

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



AMERICAN PETROLEUM INSTITUTE

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For Committee Ballot 5482
Not For General Distribution

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

Downstream Segment

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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 7:1995², *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 Code³, 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 D1.1:2003⁴, *Structural Welding Code — Steel*

DIN 910:2004⁵, *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 60034⁷, *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 841:2001⁸, *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: 2000⁹, *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 70:2002¹¹, *National Electrical Code*

SSPC SP 6:2000¹², *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.

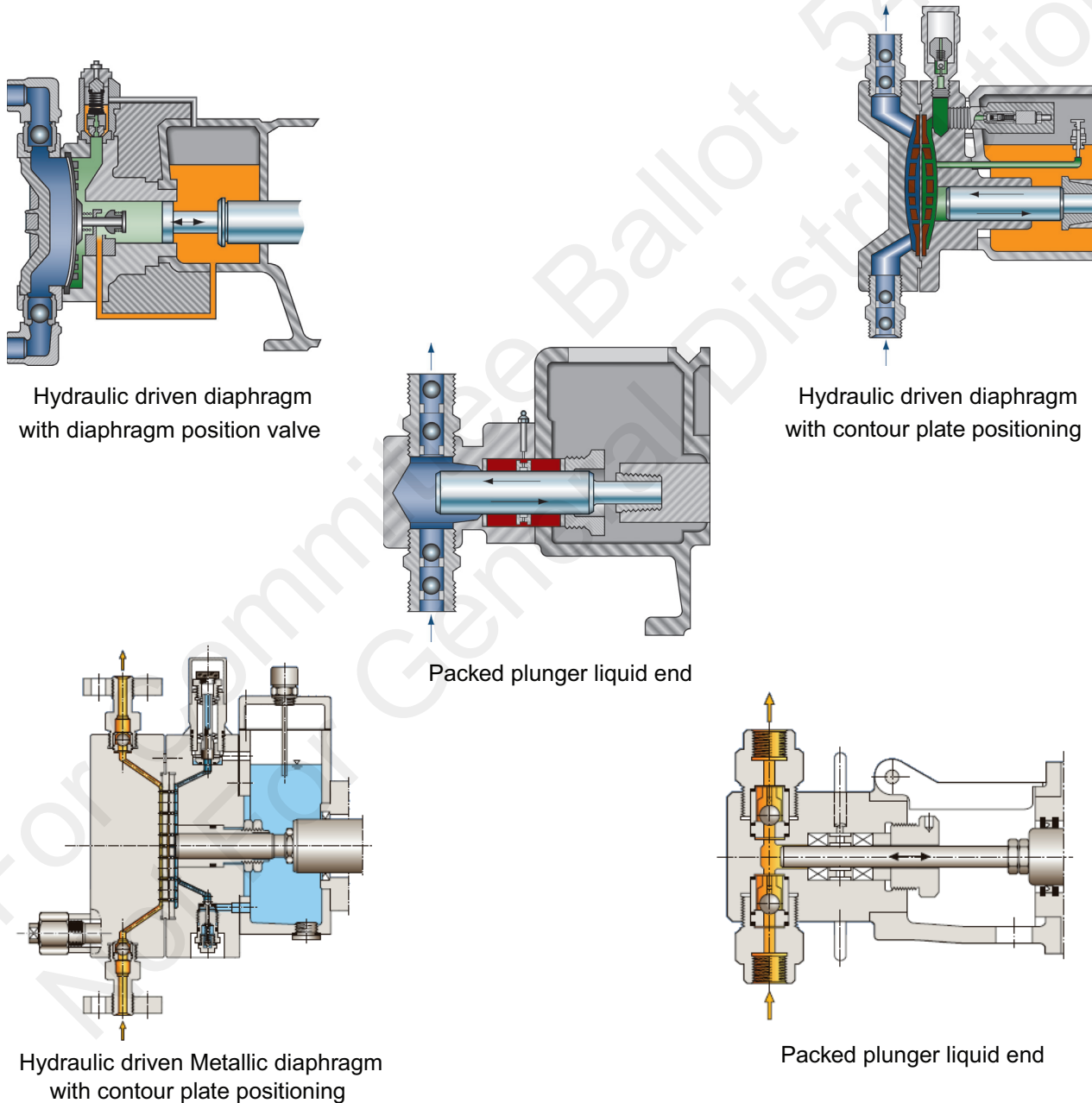


Figure 1—Typical Liquid End Pumps

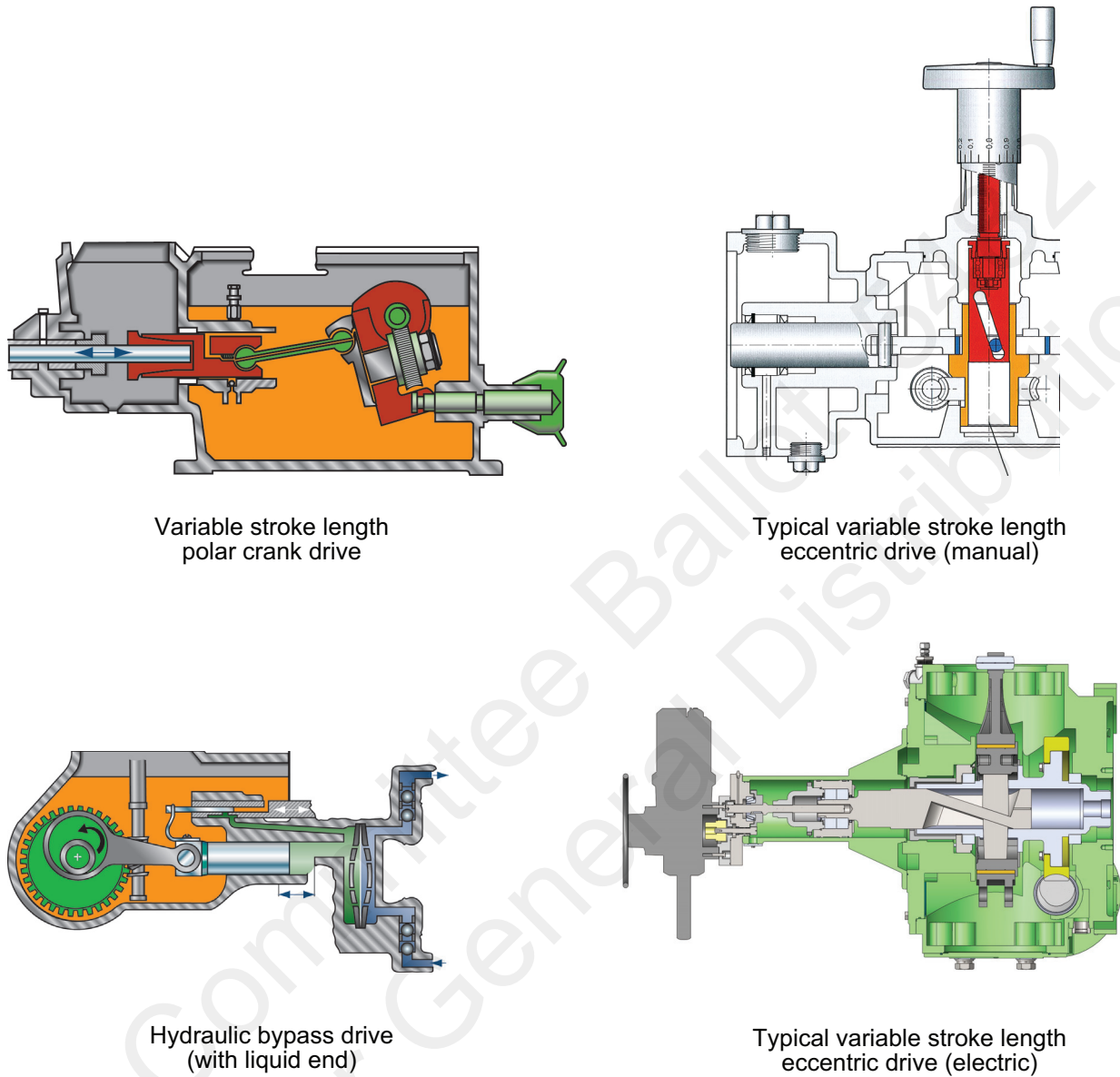


Figure 2—Typical Drive End Pumps

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.

- **6.5.3** If specified, double check valves (both suction and discharge) shall be furnished.

6.6 Diaphragms

6.6.1 Diaphragms provide isolation and transmit hydraulic motion from one fluid to another. Diaphragm materials shall be compatible with the fluids they contact at all specified temperatures. They shall be designed to withstand maximum flexing regardless of stroke-length setting and shall be of sufficient thickness and density to prevent permeation.

6.6.2 Single or double diaphragms (direct or remote mounted) may be used.

6.6.3 Single diaphragms and primary diaphragms on double diaphragm pumps shall have mechanical or hydraulic provisions to prevent excess flexure.

6.6.4 Double diaphragm designs intended to prevent overextension of the secondary diaphragm (e.g. tubular diaphragms) shall provide for a fluid (or other material) filled intermediate chamber to transmit the motion from the primary diaphragm to the secondary diaphragm. The intermediate fluid (or other material) shall be compatible with both the process fluid and the hydraulic fluid.

6.6.5 Unless otherwise specified, double diaphragm designs intended for detecting diaphragm failure shall be provided with a tapped hole for either a conductivity probe in the intermediate fluid or a pressure type detector between diaphragms in a dry design. If the probe/detector is not specified, a threaded plug shall be factory installed in the tapped hole.

6.7 Packed Plungers

6.7.1 Packed-plunger liquid ends shall provide for proper guiding of the plunger through the complete stroke cycle with minimum side loading against the packing. A lantern ring shall be provided in the stuffing box for flushing or adding lubricant to the packing. The pump body shall have a minimum NPS $\frac{1}{4}$ drilled and tapped hole on the top and bottom, in line with the lantern ring to provide inlet and outlet for flushing. When a packing lubricant is used, the bottom hole shall have a threaded plug installed.

6.7.2 Provision shall be made between the drive mechanism and the plunger liquid end to contain stuffing box leakage or to provide special liquid end conditioning.

NOTE The Purchaser and the Vendor should review any potential leakage collection system to ensure that all applicable environmental regulations are met.

6.8 Relief Valve Application

6.8.1 Diaphragm pumps shall have an integral, adjustable hydraulic relief valve to provide full protection of the pump drive mechanism from excessive discharge pressure. The relief valve setting shall be at least 10 % or 175 kPa (25 psi) over the rated discharge pressure, whichever is greater. The relief valve shall be self-seating and shall be easily accessible for adjustment, repair, or replacement.

6.8.2 Packed-plunger pumps require external relief valves for mounting in the Purchaser's piping (section 7.4).

6.9 Gears

6.9.1 All gears used in the pump drive assembly shall be metal. They shall be designed with AGMA criteria as a guide and with a minimum service factor of 1.5 per AGMA 6022 or AGMA 6013 as applicable. The gear lubrication system shall be self-contained.

6.10 Drive Train Enclosure

6.10.1 The drive train enclosure shall use materials of sufficient strength and thickness to provide stable, accurate alignment of drive parts.

6.10.2 The drive train enclosure shall be provided with an oil drain at the low point of the housing and with fill provisions so that oil may be changed without disturbing the pump installation.

6.10.3 The drive train enclosure shall be suitable for mounting on concrete slabs or masonry and shall be weatherproof and dust-tight and shall be suitable for the environmental conditions specified on the data sheets.

6.10.4 All static seals and gaskets on the drive enclosure shall be leakage free in accordance with 6.1.1. Dynamic seals shall be easily replaceable.

6.11 Drive Bearings

6.11.1 Antifriction bearings shall have a minimum L-10 rated life (see ABMA Standard 9 or ABMA Standard 11) of 25,000 hours with continuous operation at maximum rated conditions.

NOTE The rated life is the number of hours at rated bearing load and speed that 90 % of the group of identical bearings will complete or exceed before the first evidence of failure.

6.11.2 Antifriction bearings shall be retained on shafts and fitted into housings in such a way to guarantee that the required L10 life is met or exceeded. A proper locking device should be used to prevent loosening of any bearings. Single or double-row bearings shall not be of the Conrad type (no filling slots).

6.12 Lubrication

6.12.1 The lubrication system shall be of a forced-feed, splash, or submerged type and shall lubricate the reduction gears, bearings, and all other required points except the driver.

6.12.2 The Vendor shall state in the operating manual the amount and specifications for the lubricating and or hydraulic oil required.

6.13 Capacity Adjustment

6.13.1 Pump capacity shall be adjusted by changing the actual or the effective stroke length or the pump stroking speed.

6.13.2 The pump shall be capable of accepting manual or automatic capacity stroke control, either factory mounted or by field conversion.

6.13.3 Integral pump devices used to vary capacity either manually or automatically shall be provided with visual indication of capacity setting, shown as a percentage of the maximum stroke length. Manual control shall include a locking device to positively retain the capacity setting.

6.13.4 The direction of movement to increase or decrease pump flow shall be clearly marked. All adjustment means and indicators shall be easily accessible with the pump installed.

6.14 Materials

6.14.1 Material Inspection of Pressure-containing Parts

6.14.1.1 Regardless of the generalized limits presented in this section, it shall be the Vendor's responsibility to review the design limits of all materials and welds in the event that more stringent requirements are required.

6.14.1.2 Defects that exceed the limits imposed in 6.14.1.3 and 6.14.1.4 shall be removed to meet the quality standards cited, as determined by additional magnetic particle or liquid penetrant inspection as applicable before repair welding.

NOTE See 8.2.2.1.1.

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

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

6.14.1.4 All repairs to pressure containing parts shall be made as required by the following documents.

- a) The repair of plates, prior to fabrication, shall be performed in accordance with the ASTM standard to which the plate was purchased.
- b) The repair of castings or forgings shall be performed prior to final machining in accordance with the ASTM standard to which the casting or forging was purchased.
- c) The inspection of a repair of a fabricated pressure containing part or the defect in either a weld or the base metal of a cast or fabricated pressure containing part, uncovered during preliminary or final machining, shall be performed in accordance with 8.2.2.1.1.

6.14.2 Materials of Construction

6.14.2.1 Unless otherwise specified, the materials of construction of the process containing components shall be steel as a minimum.

6.14.2.2 The materials shall be the Vendor's standard for the operating conditions specified, except as required by the datasheet or this standard.

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

- **6.14.2.4** If specified, copper or copper alloys shall not be used for parts that are in contact with process fluids. Nickel-copper alloys (NW 4400 or UNS N04400), bearing Babbitt, and copper-containing precipitation-hardened stainless steels are excluded from this restriction.

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

6.14.2.5 The Vendor's response to the inquiry shall specify the optional tests and inspection procedures that are necessary to ensure that materials are satisfactory for the service. Such tests and inspections shall be listed in the proposal.

