

# Positive Displacement Pumps—Rotary

API STANDARD 676  
FOURTH EDITION, FEBRUARY 2022



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## Introduction

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

The primary purpose of this standard is to establish minimum requirements. This limitation in scope is one of charter as opposed to interest and concern.

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

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

API standards are published as an aid to procurement of standardized equipment and materials. These standards are not intended to inhibit purchasers or producers from purchasing or producing products made to other standards.



# Positive Displacement Pumps—Rotary

## 1 Scope

This standard covers the minimum requirements for rotary positive displacement process pumps and pump units for use in the petroleum, petrochemical, and gas industry services. Controlled-volume pumps, hydraulically driven pumps and positive displacement reciprocating pumps are not included (see API 674 for positive displacement reciprocating pumps and API 675 for controlled-volume pumps).

For rotary positive displacement pumps in auxiliary services (e.g. lube oil systems), manufacturer's standard with demonstrated experience is acceptable.

- Annex A contains datasheets which purchasers are encouraged to use (informative).
- Annex B provides guidance for factors affecting twin screw efficiencies (informative).
- Annex C contains an inspector's checklist (informative).
- Annex D contains information on Contract Documents and Engineering Design Data (informative)
- Annex E contains forms which may be used to indicate vendor drawing and data requirements (VDDRs) (informative).
- Annex F gives guidance regarding net positive suction head (NPSH) vs net positive inlet pressure (NPIP) (informative).
- Annex G provides a typical P&ID for multiphase pump skids (informative).

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 datasheets (see example in Annex A) or stated in the quotation request and purchase 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.

API Recommended Practice 500, *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1, and Division 2*

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

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, *Flanged Steel Pressure Relief Valves*

API Standard 541, *Form-wound Squirrel-cage Induction Motors—500 Horsepower and Larger*

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

API Standard 547, *General-purpose Form-wound Squirrel-cage Induction Motors—250 Horsepower and Larger*

API Recommended Practice 578, *Material Verification Program for New and Existing Alloy Piping Systems*

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

API Standard 613, *Special Purpose Gear Units for Petroleum, Chemical, and Gas Industry Services*

API Standard 614, *Lubrication, Shaft-sealing, and Control-oil Systems and Auxiliaries*

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

API Standard 677, *General-Purpose Gear Units for Petroleum, Chemical and Gas Industry Services*

API Standard 682, *Pumps—Shaft Sealing Systems for Centrifugal and Rotary Pumps*

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

API Recommended Practice 688, *Pulsation and Vibration Control in Positive Displacement Machinery Systems*

API Standard 691, *Risk-based Machinery Management*

ABMA 7,<sup>1</sup> *Shaft, Housing Fits for Metric Radial Ball and Roller Bearings (Except Tapered Roller Bearings) Conforming to Basic Boundary Plans*

ABMA 9, *Load Ratings and Fatigue Life for Ball Bearings*

ABMA 11, *Load Ratings and Fatigue Life for Roller Bearings*

ABMA 20, *Radial Bearings of Ball, Cylindrical Roller and Spherical Roller Types - Metric Design*

AGMA 6013, *Standard for Industrial Enclosed Gear Drives*

AGMA 6091, *Standard for Gearmotor, Shaft Mounted and Screw Conveyor Drives*

AGMA 9000, *Flexible Couplings—Potential Unbalance Classification*

AGMA 9002, *Bores and Keyways for Flexible Couplings (Inch Series)*

ASA S2.19,<sup>2</sup> *Mechanical Vibration—Balance Quality Requirements of Rigid Rotors—Part 1: Determination of Permissible Residual Unbalance, Including Marine Applications*

ASME. *Boiler and Pressure Vessel Code (BPVC),<sup>3</sup> Section V: Non-destructive Examination*

ASME. *BPVC, Section VIII: Pressure Vessels; Division 1*

ASME. *BPVC, Section IX: Welding and Brazing Qualifications*

ASME B1.1, *Unified Inch Screw Threads (UN and UNR Thread Form)*

ASME B1.20.1, *Pipe Threads, General Purpose (Inch)*

ASME B16.1, *Gray Iron Pipe Flanges and Flanged Fittings (Classes 25, 125 and 250)*

<sup>1</sup> American Bearing Manufacturers Association, 2025 M Street, NW, Suite 800, Washington, DC 20036, [www.abma-dc.org](http://www.abma-dc.org).

<sup>2</sup> American Subcontractors Association, 1004 Duke Street, Alexandria, Virginia 22314, [www.asaonline.com](http://www.asaonline.com).

<sup>3</sup> ASME International, 3 Park Avenue, New York, New York 10016–5990, [www.asme.org](http://www.asme.org).

ASME B16.5, *Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard*

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

ASME B16.42, *Ductile Iron Pipe Flanges and Flanged Fittings*

ASME B16.47, *Large Diameter Steel Flanges*

ASME B17.1, *Keys and Keyseats*

ASME B31.3, *Process Piping*

AWS D1.1,<sup>4</sup> *Structural Welding Code—Steel*

DIN 910:2004,<sup>5</sup> *Heavy-duty Hexagon Head Screw Plugs*

EN 287,<sup>6</sup> *Qualification Test of Welders—Fusion Welding*

EN 953, *Safety of Machinery—Guards—General Requirements for the Design and Construction of Fixed and Movable guards*

HI 3.1-3.5,<sup>7</sup> *Rotary Pump Standards for Nomenclature, Definitions, Applications and Operation*

HI 3.6<sup>8</sup>, *Rotary Pump Test*

IEC 60079,<sup>8</sup> *Explosive Atmospheres*

IEEE 841,<sup>9</sup> *Standard for 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, *Pipe threads where pressure-tight joints are made on the threads—Part 1: Dimensions, tolerances and designation*

ISO 7, *Pipe threads where pressure-tight joints are made on the threads—Part 2: Verification by means of limit gauges*

ISO 228-1, *Pipe threads where pressure-tight joints are not made on the threads—Part 1: Dimensions, tolerances and designation*

ISO 261, *ISO general-purpose metric screw threads—General plan*

ISO 262, *ISO general-purpose metric screw threads—Selected sizes for screws, bolts and nuts*

ISO 724, *ISO general-purpose metric screw threads—Basic dimensions*

ISO 965, *ISO general-purpose metric screw threads—Tolerances*

ISO 1940-1, *Mechanical vibration—Balance quality requirements for rotors in a constant (rigid) state—Part 1: specification and verification of balance tolerances*

<sup>4</sup> American Welding Society, 550 NW LeJeune Road, Miami, Florida 33126, [www.aws.org](http://www.aws.org).

