

Positive Displacement Pumps— Controlled Volume for Petroleum, Chemical, and Gas Industry Services

API STANDARD 675
THIRD EDITION, NOVEMBER 2012

ERRATA, JUNE 2014
ERRATA 2, APRIL 2015

REAFFIRMED, JULY 2021



American
Petroleum
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Foreword

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

The primary purpose of this standard is to establish minimum requirements.

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

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

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Positive Displacement Pumps—Controlled Volume for Petroleum, Chemical, and Gas Industry Services

1 Scope

This standard covers the minimum requirements for reciprocating, controlled volume pumps and pump units for use in the petroleum, petrochemical, and gas industry services. These pumps are either hydraulic diaphragm or packed plunger design. Rotary positive displacement pumps are not included. Diaphragm pumps that use direct mechanical actuation are also excluded.

NOTE See API 674 for positive displacement reciprocating pumps and API 676 for positive displacement rotary pumps.

This standard requires the Purchaser to specify certain details and features. A bullet (●) at the beginning of a paragraph indicates that either a decision by, or further information from, the Purchaser is required. Further information should be shown on the data sheets (see example in Annex A) or stated in the quotation request and purchase order.

Alternate Designs and Conflicting Requirements are now located in Section 6.

NOTE A bullet (●) at the beginning of a paragraph indicates that either a decision is required or further information is to be provided by the purchaser. This information should be indicated on the data sheets (see Appendix A); otherwise, it should be stated in the quotation request or in the order.

2 Normative References

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. The hierarchy of documents shall be specified.

NOTE Typical documents are user, industry, and API specifications, data sheets, meeting notes and supplemental agreements.

API Specification 5L, *Specification for Line Pipe*

API Recommended Practice 520, *Sizing, Selection and Installation of Pressure-Relieving Devices in Refineries, Part I—Sizing and Selection*

API Recommended Practice 520, *Sizing, Selection and Installation of Pressure-Relieving Devices in Refineries, Part II—Installation*

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 614 *Lubrication, Shaft-sealing, and Control-oil Systems and Auxiliaries for Petroleum, Chemical, and Gas Industry Services*

API Standard 671, *Special Purpose Couplings for Refinery Services*

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

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

AGMA 6013-A06: 2006 ¹, *Standard for Industrial Enclosed Gear Drives*

AGMA 6022-C93: 1994 (R 2008), *Design Manual for Cylindrical Wormgearing*

¹ American Gear Manufacturers Association, 500 Montgomery Street, Suite 350, Alexandria, Virginia 22314 www.agma.org

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

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

ANSI/ABMA 7:1995 ², *Shaft and Housing Fits for Metric Radial Ball and Roller Bearings (Except Tapered Roller Bearings) Conforming to Basic Boundary Plan*

ASME Boiler and Pressure Vessel Code ³, Section V:2001, *Non-destructive Examination*

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

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 B16.20:1998, *Metallic Gaskets for Pipe Flanges*

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

ASME B31.3 *Process Piping* (for pipeline applications see also ASME B31.4)

AWS D1.1:2003 ⁴, *Structural Welding Code — Steel*

DIN 910:2004 ⁵, *Heavy-duty Hexagon Head Screw Plugs*

EN 287:1997 (all parts) ⁶, *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*

IEC 60034 ⁷, *Rotating Electrical Machines — Part 1: Rating and Performance*

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

IEEE 841:2001 ⁸, *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 ⁹, *Pipe Threads where Pressure-tight Joints are Made on the Threads*

² American National Standards Institute, 25 West 43rd Street, 4th Floor, New York, New York 10036, www.ansi.org.

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

⁴ American Welding Society, 550 NW LeJeune Road, Miami, Florida 33126, www.aws.org.

⁵ Deutsches Institut für Normung E.V., Burggrafenstrasse 6, 10787 Berlin, Germany.

⁶ European Committee for Standardization, Avenue Marnix 17, B-1000, Brussels, Belgium, www.cen.eu.

⁷ International Electrotechnical Commission, 3, rue de Varembe, P.O. Box 131, CH-1211, Geneva 20, Switzerland, www.iec.ch.

⁸ Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, New Jersey 08854, www.ieee.org.

⁹ International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, www.iso.org.