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

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

6.14.2.7 Minor parts that are not identified (such as nuts, springs, washers, gaskets, and keys) shall have corrosion resistance at least equal to that of specified parts in the same environment.

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

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

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

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

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

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

- **6.14.2.11** The Purchaser shall specify the amount of wet H₂S that may be present, considering normal operation, start-up, shutdown, idle standby, upsets, or unusual operating conditions such as catalyst regeneration.

NOTE In many applications, small amounts of wet H₂S are sufficient to require materials resistant to sulfide stress-corrosion cracking. If there are trace quantities of wet H₂S known to be present, or if there is any uncertainty about the amount of wet H₂S that may be present, the Purchaser should consider specifying that reduced hardness materials are required.

- **6.14.2.12** The Purchaser shall specify if reduced hardness materials are required.

6.14.2.13 If reduced hardness materials are specified in 6.14.12, they shall be supplied in accordance with NACE MR 0103 or MR 0175 (ISO 15156).

NOTE 1 NACE MR 0103 applies to oil refineries, LNG plants and chemical plants. NACE MR 0103 applies to materials potentially subject to sulfide stress corrosion cracking.

NOTE 2 NACE MR 0175 applies to oil and gas production facilities and natural gas sweetening plants. NACE MR 0175 applies to materials potentially subject to sulfide stress corrosion cracking. NACE MR 0175 is equivalent to ISO 15156.

6.14.2.14 If reduced hardness materials are specified, ferrous material not covered by NACE MR 0103 or NACE MR 0175 (ISO 15156) shall have a yield strength not exceeding 620 N/mm² (90,000 psi) and a hardness not exceeding HRC 22. Components that are fabricated by welding shall be postweld heat treated, if required, so that both the welds and heat-affected zones meet the yield strength and hardness requirements.

6.14.2.15 If reduced hardness materials are specified, the following components shall have reduced hardness:

- a) the pumphead for packed plunger;
- b) the liquid end housing for hydraulic diaphragm;
- c) valve assemblies;
- d) other transition piping components.

6.14.2.16 The Purchaser will specify on the data sheets the presence of such agents in the media. Exceptions to this requirement may be:

- a) the surface of hardened piston rods or plungers in the packing area; and
- b) the valve components where greater hardness has proven necessary.

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

NOTE If dissimilar materials with significantly different electrical potentials are placed in contact in the presence of an electrolytic solution, galvanic couples may be created that can result in serious corrosion of the less noble material. The NACE Corrosion Engineer's Reference Book is one resource for selection of suitable materials in these situations.

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

6.14.2.19 The manufacturer's data report forms, as specified in codes such as ASME BPVC Section VIII, are not required.

NOTE For impact requirements refer to 6.14.6.4.

- **6.14.2.20** The material specification of all gaskets and O-rings exposed to the pumped fluid shall be identified in the proposal. O-rings shall be selected and their application limited in accordance with API 682. O-ring materials shall be compatible with all specified services. Special consideration shall be given to the selection of O-rings for high-pressure services to ensure that they will not be damaged upon rapid depressurization (explosive decompression). It shall be specified on the datasheet if the service is such that there is a risk of rapid depressurization.

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

6.14.2.21 Bolting material for pressure joints for cast iron casings shall be carbon steel (ASTM A307, Grade B), and for steel casings shall be high-temperature alloy steel (ASTM A193, Grade B7). Nuts shall conform to ASTM A194, Grade 2H (or ASTM A307, Grade B, case hardened, where space is limited). For temperatures below -30°C (-20°F), low-temperature bolting material in accordance with ASTM A320 shall be used.

6.14.3 Castings

6.14.3.1 Castings shall be sound and free from porosity, hot tears, shrink holes, blow holes, cracks, scale, blisters, and similar injurious defects in excess of that specified in the material specification or any additional specified acceptance criteria (see 8.2.2).

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

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

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

a) Weldable grades of steel castings may be repaired by welding in accordance with 6.14.5. Weld repairs shall be inspected according to the same quality standard used to inspect the casting.

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

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

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

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

6.14.3.8 Cast gray iron or nodular iron may be repaired by plugging within the limits specified in ASTM A278, A395, or A536. The holes drilled for plugs shall be carefully examined, using liquid penetrant, to ensure that all defective material has been removed. All repairs that are not covered by ASTM specifications shall be subject to the Purchaser's approval.

6.14.3.9 Gray cast iron (ASTM A278) shall not be used for pressure-containing parts that handle flammable or toxic fluids. With the Purchaser's approval, nodular cast iron (ASTM A395) may be used in such services.

6.14.3.10 Nodular iron castings shall be produced in accordance with ASTM A395. The production of the castings shall also conform to the conditions specified below.

a) A minimum of one set (three samples) of Charpy V-notch impact specimens at one-third the thickness of the test block shall be made from the material adjacent to the tensile specimen on each keel or Y block. These specimens shall have a minimum impact value of 14 joules (10 ft-lbs) at room temperature.

b) The keel or Y block cast at the end of the pour shall be at least as thick as the thickest section of the main casting.

c) Integrally cast test bosses, preferably at least 25 mm (1 in.) in height and diameter, shall be provided at critical areas of the casting for subsequent removal for the purposes of hardness testing and microscopic examination. Critical areas are typically heavy sections, section changes, high-stress points such as drilled lubrication points, valve ports, flanges, and other points agreed upon by the Purchaser and the Vendor. Classification of graphite nodules shall be in accordance with ASTM A247.

d) An as cast sample from each ladle shall be chemically analyzed.

e) Brinell hardness readings shall be made on the actual casting at feasible locations on section changes, flanges, and valve ports. Sufficient surface material shall be removed before hardness readings are made to eliminate any skin effect. Readings shall also be made at the extremities of the casting at locations that represent the sections poured first and last. These shall be made in addition to Brinell readings on the keel or Y blocks.

6.14.4 Forgings

6.14.4.1 Unless otherwise agreed upon by the Purchaser and the Vendor, the forging material shall be selected from those listed in Annex B.

6.14.4.2 Pressure-containing ferrous forgings shall not be repaired except as stated below.

- a) Weldable grade of steel forgings may be repaired by welding in accordance with 6.14.5. After major weld repairs, and before hydrotest, the complete forging shall be given a postweld heat treatment to ensure stress relief and continuity of mechanical properties of both weld and parent metal.
- b) All repairs that are not covered by the material specification shall be subject to the Purchaser's approval.

6.14.5 Welding

- **6.14.5.1** Welding and weld repairs shall be performed in accordance with Table 1. If specified, alternative standards may be proposed by the Vendor for Purchaser's approval and, if so, they shall be referenced in the datasheets (see Annex A).

Table 1—Welding Requirements

Requirement	Applicable Code or Standard
Welder/operator qualification	ASME IX or EN287
Welding procedure qualification	Applicable material specification or, where weld procedures are not covered by the material specification ASME IX or EN 288
Non-pressure-retaining structural welding such as mounting plates or supports	AWS D1.1
Magnetic particle or liquid penetrant examination of the plate edges	ASME VIII, Division 1, UG-93(d)(34)
Post-weld heat treatment	Applicable material specification or ASME VIII, Division 1, UW 40

6.14.5.2 The Vendor shall be responsible for the review of all repairs and repair welds to ensure that they are properly heat treated and nondestructively examined for soundness and compliance with the applicable qualified procedures (see 6.14.5.1). Repair welds shall be nondestructively tested by the same method used to detect the original flaw; however, the minimum level of inspection after the repair shall be by the magnetic particle method in accordance with 8.2.2.1.

6.14.5.3 Pressure-containing parts made of wrought materials or combinations of wrought and cast materials shall conform to the conditions specified below in 6.14.6.5.1 a) through 6.14.6.5.1 d). These requirements do not apply to casing nozzles and auxiliary connections; see 6.14.5.4.

- a) Accessible surfaces of welds shall be inspected by magnetic particle or liquid penetrant examination after back chipping or gouging and again after postweld heat treatment or, for austenitic stainless steels, after solution annealing.
- b) Pressure-containing welds, including welds of the casing to axial-joint and radial-joint flanges, shall be full-penetration welds.

- c) If dimensional stability of such casing component shall be assured for the integrity of pump operation, then post-weld heat treatment shall be performed regardless of thickness.
- d) Plate edges shall be inspected by magnetic particle or liquid penetrant examination as required by internationally recognized standards such as Section VIII, Division 1, UG-93 (d)(3), of the ASME Code.
- **6.14.5.4** Connections welded to casings shall be installed as follows.
 - a) Attachment of suction and discharge nozzles shall be by means of full-fusion, full-penetration welds. Weld neck flanges, or socket weld flanges, if approved by the Purchaser, shall be used for pumps handling flammable or hazardous liquids. Welding of dissimilar metals shall not be performed.
 - b) If specified, proposed connection designs shall be submitted for Purchaser approval before fabrication. The drawings shall show weld designs, size, materials, and pre and postweld heat treatments.
 - c) Post-weld heat treatment, if required, shall be carried out after all welds, including piping welds, have been completed.
 - d) Unless otherwise specified, auxiliary piping welded to alloy steel casings shall be of a material with the same nominal properties as the casing material.

6.14.6 Low Temperature Service

- **6.14.6.1** The Purchaser shall specify the minimum design metal temperature and concurrent pressure that the pump will be subjected to in-service. This temperature shall be used to establish impact test requirements.

NOTE Normally, this will be the lower of the minimum surrounding ambient temperature or minimum fluid pumping temperature; however, the Purchaser may specify a minimum design metal temperature based on properties of the pumped fluid, such as auto-refrigeration at reduced pressures.

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

6.14.6.3 Care shall be taken in the selection of fabrication methods, welding procedures, and materials for Vendor provided steel pressure retaining parts that may be subject to temperatures below the ductile-brittle transition temperature. The published design-allowable stresses for materials in internationally recognized standards such as the ASME Code and ANSI standards are based on minimum tensile properties. Some standards do not differentiate between rimmed, semi-killed, fully killed, hot-rolled, and normalized material, nor do they take into account whether materials were produced under fine- or course-grain practices. Therefore, the Vendor should exercise caution in the selection of materials intended for services between -29°C (-20°F) and 40°C (100°F).

- **6.14.6.4** The Purchaser shall specify whether ASME BPVC Section VIII, Division 1, shall apply with regard to impact-testing requirements.
- **6.14.6.5** If ASME BPVC Section VIII, Division 1, is specified (see 6.14.6.3), the following shall apply.
 - a) All pressure-retaining steels applied at a specified minimum design metal temperature below -29°C (-20°F) shall have a Charpy V-notch impact test of the base metal and the weld joint unless they are exempt in accordance with ASME BPVC Section VIII, Division 1, UHA-51 carbon steel and low alloy steel pressure-retaining parts applied at a specified minimum design metal temperature between -29°C (-20°F) and 40°C (100°F) shall require impact testing as stated below.
 - b) Impact testing is not required for parts with a governing thickness of 25 mm (1 in.) or less.

- c) Impact testing exemptions for parts with a governing thickness greater than 25 mm (1 in.) shall be established in accordance with Paragraph UCS-66 in ASME BPVC Section VIII, Division 1. Minimum design metal temperature without impact testing may be reduced as shown in Figure UCS-66.1. If the material is not exempt, Charpy V-notch impact test results shall meet the minimum impact energy requirements of Paragraph UG-84 of the ASME Code.

6.14.6.6 Governing thickness used to determine impact testing requirements shall be the greater of the following.

- a) The nominal thickness of the largest butt-welded joint.
- b) The largest nominal section for pressure containment, excluding:
- 1) structural support sections such as feet or lugs;
 - 2) sections with increased thickness required for rigidity to mitigate deflection;
 - 3) structural sections required for attachment or inclusion of mechanical features such as jackets or seal chambers.
- c) One fourth of the nominal flange thickness, (in recognition that the predominant flange stress is not a membrane stress).

6.15 Nameplates and Rotation Arrows

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

6.15.2 Rotation arrows shall be cast in or attached to each major item of rotating equipment in a readily visible location. Nameplates and rotation arrows (if attached) shall be of ANSI Standard Type 300 stainless steel or of nickel-copper alloy (Monel or its equivalent). Attachment pins shall be of the same material. Welding is not permitted.

- **6.15.3** The Purchaser's item number, the Vendor's name, the machine's serial number, and the machine's size and type, as well as its minimum and maximum allowable design limits and rating data (including pressures, temperatures, speeds, and power), MAWPs and temperatures, hydrostatic test pressures and critical speeds, shall appear on the machine's nameplate. The Purchaser will specify on the datasheet whether USC or SI units are to be shown.

7 Accessories

7.1 Drivers

7.1.1 General

7.1.1.1 The type of driver shall be specified. The driver shall be designed and sized to meet all the specified operating conditions, including external gear and/or coupling losses, and shall be in accordance with applicable specifications, as stated in the inquiry and order. The driver shall be sized for satisfactory operation under the utility and site conditions specified.

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

7.1.2 Motors

7.1.2.1 For motor requirements that are less than 1 HP, the Vendor and Purchaser shall agree on the motor specification.

7.1.2.2 Motor drives 1 HP or larger shall conform with IEEE 841. For applications that utilize an adjustable speed drive, coordination between the pump, motor, and adjustable speed drive Vendors may be required. The motor rating shall be at least 110 % of the greatest power required (including gear and/or coupling losses) for any of the specified operating conditions. The motor nameplate rating, including service factor, shall be suitable for operation at 100 % of the PLV accumulation pressure. Consideration shall be given to the starting conditions of both the driver and driven equipment and the possibility that these conditions may be different from the normal operating conditions. Equipment driven by induction motors shall be rated at the actual motor speed for the rated load conditions.

NOTE 1 The 110 % applies to the design phase of a project. After testing, this margin might not be available due to performance tolerances of the driven equipment.

NOTE 2 Electric motor drivers in accordance with IEEE 841 have a service factor of 1.0 for constant speed services. Motors in accordance with API 547 have a standard service factor of 1.0; however, many users of these motors prefer to use a 1.15 service factor.

NOTE 3 Where possible, the electrical adjustable speed drive and motor should be purchased from the same Vendor.

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

- a) electrical characteristics;
- b) starting conditions (including the expected voltage drop on starting);
- c) type of enclosure;
- d) electrically insulated bearings, if required;
- e) sound pressure level;
- f) area classification, based on API 500;
- g) class of winding insulation;
- h) required service factor;
- i) ambient temperature and elevation above sea level;
- j) transmission losses, if any;
- k) temperature detectors, vibration sensors, and heaters, if any;
- l) auxiliaries (such as motor-generator sets, ventilation blowers, and instrumentation);
- m) vibration acceptance criteria;
- n) use in adjustable speed drive applications.

7.1.2.4 Unless otherwise specified, the motor's starting torque shall be capable of accelerating the pump to rated speed at a voltage of 80 % of the nominal voltage.

7.1.2.5 The supporting feet of horizontal foot mounted drivers with a weight greater than 250 kg (550 lb) shall be provided with vertical jackscrews.

