INTERNATIONAL STANDARD

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Petroleum, petrochemical and natural gas industries — Reciprocating positive displacement pumps

Industries pétrolière, pétrochimique et du gaz naturel — Pompes volumétriques alternatives

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 13710 was prepared by Technical Committee ISO/TC 115, *Pumps*, Subcommittee SC 3, *Installation and special application,* in collaboration with ISO/TC 67, *Materials, equipment and offshore structures for petroleum, petrochemical and natural gas industries*, Subcommittee SC 6, *Processing equipment and systems*.

Introduction

This International Standard was developed from API Std 674, 2nd edition, 1995, with the intent that the 3rd edition of API Std 674 will be the same as this International Standard.

Users of this International Standard should be aware that further or differing requirements may be needed for individual applications. This International Standard is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This may be particularly appropriate where there is innovative or developing technology. Where an alternative is offered, the vendor should identify any variations from this International Standard and provide details.

This International Standard requires the purchaser to specify certain details and features.

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 shown on data sheets or stated in the enquiry or purchase order (see examples in Annex D).

In this International Standard, where practical, US Customary (USC) units are included in brackets for information.

Annex A lists typical materials standards used in pumps.

Annex B contains a form in which are listed the vendor drawing and data requirements (VDDR).

Annex C specifies techniques for pulsation and vibration control.

Annex D contains typical data sheets.

Annex E describes pump system interaction and explains the differences between NPIP and NPSH.

Annex F contains an inspector's checklist.

Annex G specifies requirements for the lubrication system.

Petroleum, petrochemical and natural gas industries — Reciprocating positive displacement pumps

1 Scope

This International Standard specifies requirements for reciprocating positive-displacement pumps and pump units for use in the petroleum, petrochemical and natural gas industries. It is applicable to both direct-acting and power-frame types.

This International Standard is not applicable to controlled-volume pumps and rotary pumps.

NOTE For controlled-volume pumps see API Std 675; for rotary pumps see API Std 676.

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.

ISO 7 (all parts), *Pipe threads where pressure-tight joints are made on the threads*

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

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

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

ISO 281, *Rolling bearings — Dynamic load ratings and rating life*

ISO 286-2, *ISO system of limits and fits — Part 2: Tables of standard tolerance grades and limit deviations for holes and shafts*

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

ISO 965 (all parts), *ISO general-purpose metric screw threads — Tolerances*

ISO 1328-1, *Cylindrical gears — ISO system of accuracy — Part 1: Definitions and allowable values of deviations relevant to corresponding flanks of gear teeth*

ISO 1940-1, *Mechanical vibration — Balance quality requirements of rigid rotors — Part 1: Determination of permissible residual imbalance*

ISO 3448, *Industrial liquid lubricants — ISO viscosity classification*

ISO 5753, *Rolling bearings —Radial internal clearance*

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

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

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

ISO 8501-1, *Preparation of steel substrates before application of paints and related products — Visual assessment of surface cleanliness — Part 1: Rust grades and preparation grades of uncoated steel substrates and of steel substrates after overall removal of previous coatings*

ISO 10438 (all parts), *Petroleum and natural gas industries — Lubrication, shaft-sealing and control-oil systems and auxiliaries*

ISO 13707, *Petroleum and natural gas industries — Reciprocating compressors*

ISO 15649, *Petroleum and natural gas industries — Piping*

IEC 60034 (all parts), *Rotating electrical machines*

IEC 60079 (all parts), *Electrical apparatus for explosive gas atmospheres*

EN 287 (all parts), *Qualification test of welders — Fusion welding*[1)]

EN 288 (all parts), *Specification and approval of welding procedures for metallic materials*

EN 13445 (all parts), *Unfired pressure vessels*

ABMA 7, *Shaft and housing fits for metric radial ball and roller bearings (except tapered roller bearings) conforming to basic boundary plan*[2)]

AGMA 2015-1, *Accuracy classification system — Tangential measurements for cylindrical gears*[3)]

AGMA 6010, *Standard for spur, helical, herringbone, and bevel enclosed drives*

AGMA 6091, *Standard for gearmotor, shaft mounted and screw conveyor drives*

AGMA 9002, *Bores and keyways for flexible couplings (inch series)*

API Std 526, *Flanged steel pressure relief valves*[4)]

API Std 541, *Form-wound squirrel cage induction motors — 250 horsepower and larger*

API Std 546, *Brushless synchronous machines — 500 kVA and larger*

API Std 611, *General-purpose steam turbines for petroleum, chemical, and gas industry services*

API Std 677, *General-purpose gear units for petroleum, chemical and gas industry services*

API RP 686, *Machinery installation and installation design*

ASA S2.19, *Mechanical vibration — Balance quality requirements of rigid rotors — Part 1: Determination of permissible residual unbalance, including marine applications*[5)]

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1) Comité Européen de Normalisation, 36, rue de Stassart, B-1050 Brussels, Belgium.

2) American Bearing Manufacturers Association, 2025 M Street, NW, Suite 800, Washington, DC 20036, USA.

3) American Gear Manufacturers Association, 1500 King Street, Suite 201, Alexandria, VA 22314, USA.

4) American Petroleum Institute, 1220 L Street NW , Washington, DC 20005-4070, USA.

5) Acoustical Society of America, 35 Pinelawn Road, Suite 114 East, Melville, NY 11747, USA.

ASME Boiler and pressure vessel code, Section V, *Non-destructive examination*[6)]

ASME Boiler and pressure vessel code, Section VIII, *Rules for construction of pressure vessels, division 1*

ASME Boiler and pressure vessel code, Section IX, *Welding and brazing qualifications*

ASME B1.1, *Unified inch screw threads, UN and UNR thread form*

ASME B16.1, *Cast iron pipe flanges and flanged fittings classes 25, 125 and 250*

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

ASME B16.11, *Forged fittings socket welding and threaded*

ASME B16.42, *Ductile iron pipe flanges and flanged fittings classes 150 and 300*

ASME B16.47, *Large diameter steel flanges NPS 26 through NPS 60*

AWS D1.1, *Structural welding code — Steel*[7)]

DIN 910, *Heavy-duty hexagon head screw plugs*[8)]

HI 6.6, *Reciprocating pump tests*[9)]

HI 8.1-8.5, *Direct acting (steam) pumps — Nomenclature, definitions, applications, and operation*

IEEE 841, *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)*[10)]

NACE MR0175, *Sulfide stress cracking resistant metallic materials for oilfield equipment*[11)]

NFPA 70:2002, *National Electrical Code*[12)]

SSPC SP 6, *Surface preparation specification*[13)]

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6) American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990, USA.

7) American Welding Society, 550 North LeJeune Road, Miami, FL 33136, USA.

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

9) Hydraulics Institute, 9 Sylvan Way, Parsippany, NJ 07054, USA.

10) Institute of Electrical & Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08855-1331, USA.

11) National Association of Corrosion Engineers, 1440 South Creek Drive, Houston, TX 77084-4906, USA.

12) National Fire Protection Association, 1 Battery March Park, Quincy, MA 02269-9101, USA.

13) Society for Protective Coatings, 40 24th Street, 6th Floor, Pittsburgh, PA 15222-4643, USA.

3 Terms and definitions

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

3.1
acoustical simulation
process whereby the acoustical characteristics of fluids and the reciprocating-pump dynamic flow influence are modelled

3.2
alarm point
preset value of a measured parameter at which an alarm is activated to warn of a condition that requires corrective action

3.3
anchor bolt
bolt used to attach the mounting plate to the support structure

NOTE The support structure is usually a concrete foundation or steel structure.

cf. **hold-down bolt** (3.6)

3.4
direct-acting pump
reciprocating pump consisting of a piston-powered drive end connected directly to a liquid end to which power is directly transmitted by the action of the motive fluid on the piston

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

3.5
flammable liquid
liquid that has a closed-cup flash point below 37,8 °C (100 °F), as determined by recommended test procedures and apparatus

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

3.6
hold-down bolt
mounting bolt
bolt that holds the equipment to the mounting plate

3.7
inlet reference point
position, upstream of any pulsation suppression device, at which the purchaser's connection is made

NOTE At the inlet reference point the specified inlet conditions, such as inlet pressure, inlet temperature and NPIP, apply.

3.8
local
⟨of a device⟩ mounted on the equipment mounting plate

3.9
maximum allowable speed
highest speed at which the manufacturer's design permits continuous operation

cf. **speed** (3.40)

3.10
maximum allowable temperature
maximum continuous liquid temperature permitted by the manufacturer's design when handling the specified liquid at the specified maximum operating pressure

3.11
maximum allowable working pressure
MAWP
maximum continuous pressure permitted by the manufacturer's design when handling the specified liquid at the specified maximum operating temperature

3.12
maximum continuous speed
highest speed at which the machine, as built and tested, is capable of continuous operation with the specified liquid at any of the specified operating conditions

cf. **speed** (3.40)

3.13
minimum allowable liquid temperature
lowest liquid temperature permitted by the manufacturer's design

3.14
minimum allowable speed
lowest operating speed at which the manufacturer's design permits continuous operation

cf. **speed** (3.40)

3.15
mounting plate
baseplate, skid or soleplate on which the equipment is mounted

NOTE See 7.4 for mounting plate specifications.

3.16
net positive inlet pressure
NPIP
minimum instantaneous pressure determined at the pump inlet reference point during pulsating pressure, minus the vapour pressure of the liquid at the maximum operating temperature

3.17
net positive inlet pressure available
NPIPA
NPIP determined by the vendor from the NPSHA and system data

3.18
net positive inlet pressure required
NPIPR
minimum NPIP required by the pump to achieve the required performance with the specified liquid

3.19
NPIPR test
running test conducted to validate the NPIPR

3.20
net positive suction head
NPSH
total absolute suction pressure, determined at the underside of the mounting plate, minus the vapour pressure of the liquid

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

3.21
net positive suction head available
NPSHA
minimum value of NPSH determined to be available under any specified operating condition at the underside of the mounting plate, based on steady-state flow

NOTE NPSHA is a value provided by the purchaser which can be used by the supplier to calculate the NPIPA (see 3.17). NPSHA is a function only of the system upstream of the pump and the operating conditions, and is independent of pump design.

3.22
observed inspection [test]
inspection [test] for which the purchaser is notified of the timing, and the inspection [test] is performed as scheduled irrespective of whether the purchaser or purchaser's representative is present

3.23
panel
enclosure used to mount, display and protect gauges, switches and other instruments

3.24
performance test
running test conducted to confirm the pump's mechanical and volumetric efficiency

3.25
piston pump
reciprocating pump having a seal attached to the piston and moving within a cylinder

3.26
piston load
plunger load
force acting on one piston or plunger during any portion of the pumping cycle

3.27
plunger pump
reciprocating pump having a uniform-section plunger that moves in a static seal

3.28
power pump
reciprocating pump consisting of a power end and a liquid end connected by a frame or distance piece

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

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

3.29
preliminary anticipated system acceleration head
estimated pressure change due to changes in fluid velocity in the piping system

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

3.30
pressure-containing part
part that acts as a barrier between process or motive liquid and the atmosphere

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

3.31
pressure-limiting valve accumulation pressure
pressure at which a pressure-limiting valve discharges the pump-rated flow

3.32
pressure-limiting valve set pressure
pressure at which a pressure-limiting valve starts to release pressure

3.33
pressure-retaining part
part whose failure would allow process or motive fluid to escape to the atmosphere

EXAMPLES Pressure-containing parts (3.30) and liquid and gas cylinder bolting, stuffing box bolting, gland bolting, glands, and covers that constrain plugs and valve stops, but not parts such as packing, gaskets, pistons, plungers, piston rings, rods, valves, seats (if completely surrounded by pressure-containing parts), and internal bolting.

3.34
pump efficiency
pump mechanical efficiency
ratio of the pump's hydraulic power to its power input

3.35
purchaser
issuer of the order and specification to the vendor

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

3.36
rated flow
total volume of liquid actually delivered per unit time at rated operating conditions, normalised to inlet conditions

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

3.37
remote
⟨of a control device⟩ located away from the equipment or console, typically in a control room

3.38
shutdown set point
pre-set value of a measured parameter at which automatic or manual shutdown of the system or equipment is required

3.39
special tool
tool that is not commercially available, e.g. from a catalogue

3.40
speed
⟨power pump⟩ number of revolutions of the crankshaft in a given unit of time.

NOTE It is expressed in revolutions per minute.

3.41
speed
⟨direct-acting pump⟩ number of strokes of the piston in a given unit of time.

NOTE It is expressed in strokes per minute.

3.42
unit responsibility
responsibility for coordinating the delivery and technical aspects of the equipment and all auxiliary systems included in the scope of the order

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

3.43
vendor
supplier
manufacturer or manufacturer's agent that is contractually responsible for the supply of the equipment

3.44
volumetric efficiency
ratio of the pump rated flow to the total piston or plunger displacements per unit time

NOTE Volumetric efficiency is normally expressed as a percentage.

3.45
witnessed inspection [test]
inspection [test] for which the purchaser is notified of the timing of the inspection [test] and a hold is placed on the inspection [test] until the purchaser or his representative is in attendance

4 General

4.1 Units of measurement

Drawings and maintenance dimensions of pumps shall be in SI units or US Customary (USC) units. Use of SI units on the data sheets indicates that SI units shall be used. Use of USC units on the data sheets indicates that USC units shall be used. See Annex D for typical data sheets.

4.2 Subvendor control

The vendor who has unit responsibility shall ensure that all subvendors comply with the requirements of this International Standard.

5 Statutory requirements

The purchaser and the vendor shall mutually determine the measures that must be taken to comply with any governmental codes, regulations, ordinances or rules that are applicable to the equipment.

6 Basic design

6.1 General

6.1.1 The equipment (including auxiliaries, but excluding parts listed in Table 1, which are subject to wear and maintenance) covered by this International Standard shall be designed and constructed for a minimum service life of 20 years and at least 3 years of uninterrupted operation.

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

The term “design” shall apply solely to parameters or features of the equipment supplied by the manufacturer. The term “design” should not be used in the purchaser's enquiry or specifications because it can create confusion in understanding the order.

Table 1 — Maintenance items

Item	Life (months)
Packings	4 to 12
Valves	9 to 24
Valve seats	9 to 24
Plungers	12 to 36

NOTE The actual life of these parts will depend on the liquid, the service conditions and the installation method.

6.1.2 The vendor shall assume unit responsibility for all equipment and all auxiliary systems included in the scope of the order.

● **6.1.3** The purchaser shall specify the normal operating point and all other required operating points.

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

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

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

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

6.1.8 Equipment shall be selected to run to the pressure-limiting valve accumulation pressure without suffering damage.

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

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

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

6.1.11 The arrangement of the equipment, including piping and auxiliaries, shall be developed jointly by the purchaser and the vendor. The arrangement shall provide adequate clearance areas and safe access for operation and maintenance.

Table 2 — Cooling water system design requirements

Parameter	SI units	USC units
Velocity over heat exchange surfaces	1,5 m/s to 2.5 m/s	(5 ft/s to 8 ft/s)
Maximum allowable working pressure (MAWP), gauge pressure	700 kPa	(7,0 bar) (100 psi)
Test pressure (1,5 MAWP)	1 050 kPa	(10,5 bar) (150 psi)
Maximum pressure drop	100 kPa	(1 bar) (15 psi)
Maximum inlet temperature	30 °C	(90 °F)
Maximum outlet temperature	50 °C	(120 °F)
Maximum temperature rise	20 K	(30 °R)
Fouling factor on water side	0,35 m^2K/kW	(0,002 hr-ft^2-°R/Btu)
Shell corrosion allowance	3 mm	(1/8 in)
To avoid condensation, the minimum inlet water temperature to water-cooled bearing housings should be above the ambient air temperature. The vendor shall notify the purchaser if the criteria for minimum temperature rise and velocity over heat exchange surfaces result in a conflict. The criterion for velocity over heat exchange surfaces is intended to minimise water-side fouling; the criterion for minimum temperature rise is intended to minimise the use of cooling water. If such a conflict exists, the purchaser will approve the final selection.		

6.1.12 Motors, electrical components, and electrical installations shall be suitable for the area classification (class, group, and division or zone) specified by the purchaser and shall meet the requirements of the applicable sections of IEC 60079 or NFPA 70:2002, Articles 500, 501, 502, 504 and 505 as specified, as well as any local codes specified by the purchaser (the provision of which is the purchaser's responsibility).

