up conditions.

7.1.1.3 The driver shall be capable of starting under the conditions specified and the starting method shall be agreed by the Purchaser and the Vendor. The driver's starting-torque capabilities shall exceed the speed-torque requirements of the driven equipment by a minimum of 10 %.

7.1.1.4 The supporting feet of drivers with a weight greater than 250 kg (500 lbs) shall be provided with vertical jackscrews.

7.1.2 Motors

7.1.2.1 Motor drives shall conform to internationally recognized standards such as API 541 or 546 as applicable. Motors that are below the power scope of API 541 or 546 shall be in accordance with IEEE 841. Electric motor drivers shall be rated with a service factor of 1.0. The motor rating shall be at least 110 % of the greatest power required (including gear and coupling losses) for any of the specified operating conditions. The motor nameplate rating, including service factor, shall be suitable for operation at 100 % of the pressure-limiting valve accumulation pressure. Consideration shall be given to the starting conditions of both the driver and driven equipment and the possibility that these conditions may be different from the normal operating conditions.

NOTE The 110 % applies to the design phase of a project. After testing, this margin might not be available due to performance tolerances of the driven equipment.

7.1.2.2 The Purchaser shall specify the type of motor and its characteristics and accessories, including but not limited to the following:

a) electrical characteristics,

b) starting conditions (including the expected voltage drop on starting),

c) type of enclosure,

d) sound pressure level,

e) area classification, based on, or equivalent international standard,

f) type of insulation,

g) any required service factor,

h) transmission losses, if any,

i) temperature detectors, vibration sensors, and heaters specified,

j) auxiliaries (such as motor-generator sets, ventilation blowers, and instrumentation),

k) vibration acceptance criteria,

l) use in variable frequency drive applications.

7.1.2.3 The motor's starting torque shall meet the requirements of the driven equipment, at a reduced voltage of 80 % of the normal voltage, or such other value as may be specified, and the motor shall accelerate to full speed within 15 seconds or such other period of time agreed upon by the Purchaser and the Vendor.

7.1.2.4 Motors for belt or chain drives shall be of extended-shaft construction and shall be suitable for the side loads imposed by the drive taking into account the width of the bush.

7.1.3 Steam Turbines

7.1.3.1 Steam turbine drivers shall conform to API 611. Steam turbine drivers shall be sized to deliver continuously not less than 110 % of the maximum power requirement of the driven equipment, (including all gear and coupling losses) when operating at any of the specified operating conditions, with the specified normal steam conditions. The maximum power requirement includes operation at 100 % of the pressure-limiting valve accumulation pressure.

NOTE The 110 % applies to the design phase of the project. After testing, this margin might not be available due to performance tolerances of the driven equipment.

7.1.4 Gear Units

7.1.4.1 Gear units integral with motor drivers are acceptable only if the driver nameplate rating is 18 kW (25 horsepower) or less. These integral gear units shall conform to AGMA 6091, Class III for duplex power pumps, or Class II for multiplex power pumps.

- **7.1.4.2** Coupled gears shall be either single helical or double helical type and shall conform to AGMA 6010. If specified, gear units shall conform to API 677.

7.1.4.3 The gear service factor shall be mutually agreed upon by both the gear and pump Manufacturers for given service conditions such as variable torque loading and torsional critical speeds. The gear service factor shall be

subject to approval by the Purchaser. In no case shall the service factor be less than that required by the latest editions of AGMA 6010 for standard gear reducers and/or API 677 if either has been specified.

7.2 Couplings and Guards

7.2.1 Unless otherwise specified, flexible couplings and guards between drivers and driven equipment shall be supplied by the Manufacturer of the driven equipment.

7.2.2 Information on shafts, keyway dimensions (if any), and shaft end movements due to end play and thermal effects shall be supplied to the Vendor supplying the coupling.

NOTE This information is normally supplied by the Vendor of the driven equipment or the driver Vendor.

7.2.3 The coupling-to-shaft juncture shall be designed and manufactured to be capable of transmitting power at least equal to the power rating of the coupling.

7.2.4 Unless otherwise specified, the couplings shall be mounted with taper-lock bushings or in accordance with 7.2.4 a) through 7.2.4 c). For a tapered-hub coupling, unless an alternate method of ensuring a correct fit has been agreed upon with the Purchaser, the Vendor shall provide a plug gauge. The plug gauge shall be from a matched plug and ring set, and provided for the purpose of checking the bore on the hub.

a) Flexible couplings shall be keyed to the shaft. Keys and keyways and their tolerances shall conform to ISO 286-2, (tolerance class N8) or ANSI/AGMA 9002 (Commercial Class).

b) Flexible couplings with cylindrical bores shall be mounted with an interference fit. Cylindrical shafts shall comply with ISO 286-2 (tolerance class N8) or ANSI/AGMA 9002 (Commercial Class) and the coupling hubs shall be bored to the following tolerances found in ISO 286-2:

   1) For shafts of 50 mm (2 in.) diameter and smaller—Tolerance class N7,

   2) For shafts larger than 50 mm (2 in.) diameter—Tolerance class N8.

c) Coupling hubs shall be supplied with tapped puller holes at least 10 mm (0.375 in.) on shafts with diameters greater than 40 mm (1.5 in.) diameter to facilitate removal.

7.2.5 Couplings shall be selected with a service factor not less than that recommended by the coupling Manufacturer for the intended service.

7.2.6 If the driven-equipment Vendor is not required to mount the driver, the coupling Purchaser 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 as specified by the required date. Any delay shall be added to the delivery date.

7.2.7 If the driver is a horizontal sleeve-bearing motor, limited end-float couplings shall be supplied to prevent end contact between shoulders on the motor shaft and its bearings.

7.2.8 Each coupling shall have a guard which is removable without disturbing the coupled elements and shall meet the following requirements:

- a) Guards shall enclose the moving elements and the shafts to prevent personnel from contacting moving parts during operation of the equipment train. Allowable access dimensions shall comply with specified standards, such as ISO 14120, EN 953 or ASME B15.1.

b) Guards shall be constructed with sufficient rigidity to withstand a 900 N (200 lbf) static point load in any direction without the guard contacting moving parts.

• c) Guards shall be fabricated from either solid sheet or plate with no openings, or expanded metal or perforated sheets if the size of the openings does not exceed 10 mm (0.375 in.). Guards shall be constructed of steel, brass, or non-metallic (polymer) materials. Guards of woven wire shall not be used. If specified, non-sparking guards of agreed material shall be supplied.

7.3 Belt Drives

• **7.3.1** Belt drives shall only be used for equipment of 150 kW (200 brake horsepower) or less. Unless otherwise specified, banded multi-V belts shall be provided. If more than one banded multi-V belt is required, the Vendor shall supply matched belt lengths. All belts shall be of the static-conducting type and shall be oil resistant. The drive service factor shall not be less than 1.5 for multiplex plunger pumps, 1.6 for double-acting piston pumps, and 1.75 for duplex single-acting pumps, based on the driver nameplate power rating. If specified, a cog-belt or chain-type drive shall be provided. Details shall be mutually agreed upon between the Vendor and the Purchaser.

NOTE Oil resistant belts require a core of Polychloropropene (e.g. neoprene) or an equivalent material.

7.3.2 The Vendor shall provide a positive belt-tensioning device. This device shall incorporate either a lateral adjustable base with guides and holddown bolts, two belt-tensioning screws, and locking devices, or a vertical adjustable base with four (4) belt tensioning screws, each with a locking device.

7.3.3 Belt drives shall meet the following requirements.

a) The distance between the centers of the sheaves shall be at least 1.5 times the diameter of the larger sheave.

b) The belt wrap (contact) angle on the smaller sheave shall be at least 140°.

c) The shaft length on which the sheave hub is fitted shall be at least equal to the width of the sheave hub.

d) The length of a shaft key used to mount a sheave shall be equal to the length of the sheave bore.

e) Unless otherwise agreed or specified, each sheave shall be mounted on a tapered adapter bushing.

f) To reduce the moment on shafts due to belt tension, the sheave overhang distance from the adjacent bearing, shall be minimized.

g) Sheaves shall meet the balance requirements of ISO 1940-1 or ANSI S2.19, Grade 6.3.

7.3.4 For exposed belts, guards meeting the requirements of 7.2.8, shall be supplied by the Vendor.

7.4 Mounting Plates

7.4.1 General

7.4.1.1 The type of mounting plate shall be specified by the Purchaser.

7.4.1.2 Mounting plates shall comply with the requirements of 7.4.1.3 through 7.4.1.12.

• **7.4.1.3** The upper and, if specified, lower surfaces of mounting plates, and any separate pedestals mounted thereon shall be machined parallel. Corresponding surfaces shall be in the same plane within 150 µm/m (0.002 in./ft) of distance between the pads. If specified, this requirement shall be demonstrated in the pump Vendor's shop prior to

mounting of the equipment and with the baseplate supported and clamped on the foundation bolt holes only. The surface finish shall be 3.2 μm (125 μin.) *Ra* or smoother.

7.4.1.4 If a piece of equipment, except the pump, has a mass in excess of 250kg (500 lbs), the mounting plate or plates shall be supplied with horizontal (axial and lateral) jackscrews, the same size or larger than the vertical jackscrews. The lugs holding these jackscrews shall be attached to the mounting plates in such a manner that they do not interfere with the installation of the equipment, jackscrews, or shims. Precautions shall be taken to prevent vertical jackscrews in the equipment feet from marring the shimming surfaces. Alternative methods of lifting equipment for the removal or insertion of shims or for moving equipment horizontally, such as provision for the use of hydraulic jacks, may be proposed. Such arrangements should be proposed for equipment that is too heavy to be lifted or moved horizontally using jackscrews. Jack screws shall be plated for corrosion resistance.

7.4.1.5 Machinery supports shall be designed to limit the relative displacement of the shaft end caused by the worst combination of pressure, torque, and allowable piping stress, to 50 μm (0.002 in.). Loads applied during transportation and installation shall not cause permanent deformation (see 6.6 for allowable piping loads).

7.4.1.6 Unless otherwise specified, epoxy grout shall be used for mounting plates installed on concrete foundations. The Vendor shall commercially sand blast in accordance with ISO 8501-1 Grade Sa2 or SSPC SP 6 all grout contact surfaces of the mounting plates and coat those surfaces with a primer compatible with epoxy grout. Grouts other than epoxy may require alternative surface preparation.

7.4.1.7 The anchor bolts shall not be used to fasten equipment to the mounting plates.

7.4.1.8 Mounting plates shall conform to the following.

a) Mounting plates shall not be drilled for equipment to be mounted by others.

b) Mounting plates shall be supplied with leveling screws.

c) Outside corners of mounting plates which are in contact with the grout shall have 50 mm (2 in.) minimum radius outside corners (in the plan view).

d) All machinery mounting surfaces shall be treated with a rust preventive immediately after machining.

e) Mounting plates shall extend at least 25 mm (1 in.) beyond the outer three sides of equipment feet.

f) Mounting plates shall be machined to a finish of 650 μm (250 μin.) arithmetic average roughness (Ra) or smoother.

7.4.1.9 Shims shall not be used under the pump. 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. If the Vendor mounts the components, a set of stainless steel shims at least 3 mm (0.12 in.) thick shall be supplied. Shim packs shall not be thicker than 13 mm (0.5 in.) nor contain more than 5 shims. All shim packs shall straddle the hold down bolts and vertical jackscrews and extend at least 5 mm ($^1/_4$ in.) beyond the outer edges of the equipment feet. If the Vendor does not mount the components, the pads shall not be drilled, and shims shall not be provided.

7.4.1.10 Unless otherwise specified, anchor bolts shall be supplied by the Purchaser.

7.4.1.11 Hold down bolts used to attach the equipment to the mounting plates, and all jackscrews, shall be supplied by the Vendor.

7.4.1.12 Equipment and mounting plates shall be designed for installation in accordance with API 686.

7.4.2 Baseplate and Skid

- **7.4.2.1** If a base-plate or skid is specified, the Purchaser shall indicate the major equipment to be mounted on it. A base-plate shall be a single fabricated steel unit, unless the Purchaser and the Vendor mutually agree that it may be fabricated in multiple sections. Multiple-section baseplate shall have machined and doweled mating surfaces which shall be bolted together to ensure accurate field reassembly.

NOTE A base-plate with a nominal length of more than 12 m (40 ft) or a nominal width of more than 4 m (12 ft) may have to be fabricated in multiple sections because of shipping restrictions.

7.4.2.2 If a base-plate or skid is provided, it shall extend under the drive-train components so that any leakage from these components is contained within the base-plate or skid.

- **7.4.2.3** If specified the base-plate or skid shall be designed to facilitate the use of optical, laser based or other instruments for accurate leveling in the field. The details of such facilities shall be agreed by the Purchaser and Vendor. Where the requirement is satisfied by the provisions of leveling pads and/or targets, they shall be accessible with the base-plate or skid on the foundation and the equipment mounted. Removable protective covers shall be provided. For column mounted base-plate or skid (see 7.4.2.4) leveling pads or targets shall be located close to the support points. For non-column mounted base-plate or skid, a pad or target should be located at each corner. When required for long units, additional pads shall be located at intermediate points.

- **7.4.2.4** If specified, the base-plate or skid shall be designed for column mounting (that is, of sufficient rigidity to be supported at specified points) without continuous grouting under structural members. The base-plate design shall be mutually agreed upon by the Purchaser and the Vendor.

7.4.2.5 The base-plate or skid shall be provided with lifting lugs for at least a four-point lift. Lifting the base-plate or skid complete with all equipment mounted shall not permanently distort or otherwise damage the base-plate or skid or the equipment mounted on it.

7.4.2.6 The bottom of the base-plate between structural members shall be open. When the base-plate is designed for grouting, it shall be provided with at least one grout hole having a clear area of at least 0.01 m^2 (20 $in.^2$) and no dimension less than 75 mm (3 in.) in each bulkhead section. These holes shall be located to permit grouting under all load-carrying structural members. Where practical, the holes shall be accessible for grouting with the equipment installed. The holes shall have 13 mm ($^1/_2$ in.) raised-lip edges, and if located in an area where liquids could impinge on the exposed grout, metallic covers with a minimum thickness of 16 gauge shall be provided. Vent holes at least 13 mm ($^1/_2$ in.) in size shall be provided at the highest point in each bulkhead section of the base-plate.

7.4.2.7 The underside mounting surfaces of the base-plate shall be in one plane to permit use of a single-level foundation. If the baseplate is constructed of multiple sections, the mounting pads shall be in one plane after the baseplate sections are doweled and bolted together.

7.4.2.8 Unless otherwise specified, nonskid metal decking covering all walk and work areas shall be provided on the top of the base-plate or skid.

7.4.2.9 Mounting pads shall be provided for the pump and all drive train components, such as motors and gears. The pads shall be larger than the foot of the mounted equipment to allow levelling 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. If specified, this requirement shall be demonstrated in the pump Vendor's shop prior to mounting of the equipment and with the baseplate supported and clamped at the foundation bolt holes only.

NOTE Installed baseplate flatness may be affected by transportation, handling and installation procedures beyond the Vendor's scope. Installation practices in API 686 should be followed.

7.4.2.10 Baseplate or skids shall be of the drain-rim or drain-pan type and shall have a raised lip. Connections for a drain shall be tapped DN 50 (NPS 2) minimum in the raised lip at the pump end and shall be located for complete drainage. The pan or upper surface of the base-plate or skid shall be sloped 1:120 minimum toward the drain end.

7.4.2.11 The underside of the fabricated decking located under the pump and driver supports shall be continuous welded to the cross members.

7.4.3 Soleplates and Subsoleplates

7.4.3.1 If soleplates are specified, they shall be in accordance with the requirements of API 686.

• **7.4.3.2** If specified, sub-soleplates shall be provided by the Vendor. They shall be steel plates at least 25 mm (1 in.) thick. The finish of the sub-soleplates' mating surfaces shall match that of the soleplate (see 7.4.1.3).

7.5 Controls and Instrumentation

7.5.1 General

Instrumentation and installation shall conform to the requirements of ISO 10438-1 and clauses 7.5.2 through 7.5.2.6 and satisfy the hazard conditions identified by the Purchaser.

NOTE For the purposes of this provision API 614, Chapter 1, is equivalent to ISO 10438.

7.5.2 Control Systems

7.5.2.1 Flow control shall not be achieved by throttling; it shall be obtained by flow bypass or by variation in pump speed, with or without supplemental bypass. Control systems shall be in accordance with 7.5.2.2 through 7.5.2.6.

7.5.2.2 For a variable-speed drive, the control signal shall act to adjust the set point of the driver's speed-control system. The speed of the machine shall vary linearly and directly with the control signal. Unless otherwise specified, the control range shall be from the maximum continuous speed to 95 % of the minimum speed required for any specified operating condition or 70 % of the maximum continuous speed, whichever is lower.

