Sealless Centrifugal Pumps for Petroleum, Petrochemical, and Gas Industry Process Service

API STANDARD 685
SECOND EDITION, FEBRUARY 2011

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AMERICAN PETROLEUM INSTITUTE

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Downstream Segment

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Introduction

Users of this National Standard should be aware that further or differing requirements may be needed for individual applications. This National 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 National Standard and provide details.

Annex A contains application specific information and cautions.

Annex B contains hazard-based criteria for secondary containment/control specification.

Annex C contains nomenclature for sealless pumps.

Annex D contains schematic drawings of cooling water and circulation systems.

Annex E defines options for instrumentation and protective systems.

Annex F specifies criteria for piping design.

Annex G gives guidance on material class selection.

Annex H specifies requirements and gives guidance on materials selection.

Annex I provides information on magnetic materials for magnetic couplings.

Annex J specifies requirements for determining residual unbalance.

Annex K provides information and examples for pressure temperature profiles in the recirculation flowpath.

Annex L specifies requirements for lateral analysis.

Annex M specifies requirements for standard baseplates.

Annex N contains an inspector's checklist.

Annex O contains forms which may be used to indicate Vendor drawing and data requirements.

Annex P contains forms which may be used to record test data.

Annex Q specifies calculations for specific speed and suction specific speed.

Annex R contains a data sheet format which Purchasers are encouraged to use.

This National Standard requires the Purchaser to specify certain details and features.

A bullet (•) at the beginning of a subclause or paragraph indicates that either a decision by, or further information from, the Purchaser is required. Further information should be shown on the data sheets or stated in the quotation request and purchase order.

In this National Standard, US Customary units are included in brackets for information.

Sealless Centrifugal Pumps for Petroleum, Petrochemical, and Gas Industry Process Service

1 Scope

1.1 This standard specifies the minimum requirements for sealless centrifugal pumps for use in petroleum, heavy duty petrochemical and gas industry services. Refer to Annex A for application information. Notes following a clause are informative.

1.2 This standard is applicable to single stage overhung pumps of two classifications, Magnetic Drive Pumps (MDP) and Canned Motor Pumps (CMP). Sections 2 through 8 and Section 10 cover requirements applicable to both classifications. Section 9 is divided into two subsections and covers requirements unique to each classification.

NOTE Extension of applicability to other designs such as multistage will need additional input and agreement between Purchaser and Supplier.

1.3 When application of sealless pumps is indicated, relevant industry operating experience suggests sealless pumps produced to this Standard may be used for many applications and should be applied when conditions exceed any of the following:

— Discharge pressure	1900 kPa	(275 psig)
— Suction pressure	500 kPa	(75 psig)
— Pumping temperature	150 °C	(300 °F)
— Rotative speed	3600 r/min	
— Rated total head	120 m	(400 ft)
— Impeller diameter	330 mm	(13 in.)

NOTE For sealed pumps, refer to ISO Standard 13709 (API 610).

2 Normative References

2.1 The following referenced documents are indispensable for the application of this document. The way in which these referenced documents are cited determines the extent (in whole or in part) to which they apply. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

API 611, *General-purpose Steam Turbines for Petroleum, Petrochemical, and Gas Industry Service*

API 670, *Machinery Protection Systems*

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

ABMA 7 [1], *Shaft and Housing Fits for Metric Radial Ball and Roller Bearings (Except Tapered Roller Bearings) Conforming to Basic Boundary Plan*

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

AGMA 9000 [2], *Flexible Coupling—Potential Unbalance Classification*

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

ANSI B15.1-2000 [3], *Safety Standard for Mechanical Power Transmission Apparatus*

ASME B1.1 [4], *Unified Inch Screw Threads, UN and UNR Thread Form*

ASME B16.5, *Pipe Flanges and Flanged Fittings NPS 1/2 through NPS 24*

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

ASME, *Boiler and Pressure Vessel Code, Section V, Nondestructive Examination*

ASME, *Boiler and Pressure Vessel Code, Section VIII, Rules for Construction of Pressure Vessels*

ASME, *Boiler and Pressure Vessel Code, Section IX, Welding and Brazing Qualifications*

EN 953 [5], *Safety of Machinery—General Requirements for The Design And Construction of Guards (Fixed, Movable)*

EN 13445 (all parts), *Unfired Pressure Vessels*

EN 13463-1, *Non-electrical Equipment for Potentially Explosive Atmospheres—Method and Requirements*

HI 1.6 [6], *Centrifugal Pumps—Centrifugal Tests*

IEEE 841 [7], *Standard for Petroleum and Chemical Industry—Severe Duty Totally Enclosed Fan-Cooled (TEFC) Squirrel Cage Induction Motors—Up To and Including 370 kW (500 hp)*

IEC 60079 (all parts) [8], *Electrical Apparatus for Explosive Gas Atmosphere*

ISO 7-1 [9], *Pipe Threads Where Pressure-Tight Joints are Made on the Threads—Part 1: Dimensions, Tolerances and Designation*

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 724, *ISO General-purpose Metric Screw Threads—Basic Dimensions*

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2 American Gear Manufacturers Association, 1500 King Street, Suite 201, Alexandria, VA 22314, USA.
3 American National Standards Institute, 1819 L Street, Suite 600, Washington, D.C. 20036
4 American Society of Mechanical Engineers, Three Park Avenue, New York, NY 10016-5990, USA.
5 European Committee for Standardization, Avenue Marnix 17, B-1000, Brussels, Belgium, www.cen.eu.
6 Hydraulic Institute, 6 Campus Drive, First Floor North, Parsippany NJ, 07054-4406, www.pumps.org.
7 Institute of Electrical & Electronics Engineers, 445 Hoes Lane, Piscataway, NJ 08855-1331.
8 International Electrotechnical Commission, 3, rue de Varembé, P.O. Box 131, CH-1211, Geneva 20, Switzerland, www.iec.ch.
9 International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, www.iso.org.

ISO 965 (all parts), *ISO General-purpose Metric Screw Threads—Tolerances*

ISO 1940-1, *Mechanical Vibration—Balance Quality Requirements for Rotors in a Constant (Rigid) State—Part 1: Specification and Verification of Balance Tolerances*

ISO 3117, *Tangential Keys and Keyways*

ISO 5753, *Rolling Bearings—Radial Internal Clearance*

ISO 7005-1, *Metallic Flanges—Part 1: Steel Flanges for Industrial and General Service Piping Systems*

ISO 8501 (all parts), *Preparation of Steel Substrates Before Application of Paints and Related Products—Visual Assessment of Surface Cleanliness*

ISO 9606, *Qualification Test of Welders—Fusion Welding (All Parts)*

ISO 9906, *Rotodynamic pumps—Hydraulic Performance Acceptance Tests—Grades 1 and 2*

ISO 10438:2008 (all parts), *Petroleum, Petrochemical and Natural Gas Industries—Lubrication, Shaft-Sealing and Control-oil Systems and Auxiliaries*

ISO 14120, *Safety of Machinery—Guards—General Requirements for the Design and Construction of Fixed and Moveable Guards*

ISO 14691, *Petroleum and Natural Gas Industries—Flexible Couplings for Mechanical Power Transmission—General Purpose Applications*

ISO 15156-1 *Petroleum and Natural Gas Industries—Materials for Use in H_2S-Containing Environments in Oil and Gas Production—Part 1: General Principles for Selection of Cracking-resistant Materials*

ISO 15609 (all parts), *Specification and Qualification of Welding Procedures for Metallic Materials—Welding Procedure Specification (All Parts)*

ISO TR 17766:2004, *Centrifugal Pumps Handling Viscous Liquids—Performance Corrections*

MSS-SP-55 [10], *Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components—Visual Method For Evaluation of Surface Irregularities*

NACE MR0103 [11], *Materials Resistant to Sulfide Stress Cracking in Corrosive Petroleum Refining Environments*

NACE MR0175, *Sulfide Stress Cracking Resistant Metallic Materials for Oilfield Equipment*

NFPA 70 [12], *National Electrical Code*

SSPC SP 6 [13], *Commercial Blast Cleaning*

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[10] Manufacturers Standardization Society of The Valve and Fittings Industry Inc., 127 Park Street N.E., Vienna, VA 22180-4602, USA, www.ms-hq.com.

[11] NACE International (formerly National Association of Corrosion Engineers), 1440 South Creek Drive, PO Box 218340, Houston, TX 77218-8340, USA.

[12] National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02269-9101, USA.

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

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

2.3 Notes following a section are informative.

2.4 The standards, codes, and specifications that are in effect at the time of the publication of this standard shall, to the extent specified herein, form a part of this standard.

2.5 The applicability of changes in standards, codes, and specifications that occur after the publication of this standard shall be mutually agreed between the Purchaser and the Vendor.

3 Definition of Terms

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

3.1
air gap
Radial distance between the inside of the outer magnet ring and the containment shell or, the total radial dimension between the stator inside bore and the outside diameter of the basic rotor core (armature) prior to installation of stator liner and rotor liner.

3.2
axially split
Split with the principal joint parallel to the shaft centerline.

3.3
allowable operating region
Portion of a pump's hydraulic coverage over which the pump is allowed to operate, based on vibration within the upper limit of this Standard or temperature rise or other limitation, specified by the Manufacturer.

3.4
axial thrust
Net axial load on the pump shaft caused by hydraulic forces acting on the impeller shrouds and rotor or inner magnet ring.

3.5
best efficiency point
BEP
Flowrate at which a pump achieves its highest efficiency at rated impeller diameter.

NOTE The best efficiency point flowrate at maximum impeller diameter is used to determine pump specific speed and suction specific speed. The best efficiency point flowrate at reduced impeller diameters is similarly reduced from the value at maximum impeller diameter.

3.6
canned motor pump
CMP
Type of sealless pump which has a common shaft to link pump and motor in a single sealed unit. The pumped liquid, or a flush fluid, is circulated through the motor rotor chamber, but is isolated from the motor electrical components by a thin corrosion-resistant nonmagnetic stator liner (Figure C.2).

3.7
containment shell
Pressure containing boundary located within the drive end that separates the inner and outer magnet rings of a magnetic drive pump (Figure C.1 and Figure C.3).

3.8
coupling (magnetic)
Attraction of the magnets of the Inner Magnet Ring and Outer Magnet Ring allowing both to rotate synchronously or asynchronously in the case of a torque ring drive.

3.9
critical speed
Shaft rotational speed at which the rotor-bearing-support system is in a state of resonance.

3.10
datum elevation
Elevation to which values of net positive suction head (NPSH) are referred (see 6.1.12).

cf. **net positive suction head** (3.36).

3.11
decouple
To break the magnetic linkage between inner and outer magnet rings of a synchronous coupling resulting in a failure of the magnet assemblies to rotate synchronously.

3.12
demagnetization
Loss of magnetic attraction due to such causes as mechanical damage, or elevated temperature.

3.13
design
Manufacturer's calculated parameter.

NOTE A term that may be used by the equipment Manufacturer to describe various parameters such as, design power, design pressure, design temperature, or design speed. It is not intended for the Purchaser to use this term.

3.14
drive train component
Item of the equipment used in series to drive the pump.

EXAMPLE Motor, gear, turbine, engine, fluid drive, clutch.

3.15
eddy current losses
Losses from random electrical currents generated in a conductive material when a magnetic field is rotated around it. These losses are normally dissipated as heat due to the electrical resistance of the material.

3.16
electrical feed-through barrier
Static seal in a canned motor pump through which electrical lines feed the motor stator (see Figure C.4).

3.17
hydraulic thrust balance
Axial thrust equalization achieved by means of an impeller design, by impeller balance holes or by thrust balancing through variable orifices in the drive end.

3.18
hydrodynamic bearing
Bearing that uses the principles of hydrodynamic lubrication.

NOTE The bearing surfaces are oriented so that relative motion forms a fluid wedge, or wedges, to support the load without journal-to-bearing contact.

3.19
hysteresis
Failure of a magnetic material, that has been changed by an external agent, to return to its original magnetic strength when the cause of the change is removed.

3.20
inner magnet ring
Cylindrical band of magnets operating within the containment shell of a magnetic drive pump, driven by the outer magnet ring. The inner magnet ring contains the same number of magnetic poles as the outer magnet ring, and is mounted on the same shaft as the pump impeller (see Figure C.3).

3.21
inner magnet sheathing
Protective covering of the inner magnet ring in a magnetic drive pump (see Figure C.3).

3.22
journal sleeve
Renewable component of the journal.

3.23
liquid end
End of the pump which converts mechanical energy to kinetic energy in the pumped fluid.

3.24
liquid gap
Radial distance between the containment shell inside surface and the outside surface of the inner magnet sheathing or the radial distance between the stator liner inside surface and the rotor liner outside surface.

3.25
locked rotor torque
Maximum torque which a motor will develop at zero rotation for all angular positions of the rotor with rated voltage applied at rated frequency.

3.26
magnetic drive pump
MDP
Type of sealless pump which utilizes magnets to drive an internal rotating assembly consisting of an impeller, shaft and inner drive member (torque ring or inner magnet ring) through a thin, corrosion-resistant containment shell (Figure C.1).

3.27
maximum allowable temperature
Maximum continuous temperature for which the Manufacturer has designed the equipment (or any part to which the term is referred) when pumping the specified liquid at the specified maximum operating pressure.

3.28
maximum allowable working pressure
MAWP
Maximum continuous pressure for which the Manufacturer has designed the equipment (or any part to which the term is referred) when pumping the specified liquid at the specified maximum operating temperature.

3.29
maximum continuous speed
Highest rotational speed (revolutions per minute) at which the machine, as built and tested, is capable of continuous operation with the specified fluid at any of the specified operating conditions.

3.30
maximum discharge pressure
Maximum specified suction pressure plus the maximum differential pressure the pump is able to develop when operating with the furnished impeller at rated speed with liquid of the specified normal relative density (specific gravity).

3.31
maximum operating temperature
Highest temperature of the pumped liquid, including upset conditions, to which the pump is exposed.

3.32
maximum suction pressure
Highest suction pressure to which the pump is subjected during operation (non-transient, does not include water hammer).

3.33
minimum continuous stable flow
Lowest flow at which the pump can operate with the specified fluid without exceeding the vibration limits imposed by this standard.

3.34
minimum continuous thermal flow
Lowest flow at which the pump can operate without its operation being impaired by the temperature rise of the pumped liquid.

3.35
minimum design metal temperature
Lowest mean metal temperature (through the thickness) expected in service, including operation upsets, auto-refrigeration and temperature of the surrounding environment, for which the equipment is designed.

3.36
net positive suction head
NPSH
Absolute inlet total head above the head equivalent to the vapor pressure referred to the NPSH datum plane.

NOTE It is expressed in meters (feet) of head of the pumped liquid.

3.37
net positive suction head available
NPSHA
NPSH determined by the Purchaser for the pumping system with the liquid at the rated flow and normal pumping temperature.

3.38
net positive suction head required
NPSH3
NPSH that results in a 3 % loss of head (first stage head in a multistage pump) determined by the Vendor by testing with water.

3.39
normal operating point
Point at which the pump is expected to operate under normal process conditions.

3.40
normal wear part
Part normally restored or replaced at each pump overhaul.

EXAMPLE Wear rings, throat bushing, bearings, and gaskets.

3.41
observed inspection
observed test
Inspection or test where the Purchaser is notified of the timing of the inspection or test and the inspection or test is performed as scheduled, regardless of whether the Purchaser or his representative is present.

3.42
oil mist lubrication
Lubrication provided by oil mist produced by atomization and transported to the bearing housing, or housings, by compressed air.

3.43
operating region
Portion of a pump's hydraulic coverage over which the pump operates.

3.44
outer magnet ring
The band of permanent magnets securely fixed to a cylindrical frame and evenly spaced to provide a uniform magnetic field. The outer magnet ring rotates about the containment shell, driving the inner magnet ring or torque ring.

3.45
overhung pump
Pump whose impeller is supported by a cantilever shaft from its bearing assembly.

NOTE Overhung pumps may be horizontal or vertical.

3.46
Owner
Final recipient of the equipment who may delegate another agent as the Purchaser of the equipment.

3.47
pole
Region of a magnet where flux density is concentrated.

3.48
power end
End of the pump that provides the mechanical energy necessary for the operation of the liquid end.

3.49
preferred operating region
Portion of a pump's hydraulic coverage over which the pump's vibration is within the base limit of this standard (see 6.1.16).

3.50
pressure casing
Composite of all stationary pressure containing parts of the unit, including all nozzles and other attached parts.

3.51
primary pressure casing
Composite of all stationary pressure-containing parts of the unit which normally are exposed to pumped liquids, including the stator liner or containment shell (see Figure C.1 and Figure C.2).

3.52
product lubricated bearing
Bearing bushing and journal that operate in a pumped liquid lubricated environment to support the shaft of the inner magnet ring of a magnetic drive pump or the rotor assembly of a canned motor pump.

3.53
Purchaser
Agency that issues the order and specification to the Vendor.

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

3.54
pure oil mist lubrication
(dry sump)
System in which the mist both lubricates the bearing and purges the housing and there is no oil level in the sump.

3.55
purge oil mist lubrication
(wet sump)
System in which the mist only purges the bearing housing.

NOTE Bearing lubrication is by conventional oil bath, flinger, or oil ring.

3.56
radial loading
Side load perpendicular to the pump shaft and drive shaft due to unbalanced hydraulic loading on the impeller, mechanical and magnetic rotor unbalance, rotor assembly weight, and forces of the fluid circulating through the rotor chamber.

3.57
radially split
Split with the principal joint perpendicular to the shaft centerline.

3.58
rated operating point
Point at which the Vendor certifies that pump performance is within the tolerances stated in this standard (see 8.3.3.3.2).

3.59
relative density
(specific gravity)
Property of a liquid expressed as the ratio of the liquid's density to that of water at 4 °C (39.2 °F).

3.60
rotor
Assembly of all the rotating parts of a centrifugal pump.

3.61
rotor chamber
Liquid filled cavity bounded by the inside diameter of the stator liner and the bearing housings in a canned motor pump or the liquid filled cavity in a magnetic drive pump internal to the containment shell which contains the inner magnet ring, shaft, and bearings (see Figure C.3 and Figure C.4).

3.62
rotor chamber temperature rise
Temperature increase of the fluid circulated through the rotor chamber. It is the difference between the temperature of the fluid leaving the rotor chamber and that entering.

3.63
rotor liner
Outer sheathing of the rotor assembly in a canned motor pump (see Figure C.4).

3.64
sealless pump
Pump design that does not require an external dynamic shaft seal. Static seals are the primary method of containing the fluid.

3.65
secondary containment
Confinement of the pumped liquid within a secondary pressure casing in the event of failure of the primary containment shell or stator liner.

3.66
secondary containment system
Combination of devices that, in the event of leakage from the primary containment shell or stator liner, confines the pumped liquid within a secondary pressure casing that includes provisions to indicate a failure of the primary containment shell or stator liner.

3.67
secondary control
Minimization of release of pumped liquid in the event of failure of the containment shell or stator liner.

3.68
secondary control system
Combination of devices (including a secondary pressure casing) that, in the event of leakage from the containment shell or stator liner, minimizes and safely directs the release of pumped liquid. It includes provision(s) to indicate a failure of the containment shell or liner.

3.69
secondary pressure casing
Composite of all pressure containing parts of the unit which are exposed to pressure resulting from failure of a containment shell or stator liner.

3.70
sleeve bearing
Bearing consisting of a rotating member (journal) and a stationary member (bearing bushing).

3.71
slip
Speed differential between the torque ring and outer magnet ring in a torque ring drive pump.

3.72
specific speed
Index relating flow, total head and rotational speed for pumps of similar geometry.

3.73
stator housing
Housing in which a stator assembly is mounted in a canned motor pump (see Figure C.2).

3.74
stator liner
The member that separates the liquid in the rotor chamber from the stator assembly in a canned motor pump (see Figure C.4).

3.75
suction pressure
Liquid pressure at the suction flange of the pump.

3.76
suction specific speed
Index relating flow, NPSH3 and rotational speed for pumps of similar geometry.

3.77
throat bushing
Device that forms a restrictive close clearance around the sleeve (or shaft) between the rotor chamber and the impeller.

3.78
throttle bushing
A secondary control device on a magnetic drive pump that forms a restrictive close clearance around the shaft (or sleeve) of the outer magnet ring.

3.79
total indicator reading
total indicator runout
TIR
Difference between the maximum and minimum readings of a dial indicator or similar device, monitoring a face or cylindrical surface, during one complete revolution of the monitored surface.

NOTE For a perfectly cylindrical surface, the indicator reading implies an eccentricity equal to half the reading. For a perfectly flat face the indicator reading gives an out-of-squareness equal to the reading. If the diameter in question is not perfectly cylindrical or flat, interpretation of the meaning of TIR is more complex and may represent ovality or lobing.

3.80
tolerance ring
Component which acts as an elastic shim to frictionally position mating cylindrical parts.

3.81
torque ring drive
Magnetic coupling consisting of a permanent outer magnet ring and an inner torque ring containing a network of copper rods supported on a mild steel core. The rotating outer magnet ring generates eddy currents in the copper rods which converts the core to an electromagnet. The electromagnet follows the rotating outer magnet ring, but at a slightly slower speed due to slip.

3.82
trip speed
Speed (in revolutions per minute) at which the independent emergency overspeed device operates to shut down a prime mover. Also electric motor driver synchronous speed at maximum supply frequency.

3.83
unit responsibility
Responsibility for coordinating the documentation, delivery and technical aspects of the equipment and all auxiliary systems included in the scope of the order.

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

3.84
Vendor
supplier
Manufacturer or Manufacturer's agent that supplies the equipment and is normally responsible for service support.

3.85
vertical in-line pump
Vertical-axis single stage overhung pump whose suction and discharge connections have a common centerline that intersects the shaft axis.

3.86
witnessed inspection
witnessed test
Inspection or test for which the Purchaser is notified of the timing of the inspection or test and a hold is placed on the inspection or test until the Purchaser or his representative is in attendance.

4 General

4.1 Unit Responsibility

Unless otherwise specified, the pump Vendor shall have unit responsibility. The pump Vendor shall ensure that all sub-Vendors comply with the requirements of this standard and all reference documents.

4.2 Nomenclature

A guide to sealless pump nomenclature can be found in Annex C.

5 Requirements

5.1 System of Measurements

The Purchaser will specify whether data, drawings, hardware (including fasteners) and maintenance dimensions of pumps shall be in the SI or US Customary (USC) system of measurements. Use of an SI datasheet indicates the International Standard System of measurements shall be used. Use of a USC datasheet indicates the US Customary system of measurements shall be used.

5.2 Statutory Requirements

The Purchaser and the Vendor shall mutually determine the measures to be taken to comply with any governmental codes, regulations, ordinances, directives, or rules that are applicable to the equipment, its packaging and any preservatives used, (ISO Directives Part 3:1997 Annex E). Equipment installed in the European Economic Area (EEA) shall comply with all applicable European Union Directives.

NOTE The European Economic Area includes the countries of the European Union plus Norway, Iceland and Liechtenstein.

5.3 Requirements

5.3.1 In case of conflict between this standard and the inquiry, the inquiry shall govern. At the time of the order, the order shall govern.

5.3.2 Where requirements specific to a particular pump type in Clause 9 conflict with any other clauses in this document, the requirements of Clause 9 shall govern.

6 Basic Design

6.1 General

6.1.1 The equipment (including auxiliaries) covered by this standard shall be designed and constructed for a minimum service life of 20 years (excluding normal wear parts as identified in Table 14) and at least 3 years of uninterrupted operation. Shutting down the equipment to perform maintenance or inspection does not meet the continuous uninterrupted operation requirement.

NOTE It is recognized that these are design criteria and that service or duty severity, mis-operation, or improper maintenance can result in a machine failing to meet these criteria.

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 and Vendor have a responsibility to transfer information to each other. Minimum considerations shall include all items in 6.1.3.1 through 6.1.3.8

• **6.1.3.1** The Purchaser shall specify the operating conditions, site conditions, and utility conditions, including all data shown on the process data sheet (Annex R).

6.1.3.2 The Purchaser shall generate and supply the Vendor with the Material Safety Data Sheet (MSDS) of the pumped fluid. There may be more than one MSDS for variations in pumped fluid.

6.1.3.3 Properties of the fluid being pumped are critical to the performance of the pump. The Purchaser shall furnish information including, but not limited to, the following: NPSHA, temperature/vapor pressure curve, temperature/ viscosity curve, specific heat, specific gravity, and polymerization characteristics. The Purchaser shall also furnish information on any gas entrainment or solids present including particle size, percent, and distribution.

6.1.3.4 It is important that the pumped fluid remain a liquid at all points in the pump and at all operating conditions. The Vendor shall furnish information including, but not limited to, the following: NPSH3, temperature rise based on fluid being pumped at minimum flow, rated flow, and 120 % BEP flowrate, and fluid condition after shutdown, effect of wear, minimum continuous stable flow, and minimum continuous thermal flow.

6.1.3.5 Proper pump design and selection are dependent on knowledge of the Purchaser's system. The Purchaser shall furnish information including, but not limited to, pump location, suction vessel relative position, and piping arrangement.

6.1.3.6 For parallel or series applications, knowledge of the system head/capacity curve is required for stable control and reliable operation (see Annex A). Purchaser shall provide system head /capacity curves or data for the full operating range specified.

6.1.3.7 Since sealless pumps use pumpage or other liquid to cool and lubricate the bearings, the circulating liquid must remain stable as it passes through the bearings. The Vendor shall furnish the temperature and pressure profiles of the fluid recirculation flow path through the pump and rotor chamber. These profiles are to be shown at maximum specified operating temperature and are to be provided for minimum stable flow, design conditions, and maximum rated flow. The Vendor shall also furnish the NPSH3 of any auxiliary impellers in the circulating flow path. Refer to Annex K.

NOTE The temperature versus pressure profile throughout the pump must be above the vapor pressure curve at all locations in the flow path for all conditions. This is to ensure that the fluid does not flash.

6.1.3.8 The Purchaser shall provide separate data when there are additional service conditions, such as different fluids or grossly different operating conditions. These additional services could be rare (such as an initial water run) or common (multi-product batch).

6.1.4 The equipment shall be capable of operation at the normal and rated operating points and any other anticipated operating conditions specified by the Purchaser.

6.1.5 Pumps shall be designed for flammable or hazardous services.

6.1.6 Pumps shall be capable of at least a 5 % head increase at rated conditions by replacement of the impeller(s) with one(s) of larger diameter or different hydraulic design.

NOTE This requirement is intended to prevent a change in selection caused by refinement of hydraulic requirements after the pump has been purchased. It is not intended to accommodate future expandability. If there is a future operating requirement, it should be specified separately and considered in selection. If variable speed operation has been specified, the requirements of this paragraph are not applicable.

6.1.7 Pumps shall be capable of operating at least up to the maximum continuous speed. The maximum continuous speed shall be:

a) equal to the speed corresponding to the synchronous speed at maximum supply frequency for electrical motors;

b) at least 105 % of rated speed for variable-speed pumps, and any fixed-speed pump sparing or spared by a pump whose driver is capable of exceeding rated speed.

6.1.8 Variable-speed pumping system, pump and driver, shall be designed for excursions to trip speed without damage.

6.1.9 Pumps shall use throat bushings, wear rings, impeller balance holes, auxiliary impeller, and/or flushing-line arrangements to maintain a rotor chamber pressure greater than the suction pressure. The pump design shall also ensure that the temperature and pressure in the rotor chamber prevent vaporization at all operating conditions, including minimum flow while providing continuous flow through the rotor chamber for cooling and bearing lubrication.

NOTE Vaporization in the bearing area of sealless pumps may occur at flows above minimum flow in the rotor area. Review vapor pressure-temperature diagrams for limitations.

6.1.10 All internal cavities shall be completely self-venting. When exception must be taken, the Vendor shall, as a minimum, include provision for manual venting and provide a “caution” tag attached to the pump to indicate that manual venting is required before and after maintenance.

6.1.11 Unless otherwise specified, all internal cavities, including the rotor chamber, shall be drainable through a single connection to the pump assembly. If fluid will remain in the internal cavities when this drain connection is opened, an additional connection shall be provided for purging/flushing the rotor chamber. The Vendor shall include the size and location of this connection in the proposal.

6.1.12 The Vendor shall enter on the datasheets the NPSH3 based on water at a temperature of less than 55 °C (130 °F) at the rated capacity and rated speed. A reduction or correction factor for liquids other than water (such as hydrocarbons) shall not be applied.

Unless otherwise specified, the datum elevation shall be the shaft centerline for horizontal pumps, the suction-nozzle centerline for vertical in-line pumps, and the top of the foundation for vertically suspended pumps. Other configurations are possible and the Vendor and Purchaser shall agree on a datum in those services.

NOTE 1 The Purchaser should consider an appropriate NPSH margin in addition to the NPSH3 specified. An NPSH margin is the NPSH that exists in excess of the pump's NPSH3 (see 3.38). It is desirable to have an operating NPSH margin that is sufficient at all flows (from minimum continuous stable flow to maximum expected operating flow) to protect the pump from damage caused by flow recirculation, separation, and cavitation. Consideration should be given to the effects of heated fluid when recirculated back to the pump suction in establishing the NPSH margin. The Vendor should be consulted about recommended NPSH margins for the specific pump type and intended service.

NOTE 2 In establishing NPSHA (see 3.37), the Purchaser and the Vendor should recognize the relationship between minimum continuous stable flow and the pump's suction specific speed. In general, minimum continuous stable flow, expressed as a percentage of flow at the pump's best efficiency point, increases as suction specific speed increases. However, other factors, such as the pump's energy level and hydraulic design, the pumped liquid, and the NPSH margin, also affect the pump's ability to operate satisfactorily over a wide flow range. Pump design that addresses low-flow operation is an evolving technology, and selection of suction specific speed levels and NPSH margins should take into account current industry and Vendor experience.

● **6.1.13** The pump suction-specific speed shall be calculated in accordance with Annex Q and, if specified, limited as stated on the data sheet.

6.1.14 Unless otherwise specified, pumps that handle liquids more viscous than water shall have their water performance corrected in accordance with ISO/TR 17766. Additional corrections may be necessary for viscous effects on the rotor. These additional corrections shall be highlighted in the proposal. Correction factors used for viscous fluid shall be submitted with both sales proposal curves and final test curves.

NOTE For the purpose of this provision, ANSI/HI 9.6.7 is equivalent to ISO/TR 17766.

● **6.1.15** Pumps that have stable head/flowrate curves (continuous head rise to shut-off) are preferred for all applications and are required if parallel operation is specified. If parallel operation is specified, the head rise from rated point to shutoff shall be at least 10 %. If a discharge orifice is used as a means of providing a continuous rise to shut-off, this use shall be stated in the proposal.

6.1.16 Pumps shall have a preferred operating region (see 6.8.3.1) of 70 % to 120 % of best efficiency flowrate of the pump as furnished. Rated flow shall be within the region of 80 % to 110 % of best efficiency flowrate of the pump as furnished.

Setting specific limits for the preferred operating region and the location of rated flow is not intended to lead to the development of additional sizes of small pumps or preclude the use of high specific-speed pumps. Small pumps (that are known to operate satisfactorily at flows outside the specified limits) and high specific-speed pumps (which may have a narrower preferred operating region than specified) should be offered, where appropriate, and their preferred operating region clearly shown on the proposal curve. The pump specific speed shall be calculated in accordance with Annex Q.

NOTE 1 "Best efficiency flowrate of the pump as furnished" refers to the pump with the impeller diameter properly selected to meet head-flowrate performance requirements as stated on the data sheet.

NOTE 2 Very low specific speed pumps (often with "Barske" type impellers) might not be able to reach flowrates beyond 105 % of BEP. Limits on operating range may be dictated by pressure-temperature profile in CMPs and MDPs.

• **6.1.17** If specified, the Vendor shall provide maximum sound pressure level data per octave band for the equipment. Control of the sound level (SPL) of all equipment furnished shall be a joint effort of the Purchaser and the Vendor. The equipment furnished by the Vendor shall conform to the maximum allowable sound level specified by the Purchaser.

NOTE ISO Standards 3740, 3744, and 3746 may be consulted for guidance.

6.1.18 Pumps with heads greater than 200 m (650 ft) and with power more than 225 kW (300 hp) can require special provisions to reduce vane passing frequency vibration and low-frequency vibration at reduced flow rates.

Because of the need to manage impeller tip clearances, it is common practice for the impellers of high energy pumps to be modified after initial test to correct hydraulic performance by underfiling, overfiling or “V”-cutting. Any such modifications shall be documented in accordance with 10.3.4.1, and shall mandate a retest of the pump.

6.1.19 Pumps shall be designed to prevent damage from reverse rotation on starting check-outs. The pump shall be supplied with the means to detect backward rotation.

NOTE 1 Rotation indicators are available for CMP that verify direction of rotation.

NOTE 2 Motor rotation on MDP should be checked with the motor coupling disconnected.

• **6.1.20** The need for cooling shall be determined by the Vendor, and the method shall be agreed upon by the Purchaser. If cooling is required**,** one of the plans in Annex D shall be selected. The cooling system shall be suitable for operation with the coolant type, pressure, and temperature specified by the Purchaser. The Vendor shall specify the required flow. To avoid condensation, the minimum inlet water temperature to bearing housings should be above the ambient air temperature.

6.1.21 Jackets, if provided, shall have cleanout connections arranged so that the entire passageway can be mechanically cleaned, flushed, and drained.

6.1.22 A jacket system, if provided, shall be designed to prevent the process stream from leaking into the jacket. Jacket passages shall not open into casing joints.

6.1.23 Unless otherwise specified, the cooling system shall be designed for the conditions on the cooling system side as given in Table 1.

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 minimize water-side fouling; the criterion for minimum temperature rise is intended to minimize the use of cooling water. If such a conflict exists the Purchaser will approve the final selection.

Table 1—Water Cooling Systems–Conditions on the Water Side

Parameter	SI units	USC and Other 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 shall be as a minimum	700 kPa	100 psig; 7 bar
Test pressure(≥ 1.5 x MAWP), gauge	1050 kPa	150 psi; 10.5 bar
Maximum pressure drop	100 kPa	15 psi; 1 bar
Maximum inlet temperature	30 °C	90 °F
Maximum outlet temperature	50 °C	120 °F
Minimum temperature rise	20 °C	30 °F
Fouling factor on water side	0.35 m^2 – K/kW	0.002 hr-ft^2 – °F/Btu
Shell corrosion allowance (not for tubes)	3.0 mm	0.125 in.

Provision shall be made for complete venting and draining of the system.

NOTE Some cooling systems use liquids other than water. Corrosion and fouling issues should be discussed between the Purchaser and Vendor to assure proper material selection.

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

6.1.25 Electrical classification:

6.1.25.1 Locations for installed equipment can be classified as hazardous electrical areas or they can be unclassified. An unclassified area is considered non-hazardous; therefore, motors, electrical instrumentation, equipment, components, and electrical installations for unclassified areas are not governed by hazardous area electrical codes.

6.1.25.2 If an installation location is classified as hazardous, motors, electrical instrumentation, equipment, components, and electrical installations shall be suitable for the hazardous electrical area classification designation as specified.

• **6.1.25.3** All applicable electrical codes shall be specified. Local electrical codes that apply shall be provided by the Purchaser upon request.

6.1.25.4 Electrical codes vary by installation location. Refer to Table 2 for a tabulation of common hazardous area electrical codes in use.

6.1.26 All equipment shall be designed to permit rapid and economical maintenance. Major parts such as pressure casing components and bearing housings shall be designed and manufactured to ensure accurate alignment on reassembly.

NOTE This can be accomplished by the use of shouldering, pilot or machined fits, dowels, or keys.

6.1.27 The pump and its driver shall perform on their test stands and on their permanent foundation within the vibration acceptance criteria specified in 6.8.3.4. After installation, the performance of the combined units shall be the joint responsibility of the Purchaser and the pump Vendor.

6.1.28 Spare and all replacement parts for the pump and all furnished auxiliaries shall, as a minimum, meet all the criteria of this standard.

6.1.29 The requirements of 6.1.29.1 and 6.1.29.2 apply to vertical inline pump designs.

6.1.29.1 For vertical designs with motor up, a flat contact surface shall be provided on the bottom of the casing to make the pump stable if free-standing on a pad or foundation. The ratio of the unit center of gravity height to contact surface width shall be no greater than 3:1. This stability may be achieved through the design of the casing or by a permanent external stand. For motor down designs, the pump and motor should be supported by structure.

6.1.29.2 Pumps shall be designed so that they may either float with the suction and discharge pipe, or be bolted to a pad or foundation.

NOTE Flange loading on the pump can increase if the Purchaser elects to bolt the unit down. This should be addressed in the piping design.

6.1.30 Equipment, including all auxiliaries, shall be designed for outdoor installation and the specified site environmental conditions. The Vendor shall advise of any equipment protection required for the jobsite location (i.e. winterization for low ambient temperatures, or protection against unusual humidity, dusty or corrosive conditions, etc.).

Table 2—Common Hazardous Area Electrical Codes

Standards Org.	Codes	Where Used	Hazardous Electrical Area Classification Designation
IEC[a] CENELEC[b]	IEC 60079 EN 60079	European Union (EU) countries and worldwide, except U.S.	Zone, Gas Group, Temperature Class
European Union (EU)[c]	ATEX Directive 94/9/EC	Required, in addition to IEC, in EU countries only. May be requested in other countries.	Equipment Group, Category
NEC® [d]	NFPA 70 Sections 500-502, 504	United States	Class, Division, Group, Temperature Class
NEC® [e]	NFPA 70 Section 505	United States	Class I, Zone, Gas Group, Temperature Class
CEC® [f]	CSA C22.1-06, Section 18	Canada	*Primary:* Adoption of IEC - Zone, Gas Group, Temperature Class *In Appendix*: Class, Division, Group, Temperature Class

[a] IEC:International Electrotechnical Commission

[b] CENELEC:European Committee for Electrotechnical Standardization

[c] ATEX:“Atmospheres Explosibles”, “Equipment intended for use in Potentially Explosive Atmospheres”

[d] NEC®:*National Electrical Code*®, published by National Fire Protection Association, Inc. (NFPA)

[e] CEC®:*Canadian Electrical Code*®, published by Canadian Standards Association (CSA)

NOTE The ATEX directive, 94/9/EC, became effective on June 30, 2003, and applies to all equipment (mechanical and electrical) that is intended for use in a potentially explosive atmosphere, in the European Economic Area. While not a specific electrical code, it is listed in the table because most electrical products cannot be put into use in a hazardous area in the European Economic Area without ATEX certification. Also, mechanical products, which are used in the EU, in a hazardous area, are required to conform to the ATEX directive. The ATEX directive defines categories, which determine the approach used to obtain ATEX certification. Electrical and mechanical equipment are required to meet the essential health and safety requirements set forth in the ATEX directive.

6.1.31 Bolting and threads:

6.1.31.1 The details of threading shall conform to ISO 261, ISO 262, ISO 724, and ISO 965, or to ANSI/ASME B1.1. The Vendor shall advise the type of bolting used on the pump.

6.1.31.2 If ASME B1.1 threads have been specified, the thread series shall be variable pitch series UNC. The threads shall be Class 2 for bolting, studs and nuts. For other threads and nuts they shall be Class 2 or 3.

6.1.31.3 If ISO 261 and ISO 262 have been specified, the thread series shall be coarse. Threads shall be Class 6g for bolting and studs, and Class 6H for nuts.

6.1.32 Commercial fasteners shall be manufactured in accordance with the requirements of ASME B 18.18.2M or shall be procured from distributors having quality plans in accordance with ASME B 18.18.2M.

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

6.1.34 Unless otherwise specified or agreed, studs shall be supplied on all main casing joints, and all other joints and connections shall be supplied with external hexagon-head bolting.

6.1.35 Fasteners for pressure casings shall be not less than 12 mm (0.5 in.) in diameter.

6.1.36 Fasteners (excluding washers and headless set-screws) shall have the material grade and manufacturers identification symbols applied to one end of studs 10 mm ($^3/_8$ in.) in diameter and larger and to the heads of bolts 6 mm ($^1/_4$ in.) in diameter and larger. If the available area is inadequate, the grade symbol may be marked on one end and the Manufacturer's identification symbol marked on the other end. Studs shall be marked on the exposed end.

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

6.2 Pressure Casings

6.2.1 The pressure casing (including the secondary pressure casing) shall be designed in accordance with 6.2.1.1 and 6.2.1.2 as selected by the Vendor, and the casing joint bolting shall be in accordance with 6.2.1.3. The pressure casing shall be designed to:

a) operate without leakage or internal contact between rotating and stationary components while subject simultaneously to the MAWP (and maximum operating temperature) and the worst-case combination of twice the allowable nozzle loads of Table 4 applied through each nozzle;

b) withstand the hydrostatic test (see 8.3.2).

NOTE The twice-nozzle-load requirement is a pressure-casing design criterion. Allowable nozzle loads for piping designers are the values given in Table 4. Other factors such as casing support or baseplate stiffness affect allowable nozzle loads.

6.2.1.1 The tensile stress used in the design of the pressure casing for any metallic material shall not exceed 25 % of the minimum ultimate tensile strength or 67 % of the minimum yield strength for that material, whichever is lower, across the full range of specified operating temperatures. For castings, the design tensile stress values shall be multiplied by the appropriate casting factor, as shown in Table 3. The Manufacturer shall state the source of the material properties from those listed in Table H.2 (i.e. ASTM, UNS, ISO, EN, JIS), as well as the casting factors applied, in his proposal. National material standards other than those listed in Annex H, Table H.2, may be used with specific Purchaser approval. Design criteria for application of ceramics/composite containment shells shall be agreed between the Manufacturer and Purchaser.

NOTE In general, the criteria in 6.2.1 result in deflection (strain) being the determining consideration in the design of pump casings. Ultimate tensile or yield strength is seldom the limiting factor.

Table 3—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

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

6.2.1.3 For bolting, the allowable tensile stress is used to determine the total bolting area based on hydrostatic load or gasket preload. It is recognized that to provide the initial load required to obtain a reliable bolted joint, the bolting will be tightened to produce a tensile stress higher than the design tensile stress. Values in the range of 0.7 to 0.9 times yield are common.

6.2.2 The MAWP shall be at least the maximum discharge pressure plus 10 % of the maximum differential pressure, and shall not be less than a minimum gauge pressure rating of 4 MPa (40 bar) (600 psi) at 38 °C (100 °F), or at least ISO 7005-1 PN 50. The maximum allowable working pressure is a function of the design of the casing. The maximum allowable working pressure for a casing shall not be reduced based on the particular application requirements.

NOTE 1 The 10 % differential pressure margin is intended to accommodate head increases (6.1.6), higher speed in variable-speed pumps (6.1.7), and head (testing) tolerance (see Table 11).

NOTE 2 For the purposes of this provision, ANSI/ASME B16.5 Class 300 and EN 1759-1 class 300 are equivalent to ISO 7005-1 PN 50.

NOTE 3 This subclause provides minimum requirements consistent with designs existing at the time of publication of this standard.

• **6.2.3** Maximum discharge pressure shall be stated on the data sheet. If specified, the maximum discharge pressure shall be increased by the additional differential pressure developed during one or more of the following operating circumstances:

a) maximum specified relative density at any specified operating condition;

b) installation of an impeller of the maximum diameter;

c) operation to trip speed.

The Purchaser should assess the likelihood of increases in the maximum discharge pressures before specifying them.

The additional differential pressure developed at trip speed is normally a momentary excursion that is absorbed by the hydrostatic test margin.

• **6.2.4** If vacuum conditions at the pump suction are specified, the containment shell or stator liner, as applicable, shall be designed for the resulting external pressure.

6.2.5 The pressure casing shall be designed with a corrosion allowance to meet the requirements of 6.1.1. Unless otherwise specified the minimum corrosion allowance shall be 3 mm (0.12 in.), except that containment shells and liners shall be in accordance with 9.1.2.1.1 for magnetic drive pumps and both 9.2.3.1 and 9.2.4.1 for canned motor pumps.

NOTE The Vendor is encouraged to propose alternative corrosion allowances for consideration if materials of construction with superior corrosion resistance are employed and if they result in lower cost without affecting safety and reliability.

6.2.6 Axially split casings are not allowed. Pumps with radially split casings are required.

6.2.7 Pump casings shall have metal-to-metal fits, with confined controlled-compression gaskets such as an O-ring or a spiral-wound type. Gaskets other than spiral-wound may be proposed and furnished if proven suitable for service and approved by the Purchaser. Radially-split pressure casing joints and bolting shall be designed to seat a spiral-wound gasket.

NOTE See also 9.1.2.1.3 specific to MDP.

6.2.8 Casings shall be designed to permit removal of the rotor or inner magnet ring without disconnecting the suction or discharge piping.

6.2.9 Centerline supported pump casings shall be used for horizontal magnetic drive pumps with pumped liquid temperatures of 175 °C (350 °F) or higher. Centerline supported pump casings are typically not required for canned motor pumps.

NOTE Misalignment from thermal growth is not a concern with canned motor pumps as they have the motor integral with the pump.

6.2.10 O-ring sealing surfaces, including all grooves and bores, shall have a maximum surface roughness average value (Ra) of 1.6 µm (63 µin.). Bores shall have a minimum 3 mm (0.12 in.) radius or a minimum 1.5 mm (0.06 in.) chamfered lead-in. Chamfers shall have a maximum angle of 30°.

6.2.11 Jackscrews shall be provided to facilitate disassembly of the casing. One of the contacting faces shall be relieved (counter bored or recessed) to prevent a leaking joint or an improper fit caused by marring of the face. Guide rods shall be of sufficient length to prevent damage to the internals or casing studs by the casing during disassembly and reassembly.

6.2.12 Use of threaded holes in pressure parts shall be minimized. To prevent leakage in pressure sections of casings, metal, equal in thickness to at least half the nominal bolt or stud diameter, in addition to the allowance for corrosion, shall be left around and below the bottom of drilled and threaded holes. The depth of tapped holes shall be at least 1.5 times the nominal bolt or stud diameter.

6.2.13 Internal bolting shall be of a material fully resistant to corrosive attack by the pumped liquid.

6.3 Nozzles and Pressure Casing Connections

6.3.1 Casing Opening Sizes

6.3.1.1 All openings or nozzles for piping connections on pressure casings shall be standard pipe sizes and shall be in accordance with ISO 6708. Sizes DN 32, 65, 90, 125, 175, and 225 (NPS $1^1/_4$, $2^1/_2$, $3^1/_2$, 5, 7, and 9) shall not be used unless specifically approved by the Purchaser.

NOTE DN 65 ($2^1/_2$ NPS) and DN 125 (5 NPS) are typically accepted outside the United States

6.3.1.2 Casing connections other than suction and discharge nozzles shall be at least DN 15 (NPS $^1/_2$) for pumps with discharge nozzle openings DN 50 (NPS 2) and smaller. Connections shall be at least DN 20 (NPS $^3/_4$) for pumps with discharge nozzle openings DN 80 (NPS 3) and larger, except that connections for flush piping and gauges may be DN 15 (NPS $^1/_2$) regardless of pump size.

6.3.2 Suction and Discharge Nozzles

6.3.2.1 Suction and discharge nozzles shall be flanged and of equal rating.

6.3.2.2 Flanges shall, as a minimum, conform to the dimensional requirements of ISO 7005-1 PN 50 and the flange finish requirements of ANSI/ASME B16.5.

NOTE For the purpose of this provision, ANSI/ASME B16.5 Class 300 and EN 1759-1 class 300 are equivalent to ISO 7005-1 PN 50.

6.3.2.3 Unless otherwise specified, flat face flanges with full raised face thickness are acceptable. Flanges in all materials that are thicker or have a larger outside diameter than required by the relevant ISO or ASME standards referenced in this standard are acceptable. Non-standard (oversized) flanges shall be completely dimensioned on the arrangement drawing. If flange thickness requires stud-bolts with lengths that are non-standard relative to the flange rating, the Vendor shall identify this requirement in the proposal and on the arrangement drawing.

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

6.3.2.5 To minimize nozzle loading and facilitate installation of piping, machined faces of pump flanges shall be parallel to the plane as shown on the general arrangement drawing [see 10.2.2.1a)] within 0.5 degrees. Bolt holes or studs shall straddle centerlines parallel to the main axes of the pump.

6.3.3 Pressure Casing Connections

6.3.3.1 Unless otherwise specified, all connections to the primary pressure casing shall be socket welded, butt welded or integrally flanged. Threaded connections are not permitted, even if seal welded. Purchaser interface connections shall terminate in a flange.

• **6.3.3.2** If specified, special threaded fittings for transitioning from the casing or nipple to tubing for circulation piping may be used provided a secondary sealing feature such as o-rings are used and the joint does not depend on thread contact alone to seal fluid (refer to Figure 2).

6.3.3.3 Connections, including gusseting, welded to the casing shall meet or exceed the material and pressure-temperature requirements of the casing, including impact values, rather than the requirements of the connected piping.

6.3.3.4 The first segment of piping (nipple) welded to the casing should not be more than 150 mm (6 in.) in length, shall be straight for cleaning, and shall be a minimum of schedule 160 seamless for sizes DN 25 (NPS 1) and smaller and a minimum of schedule 80 for sizes DN 40 (NPS 1$^1/_2$) and larger. The first segment can attach axially to avoid increasing centerline height (see 9.1.5.3.4).

NOTE Straight nipples are desirable especially for drains, but are not always practical and exceptions should be noted in the proposal. For example, on small pumps this requirement may cause drain flange interference with the suction nozzle.

• **6.3.3.5** If specified, piping shall be gusseted in two orthogonal planes to increase the rigidity of the piped connection in accordance with the following stipulations.

a) Gussets shall be of a material compatible with the pressure casing and the piping and shall be made of either flat bar with a minimum cross section of 25 mm by 3 mm (1 in. by 0.12 in.) or round bar with a minimum diameter of 9 mm (0.38 in.).

b) Gusset design shall be as shown in Figure 1.

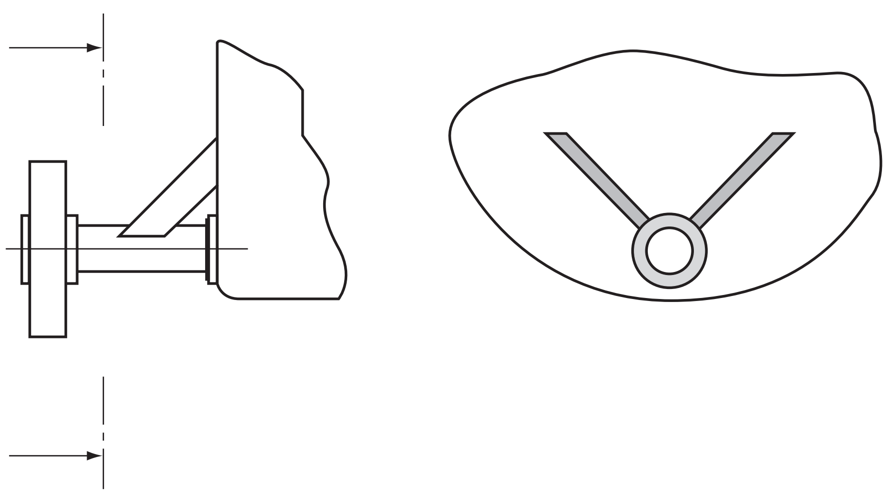


Figure 1—Typical Gusset Design

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

d) Gusset welding shall meet the fabrication requirements (see 6.10.3), including PWHT when required, and the inspection requirements of this standard (see 8.2.2).

e) Gussets may also be bolted to the casing if done prior to the hydrostatic test.

f) Proposals to use clamped or bolted gusset designs shall be submitted to the Purchaser for approval.

6.3.3.6 All connection welding shall be completed before the casing is hydrostatically tested (see 8.3.2).

• **6.3.3.7** If specified, auxiliary connections to the pressure casing shall be machined and studded. These connections shall conform to the facing and drilling requirements of ISO 7005-1 (ASME B16.5). Studs and nuts shall be furnished installed. The first 1.5 threads at both ends of each stud shall be removed.

NOTE For the purpose of this provision, ASME B16.5 is equivalent to ISO 7005-1.

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

6.3.3.9 All of the Purchaser's connections shall be accessible for disassembly without requiring the pump, or any major part of the pump to be moved.

6.3.3.10 A vent connection shall be provided if the pump is not functionally self venting by the arrangement of the suction and discharge nozzles.

NOTE A pump is considered functionally self-venting if the nozzle arrangement and the casing configuration permit sufficient venting of gases from the impeller, volute, bearing and drive areas to prevent loss of prime during the starting sequence.

6.3.3.11 Unless otherwise specified, auxiliary connections to the secondary casing may be threaded. Threaded connections shall meet requirements of 6.3.3.11.1 through 6.3.3.11.3.

6.3.3.11.1 Taper-threaded plugs shall be long shank solid round-head, or long-shank hexagon-head, bar stock plugs in accordance with ANSI/ASME B16.11. If cylindrical threads are used, plugs shall be solid hexagon-head plugs in accordance with DIN 910. Plug material shall beet the requirements of the casing. A lubricant/sealant of suitable temperature rating shall be used to ensure that the threads are vapor-tight. Plastic plugs are not permitted.

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

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

6.3.3.11.3 Cylindrical threads conforming to ISO 228-1 may 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 (see Figure 2).

6.4 External Nozzles Forces And Moments

6.4.1 Horizontal pumps and their baseplates, and vertical inline pumps with supports anchored to the foundation shall be designed for satisfactory performance if subjected to the forces and moments in Table 4 applied simultaneously to both suction and discharge nozzles in the worst case combination for the pump in question. For horizontal pumps, two effects of nozzle loads are considered: distortion of the pump casing (6.2.1) and misalignment of the pump and motor shafts (magnetic drive pumps only) (see 9.1.5.3.20).

