If venting to the atmosphere is not acceptable, the vent should be connected to the process piping at an elevation above the seal chamber.

9.1.2.5 The distance between the pump and driver shaft ends (distance between shaft ends, or DBSE) shall permit removal of the coupling spacer and back pullout assembly without disturbing the driver, coupling hubs or casing.

9.1.2.6 If specified, a device that allows direct rigging or lifting of the back-pullout assembly from outside the motor support with the driver in place shall be provided.

9.1.2.7 With the purchaser's approval, bearing housings may be arranged for grease lubrication (6.11.4). The stabilized bearing-housing temperature shall not exceed 82 °C (180 °F) when operating at an ambient temperature of 43 °C (110 °F). Recommended greases shall be suitable for operation at these temperatures.

9.1.2.8 Drivers shall be aligned in the vendor's shop prior to shipment.

9.1.3 Integral gear-driven (type OH6) pumps

9.1.3.1 The impeller shall be keyed or splined to the gearbox output shaft.

9.1.3.2 Integral-gear pumps can require removal of the driver to allow disassembly of the rotor and the seal assembly.

9.1.3.3 Impeller type shall be selected for the application and may be open, semi-open, or fully enclosed.

9.1.3.4 The need for a rotor lateral analysis shall be determined as described in 9.2.4.1. A lateral analysis should be specified only for unique, new or critical pumps.

NOTE Lateral critical speeds can be of concern with type OH6 pumps. Normally, pumps of this type are thoroughly investigated during development, and typical rotor dynamics are available and applicable.

9.1.3.5 Single-piece hydrodynamic radial bearings may be used.

9.1.3.6 Temperature and pressure gauges mounted directly on the gearbox shall be in accordance with ISO 10438 (all parts) except that the diameter of the gauges shall be 50 mm (2,0 in). If specified, separable threaded solid-bar thermowells shall be supplied for temperature gauges.

9.1.3.7 Inducers, impellers and similar major rotating components shall be dynamically balanced to ISO 1940-1, grade G2.5, or to a residual unbalance of 7 g·mm (0,01 oz·in), whichever is greater. If possible, the mass of the arbour used for balancing shall not exceed the mass of the component being balanced. The resulting vibration measured during the performance test shall not exceed the levels in Table 8.

9.2 Between-bearings pumps (types BB1, BB2, BB3 and BB5)

9.2.1 Pressure casings

9.2.1.1 Axially split casings may have a composition sheet gasket or a metal-to-metal joint; the vendor's bid shall state which is being offered.

9.2.1.2 Pumps for service temperatures below 150 °C (300 °F) may be foot-mounted.

9.2.1.3 For pumps with axially split casings, lifting lugs or tapped holes for eyebolts shall be provided for lifting only the top half of the casing and shall be so tagged. Methods for lifting the assembled machine shall be specified by the vendor [see 10.2.2.1 a) and Annex L].

9.2.1.4 If specified, proposed connection designs shall be submitted to the purchaser for approval before fabrication. The drawing shall show weld designs, size, materials, and pre-weld and post-weld heat treatments.

● **9.2.1.5** For pumps with machined and studded suction and discharge nozzles, the vendor shall provide the minimum acceptable length for break-out spool pieces to facilitate maintenance activity. Spool pieces should be provided by the purchaser.

NOTE Break-out spool pieces eliminate the requirement to remove large sections of piping in order to take the pump casing out during major overhauls.

9.2.2 Rotor

9.2.2.1 Impellers of multistage pumps shall be individually located along the shaft by a shoulder or captive split ring in the direction of normal hydraulic thrust.

9.2.2.2 Rotors with clearance-fit impellers shall have mechanical means to limit impeller movement in the direction opposite to normal hydraulic thrust to 0,75 mm (0,030 in) or less.

● **9.2.2.3** If specified, rotors with shrink-fit impellers shall have mechanical means to limit movement in the direction opposite to normal hydraulic thrust to 0,75 mm (0,030 in) or less.

9.2.2.4 The runout of shafts and assembled rotors measured with the shaft or rotor supported on V-blocks or bench rollers adjacent to its bearings shall be within the limits given in Table 17.

