

General-purpose Steam Turbines for Petroleum, Chemical, and Gas Industry Services

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Introduction

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

This standard requires the purchaser to specify certain details and features.

A bullet (●) at the beginning of a subsection or paragraph indicates that either a decision by, or further information from, the purchaser is required. Further information should be shown on the data sheet (see example in Annex A) or stated in the quotation request and purchase order.

General-purpose Steam Turbines for Petroleum, Chemical, and Gas Industry Services

1 Scope

This standard covers the minimum requirements for general-purpose steam turbines. These requirements include basic design, materials, related lubrication systems, controls, auxiliary equipment, and accessories for use in the petroleum, chemical, and gas industry services.

This standard includes only general-purpose turbines. General-purpose turbines are horizontal or vertical turbines used to drive equipment that is usually spared or is in noncritical service. They are generally used where steam conditions will not exceed a pressure of 48 bar (700 psig) and a temperature of 400 °C (750 °F). Typically, the turbine shaft speed will not exceed 6000 r/min and power not exceeding 4000 HP (3000 kW) with a single-stage turbine.

This standard does not cover special-purpose turbines. Special-purpose turbines are those horizontal turbines used to drive equipment that is usually not spared, is relatively large in size (power), or is in critical service. This category is not limited by steam conditions or turbine speed. Requirements for special-purpose turbines are defined in API 612.

In case of conflict between this standard and the inquiry or order, the information included in the order shall govern.

2 Normative References

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies. Standards referenced in the text portion of the document are undated but refer to the specific editions referenced in this section.

API Specification 5L, *Line Pipe*

API Recommended Practice 500, *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Division 1 and Division 2*

API Recommended Practice 505, *Recommended Practice for Classification of Locations for Electrical Installations at Petroleum Facilities Classified as Class I, Zone 0, Zone 1, and Zone 2*

API Standard 520, (all parts) *Sizing, Selection, and Installation of Pressure-relieving Devices in Refineries*

API Standard 526, *Flanged Steel Pressure-relief Valves*

API Recommended Practice 551, *Process Measurement Instrumentation*

API Standard 612, *Petroleum, Petrochemical, and Natural Gas Industries—Steam Turbines—Special-purpose Applications*

API Standard 614, *Lubrication, Shaft-sealing, and Control-oil Systems and Auxiliaries*

API 670, *Machinery Protection Systems*

API Standard 671, *Special-purpose Couplings for Petroleum, Chemical, and Gas Industry Services*

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

API Recommended Practice 686, *Recommended Practice for Machinery Installation and Installation Design*

API Recommended Practice 691, *Risk-based Machinery Management*

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

ABMA Standard 9, *Load Ratings and Fatigue Life for Ball Bearings*

ABMA Standard 20, *Radial Bearings of Ball, Cylindrical Roller and Spherical Roller Types—Metric Design*

AGMA 922 ², *Load Classification and Service Factors for Flexible Couplings*

AGMA 9000, *Flexible Couplings—Potential Unbalance Classification*

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

ASME B1.1 ³, *Unified Inch Screw Threads (UN and UNR Thread Form)*

ASME B1.13M, *Metric Screw Threads: M Profile*

ASME B1.20.1, *Pipe Threads, General Purpose (Inch)*

ASME B16.5, *Pipe Flanges and Flanged Fittings NPS 1/2 Through NPS 24 Metric/Inch Standard*

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

ASME B16.47, *Large Diameter Steel Flanges NPS 26 Through NPS 60 Metric/Inch Standard*

ASME B17.1, *Keys and Key Sets*

ASME B18.2.2, *Nuts for General Applications: Machine Screw Nuts; Hex, Square, Hex Flange, and Coupling Nuts (Inch Series)*

ASME B31.3, *Process Piping*

ASME BTH-1, *Design of Below-the-Hook Lifting Devices*

ASME PTC 6, *Steam Turbines*

ASME Boiler and Pressure Vessel Code (BPVC), *Section II—Materials*

ASME Boiler and Pressure Vessel Code (BPVC), *Section VIII—Rules for Construction of Pressure Vessels*

ASME Boiler and Pressure Vessel Code (BPVC), *Section IX—Welding, Brazing and Fusing*

¹ American Bearing Manufacturers Association, 1001 N. Fairfax Street, Suite 500, Alexandria, VA 22314, www.americanbearings.org.

² American Gear Manufacturers Association, 1001 N. Fairfax Street, Suite 500, Alexandria, VA 22314-1587, www.agma.org.

³ ASME International, 2 Park Avenue, New York, NY 10016-5990, www.asme.org.

ASTM A105/A105M⁴, *Standard Specification for Carbon Steel Forgings for Piping Applications*

ASTM A106/A106M, *Standard Specification for Seamless Carbon Steel Pipe for High-Temperature Service*

ASTM A153/A153M, *Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*

ASTM A181/A181M, *Standard Specification for Carbon Steel Forgings, for General-Purpose Piping*

ASTM A193/A193M, *Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications*

ASTM A194/A194M, *Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both*

ASTM A197/A197M, *Standard Specification for Cupola Malleable Iron*

ASTM A216/A216M, *Standard Specification for Steel Castings, Carbon, Suitable for Fusion Welding, for High-Temperature Service*

ASTM A217/A217M, *Standard Specification for Steel Castings, Martensitic Stainless and Alloy, for Pressure-Containing Parts, Suitable for High-Temperature Service*

ASTM A269/A269M, *Standard Specification for Seamless and Welded Austenitic Stainless Steel Tubing for General Service*

ASTM A307, *Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60,000 PSI Tensile Strength*

ASTM A312/A312M, *Standard Specification for Seamless, Welded, and Heavily Cold Worked Austenitic Stainless Steel Pipes*

ASTM A320/A320M, *Standard Specification for Alloy-Steel and Stainless Steel Bolting for Low-Temperature Service*

ASTM A335/A335M, *Standard Specification for Seamless Ferritic Alloy-Steel Pipe for High-Temperature Service*

ASTM A338, *Standard Specification for Malleable Iron Flanges, Pipe Fittings, and Valve Parts for Railroad, Marine, and Other Heavy Duty Service at Temperatures Up to 650 °F (345 °C)*

ASTM A388/A388M, *Standard Practice for Ultrasonic Examination of Steel Forgings*

ASTM A524/A524M, *Standard Specification for Seamless Carbon Steel Pipe for Atmospheric and Lower Temperatures*

ASTM A563/A563M, *Standard Specification for Carbon and Alloy Steel Nuts (Inch and Metric)*

ASTM A578/A578M, *Standard Specification for Straight-Beam Ultrasonic Examination of Rolled Steel Plates for Special Applications*

ASTM A609/A609M, *Standard Practice for Castings, Carbon, Low-Alloy, and Martensitic Stainless Steel, Ultrasonic Examination Thereof*

⁴ ASTM International, PO Box C700, 100 Barr Harbor Drive, West Conshohocken, PA 19428, www.astm.org.

ASTM B165, *Standard specification for Nickel-Copper Alloy Seamless Pipe and Tube*

ASTM D4304, *Standard Specification for Mineral and Synthetic Lubricating Oil Used in Steam or Gas Turbines*

ASTM E94/E94M, *Standard Guide for Radiographic Examination Using Industrial Radiographic Film*

ASTM E165/E165M, *Standard Practice for Liquid Penetrant Testing for General Industry*

ASTM E709, *Standard Guide for Magnetic Particle Examination*

ASTM E1003, *Standard Practice for Hydrostatic Leak Testing*

AWS D1.1/D1.1M ⁵, *Structural Welding Code—Steel*

IEC 60079 ⁶, *Explosive atmospheres*

IEC 60529, *Degrees of protection provided by enclosures (IP Code)*

ISO 7-1 ⁷, *Pipe threads where pressure-tight joints are made on the threads—Part 1: Dimensions, tolerances and designation*

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

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

ISO 286-2, *Geometrical product specifications (GPS)—ISO code system for tolerances on linear sizes, Part 2: Tables of standard tolerance classes and limit deviations for holes and shafts*

ISO 3744, *Acoustic —Determination of sound power levels and sound energy levels of noise sources using sound pressure—Engineering methods for an essentially free field over a reflecting plane*

ISO 5753, *Rolling bearings—Internal clearance*

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

ISO 8068, *Lubricants, industrial oils and related products (class L)—Family T (Turbines)—Specification for lubricating oils for turbines*

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

ISO 14691, *Petroleum, petrochemical and natural gas industries—Flexible couplings for mechanical power transmission—General-purpose applications*

ISO 21940-11, *Mechanical vibration—Rotor balancing—Part 11: Procedures and tolerances for rotors with rigid behavior*

⁵ American Welding Society, 8669 NW 36 Street, #130, Miami, FL 33166, www.aws.org.

⁶ International Electrotechnical Commission, 3 rue de Varembe, 1st Floor, PO Box 131, CH-1211 Geneva 20, Switzerland, www.iec.ch.

⁷ International Organization for Standardization, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, www.iso.org.

MSS SP-55⁸, *Quality Standard for Steel Castings for Valves, Flanges, Fittings, and Other Piping Components—Visual Method for Evaluation of Surface Irregularities*

NEMA 250⁹, *Enclosures for Electrical Equipment (1000 Volts Maximum)*

NEMA MG 1, *Motors and Generators*

NEMA Publication, *A Brief Comparison of NEMA 250 and IEC 60529*

NFPA 70¹⁰, *National Electrical Code*

SSPC SP 6¹¹, *Commercial Blast Cleaning*

3 Terms, Definitions, Acronyms, Abbreviations, and Symbols

3.1 Terms and Definitions

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

3.1.1

alarm point

Preset value of a measured parameter at which an alarm is activated to warn of a condition that requires corrective action.

3.1.2

alloy steel

Steel that is alloyed with a variety of elements in total amounts between 1.0 % and 50 % by weight.

3.1.3

anchor bolts

Bolts used to attach the mounting surface to the support structure (concrete foundation or steel structure).

cf. **hold-down bolts** (3.1.13).

3.1.4

approve

Provide written documentation confirming an agreement.

3.1.5

axially split

Joint split with the principal face parallel to the shaft centerline.

3.1.6

baseplate

Fabricated steel structure designed to support the complete steam turbine and/or the driven equipment and other ancillaries that may be mounted upon it.

⁸ Manufacturers Standardization Society of the Valve and Fittings Industry, 127 Park Street, NE, Vienna, VA 22180-4602, www.mss-hq.com

⁹ National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1752, Rosslyn, VA 22209, www.nema.org.

¹⁰ National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169, www.nfpa.org.

¹¹ Formerly The Society for Protective Coatings, now known as The Association for Materials Protection and Performance (AMPP), 15835 Park Ten Place, Houston, TX 77084, www.ampp.org/home.