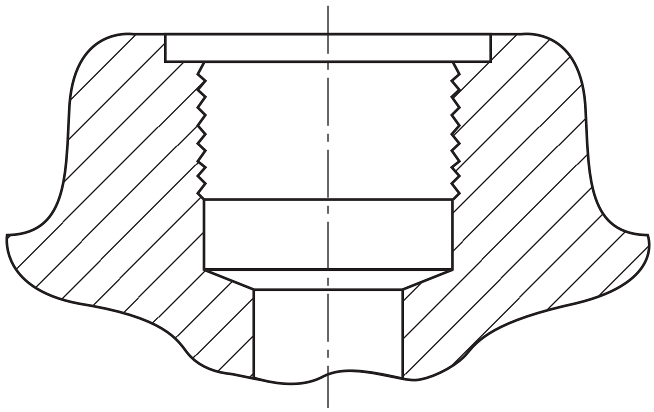


Figure 2—Machined Face Suitable for Gasket Containment if Using Cylindrical Threads

Table 4a—Nozzle Loadings (SI Units)

	SI units								
	Nominal size of flange (DN)								
	≤ 50	**80**	**100**	**150**	**200**	**250**	**300**	**350**	**400**
	Forces (N)								
Each top nozzle									
F_X	710	1070	1420	2490	3780	5340	6670	7120	8450
F_Y	580	890	1160	2050	3110	4450	5340	5780	6670
F_Z	890	1330	1780	3110	4890	6670	8000	8900	10,230
F_R	1280	1930	2560	4480	6920	9630	11,700	12,780	14,850
Each side nozzle									
F_X	710	1070	1420	2490	3780	5340	6670	7120	8450
F_Y	890	1330	1780	3110	4890	6670	8000	8900	10230
F_Z	580	890	1160	2050	3110	4450	5340	5780	6670
F_R	1280	1930	2560	4480	6920	9630	11,700	12,780	14,850
Each end nozzle									
F_X	890	1330	1780	3110	4890	6670	8000	8900	10,230
F_Y	710	1070	1420	2490	3780	5340	6670	7120	8450
F_Z	580	890	1160	2050	3110	4450	5340	5780	6670
F_R	1280	1930	2560	4480	6920	9630	11,700	12,780	14,850
	Moments (N·m)								
Each nozzle									
M_X	460	950	1330	2300	3530	5020	6100	6370	7320
M_Y	230	470	680	1180	1760	2440	2980	3120	3660
M_Z	350	720	1000	1760	2580	3800	4610	4750	5420
M_R	620	1280	1800	3130	4710	6750	8210	8540	9820

NOTE 1 See Figure 3 and Figure 4 for orientation of nozzle loads (X, Y, and Z).

NOTE 2 Each value shown above indicates range from minus that value to plus that value; for example 160 indicates a range from –160 to +160.

Table 4b—Nozzle Loading (U.S. Customary Units)

	US Customary units								
	Nominal Size of Flange (NPS)								
	≤ 2	3	4	6	8	10	12	14	16
	Forces (lbf)								
Each top nozzle									
F_X	160	240	320	560	850	1200	1500	1600	1900
F_Y	130	200	260	460	700	1000	1200	1300	1500
F_Z	200	300	400	700	1100	1500	1800	2000	2300
F_R	290	430	570	1010	1560	2200	2600	2900	3300
Each side nozzle									
F_X	160	240	320	560	850	1200	1500	1600	1900
F_Y	200	300	400	700	1100	1500	1800	2000	2300
F_Z	130	200	260	460	700	1000	1200	1300	1500
F_R	290	430	570	1010	1560	2200	2600	2900	3300
Each end nozzle									
F_X	200	300	400	700	1100	1500	1800	2000	2300
F_Y	160	240	320	560	850	1200	1500	1600	1900
F_Z	130	200	260	460	700	1000	1200	1300	1500
F_R	290	430	570	1010	1560	2200	2600	2900	3300
	Moments (ft·lbf)								
Each nozzle									
M_X	340	700	980	1700	2600	3700	4500	4700	5400
M_Y	170	350	500	870	1300	1800	2200	2300	2700
M_Z	260	530	740	1300	1900	2800	3400	3500	4000
M_R	460	950	1330	2310	3500	5000	6100	6300	7200

NOTE 1 See Figure 3 and Figure 4 for orientation of nozzle loads (X, Y, and Z).

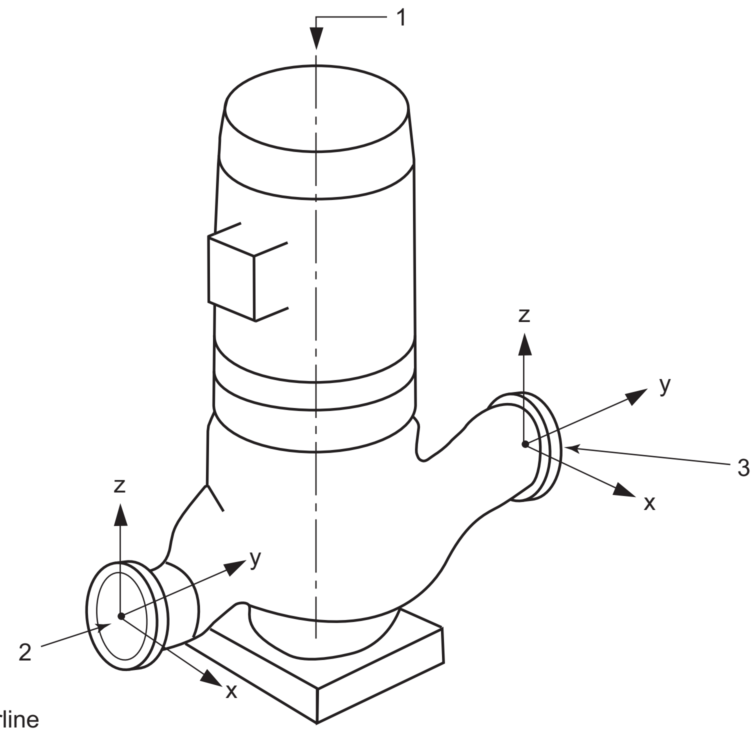
NOTE 2 Each value shown above indicates range from minus that value to plus that value; for example 160 indicates a range from –160 to +160.

6.4.2 Allowable forces and moments for vertical in-line pumps, with supports not anchored to the foundation, may be twice the values in Table 4 for side nozzles.

6.4.3 For pump casings constructed of materials other than steel or alloy steel, the Vendor shall submit allowable nozzle loads corresponding to the format in Table 4.

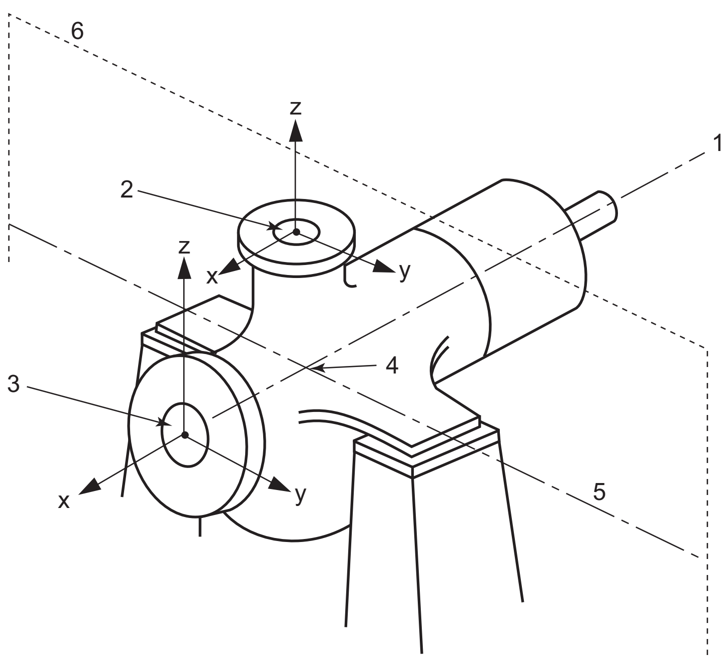
6.4.4 The coordinate system(s) shown in Figure 3 and Figure 4 shall be used to apply the forces and moments in Table 4.

6.4.5 Annex F gives methods of qualifying nozzle loads in excess of those in Table 4. The Purchaser should be aware that the use of the methods in Annex F can result in a misalignment up to 50 % greater than that based on the loads given in Table 4 and can impact equipment installation criteria. The use of the methods in Annex F requires approval by the Purchaser and specific direction to the piping designers for its use.



Key
1 shaft centerline
2 discharge (D)
3 suction (S)

Figure 3—Coordinate System for the Forces and Moments in Table 4: Vertical Inline Pumps



Key
1 shaft centerline
2 discharge nozzle
3 suction nozzle
4 center of pump
5 pedestal centerline
6 vertical centerline

Figure 4—Coordinate System for the Forces and Moments in Table 4: Horizontal Pumps

6.5 Rotors

6.5.1 Unless otherwise specified, impellers shall be of the fully enclosed, semi-open, or open type.

NOTE 1 Enclosed (closed) impellers are less sensitive to axial position and, therefore, preferable for long shaft assemblies where axial displacement due to thermal expansion/contraction or to thrust can be substantial. Semi-open impellers can offer a higher efficiency, due to the elimination of disc friction from one shroud.

NOTE 2 Barske type semi-open impellers used in low-flow, low specific-speed pumps are not as clearance sensitive as enclosed impellers of the same specific speed would be to increased wear ring clearances.

6.5.2 Impellers shall be single-piece castings, forgings or fabrications.

NOTE Impellers made as forgings or fabrications have machined waterways, which can offer improved performance for low specific speed designs.

6.5.3 Impellers shall be keyed to the shaft; pinning of impellers is not acceptable. Impellers shall be secured to the shaft by a cap screw or cap nut that does not expose shaft threads. The securing device shall be threaded to tighten by liquid drag on the impeller during normal rotation, and a positive mechanical locking method (for example, a staked and corrosion-resistant set screw or a tongue-type washer) is required. Cap screws shall have fillets and a reduced-diameter shank to decrease stress concentrations.

6.5.4 Impellers shall have solid hubs. Impellers made from a cored pattern are acceptable if the core is completely filled with a suitable metal that has a melting point of not less than 540 °C (1000 °F) for pumps with cast steel casings.

NOTE The requirement to fill cored impeller hubs is intended to minimize the danger to personnel if impellers are removed by heating.

6.5.5 Shafts shall be machined and finished throughout their length so that the TIR is not more than 25 µm (0.001 in.).

6.5.6 All shaft keyways shall have fillet radii in accordance with ISO 3117.

NOTE For the purpose of this provision, ANSI/ASME B17.1 is equivalent to ISO 3117.

6.5.7 Shaft stiffness and fluid stiffening of product lubricated bearings shall limit the total impeller displacement under the most severe dynamic conditions over the allowable operating range of the pump—with maximum impeller diameter and the specified speed and liquid—to one half the minimum impeller wear ring clearance. This displacement limit may be achieved by a combination of shaft diameter, shaft span or overhang, bearing design, and casing design (including the use of dual volutes or diffusers). No credit shall be taken for the fluid stiffening effects of impeller wear rings. The fluid stiffening of product lubricated bearings shall be calculated at both minimum and maximum design clearances for the full range of product properties, temperature, viscosity, and vapor pressure.

6.6 Wear Rings and Running Clearances

6.6.1 Radial running clearances shall be used to limit internal leakage and, where necessary, control axial thrust. Sealless pumps normally have product lubricated axial thrust bearings and devices, therefore close axial clearances are a necessity in sealless pump designs to control axial thrust. Renewable wear rings shall be provided in the pump casing. Impellers shall have either integral wear surfaces or renewable wear rings where required. For low specific speed pumps with Barske type impellers, impeller(s) may be semi-open design with ample clearances. Vendor to describe method of axial thrust compensation in proposal.

6.6.2 Mating wear surfaces of hardenable materials shall have a difference in Brinell hardness number of at least 50 unless both the stationary and the rotating wear surfaces have Brinell hardness numbers of at least 400.

6.6.3 Renewable wear rings shall be held in place by a press fit with locking pins, screws (axial or radial) or by tack welding. The diameter of a hole in a wear ring for a radial pin or threaded dowel shall not be more than one third the width of the wear ring.

6.6.4 Running clearances shall meet the requirements of 6.6.4.1 through 6.6.4.3.

6.6.4.1 When establishing running clearances between wear rings and between other moving parts, consideration shall be given to pumping temperatures, suction conditions, liquid properties, the thermal expansion and galling characteristics of the materials, and pump efficiency. Clearances shall be sufficient to assure dependability of operation and freedom from seizure under all specified operating conditions.

6.6.4.2 For hardened 11 % to 13 % chromium steel, and materials with similarly low galling tendencies, the minimum clearances given in Table 5 shall be used. For materials with higher galling tendencies and for all materials operating at temperatures above 260 °C (500 °F), 125 µm (0.005 in.) shall be added to these diametric clearances.

6.6.4.3 For non-metallic wear ring materials with very low or no galling tendencies (see Table H.3), clearances less than those given in Table 5 may be proposed by the Vendor. Factors such as distortion and thermal gradients shall be considered, to ensure clearances are sufficient to provide dependability of operation and freedom from seizure under all specified operating conditions.

NOTE There are published data showing successful applications of non-metallic wear ring materials with API clearances (see Table 5) reduced by 50 %. Reasonable reductions in clearances are believed to be dependent on the materials applied and other service conditions, such as cleanliness and temperature.

6.7 Secondary Control/Containment

• **6.7.1** Unless Annex B is invoked, the Purchaser will specify which of the following control/containment options the pump shall have:

a) Secondary control design (3.65);

b) Secondary control with primary leakage monitoring device(s) — (Secondary control system 3.66);

c) Secondary containment design (3.67);

d) Secondary containment with primary leakage monitoring device(s) — (Secondary containment system 3.68).

• **6.7.2** If Specified, the hazard-based selection procedure in Annex B shall be applied to select the required Control/ Containment option.

6.7.3 The secondary control system shall have a stand-by life of at least 25,000 hours in a pump operating mode and shall have a functional life of at least 24 hours in the event of containment shell failure.

• **6.7.4** If specified, the Vendor shall provide the maximum flow rate from the secondary control system in the event of containment shell or stator liner failure.

6.7.5 The secondary control or containment system shall be rated for the same pressure as the pressure casing. Provisions for monitoring primary containment breach shall be included in the secondary control/containment system. Unless otherwise specified, monitoring device(s) shall be provided by the pump Vendor if control/containment system is specified.

6.7.6 Material of the secondary pressure casing(s) shall be carbon steel as a minimum.

6.7.7 Secondary pressure casings are by definition pressure containing components and shall meet the requirements of 6.2.1 or 6.2.2.

Table 5—Minimum Internal Running Clearances

Diameter of Rotating Member at Clearance (mm)	**Minimum Diametral Clearance** (mm)	**Diameter of Rotating Member at Clearance** (in.)	**Minimum Diametral Clearance** (in.)
< 50	0.25	< 2.000	0.010
50 to 64.99	0.28	2.000 to 2.499	0.011
65 to 79.99	0.30	2.500 to 2.999	0.012
80 to 89.99	0.33	3.000 to 3.499	0.013
90 to 99.99	0.35	3.500 to 3.999	0.014
100 to 114.99	0.38	4.000 to 4.499	0.015
115 to 124.99	0.40	4.500 to 4.999	0.016
125 to 149.99	0.43	5.000 to 5.999	0.017
150 to 174.99	0.45	6.000 to 6.999	0.018
175 to 199.99	0.48	7.000 to 7.999	0.019
200 to 224.99	0.50	8.000 to 8.999	0.020
225 to 249.99	0.53	9.000 to 9.999	0.021
250 to 274.99	0.55	10.000 to 10.999	0.022
275 to 299.99	0.58	11.000 to 11.999	0.023
300 to 324.99	0.60	12.000 to 12.999	0.024
325 to 349.99	0.63	13.000 to 13.999	0.025
350 to 374.99	0.65	14.000 to 14.999	0.026
375 to 399.99	0.68	15.000 to 15.999	0.027
400 to 424.99	0.70	16.000 to 16.999	0.028
425 to 449.99	0.73	17.000 to 17.999	0.029
450 to 474.99	0.75	18.000 to 18.999	0.030
475 to 499.99	0.78	19.000 to 19.999	0.031
500 to 524.99	0.80	20.000 to 20.999	0.032
525 to 549.99	0.83	21.000 to 21.999	0.033
550 to 574.99	0.85	22.000 to 22.999	0.034
575 to 599.99	0.88	23.000 to 23.999	0.035
600 to 624.99	0.90	24.000 to 24.999	0.036
625 to 649.99	0.95	25.000 to 25.999	0.037

NOTE For diameters greater than 649.99 mm (25.999 in.), the minimum diametric clearances shall be 0.95 mm (0.037 in.) plus 1 μm for each additional 1 mm of diameter or fraction thereof (0.001 in. for each additional 1 in.).

6.7.8 All secondary control and containment system joints shall be rabbeted and sealed with controlled compression gasket(s), sealed with O-rings of material compatible with the process liquid, or welded.

• **6.7.9** If specified, drain connections shall be provided which completely drain and provide the capability to flush all internal areas of the secondary pressure casing.

6.8 Dynamics

6.8.1 Pump rotors shall be designed such that their first (dry) bending critical speed is at least 20 % above the pump's maximum continuous operating speed.

6.8.2 Resonances of structural support systems (base, frame, and bearing housings) may adversely affect rotor vibration amplitude. Therefore, resonance of support systems within the Vendor's scope of supply shall not occur within 10 % of the operating speed of a fixed speed machine, or from 10 % below to 10 % above the operating range of a variable speed machine.

6.8.3 Vibration:

6.8.3.1 Centrifugal pump vibration varies with flow, usually being a minimum in the vicinity of best efficiency point flow and increasing as flow is increased or decreased. The change in vibration as flow is varied from best efficiency point flow depends upon the pump's energy density, its specific speed, and its suction specific speed. In general, the change in vibration increases with increasing energy density, higher specific speed, and higher suction specific speed.

With these general characteristics, a centrifugal pump's operating flow range can be divided into two regions, one termed the best efficiency or preferred operating region, over which the pump exhibits low vibration, the other termed the allowable operating region, with the limits, both high and low, defined as those flowrates at which the pump's vibration reaches a higher but still "acceptable" level. Figure 5 illustrates the concept. Factors other than vibration, for example, temperature rise with decreasing flow or NPSH3 with increasing flow, or pressure and temperature characteristics in the rotor cavity, can dictate a narrower allowable operating region.

The allowable operating region shall be stated in the proposal. If the allowable operating region is limited by a factor other than vibration, that factor shall also be stated in the proposal.

6.8.3.2 During the performance test, overall vibration measurements over a range of 5 Hz to 1 000 Hz and a Fast Fourier Transform (FFT) spectrum shall be made at each test point except shutoff. The vibration measurements shall be taken on the bearing housing(s) or equivalent location(s) at the positions shown in Figure 6.

• **6.8.3.2.1** The FFT spectra shall include the range of frequencies from 5 hertz to 2Z times running speed (where Z is the number of impeller vanes). If specified the plotted spectra shall be included with the pump test results.

NOTE The discrete frequencies such as 1.0, 2.0 and Z times running speed are associated with various pump phenomena, and are therefore of particular interest in the spectra.

6.8.3.3 Bearing housing overall vibration measurements shall be made in root mean square (RMS) velocity, in mm/sec (in./sec).

6.8.3.4 The vibration measured during the performance test shall not exceed the values shown in Table 6.

6.8.3.5 At any speed greater than the maximum continuous speed, up to and including the trip speed of the driver, the vibration shall not exceed 150 % of the maximum value recorded at the maximum continuous speed.

6.8.3.6 Variable speed pumps shall operate over their specified speed range without exceeding the vibration limits of this specification.

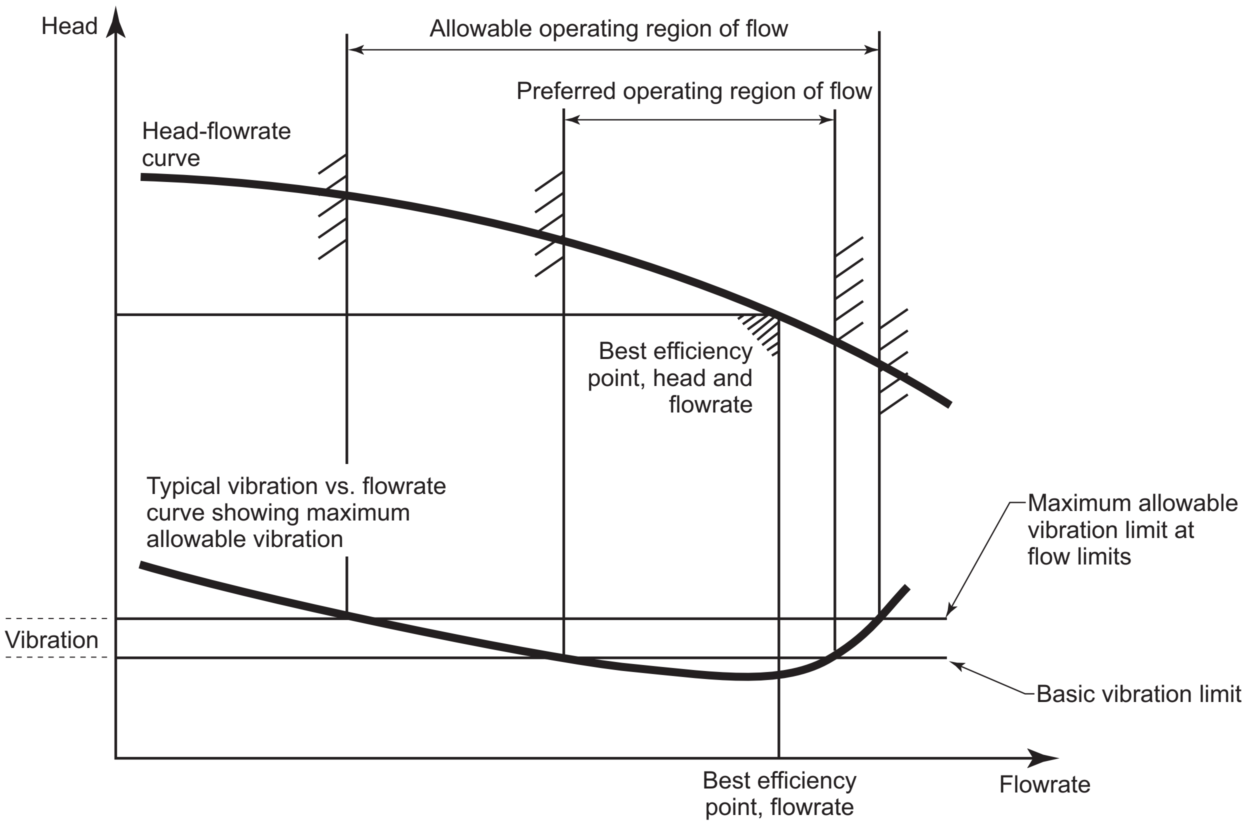
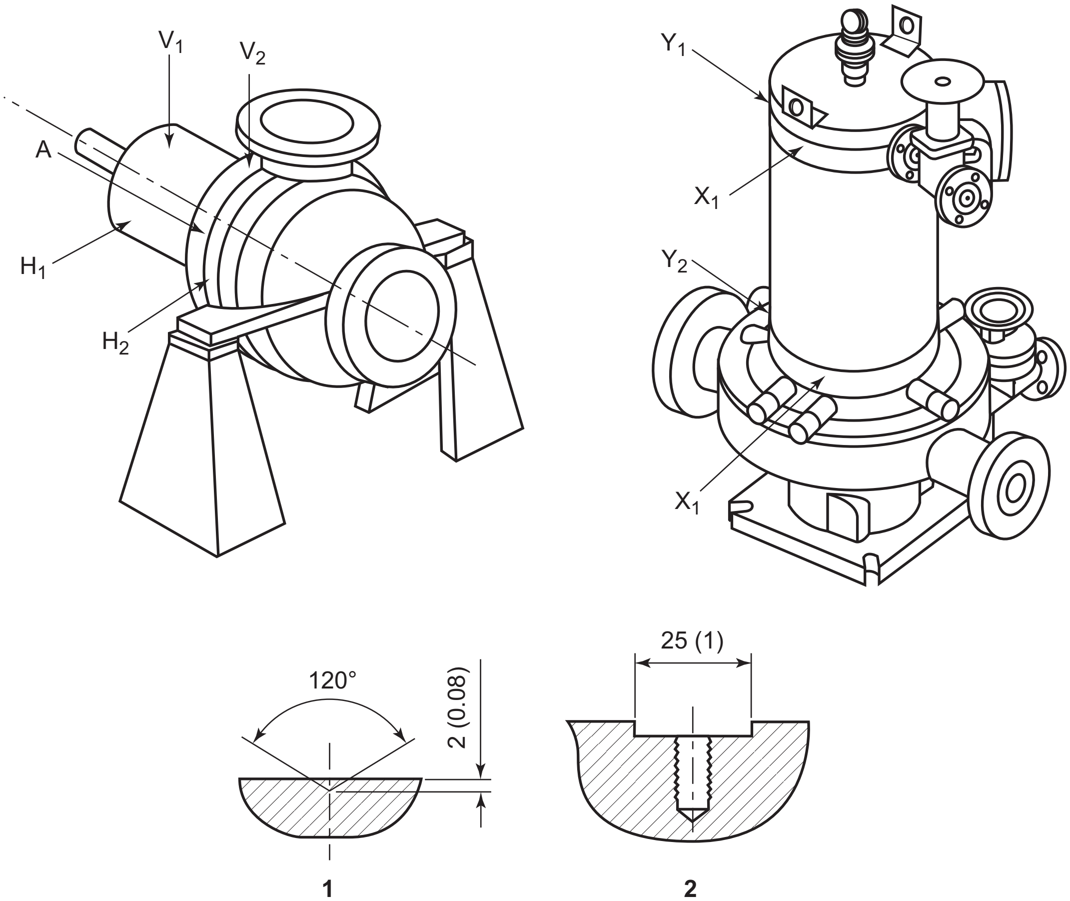


Figure 5—Relationship Between Flow and Vibration

Table 6—Vibration Limits for Overhung Pumps

Criteria	Vibration at Any Flowrate Within the Pump's Preferred Operating Region
Overall	For pumps running at up to 3600 r/min and absorbing up to 300 kW (400 hp) per stage: $v_u < 3.0$ mm/sec RMS (0.12 in./sec RMS)
	For pumps running above 3600 r/min or absorbing more than 300 kW (400 hp) per stage: see Figure 7
Discrete frequencies	$v_f < 2.0$ mm/sec RMS (0.08 in./sec RMS)
Allowable increase in vibration at flows outside the preferred operating region but within the allowable operating region	30 %
Power calculated for BEP of rated impeller with liquid relative density (specific gravity) equal to 1.0. Vibration velocity and amplitude values calculated from the basic limits shall be rounded off to two significant figures. where v_u is the overall velocity; v_f is the discrete frequency velocity, measured with a FFT spectrum using a Hanning window and a minimum frequency resolution of 400 lines.	



Key

1 dimple (see 6.9.10.1)
2 threaded connection for permanent mount (see 6.9.10.2)
A axial
H_1 horizontal; power frame bearing (MDP)/rear bearing (CMP)
H_2 horizontal; front bearing holder
V_1 vertical; power frame bearing (MDP)/rear bearing (CMP)
V_2 vertical; front bearing holder
X_1 transverse top bearing of motor (CMP)
X_2 transverse bottom bearing of motor (CMP)
Y_1 inline top bearing of motor
Y_2 inline bottom bearing of motor

Figure 6—Locations and Provisions for Taking Vibration Readings

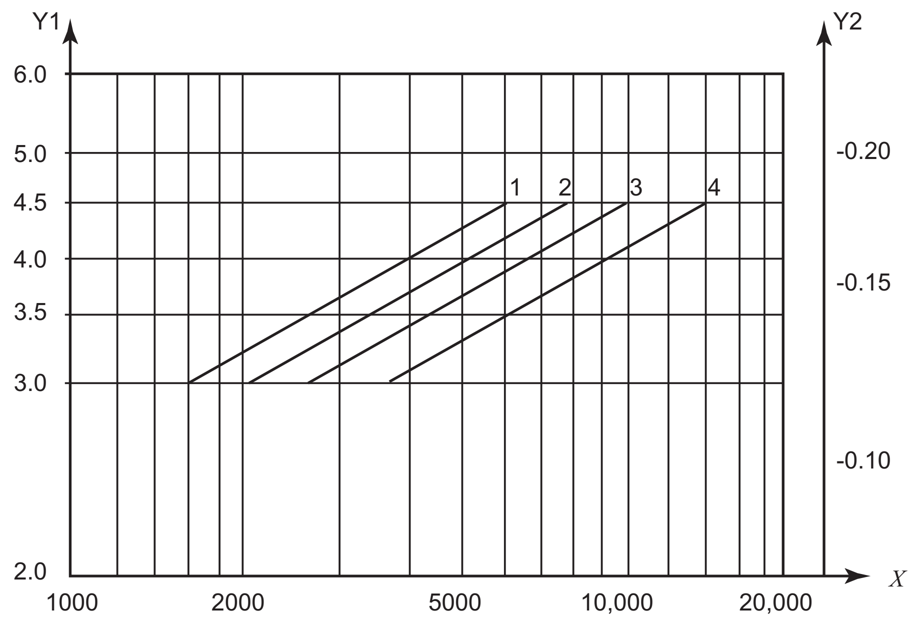
6.8.4 Balancing

6.8.4.1 Impellers and similar major rotating components shall be dynamically balanced to ISO 1940-1 grade G2.5 or 7 gm-mm (0.01 oz-in.), whichever is greater. The mass of the arbor used for balancing shall not exceed the mass of the component being balanced.

• **6.8.4.2** If specified, impellers and similar major rotating components shall be dynamically balanced to of ISO 1940-1 grade G1.0 (equivalent to $4W/n$ in USC terminology) or 7 gm-mm (0.01 oz-in.), whichever is greater.

NOTE Unbalance is expressed in USC units as the following:

$$U = \mathrm{c}W/n$$



Key

1 $P \geq$ kW/stage (1400 hp/stage)
2 P = 700 kW/stage (1000 hp/stage)
3 P = 500 kW/stage (700 hp/stage)
4 $P \leq$ 300 kW/stage (400 hp/stage)
X rotational speed, expressed in revolutions per minute
Y1 vibrational velocity, expressed in millimeters per second, RMS
Y2 vibrational velocity, expressed in inches per second, RMS

NOTE 1 The equation for transition from 3.0 mm/s to 4.5 mm/s (0.12 to 1.8 in./sec) is:

$v_u = 3.0(n/3600)^{0.3}\,[P/300]^{0.21}$

NOTE 2 The vibration limit for discrete frequencies is: $v_f < 0.67\ v_u$ allowable from Figure 7.

Figure 7—Vibration Limits for Horizontal Pumps Running Above 3600 r/min or Absorbing More than 300 kW (400 hp) per Stage

where

U is the unbalance per plane, expressed in oz/in.,

c is a constant,

W is the component mass (for components), expressed in pounds; or the load per balancing machine journal (for rotors), expressed in pounds;

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

cW/n is a balance tolerance denominated solely in USC units. In international standards, unbalance is expressed as a balance quality grade of ISO 1940-1. Each of the ISO balance quality grades covers a range of unbalance. The nominally equivalent USC unit limits given throughout this standard correspond approximately to the midpoint of the ISO range.

With modern balancing machines it is feasible to balance components mounted on their arbors to $U = 4W/n$ USC units) (nominally equivalent to ISO grade G1.0), or even lower depending upon the weight of the assembly, and to verify the unbalance of the assembly with a residual unbalance check. However, the mass eccentricity, e, associated with unbalance less than $U = 8W/n$ (nominally equivalent to ISO grade G2.5) is so small (for example, $U = 4W/n$ gives e = 0.000070 in. for an assembly intended to run at 3600 r/min) that it cannot be maintained if the assembly is dismantled and remade. Balance grades below $8W/n$ (G2.5) are, therefore, not repeatable for components.

6.8.4.3 Component balancing may be single plane if the ratio D/B (see Figure 8) is 6.0 or greater.

6.9 Process Cooled/Lubricated Bearings and Bearing Housings

6.9.1 Process cooled/lubricated bearings shall be of the precision bored sleeve type. These bearings shall be positively secured in the axial and radial directions to avoid rotation relative to the component on which it is mounted.

6.9.2 Sleeve bearings and thrust bearings shall have a surface finish of not more than 0.4 μm (16 μin.) Ra.

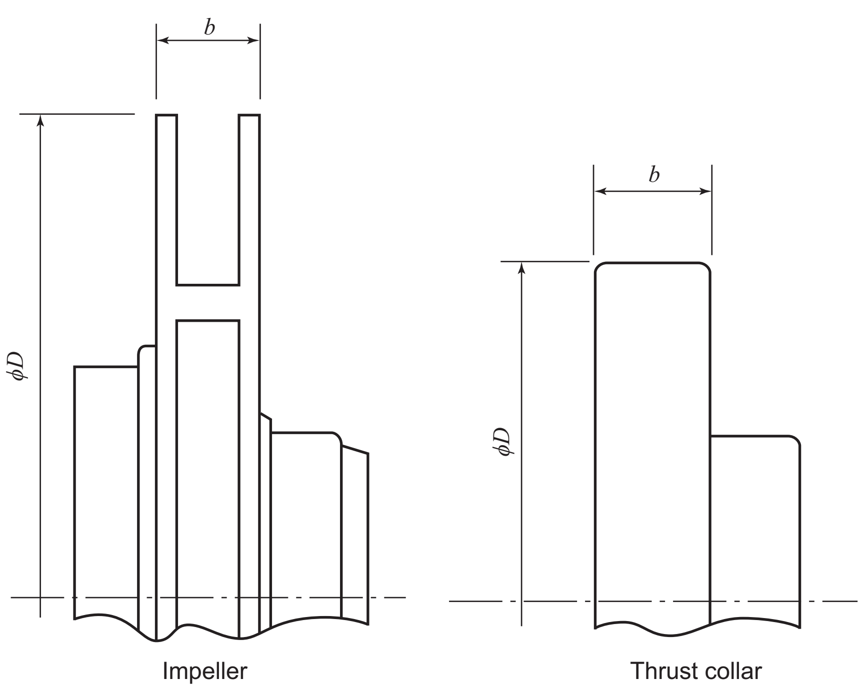
6.9.3 Bearing materials such as silicon carbide with low coefficients of thermal expansion shall have a radial clearance designed to accommodate relative thermal expansions at the maximum and minimum operating temperature specified on the pump datasheet.

6.9.4 Tolerance rings or similar bearing mounting devices shall be used to allow for relative thermal expansion and provide a resilient mounting surface for the bearings.

6.9.5 Unless otherwise approved by the Purchaser, bearings shall incorporate groove(s) for heat removal and flushing of foreign particles.

6.9.6 Pumps using only one radial bearing shall not be used for drive powers above 7.5 kW (10 hp).

6.9.7 Thrust bearings shall be designed for thrust in both directions and sized for continuous operation under all conditions within the allowed operating range, including start-up and shutdown conditions as described in the Manufacturer's operating manual. All loads shall be determined at minimum design internal clearances and also at maximum design internal clearances. Thrust bearings shall provide load capabilities if the normal direction of thrust is momentarily reversed.



Key
b width
D diameter

Figure 8—Rotating Component Dimensions to Determine if Single-Plane Balancing is Allowable

NOTE Hydraulically balanced thrust loads are sometimes designed to be in one direction and only reverse in momentary conditions of starting, stopping and upset. Therefore smaller thrust bearings are common in some designs for thrust in the abnormal direction.

6.9.8 Lubrication/cooling of the bearings shall be by the pumped liquid or by a clean liquid from an external source. The use of an external system requires Purchaser's approval (see Annex D).

6.9.9 Bearing housings for sealless pumps shall include features for vibration measurement as noted in 6.9.9.1 through 6.9.9.3

6.9.9.1 All bearing housings shall be dimpled at the locations shown on Figure 6 to facilitate consistent vibration measurements. The dimples shall be suitable for accurate location of a hand-held vibration transducer with an extension "wand." Dimples may be cast or machined and shall be nominally 2 mm (0.080 in.) deep with an included angle of 120°.

• **6.9.9.2** If specified, bearing housings shall have a threaded connection(s) for permanently mounting vibration transducers in accordance with API 670. If metric fasteners are supplied, the threads shall be M8.

• **6.9.9.3** If specified, a flat surface at least 25 mm (1 in.) in diameter shall be supplied for the location of magnetic based vibration measuring equipment.

6.10 Materials

6.10.1 General

• **6.10.1.1** The Purchaser shall specify the material class for pump parts. Table G.1 provides a guide showing material classes that can be appropriate for various services. Alternative materials recommended for the service by the Vendor, including material that can improve life and performance in service, may also be included in the proposal and listed on the final data sheets.

6.10.1.2 The material specification of all components listed in Table H.1 shall be clearly stated in the Vendor's proposal. Materials shall be identified by reference to applicable International Standards, including the material grade (Table H.2 and Table H.3 may be used for guidance). If International Standard materials are not available, internationally recognized national or other standards may be used. If no such designations are available, the Vendor's material specification, giving physical properties, chemical composition and test requirements, shall be included in the proposal.

NOTE Annex H in this standard differs from that in ISO 13709 in both components specified and material class designations.

6.10.1.3 The material specification of all gaskets and O-rings exposed to the pumped fluid shall be identified in the proposal. O-rings shall be selected and their application limited in accordance with ISO 21049.

6.10.1.4 Pump parts having strength or pressure-integrity requirements are designated as "full compliance" materials in Table H.1 and shall meet all the requirements of the agreed specifications. For any other part (e.g. if corrosion resistance is the primary concern), it is necessary that it comply only with the specified chemical composition.

• **6.10.1.5** The Vendor shall specify the optional tests and inspection procedures necessary to ensure that materials are satisfactory for the service. Such tests and inspections shall be listed in the proposal. The Purchaser shall specify if any additional tests and inspections are required, especially for materials used in critical components.

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

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

• **6.10.1.7** If specified for pressure casing parts, impellers, and shafts, the Vendor shall furnish material certificates that include chemical analysis and mechanical properties for the heat (or batch for non-metallics) from which the material is supplied. Unless otherwise specified, piping nipples, auxiliary piping components, and bolting are excluded from this requirement.

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

NOTE 1 Typical agents of concern are amines, bromides, chlorides, cyanides, fluorides, hydrogen sulfide, iodides, napthenic acid, polythionic acid. Other agents affecting elastomer selection include Ketones, ethylene oxide, benzene, methanol, sodium hydroxide, and solvents.

NOTE 2 If chlorides are present in the pumped fluid in a concentration above 10 mg/kg (10 ppm), caution should then be used if applying stainless steel.

6.10.1.9 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 compatible with the materials and specified process liquid(s).

NOTE Torque loading values required to achieve the necessary preload can vary considerably depending on the thread lubricant.

6.10.1.10 Extruded components such as containment shells with more than 5 % of cold work shall be stress-relieved to minimize stress corrosion cracking.

• **6.10.1.11** The Purchaser shall specify if reduced hardness materials in accordance with either ISO 15156 or ANSI/NACE MR0103 shall be provided.

NOTE 15156 is applicable to Oil and Gas Production facilities and natural gas sweetening plants. For the purpose of this standard, ANSI/NACE MR0175 is equivalent to ISO 15156.

NACE MR0103 for Petroleum Refining Environments applies to other process applications (e.g. oil refineries, LNG plants, and chemical plants).

The application of either ISO 15156 or ANSI/NACE MR0103 is a two-step process. First, the need for special materials is determined and, second, the materials are selected. Specification of this clause assumes the Purchaser has determined the need, and limited hardness materials shall be supplied.

• **6.10.1.11.1** The Purchaser shall specify the amount of wet H_2S that can be present, considering normal operation, start-up, shutdown, idle standby, upsets, or unusual operating conditions such as catalyst regeneration.

NOTE In many applications, small amounts of wet 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.

• **6.10.1.11.2** If reduced hardness materials are specified, the requirements of 6.10.1.11.2.1 through 6.10.1.11.2.4 shall apply.

6.10.1.11.2.1 Ferrous materials not covered by ISO 15156 or ANSI/NACE MR0103 shall have a yield strength not exceeding 620 N/mm^2 (90 000 psi) and a 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.

6.10.1.11.2.2 As a minimum, the requirements of 6.10.1.11 apply to the following components:

a) pressure casing;

b) shafting (including wetted shaft nuts);

c) wetted bolting.

6.10.1.11.2.3 Renewable impeller wear rings required to be through-hardened above HRC 22 for proper pump operation shall not be used if reduced hardness is specified. Impellers may be provided with either hard coated or surface-hardened integral wear surfaces or renewable wear rings.

6.10.1.11.2.4 Wetted parts subject to welding, including fabrication and tack welding (for example, removable wear rings) shall be stress relieved, if required, so that both the welds and the heat-affected zones meet the yield-strength and hardness requirements of this paragraph.

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

6.10.1.13 If dissimilar materials with significantly different electrochemical potentials are placed in contact in the presence of an electrolytic solution, galvanic couples can be created that can result in serious corrosion of the less noble material. The Vendor shall select materials to avoid conditions that can result in galvanic corrosion. Where such conditions cannot be avoided, the Purchaser and the Vendor shall agree on the material selection and any other precautions necessary.

NOTE See NACE Corrosion Engineer's Reference Book [86] for one source for selection of suitable materials in these situations.

• **6.10.1.14** If specified, copper or copper alloys shall not be used for parts of machines or auxiliaries in contact with process fluids. Nickel-copper alloy (UNS N04400), bearing babbitt, and precipitation-hardened stainless steels are excluded from this requirement.)

6.10.2 Castings

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

6.10.2.2 The use of chaplets in pressure castings shall be held to a minimum. The chaplets shall be clean and corrosion free (plating permitted) and of a composition compatible with the casting. Chaplets shall not be used in impeller castings.

6.10.2.3 Ferrous pressure boundary and impeller castings shall not be repaired by welding, peening, plugging, burning in or impregnating, except weldable grades of steel castings may be repaired by welding in accordance with 6.10.3.

6.10.2.4 Fully enclosed cored voids that become fully enclosed by methods such as plugging, welding, or assembly shall not be used.

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

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

6.10.3 Welding

6.10.3.1 Welding and weld repairs shall be performed by operators and in accordance with procedures qualified to the requirements of Table 7. Alternative standards may be proposed by the Vendor for the Purchaser's approval. The welding and material inspection checklist in Annex N may be used for this purpose.

Table 7—Welding Requirements

Requirement	Applicable Code or Standard
Welder/operator qualification	ASME BPVC IX or ISO 9606 (all parts)
Welding procedure qualification	Applicable material specification or, where weld procedures are not covered by the material specification, ISO 15609 (all parts), ASME BPVC IX or ANSI/ASME B31.3
Non-pressure-retaining structural welding such as baseplates or supports	ISO 10721-2
Magnetic-particle or liquid-penetrant examination of the plate edges	ASME BPVC VIII, Division 1, UG-93(d)(34)
Post-weld heat-treatment	Applicable material specification, EN 13445-4, ASME BPVC VIII, Division 1, UW 40, or ANSI/ASME B31.3
Post-weld heat-treatment of casing fabrication welds	Applicable material specification, EN 13445-4, or ASME BPVC VIII, Division I
NOTE For the purposes of this provision, AWS D1.1/D1.1M is equivalent to ISO 10721-2.	

6.10.3.2 The Vendor shall be responsible for the review of all repairs and repair welds to ensure they are properly heat treated and nondestructively examined for soundness and compliance with the applicable qualified procedures (see 6.10.3.1 and 8.2.2.3).

6.10.3.3 Pressure-containing casings made of wrought materials or combinations of wrought and cast materials shall conform to the conditions specified in 6.10.3.3.1 through 6.10.3.3.4.

NOTE These requirements do not apply to casing connections (see 6.10.3.4).

6.10.3.3.1 Plate edges shall be inspected by magnetic particle or liquid penetrant examination as required by internationally recognized standards such as ASME BPVC, Section VIII, Division 1, UG-93(d)(3).

6.10.3.3.2 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.

6.10.3.3.3 Pressure-containing welds, including welds of the case to horizontal- and vertical-joint flanges and the welds of canned motor liner/rotor assemblies or containment shells, shall be full-fusion, full-penetration welds.

6.10.3.3.4 If it is necessary that the dimensional stability of such a casing component be assured for the integrity of pump operation, then post-weld heat-treatment shall be performed regardless of thickness.

6.10.3.4 Connections welded to pressure casings shall be installed as specified in 6.10.3.4.1 through 6.10.3.4.5.

6.10.3.4.1 Attachment of suction and discharge nozzles shall be by means of full-fusion, full-penetration weld using welding neck flanges. Dissimilar-metal weldments are not allowed.

6.10.3.4.2 Auxiliary piping welded to alloy steel casings shall be of a material with the same nominal properties as the casing material or shall be of low carbon austenitic stainless steel. Other materials compatible with the casing material and intended service may be used with the Purchaser's approval.

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

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

• **6.10.3.4.5** Suction and discharge nozzle 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. The Purchaser will specify if the following additional inspection methods are required:

a) magnetic particle or liquid penetrant inspection of auxiliary connection welds;

b) ultrasonic or radiographic inspection of any casing welds.

6.10.4 Low Temperature Service

• **6.10.4.1** The Purchaser shall specify the minimum design metal temperature and concurrent pressure used to establish impact test and other material requirements.

NOTE Normally, this is 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 fluid, such as auto-refrigeration at reduced pressures.

6.10.4.2 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 upon the minimum design metal temperature and any special precautions necessary with regard to conditions that may occur during operation, maintenance, transportation, erection, commissioning and testing. Care shall be taken in the selection of fabrication methods, welding procedures, and materials for Vendor-furnished 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 internationally recognized standards such as the ASME BPVC and ANSI standards are based on minimum tensile properties. Some standards do not differentiate between rimmed, semi-killed, fully killed hot-rolled and normalized material, nor do they take into account whether materials were produced under fine- or course-grain practices all of which can affect material ductility. The Vendor should therefore exercise caution in the selection of materials intended for services between –29 °C (–20 °F) and 40 °C (100 °F).

• **6.10.4.3** The Purchaser shall specify whether EN 13445 (all parts) or ASME BPVC, Section VIII, Division 1 shall apply with regard to impact-testing requirements.

6.10.4.4 The governing thickness used to determine impact testing requirements shall be the greater of the following:

a) nominal thickness of the largest butt welded joint;

b) 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 shaft deflection;

3) structural sections required for attachment or inclusion of mechanical features as jackets.

c) one fourth of the nominal flange thickness (in recognition that the predominant flange stress is not a membrane stress).

• **6.10.4.5** If ASME BPVC, Section VIII, Division 1 is specified, the requirements of 6.10.4.5.1 and 6.10.4.5.2 shall apply:

6.10.4.5.1 All pressure retaining steels applied at a specified minimum design metal temperature (6.10.4.1) below –29 °C (–20 °F) require a Charpy V-notch impact test of the base metal and the weld joint unless they are exempt in accordance with the requirements of paragraph UHA-51

6.10.4.5.2 Carbon and low alloy steel pressure retaining parts applied at a specified minimum design metal temperature (6.10.4.1) between –29 °C (–20 °F) and 40 °C (100 °F) shall require impact testing in accordance with 6.10.4.5.2.1 and 6.10.4.5.2.2.

6.10.4.5.2.1 Impact testing is not required for parts with a governing thickness (6.10.4.4) of 25 mm (1 in.) or less.

6.10.4.5.2.2 Impact testing exemptions for parts with a governing thickness (6.10.4.4) greater than 25 mm (1 in.) shall be established in accordance with ASME BPVC Section VIII, Division 1, UCS-66. Minimum design metal temperature without impact testing may be reduced as shown in figure UCS-66.1. If the material is not exempt, Charpy V-notch impact test results shall meet the minimum impact energy requirements of ASME BPVC, Section VIII, Division 1, UG-84.

6.11 Nameplates and Rotation Arrows

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

6.11.2 The nameplate shall be stamped with the following information in units consistent with the datasheet:

a) Purchaser's item number;

b) Vendor's size and model number;

c) pump serial number;

d) rated flow;

e) rated head;

f) casing hydrostatic test pressure;

g) speed;

h) maximum allowable working pressure (MAWP);

i) temperature basis for MAWP.

NOTE Supplemental nameplate data requirements are given in 9.1.1.9 (magnetic drive pump) and 9.2.5 (canned motor pumps).

6.11.3 In addition to being stamped on the nameplate, the pump serial number shall be plainly and permanently marked on the pump casing.

6.11.4 Rotation arrows shall be cast in or attached to each major item of rotating equipment at a readily visible location.

6.11.5 Nameplates and rotation arrows (if attached) shall be of austenitic stainless steel or of nickel-copper alloy (UNS N04400 or its equivalent). Attachment pins shall be of the same material as the nameplate or rotation arrow. Welding is not permitted as an attachment method.

6.11.6 For inline pumps, if suction and discharge flanges are the same size, the direction of flow shall be clearly marked on the pump.

7 Accessories

7.1 Drivers

7.1.1 General

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

7.1.1.2 The driver shall be sized to accommodate specified process variations such as changes in pressure, temperature, or properties of the liquid handled, as well as special 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 mutually agreed by the Purchaser and the Vendor. The driver's starting torque capabilities shall exceed the speed-torque requirements of the driven equipment.

7.1.2 Electric Motors

NOTE The motor requirements in this section apply to both canned motor pumps and magnetic drive pumps. See 9.2.2 for additional requirements for canned motor pump motors.

7.1.2.1 Motors shall have nameplate power ratings, including the service factor (if any), at least equal to the percentages of power at pump rated conditions given in Table 8. However, the power at rated conditions shall not exceed the motor nameplate rating. If it appears that this procedure leads to unnecessary oversizing of the motor, an alternate proposal shall be submitted for the Purchaser's approval.

Table 8—Power Ratings for Motor Drivers

Motor Nameplate Rating		Percentage of Rated Pump Power
kW	hp	%
< 22	< 30	125
22 to 55	30 to 75	115
> 55	> 75	110

7.1.2.2 Motors shall be designed to operate under running conditions at rated load and frequency with a voltage variation of 10 % or less, above or below rated voltage.

7.1.2.3 Motors shall be designed to operate under running conditions at rated load and voltage with a frequency variation of plus or minus 5 % of rated frequency.

7.1.2.4 Motors shall be designed to operate under running conditions at rated load with a combined variation of voltage and frequency up to 10 % above or below the rated voltage and the rated frequency, provided that the frequency variation does not exceed 5 %.

7.1.2.5 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 seconds or such other period of time agreed upon by the Purchaser and the Vendor.

7.1.2.6 For variable speed motors, the Vendor shall ensure that the drive characteristics fully meet all requirements, such as motor cooling, supply waveforms/harmonics, rotor mechanical integrity, and torque availability/requirements for acceptable start-up and operating conditions.

7.1.2.7 For variable speed motors, the Vendor shall identify and supply any input or output line reactors that may be required to ensure reliable operation of the pump and power supply system to which it will be connected, under all operating conditions.

7.2 Couplings and Guards

Requirements for couplings and guards are applicable only to magnet driven sealless pumps and can be found in 9.1.

7.3 Baseplates and Support Frames

Requirements for baseplates are not applicable to the support frames or cradle for canned motor pumps. Baseplate requirements applicable to magnetic driven pumps are given in 9.1.5.3.

NOTE Rigid baseplate is not necessary for close coupled magnetic drive and all canned motor pumps since driver to pump alignment is not an issue.

7.4 Controls and Instrumentation

7.4.1 General

7.4.1.1 Instrumentation and installation shall conform to the requirements of ISO 10438, or Purchaser's specifications as specified.

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

7.4.1.2 All conduit, trays, armored cable and supports shall be designed and installed so that it can be easily removed without damage and located so that it does not hamper removal of bearings or pump internals.

• **7.4.1.3** If specified, a mechanical, hydraulic, or electrical bearing wear detector or shaft position sensor shall be provided which shall externally indicate radial and/or axial wear of the product-lubricated-bearings.

7.4.2 Protective Instrumentation

7.4.2.1 Unless otherwise specified, protective/condition monitoring instrumentation shall be provided. The following items shall be considered:

a) pump power monitoring or flow monitoring to detect pump operation outside acceptable operating range or magnetic drive decoupling;

b) leakage monitoring in the secondary containment/control area to detect containment shell or stator liner leakage;

c) temperature monitoring of the containment shell or stator liner.

NOTE If Annex B is specified (see 6.7.2), it provides a level-of-hazard based approach to instrumentation/specification of secondary control containment systems.

• **7.4.2.2** If specified, the pump power shall be monitored with a Purchaser provided device within Purchaser's starter/ switchgear. The Vendor shall specify normal and recommended alarm and shutdown conditions.

NOTE It is normal to adjust the alarm and shutdown setting based on field commissioning measurements.

• **7.4.2.3** If specified, leakage into the secondary pressure casing shall be monitored with suitable instrumentation mounted and located in accordance with Annex E and meeting the following.

a) For pumped liquid with relatively low vapor pressure (such that leakage would collect at atmospheric pressure and temperature), an optical or ultrasonic liquid sensor shall be located in a low point collection area of the secondary pressure casing.

b) For pumped liquid with a relatively high vapor pressure (such that leakage would not collect at atmospheric pressure and temperature), a pressure sensor shall be located in the secondary pressure casing. A secondary shaft leakage restriction device shall be utilized to create back pressure to activate the pressure sensor.

7.4.2.4 All instrumentation penetrating the secondary pressure casing shall be rated for the maximum design pressure and temperature.

7.5 Piping and Appurtenances

7.5.1 Piping shall be in accordance with ISO 10438.

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

7.5.2 The arrangement of piping shall conform to Annex D, Figures D.1 to D.4, as applicable.

7.5.3 The piping systems shall be fully assembled and installed. If this requirement causes difficulty in shipping and handling, alternative arrangements are acceptable with Purchaser approval.

