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

API STANDARD 611
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General-purpose Steam Turbines for Petroleum, Chemical, and Gas Industry Services

Downstream Segment

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Foreword

This standard is based on the accumulated knowledge and experience of manufacturers and users of steam turbines. The objective of this standard is to provide a purchase specification to facilitate the procurement and manufacture of steam turbines for use in petroleum, chemical, and gas industry services.

The primary purpose of this standard is to establish minimum requirements. This limitation in scope is one of charter as opposed to interest and concern.

Energy conservation is of concern and has become increasingly important in all aspects of equipment design, application, and operation. Thus, innovative energy conserving approaches should be aggressively pursued by the manufacturer and the user during these steps. Alternative approaches that can result in improving energy utilization should be thoroughly investigated and brought forth. This is especially true of new equipment proposals, since the evaluation or purchase options will be based increasingly on total life costs as opposed to acquisition cost alone. Equipment manufacturers, in particular, are encouraged to suggest alternatives to those specified when such approaches achieve improved energy effectiveness and reduced total life costs without sacrifice of safety or reliability.

Shall: As used in a standard, "shall" denotes a minimum requirement in order to conform to the specification.

Should: As used in a standard, "should" denotes a recommendation or that which is advised but not required in order to conform to the specification.

This standard requires the purchaser to specify certain details and features. Although it is recognized that the purchaser can modify, delete, or amplify clauses of this standard, it is strongly recommended that such modifications, deletions, and amplifications be made by supplementing this standard, rather than by rewriting or incorporating clauses thereof into another standard.

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Suggested revisions are invited and should be submitted to the Standards Department, API, 200 Massachusetts Avenue, NW, Suite 1100, Washington, DC 20001, standards@api.org.

Contents

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.

Annex A General Purpose Steam Turbine Datasheets

Annex B Dynamics (Information on Rotordynamic Analysis)

Annex C Vendor Drawing and Data Requirements (VDDR)

Annex D Lubrication System Schematic

Annex E Procedures for Determing Residual Unbalance

Annex F Inspector’s Checklist

Annex G Steam Turbine Nomenclature

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

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

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

1 Scope

This standard specifies the minimum requirements for general-purpose steam turbines. These requirements include basic design, materials, related lubrication systems, controls, auxiliary equipment and accessories.

This standard includes only general-purpose turbines. General-purpose turbines are horizontal or vertical turbines used to drive equipment that is usually spared, is relatively small in size (power), or is in non-critical 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) or where speed will not exceed 6,000 r/min.

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.

API Spec 5L, *Specification for Line Pipe*

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

API Std 526, *Flanged Steel Pressure Relief Valves*

API Std 614, *Lubrication, Shaft-sealing, and Control-oil Systems and Auxiliaries for Petroleum, Chemical and Gas Industry Services*

API Std 670*, Machinery Protection Systems*

API Std 671, *Special Purpose Couplings for Petroleum, Chemical and Gas Industry Services*

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

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

ABMA Std 9[1], *Load Ratings and Fatigue Life for Ball Bearings*

ABMA Std 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*

[1]American Boiler Manufacturers Association, 8221 Old Courthouse Road, Suite 207, Vienna, Virginia 22182, www.abma.com.
[2]American Gear Manufacturers Association, 500 Montgomery Street, Suite 350, Alexandria, Virginia 22314, www.agma.org.

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

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

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

ASME B16.1, *Cast Iron Pipe Flanges and Flanged Fittings*

ASME B16.5, *Pipe Flanges and Flanged Fittings*

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

ASME B16.42, *Ductile Iron Pipe Flanges and Flanged Fittings: Classes 150 and 300*

ASME B16.47, *Large Diameter Steel Flanges*

ASME B17.1, *Keys and Key Sets*

ASME B31.3, *Process Piping*

ASME PTC 6, *Power Test Code—Steam Turbines*

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

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

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

ASTM A105[4], *Standard Specification for Carbon Steel Forgings for Piping Applications*

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

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

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

ASTM A193, *Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service*

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

ASTM A197, *Standard Specification for Cupola Malleable Iron*

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

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

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

[3]ASME International, 3 Park Avenue, New York, New York 10016, www.asme.org.
[4]ASTM International, 100 Bar Harbor Drive, West Conshohocken, Pennsylvania 19428, www.astm.org.

ASTM A320, *Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for Low-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, *Standard Practice for Ultrasonic Examination of Heavy Steel Forgings*

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

ASTM A563, *Standard Specification for Carbon and Alloy Steel Nuts*

ASTM A578, *Standard Specification for Straight-Beam Ultrasonic examination of Plain and Clad Steel Plates for Special Applications*

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

ASTM E94, *Standard Guide for Radiographic Testing*

ASTM E165, *Standard Test Method for Liquid Penetrant Examination*

ASTM E709, *Standard Guide for Magnetic Particle Examination*

ASTM E1003, *Standard Test Method for Hydrostatic Leak Testing*

AWS D1.1[5], *Structural Welding Code*

IEC 60079[6], *Electrical apparatus for explosive gas atmospheres*

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, *ISO system of limits and fits*

ISO 1940-1, *Mechanical vibration—balance quality requirements for rotors in a constant (rigid) state—Part 1: Specification and verification of balance tolerances*

ISO 3744, *Acoustics—Determination of sound power levels of noise sources using sound pressure—Engineering method in an essentially free field over a reflecting plane*

ISO 5753, *Rolling bearings—Radial internal clearance*

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

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[5]American Welding Society, 550 N.W. LeJeune Road, Miami, Florida 33126, www.aws.org.
[6]International Electrochemical Commission, 3, rue de Varembé, P.O. Box 131, CH-1211, Geneva 20, Switzerland, www.iec.ch.
[7]International Organization for Standardization, 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva, Switzerland, www.iso.org.

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

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

ISO 10438, *Petroleum, petrochemical and natural gas industries—Lubrication, shaft-sealing and control-oil systems and auxiliaries (API 614)*

ISO 10441, *Petroleum and natural gas industries—Flexible couplings for mechanical power transmission—Special purpose applications (API 671)*

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

MSS SP-55[8], *Quality Standard for Steel Castings for Valves, Flanges and Fittings and Other Piping Components—Visual Method for Evaluation of Surface Irregularities*

NEMA 250[9], *Enclosures for Electrical Equipment (1000 Volts Maximum)*

NEMA MG 1, *Motors and Generators*

NEMA SM 23, *Steam Turbines for Mechanical Drive*

NFPA 70[10], *National Electrical Code*

SSPC SP 6[11], *Commercial Blast Cleaning*

3 Definitions

For the purpose of this document the following terms and definitions apply.

3.1
anchor bolts
Bolts used to attach the mounting plate to the support structure (concrete foundation or steel structure).

NOTE Refer to 3.7 for definition of hold down bolts.

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

3.3
circulating oil system
A system which withdraws oil from the housing of bearings equipped with oil rings and cools it in an external oil cooler before it is returned to the bearing housing.

[8]Manufacturers Standard Society of the Valve and Fittings Industry, Inc., 127 Park Street, N.E., Vienna, Virginia 22180-4602, www.mss-hq.com.
[9]National Electrical Manufacturers Association, 1300 North 17th Street, Suite 1752, Rosslyn, Virginia 22209, www.nema.org.
[10]National Fire Protection Association, 1 Batterymarch Park, Quincy, Massachusetts 02169-7471, www.nfpa.org.
[11]The Society for Protective Coating, 40 24th Street, 6th Floor, Pittsburg, Pennsylvania 15222, www.sspc.org.

3.4
critical speed
A shaft rotational speed at which the rotor-bearing support system is in a state of resonance.

3.5
design
A term that may be used by the equipment manufacturer to describe various parameters such as design power, design temperature, or design speed.

NOTE This terminology should be used only by the equipment manufacturer and not in the purchaser's specifications.

3.6
gauge board
A bracket or plate used to support and display instrumentation.

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

3.7
hold down bolts (mounting bolts)
Bolts holding the equipment to the mounting plate.

NOTE Refer to 3.1 for definition of anchor bolts.

3.8
HVOF
A high velocity oxygen fuel process.

3.9
hydrodynamic bearings
Bearings that use the principles of hydrodynamic lubrication.

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

3.10
local
Refers to the location of a device when mounted on or near the equipment or console.

3.11
maximum allowable speed
The highest speed at which the manufacturer's design will permit continuous operation.

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

3.12
maximum allowable temperature
The 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.

3.13
maximum allowable working pressure
The 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.

3.14
maximum continuous speed
The speed at least equal to 105 % of the highest speed required by any of the specified operating conditions.

3.15
maximum exhaust casing pressure
The 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 sentinel valve setting.

3.16
maximum exhaust pressure
The highest exhaust steam pressure at which the turbine is required to operate continuously.

3.17
maximum inlet pressure and temperature
The highest inlet steam pressure and temperature conditions at which the turbine is required to operate continuously.

3.18
minimum allowable speed
The lowest speed at which the manufacturer's design will permit continuous operation.

3.19
minimum exhaust pressure
The lowest exhaust steam pressure at which the turbine is required to operate continuously.

3.20
minimum inlet pressure and temperature
The lowest inlet steam pressure and temperature conditions at which the turbine is required to operate continuously.

3.21
mounting plates
A structure (baseplate or a mounting plate), with machined surfaces, to allow the mounting and accurate alignment of items of equipment, which may or may not operate.

NOTE Machined surfaces can be present on the upper and underside faces.

3.22
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.

3.23
normative
A requirement of the standard.

3.24
observed
An inspection or test where the purchaser is notified of the timing of the inspection or test and the inspection or test is performed as scheduled regardless of whether or not the purchaser or his representative is present.

3.25
oil mist lubrication
Lubrication systems that employ oil mist produced by atomization in a central supply unit and transported to the bearing housing by compressed air.

3.26
owner
The final recipient of the equipment who may delegate another agent as the purchaser of the equipment.

3.27
panel
An enclosure used to mount, display and protect gauges, (switches and transmitters) and other instruments.

3.28
potential maximum power
The 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-controlled valve or valves.

3.29
pressure casing
The composite of all stationary pressure-containing parts of the unit, including all nozzles and other attached parts.

3.30
purchaser
Owner or owner's agent that issues the order and specification to the vendor.

3.31
pure oil mist lubrication (dry sump)
Systems in which the mist both lubricates the bearing and purges the housing, and there is no oil level in the sump.

3.32
purge oil mist lubrication (wet sump)
Systems in which the mist purges the bearing housing.

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

3.33
radially split
Joint split with the principal joint perpendicular to the shaft centerline.

3.34
rated power
The greatest turbine power specified and the corresponding speed.

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

3.35
remote
Refers to the location of a device if located away from the equipment or console, typically in a control room.

3.36
shall
A normative (mandatory) requirement in order to conform to the specification.

3.37
special tool
A tool which is not a commercially available catalog item.

3.38
standby
A 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.

3.39
subplate
A plate usually embedded in a concrete foundation and used to accurately locate and align a baseplate or mounting plate.

NOTE Normally only the surface which interfaces with the baseplate or mounting plate is machined.

3.40
total indicator reading (TIR), also known as total indicated runout
The difference between the maximum and minimum readings of a dial indicator or similar device, monitoring a face or cylindrical surface during one complete revolution of the monitored surface.

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

3.41
trip speed
The speed 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.

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

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

3.43
vendor (also known as supplier)
The 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.

3.44
witnessed
An 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 his representative is in attendance.

4 General

4.1 Unit Responsibility

The vendor who has unit responsibility shall assure that all subvendors comply with the requirements of this standard and all reference documents.

4.2 Unit Conversion

The factors in API *MPMS* Chapter 15, were used to convert from U.S. customary (USC) to SI units. The resulting exact SI units were then rounded off.

4.3 Nomenclature

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

5 Requirements

• 5.1 Dimensions

The purchaser will specify whether data, drawings, hardware (including fasteners) and equipment supplied to this standard shall be in the SI or USC system of measurements. Use of an ISO standard datasheet (see Annex A) indicates the SI system of measurements shall be used. Use of a USC datasheet (see Annex A) indicates the USC system of measurements shall be used.

5.2 Statutory Requirements

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

5.3 Conflicting Requirements

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

6 Basic Design

6.1 General

6.1.1 The equipment (including auxiliaries) covered by this standard shall be designed and constructed for a minimum service life of 20 years and at least three years of uninterrupted operation.

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.

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

• **6.1.3** The equipment's normal operating point will be specified on the datasheets.

6.1.4 Turbines shall be capable of the following.

a) Operating at normal power and speed under 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 datasheets. 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 instead 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 supplier 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 NEMA SM 23.

NOTE Regardless of the design limit of any turbine component, the turbine should not be operated or re-rated outside the nameplate limits without consultation with the manufacturer.

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

6.1.6 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 Additional considerations may be required; consultation with the manufacturer is recommended when single-stage turbines are applied for immediate automatic unattended start-up.

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

6.1.8 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.

6.1.9 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.

6.1.10 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.

6.1.11 Unless otherwise specified, cooling water system or systems 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

Table 1—Design Criteria and Specifications for Cooling Water Systems

Criteria	SI Units	U.S. Customary Units
Water Velocity over heat exchange surfaces	≥ 1.5 m/s – 2.5 m/s	5 ft/s – 8 ft/s
Maximum allowable working pressure (MAWP)	≥ 7.0 barg	≥ 100 psig
Test pressure (≥ 1.5 MAWP)	≥ 10.5 barg	≥ 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
Minimum temperature rise	10 K	20 °F
Water side fouling factor	0.35 m^2K/kW	0.002 hr-ft^2-°F/Btu
Corrosion allowance for carbon steel shells	3 mm	$^1/_8$ in.

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.

NOTE To avoid condensation, the minimum inlet water temperature to water cooled bearing housings should preferably be above the ambient air temperature.

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

6.1.13 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) as well as any local codes specified and furnished on request by the purchaser.

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

6.1.15 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.

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

6.2 Bolting

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

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

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 manufacturers identification symbols applied to one end of studs 10 mm ($^3/_8$ in.) in diameter and larger and to the heads of bolts 6 mm ($^1/_4$ in.) in diameter and larger. If the available area is inadequate, the grade symbol may be marked on one end and the manufacturer's identification symbol marked on the other end. Studs shall be marked on the exposed end. Studs, shall be marked on the exposed end.

NOTE A set screw is a headless screw with an internal hex opening on one end.

6.3 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.

NOTE Design at no load can affect the use of cast iron.

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 Section II at the maximum operating temperature. For cast materials the factors specified in ASME Section VIII, Division 1, shall be applied. 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 Section VIII, Division 1 or Division 2.

Manufacturing data report forms, third party inspections, and stamping as specified in the ASME *Code* are not required.

6.3.3 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.

6.3.4 Each axially split casing shall be sufficiently rigid to allow removal and replacement of its upper half without disturbing rotor-to-casing running clearances.

6.3.5 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.

6.3.6 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.

6.3.7 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.). Supports and alignment bolts shall be rigid enough to permit the machine to be moved by the use of lateral and axial jackscrews.

Axially split horizontal turbines shall have centerline supports to maintain proper alignment with connected equipment.

6.3.8 Mounting surfaces shall meet the following criteria.

1) Mounting surfaces shall be machined to a finish of 6 µm (250 µin.) arithmetic average roughness (Ra) or better.

2) To prevent a soft foot, mounting surfaces shall be in the same horizontal plane within 25 µm (0.001 in.).

3) 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.

4) Different mounting planes shall be parallel to each other within 50 µm (0.002 in.).

5) 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 three times that of the hole and to allow for equipment alignment, be 15 mm ($^1/_2$ in.) larger in diameter than the hold down bolt.

6.3.9 Drain connections shall be provided for the steam chest, casing, packing glands, and cooling jackets.

● **6.3.10** On condensing turbines, if required by the orientation of the exhaust nozzle or piping, an automatic drain system is required.

NOTE Purchaser to specify if the vendor shall provide an automatic draining system with the turbine.

6.3.11 A connection shall be provided to measure steam-ring chamber pressure on single-valve turbines and the first stage pressure of multi-stage turbines.

6.3.12 Jackscrews, guide rods (for multi-stage turbines), and cylindrical casing alignment dowels shall be provided to facilitate disassembly and reassembly of the casing. One of the contacting faces shall be relieved (counter bored or recessed) to prevent a leaking joint or an improper fit caused by marring of the face. Guide rods shall be of sufficient length to prevent damage to the internals or casing studs by the casing during disassembly and reassembly.

6.3.13 Lifting lugs or eyebolts shall be provided for lifting only the top half of the casing. Methods of lifting the assembled machine shall be specified by the manufacturer.

6.3.14 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 $^1/_2$ times the stud diameter.

6.3.15 Bolting shall be furnished as specified in 6.3.16 through 6.3.17.

6.3.16 Studs shall be supplied on the main joint of axially split casings and bolted end covers of radially split casings.

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.

6.3.17 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 $^1/_2$ times the major diameter of the stud; the first 1 $^1/_2$ threads at both ends of each stud shall be removed.

6.3.18 Unless otherwise specified, the equipment feet shall be equipped with vertical jackscrews.

6.3.19 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 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 1/4, NPS 2 1/2, NPS 3 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 6.5.5. All connections shall be oriented as specified on the datasheets and suitable for the maximum allowable working pressure of the casing as defined in 3.13. Main inlet and outlet process connections shall be oriented as specified. 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.

6.5.3 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).

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

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

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

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

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

a) the nipple and flange materials shall meet the requirements of 6.5.3;

b) pipe nipples shall be provided with welding-neck or socket-weld flanges for steam pressures of 12 bar (175 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 B16.11.

6.5.7 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 1 1/2).

6.5.8 Threaded openings not required to be connected to piping shall be plugged with solid, round-head steel plugs in accordance with ASME B16.11. As a minimum, these plugs shall meet the material requirements of the pressure casing (or cylinder). Plugs with the possibility of later removal shall be of a corrosion-resistant material. Plastic plugs are not permitted.

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

6.5.10 Flanges shall conform to ASME B16.1, B16.5, B16.42 or B16.47 Series A or B, as applicable, except as specified in the following.

a) Flanges other than cast iron shall conform to the dimensional requirements of ASME B16.5 or B16.47.

b) Cast iron flanges shall be flat faced and conform to the dimensional requirements of ASME B16.1 or 16.42. Class 125 flanges shall have a minimum thickness equal to Class 250 for sizes DN 200 (8 NPS) and smaller.

c) Flat-faced flanges with full raised-face thickness are acceptable on all exhaust connections.

d) Flanges that are thicker or have a larger outside diameter than that required by ASME B16.1, B16.5, or B16.42, as applicable, are acceptable. Non-standard (oversized) flanges shall be completely dimensioned on the arrangement drawing. If oversized flanges require studs or bolts of non-standard length, this requirement shall be identified on the arrangement drawing.

e) 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.

f) For all steel flanges, imperfections in the flange facing finish shall not exceed that permitted in ASME B16.5 or ASME B16.47 as applicable.

● g) 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 B16.42 are supplied. If specified, these mating parts shall be furnished by the vendor.

6.5.11 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) µin.
Flat and raised face	Vacuum	63 – 125
	Above atmospheric	125 – 500
Ring joint	All	< 63

6.5.12 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.

6.5.13 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.

6.5.14 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 degree. 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 NEMA SM 23.

6.7 Rotating Elements

6.7.1 Rotors

6.7.1.1 Rotors shall be capable of operating without damage at momentary speeds up to 110 % of 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 110 % of trip speed. The wheels shall be keyed to the shaft and assembled with a shrink fit.

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 inlet 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. 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.

6.7.2.2 Shafts shall be accurately finished throughout their entire length and shall be ground to a finish of 0.8 μm (32 μin.) Ra or better at the coupling and bearing locations and sealing areas for carbon ring packing.

6.7.2.3 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. 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 not be metallized, sleeved, or plated. The final surface finish shall be a maximum of 1.0 μm (32 μin.) Ra, preferably obtained by honing or burnishing. These areas shall be properly demagnetized to the levels specified in API 670 or otherwise 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).

If all reasonable efforts fail to achieve the limits noted in 6.7.2.2, the vendor and purchaser shall mutually agree on alternate acceptance criteria.

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

6.7.2.4 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 datasheets.

• **6.7.2.5** If specified, the coating shall be HVOF applied chrome carbide, ground and honed to 8 Ra to 16 Ra.

6.7.2.6 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.

6.7.2.7 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 110 % of trip speed. The vendor shall assume that torque varies as speed squared unless otherwise notified by the purchaser.

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 rubbing speed at the shaft sealing surface is less than 50 m/s (160 ft/s). 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. Springs for carbon packing shall be made of nickel-chromium-iron alloy (heat treated after cold coiling) or equal material. 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.

NOTE Non-contacting (gas face) seals are normally used only if the exhaust steam conditions are superheated, and if the seals are properly drained to prevent moisture accumulation during transient conditions.

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

• **6.8.5** If specified, a separate vacuum device shall be furnished for connection to the glands to reduce external steam leakage. Unless otherwise specified, the device shall be mounted and connected by the vendor who mounts the turbine on the baseplate.

6.8.6 Glands that operate at less than atmospheric pressure shall be designed to admit steam that will seal against air ingress. 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. 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, the purchaser shall provide pressure and temperature of steam available for use as sealing steam.

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

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

6.8.9 The gland casing leakoff connections shall comply with 6.5.

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 his review and included in the instruction manual for his guidance.

6.9.1.4 For the purposes of this standard, critical speeds and other resonant conditions of concern are those with an amplification factor (*AF*) equal to or greater than 2.5.

6.9.2 Lateral Analysis

6.9.2.1 The first rigid mode 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 6.9.2.1 and Annex B.

6.9.3 Torsional Analysis

6.9.3.1 For units including gears, units comprising three or more coupled machines (excluding any gears), or if specified, the vendor having unit 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.

6.9.3.2 The undamped torsional natural frequencies of the complete train shall be 10 % above or 10 % below any possible excitation frequency.

6.9.3.3 Torsional natural frequencies at two or more times running speeds shall preferably be avoided or, in systems in which corresponding excitation frequencies occur, shall have no adverse effect. In addition to multiples of running speeds, torsional excitations that are not a function of running speeds or that are non-synchronous in nature shall be considered in the torsional analysis if applicable and shall have no adverse effect.

6.9.3.4 If torsional resonances are calculated to fall within the margin specified in 6.9.3.2, a stress analysis shall demonstrate that the resonances have no adverse effect on the complete train. The assumptions made in this analysis regarding the magnitude of excitation and the degree of damping shall be clearly stated.

6.9.3.5 In addition to the torsional analyses required in Annex B, the vendor shall perform a transient torsional vibration analysis for turbine generators sets. The acceptance criteria for this analysis shall be mutually agreed upon by the purchaser and the vendor.

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 shall be accomplished after adding no more than two major components. Balancing correction shall be 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. If specified, the weight of all half-keys used during the final balancing of the assembled element shall be recorded on the residual unbalance work sheet (see Annex E). The maximum allowable residual unbalance per plane (journal) shall be calculated as follows:

In SI units

$$U_{max} = \frac{6350 \times W}{N} \tag{1}$$

In USC units

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

where

U_{max} is the residual unbalance, in gm-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 Unless otherwise specified, 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).

● **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).

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 mutually 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

$$A = 25.4 \times \sqrt{\frac{12,000}{N}} \tag{2}$$

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 driver, the vibration shall not exceed 150 % or 0.5 mil above the maximum value recorded at the maximum continuous speed, which ever is greater.

NOTE These limits are not to be confused with the limits specified in Appendix 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 degrees 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 µm or 6 µm (0.25 mil), whichever is greater, may be vectorially subtracted from the vibration signal measured during the factory test.

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 (0.12 in./s) (unfiltered) and 2.0 mm/s (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 which may or may not be combined with one of the radial bearings. Unless otherwise specified, the bearing type and arrangement shall be selected in accordance with the limitations in Table 3.

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 L10 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 datasheets. Rolling element bearings shall be protected against over-greasing by means of an adequately sized vent.

6.10.1.4 Hydrodynamic radial bearings shall be split for ease of assembly, precision bored, and of the sleeve or pad type, with steel-backed, babbitted replaceable liners, pads, or shells. These bearings shall be equipped with antirotation pins and shall be positively secured in the axial direction.

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 and Hydrodynamic radial and thrust
Radial and thrust bearing speed or life outside limits for rolling element bearings or Turbine energy density above limits	Hydrodynamic radial and thrust

NOTE Limits are as follows.

a) Rolling element bearing speed:

Factor, Nd_m shall not exceed 300,000;

Where d_m is the mean bearing diameter $(d + D)/2$, expressed in mm;
N is the rotative 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 hr with continuous operation at rated conditions, and at least 32,000 hr 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, 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.

6.10.1.5 The bearing design shall suppress hydrodynamic instabilities and provide sufficient damping over the entire range of allowable bearing clearances 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.

6.10.1.10 The vendor who has unit responsibility shall inform other manufacturers of the connected equipment if a belt drive is to be used. The other manufacturer(s) shall be provided with the radial load resulting from the belt drive and, for reciprocating machines, the vibratory torque characteristics. These factors shall be taken into account when selecting the belt drive and sizing the bearings of the driving and driven equipment.

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 ISO 5753, Group 3 (ABMA Symbol 3, as defined in ABMA 20).

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 (7,000 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 backed, babbitted replaceable liners, pads, or shells. These bearings shall be equipped with antirotation 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 backed, babbitted multiple segment type, designed for equal thrust capacity in both directions and arranged for continuous pressurized lubrication to each side. Both sides shall be of the tilting pad type, incorporating a self-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 Integral thrust collars are preferred for hydrodynamic thrust bearings. If integral collars are furnished, they shall be provided with at least 3 mm ($^1/_8$ in.) of additional stock to enable refinishing if the collar is damaged. 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 Both faces of thrust collars for hydrodynamic thrust bearings shall have a surface finish of 0.4 microns (16 µin.) Ra, or better and after mounting the axial total indicated runout of either face shall not exceed 13 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 equipment driver or mounting (see 6.10.3.1.2).

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 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 pressure lube systems the oil inlet and drain connections shall be flanged or machined and studded. Threaded openings are permissible in DN 20 (NPS 3/4, NPS 1, and NPS 1 1/2). Pipe connections in DN 40 (NPS 1 1/2) in. tapped openings shall be installed as follows.

a) A stainless steel pipe nipple of Schedule 40S, preferably not more than 6 in. (150 mm) long, shall be provided for cast iron bearing housings.

b) A carbon steel pipe nipple of Schedule 80, not more than 12 in. (300 mm) long, shall be provided for steel bearing housings.

c) The pipe nipple shall be provided with a carbon steel slip-on flange.

d) The threaded connection shall be seal welded; however, seal welding is not required on cast iron bearing housings or where disassembly is required for maintenance. Seal-welded joints shall be in accordance with ASME B31.3. Threaded connections that are not seal welded shall be made up without thread tape.

Pipe or tube fittings on NPS 3/4 and 1 connections shall not be seal welded.