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*

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 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 10816-1, *Mechanical Vibration*

ISO 14691, *General Purpose Couplings*

NACE MR0175/:2003 (3 parts) ¹⁰, *Petroleum and Natural Gas Industries — Materials for Use in H₂S-Containing Environments in Oil and Gas Production*

NACE MR0103/:2003 (3 parts), *Petroleum and Natural Gas Industries — Materials for Use in H₂S-containing Environments in Oil and Gas Production*

NFPA 70:2002 ¹¹, *National Electrical Code*

SSPC SP 6:2000 ¹², *Commercial Blast Cleaning*

¹⁰ NACE International (formerly the National Association of Corrosion Engineers), 1440 South Creek Drive, Houston, Texas 77218-8340, www.nace.org.

¹¹ National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169-7471, www.nfpa.org.

¹² The Society for Protective Coatings, 40 24th Street, 6th Floor, Pittsburgh, Pennsylvania 15222, www.sspc.org.

3 Terms and Definitions

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

3.1

alarm point

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

3.2

anchor bolt

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

3.3

acceleration pressure

anticipated system acceleration pressure

The estimated pressure change due to changes in velocity in the piping system. It is an important factor in the application of reciprocating pumps because of the pulsating nature of the flow in the pump suction line, in addition to NPSHR, vapor pressure, and pressure required to overcome suction line losses.

NOTE This factor is accounted for in the standard calculation for NPIP. See the definition of NPIP, NPIP_a, and NPIP_r.

3.4

baseplate

Component on which the drive train and pump are bolted, which is then fastened to the support structure using anchor bolts.

3.5

Certified Material Test Report

CMTR

mill cert

Certified report documenting the actual chemical composition and/or physical properties of critical materials.

3.6

controlled volume pump

A reciprocating pump in which precise volume control is provided by varying effective stroke length.

NOTE Such pumps are also known as proportioning, chemical injection, dosing, or metering pumps.

3.7

datum elevation

Elevation to which values of NPIP are referred (the underside of the pump mounting plate); also see **net positive inlet pressure available** and Annex E.

3.8

design

Manufacturer's calculated parameter.

NOTE A term used by the equipment manufacturer to describe various parameters such as design power, design pressure, design temperature, or design speed. It is not intended for the Purchaser to use this term.

3.9

diaphragm pump

A pump designed such that the process fluid is isolated from the plunger by means of a hydraulically actuated flat or shaped diaphragm.

3.10**differential pressure**

The difference between discharge pressure and suction pressure.

3.11**discharge pressure**

The motive energy of the pumped liquid due to its pressure as measured immediately downstream of the pump discharge connection.

3.12**displacement**

Volume displaced per stroke. Displacement depends only on the physical dimensions of the pumping element.

3.13**drive train components**

Item of the equipment used in series to drive the pump. (Examples: Motor, gear, fluid drive, etc.)

3.14**fail safe**

System which will cause the equipment to revert to a permanently safe condition (shutdown and/or depressurized) in the event of a component failure or failure of the energy supply to the system.

3.15**flow repeatability**

Expressed as a percent of rated capacity, describes the reproducibility of pump flow rate under a given set of conditions when capacity setting is varied and then returned to the set point being tested.

3.16**gauge board**

Bracket or plate used to support and display gauges, switches, and other instruments.

NOTE A gauge board is open and not enclosed.

3.17**hold down bolt****mounting bolt**

Bolt holding the equipment to the baseplate.

NOTE For small controlled volume pumps baseplates and hold down bolts are sometimes omitted.

3.18**inspection and test plan****ITP**

Single project-specific document used to consolidate all inspection and test elements, the criteria required to be met, and the roles and responsibilities.

3.19**linearity**

The relationship between the actual volume of liquid discharged at a given capacity setting and a best fit straight line drawn through the plotted points of volume and capacity setting determined during calibration tests of a pump. The deviation from this line is expressed as percent of the rated capacity of the pump.

3.20**liquid end assembly**

The pump liquid end assembly (also called the *reagent head assembly* or *wet end*) includes all parts that contain the liquid being pumped.

3.21**local**

Position of devices mounted on or near the equipment or console.

3.22**lost motion**

A means of changing displacement of a constant stroke pump by altering the effective stroke length during each cycle. This may be accomplished either mechanically or hydraulically.

3.23**maximum allowable working pressure****MAWP**

Maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified maximum operating temperature.

