INTERNATIONAL STANDARD

ISO 9905

First edition
1994-05-01

Technical specifications for centrifugal pumps — Class I

Spécifications techniques pour pompes centrifuges — Classe I

Reference number
ISO 9905:1994(E)

Contents

International Organization for Standardization
Case Postale 56 • CH-1211 Genève 20 • Switzerland

Printed in Switzerland

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.

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.

International Standard ISO 9905 was prepared by Technical Committee ISO/TC 115, *Pumps*, Subcommittee SC 1, *Dimensions and technical specifications of pumps*.

Annexes A, B, C and D form an integral part of this International Standard. Annexes E, F, G, H, J, K and L are for information only.

Introduction

This International Standard is the second of a set dealing with technical specifications of centrifugal pumps; the specifications are designated as Classes I, II and III. Class I (this International Standard) comprises the most severe and Class III (see ISO 9908) the least severe requirements. For requirements for Class II centrifugal pumps, see ISO 5199.

The selection of the class to be used is made in accordance with the technical requirements for the application for which the pump is intended. **The class chosen is to be agreed between purchaser and manufacturer/supplier.**

The safety requirements of the field of application are furthermore to be taken into account.

However, it is not possible to standardize the class of technical requirements for centrifugal pumps for a certain field of application, because each field of application comprises different requirements. All classes (I, II and III) can be used in accordance with the different requirements of the pump application, e.g. for an oil refinery plant, chemical plant or power plant. It may happen that pumps built in accordance with classes I, II and III may work beside each other in one plant.

Conditions covering specific applications or industrial requirements are dealt with in separate standards.

Criteria for the selection of a pump of the class required for a certain application may be based on:

— reliability,

— operating conditions,

— environmental conditions,

— local ambient conditions.

Throughout this International Standard, text written in bold letters indicates where a decision may be required by purchaser, or where agreement is required between purchaser and manufacturer/supplier.

Technical specifications for centrifugal pumps — Class I

1 Scope

1.1 This International Standard covers the Class I (most severe) requirements for centrifugal pumps used in various industries. It consists of a basic text covering general requirements. The technical requirements refer only to the pump unit.

Storage pumps are not included in this International Standard. A separate standard will be issued by IEC.

1.2 This International Standard includes design features concerned with installation, maintenance and safety of such pumps, including baseplate, coupling and auxiliary piping.

1.3 Where this International Standard specification has been called for:

a) and requires a specific design feature, alternative designs may be offered which meet the intent of this International Standard, provided that the alternative is described in detail;

b) pumps not complying with all requirements of this International Standard may be offered for consideration, provided that all deviations are stated.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 7-1:1982, *Pipe threads where pressure-tight joints are made on the threads — Part 1: Designation, dimensions and tolerances.*

ISO 76:1987, *Rolling bearings — Static load ratings.*

ISO 185:1988, *Grey cast iron — Classification.*

ISO 228-1:1982, *Pipe threads where pressure-tight joints are not made on the threads — Part 1: Designation, dimensions and tolerances.*

ISO 281:1990, *Rolling bearings — Dynamic load ratings and rating life.*

ISO 427:1983, *Wrought copper-tin alloys — Chemical composition and forms of wrought products.*

ISO 544:1989, *Filler materials for manual welding — Size requirements.*

ISO 1940-1:1986, *Mechanical vibration — Balance quality requirements of rigid rotors — Part 1: Determination of permissible residual unbalance.*

ISO 2372:1974, *Mechanical vibration of machines with operating speeds from 10 to 200 rev/s — Basis for specifying evaluation standards.*

ISO 2548:1973, *Centrifugal, mixed flow and axial pumps — Code for acceptance tests — Class C (It is planned to combine ISO 2548 with ISO 3555 during their next revision to create a new International Standard).*

ISO 2858:1975, *End-suction centrifugal pumps (rating 16 bar) — Designation, nominal duty point and dimensions.*

ISO 3069:1974, *End suction centrifugal pumps — Dimensions of cavities for mechanical seals and for soft packing.*

ISO 3274:1975, *Instruments for the measurement of surface roughness by the profile method — Contact (stylus) instruments of consecutive profile transformation — Contact profile meters, system M.*

ISO 3506:1979, *Corrosion-resistant stainless steel fasteners — Specifications.*

ISO 3555:1977, *Centrifugal, mixed flow and axial pumps — Code for acceptance tests — Class B (It is planned to combine ISO 3555 with ISO 2548 during their next revision to create a new International Standard).*

ISO 3744:1981, *Acoustics — Determination of sound power levels of noise sources — Engineering methods for free-field conditions over a reflecting plane.*

ISO 3746:1979, *Acoustics — Determination of sound power levels of noise sources — Survey method.*

ISO 3755:1991, *Cast carbon steels for general engineering purposes.*

ISO 4863:1984, *Resilient shaft couplings — Information to be supplied by users and manufacturers.*

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

ISO 7005-2:1988, *Metallic flanges — Part 2: Cast iron flanges.*

ISO 7005-3:1988, *Metallic flanges — Part 3: Copper alloy and composite flanges.*

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1 normal conditions: Conditions at which usual operation is expected.