9.2.3 Running clearances

9.2.3.1 Renewable casing bushings and interstage sleeves or the equivalent shall be provided at all interstage points.

9.2.3.2 Running clearances associated with components used to balance axial thrust or to serve as product-lubricated internal bearings may be the manufacturer's standard, provided these clearances are stated as exceptions to this International Standard (see 6.7.4) in the proposal and are approved by the purchaser. If the manufacturer's standard clearances are based on material combinations exhibiting superior wear characteristics, supporting data shall be included in the proposal.

Table 17 — Shaft and rotor runout requirements

Flexibility factor F_f[a,b] mm^2 (in^2)	Allowable shaft runout TIR µm (in)	Component fit on shaft	Allowable rotor radial runout TIR[c] µm (in)
> $1,9 \times 10^9$ ($3,0 \times 10^6$)	40 (0,001 5)	Clearance	90 (0,003 5)
		Interference	60 (0,002 5)
u $1,9 \times 10^9$ ($3,0 \times 10^6$)	25 (0,001 0)	Clearance	75 (0,003 0)
		Interference	50 (0,002 0)

a $F_f = L^4/D^2$

where

L is the bearing span;

D is the shaft diameter (largest) at impeller.

b The shaft flexibility factor, F_f, is directly related to the static deflection of a simply supported shaft, and is, therefore, a good indicator of the runout attainable during manufacture and the quality of balance that can be achieved and maintained.

c Runout of impeller hubs, balancing drum and sleeves.

9.2.4 Dynamics

9.2.4.1 Lateral analysis

9.2.4.1.1 Depending on pump design, the first or second wet lateral critical speed of multistage and high-speed pumps can coincide with the operating speed, particularly as internal clearances increase with wear. A lateral analysis can predict whether this coincidence is likely and whether the resulting vibration will be acceptable.

9.2.4.1.2 Unless otherwise specified, the need for a lateral analysis of a pump's rotor shall be determined using the process set out in Table 18.

Table 18 — Decision logic for rotor lateral analysis

Step	Action
1	Design pump
2	Does a similar pump (3.51) or an identical pump (3.18) exist? If “yes”, go to step 5. If “no”, go to step 3.
3	Is rotor classically stiff (3.8)? If “yes”, go to step 5. If “no”, go to step 4.
4	Analysis required
5	Analysis not recommended

9.2.4.1.3 If a lateral analysis is required by the process in 9.2.4.1.2, or if specified by the purchaser, it shall be carried out and its results assessed in accordance with Clause I.1.

9.2.4.2 Rotor balancing

9.2.4.2.1 Rotors of the categories listed below shall be two-plane dynamically balanced at low speed to the balance grade in Table 19:

— multistage pumps (three or more stages);

— one- and two-stage pumps whose maximum continuous speed is greater than 3 800 r/min.

9.2.4.2.2 The sequence of rotor assembly and balance correction shall follow ISO 11342. For balancing, the rotor does not include the pump half-coupling hub or the rotary units of the mechanical seals.

Table 19 shows ISO 1940-1, grade G2.5 for all interference fit rotors to speeds of 3 800 r/min. This is based on two factors.

— At 3 800 r/min, the upper limit of balance grade G2.5 produces a force due to unbalance of 10 % of rotor weight, which means that unbalance does not have any material effect on the rotor's operating shape.

— For rotors whose flexibility is high (see Table 17), it is not practical to achieve and maintain the rotor straightness necessary for balance grade G1.

9.2.4.2.3 The mass eccentricity associated with balance grade G1 is very small; for example 2,5 µm (0,000 10 in) maximum for operation at 3 800 r/min. This has two consequences.

— It is not practical to balance the components to better than G2.5 (see 6.9.4.1) because the arbour effectively changes when the component is mounted.

— The balance quality might not be verifiable if the rotor is disturbed from its position on the balancing stand or disassembled and reassembled. It is normally possible, however, to perform a residual unbalance check to verify the accuracy of the balancing stand.