3.24**maximum rated input speed**

Highest speed (in strokes per minute) at which the machine, as built and tested, is capable of continuous, efficient operation with the specified fluid at any of the specified operating conditions.

3.25**minimum allowable fluid temperature**

Lowest continuous fluid temperature for which the manufacturer has designed the equipment (or any part to which the term is referred) when handling the specified fluid at the specified maximum operating pressure.

3.26**minimum design metal temperature**

Lowest mean device material temperature (through the thickness) expected in service, including operation upsets, auto-refrigeration and temperature of the surrounding environment.

3.27**minimum allowable speed**

The lowest speed (in strokes per minute) at which the manufacturer's design will permit continuous operation.

3.28**minimum allowable ambient temperature**

The minimum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred).

3.29**multiple feed****multiplexing**

The combination of two or more pumping elements with a common driver.

3.30**net positive inlet pressure****NPIP**

Minimum instantaneous pressure determined at the datum elevation (underside of the pump mounting plate) during pressure pulsations, minus the vapor pressure of the fluid at the maximum operating temperature and at any specified operating point (see Annex E for further discussion).

3.31**net positive inlet pressure available****NPIPA**

NPIP determined by the Purchaser from the NPSHA and system design data. NPIP shall always include acceleration losses. Minimum pressure determined at the datum elevation (underside of the pump mounting plate) minus the vapor pressure of the fluid at the maximum operating temperature at any specified point. NPIP shall always include acceleration losses.

3.32**net positive inlet pressure required****NPIPR**

Minimum NPIP required by the pump to achieve the required performance with the specified fluid at any specified point, as determined by Vendor. NPIP shall always include acceleration losses.

3.33**net positive inlet pressure required test****NPIPR test**

Test conducted to measure the NPIPR.

3.34**net positive suction head****NPSH**

Total absolute suction pressure, determined at the underside of the pump mounting plate, minus the vapor pressure of the liquid [see Annex E for a discussion of NPSH and Net Positive Inlet Pressure (NPIP)].

NOTE 1 NPSH is expressed as head of water, in meters (feet).

NOTE 2 NPIP is the most appropriate term for any reciprocating positive displacement pump because NPIP includes the additional energy losses due to acceleration.

NOTE 3 NPIP is typically expressed in units of pressure kPa (bar, psi).

3.35**net positive suction head available****NPSHA**

Not the most appropriate term for reciprocating positive displacement pumps because this is only based on steady state energy losses and doesn't include acceleration (see 3.32).

3.36**net positive suction head required****NPSHR**

Not the most appropriate term for reciprocating positive displacement pumps because this is only based on steady state energy losses and doesn't include acceleration (see 3.33).

3.37**non-destructive examination****NDE**

Inspection of materials, components or assemblies by means of radiography, liquid penetrant, magnetic particle or ultrasonic testing are the typical methods employed. Other methods may be used if agreed to by the Purchaser and supplier.

3.38**observed [test]**

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

NOTE Supplier will not hold up production for Purchaser's convenience.

3.39**Owner**

Final recipient of the equipment who may delegate another agent as the Purchaser of the equipment.

3.40**packed-plunger pump****packed piston pump**

The process fluid is in direct contact with the plunger.

3.41**panel**

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

3.42**performance test**

Running test conducted to measure flow rate at rated discharge pressure and power consumed at specified conditions.

NOTE Test results need to be corrected to service conditions, for example temperature and driver speed.

3.43**positive material identification****PMI**

Physical evaluation or test of a material to confirm that the material is consistent with the selected or specified alloy material designated.

3.44**pressure-containing part**

Any part that acts as a barrier between process or motive fluid and the atmosphere.

3.45**pressure-retaining part**

Any part whose mechanical failure would allow process or motive fluid to escape to the atmosphere.

3.46**pump efficiency**

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

3.47**pumphead**

The displacement chamber for the pump hydraulic fluid that moves the diaphragm in a hydraulic diaphragm pump.

3.48**Purchaser**

Agency that issues the order and specification to the supplier

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

3.49**Ra (surface finish)**

Arithmetic average of the absolute value of the profile height deviations recorded within the evaluation length and measured from the mean line.