6.10.4.1.4 Sufficient cooling, including an allowance for fouling, shall be provided to maintain oil and bearing temperatures as follows, based on the specified operating conditions and an ambient temperature of 40 °C (110 °F).

a) For pressurized systems, oil outlet temperature below 70 °C (160 °F) and bearing metal temperatures (if bearing temperature sensors are supplied) less than 93 °C (200 °F). During shop testing, the bearing oil temperature rise shall not exceed 28 K (50 °F).

b) For ring-oiled or splash systems, oil sump temperature below 82 °C (180 °F). During shop testing, the sump oil temperature rise shall not exceed 40 K (70 °F).

NOTE Temperature stabilization may not be attained during the mechanical running test. If the purchaser desires temperature stabilization testing, this requirement should be stated in the inquiry and addressed by the vendor in the proposal.

6.10.4.1.5 For ambient conditions which 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 which can allow water to leak into the oil reservoir. If cooling coils (including fittings) are used, they shall be of nonferrous, metallic material and shall have no internal pressure joints. 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; lip-type seals shall not be used. The seals and deflectors shall be made of non-sparking materials. The design of the seals and deflectors shall effectively retain oil in the housing and prevent 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 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 6 mm (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.

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

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.

6.10.4.3.5 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), horizontal (H) at each bearing housing and location (A) at the outboard bearing housing as shown in Figure 1 and in accordance with 8.3.3.1g to facilitate consistent vibration measurements. The dimples shall be suitable for accurate location of a hand-held vibration transducer with an extension "wand." Dimples may be cast or machined and shall be nominally 2 mm (0.080 in.) deep with an included angle of 120 ° as shown in Figure 2. The dimple shall be located as close to the bearing centerline as practical for the vertical (V) and horizontal (H) locations only..

● **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.

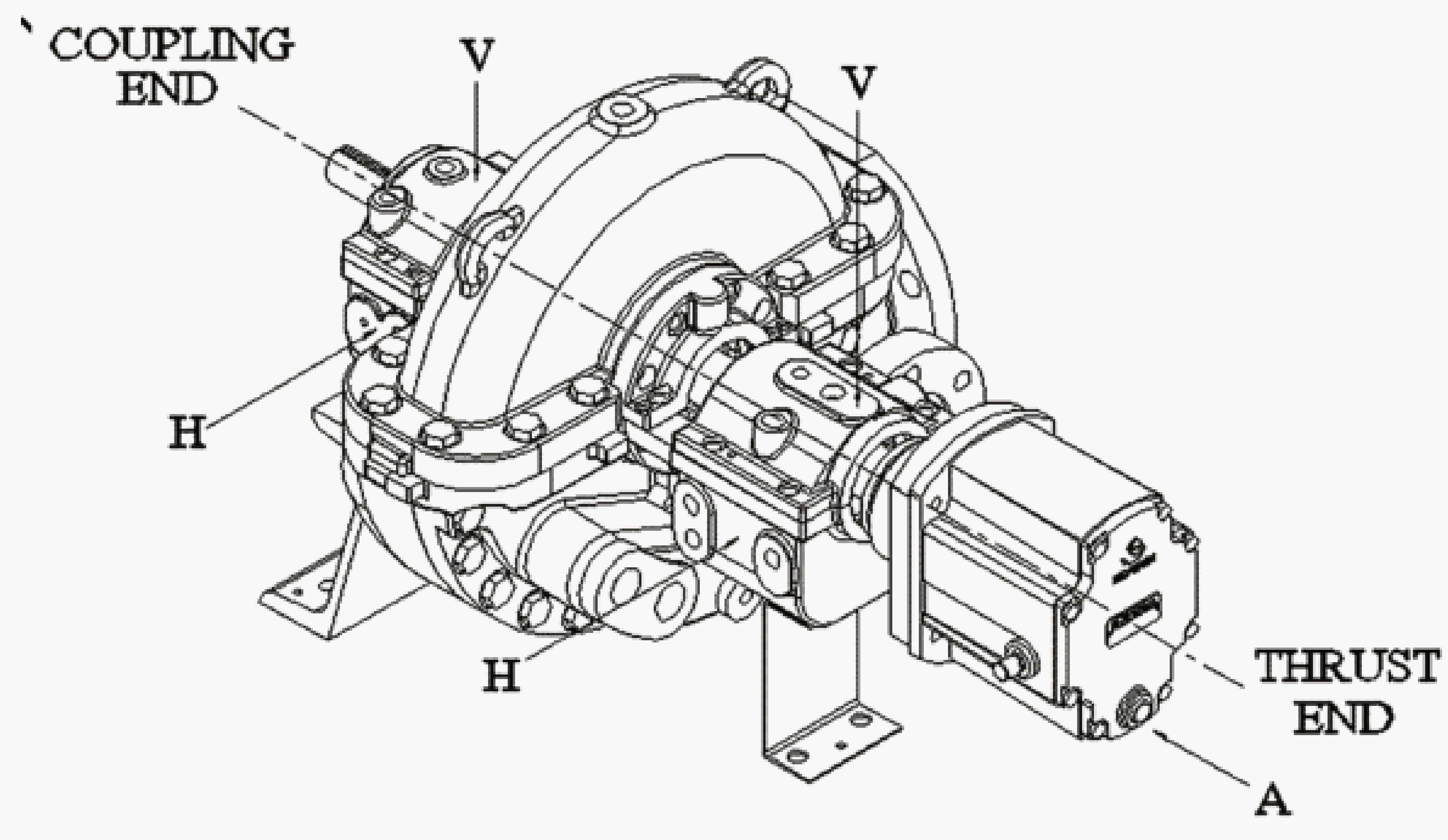

Figure 1—Bearing Housing Dimple Locations for Vibration Measurements

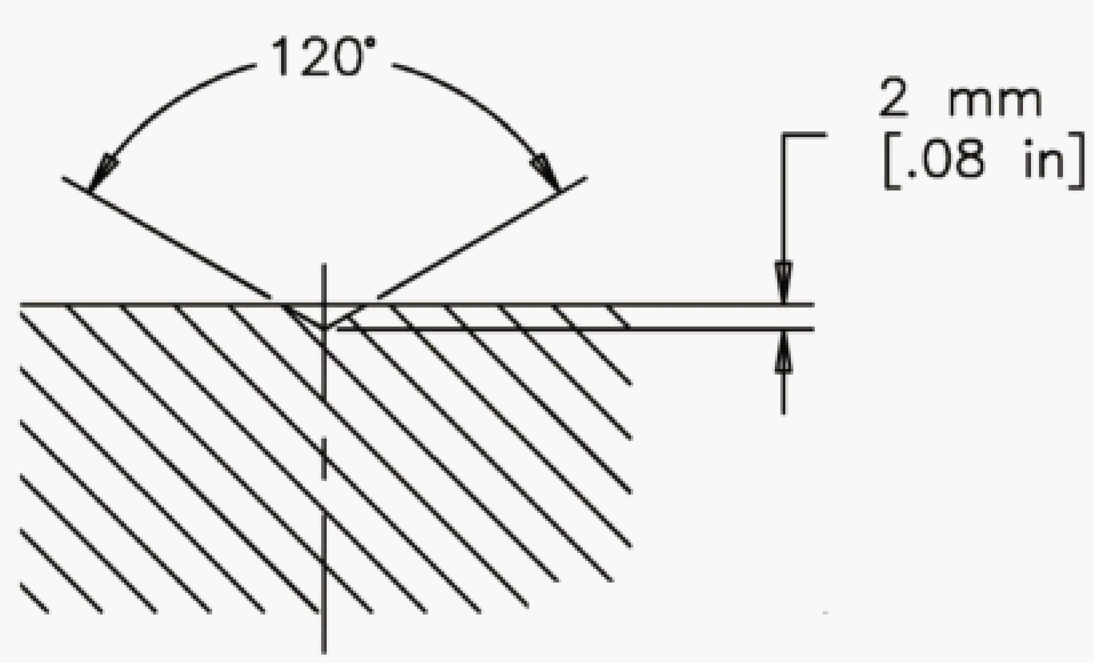

Figure 2—Dimple Dimensions

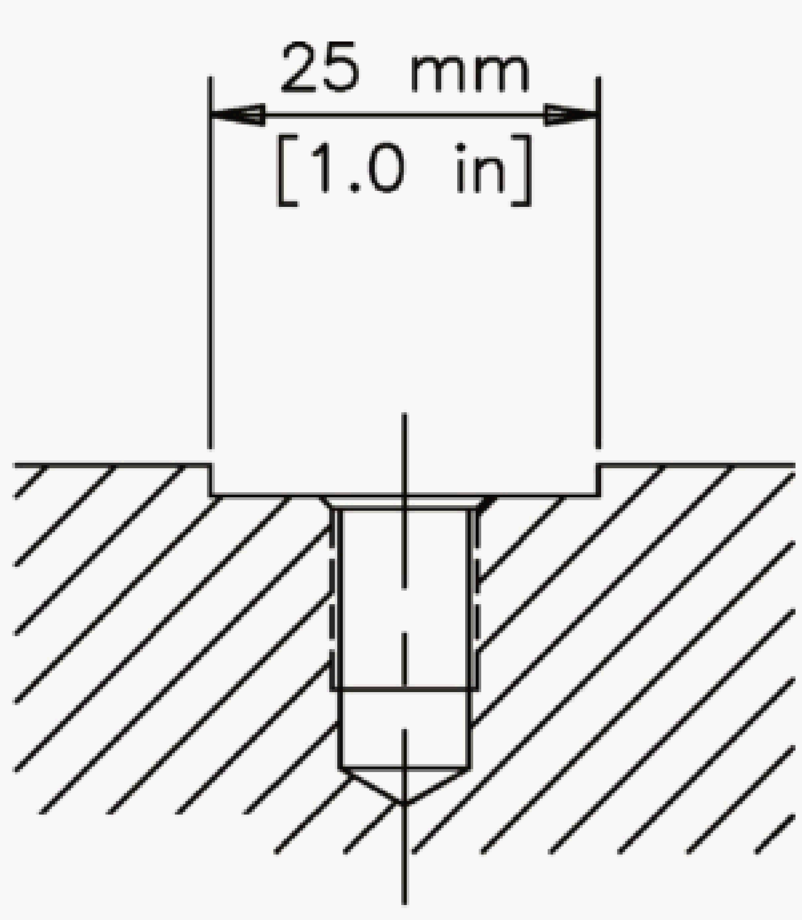

Figure 3—Transducer Mounting Hole Dimensions

● **6.10.4.4.3** If specified, bearing housings shall be prepared for permanently mounting seismic vibration transducers in accordance with API 670. The spotface 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 customer 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.

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 Unless otherwise specified, bearings and bearing housings shall be arranged for oil lubrication using a mineral oil in accordance with ISO 8068.

● **6.11.2** If specified or required by the turbine, a pressurized oil system shall be furnished to supply oil at a suitable pressure or pressures, as applicable, to the:

● a) the bearings of the driver and of the driven equipment (including any gear); and

b) any governor and control-oil system.

6.11.3 Unless otherwise specified, pressurized oil systems shall conform to the requirements of ISO 10438-3, API 614 Chapter 3 (see Annex D, Figure D.1 and Table D.1 for a schematic and the various options applicable).

6.11.4 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.

NOTE The usual lubricant employed in a common oil system is a mineral oil that corresponds to ISO 3448, Grade 32. Compatibility of lube oil requirements needs to be mutually agreed among the user and all vendors supplying equipment served by the common system. In some cases there can be significant differences in individual component needs. For example, a refrigeration compressor may need low pour point oil, a gear may need high viscosity, and a turbine may need a conventional mineral oil. In such cases it may be necessary to change the design of a component or to provide separate oil systems.

● **6.11.5** If a wide-speed-range, rapid-starting or slow-roll operation is specified, the turbine vendor shall verify that adequate lubrication is available to the turbine.

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

6.11.7 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.

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, 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.

Where international standards are not available, internationally recognized national or other standards may be used.

6.12.1.3 Pressure parts shall be made of steel if the maximum steam conditions to which they may be subjected exceed 17.2 bar (250 psig) or 260 °C (500 °F). Exhaust casings of noncondensing turbines shall be made of steel if the maximum exhaust pressure can exceed 5.2 bar (75 psi), or if the no-load exhaust temperature can exceed 260 °C (500 °F). Suitable alloy steel shall be used where the maximum steam temperatures can exceed 413 °C (775 °F). Ductile iron may be used only with the approval of the purchaser.

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** The purchaser shall specify any corrosive agents (including trace quantities) present in the steam and in the environment, including constituents that can cause stress corrosion cracking.

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 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 Section VIII, Division 1, UG-84. The purchaser and the vendor shall mutually 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, Grade B7) for steel casings. Carbon steel nuts (such as ASTM A194, Grade 2H) shall be used, where space is limited, case hardened carbon steel nuts (such as ASTM A563, Grade A) shall be used. For temperatures below –30 °C (–20 °F), low-temperature bolting material (such as ASTM A320) 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 Section VIII, Division 1, and ASME 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) Cast gray iron may be repaired by plugging within the limits specified in ASTM A278, ASTM A395, or ASTM A536. The holes drilled for plugs shall be carefully examined, using liquid penetrant, to ensure that all defective material has been removed.

● c) 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").

d) 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 Section VIII, Division 1, and ASME 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 Section VIII, Division 1, and ASME Section IX.

6.12.4.2 Unless otherwise specified, other welding, such as welding on baseplates, non-pressure ducting, lagging, and control panels, shall be performed by welders qualified in accordance with an appropriate recognized standard such as AWS D1.1.

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 6.12.2.3a). Repair welds shall be nondestructively tested by the same method used to detect the original flaw. 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 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 post-weld heat treatment. If specified, the quality control of welds that will be inaccessible on completion of the fabrication shall be agreed on by the purchaser and vendor prior to fabrication.

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 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 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 or cylinder material and intended service may be used with the purchaser's approval.

6.12.5 Low-temperature Service

● **6.12.5.1** The purchaser will specify the minimum design metal temperature and concurrent pressure used to establish impact test and other material requirements.

NOTE Normally, this will be the minimum surrounding ambient 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 in accordance with the codes and other requirements specified. The purchaser and the vendor shall agree on any special precautions necessary with regard to conditions that can occur during operation, maintenance, transportation, erection, commissioning and testing.

NOTE Good design practice should be followed 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. The published design-allowable stresses for materials in internationally recognized standards such as the ASME Code and ANSI standards are based on minimum tensile properties. Some standards do not differentiate between rimmed, semikilled, fully killed hot-rolled and normalized material, nor do they take into account whether materials were produced under fine- or course-grain practices. The vendor should exercise caution in the selection of materials intended for services between –30 °C (–20 °F) and 40 °C (100 °F).

6.12.5.3 All carbon and low alloy steel pressure containing components including nozzles, flanges, and weldments shall be impact tested in accordance with ASME Section VIII, Division 1, Sections UCS-65 through 68, or equivalent standard. High-alloy steels shall be tested in accordance with ASME Section VIII, Division 1, Section UHA-51, or equivalent standard. For materials and thicknesses not covered by ASME Section VIII, Division 1, or equivalent standards, the purchaser will specify requirements.

NOTE 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. Refer to ASME Section VIII, Division 1, Section UG-20F, for example.

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 Section VIII, Division 1, Section UG-84, or equivalent.

6.13 Nameplates and Rotation Arrows

6.13.1 A nameplate shall be securely attached at a readily visible location on the equipment and on any major piece of auxiliary 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 (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 datasheets:

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; and

l) the purchaser's equipment item number (this may be on a separate nameplate if there is insufficient space on the rating nameplate).

If critical speed values are not obtained by test, the word "calc" shall be stamped beside the number. Any critical speed below maximum continuous speed shall be determined on the test stand. Second critical speed is omitted for turbines that run below their first critical speed.

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 kilowatts (75 horsepower) of rated power.

7.1.3 Unless otherwise specified, separate parallel-shaft gear units up to 1,500 kilowatts (2,000 horsepower) shall conform to API 677.

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** Unless otherwise specified, flexible element spacer couplings and guards between horizontal turbines and driven equipment shall be supplied by the manufacturer with unit responsibility. If specified, the driver half of the coupling shall be mounted by the turbine manufacturer. For vertical turbines, a rigid non-spacer coupling between the turbine and driven equipment shall be supplied by the manufacturer with unit responsibility.

7.2.2 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. The make of the couplings shall be agreed upon by the purchaser and the vendors of the driver and driven equipment. A spacer coupling with a minimum 125-mm (5-in.) spacer shall be used, unless otherwise specified. Couplings shall be forged steel and designed to allow the necessary end float caused by expansion and other end movements of the shaft.

7.2.3 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.

7.2.4 Unless otherwise specified, if the turbine vendor supplies a separate gear, he shall also furnish a flexible element coupling between the gear and the turbine.

7.2.5 To assure accurate alignment of connected machinery, the total indicator reading of coupling alignment surfaces shall be controlled as specified in the following.

a) For all turbines, 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. All other diameters that are not used for locating, or alignment shall conform to the coupling manufacturer's standard, provided that dynamic balance requirements are met.

b) For turbines connected to their driven equipment with a flexible coupling, the locating and alignment faces shall be perpendicular to the axis within the limits of 7.2.5a.

c) Coupling faces shall be perpendicular to the axis of the coupling within 1 micrometer 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 turbines and driven equipment, the coupling diameters shall be concentric within the limits stated in 7.2.5a.

7.2.6 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; and

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.

Couplings operating (MCS) at speeds in excess of 3,800 r/min shall meet the requirements of API 671 for component balancing and assembly balance check.

- **7.2.7** If specified, couplings shall be balanced to ISO 1940 1, Grade G6.3.

- **7.2.8** If specified, couplings shall meet the requirements of ISO 14691, ISO 10441 or API 671.

7.2.9 Flexible couplings shall be keyed to the shaft. Keys, keyways, and fits shall conform to AGMA 9002, Commercial Class. Flexible couplings with cylindrical bores shall have the interference fit specified in ISO/R286, Tolerance N8, and shafting in accordance with AGMA 9002. Coupling hubs shall be finished with tapped puller holes at least 10 mm (3/8 in.) in size to aid in removal. 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.

● **7.2.9.1** If specified for shaft diameters greater than 60 mm (2.5 in.), the hub shall be mounted with a taper fit. Taper for keyed couplings shall be 1 in 10 long series conical in accordance with AGMA 9002 or alternately 1 in 16 (0.75 in./ft, diametral) for compliance with U.S. standards. Appropriate assembly and maintenance procedures shall be used to assure that taper fit couplings have an interference fit.

7.2.10 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.

7.2.11 Each coupling shall have a coupling guard in accordance with the following.

a) Coupling guards shall sufficiently enclose the coupling and the shafts to prevent any personnel from accessing the space between the guard and such moving parts during operation of equipment train.

b) Guards shall be constructed with sufficient rigidity to withstand a 90 kg (200 lb) static point load (or force) in any direction without the guard contacting moving parts.

c) Guards shall be fabricated from solid sheet or plate with no openings. Guards fabricated from expanded metal or perforated sheets may be used if the size of the openings does not exceed 10 mm (0.375 in.). Guards shall be constructed of steel, brass or non-metallic (polymer) materials. Guards of woven wire shall not be used. If specified, non-sparking guards of agreed material shall be supplied.

7.3 Mounting Plates

7.3.1 General

7.3.1.1 Unless otherwise specified, the turbine shall be furnished for mounting on a baseplate provided by others.

7.3.1.2 Turbines supplied with gear reducers shall be supplied with these drive train components mounted on a mounting plate.

● **7.3.1.3** If specified, the turbine and all auxiliaries shall be furnished mounted on a baseplate.

● **7.3.1.4** If specified, the turbine and all auxiliaries shall be furnished mounted on a mounting plate.

7.3.2 Baseplates

7.3.2.1 Single-piece drain-rim or drain-pan baseplates shall be furnished for horizontal turbines. The rim or pan of the baseplate shall be sloped at least 1 in 120 toward the driver end, where a tapped drain opening of at least DN 50 (2 NPS) shall be located to effect complete drainage.

7.3.2.2 The baseplate shall extend under the driven equipment and drive train components so that any leakage is contained within the baseplate. To minimize accidental damage to components, all pipe joints and pipe flange faces, including inlet and outlet flanges, shall be within the drain-pan or drain-rim collection area. All other projections of the equipment supplied shall fall within the maximum perimeter of the baseplate. Oversized junction boxes may overhang the perimeter of the baseplate with the purchaser’s approval.

7.3.2.3 Shims shall not be used under the driven equipment. All pads for drive train components shall be machined to allow for the installation of shims at least 3 mm (0.12 in.) thick under each component. If the vendor mounts the components, a set of stainless steel shims at least 3 mm (0.12 in.) thick shall be furnished. Shim packs shall not be thicker than 13 mm (0.5 in.) nor contain more than five shims. All shim packs shall straddle the hold-down bolts and vertical jackscrews, and extend at least 5 mm (0.25 in.) beyond the outer edges of the equipment feet. If the vendor does not mount the components, the pads shall not be drilled and shims shall not be provided.

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

7.3.2.5 All baseplates shall be provided with at least one grout hole having a clear area of at least 125 cm^2 (19 $in.^2$) and no dimension less than 75 mm (3 in.) in each bulkhead section. These holes shall be located to permit filling the entire cavity under the baseplate without creating air pockets. If practical, the holes shall be accessible for grouting with the driven equipment and driver installed on the baseplate. Grout holes in the drip pan area shall have 13 mm (0.5 in.) raised lip edges. If the holes are located in an area where liquids could impinge on the exposed grout, metallic covers with a minimum thickness of 1.5 mm (0.06 in., 16 gauge) shall be provided. Vent holes at least 13 mm (0.5 in.) in diameter shall be provided at the highest point in each bulkhead section of the baseplate

7.3.2.6 The outside corners of the baseplate in contact with the grout shall have at least 50 mm (2 in.) radii in the plan view.

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

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

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

7.3.2.10 Vertical leveling screws spaced for stability shall be provided on the outside perimeter of the baseplate. They shall be located adjacent to anchor bolts to minimize distortion during the process of installation. These screws shall be numerous enough to carry the weight of the baseplate, driven equipment, and drive train components without excessive deflection, but in no case shall fewer than six screws be provided.

7.3.2.11 The height of the driven equipment shaft centerline above the baseplate shall be minimized. Adequate clearance shall be provided under the mounted drive train components to allow for connection to piping which may extend below the equipment mounting feet, and to allow for the proper slope of any gravity drain lines.

7.3.2.12 The vendor shall commercially sand-blast, in accordance with ISO 8501 Grade Sa2 or SSPC SP 6, all grout contact surfaces of the baseplate, and coat those surfaces with a primer compatible with epoxy grout. Grouts other than epoxy may require alternative surface preparation. Full bond-strength of epoxy is not generally necessary.

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

7.3.2.14 Anchor bolts are in the purchaser's scope. The vendor shall provide for sufficient anchor bolting to withstand nozzle reaction forces during turbine start-up and operation.

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

7.3.3 Mounting Plates

7.3.3.1 If mounting plates are specified, they shall meet the requirements of 7.3.2.6, 7.3.2.9, 7.3.2.10, 7.3.2.12, 7.3.2.14, 7.3.2.15, 7.3.3.2 and 7.3.3.3.

7.3.3.2 Mounting plates shall be steel plates that are thick enough to transmit the expected loads from the equipment feet to the foundation, but in no case shall the plates be less than 40 mm (1.5 in.) thick.

7.3.3.3 Mounting plates shall be large enough to extend beyond the feet of the equipment in all directions and shall be designed such that the anchor bolts are not covered by machine feet.

7.3.4 Subplates

● **7.3.4.1** If specified, subplates shall be provided by the manufacturer with unit responsibility.

7.3.4.2 If subplates are used, mounting plates shall be fully machined top and bottom.

7.3.4.3 If subplates are specified, they shall be steel plates at least 25 mm (1 in.) thick. The finish of the subplates' mating surfaces shall match that of the mounting plates.

7.4 Controls and Instrumentation

7.4.1 General

7.4.1.1 Instrumentation and installation shall conform to the purchaser's specifications, and unless otherwise specified, instrumentation and installation shall conform to the requirements of ISO 10438 (API 614).

7.4.1.2 Unless otherwise specified, controls and instrumentation shall be designed for outdoor installation and shall meet the requirements of IP65 as detailed in IEC 60079 (NEMA 250).

7.4.1.3 Instrumentation and Controls shall be designed and manufactured for use in the area classification (class, group, and division or zone) specified.

7.4.1.4 All conduit, armored cable and supports shall be designed and installed so that it can be easily removed without damage and shall be located so that it does not hamper removal of bearings, seals, or equipment internals or any maintenance activities associated with the turbine.

7.4.2 Governing Control Systems

7.4.2.1 General

7.4.2.1.1 The governing system is the primary system necessary to match the turbine output to the application. The governing system includes the speed governor, control mechanism, and governor-controlled valve(s). The turbine vendor shall have unit responsibility for the entire governing system. For generator drive applications, the requirements shall be as agreed by the purchaser and the turbine vendor.

7.4.2.1.2 Unless otherwise specified, the primary function of the governing system shall be to maintain the turbine speed at a set value by regulating the steam flow through the turbine.

7.4.2.1.3 Turbines shall be equipped with a corrosion-resistant removable steam strainer located ahead of the governor and trip valves. The minimum effective free area of the strainer shall be twice the cross-sectional area of the turbine inlet connection. The strainer shall be removable without dismantling the inlet piping.

7.4.2.1.4 Unless otherwise specified, a NEMA Class A oil-relay governor shall be supplied. The governor shall conform to NEMA SM 23 and shall have the same or better characteristics as those shown in Table 4.

Table 4—Speed Governors

Characteristic	Class per NEMA SM 23	
	A	D
Maximum steady-rate speed regulation	10	0.5
Maximum speed variation (plus or minus)	0.75	0.25
Maximum speed rise	13	7
Trip speed	115	110

NOTE All values (except trip speed) are in percent of rated speed. Trip speed values are in percent of maximum continuous speed.

● **7.4.2.1.5** If specified, a dedicated electronic governor shall be furnished. This unit shall be separate and independent of any overall system such as a distributed control (DCS) and if required shall be provided with electrical power by a purchaser-supplied power source.

7.4.2.2 Electronic Governing System

7.4.2.2.1 The requirements of 7.4.2.2.2 through 7.4.2.2.7 apply if a dedicated electronic two-out-of-three voting trip system is supplied.

7.4.2.2.2 A multi-toothed surface for speed sensing shall be provided positively affixed to the shaft. This surface may be shared by the speed governor, overspeed shutdown system and tachometer.

7.4.2.2.3 The speed governing system shall include at least two speed sensors dedicated for speed control. These speed sensors are not to be shared with the overspeed shutdown system. The speed governor shall discriminate between the signals from the speed-sensing elements by high signal selection. The failure of any one speed-sensing element shall initiate an alarm only. The failure of all elements shall initiate a shutdown.

7.4.2.2.4 The design of the electronic speed governor shall meet the requirements specified for a NEMA Class D governor (see Table 4) and shall include as a minimum:

a) an assignable speed range corresponding to the normal range of operation (typically 85 % to 105 % of rated operating speed);

b) speed setpoint adjustment;

c) remote or process controlled speed setpoint adjustment;

d) digital speed indication;

e) outputs to control mechanism actuator;

f) adjustable speed ramp rate;

g) slow roll control;

h) manually activated override for testing the overspeed shutdown system; and

i) settings which are field changeable and protected through controlled access.

