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

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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.

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Introduction

Users of this standard should be aware that further or differing requirements may be needed for individual applications. This standard is not intended to inhibit a vendor from offering, or the purchaser from accepting, alternative equipment or engineering solutions for the individual application. This may be particularly appropriate where there is innovative or developing technology. Where an alternative is offered, the vendor should identify any variations from this standard and provide details.

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

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

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

1 Scope

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

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

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

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

2 Normative References

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

API Specification 5L, *Line Pipe*

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

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

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

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

API Recommended Practice 551, *Process Measurement Instrumentation*

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

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

API 670, *Machinery Protection Systems*

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

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

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

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

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

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

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

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

AGMA 9000, *Flexible Couplings—Potential Unbalance Classification*

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

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

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

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

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

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

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

ASME B17.1, *Keys and Key Sets*

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

ASME B31.3, *Process Piping*

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

ASME PTC 6, *Steam Turbines*

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

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

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

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

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

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

ASTM A105/A105M [4], *Standard Specification for Carbon Steel Forgings for Piping Applications*

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

ASTM E709, *Standard Guide for Magnetic Particle Examination*

ASTM E1003, *Standard Practice for Hydrostatic Leak Testing*

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

IEC 60079 [6], *Explosive atmospheres*

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

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

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

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

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

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

ISO 5753, *Rolling bearings—Internal clearance*

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

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

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

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

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

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

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

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

MSS SP-55 [8], *Quality Standard for Steel Castings for Valves, Flanges, 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 Publication, *A Brief Comparison of NEMA 250 and IEC 60529*

NFPA 70 [10], *National Electrical Code*

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

3 Terms, Definitions, Acronyms, Abbreviations, and Symbols

3.1 Terms and Definitions

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

3.1.1
alarm point
Preset value of a measured parameter at which an alarm is activated to warn of a condition that requires corrective action.

3.1.2
alloy steel
Steel that is alloyed with a variety of elements in total amounts between 1.0 % and 50 % by weight.

3.1.3
anchor bolts
Bolts used to attach the mounting surface to the support structure (concrete foundation or steel structure).

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

3.1.4
approve
Provide written documentation confirming an agreement.

3.1.5
axially split
Joint split with the principal face parallel to the shaft centerline.

3.1.6
baseplate
Fabricated steel structure designed to support the complete steam turbine and/or the driven equipment and other ancillaries that may be mounted upon it.

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

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

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

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

3.1.7
circulating oil system
A system that withdraws oil from the housing of bearings equipped with oil rings and cool the oil in an external oil cooler before it is returned to the bearing housing.

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

3.1.8
critical speed
Shaft rotational speed (revolutions per minute) at which the rotor-bearing-support system is in a state of resonance.

3.1.9
design
Manufacturer's calculated parameter.

3.1.10
diamétre nominal
DN
Alphanumeric designation of size for components of a pipework system.

EXAMPLE DN 20.

NOTE 1 Adapted from ISO 6708:1995.

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

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

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

3.1.11
gauge board
Bracket or plate used to support and display gauges, switches, and other instruments.
cf. **panel** (3.1.34).

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

3.1.12
governor valve
Device that controls the flow of steam into the turbine in response to the governor.

3.1.13
hold-down bolts
mounting bolts
Bolts holding the equipment to the mounting surface.

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

3.1.14
hydrodynamic bearings
Bearings that use the principles of hydrodynamic lubrication bearings that rely on the differential speed of the journal relative to the stator to pressurize a lubricating fluid in a wedge between the surfaces. The bearing

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

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

3.1.15
informative
For advice information only.

cf. **normative** (3.1.30).

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

3.1.16
local
Refers to the location of a device when mounted on or near the equipment or console.

3.1.17
maximum allowable speed
Highest speed (revolutions per minute) at which the manufacturer's design will permit continuous operation.

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

3.1.18
maximum allowable temperature
Maximum continuous temperature for which the manufacturer has designed the equipment (or any part to which the term is referred) when operating at the maximum allowable working pressure (MAWP).

3.1.19
maximum allowable working pressure
MAWP
Maximum continuous pressure for which the manufacturer has designed the equipment (or any part to which the term is referred) when operating at the maximum allowable temperature.

3.1.20
maximum continuous speed
Highest rotational speed (revolutions per minute) at which the turbine, as built and tested, is capable of continuous operation.

3.1.21
maximum exhaust casing pressure
Highest exhaust steam pressure that the purchaser requires the casing to contain, with steam supplied at maximum inlet conditions.

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

3.1.22
maximum exhaust pressure
Highest exhaust steam pressure at which the turbine is required to operate continuously.

3.1.23
maximum inlet pressure and temperature
Highest inlet steam pressure and temperature conditions at which the turbine is required to operate continuously.

3.1.24
minimum allowable speed
Lowest speed (revolutions per minute) at which the manufacturer's design will permit continuous operation.

3.1.25
minimum design metal temperature
Lowest mean metal temperature (through the thickness) expected in the surrounding environment, for which the equipment is designed.

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

3.1.26
minimum exhaust pressure
Lowest exhaust steam pressure at which the turbine is required to operate continuously.

3.1.27
minimum inlet pressure and temperature
Lowest inlet steam pressure and temperature conditions at which the turbine is required to operate continuously.

3.1.28
nominal pipe size
NPS
Value equal to a diameter in inches.

EXAMPLE NPS $^3/_4$.

NOTE 1 Refer to ASME B31.3.

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

3.1.29
normal
Applies to the power, speed, and steam conditions at which the equipment will usually operate.

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

3.1.30
normative
Required.

cf. **informative** (3.1.15).

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

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

3.1.31
observed
A classification of inspection or test where the purchaser is notified of the schedule and the inspection or test is performed even if the purchaser or their representative is not present.

3.1.32
oil mist lubrication
Lubrication systems that employ oil mist produced by atomization in a central supply unit and transported to the bearing housing, or housings, by compressed air.

3.1.33
owner
Final recipient of the equipment who can delegate another agent as the purchaser of the equipment.

3.1.34
panel
Enclosure used to mount, display, and protect gauges, switches, and other instruments.

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

3.1.35
positive material identification testing
PMI testing
Any physical evaluation or test of a material to confirm that the material which has been or will be placed into service is consistent with the selected or specified alloy material designated by the owner/user. These evaluations or tests may provide either qualitative or quantitative information that is sufficient to verify the nominal alloy composition.

NOTE Adapted from API 578.

3.1.36
potential maximum power
Approximate maximum power to which the turbine can be up rated at the specified normal speed and steam conditions if it is furnished with suitable (larger or additional) nozzles and, possibly, with a larger governor valve or valves.

3.1.37
pressure casing
Composite of all stationary pressure-containing parts of the unit, including all nozzles and other attached parts.

3.1.38
purchaser
Agency that issues the order and specification to the vendor.

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

3.1.39
pure oil mist lubrication (dry sump)
Lubrication systems in which the mist both lubricates the bearing and purges the housing.

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

3.1.40
purge oil mist lubrication (wet sump)
Lubrication systems in which the mist purges the bearing housing.

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

3.1.41
radially split
Joint split with the principal joint perpendicular to the shaft centerline.

3.1.42
rated power
Maximum turbine power specified and the corresponding speed.

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

3.1.43
remote
Refers to the location of a device if located away from the equipment or console, typically in a control room.

3.1.44
soleplate
Plate attached to the foundation, with a mounting surface for equipment or for a baseplate.

3.1.45
special tool
Tool that is not a commercially available catalog item.

3.1.46
standby
Service state in which a piece of equipment that is normally idle or idling and is capable of immediate automatic or manual start-up for continuous operation.

3.1.47
steam chest
High-pressure inlet of the steam turbine that may contain the governor valve and/or trip valve.

3.1.48
subplate
Plate usually embedded in a concrete foundation and used to accurately locate and align a baseplate or soleplate.

3.1.49
total indicator reading
total indicated runout
TIR
Difference between the maximum and minimum readings (of a dial indicator or similar device, monitoring a face or cylindrical surface during one complete revolution of the monitored surface.

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

3.1.50
trip speed
Speed (revolutions per minute) at which the independent emergency overspeed device operates to shut down the turbine.

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

3.1.51
unit responsibility
Obligation for coordinating the documentation, delivery, and technical aspects of all the equipment and all auxiliary systems included in the scope of the order.

3.1.52
vendor
Agency that supplies the equipment.

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

3.1.53
witnessed
Inspection or test where the purchaser is notified of the timing of the inspection or test and a hold is placed on the inspection or test until the purchaser or their representative is in attendance.

3.2 Acronyms, Abbreviations, and Symbols

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

4 General

4.1 Unit Responsibility

The vendor shall assume unit responsibility and shall assure that all subvendors comply with the requirements of this standard and all reference documents. The technical aspects to be considered by the vendor include, but are not limited to, such factors as the power requirements, speed, rotation, general arrangement, couplings, dynamics, lubrication, sealing system, material test reports, instrumentation, piping, conformance to specifications, and testing of components.

4.2 Nomenclature

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

5 Requirements

● 5.1 Units of Measure

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

5.2 Statutory Requirements

The purchaser and the vendor shall determine the measures to be taken to comply with any governmental codes, regulations, ordinances, directives, or rules that are applicable to the equipment, its packaging, and any preservatives used.

5.3 Documentation

The purchaser shall specify the hierarchy of documents.

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

6 Basic Design

6.1 General

6.1.1 Equipment Reliability

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

6.1.9 Turbines shall be capable of the following.

a) Operating at normal power and speed with normal steam conditions. The manufacturer's certified steam rate shall be at these conditions.

b) Delivering rated power at its corresponding speed with coincident minimum inlet and maximum exhaust conditions as specified on the data sheets. To prevent oversizing or to obtain higher operating efficiency, the purchaser may limit maximum turbine capability by specifying normal or a selected percentage of rated power.

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

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

c) Continuously operating at maximum continuous speed and at any speed within the range specified.

d) Continuously operating at rated power and speed under maximum inlet steam conditions and maximum or minimum exhaust steam conditions.

e) Operating with variations from rated steam conditions in accordance with Annex H.

f) Regardless of the design limit of any turbine component, the turbine shall not be operated or re-rated outside the nameplate limits without consultation with the manufacturer or engineering review.

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

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

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

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

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

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

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

6.1.16 Cooling water equipment shall be designed for the conditions specified in Table 1. The vendor shall notify the purchaser if the criteria for minimum temperature rise and velocity over heat exchange surfaces result in a conflict. The criterion for velocity over heat exchange surfaces is intended to minimize water side fouling; the criterion for minimum temperature rise is intended to minimize the use of cooling water. If such a conflict exists, the purchaser will approve the final selection.

Table 1—Design Criteria and Specifications for Cooling Water Systems

Criteria	SI Units	USC Units
Water velocity over heat exchange surfaces [a]	≥ 1.5 m/s to 2.5 m/s	5 ft/s to 8 ft/s
Maximum allowable working pressure (MAWP)	≥ 7.0 bar	≥ 100 psig
Test pressure (≥ 1.5 MAWP)	≥ 10.5 bar	≥ 150 psig
Maximum pressure drop	1 bar	15 psi
Maximum inlet temperature	30 °C	90 °F
Maximum outlet temperature	50 °C	120 °F
Maximum temperature rise	20 K	30 °F
Water side fouling factor	0.35 m^2K/kW	0.002 h-ft^2-°F/Btu
Corrosion allowance for carbon steel shells	3 mm	1/8 in.

[a] These limits are not applicable to bearing housing with internal water passages.

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

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

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

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

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

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

● **6.1.23** If specific materials are not permitted such as copper or aluminum, the purchaser shall specify if these material are restricted in the atmosphere around the equipment or in the steam path of the turbine.

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

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

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

6.2 Bolting

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

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

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

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

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

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

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

6.3 Pressure Casings

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

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

6.3.3 For cast materials, the factors specified in ASME *BPVC* Section VIII, Division 1 shall be applied.

6.3.4 Pressure casings of forged steel rolled and welded steel plate or seamless piping with welded covers shall comply with the applicable design rules of ASME *BPVC* Section VIII, Division 1 or Division 2.

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

6.3.6 Axially split casings shall use a metal-to-metal joint (with a suitable joint compound) that is tightly maintained by suitable bolting. Gaskets (including string type) shall not be used on the axial joint. If gasketed joints are used on radially split casings, they shall be securely maintained by confining the gaskets.

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

6.3.8 Axially split horizontal turbines shall be designed to permit inspection and removal of the rotor and wearing parts without removing the casing from its foundation or disconnecting inlet or exhaust steam piping (except if up-exhaust is specified). Axially split multi-stage turbine casings may also be split radially between high- and low-pressure portions.

6.3.9 Radially split horizontal turbines shall be designed to permit inspection and replacement of the bearings and outer glands without removing the casing from its foundation or disconnecting inlet or exhaust steam piping. Radially split horizontal turbines may require removal from their foundations to permit removal of rotors.

6.3.10 Casings and supports shall be designed to have sufficient strength and rigidity to limit any change in the relative position of the shaft ends at the coupling flange, caused by the worst combination of allowable pressure, torque, and piping forces and moments, to 50 μm (0.002 in.). Support and alignment bolts shall be rigid enough to permit the machine to be moved by lateral and axial jackscrews.

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

6.3.12 Mounting surfaces shall meet the following criteria.

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

6.3.14 To prevent a soft foot, mounting surfaces shall be machined on a horizontal plane flat within 25 μm (0.001 in.).

6.3.15 Each mounting surface shall be machined within a flatness of 40 μm per 1 linear m (0.0005 in. per linear ft) of mounting surface.

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

6.3.17 The upper machined or spot faced surface shall be parallel to the mounting surface. Hold-down bolt holes shall be drilled perpendicular to the mounting surface or surfaces; machined or spot faced to a diameter two times that of the hole; and to allow for equipment alignment, be 15 mm ($^1/_2$ in.) larger in diameter than the hold-down bolt.

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

6.3.19 On condensing turbines, if the orientation of the exhaust nozzle is horizontal or vertically up, an automatic drain system is required. The drain system shall be supplied by the vendor.

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

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

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

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

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

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

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

6.3.27 The use of threaded holes in pressure parts shall be minimized. To prevent leakage in pressure sections of casings, metal equal in thickness to at least half the nominal bolt diameter, in addition to the allowance for corrosion, shall be left around and below the bottom of drilled and threaded holes. The depth of the tapped holes shall be at least 1$^{1}/_{2}$ times the stud diameter.

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

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

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

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

6.4 Casing Appurtenances

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

6.5 Casing Connections

6.5.1 All openings or nozzles for piping connections on pressure casings shall be standard pipe sizes DN 20 (NPS $^{3}/_{4}$) 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 6.5.6. All connections shall be suitable for the MAWP of the casing as defined in 3.1.19.

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

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

6.5.5 Butt-welded connections, size DN 40 (NPS $1^1/_2$) and smaller, shall be reinforced by using forged welding inserts or gussets.

6.5.6 For connections other than main connections, if flanged or machined and studded openings are impractical, threaded connections for pipe sizes not exceeding DN 40 (NPS $1^1/_2$) may be used as follows:

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

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

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

a) the nipple and flange materials shall meet the requirements of 6.5.4;

b) pipe nipples shall be provided with welding-neck or socket-weld flanges for steam pressures of 5.2 bar (75 psig) or higher;

c) threaded connections shall not be seal welded;

d) threaded openings and bosses for tapered pipe threads shall conform to ASME B16.5;

e) pipe threads shall be taper threads that conform to ASME B1.20.1;

f) openings for socket-welded connections shall conform to ASME B16.5 for castings and ASME B16.11 for fittings.

6.5.8 Pipe nipples screwed or welded to the casing should not be more than 150 mm (6 in.) long and shall be a minimum of Schedule 160 seamless for sizes DN 25 (NPS 1) and smaller and a minimum of Schedule 80 for DN 40 (NPS $1^1/_2$) and larger.

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

a) round-head solid steel,

b) meets ASME B16.11,

c) made of a corrosion-resistant material if removable.

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

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

a) Flat-faced flanges with full raised-face thickness are acceptable on Class 150 exhaust connections.

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

c) The concentricity between the bolt circle and the bore of all casing flanges shall be such that the surface area for the seating of the machined gasket is adequate to accommodate a complete standard gasket that does not protrude into the fluid flow.

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

● e) For the purpose of manufacturing mating parts, the vendor shall supply equipment flange details to the purchaser if connections larger than those covered by ASME B16.5 or ASME B16.47 are supplied. If specified, these mating parts shall be furnished by the vendor.

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

Table 2—Arithmetic Average Roughness Height (Ra)

Type	**Service**	**Contact Surface Roughness** (Ra) µin.
Flat and raised face	Vacuum	63 to 125
	Above atmospheric	125 to 500
Ring joint	All	< 63

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

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

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

6.6 External Forces and Moments

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

6.7 Rotating Elements

6.7.1 Rotors

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

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

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

6.7.2 Shafts

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

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

6.7.2.3 Shafts shall be ground to a finish of 0.4 μm (16 μin.) Ra or better at the bearing locations and sealing areas for carbon ring packing.

6.7.2.4 Shaft coupling area shall be finished to 0.8 μm (32 μin.).

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

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

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

a) For areas to be observed by radial-vibration probes, 25 % of the allowed peak-to-peak vibration amplitude or 6.35 μm (0.25 mil), whichever is greater.

b) For areas to be observed by axial-position probes, 12.7 μm (0.5 mil).

c) If all reasonable efforts fail to achieve the limits noted in 6.7.2.7 a) and 6.7.2.7 b), the vendor and purchaser shall agree on alternate acceptance criteria.

d) To prevent the buildup of potential voltages, residual magnetism of the free air gauss level in the rotor assembly shall not exceed ±2 gauss when measured with a calibrated Hall effect probe on the surface of the part.

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

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

● **6.7.2.10** If specified, the coating shall be high-velocity oxygen fuel process (HVOF)-applied chrome carbide, ground and honed to 0.4 μm (16 μin.) Ra or less.

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

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

6.7.3 Blading

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

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

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

6.8 Seals

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

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

a) The number of carbon rings shall be determined by the service and venting requirements, with 2.4 bar (35 psi) being the maximum allowable average differential pressure per active sealing ring.

b) Springs for carbon packing shall be made of nickel-chromium-iron alloy (heat treated after cold coiling) or equal material.

c) Variations in operating steam temperature shall be considered when the required cold clearances for packing rings are established.

● **6.8.3** If specified, non-contacting (gas face) seals may be used as an alternate to carbon ring or labyrinth-type packing subject to the following:

a) purchaser shall specify potential standby/rapid start conditions;

b) special conditions and speed limits shall be reviewed by turbine and seal vendor

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

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

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

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

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

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

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

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

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

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

6.9 Dynamics

6.9.1 Critical Speeds

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

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

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

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

6.9.2 Lateral Analysis

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

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

● **6.9.2.3** If specified, the vendor shall provide calculations and/or available supporting test data for separation margins in accordance with 6.9.2.2 and Annex B.

6.9.3 Torsional Analysis

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

6.9.4 Vibration and Balancing

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

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

In SI units:

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

In USC units:

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

where

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

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

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

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

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

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

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

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

In SI units:

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

In USC units:

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

where

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

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

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

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

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

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

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

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

6.10 Bearings and Housings

6.10.1 Bearings—General

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

Table 3—Bearing Selection

Condition	Bearing Type and Arrangement
Radial and thrust bearing speed and life within limits for rolling element bearings and turbine energy density below limit	Rolling element radial and thrust
Radial bearing speed or life outside limits for rolling element bearings and thrust bearing speed and life within limits and turbine energy density below limits	Hydrodynamic radial and rolling element thrust
Radial and thrust bearing speed or life outside limits for rolling element bearings or turbine energy density above limits	Hydrodynamic radial and hydrodynamic thrust

NOTE Limits are as follows.

a) Rolling element bearing speed: factor, Nd_m, shall not exceed 500,000, where d_m is the mean bearing diameter $(d + D)/2$, expressed in millimeters, and N is the rotating speed, expressed in revolutions per minute.

b) Rolling element bearing life: basic rating L_{10h} per ISO 281 or ABMA 9 of at least 50,000 hours with continuous operation at rated conditions, and at least 32,000 hours at maximum radial and axial loads and rated speed.

c) Energy density is the product of rated power, kW (HP), and rated speed, r/min; if the value is 4.0 million (5.4 million) or greater, hydrodynamic radial and thrust bearings shall be used. This energy density limit is applicable only to multi-stage turbines.

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

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

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

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

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

a) fouling and variation in seal clearances at design and at twice the design internal clearances;

b) step thrust from all diameter changes;

c) stage reaction and stage differential pressure;

d) variations in pressure at all inlet and outlet nozzles;

e) external loads from the driven equipment, as described in 6.10.1.7 through 6.10.1.8.

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

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

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

6.10.2 Rolling Element Bearings

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

a) bearings shall be located on the shaft using shoulders, collars, or other positive locating devices; snap rings and spring-type washers are not acceptable;

b) bearings shall be retained on the shaft with an interference fit and fitted into the housing with a diametrical clearance, both in accordance with the recommendations of ABMA 7;

c) bearings shall be mounted directly on the shaft; bearing carriers are not acceptable.

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

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

a) A rolling element thrust bearing may be a single-row deep-groove ball bearing provided the combined axial thrust and radial load is within the capability of such a bearing and requirements of Table 3 are satisfied.

b) Where the loads exceed the capability of a single-row deep-groove bearing, a matched pair of single-row, 40° angular contact type (7000 series) bearings shall be used. The bearings shall be mounted in a paired arrangement back-to-back.

c) The device used to lock ball thrust bearings to shafts shall be restricted to a nut with a tongue-type lock washer.

d) Four-point contact (split race) ball bearings and bearings with filling slots shall not be used.

6.10.3 Hydrodynamic Bearings

6.10.3.1 Hydrodynamic Radial Bearings

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

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

6.10.3.1.3 Bearings shall be designed to prevent incorrect positioning.

6.10.3.2 Hydrodynamic Thrust Bearings

6.10.3.2.1 Thrust bearings shall be of the steel or copper/bronze backed, babbitted multiple segment type, designed for equal thrust capacity in both directions and arranged for continuous pressurized lubrication 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 If replaceable collars are furnished (for assembly and maintenance purposes), they shall be positively locked to the shaft to prevent fretting.

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

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

a) the shaft speed;

b) the temperature of the bearing babbitt;

c) the deflection of the bearing pad;

d) the minimum oil film thickness;

e) the feed rate, viscosity, and supply temperature of the oil;

f) the design configuration of the bearing;

g) the babbitt alloy; and

h) the turbulence of the oil film.

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

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

6.10.4 Bearing Housings

6.10.4.1 General

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

6.10.4.1.2 Bearing housings for oil-lubricated nonpressure fed bearings shall be provided with tapped and plugged fill and drain openings at least DN 15 (NPS 1/2) in size. The housings shall be equipped with constant level sight feed oilers at least 0.12 L (4 oz) in size, with a positive level positioner (not an external screw), heat-resistant glass containers (not subject to sunlight or heat induced opacity or deterioration), and protective wire cages. Means shall be provided for detecting overfilling of the housings. A permanent indication of the proper oil level shall be accurately located and clearly marked on the outside of the bearing housing with permanent metal tags, marks inscribed in the castings, or another durable means.

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

a) Stainless steel pipe nipple of Schedule 40S, preferably not more than 150 mm (6 in.) long, shall be provided.

b) The pipe nipple shall be provided with a stainless steel flange.

c) Pipe or tube fittings on DN 20, DN 25, and DN 40 (NPS $^3/_4$, 1, and $1^1/_2$) connections shall not be seal welded. Threaded connections shall not be made up with thread tape; all threaded connections shall be made up with a suitable thread sealant.

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

a) For pressurized fluid film bearing systems, the bearing oil temperature rise shall not exceed 28 K (50 °R) above inlet oil temperature, and if bearing metal temperature sensors are supplied, bearing metal temperatures shall not exceed 93 °C (200 °F).

b) For ring-oiled or splash systems (including such systems with purge-oil mist), the sump oil temperature rise shall not exceed 40 K (70 °R) above ambient temperature, and if bearing metal temperature sensors are supplied, bearing metal temperatures shall not exceed 93 °C (200 °F).

c) For grease-lubricated bearings, if bearing metal temperature sensors are supplied, bearing metal temperatures shall not exceed 93 °C (200 °F).

d) For pure oil mist systems, the bearing housing surface temperature shall not exceed 71 °C (160 °F), and if bearing-temperature sensors are supplied, bearing metal temperatures shall not exceed 88°C (190 °F).

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

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

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

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

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

6.10.4.2 Seals and Deflectors

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

a) lip-type seals shall not be used;

b) seals and deflectors shall be made of non-sparking materials;

c) design of the seals and deflectors shall retain oil in the housing and restrict entry of steam, condensation, and foreign material into the housing.

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

● **6.10.4.3 Oil Mist Lubrication**

6.10.4.3.1 An DN 8 (NPS $^1/_4$) oil mist inlet connection shall be provided in the top half of the bearing housing. The pure or purge oil mist fitting connections shall be located so that oil mist will flow through rolling element bearings. On pure mist systems, there shall be no internal passages to short circuit oil mist from inlet to vent.

6.10.4.3.2 A threaded DN 8 (NPS $^1/_4$) vent connection shall be provided on the housing or end cover for each of the spaces between the rolling element bearings and the housing shaft closures. Alternatively, where oil mist connections are between each housing shaft closure and the bearings, one vent central to the housing shall be supplied. Housings with only sleeve-type bearings shall have the vent located near the end of the housing.

6.10.4.3.3 Shielded or sealed bearings shall not be used.

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

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

a) heat-sink-type flingers;

b) stainless steel shafts having low thermal conductivity;

c) thermal barriers;

d) fan cooling; and

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

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

6.10.4.4 Vibration Measurement

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

a) dimples shall be suitable for accurate location of a hand-held vibration transducer with an extension "wand;"

b) dimples may be cast or machined and be nominally 2 mm (0.080 in.) deep with an included angle of 120° as shown in Figure 2;

c) dimples shall be located as close to the bearing centerline as practical for the vertical (V) and horizontal (H) locations only.