• **7.5.4** The Purchaser shall specify whether flange bolting shall be coated (such as by PTFE coating or galvanizing in accordance with ISO 10684 or ASTM A153/A153M) or painted.

7.5.5 Piping and components subject to process fluid under pressure shall have a pressure-temperature rating at least equal to the MAWP of the pump casing, but in no case less than ISO 7005 PN50 (ANSI/ASME Class 300) flange at ambient temperature.

7.5.6 Piping and components subject to the process fluid shall have a corrosion/erosion resistance equal to or better than that of the casing. Otherwise, all components shall be steel.

• **7.5.7** Orifice openings shall not be less than 3 mm (0.12 in.) in diameter. Orifice hole size shall be stamped on the orifice plate. The Purchaser shall specify orifice tagging or labeling requirements.

7.6 Special Tools

7.6.1 If special tools and fixtures are required to disassemble, assemble, or maintain the unit, they shall be included in the quotation and furnished as part of the initial supply of the machine. For multiple-unit installations, the requirements for quantities of special tools and fixtures shall be mutually agreed upon by the Purchaser and the

Vendor. These or similar special tools shall be used during shop assembly and any post-test disassembly of the equipment.

7.6.2 If special tools are provided, they shall be packaged in separate, rugged metal boxes and 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 Purchaser’s participation in the inspection and testing.

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

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

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

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

• **8.1.1.3** If specified, witnessed mechanical and performance tests shall require a written notification of a successful preliminary test. The Vendor and Purchaser shall agree whether or not to maintain the machine test set-up or whether the machine can be removed from the test stand between the preliminary and witnessed tests.

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

8.1.2 The Vendor shall notify sub-Vendors of the Purchaser’s inspection and testing requirements.

8.1.3 After the Purchaser’s advance notification to the Vendor, the Purchaser’s representative shall have resonable access to all Vendor and sub-Vendor plants where manufacturing, testing, or inspection of the equipment is in progress. The level of access shall be agreed upon.

8.1.4 Equipment, materials and utilities for the specified inspection and tests shall be provided by the Vendor.

8.1.5 The Purchaser’s representative shall have access to the Vendor's quality program for review.

• **8.1.6** 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 N by initialing, dating, and submitting the completed checklist to the Purchaser before shipment.

8.2 Inspection

8.2.1 General

• **8.2.1.1** The Vendor shall keep the following data available for at least 20 years for examination by the Purchaser or the Purchaser's representative upon request:

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) results of quality control tests and inspections;

d) records of major repairs;

e) final assembly maintenance and running clearances;

f) other data specified by the Purchaser or required by applicable codes and regulations.

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 6.10.1.5, and the ASTM material specification, 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 examination.

• **8.2.1.4** If specified, pressure boundary parts of alloy materials shall be subject to positive material identification (PMI) using recognized testing methods, instrumentation and standards. The Purchaser and Vendor shall agree on the specific parts to be tested, procedures to be used, and acceptance criteria. Only techniques providing quantitative results shall be used. Mill test reports, material composition certificates, visual stamps or markings shall not be considered substitutes for PMI testing.

NOTE PMI is not available to differentiate between grades of carbon steels.

8.2.2 Pressure Casing Material Inspection

8.2.2.1 Unless otherwise specified, pressure-casing materials shall be inspected in accordance with Table 9.

NOTE Although the pump is designed to meet specific pressure and temperature requirements and the casing is hydrostatically tested in accordance with the requirements of this standard, this alone does not guarantee that the material is of a suitable quality for the service. Casting quality can be affected by considerable variations in material processing.

Material standards, such as ASTM, provide minimum requirements for the material itself, but castings can be subject to areas of shrinkage, gas porosity, hot tears, sand inclusions, improper weld repairs, etc. In addition, some materials are prone to grain boundary tears or cracks that can propagate under in-service stresses caused by temperature, pressure, vibration, and pipe strain.

Table 9—Pressure Casing Material Inspection Requirements

Type of Component	Requirements by inspection class I Minimum	II > 80 % MAWP or > 200 °C (390 °F)	III < 0.5 SG. or > 200 °C (390 °F) and < 0.7 SG. or > 260 °C (500 °F) and Extremely Hazardous Services
Casing (cast)	VI	VI, plus MT (or PT) of critical areas	VI, plus MT (or PT) of critical areas, plus RT (or UT) of critical Areas
Casing (wrought)	VI	VI, plus MT (or PT) of critical areas	VI, plus MT (or PT) of critical areas, plus UT of critical Areas
Nozzle weld - casing	VI, plus 100 % MT or PT	VI, plus 100 % MT (or 100 % PT)	VI, plus 100 % MT (or 100 % PT) plus 100 % RT
Auxiliary connection welds	VI	VI, plus MT (or PT)	VI, plus 100 % MT (or 100 % PT)
Internals	VI	VI	VI
Auxiliary process piping – socket-welded	VI	VI, plus 100% MT (or 100 % PT)	VI, plus 100% MT (or 100 % PT)
Auxiliary process piping – butt-welded	VI, plus 5 % RT	VI, plus 100 % MT (or 100 % PT) and 5 % RT	VI, plus 100 % MT (or 100 % PT) and 10 % RT

Definitions:

VI = Visual Inspection
MT = Magnetic Particle Inspection
PT = Liquid Penetrant Inspection
RT = Radiographic Inspection
UT = Ultrasonic Examination

NOTE 1 "Casing" includes all items of the pressure boundary of the finished pump casing (e.g. the casing itself and other parts such as nozzles, flanges, etc. attached to the casing)."Critical areas" are inlet nozzle locations, outlet nozzle locations, and casing wall thickness changes. The Manufacturer shall submit details of the critical areas proposed to receive MT/PT/RT/UT inspection for Purchaser's approval. "Extremely hazardous services" applies if this designation is specified by the Purchaser.

NOTE 2 Due to complex geometry and thickness variations, it is not practical to RT butt welded auxiliary casing connections.

8.2.2.2 The timing of the inspections required by Table 9 shall be as follows:

a) VI/MT/PT shall be performed after final heat treatment (not necessarily after stress relieving for carbon steel material) in the proof (rough) machined condition. In the proof (rough) machined condition an additional amount of material remains on areas where machining to critical dimensions and tolerances is required. The additional amount of material removed shall not exceed 1 mm (0.040 in.) material stock or 5 % of minimum allowable wall thickness, whichever is less.

b) RT/UT of castings shall be performed after final heat treatment (not necessarily after stress relieving) but need not be in the final machined condition provided that the thickness is within 20 % of the final thickness. In any case the radiographic sensitivity indicator (e.g. penetrameter) shall be selected based on the final thickness.

c) RT of welds and UT of wrought material and welds shall be performed after final heat treatment (not necessarily after stress relieving). UT of wrought material shall be performed prior to any machining operations (e.g. keyways, drilled holes, etc.), that can interfere with the UT examination.

8.2.2.3 Unless otherwise specified, inspection methods and acceptance criteria shall be in accordance with those in Table 10. Acceptance criteria for other parts shall be in accordance with the material specification and the Manufacturer's documented procedures.

Table 10—Material Inspection Standards

Type of inspection	Methods	Acceptance Criteria	
		For Fabrications	**For Castings**
Radiography	ASME BPVC, Section V, Articles 2 and 22	ASME BPVC, Section VIII, Division 1, UW-51 (for 100% radiograph) and UW-52 (for spot Radiography)	ASME BPVC, Section VIII, Division 1, Appendix 7
Ultrasonic Inspection	ASME BPVC, Section V, Articles 5 and 23	ASME BPVC, Section VIII, Division 1, Appendix 12	ASME BPVC, Section VIII, Division 1, Appendix 7
Liquid Penetrant Inspection	ASME BPVC, Section V, Articles 6 and 24	ASME BPVC, Section VIII, Division 1, Appendix 8	ASME BPVC, Section VIII, Division 1, Appendix 7
Magnetic Particle Inspection	ASME BPVC, Section V, Articles 7 and 25	ASME BPVC, Section VIII, Division 1, Appendix 6	ASME BPVC, Section VIII, Division 1, Appendix 7
Visual Inspection (all surfaces)	ASME BPVC, Section V, Article 9	In accordance with the material specification and the Manufacturer's documented procedures	MSS SP-55

8.2.2.4 Where the configuration of a casting makes radiography impossible, radiographic examination may be replaced by ultrasonic testing.

• **8.2.2.5** 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 10. Alternative standards may be proposed by the Vendor or specified by the Purchaser. The welding and material inspection data sheet in Annex N can be used for this purpose.

8.2.3 Mechanical Inspection

• **8.2.3.1** If specified, the Purchaser may inspect for cleanliness of the equipment and all piping and appurtenances furnished by or through the Vendor before assembly.

• **8.2.3.2** 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** If specified, at least six weeks before the first scheduled running test, the Vendor shall submit to the Purchaser, for his review and comment, detailed procedures for all running tests and all specified optional tests (8.3.4). The test procedure shall include the actual measurement uncertainty of all data used in the calculation of flow, head, and power as well as all acceptance criteria.

8.3.1.2 Performance and NPSH tests shall be conducted using the methods and uncertainty requirements of ISO 9906 grade 1, ANSI/HI 1.6 (for centrifugal pumps). Performance tolerances shall be in accordance with Table 11. Evaluation of results shall be in accordance with 8.3.3.3.2.

Table 11—Performance Acceptance Criteria

Condition	Rated Point %	Shutoff % (Note 1)
Rated Differential Head:		
0 m to 75 m (0 ft to 250 ft)	±3	±10
76 m to 300 m (251 ft to 1000 ft)	±3	±8
> 300 m (1000 ft)	±3	±5
Rated Power	+4 (Note 2)	—
Efficiency	Note 3	—
Rated NPSH	+0	—

NOTE 1 If a rising head flow curve is specified, the negative tolerance specified here shall be allowed only if the test curve still shows a rising characteristic.

NOTE 2 With test results corrected to rated conditions (8.3.3.3.2) for flow, speed, density (specific gravity) and viscosity, it is necessary that the power not exceed 104 % of the rated value, from all causes (cumulative tolerances are not acceptable).

NOTE 3 The uncertainty of test efficiency by the test code specified is ±2.5 %; therefore, efficiency is not included in the pump's rated performance.

8.3.2 Hydrostatic Test

8.3.2.1 The intent of a hydrostatic test of a centrifugal pump casing is to ensure that the design and construction of the pump pressure containing components and joints are leak-free from ambient conditions to the maximum operation conditions defined on the data sheet.

8.3.2.2 All pressure-casing components, including secondary pressure casing(s), as defined in 3.51 and 3.73, shall be tested hydrostatically with liquid at a minimum of 1.5 times the maximum allowable working pressure, MAWP.

NOTE Some secondary casings of canned motor pumps can require pressure testing with dry gas.

8.3.2.3 The test set-up and/or apparatus shall not provide stiffening that improves the integrity of any joint.

8.3.2.4 Gaskets used during hydrostatic testing of an assembled pressure casing shall be of the same design as those supplied with the pump and shall be installed without sealant.

8.3.2.5 The test liquid shall be at a higher temperature than the nil-ductility transition temperature of the material being tested.

8.3.2.6 If the part tested will 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 room temperature by that at the rated operating temperature. The stress values used shall be determined in accordance with 6.2.1.1. For piping the stress shall conform to ASME B31.3. The pressure thus obtained shall then be the minimum pressure at which the hydrostatic test shall be performed. The data sheets shall list actual hydrostatic test pressures.

• **8.3.2.7** If specified, the hydrostatic test liquid shall include a wetting agent to reduce surface tension. This wetting agent should be considered when if one or more of the following conditions exists:

a) the liquid pumped has a relative density (specific gravity) of less than 0.7 at the pumping temperature.

b) the pumping temperature is higher than 260 °C (500 °F);

c) the casing is cast from a new or altered pattern;

d) the materials are known to have poor castability.

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

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

8.3.2.9 Austenitic or duplex stainless steel pressure casing components may be hydrostatically tested with an additional amount of material on areas where machining to critical dimensions and tolerances is required. The additional amount of material shall not exceed 1 mm (0.040 in.) material stock or 5 % of minimum allowable wall thickness, whichever is less.

Any areas which are machined after hydrostatic testing shall be identified on the hydrostatic test report.

NOTE Because of residual stresses resulting from final liquid quenching and relatively low proportional limits inherent in these materials, small amounts of permanent deformation may occur at critical dimensions during hydrostatic testing. By allowing a small amount of material to remain at these critical areas during hydrostatic testing, the necessity to add material by welding to restore close-toleranced dimensions after hydrostatic test is avoided.

8.3.2.10 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 pressure-containing parts and joints occur within 30 minutes. Large, heavy castings can require a longer testing period as agreed upon by the Purchaser and the Vendor.

8.3.2.11 Special-design pumps as approved by the Purchaser may be segmentally tested. Seepage past internal closures required for segmented testing and operation of a test pump to maintain pressure with seepage is acceptable.

8.3.2.12 Unless otherwise specified, single stage overhung pump casing components with a radial joint (mean gasket diameter) 610 mm (24 in.) in diameter or less may be hydrostatically tested as components or subassemblies provided that joint design integrity has been proven by qualification testing for the specific size of pump and pressure rating in question.

8.3.2.13 Cooling passages and components, including jackets for bearings, and oil coolers shall be tested at a minimum pressure of 1050 kPa (10.5 bar) (150 psig).

8.3.2.14 Steam and cooling water piping, if fabricated by welding, shall be tested at 1.5 times maximum operating pressure or 1050 kPa (10.5 bar) (150 psig), whichever is greater.

8.3.2.15 Piping systems fabricated by welding shall be hydrostatically tested in accordance with ASME B31.3.

NOTE It is not necessary to hydrostatically test piping systems assembled with tubing or threaded connections after assembly.

8.3.2.16 The secondary control casing of canned motor pumps may require gas testing in lieu of hydrostatic testing. Procedures shall be developed between the Purchaser and Vendor.

8.3.3 Performance Test

8.3.3.1 Unless otherwise specified, each pump shall be given a performance test. Performance tests shall be performed using water at a temperature not exceeding 55 °C (130 °F).

8.3.3.2 The requirements of 8.3.3.2.1 through 8.3.3.2.4 shall be met before the performance test is performed and while the pump is operating on the test stand.

8.3.3.2.1 Rolling-element bearings (MDP) specified to be normally lubricated from a pure oil mist system shall be pre-lubricated prior to performance testing using a suitable hydrocarbon oil.

8.3.3.2.2 All lubricating oil viscosities and temperatures shall be within the range of operating values recommended in the Vendor's operating instructions for the specified unit being tested.

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

8.3.3.2.4 All warning, protective, and control devices used during the test shall be checked for proper operation, and adjustments shall be made as required.

8.3.3.3 Unless otherwise specified, the performance test shall be conducted as specified in 8.3.3.3.1 through 8.3.3.3.5.

8.3.3.3.1 The Vendor shall take test data, including head, flowrate, power, appropriate bearing temperature(s) and vibration, at a minimum of 5 points. These points will normally be:

a) shutoff (no vibration data required);

b) minimum continuous stable flow (beginning of allowable operating region);

c) between 95 % and 99 % of rated flow;

d) between rated flow and 105 % of rated flow;

e) approximately the best efficiency flow (if rated flow is not within 5 % of best efficiency flowrate);

f) maximum allowable flow (end of allowable operating region).

NOTE 1 Bearing temperature measurements refer to rolling-element bearings if used.

NOTE 2 In the case of high-energy pumps (see 6.1.18), it may not be feasible to test at shut-off.

8.3.3.3.2 The test data shall be fit to a spline or appropriate polynomial (typically third or fourth order) for head and for power using a least squares method. The rated/guarantee flow shall be inserted into the resulting equation and a value for head and power calculated. These values shall be corrected for speed, viscosity and density (specific gravity). The corrected values of head and power shall be within the tolerance bands allowed in Table 11.

8.3.3.3.3 The test speed shall be within 3 % of the rated speed shown on the pump datasheet (see Annex R). Test results shall be converted to anticipated results at the rated speed. When testing at rated speed is not possible, test speed should not be less than 80 % or more than 120 % of rated speed. If testing at other speeds, parasitic losses (e.g. viscous and eddy current) can vary significantly. The Purchaser and Manufacturer shall agree on corrections to pump power input prior to testing. If applying magnetically coupled or canned motor pumps to very low S.G. fluids (i.e. below 0.5) testing at speeds less than 80 % of rated may be required to avoid overloading the motor or decoupling a magnetic drive. In such cases mutual agreement between Purchaser and Manufacturer must be reached prior to testing.

8.3.3.3.4 The Vendor shall maintain a complete, detailed log of all final tests and shall prepare the required number of copies, certified for correctness. Data shall include test curves and a summary of test performance data compared to guarantee points (see 10.2.4, 10.3.2.2, Annex P).

- **8.3.3.3.5** If specified, in addition to formal submittal of final data in accordance with 10.3.2.2, curves and test data (corrected for speed, specific gravity and viscosity) shall be submitted within 24 hours after completion of performance testing for Purchaser's engineering review and acceptance prior to shipment.

8.3.3.4 During the performance test, the requirements of 8.3.3.4.1 through 8.3.3.4.3 shall be met.

8.3.3.4.1 Vibration values shall be recorded at each point except shutoff during the test in accordance with 6.8.3.2. Vibration values shall not exceed those given in 6.8.3.4 through 6.8.3.6.

8.3.3.4.2 Magnetic drive pumps with splash oil or ring oil lubricated rolling-element bearings shall have sump oil temperature recorded at or near the rated flow test point. During shop testing, the sump oil temperature rise shall not exceed 40 K (70 R). Temperature stabilization is not required (see 8.3.4.2.1).

NOTE Since there is no hydraulic axial or radial load imposed upon the rolling-element bearings, the load on the rolling element bearings is virtually constant. Thus oil temperature at one test point is sufficient.

8.3.3.4.3 When corrected to operated at rated speed, pumps shall perform within the tolerances given in Table 11.

NOTE Rated power for magnetic drive pumps shall be measured at the pump-to-motor coupling. Rated power for canned motor pumps shall be measured at the motor terminals (i.e. water-to-wire values).

- **8.3.3.5** If specified, the performance test shall be conducted with test stand *NPSHA* controlled to no more than 110 % of the actual *NPSHA* specified on the data sheet.

NOTE It is the purpose of this test to evaluate pump performance with the specified *NPSHA* at pump suction.

8.3.3.6 Unless otherwise specified, the requirements of 8.3.3.6.1 through 8.3.3.6.3 shall be met after the performance test is completed.

8.3.3.6.1 If it is necessary to dismantle a pump after the performance test for the sole purpose of machining impellers to meet the tolerances for differential head, no retest will be required unless the reduction in diameter exceeds 5 % of the original diameter. The diameter of the impeller at the time of shop test, as well as the final diameter of the impeller, shall be recorded on a certified shop-test curve that shows the operating characteristics after the diameter of the impeller has been reduced.

8.3.3.6.2 If it is necessary to dismantle a pump for some other correction, such as improvement of hydraulic performance, or mechanical operation, the initial test will not be acceptable, and the final performance test shall be run after the correction is made.

8.3.3.6.3 Unless otherwise specified, pumps shall not be disassembled after final performance testing. The pump, including the rotor cavity shall be drained to the extent practical, filled with a water-displacing inhibitor within 4 hours of testing and redrained.

8.3.4 Optional Tests

8.3.4.1 General

- If specified, the shop tests described in 8.3.4.2 through 8.3.4.9 shall be performed. Test details and required data (such as vibration and temperature data) shall be agreed upon by the Purchaser and the Vendor prior to conducting the tests.

8.3.4.2 Mechanical Run Test

- **8.3.4.2.1** If specified, the pump shall be run on the test stand at the rated flow until temperature stabilization has been achieved. Test details shall be agreed upon by the Purchaser and the Vendor prior to conducting the tests.

- **8.3.4.2.2** If specified, the pump shall be mechanically run at the rated flow for 4 hours.

8.3.4.3 Thrust Bearing Load Test

- If specified, a thrust bearing load test shall be conducted by measuring the axial load of the rotor and correcting to rated conditions.

8.3.4.4 NPSH3 Required Test

- **8.3.4.4.1** If specified, NPSH3 shall be determined at each test point identified in (8.3.3.3.1) except shut-off and shall include requirements of 8.3.4.4.2 through 8.3.4.4.5.

8.3.4.4.2 NPSH3 tests at each flow point shall be initiated with a minimum of 2 times the NPSH required at that flow from the proposed NPSH3 curve.

8.3.4.4.3 A 3 % drop in head shall be interpreted as indicating performance impairment.

8.3.4.4.4 The NPSH3 test shall determine the actual NPSH3 at a 3 % head drop. Unless otherwise specified or agreed, curves shall be developed at constant flow by reducing the NPSHA to a point where the head curves break away from that developed with sufficient NPSHA (8.3.4.4.2) by at least 3 %. The NPSH required test shall start with at least the same NPSHA as the performance test and at least twice the NPSH3 shown on the proposal curve. The first two test points shall not differ by more than the uncertainty of the head measurement. If the second test point at the same flowrate shows a decrease in differential head then the NPSHA shall be increased to a value sufficient to establish two consecutive points of equal head. The first two points shall be separated by a minimum of 1 m (3 ft) of NPSHA. These NPSH3 curves shall be developed and submitted in accordance with ISO 9906 or Hydraulic Institute Standards (ANSI/HI 1.6), as specified. The test shall not proceed beyond a 20 % head breakdown.

NOTE 1 If 8.3.3.5 was specified, it is possible that the head has already been affected by insufficient NPSHA, so starting at a higher NPSHA is desirable.

NOTE 2 An NPSH3 test that only demonstrates the quoted NPSH3 value is not acceptable.

8.3.4.4.5 NPSH3 at the rated point shall not exceed the quoted value (see Table 11). Dismantling to correct NPSH3 requires a retest (see 8.3.3.6.2).

8.3.4.5 Complete-Unit Test

- If specified, the pump and driver train, complete with all auxiliaries that make up the unit, shall be tested together. The complete-unit test shall be performed in place of, or in addition to, separate tests of individual components specified by the Purchaser.

8.3.4.6 Sound-Level Test

- If specified, sound level tests shall be performed as agreed between the Purchaser and the Vendor.

NOTE ISO Standards 3740, 3744, and 3746 may be consulted for guidance.

8.3.4.7 Auxiliary-Equipment Test

- If specified, auxiliary equipment such as control systems shall be tested in the Vendor's shop. Details of the auxiliary-equipment test shall be developed jointly by the Purchaser and the Vendor.

8.3.4.8 Secondary Containment System Hydrostatic Test

- If specified, pressure integrity of the secondary containment system shall be verified by hydrostatic test using the same criteria as the pressure casing (see 8.3.2). Certification shall be provided by the Vendor.

8.3.4.9 Secondary Containment/Control System Instrumentation Test

- If specified, the operability of the instrumentation supplied with the secondary containment system or secondary control system shall be verified. Criteria for the test will be mutually agreed to by the Purchaser and the Vendor. Certifications shall be provided by Vendor.

8.4 Preparation for Shipment

8.4.1 Equipment shall be suitably prepared for the type of shipment specified. The preparation shall make the equipment suitable for six months of outdoor storage from the time of shipment, with no disassembly required before operation, except for inspection of bearings.

NOTE If storage for a longer period is contemplated, the Purchaser will need to consult with the Vendor regarding the recommended procedures to be followed.

8.4.2 The equipment shall be prepared for shipment after all testing and inspection has been completed and the equipment has been released by the Purchaser. The preparation shall include that specified in 8.4.2.1 through 8.4.2.6.

8.4.2.1 Unless otherwise specified, pumps shall not be disassembled after final performance testing. The pump, including the rotor chamber shall be drained to the extent practical, filled with a water-displacing inhibitor within 4 hours of testing and redrained. Suitable rust preventatives shall be oil-soluble and compatible with all pumped fluids.

8.4.2.2 Exterior surfaces, except for machined surfaces, shall be given at least one coat of the Manufacturer's standard paint. The paint shall not contain lead or chromates. Unless otherwise stated, it is not necessary to paint stainless steel parts. The undersides of baseplates shall be prepared for grout in accordance with either 9.1.5.3.12 or 9.1.5.3.19.

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

8.4.2.4 Flanged openings shall be provided with metal closures at least 5 mm (0.19 in.) thick, with elastomer gaskets and at least four full diameter bolts. For studded openings, all nuts required for the intended service shall be used to secure closures.

8.4.2.5 Threaded openings shall be provided with steel caps or steel plugs in accordance with ISO 10438.

8.4.2.6 Openings that have been beveled for welding shall be provided with closures designed to prevent entrance of foreign materials and damage to the bevel.

8.4.3 Auxiliary piping connections furnished 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. Symbols for all pump connections, including plugged connections shall be in accordance with Annex D.

8.4.4 Lifting points and lifting lugs shall be clearly identified.

8.4.5 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. In addition, crated equipment shall be shipped with duplicate packing lists, one inside and one on the outside of the shipping container.

8.4.6 One copy of the Manufacturer’s standard installation instructions shall be packed and shipped with the equipment.

8.4.7 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.

9 Specific Pump Sections

9.1 Magnetic Drive Pumps

9.1.1 General

9.1.1.1 Magnetic Drive Pumps are designated as Type MDP. A description of Type MDP pumps is given in Annex C.

• **9.1.1.2** Close-coupled designs require specific approval by the Purchaser. This standard does not address additional requirements important to close-coupled magnetic drive pump designs.

NOTE Although pumps with integral bearing frames are the default for horizontal magnetic drive pumps in this standard, some users have found success with close coupled designs for lower motor powers. With this design, the outer magnet ring mounts on the shaft of a standard motor and since the concentricity with the inner magnet ring does not require precision, no alignment is needed, and no coupling forces are transferred to the motor bearings.

9.1.1.3 The design clearance of the liquid gap and of the air gap shall be sufficient to ensure that contact between the magnet assemblies and the containment shell does not occur due to pressure deformation, nozzle loading, flow variations, thermal expansion or power end bearing wear.

9.1.1.4 The design shall allow maintenance of the outer magnet ring and power end bearing assembly without disturbing the pressure casing.

• **9.1.1.5** If specified, the design shall provide for the removal of the power end bearing assembly without disturbing the pressure casing or the pump driver [i.e. adequate spacer coupling provided—see 9.1.5.2.2d)].

9.1.1.6 Product lubricated bearings shall not be supported by the containment shell.

9.1.1.7 Jackscrews, guide rods, or similar devices shall be incorporated in the design to facilitate installation and maintenance of the magnet coupling.

9.1.1.8 Cooling and lubrication of product lubricated bearings and magnet area shall be in accordance with Annex D.

9.1.1.9 The torque rating of the magnetic coupling and the rolling-element bearing Manufacturer’s identity numbers shall appear on the pump nameplate or on a supplemental nameplate meeting the requirements of 6.11.2.

9.1.2 Pressure Containment

9.1.2.1 Containment Shell

9.1.2.1.1 The containment shell is by definition a pressure containing component and shall meet the requirements of 6.2 except as follows.

a) ASME BPVC, Section VIII, Division 2, can be utilized in lieu of Division 1 for design.

b) The minimum corrosion/erosion allowance shall be 0.4 mm (0.015 in.).

c) The minimum containment shell thickness shall be 1.0 mm (0.040 in.).

9.1.2.1.2 Fabrication of containment shells shall conform with 6.10.3.

9.1.2.1.3 The containment shell to casing cover joint shall have a metal-to-metal rabbeted fit utilizing a confined controlled compression gasket of material compatible with the process fluids and operating temperatures.

9.1.2.1.4 Alternative containment shell designs including non-metallic materials are subject to approval by the Purchaser.

9.1.2.2 Secondary Control System

9.1.2.2.1 The secondary control system shall protect the rolling-element bearings from contamination by the pumped fluid.

9.1.2.2.2 To minimize leakage around the external shaft in the event of a primary containment failure, the secondary control system shall include a replaceable, spark resistant restriction device. Lip seals are not acceptable.

9.1.3 Magnetic Couplings

9.1.3.1 Magnetic coupling assemblies shall be of either synchronous or asynchronous design. Couplings may be supplied with either rare earth or aluminum nickel cobalt magnets. The Vendor shall state the magnet material on the proposal datasheet (refer to Annex R). Alternate designs and/or materials require Purchaser approval for the specific application.

NOTE Information on magnets including irreversible magnetic losses is discussed in Annex I

9.1.3.2 Magnets shall be mechanically retained and/or bonded with a suitable adhesive.

NOTE Outer magnet rings with aluminum nickel cobalt magnets for applications up to 450 °C are usually not bonded, but only mechanically retained, while samarium cobalt magnet rings usually feature both (mechanically retained and bonded using adhesive).

9.1.3.3 The pump shall be designed to prevent the outer magnet ring from contacting the containment shell in the event of a shaft or bearing failure. The design shall utilize a replaceable device of spark resistant material to eliminate any sources of ignition.

9.1.3.4 The outer drive rotor (outer magnet ring) shall be keyed to the power end drive shaft. A taper fit and puller holes are required for shaft sizes equal to or greater than 60 mm (2 in.).

• **9.1.3.5** The inside surface of the outer magnet ring shall be protected to prevent damage to the magnets or the containment shell upon assembly/disassembly by guiding zones/rods, sheathing, or other means. The Vendor shall describe the protection method in the proposal. If specified, non-magnetic metallic sheathing shall be provided to prevent damage to the magnets during other steps of maintenance.

NOTE 1 While guide zones/rods protect during assembly and disassembly, unsheathed magnets are exposed to possible damage during other steps of maintenance.

NOTE 2 Sheathing increases the separation dimension between the magnets requiring derate of the potential transmitted torque of a coupling or an increase of magnetic material.

9.1.3.6 The inner magnet or torque ring material shall be shielded from the process fluid by a hermetically sealed metallic sheathing. This sheathing material must be compatible with the process fluid to ensure against chemical attack. The minimum inner magnet sheathing thickness shall be 0.40 mm (0.015 in.).

9.1.3.7 Magnetic couplings shall be designed to avoid decoupling during start-up and while operating at rated conditions. The following conditions shall be analyzed by the Manufacturer when sizing the magnetic coupling.

- • a) Torque required to accelerate the rotor assembly during start-up with the job driver and specified fluid. Starting conditions will be specified by the Purchaser. Across-the-line starting is to be assumed for medium voltage motor drives unless otherwise specified.

- b) Torque required to pump the fluid at rated conditions of flow, temperature, specific gravity and viscosity with provision to operate at a 5 % increase in head for constant speed drivers or 5 % increase in speed when variable speed drivers are applied.

- • c) If specified, torque required to cover 120 % BEP flowrate operation, such as transfer pumps, loading pumps, and pumps operating in parallel.

NOTE This sizing will result in higher losses, greater heat generation by the magnetic coupling, and potentially an oversized coupling.

9.1.3.8 The rated torque of the magnetic coupling shall equal the larger of the torques calculated in 9.1.3.7a), 9.1.3.7b), or, if specified, 9.1.3.7c), with factors applied as shown in Table 12. If it appears that this will lead to unnecessary oversizing of the magnetic coupling, an alternative proposal shall be submitted for the Purchaser's approval.

Table 12—Magnetic Coupling Torque Service Factors

Calculated torque		Minimum synchronous coupling service factor	Minimum torque ring coupling service factor
(Nm)	(ft-lbf)	(%)	(%)
<50	<37	125	110
50 to 150	37 to 111	115	110
>150	>111	110	110

• **9.1.3.9** If specified, the Vendor shall submit a torque versus temperature curve that covers the entire design temperature range of the magnetic coupling.

• **9.1.3.10** If specified, the Vendor shall submit a speed-torque curve defining capability of the synchronous magnetic coupling during start-up and operation at the rated temperature. The torque requirements of 9.1.3.7a) and 9.1.3.7b) are to be shown as well as the rating factor defined in 9.1.3.8. The speed-torque curve shall be presented in the format shown in Figure 9.

9.1.4 Rolling-element Bearings, Bearing Housings, and Lubrication

9.1.4.1 Rolling-element Bearings

9.1.4.1.1 Rolling-element bearings shall be used to support the external drive shaft such that the following conditions are satisfied:

a) Factor nd_m for individual bearings shall not exceed 500,000 for oil lubricated and 350,000 for grease lubricated bearings.

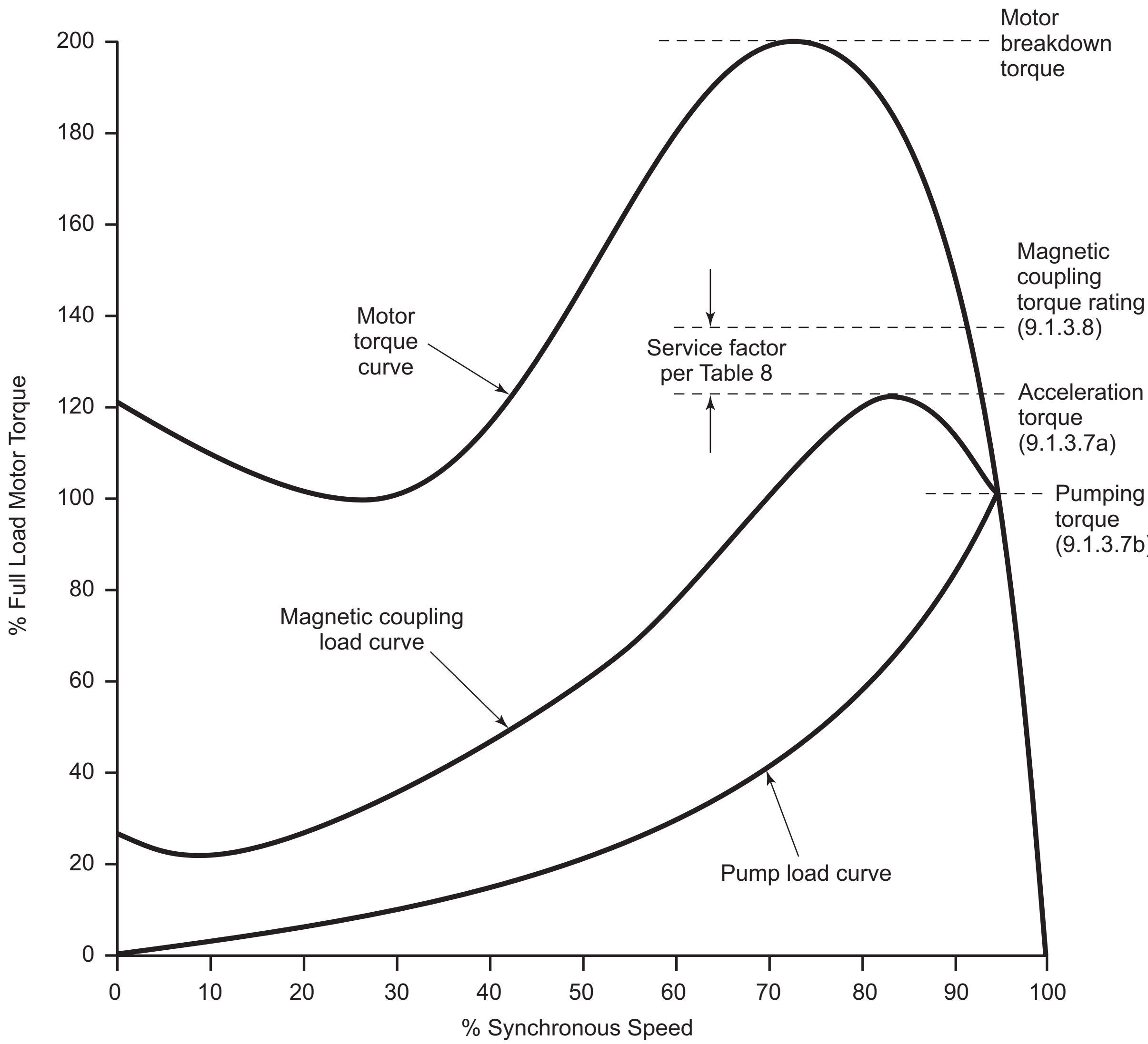


Figure 9—Speed Torque Curve

where

d_m is the mean bearing diameter $(d + D)/2$, expressed in mm,

N is the rotative speed, expressed in rpm.

NOTE The bearing temperature limits in 9.1.4.2.3 may limit $n.d_m$ factors to even lower values.

b) basic rating L10, for the bearing system in accordance with ISO 281 shall be equivalent to at least 25,000 h with continuous operation at rated conditions, and at least 16,000 h at maximum radial and axial loads and rated speed. Bearing system L10 life of 25,000 h and 16,000 h requires the L10 life of each individual bearing to be significantly higher.

NOTE 1 ISO 281 defines basic rating life, L10, in units of millions of revolutions. Industry practice is to convert this to hours and to refer to it as L10h. ISO 281 also defines the method required to calculate bearing system life from individual bearing life.

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

9.1.4.1.2 Rolling element bearings selected to support axial thrust loads shall be sized for continuous operation under all specified conditions, including the axial force generated by the flexible couplings.

Thrust forces for flexible metal element couplings shall be calculated on the basis of the maximum allowable deflection permitted by the coupling Manufacturer.

NOTE This is not typically a problem with properly aligned normal slip-fit coupling hubs.

9.1.4.1.3 Rolling-element bearings shall be located, retained and mounted 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 ABMA 7.

b) Bearings shall be mounted directly on the shaft. Bearing carriers are acceptable only with Purchaser 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 may not be appropriate.

9.1.4.1.4 Single-row deep-groove ball bearings shall have radial internal clearance in accordance with Manufacturer's standard practice. Single- or double-row bearings shall not have filling slots. Non-metallic cages shall not be used. Greater internal clearances can reduce the temperature rise of the lubricant. However, vibration velocities may be increased with greater clearances. The Vendor shall ensure that values for temperature rise (9.1.4.2.3) and vibration (6.8.3.4) meet the requirements of this Standard.

NOTE 1 For the purpose of this provision, ABMA 20 Group 3 is equivalent to ISO 5753 Group 3.

NOTE 2 Prevalent practice by most API Users is ISO 5753 Group 3 [larger than "N" (Normal) internal clearance]. Normal clearance may offer advantages in outer magnet run-out and lower vibration.

9.1.4.2 Rolling-Element Bearing Housings

• **9.1.4.2.1** Bearing housings for oil-lubricated non-pressure-fed bearings shall be provided with threaded and plugged fill and drain openings of at least DN 15 (NPS $^1/_2$). The housings shall be equipped with constant level sight feed oilers at least 0.12 liter (4 oz) in volume, with a positive level positioner (not an external screw), heat-resistant glass containers, and protective wire cages. Means shall be provided, such as a bulls-eye or an overfill plug, for detecting overfilling of the housings. A permanent indication of the proper oil level shall be accurately located and clearly marked on the outside of the bearing housing with permanent metal tags, marks inscribed in the castings, or other durable means. The Purchaser shall specify if a particular model of oiler is required, and whether the oiler should vent to atmosphere or vent to the bearing housing.

NOTE If a bearing housing isolator with a positive shutoff feature is provided, a closed system (vent to housing oiler) may avoid the over-filling of the oil sump.

• **9.1.4.2.2** If specified, an oil sump collection container shall be provided. This container shall be transparent and shall be located on the bottom of the oil sump to collect bearing housing contaminants such as water. It shall be fitted with a spring loaded drain pet cock. The collector materials of construction shall be suitable for the lubricant used.

9.1.4.2.3 Sufficient cooling, including an allowance for fouling, shall be provided to maintain the oil sump temperature below 82 °C (180 °F) for ring-oiled or splash systems, based on the specified operating conditions and ambient temperature of 43 °C (110 °F). During shop testing, the oil sump temperature rise shall not exceed 40 °K (70 °R).

NOTE Pumps equipped with ring-oiled or splash lubrication systems may not reach temperature stabilization during hydraulic performance tests of short duration. Temperature stabilization testing is addressed in 8.3.4.2.1.

9.1.4.2.4 Where water cooling is required, cooling coils are preferred. The coils (including fittings) shall be of non-ferrous material or austenitic stainless steel and shall have no internal pressure joints. Tubing or pipe shall have a minimum thickness of 1.0 mm (0.040 in.) and shall be at least 12 mm (0.50 in) outside diameter. Water jackets, if used, shall have only external connections between upper and lower housing jackets and shall have neither gasketed nor threaded connection joints which may allow water to leak into the oil reservoir. Water jackets shall be designed to cool the oil rather than the outer bearing ring.

9.1.4.2.5 Bearing housings, load-carrying bearing covers, and brackets between the pump casing or cover shall be steel.

9.1.4.2.6 Bearing housings for rolling-element bearings shall be designed to prevent contamination by moisture, dust and other foreign matter. This shall be achieved without the requirement for external service, for example air purge. Bearing housings shall be equipped with replaceable labyrinth-type or magnetic-type end seals and deflectors where the shaft passes through the housing. Lip seals shall not be used. The seals and deflectors shall be made of spark-resistant materials. The design of the seals and deflectors shall effectively retain oil in the housing and prevent entry of foreign material into the housing.

NOTE Many users consider pure aluminum and aluminum alloys with a maximum content of 2 % magnesium or 0.2 % copper, all copper and copper-based alloys (e.g. brass, bronze) to be spark-resistant. However, local standards such as EN 13463-1, might not allow aluminum or non-metallic materials within potentially explosive atmospheres.

9.1.4.2.7 Housings for ring oil lubricated bearings shall be provided with plugged ports positioned to allow visual inspection of the oil rings while the pump is running.

• **9.1.4.2.8** If oil mist lubrication is specified, the requirements of 9.1.4.2.8.1 through 9.1.4.2.8.5 shall apply.

9.1.4.2.8.1 For pure oil must lubrication, bearings and bearing housings shall meet the requirements of 9.1.4.2.8.1a) through 9.1.4.2.8.1e).

a) A threaded 6 mm (NPS $^1/_4$) oil mist inlet connection shall be provided on the housing or end cover for each of the spaces between the rolling element bearing or bearing set and the bearing housing end seal.

b) Oil mist fitting connections shall be located so that oil mist will flow through rolling element bearings. If bearing housing design is such that mist is not forced to flow through the bearings, directional oil mist reclassifiers shall be furnished to insure oil mist impingement on and flow through the bearings.

c) If a reclassifier is to be used [see 9.1.4.2.8.1b)], it shall be used for each application point.

d) Oil rings or flingers and constant level oilers shall not be provided, and a mark indicating the oil level is not required.

e) Drain back oil passages in the bearing housing shall be plugged to prevent the oil mist from bypassing the bearing(s).

NOTE At process operating temperatures above 300 °C (570 °F), bearing housings with pure oil mist lubrication may require special features to reduce heating of the bearing races by heat transfer. Typical features are:

— heat sink type flingers;

— stainless steel shafts having low thermal conductivity;

— thermal barriers;

— fan cooling;

— purge oil mist lubrication (in place of pure oil mist) with oil (sump) cooling.

9.1.4.2.8.2 For purge oil mist lubrication, bearings and bearing housings shall meet the requirements of 9.1.4.2.8.2a) through 9.1.4.2.8.2d):

a) A threaded 6 mm or 12 mm (NPS $^1/_4$ or $^1/_2$) oil mist connection shall be located in the top half of the bearing housing to act also as a vent and fill connection.

b) Constant level oilers shall be provided, and a mark indicating the oil level is required on the bearing housing. Bearing lubrication is by a conventional oil bath, flinger, or oil ring system.

c) Constant level sight feed oilers shall be equipped with overflow control to allow excess coalesced oil from the mist system to drain from the bearing housing so that oil level in the sump is maintained at proper level. The oil shall be contained to prevent it from draining onto the baseplate.

d) Constant level sight feed oilers shall be piped so that they operate at the internal pressure of the bearing housing, do not vent excess mist at the bearing housing, or allow oil to drip to the baseplate.

9.1.4.2.8.3 For both pure and purge mist applications, a drain connection shall be located on the bottom of the bearing housing to provide complete oil drainage.

9.1.4.2.8.4 Shielded or sealed bearings shall not be used in conjunction with either pure or purge oil mist systems.

9.1.4.2.8.5 The oil mist supply and drain fitting shall be provided by the Purchaser. Unless otherwise specified, directional reclassifiers shall be provided by the machine Manufacturer.

9.1.4.3 Rolling-element Bearing Lubrication

9.1.4.3.1 Unless otherwise specified, bearings and bearing housings shall be designed for oil lubrication using mineral (hydrocarbon) oil.

9.1.4.3.2 The operation and maintenance manual shall describe how the lubrication system circulates oil.

• **9.1.4.3.3** If specified, provisions only shall be made for either pure oil or purge oil mist lubrication (see 9.1.4.2.8 for requirements).

• **9.1.4.3.4** If specified, rolling-element bearings shall be grease-lubricated in accordance with 9.1.4.3.4a) through 9.1.4.3.4d):

a) Grease life (re-lubrication interval) shall be estimated using the method recommended by the bearing Manufacturer or an alternative method approved by the Purchaser.

b) Grease lubrication shall not be used if the estimated grease life is less than 2000 h.

c) If the estimated grease life is 2000 h or greater but less than 25,000 h, provision shall be made for regreasing the bearings in service and for the effective discharge of old or excess grease, and the Vendor shall advise the Purchaser of the required re-greasing interval.

d) If the estimated grease life is 25,000 h or more, grease nipples or any other system for the addition of grease in service shall not be fitted.

9.1.5 Accessories

9.1.5.1 Drivers

9.1.5.1.1 The driver shall be sized to meet the maximum specified operating conditions, including bearing, mechanical seal, external gear, and coupling losses, as applicable. The driver shall be in accordance with the applicable specifications, as stated in the inquiry specification, data sheets, and order. The driver shall be suitable for satisfactory operation under the utility and site conditions specified.

• **9.1.5.1.2** The Purchaser will specify the type of motor, its characteristics, and the accessories, including the following:

a) Electrical characteristics;

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

c) The type of enclosure;

d) The area classification, based on IEC 60079 or API RP 500;

e) The type of insulation;

f) The required service factor;

g) The ambient temperature and elevation above sea level;

h) Transmission losses;

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

j) Vibration acceptance criteria;

k) Applicability of API Standard 547, IEEE 841, or IEC60034.

9.1.5.1.3 Unless otherwise specified, steam turbine drivers shall conform to API 611. Steam turbine drivers shall be sized to deliver continuously 110 % of the pump rated power at corresponding speed with specified normal steam conditions.

9.1.5.1.4 Unless otherwise specified, gears shall conform to API 677.

9.1.5.1.5 Unless otherwise specified, for drive train components that weigh more than 250 kg (500 lbs), the equipment feet shall be provided with vertical jackscrews.

9.1.5.2 Shaft Couplings and Guards

9.1.5.2.1 Unless otherwise specified, couplings and guards between drivers and driven equipment shall be supplied and mounted by the Manufacturer of the pump.

9.1.5.2.2 Unless otherwise specified, all-metal flexible-element, spacer-type couplings manufactured to meet AGMA 9000 Class 9 shall be provided. Additionally, couplings shall comply with the following:

a) coupling hubs shall be steel;

b) flexible elements shall be of corrosion resistant material;

c) couplings shall be designed to retain the spacer if a flexible element ruptures;

d) the distance between the pump and driver shaft ends (distance between shaft ends, or DBSE) shall be at least 125 mm (5 in.) and shall permit removal of the drive magnet carrier assembly without disturbing the driver, driver coupling hub or the suction and discharge piping;

e) provision shall be made for the attachment of alignment equipment without the need to remove the spacer or dismantle the coupling in any way.

• **9.1.5.2.3** If specified, couplings shall be balanced to ISO 1940-1 grade G6.3.

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

9.1.5.2.5 Flexible couplings shall be keyed to the shaft. Keys, keyways, and fits shall conform to ISO/R773 (ANSI/AGMA 9002, Commercial Class). Shaft coupling keyways shall be cut to accommodate a rectangular cross section key. Sled-runner type keys and keyways shall not be provided. Keys shall be fabricated and fitted to minimize unbalance. Coupling hubs with cylindrical bores may be supplied with slip fits to the shaft and set screws that bear on the key.

NOTE Slip fits on cylindrical bores allow adjustment of the coupling axial position in the field without application of heat.

9.1.5.2.6 For shaft diameters greater than 60 mm (2.5 in.), the hub shall be mounted with a taper fit. The coupling fit taper for keyed couplings shall be 1:10 long series conical in accordance with ISO/R775, or alternately 1:16 (0.75 in./ft, diametral) for compliance with U.S. Standards. Other mounting methods shall be agreed upon by the Purchaser and the Vendor.

NOTE Appropriate assembly and maintenance procedures must be used to assure that taper fit couplings have an interference fit.

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

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

• **9.1.5.2.9** If specified, couplings shall meet the requirements of ISO 14691**.**

9.1.5.2.10 If the Vendor is not required to mount the driver, the fully machined half coupling shall be delivered 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.

9.1.5.2.11 Each coupling shall have a coupling guard that is removable without disturbing the coupled elements. Each coupling guard shall meet the requirements of 9.1.5.2.11.1 through 9.1.5.2.11.6.

9.1.5.2.11.1 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 ANSI B15.1.

9.1.5.2.11.2 Constructed with sufficient stiffness (rigidity) to withstand a 900 N (200 lbf) static point load in any direction without the guard contacting moving parts.

9.1.5.2.11.3 Fabricated from sheet (solid or perforated), plate, or expanded metal. Any openings shall conform to ISO 14120, EN 953 or ANSI B15.1, but in no case shall exceed 10 mm (0.375 in.). Guards of woven wire shall not be used.

9.1.5.2.11.4 Constructed of steel, brass, aluminum or non-metallic (polymer) materials, as suitable.

• **9.1.5.2.11.5** If specified, in applications within potentially explosive atmospheres, an "ignition hazard assessment" (risk analysis) as described by EN 13463-1, shall be conducted.

• **9.1.5.2.11.6** If specified, guards shall be constructed of an agreed spark-resistant material.

NOTE Many users consider pure aluminum and aluminum alloys with a maximum content of 2 % magnesium or 0.2 % copper, copper and copper-based alloys (e.g. brass, bronze) to be spark resistant. However, local regulations, such as EN 13463-1, may not allow aluminum or non-metallic materials within potentially explosive atmospheres.

9.1.5.3 Baseplates

9.1.5.3.1 Single-piece drain rim or drain pan baseplates shall be furnished for horizontal pumps.

• **9.1.5.3.1.1** The Purchaser shall specify the rim or pan type as follows:

a) drain rim surrounding the entire baseplate;

b) drain pan surrounding the entire baseplate, or;

c) partial drain pan that covers the entire width of the baseplate.

9.1.5.3.1.2 The rim or pan of the baseplate shall be sloped at least 1:120 toward the pump end, where a tapped drain opening at least DN 50 (NPS 2) shall be located to effect complete drainage.

9.1.5.3.2 Unless otherwise specified, the baseplate shall extend under the pump and drive train components so that any leakage is contained within the baseplate. To minimize accidental damage to components, all pipe joints and pipe flange faces, including pump suction and discharge flanges, shall be within the drain pan or drain rim collection area. All other projections of the equipment supplied shall fall within the maximum perimeter of the baseplate. Oversized junction boxes may overhang the perimeter of the baseplate with the Purchaser's approval.

9.1.5.3.3 If driver and pump size permit, baseplates shall have standardized dimensions as given in Annex M and shall be designed for grouting. These baseplates shall be referred to as "Standard Baseplates, Numbers 0.5–12".

9.1.5.3.4 The height of the pump shaft centerline above the baseplate shall be minimized. Adequate clearance shall be provided between the casing drain connection and the baseplate so that drain piping the same size as the connection can be installed without the use of a street (male-female) elbow.

• **9.1.5.3.5** Mounting pads shall be provided for the pump and all drive train components. The pads shall be larger than the foot of the mounted equipment, including extra width of shims under drive train components, to allow leveling of the baseplate without removal of the equipment. The pads shall be fully machined flat and parallel. Corresponding surfaces shall be in the same plane within 150 μm/m (0.002 in./ft) of distance between the pads. If specified, the requirement in this clause shall be demonstrated in the pump Vendor's shop prior to mounting of the equipment and with the baseplate supported at the foundation bolt holes only. This demonstration can only be performed when the clamps are released in the milling machine after completion of machining.

NOTE Installed baseplate flatness can be affected by transportation, handling and installation procedures beyond the Vendor's scope. Installation practices in API RP 686 should be followed.

9.1.5.3.6 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.

9.1.5.3.6.1 If the Vendor mounts the components, a set of stainless steel shims at least 3 mm (0.12 in.) thick shall be furnished. 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 5 mm (1/4 in.) beyond the outer edges of the equipment feet.

9.1.5.3.6.2 If the Vendor does not mount the components, the pads shall not be drilled, and shims shall not be provided. Shims shall not be used under the pump.

• **9.1.5.3.6.3** If specified, in addition to shim packs, a stainless steel spacer plate of not less than 5 mm (0.200 in.) thickness, machined on both sides, and of the same length and width as the specific mounting feet, shall be furnished and installed under all equipment feet, including the pump, driver, and any speed increaser or reducer.

9.1.5.3.7 All joints, including deck plate to structural members, shall be continuously seal-welded on both sides to prevent crevice corrosion. Stitch welding, top or bottom, is unacceptable.

9.1.5.3.8 The bottom of the baseplate between structural members shall be open if the baseplate is designed to be installed and grouted to a concrete foundation. Accessibility shall be provided for grouting under all load-carrying members. The bottom of the baseplate shall be in one plane to permit use of a single level foundation.

9.1.5.3.9 The underside of fabricated baseplates beneath the pump and driver supports shall be welded to reinforcing cross members, and the members shall be shaped to lock positively into the grout.