7.4.2.2.5 If a remote or process control speed set point adjustment is specified, the speed of the turbine shall vary linearly with the setpoint signal. Unless otherwise specified an increase in setpoint signal shall increase turbine speed.

● **7.4.2.2.6** If specified, the governing system shall provide for both slow roll and startup using the governor valve.

7.4.2.2.7 Failure of the governing system shall initiate a turbine shutdown.

7.4.2.2.8 Unless otherwise specified, speed shall be adjusted by means of a hand speed changer.

7.4.2.2.9 If a control signal is specified for speed adjustment, the vendor shall provide a speed-setting mechanism arranged so that:

a) The full range of the purchaser's specified control signal shall correspond to the required operating range of the driven equipment. Unless otherwise specified, the maximum control signal shall correspond to the maximum continuous speed.

b) Actuation or failure of the control signal or failure of the speed-setting mechanism shall not prevent the governor from limiting speed to the maximum permissible, nor shall either occurrence prevent manual regulation with the hand speed changer.

7.4.2.2.10 Unless otherwise specified, the adjustable speed range of the governor and hand speed changer shall be a total of 20 % of the maximum continuous speed—5 % greater and 15 % less than normal speed.

7.4.2.2.11 Unless otherwise specified, the oil relay governor shall include a manual method to safely increase the speed of the turbine over the maximum continuous speed of the governor to allow for a safe and controlled test of the independent emergency overspeed system. This system shall be arranged that releasing of the devise shall allow the turbine to return to maximum continuous speed with no further operator action. This device shall not allow the turbine to exceed the trip setting by 2 %.

7.4.2.2.12 The speed-governing valve shall be the manufacturer's standard, preferably a balanced type.

7.4.2.2.13 Trip and speed-governing valves shall have a metallic or other noncompressible type of bushing-valve stem packing and an intermediate leakoff if the maximum inlet steam pressure is 17.2 bar (250 psig) or higher.

7.4.2.3 Overspeed Shutdown System

7.4.2.3.1 The turbine shall be equipped with an independent emergency overspeed system that shuts off steam to the turbine when running speed reaches trip speed (see Table 4). The emergency trip system shall have the following characteristics:

a) easy accessibility;

b) the capability to be manually tripped with maximum inlet steam pressure and flow in the line;

c) the capability to stop the turbine by activating a force-actuated trip valve under any load condition of the turbine;

d) the capability to be reset with maximum inlet pressure on the line; and

e) spark-proof components and suitability for use in hazardous gas and outdoor locations.

NOTE The purchaser should provide a block valve on the inlet steam line close to the turbine. This valve should be closed before the overspeed trip system is reset.

● **7.4.2.3.2** If specified, a dedicated electronic two-out-of-three voting trip shall be furnished. This unit shall be separate and independent of any overall system such as a DCS or governor and if required shall be provided with electrical power by a purchaser-supplied power source.

7.4.2.3.3 The requirements of 7.4.2.3.4 through 7.4.2.3.7 apply if a dedicated electronic two-out-of-three voting trip system is supplied.

7.4.2.3.4 A multi-toothed surface for speed sensing shall be provided positively affixed to the shaft. This surface may be shared by the speed governor, overspeed shutdown system and tachometer.

7.4.2.3.5 The overspeed trip system shall include at least three speed sensors dedicated for the trip system. The speed sensors are not to be shared with the speed governing system. The failure of any one speed-sensing element shall initiate an alarm only. The failure of two of the speed-sensing elements shall initiate a shutdown.

7.4.2.3.6 The design of the electronic trip system shall include the following as a minimum.

a) An assignable trip speed range corresponding to 110 % of the maximum continuous speed.

b) Digital speed indication.

c) Output(s) to a suitable separate independent trip actuation device. The use of more than two separate independent actuation devices shall be subject to agreement between the user and supplier.

d) Manually activated override for testing the electronic portion of the overspeed shutdown system.

e) Settings that are field changeable and protected through controlled access.

7.4.2.3.7 Failure of the overspeed trip system shall initiate a turbine shutdown.

7.4.2.3.8 The purchaser and the vendor shall mutually agree on the need for an exhaust vacuum breaker, actuated by the trip system, for turbines with an exhaust pressure that is less than atmospheric.

NOTE For turbines that exhaust to sub-atmospheric pressure, even a closed emergency trip valve can leak enough steam to prevent the turbine and driven equipment from coming to a complete stop. A vacuum breaker admits air to the exhaust casing, increases exhaust pressure, and reduces coast-down time. For turbines exhausting to a common condensing system, air admission may not be feasible, and a more positive emergency trip valve(s) or other provisions may be required.

7.4.3 Instruments and Control Panels

● **7.4.3.1** If specified, a local gauge board shall be furnished. The purchaser will specify the extent of instrumentation required.

● **7.4.3.2** If specified, a panel shall be provided and shall include all panel mounted instruments for the driven equipment and the driver. Such panels shall be designed and fabricated in accordance with the purchaser's description. The panel is to be freestanding, located on the base of the unit, or in another location, as specified. The instruments on the panel shall be clearly visible to the operator from the driver control point. Typical operational ranges will be indicated for all gages. The gages may be marked with the operating range or the operating range may be indicated on a tag next to the gage. A lamp test push button shall be provided. The instruments to be mounted on the panel will be specified.

7.4.3.3 Unless otherwise specified, panels shall be made of steel plate at least 3 mm (0.12 in.) thick, reinforced, self supporting and closed on the top and sides. If specified the backs of panels shall be closed to minimize electrical hazards, to prevent tampering or to allow purging for safety or corrosion protection. All instruments shall be flush mounted on the front of the panel and all fasteners shall be of corrosion resistant material.

7.4.3.4 Panels shall be completely assembled, piped and wired, requiring only connection to the purchaser's external piping and wiring circuits. If more than one wiring point is required on a unit for control or instrumentation, the wiring to each switch or instrument shall be provided from a single terminal box, with terminal posts. Each box shall be mounted on the unit or its base, if applicable. All leads and posts on terminal strips, (switches and transmitters) and instruments shall be tagged for identification. Wiring inside panels shall be neatly run in conduits or supported on cable trays.

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

7.4.4 Instrumentation

7.4.4.1 Unless specified otherwise, instrumentation furnished shall be provided in accordance with API 614 (ISO 10438).

7.4.4.2 Tachometers

Unless otherwise specified, a tachometer shall be supplied by the turbine vendor and shall be furnished with a minimum range of 0 % to 125 % of maximum continuous speed.

7.4.4.3 Vibration, Axial Position, and Temperature Detectors

● **7.4.4.3.1** If specified, two radial proximity type vibration probes shall be mounted adjacent to each bearing. Two axial position probes shall be mounted at the thrust end and a one-event-per-revolution probe shall be provided in each machine. The installation shall be in accordance with API 670.

7.4.4.3.2 If specified, hydrodynamic thrust and radial bearings shall be fitted with bearing metal temperature detectors. If pressure lubricated hydrodynamic thrust and radial bearings are supplied with temperature detectors, the detectors and their mounting and calibration shall be supplied, installed, and tested in accordance with API 670.

7.4.4.4 Temperature Gauges

7.4.4.4.1 Dial type temperature gauges shall be heavy duty and corrosion resistant. They shall be equal to or greater than 125 mm (5 in.) diameter, bimetallic or liquid filled types and, unless otherwise agreed, shall have black marking on a white background.

7.4.4.4.2 The sensing elements of temperature gauges shall be in the flowing fluid.

NOTE This is particularly important for lines that can run partially full.

7.4.4.5 Thermowells

Temperature sensing elements for toxic or flammable fluids or in pressurized or flooded lines, shall be furnished with austenitic stainless steel, solid bar, separable thermowells. Unless otherwise specified, the thermowell shall have a 25 mm (1 in.) process connection. For pressurized lines, this connection shall be flanged. For non pressurized lines, this connection shall be threaded. The thermowell internal connection shall be 13 mm ($^1/_2$ in.).

7.4.4.6 Thermocouples and Resistance Temperature Detectors

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

7.4.4.7 Pressure Gauges

7.4.4.7.1 Pressure gauges (not including built in instrument air gauges) shall be furnished with Type 316 stainless steel bourdon tubes and stainless steel movements, 110 mm (4 1/2 in.) dials [150 mm (6 in.) dials for the range over 55 bar (800 psi)], and NPS 1/2 male alloy steel connections. Black printing on a white background is standard for gauges. Gauge ranges shall preferably be selected so that the normal operating pressure is at the middle of the gauge's range. In no case, however, shall the maximum reading on the dial be less than the applicable relief valve setting plus 10 %. Each pressure gauge shall be provided with a device such as a disk insert or blowout back designed to relieve excess case pressure.

• **7.4.4.7.2** If specified, liquid-filled gauges shall be furnished in locations subject to vibration.

7.4.4.8 Solenoid Valves

Where fitted solenoid valves shall act as a pilot to pneumatic and hydraulically operated valves.

For pneumatic systems the valve shall only use clean dry instrument air. For hydraulic systems the valve shall only use clean filtered hydraulic fluid.

7.4.4.9 Relief Valves

7.4.4.9.1 The vendor shall furnish the relief valves that are to be installed on equipment or piping that the vendor is supplying. Other relief valves related to equipment or piping outside the system that the vendor is supplying, will be furnished by the purchaser. The vendor's quotation shall list all relief valves and shall clearly state that these valves will be furnished by the vendor.

7.4.4.9.2 The sizing, selection and installation of relief valves shall meet the requirements of API 520, Part I and Part II. Relief valves shall be in accordance with API 526. The vendor shall determine the size and set pressure of all relief valves within his scope of supply and recommend the size and setting of relief valves supplied by others required to protect the equipment he supplies. Relief valve sizes and settings shall take into account all possible modes of equipment failure.

7.4.4.9.3 Unless otherwise specified, relief valves shall have steel bodies.

• **7.4.4.9.4** If specified, thermal relief valves shall be provided for accessories or cooling jackets that can be blocked-in by isolation valves.

7.4.4.10 Flow Indicators

7.4.4.10.1 Flow indicators shall be furnished in the oil drain return line from each bearing, gear, and seal. Unless otherwise specified a flow indicator shall be installed in the outlet piping of each continuously lubricated coupling.

7.4.4.10.2 Unless otherwise specified, the flow indicator shall be:

a) flanged,

b) bulls-eye type with glass on both sides,

c) steel body construction,

d) diameter of not less than one half the inside diameter of the oil pipe, and

e) clearly show the minimum oil flow.

NOTE To facilitate viewing of the flow of oil through the line, each flow indicator should be installed with its bullseye-glass in a vertical plane.

7.4.5 Alarms and Shutdowns

7.4.5.1 General

Alarm and shutdown instrumentation (switches or transmitters) and control devices shall be furnished and mounted by the vendor, as specified.

• 7.4.5.2 Sentinel Warning Valves

If specified, a sentinel warning valve shall be supplied on the turbine casing. For condensing turbines, it shall be set at 0.35 bar (5 psig). For non-condensing turbines, the minimum setting shall be either 10 % or 0.7 bar (10 psig) above the maximum exhaust pressure, whichever is greater.

NOTE A sentinel warning valve is only an audible warning device and not a pressure-relieving device.

7.4.5.3 Alarm and Trip (Switches & Transmitters)

7.4.5.3.1 Where alarm and/or shutdown functions are initiated by locally mounted switches & transmitters, such switches & transmitters shall comply with 7.4.5.3.2 through 7.4.5.3.7.

7.4.5.3.2 Each alarm switch and each shutdown switch shall be furnished in a separate housing located to facilitate inspection and maintenance.

7.4.5.3.3 Hermetically sealed, single-pole, double-throw switches with a minimum capacity of 5 amperes at 120V AC and $^{1}/_{2}$ A at 120V DC shall be used. Mercury switches shall not be used.

• **7.4.5.3.4** The purchaser will specify whether switches and transmitters shall be connected to open (deenergize) or close (energize) to initiate alarms and shutdowns.

7.4.5.3.5 Alarm and trip switch settings shall not be adjustable from outside the housing.

7.4.5.3.6 Housings for alarm and shutdown switches and transmitters shall comply with the requirements of 7.4.6.4.

7.4.5.3.7 The sensing elements of pressure switches and transmitters shall be of stainless steel (Type 300 stainless steel). Low-pressure switches & transmitters, which are actuated by falling pressure, shall be equipped with a pressure gage, valved bleed or vent connection to allow controlled depressurizing during testing. High-pressure switches and transmitters which are activated by rising pressure shall be equipped with a valved test connection so that a portable pump can be used to raise the pressure during testing. The arrangement to be used will be specified by the purchaser.

7.4.5.3.8 The vendor shall furnish with the proposal a complete description of the alarm and shutdown facilities to be provided.

7.4.6 Electrical Systems

7.4.6.1 Electrical equipment located on the unit or on any separate panel shall conform to the electrical area classification specified. Electrical starting and supervisory controls may be either AC or DC.

7.4.6.2 Power and control wiring, located on, adjacent to, or connected to the equipment, shall be resistant to oil, heat, moisture and abrasion. Stranded conductors shall be used if connected to or located on machinery or in other areas subject to vibration. Measurement and remote control panel wiring may be solid conductor. The insulation shall be flame retardant, moisture and heat resistant thermoplastic, and if necessary for abrasion resistance shall be provided with an outer covering. Wiring shall be suitable for the local temperatures to be encountered.

7.4.6.3 All leads on terminal strips, switches & transmitters, and instruments shall be permanently tagged for identification. All terminal boards in junction boxes and control panels shall have at least 20 % spare terminal points.

7.4.6.4 To guard against accidental contact, enclosures shall be provided for all terminal strips, relays, (switches and transmitters) and other energized parts. Electrical power wiring shall be segregated from instrument and control signal wiring both externally and, as far as possible, inside enclosures. Inside enclosures which may be required to be opened with the equipment in operation, for example, for alarm testing or adjustment, shall be provided with secondary shields or covers for all terminal strips and other exposed parts carrying electrical potential in excess of 50 volts. Maintenance access space shall be provided around or adjacent to electrical equipment or in accordance with the appropriate code such as NFPA 70, Article 110.

7.4.6.5 Electrical materials including insulation shall be corrosion resistant and non-hygroscopic insofar as is possible. If specified for tropical location, materials shall be given the treatments specified in the following:

a) parts (such as coils and windings) shall be protected from fungus attack;

b) unpainted surfaces shall be protected from corrosion by plating or another suitable coating.

7.4.6.6 Control, instrumentation, and power wiring, that is not within a fully enclosed panel or other enclosure, shall be in the form of armored cable or shall be run in metal conduit as specified. Cables shall be supported on cable trays. Conduit shall be properly supported to avoid damage caused by vibration and isolated and shielded to prevent interference between different services. Conduits may terminate (in the case of the leads to temperature elements, shall terminate) with a length of flexible metal conduit, long enough to facilitate maintenance without removal of the conduit. If temperature element heads are exposed to temperatures above 60 °C (140 °F), a 19 mm (0.75 in.) bronze hose with four-wall-interlocking construction and joints with packed-on heatproof couplings shall be used.

7.4.6.7 For Division 2 locations, flexible metallic conduits shall have a liquid tight thermosetting or thermoplastic outer jacket and approved fittings. For Division 1 locations, a NFPA approved connector shall be provided.

7.4.6.8 AC and DC circuits shall be clearly labeled, connected to separate terminal blocks, and isolated from each other.

7.5 Piping and Appurtenances

7.5.1 General

7.5.1.1 Auxiliary systems are piping systems that are in the following services:

a) steam, including sealing steam;

b) instrument and control air;

c) lubricating oil;

d) control oil;

e) cooling water; and

f) drains and vents associated with above systems.

Auxiliary systems shall comply with the requirements of API 614, Chapter 1.

NOTE Casing connections are discussed in 6.5.

7.5.1.2 Piping systems shall include piping, tubing where permitted, isolating valves, control valves, relief valves, pressure reducers, orifices, temperature gauges and thermowells, pressure gauges, sight flow indicators, and all related vents and drains.

7.5.1.3 If the turbine vendor provides the baseplate, the vendor shall furnish all piping systems, including mounted appurtenances, located within the confines of the main unit's base area, any oil console base area, or any auxiliary base area. The piping shall terminate with flanged connections at the edge of the base. If soleplates are specified for the equipment train, the extent of the piping system at the equipment train shall be defined by the purchaser. The purchaser will furnish only interconnecting piping between equipment groupings and off base facilities.

7.5.1.4 The design of piping systems shall achieve the following:

a) proper support and protection to prevent damage from vibration or from shipment, operation and maintenance;

b) proper flexibility and adequate accessibility for operation, maintenance and thorough cleaning;

c) installation in a neat and orderly arrangement adapted to the contours of the equipment without obstructing access areas;

d) elimination of air pockets by the use of valved vents or the use of non-accumulating piping arrangements; and

e) complete drainage through low points without disassembly of piping.

7.5.1.5 Piping shall preferably be fabricated by bending and welding to minimize the use of flanges and fittings. Flanges are permitted only at equipment connections, at the edge of any base and for ease of maintenance. The use of flanges at other points is permitted only with the purchaser's specific approval. Other than tees and reducers, welded fittings are permitted only to facilitate pipe layout in congested areas. Threaded connections shall not be used except (with the purchaser's approval) where essential for space or access reasons, pipe bushings shall not be used.

7.5.1.6 Pipe threads, where permitted shall be taper threads in accordance with ISO 7-1. Flanges shall be in accordance with ISO 7005-1. Slip-on flanges are permitted only with the purchaser's specific approval. For socket-welded construction, a 2 mm ($^1/_{16}$ in.) gap shall be left between the pipe end and the bottom of the socket.

7.5.1.7 Welding is not permitted on instruments or cast iron equipment or where disassembly is required for maintenance.

7.5.1.8 Connections, piping, valves, and fittings that are 32 mm (1 $^1/_4$ in.), 65 mm (2 $^1/_2$ in.), 90 mm (3 $^1/_2$ in.), 125 mm (5 in.), 175 mm (7 in.), or 225 mm (9 in.) in size shall not be used.

7.5.1.9 Where space does not permit the use of NPS $^1/_2$, NPS $^3/_4$, or NPS 1 pipe, seamless tubing may be furnished in accordance with Table 5.

7.5.1.10 The minimum size of any connection shall be NPS $^1/_2$.

7.5.1.11 Piping systems furnished by the vendor shall be fabricated, installed in the shop, and properly supported. Bolt holes for flanged connections shall straddle lines parallel to the main horizontal or vertical centerline of the equipment.

7.5.1.12 Pipe plugs shall be in accordance with 6.5.8.

Table 5—Minimum Requirements for Piping System Components

System	Steam		Cooling Water		Lube Oil	
	≤ 5.2 bar (75 psig)	> 5.2 bar (75 psig)	Standard (≤ NPS 1)	Optional	≤ NPS 1	≥ NPS 1 1/2
Pipe	Seamless[a]	Seamless[a]		ASTM A53 Type F, Schedule 40, galvanized to ASTM A153		ASTM A312, Type 304 or 316 stainless steel[b]
Tubing	ASTM A269, seamless Type 304 or 316 stainless steel[c]		ASTM A269, seamless Type 304 or 316 stainless steel[c]		ASTM A269, seamless Type 304 or 316 stainless steel[c]	
All Valves	Carbon steel, Class 800	Carbon steel, Class 800	Bronze, Class 200	Bronze, Class 200	Carbon steel, Class 800	Carbon steel, Class 800
Gate and Globe Valves	Bolted bonnet and gland	Bolted bonnet and gland			Bolted bonnet and gland	Bolted bonnet and gland
Pipe Fittings and Unions	Forged, Class 3000	Forged, Class 3000	ASTM A338 and A 197, Class 150 malleable iron, galvanized to ASTM A153	ASTM A338 and A 197, Class 150 malleable iron, galvanized to ASTM A153	Stainless steel	Stainless steel
Tube Fittings	Carbon steel, compression, manufacturer's standard		Manufacturer's standard		Carbon steel, compression, manufacturer's standard	
Fabricated Joints ≤ 1 1/2 in.	Threaded	Socket welded	Threaded	Threaded		Carbon steel slip-on flange
Fabricated Joints ≥ 2 in.	Slip-on flange	Socket-weld or weld-neck flange	Purchaser shall specify	Purchaser shall specify		Carbon steel slip-on flange
Gaskets	Type 304 or 316 stainless steel, spiral wound, or iron or soft steel	Type 304 or 316 stainless steel, spiral wound, or iron or soft steel				Type 304 or 316 stainless steel, spiral wound
Flange Bolting	ASTM A193, Grade B7 ASTM A194, Grade 2H	ASTM A193, Grade B7 ASTM A194, Grade 2H				ASTM A193, Grade B7; ASTM A194, Grade 2H

NOTE Carbon steel piping shall conform to ASTM A106, Grade B; ASTM A524; or API 5L, Grade A or B. Carbon steel fittings, valves, and flanged components shall conform to ASTM A105 and A181. Stainless steel piping shall conform to ASTM A312.

[a] Schedule 80 for diameters from 1/2 in. to 1 1/2 in.; Schedule 40 for diameters 2 in. and larger.

[b] Schedule 40 for a diameter of 1 1/2 in.; Schedule 10 for diameters of 2 in. and larger.

[c] 1/2 in. diameter × 0.065 in. wall, 3/4 in. diameter × 0.095 in. wall, or 1 in. diameter × 0.109 in. wall.

7.5.2 Oil Piping

7.5.2.1 Gravity return lines shall be sized to run no more than half full when flowing at a velocity of 0.3 m/s (1 ft/s) and shall be arranged to ensure good drainage (recognizing the possibility of foaming conditions). Gravity return lines shall have a downward slope towards the reservoir of not less than 4 %. If possible, lateral branches (not more than one in any transverse plane) should enter drain headers at approximately 45 ° angles in the direction of flow.

7.5.2.2 Non-consumable backup rings and sleeve type joints shall not be used. Pressure piping downstream of oil filters shall be free from internal obstructions that could accumulate dirt. Socket welded fittings shall not be used in pressure piping downstream of oil filters (see Table 5).

7.5.2.3 Unless otherwise specified, oil supply piping and tubing, including fittings (excluding slip on flanges), shall be stainless steel (see Table 5).

7.5.2.4 Provision shall be made for bypassing the bearings of equipment during oil system flushing operations.

7.6 Special Tools

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

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

7.7 Insulation and Jacketing

7.7.1 Unless otherwise specified, the turbine shall be supplied with removable blanket-type insulation extending over all portions of the casing that can reach a normal operating temperature of 75 °C (165 °F) or higher. The blanket shall consist of insulating material encapsulated in a high-temperature fabric with protective wire mesh. Jacket fasteners, wire mesh, and fittings shall be made of stainless steel.

7.7.2 The insulation shall maintain a jacket surface temperature of not more than 75 °C (165 °F) under normal operating conditions. Jacketing and insulation shall be designed to minimize possible damage during removal and replacement.

8 Inspection, Testing and Preparation for Shipment

8.1 General

8.1.1 The purchaser should specify the extent of participation in the inspection and testing.

● **8.1.2** If specified, the purchaser’s representative, the vendor’s representative or both shall indicate compliance in accordance with the inspector’s checklist (Annex F) by initialing, dating and submitting the completed checklist to the purchaser before shipment.

8.1.3 After advance notification to the vendor, the purchaser’s representative shall have entry to all vendor and sub-vendor plants where manufacturing, testing or inspection of the equipment is in progress.

8.1.4 The vendor shall notify sub-vendors of the purchaser’s inspection and testing requirements.

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

8.1.6 The purchaser will specify the amount of advanced notification required for a witnessed or observed inspection or test.

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

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

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

8.2 Inspection

8.2.1 General

● **8.2.1.1** The vendor shall supply the following data:

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

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

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

d) results of quality control tests and inspections;

e) details of all repairs;

● f) final assembled running clearances, if specified; and

g) other data specified by the purchaser or required by applicable codes and regulations.

8.2.1.2 Pressure-containing parts shall not be painted until the specified inspection and testing of the parts is complete.

● **8.2.1.3** In addition to the requirements of 6.12.4.5, the purchaser may specify the following:

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

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

8.2.1.4 Mill test reports are not required for standard components that are normally carried in inventory, including bulk raw material.

8.2.2 Material Inspection

8.2.2.1 General

8.2.2.1.1 If radiographic, ultrasonic, magnetic particle or liquid penetrant inspection of welds or materials is required or specified, the requirements in 8.2.2.2 through 8.2.2.5 shall apply unless other corresponding procedures and acceptance criteria have been specified. Cast iron may be inspected only in accordance with 8.2.2.4 and/or 8.2.2.5. Welds, cast steel and wrought material shall be inspected in accordance with 8.2.2.2 through 8.2.2.5.

8.2.2.1.2 Acceptance standards for 8.2.2.2 through 8.2.2.5 shall be mutually agreed upon between the purchaser and vendor.

8.2.2.1.3 Casting surfaces shall be examined visually by the vendor and shall be free from adhering sand, scale, cracks, and hot tears. Other surface discontinuities shall meet the visual acceptance standards specified by the purchaser. Visual method MSS SP-55 or other visual standards may be used to define acceptable surface discontinuities and finish.

8.2.2.2 Radiography

Radiography shall be in accordance with ASTM E94.

8.2.2.3 Ultrasonic Inspection

● **8.2.2.3.1** If specified, all forgings and bar stock for major rotating elements shall be 100 % ultrasonically inspected after rough machining in accordance with ASTM A388. Acceptable criteria shall be mutually agreed upon by the purchaser and the vendor.

8.2.2.3.2 Ultrasonic inspection shall be based upon the procedures ASTM A609 (castings), ASTM A388 (forgings), or ASTM A578 (plate).

8.2.2.4 Magnetic Particle Inspection

Both wet and dry methods of magnetic particle inspection shall be in accordance with ASTM E709.

8.2.2.5 Liquid Penetrant Inspection

Liquid penetrant inspection shall be based upon the procedures of ASTM E165.

8.2.3 Mechanical Inspection

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

8.2.3.2 All oil system components furnished shall meet the cleanliness requirements of API 614.

8.3 Testing

8.3.1 General

8.3.1.1 Equipment shall be tested in accordance with 8.3.2 and 8.3.3. Other tests that may be specified by the purchaser are described in 8.3.4.

8.3.1.2 At least six weeks before the first scheduled running test the vendor shall submit to the purchaser, for his review and comment, detailed procedures for the mechanical running test and all specified running optional tests (see 8.3.4) including acceptance criteria for all monitored parameters.

8.3.1.3 The vendor shall notify the purchaser not less than ten working days before the date the equipment will be ready for testing. If the testing is rescheduled, the vendor shall notify the purchaser not less than five working days before the new test date.

8.3.2 Hydrostatic Test

8.3.2.1 Pressure-containing parts (including auxiliaries) shall be tested hydrostatically with liquid at a minimum of 1 $^1/_2$ times the maximum allowable working pressure but not less than a pressure of 1.5 bar (20 psi). The test liquid shall be at a higher temperature than the nil-ductility transition temperature of the material being tested. Reference ASTM E1003.