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

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

6.1.15 The equipment (machine, driver and auxiliary equipment) shall perform on the test stand and on their permanent foundation within the specified test tolerances (see 8.3.5). After installation, the performance of the combined units shall be the joint responsibility of the purchaser and the vendor who has unit responsibility. The vendor shall review and comment on the purchaser's piping and foundation drawings in order to minimize adverse effects.

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

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

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

6.1.18 Bolting for cylinders shall conform to a) through f) below.

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

b) Adequate clearance shall be provided at all bolting locations to permit the use of socket spanners (wrenches).

c) External or internal hexagon-head bolting is required unless otherwise agreed.

d) Mounting bolts shall be not less than 12 mm (0,5 in) diameter.

e) Manufacturer's markings shall be located on all fasteners 6 mm (1/4 in) and larger (excluding washers and headless screws). For studs, the marking shall be on the end of the stud at the same end as the nut.

NOTE A set-screw is a headless screw with a hexagonal socket in one end.

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

6.1.19 Mounting surfaces shall meet the following criteria.

a) They shall be machined to a finish of 6,3 μm (250 μin) arithmetic average roughness (*Ra*) or smoother.

b) To prevent a soft foot, they shall be in the same horizontal plane within 25 μm (0,001 in).

c) Each mounting surface shall be machined within a flatness of 1:24 000; corresponding surfaces shall be in the same plane within 150 μm/m (0,002 in/ft).

d) The upper machined or spot-faced surface shall be parallel to the mounting surface.

e) Hold-down bolt holes shall be drilled perpendicular to the mounting surface or surfaces, machined or spot-faced to a diameter three times that of the hole and to allow for equipment alignment, be 15 mm (1/2 in) larger in diameter than the hold-down bolt.

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

6.2 Selection of pump type

Unless otherwise specified, a piston pump shall not be used in applications requiring continuous operation where the differential pressure across the piston is in excess of 15 MPa (150 bar) (2 175 psi).

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

6.3 Ratings

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

Table 3 — Speed ratings for power pumps in continuous service

Stroke length		Speed rating r/min	
mm	(in)	Single-acting pumps	Double-acting piston-type pumps
50	(2)	450	140
75	(3)	400	127
100	(4)	350	116
125	(5)	310	108
150	(6)	270	100
175	(7)	240	94
200	(8)	210	88
250	(10)	168	83
300	(12)	140	78
350	(14)	120	74
400	(16)	105	70
For single-acting plunger pumps with five or more cylinders, speeds may be increased by 20 % for continuous operation. For light and intermittent duties (up to 6 h per day), speeds up to 10 % higher are permissible.			

Table 4 — Speed ratings for direct-acting pumps in continuous service

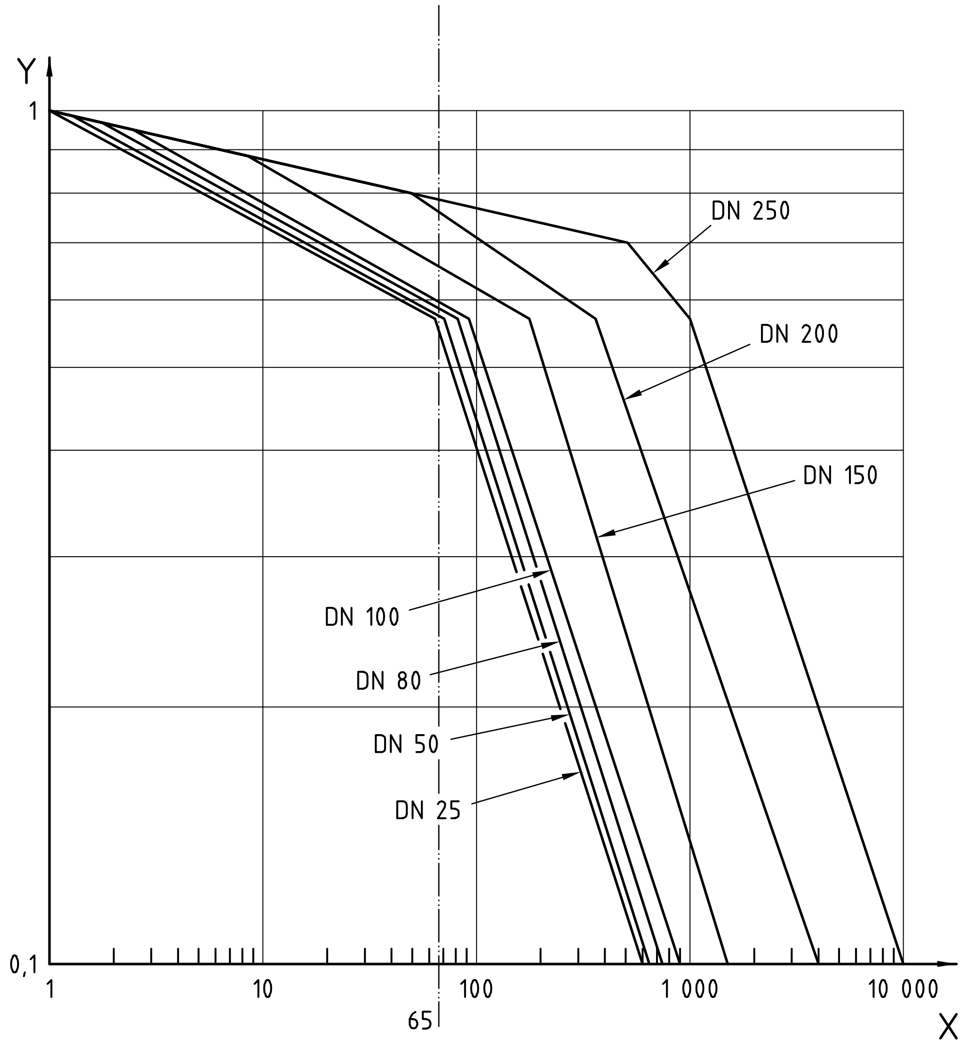
Stroke length		Speed rating
mm	(in)	strokes per minute
100	(4)	52
150	(6)	44
200	(8)	38
250	(10)	34
300	(12)	30
350	(14)	28
400	(16)	26
450	(18)	24
500	(20)	22
600	(24)	20

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

For installations where the NPIPA is less than 15 kPa (0,15 bar) (2,25 psi) above the NPIPR, consideration should be given to speeds lower than those in Tables 3 and 4.

6.3.2 For kinematic viscosities above 65 mm^2/s (65 cSt) (300 Saybolt Seconds Universal) at pumping temperature, the speeds given in Table 3 and Table 4 shall be reduced using the correction factors given in

Figure 1. These correction factors apply only to pumps with plate and plug valves; for other valve designs, refer to manufacturers' data.



Key

X Liquid viscosity, mm^2/s (cSt)

Y Speed correction factor

NOTE The correction factors apply only for viscosities above 65 mm^2/s (65 cSt).

Figure 1 — Speed reduction factors for viscous liquids for standard pumps with plate and plug valves, for inlet connection sizes DN 25, 50, 80, 100, 150, 200 and 250 (NPS 1, 2, 3, 4, 6, 8 and 10)

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

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

NOTE The power requirement is used for driver sizing.

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

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

$$p_{\mathrm{st}} = \frac{\left(d_{\mathrm{m}}^2 \times p_{\mathrm{m}}\right) + \left[\left(d_{\mathrm{p}}^2 - d_{\mathrm{r}}^2\right) \times p_1\right] - \left[\left(d_{\mathrm{m}}^2 - d_{\mathrm{r}}^2\right) \times p_{\mathrm{e}}\right]}{d_{\mathrm{p}}^2} \quad (1)$$

$$p_{\mathrm{st}} = \frac{\left(d_{\mathrm{p}}^2 \times p_1\right) + \left[\left(d_{\mathrm{m}}^2 - d_{\mathrm{r}}^2\right) \times p_{\mathrm{m}}\right] - \left(d_{\mathrm{m}}^2 \times p_{\mathrm{e}}\right)}{\left(d_{\mathrm{p}}^2 - d_{\mathrm{r}}^2\right)} \quad (2)$$

where

d_{m} is the motive piston diameter;

d_{p} is the liquid end piston or plunger diameter;

d_{r} is the rod diameter;

p_{e} is the lowest motive fluid exhaust pressure;

p_{m} is the highest motive fluid supply pressure;

p_1 is the highest process liquid inlet pressure;

p_{st} is the maximum process liquid outlet stall pressure.

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

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

$$p_{\mathrm{st}} = \frac{\left(d_{\mathrm{m}}^2 \times p_{\mathrm{m}}\right) - \left[\left(d_{\mathrm{m}}^2 - d_{\mathrm{r}}^2\right) \times p_{\mathrm{e}}\right]}{d_{\mathrm{p}}^2} \quad (3)$$

$$p_{\mathrm{st}} = \frac{\left(d_{\mathrm{p}}^2 \times p_1\right) + \left[\left(d_{\mathrm{m}}^2 - d_{\mathrm{r}}^2\right) \times p_{\mathrm{m}}\right] - \left(d_{\mathrm{m}}^2 \times p_{\mathrm{e}}\right)}{\left(d_{\mathrm{p}}^2 - d_{\mathrm{r}}^2\right)} \quad (4)$$

where

d_{m} is the motive piston diameter;

d_{p} is the liquid end piston or plunger diameter;

d_{r} is the rod diameter;

p_{e} is the lowest motive fluid exhaust pressure;

p_{m} is the highest motive fluid supply pressure;

p_1 is the highest process liquid inlet pressure;

p_{st} is the maximum process liquid outlet stall pressure.

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

6.4 Pressure-containing and pressure-retaining parts

6.4.1 General

Pressure-containing parts shall be designed in accordance with 6.4.2 or 6.4.3 (as selected by the vendor) and the bolting shall be in accordance with 6.4.4, to achieve the following.

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

b) Withstand the hydrostatic test.

6.4.2 The allowable tensile stress in the design of the pressure-containing parts for any material shall not exceed 0,25 times the minimum ultimate tensile strength for that material at the maximum specified operating temperature and, for castings, multiplied by the appropriate casting factor for the type of non-destructive examination (NDE) as given in Table 5. The manufacturer shall state which material specification is being used as the source of the material properties (see Annex A), as well as the casting factors applied.

Table 5 — Casting factors

Type of non-destructive examination (NDE)	Casting factor
Visual, magnetic particle and/or liquid penetrant	0,8
Spot radiography	0,9
Ultrasonic	0,9
Full radiography	1,0

NOTE Application of these criteria seldom results in ultimate tensile strength or yield strength governing the design; fatigue strength usually governs the design.

6.4.3 Pressure-containing parts may be designed with the aid of finite-element analysis. The value of the stress intensity and deflections shall be assessed for acceptability at 150 % of MAWP. The allowable tensile stress shall not exceed 0,25 times the minimum ultimate tensile strength for that material at the maximum specified operating temperature.

6.4.4 The allowable stress for bolts shall be used to determine the total bolting area based on hydrostatic load and gasket preload, as applicable. The preload stress shall not exceed 0,75 times the bolting material mimimum yield strength.

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

6.4.5 The pressure-limiting valve accumulation pressure shall not exceed the maximum allowable working pressure of the cylinder and shall not exceed 110 % of the specified pressure-limiting valve set pressure. Piping system pressure protection is the responsibility of the purchaser.

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

6.4.7 To prevent leakage in pressure-containing and pressure-retaining parts, metal equal in thickness to at least half the nominal bolt diameter, in addition to the allowance for corrosion, shall be left around and below the bottom of drilled and threaded holes. The depth of the threaded holes shall be at least 1,5 times the stud diameter. The use of threaded connections in pressure-containing parts shall be subject to the approval of the purchaser.

6.4.8 Jackscrews, guide rods, cylindrical alignment dowels and/or other appropriate devices shall be provided to facilitate disassembly and reassembly, if required by pump design. Guide rods shall be of sufficient length to prevent damage to the internals or studs during disassembly and reassembly.

If jackscrews are used as a means of parting contacting faces, one of the faces shall be relieved (counter-bored or recessed) to prevent a leaking joint or an improper fit caused by marring of the face.

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

6.5 Cylinder connections

6.5.1 Openings for all piping connections on cylinders shall be standard pipe sizes DN 20 (NPS 3/4) or larger and shall be in accordance with ISO 6708. The following sizes shall not be used:

DN 32, DN 65, DN 90, DN 125, DN 175 and DN 225 (NPS 1 1/4, NPS 2 1/2, NPS 3 1/2, NPS 5, NPS 7 and NPS 9).

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

● If specified, proposed connection designs shall be submitted to the purchaser for approval before fabrication. The drawing shall show weld designs, size, materials, and preweld and postweld heat treatments.

6.5.3 Connections welded to the cylinder shall meet the material requirements of the cylinder, including impact values, rather than the requirements of the connected piping (see 6.11.1.16). All welding of connections shall be completed before the cylinder is hydrostatically tested (see 8.3.2).

6.5.4 Butt-welded connections, size DN 40 (NPS 1 1/2) and smaller, shall be reinforced by using forged welding inserts or gussets.

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

a) on non-weldable materials, such as cast iron;

b) if essential for maintenance (disassembly and assembly).

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

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

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

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

6.5.9 Threaded connections shall not be seal-welded.

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

6.5.11 Nozzle connections shall be in accordance with 6.5.11.1 to 6.5.11.12 as applicable.

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

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

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

● **6.5.11.3** If specified, ASME B16.47 Series A flanges shall be provided.

6.5.11.4 Cast iron flanges shall be flat-faced and, except as noted in 6.5.11.5, conform to the dimensional requirements of ISO 7005-2 and the flange finish requirements of ASME B16.1 or ASME B16.42. Class 125 flanges shall have a minimum thickness equal to Class 250 for sizes DN 200 (NPS 8) and smaller.

6.4.11.5 Flanges other than those covered in ISO 7005-2 shall conform to the dimensional requirements specified in 6.5.11.1.

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

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

6.5.11.8 Machined and studded connections and flanges not in accordance with ISO 7005-1, 7005-2 or ASME B16.1, B16.5, B16.42 or B16.47 require purchaser's approval. Unless otherwise specified, the vendor shall supply mating flanges, studs and nuts for these non-standard connections.

6.5.11.9 To minimize nozzle loading and facilitate installation of piping, machine flanges shall be parallel, or perpendicular, to the plane shown on the general arrangement drawing to within $\pm$ 0,5°. Studs or bolt holes shall straddle centrelines parallel to the main axes of the equipment.

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

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

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

6.6 External forces and moments

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

The acceptable forces and moments shall not be less than those given in Table 6.

6.7 Liquid-end features

6.7.1 Liners

6.7.1.1 Unless otherwise specified, piston-type, liquid-end, non-replaceable cylinders shall be provided with liners as described in 6.7.1.2 through 6.7.1.5.

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

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

— flanged and bolted;

— clamped;

— held in place by jack bolts;

— held in place by followers and set-screws.

Table 6 — Forces and moments on process connections

Pipe size DN	Forces		Moments	
	$F_{x,y,z}$ N	F_{total} N	$M_{x,y,z}$ N·m	M_{total} N·m
40	255	360	115	170
50	295	420	145	210
80	425	600	215	315
100	505	720	260	385
125	610	870	325	480
150	720	1020	385	565
200	930	1320	500	735
250	1140	1620	625	920
300	1355	1920	740	1090
350	1565	2220	865	1270
400	1775	2520	980	1445
450	1980	2815	1095	1615
500	2200	3125	1220	1795

$F_{\text{total}} = \sqrt{F_x^2 + F_y^2 + F_z^2}$ and $M_{\text{total}} = \sqrt{M_x^2 + M_y^2 + M_z^2}$

NOTE Values shown indicate a range, negative value to positive value.

Table 6 (*continued*)

Pipe size NPS	Forces		Moments	
	$F_{x,y,z}$ lbf	F_{total} lbf	$M_{x,y,z}$ ft-lbf	M_{total} ft-lbf
11/2	57	81	85	125
2	66	94	107	155
3	96	135	159	232
4	114	162	192	284
5	137	196	240	354
6	162	229	284	417
8	209	297	367	542
10	256	364	461	679
12	305	432	546	804
14	352	499	638	937
16	399	567	723	1066
18	455	633	808	1191
20	495	703	890	1324
NOTE Values shown indicate a range, negative value to positive value.				