• **7.5.2.3** If specified, a combination of control modes shall be provided.

NOTE Typically, this is necessary on machines with a limited speed range, on multi-service or multi-stream applications.

7.5.2.4 The full range of the specified control signal shall correspond to the required operating range of the driven equipment. Unless otherwise specified, the maximum control signal shall correspond to the maximum continuous speed or the maximum flow.

7.5.2.5 If a direct-acting, constant-speed pump governor and governor valve are specified, the system shall be supplied as follows.

a) Unless otherwise specified, speed shall be adjustable by means of a manual speed changer.

b) Actuation of the control signal or failure of the signal or actuator shall neither prevent the governor from limiting the speed to the maximum permissible nor prevent manual regulation with the manual speed changer.

7.5.2.6 If a governor is not specified, the motive fluid throttle valve for pump speed control will be supplied by the Purchaser.

7.5.3 Instrument and Control Panels

• **7.5.3.1** Unless otherwise specified, panels shall be made of steel plate at least 3 mm ($^1/_8$ in.) thick, reinforced, self supporting and closed on the top and sides. If specified, the backs of panels shall be closed to minimize electrical hazards, to prevent tampering or to allow purging for safety or corrosion protection. All instruments shall be flush mounted on the front of the panel and all fasteners shall be of corrosion resistant material.

7.5.3.2 Interconnecting piping, tubing or wiring for controls and instrumentation, supplied by the Vendor, shall be disassembled only to the extent necessary for shipment.

7.5.4 Instrumentation

7.5.4.1 Speed Indicator, Frequency Monitor

A speed indicator (frequency monitor) shall be provided for variable speed units. The type, range and indicator provisions shall be as specified. Unless otherwise agreed, the indicator shall be supplied by the driver Vendor and shall be supplied with a minimum range of 0 % to 125 % of maximum continuous speed.

7.5.4.2 Temperature Indicators

Dial type temperature indicators shall be heavy duty and corrosion resistant. They shall be at least 125 mm (5 in.) diameter, bimetallic or liquid filled types and, unless otherwise agreed, shall have black marking on a white background.

7.5.4.3 Thermowells

7.5.4.3.1 Unless otherwise specified to suit the pumped liquid properties (such as in sour water services), austenitic stainless steel, solid-bar thermowells shall be supplied for temperature sensing elements in hazardous or flammable fluids or in pressurized or flooded line services.

7.5.4.3.2 Unless otherwise specified, the thermowells shall have a 25 mm (1 in.) process connection. For pressurized lines, this connection shall be flanged. For non-pressurized lines, this connection may be threaded subject to Purchaser's acceptance. The thermowell internal connection shall be 13 mm ($^1/_2$ in.)

7.5.4.4 Pressure-limiting Valves

7.5.4.4.1 Pressure-limiting valves or other protective devices shall be used with power pumps, and with direct-acting pumps if the stall pressure or the ram pressure exceeds the maximum allowable working pressure. Rupture disks shall not be used.

7.5.4.4.2 Pressure-limiting valves shall be in accordance with API 526. The Vendor shall determine the size and set pressure of all pressure-limiting valves within the Vendor's scope of supply and recommend the size and setting of pressure-limiting valves supplied by others required to protect the equipment the Vendor supplies. Pressure-limiting valve sizes and settings shall take into account all possible modes of equipment failure and shall meet the requirements of 6.4.2.

• **7.5.4.4.3** If specified, thermal expansion pressure-limiting valves shall be provided for accessories or cooling jackets that may be blocked-in by isolation valves.

7.5.4.4.4 Pressure-limiting valves provided for cylinder pressure shall discharge to a location outside of the pump isolation valves.

7.5.5 Alarms and Shutdowns

7.5.5.1 All alarm and trip materials in contact with the pumped liquids shall be austenitic stainless steel or, if required by the pumped liquid properties, a more suitable corrosion-resistant material.

7.5.5.2 The Vendor shall advise the Purchaser of any additional alarms and/or shutdowns considered essential to safeguard the equipment.

- **7.5.5.3** If specified, the alarm/shutdown system shall incorporate an event recorder to record the order of occurrence of alarms and shutdowns.

NOTE The special event recorder normally associated with a distributed control system (DCS) may not have a sufficiently fast scanning rate.

- **7.5.5.4** Temperatures shall be measured by thermocouples or resistance temperature detectors as specified and shall be connected to local panel mounted instruments. Multipoint instruments may be used except that alarms and shutdowns shall be connected to separate instruments, and separate alarm or shutdown contacts (switches) shall be provided for each temperature monitored. Each alarm and shutdown level shall be separately adjustable.

7.5.6 Electrical Systems

Wiring for electrical power shall be segregated from instrument and control-signal wiring, both outside enclosures and, as far as possible, inside enclosures. Enclosures which may be required to be opened with the equipment in operation, for example for alarm testing or adjustment, shall be provided with secondary shields or covers for all terminal strips and other exposed parts carrying electrical potentials in excess of 50 V. Maintenance access space shall be provided around or adjacent to electrical equipment in accordance with the appropriate code, such as NFPA 70:2002, Article 110.

7.6 Auxiliary Piping

7.6.1 Auxiliary piping, oil piping, instrument piping and process piping shall be in accordance with the appropriate part of ISO 10438, except as modified in 7.6.2.

NOTE For the purposes of this provision API 614 (all parts) is equivalent to ISO 10438 (all parts).

7.6.2 Auxiliary piping system materials shall be in accordance with Table 10. If space does not permit the use of DN 12, 20, 25 (NPS $^{1}/_{2}$, $^{3}/_{4}$, or 1) pipe, seamless tubing may be supplied.

7.6.3 Pipe plugs shall be in accordance with 6.5.12 for permanent plugs or 8.4.3.6 for shipping plugs.

7.7 Pulsation and Vibration Control Requirements

7.7.1 General

7.7.1.1 The interaction of the dynamic flow generated by the pump plungers (pistons or diaphragms) with acoustical resonance in piping systems can result in high-pressure pulsation levels in the pump and piping, cavitation with acoustical resonance and cavitation in piping systems can result in high-pressure pulsation levels in the pump and piping, excessive vibrations, and failures. Pump cavitation caused by low NPIP can also result in high pressure pulsations. Annex E describes pump system interaction and explains the differences between NPIP and NPSH. The pulsation characteristics of a piping system depend on factors such as the following:

a) complexity of the system layout,

b) number of pumps,

Table 10—Minimum Requirements for Piping Materials

System	Group I (Auxiliary Process Fluid)		Group II (Steam)		Group III (Cooling Water)		Group IV (Lubricating and Control Oil)	
	Nonflammable/ Nontoxic	Flammable/ Toxic	≤5.2 bar gauge (75 psig)	>5.2 bar gauge (75 psig)	Standard (≤ NPS 1)	Optional	≤ NPS 1	≥ NPS 1 1/2
Pipe (schedule)	Seamless [a]	Seamless [a,b]	Seamless [a]	Seamless [a]	Seamless [a]	ASTM A120, Schedule 40, galvanized to ASTM A153	ASTM A312, Type 304 or 316 stainless steel (3.6.2.3)[b]	ASTM A312, Type 304 or 316 stainless steel (3.6.2.3)[b]
Tubing [c]	Seamless ASTM A269 stainless steel or ASTM A192 steel	Seamless ASTM A269 stainless steel or ASTM A192 steel	Seamless ASTM A269 stainless steel or ASTM A192 steel	Seamless ASTM A269 stainless steel or ASTM A192 steel	Seamless ASTM A269 stainless steel or ASTM A192 steel	Seamless ASTM A269 stainless steel or ASTM A192 steel	Seamless ASTM A269 stainless steel	—
All valves	Class 800	Class 800	Class 800	Class 800	Class 200, bronze	Class 200, bronze	Carbon steel, Class 800	Carbon steel, Class 800
Gate and globe valves [d]	Bolted bonnet and gland	Bolted bonnet and gland	Bolted bonnet and gland	Bolted bonnet and gland	—	—	Bolted bonnet and gland	Bolted bonnet and gland
Pipe fittings and unions	Forged, Class 3000	Forged, Class 3000	Forged, Class 3000	Forged, Class 3000	ASTM A338 and 197, Class 150 malleable iron, galvanized to ASTM A153	ASTM A338 and A197, Class 150 malleable iron, galvanized to ASTM A153	Stainless steel (3.6.2.2)	Stainless steel (3.6.2.2)
Tube fittings	Manufacturer's standard (with Purchaser's approval)	Manufacturer's standard (with Purchaser's approval)	Manufacturer's standard (with Purchaser's approval)	Manufacturer's standard (with Purchaser's approval)	Manufacturer's standard (with Purchaser's approval)	Manufacturer's standard (with Purchaser's approval)	Manufacturer's standard (with Purchaser's approval)	—
Fabricated joints ≤1½ inches	Threaded	Socket welded Threaded [e]	Threaded	Socket welded Threaded [e]	Threaded	Threaded	—	Carbon steel slip-on flange
Fabricated joints ≥2 inches	—	—	—	—	Purchaser to specify	Purchaser to specify	—	Carbon steel slip-on flange

Table 10—Minimum Requirements for Piping Materials (Continued)

System	Group I (Auxiliary Process Fluid)		Group II (Steam)		Group III (Cooling Water)		Group IV (Lubricating and Control Oil)	
	Nonflammable/ Nontoxic	Flammable/ Toxic	≤5.2 bar gauge (75 psig)	>5.2 bar gauge (75 psig)	Standard (≤ NPS 1)	Optional	≤ NPS 1	≥ NPS 1 1/2
Gaskets	Type 304 or 316 stainless steel, spiral wound	Type 304 or 316 stainless steel, spiral wound	Type 304 or 316 stainless steel, spiral wound	Type 304 or 316 stainless steel, spiral wound	—	—	—	Type 304 or 316 stainless steel, spiral wound
Flange bolting [f]	ASTM A193, Grade B7 ASTM A194, Grade 2H	ASTM A193, Grade B7 ASTM A194, Grade 2H	ASTM A193, Grade B7 ASTM A194, Grade 2H	ASTM A193, Grade B7 ASTM A194, Grade 2H	—	—	ASTM A193, Grade B7 ASTM A194, Grade 2H	—

NOTE Carbon steel piping shall conform to ASTM A106, Grade B; ASTM A524; or API 5L, Grade A or B. Carbon steel fittings, valves, and flanged components shall conform to ASTM A105 and A181. Stainless steel piping shall be seamless in accordance with ASTM 312 or electric-fusion welded.

[a] Schedule 160 carbon steel for NPS 3/4 and smaller; Schedule 80 for NPS 1–1 1/2; Schedule 40 for NPS 2 and larger.

[b] Schedule 80S stainless steel for NPS 1 and smaller; Schedule 40S for NPS 1½ and 3; Schedule 10S for NPS 4 and larger.

[c] NPS 1/2 x 1.6 mm (0.065 in) wall, NPS 3/4 x 2.4 mm (0.095 in) wall, or NPS 1 x 2.8 mm (0.109 in) wall.

[d] For primary ANSI service pressure ratings above 62 bar gauge (900 psig), block valves may be of welded-bonnet or no-bonnet construction with a bolted gland.

These valves shall be suitable for repacking under pressure.

[e] Threaded joints require seal welding; however, seal welding is not permitted on cast iron equipment, on instruments, or where disassembly is required for maintenance. Seal-welded joints shall be made in accordance with ASME B31.3.

[f] Bolting shall be in accordance with 6.4.

c) operating speeds,

d) liquid properties,

e) pump type,

f) pump size (power),

g) number of plungers,

h) system operational conditions,

i) piping layout.

NOTE Detrimental pulsations should be avoided by ensuring sufficient flow rate and NPIP (see Annex E). Piping lengths that might resonate at the pump pulsing frequency should also be avoided.

7.7.1.2 If detrimental pulsations and vibrations exists in a pumping system**,** basic techniques used for their control include the following.

a) Pulsation control devices such as dampeners, accumulators, hydraulic isolators, inhibitors, suppressors, stabilizers, acoustic filters, and selected piping configurations. Pulsation control devices may be supplied by the Purchaser or the Vendor. If supplied by the Purchaser, full technical data relating to the pulsation device shall be provided on the data sheet.

b) System design based on studies of the interactive effects of pulsations and the attenuation requirements for satisfactory piping vibration, pump performance, and valve life.

c) Mechanical restraints including such things as type, location, and number of pipe hold-downs.

d) Good piping layout and design practice which comprises:

1) Maintaining near-ground level routing of piping when possible to facilitate effective (relatively stiff) restraints;

2) Minimizing the number of direction changes to reduce the potential for coupling pulsations into a mechanical shaking force;

3) Using adequate dynamic restraints on pulsation suppression devices to ensure vibration control of these devices;

4) Using sufficient number of piping restraints (clamp spacing) and proper restraint design;

NOTE 1 Clamps are preferred to U-bolts; weight-only type supports should be avoided.

NOTE 2 Normally control of system pulsation, cavitation, and vibration needs coordination between the pump Manufacturer and the piping system designer in order to ensure that the system pulsation and vibration characteristics are suitable for the intended purpose. Annex E can provide insight into cavitation (NPSH and NPIP) issues.

7.7.1.3 Selection and Scope of Design Analysis Methods—The Purchaser shall specify if design analysis for pulsation and vibration control is required, and, if so, which method to follow (see Annex C). The Purchaser shall also indicate whether existing pumps and their associated piping are to be included in the analysis.

NOTE When deciding which analysis approach should be used, the Purchaser should consider such things as horsepower, economics, piping layout, reliability, documentation requirements, and experience with similar pumps and installations.

7.8 Special Tools

7.8.1 If special tools or fixtures are required to disassemble, assemble or maintain the equipment, they shall be included in the quotation and supplied as part of the initial supply of the equipment. For multiple-unit installations, the requirements for quantities of special tools and fixtures shall be agreed between Purchaser and Vendor. These, or similar special tools, shall be used, and their use demonstrated, during shop assembly and any required post-test disassembly of the equipment.

7.8.2 If special tools are provided, they shall be firmly attached to the pump or packaged in a separate, rugged metal box or boxes and shall be 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** The Purchaser shall specify the extent of his participation in the inspection and testing.

- **8.1.2** If specified, the Purchaser's representative, the Vendor's representative, or both shall indicate compliance in accordance with an inspector's checklist such as that provided in Annex F by initialing, dating, and submitting the completed checklist to the Purchaser before shipment.

8.1.3 After advance notification to the Vendor, the Purchaser's representative shall have entry to all Vendor and sub-Vendor plants where manufacturing, testing, or inspection of the equipment is in progress.

8.1.4 The Vendor shall notify sub-Vendors of the Purchaser's inspection and testing requirements

8.1.5 If shop inspection and testing have been specified, the Purchaser and the Vendor shall coordinate manufacturing hold points and inspector's visits.

8.1.6 The expected dates of testing shall be communicated at least 30 days in advance and the actual dates confirmed as agreed. Unless otherwise agreed, the Vendor shall give at least five working days advanced notification of a witnessed or observed inspection or test.

NOTE 1 For smaller pumps where set-up and test time is short, five days notice may require the pump to be removed from the test stand between preliminary and witness tests.

NOTE 2 All witnessed inspections and tests are hold points. For observed tests, the Purchaser should expect to be in the factory longer than for a witnessed test.

8.1.7 If specified, witnessed mechanical and performance tests shall require a written notification of a successful preliminary test. The Vendor and Purchaser shall agree if the machine test set up is to be maintained or if the machine can be removed from the test stand between the preliminary and witnessed tests.

NOTE Many Purchasers prefer not to have preliminary tests prior to witnessed tests to understand any difficulties encountered during testing. If this is the case, Purchasers should make it clear to the Vendor.

8.1.8 Equipment, materials and utilities for the specified inspections and tests shall be provided by the Vendor.

8.1.9 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:

a) necessary or specified certification of materials, such as mill test reports;

b) test data and results to verify that the requirements of the specification have been met;

c) fully identified records of all heat treatment whether performed in the normal course of manufacture or as part of a repair procedure;

d) results of quality control tests and inspections;

e) details of all repairs;

• f) if specified, final assembly maintenance and running clearances;

g) other data specified by the Purchaser or required by applicable codes and regulations (see Section 5).

8.2.1.2 Pressure-retaining parts shall not be painted until the specified inspection and testing of the parts is complete.

8.2.1.3 In addition to the requirements of 6.11.4.1, 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.

8.2.1.4 All running tests and mechanical checks shall be completed prior to the Purchaser's final inspection.

8.2.2 Materials Inspection

8.2.2.1 General

8.2.2.1.1 NDE shall be performed as required by the material specification. If additional radiographic, ultrasonic, magnetic-particle or liquid-penetrant examination of the welds or materials is specified by the Purchaser, the methods and acceptance criteria shall be in accordance with the standards shown in Table 11. Alternative standards may be proposed by the Vendor or specified by the Purchaser and they shall be mutually agreed to by both Purchaser and Vendor. The welding and material inspection data sheet in Annex D may be used for this purpose.