3.1.7

circulating oil system

A system that withdraws oil from the housing of bearings equipped with oil rings and cool the oil in an external oil cooler before it is returned to the bearing housing.

NOTE For vertical shaft turbines with circulating oil lubrication and/or cooling, the system can be integral to the turbine with water-cooled bearing housings or separate with external cooling capability. The system can have an integral oil pump(s) or a separate motor operated oil pump.

3.1.8

critical speed

Shaft rotational speed (revolutions per minute) at which the rotor-bearing-support system is in a state of resonance.

3.1.9

design

Manufacturer's calculated parameter.

3.1.10

diamètre nominal

DN

Alphanumeric designation of size for components of a pipework system.

EXAMPLE DN 20.

NOTE 1 Adapted from ISO 6708:1995.

NOTE 2 The letters DN are followed by a dimensionless whole number that is indirectly related to the physical size, in millimeters, of the bore or outside diameter (OD) of the end connection.

NOTE 3 The number following the letters DN does not represent a measurable value.

NOTE 4 A term used by the equipment manufacturer to describe various parameters such as design power, design pressure, design temperature, or design speed. It is not intended for the purchaser to use this term.

3.1.11

gauge board

Bracket or plate used to support and display gauges, switches, and other instruments.

cf. **panel** (3.1.34).

NOTE A gauge board is not a panel. A gauge board is open and not enclosed. A panel is an enclosure.

3.1.12

governor valve

Device that controls the flow of steam into the turbine in response to the governor.

3.1.13

hold-down bolts

mounting bolts

Bolts holding the equipment to the mounting surface.

cf. **anchor bolts** (3.1.3).

3.1.14

hydrodynamic bearings

Bearings that use the principles of hydrodynamic lubrication bearings that rely on the differential speed of the journal relative to the stator to pressurize a lubricating fluid in a wedge between the surfaces. The bearing

surfaces are oriented so that relative motion forms an oil wedge or wedges to support the load without shaft-to-bearing contact.

NOTE The bearing surfaces are oriented so that relative motion forms an oil wedge, or wedges, to support the load without shaft-to-bearing contact.

3.1.15

informative

For advice information only.

cf. **normative** (3.1.30).

NOTE An informative reference or annex provides advisory or explanatory information. It is intended to assist the understanding or use of the document.

3.1.16

local

Refers to the location of a device when mounted on or near the equipment or console.

3.1.17

maximum allowable speed

Highest speed (revolutions per minute) at which the manufacturer's design will permit continuous operation.

NOTE The maximum allowable speed is usually set by rotor stress values.

3.1.18

maximum allowable temperature

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

3.1.19

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 operating at the maximum allowable temperature.

3.1.20

maximum continuous speed

Highest rotational speed (revolutions per minute) at which the turbine, as built and tested, is capable of continuous operation.

3.1.21

maximum exhaust casing pressure

Highest exhaust steam pressure that the purchaser requires the casing to contain, with steam supplied at maximum inlet conditions.

NOTE The turbine will be subjected to the maximum temperature and pressure under these conditions. The manufacturer's classification determines the maximum relief valve setting.

3.1.22

maximum exhaust pressure

Highest exhaust steam pressure at which the turbine is required to operate continuously.

3.1.23

maximum inlet pressure and temperature

Highest inlet steam pressure and temperature conditions at which the turbine is required to operate continuously.

3.1.24**minimum allowable speed**

Lowest speed (revolutions per minute) at which the manufacturer's design will permit continuous operation.

3.1.25**minimum design metal temperature**

Lowest mean metal temperature (through the thickness) expected in the surrounding environment, for which the equipment is designed.

NOTE Adapted from ASME *Boiler and Pressure Vessel Code*.

3.1.26**minimum exhaust pressure**

Lowest exhaust steam pressure at which the turbine is required to operate continuously.

3.1.27**minimum inlet pressure and temperature**

Lowest inlet steam pressure and temperature conditions at which the turbine is required to operate continuously.

3.1.28**nominal pipe size****NPS**

Value equal to a diameter in inches.

EXAMPLE NPS $\frac{3}{4}$.

NOTE 1 Refer to ASME B31.3.

NOTE 2 The letters NPS are followed by a value which is related to an approximate diameter of the bore, in inches, for piping up to and including 12 in. diameter. For piping over 12 in. (NPS 12), the NPS value is the nominal OD.

3.1.29**normal**

Applies to the power, speed, and steam conditions at which the equipment will usually operate.

NOTE These conditions are the ones at which the highest efficiency is desired.

3.1.30**normative**

Required.

cf. **informative** (3.1.15).

NOTE 1 A normative reference or annex enumerates invokes a requirement or mandate of the specification.

NOTE 2 A normative reference or annex invokes a requirement or mandate of the specification. An informative annex such as vendor drawing and data requirements (VDDR) can also become normative if required in a purchase order.

3.1.31**observed**

A classification of inspection or test where the purchaser is notified of the schedule and the inspection or test is performed even if the purchaser or their representative is not present.

3.1.32**oil mist lubrication**

Lubrication systems that employ oil mist produced by atomization in a central supply unit and transported to the bearing housing, or housings, by compressed air.

3.1.33**owner**

Final recipient of the equipment who can delegate another agent as the purchaser of the equipment.

3.1.34**panel**

Enclosure used to mount, display, and protect gauges, switches, and other instruments.

cf. **gauge board** (3.1.11).

3.1.35**positive material identification testing****PMI testing**

Any physical evaluation or test of a material to confirm that the material which has been or will be placed into service is consistent with the selected or specified alloy material designated by the owner/user. These evaluations or tests may provide either qualitative or quantitative information that is sufficient to verify the nominal alloy composition.

NOTE Adapted from API 578.

3.1.36**potential maximum power**

Approximate maximum power to which the turbine can be up rated at the specified normal speed and steam conditions if it is furnished with suitable (larger or additional) nozzles and, possibly, with a larger governor valve or valves.

3.1.37**pressure casing**

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

3.1.38**purchaser**

Agency that issues the order and specification to the vendor.

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

3.1.39**pure oil mist lubrication (dry sump)**

Lubrication systems in which the mist both lubricates the bearing and purges the housing.

NOTE There is no oil level in the bearing housing when using pure oil mist lubrication (i.e. dry sump).

3.1.40**purge oil mist lubrication (wet sump)**

Lubrication systems in which the mist purges the bearing housing.

NOTE There is an oil level in the bearing housing when using purge oil mist lubrication and the bearing is lubricated by a conventional oil-bath, oil disc, or ring-oil lubrication system (i.e. wet sump).

3.1.41**radially split**

Joint split with the principal joint perpendicular to the shaft centerline.

3.1.42**rated power**

Maximum turbine power specified and the corresponding speed.

NOTE It includes all of the margin required by the driven-equipment specifications.

3.1.43**remote**

Refers to the location of a device if located away from the equipment or console, typically in a control room.

3.1.44**soleplate**

Plate attached to the foundation, with a mounting surface for equipment or for a baseplate.

3.1.45**special tool**

Tool that is not a commercially available catalog item.

3.1.46**standby**

Service state in which a piece of equipment that is normally idle or idling and is capable of immediate automatic or manual start-up for continuous operation.

3.1.47**steam chest**

High-pressure inlet of the steam turbine that may contain the governor valve and/or trip valve.

3.1.48**subplate**

Plate usually embedded in a concrete foundation and used to accurately locate and align a baseplate or soleplate.

3.1.49**total indicator reading****total indicated 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 cylindrical surface, the total indicated runout (TIR) implies an eccentricity equal to half the reading. For a flat face, the indicated runout implies an out-of-square equal to the reading.

3.1.50**trip speed**

Speed (revolutions per minute) at which the independent emergency overspeed device operates to shut down the turbine.

NOTE The trip speed setting can vary with the class of governor.

3.1.51**unit responsibility**

Obligation for coordinating the documentation, delivery, and technical aspects of all the equipment and all auxiliary systems included in the scope of the order.

3.1.52**vendor**

Agency that supplies the equipment.

NOTE The vendor can be the manufacturer or manufacturer's agent that supplies the equipment and is normally responsible for service support.

3.1.53

witnessed

Inspection or test where 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 their representative is in attendance.

3.2 Acronyms, Abbreviations, and Symbols

<i>AF</i>	amplification factor (refer to Figure 2-70 of API 684, Second Edition)
CCW	counterclockwise (rotation)
CW	clockwise (rotation)
DCS	distributed control system
DN	diamètre nominal
FEA	finite element analysis
HVOF	high-velocity oxygen fuel process
ID	inside diameter
MAWP	maximum allowable working pressure
NDT	nondestructive testing
NPS	nominal pipe size
OD	outside diameter
P&ID	piping and instrumentation diagram
PCV	positive crankcase ventilation
PMI	positive material identification
RV	relief valve
TCV	temperature control valve
TIR	total indicator reading, total indicated runout
VDDR	vendor drawing and data requirements

4 General

4.1 Unit Responsibility

The vendor shall assume unit responsibility and shall assure that all subvendors comply with the requirements of this standard and all reference documents. The technical aspects to be considered by the vendor include, but are not limited to, such factors as the power requirements, speed, rotation, general arrangement,

couplings, dynamics, lubrication, sealing system, material test reports, instrumentation, piping, conformance to specifications, and testing of components.

4.2 Nomenclature

A guide to API 611 nomenclature can be found in Annex G.

5 Requirements

● 5.1 Units of Measure

Purchaser's use of a U.S. customary (USC) unit data sheet (see Annex A) indicates the USC system of measurements shall be used for all data, drawings, and maintenance dimensions. Purchaser's use of a metric (SI) unit data sheet (see Annex A) indicates the SI system of measurements shall be used.

5.2 Statutory Requirements

The purchaser and the vendor shall 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.

5.3 Documentation

The purchaser shall specify the hierarchy of documents.

NOTE Typical documents include company and industry specifications, meeting notes, and modifications to these documents.

6 Basic Design

6.1 General

6.1.1 Equipment Reliability

- 6.1.1.1 Only equipment that is field proven, as defined by the purchaser, is acceptable.

NOTE Purchasers can use their engineering judgment in determining what equipment is field proven. API 691 can provide guidance.

- 6.1.1.2 If specified, the vendor shall provide the documentation to demonstrate that all equipment proposed qualifies as field proven.

6.1.1.3 In the event no such equipment is available, the vendor shall submit an explanation of how their proposed equipment can be considered field proven.

NOTE A possible explanation can be that all components comprising the assembled machine satisfy the field proven definition.

- 6.1.2 The purchaser shall specify the period of uninterrupted continuous operation. Shutting down the equipment to perform required maintenance or inspection during the specified uninterrupted operation period is not acceptable.