7.1.2.6 Motors for belt drives shall be of extended-shaft construction and shall be suitable for the side loads imposed by the drive, taking into account the width of the bushing.

7.2 Couplings and Guards

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

7.2.2 Couplings shall comply with the items below.

- **7.2.2.1** If specified, couplings shall be balanced to AGMA 9000 Class 10.
- **7.2.2.2** If specified, couplings shall meet the requirements of API 671.
- **7.2.2.3** If specified, electrically insulated couplings shall be provided.

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

7.2.4 Flexible couplings shall be keyed to the shaft. Keys, keyways, and fits shall conform to AGMA 9002, "Commercial Class." Shaft coupling keyways shall be cut to accommodate a rectangular cross section key. Keys shall be fabricated and fitted to minimize unbalance.

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

7.2.6 Coupling hubs with cylindrical bores may be supplied with slip fits to the shaft and set-screws that bear on the key. Slip fits on cylindrical bores allow adjustment of the coupling axial position in the field without application of heat.

7.2.7 Coupling hubs designed for interference fits to the shaft shall be furnished with tapped puller holes at least 10 mm (0.38 in) in diameter to aid in removal.

- **7.2.8** If specified, coupling hubs shall be fitted hydraulically.

7.2.9 If the driven-equipment Vendor is not required to mount the driver, the coupling Purchaser shall deliver the fully machined half-coupling to the driver manufacturer's plant or any other designated location, together with the necessary instructions for mounting the half-coupling on the driver shaft.

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

7.2.11 Each coupling shall have a guard, which is removable without disturbing the coupled elements and shall meet the requirements below.

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

- b) Guards shall be constructed with sufficient rigidity to withstand a 900 N (200 lbf) static point load in any direction without the guard contacting moving parts.
- c) Guards shall be fabricated from either solid sheet or plate with no openings, or expanded metal or perforated sheets if the size of the openings does not exceed 10 mm (0.38 in.). Guards shall be constructed of steel, brass or nonmetallic (polymer) materials. Guards of woven wire shall not be used. If specified, non-sparking guards of agreed material shall be supplied.

7.3 Baseplates

- **7.3.1** If a baseplate is specified, the Purchaser shall indicate the major equipment to be mounted on it. A baseplate shall be a single fabricated steel unit, unless the Purchaser and the Vendor mutually agree that it may be fabricated in multiple sections. A multiple section baseplate shall have machined and doweled mating surfaces which shall be bolted together to ensure accurate field reassembly.
- **7.3.2** If specified, the baseplate shall be designed for column mounting (that is, of sufficient rigidity to be supported at specified points) without continuous grouting under structural members. The baseplate design shall be mutually agreed upon by the Purchaser and the Vendor.

7.3.3 If a baseplate is provided, it shall extend under the drive-train components so that any leakage from these components is contained within the baseplate.

7.3.4 If a piece of equipment has a mass in excess of 250 kg (550 lb), the baseplate shall be supplied with horizontal (axial and lateral) jackscrews, the same size or larger than the vertical jackscrews. The lugs holding these jackscrews shall be attached to the baseplate in such a manner that they do not interfere with the installation of the equipment, jackscrews, spacers, or shims. Precautions shall be taken to prevent vertical jackscrews in the equipment feet from marring the shimming surfaces. Alternative methods of lifting equipment for the removal or insertion of shims or for moving equipment horizontally, such as provision for the use of hydraulic jacks, may be proposed. Such arrangements should be proposed for equipment that is too heavy to be lifted or moved horizontally using jackscrews. Jackscrews shall be stainless steel or plated for corrosion resistance.

7.3.5 Baseplates shall be designed to limit the relative displacement of the shaft end caused by the worst combination of pressure, torque and allowable piping stress, to 50 μm (0.002 in.). Loads applied during transportation and installation shall not cause permanent deformation (see 6.2.2 for allowable piping loads).

7.3.6 Baseplates shall conform to the following:

- a) baseplates shall not be drilled for equipment to be mounted by others;
- b) baseplates shall be supplied with leveling screws;
- c) outside corners of baseplates which are in contact with the grout shall have 50 mm (2 in.) minimum radius outside corners (in the plan view);
- d) all machinery mounting pads shall be treated with a rust preventive immediately after machining;
- e) mounting pads shall extend at least 25 mm (1 in.) beyond the outer three sides of equipment feet;
- f) mounting pads shall be machined to a finish of 3.2 (125 $\mu\text{in.}$) arithmetic average roughness (Ra) or smoother.
- **7.3.7** Mounting pads shall be provided for the pump and all drive train components, such as motors and gears. The pads shall be larger than the foot of the mounted equipment to allow leveling of the baseplate without removal of the equipment. The pads shall be fully machined flat and parallel. Corresponding surfaces shall be in the same plane within 150 $\mu\text{m/m}$ (0.002 in./ft) of distance between the pads. If specified, this requirement shall be demonstrated in the

pump Vendor's shop prior to mounting of the equipment and with the baseplate supported and clamped at the foundation bolt holes only.

NOTE Installed baseplate flatness may be affected by transportation, handling and installation procedures beyond the Vendor's scope. Installation practices in API 686 should be followed. Because of the weight of the equipment, consideration should also be given to shipping the baseplate without the equipment mounted.

7.3.8 The underside of the fabricated decking located under the pump and drive train supports shall be continuous seal welded to the cross members.

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

7.3.10 The baseplate shall be provided with lifting lugs for at least a four-point lift. Lifting the baseplate or skid complete with all equipment mounted shall not permanently distort or otherwise damage the baseplate or the equipment mounted on it. The Vendor shall advise if a spreader bar is needed, and if equipment shall be uncoupled before lifting.

7.3.11 The lifting lugs and attachment method shall be designed using a maximum allowable stress of 1/3 of the specified minimum yield strength of the material. Any lifting lug welds shall be inspected by either liquid penetrant or magnetic particle testing.

- **7.3.12** If specified, baseplate shall be of the drain-rim or drain-pan type and shall have a raised lip. Connections for a drain shall be tapped DN 50 (NPS 2) minimum in the raised lip at the pump end and shall be located for complete drainage. The pan or upper surface of the baseplate shall be sloped 1:120 minimum toward the drain end.
- **7.3.13** If specified, nonskid metal decking covering all walk and work areas shall be provided on the top of the baseplate.

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

7.3.15 The bottom of the baseplate between structural members shall be open. If the baseplate is designed for grouting, it shall be provided with at least one grout hole having a clear area of at least 0.01 m² (20 in.²) and no dimension less than 75 mm (3 in.) in each bulkhead section. These holes shall be located to permit grouting under all load carrying structural members. If practical, the holes shall be accessible for grouting with the equipment installed. If located in an area where liquids could impinge on the exposed grout, metallic covers with a minimum thickness of 16 gauge shall be provided for the grout holes. Vent holes at least 13 mm (0.5 in.) in size shall be provided at the highest point in each bulkhead section of the baseplate.

- **7.3.16** If specified, 13 mm (0.5 in.) raised-lip edges, 13 mm (0.5 in.), shall be provided around the grout holes.

NOTE This is particularly necessary for installations that will be using cementitious grout.

7.3.17 Unless otherwise specified, shims shall not be used under the pump. All pads for drive train components shall be machined to allow for the installation of stainless steel shims at least 3 mm (0.12 in.) thick under each component. If the Vendor mounts the components, a set of shims at least 3 mm (0.12 in.) thick shall be supplied. Shim packs shall not be thicker than 13 mm (0.5 in.) nor contain more than 5 shims. All shim packs shall straddle the hold-down bolts and vertical jackscrews and extend at least 6 mm (0.25 in.) beyond the outer edges of the equipment feet. If the Vendor does not mount the components, the pads shall not be drilled, and shims shall not be provided.

- **7.3.18** If specified, in addition to shim packs, a stainless steel spacer plate of not less than 6 mm (0.25 in.) thickness, machined on both sides, and of the same length and width as the specific mounting feet, shall be furnished and installed under all equipment feet, including the pump, driver, and any speed increaser or reducer.
- **7.3.19** If specified, the baseplate shall be designed to facilitate the use of optical, laser based or other instruments for accurate leveling in the field. The details of such facilities shall be agreed by the Purchaser and Vendor. Where the requirement is satisfied by the provisions of leveling pads and/or targets, they shall be accessible with the baseplate on the foundation and the equipment mounted. Removable protective covers shall be provided. For column mounted baseplate (see 7.4.2) leveling pads or targets shall be located close to the support points. For a non-column mounted baseplate, a pad or target should be located at each corner. When required for long units, additional pads shall be located at intermediate points.

7.3.20 Equipment and baseplates shall be designed for installation in accordance with API 686.

7.3.21 Hold-down bolts used to attach the equipment to the baseplate, and all jackscrews, shall be provided by the Vendor.

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

7.3.23 The anchor bolts shall not be used to fasten equipment to the baseplate.

7.4 Pressure-limiting Valves (PLVs)

7.4.1 PLVs or other protective devices shall be used with all positive displacement pumps. Rupture disks shall not be used. The sizing, selection and installation of pressure limiting valves should meet the requirements of API 520, Part I and API 520, Part II.

7.4.2 Unless otherwise specified, the Purchaser shall provide PLVs in accordance with API 526. The Vendor shall provide the Purchaser with information on recommended flow rate and relieving pressure. The Vendor and Purchaser should review the Purchaser's valve selection. PLV sizes and settings, including accumulation, shall take into account all possible modes of equipment failure and shall meet the requirements of 6.3.2.

- **7.4.2.1** If specified, the valve shall be provided by the Vendor.

7.5 Controls and Instrumentation

7.5.1 The controls and instrumentation scope of supply shall be supplied and installed as per the Purchaser's specifications and as noted on the datasheet.

7.5.2 All controls and instrumentation shall be per API 614 and suitable for the electrical classification and the hazard conditions as identified on the datasheet.

7.6 Auxiliary Piping

7.6.1 Auxiliary piping, oil piping, instrument piping and process piping shall be in accordance with the appropriate part of API 614, except as modified in 7.7.2.

7.6.2 Auxiliary piping system materials shall be in accordance with Table 10 of API 614. If space does not permit the use of DN 12, DN 20, DN 25 (NPS $\frac{1}{2}$, NPS $\frac{3}{4}$, or NPS 1) pipe, seamless tubing may be supplied. See Table 2.

7.6.3 A thermal relief valve piped to the Purchaser's vent and drain system should be considered for auxiliary piping systems that can be blocked in by a valve closure.

7.6.4 Pipe plugs shall be in accordance with 6.3.5 for permanent plugs or 8.4.3.6 for shipping plugs.

Table 2—Minimum Requirements for Piping Materials

System	Group I (Auxiliary Process Fluid)		Group II (Steam)		Group III (Cooling Water)		Group IV (Lubricating and Control Oil)	
	Nonflammable /Nontoxic	Flammable/ Toxic	<75 pounds per square inch gauge	>75 pounds per square inch gauge	Standard (<1 in.)	Optional	<1 in.	>1½ in.
Pipe (schedule)	Seamless ^a	Seamless ^{a,b}	Seamless ^a	Seamless ^a	Seamless ^a	ASTM A53 Schedule 40	ASTM A312, Type 304 or 316 stainless steel (see 3.6.2.3) ^b	ASTM A312, Type 304 or 316 stainless steel (see 3.6.2.3) ^b
Tubing ^c	Seamless ASTM A269 stainless steel or ASTM A192 steel	Seamless ASTM A269 stainless steel or ASTM A192 steel	Seamless ASTM A269 stainless steel or ASTM A192 steel	Seamless ASTM A269 stainless steel or ASTM A192 steel	Seamless ASTM A269 stainless steel or ASTM A192 steel	Seamless ASTM A269 stainless steel or ASTM A192 steel	Seamless ASTM A269 stainless steel or ASTM A192 steel (see 3.6.2.3)	—
All Valves	Class 800	Class 800	Class 800	Class 800	Class 200, bronze	Class 200, bronze	Carbon steel, Class 800	Carbon steel, Class 800
Gate and globe valves ^d	Bolted bonnet and gland	Bolted bonnet and gland	Bolted bonnet and gland	Bolted bonnet and gland	—	—	Bolted bonnet and gland	Bolted bonnet and gland
Pipe fittings and unions	Forged, Class 3000	Forged, Class 3000	Forged, Class 3000	Forged, Class 3000	ASTM A338 and A197, Class 150 malleable iron, galvanized to ASTM A53	ASTM A338 and A197, Class 150 malleable iron, galvanized to ASTM A53	Stainless Steel (see 3.6.2.2)	Stainless Steel (see 3.6.2.2)
Tube fittings	Manufacturer's standard (with Purchaser's approval)	Manufacturer's standard (with Purchaser's approval)	Manufacturer's standard (with Purchaser's approval)	Manufacturer's standard (with Purchaser's approval)	Manufacturer's standard (with Purchaser's approval)	Manufacturer's standard (with Purchaser's approval)	Manufacturer's standard (with Purchaser's approval)	—
Fabricated joints <1½ in.	Threaded	Socket welded Threaded ^e	Threaded	Socket welded Threaded ^e	Threaded	Threaded	—	Carbon steel slip-on flange
Fabricated joints >2 in.	—	—	—	—	Purchaser to specify	Purchaser to specify	—	Carbon steel slip-on flange
Gaskets	Type 304 or 316 stainless steel, spiral wound	Type 304 or 316 stainless steel, spiral wound	Type 304 or 316 stainless steel, spiral wound	Type 304 or 316 stainless steel, spiral wound	—	—	—	Type 304 or 316 stainless steel, spiral wound
Flange bolting ^f	ASTM A193, Grade B7 ASTM A194, Grade 2H	ASTM A193, Grade B7 ASTM A194, Grade 2H	ASTM A193, Grade B7 ASTM A194, Grade 2H	ASTM A193, Grade B7 ASTM A194, Grade 2H	—	—	ASTM A193, Grade B7 ASTM A194, Grade 2H	—

NOTE Carbon steel piping shall conform to ASTM A53, Grade B; ASTM A106, Grade B; ASTM A524; or API Specification 5L, Grade A or B. Carbon steel fittings, valves, and flanged components shall conform to ASTM A105 and A181. Stainless steel piping shall be seamless in accordance with ASTM 312.

^a Schedule 160 carbon steel for diameters of ¼ in. and smaller; Schedule 80 for diameters from 1 in. to 1½ in.; Schedule 40 for diameters of 2 in. and larger.

^b Schedule 80S stainless steel for diameters 1 in. and smaller; Schedule 40S for diameters of 1½ and 3 in.; Schedule 10S for diameter 3 in. and larger.

^c ½ in. diameter x 0.065-in. wall, ¾-in. diameter x 0.095-in. wall, or 1-in. diameter x 0.109-in. wall.

^d For primary ANSI service pressure ratings above 900 pounds per inch gauge (62 bar gauge), block valves may be of welded-bonnet or no-bonnet construction with a bolted gland. These valves shall be suitable for repacking under pressure.