<sup>5</sup> Deutsches Institut für Normung E.V., Burggrafenstrasse 6, 10787 Berlin, Germany, [www.din.de](http://www.din.de).

<sup>6</sup> European Committee for Standardization, Avenue Marnix 17, B-1000, Brussels, Belgium, [www.cen.eu](http://www.cen.eu).

<sup>7</sup> Hydraulic Institute 300 Interpace Parkway, Suite 280, 3rd floor, Parsippany, NJ 07054, [www.pumps.org](http://www.pumps.org).

<sup>8</sup> International Electrotechnical Commission, 3 rue de Varembe, PO Box 131, CH-1211, Geneva 20, Switzerland, [www.iec.ch](http://www.iec.ch).

<sup>9</sup> Institute of Electrical and Electronics Engineers, 445 Hoes Lane, Piscataway, New Jersey 08854, [www.ieee.org](http://www.ieee.org).

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, *Rolling bearings—Radial internal clearance*

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

ISO 7005-1, *Metallic flanges—Steel flanges*

ISO 7005-2, *Metallic flanges—Cast iron flanges*

ISO 8501-1, *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 after overall removal of previous coatings*

ISO 14120, *Safety of machinery—Guards—General requirement for the design and construction of fixed and movable guards*

ISO 14691, *Petroleum, petrochemical and natural gas industries—Flexible couplings for mechanical power transmission—General-purpose applications*

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

NACE MR 0103,<sup>10</sup> *Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments*

NACE MR 0175, *Materials for Use in H<sub>2</sub>S-containing Environments in Oil and Gas Production*

NACE. *Corrosion Engineer's Reference Book*

NFPA 70,<sup>11</sup> *National Electrical Code*

SSPC SP 6,<sup>12</sup> *Commercial Blast Cleaning*

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

**2.3** Notes are informative, unless contained in a figure or table.

**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.

### 3 Terms and Definitions

For the purposes of this standard, the following terms and definitions apply.

#### 3.1

##### **alarm**

Preset value of a measured parameter that sends a warning of a condition that requires corrective action.

<sup>10</sup> NACE International (formerly the National Association of Corrosion Engineers), 1440 South Creek Drive, Houston, Texas 77218-8340, [www.nace.org](http://www.nace.org).

<sup>11</sup> National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169-7471, [www.nfpa.org](http://www.nfpa.org).

<sup>12</sup> The Society for Protective Coatings, 40 24th Street, 6th Floor, Pittsburgh, Pennsylvania 15222, [www.sspc.org](http://www.sspc.org).

**3.2****anchor bolt**

A sleeved stud or threaded bar used to attach the baseplate to the support structure (concrete foundation or steel structure).

**3.3****baseplate**

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

**3.4****capacity**

Flowrate i.e. volume per unit time.

**3.5****certified material test report****CMTR**

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

**3.6****critical speed**

shaft rotational speed at which the rotor-bearing-support system is in a state of resonance.

**3.7****datum elevation**

Elevation to which values of NPSH are referred (concrete foundation or steel structure to which the baseplate is attached); also see paragraph defining NPSH (see 3.39).

**3.8****design**

Vendor's calculated parameter.

**NOTE** A term used by the equipment vendor 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****differential pressure**

Change in energy of the pumped liquid due to its pressure change in the pump. Typically, the discharge pressure minus the suction pressure.

**3.10****displacement**

Volume transferred from the suction to discharge per revolution of the rotor(s). In pumps incorporating two or more rotors operating at different speeds, the displacement is the volume transferred per revolution of the driving rotor.

**3.11****drive train components**

Item of the equipment used in series to drive the pump (e.g. motor, gear, turbine, engine, fluid drive, clutch).

**3.12****gas volume fraction****GVF**

Ratio of volume of gas to that of the total volume of the fluid (oil, water, and gas) at pump suction temperature and pressure, the fraction being expressed as a percentage.

**3.13****hold-down bolt  
mounting bolt**

A fastener, such as a stud with nuts, holding the equipment to the baseplate.

**3.14****hydrostatic test pressure**

Static test pressure used for leak testing.

**3.15****inspection and test plan****ITP**

Single project-specific document used to consolidate all inspection and test requirements, acceptance criteria, and roles and responsibilities; typically, with extended scope for heavy duty pumps in complex packages,

**3.16****maximum allowable casing pressure****MACP**

Maximum pressure for which the vendor has designed the pressure-containment components at the specified operating temperature.

**3.17****maximum allowable working pressure****MAWP**

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

**3.18****maximum continuous allowable speed**

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

**3.19****minimum design metal temperature**

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

**3.20****multiphase fluid**

A process stream comprised of two or more phases where one phase is a gas, and one phase is a liquid and particulate may be present.

**3.21****multiphase pump****MPP**

Pump designed to successfully handle fluids with at least both gas and liquid present in the process stream.

**3.22****net positive inlet pressure****NPIP**

Minimum pressure determined at the datum elevation minus the vapor pressure of the fluid at the maximum operating temperature at any specified point.

**3.23****net positive inlet pressure available****NPIPA**

NPIP determined by the purchaser from the NPSHA and system design data.

**3.24****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.

**3.25****net positive suction head****NPSH**

Total absolute suction head determined at the suction nozzle and referred to the datum elevation minus the head of the vapor pressure of the fluid.

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

**3.26****net positive suction head available****NPSHA**

Minimum value of NPSH determined to be available under any specified operating condition, accounting for line losses, under steady state flow conditions.

NOTE NPSHA is a value provided by the purchaser and which the purchaser uses to calculate the NPIPA (see 3.23). NPSHA is a function only of the system upstream of the pump and the operating conditions and is independent of pump design.

**3.27****net positive suction head required****NPSHR**

Minimum value of NPSH determined to be required under any specified operating condition, based on steady state flow.

NOTE NPSHR is a value provided by the vendor by taking the equipment requirements, which are based on the centerline of inlet reference point and adjusting it to the underside of the baseplate. It correlates to the NPIPR (see 3.24).

**3.28****nominal pipe size****NPS**

Designation, usually followed by a size number designation number, corresponding approximately to the outside diameter of the pipe expressed in inches.