3.2 rated conditions: Specified guarantee-point operating conditions, including flowrate, head, power, efficiency, net positive suction head, suction pressure, temperature, density, viscosity and speed.

3.3 operating conditions: All operating parameters (for example temperature, pressure) determined by a given application and pumped liquid.

These parameters will influence the type of construction materials.

3.4 allowable operating range: Flow range, defined by the manufacturer/supplier, at the specified operating conditions using the impeller supplied, as limited by cavitation, heating, vibration, noise, shaft deflection and other similar criteria; range whose upper and lower limits are denoted by maximum and minimum continuous flow, respectively.

3.5 maximum allowable casing working pressure: Greatest outlet pressure at the specified operating temperature for which the pump casing is suitable.

3.6 basic design pressure: Pressure derived from the permitted stress at 20 °C of the material used for the pressure-containing parts.

3.7 maximum outlet working pressure: Sum of the maximum inlet pressure plus maximum differential pressure at rated conditions using the supplied impeller.

3.8 rated outlet pressure: Outlet pressure of the pump at the guarantee point with rated flow, rated speed, rated inlet pressure and density.

3.9 maximum inlet pressure: Highest inlet pressure to which the pump is subjected during operation.

3.10 rated inlet pressure: Inlet pressure for the operating conditions at the guarantee point.

3.11 maximum allowable temperature: Highest allowable continuous temperature for which the equipment (or any part to which the term refers) is suitable when handling the specified operating fluid at the specified operating pressure.

3.12 rated power input: Power required by the pump at the rated conditions.

3.13 maximum dynamic sealing pressure: Highest pressure expected at the shaft seals during any specified operating condition and during startup and shutdown.

NOTE 1 In determining this pressure, consideration should be given to the maximum inlet pressure, circulation or injection (flush) pressure and the effect of internal clearance changes.

3.14 minimum permitted flow

(1) for stable flow: Lowest flowrate at which the pump can operate without exceeding the noise and vibration limits imposed by this International Standard.

(2) for thermal flow: Lowest flowrate at which the pump can operate and still maintain the temperature of the pumped liquid below that at which net positive suction head available equals net positive suction head required.

3.15 corrosion allowance: That portion of the wall thickness of the parts wetted by the pumped liquid in excess of the theoretical thickness required to withstand the pressure limits given in 4.4.2.2 and 4.4.2.4.

3.16 maximum allowable continuous speed: Highest speed at which the manufacturer will permit continuous operation.

3.17 rated speed: Number of revolutions of the pump per unit time required to meet the rated conditions.

NOTE 2 Induction motors will operate at a speed that is a function of the load imposed.

3.18 trip speed: Speed at which the independent emergency overspeed device operates to shut down a prime mover.

3.19 first critical speed: Speed of rotation at which the lowest lateral natural frequency of vibration of the rotating parts corresponds to the frequency of rotation.

3.20 design radial load: Maximum hydraulic radial forces on the largest impeller (diameter and width) operating within the manufacturer's specified range on its maximum speed curve using the design liquid (normally 1 000 kg/m^3).

3.21 maximum radial load: Maximum hydraulic radial forces on the largest impeller (diameter and width) operating at any point on its maximum speed curve with a maximum liquid density.

3.22 shaft runout: Total radial deviation indicated by a device measuring shaft position in relation to the bearing housing as the shaft is rotated manually in its bearings with the shaft in the horizontal position.

3.23 face runout: Total axial deviation indicated at the outer radial face of the stuffing box by a device attached to and rotated with the shaft when the shaft is rotated manually in its bearings in the horizontal position.

The radial face is that which determines the alignment of a seal component.

3.24 shaft deflection: Displacement of a shaft from its geometric centre in response to the radial hydraulic forces acting on the impeller.

NOTE 3 Shaft deflection does not include shaft movement caused by tilting within the bearing clearances, bending caused by impeller unbalance or shaft runout.

3.25 circulation (flush): Return of pumped liquid from a high pressure area to seal cavity, by external piping or internal passage, to remove heat generated at the seal or to maintain positive pressure in the seal cavity or treated to improve the working environment for the seal.

NOTE 4 In some cases it may be desirable to circulate from the seal cavity to a lower pressure area (for example, the inlet).

3.26 injection (flush): Introduction of an appropriate (clean, compatible, etc.) liquid into the seal cavity from an external source and then into the pumped liquid.