9.1.5.3.10 All baseplates shall be provided with at least one grout hole having a clear area of at least 125 cm^2 (19 $in.^2$) and no dimension less than 75 mm (3 in.) in each bulkhead section. These holes shall be located to permit filling the entire cavity under the baseplate without creating air pockets. If practical, the holes shall be accessible for grouting with the pump and driver installed on the baseplate. Grout holes in the drip-pan area shall have 13 mm (0.5 in.) raised lip edges. If the holes are located in an area where liquids could impinge on the exposed grout, metallic covers with a minimum thickness of 1.5 mm (16 gauge) shall be provided. Vent holes at least 13 mm (0.5 in.) in diameter shall be provided at the highest point in each bulkhead section of the baseplate.

9.1.5.3.11 The outside corners of the baseplate in contact with the grout shall have at least 50 mm (2 in.) radii in the plan view (see Figure M.1).

9.1.5.3.12 Unless otherwise specified, the Vendor shall commercially sand blast, in accordance with ISO 8501 Grade Sa2 SSPC SP 6, all grout contact surfaces of the baseplate, and coat those surfaces with inorganic zinc silicate in preparation for epoxy grouting.

• **9.1.5.3.13** If specified, the baseplate and pedestal support assembly shall be sufficiently rigid to be mounted without grouting.

• **9.1.5.3.14** If specified, the baseplate shall be supplied without a deck plate, i.e. open deck design.

9.1.5.3.15 The baseplate shall be provided with lifting lugs for at least a 4-point lift. Lifting the baseplate, complete with all equipment mounted, shall not permanently distort or otherwise damage the baseplate or the machinery mounted on it.

9.1.5.3.16 Lifting lugs attached to the equipment shall be designed using a maximum allowable stress of one-third of the specified minimum yield strength of the material.

9.1.5.3.17 Transverse and axial alignment positioning jackscrews shall be provided for drive train components weighing more than 250 kg (500 lb) to facilitate transverse horizontal and longitudinal adjustments. The lugs holding these positioning screws shall be attached to the baseplate so that the lugs do not interfere with the installation or removal of the component. These screws shall be at least M12 ($^1/_2$ in.-13). To prevent distortion, machining of mounting pads shall be deferred until welding on the baseplate in close proximity to the mounting pads has been completed.

9.1.5.3.18 Vertical leveling screws shall be provided on the outside perimeter of the baseplate adjacent to each anchor bolts to minimize distortion during the process of installation and to carry the weight of the baseplate, pump, and drive train components without excessive deflection

9.1.5.3.19 Baseplates which are specified to be installed with cementitious grout shall have grout contact surfaces left free of paint and primer in order to promote maximum grout adhesion.

9.1.5.3.20 The Vendor shall provide for sufficient anchor bolting to withstand nozzle reaction forces during pump start-up and operation. Anchor bolts are in the Purchaser's scope.

9.1.5.3.21 To minimize misalignment of the pump and driver shafts due to piping load effects, the pump and its baseplate shall be constructed with sufficient structural stiffness to limit displacement of the pump shaft at the drive end of the shaft or at the register fit of the coupling hub to the values shown in Table 13. Grout shall not be used as a means of obtaining the required stiffness.

NOTE It is recognized that grout can significantly increase the stiffness of the baseplate assembly; by neglecting this effect, the adequacy of the baseplate can easily be verified at the Vendor's shop. It is also noted that thermal growth, piping fabrication errors, and alignment error all contribute to the actual deflection values achieved in the field. Adherence to the nozzle load values in Table 13 limits the total deflection at the pump and drive shaft ends to approximately 250 μm (0.010 in.).

Table 13—Stiffness Criteria

Baseplate Intended for Grouting		Baseplate Not Intended for Grouting	
Loading condition	**Pump shaft displacement** μm (in.)	**Pump shaft displacement** μm (in.)	**Direction**
*MY*c	175 (0.007)	125 (0.005)	+ Z
*MZ*c	75 (0.003)	50 (0.002)	– Y
*MY*c and *MZ*c equal the sum of the allowable suction and discharge nozzle moments from Table 4. *MY*c = (*MY*)suction + (*MY*)discharge *MZ*c = (*MZ*)suction + (*MZ*)discharge			

9.1.6 Testing

- **9.1.6.1** Static torque testing data shall be available for each coupling rating, and if specified shall be submitted for Purchaser review. If specified, magnetic couplings shall be given a static torque test to verify the rated torque (see 9.1.3.8) and certification shall be provided. The test shall be performed at ambient temperature and corrected for maximum allowable temperature.

9.1.6.2 Prior to actual performance testing, the pump Manufacturer shall advise the shop procedure for quantifying eddy-current losses and for correcting water test results to performance on specified job fluid(s).

- **9.1.6.3** If specified, the pump shall be mechanically run on the test stand until the sump oil temperature has stabilized. Temperature stabilization is assumed when the temperature rise is not more than 1 °C in 10 min.

9.1.7 Preparation for Shipment

9.1.7.1 Exposed shafts and shaft couplings (magnetic drive pumps) shall be wrapped with waterproof, moldable waxed cloth or volatile-corrosion inhibitor paper. The seams shall be sealed with oil-proof adhesive tape.

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

9.2 Canned Motor Pumps

9.2.1 General

Canned Motor Pumps are designated as Type CMP. A description of Type CMP is given in Annex C.

9.2.2 Motor Requirements

9.2.2.1 The stator housing of a canned motor pump, including the electrical feed through barrier, shall be designed for the pressure casing maximum allowable working pressure, associated hydrostatic test pressure and operating temperature range.

9.2.2.2 Unless otherwise specified, the stator cavity on motors for pumps built for services which have operating temperature of 160 °C (320 °F) or less shall not be filled with oil.

If approved by Purchaser the stator cavity can be filled with a liquid or solid heat transfer material used to conduct heat away from the stator windings. Motor insulation, including heat transfer material, shall be suitable for the temperature of the process fluid.

9.2.2.3 Electrical feed through barrier to canned motor junction box shall be self-draining into the stator cavity.

9.2.2.4 The connection box shall be sized at least one size larger than the standard IEC (NEMA) size for the motor used.

9.2.2.5 Motors shall be designed for across-the-line starting except in those applications where a variable frequency drive will be used to obtain a soft start.

9.2.2.6 Motors rated below 150 kW (200 hp) shall be capable of 3 starts per hour when the initial start is from ambient temperature. Motors rated 150 kW and above shall be capable of 3 starts per hour but limited to 8 starts per day.

9.2.2.7 The stator winding insulation shall be rated to allow the motor to satisfactorily operate for at least 175,000 hours at the maximum rated temperature and flow conditions.

9.2.2.8 Class H 180 °C (356 °F) is the minimum acceptable class of insulation.

NOTE Other classes seen in CMP are "C" and "R".

• **9.2.2.9** If specified, motors shall be designed for the special operating conditions, such as frequent starting and multi-speed operation, of the driven equipment. The Vendor shall state the effect of these conditions on the expected operating life.

9.2.2.10 The motor shall be rated and documented for the hazardous (classified) locations specified by the Purchaser. Third party certification (UL, FM, or equal) will be provided as necessary.

• **9.2.2.11** If specified, a decontamination flush or purge connection shall be included on the stator assembly.

9.2.3 Stator Liner

9.2.3.1 The stator assembly consisting of the stator, stator liner, liner backing supports, stator housing, and electrical feed-through is by definition a pressure-containing assembly and shall meet the requirements of 6.2 except as follows.

a) The stator liner shall be of a material that is non corrosive.

b) The minimum stator liner thickness shall be 0.38 mm (0.015 in.).

c) The stator liner shall be hydrostatically tested in the stator assembly at 1.5 times the maximum allowable working pressure.

9.2.3.2 Stator liner materials not contained in Annex H shall be subject to the approval of the Purchaser.

9.2.4 Rotor Liners

9.2.4.1 The rotor liner material shall be non corrosive.

9.2.4.2 Rotor liner materials not contained in Annex H shall be subject to the approval of the Purchaser.

9.2.5 Additional Nameplate Requirements

9.2.5.1 In addition to the nameplate information required in 6.11.2, canned motor pump nameplates shall also include the following additional information:

a) rated motor voltage;

b) full load motor amperes;

c) motor insulation class;

d) motor rated horsepower;

e) locked rotor amperes;

f) maximum allowed pump and motor working pressure at rated temperature;

g) date of manufacture;

h) pump impeller diameter;

i) pumped liquid identification;

j) motor thermal protection actuation temperature.

9.2.5.2 For service in Class I, Division 1 Hazardous Areas, the following additional nameplate information is required:

a) pumped liquid temperature limits (either by NFPA 70 or actual temperature);

b) label, note or logo indicating approval for use in Class I, Division I area.

9.2.5.3 For variable speed drives, the following additional nameplate information is required: Motor speed range.

9.2.6 Submersible Canned Motor Pumps

If pumps are designed and supplied with a vessel nozzle cover plate, the cover plate shall be designed to the same maximum working pressure and temperature as the vessel on which it is mounted. If the vessel on which it is mounted is a pressure vessel, designed to ASME Section VIII, Division 1, then the cover plate shall be designed to the same criteria. The conduit from the motor to the cover plate is a part of the pressure casing and shall be designed in accordance with all requirements imposed on the pump pressure casing such as corrosion allowance, design pressure, and design temperature.

9.2.7 Testing

• Motor tests shall consist of resistance measurements of the windings and dielectric tests to confirm the integrity of the winding insulation. Tests shall be performed in accordance with IEEE 252 or other standards as agreed to by the Purchaser. If specified, certification shall be provided by the Vendor.

10 Vendor's Data

10.1 General

10.1.1 The Vendor shall furnish the information specified in 10.2 and 10.3.

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

a) Purchaser's/Owner's corporate name;

b) job/project number;

c) equipment item number and service name;

d) inquiry or Purchaser order number;

e) any other identification specified in the inquiry or Purchaser order;

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

• **10.1.3** If specified, a coordination meeting shall be held, preferably at the Vendor's plant, within four to six weeks after order commitment. Unless otherwise specified, the Vendor shall prepare and distribute an agenda prior to this meeting, which as a minimum shall include a review of the following items:

a) purchase order, scope of supply, unit responsibility, and sub-Vendor items;

b) data sheets;

c) applicable specifications and previously agreed-upon exceptions;

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

e) quality assurance program and procedures;

f) inspection, expediting, and testing;

g) schematics and bills of material for auxiliary systems;

h) the physical orientation of the equipment, piping, and auxiliary systems;

i) magnetic coupling sizing (MDP only);

j) temperature-pressure profile;

k) Vendor-supplied maintenance data;

l) thrust-bearing sizing and estimated loadings;

m) instrumentation and controls;

n) other technical items.

10.2 Proposals

10.2.1 General

10.2.1.1 The Vendor shall forward the original proposal and the specified number of copies to the addressee specified in the inquiry documents. As a minimum, the proposal shall include the data specified in 10.2.2 through 10.2.4, as well as a specific statement that the system and all its components are in strict accordance with this standard. If the system and components are not in strict accordance, the Vendor shall include a list that details and explains each deviation. The Vendor shall provide details to enable the Purchaser to evaluate any proposed alternative designs. All correspondence shall be clearly identified in accordance with 10.1.2.

10.2.1.2 Clearances less than those required by 6.6.4 and Table 5, must be stated as exceptions to this standard in the proposal.

10.2.2 Drawings

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

a) a general arrangement or outline drawing for each major skid or system, showing direction of rotation, size and location of major Purchaser connections, overall dimensions, maintenance clearance dimensions, overall weights, erection weights, maximum maintenance weights (indicated for each piece), lifting points, and methods of lifting the assembled machine and, if applicable, the Standard Baseplate number (see Annex M);

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

c) schematics of all auxiliary systems, including control, and electrical systems with bills of material included.

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

10.2.3 Technical Data

The following data shall be included in the proposal:

a) Purchaser’s datasheets, with complete Vendor’s information entered thereon and literature to fully describe details of the offering;

b) predicted noise data;

c) Vendor Drawing and Data Requirements Form (see example in Annex O), indicating the schedule according to which the Vendor agrees to transmit all the data specified as part of the purchase order;

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

e) list of major wearing components, showing interchangeability with other items on the project or the Owner’s existing machines;.

f) list of spare parts recommended for start-up and normal maintenance purposes (see Table 14);

g) list of the special tools furnished for maintenance (see 7.6.1);

h) description of any special weather and winterization 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 furnished by the Purchaser as well as that included in the Vendor’s scope of supply;

Table 14—Recommended Spare Parts

Part	Number of identical pumps (n)						
	1 to 3	4 to 6	> 6	1 to 3	4 to 6	7 to 9	> 9
	Recommended number of spare parts						
	Start-up			Normal maintenance			
Warehouse spare pump [a]				1[a]	1[a]	1[a]	1[a]
Rotor assembly, driven [a,b,d]				1	1	1	n/20
Rotor [c]			1	1	1	2	n/5
Case [a]							1
Impeller [q]				1	1	2	n/3
Wear rings (set) [p]	1	1	1	1	1	2	n/3
Bearing set, product lubricated [p]	1	1	2	1	2	n/3	n/3
Auxiliary impeller (if applicable)	1	1	1	1	1	1	n/3
Gaskets, shims, O-rings (set)	1	2	n/3	1	2	n/3	n/3
Specific to MDP							
Pump-less-casing [f, j, k]							
Wet-end cartridge [a, b,d, j]							1 [a,b]
Power frame assembly [a, b, e, f]							1 [a,b]
Bearing housing, antifriction	1	1	1	1	1	1	n/20
Drive rotor [e]			1			1	n/10
Drive magnet assembly [a, b, n]			1			1	n/10
Rub rings [p]	1	1	2	1	2	n/3	n/3
Drive magnet shaft				1	1	1	n/10
Bearing, antifriction, front [p]	1	1	2	1	2	3	n/3
Bearing, antifriction, rear [p]	1	1	2	1	2	3	n/3
Shaft seal, AF bearing housing, inner [p]	1	1	2	1	2	3	n/3
Shaft seal, AF bearing housing, outer [p]	1	1	2	1	2	3	n/3
Bushing holder for inner rotor							n/10
Containment Shell				1	1	1	n/10
Specific to CMP							
Back pullout assembly [a, b, g]				1	1	1	1
Stator assembly [a, b, m]					1	1	n/20
Bearing housings							n/10

[a] Vital-service pumps are generally unspared. When a vital machine is down, production loss or violation of environmental permits results. At least one noted item should be available for each designated vital-service pump. Some users may choose to have an uninstalled spare pump as opposed to, or in addition to parts shown.

[b] Essential-service pumps are required for operation and have an installed spare. A production loss occurs only if main and spare fail simultaneously. At least one noted item should be available for each designated set of essential-service pumps to minimize the period without an available spare.

[c] Rotor consists of all rotating parts except the impeller and nut attached to the wetted shaft.

[d] Rotor assembly consists of the rotor, plus the bearing sleeves and bushings.

[e] Drive rotor (MDP) consists of the outer magnet assembly, drive shaft, and all attached rotating parts.

[f] Power frame assembly (MDP) consists of the drive rotor, AF bearing housing, bearings, seals and outer frame.

[g] Back pullout assembly includes everything but the volute casing, baseplate (CMP).

Table 14—Recommended Spare Parts (Continued)

h	Assembly consists of assembled element plus discharge head, seal(s) and bearing housing(s).
j	Wet-end cartridge (MDP) consists of assembled rotor plus removable stationary hydraulic parts [diffuser(s) or volute(s)], the back cover and containment shell (but not the volute/fixed diffuser casing).
k	A Pump-less-casing (MDP) would be a combined wet-end cartridge and power-frame.
m	Stator assembly (CMP) consists of the stator, stator housing, stator liner and electrical connection box.
n	Drive magnet assembly consists of the outer magnets, magnet carrier and sheathing.
p	Normal-wear parts.
q	full diameter impellers are usually ordered to allow for possible head change and interchangeability with other services using the same impeller

i) complete tabulation of utility requirements, e.g. steam, water, electricity, and external flush liquid (including the quantity and supply pressure of the liquid required). Approximate data shall be clearly indicated as such;

j) description of any optional or additional tests and inspection procedures for materials, as required by 6.10.1.5.

k) description of any special requirements whether specified in the Purchaser's inquiry or as outlined in 6.1.11, 6.1.14, 6.1.15, 6.1.16, 6.1.23, 6.1.30, 6.1.31.1, 6.2.1.1, 6.3.2.3, 6.3.3.4, 6.3.3.5f), 6.6.1, 6.8.3.1, 6.10.1.1, 6.10.1.2, 6.10.1.3, 6.10.1.5, 7.1.2.1, 9.1.3.1, 9.1.3.5, 9.1.3.8, and 9.1.4.3.4c);

• l) if specified, a list of similar machines installed and operating under similar conditions;

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

n) calculated specific speed and suction specific speed;

o) notification if testing at rated speed, per 8.3.3.3.3, is not possible or recommended. A recommendation for correction of pump power from rated to test conditions shall also be included.

10.2.4 Curves

The Vendor shall provide complete performance curves, including differential head, typical efficiency, water NPSH3, and power expressed as functions of flowrate. Except for low specific-speed designs where it would not be feasible, the curves shall be extended to at least 120 % of flowrate at peak efficiency, and the rated operating point shall be indicated. The head curve for maximum and minimum impeller diameters shall be included. The impeller identification number, specific speed and suction specific speed shall be shown on the curves. If applicable, the curves shall indicate viscosity corrections. Minimum flow (both thermal and stable), preferred and allowable operating regions, and any limitations of operation shall be indicated.

10.2.5 Options

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

10.3 Contract Data

10.3.1 General

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

10.3.1.2 Each drawing shall have a title block in the lower right-hand corner with the date of certification, project and Vendor's reference information specified in 10.1.2, revision number and date and title. Similar information shall be provided on all other documents.

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

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

10.3.2 Drawings and Technical Data

10.3.2.1 The drawings and data furnished by the Vendor shall contain sufficient information so that, together with the manuals specified in 10.3.5, 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), shall cover the agreed VDDR form (see example in Annex O) and shall satisfy the applicable detailed descriptions.

Dimensional outline drawings shall indicate the tolerance for pump suction and discharge nozzle face and centerline locations referenced from the centerline of the nearest baseplate anchor-bolt hole. The centerline of baseplate anchor-bolt hole locations shall indicate the tolerance from a common reference point on the baseplate.

10.3.2.2 Certified test curves and data (see example in Annex P) shall be submitted within 15 days after testing and shall include head, power recalculated to the proper specific gravity, and efficiency, plotted against flowrate. If applicable, viscosity corrections shall be indicated. The water NPSH3 curve shall be included, drawn from actual test data, for an impeller cast from the same pattern. The curve sheet shall include the maximum and minimum diameters of the impeller design supplied, the identification number of the impeller or impellers, and the pump serial number.

10.3.3 Progress Reports

Unless otherwise specified, the Vendor shall submit progress reports to the Purchaser at the intervals specified on the Vendor Drawing and Data Requirements Form (see Annex O).

10.3.4 Parts Lists and Recommended Spares

10.3.4.1 The Vendor shall submit complete parts lists for all equipment and accessories supplied. The lists shall include part names, Manufacturer's unique part numbers, materials of construction, and delivery times. Materials shall be identified as specified in 6.10.1.2. Each part shall be completely identified and shown on cross-sectional or assembly-type drawings so that the Purchaser can determine the interchangeability of these parts with other equipment. Parts that have been modified from standard dimensions and/or finish to satisfy specific performance requirements shall be uniquely identified by part number for interchangeability and future duplication purposes. Standard purchased items, including gaskets and O-rings, shall be identified by the original Manufacturer's name, part number, material and pressure rating, if applicable.

10.3.4.2 The Vendor shall indicate on each of these complete parts lists all those parts that are recommended spares as start-up or maintenance spares and the recommended stocking quantities of each. These should include spare parts recommendations of sub-suppliers that were not available for inclusion in the Vendor's original proposal. The Vendor shall forward the lists to the Purchaser promptly after receipt of the reviewed drawings and in time to permit order and delivery of the parts before field start-up. The transmittal letter shall be identified with the information specified in 10.1.2.

10.3.5 Data Manuals

10.3.5.1 General

10.3.5.1.1 The Vendor shall provide sufficient written instructions and all necessary drawings to enable the Purchaser to install, operate and maintain all of the equipment covered by the purchase order. This information shall be compiled in a manual or manuals with a cover sheet showing the information listed in 10.1.2, an index sheet, and a complete list of the enclosed drawings by title and drawing number. The manual or manuals shall be prepared specifically for the equipment covered by the purchase order. Pre-printed sections that are model specific may be included, but typical manuals are unacceptable.

10.3.5.1.2 Vendor manuals shall also be furnished in an agreed upon electronic format that reflect the “as supplied” equipment, with any safeguards considered necessary for legal protection of all parties.

10.3.5.2 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, centers of mass, rigging provisions and procedures, and all other installation data. Drawings and data specified in 10.3.2 that are pertinent to proper installation shall be included as part of this manual.

10.3.5.3 Manual for Operating, Maintenance, and Technical Data

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

Annex A
(informative)

Application Information

A.1 General

Some additional understanding of differences between sealless pumps and mechanically sealed centrifugal pumps is necessary for proper application. Information is presented within this section to point out factors which need to be considered in application, and identify factors which are different from considerations for centrifugal pumps with shaft seals.

A.2 Circulation Plan Selection and Application

A.2.1 General

(See Annex D for circulation plan schematics.)

It is recognized that the product lubricated bearings design and application considerations are essentially the same for canned motor pumps and magnetic drive pumps.

Selection of an appropriate circulation plan depends upon knowledge of fluid properties such as cleanliness, volatility, specific heat, toxicity, melting point, viscosity, specific gravity, vapor pressure and tendency to form solids or polymerize. Also to be considered are intended operation, flow rates, NPSH, frequency of starts, and cooling or heating availability.

Factors internal to the unit design such as pressures, temperatures, flows and heat transfer characteristics within the drive section as well as hydraulic performance of the pump end must be understood in order to properly select circulation plans and assess application questions. Possible advantages and limitations of available plans must also be understood.

The circulation plans shown in Annex D coupled with detailed knowledge of individual unit design allow for the handling of most applications.

A.2.2 Comments on Individual Considerations

A.2.2.1 Clean, Non-volatile, Moderate Temperature Fluid with Sufficient NPSH

This description fits the majority of sealless pump applications and can be handled by variations of circulation plans shown.

A.2.2.2 High Temperature

Temperature of motor windings or magnetic drive components can be controlled by a variety of circulation plans shown in the grouping for high temperature, if cooling is required.

A.2.2.3 Volatile Fluids/Limited NPSH Available

Reverse circulation and pressurized circulation plans may be used to avoid the thermal effect of drive heating on pump NPSH requirements. Consideration of vapor pressure increase with temperature and of specific heat of fluid is required. Use of a separate low volatility drive buffer fluid is also possible. Consideration should also be given to the use of a cooler to sub-cool the circulation system prior to the flow entering the rotor chamber and bearings.

A.2.2.4 Venting and Cool Down

When pumping cold fluids which are volatile at atmospheric temperature, use of a separate vent line back to the supply vessel is sometimes necessary to cool the pump and piping to near pumping temperature prior to start-up.

A.2.2.5 Fluids Containing Abrasive Particles may Cause Objectionable Wear

Centrifugal separation, mechanical filtration, or injection of a separate, clean buffer fluid may be used to remove particles from the circulation fluid or avoid exposure to those particles. In the case of mechanical filtration, consideration should be made to monitor such a system for blockage.

A.2.2.6 Jacketed Designs

Jacketed designs may be required for high melting point fluids and easily polymerizing or crystallizing fluids. Buffer fluids may also be used.

A.2.2.7 High Viscosity

Viscosities which would cause objectionable drag losses in the drive section or inadequate bearing lubrication (generally viscosity above 100 centipoise) may be handled with an external source of circulation fluid. (viscosity in centipoise (CPS) = viscosity in centistoke (cSt) times specific density; viscosity in saybolt-seconds-universal (SSU) = 4.64 times viscosity in cSt). Start-up, as well as operating viscosity, needs consideration.

A.2.2.8 Low Viscosity

Viscosities which may reduce the ability of the bearing system to develop a sufficient fluid film to support the shaft may be handled by the use of a cooler to raise the viscosity in the circulation system before passing through the bearings. Alternatively specialized tilting pad bearings can also handle low viscosities. Canned motor pumps may use a barrier fluid to provide bearing lubrication.

A.3 Pump Performance Selection

A.3.1 General

Pump selection is the same as for a shaft sealed, centrifugal pump with additional attention to the following.

A.3.1.1 Hydraulic Sizing

Caution should be used when sizing the pumps. Over sizing the pump, which results in over sizing the magnet driver, can cause excessive heat build up. The excessive heat can be caused by magnetic-drive eddy currents.

A.3.1.2 Driver Sizing for Canned Motor Pumps

The effect of load on winding temperature and rotational speed needs to be considered over anticipated performance range allowing for any projected future change in requirements. Oversizing the motor results in a larger winding (heat sink) to contribute to heating of the fluid in the rotor cavity on shutdown. Motors must conform to required area classification.

A.3.1.2.1 Canned Motor Pump Electrical Feeder Cable Sizing

Due to the integral nature of the canned pump impeller and motor construction, the motor rating required for a given duty is directly affected by the temperature of the fluid being pumped and the power rating is stated as motor input electric power, not shaft power. Due to the process fluid operating temperatures, derating of the motor winding in many cases may be required to maintain the winding insulation temperature within the limits of the class of insulation used. In these cases, the motor rating under ambient temperature conditions will be higher than that required at rated conditions.

Both of these factors need to be considered when calculating the motor feeder cable size, and associated voltage drop when starting the motor. For example, if a 40 HP motor rating is selected for a 30 HP pump duty to meet the winding temperature rise limitations, its starting current is limited to 6.5 times the full load current of the 40 HP rating, not relative to the 30 HP duty rating. The starting current would therefore be 8.7 times an equivalent 30 HP full load current value. When converting the power value into amperes, it is not required to account for the motor inefficiencies as the power value already includes the effect of the motor losses.

The correct value of starting current must be used when calculating the appropriate size of feeder cable.

A.3.1.2.2 Area Classification Considerations

If a canned pump is located in an area defined as Division 1 or 2 because of other process equipment in that area, then the canned pump design and construction must meet the appropriate regulations and authority requirements. Attention is drawn to the motor surface temperature limitation requirements in NFPA 70, especially for service in Division 1 and 2 areas when pump operating temperatures are high.

A.3.1.2.3 Electrical Protection

In addition to the circuit breakers, overcurrent sensing elements, proper sizing of the feeder cable and other protection devices used with standard motors, the canned motor windings include a thermal switch which is imbedded in the motor windings to sense the temperature of the motor windings during operation.

This switch is normally rated to limit the motor winding temperature based on temperature rating of the insulation system. However, it should also be rated based on the application data provided. If the process fluid stream is interrupted in the motor cooling circuit, this switch will sense the temperature rise and either shut the motor off or provide an alarm. This will occur even if the motor is not overloaded. In the case of process fluids with low boiling points, low autoignition temperatures, tendency to polymerize at elevated temperatures, or other sensitivity to temperature rise, the thermal switch should be sized accordingly based on discussions between the Purchaser and Vendor.

A.3.1.3 Drive and Driver Sizing—Magnetic Drive Pumps

Rapid overheating may occur if the inner and outer magnets decouple during operation. The drive motor needs to be selected to cover the projected operating range. Correct sizing of the motor should ensure the magnetic drive does not decouple during acceleration. Because of limitations on available magnetic coupling designs, motor soft-start may be necessary on some applications. Motors must conform to required area classification.

A.3.1.4 Thermal Effects on NPSH

Heat from the drive section of a sealless pump can cause cavitation and loss of suction if fluid is recirculated to the pump suction. Circulation to intermediate or discharge points or recirculation to supply tank minimizes this problem and may be used to avoid flashing in the internal circulation path. Heating of fluid at the suction eye can also occur by internal recirculation within the pump impeller at low flow rates. Volatile fluids may require higher minimum flows and use of appropriate circulation plans.

Cavitation at the pump impeller may also result in excessive and/or cyclic (positive then negative) thrust and axial vibration. This should be avoided.

The pump design and circulation system should provide the margin of safety between pressure and vapor pressure within the drive area over the projected operating range Consideration should also be given to any specified variation in suction pressures, to ensure this margin of safety is always present.

A.3.1.5 Low Specific Gravity Performance

Pumps pumping low specific gravity fluids (0.5) may perform differently than pumps pumping fluids with specific gravities close to 1.0 (water). Different specific gravities may affect thrust balance, mechanical stability, temperature rise, and power required. Low SG liquids usually also have low specific heat values, resulting in higher temperature rise, and careful consideration should be taken in selecting the correct circulation piping plan. In addition, it is also common with these fluid types that viscosities are also low, and careful attention should be given to the internal bearings, to ensure an adequate and stable fluid film is always present. Purchaser should verify with Vendor, any start-up and commissioning conditions including the use of start-up strainers or different run-in liquids.

A.3.1.6 High Specific Gravity Performance

Some liquids such as refrigerants have the characteristic of a high specific gravity but also have a low specific heat. The high SG will affect the sizing of the magnetic drive and the motor, and will also affect the temperature rise, and the low specific heat will also affect the temperature rise. Specific attention should be given to this in selecting magnetic drives and circulation plans.

A.3.1.7 Material Selection

Material selection is the responsibility of the Purchaser but the Vendor also has a responsibility to inform user of unusual corrosion requirements such as the effect pumped liquids may have on pressure containment shells, stator liners, and rotor encapsulation.

The Purchaser shall identify any potentially corrosive agents such as chlorides or hydrogen sulfide which need to be given special consideration.

The Vendor shall identify materials of construction so that Purchaser has sufficient information to ascertain proper selection.

Allowance should also be made for the temperature rise within the drive section when corrosive characteristics vary significantly with temperature.

A.3.1.8 Entrained, Non-Condensable Gas

Collection of vapors at pump suction and at fluid lubricated bearing area must be avoided by use of an appropriate circulation plan.

A.3.1.9 Efficiency

The efficiencies of magnetic drive and canned motor pumps should consider overall efficiency from power input to hydraulic work output. Power input is measured at the pump-to-motor coupling for magnetic drive pumps and at the motor terminals for canned motor pumps. This overall efficiency must also include energy consumed by auxiliary piping, seals, or other optional components. It is necessary to know pump hydraulic efficiency for proper drive selection. It is also necessary to know efficiency of the drive section as well as for separate motors (when used) to predict overall efficiency for comparison between magnetic drive and canned motor pumps.

A.4 Canned Motor or Magnet Component Temperature

A.4.1 General

Temperature capabilities for magnet materials are shown in Annex I. Operating conditions must be evaluated along with Vendor knowledge of temperature rises to assure that the proper sizing and use of circulation plans will result in satisfactory drive component temperatures. Magnet strength and motor insulation life decreases rapidly above the rated temperatures.

A.4.2 Magnetic Permeability

Magnetic permeability is a measure of the ease with which a material can be magnetized. It is the ratio of the magnetic induction to the applied magnetizing field that is applied to the material.

A.4.3 Parasitic Hydraulic Loss

Parasitic hydraulic loss is the energy lost due to internal fluid friction from the rotation of the inner magnet ring within the liquid filled containment shell of a magnetic drive pump or similar losses due to the liquid circulating between the stator and rotor liners of a canned motor.

A.5 Installation, Operation, and Maintenance

A.5.1 General

A.5.1.1 Avoid dry bearing operation. The sleeve bearings in sealless pumps are usually lubricated by the pumped liquid. If operated dry, the bearings can fail quickly due to lack of lubrication. Dry running also results in a rapid temperature rise within the bearings, and if liquid then re-enters the bearings they are likely to crack due to thermal shock. Some bearing materials have self-lubricating properties and can tolerate short term dry running under some conditions.

A.5.1.2 Avoid air entrainment. Air entrainment in the pumped liquid can have the same effect on the pumped liquid lubricated bearings as running dry. The pump casing and containment shell must be fully primed and properly vented prior to pump start-up.

A.5.1.3 The frequency of inspection will depend on the corrosive and erosive nature of the pumped liquid. The manufacturer's manual shall recommend a schedule of inspection and shall recommend inspection of certain parts based on some abnormal event.

A.5.1.4 The manufacturer’s manual shall detail the method of review of individual parts to evaluate their wear condition and recommend when they should be replaced. The manufacturer should be consulted when unusual or abnormal wear or corrosion is observed.

A.5.2 Special Consideration for Magnetic Drive Pumps

A.5.2.1 The magnets in magnetically driven centrifugal pumps may create very strong magnetic fields. The following cautions should be observed at distances within 1 m (3 ft) of pumps while servicing or maintaining the pump.

a) Pacemakers—magnets can upset the timing of pacemakers.

b) Credit cards—magnets can erase magnetic tape on credit cards.

c) Computers, computer disks and tapes—magnets can erase information stored on computer disks and tapes, or any computer memory device.

d) Watches—magnets can damage mechanical spring-driven and electronically controlled watches.

e) Magnetic implants—can be attracted to the magnets.

NOTE Extreme caution should be used when reassembling a magnetically driven pump. Magnets can cause parts and tools to slam together with force enough to injure the parts and the parts handler. The jackscrews and/or guides provided on the transition or containment shell cartridge flange should be used. Refer to the manufacturer's maintenance manual for procedures or special tools. Use of nonmagnetic tools, where practical, is recommended.

A.5.2.2 Shipping of magnets and magnet assemblies, especially by air, may require special precautions. Note: Usually the shipment of an assembled pump is not a problem; however, consultation between the pump manufacturer, the user, and the freight company is advisable.

A.5.2.3 Avoid decoupling magnets. Decoupling of the inner and outer magnets can result in demagnetization of the inner magnets in a short period. Decoupling will also result in rapid temperature rise of the liquid in the containment shell and the magnet assemblies. Decoupling can be caused by jamming of the impeller, overloading from rubbing, high viscosity, or air entrainment. Decoupling can also occur if an oversized motor accelerates the drive magnet too fast for the magnetic coupling. A power sensor on the motor circut can detect and shut off the pump if is decoupling occurs, Measuring containment shell temperature can also be used to assist with detecting decoupling.

Annex B
(informative)

Hazard-Based Specification of Control/Containment Guidelines

B.1 The selection procedure below selects the applicable secondary Control/Containment required, based on the sealed fluid "Hazard statement codes" according to the 2007 edition of the United Nations document ST/SG/AC.10/30 Rev 2, *Globally Harmonised System of Classification and Labelling of Chemicals (GHS)* and the European Union Regulation (EC) 1272/2008 on the classification, labelling, and packaging of substances and mixtures. This procedure may also be applied using the Dangerous Substances Directive 67/548/EEC risk phrase classification of the pumped fluid to be sealed.

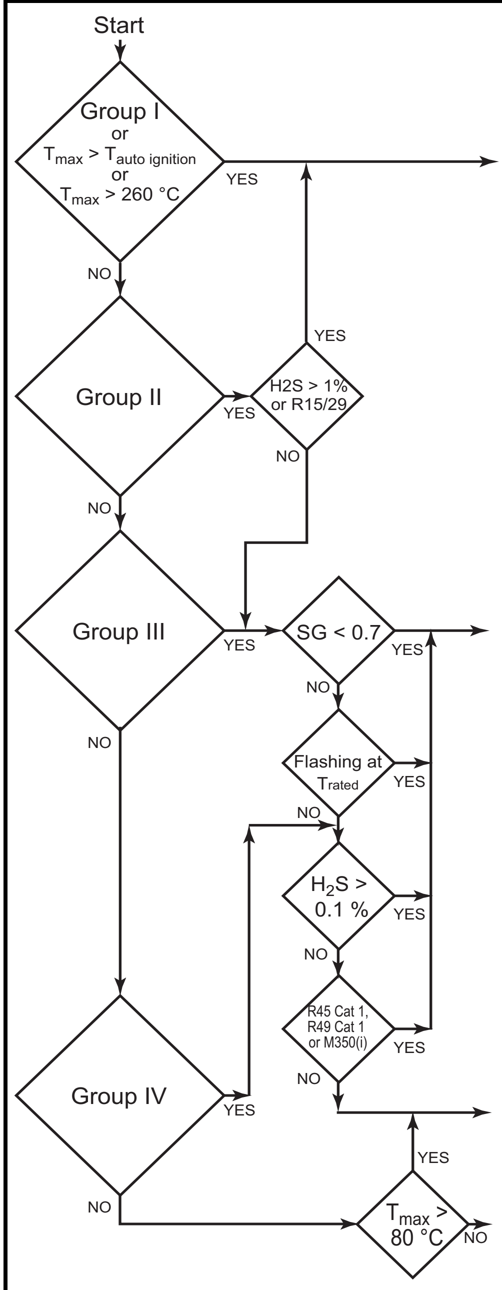
B.2 The secondary Control/Containment may be selected according to the selection logic in Figure B.1 and Table B.1 and Table B.2. The specific features shown represent a possible result to be applied at each level, but individual users and pump Vendors should agree on the measures to be applied based on each companies philosophy and practices.

B.3 The Purchaser should generate and supply the Vendor with the Material Safety Data Sheet (MSDS) of the pumped fluid. The Purchaser should also provide the Vendor with vapor pressure information covering the range between rated temperature and ambient. There may be more than one MSDS and set of vapor pressure data for variations in pumped fluid.

B.4 All possible combinations of H statements or R phrases have been grouped into 4 groups and are listed in Table B.1 and Table B.2. The H statements or R phrases used to establish the fluid group for this procedure are those of the fluid mixture not those of individual components making up that mixture.

Figure B.1—Logic Diagram

Secondary Control/Containment Logic



Secondary Control/ Containment	Canned Motor Pumps	Magnetic Drive Pumps
Secondary containment system (3.66)	— Leakage detection in pump stator (7.4.2.3). (S) — Pump power monitoring (7.4.2.2) or flow monitoring. (A) — Liquid detection in vertical section of discharge piping or on top of the heat exchanger if the pump has an external cooler. (A) — Stator Liner temperature monitoring (7.4.2.4). (A) — Motor winding thermocouple. (S) — Flanged secondary casing drain (6.7.9). — Decontamination flush (9.2.2.11).	— Secondary pressure casing. — Secondary pressure casing pressure monitoring. (S) [1] — Containment shell temperature monitoring. (A) [2] — Pump power monitoring (7.4.2.2) or flow monitoring. (A) — Liquid detection in vertical section of discharge piping. (A) — Containment shell temperature monitoring (7.4.2.4). (A) — Flanged secondary casing drain (6.7.9).
Secondary control system (3.68)	— Leakage detection in pump stator (7.4.2.3). (S) — Pump power monitoring (7.4.2.2) or flow monitoring. (A) — Liquid detection in vertical section of discharge piping or on top of the heat exchanger if the pump has an external cooler. (A) — Stator Liner temperature monitoring (7.4.2.4). (A) — Motor winding thermocouple (9.2.2.12). (S) — Flanged secondary casing drain (6.7.9). — Decontamination flush (9.2.2.11).	— Single containment shell. — Containment shell temperature monitoring. (S) [2] — Pump power monitoring (7.4.2.2) or flow monitoring. (A) — Liquid detection in vertical section of discharge piping. (A) — Containment shell temperature monitoring (7.4.2.4). (A) — Flanged secondary casing drain (6.7.9) or vent connected to plan 65 drain pot or Plan 75 vent system. (S) — Bearing protector seal to be approved by User (9.1.2.2.2).
Secondary control (3.67)	— Pump power monitoring (7.4.2.2) or flow monitoring. (A) — Liquid detection in vertical section of discharge piping or on top of the heat exchanger if the pump has an external cooler. (A) — Motor winding thermocouple (9.2.2.12). (S)	— Single containment shell. — Pump power monitoring (7.4.2.2) or flow monitoring. (A) — Liquid detection in vertical section of discharge piping. (A) — Flanged secondary casing drain (6.7.9). — Bearing protector seal to be approved by User (9.1.2.2.2).
none	— Liquid detection in vertical section of discharge piping or on top of the heat exchanger if the pump has an external cooler. (A) — Motor winding thermocouple (9.2.2.12). (S)	— Single containment shell. — Liquid detection in vertical section of discharge piping. (A) — Bearing protector seal to be approved by User (9.1.2.2.2).

Legend
- SG is the specific gravity of pumped fluid;
- T is the temperature of pumped fluid;
- A is the alarm;
- S is shutdown.

NOTE 1 A double containment shell using two containment shells with a partial vacuum between and pressure monitoring of the shell intermediate space.Or,
a single containment shell with a secondary pressure casing (3.73 and 6.7.7) including a sealing device (7.4.2.3b, 9.1.2.2.2, or 9.2.2.1), all hydrostatically tested (8.3.2.2) to ensure that any leakage is detected and contained up to the maximum discharge pressure of the pump (6.2.3) and that no leakage is possible into the antifriction bearings.

NOTE 2 Not required for submerged vertical pumps (VS4, VS5)

Table B.1—H Statement Classification Table

H Statement	Class
EUH001	I
EUH006	I
EUH014	I
EUH018	III
EUH019	III
EUH029	III
EUH031	III
EUH032	II
EUH044	III
EUH059	IV
EUH066	IV
EUH070	IV
EUH071	II
H200	I
H201	I
H202	I
H203	I
H204	III
H205	III
H220	III
H221	III
H222	III
H223	III
H224	III
H225	III
H226	IV
H227	IV
H228	n/a
H240	I
H241	I
H242	III

H Statement	Class
H242 [a]	III
H250	I
H251	I
H252	I
H260	III
H261	III
H270	III
H271	III
H272	III
H280	n/a
H281	n/a
H290	n/a
H300	III
H301	IV
H302	IV
H303	IV
H304	IV
H305	IV
H310	II
H311	IV
H312	IV
H313	IV
H314	III
H315	IV
H316	IV
H317	IV
H318	III
H319	IV
H320	IV
H330	II
H331	III

H Statement	Class
H332	IV
H333	IV
H334	III
H335	IV
H336	IV
H340	II
H341	II
H350	II
H350i	II
H351	II
H360D	II
H360Df	II
H360F	II
H360FD	II
H360Fd	II
H361d	III
H361f	III
H361fd	III
H362	III
H370	II
H371	III
H372	II
H373	III
H400	IV
H401	IV
H402	IV
H410	IV
H411	IV
H412	IV
H413	IV

a) Self reacting liquid.

Table B.2—R Phrase Classification Table

R-Phrase	Class
R 1	I
R 2	III
R 3	I
R 4	I
R 5	III
R 6	I
R 7	III
R 8	III
R 9	III
R 10	IV
R 11	III
R 12	III
R 13	n/a
R 14	I
R 14/15	I
R 15	III
R 15/29	I
R 16	III
R 17	I
R 18	III
R 19	III
R 20	IV
R 20/21	IV
R 20/21/22	IV
R 20/22	IV
R 21	IV
R 21/22	IV
R 22	IV
R 23	III
R 23/24	III
R 23/24/25	III
R 23/25	III
R 24	IV
R 24/25	IV
R 25	IV
R 26	II
R 26/27	II
R 26/27/28	II
R 26/28	II
R 27	III
R 27/28	III
R 28	III
R 29	III

R-Phrase	Class
R 30	III
R 31	III
R 32	II
R 33	III
R 34	III
R 35	III
R 36	IV
R 36/37	IV
R 36/37/38	IV
R 36/38	IV
R 37	IV
R 37/38	IV
R 38	IV
R 39	III
R 39/23	II
R 39/23/24	II
R 39/23/24/25	II
R 39/23/25	II
R 39/24	III
R 39/24/25	III
R 39/25	III
R 39/26	II
R 39/26/27	II
R 39/26/27/28	II
R 39/26/28	II
R 39/27	III
R 39/27/28	III
R 39/28	III
R 40	III
R 41	III
R 42	III
R 42/43	III
R 43	IV
R 44	III
R 45 Cat1	III
R 45 Cat 2	III
R 45 Cat 3	III
R 46	II
R 47	II
R 48	III
R 48/20	III
R 48/20/21	III
R 48/20/21/22	III

R-Phrase	Class
R 48/20/22	III
R 48/21	III
R 48/21/22	III
R 48/22	III
R 48/23	II
R 48/23/24	II
R 48/23/24/25	II
R 48/23/25	II
R 48/24	III
R 48/24/25	III
R 48/25	III
R 49 Cat 1	III
R 49 Cat 2	III
R 49 Cat 3	III
R 50	IV
R 50/53	IV
R 51	IV
R 51/53	IV
R 52	IV
R 52/53	IV
R 53	IV
R 54	IV
R 55	IV
R 56	IV
R 57	IV
R 58	IV
R 59	IV
R 60	III
R 61	III
R 62	III
R 63	III
R 64	III
R 65	IV
R 66	IV
R 67	IV
R 68	IV
R 68/20	III
R 68/20/21	III
R 68/20/21/22	III
R 68/20/22	III
R 68/21	IV
R 68/21/22	IV
R 68/22	IV

Annex C
(informative)

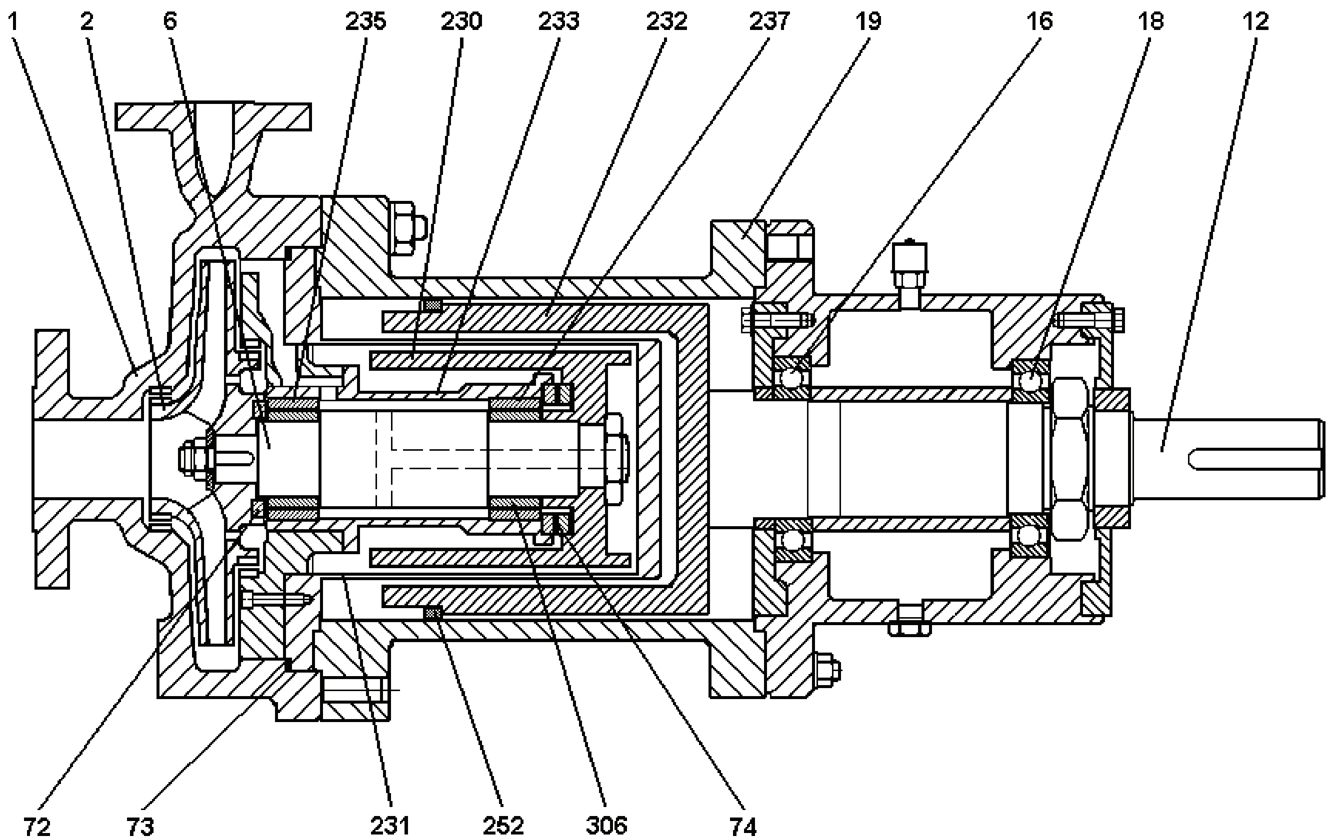
Sealless Centrifugal Pump Nomenclature

Figure C.1 shows typical nomenclature for magnet driven pump.

Figure C.2 shows typical nomenclature for canned motor pump.

Figure C.3 shows magnet driven pump terms defined in Section 3.

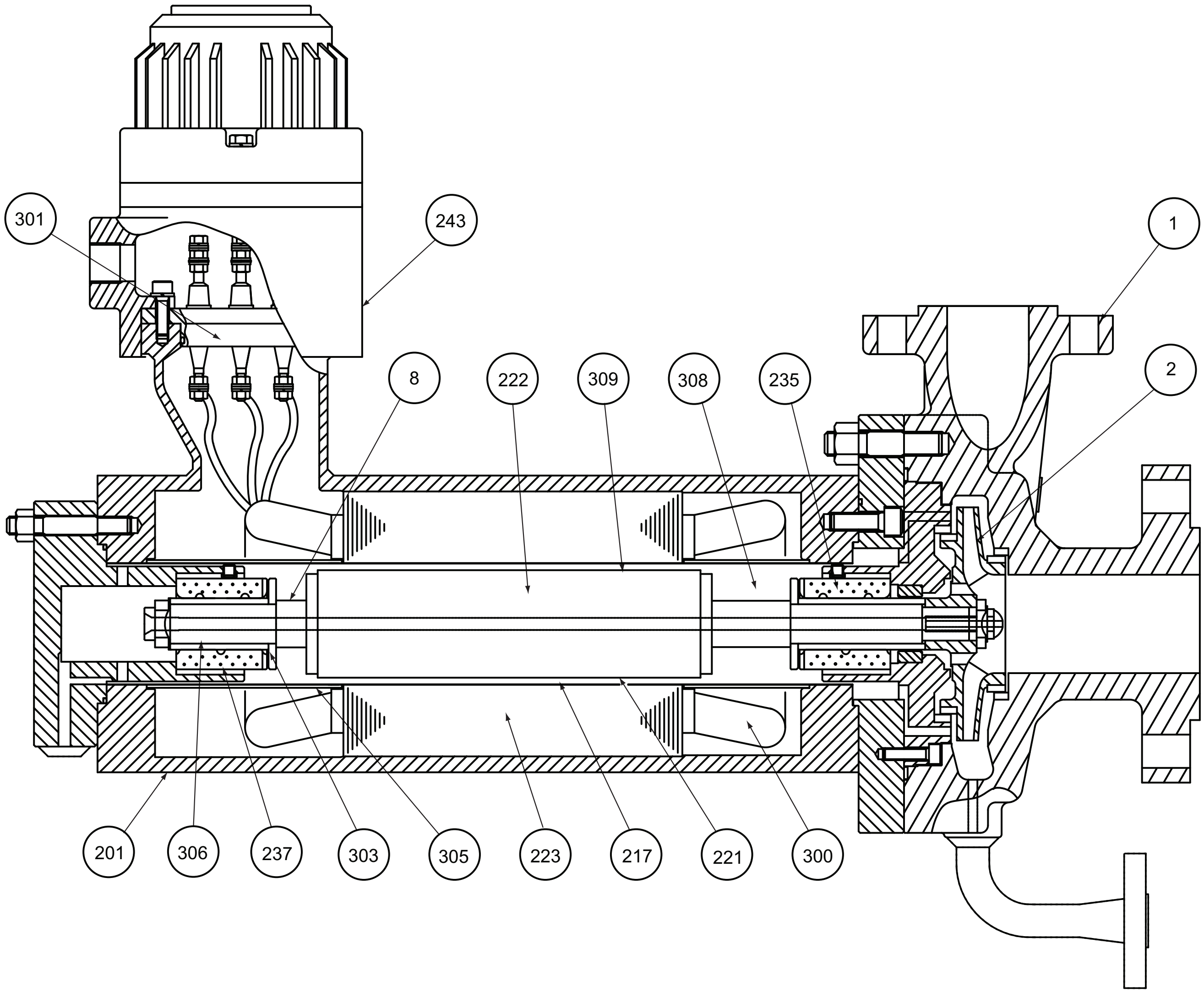
Figure C.4 shows canned motor pump terms defined in Section 3.