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

^f Bolting shall be in accordance with 6.2.8.

7.7 Special Tools

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

7.7.2 If special tools are provided, they shall be firmly attached to the pump or packaged in a separate, rugged metal box or boxes and shall be marked "special tools for (tag/item number)." Each tool shall be stamped or tagged to indicate its intended use.

7.8 Pulsation Suppression Devices

- **7.8.1** If specified, the Vendor shall furnish pulsation suppression devices to be located at the pump suction and/or discharge connections. The following are three basic types of pulsation suppression devices:

- a) volume bottles without internals;
- b) pulsation dampeners using a gas-filled chamber isolated from the pumped fluid by a piston or elastomeric diaphragm;
- c) pulsation filters and attenuators, including proprietary commercial designs based on acoustical suppression techniques.

NOTE These in-line devices are designed so that all pumped fluid flows through them.

7.8.2 The Purchaser and the Vendor shall mutually agree on the type and arrangement of pulsation suppression devices to be used for each pumping system. The following factors should be considered:

- a) pump power;
- b) discharge and suction pressure;
- c) number of cylinders per pump;
- d) number of pumps operating in parallel and any potential pulsation interaction;
- e) pump and bottle nozzle loading;
- f) bottle support arrangement;
- g) critical nature of the installation;
- h) residual pulsation level(s).

NOTE Additional information on pulsation suppression devices may be obtained from API Standard 618.

8 Inspection, Testing, and Preparation for Shipment

8.1 General

8.1.1 The Purchaser shall specify the extent of participation in the inspection and testing.

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

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

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

- **8.1.5** If specified, the Vendor shall provide their standard inspection and test plan (ITP) to the Purchaser for review and acceptance.

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

8.1.7 The expected dates of testing shall be communicated at least 30 days in advance and the actual dates confirmed as agreed. Unless otherwise agreed, the Vendor shall give at least 5 working days advanced notification of a witnessed or observed inspection or test.

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

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

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

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

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

8.1.10 The Purchaser's representative shall have access to the Vendor's quality program for review and all major sub-Vendors.

8.2 Inspection Records

8.2.1 General

8.2.1.1 The Vendor shall keep the following data available for at least 20 years:

- a) necessary or specified certification of materials, such as mill test reports;
 - b) test data and results to verify that the requirements of the specification have been met;
 - c) fully identified records of all heat treatment and nondestructive examination (NDE) whether performed in the normal course of manufacture or as part of a repair procedure;
 - d) results of quality control tests and inspections;
 - e) details of all major weld repairs including weld maps;
- f) if specified, final assembly maintenance and running clearances;

- g) other data specified by the Purchaser or required by applicable codes and regulations (see Section 5);
- h) non-conformance reports and corrective actions.

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

8.2.1.3 In addition to the requirements of 8.2.2, the Purchaser may specify the following:

- a) parts that shall be subjected to surface and subsurface examination; and
- b) the type of examination required, such as magnetic particle, liquid penetrant, radiographic, and ultrasonic examination.

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

8.2.2 Materials Inspection

8.2.2.1 General

8.2.2.1.1 NDE shall be performed as required by the material specification. If additional radiographic, ultrasonic, magnetic particle or liquid penetrant examination of the welds or materials is specified by the Purchaser, the methods and acceptance criteria shall be in accordance with the standards shown in Table 3. Alternative standards may be proposed by the Vendor or specified by the Purchaser and they shall be mutually agreed to by both Purchaser and Vendor. The welding and material inspection datasheet in Annex A may be used for this purpose.

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

8.2.2.1.3 The NDE should be done on finished machined surfaces (see Annex A datasheets).

8.2.2.1.4 If NDE testing is specified for nodular iron castings, it will be conducted using the magnetic particle and liquid penetrant test methods.

8.2.3 Mechanical Inspection

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

8.2.3.2 All oil system components supplied shall meet the cleanliness requirements of Part 3 of API 614.

- **8.2.3.3** If specified, the Purchaser may inspect the equipment and all piping and auxiliaries for cleanliness before heads are welded onto vessels, openings in vessels or exchangers are closed, or piping is finally assembled.
- **8.2.3.4** If specified, the hardness of parts, welds, and heat-affected zones shall be verified as being within the allowable values by testing. The method, extent, documentation, and witnessing of the testing shall be mutually agreed upon by the Purchaser and the Vendor.

8.2.4 Positive Material Identification (PMI)

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

Table 3—Material Inspection Standards

Type of inspection	Methods	Acceptance Criteria	
		For fabrications	For castings
		Note 2	MSS SP-55
Visual Inspection (Note 1)	ASME V, Article 9		
Radiography	Section V, Articles 2 and 22 of the ASME Code	Section VIII, Division 1, UW-51 (for 100 % radiography) and UW-52 (for spot radiography) of the ASME Code	Section VIII, Division 1, Appendix 7 of the ASME Code
Ultrasonic inspection	Section V, Articles 5 and 23 of the ASME Code	Section VIII, Division 1, Appendix 12, of the ASME Code	Section VIII, Division 1, Appendix 7, of the ASME Code
Magnetic particle inspection	Section V, Articles 7 and 25 of the ASME Code	Section VIII, Division 1, Appendix 6 of the ASME Code	Section VIII, Division 1, Appendix 7, of the ASME Code
Liquid penetrant inspection	Section V, Articles 6 and 24 of the ASME Code	Section VIII, Division 1, Appendix 8 of the ASME Code	Section VIII, Division 1, Appendix 7, of the ASME Code
NOTE 1 For visual inspection all surfaces shall be inspected.			
NOTE 2 Acceptance criteria for fabricated parts shall be in accordance with the material specification and the manufacturer's documented procedures.			

- **8.2.4.2** If PMI is specified, techniques providing quantitative results shall be used.

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

8.2.4.4 PMI results shall be within material specification governing standard(s) limits with allowance for the accuracy of the PMI device as specified by the device manufacturer.

8.3 Testing

8.3.1 General

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

- **8.3.1.2** If specified, the Vendor shall submit to the Purchaser, for review and comment, detailed procedures and acceptance criteria for all required tests. The time period between submittal of the documents and the running test shall be at least six weeks, unless otherwise agreed.

8.3.1.3 Notification requirements are covered in 8.1.7, however, hydrostatic and running test requirements shall be not less than five working days before the date the equipment will be ready for testing. If the testing is rescheduled, the Vendor shall notify the Purchaser not less than five working days before the new test date.

8.3.2 Hydrostatic Testing

8.3.2.1 All pressure casing components shall be assembled as a single unit and tested hydrostatically with liquid at a minimum of 1.5 times the MAWP, but not less than a gauge pressure of 150 kPa (1.5 bar) (20 psi).

8.3.2.1.1 The test liquid shall be at a higher temperature than the ductile-brittle transition temperature of the material being tested.

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

8.3.2.2 If the component handling the pumped liquid is to operate at a temperature at which the strength of a material is below the strength of that material at the testing temperature, the hydrostatic test pressure shall be multiplied by a factor obtained by dividing the allowable working stress for the material at the testing temperature by that at the rated operating temperature. The stress values used shall be determined in accordance with those of 6.2.1. For piping, the stress shall conform to ASME B31.3 or ISO 15649 as specified by the user. The pressure thus obtained shall then be the minimum pressure at which the hydrostatic test shall be performed. The Vendor shall list actual hydrostatic test pressures on datasheets.

NOTE The applicability of this requirement to the material being tested should be verified before hydrotest, as the properties of many grades of steel do not change appreciably at temperatures up to 200 °C (390 °F).

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

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

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

8.3.2.5 Tests shall be maintained for a sufficient period of time to permit complete examination of parts under pressure. The hydrostatic test shall be considered satisfactory when neither leaks nor seepage through the pressure containing part or joints is observed for a minimum of 30 minutes. Large, heavy pressure-containing parts may require a longer testing period to be agreed upon by the Purchaser and the Vendor. Gaskets used during the hydrostatic testing shall be of the same design as supplied with the pump. Seepage past internal closures required for testing of segmented cases and operation of a test pump to maintain pressure is acceptable (see 8.3.2.1).

8.3.3 Pre-testing Check

8.3.3.1 Oil system components downstream of the filters shall meet the cleanliness requirements of Chapter 3 of API 614 before any test is started.

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

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

8.3.4 Performance Test

8.3.4.1 Unless otherwise specified, tests shall be conducted in accordance with Section 3.6 of the Hydraulic Institute pump standards, according to the tolerances specified in 8.3.6. The manufacturer shall operate the pump in their shop for sufficient period to obtain complete test data, including speed, discharge pressure, suction pressure, power, and capacity.

- **8.3.4.2** When flow repeatability and linearity tests are specified, they shall be run by using 100 %, 75 %, 50 %, 25 %, and 10 % of rated capacity points in descending and ascending order. The flow variations shall not exceed ± 3 % of the value at rated capacity. Adjustable stroke length and adjustable speed tests shall be conducted independently.

NOTE The performance tests would typically be conducted at maximum specified pressure

- **8.3.4.2.1** If an adjustable stroke length performance test is specified, it shall be achieved by varying the stroke adjustment to achieve the rated capacity percentages.

NOTE The stroke percentage adjustment typically does not match the percentage of capacity.

- **8.3.4.2.2** If specified, an adjustable speed performance test shall be done as follows.

- a) The stroke length for this test shall be fixed at the maximum.
- b) The output percentages and accuracy should match the those in 8.3.4.2.
- c) The drive used for the test shall be agreed between Vendor and Purchaser.

8.3.4.3 The tests specified in 8.3.4.1 apply to the pump only, and the values of power are to be taken as referring to the pump. However, the recorded data and final report may include information on the complete unit, including driver and auxiliary equipment. The Purchaser and the Vendor shall agree to the test measurements to be recorded on both the driver and the auxiliary equipment.

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

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

8.3.5 Mechanical Run Test

- **8.3.5.1** If specified, a mechanical run test shall be performed either before or consecutively following the performance test. The mechanical run test shall be one hour or until oil temperatures have stabilized.
- **8.3.5.2** If specified, the pump shall be mechanically run for four hours. Unless otherwise specified or agreed, this shall be performed at the rated flow.

8.3.5.3 Unless otherwise agreed, job seals, packing, and bearings shall be used in the machine for the mechanical running test.

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

8.3.6 Test Tolerances

Unless otherwise agreed or specified, when operated on the test stand, pumps shall be within the tolerances as given in Table 4.

8.3.7 Optional Tests

- If specified, the shop tests described in 8.3.7.1, 8.7.3.2, 8.7.3.3, and 8.3.7.4 shall be performed. Test details shall be mutually agreed upon by the Purchaser and the Vendor.

8.3.7.1 NPIP Test

- If specified, the pump shall be tested for NPIP. At rated speed and with NPIPA equal to quoted NPIPR, the pump capacity shall be within 5 % of the non-cavitating capacity.

Warning—The pump shall not be run while cavitating.

Table 4—Test Tolerances

Characteristic	Capacity	Tolerance (Percent of rated capacity)
	@ 100 % capacity	±3
	@ 75 % capacity	±3
	@ 50 % capacity	±3
	@ 25 % capacity	±3
	@ 10 % capacity	±3
Rated power	(at rated capacity and maximum pressure)	+4
NPIPR	(at rated capacity)	+0

NOTE The Vendor will probably not replicate field suction piping configuration effects for test purposes which could impact acceleration pressure.

8.3.7.2 Complete Unit Test

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

8.3.7.3 Sound Level Test

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

8.3.7.4 High Discharge Pressure Test

- If specified, the pump will be operated at the PLV set pressure at the maximum rated pump speed and a fluid viscosity agreed to by the Vendor and the Purchaser to confirm that the pump continues to operate properly at these conditions typically 15 minutes. A single data point will be collected.

8.3.8 Factory Acceptance Test

- If specified, controls and instrumentation shall undergo a functional acceptance test, which includes verification of functionality of instrumentation, control, PLC control logic, alarm, and shutdown set points.

8.3.9 Test Data

Immediately upon completion of each witnessed mechanical and performance test, copies of the data logged shall be given to the witness.

8.4 Preparation for Shipment

- **8.4.1** Equipment shall be suitably prepared for the type of shipment specified. Unless otherwise specified, the preparation shall make the equipment suitable for 6 months of outdoor storage from the time of shipment, with no disassembly required before installation, except for inspection of packing, bearings, and seals. If storage for a longer period is contemplated, the Purchaser will consult with the Vendor regarding the recommended procedures to be followed. Removal of the inhibitor and periodic rotation of the pump shaft (per the Vendor's recommended procedure) to ease seal and bearing movement, shall be the responsibility of the Purchaser.

8.4.2 The Vendor shall provide the Purchaser with the instructions necessary to preserve the integrity of the storage preparation after the equipment arrives at the job site and before start-up, as described in Chapter 3 of API 686.

8.4.3 The equipment shall be prepared for shipment after all testing and inspection has been completed and the equipment has been released by the Purchaser. The preparation shall include that specified in 8.4.3.1 through 8.4.3.10.

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

NOTE Austenitic stainless steels are typically not painted.

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

8.4.3.3 The interior of the equipment shall be clean; free from scale, welding spatter, and foreign objects; and, except for corrosion-resistant material, sprayed or flushed with rust preventive that can be removed with solvent. The rust preventive shall be applied to any other exposed moving parts.

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

8.4.3.5 Flanged openings shall be provided with metal closures at least 5 mm (0.19 in.) thick with elastomeric gaskets and at least four full-diameter bolts. For studed openings, all nuts needed for the intended service shall be used to secure closures.

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

NOTE These are shipping plugs; permanent plugs are covered in 6.3.5.

8.4.3.7 Lifting points, lifting lugs, and baseplate center of gravity shall be clearly identified on the equipment, equipment drawing, or equipment package. The recommended lifting arrangement shall be as described in the installation manual and/or included with the equipment shipping documents.

8.4.3.8 The equipment shall be identified with item and serial numbers. Material shipped separately shall be identified with securely affixed, corrosion-resistant metal tags indicating the item and serial number of the equipment for which it is intended. Crated equipment shall be shipped with duplicate packing lists, one inside, and one on the outside of the shipping container.

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

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

8.4.4 Auxiliary piping connections supplied on the purchased equipment shall be impression-stamped or permanently tagged to agree with the Vendor's connection table or general arrangement drawing. Service and connection designations shall be indicated.