3.50**rated capacity**

The quantity of fluid actually delivered per unit of time at the stated operating conditions. Rated capacity includes liquid and any solids, and is also based on suction conditions. Rated capacity should be in accordance with 6.1.15.

3.51**rated discharge pressure**

The required discharge pressure of the pump at rated capacity, speed, suction pressure, specific gravity, and viscosity.

3.52**rated operating point**

Point at which the supplier certifies that pump performance is within the tolerances stated in this standard.

NOTE Normally the rated operating point is the specified operating point with the highest flow.

3.53**rated speed**

Highest stroke speed (strokes per minute) required to meet any of the specified operating conditions.

NOTE Rated speed may not be the normal operating speed since the normal operating speed is determined by the normal operating point.

3.54**remote**

Control device located away from the equipment or console.

NOTE Remote typically implies location in a local equipment or control room.

3.55**shutdown set point**

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

3.56**slip**

Quantity of fluid per unit of time that leaks through the internal clearances of a pump. Slip depends on the internal clearances, the differential pressure, the characteristics of the fluid handled, and in some cases, the speed.

3.57**special tool**

Tool that is not a commercially available catalogue item.

3.58**steady state accuracy**

The flow variation expressed as a percentage of mean delivered flow under fixed system conditions. Steady state accuracy applies over the turndown ratio.

3.59**stroke length**

The linear distance traveled by the plunger or piston. On some pumps (hydraulic by-pass) this is the effective stroke length.

3.60**suction pressure**

The motive energy of the pumped liquid due to its pressure as measured immediately upstream of the pump suction connection.

3.61**Supplier
Vendor**

Agency that supplies the equipment.

NOTE The supplier may be the manufacturer of the equipment or the manufacturer's agent and is normally responsible for service support.

3.62**total indicated reading****TIR**

Also known as total indicated run out difference between the maximum and minimum readings of a dial indicator or similar device, monitoring a face or cylindrical surface for one complete revolution.

3.63**trip speed**

Speed (strokes per minute) at which the independent emergency over-speed device operates to shut down a variable speed prime mover (for example air or hydraulic motors which are uncontrolled).

3.64**turndown ratio**

The rated capacity divided by the minimum capacity that can be obtained while maintaining specified steady state accuracy and linearity.

3.65**unit responsibility**

The entity having responsibility for coordinating the technical aspects of the equipment and all auxiliary systems included in the scope of the order. It includes responsibility for reviewing such factors as the power requirements, speed, rotation, general arrangements, couplings, noise, lubrication, material test reports, instrumentation, piping, and testing of components.

3.66**volumetric efficiency**

Ratio of the pump rated point flow to the total theoretical displacement per unit time.

NOTE Volumetric efficiency is normally expressed as a percentage.

3.67**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 Purchaser's representative is in attendance.

4 General**4.1 Unit Responsibility**

Unless otherwise specified, the pump Vendor shall have unit responsibility. The pump Vendor who has unit responsibility shall ensure that all sub-Vendors comply with the requirements of this standard and all reference documents. These include, as a minimum, such factors as the functionality, power requirements, speed, rotation, general arrangement, couplings, dynamics, noise, lubrication, sealing system, material test reports, instrumentation, piping, documentation, conformance to specifications, and testing of components by supplier and any and all sub-suppliers.

4.2 Governing Requirements and 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 A) indicates SI units shall be used. Use of a U.S. Customary datasheet (e.g. Annex A) indicates U.S. Customary units shall be used.

4.3 Pump Designations

Figure 1 shows pumps with typical liquid ends. Figure 2 shows pumps with typical drive ends.