3.27 quenching: Continuous or intermittent introduction of an appropriate (clean, compatible, etc.) fluid on the atmospheric side of the main shaft seal to exclude air or moisture, to prevent or clear deposits (including ice), lubricate an auxiliary seal, snuff out fire, dilute, heat or cool leakage.

3.28 barrier liquid (buffer): An appropriate (clean, compatible, etc.) liquid inserted between two seals (mechanical seal and/or soft packing).

NOTE 5 The barrier liquid pressure depends on the seal arrangement. The barrier liquid may be used to prevent air entering the pump. The barrier liquid is normally easier to seal than the pumped liquid and/or creates less hazard if leakage occurs.

3.29 throttle bush (safety bush): Close-clearance restrictive bush around the shaft (or sleeve) at the outboard end of a mechanical seal to reduce leakage in case of seal failure.

3.30 throat bush: Close-clearance restrictive bush around the shaft (or sleeve) between the seal (or packing) and the impeller.

3.31 pressure casing: Composite of all stationary pressure-containing parts of the unit, including all branches and other attached parts.

3.32 double casing: Type of construction in which the pressure casing is separate and distinct from the pumping elements contained in it.

3.33 barrel casing: Refers specifically to a pump of the double casing type.

3.34 vertical canned pump: Vertical pump inserted in an outer casing (can or caisson) taking its suction from the liquid in the annular space.

3.35 vertical canned motor pump: Glandless pumping set in which the stator of the (electric) motor is sealed by a can against the rotor which runs in the pumped liquid or in any other liquid.

3.36 hydraulic power recovery turbine: Pump operated with reversed flow to deliver mechanical energy at the coupling obtained from the recovery of energy released by the reduction of fluid pressure (and sometimes from the additional energy released by vapour or gas evolution from the fluid).

NOTE 6 For hydraulic power recovery turbine branches, all references in this standard to suction and discharge apply to the outlet and inlet, respectively.

3.37 radial split: Refers to casing joints that are transverse to the shaft centreline.

3.38 axial split: Refers to casing joints that are parallel to the shaft centreline.

3.39 net positive suction head (NPSH): Absolute total inlet head above the head equivalent to the vapour pressure referred to the NPSH datum plane.

NOTE 7 NPSH is referred to the datum plane, whereas inlet total head is referred to the reference plane. The NPSH datum plane is the horizontal plane through the centre of the circle described by the external points of the entrance edges of the impeller blades; in the case of double inlet pumps with vertical or inclined axis, it is the plane through the higher centre. The manufacturer/supplier should indicate the position of this plane with respect to precise reference points on the pump.

3.40 net positive suction head available (NPSHA): NPSH determined by the conditions of the installation for a specified liquid, temperature and rate of flow.

3.41 net positive suction head required (NPSHR): Minimum NPSH for a pump achieving a specified performance at the specified rate of flow and speed (occurrence of visible cavitation, increase of noise due to cavitation, appearance of head or efficiency drop, head or efficiency drop of a given amount, etc.).

3.42 suction specific speed: Parameter relating the rotational speed, the flowrate and the NPSHR, determined at the best efficiency point.

3.43 hydrodynamic bearing: Bearing whose surface is oriented to another surface such that relative motion forms an oil wedge to support the load without metal-to-metal contact.

3.44 hydrodynamic radial bearing: Bearing of sleeve-journal or tilting-shoe type construction.

3.45 hydrodynamic thrust bearing: Bearing of multiple-segment or tilting-shoe type construction.

3.46 design values: Values used in the design of a pump for the purpose of determining the performance, the minimum permissible wall thickness and physical characteristics of the different parts of the pump.

NOTE 8 Use of the word design in any term (such as design pressure, design power, design temperature or design speed) should be avoided in the purchaser's specifications. This terminology should be used only by the equipment designer and manufacturer/supplier.

3.47 coupling service factor: A factor k, by which is multiplied the nominal torque T_N of the driver in order to obtain the rated torque $T_K = kT_N$, which makes due allowance for cycle torque fluctuations from the pump and/or its driver, and therefore ensures satisfactory coupling life.

4 Design

4.1 General

Whenever the documents include contradicting technical requirements, they shall apply in the following sequence:

a) purchase order (or enquiry, if no order is placed) (see annexes C and D);

b) data sheet (see annex A);

c) this International Standard;

d) other standards to which reference is made in the order (or enquiry, if no order is placed).

The applicability of any national and local codes, regulations, ordinances or rules shall be mutually agreed upon by the purchaser and the manufacturer/supplier.

4.1.1 Characteristic curve

4.1.1.1 The characteristic curve for the supplied impeller shall show the head, efficiency, NPSHR and the power input, plotted against flowrate. It shall also show the allowable operating range of the pump. Head/flowrate curves (on the basis of calculation or test) for the largest and smallest impeller diameters shall be plotted for single stage pumps, and for multistage pumps when requested.