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

6.7.1.5 The liner bore shall be machined to a surface finish of 0,4 µm (16 µin) *Ra* or smoother.

6.7.1.6 Replaceable cylinders shall seal at each end with a gasket or O-ring and have an inside diameter finished to a surface finish of 0,4 µm (16 µin) *Ra* or smoother.

6.7.2 Pistons, plungers and piston rods

6.7.2.1 Surfaces of metallic rods or plungers in contact with packing shall be hardened or coated. All rods and plungers in contact with the packing shall have a minimum Rockwell hardness of HRC 35. Surface finish shall be 0,4 µm (16 µin) *Ra* or smoother. If packing is supplied as complete rings that must be installed over the crosshead end of the rod or plunger, the design shall ensure that packing lips shall not be damaged by threads or shoulders.

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

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

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

6.7.2.5 Tail rods shall be provided if, without the tail rod, the rod load when stroking toward the liquid end exceeds 2,5 times the rod load when stroking toward the gas end.

6.7.3 Valve seats

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

If corrosive service is specified, seats shall be

— pressed into tapers in the cylinder,

— pressed into valve adapter tapers, or

— positively retained (e.g. by a clamp or plug).

6.7.4 Gaskets

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

6.7.5 Stuffing boxes, packing and glands

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

6.7.5.2 Unless otherwise approved by the purchaser, threaded glands shall be supplied.

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

6.7.5.4 Axially split glands shall be bolted together.

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

● **6.7.5.6** If specified, or recommended by the vendor, a flush shall be supplied to the stuffing box.

6.7.5.7 A lantern ring or throat bushing shall be provided for the following purposes.

a) If the rated suction pressure is below atmospheric, a lantern ring shall be supplied to permit injection of a sealing liquid.

b) The vendor shall recommend the stuffing box design for handling the specified liquid at the specified maximum operating conditions.

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

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

6.7.5.8 The liquid end stuffing box bore finish shall be 1,6 µm (63 µin) Ra or smoother.

● **6.7.5.9** If specified, a liquid-tight, non-pressurised collection chamber shall be provided, with minimum DN 15 (NPS 1/2) drain and vent connections, to contain packing leakage.

● **6.7.5.10** If specified, a minimum DN 8 (NPS 1/4) purge connection shall be provided to directly purge fluid to a lantern ring positioned to minimise pumped fluid leakage to the atmosphere.

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

6.8 Power-end running gear

● **6.8.1** If specified, the following shall apply.

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

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

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

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

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

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

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

6.8.3 Rolling-element bearings shall be located, retained and mounted on the shaft in accordance with the following.

a) Bearings shall be retained on the shaft with an interference fit and fitted into the housing with a diametral clearance, both in accordance with ISO 5753 or ABMA 7 or as recommended by the bearing manufacturer.

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

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

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

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

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

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

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

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

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

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

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

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

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

6.8.12 If provided with a solid cover, the distance piece shall have a vent of not less than DN 15 (NPS 1/2).

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

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

6.9 Direct-acting pump

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

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

6.9.3 D-type slide valves with flat seating surfaces may be supplied for operation with steam temperatures up to 260 °C (500 °F) and steam gauge pressures up to 2 100 kPa (21 bar) (300 psi), provided lubricant carried by the steam is adequate. Valve seating surfaces shall be capable of being re-lapped.

6.9.4 If the steam temperature is above 260 °C (500 °F) or if the steam gauge pressure is above 2 100 kPa (21 bar) (300 psi), the main steam valves shall be of the radially balanced piston type with removable liners in the steam chest.

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

6.9.6 Stuffing boxes, packing, and glands for air and steam shall comply with the following.

a) Piston-rod stuffing-box bore finish shall be 1,6 µm (63 µin) *Ra* or smoother.

b) Packing requiring lubrication shall be lubricated by oil entrained in gas, by oil fed into the stuffing box on the atmospheric side of the packing, or by oil injected into a lantern ring in the stuffing box.

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

6.10 Lubrication

6.10.1 Lubrication for power pumps

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

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

6.10.1.3 Unless otherwise specified, pressurized oil systems shall be general-purpose, in accordance with ISO 10438-3, as modified or supplemented by this International Standard.

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

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

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

6.10.1.6 The oil drain piping shall be sloped 1 in 50 [20 mm/m (0,25 in/ft)].

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

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

- **6.10.1.8** If specified, the pressure-lubrication system shall be special-purpose, in accordance with 10438-2. For such a lubrication system, datasheets should be supplied.

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

6.10.2 Lubrication for liquid end and power end

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

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

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

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

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

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

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

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

6.11 Materials

6.11.1 General

6.11.1.1 The materials of construction shall be the manufacturer's/supplier's standard for the operating conditions specified, except as required by the data sheet or this International Standard.

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

● **6.11.1.3** 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.

6.11.1.4 The vendor's response to the enquiry shall specify the optional tests and inspection procedures that may be necessary to ensure that materials are satisfactory for the service (see 6.11.1.2). Such tests and inspections shall be listed in the proposal.

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

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

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

● **6.11.1.7** The purchaser shall specify in the enquiry any corrosive agents (including trace quantities) present in the motive and process liquids and in the site environment, especially constituents that might cause stress-corrosion cracking.

NOTE Typical agents of concern are hydrogen sulfide, amines, chlorides, cyanides, fluorides, naphthenic acid and polythionic acid.

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

NOTE Overlays or hard surfaces that contain more than 0,10 % carbon can sensitise both low-carbon and stabilised grades of austenitic stainless steel unless a buffer layer that is not sensitive to intergranular corrosion is applied.

6.11.1.9 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 which is of the proper temperature specification and is compatible with the specified process liquid(s).

NOTE The torque loading values to achieve the necessary preload are likely to vary considerably, depending upon whether anti-seizure compound is used.

● **6.11.1.10** The purchaser shall specify the amount of wet H_2S that may be present, considering normal operation, start-up, shutdown, standby, upsets, or unusual operating conditions such as catalyst regeneration.

The purchaser shall specify whether reduced-hardness materials in accordance with NACE MR0175 shall be provided. If reduced-hardness materials are specified, ferrous materials not covered by NACE MR0175 shall have a yield strength not exceeding 620 N/mm^2 (90 000 psi) and a Rockwell hardness not exceeding HRC 22. Components that are fabricated by welding shall be post-weld heat-treated, if required, so that both the welds and the heat-affected zones meet the yield strength and hardness requirements.

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

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

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

NOTE If dissimilar materials with significantly different electrical potentials are placed in contact in the presence of an electrolytic solution, galvanic couples that can result in serious corrosion of the less noble material can be created. The NACE Corrosion Engineer’s Reference Book [105] is one resource for selection of suitable materials in these situations.

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

NOTE For impact requirements, see 6.11.5.

6.11.1.13 Steel made to a course austenitic grain-size practice (such as ASTM A 515) shall not be used. Only fully killed or normalised steels made to fine-grain practice shall be used.

6.11.1.14 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 depressurisation (explosive decompression). It shall be specified on the datasheet if the service is such that there is a risk of explosive decompression.

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

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

6.11.1.16 Unless otherwise specified, auxiliary piping welded to alloy steel cylinders shall be of a material with the same nominal properties as the cylinder material or shall be of low-carbon austenitic stainless steel. Other materials compatible with the cylinder material and intended service may be used with the purchaser’s approval.

6.11.2 Castings

6.11.2.1 Castings shall be sound and free from porosity, hot tears, shrink holes, blow holes, cracks, scale, blisters, and similar injurious defects in excess of that specified in the material specification or any additional specified acceptance criteria. Surfaces of castings shall be cleaned by sandblasting, shotblasting, chemical cleaning, or other standard methods. Mould-parting fins and the remains of gates and risers shall be chipped, filed or ground flush.

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

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

a) Weldable grades of steel castings may be repaired by welding in accordance with 6.11.4. Weld repairs shall be inspected according to the same quality standard used to inspect the casting.

b) Iron castings may be repaired by plugging within the limits of the applicable material specification. 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 material specifications shall be subject to the purchaser's approval.

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

6.11.3 Forgings

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

a) Weldable grades of steel forgings may be repaired by welding in accordance with 6.11.4. After major weld repairs, and before hydrotest, the complete forging shall be given a post-weld heat treatment to ensure stress relief and continuity of mechanical properties of both weld and parent metal.

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

6.11.4 Welding

6.11.4.1 Welding and weld repairs shall be performed in accordance with Table 7. If specified, alternative standards may be proposed by the vendor for the purchaser's approval and, if so, they shall be referenced in data sheets (see Annex D).

Table 7 — Welding requirements

Requirement	Applicable code or standard
Welder/operator qualification	EN 287 (all parts) or ASME IX
Welding procedure qualification	Applicable material specification or, if weld procedures are not covered by the material specification, EN 288 (all parts) or ASME IX
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
Post-weld heat treatment of cylinder fabrication welds	Applicable material specification or ASME VIII, Division I

6.11.4.2 The vendor shall be responsible for the review of all repairs and repair welds to ensure that they are properly heat-treated and non-destructively examined for soundness and compliance with the applicable qualified procedures (see 6.11.4.1 and 8.2.2).

● **6.11.4.3** If specified, the purchaser shall be notified before a major repair is made. For this purpose, a major repair is defined as

— a repair of any moving part,

— a repair of a pressure-containing part in which the depth of the cavity prepared for repair-welding exceeds 50 % of the component wall thickness or is longer than 150 mm (6 in) in any direction, or

— if the total area of all repairs to the part under repair exceeds 10 % of the surface area of the part.

6.11.4.4 Pressure-containing parts made of wrought materials or combinations of wrought and cast materials shall conform to a) through e).

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

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

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

● d) The purchaser shall specify if, in addition to the requirements of 6.11.4.1, specific welds shall be subjected to NDE.

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

6.11.4.5 Connections welded to cylinders shall comply with a) and b).

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

● b) Suction and discharge nozzle welds shall be inspected in accordance with 6.11.4.4 a). The purchaser shall specify if the following additional examinations shall be performed:

1) magnetic particle or liquid penetrant examination of auxiliary connection welds;

2) ultrasonic or radiographic examination of any pressure-containing welds.

6.11.5 Low-temperature service

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

6.11.5.2 To avoid brittle failures, materials of 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. Good design practice should be followed in the selection of fabrication methods, welding procedures, and materials for vendor-supplied steel pressure-retaining parts that may be subject to temperatures below the ductile-brittle transition temperature. The published design-allowable stresses for metallic materials in 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 coarse-grain practices. The vendor should therefore exercise caution in the selection of materials intended for services between –29 °C (–20 °F) and 40 °C (100 °F).

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

6.11.5.4 The 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.

6.11.5.5 If ASME VIII, Division I is specified (see 6.11.5.3), the following shall apply:

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

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

— Impact testing is not required for parts with a governing thickness (6.11.5.4) of 25 mm (1 in) or less.

— Impact testing exemptions for parts with a governing thickness greater than 25 mm (1 in) shall be established in accordance with paragraph UCS-66 in Section VIII, Division 1 of the ASME Code. Minimum design metal temperature without impact testing may be reduced as shown in Figure UCS-66.1 of the ASME Code. 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.

6.12 Nameplates and rotation arrows

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

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

6.12.3 Nameplates and rotation arrows (if attached) shall be of austenitic stainless steel or nickel-copper (NW 4400 or UNS N04400) alloy. Attachment pins shall be of the same material. Welding is not permitted.

6.12.4 The following data (if relevant) shall be clearly stamped or engraved on the nameplate, except that on very small pieces of equipment some of these data may be omitted if approved by the purchaser.

a) vendor's name;

b) serial number;

c) size, type and model;

d) rated capacity;

e) minimum and maximum rated pressures;

f) minimum and maximum rated temperatures;

g) rated speed;

h) rated power;

i) MAWP;

j) maximum allowable temperature;

k) purchaser item number or other reference;

l) pumped liquid.

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

7 Accessories

7.1 Drivers

7.1.1 General

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

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

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

7.1.1.4 The supporting feet of drivers with a mass greater than 225 kg (500 lb) shall be provided with vertical jackscrews.

7.1.2 Motors

7.1.2.1 Motor drives shall be in accordance with IEC 60034 (all parts), or with API Std 541 or API Std 546 as applicable. Motors that are below the power scope of API Std 541 or API Std 546 shall be in accordance with IEC 60034 (all parts) or IEEE 841. Electric motor drivers shall be rated with a service factor of 1,0. The motor rating shall be at least 110 % of the greatest power required (including gear and coupling losses) for any of the specified operating conditions. The motor nameplate rating, including service factor, shall be suitable for operation at 100 % of the pressure-limiting valve accumulation pressure. Consideration shall be given to the starting conditions of both the driver and driven equipment and the possibility that these conditions may be different from the normal operating conditions.

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

● **7.1.2.2** The purchaser shall specify the type of motor, its characteristics and accessories, including the following:

a) electrical characteristics;

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

c) type of enclosure;

d) sound pressure level;

e) area classification;

f) type of insulation;

g) any required service factor;

h) transmission losses, if any;

i) temperature detectors, vibration sensors and heaters, if these are required;

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

k) vibration acceptance criteria;

l) use in variable-frequency drive applications.

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

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

7.1.3 Steam turbines

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

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

7.1.4 Gear units

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

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

7.1.4.3 The gear service factor shall be mutually agreed upon by both the gear and pump manufacturers for given service conditions such as variable torque loading and torsional critical speeds. The gear service factor shall be subject to approval by the purchaser. In no case shall the service factor be less than that required by AGMA 6010 for standard gear reducers and/or API Std 677 if either of these has been specified.

7.2 Couplings and guards

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

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

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

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

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

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

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

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

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

c) Coupling hubs shall be supplied with tapped puller holes of diameter at least 10 mm (0,375 in) on shafts with diameters greater than 40 mm (1,5 in) to facilitate removal.

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

7.2.6 If the driven-equipment vendor is not required to mount the driver, the coupling purchaser shall deliver the fully machined half-coupling to the driver manufacturer's plant or any other designated location, together with the necessary instructions for mounting the half-coupling on the driver shaft as specified by the specified date. Any delay shall be added to the delivery date.

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

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

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

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

● c) Guards shall be fabricated either from solid sheet or plate with no openings or from expanded metal or perforated sheets if the size of the openings does not exceed 10 mm (0,375 in). Guards shall be constructed of steel, brass or non-metallic (polymer) materials. Guards of woven wire shall not be used. If specified, non-sparking guards of agreed material shall be supplied.

7.3 Belt drives

● **7.3.1** Belt drives shall only be used for equipment of 150 kW (200 brake hp) or less. Unless otherwise specified, banded multi-V belts shall be provided. If more than one banded multi-V belt is required, the vendor shall supply matched belt lengths. All belts shall be of the static-conducting type and shall be oil-resistant. The drive service factor shall not be less than 1,5 for multiplex plunger pumps, 1,6 for duplex double-acting piston pumps, and 1,75 for duplex single-acting pumps based on the driver nameplate power rating. If specified, a cog-belt or chain-type drive shall be provided. Details shall be mutually agreed upon between the vendor and the purchaser.

NOTE Oil-resistant belts have a core of polychloroprene (e.g. neoprene) or an equivalent material.

7.3.2 The vendor shall provide a positive belt-tensioning device. This device shall incorporate either a lateral adjustable base with guides and hold-down bolts, two belt-tensioning screws and locking devices, or a vertical adjustable base with four belt-tensioning screws, each with a locking device.

7.3.3 Belt drives shall meet the following requirements:

a) the distance between the centres of the pulleys (sheaves) shall be at least 1,5 times the diameter of the larger sheaf;

b) the belt wrap (contact) angle on the smaller pulley shall be at least 140°;

c) the shaft length on which the pulley hub is fitted shall be at least equal to the width of the sheaf hub;

d) the length of a shaft key used to mount a pulley shall be equal to the length of the pulley bore;

e) unless otherwise agreed or specified, each pulley shall be mounted on a tapered adapter bushing;

f) to reduce the moment on shafts due to belt tension, the pulley overhang distance from the adjacent bearing shall be minimised;

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

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

7.4 Mounting plates

7.4.1 General

● **7.4.1.1** The type of mounting plate shall be specified by the purchaser.

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

● **7.4.1.3** The upper and, if specified, lower surfaces of mounting plates and any separate pedestals mounted thereon shall be machined parallel. The surface finish shall be 3,2 µm (125 µin) Ra or smoother.