**3.29****nominal pressure****PN**

Numerical designation relating to pressure that is a convenient round number for reference purposes.

**3.30****nondestructive testing****NDT**

Inspection of materials, components, or assemblies by means of radiography, liquid penetrant, magnetic particle, or ultrasonic testing (the typical methods employed)

**3.31****performance test**

Running test conducted to measure flow rate, differential pressure, and power consumed at specified conditions.

NOTE Test results need to be corrected to service conditions, e.g. viscosity.

**3.32****PMI****positive material identification testing**

Any physical evaluation or test of a material to confirm that the material which has been or will be placed into service is consistent with the selected or specified alloy material designated by the owner/user. These evaluations or tests can provide either qualitative or quantitative information that is sufficient to verify the nominal alloy composition.

NOTE Adapted from API RP 578: 2010.

**3.33****pressure-containing part**

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

**3.34****pressure-limiting valve accumulation pressure****PLV accumulation pressure**

Pressure at which a PLV discharges the pump rated flow rate.

**3.35****pressure-limiting valve set pressure****PLV set pressure**

Pressure at which a PLV starts to release pressure by discharging flow.

**3.36****pressure-retaining part**

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

**3.37****pump efficiency**

Ratio of the pump's hydraulic power at discharge to its brake power input. Rated Pump efficiency is calculated at the rated point.

NOTE The hydraulic power is calculated significantly different in compressible (multiphase) fluids (see specific paragraphs on MPPs).

**3.38****purchaser**

Agency that issues the order and specification to the vendor.

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

**3.39****rated operating point**

Point at which the vendor 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.

**3.40****rated power**

Power delivered to the pump input shaft at rated operating point. It is also called brake power (brake horsepower, brake kilowatts, etc.).

**3.41****rated speed**

Highest rotational speed (revolutions 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.

### 3.42

#### **rotary pump**

Positive displacement pump consisting of a casing containing gears, screws, lobes, cams, or vanes actuated by relative rotation between the drive shaft and the casing. There are no separate inlet and outlet valves. These pumps are characterized by their close running clearances.

### 3.43

#### **settle-out pressure**

Highest pressure the MPP will experience when not running and after equilibrium has been reached.

**NOTE** This may be a function of ambient temperature, PLV setting, and piping volume.

### 3.44

#### **shutdown set point**

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

### 3.45

#### **slip**

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

### 3.46

#### **steady state**

Condition under which specific metering parameters such as: flow rate, differential pressure, speed, GVF, suction pressure, discharge pressure, temperature, and fluid type are not changing by more than  $\pm 10\%$  over a two-minute period.

### 3.47

#### **TIR**

#### **total indicator reading**

#### **total indicated run-out**

Difference between the maximum and minimum readings (of a dial indicator or similar device), monitoring a face or cylindrical surface during one complete revolution of the monitored surface.

**NOTE** For a cylindrical surface, the total indicated run-out implies an eccentricity equal to half the reading. For a flat face, the indicated run-out implies an out-of-square equal to the reading.

### 3.48

#### **trip speed**

Speed (revolutions per minute) at which the independent emergency overspeed device operates to shut down a variable speed prime mover. The trip speed of any alternating current electric motors, except variable frequency drives, is the speed corresponding to the synchronous speed of the motor at maximum supply frequency.

### 3.49

#### **unit responsibility**

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

### 3.50

#### **vendor**

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

**3.51****volumetric efficiency**

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

NOTE Volumetric efficiency is normally expressed as a percentage.

**3.52****witnessed**

A classification of inspection or test where the purchaser is notified of the timing of the inspection or test and a hold is placed on the inspection or test until the purchaser or the purchaser's representative is in attendance.

**4 General****4.1 Unit Responsibility**

The vendor shall assume unit responsibility and shall assure that all sub-vendors comply with the requirements of this standard and all reference documents. The technical aspects to be considered by the vendor include, but are not limited to, such factors as the power requirements, speed, rotation, general arrangement, couplings, dynamics, lubrication, sealing system, certified material test reports, instrumentation, piping, conformance to specifications and testing of components.

**4.2** Whether the application is a liquid or a multiphase service, if MPP design criteria are required by the service conditions or specified by the purchaser by use of the multiphase datasheets, all of the standard clauses will apply, except where noted or qualified otherwise in this standard.

NOTE The following listing identifies the paragraphs where unique MPP design and testing requirements are described—3.12, 3.20, 3.21, 6.1.14.3, 6.7.3.2, 6.8.1.3, 6.8.1.8, 6.8.2.2, 6.10.1, 6.11.2, 7.1.1.1.2, 7.3.5, 7.6.1, 7.8, 8.1.8, 8.3.8, and Annex G.

**4.3 Pump Designations****4.3.1 General**

NOTE Pictures and modified descriptions are used with permission of the Hydraulic Institute.

The pumps described in this standard are classified and designated as shown in Table 1.

**Table 1—Pump Classification Type Identification**

| Pump Type (by Pumping Element) |       | Type                           | Type Code |
|--------------------------------|-------|--------------------------------|-----------|
| rotary pumps                   | vane  | vane in rotor                  | VR        |
|                                |       | vane in stator                 | VS        |
|                                | lobe  | single                         | LS        |
|                                |       | multiple                       | LM        |
|                                | gear  | external gears (timed)         | GET       |
|                                |       | external gears (untimed)       | GEU       |
|                                |       | internal gears (with crescent) | GI        |
|                                | screw | single                         | SS        |
|                                |       | multiple timed                 | SMT       |
|                                |       | multiple untimed               | SMU       |

NOTE Typical flows and pressures for these types of pumps are shown in Figure 9 and Figure 10, which have been provided courtesy of the Hydraulic Institute.

### 4.3.2 Sliding Vane Pump

In vane pumps, as illustrated in Figure 1, as the vane or vanes are moved by a rotor, thereby drawing fluid into, and forcing it from the pump chamber. These pumps may be made with vanes in either the rotor or stator and with radial hydraulic forces on the rotor balanced or unbalanced.