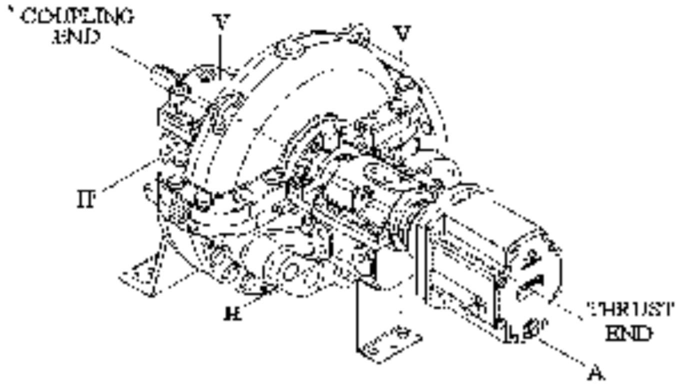


Figure 1—Bearing Housing Dimple Locations for Vibration Measurements

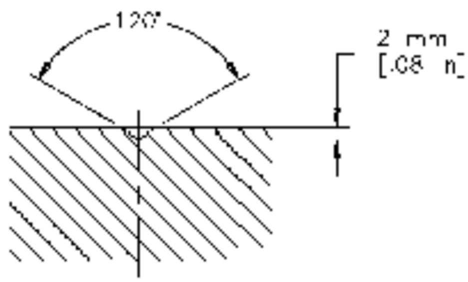


Figure 2—Dimple Dimensions

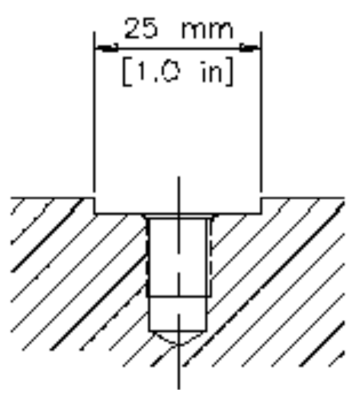


Figure 3—Transducer Mounting Hole Dimensions

● **6.10.4.4.2** If specified, a flat surface of an agreed size and location shall be provided for mounting of magnetic-based seismic vibration measuring equipment.

● **6.10.4.4.3** If specified, bearing housings shall be prepared for permanently mounting seismic vibration transducers in accordance with API 670. The spot face and drilling are to be per Figure 3 and located on the top of each bearing housing. The thread size is to be agreed upon between the purchaser and vendor.

● **6.10.4.4.4** If specified, provision shall be made for mounting two radial vibration probes adjacent to each bearing, two axial position probes at the thrust end, and a one-event-per-revolution probe in each machine. The probe installation shall be as specified in API 670.

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

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

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

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

6.11 Lubrication

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

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

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

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

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

b) any governor and control-oil system.

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

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

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

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

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

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

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

6.12 Materials

6.12.1 General

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

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

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

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

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

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

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

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

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

6.12.1.9 If mating parts such as studs and nuts of austenitic stainless steel or materials with similar galling tendencies are used, they shall be lubricated with an antiseizure compound of the proper temperature specification and compatible with the specified process fluid(s).

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

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

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

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

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

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

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

6.12.2 Castings

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

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

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

a) Weldable grades of steel castings shall be repaired by welding, using a qualified welding procedure based on the requirements of the appropriate pressure vessel code such as ASME *BPVC* Section VIII, Division 1 and ASME *BPVC* Section IX. After major weld repairs, and before hydrotest, the complete repaired casting shall be given a postweld heat treatment to ensure stress relief and continuity of mechanical properties of both weld and parent metal and dimensional stability during subsequent machining operations.

● b) If specified, for casting repairs, made in the vendor’s shop, repair procedures including weld maps shall be submitted for purchaser’s approval. The purchaser shall specify if approval is required before proceeding with repair. Repairs made at the foundry level shall be controlled by the casting material specification (“producing specification”).

c) All repairs that are not covered by ASTM specifications shall be subject to the purchaser’s approval.

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

6.12.3 Forgings

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

a) Weldable grades of steel forgings shall be repaired by welding using a qualified welding procedure based on the requirements of the appropriate pressure vessel code such as ASME *BPVC* Section VIII, Division 1 and ASME *BPVC* Section IX. After major weld repairs, and before hydrotest, the complete forging shall be given a postweld heat treatment to ensure stress relief and continuity of mechanical properties of both weld and parent metal.

b) All repairs that are not covered by ASTM specifications shall be subject to the purchaser’s approval.

6.12.4 Welding

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

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

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

a) be nondestructively tested by the same method used to detect the original flaw;

b) as a minimum, the inspection shall be by the magnetic particle method in accordance with 8.2.2.4 for magnetic material and by the liquid penetrant method in accordance with 8.2.2.5 for nonmagnetic material.

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

a) a repair of any rotating part;

b) a repair of a pressure-containing part in which the depth of the cavity prepared for repair welding exceeds 50 % of the component wall thickness and/or is longer than 150 mm (6 in.) in any direction;

c) where the total area of all repairs to the part under repair exceeds 10 % of the surface area of the part.

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

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

b) Accessible surfaces of welds shall be inspected by magnetic particle or liquid penetrant examination after back chipping or gouging and again after postweld heat treatment. The quality control of welds that will be inaccessible on completion of the fabrication shall be agreed on by the purchaser and vendor prior to fabrication.

c) Pressure-containing welds, including welds of the case to axial- and radial-joint flanges, shall be full-penetration welds.

d) Casings fabricated from materials that, according to ASME *BPVC* Section VIII, Division 1, require postweld heat treatment, shall be heat treated regardless of thickness.

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

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

6.12.5 Low-temperature Service

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

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

6.12.5.2 To avoid brittle failures, materials and construction for low-temperature service shall be suitable for the minimum design metal temperature. The purchaser and the vendor shall agree upon the minimum design metal temperature and any special precautions necessary with regard to conditions that may occur during operation, maintenance, transportation, erection, commissioning, and testing.

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

NOTE 2 Some standards do not differentiate between rimmed, semi-killed, fully killed, hot-rolled, and normalized material, nor do they take into account whether materials were produced under fine- or course-grain practices, all of which can affect material ductility.

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

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

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

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

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

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

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

a) the nominal thickness of the largest butt-welded joint;

b) the largest nominal section for pressure containment, excluding:

   1) structural support sections such as feet or lugs,

   2) sections with increased thickness required for rigidity to mitigate shaft deflection,

   3) structural sections required for attachment or inclusion of mechanical features such as jackets or seal chambers;

c) one-fourth of the nominal flange thickness, including parting flange thickness for axially split casings (in recognition that the predominant flange stress is not a membrane stress).

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

6.13 Nameplates and Rotation Arrows

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

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

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

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

a) vendor's name;

b) serial number;

c) size and type;

d) rated power and speed;

e) first critical speed;

f) second critical speed;

g) maximum continuous speed;

h) minimum allowable speed;

i) overspeed trip setting;

j) normal and maximum inlet steam temperature and pressure;

k) normal and maximum exhaust steam pressure;

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

m) if applicable, number of teeth on electronic speed pickup gear assembly.

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

7 Accessories

7.1 Gear Units

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

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

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

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

7.2 Couplings and Guards

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

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

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

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

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

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

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

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

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

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

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

a) Flexible couplings with cylindrical bores shall be mounted with an interference fit. Cylindrical shafts shall comply with AGMA 9002 and the coupling hubs shall be bored to the following tolerances as detailed in ISO 286-2.

   1) For shafts of 50 mm (2 in.) diameter and smaller—Grade N7.

   2) For shafts larger than 50 mm (2 in.) diameter—Grade N8.

b) For turbines connected to their driven equipment with a flexible coupling, the locating and alignment faces shall be perpendicular to the axis. The coupling surfaces normally used for checking alignment shall be concentric to the axis of coupling hub rotation within the following limits: 13 μm (0.0005 in.) TIR per in. of shaft diameter, with a minimum applicable tolerance of 25 μm (0.001 in.) TIR and a maximum of 75 μm (0.003 in.) TIR.

c) Coupling faces shall be perpendicular to the axis of the coupling within 1 μm per 10 mm (0.0001 in. per in.) of face diameter with a maximum of 13 μm (0.0005 in.) TIR.

d) For vertical turbines that have rigid couplings between the turbine and driven equipment, the coupling diameters shall be concentric to the axis of coupling hub rotation within the following limits: 13 μm (0.0005 in.) TIR per in. of shaft diameter, up to a maximum of 25 μm (0.001 in.) TIR.

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

Additionally, these couplings shall comply with the following:

a) flexible elements shall be of corrosion-resistant material;

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

c) coupling hubs shall be steel;

d) the spacer nominal length shall be at least 125 mm (5 in.) and shall permit removal of the coupling, bearings, seal, and rotor, as applicable, without disturbing the driven equipment or inlet and exhaust piping; and

e) couplings operating (maximum continuous speed) at speeds in excess of 3800 r/min shall meet the requirements of API 671 for component balancing and assembly balance check.

● **7.2.13** If specified, coupling components shall be balanced to ISO 21940-11, Grade 6.3.

● **7.2.14** If specified, couplings shall meet the requirements of ISO 14691 or API 671.

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

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

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

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

7.3 Baseplates and Soleplates

7.3.1 General

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

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

7.3.1.3 The upper and lower surfaces of baseplates and soleplates and any separate pedestals mounted thereon shall be machined parallel. The surface finish shall be 6 μm (250 μin.) Ra or better.

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

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

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

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

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

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

7.3.1.10 Alignment jackscrews shall be plated for rust resistance.

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

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

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

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

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

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

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

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

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

7.3.1.18 Baseplates and soleplates shall conform to the following.

a) Baseplates and soleplates shall not be drilled for equipment to be mounted by others.

b) Baseplates and soleplates shall be supplied with leveling screws. A leveling screw shall be provided near each anchor bolt. If the equipment and baseplates and soleplates are too heavy to be lifted using leveling screws, alternate methods shall be provided by the equipment vendor.

c) Outside corners of baseplates and soleplates which are embedded in the grout shall have 50 mm (2 in.) minimum radius outside corners (in the plan view). See Figure 4, Figure 5, Figure 6, and Figure 7. Embedded edges shall be rounded to prevent the potential of cracking the grout.

d) All machinery mounting surfaces shall be treated with a rust preventive immediately after machining.

e) Baseplates and soleplates shall extend at least 25 mm (1 in.) beyond the outer three sides of equipment feet.

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

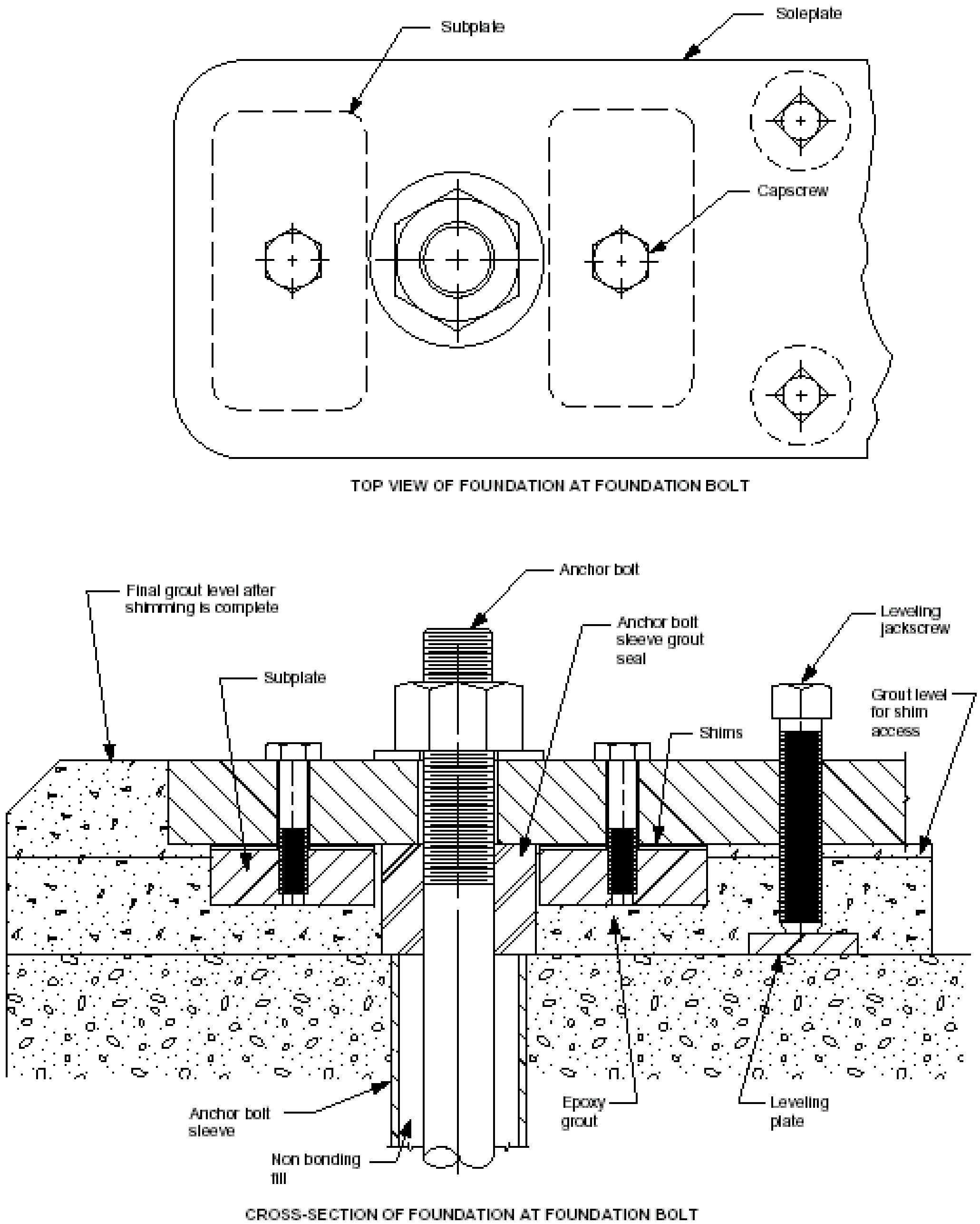


Figure 4—Typical Soleplate Arrangement

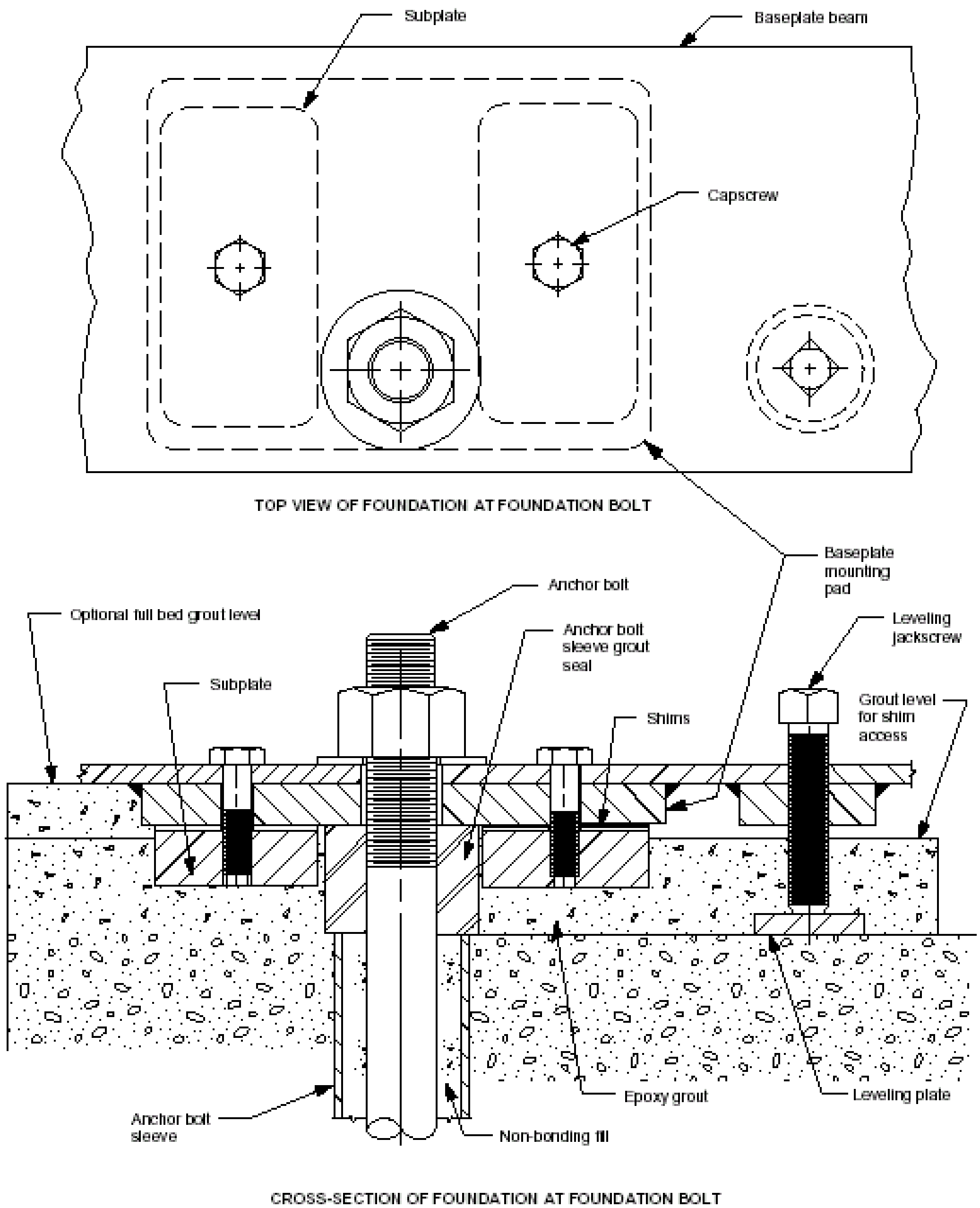


Figure 5—Typical Baseplate Arrangement

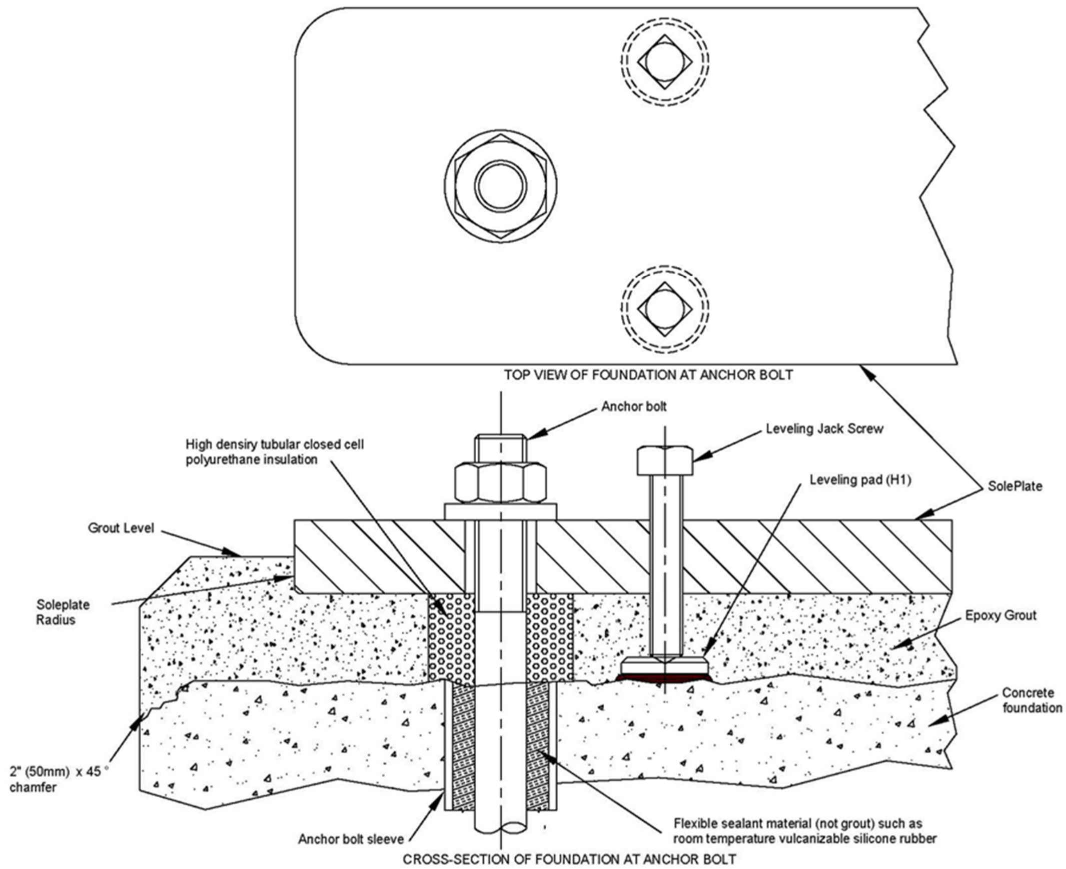


Figure 6—Typical Soleplate Arrangement

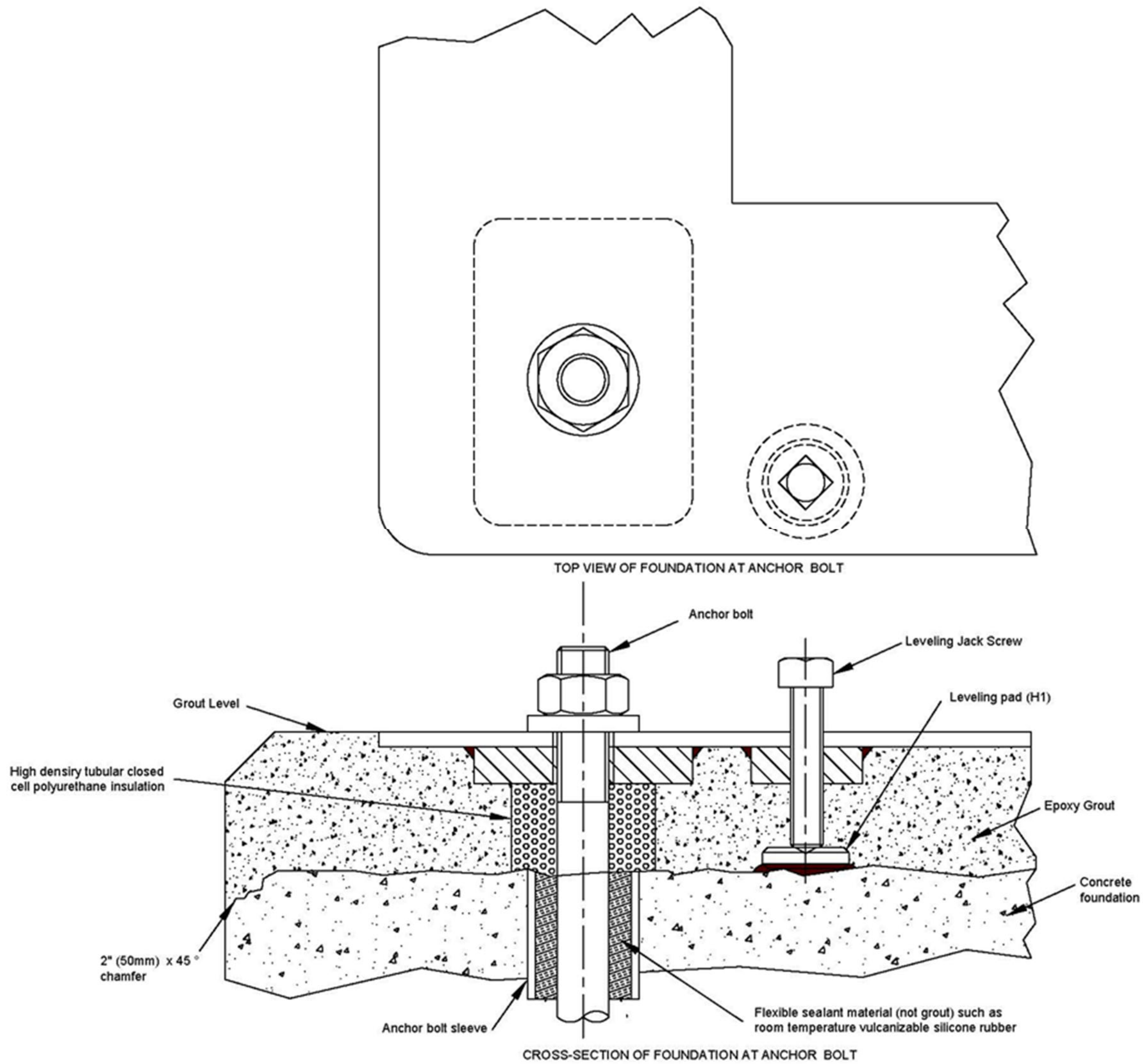


Figure 7—Typical Baseplate Arrangement

7.3.1.19 The alignment shims shall be provided by the Vendor in accordance with API 686, Chapter 7 and shall straddle the hold-down bolts and vertical jackscrews and be at least 6 mm ($^{1}/_{4}$ in.) larger on all sides than the equipment feet.

7.3.1.20 Anchor bolts shall be furnished by the purchaser.

7.3.1.21 Hold-down bolts used to attach the equipment to the baseplates and soleplates, and all jackscrews, shall be supplied by the vendor.

7.3.1.22 Equipment shall be designed for installation in accordance with API 686.

7.3.1.23 Grouted baseplates and soleplates shall be adequately sized to limit the static loading to 690 kN/m^2 (100 psi) on the grout.

7.3.1.24 Diametrical clearance between anchor bolts and the anchor bolt holes in the baseplates and soleplates shall be a minimum of 6 mm ($^{1}/_{4}$ in.).

7.3.1.25 Working clearance shall be provided at the hold-down and jack bolt locations to allow the use of standard socket or box wrenches to achieve the specified torque.

7.3.2 Baseplate

7.3.2.1 If a baseplate has been specified, the purchaser shall indicate the major equipment to be mounted on it. A baseplate shall be a single fabricated steel unit, unless the purchaser and the vendor agree that it may be fabricated in multiple sections. Multiple-section baseplates shall have machined and doweled mating surfaces that shall be bolted together to ensure accurate field reassembly. A baseplate with a nominal length of more than 12 m (40 ft) or a nominal width of more than 4 m (12 ft) may have to be fabricated in multiple sections because of shipping restrictions.

7.3.2.2 If a baseplate(s) is provided, it shall extend under all train components to contain and drain any leakage.

7.3.2.3 Single-piece baseplates shall be furnished with a gutter-type drain 75 mm (3 in.) wide and 50 mm (2 in.) deep around the circumference of the base deck. The gutter shall be sloped at least 1 in 120 toward the driven equipment end, where a tapped drain opening of at least DN 38 (NPS $1^1/_2$) shall be located to effect complete drainage.

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

● **7.3.2.5** If specified, the baseplate shall be designed to facilitate the use of optical, laser-based, or other instruments for accurate leveling in the field. The details of such facilities shall be agreed by the purchaser and vendor. Where the requirement is satisfied by the provisions of pads and/or targets, they shall be accessible with the baseplate on the foundation and the equipment mounted. Removable protective covers shall be provided. Pads or targets shall be located close to the machinery support points. For baseplates longer than 6 m (20 ft), additional pads shall be located at intermediate points.

● **7.3.2.6** If specified, the baseplate shall be designed for column mounting (i.e. of sufficient rigidity to be supported at only specified points) without continuous grouting under structural members. The baseplate design shall be agreed upon by the purchaser and the vendor. Design suitability shall be verified by FEA or similar suitable design tool.

7.3.2.7 The baseplate shall be provided with lifting attachments meeting the requirements of 7.3.2.7.1 through 7.3.2.7.7.

7.3.2.7.1 Attachments shall be provided for at least a four-point lift.

7.3.2.7.2 Lifting attachments on the baseplate or equipment shall be designed using a maximum allowable dynamic stress of one-third of the specified minimum yield strength of the material.