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

6.1.3 Vendor shall advise in the proposal any component designed for a finite life.

6.1.4 The driven equipment vendor shall assume unit responsibility for all equipment and all auxiliary systems included in the equipment train.

6.1.5 The equipment normal operating point will be specified on the data sheets.

6.1.6 The minimum steam pressure ratio across the turbine shall be limited to 2.0 or greater based on the ratio of the absolute inlet pressure to the absolute exhaust pressure.

6.1.7 Steam purity limits shall be in accordance with Annex H. The purchaser shall advise if there are corrosive agents in the steam or the environment that exceed the levels specified in Annex H, including contaminants that may cause stress corrosion cracking.

NOTE Contaminants in steam systems typically include sodium hydroxide, chlorides, aluminum, phosphates, copper, and lead.

6.1.8 Variations from maximum inlet steam pressure, maximum inlet steam temperature, and maximum exhaust pressure may be expected for short durations. Allowable swings and time durations over a 12-month period are defined in Annex H. Turbine shall be capable of withstanding these variations.

NOTE Some steel flange standards do not state that flange ratings consider variations in pressure and temperature for short durations.

6.1.9 Turbines shall be capable of the following.

- a) Operating at normal power and speed with normal steam conditions. The manufacturer's certified steam rate shall be at these conditions.
- b) Delivering rated power at its corresponding speed with coincident minimum inlet and maximum exhaust conditions as specified on the data sheets. To prevent oversizing or to obtain higher operating efficiency, the purchaser may limit maximum turbine capability by specifying normal or a selected percentage of rated power.

The rated power can be achieved by using a hand valve or valves under normal steam conditions and an additional hand valve or valves under minimum inlet and maximum exhaust steam conditions.

The turbine vendor shall indicate for the given application the optimum number of hand valves.

- c) Continuously operating at maximum continuous speed and at any speed within the range specified.
- d) Continuously operating at rated power and speed under maximum inlet steam conditions and maximum or minimum exhaust steam conditions.
- e) Operating with variations from rated steam conditions in accordance with Annex H.
- f) Regardless of the design limit of any turbine component, the turbine shall not be operated or re-rated outside the nameplate limits without consultation with the manufacturer or engineering review.

6.1.10 Equipment shall be designed to run without damage when operated simultaneously at the relief valve setting and trip speed.

6.1.11 Single-stage turbines shall be suitable for immediate start-up to full load. The purchaser shall allow for warm-up and proper drainage of the inlet piping, turbine casing, steam chest, and packing glands.

NOTE Consultation with the manufacturer is a good practice when single-stage turbines are applied for immediate automatic unattended start-up.

6.1.12 The turbine wheel or wheels for single-stage and multi-stage units shall be located between the bearings. Other arrangements require specific purchaser approval.

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

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

6.1.15 The turbine and other ancillary equipment shall perform on the test stand and on their permanent foundation within the specified acceptance criteria. After installation, the performance of the turbine, driven equipment, and auxiliaries shall be the joint responsibility of the purchaser and the vendor who has unit responsibility.

6.1.16 Cooling water equipment shall be designed for the conditions specified 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—Design Criteria and Specifications for Cooling Water Systems

Criteria	SI Units	USC Units
Water velocity over heat exchange surfaces ^a	≥ 1.5 m/s to 2.5 m/s	5 ft/s to 8 ft/s
Maximum allowable working pressure (MAWP)	≥ 7.0 bar	≥ 100 psig
Test pressure (≥ 1.5 MAWP)	≥ 10.5 bar	≥ 150 psig
Maximum pressure drop	1 bar	15 psi
Maximum inlet temperature	30 °C	90 °F
Maximum outlet temperature	50 °C	120 °F
Maximum temperature rise	20 K	30 °F
Water side fouling factor	0.35 m ² K/kW	0.002 h·ft ² ·°F/Btu
Corrosion allowance for carbon steel shells	3 mm	1/8 in.
^a These limits are not applicable to bearing housing with internal water passages.		

6.1.17 To avoid condensation in the bearing housing, the minimum inlet water temperature to water-cooled bearing housings should be maintained above the ambient air temperature.

6.1.18 Control of the sound pressure level of all equipment furnished shall be a joint effort of the purchaser and the vendor having unit responsibility.

6.1.19 The equipment furnished by the vendor shall conform to the maximum allowable sound pressure level specified.

6.1.20 The vendor shall provide expected values for maximum sound pressure levels per octave band for the equipment.

6.1.21 Motors, electrical components, and electrical installations shall be suitable for the area classification (class, group, and division or zone) specified by the purchaser and shall meet the requirements of the applicable clauses of IEC 60079 (NFPA 70, Articles 500, 501, 502, 504, and 505; API 500; API 505) as well as any local codes specified. Any local codes specified on the data sheet shall be furnished by the purchaser at the request of the vendor.

- **6.1.22** The equipment, including all auxiliaries, shall be suitable for operation under the environmental conditions specified. These conditions shall include whether the installation is indoors (heated or unheated) or outdoors (with or without a roof), maximum and minimum temperatures, sun metal temperature, unusual humidity, and dusty or corrosive conditions.
- **6.1.23** If specific materials are not permitted such as copper or aluminum, the purchaser shall specify if these material are restricted in the atmosphere around the equipment or in the steam path of the turbine.

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 Spare parts for the machine and all furnished auxiliaries shall meet all the criteria of this standard.

6.1.26 Any maintenance item with mass more than 20 kg (44 lb) shall be provided with lifting lugs or similar dedicated fixed lifting point(s). Screwed-in eyebolts are only acceptable for bearing housing covers and for internal components when other lifting arrangements are not practical. Holes for eyebolts shall be permanently marked with the correct bolt size to be used and the bolt size information shall be clearly indicated in the instruction manual.

6.2 Bolting

6.2.1 The details of threading shall conform to ASME B1.1, ASME B1.13M, or ISO 261.

6.2.2 Adequate clearance shall be provided at all bolting locations to permit the use of socket or box wrenches, per ASME B18.2.2.

6.2.3 Internal socket-type, slotted-nut, or spanner-type bolting shall not be used unless specifically approved by the purchaser.

For limited space locations, integrally flanged fasteners may be required.

6.2.4 Fasteners (excluding washers and headless set-screws) shall have the material grade and manufacturer's 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 an internal hex opening on one end.

6.2.5 Hardened washers shall be supplied for all bolting required for maintenance disassembly to prevent galling of the surfaces when removing the splitline bolting and other critical flange locations identified by the purchaser.

6.3 Pressure Casings

6.3.1 All pressure parts shall be at least suitable for operation at the most severe coincident conditions of pressure and temperature expected for the specified steam conditions.

6.3.2 The hoop stress values used in the design of the casing for any material shall not exceed the values given for that material in ASME *BPVC* Section II at the maximum operating temperature.

- 6.3.3** For cast materials, the factors specified in ASME *BPVC* Section VIII, Division 1 shall be applied.
- 6.3.4** Pressure casings of forged steel rolled and welded steel plate or seamless piping with welded covers shall comply with the applicable design rules of ASME *BPVC* Section VIII, Division 1 or Division 2.
- 6.3.5** Manufacturing data report forms, third-party inspections, and stamping as specified in the ASME *BPVC* are not required.
- 6.3.6** Axially split casings shall use a metal-to-metal joint (with a suitable joint compound) that is tightly maintained by suitable bolting. Gaskets (including string type) shall not be used on the axial joint. If gasketed joints are used on radially split casings, they shall be securely maintained by confining the gaskets.
- 6.3.7** Each axially split casing shall be sufficiently rigid to allow removal and replacement of its upper half without disturbing rotor-to-casing running clearances.
- 6.3.8** Axially split horizontal turbines shall be designed to permit inspection and removal of the rotor and wearing parts without removing the casing from its foundation or disconnecting inlet or exhaust steam piping (except if up-exhaust is specified). Axially split multi-stage turbine casings may also be split radially between high- and low-pressure portions.
- 6.3.9** Radially split horizontal turbines shall be designed to permit inspection and replacement of the bearings and outer glands without removing the casing from its foundation or disconnecting inlet or exhaust steam piping. Radially split horizontal turbines may require removal from their foundations to permit removal of rotors.
- 6.3.10** Casings and supports shall be designed to have sufficient strength and rigidity to limit any change in the relative position of the shaft ends at the coupling flange, caused by the worst combination of allowable pressure, torque, and piping forces and moments, to 50 μm (0.002 in.). Support and alignment bolts shall be rigid enough to permit the machine to be moved by lateral and axial jackscrews.
- 6.3.11** Axially split horizontal turbines shall have centerline supports to maintain proper alignment with connected equipment.
- 6.3.12** Mounting surfaces shall meet the following criteria.
- 6.3.13** Mounting surfaces shall be machined to a finish of 6 μm (250 $\mu\text{in.}$) arithmetic average roughness (Ra) or better.
- 6.3.14** To prevent a soft foot, mounting surfaces shall be machined on a horizontal plane flat within 25 μm (0.001 in.).
- 6.3.15** Each mounting surface shall be machined within a flatness of 40 μm per 1 linear m (0.0005 in. per linear ft) of mounting surface.
- 6.3.16** Different mounting planes shall be parallel to each other within 50 μm (0.002 in.).
- 6.3.17** The upper machined or spot faced surface shall be parallel to the mounting surface. Hold-down bolt holes shall be drilled perpendicular to the mounting surface or surfaces; machined or spot faced to a diameter two times that of the hole; and to allow for equipment alignment, be 15 mm ($1/2$ in.) larger in diameter than the hold-down bolt.
- 6.3.18** Drain connections shall be provided for the steam chest, casing, packing glands, and cooling jackets.
- 6.3.19** On condensing turbines, if the orientation of the exhaust nozzle is horizontal or vertically up, an automatic drain system is required. The drain system shall be supplied by the vendor.
- 6.3.20** A connection shall be provided to measure steam-ring chamber pressure on single-valve turbines and the pressure downstream of first stage pressure of multi-stage turbines.

6.3.21 Jackscrews, guide rods, cylindrical casing-alignment dowels, and/or other appropriate devices shall be provided to facilitate disassembly and reassembly.

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

6.3.23 Tapered dowels with removable nuts shall be provided on components that require disassembly and reassembly during normal maintenance.

6.3.24 Guide rods shall be of sufficient length to prevent damage to the internals or casing studs by the casing during disassembly and reassembly.

6.3.25 Lifting lugs or eyebolts shall be provided for lifting only the top half of the casing.

6.3.26 Methods of lifting the assembled machine shall be specified by the manufacturer.

6.3.27 The 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 diameter, in addition to the allowance for corrosion, shall be left around and below the bottom of drilled and threaded holes. The depth of the tapped holes shall be at least $1\frac{1}{2}$ times the stud diameter.