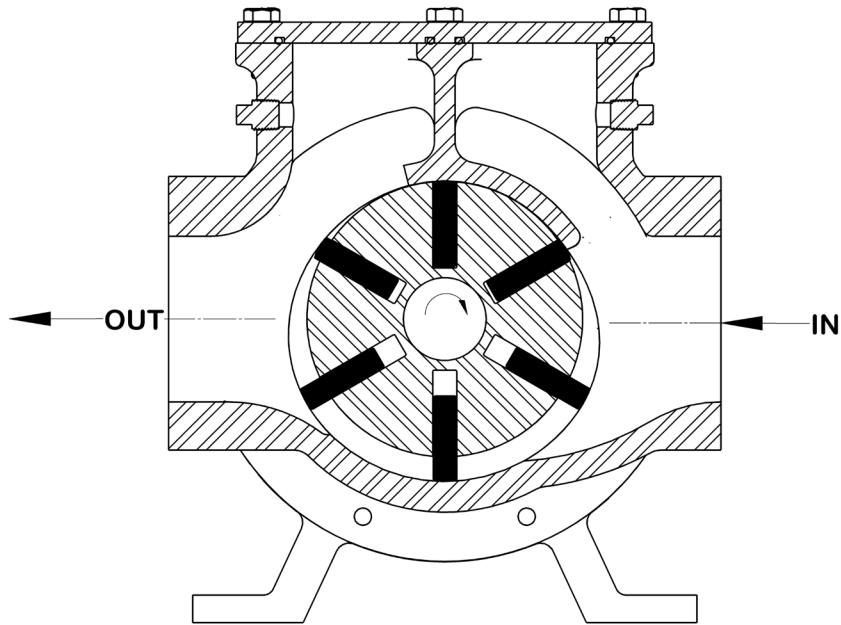


Figure 1—Sliding Vane Pump (Vane in Rotor)

### 4.3.3 Lobe Pump

In lobe pumps, as illustrated in Figure 2 and Figure 3, fluid is carried between rotor lobe surfaces and the pumping chamber from the inlet to the outlet. The rotor surfaces cooperate to provide continuous sealing. The rotors shall be timed by separate means. Each rotor has one or more lobes.

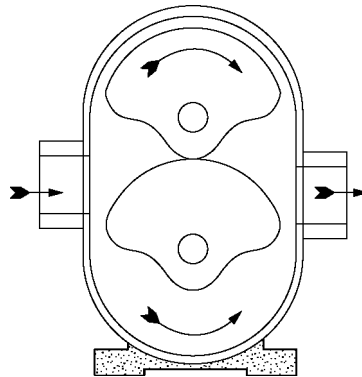


Figure 2—Single Lobe Pump

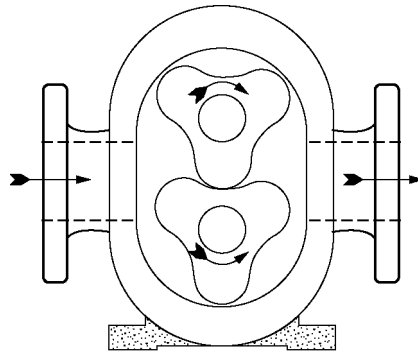


**Figure 3—Three Lobe Pump**

#### 4.3.4 External Gear Pump

In gear pumps, as illustrated in Figure 4, fluid is carried between gear teeth and displaced when they mesh. The surfaces of the rotors cooperate to provide continuous sealing and either rotor is capable of driving the other. External gear pumps have all gear rotors cut externally. These may have spur, helical, or herringbone (double helical) gear teeth and may use timing gears.

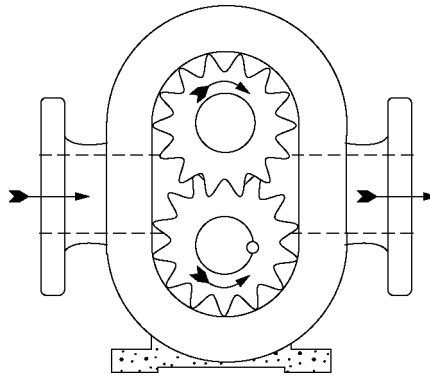


**Figure 4—External Gear Pump**

#### 4.3.5 Internal Gear Pump (with Crescent)

Internal gear pumps have one rotor with internally cut gear teeth meshing with an externally cut gear. Pumps of this type are made with a crescent-shaped partition, as illustrated in Figure 5.

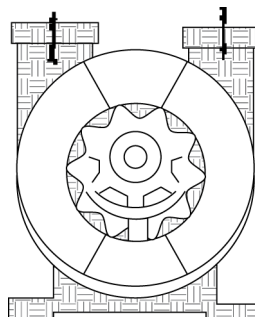


**Figure 5—Internal Gear Pump**

#### 4.3.6 Progressing/Progressive Cavity Pump (PCP)

In screw pumps, fluid is carried in spaces formed by screw(s) and the screw housing and is displaced axially as they mesh.

Single screw pumps (progressing cavity pumps), illustrated in Figure 6, have a rotor with external threads and a stator with internal threads. The rotor threads are eccentric to the axis of rotation.

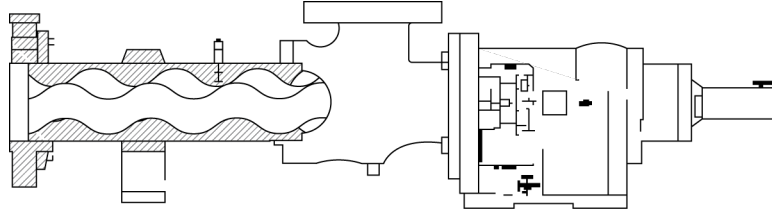


**Figure 6—Progressing/Progressive Cavity Pump (PCP)**

#### 4.3.7 Multiple Screw Pump

Multiple screw pumps have multiple external screw threads. Such pumps, as those illustrated in Figure 7 and Figure 8, may be timed or untimed.