NOTE Design of lifting attachments can be in accordance with standards such as ASME BTH-1.

7.3.2.7.3 Baseplates shall be designed for lifting with all equipment mounted.

NOTE In some cases it can be more practical to design the baseplate to remove heavy equipment prior to lifting.

7.3.2.7.4 Lifting the baseplate complete with equipment that is mounted shall not permanently distort or otherwise damage the baseplate or the equipment mounted on it.

7.3.2.7.5 Lugs or trunnions that are attached by welding shall have continuous welds and shall be 100 % (nondestructive testing) NDT tested in accordance with the applicable code.

7.3.2.7.6 Removable lugs or commercially available specialty products such as pivot-type hoisting rings can be provided with purchaser approval.

● **7.3.2.7.7** If specified, commercially available lifting attachments shall be furnished with material and load test certifications traceable to an internationally recognized standard and attested by an independently accredited third-party agency or organization.

7.3.2.8 For accessibility and grouting, the baseplate shall be designed per 7.3.2.8.1 through 7.3.2.8.6.

7.3.2.8.1 The bottom of the baseplate between structural members shall be open.

7.3.2.8.2 If the baseplate is designed for grouting, it shall be provided with at least one grout hole having a clear area of at least 125 cm^2 (20 $in.^2$) and no dimension less than 75 mm (3 in.) in each bulkhead section.

7.3.2.8.3 The holes shall be located to permit grouting under all load-carrying structural members. Where practical, the holes shall be accessible for grouting with the equipment installed.

7.3.2.8.4 The holes shall have 13 mm ($^1/2$ in.) raised-lip edges, and if located in an area where liquids could impinge on the exposed grout, austenitic stainless steel covers with a minimum thickness of 3 mm ($^1/8$ in.) shall be provided.

7.3.2.8.5 Covers shall be convex and extended to the deck surface (Figure 8).

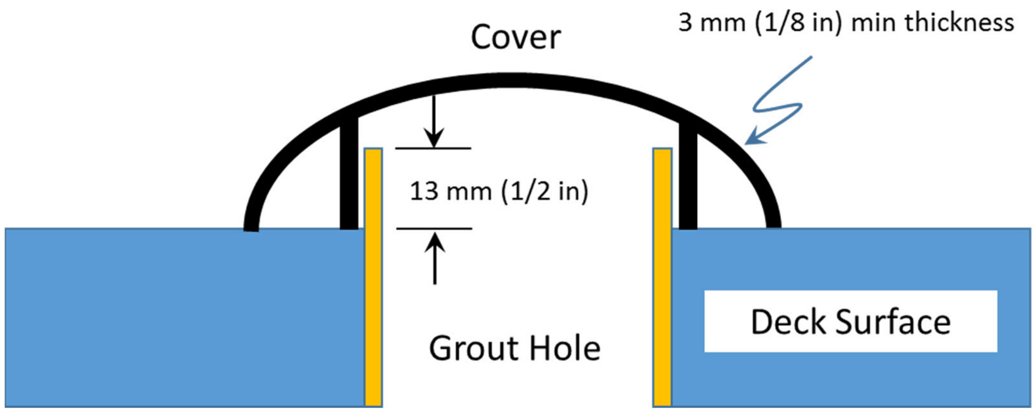


Figure 8—Cross-section of Grout Hole Cover

7.3.2.8.6 Vent holes at least 13 mm ($^1/2$ in.) in size shall be provided at the highest point and located to vent the entire cavity in each bulkhead section of the baseplate.

7.3.2.9 The underside mounting surfaces of the baseplate shall be in one plane to permit use of a single-level foundation. When multi-section baseplates are provided, the mounting pads shall be in one plane after the baseplate sections are doweled and bolted together.

7.3.2.10 Nonskid metal decking covering all walk and work areas shall be provided on the top of the baseplate.

NOTE Nonskid surfaces can be obtained by nonskid coatings or grating over the metal decking.

7.3.2.11 Two ground clips or pads shall be welded to the baseplate at diagonally opposed corners. These clips or pads shall be of the same material as the baseplate and accommodate a 13 mm ($^1/2$ in. UNC) bolt.

7.3.2.12 All baseplate machinery mounting surfaces shall meet the following criteria.

a) They shall be machined after the baseplate is fabricated.

b) They shall be machined to a finish of 3 μm (125 μin.) Ra or better.

c) They shall have each mounting surface machined within a flatness of 75 µm per linear m (0.001 in. per linear ft) of mounting surface (see Figure 9).

d) To prevent a soft foot, when the machine is installed on the baseplate, all mounting surfaces in the same horizontal plane shall be within 125 µm (0.005 in.) (see Figure 9).

e) Mounting planes for different equipment shall be machined parallel to each other within 50 µm (0.002 in.) (see Figure 9).

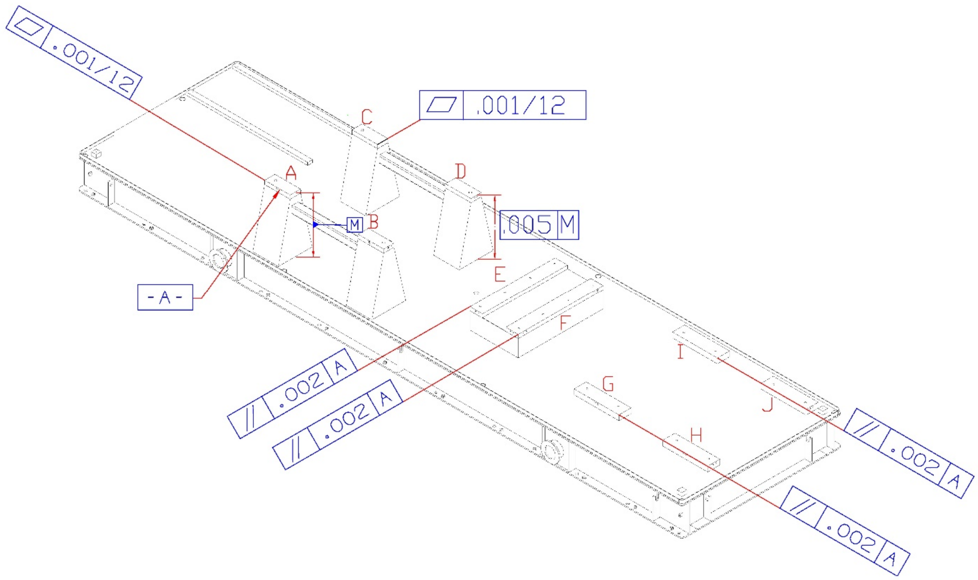


Figure 9—Mounting Surface Flatness

7.3.2.13 The tolerances in 7.3.2.12 shall be recorded and verified by placing the baseplate in unrestrained condition on a flat machined surface at the place of manufacture.

● **7.3.2.14** If specified, subplates shall be provided by the vendor.

7.3.2.15 Support for the major equipment shall be located directly beneath the equipment feet and shall extend in-line vertically to the bottom of the baseplate.

● **7.3.2.16** If specified, the bottom of the baseplate shall have machined mounting pads. These pads shall be machined in a single plane after the baseplate is fabricated.

NOTE These machined mounting pads are necessary when the baseplate is mounted on subplates or structural steel members to facilitate field leveling.

7.3.2.17 Baseplate arrangement shall have sufficient clearance to allow for operation and servicing of drain lines and valves.

7.3.3 Soleplates and Subplates

7.3.3.1 If soleplates are specified, they shall meet the requirements of 7.3.3.2 through 7.3.3.5 in addition to those of 7.3.1.

7.3.3.2 Soleplates shall be steel plates that are thick enough to transmit the expected loads from the equipment feet to the foundation; the soleplates shall not be less than 40 mm ($1^1/2$ in.) thick.

● **7.3.3.3** If subplates have been 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 soleplates.

7.3.3.4 Soleplates 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.

7.3.3.5 Soleplates in excess of 75 lb (30 kg) shall have provision for a minimum of two bolted lifting attachments. Each lifting attachment shall be designed to lift the total weight of the soleplate.

7.4 Controls and Instrumentation

7.4.1 General

7.4.1.1 Instrumentation and installation shall conform to the requirements of API 670, API 614, and/or purchaser-supplied specifications.

● **7.4.1.2** Controls and instruments shall be specified if they are to be designed for outdoor or indoor installation by purchaser.

7.4.1.3 The purchaser shall provide any special design and installation standards for the turbine controls/instruments to the supplier.

7.4.1.4 Controls and instrumentation that are installed outdoors shall have a minimum ingress protection level of IP 65 as detailed in IEC 60529 or a NEMA 4 minimum rating per NEMA 250.

7.4.1.5 For outdoor installation, the controls and instrumentation, equipment and wiring shall comply with the construction requirements of IEC 60079.

NOTE Special consideration can be required for instrumentation working below –20 °C (–4 °F) or above 55 °C (131 °F).

7.4.1.6 Terminal boxes shall have a minimum ingress protection level of IP 66 as detailed in IEC 60529 or a NEMA 4X minimum rating per NEMA 250, as specified. If IP 66 protection level is specified, the terminal boxes shall comply with the construction requirements of IEC 60079. Terminal boxes shall be 316 SS.

NOTE 1 IEC addresses environment protection and electrical protection separately. Ingress protection is covered by the IP designation in IEC 60529. Electrical protection is covered by IEC 60079.

NOTE 2 The IP Code only addresses requirements for protection of people, ingress of solid objects, and ingress of water. There are numerous other requirements covered by the NEMA type designations that are not addressed by the IEC 60529/IP Codes. IEC 60529 does not specify the following:

a) construction requirements;

b) door and cover securement;

c) corrosion resistance;

d) effects of icing;

e) gasket aging and oil resistance;

f) coolant effects.

The type designation of NEMA specifies requirements for these additional performance protections. For this reason, the IEC enclosure IP Code designations cannot be converted to enclosure NEMA type numbers. (NEMA Publication “A brief comparison of NEMA 250 and IEC 60529.”)

NOTE 3 NEMA addresses both environmental and electrical protection (construction features) in one standard NEMA 250.

7.4.1.7 Instrumentation and controls shall be designed and manufactured for use in the area classification (class, group, and division or zone) specified in 6.1.21.

7.4.1.8 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.

7.4.1.9 Where applicable, controls and instrumentation shall conform to API 551, Part 1.

7.4.2 Control Systems

7.4.2.1 Turbine Governing System

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 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 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.

7.4.2.1.4 A Class A oil-relay governor shall be supplied. The governor shall have the same or better characteristics as those shown in Table J.1 of Annex J.

7.4.2.1.5 Speed shall be adjusted by means of a manual speed changer.

● **7.4.2.1.6** If a remote 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. 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 manual speed changer.

7.4.2.1.7 The adjustable speed range of the governor and manual speed changer shall be a total of 20 % of the maximum continuous speed—5 % greater and 15 % less than normal speed.

7.4.2.1.8 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 %.

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

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

7.4.2.2 Electronic Governing System

● **7.4.2.2.1** 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 system (DCS) and if required shall be provided with electrical power by a purchaser-supplied power source.

7.4.2.2.2 A multi-toothed surface for speed sensing shall be provided affixed to the shaft either by being integral to the shaft, a keyed attachment, or a bolt on attachment. This surface may be shared by the speed governor, overspeed trip system, and tachometer. Number of teeth on multi-tooth surface shall be added to the nameplate and shall be indicated on P&ID.

7.4.2.2.3 If the multi-toothed surface is only attached by interference fit and not attached as 7.4.2.2.2, then governor and over-speed need to be on separate multi-tooth surface.

7.4.2.2.4 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 trip 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 trip.

7.4.2.2.5 The design of the electronic speed governor shall meet the requirements specified for a Class D governor (see Table J.1) and shall include as a minimum:

a) an assignable speed range corresponding to the normal range of operation as defined by the driven equipment vendor or end user;

b) speed setpoint adjustment;

c) remote or process-controlled speed setpoint adjustment;

d) digital speed indication;

e) outputs to governor valve actuator;

f) adjustable speed ramp rate;

g) slow roll control;

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

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

● **7.4.2.2.6** If a remote or process control speed set point adjustment is specified, the speed of the turbine shall vary linearly with the setpoint signal and direct acting.

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

7.4.2.2.8 Failure of the governing system shall initiate a turbine trip.

7.4.2.3 Overspeed Trip 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 J.1). The emergency trip system shall be mechanical, positively attached to the turbine shaft or electronic. 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) spark-proof components and suitability for use in hazardous gas and outdoor locations.

7.4.2.3.2 The purchaser shall provide a block valve on the inlet steam line close to the turbine to isolate the turbine before the overspeed trip system is reset.

● **7.4.2.3.3** If specified, a dedicated electronic voting trip shall be furnished in lieu of a mechanical trip. This device shall be separate and independent of any overall system such as a DCS or governor and be provided with electrical power by a purchaser-supplied power source.

7.4.2.3.4 The requirements of 7.4.2.3.5 through 7.4.2.3.9 apply if a dedicated electronic voting trip system is supplied.

7.4.2.3.5 A multi-toothed surface for speed sensing shall be provided affixed to the shaft (reference 7.4.2.2.3 for proper installation).

7.4.2.3.6 The overspeed trip system shall include at least two 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 a trip.

● **7.4.2.3.7** If specified, a 2 out of 3 voting trip shall be supplied. 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 trip.

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

a) An assignable trip speed 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 vendor;

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

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

7.4.2.3.9 Failure of the overspeed trip system shall initiate a turbine trip.

7.4.2.3.10 The purchaser and the vendor shall 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 1 For turbines that exhaust to sub-atmospheric pressure, a closed emergency trip valve can allow enough steam into the turbine 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.

NOTE 2 For turbines exhausting to a common condensing system, air admission is not feasible, and a more positive emergency trip valve(s) or other provisions could be needed.

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 include all panel-mounted instruments for the turbine and supplied as follows:

a) designed and fabricated in accordance with the purchaser's description;

b) freestanding;

● c) located on the base of the unit, or in another location, as specified.

7.4.3.3 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 gauges. The gauges may be marked with the operating range, or the operating range may be indicated on a tag next to the gauge. A lamp test push button shall be provided. The instruments to be mounted on the panel will be specified.

7.4.3.4 Panels shall be reinforced, self-supporting, and closed on the top and sides. The front shall be steel plate at least 3 mm ($^{1}/_{8}$ in.) thick. Tops and sides shall be a minimum of 12 gauge steel. All instruments shall be flush mounted on the front of the panel, and all fasteners shall be of corrosion-resistant metal. All interior and exterior surfaces of carbon steel panels shall be prepared and coated with an industrial grade coating system.

● **7.4.3.5** If specified, panels shall be totally enclosed to minimize electrical hazards, to prevent tampering, or to allow purging for safety or corrosion protection.

7.4.3.6 Gauge boards and panels shall be completely assembled, piped, and wired, requiring only connection to the purchaser's external piping and wiring circuits.

7.4.3.7 If more than one wiring point is required on a unit for control or instrumentation, the wiring to each electrical control device or instrument shall be provided from common terminal box(es), with terminal blocks.

7.4.3.8 Separate terminal boxes shall be supplied for segregation of the AC and DC electrical signals. With purchaser's, approval one terminal box may be provided if it is provided with an internal barrier that separates the AC and DC wiring.

● **7.4.3.9** If specified, additional signal segregation by terminal boxes shall be required.

7.4.3.10 Each terminal box shall be mounted on the unit, baseplate, or shipped loose as specified.

7.4.3.11 Each terminal box shall be mounted on the unit or baseplate.

NOTE Terminal boxes on some soleplate mounted equipment can result in maintenance access problems. Maintenance access problems can be addressed by shipping terminal boxes loose for field wiring to a nearby location.

7.4.3.12 All leads and posts on terminal strips, switches, and instruments shall be tagged for identification. If specified, purchasers tagging shall be applied in addition to the vendors tagging. Wiring inside panels shall be neatly run in wire ducting.

7.4.3.13 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 Instrumentation and installation shall conform to the requirements of API 670, API 614, and/or purchaser-supplied specifications.

● **7.4.4.2 Tachometers**

A tachometer shall be supplied by the turbine vendor and furnished with a minimum range of 0 % to 125 % of maximum continuous speed. The tachometer shall be visible from the turbine speed adjustment location on the governor. If an electronic governor is supplied, the tachometer on the electronic governor is sufficient, an additional tachometer is not provided unless otherwise specified.

7.4.4.3 Vibration, Axial Position, and One-event-per-revolution Detectors

● **7.4.4.3.1** If specified, hydrodynamic radial bearings shall be fitted with two radial-proximity-type vibration probes mounted adjacent to each bearing. Mounting, calibration, and testing of the sensors shall be in accordance with API 670.

● **7.4.4.3.2** If specified, hydrodynamic thrust bearings shall be fitted with two axial position probes mounted at the thrust end. Mounting, calibration, and testing of the sensors shall be in accordance with API 670.

● **7.4.4.3.3** If specified, one-event-per-revolution probe shall be provided. Mounting, calibration, and testing of the sensors shall be 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.

7.4.4.4.2 They shall be equal to or greater than 100 mm (4 in.) diameter, bimetallic or liquid-filled types.

7.4.4.4.3 Shall have black marking on a white background.

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

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

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.

7.4.4.5.1 The thermowell shall have a 25 mm (1 in.) process connection.

7.4.4.5.2 For pressurized lines, this connection shall be flanged. For non-pressurized lines, this connection maybe threaded.

7.4.4.5.3 The thermowell internal connection shall be 13 mm ($^1/_2$ in.).

7.4.4.6 Thermocouples and Resistance Temperature Detectors

● **7.4.4.6.1** If specified, hydrodynamic thrust and/or radial bearings shall be fitted with bearing metal temperature sensors. Mounting, calibration and testing of the sensors shall be in accordance with API 670; refer to 6.10.1.9 for limitations to instrumentation.

7.4.4.6.2 The design and location of thermocouples and resistance temperature detectors shall permit replacement. 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. The fittings used to extract the wires from the bearing case shall prevent leakage.

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, 100 mm (4 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. High-temperature steam lines a pigtail or syphon shall be used to protect the gauge from damage.

● **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 oil.

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 their scope of supply and recommend the maximum flow for relief valves supplied by others required to protect the equipment supplied. Relief valve sizes and settings shall take into account all possible modes of equipment failure.

7.4.4.9.3 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.

7.4.4.9.5 Full-flow Relief Valve

7.4.4.9.5.1 The turbine casing and internal parts shall be protected against excessive pressure by the installation of a full-flow relief valve. The relief valve is installed into the piping system between the turbine exhaust connection and the first shut-off valve. This relief valve should not be confused with the sentinel warning valve that, when supplied, is mounted on the turbine casing.

7.4.4.9.5.2 The full-flow relief device shall be provided by the user as part of the piping installation that is external to the turbine. In condensing applications, a full-flow relief valve or rupture disc may be provided as part of the condenser or the turbine.

7.4.4.9.5.3 The size of the full-flow device shall be such that it will exhaust to the atmosphere the maximum quantity of steam (as determined by the turbine manufacturer) that will pass through the turbine nozzles with maximum initial steam conditions.

7.4.4.9.5.4 For condensing turbines, the full-flow relief device shall give full relief at no more than 10 psig [70 kPa (gauge)].

7.4.4.9.5.5 For extraction turbines or back-pressure turbines, the full-flow relief device shall open at 10 psig (70 kPa) or 10 % (whichever is greater) above the maximum extraction pressure or maximum exhaust pressure. The relief device shall give full relief at no more than 10 % above the "start-to-open" pressure.

7.4.4.9.5.6 If a high-back-pressure or high-extraction or high-admission pressure trip is furnished, the relief device pressures should be raised 5 psi [35 kPa (gauge)] and the high-steam-pressure trip should be set below "start-to-open" pressure.

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. A flow indicator shall be installed in the outlet piping of each continuously lubricated coupling.

7.4.4.10.2 The flow indicator shall be:

a) flanged or screwed,

b) bulls-eye type with glass on both sides, installed in the vertical plane, to facilitate viewing in the line,

c) steel body construction,

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

e) clearly show the minimum oil flow.

7.4.5 Alarms and Trips

7.4.5.1 General

Alarm and trip 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 noncondensing 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 Switches and Transmitters

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

7.4.5.3.2 Each alarm switch or transmitter and each trip switch or transmitter 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. Switches containing mercury 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 trips.

7.4.5.3.5 Alarm and trip set point shall not be adjustable from outside the housing.

7.4.5.3.6 The sensing elements of pressure switches and transmitters shall be of stainless steel (Type 300 stainless steel).

7.4.5.3.7 Low-pressure switches and transmitters, which are actuated by falling pressure, shall be equipped with a pressure gauge, valved bleed, or vent connection to allow controlled depressurizing during testing.

7.4.5.3.8 High-pressure switches and transmitters that 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.

7.4.5.3.9 For high-temperature steam lines, a pigtail or syphon shall be used to protect the gauge from damage.

7.4.5.3.10 The vendor shall furnish with the proposal a complete description of the alarm points and trip 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 and 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 that may be required to be opened with the equipment in operation, for example, for alarm point 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 *National Electrical Code*, Article 110 or other internationally recognized standard as approved by the purchaser. Electrical materials including insulation shall be corrosion resistant and non-hygroscopic insofar as is possible.

● **7.4.6.5** 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.

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 following shall apply:

a) 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;

b) piping shall terminate with flanged connections at the edge of the base;

c) if soleplates are specified for the equipment train, the extent of the piping system at the equipment train shall be defined by the purchaser;

d) 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 for 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 or ASME B1.20.1 as specified. If ISO 7-1 has been specified, tapered or straight internal threads shall also be specified. Flanges shall be steel and in accordance with 6.5.11.

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 4.

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 6.5.9.

Table 4—Minimum Requirements for Piping System Components

System		Steam		Cooling Water		Lube Oil	Air
		≤ 5.2 bar (75 psig)	> 5.2 bar (75 psig)	**Standard** (≤ NPS 1)	**Optional**	**Standard**	**Standard**
Piping	Temperature < 400 °C (750 °F)	Seamless [a], carbon steel (e.g. ASTM A106/A106M, Grade B, ASTM A53/A53M, Grade B, or equivalent)	Seamless [a], carbon steel (e.g. ASTM A106/A106M, Grade B, ASTM A53/A53M, Grade B, or equivalent)	Carbon steel (e.g. ASTM A106/A106M, Grade B and ASTM A53/A53M, Grade B, or equivalent) seamless	ASTM A53/A53M, Type F, Grade A, Schedule 40, galvanized to ASTM A153/A153M. Stainless steel ASTM A312/A312M, Type 304 or 316 or equivalent.	Stainless steel ASTM A312/A312M, Type 304 or 316, or equivalent [b]. Seamless, except Schedule 40S may be electric fusion welded.	Seamless [a], carbon steel (e.g. ASTM A106/A106M, Grade B, and ASTM A53/A53M, Grade B, or equivalent)
	Temperature > 400 °C (750 °F)	Seamless [a], chromium-molybdenum steel pipe ASTM A335, Grade P11 or equivalent	Seamless [a], chromium-molybdenum steel pipe ASTM A335, Grade P11 or equivalent				
Tubing		Stainless steel [c] ASTM A269/ASTM269M or equivalent Type 304 or 316	Stainless steel [c] ASTM A269/ASTM269M or equivalent Type 304 or 316	Stainless steel [c] ASTM A269/ASTM269M or equivalent Type 304 or 316		Stainless steel [c] ASTM A269/ASTM269M or equivalent Type 304 or 316	Stainless steel [c] ASTM A269/ASTM269M or equivalent Type 304 or 316
All valves	Temperature < 400 °C (750 °F)	Carbon steel casting ASTM A216, Grade WCB, forging ASTM A105/A105M or equivalent, Class 800	Carbon steel casting ASTM A216, Grade WCB, forging ASTM A105/A105M or equivalent, Class 800	Carbon steel casting ASTM A216, Grade WCB, forging ASTM A105/A105M or equivalent	Stainless steel	Stainless steel	Carbon steel casting ASTM A216, Grade WCB, forging ASTM A105/A105M or equivalent, Class 800
	Temperature > 400 °C (750 °F)	Chromium-molybdenum steel casting ASME A217, Grade WC6 or forging ASME SA182, Grade F11 Cl 2 or equivalent	Chromium-molybdenum steel casting ASME A217, Grade WC6 or forging ASME SA182, Grade F11 Cl 2 or equivalent				

System		Steam		Cooling Water		Lube Oil	Air
		≤ 5.2 bar (75 psig)	> 5.2 bar (75 psig)	Standard (≤ NPS 1)	Optional	Standard	Standard
Gate and globe valves	Rating < 900#	Bolted bonnet and gland	Bolted bonnet and gland	Bolted bonnet and gland	Bolted bonnet and gland	Bolted bonnets and glands	Bolted bonnet and gland
	Rating > 900#	N/A	Bolted bonnet, welded bonnet, or no-bonnet construction with a bolted gland; these valves shall be suitable for repacking under pressure			Bolted bonnet, welded bonnet, or no-bonnet construction with a bolted gland; these valves shall be suitable for repacking under pressure	
Pipe fittings and unions	Temperature < 400 °C (750 °F)	Carbon steel casting ASTM A216, Grade WCB, forging ASTM A105/A105M or equivalent	Carbon steel forging ASTM A105/A105M or equivalent, Class 3000#	ASTM A338 and ASTM A197/A197M, Class 150 malleable iron, galvanized to ASTM A153/A153M	Stainless steel Type 304 or 316 (vendor's standard)	Stainless steel Type 304 or 316 (vendor's standard)	Carbon steel casting ASTM A216, Grade WCB, forging ASTM A105/A105M or equivalent
	Temperature > 400 °C (750 °F)	Chromium-molybdenum steel forging ASME SA182, Grade F11 Cl 2 or equivalent, Class 3000#	Chromium-molybdenum steel casting ASME A217, Grade WC6 or forging ASME SA182, Grade F11 Cl 2 or equivalent				
Tube fittings		Stainless steel Type 304 or 316 (vendor’s standard)	Stainless steel Type 304 or 316 (vendor’s standard)	Stainless steel Type 304 or 316 (vendor’s standard)	Stainless steel Type 304 or 316 (vendor’s standard)	Stainless steel Type 304 or 316 (vendor’s standard)	Stainless steel Type 304 or 316 (vendor’s standard)
Fabricated joints < 1 1/2 in.		Threaded	Socket-welded	Threaded	Threaded	Carbon steel slip-on flange, or stainless steel weld-neck flange	Carbon steel slip-on flange, or stainless steel weld-neck flange

System		Steam		Cooling Water		Lube Oil	Air
		≤ 5.2 bar (75 psig)	> 5.2 bar (75 psig)	**Standard** (≤ NPS 1)	**Optional**	**Standard**	**Standard**
Fabricated joints > 2 in.		Slip-on flange, socket-weld, or weld-neck flange	Socket-weld or weld-neck flange	Slip-on flange	Weld neck flange	Carbon steel slip-on flange, or stainless steel weld-neck flange	Carbon steel slip-on flange, or stainless steel weld-neck flange
Gaskets	Rating < 600#	Flat, non-asbestos type or spiral wound	Flat, non-asbestos type or spiral wound	Flat, non-asbestos type or spiral wound	Spiral wound with non-asbestos filler, 304 or 316 windings and inner ring; external centering ring may be coated carbon steel	Flat, non-asbestos type, excluding expanded graphite or graphite-coated or spiral wound	Flat, non-asbestos type or spiral wound
	Rating > 600#	N/A	Spiral wound with non-asbestos filler, 304 or 316 windings and inner ring; external centering ring may be coated carbon steel			Spiral wound with non-asbestos filler, 304 or 316 windings and inner ring; external centering ring may be coated carbon steel.	
Flange bolting	Temperature < 400 °C (750 °F)	ASTM A193/A193M, Grade B7; ASTM A194/A194M, Grade 2H	ASTM A193/A193M, Grade B7; ASTM A194/A194M, Grade 2H	ASTM A193, Grade B7; ASTM A194/A194M, Grade 2H	Stainless steel Type 304 or 316 (vendor's standard)	ASTM A193/A193M, Grade B7; ASTM A194/A194M, Grade 2H	ASTM A193/A193M, Grade B7 ASTM A194/A194M, Grade 2H
	Temperature > 400 °C (750 °F)	ASTM A193/A193M, Grade B16; ASTM A194/A194M, Grade 7	ASTM A193/A193M, Grade B16; ASTM A194/A194M, Grade 7				

NOTE Carbon steel piping shall conform to ASTM A106/ASTM A106M, Grade B; ASTM A524/A524M; or API 5L, Grade A or B. Carbon steel fittings, valves, and flanged components shall conform to ASTM A105/A105M and ASTM A181/A181M. Stainless steel piping shall conform to ASTM A312/A312M.