6.3.28 For "multi-stage" turbines, studs shall be used on the main joint of axially split casings. For single-stage turbines, due to the small size of the equipment, hexagonal head or socket head cap screws may be used on the main casing joint for ease of maintenance provided that the stress is limited to 60 % of bolt material yield. Studs shall be used instead of cap screws, on all other joints, except where hexagonal head cap screws are essential for assembly purposes and have been approved by the purchaser.

6.3.29 Studded connections shall be furnished with studs and nuts installed. Blind stud holes should be drilled only deep enough to allow a preferred tap depth of $1\frac{1}{2}$ times the major diameter of the stud; the first $1\frac{1}{2}$ threads at both ends of each stud shall be removed.

6.3.30 The equipment feet of horizontal shaft turbines shall be equipped with vertical jackscrews.

6.3.31 If equipment feet are drilled with pilot holes for use in final doweling, there shall be sufficient clearance to allow the field to use standard tools to finish machine the dowelling operation.

6.4 Casing Appurtenances

All nozzles or nozzle blocks shall be replaceable. All other stationary blading shall be mounted in replaceable diaphragms or segments.

6.5 Casing Connections

6.5.1 All openings or nozzles for piping connections on pressure casings shall be standard pipe sizes DN 20 (NPS $\frac{3}{4}$) or larger and shall be in accordance with ISO 6708. Sizes DN 32, DN 65, DN 90, DN 125, DN 175, and DN 225 (NPS $1\frac{1}{4}$, NPS $2\frac{1}{2}$, NPS $3\frac{1}{2}$, NPS 5, NPS 7, and NPS 9) shall not be used.

6.5.2 All connections shall be flanged or machined and studded, except where threaded connections are permitted by 6.5.6. All connections shall be suitable for the MAWP of the casing as defined in 3.1.19.

6.5.3 Flanged connections may be integral with the casing or, for casings of weldable material, may be formed by a socket-welded or butt-welded pipe nipple or transition piece and shall terminate with a welding-neck or socket-weld flange.

6.5.4 Connections welded to the casing shall meet the material requirements of the casing (see 6.12.4.7), including impact values, rather than the requirements of the connected piping (see 7.5.1.1). All welding of connections shall be completed before the casing is hydrostatically tested (see 8.3.2).



6.5.5 Butt-welded connections, size DN 40 (NPS 1½) and smaller, shall be reinforced by using forged welding inserts or gussets.

6.5.6 For connections other than main connections, if flanged or machined and studded openings are impractical, threaded connections for pipe sizes not exceeding DN 40 (NPS 1½) may be used as follows:

- a) on non-weldable materials, such as cast iron;
- b) where essential for maintenance (disassembly and assembly).

6.5.7 Connections other than main connections shall be installed as follows:

- a) the nipple and flange materials shall meet the requirements of 6.5.4;
- b) pipe nipples shall be provided with welding-neck or socket-weld flanges for steam pressures of 5.2 bar (75 psig) or higher;
- c) threaded connections shall not be seal welded;
- d) threaded openings and bosses for tapered pipe threads shall conform to ASME B16.5;
- e) pipe threads shall be taper threads that conform to ASME B1.20.1;
- f) openings for socket-welded connections shall conform to ASME B16.5 for castings and ASME B16.11 for fittings.

6.5.8 Pipe nipples screwed or welded to the casing should not be more than 150 mm (6 in.) long and shall be a minimum of Schedule 160 seamless for sizes DN 25 (NPS 1) and smaller and a minimum of Schedule 80 for DN 40 (NPS 1½) and larger.

6.5.9 Threaded openings not required to be connected to piping shall be plugged and the plugs shall meet the following requirements:

- a) round-head solid steel,
- b) meets ASME B16.11,
- c) made of a corrosion-resistant material if removable.

6.5.10 A process compatible thread lubricant of proper temperature specification shall be used on all threaded connections. Thread tape shall not be used.

6.5.11 Flanges shall conform to ASME B16.5 or ASME B16.47, Series A or B, as applicable, except as specified in the following.

- a) Flat-faced flanges with full raised-face thickness are acceptable on Class 150 exhaust connections.
- b) Flanges that are thicker or have a larger outside diameter than that required by ASME B16.5 or, as applicable, are acceptable. Nonstandard (oversized) flanges shall be completely dimensioned on the arrangement drawing. If oversized flanges require studs or bolts of nonstandard length, this requirement shall be identified on the arrangement drawing.
- c) The concentricity between the bolt circle and the bore of all casing flanges shall be such that the surface area for the seating of the machined gasket is adequate to accommodate a complete standard gasket that does not protrude into the fluid flow.

- d) For all flanges, imperfections in the flange facing finish shall not exceed that permitted in ASME B16.5 or ASME B16.47 as applicable.
- e) For the purpose of manufacturing mating parts, the vendor shall supply equipment flange details to the purchaser if connections larger than those covered by ASME B16.5 or ASME B16.47 are supplied. If specified, these mating parts shall be furnished by the vendor.

6.5.12 The finish of the contact faces of flanges and nozzles shall conform to the flange-finish roughness requirements in Table 2. Milled flanged surfaces are acceptable with the purchaser's approval.

Table 2—Arithmetic Average Roughness Height (Ra)

Type	Service	Contact Surface Roughness (Ra) $\mu\text{in.}$
Flat and raised face	Vacuum	63 to 125
	Above atmospheric	125 to 500
Ring joint	All	< 63

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

6.5.14 Mounting flanges for vertical turbines shall be made of cast iron or steel and shall be adequately bolted and ribbed for rigidity. Mounting flanges shall be as specified, of the rabbeted design, or flat-faced with provision for accurate centering and doweling conforming to NEMA MG 1 or as otherwise specified.

6.5.15 To minimize nozzle loading and facilitate installation of piping, machine flanges shall be parallel to the plane of the flange shown on the general arrangement drawing to within 0.5° . Studs or bolt holes shall straddle centerlines parallel to the main axes of the equipment.

6.6 External Forces and Moments

Turbines shall be designed to withstand the external forces and moments calculated in accordance with Annex I. All forces and moments shall be shown on the general arrangement drawing.

6.7 Rotating Elements

6.7.1 Rotors

6.7.1.1 Rotors shall be capable of operating from the minimum allowable speed up to trip speed.

6.7.1.2 Rotors (other than integrally forged shafts and disks) shall be assembled to prevent movement of the disk relative to the shaft when operating at any specified start-up or operating condition and any speed up to trip speed. The wheels shall be keyed to the shaft and assembled with a shrink fit.

6.7.1.3 The purchaser's approval is required for built-up rotors if blade tip velocities at maximum continuous speed exceed 250 m/s (825 ft/s) or if stage discharge steam temperatures exceed 400°C (750°F).

6.7.2 Shafts

6.7.2.1 Shafts shall be machined from one-piece heat-treated steel.

6.7.2.2 Shafts with finished diameters 200 mm (8 in.) and larger shall be forged. Shafts with finished diameters less than 200 mm (8 in.) may be hot-rolled bar stock purchased to the same quality and heat treatment criteria as shaft forgings.

6.7.2.3 Shafts shall be ground to a finish of 0.4 μm (16 $\mu\text{in.}$) Ra or better at the bearing locations and sealing areas for carbon ring packing.

6.7.2.4 Shaft coupling area shall be finished to 0.8 μm (32 $\mu\text{in.}$).

6.7.2.5 If vibration and/or axial-position probes are furnished, the rotor shaft sensing areas to be observed by the probes shall be concentric with the bearing journals.

6.7.2.6 All sensing areas (both radial vibration and axial position) shall be free from stencil and scribe marks or any other surface discontinuity, such as an oil hole or a keyway, for a minimum of one probe-tip diameter on each side of the probe. These areas shall be honed or burnished and not be metallized, sleeved, or plated.

6.7.2.7 These areas shall be properly demagnetized to the levels specified below and treated so that the combined total electrical and mechanical runout does not exceed the following.

- a) For areas to be observed by radial-vibration probes, 25 % of the allowed peak-to-peak vibration amplitude or 6.35 μm (0.25 mil), whichever is greater.
- b) For areas to be observed by axial-position probes, 12.7 μm (0.5 mil).
- c) If all reasonable efforts fail to achieve the limits noted in 6.7.2.7 a) and 6.7.2.7 b), the vendor and purchaser shall agree on alternate acceptance criteria.
- d) To prevent the buildup of potential voltages, residual magnetism of the free air gauss level in the rotor assembly shall not exceed ± 2 gauss when measured with a calibrated Hall effect probe on the surface of the part.

6.7.2.8 To prevent rusting on probe surface areas during storage or in operation, a nonconductive coating such as epoxy that does not affect the probe surface electrical runout may be used.

6.7.2.9 Shafts shall be protected by corrosion-resistant material under carbon ring packing for casing end glands. The manufacturer's application method, the coating material used, and the finished coating thickness shall be stated on the data sheets.

- **6.7.2.10** If specified, the coating shall be high-velocity oxygen fuel process (HVOF)-applied chrome carbide, ground and honed to 0.4 μm (16 $\mu\text{in.}$) Ra or less.

6.7.2.11 Each rotor shall be clearly marked with a unique identification number. This number shall be on the drive end of the shaft or in another accessible area that is not prone to maintenance damage.

6.7.2.12 All shaft keyways shall have fillet radii conforming to ASME B17.1.

6.7.3 Blading

6.7.3.1 Combined stress levels (steady state plus cyclic) developed in rotating blades at any equipment operating condition shall be low enough to ensure trouble-free operation even if resonant vibration occurs.

6.7.3.2 All blades shall be mechanically suitable for operation (including transient conditions) over the specified speed range and momentarily up to trip speed. The vendor shall assume that torque varies as speed squared unless otherwise notified by the purchaser.

6.7.3.3 If applicable the vendor is responsible to determine the resonance or frequencies of each blade banded group, to ensure that it will not be excited by excitation frequencies.

6.8 Seals

6.8.1 Outer glands shall be sealed at the shaft by carbon-ring or replaceable labyrinth packing, a combination of both, or by non-contacting end face mechanical seals.

6.8.2 Carbon-ring packing shall be used only if the surface speed at the shaft sealing surface is less than 50 m/s (160 ft/s) and meet the following requirements.

- a) The number of carbon rings shall be determined by the service and venting requirements, with 2.4 bar (35 psi) being the maximum allowable average differential pressure per active sealing ring.
 - b) Springs for carbon packing shall be made of nickel-chromium-iron alloy (heat treated after cold coiling) or equal material.
 - c) Variations in operating steam temperature shall be considered when the required cold clearances for packing rings are established.
- **6.8.3** If specified, non-contacting (gas face) seals may be used as an alternate to carbon ring or labyrinth-type packing subject to the following:
 - a) purchaser shall specify potential standby/rapid start conditions;
 - b) special conditions and speed limits shall be reviewed by turbine and seal vendor

NOTE Non-contacting gas seals are best used in continuous duty with acceptable steam quality, 14 °C (25 °F) super heat at the seal area, and the seals properly drained to prevent moisture accumulation.