Legend

1	Casing	74	Collar, thrust outboard
2	Impeller	230	Magnetic assembly, inner
6	Shaft, pump	231	Shell, containment
12	Shaft, drive	232	Magnet assembly, outer
16	Bearing, inboard	233	Housing, bearing
18	Bearing, outboard	235	Bushing, bearing inboard
19	Frame (magnet coupling housing)	237	Bushing, bearing outboard
72	Collar, thrust inboard	252	Ring, rub
73	Gasket	306	Sleeve, journal

Figure C.1—Magnetic Drive Pump, Separately Coupled



Legend

1	Casing	237	Bushing, bearing outboard
2	Impeller	243	Box, electrical connection
8	Shaft, rotor assembly	300	Switch, thermal
201	Stator housing (secondary containment)	301	Feed through barrier
217	Stator liner	303	Bearing, thrust
221	Rotor liner	305	Sleeve, backup
222	Assembly, rotor	306	Sleeve, journal
223	Assembly, stator	308	Rotor chamber
235	bushing, bearing, inboard	309	Liquid gap

Figure C.2—Canned Motor Pump

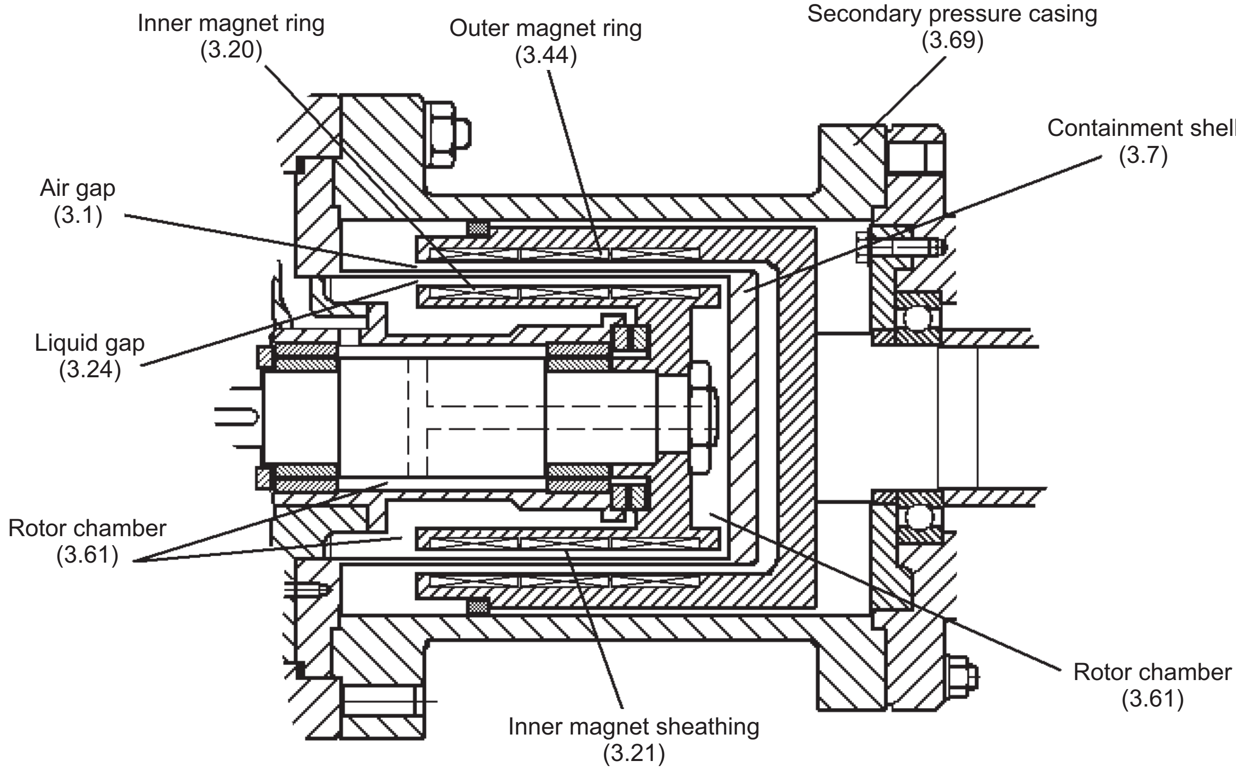


Figure C.3—Magnetic Drive Pump Terms Defined in Section 3

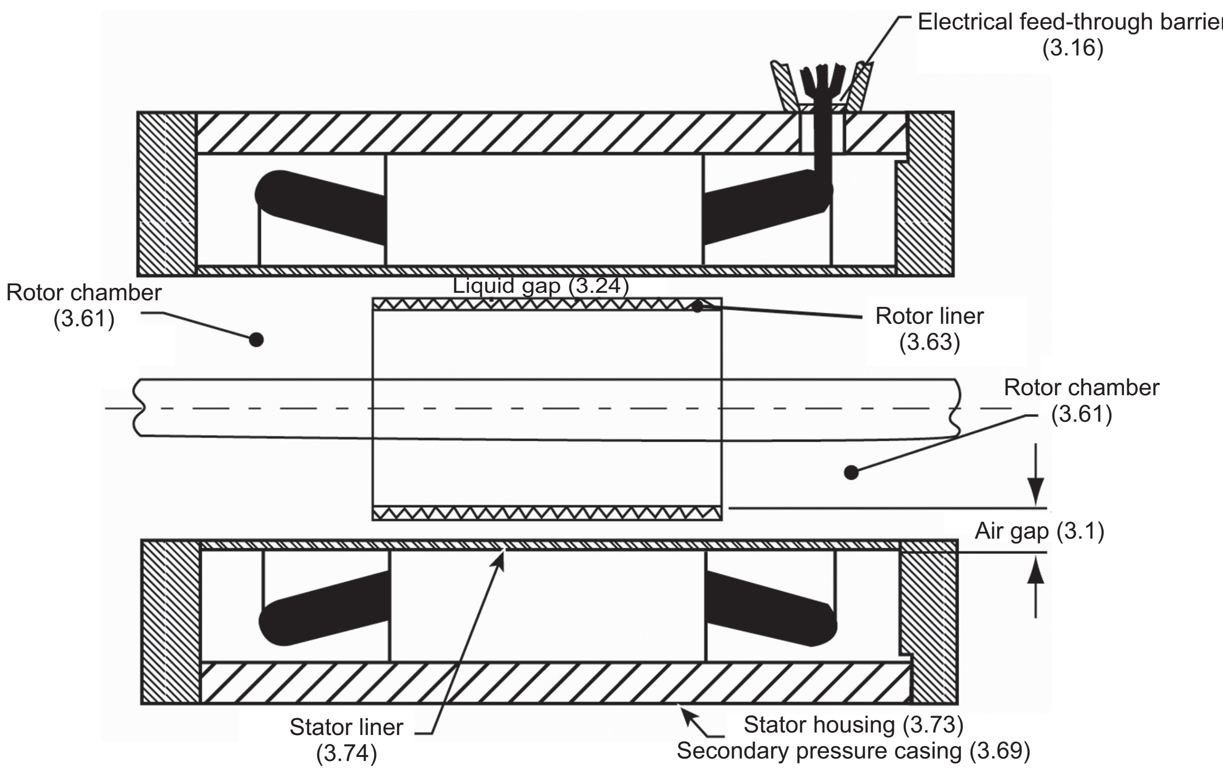


Figure C.4—Canned Motor Pump Terms Defined in Section 3

Annex D
(normative)

Circulation and Cooling Water Piping Schematics

This annex contains schematic diagrams for rotor cavity fluid circulation and cooling water plans. The symbols used in Figure D.2, Figure D.3, and Figure D.4 are shown and identified in Figure D.1. These symbols represent commonly used systems. Other configurations and systems are available and may be used if specified or if agreed upon by the Purchaser and the Vendor.

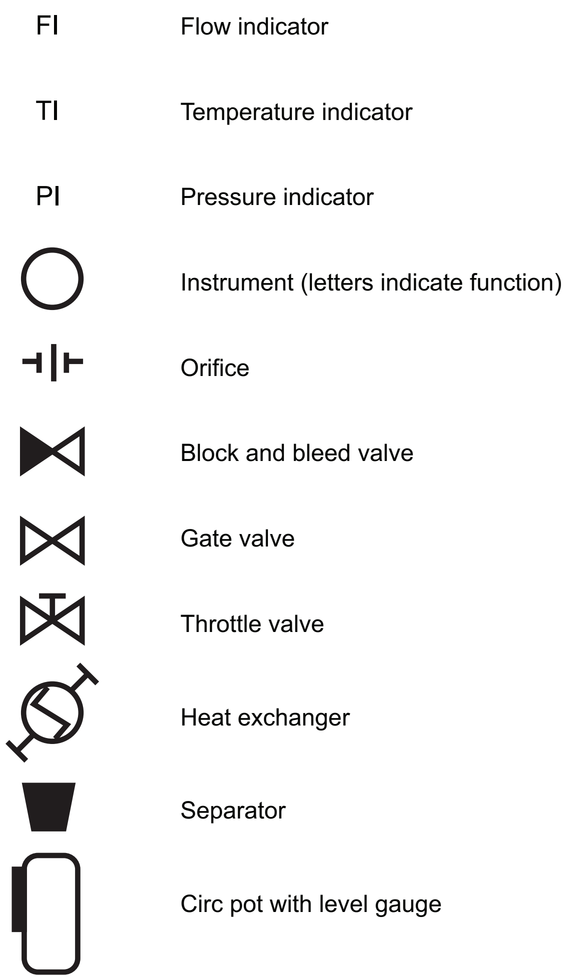
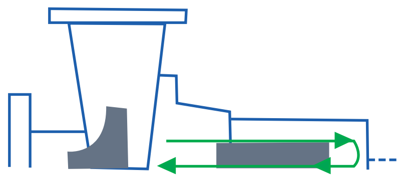
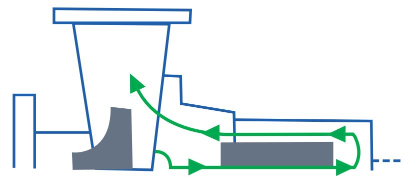


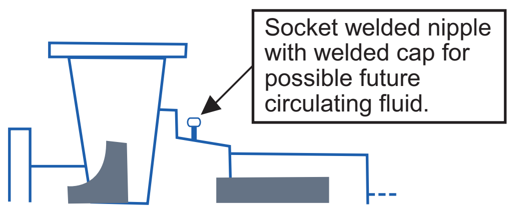
Figure D.1—Annex D Legend



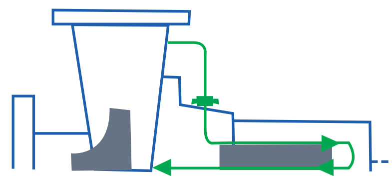
PLAN 1-S	Internal recirculation through drive chamber back to suction.



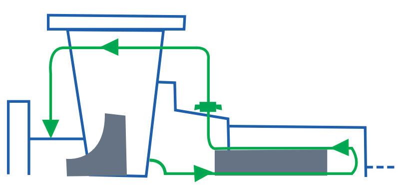
PLAN 1-SD	Internal recirculation from high pressure through the rotor chamber to an auxiliary impeller and back to pump discharge.



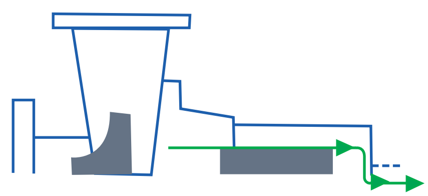
PLAN 2-S	Dead-ended rotor chamber with no circulation of flushed fluid (used for temperature thinning viscous fluids).



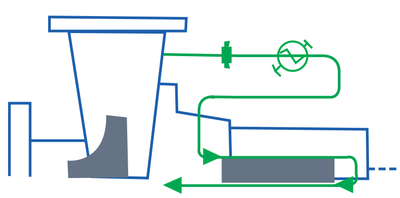
PLAN 11-S	Recirculation from pump discharge through an orifice to the rotor chamber and back to suction.



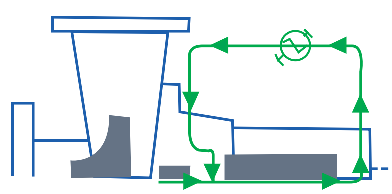
PLAN 13-S	Recirculation from impeller discharge to the rotor chamber, through an orifice and back to pump suction.



PLAN 13-SE	Reverse circulation from impeller discharge through the rotor chamber to an external suction vessel.

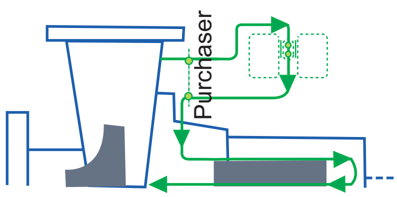


PLAN 21-S	Recirculation from pump discharge through an orifice and cooler to the rotor chamber and back to pump suction.

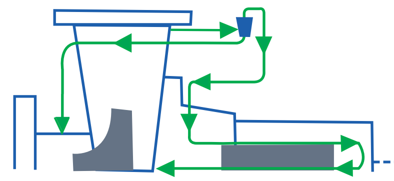


PLAN 23-S	Recirculation from rotor chamber through a cooler back to rotor chamber using an auxiliary pumping device.

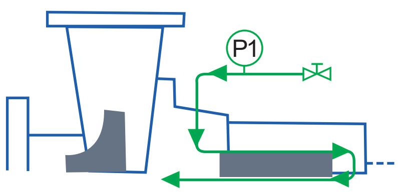
Figure D.2—Clean Circulating Fluid Arrangements



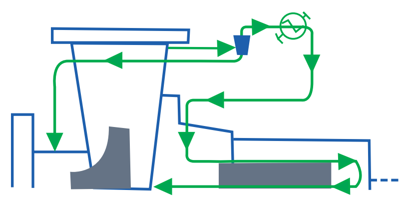
PLAN 12-SE	Circulation from pump discharge through Purchaser's filter system to rotor chamber.



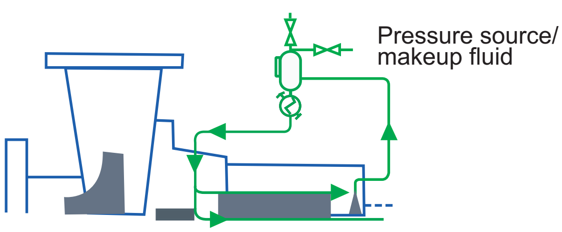
PLAN 31-S	Circulation of discharge liquid through a separator with clean liquid to the rotor chamber and separated solids back to pump suction



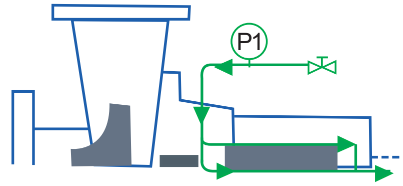
PLAN 32-S	Injection to rotor chamber from external source.



PLAN 41-S	Recirculation from pump discharge of cleaned fluid from a separator through a cooler to the rotor chamber.

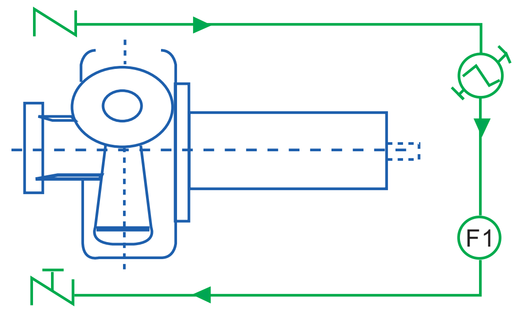


PLAN 53-S	Circulation of externally pressurized fluid from a surge pot through a cooler and the rotor chamber using an auxiliary impeller. Includes minor seepage of circulated fluid into the process stream

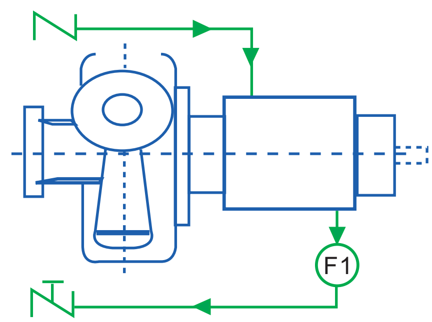


PLAN 54-S	Circulation of external source fluid through the rotor chamber, and back to the fluid source using an external pumping device. Includes minor seepage of circulated fluid into the process stream

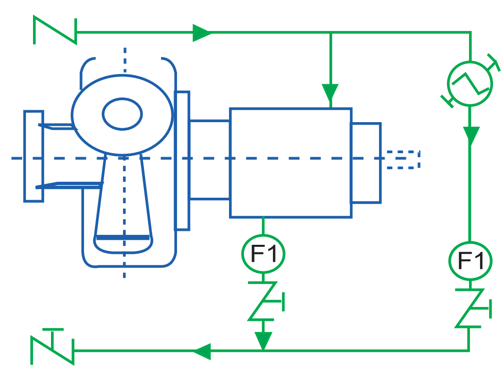
Figure D.3—Dirty or Special Circulating Fluid Arrangements



PLAN MS	Cooling water to rotor chamber circulating fluid heat exchanger.



PLAN BS	Cooling water to rotor housing jacket.



PLAN KS	Cooling water to rotor housing jacket with parallel flow to circulating fluid heat exchanger.

Figure D.4—Cooling Water Piping Arrangements

Annex E
(informative)

Instrumentation and Protective Systems

Table E.1 lists instrumentation and protective features that may be applied to Sealless Centrifugal Pumps.

Figure E.1 shows a typical magnet driven pump with instrumentation and protective features identified.

Figure E.2 shows a typical canned motor pump with instrumentation and protective features identified.

Table E.1—Instrumentation and Protective systems

Tag	Description	Location	Function
DI	Primary Casing Drain	Low point of primary casing	Remove all fluids from primary casing for decommissioning.
D2	Secondary Casing Drain	Low point of secondary containment casing	Remove all fluids from secondary casing for decommissioning.
D3	Secondary Control drain	Low point of area just outside of secondary control barrier	Controlled leakage path for liquids from the secondary control casing.
JE	Power Sensor	Motor Wiring	Indication or alarm/shutdown on high or low power due to dry running, excess load, or single phasing.
LE1	Level Sensor	Pump suction or discharge piping	Permissive/shutdown on absence of liquid level to avoid dry-run.
LE2	Liquid Sensor	Low point of secondary containment area	Shutdown on detection of liquid indicating a failure of the primary containment.
PE	Pressure Sensor	Secondary pressure casing	Shutdown on rising pressure due to containment shell leakage.
TEI	Thermal cutout device	Motor stator windings	Alarm shutdown on excessive temperature in windings due to loss of circulating fluid or over load.
TE2	Temperature sensor with thermowell	Circulation flow path	Indication or alarm/shutdown on increasing temperature due to loss of circulation or magnetic drive decoupling.
TE3	Temperature sensor directly applied	On containment shell/can	Indication or alarm/shutdown on increasing temperature due to loss of circulation or magnetic drive decoupling.
V1	Primary Casing Vent	High point of primary casing	Venting of vapors from primary casing.
V2	Secondary Casing Vent	High point of secondary casing	Venting of vapors from secondary casing.
VE	Vibration sensor	On pump (near) bearing housing	Indication or alarm/shutdown on excessive vibration.
ZE	Shaft position sensor	On pump housing or embedded in stator	Indication or alarm/shutdown on excessive change in shaft position. May be either radial or axial and indicates the wear on the product lubricated bearings.

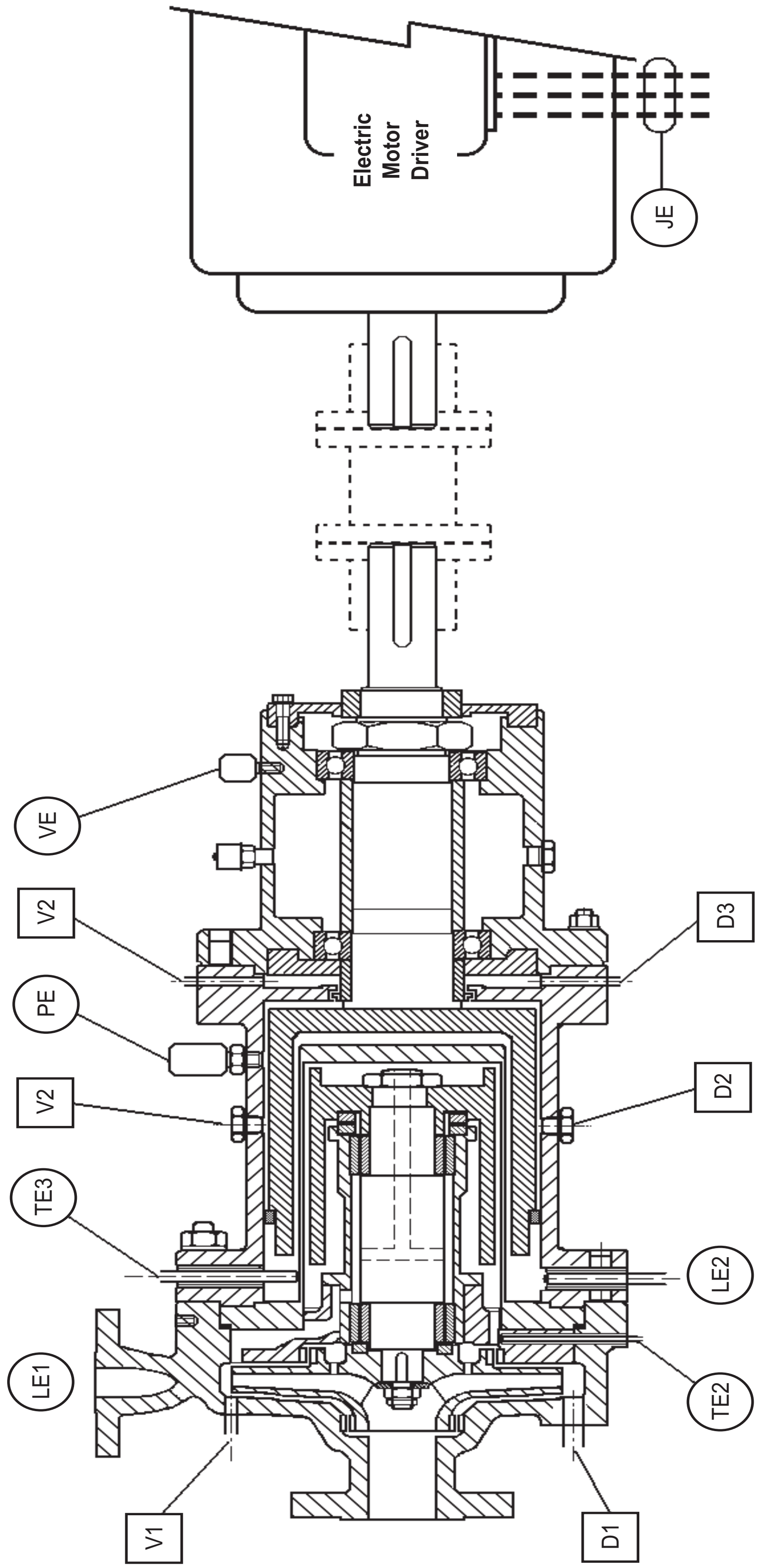


Figure E.1—Magnetic Driven Pump

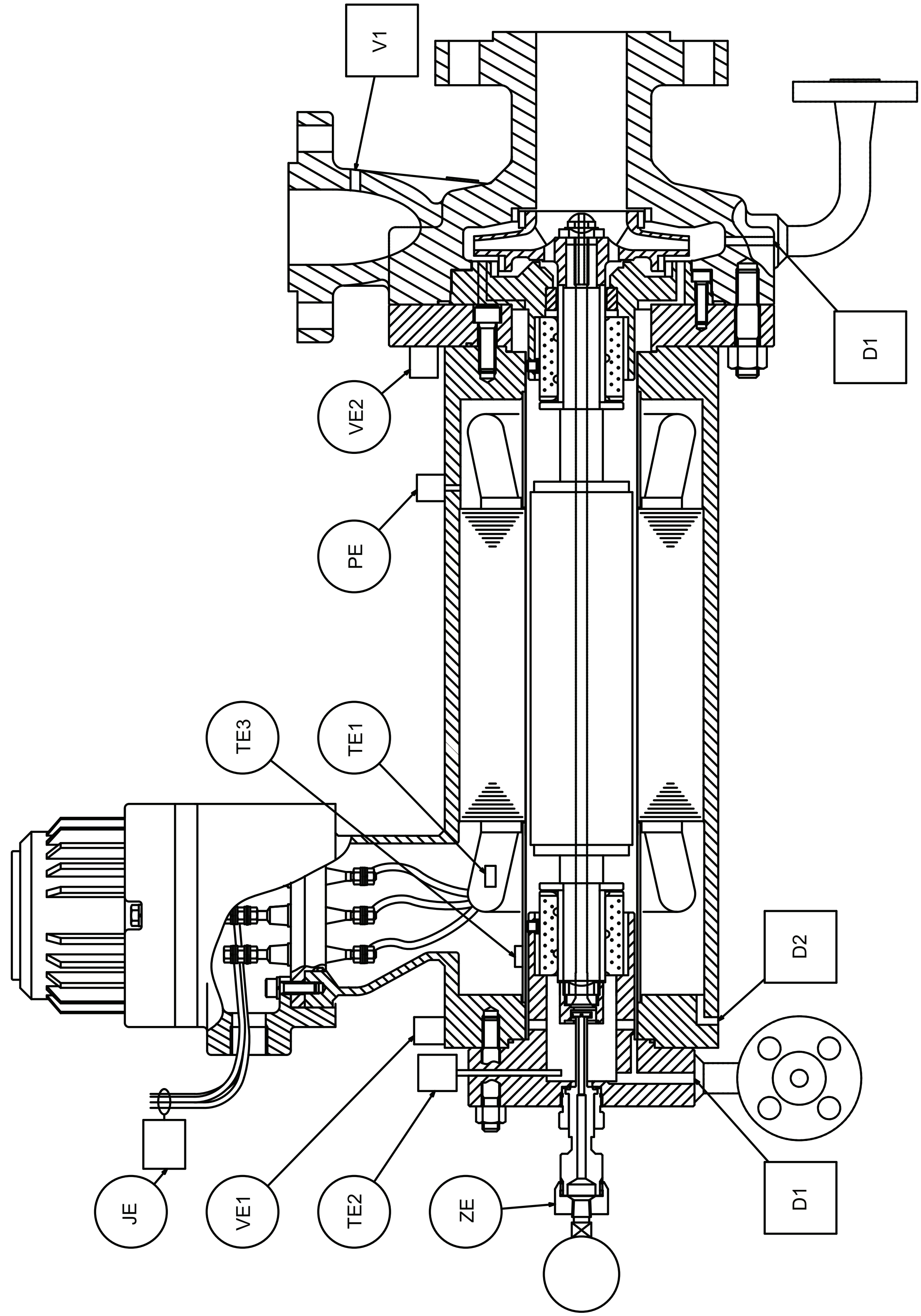


Figure E.2—Canned Motor Pump

Annex F
(normative)

Criteria for Piping Design

F.1 Horizontal pumps

F.1.1 Acceptable piping configurations should not cause excessive misalignment between the pump and driver. Piping configurations that produce component nozzle loads lying within the ranges specified in Table F.3 limit casing distortion to one-half the pump Vendor's design criterion (see 6.2.1) and ensure pump shaft displacement of less than 250 µm (0.010 in).

F.1.2 Piping configurations that produce loads outside the ranges specified in Table F.3 are also acceptable without consultation with the pump Vendor if the conditions specified in F.1.2a) through F.1.2c) are satisfied. Satisfying these conditions ensures that any pump casing distortion will be within the Vendor's design criteria (see 6.2.1) and that the displacement of the pump shaft will be less than 380 µm (0.015 in.).

a) The individual component forces and moments acting on each pump nozzle flange shall not exceed the range specified in Table F.3 (T3) by a factor of more than 2.

b) The resultant applied force (F_{RSA}, F_{RDA}) and the resultant applied moment (M_{RSA}, M_{RDA}) acting on each pump nozzle flange shall satisfy the appropriate interaction equations below.

$$[F_{RSA} / (1.5 \times F_{RST3})] + [M_{RSA} / (1.5 \times M_{RST3})] \text{ u } 2 \qquad \text{(F.1)}$$

$$[F_{RDA} / (1.5 \times F_{RDT3})] + [M_{RDA} / (1.5 \times M_{RDT3})] \text{ u } 2 \qquad \text{(F.2)}$$

c) The applied component forces and moments acting on each pump nozzle flange shall be translated to the center of the pump. The magnitude of the resultant applied force (F_{RCA}), the resultant applied moment (M_{RCA}), and the applied moment shall be limited by Equation (F.3), Equation (F.4) and Equation (F.5) (the sign convention shown in Figure 3 and Figure 4 and the right-hand rule should be used in evaluating these equations).

$$F_{RCA} < 1.5\ (F_{RST3} + F_{RDT3}) \qquad \text{(F.3)}$$

$$|\ M_{YCA}\ | < 2.0\ (M_{YST3} + M_{YDT3}) \qquad \text{(F.4)}$$

$$M_{RCA} < 1.5\ (M_{RST3} + M_{RDT3}) \qquad \text{(F.5)}$$

where

$$F_{RCA} = [(F_{XCA})^2 + (F_{YCA})^2 + (F_{ZCA})2]^{0.5}$$

where

$$F_{XCA} = F_{XSA} + F_{XDA}$$

$$F_{YCA} = F_{YSA} + F_{YDA}$$

$$F_{ZCA} = F_{ZSA} + F_{ZDA}$$

$$M_{RCA} = [(M_{XCA})^2 + (M_{YCA})^2 + (M_{ZCA})^2]^{0.5}$$

where

$$M_{XCA} = M_{XSA} + M_{XDA} - [(F_{YSA})(zS) + (F_{YDA})(zD) - (F_{ZSA})(yS) - (F_{ZDA})(yD)]/1000$$

$$M_{YCA} = M_{YSA} + M_{YDA} + [(F_{XSA})(zS) + (F_{XDA})(zD) - (F_{ZSA})(xS) - (F_{ZDA})(xD)]/1000$$

$$M_{ZCA} = M_{ZSA} + M_{ZDA} - [(F_{XSA})(yS) + (F_{XDA})(yD) - (F_{YSA})(xS) - (F_{YDA})(xD)]/1000$$

In USC units, the constant 1000 shall be changed to 12. This constant is the conversion factor to change millimeters to meters or inches to feet.

F.1.3 Piping configurations that produce loads greater than those allowed in F.1.2 shall be approved by the Purchaser and the Vendor.

NOTE In order to evaluate the actual machine distortion (at ambient conditions), the piping alignment checks required in API 686 (Chapter 7) should be performed. API 686 allows only a small fraction of the permitted distortion resulting from use of the values from this annex.

F.2 Vertical In-line Pumps

Vertical in-line pumps that are supported only by the attached piping may be subjected to component piping loads that are more than double the values shown in Table F.3 if these loads do not cause a principal stress greater than 41 N/mm^2 (5950 psi) in either nozzle. For calculation purposes, the section properties of the pump nozzles shall be based on Schedule 40 pipe whose nominal size is equal to that of the appropriate pump nozzle. Equation (F.6), Equation (F.7), and Equation (F.8) can be used to evaluate principal stress, longitudinal stress, and shear stress, respectively, in the nozzles.

For SI units, the following equations apply:

$$\sigma_p = (\sigma/2) + (\sigma^2/4 + \tau^2)^{0.5} < 41 \tag{F.6}$$

$$\sigma_l = [1.27 \times F_Y / (D_o^2 - D_i^2)] + [10{,}200 \times D_o (M_X^2 + M_Z^2)^{0.5}] / (D_o^4 - D_i^4) \tag{F.7}$$

$$\tau = [1.27 \times (F_X^2 + F_Z^2)^{0.5}] / (D_o^2 - D_i^2) + [5100 \times D_o (|M_Y|)] / (D_o^4 - D_i^4) \tag{F.8}$$

For USC units, the following equations apply:

$$\sigma_p = (\sigma/2) + (\sigma^2/4 + \tau^2)^{0.5} < 5950 \tag{F.9}$$

$$\sigma_l = [1.27 \times F_Y / (D_o^2 - D_i^2)] + [122 \times D_o (M_X^2 + M_Z^2)^{0.5}] / (D_o^4 - D_i^4) \tag{F.10}$$

$$\tau = [1.27 \times (F_X^2 + F_Z^2)^{0.5}] / (D_o^2 - D_i^2) + [61 \times D_o (|M_Y|)] / (D_o^4 - D_i^4) \tag{F.11}$$

where

σ_p is the principal stress, expressed in MPa (lbf/in.^{2});

σ_l is the longitudinal stress, expressed in MPa (lbf/in.^{2});

τ is the shear stress, expressed in MPa (lbf/in.^{2});

F_X is the applied force on the X axis;

F_Y is the applied force on the Y axis;

F_Z is the applied force on the Z axis;

M_X is the applied moment on the X axis;

M_Y is the applied moment on the Y axis;

M_Z is the applied moment on the Z axis;

D_i is the inner diameter of the nozzles, expressed in millimeters (inches);

D_o is the outer diameter of the nozzles, expressed in millimeters (inches).

F_X, F_Y, F_Z, M_X, M_Y, and M_Z represent the applied loads acting on the suction or discharge nozzles. The sign of F_Y is positive if the load puts the nozzle in tension; the sign is negative if the load puts the nozzle in compression. One should refer to Figure 3 and the applied nozzle loads to determine whether the nozzle is in tension or compression. The absolute value of M_Y should be used in Equations (F.8) to (F.11).

F.3 Nomenclature

The following definitions apply to the sample problems in F.4

where

C is the center of the pump. For overhung pump types with two support pedestals, the center is defined by the intersection of the pump shaft centerline and a vertical plane passing through the center of the two pedestals (see Figure 3 and Figure 4);

D is the discharge nozzle;

D_i is the inside diameter of Schedule 40 pipe whose nominal size is equal to that of the pump nozzle in question, expressed in millimeters (inches);

D_o is the outside diameter of Schedule 40 pipe whose nominal size is equal to that of the pump nozzle in question, expressed in millimeters (inches);

F is the force, expressed in newtons (pounds force);

F_R is the resultant force. (F_{RSA} and F_{RDA} are calculated by the square root of the sum of the squares method using the applied component forces acting on the nozzle flange. F_{RST3} and F_{RDT3} are extracted from Table F.3, using the appropriate nozzle size);

M is the moment, expressed in newton meters (foot-pounds force);

M_R is the resultant moment. (M_{RSA} and M_{RDA} are calculated by the square root of the squares method using the applied component moments acting on the nozzle flange. M_{RST3} and M_{RDT3} are extracted from Table F.3 using the appropriate nozzle size);

σ_p is the principal stress, expressed in megapascals (pounds force per square inch);

σ_l is the longitudinal stress, expressed in newtons per square millimeter (pounds per square inch);

τ is the shear stress, expressed in newtons per square millimeter (pounds per square inch);

S is the suction nozzle;

x, y, z are the location coordinates of the nozzle flanges with respect to the center of the pump, expressed in millimeters (inches);

X, Y, Z are the directions of the load (see Figure 3 and Figure 4);

Subscript A is an applied load;

Subscript $T3$ is a load extracted from Table F.3.

F.4 Sample Problems [14]

F.4.1 Example 1A (SI units)

Problem

For an overhung-end suction process pump (OH2), the nozzle sizes and location coordinates are as given in Table F.1. The applied nozzle loadings are as given in Table F.2. The problem is to determine whether the conditions specified in F.1.2a), F.1.2b), and F.1.2c) are satisfied.

Solution

F.4.1.1 A check of condition F.1.2 a) is as follows.

For the DN 250 end suction nozzle,

$$|F_{XSA} / F_{XST3}| = |+ 12{,}900 / 6670| = 1.93 < 2.00$$

$$|F_{YSA} / F_{YST3}| = |0 / 5340| = 0 < 2.00$$

$$|F_{ZSA} / F_{ZST3}| = |- 8852 / 4450| = 1.99 < 2.00$$

$$|M_{XSA} / M_{XST3}| = |- 1356 / 5020| = 0.27 < 2.00$$

$$|M_{YSA} / M_{YST3}| = |- 5017 / 2440| = 2.06 > 2.00$$

$$|M_{ZSA} / M_{ZST3}| = |- 7458 / 3800| = 1.96 < 2.00$$

Since M_{YSA} exceeds the value specified in Table F.3 (SI units) by more than a factor of 2, it is not satisfactory. Assume that M_{YSA} can be reduced to – 4879. Then,

$$|M_{YSA} / M_{YST3}| = |- 4879 / 2440| = 1{,}999 > 2.00$$

For the DN 200 top discharge nozzle,

$$|F_{XDA} / F_{XDT3}| = |+ 7117 / 3780| = 1.88 < 2.00$$

$$|F_{YDA} / F_{YDT3}| = |- 445 / 3110| = 0.14 < 2.00$$

$$|F_{ZDA} / F_{ZDT3}| = |+ 8674 / 4890| = 1.77 < 2.00$$

$$|M_{XDA} / M_{XDT3}| = |+ 678 / 3530| = 0.19 < 2.00$$

[14] "These Sample Problems are merely examples for illustration purposes only. Each company should develop its own approach. They are not to be considered exclusive or exhaustive in nature. API makes no warranties, express or implied for reliance on or any omissions from the information contained in this document.

$|M_{YDA} / M_{YDT3}| = |-3390 / 1760| = 1.93 > 2.00$

$|M_{ZDA} / M_{ZDT3}| = |-4882 / 2580| = 1.89 < 2.00$

Provided that M_{YSA} can be reduced to – 4879, the applied piping loads acting on each nozzle satisfy the condition specified in F.1.2 a).

Table F.1—Nozzle Sizes and Location Coordinates for Example 1A

Nozzle	Size DN	*x* mm	*y* mm	*z* mm
Suction	250	+ 267	0	0
Discharge	200	0	– 311	+ 381

Table F.2—Applied Nozzle Loadings for Example 1A

Force	Value N	Moment	Value N·m
		Suction	
F_{XSA}	+ 12,900	M_{XSA}	– 1356
F_{YSA}	0	M_{YSA}	– 5017[a]
F_{ZSA}	– 8852	M_{ZSA}	– 7458
		Discharge	
F_{XDA}	+ 7117	M_{XDA}	+ 678
F_{YDA}	– 445	M_{YDA}	– 3390
F_{ZDA}	8674	M_{ZDA}	– 4882

[a]See F.4.1.2.1.

F.4.1.2 A check of condition F.1.2b) is as follows:

For the suction nozzle, F_{RSA} and M_{RSA} are determined using the square root of the sum of the squares method:

$$F_{RSA} = [(F_{XSA})^2 + (F_{YSA})^2 + (F_{ZSA})^2]^{0.5} = [(+12{,}900)^2 + (0)^2 + (-8852)^2]^{0.5} = 15{,}645$$

$$M_{RSA} = [(M_{XSA})^2 + (M_{YSA})^2 + (M_{ZSA})^2]^{0.5} = [(-1356)^2 + (-4879)^2 + (-7458)^2]^{0.5} = 9015$$

Referring to Equation (F.1):

$$F_{RSA} /(1.5 \times F_{RST3}) + M_{RSA} /(1.5 \times M_{RST3}) \quad \leq 2$$

$$15{,}645 /(1.5 \times 9630) + 9015 /(1.5 \times 6750) \quad \leq 2$$

$$1.96 \quad < 2$$

For the discharge nozzle, F_{RDA} and M_{RDA} are determined by the same method used to find F_{RSA} and M_{RSA}:

$$F_{RDA} = [(F_{XDA})^2 + (F_{YDA})^2 + (F_{ZDA})^2]^{0.5} = [(+7117)^2 + (-445)^2 + (-8674)^2]^{0.5} = 11{,}229$$

$$M_{RDA} = [(M_{XDA})^2 + (M_{YDA})^2 + (M_{ZDA})^2]^{0.5} = [(-678)^2 + (-3390)^2 + (-4882)^2]^{0.5} = 5982$$

Referring to Equation (F.2):

$$F_{RDA} /(1.5 \times F_{RDT3}) + M_{RDA} /(1.5 \times M_{RDT3}) \leq 2$$

$$11{,}229 /(1.5 \times 6920) + 5982 /(1.5 \times 4710) \leq 2$$

$$1.93 < 2$$

The loads acting on each nozzle satisfy the appropriate interaction equation, so the condition specified in F.1.2b) is satisfied.

F.4.1.3 A check of condition F.1.2c) is as follows:

To check this condition, the applied component forces and moments are translated and resolved to the center of the pump. F_{RCA} is determined as follows [see F.1.2c)]:

$$F_{XCA} = F_{XSA} + F_{XDA}$$

$$F_{YCA} = F_{YSA} + F_{YDA}$$

$$F_{ZCA} = F_{ZSA} + F_{ZDA}$$

$$F_{RCA} = [(F_{XCA})^2 + (F_{YCA})^2 + (F_{XCA})^2]^{0.5}$$

$$F_{XCA} = (+12{,}900) + (+7117) = +20{,}017$$

$$F_{YCA} = (0) + (-445) = -445$$

$$F_{ZCA} = (-8852) + (+8674) = -178$$

$$F_{RCA} = [(+20{,}017)^2 + (-445)^2 + (-178)2]^{0.5} = 20{,}023$$

Referring to Equation (F.3):

$$F_{RCA} < 1.5 \times (F_{RST3} + F_{RDT3})$$

$$20{,}023 < 1.5 \times (9630 + 6920)$$

$$20{,}023 < 24{,}825$$

M_{YCA} is determined as follows [see F.1.2c)]:

$$M_{YCA} = M_{YSA} + M_{YDA} + [(F_{XSA})\,(\mathrm{zS}) + (F_{XDA})\,(zD) - (F_{ZSA})(xS) - (F_{ZDA})\,(xD)] / 1000$$

$$= (-4879) + (-3390) + [(+12{,}900)\,(0.00) + (+7117)\,(+381) - (-8852)(+267) - (8674)(0.00)] / 1000$$

$$= -3194$$

Referring to Equation (F.4):

$$| M_{YCA} | < 2.0\ (M_{YST3} + M_{YDT3})$$

$$| -3194 | < 2.0\ (2440 + 1760)$$

$$3194 < 8400$$

*M*RCA is determined as follows [see F.1.2c)]:

$$M_{XCA} = M_{XSA} + M_{XDA} - [(F_{YSA})\ (zS) + (F_{YDA})\ (\mathrm{zD}) - (F_{ZSA})\ (yS) - (F_{ZDA})\ (yD)]\ /\ 1000$$

$$M_{YCA} = M_{YSA} + M_{YDA} + [(F_{XSA})\ (zS) + (F_{XDA})\ (\mathrm{zD}) - (F_{ZSA})(xS) - (F_{ZDA})\ (xD)]\ /\ 1000$$

$$M_{ZCA} = M_{ZSA} + M_{ZDA} - [(F_{XSA})\ (yS) + (F_{XDA})\ (\mathrm{yD}) - (F_{YSA})\ (xS) - (F_{YDA})\ (xD)]\ /\ 1000$$

$$M_{RCA} = [(M_{XCA})^2 + (M_{YCA})^2 + (M_{ZCA})^2]^{0.5}$$

$$M_{XCA} = (-1356) + (+678) - [(0)\ (0.00) + (-445)(+381) - (-8852)\ (0.00) - (+8674)(-311)]\ /\ 1000$$

$$= -3206$$

$$M_{YCA} = -3194 \text{ (see previous calculation)}$$

$$M_{ZCA} = (-7458) + (-4882) - [(+12{,}900)(0.00) + (+7117)\ (-311) - (0)(+267) - (-445)(0.00)]\ /\ 1000$$

$$= -10{,}127$$

$$M_{RCA} = [(-3206)^2 + (-3194)^2 + (-10{,}127)^2]^{0.5} = 11{,}092$$

Referring to Equation (F.5):

$$M_{RCA} < 1.5 \times (M_{RST3} + M_{RDT3})$$

$$11{,}092 < 1.5 \times (6750 + 4710)$$

$$11{,}092 < 17{,}190$$

Thus, all the requirements of F.1.2c) have been satisfied.

F.4.2 Example 2A (SI units)

Problem

For a DN 80 × DN 100 × 178 mm vertical in-line pump (OH3 through OH6), the proposed applied nozzle loadings are as given in Table F.3. By inspection, F_{ZSA}, M_{ZSA}, and M_{XDA} are greater than two times the values shown in Table F.3 (SI units). As stated in F.2, these component loads are acceptable provided that the calculated principal stress is less than 41 MPa. The problem is to determine the principal stress for the suction nozzle and the discharge nozzle.

Solution

F.4.2.1 Suction nozzle calculations are as follows:

Table F.3—Proposed Applied Nozzle Loadings for Example 2A

Force	Value N	Moment	Value N·m
		DN 100 suction	
F_{XSA}	– 2224	M_{XSA}	+ 136
F_{YSA}	– 5338	M_{YSA}	– 2034
F_{ZSA}	+ 1334	M_{ZSA}	+ 1356
		DN 80 discharge	
F_{XDA}	+ 1334	M_{XDA}	+ 2712
F_{YDA}	– 2224	M_{YDA}	+ 271
F_{ZDA}	+ 445	M_{ZDA}	+ 136

For Schedule 40 pipe with a nominal size of DN 100, D_o = 114 mm and D_i = 102 mm. Therefore,

$$D_o^2 - D_i^2 = (114)^2 - (102)^2 = 2592$$

$$D_o^4 - D_i^4 = (114)^4 - (102)^4 = 6.065 \times 107$$

$$[(F_{XSA})^2 + (F_{ZSA})^2]^{0.5} = [(-2224)^2 + (+1334)^2]^{0.5} = 2593$$

$$[(M_{XSA})^2 + (M_{ZSA})^2]^{0.5} = [(+136)^2 + (+1356)^2]^{0.5} = 1363$$

Equation (F.7) is used to determine the longitudinal stress for the suction nozzle, σ_s.

The applied F_{YSA} load acting on the suction nozzle is in the negative Y direction and produces a compressive stress; therefore, the negative sign on F_{YSA} is used.

$$\sigma_s = [1.27 \times F_{YSA} / (D_o^2 - D_i^2)]\ \ [10{,}200 \times D_o\ (M_{XSA}^2\ M_{ZSA}^2)^{0.5} / (D_o^4 - D_i^4)]$$

$$= [1.27 \times (-5338) / 2592] + [10{,}200 \times 114 \times 1363 / (6.065 \times 107)] = 23.52$$

Equation (F.8) is used to determine the shear stress for the suction nozzle, $_s$.

$$\tau_s = [1.27(F_{XSA})^2 + (F_{ZSA})^2]^{0.5} / (D_o^2 - D_i^2)] + [0.51 \times 10^4\ D_o\ (\ |M_{YSA}^2|\ )] / (D_o^4 - D_i^2)$$

$$= (1.27 \times 2593 / 2592) + [5100 \times 114 \times (\ |-2034|\ )] / (6.065 \times 107)] = 20.77$$

The principal stress for the suction nozzle, $\sigma_{p,s}$, is calculated using Equation (F.6):

$$\sigma_{p,s} = (\sigma_s /2) + (\sigma_s^2 / 4 + \tau_s^2\ )^{0.5} < 41$$

$$= (+23.52 /2) + [(+23.52)^2 / 4 + (+20.77)^2]^{0.5} < 41$$

$$= +35.63 < 41$$

Thus, the suction nozzle loads are satisfactory.

F.4.2.2 Discharge nozzle calculations are as follows:

For Schedule 40 pipe with a nominal size of 80 mm, D_o = 89 mm and D_i = 78 mm. Therefore,

$$D_o^2 - D_i^2 = (89)^2 - (78)^2 = 1837$$

$$D_o^4 - D_i^4 = (89)^4 - (78)^4 = 2.573 \times 10^7$$

$$[(F_{\mathrm{XDA}})^2 + (F_{\mathrm{ZDA}})^2]^{0.5} = [(+1334)^2 + (+\,445)^2]^{0.5} = 1406$$

$$[(M_{\mathrm{XDA}})^2 + (M_{\mathrm{ZDA}})^2]^{0.5} = [(+2712)^2 + (+\,136)^2]^{0.5} = 2715$$

Equation (F.7) is used to determine the longitudinal stress for the discharge nozzle, σ_D.

The applied F_{YDA} load acting on the discharge nozzle is in the negative Y direction and produces a tensile stress; therefore, a positive sign on F_{YDA} is used.

$$\sigma_D = [1.27\ F_{\mathrm{YDA}} / (D_o^2 - D_i^2)]\ \ [10{,}200\ D_o\ (M_{\mathrm{XDA}}^2 + M_{\mathrm{ZDA}}^2)^{0.5}] / (D_o^4 - D_i^4)$$

$$= [1.27(+\,2224) / 1837] + [10{,}200\ (89)\ (2715)] / 2.573 \times 107 = 97.33$$

Equation (F.8) is used to determine the shear stress for the discharge nozzle, D.

$$\tau_D = [1.27(F_{\mathrm{XDA}})^2 + (F_{\mathrm{ZDA}})^2]^{0.5} / (D_o^2 - D_i^2)] + [5100\ D_o\ (\ |M_{\mathrm{YDA}}|\ )] / (D_o^4 - D_i^4)$$

$$= [1.27 \times 1406 / 1837] + [5100 \times 89 \times (+\,271\ |\ ) / (2.573 \times 10^7)] = 5.75$$

The principal stress for the discharge nozzle, $\sigma_{p,D}$, is calculated using Equation (F.6):

$$\sigma_{p,D} = (\sigma_D/2) + (\sigma_D^2/4 + \tau_D^2)^{0.5} < 41$$

$$= (+\,97.33/2) + [(+\,97.33)^2/ 4 + (+\,5.75)^2]^{0.5}$$

$$= +\,97.67 > 41$$

Thus, the discharge nozzle loads are too large. By inspection, if M_{XDA} is reduced by 50 % to 1356 N·m, the resulting principal stress will still exceed 41 MPa. Therefore, the maximum value for M_{XDA} is twice M_{XDT3}, or 1900 N·m.

F.4.3 Example 1B (US Customary units)

Problem

For an overhung end-suction process pump (OH2), the nozzle sizes and location coordinates are as given in Table F.4. The applied nozzle loadings are as given in Table F.5. The problem is to determine whether the conditions specified in F.1.2a), F.1.2b), and F.1.2c) are satisfied.

Table F.4—Nozzle Sizes and Location Coordinates for Example 1B

Dimensions in inches

Nozzle	Size	*x*	*y*	*z*
Suction	10	+ 10.50	0	0
Discharge	8	0	– 12.25	+ 15

Table F.5—Nozzle Sizes and Location Coordinates for Example 1B

Force	Value lbf	Moment	Value ft·lbf
		Suction	
F_{XSA}	+ 2900	M_{XSA}	– 1000
F_{YSA}	0	M_{YSA}	– 3700[a]
F_{ZSA}	– 1990	M_{ZSA}	– 5500
		Discharge	
F_{XDA}	+ 1600	M_{XDA}	+ 500
F_{YDA}	– 100	M_{YDA}	– 2500
F_{ZDA}	+ 1950	M_{ZDA}	– 3600

[a]See F.4.1.2.1.

Solution

F.4.3.1 A check of condition of F.1.2a) is as follows:

For the 10-in. end suction nozzle,

$$|F_{XSA}/F_{XST3}| = |+ 2900/1500| = 1.93 < 2.00$$

$$|F_{YSA}/F_{YST3} = |0/1200| = 0 < 2.00$$

$$|F_{ZSA}/F_{ZST3} = |– 1990/1000| = 1.99 < 2.00$$

$$|M_{XSA}/M_{XST3}| = – 1000/3700| = 0.27 < 2.00$$

$$|M_{YSA}/M_{YST3}| = – 3700/1800| = 2.06 > 2.00$$

$$|M_{ZSA}/M_{ZST3}| = |– 5500/2800| = 1.96 < 2.00$$

Since M_{YSA} exceeds the value specified in Table F.3 (US Customary units) by more than a factor of 2, it is not satisfactory. Assume that M_{YSA} can be reduced to –3599. Then,

$$|M_{YSA}/M_{YST3}| = |– 3599/1800| = 1.999 < 2.00$$

For the 8-in. top discharge nozzle,

$$|F_{XDA}/F_{XDT}| = |+ 1600/850| = 1.88 < 2.00$$

$$|F_{YDA}/F_{YDT}| = |– 100/700| = 0.14 < 2.00$$

$$|F_{ZDA}/F_{ZDT3}| = |+ 1950/1100| = 1.77 < 2.00$$

$$|M_{XDA}/M_{XDT3}| = |+ 500/2600| = 0.19 < 2.00$$

$$|M_{YDA}/M_{YDT3}| = |– 2500/1300| = 1.93 < 2.00$$

$$|M_{ZDA}/M_{ZDT3}| = |– 3600/1900| = 1.89 < 2.00$$

Provided that M_{YSA} can be reduced to – 3599, the applied piping loads acting on each nozzle satisfy the condition specified in F.1.2a).

F.4.3.2 A check of condition F.1.2b) is as follows:

For the suction nozzle, F_{RSA} and M_{RSA} are determined using the square root of the sum of the squares method:

$$F_{RSA} = [(F_{XSA})^2 + (F_{YSA})^2 + (F_{ZSA})^{20.5} = [(+ 2900)^2 + (0)^2 + (- 1990)^2]^{0.5} = 3517$$

$$M_{RSA} = [(M_{XSA})^2 (M_{YSA})^2 + (M_{ZSA})^2]^{0.5} = [(- 1000)^2 + (-3599)^2 + (-5500)^2]^{0.5} = 6649$$

Referring to Equation (F.1),

$$F_{RSA}/(1.5 \times F_{RST3}) + M_{RSA}/(1.5 \times M_{RST3}) \text{ u } 2$$

$$3517/(1.5 \times 2200) + 6649/(1.5 \times 5000) \text{ u } 2$$

$$1.95 < 2$$

For the discharge nozzle, F_{RDA} and M_{RDA} are determined by the same method used to find F_{RSA} and M_{RSA}:

$$F_{RDA} = [(F_{XDA})^2 + (F_{YDA})^2 + (F_{ZDA})^2]^{0.5} = [(+ 1600)2 + (- 100)^2 + (+ 1950)^2]^{0.5} = 2524$$

$$M_{RDA} = [M_{XDA})^2 (M_{YDA})^2 + (M_{ZDA})^2]^{0.5} = [(+ 500)2 + (- 2500)^2 + (- 3600)^2]^{0.5} = 4411$$

Referring to Equation (F.2),

$$F_{RDA}/(1.5 \times F_{RDT3}) + M_{RDA}/ (1.5 \times M_{RDT3}) \text{ u } 2$$

$$2524/(1.5 \times 1560) + 4411 / (1.5 \times 3500) \text{ u } 2$$

$$1.92 < 2$$

The loads acting on each nozzle satisfy the appropriate interaction equation, so the condition specified in F.1.2b) is satisfied.