Table 19 — Rotor balance requirements

Component fit on shaft	Maximum continuous speed r/min	Flexibility factor, L^4/D^2 mm^2 (in^2)	Rotor balance procedure(s)[b]	Rotor balance grade
Clearance	u 3 800[a]	No limit	C	[c]
Interference	u 3 800	No limit	C + B or D	G2.5 ($8W/n$)[d]
	> 3 800	u 1,9 × 10^9 (3,0 × 10^6)	C + B or D	G1 ($4W/n$)[d,e]

NOTE See Table 17 for shaft and rotor runout requirements.

[a] To allow for 5 % speed increase.

[b] See ISO 11342.

[c] Balance correction during assembly is not feasible because clearance fit does not maintain corrected balance.

[d] Approximately equal to the midpoint of the corresponding ISO balance quality grade.

[e] If rotors of higher flexibility are used at speeds above 3 800 r/min, achieving and maintaining this balance level requires special attention to design, manufacture and maintenance.

9.2.4.2.4 For rotor balancing, any vacant single keyways shall be filled completely with crowned half keys.

9.2.4.2.5 If a rotor is balanced as an assembly, a residual unbalance test shall be performed. The check shall be carried out after final balancing of the rotor, following the procedure given in Annex J. The mass and location of all half keys used during final balancing of the assembled rotor shall be recorded on the residual unbalance worksheet as part of the "rotor sketch", or separately sketched and recorded on an attachment to the Annex J worksheet.

9.2.5 Bearings and bearing housings

9.2.5.1 If supplied, hydrodynamic radial bearings shall be in accordance with 9.2.5.1.1 through 9.2.5.1.4.

9.2.5.1.1 Bearings shall be split for ease of assembly, precision-bored, and of the sleeve or pad type, with steel-backed, babbitted replaceable liners, pads or shells. The bearings shall be equipped with anti-rotation pins and shall be positively secured in the axial direction.

9.2.5.1.2 The liners, pads or shells shall be in axially split housings and shall be replaceable without having to dismantle any portion of the casing or remove the coupling hub.

9.2.5.1.3 Bearings shall be designed to prevent installation backwards or upside down or both.

9.2.5.1.4 If the shaft contains more than 1,0 % chromium and the journal surface speed is above 20 m/s (65 ft/s), the shaft's journal shall be hard-chromium-plated, hard-coated or sleeved with carbon steel.

NOTE The purpose of this construction is to avoid damage to the bearing from "wire wooling".

9.2.5.2 Hydrodynamic thrust bearings shall be in accordance with 9.2.5.2.1 through 9.2.5.2.5 below.

9.2.5.2.1 Thrust bearings shall be of the steel-backed, babbitted multiple-segment type, designed for equal thrust capacity in both directions and arranged for continuous, pressurized lubrication to each side. Both sides shall be of the tilting-pad type, incorporating a self-levelling feature that assures that each pad carries an equal share of the thrust load with minor variation in pad thickness.

9.2.5.2.2 Thrust collars shall be replaceable and shall be mounted to the shaft with an interference fit to prevent fretting and positively locked to prevent axial movement.

9.2.5.2.3 Both faces of thrust collars shall have a surface roughness of not more than 0,4 µm (16 µin) Ra, and, after mounting, the axial total indicated runout of either face shall not exceed 13 µm (0,000 5 in).

9.2.5.2.4 Thrust bearings shall be sized for the maximum, continuous, applied load (see 6.10.1.2). At this load, and the corresponding rotative speed, the following parameters shall be met:

a) minimum oil-film thickness of 8 µm (0,000 3 in);

b) maximum unit pressure (load divided by area) of 3 500 kPa (35 bar; 500 psi);

c) maximum calculated babbitt surface temperature of 130 °C (265 °F).

If specified, thrust-bearing sizing shall be reviewed and approved by the purchaser.

The limits given above correspond to a design factor of two or more, based on the bearing's ultimate capacity. The calculated babbitt surface temperature is a design value and is not representative of actual babbitt temperatures under these conditions. Bearings sized to meet the above criteria have the following allowable metal temperatures on shop test and in the field (see 6.10.2.4):

— shop test on water and normal operation in the field [see 8.3.3.5 c)]: 93 °C (200 °F);

— field alarm or trip: 115 °C (240 °F).