4.1.1.2 Pumps that have stable head/flowrate curves which continuously rise to shutoff are preferred for most applications and are required when parallel operation is specified by the purchaser. Unstable head/flowrate curves or curves with dips (such as propeller pump curves) can be offered providing the application is suitable and the curve shape deviations are shown. When service conditions are such that a stable curve is technically impossible, other means of ensuring the desired flow(s) must be used. When parallel operation is specified, the rise of the head at rated flowrate shall have sufficient slope to avoid instability of flow.

4.1.1.3 The best efficiency point for the supplied impeller should preferably be between the rated point and the normal point (see 3.1).

4.1.1.4 When the pump design permits a constant-speed driver, the pump shall be capable of approximately a 5 % head increase at rated conditions by installing a new larger impeller or impellers.

4.1.1.5 Pumps that handle Newtonian liquids more viscous than water shall have their performance corrected in accordance with the conversion factors to be agreed between purchaser and manufacturer/supplier. Non-Newtonian liquids require special consideration.

4.1.2 Net positive suction head (NPSH)

NPSHR shall be based on cold water according to ISO 2548 and/or ISO 3555[1)] unless otherwise agreed.

The NPSHR curve as a function of flow for water shall be provided.

NPSHA must exceed NPSHR by a 10 % margin but in each case by not less than 0,5 m. The basis for use in performance curves is the NPSH corresponding to a drop of 3 % of the total head of the first stage of the pump (NPSH3).

Should the pump manufacturer/supplier consider that, because of the construction material and liquid pumped, a greater NPSH is required, this should be stated in the proposal and the appropriate curve provided.

The manufacturer/supplier shall specify on the data sheet the net positive suction head required (NPSHR) when the pump is operated with water at the rated flowrate and rated speed.

Hydrocarbon reduction or correction shall not be applied.

For NPSH tests, see 6.3.5.

4.1.3 Pump design

4.1.3.1 Pumping units may be of single-stage or multistage design. When the rated inlet gauge pressure is positive or the differential pressure is more than 3,5 bar, the pump should be designed to minimize the pressure on the shaft seals unless thrust balance requirements dictate otherwise. On single-stage overhang designs this can be accomplished with rings or pumping vanes on the back of the impeller. On multistage pumps this can be accomplished either by a back-to-back impeller arrangement combined with a close clearance throttle bush, or by an in-line impeller arrangement using balance drums or discs.

Other means can be used after agreement between purchaser and manufacturer/supplier.

4.1.3.2 High-energy pumps (head greater than 200 m per stage and power more than 225 kW per stage) require special consideration to ensure that the radial distance between the volute tongue (including double volute casing) or diffuser vane and the impeller periphery is so dimensioned to avoid undue vibrations and noise (blade-passing frequency and low frequency at reduced flowrates).

4.1.3.3 Vertical pumps with threaded line shaft coupling that could be damaged by reverse rotation shall be provided with a non-reverse ratchet or other approved means.

1) A combination of ISO 2548 and ISO 3555 and their simultaneous revision in a new International Standard is foreseen.

4.1.3.4 All equipment shall be designed to permit rapid and economical maintenance. Major parts such as casing components and bearing housings shall be designed (shouldered or dowelled) to ensure accurate alignment on reassembly.

4.1.3.5 Control of the sound level of all equipment supplied shall be a joint effort of the purchaser and the manufacturer/supplier. Unless otherwise specified, the equipment supplied by the manufacturer/supplier shall conform to the requirements of local regulations and to the maximum allowable sound level specified by the purchaser.

NOTE 9 The scope of this International Standard excludes the driver, but a contribution of the driver to the sound level should be taken into account.

4.1.4 Outdoor installation

The purchaser shall specify whether the installation is indoors (heated or unheated) or outdoors (with or without a roof) and the local ambient conditions in which the equipment must operate (including maximum and minimum temperatures, unusual humidity, corrosive air or dust problems). The unit and its auxiliaries shall be suitable for operation in these specified conditions. For the purchaser's guidance, the manufacturer/supplier shall list in the proposal any special protection that the purchaser is required to supply.

4.2 Drivers

4.2.1 General

4.2.1.1 Requirements for determining rated drive performance

The following shall be considered when determining the rated performance of the drive:

a) application and method of operation of the pump. For instance in the case of parallel operation, the possible performance range with only one pump in operation, taking into account the system characteristics, shall be considered;

b) position of the operating point on the characteristic curve of the pump;

c) shaft seal friction loss;

d) circulation flow for the mechanical seal (especially for pumps with low rate of flow);

e) properties of the pumped medium (viscosity, solids content, density);

f) power loss and slip through the transmission;

g) atmospheric conditions at the pump site.