[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 Nonconsumable 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 4).

7.5.2.3 Oil supply piping and tubing, including fittings (excluding slip on flanges), shall be stainless steel (see Table 4).

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 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 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. The surface temperature of the blanket shall be limited per 7.7.3.

7.7.2 If specified, an alternate painted steel or aluminum jacket with sufficient internal insulation shall cover all portions of the casing that can reach a normal operating temperature of 75 °C (165 °F) or higher. The surface temperature of the jacket shall be limited per 7.7.3.

7.7.3 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 shall 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 subvendor plants where manufacturing, testing, or inspection of the equipment is in progress.

8.1.4 The vendor shall notify subvendors 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 expected dates of testing shall be communicated at least 30 days in advance of testing and the actual dates confirmed as agreed. The vendor shall give at least 5 working days advanced notification of 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. The pre-test shall take place at least 3 business days before the witness 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, 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, positive material identification, or liquid penetrant inspection of welds or materials is required or specified, the requirements in 8.2.2.2 through 8.2.2.6 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 8.2.2.6.

8.2.2.1.2 Acceptance standards for 8.2.2.2 through 8.2.2.6 shall be 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/E94M.

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/A388M. Acceptable criteria shall be agreed upon by the purchaser and the vendor.

8.2.2.3.2 Ultrasonic inspection shall be based upon the procedures ASTM A609/A609M (castings), ASTM A388/A388M (forgings), or ASTM A578/A578M (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/E165M.

8.2.2.6 Positive Material Identification (PMI)

8.2.2.6.1 PMI testing shall be in accordance with 8.2.2.6.2 through 8.2.2.6.7.

● **8.2.2.6.2** If specified, alloy steel items shall be subject to PMI testing.

8.2.2.6.3 If PMI testing has been specified for a fabrication, the components comprising the fabrication, including welds, shall be checked after the fabrication is complete.

8.2.2.6.4 Unique (nonstock) components such as turbine blading and shafts may be tested after manufacturing and prior to rotor assembly.

8.2.2.6.5 If PMI is specified, techniques providing quantitative results shall be used.

NOTE 1 PMI test methods are intended to identify alloy materials and are not intended to establish the exact conformance of a material to an alloy specification.

NOTE 2 API 578 includes additional information on PMI testing.

NOTE 3 PMI is used to verify that the specified materials are used in the manufacturing, fabrication, and assembly of components.

8.2.2.6.6 Mill test reports, material composition certificates, visual stamps, or markings shall not be considered as substitutes for PMI testing, or vice versa.

8.2.2.6.7 PMI results shall be within the material specification limits, allowing for the measurement uncertainty (inaccuracy) of the PMI device as specified by the device vendor (manufacturer).

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.

8.2.3.3 If specified, a record of the bluing contact between shaft and liner bearings shall be provided.

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 6 weeks before the first scheduled running test, the vendor shall submit to the purchaser, for their 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 10 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 5 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 MAWP 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 *BPVC* 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 data sheets shall list actual hydrostatic test pressures.

NOTE Applicability of this requirement to the material being tested is to 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) 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.

b) Test-stand oil shall meet the cleanliness requirements of API 614 before any test is started.

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

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

e) 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.

f) 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).

g) 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.

h) The vibration characteristics determined by the use of the instrumentation specified in 8.3.3.1 f) or 8.3.3.1 g) 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 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.

8.3.3.3 The equipment shall be operated at speed increments of approximately 10 % of maximum continuous speed from zero to the maximum continuous speed and run at the maximum continuous speed until bearings, lube-oil temperatures, and shaft vibrations have stabilized. A typical guideline for bearing and lube oil temperature stabilization is not more than 2 °F (1 °C) over a 10-minute period.

NOTE Machines equipped with ring-oiled or splash lubrication systems do not always reach absolute temperature stabilization during shop tests of short duration. The speed shall be increased to approximately 100 rpm below the minimum trip speed and the equipment shall be run for a minimum of 15 minutes at the increased speed.

a) Mechanical overspeed trip devices shall be checked and adjusted until three consecutive non-trending trip values within ± 2 % of the nominal trip setting are attained.

b) Electronic overspeed trip system shall be verified that three consecutive non-trending trip values within ± 3 rpm of the nominal trip setting are attained.

c) The speed governor and any other speed-regulating devices shall be tested for smooth performance over the operating speed range. No-load stability (the maximum speed variation at maximum continuous speed, the acceptance value is to be agreed upon between the vendor and purchaser) and response to the control signal shall be checked, if the governor is equipped with a manual or pneumatic speed changer.

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

e) Vibration readings shall be taken at maximum continuous speed, just below trip speed and at minimum specified governor speed, after the stabilization described in 8.3.3.3. 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 6.9.4.6 are 1.5 times the stated values.

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

8.3.3.4 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

● 8.3.4.1 General

If specified, the shop tests described in 8.3.4.2 through 8.3.4.6 shall be performed. Test details shall be agreed upon by the purchaser and the vendor.

8.3.4.2 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 they propose to conduct the tests. Performance tests should follow guidelines noted in ASME PTC 6. Details shall be agreed between purchaser and vendor.

NOTE Performance tests are not normally required for general-purpose steam turbines.

● 8.3.4.3 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.

● **8.3.4.4 Gear Test**

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

8.3.4.5 Sound-level Test

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

NOTE This test does not reflect field sound levels due to shop test environment.

8.3.4.6 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.

8.4.2 Rotors shall be protected to mitigate damage during shipment.

8.4.3 If the turbine is shipped with a blocked rotor or is shipped with a protective film between the bearings and bearing journals, corrosion-resistant warning tags shall be positively attached to warn that the blocking device or protective film be removed before commissioning.

8.4.4 The preparation shall make the equipment suitable for 6 months of outdoor storage from the time of shipment, with no disassembly required before operation, except for inspection of bearings and seals.

8.4.5 If storage for a longer period is contemplated, the purchaser will consult with the vendor regarding the recommended procedures to be followed.

8.4.6 The vendor shall provide the purchaser with the instructions necessary to preserve the integrity of the storage preparation before start-up, as described in API 686.

8.4.7 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 Items a) through l) 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 preventative.

c) The interior of the equipment shall be clean; free from scale, welding spatter, and foreign objects; and sprayed or flushed with a rust preventative that can be removed with solvent. The rust preventative 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 preventative 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 nonmetallic (such as plastic) caps or plugs be used.

NOTE These are shipping plugs; permanent plugs are covered in 6.5.9.

g) 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.

h) 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.

i) If a spare rotor is purchased, the rotor shall be prepared for unheated indoor storage for a period of at least 3 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.

j) 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.

k) All turbines that are supplied without self-supporting baseplates 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.

l) 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.

8.4.8 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.

8.4.9 Bearing housing 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.

8.4.10 If vapor phase inhibitor crystal bags are provided in casing, they 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.

8.4.11 One copy of the manufacturer’s standard installation instructions shall be packed and shipped with the equipment. Instructions to describe means to maintain integrity of storage preservation if disturbed shall be included.

8.4.12 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 purchaser may specify the content of proposals, meeting frequency and vendor data content/format identified in Annex C. Annex C provides a general outline of information that potentially may be requested by the purchaser.

9.1.2 If specified, the information specified in Annex C shall be provided.

Annex A
(informative)

General-purpose Steam Turbine Data Sheet

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

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

The data sheet 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 data sheet 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.

GENERAL-PURPOSE STEAM TURBINE
API 611 6TH 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: ______ UNITS OF MEASURE (5.1): SI
2 FOR ______ NO. REQUIRED ______
3 SITE ______ DRIVEN EQUIPMENT ______
4 SERVICE / UNIT ______ MODEL ______ SERIAL NO. ______
5 MANUFACTURER ______ EQUIPMENT RELIABILITY (6.1.1.1) ______ DOCUMENTATION REQUIRED (6.1.1.2) ______
6

7	OPERATING CONDITIONS (6.1.4)		
8–9	OPERATING POINT	ABSORBED POWER, kW	SPEED, RPM
10	NORMAL		
11	RATED		
12	OTHER		

7	PERFORMANCE (6.1.9)		
8–9	OPERATING POINT/ STEAM CONDITION	NO. HAND VALVES OPEN	STEAM RATE, kg/kW-h
10	NORMAL/NORMAL CERTIFIED STEAM RATE		
11	RATED/NORMAL		
12	RATED @ MINIMUM INLET & MAXIMUM EXHAUST		
13	OTHER/NORMAL CONDITIONS		

13 DUTY, SITE, AND UTILITY DATA

14 APPLICATION IS: ______ OPERATION (6.1.2) ______
15 PERIOD OF UNINTERRUPTED OPERATION (6.1.2) ______ Years
16 WIDE SPEED RANGE (6.11.6) ______ RAPID START ______
17 SLOW ROLL REQUIRED (6.11.6) ______ HAND VALVES ______
18 IMMEDIATE UNATTENDED AUTO START (6.1.11) ______
19 LOCATION (6.1.22) ______ ______ ______
20 AMBIENT TEMP. (6.1.22) MIN. ______ MAX. ______ °K
21 SUN METAL TEMP. (6.1.22) ______ °K MDMT(6.12.5.1) ______ °K
22 UNUSUAL CONDITIONS (6.1.22) ______
23 MATERIALS NOT PERMITTED (6.1.23) ______
24 RESTRICTED ENVIRONMENT (6.1.23) Atmosphere
25 AREA CLASSIFICATION (6.1.21 ZONE 2
26 GROUP Class I / Group A TEMPERATURE CLASS T2
27 CONTROL POWER V ______ PH. ______ HZ ______
28 AUX. MOTORS V ______ PH. ______ HZ ______
29 COOLING WATER: PRESS, ______ kPa g DP ______ kPa
30 FLOW ______ m³/s DT ______ °K
31 ALLOW. SOUND PRESS LEVEL (6.1.19) ______ dBA @ ______ m

32 STEAM CONDITIONS (6.1.5)

33		MAX	NORMAL	MIN.	
34	INLET PRESS,				kPa g
35	INLET TEMP				kPa g
36	EXHAUST PRESS				kPa g

37 STEAM CONTAMINANTS ______

38 TURBINE DATA

39 ALLOW SPEEDS, RPM, MAX ______ MIN ______
40 MAX CONT. SPEED, RPM MAX ______ MIN ______
41 TRIP SPEED, RPM ______ BLADE TIP VEL, ______ m/s
42 FIRST CRITICAL SPEED, RPM ______
43 EXH. TEMP NORMAL ______ NO LOAD ______ N
44 POTENTIAL MAX POWER (3.1.36) ______ kW
45 MAX. NOZZLE STEAM FLOW, ______ kg/h
46 ROTATION FACING TURBINE NON DRIVE END ______
47 VERTICAL DRIVEN EQUIPMENT THRUST (6.10.1.3) ______
48 VERTICAL TURBINE THRUST CPTY DOWN ______ N UP ______ N
49 COOLING WATER PIPING REQUIRED: ______
50 FURNISHED BY: ______
51 OIL PIPING REQUIRED: ______
52 FURNISHED BY: ______
53 REMARKS: ______
54 ______

14 APPLICABLE SPECIFICATION

15 API-611 OTHER ______
16 ______
17 ______

19 CONSTRUCTION

20 TURBINE TYPE ______
21 NO STAGES ______ WHEEL DIA., ______ mm
22 ROTOR: CONSTRUCTION ______
23 ARRANGEMENT ______
24 BLADING ______
25 CASING SPLIT ______
26 CASING SUPPORT ______
27 VERTICAL JACKSCREWS FURNISHED (6.3.30) ______
28 VERTICAL TURBINE BASE DESIGN (6.5.14) OTHER
29 OTHER ______
30 TRIP VALVE ______
31 INTERSTAGE SEALS ______
32 END SEALS (6.8.1/ 6.8.3 / 6.8.12) ______
33 ______
34 TYPE RADIAL BEARINGS (6.10.1.1) ______
35 TYPE THRUST BEARING ______
36 THRUST COLLAR (6.10.3.2.4) ______
37 LUBE OIL VISCOSITY ISO GRADE (6.11.2) ______ ______
38 LUBRICATION ______
39 OIL MIST ______
40 OIL MIST SYSTEM ______
41 BEARING HOUSING OILER TYPE (6.10.4.1.2) ______
42 BEARING HOUSING SEAL (6.10.4.2.1 /2) Bearing Isolation Seal
43 SEAL SUPPLIER ______

44	CASING DESIGN	INLET	EXHAUST	
45	MAX. ALLOW. PRESS,			kPa g
46	MAX ALLOW. TEMP,			°K
47	HYDRO TEST PRESS.,			kPa g
48				

50 REMARKS: ______
51 ______
52 ______
53 ______
54 ______

Figure A.1—Data Sheet, SI Units

GENERAL-PURPOSE STEAM TURBINE
API 611 6TH EDITION DATA SHEET
SI Units

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

No.							
1	**MATERIALS (6.121.1/6.12.1.2)**						**ACCESSORY EQUIPMENT BY VENDOR**
2	HIGH PRESSURE CASING	GRADE					REMOTE TRIP SOLENOID
3							TURBINE TRIPPED SIGNAL
4	EXHAUST CASING	GRADE					VACUUM BREAKER (7.3.4.2.10)
5	NOZZLES	GRADE					AUTOMATIC STEAM SEALING SYSTEM (6.8.8)
6	BLADING	GRADE					SEALING STEAM ______ kPa g ______ °K
7	WHEELS	GRADE					GLAND VACUUM DEVICE WITH: (6.8.5)
8	SHAFT	GRADE					SENTINEL WARNING VALVE (7.4.5.2)
9	SHAFT COATING UNDER PACKING (6.7.2.9)						ALTERNATE INSULATION, TYPE (7.7.2)
10	MATERIAL (6.7.2.10)						TACHOMETER TYPE
11	APPLICATION METHOD (6.7.2.9)						MFR. ______ MODEL
12	THICKNESS						MOUNTED BY
13	GOV. VALVE TRIM						THERMAL RELIEF VALVES (7.4.4.9.4)
14	INLET STRAINER (7.4.2.1.3)	MESH SIZE					**REMARKS;**
15							
16	**CONNECTIONS (6.5.1/6.5.2/6.5.11.e)**						
17		SIZE	RATING	FACING	POSITION	MATE	
18	INLET						
19	EXHAUST						
20	DRAINS HP						
21	DRAINS LP						
22	LEAKOFF						**EXTERNAL LUBE OIL SYSTEM**
23							TYPE OF LUBE SYSTEM SUPPLIED (6.11.3)
24	**COUPLINGS (7.2)**						VENDOR FURNISH SYSTEM FOR: (6.11.3 a)
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 (7.2.7)						
32	SERVICE FACTOR						**VIBRATION, AXIAL POSITION, ONE-EVENT-PER-REVOLUTION DETECTOR (7.4.4.3)**
33	COUPLING SPACER/HUBS MATL. (7.2.12c)						
34	COUPLING DIAPHRAGMS (DISKS) MATL. (7.2.12a)						**FURNISH PROVISIONS FOR MOUNTING NON-CONTACTING**
35	TURBINE VENDOR MOUNTS HUB (7.2.4)						VIBRATION PROBES (7.4.4.3.1)
36	COUPLING CONSTRUCTED TO (7.2.14)						FURN. AXIAL POSITION PROBES 7.4.4.3.2 ______ NO. OF PROBES
37	SEE SEPARATE DATA SHEET						MFR. ______ MODEL
38	COUPLING BALANCED TO (7.2.13)						FURN. ONE EVENT PER REV PROBE (7.4.4.3.3)
39	TURBINE SHAFT						MFR. ______ MODEL
40							FURN. RADIAL PROBES ______ NO. OF PROBES/BEARING
41							MFR. ______ MODEL
42	**BASE/SOLE PLATES**						FURNISH BEARING METAL TEMP SENSORS FOR:
43	TURBINE MOUNTED ON (7.3.1.1, 7.3.2.16)						RADIAL BEARINGS ______ THRUST BEARINGS
44	FURN. BY:						MAGNETIC SEISMIC TRANSDUCERS (6.10.4.4.2)
45	EPOXY GROUT(7.3.1.13)						PERMANENT SEISMIC TRANSDUCERS (6.10.4.4.3)
46	EQUIPMENT MOUNTED: (7.3.2.1) ______ OTHER						MFR. ______ MODEL
47	OTHER						**TURBINE VENDOR SUPPLIES MONITORS**
48	COLUMN MOUNTED BASEPLATE (7.3.2.6)						AXIAL AND RADIAL PROBES
49	BASEPLATE DESIGNED FOR OPTICAL LASER (7.3.2.5)						BEARING TEMPERATURE SENSORS
50	SUBPLATES REQUIRED (7.3.2.14)						SEE SEPARATE DATA SHEETS FOR DETAILS
51	COMMERCIAL AVAILABLE LIFTING ATTACHMENTS(7.3.2.7.7)						**REMARKS:**
52	**GEARBOX**						
53	GEARBOX REQUIRED						
54	FURN. BY:						
55	APPLICABLE SPECIFICATION						
56	GEARBOX DATA SHEET NUMBER						

Figure A.1—Data Sheet, SI Units (Continued)

GENERAL-PURPOSE STEAM TURBINE
API 611 6TH EDITION DATA SHEET
SI Units

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

GOVERNING SYSTEM (7.4.2.1)

GOVERNOR TYPE (7.4.2.2.1) ______
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 ____ kPa g

GOVERNOR POWER SUPPLY ______

REMOTE TRIP INPUT TO ELECTRONIC GOVERNOR ______
ELECTRONIC GOVERNOR SUITABLE FOR SLOW ROLL (7.4.2.2.7) ______

OVERSPEED TRIP (7.4.2.3.3) ______
OVERSPEED VOTING (7.4.2.3.7) ______
No. ACTUATION DEVICES ______
MANUFACTURER ______
MODEL ______
REMARKS: ______

CONTROL PANELS AND INSTRUMENTATION (7.4.3)

CONTROL PANELS AND INSTRUMENTATION (7.4.1.2) OUTDOOR
TERMINAL BOXES SPECIFICATIONS (7.4.1.6) NEMA 7
LOCAL GAUGE BOARD WITH GAUGES (7.4.3.1/7.4.3.2) NO
THROTTLE STEAM YES RING PRESSURE ____ FREE STANDING YES
1st STAGE PRESSURE YES EXHAUST YES
GAUGE BOARD LOCATION ______
OTHER LOCATION [7.4.3.2 c)] ______
CONTROL PANEL ENCLOSED (7.4.3.5) ______
SIGNAL SEGREGATION (7.4.3.9) ______
GAUGES LIQUID-FILLED (7.4.4.7.2) ______
TROPICAL LOCATION (7.4.6.5) ______
SWITCHES OR TRANSMITTERS (7.4.5.3.4) ______
REMARKS: ______

ENGINEERING REQUIREMENTS

SUPPLY ENGR. DATA FOR LATERAL/TORSIONAL ANALYSES (6.9.2.2)

BY TURBINE VENDOR ______
CALCS AND/OR DATA FOR SEPARATION MARGIN (6.9.2.3) ______
TRAIN TORSIONAL VIBRATION ANALYSIS (6.9.3) ______
PARTY HAVING UNIT RESPONSIBILITY (4.1) ______
ROTOR RUNNING CLEARANCES [8.2.1.1 f)] ______
REMARKS: ______

INSPECTION REQUIREMENTS

USE INSPECTOR'S CHECK LIST (8.1.2) ______
FORGING 100% UT INSPECTION AFTER ROUGH MACHINING ______
CASTING SURFACE INSPECTION (8.2.2.1.3) MSS. SP-55 ______

CASTING WELD REPAIR APPROVAL [6.12.2.3 b)] ______
FABRICATION WELD INSPECTION [6.12.4.5 b)] ______
SPECIAL INSPECTION (8.2.1.3) ______
PMI OF ALLOY MATERIALS (8.2.2.6.2) ______

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

PREPARATION FOR SHIPMENT

TURBINE, AUX. EQUIP. AND SPARE ROTOR PREPARED FOR : (8.4.1)
DOMESTIC SHIPMENT
OUTDOOR STORAGE LONGER THAN (8.4.4 / 8.4.5) ____ Months
REMARKS: ______

TESTS (8.3)	REQ'D.	WITNESS.	OBSVD. (3.1.31)
HYDROSTATIC (8.3.2.1)			
DYNAMIC BALANCE (6.9.4.2)			
MECH. RUN (8.3.3.1) 1 h			
PERFORMANCE (8.3.4.2)			
COMPLETE UNIT (8.3.4.3)			
GEAR (8.3.4.4)			
SOUND LEVEL (8.3.4.5)			
AUX. EQUIPMENT (8.3.4.6)			
RESIDUAL UNBALANCE (6.9.4.4)			
OPTIONAL TEST (8.3.4)			
______			

REMARKS: ______

DOCUMENTATION

PERFORMANCE CURVES (C 2.4) ______
PROGRESS REPORTS (C 3.3) ______
TECHNICAL DATA MANUAL (C 3.5.1) ______

WEIGHTS

TURBINE ____ kg
ROTOR ____ kg
TURBINE UPPER HALF CASING ____ kg
MAX MAINTENANCE (IDENTIFY) ______ ____ kg
T & T VALVE (IF SEPARATE) ____ kg
BASEPLATE (IF SUPPLIED) ____ kg
MISC. ____ kg
TOTAL SHIPPING WEIGHT ____ kg
REMARKS: ______

Figure A.1—Data Sheet, SI Units (Continued)

GENERAL-PURPOSE STEAM TURBINE API 611 6TH EDITION DATA SHEET Customary Units

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

APPLICABLE TO: ______ APPLICABLE STANDARD: ______ UNITS OF MEASURE (5.1): **Customary**
FOR ______ NO. REQUIRED ______
SITE ______ DRIVEN EQUIPMENT ______
SERVICE / UNIT ______ MODEL ______ SERIAL NO. ______
MANUFACTURER ______ EQUIPMENT RELIABILITY (6.1.1.1) ______ DOCUMENTATION REQUIRED (6.1.1.2) ______

OPERATING CONDITIONS (6.1.4)

OPERATING POINT	ABSORBED POWER, HP	SPEED, RPM
NORMAL		
RATED		
OTHER		

DUTY, SITE, AND UTILITY DATA

APPLICATION IS: ______ OPERATION (6.1.2) ______
PERIOD OF UNINTERRUPTED OPERATION (6.1.2) ______ Years
WIDE SPEED RANGE (6.11.6) ______ RAPID START ______
SLOW ROLL REQUIRED (6.11.6) ______ HAND VALVES ______
IMMEDIATE UNATTENDED AUTO START (6.1.11) ______
LOCATION (6.1.22) ______ ______ ______
AMBIENT TEMP. (6.1.22) MIN. ______ MAX. ______ °F
SUN METAL TEMP. (6.1.22) ______ °F MDMT(6.12.5.1) ______ °F
UNUSUAL CONDITIONS (6.1.22) ______
MATERIALS NOT PERMITTED (6.1.23) ______
RESTRICTED ENVIRONMENT (6.1.23) Atmosphere
AREA CLASSIFICATION (6.1.21 DIVISION 2
GROUP Class I / Group A TEMPERATURE CLASS T2
CONTROL POWER V ______ PH. ______ HZ ______
AUX. MOTORS V ______ PH. ______ HZ ______
COOLING WATER: PRESS, ______ psig DP ______ psi
FLOW ______ gpm DT ______ °F
ALLOW. SOUND PRESS LEVEL (6.1.19) ______ dBA @ ______ ft

STEAM CONDITIONS (6.1.5)

	MAX	NORMAL	MIN.	
INLET PRESS,				psig
INLET TEMP				psig
EXHAUST PRESS				psig

STEAM CONTAMINANTS ______

TURBINE DATA

ALLOW SPEEDS, RPM, MAX ______ MIN ______
MAX CONT. SPEED, RPM MAX ______ MIN ______
TRIP SPEED, RPM ______ BLADE TIP VEL, ______ ft/s
FIRST CRITICAL SPEED, RPM ______
EXH. TEMP NORMAL ______ NO LOAD ______ lbf
POTENTIAL MAX POWER (3.1.36) ______ HP
MAX. NOZZLE STEAM FLOW, ______ lb/h
ROTATION FACING TURBINE NON DRIVE END ______
VERTICAL DRIVEN EQUIPMENT THRUST (6.10.1.3) ______
VERTICAL TURBINE THRUST CPTY DOWN ______ lbf UP ______ lbf
COOLING WATER PIPING REQUIRED: ______
FURNISHED BY: ______
OIL PIPING REQUIRED: ______
FURNISHED BY: ______
REMARKS: ______

PERFORMANCE (6.1.9)

OPERATING POINT/ STEAM CONDITION	NO. HAND VALVES OPEN	STEAM RATE, lb/HP-h
NORMAL/NORMAL CERTIFIED STEAM RATE		
RATED/NORMAL		
RATED @ MINIMUM INLET & MAXIMUM EXHAUST		
OTHER/NORMAL CONDITIONS		