9.2.5.2.5 Thrust bearings shall be arranged to allow axial positioning of each rotor relative to the casing and the setting of the bearing's clearance or preload.

9.2.5.3 If the inlet oil temperature exceeds 50 °C (120 °F), special consideration shall be given to bearing design, oil flow and allowable temperature rise. Oil outlets from thrust bearings shall be as recommended by the bearing manufacturer for the collar speed and lubrication method involved. Oil connections on bearing housings shall be in accordance with 7.5.

9.2.5.4 Axially split bearing housings shall have a metal-to-metal split joint whose halves are located by means of cylindrical dowels.

9.2.6 Lubrication

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

9.2.6.2 External pressure-lubrication systems shall comply with the requirements of ISO 10438-3. Figure B.8 and Table B.1 show details of the minimum acceptable system for equipment furnished to this International Standard.

9.2.6.3 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 from 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 Grades 32 through 68, as specified in ISO 3448.

● **9.2.6.4** If specified, the pressure-lubrication system shall conform to the requirements of ISO 10438-2. For such a lubrication system, data sheets should be supplied.

9.2.7 Testing

9.2.7.1 For pressure-lubricated bearings, test stand oil and oil system components downstream of the filters shall meet the cleanliness requirements specified in ISO 10438-3.

9.2.7.2 During the shop test of pumps with pressure-lubricated bearings, the oil flowrate to each bearing housing shall be measured and recorded.

9.2.7.3 All purchased vibration probes, transducers and oscillator-demodulators shall be in use during the test. If vibration probes are not furnished by the vendor or if the purchased probes are not compatible with shop readout facilities, shop probes and readouts that meet the accuracy requirements of ANSI/API Std 670 shall be used. The vibration measured with this instrumentation shall be the basis for acceptance or rejection of the pump (see 6.9.3.6).

9.2.7.4 With the purchaser's approval, single-stage, double-suction pumps may be assembled for testing by driving from the opposite end of the pump when compared to the general arrangement for the contract pump and driver. No retest is required after final assembly. If such an arrangement is required, it shall be stated in the proposal.

NOTE This is sometimes required to accommodate test stand piping constraints.

● **9.2.7.5** If specified, hydrodynamic bearings shall be removed, inspected by the purchaser or his representative, and reassembled after the performance test is completed.

9.2.8 Preparation for shipment

9.2.8.1 If a spare rotor or element is purchased, it shall be prepared for unheated indoor storage for three years. Storage preparation shall include treatment with a rust preventive and enclosure in a vapour-barrier envelope with slow-release vapour-phase inhibitor. The rotor or element shall be boxed for the type of shipment specified. A rotor shall have a resilient material (but not lead, TFE or PTFE), at least 3 mm (0,12 in) thick, between the rotor and its support cradle; support shall not be at the rotor's journals. An element shall have its rotor secured to prevent movement within the stator.

● **9.2.8.2** If specified, spare rotors and cartridge-type elements shall be prepared for vertical storage. A rotor shall be supported from its coupling end with a fixture designed to support 1,5 times the rotor's mass without damaging the shaft. A cartridge-type element shall be supported from the casing cover (with the rotor hanging from its thrust bearing).

● **9.2.8.3** If specified, a shipping and storage container designed to store the rotor or cartridge vertically shall be provided.

● **9.2.8.4** If specified, the shipping and storage container shall be designed to allow inert-gas inhibition during storage.

9.3 Vertically suspended pumps (types VS1 through VS7)

9.3.1 General

9.3.1.1 Specified discharge pressure shall be at the purchaser discharge connection. Hydraulic performance shall be corrected for column static and friction head losses. Bowl or pump casing performance curves shall be furnished with the correction indicated.

9.3.1.2 It is not necessary that bearing housings for vertically suspended pumps be arranged so that bearings can be replaced without disturbing pump drives or mountings.