8.2.2.1.2 The acceptability of defects in castings shall be based on a comparison with the photographs in ASTM E 125. For each type of defect, the degree of severity shall not exceed the limits specified in Table 12.

8.2.3 Mechanical Inspection

8.2.3.1 During assembly of the equipment, each component (including integrally cast-in passages) and all piping and auxiliaries shall be inspected to ensure they have been cleaned and are free of foreign materials, corrosion products, and mill scale.

8.2.3.2 All oil system components supplied shall meet the cleanliness requirements of ISO 10438-3.

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

Table 11—Materials Inspection Standards

Type of Inspection	Methods	Acceptance Criteria	
		For Fabrications	For Castings
Radiography	Section V, Articles 2 and 22 of the *ASME Code*	Section VIII, Division 1, UW-51 (for 100 % radiography) and UW-52 (for spot radiography) of the *ASME Code*	Section VIII, Division 1, Appendix 7 of the *ASME Code*
Ultrasonic inspection	Section V, Articles 4, 5 and 23 of the *ASME Code*	Section VIII, Division 1, UW53 and Appendix 12, of the *ASME Code*	Section VIII, Division 1, Appendix 7, of the *ASME Code*
Magnetic particle inspection	Section V, Articles 7 and 25 of the *ASME Code*	Section VIII, Division 1, Appendix 6 of the *ASME Code*	See acceptance criteria in 8.2.2.1.2 and Table 12
Liquid penetrant inspection	Section V, Articles 6 and 24 of the *ASME Code*	Section VIII, Division 1, Appendix 8 of the *ASME Code*	Section VIII, Division 1, Appendix 7, of the *ASME Code*

Table 12—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

- **8.2.3.3** If specified, the Purchaser may inspect the equipment and all piping and auxiliaries for cleanliness before heads are welded onto vessels, openings in vessels or exchangers are closed, or piping is finally assembled.

- **8.2.3.4** If 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.

8.3 Testing

8.3.1 General

8.3.1.1 Equipment shall be tested in accordance with 8.3.2 and either 8.3.3. or 8.3.4 as appropriate.

8.3.1.2 If specified, the Vendor shall submit to the Purchaser, for his review and comment, detailed procedures and acceptance criteria for all specified tests. The time period between submittal of the documents and the running test shall be at least 6 weeks, or 25 % of the lead time for the test, whichever is the shorter.

8.3.2 Hydrostatic Testing

8.3.2.1 All components handling the pumped liquid (including auxiliaries) shall be assembled as a single unit and tested hydrostatically with liquid at a minimum of $1^1/_2$ times the maximum allowable working pressure but not less than a gauge pressure of 150 kPa (1.5 bar) (20 psi). The test liquid shall be at a higher temperature than the nil-ductility transition temperature of the material being tested.

NOTE The nil-ductility temperature is the highest temperature at which a material experiences complete brittle fracture without appreciable plastic deformation.

8.3.2.2 If the component handling the pumped liquid is to operate at a temperature at which the strength of a material is below the strength of that material at the testing temperature, the hydrostatic test pressure shall be multiplied by a factor obtained by dividing the allowable working stress for the material at the testing temperature by that at the rated operating temperature. The stress values used shall be determined in accordance with those of SECTION VII, Division 1 of ASME Code for vessels. For piping, the stress shall conform to ISO 15649. The pressure thus obtained shall then be the minimum pressure at which the hydrostatic test shall be performed. The Vendor shall list actual hydrostatic test pressures on data sheets.

NOTE 1 For the purposes of this provision, ISO 15649 is equivalent to ASME B31.3.

NOTE 2 Applicability of this requirement to the material being tested should be verified before hydro-test, as the properties of many grades of steel do not change appreciably at temperatures up to 200 °C (400 °F).

8.3.2.3 If applicable, tests shall be in accordance with the code or standard to which the part has been designed. In the event that a discrepancy exists between the code test pressure and the test pressure in this standard, the higher pressure shall govern.

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

NOTE Chloride content is limited in order to prevent stress corrosion cracking.

8.3.2.5 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 fluid cylinder or cylinder joint is observed for a minimum of 30 minutes. Large, heavy pressure-containing parts may require a longer testing period to be agreed upon by the Purchaser and the Vendor. Gaskets used during the hydrostatic testing shall be of the same design as supplied with the pump.

8.3.2.6 All water-side cooling passages shall be tested at a minimum gauge pressure of 1000 kPa (10 bar) (150 psi).

8.3.3 Pre-testing Check

8.3.3.1 Oil system components downstream of the filters shall meet the cleanliness requirements of ISO 10438-3 before any test is started.

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

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

8.3.3.3 All warning, protective and control devices used during the test shall be checked and adjusted as required.

8.3.4 Mechanical Run Test

- **8.3.4.1** If specified, the beginning of the mechanical run test shall not occur until oil temperatures have stabilized.

- **8.3.4.2** If specified, the pump shall be mechanically run for four hours. Unless otherwise specified or agreed, this shall be performed at the rated flow.

- **8.3.4.3** Unless otherwise agreed, the contract shaft seals and bearings shall be used in the machine for the mechanical running test.

8.3.4.4 If supplied with an over-speed trip, the speed shall be increased to 99 % of trip speed and the equipment shall be run for a minimum of 15 minutes.

8.3.4.5 If supplied with an overspeed trip, the trip device(s) shall be checked and adjusted until values within 1 % of the nominal trip setting are attained. Mechanical speed trip overspeed devices shall attain three consecutive non-trending trip values that meet this criterion.

8.3.4.6 If supplied, the governor and any other speed-regulating devices shall be tested for smooth performance over the operating speed range. No-load stability and response to the control signal shall be checked.

8.3.4.7 Unless otherwise agreed, the contract shaft seals and bearings shall be used in the machine for the mechanical run test.

8.3.4.8 If replacement or modification of bearings or seals or dismantling of the case to replace or modify other parts is required to correct mechanical or performance deficiencies, the initial test will not be acceptable and the final shop tests shall be run after these deficiencies are corrected.

8.3.5 Performance Test, Direct-Acting Pump

8.3.5.1 Unless otherwise specified, tests shall be conducted in accordance with the standards of the Hydraulic Institute. The Manufacturer shall operate the pump in his shop for a sufficient period to obtain complete test data, including speed, discharge pressure, suction pressure, power, and flow rate.

8.3.5.2 If the test facility does not have the capability to meet the rated conditions, the following tests shall be run sequentially instead of concurrently:

a) run the pump at the specified discharge pressure with reduced speed,

b) run the pump at the rated speed with reduced discharge pressure.

The Purchaser and the Vendor shall agree to the test methods and their limitations prior to performing the tests.

8.3.5.3 During the shop tests, the pump shall operate smoothly over the specified operating range, except when reaching cavitating conditions during the NPIP/NPSH test.

8.3.5.4 At rated speed, the motive fluid power required shall not exceed the motive fluid power quoted.

8.3.5.5 If dismantling is necessary to correct pump deficiencies, the pump characteristics affected by the correction shall be reestablished by testing.

8.3.6 Performance Test, Power Pump

8.3.6.1 Unless otherwise specified, tests shall be conducted in accordance with the standards of the Hydraulic Institute Pump Standards (see 8.3.5.1). The Manufacturer shall operate the pump in his shop for sufficient period to obtain complete test data, including speed, discharge pressure, suction pressure, power, and capacity.

8.3.6.2 If the pump is to be operated at variable speeds, the pump shall be operated at speeds within five percentage points of 25, 50, 75, 100, and 125 percent of the rated speed, provided the pump does not cavitate at speeds above maximum operating speed.

8.3.6.3 The tests specified in 8.3.6.1 apply to the pump only, and the values of power are to be taken as referring to the pump. However, the recorded data and final report may include information on the complete unit, including driver and auxiliary equipment. The Purchaser and the Vendor shall agree to the test measurements to be recorded on both the driver and the auxiliary equipment.

8.3.6.4 If the test facility does not have the capability to meet the rated conditions, the tests shall be run at both the specified discharge pressure with reduced speed and at the rated speed with reduced discharge pressure. The Purchaser and the Vendor shall agree to the test methods and their limitations prior to performing the tests.

8.3.6.5 If dismantling is necessary to correct pump deficiencies, the pump characteristics affected by the correction shall be reestablished by testing.

8.3.7 Test Tolerances

Unless otherwise agreed or specified, when operated on the test stand, pumps shall be within the tolerances as given in Table 13.

Table 13—Test Tolerances

Measurements in %.

Characteristic	Tolerance (%)	
	Power Pump	Direct-Acting Pump
Rated capacity	≤3, –0	≤3, –0
Rated power (at rated pressure and capacity)	≤4	—
NPIP/NPSHR	+0	+0

8.3.8 NPIP/NPSH Test

For the NPIP test, a trace (plot) of the inlet pressure shall be made just upstream of any device used to improve inlet flow (e.g., a stabilizer) and compared with the vapor pressure of the pumped liquid at the maximum allowable temperature. The NPIP test result shall be considered acceptable if there are no pressure spikes with a peak instantaneous value greater than three times the mean inlet pressure, or a minimum value less than 110 % of the above vapor pressure.

If specified, the pump shall be tested for NPSH. At rated speed and with NPSHA equal to quoted NPSHR, the pump capacity shall be within three percent of the non-cavitating capacity.

Warning—The pump shall not be run while cavitating.

- **8.3.9 Optional Tests**

If specified, the shop tests described in 8.3.9.1 through 8.3.9.3 shall be performed. Test details shall be mutually agreed upon by the Purchaser and the Vendor.

- **8.3.9.1 Complete Unit Test**

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

- **8.3.9.2 Sound-Level Test**

If specified, the sound-level test shall be performed in accordance with ISO 3744 or other agreed standard.

8.3.9.3 Governor Response and Emergency Overspeed Trip Systems Test

If specified, the governor response and emergency overspeed trip systems test shall be conducted as agreed between Purchaser and Supplier.

8.4 Preparation for Shipment

8.4.1 Equipment shall be prepared for the type of shipment specified. Unless otherwise agreed, the preparation shall make the equipment suitable for six months of outdoor storage from the time of shipment, with no disassembly required before installation, 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.

Removal of the inhibitor and periodic very slow rotation of the pump shaft, to ease seal and bearing movement, shall be the responsibility of the Purchaser.

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, as described in API 686, Chapter 3.

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 8.4.3.10.

8.4.3.1 Except for machined surfaces, all exterior surfaces that may corrode during shipment, storage, or in service, shall be given at least one coat of the Manufacturer's standard paint. The paint shall not contain lead or chromates.

NOTE Austenitic stainless steels are typically not painted.

8.4.3.2 Exterior machined surfaces except for corrosion-resistant material shall be coated with rust preventive.

8.4.3.3 The interior of the equipment shall be clean (free from scale, welding spatter and foreign objects) and, except for corrosion-resistant material, sprayed or flushed with rust preventive that can be removed with solvent. The rust preventive shall be applied through all openings while the shaft is rotated.

8.4.3.4 Internal surfaces of bearing housings and carbon steel oil systems' components shall be coated with oil-soluble rust preventive that is compatible with the lubricating oil.

8.4.3.5 Flanged openings shall be provided with metal closures at least 5 mm ($^3/_{16}$ in.) thick with elastomeric gaskets and at least four full-diameter bolts. For studded openings, all nuts needed for the intended service shall be used to secure closures. Each opening shall be car-sealed so that the protective cover cannot be removed without the seal being broken.

8.4.3.6 Threaded openings shall be provided with steel caps or round-head steel plugs. In no case shall non-metallic (such as plastic) caps or plugs be used.

NOTE These are shipping plugs; permanent plugs are covered in 6.5.12.

8.4.3.7 Lifting points and lifting lugs shall be clearly identified on the equipment or equipment package. The recommended lifting arrangement shall be as described in the installation manual.

8.4.3.8 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. Crated equipment shall be shipped with duplicate packing lists, one inside and one on the outside of the shipping container.

8.4.3.9 Exposed shafts, and coupling fit areas shall be protected with a corrosion barrier followed by a separate barrier material to protect against incidental mechanical damage.

8.4.3.10 Loose components shall be dipped in wax or placed in plastic bags and contained by cardboard boxes. Loose boxes are to be securely blocked in the shipping container.

8.4.4 Auxiliary piping connections supplied 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.

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

8.4.6 One copy of the Manufacturer's installation instructions shall be packed and shipped with the equipment.

8.4.7 Connections on auxiliary piping, removed for shipment, shall be match marked for ease of reassembly.

8.4.8 If specified, the fit-up and assembly of machine-mounted piping, intercoolers, etc. shall be completed in the Vendor's shop prior to shipment.

9 Vendor's Data

9.1 General

9.1.1 The information to be supplied by the Vendor is specified in 9.2 and 9.3. (See Annex B.)

9.1.2 The data shall be annotated on transmittal (cover) letters, title pages and in title blocks or other prominent position on drawings, with the following information:

a) Purchaser's/Owner's corporate name;

b) job/project number;

c) equipment item number and service name;

d) inquiry or purchase order number;

e) any other identification specified in the inquiry or purchase order;

f) Vendor's identifying proposal number, shop order number, serial number, or other reference required to completely identify return correspondence.

9.1.3 A coordination meeting should be held, preferably at the Vendor's plant, within 4-6 weeks after order commitment. Unless otherwise specified, the Vendor shall prepare and distribute an agenda prior to this meeting, which as a minimum shall include a review of the following items:

a) purchase order, scope of supply, unit responsibility, sub-Vendor items, and lines of communications;

b) data sheets;

c) applicable specifications and previously agreed exceptions;

d) schedules for the transmittal of data, production, and testing;

e) quality assurance program and procedures;

f) inspection, expediting, and testing;

g) schematics and bills of materials for auxiliary systems;

h) physical orientation of the equipment, piping and auxiliary systems, including access for operation and maintenance;

i) coupling selection and rating;

j) stuffing box and controls;

k) torsional analysis if required;

l) equipment performance, alternate operating conditions, startup, shutdown, and any operating limitations;

m) scope and details of any pulsation or vibration analysis;

n) instrumentation and controls;

o) identification of items design reviews;

p) inspection, related acceptance criteria, and testing;

q) expediting;

r) other technical items.

9.2 Proposals

9.2.1 General

The Vendor shall forward the original proposal, with the specified number of copies, to the addressee specified in the inquiry documents. The proposal shall include, as a minimum, the data specified in 9.2.2 through 9.2.4, and a specific statement that the equipment and all its components and auxiliaries are in strict accordance with this International Standard. If the equipment or any of its components or auxiliaries is not in strict accordance, the Vendor shall include a list that details and explains each deviation. The Vendor shall provide sufficient detail to enable the Purchaser to evaluate any proposed alternative designs. All correspondence shall be clearly identified in accordance with 9.1.2.

9.2.2 Drawings

9.2.2.1 Data requirements and/or VDDR form (see Annex B) shall be included in the proposal. As a minimum, the following shall be included.

a) A general arrangement or outline drawing for each machine train or skid-mounted package, showing overall dimensions, maintenance clearance dimensions, overall weights, erection weights, and the largest maintenance weight for each item. The direction of rotation and the size and location of major Purchaser connections shall also be indicated.

b) Cross-sectional drawings showing the details of the proposed equipment.

c) Schematics of all auxiliary systems including fuel, lube oil, control, and electrical systems. Bills of material may be included.

d) Sketches that show methods of lifting the assembled machine or machines, packages, and major components and auxiliaries. (This information may be included on the drawings specified in item “a” above.)

9.2.2.2 If “typical” drawings, schematics and bills of material are used, they shall be marked up to show the weight and dimension data to reflect the actual equipment and scope proposed.

9.2.3 Technical Data

The following data shall be included in the proposal.

a) Purchaser’s data sheets with complete Vendor’s information entered thereon and literature to fully describe details of the offering.

b) Predicted noise data (6.1.5).

c) Vendor Drawing and Data Requirements form (see Annex B) indicating the schedule according to which the Vendor agrees to transmit all the data specified.

d) Schedule for shipment of the equipment, in weeks after receipt of an order.

e) List of major wearing components, showing any interchangeability with the Owner’s existing machines.

f) List of spare parts recommended for start-up and normal maintenance purposes.

g) List of the special tools supplied for maintenance.

h) Description of any special weather protection and winterization required for start-up, operation, and periods of idleness under the site conditions specified on the data sheets. This description shall clearly indicate the protection to be supplied by the Purchaser as well as that included in the Vendor’s scope of supply.

i) Complete tabulation of utility requirements, e.g. steam, water, electricity, air, gas, lube oil (including the quantity and supply pressure of the oil required, and the heat load to be removed by the oil), and the nameplate power rating and operating power requirements of auxiliary drivers. Approximate data shall be clearly indicated as such.

j) Description of any optional or additional tests and inspection procedures for materials as required by 6.11.1.10 and 6.11.1.11.

k) Description of any special requirements specified in the Purchaser’s inquiry.

l) List of machines, similar to the proposed machine(s) that have been installed and are operating under conditions analogous to those specified in the inquiry.

m) Any start-up, shutdown, or operating restrictions required to protect the integrity of the equipment.

n) List of any components that can be construed as being of alternative design, hence requiring Purchaser’s acceptance.