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

8.3.2.2 If the part tested is to operate at a temperature at which the strength of a material is below the strength of that material at the testing temperature, the hydrostatic test pressure shall be multiplied by a factor obtained by dividing the allowable working stress for the material at the testing temperature by that at the rated operating temperature. The stress values used shall conform to those given in ASME B31.3 for piping or in ASME Section VIII, Division 1, for vessels. The pressure thus obtained shall then be the minimum pressure at which the hydrostatic test shall be performed. The datasheets shall list actual hydrostatic test pressures.

NOTE Applicability of this requirement to the material being tested should be verified before hydrotest, as the properties of many grades of steel do not change appreciably at temperatures up to 200 °C (400 °F).

8.3.2.3 Tests shall be maintained for a sufficient period of time to permit complete examination of parts under pressure. The hydrostatic test shall be considered satisfactory when neither leaks nor seepage through the pressure containing parts or joints is observed for a minimum of 30 minutes. Large, heavy pressure containing parts or complex systems may require a longer testing period to be agreed upon by the purchaser and the vendor. Seepage past internal closures required for testing of segmented cases and operation of a test pump to maintain pressure is acceptable.

8.3.2.4 The use of a sealant compound or gasket on the casing joints is acceptable during the casing integrity hydrotest.

8.3.3 Mechanical Running Test

8.3.3.1 The following requirements shall be met before the mechanical running test is performed.

a) The contract shaft seals and bearings shall be used in the machine for the mechanical running test. Bearing housing seals shall be checked and any leaks shall be corrected.

● b) All oil pressures, flows, viscosities, and temperatures shall be within the range of operating values recommended in the vendor's operating instructions for the specific unit being tested. If specified, for pressure lubrication systems, oil flow rates for each bearing housing shall be measured.

c) Test-stand oil filtration shall meet the cleanliness requirements of ISO 10438 (API 614) before any test is started.

d) Bearings intended to be lubricated by an oil mist lubrication system shall be pre-lubricated.

e) All joints and connections shall be checked for tightness, and any leaks shall be corrected.

f) All warning, protective, and control devices used during the test shall be checked, and adjustments shall be made as required. After final linkage adjustments, the turbine shall be operated to prove the capability of the governor to stroke from the full open to full close positions.

g) If non-contacting probes are not provided and if vibration cannot be measured on the shaft, vibration of the housings shall be recorded using shop instrumentation during the test. The measurements shall be taken on the top and side of each bearing housing and axial location of the outboard housing per Figure 1 (see 6.9.4.9 for vibration velocity limits).

h) All purchased vibration probes, cables, oscillator-de modulators, and accelerometers shall be in use during the test. If vibration probes are not furnished by the equipment vendor or if the purchased probes are not compatible with shop readout facilities, then shop probes and readouts that meet the accuracy requirements of API 670 shall be used.

i) The vibration characteristics determined by the use of the instrumentation specified in 8.3.3.1g or 8.3.3.1h shall serve as the basis for acceptance or rejection of the machine (see 6.9.4.6 or 6.9.4.9).

8.3.3.2 Unless otherwise specified, the control system shall be demonstrated and the mechanical running test of the steam turbine shall be conducted as follows.

Steam conditions shall be as close to design as practical. Due to no-load operation for extended periods of time during the test, the inlet steam conditions may need to be reduced to prevent overheating of the unit and exceeding design clearances.

a) The equipment shall be operated at speed increments of approximately 10 % from minimum allowable speed to the maximum continuous speed and run at the maximum continuous speed until bearings, lube-oil temperatures and shaft vibrations have stabilized.

b) The speed shall be increased to 110 % of the maximum continuous speed (just below trip speed), and the equipment shall be run for a minimum of 15 minutes at the increased speed.

c) Overspeed trip devices shall be checked and adjusted until three consecutive nontrending trip values within ± 2 % of the nominal trip setting are attained.

d) The speed governor and any other speed-regulating devices shall be tested for smooth performance over the operating speed range. No-load stability and response to the control signal shall be checked.

e) The speed shall be reduced to the maximum continuous speed and the equipment shall be run for 1 hour continuously.

f) Vibration readings shall be taken at maximum continuous speed, just below trip speed and at minimum specified governor speed, after the stabilization described in 8.3.3.2a. Maximum allowable vibration limits are described in 6.9.4.6 or 6.9.4.9 as applicable. Any critical speeds below maximum continuous shall be determined. Vibration limits for operation just below trip speed for turbines covered by 6.9.4.9 are 1.5 times the stated values.

g) As a minimum, the following data shall be recorded for variable-speed governors: the sensitivity and linearity of the relationship between speed and the control signal, and for adjustable governors, the response speed range.

8.3.3.3 Unless otherwise specified, the following shall be met after the mechanical running test is completed.

a) Hydrodynamic bearings shall be removed, inspected, and reassembled after the mechanical running test is completed.

b) If replacement or modification of bearings or seals or dismantling of the case to replace or modify other parts is required to correct mechanical or performance deficiencies, the initial test will not be acceptable and the final shop tests shall be run after these deficiencies are corrected.

c) If spare rotors are ordered to permit concurrent manufacture, each spare rotor shall also be given a mechanical running test in accordance with the requirements of this standard.

● **8.3.4 Optional Tests**

If specified, the shop tests described in 8.3.4.1 through 8.3.4.5 shall be performed. Test details shall be mutually agreed upon by the purchaser and the vendor.

● **8.3.4.1 Performance Tests**

Performance tests shall preferably be conducted at normal power and speed under normal steam conditions. If this is not practical, the vendor shall state the conditions under which he proposes to conduct the tests. Performance tests shall generally be conducted in accordance with ASME PTC 6. Details shall be subject to negotiation.

NOTE Performance tests are not normally required on this class of equipment.

• 8.3.4.2 Complete-unit Test

Such components as driven equipment and auxiliaries that make up a complete unit shall be tested together during the mechanical running test. The complete-unit test shall be performed in place of or in addition to separate tests of individual components as specified by the purchaser.

• 8.3.4.3 Gear Test

The gear shall be tested with the turbine during the mechanical running test, as mutually agreed upon between the purchaser and the vendor.

• 8.3.4.4 Sound-level Test

The sound-level test shall be performed in accordance with ISO 3744 or other agreed standard.

• 8.3.4.5 Auxiliary-equipment Test

Auxiliary equipment such as oil systems and control systems shall be tested in the vendor's shop. Details of the auxiliary-equipment tests shall be developed jointly by the purchaser and the vendor.

8.4 Preparation for Shipment

8.4.1 Equipment shall be prepared for the type of shipment specified, including blocking of the rotor if necessary. Blocked rotors shall be identified by means of corrosion resistant tags attached with stainless steel wire. The preparation shall make the equipment suitable for six months of outdoor storage from the time of shipment, with no disassembly required before operation, except for inspection of bearings and seals. If storage for a longer period is contemplated, the purchaser will consult with the vendor regarding the recommended procedures to be followed.

8.4.2 The vendor shall provide the purchaser with the instructions necessary to preserve the integrity of the storage preparation after the equipment arrives at the job site and before start-up, as described in API 686, Chapter 3.

8.4.3 The equipment shall be prepared for shipment after all testing and inspection has been completed and the equipment has been released by the purchaser. The preparation shall include that specified in items a through m as follows.

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

NOTE Austenitic stainless steels are typically not painted.

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

c) The interior of the equipment shall be clean; free from scale, welding spatter, and foreign objects; and sprayed or flushed with a rust preventive that can be removed with solvent. The rust preventive shall be applied through all openings while the machine is rotated.

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

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

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

NOTE These are shipping plugs; permanent plugs are covered in 6.5.8.

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

h) Lifting points and lifting lugs shall be clearly identified on the equipment or equipment package. The recommended lifting points shall be identified on boxed equipment.

i) The equipment shall be identified with item and serial numbers. Material shipped separately shall be identified with securely affixed, corrosion-resistant metal tags indicating the item and serial number of the equipment for which it is intended. Crated equipment shall be shipped with duplicate packing lists, one inside and one on the outside of the shipping container.

j) If a spare rotor is purchased, the rotor shall be prepared for unheated indoor storage for a period of at least three years. The rotor shall be treated with a rust preventive and shall be housed in a vapor-barrier envelope with a slow-release volatile-corrosion inhibitor. A purchaser-approved resilient material 3 mm ($^1/_8$ in.) thick [not tetrafluoroethylene (TFE) or polytetrafluoroethylene (PTFE)], shall be used between the rotor and the cradle at the support areas. The rotor shall not be supported at journals. Mark the probe target area barriers with the words “Probe Area—Do Not Cut.”

NOTE TFE and PTFE are not recommended as cradle support liners since they could flow and impregnate into the surface.

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

l) All turbines that are supplied without self-supporting base plates shall be bolted to a shipping skid formed of heavy timbers and suitable for handling by a forklift truck or sling. Larger turbines shall have supports as required by the mode of transportation and handling.

m) Turbines that have carbon rings shall be shipped with the rings installed. The vendor shall indicate in the instruction manual if the carbon-ring gland housing must be cleaned before initial start-up.

8.4.4 Auxiliary piping connections furnished on the purchased equipment shall be impression stamped or permanently tagged to agree with the vendor’s connection table or general-arrangement drawing. Service and connection designations shall be indicated.

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

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

8.4.7 Connections on auxiliary piping removed for shipment shall be match-marked for ease of reassembly.

9 Vendor's Data

9.1 General

9.1.1 The information to be furnished by the vendor is specified in 9.2 and 9.3. The vendor shall complete and forward the VDDR form (see Annex C) to the address or addresses noted on the inquiry or order. This form shall detail the schedule for transmission of drawings, curves and data as agreed to at the time of the order, as well as the number and type of copies required by the purchaser.

9.1.2 The data shall be identified on transmittal (cover) letters, title pages and in title blocks or other prominent position on drawings, with the following information (see 9.2.1, 9.3.1.1, 9.3.5.1):

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

b) the job/project number;

c) the equipment item number and service name;

d) the inquiry or purchase order number;

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

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

9.2 Proposals

9.2.1 General

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

9.2.2 Drawings

9.2.2.1 The drawings indicated on the VDDR form (see Annex C) shall be included in the proposal. As a minimum, the following shall be included.

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

b) Cross-sectional drawings showing the details of the proposed equipment.

c) Schematics of all auxiliary systems including fuel, lube oil, control, and electrical systems. bills of material shall be included.

d) Sketches that show methods of lifting the assembled machine or machines, packages, and major components and auxiliaries (this information may be included on the drawings specified in Item a).

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

9.2.3 Technical Data

The following data shall be included in the proposal.

a) The purchaser's datasheets with complete vendor's information entered thereon and literature to fully describe details of the offering.

b) The predicted noise data.

c) The VDDR form (see Annex C) indicating the schedule according to which the vendor agrees to transmit all the data specified.

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

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

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

g) A list of the special tools furnished for maintenance

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

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

j) A description of any optional or additional tests and inspection procedures for materials as required.

k) A description of any special requirements, whether specified in the purchaser's inquiry or as outlined in 6.12.1.2 and 7.4.4.9.2.

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

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

n) A list of any components that can be construed as being of alternative design, hence requiring purchaser's acceptance (see 9.2.1).

● 9.2.4 Curves

If specified, the vendor shall provide the following performance curves:

a) steam flow versus power for various settings of the hand valve or valves when the turbines are operating at normal speed;

b) for multi-stage turbines, first-stage pressure versus steam flow when the turbines are operating at normal speed and steam conditions.

9.3 Contract Data

9.3.1 General

9.3.1.1 Contract data shall be furnished by the vendor in accordance with the agreed VDDR form.

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

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

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

9.3.2 Drawings and Technical Data

9.3.2.1 The drawings and data furnished by the vendor shall contain sufficient information so that together with the manuals specified in 9.3.5, the purchaser can properly install, operate, and maintain the equipment covered by the purchase order. All contract drawings and data shall be clearly legible (8 point minimum font size even if reduced from a larger size drawing), shall cover the scope of the agreed VDDR form, and shall satisfy the applicable detailed descriptions in Annex C.

9.3.2.2 The data shall be submitted in accordance with Annex C and identified in accordance with 9.2.2.1. Any comments on the drawings or revisions of specifications that necessitate a change in the data shall be noted by the vendor. These notations will result in the purchaser's issue of completed, corrected datasheets as part of the order specifications.

9.3.3 Progress Reports

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

9.3.4 Parts Lists and Recommended Spares

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

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

9.3.5 Installation, Operation, Maintenance, and Technical Data Manuals

9.3.5.1 General

The vendor shall provide sufficient written instructions and all necessary drawings to enable the purchaser to install, operate, and maintain all of the equipment covered by the purchase order. This information shall be compiled in a manual or manuals with a cover sheet showing the information listed in 9.1.2, an index sheet, and a complete list of the enclosed drawings by title and drawing number. The manual or manuals shall be prepared specifically for the equipment covered by the purchase order. “Typical” manuals are unacceptable.

9.3.5.2 Installation Manual

All information required for the proper installation of the equipment shall be compiled in a manual that shall be issued no later than the time of issue of final certified drawings. For this reason, it may be separate from the operating and maintenance instructions. This manual shall contain information on alignment and grouting procedures, normal and maximum utility requirements, centers of mass, rigging provisions and procedures, and all other installation data. All drawings and data specified in 9.2.2 and 9.2.3 that are pertinent to proper installation shall be included as part of this manual (see also description of line Item 33 in Annex C).

9.3.5.3 Operating and Maintenance Manual

A manual containing all required operating and maintenance instructions shall be supplied not later than two weeks after all specified tests have been successfully completed. In addition to covering operation at all specified process conditions, this manual shall also contain separate sections covering operation under any specified extreme environmental conditions (see also description of line Item 33 in Annex C).

● 9.3.5.4 Technical Data Manual

If specified, the vendor shall provide the purchaser with a technical data manual within 30 days of completion of shop testing. (See description of line Item 33 in Annex C for minimum requirements of this manual.)

Annex A
(informative)

General Purpose Steam Turbine Datasheets

This annex contains typical datasheets for use by the purchaser and the vendor as shown in Figure A.1 and Figure A.2.

The datasheets, in both SI and USC units, are copies of the electronic form of the datasheets (Microsoft Excel Spreadsheets). In the electronic form, selection of the units on the datasheet will automatically change all the units on the datasheet to the units selected. Note however, that this electronic datasheet does not contain in-built calculations, therefore changing the units will not impact any data entered onto the datasheet.

The datasheet is intended to be used in its electronic format and as such, there are numerous cells that contain drop-down selections. As these selections are not presented to the user until the cell is selected, the copies in this document indicate which cells contain a drop-down selection in the shaded areas. Another feature of the electronic datasheet is that when the user selects a data entry cell, if there is a cross reference back to the standard a pop-up box will appear indicating the reference paragraph and some or all of the content of the referenced paragraph.

To assist the reader a document map (See Figure A.3), which is basically the datasheet less all content, has been prepared which lists the content of the drop-down selection at each line as applicable. In addition to the drop-down list, there are some lines with numbers listed on the left-hand side of the area. These numbers are the numbers of the crossed referenced paragraphs, which pop-up as mentioned above.

In all instances the document map lists the information on the same line as the electronic datasheet.

GENERAL-PURPOSE STEAM TURBINE API 611 5TH EDITION DATA SHEET SI Units	JOB NO. ____ ITEM NO. ____
	PURCHASE ORDER NO. ____
	DATA SHEET NO. ____
	REVISION NO. ____ DATE ____
	PAGE 1 OF 3 BY ____
CHECKED ____	APPROVED ____

1	APPLICABLE TO: ____ **APPLICABLE STANDARD:** **API-611**	UNITS OF MEASURE: **SI**
2	FOR ____	UNIT ____
3	SITE ____	NO. REQUIRED ____
4	SERVICE ____	DRIVEN EQUIPMENT ____
5	MANUFACTURER ____	MODEL ____ SERIAL NO. ____
6		
7	**OPERATING CONDITIONS**	**PERFORMANCE**
8–9	**OPERATING POINT** | **ABSORBED POWER, kW** | **SPEED, RPM**	**OPERATING POINT/ STEAM CONDITION** | **NO. HAND VALVES OPEN** | **STEAM RATE, kg/kW-h**
10	NORMAL	NORMAL/NORMAL CERTIFIED STEAM RATE
11	RATED	RATED/NORMAL
12	OTHER (6.1.4)	RATED @ MINIMUM INLET & MAXIMUM EXHAUST
13	**DUTY, SITE, AND UTILITY DATA**	OTHER/NORMAL CONDITIONS
14	APPLICATION IS: ____	
15	WIDE SPEED RANGE ____ RAPID START ____	**APPLICABLE SPECIFICATION**
16	SLOW ROLL REQUIRED ____ HAND VALVES ____	API-611 OTHER ____
17	OPERATION ____	____
18	MDMT ____ °K @ ____ kPa	____
19	UNATTENDED AUTO START (6.1.6) ____	**CONSTRUCTION**
20	LOCATION (6.1.14) ____ ____ ____	TURBINE TYPE ____
21	AMBIENT TEMP. MIN. ____ MAX ____ °K	NO STAGES ____ WHEEL DIA., ____ mm
22	UNUSUAL CONDITIONS (6.1.14) ____	ROTOR: CONSTRUCTION ____
23	____	ARRANGEMENT ____
24	AREA CLASSIFICATION ZONE ____	BLADING ____
25	GROUP ____ TEMPERATURE CLASS ____	CASING SPLIT ____
26		CASING SUPPORT ____
27	CONTROL POWER V ____ PH. ____ HZ ____	VERTICAL JACKSCREWS FURNISHED ____
28	AUX. MOTORS V ____ PH. ____ HZ ____	____
29	COOLING WATER: PRESS, ____ kPa g DP ____ kPa	
30	FLOW ____ m³/s DT ____ °K	TRIP VALVE ____
31	ALLOW. SOUND PRESS LEVEL (6.1.12) ____ dBA @ ____ m	INTERSTAGE SEALS ____
32	**STEAM CONDITIONS (6.1.4)**	END SEALS ____
33	| **MAX** | **NORMAL** | **MIN.**	____
34	INLET PRESS, | | | | kPa g	
35	INLET TEMP | | | | kPa g	TYPE RADIAL BEARINGS ____
36	EXHAUST PRESS | | | | kPa g	TYPE THRUST BEARING ____
37	STEAM CONTAMINANTS ____	LUBE OIL VISCOSITY ISO GRADE ____ ____
38	**TURBINE DATA**	LUBRICATION ____
39	ALLOW SPEEDS, RPM, MAX ____ MIN ____	OIL MIST ____
40	MAX CONT SPEED, RPM MAX ____ MIN ____	OIL MIST SYSTEM ____
41	TRIP SPEED, RPM ____ BLADE TIP VEL, ____ m/s	BEARING HOUSING OILER TYPE ____
42	FIRST CRITICAL SPEED, RPM ____	BEARING HOUSING SEAL ____
43	EXH. TEMP NORMAL ____ NO LOAD ____ N	SEAL SUPPLIER ____
44	POTENTIAL MAX POWER ____ kW	**CASING DESIGN** | **INLET** | **EXHAUST**
45	MAX. NOZZLE STEAM FLOW, ____ kg/h	MAX. ALLOW. PRESS, | | | kPa g
46	ROTATION FACING GOVERNOR END ____	MAX ALLOW. TEMP, | | | °K
47	VERTICAL DRIVEN EQUIPMENT THRUST ____ N	HYDRO TEST PRESS., | | | kPa g
48	VERTICAL TURBINE THRUST CAPACITY ____ N	
49	WATER PIPING REQUIRED: ____	
50	FURNISHED BY: ____	REMARKS: ____
51	OIL PIPING REQUIRED: ____	____
52	FURNISHED BY: ____	____
53	AUTO DRAIN SYSTEM REQ'D (6.3.10): ____	____
54	FURNISHED BY: ____	____

Figure A.1—Datasheets, SI Units

GENERAL-PURPOSE STEAM TURBINE
API 611 5TH EDITION DATA SHEET
SI Units

JOB NO. ______ ITEM NO. ______
REVISION NO. ______ DATE ______
PAGE 2 OF 3 BY ______

1	**MATERIALS (6.12)**	**ACCESSORY EQUIPMENT BY VENDOR**
2	HIGH PRESSURE CASING ______ GRADE ______	REMOTE TRIP SOLENOID
3		TURBINE TRIPPED SIGNAL
4	EXHAUST CASING ______ GRADE ______	VACUUM BREAKER
5	NOZZLES ______ GRADE ______	AUTOMATIC STEAM SEALING SYSTEM
6	BLADING ______ GRADE ______	SEALING STEAM ______ kPa g ______ °K
7	WHEELS ______ GRADE ______	GLAND VACUUM DEVICE WITH:
8	SHAFT ______ GRADE ______	SENTINEL WARNING VALVE
9	SHAFT COATING UNDER PACKING	INSULATION, TYPE: BLANKET
10	MATERIAL	TACHOMETER TYPE
11	APPLICATION METHOD	MFR. ______ MODEL ______
12	THICKNESS	MOUNTED BY
13	GOV. VALVE TRIM	THERMAL RELIEF VALVES
14	INLET STRAINER ______ MESH SIZE ______	
15		LOCAL GAUGE BOARD WITH PRESSURE GAUGES:
16	**CONNECTIONS (6.4.2)**	THROTTLE STEAM ______ FIRST STAGE ______
17	SIZE / RATING / FACING / POSITION	NOZZLE RING ______ EXHAUST ______
18	INLET	LIQUID FILLED GAUGES
19	EXHAUST	INSTRUMENT PANEL
20	DRAINS HP	
21	DRAINS EXP	
22		**EXTERNAL LUBE OIL SYSTEM**
23		TYPE OF LUBE SYSTEM SUPPLIED
24	**COUPLINGS (7.2)**	VENDOR FURNISH SYSTEM FOR:
25	**LOCATION** / **TURBINE** / **DRIVEN**	
26	MAKE	OIL SYSTEM TO BE:
27	MODEL	
28	RATING (HP/100RPM)	**REMARKS:**
29	LUBRICATION	
30	LIMITED END FLOAT	
31	SPACER LENGTH	
32	SERVICE FACTOR	**VIBRATION AND POSITION DETECTORS (7.4.4.3)**
33	COUPLING SPACER/HUBS MATL.	
34	COUPLING DIAPHRAGMS (DISKS) MATL.	**FURNISH PROVISIONS FOR MOUNTING NON-CONTACTING**
35	TURBINE VENDOR MOUNTS HALF COUPLING	VIBRATION PROBES
36	COUPLING CONSTRUCTED TO	FURN. AXIAL POSITION PROBES ______ NO. OF PROBES ______
37	SEE SEPARATE DATA SHEET	MFR. ______ MODEL ______
38	COUPLING BALANCED TO	FURN. ONE EVENT PER REV PROBE
39	TURBINE SHAFT	FURN. RADIAL PROBES ______ NO. OF PROBES/BEARING ______
40		MFR. ______ MODEL ______
41		
42	**MOUNTING PLATES**	FURNISH BEARING METAL TEMP SENSORS FOR:
43	TURBINE MOUNTED ON	RADIAL BEARINGS ______ THRUST BEARINGS ______
44	FURN. BY:	MAGNETIC SEISMIC PROBES
45	EQUIPMENT TO BE MOUNTED:	PERMANENT SEISMIC PROBES
46		MFR. ______ MODEL ______
47		**TURBINE VENDOR SUPPLIES MONITORS**
48	UNGROUTED BASEPLATE	AXIAL AND RADIAL PROBES
49		BEARING TEMPERATURE SENSORS
50	SUBPLATES REQUIRED	SEE SEPARATE DATA SHEETS FOR DETAILS
51		**REMARKS:**
52	**GEARBOX**	
53	GEARBOX REQUIRED	
54	FURN. BY:	
55	APPLICABLE SPECIFICATION	
56	GEARBOX DATA SHEET NUMBER	

Figure A.1—Datasheets, SI Units (Continued)

GENERAL-PURPOSE STEAM TURBINE DATA SHEET SI Units

JOB NO. ITEM NO.
REVISION NO. DATE
PAGE 3 OF 3 BY

1	**GOVERNING SYSTEM**	**PREPARATION FOR SHIPMENT**
2	GOVERNOR TYPE	TURBINE, AUX. EQUIP. AND SPARE ROTOR PREPARED FOR :
3	GOVERNOR MANUFACTURER	
4	GOVERNOR MODEL	OUTDOOR STORAGE LONGER THAN Months
5	SPEED RANGE	**REMARKS:**
6	SPEED SETPOINT ADJUSTMENT	
7	LOCAL HAND SPEED CHANGER	
8	REMOTE SPEED SETPOINT	
9	**VARIABLE** / OPERATING RANGE / CONTROL SIGNAL	
10	**SPEED** TO RPM / TO mA	
11	**SPEED** TO RPM / TO kPa g	

		TESTS (8.3)	**REQ'D.**	**WITN.**	**OBSVD. (8.1.1)**
12	GOVERNOR POWER SUPPLY				
13		HYDROSTATIC			
14	REMOTE TRIP INPUT TO ELECTRONIC GOVERNOR	DYNAMIC BALANCE			
15	ELECTRONIC GOVERNOR SUITABLE FOR SLOW ROLL	MECH. RUN h			
16	OVERSPEED TRIP	PERFORMANCE			
17		COMPLETE UNIT			
18		GEAR			
19	No. ACTUATION DEVICES	SOUND LEVEL			
20	MANUFACTURER	AUX. EQUIPMENT			
21	MODEL	RESIDUAL UNBALANCE CHECK			
22	**REMARKS:**				
23					
24		**REMARKS:**			

25	**ENGINEERING REQUIREMENTS**	
26	SUPPLY ENGR. DATA FOR LATERAL/TORSIONAL ANALYSES	
27	BY OTHERS	**DOCUMENTATION**
28	CALCS AND/OR DATA FOR SEPARATION MARGIN	PREFORMANCE CURVES
29	TRAIN TORSIONAL VIBRATION ANALYSIS	PROGRESS REPORTS
30		TECHNICAL DATA MANUAL
31		**WEIGHTS**
32	PARTY HAVING UNIT RESPONSIBILITY	TURBINE kg
33	ROTOR RUNNING CLEARANCES	ROTOR kg
34	**INSPECTION REQUIREMENTS**	TURBINE UPPER HALF CASING kg
35	USE INSPECTOR'S CHECK LIST	MAX MAINTENANCE (IDENTIFY) kg
36	100% US INSPECTION AFTER ROUGH MACHINING	T & T VALVE kg
37	CASTING SURFACE INSPECTION MSS SP-55	BASEPLATE kg
38		MISC. kg
39	CASTING WELD REPAIR APPROVAL	TOTAL SHIPPING WEIGHT kg
40	WELD INSPECTION	**REMARKS:**
41	SPECIAL NDT INSPECTION	
42		

	COMPONENT	MAG. PART.	DYE PENET.	RADIO-GRAPHIC	ULTRA-SONIC	OBSER-VED	WIT-NESS
45	T&T VALVE						YES
46	STM CHEST						
47	CASING						
48	PIPING						
49	ROTOR WHEEL						
50	ROTOR SHAFT						
51							

Figure A.1—Datasheets, SI Units (Continued)