9.3.2 Pressure casings

9.3.2.1 Jackscrews and casing alignment dowels are not required for rabbeted bowl assemblies.

9.3.2.2 Pumps shall be provided with vent connections for suction barrels and seal chambers.

9.3.2.3 Assemblies designed for O-ring seals only do not require flanges and bolting designed to seat a spiral-wound gasket (see 6.3.10).

9.3.3 Rotors

9.3.3.1 All pump shafts shall be machined or ground and finished throughout their entire length. The total indicated runout shall not exceed 40 µm/m (0,000 5 in/ft) of length. Total runout shall not exceed 80 µm (0,003 in) over total shaft length.

For pumps with a shaft length over 4 500 mm (177 in), the vendor may propose an alternative total indicated runout [over 80 µm (0,003 in)] limit to the purchaser for approval.

9.3.3.2 The pump shaft shall be in one piece unless otherwise approved by the purchaser (because of total shaft length or shipping restrictions).

9.3.4 Wear parts and running clearances

9.3.4.1 Renewable casing bushings shall be provided at all interstage and other bushing locations. However, the interstage pressure differential and the character of the liquid handled (for example, dirty or non-lubricating) should determine the need for corresponding shaft sleeves.

9.3.4.2 The running clearances specified in 6.7.4 do not apply to the clearances of bushings. The clearances used shall be stated in the proposal and approved by the purchaser.

9.3.4.3 Pumps with semi-open impellers in an erosive service shall have a replaceable casing liner.

9.3.5 Dynamics

If specified, the vendor shall furnish a dynamic analysis of the pump and its support structure to confirm acceptability of the design. The purchaser and the vendor shall agree on the extent, method and acceptance criteria for this analysis.

Vertically suspended pumps are generally flexible structures with running speeds located between natural frequencies. As such, they are susceptible to resonant vibration if their separation margins are not verified during design. The basic structural elements typically include the foundation, pump structures and motor frames. Typically, the deflection of the foundation represents less than 5 % of the total deflection of the structural elements. If foundation data are not available when the analysis is being conducted, an agreed-upon value should be used. Generally, a 20 % margin of separation should be maintained between the natural frequency of the motor support structure and the operating speed.

9.3.6 Bushings and bearings

9.3.6.1 Bushings shall be suitably corrosion-resistant and abrasion-resistant for the specified product and temperature. The maximum spacing between shaft bushings shall be in accordance with Figure 37 in order to maintain the first critical speed above the maximum allowable continuous speed.