7.4.1.4 If a piece of equipment, except the pump, has a mass in excess of 225 kg (500 lb), the mounting plate or plates shall be supplied with horizontal (axial and lateral) jackscrews, the same size or larger than the vertical jackscrews. The lugs holding these jackscrews shall be attached to the mounting plates in such a manner that they do not interfere with the installation of the equipment, jackscrews or shims. Precautions shall be taken to prevent vertical jackscrews in the equipment feet from marring the shimming surfaces. Alternative methods of lifting equipment for the removal or insertion of shims or for moving equipment horizontally, such as provision for the use of hydraulic jacks, may be proposed. Such arrangements should be proposed for equipment that is too heavy to be lifted or moved horizontally using jackscrews. Jackscrews shall be plated for corrosion resistance.

7.4.1.5 Machinery supports shall be designed to limit the relative displacement of the shaft end caused by the worst-case combination of pressure, torque and allowable piping stress, to 50 µm (0,002 in). Loads applied during transportation and installation shall not cause permanent deformation (See 6.6 for allowable piping loads).

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

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

7.4.1.8 Mounting plates shall conform to the following.

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

b) Mounting plates shall be supplied with levelling screws.

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

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

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

f) Mounting plates shall be machined to a finish of 6,3 µm (250 µin) arithmetic average roughness (Ra) or better.

7.4.1.9 Shims shall not be used under the pump. All pads for drive-train components shall be machined to allow for the installation of shims at least 3 mm (0,12 in) thick under each component. If the vendor mounts the components, a set of stainless steel shims at least 3 mm (0,12 in) thick shall be supplied. Shim packs shall not be thicker than 13 mm (0,5 in) nor contain more than 5 shims. All shim packs shall straddle the hold-down bolts and vertical jackscrews, and extend at least 6 mm (1/4 in) beyond the outer edges of the equipment feet. If the vendor does not mount the components, the pads shall not be drilled and shims shall not be provided.

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

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

7.4.1.12 Equipment shall be designed for installation in accordance with API RP 686.

7.4.2 Baseplate and skid

● **7.4.2.1** If a baseplate or skid 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. Multiple-section baseplates shall have machined and dowelled mating surfaces which shall be bolted together to ensure accurate field reassembly.

NOTE A baseplate with a nominal length of more than 12 m (40 ft) or a nominal width of more than 3,6 m (12 ft) might have to be fabricated in multiple sections because of shipping restrictions.

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

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

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

7.4.2.5 The baseplate or skid 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 skid or the equipment mounted on it.

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

7.4.2.7 The underside mounting surfaces of the baseplate shall be in one plane to permit use of a single-level foundation. If multi-section baseplates are provided, the mounting pads shall be in one plane after the baseplate sections are dowelled and bolted together.

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

7.4.2.9 All baseplate or skid equipment mounting surfaces shall comply with the following.

a) They shall be machined after the baseplate is fabricated.

b) Each mounting surface shall be machined within a flatness of 42 µm/m (0,000 5 in/ft) of mounting surface.

NOTE This equates to a flatness of 1 in 24 000.

c) Different mounting planes shall be parallel to each other within 50 µm/m (0,000 6 in/ft).

7.4.2.10 Baseplates or skids shall be of the drain-rim or drain-pan type and shall have a raised lip. Connections for a drain shall be tapped [DN 25 (NPS 1) 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 at least 1 in 120 toward the drain end.

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

7.4.3 Soleplates and sub-soleplates

● **7.4.3.1** If soleplates are specified, they shall meet the requirements of a) through c).

a) Soleplates shall be steel plates that are thick enough to transmit the expected loads from the equipment feet to the foundation, but in no case shall the plates be less than 40 mm (1 1/2 in) thick.

● b) Soleplates shall be large enough to extend beyond the feet of the equipment in all directions and shall be designed such that the anchor bolts are not covered by machine feet. If specified, anchor bolt holes shall be counterbored so that the hold-down nuts do not extend beyond the upper surface of the soleplate.

c) If sub-soleplates are used (see 7.4.3.2), soleplates shall be fully machined top and bottom.

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

7.5 Controls and instrumentation

7.5.1 General

Instrumentation and installation shall conform to ISO 10438 (all parts) and satisfy the hazardous conditions identified by the purchaser.

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

7.5.2 Control systems

7.5.2.1 Flow control should not be achieved by throttling; it should be obtained by flow bypass or by variation in pump speed, with or without supplemental bypass.

Control systems shall be in accordance with 7.5.2.2 through 7.5.2.6.

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

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

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

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

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

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

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

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

7.5.3 Instrument and control panels

● **7.5.3.1** Unless otherwise specified, panels shall be made of steel plate at least 3 mm (1/8 in) thick, reinforced, self-supporting and closed on the top and sides. If specified, the backs of panels shall be closed to minimise electrical hazards, to prevent tampering or to allow purging for safety or corrosion protection. All instruments shall be flush-mounted on the front of the panel and all fasteners shall be of corrosion-resistant material.

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

7.5.4 Instrumentation

7.5.4.1 Speed indicator (frequency monitor)

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

7.5.4.2 Temperature indicators

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

7.5.4.2.2 The sensing elements of temperature indicators shall be in the flowing fluid. This is particularly important for lines that might run partially full.

7.5.4.3 Thermowells

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

7.5.4.3.2 Unless otherwise specified, the thermowells shall have a 25 mm (1 in) process connection. For pressurized lines, this connection shall be flanged. For non-pressurized lines, this connection may be threaded subject to purchaser's acceptance. The thermowell internal connection shall be 13 mm (1/2 in).

7.5.4.4 Thermocouples and resistance temperature-detectors

Where practical, the design and location of thermocouples and resistance temperature-detectors shall permit replacement while the unit is operating. The lead wires of thermocouples and resistance temperature-detectors shall be installed as continuous leads between the thermocouple or detector and the terminal box located on the equipment or the baseplate.

7.5.4.5 Pressure indicators

Pressure indicators shall be in accordance with ISO 10438-1.

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

7.5.4.6 Solenoid valves

Direct solenoid-operated valves shall be used only with clean, dry instrument-air, shall have Class F insulation or better, and shall have a continuous-service rating. If required for other services, the solenoid shall act as a pilot valve to pneumatic valves and hydraulically operated valves.

7.5.4.7 Pressure-limiting valves

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

7.5.4.7.2 Pressure-limiting valves shall be in accordance with API Std 526. The vendor shall determine the size and set pressure of all pressure-limiting valves within the vendor’s scope of supply and recommend the size and setting of pressure-limiting valves supplied by others required to protect the equipment the vendor supplies. Pressure-limiting valve sizes and settings shall take into account all possible modes of equipment failure and shall meet the requirements of 6.4.5.

7.5.4.7.3 Unless otherwise specified to suit the liquid properties (such as in sour-water services), wetted parts of pressure-limiting valves shall be austenitic stainless steel.

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

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

7.5.4.8 Flow indicators

Flow indicators shall be in accordance with ISO 10438-1.

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

7.5.5 Alarms and shutdowns

7.5.5.1 Alarms and shutdowns shall be in accordance with the appropriate part of ISO 10438, except as specified in 7.5.5.2 through 7.5.5.5.

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

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

7.5.5.3 The vendor shall advise the purchaser of any additional alarms and/or shutdowns considered essential to safeguard the equipment.

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

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

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

7.5.6 Electrical systems

7.5.6.1 Electrical systems shall be in accordance with the appropriate part of ISO 10438, except as specified in 7.5.6.2.

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

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

7.6 Auxiliary piping

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

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

7.6.2 Auxiliary systems are piping systems that include the services listed in Table 8.

Table 8 — Piping system services

Group I
1) Gland and flushing fluid.
2) Fuel gas or oil.
3) Process-side drains and vents.
Group II
1) Sealing steam.
2) Starting air.
3) Instrument and control air.
4) Drains and vents associated with above systems.
Group III
1) Cooling water.
2) Drains and vents associated with above systems.
Group IV
1) Lubricating oil.
2) Control oil.
3) Oil-system drains and vents.
NOTE Cylinder connections are specified in 6.5.

7.6.3 Pipe plugs shall be in accordance with 6.5.10 for permanent plugs or 8.4.3 f) for shipping plugs.

7.7 Pulsation and vibration control requirements

7.7.1 General

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

a) complexity of the system layout;

b) number of pumps;

c) operating speeds;

d) liquid properties;

e) pump type;

f) pump size (power);

g) number of plungers;

h) system operational conditions;

i) piping layout.

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

7.7.1.3 If detrimental pulsations and vibrations cannot be avoided by 7.7.1.2 or other methods, the basic techniques used for their control are the following:

a) pulsation control devices, such as dampeners, accumulators, dampers, preventers, hydraulic isolators, inhibitors, suppressors, stabilisers, acoustic filters and selected piping configurations;

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

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

d) good piping layout and design practice, which comprises the following:

   1) maintaining near-ground-level routing of piping if possible, to facilitate effective (relatively stiff) restraints;

   2) minimising the number of direction changes (e.g. elbows) to reduce the potential for coupling pulsations into a mechanical shaking force;

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

   4) use of sufficient number of piping restraints (clamp spacing) and proper restraint design. Clamps are preferred to U-bolts; mass-only type supports should be avoided.

NOTE Normally, control of system pulsation, cavitation and vibration needs coordination between the pump manufacturer and the piping system designer in order to ensure that the system pulsation and vibration characteristics are suitable for the intended purpose.

7.7.2 Selection and scope of design analysis methods

● The purchaser shall specify if design analysis for pulsation and vibration control is required and, if so, which method to follow (see Annex C). The purchaser shall also indicate whether existing pumps and their associated piping are to be included in the analysis.

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

7.8 Special tools

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

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

8 Inspection, testing and preparation for shipment

8.1 General

● **8.1.1** The purchaser shall specify the extent of participation in the inspection and testing.

● **8.1.2** If specified, the purchaser's representative, the vendor's representative, or both, shall indicate compliance in accordance with an inspector's checklist, such as that provided in Annex F, by initialling, 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 subvendor plants where manufacturing, testing, or inspection of the equipment is in progress.

8.1.4 The vendor shall notify subvendors of the purchaser's inspection and testing requirements.

8.1.5 If shop inspection and testing have been specified, the purchaser and the vendor shall coordinate manufacturing hold-points and inspectors' visits.

● **8.1.6** The purchaser shall specify the amount of advance notification required for witnessed or observed inspections or tests.

8.1.7 A witnessed performance test requires confirmation of the successful completion of a preliminary test.

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

8.1.9 The purchaser's representative shall have access to the vendor's quality programme for review.

8.2 Inspection

8.2.1 General

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

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

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

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

d) results of quality control tests and inspections;

e) details of all repairs;

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

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

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 6.11.4.1, the purchaser may specify the following:

a) parts that shall be subjected to surface and subsurface examination;

b) the type of examination required, such as magnetic-particle, liquid-penetrant, radiographic and ultrasonic examinations.

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

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 9. Alternative standards may be proposed by the vendor or specified by the purchaser. The data sheets in Annex D may be used for this purpose.

Table 9 — Materials inspection standards

Type of inspection	Methods	Acceptance criteria	
		For fabrications	For castings
Radiography	Section V, Articles 2 and 22 of the ASME Code	Section VIII , Division 1, UW-51 (for 100 % radiography) and UW-52 (for spot radiography) of the ASME Code	Section VIII, Division 1, Appendix 7 of the ASME Code
Ultrasonic inspection	Section V, Articles 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 "ASME Code" means the ASME Boiler and Pressure Vessel Code.			

8.2.3 Mechanical inspection

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

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

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

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

● **8.2.3.4** If specified, the hardness of parts, welds and heat-affected zones shall be verified as being within the allowable values by testing. The method, extent, documentation and witnessing of the testing shall be mutually agreed upon by the purchaser and the vendor.

8.3 Testing

8.3.1 General

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

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

8.3.2 Hydrostatic test

8.3.2.1 Pressure-containing parts (including auxiliaries) shall be tested hydrostatically with liquid at a minimum of 1,5 times the maximum allowable working pressure but not less than a gauge pressure of 150 kPa (1,5 bar) (20 psi). The test liquid shall be at a higher temperature than the nil-ductility transition temperature of the material being tested.

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

8.3.2.2 If the part tested 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 value used shall be determined in accordance with 6.4.2. For piping, the stress shall conform to ISO 15649. The pressure thus obtained shall then be the minimum pressure at which the hydrostatic test shall be performed. The vendor shall list actual hydrostatic test pressures on the data sheets.

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 (400 °F).

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

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 International 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 mg/kg (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 if neither leaks nor seepage through the fluid cylinder or cylinder joint are observed for at least 30 min. Large, heavy pressure-containing parts may require a longer testing period to be agreed upon by the purchaser and the vendor. Seepage past stuffing boxes or internal closures required for testing of segmented cylinders and operation of a test pump to maintain pressure is acceptable. Gaskets used during the hydrostatic testing of the assembled pressure-containing part shall be of the same design as those supplied with the pump.

8.3.2.6 All water-side cooling passages shall be tested at a minimum gauge pressure of 1 000 kPa (10 bar) (150 psi).

8.3.3 Performance test for direct-acting pump

8.3.3.1 Unless otherwise specified, tests shall be conducted in accordance with HI 8.1 to HI 8.5 (see Clause 2). The manufacturer shall operate the pump in his shop for a sufficient period to obtain complete test data, including speed, discharge pressure, suction pressure, power, and capacity.

8.3.3.2 The pump shall be operated at speeds within five percentage points of 25 %, 50 %, 75 %, 100 %, and 125 % of the rated speed.

8.3.3.3 The pump shall be operated at pressures as near the rated pressures as permitted by the test facility.

8.3.3.4 During the shop tests, the pump shall operate smoothly over the specified operating range, except when running under cavitating conditions during the NPSH test.

8.3.3.5 At rated speed, the pump power shall not exceed the quoted power.

8.3.4 Performance test for power pump

8.3.4.1 Unless otherwise specified, tests shall be conducted in accordance with HI 6.6 (see Clause 2). The manufacturer shall operate the pump in his shop for a sufficient period to obtain complete test data, including speed, discharge pressure, suction pressure, power, and capacity.

8.3.4.2 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. Test measurements relating to the driver and auxiliary equipment shall be agreed between purchaser and manufacturer.

8.3.4.3 If the test facility does not have the capability to meet the rated conditions, two tests shall be run: one at the specified discharge pressure with reduced speed and the other at 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 re-established by testing.

8.3.5 Test tolerances

- Unless otherwise agreed or specified, when operated on the test stand, pumps shall be within the tolerances of the rated characteristics or the test equivalent as given in Table 10.

Table 10 — Test tolerances

Characteristic	Tolerance (%)	
	Power pump	Direct-acting pump
Rated capacity	$^{+3}_{0}$	$^{+3}_{0}$
Rated power (at rated pressure and capacity)	+4	—
NPIPR/NPSHR	$\leqslant 0$	$\leqslant 0$

8.3.6 NPIP/NPSH test

For the NPIP test, a trace (plot) of the inlet pressure shall be made just upstream of any device used to improve inlet flow (e.g. a stabiliser) and compared with the vapour pressure of the pumped liquid at the maximum allowable temperature. The NPIP test result shall be considered acceptable if there are no pressure spikes with a peak instantaneous value greater than 3 times the mean inlet pressure nor a minimum instantaneous value less than 110 % of the above vapour pressure.

- If specified, the pump shall be tested for NPSH. At rated speed and with NPSHA equal to quoted NPSHR, the pump capacity shall be within 3 % of the nominal capacity.

WARNING — The pump shall not be run while cavitating.

8.4 Preparation for shipment

8.4.1 Equipment shall be prepared for the type of shipment specified. Unless otherwise agreed, the preparation shall make the equipment suitable for 6 months of outdoor storage from the time of shipment, with no disassembly required before installation, except for inspection of bearings and seals. If storage for a longer period is contemplated, the purchaser shall consult with the vendor regarding the recommended procedures to be followed.

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

8.4.2 The vendor shall provide the purchaser with the instructions necessary to preserve the integrity of the storage preparation after the equipment arrives at the job site and before start-up, which should be in accordance with API RP 686.

8.4.3 The equipment shall be prepared for shipment after all testing and inspection have been completed. The preparation shall include that specified in a) through j).

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

b) Exterior machined surfaces, except for corrosion-resistant material, shall be coated with a rust preventive.

c) The interior of the equipment shall be

   1) clean,

   2) free from scale, welding spatter and foreign objects,

   3) except for corrosion-resistant material, sprayed or flushed with a rust preventive that can be removed with solvent.