9.2.4 Performance Curves

The Vendor shall provide full details of the performance envelope of the equipment offered with any limitations indicated thereon.

9.2.5 Optional Tests

The Vendor shall supply an outline of the procedures to be used for each of the special or optional tests that have been specified by the Purchaser or proposed by the Vendor.

9.3 Contract Data

9.3.1 General

9.3.1.1 Contract data shall be supplied by the Vendor in accordance with the VDDR form (see Annex B).

9.3.1.2 Each drawing shall have a title block in the lower right-hand corner with the date of certification, identification data specified in 9.1.2, revision number and date and title. Similar information shall be provided on all other documents including sub-Vendor items.

9.3.1.3 The Purchaser will promptly review the Vendor's data upon receipt; however, this review shall not constitute permission to deviate from any requirements in the order unless specifically agreed upon in writing. After the data has been reviewed and accepted, the Vendor shall supply certified copies in the quantities specified.

9.3.1.4 A complete list of Vendor data shall be included with the first issue of major drawings. This list shall contain titles, drawing numbers, and a schedule for transmittal of each item listed. This list shall cross-reference data with respect to the VDDR form in Annex B.

9.3.2 Drawings and Technical Data

The drawings and data supplied by the Vendor shall contain sufficient information so that together with the manuals specified in 9.3.5, the Purchaser can properly install, operate, and maintain the equipment covered by the purchase order. All contract drawings and data shall be clearly legible (8-point minimum font size even if reduced from a larger size drawing), and shall cover the scope of the VDDR form. (See Annex B.)

• 9.3.3 Progress Reports

The Vendor shall submit progress reports to the Purchaser at intervals specified.

NOTE See the VDDR form (Annex B).

9.3.4 Parts Lists and Recommended Spares

9.3.4.1 The Vendor shall submit complete parts lists for all equipment and accessories supplied. These lists shall include part names, Manufacturers' unique part numbers, and materials of construction (identified by applicable international standards). Each part shall be completely identified and shown on appropriate cross-sectional, assembly-type cutaway or exploded-view isometric drawings. Interchangeable parts shall be identified as such. Parts that have been modified from standard dimensions or finish to satisfy specific performance requirements shall be uniquely identified by part number. Standard purchased items shall be identified by the original Manufacturer's name and part number.

9.3.4.2 The Vendor shall indicate on each of these complete parts lists all those parts that are recommended as start-up or maintenance spares, and the recommended stocking quantities of each. These should include spare parts recommendations of sub-Vendors that were not available for inclusion in the Vendor's original proposal.

9.3.5 Installation, Operation, Maintenance, and Technical Data Manuals

9.3.5.1 General

The Vendor shall provide sufficient written instructions and all necessary drawings to enable the Purchaser to install, operate, and maintain all of the equipment covered by the purchase order. This information shall be compiled in a manual or manuals with a cover sheet showing the information listed in 9.1.2, an index sheet, and a complete list of the enclosed drawings by title and drawing number. The manual or manuals shall be prepared specifically for the equipment covered by the purchase order. “Typical” manuals are unacceptable.

9.3.5.2 Installation Manual

All information required for the proper installation of the equipment shall be compiled in a manual that shall be issued no later than the time of issue of final certified drawings. For this reason, it may be separate from the operating and maintenance instructions. This manual shall contain information on alignment and grouting procedures, normal and maximum utility requirements, centers of mass, rigging provisions and procedures, and all other installation data. All drawings and data specified in 9.2.2 and 9.2.3 that are pertinent to proper installation shall be included as part of this manual. See the VDDR form (Annex B).

9.3.5.3 Operating and Maintenance Manual

A manual containing all required operating and maintenance instructions shall be supplied not later than 2 weeks after all specified tests have been successfully completed. In addition to covering operation at all specified process conditions, this manual shall also contain separate sections covering operation under any specified extreme environmental conditions. See the VDDR form (Annex B).

9.3.5.4 Technical Data Manual

If specified, the Vendor shall provide the Purchaser with a technical data manual within 30 days of completion of shop testing. See the VDDR form (Annex B).

Annex A
(informative)

Pump Material Specifications

Table A.1 may be used for guidance regarding materials specifications. If this table is used, it should not be assumed that the material specifications are acceptable without taking full account of the service in which they will be applied. Table A.1 lists corresponding materials according to International (ISO), American, European, and Japanese standards which may be acceptable. These materials represent family/ type and grade only. The final required condition or hardness level (where appropriate) is not specified. These materials might not be interchangeable for all applications.

Table A.1—Materials Specifications for Reciprocating Pump Parts

Material Class	Applications	USA		International ISO	Europe		Japan JIS
		ASTM	UNS[a]		EN[b]	Grade	
Cast Iron	Pressure Castings	A278 Class 30	F12401	185/Gr. 250	EN 1561	EN-GJL-250	G 5501, FC 300
	General Castings	A48 Class 25/30/40	F11701/ F12101	185/Gr. 300	EN 1561	EN-GJL-250 EN-GJL-300	G 5501, FC 250/ 300
Ductile iron	General Castings	A536 Gr 60-40-18	F32800	1083, 400-18	EN-1561	EN-GJS-400-18	
Ni-resist	General Castings	A436 Type 1	F41000	2892, L-NiCuCr 15 6 3	EN-13835	EN-GJLA-XniCuCr 15 6 3	
		A439 Type D-2	F43000	2892, S-NiCr 20 2	En-13835	EN-GJSA-XniCr20-2	
Carbon Steel	Pressure Castings	A216 Gr WCB	J03002	4991 C23-45 AH	EN 10213-2	GP 240 GH	G 5151, Cl SCPH 2
	Wrought / Forgings	A266 Class 2	K03506	683-18-C25	EN 10222-2	P 280 GH	G 3202, Cl SFVC 2A
	Bar Stock: Pressure	A696 Gr B40	G10200	683-18-C 25	EN 10273	P 295 GH	G 4051, Cl S25C
	Bar Stock: General	A576 Gr 1045	G10450	683-18-C45[e]	EN 10083-2	C 45	G 4051, Cl S45C
	Bolts and Studs (General)	A193 Gr B7	G41400	2604-2-F31	EN 10269	42 Cr Mo 4	G 4107, Class 2, SNB7
	Nuts (General)	A194 Gr 2H	K04002	683-1-C35[e]	EN 10269	C 35 E	G 4051, Cl S45C
	Plate	A516 Gr 65/70	K02403/ K02700	9328-4 P355 TN/PL 355TN	EN 10028-3	P 295 GH	G 3106, Gr SM400B
	Pipe	A106 GrB	K03006	9329-2 PH26	EN 10208-1	L 245 GA	G 3456, Gr. STPT 370/410
	Fittings	A105	K03504				G 4051, Cl S25C G 3202, Cl SFVC 2A, SFVC2B
AISI 4140 Steel	Bar Stock	A434 Class BB A434 Class BC	G41400[c]		EN 10083-1	42 Cr Mo 4	G 4105, C1 SCM 440
	Bolts and Studs	A193 Gr B7	G41400		EN 10269	42 Cr Mo 4	G 4107, Class 2, SNB7
	Nuts	A194 Gr 2H	K04002	2604-2-F31	EN 10269	C 35 E	G 4051, C1 S45C
12% Chrome Steel	Pressure Castings	A217 Gr CA 15	J91150		EN 10213-2	GX 8 Cr Ni 12	G 5121, C1 SCS 1
		A487 Gr CA6NM	J91540		EN 10213-2	GX 4 Cr Ni 13-4	G 5121, C1 SCS 6
	General Castings	A743 Gr CA 15	J91150		EN 10283	GX 12 Cr 12	

Table A.1—Materials Specifications for Reciprocating Pump Parts (Continued)

Material Class	Applications	USA		International ISO	Europe		Japan JIS
		ASTM	UNS[a]		EN[b]	Grade	
		A743 Gr CA6NM	J91540		EN 10283	GX 4 Cr Ni 13-4	
	Wrought / Forgings: Pressure	A182 Gr F6a Cl 1	S41000	683-13-3	EN 10250-4	X12 Cr 13 X 3	G 3214, Gr. SUS F 410-A
		A 182 Gr F 6 NM	S41500		EN 10222-5	Cr NiMo 13-4-1	G 3214, C1 SUS F6NM
	Wrought / Forgings: General	A473 Type 410	S41000	683-13-2	EN 10088-3	X 12 Cr 13	G 3214, Gr. SUS F 410-A
	Bar Stock: Pressure	A479 Type 410	S41000	683-13-3	EN 10272	X12 Cr 13	G 4303, Gr. SUS 410 or 403
	Bar Stock: General	A276 Type 410	S41400	683-13-3	EN 10088-3	X 12 Cr 13	G 4303, Gr. SUS 403 or 410
	Bar Stock: Forgings[c]	A276 Type 420	S42000	683-13-4	EN 10088-3	X 20 Cr 13	G 4303, Gr. SUS 420J1 or 420J2
		A473 Type 416	S41600			X 20 Cr S 13	
		A582 Type 416	S41600			X 20 Cr S 13	
	Bolts and Studs[d]	A193 Gr B6	S41000	3506-1, C4-70	EN 10269	X22CrMoV 12-1	G 4303, Gr SUS 403 or 410
	Nuts[d]	A194 Gr 6	S41000	3506-2, C4-70	EN 10269	X22CrMoV 12-1	G 4303, Gr SUS 403 or 410
	Plate	A240 Type 410	S41000	683-13-3	EN 10088-2	X 12 Cr 13	G 4304/4305, Gr. SUS 403 or 410
Austenitic Stainless Steel	Pressure Castings	A351 Gr CF3	J92500	683-13-10	EN 10213-4	GX2 Cr Ni 19-11	G 5121, C1 SCS 13A
		A351 Gr CF3M	J92800	683-13-19	EN 10213-4	GX2 Cr Ni Mo 19-11-2	G 5121, C1 SCS 14A
	General Castings	A743 Gr CF3	J92500		EN 10283	GX2 Cr Ni 19-11	G5121, Cl SCS 13A
		A743 Gr CF3M	J92800		EN 10283	GX2 Cr Ni Mo 19-11-2	G5121, Cl SCS 14A
	Wrought / Forgings	A182 Gr F 304L	S30403	9327-5 XCrNi 18-10	EN 10222-5 EN 10250-4	X2 Cr Ni 19-11	G 3214, C1 SUS F 304 L
		A182 Gr F 316L	S31603	9327-5 XCrNiMo 17-12	EN 10222-5 EN 10250-4	X2 Cr Ni Mo 17-12-2	G 3214, C1 SUS F 316 L
	Bar Stock[f]	A479 Type 304L	S30403	9327-5 X2CrNi 18-10,	EN 10088-3	X2 Cr Ni 19-11	G 4303, Gr. SUS 304L
		A479 Type 316L	S31603	XCrNiMo 17-12	EN 10088-3	X2 Cr Ni Mo 17-12-2	G 4303, Gr. SUS 316L
		A479 Type XM19 e	S20910				

Table A.1—Materials Specifications for Reciprocating Pump Parts (Continued)

Material Class	Applications	USA		International ISO	Europe		Japan JIS
		ASTM	UNS[a]		EN[b]	Grade	
	Plate	A240 Gr 304L / 316L	S30403 S31603	9328-5 XCrNi-17-12-2	EN 10028-7 EN 10028-7	X2 Cr Ni 19-11 X2 Cr Ni Mo 17-12-2	G 4304/4305, Gr. SUS 304L / 316L
	Pipe	A312 Type 304L 316L	S30403 S31603	683-13-10 683-13-19			G 3459, Gr. SUS 304LTP/316LTP
	Fittings	A182 Gr F304L Gr 316L	S30403 S31603	9327-5 X2CrNi 18-10, X2CrNiMo 17-12	EN 10222-5	X2 Cr Ni 19-11 X2 Cr Ni Mo 17-12-2	G 3214, Gr. SUS F304L / 316L
	Bolts and Studs	A193 Gr B 8 M	S31600	3506-1, A4-70	EN 10250-4	X6 Cr Ni Mo Ti 17-12-2	G 4303, Gr. SUS 316
	Nuts	A194 Gr B 8 M	S31 00	3506-2, A4-70	EN 10250-4	X6 Cr Ni Mo Ti 17-12-2	G 4303, Gr. SUS 316
Duplex Stainless Steel	Pressure Castings	A351 Gr CD4 MCu A890 Gr 1 B	J93370 J93372		EN 10213-4	GX2 CrNiMoCuN 25-6-3-3	
		A890 Gr 3A	J93371				G 5121, Gr. SCS 11
		A890 Gr 4A	J92205		EN 10213-4	GX2 CrNiMoCuN 25-6-3-3	G 5121, Gr. SCS 10
	Wrought / Forgings	A182 Gr F 51	S31803		EN 10250-4 EN 10222-5	X2 Cr Ni Mo N 22-5-3	G 4319, Cl SUS 329J1FB
		A479	S32550		EN 10088-3	X2 Cr Ni Mo Cu N 25-6-3	
	Bar Stock	A276-S31803	S31803		EN 10088-3	X2 Cr Ni Mo N 22-5-3	G 4303, Gr. SUS 329J3L
	Plate	A240-S31803	S31803		EN 10028-7	X2 Cr Ni Mo N 22-5-3	G 4303/G4305 Gr. SUS 329 J3L
	Pipe	A790-S31803	S31803				G 3459, Gr. SUS 329J3LTP
	Fittings	A182 Gr F 51	S31803		EN 10250-4 EN 10222-5	X2 Cr Ni Mo N 22-5-3	B2312 / B2316, Gr. SUS 329J3L
	Bolts and Studs	A276-S31803	S31803		EN 10088-3	X2 Cr Ni Mo N 22-5-3	G 4303, Gr. SUS 329 J3L
	Nuts	A276-S31803	S31803		EN 10088-3	X2 Cr Ni Mo N 22-5-3	G 4303, Gr SUS 329 J3L

Table A.1—Materials Specifications for Reciprocating Pump Parts (Continued)

Material Class	Applications	USA		International ISO	Europe		Japan JIS
		ASTM	UNS[a]		EN[b]	Grade	
Super Duplex Stainless Steel[g]	Pressure Castings	A351 Gr CD3MWCuN	J93380				
		A890 Gr 5A	J93404		EN 10213-4	GX2 Cr Ni Mo N 26-7-4	
		A890 Gr 6A	J93380				
	Wrought / Forgings	A182 Gr 55	S32760		EN 10250-4 EN 10088-3	X2 Cr Ni Mo Cu WN 25-7-4	
	Bar Stock	A276-S32760 A479-S32760	S32760		EN 10088-3	X2 Cr Ni Mo Cu WN 25-7-4	G 4303, Gr. SUS 329 J4L
	Plate	A240-S32760	S32760		EN 10028-7	X2 Cr Ni Mo Cu WN 25-7-4	G 4304 / 4305, Gr. SUS 329 J4L
	Pipe	A790-S32760	S32760				G 3459, Gr. SUS 329 J4LTP
	Fittings	A182 Gr F55	S32760		EN 10250-4 EN 10088-3	X2 Cr Ni Mo Cu WN 25-7-4	B 2312 / B 2316, Gr. SUS 329 J4L
	Bolts and Studs	A276-S32760	S32760		EN 10088-3	X2 Cr Ni Mo Cu WN 25-7-4	G 4303, Gr. SUS 329 J4L
	Nuts	A276-S32760	S32760		EN 10088-3	X2 Cr Ni Mo Cu WN 25-7-4	G 4303, Gr. SUS 329 J4L

NOTE 1 This table lists corresponding (not necessarily equivalent) International Materials that 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.

NOTE 2 Materials listed for pressure applications may be utilized for non-pressure applications.

NOTE 3 When approved by the Purchaser, alternative materials of the same nominal chemistry and mechanical properties may be substituted.

[a] UNS (unified numbering system) designation for chemistry only.

[b] If EN standards do not yet exist, European national standards, e.g. AFNOR, BS, DIN, etc., are available.

[c] Do not use for shafts in the hardened condition (over 302 HB).

[d] Special, normally use AISI 4140.

[e] Nitronic 50 or equivalent.