APPLICABLE SPECIFICATION

API-611 OTHER ______

CONSTRUCTION

TURBINE TYPE ______
NO STAGES ______ WHEEL DIA., ______ in
ROTOR: CONSTRUCTION ______
ARRANGEMENT ______
BLADING ______
CASING SPLIT ______
CASING SUPPORT ______
VERTICAL JACKSCREWS FURNISHED (6.3.30) ______
VERTICAL TURBINE BASE DESIGN (6.5.14) OTHER
OTHER ______
TRIP VALVE ______
INTERSTAGE SEALS ______
END SEALS (6.8.1/ 6.8.3 / 6.8.12) ______
TYPE RADIAL BEARINGS (6.10.1.1) ______
TYPE THRUST BEARING ______
THRUST COLLAR (6.10.3.2.4) ______
LUBE OIL VISCOSITY ISO GRADE (6.11.2) ______
LUBRICATION ______
OIL MIST ______
OIL MIST SYSTEM ______
BEARING HOUSING OILER TYPE (6.10.4.1.2) ______
BEARING HOUSING SEAL (6.10.4.2.1 /2) Bearing Isolation Seal
SEAL SUPPLIER ______

CASING DESIGN	INLET	EXHAUST	
MAX. ALLOW. PRESS,			psig
MAX ALLOW. TEMP,			°F
HYDRO TEST PRESS.,			psig

REMARKS: ______

Figure A.2—Data Sheet, USC Units

GENERAL-PURPOSE STEAM TURBINE
API 611 6TH EDITION DATA SHEET
Customary Units

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

MATERIALS (6.121.1/6.12.1.2)

HIGH PRESSURE CASING ______ GRADE ______

EXHAUST CASING ______ GRADE ______
NOZZLES ______ GRADE ______
BLADING ______ GRADE ______
WHEELS ______ GRADE ______
SHAFT ______ GRADE ______
SHAFT COATING UNDER PACKING (6.7.2.9) ______
MATERIAL (6.7.2.10) ______
APPLICATION METHOD (6.7.2.9) ______
THICKNESS ______
GOV. VALVE TRIM ______
INLET STRAINER (7.4.2.1.3) ______ MESH SIZE ______

CONNECTIONS (6.5.1/6.5.2/6.5.11.e)

	SIZE	RATING	FACING	POSITION	MATE
INLET					
EXHAUST					
DRAINS HP					
DRAINS LP					
LEAKOFF					

COUPLINGS (7.2)

LOCATION	TURBINE	DRIVEN
MAKE		
MODEL		
RATING (HP/100RPM)		
LUBRICATION		
LIMITED END FLOAT		
SPACER LENGTH (7.2.7)		
SERVICE FACTOR		

COUPLING SPACER/HUBS MATL. (7.2.12c) ______
COUPLING DIAPHRAGMS (DISKS) MATL. (7.2.12a) ______
TURBINE VENDOR MOUNTS HUB (7.2.4) ______
COUPLING CONSTRUCTED TO (7.2.14) ______
SEE SEPARATE DATA SHEET ______
COUPLING BALANCED TO (7.2.13) ______
TURBINE SHAFT ______

BASE/SOLE PLATES

TURBINE MOUNTED ON (7.3.1.1, 7.3.2.16) ______
FURN. BY: ______
EPOXY GROUT(7.3.1.13) ______
EQUIPMENT MOUNTED: (7.3.2.1) ______ OTHER
OTHER ______
COLUMN MOUNTED BASEPLATE (7.3.2.6) ______
BASEPLATE DESIGNED FOR OPTICAL LASER (7.3.2.5) ______
SUBPLATES REQUIRED (7.3.2.14) ______
COMMERCIAL AVAILABLE LIFTING ATTACHMENTS(7.3.2.7.7) ______

GEARBOX

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

ACCESSORY EQUIPMENT BY VENDOR

REMOTE TRIP SOLENOID ______
TURBINE TRIPPED SIGNAL ______
VACUUM BREAKER (7.3.4.2.10) ______
AUTOMATIC STEAM SEALING SYSTEM (6.8.8) ______
SEALING STEAM ______ psig ______ °F
GLAND VACUUM DEVICE WITH: (6.8.5) ______
SENTINEL WARNING VALVE (7.4.5.2) ______
ALTERNATE INSULATION, TYPE (7.7.2) ______
TACHOMETER TYPE ______
MFR. ______ MODEL ______
MOUNTED BY ______
THERMAL RELIEF VALVES (7.4.4.9.4) ______

REMARKS; ______

EXTERNAL LUBE OIL SYSTEM

TYPE OF LUBE SYSTEM SUPPLIED (6.11.3) ______
VENDOR FURNISH SYSTEM FOR: (6.11.3 a) ______
OIL SYSTEM TO BE: ______

REMARKS: ______

VIBRATION, AXIAL POSITION, ONE-EVENT-PER-REVOLUTION DETECTOR (7.4.4.3)

FURNISH PROVISIONS FOR MOUNTING NON-CONTACTING
VIBRATION PROBES (7.4.4.3.1) ______
FURN. AXIAL POSITION PROBES 7.4.4.3.2 ______ NO. OF PROBES ______
MFR. ______ MODEL ______
FURN. ONE EVENT PER REV PROBE (7.4.4.3.3) ______
MFR. ______ MODEL ______
FURN. RADIAL PROBES ______ NO. OF PROBES/BEARING ______
MFR. ______ MODEL ______
FURNISH BEARING METAL TEMP SENSORS FOR:
RADIAL BEARINGS ______ THRUST BEARINGS ______
MAGNETIC SEISMIC TRANSDUCERS (6.10.4.4.2) ______
PERMANENT SEISMIC TRANSDUCERS (6.10.4.4.3) ______
MFR. ______ MODEL ______
TURBINE VENDOR SUPPLIES MONITORS ______
AXIAL AND RADIAL PROBES ______
BEARING TEMPERATURE SENSORS ______
SEE SEPARATE DATA SHEETS FOR DETAILS ______

REMARKS: ______

Figure A.2—Data Sheet, USC Units (Continued)

GENERAL-PURPOSE STEAM TURBINE
API 611 6TH EDITION DATA SHEET
Customary Units

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

GOVERNING SYSTEM (7.4.2.1)

GOVERNOR TYPE (7.4.2.2.1) ______
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 (7.4.2.2.7) ______
OVERSPEED TRIP (7.4.2.3.3) ______
OVERSPEED VOTING (7.4.2.3.7) ______
No. ACTUATION DEVICES ______
MANUFACTURER ______
MODEL ______
REMARKS: ______

CONTROL PANELS AND INSTRUMENTATION (7.4.3)

CONTROL PANELS AND INSTRUMENTATION (7.4.1.2) OUTDOOR
TERMINAL BOXES SPECIFICATIONS (7.4.1.6) NEMA 7
LOCAL GAUGE BOARD WITH GAUGES (7.4.3.1/7.4.3.2) NO
THROTTLE STEAM YES RING PRESSURE ______ FREE STANDING YES
1st STAGE PRESSURE YES EXHAUST YES
GAUGE BOARD LOCATION ______
OTHER LOCATION [7.4.3.2 c)] ______
CONTROL PANEL ENCLOSED (7.4.3.5) ______
SIGNAL SEGREGATION (7.4.3.9) ______
GAUGES LIQUID-FILLED (7.4.4.7.2) ______
TROPICAL LOCATION (7.4.6.5) ______
SWITCHES OR TRANSMITTERS (7.4.5.3.4) ______
REMARKS: ______

ENGINEERING REQUIREMENTS

SUPPLY ENGR. DATA FOR LATERAL/TORSIONAL ANALYSES (6.9.2.2)
BY TURBINE VENDOR ______
CALCS AND/OR DATA FOR SEPARATION MARGIN (6.9.2.3) ______
TRAIN TORSIONAL VIBRATION ANALYSIS (6.9.3) ______
PARTY HAVING UNIT RESPONSIBILITY (4.1) ______
ROTOR RUNNING CLEARANCES [8.2.1.1 f)] ______
REMARKS: ______

INSPECTION REQUIREMENTS

USE INSPECTOR'S CHECK LIST (8.1.2) ______
FORGING 100% UT INSPECTION AFTER ROUGH MACHINING ______
CASTING SURFACE INSPECTION (8.2.2.1.3) MSS. SP-55 ______
CASTING WELD REPAIR APPROVAL [6.12.2.3 b)] ______
FABRICATION WELD INSPECTION [6.12.4.5 b)] ______
SPECIAL INSPECTION (8.2.1.3) ______
PMI OF ALLOY MATERIALS (8.2.2.6.2) ______

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

PREPARATION FOR SHIPMENT

TURBINE, AUX. EQUIP. AND SPARE ROTOR PREPARED FOR : (8.4.1)
DOMESTIC SHIPMENT
OUTDOOR STORAGE LONGER THAN (8.4.4 / 8.4.5) ______ Months
REMARKS: ______

TESTS (8.3)	REQ'D.	WITNESS.	OBSVD. (3.1.31)
HYDROSTATIC (8.3.2.1)			
DYNAMIC BALANCE (6.9.4.2)			
MECH. RUN (8.3.3.1) 1 h			
PERFORMANCE (8.3.4.2)			
COMPLETE UNIT (8.3.4.3)			
GEAR (8.3.4.4)			
SOUND LEVEL (8.3.4.5)			
AUX. EQUIPMENT (8.3.4.6)			
RESIDUAL UNBALANCE (6.9.4.4)			
OPTIONAL TEST (8.3.4)			
______			

REMARKS: ______

DOCUMENTATION

PERFORMANCE CURVES (C 2.4) ______
PROGRESS REPORTS (C 3.3) ______
TECHNICAL DATA MANUAL (C 3.5.1) ______

WEIGHTS

TURBINE ______ lb
ROTOR ______ lb
TURBINE UPPER HALF CASING ______ lb
MAX MAINTENANCE (IDENTIFY) ______ ______ lb
T & T VALVE (IF SEPARATE) ______ lb
BASEPLATE (IF SUPPLIED) ______ lb
MISC. ______ lb
TOTAL SHIPPING WEIGHT ______ lb
REMARKS: ______

Figure A.2—Data Sheet, USC Units (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 shall be given to all potential sources of periodic forcing phenomena (excitation) that shall 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 1 The frequency of a potential source of excitation can be less than, equal to, or greater than the rotational speed of the rotor.

NOTE 2 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 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 operating speed range or the specified separation margins (see B.2.10). The effective stiffness of the structural support shall be considered in the analysis of the dynamics of the rotor-bearing-support system [see B.2.4 d)].

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

B.1.3 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 shall 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 shall 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 shall be confirmed on the test stand during the mechanical running test (see B.3.1). The accuracy of the analytical model shall be demonstrated (see B.3).

B.2.3 Before carrying out the damped unbalanced response analysis, the vendor shall 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 shall be furnished. The presentation of the results shall 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 shall 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.

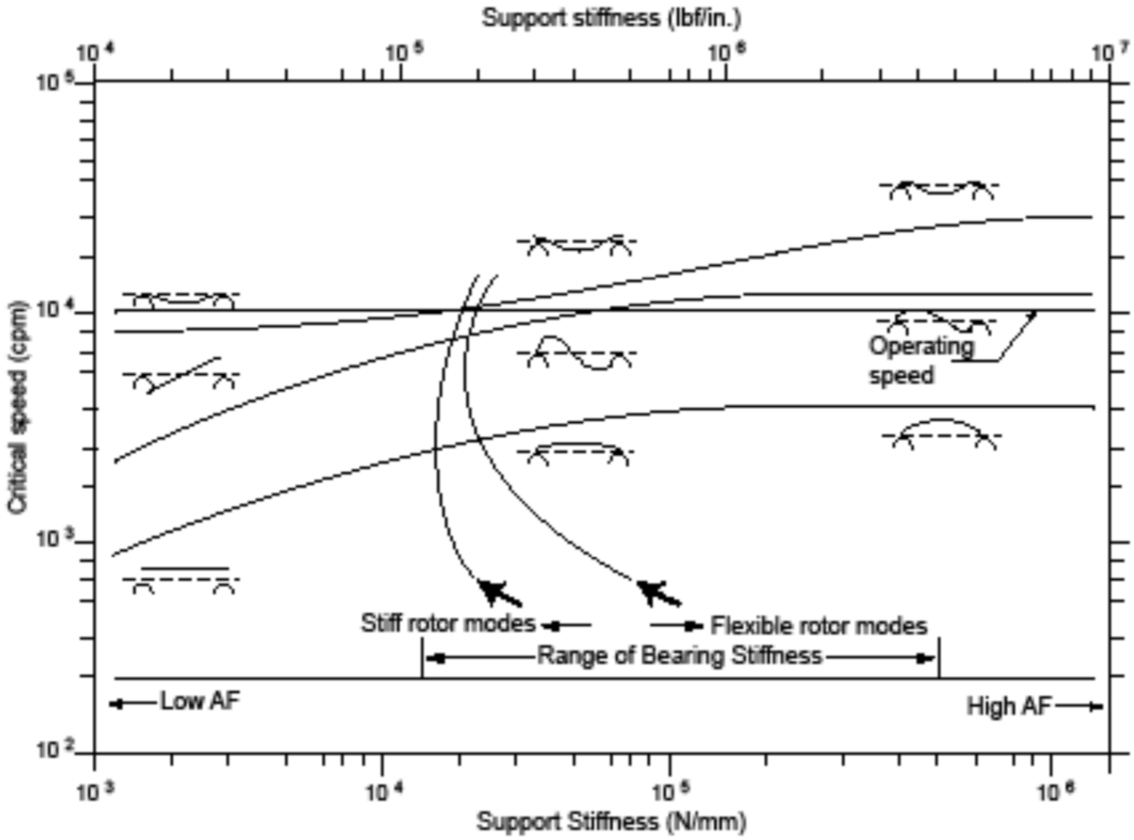


Figure B.1—Undamped Unbalanced Response Analysis

B.2.4 The damped unbalanced response analysis shall include but shall 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) shall be used. The vendor shall 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 1 The support stiffness in most cases can be no more than 8.75 × 106 N/mm (5 × 106 lb/in.).

NOTE 2 Guidelines are used to define whether or not bearing support stiffness is 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 that shall 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 shall 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 shall only be performed if the drive train is rigidly coupled to the compressor.

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

B.2.7 A separate damped unbalanced response analysis shall be conducted for each critical speed within the speed range of 0 % to 125 % of trip speed. Unbalance or side load shall 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 shall be based on the sum of the journal static loads and shall be applied at the location of maximum displacement. For conical (asymmetric) modes, an unbalance shall be added at the location of maximum displacement nearest to each journal bearing. These unbalances shall 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 shall be four times the value of U as calculated by Equation (B.1).

In SI units:

$$U = 6350 W/N \qquad \text{(B.1)}$$

In USC units:

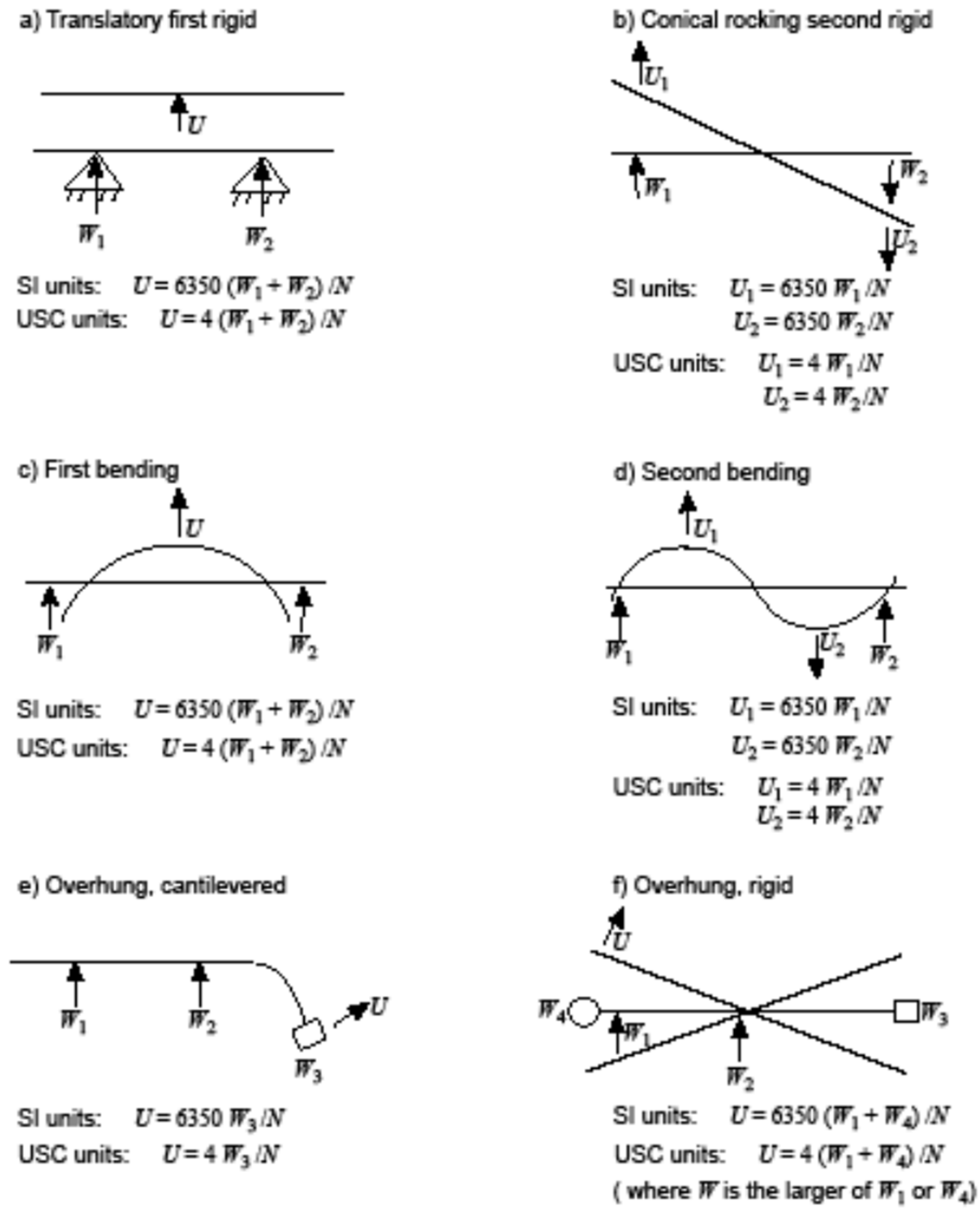
$$U = 4 W/N$$

where

U is the input unbalance for the rotor dynamic response analysis in g·mm (oz-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.



Key

U unbalance mass in g·mm (oz-in.)

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.2.8 As a minimum, the unbalanced response analysis shall 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 shall 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 shall be made for use with the verification test described in B.3. The vendor shall determine the location of the unbalance. Any test stand parameters that influence the results of the analysis shall be included.

NOTE For most machines, there will only be one plane readily accessible for the placement of an unbalance, e.g. 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.

B.2.10 The damped unbalanced response analysis shall 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 AF 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) shall not be less than the value from Equation (B.2) or the value 16, whichever is less.

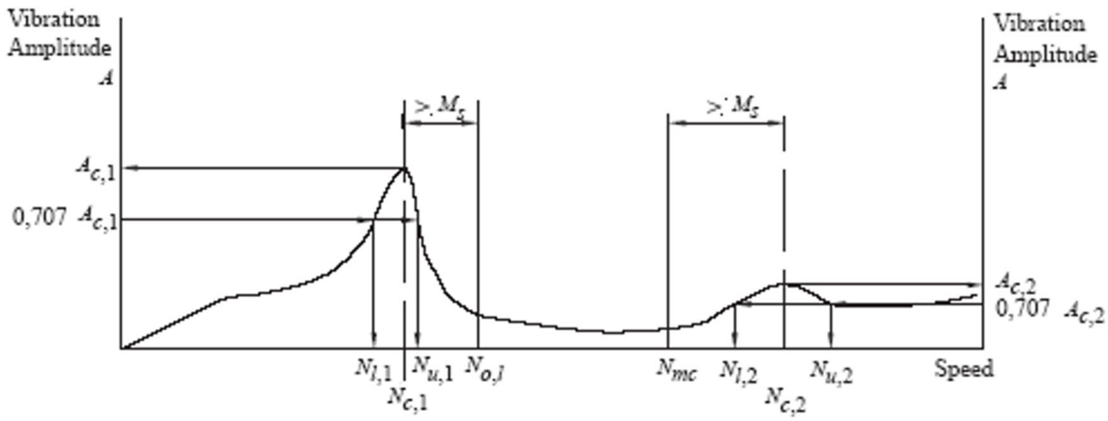
$$SM = 17\left(1 - \frac{1}{AF - 1.5}\right) \tag{B.2}$$

c) If the AF 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) shall not be less than the value from Equation (B.3) or the value of 26, whichever 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)] shall be multiplied using the correction factor calculated from Equation (B.4).

$$CF = \frac{A_{\text{l}}}{A_{4\text{x}}} \tag{B.4}$$



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 any 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_l 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:

$$A_l = 25\sqrt{\frac{12{,}000}{N}} \tag{B.5}$$

In USC units:

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

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 shall 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 shall be 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 shall be performed as part of the mechanical running test (see 8.3.3), and the results shall 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 shall 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 shall 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 shall be recorded. The gain of any analog recording instruments used shall 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 could be the result of residual unbalance and mechanical and electrical runout.

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

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

B.3.1.4 The machine shall then be brought up to the operating speed nearest the critical and the indicated vibration amplitudes and phase shall 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 shall 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 shall be compared with those from the analytical model specified at B.2.9.

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

a) The actual critical speeds determined on test shall 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 shall 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. If the operating speed fall between these critical speeds, these two critical speeds are to 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, shall not exceed the predicted values. The predicted peak response amplitude range shall be determined from the computer model based on the four radial probe locations.

NOTE The AF 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 AF using test data can be difficult to calculate. This diminishes the value of calculating the AF 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 AF 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 shall 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 shall be compared with the predicted absolute shaft movement.

B.3.4 The verification test of the rotor unbalance shall 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 shall 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 shall 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 exist:

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 shall be placed as described in B.2.7; this may require disassembly of the machine. Unbalance magnitudes shall 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 shall 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, shall meet the following criteria:

a) at no speed outside the operating speed range, including the separation margins, shall 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, shall 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) shall 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 shall 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 shall 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 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 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 shall be considered in the analysis. These sources shall 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 shall 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 shall preferably be avoided or, in systems in which corresponding excitation frequencies occur, shall 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 shall 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 shall be clearly stated. The purchaser and the vendor shall 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 shall perform a transient torsional vibration analysis for turbine generators sets. The purchaser and the vendor shall agree upon the acceptance criteria for this analysis.

Annex C
(informative)

Contract Documents and Engineering Design Data

C.1 When specified by the purchaser in 9.1.2, the contract documents and engineering design data shall be supplied by the vendor, as listed in this annex.

C.1.1 The following data shall be identified with the following information on transmittal (cover) letters, title pages, and correspondence:

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

b) job/project number;

c) equipment item number and service name;

d) inquiry or purchase order number;

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

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

C.1.2 Each drawing shall have a title block in the lower right-hand corner with the date of certification, identification data specified in C.1.1, revision number, and date and title. Similar information shall be provided on all other documents including subvendor items.

C.2 Proposals

C.2.1 General

C.2.1.1 The vendor shall forward the original proposal, with the specified number of copies, to the addressee specified in the inquiry documents.

C.2.1.2 The proposal shall include, as a minimum, the data specified in C.2.2 through C.2.5 and a specific statement that the equipment and all its components and auxiliaries are in strict accordance with this standard.

C.2.1.3 If the equipment or any of its components or auxiliaries are not in strict accordance, the vendor shall include a list that details and explains each deviation.

C.2.1.4 The vendor shall provide sufficient detail to enable the purchaser to evaluate any proposed alternative designs.

C.2.1.5 All correspondence shall be clearly identified in accordance with C.1.2.

C.2.2 Drawings

C.2.2.1 The drawings indicated on the VDDR form in this annex 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 shall show the following:

   1) showing overall dimensions,

   2) maintenance clearance dimensions,

   3) overall weights, erection weights, and the largest maintenance weight for each item,

   4) the direction of rotation,

   5) the size and location of major purchaser connections,

   6) allowable forces and moments.

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.

d) Bills of material.

e) 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) above.]

C.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.

C.2.3 Technical Data for Proposal

C.2.3.1 All technical data shall be given in units of measurement according to the purchase order. If needed, the technical data in alternate units can be included in parentheses.

C.2.3.2 The following data shall be included in the proposal.

a) Purchaser's data sheets with complete vendor's information entered thereon and literature to fully describe details of the offering.

b) Predicted noise data (8.3.4.5).

c) VDDR form (or equivalent listing) indicating the schedule according to which the vendor agrees to transmit all the data specified.

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

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

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

g) List of the special tools furnished for maintenance.

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

i) 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) Description of any optional or additional tests and inspection procedures for materials as required by 8.2.2.

k) 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.

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

m) A list of any components that can be construed as being of alternative design, hence requiring purchaser's acceptance (C.2.1.4).

n) Component designed for a finite life (6.1.3).

C.2.4 Curves

The vendor shall provide complete performance curves to encompass the map of operations, with any limitations indicated thereon.

C.2.5 Optional Tests

The vendor shall furnish an outline of the procedures to be used for each of the special or optional tests that have been specified by the purchaser or proposed by the vendor.

C.3 Engineering Design Data

C.3.1 General

C.3.1.1 Engineering data shall be furnished by the vendor in accordance with the agreed VDDR form.

NOTE Typical VDDR form can be modified by the purchaser to match the specific inquiry requirements.

C.3.1.2 The purchaser shall 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 in writing. After the data have been reviewed and accepted, the vendor shall furnish certified copies in the quantities specified.

C.3.1.3 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.

C.3.2 Drawings and Technical Data

The drawings and data furnished by the vendor shall contain sufficient information so that together with the manuals specified in C.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 this annex.

C.3.3 Progress Reports

The vendor shall submit progress reports to the purchaser at intervals specified that shall, as a minimum, include the following:

a) overall progress summary,

b) status of engineering,

c) status of document submittals,

d) status of major suborders,

e) updated production schedule,

f) inspection/testing highlights for the month,

g) any pending issues.

C.3.4 Parts Lists and Recommended Spares

C.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.

C.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 shall include spare parts recommendations of subvendors that were not available for inclusion in the vendor's original proposal.

C.3.5 Installation, Operation, Maintenance, and Technical Data Manuals

C.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 C.1.2, an index sheet, and a complete list of the enclosed drawings by title and drawing number. The manual pages and drawings shall be numbered. The manual or manuals shall be prepared specifically for the equipment covered by the purchase order. "Typical" manuals are unacceptable.

C.3.5.1.1 A draft manual(s) shall be issued to purchaser 8 weeks prior to mechanical testing for review and comment.

C.3.5.1.2 Refer to the VDDR form for number of copies. Hard copies as well as electronic copies shall be provided as described on VDDR.

C.3.5.2 Installation Manual

C.3.5.2.1 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.

C.3.5.2.2 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. Vendor supplying the package shall provide the alignment offsets.

C.3.5.2.3 All drawings and data specified in C.2.2 and C.2.3 that are pertinent to proper installation shall be included as part of this manual.

C.3.5.2.4 One extra manual, over and above the specified quantity, shall be included with the first equipment shipped.

C.3.5.2.5 All recommended receiving and storage procedures shall be included.