F.4.3.3 A check of condition F.1.2c) is as follows:

To check this condition, the applied component forces and moments are translated and resolved to the center of the pump. F_{RCA} is determined as follows [see F.1.2c)]:

$$F_{XCA} = F_{XSA} + F_{XDA}$$

$$F_{YCA} = F_{YSA} + F_{YDA}$$

$$F_{ZCA} = F_{ZSA} + F_{ZDA}$$

$$F_{RCA} = [(F_{XCA})^2 + (F_{YCA})^2 + (F_{ZCA})^2]^{0.5}$$

$$F_{XCA} = (+ 2900) + (+ 1600) = + 4500$$

$$F_{YCA} = (0) + (- 100) = - 100$$

F_{ZCA} = (– 1990) + (+ 1950) = – 40

F_{RCA} = [(+ 4500)^2 + (– 100)^2 + (– 40)^2]$^{0.5}$ = 4501

Referring to Equation (F.3),

$F_{RCA} < 1.5 \times (F_{RST3} + F_{RDT3})$

$4501 < 1.5 \times (2200 + 1560)$

$4501 < 5640$

M_{YCA} is determined as follows [see F.1.2c)]:

$M_{YCA} = M_{YSA} + M_{YDA} + [(F_{XSA})\,(zS) + (F_{XDA})(zD) - (F_{XSA})(xS) - (F_{XDA})\,(xD)]/12$

$= (-3599) + (-2500) + [(+2900)\,(0.00) + (+1600)\,(+15) - (-1990)(+10.5) - (+1950)(0.00)]/12$

$= -2358$

Referring to Equation (F.4),

$|M_{YCA}| < 2.0 \times (M_{YST3} + M_{YDT3})$

$|-2358| < 2.0 \times (1800 + 1300)$

$2358 < 6200$

M_{RCA} is determined as follows [see F.1.2c)]:

$M_{XCA} = M_{XSA} + M_{XDA} - [(F_{YSA})(zS) + (F_{YDA})(zD) - (F_{ZSA})(yS) - (F_{ZDA})\,(yD)]/12$

$M_{YCA} = M_{YSA} + M_{YDA} + [(F_{XSA})(zS) + (F_{XDA})(zD) - (F_{ZSA})(xS) - (F_{ZDA})\,(xD)]/12$

$M_{ZCA} = M_{ZSA} + M_{ZDA} - [(F_{XSA})(yS) + (F_{XDA})(yD) - (F_{YSA})(xS) - (F_{YDA})\,(xD)]/12$

$M_{RCA} = [(M_{XCA})^2 + (M_{YCA})^2 + (M_{ZCA})^2]^{0.5}$

$M_{XCA} = (-1000) + (+500) - [(0)\,(0.00) + (-100)\,(15.00) - (-1990)\,(0.00) - (+1950)\,(-12.25)]/12$

$= -2366$

$M_{YCA} = -2358$ (see previous calculation)

$M_{ZCA} = (-5500) + (-3600) - [(+2900)(0.00) + (+1600)\,(-12.25) - (0)(+10.50) - (-100)(0.00)]/12 =$

$= -7467$

$M_{RCA} = [(-2366)^2 + (-2358)^2 + (-7467)^2]^{0.5} = 8180$

Referring to Equation (F.5),

$$M_{RCA} < 1.5 \times (M_{RST3} + M_{RDT3})$$

$$8180 < 1.5 \times (5000 + 3500)$$

$$8180 < 12.750$$

Thus, all the requirements of F.1.2c) have been satisfied.

F.4.4 Example 2B (US Customary units)

Problem

For a NPS 3 × NPS 4 × 7 in vertical in-line pump (OH3 through OH6), the proposed applied nozzle loadings are as given in Table F.6. By inspection, F_{ZSA}, M_{ZSA}, and M_{XDA} are greater than two times the values shown in Table F.3 (US Customary units). As stated in F.2, these component loads are acceptable provided that the calculated principal stress is less than 5950 psi. The problem is to determine the principal stress for the suction nozzle and the discharge nozzle.

Table F.6—Proposed Applied Nozzle Loadings for Example 2B

Force	Value lbf	Moment	Value ft·lbf
		NPS 4 suction	
F_{XSA}	– 500	M_{XSA}	+ 100
F_{YSA}	– 1200	M_{YSA}	– 1500
F_{ZSA}	+ 300	M_{ZSA}	+ 1000
		NPS 3 discharge	
F_{XDA}	+ 300	M_{XDA}	+ 2000
F_{YDA}	– 500	M_{YDA}	+ 200
F_{ZDA}	+100	M_{ZDA}	+ 100

Solution

Suction nozzle calculations are as follows:

For Schedule 40 pipe with a nominal size of 4 in., D_o = 4.500 in. and D_i = 4.026 in. Therefore,

$$D_o^2 - D_i^2 = (4.500)^2 - (4.026)^2 = 4.04$$

$$D_o^4 - D_i^4 = (4.500)^4 - (4.026)^4 = 147.34$$

$$[(F_{XSA})^2 + (F_{ZSA})^2]^{0.5} = [(-500)^2 + (+300)^2]^{0.5} = 583$$

$$[(M_{XSA})^2 + (M_{ZSA})^2]^{0.5} = [(+100)^2 + (+1000)^2]^{0.5} = 1005$$

Equation (F.10) is used to determine the longitudinal stress for the suction nozzle, $\sigma_{l,s}$.

The applied F_{YSA} load acting on the suction nozzle is in the negative Y direction and produces a compressive stress; therefore, the negative sign on F_{YSA} is used.

$$\sigma_{l,s} = [1.27 \times F_{\mathrm{YSA}}/(D_o^2 - D_i^2)] + [122 \times D_o\,(M_{\mathrm{XSA2}} + M_{\mathrm{ZSA2}})^{0.5}]/(D_o^4 - D_i^4)$$

$$= [1.27 \times (-\,1200)/4.04] + [122 \times 4.500 \times 1005)]/147.34$$

$$= 3367$$

Equation (F.11) is used to determine the shear stress for the suction nozzle, τ_s.

$$\tau_s = [1.27 \times (F_{\mathrm{XSA2}} + F_{\mathrm{ZSA2}})^{0.5}]/(D_o^2 - D_i^2)] + [61 \times D_o\,(|M_{\mathrm{YSA}}\,|)]/(D_o^4 - D_i^4)$$

$$= (1.27 \times 583/4.04) + [61 \times 4.500 \times (\,|-\,1500\,|)/147.34]$$

$$= 2978$$

The principal stress for the suction nozzle, $\sigma_{p,s}$ is calculated using Equation (F.9):

$$\sigma_{p,s} = (\sigma s/2) + (\sigma_s^2/4 + \tau_s^2)^{0.5} < 5950$$

$$= (+3367/2) + [(+\,3367)^2/4 + (+\,2978)^2]^{0.5}$$

$$= +\,5105 < 5950$$

Thus, the suction nozzle loads are satisfactory.

Discharge nozzle calculations are as follows:

For Schedule-40 pipe with a nominal size of 3 in., D_o = 3,500, and D_i = 3,068. Therefore,

$$D_o^2 - D_i^2 = (3{,}500)^2 - (3{,}068)^2 = 2.84$$

$$D_o^4 - D_i^4 = (3{,}500)^4 - (3{,}068)^4 = 61.47$$

$$[(F_{\mathrm{XDA}})^2 + (F_{\mathrm{ZDA}})^2]^{0.5} = [(+\,300)^2 + (+\,100)^2]^{0.5} = 316$$

$$[(M_{\mathrm{XDA}})^2 + (M_{\mathrm{ZDA}})^2]^{0.5} = [(+\,2000)^2 + (+\,100)^2]^{0.5} = 2002$$

Equation (F.10) is used to determine the longitudinal stress for the discharge nozzle, $\sigma_{l,D}$

The applied F_{YDA} load acting on the discharge nozzle is in the negative Y direction and produces a tensile stress; therefore, a positive sign on F_{YDA} is used.

$$\sigma_{l,D} = [1.27\,F_{\mathrm{YDA}}/(D_o^2 - D_i^2)] + [122\,D_o\,(M_{\mathrm{XDA2}} + M_{\mathrm{ZDA2}})^{0.5}]/(D_o^4 - D_i^4)$$

$$= [1.27(+\,500)/2.84] + [122(3.5)\,(2002)]/61.47$$

$$= 14{,}131$$

Equation (F.11) is used to determine the shear stress for the discharge nozzle, τ_D.

$$\tau_D = [1.27(F_{\mathrm{XDA2}} + F_{\mathrm{ZDA2}})^{0.5}]/(D_o^2 - D_i^2)] + [61\ D_o\ (\ |\ M_{\mathrm{YDA}}\ |\ )/(D_o^4 - D_i^4)]$$

$$= (1.27 \times 316/2.84) + [61 \times 3.500 \times (\ |+200\ |)/61.47] = 836$$

The principal stress for the discharge nozzle, $\sigma_{p,D}$, is calculated using Equation (F.9):

$$\sigma_{p,D} = (\sigma_D/2) + (\sigma_D^2/4 + \tau_D^2)^{0.5} < 5950$$

$$= (+\ 14{,}131/2) + [(+\ 14{,}131)2/4 + (+\ 836)^2]^{0.5} = 14{,}181 > 5950$$

Thus, the discharge nozzle loads are too large. By inspection, if M_{XDA} is reduced by 50 % to 1000 ft·lbf. the resulting principal stress will still exceed 5950 psi. Therefore, the maximum value for M_{XDA} is twice M_{XDT3}, or 1400 ft·lbf.

Annex G
(informative)

Materials Class Selection Guidance

Table G.1 is intended to provide general guidance for on-plot process plants and off-plot transfer and loading services. It should not be used without a knowledgeable review of the specific services involved.

Table G.1—Material Classes for Sealless Centrifugal Pump Services

	Temperature Range		Pressure Range	Material Class	See Reference Notes
	Degrees C	Degrees F			
Boiling Water and process water	<120	<250	All	S-1	4
	120-175	250-350	All	S-5	4
	>175	>350	All	S-6, C-6	4
Boiler circulator	>95	>200	All	C-6	
Foul water, reflux drum water, water draw, and hydrocarbons containing these water, including reflux streams	<175	<350	All	S-3 or S-6	5
	>175	>350	All	C-6	5
Propane, butane, liquefied petroleum gas, and ammonia (NH3)	<230	<450	All	S-1	
	> –46	> –50	All	S-1(LCB)	11
	> –73	> –100	All	S-1(LC2)	11
	> –100	> –150	All	S-1(LC3)	11
	> –196	> –320	All	A-7 or A-8	12
Diesel oil, gasoline, naphtha, kerosene, gas oils, light, medium, and heave lube oils, fuel oil, residuum, crude oil, asphalt, synthetic crude bottoms	<230	<450	All	S-1	
	230 – 370	450 – 700	All	S-6	5, 6
	>370	>700	All	C-6	5
Noncorrosive hydrocarbons, e.g. catalytic reformate, isomaxate, desulfurized oils	230-370	450-700	All	S-4	6
Xylene, toluene, acetone, benzene, furfural, MEK, cumene	<230	<450	All	S-1	
Sodium carbonate, doctor solution	<175	<350	All	S-1	
Caustic (sodium hydroxide) concentration of <= 20 %	<100	<210	All	S-1	7
	≥100	≥210	All		10
Sour water	<260	<470	All	D-1	
Sulfur (liquid state)	All	All	All	S-1	
FCC slurry	<370	<700	All	C-6	
Potassium carbonate	<175	<350	All	C-6	
	<370	<700	All	A-8	

Table G.1—Material Classes for Sealless Centrifugal Pump Services (Continued)

	Temperature Range		Pressure Range	Material Class	See Reference Notes
	Degrees C	Degrees F			
MEA, DEA, TEA-stock solutions	<120	<250	All	S-1	
DEA, TEA-lean solutions	<120	<250	All	S-1	8
MEA-lean solution (CO_2 only)	80 – 150	175 – 300	All	S-9	8
MEA-lean solution (CO_2 and H_2S)	80 – 150	175 – 300	All	S-8	7, 8
MEA-, DEA-, TEA-rich solutons	<80	<175	All	S-1 or S-8	8
Sulfuric acid concentration > 85 %	<38	<100	All	S-1	5
85% - <1 %	<230	<450	All	A-8	5
Hydrofluoric acid concentration of >96 %	<65	<150	All	S-9	5
Hydrofluoric acid, anhydrous (100 %)	<65	<150	All	A-8	
Hydrofluoric acid, concentrations of >90 %	<65	<150	All	H-2	9

General Notes:

1) The materials for pump parts for each material class are given in Annex H.

2) Specific materials recommendations should be obtained for services not clearly identified by the service description listed in this table.

3) Caution should be used when considering the use of nickel containing stainless steel in applications where various concentrations of chloride containing liquids exist. Generally, nickel does not withstand chlorides well.

Reference Notes:

4) Oxygen content and buffering of water should be considered in material selection. For all temperatures greater than 95 °C (200 °F) shaft material shall be 12 % Chrome. Bearings shall be Antimony impregnated Carbon or graphite/metal alloys such as Graphalloy® [15]. Various self-lubricating polymer based materials could also be considered where there is experience.

5) The corrosiveness of foul waters, hydrocarbons over 230 °C (450 °F), acids, and acid sludges may vary widely. Material recommendations should be obtained for each service. The material class indicated above will be satisfactory for many of these services but must be verified.

6) If product corrosivity is low, Class S-4 materials may be used for services at 231 °C to 370 °C (451 °F to 700 °F), Specific material recommendations should be obtained in each instance.

7) All welds shall be stress relieved.

8) Class A-7 materials should be used except for carbon steel casings.

9) Hasteloy C may be cost effective due to ease of manufacturing. Recommend pressure boundary bolts be Hasteloy C.

10) UNS N08007 or Ni-Cu alloy pump material should be used.

11) Materials selected for low-temperature services shall meet the requirements of . Casting alloy grades LCB, LC2, and LC# are shown only for reference. Grades LCB, LC2, and LC3 refer to ISO 4991.C23-45BL, C43E2aL and C43L are equivalent to ASTM A352.A352M, Grades LCB, LC2, and LC3. Use equivalent materials for wrought alloys.

12) Material alloys based on aluminum, bronze, aluminum bronze, and nickel may also be considered for temperatures as low as –96 °C (–325 °F).

[15] This term is used as an example only, and does not constitute an endorsement of this product by API.

Annex H
(normative)

Materials and Material Specifications for Pump Parts

Table H.1 lists material classes for the purchaser to select (see 6.10.1.2).

Tables H.2, and H.3 may be used for guidance regarding materials specifications. If these tables are 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 H.2 lists corresponding international materials that may be considered 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 H.1—Material Classes for Pump Parts

Part	Material Classes and Abbreviations																
	Material Class	S-1	S-3	S-4	S-5	S-6	S-8l	S-9l	C-6	A-7	A-8	A-9	D-1j	D-2j	H-1	H-2	T-1
	Full Compliance Material[a]	STL	STL	STL	STL	STL	STL	STL	12 % CR	AUS	316 AUS	Alloy 20	Duplex	Super Duplex	Hast B	Hast C	Ti
	Trim Material	CI	Ni-resist	STL	STL 12 % CR	12 % CR	316 AUS	Ni-Cu alloy	12 % CR	AUS[c,d]	316 AUS[d]	Alloy 20	Duplex	Super Duplex	Hast B	Hast C	Ti
Pressure casing	Yes	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	Carbon steel	12 % CR	AUS	316 AUS	Alloy 20	Duplex	Super Duplex	Hast B	Hast C	Ti
Inner case parts (bowls, diffusers, diaphragms)	No	Cast iron	Ni-Resist	Cast iron	Carbon Steel	12 % CR	316 AUS	Ni-Cu alloy	12 % CR	AUS	316 AUS	Alloy 20	Duplex	Super Duplex	Hast B	Hast C	Ti
Impeller	Yes	Cast Iron	Ni-Resist	Carbon steel	Carbon Steel	12 % CR	316 AUS	Ni-Cu alloy	12 % CR	AUS	316 AUS	Alloy 20	Duplex	Super Duplex	Hast B	Hast C	Ti
Case wear ringsk	No	Cast Iron	Ni-Resist	Cast iron	12 % CR Hardened	12 % CR Hardened	Hard-faced 316 AUS[e]	Ni-Cu alloy	12 % CR Harden-ed	Hard-faced AUS[e]	Hard-faced 316 AUS[e]	Alloy 20	Hard-faced Duplex[e]	Hard-faced Super Duplex[e]	Hast B	Hast C	Ti
Impeller wear rings[k]	No	Cast Iron	Ni-Resist	Cast iron	12 % CR Hardened	12 % CR Hardened	Hard-faced 316 AUS[e]	Ni-Cu alloy	12 % CR Harden-ed	Hard-faced AUS[e]	Hard-faced 316 AUS[e]	Alloy 20	Hard-faced Duplex[e]	Hard-faced Super Duplex[e]	Hast B	Hast C	Ti
Shaft[d]	Yes	Carbon steel	Carbon steel	Carbon steel	4140 alloy steel	4140 alloy steelf	316 AUS	Ni-Cu alloy	12 % CR	AUS	316 AUS	Alloy 20	Duplex	Super Duplex	Hast B	Hast C	Ti
Throat bushings[k]	No	Cast iron	Ni-Resist	Cast iron	12 % CR Hardened	12 % CR Hardened	316 AUS	Ni-Cu alloy	12 % CR Harden-ed	AUS	316 AUS	Alloy 20	Duplex	Super Duplex	Hast B	Hast C	Ti
Interstage sleeves[k]	No	Cast iron	Ni-Resist	Cast iron	12 % CR Hardened	12 % CR Hardened	Hard-faced 316 AUS e	Ni-Cu alloy	12 % CR Harden-ed	Hard-faced AUS[e]	Hard-faced 316 AUS[e]	Alloy 20	Hard-faced Duplex[e]	Hard-faced Super Duplex[e]	Hast B	Hast C	Ti
Interstage bushings[k]	No	Cast iron	Ni-Resist	Cast iron	12 % CR Hardened	12 % CR Hardened	Hard-faced 316 AUS e	Ni-Cu alloy	12 % CR Harden-ed	Hard-faced AUS[e]	Hard-faced 316 AUS[e]	Alloy 20	Hard-faced Duplex[e]	Hard-faced Super Duplex[e]	Hast B	Hast C	Ti
Case and gland studs	Yes	4140 alloy steel	4140 alloy steel	4140 alloy steel	4140 alloy steel	4140 alloy steel	4140 alloy steel	Ni-Cu alloy Harden-ed[i]	4140 alloy steel	4140 alloy steel	4140 alloy steel	Alloy 20	Duplex[i]	Super Duplex[i]	Hast B	Hast C	Ti

Table H.1—Material Classes for Pump Parts

Part	Material Classes and Abbreviations																
	Material Class	**S-1**	**S-3**	**S-4**	**S-5**	**S-6**	**S-8l**	**S-9l**	**C-6**	**A-7**	**A-8**	**A-9**	**D-1j**	**D-2j**	**H-1**	**H-2**	**T-1**
	Full Compliance Material[a]	**STL**	**STL**	**STL**	**STL**	**STL**	**STL**	**STL**	**12 % CR**	**AUS**	**316 AUS**	**Alloy 20**	**Duplex**	**Super Duplex**	**Hast B**	**Hast C**	**Ti**
	Trim Material	**CI**	**Ni-resist**	**STL**	**STL 12 % CR**	**12 % CR**	**316 AUS**	**Ni-Cu alloy**	**12 % CR**	**AUS[c,d]**	**316 AUS[d]**	**Alloy 20**	**Duplex**	**Super Duplex**	**Hast B**	**Hast C**	**Ti**
Case gasket	No	AUS, spiral-wound[g]		AUS, spiral-wound[g]	AUS, spiral-wound[g]	AUS, spiral- wound[g]		AUS, spiral-wound[g]	316 AUS spiral-wound[g]	Ni-Cu alloy, spiral-wound, PTFE filled[g]	AUS, spiral-wound[g]	AUS, spiral-wound[g]	316 AUS spiral-wound[g]		Alloy 20 spiral-wound[g]	Duplex SS spiral-wound[g]	Duplex SS spiral-wound[g]
Wetted fasteners (bolts)	Yes	Carbon steel		Carbon steel	Carbon steel	316 AUS[m]		316 AUS[m]	316 AUS	Ni-Cu alloy	316 AUS[m]	316 AUS	316 AUS		Alloy 20	Duplex	Super Duplex

a) See 6.10.1.2.

b) The abbreviations in the upper part of the third row indicate the case material; the abbreviations in the lower part of the fourth row indicate trim material. Abbreviations are as follows:

STL steel
CI cast iron
CR chromium
AUS austenitic stainless steel
Ti Titanium
316 AUS austenitic stainless steel containing at least 2,0 % molybdenum
Hast Hastelloy®[16] Haynes International)

c) Austenitic stainless steels include ISO types 683-13-10/19 (AISI standard types 302, 303, 304, 316, 321, and 347).

d) Unless otherwise specified, the requirement for hard-facing and the specific hard-facing material for each application is determined by the vendor and described in the proposal. Alternatives to hard-facing may include opening running clearances (6.6.4) or the use of non-galling materials or non-metallic materials, depending on the corrosiveness of the pumped liquid.

e) For class S-6, the standard shaft material for boiler feed service and for liquid temperatures above 175 °C (350 °F) is 12 % chrome (see Table G.1).

f) Spiral-wound gaskets should contain a filler material suitable for the service. Gaskets other than spiral-wound may be proposed and furnished if proven suitable for service and approved by the purchaser. See 6.2.7.

g) Alternative materials may be substituted for liquid temperatures greater than 45 °C (110 °F) or for other special services.

h) Unless otherwise specified, AISI 4140 alloy steel may be used for non-wetted case and gland studs.

i) Some applications may require alloy grades higher than the Duplex materials given in Table H.2. "Super Duplex" material grades with pitting resistance equivalency (PRE) values greater than 40 can be necessary.

PRE W 40, where the PRE is based on actual chemical analysis.

PRE $= w_{Cr} + 3.3w_{Mo} + 16w_N$, where w is the percentage mass fraction of the element indicated by the subscript.

Note that alternative materials such as "super austenitic" may also be considered.

j) Non-metallic wear part materials, proven compatible with the specified process liquid, may be proposed within the applicable limits shown in Table H.3. Also see 6.6.4.3).

k) The vendor shall consider the effects of differential material expansion between casing and rotor and confirm suitability if operating temperatures can exceed 95 °C (200 °F).

l) For applications where large differences of thermal expansion can result if austenitic stainless steel fasteners are used, alternative fastener materials, such as 12 % or 17 % Cr martensitic steel, with appropriate corrosion resistance, may be used.

[16] This term is used as an example only, and does not constitute an endorsement of this product by API.

Table H.2—Material Specifications for Pump Parts

Material Class	Applications	International	USA		Europe			Japan
		ISO	ASTM	UNS[a]	EN[b]	Grade	Material no.	JIS
Cast iron	Pressure castings	185/Gr 250	A278/A278M Class 30	F12401	EN 1561	EN-GJL-250	JL 1040	G 5501, FC 250
	General castings	185/Gr 300	A48/A48M Class 25/30/40	F11701/ F12101	EN 1561	EN-GJL-250 EN-GJL-300	JL 1040 JL 1050	G 5501, FC 250/ 300
Carbon steel	Pressure castings	4991 C2345 AH	A216/A216M Gr WCB	J03002	EN 10213	GP 240 GH	1.0619	G 5151, Cl SCPH 2
	Wrought/ forgings	683-18-C25	A266 Class 4	K03506	EN 10222-2	P 280 GH	1.0426	G 3202, Cl SFVC 2A
	Bar stock: pressure	683-18-C25	A696 Gr B40	G10200	EN 10273	P 295 GH	1.0481	G 4051, Cl S25C
	Bar stock: general	683-18-C45e	A576 Gr 1045	G10450	EN 10083-2	C 45	1.0503	G 4051, Cl S45C
	Bolts and studs	2604-2-F31	A193/A193M Gr B7	G41400	EN 10269	42 Cr Mo 4	1.7225	G 4107, Class 2, SNB7
	Nuts	683-1-C45	A194/A194M Gr 2H	K04002	EN 10269	C 35 E	1.1181	G 4051, Cl S45C
	Plate	9328-4, P 355 TN/ PL 355 TN	A516/A516M Gr 65/70	K02403/ K02700	EN 10028-3	P 355 N P 355 NL1	1.0562 1.0566	G 3106, Gr SM400B
	Pipe	9329-2 PH26	A106/A106M Gr B	K03006	EN 10208-1	L 245 GA	1.0459	G 3456, Gr. STPT 370/ 410
	Fittings	—	A105/A105M	K03504	—	—	—	G 4051, Cl S25C G 3202, Cl SFVC 2A, SFVC2B
4140 alloy steel	Bar stock	—	A434 Class BB A434 Class BC	G41400c	EN 10083-1	42 Cr Mo 4	1.7225	G 4105, Cl SCM 440
	Bolts and studs	2604-2-F31	A193/A193M Gr B7	G41400	EN 10269	42 Cr Mo 4	1.7225	G 4107, Class 2, SNB7
	Nuts	683-1C45	A194/A194M Gr 2H	K04002	EN 10269	C 45 E	1.1191	G 4051, Cl S45C

Table H.2—Material Specifications for Pump Parts (Continued)

Material Class	Applications	International	USA		Europe			Japan
		ISO	ASTM	UNS[a]	EN[b]	Grade	Material no.	JIS
12 % Chrome steel	Pressure castings	—	A487/A487M Gr CA6NM	J91540	EN 10213	GX 4 Cr Ni 134	1.4317	G 5121, C1 SCS 6, SCS 6X
	General castings	—	A743/A743M Gr CA 15	J91150	EN 10283	GX 12 Cr 12	1.4011	G 5121,Cl SCS 1, SCS 1X1
		—	A743/A743M Gr CA6NM	J91540	EN 10283	GX 4 Cr Ni 134	1.4317	G 5121, Cl SCS 6, SCS 1X1
	Wrought/ forgings: pressure	683-13-3	A182/A182M Gr F6a Cl 1 A182/A182M Gr F6 NM	S41000 S41500	EN 10250-4 EN 10222-5	X12 Cr13 X 3 Cr NiMo 13-4-1	1.4006 1.4313	G 3214, Gr. SUS 410-A G 3214, Cl SUS F6 NM
	Wrought/ forgings: general	683-13-2	A473 Type 410	S41000	EN 10088-3	X 12 Cr 13	1.4006	G 3214, Gr. SUS 410-A
	Bar stock: pressure	683-13-3	A479/A479M Type 410	S41000	EN 10272	X12 Cr 13	1.4006	G 4303 Gr. SUS 410 or 403
	Bar stock: general	683-13-3	A276 Type 410	S41400	EN 10088-3	X 12 Cr 13	1.4006	G 4303 Gr. SUS 410 or 403
	Bar stock: forgings[c]	683-13-4	A276 Type 420 A473 Type 416 A582/A582M Type 416	S42000 S41600 S41600	EN 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
	Bolts and studs[d]	3506-1, C470	A193/A193M Gr B6	S41000	EN 10269	X22CrMo V 12-1	1.4923	G 4303 Gr. SUS 410 or 403
	Nuts[d]	3506-2, C470	A194/A194M Gr 6	S41000	EN 10269	X22CrMo V 12-1	1.4923	G 4303 Gr. SUS 410 or 403
	Plate	683-13-3	A240/A240M Type 410	S41000	EN 10088-2	X 12 Cr 13	1.4006	G 4304/4305 Gr. SUS 403 or 410

Table H.2—Material Specifications for Pump Parts (Continued)

Material Class	Applications	International	USA		Europe			Japan
		ISO	ASTM	UNS[a]	EN[b]	Grade	Material no.	JIS
Austenitic stainless steel	Pressure castings	683-13-10	A351/A351M Gr CF3	J92500	BSI/BS/ EN 10213-4	GX2 Cr Ni 1911	1.4309	G 5121, Cl SCS 19A
		683-13-19	A351/A351M Gr CF3M	J92800	BSI/BS/ EN 10213-4	GX2 Cr Ni Mo 19-11-2	1.4409	G 5121, Cl SCS 16A SCS 16AX
			A351/A351M Gr CF8M	J92900				G 5121, Cl SCS 14A SCS 14AX
	General castings	—	A743/A743M Gr CF3	J92500	EN 10283	GX2 Cr Ni 1911	1.4309	G 5121, Cl SCS 19A
		—	A743/A743M Gr CF3M	J92800	EN 10283	GX2 Cr Ni Mo 19-11-2	1.4409	G 5121, Cl SCS 16A, SCS 16AX
	Wrought/ forgings	9327-5, XCrNi18-10 683/XIII Type 10	A182/A182M Gr F 304L	S30403	EN 10222-5	X2 Cr Ni 19-11	1.4306	G 3214, Gr. SUS F 304 L
		9327-5, XCrNiMo 17-12 683/XIII Type 19	A182/A182M Gr F 316L	S31603	EN 10222-5 EN 10250-4	X2 Cr Ni Mo 17-12-2	1.4404	G 4304/4305, Gr. SUS 304L/ 316L
	Bar stock[e]	9327-5 X2CrNi18-10	A479/A479M Type 304L A479/A479M Type 316L A276 grade 316L	S30403 S31603	EN 10088-3 EN 10088-3	X2 Cr Ni 19-11 X2 Cr Ni Mo 17-12-2	1.4306 1.4404	G 4303 Gr. SUS 304 L G 4303 Gr. SUS 316 L
		9327-5 X2CrNiMo 17-12	A479/A479M Type XM19	S20910	—	—	—	—
	Plate	9328-5 X2CrNiMo 17-12-2	A240/A240M Gr 304L/316L	S30403 S31603	EN 10028-7 EN 10028-7	X2 Cr Ni 19-11 X2 Cr Ni Mo 17-12-2	1.4306 1.4404	G 4304/4305, Gr. SUS 304 L/ 316 L
	Pipe	683-13-10 683-13-19	A312/A312M Type 304L 316L	S30403 S31603	—	—	—	G 3459 Gr. SUS 304 LTP / 316 LTP
	Fittings	9327-5, X2CrNi18-10 9327-5, X2CrNiMo 17-12	A182/A182M Gr F304L, Gr 316L	S30403 S31603	EN 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	A193/A193M Gr B 8 M	S31600	EN 10250-4	X6 Cr Ni Mo Ti 17-12-2	1.4571	G 4303, Gr. SUS 316
	Nuts	3506-2, A4-70	A194/A194M Gr B 8 M	S31600	EN 10250-4	X6 Cr Ni Mo Ti 17-12-2	1.4571	G 4303, Gr. SUS 316

Table H.2—Material Specifications for Pump Parts (Continued)

Material Class	Applications	International	USA		Europe			Japan
		ISO	ASTM	UNS[a]	EN[b]	Grade	Material no.	JIS
Alloy 20	Pressure Casings		A743 Gr CF-20	J92602		X5NiCrMoCu3620		
	General Castings		A743 Gr CN7M					
	Wrought/ forgings			N08020		X2NiCrAlTi3220	1.4458	
	Bar stock			N08020				
	Plate			N08020				
	Pipe			N08020				
	Fittings			N08020				
	Bolts & Studs			N08020				
	Nuts			N08020				
Duplex stainless steel (CD4MCu)	Pressure castings	—	A890/A890M Gr 1 B A995/A995M Gr 1 B	J93372	BSI/BS/ EN 10213-4	GX2 CrNiMoCuN-25-6-3-3	1.4517	—
		—	A890/A890M Gr 3 A A995/A995M Gr 3 A	J93371 J93371	—	—	—	G 5121, Gr. SCS 11
		—	A890/A890M Gr 4 A A995/A995M Gr 4 A	J92205 J92205	BSI/BS/ EN 10213-4	GX2 CrNiMoCuN-25-6-3-3	1.4517	G 5121, Gr. SCS 10
	Wrought/ forgings	9327-5, X2CrNiMoN 22-5-3	A182/A182M Gr F 51	S31803	EN 10250-4 EN 10222-5	X2CrNiMoN-22-5-3	1.4462	—
		—	A479/A479M	S32550	EN 10088-3	X2CrNiMoCuN-25-6-3	1.4507	—
	Bar stock	9327-5, X2CrNiMo N22-5-3	A276-S31803	S31803	EN 10088-3	X2CrNiMoN-22-5-3	1.4462	B 2312/B 2316 Gr. SUS 329 J3L
	Plate	—	A240/A240M-S31803	S31803	EN 10028-7	X2CrNiMoN-22-5-3	1.4462	G 4304/G 4305 Gr. SUS 329 J3L
	Pipe	—	A790/A790M-S31803	S31803	—	—	—	G 3459 Gr. SUS 329 J3L TP
	Fittings	9327-5, X2CrNiMo N22-5-3	A182/A182M Gr F 51	S31803	EN 10250-4 EN 10222-5	X2CrNiMoN-22-5-3	1.4462	B 2312/B 2316 Gr. SUS329J3L
	Bolts and studs	—	A276-S31803	S31803	EN 10088-3	X2CrNiMoN-22-5-3	1.4462	G 4303 Gr. SUS 329 J3L
	Nuts	—	A276-S31803	S31803	EN 10088-3	X2CrNiMoN-22-5-3	1.4462	G 4303 Gr. SUS 329 J3L

Table H.2—Material Specifications for Pump Parts (Continued)

Material Class	Applications	International	USA		Europe			Japan
		ISO	ASTM	UNS[a]	EN[b]	Grade	Material no.	JIS
Super duplex stainless steel[f]	Pressure castings	—	A890/A890M Gr 5A	J93404	BSI/BS/ EN 10213-4	GX2CrNiMoN26-7-4	1.4469	—
		—	A890/A890M Gr 6A	J93380	—	—	—	—
	Wrought/ forgings	—	A182/A182M Gr 55	S32750 S32760	EN 10250-4 EN 10088-3	X2CrNiMoCuWN 25-7-4	1.4501	G 4303, Gr. SUS 329 J4L
	Bar stock	—	A276-S32760 A479/A479M-S32760	S32750 S32760	EN 10088-3	X2CrNiMoCuWN 25-7-4	1.4501	G 4304/G 4305 Gr. SUS 329 J4L
	Plate	—	A240/A240M-S32760	S32750 S32760	EN 10028-7	X2CrNiMoCuWN 25-7-4	1.4501	—
	Pipe	—	A790/A790M-S32760	S32750 S32760	—	—	—	G 3459, Gr. SUS 329 J4L TP
	Fittings	—	A182/A182M Gr F55	S32750 S32760	EN 10250-4 EN 10088-3	X2CrNiMoCuWN 25-7-4	1.4501	B 2312/B 2316 Gr. SUS 329 J4L
Super duplex stainless steel[f]	Bolts and studs	—	A276-S32760	S32750 S32760	EN 10088-3	X2CrNiMoCuWN 25-7-4	1.4501	G 4303 Gr. SUS 329 J4L
	Nuts	—	A276-S32760	S32750 S32760	EN 10088-3	X2CrNiMoCuWN 25-7-4	1.4501	G 4303 Gr. SUS 329 J4L
Monel 400	Pressure Casting			N04400			2.4360	
	Wrought/ forgings							
	Bar stock							
	Plte							
	Pipe							
	Fitings							
	Bolts ^& Studs							
	Nuts							

Table H.2—Material Specifications for Pump Parts (Continued)

Material Class	Applications	International	USA		Europe			Japan
		ISO	ASTM	UNS[a]	EN[b]	Grade	Material no.	JIS
Hast B	Pressure Castings (B3)		A494 Gr N-12MV	J30012 N10675		G-NiMo30	2.4810 2.4600	
	(B-2)			N10665		G-NiMo28	2.4617	
	-		A494 Gr N7M	J30007				
	General Castings		A743 Gr N12M					
	Wrought/ forgings		B564	N10665 N10675		NiMo28	2.4617	
	Bar stock		B335	N10665 N10675		NiMo28	2.4617	
	Plate		B333	N10665 N10675		NiMo28	2.4617	
	Pipe		B619, B622	N10665 N10675		NiMo28	2.4617	
	Fittings		B366	N10665 N10675		NiMo28	2.4617	
	Bolts & Studs		F468	N10001				
	Nuts		F467	N10001				
Hast C	Pressure Castings		A494 Gr CW12MW	N10276		G-NiMo16Cr15 G-NiMo17Cr	2.4819 2.4686	
			A494 Gr CX2M					
	General Castings		A743 Gr N-12M					
	Wrought/ forgings		B564	N10276		NiMo16Cr15W	2.4819	
	Bar stock		B574	N10276		NiMo16Cr15W	2.4819	
	Plate		B575	N10276		NiMo16Cr15W	2.4819	
	Pipe		B619,B622,B626	N10276		NiMo16Cr15W	2.4819	
	Fittings		B366	N10276		NiMo16Cr15W	2.4819	
	Bolts & Studs		F468	N10276		NiMo16Cr15W	2.4819	
	Nuts		F467	N10276		NiMo16Cr15W	2.4819	

Table H.2—Material Specifications for Pump Parts (Continued)

Material Class	Applications	International	USA		Europe			Japan
		ISO	ASTM	UNS[a]	EN[b]	Grade	Material no.	JIS
Titanium	Pressure Castings		B367 Gr C-3	R5xxxx		G-Ti99.4	3.7031	H5801 Gr.3
	General Castings			R50250				
	Wrought/ forgings		B381	R50400 R56400 R58640		Titan Gr.2	3.7035	H4657 Gr.2
	Bar stock		B348 Gr2 B348 Gr5	R50400 R56400				H4650 Gr.2 H4650 Gr.50
	Plate		B265					H4600 Gr.2
	Pipe		B861, B862					H4630 Gr.2
	Fittings		B363					
	Bolts & Studs		F467 F468	R56400				
	Nuts		F467 F468	R56400				

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

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

[c] Do not use for shafts in the hardened condition (over 302 HB).

[d] Special, normally use 4140 alloy steel.

[e] For shafts, standard grades of austenitic stainless steel may be substituted in place of low-carbon (L) grades.

[f] Super Duplex stainless steel classified with pitting resistance equivalent (PRE) number greater than or equal to 40:

PRE = $w_{Cr} + 3.3w_{Mo} + 16w_N$, where w is the percentage mass fraction of the element indicated by the subscript.

Table H.3—Non-metallic Wear Part Materials

Material	Temperature Limits °C (°F) min.	Temperature Limits °C (°F) max.	Application
Polyether ether ketone (PEEK) Chopped-carbon-fibre filled	–30 (–20)	135 (275)	Stationary parts
Polyether ether ketone (PEEK) Continuous-carbon-fibre wound	–30 (–20)	230 (450)	Stationary or rotating
PFA/CF reinforced composite 20 % mass fraction random X-Y oriented carbon-fiber	–46 (–50)	230 (450)	Stationary parts
Carbon graphite			Stationary parts
Resin-impregnated	–50 (–55)	285 (550)	
Babbitt-impregnated	–100 (–150)	150 (300)	
Nickel-impregnated	–195 (–320)	400 (750)	
Copper-impregnated	–100 (–450)		
Silicon carbide Alpha sintered		450 (840)	Stationary or rotating
Reaction bonded		450 (840)	Stationary or rotating
Carbon loaded		450 (840)	Stationary or rotating
Tungsten carbide Cobalt binder		400 (750)	Stationary or rotating
Nickel binder		400 (750)	Stationary or rotating
Non-metallic wear part materials that are proven compatible with the specified process liquid may be proposed within the above limits. See 6.6.4.3. Such materials may be selected as wear components for mating against a suitably selected metallic component such as hardened 12 % Cr steel or hard-faced austenitic stainless steel. Materials may be used beyond these limits if proven application experience can be provided, and if approved by the purchaser.			

Annex I
(informative)

Magnet Materials for Magnetic Couplings

I.1 General

The magnet alloys discussed within this annex represent present technology at time of publication. As the state-of-the-art in permanent magnet materials advance (i.e. temperature stability, coercive force, energy product, and corrosion resistance) higher magnet operating temperatures than those in Table I.1 may be achieved. It should be noted that higher magnet operating temperatures may require advancements in the adhesives and epoxies used to bond and hold the magnets within the inner and outer magnet rings. Selected adhesives and epoxies should have long-term working temperatures comparable to that of the maximum magnet operating temperatures. Purchaser shall approve the use of advanced grades of permanent magnet materials.

I.2 Magnet Materials

To obtain high torque transmission values in synchronous magnetic couplings, while keeping the coupling drive radius and length to a minimum (reduce eddy current losses), the strongest available magnets need to be used. The strongest commercial permanent magnet materials today all stem from the "Rare Earth" family of compounds. Rare Earth magnets are so termed because they are alloys of the Rare Earth group of elements such as Samarium or Neodymium.

These magnet alloys are commercially available as Samarium Cobalt (SmCo) and Neodymium Iron Boron (NdFeB). Properties for commercially available grades of SmCo and NdFeB are listed in Table I.1.

With torque ring couplings, magnets can be of the Rare Earth type or Aluminum Nickel Cobalt (Alnico). Alnico magnet materials exhibit coercivity values and maximum BH products that are significantly lower than values for the Rare Earth magnet alloys. However, Alnico magnets are characterized by excellent temperature stability and are generally used in high temperature sealless pumps with torque ring couplings. Properties for several commercially available grades of Alnico magnet material are listed in Table I.1.

I.3 Magnet Alloy Notes

a) The properties and temperature limits reflect "modified" or "temperature compensated" SmCo Alloys exhibiting high coercivity values and greater temperature stability. Traditionally, Sm2Co17 grades exhibit better temperature characteristics and corrosion resistance than that of grade Sm1Co5. Samarium Cobalt magnet alloys are manufactured by a process of pressing and sintering. These alloys are brittle in nature and require great care in handling. SmCo magnet alloys contain appreciable quantities of cobalt giving this alloy good corrosion resistance.

b) The properties and temperature limits reflect NdFeB alloys that have been alloyed and processed to produce high coercivity values and temperature stability. NdFeB alloys contain iron and are very susceptible to oxidation in the presence of moisture. It is highly recommended that magnets made from NdFeB alloys be coated (i.e. epoxy sealer) or metal plated during the manufacturing process. Prior to coating or plating NdFeB magnet alloys should be baked at low temperature in order to drive out any remnant moisture. Neodymium Iron Boron magnet alloys are manufactured by a process of pressing and sintering. NdFeB alloys exhibit higher mechanical strength than those of the SmCo alloys and tend to be less brittle.

c) Alnico magnet alloys are manufactured through either a casting or sintering process. Sintered Alnico materials offer slightly lower magnetic properties but better mechanical characteristics than the cast Alnico alloys. Alnico alloys are very hard and brittle. These alloys are cast or sintered as closely as possible to required sizes so that grinding to finished dimensions is minimized. Corrosion resistance ranges from "fair" for castings to "good" for the sintered forms. Alnico magnets exhibit excellent high temperature stability.

Table I.1—Magnetic Materials Properties Overview and Temperature Limits

Magnetic Alloys	Typical Values				Maximum Magnet Operating Temp. (°C)d	Related Notes (See I.3)
	Commercial Grades	Remanence B_r $(Mt)^a$	Coercivity $H_{CB}(K/m)^b$	Maximum BH Product $(BH)_{max}$ $(Kj/M^3)^c$		
Samarium Cobalt (SmCo)	Sm1Co5	850 – 870 (8.5 – 8.7 kG)	637 – 684 (8.0 – 8.6 kOe)	143 (18 MGOe)	200 (392 °F)	a
	Sm2Co17	950 – 1060 (9.5 – 10.6 kG)	716 – 796 (9.0 – 10.0 kOe	175 – 223 (22 – 32 MGOe)	350 (662 °F)	
Neodymium Iron Boron (NdFeB)	NdFeB	1040 – 1210 (10.4 – 12.1 kG)	796 – 923 (10.0 – 11.6 kOe)	207 – 279 (34 – 42 MGOe)	150 (302 °F)	b
Aluminum Nickel Cobalt (Alnico)	Alnico 5	1090 – 1210 (10.9 – 12.8 kG)	49 – 51 (0.62 – 0.64 kOe)	32 – 44 (4.0 – 5.5 MGOe)	150 (302 °F)	c
	Alnico 8	740 – 820 (7.4 – 8.2 kG)	119 – 131 (1.5 – 1.7 kOe)	32 – 42 (4.0 – 5.3 MGOe)	450 (842 °F)	

[a] B_r—represents the remanence of maximum magnetic flux density remaining in the material after the magnetizing force has been removed.

[b] H_{CB}—represents coercivity or the coercive force which is the demagnetizing force necessary to remove all the magnetic lines of force to a flux density of zero.

[c] $(BH)_{max}$—represents the energy product, a measure of overall magnetic strength and is the product of the induction and demagnetizing forces.

[d] Maximum Magnet Operating Temperature—is based on long-term thermal aging of less than 4 % irreversible loss in flux density.* Operating above this temperature can result in long-term irreversible loss in flux density that could affect coupling performance. For synchronous magnetic couplings, the maximum magnet operating temperature will be that temperature indicated on the outer surface of the containment shell during operation and at maximum pumpage temperature. For torque ring couplings, which carry the permanent magnets in the outer magnet ring and not directly in contact with the pumpage, the maximum magnet operating temperature will relate to the maximum pumpage temperature as follows: For Sm2Co17 = 350 °C (662 °F) pumpage temperature, for Alnico = 450 °C (842 °F) pumpage temperature.

* "Some Properties of High Coercivity 2-17 Magnet Materials," By W. Ervens, International Rare Earth Symposium, Paper No. IV-2.

Annex J
(normative)

Determination of Residual Unbalance

J.1 General

This annex describes the procedure used to determine residual unbalance in machine rotors. Although some balancing machines may be set up to read out the exact amount of unbalance, the calibration can be in error. The only sure method of determining residual unbalance is to test the rotor with a known amount of unbalance.

J.2 Terms and Definitions

J.2.1

residual unbalance

Amount of unbalance remaining in a rotor after balancing.

NOTE Unless otherwise specified, residual unbalance is expressed in gram-millimetres (g·mm) [ounce-inches (oz·in.)].

J.3 Maximum Allowable Residual Unbalance

J.3.1 The maximum allowable residual unbalance per plane is specified in 6.8.4.

J.3.2 If the actual static load on each journal is not known, assume that the total rotor mass is equally supported by the bearings. For example, a two-bearing rotor with a mass of 27 kg (60 lb) can be assumed to impose a mass of 13.5 kg (30 lb) on each journal.

J.4 Residual Unbalance Check

J.4.1 General

J.4.1.1 When the balancing machine readings indicate that the rotor has been balanced to within the specified tolerance, a residual unbalance check shall be performed before the rotor is removed from the balancing machine.

J.4.1.2 To check the residual unbalance, a known trial mass is attached to the rotor sequentially in 6 equally spaced radial positions, each at the same radial distance. The check is run in each correction plane, and the readings in each plane are plotted on a graph using the procedure specified in J.4.2.

J.4.2 Procedure

J.4.2.1 Select a trial mass and radius that provides between one and two times the maximum allowable residual unbalance [that is, if U_{max} is 720 g·mm (1 oz·in.), the trial mass is expected to cause 720 g·mm to 1 440 g·mm (1 oz·in. to 2 oz·in.) of unbalance].

J.4.2.2 Starting at the last known heavy spot in each correction plane, mark off the 6 radial positions in equal 60° increments around the rotor. Add the trial mass to the last known heavy spot in one plane. If the rotor has been balanced very precisely and the final heavy spot cannot be determined, add the trial mass to any one of the marked radial positions.

J.4.2.3 To verify that an appropriate trial mass has been selected, operate the balancing machine and record the reading on the meter. If the reading is at the upper limit of the meter range, a smaller trial mass shall be used. If there is little or no meter reading, a larger trial mass shall be used. Little or no meter reading generally indicates that the rotor was either not balanced correctly, or the balancing machine is not sensitive enough, or the balancing machine is faulty (e.g. a faulty transducer). Whatever the error, it shall be corrected before proceeding with the residual check.

J.4.2.4 Locate the mass at each of the equally spaced positions in turn, and record the amount of unbalance indicated on the meter for each position. Repeat the initial position as a check. All verification shall be performed using only one sensitivity range on the balance machine.

J.4.2.5 Plot the readings on the residual unbalance work sheet and calculate the amount of residual unbalance (see Figure J.1 and Figure J.2). The maximum meter reading occurs when the trial mass is added at the rotor's heavy spot; the minimum reading occurs when the trial mass is located opposite the heavy spot. Thus, the plotted readings are expected to form an approximate circle (see Figure J.3 and Figure J.4). An average of the maximum and minimum meter readings represents the effect of the trial mass. The distance of the circle's centre from the origin of the polar plot represents the residual unbalance in that plane.

J.4.2.6 Repeat the steps described in J.4.2.1 through J.4.2.5 for each balance plane. If the specified maximum allowable residual unbalance is exceeded in any balance plane, the rotor shall be balanced more precisely and checked again. If a correction is made to any balance plane, the residual unbalance check shall be repeated in all planes.

J.4.2.7 For progressively balanced rotors, a residual unbalance check shall be performed after the addition and balancing of the first rotor component, and at the completion of balancing of the entire rotor, as a minimum.

NOTE This ensures that time is not wasted and rotor components are not subjected to unnecessary material removal in attempting to balance a multiple-component rotor with a faulty balancing machine.

Equipment (rotor) No.: __________

Purchase order No.: __________

Correction plane (inlet, drive end, etc. — use sketch): __________

Balancing speed: __________ r/min

n = maximum allowable rotor speed: __________ r/min

m (or W) = mass of journal (closest to this correction plane): __________ kg (lb)

U_{max} = maximum allowable residual unbalance = 6350m/n (4$W/_n$)

6350 × ______ kg/______ r/min; (4 × ______lb/______r/min) __________ g·mm (oz·in.)

Trial unbalance (2 × U_{max}) __________ g·mm (oz·in.)

R = radius of mass placement: __________ mm (in.)

Trial unbalance mass = Trial unbalance/R

_____ g·mm/_____ mm (_____ oz·in./______in.) __________ g (oz)

NOTE Conversion information: 1 oz = 28,350 g

Test data			Rotor sketch
Position	Trial mass angular location	Balancing machine amplitude readout	
1			
2			
3			
4			
5			
6			
7			

Test Data — Graphic Analysis

Step 1: Plot data on the polar chart (Figure J.2). Scale the chart so the largest and smallest amplitudes will fit conveniently.

Step 2: With a compass, draw the best-fit circle through the six points and mark the centre of this circle.

Step 3: Measure the diameter of the circle in units of scale chosen in Step 1 and record. units.

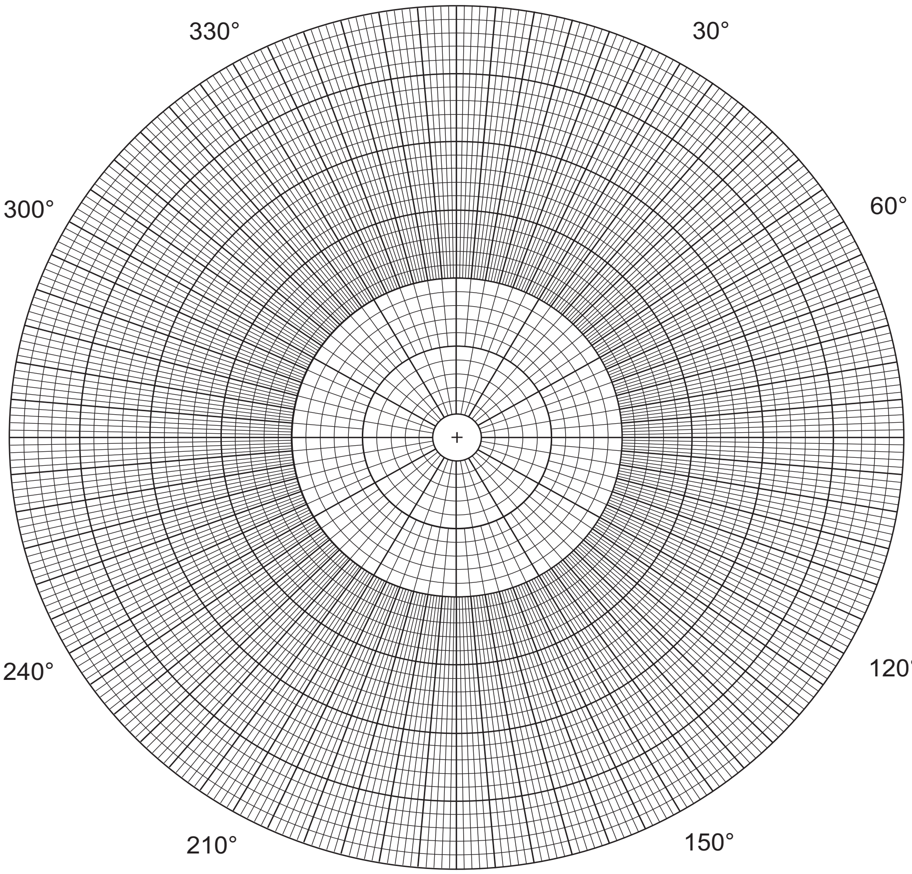
Step 4: Record the trial unbalance from above. g·mm (oz·in.).

Step 5: Double the trial unbalance in Step 4 (may use twice the actual residual unbalance). g·mm (oz·in.).

Step 6: Divide the answer in Step 5 by the answer in Step 3. scale factor.

You now have a correlation between the units on the polar chart and the actual balance.

Figure J.1—Residual Unbalance Worksheet



The circle you have drawn shall contain the origin of the polar chart. If it doesn't, the residual unbalance of the rotor exceeds the applied test unbalance.

NOTE Several possibilities for the drawn circle not including the origin of the polar chart are operator error during balancing, a faulty balancing machine transducer or cable, or a balancing machine not sensitive enough.

If the circle does contain the origin of the polar chart, the distance between origin of the chart and the centre of your circle is the actual residual unbalance present on the rotor correction plane. Measure the distance in units of scale you chose in Step 1 and multiply this number by the scale factor determined in Step 6. Distance in units of scale between origin and centre of the circle times scale factor equals actual residual unbalance.

Record actual residual unbalance ________________________________ g·mm (oz·in.)

Record allowable residual unbalance ______________________________ g·mm (oz·in.)

Correction plane ________ for rotor No. ______________________ (has/has not) passed.