[f] For shafts, standard grades of 304 and 316 may be substituted in place of low carbon (L) grades

[g] Super duplex stainless steel classified with Pitting Resistance Equivalent (PRE) number greater than or equal to 40

PRE = $\%Cr_{free}$ + (3.3 x % Molybdenum) + (2 x % Copper) + (2 x %Tungsten) + (16 x % Nitrogen)

= [(% Chromium – (14.5 x % Carbon)] + (3.3 x % Molybdenum) + (2 x % Copper) + (2 x % Tungsten) + (16 x % Nitrogen)

Annex B

(informative)

Vendor Drawing and Data Requirements (VDDR) (Typical)

Table B.1—Vendor Drawing and Data Requirements (VDOR) (Typical)

Document	Drawing Number	First Issue	Included in Maintenance Manual	Included In Data Book	Copies for Review	Copies Final	Format
VDDR Form			N	N			
Quality Plan			N	N			
Quality Manual			N	N			
Production Program			N	N			
Status Report			N	N			
Index of Operation and Maintenance Manual			Y	N			
Index of Installation Manual			N	N			
Index of Data Book			N	Y			
General Arrangement Drawing			Y	N			
Out of Balance Forces and Moments			Y	N			
Pump Cross Sectional Drawings			Y	N			
Pump Data Sheet			Y	Y			
Pump Lube Oil P & ID			Y	N			
Stuffing Box Lube Oil P & ID			Y	N			
Stuffing Box Quench P & ID			Y	N			
Stuffing Box Leakage Header P & ID			Y	N			
Cooling Water P & ID			Y	N			
Special Installation Instructions			Y	N			
Bill(s) of Material			Y	N			
Motor General Arrangement Drawing			Y	N			
Motor Data Sheet			Y	Y			
Pump / Motor Speed / Torque Curve			Y	Y			
Motor(s) Hazardous Area Certification			N	Y			
Motor(s) Protection Certificate			N	Y			
Motor(s) Type Test Certificate			N	Y			
Motor(s) Work Test Certificate			N	Y			
Inverter General Arrangement Drawing			Y	N			
Inverter Data Sheet			Y	N			

Table B.1—Vendor Drawing and Data Requirements (VDOR) (Typical) (Continued)

Document	Drawing Number	First Issue	Included in Maintenance Manual	Included In Data Book	Copies for Review	Copies Final	Format
Inverter Wiring Diagram			Y	N			
Inverter Component Checklist			N	Y			
Inverter Continuity / Integrity Certificate			N	Y			
Inverter Insulation Certificate			N	Y			
Inverter Short Circuit Certificate			N	Y			
Inverter No Load Test with Motor Certificate			N	Y			
Inverter 24-Hour Full Load Test Certificate			N	Y			
Inverter Control Function Certificate			N	Y			
Gearbox General Arrangement Drawing			Y	N			
Gearbox Cross Sectional Drawings			Y	N			
Gearbox Bill(s) of Material			Y	N			
Coupling Drawings			Y	N			
Utilities Consumption List			Y	N			
Lube Oil Schedule			Y	N			
Control Logic			Y	N			
Instrument Schedule(s)			Y	Y			
Instrument Wiring Diagram			Y	N			
Instrument(s) Hazardous Area Certification			N	Y			
Instrument(s) Protection Certificate			N	Y			
Instrument(s) Calibration Certificate			N	Y			
Hydrotest Procedure			N	N			
Performance Test Procedure			N	N			
NPSH Test Procedure			N	N			
Mechanical Run Test Procedure			N	N			
Endurance Run Test Procedure			N	N			
String Test Procedure			N	N			
Pressure-limiting Valve Test Procedure			N	N			

Table B.1—Vendor Drawing and Data Requirements (VDOR) (Typical) (Continued)

Document	Drawing Number	First Issue	Included in Maintenance Manual	Included In Data Book	Copies for Review	Copies Final	Format
Pulsation Measurement Test Procedure			N	N			
Vibration Survey Procedure			N	N			
Noise Survey Procedure			N	N			
Functional Test Procedure			N	N			
Dye Penetrant Inspection Procedure			N	N			
Magnetic Particle Inspection Procedure			N	N			
Radiography Inspection Procedure			N	N			
Weld Procedure			N	N			
Welder Qualifications			N	Y			
Paint Procedure			N	N			
Storage / Preservation Procedure			Y	N			
Commissioning Spares Quotation			N	N			
1 Years Operation Spares Quotation			N	N			
2 Years Operating Spares Quotation			N	N			
List of Special Tools Supplied			Y	N			
Certificate of Conformity			N	Y			
Certificate of Mechanical Properties			N	Y			
Certificate of Chemical Analysis			N	Y			
Certificate of Hardness			N	Y			
Dye Penetrant Inspection Certificate			N	Y			
Magnetic Particle Inspection Certificate			N	Y			
Radiography Inspection Certificate			N	Y			
Hydrotest Certificates			N	Y			
Mechanical Run Certificate			N	Y			
Performance Test Certificate			N	Y			
NPSH Test Certificate			N	Y			
String Test Certificate			N	Y			

Table B.1—Vendor Drawing and Data Requirements (VDOR) (Typical) (Continued)

Document	Drawing Number	First Issue	Included in Maintenance Manual	Included In Data Book	Copies for Review	Copies Final	Format
Endurance Test Certificate			N	Y			
Pressure-limiting Valve Test Certificate			N	Y			
Pulsation Test Certificate			N	Y			
Vibration Survey Certificate			N	Y			
Noise Survey Certificate			N	Y			
Certificate of Paint Thickness			N	Y			
Certificate of Cleanliness			N	Y			
Instrumentation Wiring Certification			N	Y			
Functional Test Certificate			N	Y			
Weight Schedule			N	Y			
Release Certificate			N	Y			
Installation, Operation and Maintenance Manual							
Data Book							

WAO = Weeks after order

WBT = Weeks before test

WAT = Weeks after test

WBD = Weeks before dispatch

WAD = Weeks after dispatch

Annex C
(informative)

Pulsation and Vibration Control Techniques

C.1 Definition of Design Analysis

C.1.1 General

The definition of the design analysis includes the following:

a) Analysis Approach 1: Item C.1.2;

b) Analysis Approach 2: Item C.1.3 and C.1.4.

The analysis approaches provided in Annex C may not give sufficient accuracy if the following conditions apply:

— long inlet lines;

— inlet flow velocities below 0.3 m/sec (1 ft/sec) or above 3 m/sec (10 ft/sec);

— the inlet liquid temperature is high enough that cavitation can be anticipated;

— the service has a critical hazard condition.

Annex E can provide an insight into the limitations.

C.1.2 Analysis Approach 1

C.1.2.1 The analytical study includes the design of a pump pulsation suppression device using proprietary and/or empirical analytical techniques to meet the pulsation levels specified in C.1.5 to C.1.7. This approach includes the study, good piping layout, good support/restraint principles, and adequate NPIP to design a pulsation solution.

NOTE When deciding which approach should be used, the Purchaser should consider such things as horsepower, economics, piping layout, reliability, documentation requirements, and experience with similar pumps and installations.

C.1.2.2 The analytical study should also include a simplified analysis of the Purchaser's piping system by the Purchaser with frequency data from the Supplier to determine critical piping lengths that may be in resonance with the acoustical excitation frequencies.

C.1.3 Analysis Approach 2 (Acoustical Simulation)

This approach involves pulsation control through the use of pulsation control devices developed using proven acoustical simulation techniques in conjunction with mechanical analysis of pipe runs and support systems (clamp design and spacing) to achieve control of vibration response.

C.1.3.1, C.1.3.2, and C.1.3.3 should be considered.

C.1.3.1 Calculation of Peak-to-Peak Pulsation Levels

Operating conditions and pump pressure steps are chosen to yield the highest expected pulsation amplitudes throughout the piping system. Pulsation amplitudes are then compared to the levels identified in C.1.5.

C.1.3.2 Calculation of Pulsation-Induced Shaking Forces (Unbalanced Forces)

Predict the maximum pulsation-induced shaking forces and unbalanced pressure acting on the critical elements of the piping system, such as pulsation control devices, pulsation control device internals, vessels, closed-end headers, and the like.

C.1.3.3 Development of Piping Modifications

If the pulsation analysis indicates that pulsation levels and/or shaking forces are excessive, modifications to the pulsation control devices and/or piping systems will be made and the analysis continued until the system meets the guidelines defined in C.1.5 or other criteria as agreed upon by the Purchaser and Vendor.

C.1.4 Mechanical Review and Piping Restraint Analysis

A simple mechanical review shall be performed using span and vessel mechanical natural frequency calculations to avoid mechanical resonance. This review shall result in a table of various pipe sizes that indicates the maximum allowable span (based on the maximum pump operating speed) between piping supports as a function of pipe diameter, and the separation margin requirements of C.1.8.

In the piping design, when clamps are used to avoid mechanical resonance, the thermal flexibility effects and static stresses should also be considered. To accurately predict and avoid piping resonance, the supports and clamps must rigidly restrain the piping. The piping restraint is not considered to be rigid unless the restraints have either enough mass or stiffness sufficient to emulate a vibration node at the restraint and the pipe is attached to the restraint using clamps. This requirement is difficult to attain with overhead piping and/or the use of simple supports, hangers, and guides.

C.1.5 Maximum Allowable Pulsation Levels

For Analysis Approach 1 or 2, the peak-to-peak pulsation levels in the suction and discharge piping systems beyond the pulsation control devices shall not exceed the levels calculated by Equation A.1 which specifies the allowable peak-to-peak pulsation level of each individual pulsation frequency component.

In SI Units:

$$P_1 = 3500 / (\mathrm{ID} \times f)^{1/2} \qquad \text{(A.1)}$$

In U.S. Customary Units:

$$P_1 = 100 / (\mathrm{ID} \times f)^{1/2}$$

where

P_1 is the maximum allowable peak to peak pulsation level of the individual pulsation frequency components, expressed in kPa (psi), (suction and discharge pulsation levels also must be limited to values that will not cause cavitation or relief valve lifting),

ID is the inside diameter of line pipe, in millimeters (in.),

f is the pulsation frequency, in Hertz, derived from the following equation:

$$f = (\text{RPM})n / 60 \quad \text{(A.2)}$$

where

RPM is pump speed, and

n corresponds to the fundamental frequency and harmonics of the pump speed.

For multiple units in parallel, the Purchaser and Vendor shall consider and agree upon the additive effects of pulsation due to simultaneous operation of all pumps or the level of pulsation at a particular test point.

C.1.6 Inlet Pressure Versus Liquid Vapor Pressure

Unless otherwise specified, the minimum value of the suction complex pressure wave P_{min} at the inlet reference point shall not be lower than the highest liquid vapor pressure with a margin of 10 % as shown in Equation A.3.

$$P_{\text{min}} > 1.1 \times P_{\text{v}} \quad \text{(A.3)}$$

where

P_{v} is the highest liquid vapor pressure or the gas dissolution pressure, expressed in kilopascals (pounds force per in.^{2}.

Results on the Vendors test rig shall be above this limit by at least an additional 10 %.

NOTE 1 The theoretical maximum amplitude of the suction pulsation occurs when the negative peak of the pulsation complex wave equals the average suction pressure minus the vapor pressure. Equation A.3 provides for a margin of safety between the negative peak of pulsation and vapor pressure.

NOTE 2 Entrained and/or dissolved gases can also significantly alter the cavitation characteristics of liquids.

C.1.7 Pressure-limiting Valve Protection

Unless otherwise specified, the margin of separation between the positive peak of the pulsation complex wave at the relief valve and the relief valve setting shall be 5 % of the maximum specified discharge pressure or 165 kPa (25 psi), whichever is greater (Figure C.1). See Equation A.4.

$$P_{\text{p}} < P_{\text{rv}} - P_{\text{d}} - (0.05 \times P_{\text{d}})^* \quad \text{(A.4)}$$

*[Or use a pressure of 1.65 bar (25 psi) whichever is greater.]

where

P_{d} is the maximum specified value of average discharge gauge pressure, expressed in bar (psi);

P_{P} is the positive peak of pulsation complex wave, expressed in bar (psi);

P_{rv} is the required relief valve setting in gauge pressure, expressed in bar (psi).

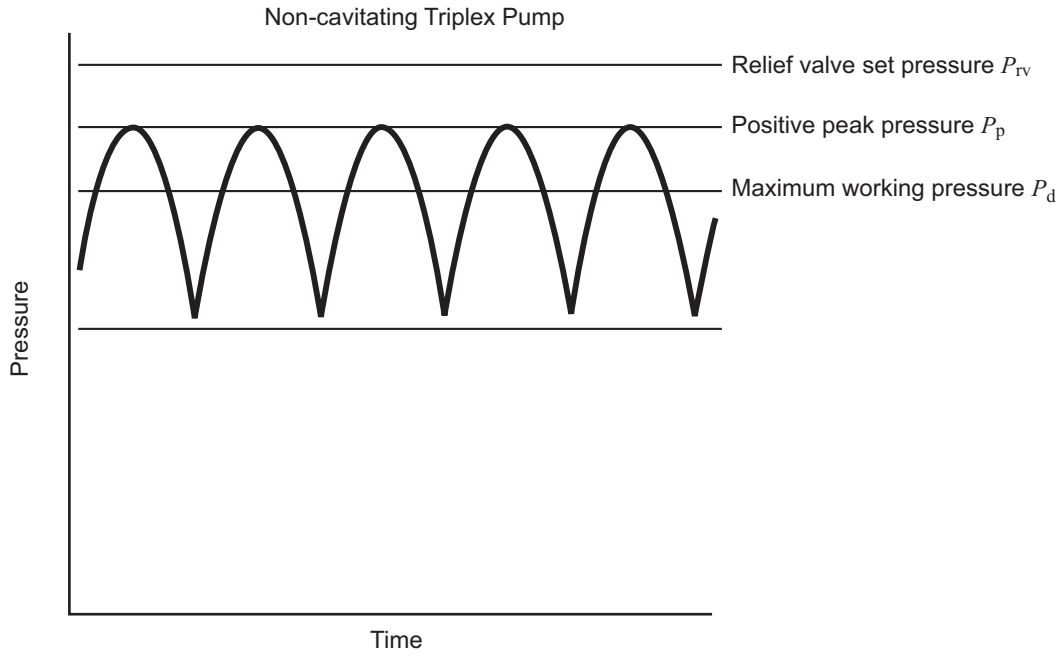


Figure C.1—Discharge Pressure Pulsations

C.1.8 Separation Margin Requirements for Piping Systems

Unless otherwise specified, to ensure that separation requirements are met, both of the following guidelines are to be used together to avoid coincidence of excitation frequencies with mechanical natural frequencies of the pump, pulsation suppression devices, and the piping system.

a) The minimum mechanical natural frequency of any manifold or pipe system element shall be designed to be greater than 20 % above the significant frequency of the unbalanced forces and cylinder stretching loads (RPM x Number of Cylinders) plus the inertial loads at 1 and 2 times RPM. In certain pump configurations, there can be significant excitation energy at higher orders of running speed and the system design shall take this into account. When the minimum mechanical natural frequency guideline is not met, or when there is significant excitation energy at higher orders, the separation margins as defined in b) shall be maintained.

NOTE The intent is to prevent the mechanical natural frequencies of the piping system being excited by forces generated by the pump.

b) The predicted mechanical natural frequencies shall be designed to be separated from significant excitation frequencies by at least 20 %.

NOTE The intent is that at least 10 % separation for the actual system is achieved and, due to modeling limitations, if 20 % is used for predicted designs, then 10 % for the actual system will generally be attained.

Annex D
(informative)

Reciprocating Positive–Displacement Data Sheets

D.1 Dimensions

Drawings and maintenance dimensions of pumps shall be in SI units or USC units.

CLIENT: _____

PROJECT TITLE: _____

JOB NUMBER: _____

EQUIPMENT NUMBER: _____

EQUIPMENT SERVICE: _____

SERIAL NUMBER: _____

All font this color By Purchaser
All font this color By Supplier

This cell contains specification specific information

This cell contains drop down selections

This cell contains drop down selections and contains specification specific information

COMMENTS: _____

Note: The attached data sheets have been modified from those in the appendix of API Standard 674, Third Edition

000		**ISSUED FOR QUOTATION**						
Rev	Date	Description	By	Checked		PROJ. ENG'R	CHIEF ENG'R	CLIENT

energy API AMERICAN PETROLEUM INSTITUTE

RECIPROCATING PUMP DATA SHEET

DATA SHEET No.

Sheet 1 of 6

RECIPROCATING PUMP DATA SHEET

SI Units

Note		Rev
	APPLICABLE TO :	
	FOR / UNIT	
	SITE / NO. REQUIRED	
	SERVICE / SIZE & TYPE	
	MANUFACTURER / MODEL / SERIAL NO.	

GENERAL

NO. MOTOR DRIVEN		OTHER DRIVER TYPE			
PUMP ITEM NO'S		PUMP ITEM NO'S			
MOTOR ITEM NO'S		DRIVER ITEM NO'S		GEAR ITEM NO'S	
MOTOR PROVIDED BY		DRIVER PROVIDED BY		GEAR PROVIDED BY	
MOTOR MOUNTED BY		DRIVER MOUNTED BY		GEAR MOUNTED BY	
MOTOR DATA SHEET NO.		DRIVER DATA SHEET NO.		GEAR DATA SHEET NO.	