GENERAL-PURPOSE STEAM TURBINE
API 611 5TH EDITION DATA SHEET
U.S. Customary Units

JOB NO.		ITEM NO.	
PURCHASE ORDER NO.			
DATA SHEET NO.			
REVISION NO.		DATE	
PAGE 1 OF 3		BY	
CHECKED		APPROVED	

1	APPLICABLE TO:		**APPLICABLE STANDARD:**	**API-611**	UNITS OF MEASURE:	**Customary**
2	FOR		UNIT			
3	SITE		NO. REQUIRED			
4	SERVICE		DRIVEN EQUIPMENT			
5	MANUFACTURER		MODEL		SERIAL NO.	
6						

No.	**OPERATING CONDITIONS**			**PERFORMANCE**		
8–9	**OPERATING POINT**	**ABSORBED POWER, HP**	**SPEED, RPM**	**OPERATING POINT/ STEAM CONDITION**	**NO. HAND VALVES OPEN**	**STEAM RATE, lb/HP-h**
10	NORMAL			NORMAL/NORMAL CERTIFIED STEAM RATE		
11	RATED			RATED/NORMAL		
12	OTHER (6.1.4)			RATED @ MINIMUM INLET & MAXIMUM EXHAUST		
13	**DUTY, SITE, AND UTILITY DATA**			OTHER/NORMAL CONDITIONS		

14	APPLICATION IS:	
15	WIDE SPEED RANGE ___ RAPID START ___	**APPLICABLE SPECIFICATION**
16	SLOW ROLL REQUIRED ___ HAND VALVES ___	API-611 OTHER
17	OPERATION	
18	MDMT ___ °F @ ___ psi	
19	UNATTENDED AUTO START (6.1.6)	**CONSTRUCTION**
20	LOCATION (6.1.14)	TURBINE TYPE
21	AMBIENT TEMP. MIN. ___ MAX ___ °F	NO STAGES ___ WHEEL DIA., ___ in
22	UNUSUAL CONDITIONS (6.1.14)	ROTOR: CONSTRUCTION
23		ARRANGEMENT
24	AREA CLASSIFICATION DIVISION	BLADING
25	GROUP ___ TEMPERATURE CLASS	CASING SPLIT
26		CASING SUPPORT
27	CONTROL POWER V ___ PH. ___ HZ ___	VERTICAL JACKSCREWS FURNISHED
28	AUX. MOTORS V ___ PH. ___ HZ ___	
29	COOLING WATER: PRESS, ___ psig DP ___ psi	
30	FLOW ___ gpm DT ___ °F	TRIP VALVE
31	ALLOW. SOUND PRESS LEVEL (6.1.12) ___ dBA @ ___ ft	INTERSTAGE SEALS
32	**STEAM CONDITIONS (6.1.4)**	END SEALS
33	**MAX** / **NORMAL** / **MIN.**	
34	INLET PRESS, ___ psig	
35	INLET TEMP ___ psig	TYPE RADIAL BEARINGS
36	EXHAUST PRESS ___ psig	TYPE THRUST BEARING
37	STEAM CONTAMINANTS	LUBE OIL VISCOSITY ISO GRADE
38	**TURBINE DATA**	LUBRICATION
39	ALLOW SPEEDS, RPM, MAX ___ MIN ___	OIL MIST
40	MAX CONT SPEED, RPM MAX ___ MIN ___	OIL MIST SYSTEM
41	TRIP SPEED, RPM ___ BLADE TIP VEL, ___ ft/s	BEARING HOUSING OILER TYPE
42	FIRST CRITICAL SPEED, RPM	BEARING HOUSING SEAL
43	EXH. TEMP NORMAL ___ NO LOAD ___ lbf	SEAL SUPPLIER
44	POTENTIAL MAX POWER ___ HP	**CASING DESIGN** / **INLET** / **EXHAUST**
45	MAX. NOZZLE STEAM FLOW, ___ lb/h	MAX. ALLOW. PRESS, ___ psig
46	ROTATION FACING GOVERNOR END	MAX ALLOW. TEMP, ___ °F
47	VERTICAL DRIVEN EQUIPMENT THRUST ___ lbf	HYDRO TEST PRESS., ___ psig
48	VERTICAL TURBINE THRUST CAPACITY ___ lbf	
49	WATER PIPING REQUIRED:	
50	FURNISHED BY:	REMARKS:
51	OIL PIPING REQUIRED:	
52	FURNISHED BY:	
53	AUTO DRAIN SYSTEM REQ'D (6.3.10):	
54	FURNISHED BY:	

Figure A.2—Datasheets, USC Units

GENERAL-PURPOSE STEAM TURBINE
API 611 5TH EDITION DATA SHEET
U.S. Customary Units

JOB NO. ______ ITEM NO. ______
REVISION NO. ______ DATE ______
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MATERIALS (6.12)

HIGH PRESSURE CASING		GRADE	
EXHAUST CASING		GRADE	
NOZZLES		GRADE	
BLADING		GRADE	
WHEELS		GRADE	
SHAFT		GRADE	

SHAFT COATING UNDER PACKING
MATERIAL ______
APPLICATION METHOD ______
THICKNESS ______
GOV. VALVE TRIM ______
INLET STRAINER ______ MESH SIZE ______

CONNECTIONS (6.4.2)

	SIZE	RATING	FACING	POSITION
INLET				
EXHAUST				
DRAINS HP				
DRAINS EXP				

COUPLINGS (7.2)

LOCATION	TURBINE	DRIVEN
MAKE		
MODEL		
RATING (HP/100RPM)		
LUBRICATION		
LIMITED END FLOAT		
SPACER LENGTH		
SERVICE FACTOR		

COUPLING SPACER/HUBS MATL. ______
COUPLING DIAPHRAGMS (DISKS) MATL. ______
TURBINE VENDOR MOUNTS HALF COUPLING ______
COUPLING CONSTRUCTED TO ______
SEE SEPARATE DATA SHEET ______
COUPLING BALANCED TO ______
TURBINE SHAFT ______

MOUNTING PLATES

TURBINE MOUNTED ON ______
FURN. BY: ______
EQUIPMENT TO BE MOUNTED: ______

UNGROUTED BASEPLATE ______

SUBPLATES REQUIRED ______

GEARBOX

GEARBOX REQUIRED ______
FURN. BY: ______
APPLICABLE SPECIFICATION ______
GEARBOX DATA SHEET NUMBER ______

ACCESSORY EQUIPMENT BY VENDOR

REMOTE TRIP SOLENOID ______
TURBINE TRIPPED SIGNAL ______
VACUUM BREAKER ______
AUTOMATIC STEAM SEALING SYSTEM ______
SEALING STEAM ______ psig ______ °F
GLAND VACUUM DEVICE WITH: ______
SENTINEL WARNING VALVE ______
INSULATION, TYPE: BLANKET
TACHOMETER TYPE ______
MFR. ______ MODEL ______
MOUNTED BY ______
THERMAL RELIEF VALVES ______

LOCAL GAUGE BOARD WITH PRESSURE GAUGES: ______
THROTTLE STEAM ______ FIRST STAGE ______
NOZZLE RING ______ EXHAUST ______
LIQUID FILLED GAUGES ______
INSTRUMENT PANEL ______

EXTERNAL LUBE OIL SYSTEM

TYPE OF LUBE SYSTEM SUPPLIED ______
VENDOR FURNISH SYSTEM FOR: ______

OIL SYSTEM TO BE: ______

REMARKS: ______

VIBRATION AND POSITION DETECTORS (7.4.4.3)

FURNISH PROVISIONS FOR MOUNTING NON-CONTACTING
VIBRATION PROBES ______
FURN. AXIAL POSITION PROBES ______ NO. OF PROBES ______
MFR. ______ MODEL ______
FURN. ONE EVENT PER REV PROBE ______
FURN. RADIAL PROBES ______ NO. OF PROBES/BEARING ______
MFR. ______ MODEL ______

FURNISH BEARING METAL TEMP SENSORS FOR:
RADIAL BEARINGS ______ THRUST BEARINGS ______
MAGNETIC SEISMIC PROBES ______
PERMANENT SEISMIC PROBES ______
MFR. ______ MODEL ______
TURBINE VENDOR SUPPLIES MONITORS ______
AXIAL AND RADIAL PROBES ______
BEARING TEMPERATURE SENSORS ______
SEE SEPARATE DATA SHEETS FOR DETAILS ______
REMARKS: ______

Figure A.2—Datasheets, USC Units (Continued)

GENERAL-PURPOSE STEAM TURBINE DATA SHEET
U.S. Customary Units

JOB NO. ______ ITEM NO. ______
REVISION NO. ______ DATE ______
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GOVERNING SYSTEM

GOVERNOR TYPE
GOVERNOR MANUFACTURER
GOVERNOR MODEL
SPEED RANGE
SPEED SETPOINT ADJUSTMENT
LOCAL HAND SPEED CHANGER
REMOTE SPEED SETPOINT

VARIABLE	OPERATING RANGE	CONTROL SIGNAL
SPEED	TO RPM	TO mA
SPEED	TO RPM	TO psig

GOVERNOR POWER SUPPLY

REMOTE TRIP INPUT TO ELECTRONIC GOVERNOR
ELECTRONIC GOVERNOR SUITABLE FOR SLOW ROLL
OVERSPEED TRIP
No. ACTUATION DEVICES
MANUFACTURER
MODEL
REMARKS:

ENGINEERING REQUIREMENTS

SUPPLY ENGR. DATA FOR LATERAL/TORSIONAL ANALYSES
BY OTHERS
CALCS AND/OR DATA FOR SEPARATION MARGIN
TRAIN TORSIONAL VIBRATION ANALYSIS

PARTY HAVING UNIT RESPONSIBILITY
ROTOR RUNNING CLEARANCES

INSPECTION REQUIREMENTS

USE INSPECTOR'S CHECK LIST
100% US INSPECTION AFTER ROUGH MACHINING
CASTING SURFACE INSPECTION MSS SP-55

CASTING WELD REPAIR APPROVAL
WELD INSPECTION
SPECIAL NDT INSPECTION

COMPONENT	MAG. PART.	DYE PENET.	RADIO-GRAPHIC	ULTRA-SONIC	OBSER-VED	WIT-NESS
T&T VALVE						
STM CHEST						
CASING						
PIPING						
ROTOR WHEEL						
ROTOR SHAFT						

PREPARATION FOR SHIPMENT

TURBINE, AUX. EQUIP. AND SPARE ROTOR PREPARED FOR :
OUTDOOR STORAGE LONGER THAN ______ Months
REMARKS:

TESTS (8.3)	REQ'D.	WITN.	OBSVD. (8.1.1)
HYDROSTATIC			
DYNAMIC BALANCE			
MECH. RUN ______ h			
PERFORMANCE			
COMPLETE UNIT			
GEAR			
SOUND LEVEL			
AUX. EQUIPMENT			
RESIDUAL UNBALANCE CHECK			

REMARKS:

DOCUMENTATION

PREFORMANCE CURVES
PROGRESS REPORTS
TECHNICAL DATA MANUAL

WEIGHTS

TURBINE	lb
ROTOR	lb
TURBINE UPPER HALF CASING	lb
MAX MAINTENANCE (IDENTIFY)	lb
T & T VALVE	lb
BASEPLATE	lb
MISC.	lb
TOTAL SHIPPING WEIGHT	lb

REMARKS:

Figure A.2—Datasheets, USC Units (Continued)

GENERAL-PURPOSE STEAM TURBINE DATA SHEET

JOB NO.		ITEM NO.	
PURCHASE ORDER NO.			
DATA SHEET NO.			
REVISION NO.		DATE	
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CHECKED		APPROVED	

1		PROPOSAL, PURCHASE, AS BUILT / API-611,MANF. STD.,OTHER / Customary,SI Ind	5.1	
2				
3				
4				
5				
6				
7		**OPERATING CONDITIONS**	6.1.4	**PERFORMANCE**
8				
9				
10				
11				
12				
13				
14		**DUTY, SITE AND UTILITY DATA**		
15		SPARED,UNSPARED		
16	6.11.5	YES,NO / YES,NO		**APPLICABLE SPECIFICATION**
17	6.11.5 & 6.1.4b	YES,NO / YES,NO		
18		CONTINUOUS,STANDBY,INTERMITENT		
19				
20		YES,NO		**CONSTRUCTION**
21		INDOOR,OUTDOOR / HEATED,UNHEATED / ROOF,W/O ROOF		HORIZONTAL,VERTICAL
22				
23		DUST,SALT ATMOSPHERE,OTHER		BUILT-UP,INTEGRALLY FORGED
24				OVERHUNG,BTWN BRGS
25		0,1,2,SAFE		1 ROW,2 ROW,3 ROW,RATEAU
26		For Elec Group & Temp Class A selection based on units used		AXIAL,RADIAL
27				CENTRELINE,FOOT,VERTICAL
28			6.3.18	YES,NO
29			6.5.13	NEMA "P" BASE,OTHER
30				
31				INTEGRAL BODY,SEPARATE BODY
31				LABYRINTH,CARBON
32		**STEAM CONDITIONS (6.1.4)**	6.8	CARBON RING,LABYRINTH,CARBON/ LABY,DRY GAS
33				
34				
35			6.10.1.1	ANTIFRICTION,SLEEVE
36			6.10.1.1	ANTIFRICTION,TILT PAD
37	6.12.1.7		6.11.4	SYNTHETIC 32,46,68,100,GREASE
38		**TURBINE DATA**		RING OILED,CIRCULATING,PRESSURE,GREASE
39			6.10.4.3	YES,NO
40	3.14			PURGE OIL MIST,PURE OIL MIST
41			6.10.4.1.2	CONSTANT LEVEL
42	6.9.2.2		6.10.4.2	Std Labyrinth Seal,Bearing Isolation Seal
43				
44	3.28			
45	7.4.4.9.2			
46		CCW,CW		
47		UP,DOWN,UP/DOWN,NONE		
48		UP,DOWN,UP/DOWN		
49		YES,NO		
50		SUPPLIER,TURBINE SUPPLIER,OTHERS		
51		YES,NO		
52		SUPPLIER,TURBINE SUPPLIER,OTHERS		
53		YES,NO		
54		SUPPLIER,TURBINE SUPPLIER,OTHERS		

Figure A.3—Datasheet Document Map

GENERAL-PURPOSE STEAM TURBINE DATA SHEET

JOB NO. ______ ITEM NO. ______
REVISION NO. 0 DATE ______
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	MATERIALS (6.12)		**ACCESSORY EQUIPMENT BY VENDOR**
			YES,NO
			MECHANICAL SWITCH,PROXIMITY SWITCH
		7.4.2.3.8	YES,NO
		6.8.6	YES,NO
		6.8.5	WATER EDUCTOR,STEAM EJECTOR
			YES,NO
		7.7	
		7.4.4.2	
6.7.2.5			
		7.4.4.9.4	YES,NO
7.4.2.1.3	YES,NO		YES,NO
		7.4.3.1	YES,NO
	CONNECTIONS (6.4.2)		YES,NO / YES,NO
			YES,NO / YES,NO
	250,300,600,900 / FF,RF,RTJ	7.4.4.7.2	YES,NO
	125,150,300 / FF,RF	7.4.3.2	YES,NO
	300,600,900,1500 / FF,RF,RTJ		BASEMOUNT,FREE STANDING
	150,300,600,900,1500 / FF,RF,RTJ		
			EXTERNAL LUBE OIL SYSTEM
			CIRCULATING,VENDOR STANDARD, API 611,API 614 Ch 3 GP,API 614 Ch 2 SP
	COUPLINGS (7.2)		TURBINE,TURBINE & GEAR,OTHER
		6.11.3	CONSOLE TYPE,MOUNTED ON BASEPLATE
			VIBRATION AND POSITION DETECTORS (7.4.4.3)
7.2.6			
7.2.1	YES,NO	6.10.4.4.4	YES,NO
7.2	API 611,ISO 14691,ISO 10441,API 671,OTHER		YES,NO / 1,2
			YES,NO
	TAPER,CYLINDRICAL,HYDRAULIC FIT HUB		YES,NO / 1,2
	US STANDARD,ISO/R775,OTHER		
	MOUNTING PLATES		
7.3.1.1	BASEPLATE,SOLE PLATE		YES,NO / YES,NO
	TURBINE VENDOR,DRIVEN EQUIPMENT VENDOR,OTHER	6.10.4.4.2	YES,NO,PROVISION ONLY
		6.10.4.4.3	YES,NO,PROVISION ONLY
	TURBINE,TURBINE & GEAR,DRIVEN EQUIPMENT		
	+ TURBINE,DRIVEN EQUIP + TURBINE & GEAR,OTHER		YES,NO
7.3.2.8	YES,NO		YES,NO
			YES,NO
7.3.4.1	YES,NO		YES,NO
	GEARBOX		
	YES,NO		
	TURBINE VENDOR,DRIVEN EQUIPMENT VENDOR,OTHER		
	API 677,AGMA,OTHER		

Figure A.3—Datasheet Document Map (Continued)

GENERAL-PURPOSE STEAM TURBINE DATA SHEET

JOB NO.		ITEM NO.	
REVISION NO.	0	DATE	
PAGE	3 OF 3	BY	

GOVERNING SYSTEM

7.4.2.1.4 7.4.2.2	HYDRAULIC,ELECTRONIC
	85 to 105%,OTHER
	YES,NO
	YES,NO
	SELF POWERED,EXTERNAL
	YES,NO
	YES,NO
7.4.2.3	
7.4.2.11 & 12	MECHANICAL,ELECTRONIC
	None,2 out of 3
7.4.2.3b	ONE,TWO

ENGINEERING REQUIREMENTS

	YES,NO
6.9.3.2	YES,NO
6.9.3.1	YES,NO
6.9.4.2	YES,NO
4.1	DRIVEN EQUIPVENDOR,TURBINE VENDOR

INSPECTION REQUIREMENTS

8.1.2	YES,NO
8.2.2.3.1	YES,NO
8.2.2.1.3	YES,NO,OTHER
6.12.2.3c	YES,NO
6.12.4.5b	YES,NO
8.2.1.3	YES,NO
	YES,NO

YES,NO / YES,NO / YES,NO / YES,NO / YES,NO / YES,NO
YES,NO / YES,NO / YES,NO / YES,NO / YES,NO / YES,NO
YES,NO / YES,NO / YES,NO / YES,NO / YES,NO / YES,NO
YES,NO / YES,NO / YES,NO / YES,NO / YES,NO / YES,NO
YES,NO / YES,NO / YES,NO / YES,NO / YES,NO / YES,NO
YES,NO / YES,NO / YES,NO / YES,NO / YES,NO / YES,NO
YES,NO / YES,NO / YES,NO / YES,NO / YES,NO / YES,NO

PREPARATION FOR SHIPMENT

8.4.1	DOMESTIC SHIPMENT,EXPORT SHIPMENT

TESTS (8.3)

8.3.2		YES,NO	/ YES,NO	/ YES,NO
6.9.4.2		YES,NO	/ YES,NO	/ YES,NO
8.3.3.1	1 / 4 /	YES,NO	/ YES,NO	/ YES,NO
8.3.4.1		YES,NO	/ YES,NO	/ YES,NO
8.3.4.2		YES,NO	/ YES,NO	/ YES,NO
8.3.4.3		YES,NO	/ YES,NO	/ YES,NO
8.3.4.4		YES,NO	/ YES,NO	/ YES,NO
8.3.4.5		YES,NO	/ YES,NO	/ YES,NO
6.9.4.3 & 4		YES,NO	/ YES,NO	/ YES,NO
		YES,NO	/ YES,NO	/ YES,NO
		YES,NO	/ YES,NO	/ YES,NO

DOCUMENTATION

YES,NO
YES,NO
YES,NO

WEIGHTS

Figure A.3—Datasheet Document Map (Continued)

Annex B
(normative)

Dynamics (Information on Rotordynamic Analysis)

B.1 General

Refer to API 684 for more information on rotor dynamics.

B.1.1 In the design of rotor-bearing systems, consideration should be given to all potential sources of periodic forcing phenomena (excitation) that should include, but are not limited to, the following sources:

a) unbalance in the rotor system;

b) oil film instabilities (whirl);

c) internal rubs;

d) blade, vane, nozzle, and diffuser passing frequencies;

e) gear tooth meshing and side bands;

f) coupling misalignment;

g) loose rotor system components;

h) hysteretic and friction whirl;

i) boundary layer flow separation;

j) acoustic and aerodynamic cross coupling forces;

k) asynchronous whirl; and

l) electrical line frequency.

NOTE The frequency of a potential source of excitation can be less than, equal to, or greater than the rotational speed of the rotor.

NOTE When the frequency of a periodic forcing phenomenon (excitation) applied to a rotor bearing-support system coincides with a natural frequency of that system, the system will be in a state of resonance. A rotor bearing-support-system in resonance can have the magnitude of its normal vibration amplified. The magnitude of amplification and, in the case of critical speeds, the rate of change of the phase angle with respect to speed, are related to the amount of damping in the system.

B.1.2 For the purposes of this standard, critical speeds and other resonant conditions of concern are those with an amplification factor (*AF*) equal to or greater than 2.5.

B.1.3 Resonances of structural support systems that are within the vendor's scope of supply and that affect the rotor vibration amplitude should not occur within the specified operating speed range or the specified separation margins (see B.2.10). The effective stiffness of the structural support should be considered in the analysis of the dynamics of the rotor-bearing-support system (see B.2.4c).

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

B.1.4 The vendor who is specified to have unit responsibility for the complete drive train communicates the existence of any undesirable running speeds in the range from zero to trip speed. This is illustrated by the use of Campbell (forced frequency) diagrams for individual machines and/or for the complete train when such has been specified. These diagrams should be submitted for purchaser review and included in the instruction manual.

NOTE Examples of undesirable speeds are those caused by the rotor lateral criticals of concern, system torsionals, and blading modes.

B.2 Lateral Analysis

B.2.1 Unless previously derived and confirmed by actual tests of a given design, critical speeds and their associated amplification factors should be determined by means of a damped unbalanced rotor response analysis.

B.2.2 Unless known from previous tests of a given design, the location of all critical speeds below the trip speed should be confirmed on the test stand during the mechanical running test (see B.3.1). The accuracy of the analytical model should be demonstrated (see B.3).

B.2.3 Before carrying out the damped unbalanced response analysis, the vendor should conduct an undamped analysis to identify the undamped critical speeds and determine their mode shapes located in the range from 0 % to 125 % of trip speed. For any new designs, the results of the undamped analysis should be furnished. The presentation of the results should include the following:

a) Mode shape plots (relative amplitude vs. axial position on the rotor).

b) Critical speed-support stiffness map (frequency vs. support stiffness). Superimposed on this map should be the calculated system support stiffness'; horizontal (*kxx*) and vertical (*kyy*) as shown in Figure B.1.

NOTE For machinery with widely varying bearing loads and/or load direction such as overhung style machines, the vendor may propose to substitute mode shape plots for the undamped critical speed map and list the undamped critical speed for each of the identified modes.

B.2.4 The damped unbalanced response analysis should include but should not be limited to the following.

NOTE The following is a list of items the analyst is to consider. It does not address the details and product of the analysis that is covered in B.2.7 and B.2.8.

a) Rotor masses, including the mass moment of coupling halves, stiffness, and damping effects (e.g. accumulated fit tolerances, fluid stiffening and damping).

b) Bearing lubricant film stiffness and damping values including changes due to speed, load, preload, range of oil temperatures, maximum to minimum clearances resulting from accumulated assembly tolerances, and the effect of asymmetrical loading that can be caused by partial arc admission, gear forces, side streams, eccentric clearances, etc.

c) For tilt-pad bearings, the pad pivot stiffness.

d) Support stiffness, mass, and damping characteristics, including effects of frequency dependent variation. The term "support" includes the foundation or support structure, the base, the machine frame and the bearing housing as appropriate. For machines whose bearing support system stiffness values are less than or equal to 3.5 times the bearing oil film stiffness values, support stiffness values derived from modal testing or calculated frequency dependent support stiffness and damping values (impedances) should be used. The vendor should state the support stiffness values used in the analysis and the basis for these values (e.g. modal tests of similar rotor support systems, or calculated support stiffness values).

NOTE The support stiffness should in most cases be no more than 8.75 × 106 N/mm (5 × 106 lb/in.).

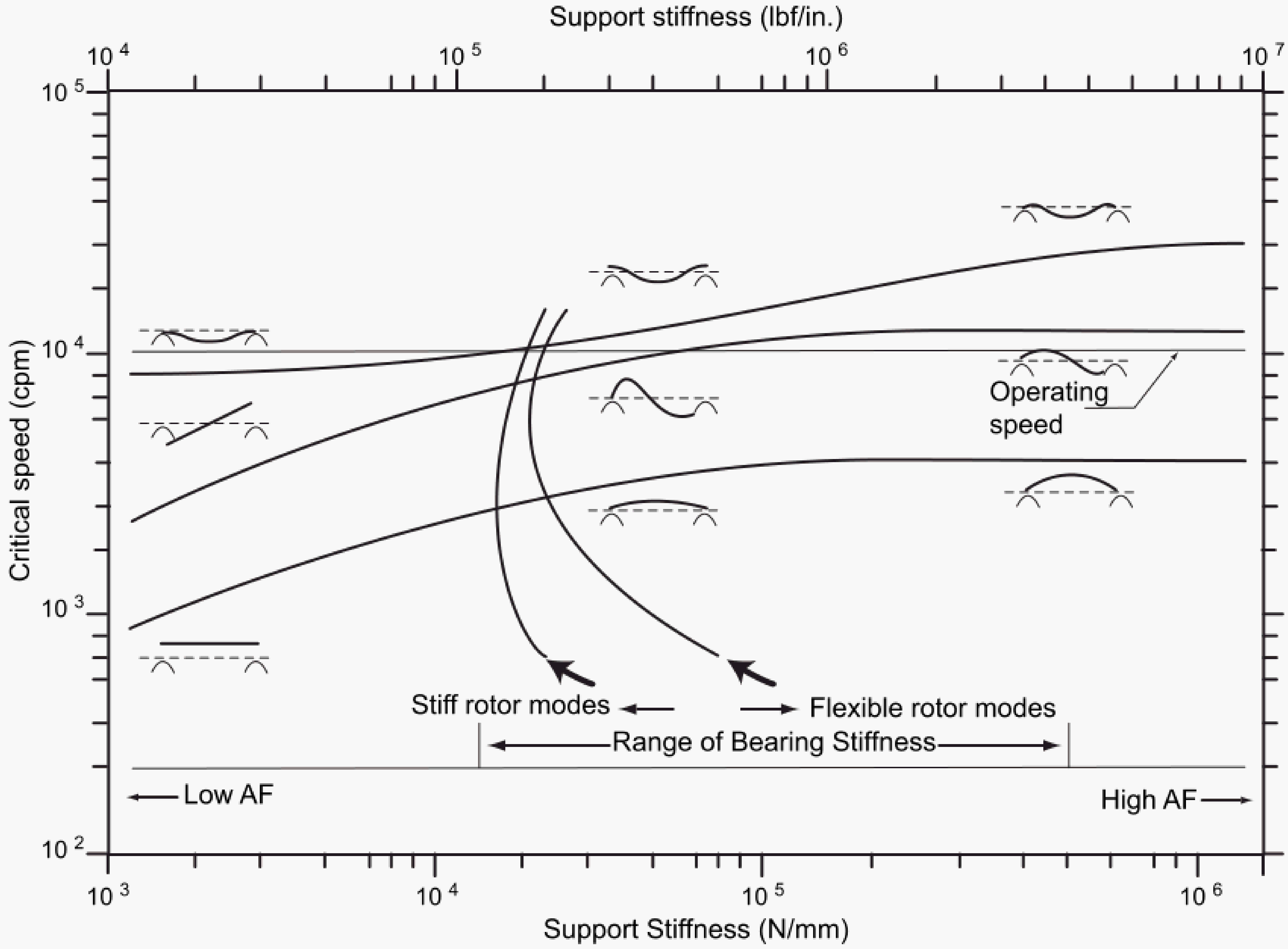


Figure B.1—Undamped Unbalanced Response Analysis

NOTE Guidelines are used to define whether or not bearing support stiffness should be considered. While modal testing of the actual bearing support system would be preferred, an analytical analysis (such as FEA) is permitted.

e) Rotational speed, including the various starting speed detents, operating speed and load ranges (including agreed upon test conditions if different from those specified), trip speed, and coast down conditions.

f) The influence, over the operating range, of the hydrodynamic stiffness and damping generated by the casing end seals.

g) The location and orientation of the radial vibration probes which should be the same in the analysis as in the machine.