By _____________________________ Date____________________________________

Figure J.2 — Residual Unbalance Worksheet — Polar Chart

Equipment (rotor) No.:	P–101	
Purchase order No.:		
Correction plane (inlet, drive end, etc. — use sketch):	A	
Balancing speed:	800	r/min
n = maximum allowable rotor speed:	4000	r/min
m (or W) = mass of journal (closest to this correction plane):	90.8	(lb)
$U\mathrm{max}$ = maximum allowable residual unbalance = 6 350m/n (4W/n)		
4 × 90.8 lb/ 4000 r/min	0.091	(oz·in.)
Trial unbalance (2 × $U\mathrm{max}$)	0.18	(oz·in.)
R = radius of mass placement:	6.0	(in.)
Trial unbalance mass = Trial unbalance/R		
0.18 oz-in./ 6.0 in.	0.03	(oz)

NOTE Conversion information: 1 oz = 28,350 g

Test data **Rotor sketch**

Position	Trial mass angular location	Balancing machine amplitude readout
1	0°	14,0
2	60°	12,0
3	120°	14,0
4	180°	23,5
5	240°	23,0
6	300°	15,5
7	0°	13,5

Test Data — Graphic Analysis

Step 1: Plot data on the polar chart (Figure J.4). Scale the chart so the largest and smallest amplitudes will fit conveniently.

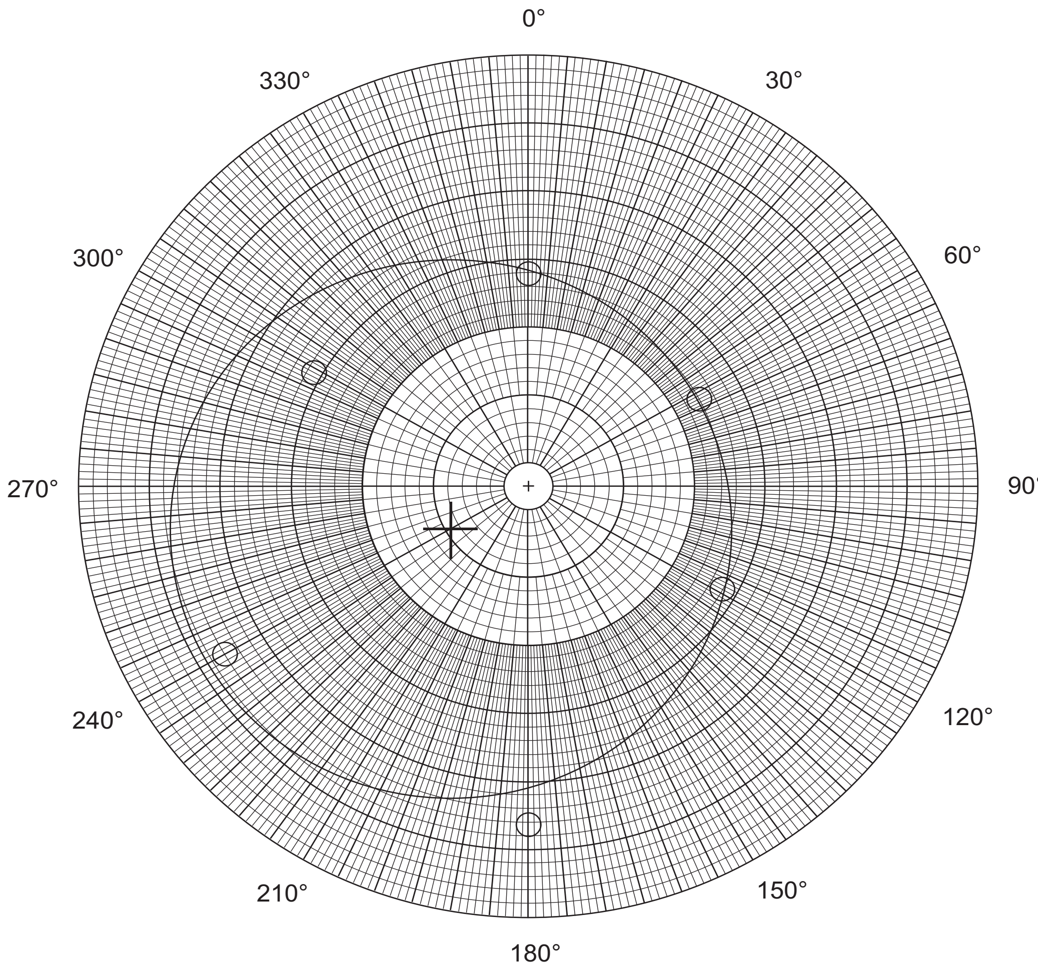
Step 2: With a compass, draw the best-fit circle through the six points and mark the centre of this circle.

Step 3: Measure the diameter of the circle in units of scale chosen in Step 1 and record.	35	units
Step 4: Record the trial unbalance from above.	0.18	(oz·in.)
Step 5: Double the trial unbalance in Step 4 (may use twice the actual residual unbalance).	0.36	(oz·in.)
Step 6: Divide the answer in Step 5 by the answer in Step 3.	0.01	scale factor

You now have a correlation between the units on the polar chart and the actual balance.

Figure J.3—Example of Completed Residual Unbalance Worksheet [17]

[17] This Example is merely an example for illustration purposes only. Each company should develop its own approach. It is not to be considered exclusive or exhaustive in nature. API makes no warranties, express or implied for reliance on or any omissions from the information contained in this document.



The circle you have drawn shall contain the origin of the polar chart. If it doesn't, the residual unbalance of the rotor exceeds the applied test unbalance.

NOTE Several possibilities for the drawn circle not including the origin of the polar chart are operator error during balancing, a faulty balancing machine transducer or cable, or a balancing machine not sensitive enough.

If the circle does contain the origin of the polar chart, the distance between origin of the chart and the centre of your circle is the actual residual unbalance present on the rotor correction plane. Measure the distance in units of scale you chose in Step 1 and multiply this number by the scale factor determined in Step 6. Distance in units of scale between origin and centre of the circle times scale factor equals actual residual unbalance.

Record actual residual unbalance 5.0 (0.01) = 0.05 g·mm (oz·in.)

Record allowable residual unbalance 0.091 g·mm (oz·in.)

Correction plane A for rotor No. P-01 (has) passed.

By John Inspector Date 2002-04-30

Figure J.4—Example of Completed Residual Unbalance Worksheet—Best-fit Circle for Residual Unbalance [18]

[18] This Example is merely an example for illustration purposes only. Each company should develop its own approach. It is not to be considered exclusive or exhaustive in nature. API makes no warranties, express or implied for reliance on or any omissions from the information contained in this document.

Annex K
(normative)

Pressure Temperature Profiles in the Recirculation Circuit

K.1 General

In general, pumpage from the pump casing enters the recirculation circuit to provide cooling and lubrication to the product lubricated bearings and cooling to the primary containment shell (MDP) and stator liner (CMP). Heat is added to the pumpage as it passes through the recirculation circuit. If sufficient pressure is not provided in the circuit, flashing of the pumpage will occur, and bearing failure could result. Flashing at the containment shell (MDP) and stator liner (CMP) could result in excessive temperature rise of the shell and subsequent cavitation or vapor lock in the recirculation circuit. To avoid these occurrences, the pressure temperature profile for the proposed pump unit is to be analyzed by the manufacturer for the minimum, rated, and maximum flow conditions and controlling properties of the pumped fluid to assure that an adequate pressure margin exists at all points in the recirculation circuit.

K.2 Profile Diagram

K.2.1 A pressure temperature profile diagram, defining all critical points in the recirculation circuit should be provided as a part of the vendor proposal and/or data package. Rated conditions and pumpage should be used to construct the profile. Figure K.1 shows a typical diagram for a magnetic drive pump. Figure K.2 shows a typical diagram for a canned motor pump.

K.2.2 Temperature rise through the recirculation circuit is plotted on the profile. Pressure should be plotted in absolute units. Vapor pressure of the pumpage should be plotted on the profile diagram for each critical point in the circuit for direct comparison to the circuit pressure.

K.2.3 Temperature rise through the pump must be calculated to determine the recirculation circuit inlet temperature, if the circuit is designed to use discharge volute pumpage. Alternative designs that utilize a heat exchanger require calculation of the temperature at the circuit inlet by the vendor. Circuits which are to be flushed from any outside source require the purchaser to supply flush liquid temperature.

K.2.4 Temperature rise and absolute pressure characteristics of the recirculation circuit should be based on qualification testing of a unit of similar design and construction when running on water. The qualification test records should be retained by the vendor as documentation of recirculation circuit assumptions.

K.2.5 Temperature rise in the recirculation circuit is a function of flow condition, pumpage specific gravity and specific heat. The temperature rise data developed on water must be factored to account for pumpage properties.

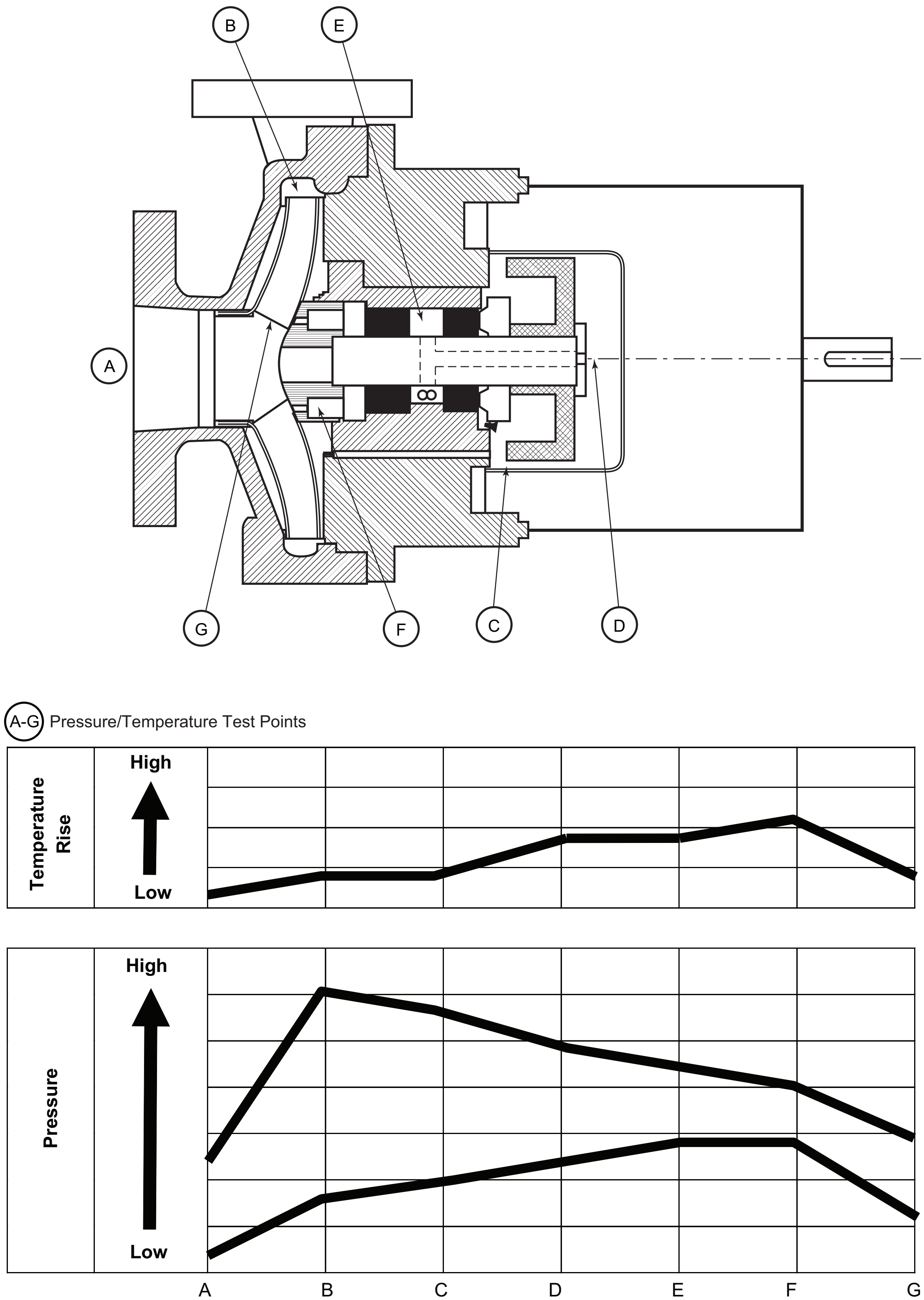


Figure K.1—Typical Pressure-Temperature Profile in Magnetic Drive Pump

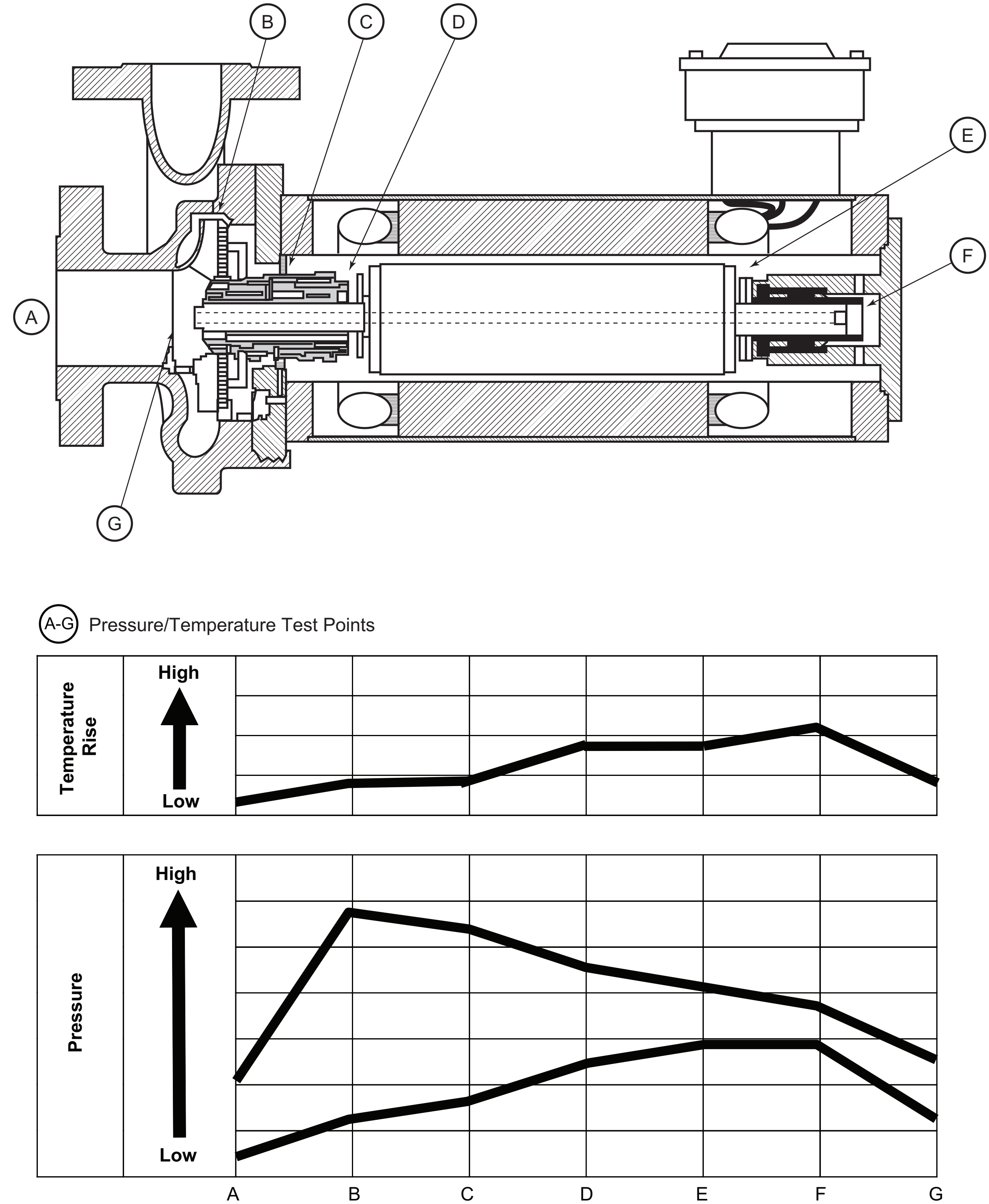


Figure K.2—Typical Pressure-Temperature Profile in Canned Motor Pump

Annex L
(informative)

Lateral Analysis

L.1 Lateral Analysis

L.1.1 General

Pumps covered by API 685 are designed to be classically stiff (see 6.8.1). However, a User is not prevented from applying these standards to high-speed applications or multistage designs. Under those circumstances the method and assessment of results recommended in this annex should be as specified in L.1.2 through L.1.5. Table L.1 illustrates the analysis process. The method and assessment specified are peculiar to liquid-handling turbomachines.

Table L.1—Rotor Lateral Analysis Logic Diagram

Step	If…	Then…
1	the pump is identical or similar to an existing pump…	analysis is not needed.
2	the rotor is classically stiff…	analysis is not needed.
3	neither 1 nor 2 is true…	analysis is required.

L.1.2 Natural Frequencies

The report shall state the following:

a) the rotor's first, second, and third "dry" bending natural frequencies;

NOTE These serve as useful reference points for subsequent analysis of the damped natural frequencies.

b) All the rotor's damped natural frequencies within the frequency range zero to 2.2 times maximum continuous speed, all the rotor's natural frequencies shall be calculated for the speed range 25 % to 125 % of rated, taking account of the following:

   1) Stiffness and damping at the following internal running clearances at the expected temperature:

      — as-new clearances, with water;

      — as-new clearances, with the pumped liquid;

      — twice (2×) the as-new clearances, with the pumped liquid.

   2) Stiffness and damping at the shaft seals (if labyrinth type);

   3) Stiffness and damping within the bearings for the average clearance and oil temperature. The effect of bearing stiffness and damping in pumps is generally minor in comparison to that of the internal running clearances; therefore, it is sufficient to analyse the bearings at their average clearance and oil temperature;

   4) Mass and stiffness of the bearing support structure;

   5) Inertia of the pump half-coupling hub and half the coupling spacer;

c) Values or the basis of the stiffness and damping coefficients used in the calculation.

L.1.3 Separation Margins and Damping

For both as-new and 2× as-new clearances, the damping factor versus separation margin between any bending natural frequency and the synchronous run line shall be within the "acceptable" region shown on Figure L.1. If this condition cannot be satisfied, the damped response to unbalance shall be determined (see L.1.4).

NOTE In liquid-handling turbomachines, the first assessment of a rotor's dynamic characteristics is based on damping versus separation margin, rather than amplification factor versus separation margin. Two factors account for this basis. First, the rotor's natural frequencies increase with rotative speed, a consequence of the differential pressure across internal clearances also increasing with rotative speed. On a Campbell diagram, Figure L.2, this means the closer separations are between the running speed and natural frequencies rather than between the running speed and the critical speeds. Because the amplification factor at the closer separations is not related to synchronous (unbalance) excitation of the rotor, it can only be developed by an approximate calculation based on the damping. Second, employing damping allows a minimum value to be specified for natural frequency to running speed ratios from 0.8 to 0.4, thereby assuring the rotor of freedom from significant subsynchronous vibration.

Logarithmic decrement, σ, is related to damping factor, π as given in Equation (L.1):

$$\sigma = (2 \times \pi)/(1 - Xi^2)^{0,5120} \qquad \text{(L.1)}$$

For π up to 0,4, the following approximate relationships between π, δ and amplification factor, F_a, are sufficiently accurate for practical purposes:

$$Xi = \delta/(2 \times \pi) = {}^1/2 \times F_a \qquad \text{(L.2)}$$

In liquid-handling turbomachines, critically damped conditions correspond to the following:

$\pi \geq 0.15$,

$\delta \geq 0.95$,

$F_a \leq 3.33$

L.1.4 Damped Unbalance Response Analysis

If the damping factor versus separation margin for a mode or modes is not acceptable by the criteria in Figure L.1, the rotor's damped response to unbalance shall be determined for the mode(s) in question on the following basis:

a) the pumped liquid;

b) clearance condition(s), as-new or 2× as-new, causing inadequate separation margin versus damping;

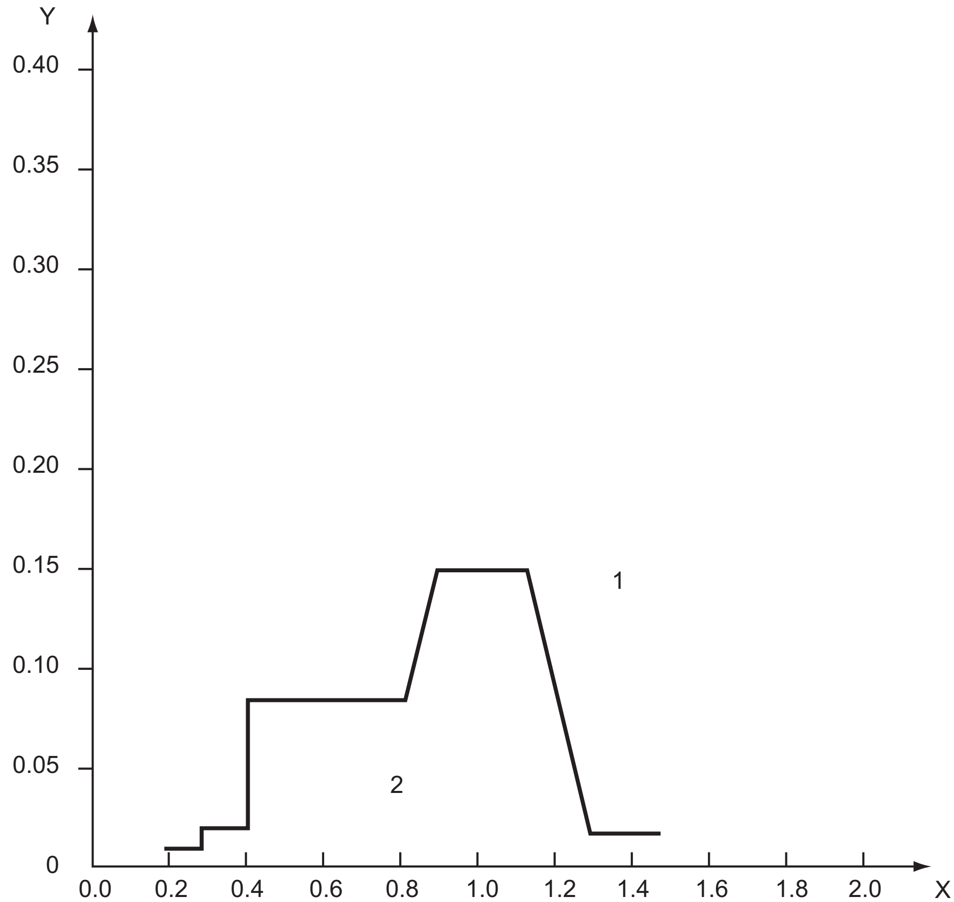
c) total unbalance of four times (4×) the allowable value (see 6.8.4.1) lumped at one or more points to excite the mode(s) being investigated.

Only one mode shall be investigated in each computer run.

L.1.5 Allowable Displacement

The peak-to-peak displacement of the unbalanced rotor at the point(s) of maximum displacement shall not exceed 35 % of the diametral running clearance at that point.

NOTE In centrifugal pumps, the typical damped response to unbalance does not show a peak in displacement at resonance large enough to assess the amplification factor. With this limitation, assessment of the damped response to unbalance is restricted to comparing rotor displacement to the available clearance.



Key

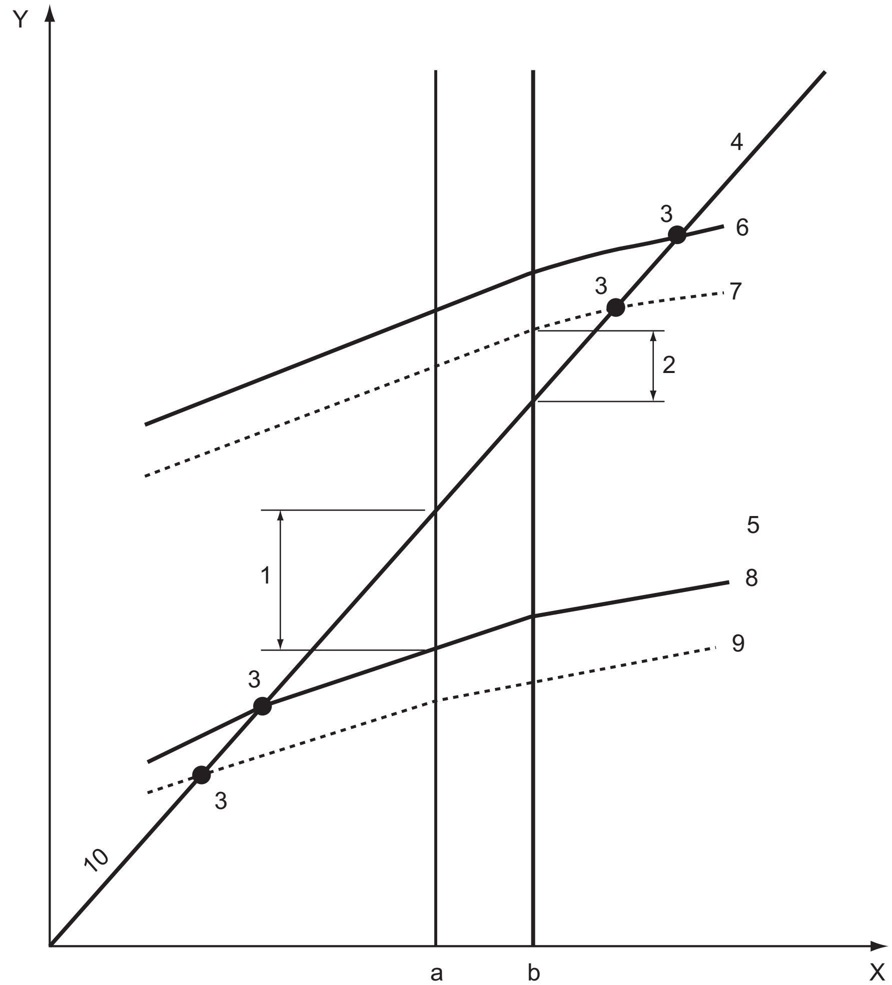
X frequency ratio

Y damping factor

1 acceptable region

2 unacceptable region

Figure L.1—Damping Factor versus Frequency Ratio



Key

X	pumping speed, expressed in rpm	6	as-new clearance
Y	frequency, f_n	7	2x clearance
1	minimum separation margin, 1st f_n	8	as-new clearance
2	minimum separation margin, 2nd f_n	9	2x clearance
3	critical speeds	10	run line
4	second bending	a	min.
5	first bending	b	max.

Figure L.2—Typical Campbell Diagram

L.2 Shop Verification of Rotor Dynamic Characteristics

L.2.1 If specified, the dynamic characteristics of the rotor shall be verified during the shop test. The rotor's actual response to unbalance shall be the basis for confirming the validity of the damped lateral analysis. This response is measured during either variable-speed operation from rated speed down to 75 % of the first critical speed or during coast-down. If the damped response to unbalance was not determined in the original rotor analysis (see L.1.4), this response shall be determined for a pump with new clearances handling water before proceeding with shop verification. The test unbalances shall be vectorially added in phase with the residual unbalance, at locations determined by the manufacturer (usually at the coupling and/or thrust collar).

NOTE The principal objective of shop verification by response to unbalance is to verify the existence of a critical speed (vibration peak) within the tolerance of the calculated value, or, if the analysis predicted a highly damped critical speed, the absence of a vibration peak within tolerance of the calculated value. Shop verification by this method is feasible only for pumps that have sleeve bearings and are furnished with proximity probe pairs at each journal bearing.

L.2.2 The magnitude and location of the test unbalance(s) shall be determined from a calibration of the rotor's sensitivity to unbalance. The calibration shall be performed by obtaining the vibration orbits at each bearing, filtered to rotor speed (1×), during two trial runs as follows:

a) with the rotor as-built;

b) with trial unbalance weights added 90° from the maximum displacement in run a).

The magnitude of the test unbalances should be such that the calculated maximum shaft displacement caused by the resultant total unbalance (residual plus test) is 150 % to 200 % of the allowable displacement from Table 6 at the bearing probes, but shall not exceed eight times the maximum allowable rotor unbalance.

L.2.3 During the test, the rotor's speed, vibration displacement and corresponding phase angle, filtered to rotor speed (1×), shall be measured and recorded.

L.2.4 The rotor's characteristics shall be considered verified if the following requirements are met:

a) observed critical speed(s) (distinct vibration peak and appropriate phase shift) within ± 10 % of the calculated value(s);

b) measured vibration amplitudes within 35 % of the calculated values.

Highly damped critical speeds may not be observable, therefore the absence of rotor response in the region of a calculated highly damped critical speed is verification of the analysis.

L.2.5 If the acceptance criteria given in L.2.4 are not met, the stiffness or damping coefficients, or both, used in the natural frequency calculation shall be adjusted to produce agreement between the calculated and measured results. The coefficients of one type of element, annular clearances with $L/D < 0.15$, annular clearances $L/D > 0.15$, impeller interaction, and bearings shall be adjusted with the same correction factor. Once agreement is reached, the same correction factors shall be applied to the calculation of the rotor's natural frequencies and damping for the pumped liquid, and the rotor's separation margins versus damping factors rechecked for acceptability.

Of the coefficients used in rotor lateral analysis, those for damping in annular clearances have the highest uncertainty and are therefore usually the first to be adjusted. The stiffness coefficients of annular clearances typically have low uncertainty and, therefore, should be adjusted only on the basis of supporting data. Adjustments of bearing coefficients require specific justification because the typical values are based on reliable empirical data.

L.2.6 Alternative methods of verifying the rotor's dynamic characteristics, for example, variable frequency excitation with the pump at running speed to determine the rotor's natural frequencies, are available. The use of alternative methods and the interpretation of the results shall be agreed between the purchaser and manufacturer.

L.3 Documentation

The report on a lateral analysis shall include the following:

a) results of initial assessment;

b) fundamental rotor data used for the analysis;

c) Campbell diagram (see Figure L.2);

d) plot of damping ratio versus separation margin;

e) mode shape at the critical speed(s) for which the damped response to unbalance was determined (see L.1.4);

f) Bode plot(s) from shop verification by unbalance (see L.2.3);

g) summary of analysis corrections to reach agreement with shop verification (see L.2.5).

Items e) through g) shall be furnished only if the activity documented was required by the analysis or specified by the purchaser.

Annex M
(normative)

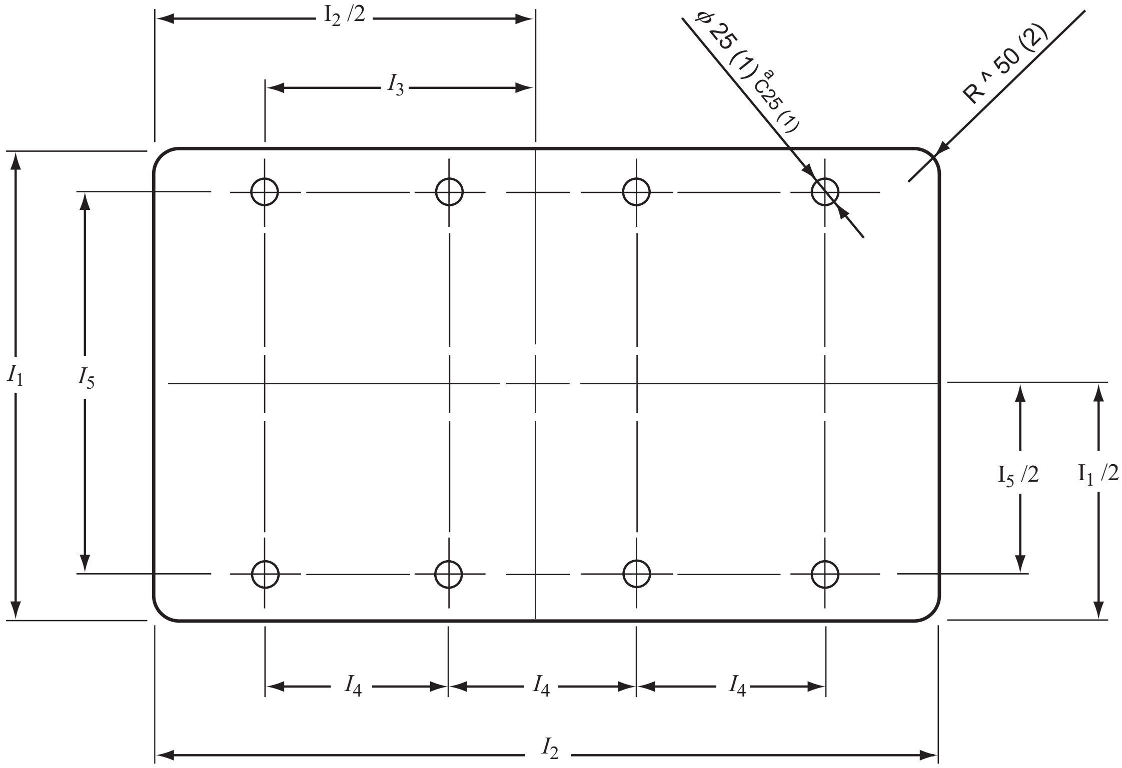
Standard Baseplates

Table M.1—Dimensions of Standard Baseplates

Dimensions in millimeters (inches)

Baseplate number	Number of holes per side	l_1 ±13 (0.5)	l_2 ±25 (1.0)	l_3 ±3 (0.12)	l_4 ±3 (0.12)	l_5 ±3 (0.12)
0.5	3	760 (30.0)	1230 (48.5)	465 (18.25)	465 (18.25)	685 (27.0)
1	3	760 (30.0)	1535 (60.5)	615 (24.25)	615 (24.25)	685 (27.0)
1.5	3	760 (30.0)	1840 (72.5)	770 (30.25)	770 (30.25)	685 (27.0)
2	4	760 (30.0)	2145 (84.5)	920 (36.25)	615 (24.16)	685 (27.0)
2.5	3	915 (36.0)	1535 (60.5)	615 (24.25)	615 (24.25)	840 (33.0)
3	3	915 (36.0)	1840 (72.5)	770 (30.25)	770 (30.25)	840 (33.0)
3.5	4	915 (36.0)	2145 (84.5)	920 (36.25)	615 (24.16)	840 (330)
4	4	915 (36.0)	2450 (96.5)	1075 (42.25)	715 (28.16)	840 (33.0)
5	3	1065 (42.0)	1840 (72.5)	770 (30.25)	770 (30.25)	990 (39.0)
5.5	4	1065 (42.0)	2145 (84.5)	920 (36.25)	615 (24.16)	990 (39.0)
6	4	1065 (42.0)	2450 (96.5)	1075 (42.25)	715 (28.16)	990 (39.0)
6.5	5	1065 (42.0)	2755 (108.5)	1225 (48.25)	615 (24.12)	990 (39.0)
7	4	1245 (49.0)	2145 (84.5)	920 (36.25)	615 (24.16)	1170 (46.0)
7.5	4	1245 (49.0)	2450 (96.5)	1075 (42.25)	715 (28.16)	1170 (46.0)
8	5	1245 (49.0)	2755 (108.5)	1225 (48.25)	615 (24.12)	1170 (46.0)
9	4	1395 (55.0)	2145 (84.5)	920 (36.25)	615 (24.16)	1320 (52.0)
9.5	4	1395 (55.0)	2450 (96.5)	1075 (42.25)	715 (28.16)	1320 (52.0)
10	5	1395 (55.0)	2755 (108.5)	1225 (48.25)	615 (24.12)	1320 (52.0)
11	4	1550 (61.0)	2145 (84.5)	920 (36.25)	615 (24.16)	1475 (58.0)
11.5	4	1550 (61.0)	2450 (96.5)	1075 (42.25)	715 (28.16)	1475 (58.0)
12	5	1550 (61.0)	2755 (108.5)	1225 (48.25)	615 (24.12)	1475 (58.0)

NOTE See Figure M.1 for explanation of dimensions.



a For 20 mm (3/4 in.) anchor bolts.

Figure M.1—Standard Baseplate

Annex N
(informative)

Inspector's Checklist

The levels indicated in Table N.1 may be characterized as follows:

— Level 1 is typically used for pumps in general service;

— Level 2 comprises performance and material requirements and is more stringent than level 1;

— Level 3 items should be considered for pumps in critical services.

The required inspection shall be indicated in the first column as:

— C: Certification only;

— O: Observed inspection;

— W: Witnessed inspection.

Table N.1—Inspector's Checklist

Inspection required C, O, or W	Item	API 685-2nd subclause number	Date inspected	Inspected by	Status
Level 1 - Basic					
	Caution tag if manual venting is required	6.1.10			
	Casing marking (serial no.)	6.11.3			
	Motors and electrical components area classification	6.1.25			
	Material grade and manufacturer's ID symbols on fasteners	6.1.36			
	Casing jackscrews	6.2.11			
	Nozzle size, rating and finish	6.3.2			
	Baseplate requirements	9.1.5.3			
	Certified hydrotest	8.3.2			
	Performance within tolerance (certified)	8.3.3			
	NPSH3 within tolerance (certified)	8.3.4.4			
	Vibration within tolerance	8.3.3.4.1			
	Rotation arrow	6.11.4			
	Overall dimensions and connection locations [a]	Outline drawing			
	Anchor bolt layout and size	Outline drawing			
	Auxiliary piping flow diagram	Outline drawing			
	Piping fabrication and installation	7.5			
	Equipment nameplate data	6.11.2, 9.1.1.9, and 9.2.5			

Table N.1—Inspector's Checklist (Continued)

Inspection required C, O, or W	Item	API 685-2nd subclause number	Date inspected	Inspected by	Status
	Inspect for cleanliness	8.2.3.1			
	Storage preservation instructions	8.4.7			
	Rust prevention	8.4.2.3			
	Painting	8.4.2.2			
	Preparation for shipment	8.4			
	Impression stamp of auxiliary connections	8.4.3			
	Shipping documents and tags	8.4.5			
	Torque rating of coupling on nameplate	9.1.1.9			
	Bearing ID on nameplate	9.1.1.9			
	Motor resistance and dielectric tests	9.2.7			
Level 2 – Intermediate (Add to Level 1)					
	Copies of sub-vendor purchase				
	Material certification	8.2.1.1			
	Non-destructive examination (Components)	8.2.2.1			
	Hydrotest witnessed	8.3.2			
	Building records (runouts, clearances)	6.6.4			
	Performance and NPSH tests witnessed	8.3.3 and 8.3.4.4			
Level 3 – Special (add to levels 1 and 2)					
	Welding procedures approved	6.10.3.1			
	Welding repairs approved	6.10.2.5			
	Welding repair maps	6.10.2.5			
	Impeller / rotor balancing	6.8.4			
	Mech run to temperature stabilization	8.3.4.2.1			
	Mech run for 4 hours	8.3.4.2.2			
	Complete unit test	8.3.4.5			
	Sound level test	8.3.4.6			
	Auxiliary equipment test	8.3.4.7			
	Thrust Bearing Load Test	8.3.4.3			
	Secondary Containment/Control System Hydrotest	8.3.4.8 8.3.2.16			
	Secondary Containment/Control System Instrument Functional Test	8.3.4.9			
	Magnetic coupling static torque test	9.1.6.1			
	Hardness testing of parts, etc.	8.2.3.2			

[a] Check against certified dimensional outline drawing.

Annex O
(informative)

Vendor Drawing and Data Requirements

O.1 General

Figure O.1 shows an example distribution record (schedule). A more detailed description of the entries, keyed to the list number (a, b, c, etc.), is given in O.2.1 for the pump and in O.2.2 for the motor.

TYPICAL
VENDOR DRAWING AND DATA REQUIREMENTS

JOB NO. ____________ ITEM NO. ____________
PURCHASE ORDER NO. ____________ DATE ____________
REQUISITION NO. ____________ DATE ____________
ENQUIRY NO. DATE ____________
PAGE __1__ OF __2__ BY ____________

FOR ____________
SITE ____________
SERVICE ____________

REVISION ____________
UNIT ____________
NO. REQUIRED ____________

Proposal [a] Bidder shall furnish an electronic copy and _____ paper copies of data for all items indicated by an X.

Review [b] Vendor shall furnish an electronic copy and _____ paper copies of drawings and data indicated.

Final Vendor shall furnish an electronic copy and _____ paper copies of drawings and data indicated.
Vendor shall furnish _____ physical copies of operating & maintenance manuals / data books & _____ CD's of same.

DISTRIBUTION RECORD

Final - Received from vendor
FINAL - Due from vendor [c]
Review - Returned to vendor
Review - Received from vendor
Review - Due from vendor [c]

Proposal	Review	Final	DESCRIPTION	Review - Due from vendor	Review - Received from vendor	Review - Returned to vendor	FINAL - Due from vendor	Final - Received from vendor
			Pump					
			a Certified dimensional outline drawing					
			b Cross-sectional drawings and bills of materials					
			c Secondary sealing feature drawing and bills of materials					
			d Shaft coupling assembly drawing and bill of materials (MDP only)					
			e Rotor cavity flush piping schematic and bill of materials					
			f Cooling or heating piping schematic and bill of materials					
			g Electrical and instrumentation schematics, wiring diagrams, and bills of materials					
			h Electrical and instrumentation arrangement drawing and list of connections					
			i Performance curves					
			j Breakaway torque (MDP only)					
			k Speed-torque curve (MDP only)					
			l Temperature-pressure profile					
			m Vibration analysis data					
			n Damped unbalanced response analysis (flexible shaft designs)					
			o Lateral critical speed analysis (prototype designs)					
			p Certified hydrostatic test data					
			q Material certifications					
			r Progress reports					
			s Weld procedures					
			t Performance test data					
			u Optional test data and reports					
			v Residual unbalance check					
			w Data sheets applicable to proposals, purchase and as-built					
			x Noise data sheets					
			y As-built clearances					
			z Installation, operation and maintenance manuals					
			aa Spare parts recommendations and price list					
			bb Preservation, packaging and shipping procedures					
			cc Material safety data sheets					

Figure O.1—Example Distribution Record

TYPICAL
VENDOR DRAWING AND DATA REQUIREMENTS

JOB NO. ____________ ITEM NO. ____________
PURCHASE ORDER NO. ____________ DATE ____________
REQUISITION NO. ____________ DATE ____________
ENQUIRY NO. DATE ____________
PAGE __2__ OF __2__ BY ____________

FOR ____________
SITE ____________
SERVICE ____________

REVISION ____________
UNIT ____________
NO. REQUIRED ____________

Proposal [a] Bidder shall furnish an electronic copy and _____ paper copies of data for all items indicated by an X.

Review [b] Vendor shall furnish an electronic copy and _____ paper copies of drawings and data indicated.

Vendor shall furnish an electronic copy and _____ paper copies of drawings and data indicated.

Final Vendor shall furnish _____ physical copies of operating & maintenance manuals / data books & _____ CD's of same.

DISTRIBUTION RECORD

Final - Received from vendor
FINAL - Due from vendor [c]
Review - Returned to vendor
Review - Received from vendor
Review - Due from vendor [c]

Proposal	Review	Final	DESCRIPTION	Review - Due from vendor	Review - Received from vendor	Review - Returned to vendor	FINAL - Due from vendor	Final - Received from vendor
			Motor (MDP only)					
			a Certified dimensional outline drawing					
			b Cross-sectional drawing and bill of materials					
			c Data sheets applicable to proposals, purchase and as-built					
			d Noise data sheets					
			e Performance data					
			f Certified drawings of auxiliary systems					
			g Installation operation and maintenance manuals					
			h Spare parts recommendations and price list					
			i Material safety data sheets					

[a] Proposal drawings and data do not have to be certified or as-built. Typical data shall be clearly identified as such.
[b] Purchaser will indicate in this column the time frame or submission of materials using the nomenclature given below.
[c] Bidder shall complete these two columns to reflect promised actual distribution schedule and include this form with the proposal.

Send all drawings and data to ____________

____

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

Nomenclature:
_________ S — number of weeks prior to shipment.
_________ F — number of weeks after firm order.
_________ D — number of weeks after receipt of approved drawings.

Vendor ____________
Date ____________ Vendor reference ____________
Signature ____________

Figure O.1—Example Distribution Record (continued)

O.2 Description

O.2.1 Pump

a) Certified dimensional outline drawing, including the following:

   1) size, rating and location of all purchaser connections,

   2) approximate overall and handling masses,

   3) overall dimensions, and maintenance and dismantling clearances,

   4) shaft centreline height,

   5) dimensions of baseplates (if furnished) complete with diameters, number and locations of bolt holes, and the thicknesses of sections through which it is necessary that the bolts pass,

   6) grouting details,

   7) forces and moments for suction and discharge nozzles,

   8) center of gravity and lifting points,

   9) shaft end separation and alignment data (MDP only),

   10) direction of rotation,

   11) winterization, tropicalization and/or noise attenuation details, if required.

b) cross-sectional drawings and bills of materials;

c) secondary sealing feature drawing and bill of materials;

d) shaft coupling assembly drawing and bill of materials, including allowable misalignment tolerances and the style of the coupling guard;

e) rotor cavity flush piping schematic and bill of materials, including fluid flows, pressure, pipe and valve sizes, instrumentation, and orifice sizes;

f) cooling or heating schematic and bill of materials, including cooling or heating media, liquid flows, pressure, pipe and valve sizes, instrumentation, and orifice sizes;

g) electrical and instrumentation schematics, wiring diagrams and bills of materials, including the following:

   1) vibration alarm and shutdown limits,

   2) temperature alarm and shutdown limits,

   3) pressure alarm and shutdown limits,

   4) level alarm and shutdown limits,

   5) driver;

h) electrical and instrumentation arrangement drawing and list of connections;

i) performance curves;

j) breakaway torque (MDP only);

k) speed-torque curve (MDP only);

l) temperature-pressure profile;

m) vibration analysis data;

n) damped unbalanced response analysis (flexible shaft designs);

o) lateral critical speed analysis (applicable to prototype pump designs): the required number of lateral critical analysis reports, no later than 3 months after the date of order. The reports shall be as required in O.1.2 and O.1.3.

p) certified hydrostatic test data;

q) material certifications: the vendor's physical and chemical data from mill reports (or certification) of pressure parts, impellers and shafts;

r) progress reports detailing the cause of any delays: the reports shall include engineering, purchasing, manufacturing and testing schedules for all major components. Planned and actual dates, and the percentage completed, shall be indicated for each milestone in the schedule.

s) weld procedures;

t) performance test data: certified shop logs of the performance test, record of shop test data (which the vendor shall maintain for at least 20 years after the date of shipment); the vendor shall submit certified copies of the test data to the purchaser before shipment;

u) optional tests data and reports: optional tests data and reports include thrust balance test, NPSH required test, complete unit test, sound level test, auxiliary equipment test, bearing housing resonance test, and any other tests mutually agreed upon by the purchaser and vendor;

v) certified rotor balance data for multistage pumps;

w) residual unbalance check;

x) data sheets applicable to proposals, purchase, and as-built;

y) noise data sheets;

z) as-built clearances;

aa) instruction manuals describing installation, operation and maintenance procedures; each manual shall include the following sections:

1) Section 1 — Installation:

   i) storage,

   ii) foundation,

iii) grouting,

iv) setting equipment, rigging procedures, component masses and lifting diagram,

v) alignment (MDP only),

vi) piping recommendations,

vii) composite outline drawing for pump/driver train, including anchor-bolt locations,

viii) dismantling clearances;

2) Section 2 — Operation:

   i) start-up, including tests and checks before start-up,

   ii) routine operational procedures,

   iii) lubricating oil recommendations;

3) Section 3 — Disassembly and assembly:

   i) rotor in pump casing,

   ii) journal bearings,

   iii) thrust bearings (including clearance and preload on rolling element bearings),

   iv) secondary shaft seals (MDP only),

   v) thrust pads,

   vi) allowable wear of running clearances,

   vii) fits and clearances for rebuilding,

   viii) routine maintenance procedures and intervals,

   ix) safety concerns;

4) Section 4 — Performance curves, including differential head, efficiency, water NPSH3, and brake horsepower versus flowrate for all operating conditions specified on the data sheets;

5) Section 5 — Vibration data:

   i) vibration analysis data,

   ii) lateral critical speed analysis (for prototype pump designs only);

6) Section 6 — Technical data:

   i) Break-away torque (MDP only),

   ii) Speed-torque curves (MDP only),

   iii) Temperature – pressure profile;

7) Section 7 — As-built data:

   i) as-built data sheets,

   ii) as-built clearances,

   iii) rotor balance data for multi-stage pumps,

   iv) noise data sheets,

   v) performance data;

8) Section 8 — Drawing and data requirements:

   i) certified dimensional outline drawing and list of connections,
   ii) cross-sectional drawing and bill of materials,
   iii) secondary shaft seal drawing and bill of materials,
   iv) electrical and instrumentation schematics, wiring diagrams and bills of materials,
   v) electrical and instrumentation arrangement drawing and list of connections,
   vi) coupling assembly drawing and bill of materials (MDP only),
   vii) rotor cavity circulation schematic and bill of materials,
   viii) rotor cavity flush piping, instrumentation, arrangement and list of connections,
   ix) cooling and heating schematic and bill of materials,
   x) cooling or heating piping, instrumentation arrangement and list of connections;

ab) spare parts recommendations and price list;

ac) preservation, packaging and shipping procedure;

ad) material safety data sheets (MSDS) for shipping lubricants and preservatives.

O.2.2 Motor

a) Certified dimensional outline drawing for motor and all auxiliary equipment, including the following:

   1) size, location, and purpose of all purchaser connections, including conduit, instrumentation, and any piping or ducting,

   2) ASME rating and facing for any flanged connections,

   3) size and location of anchor bolt holes and thicknesses of sections through which bolts must pass,

   4) total mass of each item of equipment (motor and auxiliary equipment) plus loading diagrams, heaviest mass, and name of the part,

   5) overall dimensions and all horizontal and vertical clearances necessary for dismantling, and the approximate location of lifting lugs,

   6) shaft centreline height,

   7) shaft end dimensions, plus tolerances for the coupling,

   8) direction of rotation;

b) cross-sectional drawing and bill of materials, including the axial rotor float;

c) data sheets applicable to proposals, purchase, and as-built;

d) noise data sheets;

e) performance data including the following:

1) for induction motors 150 kW (200 hp) and smaller:
   i) efficiency and power factor at one-half, three-quarter, and full load,
   ii) speed-torque curves;
2) for induction motors larger than 150 kW (200 hp) and larger, certified test reports for all test run and performance curves as follows:
   i) time-current heating curve,
   ii) speed-torque curves at 70 %, 80 %, 90 % and 100 % of rated voltage,
   iii) efficiency and power factor curves from 0 to rated service factor,
   iv) current versus load curves from 0 to rated service factor,
   v) current versus speed curves from 0 to 100 % of rated speed;

f) certified drawings of auxiliary systems, including wiring diagrams, for each auxiliary system supplied; the drawings shall clearly indicate the extent of the system being supplied by the manufacturer and the extent being supplied by others;

g) motor instruction manuals describing installation, operating and maintenance procedures. Each manual shall include the following sections:

1) Section 1 — Installation:
   i) storage,
   ii) setting motor, rigging procedures, component masses and lifting diagram,
   iii) piping and conduit recommendations,
   iv) composite outline drawing for motor, including locations of anchor-bolt holes,
   v) dismantling clearances;
2) Section 2 — Operation:
   i) start-up, including check before start-up,
   ii) normal shutdown,
   iii) operating limits, including number of successive starts,
   iv) lubricating oil recommendations;
3) Section 3 — Disassembly and assembly instructions:
   i) rotor in motor,
   ii) journal bearings,
   iii) seals,
   iv) routine maintenance procedures and intervals;
4) Section 4 — Performance data required by O.2.2e):
5) Section 5 — Data sheets:
   i) as-built data sheets,
   ii) noise data sheets;

6) Section 6 — Drawing and data requirements:

   i) certified dimensional outline drawing for motor and all auxiliary equipment, with list of connections,

   ii) cross-sectional drawing and bill of materials;

h) spare parts recommendations and price list;

i) material safety data sheets for shipping lubricants and preservatives.

Annex P
(informative)

Test Data Summary

Figure P.1 shows an example of a test data summary form. Figures P.2 and P.3 show examples of a test curve format in SI units and USC units, respectively.