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

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

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

NOTE These are shipping plugs; permanent plugs are covered in 6.5.10.

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

h) 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.

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

j) Loose components shall be dipped in wax or placed in plastic bags and contained by cardboard boxes. Loose boxes shall 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 vapour-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. Where applicable, bags shall be installed in wire cages attached to flanged covers, and bag locations shall be indicated by corrosion-resistant tags attached with stainless steel wire.

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

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

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

9 Vendor's data

9.1 General

9.1.1 The information to be supplied by the vendor shall be as specified in 9.2 and 9.3 (see Annex B).

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

a) purchaser's/owner's corporate name;

b) job/project number;

c) equipment item number and service name;

d) enquiry or purchase order number;

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

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

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

a) purchase order, scope of supply, unit responsibility, subvendor items and lines of communications;

b) data sheets;

c) applicable specifications and previously agreed exceptions;

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

e) quality assurance programme and procedures;

f) inspecting, expediting, and testing;

g) schematics and bills of material for auxiliary systems;

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

i) coupling selection and rating;

j) equipment performance, alternative operating conditions, start-up, shutdown and any operating limitations;

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

l) instrumentation and controls;

m) identification of design reviews;

n) inspection, related acceptance criteria and testing;

o) expediting;

p) other technical items.

9.2 Proposals

9.2.1 General

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

9.2.2 Drawings

9.2.2.1 The drawings indicated on the vendor drawing and data requirements (VDDR) form (see Annex B) shall be included in the proposal. As a minimum, the following shall be included:

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

b) cross-sectional drawings showing the details of the proposed equipment;

c) schematics of all auxiliary systems, including fuel, lube oil, control and electrical systems. Bills of material shall be included, if available;

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

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

9.2.3 Technical data

The following data shall be included in the proposal:

a) purchaser’s data sheets with complete vendor’s information entered thereon, and literature to fully describe details of the offering;

b) predicted noise data (6.1.5);

c) vendor drawing and data requirements (VDDR) form (see Annex B), indicating the schedule according to which the vendor agrees to transmit all the data specified;

d) schedule for shipment of the equipment, in weeks after receipt of an order;

e) list of major wearing components, showing any interchangeability with the owner's existing machines;

f) list of spare parts recommended for start-up and normal maintenance purposes;

g) list of the special tools supplied for maintenance;

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

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

j) description of any optional or additional tests and inspection procedures for materials as required by 6.11.1.4;

k) description of any special requirements, whether specified in the purchaser's enquiry or as outlined in 6.1.6, 6.3.5, 6.3.6, 6.3.7, 6.8.6, 6.11.1.2 and 6.11.1.4;

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

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

n) list of any components that can be construed as being of alternative design, hence requiring purchaser's acceptance.

9.2.4 Performance envelope

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

9.2.5 Optional tests

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

9.3 Contract data

9.3.1 General

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

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

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

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

9.3.2 Drawings and technical data

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

9.3.3 Progress reports

● The vendor shall submit progress reports to the purchaser at intervals specified.

NOTE See the VDDR form (Annex B).

9.3.4 Parts lists and recommended spares

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

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

9.3.5 Installation, operation, maintenance and technical data manuals

9.3.5.1 General

The vendor shall provide sufficient written instructions and all necessary drawings to enable the purchaser to install, operate and maintain all of the equipment covered by the purchase order. This information shall be compiled in a manual(s) with a cover sheet giving the information listed in 9.1.2, a table of contents, and a complete list of the enclosed drawings by title and drawing number. The manual(s) shall be prepared specifically for the equipment covered by the purchase order. "Typical" manuals are unacceptable.

9.3.5.2 Installation manual

All information required for the proper installation of the equipment shall be compiled in a manual that shall be issued no later than the time of issue of the 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, centres of mass, rigging provisions and procedures, and all other installation data. All drawings and data specified in 9.2.2 and 9.2.3 that are pertinent to proper installation shall be included as part of this manual. See the VDDR form (Annex B).

9.3.5.3 Operating and maintenance manual

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

9.3.5.4 Technical data manual

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

Annex A
(informative)

Pump material specifications

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

Table A.1 — Materials specifications for pump parts

Material class	Applications	International ISO	USA ASTM	USA UNS [a]	Europe EN [b]	Europe Name	Europe Number	Japan JIS
Cast iron	Pressure castings	185/ Gr. 250	A 278 Class 30	F12401	1561	EN-GJL-250	JL1040	G 5501, FC 300
	General castings	185/ Gr. 300	A 48 Class 25/30/40	F11701/ F12101	1561	EN-GJL-250 EN-GJL-300	JL1040 JL1050	G 5501, FC 250 G 5501, FC 300
Ductile iron	General castings	1083, 400-18	A 536 Gr 60-40-18	F32800	1563	EN-GJS-400-18	JS1020	
Ni-resist	Special castings	2892, L-NiCuCr 15 6 3 2892, S-NiCr 20 2	A 436 Type 1 A 439 Type D-2	F41000 F43000	13835 13835	EN-GJLA-XNiCuCr15-6-2 EN-GJSA-XNiCr20-2		
Carbon steel	Pressure castings	4991 C23-45AH	A 216 Gr WCB	J03002	10213-2	GP 240 GH	1.0619	G 5151, Cl SCPH 2
	Low-temperature castings	4991, C23-45BL 4991, C43E2aL 4991, C43L	A 352 Gr LCB A 352 Gr LC2 A 352 Gr LC3	J 03003 J 22500 J 31550	10213-3 10213-3 10213-3	G18Mo5 G9Ni10 G9Ni14	1.5422 1.5636 1.5638	
	Wrought/ forgings	683-18-C25, 9327-2 - PH26-PH31, 9327-4	A 266 Class 2	K03506	10222-2	P 280 GH	1.0426	G 3202, Cl SFVC 2A
	Bar stock: Pressure	683-18-C 25, 9327-2, PH26-PH31, 9327-4	A 696 Gr B40	G10200	10273	P 295 GH	1.0481	G 4051, Cl S25C
	Bar stock: General	683-18-C45e 9327-2 - PH26-PH31, 9327-4	A 576 Gr 1045	G10450	10083-2	C 45	1.0503	G 4051, Cl S45C
	Bolts and studs (general)	9327-2-F31	A 193 Gr B7	G41400	10269	42 Cr Mo 4	1.7225	G 4107, Class 2, SNB7
	Nuts (general)	683-1-C35e	A 194 Gr 2H	K04002	10269	C 35 E	1.1181	G 4051, Cl S45C
	Plate	9328-4, P 355 TN/PL 355 TN	A 516 Gr 65/70	K02403/ K02700	10028-3 10028-2	P 355 N P 355 NL1 P 295 GH P 355 GH	1.0562 1.0566 1.0481 1.0473	G 3106, Gr. SM400B

Table A.1 — (*continued*)

Material class	Applications	International	USA		Europe			Japan
		ISO	ASTM	UNS [a]	EN [b]	Name	Number	JIS
Carbon steel (cont.)	Pipe	9329-2, PH26-PH35	A 106 GrB	K03006	10208-1	L 245 GA	1.0459	G 3456, Gr. STPT 370/410
	Fittings		A 105	K03504				G 4051, Cl S25C G 3202, Cl SFVC 2A, SFVC2B
AISI 4140 steel	Bar stock		A 434 Class BB A 434 Class BC	G41400 [c]	10083-1	42 Cr Mo 4	1.7225	G 4105, Cl SCM 440
	Bolts and studs		A 193 Gr B7	G41400	10269	42 Cr Mo 4	1.7225	G 4107, Class 2, SNB7
	Nuts	9327-2-F31	A 194 Gr 2H	K04002	10269	C 45 E	1.1191	G 4051, Cl S45C
12% Chromium steel	Pressure castings		A 217 Gr CA 15	J91150	10213-2	GX 8 Cr Ni 12	1.4107	G 5121, Cl SCS 1
			A 487 Gr CA6NM	J91540	10213-2	GX 4 Cr Ni 13-4	1.4317	G 5121, Cl SCS 6
	General castings		A 743 Gr CA 15	J91150	10283	GX 12 Cr 12	1.4011	
			A 743 Gr CA6NM	J91540	10283	GX 4 Cr Ni 13-4	1.4317	
	Wrought/ forgings: Pressure		A 182 Gr F6a Cl 1 A 182 Gr F 6 NM	S41000 S41500	10250-4 10222-5	X12 Cr 13 X 3 Cr NiMo 13-4-1	1.4006 1.4313	G 3214, Gr. SUS F 410-A G 3214, Cl SUS F6 NM
	Wrought/ forgings: General		A 473 Type 410	S41000	10088-3	X 12 Cr 13	1.4006	G 3214, Gr. SUS F 410-A
	Bar stock: Pressure		A 479 Type 410	S41000	10272	X12 Cr 13	1.4006	G 4303, Gr. SUS 410 or 403
	Bar stock: General		A 276 Type 410	S41400	10088-3	X 12 Cr 13	1.4006	G 4303, Gr. SUS 410 or 403
	Bar stock: Forgings [c]		A 276 Type 420 A 473 Type 416 A 582 Type 416	S 42 000 S41600 S41600	10088-3	X 20 Cr 13 X 20 Cr S 13 X 20 Cr S 13	1.4021 1.4005 1.4005	G 4303, Gr. SUS 420J1 or 420J2

Table A.1 — (*continued*)

Material class	Applications	International	USA		Europe			Japan
		ISO	ASTM	UNS [a]	EN [b]	Name	Number	JIS
12% Chromium steel (cont.)	Bolts and studs [d]	3506-1, C4-70	A 193 Gr B6	S41000	10269	X22CrMoV 12-1	1.4923	G 4303, Gr. SUS 410 or 403
	Nuts [d]	3506-2, C4-70	A 194 Gr 6	S41000	10269	X22CrMoV 12-1	1.4923	G 4303, Gr. SUS 410 or 403
	Plate		A 240 Type 410	S41000	10088-2	X 12 Cr 13	1.4006	G 4304/4305 Gr. SUS 410 or 403
Austenitic stainless steel	Pressure castings	11972, GX2CrNi18-10	A 351 Gr CF3	J92500	10213-4	GX2 Cr Ni 19-11	1.4309	G 5121, Cl SCS 13A
		11972, GX2CrNiMo19-11-2	A 351 Gr CF3M	J92800	10213-4	GX2 Cr Ni Mo 19-11-2	1.4409	G 5121, Cl SCS 14A
	General castings	11972, GX2CrNi18-10	A 743 Gr CF3	J92500	10283	GX2 Cr Ni 19-11	1.4309	G 5121, Cl SCS 13A
		11972, GX2CrNiMo19-11-2	A 743 Gr CF3M	J92800	10283	GX2 Cr Ni Mo 19-11-2	1.4409	G 5121, Cl SCS 14A
	Wrought / forgings	9327-5, XCrNi18-10	A 182 Gr F 304L	S30403	10222-5	X2 Cr Ni 19-11	1.4306	G 3214, Gr. SUS F 304 L
		9327-5, XCrNiMo17-12	A 182 Gr F 316L	S31603	10222-5 10250-4	X2 Cr Ni Mo 17-12-2	1.4404	G 3214, Gr. SUS F 316 L
	Bar stock [e]	9327-5, X2CrNi18-10 9327-5, X2CrNiMo17-12	A 479 Type 304L A 479 Type 316L A 479 Type 317 A 479 Type XM19	S30403 S31603 S31700 S20910	10088-3 10088-3 10088-3	X2 Cr Ni 19-11 X2 Cr Ni Mo 17-12-2 X2 Cr Ni Mo 18-15-4	1.4306 1.4404 1.4361	G 4303, Gr. SUS 304 L G 4303, Gr. SUS 316 L
			A 240 Type XM19	S20910				
	Plate		A 240 Gr 304L / 316L	S30403 S31603	10028-7 10028-7	X2 Cr Ni 19-11 X2 Cr Ni Mo 17-12-2	1.4306 1.4404	G 4304/4305, Gr. SUS 304L/316L
	Pipe	9329-4, X2CrNi18-10, 9329-4, X2CrNiMo17-13,	A 312 Type 304L 316L	S30403 S31603				G 3459, Gr. SUS 304LTP/316LTP

Table A.1 — (*continued*)

Material class	Applications	International ISO	USA ASTM	USA UNS [a]	EN [b]	Europe Name	Europe Number	Japan JIS
Austenitic stainless steel (cont.)	Fittings	9327-5, X2CrNi18-10 9327-5, X2CrNiMo17-12	A 182 Gr F304L, Gr 316L	S30403 S31603	10222-5	X2 Cr Ni 19-11 X2 Cr Ni Mo 17-12-2	1.4306 1.4404	G 3214, Gr. SUS F304L/F316L
	Bolts and studs	3506-1, A4-70	A 193 Gr B8M	S31600	10250-4	X6 Cr Ni Mo Ti 17-12-2	1.4571	G 4303, Gr. SUS 316
	Nuts	3506-2, A4-70	A 194 Gr B8M	S31600	10250-4	X6 Cr Ni Mo Ti 17-12-2	1.4571	G 4303, Gr. SUS 316
Precipitation-hardened stainless steel	Pressure forgings		A 705 ("15-5 PH") A 705 ("17-4 PH")	S 15500 S 17400				
Duplex stainless steel	Pressure castings	11972, GX2CrNiCuMoN 26 5 3 3	A 351 Gr CD4 MCu A 890 Gr 1 B	J93370 J93372	10213-4	GX2 CrNiMoCuN 25-6-3-3	1.4517	
		11972, GX2CrNiMoN 26 5 3	A 890 Gr 3A [c]	J93371	10213-4	GX2 CrNiMoN 26-7-4	1.4469	G 5121, Gr. SCS 11
			A 890 Gr 4A [c]	J92205	10213-4	GX2 CrNiMoN 22-5-3	1.4470	G 5121, Gr. SCS 10
	Wrought / forgings	9327-5, X2CrNiMoN22-5-3	A 182 Gr F 51	S31803	10250-4 10222-5	X2 Cr Ni Mo N 22-5-3	1.4462	G 4319, Cl SUS 329J1FB
			A 479	S32550	10088-3	X2 Cr Ni Mo Cu N 25-6-3	1.4507	
	Bar stock	9327-5, X2CrNiMoN22-5-3	A 276-S31803	S31803	10088-3	X2 Cr Ni Mo N 22-5-3	1.4462	G 4303, Gr. SUS 329J3L
	Plate		A 240-S31803	S31803	10028-7	X2 Cr Ni Mo N 22-5-3	1.4462	G 4304/G 4305, Gr. SUS 329J3L
	Pipe		A 790-S31803	S31803				G 3459, Gr. SUS 329J3LTP
	Fittings	9327-5, X2CrNiMoN22-5-3	A 182 Gr F 51	S31803	10250-4 10222-5	X2 Cr Ni Mo N 22-5-3	1.4462	B 2312/B 2316 Gr. SUS329J3L

Table A.1 — (*continued*)

Material class	Applications	International	USA		Europe			Japan
		ISO	ASTM	UNS [a]	EN [b]	Name	Number	JIS
Duplex stainless steel (cont.)	Bolts and studs	9327-5, X2CrNiMoN22-5-3	A 276-S31803	S31803	10088-3	X2 Cr Ni Mo N 22-5-3	1.4462	G 4303, Gr. SUS 329J3L
	Nuts	9327-5, X2CrNiMoN22-5-3	A 276-S31803	S31803	10088-3	X2 Cr Ni Mo N 22-5-3	1.4462	G 4303, Gr. SUS 329J3L
Super duplex stainless steel [f]	Pressure castings		A 351 Gr CD3MWCuN	J93380				
			A 890 Gr 5A	J93404	10213-4	GX2 Cr Ni Mo N 26-7-4	1.4469	
			A 890 Gr 6A	J93380				
	Wrought / forgings		A 182 Gr 55	S32760	10250-4 10088-3	X2 Cr Ni Mo Cu WN 25-7-4	1.4501	
	Bar stock		A 276-S32760 A 479-S32760	S32760	10088-3	X2 Cr Ni Mo Cu WN 25-7-4	1.4501	G 4303, Gr. SUS 329J4L
	Plate		A 240-S32760	S32760	10028-7	X2 Cr Ni Mo Cu WN 25-7-4	1.4501	G 4304/G 4305, Gr. SUS 329J4L
	Pipe		A 790-S32760	S32760				G 3459, Gr. SUS 329 J4LTP
	Fittings		A 182 Gr F55	S32760	10250-4 10088-3	X2 Cr Ni Mo Cu WN 25-7-4	1.4501	B 2312/B 2316 Gr. SUS329J4L
	Bolts and studs		A 276-S32760	S32760	10088-3	X2 Cr Ni Mo Cu WN 25-7-4	1.4501	G 4303, Gr. SUS 329J4L
	Nuts		A 276-S32760	S32760	10088-3	X2 Cr Ni Mo Cu WN 25-7-4	1.4501	G 4303, Gr. SUS 329J4L

Table A.1 — (*continued*)

Material class	Applications	International ISO	USA ASTM	USA UNS [a]	Europe EN [b]	Europe Name	Europe Number	Japan JIS
Admiralty metal	Tubes		B 111-C44300	C44300	12451	CuZn28Sn1As	CW706R	
Monel	Wrought / forgings	9725, NiCu30 - NW4400	B 164 B 564	N04400 N04400				
K-Monel		9725, NiCu30Al3Ti						
Inconel 625		9725, NiCr22Mo9Nb - NW6625	B 446	N06625	10095	NiCr22Mo9Nb	2.4856	
Inconel 718		9725, NiCr19Fe19Nb5Mo3 - NW7718		N07718				

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

b Where EN standards do not yet exist, there are available European national standards, e.g. AFNOR, BS, DIN, etc.

c Do not use for shafts in the hardened condition (over 302 HBW).

d Special, normally use AISI 4140.