Drivers for any pumps covered by this International Standard shall have power output ratings at least equal to the percentage of rated pump power input given in figure 1 but not less than 1 kW. Where it appears that this will lead to unnecessary oversizing of the driver, an alternative proposal shall be submitted for the purchaser's approval.

4.2.1.2 Thrust load

When the thrust bearing is not part of the pump, and unless otherwise approved by the purchaser, motor, turbine or gear drivers for vertical pumps, including in-line vertical pumps, shall be designed to carry the maximum thrust the pump may develop while starting, stopping or operating at any flowrate. The maximum thrust load shall be determined at double the initial internal clearances. If the driver is not supplied by the manufacturer/supplier he shall notify the purchaser of such requirements.

4.2.2 Turbine-driven pumps

4.2.2.1 Steam turbines

The steam turbines selected shall be capable of carrying the pump rated power input required for the rated conditions based on the guaranteed pump efficiency, or alternatively the maximum power input required for the full operating range of the pump. The steam turbine power rating shall be based on the minimum inlet and maximum exhaust steam conditions specified.

4.2.2.2 Turbine-driven pump speed

The turbine-driven pumps shall be designed to operate continuously at 105 % of rated speed and to operate briefly, under emergency conditions, at up to 110 % of rated speed (turbine overspeed trip setting).

For steam turbines and reciprocating engines, the trip speed shall be at least 110 % of the maximum allowable continuous speed. For gas turbines the trip speed shall be at least 105 % of the maximum allowable continuous speed.

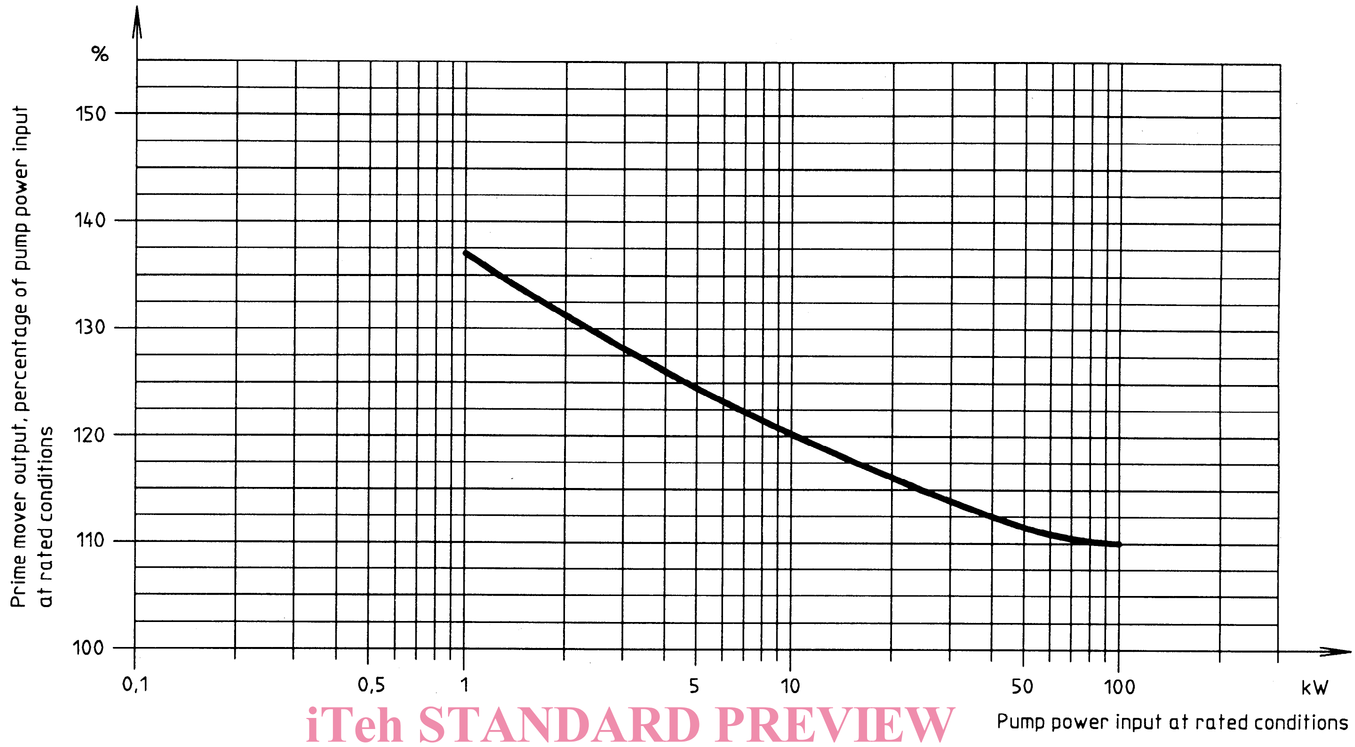

Figure 1 — Driver output percentage of rated pump power required in the range of 1 kW to 100 kW

4.3 Critical speed, balance and vibration

4.3.1 Critical speed

4.3.1.1 Critical speeds correspond to resonant frequencies of the rotor-bearing support system. The basic identification of critical speeds is made from the natural frequencies of the system and of the forcing phenomena. If the frequency of any harmonic component of a periodic forcing phenomenon is equal to or approximates the frequency of any mode of rotor vibration, a condition of resonance may exist. If resonance exists at a finite speed, that speed is called a critical speed. This specification is concerned with actual critical speeds rather than various calculated values both in lateral vibration and in torsional oscillation.