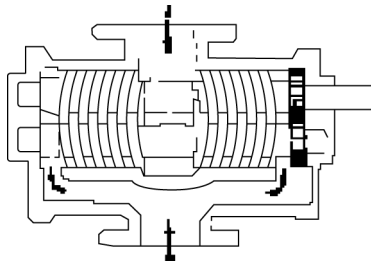


**Figure 7—Twin Screw Pump (with Timed Gears)**

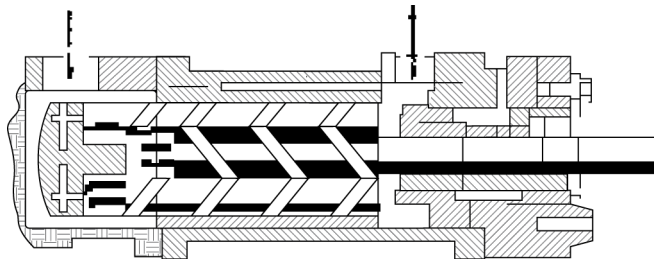


**Figure 8—Three-screw Pump (with Untimed Gears)**

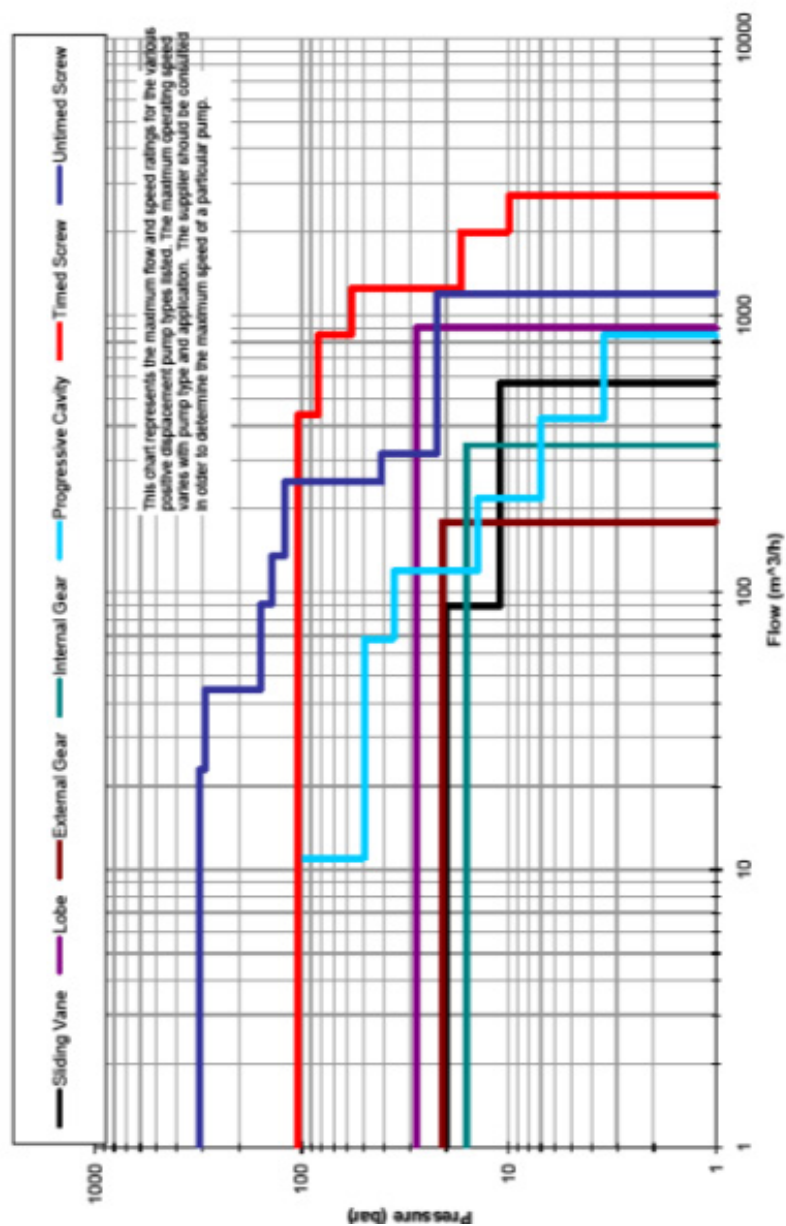


Figure 9—Rotary Pump Consolidated Range Chart (Typical Range in SI Units)

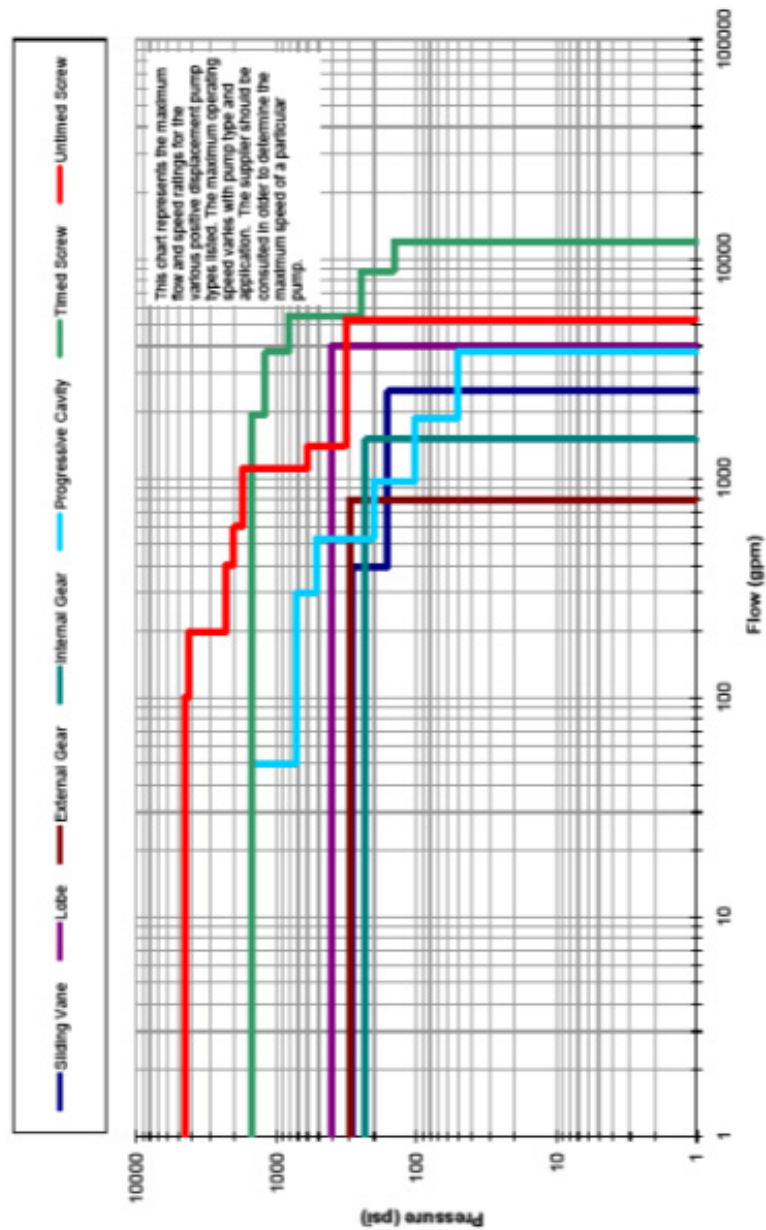


Figure 10—Rotary Pump Consolidated Range Chart (Typical Range in USC Units)

## 5.1 [•] Units of Measure

Drawings and maintenance dimensions of pumps shall be in SI units or U.S. customary (USC) units.