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

f Super duplex stainless steel classified with Pitting Resistance Equivalent Number (PREN) greater than or equal to 40. A typical empirical formula for PREN is given below:

PREN = [(%Chromium - (14,5 × %Carbon)] + (3,3 × %Molybdenum) + (2 × %Copper) + (2 × %Tungsten) + (16 × %Nitrogen)

Annex B
(normative)

Vendor drawing and data requirements (VDDR) form

The VDDR form is given in Table B.1.

Table B.1 — VDDR form

CONTRACT START DATE:

DOCUMENT	DRAWING NUMBER	FIRST ISSUE	INCLUDED IN MAIN-TENANCE MANUAL	INCLUDED IN DATA BOOK	COPIES FOR REVIEW	COPIES FINAL	FORMAT
VDDR Form			N	N			
Quality plan			N	N			
Quality manual			N	N			
Production programme			N	N			
Status report			N	N			
Index of operation and maintenance manual			Y	N			
Index of installation manual			N	N			
Index of data book			N	Y			
General arrangement drawing			Y	N			
Out-of-balance forces and moments			O	N			
Pump cross-sectional drawings			Y	N			
Pump data sheet			Y	Y			
Pump lube oil piping and instrumentation diagram (P & ID)			O	N			
Stuffing box lube oil P & ID			O	N			
Stuffing box quench P & ID			O	N			
Stuffing box leakage header P & ID			O	N			
Cooling water P & ID			O	N			
Special installation instructions			Y	N			
Bill(s) of material			Y	N			
Motor general arrangement drawing			Y	N			
Motor data sheet			Y	Y			
VSD pump/motor torque curves			N	Y			
Motor(s) hazardous area certification			N	Y			
Motor(s) protection certificate			N	O			
Motor(s) type test certificate			N	O			
Motor(s) works test certificate			N	O			
Inverter general arrangement drawing			Y	N			
Inverter data sheet			Y	N			
Inverter hook-up diagram			Y	N			
Inverter component checklist			N	Y			
Inverter continuity/integrity certificate			N	O			
Inverter insulation certificate			N	O			
Inverter short-circuit certificate			N	O			
Inverter no load test with motor certificate			N	O			
Inverter 24-h full load test certificate			N	O			
Inverter control function certificate			N	O			
Gearbox general arrangement drawing			Y	N			
Gearbox cross-sectional drawings			Y	N			
Gearbox bill(s) of material			Y	N			
Coupling drawings			O	N			
Utilities consumption list			O	N			
Lube oil schedule			Y	N			
Control logic			Y	N			
Instrument schedule(s)			O	O			
Instrument wiring diagram			Y	N			
Instrument(s) hazardous area certification			N	Y			
Instrument(s) protection certificate			N	O			
Instrument(s) calibration certificate			N	Y			
Hydrotest procedure			N	O			

Table B.1 — (*continued*)

DOCUMENT	DRAWING NUMBER	FIRST ISSUE	INCLUDED IN MAIN-TENANCE MANUAL	INCLUDED IN DATA BOOK	COPIES FOR REVIEW	COPIES FINAL	FORMAT
Performance test procedure			N	O			
NPSH Test procedure			N	O			
Mechanical run test procedure			N	O			
Endurance run test procedure			N	O			
String test procedure			N	O			
Pressure-limiting valve test procedure			N	N			
Pulsation measurement test procedure			N	N			
Vibration survey procedure			N	N			
Noise survey procedure			N	O			
Functional test procedure			N	Y			
Liquid penetrant inspection procedure			N	O			
Magnetic particle inspection procedure			N	O			
Radiography inspection procedure			N	O			
Weld procedure			N	O			
Welder qualifications			N	O			
Paint procedure			N	O			
Storage/preservation procedure			Y	N			
Commissioning spares quotation			N	N			
1-year operation spares quotation			N	N			
2-year operating spares quotation			N	N			
List of special tools supplied			Y	N			
Certificate of conformity			N	Y			
Certificate of mechanical properties			N	Y			
Certificate of chemical analysis			N	Y			
Certificate of hardness			N	O			
Liquid penetrant inspection certificate			N	O			
Magnetic particle inspection certificate			N	O			
Radiography inspection certificate			N	O			
Hydrotest certificates			N	Y			
Mechanical run test certificate			N	Y			
Performance test certificate			N	Y			
NPIP test certificate			N	Y			
String test certificate			N	Y			
Endurance test certificate			N	O			
Pressure-limiting valve test certificate			N	O			
Pulsation test certificate			N	O			
Vibration survey certificate			N	O			
Noise survey certificate			N	O			
Certificate of paint thickness			N	O			
Certificate of cleanliness			N	O			
Instrumentation wiring certification			N	O			
Functional test certificate			N	Y			
Weight schedule			N	Y			
Release certificate			N	Y			
Installation, operation and maintenance manual							
Data book							

Y = Yes, item typically included.
N = No, item typically not included.
O = Optional, included if specified by purchaser.

Annex C
(normative)

Pulsation and vibration control techniques

C.1 Design analysis methods — General

If the purchaser has specified design analysis (see 7.7.2), one of the following methods shall be used

a) Method 1 (see C.2);

b) Method 2 (see C.3).

Methods 1 and 2 might not give sufficient accuracy when the following conditions apply:

— long inlet lines;

— inlet flow velocities below 0,3 m/s (1 ft/s) or above 3 m/s (10 ft/s);

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

— the service has a critical hazard condition.

For these conditions, if specified by the purchaser, the forced vibration analysis techniques as specified in ISO 13707 shall be applied.

NOTE 1 For the purposes of this provision, API Std 618 is equivalent to ISO 13707.

NOTE 2 Cavitation problems in pump systems are significantly influenced by pulsations; therefore, suction-head assessment based on acceleration-head calculations (which is a quasi-static method of considering pulsations in piping systems) might not ensure adequate NPIP.

C.2 Analysis Method 1

C.2.1 The analytical study shall include the design of a pump pulsation suppression device, using proprietary and/or empirical analytical techniques to meet the pulsation levels specified in C.5 to C.7, together with good piping layout, using good support/restraint principles and adequate NPIP.

C.2.2 The analytical study should also include a simplified analysis of the purchaser's piping system by the purchaser, with frequency data from the supplier, to determine critical piping lengths that may be in resonance with the acoustical excitation frequencies.

C.3 Analysis Method 2 (acoustical simulation)

C.3.1 General

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 vibrational response. The following should be considered.

a) Calculation of peak-to-peak pulsation levels

Operating conditions and pump pressure steps are chosen to yield the highest expected pulsation amplitudes throughout the piping system. Pulsation amplitudes are then compared to the levels identified in C.4.

b) Calculation of pulsation-induced shaking forces (unbalanced forces)

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, can be predicted.

c) 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/pr piping systems will be made and the analysis continued until the system meets the guidelines defined in C.4 or other criteria as agreed upon by the purchaser and vendor.

C.3.2 Mechanical review and piping restraint analysis

A simple mechanical review shall be performed using span and vessel mechanical natural-frequency calculations to avoid mechanical resonance. This review shall result in a table of various pipe sizes that indicates the maximum allowable span (based on the maximum pump operating speed) between piping supports as a function of pipe diameter, and the separation margin requirements of C.7.

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

C.4 Maximum allowable pulsation levels

For Analysis Methods 1 and 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 (C.1) [Equation (C.2)] which specifies the allowable peak-to-peak pulsation level of each individual pulsation frequency component. Suction and discharge pulsation levels also shall be limited to values that will not cause cavitation or pressure-limiting valve-lifting.

In SI units:

$$p_1 = \frac{3\,500}{(d_\mathrm{i} \times f)^{0,5}} \qquad \text{(C.1)}$$

In US Customary (USC) units:

$$p_1 = \frac{100}{(d_\mathrm{i} \times f)^{0,5}} \qquad \text{(C.2)}$$

where

p_1 is the maximum allowable peak-to-peak pulsation level of individual pulsation frequency components, expressed in kilopascals (pounds force per square inch);

d_i is the inside diameter of line pipe, expressed in millimetres (inches);

f is the pulsation frequency derived from the following equation, expressed in hertz.

$$f = \frac{n_x}{60} \quad \text{(C.3)}$$

where

n is the pump rotational speed, expressed in revolutions per minute;

x = 1, 2, 3 …, corresponding to the fundamental frequency and harmonics of the pump speed.

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

C.5 Inlet pressure versus liquid vapour pressure

Unless otherwise specified, the minimum value (absolute) of the suction complex pressure wave, p_{min}, at the inlet reference point shall be at least 10 % higher than the highest (absolute) liquid vapour pressure, $p_{\text{v,max}}$, as shown in Equation (C.4) (see Figure C.1).

$$p_{\text{min}} \geqslant 1{,}1 \times p_{\text{v,max}} \quad \text{(C.4)}$$

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

NOTE 1 The theoretical maximum amplitude of the suction pulsation occurs when the negative peak of the pulsation complex wave equals the average suction pressure minus the vapour pressure. Equation (C.4) provides for a margin of safety between the negative peak of pulsation and vapour pressure.

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

C.6 Pressure-limiting valve protection

Unless otherwise specified, the margin of separation between the positive peak of the pulsation complex wave at the pressure-limiting valve and the pressure-limiting valve setting shall be 5 % of the maximum specified discharge pressure or 165 kPa (1,65 bar) (25 psi), whichever is greater (see Figure C.2).

The positive peak of pulsation, p_{p}, shall be less than the value determined by Equation (C.5) or 165 kPa (25 psi), whichever is greater.

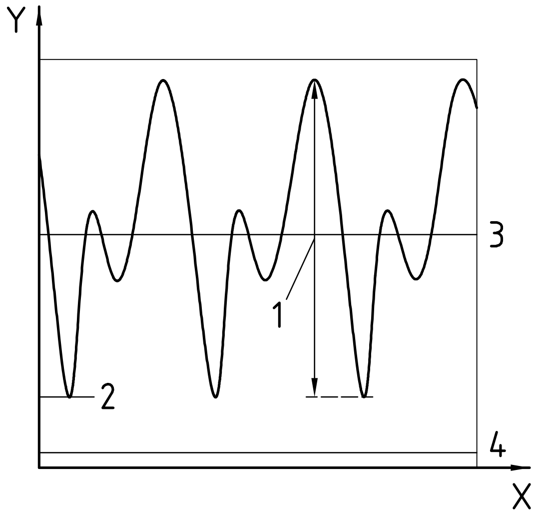
$$p_{\text{p}} < p_{\text{rv}} - p_{\text{d}} - (0{,}05 \times p_{\text{d}}) \quad \text{(C.5)}$$

where

p_{p} is the positive peak of pulsation complex wave, expressed in kilopascals (pounds force per square inch);

p_{d} is the maximum specified value of average discharge gauge pressure, expressed in kilopascals (pounds force per square inch);

p_{rv} is the required pressure-limiting valve setting gauge pressure, expressed in kilopascals (pounds force per square inch).



Key

X time, t

Y pressure, p

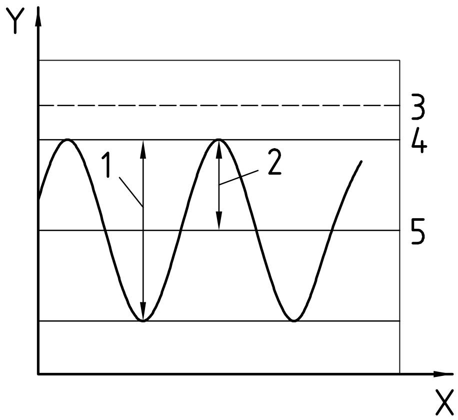
1 pulsation

2 negative peak of pulsation, p_{min}

3 average absolute suction pressure

4 highest absolute liquid vapour pressure, p_{vmax}

Figure C.1 — Suction complex pressure wave



Key

X time, t

Y pressure, p

1 pulsation

2 positive peak of pulsation

3 pressure-limiting valve set pressure, p_{rv}

4 pressure at positive peak of pulsation, p_p

5 average absolute discharge pressure, p_d (maximum specified value)

Figure C.2 — Discharge pressure pulsations

C.7 Separation margin requirements for piping systems

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

a) The minimum mechanical natural frequency of any manifold or pipe system element shall be designed to be at least 20 % above the significant frequency of the unbalanced forces and cylinder stretching loads (rotational speed multiplied by number of cylinders) plus the inertial loads at one and two times the rotational speed. 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. If the minimum mechanical natural frequency guideline is not met, or when there is significant excitation energy at higher orders, the separation margins as defined in b) shall be maintained.

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

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

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

Annex D
(informative)

Reciprocating positive-displacement pump data sheets

ITEM NO.	PURCHASER	
	PURCHASER REF	
	SERVICE	
	SITE/LOCATION	
	PUMP TYPE	
NO. OF PUMPS RUNNING		NO. OF PUMPS STANDBY
DRIVER FOR RUNNING PUMPS		DRIVER FOR STANDBY PUMPS
BASEPLATE/SKID/TRAILER (7.4.1.1)		BASEPLATE/TRAILER/SKID (7.4.1.1)

LIQUID PROPERTIES (6.3.3)

LIQUID DENSITY SPECIFIC HEAT CAPACITY pH CORROSIVE Y/N (6.11.1.7) (IF "Y", GIVE VALUES ON NEXT SHEET) ABRASIVE Y/N ALLOWABLE LEAKAGE RATE TO ATMOSPHERE AT RATED OPERATING CONDITIONS
SOLIDS DENSITY HARDNESS MASS FRACTION FRIABLE Y/N SETTLING VELOCITY MAXIMUM PARTICLE SIZE

NORMAL OPERATING CONDITIONS FOR EACH PUMP (6.1.3)

	UNITS	RATED CONDITIONS	MAXIMUM	MINIMUM
FLOW [a] (3.36)				
OUTLET PRESSURE				
INLET PRESSURE				
DIFFERENTIAL PRESSURE.				
INLET LIQUID TEMPERATURE				
VAPOUR PRESSURE				
VISCOSITY				
COMPRESSIBILITY				
NPIPA / NPSH[b] (3.17)				
INLET P & ID SUPPLIED Y / N				
[a] For compressible liquids, outlet flow will be less than inlet flow.				
[b] At underside of baseplate.				