OPERATING CONDITIONS

CAPACITY @ PT m^3/s :
@ MAXIMUM VISCOSITY / @ MINIMUM VISCOSITY
DISCHARGE PRESSURE kPa a :
MAXIMUM / MINIMUM
SUCTION PRESSURE kPa a :
MAXIMUM / MINIMUM
DIFFERENTIAL PRESSURE kPa
MAXIMUM / MINIMUM
NPSHA WITHOUT ACCELERATION HEAD m
ACCELERATION HEAD NET
MAXIMUM ALLOWABLE SOUND PRESSURE LEVEL

LIQUID

TYPE OR NAME OF LIQUID :
LIQUID COMPRESSIBILITY %
PUMPING TEMPERATURE °K :
NORM / MAX / MIN
SPECIFIC GRAVITY : NORM / MAX / MIN
SPECIFIC HEAT (Cp) kJ/(kg-K)
VISCOSITY Pa s NORM / MAX
CORROSIVE/EROSIVE AGENTS
CHLORIDE CONCENTRATION (PPM)
H_2S CONCENTRATION (PPM)
LIQUID :

SITE AND UTILITY DATA

LOCATION:
MOUNTED AT : TROPICALISATION REQD
ELECTRIC AREA CLASSIFICATION: ZONE
GROUP / TEMP CLASS
SITE DATA :
ELEVATION (MSL) : m **BAROMETER :** mmHg
RANGE OF AMBIENT TEMPS:MIN / MAX °K
RELATIVE HUMIDITY: MIN / MAX %
UNUSUAL CONDITIONS:

UTILITY CONDITIONS :

ELECTRICITY :	DRIVERS	HEATING	CONTROL	SHUTDOWN
VOLTAGE				
HERTZ				
PHASE				

COOLING WATER :

	INLET	RETURN	DESIGN	MAX D
TEMP °K		MAX		
PRESS. kPa g		MIN		
SOURCE				

INSTRUMENT AIR : MAX / MIN kPa g

PERFORMANCE

RATED CAPACITY	m^3/s
NPSH REQUIRED	m
PISTON SPEED	m/s
DISPLACEMENT	l
VOLUMETRIC EFFICIENCY	%
MECHANICAL EFFICIENCY	%
POWER @ MAXIMUM VISCOSITY	kW
POWER @ RELIEF VALVE SETTING	kW
MAXIMUM ALLOWABLE SPEED	RPM
MINIMUM ALLOWABLE SPEED	RPM
PINION SHAFT	RPM
HYDRAULIC POWER	kW
BRAKE POWER	kW

FOR DIRECT-ACTING PUMPS:

DRIVE GAS	
GOVERNOR TYPE	
INLET PRESSURE	kPa g
INLET TEMPERATURE	°K
EXHAUST PRESSURE	kPa g
STALL PRESSURE	kPa g
GAS CONSUMPTION	Nm3/s

APPLICABLE SPECIFICATIONS

API 674 POSITIVE DISPLACEMENT PUMPS-RECIPROCATING

GOVERNING SPECIFICATION (IF DIFFERENT)

REMARKS:

RECIPROCATING PUMP DATA SHEET

SI Units

CONSTRUCTION

LIQUID END :

VALVES PER CYLINDER :

	NUMBER	AREA mm²	VELOCITY m/s
SUCTION			
DISCHARGE			

VALVE TYPE:

NOZZLES	SIZE	ANSI RATING	ANSI FACING	ANSI LOCATION
LIQUID SUCTION				
LIQUID DISCHARGE				
GAS INLET				
GAS EXHAUST				
GLAND FLUSH				
DRAINS				
OTHER				
OTHER				
OTHER				

MATERIALS

PART	LIQUID END	ASTM NO.	GAS END
CYLINDER			
LINER			
PISTON OR PLUNGER			
PISTON RINGS			
PISTON ROD			
VALVES/VALVE SEATS			
GLAND			
THROAT BUSHING			
PACKING			
LANTERN RING			
DISTANCE PIECE			
BOLTING			
JACKETS			
OTHER			

LIQUID END LUBRICATION

PACKING LUBE

FLUSH SOURCE

LUBRICATOR MAKE

SIZE NO. OF FEEDS

PACKING

	LIQUID END	GAS END	VALVE ROD
NO. OF RINGS			
SIZE OF RINGS			
OTHER			

PRESSURE RATINGS

		LIQUID CYLINDER	GAS CYLINDER
MAXIMUM PRESSURE	kPa g		
MAXIMUM TEMPERATURE	°K		
HYDROSTATIC TEST PRESS.	kPa g		
OTHER			

DRIVE MECHANISM

TYPE

COUPLING MANUFACTURER

BASEPLATE

- ❍ BY PUMP MANUFACTURER
- ❍ SUITABLE FOR EPOXY GROUT
- EXTENDED FOR
- ❍ SUBPLATES BY PUMP MANUFACTURER
- ❍ DRAIN-RIM
- ❍ DRAIN-PAN
- ❍ LEVELING PADS
- ❍ SUITABLE FOR COLUMN MOUNTING

QA INSPECTION AND TEST

- ❍ COMPLIANCE WITH INSPECTORS CHECK LIST
- ❍ CERTIFICATION OF MATERIALS
- ❍ REPAIR MAPS & PROCEDURES
- ❍ FINAL ASSEMBLY CLEARANCES
- ❍ SURFACE AND SUBSURFACE EXAMINATIONS
- ❍ RADIOGRAPHY
- ❍ MAGNETIC PARTICLE
- ❍ ULTRASONIC
- ❍ LIQUID PENETRANT
- ❍ CLEANLINESS PRIOR TO FINAL ASSEMBLY
- ❍ HARDNESS OF PARTS, WELDS & HEAT AFFECTED ZONES
- ❍ FURNISH PROCEDURES FOR OPTIONAL TESTS
- ❍ FURNISH PMI CERTIFICATES

TESTS

- HYDROSTATIC
- PERFORMANCE
- NPSH
- OTHER

REMARKS:

RECIPROCATING PUMP DATA SHEET

SI Units

Note	POWER FRAME	CONTROLS	Rev
	MAXIMUM FRAME RATING:	**TYPE:**	
	kW @ RPM		
	MAXIMUM PRESSURE RATING kPa g	**SIGNAL:**	
	CRANKSHAFT MATERIAL		
	NO. OF MAIN BEARINGS	**CAPACITY CONTROL:**	
	TYPE OF MAIN BEARINGS	❍	
	INTERNAL GEARS		
	GEAR RATIO	VENDOR FURNISHES CS GOVERNOR & VALVE :	
	GEAR SERVICE FACTOR	VENDOR TO FURNISH CONTROL PANEL :	
	POWER END LUBRICATION:		
	TYPE :	TACHOMETER REQUIRED : TYPE	
	OIL PUMP:	**DRIVERS**	
	MAIN	**MOTOR :**	
	AUXILIARY	**DRIVER MANUFACTURER :**	
	DRIVEN BY MAIN	**DRIVER POWER :** kW	
	AUXILIARY	**DRIVER RPM :**	
		(Note : For details of the driver see the individual driver data sheets)	
	OIL FILTER:		
	TYPE MAKE		
	FILTRATION SIZE MODEL	OTHER (SEE SEPARATE DATA SHEETS) :	
	OIL COOLER		
	TYPE	**OTHER PURCHASE REQUIREMENTS**	
	SIZE		
	ADDITIONAL OIL SYSTEM ITEMS	NAMEPLATE UNITS :	
	❍ FLOW INDICATOR ❍ PRESSURE GAUGES ❍ TEMPERATURE GAUGES	❍ VENDOR FURNISHED PROCESS PIPING	
	❍ STRAINER ❍ OTHER	• VENDOR REVIEW PIPING DRAWINGS :	
	OIL HEATER REQUIRED :	• VENDOR FURNISHED PULSATION SUPPRESSION DEVICES :	
	TYPE :	• VENDOR FURNISHED RELIEF VALVE :	
	MECHANICAL LUBRICATION REQUIRED :	TYPE :	
		RELIEF VALVE SETTING kPa g	
	GEAR REDUCER	• LIQUID-FILLED PRESSURE GAUGES REQUIRED :	
	REQUIRED :	• TECHNICAL DATA MANUAL REQUIRED :	
	GEARS COMPLY WITH :	MAXIMUM ALLOWABLE SOUND PRESSURE LEVEL	
	MANUFACTURER	dB(A) @ m	
	MODEL	• OVERSIZE NOZZLE MATING PARTS BY VENDOR :	
	TYPE	• QUENCH-TYPE GLANDS REQUIRED :	
	SERVICE FACTOR	• PROVIDE PACKING COLLECTION CHAMBER :	
	RATING	• PROVIDE LANTERN RING PURGE :	
		SIZE	
	V-BELT OR CHAIN DRIVE	• OIL HEATER CONNECTION REQUIRED :	
	REQUIRED :	• DISTANCE PIECE COVERS :	
	NO. OF BELTS	**TYPE :**	
	SIZE OF BELTS	MINIMUM DESIGN METAL TEMPERATURE °K	
	CHAIN DETAILS	PRESSURE kPa g	
	TOTALLY ENCLOSED GUARD :	• API 671 COUPLINGS AND GUARDS REQUIRED :	
	SLIDE RAILS FOR ADJUSTMENT :		
	PREPARATION FOR SHIPMENT	**WEIGHTS**	
	SHIPMENT:	PUMP kg GEAR kg	
	EXPORT BOXING REQUIRED :		
	OUTDOOR STORAGE MORE THAN 6 MONTHS :	BASE kg DRIVER kg	

RECIPROCATING PUMP DATA SHEET

SI Units

PULSATION SUPPRESSION DEVICES FOR RECIPROCATING PUMPS — SERVICE _____ — Rev

THESE SHEETS TO BE FILLED OUT FOR EACH SERVICE AND / OR STAGE — STAGE NO. _____

APPLICABLE TO: _____

FOR / USER _____

SITE / LOCATION _____ — AMBIENT TEMPERATURE MIN / MAX _____ / _____ °K

PUMP SERVICE _____ — NUMBER OF PUMPS _____

PUMP MFG. _____ — MODEL / TYPE _____

SUPPRESSOR MFG. _____

GENRAL INFORMATION APPLICABLE TO ALL SUPPRESSORS

TOTAL NUMBER OF SERVICES AND / OR STAGES _____

❍ ASME CODE STAMP _____ OF _____ CODE AND REGULATIONS APPLY

❍ OTHER APPLICABLE PRESSURE VESSEL SPEC. OR CODE _____

RADIOGRAPHY (X-RAY OF WELDS): _____ ❍ IMPACT TEST ❍ SPECIAL WELDING REQUIREMENTS

❍ SHOP INSPECTION HYDROTEST : _____ ❍ SPECIAL PAINT SPEC _____

SHIPMENT: _____ **DESIGN APPROACH:** _____

EXPORT BOXING REQUIRED : _____ STUDY TO BE WITNESSED: _____

OUTDOOR STORAGE MORE THAN 6 MONTHS : _____

OPERATING AND SUPPRESSOR DESIGN DATA

PUMP DATA, THIS SERVICE OR STAGE ONLY — NUMBER OF CYL. _____ INTERNAL PASSAGES _____

NOTES: _____

BORE DIA _____ mm STROKE _____ mm _____ RPM

PUMP VALVE DATA

TYPE _____ LIFT _____ mm WEIGHT _____ kg

SPRING PRELOAD _____ N SPRING RATE _____ LIFT AREA _____

FULL PROJECTED AREA _____ EFF. FULL LIFT AREA _____

LIQUID HANDLED -SEE DATA SHEET PAGE 2

NORMAL OPERATING _____

CORR. PRESENT (DESCRIBE) _____

SPECIFIC GRAVITY _____

COMPRESSIBILITY% _____

m OPERATION IN PARALLEL WITH _____

	INLET SUPPRESSOR	DISCHARGE SUPPRESSOR
PUMP MANUFACTURER'S RATED CAPACITY :	GPM _____	
LINE SIDE OPERATING PRESSURE	INLET _____ kPa g	DISCHARGE _____ kPa g
OPERATING TEMP WITHIN SUPRESSORS	INLET _____ kPa g	DISCHARGE _____ kPa g
ALLOWABLE PRESSURE DROP THROUGH SUPPRESSORS	D P _____ kPa / _____ %	D P _____ kPa / _____ %
COMBINATION INLET SUPPRESSOR SEPARATOR / INTERNALS	YES YES	YES
NO. (QTY) OF INLET & DISCHARGE SUPPRESSORS PER STAGE	_____	_____
ALLOWABLE PEAK-PEAK PULSE @ LINE SIDE NOZZLE	_____ kPa ς / _____ %	_____ kPa ς / _____ %
ALLOWABLE PEAK-PEAK PUSLE @ CYL FLANGE NOZZLE	_____ kPa ς / _____ %	_____ kPa ς / _____ %
MIN. REQ'D WORKING PRESSURE & TEMPERATURE	_____ kPa g @ _____ °K	_____ kPa g @ _____ °K

NOTE: After design, the actual Mawp & temp are to be determined based on the weakest component and stamped on the vessel. The actual Mawp is to be shown on pg. 6 line 11 and on the U1A Forms.

REMARKS: _____

RECIPROCATING PUMP DATA SHEET

SI Units

PULSATION SUPPRESSION DEVICES FOR RECIPROCATING PUMPS (CONT'D) — SERVICE _____ — Rev

THESE SHEETS TO BE FILLED OUT FOR EACH SERVICE AND/OR STAGE — STAGE NO. _____

Note	CONSTRUCTION REQUIREMENTS & DATA	INLET SUPPRESSOR	DISCHARGE SUPPRESSOR
	BASIC MATERIAL REQUIRED, CS, SS, ETC.		
	ACTUAL MATERIAL, ASTM OR SA DESIGNATION SHELL / HEAD	/	/
	SPECIAL HARDNESS LIMITATIONS Rc ❍ YES ❍ NO		
	CORROSION ALLOW. ❍ REQUIRED	mm	mm
	WALL THICKNESS, SHELL / HEAD	mm / mm	mm / mm
	NOMINAL SHELL DIAMETER x OVERALL LENGTH / VOLUME	x m / m³	x m / m³
	PIPE OR ROLLED PLATE CONSTRUCTION		
	ACTUAL MAX ALLOWABLE WORKING PRESS AND TEMPERATURE	kPa @ °K	kPa @ °K
	MAX EXPECTED PRESSURE DROP D P, } kPa / % LINE PRESS	D P kPa / %	D P kPa / %
	WEIGHT, EACH	kg	kg
	INSULATION NUTS & ALLOWANCE FOR INSULATION REQUIRED		
	EXPECTED P-P PULSE @ LINE SIDE CYL FLG, % Based on final	%	%
	EXPECTED P-P PULSE @ LINE PRESSURE, % suppressor dgn	%	%
	SUPPORTS, TYPE / QUANTITY		
	CONNECTION REQUIREMENTS & DATA		
	LINE SIDE FLANGE, SIZE / RATING/FACING		
	PUMP FLANGE(S),QTY: SIZE / RATING/FACING		
	FLANGE FINISH, ❍ SPECIAL (SPECIFY)		
	❍ PER ASME 16.5		
	INSPECTION OPENINGS REQUIRED		
	SPEC. QTY, SIZE, 6000 LB NPT CPLG, FLG TYPE & RATING		
	*QTY, SIZE, 6000 LB NPT CPLG, FLG TYPE & RATING		
	VENT CONNECTIONS REQUIRED		
	SPECIFY QTY, SIZE, 6000 LB NPT CPLG, FLG TYPE & RATING		
	*QTY, SIZE, 6000 LB NPT CPLG, FLG TYPE & RATING		
	DRAIN CONNECTIONS REQUIRED		
	SPECIFY QTY, SIZE, 6000 LB NPT CPLG, FLG TYPE & RATING		
	*QTY, SIZE, 6000 LB NPT CPLG, FLG TYPE & RATING		
	PRESSURE CONNECTIONS REQUIRED		
	SPECIFY QTY, SIZE, 6000 LB NPT CPLG, FLG TYPE & RATING		
	*QTY, SIZE, 6000 LB NPT CPLG, FLG TYPE & RATING		
	TEMPERATURE CONNECTIONS REQUIRED		
	SPECIFY QTY, SIZE, 6000 LB NPT CPLG, FLG TYPE & RATING		
	❍ CYL NOZZLE ❍ MAIN BODY		
	*QTY, SIZE, 6000 LB NPT CPLG, FLG TYPE & RATING		
	OTHER DATA AND NOTES		
	PUMP MFG'S SUPP. OUTLINE OR DRAWING NO.		
	SUPPRESSOR MFG'S OUTLINE OR DRAWING NO.		