Purchaser's use of a USC data sheet (see Annex A.2) indicates the USC system of measurements shall be used for all data, drawings, and maintenance dimensions. Purchaser's use of an SI data sheet (see Annex A.1) indicates the SI system of measurements shall be used.

NOTE Dedicated Data Sheets for SI units and for U.S. customary units are provided in Annex A.

## 5.2 Statutory Requirements

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

## 5.3 Documentation Requirements

The hierarchy of documents shall be specified.

NOTE Typical documents include company and industry specifications, meeting notes, and modifications to these documents.

# 6 Basic Design

## 6.1 General

- [•] **6.1.1** The purchaser shall specify the period of uninterrupted continuous operation. Shutting down the equipment to perform required maintenance or inspection during the uninterrupted operation period is not acceptable.

**6.1.1.1** If a range of operating conditions is specified, the pump vendor shall advise the purchaser about the pump's minimum and maximum capacity and normal operating point at its rated differential pressure and its required brake horsepower.

**6.1.1.2** Anticipated process variations that may affect the sizing of the pump and the driver (such as changes in pressure, temperature, or properties of fluids handled, and special plant startup conditions) shall be specified.

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.

**6.1.1.3** Only equipment that is field proven, as defined by the purchaser, is acceptable.

NOTE Purchasers can use their engineering judgment in determining what equipment is field proven. API 691 can provide guidance.

- [•] **6.1.1.4** If specified, the vendor shall provide the documentation to demonstrate that all equipment proposed qualifies as field proven.

**6.1.1.5** In the event no such equipment is available, the vendor shall submit an explanation of how their proposed equipment can be considered field proven.

NOTE A possible explanation can be that all components comprising the assembled machine satisfy the field proven definition.

**6.1.2** The vendor shall advise in the proposal of any components designed for a finite life.

NOTE It is recognized that these are design criteria.

- [•] **6.1.3** The purchaser shall specify if equipment will be supplied in accordance with API RP 691. If API RP 691 has been specified, the vendor shall identify all machinery components that have a TRL < 7 per API RP 691 Section 4.3.2 Table 1.

- [•] **6.1.4** Unless otherwise specified, pumps shall be designed for flammable or hazardous services.

**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. 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** Equipment shall be selected to run simultaneously at the pressure-limiting valve accumulation pressure and at trip speed without suffering damage. Vendor shall advise purchaser of increased power operating requirements necessary to achieve this.

**6.1.7** For direct-driven equipment, the equipment's maximum continuous allowable speed shall be not less than 105 % of the rated speed for adjustable speed machines and shall be equal to the synchronous speed for constant speed motor drives.

**6.1.8** For gear-driven equipment, the gear input shaft maximum continuous allowable speed shall not be less than 105 % of the rated speed for adjustable speed machines and shall be equal to the synchronous speed for constant speed motor drives.

**6.1.9** The equipment's trip speed shall not be less than the following percentages of maximum continuous allowable speed:

- a) adjustable speed driver—110 %,
- b) constant speed motor—100 %.

**6.1.10** 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.

- [•] **6.1.11** 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 RP 500, and NEC as specified, as well as any local codes specified and supplied by the purchaser.

**6.1.12** 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 prevent contamination by moisture, dust, and other foreign matter during periods of operation and idleness.

**6.1.13** 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.

**6.1.14** All equipment (machine, driver, and auxiliary equipment as specified) shall be designed to perform on the test stand and on its permanent foundation within the specified test tolerances (see 6.11 and 8.3.6).

**6.1.14.1** After installation, the performance of the combined units shall be the joint responsibility of the purchaser and the vendor who has unit responsibility.

**6.1.14.2** 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.

- [●] **6.1.14.2.1** To minimize the influence of these factors, the vendor shall review and comment on the purchaser's piping and foundation drawings, when specified.

**6.1.14.2.2** If specified, the vendor's representative shall witness:

- a) A check of the piping alignment performed by unfastening the major flanged connections of the equipment.
- b) The initial shaft alignment check at ambient conditions.
- c) Shaft alignment at operating temperature, (i.e. hot alignment check).

NOTE Refer to API RP 686 for basic guidelines for conducting piping alignments, shaft hot and cold alignments.

**6.1.14.3** If specified, for MPPs, the vendor shall confirm that the unit is capable of start-up at settle-out and maximum suction pressure.

**6.1.15** The equipment, including all auxiliaries, shall be suitable for operation under the environmental conditions specified. These conditions shall include whether the installation is indoors (heated or unheated) or outdoors (with or without a roof), maximum and minimum temperatures, sun metal temperature, unusual humidity, and dusty or corrosive conditions.

**6.1.16** The equipment, including all auxiliaries shall be suitable for operation using the utility conditions specified.

**6.1.17** Spare and replacement parts for the equipment and all furnished auxiliaries shall meet all the criteria of this standard.

### **6.1.18 Bolting**

**6.1.18.1** Bolting shall conform to 6.1.18.2 through 6.1.18.5.

**6.1.18.2** Details of threading shall conform to ASME B1.1, ISO 261, ISO 262, ISO 724, and ISO 965.

**6.1.18.3** Internal socket-type, slotted-nut, or spanner-type bolting shall not be used unless approved by the purchaser. This restriction does not apply to set-screws for mechanical seals.

NOTE 1 For limited space locations, integrally flanged fasteners can be supplied.

NOTE 2 A set-screw is a headless screw with an internal hexagonal opening in one end.

**6.1.18.4** Fasteners (excluding washers and set-screws) shall have the material grade and vendor'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 vendor's identification symbol marked on the other end. Studs shall be marked on the exposed end.