DUTY

CONTINUOUS	LIGHT	INTERMITTENT	CYCLIC	IRREGULAR
8 / 24 h/DAY	3 / 8 h/DAY	0 / 3 h/DAY	DESCRIBE	DESCRIBE
DESCRIPTION				

AUXILIARIES

PRESSURE-LIMITING VALVE DATA:	SET PRESSURE:	ACCUMULATION PRESSURE:
UNITS		
THERMAL VALVE (7.5.4.7.4) Y / N		
FLUSH (6.7.5.6) Y / N		
LEAKAGE CONTAINMENT (6.7.5.9) Y / N		
PURGE (6.7.5.10) Y / N		
PROCESS CONNECTION REVIEW (6.5.2) Y / N		
PULSATION SUPPRESSION	RESIDUAL INLET PRESSURE PULSATIONS +/–%	
OUTLET PIPE BORE × LENGTH	RESIDUAL OUTLET PRESSURE PULSATIONS +/–%	
PULSATION DESIGN ANALYSIS (7.7.2)		
COOLING SYSTEM FLUID DESIGN PRESSURE TEMPERATURE	HEATING SYSTEM FLUID DESIGN PRESSURE TEMPERATURE	

POWER END

SPECIFICATIONS (6.8.1)	6.8.1 a) 6.8.1 b) 6.8.1 c) 6.8.1d)
OIL HEATER (6.8.9)	Y / N
LUBRICATION TYPE (6.10.1.2)	SPLASH/POSITIVE-PRESSURE/GRAVITY
LUBRICANT APPROVAL (6.10.1.7) (6.10.1.8)	Y /N

DRIVE

MOTOR / ENGINE / HYDRAULIC	
MOTOR (7.1.2.2)	MOTOR STARTING (S-D/DOL/etc.) (7.5.2.3)
PUMP STARTING (ON LOAD/BY-PASS)	NO. OF PUMPS RUNNING ON THIS INLET PIPE
GEAR STANDARD (7.1.4.2)	NON-SPARKING GUARDS [7.2.8 c)]
BELT SPECIFICATION (7.3.1)	FLANGE SPECIFICATION (6.5.11.3)

MOUNTING

MOUNTING PLATE	(7.4.1.3) Y / N	(7.4.2.1) Y / N	(7.4.2.3) Y / N	(7.4.2.4) Y / N
	(7.4.3.1) Y / N	(7.4.3.2) Y / N		

INSTRUMENTS AND ALARMS

INSTRUMENTS	(7.5.3.1) Y / N			
ALARMS	(7.5.5.2) Y / N	(7.5.5.4) Y / N	(7.5.5.5) Y / N	

MATERIALS

NO COPPER	(6.11.1.3) Y / N	(6.11.1.7) Y / N		
IMPACT TESTING	(6.11.5.3) Y / N			
WELD NOTIFICATION	(6.11.4.3) Y / N	(6.11.4.4) Y / N	(6.11.4.5) Y / N	

PURCHASER MATERIAL RECOMMENDATIONS

Metallic materials in contact with liquid:
state corrosion rate [mm/year]
a) ______________________________
b) ______________________________
c) ______________________________
d) ______________________________
e) ______________________________
Non-metallic materials in contact with liquid:
f) ______________________________
g) ______________________________
h) ______________________________
j) ______________________________
k) ______________________________

Materials not allowed in contact with liquid:
m) ______________________________
n) ______________________________
o) ______________________________
p) ______________________________
q) ______________________________
r) ______________________________
s) ______________________________
t) ______________________________
u) ______________________________
v) ______________________________
w) ______________________________

MISCELLANEOUS

INSPECTION	(8.1.1) Y / N	(8.1.2) Y / N	(8.1.6) Y / N	(8.2.1.1) Y / N
	(8.2.1.3) Y / N	(8.2.3.3) Y / N	(8.3.1.2) Y / N	(8.3.5) Y / N
SHIPPING	(8.4.8) Y / N			
PROGRESS	(9.3.3) Y / N			
MANUAL	(9.3.5.4) Y / N			

APPLICABLE STANDARDS, CERTIFICATION AND TESTING REQUIREMENTS

____
____
____
____
____

SITE CONDITIONS

INDOOR/OUTDOOR/ONSHORE/OFFSHORE	CONCRETE/STRUCTURAL STEEL FOUNDATIONS
ATTENDED/UNATTENDED	
ATMOSPHERIC POLLUTION	MAINTENANCE INTERVAL
SPECIAL PRECAUTIONS	MAX/MIN TEMPERATURE (6.11.5.1)
TARGET SOUND PRESSURE LEVEL (6.1.5) dBA	BLACK-BULB TEMPERATURE
COOLING WATER	HUMIDITY
COMPRESSED AIR	ALTITUDE
STEAM	WATER AVAILABLE FOR QUENCH/FLUSH Y/N
ELECTRICAL SUPPLIES	UNITS FOR NAMEPLATES
ELECTRICAL AREA CLASSIFICATION	
ELECTRICAL EQUIPMENT PHYSICAL PROTECTION	

COMMENTS

____
____
____
____
____

HAZARD ANALYSIS

PERSONNEL HAZARDS

- ❑ Intoxicating by inhalation
- ❑ Intoxicating in contact with skin
- ❑ Intoxicating if swallowed
- ❑ Harmful by inhalation
- ❑ Harmful in contact with skin
- ❑ Harmful if swallowed
- ❑ Toxic by inhalation
- ❑ Toxic in contact with skin
- ❑ Toxic if swallowed
- ❑ Very toxic by inhalation
- ❑ Very toxic in contact with skin
- ❑ Very toxic if swallowed
- ❑ Contact with water liberates toxic gas
- ❑ Contact with acids liberates toxic gas
- ❑ Contact with acids liberates very toxic gas
- ❑ Harmful/toxic by inhalation when smoking
- ❑ Danger of harmful reaction with clothing
- ❑ Danger of cumulative effects
- ❑ Causes burns
- ❑ Causes severe burns
- ❑ Irritating to eyes
- ❑ Irritating to respiratory system
- ❑ Irritating to skin
- ❑ Danger of very serious irreversible effects
- ❑ Possible risk of irreversible effects
- ❑ Risk of serious damage to eyes
- ❑ May cause sensitization by inhalation
- ❑ May cause sensitization by skin contact
- ❑ May cause cancer
- ❑ May cause heritable genetic damage
- ❑ May cause birth defects
- ❑ Danger of serious damage to health by prolonged exposure

GENERAL HAZARDS

- ❑ Explosive when dry
- ❑ Risk of explosion by shock, friction, fire or other sources of ignition
- ❑ Extreme risk of explosion by shock, friction, fire or other sources of ignition
- ❑ Forms very sensitive explosive compounds
- ❑ Heating may cause an explosion
- ❑ Explosive with or without contact with air
- ❑ May cause fire
- ❑ Contact with combustible material may cause fire
- ❑ Explosive when mixed with combustible material
- ❑ Flammable
- ❑ Highly flammable
- ❑ Extremely flammable
- ❑ Low ignition temperature °C (°F)
- ❑ Reacts violently with water
- ❑ Contact with water liberates highly flammable gases
- ❑ Explosive when mixed with oxidizing substances
- ❑ Spontaneously flammable in air
- ❑ May cause flammable/explosive vapour-air mixture
- ❑ May form explosive peroxides
- ❑ Can become highly flammable in use
- ❑ Risk of explosion if heated when confined
- ❑ Risk from static electricity

PUMP/PERFORMANCE HAZARDS

- ❑ Corrodes cast iron
- ❑ May crystallize on contact with air
- ❑ May crystallize on cold surfaces, < °C (°F)
- ❑ May crystallize at low velocity, < m/s (ft/s)
- ❑ May solidify on contact with air
- ❑ May deposit wax on cold surfaces, < °C (°F)
- ❑ May deposit wax at low velocity, < m/s (ft/s)
- ❑ May deposit solids at low velocity, < m/s (ft/s)
- ❑ Contains dissolved gas, volume fraction %
- ❑ Contains entrained gas, volume fraction %
- ❑ Gas evolves at absolute pressures below kPa (bar) (psi)
- ❑ Good solvent for petroleum-based lubricants
- ❑ Excellent solvent for petroleum-based lubricants
- ❑ Mixture emulsifies at high velocity, > m/s (ft/s)
- ❑ Liquid is pseudoplastic
- ❑ Liquid is dilitant
- ❑ Liquid is thixotropic
- ❑ Liquid is rheopectic
- ❑ Liquid is Bingham plastic
- ❑ Liquid may not be contaminated with hydrocarbon-based lubricants
- ❑ Liquid may not be contaminated with water
- ❑ Lubricants shall be food quality
- ❑ Pump will be cleaned with steam °C (°F)
- ❑ Pump will be cleaned with chemicals/solvents
- ❑ Especially consider explosive decompression

Annex E
(informative)

NPIP and NPSH

E.1 General

Because centrifugal pumps and positive-displacement pumps operate on entirely different principles, common usage has created two different ways to identify the pressures associated with them. In its simplest form, a centrifugal pump is a velocity generator, whereas the positive-displacement pump is a flow generator.

In the case of the centrifugal pump, the liquid to be pumped is directed into the centre of a rotating impeller where it is guided by the impeller vanes and accelerated to a higher velocity. The casing surrounding the impeller then converts the high velocity into pressure. Because it is a velocity generator, if pressure is measured in units of liquid length, all units of measure become consistent. Velocity is measured in metres/second (feet/second) and discharge pressure is measured in metres (feet) of liquid, i.e. the pressure created by the height of a column of the liquid being pumped. This consistent use of units greatly simplifies pump calculations and allows the effects of certain liquid properties (e.g. relative density) to be ignored. For a centrifugal pump, the discharge pressure developed is a function of flow through the pump impeller. With decreasing flow (as in the case of increased system resistance), the centrifugal pump develops an ever-increasing pressure up to the point defined as the shutoff head at zero flow. Shutoff head is normally the maximum pressure rise that a centrifugal pump can develop, but there are instances when the shutoff head is less than the maximum head generated by the pump.

By contrast, a positive-displacement pump does not generate energy solely by increasing fluid velocity. Instead these pumps convert rotary motion and torque into constant linear fluid motion and force, generating a fixed flow rate at the discharge connection. Positive-displacement pumps have no theoretical discharge pressure limitation. They respond solely to the pumping system, and require system discharge control, usually in the form of a pressure-limiting valve, to prevent damage to the pump mechanism, the pumping system and/or stalling of the driver. For a positive-displacement pump, flow is a function of pump stroke and/or rotational speed.

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

E.2 Calculation of NPIPA

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

$$\text{NPIPA} = p_\text{a} + p_\text{z} - p_\text{f} - p_\text{vp} - p_\text{ha} \quad \text{(E.1)}$$

where

p_a is the absolute pressure at surface of liquid, expressed in kilopascals (pounds force per square inch);

p_z is the static head (+) or static lift (–), expressed in kilopascals (pounds force per square inch), for level of fluid above or below inlet;

p_f is the inlet line, valve, and fitting friction losses at maximum viscosity, expressed in kilopascals (pounds force per square inch);

p_{vp} is the fluid vapour pressure or gas dissolution pressure, expressed in kilopascals (pounds force per square inch);

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

E.3 Calculation of acceleration head

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

$$p_{ha} = \frac{l \cdot v \cdot n \cdot C}{K \cdot g} \qquad \text{(E.2)}$$

where:

p_{ha} is the acceleration head, expressed in metres (feet);

l is the length of suction line, expressed in metres (feet);

v is the velocity in suction line, expressed in metres per second (feet per second);

n is the pump speed, expressed in revolutions per minute;

C is a constant, as follows:

0,400 for simplex single-acting;

0,200 for simplex double-acting;

0,200 for duplex single-acting;

0,115 for duplex double-acting;

0,066 for triplex single- or double-acting;

0,040 for quintuplex single- or double-acting;

0,028 for septuplex single- or double-acting;

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

1,4 for hot water;

2,5 for hot oil;

g is the acceleration due to gravity [9,81 m/s^2 (32,2 ft/s^2)].

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

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

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

E.4 Effect of impedance on acceleration

The resistance of the flow rate of a liquid column to accelerate and decelerate is called impedance. A positive-displacement pump moves a discrete volume of liquid with each stroke of a pumping element (e.g. piston, plunger or diaphragm). The inlet liquid column has to reflect the requirement to start and stop flowing as an inlet valve opens and closes. With simplex and duplex pumps, the total flow in the inlet line has to start and stop, hence such designs are not frequently encountered.

With a multiplex pump there is always a minimum fluid velocity in the inlet column. The action of the valves causes the flow to speed up to a maximum and then slow down to the minimum in a series of waves. The amplitude of the velocity change is greatly reduced, but the frequency is increased. The higher frequencies are most affected by the impedance. The inlet column should be able to deliver sufficient flow volume to meet the amplitude requirement.

The discharge from a rotodynamic pump is characterised by a slow response to changes in demand. The discharge from a header tank is also slow to respond to velocity changes. Both of these, the normal sources of liquid for positive-displacement pumps, are high-impedance sources. Various devices are available to convert the high-impedance source to a low-impedance feed. Depending upon the installation, some are more effective than others.

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

In general, the purchaser may only be able to calculate the NPSH using rotodynamic rules, and will need to work together with the supplier to ensure that, when the pump is tested, the NPIP is adequate.

By limiting the maximum speed of the pump for a given stroke, the impedance requirement is limited. However this is only a general guideline. Long tortuous inlet columns with many bends, elbows and other fittings may dictate a larger pump running slower. A good impedance-matching device could allow the pump to run faster.

Excessive turbulence/out-gassing of the inlet column should be avoided. The piping elements most likely to cause this are tees and sharp elbows. Any merging or splitting of the inlet column should be via a Y-connection. Any change in direction should be via a long-radius bend.

To cater for amplitude, the inlet column should be capable of delivering sufficient free flow. For a triplex pump, the value of two times the rated flow is recommended. For simplex and duplex pumps, the factor should be considerably larger. For quintuplex pumps and above, the factor can be a little lower.

Annex F
(informative)

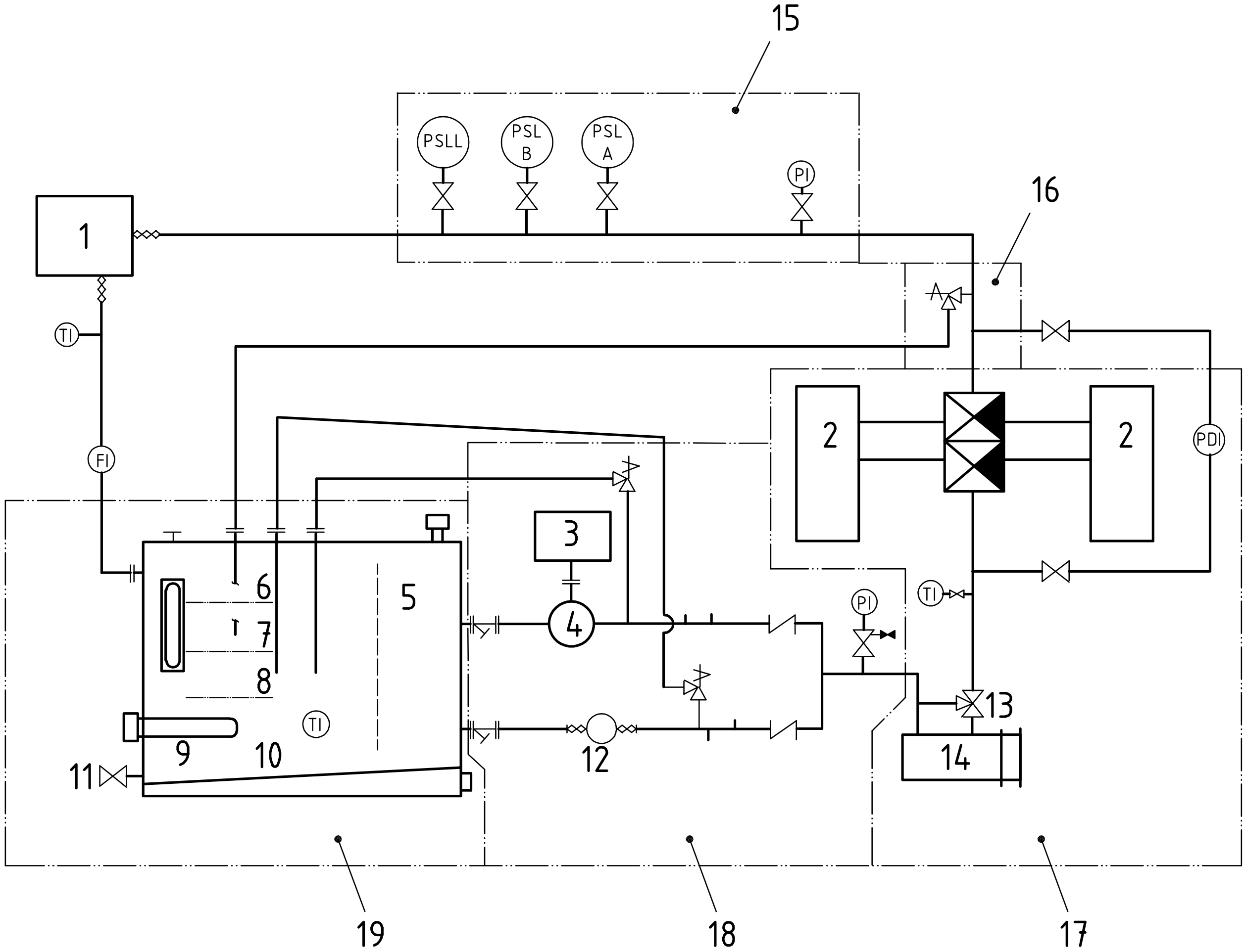
Inspector's checklist

No.	Item	ISO 13710 subclause number	Date inspected	Inspected by	Status
1	Cylinder liners	6.7.1			
2	Valve seats	6.7.3			
3	Material certification	6.11.1.2, 8.2.1.1 a)			
4	Non-destructive examination (components)	6.11.1.4			
5	Welding operators and procedures qualified	6.11.4.1			
6	Rotation arrow [a]	6.12.2			
7	Equipment nameplate data	6.12.4			
8	Overall dimensions and connection locations	[a]			
9	Nozzle flange dimensions	6.5.11			
10	Anchor bolt layout and size	7.4.3.1 b)			
11	Shaft and keyway dimensions [a]	7.2.2			
12	Mounting plate precoat for epoxy grout	7.4.1.6			
13	Equipment feet pilot holes	6.1.19			
14	Pressure-limiting valve characteristics	7.5.4.7			
15	Piping inspection	7.6			
16	Pulsation control devices	7.7.1			
17	Special tools [a]	7.8			
18	Certified performance data	8.3.3, 8.3.4			
19	Maintenance and clearance	8.2.1.1 d)			
20	Components inspected for cleanliness (list each)	8.2.3.3			
21	Hardness testing	8.2.3.4			
22	Hydrostatic tests	8.3.2			
23	Performance test, direct acting pump	8.3.3			
24	Performance test, power pump	8.3.4			
25	NPIP/NPSH test	8.3.6			
26	Preparation for shipment	8.4			
27	Painting	8.4.3 a)			
28	Shipping documents and tags	8.4.3 h)			
29	Bearing assembly protection	8.4.5			
[a] Check against certified dimensional outline drawing.					