B.2.5 In addition to the damped unbalanced response analysis requirements of B.2.4, for machines equipped with rolling element bearings, the vendor should state the bearing stiffness and damping values used for the analysis and either the basis for these values or the assumptions made in calculating the values.

B.2.6 The effect of other equipment in the train is rarely necessary to be included in the damped unbalanced response analysis. A train lateral analysis should only be performed if the drive train is rigidly coupled to the compressor.

NOTE In particular this analysis should be considered for machinery trains with rigid couplings.

B.2.7 A separate damped unbalanced response analysis should be conducted for each critical speed within the speed range of 0 % to 125 % of trip speed. Unbalance or side load should analytically be placed at the locations that have been determined by the undamped analysis to affect the particular mode most adversely. For the translatory (symmetric) modes, the unbalance should be based on the sum of the journal static loads and should be applied at the location of maximum displacement. For conical (asymmetric) modes, an unbalance should be added at the location of maximum displacement nearest to each journal bearing. These unbalances should be 180° out of phase and of magnitude based on the static load on the adjacent bearing. Figure B.2 indicates the location and definition of U for each of the shapes. The magnitude of the unbalances should be four times the value of U as calculated by Equation B.1.

In SI units:

$$U = 6350\ W/N \tag{B.1}$$

In USC units;

$$U = 4\ W/N$$

where

U is the input unbalance for the rotor dynamic response analysis in g-mm (ounce-in.);

N is the operating speed nearest to the critical speed of concern, in revolutions per minute;

W is the journal static load in kg (lb), or for bending modes where the maximum deflection occurs at the shaft ends, the overhung mass (that is the mass of the rotor outboard of the bearing) in kg (lb). See diagram of typical mode shapes.

B.2.8 As a minimum, the unbalanced response analysis should produce the following.

a) Identification of the frequency of each critical speed in the range from 0 % to 125 % of the trip speed.

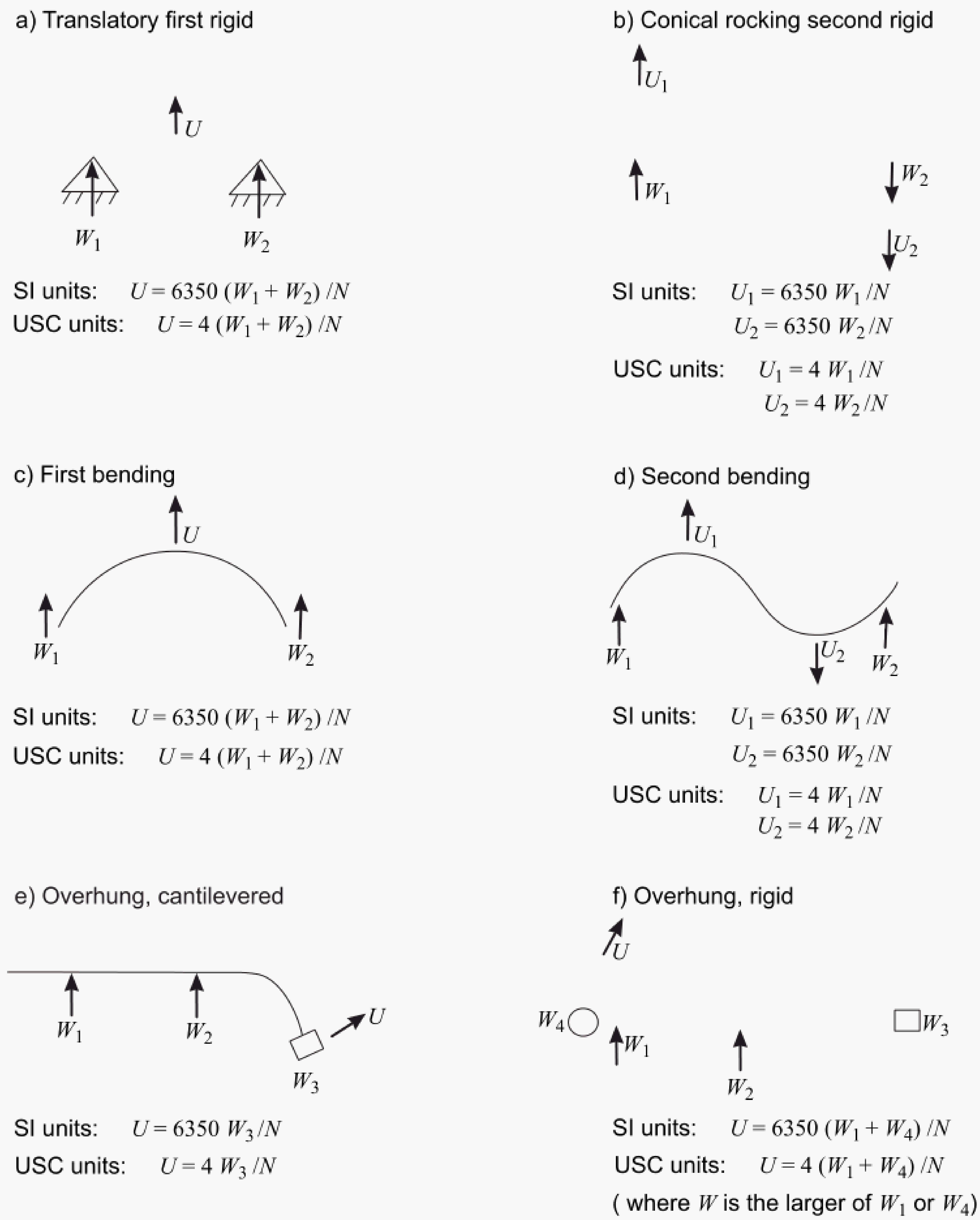
b) Frequency, phase and response amplitude data (Bode plots) at the vibration probe locations through the range of each critical speed resulting from the unbalance specified in B.2.6.

c) The plot of deflected rotor shape for each critical speed resulting from the unbalances specified in B.2.7, showing the major-axis amplitude at each coupling plane of flexure, the centerlines of each bearing, the locations of each radial probe, and at each seal throughout the machine as appropriate. The minimum design diametrical running clearance of the seals should also be indicated.

d) Additional Bode plots that compare absolute shaft motion with shaft motion relative to the bearing housing for machines where the support stiffness is less than 3.5 times the oil-film stiffness.

B.2.9 Additional analyses should be made for use with the verification test described in B.3. The vendor should determine the location of the unbalance. Any test stand parameters that influence the results of the analysis should be included.

NOTE For most machines, there will only be one plane readily accessible for the placement of an unbalance, for example the coupling flange on a single ended drive machine. However, there is the possibility that more planes are available such as special purpose steam turbine balance planes, when this occurs and there is the possibility of exciting other criticals, multiple runs may be required.



Key

U unbalance mass in gram-millimeters (ounce-inches)

W see B.2.7

N operating speed nearest speed of concern in revolutions per minute

The position of the arrows labeled U indicates the location of the applied unbalances.

Figure B.2—Typical Mode Shapes

B.2.10 The damped unbalanced response analysis should indicate that the machine would meet the following separation margins (see Figure B.1):

a) if the amplification factor (*AF*) at a particular critical speed is less than 2.5, the response is considered critically damped and no separation margin is required; and

b) if the amplification factor at a particular critical speed is 2.5 or greater and that critical speed is below the minimum speed, the separation margin (*SM*) (as a percentage of the minimum speed) should not be less than the value from Equation B.2 or the value 16 which ever is less.

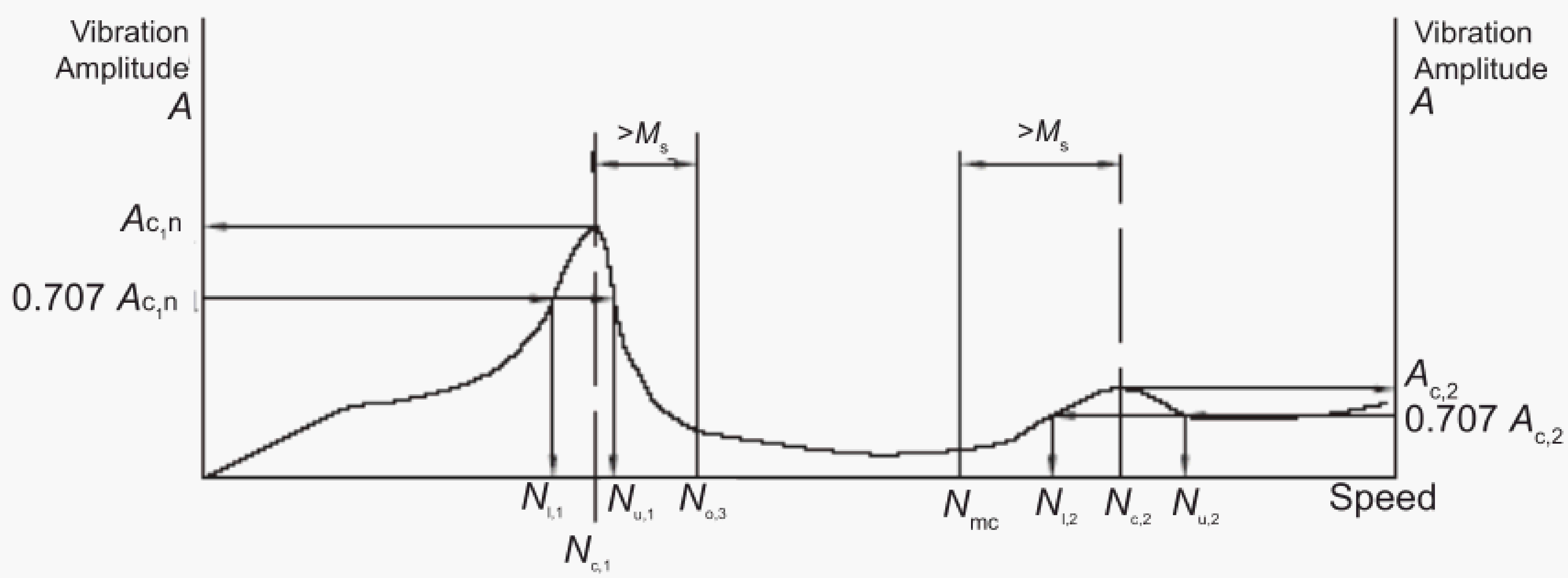
$$SM = 17\left(1 - \frac{1}{AF - 1.5}\right) \tag{B.2}$$

c) If the amplification factor at a particular critical speed is equal to 2.5 or greater and that critical speed is above the maximum continuous speed, the separation margin (as a percentage of the maximum continuous speed) should not be less than the value from Equation B.3 or the value of 26 which ever is less.

$$SM = 10 + 17\left(1 - \frac{1}{AF - 1.5}\right) \tag{B.3}$$

B.2.11 The calculated unbalanced peak to peak amplitudes (see B.2.8, Item b) should be multiplied using the correction factor calculated from Equation B.4.

$$CF = \frac{A_l}{A_{4X}} \tag{B.4}$$



Key

$N_{c,n}$	Critical speed n	N_{mc}	Maximum operating speed, 105 % rated speed
$N_{l,n}$	Lower speed at 0.707 of amplitude at critical speed n	$A_{c,n}$	Amplitude at critical speed *n*
$N_{u,n}$	Upper speed at 0.707 of amplitude at critical speed n	M_s	Separation margin, function of F_a
$N_{o,l}$	Minimum operating speed	F_a	Amplification factor = $N_{c,n}$ / ($N_{u,n}$ - $N_{l,n}$)

NOTE 1 Operating speed range is from $N_{o,l}$ to N_{mc}

NOTE 2 The shape of the curve is for illustration only and does not necessarily represent an actual rotor response plot. Multiple critical speeds can be present below and above operating speed range.

Figure B.3—Rotor Response Plot

where

CF is the correction factor;

A_1 is the amplitude limit, calculated using Equation B.5 in. microns (mils) peak-to-peak;

A_{4X} is the peak-to-peak amplitude at the probe location per requirements of B.2.8, Item c in microns (mils) peak-to-peak.

In SI units

$$A_1 = 25\sqrt{\frac{12000}{N}} \quad \text{(B.5)}$$

In USC units

$$A_1 = \sqrt{\frac{12000}{N}}$$

where

N is the operating speed nearest to the critical speed of concern, in revolutions per minute.

B.2.12 The calculated major-axis, peak-to-peak, unbalanced rotor response amplitudes, corrected in accordance with B.2.11 at any speed from zero to trip speed should not exceed 75 % of the minimum design diametrical running clearances throughout the machine (with the exception of floating ring seal locations).

NOTE Running clearances may be different than the assembled clearances with the machine shutdown.

B.2.13 If the analysis indicates that the separation margins still cannot be met or that a non-critically damped response peak falls within the operating speed range and the purchaser and vendor have agreed that all practical design efforts have been exhausted, then acceptable amplitudes should be mutually agreed upon by the purchaser and the vendor, subject to the requirements of B.3.3.

B.3 Unbalanced Rotor Response Verification Test

B.3.1 For previously untested designs, an unbalanced rotor response test should be performed as part of the mechanical running test (see 8.3.3), and the results should be used to verify the analytical model. The actual response of the rotor on the test stand to the same arrangement of unbalance as was used in the analysis specified in B.2.9 should be the criterion for determining the validity of the damped unbalanced response analysis. To accomplish this, the requirements of B.3.1.1 through B.3.1.6 should be followed.

B.3.1.1 During the mechanical running test (see 8.3.3), the amplitudes and phase angle of the shaft vibration from zero to trip speed should be recorded. The gain of any analog recording instruments used should be preset before the test so that the highest response peak is within 60 % to 100 % of the recorder's full scale on the test unit coast-down (deceleration).

NOTE This set of readings is normally taken during a coast down, with convenient increments of speed such as 50 rpm. Since at this point the rotor is balanced, any vibration amplitude and phase detected should be the result of residual unbalance and mechanical and electrical runout.

B.3.1.2 The location of critical speeds below the trip speed should be established.

B.3.1.3 The unbalance that was used in the analysis performed in B.2.9 should be added to the rotor in the location used in the analysis. The unbalance should not exceed 8 times the value from Equation B.1.

B.3.1.4 The machine should then be brought up to the operating speed nearest the critical and the indicated vibration amplitudes and phase should be recorded using the same procedure used for B.3.1.1.

B.3.1.5 The corresponding indicated vibration data taken in accordance with B.3.1.1 should be vectorially subtracted from the results of this test. It is necessary that probe orientation be the same for the analysis and the machine for the vectorial subtraction to be valid.

B.3.1.6 The results of the mechanical run including the unbalance response verification test should be compared with those from the analytical model specified at B.2.9.

B.3.2 The vendor should correct the model if it fails to meet either of the following criteria.

a) The actual critical speeds determined on test should not deviate from the corresponding critical speeds predicted by analysis by more than 5 %. Where the analysis predicts more than one critical speed in a particular mode (due, for example, to the bearing characteristics being significantly different horizontally and vertically or between the two ends of the machine), the test value should not be lower than 5 % below the lowest predicted value nor higher than 5 % above the highest predicted value.

NOTE It is possible that the vertical and horizontal stiffness are significantly different and the analysis will predict two differing critical speeds. Should the operating speed fall between these critical speeds, these two critical speeds should be treated separately, as if they resulted from separate modes.

b) The actual major axis amplitude of peak responses from test, including those critically damped should not exceed the predicted values. The predicted peak response amplitude range should be determined from the computer model based on the four radial probe locations.

NOTE The amplification factor has been removed as a verification test criterion since when the conditions of frequency (see Item a) and amplitude (see Item b) are satisfied the computer model is calibrated. Additionally, with split criticals and broad response curves, related to highly damped rotors, the actual amplification factor using test data can be difficult to calculate. This diminishes the value of calculating the amplification factor from test data as a valid comparison tool. The 45° probe mounting has a tendency to distort the data in the case of a split critical by showing a broad critical rather than two distinct criticals. This distortion can be corrected by electronically rotating the probes to true vertical and horizontal to permit the visualization of the true response.

Contrary to test data, the amplification factor can be accurately calculated from the computer model, which then sets the required separation margins.

B.3.3 If the support stiffness is less than two times the bearing oil film stiffness, the absolute vibration of the bearing housing should be measured and vectorially added to the relative shaft vibration, in both the balanced (see B.3.1.1) and in the unbalanced (see B.3.1.4) condition before proceeding with the step specified in B.3.1.5. In such a case, the measured response should be compared with the predicted absolute shaft movement.

B.3.4 The verification test of the rotor unbalance should be performed only on the first rotor tested, if multiple identical rotors are produced.

B.3.5 The vibration amplitudes and phase from each pair of *x-y* vibration probes should be vectorially summed at each vibration response peak after correcting the model, if required, to determine the maximum amplitude of vibration. The major axis amplitudes of each response peak should not exceed the limits specified in B.2.12.

B.4 Additional Testing

B.4.1 Additional testing is required (see B.4.2) if, from the shop verification test data (see B.3) or from the damped, corrected unbalanced response analysis (see B.3.3), it appears that either of the following conditions exists:

a) any critical response will fail to meet the separation margin requirements (see B.2.10) or will fall within the operating speed range;

b) the clearance requirements of B.2.12 have not been met.

NOTE When the analysis or test data does not meet the requirements of the standard, additional more stringent testing is required. The purpose of this additional testing is to determine on the test stand that the machine will operate successfully.

B.4.2 Unbalance weights should be placed as described in B.2.7; this may require disassembly of the machine. Unbalance magnitudes should be achieved by adjusting the indicated unbalance that exists in the rotor from the initial run to raise the displacement of the rotor at the probe locations to the vibration limit defined by Equation B.5 (see B.2.11) at the maximum continuous speed; however, the unbalance used should be no less than twice or greater than 8 times the unbalance limit specified in B.2.7 Equation B.1. The measurements from this test, taken in accordance with B.3.1.1 and B.3.1.2, should meet the following criteria:

a) at no speed outside the operating speed range, including the separation margins, should the shaft deflections exceed 90 % of the minimum design running clearances; and

b) at no speed within the operating speed range, including the separation margins, should the shaft deflections exceed 55 % of the minimum design running clearances or 150 % of the allowable vibration limit at the probes (see B.2.11).

B.4.3 The internal deflection limits specified in B.4.2 Items a and b should be based on the calculated displacement ratios between the probe locations and the areas of concern identified in B.2.12 based on a corrected model if required. Actual internal displacements for these tests should be calculated by multiplying these ratios by the peak readings from the probes. Acceptance will be based on these calculated displacements or inspection of the seals if the machine is opened. Damage to any portion of the machine as a result of this testing should constitute failure of the test. Minor internal seal rubs that do not cause clearance changes outside the vendor's new part tolerance do not constitute damage.

B.5 Torsional Analysis

B.5.1 For units including gears, units comprising three or more coupled machines, or when specified, the vendor having unit responsibility should ensure that a torsional vibration analysis of the complete coupled train is carried out and should be responsible for directing any modifications necessary to meet the requirements of B.5.2 through B.5.6.

B.5.2 Excitation of torsional natural frequencies can come from many sources that may or may not be a function of running speed and should be considered in the analysis. These sources should include but are not limited to the following:

a) gear characteristics such as unbalance, pitch line runout, and cumulative pitch error;

b) cyclic process impulses;

c) torsional transients such as generator phase-to-phase or phase-to-ground faults;

d) torsional excitation resulting from electric motors, reciprocating engines, and rotary type positive displacement machines;

e) control loop resonances from hydraulic and electronic governors;

f) one and two times line frequency; and

g) running speed or speeds.

B.5.3 The torsional natural frequencies of the complete train should be at least 10 % above or 10 % below any possible excitation frequency within the specified operating speed range (from minimum to maximum continuous speed).

B.5.4 Torsional natural frequencies at two or more times running speeds should preferably be avoided or, in systems in which corresponding excitation frequencies occur, should be shown to have no adverse effect.

B.5.5 When torsional resonances are calculated to fall within the margin specified in B.5.3 (and the purchaser and the vendor have agreed that all efforts to remove the critical from within the limiting frequency range have been exhausted), a stress analysis should be performed to demonstrate that the resonances have no adverse effect on the complete train. The assumptions made in this analysis regarding the magnitude of excitation and the degree of damping should be clearly stated. The purchaser and the vendor should mutually agree upon the acceptance criteria for this analysis.

B.5.6 In addition to the torsional analyses required in B.5.2 through B.5.5, the vendor should perform a transient torsional vibration analysis for turbine generators sets. The purchaser and the vendor should mutually agree upon the acceptance criteria for this analysis.

Annex C
(informative)

Vendor Drawing and Data Requirements

GENERAL PURPOSE STEAM TURBINE VENDOR DRAWING AND DATA REQUIREMENTS

JOB NO. ____ ITEM NO. ____
PURCHASE ORDER NO ____ DATE ____
REQUISITION NO. ____ DATE ____
INQUIRY NO. ____ DATE ____
PAGE 1 OF 2 BY ____
REVISION ____
UNIT ____
NO. REQUIRED ____

FOR ____
SITE ____
SERVICE ____

Proposal[a] Bidder shall furnish ____ copies of data for all items indicated by an X.

Review[b] Vendor shall furnish ____ copies and e-files of drawings and data indicated.

Final[c] Vendor shall furnish ____ copies and e-files of drawings and data indicated.
Vendor shall furnish ____ operating and maintenance manuals.

DISTRIBUTION RECORD

Final-Received from vendor
Final-Due from vendor[a]
Review-Returned to vendor
Review-Received from vendor
Review-Due from vendor[a]

Proposal	Review	Final	DESCRIPTION	Review-Due from vendor	Review-Received from vendor	Review-Returned to vendor	Final-Due from vendor	Final-Received from vendor
			1. Certified dimensional outline drawing and list of connections.					
			2. Cross-sectional drawings and part numbers.[b]					
			3. Rotor assembly drawings and part numbers.[b]					
			4. Thrust-bearing assembly drawing and part numbers.[b]					
			5. Journal-bearing assembly drawings and bills of materials.[b]					
			6. Packing and labyrinth drawings and bill of materials[b]					
			7. Coupling assembly drawing and bill of materials					
			8. Gland sealing and leak-off schematic and bill of materials[b]					
			9. Gland sealing and leak-off arrangement drawing and list of connections[b]					
			10. Gland sealing and leak-off component drawings and data[c]					
			11. Lube-oil system schematic and bill of materials[b]					
			12. Lube-oil system arrangement drawing and list of connections[b]					
			13. Lube-oil component drawings and data[c]					
			14. Electrical and instrumentation schematics and bill of materials					
			15. Electrical and instrumentation arrangement drawing and list of connections[b]					
			16. Governor-valve cross section, trip system drawings and details[b]					
			17. Steam flow versus horsepower curve					
			18. Steam flow versus first-stage pressure curve[c]					
			19. Steam flow versus speed and efficiency curve[c]					
			20. Steam flow versus thrust-bearing load curve[c]					
			21. Steam-rate correction factors charts[c]					
			22. Vibration analysis data[c]					
			23. Lateral critical speed analysis report[c]					
			24 Torsional Analysis Study Report[c]					
			25 Coupling and Shaft Alignment diagram[c]					
			26 Weld procedures (fabrication and repar)[c]					
			27 Hydrostatic test logs					
			28 Mechanical running test logs					
			29 Rotor balance logs					

[a]Bidder shall complete these two columns to reflect his actual distribution schedule and include this form with his proposal.
[b]For single stage units, these items normally provided only in instrction manauls.
[c]These items normally applicable for multistage units only.

Figure C.1—Vendor Drawing and Data Requirements Form

GENERAL-PURPOSE STEAM TURBINE VENDOR DRAWING AND DATA REQUIREMENTS

JOB NO. ____________ ITEM NO. ____________
PAGE 2 OF 2 BY ____________
DATE ____________ REVISION ____________

Proposal[a] Bidder shall furnish ____ copies of data for all items indicated by an X.

Review[b] Vendor shall furnish ____ copies and ____ transparencies of drawings and data indicated.

Final[c] Vendor shall furnish ____ copies and ____ transparencies of drawings and data indicated.
Vendor shall furnish ____ operating and maintenance manuals.

DISTRIBUTION RECORD

Final-Receive from vendor
Final-Due from vendor[a]
Review-Returned to vendor
Review-Received from vendor
Review-Due from vendor[a]

Proposal	Review	Final	DESCRIPTION	Review-Due from vendor	Review-Received from vendor	Review-Returned to vendor	Final-Due from vendor	Final-Receive from vendor
			30 Rotor mechanical and electrical runout[c]					
			31 As-built data sheets.					
			32 As-built dimensions and data					
			33 Installation, operating and maintenance and technical data manual.					
			34 Spare parts recommendation and price list.					

[a]Bidder shall complete these two columns to reflect his actual distribution schedule and include this form with his proposal.
[b]For single stage units, these items normally provided only in instruction manuals.
[c]These items normally applicable for multistage units only.

Notes:

1. The vendor shall proceed with manufacture upon receipt of the order. The vendor may proceed with manufacture without the purchaser's approval of the drawings when necessary to meet the scheduled shipping date.
2. Send all drawings and data to ____________________
3. All drawings and data shall show project, purchase order, and item numbers as well as plant location and unit. One set of the drawings and instructions necessary for field installation, in addition to the copies specified above, shall be forwarded with shipment.
4. See the descriptions of required items that follow.
5. All of the information indicated on the distributuion schedule shall be received before final payment is made.
6. All documentation including the O&M manuals shall also be submitted to Purchaser in electronic format.

Nomenclature:

S number of weeks before shipment.
F number of weeks after firm order.
D number of weeks after receipt of approved drawings.