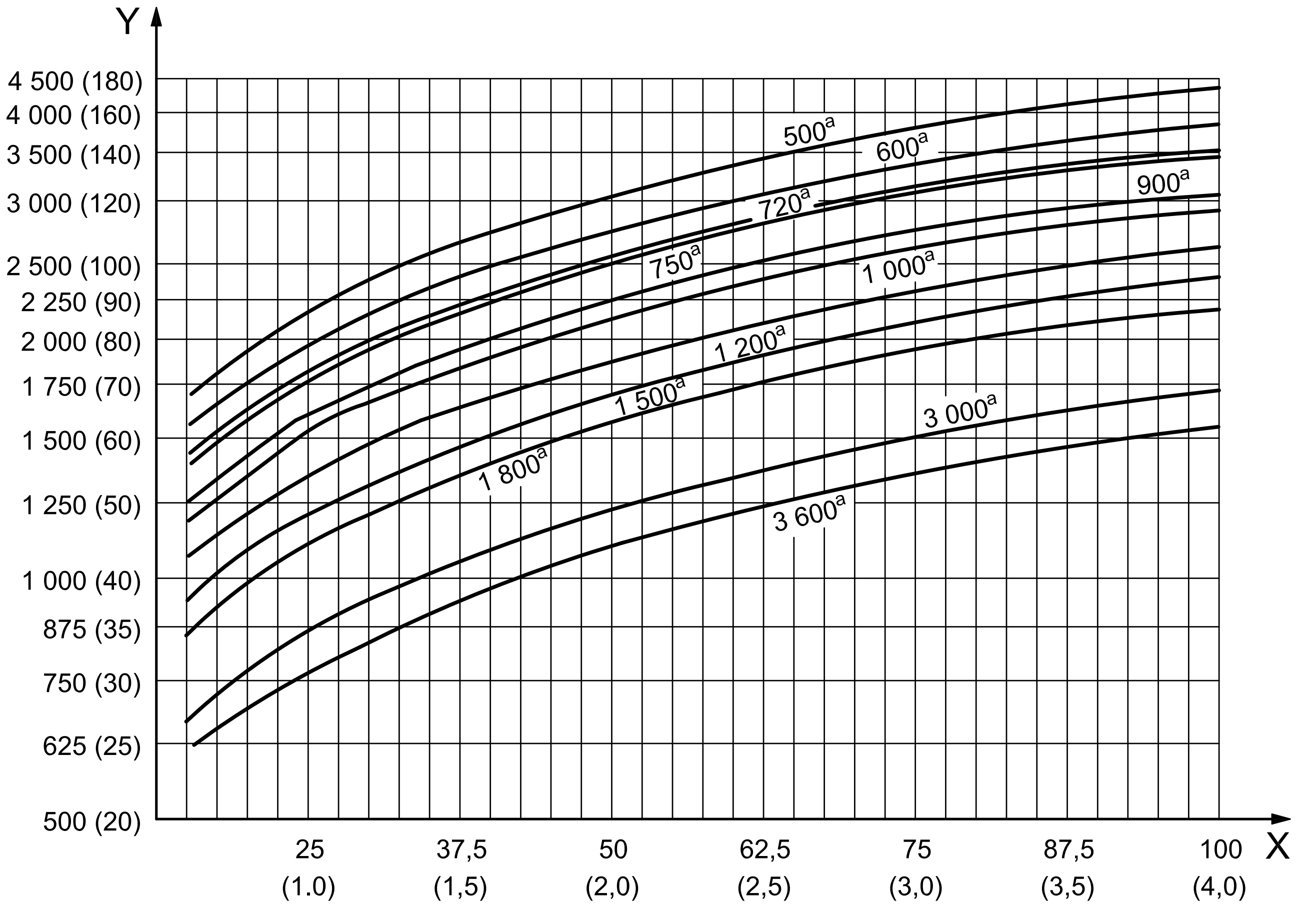
9.3.6.2 Thrust bearings that are integral with the driver shall meet the requirements of 7.1.8. Thrust bearings and housings integral with the pump shall meet the applicable requirements of 6.10. To allow axial rotor adjustment and oil lubrication, the thrust bearing shall be mounted with an interference fit on a slide-fit, key-driven sleeve.

9.3.6.3 Except for sump pumps of type VS4, the first-stage impeller shall be located between bushings.

NOTE Although between-bushing first-stage impellers can result in superior rotor support, certain applications, such as for sumps, require superior suction performance and can benefit from an overhung first-stage impeller arrangement.

9.3.7 Lubrication

Bushings in vertical pumps are normally lubricated by the liquid pumped. Alternative methods of lubrication shall be proposed if the pumped liquid is not suitable.



Key

X shaft diameter, expressed in millimetres (inches)

Y maximum bushing spacing, expressed in millimetres (inches)

a Curves for various rotational speeds, expressed in revolutions per minute.

Figure 37 — Maximum spacing between shaft guide bushings

9.3.8 Accessories

9.3.8.1 Drivers

9.3.8.1.1 Pumps and motor assemblies that can be damaged by reverse rotation shall be provided with a non-reverse ratchet or another purchaser-approved device to prevent reverse rotation.

9.3.8.1.2 Unless otherwise specified, motors for vertical pumps shall have solid shafts. If the pump thrust bearings are in the motor, the motors shall meet the shaft and base tolerances shown in Figure 36.

9.3.8.2 Couplings and guards

9.3.8.2.1 Coupling faces shall be perpendicular to the axis of the coupling within 0,1 µm/mm (0,000 1 in/in) of face diameter or 13 µm (0,000 5 in) total indicated runout, whichever is greater.

9.3.8.2.2 Vertical pumps without integral thrust bearings require rigid adjustable-type couplings.

9.3.8.2.3 On vertical pumps equipped with rigid couplings and mechanical seals, the coupling shall be a spacer type. The spacer shall be of sufficient length to permit replacement of the seal assembly, including the sleeve, without removal of the driver.