6.8.4 Gland cases shall be furnished with a full complement of carbon rings.

- **6.8.5** If specified or when outer glands are sealed at the shaft with labyrinth packing or the exhaust pressure exceeds 105 psi (7.2 bar) with carbon rings, a separate vacuum device shall be furnished by the turbine vendor for connection to the glands to reduce external steam leakage. the device shall be mounted and connected by the vendor who mounts the turbine on the baseplate.

6.8.6 For condensing turbines, sealing glands that operate at less than atmospheric pressure shall be designed to admit steam that will seal against air ingress and comply with 6.8.7 and 6.8.8.

6.8.7 Piping with relief valves, pressure gauges, regulators, and other necessary valves shall be provided to interconnect the end glands. Piping shall have one common connection to the purchaser's sealing-steam supply.

- **6.8.8** If specified, the admission of sealing steam shall be automatically controlled throughout the load range. For multi-stage turbines, the normal operating sealing-steam supply shall preferably come from a positive-pressure section of the turbine. For single-stage turbines, and multi-stage turbine start-up, the purchaser shall provide pressure and temperature of steam available for use as sealing steam.

6.8.9 All piping and components of shaft seal and vacuum systems shall be sized for 300 % of the calculated new clearance leakage.

6.8.10 Sealing of interstage diaphragms on multi-stage turbines shall be by replaceable labyrinth packing.

6.8.11 The gland casing leak-off connections shall comply with 6.5.

- **6.8.12** Brush seals if specified or offered by the turbine vendor shall be configured to minimize gland seal leakage and shall be agreed to by the purchaser and vendor.

6.9 Dynamics

6.9.1 Critical Speeds

6.9.1.1 For information on critical speeds, refer to Annex B.

6.9.1.2 Resonances of structural support systems that are within the vendor's scope of supply and that affect the rotor vibration amplitude shall not occur within the specified separation margins (see B.2.10) unless the resonances are critically damped. The effective stiffness of the structural support shall be considered in the analysis of the dynamics of the rotor-bearing-support system.

NOTE Resonances of structural support systems can adversely affect the rotor vibration amplitude.

6.9.1.3 The vendor with unit responsibility shall determine that the drive-train critical speeds (rotor lateral, system torsional, blading modes, and the like) will not excite any critical speed of the machinery being supplied and the entire train is suitable for the rated speed and any starting-speed detent (hold point) requirements of the train. A list of all undesirable speeds from zero to trip shall be submitted to the purchaser for their review and included in the instruction manual for their guidance.

6.9.2 Lateral Analysis

6.9.2.1 The first lateral critical speed of single-stage turbines shall be at least 120 % of maximum continuous speed.

- **6.9.2.2** The vendor's standard critical speed values that have previously been analytically derived and test proven for previously manufactured turbines of the same frame size and rotor/bearing configuration are acceptable and shall be submitted to the purchaser as part of the proposal. For new turbine designs and rotor/bearing configurations, or if specified, the vendor shall perform a lateral critical analysis in accordance with the guidelines outlined in Annex B and provide a damped unbalanced rotor response plot (see Figure B.3), which meets the separation requirements in B.2.10.
- **6.9.2.3** If specified, the vendor shall provide calculations and/or available supporting test data for separation margins in accordance with 6.9.2.2 and Annex B.

6.9.3 Torsional Analysis

6.9.3.1 For units including gears or units comprising three or more coupled machines (excluding any gears), the vendor having system responsibility shall ensure that a torsional vibration analysis of the complete coupled train is carried out and shall be responsible for directing any modifications necessary to meet the requirements of Annex B.

6.9.4 Vibration and Balancing

6.9.4.1 Each thrust disk or collar shall be given a single-plane balance before it is assembled on its own shaft. Other major parts shall be given an individual dynamic balance before they are assembled on the shaft.

6.9.4.2 The rotating element shall be multi-plane dynamically balanced during assembly. This is accomplished after adding no more than two major components. Balancing correction applied only to the elements that are added. Other components may require minor corrections during the final trim balancing of the completely assembled element. On rotors that have single keyways, the keyway shall be filled with a fully crowned half-key. The maximum allowable residual unbalance per plane (journal) are calculated as follows:

In SI units:

$$U_{\max} = \frac{6350 \times W}{N} \quad (1)$$

In USC units:

$$U_{\max} = \frac{4 \times W}{N}$$

where

$U_{\max}$ is the residual unbalance, in g·mm (oz-in.);

W is the journal static weight load, in kg (lb);

N is the maximum continuous speed, in revolutions per minute.

If spare rotors are supplied, they shall be dynamically balanced to the same tolerances as the main rotor.

6.9.4.3 After the final balancing of each assembled multi-stage rotating element has been completed, a residual unbalance check shall be performed and recorded in accordance with the residual unbalance work sheet (see Annex E). The weight of all half-keys used during the final balancing of the assembled element shall be recorded on the residual unbalance work sheet.

- **6.9.4.4** If specified, after the final balancing of each assembled single-stage rotating element has been completed, a residual unbalance check shall be performed and recorded in accordance with the residual unbalance work sheet (see Annex E). The weight of all half-keys used during the final balancing of the assembled element shall be recorded on the residual unbalance work sheet.

6.9.4.5 Operating speed balancing (balancing in a high-speed balancing machine at the operating speed) shall be done only with the purchaser's specific approval. The acceptance criteria for this balancing shall be agreed upon by the purchaser and the vendor.

6.9.4.6 During the shop test of the machine, assembled with the balanced rotor, operating at its maximum continuous speed or at any other speed within the specified operating speed range, the peak-to-peak amplitude of unfiltered vibration in any plane, measured on the shaft adjacent and relative to each radial bearing, shall not exceed the following value or 50 µm (2 mils), whichever is less.

In SI units:

$$A = 25.4 \times \sqrt{\frac{12,000}{N}} \quad (2)$$

In USC units:

$$A = \sqrt{\frac{12,000}{N}}$$

where

A is the amplitude of unfiltered vibration, in µm (mils) true peak-to-peak;

N is the maximum continuous speed, in revolutions per minute.

At any speed greater than the maximum continuous speed, up to and including the trip speed of the turbine, the vibration shall not exceed 150 % or 0.5 mil above the maximum value recorded at the maximum continuous speed, whichever is greater.

NOTE These limits are not to be confused with the limits specified in Annex B for shop verification of unbalanced response.

6.9.4.7 If non-contacting probes or provisions for them have been specified, electrical and mechanical runout shall be determined and recorded by rolling the rotor in V blocks at the journal centerline while measuring runout with a non-contacting vibration probe and a dial indicator at the centerline of the probe location and one probe-tip diameter to either side.

The mechanical test report shall include the mechanical and electrical runout for 360° of rotation at each probe location.

6.9.4.8 If the vendor can demonstrate that electrical or mechanical runout is present, a maximum of 25 % of the test level calculated from Equation (2) or 6 μm (0.25 mil), whichever is greater, may be subtracted from the vibration signal measured during the factory test. The vendor shall make three attempts to minimize the electrical runout reading. After three attempts, final value shall be accepted if lower than 12.7 μm (0.5 mil). Values in excess of 12.7 μm (0.5 mil) are indicative of subsurface anomalies.

6.9.4.9 If non-contacting vibration probes are not provided or if vibration cannot be measured on the shaft, the peak vibration velocity measured on the bearing housing while it operates at speeds described in 6.9.4.6 shall not exceed 3.0 mm/s peak (0.12 in./s) (unfiltered) and 2.0 mm/s peak (0.08 in./s) at running speed frequency (filtered).

6.10 Bearings and Housings

6.10.1 Bearings—General

6.10.1.1 Bearings shall be one of the following arrangements: rolling element radial and thrust, hydrodynamic radial and rolling element thrust, or hydrodynamic radial and thrust. Each shaft shall be supported by two radial bearings and one double acting axial (thrust) bearing that may or may not be combined with one of the radial bearings. the bearing type and arrangement shall be selected in accordance with the limitations in Table 3 as a minimum.

Table 3—Bearing Selection

Condition	Bearing Type and Arrangement
Radial and thrust bearing speed and life within limits for rolling element bearings and turbine energy density below limit	Rolling element radial and thrust
Radial bearing speed or life outside limits for rolling element bearings and thrust bearing speed and life within limits and turbine energy density below limits	Hydrodynamic radial and rolling element thrust
Radial and thrust bearing speed or life outside limits for rolling element bearings or turbine energy density above limits	Hydrodynamic radial and hydrodynamic thrust
NOTE Limits are as follows. a) Rolling element bearing speed: factor, Nd_m, shall not exceed 500,000, where d_m is the mean bearing diameter $(d + D)/2$, expressed in millimeters, and N is the rotating speed, expressed in revolutions per minute. b) Rolling element bearing life: basic rating L_{10h} per ISO 281 or ABMA 9 of at least 50,000 hours with continuous operation at rated conditions, and at least 32,000 hours at maximum radial and axial loads and rated speed. c) Energy density is the product of rated power, kW (HP), and rated speed, r/min; if the value is 4.0 million (5.4 million) or greater, hydrodynamic radial and thrust bearings shall be used. This energy density limit is applicable only to multi-stage turbines.	

- **6.10.1.2** Horizontal turbines shall be equipped with thrust bearings designed to handle axial loads in either direction. Multi-stage turbines shall have hydrodynamic thrust bearings, if specified, or where antifriction bearings fail to meet the minimum L_{10} rating life [see Table 3, Item b)].

6.10.1.3 Vertical turbines can have oil- or grease-lubricated ball- or roller-type radial and thrust bearings. Thrust bearings shall be sized for continuous operation under all specified conditions of the driven equipment. The thrust load of the driven equipment (up and/or down) shall be specified on the data sheets.

6.10.1.4 Rolling element bearings shall be protected against over-greasing by means of an adequately sized vent.

6.10.1.5 The bearing design shall suppress hydrodynamic instabilities and provide sufficient damping over the entire range of allowable bearing clearances and oil temperatures to limit rotor vibration to the maximum specified amplitudes (see 6.9.4.6) while the equipment is operating loaded or unloaded at specified operating speeds, including operation at any critical frequency.

6.10.1.6 Thrust bearings shall be sized for continuous operation through the full operating range including the most adverse specified operating conditions. Calculation of the thrust load shall include but shall not be limited to the following factors:

- a) fouling and variation in seal clearances at design and at twice the design internal clearances;
- b) step thrust from all diameter changes;
- c) stage reaction and stage differential pressure;
- d) variations in pressure at all inlet and outlet nozzles;
- e) external loads from the driven equipment, as described in 6.10.1.7 through 6.10.1.8.