4.3.1.2 A forcing phenomenon or exciting frequency may be less than, equal to, or greater than the synchronous frequency of the rotor. Such forcing frequencies may include but are not limited to the following phenomena:

a) unbalance in the rotor system,

b) oil film effects,

c) internal rub frequencies,

d) blade, vane, nozzle or diffuser passing frequencies,

e) gear meshing and side band frequencies,

f) coupling misalignment frequencies,

g) loose rotor system component frequencies,

h) hysteresis and friction whirl frequencies,

i) boundary layer (vortex shedding),

j) acoustic or aerodynamic effects,

k) start-up conditions, for example, speed detents (under inertial impedance) or torsional deflections contributing to torsional resonances,

l) number of cylinders, angle between banks, and whether two- or four-stroke in the case of internal combustion engines.

4.3.1.3 Actual critical speeds shall not encroach upon specified speed ranges.

The first critical speed (in bending) shall preferably be at least 20 % above the maximum operating speed, except when it is not possible to design a stiff shaft pump, and shall have the purchaser's agreement.

For vertical shaft pumps, this applies particularly when the liquid handled contains an appreciable proportion of solid particles.

When it is not possible to design a stiff shaft pump and with the purchaser's agreement

— the first critical speed N_{c1} shall not exceed 0,37 (= 1/2,7) times the minimum operating speed N_{min},

— the second critical speed N_{c2} shall not be less than 1,2 times the maximum continuous speed N_{max}.

This can be illustrated as in figure 2.

4.3.1.4 The separation margin of encroachment from all lateral modes (including rigid and bending) shall be at least

a) 20 % over the maximum continuous speed for rigid rotor systems, or

b) 15 % below any operating speed and 20 % above the maximum continuous speed for flexible-shaft rotor systems.

Torsional modes of the complete unit shall be at least 10 % below any operating speed or at least 10 % above the trip speed.

The separation margins specified are intended to prevent the overlapping of the critical response envelope into the operating speed range.

4.3.1.5 Slow roll, start-up and shutdown of rotating equipment shall not cause any damage as critical speeds are passed.

4.3.1.6 Support and bearing housing resonances of the driver and driven equipment shall not occur within the specified operating speed range or the specified separation margins.

4.3.1.7 When specified by purchaser, critical speeds shall be confirmed by test stand data, or if above test speeds, they shall be

a) **calculated damped values, or**

b) **values determined by externally applied rotor excitations.**

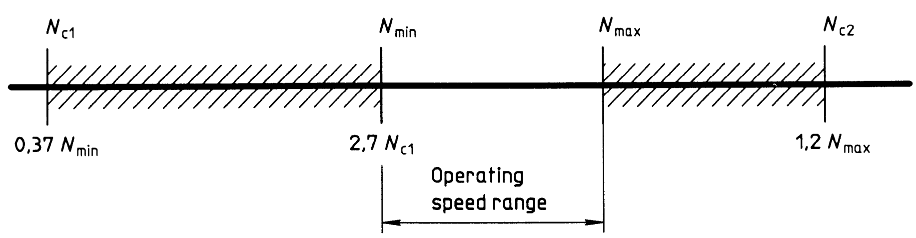

Figure 2 — Conditions of critical speed (see 4.3.1.3)

4.3.1.8 When specified by the purchaser, the calculations detailed in items a) and b) below shall be provided by the manufacturer/supplier. If the purchaser supplies the driving equipment, it shall be his responsibility to provide the data for these calculations:

a) a lateral critical speed analysis to determine that the critical speeds of the driver are compatible with the critical speeds of the pump and that the combination is suitable for the specified operating speed range;

b) a torsional vibration analysis of the pump-driver system and a transient torsional vibration analysis for synchronous motor-driven systems. The manufacturer/supplier shall be responsible for the satisfactory performance of the system.

   In case of drive by internal combustion engine, the manufacturer/supplier of the latter is responsible for the analysis.