9.3.8.3 Mounting plates

9.3.8.3.1 If specified, the mounting plate for double-casing pumps shall be separate from the main body flange and located sufficiently below it to permit the use of through-bolting on the body flange (see Figure 38).This results in a higher joint integrity and should be considered for critical and cryogenic services.

9.3.8.3.2 A minimum of four alignment-positioning screws shall be provided for each drive-train component that has a mass greater than 250 kg (500 lb) to facilitate horizontal adjustment.

9.3.8.3.3 If specified, pumps shall be provided with a separate sole plate for bolting and grouting to the foundation (see Figure 38). This plate shall be machined on its top surface for mounting of the discharge head, can or motor support.

9.3.8.3.4 The outside corners of the sole plate or mounting plate imbedded in the grout shall have at least 50 mm (2 in) radii in the plan view (see Figure D.1).

9.3.8.4 Piping and appurtenances

If mechanical seals and drivers are not installed prior to shipment, the seal piping system shall not be fully assembled.

9.3.9 Testing

9.3.9.1 Pumps shall be tested as complete assemblies. Tests using only bowls and impellers are not recommended. In cases where assembled-unit testing is impractical, the vendor shall submit alternative testing procedures with the proposal. Suction cans, if supplied, are not required for performance testing.

9.3.9.2 If specified, a resonance test with the pump unpiped shall be conducted on the pump structure/driver frame assembly. The test shall be performed as follows.

— Excite the assembly by making an impact on the driver frame in the direction of the discharge flange.

— Determine the natural frequencies by the response.

— Excite the assembly by making an impact on the driver frame at 90° to the direction of the discharge flange.

— Determine the natural frequencies by the response.

The natural frequencies so determined shall be at least 10 % below the minimum continuous operating speed or shall be at least 10 % above the maximum continuous operating speed.

9.3.10 Single-case diffuser (VS1) and volute (VS2) pumps

9.3.10.1 The components that constitute the pressure casing are the casing (bowls), column and discharge head.

NOTE It is not necessary that bowls on VS1 pumps in S-6 materials be 12 % chrome; they can be carbon steel.

9.3.10.2 Line shafts may be open or enclosed. For enclosed line shafts, the type of lubrication shall be approved by the purchaser.

Open line-shafting is lubricated by the pumped liquid. If the pumped liquid is not suitable as a lubricant, enclosed line-shafting may be provided to ensure a clean lubrication supply for line-shaft bearings.

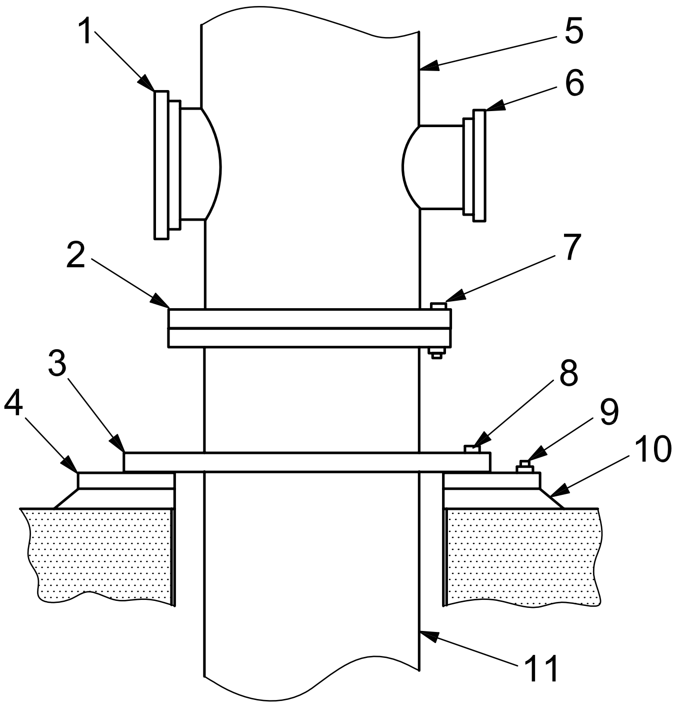
9.3.10.3 The discharge-head mounting surface shall be suitable for both grouting and mounting on a machined sole plate.