6.10.1.7 Thrust forces from metallic flexible element couplings shall be calculated on the basis of the maximum allowable deflection permitted by the coupling manufacturer.

6.10.1.8 If two or more rotor thrust forces are to be carried by one thrust bearing (such as in a gear box), the resultant of the forces shall be used provided the directions of the forces make them numerically additive; otherwise, the largest of the forces shall be used.

- **6.10.1.9** If specified, hydrodynamic thrust and radial bearings shall be fitted with bearing metal temperature sensors installed in accordance with API 670. Radial bearings with journal sizes 100 mm (4.0 in.) or smaller shall be fitted with a contact metal temperature sensor and/or oil throw-off temperature sensor.

6.10.2 Rolling Element Bearings

6.10.2.1 Rolling element bearings shall be located, retained, and mounted in accordance with the following:

- a) bearings shall be located on the shaft using shoulders, collars, or other positive locating devices; snap rings and spring-type washers are not acceptable;
- b) bearings shall be retained on the shaft with an interference fit and fitted into the housing with a diametrical clearance, both in accordance with the recommendations of ABMA 7;
- c) bearings shall be mounted directly on the shaft; bearing carriers are not acceptable.

6.10.2.2 Single-row deep-groove ball bearings shall have greater than normal internal clearance according to ABMA Symbol 3, as defined in ABMA 20 (ISO 5753, Group 3).

6.10.2.3 Rolling element bearings shall be selected in accordance with the following.

- a) A rolling element thrust bearing may be a single-row deep-groove ball bearing provided the combined axial thrust and radial load is within the capability of such a bearing and requirements of Table 3 are satisfied.
- b) Where the loads exceed the capability of a single-row deep-groove bearing, a matched pair of single-row, 40° angular contact type (7000 series) bearings shall be used. The bearings shall be mounted in a paired arrangement back-to-back.
- c) The device used to lock ball thrust bearings to shafts shall be restricted to a nut with a tongue-type lock washer.
- d) Four-point contact (split race) ball bearings and bearings with filling slots shall not be used.

6.10.3 Hydrodynamic Bearings

6.10.3.1 Hydrodynamic Radial Bearings

6.10.3.1.1 Hydrodynamic radial bearings shall be split for ease of assembly, precision bored, and of the sleeve or pad type, with steel or copper/bronze backed, babbitted replaceable liners, pads, or shells. These bearings shall be equipped with anti-rotation pins and shall be positively secured in the axial direction (see 6.10.4.1.1).

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

6.10.3.1.3 Bearings shall be designed to prevent incorrect positioning.

6.10.3.2 Hydrodynamic Thrust Bearings

6.10.3.2.1 Thrust bearings shall be of the steel or copper/bronze backed, babbitted multiple segment type, designed for equal thrust capacity in both directions and arranged for continuous pressurized lubrication.

each side. Both sides shall be of the tilting pad type, incorporating a self-leveling feature that ensures that each pad carries an equal share of the thrust load with minor variation in pad thickness.

6.10.3.2.2 Each pad shall be designed and manufactured with the dimensional precision (thickness variation) that will allow the interchange or replacement of individual pads.

6.10.3.2.3 If replaceable collars are furnished (for assembly and maintenance purposes), they shall be positively locked to the shaft to prevent fretting.

- **6.10.3.2.4** If specified, integral thrust collars shall be supplied for multi-stage turbines. Integral collars shall be provided with at least 3 mm ($\frac{1}{8}$ in.) of additional stock to enable refinishing if the collar is damaged. Both faces of thrust collars for hydrodynamic thrust bearings shall have a surface finish of 0.4 μm (16 $\mu\text{in.}$) Ra or better, and after mounting, the axial TIR of either face shall not exceed 12.7 μm (0.0005 in.).

6.10.3.2.5 Thrust bearings shall be selected such that under any operating condition the load does not exceed 50 % of the bearing manufacturer's ultimate load rating. The ultimate load rating is the load that will produce the minimum acceptable oil-film thickness without inducing failure during continuous service or the load that will not exceed the creep initiation or yield strength of the babbitt at the location of maximum temperature on the pad, whichever load is less. In sizing thrust bearings, consideration shall be given to the following for each specific application:

- a) the shaft speed;
- b) the temperature of the bearing babbitt;
- c) the deflection of the bearing pad;
- d) the minimum oil film thickness;
- e) the feed rate, viscosity, and supply temperature of the oil;
- f) the design configuration of the bearing;
- g) the babbitt alloy; and
- h) the turbulence of the oil film.

The sizing of hydrodynamic thrust bearings shall be reviewed and approved by the purchaser.

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

6.10.4 Bearing Housings

6.10.4.1 General

6.10.4.1.1 Bearing housings shall be arranged so that bearings can be replaced without disturbing driven equipment or mounting and do not require removal of thrust collars or couplings (see 6.10.3.1.1).

6.10.4.1.2 Bearing housings for oil-lubricated nonpressure fed bearings shall be provided with tapped and plugged fill and drain openings at least DN 15 (NPS $\frac{1}{2}$) in size. The housings shall be equipped with constant level sight feed oilers at least 0.12 L (4 oz) in size, with a positive level positioner (not an external screw), heat-resistant glass containers (not subject to sunlight or heat induced opacity or deterioration), and protective wire cages. Means shall be provided 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 another durable means.

6.10.4.1.3 For pressurized oil systems, the oil inlet and drain connections shall be flanged or machined and studded. Threaded openings shall be installed as follows.

- a) Stainless steel pipe nipple of Schedule 40S, preferably not more than 150 mm (6 in.) long, shall be provided.
- b) The pipe nipple shall be provided with a stainless steel flange.
- c) Pipe or tube fittings on DN 20, DN 25, and DN 40 (NPS $\frac{3}{4}$, 1, and $1\frac{1}{2}$) connections shall not be seal welded. Threaded connections shall not be made up with thread tape; all threaded connections shall be made up with a suitable thread sealant.

6.10.4.1.4 Sufficient cooling, including an allowance for fouling, shall be provided to maintain oil and bearing temperatures during shop testing and in field operation under the most adverse specified operating condition as follows.

- a) For pressurized fluid film bearing systems, the bearing oil temperature rise shall not exceed 28 K (50 °R) above inlet oil temperature, and if bearing metal temperature sensors are supplied, bearing metal temperatures shall not exceed 93 °C (200 °F).
- b) For ring-oiled or splash systems (including such systems with purge-oil mist), the sump oil temperature rise shall not exceed 40 K (70 °R) above ambient temperature, and if bearing metal temperature sensors are supplied, bearing metal temperatures shall not exceed 93 °C (200 °F).
- c) For grease-lubricated bearings, if bearing metal temperature sensors are supplied, bearing metal temperatures shall not exceed 93 °C (200 °F).
- d) For pure oil mist systems, the bearing housing surface temperature shall not exceed 71 °C (160 °F), and if bearing-temperature sensors are supplied, bearing metal temperatures shall not exceed 88 °C (190 °F).

6.10.4.1.5 For ambient conditions that exceed 42 °C (110 °F) or if the inlet oil temperature exceeds 50 °C (120 °F), special consideration shall be given to bearing design, oil flow, and allowable temperature rise.

6.10.4.1.6 Where water cooling is required, water jackets shall have only external connections between upper and lower housing jackets and shall not have gasketed or threaded connection joints that can allow water to leak into the oil reservoir.

6.10.4.1.6.1 If cooling coils (including fittings) are used, they shall be of nonferrous, metallic material and shall have no internal pressure joints.

6.10.4.1.6.2 Tubing or pipe shall have a minimum wall thickness of 1.0 mm (0.040 in.) and shall be at least 12 mm (0.50 in.) outside diameter.

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

6.10.4.2 Seals and Deflectors

6.10.4.2.1 Bearing housings shall be equipped with replaceable labyrinth-style end seals and deflectors where the shaft passes through the housing and meet the following:

- a) lip-type seals shall not be used;
- b) seals and deflectors shall be made of non-sparking materials;
- c) design of the seals and deflectors shall retain oil in the housing and restrict entry of steam, condensation, and foreign material into the housing.

- **6.10.4.2.2** If specified, bearing isolation seals providing a positive tight seal to prevent the ingress of atmospheric contaminants shall be supplied.

- **6.10.4.3 Oil Mist Lubrication**

6.10.4.3.1 An DN 8 (NPS 1/4) oil mist inlet connection shall be provided in the top half of the bearing housing. The pure or purge oil mist fitting connections shall be located so that oil mist will flow through rolling element bearings. On pure mist systems, there shall be no internal passages to short circuit oil mist from inlet to vent.

6.10.4.3.2 A threaded DN 8 (NPS 1/4) vent connection shall be provided on the housing or end cover for each of the spaces between the rolling element bearings and the housing shaft closures. Alternatively, where oil mist connections are between each housing shaft closure and the bearings, one vent central to the housing shall be supplied. Housings with only sleeve-type bearings shall have the vent located near the end of the housing.

6.10.4.3.3 Shielded or sealed bearings shall not be used.

6.10.4.3.4 If pure oil mist lubrication is specified, oil rings or flingers (if any) and constant level oilers shall not be provided, and a mark indicating the oil level is not required. If purge oil mist lubrication is specified, these items shall be provided and the oiler shall be piped so that it is maintained at the internal pressure of the bearing housing.

6.10.4.3.5 At steam exhaust 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:

- a) heat-sink-type flingers;
- b) stainless steel shafts having low thermal conductivity;
- c) thermal barriers;
- d) fan cooling; and
- e) purge oil mist lubrication (in place of pure oil mist) with oil (sump) cooling.

6.10.4.3.6 The oil mist supply and drain fittings shall be provided by the purchaser.

6.10.4.4 Vibration Measurement

6.10.4.4.1 All bearing housings shall have dimpled locations in the vertical (V) and horizontal (H) at each bearing housing and location (A) at the outboard bearing housing as shown in Figure 1 and in accordance with 8.3.3.1 a) to facilitate consistent vibration measurements, and meet the following:

- a) dimples shall be suitable for accurate location of a hand-held vibration transducer with an extension "wand;"
- b) dimples may be cast or machined and be nominally 2 mm (0.080 in.) deep with an included angle of 120° as shown in Figure 2;
- c) dimples shall be located as close to the bearing centerline as practical for the vertical (V) and horizontal (H) locations only.