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

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

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

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

9 Vendor's Data

9.1 General

9.1.1 The information to be furnished by the Vendor is specified in 9.2 and 9.3.

9.1.2 The Vendor's data shall be present on transmittal (cover) letters, title pages and in title blocks or other prominent position on drawings, and shall include the following information:

- a) the Purchaser's/Owner's corporate name;
 - b) the job/project number;
 - c) the Purchaser's/Owner's equipment item number and service name;
 - d) the inquiry or Purchaser's order number;
 - e) any other identification specified in the inquiry or Purchaser order;
 - f) the Vendor's identifying proposal number, shop order number, serial number, or other reference required to completely identify return correspondence.
- **9.1.3** If specified, a coordination meeting shall be held, preferably at the Vendor's plant, within four to six weeks after order commitment. Unless otherwise specified, the Vendor shall prepare and distribute an agenda prior to this meeting, which as a minimum shall include a review of the following items:
 - a) the purchase order, scope of supply, unit responsibility, and sub-Vendor items;
 - b) the datasheets;
 - c) applicable specifications and previously agreed-upon exceptions;
 - d) schedules for transmittal of data, production, and testing;
 - e) the quality assurance program and procedures;
 - f) inspection, expediting, and testing;
 - g) schematics and bills of material for auxiliary systems;
 - h) the physical orientation of the equipment, piping, and auxiliary systems;
 - i) equipment performance, alternative operating conditions, start-up, shutdown, and any operating limitations;
 - j) scope and details of any pulsation or vibration analysis;

- k) instrumentation and controls;
- l) identification of items for design reviews;
- m) other technical items.

9.2 Proposals

9.2.1 General

9.2.1.1 The Vendor shall forward the original proposal and the specified number of copies to the addressees specified in the inquiry documents. As a minimum, the proposal shall include the data specified in 9.2.2, 9.2.3, 9.2.4, and 9.2.5, as well as a specific statement that the system and all its components are in strict accordance with this international standard. If the system and components are not in strict accordance, the Vendor shall include a list that details and explains each deviation. The Vendor shall provide details to enable the Purchaser to evaluate any proposed alternative designs. All correspondence shall be clearly identified in accordance with 9.1.2.

9.2.2 Drawings

9.2.2.1 The drawings indicated on the Vendor Drawing and Data Requirements (VDDR) Form (see example in Annex D) shall be included in the proposal. As a minimum, the following data shall be furnished.

- a) A general arrangement or outline drawing for each major skid or system, showing direction of rotation, size and location of major Purchaser connections; overall dimensions; maintenance clearance dimensions; overall weights; erection weights; maximum maintenance weights (indicated for each piece), lifting points and methods of lifting the assembled machine.
- b) Cross-sectional drawings showing the details of the proposed equipment.
- c) Schematics of all auxiliary systems, including the seal flush, lubricating oil, control, and electrical systems. Bills of material shall be included.

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

• 9.2.3 Technical Data

The following data shall be included in the proposal.

- a) The Purchaser's datasheets, with complete Vendor's information entered thereon and literature to fully describe details of the offering.
- b) The predicted noise data.
- c) The VDDR Form (see example in Annex D), indicating the schedule according to which the Vendor agrees to transmit all the data specified as part of the purchase order.
- d) A schedule for shipment of the equipment, in weeks after receipt of the order.
- e) A list of major wearing components, showing interchangeability with other items on the project or the Owner's existing machines.
- f) A list of spare parts recommended for start-up and normal maintenance purposes.

- g) A list of the special tools furnished for maintenance.
- h) A description of any special weather protection and winterization required for start-up, operation, and periods of idleness, under the site conditions specified on the datasheets. This description shall clearly indicate the protection to be furnished by the Purchaser as well as that included in the Vendor's scope of supply.
- i) A complete tabulation of utility requirements, e.g. steam, water, electricity, air, gas, lubricating oil (including the quantity and supply pressure of the oil required, and the heat load to be removed by the oil), and the nameplate power rating and operating power requirements of auxiliary drivers. Approximate data shall be clearly indicated as such.
- j) A description of any optional or additional tests and inspection procedures for materials as required by 8.2.2.
- k) A description of any special requirements whether specified in the Purchaser's inquiry or as outlined in bulleted paragraphs of this specification.
- l) If specified, a list of similar machines installed and operating under similar conditions.
- m) Any start-up, shutdown, or operating restrictions required to protect the integrity of the equipment.
- n) Any test facility limitations.
- o) A list of any components that can be construed as being of alternative design, hence requiring Purchaser's acceptance.

9.2.4 Curves

The Vendor shall provide complete performance curves, including discharge pressure, NPSHR/Net Positive Inlet Pressure Required (NPIPR may be a single number stated for maximum flow), and power at relief valve set pressure at the specified viscosity. Preferred and allowable operating regions, and any limitations of operation shall be indicated.

• 9.2.5 Options

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

9.3 Contract Data

9.3.1 General

9.3.1.1 Contract data shall be furnished by the Vendor in accordance with the agreed VDDR form (see example in Annex D).

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

9.3.1.3 The Purchaser and Vendor shall agree to the timing and extent of drawing and data review. Review by the Purchaser does not constitute permission to deviate from any requirements in the order unless specifically agreed upon in writing.

9.3.1.4 A complete list of Vendor data shall be included with the first issue of the major drawings. This list shall contain titles, drawing numbers, and a schedule for transmission of all the data the Vendor will furnish (see example in Annex D).

9.3.2 Drawings and Technical Data

9.3.2.1 The drawings and data furnished by the Vendor shall contain sufficient information so that, together with the manuals specified in 9.3.5, the Purchaser can properly install, operate and maintain the equipment covered by the purchase order. Regardless of use of this standard's datasheets in the procurement process, a completed API 675 data sheet shall be included in the as-built data to document the pump. All contract drawings and data shall be clearly legible (8-point minimum font size even if reduced from a larger size drawing), shall cover the scope of the agreed VDDR form (see example in Annex D) and shall satisfy the applicable detailed descriptions. Dimensional outline drawings shall indicate the tolerance for pump suction and discharge nozzle face and centerline locations referenced from the centerline of the nearest baseplate anchor-bolt hole. The centerline of baseplate anchor-bolt locations shall indicate the tolerance from a common reference point on the baseplate.

- **9.3.2.2** Certified test curves and data shall be submitted within 15 days after testing and shall provide complete performance curves, including NPIPR (may be a single number stated at maximum flow), and power at relief valve set pressure. If specified by the Purchaser and agreed to by the Vendor, curves shall be adjusted based on viscosity. The curve sheet shall include piston/plunger size, maximum strokes per minute, order number, etc. and the pump serial number. If an NPIP test is specified, NPIPR data will also be provided.

9.3.3 Progress Reports

The Vendor shall submit progress reports to the Purchaser at the intervals specified on the VDDR Form (see example in Annex D).

9.3.4 Parts Lists and Recommended Spares

9.3.4.1 The Vendor shall submit complete parts lists for all equipment and accessories supplied. The lists shall include manufacturer's unique part numbers, materials of construction, and delivery times. Each part shall be completely identified and shown on cross-sectional or assembly-type drawings so that the Purchaser may determine the interchangeability of these parts with other equipment. Parts that have been modified from standard dimensions and/or finish to satisfy specific performance requirements shall be uniquely identified by part number for interchangeability and future duplication purposes. Standard purchased items, including gaskets and O-rings, shall be identified by the original manufacturer's name, part number, material and pressure rating, if applicable.

9.3.4.2 The Vendor shall indicate on each of these complete parts lists all those parts that are recommended as start-up or maintenance spares, and the recommended stocking quantities of each. These should include spare parts recommendations of sub-Vendors that were not available for inclusion in the Vendor's original proposal. The Vendor shall forward the lists to the Purchaser promptly after receipt of the reviewed drawings and in time to permit order and delivery of the parts before field start-up. The transmittal letter shall include the data specified in 9.1.2.

9.3.5 Data Manuals

9.3.5.1 General

The Vendor shall provide sufficient written instructions and all necessary drawings to enable the Purchaser to install, operate, and maintain all of the equipment covered by the purchase order. This information shall be compiled in a manual or manuals with a cover sheet showing the information listed in 9.1.2, an index sheet, and a complete list of the enclosed drawings by title and drawing number. The manual or manuals shall be prepared specifically for the equipment covered by the purchase order. Pre-printed sections that are model specific may be included, but "typical" manuals are unacceptable. Vendor manuals shall also be furnished in an agreed upon electronic format that reflect the "as-supplied" equipment, with any safeguards considered necessary for legal protection of all parties.

9.3.5.2 Installation Manual

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

9.3.5.3 Manual for Operating, Maintenance and Technical Data

A manual containing operating, maintenance and technical data shall be sent at the time of shipment. In addition to covering operation at all specified process conditions, this manual shall include a section that provides special instructions for operation at specified extreme environmental conditions. The manual shall also include sketches that show the location of the center of gravity and rigging provisions to permit the removal of the top half of the casings, rotors and any subassemblies having a mass greater than 135 kg (300 lb). As a minimum, the manual shall also include all of the data listed in Annex D that are not uniquely related to installation.

- **9.3.5.4 Technical Data Manual**

If specified, the Vendor shall provide a technical data manual to the Purchaser within 30 days of completion of shop testing. See Annex D for detail requirements.

Annex A **(informative)**

Data Sheets

CONTROLLED VOLUME PUMP (API 675-3RD) DATA SHEET U.S. CUSTOMARY					JOB NO. _____ ITEM NO. _____ PURCHASE ORDER NO. _____ SPECIFICATION NO. _____ REVISION NO. _____ DATE _____ PAGE 1 OF 2 BY _____																								
1 APPLICABLE TO: <input type="radio"/> PROPOSAL <input type="radio"/> PURCHASE <input type="radio"/> AS BUILT 2 FOR _____ UNIT _____ 3 SITE _____ NO. OF PUMPS REQUIRED _____ 4 SERVICE _____ MODEL _____ SIZE AND TYPE _____ 5 MANUFACTURER _____ SERIAL NO. _____																													
6 NOTE: <input type="radio"/> INDICATES INFORMATION TO BE COMPLETED BY PURCHASER <input type="checkbox"/> BY MANUFACTURER																													
7 GENERAL																													
8 NO. MOTORS DRIVEN _____ OTHER DRIVER TYPE _____ 9 PUMP ITEM NO'S _____ PUMP ITEM NO'S _____ 10 MOTOR ITEM NO'S _____ DRIVER ITEM NO'S _____ GEAR ITEM NO'S _____ 11 MOTOR PROVIDED BY _____ DRIVER PROVIDED BY _____ GEAR PROVIDED BY _____ 12 MOTOR MOUNTED BY _____ DRIVER MOUNTED BY _____ GEAR MOUNTED BY _____ 13 MOTOR DATA SHEET NO. _____ DRIVER DATA SHEET NO. _____ GEAR DATA SHEET NO. _____																													
14 <input type="radio"/> OPERATING CONDITIONS					14 <input type="radio"/> LIQUID																								
15 <input type="radio"/> CAPACITY @ PT: (gph) 16 MAXIMUM _____ MINIMUM _____ RATED _____ 17 <input type="radio"/> DISCHARGE PRESSURE: (psig) 18 MAXIMUM _____ MINIMUM _____ 19 <input type="radio"/> SUCTION PRESSURE: (psig) 20 MAXIMUM _____ MINIMUM _____ 21 <input type="radio"/> DIFFERENTIAL PRESSURE: (psi) 22 MAXIMUM _____ MINIMUM _____ 23 <input type="radio"/> NPIP AVAILABLE: (psig) 24 (INCLUDING ACCELERATION LOSSES) 25 <input type="radio"/> TURNDOWN RATIO _____					15 <input type="radio"/> TYPE OR NAME OF LIQUID _____ 16 <input type="radio"/> PUMPING TEMPERATURE: (°F) 17 NORMAL _____ MAX _____ MIN _____ 18 <input type="radio"/> SPECIFIC GRAVITY _____ MAXIMUM _____ MINIMUM _____ 19 <input type="radio"/> SPECIFIC HEAT _____ Cp (BTU/lb °F) 20 <input type="radio"/> VISCOSITY (cP) _____ MINIMUM _____ MAXIMUM _____ 21 <input type="radio"/> CORROSIVE/EROSIVE AGENTS _____ 22 <input type="radio"/> CHLORIDE CONCENTRATION (PPM) _____ 23 <input type="radio"/> H ₂ S CONCENTRATION (PPM) _____ 24 LIQUID <input type="radio"/> TOXIC <input type="radio"/> FLAMMABLE <input type="radio"/> OTHER _____																								
26 <input type="checkbox"/> PERFORMANCE					26 <input type="radio"/> SITE AND UTILITY DATA																								
27 <input type="checkbox"/> NUMBER OF FEEDS _____ RATED CAPACITY (gph) _____ 28 <input type="checkbox"/> NPIP REQUIRED (INCLUDING ACCEL LOSSES) (psig) _____ 29 <input type="checkbox"/> BHP RATED _____ AT RELIEF SETTING _____ 30 <input type="checkbox"/> PLUNGER SPEED (strokes/min) _____ DESIGN MAX _____ 31 <input type="checkbox"/> DIAMETER (in) _____ LENGTH OF STROKE (in) _____ 32 PUMP HEAD: _____ 33 MAXIMUM PRESSURE (psig) _____ 34 <input type="checkbox"/> HYDRO TEST PRESSURE (psig) _____ 35 <input type="checkbox"/> MAX DISCH PRESS. W/ JOB DRIVER (psig) _____ 36 <input type="checkbox"/> MAX BHP BASIS GEAR STRENGTH _____					LOCATION <input type="radio"/> INDOOR <input type="radio"/> OUTDOOR <input type="radio"/> HEATED <input type="radio"/> UNHEATED <input type="radio"/> UNDER ROOF <input type="radio"/> ELECTRICAL AREA CLASS _____ GROUP _____ DIV _____ <input type="radio"/> WINTERIZATION REQD <input type="radio"/> TROPICALIZATION REQD SITE DATA <input type="radio"/> RANGE OF AMBIENT TEMPS: MIN/MAX _____ / _____ °F UNUSUAL CONDITIONS <input type="radio"/> DUST <input type="radio"/> FUMES <input type="radio"/> SALT ATMOSPHERE <input type="radio"/> OTHER _____ <input type="radio"/> UTILITY CONDITIONS _____																								
37 <input type="checkbox"/> CONSTRUCTION					37 ELECTRICITY DRIVERS HEATING CONTROL SHUTDOWN																								
<table border="1" style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 20%;">CONNECTIONS</th> <th style="width: 10%;">SIZE</th> <th style="width: 10%;">ANSI RATING</th> <th style="width: 10%;">FACING</th> <th style="width: 10%;">POSITION</th> </tr> </thead> <tbody> <tr> <td>39 SUCTION</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>40 DISCHARGE</td> <td></td> <td></td> <td></td> <td></td> </tr> <tr> <td>41 FLUSH</td> <td></td> <td></td> <td></td> <td></td> </tr> </tbody> </table>					CONNECTIONS	SIZE	ANSI RATING	FACING	POSITION	39 SUCTION					40 DISCHARGE					41 FLUSH					VOLTAGE _____ HERTZ _____ PHASE _____ COOLING WATER INLET RETURN DESIGN MAX Δ TEMP °F _____ MAX _____ PRESS. (PSIG) _____ MIN _____ SOURCE _____ INSTRUMENT AIR _____ MAX _____ MIN _____ PRESSURE (PSIG) _____				
CONNECTIONS	SIZE	ANSI RATING	FACING	POSITION																									
39 SUCTION																													
40 DISCHARGE																													
41 FLUSH																													
44 LIQUID END <input type="radio"/> JACKET REQ'D 45 TYPE <input type="radio"/> DIAPHRAGM <input type="radio"/> PLUNGER 46 <input type="checkbox"/> DIAPHRAGM DIA (IN) _____ NO REQ. _____ 47 <input type="checkbox"/> VALVES/FEED _____ SUCTION _____ DISCHARGE _____ 48 TYPE _____ 49 NUMBER _____					47 APPLICABLE SPECIFICATIONS: <input type="radio"/> API 675 POSITIVE DISPLACEMENT PUMPS - CONTROLLED VOLUME <input type="radio"/> GOVERNING SPECIFICATION (IF DIFFERENT) <input type="radio"/> NACE MR-0103 (6.14.2.13) <input type="radio"/> NACE MR-0175 (6.14.2.13) <input type="radio"/> OTHER																								
52 REMARKS _____																													
53 _____																													