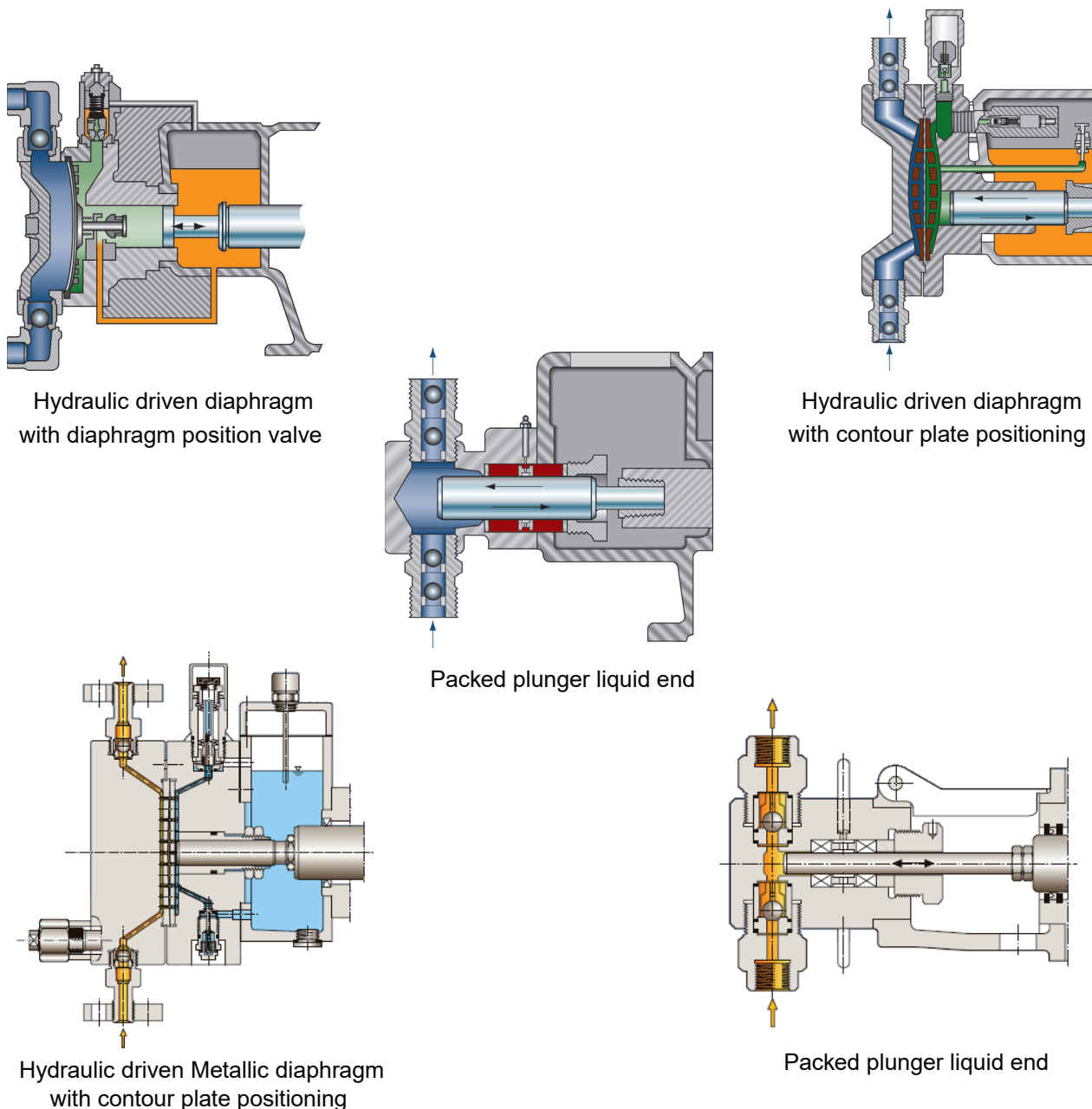


Figure 1—Typical Liquid End Pumps

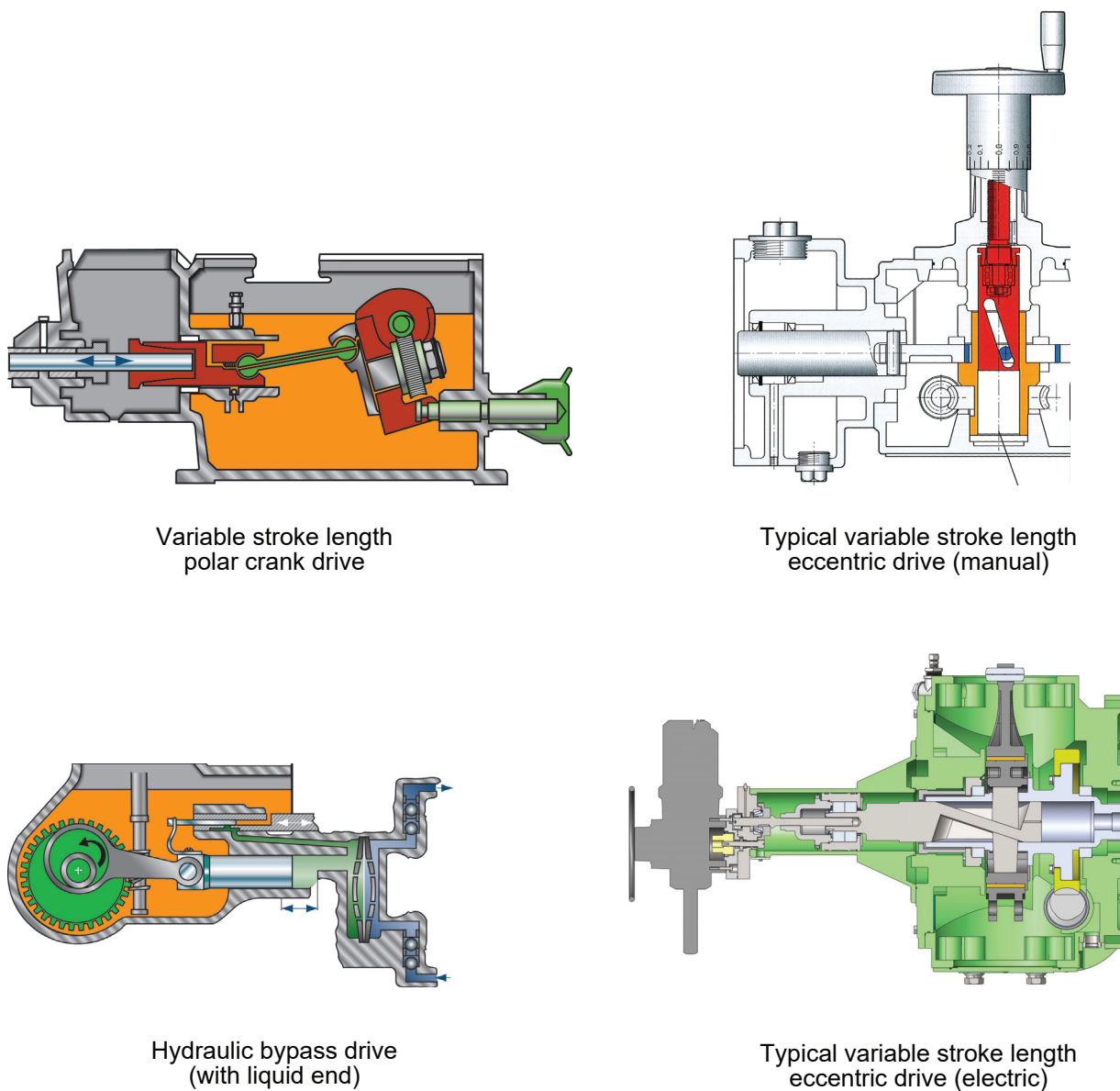


Figure 2—Typical Drive End Pumps

5 Statutory

5.1 Statutory Requirements

The Purchaser and the Vendor shall mutually determine the measures to be taken to comply with any governmental codes, regulations, ordinances, or rules that are applicable to the equipment, its packaging and any preservatives used.

5.2 Requirements

5.2.1 In case of conflict between this standard and the inquiry, the inquiry shall govern. At the time of the order, the order shall govern.

5.2.2 If requirements specific to a particular pump type in Section 6 conflict with any other clauses, the requirements of Section 6 shall govern.

6 Basic Design

6.1 General

- **6.1.1** The Purchaser shall specify the period of uninterrupted continuous operation, during which time the equipment should not require shut down to perform maintenance or inspection.

NOTE 1 It is realized that there are some services where this objective is easily attainable and others where it is difficult.

NOTE 2 Auxiliary system design and design of the process in which the equipment is installed are very important in meeting this objective.

6.1.2 Vendor shall advise in the proposal any component designed for finite life.

6.1.3 The Vendor shall assume responsibility for the pump and all auxiliary equipment included in the scope of the order.

- **6.1.4** The Purchaser shall specify the equipment's normal operating point on the data sheets. Anticipated process variations that may affect this equipment (such as changes in pressure, temperature, or properties of fluids handled, and special plant startup conditions) shall be specified by the Purchaser.
- **6.1.5** Control of the sound pressure level of all equipment supplied shall be a joint effort of the Purchaser and the Vendor having unit responsibility. The equipment provided by the Vendor shall conform to the maximum allowable sound pressure level specified. If requested by the Purchaser, the Vendor shall provide data confirming compliance to the maximum sound pressure level specified.