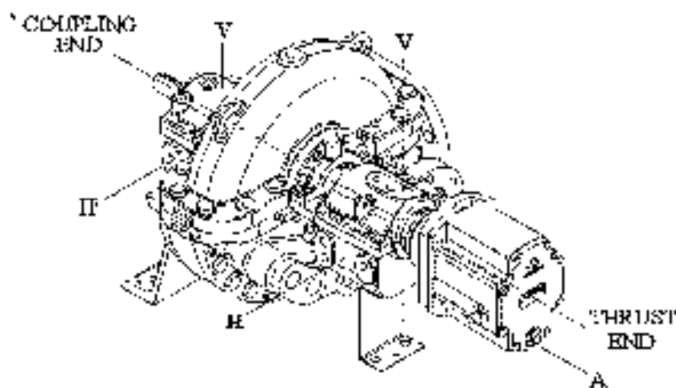


Figure 1—Bearing Housing Dimple Locations for Vibration Measurements

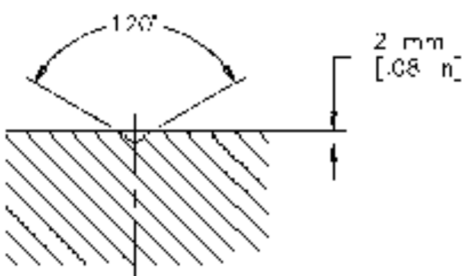


Figure 2—Dimple Dimensions

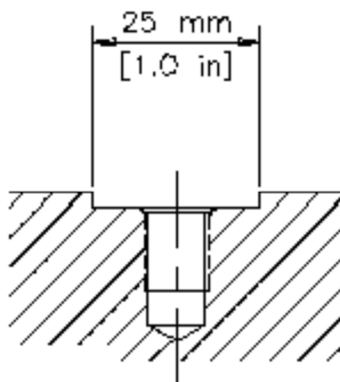


Figure 3—Transducer Mounting Hole Dimensions

- **6.10.4.4.2** If specified, a flat surface of an agreed size and location shall be provided for mounting of magnetic-based seismic vibration measuring equipment.
- **6.10.4.4.3** If specified, bearing housings shall be prepared for permanently mounting seismic vibration transducers in accordance with API 670. The spot face and drilling are to be per Figure 3 and located on the top of each bearing housing. The thread size is to be agreed upon between the purchaser and vendor.
- **6.10.4.4.4** If specified, provision shall be made for mounting two radial vibration probes adjacent to each bearing, two axial position probes at the thrust end, and a one-event-per-revolution probe in each machine. The probe installation shall be as specified in API 670.

NOTE Typically non-contacting proximity probes are replaced with seismic transducers on turbines with anti-friction radial bearings and thrust bearings.

6.10.4.4.5 Bearing housings for pressure-lubricated hydrodynamic bearings shall be arranged to minimize foaming. The drain system shall be adequate to maintain the oil and foam level below shaft end seals.

6.10.4.4.6 Oil connections on bearing housings shall be in accordance with 6.10.4.1.3.

6.10.4.4.7 Axially split bearing housings shall have a metal-to-metal joint with cylindrical locating dowels.

6.11 Lubrication

6.11.1 Bearings and bearing housings shall be designed for oil lubrication using a mineral oil in accordance with ASTM D4304 or ISO 8068, Type TSA or TGA.

- **6.11.2** If specified by the purchaser or required by the vendor, a synthetic lubrication oil may be used. If synthetic oil is required by the vendor, they shall provide a complete description of the proposed lubricant. Material compatibility with other components receiving the synthetic oil shall be confirmed.

NOTE Synthetic oils may act as solvents and dissolve coatings or attack seals.

- **6.11.3** If specified by the purchaser or required by the turbine vendor, a pressurized oil system shall be furnished to supply oil at a suitable pressure or pressures, as applicable, to:
 - a) the bearings of the driver and of the driven equipment (including any gear); and
 - b) any governor and control-oil system.

6.11.4 Pressurized oil systems shall conform to the requirements of API 614.

6.11.5 Where oil is supplied from a common system to two or more components of a machinery train (such as a compressor, a gear, and a turbine), the vendor having unit responsibility shall ensure compatibility of type, grade, pressure, and temperature of oil for all equipment served by the common system.

- **6.11.6** If specified that a wide-speed-range, rapid-starting, or slow-roll operation is required, the turbine vendor shall confirm the lubrication requirements for these conditions.

6.11.7 Where a circulation system is proposed, details shall be submitted to the purchaser for review.

6.11.8 Oil disks and oil rings shall be metal. Oil disks shall have mounting hubs to maintain concentricity and shall be positively secured to the shaft.

NOTE Oil flingers (slingers) are used to prevent oil migration along a shaft, not as a means of transporting oil.

6.11.9 The required oil ring submergence will be defined in the instructions and operations manual supplied by the manufacturer.

6.12 Materials

6.12.1 General

6.12.1.1 Except as required or prohibited by this standard or by the purchaser, materials of construction shall be selected by the manufacturer for the operating and site environmental conditions specified (see 6.12.1.7).

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

6.12.1.3 In cases where the inlet temperature exceeds 413 °C (775 °F), alloy steel meeting the temperature requirements shall be used. In these cases, ASTM A193/A193M, Grade B16 bolting shall be applied for pressure-containing joints.

6.12.1.4 Materials for other turbine parts shall be the manufacturer's standard for the shaft and wheels, 11-13 Cr for blading and nozzles (rotating and stationary), 11-13 Cr or nickel-copper for the shrouding, and 18-8 stainless steel for the steam strainer.

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

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

- **6.12.1.7** If specified, any corrosive agents (including trace quantities) present in the steam and in the environment, including constituents that can cause stress corrosion cracking, shall be noted on data sheet.

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

6.12.1.9 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 antiseizure compound of the proper temperature specification and compatible with the specified process fluid(s).

NOTE With and without the use of antiseizure compounds, the required torque loading values to achieve the necessary preload will vary considerably.

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

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

6.12.1.11 Materials, casting factors, and the quality of any welding shall be equal to those required by ASME BPVC Section VIII, Division 1. The manufacturer's data report forms, as specified in the code, are not required.

6.12.1.12 O-ring materials shall be compatible with all specified services.

6.12.1.13 For ambient temperatures below –30 °C (–20 °F), generally available steel casing materials, at the lowest specified temperature, do not have an impact strength sufficient to qualify under the minimum Charpy V-notch impact energy requirements of ASME BPVC Section VIII, Division 1, UG-84. The purchaser and the vendor shall agree upon the protection required.

6.12.1.14 The minimum quality bolting material for pressure joints shall be carbon steel (such as ASTM A307, Grade B) for cast iron casings and high-temperature alloy steel (such as ASTM A193/A193M, Grade B7) for steel casings. Carbon steel nuts (such as ASTM A194/A194M, Grade 2H) shall be used; where space is limited, case hardened carbon steel nuts (such as ASTM A563/A563M, Grade A) shall be used. For temperatures below –30 °C (–20 °F), low-temperature bolting material (such as ASTM A320/A320M) shall be used.

6.12.2 Castings

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

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

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

- a) Weldable grades of steel castings shall be repaired by welding, using a qualified welding procedure based on the requirements of the appropriate pressure vessel code such as ASME *BPVC* Section VIII, Division 1 and ASME *BPVC* Section IX. After major weld repairs, and before hydrotest, the complete repaired casting shall be given a postweld heat treatment to ensure stress relief and continuity of mechanical properties of both weld and parent metal and dimensional stability during subsequent machining operations.
- b) 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").
- c) All repairs that are not covered by ASTM specifications shall be subject to the purchaser's approval.

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

6.12.3 Forgings

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

- a) Weldable grades of steel forgings shall be repaired by welding using a qualified welding procedure based on the requirements of the appropriate pressure vessel code such as ASME *BPVC* Section VIII, Division 1 and ASME *BPVC* Section IX. After major weld repairs, and before hydrotest, the complete forging shall be given a postweld heat treatment to ensure stress relief and continuity of mechanical properties of both weld and parent metal.
- b) All repairs that are not covered by ASTM specifications shall be subject to the purchaser's approval.

6.12.4 Welding

6.12.4.1 Welding of piping, pressure-containing parts, rotating parts, and other highly stressed parts; weld repairs; and any dissimilar-metal welds shall be performed and inspected by operators and procedures qualified in accordance with ASME *BPVC* Section VIII, Division 1 and ASME *BPVC* Section IX.

6.12.4.2 Other welding, such as welding on baseplates, nonpressure ducting, lagging, and control panels, shall be performed by welders qualified in accordance with an appropriate recognized standard such as AWS D1.1/D1.1M.

6.12.4.3 The vendor shall be responsible for the review of all repairs and repair welds to ensure that they are properly heat treated and nondestructively examined for soundness and compliance with the applicable qualified procedures [see 6.12.2.3 a)]. Repair welds shall meet the following:

- a) be nondestructively tested by the same method used to detect the original flaw;
- b) as a minimum, the inspection shall be by the magnetic particle method in accordance with 8.2.2.4 for magnetic material and by the liquid penetrant method in accordance with 8.2.2.5 for nonmagnetic material.

6.12.4.4 The purchaser shall be notified before making a major repair. A major repair, for the purpose of purchaser notification, is any defect that equals or exceeds any of the following criteria:

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

6.12.4.5 Pressure-containing casings made from wrought materials or combinations of wrought and cast materials shall conform to the conditions specified in the following.

- a) 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).
- b) Accessible surfaces of welds shall be inspected by magnetic particle or liquid penetrant examination after back chipping or gouging and again after postweld heat treatment. The quality control of welds that will be inaccessible on completion of the fabrication shall be agreed on by the purchaser and vendor prior to fabrication.
- c) Pressure-containing welds, including welds of the case to axial- and radial-joint flanges, shall be full-penetration welds.
- d) Casings fabricated from materials that, according to ASME *BPVC* Section VIII, Division 1, require postweld heat treatment, shall be heat treated regardless of thickness.

6.12.4.6 All welds shall be heat treated in accordance with ASME *BPVC* Section VIII, Division 1, Sections UW-10 and UW-40.

6.12.4.7 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.

6.12.5 Low-temperature Service

- **6.12.5.1** The purchaser shall specify the minimum temperature. Vendor shall establish the minimum design metal temperature, impact test, and other material requirements based on the information supplied by the purchaser.

NOTE Normally, this will be the lower of the minimum surrounding ambient temperature or minimum exhaust temperature.

6.12.5.2 To avoid brittle failures, materials and construction for low-temperature service shall be suitable for the minimum design metal temperature. 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.

NOTE 1 Care shall be taken in the selection of fabrication methods, welding procedures, and materials for vendor-furnished steel pressure-retaining parts that can be subject to temperatures below the ductile-brittle transition temperature.

NOTE 2 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.