NOTES * = AS BUILT

DATA SHEET No. _____ Rev: **000** SHEET 6 of 6

RECIPROCATING PUMP DATA SHEET — US Customary Units

Note | Rev

APPLICABLE TO :

FOR | UNIT

SITE | NO. REQUIRED

SERVICE | SIZE & TYPE

MANUFACTURER | MODEL | SERIAL NO.

GENERAL

NO. MOTOR DRIVEN		OTHER DRIVER TYPE			
PUMP ITEM NO'S		PUMP ITEM NO'S			
MOTOR ITEM NO'S		DRIVER ITEM NO'S		GEAR ITEM NO'S	
MOTOR PROVIDED BY		DRIVER PROVIDED BY		GEAR PROVIDED BY	
MOTOR MOUNTED BY		DRIVER MOUNTED BY		GEAR MOUNTED BY	
MOTOR DATA SHEET NO.		DRIVER DATA SHEET NO.		GEAR DATA SHEET NO.	

OPERATING CONDITIONS

CAPACITY @ PT **gpm :**

@ MAXIMUM VISCOSITY | @ MINIMUM VISCOSITY

DISCHARGE PRESSURE **psia :**

MAXIMUM | MINIMUM

SUCTION PRESSURE **psia :**

MAXIMUM | MINIMUM

DIFFERENTIAL PRESSURE **psi**

MAXIMUM | MINIMUM

NPSHA WITHOUT ACCELERATION HEAD **ft**

ACCELERATION HEAD NET

MAXIMUM ALLOWABLE SOUND PRESSURE LEVEL

LIQUID

TYPE OR NAME OF LIQUID :

LIQUID COMPRESSIBILITY %

PUMPING TEMPERATURE **°F :**

NORM | MAX | MIN

SPECIFIC GRAVITY : NORM | MAX | MIN

SPECIFIC HEAT **(Cp)** Btu/(lbm-oF)

VISCOSITY **cP** NORM | MAX

CORROSIVE/EROSIVE AGENTS

CHLORIDE CONCENTRATION (PPM)

H_2S CONCENTRATION (PPM)

LIQUID :

SITE AND UTILITY DATA

LOCATION:

MOUNTED AT : ○ TROPICALISATION REQD

ELECTRIC AREA CLASSIFICATION: DIVISION

GROUP | TEMP CLASS

SITE DATA :

ELEVATION (MSL) : ft **BAROMETER :** in Hg

RANGE OF AMBIENT TEMPS:MIN / MAX / °F

RELATIVE HUMIDITY: MIN / MAX / %

UNUSUAL CONDITIONS:

UTILITY CONDITIONS :

ELECTRICITY :	DRIVERS	HEATING	CONTROL	SHUTDOWN
VOLTAGE				
HERTZ				
PHASE				

COOLING WATER :

	INLET	RETURN	DESIGN	MAX D
TEMP °F		MAX		
PRESS. psig		MIN		
SOURCE				

INSTRUMENT AIR : MAX | MIN psig

PERFORMANCE

RATED CAPACITY	gpm
NPSH REQUIRED	ft
PISTON SPEED	ft/s
DISPLACEMENT	gal
VOLUMETRIC EFFICIENCY	%
MECHANICAL EFFICIENCY	%
POWER @ MAXIMUM VISCOSITY	HP
POWER @ RELIEF VALVE SETTING	HP
MAXIMUM ALLOWABLE SPEED	RPM
MINIMUM ALLOWABLE SPEED	RPM
PINION SHAFT	RPM
HYDRAULIC POWER	HP
BRAKE POWER	HP

FOR DIRECT-ACTING PUMPS:

DRIVE GAS	
GOVERNOR TYPE	
INLET PRESSURE	psig
INLET TEMPERATURE	°F
EXHAUST PRESSURE	psig
STALL PRESSURE	psig
GAS CONSUMPTION	SFCM

APPLICABLE SPECIFICATIONS

API 674 POSITIVE DISPLACEMENT PUMPS-RECIPROCATING

GOVERNING SPECIFICATION (IF DIFFERENT)

REMARKS:

RECIPROCATING PUMP DATA SHEET — US Customary Units

CONSTRUCTION

LIQUID END :

VALVES PER CYLINDER :

	NUMBER	AREA in²	VELOCITY ft/s
SUCTION			
DISCHARGE			

VALVE TYPE:

NOZZLES	SIZE	ANSI RATING	FACING	LOCATION
LIQUID SUCTION				
LIQUID DISCHARGE				
GAS INLET				
GAS EXHAUST				
GLAND FLUSH				
DRAINS				
OTHER				
OTHER				
OTHER				

MATERIALS

PART	LIQUID END	ASTM NO.	GAS END
CYLINDER			
LINER			
PISTON OR PLUNGER			
PISTON RINGS			
PISTON ROD			
VALVES/VALVE SEATS			
GLAND			
THROAT BUSHING			
PACKING			
LANTERN RING			
DISTANCE PIECE			
BOLTING			
JACKETS			
OTHER			

LIQUID END LUBRICATION

PACKING LUBE

FLUSH SOURCE

LUBRICATOR MAKE

SIZE NO. OF FEEDS

PACKING

	LIQUID END	GAS END	VALVE ROD
NO. OF RINGS			
SIZE OF RINGS			
OTHER			

PRESSURE RATINGS

	LIQUID CYLINDER	GAS CYLINDER
MAXIMUM PRESSURE psig		
MAXIMUM TEMPERATURE °F		
HYDROSTATIC TEST PRESS. psig		
OTHER		

DRIVE MECHANISM

TYPE

COUPLING MANUFACTURER

BASEPLATE

- ○ BY PUMP MANUFACTURER
- ○ SUITABLE FOR EPOXY GROUT

EXTENDED FOR

- ○ SUBPLATES BY PUMP MANUFACTURER
- ○ DRAIN-RIM
- ○ DRAIN-PAN
- ○ LEVELING PADS
- ○ SUITABLE FOR COLUMN MOUNTING

QA INSPECTION AND TEST

- ○ COMPLIANCE WITH INSPECTORS CHECK LIST
- ○ CERTIFICATION OF MATERIALS
- ○ REPAIR MAPS & PROCEDURES
- ○ FINAL ASSEMBLY CLEARANCES
- ○ SURFACE AND SUBSURFACE EXAMINATIONS
- ○ RADIOGRAPHY
- ○ MAGNETIC PARTICLE
- ○ ULTRASONIC
- ○ LIQUID PENETRANT
- ○ CLEANLINESS PRIOR TO FINAL ASSEMBLY
- ○ HARDNESS OF PARTS, WELDS & HEAT AFFECTED ZONES
- ○ FURNISH PROCEDURES FOR OPTIONAL TESTS
- ○ FURNISH PMI CERTIFICATES

TESTS

HYDROSTATIC	
PERFORMANCE	
NPSH	
OTHER	

REMARKS:

RECIPROCATING PUMP DATA SHEET

US Customary Units

Note	POWER FRAME	CONTROLS	Rev
	MAXIMUM FRAME RATING:	**TYPE:**	
	HP @ RPM		
	MAXIMUM PRESSURE RATING psig		
	CRANKSHAFT MATERIAL	**SIGNAL:**	
	NO. OF MAIN BEARINGS		
	TYPE OF MAIN BEARINGS	**CAPACITY CONTROL:**	
	INTERNAL GEARS	❍	
	GEAR RATIO		
	GEAR SERVICE FACTOR	VENDOR FURNISHES CS GOVERNOR & VALVE :	
	POWER END LUBRICATION:	VENDOR TO FURNISH CONTROL PANEL :	
	TYPE :		
	OIL PUMP:	TACHOMETER REQUIRED : TYPE	
	MAIN	**DRIVERS**	
	AUXILIARY	**MOTOR :**	
	DRIVEN BY MAIN	**DRIVER MANUFACTURER :**	
	AUXILIARY	**DRIVER POWER :** **HP**	
		DRIVER RPM :	
	OIL FILTER:	**(Note : For details of the driver see the individual driver data sheets)**	
	TYPE MAKE		
	FILTRATION SIZE MODEL	OTHER (SEE SEPARATE DATA SHEETS) :	
	OIL COOLER		
	TYPE	**OTHER PURCHASE REQUIREMENTS**	
	SIZE		
	ADDITIONAL OIL SYSTEM ITEMS	NAMEPLATE UNITS :	
	❍ FLOW INDICATOR ❍ PRESSURE GAUGES ❍ TEMPERATURE GAUGES	❍ VENDOR FURNISHED PROCESS PIPING	
	❍ STRAINER ❍ OTHER	• VENDOR REVIEW PIPING DRAWINGS :	
	OIL HEATER REQUIRED :	• VENDOR FURNISHED PULSATION SUPPRESSION DEVICES :	
	TYPE :	• VENDOR FURNISHED RELIEF VALVE :	
	MECHANICAL LUBRICATION REQUIRED :	TYPE :	
		RELIEF VALVE SETTING psig	
	GEAR REDUCER	• LIQUID-FILLED PRESSURE GAUGES REQUIRED :	
	REQUIRED :	• TECHNICAL DATA MANUAL REQUIRED :	
	GEARS COMPLY WITH :	MAXIMUM ALLOWABLE SOUND PRESSURE LEVEL	
	MANUFACTURER	dB(A) @ ft	
	MODEL	• OVERSIZE NOZZLE MATING PARTS BY VENDOR :	
	TYPE	• QUENCH-TYPE GLANDS REQUIRED :	
	SERVICE FACTOR	• PROVIDE PACKING COLLECTION CHAMBER :	
	RATING	• PROVIDE LANTERN RING PURGE :	
		SIZE	
	V-BELT OR CHAIN DRIVE	• OIL HEATER CONNECTION REQUIRED :	
	REQUIRED :	• DISTANCE PIECE COVERS :	
	NO. OF BELTS	**TYPE :**	
	SIZE OF BELTS	MINIMUM DESIGN METAL TEMPERATURE °F	
	CHAIN DETAILS	PRESSURE psig	
	TOTALLY ENCLOSED GUARD :	• API 671 COUPLINGS AND GUARDS REQUIRED :	
	SLIDE RAILS FOR ADJUSTMENT :		
	PREPARATION FOR SHIPMENT	**WEIGHTS**	
	SHIPMENT:	PUMP **lb** GEAR **lb**	
	EXPORT BOXING REQUIRED :		
	OUTDOOR STORAGE MORE THAN 6 MONTHS :	BASE **lb** DRIVER **lb**	

RECIPROCATING PUMP DATA SHEET — US Customary Units

Note | PULSATION SUPPRESSION DEVICES FOR RECIPROCATING PUMPS | SERVICE _____ | Rev
THESE SHEETS TO BE FILLED OUT FOR EACH SERVICE AND / OR STAGE | STAGE NO. _____

APPLICABLE TO: _____
FOR / USER _____
SITE / LOCATION _____ | AMBIENT TEMPERATURE MIN / MAX _____ / _____ °F
PUMP SERVICE _____ | NUMBER OF PUMPS _____
PUMP MFG. _____ | MODEL / TYPE _____
SUPPRESSOR MFG. _____

GENRAL INFORMATION APPLICABLE TO ALL SUPPRESSORS

TOTAL NUMBER OF SERVICES AND / OR STAGES _____
❍ ASME CODE STAMP _____ OF _____ CODE AND REGULATIONS APPLY
❍ OTHER APPLICABLE PRESSURE VESSEL SPEC. OR CODE _____
RADIOGRAPHY (X-RAY OF WELDS): _____ ❍ IMPACT TEST ❍ SPECIAL WELDING REQUIREMENTS
❍ SHOP INSPECTION HYDROTEST : _____ ❍ SPECIAL PAINT SPEC _____
DESIGN APPROACH: _____
SHIPMENT: _____
EXPORT BOXING REQUIRED : _____ STUDY TO BE WITNESSED: _____
OUTDOOR STORAGE MORE THAN 6 MONTHS : _____

OPERATING AND SUPPRESSOR DESIGN DATA

PUMP DATA, THIS SERVICE OR STAGE ONLY
NOTES: _____

NUMBER OF CYL. _____ INTERNAL PASSAGES _____
BORE DIA _____ in STROKE _____ in _____ RPM
PUMP VALVE DATA
TYPE _____ LIFT _____ in WEIGHT _____ lb
SPRING PRELOAD _____ lbf SPRING RATE _____ LIFT AREA _____
FULL PROJECTED AREA _____ EFF. FULL LIFT AREA _____

LIQUID HANDLED -SEE DATA SHEET PAGE 2

NORMAL OPERATING _____
CORR. PRESENT (DESCRIBE) _____
SPECIFIC GRAVITY _____
COMPRESSIBILITY% _____
m OPERATION IN PARALLEL WITH _____

PUMP MANUFACTURER'S RATED CAPACITY :	GPM _____	
LINE SIDE OPERATING PRESSURE	INLET _____ psig	DISCHARGE _____ psig
OPERATING TEMP WITHIN SUPRESSORS	INLET _____ psig	DISCHARGE _____ psig
ALLOWABLE PRESSURE DROP THROUGH SUPPRESSORS	D P _____ psi / _____ %	D P _____ psi / _____ %

	INLET SUPPRESSOR	DISCHARGE SUPPRESSOR
COMBINATION INLET SUPPRESSOR SEPARATOR / INTERNALS	YES / YES	/ YES
NO. (QTY) OF INLET & DISCHARGE SUPPRESSORS PER STAGE	_____	_____
ALLOWABLE PEAK-PEAK PULSE @ LINE SIDE NOZZLE	_____ psig / _____ %	_____ psig / _____ %
ALLOWABLE PEAK-PEAK PUSLE @ CYL FLANGE NOZZLE	_____ psig / _____ %	_____ psig / _____ %
MIN. REQ'D WORKING PRESSURE & TEMPERATURE	_____ psig @ _____ °F	_____ psig @ _____ °F

NOTE: After design, the actual Mawp & temp are to be determined based on the weakest component and stamped on the vessel. The actual Mawp is to be shown on pg. 6 line 11 and on the U1A Forms.

REMARKS: _____

RECIPROCATING PUMP DATA SHEET — US Customary Units

PULSATION SUPPRESSION DEVICES FOR RECIPROCATING PUMPS (CONT'D) — SERVICE _____ — Rev

THESE SHEETS TO BE FILLED OUT FOR EACH SERVICE AND/OR STAGE — STAGE NO. _____

Note	CONSTRUCTION REQUIREMENTS & DATA	INLET SUPPRESSOR	DISCHARGE SUPPRESSOR
	BASIC MATERIAL REQUIRED, CS, SS, ETC.		
	ACTUAL MATERIAL, ASTM OR SA DESIGNATION SHELL / HEAD	/	/
	SPECIAL HARDNESS LIMITATIONS Rc ❍ YES ❍ NO		
	CORROSION ALLOW. ❍ REQUIRED	in	in
	WALL THICKNESS, SHELL / HEAD	in / in	in / in
	NOMINAL SHELL DIAMETER x OVERALL LENGTH / VOLUME	x ft / ft³	x ft / ft³
	PIPE OR ROLLED PLATE CONSTRUCTION		
	ACTUAL MAX ALLOWABLE WORKING PRESS AND TEMPERATURE	psig @ °F	psig @ °F
	MAX EXPECTED PRESSURE DROP D P, psi / % LINE PRESS	D P psi / %	D P psi / %
	WEIGHT, EACH	lb	lb
	INSULATION NUTS & ALLOWANCE FOR INSULATION REQUIRED		
	EXPECTED P-P PULSE @ LINE SIDE CYL FLG, % } Based on final	%	%
	EXPECTED P-P PULSE @ LINE PRESSURE, % } suppressor dgn	%	%
	SUPPORTS, TYPE / QUANTITY		
	CONNECTION REQUIREMENTS & DATA		
	LINE SIDE FLANGE, SIZE / RATING/FACING		
	PUMP FLANGE(S),QTY: SIZE / RATING/FACING		
	FLANGE FINISH, ❍ SPECIAL (SPECIFY)		
	❍ PER ASME 16.5		
	INSPECTION OPENINGS REQUIRED		
	SPEC. QTY, SIZE, 6000 LB NPT CPLG, FLG TYPE & RATING		
	*QTY, SIZE, 6000 LB NPT CPLG, FLG TYPE & RATING		
	VENT CONNECTIONS REQUIRED		
	SPECIFY QTY, SIZE, 6000 LB NPT CPLG, FLG TYPE & RATING		
	*QTY, SIZE, 6000 LB NPT CPLG, FLG TYPE & RATING		
	DRAIN CONNECTIONS REQUIRED		
	SPECIFY QTY, SIZE, 6000 LB NPT CPLG, FLG TYPE & RATING		
	*QTY, SIZE, 6000 LB NPT CPLG, FLG TYPE & RATING		
	PRESSURE CONNECTIONS REQUIRED		
	SPECIFY QTY, SIZE, 6000 LB NPT CPLG, FLG TYPE & RATING		
	*QTY, SIZE, 6000 LB NPT CPLG, FLG TYPE & RATING		
	TEMPERATURE CONNECTIONS REQUIRED		
	SPECIFY QTY, SIZE, 6000 LB NPT CPLG, FLG TYPE & RATING		
	❍ CYL NOZZLE ❍ MAIN BODY		
	*QTY, SIZE, 6000 LB NPT CPLG, FLG TYPE & RATING		
	OTHER DATA AND NOTES		
	PUMP MFG'S SUPP. OUTLINE OR DRAWING NO.		
	SUPPRESSOR MFG'S OUTLINE OR DRAWING NO.		