**6.1.18.5** Metric fine and UNF threads shall not be used.

### **6.1.19 Pump Mounting Surfaces**

**6.1.19.1** The pump mounting surfaces shall meet the following criteria.

**6.1.19.2** They shall be fully machined to a finish of 6.3  $\mu\text{m}$  (250  $\mu\text{in.}$ ) arithmetic average roughness (Ra) or smoother.

**6.1.19.3** To prevent a soft foot, each individual mounting surface shall be machined with a flatness tolerance of 25  $\mu\text{m}$  (0.001 in.).

**6.1.19.4** The mounting surfaces shall be machined flat and parallel. Corresponding surfaces shall be in the same plane within 150  $\mu\text{m}/\text{m}$  (0.002 in./ft) of distance between the mounting surfaces.

NOTE Some users require 0.0005 in./ft not to exceed a maximum of 0.010 in.

**6.1.19.5** The upper machined, or spot faced surface, shall be parallel to the mounting surface.

NOTE Typically, the spot-face is parallel  $\leq 0.002$  in.

**6.1.19.6** Hold-down bolt holes shall be drilled perpendicular to the mounting surface or surfaces, machined or spot faced to a diameter three times that of the hole and to allow for equipment alignment. For hold-down bolts 25 mm (1 in.) and larger the hole shall be 13 mm (0.50 in.) larger in diameter than the hold-down bolt. For bolts less than 25 mm (1 in.) in diameter, the holes shall be 5 mm (0.25 in.) larger in diameter than the bolt.

NOTE Typically, perpendicularity  $\leq 0.001$  in. per inch of bolt hole bore.

## 6.2 Selection and Rating of Pump Type

The vendor shall recommend the pump speed for the specified service, considering such factors as net positive suction head available (NPIPA/NPSHA), net positive suction head required (NPIPR/NPSHR), maximum fluid viscosity, solids and abrasives content, and wear allowance if required.

NOTE Recognize that different rotary pump designs operate on different principles so that no one speed criterion can be applied.

## 6.3 Pressure-containing and Pressure-retaining Parts

**6.3.1** The pressure-containing parts shall be designed in accordance with 6.3.1.1 (or 6.3.1.2, as selected by the vendor) and 6.3.1.3 to achieve the following:

- a) operate without leakage while subject simultaneously to the maximum allowable casing pressure (MACP) (and corresponding temperature) and the worst case combination of maximum allowable nozzle loads applied to all nozzles,
- b) withstand the hydrostatic test in 8.3.2.

**6.3.1.1** Pressure-containing components may be designed with the aid of finite element analysis provided that the value of the stress intensity reflects a requirement to perform a hydrostatic test at 150 % of MACP.

**6.3.1.2** The allowable tensile stress used in the design of the pressure components, excluding bolting, for any material shall not exceed 0.25 times the minimum ultimate tensile strength or 0.67 times the minimum yield strength for the material whichever is lower across the full range of specified operating temperature.

**6.3.1.3** For casing joint bolting, the allowable stress, as determined in 6.3.1.2 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 the bolting is required to prevent unloading the bolted joint due to cyclic operation.

**6.3.1.4** A corrosion allowance of at least 3 mm (0.12 in.) shall be added to the casing thickness used in 6.3.1. The corrosion allowance shall also be added to all auxiliary connections exposed to the same fluid as the pressure-containing casing.

**6.3.1.5** The vendor may propose alternative corrosion allowances for consideration if materials of construction with superior corrosion resistance are employed.

**6.3.2** The purchaser shall install a pressure-limiting valve (PLV) for each positive displacement pump. The PLV accumulation pressure shall not exceed the maximum allowable working pressure (MAWP) of the pump.

**6.3.3** Casing and other pressure-retaining parts and supports shall be designed to prevent detrimental distortion (e.g. reduced MTBF) caused by the worst combination of temperature, pressure, torque, and allowable external forces and moments based on the specified operating conditions.

**6.3.3.1** Unless otherwise specified, the suction region and the discharge region of the pump shall be designed for different pressure ratings.

**[●] 6.3.3.2** If specified, suction regions shall be designed for the same MACP as the discharge section.

**6.3.3.3** Casings shall be sealed using flat gaskets; confined, controlled-compression spiral wound gaskets, or O-rings.

**NOTE** Information on controlled compression gaskets is found in ASME B16.20.

**6.3.4** 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 (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.

**6.3.5** If required by the pump design, jackscrews, cylindrical alignment dowels 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.

**6.3.6** If jacketed pump casings are required, jacket passages shall not open into casing joints.

**6.3.7** Jackets shall be designed for minimum of 5.2 bar (75 psi) working pressure and shall be suitable for hydrostatic testing at a minimum of 8 bar (115 psi).

## **6.4 Casing Connections**

**6.4.1** Provision shall be made for complete venting (unless it is self-venting) and draining of the pump and systems provided by the vendor.

**6.4.2** All pumps shall be provided with vent and drain connections, except that vent connections may be omitted if the pump is made self-venting by the arrangement of the nozzles.

**6.4.2.1** If specified, drain(s) and/or vent(s) shall be piped to the edge of the baseplate or mounting plate.

**6.4.2.2** If the pump cannot be completely drained for geometrical reasons, this shall be stated in the proposal.

**6.4.2.3** The operating manual shall include a drawing indicating the quantity and location(s) of the fluid remaining in the pump.

**NOTE** A pump is considered functionally self-venting if the nozzle arrangement and the casing configuration permit sufficient venting of gases to prevent loss of prime during the starting sequence.

### 6.4.3 Casing Opening Sizes

**6.4.3.1** 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 1½, 2½, 3½, 5, 7, and 9) shall not be used.

**6.4.3.2** Casing connections other than suction and discharge nozzles shall be at least DN 15 (NPS ½) for pumps with discharge nozzle openings DN 50 (NPS 2) and smaller. Connections shall be at least DN 20 (NPS ¾) for pumps with discharge nozzle openings DN 80 (NPS 3) and larger, except that connections for seal flush piping and gauges may be DN 15 (NPS ½) regardless of pump size.

### 6.4.4 Suction and Discharge Nozzles

**6.4.4.1** Suction and discharge nozzles shall be flanged or machined and studded for sizes DN 50 (NPS 2) and larger. Sizes DN 40 (NPS 1½) and smaller may be threaded connections. When machined and studded suction and discharge nozzles are provided, the purchaser shall be provided nozzle details.