6.1.6 Equipment shall be designed to run at the maximum rated input speed and relief valve settings simultaneously without damage. Vendor shall advise Purchaser of increased power operating requirements necessary to achieve this.

6.1.7 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.

- **6.1.8** 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, API 500, and NEC as specified, as well as any local codes specified and supplied by the Purchaser.

6.1.9 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 idle periods.

6.1.10 All equipment shall be designed to permit rapid and economical maintenance, particularly regarding packing and valves. Major parts or components (such as the gearbox/drive, pump head, liquid end housing, and valves) shall be designed and manufactured to ensure accurate alignment on reassembly.

6.1.11 The pump design shall allow access for adjustment or replacement of liquid end components including packing, seals, check valves, and other wetted parts that require maintenance.

6.1.12 The check valves shall be removable from the liquid end for servicing or replacement. If removable spool pieces are required in the Purchaser's piping to accomplish this, the Vendor shall so state in the proposal.

- **6.1.13** 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.

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

6.1.15 The pump flow rate shall be adjustable over the specified turndown ratio while the pump is running.

6.1.16 Rated capacity shall be at least 110 % of the maximum capacity specified.

6.1.17 The steady state flow accuracy shall be within ± 1 % of rated flow over a turndown ratio of at least 10:1.

NOTE It should be recognized that this accuracy generally cannot be guaranteed below 10 percent of rated flow.

6.1.18 The flow repeatability shall be within ± 3 % of rated flow over the specified turndown ratio.

6.1.19 Deviation from linearity shall not exceed ± 3 % of rated flow over the specified turndown ratio.

6.1.20 If the operating differential pressure is below the minimum pressure required to ensure the specified flow accuracy, the Vendor shall specify the minimum differential pressure in the quotation.

- **6.1.21** If specified, liquid ends shall be supplied with jacketed housings or other provisions for heating or cooling the fluid being pumped.

6.2 Pressure Containing Parts

6.2.1 The stress values used in the design of pressure containing parts shall not exceed the maximum allowable stress values specified in Section VIII of the ASME Code at the maximum operating temperature of the material used.

6.2.2 Pressure containing parts shall be positively bolted together (wing bolts, set screws, and clamps shall not be used) and Casing 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.

6.2.3 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 (including 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.

6.2.4 Machined and studded pump connections shall conform to the facing and drilling requirements of ANSI/ASME B16.1, B16.5, B16.42, or B16.47 (ISO 7005-1 or 7005-2). Studs and nuts shall be furnished, installed, and the first 1.5 threads at both ends of each stud shall be removed.

NOTE Threads are removed at the end of the stud to allow the stud to bottom without damaging the end threads in the hole. Threads are removed from both ends of the stud to allow either end of the stud to be inserted into the threaded hole.

6.2.5 Bolting shall be furnished as specified in 6.2.5.1 and 6.2.5.2.

6.2.5.1 The details of threading shall conform to ASME B1.1 (or ISO 261, ISO 262, ISO 724, ISO 965).

6.2.5.2 Studs shall be supplied unless cap screws are specifically approved by the Purchaser.

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

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

6.2.8 Fasteners (excluding washers and set-screws) shall have the material grade and manufacturer's identification symbols applied to one end of studs 10 mm (0.38 in.) in diameter and larger and to the heads of bolts 6 mm (0.25 in.) in diameter and larger. If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's identification symbol marked on the other end. Studs shall be marked on the exposed end.

NOTE A set-screw is a headless screw with an internal hexagonal opening in one end.

6.2.9 Jackscrews, lifting lugs, eyebolts, guide dowels, and alignment dowels shall be provided to facilitate disassembly and reassembly when required by pump design.

6.2.10 If required by the pump design, jackscrews, cylindrical alignment dowels and/or other appropriate devices shall be provided to facilitate disassembly. 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.

6.3 Liquid End Connections

- **6.3.1** Inlet and outlet connections shall be flanged or machined and studded, oriented as specified, and shall be suitable for the working pressure to which it is normally subjected as defined in 3.23.