NOTES * = AS BUILT

DATA SHEET No. _____ Rev: **000** SHEET 6 of 6

Annex E
(informative)

Net Positive Suction Head Versus Net Positive Inlet Pressure

E.1 General

Because centrifugal pumps and positive-displacement pumps operate on entirely different principles, common usage has created two different ways to identify the pressures associated with them. In its simplest form, a centrifugal pump is a velocity generator, whereas the positive-displacement pump is a flow generator. In the case of the centrifugal pump, the liquid to be pumped is directed into the centre of a rotating impeller where it is guided by the impeller vanes and accelerated to a higher velocity. The casing surrounding the impeller then converts the high velocity into pressure. Because it is a velocity generator, if pressure is measured in units of liquid length, all units of measure become consistent. Velocity is measured in m/sec (ft/sec) and discharge pressure is measured in m (ft) of liquid, i.e. the pressure created by the height of a column of the liquid being pumped. This consistent use of units greatly simplifies pump calculations and allows the effects of certain liquid properties (e.g. relative density) to be ignored.

For a centrifugal pump, the discharge pressure developed is a function of flow through the pump impeller. With decreasing flow (as in the case of increased system resistance), the centrifugal pump develops an ever increasing pressure up to the point defined as the shutoff head at zero flow. Shutoff head is normally the maximum pressure rise that a centrifugal pump can develop, but there are instances when the shutoff head is less than the maximum head generated by the pump. By contrast, a positive-displacement pump does not generate energy solely by increasing fluid velocity. Instead, these pumps convert rotary motion and torque into constant linear fluid motion and force, generating a fixed flow rate at the discharge connection.

Positive-displacement pumps have no theoretical discharge pressure limitation. They respond solely to the pumping system, and require system discharge control, usually in the form of a pressure-limiting valve, to prevent damage to the pump mechanism, the pumping system and/or stalling of the driver. For a positive-displacement pump, flow is a function of pump stroke and/or rpm.

E.2 Calculation of NPSH or NPIP

Both types of pumps require sufficient fluid pressure at the inlet to prevent a release of dissolved gases and/or a change in the state of the pumped fluid from liquid to gas. The term for pressure at the inlet is either Net Positive Suction Head (NPSH) or Net Positive Inlet Pressure (NPIP). To be consistent, the API standards for both centrifugal and reciprocating pumps, as well as the latest editions of the Hydraulic Institute standards refer to the total suction head as NPSH rather than NPIP. Although the Hydraulic Institute indicates that NPSH is normally expressed in either kilopascals (pounds force per in.^{2}) or m (ft), the latest API standards refer to NPSH in m (ft), the preferred unit terminology for both pump types, to avoid confusion. Positive-displacement pump manufacturers generally refer to NPIP, expressed in kilopascals (pounds force per in.^{2}). ISO 16330 also uses the term NPIP rather than NPSH. NPSH or NPIP is indicated as either Available or Required. The Net Positive Inlet Pressure Available (NPIPA) is the absolute pressure above fluid vapor pressure at the pump inlet, and is determined as follows:

$$\text{NPIPA} = p_a + p_z - p_f - p_{vp} - p_{ha} \tag{E.1}$$

where

p_a is the absolute pressure at surface of liquid, expressed in kilopascals (pounds force per in.^{2});

p_z is the static head (+) or static lift (–), expressed in kilopascals (pounds force per in.^{2}), for level of fluid above or below inlet;

p_f is the inlet line, valve, and fitting friction losses at maximum viscosity, expressed in kilopascals (pounds force per in.^{2});

p_{vp} is the fluid vapor pressure or gas dissolution pressure, expressed in kilopascals (pounds force per in.^{2});

p_{ha} is the pressure loss due to acceleration head (see below), converted to kilopascals (pounds force per in.^{2}).

E.3 Calculation of acceleration head

NPIPA calculation for a reciprocating power pump must include the effects of system acceleration head. This is the head required to accelerate the liquid column on each suction stroke so that there will be no separation of this column in the pump or suction line. From the Hydraulic Institute standards, the head required to accelerate the fluid column is a function of the length of the suction line, the average velocity in this line, the rotative speed, the type of pump, and the relative elasticity of the fluid and the pipe. For short suction lines, acceleration head may be calculated as follows:

$$p_{ha} = [(l)\ (v)\ (n)\ (\mathrm{C})]/\ [(\mathrm{K})\ (g)] \qquad \text{(E.2)}$$

where

p_{ha} is the acceleration head, expressed in m (ft);

l is the length of suction line, expressed in m (ft);

v is the velocity in suction line, expressed in m/sec (ft/sec);

n is the pump speed, expressed in RPM;

C is a constant, as follows:

0.400 for simplex single-acting;

0.200 for simplex double-acting;

0.200 for duplex single-acting;

0.115 for duplex double-acting;

0.066 for triplex single- or double-acting;

0.040 for quintuplex single- or double-acting;

0.028 for septuplex single- or double-acting;

K is a factor representing the relative compressibility of the liquid, as follows:

1.4 for hot water;

2.5 for hot oil;

g is the acceleration due to gravity [9.81 m/s^2 (32.2 ft/s^2)].

NOTE 1 The constant C will differ from these values for unusual ratios of connecting rod length to crank radius.

NOTE 2 The constant C includes the conversion factor from minutes to seconds (value of n).

It is the responsibility of the Purchaser to define the acceleration head, yet the value is dependent on the characteristics of the pump selected. Consequently, the value should be reviewed by both the Purchaser and the vendor before a final selection is made. NPIP Required (NPIPR) is a function of pump type and speed and of the viscosity of the fluid pumped. NPIPA must always be greater than NPIPR to prevent cavitation. Typically, NPIPR values published by positive-displacement pump manufacturers are expressed in kilopascals (bar) (pounds per in.^{2}).

E.4 Effect of impedance on acceleration

The resistance of the flow rate of a liquid column to accelerate and decelerate is called impedance. A positive displacement pump moves a discrete volume of liquid with each stroke of a pumping element (e.g. piston, plunger or diaphragm). The inlet liquid column has to reflect the requirement to start and stop flowing as an inlet valve opens and closes. With simplex and duplex pumps, the total flow in the inlet line has to start and stop, hence such designs are not frequently encountered. With a multiplex pump there is always a minimum fluid velocity in the inlet column. The action of the valves causes the flow to speed up to a maximum and then slow down to the minimum in a series of waves. The amplitude of the velocity change is greatly reduced, but the frequency is increased. The higher frequencies are most affected by the impedance. The inlet column should be able to deliver sufficient flow volume to meet the amplitude requirement.

The discharge from a rotordynamic pump is characterized by a slow response to changes in demand. The discharge from a header tank is also slow to respond to velocity changes. Both of these, the normal sources of liquid for positive-displacement pumps, are high-impedance sources. Various devices are available to convert the high-impedance source to a low-impedance feed. Depending upon the installation, some are more effective than others. This is a complex problem to solve analytically, and pragmatic design constraints are usually used.

The only way to be sure that the installation will provide trouble-free service life is to measure the inlet pressure using a pressure transducer/recorder capable of showing short-duration pressure transients of the order of 1 ms. The minimum pressure recorded in the inlet column before any impedance-improving device should be positive, with a margin over the vapor pressure of the liquid at the maximum temperature to be pumped. The measured inlet pressure is then the net positive value above the vapor pressure, i.e. the NPIP.

In general, the Purchaser may only be able to calculate the NPSH using rotordynamic rules, and will need to work together with the supplier to ensure that, when the pump is tested, the NPIP is adequate. By limiting the maximum speed of the pump for a given stroke, the impedance requirement is limited; however this is only a general guideline. Long tortuous inlet columns with many bends, elbows and other fittings may dictate a larger pump running slower. A good impedance-matching device could allow the pump to run faster.

Excessive turbulence/out-gassing of the inlet column should be avoided. The piping elements most likely to cause this are tees and sharp elbows. Any merging or splitting of the inlet column should be via a Y-connection. Any change in direction should be via a long-radius bend. To cater for amplitude, the inlet column should be capable of delivering sufficient free flow. For simplex and duplex pumps, a value of 4 times the rated flow is recommended. For a triplex pump, the factor is 2 times the rated flow. For quintuplex pumps and above, the factor can be a 1.5.

Annex F
(informative)

Inspector's Checklist

Inspection Required C, O, or W [b]	No.	Item	API 674 Subclause Number	Date Inspected	Inspected By	Status
	1	Cylinder liners				
	2	Valve seats				
	3	Material certification				
	4	Non-destructive examination (components)				
	5	Welding operators and procedures qualified				
	6	Rotation arrow [a]				
	7	Equipment nameplate data				
	8	Overall dimensions and connection locations [a]				
	9	Nozzle flange dimensions				
	10	Anchor bolt layout and size				
	11	Shaft and Keyway dimensions [a]				
	12	Mounting plate pre-coat for epoxy grout				
	13	Equipment feet pilot holes				
	14	Pressure-limiting valve characteristics				
	15	Piping inspection				
	16	Pulsation support devices				
	17	Special tools [a]				
	18	Certified performance data				
	19	Maintenance and clearance				
	20	Components inspected for cleanliness (list each)				
	21	Hardness testing				

Inspection Required C, O, or W [b]	No.	Item	API 674 Subclause Number	Date Inspected	Inspected By	Status
	22	Hydrostatic tests				
	23	Performance test, direct acting pump				
	24	Performance test, power pump				
	25	NPSH test				
	26	Preparation for shipment				
	27	Painting				
	28	Shipping documents and tags				
	29	Bearing assembly protection				

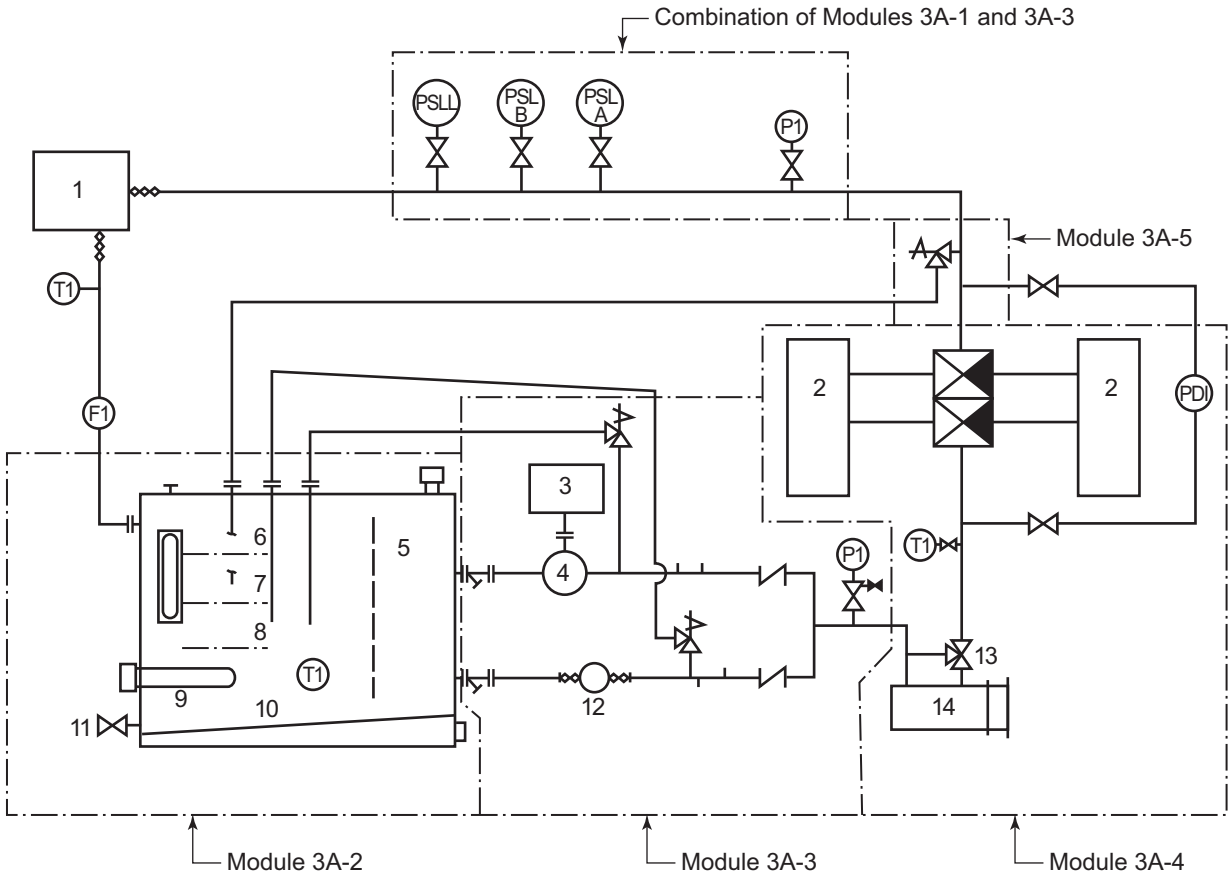
[a] Check against certified dimensional outline drawing.

[b] Indicate in first column:

C – certification only;
O – observed, inspection;
W – witnessed inspection.

Annex G
(informative)

Lubrication System



Key

1. rotating equipment
2. filter
3. electric motor
4. pump
5. internal baffle
6. max operating level
7. min operating level
8. pump suction level
9. heater (optional)
10. sloped bottom
11. drain
12. shaft-driven oil pump with integral pressure relief
13. TCV (optional)
14. cooler

Figure G.1—Lube Oil System Schematic

Table G.1—Lube Oil System Schematic

ISO 10438-3 sub-clause or API 614, Chapter 3, sub-clause	Note/Option[a]	Comments
3A-1 Minimum requirements for general purpose oil systems	Add	TI, FI on oil return lines from pump (and driver)
3A-2 Reservoir	Option 1	A level switch is not required
	Option 2	A temperature indicator with thermowell is required
	Option 3	An electric immersion or steam heater is optional
	Option 4	Additional connections are required for : 1. Shaft-driven oil pump relief valve return (not required with integral relief valve) 2. Motor-driven oil pump relief valve return (not required with integral relief valve) 3. System PCV return 4. Aux. oil pump to have independent suction w/ strainer
	Option 5	One tapped grounding lug is required
	Option 6	Gauge glass may be armored and extended
	Add	A vent (breather) with screen is required
	Add	The reservoir shall have a sloped bottom
	Add	A flanged drain connection with valve and blind at least 2 inches in size shall be included
	Add	A level glass shall be provided in accordance with ISO 10438-3
	Add Additional item	(If so, the return line from the system PCV shall be located below the minimum operating oil level.)
3A-3 Pumps	Option 1	A 100% capacity motor-driven auxiliary pump is required
	Option 2	Block valves are not required
	Option 3	A pre/post lube oil pump is not required
	Option 4	Pressure switches are required for low pressure trip, alarm, and aux. pump start
	Option 5	The pressure transmitter is not required
	Additional item	The pressure switches shall be located in accordance with ISO 10438-3, Figure A.5

Table G.1—Lube Oil System Schematic (Continued)

ISO 10438-3 sub-clause or API 614, Chapter 3, sub-clause	Note/Option[a]	Comments
3A-4 Pumps and coolers (and filters)	Option 1	One oil cooler is required
	Option 2	Duplex filters are required
	Option 3	A three-way constant temperature control valve with bypass line is optional
	Option 4	A two or three way variable temperature control valve with bypass line is not required
	Option 5	A temperature switch is required. Temperature switch is not represented in ISO 10438-3 (API 614, Chapter 3), Figure A.5.
	Option 6	A single transfer valve with cooler and filter in parallel with separate TCV is not required. Valve is not represented in ISO 10438-3 (API 614, Chapter 3), Figure A.5.
	Option 7	A pressure differential indicator is required
	Add Additional item	A single transfer valve for the duplex filters is required The replaceable filter shall be in accordance with ISO 10438-3 (API 614, Chapter 3).
3A-5 Pressure control	Option 1	A pressure regulator (relief valve) is required
	Option 2	A back-pressure control valve – direct acting is not required
	Option 3	Block valves around the PCV / regulator are not required
	Option 4	A globe bypass valve is not required

[a] "Option" means an optional item as specified.
"Add" means an additional requirement to those available in ISO 10438-3.

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

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