4.3.2 Balance and vibration

4.3.2.1 General

4.3.2.1.1 All major rotating components shall be balanced. **When specified by the purchaser, the assembled rotors shall be balanced.**

4.3.2.1.2 When specified by the purchaser, the manufacturer/supplier shall demonstrate that the pump can operate at the quoted minimum continuous stable flow without exceeding the vibration limits given in 4.3.2.2.

4.3.2.1.3 Pumps shall operate smoothly throughout their speed range in reaching rated speed, and to the overspeed limit in the case of turbine-driven units.

4.3.2.1.4 The smooth running of the pump (and its driver) after installation shall be the joint responsibility of the manufacturer/supplier and the purchaser. The units shall perform as well on their permanent foundation as they do on the manufacturer/supplier's test stand.

4.3.2.2 Horizontal pumps

Unfiltered vibration shall not exceed the vibration severity limits given in table 1 when measured on the manufacturer/supplier's test facilities. These values are measured radially at the bearing housing at a single operating point at rated speed (± 5 %) and rated flow (± 5 %) when operating without cavitation. This can normally be achieved by balancing in accordance with grade G 6.3 of ISO 1940-1; for further information see ISO 5343 and ISO 8821.

Pumps with a special impeller, for example a single channel impeller, may exceed the limits given in table 1. In such case the pump manufacturer/supplier should indicate this in his offer.

Table 1 — Limits of vibration severity for horizontal pumps with multivane impellers (based on ISO 2372)

Speed of rotation, N	**Maximum rms values, in mm/s, of the vibration velocity for the shaft centreline height h_1** [1)]	
min⁻¹	$h_1 \leqslant 225$ mm	$h_1 > 225$ mm
$N \leqslant 1\,800$	2,8	4,5
$1\,800 < N \leqslant 4\,500$	4,5	7,1

1) For horizontal foot-mounted pumps h_1 is the distance between baseplate area in contact with pump feet (including supports) and pump shaft centreline.

4.3.2.3 Vertical pumps

4.3.2.3.1 Vibration readings shall be taken on the top flange of the driver mount on vertical pumps with rigid couplings and near to the top pump bearing on vertical pumps with flexible couplings.

4.3.2.3.2 Vibration limits for both rolling and sleeve bearing pumps shall not exceed a velocity of 7,1 mm/s during shop test at rated speed (± 5 %), and rated flow (± 5 %) operating without cavitation.

4.4 Pressure-containing parts (see also 5.1)

4.4.1 Pressure-temperature rating

The maximum allowable working pressure of the pump at the most severe operating conditions must be clearly defined by the manufacturer/supplier. In no case shall the maximum allowable working pressure of the pump (casing and cover, including shaft seal housing and gland follower/end plate) exceed that of the pump flanges.

4.4.2 Pump casing

4.4.2.1 Pumps with radially split cases are required if any of the following operating conditions are specified:

a) pumping temperature of 200 °C or higher (a lower temperature limit should be considered when thermal shock is probable);

b) toxic pumped liquid or flammable liquid with a density of less than 0,7 kg/dm^3 at the specified pumping temperature;

c) flammable pumped liquid at a rated discharge gauge pressure above 70 bar.

NOTE 10 Pumps with axially split cases may be supplied for the conditions specified above with the specific approval of the purchaser. (It is recommended that the purchaser consider design details and previous manufacturer/supplier operating experience before approving pumps with axially split cases for these conditions. Maximum hydrostatic test, horizontal joint sealing technique, pump location, and the skill of field maintenance personnel should be factors in the decision.)

4.4.2.2 The thickness of the pressure casing shall be suitable for the maximum outlet working pressure plus allowances for head and speed increases at pumping temperature, and for hydrostatic test pressure at ambient temperature.

The maximum allowable casing working pressure shall be equal to or greater than the maximum outlet pressure.

Areas of double-casing, horizontal multistage (three or more stages) and axially split casing pumps normally subjected to inlet pressure need not be designed for discharge pressure. (The purchaser should consider installation of relief valves on the suction side of such installations.) **The purchaser shall specify if the vertical canned pump inlet can is to be suitable for maximum discharge pressure.** (This is advisable when two or more pumps are connected to a common discharge system.) The stress used in design for any given material shall not be in excess of the values given in specified material standards. The calculation methods for pressure-containing parts and the safety factors for the selected materials shall be in accordance with the relevant national rules.

The pressure-containing parts shall have a corrosion allowance of 3 mm unless a lower corrosion allowance can be accepted (e.g. for titanium).

4.4.2.3 The maximum discharge pressure shall apply to all parts referred to in the definition of pressure casing (see 3.31), except in the case of double-casing pumps, horizontal multistage (three or more stages) and axially split casing pumps.

4.4.2.4 The inner casing of double-casing pumps shall be designed to withstand the maximum internal differential pressure or 3,5 bar, whichever is greater.