6.12.5.3 Impact testing shall be performed in accordance with 6.12.5.3.1 through 6.12.5.3.4.

6.12.5.3.1 All carbon and low-alloy steel pressure-containing components including nozzles, flanges, and weldments shall be impact tested in accordance with the requirements of ASME *BPVC* Section VIII, Division 1, Sections UCS-65 through 68 or purchaser's approved equivalent standard.

6.12.5.3.2 High-alloy steels shall be tested in accordance with ASME *BPVC* Section VIII, Division 1, UHA-51 or purchaser's approved equivalent standard.

6.12.5.3.3 For materials and thicknesses not covered by ASME *BPVC* Section VIII, Division 1 or equivalent standards, the purchaser shall specify requirements.

6.12.5.3.4 Impact testing of a material may not be required depending on the minimum design metal temperature, thermal, mechanical, and cyclic loading and the governing thickness.

NOTE Refer to requirements of ASME *BPVC* Section VIII, Division I, UG-20F, for example.

6.12.5.4 Governing thickness used to determine impact testing requirements shall be the greater of the following:

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

The results of the impact testing shall meet the minimum impact energy requirements of ASME *BPVC* Section VIII, Division I, UG-84 or equivalent standard.

6.13 Nameplates and Rotation Arrows

6.13.1 A nameplate shall be securely attached at a readily visible location on the equipment.

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

6.13.3 Nameplates and rotation arrows (if attached) shall be of austenitic stainless steel or nickel-copper (ASTM B165, UNS N04400) alloy. Attachment pins shall be of the same material. Welding is not permitted.

6.13.4 The following data, as a minimum, shall be clearly stamped on the nameplate in units consistent with the data sheets:

- a) vendor's name;
- b) serial number;
- c) size and type;
- d) rated power and speed;
- e) first critical speed;

- f) second critical speed;
- g) maximum continuous speed;
- h) minimum allowable speed;
- i) overspeed trip setting;
- j) normal and maximum inlet steam temperature and pressure;
- k) normal and maximum exhaust steam pressure;
- l) the purchaser's equipment item number (this may be on a separate nameplate if there is insufficient space on the rating nameplate);
- m) if applicable, number of teeth on electronic speed pickup gear assembly.

6.13.5 Lateral critical speeds determined from running test shall be stamped on the nameplate followed by the word "TESTS." Critical speeds predicted by calculation up to and including first critical speed above trip speed, and not identifiable by test, shall be stamped on the nameplate followed by the abbreviation "CALC."

7 Accessories

7.1 Gear Units

7.1.1 Gears may be considered for applications where their inclusion will result in a more efficient turbine. Steam rates and performance curves shall be based on gear output power.

7.1.2 Integral (built-in) gear units shall not be used for driven equipment that requires more than 55 kW (75 HP) of rated power.

7.1.3 Separate parallel-shaft gears shall conform to API 677 double helical design.

7.1.4 The output shaft rotation of the gear unit shall be noted clearly in all data, as well as on the machine.

7.2 Couplings and Guards

7.2.1 Couplings for general-purpose applications shall be disc or diaphragm style.

7.2.2 Coupling and guards between horizontal turbines and driven equipment shall be supplied by the manufacturer with unit responsibility.

7.2.3 For vertical turbines, a rigid non-spacer coupling between the turbine and driven equipment if applicable shall be supplied by the manufacturer with unit responsibility.

- **7.2.4** If specified, the driver half of the coupling shall be mounted by the turbine manufacturer before shipment or before testing.

7.2.5 Couplings and coupling to shaft junctures shall be rated for at least the turbine rated power times the coupling service factor for the application per AGMA 922.

7.2.6 The make and model of the couplings shall be agreed upon by the purchaser and the vendors of the driver and driven equipment.

- **7.2.7** A spacer coupling with a minimum 125 mm (5 in.) spacer shall be used, unless otherwise specified.

7.2.8 Couplings shall be forged steel and designed to allow the necessary end float caused by expansion and other end movements of the shaft.

7.2.9 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.

7.2.10 If the turbine vendor supplies a separate gear, the vendor shall also supply and mount a flexible element coupling between the gear and the turbine.

7.2.11 To assure accurate alignment of connected machinery, the TIR of coupling alignment surfaces shall be controlled as specified in the following.

- a) Flexible couplings with cylindrical bores shall be mounted with an interference fit. Cylindrical shafts shall comply with AGMA 9002 and the coupling hubs shall be bored to the following tolerances as detailed in ISO 286-2.
 - 1) For shafts of 50 mm (2 in.) diameter and smaller—Grade N7.
 - 2) For shafts larger than 50 mm (2 in.) diameter—Grade N8.
- b) For turbines connected to their driven equipment with a flexible coupling, the locating and alignment faces shall be perpendicular to the axis. The coupling surfaces normally used for checking alignment shall be concentric to the axis of coupling hub rotation within the following limits: 13 μm (0.0005 in.) TIR per in. of shaft diameter, with a minimum applicable tolerance of 25 μm (0.001 in.) TIR and a maximum of 75 μm (0.003 in.) TIR.
- c) Coupling faces shall be perpendicular to the axis of the coupling within 1 μm per 10 mm (0.0001 in. per in.) of face diameter with a maximum of 13 μm (0.0005 in.) TIR.
- d) For vertical turbines that have rigid couplings between the turbine and driven equipment, the coupling diameters shall be concentric to the axis of coupling hub rotation within the following limits: 13 μm (0.0005 in.) TIR per in. of shaft diameter, up to a maximum of 25 μm (0.001 in.) TIR.

7.2.12 All-metal flexible element, spacer-type couplings shall be in accordance with AGMA 9000, Class 9.

Additionally, these couplings shall comply with the following:

- a) flexible elements shall be of corrosion-resistant material;
 - b) couplings shall be designed to retain the spacer if a flexible element ruptures;
 - c) coupling hubs shall be steel;
 - d) the spacer nominal length shall be at least 125 mm (5 in.) and shall permit removal of the coupling, bearings, seal, and rotor, as applicable, without disturbing the driven equipment or inlet and exhaust piping; and
 - e) couplings operating (maximum continuous speed) at speeds in excess of 3800 r/min shall meet the requirements of API 671 for component balancing and assembly balance check.
- **7.2.13** If specified, coupling components shall be balanced to ISO 21940-11, Grade 6.3.
 - **7.2.14** If specified, couplings shall meet the requirements of ISO 14691 or API 671.

7.2.15 Flexible couplings shall be keyed to the shaft. Keys and keyways shall conform to AGMA 9002, Commercial Class. Coupling hubs shall be furnished with tapped puller holes at least 10 mm ($3/8$ in.) in size to aid in removal.

7.2.16 If maintenance (such as for mechanical seal) requires removal of the coupling hub from the shaft, and the shaft diameter is greater than 60 mm (2.5 in.), the coupling hub shall be a taper fit. Taper for keyed couplings shall be $1/16$ slope (0.75 in./ft, diametrical).

7.2.17 Where a keyway extends beyond the fitted coupling hub, the supplied shaft key shall be fitted to the shaft keyway and stepped up at the hub.

7.2.18 Guards over couplings between drivers and driven equipment, and shaft guards between bearing housings and seal glands, shall be supplied and mounted by the vendor with unit responsibility. Coupling guards shall meet the requirements of API 671.

7.3 Baseplates and Soleplates

7.3.1 General

7.3.1.1 The equipment shall be furnished with soleplates or a baseplate as specified.

7.3.1.2 Baseplates and soleplates shall comply with the requirements of 7.3.1.3 through 7.3.1.25.

7.3.1.3 The upper and lower surfaces of baseplates and soleplates and any separate pedestals mounted thereon shall be machined parallel. The surface finish shall be 6 μm (250 $\mu\text{in.}$) Ra or better.

7.3.1.4 The baseplate and soleplate shall be furnished in accordance with 7.3.1.4 through 7.3.1.12.

7.3.1.5 Horizontal (axial and lateral) jackscrews of the same size or larger than the vertical jackscrews in the equipment feet shall be provided.

7.3.1.6 The lugs holding these jackscrews shall be removable or as a minimum attached to the baseplates and soleplates in such a manner that they do not interfere with the installation of the equipment, jackscrews, or shims.

7.3.1.7 Precautions shall be taken to prevent vertical jackscrews (if provided) in the equipment feet from marring the shimming surfaces such that shimming or alignment issues are not created.

7.3.1.8 Alternative methods of lifting equipment for the removal or insertion of shims or for moving equipment horizontally, such as provision for the use of hydraulic jacks, may be proposed.

7.3.1.9 Arrangements should be proposed for equipment that is too heavy to be lifted or moved horizontally using jackscrews.

7.3.1.10 Alignment jackscrews shall be plated for rust resistance.

7.3.1.11 Machinery supports shall be designed to limit the relative displacement of the shaft end caused by the worst combination of pressure, torque, and allowable piping stress to 50 μm (0.002 in.) (see 6.6 for allowable piping loads).

7.3.1.12 If pedestals or similar structures are provided for centerline supported equipment, the pedestals shall be designed and fabricated to permit the machine to be moved using horizontal jackscrews.

7.3.1.13 The purchaser shall specify the epoxy grout to be used for field installation.

7.3.1.14 Epoxy grout shall be used for machines mounted on concrete foundations

7.3.1.15 The vendor shall blast-clean in accordance with SSPC SP 6 or ISO 8501-1, Grade Sa2 all grout contact surfaces of the baseplates and soleplates.

7.3.1.15.1 Coat those surfaces with a primer compatible with specified epoxy grout.

7.3.1.16 The manufacturer shall advise the purchaser the actual primer used.

7.3.1.16.1 The grout manufacturer should be consulted to ensure proper field preparation of the baseplates and soleplates for satisfactory bonding of the grout to the grout primer.

7.3.1.17 The anchor bolts shall not be used to fasten equipment to the baseplates and soleplates.

7.3.1.18 Baseplates and soleplates shall conform to the following.

- a) Baseplates and soleplates shall not be drilled for equipment to be mounted by others.
- b) Baseplates and soleplates shall be supplied with leveling screws. A leveling screw shall be provided near each anchor bolt. If the equipment and baseplates and soleplates are too heavy to be lifted using leveling screws, alternate methods shall be provided by the equipment vendor.
- c) Outside corners of baseplates and soleplates which are embedded in the grout shall have 50 mm (2 in.) minimum radius outside corners (in the plan view). See Figure 4, Figure 5, Figure 6, and Figure 7. Embedded edges shall be rounded to prevent the potential of cracking the grout.
- d) All machinery mounting surfaces shall be treated with a rust preventive immediately after machining.
- e) Baseplates and soleplates shall extend at least 25 mm (1 in.) beyond the outer three sides of equipment feet.

NOTE This requirement allows handling of shims and mounting level or laser-type instruments to check alignment.