CONTROLLED VOLUME PUMP (API 675-3RD) DATA SHEET U.S. CUSTOMARY				JOB NO. _____	ITEM NO. _____
				REVISION NO. _____	DATE _____
				PAGE 2 OF 2	BY _____
1		<input type="checkbox"/> MATERIALS		CONTROLS	
2		LIQUID END		TYPE:	
3		CONTOUR PLATE		<input type="radio"/> MANUAL <input type="radio"/> REMOTE <input type="radio"/> PNEUMATIC <input type="radio"/> AUTOMATIC <input type="radio"/> LOCAL <input type="radio"/> ELECTRONIC	
4		HYDRAULIC DIAPHRAGM		STROKE CONTROL:	
5		PROCESS DIAPHRAGM		PNEUMATIC: (psig)	
6		PLUNGER		MINIMUM _____ MAXIMUM _____	
7		LANTERN RING		ELECTRONIC (mA):	
8		PACKING GLAND		MINIMUM _____ MAXIMUM _____	
9		PACKING			
10		VALVE		OTHER PURCHASE REQUIREMENTS	
11		VALVE SEAT		NAMEPLATE UNITS <input type="radio"/> U.S. CUSTOMARY <input type="radio"/> SI	
12		VALVE GUIDE		<input type="radio"/> VENDOR FURNISHED PROCESS PIPING	
13		VALVE BODY		<input type="radio"/> VENDOR REVIEW PIPING DRAWINGS	
14		VALVE GASKET		<input type="radio"/> VENDOR FURNISHED PULSATION SUPPRESSION DEVICES	
15		FRAME		<input type="radio"/> VENDOR FURNISHED RELIEF VALVE	
16		SPECIAL MATERIAL TESTS (6.14.2.5)		<input type="radio"/> INTERNAL <input type="radio"/> EXTERNAL	
17				<input checked="" type="checkbox"/> RELIEF VALVE SETTING (psig)	
18		<input type="radio"/> LOW AMBIENT TEMPERATURE MATERIALS TESTS (6.14.6)		<input type="radio"/> VENDOR FURNISHED BACK-PRESSURE VALVE	
19					
20		QA INSPECTION AND TEST		<input type="radio"/> DOUBLE CHECK VALVES REQUIRED	
21		<input type="radio"/> COMPLIANCE WITH INSPECTORS CHECK LIST		<input type="radio"/> OIL-FILLED PRESSURE GAUGES REQUIRED	
22		<input type="radio"/> CERTIFICATION OF MATERIALS (user to define components in remarks)		<input type="radio"/> VENDOR FURNISHED CONTROL PANEL	
23		<input type="radio"/> FINAL ASSEMBLY CLEARANCES (user to define components in remarks)		<input type="radio"/> BASEPLATE PREPARED FOR EPOXY GROUT	
24		<input type="radio"/> SURFACE AND SUBSURFACE EXAMINATIONS		<input type="radio"/> PROVIDE TECHNICAL DATA MANUAL	
25		<input type="radio"/> RADIOGRAPHY		<input type="radio"/>	
26		<input type="radio"/> ULTRASONIC		<input type="radio"/>	
27		<input type="radio"/> MAGNETIC PARTICLE		PREPARATION FOR SHIPMENT	
28		<input type="radio"/> LIQUID PENETRANT		<input type="radio"/> DOMESTIC <input type="radio"/> EXPORT <input type="radio"/> EXPORT BOXING	
29		<input type="radio"/> CLEANLINESS PRIOR TO FINAL ASSEMBLY		<input type="radio"/> OUTDOOR STORAGE MORE THAN 6 MONTHS	
30		<input type="radio"/> HARDNESS OF PARTS, WELDS & HEAT AFFECTED ZONES		WEIGHTS (LBS)	
31		<input type="radio"/> FURNISH PROCEDURES FOR OPTIONAL TESTS		<input type="checkbox"/> PUMP <input type="checkbox"/> BASE <input type="checkbox"/> GEAR <input type="checkbox"/> DRIVER	
32		TESTS REQ'D WIT OBS		DRIVERS	
33		HYDROSTATIC (8.3.2) <input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>		<input type="radio"/> MOTOR:	
34		STEADY STATE ACCURACY <input checked="" type="radio"/> <input type="radio"/> <input type="radio"/>		<input type="checkbox"/> MANUFACTURER	
35		REPEATABILITY <input type="radio"/> <input type="radio"/> <input type="radio"/>		<input type="checkbox"/> TYPE	
36		LINEARITY <input type="radio"/> <input type="radio"/> <input type="radio"/>		<input type="checkbox"/> FRAME NO.	
37		PERFORMANCE (8.3.4) <input type="radio"/> <input type="radio"/> <input type="radio"/>		<input type="radio"/> CONSTANT SPEED	
38		MECHANICAL RUN (8.3.5) <input type="radio"/> <input type="radio"/> <input type="radio"/>			
39		NPIP(8.3.7.1) <input type="radio"/> <input type="radio"/> <input type="radio"/>			
40		COMPLETE UNIT (8.3.7.2) <input type="radio"/> <input type="radio"/> <input type="radio"/>			
41		SOUND LEVEL (8.3.7.3) <input type="radio"/> <input type="radio"/> <input type="radio"/>			
42		HIGH DISCHARGE PRES (8.3.7.4) <input type="radio"/> <input type="radio"/> <input type="radio"/>			
43		FACTORY ACCEPTANCE (8.3.8) <input type="radio"/> <input type="radio"/> <input type="radio"/>		<input type="checkbox"/> VARIABLE SPEED	
44		LUBRICATION FLUID		<input type="checkbox"/> HP RPM	
45		<input type="checkbox"/> CRANKCASE <input type="checkbox"/> INTERMEDIATE		<input type="radio"/> VOLTS PHASE	
46		<input type="checkbox"/> HYDRAULIC FLUID		<input type="radio"/> HERTZ SERVICE FACTOR	
47		ACCESSORIES		<input type="radio"/> ENCLOSURE	
48		<input type="checkbox"/> SPEED REDUCER MANUFACTURER		<input type="radio"/> OTHER (SEE SEPARATE DATA SHEETS)	
49		<input type="radio"/> INTEGRAL <input type="radio"/> SEPARATE		<input type="radio"/> GAS DRIVEN	
50		MODEL		<input type="radio"/> STEAM TURBINE	
51		RATIO		<input type="radio"/> OTHER	
52		<input type="checkbox"/> BASEPLATE UNDER			
53		<input type="checkbox"/> COUPLING MANUFACTURER			
54		<input type="checkbox"/> TYPE			
55		REMARKS			
56					

CONTROLLED VOLUME PUMP (API 675-3RD) DATA SHEET SI UNITS (kPa)		JOB NO. _____ ITEM NO. _____ PURCHASE ORDER NO. _____ SPECIFICATION NO. _____ REVISION NO. _____ DATE _____ PAGE <u>1</u> OF <u>2</u> BY _____																					
1 APPLICABLE TO: <input type="radio"/> PROPOSAL <input type="radio"/> PURCHASE <input type="radio"/> AS BUILT 2 FOR _____ 3 SITE _____ 4 SERVICE _____ MODEL _____ 5 MANUFACTURER _____		UNIT _____ NO. OF PUMPS REQUIRED _____ SIZE AND TYPE _____ SERIAL NO. _____																					
6 NOTE: <input type="radio"/> INDICATES INFORMATION TO BE COMPLETED BY PURCHASER <input type="checkbox"/> BY MANUFACTURER																							
GENERAL																							
8 NO. MOTORS DRIVEN _____ OTHER DRIVER TYPE _____ 9 PUMP ITEM NO'S _____ PUMP ITEM NO'S _____ 10 MOTOR ITEM NO'S _____ DRIVER ITEM NO'S _____ GEAR ITEM NO'S _____ 11 MOTOR PROVIDED BY _____ DRIVER PROVIDED BY _____ GEAR PROVIDED BY _____ 12 MOTOR MOUNTED BY _____ DRIVER MOUNTED BY _____ GEAR MOUNTED BY _____ 13 MOTOR DATA SHEET NO. _____ DRIVER DATA SHEET NO. _____ GEAR DATA SHEET NO. _____																							
<input type="radio"/> OPERATING CONDITIONS		<input type="radio"/> LIQUID																					
15 <input type="radio"/> CAPACITY @ PT: (L/min) MAXIMUM _____ MINIMUM _____ RATED _____ 17 <input type="radio"/> DISCHARGE PRESSURE: (kPaG) MAXIMUM _____ MINIMUM _____ 19 <input type="radio"/> SUCTION PRESSURE: (kPaG) MAXIMUM _____ MINIMUM _____ 21 <input type="radio"/> DIFFERENTIAL PRESSURE: (kPa) MAXIMUM _____ MINIMUM _____ 23 <input type="radio"/> NPIP AVAILABLE: (kPaG) (INCLUDING ACCELERATION LOSSES) 25 <input type="radio"/> TURNDOWN RATIO _____		15 <input type="radio"/> TYPE OR NAME OF LIQUID _____ 16 <input type="radio"/> PUMPING TEMPERATURE: (°C) NORMAL _____ MAX _____ MIN _____ 18 <input type="radio"/> SPECIFIC GRAVITY _____ MAXIMUM _____ MINIMUM _____ 19 <input type="radio"/> SPECIFIC HEAT _____ Cp (kJ/kg °C) 20 <input type="radio"/> VISCOSITY (mPa-s) _____ MINIMUM _____ MAXIMUM _____ 21 <input type="radio"/> CORROSIVE/EROSIVE AGENTS _____ 22 <input type="radio"/> CHLORIDE CONCENTRATION (PPM) _____ 23 <input type="radio"/> H ₂ S CONCENTRATION (PPM) _____ 24 LIQUID <input type="radio"/> TOXIC <input type="radio"/> FLAMMABLE <input type="radio"/> OTHER _____																					
<input type="checkbox"/> PERFORMANCE		<input type="radio"/> SITE AND UTILITY DATA																					
27 <input type="checkbox"/> NUMBER OF FEEDS _____ RATED CAPACITY (L/min) _____ 28 <input type="checkbox"/> NPIP REQUIRED (INCLUDING ACCEL LOSSES) (kPaG) _____ 29 <input type="checkbox"/> BHP RATED _____ AT RELIEF SETTING _____ 30 <input type="checkbox"/> PLUNGER SPEED (strokes/min) _____ DESIGN MAX _____ 31 <input type="checkbox"/> DIAMETER (mm) _____ LENGTH OF STROKE (mm) _____ 32 PUMP HEAD: _____ 33 MAXIMUM PRESSURE (kPaG) _____ 34 <input type="checkbox"/> HYDRO TEST PRESSURE (kPaG) _____ 35 <input type="checkbox"/> MAX DISCH PRESS. W/ JOB DRIVER (kPaG) _____ 36 <input type="checkbox"/> MAX BHP BASIS GEAR STRENGTH _____		LOCATION <input type="radio"/> INDOOR <input type="radio"/> OUTDOOR 28 <input type="radio"/> HEATED <input type="radio"/> UNHEATED <input type="radio"/> UNDER ROOF 29 <input type="radio"/> ELECTRICAL AREA CLASS _____ GROUP _____ DIV _____ 30 <input type="radio"/> WINTERIZATION REQD <input type="radio"/> TROPICALIZATION REQD SITE DATA 31 <input type="radio"/> RANGE OF AMBIENT TEMPS: MIN/MAX _____ / _____ °F UNUSUAL CONDITIONS 32 <input type="radio"/> DUST <input type="radio"/> FUMES <input type="radio"/> SALT ATMOSPHERE 33 <input type="radio"/> OTHER _____ 34 <input type="radio"/> UTILITY CONDITIONS _____																					
<input type="checkbox"/> CONSTRUCTION		ELECTRICITY DRIVERS HEATING CONTROL SHUTDOWN																					
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CONNECTIONS	SIZE	ANSI RATING	FACING	POSITION																			
39 SUCTION																							
40 DISCHARGE																							
41 FLUSH																							
44 LIQUID END <input type="radio"/> JACKET REQ'D TYPE <input type="radio"/> DIAPHRAGM <input type="radio"/> PLUNGER 46 <input type="checkbox"/> DIAPHRAGM DIA (IN) _____ NO REQ. _____ 47 <input type="checkbox"/> VALVES/FEED _____ SUCTION _____ DISCHARGE _____ TYPE _____ NUMBER _____		APPLICABLE SPECIFICATIONS:																					
		<input type="radio"/> API 675 POSITIVE DISPLACEMENT PUMPS - CONTROLLED VOLUME <input type="radio"/> GOVERNING SPECIFICATION (IF DIFFERENT) <input type="radio"/> NACE MR-0103 (6.14.2.13) <input type="radio"/> NACE MR-0175 (6.14.2.13) <input type="radio"/> OTHER																					
52 REMARKS _____ 53 _____																							