NOTE Refer to API 686 for data required for installation.

C.3.5.3 Operating and Maintenance Manual

A manual containing all required operating and maintenance instructions shall be supplied at shipment. 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.

C.3.5.4 Technical Data Manual

The vendor shall provide the purchaser with a technical data manual at shipment.

See Figure C.1, Vendor Drawing and Data Requirements Form, on the next two pages.

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 ____
FOR ____ REVISION ____
SITE ____ UNIT ____
SERVICE ____ NO. REQUIRED ____

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 repair)[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 proposal.
[b] For single stage units, these items normally provided only in instruction manuals.
[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 purchaser connections, with allowable flange loading for inlet and exhaust steam connections;

   b) approximate overall handling weights;

   c) overall dimensions;

   d) shaft centerline 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 should 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 centerline;

      iv) one-event-per-revolution mark.

   a) 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 purchaser 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 points, 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 purchaser 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 data sheets for pumps and drivers.

b) Coolers, filters, and reservoir:

i) fabrication drawings;

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

iii) completed data sheets 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 trip limits;

b) bearing temperature warning and trip limits;

c) lube-oil temperature warning and trip 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 vs horsepower curves at normal and rated speeds under normal steam conditions (including hand valves).

18) Steam flow vs first-stage pressure curve for multi-stage machines or vs 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 vs 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 data sheets in increments and agreed upon at the time of the order;

b) inlet temperature to maximum and minimum values listed on the data sheets 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 data sheets 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 vs 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 data sheets.

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 ID;

   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.

NOTE Dismantling clearances.

Section 2—Operation:

a) start-up;

b) normal shutdown;

c) emergency trip;

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 vs horsepower;

b) steam flow vs first-stage pressure;

c) steam flow vs speed and efficiency;

d) steam flow vs 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 data sheets;

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;

NOTE Lube-oil arrangement drawing and list of connections.

h) lube-oil component drawings and data;

i) electrical and instrumentation schematics and bill of materials;

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

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

l) trip- and throttle-valve construction drawings.

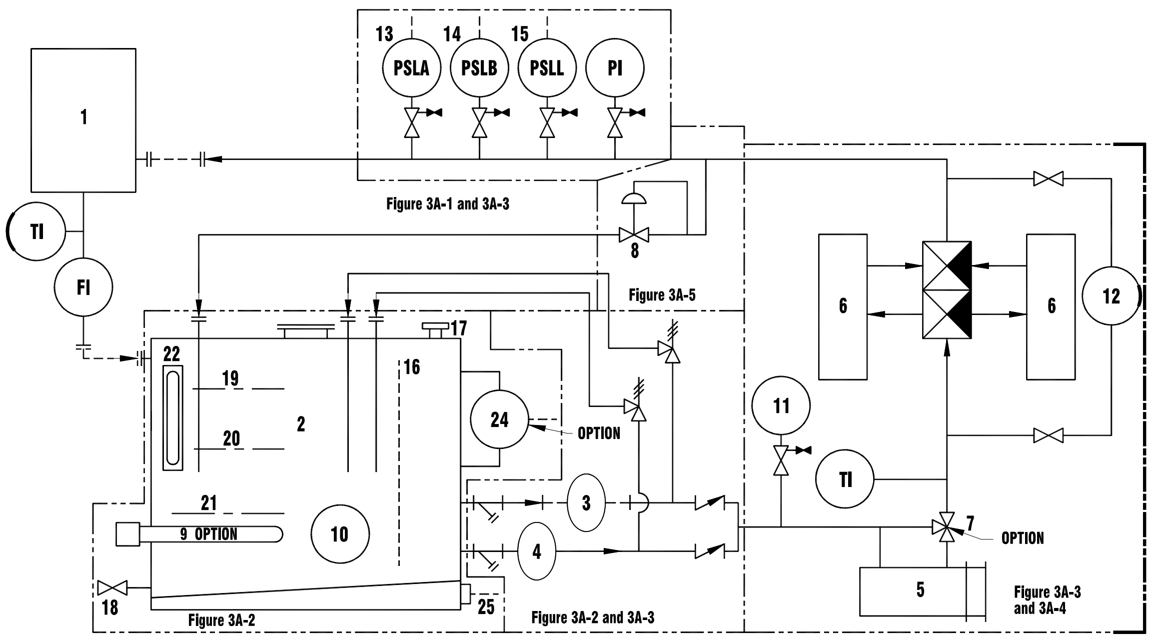
NOTE Items 7), 11), 12), 13), 22 f), and 32 [see Section 7, Items g) through i)] are required only for the turbine manufacturer's scope of supply.

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

Annex D
(normative)

Lubrication System Schematic

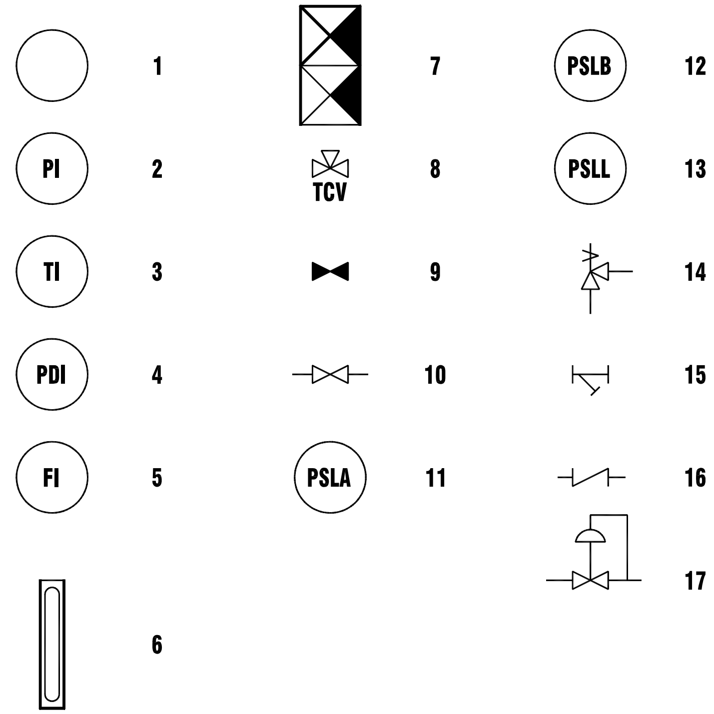
This annex contains the schematic for a standard API 611 lubrication system (see Figure D.1). This is the default lubrication system for an API 611 steam turbine in accordance with API 614 requirements with options. The default API 611 system, with or without standard options, can be indicated on the API 611 data sheet. If the purchaser requires a different lubrication system, the API 614, data sheets are required to be completed. The notes and key to symbols are shown in Figure D.2. The lube oil system schematic is shown in Table D.1.



Key

1 Rotating equipment
2 Reservoir
3 Shaft driven main oil pump
4 Motor driven main oil pump
5 Oil cooler
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 pressure indicator (3A-4 Option 7)
13 Aux. pump start signal (3A-3 Option 4)
14 Low pressure alarm signal
15 Low pressure shutdown signal
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 gauge
23 Provision for priming (3A-3 Option 2)
24 Level switch (3A-2 Option 1)
25 Grounding (3A-2 Option 5)

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 (auxiliary 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

API 614	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 the following. 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. Auxiliary 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 API 614. 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 auxiliary 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.)

API 614	Note/Option	Comments
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 API 614.
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. 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 [i.e. 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 (60° or 30°) 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 shall 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.

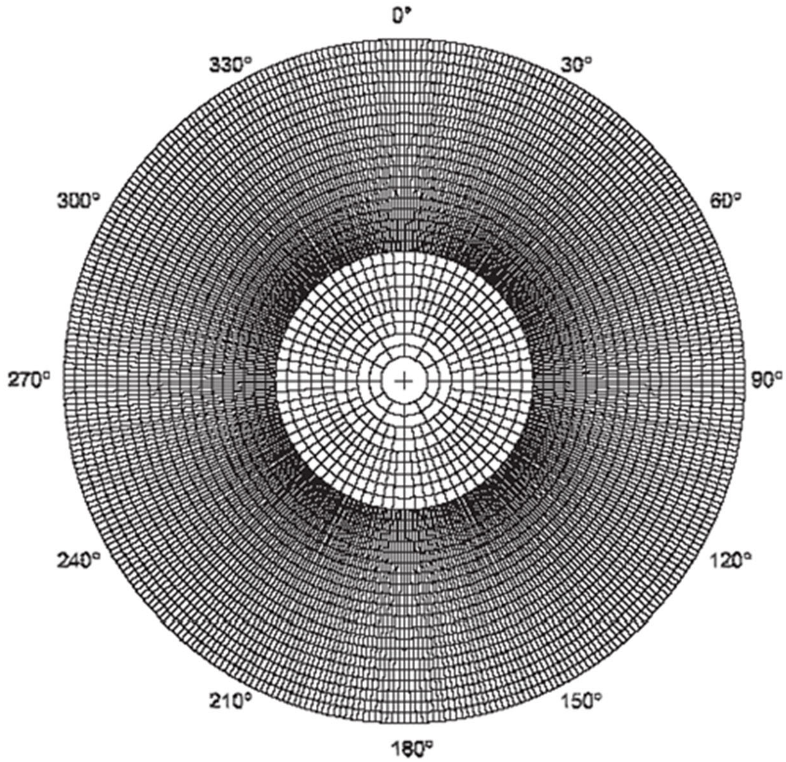
Step 4: Record the trial unbalance from above. ____________ g·mm (oz-in.)

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 Balance 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 balancing 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 E.1) ___________________ (g·mm)(oz-in.)

Correction plane _________ for rotor no. __________________________ (has/has not) passed.

By ____ Date __________________________

Figure E.1—Residual Balance Work Sheet (Continued)

Annex F
(informative)

Inspector's Checklist

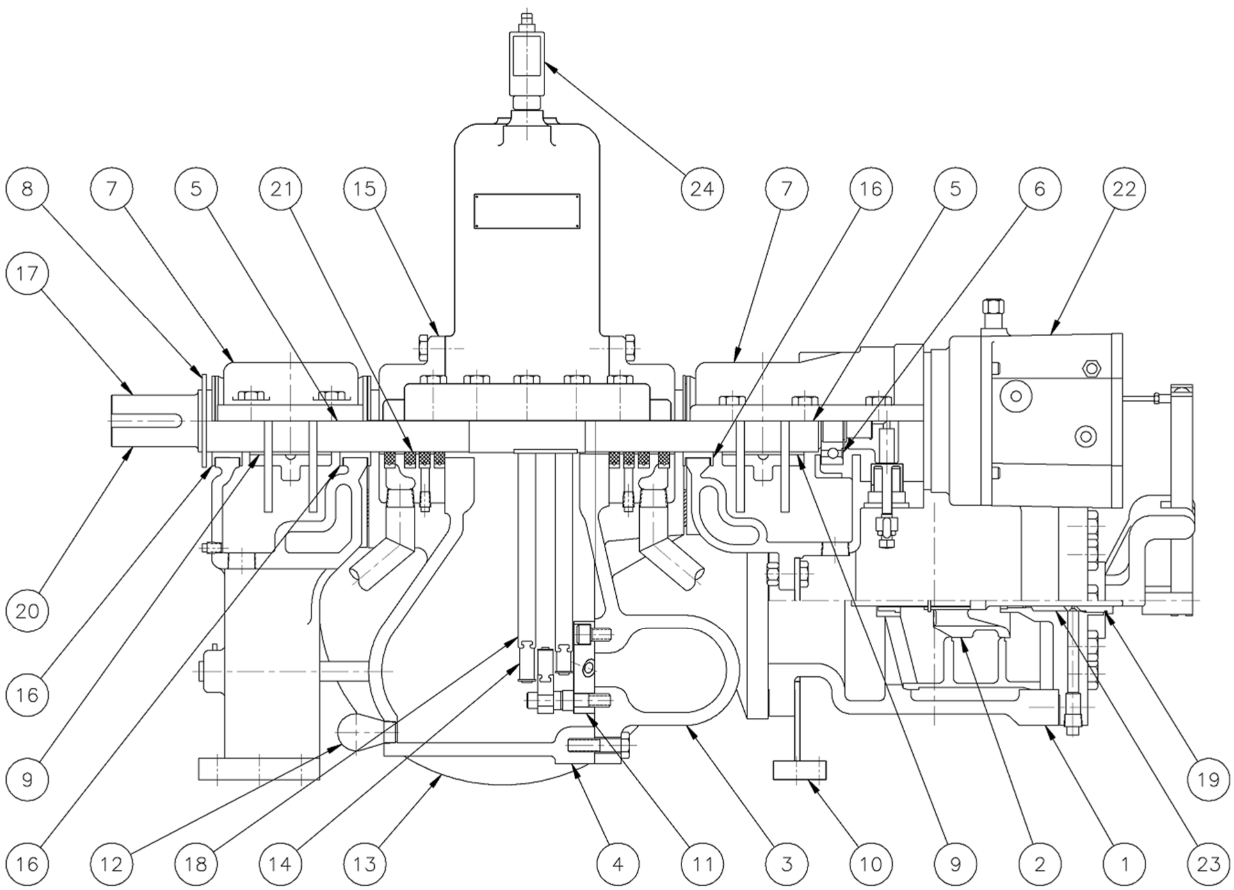
Item	API 611, 6th Edition Reference	Reviewed	Observed	Witnessed	Inspected By	Status
General						
Final assembly maintenance and assembly clearances (optional)	8.2.1.1 f)					
Surface and subsurface inspection (optional)	8.2.1.3					
Material Inspection						
Material inspection certification/testing (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	6.9.4.6/6.9.4.9 8.3.3.1 h)					
Contract shaft seals and bearings	8.3.3.1 a)					
Oil flows, pressure, and temperature as specified (optional)	8.3.3.1 b)					
No leaks observed	8.3.3.1 e)					
Protective devices operational	8.3.3.1 f)					
Bearing inspection after test satisfactory	8.3.3.3 a)					
Spare rotor fit and run	8.3.3.3 c)					

Item	API 611, 6th Edition Reference	Reviewed	Observed	Witnessed	Inspected By	Status
Optional Tests						
Performance	8.3.4.2					
Complete unit test	8.3.4.3					
Gear test	8.3.4.4					
Sound level test	8.3.4.5					
Auxiliary equipment test	8.3.4.6					
Preparation for Shipment						
Preparation complete	8.4.1					
Paint	8.4.7 a)					
Rust preventative (exterior and interior)	8.4.7 b)/8.4.7 c)					
Tags complete	8.4.8/8.4.7 h)					
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 do they 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.



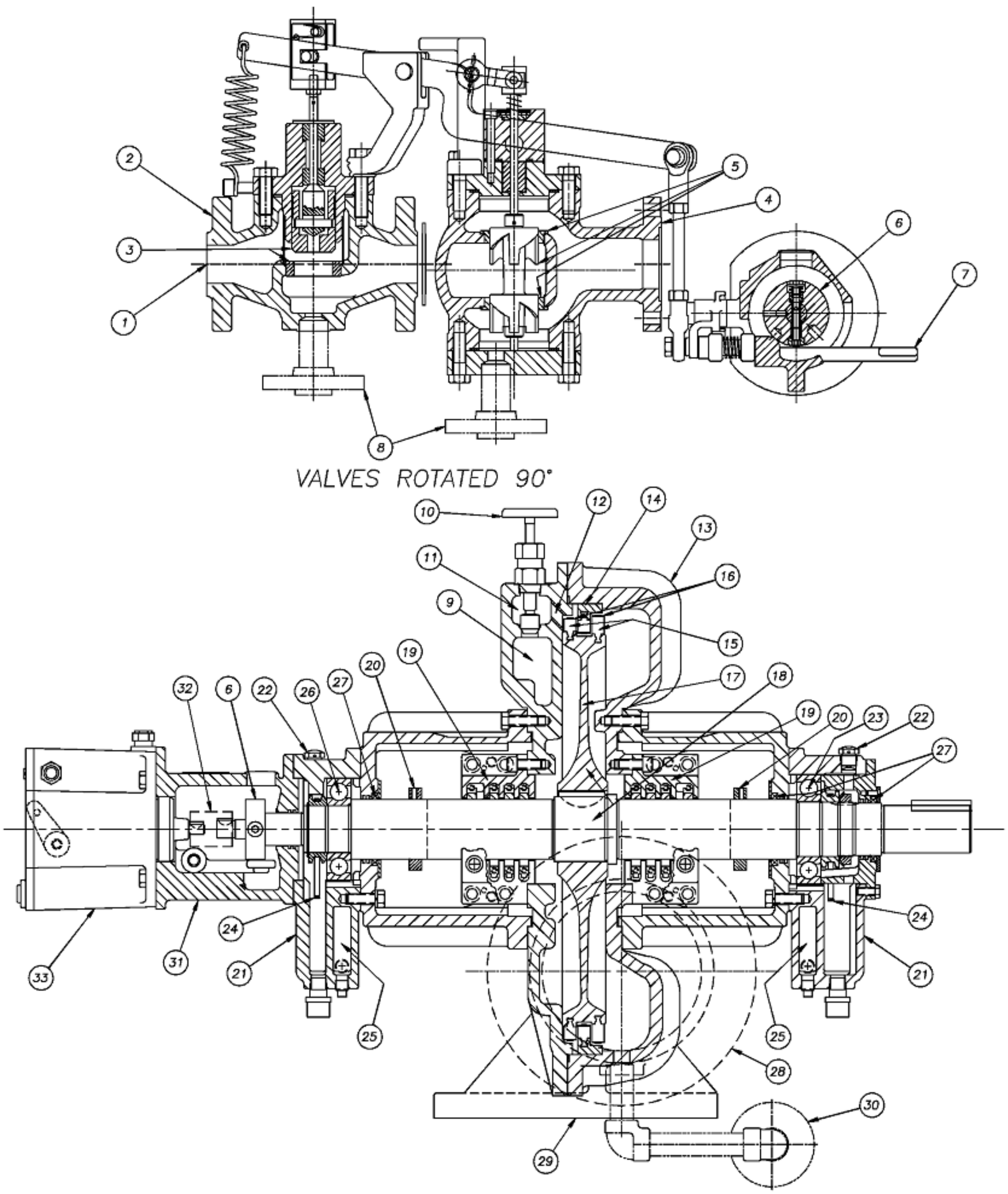
Key

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. Sentinel warning valve

25.* Thrust collar
26.* Tip seal
27.* Bearing housing deflector
28.* Breather vent
29.* Steam balance holes
30.* Hand operated nozzle valve
31.* Trip valve

* Items not shown

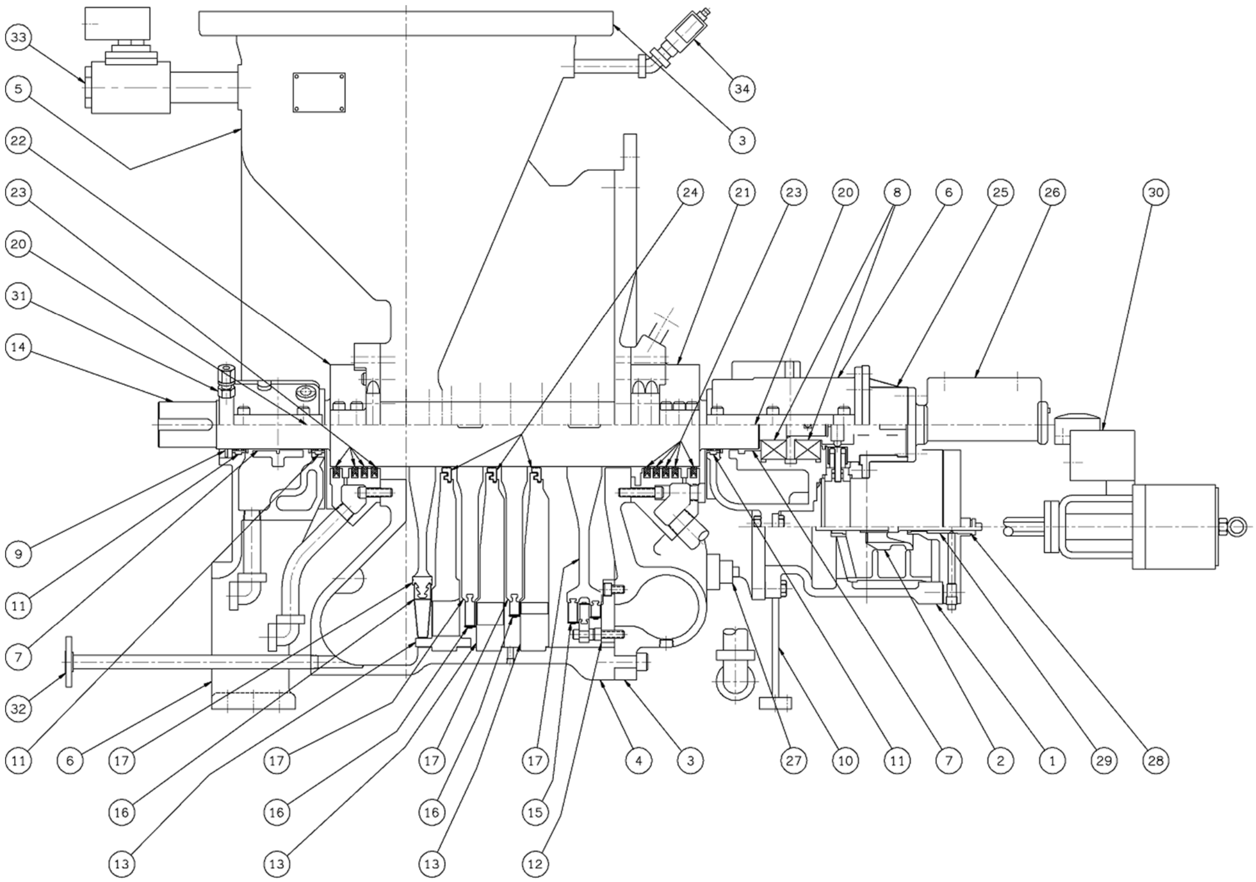
Figure G.1—Axial Split Single-stage Turbine



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. 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

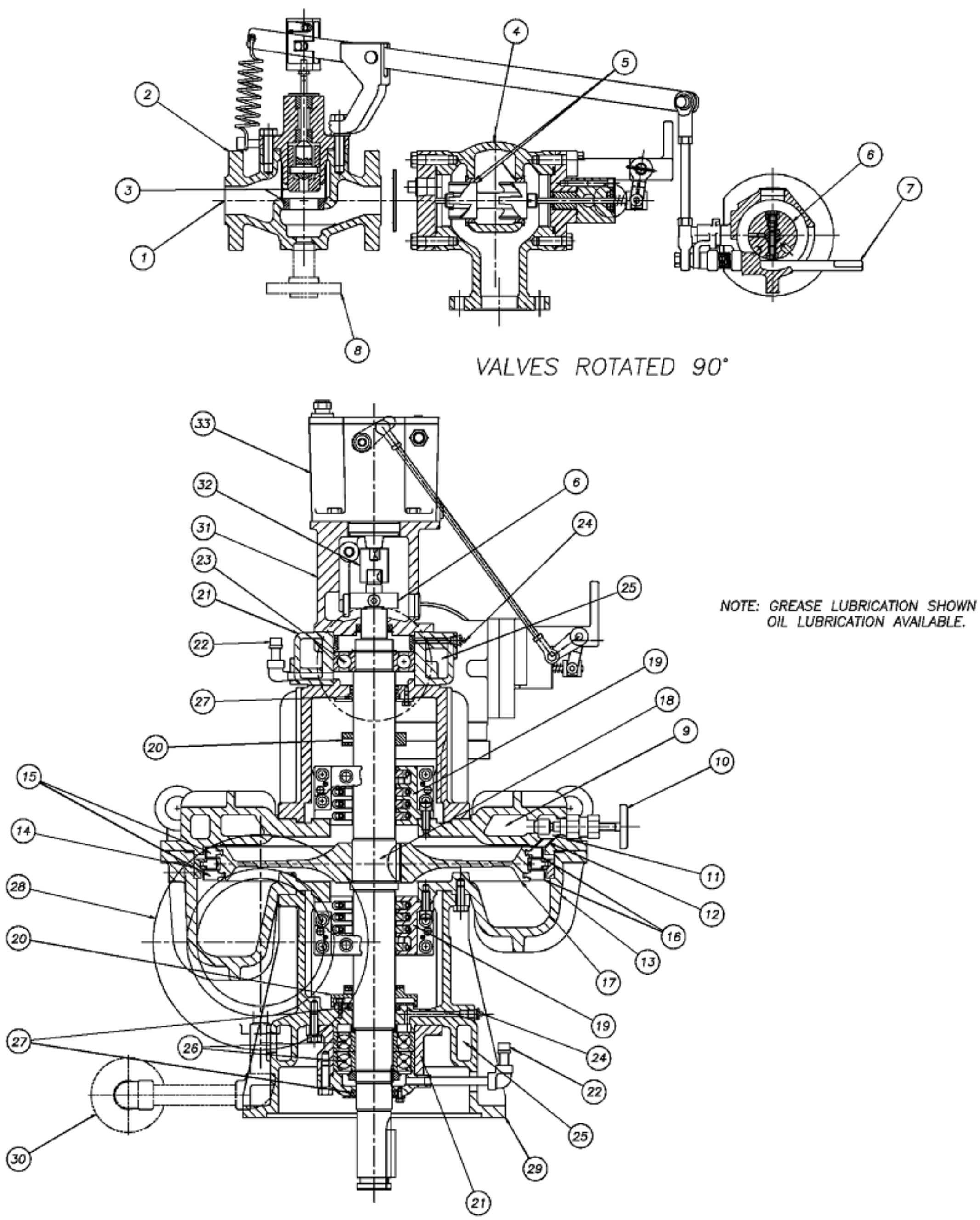


Key

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. Thrust 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. Sentinel warning valve

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. Rotor/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

Annex H
(normative)

Steam Purity and Variations in Steam Conditions

H.1 Steam Purity

H.1.1 Steam turbine users shall be aware of the hazards associated with contamination of the steam by agents that may promote stress corrosion cracking, solids buildup, erosion, and corrosion. Contaminants such as sodium, hydroxides, chlorides, sulfates, copper, lead, and silicates may result in shortened turbine life and failure of internal parts of the turbine.

H.1.2 Since it is not possible to prescribe the degree of contamination that steam turbine materials may tolerate in order to achieve the long life expected of internal turbine components, only general guidelines are included in Table H.1.

Table H.1—Steam Purity Limits

Contaminant	Continuous	Start-up
Conductivity—		
Micromhos/centimeter at 25 °C (77 °F)		
Drum	0.3	1.0
Once through	0.2	0.5
SiO, (ppb), max	20	50
Fe, (ppb), max	20	50
Cu, (ppb), max	3	10
Na + K, (ppb), max		
Up to 5,516 kPag (800 psig)	20	20
5,517 kPag to 9,998 kPag (801 psig to 1,450 psig)	10	10
9,999 kPag to 16,548 kPag (1,451 psig to 2,400 psig)	5	5
Over 16,548 kPag (2,400 psig)	3	3

H.2 Variations in Steam Conditions

H.2.1 The rating, capability, steam flow, speed regulation, and pressure control shall be based on operation at maximum steam conditions.