6.3.2 Any welded connection to the liquid end shall meet the material requirements of the liquid end, including impact values, rather than the requirements of the connected piping (see 6.14.5). All welding of connections shall be done before hydrostatic testing (see 8.3.2).

6.3.3 Suction and discharge nozzles shall be flanged or machined and studded for sizes NPS 2 (50 mm) and larger. Sizes NPS 1½ (40 mm) and smaller may be threaded connections. These threaded connections shall be installed as specified in 6.3.3.1 a) through 6.3.3.1 f).

6.3.3.1 Unless otherwise recommended by the Vendor and approved by the Purchaser, pipe nipples screwed or welded to the casing should not be more than 150 mm (6 in.) long and shall be a minimum of Schedule 160 seamless for sizes 25 mm (NPS 1) and smaller and a minimum of Schedule 80 for 40 mm (NPS 1½) and larger.

a) If nipples longer than 150 mm (6 in.) are recommended and approved, they shall be gusseted.

b) The pipe nipple shall be provided with a welding-neck or socket-weld flange.

c) The nipple and flange materials shall meet the requirements of 6.3.2.

d) Seal welding is not permitted.

e) Unless otherwise specified, pipe threads shall be tapered threads conforming to ASME B1.20.1.

f) 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.

6.3.4 Openings for nozzles and other pressure casing connections shall be standard pipe sizes in accordance with ISO 6708 or ASME B16.5. Openings of DN 32, 65, 90, 125, 175, and 225 (NPS 1¹/₄, 2¹/₂, 3¹/₂, 5, 7, and 9) shall not be used.

6.3.5 Threaded openings not connected to piping shall be plugged. Tapered, 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 casing. 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.

6.4 Flanges

- **6.4.1** Purchaser to specify whether ISO or ASME flanges are to be provided.

6.4.1.1 Cast iron flanges shall be flat-faced and, except as noted in 6.4.1.3, conform to the dimensional requirements of ISO 7005-2 and the flange finish requirements of ASME B16.1 or ASME B16.42. Nominal pressure (PN) 20 (Class 125) flanges shall have a minimum thickness equal to that of PN 40 (Class 250) flanges for sizes DN 200 (NPS 8) and smaller.

NOTE ISO 7005-2 (cast iron) flanges PN 20 and PN 50 are designed to be interchangeable with ASME B16.1 (gray cast iron) and B16.42 (ductile cast iron) but they are not identical. They are deemed to comply with dimensions specified in ASME B16.1 (gray cast iron) and B16.42 (ductile cast iron).

6.4.1.2 Flanges other than cast iron shall, as a minimum requirement, conform to the dimensional requirements of ISO 7005-1 PN 50 except as noted in 6.4.1.3 and the flange finish requirements of ASME B16.5 or ASME B16.47.

NOTE 1 For the purpose of this provision, ASME B16.5 Class 300, ASME B16.47 Class 300, and EN 1759-1 Class 300 are equivalent to ISO 7005-1 PN 50.

NOTE 2 ISO 7005-1 (steel flanges) PN 20, PN 50, PN110, PN150, PN260, and PN420 are designed to be interchangeable with ASME B16.5 and MSS SP-44 flanges. ISO 7005-1 flanges are not identical to ASME B16.5 and MSS SP-44 flanges but are deemed to comply with the dimensions specified in the ASME B16.5 and MSS SP-44.

6.4.1.3 Flanges in all materials that are thicker or have a larger outside diameter than required by the relevant ASME standards in this standard are acceptable. Nonstandard (oversized) flanges shall be identified as such and completely dimensioned on the arrangement drawing. If oversized flanges require studs or bolts of non-standard length, this requirement shall be identified as such on the arrangement drawing.

6.4.1.4 Flanges shall be full-faced or spot-faced on the back and shall be designed for through-bolting, except for jacketed casings.

6.4.1.5 Unless otherwise specified, the Vendor shall provide mating flanges, studs, and nuts for non-standard connections.

6.4.1.6 Studs or bolt holes shall straddle center lines parallel to the main axes of the equipment.

6.4.1.7 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 Pump Check Valves

6.5.1 The suction and discharge check valve cartridges or seats and elements shall be field replaceable.

6.5.2 Check valves shall be guided to provide effective seating action which promotes good flow accuracy and maximum check valve life.