Vendor ____________________

Date ____________ Vendor Reference ____________________

Signature ____________________

(Signature acknowledges receipt of all instructions)

Figure C.1—Vendor Drawing and Data Requirements Form (Continued)

Description

1) Certified dimensional outline drawing including the following:

   a) size, rating, and location of all customer connections, with allowable flange loading for inlet and exhaust steam connections;

   b) approximate overall handling weights;

   c) overall dimensions;

   d) shaft centreline height and dimensioned shaft end for coupling mounting;

   e) dimensions of baseplates (if furnished), complete with diameter, number, and locations of bolt holes and the thickness of the metal through which bolts must pass;

   f) the location of the center of gravity.

2) Cross-sectional drawings and bill of materials including the following:

   a) journal-bearing clearances and tolerance;

   b) rotor float (axial);

   c) seal clearances (shaft end and internal labyrinth) and tolerance;

   d) axial position of wheel(s) relative to inlet nozzle or diaphragms and tolerance allowed;

   e) outside diameters of all wheels at blade tip.

3) Rotor assembly drawing including the following:

   a) axial position from active thrust-collar face to the following:

      i) each wheel (inlet side);

      ii) each radial probe;

      iii) each journal-bearing centreline;

      iv) one-event-per-revolution mark.

   b) thrust-collar assembly details including the following:

      i) collar-to-shaft fit with tolerance;

      ii) axial runout with tolerance;

      iii) required torque for locknut;

      iv) surface finish requirements for collar faces;

      v) preheat method and temperature requirements for shrunk-on collar installation.

4) Hydrodynamic thrust-bearing assembly drawing (see Item 32).

5) Hydrodynamic journal-bearing assembly drawing (see Item 32).

6) Packing or labyrinth drawings (see Item 32).

7) Coupling assembly drawing and bill of materials.

8) Gland-sealing and leak-off schematic including the following:

   a) flows and pressures for steady-state and transient steam and air;

   b) relief and control valve settings;

   c) utility requirements (including electrical, water, steam, and air);

   d) pipe and valve sizes;

   e) instrumentation, safety devices, and control schemes;

   f) bill of materials.

9) Gland-sealing and leak-off arrangement drawing including size, rating, and location of all customer connections.

10) Gland-sealing and leak-off component outline and sectional drawings and data including the following:

   a) gland-condenser fabrication drawing and bill of materials;

   b) completed data sheet for condenser;

   c) ejector drawing and performance curves;

   d) control valves, relief valves, and instrumentation;

   e) vacuum pump schematic, performance curves, cross section, outline drawing, and utility requirements (if pump is furnished).

11) Lube-oil schematic including the following:

   a) steady-state and transient oil flows and pressures at each use point;

   b) control, alarm, and trip settings (pressure and recommended temperatures);

   c) heat loads at each use point at maximum load;

   d) utility requirements (including electrical, water, and air);

   e) pipe and valve sizes;

   f) instrumentation, safety devices, and control schemes;

   g) bill of materials.

12) Lube-oil system arrangement drawing including size, rating, and location of all customer connections.

13) Lube-oil component drawings and data including the following:

   a) pumps and drivers:

      i) certified dimensional outline drawing;

      ii) cross section and bill of materials;

      iii) mechanical seal drawing and bill of materials;

      iv) performance curves for centrifugal pumps;

      v) instruction and operating manuals;

      vi) completed datasheets for pumps and drivers.

   b) coolers, filters, and reservoir:

      i) fabrication drawings;

      ii) maximum, minimum, and normal liquid levels in reservoir;

      iii) completed datasheets for cooler(s).

   c) instrumentation:

      i) controllers;

      ii) switches;

      iii) control valves;

      iv) gauges.

14) Electrical and instrumentation schematics and bill of materials:

   a) vibration warning and shutdown limits;

   b) bearing temperature warning and shutdown limits;

   c) lube-oil temperature warning and shutdown limits.

15) Electrical and instrumentation arrangement drawing(s) and list(s) of connections.

16) Governor-valve cross section and setting instructions. Trip system drawings and setting instructions.

17) Steam flow versus horsepower curves at normal and rated speeds under normal steam conditions (including hand valves).

18) Steam flow versus first-stage pressure curve for multi-stage machines or versus nozzle-bowl pressure for single-stage machines at normal and rated speed with normal steam.

19) Steam flow versus speed and efficiency curves at normal steam conditions.

20) Steam flow versus thrust-bearing-load curve.

21) Steam-rate correction factors for Curves 17 through 20, with off-design steam as follows:

a) inlet pressure to maximum and minimum values listed on the datasheets in increments and agreed upon at the time of the order;

b) inlet temperature to maximum and minimum values listed on the datasheets in increments agreed upon at the time of the order;

c) speed (80 % to 105 %, 5 % increments);

d) exhaust pressure to maximum and minimum values listed on the datasheets in increments agreed upon at the time of the order.

22) Vibration analysis data including the following:

a) number of blades—each wheel;

b) number of vanes—each diaphragm;

c) number of nozzles—nozzle block, single valve only;

d) campbell diagram for each stage;

e) goodman diagram for each stage;

f) number of teeth on gear-type coupling (when furnished by the turbine vendor).

23) Lateral critical speed analysis report including the following:

a) method used;

b) graphic display of bearing and support stiffness and its effect on critical speeds;

c) graphic display of rotor response to unbalance (including damping);

d) graphic display of overhung moment and its effect on critical speed (including damping);

e) journal static loads;

f) stiffness and damping coefficients;

g) tilting-pad geometry and configuration:

i) pad angle;

ii) pivot clearance;

iii) pad clearance;

iv) preload.

24) Torsional analysis.

25) Coupling alignment diagram, including recommended limits during operation.

NOTE All shaft-end position changes and support growths from (15 °C) 60 °F ambient reference.

26) Weld procedures.

27) Hydrostatic test logs.

28) Mechanical running test logs including the following:

a) overspeed trip and governor settings;

b) vibration, including *x-y* plot of amplitude and phase angle versus revolutions per minute during start-up and shutdown;

c) auxiliary trip settings;

d) observed critical speeds (for flexible rotor).

29) Rotor balance logs.

30) Rotor mechanical and electrical runout.

31) As-built datasheets.

32) As-built dimensions (including design tolerances) or data:

a) shaft or sleeve diameters at:

i) thrust collar (for separate collars);

ii) each seal component;

iii) each wheel (for stacked rotors);

iv) each interstage labyrinth;

v) each journal bearing.

b) each wheel bore (for stacked rotors) and outside diameter;

c) each labyrinth or seal-ring bore;

d) thrust-collar bore (for separate collars);

e) each journal-bearing inside diameter;

f) thrust-bearing concentricity (axial runout);

g) metallurgy and heat treatment for the following:

i) shaft;

ii) wheels;

iii) thrust collar;

iv) blades (buckets).

33) Installation, operating and maintenance and technical data manual. Each manual shall include the following sections:

Section 1—Installation:

a) storage;

b) foundation;

c) setting equipment, rigging procedures, component weights, and lifting diagram;

d) alignment;

e) grouting;

f) piping recommendations, including allowable flange loads;

g) composite outline drawing for driven/driver train, including anchor-bolt locations;

h) dismantling clearances.

Section 2—Operation:

a) start-up;

b) normal shutdown;

c) emergency shutdown;

d) operating limits;

e) lube-oil recommendations.

Section 3—Disassembly and reassembly instructions:

a) rotor in casing;

b) rotor unstacking and restacking procedures;

c) journal bearings for tilting-pad bearings, providing “go/no-go” dimensions with tolerances for three-step plug gauges;

d) thrust bearing;

e) seals;

f) thrust collar;

g) wheel reblading procedures.

Section 4—Performance curves:

a) steam flow versus horsepower;

b) steam flow versus first-stage pressure;

c) steam flow versus speed and efficiency;

d) steam flow versus thrust-bearing load;

e) extraction curves;

f) steam condition correction factors (prefer nomograph).

Section 5—Vibration data:

a) vibration analysis data;

b) lateral critical speed analysis.

Section 6—As-built data:

a) as-built datasheets;

b) as-built dimensions or data;

c) hydrostatic test logs;

d) mechanical running test logs;

e) rotor balance logs;

f) rotor mechanical and electrical runout at each journal.

Section 7—Drawing and data requirements:

a) certified dimensional outline drawing and list of connections;

b) cross-sectional drawing and bill of materials;

c) rotor drawing and bill of materials;

d) thrust-bearing assembly drawing and bill of materials;

e) journal-bearing assembly drawing and bill of materials;

f) seal component drawing and bill of materials;

g) lube-oil schematic and bill of materials;

h) lube-oil arrangement drawing and list of connections;

i) lube-oil component drawings and data;

j) electrical and instrumentation schematics and bill of materials;

k) electrical and instrumentation arrangement drawing and list of connections;

l) control- and trip-system drawings and data;

m) trip- and throttle-valve construction drawings.

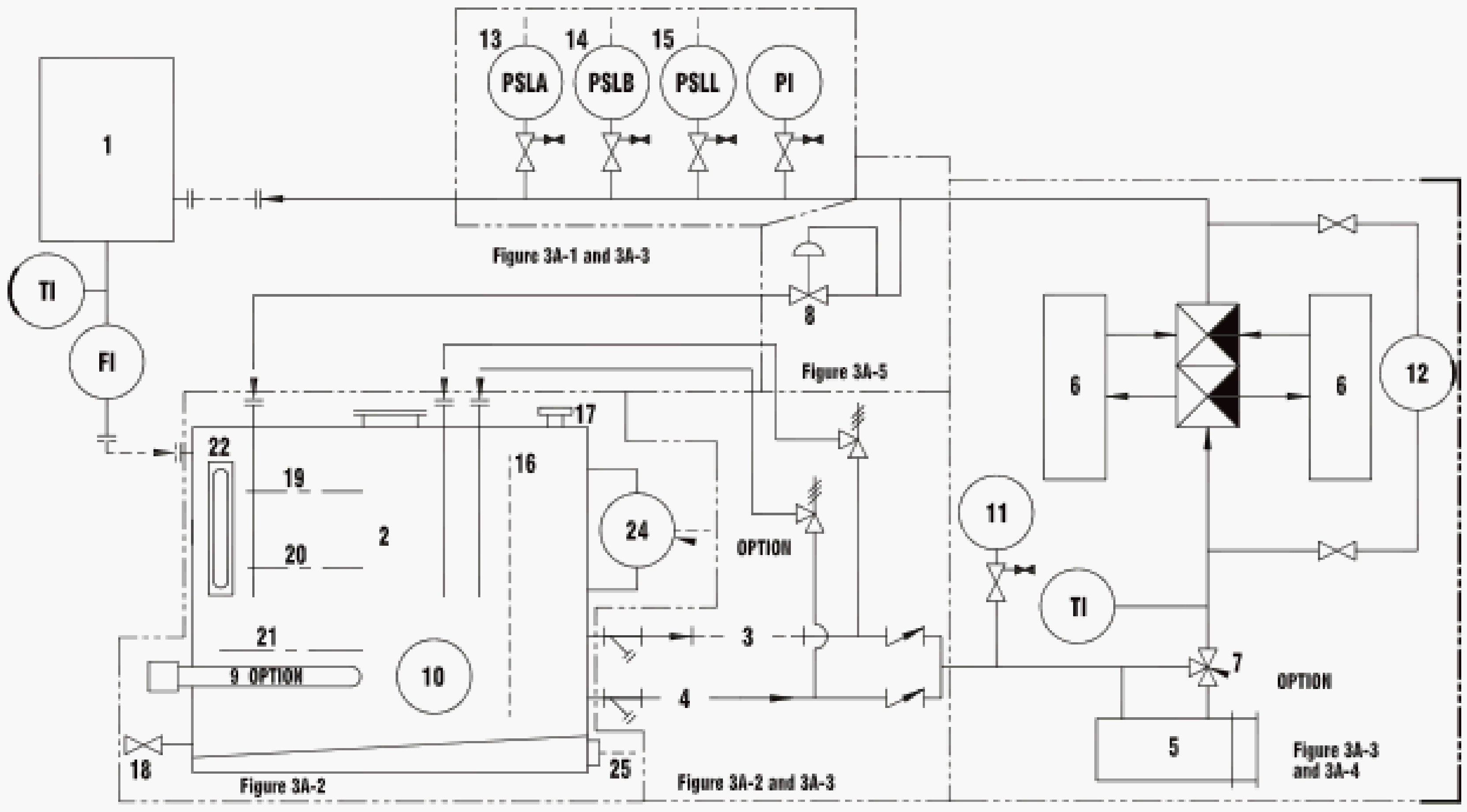
NOTE Items 7, 11, 12, 13, 22f and 32 (see Section 7, Items g through i) are required only for the turbine manufacturer's scope of supply.

34) Spare parts recommendation and price list (see 7.2.5 in text of standard).

Annex D
(normative)

Lubrication System Schematic

This annex contains the schematic for a standard API 611 lubrication system (see Figure D.1). This is the default lubrication system for an API 611 steam turbine in accordance with API 614, Chapter 3 requirements with options. The default API 611 system, with or with out standard options, can be indicated on the API 611 data sheet. If the purchaser requires a different lubrication system, the API 614, Chapter 2 or Chapter 3 datasheets are required to be completed. The notes and key to symbols are shown in Figure D.2.

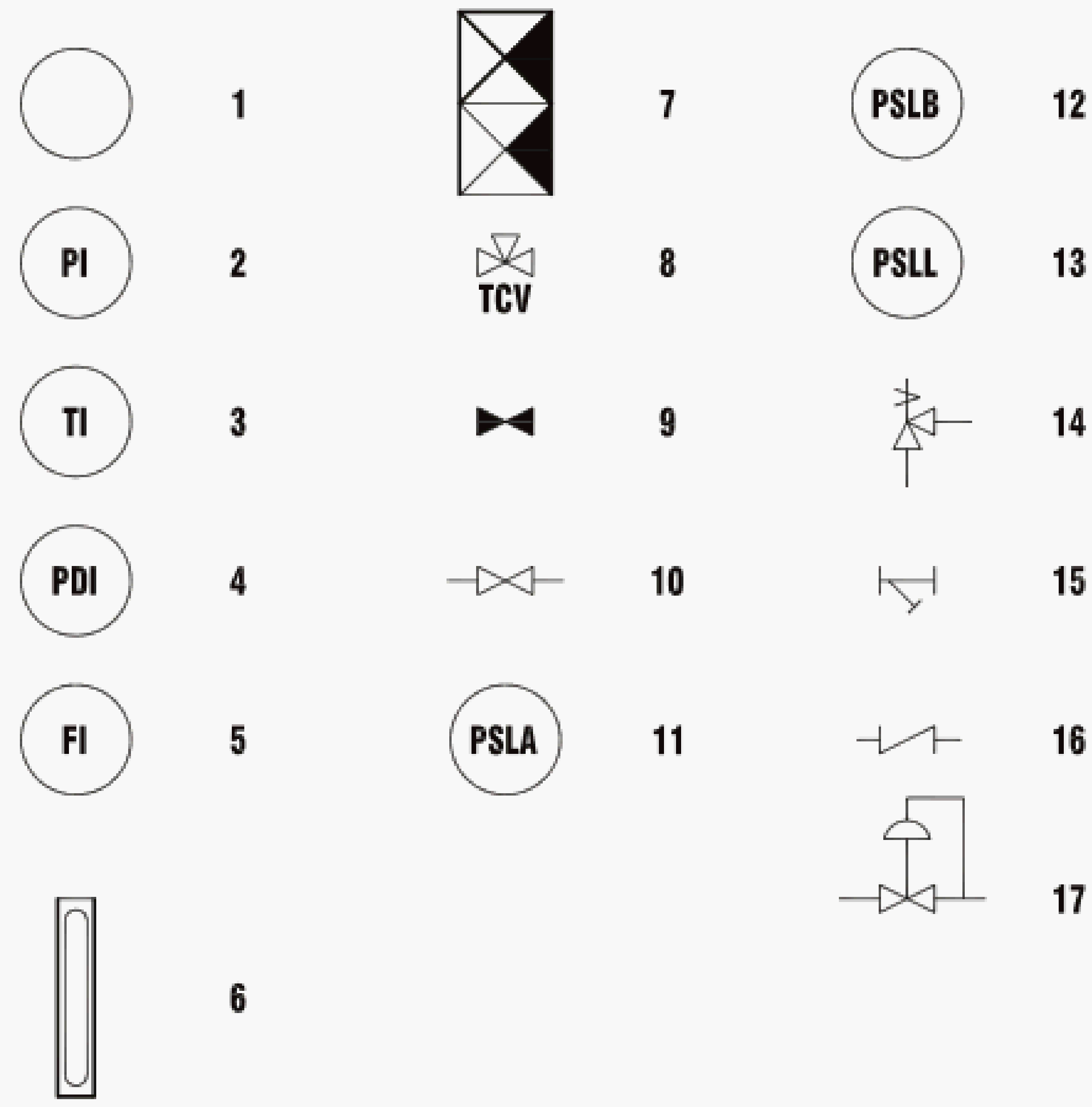


Key

1. Rotating Equipment
2. Reservoir
3. Shaft Driven Mail Oil Pump
4. Motor Driven Main Oil Pump
5. Oil Cooler (3A-4 Option 1)
6. Duplex Oil Filter (3A-4 Option 2)
7. Temperature Control Valve (3A-4 Option 3)
8. Pressure Regulator (3A-5 Option 1, 2, 3 & 4)
9. Heater (3A-2 Option 3)
10. Temperature Indicator (3A-2 Option 2)
11. Pump Discharge Pressure Indicator
12. Differential Pressur Indicator (3A-4 Option 7)
13. Aux. Pump Start Signal (3A-3 Option 4)
14. Low Pressure Alarm Signal
15. Low Pressure Shutdown Signal (3A-3 Option 1)
16. Reservoir Internal Baffle
17. Breather (3A-2 Option 1)
18. Drain Valve (3A-2 Option 2)
19. Maximum Operation Level
20. Minimum Operating Level
21. Pump Suction Loss Level
22. Level Guage
23. Provision for Priming (3A-3 Option 2)
24. Level Switch (3A-2 Option 1)
25. Grounding Lug (3A-2 Option 5)

NOTE The dashed boxes represent “modules” from ISO 10438.

Figure D.1—Lubrication System Schematic



Key

1. Instrument (Letters Indicate Function)
2. Pressure Indicator
3. Temperature Indicator
4. Pressure Differential Indicator
5. Flow Indicator
6. Reflex Type Level Indicator
7. Manual 3-way Valve (or Single Transfer Valve)
8. Temperature Control Valve
9. Block and Bleed Valve
10. Block Valve (Gate Valve)
11. Low Pressure Switch (Auxilary Pump Start)
12. Low Pressure Switch (Alarm)
13. Low Pressure Switch (Trip)
14. Relief Valve
15. Line Strainer
16. Check Valve
17. Pressure Control Valve

Figure D.2—Lubrication System Symbols

Table D.1—Lube-oil System Schematic

ISO 10438 (API 614) Chapter 3 Sub-clause	Note/Option	Comments
3A-1 Minimum requirements for general purpose oil systems	Add	TI, FI on oil return lines from turbine (and gear reducer and driven equipment when applicable).
3A-2 Reservoir	Option 1	A level switch is optional.
	Option 2	A temperature indicator with thermowell is required.
	Option 3	An electric immersion or steam heater is optional.
	Option 4	Additional connections are required for 1. Shaft-driven oil pump relief valve return is required. 2. Motor-driven oil pump relief valve return is required. 3. System PCV return. 4. Aux. oil pump to have independent suction with strainer. (Strainer may be omitted for submerged pumps.)
	Option 5	One tapped grounding lug is required.
	Option 6	Gauge glass (armored and extended), is optional.
	Add Add Add Add Add Additional item	A vent (breather) with screen is required. The reservoir shall have a sloped bottom. A flanged drain connection with valve and blind at least 2 in. in size shall be included. A level glass shall be provided in accordance with ISO 10438-3. If so, the return lines from the system RVs shall discharge below the minimum operating oil level.
3A-3 Pumps	Option 1	A 100 % capacity motor-driven auxiliary pump is required.
	Option 2	Block valves are not required.
	Option 3	A pre/post lube oil pump is not required.
	Option 4	Pressure switches are required for low pressure trip, alarm, and aux. pump start.
	Option 5	The pressure transmitter is not required.
	Additional item	The pressure switches shall be located in accordance with Figure D.1.
	Additional item	Shaft driven pumps may use a drilled check valve or an orificed line to prime the pump. (Not represented in Figure D.1.)
3A-4 Pumps and coolers (and filters)	Option 1	One oil cooler is required.
	Option 2	Duplex filters are required.
	Option 3	A three-way constant temperature control valve with bypass line is optional.
	Option 4	A two or three way variable temperature control valve with bypass line is not required.
	Option 5	A temperature switch is not required.
	Option 6	A single transfer valve with cooler and filter in parallel with separate TCV is not required. Valve is not represented in Figure D.1.
	Option 7	A pressure differential indicator is required.
	Add additional item	A single transfer valve for the duplex filters is required.The replaceable filter shall be in accordance with ISO 10438-3.
3A-5 Pressure control	Option 1	A pressure regulator (relief valve) is required.
	Option 2	A direct acting back-pressure control valve is required.
	Option 3	Block valves around the PCV/regulator are not required.
	Option 4	A globe bypass valve is not required.

Annex E
(normative)

Procedures for Determining Residual Unbalance

E.1 Scope

This annex describes the procedure to be used to determine residual unbalance in machine rotors. Although some balancing machines can be set up to read out the exact amount of unbalance, the calibration can be in error. The only sure method of determining residual unbalance is to test the rotor with a known amount of unbalance.

E.2 Definition

Residual unbalance refers to the amount of unbalance remaining in a rotor after balancing. Unless otherwise specified, residual unbalance shall be expressed in g•mm (oz-in.).

E.3 Maximum allowable residual unbalance

E.3.1 The maximum allowable residual unbalance per plane shall be calculated using 6.9.4.2, Equation 1.

E.3.2 If the actual static load on each journal is not known, assume that the total rotor mass is equally supported by the bearings. For example, a two-bearing rotor with a mass of 2700 kg (6000 lb) would be assumed to impose a mass of 1350 kg (3000 lb) on each journal.

E.4 Residual unbalance check

E.4.1 General

E.4.1.1 When the balancing machine readings indicate that the rotor has been balanced to within the specified tolerance, a residual unbalance check shall be performed before the rotor is removed from the balancing machine.

E.4.1.2 To check the residual unbalance, a known trial mass is attached to the rotor sequentially in 6 (or 12, if specified by the purchaser) equally spaced radial positions, each at the same radius. The check is run in each correction plane, and the readings in each plane are plotted on a graph using the procedure specified in E.4.2.

E.4.2 Procedure

E.4.2.1 Select a trial mass and radius that is equivalent to between one and two times the maximum allowable residual unbalance [that is, if U_{max} is 1440 g•mm (2 oz-in.), the trial mass should cause 1440 g•mm to 2880 g•mm (2 oz-in. to 4 oz-in.) of unbalance].

E.4.2.2 Starting at the last known heavy spot in each correction plane, mark off the specified number of radial positions (6 or 12) in equal (60º or 30º) increments around the rotor. Add the trial mass to the last known heavy spot in one plane. If the rotor has been balanced very precisely and the final heavy spot cannot be determined, add the trial mass to any one of the marked radial positions.

E.4.2.3 To verify that an appropriate trial mass has been selected, operate the balancing machine and note the units of unbalance indicated on the meter. If the meter pegs, a smaller trial mass should be used. If little or no meter reading results, a larger trial mass should be used. Little or no meter reading generally indicates that the rotor was not balanced correctly, the balancing machine is not sensitive enough, or a balancing machine fault exists (i.e. a faulty pickup). Whatever the error, it must be corrected before proceeding with the residual check.

E.4.2.4 Locate the mass at each of the equally spaced positions in turn, and record the amount of unbalance indicated on the meter for each position. Repeat the initial position as a check. All verification shall be performed using only one sensitivity range on the balance machine.

E.4.2.5 Plot the readings on the residual unbalance work sheet and calculate the amount of residual unbalance (see Figure E.1). The maximum meter reading occurs when the trial mass is added at the rotor's heavy spot; the minimum reading occurs when the trial mass is opposite the heavy spot. Thus, the plotted readings should form an approximate circle (see Figure E.2). An average of the maximum and minimum meter readings represents the effect of the trial mass. The distance of the circle's center from the origin of the polar plot represents the residual unbalance in that plane.

E.4.2.6 Repeat the steps described in E.4.2.1 through E.4.2.5 for each balance plane. If the specified maximum allowable residual unbalance has been exceeded in any balance plane, the rotor shall be balanced more precisely and checked again. If a correction is made to any balance plane, the residual unbalance check shall be repeated in all planes.

E.4.2.7 For stack component balanced rotors, a residual unbalance check shall be performed after the addition and balancing of the first rotor component, and at the completion of balancing of the entire rotor, as a minimum.

NOTE This ensures that time is not wasted and rotor components are not subjected to unnecessary material removal in attempting to balance a multiple component rotor with a faulty balancing machine.

Equipment (rotor) no.:
Purchase order no.:
Correction plane (inlet, drive end, etc.—use sketch):
Balancing speed: __________ r/min
N— Maximum allowable rotor speed: __________ r/min
W— Mass of journal (closest to this correction plane): __________ kg (lb)
U_{max} = Maximum allowable residual unbalance = 6 350 *W*/*N* (4 *W*/*N*)
6 350 x ______ kg/______ r/min; (4 x ______lb/______r/min) g·mm (oz-in.)
Trial unbalance (2 · U_{max}) ________ g·mm (oz-in.)
R—Radius (at which mass shall be placed): ________ mm (in.)
Trial unbalance mass = Trial unbalance/*R*
_____g·mm/_____mm (_____oz-in./______in.) __________g (oz)
Conversion Information: 1 ounce = 28,350 grams

Test Data **Rotor Sketch**

Position	Trial Mass Angular Location	Balancing Machine Amplitude Readout
1	0°	
2	60°	
3	120°	
4	180°	
5	240°	
6	360°	
Repeat 1	0°	

Test Data — Graphic Analysis

Step 1: Plot data on the polar chart (Figure E.1 continued). Scale the chart so the largest and smallest amplitude fits conveniently.

Step 2: With a compass, draw the best fit circle through the six points and mark the center of this circle.

Step 3: Measure the diameter of the circle in units of scale chosen in Step 1 and record units.