CONTROLLED VOLUME PUMP (API 675-3RD) DATA SHEET SI UNITS (kPa)				JOB NO. _____ ITEM NO. _____ REVISION NO. _____ DATE _____ PAGE 2 OF 2 BY _____	
<div style="display: flex; justify-content: space-between;"> <div> 1 <input type="checkbox"/> MATERIALS 2 LIQUID END 3 CONTOUR PLATE 4 HYDRAULIC DIAPHRAGM 5 PROCESS DIAPHRAGM 6 PLUNGER 7 LANTERN RING 8 PACKING GLAND 9 PACKING 10 VALVE 11 VALVE SEAT 12 VALVE GUIDE 13 VALVE BODY 14 VALVE GASKET 15 FRAME 16 SPECIAL MATERIAL TESTS (6.14.2.5) 17 18 <input type="radio"/> LOW AMBIENT TEMPERATURE MATERIALS TESTS (6.14.6) 19 </div> <div> CONTROLS TYPE: <input type="radio"/> MANUAL <input type="radio"/> REMOTE <input type="radio"/> PNEUMATIC <input type="radio"/> AUTOMATIC <input type="radio"/> LOCAL <input type="radio"/> ELECTRONIC STROKE CONTROL: PNEUMATIC: (kPaG) MINIMUM _____ MAXIMUM _____ ELECTRONIC (mA): MINIMUM _____ MAXIMUM _____ </div> </div>				OTHER PURCHASE REQUIREMENTS NAMEPLATE UNITS <input type="radio"/> U.S. CUSTOMARY <input type="radio"/> SI <input type="radio"/> VENDOR FURNISHED PROCESS PIPING <input type="radio"/> VENDOR REVIEW PIPING DRAWINGS <input type="radio"/> VENDOR FURNISHED PULSATION SUPPRESSION DEVICES <input type="radio"/> VENDOR FURNISHED RELIEF VALVE <input type="radio"/> INTERNAL <input type="radio"/> EXTERNAL <input checked="" type="checkbox"/> RELIEF VALVE SETTING (kPaG) <input type="radio"/> VENDOR FURNISHED BACK-PRESSURE VALVE <input type="radio"/> DOUBLE CHECK VALVES REQUIRED <input type="radio"/> OIL-FILLED PRESSURE GAUGES REQUIRED <input type="radio"/> VENDOR FURNISHED CONTROL PANEL <input type="radio"/> BASEPLATE PREPARED FOR EPOXY GROUT <input type="radio"/> PROVIDE TECHNICAL DATA MANUAL <input type="radio"/>	
QA INSPECTION AND TEST 20 21 <input type="radio"/> COMPLIANCE WITH INSPECTORS CHECK LIST 22 <input type="radio"/> CERTIFICATION OF MATERIALS (user to define components in remarks) 23 <input type="radio"/> FINAL ASSEMBLY CLEARANCES (user to define components in remarks) 24 <input type="radio"/> SURFACE AND SUBSURFACE EXAMINATIONS 25 <input type="radio"/> RADIOGRAPHY 26 <input type="radio"/> ULTRASONIC 27 <input type="radio"/> MAGNETIC PARTICLE 28 <input type="radio"/> LIQUID PENETRANT 29 <input type="radio"/> CLEANLINESS PRIOR TO FINAL ASSEMBLY 30 <input type="radio"/> HARDNESS OF PARTS, WELDS & HEAT AFFECTED ZONES 31 <input type="radio"/> FURNISH PROCEDURES FOR OPTIONAL TESTS				PREPARATION FOR SHIPMENT <input type="radio"/> DOMESTIC <input type="radio"/> EXPORT <input type="radio"/> EXPORT BOXING <input type="radio"/> OUTDOOR STORAGE MORE THAN 6 MONTHS WEIGHTS (LBS) <input type="checkbox"/> PUMP <input type="checkbox"/> BASE <input type="checkbox"/> GEAR <input type="checkbox"/> DRIVER	
32 TESTS REQ'D WIT OBS 33 HYDROSTATIC (8.3.2) <input checked="" type="radio"/> <input type="radio"/> <input type="radio"/> 34 STEADY STATE ACCURACY <input checked="" type="radio"/> <input type="radio"/> <input type="radio"/> 35 REPEATABILITY <input type="radio"/> <input type="radio"/> <input type="radio"/> 36 LINEARITY <input type="radio"/> <input type="radio"/> <input type="radio"/> 37 PERFORMANCE (8.3.4) <input type="radio"/> <input type="radio"/> <input type="radio"/> 38 MECHANICAL RUN (8.3.5) <input type="radio"/> <input type="radio"/> <input type="radio"/> 39 NPIP(8.3.7.1) <input type="radio"/> <input type="radio"/> <input type="radio"/> 40 COMPLETE UNIT (8.3.7.2) <input type="radio"/> <input type="radio"/> <input type="radio"/> 41 SOUND LEVEL (8.3.7.3) <input type="radio"/> <input type="radio"/> <input type="radio"/> 42 HIGH DISCHARGE PRES (8.3.7.4) <input type="radio"/> <input type="radio"/> <input type="radio"/> 43 FACTORY ACCEPTANCE (8.3.8) <input type="radio"/> <input type="radio"/> <input type="radio"/>				DRIVERS <input type="radio"/> MOTOR: <input type="checkbox"/> MANUFACTURER <input type="checkbox"/> TYPE <input type="checkbox"/> FRAME NO. <input type="radio"/> CONSTANT SPEED <input type="checkbox"/> VARIABLE SPEED	
LUBRICATION FLUID 44 45 <input type="checkbox"/> CRANKCASE <input type="checkbox"/> INTERMEDIATE 46 <input type="checkbox"/> HYDRAULIC FLUID				<input type="checkbox"/> HP RPM <input type="radio"/> VOLTS PHASE <input type="radio"/> HERTZ SERVICE FACTOR <input type="radio"/> ENCLOSURE <input type="radio"/> OTHER (SEE SEPARATE DATA SHEETS) <input type="radio"/> GAS DRIVEN <input type="radio"/> STEAM TURBINE <input type="radio"/> OTHER	
ACCESSORIES 47 48 <input type="checkbox"/> SPEED REDUCER MANUFACTURER 49 <input type="radio"/> INTEGRAL <input type="radio"/> SEPARATE 50 MODEL 51 RATIO 52 <input type="checkbox"/> BASEPLATE UNDER 53 <input type="checkbox"/> COUPLING MANUFACTURER 54 <input type="checkbox"/> TYPE					
55 REMARKS 56					

Annex B (informative)

Materials

Table B.1—Miscellaneous Material Specifications

Babbitt	ASTM B23, Grades 1 through 9, as required by Vendor for service conditions
Bronze	UNS C87200 (silicon bronze), C90700 or C92200 (tin bronze), C95200 (aluminum bronze) or C95800 (nickel aluminum bronze)
Hard-facing	Type 3 tungsten carbide, etc.; overlay-weld deposit of 0.8 mm (0.030 in.) minimum finished thickness or, if available, a solid cast part of equal material may be substituted.
	Type 1 tungsten carbide as required for service conditions, with cobalt binder (solid part, not overlay),
	Type 2 tungsten carbide as required for service conditions, with nickel binder (solid part, not overlay);
	Type 3 tungsten carbide-sprayed overlay as required for service conditions.
Low-carbon nickel-molybdenum-chromium Alloy	ASTM B564, UNS N10276 (forgings) ASTM B574, UNS N10276 (bar and rod) ASTM B575, UNS N10276 (plate, sheet, and strip) ASTM A494, Grade CW-2M (weldable cast)
Nickel copper alloy	ASTM B564, UNS N04400 (forgings) ASTM B164, Class A, UNS N04400 (bar and rod) ASTM B127, UNS N04400 (plate, sheet, and strip) ASTM A494, Grade M30C (weldable cast)
Ni resist	ASTM A436, Type 1, 2, or 3, UNS F41000, F41002, and F41004 respectively (austenitic cast iron), ASTM A439, Type D2, UNS F43000 (austenitic ductile iron)
Precipitation-hardening nickel alloy	ASTM B637, UNS N07718 (forgings and bars) ASTM B670, UNS N07718 (plate, sheet, and strip)
Precipitation-hardening stainless steel	ASTM A564, Grade 630, UNS S 17400 or Grade 631, UNS 17700 (wrought) ASTM A747, Grade CB7Cu-1, UNS J92180 (cast)
Sheet gasket	Long-fiber material with synthetic rubber binder suitable for service conditions, or spiral wound stainless steel and equal gasket material
Perfluoroelastomer FFKM	ASTM D1418 FFKM
Fluoroelastomer FKM	ASTM D1418 FKM
Nitrile, Buna N	ASTM D1418 NBR

Annex C (informative)

Inspector's Checklist

	Item	Date Inspected	Inspected By	Status
1	Capacity adjustment (6.1.14) (6.13.4)			
2	Material certification (6.14.1.2) (8.2.1.1a-c)			
3	Nondestructive examination (components) (8.2.2)			
4	Welding operators and procedures qualified (6.14.5, Table 1)			
5	Rotation arrow [6.15.2(*)]			
6	Equipment nameplate data (6.14.3)			
7	Equipment baseplate dimensions (7.3)			
8	Overall dimensions and connection locations (*)			
9	Nozzle and/or flange dimensions (*)			
10	Anchor bolt layout and size (*)			
11	Mounting plate pre-coat for epoxy grout (7.3.13)			
13	Piping inspection (7.6)			
14	Pulsation suppression (7.8)			
15	Special tools (7.7)			
16	Maintenance and clearance data [8.2.1.1. f)]			
17	Components inspected for cleanliness (list each) (8.2.3.3)			
18	Hardness testing (8.2.3.4)			
19	Hydrostatic tests (8.3.2)			
20	Performance tests (8.3.3)			
21	Preparation for shipment (8.4)			
22	Painting (8.4.3.1)			
23	Shipping documents and tags (8.4.3.8)			
24	Match marked removed piping (8.4.7)			
(*) Check against certified dimensional outline drawing.				

Annex D (normative)

Controlled Volume Pump Vendor Drawing and Data Requirements

[illegible]

ANNEX D - CONTROLLED VOLUME PUMI JOB NO.

**ANNEX D – CONTROLLED
VENDOR DRAWING &
DATA REQUIREMENTS
API 675 3rd Edition**

PURCHASE ORDER NO. _____
 REQUISITION NO. _____
 INQUIRY NO. _____

ITEM NO.

DATE _____
DATE _____
DATE _____

FOR _____ PAGE _____ OF _____ BY _____
 SITE _____ REVISION _____
 SERVICE _____ UNIT _____
 NO. REQUIRED _____

Proposal a

Bidder shall email pdf files of all items indicated by an X.

Review b

Vendor shall email pdf files of drawings and data indicated.

Final c

Vendor shall email pdf files of drawings and data indicated.

Vendor shall furnish _____ copies of operating and maintenance manuals / data books and _____ CD's of pdf files of same.

DISTRIBUTION RECORD

Final – Received from vendor

Final - Due from vendor c	
---------------------------	--

Review – Returned from vendor

Review – Received from vendor

Review – Due from vendor c

Note: Mark through those items that will not be furnished & add items that will.

	D2.5	Performance data								
	D2.6	Performance test data								
	D2.7	Certified drawings of auxiliary systems								
	D2.8	Installation operation and maintenance manuals								
	D2.8	Spare parts recommendations								

a Proposal drawings and data do not have to be certified or as-built. Typical data shall be clearly identified as such.

b Purchaser will indicate in this column the time frame for submission of materials using the nomenclature given at the end of this form

c Vendor shall complete these two columns to reflect his actual distribution schedule and include this form with his proposal

Email all drawings and data to

Ship final IOM's and Data books to:

All drawings and data shall show project, appropriation, purchase order, and item numbers in addition to the plant location and unit. In addition to the copies specified above, one set of the drawings/instructions necessary for field installation shall be forwarded with the shipment.

Nomenclature:

S — number of weeks prior to shipment.

F — number of weeks after firm order.

D — number of weeks after receipt of approved drawings.

Vendor:

Date: _____

Vendor Reference:

Note: Vendor and purchaser to mark out items that do not apply to this order and sign below.

Vendor Signature:

VDDR Notes

D.1—Pump

Ref. Description

- 1 Certified dimensional outline drawing and list of connections, including the following:
 - a. Size, rating, and location of all customer connections.
 - b. Approximate overall handling weights.
 - c. Overall dimensions.
 - d. Shaft centerline height.
 - e. Dimensions of baseplates (if furnished), complete with diameter, number, and locations of bolt holes and thickness of the metal through which the bolts must pass; centers of gravity; and details for foundation design.
 - f. Grouting details.
 - g. Allowable forces and moments for suction and discharge nozzles.
 - h. Center of gravity and lifting points.
 - i. Shaft end separation and alignment data.
 - j. Direction of rotation.
- 2 Anticipated thermal movements referenced to a defined point.
- 3 Cross-sectional drawing and bill of materials, including the following:
 - a. Journal-bearing shaft and housing fits and tolerances.
 - b. Rolling element bearing shaft and housing fits and tolerances.
 - c. Shaft end details, fits and tolerances.
- 4 Shaft-coupling assembly drawings and bills of materials, including the following:
 - a. Hydraulic mounting procedure (if applicable).
 - b. Shaft end gap and tolerance.
 - c. Coupling guards.
- 5 Coupling alignment diagram, including recommended coupling limits during operation. Note all shaft-end position changes and support growth from a reference ambient temperature of 15 °C (59 °F) or another temperature specified by the purchaser. Include the recommended alignment method and cold setting targets.
- 6 Auxiliary flush flow sealing schematic and bill of materials, including flow rate, fluid flows, pressure, pipe and valve sizes, instrumentation, and orifice sizes.
- 7 Cooling or heating schematic and bill of materials, including cooling or heating media, fluid flows, pressure, pipe and valve sizes, instrumentation, and orifice sizes.
- 8 Lube-oil schematic and bills of materials, including the following:
 - a. Steady-state and transient oil flows and pressures at each use point.
 - b. Control, alarm, and trip settings (pressures and recommended temperatures).
 - c. Total heat loads
 - d. Utility requirements, including electricity, water, and air.
 - e. Pipe, valve and orifice sizes.
 - f. Instrumentation, safety devices, control schemes and wiring diagrams.
 - g. Lubricating oil system arrangement drawing, including size, rating, and location of all purchaser connections
 - h. Lubricating oil component drawings and data, including the following:

- i. Pumps and drivers;
 - ii. Coolers, filters and reservoir;
 - iii. Instrumentation;
 - iv. Spare parts lists and recommendations.
- 9 Electrical and instrumentation schematics and bills of materials for all systems. The schematics shall show all alarm and shutdown limits (set points).
 - a. Vibration alarm and shutdown limits;
 - b. Bearing temperature alarm and shutdown limits;
 - c. Lubricating oil temperature alarm and shutdown limits;
 - d. Driver.
- 10 Electrical and instrumentation assembly drawings and lists of connections.
- 11 Tabulation of utility requirements (may be on as-built purchaser data sheets).
- 12 Performance curves shall include discharge pressure, NPIPR and power at the specified viscosity. Preferred and allowable operating regions and any limitations of operation shall also be indicated.
- 13 Vibration analysis data.
- 14 Certified hydrostatic test data/logs.
- 15 Certified mill test reports of items as agreed upon in the pre-commitment or pre-inspection meetings.
- 16 Welding procedures for fabrication and repair.
- 17 Nondestructive test procedures as itemized on the purchase order data sheets or the Vendor Drawing and Data Requirements form.
- 18 Procedures for any special or optional tests.
- 19 Performance test logs and report.
- 20 As-built data sheets.
- 21 Material Safety Data Sheets (OSHA Form 20).
- 22 Noise data sheets.
- 23 As-built dimensions (including nominal dimensions with design tolerances), metallurgy and heat treatment data for all parts as mutually agreed by Vendor and Purchaser.
- 24 Installation manual describing the following:
 - a. Storage procedures including winterization, tropicalization and/or noise attenuation details, if required.
 - b. Foundation plan.
 - c. Grouting details.
 - d. Setting equipment, rigging procedures, component weights, and lifting diagrams.
 - e. Coupling alignment diagram.
 - f. Piping recommendations, including allowable flange loads.
 - g. Composite outline drawings for the driver/driven-equipment train, including anchor bolt locations.
 - h. Dismantling clearances.