4.4.2.5 If there is a risk of misalignment between pump and driver due to temperature differences or any other cause, precautions shall be taken to minimize this, for example centreline support, cooled pedestals, pre-alignment.

4.4.3 Materials

The materials used for pressure-containing parts shall depend on the liquid pumped, the pump configuration and the application of the pump (see clause 5).

4.4.4 Mechanical features

4.4.4.1 Dismantling

With the exception of vertical lineshaft pumps and ring-section type multistage pumps, the pump shall be designed to permit removal of the impeller, shaft, shaft seal and bearing assembly without disturbing the inlet and outlet flange connections.

For axially split pumps, lifting lugs or eyebolts shall be provided for lifting only the top half of the casing. Methods of lifting the assembled pump shall be specified by the manufacturer/supplier.

4.4.4.2 Jackscrew and casing alignment dowels

Jackscrew and casing alignment dowels shall be provided to facilitate dismantling and reassembly. When jackscrews are used as a means of parting contacting faces, one of the faces shall be relieved (counterbored or recessed) to prevent a leaking joint or improper fit caused by marring.

4.4.4.3 Jackets

Jackets for heating or cooling the casing or stuffing box, or both, are optional. Jackets shall be designed for an operating pressure of at least 6 bar at a temperature of 170 °C.

Jacket cooling systems shall be designed to positively prevent leakage of pumped liquid into the coolant. Coolant passage shall not open into casing joints.

4.4.4.4 Casing gaskets

Casing gaskets shall be of a design suitable for the working conditions and for hydrostatic test conditions at ambient temperature.

For radial split casings the casing-cover gaskets shall be confined on the atmospheric side to prevent blow-out.

Radially split casings (including mechanical seal end plate gaskets) shall have metal-to-metal fits with confined controlled compression gaskets.

4.4.4.5 External bolting

4.4.4.5.1 Bolts or studs that connect parts of the pressure casing, including shaft seal housing, shall be at least 12 mm diameter (ISO metric series).

The use of bolts or studs smaller than 12 mm diameter, if necessary due to space limitations, shall be agreed upon between purchaser and manufacturer/supplier. In such a case the bolting torque should be specified by the manufacturer/supplier.

4.4.4.5.2 The bolting selected (property class according to information in annex L) shall be adequate for the maximum allowable working pressure and temperature and for normal tightening procedures. If at some points it is necessary to use a fastener of special quality, interchangeable fasteners for other joints shall be of the same special quality.

4.4.4.5.3 Tapped holes in pressure parts shall be held to a minimum. Sufficient metal in addition to the metal allowance for corrosion shall be left around and below the bottom of drilled and tapped holes in pressure sections of casings to prevent leakage.

4.4.4.5.4 To facilitate dismantling, internal bolting for vertical pumps shall be of a material fully resistant to corrosive attack by the fluid pumped.

4.4.4.5.5 Studded connections shall be supplied with studs installed. Blind stud holes should be drilled only deep enough to allow a preferred tap depth 1,5 times the major diameter of the stud.

4.4.4.5.6 Studs are preferred to cap screws.

4.4.4.5.7 A clearance shall be provided at bolting locations to permit the use of socket or box-type wrenches. The manufacturer/supplier shall supply any required special tools and fixtures.

4.5 Branches (nozzles) and miscellaneous connections

4.5.1 General

For the purpose of this International Standard, the terms branch and nozzle are synonymous.

This subclause is concerned with all fluid connections to the pump, whether for operation or maintenance.

4.5.2 Vent, pressure-gauge and drain

4.5.2.1 All pumps shall be provided with a vent connection unless the pump is made self-venting by the arrangement of the nozzles.

4.5.2.2 Preferably, no tapped openings shall be supplied in the suction or discharge passages or in other high-velocity areas of the pump unless they are essential for pump operation. **If drain, vent, or pressure gauge connections are required, they shall be specified by the purchaser in the enquiry and order.**

4.5.3 Closures

The material for the closures (plugs, blank/blind flanges etc.) shall be appropriate for the pumped liquid. Attention shall be paid to the suitability of material combinations to resist corrosion and to minimize the risk of seizure or galling of screw threads.

All openings exposed to the pumped liquid under pressure, including all shaft seal openings, shall be fitted with removable closures adequate for containing pressure.

4.5.4 Auxiliary pipe connections

4.5.4.1 All auxiliary pipe connections shall be of adequate material, size and thickness for the intended duty (see also 4.14).

4.5.4.2 Connections shall be at least 15 mm (outside diameter) for pumps with discharge openings of 50 mm and smaller. Connections shall be at least 20 mm (outside diameter) for pumps with discharge openings of 80 mm and larger, except that connections for seal flush piping and lantern rings may be 15 mm (outside diameter) without regard to pump size. When, because of space limitations, smaller connections must be used, all precautions shall be taken to protect them from damage and ensure their reliability.