NOTE Maximum steam conditions are the highest inlet steam pressure and temperature and exhaust pressure to which the turbine is subjected in continuous operation.

H.2.2 Steam turbines shall be capable of operating under the following variations in inlet pressure and temperature, but performance shall not necessarily be in accordance with the standards established for operating at maximum steam conditions. Continuous operation at other than maximum steam conditions shall require review by the turbine vendor.

H.2.2.1 Variations from Maximum Inlet Steam Pressure

H.2.2.1.1 The turbine shall be capable of operating without damage at less than the guaranteed steam flow to the turbine with average inlet pressure of 105 % of maximum inlet steam pressure (this permissible variation recognizes the increase in pressure with decrease in steam flow encountered in operation).

H.2.2.1.2 The inlet steam pressure shall average not more than maximum pressure over any 12-month operating period. The inlet steam pressure shall not exceed 110 % of maximum pressure in maintaining these averages, except during abnormal conditions.

H.2.2.1.3 During abnormal conditions, the steam pressure at the turbine inlet connection shall be permitted to exceed maximum pressure briefly by as much as 20 %, but the aggregate duration of such swings beyond 105 % of maximum pressure shall not exceed 12 hours per 12-month operating period.

H.2.2.2 Variations from Maximum Inlet Steam Temperature

H.2.2.2.1 The inlet steam temperature shall average not more than maximum temperature over any 12-month operating period.

H.2.2.2.2 In maintaining this average, the temperature shall not exceed maximum temperature by more than 8 °C (15 °F) except during abnormal conditions. During abnormal conditions, the temperature shall not exceed maximum temperature by more than 14 °C (25 °F) for operating periods of not more than 400 hours per 12-month operating period nor by more than 28 °C (50 °F) for swings of 15 minutes duration or less, aggregating not more than 80 hours per 12-month operating period.

H.2.2.3 Variations from Maximum Exhaust Steam Pressure on Noncondensing Turbines

H.2.2.3.1 The exhaust steam pressure shall average not more than the maximum exhaust steam pressure over any 12-month operating period.

H.2.2.3.2 In maintaining this average, the exhaust steam pressure shall not exceed maximum pressure by more than 10 % nor drop more than 20 % below the maximum exhaust pressure.

H.2.2.4 Variations in Exhaust Steam Pressure on Condensing Turbines

Any anticipated variations in the exhaust steam pressure specified by the purchaser on the data sheet shall be considered in the design of the turbine.

Annex I
(normative)

Allowable Forces and Moments

I.1 Allowable Forces and Moments on Steam Turbines

I.1.1 The forces and moments acting on steam turbines due to the steam inlet, extraction, and exhaust connections shall be limited by the following.

I.1.1.1 The total resultant force and total resultant moment imposed on the turbine at any connection shall not exceed the value calculated by Equation (I.1).

In SI units:

$$0.674 F_R + 0.738 M_R \leq 19.7 D_e \tag{I.1}$$

In USC units:

$$3 F_R + M_R \leq 500 D_e$$

where

F_R Resultant force in N (lbf) at the connection. It is calculated by Equation (I.3). This includes pressure forces where unrestrained expansion joints are used except on vertical down exhausts. Full vacuum load is allowed on vertical down exhaust flanges. It is not included as part of the piping load from Figure I.1.

M_R Resultant moment in N·m (lbf-ft) at the connection from Figure I.1. It is calculated by Equation (I.4).

D_e Nominal pipe size of the connection in millimeters up to 200 mm DN (NPS 8) in diameter. For sizes greater than 200 mm DN (NPS 8) in diameter, use value calculated by Equation (I.2).

In SI units:

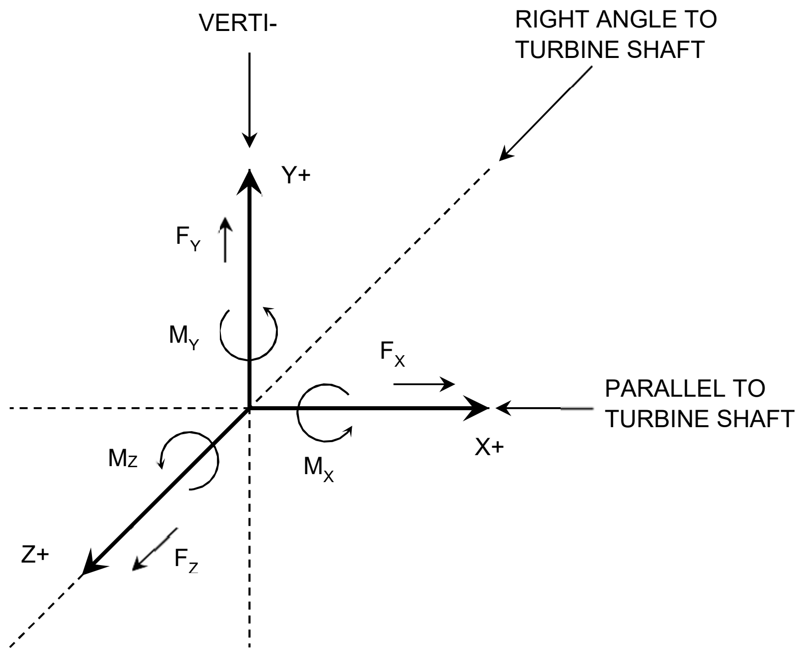
$$D_e = \frac{(406 + \text{Nominal Diameter})}{3} \tag{I.2}$$

In USC units:

$$D_e = \frac{(16 + \text{Nominal Diameter})}{3}$$

$$F_R = \sqrt{F_x^2 + F_y^2 + F_z^2} \tag{I.3}$$

$$M_R = \sqrt{M_x^2 + M_y^2 + M_z^2} \tag{I.4}$$



NOTE Positive moments rotate counterclockwise when viewed looking into positive forces.

Figure I.1—Components of Forces and Moments on Turbine Construction

I.1.1.2 The combined resultants of the forces and moments of the inlet, extraction, and exhaust connections, resolved at the centerlines of the exhaust connection shall not exceed the values calculated by Equation (I.5).

In SI units:

$$0.450F_c + 0.738M_c \leq 9.84D_c \tag{I.5}$$

In USC units:

$$2F_c + M_c \leq 250D_c$$

where

F_c is the combined resultant of inlet, extraction, and exhaust forces, N (lbf);

M_c is the combined resultant of inlet, extraction, and exhaust moments, and moments resulting from forces, N·m (lbf-ft);

D_c is the diameter in mm (in.) of a circular opening equal to the total areas of the inlet, extraction, and exhaust openings up to a value of 229 mm (9 in.) in diameter. For diameter greater than this, use a value of D_c calculated by Equation (I.6).

In SI units:

$$D_c = \frac{(457 + \text{Nominal Diameter})}{3} \tag{I.6}$$

In USC units:

$$D_c = \frac{(18 + \text{Nominal Diameter})}{3}$$

The components (see Figure I.1) of these resultants shall not exceed the values given in Equation (I.7)

In SI units:

$$F_x = 8.76 D_c \tag{I.7}$$

$$F_y = 21.9 D_c$$

$$F_z = 17.5 D_c$$

$$M_x = 13.3 D_c$$

$$M_y = 6.67 D_c$$

$$M_z = 6.67 D_c$$

In USC units:

$$F_x = 50 D_c$$

$$F_y = 125 D_c$$

$$F_z = 100 D_c$$

$$M_x = 250 D_c$$

$$M_y = 125 D_c$$

$$M_z = 125 D_c$$

where

F_x is the horizontal components of F_c parallel to the turbine shaft, mm (in.);

F_y is the vertical component of F_c, mm (in.);

F_z is the horizontal component of F_c at right angles to the turbine shaft, mm (in.);

M_x is the component of M_c around the horizontal axis parallel to the turbine shaft, N·m (lbf-ft);

M_y is the component of M_c around the vertical axis, N·m (lbf-ft);

M_z is the component of M_c around the horizontal axis at right angles to the turbine shaft, N·m (lbf-ft).

I.1.1.2.1 Allowable forces and moments for turbines with various inlet and exhaust sizes are shown in Table I.1 and Table I.2.

I.1.1.3 For condensing turbines with a vertical down exhaust and an unrestrained expansion joint at the exhaust, an additional amount of force (i.e. the vertical force component on the exhaust connection excluding pressure loading) shall be calculated.

I.1.1.3.1 This calculated vertical force component shall be used in the equations in I.1.1.1 and I.1.1.2 to determine the total resultant force on the exhaust connection.

NOTE This additional force is perpendicular to the face of the exhaust flange and central.

I.1.1.3.2 The force caused by the pressure loading on the exhaust is allowed in addition to the values established in I.1.1.3.1 up to a maximum value of vertical force in Newtons on the exhaust connection (including pressure loading) of 0.107 times the area in square millimeters [in pounds on the exhaust connection (including pressure loading) of 15.5 times the exhaust area in square inches].

I.1.1.4 The values of allowable forces and moments in Table I.1 and Table I.2 pertain to the turbine structure only. They do not pertain to the forces and moments in the connecting piping, flange, and flange bolting, which should not exceed the allowable stress as defined by applicable codes and regulatory bodies.

I.1.1.5 See sample problems 1, 2, and 3 for examples of how force and moment limitations are applied to turbine installations.

NOTE Sample problems 1.a, 2.a, and 3.a are in SI units. Sample problems 1.b, 2.b, and 3.b are in USC units.

Table I.1—Allowable Forces and Moments (SI Units)

Inlet (mm)	**Exhaust** (mm)	F_x (N)	F_y (N)	F_z (N)	M_x (N·m)	M_y (N·m)	M_z (N·m)
50	150	1,385	3,463	2,767	2,103	1,055	1,055
50	200	1,806	4,515	3,608	2,742	1,375	1,375
80	150	1,489	3,723	2,975	2,261	1,134	1,134
80	200	1,887	4,717	3,770	2,865	1,437	1,437
100	200	1,959	4,897	3,913	2,974	1,491	1,491
100	250	2,121	5,303	4,238	3,221	1,615	1,615
100	300	2,258	5,646	4,512	3,429	1,720	1,720
100	400	2,539	6,347	5,072	3,855	1,933	1,933
100	450	2,681	6,703	5,356	4,071	2,041	2,041
100	500	2,824	7,060	5,641	4,287	2,150	2,150
100	600	3,111	7,778	6,215	4,724	2,369	2,369
100	750	3,544	8,861	7,081	5,381	2,699	2,699
100	900	3,979	9,948	7,949	6,041	3,030	3,030
150	300	2,314	5,786	4,624	3,514	1,762	1,762
150	400	2,582	6,456	5,159	3,921	1,966	1,966
150	450	2,720	6,800	5,434	4,130	2,071	2,071
150	500	2,859	7,148	5,712	4,341	2,177	2,177
150	600	3,141	7,852	6,275	4,769	2,392	2,392
150	750	3,568	8,921	7,129	5,418	2,717	2,717
150	900	3,999	9,998	7,989	6,072	3,045	3,045
200	300	2,388	5,970	4,770	3,625	1,818	1,818
200	400	2,641	6,602	5,276	4,010	2,011	2,011
200	450	2,773	6,932	5,540	4,210	2,111	2,111
200	500	2,907	7,269	5,808	4,414	2,214	2,214
200	600	3,182	7,954	6,356	4,831	2,423	2,423
200	750	3,602	9,004	7,195	5,468	2,742	2,742
200	900	4,027	10,068	8,045	6,114	3,066	3,066
200	1200	4,887	12,218	9,764	7,420	3,721	3,721
250	300	2,475	6,188	4,945	3,758	1,885	1,885
250	400	2,712	6,781	5,419	4,118	2,065	2,065
250	450	2,838	7,095	5,670	4,309	2,161	2,161
250	500	2,967	7,418	5,928	4,505	2,259	2,259
250	600	3,233	8,083	6,459	4,909	2,462	2,462
250	750	3,643	9,109	7,279	5,532	2,774	2,774
250	900	4,063	10,156	8,116	6,168	3,093	3,093
250	1200	4,914	12,286	9,817	7,461	3,742	3,742
300	450	2,914	7,286	5,822	4,425	2,219	2,219
300	500	3,038	7,594	6,068	4,612	2,313	2,313
300	600	3,294	8,235	6,580	5,001	2,508	2,508
300	750	3,694	9,234	7,379	5,608	2,812	2,812
300	900	4,105	10,263	8,201	6,233	3,126	3,126
300	1,200	4,947	12,367	9,882	7,511	3,767	3,767
400	600	3,441	8,602	6,873	5,224	2,620	2,620
400	750	3,817	9,543	7,625	5,795	2,906	2,906
400	900	4,211	10,527	8,412	6,393	3,206	3,206
400	1,200	5,029	12,571	10,046	7,635	3,829	3,829

NOTE Sizes of inlet and exhaust nozzles are DN.

Table I.2—Allowable Forces and Moments (USC Units)

Inlet (in.)	Exhaust (in.)	F_x (lb)	F_y (lb)	F_z (lb)	M_x (lb-ft)	M_y (lb-ft)	M_z (lb-ft)
2	6	316	791	632	1,581	791	791
2	8	412	1,031	825	2,062	1,031	1,031
3	6	335	839	671	1,677	839	839
3	8	427	1,068	854	2,136	1,068	1,068
4	8	447	1,118	894	2,236	1,118	1,118
4	10	480	1,199	959	2,398	1,199	1,199
4	12	511	1,277	1,022	2,554	1,277	1,277
4	16	575	1,437	1,150	2,874	1,437	1,437
4	18	607	1,518	1,215	3,037	1,518	1,518
4	20	640	1,600	1,280	3,200	1,600	1,600
4	24	706	1,764	1,411	3,528	1,764	1,764
4	30	804	2,011	1,609	4,022	2,011	2,011
4	36	904	2,259	1,807	4,518	2,259	2,259
6	12	524	1,309	1,047	2,618	1,309	1,309
6	16	585	1,462	1,170	2,924	1,462	1,462
6	18	616	1,541	1,232	3,081	1,541	1,541
6	20	648	1,620	1,296	3,240	1,620	1,620
6	24	712	1,781	1,425	3,562	1,781	1,781
6	30	810	2,025	1,620	4,050	2,025	2,025
6	36	908	2,271	1,817	4,541	2,271	2,271
8	12	540	1,351	1,081	2,702	1,351	1,351
8	16	598	1,495	1,196	2,991	1,495	1,495
8	18	628	1,571	1,257	3,141	1,571	1,571
8	20	659	1,648	1,318	3,295	1,648	1,648
8	24	722	1,804	1,443	3,608	1,804	1,804
8	30	817	2,044	1,635	4,087	2,044	2,044
8	36	915	2,287	1,829	4,573	2,287	2,287
8	48	1,111	2,778	2,222	5,555	2,778	2,778
10	12	560	1,401	1,121	2,802	1,401	1,401
10	16	614	1,536	1,229	3,072	1,536	1,536
10	18	643	1,608	1,286	3,216	1,608	1,608
10	20	673	1,682	1,345	3,363	1,682	1,682
10	24	733	1,833	1,467	3,667	1,833	1,833
10	30	827	2,068	1,654	4,135	2,068	2,068
10	36	923	2,307	1,845	4,614	2,307	2,307
10	48	1,117	2,793	2,234	5,586	2,793	2,793
12	18	661	1,651	1,321	3,303	1,651	1,651
12	20	689	1,722	1,377	3,444	1,722	1,722
12	24	747	1,868	1,494	3,736	1,868	1,868
12	30	839	2,096	1,677	4,193	2,096	2,096
12	36	932	2,331	1,865	4,662	2,331	2,331
12	48	1,125	2,812	2,249	5,623	2,812	2,812
16	24	781	1,952	1,561	3,904	1,952	1,952
16	30	867	2,167	1,733	4,333	2,167	2,167
16	36	957	2,391	1,913	4,783	2,391	2,391
16	48	1,143	2,858	2,287	5,716	2,858	2,858

NOTE Sizes of inlet and exhaust nozzles are NPS.

Sample Problem 1.a (SI Units)

(Allowable Forces and Moments on Steam Turbines)

A steam turbine has a 100 mm side inlet and a 200 mm side exhaust. Analysis of the steam piping system proposed for the turbine has determined the components of the force and moments imposed on the inlet and exhaust flange as listed below.

Inlet Flange

$F_x = 178$ N $\quad M_x = 271$ N·m

$F_y = -445$ N $\quad M_y = 203$ N·m

$F_z = -311$ N $\quad M_z = -163$ N·m

Exhaust Flange

$F_x = -489$ N $\quad M_x = 678$ N·m

$F_y = -1112$ N $\quad M_y = 407$ N·m

$F_z = 801$ N $\quad M_z = 475$ N·m

Part 1

Check the resultant forces and moments on individual flanges against the limit given by Equation (I.1).

Inlet Flange

$$F_R = \sqrt{(178)^2 + (-445)^2 + (-311)^2} = 571 \text{ N}$$

$$M_R = \sqrt{(271)^2 + (203)^2 + (-163)^2} = 376 \text{ N·m}$$

$D_e = 100$ mm (correction is not needed for flanges 200 mm and smaller)

$$0.674 F_R (\text{N}) + 0.738 M_R (\text{N·m}) \leq 19.7 D_e (\text{mm})$$

$$(0.674)(571) + (0.738)(376) \leq (19.7)(100)$$

662 ≤ 1970 is true; therefore, the forces and moments on the inlet flange are within the limit given by Equation (I.1).

Exhaust Flange

$$F_R = \sqrt{(-489)^2 + (-1112)^2 + (801)^2} = 1456 \text{ N}$$

$$M_R = \sqrt{(678)^2 + (407)^2 + (475)^2} = 925 \text{ N·m}$$

$D_e = 200$ mm (correction is not needed for flanges 200 mm and smaller)

$$0.674F_R(\text{N}) + 0.738M_R(\text{N}\cdot\text{m}) \le 19.7D_e(\text{mm})$$

$$(0.674)(1456) + (0.738)(925) \le (250.73)(200)$$

1664 ≤ 3940 is true; therefore, the forces and moments on the exhaust flange are within the limit given by Equation (I.1).

Part 2

Check the combined resultant forces and moments on the turbine against the limit given by Equation (I.5).

$$F_x = 178 + (-489) = -311 \text{ N}$$

$$F_y = -445 + (-1{,}112) = -1{,}557 \text{ N}$$

$$F_z = -311 + 801 = 409 \text{ N}$$

$$M_x = 271 + 678 = 949 \text{ N}\cdot\text{m}$$

$$M_y = 203 + 407 = 610 \text{ N}\cdot\text{m}$$

$$M_z = -163 + 475 = 312 \text{ N}\cdot\text{m}$$

$$F_c = \sqrt{(-311)^2 + (-1{,}557)^2 + (490)^2} = 1{,}662 \text{ N}$$

$$M_c = \sqrt{(949)^2 + (610)^2 + (312)^2} = 1{,}170 \text{ N}\cdot\text{m}$$

$$\text{Nominal Inlet Flange Area} = \frac{\pi(100 \text{ mm})^2}{4} = 7{,}854 \text{ mm}^2$$

$$\text{Nominal Exhaust Flange Area} = \frac{\pi(200 \text{ mm})^2}{4} = 31{,}416 \text{ mm}^2$$

$$\text{Total Flange Area} = 7{,}854 + 31{,}416 = 39{,}270 \text{ mm}^2$$

$$D_c = \sqrt{\frac{(4)(39{,}270)}{\pi}} = 224 \text{ mm (correction is not needed for flanges 299 mm and smaller)}$$

$$0.450F_c(\text{N}) + 0.738M_c(\text{N}\cdot\text{m}) \le 9.84D_c(\text{mm})$$

$$(0.450)(1{,}662) + (0.738)(1{,}170) \le (9.84)(224)$$

1,608 ≤ 2,204 is true; therefore, the resultant forces and moments on the turbine are within the limit given by Equation (I.5).

Part 3

Check the components of the combined forces and moments on the turbine against the limits given by Equation (I.7).

Allowable Forces and Moments

$F_x = 8.76(D_c) = 1962$ N; $\quad |-311 \text{ N}| < 1962$ N

$F_y = 21.9(D_c) = 4906$ N; $\quad |-1557 \text{ N}| < 4906$ N

$F_z = 17.5(D_c) = 9811$ N; $\quad |490 \text{ N}| < 3920$ N

$M_x = 13.3(D_c) = 2979$ N·m; $\quad |949 \text{ N·m}| < 2979$ N·m

$M_y = 6.67(D_c) = 1494$ N·m; $\quad |610 \text{ N·m}| < 1494$ N·m

$M_z = 6.67(D_c) = 1494$ N·m; $\quad |312 \text{ N·m}| < 1494$ N·m

The magnitudes of the actual forces and moments calculated in Part 2 of this problem are lower than the allowable magnitudes calculated above. Therefore, the components of the combined force and moments on the turbine are within the limits given by Equation (I.7).

Results from Parts 1, 2, and 3 of this problem show that the forces and moments imposed by the piping system are within the limits given by Equation (I.7).

Sample Problem 2.a (SI Units)

(Allowable Forces and Moments on Steam Turbines)

A condensing turbine has a 150 mm side inlet and a 900 mm down exhaust. Analysis of the steam piping system proposed for the turbine has determined the components of the forces and moments imposed on the inlet and exhaust flanges (excluding force on the exhaust flange due to pressure forces in the unrestrained expansion joint in the exhaust line) as listed below.

Inlet Flange

$F_x = 400 \text{ N}$ $\qquad$ $M_x = -475 \text{ N}\cdot\text{m}$

$F_y = -667 \text{ N}$ $\qquad$ $M_y = 271 \text{ N}\cdot\text{m}$

$F_z = 890 \text{ N}$ $\qquad$ $M_z = 203 \text{ N}\cdot\text{m}$

Exhaust Flange

$F_x = 0 \text{ N}$ $\qquad$ $M_x = 0 \text{ N}\cdot\text{m}$

$F_y = -1112 \text{ N}$ $\qquad$ $M_y = 0 \text{ N}\cdot\text{m}$

$F_z = 0 \text{ N}$ $\qquad$ $M_z = -0 \text{ N}\cdot\text{m}$

Bellows area for the expansion joint (obtained from expansion joint manufacturer) is 660,000 mm^2. Pressure force developed by full vacuum in the expansion joint is:

$$\left(0.101 \text{ N/mm}^2\right)\left(660{,}000 \text{ mm}^2\right) = 66{,}660 \text{ N}$$

This is additional force in the -Y direction.

Part 1

Check the resultant forces and moments on individual flanges against the limit given by Equation (I.1).

Inlet Flange

$$F_R = \sqrt{(400)^2 + (-667)^2 + (890)^2} = 1182 \text{ N}$$

$$M_R = \sqrt{(-475)^2 + (271)^2 + (203)^2} = 583 \text{ N}\cdot\text{m}$$

$D_e = 150$ mm (correction is not needed for flanges 200 mm and smaller)

$$0.674 F_R\,(\text{N}) + 0.738 M_R\,(\text{N}\cdot\text{m}) \le 19.7 D_e\,(\text{mm})$$

$$(0.674)(1182) + (0.738)(583) \le (19.7)(150)$$

1227 ≤ 2955 is true; therefore, the forces and moments on the inlet flange are within the limit given by Equation (I.1).

Exhaust Flange

$$F_R \left(\text{excluding pressure force}\right) = \sqrt{(0)^2 + (-1112)^2 + (0)^2} = 1112 \text{ N}$$

$$M_R = \sqrt{(0)^2 + (0)^2 + (0)^2} = 0 \text{ N·m}$$

$D_{exhaust} = 900 \text{ mm} > 203 \text{ mm}$; therefore, correction is required

$$D_e = \frac{(406 + 900)}{3} = 435 \text{ mm}$$

$$0.674 F_R (\text{N}) + 0.738 M_R (\text{N·m}) \le 19.7 D_e (\text{mm})$$

$$(0.674)(1112) + (0.738)(0) \le (19.7)(435)$$

749 ≤ 8570 is true; therefore, the forces and moments on the exhaust flange are within the limit given by Equation (I.1).

Part 2

Check the combined resultant forces and moments on the turbine against the limit given by Equation (I.5).

$$F_x = 400 + 0 = 400 \text{ N}$$

$$F_y = -667 + (-1{,}112) = -1{,}779 \text{ N}$$

$$F_z = 890 + 0 = 8{,}909 \text{ N}$$

$$M_x = -475 + 0 = -475 \text{ N·m}$$

$$M_y = 271 + 0 = 271 \text{ N·m}$$

$$M_z = 203 + 0 = 203 \text{ N·m}$$

$$F_c = \sqrt{(400)^2 + (-1{,}779)^2 + (890)^2} = 2{,}029 \text{ N}$$

$$M_c = \sqrt{(-475)^2 + (271)^2 + (203)^2} = 583 \text{ N·m}$$

$$\text{Nominal Inlet Flange Area} = \frac{\pi (150 \text{ mm})^2}{4} = 17{,}671 \text{ mm}^2$$

$$\text{Nominal Exhaust Flange Area} = \frac{\pi (900 \text{ mm})^2}{4} = 636{,}173 \text{ mm}^2$$

$$\text{Total Flange Area} = 17{,}671 + 636{,}173 = 653{,}844 \text{ mm}^2$$

$$D_c = \sqrt{\frac{(4)(653,844)}{\pi}} = 912 \text{ mm} > 229 \text{ mm; therefore, correction is required}$$

$$D_c = \frac{(457 + 912)}{3} = 456 \text{ mm}$$

$$0.450 F_c \text{ (N)} + 0.735 M_c \text{ (N·m)} \le 9.84 D_c \text{ (mm)}$$

$$(0.450)(2,029) + (0.735)(583) \le (9.84)(456)$$

1,342 ≤ 4,487 is true; therefore, the resultant forces and moments on the turbine are within the limit given by Equation (I.5).

Part 3

Check the components of the combined forces and moments on the turbine against the limits given by Equation (I.7).

Allowable Forces and Moments

$F_x = 8.76(D_c) = 3995 \text{ N}; \qquad |400 \text{ N}| < 3995 \text{ N}$

$F_y = 21.9(D_c) = 9986 \text{ N}; \qquad |-1779 \text{ N}| < 9986 \text{ N}$

$F_z = 17.5(D_c) = 7980 \text{ N}; \qquad |890 \text{ N}| < 7980 \text{ N}$

$M_x = 13.3(D_c) = 6016 \text{ N·m}; \qquad |-475 \text{ N·m}| < 6016 \text{ N·m}$

$M_y = 6.67(D_c) = 3042 \text{ N·m}; \qquad |271 \text{ N·m}| < 3042 \text{ N·m}$

$M_z = 6.67(D_c) = 3042 \text{ N·m}; \qquad |203 \text{ N·m}| < 3042 \text{ N·m}$

The magnitudes of the actual forces and moments calculated in Part 2 of this problem are lower than the allowable magnitudes calculated above. Therefore, the components of the combined force and moments on the turbine are within the limits given by Equation (I.7).