Annex G
(normative)

Lubrication system

Figure G.1 presents a typical lubricating oil system schematic, for which details are given in Table G.1.



Key

1 rotating equipment
2 filter
3 electric motor
4 pump
5 internal baffle
6 maximum operating level
7 minimum operating level
8 pump suction level
9 heater (optional)
10 sloped bottom
11 drain
12 shaft-driven oil pump with integral pressure relief
13 TCV (optional)
14 cooler
15 Combination of ISO 10438-3:2003, Figures A.1 and A.3
16 ISO 10438-3:2003, Figure A.5
17 ISO 10438-3:2003, Figure A.4
18 ISO 10438-3:2003, Figure A.3
19 ISO 10438-3:2003, Figure A.2
FI flow indicator
PDI pressure differential indicator
PI pressure indicator
PSL pressure switch low
PSLL pressure switch low-low
TI temperature indicator

NOTE See also Table G.1. The modules are further described in ISO 10438-3

Figure G.1 — Lubricating oil system schematic

Table G.1 — Lubricating oil system details

ISO 10438-3:2003 reference	Note/Option[a]	Comments
Figure A.1 Minimum requirements for general-purpose oil systems	Add	TI, FI on oil return lines from pump (and driver)
Figure A.2 Reservoir	Option 1	A level switch is not required
	Option 2	A temperature indicator with thermowell is required
	Option 3	An electric immersion or steam heater is optional
	Option 4	Additional connections are required for 1. Shaft-driven oil pump relief valve return (not required with integral relief valve) 2. Motor-driven oil pump relief valve return (not required with integral relief valve) 3. System PCV return 4. Auxiliary oil pump to have independent suction with strainer
	Option 5	One tapped grounding lug is required
	Option 6	Gauge glass may be armoured and extended
	Add	A vent (breather) with screen is required
	Add	The reservoir shall have a sloped bottom
	Add	A flanged drain connection with valve and blind at least DN 50 (NPS 2) in size shall be included
	Add	A level glass shall be provided in accordance with ISO 10438-3
	Add	The return line from the system PCV shall be located below the minimum operating oil level.
Figure A.3 Pumps	Option 1	A 100% capacity motor-driven auxiliary pump is required
	Option 2	Block valves are not required
	Option 3	A pre/post lubricating oil pump is not required
	Option 4	Pressure switches are required for low-pressure trip, alarm, and auxiliary pump start
	Option 5	The pressure transmitter is not required
	Add	The pressure switches shall be located in accordance with ISO 10438-3:2003, Figure A.5
Figure A.4 Pumps and coolers (and filters)	Option 1	One oil cooler is required
	Option 2	Duplex filters are required
	Option 3	A three-way constant temperature control valve with bypass line is optional
	Option 4	A two- or three-way variable temperature control valve with bypass line is not required
	Option 5	A temperature switch is required. Temperature switch is not represented in ISO 10438-3:2003, Figure A.5.
	Option 6	A single transfer valve with cooler and filter in parallel with separate TCV is not required. Valve is not represented in ISO 10438-3:2003, Figure A.5.
	Option 7	A pressure differential indicator is required
	Add	A single transfer valve for the duplex filters is required
	Add	The replaceable filter shall be in accordance with ISO 10438-3
Figure A.5 Pressure control	Option 1	A pressure regulator (relief valve) is required
	Option 2	A back-pressure control valve; direct-acting is not required
	Option 3	Block valves around the PCV/regulator are not required
	Option 4	A globe bypass valve is not required

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

Bibliography

[1] ISO 185, *Grey (lamellar graphite) cast iron — Classification*

[2] ISO 683-1, *Heat-treatable steels, alloy steels and free-cutting steels — Part 1: Direct-hardening unalloyed and low-alloyed wrought steel in form of different black products*

[3] ISO 683-18, *Heat-treatable steels, alloy steels and free-cutting steels — Part 18: Bright products of unalloyed and low alloy steels*

[4] ISO 1083, *Spheroidal graphite cast iron — Classification*

[5] ISO 2892, *Austenitic cast iron*

[6] ISO 3506-1, *Mechanical properties of corrosion-resistant stainless-steel fasteners — Part 1: Bolts, screws and studs*

[7] ISO 3506-2, *Mechanical properties of corrosion-resistant stainless-steel fasteners — Part 2: Nuts*

[8] ISO 4991, *Steel castings for pressure purposes*

[9] ISO 9327-2, *Steel forgings and rolled or forged bars for pressure purposes — Technical delivery conditions — Part 2: Non-alloy and alloy (Mo, Cr and CrMo) steels with specified elevated temperature properties*

[10] ISO 9327-4, *Steel forgings and rolled or forged bars for pressure purposes — Technical delivery conditions — Part 4: Weldable fine grain steels with high proof strength*

[11] ISO 9327-5, *Steel forgings and rolled or forged bars for pressure purposes — Technical delivery conditions — Part 5: Stainless steels*

[12] ISO 9328-4, *Steel flat products for pressure purposes — Technical delivery conditions — Part 4: Nickel-alloy steels with specified low temperature properties*

[13] ISO 9329-2, *Seamless steel tubes for pressure purposes — Technical delivery conditions — Part 2: Unalloyed and alloyed steels with specified elevated temperature properties*

[14] ISO 9329-4, *Seamless steel tubes for pressure purposes — Technical delivery conditions — Part 4: Austenitic stainless steels*

[15] ISO 9725, *Nickel and nickel alloy forgings*

[16] ISO 11972, *Corrosion-resistant cast steels for general applications*

[17] ISO 14120, *Safety of machinery — Guards — General requirements for the design and construction of fixed and movable guards*

[18] ISO 16330, *Reciprocating positive displacement pumps and pump units — Technical requirements*

[19] EN 953, *Safety of machinery — Guards — General requirements for the design and construction of fixed and movable guards*

[20] EN 1561, *Founding — Grey cast irons*

[21] EN 1563, *Founding — Spheroidal graphite cast irons*

[22] EN 10028-2, *Flat products made of steels for pressure purposes — Part 2: Non-alloy and alloy steels with specified elevated temperature properties.*

[23] EN 10028-3, *Flat products made of steels for pressure purposes — Part 3: Weldable fine grain steels, normalized*

[24] EN 10028-7, *Flat products made of steels for pressure purposes — Part 7: Stainless steels*

[25] EN 10083-1, *Quenched and tempered steels — Part 1: Technical delivery conditions for special steels*

[26] EN 10083-2, *Quenched and tempered steels — Part 2: Technical delivery conditions for unalloyed quality steels*

[27] EN 10088-2, *Stainless steels — Part 2: Technical delivery conditions for sheet/plate and strip for general purposes*

[28] EN 10088-3, *Stainless steels — Part 3: Technical delivery conditions for semi-finished products, bars, rods and sections for general purposes*

[29] EN 10095, *Heat resisting steels and nickel alloys*

[30] EN 10208-1, *Steel pipes for pipelines for combustible fluids — Technical Delivery Conditions — Part 1: Pipes of requirement class A*

[31] EN 10213-2, *Technical delivery conditions for steel castings for pressure purposes — Part 2: Steel grades for use at room temperature and elevated temperatures*

[32] EN 10213-3, *Technical delivery conditions for steel castings for pressure purposes — Part 2: Steels for use at low temperatures*

[33] EN 10213-4, *Technical delivery conditions for steel castings for pressure purposes — Part 4: Austenitic and austenitic-ferritic steel grades*

[34] EN 10222-2, *Steel forgings for pressure purposes — Part 2: Ferritic and martensitic steels with specified elevated temperature properties*

[35] EN 10222-5, *Steel forgings for pressure purposes — Part 5: Martensitic, austenitic and austenitic-ferritic stainless steels*

[36] EN 10250-4, *Open die steel forgings for general engineering purposes — Part 4: Stainless steels*

[37] EN 10269, *Steels and nickel alloys for fasteners with specified elevated and/or low temperature properties*

[38] EN 10272, *Stainless steel bars for pressure purposes*

[39] EN 10273, *Hot rolled weldable steel bars for pressure purposes with specified elevated temperature properties*

[40] EN 10283, *Corrosion resistant steel castings*

[41] EN 12451, *Copper and copper alloys — Seamless, round tubes for heat exchangers*

[42] EN 13835, *Founding — Austenitic cast irons*

[43] ABMA 9, *Load ratings and fatigue life for ball bearings*

[44] API Std 614, *Lubrication, shaft-sealing, and control-oil systems for special-purpose applications*

[45] API Std 618, *Reciprocating compressors for petroleum, chemical, and gas industry services*

[46] API Std 675, *Positive-displacement pumps — Controlled volume*

[47] API Std 676, *Positive-displacement pumps — Rotary*

[48] ASME B1.20.1, *Pipe threads, general purpose (inch)*

[49] ASME B15.1, *Safety standard for mechanical power transmission apparatus*

[50] ASME B31.3, *Process piping*

[51] ASTM A 48, *Standard specification for gray iron castings*[14)]

[52] ASTM A 105, *Standard specification for carbon steel forgings for piping applications*

[53] ASTM A 106, *Standard specification for seamless carbon steel pipe for high-temperature service*

[54] ASTM A 182, *Standard specification for forged or rolled alloy-steel pipe flanges, forged fittings, and valves and parts for high-temperature service*

[55] ASTM A 193, *Standard specification for alloy-steel and stainless steel bolting materials for high-temperature service*

[56] ASTM A 194, *Standard specification for carbon and alloy steel nuts for bolts for high-pressure or high-temperature service, or both*

[57] ASTM A 216, *Standard specification for steel castings, carbon, suitable for fusion welding, for high- temperature service.*

[58] ASTM A 217, *Standard specification for steel castings, martensitic stainless and alloy, for pressure-containing parts, suitable for high-temperature service.*

[59] ASTM A 240, *Standard specification for chromium and chromium-nickel stainless steel plate, sheet, and strip for pressure vessels and for general applications*

[60] ASTM A 266, *Standard specification for carbon steel forgings for pressure vessel components*

[61] ASTM A 276, *Standard specification for stainless steel bars and shapes*

[62] ASTM A 278, *Standard specification for gray iron castings for pressure-containing parts for temperatures up to 650 °F*

[63] ASTM A 307, *Standard specification for carbon steel bolts and studs, 60 000 psi tensile strength*

[64] ASTM A 312, *Standard specification for seamless and welded austenitic stainless steel pipes*

[65] ASTM A 320, *Standard specification for alloy-steel and stainless steel bolting materials for low-temperature service*

[66] ASTM A 351, *Standard specification for castings, austenitic, austenitic-ferritic (duplex), for pressure-containing parts*

[67] ASTM A 352, *Standard specification for steel castings, ferritic and martensitic, for pressure-containing parts, suitable for low-temperature service*

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14) American Society for Testing and Materials, 100 Barr Harbor Drive, West Conshohocken, PA 19428-2959, USA.

[68] ASTM A 434, *Standard specification for steel bars, alloy, hot-wrought or cold-finished, quenched and tempered*

[69] ASTM A 436, *Standard specification for austenitic gray iron castings*

[70] ASTM A 439, *Standard specification for austenitic ductile iron castings*

[71] ASTM A 473, *Standard specification for stainless steel forgings*

[72] ASTM A 479, *Standard specification for stainless steel bars and shapes for use in boilers and other pressure vessels*

[73] ASTM A 487, *Standard specification for steel castings suitable for pressure service*

[74] ASTM A 515, *Standard specification for pressure vessel plates, carbon steel, for intermediate- and higher-temperature service*

[75] ASTM A 516, *Standard specification for pressure vessel plates, carbon steel, for moderate- and lower-temperature service*

[76] ASTM A 536, *Standard specification for ductile iron castings*

[77] ASTM A 563, *Standard specification for carbon and alloy steel nuts*

[78] ASTM A 576, *Standard specification for steel bars, carbon, hot-wrought, special quality*

[79] ASTM A 582, *Standard specification for free-machining stainless steel bars*

[80] ASTM A 696, *Standard specification for steel bars, carbon, hot-wrought or cold-finished, special quality, for pressure piping components*

[81] ASTM A 743, *Standard specification for castings, iron-chromium, iron-chromium-nickel, corrosion resistant, for general application*

[82] ASTM A 705, *Standard specification for age-hardening stainless steel forgings*

[83] ASTM A 790, *Standard specification for seamless and welded ferritic/austenitic stainless steel pipe*

[84] ASTM A 890, *Standard specification for castings, iron-chromium-nickel-molybdenum corrosion-resistant, duplex (austenitic/ferritic) for general application*

[85] ASTM B 111, *Standard specification for copper and copper-alloy seamless condenser tubes and ferrule stock*

[86] ASTM B 164, *Standard specification for nickel-copper alloy rod, bar, and wire*

[87] ASTM B 446, *Standard specification for nickel-chromium-molybdenum-columbium alloy (UNS N06625), Nickel-chromium-molybdenum-silicon alloy (UNS N06219), and Nickel-chromium-molybdenum-tungsten alloy (UNS N06650)* rod and bar*

[88] ASTM B 564, *Standard specification for nickel alloy forgings*

[89] JIS B 2312, *Steel butt-welding pipe fittings*[15]

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15) Japanese Industrial Standards, 1-24 Akaska 4 Minato-Ku, Tokyo, Japan 107.

[90] JIS B 2316, *Steel socket-welding pipe fittings*

[91] JIS G 3106, *Rolled steels for welded structures*

[92] JIS G 3202, *Carbon steel forgings for pressure vessels*

[93] JIS G 3214, *Stainless steel forgings for pressure vessels*

[94] JIS G 3456, *Carbon steel pipes for high temperature service*

[95] JIS G 3459, *Stainless steel pipes*

[96] JIS G 4051, *Carbon steels for machine structural use*

[97] JIS G 4105, *Chromium molybdenum steels*

[98] JIS G 4107, *Alloy steel bolting materials for high temperature service*

[99] JIS G 4303, *Stainless steel bars*

[100] JIS G 4304, *Hot rolled stainless steel plates, sheets and strip*

[101] JIS G 4305, *Cold rolled stainless steel plates, sheets and strip*

[102] JIS G 5121, *Stainless steel castings*

[103] JIS G 5501, *Grey iron castings*

[104] JIS G 5151, *Steel castings for high temperature and high pressure service*

[105] NACE*, Corrosion Engineer's Reference Book*

[106] NFPA 30, *Flammable and combustible liquids code*

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