[•] **6.4.4.2** If specified, all connections shall be suitable for the MACP.

## 6.5 Auxiliary Connections

**6.5.1** Connections welded to the casing shall meet the material requirements of the casing including impact values, rather than the requirements of the connected piping. All welding of connections, gussets, etc. shall be completed before the casing is hydrostatically tested (see 8.3.2).

[•] **6.5.2** If specified, piping shall be gusseted in two orthogonal planes to increase the rigidity of the piped connection.

**6.5.2.1** Gussets shall be of a material compatible with the pressure casing and the piping and shall be made of flat bar with a minimum cross section of 25 mm to 3 mm (1 in. to 0.12 in.).

**6.5.2.2** Gussets shall be located at or near the connection end of the piping and fitted to the closest convenient location on the casing to provide maximum rigidity. The long width of the bar shall be perpendicular to the pipe and shall be located to avoid interference with the flange bolting or any maintenance areas on the pump.

**6.5.2.3** Gusset welding shall meet the fabrication requirements of 6.13.5, including post-weld heat treatment when required, and the inspection requirements of this standard (see 8.2.2).

**6.5.2.4** Gussets may also be bolted to the casing if drilling and tapping is done prior to the hydrostatic test.

**6.5.2.5** Piping may be clamped to gussets.

**6.5.3** If recommended by the vendor and approved by the purchaser, threaded connections for pipe sizes exceeding DN 40 (NPS 1½) may be used.

NOTE For example:

- a) on nonweldable materials, such as cast iron;
- b) if essential for maintenance (disassembly and assembly); and
- c) where flanged or machined and studded openings are impractical.

**6.5.3.1** 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 DN 25 (NPS 1) and smaller and a minimum of Schedule 80 for DN 40 (NPS 1½).

**6.5.3.2** Nipples longer than 150 mm (6 in.) shall be gusseted.

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

**6.5.3.4** All auxiliary connections to the pressure casing, except seal gland, shall terminate in a flange meeting the requirements of 6.6.1.1 or 6.6.1.2. These connections shall be integrally flanged, socket welded or butt welded as specified by the purchaser. Seal welding of threaded connections is not permitted. Purchaser interface connections shall terminate in a flange.

- [●] **6.5.3.5** If specified, special threaded fittings for transitioning from the casing to tubing for seal flush piping may be used provided a secondary sealing feature such as O-rings are used, and the joint does not depend on thread contact alone to seal fluid. The connection boss shall have a machined face suitable for sealing contact.

**6.5.3.6** The nipple and flange materials shall meet the requirements of API 614.

**6.5.3.7** Unless otherwise specified, pipe threads shall be tapered threads conforming to ASME B1.20.1. Openings and bosses for pipe threads shall conform to ASME B16.5.

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

- [●] **6.5.4** If specified, cylindrical threads conforming to ISO 228-1 shall be used. If cylindrical threads are used, they shall be sealed with a contained face gasket, and the connection boss shall have a machined face suitable for gasket containment.

- [●] **6.5.4.1** If specified, auxiliary connections to the pressure casing shall be machined and studded. These connections shall conform to the facing and drilling requirements of ASME B16.5 or ASME B16.1. Studs and nuts shall be furnished installed. The first 1½ threads at both ends of each stud shall be removed.

**6.5.4.2** All connections shall be suitable for the hydrostatic test pressure of the region of the casing to which they are attached.

**6.5.4.3** Threaded openings not connected to piping shall be plugged.

- a) Taper-threaded plugs shall be long-shank solid round-head, or long-shank hexagon-head bar stock plugs in accordance with ASME B16.11.
- b) 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.
- c) 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.

## 6.6 Flanges

- [●] **6.6.1** Purchaser to specify whether ISO or ASME flanges are to be provided.

**6.6.1.1** Gray cast iron flanges shall be flat-faced and, except as noted in 6.6.1.3, 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).

**6.6.1.2** Flanges other than gray cast iron shall, as a minimum requirement, conform to the dimensional requirements of ISO 7005-1 PN 50 except as noted in 6.6.1.3 and the flange finish requirements of ASME B16.5 or ASME B16.47.

**6.6.1.3** Flanges in all materials that are thicker or have a larger outside diameter than required by the relevant ISO (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.

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

**6.6.1.5** The vendor shall provide mating flanges, studs, and nuts for non-standard connections.

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

**6.6.1.7** 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.

## 6.7 External Forces and Moments

**6.7.1** 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. As a minimum, the pump inlet and outlet connections shall be capable of withstanding the limits indicated in Table 2.

**Table 2—Nozzle Loadings**

| SI Units<br>Nominal Size of Flange<br>(DN)   | Forces Each Nozzle<br>$F_x$ , $F_y$ and $F_z$<br>(N)   | Moments Each Nozzle<br>$M_x$ , $M_y$ and $M_z$<br>(N•m)    |
|----------------------------------------------|--------------------------------------------------------|------------------------------------------------------------|
| ≤50                                          | 650                                                    | 350                                                        |
| 80                                           | 1040                                                   | 560                                                        |
| 100                                          | 1300                                                   | 700                                                        |
| 150                                          | 1950                                                   | 1050                                                       |
| 200                                          | 2600                                                   | 1400                                                       |
| 250                                          | 3250                                                   | 1750                                                       |
| 300                                          | 3900                                                   | 2100                                                       |
| 350                                          | 4550                                                   | 2450                                                       |
| 400                                          | 5200                                                   | 2800                                                       |
| 500                                          | 6500                                                   | 3500                                                       |
| 600                                          | 7800                                                   | 4200                                                       |
| USC Units<br>Nominal Size of Flange<br>(NPS) | Forces Each nozzle<br>$F_x$ , $F_y$ and $F_z$<br>(lbf) | Moments Each Nozzle<br>$M_x$ , $M_y$ and $M_z$<br>(ft-lbf) |
| ≤2                                           | 150                                                    | 250                                                        |
| 3                                            | 225                                                    | 375                                                        |
| 4                                            | 300                                                    | 500                                                        |
| 6                                            | 450                                                    | 750                                                        |
| 8                                            | 600                                                    | 1000                                                       |
| 10                                           | 750                                                    | 1250                                                       |
| 12                                           | 900                                                    | 1500                                                       |
| 14                                           | 1050                                                   | 1750                                                       |