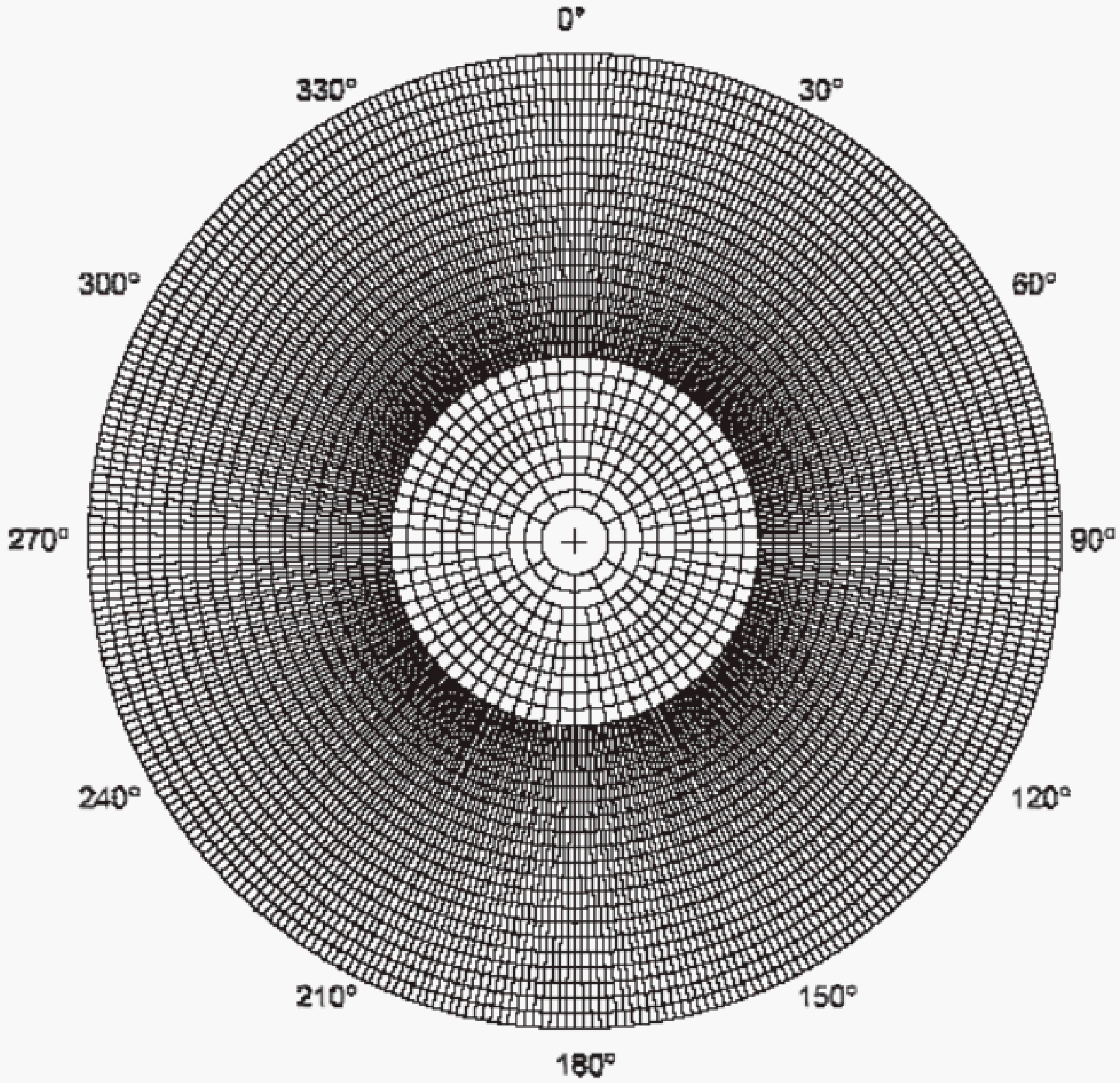
Step 4: Record the trial unbalance from above. ___________ g·mm (oz-in.)

Step 5: Double the trial unbalance in Step 4 (may use twice the actual residual unbalance). ___________ g·mm (oz-in.)

Step 6: Divide the answer in Step 5 by the answer in Step 3. ___________ Scale Factor

You now have a correlation between the units on the polar chart and the actual balance.

Figure E.1—Residual Unbalance Work Sheet



The circle you have drawn must contain the origin of the polar chart. If it doesn't, the residual unbalance of the rotor exceeds the applied test unbalance.

NOTE Several possibilities for the drawn circle not including the origin of the polar chart are: operator error during balancing, a faulty blancing machine pickup or cable, or the balancing machine is not sensitive enough.

If the circle does contain the origin of the polar chart, the distance between origin of the chart and the center of your circle is the actual residual unbalance present on the rotor correction plane. Measure the distance in units of scale you choose in Step 1 and multiply this number by the scale factor determined in Step 6. Distance in units of scale between origin and center of the circle times scale factor equals actual residual unbalance.

Record actual residual unbalance ______________________________ (g•mm) (oz-in.)

Record allowable residual unbalance (from Figure C.1) ________________ (g•mm) (oz-in.)

Correction plane __________ for rotor no. ________________ (has/has not) passed.

By ______________________________ Date ____________________

Figure E.1—Residual Unbalance Work Sheet (Continued)

Annex F
(informative)

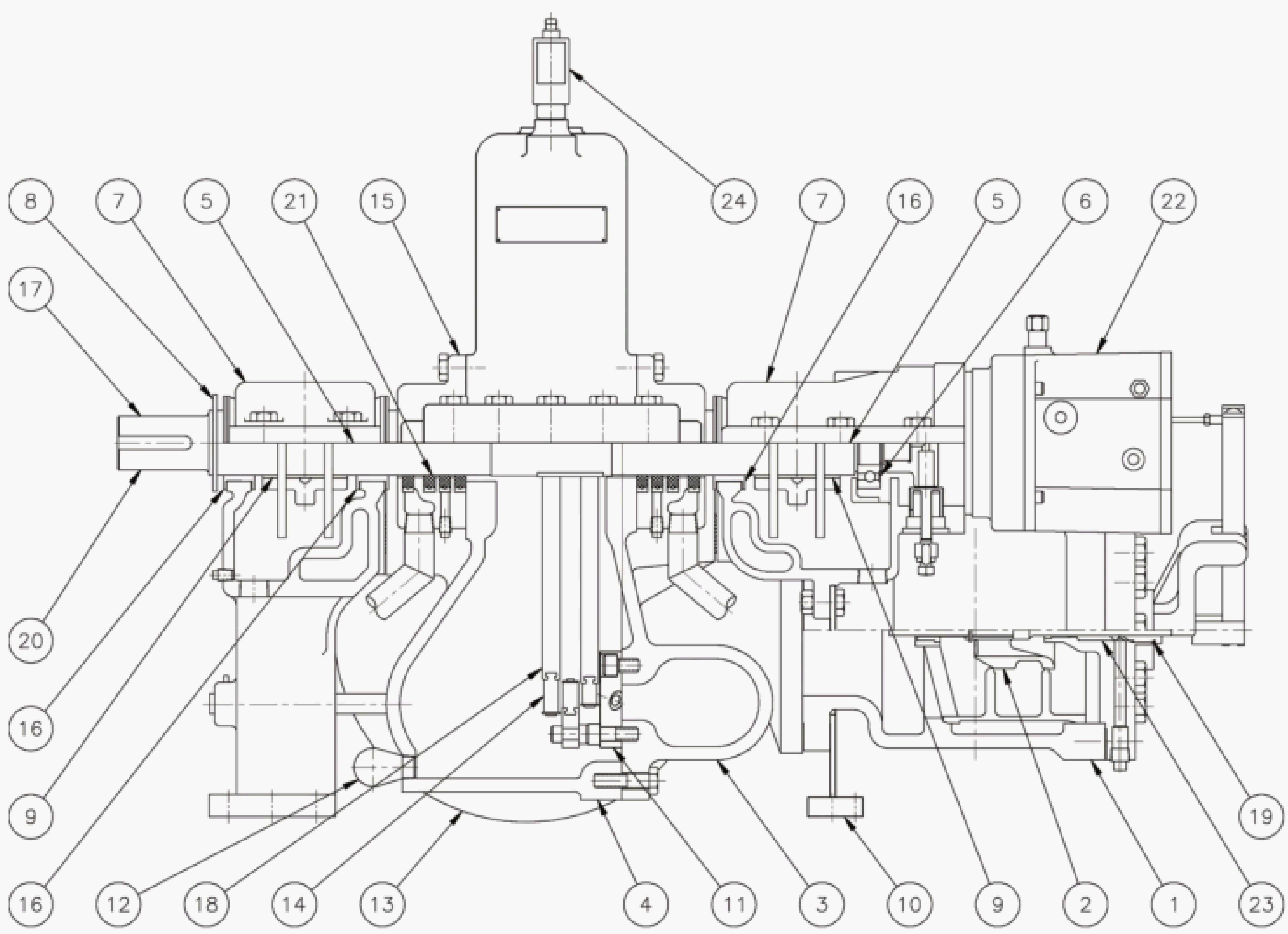
Inspector's Checklist

Item	API 611 5th Edition Reference	Reviewed	Observed	Witnessed	Inspected By	Status
General						
Final assembly maintenance and assembly clearances (optional)	8.2.1.1f					
Surface and subsurface inspection (optional)	8.2.1.3					
Material Inspection						
Material inspection certification/testing (optional)	8.2.2.1.1					
Mechanical Inspection						
Casing openings size/finish	6.5.1/6.5.10					
Shaft finishes	6.7.2.2					
Shaft electrical and mechanical run-out (optional)	6.7.2.3					
Couplings and guards	7.2					
Rotor balance	6.9.4.2					
Balance machine residual unbalance check, multi-stage	6.9.4.3					
Balance machine residual unbalance check, single-stage (optional)	6.9.4.4					
Rotation arrow/nameplate data/units	6.13					
Oil system cleanliness (API 614)	8.2.3.2					
Hydrostatic test	8.3.2					
Mechanical Running Test						
Vibration	6.4.9.6/8.3.3.2f					
Contract shaft seals and bearings	8.3.3.1a					
Oil flows, P,T as specified (optional)	8.3.3.1b					
No leaks observed	8.3.3.1e					
Protective devices operational	8.3.3.1f					
Bearing inspection after test satisfactory	8.3.3.3a					
Spare rotor fit and run	8.3.3.3c					
Optional Tests						
Performance	8.3.4.1					
Complete unit test	8.3.4.2					
Gear test	8.3.4.3					
Sound level test	8.3.4.4					
Auxiliary equipment test	8.3.4.5					
Preparation for Shipment						
Preparation complete	8.4.1					
Paint	8.4.3a					
Rust preventative (exterior and interior)	8.4.3b/8.4.3c					
Tags complete	8.4.3i/8.4.4/8.4.5					
Installation instructions shipped	8.4.6					

Annex G
(informative)

Steam Turbine Nomenclature

Figures G.1 through G.4 are included only to clarify standard machine parts' nomenclature and in no way does it have the purpose to show preferable design solutions or to establish any design requirements. The machine parts depicted here may not be present in each turbine or may look different, depending on the machine type selected by the vendor to suit the service specified by the purchaser. These figures have no influence on the compliance of a specific turbine design to this standard.

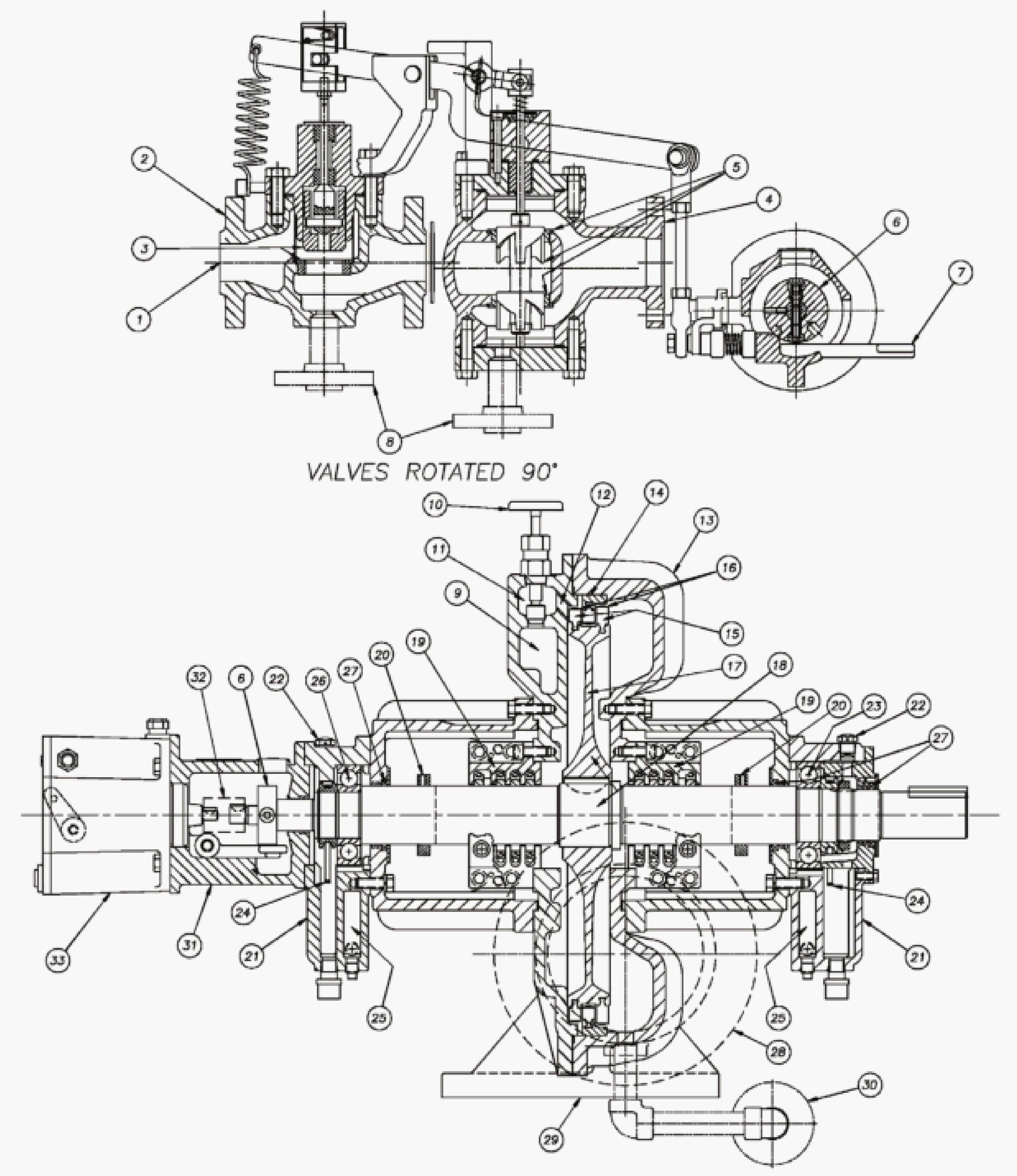


Key

1. Steam Chest
2. Speed Governing Valve
3. Steam Ring Chamber
4. Casing
5. Rotor Shaft Sensing Area
6. Rolling Element Thrust Bearing
7. Bearing Housing
8. Multi-tooth Speed Sensing Wheel
9. Hydrodynamic Radial Bearing
10. Support
11. Nozzle Ring
12. Casing Drain
13. Exhaust Connection
14. Rotor Blades
15. Outer Packing Gland
16. Bearing Housing Seals
17. Rotor
18. Disk
19. Packing Gland
20. Shaft
21. Carbon Ring
22. Oil-relay Governor
23. Valve Stem Packing
24. Sentinet Warning Valve
25.* Thrust Collar
26.* Tip Seal
27.* Being Housing Deflector
28.* Breather Vent
29.* Steam Balance Holes
30.* Hand Operated Nozzle Valve
31.* Trip Valve

* Items not shown

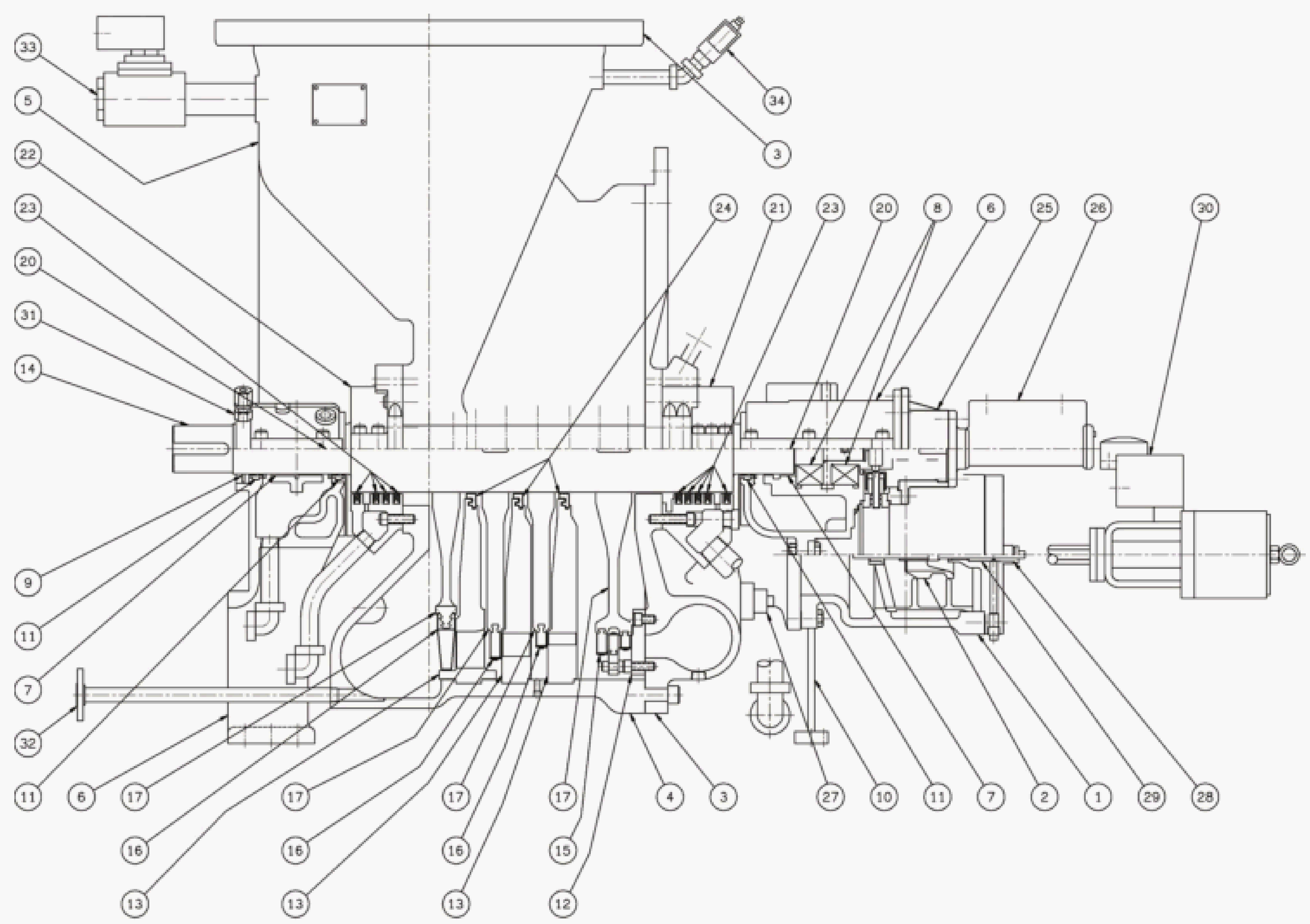
Figure G.1—Single-stage Turbine



Key

1. Inlet Connection
2. Trip Valve Body
3. Trip & Pilot Valve & Seats
4. Throttle Vavle Body
5. Inlet Throttle Valve and Seats
6. Shaft Mounted Overspeed Trip Bolt
7. Manual Trip Lever
8. Valve Body Drain
9. Steam Chest
10. Hand Operated Nozzle Valve
11. Nozzle Chamber
12. Nozzle Insert
13. Exhaust Casing
14. Stationary Reversing Sector & Blades
15. Rotor Blades
16. Blade Shroud Band
17. Wheel (Disk)
18. Rotor/Shaft & Wheel Assembly
19. Gland Housing & Shaft Outer Seals
20. Bearing Housing Deflector
21. Bearing Housing(s)
22. Breather/Vent(s)
23. Ball Journal Bearing
24. Oil Rings
25. Cooling Water Chambers
26. Ball Journal/Thrust Bearing
27. Bearing Housing End Seals
28. Exhaust Connection
29. Turbine Support Feet
30. Casing Drain
31. Mounting Housing
32. Governor Drive Coupling
33. Oil-relay Governor

Figure G.2—Radial Split Single-stage Turbine Key



Key

1. Steam Chest
2. Speed Governing Valve
3. Steam Ring Chamber
4. Intermediate Pressure Casing
5. Exhaust Casing
6. Bearing Housing
7. Hydrodynamic Radial Bearing
8. Double Acting Thrust Bearing
9. Multi-tooth Speed Sensing Wheel
10. Support
11. Bearing Housing Seals
12. Nozzle Ring
13. Rateau Stage Diagram
14. Rotor
15. Curtis Stage Rotor Buckets
16. Rateau Stage Blading
17. Disk
18. Shaft
19. Thurst Collar
20. Shaft Probe Sensing Area
21. Steam End Packing Gland
22. Exhaust End Packing Gland
23. Carbon Ring
24. Interstage Labyrinth Seal
25. Oil Pump Adapter
26. Oil Pump
27. Hand Operated Nozzle Valve
28. Packing Gland
29. Valve Stem Packing
30. Governor Valve Actuator
31. Magnetic Pickup
32. Casing Drain
33. Vacuum Breaker
34. Sentinet Warning Vavle

35.* Tip Seal

36.* Bearing Housing Deflector

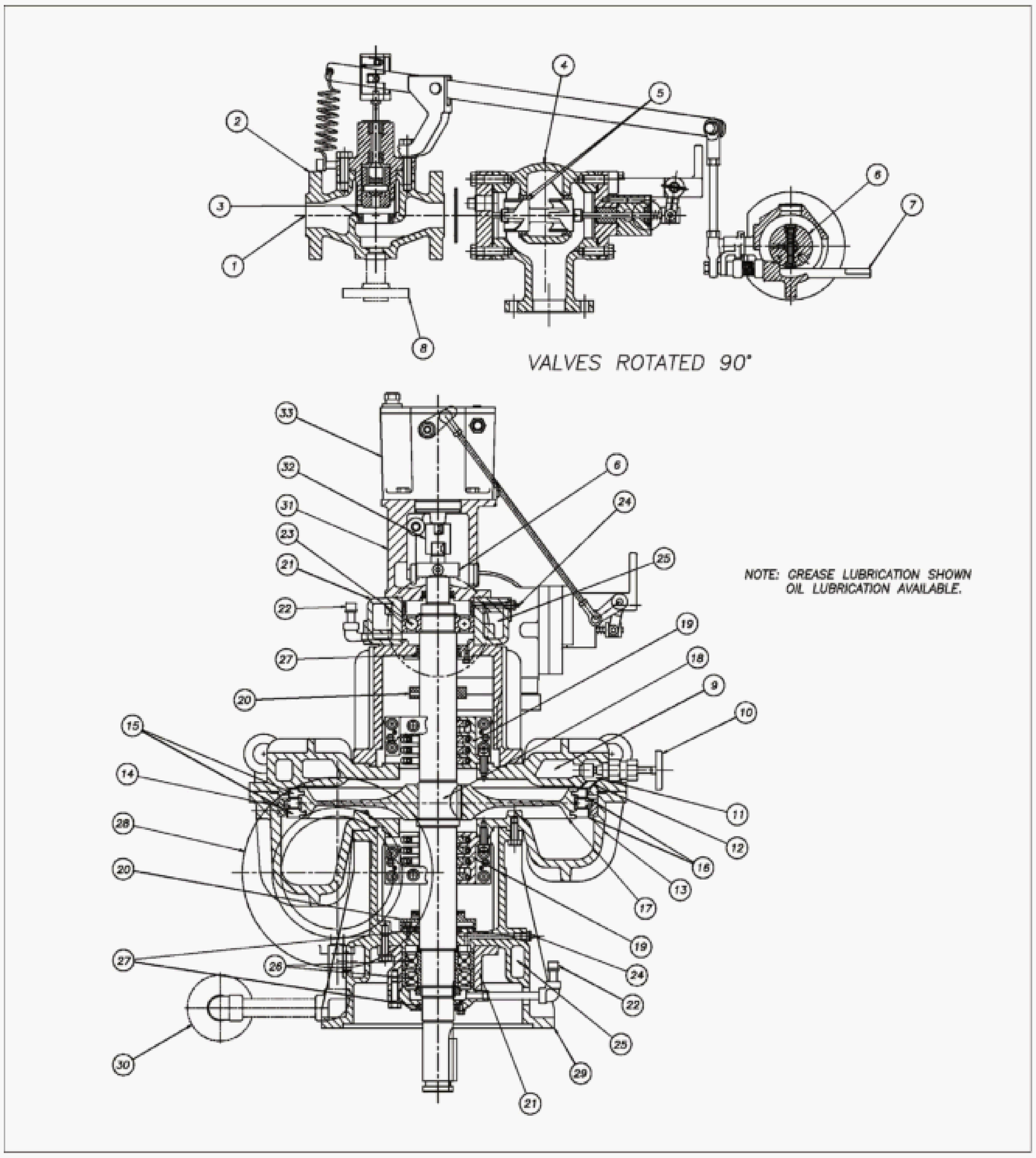
37.* Breather Vent

38.* Steam Balance Holes

39.* Trip Valve

* Items not shown

Figure G.3—Multi-stage Turbine



Key

1. Inlet Connection
2. Trip Valve Body
3. Trip & Pilot Valve & Seats
4. Throttle Valve Body
5. Inlet Throttle Valve and Seats
6. Shaft Mounted Overspeed Trip Bolt
7. Manual Trip Lever
8. Valve Body Drain
9. Steam Chest
10. Hand Operated Nozzle Valve
11. Nozzle Chamber
12. Nozzle Insert
13. Exhaust Casing
14. Stationary Reversing Sector & Blades
15. Rotor Blades
16. Blade Shroud Band
17. Wheel (Disk)
18. Roto/Shaft & Wheel Assembly
19. Gland Housing & Shaft Outer Seals
20. Bearing Housing Deflector
21. Bearing Housing(s)
22. Breather/Vents & Grease Overflow
23. Ball Journal Bearing
24. Grease Fitting
25. Cooling Water Chambers
26. Ball Journal/Thrust Bearing
27. Bearing Housing End Seals
28. Exhaust Connection
29. Turbine Mounting Flange
30. Casing Drain
31. Mounting Housing
32. Governor Drive Coupling
33. Oil-relay Governor

Figure G.4—Radial Split Single-stage Vertical Turbine

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[3] ABMA Std 7[12], *Shaft and Housing Fits for Metric Radial Ball and Roller Bearings (Except Tapered Roller Bearings) Conforming to Basic Boundary Plan*

[4] ASTM A53[13], *Standard Specification for Pipe, Steel, Black and Hot-Dipped, Zinc-Coated, Welded and Seamless*

[5] ASTM A278, *Standard Specification for Gray Iron Castings for Pressure-Containing Parts for Temperatures Up to 650 °F (350 °C)*

[6] ASTM A395, *Standard Specification for Ferritic Ductile Iron Pressure-Retaining Castings for Use at Elevated Temperatures*

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[12] American Boiler Manufacturers Association, 8221 Old Courthouse Road, Suite 207, Vienna, Virginia 22182, www.abma.com.
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[14] International Organization for Standardization, 1, ch. de la Voie-Creuse, case postale 56, CH-1211, Geneva, Switzerland, www.iso.org.
[15] NACE International (formerly the National Association of Corrosion Engineers), 1440 South Creek Drive, Houston, Texas 77218-8340, www.nace.org.

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