9.3.10.4 Thrust restraints are required at the pump if an expansion joint is installed on the discharge nozzle. Design review of the proposed installation and piping by the vendor is recommended.

● **9.3.10.5** If specified, line shafting shall be furnished with hardened sleeves under each bushing.

9.3.10.6 Unless otherwise specified, integral bushing spiders and rabbeted fits shall be used for all column sizes.

9.3.10.7 Unless otherwise specified, bowls shall be flanged and shall have metal-to-metal rabbeted fits.



Key

1 suction flange
2 main body flange
3 mounting flange
4 sole plate
5 pump head
6 discharge flange
7 main body flange through-bolting (typical)
8 hold-down bolts (typical)
9 anchor bolts (typical)
10 grout
11 can (outer casing)

Figure 38 — Typical mounting for vertically suspended, double-case pumps (VS6 and VS7) with sole plate

9.3.11 Single-casing axial flow (VS3) pumps

9.3.11.1 The components that constitute the pressure casing are the casing (bowl), column and discharge head.

9.3.11.2 Unless otherwise specified, integral bushing spiders and rabbeted fits shall be used for all column sizes.

9.3.11.3 Bowls shall have metal-to-metal rabbeted fits.

9.3.12 Single-casing line shaft (VS4) and cantilever (VS5) pumps

9.3.12.1 For VS4 pumps, bushings shall be provided to support the shaft and impeller.

9.3.12.2 VS5 pumps shall comply with a) through d) as follows.

a) The rotor shall be cantilevered from its bearing assembly. Submerged bottom bushings are not used to guide the shaft.

b) The shaft stiffness shall limit total deflection, without the use of a casing bushing, such that the impeller does not contact the pump casing under the most severe dynamic conditions over the complete head-flow curve with a maximum diameter impeller and at the maximum speed and liquid density.

c) Cantilever type pumps shall have their first dry critical speed, for their rotors, 30 % above their maximum allowable continuous speed.

d) For cantilever-type VS5 pumps, the shaft total indicated runout shall not exceed 50 µm (0,002 in) as measured on the shaft directly above the mechanical seal or stuffing box.

9.3.12.3 For open-system sump-pump service, the pressure-containing components of the type VS4 and type VS5 pumps are the casing, suction cover and discharge line. For closed-system pressurized or vacuum tank service, the seal chamber, pump cover plate and tank cover also become pressure-containing components.

9.3.12.4 For VS4 pumps, the thrust bearing shall be designed for either grease or oil-mist lubrication. Bushings may be lubricated with water, grease or product, or be self-lubricated. Type VS5 pump bearings shall be grease-lubricated. The stabilized bearing housing temperature shall not exceed 82 °C (180 °F) when operating at an ambient temperature of 43 °C (110 °F). Recommended greases shall be suitable for operation at these temperatures.

9.3.12.5 Mechanical seals are typically not supplied on VS4 and VS5 pumps unless required for closed-system service.

9.3.12.6 Lifting lugs shall be provided in the cover plate for lifting the pump assembly, including the driver.

9.3.12.7 The discharge nozzle and cover plate shall be designed as required in 6.3.3.

If the pump is mounted in a vessel, the pump-mounting nozzle of the vessel should also be designed to withstand the allowable nozzle loads. See 6.5 for allowable nozzle loads.

9.3.12.8 Cover-plate joints shall be vapour-tight for closed-system services. The cover-plate design and mounting shall be agreed to by the purchaser and vendor.

9.3.12.9 Mechanical seals, if supplied, shall be located at the cover plate to seal the vapour in the supply tank or vessel. Mechanical seals normally seal vapour; however, they shall be designed to operate in liquid in the event of tank or vessel overfilling. The seal chamber shall have provisions for a high-point vent.

9.3.12.10 Pump-out vanes may be used in lieu of wear rings to reduce leakage back to the sump.