Part 4

Check total force on the turbine exhaust flange against the limit in I.1.1.3.2. This paragraph states that force on the exhaust flange should not exceed 0.107 times the nominal exhaust area.

$$\left(0.107 \text{ N/mm}^2\right)\left(636,173 \text{ mm}^2\right) = 68,070 \text{ N}$$

Total force on the exhaust flange is the vector total of pressure force from the expansion joint and the forces calculated with pressure force excluded.

$$\text{Total Force} = -66,660 + (-1,112) = -67,772 \text{ N}$$

$$|-67,772 \text{ N}| < 68,070 \text{ N}$$

Results from Parts 1, 2, 3, and 4 of this problem show that the forces and moments imposed by the piping system are within the limits given by Equation (I.7) and I.1.1.3.2.

Sample Problem 3.a (SI Units)

(Allowable Forces and Moments for a Steam Turbine with four Extraction Openings)

Opening	**Size of Opening** (mm)	**Area of Opening** (mm^2)
Inlet	350	96,211
Extraction #1	250	49,087
Extraction #2	200	31,416
Extraction #3	400	125,664
Extraction #4	750	441,786
Exhaust	3,800	11,341,149

Find the diameter of a circular opening equal to the total area:

$$\text{Equivalent Diameter} = \frac{4(96,211 + 49,087 + 31,416 + 125,664 + 441,786 + 11,341,149)}{\pi} = 3,923 \text{ mm}$$

$$\text{Equivalent Diameter} = 3,923 \text{ mm (correction is required if the value exceeds 229 mm)}$$

$$D_c = \frac{(457 + 3,923)}{3} = 1,460 \text{ mm}$$

$$0.674 F_R (\text{N}) + 0.738 M_R (\text{N}\cdot\text{m}) \leq 19.7 D_e (\text{mm})$$

$$(0.674)(1,182) + (0.738)(583) \leq (19.7)(150)$$

Calculate the maximum allowable forces and moments:

$$F_x = 8.76(1,460) = 12,790 \text{ N}$$

$$F_y = 21.9(1,460) = 31,974 \text{ N}$$

$$F_z = 17.5(1,460) = 25,550 \text{ N}$$

$$M_x = 13.3(1,460) = 19,418 \text{ N}\cdot\text{m}$$

$$M_y = 6.67(1,460) = 9,738 \text{ N}\cdot\text{m}$$

$$M_z = 6.67(1,460) = 9,738 \text{ N}\cdot\text{m}$$

Sample Problem 1.b (USC Units)

(Allowable Forces and Moments on Steam Turbines)

A steam turbine has a 4 in. side inlet and an 8 in. side exhaust. Analysis of the steam piping system proposed for the turbine has determined the components of the force and moments imposed on the inlet and exhaust flange as listed below.

Inlet Flange

$F_{\text{x}} = 40$ lbf $\quad M_{\text{x}} = 200$ lbf-ft

$F_{\text{y}} = -100$ lbf $\quad M_{\text{y}} = 150$ lbf-ft

$F_{\text{z}} = -70$ lbf $\quad M_{\text{z}} = -120$ lbf-ft

Exhaust Flange

$F_{\text{x}} = -110$ lbf $\quad M_{\text{x}} = 500$ lbf-ft

$F_{\text{y}} = -250$ lbf $\quad M_{\text{y}} = 300$ lbf-ft

$F_{\text{z}} = 180$ lbf $\quad M_{\text{z}} = 350$ lbf-ft

Part 1

Check the resultant forces and moments on individual flanges against the limit given by Equation (I.1).

Inlet Flange

$$F_{\text{R}} = \sqrt{(40)^2 + (-100)^2 + (-70)^2} = 128 \text{ lbf}$$

$$M_{\text{R}} = \sqrt{(200)^2 + (150)^2 + (-120)^2} = 277 \text{ lbf-ft}$$

$D_{\text{e}} = 4$ in. (correction is not needed for flanges 8 in. and smaller)

$$3F_{\text{R}}(\text{lbf}) + M_{\text{R}}(\text{lbf-ft}) \leq 500D_{\text{e}}(\text{in.})$$

$$(3)(128) + 277 \leq (500)(4)$$

661 ≤ 2000 is true; therefore, the forces and moments on the inlet flange are within the limit given by Equation (I.1).

Exhaust Flange

$$F_{\text{R}} = \sqrt{(-110)^2 + (-250)^2 + (180)^2} = 327 \text{ lbf}$$

$$M_{\text{R}} = \sqrt{(500)^2 + (300)^2 + (350)^2} = 680 \text{ lbf-ft}$$

$D_{\text{e}} = 8$ in. (correction is not needed for flanges 8 in. and smaller)

$$3F_R + M_R \le 500D_e$$

$$(3)(327) + 680 \le (500)(8)$$

1661 ≤ 4000 is true; therefore, the forces and moments on the exhaust flange are within the limit given by Equation (I.1).

Part 2

Check the combined resultant forces and moments on the turbine against the limit given by Equation (I.5).

$$F_x = 40 + (-110) = -70 \text{ lbf}$$

$$F_y = -100 + (-250) = -350 \text{ lbf}$$

$$F_z = -70 + 180 = 110 \text{ lbf}$$

$$M_x = 200 + 500 = 700 \text{ lbf-ft}$$

$$M_y = 150 + 300 = 450 \text{ lbf-ft}$$

$$M_z = -120 + 350 = 230 \text{ lbf-ft}$$

$$F_c = \sqrt{(-70)^2 + (-350)^2 + (110)^2} = 373 \text{ lbf}$$

$$M_c = \sqrt{(700)^2 + (450)^2 + (230)^2} = 863 \text{ lbf-ft}$$

$$\text{Nominal Inlet Flange Area} = \frac{\pi(4 \text{ in.})^2}{4} = 12.57 \text{ in.}^2$$

$$\text{Nominal Exhaust Flange Area} = \frac{\pi(8 \text{ in.})^2}{4} = 50.27 \text{ in.}^2$$

$$\text{Total Flange Area} = 12.57 + 50.27 = 62.84 \text{ in.}^2$$

$$D_c = \sqrt{\frac{(4)(62.84)}{\pi}} = 8.94 \text{ in. (correction is not needed for flanges 9 in. and smaller)}$$

$$2F_c + M_c \le 250D_c$$

$$(2)(373) + 1170 \le (250)(8.94)$$

1609 ≤ 2235 is true; therefore, the resultant forces and moments on the turbine are within the limit given by Equation (I.5).

Part 3

Check the components of the combined forces and moments on the turbine against the limits given by Equation (I.7).

Allowable Forces and Moments

$F_x = 50(D_c) = 447$ lbf; $\quad |-70 \text{ lbf}| < 447$ lbf

$F_y = 125(D_c) = 1118$ lbf; $\quad |-350 \text{ lbf}| < 1118$ lbf

$F_z = 100(D_c) = 894$ lbf; $\quad |110 \text{ lbf}| < 894$ lbf

$M_x = 250(D_c) = 2236$ lbf-ft; $\quad |700 \text{ lbf-ft}| < 2236$ lbf-ft

$M_y = 125(D_c) = 1118$ lbf-ft; $\quad |450 \text{ lbf-ft}| < 1118$ lbf-ft

$M_z = 125(D_c) = 1118$ lbf-ft; $\quad |230 \text{ lbf-ft}| < 1118$ lbf-ft

The magnitudes of the actual forces and moments calculated in Part 2 of this problem are lower than the allowable magnitudes calculated above. Therefore, the components of the combined force and moments on the turbine are within the limits given by Equation (I.7).

Results from Parts 1, 2, and 3 of this problem show that the forces and moments imposed by the piping system are within the limits given by Equation (I.7).

Sample Problem 2.a (USC Units)

(Allowable Forces and Moments on Steam Turbines)

A condensing turbine has a 6 in. side inlet and a 36 in. down exhaust. Analysis of the steam piping system proposed for the turbine has determined the components of the forces and moments imposed on the inlet and exhaust flanges (excluding force on the exhaust flange due to pressure forces in the unrestrained expansion joint in the exhaust line) as listed below.

Inlet Flange

$F_x = 90$ lbf $\quad M_x = -350$ lbf-ft

$F_y = -150$ lbf $\quad M_y = 200$ lbf-ft

$F_z = 200$ lbf $\quad M_z = 150$ lbf-ft

Exhaust Flange

$F_x = 0$ lbf $\quad M_x = 0$ lbf-ft

$F_y = -250$ lbf $\quad M_y = 0$ lbf-ft

$F_z = 0$ lbf $\quad M_z = -0$ lbf-ft

Bellows area for the expansion joint (obtained from expansion joint manufacturer) is 1030 in.^{2}. Pressure force developed by full vacuum in the expansion joint is:

$$\left(14.7 \text{ lbf/in.}^2\right)\left(1{,}030 \text{ in.}^2\right) = 15{,}141 \text{ lbf}$$

This is additional force in the -Y direction.

Part 1

Check the resultant forces and moments on individual flanges against the limit given by Equation (I.1).

Inlet Flange

$$F_R = \sqrt{(90)^2 + (-150)^2 + (200)^2} = 266 \text{ lbf}$$

$$M_R = \sqrt{(-350)^2 + (200)^2 + (150)^2} = 430 \text{ lbf-ft}$$

$D_e = 6$ in. (correction is not needed for flanges 8 in. and smaller)

$$3F_R + M_R \le 500 D_e$$

$$(3)(266) + 430 \le (500)(6)$$

1228 ≤ 3000 is true; therefore, the forces and moments on the inlet flange are within the limit given by Equation (I.1).

Exhaust Flange

$$F_R\left(\text{excluding pressure force}\right)=\sqrt{(0)^2+(250)^2+(0)^2}=250\text{ lbf}$$

$$M_R=\sqrt{(0)^2+(0)^2+(0)^2}=0\text{ lbf-ft}$$

$D_{exhaust}=36$ in. $>$ 8 in.; therefore, correction is required

$$D_e=\frac{(16+36)}{3}=17.33\text{ in.}$$

$$2F_R+M_R\le 250D_e$$

$$(2)(250)+0\le(250)(17.33)$$

750 ≤ 8665 is true; therefore, the forces and moments on the exhaust flange are within the limit given by Equation (I.1).

Part 2

Check the combined resultant forces and moments on the turbine against the limit given by Equation (I.5).

$$F_x=90+0=90\text{ lbf}$$

$$F_y=-150+(-250)=-400\text{ lbf}$$

$$F_z=200+0=200\text{ lbf}$$

$$M_x=-350+0=-350\text{ lbf-ft}$$

$$M_y=200+0=200\text{ lbf-ft}$$

$$M_z=150+0=150\text{ lbf-ft}$$

$$F_c=\sqrt{(90)^2+(-400)^2+(200)^2}=456\text{ lbf}$$

$$M_c=\sqrt{(-350)^2+(200)^2+(150)^2}=430\text{ lbf-ft}$$

$$\text{Nominal Inlet Flange Area}=\frac{\pi(6\text{ in.})^2}{4}=28.3\text{ in.}^2$$

$$\text{Nominal Exhaust Flange Area}=\frac{\pi(36\text{ in.})^2}{4}=1017.9\text{ in.}^2$$

$$\text{Total Flange Area}=28.3+1017.9=1046.2\text{ in.}^2$$

$D_c = \sqrt{\frac{(4)(1046.2)}{\pi}} = 36.5$ in. > 9 in.; therefore, correction is required

$D_c = \sqrt{\frac{(18 + 36.5)}{3}} = 18.166$ in.

$2F_c + M_c \le 250 D_c$

$(2)(456) + 430 \le (250)(18.166)$

1342 ≤ 4542 is true; therefore, the resultant forces and moments on the turbine are within the limit given by Equation (I.5).

Part 3

Check the components of the combined forces and moments on the turbine against the limits given by Equation (I.7).

Allowable Forces and Moments

$F_x = 50(D_c) = 908$ lbf; $|90 \text{ lbf}| < 447$ lbf

$F_y = 125(D_c) = 2271$ lbf; $|-400 \text{ lbf}| < 1118$ lbf

$F_z = 100(D_c) = 1817$ lbf; $|200 \text{ lbf}| < 894$ lbf

$M_x = 250(D_c) = 4541$ lbf-ft; $|-350 \text{ lbf-ft}| < 2236$ lbf-ft

$M_y = 125(D_c) = 2271$ lbf-ft; $|200 \text{ lbf-ft}| < 1118$ lbf-ft

$M_z = 125(D_c) = 2271$ lbf-ft; $|150 \text{ lbf-ft}| < 1118$ lbf-ft

The magnitudes of the actual forces and moments calculated in Part 2 of this problem are lower than the allowable magnitudes calculated above. Therefore, the components of the combined force and moments on the turbine are within the limits given by Equation (I.7).

Part 4

Check total force on the turbine exhaust flange against the limit in I.1.1.3.2. This paragraph states that force on the exhaust flange should not exceed 15.5 times the nominal exhaust area.

$(15.5 \text{ lbf/in.}^2)(1{,}017.9 \text{ in.}^2) = 15{,}777$ lbf

Total force on the exhaust flange is the vector total of pressure force from the expansion joint and the forces calculated with pressure force excluded.

Total Force $= -15{,}141 + (-250) = -15{,}391$ lbf

$|-15{,}391 \text{ lbf}| < 15{,}777$ lbf

Results from Parts 1, 2, 3 and 4 of this problem show that the forces and moments imposed by the piping system are within the limits given by Equation (I.7) and I.1.1.3.2.

Sample Problem 3.a (SI Units)

(Allowable Forces and Moments for a Steam Turbine with four Extraction Openings)

Opening	**Size of Opening** (in.)	**Area of Opening** ($in.^2$)
Inlet	14	153.94
Extraction #1	10	78.54
Extraction #2	8	50.26
Extraction #3	16	201.06
Extraction #4	30	706.86
Exhaust	148	17,203.40

Find the diameter of a circular opening equal to the total area:

$$\text{Equivalent Diameter} = \frac{4(153.94 + 78.54 + 50.26 + 201.06 + 706.86 + 17{,}203.40)}{\pi} = 153.04 \text{ in.}$$

Equivalent Diameter $= 153.04$ in. (correction is required if the value exceeds 9 in.)

$$D_c = \frac{(18 + 13.04)}{3} = 57.01 \text{ in.}$$

Calculate the maximum allowable forces and moments:

$$F_x = 50(57.01) = 2{,}851 \text{ lbf}$$

$$F_y = 125(57.01) = 7{,}126 \text{ lbf}$$

$$F_z = 100(57.01) = 5{,}701 \text{ lbf}$$

$$M_x = 250(57.01) = 14{,}253 \text{ lbf-ft}$$

$$M_y = 125(57.01) = 7{,}126 \text{ lbf-ft}$$

$$M_z = 125(57.01) = 7{,}126 \text{ lbf-ft}$$

Annex J
(normative)

Controls

J.1 Governing System

J.1.1 General

The governing system includes the speed governor, the control mechanism, the governor-controlled valve(s), the speed changer, and external control devices. The governing system is the primary system necessary to match the turbine to the application. Various types of governors are available to meet specific user requirements.

J.1.2 Speed Governor

The speed governor includes those elements that are directly responsive to speed and that position or influence the action of other elements of the governing system to maintain the operating speed within the limits shown in J.2.

J.1.3 Multivariable Governor

The multivariable governor shall have the capability to control two or more parameters simultaneously.

J.1.4 Control Mechanism

The control mechanism includes all of the equipment between the governor and the governor-controlled valve(s) (e.g. levers, linkages, relays, servomotors, and pressure or power amplifying devices).

J.1.5 Governor Controlled Valve(s)

The governor-controlled valve(s) controls the flow of steam to the turbine in response to the governor or external controlling device(s).

There are two methods of controlling the admission of steam:

a) by single throttling valve,

b) multiple automatic valves.

J.1.6 Servomotor System

A servomotor system includes a pilot valve actuated by the governor or control mechanism and a power cylinder to actuate the governor-controlled valve(s), which allows steam to enter the turbine. The pilot valve controls the flow of high-pressure fluid to the power cylinder. This flow of high-pressure fluid causes the piston in the power cylinder to move in response to the signal from the governor or control mechanism.

J.1.7 External Control Devices

J.1.7.1 General

External control devices shall be one of three types described below.

J.1.7.2 Speed Changer Type

The speed changer type is incorporated directly into the governing system, which in turn positions the governor-controlled valve(s). The governor shall be selected to provide the specified adjustable speed range.

J.1.7.3 Remote Setpoint Type

The remote set point type is incorporated directly into the governing system, which in turn positions the governor-controlled valve(s). The governor shall be selected to provide the specified adjustable ranges for all controlling parameters.

J.1.7.4 Valve Actuating Type

The valve actuating type is separate from the governor. The external signal acts to position either the governor-controlled valve(s) or a separate line-mounted valve. In this case, the governor acts only as a speed-limiting (pre-emergency) governor.

J.1.8 Speed Changer

The speed changer is a device for changing the setting of the governing system within the specified speed range while the turbine is in operation.

J.2 Speed Governing System Classification

J.2.1 Speed governing systems shall be classified as shown in Table J.1.

Table J.1—Speed Governing System Classification

Governing System Class	Percent of Maximum Continuous Speed		
	Maximum Speed Regulation	Maximum Speed Variation	Maximum Speed Rise
A	10 %	0.75 %	13 %
B	6 %	0.50 %	7 %
C	4 %	0.25 %	7 %
D	0.5 %	0.25 %	7 %

J.2.2 These maximum speed rise percent values can be achieved under the following conditions.

a) Governor system adjusted for maximum sensitivity.

b) Rotational inertia of the equipment is relatively large for the power rating.

c) Steam conditions produce a relatively low theoretical steam rate.

J.2.3 A governor system in service that meets all the following conditions shall be capable of limiting speed to prevent overspeed trip when load is suddenly reduced from rated to zero.

a) The driven machine is synchronous generator.

b) The governor system is operating in a mode in which it responds to demand for electrical power.

c) The steam turbine has an inlet pressure of at least 1035 kPa(g) (150 psig).

d) The steam turbine exhausts to a condenser.

J.2.4 Speed Range

Speed range, expressed as a percentage of rated speed, is the specified range of operating speeds below or above rated speed, or both, for which the governor shall be adjustable when the turbine is operating under the control of the speed governor.

J.2.5 Maximum Speed Rise

The maximum speed rise, expressed as a percentage of rated speed, is the maximum momentary increase in speed that is obtained when the turbine is developing rated power output at rated speed and the load is suddenly and completely reduced to zero.

$$\text{Maximum Speed Rise (\%)} = \frac{(\text{Maximum Speed at Zero Power Output} - \text{Rated Speed})}{\text{Rated Speed}} \times 100$$

See Figure J.1 for a graphic representation of speed rise characteristics of a Class D governor.

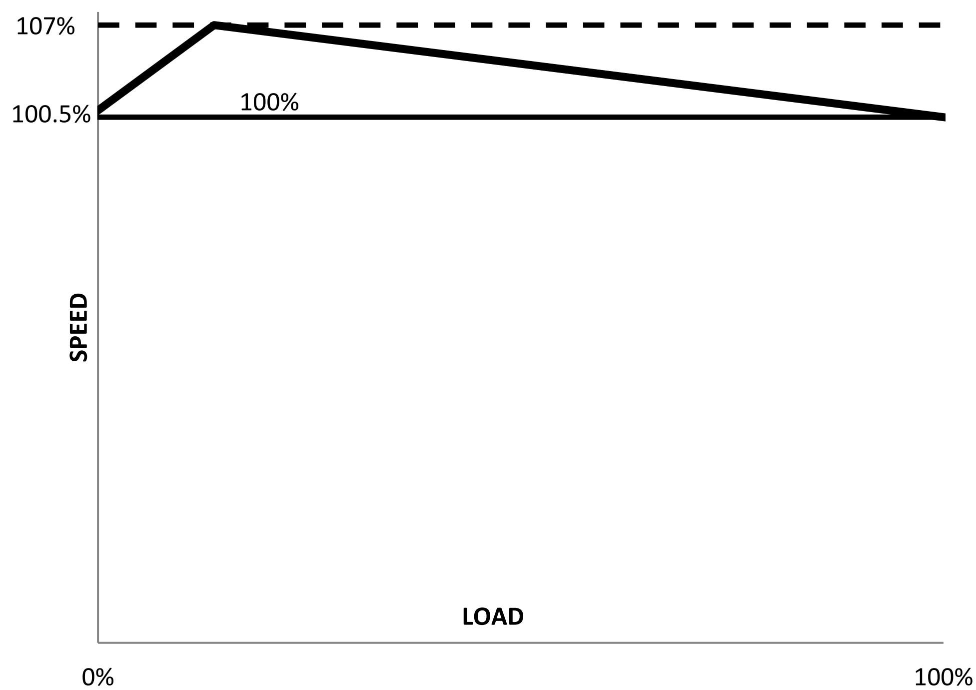


Figure J.1—Speed Rise Class D Governor

J.2.6 Speed Variation

Speed variation, expressed as a percentage of rated speed, is the total magnitude of speed change or fluctuations from the speed setting under the steady state conditions given in J.2.9. The speed change is determined as the difference in speed variation between the governing system in operation and the governing system blocked to be inoperative, with all other conditions constant. Speed variation includes dead band and sustained oscillations.

$$\text{Speed Variation (+ \%)} = \frac{(\text{Change in rpm Above Set Speed}) + (\text{Change in rpm Below Set Speed})}{2 \times \text{Rated Speed}} \times 100$$

See Figure J.2 for graphic representation of speed variation characteristics of a Class D governor.

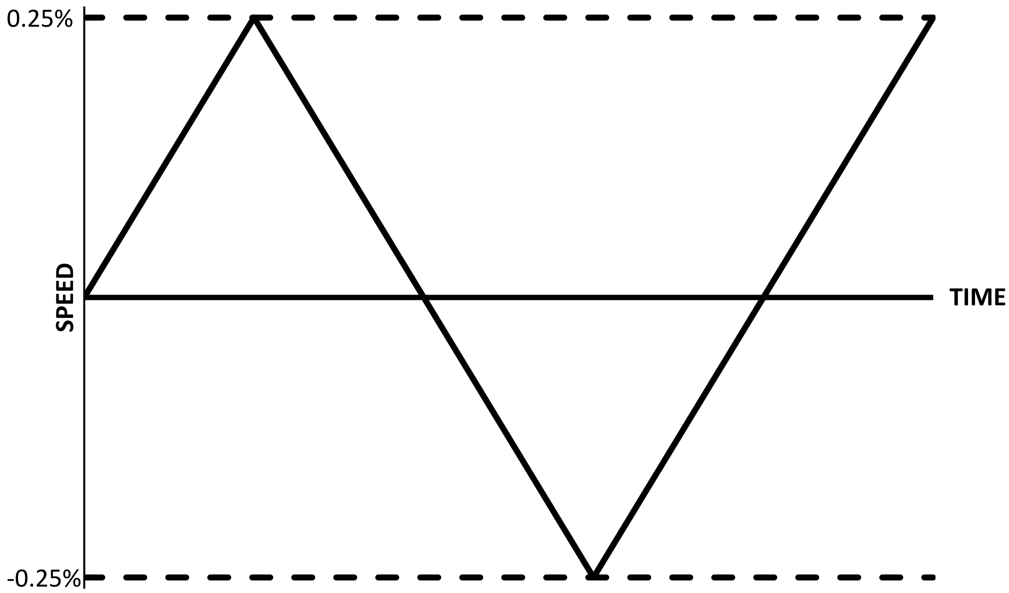


Figure J.2—Speed Variation Class D Governor

J.2.7 Dead Band

Dead band is the total magnitude of the change in steady state speed within which there is no resulting measurable change in the position of the governor-controlled valve(s). It is a measure of the speed governing system insensitivity and is expressed in percent of rated speed.

J.2.8 Stability

Stability is the ability of the speed governing system to position the governor-controlled valve(s) so that a sustained oscillation of speed or of energy input to the turbine is not produced by the speed governing system during operation under sustained load demand or following a change to a new sustained load demand.

J.2.9 Speed Regulation, Steady State

Speed regulation, expressed as a percentage of rated speed, is the change in sustained speed when the power output of the turbine is gradually changed from rated power output to zero power output under the following steady state conditions.

a) When the steam conditions (inlet pressure, inlet temperature, and exhaust pressure) are set at rated values and held constant.

b) When the speed changer is adjusted to give rated speed with rated power output.

c) When any external control device is rendered inoperative and blocked in the open position so as to offer no restrictions to the free flow of steam to the governor-controlled valve(s).

$$\text{Speed Regulation (\%)} = \frac{(\text{Speed at Zero Power Output}) - (\text{Speed at Rated Power Output})}{\text{Speed at Rated Power Output}} \times 100$$

Speed regulation is referred to as droop when the speed change is from no load to full load.

See Figure J.3 for a graphic representation of speed regulation characteristics of a Class D Governor.

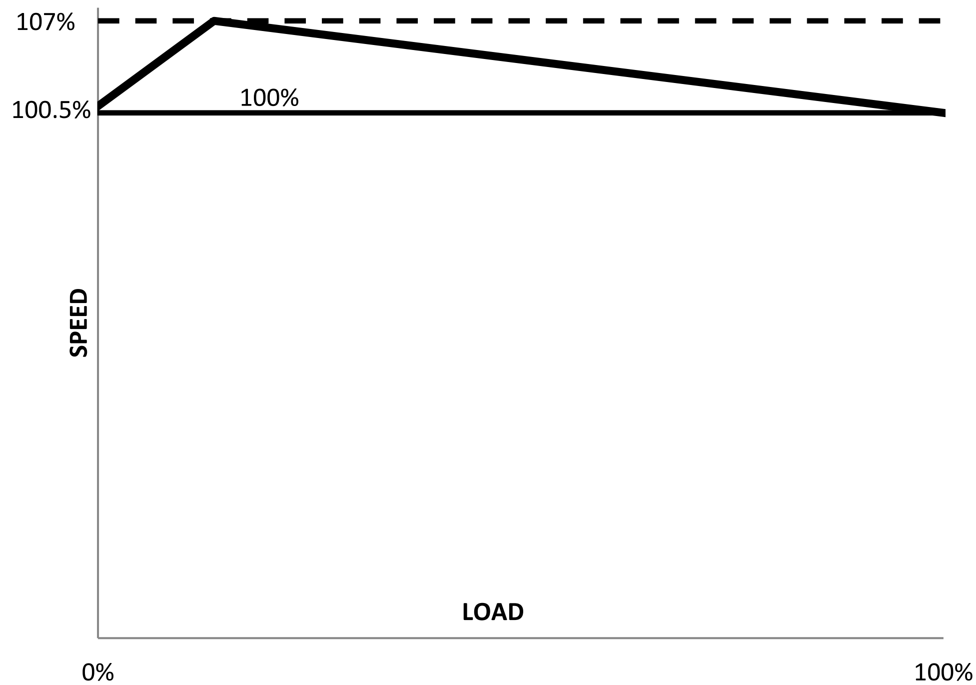


Figure J.3—Steady State Speed Regulation Class D Governor

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