- 25 Operating and maintenance manuals describing the following:
 - a. Start-up.
 - b. Normal shutdown.
 - c. Emergency shutdown.
 - d. Lube-oil recommendations.
 - e. Routine operational procedures, including recommended inspection schedules and procedures.
 - f. Instructions for:
 - i. Disassembly and reassembly of all bearings;
 - ii. Disassembly and reassembly of pump wetted end;
 - iii. Disassembly and reassembly of gears;
 - g. Performance curves, including:
 - i. Discharge pressure at the specified viscosity;
 - ii. NPIPR at the specified viscosity;
 - iii. Power at the specified viscosity;
 - iv. Preferred and allowable operating regions;
 - v. Any limitation of operation.
 - h. As-built data, including:
 - i. As-built data sheets;
 - ii. As-built dimensions or data, including assembly clearances;
 - iii. Hydrostatic test logs;
 - iv. Mechanical running test logs.
 - i. Drawings and data, including:
 - i. Certified dimensional outline drawing and list of connections;
 - ii. Cross-sectional drawing and bill of materials;
 - iii. Lube-oil schematics and bills of materials;
 - iv. Electrical and instrumentation schematics and bills of materials;
 - v. Electrical and instrumentation assembly drawings and list of connections.
- 26 Spare parts list with stocking level recommendations.
- 27 Progress reports and delivery schedules, including vendor buy-outs and milestones. progress reports detailing the cause of any delays: the reports shall include engineering, purchasing, manufacturing and testing schedules for all major components. Planned and actual dates, and the percentage completed, shall be indicated for each milestone in the schedule.
- 28 List of drawings, including latest revision numbers and dates.
- 29 Shipping list, including all major components that will ship separately.
- 30 List of special tools furnished for maintenance.
- 31 Technical data manual, including the following:
 - a. As-built purchaser data sheets;
 - b. Certified performance curves;
 - c. Drawings;
 - d. As-built assembly clearances;
 - e. Spare parts list;
 - f. Utility data;
 - g. Reports.

D.2—Driver and external gear if applicable

Ref. Description

- 1 Certified dimensional outline drawing for motor and all auxiliary equipment, including the following:
 - a. Size, location, and purpose of all purchaser connections, including conduit, instrumentation, and any piping or ducting;
 - b. ASME rating and facing for any flanged connections;
 - c. Size and location of anchor bolt holes and thicknesses of sections through which bolts must pass;
 - d. Total mass of each item of equipment (motor and auxiliary equipment) plus loading diagrams, heaviest mass, and name of the part;
 - e. Overall dimensions and all horizontal and vertical clearances necessary for dismantling, and the approximate location of lifting lugs;
 - f. Shaft centerline height;
 - g. Shaft end dimensions, plus tolerances for the coupling;
 - h. Direction of rotation.
- 2 Cross-sectional drawing and bill of materials.
- 3 Data sheets applicable to proposals, purchase, and as-built;
- 4 Noise data sheets;
- 5 For induction motors 150 kW (200 hp) and smaller:
 - a. Efficiency and power factor at one-half, three-quarter, and full load;
 - b. Speed-torque curves.
- 6 For induction motors larger than 150 kW (200 hp) and larger, certified test reports for all tests, including:
 - a. Time-current heating curve;
 - b. Speed-torque curves at 70 %, 80 %, 90 %, and 100 % of rated voltage;
 - c. Efficiency and power factor curves from 0 to rated service factor;
 - d. Current versus load curves from 0 to rated service factor;
 - e. Current versus speed curves from 0 % to 100 % of rated speed.
 - f. For gears, test data shall include:
 - i) Oil temperatures and inlet pressures;
 - ii) Outlet oil (drain) temperatures;
 - iii) Vibration amplitudes, unfiltered and filtered at 1 time operating speed;
 - iv) Bearing temperatures.
- 7 Certified drawings of auxiliary systems, including wiring diagrams, for each auxiliary system supplied. The drawings shall clearly indicate the extent of the system to be supplied by the manufacturer and the extent to be supplied by others.
- 8 Driver instruction manuals describing installation, operating and maintenance procedures. Each manual shall include the following sections:
 - a. Section 1 - Installation:
 - i. Storage;
 - ii. Setting motor, rigging procedures, component masses and lifting diagram;
 - iii. Piping and conduit recommendations;
 - iv. Composite outline drawing for motor, including locations of anchor-bolt holes;
 - v. Dismantling clearances.
 - b. Section 2 - Operation:

- i. Start-up, including check before start-up;
 - ii. Normal shutdown;
 - iii. Operating limits, including number of successive starts;
 - iv. Lubricating oil recommendations.
- c. Section 3 - Disassembly and assembly instructions:
 - i. Drive components;
 - ii. Bearings;
 - iii. Routine maintenance procedures and intervals.
- d. Section 4 - Performance data required
- e. Section 5 - Data sheets:
 - i. As-built data sheets;
 - ii. Noise data sheets.
- f. Section 6 - Drawing and data requirements:
 - i. Certified dimensional outline drawing for motor and all auxiliary equipment, with list of connections
 - ii. Cross-sectional drawing and bill of materials.
 - iii. Spare parts recommendations and price list;
 - iv. Material safety data sheets.

Annex E (informative)

Net Positive Suction Head Versus Net Positive Inlet Pressure

Because centrifugal pumps and positive displacement pumps operate on entirely different principles, common usage has created two different ways to identify the pressures associated with them. In its simplest form, a centrifugal pump is a velocity machine. The liquid to be pumped is directed into the center of a rotating impeller where it is entrained in the impeller vanes and accelerated to a higher velocity. The casing surrounding the impeller then converts the high velocity to pressure. Because it is a velocity machine, if pressure is measured in units of liquid length, all units of measure become consistent. Velocity is measured in meters/second (feet/second), and pressure is measured in meters (feet), i.e., the pressure created by the height of a column of the liquid being pumped. This consistent use of units greatly simplifies pump calculations and allows the effects of certain liquid properties (specific gravity, for example) to be ignored.

By contrast, a positive displacement pump does not generate pressure solely by increasing fluid velocity. Instead these pumps convert reciprocating motion and torque into fluid motion and force, generating variable flow at the discharge connection. This occurs as the pump cycles separately through each suction and discharge stroke. Positive displacement pumps have no theoretical discharge pressure limitation. They respond solely to the pumping system and require system discharge pressure control, usually in the form of a relief valve, to prevent damage to the pump mechanism and/or stalling of the driver. A centrifugal pump, however, responds quite differently in that the discharge pressure developed is a function of flow through the pump impeller. With decreasing flow (as in the case of increased system resistance), the centrifugal pump develops an ever-increasing pressure rise up to the point defined as shutoff head at zero flow. Shutoff head is the maximum pressure rise that a centrifugal pump can develop. For a reciprocating positive displacement pump, flow is a function of pump stroke length and/or rpm.

Either type of pump requires sufficient fluid pressure at the inlet to prevent release of dissolved gasses and/or change of state of the pumped fluid from liquid to gas. The term for pressure at the inlet is either Net Positive Suction Head (NPSH) or Net Positive Inlet Pressure (NPIP). To be consistent, the API Standards for both centrifugal and reciprocating pumps, as well as the latest editions of the Hydraulic Institute Standards, refer to the total suction head as NPSH rather than NPIP. Although the Hydraulic Institute indicates that NPSH is normally expressed in either kPa (psi) or m (ft), the latest API Standards refer to NPSH in m (ft), the preferred terminology for both pump types, to avoid confusion. Positive displacement pump manufacturers generally refer to NPIP, expressed in kPa absolute (psi or bar, absolute).

NPSH or NPIP is indicated as either Available or Required. The Net Positive Inlet Pressure Available (NPIPA) is the absolute pressure above fluid vapor pressure at the pump inlet and is determined as follows:

$$\text{NPIPA} = P_a + P_z - P_f - P_{vp} - P_{amax} \quad (\text{E.1})$$

where

- P_a is the absolute pressure at surface of liquid in kPa absolute (psi or bar, absolute);
- P_z is the static Head (+) or Static Lift (–) in kPa (psi) for level of fluid above or below inlet;
- P_f is the inlet line, valve & fitting friction losses at maximum viscosity in kPa (psi or bar);
- P_{vp} is the fluid vapor pressure or gas dissolution pressure in kPa absolute (psi or bar, absolute);
- P_{amax} is the pressure loss due to acceleration (see P_{amax} below) in kPa (psi or bar).

NIIPA calculation for a reciprocating controlled volume pump shall include the effects of system acceleration head (see 3.3, acceleration pressure). From the Hydraulics Institute Standards, Fourteenth Edition, liquid in the suction and discharge lines of controlled volume pumps has to be accelerated because flow varies with time. This produces alternate pressure drops and surges. The instantaneous pressure drop required to accelerate the mass of fluid in the suction line, or the instantaneous pressure rise required to accelerate the mass of fluid in the discharge, is referred to as acceleration pressure. When computing this value for a reciprocating controlled volume pump, the equation below defines the maximum instantaneous value of h_{amax} :

$$h_{amax} = \frac{LVnC}{Kg} \quad \text{or} \quad P_{amax} = \frac{LVnC(Sp \ Gr)}{Kg} \quad (E.2)$$

where

- h_{amax} is the maximum instantaneous acceleration head in meters (feet);
- P_{amax} is the maximum instantaneous acceleration pressure in kPa (psi or bar);
- L is the length of pipe in meters (feet);
- C is 0.628 for simplex single-acting;
- K is 1.4;
- V is the average velocity in meter/sec (feet/sec);
- n is the pump speed in rpm;
- g is the gravitational constant, 9.82 m/s² (32.2 ft/sec²).

NOTE It is the responsibility of the Purchaser to define acceleration pressure, yet the value is dependent on the characteristics of the pump selected. Consequently, the value should be reviewed by both the Purchaser and the Vendor before a final selection is made.

NIIP Required (NIIPR) is a function of pump type, speed, and viscosity of fluid pumped. NIIP Available must always be greater than NIIPR to prevent occurrence of cavitation. Typically, NIIPR values published by positive displacement pump manufacturers are expressed in kPa (psi or bar) units. The preferred means of communicating suction pressure requirements is: NIIP, NIIPA, and NIIPR.

Annex F **(informative)**

Pulsation and Vibration Control Techniques

F.1 Definition of Design Analyses

The definition of the design analyses includes the following:

- a) Analysis Approach 1: F.1.1;
- b) Analysis Approach 2: F.1.2 and F.1.3.

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

- a) inlet flow velocities below 0.3 m/s (1 ft/s) or above 3 m/s (10 ft/s);
- b) the inlet liquid temperature is high enough that cavitation can be anticipated;
- c) the service has a critical hazard condition.

Annex E can provide an insight into the limitations.

F.1.1 Analysis Approach 1

F.1.1.1 The analytical study includes the design of a pump pulsation suppression device using proprietary and/or empirical analytical techniques to meet the pulsation levels specified in F.1.4, F.1.5, and F.1.6. This approach includes the study, good piping layout, good support/restraint principles, and adequate NPIP to design a pulsation solution.

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

F.1.1.2 The analytical study should also include a simplified analysis of the Purchaser's piping system by the Purchaser with frequency data from the Vendor to determine critical piping lengths that may be in resonance with the acoustical excitation frequencies.

F.1.2 Analysis Approach 2 (Acoustical Simulation)

This approach involves pulsation control through the use of pulsation control devices developed using proven acoustical simulation techniques in conjunction with mechanical analysis of pipe runs and support systems (clamp design and spacing) to achieve control of vibration response. F.1.2.1, F.1.2.2, and F.1.2.3 should be considered.

F.1.2.1 Calculation of Peak-to-peak Pulsation Levels

Operating conditions and pump pressure steps are chosen to yield the highest expected pulsation amplitudes throughout the piping system. Pulsation amplitudes are then compared to the levels identified in F.1.4.

F.1.2.2 Calculation of Pulsation-induced Shaking Forces (Unbalanced Forces)

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

F.1.2.3 Development of Piping Modifications

If the pulsation analysis indicates that pulsation levels and/or shaking forces are excessive, modifications to the pulsation control devices and/or piping systems will be made and the analysis continued until the system meets the guidelines defined in F.1.4 or other criteria as agreed upon by the Purchaser and Vendor.

F.1.3 Mechanical Review and Piping Restraint Analysis

A simple mechanical review shall be performed using span and vessel mechanical natural frequency calculations to avoid mechanical resonance. This review shall result in a table of various pipe sizes that indicates the maximum allowable span (based on the maximum pump operating speed) between piping supports as a function of pipe diameter, and the separation margin requirements of F.1.7.

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

F.1.4 Maximum Allowable Pulsation Levels

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

$$P_1 = 3500 / (ID \times f)^{0.5} \quad (F.1)$$

Or, in USC units:

$$P_1 = 100 / (ID \times f)^{0.5} \quad (F.2)$$

where

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

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

F is the pulsation frequency, in Hertz, derived from Equation (F.3) below.

$$f = (rpm)n/60 \quad (F.3)$$

where

rpm is the pump speed; and

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

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

F.1.5 Inlet Pressure versus Liquid Vapor Pressure

Unless otherwise specified, the minimum value of the suction complex pressure wave P_{min} at the inlet reference point (see 3.7 datum elevation) shall not be lower than the highest liquid vapor pressure with a margin of 10 % as shown in Equation (F.4).

$$P_{min} > 1.1 \cdot P_v \quad (F.4)$$

where

P_v is the highest liquid vapor pressure or the gas dissolution pressure, expressed in kilopascals (pounds force per in²).

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

Pressure-limiting Valve Protection

Unless otherwise specified, the margin of separation between the positive peak of the pulsation complex wave at the relief valve and the relief valve setting shall be 10 % of the maximum specified discharge pressure or 165 kPa (25 psi), whichever is greater.

F.1.6 Separation Margin Requirements for Piping Systems

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

The minimum mechanical natural frequency of any manifold or pipe system element shall be designed to be greater than 20 % above the significant frequency of the unbalanced forces and the pocket passing frequency. In certain pump configurations, there can be significant excitation energy at higher orders of running speed and the system design shall take this into account. When the minimum mechanical natural frequency guideline is not met, or when there is significant excitation energy at higher orders, the separation margins as defined in Item b) shall be maintained.

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

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

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

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