TEST DATA SUMMARY			
	Customer		Curve No.
	Purchaser		Test date
	Purchase order No.		
	Item No.		Certified by:
	Pump serial No.		(Vendor representative)
	Size and type		Witnessed by:
	No. of stages		(Purchaser representative)

Overall pump performance (Table 11)

		Rated	Interpolate value	Actual deviation ± %	Acceptance tolerance ± %
	Flow				
	Head				
	Power				
	NPSH3				
	Shutoff head				
	Speed, r/min				

Pump construction data

Stage 1			Series stages		
	Impeller diameter	mm (in)		Impeller diameter	mm (in.)
	Impeller pattern No.			Impeller pattern No.	
	No. of vanes			No. of vanes	
	Volute/diffuser pattern No.			Volute/diffuser pattern No.	
	Blade tip clearance	%		Blade tip clearance	%

Mechanical performance

Maximum vibration levels recorded within specified flow region (6.8.3)

	Rated flow		Preferred operating region		Allowable operating region	
	Tested	Specified	Tested	Specified	Tested	Specified
Housing velocity: Drive end: Overall/filtered						
Non-drive end: Overall/filtered						
Shaft displacement: Drive end: Overall/filtered						
Non-drive end: Overall/filtered						

Bearing Lubrication / circulated Fluid temperatures °C (°F)
[8.3.3.2.2, 8.3.3.4.2, and 9.1.4.2.3]

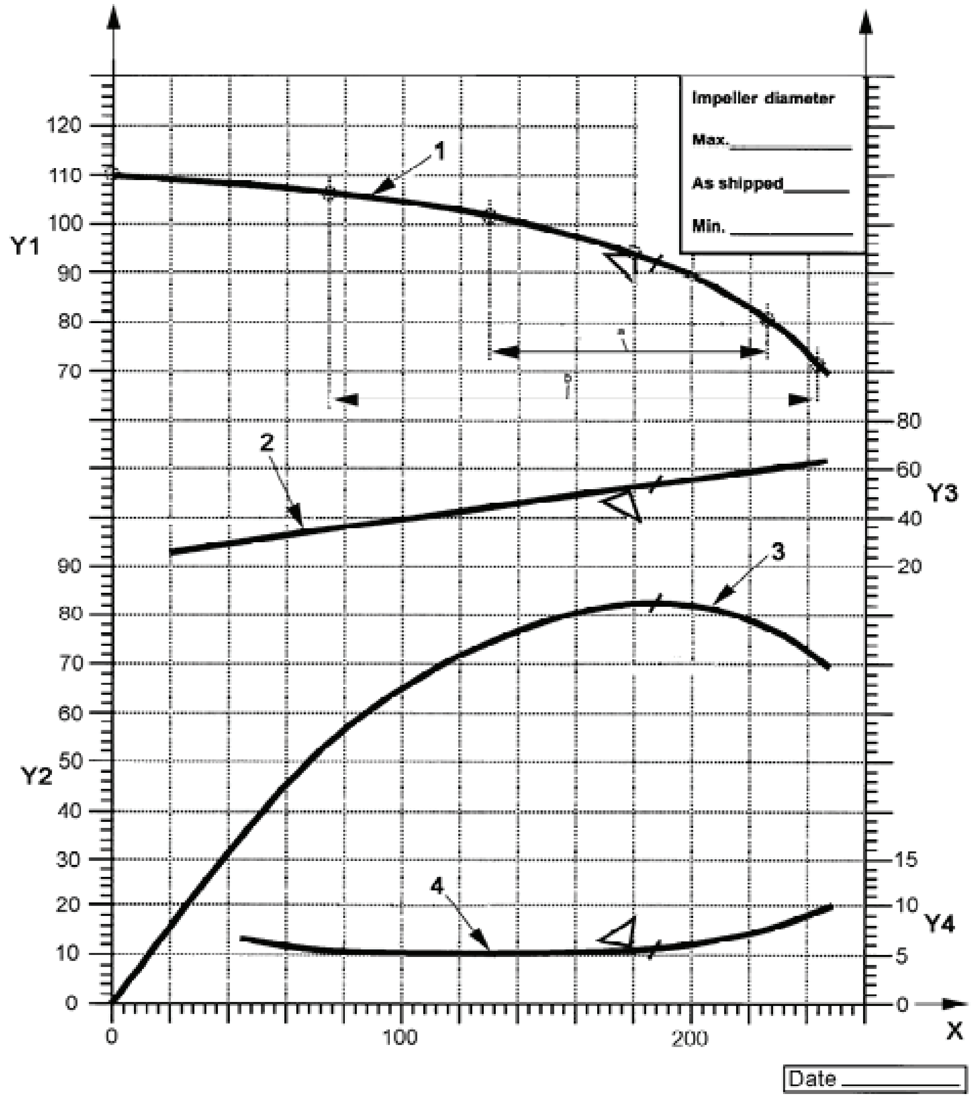
Circulated Fluid			Ring oil or splash lubrication		
	Fluid supply temp.			Ambient temp.	
	Fluid temp. rise			Oil temp. rise	
	Fluid return temp.			Oil sump temp.	

NOTE 1 This mechanical performance summary is for recording test levels for each operating region relative to specified values. It is not intended to replace shop test data logs.

NOTE 2 Units of measurement shall be mm/s (in./s) RMS for velocity, mm (mils) peak/peak for displacement, and °C (°F) for temperature.

Figure P.1—Test Data Summary Form

Pump serial no. ________	Pumped liquid ________	Curve No.
Size and type ________	Relative density ________	Rated point
No. of stages ________	Temperature ________ °C	Flowrate m³/h = 180.0
Speed, r/min ________	Kinematic viscosity ________ mm²/s	Head m= 94
Impeller no. ________	Impeller eye area ________ mm²	NPSH3 m= 6.3
		Power kW = 55.9
		Calculated efficiency %: 82.3 Ref.



Key

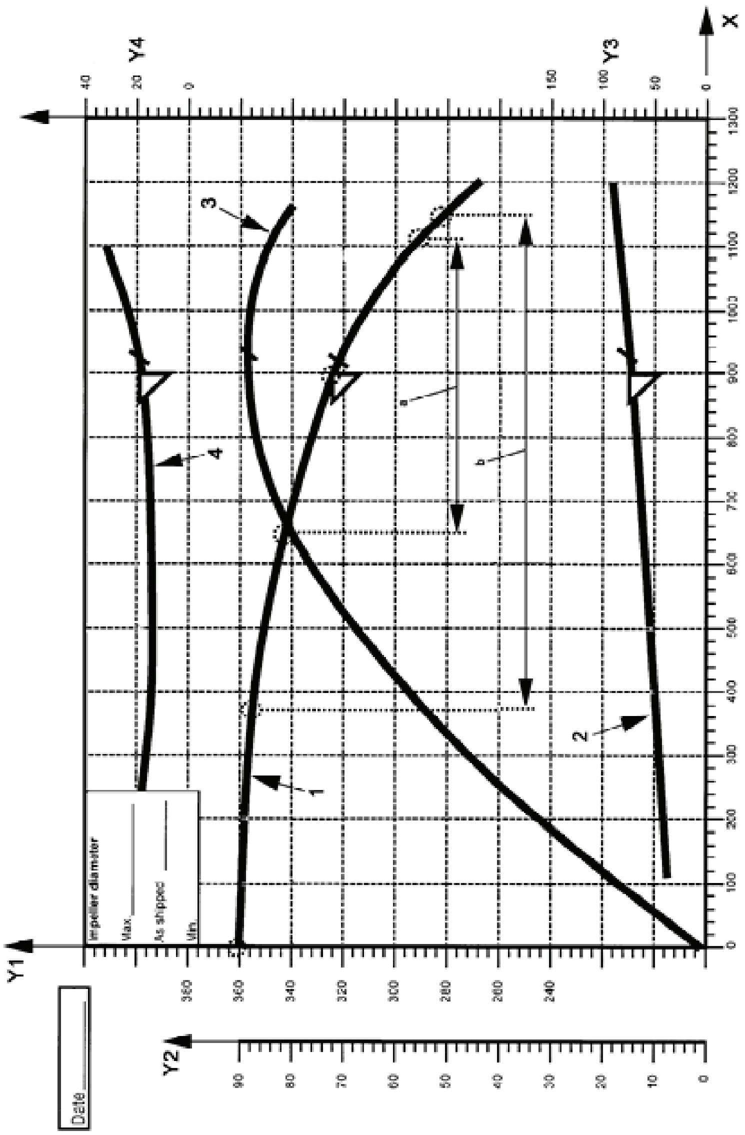
X	flowrate, expressed in cubic meters per hour	1	head
Y1	head, expressed in meters	2	power
Y2	efficiency, expressed in percentage	3	efficiency
Y3	power, expressed in kilowatts	4	NPSH3
Y4	NPSH3, expressed in meters		

[a] Preferred operating region.
[b] Allowable operating region

NOTE Values for scales, flow, head, NPSH3, power efficiency are for illustration only.

Figure P.2—Example of Test Curve Format (SI units)

Pump serial no. ____________	Pumped liquid ____________	Curve No.
Size and type ____________	Relative density ____________	Rated point
No. of stages ____________	Temperature ____________ °F	Flowrate U.S.gal/min = 900.0
Speed, r/min ____________	Kinematic viscosity ____________ cSt	Head ft = 325
Impeller no. ____________	Impeller eye area ____________ in.²	NPSH3 ft = 17.1
		Power bhp = 72.4
		Calculated efficiency %: 88.3 Ref.



Key

X flowrate, expressed in U.S. gallons per minute
Y1 head, expressed in feet
Y2 efficiency, expressed in percentage
Y3 power, expressed in brake horsepower
Y4 NPSH3, expressed in feet

1 head
2 power
3 efficiency
4 NPSH3

[a] Preferred operating region.
[b] Allowable operating region

NOTE Values for scales, flow, head, NPSH3, power efficiency are for illustration only.

Figure P.3—Example of Test Curve Format (USC units)

Annex Q
(informative)

Specific Speed and Suction-Specific Speed

Specific speed, *n*s, is an index number relating to a pump's performance at best efficiency point flowrate with the maximum diameter impeller at a given rotative speed. Specific speed is defined by equation (Q.1):

$$n_s = n(q)^{0.5}/(H)^{0.75} \tag{Q.1}$$

where

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

q is the total pump flowrate, expressed in cubic meters per second;

H is the head per stage, expressed in meters.

NOTE 1 Specific speed derived using SI units multiplied by a factor of 51.64 is equal to specific speed in USC units.

NOTE 2 For simplicity, industry omits the gravitational constant from the dimensionless equations for specific speed and suction-specific speed.

An alternative definition of specific speed is sometimes used (flowrate per impeller eye rather than total flowrate). The purchaser is cautioned to understand which definition is being used when comparing data.

Suction-specific speed, *S*, an index number relating to a pump's suction performance, is calculated at best efficiency point flowrate with the maximum diameter impeller at a given rotative speed and provides an assessment of a pump's susceptibility to internal recirculation. It is defined by equation (Q.2):

$$S = n(q)^{0.5}/(NPSH3)^{0.75} \tag{Q.2}$$

where

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

q is the flowrate per impeller eye, expressed in cubic metres per second (US gallons per minute), equal to one of the following:

— total flowrate for single-suction impellers,

— one-half the total flowrate for double-suction impellers;

$NPSH3$ is the net positive suction head required, expressed in meters.

NOTE 3 Suction-specific speed derived using SI units multiplied by a factor of 51.64 is equal to suction-specific speed in USC units. The USC symbol N_{SS} is sometimes used to designate suction-specific speed.

Annex R
(informative)

Typical Datasheets

This annex contains typical datasheets for use by the purchaser and the vendor. The datasheets, in both SI and USC units, are copies of the electronic form of the datasheets (Microsoft Excel Spreadsheets). In the electronic form, selection of the units on the datasheet will automatically change all the units on the datasheet to the units selected. Note however, that this electronic datasheet does not contain in-built calculations, therefore changing the units will not impact any data entered onto the datasheet.

IMPORTANT NOTE Electrical Area Classificatioı Note that the selections available allow for both Europe and US designations
Some of the drop-down selections may not adequately cover the project requirements.

TEXT COLOR CODE: GREEN = TYP. BY PURCHASER RED = TYP. BY VENDOR BLUE = BY PURCHASER OR VENDOR

PROJECT UNITS Customary

CLIENT: ____________________

PROJECT TITLE: ____________________

JOB NUMBER: ____________________

EQUIPMENT NUMBER: ____________________

EQUIPMENT SERVICE: ____________________

SERIAL NUMBER: ____________________

REQ / SPEC NO. : __________ / __________

PURCH ORDER NO. ____________________

Cells colored thus [green] contain drop-down options

[yellow] contain calculated values based on input data do not change.

[grey] identifies a cross referenced paragraph in the document
note may also contain a drop down list

When you have completed the DS highlight the whole page and set format / cells / pattern to "none"
Delete these notes on completion

COMMENTS: ____________________

	DATA SHEETS					
	ITEM No.	ATT	ITEM No.	ATT	ITEM No.	ATT
PUMP						
MOTOR						
GEAR						
TURBINE						

APPLICABLE OVERLAY STANDARDS ____________________

Rev	Date	Description	By	CHK	APPV			

	CENTRIFUGAL PUMP DATA SHEET	DATA SHEET No.
		Sheet 1 of

CENTRIFUGAL PUMP DATA SHEET

Note			Rev
	APPLICABLE TO:	APPLICABLE STANDARD:	
	FOR	UNIT	
	SITE	SERVICE	
	NO. REQ PUMP SIZE	TYPE No. STAGES	
	MANUFACTURER MODEL	SERIAL NO.	

LIQUID CHARACTERISTICS

LIQUID TYPE OR NAME :

	UNITS	MAXIMUM	MINUMUM	RATED
VAPOR PRESSURE :	psia			
RELATIVE DENSITY :				
SPECIFIC HEAT :	Btu/(lbm-oF			
VISCOSITY :	cP			

NOTE: Max, min & Rated values refer only to the property listed

OPERATING CONDITIONS - CONTINUED

SERVICE :

• IF INTERMITTENT STARTS/DAY :

PUMPS OPERATE IN:

TEMP. - VAPOR PRESS. CURVE

CORROSION DUE TO : (6.10.1.8)

EROSION DUE TO : (6.10.1.8)

CHLORIDE CONCENTRATION (ppm) :

H2S CONCENTRATION (ppm) : (6.10.1.11)

PARTICULATE SIZE (DIA IN MICRONS)

PARTICULATE SIZE DISTRIBUTION:

PARTICULATE CONCENTRATION (ppm):

PARTICULATE HARDNESS:

THERMAL CONDUCTIVITY Btu/(h-ft-oF

THERMAL EXPANSION in/in/oF

POLYMERIZATION CHARACTERISTICS: (6.1.3.3)

OPERATING CONDITIONS (6.1.2)

	UNITS	Maximum	RATED	Normal	Minimum
NPSHa Datum:					
PUMPING TEMPERATURE :	°F				
FLOW :	gpm				
DISCHARGE PRESSURE : (6.3.2)	psia				
SUCTION PRESSURE :	psia				
DIFFERENTIAL PRESSURE :	psi		0		
DIFFERENTIAL HEAD :	ft				
$NPSH_A$:	ft				
HYDRAULIC POWER :	HP				

SITE AND UTILITY DATA

LOCATION:

MOUNTED AT : WINTERIZATION

SITE DATA : TROPICALIZATION

ELEVATION (MSL) : ft **BAROMETER :** in Hg

RANGE OF AMBIENT TEMPS:MIN / MAX / °F

RELATIVE HUMIDITY: MIN / MAX / %

UNUSUAL CONDITIONS:

ELECTRIC AREA CLASSIFICATION:

CLASS: GROUP: TEMP CLASS

ZONE: GROUP: DIVISION:

UTILITY CONDITIONS :

ELECTRICITY :	DRIVERS	HEATING	CONTROL	SHUTDOWN
VOLTAGE				
PHASE				
HERTZ				

COOLING WATER :

	INLET	RETURN		MECH DESIGN
TEMP °F			(max)	
PRESS psig			(min)	
SOURCE				

COOLING WATER CHLORIDE CONCENTRATION: ppm

INSTRUMENT AIR MAX psig MIN psig

NITROGEN MAX psig MIN psig

STEAM

		DRIVERS	HEATING
TEMP °F	Max		
	Min		
PRESS. psi	Max		
	Min		

PERFORMANCE

PROPOSAL CURVE NO. RPM

As Tested Curve No.

IMPELLER DIA RATED MAX. MIN. in

HYDRAULIC EFFICIENCY AT RATED POINT %

HYSTERESIS & MECHANICAL LOSSES HP

OVERALL EFFICIENCY (%) RATED POWER HP

RATED CURVE BEP FLOW (at rated impeller dia) gpm

MIN FLOW :THERMAL gpm STABLE gpm

MAX POWER @ RATED IMPELLER (6.8.9) HP

MAX HEAD @ RATED IMPELLER ft

PERCENT RISE TO SHUTOFF %

ORIFICE USED TO STEEPEN CURVE OR GIVE CONT. RISE?

PREFERRED OPERATING REGION (6.1.11) to gpm

ALLOWABLE OPERATING REGION to gpm

NPSH3 AT RATED FLOW : ft

CL PUMP TO U/S BASEPLATE ft

NPSH MARGIN AT RATED FLOW : ft

SPECIFIC SPEED (6.1.16)

SUCTION SPECIFIC SPEED LIMIT

SUCTION SPECIFIC SPEED gpm,rpm,ft

PERFORMANCE - CONTINUED

ROTOR CHAMBER TEMP RISE OPERATING:

AT RATED CONDITIONS °F

AT MAXIMUM PUMP FLOW °F

ROTOR CHAMBER TEMP RISE ON SHUTDOWN: °F

SOUND LEVELS

MAX ALLOWABLE SOUND PRESS. LEVEL (dBA)

EST MAX SOUND PRESSURE LEVEL (dBA)

SYSTEM DESCRIPTION

SUCTION VESSEL:

PUMP LOCATION:

SUCTION VESSEL ON LEVEL CONTROL?

PRESSURE SENSOR ON SUCTION VESSEL?

SUCTION VESSEL PRESSURE MAINTAINED BY LIQUID LEVEL PLUS:

IF FLUID LEVEL OR TANK PRESSURE DROPS TOO LOW, WILL SYSTEM AUTOMATICALLY STOP THE PUMP?

WILL THE PUMP RUN DRY IN NORMAL OPERATION?

REMARKS:

DATA SHEET No. 0 Rev: 0 SHEET 2 of

CENTRIFUGAL PUMP DATA SHEET

Note	CONSTRUCTION	MATERIALS (6.10.1.1)	Rev
	API PUMP TYPE: [Based on API 610 definitions]	APPENDIX H CLASS (show material designation)	
	ROTATION: (VIEWED FROM COUPLING END)	CASING & COVER:	
	CASING MOUNTING:	IMPELLER :	
	CASING TYPE: (6.3.10)	SHAFT:	
	CASE PRESSURE RATING:	WEAR RINGS	
	MAWP : (6.2.2) psig @ °F	CONTAINMENT SHELL/STATOR LINER	
	HYDROTEST : psig @ °F	INNER MAG SHEATH/ROTOR LINER	
	TYPE BOLTING USED ON PUMP (6.12.1.1)	BEARING SLEEVE	
	NOZZLE CONNECTIONS: (6.5.5)	BEARING BUSHING	
		STATOR HOUSING/FRAME	
		INSPECTION CLASS	
		MIN DESIGN METAL TEMP (6.10.4.1) °F at psig	
	FLANGE THICKNESS REQ'S NON-STD BOLT LENGTH	IMPACT TEST SPECIFICATION	
		REDUCED-HARDNESS MATERIALS REQ'D (6.10.1.11)	
	PRESSURE CASING AUX. CONNECTIONS: (6.4.3.2)	APPLICABLE HARDNESS STANDARD (6.10.1.11)	
		COPPER IN CONTACT w/ PROCESS FLUIDS	

	Size	Facing	Rating	Position
SUCTION				
DISCHARGE				

	No.	Size	Type	Facing	Rating	Posn.
PURGE/FLUSH OUT						
DRAIN						
VENT						
PRESS SENSOR						
TEMP SENSOR						
WARM-UP LINE						
EXTERNAL						
2ND DRAIN						

GUSSET SUPPORT REQUIRED (6.3.3.5)
DRAIN CONNECTION FOR SECONDARY CASING
ROTOR CAVITY DRAINABLE THRU 2ND DRAIN
DRAIN VALVE SUPPLIED BY:
VENT VALVE SUPPLIED BY:
NO THREAD CONS TO SECONDARY CASING
SPECIAL FITTINGS FOR TRANSITIONING (6.3.3.2)
CYLINDRICAL THREADS REQUIRED (6.3.3.11.3)
MACHINED AND STUDDED CONNECTIONS (6.3.3.7)

AUXILIARY CIRCULATION PIPING PLAN
PIPING FORM:
PIPING MATERIAL:
PIPING ASSEMBLY
IF FLANGED,
COOLING WATER REQUIREMENTS:
COOLING WATER PIPING PLAN
PIPING FORM:
PIPING MATERIAL:
PIPING ASSEMBLY
IF FLANGED,
FOR: JACKET gpm
HEAT EXCHANGER gpm
TOTAL COOLING WATER gpm
HEATING REQUIREMENTS
HEATING MEDIUM gpm
HEATING PIPING MATERIAL
ROTOR:
IMPELLER TYPE
RENEWABLE IMPELLER WEAR RINGS REQUIRED
RENEWABLE CASE WEAR RINGS REQUIRED
COMPONENT BALANCE TO ISO 1940 G1.0

PRESSURE VESSEL DESIGN CODE REFERENCES
THESE REFERENCES MUST BE LISTED BY THE MANUFACTURER:
SOURCE OF MATERIAL PROPERTIES
CASTING FACTORS USED IN DESIGN (TABLE 3)

WELDING AND REPAIRS
ALTERNATE WELDING CODES AND STANDARDS
Welder Qualification
Weld Procedure Qualification
Non-pressure structural weld
MP or LP exam of plate edge
Post weld Heat treat
Post weld Heat treat of casing

ALTERNATIVE STD/ACCEPT CRITERIA APPLIES

INSPECTION	METHOD	CASTINGS	FABRICATIONS
Radiograph			
Ultrasonic			
Mag Particle			
Liq. Penetrate			
Visual			

see page 5 for required material testing

MOTOR REQUIREMENTS APPLICABLE TO ALL (7.1.2)
MANUFACTURER
FRAME OR MODEL
ORIENTATION
NAMEPLATE POWER HP SERVICE FACTOR
NOMINAL RPM RATED LOAD RPM
VARIABLE SPEED REQUIRED
SOURCE OF VARIABLE SPEED
VOLTAGE PHASE 3 HERTZ
MINIMUM STARTING VOLTAGE
INSULATION CLASS
FULL LOAD AMPS
LOCKED ROTOR AMPS
START CONDITION

DATA SHEET No. Rev: SHEET 3 of

CENTRIFUGAL PUMP DATA SHEET

1	Note	MAGNETIC DRIVEN PUMP SPECIFIC (9.1)	CANNED MOTOR PUMP SPECIFIC (9.2)	Rev
2		DRIVER TYPE GEAR		
3		CLOSE COUPLED DESIGN APPROVED: (9.1.1.2)	MOTOR WINDING INSULATION CLASS (9.2.2.8)	
4		DESIGN FOR REMOVAL OF DRIVE END WITHOUT DISTURBING THE	SOLID OR LIQUID HEAT TRANS. MEDIA ALLOWED IN STATOR?	
5		PRESSURE CASING OR DRIVER (9.1.1.4)		
		DESIGN CONTAINMENT SHELL FOR VACUUM (6.2.4)	DESIGN MOTOR FOR FREQUENT STARTS (9.2.2.9)	
6		CONTAINMENT SHELL VACUUM DESIGN: psig	STARTS PER	
7		MAGNETIC COUPLING TYPE:	IMPACT ON LIFE:	
8		MAGNETS: OUTER / INNER	DESIGN MOTOR FOR: (9.2.2.9)	
9		MAG. MATERIAL	UL, FM, ATEX OR EQUIVALENT REQUIRED (9.2.2.10)	
10		MOUNT. METHOD	CERTIFICATION OF IEEE 252 TEST REQUIRED (5.2.7.1)	
11		TEMP. LIMIT, °F	DESIGN STATOR LINER FOR VACUUM (6.2.4)	
12		HERMETIC. SEALED	STATOR LINER VACUUM DESIGN: psig	
13		NO. OF MAGNETS	DECONTAMINATION CONNECTION ON STATOR (9.2.2.11)	
14		PROTECTION OF OUTER MAG RING (9.1.3.5):		
15		STARTING REQUIREMENT:	SECONDARY CONTROL / CONTAINMENT	
16		TORQUE RATING (DECOUPLING), ft-lb	NFPA RATING:	
17		MAX TORQUE REQ'D ON STARTING, (9.1.3.7a) ft-lb	HEALTH FLAMMABILITY INSTABILITY	
18		PUMP TORQUE AT RATED (+5%), (9.1.3.7b) ft-lb		
19		DESIGN FOR FULL CURVE TORQUE REQMTS (9.1.3.7c)	USE ANNEX B HAZARD BASED PROCEDURE	
20		TORQUE REQ'D FOR FULL CURVE (120% BEP), (9.1.3.7c) ft-lb	HAZARD STATEMENT HAZARD	
21		REQUIRED/ACTUAL SERVICE FACTOR (9.1.3.8) /	RISK PHRASE GROUP	
22		SUBMIT MAG-COUPLING TORQUE VS TEMP. CURVE		
23		SUBMIT SPEED VS TORQUE CURVE (9.1.3.10)	REQUIRED MEASURE:	
24		BEARINGS AND LUBRICATION (9.1.4)	SECONDARY CONTROL (3.67)	
25		DRIVE MAGNET BEARING (TYPE / NUMBER):	MAX LEAKAGE ON PRIMARY FAILURE: gpm	
26		RADIAL /	FLOW RESTRICTION:	
27		THRUST /	DEVICE MANUFACTURER	
28		LUBRICATION METHOD:	MATERIAL	
29		OIL VISC. ISO GRADE VG	ELASTOMERS	
30		CONSTANT LEVEL OILER : (9.1.4.2.1	MANUFACTURER CODE	
31		PREFERENCE		
32		OILER VENT	SECONDARY CONTAINMENT (3.65)	
33		SUMP COLLECTOR REQUIRED (9.1.4.2.2)	SECONDARY SEAL:	
34		BEARING HOUSING END SEALS	DESIGN PRESSURE: psig	
35		SHAFT COUPLING & GUARD: (9.1.5.2)	INSTRUMENTATION (7.4.2)	
36		COUPLING MANUFACTURER:	DETECT OPER. OUTSIDE ACCEPT. RANGE OR DECOUPLE (7.4.2.1)	
37		MODEL SPACER LENGTH in	METHOD:	
38		RATING (POWER/100 RPM) SERVICE FACTOR	LOCATION:	
39		COUPLING BALANCED TO ISO 1940-1 G6.3 (9.1.5.2.3)	IF LOCAL, PROVIDED BY:	
40		COUPLING TO ISO 14691 (9.1.5.2.9)	USE FOR:	
41		COUPLING GUARD STANDARD (9.1.5.2.11)		
42		IGNITION HAZARD ASSESSMENT REQUIRED (9.1.5.2.11.5)	MONITOR LEAKAGE INTO SECONDARY CASING:	
43		SPARK RESISTANT MATERIAL (9.1.5.2.11.6)	METHOD:	
44		BASEPLATE (9.1.5.3)	SENSOR BY:	
45		API BASEPLATE NUMBER: (9.1.5.3.3)	TYPE:	
46		BASEPLATE CONSTRUCTION (9.1.5.3.1.1)	USE FOR:	
47		BASEPLATE DRAINAGE (7.3.1)		
48		MOUNTING :		
49		NON-GROUT CONSTRUCTION: (9.1.5.3.13)	MONITOR TEMPERATURE OF:	
50		OPEN DECK DESIGN: (9.1.5.3.14)	METHOD:	
51		PROVIDE STAINLESS SPACER PLATE UNDER ALL EQUIPMENT	SENSOR BY:	
52		FEET (9.1.5.3.6)	TYPE:	
53		OTHER	USE FOR:	
54		SEPARATE MOTOR DRIVER		
55		APPLICABLE SPEC:	MONITOR VIBRATION:	
56		ENCLOSURE	METHOD:	
57		INCLUDE: SPACE HEATER VIB. SENSOR	PROVISION REQUIRED:	
58		LUBRICATION:	SENSOR BY:	
59		DRIVE MOTOR BEARING (TYPE / NUMBER):	IF FULL TIME, USE FOR:	

CENTRIFUGAL PUMP DATA SHEET

1	Note	SURFACE PREPARATION AND PAINT						INSPECTION AND TESTING	Rev
2		MANUFACTURER'S STANDARD						GENERAL (8.1)	
3								DAYS ADVANCED NOTIFICATION OF WITNESSED OR OBSERVED	
4								TESTS AND INSPECTIONS	
5		PUMP:						NOTIFICATION OF SUCCESSFUL PRELIMINARY SHOP	
6		PUMP SURFACE PREPARATION						PERFORMANCE TEST (8.1.13)	
7		PRIMER						SUBMIT INSPECTION CHECK LIST (8.1.7)	
8		FINISH COAT							
9								SHOP INSPECTION (8.2)	
10		BASEPLATE:						ADDNL SUBSURFACE EXAMINATION (6.10.1.5) (8.2.1.3)	
		BASEPLATE SURFACE PREPARATION						PART EXAM	
11		PRIMER:						PART EXAM	
12		FINISH COAT						PART EXAM	
13								PART EXAM	
14		PREPARATION FOR SHIPMENT: (8.4.1)						PMI TESTING REQUIRED (8.2.1.4)	
15		TYPE OF SHIPMENT: (8.4.1)						PARTS TO BE TESTED	
16		EXPORT BOXING						INSPECTION REQUIRED FOR CASTINGS (8.2.2.1)	
17								MAG PARTICLE	
18		N2 PURGE DURING SHIPPING (9.2.8.4)						RADIOGRAPHY	
19		OUTDOOR STORAGE MORE THAN 6 MONTHS						LIQUID PENETRANT	
20		PURGE DURING STORAGE (9.2.8.4)						ULTRASONIC	
21		DETAILS OF LIFTING DEVICES						INSPECTION REQUIRED FOR CONNECTION WELDS (6.10.3.4.5)	
22								MAG PARTICLE	
23		SPARE PARTS (include cost & details w/ proposal)						LIQUID PENETRANT	
24		START-UP						INSPECTION REQUIRED FOR CONNECTION WELDS (6.10.3.4.5)	
25		NORMAL MAINTENANCE						RADIOGRAPHY	
26		SPARE ASSEMBLY:						ULTRASONIC	
27		OTHER:						CLEANLINESS PRIOR TO FINAL ASSEMBLY (8.2.3.1)	
28		WEIGHTS lb						TESTING (8.3)	
		ITEM No	PUMP	DRIVER	GEAR	BASE	TOTAL	HARDNESS TEST REQUIRED (8.2.3.2)	
29								FOR	
30								METHOD	
31								COMPONENTS TO BE TESTED	
32								IMPACT TEST- TO	
33		OTHER PURCHASER REQUIREMENTS						HYDROSTATIC (8.3.2)	
34		COORDINATION MEETING REQUIRED (10.1.3)						WETTING AGENT INCLUDED (8.3.2.7)	
35		CASTING REPAIR WELD PROCEDURE APPR REQD (6.10.2.5)						PERFORMANCE TEST (8.3.3)	
36		MAXIMUM DISCHARGE PRESSURE TO INCLUDE (6.2.3):						TEST DATA POINTS-	
37		MAX RELATIVE DENSITY						PERFORMANCE CURVE & DATA APPROVAL PRIOR	
38		OPERATION TO TRIP SPEED						TO SHIPMENT (8.3.3.3.5)	
39		MAX DIA. IMPELLERS						TEST W/ NPSHA LIMITED TO 110% SITE NPSHA	
40		CONNECTION DESIGN APPROVAL (6.10.3.4.4)						RUN UNTIL TEMP STABILIZATION ACHIEVED	
41		DEMONSTRATE CO-PLANAR MOUNTING PAD SURFACES						4 HR. MECH RUN TEST (8.3.4.2.2)	
42		IN PUMP VENDOR SHOP (9.1.5.3.5)						THRUST BEARING LOAD TEST (8.3.4.3)	
43		DYNAMIC BALANCE TO ISO 1940-1 GR. G1.0 (6.8.4.2)						NPSH3 TEST (8.3.4.4.1)	
44		INSTALLATION LIST IN PROPOSAL (10.2.3.l)						COMPLETE UNIT TEST (8.3.4.5)	
45		INCLUDE PLOTTED VIBRATION SPECTRA (6.8.3.2.1)						SOUND LEVEL TEST (8.3.4.6)	
46		CONNECTION BOLTING COATING						AUXILIARY EQUIPMENT TEST (8.3.4.7)	
47		SUBMIT EST. SPL BY OCTAVE BAND						SECONDARY CONTROL SYSTEM HYDRO	
48		MATERIAL CERTIFICATION REQUIRED (6.10.1.7)						SECONDARY CONTAINMENT / CONTROL SYSTEM INSTRUMENT	
49		CASING						TEST (8.3.4.9)	
50		IMPELLER						STATIC TORQUE TEST (9.16.1)	
51		SHAFT						RUN UNTIL OIL TEMP STABILIZED (9.16.3)	
52		OTHER						RESIDUAL UNBALANCE TEST (J.4.1.2)	
53		VENDOR SUBMIT TEST PROCEDURES (8.3.1.1)						OTHER	
54		ADDITIONAL DATA REQUIRING 20 YEARS RETENTION (8.2.1.1g)							
55									

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IMPORTANT NOTE Electrical Area Classificatio Note that the selections available allow for both Europe and US designations
Some of the drop-down selections may not adequately cover the project requirements.

TEXT COLOR CODE: GREEN = TYP. BY PURCHASER RED = TYP. BY VENDOR BLUE = BY PURCHASER OR VENDOR

PROJECT UNITS SI

CLIENT:

PROJECT TITLE:

JOB NUMBER:

EQUIPMENT NUMBER:

EQUIPMENT SERVICE:

SERIAL NUMBER:

REQ / SPEC NO. : /

PURCH ORDER NO.

Cells colored thus contain drop-down options

contain calculated values based on input data do not change.

identifies a cross referenced paragraph in the document
note may also contain a drop down list

When you have completed the DS highlight the whole page and set format / cells / pattern to "none"
Delete these notes on completion

COMMENTS:

	DATA SHEETS					
	ITEM No.	ATT	ITEM No.	ATT	ITEM No.	ATT
PUMP						
MOTOR						
GEAR						
TURBINE						

APPLICABLE OVERLAY STANDARDS

Rev	Date	Description	By	CHK	APPV			

	CENTRIFUGAL PUMP DATA SHEET	DATA SHEET No.
		Sheet 1 of

CENTRIFUGAL PUMP DATA SHEET

Note | Rev

APPLICABLE TO: ______ APPLICABLE STANDARD: ______
FOR ______ UNIT ______
SITE ______ SERVICE ______
NO. REQ ______ PUMP SIZE ______ TYPE ______ No. STAGES ______
MANUFACTURER ______ MODEL ______ SERIAL NO. ______

LIQUID CHARACTERISTICS

LIQUID TYPE OR NAME :

	UNITS	MAXIMUM	MINUMUM	RATED	NOTE:
VAPOR PRESSURE :	kPa				Max, min & Rated values refer only to the property listed
RELATIVE DENSITY :					
SPECIFIC HEAT :	kJ/(kg-K)				
VISCOSITY :	Pa s				

OPERATING CONDITIONS (6.1.2)

	UNITS	Maximum	RATED	Normal	Minimum
NPSHa Datum:					
PUMPING TEMPERATURE :	°K				
FLOW :	m³/s				
DISCHARGE PRESSURE : (6.3.2)	kPa				
SUCTION PRESSURE :	kPa				
DIFFERENTIAL PRESSURE :	kPa		0		
DIFFERENTIAL HEAD :	m				
$NPSH_A$:	m				
HYDRAULIC POWER :	kW				

OPERATING CONDITIONS - CONTINUED

SERVICE :
• IF INTERMITTENT STARTS/DAY :
PUMPS OPERATE IN:
TEMP. - VAPOR PRESS. CURVE
CORROSION DUE TO : (6.10.1.8)
EROSION DUE TO : (6.10.1.8)
CHLORIDE CONCENTRATION (ppm) :
H2S CONCENTRATION (ppm) : (6.10.1.11)
PARTICULATE SIZE (DIA IN MICRONS)
PARTICULATE SIZE DISTRIBUTION:
PARTICULATE CONCENTRATION (ppm):
PARTICULATE HARDNESS:
THERMAL CONDUCTIVITY W/(m-K)
THERMAL EXPANSION mm/mm/oK
POLYMERIZATION CHARACTERISTICS: (6.1.3.3)

SITE AND UTILITY DATA

LOCATION:

MOUNTED AT : ______ WINTERIZATION ______
SITE DATA : TROPICALIZATION ______
ELEVATION (MSL) : ______ m **BAROMETER :** ______ mmHg
RANGE OF AMBIENT TEMPS:MIN / MAX ______ / ______ °K
RELATIVE HUMIDITY: MIN / MAX ______ / ______ %
UNUSUAL CONDITIONS:

ELECTRIC AREA CLASSIFICATION:
CLASS: ______ GROUP: ______ TEMP CLASS ______
ZONE: ______ GROUP: ______ DIVISION: ______

UTILITY CONDITIONS :

ELECTRICITY :	DRIVERS	HEATING	CONTROL	SHUTDOWN
VOLTAGE				
PHASE				
HERTZ				

COOLING WATER :

	INLET	RETURN		MECH DESIGN
TEMP °K			(max)	
PRESS kPa			(min)	
SOURCE				

COOLING WATER CHLORIDE CONCENTRATION: ______ ppm

INSTRUMENT AIR MAX ______ kPa MIN ______ kPa

NITROGEN MAX ______ kPa MIN ______ kPa

STEAM

		DRIVERS	HEATING
TEMP °K	Max		
	Min		
PRESS. kPa	Max		
	Min		

PERFORMANCE

PROPOSAL CURVE NO. ______ RPM ______
As Tested Curve No. ______
IMPELLER DIA RATED ______ MAX. ______ MIN. ______ mm
HYDRAULIC EFFICIENCY AT RATED POINT ______ %
HYSTERESIS & MECHANICAL LOSSES ______ kW
OVERALL EFFICIENCY ______ (%) RATED POWER ______ kW
RATED CURVE BEP FLOW (at rated impeller dia) ______ m³/s
MIN FLOW :THERMAL ______ m³/s STABLE ______ m³/s
MAX POWER @ RATED IMPELLER (6.8.9) ______ kW
MAX HEAD @ RATED IMPELLER ______ m
PERCENT RISE TO SHUTOFF ______ %
ORIFICE USED TO STEEPEN CURVE OR GIVE CONT. RISE? ______
PREFERRED OPERATING REGION (6.1.11) ______ to ______ m³/s
ALLOWABLE OPERATING REGION ______ to ______ m³/s
NPSH3 AT RATED FLOW : ______ m
CL PUMP TO U/S BASEPLATE ______ m
NPSH MARGIN AT RATED FLOW : ______ m
SPECIFIC SPEED (6.1.16) ______
SUCTION SPECIFIC SPEED LIMIT ______
SUCTION SPECIFIC SPEED m3/s, rpm, m ______

PERFORMANCE - CONTINUED

ROTOR CHAMBER TEMP RISE OPERATING:
AT RATED CONDITIONS ______ °K
AT MAXIMUM PUMP FLOW ______ °K
ROTOR CHAMBER TEMP RISE ON SHUTDOWN: ______ °K

SOUND LEVELS
MAX ALLOWABLE SOUND PRESS. LEVEL ______ (dBA)
EST MAX SOUND PRESSURE LEVEL ______ (dBA)

SYSTEM DESCRIPTION

SUCTION VESSEL: ______
PUMP LOCATION: ______
SUCTION VESSEL ON LEVEL CONTROL? ______
PRESSURE SENSOR ON SUCTION VESSEL? ______
SUCTION VESSEL PRESSURE MAINTAINED BY LIQUID LEVEL PLUS:
IF FLUID LEVEL OR TANK PRESSURE DROPS TOO LOW, WILL SYSTEM AUTOMATICALLY STOP THE PUMP? ______
WILL THE PUMP RUN DRY IN NORMAL OPERATION? ______
REMARKS: ______

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CENTRIFUGAL PUMP DATA SHEET

Note	CONSTRUCTION	MATERIALS (6.10.1.1)	Rev

CONSTRUCTION

API PUMP TYPE: [Based on API 610 definitions]

ROTATION: (VIEWED FROM COUPLING END)

CASING MOUNTING:

CASING TYPE: (6.3.10)

CASE PRESSURE RATING:

MAWP : (6.2.2) kPa @ °K

HYDROTEST : kPa @ °K

TYPE BOLTING USED ON PUMP (6.12.1.1)

NOZZLE CONNECTIONS: (6.5.5)

	Size	Facing	Rating	Position
SUCTION				
DISCHARGE				

FLANGE THICKNESS REQ'S NON-STD BOLT LENGTH

PRESSURE CASING AUX. CONNECTIONS: (6.4.3.2)

	No.	Size	Type	Facing	Rating	Posn.
PURGE/FLUSH OUT						
DRAIN						
VENT						
PRESS SENSOR						
TEMP SENSOR						
WARM-UP LINE						
EXTERNAL						
2ND DRAIN						

GUSSET SUPPORT REQUIRED (6.3.3.5)

DRAIN CONNECTION FOR SECONDARY CASING

ROTOR CAVITY DRAINABLE THRU 2ND DRAIN

DRAIN VALVE SUPPLIED BY:

VENT VALVE SUPPLIED BY:

NO THREAD CONS TO SECONDARY CASING

SPECIAL FITTINGS FOR TRANSITIONING (6.3.3.2)

CYLINDRICAL THREADS REQUIRED (6.3.3.11.3)

MACHINED AND STUDDED CONNECTIONS (6.3.3.7)

AUXILIARY CIRCULATION PIPING PLAN

PIPING FORM:

PIPING MATERIAL:

PIPING ASSEMBLY

IF FLANGED,

COOLING WATER REQUIREMENTS:

COOLING WATER PIPING PLAN

PIPING FORM:

PIPING MATERIAL:

PIPING ASSEMBLY

IF FLANGED,

FOR: JACKET m³/s

HEAT EXCHANGER m³/s

TOTAL COOLING WATER m³/s

HEATING REQUIREMENTS

HEATING MEDIUM m³/s

HEATING PIPING MATERIAL

ROTOR:

IMPELLER TYPE

RENEWABLE IMPELLER WEAR RINGS REQUIRED

RENEWABLE CASE WEAR RINGS REQUIRED

COMPONENT BALANCE TO ISO 1940 G1.0

MATERIALS (6.10.1.1)

APPENDIX H CLASS (show material designation)

CASING & COVER:

IMPELLER :

SHAFT:

WEAR RINGS

CONTAINMENT SHELL/STATOR LINER

INNER MAG SHEATH/ROTOR LINER

BEARING SLEEVE

BEARING BUSHING

STATOR HOUSING/FRAME

INSPECTION CLASS

MIN DESIGN METAL TEMP (6.10.4.1) °K at kPa

IMPACT TEST SPECIFICATION

REDUCED-HARDNESS MATERIALS REQ'D (6.10.1.11)

APPLICABLE HARDNESS STANDARD (6.10.1.11)

COPPER IN CONTACT w/ PROCESS FLUIDS

PRESSURE VESSEL DESIGN CODE REFERENCES

THESE REFERENCES MUST BE LISTED BY THE MANUFACTURER:

SOURCE OF MATERIAL PROPERTIES

CASTING FACTORS USED IN DESIGN (TABLE 3)

WELDING AND REPAIRS

ALTERNATE WELDING CODES AND STANDARDS

Welder Qualification

Weld Procedure Qualification

Non-pressure structural weld

MP or LP exam of plate edge

Post weld Heat treat

Post weld Heat treat of casing

ALTERNATIVE STD/ACCEPT CRITERIA APPLIES

INSPECTION	METHOD	CASTINGS	FABRICATIONS
Radiograph			
Ultrasonic			
Mag Particle			
Liq. Penetrate			
Visual			

see page 5 for required material testing

MOTOR REQUIREMENTS APPLICABLE TO ALL (7.1.2)

MANUFACTURER

FRAME OR MODEL

ORIENTATION

NAMEPLATE POWER kW SERVICE FACTOR

NOMINAL RPM RATED LOAD RPM

VARIABLE SPEED REQUIRED

SOURCE OF VARIABLE SPEED

VOLTAGE PHASE **3** HERTZ

MINIMUM STARTING VOLTAGE

INSULATION CLASS

FULL LOAD AMPS

LOCKED ROTOR AMPS

START CONDITION

DATA SHEET No. Rev: SHEET 3 of

CENTRIFUGAL PUMP DATA SHEET

1	Note	**MAGNETIC DRIVEN PUMP SPECIFIC (9.1)**	**CANNED MOTOR PUMP SPECIFIC (9.2)**	Rev
2		DRIVER TYPE GEAR		
3		CLOSE COUPLED DESIGN APPROVED: (9.1.12)	MOTOR WINDING INSULATION CLASS (9.2.2.8)	
4		DESIGN FOR REMOVAL OF DRIVE END WITHOUT DISTURBING THE	SOLID OR LIQUID HEAT TRANS. MEDIA ALLOWED IN STATOR?	
5		PRESSURE CASING OR DRIVER (9.1.14)		
		DESIGN CONTAINMENT SHELL FOR VACUUM (6.2.4)	DESIGN MOTOR FOR FREQUENT STARTS (9.2.2.9)	
6		CONTAINMENT SHELL VACUUM DESIGN: kPa	STARTS PER	
7		MAGNETIC COUPLING TYPE:	IMPACT ON LIFE:	
8		**MAGNETS:** OUTER INNER	DESIGN MOTOR FOR: (9.2.2.9)	
9		MAG. MATERIAL	UL, FM, ATEX OR EQUIVALENT REQUIRED (9.2.2.10)	
10		MOUNT. METHOD	CERTIFICATION OF IEEE 252 TEST REQUIRED (5.2.7.1)	
11		TEMP. LIMIT, °K	DESIGN STATOR LINER FOR VACUUM (6.2.4)	
12		HERMETIC. SEALED	STATOR LINER VACUUM DESIGN: kPa	
13		NO. OF MAGNETS	DECONTAMINATION CONNECTION ON STATOR (9.2.2.11)	
14		PROTECTION OF OUTER MAG RING (9.13.5):		
15		STARTING REQUIREMENT:	**SECONDARY CONTROL / CONTAINMENT**	
16		TORQUE RATING (DECOUPLING), N-m	**NFPA RATING:**	
17		MAX TORQUE REQ'D ON STARTING, (9.13.7a) N-m	HEALTH FLAMMABILITY INSTABILITY	
18		PUMP TORQUE AT RATED (+5%), (9.13.7b) N-m		
19		DESIGN FOR FULL CURVE TORQUE REQMTS (9.13.7c)	**USE ANNEX B HAZARD BASED PROCEDURE**	
20		TORQUE REQ'D FOR FULL CURVE (120% BEP), (9.13.7c) N-m	HAZARD STATEMENT HAZARD	
21		REQUIRED/ACTUAL SERVICE FACTOR (9.13.8) /	RISK PHRASE GROUP	
22		SUBMIT MAG-COUPLING TORQUE VS TEMP. CURVE		
23		SUBMIT SPEED VS TORQUE CURVE (9.13.10)	REQUIRED MEASURE:	
24		**BEARINGS AND LUBRICATION (9.1.4)**	**SECONDARY CONTROL (3.67)**	
25		DRIVE MAGNET BEARING (TYPE / NUMBER):	MAX LEAKAGE ON PRIMARY FAILURE: m³/s	
26		RADIAL /	FLOW RESTRICTION:	
27		THRUST /	DEVICE MANUFACTURER	
28		LUBRICATION METHOD:	MATERIAL	
29		OIL VISC. ISO GRADE VG	ELASTOMERS	
30		CONSTANT LEVEL OILER : (9.14.2.1	MANUFACTURER CODE	
31		PREFERENCE		
32		OILER VENT	**SECONDARY CONTAINMENT (3.65)**	
33		SUMP COLLECTOR REQUIRED (9.14.2.2)	SECONDARY SEAL:	
34		BEARING HOUSING END SEALS	DESIGN PRESSURE: kPa	
35		**SHAFT COUPLING & GUARD: (9.1.5.2)**	**INSTRUMENTATION (7.4.2)**	
36		COUPLING MANUFACTURER:	DETECT OPER. OUTSIDE ACCEPT. RANGE OR DECOUPLE (7.4.2.1)	
37		MODEL SPACER LENGTH mm	METHOD:	
38		RATING (POWER/100 RPM) SERVICE FACTOR	LOCATION:	
39		COUPLING BALANCED TO ISO 1940-1 G6.3 (9.1.5.2.3)	IF LOCAL, PROVIDED BY:	
40		COUPLING TO ISO 14691 (9.1.5.2.9)	USE FOR:	
41		COUPLING GUARD STANDARD (9.1.5.2.11)		
42		IGNITION HAZARD ASSESSMENT REQUIRED (9.1.5.2.11.5)	MONITOR LEAKAGE INTO SECONDARY CASING:	
43		SPARK RESISTANT MATERIAL (9.1.5.2.11.6)	METHOD:	
44		**BASEPLATE (9.1.5.3)**	SENSOR BY:	
45		API BASEPLATE NUMBER: (9.1.5.3.3)	TYPE:	
46		BASEPLATE CONSTRUCTION (9.1.5.3.1.1)	USE FOR:	
47		BASEPLATE DRAINAGE (7.3.1)		
48		MOUNTING :		
49		NON-GROUT CONSTRUCTION: (9.1.5.3.13)	MONITOR TEMPERATURE OF:	
50		OPEN DECK DESIGN: (9.1.5.3.14)	METHOD:	
51		PROVIDE STAINLESS SPACER PLATE UNDER ALL EQUIPMENT	SENSOR BY:	
52		FEET (9.1.5.3.6)	TYPE:	
53		OTHER	USE FOR:	
54		**SEPARATE MOTOR DRIVER**		
55		APPLICABLE SPEC:	MONITOR VIBRATION:	
56		ENCLOSURE	METHOD:	
57		INCLUDE: SPACE HEATER VIB. SENSOR	PROVISION REQUIRED:	
58		LUBRICATION:	SENSOR BY:	

CENTRIFUGAL PUMP DATA SHEET

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1		**SURFACE PREPARATION AND PAINT**						**INSPECTION AND TESTING**	
2		MANUFACTURER'S STANDARD						**GENERAL (8.1)**	
3								DAYS ADVANCED NOTIFICATION OF WITNESSED OR OBSERVED	
4								TESTS AND INSPECTIONS	
5		**PUMP:**						NOTIFICATION OF SUCCESSFUL PRELIMINARY SHOP	
6		PUMP SURFACE PREPARATION						PERFORMANCE TEST (8.1.13)	
7		PRIMER						SUBMIT INSPECTION CHECK LIST (8.1.7)	
8		FINISH COAT							
9								**SHOP INSPECTION (8.2)**	
10		**BASEPLATE:**						ADDNL SUBSURFACE EXAMINATION (6.10.1.5) (8.2.1.3)	
		BASEPLATE SURFACE PREPARATION						PART EXAM	
11		PRIMER:						PART EXAM	
12		FINISH COAT						PART EXAM	
13								PART EXAM	
14		**PREPARATION FOR SHIPMENT: (8.4.1)**						PMI TESTING REQUIRED (8.2.1.4)	
15		TYPE OF SHIPMENT: (8.4.1)						PARTS TO BE TESTED	
16		EXPORT BOXING						INSPECTION REQUIRED FOR CASTINGS (8.2.2.1)	
17								MAG PARTICLE	
18		N2 PURGE DURING SHIPPING (9.2.8.4)						RADIOGRAPHY	
19		OUTDOOR STORAGE MORE THAN 6 MONTHS						LIQUID PENETRANT	
20		PURGE DURING STORAGE (9.2.8.4)						ULTRASONIC	
21		DETAILS OF LIFTING DEVICES						INSPECTION REQUIRED FOR CONNECTION WELDS (6.10.3.4.5)	
22								MAG PARTICLE	
23		**SPARE PARTS (include cost & details w/ proposal)**						LIQUID PENETRANT	
24		START-UP						INSPECTION REQUIRED FOR CONNECTION WELDS (6.10.3.4.5)	
25		NORMAL MAINTENANCE						RADIOGRAPHY	
26		SPARE ASSEMBLY:						ULTRASONIC	
27		OTHER:						CLEANLINESS PRIOR TO FINAL ASSEMBLY (8.2.3.1)	
28		**WEIGHTS** lb						**TESTING (8.3)**	
		ITEM No	PUMP	DRIVER	GEAR	BASE	TOTAL	HARDNESS TEST REQUIRED (8.2.3.2)	
29								FOR	
30								METHOD	
31								COMPONENTS TO BE TESTED	
32								IMPACT TEST- TO	
33		**OTHER PURCHASER REQUIREMENTS**						HYDROSTATIC (8.3.2)	
34		COORDINATION MEETING REQUIRED (10.1.3)						WETTING AGENT INCLUDED (8.3.2.7)	
35		CASTING REPAIR WELD PROCEDURE APPR REQD (6.10.2.5)						PERFORMANCE TEST (8.3.3)	
36		MAXIMUM DISCHARGE PRESSURE TO INCLUDE (6.2.3):						TEST DATA POINTS-	
37		MAX RELATIVE DENSITY						PERFORMANCE CURVE & DATA APPROVAL PRIOR	
38		OPERATION TO TRIP SPEED						TO SHIPMENT (8.3.3.3.5)	
39		MAX DIA. IMPELLERS						TEST W/ NPSHA LIMITED TO 110% SITE NPSHA	
40		CONNECTION DESIGN APPROVAL (6.10.3.4.4)						RUN UNTIL TEMP STABILIZATION ACHIEVED	
41		DEMONSTRATE CO-PLANAR MOUNTING PAD SURFACES						4 HR. MECH RUN TEST (8.3.4.2.2)	
42		IN PUMP VENDOR SHOP (9.1.5.3.5)						THRUST BEARING LOAD TEST (8.3.4.3)	
43		DYNAMIC BALANCE TO ISO 1940-1GR. G1.0 (6.8.4.2)						NPSH3 TEST (8.3.4.4.1)	
44		INSTALLATION LIST IN PROPOSAL (10.2.3.l)						COMPLETE UNIT TEST (8.3.4.5)	
45		INCLUDE PLOTTED VIBRATION SPECTRA (6.8.3.2.1)						SOUND LEVEL TEST (8.3.4.6)	
46		CONNECTION BOLTING COATING						AUXILIARY EQUIPMENT TEST (8.3.4.7)	
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49		CASING						TEST (8.3.4.9)	
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52		OTHER						RESIDUAL UNBALANCE TEST (J.4.1.2)	
53		VENDOR SUBMIT TEST PROCEDURES (8.3.1.1)						OTHER	
54		ADDITIONAL DATA REQUIRING 20 YEARS RETENTION (8.2.1.1g)							
55									

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